Anexo C

Hoja de Datos de placas adquisidoras LabJack U3

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U3 User's Guide

The complete user's guide for the U3, including documentation for the LabJackUD driver. Covers hardware versions 1.20, 1.21, and 1.30 (LV/HV).

To make a PDF of the whole manual, click "Export all" towards the upper-right of this page. Doing so converts these pages to a PDF on-the-fly, using the latest content, and can take 20-30 seconds. If it is not working for you try the "Print all" option instead.

If you are looking at a PDF or hardcopy, realize that the original is an online document at http://labjack.com/support/u3/users-guide.

Rather than using a PDF, though, we encourage you to use this web-based documentation. Some advantages:

- We can quickly change or update content.
- The site search includes the user's guide, forum, and all other resources at labjack.com. When you are looking for something try using the site search.
- For support, try going to the applicable user's guide page and post a comment. When appropriate we can then immediately add/change content on that page to address the question.

One other trick worth mentioning, is to browse the table of contents to the left. Rather than clicking on all the links to browse, you can click on the small black triangles to expand without reloading the whole page.

User's Guide

1 - Installation on Windows

The LJUD driver requires a PC running Windows. For other operating systems, go to labjack.com for available support. Software will be installed to the LabJack directory which defaults to c:\Program Files\LabJack\.

Install the software first by going to labjack.com/support/u3.

Connect the USB cable: The USB cable provides data and power. After the UD software installation is complete, connect the hardware and Windows should prompt with “Found New Hardware” and shortly after the Found New Hardware Wizard will open. When the Wizard appears allow Windows to install automatically by accepting all defaults.

Run LJControlPanel: From the Windows Start Menu, go to the LabJack group and run LJControlPanel. Click the “Find Devices” button, and an entry should appear for the connected U3 showing the serial number. Click on the “USB – 1” entry below the serial number to bring up the U3 configuration panel. Click on “Test” in the configuration panel to bring up the test panel where you can view and control the various I/O on the U3.

If LJControlPanel does not find the U3, check Windows Device Manager to see if the U3 installed correctly. One way to get to the Device Manager is:

Start => Control Panel => System => Hardware => Device Manager

The entry for the U3 should appear as in the following figure. If it has a yellow caution symbol or exclamation point symbol, right-click and select “Uninstall” or “Remove”. Then disconnect and reconnect the U3 and repeat the Found New Hardware Wizard as described above.

Correctly Functioning U3 in Windows Device Manager

1.1 - Control Panel Application (LJControlPanel)

The LabJack Control Panel application (LJCP) handles configuration and testing of the U3. Click on the “Find Devices” button to search for connected devices.

Figure 1-1. LJControlPanel Main Window

Figure 1-1 shows the results from a typical search. The application found one U3 connected by USB. The USB connection has been selected in Figure 1-1, bringing up the configuration window on the right side.

- Refresh: Reload the window using values read from the device.
- Write Values: Write the Local ID from the window to the device.
- Config. IO Defaults: Opens the window shown in Figure 1-2.
- Reset: Click to reset the selected device.
- Test: Opens the window shown in Figure 1-3.

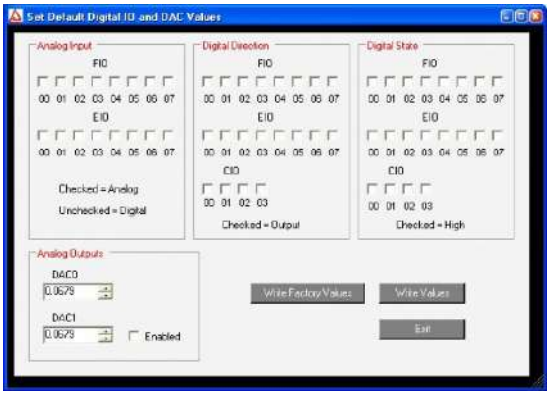


Figure 1-2. LJControlPanel U3 Configure Defaults Window

Figure 1-2 shows the configuration window for U3 defaults. These are the values that will be loaded by the U3 at power-up or reset. The factory defaults, as shown above, are all lines configured as digital input.

Figure 1-3 shows the U3 test window. This window continuously (once per second) writes to and reads from the selected LabJack.

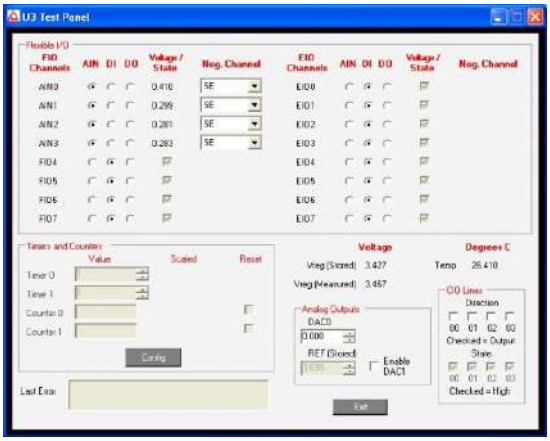


Figure 1-3. LJControlPanel U3 Test Window

Selecting Options=>Settings from the main LJControlPanel menu brings up the window shown in Figure 1-4. This window allows some features to of the LJControlPanel application to be customized.

Figure 1-4. LJControlPanel Settings Window

- Search for USB devices: If selected, LJControlPanel will include USB when searching for devices.
- Search for Ethernet devices using UDP broadcast packet: Does not apply to the U3.
- Search for Ethernet devices using specified IP addresses: Does not apply to the U3.

1.2 - Self-Upgrade Application (LJSelfUpgrade)

The processor in the U3 has field upgradeable flash memory. The self-upgrade application shown in Figure 1-5 programs the latest firmware onto the processor.

USB is the only interface on the U3, and first found is the only option for self-upgrading the U3, so no changes are needed in the "Connect by:" box. There must only be one U3 connected to the PC when running LJSelfUpgrade.

Click on "Get Version Numbers", to find out the current firmware versions on the device. Then use the provided Internet link to go to labjack.com and check for more recent firmware. Download firmware files to the …\LabJack\LJSelfUpgrade\upgradefiles\ directory.

Click the Browse button and select the upgrade file to program. Click the Program button to begin the self-upgrade process.

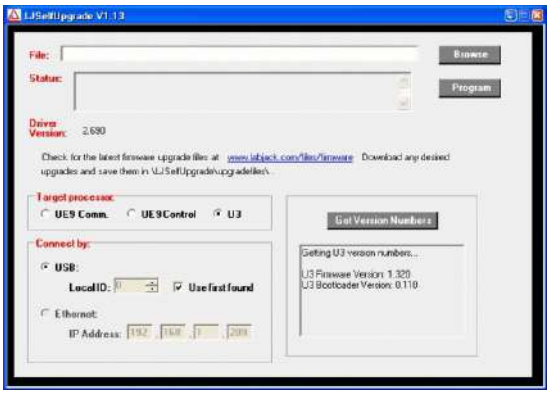


Figure 1-5. Self-Upgrade Application

If problems are encountered during programming, try the following:

1. Unplug the U3, wait 5 seconds then reconnect the U3. Click OK then press program again.
2. If step 1 does not fix the problem unplug the U3 and watch the LED while plugging the U3 back in. Follow the following steps based on the LED's activity.
    1. **If the LED is blinking continuously (flash mode)**, connect a jumper between FIO4 and SPC (FIO0 to SCL on U3 1.20/1.21), then unplug the U3, wait 5 seconds and plug the U3 back in. Try programming again (disconnect the jumper before programming).
    2. **If the LED blinks several times and stays on**, connect a jumper between FIO5 and SPC (FIO1 to SCL on U3 1.20/1.21), then unplug the U3, wait 5 seconds and plug the U3 back in. Try programming again (disconnect the jumper before programming).
    3. **If the LED blinks several times and stays off**, the U3 is not enumerating. Please restart your computer and try to program again.
    4. **If there is no LED activity**, connect a jumper between FIO5 and SPC (FIO1 to SCL on U3 1.20/1.21), then unplug the U3, wait 5 seconds and plug the U3 back in. If the LED is blinking continuously click OK and program again (after removing the jumper). If the LED does not blink connect a jumper between FIO4 and SPC (FIO0 to SCL on U3 1.20/1.21), then unplug the U3, wait 5 seconds and plug the U3 back in.
    5. **If the LED does a repeating pattern of 3 blinks then pause**, the U3 has detected internal memory corruption and you will have to contact LabJack Support.
3. If there is no activity from the U3's LED after following the above steps, please contact support.

2 - Hardware Description

The U3 has 3 different I/O areas:

- Communication Edge,
- Screw Terminal Edge,
- DB Edge.

The communication edge has a USB type B connector (with black cable connected in Figure 2-1). All power and communication is handled by the USB interface.

The screw terminal edge has convenient connections for the analog outputs and 8 flexible I/O (digital I/O, analog inputs, timers, or counters). The screw terminals are arranged in blocks of 4, with each block consisting of Vs, GND, and two I/O. There is also a status LED located on the left edge.

The DB Edge has a D-sub type connectors called DB15 which has the 8 EIO lines and 4 CIO lines. The EIO lines are flexible like the FIO lines, while the CIO are dedicated digital I/O.

Figure 2-1. LabJack U3

2.1 - USB

For information about USB installation, see Section 1.

The U3 has a full-speed USB connection compatible with USB version 1.1 or 2.0. This connection provides communication and power (Vusb). USB ground is connected to the U3 ground (GND), and USB ground is generally the same as the ground of the PC chassis and AC mains.

The details of the U3 USB interface are handled by the high level drivers (Windows LabJackUD DLL), so the following information is really only needed when developing low-level drivers.

The LabJack vendor ID is 0x0CD5. The product ID for the U3 is 0x0003.

The USB interface consists of the normal bidirectional control endpoint (0 OUT & IN), 3 used bulk endpoints (1 OUT, 2 IN, 3 IN), and 1 dummy endpoint (3 OUT). Endpoint 1 consists of a 64 byte OUT endpoint (address = 0x01). Endpoint 2 consists of a 64 byte IN endpoint (address = 0x82). Endpoint 3 consists of a dummy OUT endpoint (address = 0x03) and a 64 byte IN endpoint (address = 0x83). Endpoint 3 OUT is not supported by the firmware, and should never be used.

All commands should always be sent on Endpoint 1, and the responses to commands will always be on Endpoint 2. Endpoint 3 is only used to send stream data from the U3 to the host.

2.2 - Status LED

There is a green status LED on the LabJack U3. This LED blinks on reset, and then remains steadily lit. Other LED behavior is generally related to flash upgrade modes (Section 1.2).

2.3 - GND and SGND

The GND connections available at the screw-terminals and DB connectors provide a common ground for all LabJack functions. This ground is the same as the ground line on the USB connection, which is often the same as ground on the PC chassis and therefore AC mains ground.

SGND is located near the upper-left of the device. This terminal has a self-resetting thermal fuse in series with GND. This is often a good terminal to use when connecting the ground from another separately powered system that could unknowingly already share a common ground with the U3.

See the AIN, DAC, and Digital I/O Sections for more information about grounding.

2.4 - VS

The Vs terminals are designed as outputs for the internal supply voltage (nominally 5 volts). This will be the voltage provided from the USB cable. The Vs connections are outputs, not inputs. Do not connect a power source to Vs in normal situations. All Vs terminals are the same.

2.5 - Flexible I/O (FIO/EIO)

The FIO and EIO ports on the LabJack U3 can be individually configured as digital input, digital output, or analog input. This is FIO0-EIO7 on the U3-LV (16 lines), or FIO4-EIO7 on the U3-HV (12 lines). In addition, up to 2 of these lines can be configured as timers, and up to 2 of these lines can be configured as counters. If a line is configured as analog, it is called AINx according to the following table:

AIN0	FIO0		AIN8	EIO0	
AIN1	FIO1		AIN9	EIO1	
AIN2	FIO2		AIN10	EIO2	
AIN3	FIO3		AIN11	EIO3	
AIN4	FIO4		AIN12	EIO4	
AIN5	FIO5		AIN13	EIO5	
AIN6	FIO6		AIN14	EIO6	
AIN7	FIO7		AIN15	EIO7	

Table 2.5-1. Analog Input Pin Locations

On the U3-HV, compared to the -LV, the first four flexible I/O are fixed as analog inputs (AIN0-AIN3) with a nominal ±10 volt input range. All digital operations, including analog/digital configuration, are ignored on these 4 fixed analog inputs.

Timers and counters can appear on various pins, but other I/O lines never move. For example, Timer1 can appear anywhere from FIO4 to EIO1, depending on TimerCounterPinOffset and whether Timer0 is enabled. On the other hand, FIO5 (for example), is always on the screw terminal labeled FIO5, and AIN5 (if enabled) is always on that same screw terminal.

The first 8 flexible I/O lines (FIO0-FIO7) appear on built-in screw terminals. The other 8 flexible I/O lines (EIO0-EIO7) are available on the DB15 connector.

Many software applications will need to initialize the flexible I/O to a known pin configuration. That requires calls to the low-level functions ConfigIO and ConfigTimerClock. Following are the values to set the pin configuration to the factory default state:

Byte #			
6	WriteMask	15	Write all parameters
8	TimerCounterConfig	0	No Timers/Counters. Offset = 4
9	DAC1 Enable	0	DAC1 Disabled. (Ignored on HW 1.3)
10	FIOAnalog	0	FIO all digital.
11	EIOAnalog	0	EIO all digital.

Table 2.5-2. ConfigIO Factory Default Values

Byte #			
8	TimerClockConfig	130	Set clock to 48MHz.
9	TimerClockDivisor	0	Divisor = 0.

Table 2.5-3. ConfigTimerClock Factory Default Values

When using the high-level LabJackUD driver, this could be done with the following requests:

```
ePut (lngHandle, LJ_ioPUT_CONFIG, LJ_chNUMBER_TIMERS_ENABLED, 0, 0);
ePut (lngHandle, LJ_ioPUT_CONFIG, LJ_chTIMER_COUNTER_PIN_OFFSET, 4, 0);
ePut (lngHandle, LJ_ioPUT_CONFIG, LJ_chTIMER_CLOCK_BASE, LJ_tc48MHZ, 0);
ePut (lngHandle, LJ_ioPUT_CONFIG, LJ_chTIMER_CLOCK_DIVISOR, 0, 0);
ePut (lngHandle, LJ_ioPUT_COUNTER_ENABLE, 0, 0, 0);
ePut (lngHandle, LJ_ioPUT_COUNTER_ENABLE, 1, 0, 0);
ePut (lngHandle, LJ_ioPUT_DAC_ENABLE, 1, 0, 0);  //Ignored on hardware rev 1.30+.
ePut (lngHandle, LJ_ioPUT_ANALOG_ENABLE_PORT, 0, 0, 16);
```

… or with a single request to the following IOType created exactly for this purpose:

```
ePut (lngHandle, LJ_ioPIN_CONFIGURATION_RESET, 0, 0, 0);
```

2.6 - AIN

The LabJack U3 has up to 16 analog inputs available on the flexible I/O lines (FIO0-FIO7 and EIO0-EIO7). Single-ended measurements can be taken of any line compared to ground, or differential measurements can be taken of any line to any other line.

Analog input resolution is 12-bits. The range of single-ended analog inputs is normally about 0-2.44, and there is a “special” 0-3.6 volt range available. The range of differential analog inputs is typically ± 2.4 volts, but is pseudobipolar, not true bipolar. The difference (positive channel minus negative channel) can be -2.4 volts, but neither input can have a voltage less than -0.3 volts to ground. For valid measurements, the voltage on every low-voltage analog input pin, with respect to ground, must be within -0.3 to +3.6 volts. See Appendix A for voltage limits to avoid damage.

On the U3-HV, compared to the -LV, the first four flexible I/O are fixed as analog inputs (AIN0-AIN3), and have scaling such that the input range is a true bipolar ±10 volts normally, and -10 to +20 volts when using the “special” range. The input impedance of these four lines is roughly 1 MΩ, which is good, but less than the normal low voltage analog inputs. Analog/digital configuration and all other digital operations on these pins are ignored. FIO4-EIO7 are still available as flexible I/O, same as the U3-LV.

Because the scaling on the high-voltage inputs on the U3-HV (AIN0-AIN3) is inherently single-ended, a factory calibration is not possible for differential readings. If a differential reading is requested where either channel is a high-voltage channel, the driver will return the raw binary reading and the user must handle calibration/conversion.

The analog inputs have a QuickSample option where each conversion is done faster at the expense of increased noise. This is enabled by passing a nonzero value for put_config special channel *LJ_chAIN_RESOLUTION*. There is also a LongSettling option where additional settling time is added between the internal multiplexer configuration and the analog to digital conversion. This allows signals with more source impedance, and is enabled by passing a nonzero value for put_config special channel *LJ_chAIN_SETTLING_TIME*. Both of these options are disabled by default. This applies to command/response mode only, and the resulting typical data rates are discussed in Section 3.1. For stream mode, see Section 3.2.

Note that sinking excessive current into digital outputs can cause substantial errors in analog input readings. See Section 2.8.1.4 for more info.

2.6.1 - Channel Numbers

The LabJack U3 has up to 16 external analog inputs, plus a few internal channels. The low-level functions specify a positive and negative channel for each analog input conversion. With the LabJackUD driver, the IOType LJ_ioGET_AIN is used for single-ended channels only, and thus the negative channel is internally set to 31. There is an additional IOType called LJ_ioGET_AIN_DIFF that allows the user to specify the positive and negative channel.

Positive Channel #	
0-7	AIN0-AIN7 (FIO0-FIO7)
8-15	AIN8-AIN15 (EIO0-EIO7)
30	Temp Sensor
31	Vreg

Table 2.6.1-1. Positive Channel Numbers

Negative Channel #	
0-7	AIN0-AIN7 (FIO0-FIO7)
8-15	AIN8-AIN15 (EIO0-EIO7)
30	Vref
31 or 199	Single-Ended
32	Special 0-3.6 or -10/+20 (UD Only)

Table 2.6.1-2 Negative Channel Numbers

Positive channel 31 puts the internal Vreg (~3.3 volts) on the positive input of the ADC. See Section 2.6.4 for information about the internal temperature sensor.

If the negative channel is set to anything besides 31/199, the U3 does a differential conversion and returns a pseudobipolar value. If the negative channel is set to 31/199, the U3 does a single-ended conversion and returns a unipolar value. Channel 30 puts the internal voltage reference Vref (~2.44 volts) on the negative input of the ADC.

Channel 32 is a special negative channel supported by the LabJack UD driver. When used, the driver will actually pass 30 as the negative channel to the U3, and when the result is returned the driver adds Vref to the value. For a low-voltage analog input this results in a full span on the positive channel of about 0 to 4.88 volts (versus ground), but since the voltage on any analog input cannot exceed 3.6 volts, only 75% of the converter's range is used and the span is about 0 to 3.6 volts. For a high-voltage analog input, channel 32 (special range) results in a span of about -10 to +20 volts.

In the U3 examples that accompany the Exodriver, u3.c also supports channel 32 in calls to eAIN().

Channel 32 is also supported in LabJackPython:

```
# On the U3, wire a jumper from DAC0 to FIO0, then run:
>>> import u3
>>> d = u3.U3()
>>> d.configIO(FIOAnalog = 1) # Set FIO0 to analog
>>> d.writeRegister(5000, 3) # Set DAC0 to 3 V
```

```
>>> d.getAIN(0, 32)
3.0141140941996127
```

For the four high-voltage channels on the U3-HV, the special channel negative channel also puts Vref on the negative. This results in an overall range of about -10 to +20 volts on the positive input.

2.6.2 - Converting Binary Readings to Voltages

Following are the nominal input voltage ranges for the low-voltage analog inputs. This is all analog inputs on the U3-LV, and AIN4-AIN15 on the U3-HV.

	Max V	Min V		
Single-Ended	2.44	0		
Differential	2.44	-2.44		
Special 0-3.6	3.6	0		

Table 2.6.2-1. Nominal Analog Input Voltage Ranges for Low-Voltage Channels

	Max V	Min V		
Single-Ended	10.3	-10.3		
Differential	N/A	N/A		
Special -10/+20	20.1	-10.3		

Table 2.6.2-2. Nominal Analog Input Voltage Ranges for High-Voltage Channels

Note that the minimum differential input voltage of -2.44 volts means that the positive channel can be as much as 2.44 volts less than the negative channel, not that a channel can measure 2.44 volts less than ground. The voltage of any low-voltage analog input pin, compared to ground, must be in the range -0.3 to +3.6 volts.

The “special” range (0-3.6 on low-voltage channels and -10/+20 volts on high-voltage channels) is obtained by doing a differential measurement where the negative channel is set to the internal Vref (2.44 volts). For low-voltage channels, simply do the low-voltage differential conversion as described below, then add the stored Vref value. For high-voltage channels, do the same thing, then multiply by the proper high-voltage slope, divide by the single-ended low-voltage slope, and add the proper high-voltage offset. The UD driver handles these conversions automatically.

Although the binary readings have 12-bit resolution, they are returned justified as 16-bit values, so the approximate nominal conversion from binary to voltage is:

```
Volts(uncalibrated) = (Bits/65536)*Span (Single-Ended)
```

```
Volts(uncalibrated) = (Bits/65536)*Span – Span/2 (Differential)
```

Binary readings are always unsigned integers.

Where span is the maximum voltage minus the minimum voltage from the tables above. The actual nominal conversions are provided in the tables below, and should be used if the actual calibration constants are not read for some reason. Most applications will use the actual calibrations constants (Slope and Offset) stored in the internal flash.

```
Volts = (Slope * Bits) + Offset
```

Since the U3 uses multiplexed channels connected to a single analog-to-digital converter (ADC), all low-voltage channels have the same calibration for a given configuration. High-voltage channels have individual scaling circuitry out front, and thus the calibration is unique for each channel.

See Section 5.4 for detail about the location of the U3 calibration constants.

2.6.2.1 - Analog Inputs With DAC1 Enabled (Hardware Revisions 1.20 & 1.21 only)

This Section only applies to the older hardware revisions 1.20 and 1.21. Starting with hardware revision 1.30, DAC1 is always enabled and does not affect the analog inputs.

The previous information assumed that DAC1 is disabled. If DAC1 is enabled, then the internal reference (Vref = 2.44 volts) is not available for the ADC, and instead the internal regulator voltage (Vreg = 3.3 volts) is used as the reference for the ADC. Vreg is not as stable as Vref, but more stable than Vs (5 volt power supply). Following are the nominal input voltage ranges for the analog inputs, assuming that DAC1 is enabled.

	Max V	Min V		
Single-Ended	3.3	0		
Differential	3.3	-3.3		
Special -10/+20	N/A	N/A		

Table 2.6.2.1-1. Nominal Analog Input Voltage Ranges (DAC1 Enabled)

Note that the minimum differential input voltage of -3.3 volts means that the positive channel can be as much as 3.3 volts less than the negative channel, not that a channel can measure 3.3 volts less than ground. The voltage of any analog input pin, compared to ground, must be in the range -0.3 to +3.6 volts, for specified performance. See Appendix A for voltage limits to avoid damage.

Negative channel numbers 30 and 32 are not valid with DAC1 enabled.

When DAC1 is enabled, the slope/offset calibration constants are not used to convert raw readings to voltages. Rather, the Vreg value is retrieved from the Mem area, and used with the approximate single-ended or differential conversion equations above, where Span is Vreg (single-ended) or 2Vreg (differential).

2.6.3 - Typical Analog Input Connections

A common question is “can this sensor/signal be measured with the U3”. Unless the signal has a voltage (referred to U3 ground) beyond the limits in Appendix A, it can be connected without damaging the U3, but more thought is required to determine what is necessary to make useful measurements with the U3 or any measurement device.

Voltage (versus ground): The single-ended analog inputs on the U3 measure a voltage with respect to U3 ground. The differential inputs measure the voltage difference between two channels, but the voltage on each channel with respect to ground must still be within the common mode limits specified in Appendix A. When measuring parameters other than voltage, or voltages too big or too small for the U3, some sort of sensor or transducer is required to produce the proper voltage signal. Examples are a temperature sensor, amplifier, resistive voltage divider, or perhaps a combination of such things.

Impedance: When connecting the U3, or any measuring device, to a signal source, it must be considered what impact the measuring device will have on the signal. The main consideration is whether the currents going into or out of the U3 analog input will cause noticeable voltage errors due to the impedance of the source. To maintain consistent 12-bit results, it is recommended to keep the source impedance within the limits specified in Appendix A.

Resolution (and Accuracy): Based on the measurement type and resolution of the U3, the resolution can be determined in terms of

voltage or engineering units. For example, assume some temperature sensor provides a 0-10 mV signal, corresponding to 0-100 degrees C. Samples are then acquired with the U3 using the 0-2.44 volt single-ended input range, resulting in a voltage resolution of about 2.44/4096 = 596 µV. That means there will be about 17 discrete steps across the 10 mV span of the signal, and the temperature resolution is about 6 degrees C. If this experiment required a resolution of 1 degrees C, this configuration would not be sufficient. Accuracy will also need to be considered. Appendix A places some boundaries on expected accuracy, but an in-system calibration can generally be done to provide absolute accuracy down to the linearity (INL) limits of the U3.

Speed: How fast does the signal need to be sampled? For instance, if the signal is a waveform, what information is needed: peak, average, RMS, shape, frequency, … ? Answers to these questions will help decide how many points are needed per waveform cycle, and thus what sampling rate is required. In the case of multiple channels, the scan rate is also considered. See Sections 3.1 and 3.2.

2.6.3.1 - Signal from the LabJack

One example of measuring a signal from the U3 itself, is with an analog output. All I/O on the U3 share a common ground, so the voltage on an analog output (DAC) can be measured by simply connecting a single wire from that terminal to an AIN terminal (FIO/EIO). The analog output must be set to a voltage within the range of the analog input.

2.6.3.2 - Unpowered Isolated Signal

An example of an unpowered isolated signal would be a photocell where the sensor leads are not shorted to any external voltages. Such a sensor typically has two leads, where the positive lead connects to an AIN terminal and the negative lead connects to a GND terminal.

2.6.3.3 - Signal Powered By the LabJack

A typical example of this type of signal is a 3-wire temperature sensor. The sensor has a power and ground wire that connect to Vs and GND on the LabJack, and then has a signal wire that simply connects to an AIN terminal.

Another variation is a 4-wire sensor where there are two signal wires (positive and negative) rather than one. If the negative signal is the same as power ground, or can be shorted ground, then the positive signal can be connected to AIN and a single-ended measurement can be made. A typical example where this does not work is a bridge type sensor, such as pressure sensor, providing the raw bridge output (and no amplifier). In this case the signal voltage is the difference between the positive and negative signal, and the negative signal cannot be shorted to ground. Such a signal could be measured using a differential input on the U3.

2.6.3.4 - Signal Powered Externally

An example is a box with a wire coming out that is defined as a 0-2 volt analog signal and a second wire labeled as ground. The signal is known to have 0-2 volts compared to the ground wire, but the complication is what is the voltage of the box ground compared to the LabJack ground.

If the box is known to be electrically isolated from the LabJack, the box ground can simply be connected to LabJack GND. An example would be if the box was plastic, powered by an internal battery, and does not have any wires besides the signal and ground which are connected to AINx and GND on the LabJack.

If the box ground is known to be the same as the LabJack GND, then perhaps only the one signal wire needs to be connected to the LabJack, but it generally does not hurt to go ahead and connect the ground wire to LabJack GND with a 100 Ω resistor. You definitely do not want to connect the grounds without a resistor.

If little is known about the box ground, a DMM can be used to measure the voltage of box ground compared to LabJack GND. As long as an extreme voltage is not measured, it is generally OK to connect the box ground to LabJack GND, but it is a good idea to put in a 100 Ω series resistor to prevent large currents from flowing on the ground. Use a small wattage resistor (typically 1/8 or 1/4 watt) so that it blows if too much current does flow. The only current that should flow on the ground is the return of the analog input bias current, which is only microamps.

The SGND terminals (on the same terminal block as SPC) can be used instead of GND for externally powered signals. A series resistor is not needed as SGND is fused to prevent overcurrent, but a resistor will eliminate confusion that can be caused if the fuse is tripping and resetting.

In general, if there is uncertainty, a good approach is to use a DMM to measure the voltage on each signal/ground wire without any connections to the U3. If no large voltages are noted, connect the ground to U3 SGND with a 100 Ω series resistor. Then again use the DMM to measure the voltage of each signal wire before connecting to the U3.

Another good general rule is to use the minimum number of ground connections. For instance, if connecting 8 sensors powered by the same external supply, or otherwise referred to the same external ground, only a single ground connection is needed to the U3. Perhaps the ground leads from the 8 sensors would be twisted together, and then a single wire would be connected to a 100 Ω resistor which is connected to U3 ground.

2.6.3.5 - Amplifying Small Signal Voltages

The best results are generally obtained when a signal voltage spans the full analog input range of the LabJack. If the signal is too small it can be amplified before connecting to the LabJack. One good way to handle low-level signals such as thermocouples is the LJTick-InAmp, which is a 2-channel instrumentation amplifier module that plugs into the U3 screw-terminals.

For a do-it-yourself solution, the following figure shows an operational amplifier (op-amp) configured as non-inverting:

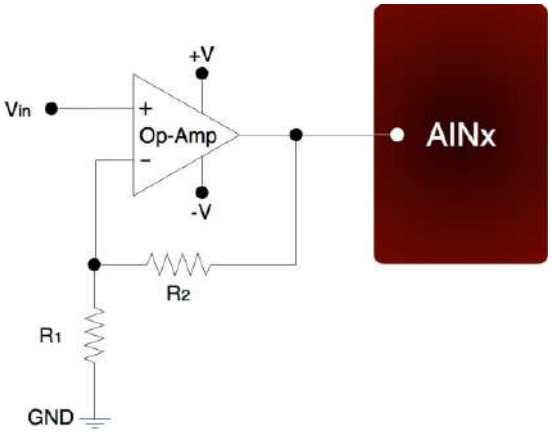


Figure 2-3. Non-Inverting Op-Amp Configuration

The gain of this configuration is:

```
Vout = Vin * (1 + (R2/R1))
```

100 kΩ is a typical value for R2. Note that if R2=0 (short-circuit) and R1=inf (not installed), a simple buffer with a gain equal to 1 is the result.

There are numerous criteria used to choose an op-amp from the thousands that are available. One of the main criteria is that the op-amp can handle the input and output signal range. Often, a single-supply rail-to-rail input and output (RIRO) is used as it can be powered from Vs and GND and pass signals within the range 0-Vs. The OPA344 from Texas Instruments (ti.com) is good for many 5 volt applications.

The op-amp is used to amplify (and buffer) a signal that is referred to the same ground as the LabJack (single-ended). If instead the signal is differential (i.e. there is a positive and negative signal both of which are different than ground), an instrumentation amplifier (in-amp) should be used. An in-amp converts a differential signal to single-ended, and generally has a simple method to set gain.

2.6.3.6 - Signal Voltages Beyond 0-2.44 Volts (and Resistance Measurement)

The normal input range for a low voltage channel on the U3 is about 0-2.44 volts. The easiest way to handle larger voltages is often by using the LJTick-Divider, which is a two channel buffered divider module that plugs into the U3 screw-terminals.

The basic way to handle higher unipolar voltages is with a resistive voltage divider. The following figure shows the resistive voltage divider assuming that the source voltage (Vin) is referred to the same ground as the U3 (GND).

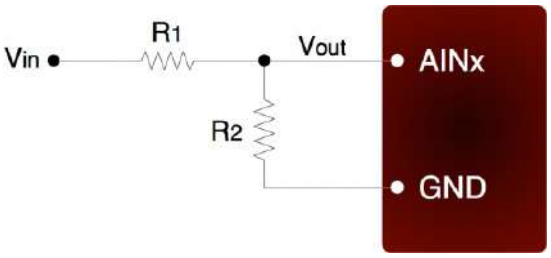


Figure 2-4. Voltage Divider Circuit

The attenuation of this circuit is determined by the equation:

```
Vout = Vin * ( R2 / (R1+R2))
```

This divider is easily implemented by putting a resistor (R1) in series with the signal wire, and placing a second resistor (R2) from the AIN terminal to a GND terminal. To maintain specified analog input performance, R1 should not exceed the values specified in Appendix A, so R1 can generally be fixed at the max recommended value and R2 can be adjusted for the desired attenuation.

The divide by 2 configuration where R1 = R2 = 10 kΩ (max source impedance limit for low-voltage channels), presents a 20 kΩ load to the source, meaning that a 5 volt signal will have to be able to source/sink up to +250 µA. Some signal sources might require a load with higher resistance, in which case a buffer should be used. The following figure shows a resistive voltage divider followed by an op-amp configured as non-inverting unity-gain (i.e. a buffer).

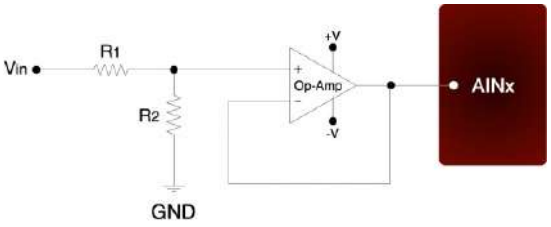


Figure 2-5. Buffered Voltage Divider Circuit

The op-amp is chosen to have low input bias currents so that large resistors can be used in the voltage divider. For 0-5 volt applications, where the amp will be powered from Vs and GND, a good choice would be the OPA344 from Texas Instruments (ti.com). The OPA344 has a very small bias current that changes little across the entire voltage range. Note that when powering the amp from Vs and GND, the input and output to the op-amp is limited to that range, so if Vs is 4.8 volts your signal range will be 0-4.8 volts.

The information above also applies to resistance measurement. A common way to measure resistance is to build a voltage divider as shown in Figure 2-4, where one of the resistors is known and the other is the unknown. If Vin is known and Vout is measured, the voltage divider equation can be rearranged to solve for the unknown resistance.

2.6.3.7 - Measuring Current (Including 4-20 mA) with a Resistive Shunt

The following figure shows a typical method to measure the current through a load, or to measure the 4-20 mA signal produced by a 2-wire (loop-powered) current loop sensor. The current shunt shown in the figure is simply a resistor.

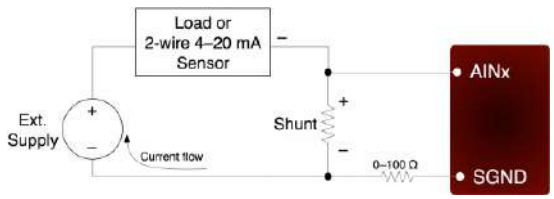


Figure 2-5. Current Measurement With Arbitrary Load or 2-Wire 4-20 mA Sensor

When measuring a 4-20 mA signal, a typical value for the shunt would be 120 Ω. This results in a 0.48 to 2.40 volt signal corresponding to 4-20 mA. The external supply must provide enough voltage for the sensor and the shunt, so if the sensor requires 5 volts the supply must provide at least 7.4 volts.

For applications besides 4-20 mA, the shunt is chosen based on the maximum current and how much voltage drop can be tolerated across the shunt. For instance, if the maximum current is 1.0 amp, and 1.0 volts of drop is the most that can be tolerated without affecting the load, a 1.0 Ω resistor could be used. That equates to 1.0 watts, though, which would require a special high wattage resistor. A better solution would be to use a 0.1 Ω shunt, and then use an amplifier to increase the small voltage produced by that shunt. If the maximum current to measure is too high (e.g. 100 amps), it will be difficult to find a small enough resistor and a hall-effect sensor should be considered instead of a shunt.

The following figure shows typical connections for a 3-wire 4-20 mA sensor. A typical value for the shunt would be 120 Ω which results in 0.48 to 2.40 volts.

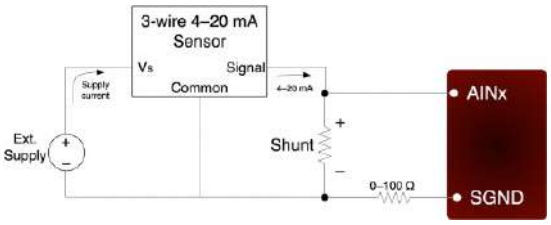


Figure 2-6. Current Measurement With 3-Wire 4-20 mA (Sourcing) Sensor

The sensor shown in Figure 2-6 is a sourcing type, where the signal sources the 4-20 mA current which is then sent through the shunt resistor and sunk into ground. Another type of 3-wire sensor is the sinking type, where the 4-20 mA current is sourced from the positive supply, sent through the shunt resistor, and then sunk into the signal wire. If sensor ground is connected to U3 ground, the sinking type of sensor presents a problem, as at least one side of the resistor has a high common mode voltage (equal to the positive sensor supply). If the sensor is isolated, a possible solution is to connect the sensor signal or positive sensor supply to U3 ground (instead of sensor ground). This requires a good understanding of grounding and isolation in the system. The LJTick-CurrentShunt is often a simple solution.

Both Figure 2-5 and 2-6 show a 0-100 Ω resistor in series with SGND, which is discussed in general in Section 2.6.3.4. In this case, if SGND is used (rather than GND), a direct connection (0 Ω) should be good.

The best way to handle 4-20 mA signals is with the LJTick-CurrentShunt, which is a two channel active current to voltage converter module that plugs into the U3 screw-terminals.

2.6.3.8 - Floating/Unconnected Inputs

The reading from a floating (no external connection) analog input channel can be tough to predict and is likely to vary with sample timing and adjacent sampled channels. Keep in mind that a floating channel is not at 0 volts, but rather is at an undefined voltage. In order to see 0 volts, a 0 volt signal (such as GND) should be connected to the input.

Some data acquisition devices use a resistor, from the input to ground, to bias an unconnected input to read 0. This is often just for “cosmetic” reasons so that the input reads close to 0 with floating inputs, and a reason not to do that is that this resistor can degrade the input impedance of the analog input.

In a situation where it is desired that a floating channel read a particular voltage, say to detect a broken wire, a resistor (pull-down or pull-up) can be placed from the AINx screw terminal to the desired voltage (GND, VS, DACx, …). A 100 kΩ resistor should pull the analog input readings to within 50 mV of any desired voltage, but obviously degrades the input impedance to 100 kΩ. For the specific case of pulling a floating channel to 0 volts, a 1 MΩ resistor to GND can typically be used to provide analog input readings of less than 50 mV. This information is for a low-voltage analog input channel on a U3.

Note that the four high-voltage channels on the U3-HV do sit at a predictable 1.4 volts. You can use a pull-down or pull-up resistor with the high-voltage inputs, but because their input impedance is lower the resistor must be lower (~1k might be typical) and thus the signal is going to have to drive substantial current.

2.6.3.9 - Signal Voltages Near Ground

The nominal input range of a low-voltage single-ended analog input is 0-2.44 volts. So the nominal minimum voltage is 0.0 volts, but the variation in that minimum can be about +/-40 mV, and thus the actual minimum voltage could be 0.04 volts.

This is not an offset error, but just a minimum limit. Assume the minimum limit of your U3 happens to be 10 mV. If you apply a voltage of 0.02 volts it will read 0.02 volts. If you apply a voltage of 0.01 volts it will read 0.01 volts. If you apply a voltage less than 0.01 volts, however, it will still read the minimum limit of 0.01 volts in this case.

One impact of this, is that a short to GND is usually not a good test for noise and accuracy. We often use a 1.5 volt battery for simple tests.

If performance all the way to 0.0 is needed, use a differential reading (which is pseudobipolar). Connect some other channel to GND with a small jumper, and then take a differential reading of your channel compared to that grounded channel.

The nominal input range of a high-voltage single-ended analog input is +/-10 volts, so readings around 0.0 are right in the middle of the range and not an issue.

2.6.4 - Internal Temperature Sensor

The U3 has an internal temperature sensor. Although this sensor measures the temperature inside the U3, which is warmer than ambient, it has been calibrated to read actual ambient temperature. For accurate measurements the temperature of the entire U3 must stabilize relative to the ambient temperature, which can take on the order of 1 hour. Best results will be obtained in still air in an environment with slowly changing ambient temperatures.

With the UD driver, the internal temperature sensor is read by acquiring single-ended analog input channel 30, and returns degrees K.

2.7 - DAC

The LabJack U3 has 2 analog outputs (DAC0 and DAC1) that are available on the screw terminals. Each analog output can be set to a voltage between about 0.04 and 4.95 volts with 10 bits of resolution (8 bits on older hardware revision 1.20/1.21). The maximum output voltage is limited by the supply voltage to the U3.

Starting with hardware revision 1.30, DAC1 is always enabled and does not affect the analog inputs, but with older hardware the second analog output is only available in certain configurations. With hardware revisions <1.30, if the analog inputs are using the internal 2.4 volt reference (the most accurate option), then DAC1 outputs a fixed voltage of 1.5*Vref. Also with hardware revisions <1.30, if DAC1 is enabled the analog inputs use Vreg (3.3 volts) as the ADC reference, which is not as stable as the internal 2.4 volt reference.

The DAC outputs are derived as a percentage of Vreg, and then amplified by 1.5, so any changes in Vreg will have a proportionate affect on the DAC outputs. Vreg is more stable than Vs (5 volt supply voltage), as it is the output from a 3.3 volt regulator.

The DACs are derived from PWM signals that are affected by the timer clock frequency (Section 2.9). The default timer clock frequency of the U3 is set to 48 MHz, and this results in the minimum DAC output noise. If the frequency is lowered, the DACs will have more noise, where the frequency of the noise is the timer clock frequency divided by 216. This effect is more exaggerated with the 10-bit DACs on hardware revision 1.30+, compared to the 8-bit DACs on previous hardware revisions. The noise with a timer clock of 48/12/4/1 MHz is roughly 5/20/100/600 mV. If lower noise performance is needed at lower timer clock frequencies, use the power-up default setting in LJControlPanel to force the device to use 8-bit DAC mode (uses the low-level CompatibilityOptions byte documented in Section 5.2.2). A large capacitor (at least 220 uF) from DACn to GND can also be used to reduce noise.

The analog outputs have filters with a 3 dB cutoff around 16 Hz, limiting the frequency of output waveforms to less than that.

The analog output commands are sent as raw binary values (low level functions). For a desired output voltage, the binary value can be approximated as:

```
Bits(uncalibrated) = (Volts/4.95)*256
```

For a proper calculation, though, use the calibration values (Slope and Offset) stored in the internal flash on the processor (Table 2-7):

```
Bits = (Slope * Volts) + Offset
```

The previous apply when using the original 8-bit DAC commands supported on all hardware versions. To take advantage of the 10-bit resolution on hardware revision 1.30, new commands have been added (Section 5.2.5) where the binary values are aligned to 16-bits. The cal constants are still aligned to 8-bits, however, so the slope and offset should each be multiplied by 256 before using in the above formula.

The analog outputs can withstand a continuous short-circuit to ground, even when set at maximum output.

Voltage should never be applied to the analog outputs, as they are voltage sources themselves. In the event that a voltage is accidentally applied to either analog output, they do have protection against transient events such as ESD (electrostatic discharge) and continuous overvoltage (or undervoltage) of a few volts.

There is an accessory available from LabJack called the LJTick-DAC that provides a pair of 14-bit analog outputs with a range of ±10 volts. The LJTick-DAC plugs into any digital I/O block, and thus up to 10 of these can be used per U3 to add 20 analog outputs. TheLJTick-DAC improves on the various shortcomings of the built-in DACs on the U3:

- Range of +10.0 to -10.0 volts.
- Resolution of 14-bits.
- Slew rate of 0.1 V/µs.
- Based on a reference, rather than regulator, so more accurate and stable.
- Does not affect analog inputs in any configuration.

2.7.1 - Typical Analog Output Connections

2.7.1.1 - High Current Output

The DACs on the U3 can output quite a bit of current, but they have 50 Ω of source impedance that will cause voltage drop. To avoid this voltage drop, an op-amp can be used to buffer the output, such as the non-inverting configuration shown in Figure 2-3. A simple RC filter can be added between the DAC output and the amp input for further noise reduction. Note that the ability of the amp to source/sink current near the power rails must still be considered. A possible op-amp choice would be the TLV246x family (ti.com).

2.7.1.2 - Different Output Ranges

The typical output range of the DACs is about 0.04 to 4.95 volts. For other unipolar ranges, an op-amp in the non-inverting configuration (Figure 2-3) can be used to provide the desired gain. For example, to increase the maximum output from 4.95 volts to 10.0 volts, a gain of 2.02 is required. If R2 (in Figure 2-3) is chosen as 100 kΩ, then an R1 of 97.6 kΩ is the closest 1% resistor that provides a gain greater than 2.02. The +V supply for the op-amp would have to be greater than 10 volts.

For bipolar output ranges, such as ±10 volts, a similar op-amp circuit can be used to provide gain and offset, but of course the op-amp must be powered with supplies greater than the desired output range (depending on the ability of the op-amp to drive it's outputs close to the power rails). If ±10, ±12, or ±15 volt supplies are available, consider using the LT1490A op-amp (linear.com), which can handle a supply span up to 44 volts.

A reference voltage is also required to provide the offset. In the following circuit, DAC1 is used to provide a reference voltage. The actual value of DAC1 can be adjusted such that the circuit output is 0 volts at the DAC0 mid-scale voltage, and the value of R1 can be adjusted to get the desired gain. A fixed reference (such as 2.5 volts) could also be used instead of DAC1.

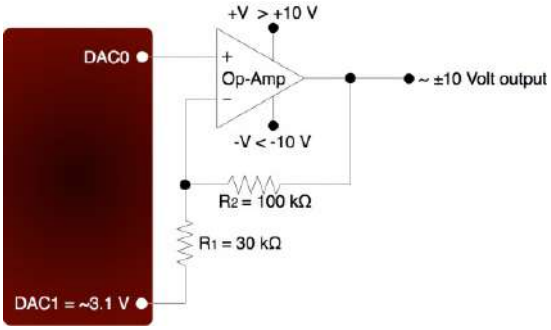


Figure 2-8. ±10 Volt DAC Output Circuit

A two-point calibration should be done to determine the exact input/output relationship of this circuit. Refer to application note SLOA097 from ti.com for further information about gain and offset design with op-amps.

2.8 - Digital I/O

The LabJack U3 has up to 20 digital I/O channels. 16 are available from the flexible I/O lines, and 4 dedicated digital I/O (CIO0-CIO3) are available on the DB15 connector. The first 4 lines, FIO0-FIO3, are unavailable on the U3-HV. Each digital line can be individually configured as input, output-high, or output-low. The digital I/O use 3.3 volt logic and are 5 volt tolerant.

The LabJackUD driver uses the following bit numbers to specify all the digital lines:

```
0-7    FIO0-FIO7  (0-3 unavailable on U3-HV)
8-15   EIO0-EIO7
16-19  CIO0-CIO3
```

The 8 FIO lines appear on the built-in screw-terminals, while the 8 EIO and 4 CIO lines appear only on the DB15 connector. See the DB15 Section of this User's Guide for more information.

All the digital I/O include an internal series resistor that provides overvoltage/short-circuit protection. These series resistors also limit the ability of these lines to sink or source current. Refer to the specifications in Appendix A.

All digital I/O on the U3 have 3 possible states: input, output-high, or output-low. Each bit of I/O can be configured individually. When configured as an input, a bit has a ~100 kΩ pull-up resistor to 3.3 volts (all digital I/O are 5 volt tolerant). When configured as output-high, a bit is connected to the internal 3.3 volt supply (through a series resistor). When configured as output-low, a bit is connected to GND (through a series resistor).

The power-up condition of the digital I/O can be configured by the user. From the factory, all digital I/O are configured to power-up as inputs. Note that even if the power-up default for a line is changed to output-high or output-low, there is a delay of about 5 ms at power-up where all digital I/O are in the factory default condition.

The low-level Feedback function (Section 5.2.5) writes and reads all digital I/O. For information about using digital I/O under the Windows LabJackUD driver, see Section 4.3.5. See Section 3.1 for timing information.

Many function parameters contain specific bits within a single integer parameter to write/read specific information. In particular, most digital I/O parameters contain the information for each bit of I/O in one integer, where each bit of I/O corresponds to the same bit in the parameter (e.g. the direction of FIO0 is set in bit 0 of parameter FIODir). For instance, in the low-level function ConfigU3, the parameter FIODirection is a single byte (8 bits) that writes/reads the power-up direction of each of the 8 FIO lines:

- if FIODirection is 0, all FIO lines are input,
- if FIODirection is 1 (2^0), FIO0 is output, FIO1-FIO7 are input,
- if FIODirection is 5 ($2^0 + 2^2$), FIO0 and FIO2 are output, all other FIO lines are input,
- if FIODirection is 255 ($2^0 + \ldots + 2^7$), FIO0-FIO7 are output.

2.8.1 - Typical Digital I/O Connections

2.8.1.1 - Input: Driven Signals

The most basic connection to a U3 digital input is a driven signal, often called push-pull. With a push-pull signal the source is typically providing a high voltage for logic high and zero volts for logic low. This signal is generally connected directly to the U3 digital input, considering the voltage specifications in Appendix A. If the signal is over 5 volts, it can still be connected with a series resistor. The digital inputs have protective devices that clamp the voltage at GND and VS, so the series resistor is used to limit the current through these protective devices. For instance, if a 24 volt signal is connected through a 22 kΩ series resistor, about 19 volts will be dropped across the resistor, resulting in a current of 1.1 mA, which is no problem for the U3. The series resistor should be 22 kΩ or less, to make sure the voltage on the I/O line when low is pulled below 0.8 volts.

The other possible consideration with the basic push-pull signal is the ground connection. If the signal is known to already have a common ground with the U3, then no additional ground connection is used. If the signal is known to not have a common ground with the U3, then the signal ground can simply be connected to U3 GND. If there is uncertainty about the relationship between signal ground and U3 ground (e.g. possible common ground through AC mains), then a ground connection with a ~10 Ω series resistor is generally recommended (see Section 2.6.3.4).

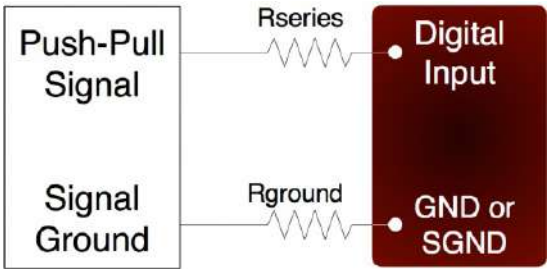


Figure 2-8. Driven Signal Connection To Digital Input

Figure 2-8 shows typical connections. Rground is typically 0-100 Ω. Rseries is typically 0 Ω (short-circuit) for 3.3/5 volt logic, or 22 kΩ (max) for high-voltage logic. Note that an individual ground connection is often not needed for every signal. Any signals powered by the same external supply, or otherwise referred to the same external ground, should share a single ground connection to the U3 if possible.

When dealing with a new sensor, a push-pull signal is often incorrectly assumed when in fact the sensor provides an open-collector signal as described next.

2.8.1.2 - Input: Open-Collector Signals

Open-collector (also called open-drain or NPN) is a very common type of digital signal. Rather than providing 5 volts and ground, like the push-pull signal, an open-collector signal provides ground and high-impedance. This type of signal can be thought of as a switch connected to ground. Since the U3 digital inputs have a 100 kΩ internal pull-up resistor, an open-collector signal can generally be connected directly to the input. When the signal is inactive, it is not driving any voltage and the pull-up resistor pulls the digital input to logic high. When the signal is active, it drives 0 volts which overpowers the pull-up and pulls the digital input to logic low. Sometimes, an external pull-up (e.g. 4.7 kΩ from Vs to digital input) will be installed to increase the strength and speed of the logic high condition.

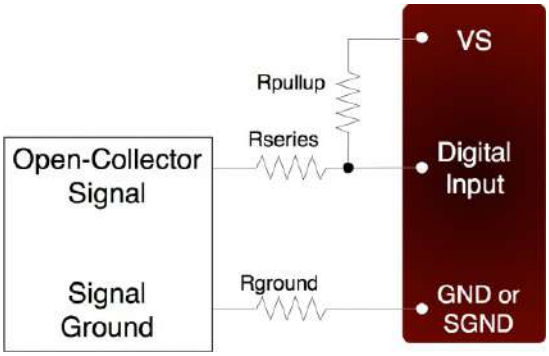


Figure 2-9. Open-Collector (NPN) Connection To Digital Input

Figure 2-9 shows typical connections. Rground is typically 0-100 Ω, Rseries is typically 0 Ω, and Rpullup, the external pull-up resistor, is generally not required. If there is some uncertainty about whether the signal is really open-collector or could drive a voltage beyond 5.8 volts, use an Rseries of 22 kΩ as discussed in Section 2.8.1.1, and the input should be compatible with an

open-collector signal or a driven signal up to at least 48 volts.

Without the optional resistors, the figure simplifies to:

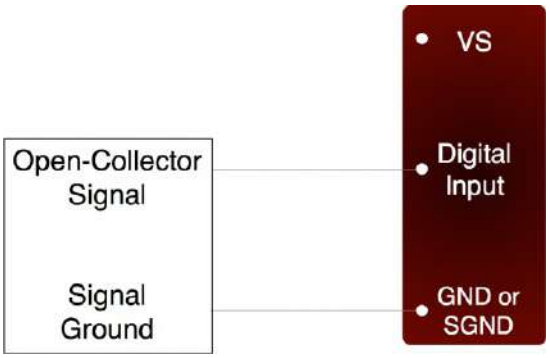


Figure 2-9b. Simplified Open-Collector (NPN) Connection To Digital Input Without Optional Resistors

Note that an individual ground connection is often not needed for every signal. Any signals powered by the same external supply, or otherwise referred to the same external ground, should share a single ground connection to the U3 if possible.

2.8.1.3 - Input: Mechanical Switch Closure

To detect whether a mechanical switch is open or closed, connect one side of the switch to U3 ground and the other side to a digital input. The behavior is very similar to the open-collector described above.

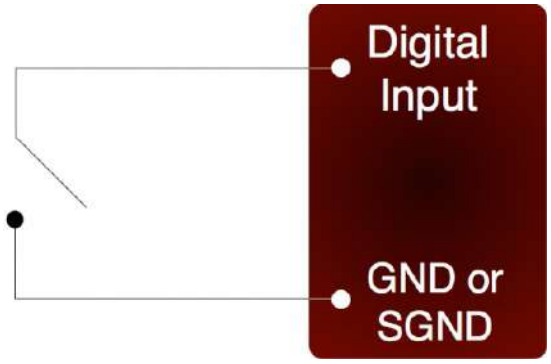


Figure 2-10. Basic Mechanical Switch Connection To Digital Input

When the switch is open, the internal 100 kΩ pull-up resistor will pull the digital input to about 3.3 volts (logic high). When the switch is closed, the ground connection will overpower the pull-up resistor and pull the digital input to 0 volts (logic low). Since the mechanical switch does not have any electrical connections, besides to the LabJack, it can safely be connected directly to GND, without using a series resistor or SGND.

When the mechanical switch is closed (and even perhaps when opened), it will bounce briefly and produce multiple electrical edges rather than a single high/low transition. For many basic digital input applications, this is not a problem as the software can simply poll the input a few times in succession to make sure the measured state is the steady state and not a bounce. For applications using timers or counters, however, this usually is a problem. The hardware counters, for instance, are very fast and will increment on all the bounces. Some solutions to this issue are:

- Software Debounce: If it is known that a real closure cannot occur more than once per some interval, then software can be used to limit the number of counts to that rate.
- Firmware Debounce: See Section 2.9.1 for information about timer mode 6.
- Active Hardware Debounce: Integrated circuits are available to debounce switch signals. This is the most reliable hardware solution. See the MAX6816 (maxim-ic.com) or EDE2008 (elabinc.com).
- Passive Hardware Debounce: A combination of resistors and capacitors can be used to debounce a signal. This is not foolproof, but works fine in most applications.

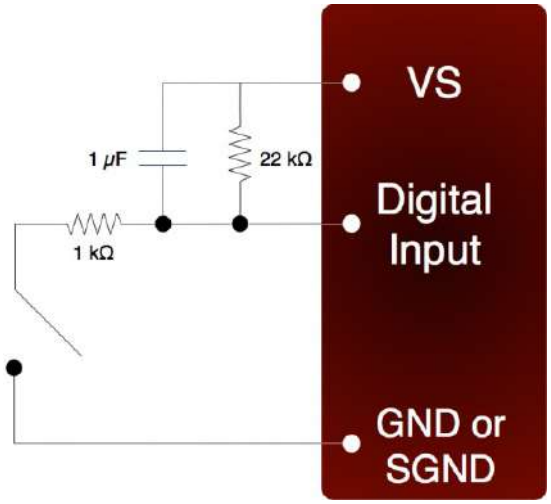


Figure 2-11. Passive Hardware Debounce

Figure 2-11 shows one possible configuration for passive hardware debounce. First, consider the case where the 1 kΩ resistor is

replaced by a short circuit. When the switch closes it immediately charges the capacitor and the digital input sees logic low, but when the switch opens the capacitor slowly discharges through the 22 kΩ resistor with a time constant of 22 ms. By the time the capacitor has discharged enough for the digital input to see logic high, the mechanical bouncing is done. The main purpose of the 1 kΩ resistor is to limit the current surge when the switch is closed. 1 kΩ limits the maximum current to about 5 mA, but better results might be obtained with smaller resistor values.

2.8.1.4 - Output: Controlling Relays

All the digital I/O lines have series resistance that restricts the amount of current they can sink or source, but solid-state relays (SSRs) can usually be controlled directly by the digital I/O. The SSR is connected as shown in the following diagram, where VS (~5 volts) connects to the positive control input and the digital I/O line connects to the negative control input (sinking configuration).

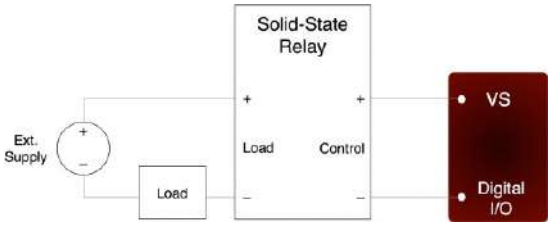


Figure 2-13. Relay Connections (Sinking Control, High-Side Load Switching)

When the digital line is set to output-low, control current flows and the relay turns on. When the digital line is set to input, control current does not flow and the relay turns off. When the digital line is set to output-high, some current flows, but whether the relay is on or off depends on the specifications of a particular relay. It is recommended to only use output-low and input.

For example, the Series 1 (D12/D24) or Series T (TD12/TD24) relays from Crydom specify a max turn-on of 3.0 volts, a min turn-off of 1.0 volts, and a nominal input impedance of 1500 Ω.

- When the digital line is set to output-low, it is the equivalent of a ground connection with 180 Ω (EIO/CIO) or 550 Ω (FIO) in series. When using an EIO/CIO line, the resulting voltage across the control inputs of the relay will be about 5*1500/(1500+180) = 4.5 volts (the other 0.5 volts is dropped across the internal resistance of the EIO/CIO line). With an FIO line the voltage across the inputs of the relay will be about 5*1500/(1500+550) = 3.7 volts (the other 1.3 volts are dropped across the internal resistance of the FIO line). Both of these are well above the 3.0 volt threshold for the relay, so it will turn on.
- When the digital line is set to input, it is the equivalent of a 3.3 volt connection with 100 kΩ in series. The resulting voltage across the control inputs of the relay will be close to zero, as virtually all of the 1.7 volt difference (between VS and 3.3) is dropped across the internal 100 kΩ resistance. This is well below the 1.0 volt threshold for the relay, so it will turn off.
- When the digital line is set to output-high, it is the equivalent of a 3.3 volt connection with 180 Ω (EIO/CIO) or 550 Ω (FIO) in series. When using an EIO/CIO line, the resulting voltage across the control inputs of the relay will be about 1.7*1500/(1500+180) = 1.5 volts. With an FIO line the voltage across the inputs of the relay will be about 1.7*1500/(1500+550) = 1.2 volts. Both of these in the 1.0-3.0 volt region that is not defined for these example relays, so the resulting state is unknown.

Note that sinking excessive current into digital outputs can cause noticeable shifts in analog input readings. For example, the FIO sinking configuration above sinks about 2.4 mA into the digital output to turn the SSR on, which could cause a shift of roughly 1 mV to analog input readings.

Mechanical relays require more control current than SSRs, and cannot be controlled directly by the digital I/O on the U3. To control higher currents with the digital I/O, some sort of buffer is used. Some options are a discrete transistor (e.g. 2N2222), a specific chip (e.g. ULN2003), or an op-amp.

Note that the U3 DACs can source enough current to control almost any SSR and even some mechanical relays, and thus can be a convenient way to control 1 or 2 relays. With the DACs you would typically use a sourcing configuration (DAC/GND) rather than sinking (VS/DAC).

The RB12 relay board is a useful accessory available from LabJack. This board connects to the DB15 connector on the U3 and accepts up to 12 industry standard I/O modules (designed for Opto22 G4 modules and similar).

Another accessory available from LabJack is the LJTick-RelayDriver. This is a two channel module that plugs into the U3 screw-terminals, and allows two digital lines to each hold off up to 50 volts and sink up to 200 mA. This allows control of virtually any solid-state or mechanical relay.

2.9 - Timers/Counters

The U3 has 2 timers (Timer0-Timer1) and 2 counters (Counter0-Counter1). When any of these timers or counters are enabled, they take over an FIO/EIO line in sequence (Timer0, Timer1, Counter0, then Counter1), starting with FIO0+TimerCounterPinOffset. Some examples:

1 Timer enabled, Counter0 disabled, Counter1 disabled, and TimerCounterPinOffset=4:
FIO4=Timer0

1 Timer enabled, Counter0 disabled, Counter1 enabled, and TimerCounterPinOffset=6:
FIO6=Timer0
FIO7=Counter1

2 Timers enabled, Counter0 enabled, Counter1 enabled, and TimerCounterPinOffset=8:
EIO0=Timer0
EIO1=Timer1
EIO2=Counter0
EIO3=Counter1

Starting with hardware revision 1.30, timers/counters cannot appear on FIO0-3, and thus **TimerCounterPinOffset must be 4-8**. A value of 0-3 will result in an error. This error can be suppressed by a power-up default setting in LJControlPanel. If suppressed, a 0-3 will result in an offset of 4.

Timers and counters can appear on various pins, but other I/O lines never move. For example, Timer1 can appear anywhere from FIO4 to EIO1, depending on TimerCounterPinOffset and whether Timer0 is enabled. On the other hand, FIO5 (for example), is always on the screw terminal labeled FIO5, and AIN5 (if enabled) is always on that same screw terminal.

Note that Counter0 is not available with certain timer clock base frequencies. In such a case, it does not use an external FIO/EIO pin. An error will result if an attempt is made to enable Counter0 when one of these frequencies is configured. Similarly, an error will result if an attempt is made to configure one of these frequencies when Counter0 is enabled.

Applicable digital I/O are automatically configured as input or output as needed when timers and counters are enabled, and stay that way when the timers/counters are disabled.

See Section 2.8.1 for information about signal connections.

Each counter (Counter0 or Counter1) consists of a 32-bit register that accumulates the number of falling edges detected on the external pin. If a counter is reset and read in the same function call, the read returns the value just before the reset.

The timers (Timer0-Timer1) have various modes available:

Timer Modes	
0	16-bit PWM output
1	8-bit PWM output
2	Period input (32-bit, rising edges)
3	Period input (32-bit, falling edges)
4	Duty cycle input
5	Firmware counter input
6	Firmware counter input (with debounce)
7	Frequency output
8	Quadrature input
9	Timer stop input (odd timers only)
10	**System timer low read (default mode)**
11	System timer hight read
12	Period input (16-bit, rising edges)
13	Period input (16-bit, falling edges)

Table 2.9-1. U3 Timer Modes

Both timers use the same timer clock.
There are 7 choices for the timer base clock:

TimerBaseClock	
0	4 MHz
1	12 MHz
2	48 MHz (default)
3	1 MHz /Divisor
4	4 MHz /Divisor
5	12 MHz /Divisor
6	48 MHz /Divisor

Table 2.9-2. U3 Timer Base Clock Options

Note that these clocks apply to the U3 hardware revision 1.21+. With hardware revision 1.20 all clocks are half of the values above.

The first 3 clocks have a fixed frequency, and are not affected by TimerClockDivisor. The frequency of the last 4 clocks can be further adjusted by TimerClockDivisor, but when using these clocks Counter0 is not available. When Counter0 is not available, it does not use an external FIO/EIO pin. The divisor has a range of 0-255, where 0 corresponds to a division of 256.

Note that the DACs (Section 2.7) are derived from PWM signals that are affected by the timer clock frequency. The default timer clock frequency of the U3 is set to 48 MHz, as this results in the minimum DAC output noise. If the frequency is lowered, the DACs will have more noise, where the frequency of the noise is the timer clock frequency divided by 2^{16}.

2.9.1 - Timer Mode Descriptions

2.9.1.1 - PWM Output (16-Bit, Mode 0)

Outputs a pulse width modulated rectangular wave output. Value passed should be 0-65535, and determines what portion of the total time is spent low (out of 65536 total increments). That means the duty cycle can be varied from 100% (0 out of 65536 are low) to 0.0015% (65535 out of 65536 are low).

The overall frequency of the PWM output is the clock frequency specified by TimerClockBase/TimerClockDivisor divided by 2^{16}. The following table shows the range of available PWM frequencies based on timer clock settings.

		PWM16 Frequency Ranges	
TimerBaseClock		Divisor=1	Divisor=256
0	4 MHz	61.04	N/A
1	12 MHz	183.11	N/A
2	48 MHz (default)	732.42	N/A
3	1 MHz /Divisor	15.26	0.06
4	4 MHz /Divisor	61.04	0.238
5	12 MHz /Divisor	183.11	0.715
6	48 MHz /Divisor	732.42	2.861

Table 2.9.1.1-1. 16-bit PWM Frequencies

Note that the clocks above apply to the U3 hardware revision 1.21. With hardware revision 1.20 all clocks are half of those values.

The same clock applies to all timers, so all 16-bit PWM channels will have the same frequency and will have their falling edges at the same time.

PWM output starts by setting the digital line to output-low for the specified amount of time. The output does not necessarily start instantly, but rather waits for the internal clock to roll. For example, if the PWM frequency is 100 Hz, that means the period is 10 milliseconds, and thus after the command is received by the device it could be anywhere from 0 to 10 milliseconds before the start of the PWM output.

2.9.1.2 - PWM Output (8-Bit, Mode 1)

Outputs a pulse width modulated rectangular wave output. Value passed should be 0-65535, and determines what portion of the total time is spent low (out of 65536 total increments). The lower byte is actually ignored since this is 8-bit PWM. That means the duty cycle can be varied from 100% (0 out of 65536 are low) to 0.4% (65280 out of 65536 are low).

The overall frequency of the PWM output is the clock frequency specified by TimerClockBase/TimerClockDivisor divided by 2^{8}. The following table shows the range of available PWM frequencies based on timer clock settings.

		PWM8 Frequency Ranges	
TimerBa		Divisor=1	Divisor=256
0	4 MHz	15625	N/A
1	12 MHz	46875	N/A
2	48 MHz (default)	187500	N/A
3	1 MHz /Divisor	3906.25	15.259
4	4 MHz /Divisor	15625	61.035
5	12 MHz /Divisor	46875	183.105
6	48 MHz /Divisor	187500	732.422

Table 2.9.1.2-1. 8-bit PWM Frequencies

Note that the clocks above apply to the U3 hardware revision 1.21. With hardware revision 1.20 all clocks are half of those values.

The same clock applies to all timers, so all 8-bit PWM channels will have the same frequency and will have their falling edges at the same time.

PWM output starts by setting the digital line to output-low for the specified amount of time. The output does not necessarily start instantly, but rather waits for the internal clock to roll. For example, if the PWM frequency is 100 Hz, that means the period is 10 milliseconds, and thus after the command is received by the device it could be anywhere from 0 to 10 milliseconds before the start of the PWM output.

2.9.1.3 - Period Measurement (32-Bit, Modes 2 & 3)

Mode 2: On every rising edge seen by the external pin, this mode records the number of clock cycles (clock frequency determined by TimerClockBase/TimerClockDivisor) between this rising edge and the previous rising edge. The value is updated on every rising edge, so a read returns the time between the most recent pair of rising edges.

In this 32-bit mode, the processor must jump to an interrupt service routine to record the time, so small errors can occur if another interrupt is already in progress. The possible error sources are:

- Other edge interrupt timer modes (2/3/4/5/8/9/12/13). If an interrupt is already being handled due to an edge on the other timer, delays of a few microseconds are possible.
- If a stream is in progress, every sample is acquired in a high-priority interrupt. These interrupts could cause delays on the order of 10 microseconds.
- The always active U3 system timer causes an interrupt 61 times per second. If this interrupt happens to be in progress when the edge occurs, a delay of about 1 microsecond is possible. If the software watchdog is enabled, the system timer interrupt takes longer to execute and a delay of a few microseconds is possible.

Note that the minimum measurable period is limited by the edge rate limit discussed in Section 2.9.2.

See Section 3.2.1 for a special condition if stream mode is used to acquire timer data in this mode.

Writing a value of zero to the timer performs a reset. After reset, a read of the timer value will return zero until a new edge is detected. If a timer is reset and read in the same function call, the read returns the value just before the reset.

Mode 3 is the same except that falling edges are used instead of rising edges.

2.9.1.4 - Duty Cycle Measurement (Mode 4)

Records the high and low time of a signal on the external pin, which provides the duty cycle, pulse width, and period of the signal. Returns 4 bytes, where the first two bytes (least significant word or LSW) are a 16-bit value representing the number of clock ticks during the high signal, and the second two bytes (most significant word or MSW) are a 16-bit value representing the number of clock ticks during the low signal. The clock frequency is determined by TimerClockBase/TimerClockDivisor.

The appropriate value is updated on every edge, so a read returns the most recent high/low times. Note that a duty cycle of 0% or 100% does not have any edges.

To select a clock frequency, consider the longest expected high or low time, and set the clock frequency such that the 16-bit registers will not overflow.

Note that the minimum measurable high/low time is limited by the edge rate limit discussed in Section 2.9.2.

When using the LabJackUD driver the value returned is the entire 32-bit value. To determine the high and low time this value should be split into a high and low word. One way to do this is to do a modulus divide by 2^{16} to determine the LSW, and a normal divide by 2^{16} (keep the quotient and discard the remainder) to determine the MSW.

Writing a value of zero to the timer performs a reset. After reset, a read of the timer value will return zero until a new edge is detected. If a timer is reset and read in the same function call, the read returns the value just before the reset. The duty cycle reset is special, in that if the signal is low at the time of reset, the high-time/low-time registers are set to 0/65535, but if the signal is high at the time of reset, the high-time/low-time registers are set to 65535/0. Thus if no edges occur before the next read, it is possible to tell if the duty cycle is 0% or 100%.

2.9.1.5 - Firmware Counter Input (Mode 5)

On every rising edge seen by the external pin, this mode increments a 32-bit register. Unlike the pure hardware counters, these timer counters require that the firmware jump to an interrupt service routine on each edge.

Writing a value of zero to the timer performs a reset. After reset, a read of the timer value will return zero until a new edge is detected. If a timer is reset and read in the same function call, the read returns the value just before the reset.

2.9.1.6 - Firmware Counter Input With Debounce (Mode 6)

Intended for frequencies less than 10 Hz, this mode adds a debounce feature to the firmware counter, which is particularly useful for signals from mechanical switches. On every applicable edge seen by the external pin, this mode increments a 32-bit register. Unlike the pure hardware counters, these timer counters require that the firmware jump to an interrupt service routine on each edge.

The debounce period is set by writing the timer value. The low byte of the timer value is a number from 0-255 that specifies a debounce period in 16 ms increments (plus an extra 0-16 ms of variability):

Debounce Period = (0-16 ms) + (TimerValue * 16 ms)

In the high byte (bits 8-16) of the timer value, bit 0 determines whether negative edges (bit 0 clear) or positive edges (bit 0 set) are counted.

Assume this mode is enabled with a value of 1, meaning that the debounce period is 16-32 ms and negative edges will be counted. When the input detects a negative edge, it increments the count by 1, and then waits 16-32 ms before re-arming the edge detector. Any negative edges within the debounce period are ignored. This is good behavior for a normally-high signal where the switch closure causes a brief low signal (Figure 2-10). The debounce period can be set long enough so that bouncing on both the switch closure and switch open is ignored.

Writing a value of zero to the timer performs a reset. After reset, a read of the timer value will return zero until a new edge is detected. If a timer is reset and read in the same function call, the read returns the value just before the reset.

2.9.1.7 - Frequency Output (Mode 7)

Outputs a square wave at a frequency determined by TimerClockBase/TimerClockDivisor divided by 2*Timer#Value. The Value passed should be between 0-255, where 0 is a divisor of 256. By changing the clock configuration and timer value, a wide range of frequencies can be output, as shown in the following table:

		Mode 7 Frequency Ranges	
		Divisor=1	Divisor=1
TimerBaseClock		Value=1	Value=256
0	4 MHz	2000000	7812.5
1	12 MHz	6000000	23437.5
2	48 MHz (default)	24000000	93750
		Divisor=1	Divisor=256
		Value=1	Value=256
3	1 MHz /Divisor	500000	7.629
4	4 MHz /Divisor	2000000	30.518
5	12 MHz /Divisor	6000000	91.553
6	48 MHz /Divisor	24000000	366.211

Table 2.9.1.7-1. Mode 7 Frequency Ranges

Note that the clocks above apply to the U3 hardware revision 1.21. With hardware revision 1.20 all clocks are half of those values.

The frequency output has a -3 dB frequency of about 10 MHz on the FIO lines. Accordingly, at high frequencies the output waveform will get less square and the amplitude will decrease.

The output does not necessarily start instantly, but rather waits for the internal clock to roll. For example, if the output frequency is 100 Hz, that means the period is 10 milliseconds, and thus after the command is received by the device it could be anywhere from 0 to 10 milliseconds before the start of the frequency output.

2.9.1.8 - Quadrature Input (Mode 8)

Requires both timers, where Timer0 will be quadrature channel A, and Timer1 will be quadrature channel B. Timer#Value passed has no effect. The U3 does 4x quadrature counting, and returns the current count as a signed 32-bit integer (2's complement). The same current count is returned on both timer value parameters.

Writing a value of zero to either or both timers performs a reset of both. After reset, a read of either timer value will return zero until a new quadrature count is detected. If a timer is reset and read in the same function call, the read returns the value just before the reset.

Z-phase support

Quadrature mode supports Z-Phase. When enabled this feature will set the count to zero when the specified IO line sees a logic high.

Z-phase is controlled by the value written to the timer during initialization. To enable z-phase support set bit 15 to 1 and set bits 0 through 4 to the DIO number that Z is connected to. EG: for a Z-line on EIO3 set the timer value to 0x800B or 32779. This value should be sent to both the A and B timers. When enabled this feature will set the count to zero when the specified IO line sees a logic high.

Note that the LabJack will only check Z when it sees an edge on A or B.

Z-phase support requires Firmware 1.30 or later.

2.9.1.9 - Timer Stop Input (Mode 9)

This mode should only be assigned to Timer1. On every rising edge seen by the external pin, this mode increments a 16-bit register. When that register matches the specified timer value (stop count value), Timer0 is stopped. The range for the stop count value is 1-65535. Generally, the signal applied to Timer1 is from Timer0, which is configured in some output timer mode. One place where this might be useful is for stepper motors, allowing control over a certain number of steps.

Once this timer reaches the specified stop count value, and stops the adjacent timer, the timers must be reconfigured to restart the output.

When Timer0 is stopped, it is still enabled but just not outputting anything. Thus rather than returning to whatever previous digital I/O state was on that terminal, it goes to the state "digital-input" (which has a 100 kΩ pull-up to 3.3 volts). That means the best results are generally obtained if the terminal used by Timer0 was initially configured as digital input (factory default), rather than output-high or output-low.

The MSW of the read from this timer mode returns the number of edges counted, but does not increment past the stop count value. The LSW of the read returns edges waiting for.

2.9.1.10 - System Timer Low/High Read (Modes 10 & 11)

The LabJack U3 has a free-running internal 64-bit system timer with a frequency of 4 MHz. Timer modes 10 & 11 return the lower or upper 32-bits of this timer. An FIO line is allocated for these modes like normal, even though they are internal readings and do not require any external connections. This system timer cannot be reset, and is not affected by the timer clock.

If using both modes 10 & 11, read both in the same low-level command and read 10 before 11.

Mode 11, the upper 32 bits of the system timer, is not available for stream reads. Note that when streaming on the U3, the timing is known anyway (elapsed time = scan rate * scan number) and it does not make sense to stream the system timer modes 10 or 11.

2.9.1.11 - Period Measurement (16-Bit, Modes 12 & 13)

Similar to the 32-bit edge-to-edge timing modes described above (modes 2 & 3), except that hardware capture registers are used to record the edge times. This limits the times to 16-bit values, but is accurate to the resolution of the clock, and not subject to any errors due to firmware processing delays.

Note that the minimum measurable period is limited by the edge rate limit discussed in Section 2.9.2.

2.9.1.12 - Line-to-Line Measurement (Mode 14)

This timer mode requires firmware 1.30 or later.

Introduction:

The Line-to-Line timer mode uses two timers to measure the time between specified edges on two different lines. For instance, you can measure the time between a rising edge on Timer0 and a falling edge on Timer1. When the LabJack sees the specified edge on Timer0 it starts counting until it sees the specified edge on Timer1. High resolution up to 20.8ns can be achieved with this mode.

Configuring:

To configure a LabJack for Line-to-Line mode set an even timer and the next (odd) timer to mode 14. The timer values determine the edge that the timer will respond to, 1 being rising, 0 being falling. So, if Timer0's value is 0 and Timer1's is 1 then the LabJack will measure the time between a falling edge on Timer0 to a rising edge on Timer1.

Readings:

Once configured the timer will return zero until both specified edges have been detected. The time difference in TimerClock periods is then returned by both timers until they are reset. Both timers will return the same reading, so it is only necessary to read one or the other. To convert to time, divide the value returned by the timer clock. This mode returns 16-bit values, so care should be taken to be sure that the specified condition does not exceed the maximum time. The maximum time can be calculated by (2^16-1)/TimerClock.

Reseting:

Once a measurement has been acquired the even timer needs to be reset before the LabJack will measure again. Values specified when resetting have no effect. Once reset the even timer will return zero until a new measurement has been completed. Resetting the odd timer is optional, if not reset it will continue to return the last measurement until a new one has been completed.

2.9.1.12 - Line-to-Line (Mode 14)

2.9.2 - Timer Operation/Performance Notes

Note that the specified timer clock frequency is the same for all timers. That is, TimerClockBase and TimerClockDivisor are singular values that apply to all timers. Modes 0, 1, 2, 3, 4, 7, 12, and 13, all are affected by the clock frequency, and thus the simultaneous use of these modes has limited flexibility. This is often not an issue for modes 2 and 3 since they use 32-bit registers.

The output timer modes (0, 1, and 7) are handled totally by hardware. Once started, no processing resources are used and other U3 operations do not affect the output.

The edge-detecting timer input modes do require U3 processing resources, as an interrupt is required to handle each edge. Timer modes 2, 3, 5, 9, 12, and 13 must process every applicable edge (rising **or** falling). Timer modes 4 and 8 must process every edge (rising **and** falling). To avoid missing counts, keep the total number of processed edges (all timers) less than 30,000 per second (hardware V1.21). That means that in the case of a single timer, there should be no more than 1 edge per 33 µs. For multiple timers, all can process an edge simultaneously, but if for instance both timers get an edge at the same time, 66 µs should be allowed before any further edges are applied. If streaming is occurring at the same time, the maximum edge rate will be less (7,000 per second), and since each edge requires processing time the sustainable stream rates can also be reduced.

2.10 - SPC (… and SCL/SDA/SCA)

The SPC terminal is used for manually resetting default values or jumping in/out of flash programming mode.

Hardware revision 1.20 and 1.21, had terminals labeled SCL, SDA, and/or SCA. On revision 1.20, these terminals did nothing except that SCL is used for the SPC functionality described above. On revision 1.21, these terminals were used for asynchronous functionality, and SCL is used for the SPC functionality described above. Note that these terminals never have anything to do with I²C.

2.11 - DB15

The DB15 connector brings out 12 additional digital I/O. It has the potential to be used as an expansion bus, where the 8 EIO are data lines and the 4 CIO are control lines.

In the Windows LabJackUD driver, the EIO are addressed as digital I/O bits 8 through 15, and the CIO are addressed as bits 16-19.

```
0-7    FIO0-FIO7
8-15   EIO0-EIO7
16-19  CIO0-CIO3
```

These 12 channels include an internal series resistor that provides overvoltage/short-circuit protection. These series resistors also limit the ability of these lines to sink or source current. Refer to the specifications in Appendix A.

All digital I/O on the U3 have 3 possible states: input, output-high, or output-low. Each bit of I/O can be configured individually. When configured as an input, a bit has a ~100 kΩ pull-up resistor to 3.3 volts. When configured as output-high, a bit is connected to the internal 3.3 volt supply (through a series resistor). When configured as output-low, a bit is connected to GND (through a series resistor).

DB15 Pinouts				
1	Vs	9	CIO0	
2	CIO1	10	CIO2	
3	CIO3	11	GND	
4	EIO0	12	EIO1	
5	EIO2	13	EIO3	
6	EIO4	14	EIO5	
7	EIO6	15	EIO7	
8	GND			

Table 2.11-1. DB15 Connector Pinouts

2.11.1 - CB15 Terminal Board

The CB15 terminal board connects to the LabJack U3's DB15 connector. It provides convenient screw terminal access to the 12 digital I/O available on the DB15 connector. The CB15 is designed to connect directly to the LabJack, or can connect via a standard 15-line 1:1 male-female DB15 cable.

2.11.2 - RB12 Relay Board

The RB12 relay board provides a convenient interface for the U3 to industry standard digital I/O modules, allowing electricians,

engineers, and other qualified individuals, to interface a LabJack with high voltages/currents. The RB12 relay board connects to the DB15 connector on the LabJack, using the 12 EIO/CIO lines to control up to 12 I/O modules. Output or input types of digital I/O modules can be used. The RB12 is designed to accept G4 series digital I/O modules from Opto22, and compatible modules from other manufacturers such as the G5 series from Grayhill. Output modules are available with voltage ratings up to 200 VDC or 280 VAC, and current ratings up to 3.5 amps.

2.12 - U3-OEM

There is an OEM version of the U3 available (-LV and -HV). It is a board only (no enclosure, no screwdriver, no cable), and does not have most of the through-hole components installed. The picture below shows how the U3-OEM ships by default. Leaving the through-hole parts off makes the OEM board very flexible. Many applications do not need the through-hole parts, but if needed they are much easier to install than uninstall.

The U3 PCB has alternate holes available for standard 0.1" pin-header installation. Example connectors are the Digikey WM268xx (where, for example, xx is 16 for the 2x8 header).

The 2x5 header JTAG is normally installed on the U3 and U3-OEM. This header is for factory use. You can use a mating header for physical support purposes, but it should not connect to anything.

Connectors J3 & J4 provide pin-header access to the connections that would normally appear on the left and right screw-terminals. Connector J2 provides a pin-header alternative to the DB15 connector. All these connector holes are always present, but J2 is obstructed when the DB15 is installed. The idea is that an OEM can connect ribbon cables to the pin-headers, or even plug the U3 directly to the customers main board designed with mating pin-header receptacles. See Appendix B for connector coordinates on the PCB.

J2				
1	GND		2	VS
3	CIO0		4	CIO1
5	CIO2		6	CIO3
7	GND		8	EIO0
9	EIO1		10	EIO2
11	EIO3		12	EIO4
13	EIO5		14	EIO6
15	EIO7		16	GND

Table 2.12-1. J2 Connector Pin-Headers

J3				
1	FIO4		2	FIO5
3	FIO6		4	FIO7
5	VS		6	GND
7	GND *		8	SPC **
9	VS		10	GND

* SDA on <1.30
** SCL on <1.30

Table 2.12-2. J3 Connector Pin-Headers

J4				
1	FIO0		2	FIO1
3	FIO2		4	FIO3
5	VS		6	GND
7	DAC0		8	DAC1
9	VS		10	GND

Table 2.12-3. J4 Connector Pin-Headers

USB (USB1)

There are 4 holes for a standard Type-B USB connection (plus a couple large holes for mounting tabs). Looking at the bottom (solder-side) of the PCB with the USB/LED end of the PCB up, GND (pin 4, black wire) is in the upper-right corner. Then clockwise it goes Vbus (5 volts, lower-right, pin 1, red wire), D- (lower-left, pin 2, white wire), and D+ (upper-left, pin 3, green wire). If using a normal Type-B USB connector (such as the Digikey 609-1039), it must be installed on the component side of the PCB.

Alternative Power Supply

Generally 5 volt power is provided via the USB connector holes, and usually it is provided from the USB host. There are few reasons, if any, to power the U3 from anything besides the USB host. The only valid reason we hear has to do with keeping the U3 powered even when the USB host loses power, which is an unusual requirement in itself since the U3 does not really do anything without a USB host connected. If you are considering an external supply for reasons related to noise or stability, you are probably "barking up the wrong tree" and should contact support@labjack.com.

The power supply provided by USB is typically 5 volts +/-5% @500 mA. The basic way to use an alternate supply is connecting it to hole 1 of the USB connector holes, instead of the supply from the USB host. Or if using a USB cable, cut the red wire inside the cable and connect your positive supply lead to that (also might need a connection of the negative supply lead to the black wire but

don't cut it). You can also connect an external supply to VS/GND screw-terminals (after cutting the red wire in the USB cable), but it is preferable to bring the supply in through the USB connector.

Note that USB ground and the external supply common/negative/ground must both connect to GND on the U3 (which could mean just the ground in the USB cable is needed if the power supply is already connected to that same ground). Also note that you never want 2 supplies connected directly to each other without any mechanism to prevent one supply from backfeeding the other.

2.13 - Hardware Revision Notes

U3A = Revision 1.20
U3B = Revision 1.21
U3C = Revision 1.30

Starting September of 2006, all U3 shipments changed from hardware revision 1.20 to 1.21. Following are the some of the main changes in revision 1.21:

- The default timer clock frequency is 48 MHz.
- All TimerBaseClock frequencies are twice the previous frequencies.
- The input timer edge limit is now 30,000 edges/second, compared to the old limit of 10,000 edges/second.
- Stream mode is now supported. See Section 3.2.
- Other new functions are supported, including Watchdog, SPI, Asynch, I2C, and SHT1X.
- Typical supply current is 50 mA.

Revision 1.20 can be upgraded to 1.21 by LabJack for a small fee. For information about upgrading a rev 1.20 unit, contact LabJack Corporation.

Hardware revision 1.30 was released in mid-March 2008 with 2 variations: U3-LV and U3-HV. The U3-LV is the most compatible with the previous U3, and the only changes possibly affecting backwards compatibility are:

- Timers/Counters cannot appear on FIO0-3. TimerCounterPinOffset must be 4-8. A value of 0-3 will result in an error. This error can be suppressed by a power-up default setting in LJControlPanel. If suppressed, a 0-3 will result in an offset of 4.
- The 3.66 reference voltage is no longer available on the REF/DAC1 terminal.
- There is no longer a buzzer.
- SDA terminal is gone. SCL terminal changed to SPC.
- UART (Asynch functionality) no longer uses SDA and SPC terminals, but rather uses terminals dynamically assigned after timers and counters. Also, the BaudFactor is different.

Other changes:

- Analog outputs are now specified for 10-bit resolution and DAC1 is always enabled. The higher resolution is available with a new IOType in the low-level Feedback function, which the high-level UD driver uses automatically. This causes the DACs to have more noise when the timer clock is decreased from the default of 48 MHz, so there is a compatibility option available in LJControlPanel to use 8-bit DACs.
- On the U3-HV only, the first four flexible I/O are fixed as analog inputs (AIN0-AIN3), and have scaling such that the input range is ±10 volts normally, and +20 to -10 volts when using the “Special” range. The input impedance of these four lines is roughly 1 MΩ, which is good, but less than the normal low voltage analog inputs. Analog/digital configuration and all other digital operations on these pins are ignored. FIO4-EIO7 are still available as flexible I/O, same as the U3-LV.

Revision 1.20/21 U3s cannot be upgraded to 1.30.

3 - Operation

The following sections discuss command/response mode and stream mode.

Command/response mode is where communication is initiated by a command from the host which is followed by a response from the LabJack. Command/response is generally used at 1000 scans/second or slower and is generally simpler than stream mode.

Stream mode is a continuous hardware-timed input mode where a list of channels is scanned at a specified scan rate. The scan rate specifies the interval between the beginning of each scan. The samples within each scan are acquired as fast as possible. As samples are collected automatically by the LabJack, they are placed in a buffer on the LabJack, until retrieved by the host. Stream mode is generally used at 10 scans/second or faster.

Command/response mode is generally best for minimum-latency applications such as feedback control. By latency here we mean the time from when a reading is acquired to when it is available in the host software. A reading or group of readings can be acquired in times on the order of a millisecond.

Stream mode is generally best for maximum-throughput applications where latency is not so important. Data is acquired very fast, but to sustain the fast rates it must be buffered and moved from the LabJack to the host in large chunks. For example, a typical stream application might set up the LabJack to acquire a single analog input at 50,000 samples/second. The LabJack moves this data to the host in chunks of 25 samples each. The Windows UD driver moves data from the USB host memory to the UD driver memory in chunks of 2000 samples. The user application might read data from the UD driver memory once a second in a chunk of 50,000 samples. The computer has no problem retrieving, processing, and storing, 50k samples once per second, but it could not do that with a single sample 50k times per second.

3.1 - Command/Response

Everything besides streaming is done in command/response mode, meaning that all communication is initiated by a command from the host which is followed by a response from the U3.

For everything besides pin configuration, the low-level Feedback function is the primary function used, as it writes and reads virtually all I/O on the U3. The Windows UD driver uses the Feedback function under-the-hood to handle most requests besides configuration and streaming.

The following tables show typical measured execution times for command/response mode. The time varies primarily with the number of analog inputs requested, and is not noticeably affected by the number of digital I/O, DAC, timer, and counter operations.

These times were measured using the example program “allio.c” (VC6_LJUD). The program executes a loop 1000 times and divides the total time by 1000, and thus include everything (Windows latency, UD driver overhead, communication time, U3 processing time, etc.).

# AIN	USB high-high [miliseconds]	USB other [miliseconds]	
0	0.6	4	<- Write/Read all DIO, DACs, Timers and Counters
1	1	4	
4	2.4	4	
8	4.7	9.2	
16	8.3	12.2	

Table 3.1-1. Typical Feedback Function Execution Times (QuickSample=0, LongSettling=0)

# AIN	USB high-high [miliseconds]	USB other [miliseconds]	
0	0.6	4	<- Write/Read all DIO, DACs, Timers and Counters
1	0.7	4	
4	1	4	
8	2.1	8	
16	3	8	

Table 3.1-2. Typical Feedback Function Execution Times (QuickSample=1, LongSettling=0)

# AIN	USB high-high [miliseconds]	USB other [miliseconds]	
0	0.6	4	<- Write/Read all DIO, DACs, Timers and Counters
1	4.2	5.2	
4	16	17	
8	31	36	
16	60	62	

Table 3.1-3. Typical Feedback Function Execution Times (QuickSample=0, LongSettling=1)

A “USB high-high” configuration means the U3 is connected to a high-speed USB2 hub which is then connected to a high-speed USB2 host. Even though the U3 is not a high-speed USB device, such a configuration does provide improved performance.

The analog inputs have a QuickSample option where each conversion is done faster at the expense of increased noise. This is enabled by passing a nonzero value for put_config special channel *LJ_chAIN_RESOLUTION*. There is also a LongSettling option where additional settling time is added between the internal multiplexer configuration and the analog to digital conversion. This allows signals with more source impedance, and is enabled by passing a nonzero value for put_config special channel *LJ_chAIN_SETTLING_TIME*. Both of these options are disabled by default, so the first table above shows the default conditions.

The first row in each of the above tables (# AIN = 0) includes a write and read to all I/O on the U3 besides analog inputs (digital I/O, DACs, timers, and counters). The times in other rows basically consist of that fixed overhead plus the time per analog input channel, so times can be interpolated for other numbers of channels.

How about for 2 analog input channels with QuickSample=0 and LongSettling=0? You know that 1 channel takes about 1.0 ms and 4 channels takes about 2.4 ms. That means it takes about (2.4-1.0)/(4-1) = 0.46 ms/channel plus overhead of about 0.6 ms, so 2 channels would take about (2*0.46)+0.6 = 1.5 ms.

How about for 20 channels? This is a little different because the commands and/or responses for 20 channels can't fit in one low-level packet. From Section 5.2.5, the Feedback command has room for 57 bytes of command data and 55 bytes of response data. From Section 5.2.5.1, the AIN low-level IOType has 3 command bytes and 2 response bytes. That means the low-level Feedback command can hold 19 commands and 27 responses. Thus the commands are limiting and 19 channels is the most we can get into 1 low-level Feedback packet. The timing for 20-channels can then be calculated as a 19-channel read plus a subsequent 1-channel read. If you do an Add/Go/Get block with 20 channels the UD driver will split it like that.

The tables above were measured with U3 hardware version 1.21 which started shipping in late August of 2006. The times could be up to twice as long with hardware version 1.20 or less.

3.2 - Stream Mode

The highest input data rates are obtained in stream mode, which is supported with U3 hardware version 1.21 or higher. Hardware version 1.21 started shipping in late August of 2006. Contact LabJack for information about upgrading older U3s. Stream is a continuous hardware timed input mode where a list of channels is scanned at a specified scan rate. The scan rate specifies the interval between the beginning of each scan. The samples within each scan are acquired as fast as possible.

As samples are collected, they are placed in a small FIFO buffer on the U3, until retrieved by the host. The buffer typically holds 984 samples, but the size ranges from 512 to 984 depending on the number of samples per packet. Each data packet has various measures to ensure the integrity and completeness of the data received by the host.

Since the data buffer on the U3 is very small it uses a feature called auto-recovery. If the buffer overflows, the U3 will continue streaming but discard data until the buffer is emptied, and then data will be stored in the buffer again. The U3 keeps track of how many packets are discarded and reports that value. Based on the number of packets discarded, the UD driver adds the proper number of dummy samples (-9999.0) such that the correct timing is maintained.

The table below shows various stream performance parameters. Some systems might require a USB high-high configuration to obtain the maximum speed in the last row of the table. A “USB high-high” configuration means the U3 is connected to a high-speed USB2 hub which is then connected to a high-speed USB2 host. Even though the U3 is not a high-speed USB device, such a configuration does often provide improved performance.

Stream data rates over USB can also be limited by other factors such as speed of the PC and program design. One general technique for robust continuous streaming would be increasing the priority of the stream process.

A sample is defined as a single conversion of a single channel, while a scan is defined as a single conversion of all channels being acquired. That means the maximum scan rate for a stream of five channels is 50k/5 = 10 kscans/second.

Low-Level Res Index	UD Res Index	Max Stream (Samples/s)	ENOB (RMB)	ENOB (Noise-Free)	Noise (Counts)	Interchannel Delay (µs)
0	100	2500	12.8	10	±2	320
1	101	10000	11.9	9	±4	82
2	102	20000	11.3	8.4	±6	42
3	103	50000	10.5	7.5	±11	12.5

Table 3.2-1. Streaming at Various Resolutions

Full resolution streaming is limited to 2500 samples/s, but higher speeds are possible at the expense of reduced effective resolution (increased noise). The first column above is the index passed in the Resolution parameter to the low-level StreamConfig function, while the second column is the corresponding index for the Resolution parameter in the UD driver. In the UD driver, the default Resolution index is 0, which corresponds to automatic selection. In this case, the driver will use the highest resolution for the specified sample rate.

ENOB stands for effective number of bits. The first ENOB column is the commonly used “effective” resolution, and can be thought of as the resolution obtained by most readings. This data is calculated by collecting 128 samples and evaluating the standard deviation (RMS noise). The second ENOB column is the noise-free resolution, and is the resolution obtained by all readings. This data is calculated by collecting 128 samples and evaluating the maximum value minus the minimum value (peak-to-peak noise). Similarly, the Noise Counts column is the peak-to-peak noise based on counts from a 12-bit reading.

Interchannel delay is the time between successive channels within a stream scan.

3.2.1 - Streaming Digital Inputs, Timers, and Counters

There are special channel numbers that allow digital inputs, timers, and counters, to be streamed in with analog input data.

Channel #	
193	EIO_FIO
194	CIO
200	Timer0
201	Timer1
210	Counter0
211	Counter1
224	TC_Capture
230	Timer0 with reset
231	Timer1 with reset
240	Counter0 with reset
241	Counter1 with reset

Special Channels:

193: Returns the input states of 16 bits of digital I/O. FIO is the lower 8 bits and EIO is the upper 8 bits.

194: Returns the input states of 16 bits of digital I/O. CIO is the lower 8 bits.

200-201 and 210-211: Retrieves the least significant word (LSW, lower 2 bytes) of the specified timer/counter. At the same time that any one of these is sampled, the most significant word (MSW, upper 2 bytes) of that particular timer/counter is stored in an internal capture register (TC_Capture), so that the proper value can be sampled later in the scan. For any timer/counter where the MSW is wanted, channel number 224 must be sampled after that channel and before any other timer/counter channel. For example, a scan list of {200,224,201,224} would get the LSW of Timer0, the MSW of Timer0, the LSW of Timer1, and the MSW of Timer1. A scan list of {200,201,224} would get the LSW of Timer0, the LSW of Timer1, and the MSW of Timer1 (MSW of Timer0 is lost).

230-231 and 240-241: These channels perform the same operation as their 200-211 counterpart above, then reset the timer or counter.

Adding these special channels to the stream scan list does not configure those inputs. If any of the FIO or EIO lines have been configured as outputs, timers, counter, or analog inputs, a channel 193 read will still be performed without error but the values from those bits should be ignored. The timers/counters (200-224) must be configured before streaming using normal timer/counter configuration commands.

The timing for these special channels is the same as for normal analog channels. For instance, a stream of the scan list {0,1,200,224,201,224} counts as 6 channels, and the maximum scan rate is determined by taking the maximum sample rate at the specified resolution and dividing by 6.

Special care must be taken when streaming timers configured in mode 2 or 3 (32-bit period measurement). It is possible for the LSW to roll, but the MSW be captured before it is incremented. That means the resulting value will be low by 65536 clock ticks, which is easy to detect in many applications, but if this is an unacceptable situation then only the LSW or MSW should be used and not both.

Mode 11, the upper 32 bits of the system timer, is not available for stream reads. Note that when streaming on the U3, the timing is known anyway (elapsed time = scan rate * scan number) and it does not make sense to stream the system timer modes 10 or 11.

4 - LabJackUD High-Level Driver

The low-level U3 functions are described in Section 5, but most Windows applications will use the LabJackUD driver instead.

The latest version of the driver driver requires a PC running Windows XP, Vista, or 7. The 3.07 version, supports Windows 98, ME, 2000. It is recommended to install the software before making a USB connection to a LabJack.

The download version of the installer consists of a single executable. This installer places the driver (LabJackUD.dll) in the Windows System directory, along with a support DLL (LabJackUSB.dll). Generally this is c:\Windows\System\ on Windows 98/ME, and c:\Windows\System32\ on Windows 2000/XP.

Other files, including the header and Visual C library file, are installed to the LabJack drivers directory which defaults to c:\Program Files\LabJack\drivers\.

4.1 - Overview

The general operation of the LabJackUD functions is as follows:

- Open a LabJack.
- Build a list of requests to perform (Add).
- Execute the list (Go).
- Read the result of each request (Get).

At the core, the UD driver only has 4 basic functions: Open, AddRequest, Go, and GetResult. Then with these few functions, there are many constants used to specify the desired actions. When programming in any language, it is recommended to have the header file handy, so that constants can be copied and pasted into the code.

The first type of constant is an IOType, which is always passed in the IOType parameter of a function call. One example of an IOType is the constant *LJ_ioPUT_DAC*, which is used to update the value of an analog output (DAC).

The second type of constant is a Channel Constant, also called a Special Channel. These constants are always passed in the Channel parameter of a function call. For the most part, these are used when a request is not specific to a particular channel, and go with the configuration IOTypes (*LJ_ioPUT_CONFIG* or *LJ_ioGET_CONFIG*). One example of a Special Channel is the constant *LJ_chLOCALID*, which is used to write or read the local ID of the device.

The third major type of constant used by the UD driver is a Value Constant. These constants are always passed in the Value parameter of a function call. One example of a Value Constant is the constant *LJ_tmPWM8*, which specifies a timer mode. This constant has a numeric value of 1, which could be passed instead, but using the constant *LJ_tmPWM8* makes for programming code that is easier to read.

Following is pseudocode that performs various actions. First, a call is done to open the device. The primary work done with this call is finding the desired device and creating a handle that points to the device for further function calls. In addition, opening the device performs various configuration and initialization actions, such as reading the calibration constants from the device:

```
//Use the following line to open the first found LabJack U3
//over USB and get a handle to the device.
//The general form of the open function is:
//OpenLabJack (DeviceType, ConnectionType, Address, FirstFound, *Handle)

//Open the first found LabJack U3 over USB.
lngErrorcode = OpenLabJack (LJ_dtU3, LJ_ctUSB, "1", TRUE, &lngHandle);
```

Second, a list of requests is built in the UD driver using AddRequest calls. This does not involve any low-level communication with

the device, and thus the execution time is relatively instantaneous:

```
//Request that DAC0 be set to 2.5 volts.
//The general form of the AddRequest function is:
//AddRequest (Handle, IOType, Channel, Value, x1, UserData)
lngErrorcode = AddRequest (lngHandle, LJ_ioPUT_DAC, 0, 2.50, 0, 0);

//Request a read from AIN3 (FIO3), assuming it has been enabled as
//an analog line.
lngErrorcode = AddRequest (lngHandle, LJ_ioGET_AIN, 3, 0, 0, 0);
```

Third, the list of requests is processed and executed using a Go call. In this step, the driver determines which low-level commands must be executed to process all the requests, calls those low-level functions, and stores the results. This example consists of two requests, one analog input read and one analog output write, which can both be handled in a single low-level Feedback call (Section 5.2.5):

```
//Execute the requests.
lngErrorcode = GoOne (lngHandle);
```

Finally, GetResult calls are used to retrieve the results (errorcodes and values) that were stored by the driver during the Go call. This does not involve any low-level communication with the device, and thus the execution time is relatively instantaneous:

```
//Get the result of the DAC0 request just to check for an errorcode.
//The general form of the GetResult function is:
//GetResult (Handle, IOType, Channel, *Value)
lngErrorcode = GetResult (lngHandle, LJ_ioPUT_DAC, 0, 0);

//Get the AIN3 voltage.  We pass the address to dblValue and the
//voltage will be returned in that variable.
lngErrorcode = GetResult (lngHandle, LJ_ioGET_AIN, 3, &dblValue);
```

The AddRequest/Go/GetResult method is often the most efficient. As shown above, multiple requests can be executed with a single Go() or GoOne() call, and the driver might be able to optimize the requests into fewer low-level calls. The other option is to use the eGet or ePut functions which combine the AddRequest/Go/GetResult into one call. The above code would then look like (assuming the U3 is already open):

```
//Set DAC0 to 2.5 volts.
//The general form of the ePut function is:
//ePut (Handle, IOType, Channel, Value, x1)
lngErrorcode = ePut (lngHandle, LJ_ioPUT_DAC, 0, 2.50, 0);

//Read AIN3.
//The general form of the eGet function is:
//eGet (Handle, IOType, Channel, *Value, x1)
lngErrorcode = eGet (lngHandle, LJ_ioGET_AIN, 3, &dblValue, 0);
```

In the case of the U3, the first example using add/go/get handles both the DAC command and AIN read in a single low-level call, while in the second example using ePut/eGet two low-level commands are used. Examples in the following documentation will use both the add/go/get method and the ePut/eGet method, and they are generally interchangeable. See Section 4.3 for more pseudocode examples.

All the request and result functions always have 4 common parameters, and some of the functions have 2 extra parameters:

- **Handle** – This is an input to all request/result functions that tells the function what LabJack it is talking to. The handle is obtained from the OpenLabJack function.
- **IOType** – This is an input to all request/result functions that specifies what type of action is being done.
- **Channel** – This is an input to all request/result functions that generally specifies which channel of I/O is being written/read, although with the config IOTypes special constants are passed for channel to specify what is being configured.
- **Value** – This is an input or output to all request/result functions that is used to write or read the value for the item being operated on.
- **x1** – This parameter is only used in some of the request/result functions, and is used when extra information is needed for certain IOTypes.
- **UserData** – This parameter is only used in some of the request/result functions, and is data that is simply passed along with the request, and returned unmodified by the result. Can be used to store any sort of information with the request, to allow a generic parser to determine what should be done when the results are received.

4.1.1 - Function Flexibility

The driver is designed to be flexible so that it can work with various different LabJacks with different capabilities. It is also designed to work with different development platforms with different capabilities. For this reason, many of the functions are repeated with different forms of parameters, although their internal functionality remains mostly the same. In this documentation, a group of functions will often be referred to by their shortest name. For example, a reference to Add or AddRequest most likely refers to any of the three variations: AddRequest(), AddRequestS() or AddRequestSS(). In the sample code, alternate functions (S or SS versions) can generally be substituted as desired, changing the parameter types accordingly. All samples here are written in pseudo-C. Functions with an “S” or “SS” appended are provided for programming languages that can’t include the LabJackUD.h file and therefore can’t use the constants included. It is generally poor programming form to hardcode numbers into function calls, if for no other reason than it is hard to read. Functions with a single “S” replace the IOType parameter with a const char * which is a string. A string can then be passed with the name of the desired constant. Functions with a double “SS” replace both the IOType and Channel with strings. OpenLabJackS replaces both DeviceType and ConnectionType with strings since both take constants. For example: In C, where the LabJackUD.h file can be included and the constants used directly:

```
AddRequest(Handle, LJ_ioGET_CONFIG, LJ_chHARDWARE_VERSION,0,0,0);
```

The bad way (hard to read) when LabJackUD.h cannot be included:

```
AddRequest(Handle, 1001, 10, 0, 0, 0);
```

The better way when LabJackUD.h cannot be included, is to pass strings:

```
AddRequestSS(Handle, “LJ_ioGET_CONFIG”, “LJ_chHARDWARE_VERSION”,0,0,0);
```

Continuing on this vein, the function StringToConstant() is useful for error handling routines, or with the GetFirst/Next functions which do not take strings. The StringToConstant() function takes a string and returns the numeric constant. So, for example:

```
LJ_ERROR err;
err = AddRequestSS(Handle, “LJ_ioGETCONFIG”, “LJ_chHARDWARE_VERSION”,0,0,0);
if (err == StringToConstant(“LJE_INVALID_DEVICE_TYPE”))
  do some error handling..
```

Once again, this is much clearer than:

```
if (err == 2)
```

4.1.2 - Multi-Threaded Operation

The UD driver is completely thread safe. With some very minor exceptions, all these functions can be called from multiple threads at the same time and the driver will keep everything straight. Because of this Add, Go, and Get must be called from the same

thread for a particular set of requests/results. Internally the list of requests and results are split by thread. This allows multiple threads to be used to make requests without accidentally getting data from one thread into another. If requests are added, and then results return *LJE_NO_DATA_AVAILABLE* or a similar error, chances are the requests and results are in different threads.

The driver tracks which thread a request is made in by the thread ID. If a thread is killed and then a new one is created, it is possible for the new thread to have the same ID. Its not really a problem if Add is called first, but if Get is called on a new thread results could be returned from the thread that already ended.

As mentioned, the list of requests and results is kept on a thread-by-thread basis. Since the driver cannot tell when a thread has ended, the results are kept in memory for that thread regardless. This is not a problem in general as the driver will clean it all up when unloaded. When it can be a problem is in situations where threads are created and destroyed continuously. This will result in the slow consumption of memory as requests on old threads are left behind. Since each request only uses 44 bytes, and as mentioned the ID's will eventually get recycled, it will not be a huge memory loss. In general, even without this issue, it is strongly recommended to not create and destroy a lot of threads. It is terribly slow and inefficient. Use thread pools and other techniques to keep new thread creation to a minimum. That is what is done internally.

The one big exception to the thread safety of this driver is in the use of the Windows TerminateThread() function. As is warned in the MSDN documentation, using TerminateThread() will kill the thread without releasing any resources, and more importantly, releasing any synchronization objects. If TerminateThread() is used on a thread that is currently in the middle of a call to this driver, more than likely a synchronization object will be left open on the particular device and access to the device will be impossible until the application is restarted. On some devices, it can be worse. On devices that have interprocess synchronization, such as the U12, calling TerminateThread() may kill all access to the device through this driver no matter which process is using it and even if the application is restarted. Avoid using TerminateThread()! All device calls have a timeout, which defaults to 1 second, but can be changed. Make sure to wait at least as long as the timeout for the driver to finish.

4.2 - Function Reference

The LabJack driver file is named LabJackUD.dll, and contains the functions described in this section.

Some parameters are common to many functions:

- **LJ_ERROR** – A LabJack specific numeric errorcode. 0 means no error. (long, signed 32-bit integer).
- **LJ_HANDLE** – This value is returned by OpenLabJack, and then passed on to other functions to identify the opened LabJack. (long, signed 32-bit integer).

To maintain compatibility with as many languages as possible, every attempt has been made to keep the parameter types very basic. Also, many functions have multiple prototypes. The declarations that follow, are written in C.

To help those unfamiliar with strings in C, these functions expect null terminated 8 bit ASCII strings. How this translates to a particular development environment is beyond the scope of this documentation. A const char * is a pointer to a string that won't be changed by the driver. Usually this means it can simply be a constant such as "this is a string". A char * is a pointer to a string that will be changed. Enough bytes must be preallocated to hold the possible strings that will be returned. Functions with char * in their declaration will have the required length of the buffer documented below.

Pointers must be initialized in general, although null (0) can be passed for unused or unneeded values. The pointers for GetStreamData and RawIn/RawOut requests are not optional. Arrays and char * type strings must be initialized to the proper size before passing to the DLL.

4.2.1 - ListAll()

Returns all the devices found of a given DeviceType and ConnectionType. Currently only USB is supported.

ListAllS() is a special version where DeviceType and ConnectionType are strings rather than longs. This is useful for passing string constants in languages that cannot include the header file. The strings should contain the constant name as indicated in the header file (such as "LJ_dtU3" and "LJ_ctUSB"). The declaration for the S version of open is the same as below except for (const char *pDeviceType, const char *pConnectionType, …).

Declaration:

```
LJ_ERROR _stdcall ListAll (  long DeviceType,
                             long ConnectionType,
                             long *pNumFound,
                             long *pSerialNumbers,
                             long *pIDs,
                             double *pAddresses)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **DeviceType** – The type of LabJack to search for. Constants are in the labjackud.h file.
- **ConnectionType** – Enter the constant for the type of connection to use in the search. Currently, only USB is supported for this function.
- **pSerialNumbers** – Must pass a pointer to a buffer with at least 128 elements.
- **pIDs** – Must pass a pointer to a buffer with at least 128 elements.
- **pAddresses** – Must pass a pointer to a buffer with at least 128 elements.

Outputs:

- **pNumFound** – Returns the number of devices found, and thus the number of valid elements in the return arrays.
- **pSerialNumbers** – Array contains serial numbers of any found devices.
- **pIDs** – Array contains local IDs of any found devices.
- **pAddresses** – Array contains IP addresses of any found devices. The function DoubleToStringAddress() is useful to convert these to string notation.

4.2.2 - OpenLabJack()

Call OpenLabJack() before communicating with a device. This function can be called multiple times, however, once a LabJack is open, it remains open until your application ends (or the DLL is unloaded). If OpenLabJack is called repeatedly with the same parameters, thus requesting the same type of connection to the same LabJack, the driver will simply return the same LJ_HANDLE every time. Internally, nothing else happens. This includes when the device is reset, or disconnected. Once the device is reconnected, the driver will maintain the same handle. If an open call is made for USB, and then Ethernet, a different handle will be returned for each connection type and both connections will be open.

OpenLabJackS() is a special version of open where DeviceType and ConnectionType are strings rather than longs. This is useful for passing string constants in languages that cannot include the header file. The strings should contain the constant name as indicated in the header file (such as "LJ_dtU3" and "LJ_ctUSB"). The declaration for the S version of open is the same as below except for (const char *pDeviceType, const char *pConnectionType, …).

Declaration:

```
LJ_ERROR _stdcall OpenLabJack (  long DeviceType,
                                 long ConnectionType,
                                 const char *pAddress,
                                 long FirstFound,
                                 LJ_HANDLE *pHandle)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **DeviceType** – The type of LabJack to open. Constants are in the labjackud.h file.
- **ConnectionType** – Enter the constant for the type of connection. USB only for the U3.
- **pAddress** – Pass the local ID or serial number of the desired LabJack. If FirstFound is true, Address is ignored.
- **FirstFound** – If true, then the Address and ConnectionType parameters are ignored and the driver opens the first LabJack found with the specified DeviceType. Generally only recommended when a single LabJack is connected.

Outputs:

- **pHandle** – A pointer to a handle for a LabJack.

4.2.3 - eGet() and ePut()

The eGet and ePut functions do AddRequest, Go, and GetResult, in one step.

The eGet versions are designed for inputs or retrieving parameters as they take a pointer to a double where the result is placed, but can be used for outputs if pValue is preset to the desired value. This is also useful for things like StreamRead where a value is input and output (number of scans requested and number of scans returned).

The ePut versions are designed for outputs or setting configuration parameters and will not return anything except the errorcode.

eGetS() and ePutS() are special versions of these functions where IOType is a string rather than a long. This is useful for passing string constants in languages that cannot include the header file, and is generally used with all IOTypes except put/get config. The string should contain the constant name as indicated in the header file (such as "LJ_ioANALOG_INPUT"). The declarations for the S versions are the same as the normal versions except for (…, const char *pIOType, …).

eGetSS() and ePutSS() are special versions of these functions where IOType and Channel are strings rather than longs. This is useful for passing string constants in languages that cannot include the header file, and is generally only used with the put/get config IOTypes. The strings should contain the constant name as indicated in the header file (such as "LJ_ioPUT_CONFIG" and "LJ_chLOCALID"). The declaration for the SS versions are the same as the normal versions except for (…, const char *pIOType, const char *pChannel, …).

The declaration for ePut is the same as eGet except that Value is not a pointer (…, double Value, …), and thus is an input only.

Declaration:

```
LJ_ERROR _stdcall eGet (  LJ_HANDLE Handle,
                          long IOType,
                          long Channel,
                          double *pValue,
                          long x1)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().
- **IOType** – The type of request. See Section 4.3.
- **Channel** – The channel number of the particular IOType.
- **pValue** – Pointer to Value sends and receives data.
- **x1** – Optional parameter used by some IOTypes.

Outputs:

- **pValue** – Pointer to Value sends and receives data.

4.2.4 - eAddGoGet()

This function passes multiple requests via arrays, then executes a GoOne() and returns all the results via the same arrays.

The parameters that start with "*a" are arrays, and all must be initialized with at least a number of elements equal to NumRequests.

Declaration:

```
LJ_ERROR _stdcall eAddGoGet (  LJ_HANDLE Handle,
                               long NumRequests,
                               long *aIOTypes,
                               long *aChannels,
                               double *aValues,
                               long *ax1s,
                               long *aRequestErrors,
                               long *GoError,
                               long *aResultErrors)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().
- **NumRequests** – This is the number of requests that will be made, and thus the number of results that will be returned. All the arrays must be initialized with at least this many elements.
- **aIOTypes** – An array which is the list of IOTypes.
- **aChannels** – An array which is the list of Channels.
- **aValues** – An array which is the list of Values to write.
- **ax1s** – An array which is the list of x1s.

Outputs:

- **aValues** – An array which is the list of Values read.
- **aRequestErrors** – An array which is the list of errorcodes from each AddRequest().
- **GoError** – The errorcode returned by the GoOne() call.
- **aResultErrors** – An array which is the list of errorcodes from each GetResult().

4.2.5 - AddRequest()

Adds an item to the list of requests to be performed on the next call to Go() or GoOne().

When AddRequest() is called on a particular Handle, all previous data is erased and cannot be retrieved by any of the Get functions until a Go function is called again. This is on a device by device basis, so you can call AddRequest() with a different handle while a device is busy performing its I/O.

AddRequest() only clears the request and result lists on the device handle passed and only for the current thread. For example, if a

request is added to each of two different devices, and then a new request is added to the first device but not the second, a call to Go() will cause the first device to execute the new request and the second device to execute the original request.

In general, the execution order of a list of requests in a single Go call is unpredictable, except that all configuration type requests are executed before acquisition and output type requests.

AddRequestS() is a special version of the Add function where IOType is a string rather than a long. This is useful for passing string constants in languages that cannot include the header file, and is generally used with all IOTypes except put/get config. The string should contain the constant name as indicated in the header file (such as "LJ_ioANALOG_INPUT"). The declaration for the S version of Add is the same as below except for (…, const char *pIOType, …).

AddRequestSS() is a special version of the Add function where IOType and Channel are strings rather than longs. This is useful for passing string constants in languages that cannot include the header file, and is generally only used with the put/get config IOTypes. The strings should contain the constant name as indicated in the header file (such as "LJ_ioPUT_CONFIG" and "LJ_chLOCALID"). The declaration for the SS version of Add is the same as below except for (…, const char *pIOType, const char *pChannel, …).

Declaration:

```
LJ_ERROR _stdcall AddRequest (  LJ_HANDLE Handle,
                                long IOType,
                                long Channel,
                                double Value,
                                long x1,
                                double UserData)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().
- **IOType** – The type of request. See Section 4.3.
- **Channel** – The channel number of the particular IOType.
- **Value** – Value passed for output channels.
- **x1** – Optional parameter used by some IOTypes.
- **UserData** – Data that is simply passed along with the request, and returned unmodified by GetFirstResult() or GetNextResult(). Can be used to store any sort of information with the request, to allow a generic parser to determine what should be done when the results are received.

Outputs:

- **None**

4.2.6 - Go()

After using AddRequest() to make an internal list of requests to perform, call Go() to actually perform the requests. This function causes all requests on all open LabJacks to be performed. After calling Go(), call GetResult() or similar to retrieve any returned data or errors.

Go() can be called repeatedly to repeat the current list of requests. Go() does not clear the list of requests. Rather, after a call to Go(), the first subsequent AddRequest() call to a particular device will clear the previous list of requests on that particular device only.

Note that for a single Go() or GoOne() call, the order of execution of the request list cannot be predicted. Since the driver does internal optimization, it is quite likely not the same as the order of AddRequest() function calls. One thing that is known, is that configuration settings like ranges, stream settings, and such, will be done before the actual acquisition or setting of outputs.

Declaration:

```
LJ_ERROR _stdcall Go()
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **None**

Outputs:

- **None**

4.2.7 - GoOne()

After using AddRequest() to make an internal list of requests to perform, call GoOne() to actually perform the requests. This function causes all requests on one particular LabJack to be performed. After calling GoOne(), call GetResult() or similar to retrieve any returned data or errors.

GoOne() can be called repeatedly to repeat the current list of requests. GoOne() does not clear the list of requests. Rather, after a particular device has performed a GoOne(), the first subsequent AddRequest() call to that device will clear the previous list of requests on that particular device only.

Note that for a single Go() or GoOne() call, the order of execution of the request list cannot be predicted. Since the driver does internal optimization, it is quite likely not the same as the order of AddRequest() function calls. One thing that is known, is that configuration settings like ranges, stream settings, and such, will be done before the actual acquisition or setting of outputs.

Declaration:

```
LJ_ERROR _stdcall GoOne(  LJ_HANDLE Handle)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().

Outputs:

- **None**

4.2.8 - GetResult()

Calling either Go function creates a list of results that matches the list of requests. Use GetResult() to read the result and errorcode for a particular IOType and Channel. Normally this function is called for each associated AddRequest() item. Even if the request was an output, the errorcode should be evaluated.

None of the Get functions will clear results from the list. The first AddRequest() call subsequent to a Go call will clear the internal lists of requests and results for a particular device.

When processing raw in/out or stream data requests, the call to a Get function does not actually cause the data arrays to be filled. The arrays are filled during the Go call (if data is available), and the Get call is used to find out many elements were placed in the array.

GetResultS() is a special version of the Get function where IOType is a string rather than a long. This is useful for passing string constants in languages that cannot include the header file, and is generally used with all IOTypes except put/get config. The string should contain the constant name as indicated in the header file (such as "LJ_ioANALOG_INPUT"). The declaration for the S version of Get is the same as below except for (…, const char *pIOType, …).

GetResultSS() is a special version of the Get function where IOType and Channel are strings rather than longs. This is useful for passing string constants in languages that cannot include the header file, and is generally only used with the put/get config IOTypes. The strings should contain the constant name as indicated in the header file (such as "LJ_ioPUT_CONFIG" and "LJ_chLOCALID"). The declaration for the SS version of Get is the same as below except for (…, const char *pIOType, const char *pChannel, …).

It is acceptable to pass NULL (or 0) for any pointer that is not required.

Declaration:
LJ_ERROR _stdcall GetResult (LJ_HANDLE Handle, long IOType, long Channel, double *pValue)

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().
- **IOType** – The type of request. See Section 4.3.
- **Channel** – The channel number of the particular IOType.

Outputs:

- **pValue** – A pointer to the result value.

4.2.9 - GetFirstResult() and GetNextResult()

Calling either Go function creates a list of results that matches the list of requests. Use GetFirstResult() and GetNextResult() to step through the list of results in order. When either function returns LJE_NO_MORE_DATA_AVAILABLE, there are no more items in the list of results. Items can be read more than once by calling GetFirstResult() to move back to the beginning of the list.

UserData is provided for tracking information, or whatever else the user might need.

None of the Get functions clear results from the list. The first AddRequest() call subsequent to a Go call will clear the internal lists of requests and results for a particular device.

When processing raw in/out or stream data requests, the call to a Get function does not actually cause the data arrays to be filled. The arrays are filled during the Go call (if data is available), and the Get call is used to find out many elements were placed in the array.

It is acceptable to pass NULL (or 0) for any pointer that is not required.

The parameter lists are the same for the GetFirstResult() and GetNextResult() declarations.

Declaration:

```
LJ_ERROR _stdcall GetFirstResult (  LJ_HANDLE Handle,
                                    long *pIOType,
                                    long *pChannel,
                                    double *pValue,
                                    long *px1,
                                    double *pUserData)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().

Outputs:

- **pIOType** – A pointer to the IOType of this item in the list.
- **pChannel** – A pointer to the channel number of this item in the list.
- **pValue** – A pointer to the result value.
- **px1** – A pointer to the x1 parameter of this item in the list.
- **pUserData** – A pointer to data that is simply passed along with the request, and returned unmodified. Can be used to store any sort of information with the request, to allow a generic parser to determine what should be done when the results are received.

4.2.10 - DoubleToStringAddress()

Some special-channels of the config IOType pass IP address (and others) in a double. This function is used to convert the double into a string in normal decimal-dot or hex-dot notation.

Declaration:

```
LJ_ERROR _stdcall DoubleToStringAddress (  double Number,
                                           char *pString,
                                           long HexDot)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Number** – Double precision number to be converted.
- **pString** – Must pass a buffer for the string of at least 24 bytes.
- **HexDot** – If not equal to zero, the string will be in hex-dot notation rather than decimal-dot.

Outputs:

- **pString** – A pointer to the string representation.

4.2.11 - StringToDoubleAddress()

Some special-channels of the config IOType pass IP address (and others) in a double. This function is used to convert a string in normal decimal-dot or hex-dot notation into a double.

Declaration:

```
LJ_ERROR _stdcall StringToDoubleAddress (  const char *pString,
                                           double *pNumber,
                                           long HexDot)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **pString** – A pointer to the string representation.
- **HexDot** – If not equal to zero, the passed string should be in hex-dot notation rather than decimal-dot.

Outputs:

- **pNumber** – A pointer to the double precision representation.

4.2.12 - StringToConstant()

Converts the given string to the appropriate constant number. Used internally by the S functions, but could be useful to the end user when using the GetFirst/Next functions without the ability to include the header file. In this case a comparison could be done on the return values such as:

```
if (IOType == StringToConstant("LJ_ioANALOG_INPUT"))
```

This function returns *LJ_INVALID_CONSTANT* if the string is not recognized.

Declaration:
long _stdcall StringToConstant (const char *pString)

Parameter Description:
Returns: Constant number of the passed string.
Inputs:

- **pString** – A pointer to the string representation of the constant.

Outputs:

- **None**

4.2.13 - ErrorToString()

Outputs a string describing the given errorcode or an empty string if not found.

Declaration:
void _stdcall ErrorToString (LJ_ERROR ErrorCode,
char *pString)

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **ErrorCode** – LabJack errorcode.
- ***pString** – Must pass a buffer for the string of at least 256 bytes.

Outputs:

- ***pString** – A pointer to the string representation of the errorcode.

4.2.14 - GetDriverVersion()

Returns the version number of this Windows LabJack driver.

Declaration:

```
double _stdcall GetDriverVersion();
```

Parameter Description:
Returns: Driver version.
Inputs:

- **None**

Outputs:

- **None**

4.2.15 - TCVoltsToTemp()

A utility function to convert thermocouple voltage readings to temperature.

Declaration:

```
LJ_ERROR _stdcall TCVoltsToTemp (  long TCType,
                                   double TCVolts,
                                   double CJTempK,
                                   double *pTCTempK)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **TCType** – A constant that specifies the thermocouple type, such as LJ_ttK.
- **TCVolts** – The thermocouple voltage.
- **CJTempK** – The temperature of the cold junction in degrees K.

Outputs:

- **pTCTempK** – Returns the calculated thermocouple temperature.

4.2.16 - ResetLabJack()

Sends a reset command to the LabJack hardware.

Resetting the LabJack does not invalidate the handle, thus the device does not have to be opened again after a reset, but a Go call is likely to fail for a couple seconds after until the LabJack is ready.

In a future driver release, this function might be given an additional parameter that determines the type of reset.

Declaration:

```
LJ_ERROR _stdcall ResetLabJack ( LJ_HANDLE Handle);
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().

Outputs:

- **None**

4.2.17 - eAIN()

An easy function that returns a reading from one analog input. This is a simple alternative to the very flexible IOType based method normally used by this driver.

When needed, this function automatically configures the specified channel(s) for analog input.

Declaration:

```
LJ_ERROR _stdcall eAIN (  LJ_HANDLE Handle,
                          long ChannelP,
                          long ChannelN,
                          double *Voltage,
                          long Range,
                          long Resolution,
                          long Settling,
                          long Binary,
                          long Reserved1,
                          long Reserved2)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().
- **ChannelP** – The positive AIN channel to acquire.
- **ChannelN** – The negative AIN channel to acquire. For single-ended channels on the U3, this parameter should be 31 or 199 (see Section 2.6.1).
- **Range** – Ignored on the U3.
- **Resolution** – Pass a nonzero value to enable QuickSample.
- **Settling** – Pass a nonzero value to enable LongSettling.
- **Binary** – If this is nonzero (True), the Voltage parameter will return the raw binary value.
- **Reserved (1&2)** – Pass 0.

Outputs:

- **Voltage** – Returns the analog input reading, which is generally a voltage.

4.2.18 - eDAC()

An easy function that writes a value to one analog output. This is a simple alternative to the very flexible IOType based method normally used by this driver.

When needed (on hardware revisions <1.30 perhaps), this function automatically enables the specified analog output.

Declaration:

```
LJ_ERROR _stdcall eDAC (  LJ_HANDLE Handle,
                          long Channel,
                          double Voltage,
                          long Binary,
                          long Reserved1,
                          long Reserved2)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().
- **Channel** – The analog output channel to write to.
- **Voltage** – The voltage to write to the analog output.
- **Binary** – If this is nonzero (True), the value passed for Voltage should be binary.
- **Reserved (1&2)** – Pass 0.

4.2.19 - eDI()

An easy function that reads the state of one digital input. This is a simple alternative to the very flexible IOType based method normally used by this driver.

When needed, this function automatically configures the specified channel as a digital input.

Declaration:

```
LJ_ERROR _stdcall eDI (  LJ_HANDLE Handle,
                         long Channel,
                         long *State)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().
- **Channel** – The channel to read. 0-19 corresponds to FIO0-CIO3.

Outputs:

- **State** – Returns the state of the digital input. 0=False=Low and 1=True=High.

4.2.20 - eDO()

An easy function that writes the state of one digital output. This is a simple alternative to the very flexible IOType based method normally used by this driver.

When needed, this function automatically configures the specified channel as a digital output.

Declaration:

```
LJ_ERROR _stdcall eDO (  LJ_HANDLE Handle,
                         long Channel,
                         long State)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().
- **Channel** – The channel to write to. 0-19 corresponds to FIO0-CIO3.
- **State** – The state to write to the digital output. 0=False=Low and 1=True=High.

4.2.21 - eTCConfig()

An easy function that configures and initializes all the timers and counters. This is a simple alternative to the very flexible IOType based method normally used by this driver.

When needed, this function automatically configures the needed lines as digital.

Declaration:

```
LJ_ERROR _stdcall eTCConfig (  LJ_HANDLE Handle,
                               long *aEnableTimers,
                               long *aEnableCounters,
                               long TCPinOffset,
                               long TimerClockBaseIndex,
                               long TimerClockDivisor,
                               long *aTimerModes,
                               double *aTimerValues,
                               long Reserved1,
                               long Reserved2)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().
- **aEnableTimers** – An array where each element specifies whether that timer is enabled. Timers must be enabled in order starting from 0, so for instance, Timer1 cannot be enabled without enabling Timer0 also. A nonzero value for an array element specifies to enable that timer. For the U3, this array must always have at least 2 elements.
- **aEnableCounters** – An array where each element specifies whether that counter is enabled. Counters do not have to be enabled in order starting from 0, so Counter1 can be enabled when Counter0 is disabled. A nonzero value for an array element specifies to enable that counter. For the U3, this array must always have at least 2 elements.
- **TCPinOffset** – Value from 4-8 specifies where to start assigning timers and counters.
- **TimerClockBaseIndex** – Pass a constant to set the timer base clock. The default is LJ_tc48MHZ.
- **TimerClockDivisor** – Pass a divisor from 0-255 where 0 is a divisor of 256.
- **aTimerModes** – An array where each element is a constant specifying the mode for that timer. For the U3, this array must always have at least 2 elements.
- **aTimerValues** – An array where each element is specifies the initial value for that timer. For the U3, this array must always have at least 2 elements.
- **Reserved (1&2)** – Pass 0.

4.2.22 - eTCValues()

An easy function that updates and reads all the timers and counters. This is a simple alternative to the very flexible IOType based method normally used by this driver.

Declaration:

```
LJ_ERROR _stdcall eTCValues (  LJ_HANDLE Handle,
                               long *aReadTimers,
                               long *aUpdateResetTimers,
                               long *aReadCounters,
                               long *aResetCounters,
                               double *aTimerValues,
                               double *aCounterValues,
                               long Reserved1,
                               long Reserved2)
```

Parameter Description:
Returns: LabJack errorcodes or 0 for no error.
Inputs:

- **Handle** – Handle returned by OpenLabJack().
- **aReadTimers** – An array where each element specifies whether to read that timer. A nonzero value for an array element specifies to read that timer. For the U3, this array must always have at least 2 elements.
- **aUpdateResetTimers** – An array where each element specifies whether to update/reset that timer. A nonzero value for an array element specifies to update/reset that timer. For the U3, this array must always have at least 2 elements.
- **aReadCounters** – An array where each element specifies whether to read that counter. A nonzero value for an array element specifies to read that counter. For the U3, this array must always have at least 2 elements.
- **aResetCounters** – An array where each element specifies whether to reset that counter. A nonzero value for an array element specifies to reset that counter. For the U3, this array must always have at least 2 elements.
- **aTimerValues** – An array where each element is the new value for that timer. Each value is only updated if the appropriate element is set in the aUpdateResetTimers array. For the U3, this array must always have at least 2 elements.
- **Reserved (1&2)** – Pass 0.

Outputs:

- **aTimerValues** – An array where each element is the value read from that timer if the appropriate element is set in the aReadTimers array.
- **aCounterValues** – An array where each element is the value read from that counter if the appropriate element is set in the aReadCounters array.

4.3 - Example Pseudocode

The following pseudocode examples are simplified for clarity, and in particular no error checking is shown. The language used for the pseudocode is C.

4.3.1 - Open

The initial step is to open the LabJack and get a handle that the driver uses for further interaction. The DeviceType for the U3 is:

```
LJ_dtU3
```

There is only one valid ConnectionType for the U3:

```
LJ_ctUSB
```

Following is example pseudocode to open a U3 over USB:

```
//Open the first found LabJack U3 over USB.
OpenLabJack (LJ_dtU3, LJ_ctUSB, "1", TRUE, &lngHandle);
```

The reason for the quotes around the address (“1”), is because the address parameter is a string in the OpenLabJack function.

The ampersand (&) in front of lngHandle is a C notation that means we are passing the address of that variable, rather than the value of that variable. In the definition of the OpenLabJack function, the handle parameter is defined with an asterisk (*) in front, meaning that the function expects a pointer, i.e. an address.

In general, a function parameter is passed as a pointer (address) rather than a value, when the parameter might need to output something. The parameter value passed to a function in C cannot be modified in the function, but the parameter can be an address that points to a value that can be changed. Pointers are also used when passing arrays, as rather than actually passing the array, an address to the first element in the array is passed.

Talking to multiple devices from a single application is no problem. Make multiple open calls to get a handle to each device and be sure to set FirstFound=FALSE:

```
//Open U3s with Local ID #2 and #3.
OpenLabJack (LJ_dtU3, LJ_ctUSB, "2", FALSE, &lngHandleA);
OpenLabJack (LJ_dtU3, LJ_ctUSB, "3", FALSE, &lngHandleB);
```

… then when making further calls use the handle for the desired device.

4.3.2 - Configuration

One of the most important operations on the U3 is configuring the flexible I/O as digital or analog. The following 4 IOTypes are used for that:

```
LJ_ioPUT_ANALOG_ENABLE_BIT
LJ_ioGET_ANALOG_ENABLE_BIT
LJ_ioPUT_ANALOG_ENABLE_PORT    //x1 is number of bits.
LJ_ioGET_ANALOG_ENABLE_PORT    //x1 is number of bits.
```

When a request is done with one of the port IOTypes, the Channel parameter is used to specify the starting bit number, and the x1 parameter is used to specify the number of applicable bits. Following are some pseudocode examples:

```
//Configure FIO3 as an analog input.
ePut (lngHandle, LJ_ioPUT_ANALOG_ENABLE_BIT, 3, 1, 0);

//Configure FIO3 as digital I/O.
ePut (lngHandle, LJ_ioPUT_ANALOG_ENABLE_BIT, 3, 0, 0);

//Configure FIO0-FIO2 and EIO0-EIO7 as analog, all others as digital.  That
//means a starting channel of 0, a value of b1111111100000111 (=d65287), and
//all 16 bits will be updated.
ePut (lngHandle, LJ_ioPUT_ANALOG_ENABLE_PORT, 0, 65287, 16);

//Configure FIO2-FIO4 as analog, and FIO5-FIO6 as digital, without
//configuring any other bits.   That means a starting channel of 2,
//a value of b00111 (=d7), and 5 bits will be updated.
ePut (lngHandle, LJ_ioPUT_ANALOG_ENABLE_PORT, 2, 7, 5);
```

Because of the pin configuration interaction between digital I/O, analog inputs, and timers/counters, many software applications will need to initialize the flexible I/O to a known pin configuration. One way to do this is with the following pseudocode:

```
ePut (lngHandle, LJ_ioPUT_CONFIG, LJ_chNUMBER_TIMERS_ENABLED, 0, 0);
ePut (lngHandle, LJ_ioPUT_CONFIG, LJ_chTIMER_COUNTER_PIN_OFFSET, 4, 0);
ePut (lngHandle, LJ_ioPUT_CONFIG, LJ_chTIMER_CLOCK_BASE, LJ_tc48MHZ, 0);
ePut (lngHandle, LJ_ioPUT_CONFIG, LJ_chTIMER_CLOCK_DIVISOR, 0, 0);
ePut (lngHandle, LJ_ioPUT_COUNTER_ENABLE, 0, 0, 0);
ePut (lngHandle, LJ_ioPUT_COUNTER_ENABLE, 1, 0, 0);
ePut (lngHandle, LJ_ioPUT_DAC_ENABLE, 1, 0, 0);  //Ignored on hardware rev 1.30+.
ePut (lngHandle, LJ_ioPUT_ANALOG_ENABLE_PORT, 0, 0, 16);
```

This disables all timers and counters, sets the timer/counter pin offset to 4, sets the timer clock base to 48 MHz (no divisor), sets the timer clock divisor to 0, and sets all flexible I/O to digital. A simpler option is using the following IOType created exactly for this purpose, which does the same thing as the 8 function calls above:

```
ePut (lngHandle, LJ_ioPIN_CONFIGURATION_RESET, 0, 0, 0);
```

There are two IOTypes used to write or read general U3 configuration parameters:

```
LJ_ioPUT_CONFIG
LJ_ioGET_CONFIG
```

The following constants are then used in the channel parameter of the config function call to specify what is being written or read:

```
LJ_chLOCALID
LJ_chHARDWARE_VERSION
LJ_chSERIAL_NUMBER
LJ_chFIRMWARE_VERSION
LJ_chBOOTLOADER_VERSION
LJ_chPRODUCTID
LJ_chLED_STATE
```

Following is example pseudocode to write and read the local ID:

```
//Set the local ID to 4.
ePut (lngHandle, LJ_ioPUT_CONFIG, LJ_chLOCALID, 4, 0);

//Read the local ID.
```

```
eGet (lngHandle, LJ_ioGET_CONFIG, LJ_chLOCALID, &dblValue, 0);
```

4.3.3 - Analog Inputs

The IOTypes to retrieve a command/response analog input reading are:

```
LJ_ioGET_AIN       //Single-ended.  Negative channel is fixed as 31/199.
LJ_ioGET_AIN_DIFF  //Specify negative channel in x1.
```

The following are special channels, used with the get/put config IOTypes, to configure parameters that apply to all analog inputs:

```
LJ_chAIN_RESOLUTION     //QuickSample enabled if TRUE.
LJ_chAIN_SETTLING_TIME  //LongSettling enabled if TRUE.
LJ_chAIN_BINARY
```

Following is example pseudocode to read analog inputs:

```
//Execute the pin_configuration_reset IOType so that all
//pin assignments are in the factory default condition.
//The ePut function is used, which combines the add/go/get.
ePut (lngHandle, LJ_ioPIN_CONFIGURATION_RESET, 0, 0, 0);

//Configure FIO1, FIO2, and FIO6 as analog, all others as
//digital (see Section 4.3.2).
//The ePut function is used, which combines the add/go/get.
ePut (lngHandle, LJ_ioPUT_ANALOG_ENABLE_PORT, 0, 70, 16);


//Now, an add/go/get block to execute multiple requests.

//Request a single-ended read from AIN2.
AddRequest (lngHandle, LJ_ioGET_AIN, 2, 0, 0, 0);

//Request a differential read of AIN1-AIN6.
AddRequest (lngHandle, LJ_ioGET_AIN_DIFF, 1, 0, 6, 0);

//Request a differential read of AIN1-Vref.
AddRequest (lngHandle, LJ_ioGET_AIN_DIFF, 1, 0, 30, 0);

//Request a single-ended read of AIN1.
AddRequest (lngHandle, LJ_ioGET_AIN_DIFF, 1, 0,199, 0);

//Request a read of AIN1 using the special 0-3.6 volt range.
AddRequest (lngHandle, LJ_ioGET_AIN_DIFF, 1, 0, 32, 0);

//Execute the requests.
GoOne (lngHandle);

//Since multiple requests were made with the same IOType
//and Channel, and only x1 was different, GetFirst/GetNext
//must be used to retrieve the results.  The simple
//GetResult function does not use the x1 parameter and
//thus there is no way to specify which result is desired.
//Rather than specifying the IOType and Channel of the
//result to be read, the GetFirst/GetNext functions retrieve
//the results in order.  Normally, GetFirst/GetNext are best
//used in a loop, but here they are simply called in succession.

//Retrieve AIN2 voltage.  GetFirstResult returns the IOType,
//Channel, Value, x1, and UserData from the first request.
//In this example we are just retrieving the results in order
//and Value is the only parameter we need.
GetFirstResult (lngHandle, 0, 0, &dblValue, 0, 0);

//Get the AIN1-AIN6 voltage.
GetNextResult (lngHandle, 0, 0, &dblValue, 0, 0);

//Get the AIN1-Vref voltage.
GetNextResult (lngHandle, 0, 0, &dblValue, 0, 0);

//Get the AIN1 voltage.
GetNextResult (lngHandle, 0, 0, &dblValue, 0, 0);

//Get the AIN1 voltage (special 0-3.6 volt range).
GetNextResult (lngHandle, 0, 0, &dblValue, 0, 0);
```

4.3.4 - Analog Outputs

The IOType to set the voltage on an analog output is:

```
LJ_ioPUT_DAC
```

The following are IOTypes used to write/read the enable bit for DAC1:

```
LJ_ioPUT_DAC_ENABLE  //Ignored on hardware rev 1.30+, as DAC1 always enabled.
LJ_ioGET_DAC_ENABLE
```

The following is a special channel, used with the get/put config IOTypes, to configure a parameter that applies to all DACs:

```
LJ_chDAC_BINARY
```

Following is example pseudocode to set DAC0 to 2.5 volts:

```
//Set DAC0 to 2.5 volts.
ePut (lngHandle, LJ_ioPUT_DAC, 0, 2.50, 0);
```

4.3.5 - Digital I/O

There are eight IOTypes used to write or read digital I/O information:

```
LJ_ioGET_DIGITAL_BIT         //Also sets direction to input.
LJ_ioGET_DIGITAL_BIT_DIR
LJ_ioGET_DIGITAL_BIT_STATE
LJ_ioGET_DIGITAL_PORT        //Also sets directions to input.  x1 is number of bits.
LJ_ioGET_DIGITAL_PORT_DIR    //x1 is number of bits.
LJ_ioGET_DIGITAL_PORT_STATE  //x1 is number of bits.

LJ_ioPUT_DIGITAL_BIT         //Also sets direction to output.
LJ_ioPUT_DIGITAL_PORT        //Also sets directions to output.  x1 is number of bits.
```

When a request is done with one of the port IOTypes, the Channel parameter is used to specify the starting bit number, and the x1 parameter is used to specify the number of applicable bits. The bit numbers corresponding to different I/O are:

```
0-7    FIO0-FIO7
8-15   EIO0-EIO7
16-19  CIO0-CIO3
```

Note that the GetResult function does not have an x1 parameter. That means that if two (or more) port requests are added with the same IOType and Channel, but different x1, the result retrieved by GetResult would be undefined. The GetFirstResult/GetNextResult commands do have the x1 parameter, and thus can handle retrieving responses from multiple port requests with the same IOType and Channel.

Following is example pseudocode for various digital I/O operations:

```
//Execute the pin_configuration_reset IOType so that all
//pin assignments are in the factory default condition.
//The ePut function is used, which combines the add/go/get.
ePut (lngHandle, LJ_ioPIN_CONFIGURATION_RESET, 0, 0, 0);


//Now, an add/go/get block to execute multiple requests.

//Request a read from FIO2.
AddRequest (lngHandle, LJ_ioGET_DIGITAL_BIT, 2, 0, 0, 0);

//Request a read from FIO4-EIO5 (10-bits starting
//from digital channel #4).
AddRequest (lngHandle, LJ_ioGET_DIGITAL_PORT, 4, 0, 10, 0);

//Set FIO3 to output-high.
AddRequest (lngHandle, LJ_ioPUT_DIGITAL_BIT, 3, 1, 0, 0);

//Set EIO6-CIO2 (5-bits starting from digital channel #14)
//to b10100 (=d20).  That is EIO6=0, EIO7=0, CIO0=1,
//CIO1=0, and CIO2=1.
AddRequest (lngHandle, LJ_ioPUT_DIGITAL_PORT, 14, 20, 5, 0);

//Execute the requests.
GoOne (lngHandle);

//Get the FIO2 read.
GetResult (lngHandle, LJ_ioGET_DIGITAL_BIT, 2, &dblValue);

//Get the FIO4-EIO5 read.
GetResult (lngHandle, LJ_ioGET_DIGITAL_PORT, 4, &dblValue);
```

4.3.6 - Timers & Counters

There are eight IOTypes used to write or read timer and counter information:

```
LJ_ioGET_COUNTER
LJ_ioPUT_COUNTER_ENABLE
LJ_ioGET_COUNTER_ENABLE
LJ_ioPUT_COUNTER_RESET

LJ_ioGET_TIMER
LJ_ioPUT_TIMER_VALUE
LJ_ioPUT_TIMER_MODE
LJ_ioGET_TIMER_MODE
```

In addition to specifying the channel number, the following mode constants are passed in the value parameter when doing a request with the timer mode IOType:

```
LJ_tmPWM16                //16-bit PWM output
LJ_tmPWM8                 //8-bit PWM output
LJ_tmRISINGEDGES32        //Period input (32-bit, rising edges)
LJ_tmFALLINGEDGES32       //Period input (32-bit, falling edges)
LJ_tmDUTYCYCLE            //Duty cycle input
LJ_tmFIRMCOUNTER          //Firmware counter input
LJ_tmFIRMCOUNTERDEBOUNCE  //Firmware counter input (with debounce)
LJ_tmFREQOUT              //Frequency output
LJ_tmQUAD                 //Quadrature input
LJ_tmTIMERSTOP            //Timer stop input (odd timers only)
LJ_tmSYSTIMERLOW          //System timer low read (no FIO)
LJ_tmSYSTIMERHIGH         //System timer high read (no FIO)
LJ_tmRISINGEDGES16        //Period input (16-bit, rising edges)
LJ_tmFALLINGEDGES16       //Period input (16-bit, falling edges)
```

The following are special channels, used with the get/put config IOTypes, to configure a parameter that applies to all timers/counters:

```
LJ_chNUMBER_TIMERS_ENABLED     //0-2
LJ_chTIMER_CLOCK_BASE          //Value constants below
LJ_chTIMER_CLOCK_DIVISOR       //0-255, where 0=256
LJ_chTIMER_COUNTER_PIN_OFFSET  //4-8 only starting with hardware rev 1.30.
```

With the clock base special channel above, the following constants are passed in the value parameter to select the frequency:

```
LJ_tc4MHZ       //4 MHz clock base
LJ_tc12MHZ      //12 MHz clock base
LJ_tc48MHZ      //48 MHz clock base
LJ_tc1MHZ_DIV   //1 MHz clock base w/ divisor (no Counter0)
LJ_tc4MHZ_DIV   //4 MHz clock base w/ divisor (no Counter0)
LJ_tc12MHZ_DIV  //12 MHz clock base w/ divisor (no Counter0)
LJ_tc48MHZ_DIV  //48 MHz clock base w/ divisor (no Counter0)
LJ_tcSYS        //Equivalent to LJ_tc48MHZ
```

Following is example pseudocode for configuring various timers and a hardware counter:

```
//Execute the pin_configuration_reset IOType so that all
//pin assignments are in the factory default condition.
//The ePut function is used, which combines the add/go/get.
ePut (lngHandle, LJ_ioPIN_CONFIGURATION_RESET, 0, 0, 0);


//First, an add/go/get block to configure the timers and counters.

//Set the pin offset to 4, which causes the timers to start on FIO4.
AddRequest (lngHandle, LJ_ioPUT_CONFIG, LJ_chTIMER_COUNTER_PIN_OFFSET, 4, 0, 0);

//Enable both timers.  They will use FIO4-FIO5
AddRequest (lngHandle, LJ_ioPUT_CONFIG, LJ_chNUMBER_TIMERS_ENABLED, 2, 0, 0);

//Make sure Counter0 is disabled.
AddRequest (lngHandle, LJ_ioPUT_COUNTER_ENABLE, 0, 0, 0, 0);

//Enable Counter1.  It will use the next available line, FIO6.
```

```
AddRequest (lngHandle, LJ_ioPUT_COUNTER_ENABLE, 1, 1, 0, 0);

//All output timers use the same timer clock, configured here. The
//base clock is set to 48MHZ_DIV, meaning that the clock divisor
//is supported and Counter0 is not available.  Note that this timer
//clock base is not valid with U3 hardware version 1.20.
AddRequest (lngHandle, LJ_ioPUT_CONFIG, LJ_chTIMER_CLOCK_BASE, LJ_tc48MHZ_DIV, 0, 0);

//Set the timer clock divisor to 48, creating a 1 MHz timer clock.
AddRequest (lngHandle, LJ_ioPUT_CONFIG, LJ_chTIMER_CLOCK_DIVISOR, 48, 0, 0);

//Configure Timer0 as 8-bit PWM.  It will have a frequency
//of 1M/256 = 3906.25 Hz.
AddRequest (lngHandle, LJ_ioPUT_TIMER_MODE, 0, LJ_tmPWM8, 0, 0);

//Initialize the 8-bit PWM with a 50% duty cycle.
AddRequest (lngHandle, LJ_ioPUT_TIMER_VALUE, 0, 32768, 0, 0);

//Configure Timer1 as duty cycle input.
AddRequest (lngHandle, LJ_ioPUT_TIMER_MODE, 1, LJ_tmDUTYCYCLE, 0, 0);

//Execute the requests.
GoOne (lngHandle);
```

The following pseudocode demonstrates reading input timers/counters and updating the values of output timers. The e-functions are used in the following pseudocode, but some applications might combine the following calls into a single add/go/get block so that a single low-level call is used.

```
//Change Timer0 PWM duty cycle to 25%.
ePut (lngHandle, LJ_ioPUT_TIMER_VALUE, 0, 49152, 0);

//Read duty-cycle from Timer1.
eGet (lngHandle, LJ_ioGET_TIMER, 1, &dblValue, 0);

//The duty cycle read returns a 32-bit value where the
//least significant word (LSW) represents the high time
//and the most significant word (MSW) represents the low
//time.  The times returned are the number of cycles of
//the timer clock.  In this case the timer clock was set
//to 1 MHz, so each cycle is 1 microsecond.
dblHighCycles = (double)(((unsigned long)dblValue) % (65536));
dblLowCycles = (double)(((unsigned long)dblValue) / (65536));
dblDutyCycle = 100 * dblHighCycles / (dblHighCycles + dblLowCycles));
dblHighTime = 0.000001 * dblHighCycles;
dblLowTime = 0.000001 * dblLowCycles;

//Read the count from Counter1.  This is an unsigned 32-bit value.
eGet (lngHandle, LJ_ioGET_COUNTER, 1, &dblValue, 0);
```

Following is pseudocode to reset the input timer and the counter:

```
//Reset the duty-cycle measurement (Timer1) to zero, by writing
//a value of zero.  The duty-cycle measurement is continuously
//updated, so a reset is normally not needed, but one reason
//to reset to zero is to detect whether there has been a new
//measurement or not.
ePut (lngHandle, LJ_ioPUT_TIMER_VALUE, 1, 0, 0);

//Reset Counter1 to zero.
ePut (lngHandle, LJ_ioPUT_COUNTER_RESET, 1, 1, 0);
```

Note that if a timer/counter is read and reset at the same time (in the same Add/Go/Get block), the read will return the value just before reset.

4.3.7 - Stream Mode

The highest input data rates are obtained in stream mode, which is supported with U3 hardware version 1.21 or higher. See Section 3.2 for more information about stream mode.

There are five IOTypes used to control streaming:

```
LJ_ioCLEAR_STREAM_CHANNELS
LJ_ioADD_STREAM_CHANNEL
LJ_ioADD_STREAM_CHANNEL_DIFF  //Put negative channel in x1.
LJ_ioSTART_STREAM             //Value returns actual scan rate.
LJ_ioSTOP_STREAM
LJ_ioGET_STREAM_DATA
```

The following constant is passed in the Channel parameter with the get stream data IOType to specify a read returning all scanned channels, rather than retrieving each scanned channel separately:

```
LJ_chALL_CHANNELS
```

The following are special channels, used with the get/put config IOTypes, to write or read various stream values:

```
LJ_chSTREAM_SCAN_FREQUENCY
LJ_chSTREAM_BUFFER_SIZE          //UD driver stream buffer size in samples.
LJ_chSTREAM_WAIT_MODE
LJ_chSTREAM_DISABLE_AUTORECOVERY
LJ_chSTREAM_BACKLOG_COMM         //Read-only.  0=0% and 256=100%.
LJ_chSTREAM_BACKLOG_UD           //Read-only.  Number of samples.
LJ_chSTREAM_SAMPLES_PER_PACKET   //Default 25. Range 1-25.
LJ_chSTREAM_READS_PER_SECOND     //Default 25.
```

With the wait mode special channel above, the following constants are passed in the value parameter to select the behavior when reading data:

```
LJ_swNONE        //No wait.  Immediately return available data.
LJ_swALL_OR_NONE  //No wait.  Immediately return requested amount, or none.
LJ_swPUMP        //Advanced message pump wait mode.
LJ_swSLEEP       //Wait until requested amount available.
```

The backlog special channels return information about how much data is left in the stream buffer on the U3 or in the UD driver. These parameters are updated whenever a stream packet is read by the driver, and thus might not exactly reflect the current state of the buffers, but can be useful to detect problems.

When streaming, the processor acquires data at precise intervals, and transfers it to a buffer on the U3 itself. The U3 has a small buffer (512-984 samples) for data waiting to be transferred to the host. The *LJ_chSTREAM_BACKLOG_COMM* special channel specifies how much data is left in the U3 buffer (*COMM* or *CONTROL* are the same thing on the U3), where 0 means 0% full and 256 would mean 100% full. The UD driver retrieves stream data from the U3 in the background, but if the computer or communication link is too slow for some reason, the driver might not be able to read the data as fast as the U3 is acquiring it, and thus there will be data left over in the U3 buffer.

To obtain the maximum stream rates documented in Section 3.2, the data must be transferred between host and U3 in large chunks. The amount of data transferred per low-level packet is controlled by *LJ_chSTREAM_SAMPLES_PER_PACKET*. The

driver will use the parameter *LJ_chSTREAM_READS_PER_SECOND* to determine how many low-level packets to retrieve per read.

The size of the UD stream buffer on the host is controlled by *LJ_chSTREAM_BUFFER_SIZE*. The application software on the host must read data out of the UD stream buffer fast enough to prevent overflow. After each read, use *LJ_chSTREAM_BACKLOG_UD* to determine how many samples are left in the buffer.

Since the data buffer on the U3 is very small a feature called auto-recovery is used. If the buffer overflows, the U3 will continue streaming but discard data until the buffer is emptied, and then data will be stored in the buffer again. The U3 keeps track of how many packets are discarded and reports that value. Based on the number of packets discarded, the UD driver adds the proper number of dummy samples (-9999.0) such that the correct timing is maintained. Auto-recovery will generally occur when the U3 buffer is 90-95% full.

In stream mode the LabJack acquires inputs at a fixed interval, controlled by the hardware clock on the device itself, and stores the data in a buffer. The LabJackUD driver automatically reads data from the hardware buffer and stores it in a PC RAM buffer until requested. The general procedure for streaming is:

- Update configuration parameters.
- Build the scan list.
- Start the stream.
- Periodically retrieve stream data in a loop.
- Stop the stream.

Following is example pseudocode to configure a 2-channel stream.

```
//Set the scan rate.
AddRequest (lngHandle, LJ_ioPUT_CONFIG, LJ_chSTREAM_SCAN_FREQUENCY, scanRate, 0, 0);

//Give the UD driver a 5 second buffer (scanRate * 2 channels * 5 seconds).
AddRequest (lngHandle, LJ_ioPUT_CONFIG, LJ_chSTREAM_BUFFER_SIZE, scanRate*2*5, 0, 0);

//Configure reads to wait and retrieve the desired amount of data.
AddRequest (lngHandle, LJ_ioPUT_CONFIG, LJ_chSTREAM_WAIT_MODE, LJ_swSLEEP, 0, 0);

//Define the scan list as singled ended AIN2 then differential AIN3-AIN9.
AddRequest (lngHandle, LJ_ioCLEAR_STREAM_CHANNELS, 0, 0, 0, 0);
AddRequest (lngHandle, LJ_ioADD_STREAM_CHANNEL, 2, 0, 0, 0);
AddRequest (lngHandle, LJ_ioADD_STREAM_CHANNEL_DIFF, 3, 0, 9, 0);

//Execute the requests.
GoOne (lngHandle);
```

Next, start the stream:

```
//Start the stream.
eGet(lngHandle, LJ_ioSTART_STREAM, 0, &dblValue, 0);

//The actual scan rate is dependent on how the desired scan rate divides into
//the LabJack clock.  The actual scan rate is returned in the value parameter
//from the start stream command.
actualScanRate = dblValue;
actualSampleRate = 2*dblValue;
```

Once a stream is started, the data must be retrieved periodically to prevent the buffer from overflowing. To retrieve data, add a request with IOType *LJ_ioGET_STREAM_DATA*. The Channel parameter should be *LJ_chALL_CHANNELS* or a specific channel number (ignored for a single channel stream). The Value parameter should be the number of scans (all channels) or samples (single channel) to retrieve. The x1 parameter should be a pointer to an array that has been initialized to a sufficient size. Keep in mind that the required number of elements if retrieving all channels is number of scans * number of channels.

Data is stored interleaved across all streaming channels. In other words, if two channels are streaming, 0 and 1, and *LJ_chALL_CHANNELS* is the channel number for the read request, the data will be returned as Channel0, Channel1, Channel0, Channel1, etc. Once the data is read it is removed from the internal buffer, and the next read will give new data.

If multiple channels are being streamed, data can be retrieved one channel at a time by passing a specific channel number in the request. In this case the data is not removed from the internal buffer until the last channel in the scan is requested. Reading the data from the last channel (not necessarily all channels) is the trigger that causes the block of data to be removed from the buffer. This means that if three channels are streaming, 0, 1 and 2 (in that order in the scan list), and data is requested from channel 0, then channel 1, then channel 0 again, the request for channel 0 the second time will return the same data as the first request. New data will not be retrieved until after channel 2 is read, since channel 2 is last in the scan list. If the first get stream data request is for 10 samples from channel 1, the reads from channels 0 and 2 also must be for 10 samples. Note that when reading stream data one channel at a time (not using *LJ_chALL_CHANNELS*), the scan list cannot have duplicate channel numbers.

There are three basic wait modes for retrieving the data:

- LJ_swNONE: The Go call will retrieve whatever data is available at the time of the call up to the requested amount of data. A Get command should be called to determine how many scans were retrieved. This is generally used with a software timed read interval. The number of samples read per loop iteration will vary, but the time per loop iteration will be pretty consistent. Since the LabJack clock could be faster than the PC clock, it is recommended to request more scans than are expected each time so that the application does not get behind.
- LJ_swSLEEP: This makes the Go command a blocking call. The Go command will loop until the requested amount of is retrieved or no new data arrives from the device before timeout. In this mode, the hardware dictates the timing of the application. The time per loop iteration will vary, but the number of samples read per loop will be the same every time. A Get command should be called to determine whether all the data was retrieved, or a timeout condition occurred and none of the data was retrieved.
- LJ_swALL_OR_NONE: If available, the Go call will retrieve the amount of data requested, otherwise it will retrieve no data. A Get command should be called to determine whether all the data was returned or none. This could be a good mode if hardware timed execution is desirable, but without the application continuously waiting in SLEEP mode.

The following pseudocode reads data continuously in SLEEP mode as configured above:

```
//Read data until done.
while(!done)
{
    //Must set the number of scans to read each iteration, as the read
    //returns the actual number read.
    numScans = 1000;

    //Read the data.  Note that the array passed must be sized to hold
    //enough SAMPLES, and the Value passed specifies the number of SCANS
    //to read.
    eGet(lngHandle, LJ_ioGET_STREAM_DATA, LJ_chALL_CHANNELS, &numScans, array);
    actualNumberRead = numScans;

    //When all channels are retrieved in a single read, the data
    //is interleaved in a 1-dimensional array.  The following lines
    //get the first sample from each channel.
    channelA = array[0];
    channelB = array[1];

    //Retrieve the current U3 backlog.  The UD driver retrieves
    //stream data from the U3 in the background, but if the computer
    //is too slow for some reason the driver might not be able to read
    //the data as fast as the U3 is acquiring it, and thus there will
    //be data left over in the U3 buffer.
    eGet(lngHandle, LJ_ioGET_CONFIG, LJ_chSTREAM_BACKLOG_COMM, &dblCommBacklog, 0);
```

```
    //Retrieve the current UD driver backlog.  If this is growing, then
    //the application software is not pulling data from the UD driver
    //fast enough.
    eGet(lngHandle, LJ_ioGET_CONFIG, LJ_chSTREAM_BACKLOG_UD, &dblUDBacklog, 0);
}
```

Finally, stop the stream:

```
//Stop the stream.
errorcode = ePut (Handle, LJ_ioSTOP_STREAM, 0, 0, 0);
```

4.3.8 - Raw Output/Input

There are two IOTypes used to write or read raw data. These can be used to make low-level function calls (Section 5) through the UD driver. The only time these generally might be used is to access some low-level device functionality not available in the UD driver.

```
LJ_ioRAW_OUT
LJ_ioRAW_IN
```

When using these IOTypes, channel # specifies the desired communication pipe. For the U3, 0 is the normal pipe while 1 is the streaming pipe. The number of bytes to write/read is specified in value (1-16384), and x1 is a pointer to a byte array for the data. When retrieving the result, the value returned is the number of bytes actually read/written.

Following is example pseudocode to write and read the low-level command ConfigTimerClock (Section 5.2.4).

```
writeArray[2] = {0x05,0xF8,0x02,0x0A,0x00,0x00,0x00,0x00,0x00,0x00};
numBytesToWrite = 10;
numBytesToRead = 10;

//Raw Out.  This command writes the bytes to the device.
eGet(lngHandle, LJ_ioRAW_OUT, 0, &numBytesToWrite, pwriteArray);

//Raw In.  This command reads the bytes from the device.
eGet(lngHandle, LJ_ioRAW_IN, 0, &numBytesToRead, preadArray);
```

4.3.9 - Easy Functions

The easy functions are simple alternatives to the very flexible IOType based method normally used by this driver. There are 6 functions available:

```
eAIN()       //Read 1 analog input.
eDAC()       //Write to 1 analog output.
eDI()         //Read 1 digital input.
eDO()        //Write to 1 digital output.
eTCConfig()  //Configure all timers and counters.
eTCValues()  //Update/reset and read all timers and counters.
```

In addition to the basic operations, these functions also automatically handle configuration as needed. For example, eDO() sets the specified line to digital output if previously configured as analog and/or input, and eAIN() sets the line to analog if previously configured as digital.

The first 4 functions should not be used when speed is critical with multi-channel reads. These functions use one low-level function per operation, whereas using the normal Add/Go/Get method with IOTypes, many operations can be combined into a single low-level call. With single channel operations, however, there will be little difference between using an easy function or Add/Go/Get.

The last two functions handle almost all functionality related to timers and counters, and will usually be as efficient as any other method. These easy functions are recommended for most timer/counter applications.

Following is example pseudocode:

```
//Take a single-ended measurement from AIN3.
//eAIN (Handle, ChannelP, ChannelN, *Voltage, Range, Resolution,
// Settling, Binary,  Reserved1, Reserved2)
//
eAIN(lngHandle, 3, 31, &dblVoltage, 0, 0, 0, 0, 0, 0);
printf("AIN3 value = %.3f\n",dblVoltage);

//Set DAC0 to 3.1 volts.
//eDAC (Handle, Channel, Voltage, Binary, Reserved1, Reserved2)
//
eDAC(lngHandle, 0, 3.1, 0, 0, 0);

//Read state of FIO2.
//eDI (Handle, Channel, *State)
//
eDI(lngHandle, 2, &lngState);
printf("FIO2 state = %.0f\n",lngState);

//Set FIO3 to output-high.
//eDO (Handle, Channel, State)
//
eDO(lngHandle, 3, 1);


//Enable and configure 1 output timer and 1 input timer, and enable Counter0.
//Fill the arrays with the desired values, then make the call.
alngEnableTimers = {1,1}; //Enable Timer0-Timer1
alngTimerModes = {LJ_tmPWM8,LJ_tmRISINGEDGES32}; //Set timer modes
adblTimerValues = {16384,0}; //Set PWM8 duty-cycle to 75%.
alngEnableCounters = {1,0}; //Enable Counter0
//
//eTCConfig (Handle, *aEnableTimers, *aEnableCounters, TCPinOffset,
//  TimerClockBaseIndex, TimerClockDivisor, *aTimerModes,
//  *aTimerValues, Reserved1, Reserved2);
//
eTCConfig(lngHandle, alngEnableTimers, alngEnableCounters, 4, LJ_tc48MHZ, 0, alngTimerModes, adblTimerValues, 0, 0);


//Read and reset the input timer (Timer1), read and reset Counter0, and update
//the value (duty-cycle) of the output timer (Timer0).
//Fill the arrays with the desired values, then make the call.
alngReadTimers = {0,1}; //Read Timer1
alngUpdateResetTimers = {1,1}; //Update Timer0 and reset Timer1
alngReadCounters = {1,0}; //Read Counter0
alngResetCounters = {1,0}; //Reset Counter0
adblTimerValues = {32768,0}; //Change Timer0 duty-cycle to 50%
//
//eTCValues (Handle, *aReadTimers, *aUpdateResetTimers, *aReadCounters,
//  *aResetCounters, *aTimerValues, *aCounterValues, Reserved1,
//  Reserved2);
//
eTCValues(lngHandle, alngReadTimers, alngUpdateResetTimers, alngReadCounters, alngResetCounters, adblTimerValues, adblCounterValues, 0, 0);
printf("Timer1 value = %.0f\n",adblTimerValues[1]);
```

```
printf("Counter0 value = %.0f\n",adblCounterValues[0]);
```

4.3.10 - SPI Serial Communication

The U3 (hardware version 1.21+ only) supports Serial Peripheral Interface (SPI) communication as the master only. SPI is a synchronous serial protocol typically used to communicate with chips that support SPI as slave devices.

This serial link is not an alternative to the USB connection. Rather, the host application will write/read data to/from the U3 over USB, and the U3 communicates with some other device using the serial protocol. Using this serial protocol is considered an advanced topic. A good knowledge of the protocol is recommended, and a logic analyzer or oscilloscope might be needed for troubleshooting.

There is one IOType used to write/read data over the SPI bus:

```
LJ_ioSPI_COMMUNICATION // Value= number of bytes (1-50). x1= array.
```

The following are special channels, used with the get/put config IOTypes, to configure various parameters related to the SPI bus. See the low-level function description in Section 5.2.15 for more information about these parameters:

```
LJ_chSPI_AUTO_CS
LJ_chSPI_DISABLE_DIR_CONFIG
LJ_chSPI_MODE
LJ_chSPI_CLOCK_FACTOR
LJ_chSPI_MOSI_PIN_NUM
LJ_chSPI_MISO_PIN_NUM
LJ_chSPI_CLK_PIN_NUM
LJ_chSPI_CS_PIN_NUM
```

Following is example pseudocode to configure SPI communication:

```
//First, configure the SPI communication.

//Enable automatic chip-select control.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSPI_AUTO_CS,1,0,0);

//Do not disable automatic digital i/o direction configuration.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSPI_DISABLE_DIR_CONFIG,0,0,0);

//Mode A:  CPHA=1, CPOL=1.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSPI_MODE,0,0,0);

//Maximum clock rate (~100kHz).
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSPI_CLOCK_FACTOR,0,0,0);

//Set MOSI to FIO2.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSPI_MOSI_PIN_NUM,2,0,0);

//Set MISO to FIO3.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSPI_MISO_PIN_NUM,3,0,0);

//Set CLK to FIO0.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSPI_CLK_PIN_NUM,0,0,0);

//Set CS to FIO1.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSPI_CS_PIN_NUM,1,0,0);

//Execute the configuration requests.
GoOne(lngHandle);
```

Following is pseudocode to do the actual SPI communication:

```
//Transfer the data.
eGet(lngHandle, LJ_ioSPI_COMMUNICATION, 0, &numBytesToTransfer, array);
```

4.3.11 - I²C Serial Communication

The U3 (hardware version 1.21+ only) supports Inter-Integrated Circuit (I²C or I2C) communication as the master only. I²C is a synchronous serial protocol typically used to communicate with chips that support I²C as slave devices. Any 2 digital I/O lines are used for SDA and SCL. Note that the I²C bus generally requires pull-up resistors of perhaps 4.7 kΩ from SDA to Vs and SCL to Vs, and also note that the screw terminals labeled SDA and SCL (if present) are not used for I²C.

This serial link is not an alternative to the USB connection. Rather, the host application will write/read data to/from the U3 over USB, and the U3 communicates with some other device using the serial protocol. Using this serial protocol is considered an advanced topic. A good knowledge of the protocol is recommended, and a logic analyzer or oscilloscope might be needed for troubleshooting.

There is one IOType used to write/read I²C data:

```
LJ_ioI2C_COMMUNICATION
```

The following are special channels used with the I²C IOType above:

```
LJ_chI2C_READ      // Value= number of bytes (0-52). x1= array.
LJ_chI2C_WRITE     // Value= number of bytes (0-50). x1= array.
LJ_chI2C_GET_ACKS
```

The following are special channels, used with the get/put config IOTypes, to configure various parameters related to the I²C bus. See the low-level function description in Section 5.2.19 for more information about these parameters:

```
LJ_chI2C_ADDRESS_BYTE
LJ_chI2C_SCL_PIN_NUM   // 0-19. Pull-up resistor usually required.
LJ_chI2C_SDA_PIN_NUM   // 0-19. Pull-up resistor usually required.
LJ_chI2C_OPTIONS
LJ_chI2C_SPEED_ADJUST
```

The LJTick-DAC is an accessory from LabJack with an I²C 24C01C EEPROM chip. Following is example pseudocode to configure I²C to talk to that chip:

```
//The AddressByte of the EEPROM on the LJTick-DAC is 0xA0 or decimal 160.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chI2C_ADDRESS_BYTE,160,0,0);

//SCL is FIO0
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chI2C_SCL_PIN_NUM,0,0,0);

//SDA is FIO1
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chI2C_SDA_PIN_NUM,1,0,0);

//See description of low-level I2C function.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chI2C_OPTIONS,0,0,0);
```

```
//See description of low-level I2C function.  0 is max speed of about 150 kHz.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chI2C_SPEED_ADJUST,0,0,0);

//Execute the configuration requests.
GoOne(lngHandle);
```

Following is pseudocode to read 4 bytes from the EEPROM:

```
//Initial read of EEPROM bytes 0-3 in the user memory area.
//We need a single I2C transmission that writes the address and then reads
//the data.  That is, there needs to be an ack after writing the address,
//not a stop condition.  To accomplish this, we use Add/Go/Get to combine
//the write and read into a single low-level call.
numWrite = 1;
array[0] = 0;  //Memory address.  User area is 0-63.
AddRequest(lngHandle, LJ_ioI2C_COMMUNICATION, LJ_chI2C_WRITE, numWrite, array, 0);

numRead = 4;
AddRequest(lngHandle, LJ_ioI2C_COMMUNICATION, LJ_chI2C_READ, numRead, array, 0);

//Execute the requests.
GoOne(lngHandle);
```

For more example code, see the I2C.cpp example in the VC6_LJUD archive.

4.3.12 - Asynchronous Serial Communication

The U3 (hardware version 1.21+ only) has a UART available that supports asynchronous serial communication. On hardware version 1.30 the TX (transmit) and RX (receive) lines appear on FIO/EIO after any timers and counters, so with no timers/counters enabled, and pin offset set to 4, TX=FIO4 and RX=FIO5. On hardware version 1.21, the UART uses SDA for TX and SCL for RX.

Communication is in the common 8/n/1 format. Similar to RS232, except that the logic is normal CMOS/TTL. Connection to an RS232 device will require a converter chip such as the MAX233, which inverts the logic and shifts the voltage levels.

This serial link is not an alternative to the USB connection. Rather, the host application will write/read data to/from the U3 over USB, and the U3 communicates with some other device using the serial protocol. Using this serial protocol is considered an advanced topic. A good knowledge of the protocol is recommended, and a logic analyzer or oscilloscope might be needed for troubleshooting.

There is one IOType used to write/read asynchronous data:

```
LJ_ioASYNCH_COMMUNICATION
```

The following are special channels used with the asynch IOType above:

```
LJ_chASYNCH_ENABLE  // Enables UART to begin buffering rx data.
LJ_chASYNCH_RX      // Value= returns pre-read buffer size. x1= array.
LJ_chASYNCH_TX      // Value= number to send (0-56), number in rx buffer. x1= array.
LJ_chASYNCH_FLUSH   // Flushes the rx buffer.  All data discarded. Value ignored.
```

When using *LJ_chASYNCH_RX*, the Value parameter returns the size of the Asynch buffer before the read. If the size is 32 bytes or less, that is how many bytes were read. If the size is more than 32 bytes, then the call read 32 this time and there are still bytes left in the buffer.

When using *LJ_chASYNCH_TX*, specify the number of bytes to send in the Value parameter. The Value parameter returns the size of the Asynch read buffer.

The following is a special channel, used with the get/put config IOTypes, to specify the baud rate for the asynchronous communication:

```
LJ_chASYNCH_BAUDFACTOR  // 16-bit value for hardware V1.30.  8-bit for V1.21.
```

With hardware revision 1.30 this is a 16-bit value that sets the baud rate according the following formula: BaudFactor16 = 2^16 – 48000000/(2 * Desired Baud). For example, a BaudFactor16 = 63036 provides a baud rate of 9600 bps. With hardware revision 1.21, the value is only 8-bit and the formula is BaudFactor8 = 2^8 – TimerClockBase/(Desired Baud).

Following is example pseudocode for asynchronous communication:

```
//Set data rate for 9600 bps communication.
ePut(lngHandle, LJ_ioPUT_CONFIG, LJ_chASYNCH_BAUDFACTOR, 63036, 0);

//Enable UART.
ePut(lngHandle, LJ_ioASYNCH_COMMUNICATION, LJ_chASYNCH_ENABLE, 1, 0);

//Write data.
eGet(lngHandle, LJ_ioASYNCH_COMMUNICATION, LJ_chASYNCH_TX, &numBytes, array);

//Read data.  Always initialize array to 32 bytes.
eGet(lngHandle, LJ_ioASYNCH_COMMUNICATION, LJ_chASYNCH_RX, &numBytes, array);
```

4.3.13 - Watchdog Timer

The U3 (hardware version 1.21+ only) has firmware based watchdog capability. Unattended systems requiring maximum up-time might use this capability to reset the U3 or the entire system. When any of the options are enabled, an internal timer is enabled which resets on any incoming USB communication. If this timer reaches the defined TimeoutPeriod before being reset, the specified actions will occur. Note that while streaming, data is only going out, so some other command will have to be called periodically to reset the watchdog timer.

Timeout of the watchdog on the U3 can be specified to cause a device reset, update the state of 1 digital I/O (must be configured as output by user), or both.

Typical usage of the watchdog is to configure the reset defaults as desired, and then use the watchdog simply to reset the device on timeout.

Note that some USB hubs do not like to have any USB device repeatedly reset. With such hubs, the operating system will quit reenumerating the device on reset and the computer will have to be rebooted, so avoid excessive resets with hubs that seem to have this problem.

If the watchdog is accidentally configured to reset the processor with a very low timeout period (such as 1 second), it could be difficult to establish any communication with the device. In such a case, the reset-to-default jumper can be used to turn off the watchdog. Power up the U3 with a short from FIO6 to SPC (FIO2 to SCL on U3 1.20/1.21), then remove the jumper and power cycle the device again. This resets all power-up settings to factory default values.

There is one IOType used to configure and control the watchdog:

```
LJ_ioSWDT_CONFIG  // Channel is enable or disable constant.
```

The watchdog settings are stored in non-volatile flash memory (and reloaded at reset), so every request with this IOType causes a flash erase/write. The flash has a rated endurance of at least 20000 writes, which is plenty for reasonable operation, but if this

IOType is called in a high-speed loop the flash could be damaged.

The following are special channels used with the watchdog config IOType above:

```
LJ_chSWDT_ENABLE  // Value is timeout in seconds (1-65535).
LJ_chSWDT_DISABLE
```

The following are special channels, used with the put config IOType, to configure watchdog options. These parameters cause settings to be updated in the driver only. The settings are not actually sent to the hardware until the LJ_ioSWDT_CONFIG IOType (above) is used:

```
LJ_chSWDT_RESET_DEVICE
LJ_chSWDT_UDPATE_DIOA
LJ_chSWDT_DIOA_CHANNEL
LJ_chSWDT_DIOA_STATE
```

Following is example pseudocode to configure and enable the watchdog:

```
//Initialize EIO2 to output-low, which also forces the direction to output.
//It would probably be better to do this by configuring the power-up defaults.
AddRequest(lngHandle, LJ_ioPUT_DIGITAL_BIT, 10,0,0,0);

//Specify that the device should be reset on timeout.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSWDT_RESET_DEVICE,1,0,0);

//Specify that the state of the digital line should be updated on timeout.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSWDT_UDPATE_DIOA,1,0,0);

//Specify that EIO2 is the desired digital line.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSWDT_DIOA_CHANNEL,10,0,0);

//Specify that the digital line should be set high.
AddRequest(lngHandle, LJ_ioPUT_CONFIG, LJ_chSWDT_DIOA_STATE,1,0,0);

//Enable the watchdog with a 60 second timeout.
AddRequest(lngHandle, LJ_ioSWDT_CONFIG, LJ_chSWDT_ENABLE,60,0,0);

//Execute the requests.
GoOne(lngHandle);
```

Following is pseudocode to disable the watchdog:

```
//Disable the watchdog.
ePut(lngHandle, LJ_ioSWDT_CONFIG, LJ_chSWDT_DISABLE,0,0);
```

4.3.14 - Miscellaneous

The following are special channels, used with the get/put config IOTypes, to read/write the calibration memory and user memory:

```
LJ_chCAL_CONSTANTS    // x1 points to an array with 64 doubles.
LJ_chUSER_MEM    // x1 points to an array with 256 bytes.
```

For more information, see the low-level descriptions in Sections 5.2.6 – 5.2.8, and see the Memory example in the VC6_LJUD archive.

The following wait IOType is used to create a delay between other actions:

```
LJ_ioPUT_WAIT  // Channel ignored. Value = 0-8388480 microseconds.
```

Any value (in microseconds) from 0-8388480 can be passed, but the actual resolution is 128 microseconds. On hardware V1.20, the delay and resolution are 2x.

This is typically used to put a small delay between two actions that will execute in the same low-level Feedback command. It is useful when the desired delay is less than what can be accomplished through software.

For example, a 1.024 millisecond pulse can be created by executing a single Add/Go/Get block that sequentially requests to set FIO4 to output-high, wait 1024 microseconds, then set FIO4 to output-low.

4.4 - Errorcodes

All functions return an LJ_ERROR errorcode as listed in the following tables.

Errorcode	Name	Description
-2	LJE_UNABLE_TO_READ_CALDATA	Warning: Defaults used instead.
-1	LJE_DEVICE_NOT_CALIBRATED	Warning: Defaults used instead.
0	LJE_NOERROR	
2	LJE_INVALID_CHANNEL_NUMBER	Channel that does not exist (e.g. DAC2 on a UE9), or data from stream is requested on a channel that is not in the scan list.
3	LJE_INVALID_RAW_INOUT_PARAMETER	
4	LJE_UNABLE_TO_START_STREAM	
5	LJE_UNABLE_TO_STOP_STREAM	
6	LJE_NOTHING_TO_STREAM	
7	LJE_UNABLE_TO_CONFIG_STREAM	
8	LJE_BUFFER_OVERRUN	Overrun of the UD stream buffer.
9	LJE_STREAM_NOT_RUNNING	
10	LJE_INVALID_PARAMETER	
11	LJE_INVALID_STREAM_FREQUENCY	
12	LJE_INVALID_AIN_RANGE	
13	LJE_STREAM_CHECKSUM_ERROR	
14	LJE_STREAM_COMMAND_ERROR	
15	LJE_STREAM_ORDER_ERROR	Stream packet recieved out of sequence.
16	LJE_AD_PIN_CONFIGURATION_ERROR	Analog request on a digital pin, or vice versa
17	LJE_REQUEST_NOT_PROCESSED	Previous request had an error.
19	LJE_SCRATCH_ERROR	
20	LJE_DATA_BUFFER_OVERFLOW	
21	LJE_ADC0_BUFFER_OVERFLOW	
22	LJE_FUNCTION_INVALID	
23	LJE_SWDT_TIME_INVALID	
24	LJE_FLASH_ERROR	
25	LJE_STREAM_IS_ACTIVE	
26	LJE_STREAM_TABLE_INVALID	
27	LJE_STREAM_CONFIG_INVALID	
28	LJE_STREAM_BAD_TRIGGER_SOURCE	
30	LJE_STREAM_INVALID_TRIGGER	
31	LJE_STREAM_ADC0_BUFFER_OVERFLOW	
33	LJE_STREAM_SAMPLE_NUM_INVALID	
34	LJE_STREAM_BIPOLAR_GAIN_INVALID	
35	LJE_STREAM_SCAN_RATE_INVALID	
36	LJE_TIMER_INVALID_MODE	
37	LJE_TIMER_QUADRATURE_AB_ERROR	
38	LJE_TIMER_QUAD_PULSE_SQUENCE	
39	LJE_TIMER_BAD_CLOCK_SOURCE	
40	LJE_TIMER_STREAM_ACTIVE	
41	LJE_TIMER_PWMSTAOP_MODULE_ERROR	
42	LJE_TIMER_SEQUENCE_ERROR	
43	LJE_TIMER_SHARING_ERROR	
44	LJE_TIMER_LINE_SEQUENCE_ERROR	
45	LJE_EXT_OSC_NOT_STABLE	
46	LJE_INVALID_POWER_SETTING	
47	LJE_PLL_NOT_LOCKED	
48	LJE_INVALID_PIN	
49	LJE_IOTYPE_SYNCH_ERROR	
50	LJE_INVALID_OFFSET	
51	LJE_FEEDBACK_IOTYPE_NOT_valid	
52	LJE_SHT_CRC	
53	LJE_SHT_MEASREADY	
54	LJE_SHT_ACK	
55	LJE_SHT_SERIAL_RESET	
56	LJE_SHT_COMMUNICATION	
57	LJE_AIN_WHILE_STREAMING	AIN not available to command/response functions while the UE9 is stream.
58	LJE_STREAM_TIMEOUT	
60	LJE_STREAM_SCAN_OVERLAP	New scan started before the previous scan completed. Scan rate is too high.
61	LJE_FIRMWARE_VERSION_IOTYPE	IOType not supported with this firmware.
62	LJE_FIRMWARE_VERSION_CHANNEL	Channel not supported with this firmware.
63	LJE_FIRMWARE_VERSION_VALUE	Value not supported with this firmware.
64	LJE_HARDWARE_VERSION_IOTYPE	IOType not supported with this hardware.
65	LJE_HARDWARE_VERSION_CHANNEL	Channel not supported with this hardware.
66	LJE_HARDWARE_VERSION_VALUE	Value not supported with this hardware.
67	LJE_CANT_CONFIGURE_PIN_FOR_ANALOG	
68	LJE_CANT_CONFIGURE_PIN_FOR_DIGITAL	
70	LJE_TC_PIN_OFFSET_MUST_BE_4_TO_8	

Table 4.4-1. Request Level Errorcodes

Errorcode	Name	Description
1000	LJE_MIN_GROUP_ERROR	Errors above this number stop all requests.
1001	LJE_UNKNOWN_ERROR	Unrecognized error that is caught.
1002	LJE_INVALID_DEVICE_TYPE	
1003	LJE_INVALID_HANDLE	
1004	LJE_DEVICE_NOT_OPEN	AddRequest() called even thought Open() failed.
1005	LJE_NO_DATA_AVAILABLE	GetResult() call without calling a Go function, or a channel is passed that was not in the request list.
1006	LJE_NO_MORE_DATA_AVAILABLE	
1007	LJE_LABJACK_NOT_FOUND	LabJack not found at the given id or address.
1008	LJE_COMM_FAILURE	Unable to send or receive the correct number of bytes.
1009	LJE_CHECKSUM_ERROR	
1010	LJE_DEVICE_ALREADY_OPEN	
1011	LJE_COMM_TIMEOUT	
1012	LJE_USB_DRIVER_NOT_FOUND	
1013	LJE_INVALID_CONNETION_TYPE	
1014	LJE_INVALID_MODE	

Table 4.4-2. Group Level Errorcodes

Table 4-1 lists the errors which are specific to a request. For example, LJE_INVALID_CHANNEL_NUMBER. If this error occurs, other requests are not affected. Table 4-2 lists errors which cause all pending requests for a particular Go() to fail with the same error. If this type of error is received the state of any of the request is not known. For example, if requests are executed with a single Go() to set the AIN range and read an AIN, and the read fails with an LJE_COMM_FAILURE, it is not known whether the AIN range was set to the new value or whether it is still set at the old value.

5 - Low-level Function Reference

This section describes the low level functions of the U3. These are commands sent over USB directly to the processor on the U3.

The majority of Windows users will use the high-level UD driver rather than these low-level functions.

5.1 - General Protocol

Following is a description of the general U3 low-level communication protocol. There are two types of commands:

Normal: 1 command word plus 0-7 data words.

Extended: 3 command words plus 0-125 data words.

Normal commands have a smaller packet size and can be faster in some situations. Extended commands provide more commands, better error detection, and a larger maximum data payload.

Normal command format:

Byte	
0	Checksum8: Includes bytes 1-15.
1	Command Byte: DCCCWWW
	Bit 7: Destination bit:
	0 = Local,
	1 = Remote.
	Bits 6-3: Normal command number (0-14).
	Bits 2-0: Number of data words.
2-15	Data Words.

Extended command format:

Extended Command Format:	
Byte	
0	Checksum8: Includes bytes 1-5.
1	Command Byte: D111WWW
	Bit 7: Destination bit:
	0 = Local,
	1 = Remote.
	Bits 6-3: 1111 specifies that this is an extended Command.
	Bits 2-0: Used with some commands.
2	Number of data words
3	Extended command number.
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6-255	Data words.

Checksum calculations:

All checksums are a “1’s complement checksum”. Both the 8-bit and 16-bit checksum are unsigned. Sum all applicable bytes in an accumulator, 1 at a time. Each time another byte is added, check for overflow (carry bit), and if true add one to the accumulator.

In a high-level language, do the following for the 8-bit normal command checksum:

1. Get the subarray consisting of bytes 1 and up.
2. Convert bytes to U16 and sum into a U16 accumulator.
3. Divide by 2^8 and sum the quotient and remainder.
4. Divide by 2^8 and sum the quotient and remainder.

In a high-level language, do the following for an extended command 16-bit checksum:

1. Get the subarray consisting of bytes 6 and up.
2. Convert bytes to U16 and sum into a U16 accumulator (can’t overflow).

Then do the following for the 8-bit extended checksum:

1. Get the subarray consisting of bytes 1 through 5.
2. Convert bytes to U16 and sum into a U16 accumulator.
3. Divide by 2^8 and sum the quotient and remainder.
4. Divide by 2^8 and sum the quotient and remainder.

Destination bit:

This bit specifies whether the command is destined for the local or remote target. This bit is ignored on the U3.

Multi-byte parameters:

In the following function definitions there are various multi-byte parameters. The least significant byte of the parameter will always be found at the lowest byte number. For instance, bytes 10 through 13 of CommConfig are the IP address which is 4 bytes long. Byte 10 is the least significant byte (LSB), and byte 13 is the most significant byte (MSB).

Masks:

Some functions have mask parameters. The WriteMask found in some functions specifies which parameters are to be written. If a bit is 1, that parameter will be updated with the new passed value. If a bit is 0, the parameter is not changed and only a read is performed.

The AINMask found in some functions specifies which analog inputs are acquired. This is a 16-bit parameter where each bit corresponds to AIN0-AIN15. If a bit is 1, that channel will be acquired.

The digital I/O masks, such as FIOMask, specify that the passed value for direction and state are updated if a bit 1. If a bit of the mask is 0 only a read is performed on that bit of I/O.

Binary Encoded Parameters:

Many parameters in the following functions use specific bits within a single integer parameter to write/read specific information. In particular, most digital I/O parameters contain the information for each bit of I/O in one integer, where each bit of I/O corresponds to the same bit in the parameter (e.g. the direction of FIO0 is set in bit 0 of parameter FIODir). For instance, in the function ControlConfig, the parameter FIODir is a single byte (8 bits) that writes/reads the direction of each of the 8 FIO lines:

- if FIODir is 0, all FIO lines are input,
- if FIODir is 1 (2^0), FIO0 is output, FIO1-FIO7 are input,
- if FIODir is 5 ($2^0 + 2^2$), FIO0 and FIO2 are output, all other FIO lines are input,
- if FIODir is 255 ($2^0 + \ldots + 2^7$), FIO0-FIO7 are output.

5.2 - Low-Level Functions

5.2.1 - Bad Checksum

If the processor detects a bad checksum in any command, the following 2-byte normal response will be sent and nothing further will be done.

Response:	
Byte	
0	0xB8
1	0xB8

5.2.2 - ConfigU3

Writes and reads various configuration settings. Although this function has many of the same parameters as other functions, most parameters in this case are affecting the power-up values, not the current values. There is a hardware method to restore bytes 9-20 to the factory default value of 0x00: Power up the U3 with a short from FIO6 to SPC (FIO2 to SCL on U3 1.20/1.21), then remove the jumper and power cycle the device again.

If WriteMask is nonzero, some or all default values are written to flash. The U3 flash has a rated endurance of at least 20000 writes, which is plenty for reasonable operation, but if this function is called in a high-speed loop with a nonzero WriteMask, the flash could eventually be damaged.

Note: If the stream is running, you cannot update any of the values (WriteMask must equal 0).

Command:		
Byte		
0	Checksum8	
1	0xF8	
2	0x0A	
3	0x08	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	WriteMask0	
		Bit 3: LocalID
		Bit 2: DAC Defaults
		Bit 1: Digital I/O Defaults
		Bit 0: Reserved
7	WriteMask1 (Reserved)	
8	LocalID	
9	TimerCounterConfig	
		Bits 4-7: TimerCounterPinOffset
		Bit 3: Enable Counter1
		Bit 2: Enable Counter0
		Bit 0-1: Number of timers enabled
10	FIOAnalog	
11	FIODirection	
12	FIOState	
13	EIOAnalog	
14	EIODirection	
15	EIOState	
16	CIODirection	
17	CIOState	
18	DAC1Enable	
19	DAC0	
20	DAC1	
21	TimerClockConfig	
22	TimerClockDivisor (0 = ÷256)	
23	CompatibilityOptions	
24	0x00	
25	0x00	
Response:		
Byte		
0	Checksum8	
1	0xF8	
2	0x10	
3	0x08	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	Errorcode	
7	Reserved	
8	Reserved	
9-10	FirmwareVersion	
11-12	BootloaderVersion	
13-14	HardwareVersion	
15-18	SerialNumber	
19-20	ProductID	
21	LocalID	
22	TimerCounterMask	
23	FIOAnalog	
24	FIODirection	
25	FIOState	
26	EIOAnalog	
27	EIODirection	
28	EIOState	
29	CIODirection	
30	CIOState	
31	DAC1Enable	
32	DAC0	
33	DAC1	
34	TimerClockConfig	
35	TimerClockDivisor (0 = ÷256)	
36	CompatibilityOptions	
37	VersionInfo	

- **WriteMask**: Has bits that determine which, if any, of the parameters will be written to flash as the reset defaults. If a bit is 1, that parameter will be updated with the new passed value. If a bit is 0, the parameter is not changed and only a read is performed. Note that reads return reset defaults, not necessarily current values (except for LocalID). For instance, the value returned by FIODirection is the directions at reset, not necessarily the current directions.
- **LocalID**: If the WriteMask bit 3 is set, the value passed become the default value, meaning it is written to flash and used at reset. This is a user-configurable ID that can be used to identify a specific LabJack. The return value of this parameter is the current value and the power-up default value.
- **TimerCounterConfig**: If the WriteMask bit 1 is set, the value passed becomes the default value, meaning it is written to flash and used at reset. The return value of this parameter is a read of the power-up default. See Section 5.2.3.
- **FIO/EIO/CIO**: If the WriteMask bit 1 is set, the values passed become the default values, meaning they are written to flash and used at reset. Regardless of the mask bit, this function has no effect on the current settings. The return value of these parameters are a read of the power-up defaults.

- **DAC**: If the WriteMask bit 2 is set, the values passed become the default values, meaning they are written to flash and used at reset. Regardless of the mask bit, this function has no effect on the current settings. The return values of these parameters are a read of the power-up defaults.
- **TimerClockConfig & TimerClockDivisor**: If the WriteMask bit 4 is set, the values passed become the default values, meaning they are written to flash and used at reset. The return values of these parameters are a read of the power-up defaults. See Section 5.2.4.
- **CompatibilityOptions**: If the WriteMask bit 5 is set, the value passed becomes the default value, meaning it is written to flash and used at reset. The return value of this parameter is a read of the power-up default. If bit 0 is set, Timer Counter Pin Offset errors are ignored. If bit 1 is set, all DAC operations will use 8-bit mode rather than 10-bit mode. Once this value has been changed the U3 will need to be restarted before the new setting will take affect.
- **FirmwareVersion**: Fixed parameter specifies the version number of the main firmware. A firmware upgrade will generally cause this parameter to change. The lower byte is the integer portion of the version and the higher byte is the fractional portion of the version.
- **BootloaderVersion**: Fixed parameter specifies the version number of the bootloader. The lower byte is the integer portion of the version and the higher byte is the fractional portion of the version.
- **HardwareVersion**: Fixed parameter specifies the version number of the hardware. The lower byte is the integer portion of the version and the higher byte is the fractional portion of the version.
- **SerialNumber**: Fixed parameter that is unique for every LabJack.
- **ProductID**: (3) Fixed parameter identifies this LabJack as a U3.
- **VersionInfo**: Bit 0 specifies U3B. Bit 1 specifies U3C and if set then bit 4 specifies -HV version.

5.2.3 - ConfigIO

Writes and reads the current IO configuration.

Command:		
Byte		
0	Checksum8	
1	0xF8	
2	0x03	
3	0x0B	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	WriteMask	
		Bit 5: Write UART Related settings
		Bit 4: Reserved, Pass 0
		Bit 3: EIOAnalog
		Bit 2: FIOAnalog
		Bit 1: DAC1Enable
		Bit 0 : TimerCounterConfig
7	Reserved	
8	TimerCounterConfig	
		Bits 4-7: TimerCounterPinOffset
		Bit 3: Enable Counter1
		Bit 2: Enable Counter0
		Bits 0-1: Number of timers enabled
9	DAC1Enable (ignored on hardware rev 1.30+)	
		Bit 2: Assign UART Pins (HW 1.30 only)
		Bit 1: Reserved, Pass 0
		Bit 0: Enable DAC1
10	FIOAnalog	
11	EIOAnalog	
Response:		
Byte		
0	Checksum8	
1	0xF8	
2	0x03	
3	0x0B	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	Errorcode	
7	Reserved	
8	TimerCounterConfig	
9	DAC1Enable	
10	FIOAnalog	
11	EIOAnalog	

- **WriteMask**: Has bits that determine which, if any, of the parameters will be written.
- **TimerCounterConfig**: Used to enable/disable timers and counters. Timers/counters will be assigned to IO pins starting with FIO0 plus TimerCounterPinOffset (4-8 only starting with hardware revision 1.30). Timer0 takes the first IO pin, then Timer1, Counter0, and Counter1. Whenever this function is called and timers are enabled, the timers are initialized to mode 10, so the desired timer mode must always be specified after every call to this function. Note that Counter0 is not available when using a timer clock base that supports a timer clock divisor (TimerClockBase = 3-6).
- **Assign UART Pins**: On hardware 1.30 setting this bit will assign IO lines to the UART module. This setting will be ignored unless the UART write bit is set in the WriteMask byte.
- **DAC1Enable**: On hardware revisions 1.20/1.21 only, bit 0 enables DAC1. When DAC1 is disabled, it outputs a constant voltage of 1.5 times the internal Vref (~2.44 volts). When DAC1 is enabled, the internal Vref is not available for the analog inputs and Vreg (~3.3 volts) is used as the AIN reference. Starting with hardware revision 1.30, DAC1 is always enabled.
- **FIOAnalog**: Each bit determines whether that bit of FIO is analog input (=1) or digital I/O (=0).
- **EIOAnalog**: Each bit determines whether that bit of EIO is analog input (=1) or digital I/O (=0).

LabJackPython Example

```
>>> import u3
>>> d = u3.U3()
>>> d.debug = True
'''Assign timer0 to FIO6, set FIO4, FIO5 as analog input, and set EIO1, EIO2 as analog input'''
>>> d.configIO(TimerCounterPinOffset = 6, NumberOfTimersEnabled = 1, FIOAnalog = 48, EIOAnalog = 3)
Sent:  [0xa8, 0xf8, 0x3, 0xb, 0xa1, 0x0, 0xd, 0x0, 0x61, 0x0, 0x30, 0x3]
Result:  [0x9b, 0xf8, 0x3, 0xb, 0x94, 0x0, 0x0, 0x0, 0x61, 0x0, 0x30, 0x3]
{'NumberOfTimersEnabled': 1, 'TimerCounterPinOffset': 6, 'DAC1Enable': 0, 'FIOAnalog': 48, 'EIOAnalog': 3, 'TimerCounterConfig': 97, 'EnableCounter1': False, 'EnableCounter0': False}
```

5.2.4 - ConfigTimerClock

Writes and read the timer clock configuration.

Command:			
Byte			
0	Checksum8		
1	0xF8		
2	0x02		
3	0x0A		
4	Checksum16 (LSB)		
5	Checksum16 (MSB)		
6	Reserved		
7	Reserved		
8	TimerClockConfig		
		Bit 7: Configure the clock	
		Bits 2-0: TimerClockBase	
			b000: 4 MHz
			b001: 12 MHz
			b010: 48 MHz (Default)
			b011: 1 MHz/Divisor
			b100: 4 MHz/Divisor
			b101: 12 MHz/Divisor
			b110: 48 MHz/Divisor
9	TimerClockDivisor (0 = ÷256)		
Response:			
Byte			
0	Checksum8		
1	0xF8		
2	0x02		
3	0x0A		
4	Checksum16 (LSB)		
5	Checksum16 (MSB)		
6	Errorcode		
7	Reserved		
8	TimerClockConfig		
9	TimerClockDivisor (0 = ÷256)		

- **TimerClockConfig**: Bit 7 determines whether the new TimerClockBase and TimerClockDivisor are written, or if just a read is performed. Bits 0-2 specify the TimerClockBase. If TimerClockBase is 3-6, then Counter0 is not available.
- **TimerClockDivisor**: The base timer clock is divided by this value, or divided by 256 if this value is 0. Only applies if TimerClockBase is 3-6.

5.2.5 - Feedback

A flexible function that handles all command/response functionality. One or more IOTypes are used to perform a single write/read or multiple writes/reads.

Note that the general protocol described in Section 5.1 defines byte 2 of an extended command as the number of data words, which is the number of words in a packet beyond the first 3 (a word is 2 bytes). Also note that the overall size of a packet must be an even number of bytes, so in this case an extra 0x00 is added to the end of the command and/or response if needed to accomplish this.

Since this command has a flexible size, byte 2 will vary. For instance, if a single IOType of PortStateRead (d26) is passed, byte 2 would be equal to 1 for the command and 3 for the response. If a single IOType of LED (d9) is passed, an extra 0 must be added to the command to make the packet have an even number of bytes, and byte 2 would be equal to 2. The response would also need an extra 0 to be even, and byte 2 would be equal to 2.

Command:	
Byte	
0	Checksum8
1	0xF8
2	0.5 + Number of Data Words (IOTypes and Data)
3	0x00
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	Echo
7-63	IOTypes and Data
Response:	
Byte	
0	Checksum8
1	0xF8
2	1.5 + Number of Data Words (If Errorcode = 0)
3	0x00
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	Errorcode
7	ErrorFrame
8	Echo
9-63	Data

- **IOTypes & Data**: One or more IOTypes can be passed in a single command, up to the maximum packet size. More info about the available IOTypes is below. In the outgoing command each IOType is passed and accompanied by 0 or more data bytes. In the incoming response, only data bytes are returned without the IOTypes.
- **Echo**: This byte is simply echoed back in the response. A host application might pass sequential numbers to ensure the responses are in order and associated with the proper command.
- **ErrorFrame**: If Errorcode is not zero, this parameter indicates which IOType caused the error. For instance, if the 3rd passed IOType caused the error, the ErrorFrame would be equal to 3. Also note that data is only returned for IOTypes before the one that caused the error, so if any IOType causes an error the overall function response will have less bytes than expected.

Name	IOType (dec)	WriteBytes	ReadBytes
AIN	1	3	2
WaitShort	5	2	0
WaitLong	6	2	0
LED	9	2	0
BitStateRead	10	2	1
BitStateWrite	11	2	0
BitDirRead	12	2	1
BitDirWrite	13	2	0
PortStateRead	26	1	3
PortStateWrite	27	7	0
PortDirRead	28	1	3
PortDirWrite	29	7	0
DAC0 (8-bit)	34	2	0
DAC1 (8-bit)	35	2	0
DAC0 (16-bit)	38	3	0
DAC1 (16-bit)	39	3	0
Timer0	42	4	4
Timer0Config	43	4	0
Timer1	44	4	4
Timer1Config	45	4	0
Counter0	54	2	4
Counter1	55	2	4
Buzzer	63	6	0

5.2.5.1 - AIN: IOType = 1

AIN, 3 Command Bytes:	
0	IOType = 1
1	Bits 4-0: Positive Channel
	Bit 6: LongSettling
	Bit 7: QuickSample
2	Negative Channel
2 Response Bytes:	
0	AIN LSB
1	AIN MSB

This IOType returns a single analog input reading.

Note: Do **not** use this IO type while streaming.

- **Positive Channel**: 0-15 for AIN0-AIN15, 30 for temp sensor, or 31 for Vreg. Note that AIN0-AIN7 appear on FIO0-FIO7, and AIN8-AIN15 appear on EIO0-EIO7.
- **LongSettling**: If this bit is set, additional settling time is added between the multiplexer configuration and the analog to digital conversion.
- **QuickSample**: If this bit is set, a faster analog input conversion is done, at the expense of increased noise.
- **Negative Channel**: 0-15 for AIN0-AIN15, 30 for Vref, or 31 for single-ended. Note that AIN0-AIN7 appear on FIO0-FIO7, and AIN8-AIN15 appear on EIO0-EIO7.
- **AIN LSB & MSB**: Analog input reading is returned justified as a 16-bit value (always unsigned).

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
Analog Input Feedback command

    specify the positive and negative channels to use
    (0-16, 30 and 31 are possible)
    also specify whether to turn on longSettle or quick Sample

    returns 16-bit signed int sample

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.AIN(PositiveChannel = 0, NegativeChannel=31, LongSettling=False
    Sent:  [0x1b, 0xf8, 0x2, 0x0, 0x20, 0x0, 0x0, 0x1, 0x0, 0x1f]
    Response:  [0xab, 0xf8, 0x3, 0x0, 0xaf, 0x0, 0x0, 0x0, 0x0, 0x20, 0x8f, 0x0]
    [36640]
```

This Gist brought to you by GitHub. u3-feedback-AIN.txt view raw

5.2.5.2 - WaitShort: IOType=5

WaitShort, 2 Command Bytes:	
0	IOType = 5
1	Time (*128 us)
0 Response Bytes:	

This IOType provides a way to add a delay during execution of the Feedback function. The typical use would be putting this IOType in between IOTypes that set a digital output line high and low, thus providing a simple way to create a pulse. Note that this IOType uses the same internal timer as stream mode, so cannot be used while streaming.

- **Time**: This value (0-255) is multiplied by 128 microseconds (256 on hardware V1.20) to determine the delay.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
WaitShort Feedback command

    specify the number of 128us time increments to wait

    >>> import u3
```

```
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.WaitShort(Time = 9))
    Sent:  [0x9, 0xf8, 0x2, 0x0, 0xe, 0x0, 0x0, 0x5, 0x9, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-WaitShort.txt view raw

5.2.5.3 - WaitLong: IOType=6

WaitLong, 2 Command Bytes:	
0	IOType = 6
1	Time (*32 ms)
0 Response Bytes:	

This IOType provides a way to add a delay during execution of the Feedback function. The typical use would be putting this IOType in between IOTypes that set a digital output line high and low, thus providing a simple way to create a pulse. Note that this IOType uses the same internal timer as stream mode, so cannot be used while streaming.

- **Time**: This value (0-255) is multiplied by 32 milliseconds (64 on hardware V1.20) to determine the delay.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
WaitLong Feedback command

    specify the number of 32ms time increments to wait

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.WaitLong(Time = 70))
    Sent:  [0x47, 0xf8, 0x2, 0x0, 0x4c, 0x0, 0x0, 0x6, 0x46, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-WaitLong.txt view raw

5.2.5.4 - LED: IOType=9

LED, 2 Command Bytes:	
0	IOType = 9
1	State
0 Response Bytes:	

This IOType simply turns the status LED on or off.

- **State**: 1=On, 0=Off.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
LED Toggle

    specify whether the LED should be on or off by truth value

    1 or True = On, 0 or False = Off

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.LED(State = False))
    Sent:  [0x4, 0xf8, 0x2, 0x0, 0x9, 0x0, 0x0, 0x9, 0x0, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
    >>> d.getFeedback(u3.LED(State = True))
    Sent:  [0x5, 0xf8, 0x2, 0x0, 0xa, 0x0, 0x0, 0x9, 0x1, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-LED.txt view raw

5.2.5.5 - BitStateRead: IOType=10

BitStateRead, 2 Command Bytes:	
0	IOType = 10
1	Bits 0-4: IONumber
1 Response Byte:	
0	Bit 0: State

This IOType reads the state of a single bit of digital I/O. Only lines configured as digital (not analog) return valid readings.

- **IO Number**: 0-7=FIO, 8-15=EIO, or 16-19=CIO.
- **State**: 1=High, 0=Low.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
BitStateRead Feedback command

    read the state of a single bit of digital I/O.  Only digital
    lines return valid readings.

    IONumber: 0-7=FIO, 8-15=EIO, 16-19=CIO
    return 0 or 1

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.BitStateRead(IONumber = 5))
    Sent:  [0xa, 0xf8, 0x2, 0x0, 0xf, 0x0, 0x0, 0xa, 0x5, 0x0]
    Response:  [0xfb, 0xf8, 0x2, 0x0, 0x1, 0x0, 0x0, 0x0, 0x0, 0x1]
    [1]
```


5.2.5.6 - BitStateWrite: IOType=11

BitStateWrite, 2 Command Bytes:	
0	IOType = 11
1	Bits 0-4: IO Number
	Bit 7: State
0 Response Byte:	

This IOType writes the state of a single bit of digital I/O. The direction of the specified line is forced to output.

- **IO Number**: 0-7=FIO, 8-15=EIO, or 16-19=CIO.
- **State**: 1=High, 0=Low.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
BitStateWrite Feedback command

    write a single bit of digital I/O.  The direction of the
    specified line is forced to output.

    IONumber: 0-7=FIO, 8-15=EIO, 16-19=CIO
    State: 0 or 1

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.BitStateWrite(IONumber = 5, State = 0))
    Sent:  [0xb, 0xf8, 0x2, 0x0, 0x10, 0x0, 0x0, 0xb, 0x5, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```


5.2.5.7 - BitDirRead: IOType=12

BitDirRead, 2 Command Bytes:	
0	IOType = 12
1	Bits 0-4: IO Number
1 Response Byte:	
0	Bit 0: Direction

This IOType reads the direction of a single bit of digital I/O. This is the digital direction only, and does not provide any information as to whether the line is configured as digital or analog.

- **IO Number**: 0-7=FIO, 8-15=EIO, or 16-19=CIO.
- **Direction**: 1=Output, 0=Input.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
Read the digital direction of one I/O

    IONumber: 0-7=FIO, 8-15=EIO, 16-19=CIO
    returns 1 = Output, 0 = Input

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.BitDirRead(IONumber = 5))
    Sent:  [0xc, 0xf8, 0x2, 0x0, 0x11, 0x0, 0x0, 0xc, 0x5, 0x0]
    Response:  [0xfb, 0xf8, 0x2, 0x0, 0x1, 0x0, 0x0, 0x0, 0x0, 0x1]
    [1]
```


5.2.5.8 - BitDirWrite: IOType=13

BitDirWrite, 2 Command Bytes:	
0	IOType = 13
1	Bits 0-4: IO Number
	Bit 7: Direction
0 Response Bytes:	

This IOType writes the direction of a single bit of digital I/O.

- **IO Number**: 0-7=FIO, 8-15=EIO, or 16-19=CIO.
- **Direction**: 1=Output, 0=Input.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
BitDirWrite Feedback command

    Set the digital direction of one I/O

    IONumber: 0-7=FIO, 8-15=EIO, 16-19=CIO
    Direction: 1 = Output, 0 = Input

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.BitDirWrite(IONumber = 5, Direction = 0))
    Sent:  [0xd, 0xf8, 0x2, 0x0, 0x12, 0x0, 0x0, 0xd, 0x5, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-BitDirWrite.txt view raw

5.2.5.9 - PortStateRead: IOType=26

PortStateRead, 1 Command Byte:	
0	IOType = 26
3 Response Bytes:	
0-2	State

This IOType reads the state of all digital I/O, where 0-7=FIO, 8-15=EIO, and 16-19=CIO. Only lines configured as digital (not analog) return valid readings.

- **State**: Each bit of this value corresponds to the specified bit of I/O such that 1=High and 0=Low. If all are low, State=d0. If all 20 standard digital I/O are high, State=d1048575. If FIO0-FIO2 are high, EIO0-EIO2 are high, CIO0 are high, and all other I/O are low (b00000001000001100000111), State=d67335.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
PortStateRead Feedback command
    Reads the state of all digital I/O.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.PortStateRead())
    Sent:  [0x14, 0xf8, 0x1, 0x0, 0x1a, 0x0, 0x0, 0x1a]
    Response:  [0xeb, 0xf8, 0x3, 0x0, 0xee, 0x1, 0x0, 0x0, 0x0, 0xe0, 0xff, 0xf]
    [{'CIO': 15, 'FIO': 224, 'EIO': 255}]
```

This Gist brought to you by GitHub. u3-feedback-PortStateRead.txt view raw

5.2.5.10 - PortStateWrite: IOType=27

PortStateWrite, 7 Command Bytes:	
0	IOType = 27
1-3	WriteMask
4-6	State
0 Response Bytes:	

This IOType writes the state of all digital I/O, where 0-7=FIO, 8-15=EIO, and 16-19=CIO. The direction of the selected lines is forced to output.

- **WriteMask**: Each bit specifies whether to update the corresponding bit of I/O.
- **State**: Each bit of this value corresponds to the specified bit of I/O such that 1=High and 0=Low. To set all low, State=d0. To set all 20 standard digital I/O high, State=d1048575. To set FIO0-FIO2 high, EIO0-EIO2 high, CIO0 high, and all other I/O low (b00000001000001100000111), State=d67335.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
PortStateWrite Feedback command

    State: A list of 3 bytes representing FIO, EIO, CIO
    WriteMask: A list of 3 bytes, representing which to update.
               The Default is all ones.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.PortStateWrite(State = [0xab, 0xcd, 0xef], WriteMask = [0xff, 0
```

```
    Sent:  [0x81, 0xf8, 0x4, 0x0, 0x7f, 0x5, 0x0, 0x1b, 0xff, 0xff, 0xff, 0xab, 0xcd, 0x
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-PortStateWrite.txt view raw

5.2.5.11 - PortDirRead: IOType=28

PortDirRead, 1 Command Byte:	
0	IOType = 28
3 Response Bytes:	
0-2	Direction

This IOType reads the directions of all digital I/O, where 0-7=FIO, 8-15=EIO, and 16-19=CIO. These are the digital directions only, and do not provide any information as to whether the lines are configured as digital or analog.

- **Direction**: Each bit of this value corresponds to the specified bit of I/O such that 1=Output and 0=Input. If all are input, Direction=d0. If all 20 standard digital I/O are output, Direction=d1048575. If FIO0-FIO2 are output, EIO0-EIO2 are output, CIO0 are output, and all other I/O are input (b00000001000001110000111), Direction=d67335.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
PortDirRead Feedback command
    Reads the direction of all digital I/O.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.PortDirRead())
    Sent:  [0x16, 0xf8, 0x1, 0x0, 0x1c, 0x0, 0x0, 0x1c]
    Response:  [0xfb, 0xf8, 0x3, 0x0, 0xfe, 0x1, 0x0, 0x0, 0x0, 0xf0, 0xff, 0xf]
    [{'CIO': 15, 'FIO': 240, 'EIO': 255}]
```

This Gist brought to you by GitHub. u3-feedback-PortDirRead.txt view raw

5.2.5.12 - PortDirWrite: IOType=29

PortDirWrite, 7 Command Bytes:	
0	IOType = 29
1-3	WriteMask
4-6	Direction
0 Response Bytes:	

This IOType writes the direction of all digital I/O, where 0-7=FIO, 8-15=EIO, and 16-19=CIO. Note that the desired lines must be configured as digital (not analog).

- **WriteMask**: Each bit specifies whether to update the corresponding bit of I/O.
- **Direction**: Each bit of this value corresponds to the specified bit of I/O such that 1=Output and 0=Input. To configure all as input, Direction=d0. For all 20 standard digital I/O as output, Direction=d1048575. To configure FIO0-FIO2 as output, EIO0-EIO2 as output, CIO0 as output, and all other I/O as input (b00000001000001110000111), Direction=d67335.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
PortDirWrite Feedback command

    Direction: A list of 3 bytes representing FIO, EIO, CIO
    WriteMask: A list of 3 bytes, representing which to update. Default is all ones.


    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.PortDirWrite(Direction = [0xaa, 0xcc, 0xff], WriteMask = [0xff,
    Sent:  [0x91, 0xf8, 0x4, 0x0, 0x8f, 0x5, 0x0, 0x1d, 0xff, 0xff, 0xff, 0xaa, 0xcc, 0x
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-PortDirWrite.txt view raw

5.2.5.13 - DAC# (8-bit): IOType=34,35

DAC# (8-bit), 2 Command Bytes:	
0	IOType = 34, 35
1	Value
0 Response Bytes:	

This IOType controls a single analog output.

- **Value**: 0=Minimum, 255=Maximum.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
8-bit DAC Feedback command
```

```
    Controls a single analog output

    Dac: 0 or 1
    Value: 0-255

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.DAC8(Dac = 0, Value = 0x55))
    Sent:  [0x72, 0xf8, 0x2, 0x0, 0x77, 0x0, 0x0, 0x22, 0x55, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-DAC8.txt view raw

```
8-bit DAC Feedback command for DAC0

    Controls DAC0 in 8-bit mode.

    Value: 0-255

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.DAC0_8(Value = 0x33))
    Sent:  [0x50, 0xf8, 0x2, 0x0, 0x55, 0x0, 0x0, 0x22, 0x33, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-DAC0_8.txt view raw

```
8-bit DAC Feedback command for DAC1

    Controls DAC1 in 8-bit mode.

    Value: 0-255

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.DAC1_8(Value = 0x22))
    Sent:  [0x40, 0xf8, 0x2, 0x0, 0x45, 0x0, 0x0, 0x23, 0x22, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-DAC1_8.txt view raw

5.2.5.14 - DAC# (16-bit): IOType=38,39

DAC# (16-bit), 3 Command Bytes:	
0	IOType = 38, 39
1	Value LSB
2	Value MSB
0 Response Bytes:	

This IOType controls a single analog output.

- **Value**: 0=Minimum, 65535=Maximum.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
16-bit DAC Feedback command

    Controls a single analog output

    Dac: 0 or 1
    Value: 0-65535

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.DAC16(Dac = 0, Value = 0x5566))
    Sent:  [0xdc, 0xf8, 0x2, 0x0, 0xe1, 0x0, 0x0, 0x26, 0x66, 0x55]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-DAC16.txt view raw

```
16-bit DAC Feedback command for DAC0

    Controls DAC0 in 16-bit mode.

    Value: 0-65535

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.DAC0_16(Value = 0x1122))
    Sent:  [0x54, 0xf8, 0x2, 0x0, 0x59, 0x0, 0x0, 0x26, 0x22, 0x11]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-DAC0_16.txt view raw

```
16-bit DAC Feedback command for DAC1

    Controls DAC1 in 16-bit mode.

    Value: 0-65535

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.getFeedback(u3.DAC1_16(Value = 0x2233))
    Sent:  [0x77, 0xf8, 0x2, 0x0, 0x7c, 0x0, 0x0, 0x27, 0x33, 0x22]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-DAC1_16.txt view raw

5.2.5.15 - Timer#: IOType=42,44

Timer#, 4 Command Bytes:	
0	IOType = 42, 44
1	Bit 0: UpdateReset
2	Value LSB
3	Value MSB
4 Response Bytes:	
0	Timer LSB
1	Timer
2	Timer
3	Timer MSB

This IOType provides the ability to update/reset a given timer, and read the timer value.

- **Value**: These values are only updated if the UpdateReset bit is 1. The meaning of this parameter varies with the timer mode.
- **Timer**: Returns the value from the timer module. This is the value before reset (if reset was done).

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
For reading the value of the Timer. It provides the ability to update/reset
    a given timer, and read the timer value.
    (Section 5.2.5.14 of the User's Guide)

    timer: Either 0 or 1 for timer 0 or timer 1

    UpdateReset: Set True if you want to update the value

    Value: Only updated if the UpdateReset bit is 1.  The meaning of this
           parameter varies with the timer mode.

    Mode: Set to the timer mode to handle any special processing. See classes
          QuadratureInputTimer and TimerStopInput1.

    Returns an unsigned integer of the timer value, unless Mode has been
    specified and there are special return values. See Section 2.9.1 for
    expected return values.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(NumberOfTimersEnabled = 1)
    Sent:  [0x49, 0xf8, 0x3, 0xb, 0x42, 0x0, 0x1, 0x0, 0x41, 0x0, 0x0, 0x0]
    Response:  [0x57, 0xf8, 0x3, 0xb, 0x50, 0x0, 0x0, 0x0, 0x41, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 1, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> d.getFeedback(u3.Timer(timer = 0, UpdateReset = False, Value = 0, Mode = None))
    Sent:  [0x26, 0xf8, 0x3, 0x0, 0x2a, 0x0, 0x0, 0x2a, 0x0, 0x0, 0x0, 0x0]
    Response:  [0xfc, 0xf8, 0x4, 0x0, 0xfe, 0x1, 0x0, 0x0, 0x0, 0x63, 0xdd, 0x4c, 0x72, (
    [1917640035]
```

This Gist brought to you by GitHub. u3-feedback-Timer.txt view raw

```
For reading the value of the Timer0. It provides the ability to
    update/reset Timer0, and read the timer value.
    (Section 5.2.5.14 of the User's Guide)

    UpdateReset: Set True if you want to update the value

    Value: Only updated if the UpdateReset bit is 1.  The meaning of this
           parameter varies with the timer mode.

    Mode: Set to the timer mode to handle any special processing. See classes
          QuadratureInputTimer and TimerStopInput1.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(NumberOfTimersEnabled = 1)
    Sent:  [0x49, 0xf8, 0x3, 0xb, 0x42, 0x0, 0x1, 0x0, 0x41, 0x0, 0x0, 0x0]
    Response:  [0x57, 0xf8, 0x3, 0xb, 0x50, 0x0, 0x0, 0x0, 0x41, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 1, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> d.getFeedback(u3.Timer0(UpdateReset = False, Value = 0, Mode = None))
    Sent:  [0x26, 0xf8, 0x3, 0x0, 0x2a, 0x0, 0x0, 0x2a, 0x0, 0x0, 0x0, 0x0]
    Response:  [0x51, 0xf8, 0x4, 0x0, 0x52, 0x2, 0x0, 0x0, 0x0, 0xf6, 0x90, 0x46, 0x86, (
    [2252771574]
```

This Gist brought to you by GitHub. u3-feedback-Timer0.txt view raw

```
For reading the value of the Timer1. It provides the ability to
    update/reset Timer1, and read the timer value.
    (Section 5.2.5.14 of the User's Guide)

    UpdateReset: Set True if you want to update the value

    Value: Only updated if the UpdateReset bit is 1.  The meaning of this
           parameter varies with the timer mode.

    Mode: Set to the timer mode to handle any special processing. See classes
          QuadratureInputTimer and TimerStopInput1.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(NumberOfTimersEnabled = 2)
    Sent:  [0x4a, 0xf8, 0x3, 0xb, 0x43, 0x0, 0x1, 0x0, 0x42, 0x0, 0x0, 0x0]
    Response:  [0x58, 0xf8, 0x3, 0xb, 0x51, 0x0, 0x0, 0x0, 0x42, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 2, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> d.getFeedback(u3.Timer1(UpdateReset = False, Value = 0, Mode = None))
    Sent:  [0x28, 0xf8, 0x3, 0x0, 0x2c, 0x0, 0x0, 0x2c, 0x0, 0x0, 0x0, 0x0]
    Response:  [0x8d, 0xf8, 0x4, 0x0, 0x8e, 0x2, 0x0, 0x0, 0x0, 0xf3, 0x31, 0xd0, 0x9a, (
    [2597335539]
```



```
For reading Quadrature input timers. They are special because their values
    are signed.

    (Section 2.9.1.8 of the User's Guide)

    Args:
       UpdateReset: Set True if you want to reset the counter.
       Value: Set to 0, and UpdateReset to True to reset the counter.

    Returns a signed integer.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(NumberOfTimersEnabled = 2)
    Sent:  [0x4a, 0xf8, 0x3, 0xb, 0x43, 0x0, 0x1, 0x0, 0x42, 0x0, 0x0, 0x0]
    Response:  [0x58, 0xf8, 0x3, 0xb, 0x51, 0x0, 0x0, 0x0, 0x42, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 2, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> # Setup the two timers to be quadrature
    >>> d.getFeedback(u3.Timer0Config(8), u3.Timer1Config(8))
    Sent:  [0x66, 0xf8, 0x5, 0x0, 0x68, 0x0, 0x0, 0x2b, 0x8, 0x0, 0x0, 0x2d, 0x8, 0x0, 0x
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None, None]
    >>> # Read the value
    [0]
    >>> d.getFeedback(u3.QuadratureInputTimer())
    Sent:  [0x26, 0xf8, 0x3, 0x0, 0x2a, 0x0, 0x0, 0x2a, 0x0, 0x0, 0x0, 0x0]
    Response:  [0xf5, 0xf8, 0x4, 0x0, 0xf5, 0x3, 0x0, 0x0, 0x0, 0xf8, 0xff, 0xff, 0xff, (
    [-8]
    >>> d.getFeedback(u3.QuadratureInputTimer())
    Sent:  [0x26, 0xf8, 0x3, 0x0, 0x2a, 0x0, 0x0, 0x2a, 0x0, 0x0, 0x0, 0x0]
    Response:  [0x9, 0xf8, 0x4, 0x0, 0xc, 0x0, 0x0, 0x0, 0x0, 0xc, 0x0, 0x0, 0x0, 0x0]
    [12]
```



```
For reading a stop input timer. They are special because the value returns
    the current edge count and the stop value.

    (Section 2.9.1.9 of the User's Guide)

    Args:
        UpdateReset: Set True if you want to update the value.
        Value: The stop value. Only updated if the UpdateReset bit is 1.

    Returns a tuple where the first value is current edge count, and the second
    value is the stop value.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(NumberOfTimersEnabled = 2)
    Sent:  [0x4a, 0xf8, 0x3, 0xb, 0x43, 0x0, 0x1, 0x0, 0x42, 0x0, 0x0, 0x0]
    Response:  [0x58, 0xf8, 0x3, 0xb, 0x51, 0x0, 0x0, 0x0, 0x42, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 2, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> # Setup the timer to be Stop Input
    >>> d.getFeedback(u3.Timer1Config(9, Value = 30))
    Sent:  [0x50, 0xf8, 0x3, 0x0, 0x54, 0x0, 0x0, 0x2d, 0x9, 0x1e, 0x0, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
    >>> d.getFeedback(u3.TimerStopInput1())
    Sent:  [0x28, 0xf8, 0x3, 0x0, 0x2c, 0x0, 0x0, 0x2c, 0x0, 0x0, 0x0, 0x0]
    Response:  [0x1b, 0xf8, 0x4, 0x0, 0x1e, 0x0, 0x0, 0x0, 0x0, 0x1e, 0x0, 0x0, 0x0, 0x0
    [(0, 0)]
```


5.2.5.16 - Timer#Config: IOType=43,45

Timer#Config, 4 Command Bytes:	
0	IOType = 43, 45
1	TimerMode
2	Value LSB
3	Value MSB
0 Response Bytes:	

This IOType configures a particular timer.

- **TimerMode**: See Section 2.9 for more information about the available modes.
- **Value**: The meaning of this parameter varies with the timer mode.

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
This IOType configures a particular timer.

    timer = # of the timer to configure

    TimerMode = See Section 2.9 for more information about the available modes.

    Value = The meaning of this parameter varies with the timer mode.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(NumberOfTimersEnabled = 1)
    Sent:  [0x49, 0xf8, 0x3, 0xb, 0x42, 0x0, 0x1, 0x0, 0x41, 0x0, 0x0, 0x0]
    Response:  [0x57, 0xf8, 0x3, 0xb, 0x50, 0x0, 0x0, 0x0, 0x41, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 1, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> d.getFeedback(u3.TimerConfig(timer = 0, TimerMode = 0, Value = 0))
    Sent:  [0x27, 0xf8, 0x3, 0x0, 0x2b, 0x0, 0x0, 0x2b, 0x0, 0x0, 0x0, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
    >>> d.getFeedback(u3.TimerConfig(timer = 0, TimerMode = 0, Value = 65535))
    Sent:  [0x27, 0xf8, 0x3, 0x0, 0x29, 0x2, 0x0, 0x2b, 0x0, 0xff, 0xff, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-TimerConfig.txt view raw

```
This IOType configures Timer0.

    TimerMode = See Section 2.9 for more information about the available modes.

    Value = The meaning of this parameter varies with the timer mode.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(NumberOfTimersEnabled = 1)
    Sent:  [0x49, 0xf8, 0x3, 0xb, 0x42, 0x0, 0x1, 0x0, 0x41, 0x0, 0x0, 0x0]
    Response:  [0x57, 0xf8, 0x3, 0xb, 0x50, 0x0, 0x0, 0x0, 0x41, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 1, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> d.getFeedback(u3.Timer0Config(TimerMode = 1, Value = 0))
    Sent:  [0x28, 0xf8, 0x3, 0x0, 0x2c, 0x0, 0x0, 0x2b, 0x1, 0x0, 0x0, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
    >>> d.getFeedback(u3.Timer0Config(TimerMode = 1, Value = 65535))
    Sent:  [0x28, 0xf8, 0x3, 0x0, 0x2a, 0x2, 0x0, 0x2b, 0x1, 0xff, 0xff, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-Timer0Config.txt view raw

```
This IOType configures Timer1.

    TimerMode = See Section 2.9 for more information about the available modes.

    Value = The meaning of this parameter varies with the timer mode.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(NumberOfTimersEnabled = 2)
    Sent:  [0x4a, 0xf8, 0x3, 0xb, 0x43, 0x0, 0x1, 0x0, 0x42, 0x0, 0x0, 0x0]
    Response:  [0x58, 0xf8, 0x3, 0xb, 0x51, 0x0, 0x0, 0x0, 0x42, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 2, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> d.getFeedback(u3.Timer1Config(TimerMode = 6, Value = 1))
    Sent:  [0x30, 0xf8, 0x3, 0x0, 0x34, 0x0, 0x0, 0x2d, 0x6, 0x1, 0x0, 0x0]
    Response:  [0xfa, 0xf8, 0x2, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [None]
```

This Gist brought to you by GitHub. u3-feedback-Timer1Config.txt view raw

5.2.5.17 - Counter#: IOType=54,55

Counter#, 2 Command Bytes:	
0	IOType = 54, 55
1	Bit 0: Reset
4 Response Bytes:	
0	Counter LSB
1	Counter
2	Counter
3	Counter MSB

This IOType reads a hardware counter, and optionally can do a reset.

- **Reset**: Setting this bit resets the counter to 0 after reading.
- **Counter**: Returns the current count from the counter if enabled. This is the value before reset (if reset was done).

LabJackPython example session

Automatically extracted from u3.py. Debugging turned on to show the bytes sent and received.

```
Counter Feedback command

    Reads a hardware counter, optionally resetting it

    counter: 0 or 1
    Reset: True ( or 1 ) = Reset, False ( or 0 ) = Don't Reset

    Returns the current count from the counter if enabled.  If reset,
    this is the value before the reset.
    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(EnableCounter0 = True, FIOAnalog = 15)
    Sent:  [0x5f, 0xf8, 0x3, 0xb, 0x58, 0x0, 0x5, 0x0, 0x44, 0x0, 0xf, 0x0]
    Response:  [0x5a, 0xf8, 0x3, 0xb, 0x53, 0x0, 0x0, 0x0, 0x44, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 0, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> d.getFeedback(u3.Counter(counter = 0, Reset = False))
    Sent:  [0x31, 0xf8, 0x2, 0x0, 0x36, 0x0, 0x0, 0x36, 0x0, 0x0]
    Response:  [0xfc, 0xf8, 0x4, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [0]
    >>> # Tap a ground wire to counter 0
    >>> d.getFeedback(u3.Counter(counter = 0, Reset = False))
    Sent:  [0x31, 0xf8, 0x2, 0x0, 0x36, 0x0, 0x0, 0x36, 0x0, 0x0]
    Response:  [0xe9, 0xf8, 0x4, 0x0, 0xec, 0x0, 0x0, 0x0, 0x0, 0xe8, 0x4, 0x0, 0x0, 0x0
    [1256]
```

This Gist brought to you by GitHub. u3-feedback-Counter.txt view raw

```
Counter0 Feedback command

    Reads hardware counter0, optionally resetting it

    Reset: True ( or 1 ) = Reset, False ( or 0 ) = Don't Reset

    Returns the current count from the counter if enabled.  If reset,
    this is the value before the reset.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(EnableCounter0 = True, FIOAnalog = 15)
    Sent:  [0x5f, 0xf8, 0x3, 0xb, 0x58, 0x0, 0x5, 0x0, 0x44, 0x0, 0xf, 0x0]
    Response:  [0x5a, 0xf8, 0x3, 0xb, 0x53, 0x0, 0x0, 0x0, 0x44, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 0, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> d.getFeedback(u3.Counter0( Reset = False ) )
    Sent:  [0x31, 0xf8, 0x2, 0x0, 0x36, 0x0, 0x0, 0x36, 0x0, 0x0]
    Response:  [0xfc, 0xf8, 0x4, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
    [0]
    >>> # Tap a ground wire to counter 0
    >>> d.getFeedback(u3.Counter0(Reset = False))
    Sent:  [0x31, 0xf8, 0x2, 0x0, 0x36, 0x0, 0x0, 0x36, 0x0, 0x0]
    Response:  [0xe, 0xf8, 0x4, 0x0, 0x11, 0x0, 0x0, 0x0, 0x0, 0x11, 0x0, 0x0, 0x0, 0x0]
    [17]
    >>> # Tap a ground wire to counter 0
    >>> d.getFeedback(u3.Counter0(Reset = False))
    Sent:  [0x31, 0xf8, 0x2, 0x0, 0x36, 0x0, 0x0, 0x36, 0x0, 0x0]
    Response:  [0x19, 0xf8, 0x4, 0x0, 0x1c, 0x0, 0x0, 0x0, 0x0, 0xb, 0x11, 0x0, 0x0, 0x0
    [4363]
```

This Gist brought to you by GitHub. u3-feedback-Counter0.txt view raw

```
Counter1 Feedback command

    Reads hardware counter1, optionally resetting it

    Reset: True ( or 1 ) = Reset, False ( or 0 ) = Don't Reset

    Returns the current count from the counter if enabled.  If reset,
    this is the value before the reset.

    >>> import u3
    >>> d = u3.U3()
    >>> d.debug = True
    >>> d.configIO(EnableCounter1 = True, FIOAnalog = 15)
    Sent:  [0x63, 0xf8, 0x3, 0xb, 0x5c, 0x0, 0x5, 0x0, 0x48, 0x0, 0xf, 0x0]
    Response:  [0x5e, 0xf8, 0x3, 0xb, 0x57, 0x0, 0x0, 0x0, 0x48, 0x0, 0xf, 0x0]
    {'NumberOfTimersEnabled': 0, 'TimerCounterPinOffset': 4, 'DAC1Enable': 0, 'FIOAnalog
    >>> d.getFeedback(u3.Counter1(Reset = False))
```

```
Sent:  [0x32, 0xf8, 0x2, 0x0, 0x37, 0x0, 0x0, 0x37, 0x0, 0x0]
Response:  [0xfc, 0xf8, 0x4, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0, 0x0]
[0]
>>> # Tap a ground wire to counter 1
>>> d.getFeedback(u3.Counter1(Reset = False))
Sent:  [0x32, 0xf8, 0x2, 0x0, 0x37, 0x0, 0x0, 0x37, 0x0, 0x0]
Response:  [0xfd, 0xf8, 0x4, 0x0, 0x1, 0x0, 0x0, 0x0, 0x0, 0x1, 0x0, 0x0, 0x0, 0x0]
[1]
>>> # Tap a ground wire to counter 1
>>> d.getFeedback(u3.Counter1(Reset = False))
Sent:  [0x32, 0xf8, 0x2, 0x0, 0x37, 0x0, 0x0, 0x37, 0x0, 0x0]
Response:  [0xb4, 0xf8, 0x4, 0x0, 0xb7, 0x0, 0x0, 0x0, 0x0, 0x6b, 0x2b, 0x21, 0x0, 0x
[2173803]
```


5.2.5.18 - Buzzer: IOType=63

Buzzer, 6 Command Bytes:	
0	IOType = 63
1	Bit 0: Continuous
2	Period LSB
3	Period MSB
4	Toggles LSB
5	Toggles MSB
0 Response Bytes:	

This IOType is used to make the buzzer buzz. The buzzer is only available on hardware revisions 1.20 and 1.21, not on 1.30.

- **Continuous**: If this bit is set, the buzzer will toggle continuously.
- **Period**: This value determines how many main firmware loops the processor will execute before toggling the buzzer voltage.
- **Toggles**: If Continuous is false, this value specifies how many times the buzzer will toggle.

5.2.6 - ReadMem (ReadCal)

Reads 1 block (32 bytes) from the non-volatile user or calibration memory. Command number 0x2A accesses the user memory area which consists of 256 bytes (block numbers 0-7). Command number 0x2D accesses the calibration memory area consisting of 512 bytes (block numbers 0-15), of which the last 8 blocks are not used. Do not call this function while streaming.

Command:	
Byte	
0	Checksum8
1	0xF8
2	0x01
3	0x2A (0x2D)
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	0x00
7	BlockNum
Response:	
Byte	
0	Checksum8
1	0xF8
2	0x11
3	0x2A (0x2D)
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	Errorcode
7	0x00
8-39	32 Bytes of Data

5.2.7 - WriteMem (WriteCal)

Writes 1 block (32 bytes) to the non-volatile user or calibration memory. Command number 0x28 accesses the user memory area which consists of 256 bytes (block numbers 0-7). Command number 0x2B accesses the calibration memory area consisting of 512 bytes (block numbers 0-15), of which the last 8 blocks are not used. Memory must be erased before writing. Do not call this function while streaming.

Command:	
Byte	
0	Checksum8
1	0xF8
2	0x11
3	0x28 (0x2b)
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	0x00
7	BlockNum
8-39	32 Bytes of Data
Response:	
Byte	
0	Checksum8
1	0xF8
2	0x01
3	0x28 (0x2B)
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	Errorcode
7	0x00

5.2.8 - EraseMem (EraseCal)

The U3 uses flash memory that must be erased before writing. Command number 0x29 erases the entire user memory area. Command number 0x2C erases the entire calibration memory area. The EraseCal command has two extra constant bytes, to

make it more difficult to call the function accidentally. Do not call this function while streaming.

Command:	
Byte	
0	Checksum8
1	0xF8
2	0x00 (0x01)
3	0x29 (0x2C)
4	Checksum16 (LSB)
5	Checksum16 (MSB)
(6)	(0x4C)
(7)	(0x6C)
Response:	
Byte	
0	Checksum8
1	0xF8
2	0x01
3	0x29 (0x2C)
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	Errorcode
7	0x00

5.2.9 - Reset

Causes a soft or hard reset. A soft reset consists of re-initializing most variables without re-enumeration. A hard reset is a reboot of the processor and does cause re-enumeration.

Command:		
Byte		
0	Checksum8	
1	0x99	
2	ResetOptions	
		Bit 1: Hard Reset
		Bit 0: Soft Reset
3	0x00	
Response:		
Byte		
0	Checksum8	
1	0x99	
2	0x00	
3	Errorcode	

5.2.10 - StreamConfig

Stream mode operates on a table of channels that are scanned at the specified scan rate. Before starting a stream, you need to call this function to configure the table and scan clock. Requires U3 hardware version 1.21.

Command:			
Byte			
0	Checksum8		
1	0xF8		
2	NumChannels + 3		
3	0x11		
4	Checksum16 (LSB)		
5	Checksum16 (MSB)		
6	NumChannels		
7	SamplesPerPacket (1-25)		
8	Reserved		
9	ScanConfig		
		Bit 7: Reserved	
		Bit 6: Reserved	
		Bit 3: Internal stream clock frequency.	
			b0: 4 MHz
			b1: 48 MHz
		Bit 2: Divide Clock by 256	
		Bits 0-1: Resolution	
			b00: 12.8-bit effective
			b01: 11.9-bit effective
			b10: 11.3-bit effective
			b11: 10.5-bit effective
10-11	Scan Interval (1-65535)		
12	PChannel		
13	NChannel		
Repeat 12-13 for each channel			
Response:			
Byte			
0	Checksum8		
1	0xF8		
2	0x01		
3	0x11		
4	Checksum16 (LSB)		
5	Checksum16 (MSB)		
6	Errorcode		
7	0x00		

- **NumChannels**: This is the number of channels you will sample per scan (1-25).
- **SamplesPerPacket**: Specifies how many samples will be pulled out of the U3 FIFO buffer and returned per data read packet. For faster stream speeds, 25 samples per packet are required for data transfer efficiency. A small number of samples per packet would be desirable for low-latency data retrieval. Note that this parameter is not necessarily the same as the number of channels per scan. Even if only 1 channel is being scanned, SamplesPerPacket will usually be set to 25, so there are usually multiple scans per packet.
- **ScanConfig**: Has bits to specify the stream bas clock and effective resolution.
- **ScanInterval**: (1-65535) This value divided by the clock frequency defined in the ScanConfig parameter, gives the interval (in seconds) between scans.
- **PChannel/NChannel**: For each channel, these two parameters specify the positive and negative voltage measurement point. PChannel is 0-7 for FIO0-FIO7, 8-15 for EIO0-EIO15, 30 for temp sensor, 31 for Vreg, or 193.-224 for digital/timer/counter channels. NChannel is 0-7 for FIO0-FIO7, 8-15 for EIO0-EIO15, 30 for Vref, or 31 for single-ended.

5.2.11 - StreamStart

Once the stream settings are configured, this function is called to start the stream. Requires U3 hardware version 1.21.

Command:	
Byte	
0	0xA8
1	0xA8
Response:	
Byte	
0	Checksum8
1	0xA9
2	Errorcode
3	0x00

5.2.12 - StreamData

After starting the stream, the data will be sent as available in the following format. Reads oldest data from buffer. Requires U3 hardware version 1.21.

Response:	
Byte	
0	Checksum8
1	0xF9
2	4 + SamplesPerPacket
3	0xC0
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6-9	TimeStamp
10	PacketCounter
11	Errorcode
12-13	Sample0
62 (max)	Backlog
63 (max)	0x00

- **SamplesPerPacket**: From StreamConfig function.
- **TimeStamp**: Not currently implemented during normal operation, but after auto-recovery bytes 6-7 reports the number of packets missed (1-65535).
- **PacketCounter**: An 8-bit (0-255) counter that is incremented by one for each packet of data. Useful to make sure packets are in order and no packets are missing.
- **Sample#**: Stream data is placed in a FIFO (first in first out) buffer, so Sample0 is the oldest data read from the buffer. The analog input reading is returned justified as a 16-bit value. Differential readings are signed, while single-ended readings are unsigned.
- **Backlog**: When streaming, the processor acquires data at precise intervals, and transfers it to a FIFO buffer until it can be sent to the host. This value represents how much data is left in the buffer after this read. The value ranges from 0-255, where 256 would equal 100% full.

Stream mode on the U3 uses a feature called auto-recovery. If the stream buffer gets too full, the U3 will go into auto-recovery mode. In this mode, the U3 no longer stores new scans in the buffer, but rather new scans are discarded. Data already in the buffer will be sent until the buffer contains less samples than SamplesPerPacket, and every StreamData packet will have errorcode 59. Once the stream buffer contains less samples than SamplesPerPacket, the U3 will start to buffer new scans again. The next packet returned will have errorcode 60. This packet will have 1 dummy scan where each sample is 0xFFFF, and this scan separates new data from any pre auto-recovery data. Note that the dummy scan could be at the beginning, middle, or end of this packet, and can even extend to following packets. Also, the TimeStamp parameter in this packet contains the number of scans that were discarded, allowing correct time to be calculated. The dummy scan counts as one of the missing scans included in the TimeStamp value.

5.2.13 - StreamStop

Requires U3 hardware version 1.21.

Command:	
Byte	
0	0xB0
1	0xB0
Response:	
Byte	
0	Checksum8
1	0xB1
2	Errorcode
3	0x00

5.2.14 - Watchdog

Requires U3 hardware version 1.21. Controls a firmware based watchdog timer. Unattended systems requiring maximum up-time might use this capability to reset the U3 or the entire system. When any of the options are enabled, an internal timer is enabled which resets on any incoming USB communication. If this timer reaches the defined TimeoutPeriod before being reset, the specified actions will occur. Note that while streaming, data is only going out, so some other command will have to be called periodically to reset the watchdog timer.

If the watchdog is accidentally configured to reset the processor with a very low timeout period (such as 1 second), it could be difficult to establish any communication with the device. In such a case, the reset-to-default jumper can be used to turn off the watchdog (sets bytes 7-10 to 0). Power up the U3 with a short from FIO6 to SPC (FIO2 to SCL on U3 1.20/1.21), then remove the jumper and power cycle the device again. This also affects the parameters in the ConfigU3 function.

The watchdog settings (bytes 7-10) are stored in non-volatile flash memory, so every call to this function where settings are written causes a flash erase/write. The flash has a rated endurance of at least 20000 writes, which is plenty for reasonable operation, but if this function is called in a high-speed loop the flash could be damaged.

Note: Do **not** call this function while streaming.

Command:		
Byte		
0	Checksum8	
1	0xF8	
2	0x05	
3	0x09	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	WriteMask	
		Bit 0: Write
7	WatchdogOptions	
		Bit 5: Reset on Timeout
		Bit 4: Set DIO State on Timeout
8-9	TimeoutPeriod	
10	DIOConfig	
		Bit 7: State
		Bit 0-4: DIO#
11	Reserved	
12	Reserved	
13	Reserved	
14	Reserved	
15	Reserved	
Response:		
Byte		
0	Checksum8	
1	0xF8	
2	0x05	
3	0x09	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	Errorcode	
7	WatchdogOptions	
8-9	TimeoutPeriod	
10	DIOConfig	
11	Reserved	
12	Reserved	
13	Reserved	
14	Reserved	
15	Reserved	

- **WatchdogOptions**: The watchdog is enabled when this byte is nonzero. Set the appropriate bits to reset the device and/or update the state of 1 digital output.
- **TimeoutPeriod**: The watchdog timer is reset to zero on any incoming USB communication. Note that most functions consist of a write and read, but StreamData is outgoing only and does not reset the watchdog. If the watchdog timer is not reset before it counts up to TimeoutPeriod, the actions specified by WatchdogOptions will occur. The watchdog timer has a clock rate of about 1 Hz, so a TimeoutPeriod range of 1-65535 corresponds to about 1 to 65535 seconds.
- **DIOConfig**: Determines which digital I/O is affected by the watchdog, and the state it is set to. The specified DIO must have previously been configured for output. DIO# is a value from 0-19 according to the following: 0-7 => FIO0-FIO7, 8-15 => EIO0-EIO7, 16-19 => CIO0-CIO3

5.2.15 - SPI

Requires U3 hardware version 1.21. Sends and receives serial data using SPI synchronous communication.

Command:		
Byte		
0	Checksum8	
1	0xF8	
2	4 + NumSPIWords	
3	0x3A	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	SPIOptions	
		Bit 7: AutoCS
		Bit 6: DisableDirConfig
		Bits 1-0: SPIMode (0=A, 1=B, 2=C, 3=D)
7	SPIClockFactor	
8	Reserved	
9	CSPinNum	
10	CLKPinNum	
11	MISOPinNum	
12	MOSIPinNum	
13	NumSPIBytesToTransfer	
14	SPIByte0	
...	...	
Response:		
Byte		
0	Checksum8	
1	0xF8	
2	1 + NumSPIWords	
3	0x3A	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	Errorcode	
7	NumSPIBytesTransferred	
8	SPIByte0	
...	...	

- **NumSPIWords**: This is the number of SPI bytes divided by 2. If the number of SPI bytes is odd, round up and add an extra zero to the packet.
- **SPIOptions**: If AutoCS is true, the CS line is automatically driven low during the SPI communication and brought back high when done. If DisableDirConfig is true, this function does not set the direction of the lines, whereas if it is false the lines are configured as CS=output, CLK=output, MISO=input, and MOSI=output. SPIMode specifies the standard SPI mode as discussed below.
- **SPIClockFactor**: Sets the frequency of the SPI clock. A zero corresponds to the maximum speed of about 80kHz and 255 the minimum speed of about 5.5kHz.
- **CS/CLK/MISO/MOSI -PinNum**: Assigns which digital I/O line is used for each SPI line. Value passed is 0-19 corresponding to the normal digital I/O numbers as specified in Section 2.8.
- **NumSPIBytesToTransfer**: Specifies how many SPI bytes will be transferred (1-50).

The initial state of SCK is set properly (CPOL), by this function, before CS (chip select) is brought low (final state is also set properly before CS is brought high again). If CS is being handled manually, outside of this function, care must be taken to make

sure SCK is initially set to CPOL before asserting CS.

All standard SPI modes supported (A, B, C, and D).

Mode A: CPHA=0, CPOL=0
Mode B: CPHA=0, CPOL=1
Mode C: CPHA=1, CPOL=0
Mode D: CPHA=1, CPOL=1

If Clock Phase (CPHA) is 1, data is valid on the edge going to CPOL. If CPHA is 0, data is valid on the edge going away from CPOL. Clock Polarity (CPOL) determines the idle state of SCK.

Up to 50 bytes can be written/read. Communication is full duplex so 1 byte is read at the same time each byte is written.

5.2.16 - AsynchConfig

Requires U3 hardware version 1.21+. Configures the U3 UART for asynchronous communication. On hardware version 1.30 the TX (transmit) and RX (receive) lines appear on FIO/EIO after any timers and counters, so with no timers/counters enabled, and pin offset set to 4, TX=FIO4 and RX=FIO5. On hardware version 1.21, the UART uses SDA for TX and SCL for RX. Communication is in the common 8/n/1 format. Similar to RS232, except that the logic is normal CMOS/TTL. Connection to an RS232 device will require a converter chip such as the MAX233, which inverts the logic and shifts the voltage levels.

Command:		
Byte		
0	Checksum8	
1	0xF8	
2	0x02	
3	0x14	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	0x00	
7	AsynchOptions	
		Bit 7: Update
		Bit 6: UARTEnable
		Bit 5: Reserved
8	BaudFactor LSB (1.30 only)	
9	BaudFactor MSB	
Response:		
Byte		
0	Checksum8	
1	0xF8	
2	0x02	
3	0x14	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	Errorcode	
7	AsynchOptions	
8	BaudFactor LSB (1.30 only)	
9	BaudFactor MSB	

- **AsynchOptions**:
  Bit 7: Update If true, the new parameters are written (otherwise just a read is done).
  Bit 6: UARTEnable If true, the UART module is enabled. Note that no data can be transfered until pins have been assigned to the UART module using the ConfigIO function.
- **BaudFactor16 (BaudFactor8)**: This 16-bit value sets the baud rate according the following formula: BaudFactor16 = 2^{16} – 48000000/(2 x Desired Baud). For example, a BaudFactor16 = 63036 provides a baud rate of 9600 bps. (With hardware revision 1.21, the value is only 8-bit and the formula is BaudFactor8 = 2^{8} – TimerClockBase/(Desired Baud)).

5.2.17 - AsynchTX

Requires U3 hardware version 1.21. Sends bytes to the U3 UART which will be sent asynchronously on the transmit line.

Command:	
Byte	
0	Checksum8
1	0xF8
2	1 + NumAsynchWords
3	0x15
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	0x00
7	NumAsynchBytesToSend
8	AsynchByte0
...	...
Response:	
Byte	
0	Checksum8
1	0xF8
2	0x02
3	0x15
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	Errorcode
7	NumAsynchBytesSent
8	NumAsynchBytesInRXBuffer
9	0x00

- **NumAsynchWords**: This is the number of asynch data bytes divided by 2. If the number of bytes is odd, round up and add an extra zero to the packet.
- **NumAsynchBytesToSend**: Specifies how many bytes will be sent (0-56).
- **NumAsynchBytesInRXBuffer**: Returns how many bytes are currently in the RX buffer.

5.2.18 - AsynchRX

Requires U3 hardware version 1.21. Reads the oldest 32 bytes from the U3 UART RX buffer (received on receive terminal). The buffer holds 256 bytes.

Command:	
Byte	
0	Checksum8
1	0xF8
2	0x01
3	0x16
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	0x00
7	Flush
Response:	
Byte	
0	Checksum8
1	0xF8
2	1 + NumAsynchWords
3	0x15
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	Errorcode
7	NumAsynchBytesInRXBuffer
8	AsynchByte0
…	…
39	AsynchByte31

- **Flush**: If nonzero, the entire 256-byte RX buffer is emptied. If there are more than 32 bytes in the buffer that data is lost.
- **NumAsynchBytesInRXBuffer**: Returns the number of bytes in the buffer before this read.
- **AsynchByte#**: Returns the 32 oldest bytes from the RX buffer.

5.2.19 - I²C

Requires U3 hardware version 1.21+. Sends and receives serial data using I²C (I2C) synchronous communication.

Command:		
Byte		
0	Checksum8	
1	0xF8	
2	4 + NumI2CWordsSend	
3	0x3B	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	I2COptions	
		Bits 7-4: Reserved
		Bit 3: Enable Clock Stretching
		Bit 2: No Stop when restarting
		Bit 1: ResetAtStart
		Bit 0: Reserved
7	SpeedAdjust	
8	SDAPinNum	
9	SCLPinNum	
10	AddressByte	
11	Reserved	
12	NumI2CBytesToSend	
13	NumI2CBytesToReceive	
14	I2CByte0	
…	…	
Response:		
Byte		
0	Checksum8	
1	0xF8	
2	3 + NumI2CWordsReceive	
3	0x3B	
4	Checksum16 (LSB)	
5	Checksum16 (MSB)	
6	Errorcode	
7	Reserved	
8	AckArray0	
9	AckArray1	
10	AckArray2	
11	AckArray3	
12	I2CByte0	
…	…	

- **NumI2CWordsSend:** This is the number of I²C bytes to send divided by 2. If the number of bytes is odd, round up and add an extra zero to the packet. This parameter is actually just to specify the size of this packet, as the NumI2CbytesToSend parameter below actually specifies how many bytes will be sent.
- **I2COptions:** If ResetAtStart is true, an I²C bus reset will be done before communicating.
- **SpeedAdjust:** Allows the communication frequency to be reduced. 0 is the maximum speed of about 150 kHz. 20 is a speed of about 70 kHz. 255 is the minimum speed of about 10 kHz.
- **SDAP/SCLP -PinNum:** Assigns which digital I/O line is used for each I²C line. Value passed is 0-19 corresponding to the normal digital I/O numbers as specified in Section 2.8. Note that the screw terminals labeled “SDA” and “SCL” on hardware revision 1.20 or 1.21 are not used for I²C. Note that the I²C bus generally requires pull-up resistors of perhaps 4.7 kΩ from SDA to Vs and SCL to Vs.
- **AddressByte:** This is the first byte of data sent on the I²C bus. The upper 7 bits are the address of the slave chip and bit 0 is the read/write bit. Note that the read/write bit is controlled automatically by the LabJack, and thus bit 0 is ignored.
- **NumI2CBytesToSend:** Specifies how many I²C bytes will be sent (0-50).
- **NumI2CBytesToReceive:** Specifies how many I²C bytes will be read (0-52).
- **I2Cbyte#**: In the command, these are the bytes to send. In the response, these are the bytes read.
- **NumI2CWordsReceive:** This is the number of I²C bytes to receive divided by 2. If the number of bytes is odd, the value is rounded up and an extra zero is added to the packet. This parameter is actually just to specify the size of this packet, as the NumI2CbytesToReceive parameter above actually specifies how many bytes to read.
- **AckArray#:** Represents a 32-bit value where bits are set if the corresponding I²C write byte was ack’ed. Useful for debugging up to the first 32 write bytes of communication. Bit 0 corresponds to the last data byte, bit 1 corresponds to the second to last data byte, and so on up to the address byte. So if n is the number of data bytes, the ACKs value should be (2^(n+1))-1.

5.2.20 - SHT1X

Requires U3 hardware version 1.21. Reads temperature and humidity from a Sensirion SHT1X sensor (which is used by the EI-

1050). For more information, see the EI-1050 datasheet, and the SHT1X datasheet from sensirion.com.

Command:	
Byte	
0	Checksum8
1	0xF8
2	0x02
3	0x39
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	DataPinNum (0-19)
7	ClockPinNum (0-19)
8	Reserved
9	Reserved
Response:	
Byte	
0	Checksum8
1	0xF8
2	0x05
3	0x39
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	Errorcode
7	0x00
8	StatusReg
9	StatusRegCRC
10-11	Temperature
12	TemperatureCRC
13-14	Humidity
15	HumidityCRC

- **Data/Clock -PinNum**: Assigns which digital I/O line is used for each SPI line. Value passed is 0-7 corresponding to FIO0-FIO7. State and direction are controlled automatically for the specified lines.
- **StatusReg**: Returns a read of the SHT1X status register.
- **Temperature**: Returns the raw binary temperature reading.
- **Humidity**: Returns the raw binary humidity reading.
- **#CRC**: Returns the CRC values from the sensor.

5.2.21 - SetDefaults (SetToFactoryDefaults)

Executing this function causes the current or last used values (or the factory defaults) to be stored in flash as the power-up defaults.

The U3 flash has a rated endurance of at least 20000 writes, which is plenty for reasonable operation, but if this function is called in a high-speed loop the flash could eventually be damaged.

Note: Do **not** call this function while streaming.

Command:	
Byte	
0	Checksum8
1	0xF8
2	0x01
3	0x0E
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	0xBA (0x82)
7	0x26 (0xC7)
Response:	
Byte	
0	Checksum8
1	0xF8
2	0x01
3	0x0E
4	Checksum16 (LSB)
5	Checksum16 (MSB)
6	Errorcode
7	0x00

5.2.22 - ReadDefaults (ReadCurrent)

Reads the power-up defaults from flash (Read the current configuration).

Command:			Defaults Map		
Byte		Block Number	Byte Offset	Description	Nominal Values
0	Checksum8	0	0-3	Not Used	0x00
1	0xF8	0	4	FIO Directions	0x00
2	0x01	0	5	FIO States	0xFF
3	0x0E	0	6	FIO Analog	0x00
4	Checksum16 (LSB)	0	7	Not Used	0x00
5	Checksum16 (MSB)	0	8	EIO Directions	0x00
6	0x00	0	9	EIO States	0xFF
7	bits[0:6] BlockNum 0-7	0	10	EIO Analog	0x00
	bit 7: 1 = ReadCurrent	0	11	Not Used	0x00
		0	12	CIO Directions	0x00
Response:		0	13	CIO States	0xFF
Byte		0	14-15	Not Used	0x00
0	Checksum8	0	16	Config Write Mask	0x00 (NM)
1	0xF8	0	17	NumOfTimersEnabled	0x00
2	0x01	0	18	Counter Mask	0x00
3	0x0E	0	19	Pin Offset	0x04
4	Checksum16 (LSB)	0	20	Options	0x00
5	Checksum16 (MSB)	0	21-31	Not Used	0x00
6	Errorcode	1	0 (32)	Clock_Source	0x02
7	0x00	1	1 (33)	Divisor	0x00
8-39	Data	1	2-15 (33-47)	Not Used	0x00
		1	16 (48)	TMR0 Mode	0x0A
		1	17 (49)	TMR0 Value L	0x00
		1	18 (50)	TMR0 Value H	0x00
		1	19 (51)	Not Used	0x00
		1	20 (52)	TMR1 Mode	0x0A
		1	21 (53)	TMR1 Value L	0x00
		1	22 (54)	TMR1 Value H	0x00
		1	23-31 (55-63)	Not Used	0x00
		2	0-15 (64-79)	Not Used	0x00
		2	16-17 (80-81)	DAC0 (2 Bytes)	0x0000
		2	18-19 (82-83)	Not Used	0x00
		2	20-21 (84-85)	DAC1 (2 Bytes)	0x0000
		2	22-31 (86-95)	Not Used	0x00
		3	0-15 (96-111)	AIN Neg Channel	0x1F
		3	16-31 (112-127)	Not Used	0x00

5.3 - Errorcodes

Following is a list of the low-level function errorcodes.

Code	Description
1	SCRATCH_WRT_FAIL
2	SCRATCH_ERASE_FAIL
3	DATA_BUFFER_OVERFLOW
4	ADC0_BUFFER_OVERFLOW
5	FUNCTION_INVALID
6	SWDT_TIME_INVALID
7	XBR_CONFIG_ERROR
16	FLASH_WRITE_FAIL
17	FLASH_ERASE_FAIL
18	FLASH_JMP_FAIL
19	FLASH_PSP_TIMEOUT
20	FLASH_ABORT_RECEIVED
21	FLASH_PAGE_MISMATCH
22	FLASH_BLOCK_MISMATCH
23	FLASH_PAGE_NOT_IN_CODE_AREA
24	MEM_ILLEGAL_ADDRESS
25	FLASH_LOCKED
26	INVALID_BLOCK
27	FLASH_ILLEGAL_PAGE
28	FLASH_TOO_MANY_BYTES
29	FLASH_INVALID_STRING_NUM
40	SHT1x_COMM_TIME_OUT
41	SHT1x_NO_ACK
42	SHT1x_CRC_FAILED
43	SHT1X_TOO_MANY_W_BYTES
44	SHT1X_TOO_MANY_R_BYTES
45	SHT1X_INVALID_MODE
46	SHT1X_INVALID_LINE
48	STREAM_IS_ACTIVE
49	STREAM_TABLE_INVALID
50	STREAM_CONFIG_INVALID
51	STREAM_BAD_TRIGGER_SOURCE
52	STREAM_NOT_RUNNING
53	STREAM_INVALID_TRIGGER
54	STREAM_ADC0_BUFFER_OVERFLOW
55	STREAM_SCAN_OVERLAP
56	STREAM_SAMPLE_NUM_INVALID
57	STREAM_BIPOLAR_GAIN_INVALID
58	STREAM_SCAN_RATE_INVALID
59	STREAM_AUTORECOVER_ACTIVE
60	STREAM_AUTORECOVER_REPORT
63	STREAM_AUTORECOVER_OVERFLOW
64	TIMER_INVALID_MODE
65	TIMER_QUADRATURE_AB_ERROR
66	TIMER_QUAD_PULSE_SEQUENCE
67	TIMER_BAD_CLOCK_SOURCE
68	TIMER_STREAM_ACTIVE
69	TIMER_PWMSTOP_MODULE_ERROR
70	TIMER_SEQUENCE_ERROR
71	TIMER_LINE_SEQUENCE_ERROR
72	TIMER_SHARING_ERROR
80	EXT_OSC_NOT_STABLE
81	INVALID_POWER_SETTING
82	PLL_NOT_LOCKED
96	INVALID_PIN
97	PIN_CONFIGURED_FOR_ANALOG
98	PIN_CONFIGURED_FOR_DIGITAL
99	IOTYPE_SYNCH_ERROR
100	INVALID_OFFSET
101	IOTYPE_NOT_VALID
102	TC_PIN_OFFSET_MUST_BE_4-8
112	UART_TIMEOUT
113	UART_NOT_CONNECTED
114	UART_NOT_ENABLED

5.4 - Calibration Constants

Calibration Constant

The majority of the U3's analog interface functions return or require binary values. Converting between binary and voltages requires the use of calibration constants and formulas.

When using ModBus the U3 will apply calibration automatically, so voltages are sent to and read from the U3, formatted as a float.

Which Constants Should I Use?

The calibration constants stored on the U3 can be categorized as follows:

- Analog Input
- Analog Output
- Internal Temperature

Analog Input: Since the U3 uses multiplexed channels connected to a single analog-to-digital converter (ADC), all low-voltage channels have the same calibration for a given configuration. High-voltage channels have individual scaling circuitry out front, and thus the calibration is unique for each channel. The table below shows where the various calibration values are stored in the Mem area. Generally when communication is initiated with the U3, four calls will be made to the ReadMem function to retrieve the first 4 blocks of memory. This information can then be used to convert all analog input readings to voltages. Again, the high level Windows DLL (LabJackUD) does this automatically.

Analog Output: Only two calibrations are provided, one for DAC0 and one for DAC1.

Internal Temperature: This calibration is applied to the bits of a reading from channel 30 (internal temp).

U3 Input Ranges

The U3 input ranges can be found in section 2.6.2 of the User's Guide. For your convenience, that table has been provided again below.

	Max V	Min V		
Single-Ended	2.44	0		
Differential	2.44	-2.44		
Special 0-3.6	3.6	0		

Table 2.6.2-1. Nominal Analog Input Voltage Ranges for Low-Voltage Channels

	Max V	Min V		
Single-Ended	10.3	-10.3		
Differential	N/A	N/A		
Special -10/+20	20.1	-10.3		

Table 2.6.2-2. Nominal Analog Input Voltage Ranges for High-Voltage Channels

U3 Calibration Formulas (Analog In)

The readings returned by the analog inputs are raw binary values (low level functions). An approximate voltage conversion can be performed as:

```
Volts(uncalibrated) = (Bits/65536)*Span (Single-Ended)
```

```
Volts(uncalibrated) = (Bits/65536)*Span - Span/2 (Differential)
```

Where span is the maximum voltage minus the minimum voltage from the table above. For a proper voltage conversion, though, use the calibration values (Slope and Offset) stored in the internal flash on the Control processor.

```
Volts = (Slope * Bits) + Offset
```

U3 Calibration Formulas (Analog Out)

Writing to the U3's DAC require that the desired voltage be converted into a binary value. To convert the desired voltage to binary select the Slope and Offset calibration constants for the DAC being used and plug into the following formula.

```
Bits = (DesiredVolts * Slope) + Offset
```

U3 Calibration Formulas (Internal Temp)

Internal Temperature can be obtained by reading channel 30 and using the following formula.

```
Temp (K) = Bits *  TemperatureSlope
```

U3 Calibration Constants

Below are the various calibration values are stored in the Mem area. Generally when communication is initiated with the U3, eight calls will be made to the ReadMem function to retrieve the first 8 blocks of memory. This information can then be used to convert all analog input readings to voltages. Again, the high level Windows DLL (LabJackUD) does this automatically.

	Starting			
Block #	Byte		Nominal Value	
0	0	LV AIN SE Slope	3.7231E-05	volts/bit
0	8	LV AIN SE Offset	0.0000E+00	volts
0	16	LV AIN Diff Slope	7.4463E-05	volts/bit
0	24	LV AIN Diff Offset	-2.4400E+00	volts
1	0	DAC0 Slope	5.1717E_01	bits/volt
1	8	DAC0 Offset	0.0000E+00	bits
1	16	DAC1 Slope	5.1717E+1	bits/volt
1	24	DAC1 Offset	0.0000E+00	bits
2	0	Temp Slope	1.3021E-02	degK/bit
2	8	Vref @Cal	2.4400E+00	volts
2	16	Vref*1.5 @Cal	3.6600E+00	volts
2	24	Vreg @Cal	3.3000E+00	volts

Table 5.4-1. Normal Calibration Constant Memory Locations

	Starting			
Block #	Byte		Nominal Value	
3	0	HV AIN0 Slope	3.1400E-4	volts/bit
3	8	HV AIN1 Slope	3.1400E-4	volts/bit
3	16	HV AIN2 Slope	3.1400E-4	volts/bit
3	24	HV AIN3 Slope	3.1400E-4	volts/bit
4	0	HV AIN0 Offset	-10.3	volts
4	8	HV AIN1 Offset	-10.3	volts
4	16	HV AIN2 Offset	-10.3	volts
4	24	HV AIN3 Offset	-10.3	volts

Table 5.4-2. Additional High-Voltage Calibration Constant Memory Locations

Format of the Calibration Constants

Each value is stored in 64-bit fixed point format (signed 32.32 little endian, 2's complement). Following are some examples of fixed point arrays and the associated floating point double values.

Fixed Point Byte Array	
{LSB, ..., MSB}	Floating Point Double
{0,0,0,0,0,0,0,0}	0.0000000000
{0,0,0,0,1,0,0,0}	1.0000000000
{0,0,0,0,255,255,255,255}	-1.0000000000
{51,51,51,51,0,0,0,0}	0.2000000000
{205,204,204,204,255,255,255,255}	-0.2000000000
{73,20,5,0,0,0,0,0}	0.0000775030
{255,122,20,110,2,0,0,0}	2.4300000000
{102,102,102,38,42,1,0,0}	298.1500000000

Table 5.4-3. Fixed Point Conversion Examples

Appendix A - Specifications

Specifications at 25 degrees C and Vusb/Vext = 5.0V, except where noted.

Parameter	Conditions	Min	Typical	Max	Units
General					
USB Cable Length				5	meters
Supply Voltage		4	5	5.25	volts
Supply Current (1)	Hardware V1.21+		50		mA
Operating Temperature		-40		85	°C
Clock Error	-40 to 85 °C			1.5	%
Typ. Command Execution Time (2)	USB high-high	0.6			ms
	USB other	4			ms
VS Outputs					
Typical Voltage (3)	Self-Powered	4.75	5	5.25	volts
	Bus-Powered	4	5	5.25	
Maximum Currrent (3)	Self-Powered		450		mA
	Bus-Powered		50		mA

(1) Typical current drawn by the U3 itself, not including any user connections.
(2) Total typical time to execute a single Feedback function with no analog inputs. Measured by timing a Windows application that performs 1000 calls to the Feedback function. See Section 3.1 for more timing information.
(3) These specifications are related to the power provided by the host/hub. Self- and bus-powered describes the host/hub, not the U3. Self-powered would apply to USB hubs with a power supply, all known desktop computer USB hosts, and some notebook computer USB hosts. An example of bus-powered would be a hub with no power supply, or many PDA ports. The current rating is the maximum current that should be sources through the U3 and out of the Vs terminals.

Parameter	Conditions	Min	Typical	Max	Units
Analog Inputs					
Typical input Range (1)	Single-Ended, LV	0		2.44	volts
	Differential, LV	-2.44		2.44	volts
	Special, LV	0		3.6	volts
	Single-Ended, HV	-10.3		10.3	volts
	Special, HV	-10.3		20.1	volts
Max AIN Voltage to GND (2)	Valid Readings, LV	-0.3		3.6	volts
Max AIN Voltage to GND (3)	No Damage, FIO	-10		10	volts
	No Damage, EIO	-6		6	volts
	No Damage, HV	-40		40	volts
Input Impedance (4)	LV		40		MΩ
	HV		1.3		MΩ
Source Impedance (4)	LongSettling Off, LV			10	kΩ
	LongSettling On, LV			200	kΩ
	LongSettling Off, HV			1	kΩ
	LongSettling On, HV			1	kΩ
Resolution			12		bits
Integral Linearity Error			±0.05		% FS
Differential Linearity Error			±1		counts
Absolute Accuracy	Single-Ended		±0.13		% FS
	Differential		±0.25		% FS
	Special 0-3.6		±0.25		% FS
Temperature Drift			15		ppm/°C
Noise (Peak-To-Peak) (5)	QuickSample Off		±1		counts
	QuickSample On		±2		counts
Effective Resolution (RMS) (6)	QuickSample Off		>12		bits
Noise-Free Resolution (5)	QuickSample Off		11		bits
	Single-Ended, LV		1.2		mV
	Diff., Special, LV		2.4		mV
	Single-Ended, HV		9.8		mV
	Special, HV		19.5		mV
Command/Response Speed	See Section 3.1				
Stream Perfromance	See Section 3.2				

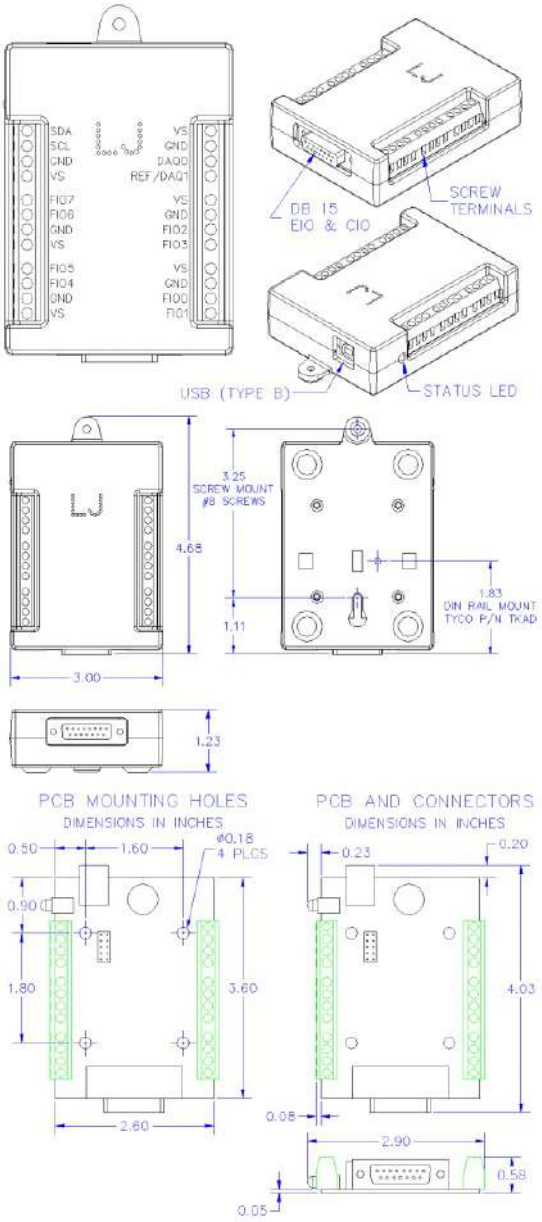
(1) With DAC1 disabled on hardware version < 1.30
(2) This is the maximum voltage on any AIN pin compared to ground for valid measurements. Not that differential channel has a minimum voltage of -2.44 volts, meaning that the positive channel can be 2.44 volts less than the negative channel, but no AIN pin can go more than 0.3 volts below ground.
(3) Maximum voltage, compared to ground, to avoid damage to the device. Protection level is the same whether the device is powered or not.
(4) The low-voltage analog inputs essentially connect directly to a SAR ADC on the U3, presenting a capacitive load to the signal source. The high-voltage inputs connect first to a resistive level-shifter/divider. The key specification in both cases is the maximum source impedance. As long as the source impedance is not over this value, there will be no substantial errors due to impedance problems.
(5) Measurements taken with AIN connected to a 2.048 reference (REF191 from Analog Devices) or GND. All "counts" data are aligned as 12-bit values. Noise-free data is determined by taking 128 readings and subtracting the minimum value from the maximum value.
(6) Effective (RMS) data is determined from the standard deviation of 128 readings. In other words, this data represents _most_ readings, whereas noise-free data represents all readings.

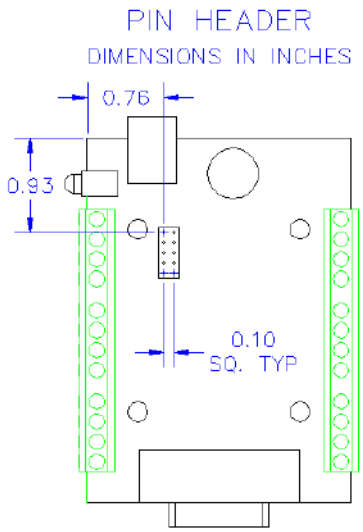
Parameter	Conditions	Min	Typical	Max	Units
Analog Outputs (DAC)					
Nominal Output Range (1)	No Load	0.04		4.95	volts
	@ ±2.5 mA	0.225		4.775	volts
Resolution			10		bits
Absolute Accuracy	5% to 95% FS		±5		% FS
Integral Linearity Error			±1		counts
Differential Linearity Error			±1		counts
Error Due To Loading	@ 100 µA		0.1		%
	@ 1 mA		1		%
Source Impedance			50		Ω
Short Circuit Current (2)	Max to GND		45		mA
Slew Rate			0.4		V/ms
Digital I/O, Timers, Counters					
Low Level Input Voltage		-0.3		0.8	volts
Hight Level Input Voltage		2		5.8	volts
Maximum Input Voltage (3)	FIO	-10		10	volts
	EIO/CIO	-6		6	volts
Output Low Voltage (4)	No Load		0		volts
--- FIO	Sinking 1 mA		0.55		volts
--- EIO/CIO	Sinking 1 mA		0.18		volts
--- EIO/CIO	Sinking 5 mA		0.9		volts
Output High Voltage (4)	No Load		3.3		volts
--- FIO	Sourcing 1 mA		2.75		volts
--- EIO/CIO	Sourcing 1 mA		3.12		volts
--- EIO/CIO	Sourcing 5 mA		2.4		volts
Short Circuit Current (4)	FIO		6		mA
	EIO/CIO		18		mA
Output Impedance (4)	FIO		550		Ω
	EIO/CIO		180		Ω
Counter Input Frequency (5)	Hardware V1.21+			8	MHz
Input Timer Total Edge Rate (6)	No Stream, V1.21+			30000	edges/s

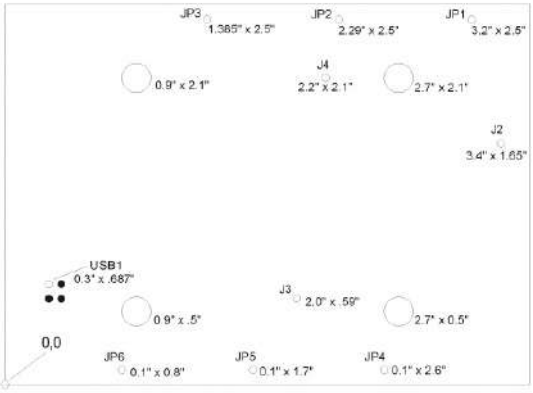
		While Streaming			7000	edges/s	
	(1) Maximum and minimum analog output voltage is limited by the supply voltages (Vs and GND). The specifications assume Vs is 5.0 volts. Also, the ability of the DAC output bufffer to driver voltages close to the power rails, decreases with increasing output current, but in most applications the output is not sinking/sourcing much current as the output voltage approaches GND.						
	(2) Continuous short circuit will not cause damage.						
	(3) Maximum voltage to avoid damage to the device. Protection works whether the device is powered or not, but continuous voltages over 5.8 volts or less than -0.3 volts are not recommended when the U3 is unpowered, as the voltage will attempt to supply operating power to the U3 possible causing poor start-up behavior.						
	(4) These specifications provide the answer to the question: "How much current can the digital I/O sink or source?". For instance, if EIO0 is configured as output-high and shorted to ground, the current sourced by EIO0 into ground will be about 18 mA (3.3/180). If connected to a load that draws 5 mA, EIO0 can provide that current but the voltage will droop to about 2.4 volts instead of the nominal 3.3 volts. If connected to a 180 ohm load to ground, the resulting voltage and current will be about 1.65 volts @ 9 mA.						
	(5) Hardware counters. 0 to 3.3 volt square wave. Limit about 2 MHz with older hardware versions.						
	(6) To avoid missing edges, keep the total number of applicable edges on all applicable timers below this limit. See Section 2.9 for more information. Limit about 10000 with older hardware versions.						

Appendix B - Enclosure and PCB Drawings

Various drawings follow. CAD drawings of the U3 attached to the bottom of this page (DWG, DXF, IGES, STEP).







U3 PCB drawing showing the coordinates (in Inches) for pin 1 of each connector.
File attachment:
U3 Enclosure CAD Drawings.zip

Anexo D

Manual de Uso de Placa de LabJack con MATLAB®

Manual de Uso

Placa LabJack

Mediante

MATLAB

2014

Autor: Pablo Emmanuel Saiz

Índice

1. Introducción

Las placas adquisidoras de datos LabJack (U3, U6, UE9) particularmente trabajan con una programación a alto nivel de bits mediante funciones especializadas a tipos de operaciones tales como apertura de enlace con placa, configuraciones de entrada y/o salida, reseteos, entre otros.

Con la instalación del controlador de la placa (es recomendable descargar la última versión disponible en la página oficial, www.labjack.com), se instalan diversos programas y librerías, donde una de ellas y de suma importancia es la labjackud.h que permite realizar la programación descrita con anterioridad.

Este no es el único método disponible, ya que el controlador permite, además, que se pueda operar mediante interfaces de diversos y reconocidos programas.

En el siguiente manual se hará hincapié en las funciones mencionadas, en los errores de codificación (errorcodes) y en la programación mediante el uso de MATLAB.

2. Funciones

2.1. ListAll()

Esta función devuelve un cero si el resultado de la búsqueda es positivo y un código de error si es negativo.

Declaración:

LJ_ERROR_stdcall ListAll (long DeviceType, long ConnectionType, long *pNumFound, long *pSerialNumbers, long *PIDS, double *pAddresses)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- DeviceType: Tipo de LabJack a utilizar. Las constantes se hallan en labjackud.h
- ConnectionType: Constante para el tipo de conexión.

Salidas:

- pNumFound: Puntero que devuelve el número de dispositivos encontrados.
- pSerialNumbers: Matriz que contiene los números de serie de los dispositivos encontrados.
- PIDS: Matriz que contiene indentificadores locales de los dispositivos encontrados.

- pAddresses: Matriz que contiene las direcciones IP de los dispositivos encontrados.

2.2. OpenLabJack()

Es la función llamada a un dispositivo LabJack.

Declaración:

LJ_ERROR_stdcall OpenLabJack (long DeviceType, long ConnectionType, const char *pAddress, long FirstFound, LJ_HANDLE *pHandle)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- DeviceType: Tipo de LabJack a utilizar. Las constantes se hallan en labjackud.h
- ConnectionType: Constante para el tipo de conexión, USB o Ethernet.
- pAddress: Por USB, pase el ID local o número de serie de LabJack. Si FirstFound es verdadero, éste se ignora.
- FirstFound: Si es verdadero, ignora el tipo de conexión y la dirección, luego abre el primer dispositivo encontrado. Se recomienda en la conexión USB de un solo dispositivo.

Salidas:

- pHandle: Un puntero a una referencia de LabJack.

2.3. eGet() y ePut()

Facilitan las funciones AddRequest, Go y GetResult en un solo paso.

La versión eGet está diseñada para entradas o recuperación de parámetros, que colocan el resultado en una cadena doble como si fueran punteros, pero pueden ser usados en salidas si pValue esta preseteado en el valor deseado.

La versión ePut está diseñada para salidas o parámetros de configuración de seteo y no retorna nada salvo un código de error (errorcode).

Declaración:

LJ_ERROR_stdcall eGet (LJ_HANDLE Handle, long IOType, long Channel, double *pValue, long x1)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de LabJack.
- IOType: Tipo de conexión (Entrada/Salida, “FIO”, “CIO”, etc.).
- Channel: Número de canal para cada tipo de conexión.
- pValue: Puntero del valor que envía o recibe datos.
- x1: Parámetro opcional utilizado para algunas conexiones.

Salidas:

- pValue: Puntero del valor que envía o recibe datos.

2.4. eAddGoGet()

Esta función pasa múltiples requisitos vía matriz, luego ejecuta la función GoOne() y retorna todos los resultados a través de las mismas matrices.

Los parámetros que comienzan con *a son matrices, y todas deben ser inicializadas con al menos un número de elementos igual a NumRequests.

Declaración:

LJ_ERROR_stdcall eAddGoGet (LJ_HANDLE Handle, long NumRequests, long *aIOTypes, long *aChannels, double *aValues, long *ax1s, long *aRequestErrors, long *GoError, long *aResultErrors)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de LabJack.
- NumRequests: Es el número de solicitudes que se pueden realizar, y por lo tanto el número de resultados a retornar. Todas las matrices deben ser inicializadas con el mínimo de estos elementos.
- aIOTypes: Una matriz que es la lista de tipos de conexiones.
- aChannels: Una matriz que es la lista de canales.
- aValues: Una matriz que es la lista de valores a escribir.
- ax1s: Una matriz que es la lista de funciones especiales x1.

Salidas:

- aValues: Una matriz que es la lista de valores leídos.
- aRequestErrors: Una matriz que es la lista de códigos de error de cada AddRequest().

- GoError: El código de error devuelto de la llamada del GoOne().
- aResultErrors: Una matriz que es la lista de códigos de error de cada GetResult().

2.5. AddRequest()

Agrega un ítem a la lista de solicitudes a realizar en la próxima llamada de Go() o GoOne().

Cuando se llama a AddRequest desde una referencia en particular, toda la información anterior se borra y no puede ser recuperada por cualquiera de las funciones Get hasta que una función Go sea llamada de nuevo. Se trata de un dispositivo de base del U3, por lo que se puede llamar a AddRequest con una referencia diferente, mientras que un dispositivo este ocupado efectuando sus Entradas/Salidas.

AddRequest solo borra las listas de solicitudes y resultados en la referencia del dispositivo, y solo para el subproceso actual.

En general, la orden de ejecución para la lista de solicitudes en una sola llamada de Go es imprevisible, salvo que todas las solicitudes del tipo de configuración sean ejecutadas antes de las solicitudes de adquisición y salida.

Declaración:

LJ_ERROR_stdcall AddRequest (LJ_HANDLE Handle, long IOType, long Channel, double Value, long x1, double Userdata)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de LabJack.
- IOType: Solicitud de tipo de conexión.
- Channel: Número de canal para tipo de conexión.
- Value: Valor pasado para canales de salida.
- x1: Parámetro opcional usado para algunas conexiones.
- Userdata: Son los datos que se pasan con las solicitudes y regresan sin modificarse a través de GetFirstResult o GetNextResult. Se puede utilizar para almacenar información con la solicitud, para permitir un analizador genérico para determinar que se debe hacer cuando se reciben los resultados.

Salidas: No posee.

2.6. Go()

Luego de usar AddRequest para hacer la lista interna de solicitudes a desarrollar, se llama a la función Go para llevarlas a cabo. Esta función hace que todas las solicitudes en todos los dispositivos LabJack abiertos se lleven a cabo. Después, se puede llamar a GetResult o similares para recuperar cualquier dato o error obtenido.

Go() puede ser llamado reiteradas veces con la lista actual de solicitudes. Go no limpia la lista. Por lo tanto, luego de cada llamada, la primera llamada AddRequest a continuación para cualquier dispositivo deberá limpiar la lista previa de solicitudes en ese dispositivo particular solamente.

Note que para la llamada Go o GoOne solamente, la orden de ejecución de la lista de solicitudes no puede preverse. Desde el controlador se hace la optimización interna, esto probablemente no sea la misma orden de las funciones AddRequest. Una cosa es sabida, es que los ajustes de configuración, tales como rangos, ajustes automáticos y demás, deben hacerse antes de la actual adquisición o ajustes de las salidas.

Declaración:

LJ_ERROR_stdcall Go ()

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas: No posee.

Salidas: No posee.

2.7. GoOne()

Luego de usar AddRequest para hacer la lista interna de solicitudes a desarrollar, se llama a la función GoOne para llevarlas a cabo. Esta función hace que todas las solicitudes de un solo dispositivo LabJack conectado se lleven a cabo, en particular. Después, se puede llamar a GetResult o similares para recuperar cualquier dato o error obtenido.

GoOne() puede ser llamado reiteradas veces con la lista actual de solicitudes. GoOne no limpia la lista. Por lo tanto, luego de cada llamada, la primera llamada AddRequest a continuación para cualquier dispositivo deberá limpiar la lista previa de solicitudes en ese dispositivo particular solamente.

Note que para la llamada Go o GoOne solamente, la orden de ejecución de la lista de solicitudes no puede preverse. Desde el controlador se hace la optimización interna, esto probablemente no sea la misma orden de las funciones AddRequest. Una cosa es sabida, es que los ajustes de configuración, tales como rangos, ajustes automáticos y demás, deben hacerse antes de la actual adquisición o ajustes de las salidas.

Declaración:

LJ_ERROR_stdcall GoOne (LJ_HANDLE Handle)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de LabJack.

Salidas: No posee.

2.8. GetResult()

Las llamadas a cada función Go crea una lista de resultados que encaja con la lista de solicitudes. Use GetResult para leer el resultado y código de error para cada tipo de conexión y canal en particular. Normalmente esta función es llamada para cada ítem asociado a AddRequest. Incluso si la solicitud fuera una salida, el código de error debería estar evaluado. Ninguna de las funciones Get limpiará los resultados de la lista. La primera llamada AddRequest subsiguiente a la llamada Go limpiará la lista interna de solicitudes y resultados para un dispositivo en particular.

Cuando se procesan las solicitudes de Entrada/Salida o datos en modo automático, la llamada a Get no es realmente la causa de que las matrices de datos estén llenas. Las matrices son llenadas durante la llamada Go (si los datos están disponibles), y la llamada Get es usada para averiguar cuantos elementos están guardados en la matriz.

Declaración:

LJ_ERROR_stdcall GetResult (LJ_HANDLE Handle, long IOType, long Channel, double *pValue)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de LabJack.
- IOType: Tipo de conexión.
- Channel: Número de canal para cada tipo de conexión.

Salidas:

- pValue: Puntero al valor resultante.

2.9. GetFirstResult() y GetNextResult()

Use GetFirstResult y GetNextResult para ir de a pasos a través de la lista de resultados en orden. Cuando una función devuelve LJE_NO_MORE_DATA_AVAILABLE es que no hay más ítems en la lista de resultados. Los ítems pueden ser leídos más de una vez llamando a GetFirstResult y moviéndose desde el inicio de la lista.

Userdata proporciona información de seguimiento o cualquier otra cosa que el usuario pueda necesitar.

Es aceptable pasar NULL (o 0) para cualquier puntero que no sea necesario.

Los parámetros son los mismos para la declaración de GetFirstResult como para GetNextResult.

Declaración:

LJ_ERROR_stdcall GetFirstResult (LJ_HANDLE Handle, long *pIOType, long *pChannel, double *pValue, long *px1, double *pUserData)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de LabJack.

Salidas:

- pIOType: Puntero al tipo de conexión de la lista.
- pChannel: Puntero al número de canal de la lista.
- pValue: Puntero al valor resultante.
- px1: Puntero al parámetro x1 de la lista.
- pUserData: Puntero de datos simplemente pasado con la solicitud y devuelto sin modificación. Puede ser usado para almacenar cualquier tipo de información con la solicitud, para permitir un analizador genérico para determinar que se debe hacer cuando se reciben los datos.

2.10. ResetLabJack()

Envía un comando de reinicio al hardware de LabJack.

El reseteo de la LabJack no invalidaré la referencia, asique el dispositivo no tiene que ser abierto de nuevo después del reinicio, pero la llamada Go es probable que falle durante un par de segundos después, hasta que LabJack esté lista.

En un futuro comunicado del controlador, esta función podría dar un parámetro adicional que determine el tipo de reseteo.

Declaración:

LJ_ERROR_stdcall ResetLabJack (LJ_HANDLE Handle)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de OpenLabJack.

Salidas: No posee.

2.11. eAIN()

Una función sencilla que devuelve una lectura de una entrada analógica. Esta es una alternativa simple al método basado en los tipos de conexiones en pines flexibles normalmente usado por este controlador.

Cuando sea necesario, esta función configura automáticamente el canal especificado para la entrada analógica.

Declaración:

LJ_ERROR_stdcall eAIN (LJ_HANDLE Handle, long ChannelP, long ChannelN, double *Voltage, long Range, long Resolution, long Settling, long Binary, long Reserved1, long Reserved2)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de OpenLabJack.
- ChannelP: El canal AIN positivo a adquirir.
- ChannelN: El canal AIN negativo a adquirir. Para canales unipolares en la U3, este parámetro debería ser 31 o 199.
- Range: Ignorado en la U3.
- Resolution: Pase un valor distinto de cero para habilitar QuickSample.
- Settling: Pase un valor distinto de cero para habilitar LongSettling.
- Binary: Si es distinto de cero (verdadero), el parámetro de voltaje regresara un valor en binario crudo.
- Reserved (1&2): Pasar 0.

Salidas:

- Voltage: Retorna la lectura de la entrada analógica, que es generalmente una tensión.

2.12. eDAC()

Una función sencilla que escribe un valor en una salida analógica. Esta es una alternativa simple al método basado en los tipos de conexiones en pines flexibles normalmente usado por este controlador.

Cuando sea necesario, esta función habilita las salidas analógicas especificadas.

Declaración:

LJ_ERROR_stdcall eDAC (LJ_HANDLE Handle, long Channel, double Voltage, long Binary, long Reserved1, long Reserved2)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de OpenLabJack.
- Channel: El canal de salida analógica a escribir.
- Voltage: La tensión a escribir en la salida analógica.
- Binary: Si es distinto de cero (verdadero), el valor pasado de tensión debe ser binario.
- Reserved (1&2): Pasar 0.

Salidas: No posee.

2.13. eDI()

Una función sencilla que lee el estado de una entrada digital. Esta es una alternativa simple al método basado en los tipos de conexiones en pines flexibles normalmente usado por este controlador.

Cuando sea necesario, esta función configura automáticamente un canal específico como una entrada digital.

Declaración:

LJ_ERROR_stdcall eDI (LJ_HANDLE Handle, long Channel, long *State)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de OpenLabJack.
- Channel: Canales a leer 0-19 correspondientes a FIO0-CIO3.

Salidas:

- State: Retorna el estado de la entrada digital, 0=Falso=Baja y 1=Verdadero=Alta.

2.14. eDO()

Una función sencilla que escribe el estado de una salida digital. Esta es una alternativa simple al método basado en los tipos de conexiones en pines flexibles normalmente usado por este controlador.

Cuando sea necesario, esta función configura automáticamente un canal específico como una salida digital.

Declaración:

LJ_ERROR_stdcall eDO (LJ_HANDLE Handle, long Channel, long State)

Devolución: Códigos de error (Errorcodes) o 0 (sin error).

Entradas:

- Handle: Retorno a referencia de OpenLabJack.
- Channel: Canales a leer 0-19 correspondientes a FIO0-CIO3.
- State: Retorna el estado de la entrada digital, 0=Falso=Baja y 1=Verdadero=Alta.

Salidas: No posee.

2.15. Configuraciones de entradas y salidas

Para el reseteo de entradas y salidas

ePut (lngHandle, LJ_ioPIN_CONFIGURATION_RESET,0, 0, 0);

Para la lectura y escritura de parámetros de configuración se utilizaran dos comandos especiales

LJ_ioPUT_CONFIG

LJ_ioGET_CONFIG

De los cuales los canales de configuración predeterminados son

LJ_chLOCALID

LJ_chHARDWARE_VERSION

LJ_chSERIAL_NUMBER

LJ_chFIRMWARE_VERSION

LJ_chBOOTLOADER_VERSION

LJ_chPRODUCTID

LJ_chLED_STATE

Si deseamos configurar los flexibles de entrada/salida como analógicos o digitales, como por ejemplo configurar la FIO2 como entrada analógica y FIO3 como E/S digital, utilizamos

ePut (lngHandle, LJ_ioPUT_ANALOG_ENABLE_BIT,2,1,0):

ePut (lngHandle, LJ_ioPUT_ANALOG_ENABLE_BIT,3,0,0);

Notar que el cuarto parámetro determina si es analógico (1) o digital (0). En el caso que se desee configurar mas de un pin por vez, por ejemplo si se quiere que de FIO3 a FIO7 sean entradas analógicas, al igual que de EIO4 a EIO6 inclusive, y que los demás sean digitales. Con lo que se arrancara una serie de bits desde el canal 3 de las FIO

B01110000 11111000=D28920

EIO FIO

7, … , 0 7, … , 0

U omitiendo los últimos 3 dígitos

B111000011111=D3615

De esta manera, el tercer parámetro es el canal de inicio del bit, el cuarto es el número en decimal, y el quinto es la cantidad de pines a habilitar. Quedando

ePut (lngHandle,LJ_ioPUT_ANALOG_ENABLE_PORT,0,28920,16);

O

ePut (lngHandle,LJ_ioPU_NALOG_ENABLE_PORT,3,3615,16);

Si las entradas son las analógicas pre configuradas, o sea las AIN, los comandos IOTypes son

LJ_ioGET_AIN // Para una lectura simple, donde el negativo esta fijado en 31/199.

LJ_ioGET_AIN_DIFF //Donde se debe especificar el canal negativo en el parámetro x1.

A modo de ejemplo si se desea una lectura sencilla de AIN0 y una lectura diferencial entre AIN0 y AIN1, siendo AIN1 el canal negativo, se tendrá

AddRequest(lngHandle,LJ_ioGET_AIN,0,0,0,0);

AddRequest(lngHandle,LJ_ioGET_AIN_DIFF,0,0,1,0);

GoOne(lngHandle);

3. Programación mediante MATLAB

Las placas adquisidoras de datos LabJack pueden ser operadas mediante diversos y variados programas, tales como LabView, Python, VisualBasic, Java, C, C++, entre otros. En particular, también trabajan con MATLAB.

La peculiaridad de utilizar MATLAB radica en el tipo de programación a utilizar, que es mediante objetos. Esto significa que se trabajaran con librerías específicas contenidas en el software de la placa, y se hará mediante niveles. El comando "." es el destinado para pasar a subcarpetas.

Es pertinente destacar que no solo se trabaja en el entorno de MATLAB, sino que también se encuentra en correlación con el entorno .NET de Microsoft Framework.

A continuación se demostraran varios ejemplos de utilización de la placa U3 en particular. Tener en cuenta que antes de ejecutar dichos programas .m se deben tener incluidas las librerías correspondientes. Otro detalle a tener en cuenta, se debe trasladar una copia del programa "ShowErrorMessage" a la carpeta correspondiente para lograr que este funcione correctamente.

3.1. Lectura de Entrada Analógica

```
clc
clear
NET.addAssembly('C:\WINDOWS\assembly\GAC_MSIL\LJUDDotNet\3.42.0.0__9d6
c109908595016\LJUDDotNet.dll'); // ubicación del software de la placa

ljudObj= LabJack.LabJackUD.LJUD;
try
    [ljerror,ljhandle] =
ljudObj.OpenLabJack(LabJack.LabJackUD.DEVICE.U3,LabJack.LabJackUD.CONN
ECTION.USB,'0',true,0);
```

```
    chanObj=0;


ljudObj.ePut(ljhandle,LabJack.LabJackUD.IO.PIN_CONFIGURATION_RESET,cha
nObj,0,0);


errorcode=ljudObj.AddRequest(ljhandle,LabJack.LabJackUD.IO.GET_AIN,0,0
,0,0);

    ljudObj.AddRequest(ljhandle, LabJack.LabJackUD.IO.PUT_DAC, 0, 3,
0, 0);


   vector(10)=0;
    for n=1:10
        errorcode=ljudObj.GoOne(ljhandle);
        n;
        pause(0.01);

[ljerror,dblValue]=ljudObj.GetResult(ljhandle,LabJack.LabJackUD.IO.GET
_AIN,0,0);
        vector(n)=dblValue;

    end
catch e
    showErrorMessage(e)
end

ljudObj.Close()
```

3.2. Escritura de Salida Analógica

```
clc
clear

size=180;
tiempo_de_espera=0.5;

NET.addAssembly('C:\WINDOWS\assembly\GAC_MSIL\LJUDDotNet\3.42.0.0__9d6
c109908595016\LJUDDotNet.dll');
ljudObj= LabJack.LabJackUD.LJUD;
try

    [ljerror,ljhandle] =
ljudObj.OpenLabJack(LabJack.LabJackUD.DEVICE.U3,LabJack.LabJackUD.CONN
ECTION.USB,'0',true,0);


ljudObj.ePut(ljhandle,LabJack.LabJackUD.IO.PIN_CONFIGURATION_RESET,0,0
,0);

    ljudObj.AddRequest(ljhandle, LabJack.LabJackUD.IO.PUT_DAC, 1, 3.5,
0, 0);
```

```
    ljudObj.AddRequest(ljhandle, LabJack.LabJackUD.IO.PUT_DAC, 0, 0,
0, 0);

    ljudObj.GoOne(ljhandle);

catch e
    showErrorMessage(e)
end
ljudObj.Close()
```

3.3. Lectura de Entrada Digital

```
clc
clear

size=10;
tiempo_de_espera=1;

NET.addAssembly('C:\WINDOWS\assembly\GAC_MSIL\LJUDDotNet\3.42.0.0__9d6
c109908595016\LJUDDotNet.dll');
ljudObj= LabJack.LabJackUD.LJUD;
try

    [ljerror,ljhandle] =
ljudObj.OpenLabJack(LabJack.LabJackUD.DEVICE.U3,LabJack.LabJackUD.CONN
ECTION.USB,'0',true,0);


ljudObj.ePut(ljhandle,LabJack.LabJackUD.IO.PIN_CONFIGURATION_RESET,0,0
,0);

ljudObj.AddRequest(ljhandle,LabJack.LabJackUD.IO.GET_DIGITAL_BIT, 6,
0, 0, 0);

    for n=1:size
        ljudObj.GoOne(ljhandle);
        [ljerror,dblValue]=ljudObj.GetResult
(ljhandle,LabJack.LabJackUD.IO.GET_DIGITAL_BIT, 6,0);
        pause(tiempo_de_espera);
        vector(n)=dblValue;

    end

catch e
    showErrorMessage(e)
end
ljudObj.Close()
```

3.4. Escritura de Salida Digital

```
clc
clear

NET.addAssembly('C:\WINDOWS\assembly\GAC_MSIL\LJUDDotNet\3.42.0.0__9d6
c109908595016\LJUDDotNet.dll');
ljudObj= LabJack.LabJackUD.LJUD;
try

    [ljerror,ljhandle] =
ljudObj.OpenLabJack(LabJack.LabJackUD.DEVICE.U3,LabJack.LabJackUD.CONN
ECTION.USB,'0',true,0);


ljudObj.ePut(ljhandle,LabJack.LabJackUD.IO.PIN_CONFIGURATION_RESET,0,0
,0);

    ljudObj.AddRequest(ljhandle,LabJack.LabJackUD.IO.PUT_DIGITAL_BIT,
5, 0, 0, 0);

    ljudObj.AddRequest(ljhandle,LabJack.LabJackUD.IO.PUT_DIGITAL_BIT,
7, 1, 0, 0);
    ljudObj.GoOne(ljhandle);


catch e
    showErrorMessage(e)
end
ljudObj.Close()
```

4. Códigos de Error (Errorcodes)

La siguiente tabla muestra los típicos errores que surgen de alguna operación errónea con la placa.

Errorcode	Name	Description
-2	LJE_UNABLE_TO_READ_CALDATA	Warning: Defaults used instead.
-1	LJE_DEVICE_NOT_CALIBRATED	Warning: Defaults used instead.
0	LJE_NOERROR	
2	LJE_INVALID_CHANNEL_NUMBER	Channel that does not exist (e.g. DAC2 on a UE9), or data from stream is requested on a channel that is not in the scan list.
3	LJE_INVALID_RAW_INOUT_PARAMETER	
4	LJE_UNABLE_TO_START_STREAM	
5	LJE_UNABLE_TO_STOP_STREAM	
6	LJE_NOTHING_TO_STREAM	
7	LJE_UNABLE_TO_CONFIG_STREAM	
8	LJE_BUFFER_OVERRUN	Overrun of the UD stream buffer.
9	LJE_STREAM_NOT_RUNNING	
10	LJE_INVALID_PARAMETER	
11	LJE_INVALID_STREAM_FREQUENCY	
12	LJE_INVALID_AIN_RANGE	
13	LJE_STREAM_CHECKSUM_ERROR	
14	LJE_STREAM_COMMAND_ERROR	
15	LJE_STREAM_ORDER_ERROR	Stream packet recieved out of sequence.
16	LJE_AD_PIN_CONFIGURATION_ERROR	Analog request on a digital pin, or vice versa
17	LJE_REQUEST_NOT_PROCESSED	Previous request had an error.
19	LJE_SCRATCH_ERROR	
20	LJE_DATA_BUFFER_OVERFLOW	
21	LJE_ADC0_BUFFER_OVERFLOW	
22	LJE_FUNCTION_INVALID	
23	LJE_SWDT_TIME_INVALID	
24	LJE_FLASH_ERROR	
25	LJE_STREAM_IS_ACTIVE	
26	LJE_STREAM_TABLE_INVALID	
27	LJE_STREAM_CONFIG_INVALID	
28	LJE_STREAM_BAD_TRIGGER_SOURCE	
30	LJE_STREAM_INVALID_TRIGGER	
31	LJE_STREAM_ADC0_BUFFER_OVERFLOW	
33	LJE_STREAM_SAMPLE_NUM_INVALID	
34	LJE_STREAM_BIPOLAR_GAIN_INVALID	
35	LJE_STREAM_SCAN_RATE_INVALID	
36	LJE_TIMER_INVALID_MODE	
37	LJE_TIMER_QUADRATURE_AB_ERROR	
38	LJE_TIMER_QUAD_PULSE_SQUENCE	
39	LJE_TIMER_BAD_CLOCK_SOURCE	
40	LJE_TIMER_STREAM_ACTIVE	
41	LJE_TIMER_PWMSTAOP_MODULE_ERROR	
42	LJE_TIMER_SEQUENCE_ERROR	
43	LJE_TIMER_SHARING_ERROR	
44	LJE_TIMER_LINE_SEQUENCE_ERROR	
45	LJE_EXT_OSC_NOT_STABLE	
46	LJE_INVALID_POWER_SETTING	
47	LJE_PLL_NOT_LOCKED	
48	LJE_INVALID_PIN	
49	LJE_IOTYPE_SYNCH_ERROR	

50	LJE_INVALID_OFFSET	
51	LJE_FEEDBACK_IOTYPE_NOT_valid	
52	LJE_SHT_CRC	
53	LJE_SHT_MEASREADY	
54	LJE_SHT_ACK	
55	LJE_SHT_SERIAL_RESET	
56	LJE_SHT_COMMUNICATION	
57	LJE_AIN_WHILE_STREAMING	AIN not available to command/response functions while the UE9 is stream.
58	LJE_STREAM_TIMEOUT	
60	LJE_STREAM_SCAN_OVERLAP	New scan started before the previous scan completed. Scan rate is too high.
61	LJE_FIRMWARE_VERSION_IOTYPE	IOType not supported with this firmware.
62	LJE_FIRMWARE_VERSION_CHANNEL	Channel not supported with this firmware.
63	LJE_FIRMWARE_VERSION_VALUE	Value not supported with this firmware.
64	LJE_HARDWARE_VERSION_IOTYPE	IOType not supported with this hardware.
65	LJE_HARDWARE_VERSION_CHANNEL	Channel not supported with this hardware.
66	LJE_HARDWARE_VERSION_VALUE	Value not supported with this hardware.
67	LJE_CANT_CONFIGURE_PIN_FOR_ANALOG	
68	LJE_CANT_CONFIGURE_PIN_FOR_DIGITAL	
70	LJE_TC_PIN_OFFSET_MUST_BE_4_TO_8	

Table 4.4-1. Request Level Errorcodes

Errorcode	Name	Description
1000	LJE_MIN_GROUP_ERROR	Errors above this number stop all requests.
1001	LJE_UNKNOWN_ERROR	Unrecognized error that is caught.
1002	LJE_INVALID_DEVICE_TYPE	
1003	LJE_INVALID_HANDLE	
1004	LJE_DEVICE_NOT_OPEN	AddRequest() called even thought Open() failed.
1005	LJE_NO_DATA_AVAILABLE	GetResult() call without calling a Go function, or a channel is passed that was not in the request list.
1006	LJE_NO_MORE_DATA_AVAILABLE	
1007	LJE_LABJACK_NOT_FOUND	LabJack not found at the given id or address.
1008	LJE_COMM_FAILURE	Unable to send or receive the correct number of bytes.
1009	LJE_CHECKSUM_ERROR	
1010	LJE_DEVICE_ALREADY_OPEN	
1011	LJE_COMM_TIMEOUT	
1012	LJE_USB_DRIVER_NOT_FOUND	
1013	LJE_INVALID_CONNETION_TYPE	
1014	LJE_INVALID_MODE	

Table 4.4-2. Group Level Errorcodes

5. Referencias

http://labjack.com/support/u3/users-guide

Anexo E

Hoja de Datos de Electroválvula

FLOWSERVE

Worcester Actuation Systems

FCD WCAIM2037-00
(Part 17522)

DataFlo Digital Electronic Positioner DFP17

Installation, Operation and Maintenance Instructions

MODELS:

10 - For *DataFlo* Boards Mounted Inside 10-23 75 Actuators.

25 - For *DataFlo* Boards Mounted Inside 25/30 75 Actuators.

Inputs:

DFP17 - 1K (120A, 240A, 24D)	1000 ohm Input
DFP17 - 13 (120A, 240A, 24D)	135 ohm Input
DFP17 - 1 (120A, 240A, 24D)	1 to 5 milliamp Input
DFP17 - 4 (120A, 240A, 24D)	4 to 20 milliamp Input
DFP17 - 10 (120A, 240A, 24D)	10 to 50 milliamp Input
DFP17 - 5V (120A, 240A, 24D)	0 to 5 VDC Input
DFP17 - XV (120A, 240A, 24D)	0 to 10 VDC Input

Voltages:

120A - 120 VAC Power Circuits

240A - 240 VAC Power Circuits

24D - 24 VDC Power Circuits

TABLE OF CONTENTS

1.0 GENERAL

1.1 Basic Design

The Worcester/McCANNA *DataFlo* Digital Electronic Positioner (DFP17) was designed for use with the Worcester/McCANNA Series 75 electric actuators. However, it may also be used with other actuators or electrically operated rotary devices, provided the specified load parameters as given in Section 5.3 are not exceeded.

⚠ **CAUTION: This positioner is sensitive to electrical noise; please see Section 1.2.**

PLEASE READ THIS SECTION

A. The 4–20 mA signal input circuit of both the AC and DC Digital Positioner board is protected with a 62 mA fuse (F1). The fuse is used to protect the input circuit from an excessively high voltage. The fuse used in the input circuit is a Littlefuse PICO II very fast acting fuse rated at 62 mA.

   All DC Digital Positioner boards also use a standard 1 1/4", 250 V, 3 A fuse (F2) to protect the circuit board and the power source in case of a fault in the DC motor driver integrated circuit on the circuit board.

   ⚠ **CAUTION:** It is important that the DC voltage power source be properly connected to the actuator's terminal strip. Terminal one (1) of this strip is to have the negative or common wire connected to it. Terminal two (2) is to have the positive wire connected to it.

   NOTE: All wiring to terminal strip should be inserted only to the midpoint of terminal strip.

B. The Digital Positioner board is designed to receive a floating current input signal. This allows several pieces of equipment to be operated from the same current loop while at the same time remaining electrically independent of each other. A floating input signal means that the current input signal should not be referenced to the circuit board ground. This is especially important with DC powered circuit boards. The board power source must have a ground independent from that of the signal source.

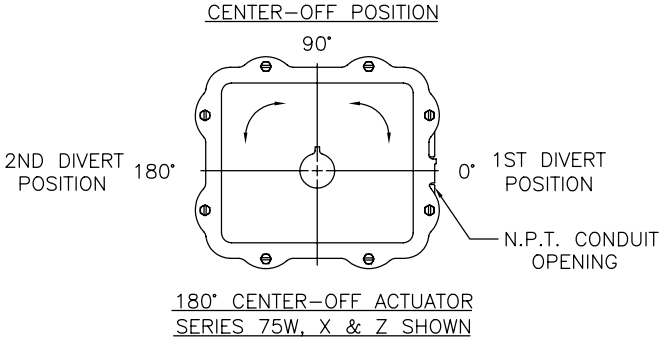
C. The Digital Positioner board can be set up in several ways for normal operation. The board is designed to control in 90˚ quadrants only (with alternate potentiometer gearing, 180˚ of rotation is available). The number of quadrants over which the board will control is determined by the number of teeth on the feedback pot pinion gear.

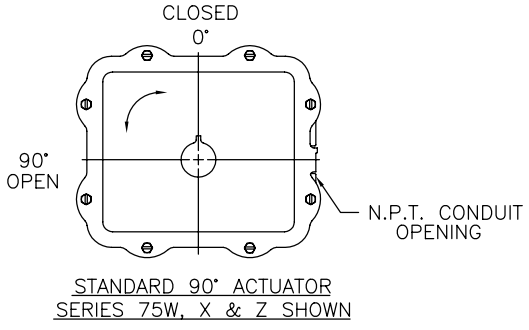
   The standard setup is 4 mA for full clockwise rotation - i.e., 0˚ and 20 mA for full counter-clockwise Rotation - i.e., 90˚ or 180˚.

D. Quite often when we receive an actuator for repair, we find that the only thing wrong with the unit is that the feedback potentiometer is out of calibration. It is very important that the feedback pot be properly calibrated for correct operation of the positioner board. It is also very important that the actuator shaft not be rotated out of the quadrant for which the feedback pot has been calibrated. Whenever you have a problem with the positioner calibration, always check the feedback pot calibration first. This must be done with no power applied to the circuit board. If the actuator is in the full clockwise position, check the resistance between the purple and white/black potentiometer leads. The reading should be 80-90 ohms. If it is not, rotate the face gear until the proper reading is achieved. If the actuator happens to be in the full counter-clockwise position then check the resistance between the green and white/black potentiometer leads. If necessary adjust the face gear for an 80-90 ohm reading.

   NOTE: It is not necessary to loosen or remove face gear snap ring(s) (if present) to rotate gear, it is a friction fit. For gears that do have snap rings, and if for any reason the snap ring(s) are to be removed, do not over stretch them; use the minimum opening to allow them to slip over the gear.

Figure 1 – Quadrants of Operation





1.2 Environmental Considerations

⚠ **CAUTION:** The DataFlo Digital Electronic Positioner is sensitive to electrical noise on signal or supply lines and in the environment. For maximum positioner sensitivity, the electrical noise level should be as low as possible. Follow installation, calibration and adjustment guidelines carefully and use shielded wire as stated in section 1.2.3.

Flowserve recommends that all products which must be stored prior to installation, be stored indoors, in an environment suitable for human occupancy. Do not store product in areas where exposure to relative humidity above 85%, acid or alkali fumes, radiation above normal background, ultraviolet light, or temperatures above 120˚F or below 40˚F may occur. Do not store within 50 feet of any source of ozone.

Temperature and humidity are the two most important factors that determine the usefulness and life of electronic equipment.

1.2.1 Temperature

Operating solid state electronic equipment near or beyond its high temperature ratings is the primary cause for most failures. It is, therefore, very important that the user be aware of and take into consideration, factors that affect the temperature at which the electronic circuits will operate.

Operating an electronic device at or below its low temperature rating generally results in a unit operating poorly or not at all, but it will usually resume normal operation as soon as rated operating temperatures are reached. Low temperature problems can be easily cured by addition of a thermostatically controlled heater to the unit's housing.

The Worcester/McCANNA *DataFlo* Digital Electronic Positioner is rated for operation between -40˚F (with heater and thermostat) and 160˚F. When using the Positioner inside the Worcester/McCANNA 75 Series actuators, a maximum ambient temperature of 115˚F is required to ensure the circuit board maximum temperature of 160˚F is not exceeded.

1.2.2 Humidity

Most electronic equipment has a reasonable degree of inherent humidity protection and additional protection is supplied by the manufacturer, in the form of moisture proofing and fungicidal coatings.

Such protection, and the 3 to 4 watts of heat generated by the circuit board assembly will generally suffice for environments where the average relative humidity is in the area of 80% or less and ambient temperatures are in the order of 70˚F average.

Where relative humidity is consistently 80 to 90% and the ambient temperature is subject to large variations, consideration should be given to installing a heater and thermostat option in the enclosure. The heater should not increase the enclosure temperature to the point where the circuit board assembly's temperature rating of 160˚F is exceeded.

In those instances where the internal heater would bring the circuit board operating temperature near or above its maximum rating, the user might consider purging the enclosure with a cool, dry gas. The initial costs can usually be paid off quickly in the form of greatly extended equipment life, low maintenance needs, and much less process downtime.

1.2.3 Input Circuit Noise Protection

Shielded wiring should be used for all signal input circuit wiring regardless of length.

With separately housed positioners, the wiring from the feedback potentiometer to remote positioner, would be considered as signal input wiring and should also be shielded wire.

The shields should never be used in place of one of the input wires, and the shields should be grounded to equipment housings at one end of the wiring run only. Grounding both ends of shielding can eliminate the shielding benefits because of current ground loops. If two or more shielded cables come to the positioner from different locations, ground the shields at the positioner.

Figure 2 – Digital Electronic Positioner Circuit Board

120/240 VAC

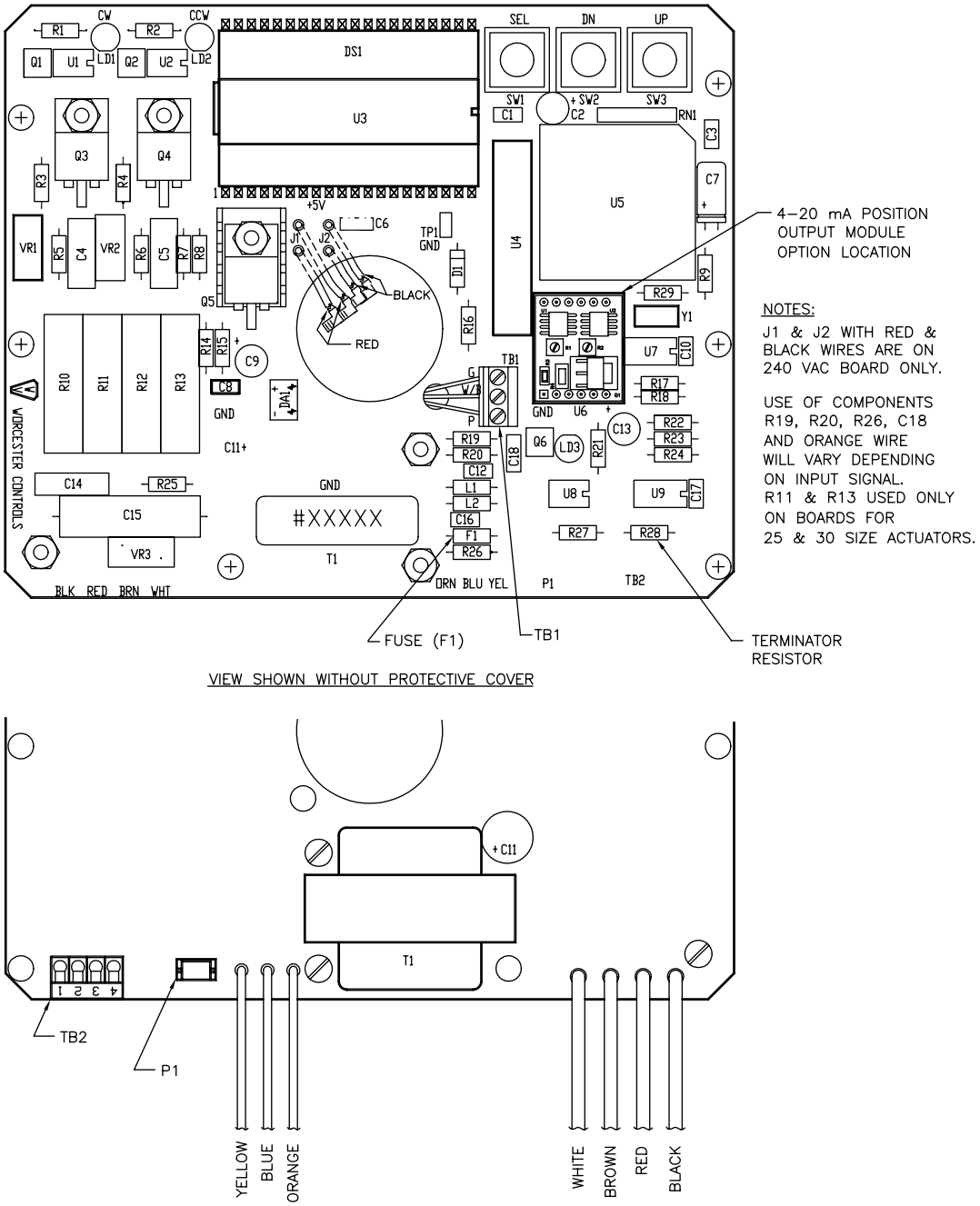
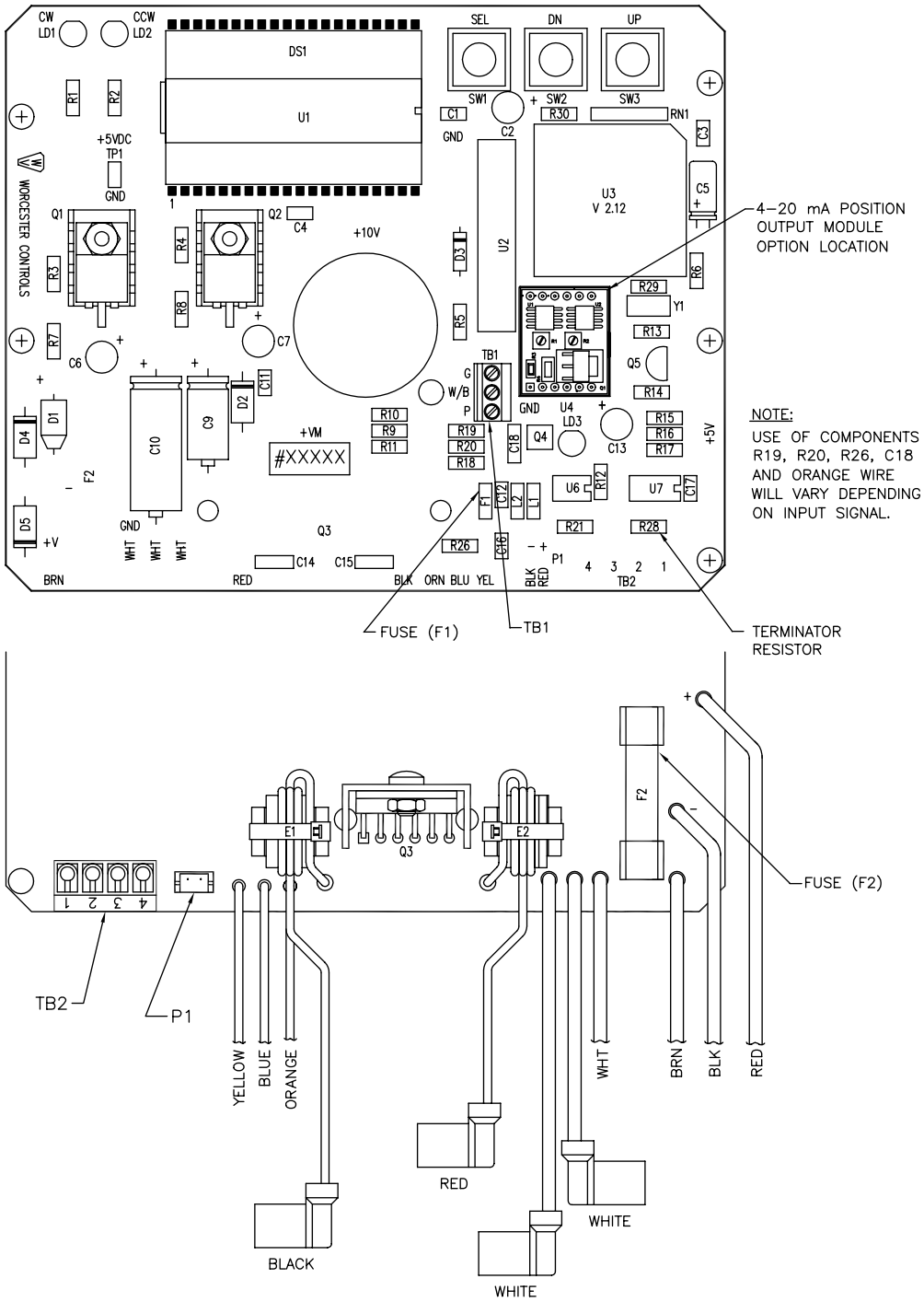


Figure 2 – Digital Electronic Positioner Circuit Board (continued)

24 VDC



2.0 *DataFlo* ELECTRONIC POSITIONER CIRCUIT BOARD

2.1 General

Figure 2 defines the location of major components and wires from the Positioner Board to terminal strip connections. The Digital Positioner Board is factory wired to the terminal strip either per Figure 4, Figure 5, Figure 6 or Figure 7, as found in Section 3.0, depending on power circuit voltage and if 4–20mA position output option is installed.

The feedback potentiometer leads are factory connected to the terminal block (TB1) on the Digital Positioner Board.

If a dual pot option is installed, the "B" pot leads will have to be wired directly to external device. The "A" pot leads are factory connected to the terminal block (TB1) on the Digital Positioner Board. Also, note that the "B" pot has a voltage limit of 30 volts maximum.

2.2 Circuit Board Configurations

The positioner board is factory supplied for one of the seven input signal options plus a two-wire RS-485 interface.

NOTE: Field changes to the positioner board are not advised. Consult Flowserve before attempting any modification.

2.3 LED Indicators

Light emitting diodes (LEDs) marked LD1 (CW) and LD2 (CCW) are in the output circuits and, when lit, indicate which direction the actuator is trying to drive. A third LED, LD3, is used to indicate when an alarm condition exists. If LD3 is lit, the alarm that caused it to light must be determined by looking at the Liquid Crystal Display (LCD) and finding the alarm parameter with the **UP** or **DN** switch.

2.4 Controls (Override)

There are no adjustable controls provided on the circuit board, because none are necessary. All parameters are set through the programming switches (keys) or the RS485 interface. Local push-button control is provided at the actuator by simultaneously pressing the **SEL** and **UP** switches (keys) for three seconds. At this point the **UP** and the **DN** switches (keys) can be used to manually position the actuator shaft. Pressing the **SEL** switch for three seconds will return the positioner to the run mode.

2.5 AC Power Control

The AC output circuits are controlled by solid state switches (triacs Q3, Q4), which will provide trouble-free operation for the life of the equipment they are used with, AS LONG AS THEY ARE OPERATED WITHIN THEIR RATINGS.

The ratings for the solid state switches used in the Worcester/ McCANNA *DataFlo* Digital Electronic Positioner are listed in Section 5.3.

3.0 WIRING OF DIGITAL POSITIONER AND SERIES 75 ELECTRIC ACTUATOR

See wiring diagrams located under actuator cover and/or in Figures 4 through 7 for customer connections.

3.1 Actuator Power

⚠ **CAUTION:** Wiring should be inserted only to midpoint of terminal strip.

3.1.1 Wire Size

Power to the positioner and from the positioner to the actuator should be with wire no smaller than 18 gauge and with insulation rated for the particular application. The 18 gauge wire size is sufficient for all Worcester/ McCANNA Series 75 actuators. When using the Positioner with other makes of actuators, check the manufacturer's current rating to determine the correct wire size.

3.1.2 Termination and Voltage

Power connections are made to terminals 1 and 2 of the terminal strip. The AC neutral or common, or DC negative wire should be connected to terminal #1 and the AC "hot" or DC positive wire to terminal #2. Note that the AC Positioner requires a minimum of 110 VAC, and a maximum of 130 VAC for the 120 VAC version and a 220 VAC minimum, 250 VAC maximum for the 240 VAC version.

Grounding wires should be connected to green colored grounding screw (if present) on the actuator base or to any base plate mounting screw in the actuator.

3.1.3 Minimum Fuse Ratings

See table below for minimum fuse rating when over current protection is used in motor power circuit.

Minimum Fuse Rating for Over Current Protection

Actuator Size	Voltage	Fuse Rating
10-23	120 VAC	5 A
25/30	120 VAC	10 A
10-23	240 VAC	3 A
25/30	240 VAC	5 A
10-23	24 VDC	5 A

NOTE: This table shows the minimum rating to prevent inrush current from blowing the fuse.

3.2 Input Signal Connections

NOTE: The Digital Positioner signal input circuit is protected by a 1/16 amp fuse, F1 (See Figure 2 and Section A of Section 1.1).

See Section 5.2 for input circuit specifications.

After input signal connections have been made, securely tighten all terminal screws. Keep wiring away from all rotating parts and ensure it will not be pinched when the actuator cover is installed.

3.2.1 Milliamp

DFP17-1, DFP17-4, DFP17-10 (Milliamp Input Signal for Digital Positioner)

For a milliamp signal input, the more positive or "High" signal lead should connect to actuator terminal 11. The less positive or "Common" lead should connect to actuator terminal 10. (Terminal 10 is (-), Terminal 11 is (+).)

This positioner is available for use with the standard milliamp signals: 1 to 5, 4 to 20, and 10 to 50 milliamps. The positioner board is factory calibrated for one of the three milliamp signal ranges. A label on the circuit board indicates the positioner's signal range.

Section 5.4 gives the nominal resistance load, which the positioner presents to the control circuit for the three signal ranges.

Comparison of resistance measurements made at terminals 10 and 11 (on the yellow and blue wires from the circuit board) against the resistances shown in part 5.4 provides a quick way to determine the milliamp range for which a particular board is calibrated. If fuse F1 is blown, an open circuit will be indicated.

NOTE: If the circuit board has an orange wire attached to it (See Figure 2), the board is set up for a Potentiometer Input. See section 3.2.2 and Figure 3.

3.2.2 Resistive

DFP17-13, DFP17-1K (Potentiometer Input for Digital Positioner)

NOTE: The Input Potentiometer is not the Feedback Potentiometer, but is an additional potentiometer provided by and externally located by the end user.

For a potentiometer input signal, the usual connections will be similar to that shown in Figure 3 with a "Close" command being generated when the potentiometer of Figure 3 is rotated to its full CCW position and an "Open" command when it is in the full CW position.

If the command signal is derived from other than a rotary pot, it is only necessary to keep in mind that a "Closed" (full CW) valve is called for when the command potentiometer presents the least resistance between terminals 10 and 11 and the most resistance between terminals 11 and 12. A full "Open" (full CCW) valve would be the reverse condition; the least resistance between terminals 11 and 12 and the most resistance between terminals 10 and 11.

If the "Command" potentiometer is reasonably linear, the actuator/valve will be approximately 50% open when the potentiometer shaft is halfway through its travel and the resistances between terminals 10 to 11 and 11 to 12 are equal.

Potentiometer input circuit boards are made in two versions, one for high resistance command circuits - 1000 ohms nominal, and one for low resistance command circuits - 135 ohms nominal.

3.2.3 DC Voltage

DFP17-5V, DFP17-XV (Direct Voltage Input Signal for Digital Positioner).

For a voltage input signal, the more positive or "High" signal lead should connect to terminal 11. The less positive or "Common" lead should connect to terminal 10 [Terminal 10 is (-), Terminal 11 is (+)]

This positioner is available for use with the standard direct voltage signals: 0 to 5 VDC and 0 to 10 VDC. The positioner board is factory calibrated for one of these two signal ranges and field changes are not advised.

Section 5.4 gives the nominal resistance load which the positioner presents to the control circuit for the two signal ranges.

Figure 3

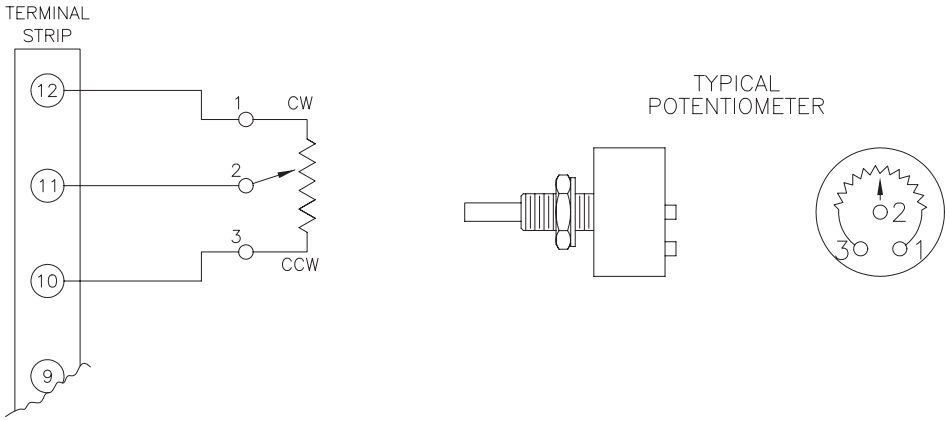


Figure 4

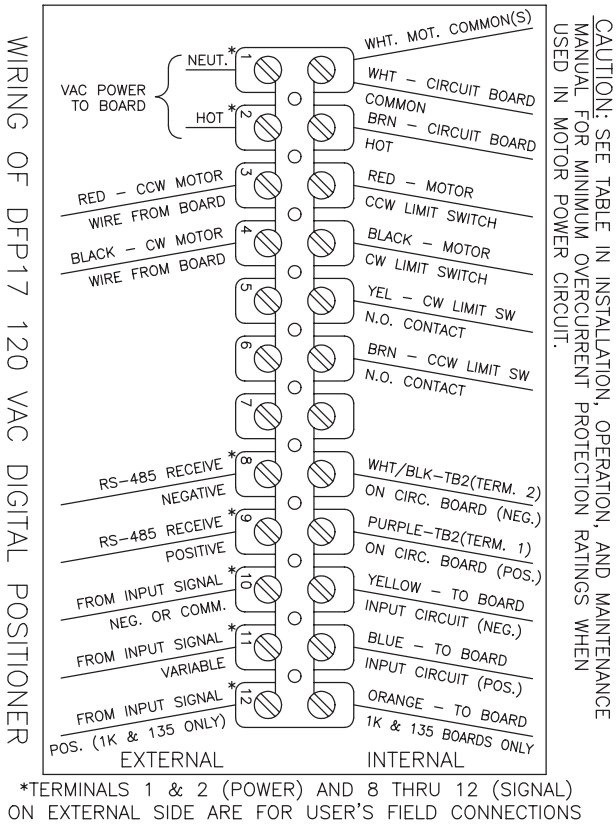
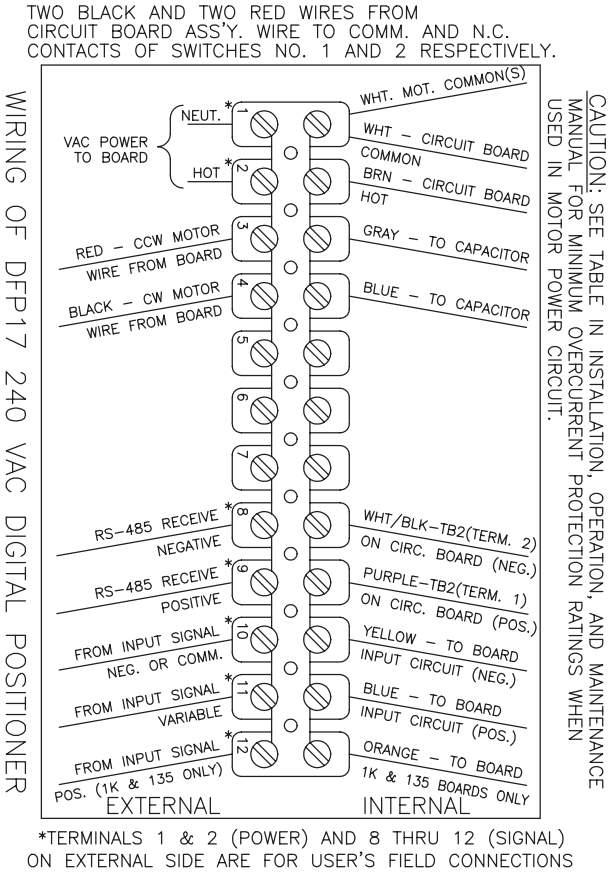


Figure 5



NOTE: For all input signal circuit wiring, regardless of length, shielded wiring should be used. See Section 1.2.

Figure 6 - 24 VDC DFP17 Circuit Board Wiring

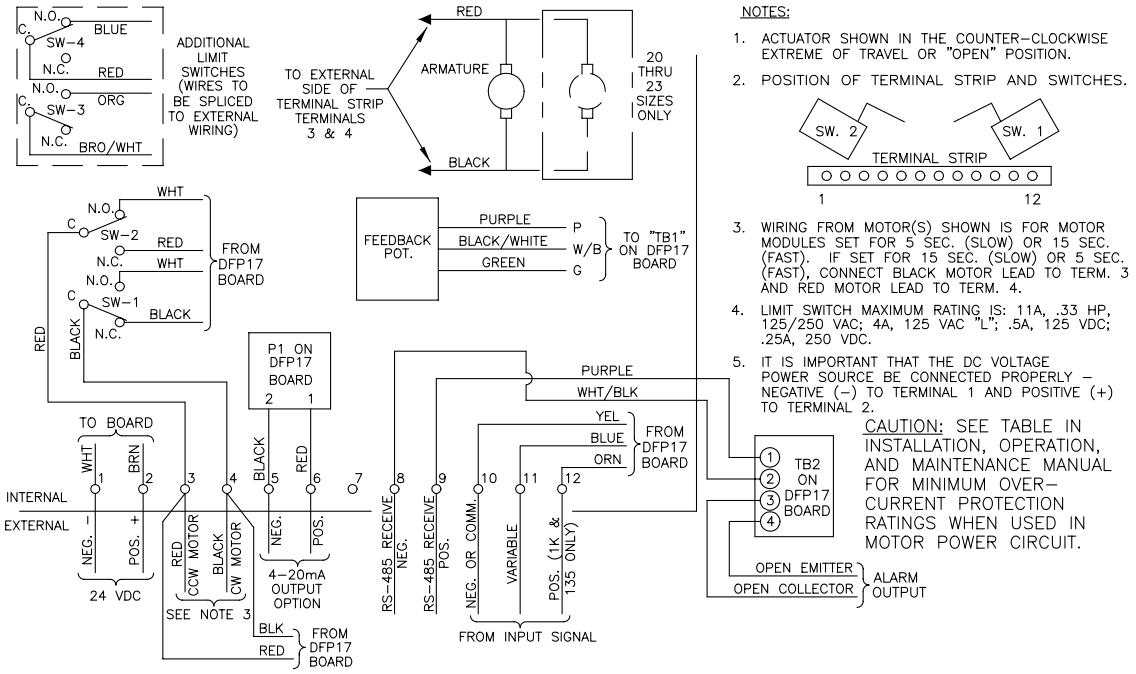
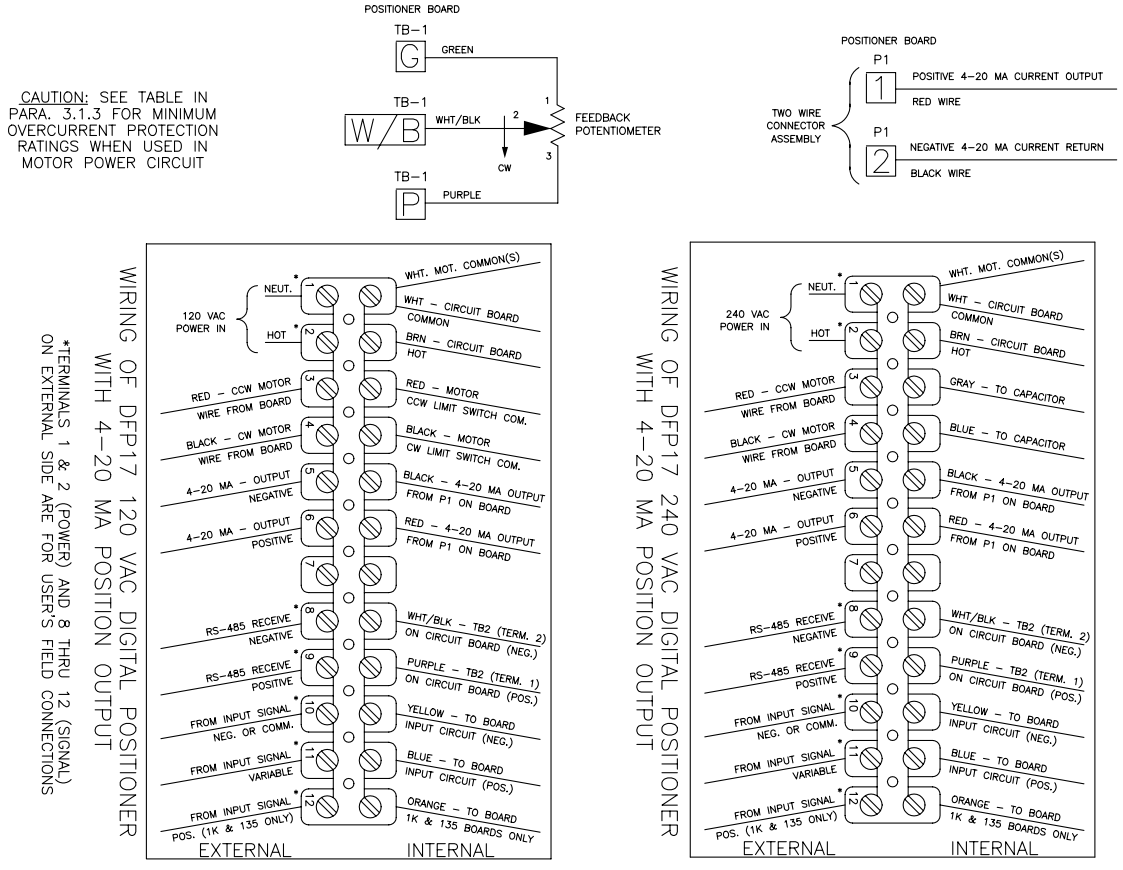


Figure 7
The Digital Positioner board 4–20 mA position has been calibrated at the factory and should require no further adjustment.



4.0 CALIBRATION AND ADJUSTMENT

4.1 *DataFlo* Calibration Procedures, Initial Set-Up and Adjustment (Applies to All Models)

4.1.1 Calibration Procedures for Microchip U5 (AC Board) or U3 (DC board) REV. V2.12 and Newer

NOTE: See Section 4.5.1 for more detailed information

A. If not already done, remove the cover and apply correct voltage per Section 3.0 to terminals 1 and 2.

B. If not already done, connect an input source to terminals 10 (-) and 11 (+), and 12 (if applicable) per Section 3.0.

C. When power is applied the unit will be in the Run Mode. The display should be flashing between **POS** and a number between 0 and 100.

D. Simultaneously press and hold the **SEL** and **DN** switches (keys) for three seconds. When first entering the Calibration Mode, **CAL** will be displayed for two seconds and the security code will be checked. If the required security code is not zero ("0000"), the display will begin alternating between **codE** and **0000**. Enter the security code as described in section 4.3.1.A and per section 4.2.6. If the required security code is zero, it will not need to be entered by the user, i.e., it will be bypassed and display will automatically flash **SEtL**, and you can skip to section F.

NOTE: If the security code is forgotten, the special number 4800 can be used to gain entry. However, this number will now be the new security code and if another code number is still desired, it will have to be reprogrammed.

E. If, and after, a security code has been entered, press and release **SEL** to accept the code. The display will now flash **SEtL** and a value.

F. Simultaneously press and release the **SEL** and **UP** keys, then adjust input signal to lower input value, e.g., 4 mA. Press and release **SEL** to lock in value.

G. Press and release the **DN** key, the display will now flash **SEtU** and a value. Simultaneously press and release **SEL** and **UP**, then adjust input signal to higher input value, e.g., 20 mA. Press and release **SEL** to lock in value.

H. Press and release **DN**, the display will now flash **PoC** and a number between 0 and 5 volts. Simultaneously press and release **SEL** and **UP**. Adjust so shaft is full CW using the **DN** key.

Important: Be careful not to go past 90˚, see section 4.1.3. The display should read between .200 and .400 volts. If not, rotate the face gear located on the actuator shaft until you read between .200 and .400 volts. The gear is held in place by means of a friction lock and snap ring(s). No tools are needed nor is it necessary to loosen or remove the snap ring(s) to move the gear. Steady gentle finger pressure will move the gear to allow you to adjust the feedback pot. Press and release **SEL** to lock in value.

I. Press and release **DN**, the display will now flash **PoCC** and the feedback voltage value. Simultaneously press and release **SEL** and **UP**. Adjust so shaft is full CCW using the **UP** key (do not go past 90˚). Press and release **SEL** to lock in value.

J. Press and release **DN**, the display will now flash **Cyt** and a cycle time reading. Simultaneously press and release the **SEL** and **UP** keys. At this time the actuator will perform one cycle to measure its cycle time displaying **PoC** as the actuator travels to the full CW position and **PoCC** for the CCW position.

K. The calibration is now complete. Press and hold the **SEL** key for three seconds and the positioner will revert back to the normal run mode and will respond to input signal.

4.1.2 Calibration Procedure for Microchip U5 (AC board) or U3 (DC board) REV. V2.11 and Older

Note: *See Section 4.5.2 for more detailed information.*

A. If not already done, remove the cover and apply correct voltage per Section 3.0 to terminals 1 and 2.

B. If not already done, connect an input source to terminals 10 (-) and 11 (+), and 12 (if applicable) per Section 3.0.

C. The display should be flashing between **POS** and a number between 0 and 100.

D. Press and hold both the **SEL** and the **DN** keys down for three seconds. The display will read **None** then **Cal** for two seconds, then it will flash between Code and 0000.

E. Enter the security code as described in sections 4.3.1.B and 4.2.6.

F. Press and release the **SEL** key to accept code.

G. The display will now flash **CAPo** and **no**. Press and release the **SEL** key and the display will read **PoC** and a number between 0 and 5 volts.

H. Press and hold the **DN** key and the actuator will move clockwise. Release the **DN** key when the valve and actuator are in the closed position. The display should read between .200 and .400 volts. **If Not,** rotate the face gear located on the actuator shaft until you read between .200 and .400 volts. The gear is held in place by means of a friction lock and snap ring(s). No tools are needed nor is it necessary to loosen or remove the snap ring(s) to move the gear. Steady gentle finger pressure will move the gear to allow you to adjust the feedback potentiometer.

I. Once you have set the feedback pot you press and release the **SEL** key once. The display will flash **PoCC** and the voltage you just adjusted to.

J. Press and hold the **UP** key and the actuator will move counterclockwise. Release the **UP** key when the actuator and valve are in the full open position. **Be careful not to go past 90 degrees. The limit switch should be set at 92 degrees and should not be tripped when the valve is in the full open position.**

K. The display will now read a new feedback voltage, approximately 4 volts. Press and release the **SEL** key.

L. The display will now flash **CAPo** and **no**. Press and release the **UP** key. The display will now flash between **CASE** and **no**.

M. Press and release the **SEL** key and the display will read **SEC** and read a voltage between 0 and 5 volts. Set your input to 4 mA. (**The actuator will not move.**) The display will read approximately .8 volts. Press and release the **SEL** key.

N. The display will flash between **SECC** and your set voltage. Apply 20 mA to your signal input. The display should read approximately 4 volts. Press and release the **SEL** key.

O. The display will now flash between **CASE** and **no** again. Press and release the **UP** key once. The display will now flash between **CACY** and **no**.

P. Press and release the **SEL** key once and the display will flash **posn** and then **Close** and the actuator will cycle close then the display will read **open** and the actuator will cycle open. The unit is measuring its cycle time. When the cycling is done the display will flash **CASY** and **no** again.

Q. The calibration is now complete. Press and hold the **SEL** key for three seconds and the positioner will revert back to the normal run mode and will respond to input signal.

4.1.3 Initial Setup and Adjustments

When properly adjusted, the actuator will stop at the full open and full closed points as a result of having reached one of the limits of the input signal span, and the actuator's limit switches will be used only in a backup mode to stop the actuator, should an electronic component failure occur. The switch cams should be set 2° beyond the normal end of travel.

For the Series 75, 240 VAC Actuator with a 240 VAC Digital Positioner, the two limit switches do not limit actuator travel in the event of a component failure, they are used to switch off the optocouplers (U1, U2) outputs at the end of CW and CCW strokes instead of directly switching off the motor. This protects the triacs (Q3, Q4) by ensuring that they are switched off via their gate circuit and do not shut off on full power.

▲ **CAUTION:** Do not manually position the actuator shaft beyond where the limit switches would have stopped shaft travel.

Actuators with factory mounted positioners will be shipped with their limit switches properly adjusted to trip at 13 degrees AFTER the positioner electronics would normally have shut the actuator off upon reaching the upper or lower input signal limit.

4.2 General Description of the Digital Positioner

The digital positioner will be used for intelligent control and operation of an electric valve actuator.

4.2.1 Valve Position Setpoint Input

The valve position setpoint input signal is derived from either an analog input signal or from a digital RS485 serial input.

4.2.2 Valve Position Feedback

Valve position feedback to the digital positioner board is from the 1000 ohm potentiometer geared to the actuator shaft.

IMPORTANT: The feedback potentiometer is calibrated for only one 90° quadrant of valve operation If the output shaft is repositioned to another 90° quadrant or if the output shaft is rotated a multiple of 360° from its original position, the feedback potentiometer will no longer be in calibration and must be recalibrated. See sections C and D of part 1.1.

The Series 75 actuators offer a manual override feature. Whenever repositioning the valve using the manual override capability on these actuators, move the valve only within the 90° quadrant for which the feedback potentiometer has been calibrated.

4.2.3 Key Features of the Digital Positioner

- Easy push-button calibration of the positioner
- Programmable set-point direction
- Microprocessor-based positioner
- Programmable split range
- High resolution
- Programmable deadband as well as auto adjust
- Cycle count
- Programmable operating parameters
- High, low and deviation alarms
- Four programmable position response curves
- Loss of signal position and time delay
- Local and remote positioner operation
- Loss of power position and time delay
- Electronic travel limits
- ASCII text area in **EEPROM** (420+ bytes)

4.2.4 Operating Modes

The four modes of operation are:
PROGRAM (see section 4.3)
LOCAL (see section 4.4)
CALIBRATION (see section 4.1.1 or 4.1.2 and section 4.5)
RUN [This is also the default mode (see section 4.6).]

4.2.5 Data Readout

A four-digit LCD mounted on the positioner board provides local data readout. Each LCD segment is controllable, which allows display of some letters in addition to all digits. Parameters will be identified by names, not numbers. Provisions for numerical values with decimal points will be made.

4.2.6 Local Data Entry

Three push-button switches on the positioner board are used for local data entry:

SEL Selects a parameter for editing or changes modes of operation.

▲ Increases selected value or selects next parameter. Hereafter this switch will be called **UP.**

▼ Decreases selected value or selects previous parameter. Hereafter this switch will be called **DOWN.**

In the Program Mode of operation, data is edited by pressing the **SEL** switch while the parameter name is alternating with its value. The display will then be in the Fixed Mode where one or more digits will flash.

With a single digit flashing, pressing the **UP** switch will increase the digit value by one, wrapping from 9 to 0. Pressing the **DOWN** switch will cause the next digit to blink and allow it to be edited. Pressing the **SEL** switch will store the value in non-volatile memory, discontinue editing, and return the display to the Toggle Mode.

NOTE: Displayed data cannot be edited in the Run Mode. Pressing the SEL switch in that mode causes the display to stop alternating and only the parameter value is displayed.

4.2.7 Display Modes

The display has two modes of operation:
Toggle Mode and Fixed Mode.

In Toggle Mode (default), the display will alternate between a parameter name and its value. In Fixed Mode (press **SEL** switch), only the value appears on the display. If a parameter is being edited, one or more digits are blinking as the value of the parameter is being displayed.

4.3 Program Mode

The Program Mode is entered from the Run Mode by pressing the onboard **SEL** switch for three seconds.

When first entering the Program Mode, **Prog** will be displayed for two seconds and the security code will be checked. If the required security code is not zero, the display will begin alternating between **CodE** and **0000**. Enter the security code as described in section 4.3.1. If the required security code is zero ("0000") it will not need to be entered by the user, i.e., it will be bypassed.

After any required security code is correctly entered, a menu allows the user to select individual parameters they wish to program.

For all parameters below, the display will be in Toggle Mode alternating between showing the parameter name for one second then its value for one second. Pressing the **UP** or **DOWN** switches in the Toggle Mode will display the next or previous parameter (respectively). Pressing the **SEL** switch while in the Toggle Mode will enter the Fixed Mode of display where the value can be altered.

As explained in section 4.2.6, values are edited by pressing the **UP** or **DOWN** switches (**UP** to increment digit and **DOWN** to advance to the next digit) until the desired value is obtained. Pressing the **SEL** switch while editing will record the current value and return the display to the Toggle Mode.

If an invalid value is entered for a parameter, the display will flash an error message until acknowledged by the user. The user can acknowledge an error by pressing the **SEL** switch.

4.3.1 Security Code Screen

A. Security Code Screen for Microchip U5 (AC board) or U3 (DC board) Rev. V2.12 and newer.

The display will alternately display **CodE** and **0000.**

The correct security code number must be entered to gain access to Program and Calibration Modes. Once in the Program Mode, the security code can be reprogrammed.

Legal security code values are **0000** to **9999**. Note that when the security code of **0000** is used, the security option will be bypassed. With a code of **0000** the user is not required to enter the code to gain access to modes that use the security code.

If the security code is forgotten, the special number **4800** can be used to gain entry to modes that require a security code. However, this number will now be the new security code and if another code number is still desired, it will have to be reprogrammed.

B. Security Code Screen for microchip U5 (AC board) or U3 (DC board) REV. V2.11 and older.

The display will alternately display **CodE** and **0000**.

The correct security code number must be entered to gain access to the parameter entry screens.

Legal security code values are **0001** to **9999**. The security code is set to **1000** at the factory. For some units the special code of **4800** may have to be used.

When the correct code is entered, any programmable parameter can be modified including the security code. Once a security code is established, it cannot be displayed and must be remembered.

4.3.2 Unit Address Screen

The display will alternately display **Addr** and the communications address, which is factory set at 1 on new units.

⚠ **CAUTION:** Do not install two units with the same address on the same RS-485 bus.

To edit the value, use the **UP** or **DOWN** switches to select a value from 1 thru 255.

4.3.3 Output Current Range

The display will alternately display **Ocur** and either **4-20** or **0-20.**

Edit the value and use the **UP** or **DOWN** switches to select **0-20** or **4-20**.

4-20 selects a 4-20 mA output current range.

0-20 selects a 0-20 mA output current range.

A voltage output can be achieved by connecting a resistor across the current output.

The output current feedback is linear.

4.3.4 Analog Setpoint (Input) Range

The analog setpoint (input) signal range is fixed.

4.3.5 Setpoint Direction - Direct-Acting (Rise), Reverse-Acting (Fall)

The display will alternately display **Sdir** and either **riSE** or **FALL.**

Use the **UP** or **DOWN** switches to select **riSE** or **FALL**.

riSE selects direct-acting positioner control where the actuator rotates in the CCW direction (opens the valve) as the setpoint signal increases. The valve is closed (full CW) at the minimum setpoint signal value.

FALL selects reverse-acting positioner control where the actuator rotates in the CCW (open) direction as the setpoint signal decreases. The valve is full CCW (open) at the minimum setpoint signal value and full CW (closed) at the maximum setpoint signal value.

4.3.6 Setpoint Split Range START Selection

The display will alternately display **SPrS** and its value.

For a direct-acting positioner, **SPrS** specifies the START of the split range input signal for the full CW (closed) actuator position, and must be less than **SPrE**. For a reverse-acting positioner, **SPrS** specifies the START of the split range input signal for the full CCW (open) actuator position, and must be less than **SPrE**.

The setting can be anywhere from 0.0 to 99.9% of the input signal range in 0.1% increments.

Split ranging is useful when more than one valve is used in a control system. As an example, one actuator can be calibrated to open for an input signal between 4-12 mA and another to open for an input signal between 12 and 20 mA.

4.3.7 Setpoint Split Range END Selection

The display will alternately display **SPrE** and its value.

For a direct-acting positioner, **SPrE** specifies the **END** of the split range input signal for the full CCW (open) actuator position, and must be greater than **SPrS**. For a reverse-acting positioner, **SPrE** specifies the END of the split range input signal for the full CW (closed) actuator position, and must be less than **SPrS.**

The setting can be anywhere from 0.1 to 100.0% of the input signal range in 0.1% increments.

4.3.8 Setpoint Ramp - Time to Open

The display alternately displays **OPEn** and the selected time to open.

Times from 0 to 200 seconds can be selected as the time for the actuator to travel from the full closed (CW) to the full open (CCW) position.

If “0” (or a time less than the CCW travel time) is selected, the rate of response to a step change in the input signal will be as fast as the valve actuator can operate. The slowest time to open is 200 seconds.

The actuator will run to the setpoint at full speed and then brake if the time to open time setting is less than that measured in the calibration routine.

4.3.9 Setpoint Ramp - Time to Close

The display alternately displays **CLOS** and the selected time to close.

Times from 0 to 200 seconds can be selected as the time for the actuator to travel from the full open (CCW) to the full closed (CW) position.

If “0” (or a time less than the CW travel time) is selected, the rate of response to a step change in the input signal will be as fast as the valve actuator can operate. The slowest time to close that can be selected is 200 seconds.

The actuator will run to the setpoint at full speed and then brake if the time to close time setting is less than that measured in the calibration routine.

4.3.10 Setpoint Curve Function

The display will alternately display **SFc** and either **Lin** or **FrE1, FrE2, FrE3, or FrE4**.

This function tells the positioner the desired shaft positioning characteristic with respect to input signal.

Lin causes the shaft position to vary in a linear fashion as the input signal changes (i.e., if the signal is at 50 percent, the shaft position will be at 50 percent of the selected operating range).

The **FrE1-FrE4** curves allow 21 setpoint vertices to be set. In this way, a custom shaft positioning characteristic can be entered. There is a vertices set (data point) at 4 mA and then every 0.8 mA up to and including 20 mA. The vertices are displayed as **SL 0** to **SL 20** and will only be displayed when one of the **FrE1-FrE4** curves is chosen as the setting. The SL parameters can be found in the menu between the **PrSt** parameter and the **CodE** parameter. Use the **UP** and **DOWN** switches to select and change the vertices settings.

The factory installed default curve for the **FrE1** setting is the 1:25 equal percentage curve and for the **FrE2** setting it is the 1:50 equal percentage curve. The factory default settings for the **FrE3** and **FrE4** curves are linear.

NOTE: Definition of equal percentage: for equal increments of valve rotation, the Cv increases by a given percentage over what it was at the previous setpoint.

4.3.11 Positioner Deadband

The display will alternately display **dEbA** and the deadband value.

The deadband is used to prevent oscillations about a setpoint because of small fluctuations in either the setpoint signal or the position feedback signal. The deadband represents a plus and minus percentage of the full range of either the input signal or the feedback signal. Fixed deadband values can be selected from **0.1** to **10.0** (percent) of range. When the **DOWN** switch is pressed when the right most digit is selected, the display will show **Auto**. Pressing **SEL** while on that screen will select **Auto** deadband.

A deadband setting of **Auto** will allow constant automatic adjustment of the deadband in an adaptive fashion as required for best performance. This is the recommended setting. The lower **Auto** default value is .5 but this can be changed with the manual setting. Whatever value has been set for the manual deadband setting, becomes the lower limit for the **Auto** deadband mode.

4.3.12 Loss of Signal Position and Delay Time

The display will alternately display **SPOS** and the position the valve will move to if there is a loss of signal. A loss of signal condition occurs in either of two situations: 1) When the positioner is in analog position control and the input signal is less than 2 mA; or 2) When the positioner is controlled by the serial data link (digital control) and no signal has been received within the **SPt** time period.

When a loss of signal occurs in the analog control mode, the positioner will immediately go to the **SPOS** position. A **HOld** option specifies the positioner is to hold its current position. The positioner will hold the **SPOS** position until a valid analog input signal is present for the **SPt** delay period. If the **SPt** parameter is set to zero seconds, restoration of the signal will cause the positioner to work as normal with no time delay.

A loss of signal in the digital control mode means the positioner has not received a valid command within the **SPt** time period. In that case, the positioner will immediately go to the **SPOS** position. A **HOld** option specifies the positioner is to hold its current position. The positioner will hold the **SPOS** position until a valid digital position command is received.

The display will alternately display **SPt** and the delay time (in seconds). The time range is 0 to 9999 seconds. A time of 0 in analog control mode disables the loss of signal option. A time of 0 in digital control mode effectively disables the loss of signal option by allowing an infinite time between received commands. In digital control mode, non-zero **SPt** time values less than three seconds will use three seconds as the delay.

4.3.13 Power-On Position and Delay Time

When power is first applied to the positioner and the unit is in analog signal control mode, it will go to the position specified by the **PPOS** parameter for a time specified by the **PPt** parameter. During that time, any input signal is ignored.

If the unit is in **PC Cmd** control mode and there is a valid **PC** signal, the unit will respond to the signal immediately, otherwise, it will go to the power on position for the **PPt** time and then go to the **SPOS** position for the **SPt** time.

The display will alternately display **PPOS** and the position (in percent) the valve will move to when power is first applied or when power is restored. The actuator will hold that position for the time specified in the next step. The position range is 0.0 to 100.0% and **HOLd**. A **HOLd** option specifies the positioner is to hold the last position (i.e., the actuator will not move).

The display will alternately display **PPt** and the time (in seconds) that the **PPOS** position will be held. During that time, the positioner will ignore any input signal and will hold the **PPOS** position. The time range is 0 to 9999 seconds. A time of 0 disables this option such that the positioner will immediately respond to the input signal when power is first applied or restored.

4.3.14 Electronic Positioner Rotation Limits (Electronic Travel Stops)

The display will alternately display **yA** and its position value.

yA is the electronic lower rotation limit for shaft position at the start of the signal range. It can be set to a value from **0.0** to **100.0** in increments of 0.1 percent.

Press the **UP** switch to advance to the **yE** parameter screen.

The display will alternately display **yE** and its position value.

yE is the electronic upper rotation limit for shaft position at the end of the signal range. It can be set to a value from **0.0** to **100.0** in increments of 0.1 percent.

If **yA** were set at 20.0 then the actuator shaft would never rotate further CW than 20 percent open. If **yE** is set to 70 percent then the actuator shaft would never rotate further CCW than 70 percent open. These electronic limits restrict the range of actuator shaft rotation.

yA must always be less than or equal to **yE**. **yE** must always be greater than or equal to **yA**.

4.3.15 Tight Valve Shutoff

The display will alternately display **yCLS** and its setting.

yCLS is how we specify whether tight valve shutoff is desired when the input signal reaches the low end of its range. It is significant when the **yA** function is set to a value other than 0.0 percent. The two choices are **yES** and **no**. As an example, if the actuator/valve is controlling fuel flow to a burner, yA might be set to 30 percent as a low fire position, but between 4.1 and 4.2 mA the valve would fully close if **yCLS** is set to **yES** to allow maintenance to be performed on the burner.

4.3.16 Full Open Operation of Valve with Open Travel Limit Set

The display will alternately display **yOPn** and its setting.

yOPn is how we specify whether the valve will fully open when the input signal reaches the upper end of its range. It is significant when the **yE** function is set to a value other than 100.0 percent. The two choices are **yES** and **no**. As an example, if **yE** is set at 70 percent and **yOPn** is set to **yES**, then the actuator/valve would be 70 percent open at 19.8 mA. but would open fully when the signal is increased to 19.9 mA.

4.3.17 Brake on Time

The display will alternately display **br** and the brake time.

Actuator brake times from **0.10** to **0.99** seconds can be selected in 0.01 second increments. The actuator brake time begins after either the CW or CCW signal to the actuator drive motors turns off.

Any control signal change will be ignored during the brake **ON** period. The factory setting is .25 seconds, and it is not recommended that this be changed. Ideally, the brake **ON** time should be as short as possible to minimize motor heating while at the same time minimizing any overshoot caused by motor rotor inertia.

4.3.18 Restore Factory Default Values

The display will alternately display **PrSt** and **no**.

If **yES** is selected instead of **no** then the factory default values for all parameters will be selected. This flag is not a parameter but must be edited the same way to select **yES**. This is a momentary function and values can be altered after the default values have been selected. After the factory default values have been reloaded, the display will once again display **no**.

See Section 4.7 for a list of the default values.

4.3.19 Run Time Cycles for Maintenance

The display will alternately display **CyS** and the total number of seconds for the valve to travel from full CCW to full CW then back to full CCW. This cycle time is measured in the cycle time calibration routine which is performed after the feedback potentiometer calibration routine.

The microprocessor converts run time into cycles.

The next screen displays accumulated cycles **CyCn**. The number shown represents thousands of cycles. The display can show up to 9.999 million cycles. Obviously at higher cycles, less resolution is available on the display. Only whole cycles are displayed.

With **CyCn** displayed, the user can press the **SEL** switch and the total will begin flashing. At that point, holding down the **DOWN** switch for four seconds will clear the total.

Because the life of EEPROM is based on the number of write operations, only every 100 cycles will cause the total to be written to the nonvolatile memory.

4.3.20 Alarm Functions

The DEVIATION alarm becomes active if the valve does not move to the desired position within a certain time period. The time period is ten seconds plus either the ramp time for the direction in which the actuator is moving, or the open/close time from calibration, whichever is greater.

A means to set UPPER and LOWER rotation alarm limits on the actuator/valve shaft position is provided. An alarm shall occur if the positioner rotates beyond either the upper or lower set limit. The range of rotation limits is from 0 to 100%. An example of typical alarm limits would be 20% for LOWER and 80% for UPPER.

An opto-isolated open collector alarm output will be on whenever any alarm condition exists.

NOTE: For wiring of alarm outputs refer to diagram on the right.

Two alarm parameters will be programmable:

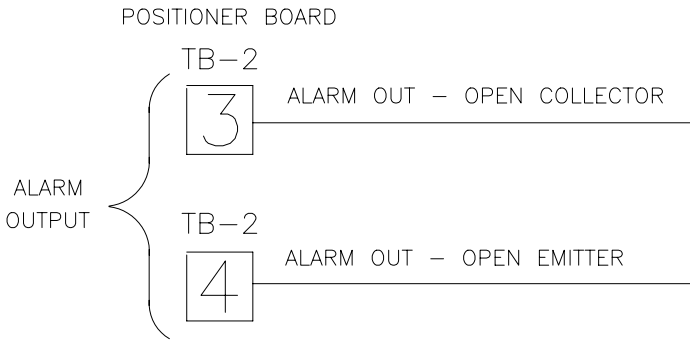
Ahi: 0.0 to 100.0% For the upper rotation alarm.

Alo: 0.0 to 100.0% For the lower rotation alarm.

Load Specifications for Alarm Output:
Maximum Collector/Emitter Voltage is 50 volts DC, maximum Collector/Emitter Current is 100 mA.

The **AdE** value is also shown with the programmable parameters to show the deviation alarm time. This value cannot be edited.

The **thEr** display indicate a thermal warning condition for the DC motor driver IC.



4.4 Local Mode

Local Mode is provided to allow manual control of the positioner. Local Mode is entered from the Run Mode by holding down the **SEL** and **UP** switches simultaneously for three seconds. From the Local Mode, pressing and holding the **SEL** switch for two seconds will return to the Run Mode.

In the Local Mode, the display will show **POS** alternating with the position. Pressing the **SEL** switch will stop the alternating.

Press either the **UP** switch to travel **CCW** or the **DOWN** switch to travel **CW**. When either switch has been pressed and let up, the brake will be applied for the programmed brake time.

4.5 Feedback Calibration Routine and Cycle Time Measurement

4.5.1 For Microchip U5 (AC board) or U3 (DC board) Rev. V2.12 and newer only

The Calibration Mode provides a way to properly calibrate signals used by the positioner. Periodic calibration is recommended to maintain accurate positioning. This mode is entered from the Run Mode by simultaneously holding down the **SEL** and **DOWN** switches for three seconds. From the Calibration Mode, pressing and holding the **SEL** switch for two seconds will return to the Run Mode.

When first entering the Calibration Mode, **CAL**, will be displayed for two seconds and the security code will be checked. If the required security code is not zero ("0000") the display will begin alternating between **CodE** and **0000**. Enter the security code as described earlier in section 4.3.1.A and per section 4.2.6. If the required security code is zero, it will not need to be entered by the user (i.e., it will be bypassed).

After any required security code is correctly entered, a menu allows the user to select individual calibration procedures they wish to perform.

The user is presented with the first of several calibration parameters. Calibration is performed in a manner similar to parameter editing in the Program Mode. A parameter is shown alternating with its current value. Pressing the **DOWN** switch will select the next calibration parameter. To perform the calibration procedure for a displayed parameter, simultaneously press the **SEL** and **UP** switches. When calibration of the selected item is completed, press the **SEL** switch to return to the menu. Also refer to section 4.1.1 for step by step procedures.

In the table below, calibration names are shown as they appear on the display with their definition. The table also shows the order of the procedures.

Parameter Name	Description
SEtL	Setpoint range lower limit signal value.
SEtU	Setpoint range upper limit signal value.
PoC	Shaft position feedback value in clockwise position.
PoCC	Shaft position feedback value in counter-clockwise position.
Cyt	Cycle time measurement.

A. Input (setpoint) Signal Calibration

1. Use the **DOWN** switch to go to **SEtL**.
2. The display will alternate between **SEtL** and the voltage resulting from the input current signal.
3. To edit, simultaneously Press and release **SEL** and **UP** switches then: Adjust the signal source to produce the lower input reading, e.g., a 4 mA signal. The voltage reading should be less than 1.0 volts. Press the **SEL** switch to lock in the full CW reading. Control returns to the Calibration Menu.
4. Use the **DOWN** switch to go to **SEtU**.

5. The display will alternate between **SEtU** and the voltage resulting from the current signal.

6. To edit, simultaneously press and release **SEL** and **UP** switches then: Adjust the signal source to produce the higher input reading, e.g., a 20 mA signal. Press the **SEL** switch to lock in the full CCW input reading. Control returns to the Calibration Menu.

B. Position Endpoint Calibration

1. Use the **DOWN** switch to go to **PoC**.

2. The display will alternate between **PoC** and the feedback voltage value.

3. To edit, simultaneously press and release **SEL** and **UP** switches, then use either the **UP** or **DOWN** switches to manually rotate the actuator to its full CW position. With the actuator in the full CW position, adjust the feedback potentiometer for a reading between .200 and .400 volts. Press the **SEL** switch to lock in the full CW feedback reading. Control returns to the Calibration Menu.

4. Use the **DOWN** switch to go to **PoCC**.

5. The display will alternate between **PoCC** and the feedback voltage value.

6. To edit, simultaneously press and release **SEL** and **UP** switches then: Use the **UP** switch to manually rotate the actuator to its full CCW position. If the shaft rotates too far, use the **DOWN** switch to bring the shaft back to the full CCW position. Press the **SEL** switch to lock in the full CCW feedback reading. Control returns to the Calibration menu.

C. Cycle Time Calibration

NOTE: THIS PROCEDURE SHOULD ONLY BE PERFORMED AFTER A VALID POSITION ENDPOINT CALIBRATION PROCEDURE HAS BEEN COMPLETED.

1. Use the **DOWN** switch to go to **Cyt**.

2. The display will alternate between **Cyt** and a cycle time reading.

3. Simultaneously press and release **SEL** and **UP** switches.

   If this is selected, the actuator will first go to the fully CCW position (if is not already there).

   The display will than show **PoC** and the actuator will travel to the full CW (closed) position and record the travel time. At that point, the CW time measurement will begin.

   The display will then show **PoCC** and the actuator will travel the full CCW (open) position and record the travel time. At that point, the cycle time calibration is complete and control returns to the calibration menu.

4.5.2 For Microchip U5 (AC board) or U3 (DC board) Rev. V2.11 and older only:

Calibration mode is entered from the Run Mode the same as the program and Local Modes.

The Calibration Mode has three procedures. Any one or all of the three procedures may be performed. The procedures are: Position Endpoint Calibration, Input Signal Calibration, and Cycle Time Measurement. They are each described separately below.

When first entering the Calibration Mode, the display will show **CAL** for one second then will begin alternating between **CodE** and **0000**. Enter the security code as described earlier in sections 4.3.1.B. and 4.2.6. After the code is correctly entered, press the **SEL** switch to accept code. A series of menu selections allows the user to pick which calibration procedures they wish to perform.

After entering the correct security code, the display will alternate between **CAPo** and **no**. This is the menu for the calibrate position procedure. Pressing the **SEL** switch will enter the position endpoint calibration procedure, or pressing the **UP** or **DOWN** switches will select another procedure.

The menu for entering the input signal calibration procedure is shown with a display that alternates between **CASE** and **no**. Pressing the **SEL** switch will enter the setpoint input calibration procedure, or pressing the **UP** or **DOWN** switches will select another procedure.

The menu for entering the cycle time calibration procedure is shown with a display that alternates between **CACy** and **no**. Pressing the **SEL** switch will start the cycle time calibration procedure, or pressing the **UP** or **DOWN** switches will select another procedure.

A. Position Endpoint Calibration

1. The display will alternate between PoC and the feedback voltage value.

2. Full CW position feedback reading:

   Use either the **UP** or **DOWN** switches to manually rotate the actuator to its full CW position.

   With the actuator in the full CW position, adjust the feedback potentiometer for a reading between .200 and .400 volts.

   Press the **SEL** switch to lock in the full CW feedback reading.

   After the full CW feedback value has been recorded, control sequences to the next screen.

3. The display will alternate between **PoCC** and the feedback voltage value.

4. Full CCW position feedback reading:

Use the **UP** switch to manually rotate the actuator to its full CCW position. If the shaft rotates too far, use the **DOWN** switch to bring the shaft back to the full CCW position.

Press the **SEL** switch to lock in the full CCW feedback reading.

After the full CCW feedback position has been recorded, control returns to the calibration menu.

B. Input (setpoint) Signal Calibration

1. The display will alternate between **SEC** and the voltage resulting from the input current signal.
2. Full CW input reading:

   Adjust the signal source to produce a 4 mA signal. The voltage reading should be less than 1.0 volts.

   Press the **SEL** switch to lock in the full CW input reading.

   After the full CW input value has been recorded, control sequences to the next screen.
3. The display will alternate between **SECC** and the voltage resulting from the current signal.
4. Full CCW input reading:

   Adjust the signal source to produce a 20 mA signal.

   Press the **SEL** switch to lock in the full CCW input reading.

   After the full CCW feedback position has been entered control returns to the calibration menu.

C. Cycle Time Calibration

If this is selected, the actuator will first go to the fully CCW position (if it is not already there) with the display showing **POSn.**

The display will then show **CLOS** and the actuator will travel to the full CW (closed) position and record the travel time. At that point, the CW time measurement will begin.

The display will then show **OPEn** and the actuator will travel to the full CCW (open) position and record the travel time. At that point, the cycle time calibration is complete and control returns to the calibration menu.

⚠ **CAUTION:** THIS PROCEDURE SHOULD ONLY BE PERFORMED AFTER A VALID POSITION ENDPOINT CALIBRATION PROCEDURE HAS BEEN COMPLETED.

Position Current Output

In the Run Mode, the full CW (closed) position will produce either 0 mA current output (for the 0-20 mA range) or 4 mA current output (for the 4-20 mA range). The full CCW (open) position always produces 20 mA output. This output does not require calibration.

4.6 Run Mode

The valve actuator run mode display depends upon how the digital positioner board has been programmed.

There are seven Run Mode display screens: **POS, SEt, CyCn, dbnd, CyC, CyCC**, and **ALr**. The **UP** and **DOWN** switches are used to sequence to the next or previous screen when the parameter name screen is displayed.

For all screens described below, the display will alternate between the name and its value. Pressing the **SEL** switch will lock the value on the screen.

4.6.1 Valve Position Screen

The display alternately displays **POS** and **xx.x,** the valve position in percent.

4.6.2 Input Setpoint

The display alternately displays **SEt** and **xx.x** in percent.

4.6.3 Cycle Count

The display alternately displays **CyCn** and the total run mode cycles.

4.6.4 Deadband Readout

The display alternates between **dbnd** and the current deadband value (even when **Auto dbnd** is selected).

4.6.5 CW and CCW Travel Time Readout

The display alternates between **CyC** and the calibrated time it took (in seconds) to go from the full CCW position to the full CW position.

Pressing the **SEL** key then shows the CCW time. The display alternates between **CyCC** and the calibrated time it took (in seconds) to go from the full CW position to the full CCW position. This is useful for comparing calibrated times with current times.

4.6.6 Alarm Status Readout

The display alternates between **Alr** and the current alarm condition. A high limit alarm condition will display **Hi**; a low alarm condition will display **Lo**; a deviation alarm condition will display **dE**. For the DC positioner, the DC motor driver IC can issue a thermal warning condition. If that occurs, the alarm status will display **thEr**. Since only one alarm condition can be shown on the display, the deviation alarm takes priority over the other alarms. When the deviation alarm is no longer active, the other alarms will be shown as described above.

4.6.7 Changing Operating Modes

In the Run Mode, holding down the **SEL** switch alone for three seconds will switch to the Program Mode. In the Run Mode, holding down the **SEL** and **DOWN** switches simultaneously for three seconds will enter the Calibration Mode. Holding down the SEL and UP switches simultaneously for three seconds will enter the Local Mode.

When the Program Mode is entered, **Prog** will briefly be displayed before the sequence described in Section 4.3 begins.

Pressing and holding the **SEL** switch in the Program Mode will exit and return to the Run Mode.

When the Local Mode is entered, **Loc** will briefly be displayed before the sequence described in Section 4.4 begins. Pressing and holding the **SEL** switch in the Local Mode will exit and return to the Run Mode.

When the Calibration Mode is entered, **CAL** will briefly be displayed before the sequence described in Section 4.5 begins.

Pressing and holding the **SEL** switch in the Calibration Mode will exit and return to the Run Mode.

When the Run Mode is reentered, **run** will be displayed briefly.

4.7 Default Values (Factory Installed)

When default parameters (described below) are loaded in Program Mode, they are set as follows: See section 4.8.2 for the procedure to set default values.

Parameter	Default Value
Output Current	4-20 mA
Setpoint Direction	RISE
Split Range Start	0%
Split Range End	100%
Ramp Open Time	0 (ASAP)
Ramp Close Time	0 (ASAP)
Setpoint Function	LINEAR
Deadband	.5%
Loss of Signal Position	0%
Loss of Signal Time	0 seconds
PowerOn Position	0%
PowerOn Delay Time	0 seconds
Lower Limit (Ya)	0%
Upper Limit (Ye)	100%
Tight Shutoff	NO
Full Open	NO
Brake Time	0.25 seconds
Upper Travel Alarm	100%
Lower Travel Alarm	0%
Curve Data	Linear from 0.0% to 100.0%

The 21-point **FrE1** curve is set to the following values when the factory default parameters are loaded (approximate 1:25 equal percentage positioner response curve):

Parameter	Value
SL 0	0.0%
SL 1	0.8%
SL 2	2.1%
SL 3	3.2%
SL 4	4.9%
SL 5	6.5%
SL 6	8.4%
SL 7	10.7%
SL 8	13.2%
SL 9	15.7%
SL 10	18.7%
SL 11	22.6%
SL 12	27.2%
SL 13	33.4%
SL 14	40.0%
SL 15	46.0%
SL 16	53.8%
SL 17	63.2%
SL 18	73.7%
SL 19	86.2%
SL 20	100.0%

The 21-point **FrE2** curve is set to the following values when the factory default parameters are loaded (approximate 1:50 equal percentage positioner response curve):

Parameter	Value
SL 0	0.0%
SL 1	0.3%
SL 2	0.8%
SL 3	1.5%
SL 4	2.6%
SL 5	3.7%
SL 6	5.0%
SL 7	6.6%
SL 8	8.4%
SL 9	10.9%
SL 10	13.5%
SL 11	16.5%
SL 12	20.3%
SL 13	25.0%
SL 14	31.1%
SL 15	36.8%
SL 16	45.4%
SL 17	54.4%
SL 18	67.5%
SL 19	85.0%
SL 20	100.0%

The 21-point **FrE3** and **FrE4** curves are set to the following values when the factory default parameters are loaded (linear curve):

NOTE: When installed on standard round port valves, these curves will produce equal percentage flow characteristics.

Parameter	Value
SL 0	0%
SL 1	5%
SL 2	10%
SL 3	15%
SL 4	20%
SL 5	25%
SL 6	30%
SL 7	35%
SL 8	40%
SL 9	45%
SL 10	50%
SL 11	55%
SL 12	60%
SL 13	65%
SL 14	70%
SL 15	75%
SL 16	80%
SL 17	85%
SL 18	90%
SL 19	95%
SL 20	100%

4.8 Calibrating And Programming The Digital Positioner

4.8.1 Programming Switches

There are three switches on the circuit board which are labeled **SEL** for select, **DN** for down, and **UP** for up. These are the switches which are used to calibrate and program the Digital Positioner Board locally.

4.8.2 Programming the Positioner Board

In order to program the positioner board, it is necessary to enter the programming mode. It is also necessary to enter the correct security code when asked to do so before any parameters can be changed. To program one of the parameters, follow this procedure:

1. Press the **SEL** switch for about three seconds until the display shows **Pro9** for two seconds and then begins flashing between **CodE** and **0000**.
2. At this time enter the correct securtiy code as described in section 4.3.1. When the correct code is entered, the display will begin flashing between **Addr** and some number from 1 to 255. This number is the address to which the unit has been set. The positioner is now in the programming mode.
3. At this point, the **UP** and the **DN** switches can be used to advance through the menu until the desired parameter is reached. At this time, the display will be flashing between the parameter name and its current setting. Momentarily pressing the **SEL** switch will lock in that parameter's current setting and allow the user to change it. If the display is alphabetic such as **riSE** or **FALL** for setpoint direction, momentarily pressing the **UP** switch will cycle through the setting options for that parameter. When the desired setting option is reached, momentarily pressing the **SEL** switch will set the parameter to that option and store it in non-volatile memory. If the display is numeric, momentarily pressing the **SEL** switch will lock in the value with the left most digit flashing. Pressing the **UP** switch will increment this digit. Pressing the **DN** switch will advance the flashing digit to the next digit to the right. Therefore, the **UP** switch is used to set the flashing digit to the desired value while the **DN** switch is used to select the flashing digit. Once the overall value is entered, momentarily press the **SEL** switch to store the value in non-volatile memory.
4. To restore all the parameters to the factory default settings as listed in section 4.7, advance to the **PrSt** parameter, momentarily press the **SEL** switch, and then momentarily press the **UP** switch. The display will show **yES** for several seconds and then again begin flashing between **PrSt** and **no**. The factory defaults are now installed.

4.8.3 Programming the FrE1, FrE2, FrE3, and FrE4 Curves

There are a total of five curves programmed into the positioner. These consist of one **Lin** (linear—not programmable) curve and four **FrE** (programmable) curves. The linear curve is not programmable and is labeled **Lin**. The other four curves are labeled **FrE1, FrE2, Fre3**, and **FrE4. FrE1** and **FrE2** are set to 1:25 and 1:50 equal percentage curves respectively as factory defaults. **FrE3** and **FrE4** are both set to a linear curve as factory defaults. **FrE1** through **FrE4** are each programmable. To program a curve, it is first necessary to enter the program mode and then select the **FrE** curve the user wishes to edit. When a **FrE** curve is selected in the main menu the **SL0 SL20** parameters become available following the **PrSt** parameter.

4.9 RS-485 Communications

The Digital Positioner Board may be connected to a computer or PLC via an RS-485 two-wire serial bus. Unless the computer has an RS-485 port built in, it will be necessary to use an RS-232 to RS-485 Converter on one of the computer's serial ports. If there will be more than one positioner on the serial bus, all positioner boards except for the last one on the bus must have the 120 ohm terminator resistor removed (see figure 2 for resistor location). The terminator resistor is in socket pins. The positioners should be connected to the RS-485 bus in a daisy chain fashion.

⚠ **CAUTION:** Do not connect two units with the same address to the same RS-485 bus.

4.9.1 Packet Communications Software

See the Worcester/McCANNA Packet Communications specification for the communications protocol information.

It is on the software floppy diskette in the form of a text file in the commspec directory and is called commspec.txt.

4.9.2 RS-485 Connection

The RS-485 Converter must be connected to the positioner at the TB2 terminal block through the actuator terminal strip (see Figure 8).

4.9.3 Communications Software

A floppy disc is provided with the software to be installed on the computer which will allow communication with the positioner. There are four programs on the floppy—ICP1.EXE, ICP2.EXE, ICP3.EXE, and ICP4.EXE as well as several support files. These programs work with COM1, COM2, COM3, and COM4 respectively. The programs may be run from the floppy (Flowserve strongly recommends that one or two backups be made of the software diskette before using it. Write protect the disks), or the software may be copied to the computers hard drive (create an ICP directory and then copy all the files to that directory).

4.9.4 Serial Port Setup

The serial port to be used must be set up as follows:

Baud Rate	1200 bps to 38.4 kbps
Data Bits	8
Stop Bits	1
Parity	None

The correct communications program to run is based on the COM port to be used (i.e., ICP1.EXE for COM1).

4.9.5 Monitor Display

Once the program has been started, the following screen will appear (see Figure 9).

The program will start up looking for address 1. If that unit exists, communications are established. Otherwise, to establish communications with the positioner, tap the space bar. The cursor to the right of the arrow next to the address parameter will begin flashing. Type in the positioner address and then hit the enter key (factory default is 1). The words **Reading data**... will appear to the right of the arrow. In about two seconds the screen will fill with the positioner data. The arrow just to the left of the Status area indicates whether the positioner is under control of the analog signal or under the control of the computer (PC). The **F4** key toggles between computer and analog control of the positioner.

The **PC Cmd** value in the Status area is the position output of the computer. This value can be changed with the left and right cursor keys but will only control position when the **F4** key toggles to **PC Cmd**. Position can also be changed by hitting the **F12** key, entering the desired position on the numeric keypad and then hitting the enter key.

Input is the value of the analog signal being received by the positioner board and controls position only when the **F4** key toggles to **Input.**

Output is the value of the 4-20 mA output signal for shaft position feedback (when this option is installed). Shaft Pos is the actual readout of the actuator shaft position in percent of shaft travel.

DB Run is the current setting for positioner deadband. When shaft motion stops, shaft position should always be within the deadband of the position command signal.

The **Alarms** are **Over**, **Under, Dev (Deviate)** and **Therm (Thermal)**. The area immediately under one of these alarms will light up if that alarm condition exists. The alarms are defined as follows:

Over - Shaft position is greater than the value set in the **Over-travel Alarm**.

Under - Shaft position is less than the value set in the **Under-travel Alarm**.

Dev - Shaft has not reached position called for by signal within the time specified by **Deviation Alarm**.

Therm - High temperature alarm for DC motor driver IC.

The **Calibration Data** is a listing of the stroke times measured during calibration.

The listings under **Ver x.xx** are the keys required to control the screen and the positioner.

F2 - Load a file of all parameters including curve data from the hard drive and download it to the positioner (about 40 seconds).

F3 - Save the data in the positioner to a file on the hard drive (about 20 seconds).

F4 - Toggle control of the positioner between the analog signal and the computer.

F9 - Enter the positioner response curve edit screen.

F10 - Enter the positioner ASCII EEPROM edit screen. (Customer information for this unit)

F12 - Enter desired position on numeric keypad then press enter.

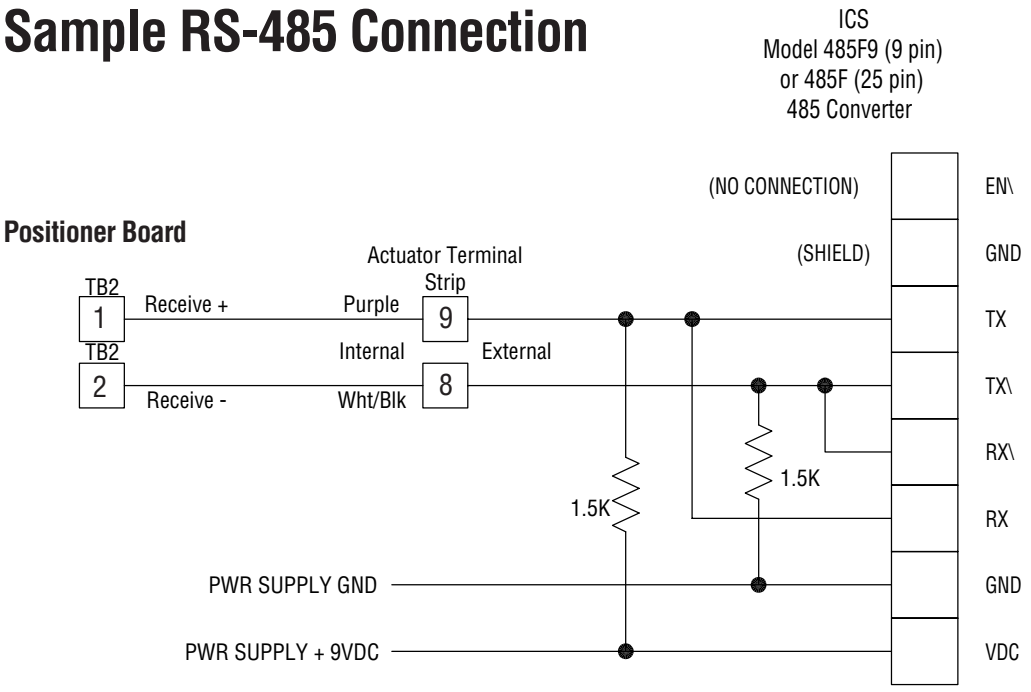
→ - Increment the **PC Cmd** position output signal.

← - Decrement the **PC Cmd** position output signal.

Alt-x - Exit the ICP program and return to DOS or Windows.

Figure 8

Sample RS-485 Connection



NOTE: If you are not using the RS-485 converter that is shown above, then refer to the documentation that came with your converter for proper connections.

Figure 9

The following screen appears when the ICP program is first started:

Security Code:	Comm Link:
Unit Address:	**Status**
Output Current Rng (mA):	Input:
Setpoint Direction	PC Cmd:
Split Range Start (%):	Output:
Split Range End (%):	Shaft Pos:
Ramp Open Time (sec):	DB Run:
Ramp Close Time (sec):	**Alarms**
Setpoint Function:	Over Under Dev Therm
Dead Band:	**Calibration Data**
Loss of Sig Position:	Open Time:
Loss fo Sig Time:	Close Time:
Power-on Position:	Cycle Time:
Power-on Time:	**Ver. x.xx**
Lower Limit (%):	F2 - Load File
Upper Limit (%):	F3 - Save File
Tight Shutoff OK?:	F4 - Toggle Control
Full Open OK?:	F9 - Free Curve Edit
Brake ON Time (sec):	F10 - Text Area Edit
Run Cycles:	F12 - Change Position
Deviation Alarm (sec):	↔ - Dec/Inc Position
Over-travel Alarm (%):	Alt-x - Exit Program
Under-travel Alarm (%):	

The following screen appears after the Positioner Default Data is Loaded: (Some values may vary)

Security Code:	XXXX	Comm Link: CONNECTED
Unit Address:	1	**Status**
Output Current Rng (mA):	4-20	Input: 45.0%
Setpoint Direction:	RISE	PC Cmd: 50.0%
Split Range Start (%):	0	Output: 12.0 mA
Split Range End (%):	100	Shaft Pos: 50.1%
Ramp Open Time (sec):	0	DB Run: 0.5%
Ramp Close Time (sec):	0	**Alarms**
Setpoint Function:	LINEAR	Over Under Dev Therm
Dead Band:	0.5	**Calibration Data**
Loss of Sig Position:	0	Open Time: 25s
Loss fo Sig Time:	0	Close Time: 25s
Power-on Position:	0	Cycle Time: 50s
Power-on Time:	0	**Ver. x.xx**
Lower Limit (%):	0	F2 - Load File
Upper Limit (%):	100	F3 - Save File
Tight Shutoff OK?:	NO	F4 - Toggle Control
Full Open OK?:	NO	F9 - Free Curve Edit
Brake ON Time (sec):	0.25	F10 - Text Area Edit
Run Cycles:	0	F12 - Change Position
Deviation Alarm (sec):	35	↔ - Dec/Inc Position
Over-travel Alarm (%):	100	Alt-x - Exit Program
Under-travel Alarm (%):	0	

5.0 TECHNICAL DATA

5.1 Allowable Supply Voltage Range

All Voltages ±10%

Power Consumption (Circuit Board Only): 2.5 Watts

5.2 Input Circuit Specifications

Maximum Tolerated Noise Level at Maximum Positioner Resolution/Sensitivity Approx. 3.5 mV (16 microamps)

Resistance Input

DFP-1K	Nom. 1000 ohms
DFP-13	Nom. 135 ohms

Current Input

DFP-1	1 to 5 mA
DFP-4	4 to 20 mA
DFP-10	10 to 50 mA

Voltage Input

DFP-5V	0 to 5 VDC
DFP-XV	0 to 10 VDC

5.3 Output Circuits Specifications

All Models

Maximum Surge Current	100 A for 1 Cycle
Maximum Normal Starting or In-Rush Current	10 A for 1 Second
Maximum Stall Current	8 A for 1 Minute
Maximum Running Current - Resistive Load 90% Duty Cycle	5 A
Maximum Running Current - Inductive Load 90% Duty Cycle	3 A
Maximum Peak Voltage at Load Circuit (All 120 VAC and 240 VAC models)	800 VAC
Maximum Driver Circuit Current (All 12 VDC and 24 VDC Models)	3 A Continuous

4-20 mA output will drive 20 mA into a 600 ohm maximum load.

Alarm Output - 100 mA maximum at 50 volts DC maximum.

5.4 Input Circuit Load Resistances

1 to 5 milliamp models	Approx. 1000 ohms
4 to 20 milliamp models	Approx. 220 ohms
10 to 50 milliamp models	Approx. 100 ohms
0 to 5 VDC Models	Approx. 800 ohms
0 to 10 VDC Models	Approx. 1100 ohms

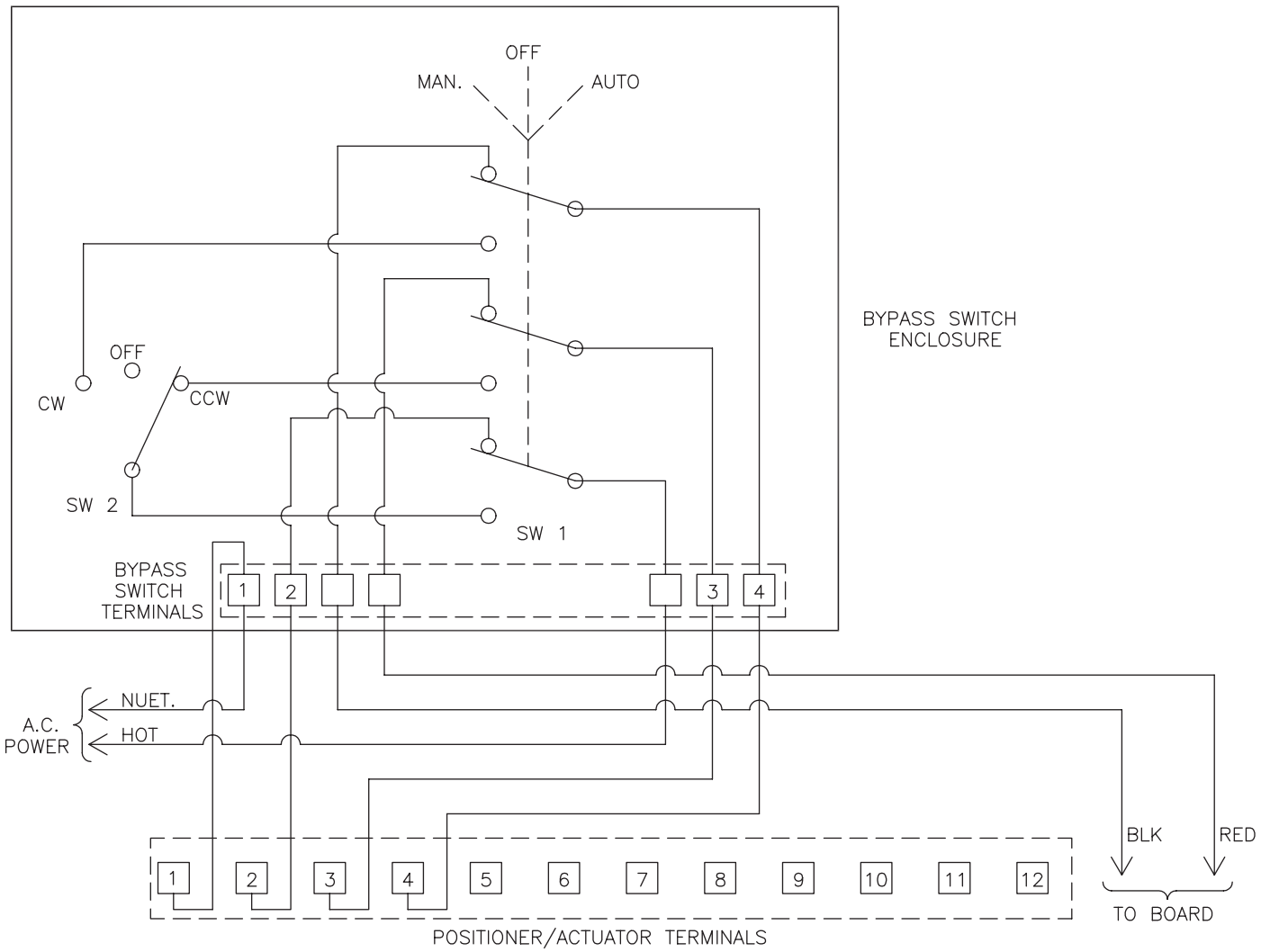
6.0 APPLICATION NOTES

6.1 Bypass Switch for Manual Control (For 120 VAC Only)

This application is offered as a nonstandard option through Flowserve's Custom Products Department or may be altered by end user. Figure 10 shows a schematic diagram of two switches for controlling the following functions:

- One triple-pole, double-throw (TPDT) switch with center-off, switching from automatic to manual operation.
- One single-pole, double-throw (SPDT) switch with center-off position for manually controlling clockwise (CW), counter-clockwise (CCW) directions of actuator.

Figure 10



7.0 TROUBLESHOOTING

7.1 General

The following sections and charts are a troubleshooting guide for servicing the Positioner, should a malfunction occur. If the problem cannot be solved, the unit should be returned to the factory for service.

The first thing to be checked, before proceeding to the troubleshooting guide, is to determine if the malfunction is in the Positioner, or in the actuator. To do this for AC boards, remove the red and black Positioner leads from terminals 3 and 4 of the actuator, and the AC line connections from terminals 1 and 2. Tape these leads. Using a test cable, apply power to actuator terminals 1 and 3. The actuator should rotate CCW until stopped by the CCW limit switch. Then apply power to terminals 1 and 4 to check CW actuation and the CW limit switch.

For Digital Positioner-240 VAC Positioner only, switches do not directly limit travel. Exercise caution not to override limit switches. Operate the unit to its limits in each direction, to assure that the basic actuator is functional.

If the AC actuator does not operate, check wiring from the terminal strip, through the limit switches to the motor and capacitor. For 240 VAC actuator with Digital Positioner, check wiring from the terminal strip to the capacitor and to the motor. Check switch continuity. Check for an open motor winding, and check for a shorted capacitor. If the problem in the actuator still cannot be determined, return the unit for service. If the actuator functions properly, then proceed to the troubleshooting guide.

For DC boards, remove red and black leads coming from motor(s) at terminals 3 and 4. Connect these leads to power supply to check motor(s) operation. If motor(s) run properly, then proceed to the troubleshooting guide or return unit for service.

To facilitate troubleshooting a Positioner, it would be advantageous on resistive input units to connect a potentiometer directly to the signal input terminals in place of the standard process input. Use a 150 ohm or 1000 ohm potentiometer depending on which model is used. Figure 11 shows a schematic of a simple test unit that can be connected to the input terminals to stimulate the process signal for a milliamp rating.

7.1.1 Cam Adjustment

The actuator cams should actuate the limit switches 1° to 3° after the actuator stops at either the fully open or fully closed position.

If the actuator is closed at 0 degrees, the limit switch must actuate by the time the actuator is at the minus 1 to 3 degree position. Similarly, at the open or 90 degree position, the limit switch must actuate by the time the actuator is at the 91 to 93 degree position.

NOTE: See CAUTION in section 4.1.3.

7.1.2 Check Fuse F1

Check fuse F1 to see if it is blown. If it is, replace it with Littlefuse PICO II very fast acting fuse rated at 62 mA. (Newark part number 94F2146).

For DC boards, also check fuse F2 to see if it is blown. If it is, replace it with a 1 1/4", 250 volt, 3 amp fuse, available through any electrical supplier.

IMPORTANT: To check fuse F1, remove it from circuit and test with ohmmeter. Resistance should be about 6 ohms.

NOTE: If fuse F1 is blown, excessive voltage (possibly 120 VAC) was applied to the signal input circuit. If so, correct this condition before changing fuse. See section A of part 1.1.

7.1.3 Check Basic Actuator for Proper Operation

For AC boards, check basic actuator for proper operation using the correct AC Voltage.

A. Remove red and black leads coming from AC circuit board at terminals 3 and 4 (if already installed). Tape stripped ends of these wires.

B. For AC boards, alternately energize, with the appropriate AC voltage, terminals 1 and 3 and 1 and 4. The actuator should move clockwise when energizing terminals 1 and 4, stopping only at the clockwise limit switch. The actuator should move counter-clockwise when energizing terminals 1 and 3, stopping only at the counter-clockwise limit switch.

   NOTE: For 240 VAC Digital Positioner only, limit switches do not directly control motor. Therefore, the actuator will not stop when the limit switches trip. Use care not to drive the actuator past its normal limits. Run the actuator to its limits in each direction, to assure proper operation of the actuator.

7.1.4 Check for Noise Problems

If the circuit board's light emitting diodes (LEDs) blink or seem to continuously glow, electrical noise is interfering with the Positioner's input process signal. (Always use shielded cable for the process signal coming to the Digital Positioner board. Ground the shield at only one end.) Adjust Digital Positioner as necessary. See Section 4.0.

7.1.5 Replace Circuit Board

The following information is provided if it becomes necessary to replace the circuit board.

A. Turn off the power supply and disconnect the circuit board wires from the terminal strip and limit switches. Disconnect the pot wires at TB1, and also any wires at TB2. Disconnect 4-20 mA output wires from connector P1 on circuit board, if used.

B. Remove circuit board mounting screws, nylon washers, circuit board and insulator board with rubber grommets from the brackets.

C. Install new circuit board onto the brackets using the procedure in section B above in reverse order. Tighten the mounting screws so that the grommets are about half compressed. Note that 23 size 75 actuators use a spacer in place of a grommet at the transformer support bracket.

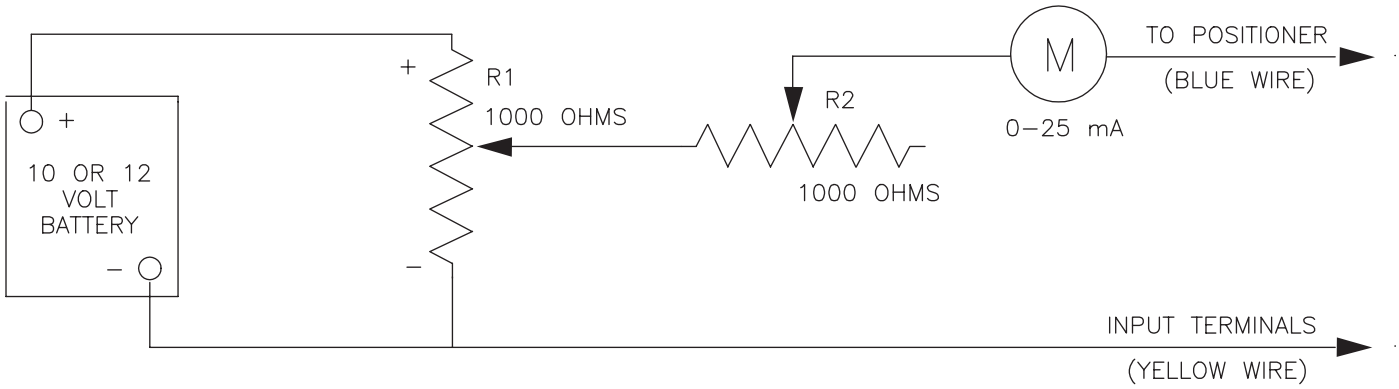
D. Make electrical connections per the appropriate wiring diagrams (see section 3.0). Feed the three feedback pot wires up through the hole in the board near TB-1 (see Figure 2 on either page 6 or 7).

E. Calibrate the new circuit board per section 4.0.

7.2 Symptom Table

	SYMPTOM	GUIDELINES TO FOLLOW
7.2.1	Actuator will not operate in either direction [no sound from motor(s)].	7.3.1, 7.3.2, 7.3.3, 7.3.4, 7.3.5, 7.3.6, 7.3.7, 7.3.10
7.2.2	Actuator will not operate in either direction [humming or buzzing sound from motor(s)].	7.3.2, 7.3.3, 7.3.4, 7.3.5, 7.3.6, 7.3.9, 7.3.10, 7.3.11, 7.3.12
7.2.3	Actuator slowly moves in one direction on its own.	7.3.4
7.2.4	Actuator runs normally for 7-8° while coming off limit switch, then slows down or stops [motor(s) hum or buzz].	7.3.4, 7.3.15
7.2.5	Actuator oscillates intermittently or upon reaching a new position.	7.3.2, 7.3.8, 7.3.13
7.2.6	Actuator runs slowly in one or both directions, but otherwise operates normally.	7.3.2, 7.3.4, 7.3.9, 7.3.10, 7.3.11, 7.3.12
7.2.7	Actuator works intermittently.	7.3.2, 7.3.10, 7.3.12
7.2.8	Actuator runs normally in one direction but will not operate in the other direction [no hum or buzz from motor(s)].	7.3.2, 7.3.4, 7.3.7
7.2.9	Actuator will not move valve after a stop when signaled to travel in same direction as previous command.	7.3.14

Figure 11



Test Unit for Milliamp Input Positioner—Set R1 all the way toward the plus end. Adjust R2 for a 20 mA reading. Varying R1 will now provide input signals between 4 and 20 milliamps.

7.3 Troubleshooting Guidelines

Use the following troubleshooting guidelines to isolate problems/bad components.

Prior to beginning any procedure, read all of Check, Action, and Note and Caution sections.

	CHECK	ACTION	NOTES AND CAUTIONS
7.3.1	Check for proper AC/DC power to actuator and circuit board. See Figures 4, 5, 6 or 7.	Correct as necessary.	
7.3.2	With power off, check for broken wires and/or loose connections.	Repair broken wires and tighten loose connections.	
7.3.3	With power off, check to see if fuse F1 is blown. (For DC boards, see section 7.1.2 also.)	Remove F1 from socket pins and check for continuity through fuse with an ohmmeter. If F1 is bad, replace it with a new fuse.	Before restoring power, try to determine what caused F1 to blow and correct problem. See Section 3.2 note and section A of Section 1.1, and also section 7.1.2.
7.3.4	Check operation of basic actuator per Section 7.1.	See Section 7.1.	This check will isolate the problem to either the actuator or the circuit board.
7.3.5	Check for proper range of input signal.	Use ammeter, voltmeter or ohmmeter to verify input signal range.	See models listed at beginning of IOM for ranges. 4-20 mA is most common.
7.3.6	With power off, check calibration of feedback potentiometer per section D of Section 1.1.	A quick check to see if this is the problem is to declutch the actuator shaft and reposition the shaft to about 45° (if valve torque permits). If the actuator now runs normally in each direction (after clutch reengages), recalibrate the feedback potentiometer.	When trying to move the valve manually with the clutch disengaged, be certain that the wrench fits properly on the flats of the actuator shaft. Improper fit can cause shaft damage with consequent damage to cover bearing surface. Stay within the preset bearing surface. Stay within the preset quadrant of operation. See section C of Section 1.1.
7.3.7	Check to see that varying input signal from 4-20 mA causes the light emitting diodes (LEDs) to turn on and off individually.	If LEDs do not turn on and off, replace board.	The turning on and off of the LEDs is indicative that the input side of the circuit board is OK.
7.3.8	Check the operation of the Positioner with a portable, battery operated signal source.	If intermittent or jittery operation stops, it is indicative of a noisy online signal input. To avoid damaging the actuator, it is necessary to “clean up” the signal. Also, follow the shielding guidelines of sections 1.2 and 1.2.3.	Increasing the deadband may help to alleviate the problem.
7.3.9	Check the motor run capacitor for a short, excessively high leakage and low capacitance. Use a capacitance meter to check. (AC boards only.)	Replace as necessary.	Disconnect all leads from capacitor terminals (power off) prior to testing. Do not exceed rated voltage of capacitor. Make certain that capacitor is discharged before reconnecting.

	CHECK	ACTION	NOTES AND CAUTIONS
7.3.10	Check temperature of motor(s). One AC motor has a thermal cutout switch built-in that opens at about 210°F (winding temperature). If the thermal cutout has opened, both motors are de-energized until the thermal switch resets (20-2375 sizes).	Allow the motor(s) to cool so that the thermal switch can reset. Normally the thermal switch will not open unless the motor's rated duty cycle is exceeded and/or the ambient temperature is very high. Correct the problem.	Duty cycle is specified at an ambient temperature of 70°F, 60 Hz.
7.3.11	Check the operating torque of the valve. If necessary, remove the actuator from the valve. Measure valve torque with an accurate torque wrench. Check torque under actual operating conditions if possible.	If operating torque of valve exceeds the specified torque for the seats used and the DP across the valve, determine cause and correct. If torque falls within normal range, it is possible that the actuator is undersized.	If the actuator is removed from a three-piece valve that requires the body bolts to also be removed, the valve body bolts must be retorqued to specifications before checking valve torque. See Valve IOM.
7.3.12	Check ambient temperature.	Actuator duty cycles are specified at an ambient temperature of 70°F.	Higher ambient derates duty cycle.
7.3.13	Check to see that mechanical brake is operating correctly.	Replace defective mechanical brake. If one was never installed, order a kit and install it in actuator.	All 2" CPT valves with Positioner boards in actuator must have mechanical brake installed to prevent oscillation.
7.3.14	Check to see if actuator can move a high torque valve from a stop under load when moving in the same direction as last command (mechanical brake does not allow motor(s) to unwind).	If motor(s) cannot start, go to next larger size actuator.	
7.3.15	Check to see which direction of travel causes problem. If actuator is coming off open limit switch (traveling CW) when it slows down or stops, then either Q1 or U1 is bad. If actuator is coming off closed limit switch (traveling CCW), then either Q2 or U2 is bad. (AC boards only.)	Replace circuit board.	

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Anexo F

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Controlador N1200

CONTROLADOR UNIVERSAL - MANUAL DE INSTRUCCIONES – V1.1x

ALERTAS DE SEGURIDAD

Los siguientes símbolos son usados en el equipo y a lo largo de este manual para llamar la atención del usuario para informaciones importantes relacionadas con la seguridad y el uso del equipo.

	
CUIDADO: Lea completamente el manual antes de instalar y operar el equipo.	**CUIDADO O PELIGRO:** Riesgo de choque eléctrico

Todas las recomendaciones de seguridad que aparecen en este manual deben ser observadas para garantizar la seguridad personal y prevenir daños al instrumento o sistema. Si el instrumento es utilizado de una manera distinta a la especificada en este manual, las protecciones de seguridad del equipo pueden no ser eficaces.

PRESENTACIÓN

Controlador de proceso sumamente versátil. Acepta en un único modelo la mayoría de los sensores y señales utilizados en la industria y proporciona los principales tipos de salida necesarios a la actuación en los diversos procesos.

Toda la configuración del controlador es realizada a través del teclado, sin cualquier alteración en el circuito. Siendo así, la selección del tipo de entrada y de salida, de la forma de actuación de las alarmas, además de otras funciones, son todas accesadas y programadas vía teclado frontal.

Es importante que el usuario lea atentamente este manual antes de utilizar el controlador. Verifique que la versión de este manual coincida con la del instrumento (el número de la versión de software es mostrado cuando el controlador es energizado). Sus principales características son:

- Entrada universal multisensor, sin alteración de hardware;
- Protección para sensor abierto en cualquier condición;
- Salidas de control del tipo relé, 4-20 mA y pulso, todas disponibles;
- Sintonía automática de los parámetros PID;
- Función Automático / Manual con transferencia "bumpless";
- Tres salidas de alarma en la versión básica, con funciones de mínimo, máximo, diferencial (desvío), sensor abierto y evento;
- Temporización para todas las alarmas;
- Retransmisión de PV o SP en 0-20 mA o 4-20 mA;
- Entrada para *setpoint* remoto;
- Entrada digital con 5 funciones;
- *Soft-start* programable;
- Rampas y mesetas con 20 programas de 9 segmentos, interconectables en un total de 180 segmentos;
- Contraseña para protección del teclado;
- Función *LBD* (*Loop Break Detector*);
- Alimentación bi-volt.

CONFIGURACIÓN / RECURSOS

SELECCIÓN DE LA ENTRADA

El tipo de entrada a ser utilizado por el controlador es definido en la configuración del equipo. La **Tabla 1** presenta todas las opciones disponibles.

TIPO	CÓDIGO	RANGO DE MEDICIÓN
J	tc J	Rango: -110 a 950 ºC (-166 a 1742 ºF)
K	tc K	Rango: -150 a 1370 ºC (-238 a 2498 ºF)
T	tc t	Rango: -160 a 400 ºC (-256 a 752 ºF)
N	tc n	Rango: -270 a 1300 ºC (-454 a 2372 ºF)
R	tc r	Rango: -50 a 1760 ºC (-58 a 3200 ºF)
S	tc S	Rango: -50 a 1760 ºC (-58 a 3200 ºF)
B	tc b	Rango: 400 a 1800 ºC (752 a 3272 ºF)
E	tc E	Rango:-90 a 730 ºC (-130 a 1346 ºF)
Pt100	Pt	Rango: -200 a 850 ºC (-328 a 1562 ºF)
0-20 mA	L0.20	Señal Analógico Lineal Indicación programable de -1999 a 9999.
4-20 mA	L4.20	
0–50 mV	L0.50	
0-5 Vdc	L0.5	
0-10 Vdc	L0.10	
4-20 mA NO LINEAL	Ln J	Señal Analógico no-Lineal Rango de indicación de acuerdo con el sensor asociado.
	Ln K	
	Ln t	
	Ln n	
	Ln r	
	Ln S	
	Ln b	
	Ln E	
	LnPt	

Tabla 1 - Tipos de entradas

Notas: Todos los tipos de entrada disponibles ya vienen calibrados de fábrica.

SELECIÓN DE SALIDAS, ALARMAS Y ENTRADAS DIGITALES

El controlador posee canales de entrada y salida (I/O) que pueden asumir múltiples funciones: salida de control, entrada digital, salida digital, salida de alarme, retransmisión de PV y SP. Esos canales son identificados como **I/O 1**, **I/O 2**, **I/O 3**, **I/O 4** y **I/O 5**.

El controlador básico viene equipado con los siguientes recursos:

I/O 1- salida a Relé SPST-NA;
I/O 2- salida a Relé SPST-NA;
I/O 5- salida de corriente, salida digital, entrada digital;

Opcionalmente, podrá ser incrementado con otros recursos, conforme muestra el tópico *Identificación* en este manual:

- **3R** : I/O3 con salida a relé SPDT;
- **DIO** : I/O3 y I/O4 como canales de entrada y salida digital;
- **485** : Comunicación Serial;

La función a ser utilizada en cada canal de I/O es definida por el usuario de acuerdo con las opciones mostradas en la **Tabla 2**.

Función de I/O	Código	Tipo de I/O
Sin Función	oFF	Salida
Salida de Alarma 1	A1	Salida
Salida de Alarma 2	A2	Salida
Salida de Alarma 3	A3	Salida
Salida de Alarma 4	A4	Salida
Salida de la función LBD - *Loop break detection*	Lbd	Salida
Salida de Control (Relé o Pulso Digital)	ctrL	Salida
Alterna modo Automático/Man	MAn	Entrada Digital
Alterna modo Run/Stop	run	Entrada Digital
Selecciona SP Remoto	rSP	Entrada Digital
Congela programa	HPrG	Entrada Digital
Selecciona programa 1	Pr 1	Entrada Digital
Salida de Control Analógica 0 a 20mA	C.0.20	Salida Analógica
Salida de Control Analógica 4 a 20mA	C.4.20	Salida Analógica
Retransmisión de PV 0 a 20mA	P.0.20	Salida Analógica
Retransmisión de PV 4 a 20mA	P.4.20	Salida Analógica
Retransmisión de SP 0 a 20mA	S.0.20	Salida Analógica
Retransmisión de SP 4 a 20mA	S.4.20	Salida Analógica

Tabla 2 - Tipos de funciones para los canales I/O

En la configuración de los canales, solamente son mostradas en el display las opciones válidas para cada canal. Estas funciones son descritas a seguir:

- **oFF** - Sin función

El canal I/O programado con código off no será utilizado por el controlador. Aunque sin función, este canal podrá ser accionado a través de comandos vía comunicación serial (comando 5 MODBUS).

- **A1**, **A2**, **A3**, **A4** - Salidas de Alarme

Define que el canal I/O programado actúe como salidas de alarma. Disponible para todos los canales I/O.

- **Lbd** – Función *Loop break detector*.

Define al canal I/O como la salida de la función de Loop break detector. Disponible para todos los canales de I/O.

- **CtrL** - Salida de Control PWM

Define el canal I/O que será utilizado como salida de control con accionamiento por relé o pulso digital. Disponible para todos los canales I/O. La salida con pulso digital es obtenida en el I/O5 ó I/O3 y I/O4, cuando están disponibles. Verificar las especificaciones de cada canal.

- **MAn** - Entrada Digital con función Auto / Manual

Define el canal como Entrada Digital (ED) con la función de Alternar el modo de control entrada **Automático** y **Manual**. Disponible para I/O5 o I/O3 y I/O4, cuando están disponibles.

Cerrado = control Manual;
Abierto = control Automático

- **run** - Entrada Digital con función *RUN*

Define canal como Entrada Digital (ED) con la función de habilitar / Deshabilitar las salidas de control y alarma ("**run**": **YES** / **NO**). Disponible para I/O5 o I/O3 y I/O4, cuando están disponibles.

Cerrado = salidas habilitadas
Abierto = salida de control y alarmas desconectados;

- **rSP** - Entrada Digital con función SP Remoto

Define canal como Entrada Digital (ED) con la función de seleccionar SP remoto. Disponible para I/O5 o I/O3 y I/O4, cuando disponibles.

Cerrado = utiliza SP remoto
Abierto = utiliza SP principal

- **HPrG** - Entrada Digital con función *Hold Program*

Define canal como Entrada Digital (ED) con la función de comandar la ejecución del **programa en proceso**. Disponible para I/O5 o I/O3 y I/O4, cuando disponibles.

Cerrado = Habilita ejecución del programa
Abierto = interrumpe ejecución del programa

Nota: Incluso con la interrupción del programa en ejecución, el control sigue actuando en el punto (Setpoint) de interrupción. Cuando la ED es accionada, el programa retoma su ejecución normal a partir de este mismo punto.

- **Pr 1** - Entrada Digital con función Ejecutar programa 1

Define canal como Entrada Digital (ED) con la función de comandar la ejecución del **programa 1**. Disponible para I/O5 o I/O3 y I/O4, cuando están disponibles.

Función útil cuando es necesario alternar entre el *setpoint* principal y un segundo *setpoint* definido por el **programa 1**.

Cerrado = selecciona programa 1;
Abierto = selecciona *setpoint* principal

- **C.0.20** - Salida de Control Analógico en 0-20 mA

Define canal para actuar como salida de control analogico. Disponible apenas para I/O 5.

- **C.4.20** - Salida de Control Analógico en 4-20 mA

Define canal para actuar como salida de control analógico. Disponible apenas para I/O 5.

- **P.0.20** – Salida de Retransmissão de PV em 0-20 mA

Define canal para actuar como salida de Retransmisión de los valores de PV. Disponible apenas para I/O 5.

- **P.4.20** – Salida de Retransmisión de PV en 4-20 mA

Define canal para actuar como salida de Retransmisión de los valores de PV. Disponible apenas para I/O 5.

- **S.0.20** – Salida de Retransmisión de SP en 0-20 mA

Define canal para actuar como salida de Retransmisión de los valores de SP. Disponible apenas para I/O 5.

- **S.4.20** – Salida de Retransmisión de SP en 4-20 mA

Define canal para actuar como salida de Retransmisión de los valores de SP. Disponible sólo para I/O 5.

CONFIGURACIÓN DE ALARMAS

El controlador posee 4 alarmas independientes. Estas alarmas pueden ser configuradas para operar con ocho funciones distintas, presentadas en la **Tabla 3**.

- **oFF** – Alarmas desligadas.
- **IErr** – Alarmas de Sensor Abierto – (*Loop Break*)

La alarma de sensor abierto actúa siempre que el sensor de entrada esté roto o mal conectado.

- **rS** – Alarma de Evento de programa

Configura la alarma para actuar en segmento(s) específico(s) de los programas de rampas y mesetas a serán creados por el usuario.

- **rFAIL** – Alarma de Resistencia Quemada – (*Reat Break*)

Señaliza que la resistencia de calientamiento del proceso rompió. Esa función de alarma exige la presencia de un accesorio TC. Detalles de uso de la opción "resistencia quemada" están en documentación específica que acompaña el producto siempre que esa opción es solicitada.

- **Lo** – Alarma de Valor Mínimo Absoluto

Dispara cuando el valor de PV medido esté **abajo** del valor definido por el *Setpoint* de alarma.

- **HI** – Alarma de Valor Máximo Absoluto

Dispara cuando el valor de PV medido esté **arriba** del valor definido por el *Setpoint* de alarma.

- **dIF** – Alarma de Valor Diferencial

En esta función los parámetros "**SPA1**", "**SPA2**", "**SPA3**" y "**SPA4**" representan el Desvío de la PV en relación al SP principal.

Utilizando la Alarma 1 como ejemplo: para valores Positivos SPA1, la alarma Diferencial dispara cuando el valor de PV esté **fuera** del rango definido por:

(SP – SPA1) hasta (SP + SPA1)

Para un valor negativo en SPA1, la alarma Diferencial dispara cuando el valor de PV esté **dentro** del rango definido arriba.

- **d IFL** – Alarma de Valor Mínimo Diferencial

Dispara cuando el valor de PV esté **abajo** del punto definido por:

(SP – SPA1)

Utilizando la Alarma 1 como ejemplo.

- **d IFH** – Alarma de Valor Máximo Diferencial

Dispara cuando el valor de PV esté **arriba** del punto definido por:

(SP + SPA1)

Utilizando la Alarma 1 como ejemplo.

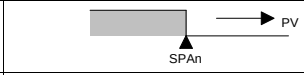
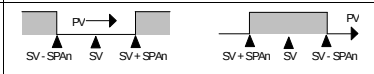
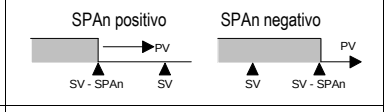
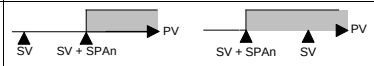
PANTALLA	TIPO	ACTUACIÓN
oFF	Inoperante	Salida no es utilizada como alarma.
IErr	Sensor abierto (**i**nput **Err**or)	Accionado cuando la señal de entrada de la PV es interrumpido, queda fuera de los límites de rango o Pt100 en corto.
rS	Evento (**r**amp and **S**oak)	Accionado en un segmento específico de programa.
rFAIL	Resist. quemada (**r**esistence **fail**)	Señaliza falla en la resistencia de calentamiento. Detecta la falta de presencia de corriente.
Lo	Valor mínimo (**Lo**w)	
HI	Valor máximo (**Hi**gh)	
d IF	Diferencial (**diF**erential)	 SPAn positivo SPAn negativo
d IFL	mínimo Diferencial (**diF**erential **L**ow)	
d IFH	máximo Diferencial (**diF**erential **H**igh)	 SPAn positivo SPAn negativo

Tabla 3 – Funciones de alarma

Donde SPAn refiere a los *Setpoints* de Alarma "**SPA1**", "**SPA2**", "**SPA3**" y "**SPA4**".

TEMPORIZACIÓN DE ALARMA

El controlador permite tres variaciones en el modo de accionamiento de las alarmas:

- Accionamiento por tiempo definido;
- Atraso en el accionamiento;
- Accionamiento intermitente;

Las figuras en la **Tabla 4** muestran el comportamiento de las salidas de alarma con estas variaciones de accionamientos definidas por los intervalos de tiempo **t1** y **t2** disponibles en los parámetros **A1t1**, **A1t2**, **A2t1**, **A2t2**, **A3t1**, **A3t2**, **A4t1** y **A4t2**.

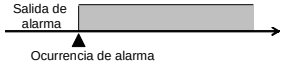
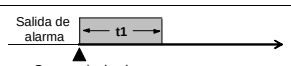
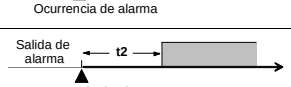
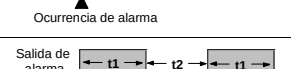
Operación	t 1	t 2	ATUACIÓN
Operación normal	0	0	
Accionamiento con tiempo definido	1 a 6500 s	0	
Acionamiento con atraso	0	1 a 6500 s	
Acionamiento intermitente	1 a 6500 s	1 a 6500 s	

Tabla 4 - Funciones de Temporización para las Alarmas

Los señalizadores asociados a las alarmas encienden siempre que ocurre la condición de alarma, independientemente del estado de la salida de alarma.

BLOQUEO INICIAL DE ALARMA

La opción de **bloqueo inicial** inhibe el accionamiento de la alarma cuando exista la condición de alarma en el momento en que el controlador es conectado. La alarma solamente es habilitada después que el proceso pasa por una condición de no alarma.

El bloqueo inicial es útil, por ejemplo, cuando una de las alarmas está configurado como alarma de valor mínimo, lo que puede causar el accionamiento de la alarme en el momento del arranque del proceso, comportamiento muchas veces indeseado.

El bloqueo inicial no es válido para la función Sensor Abierto.

EXTRACCIÓN DE LA RAÍZ CUADRADA

Con este recurso habilitado el controlador pasa a presentar en el visor el valor correspondiente a la raíz cuadrada de la señal de entrada aplicada.

Disponible apenas para las entradas del grupo de señales analógicas lineales: 0-20 mA, 4-20 mA, 0-50 mV, 0-5 V y 0-10 V.

RETRANSMISIÓN ANALÓGICA DEL PV Y SP

El controlador posee una salida analógica (disponible en I/O5) que puede realizar la retransmisión de los valores de PV o SP en señal de 0-20 mA o 4-20 mA. La retransmisión analógica es escalable, es decir, tiene los límites mínimo y máximo, que definen el rango de salida, definidos en los parámetros "**rtLL**" y "**rtHL**".

Para obtener una retransmisión en tensión el usuario debe instalar un resistor *shunt* (550 Ω máx.) en los terminales de la salida analógica. El valor de este resistor depende del rango de tensión deseada.

SOFT-START

Recurso que impide variaciones abruptas en la potencia entregada a la carga por la salida de control del controlador.

Un intervalo de tiempo define la tasa máxima de subida de la potencia entregada a la carga, donde 100 % de la potencia solamente será alcanzada al final de este intervalo.

El valor de potencia entregada a la carga continúa siendo determinado por el controlador. La función *Soft-start* simplemente limita la velocidad de subida de este valor de potencia, a lo largo del intervalo de tiempo definido por el usuario.

La función *Soft-start* es normalmente utilizada en procesos que requieran partida lenta, donde la aplicación instantánea de 100 % de la potencia disponible sobre la carga puede damnificar partes del proceso.

Para inhabilitar esta función, el respectivo parámetro debe ser configurado con 0 (cero).

SETPOINT REMOTO

El controlador puede tener su valor de SP definido a través de una señal analógica generado remotamente. Este recurso es habilitado a través de los canales de I/O3, I/O4 o I/O5 cuando son utilizados como entrada digital y configurados con la función **rSP** (Selecciona SP Remoto) o en la configuración del parámetro **Er SP**. Las señales aceptados son 0-20 mA, 4-20 mA, 0-5 V y 0-10 V.

Para los señales de 0-20 y 4-20 mA, un resistor *shunt* de **100 Ω** debe ser montado externamente junto a los terminales del controlador y conectado conforme **Figura 4c**.

MODO DE CONTROL

El controlador puede actuar en dos modos diferentes: Modo Automático o modo Manual. En modo automático el controlador define la cantidad de potencia que será aplicada al proceso, basado en los parámetros definidos (SP, PID, etc.). En el modo manual es el propio usuario que define esta cantidad de potencia. El parámetro "**CtrL**" define el modo de control que será adoptado.

MODO AUTOMÁTICO PID

Para el modo Automático existen dos estrategias de control distintas: control PID y control ON/OFF.

El control PID tiene su ación basada en un algoritmo de control que actúa en función del desvío de la PV con relación al SP, con base en los parámetros **Pb**, **Ir** y **dt** estabelecidos.

Mientras que el control ON/OFF (obtenido cuando Pb=0) actúa con 0% o 100% de potencia, cuando la PV se desvía del SP.

La determinación de los parámetros **Pb**, **Ir** y **dt** están descritas en el tópico DETERMINACIÓN DE LOS PARÁMETROS PID de este manual.

FUNCIÓN *LBD - LOOP BREAK DETECTION*

El parámetro **Lbdt** define un intervalo de tiempo máximo, en minutos, para que PV reaccione al comando de la salida de control. Si PV no reacciona mínimamente y adecuadamente en este intervalo, el controlador señaliza en su display la ocurrencia del evento LBD que indica problemas en el lazo (*loop*) de control.

El evento LBD puede también ser direccionado para un de los canales I/O del controlador. Para eso basta configurar el canal I/O deseado con la función **Ldb** que, en la ocurrencia de este evento, tiene la respectiva salida accionada.

Con valor 0 (cero) esta función queda deshabilitada.

Esta función permite al usuario detectar problemas en la instalación, como por ejemplo, actuador con defecto, falla en la alimentación eléctrica de la carga, etc.

FUNCIÓN *HBD* - HEATER *BREAK DETECTION*

Disponible en los modelos identificados como HBD. Función descripta en el Apéndice 1 de este manual.

FUNCIÓN SALIDA SEGURA EN LA FALLA DEL SENSOR

Función que coloca la salida de control en una condición segura (conocida) para el proceso cuando un error en la entrada del sensor es identificado.

Con uma falla identificada en el sensor (entrada), el controlador pasa para el modo MANUAL y MV asume el valor porcentual definido en el parámetro **IEou**. El controlador permanecerá en esta nueva condición, mismo que la falla en el sensor desaparezca.

Para habilitar esta función, es necesaria una alarma configurada con la función **IErr** y el parámetro **IEou** diferente de cero.

Con **IEou** 0 (cero) esta función es deshabilitada y la salida de control es desligada.

INSTALACIÓN / CONEXIONES

El controlador debe ser fijado en el panel, seguiendo la secuencia de pasos abajo:

- Haga un recorte de 45,5 x 45,5 mm en el panel;
- Retirar las presillas de fijación del controlador;
- Inserte el controlador en el recorte por la parte frontal del panel;
- Recoloque las presillas en el controlador presionando hasta obtener una fijación firme con el panel.

RECOMENDACIONES PARA LA INSTALACIÓN

- Conductores de señales de entrada, deben recorrer la planta del sistema separados de los conductores de salida y de alimentación, si es posible en electroductos aterrados..
- La alimentación de los instrumentos electrónicos debe venir de una red propia para instrumentación.
- Es recomendable el uso de FILTROS RC (eliminador de ruido) en bobinas de contactoras, solenoides, etc.
- En aplicaciones de control es esencial considerar lo que puede ocurrir cuando cualquier parte del sistema falla. Los dispositivos internos del controlador no garantizan protección total.

CONEXIONES ELÉCTRICAS

Los circuitos internos del controlador pueden ser retirados sin deshacer las conexiones en el panel trasero.

La disposición de los recursos en el panel trasero del controlador es mostrada en la **Figura 1**:

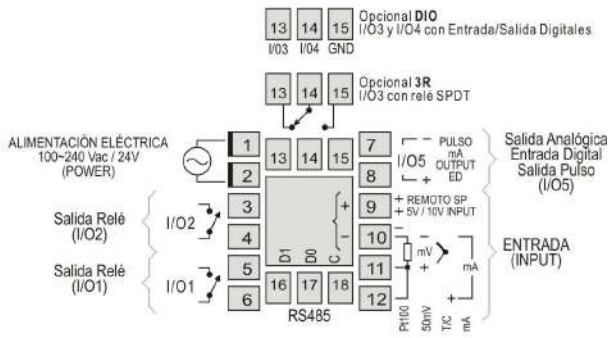


Figura 1 - Conexiones del panel trasero

Conexiones de Alimentación

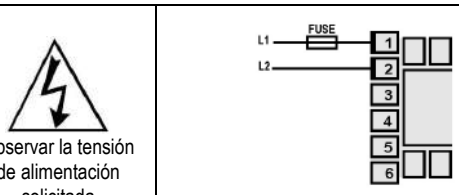


Figura 2 – Conexiones de alimentación

Conexiones de Entrada

- Termocupla (T/C) y 0-50 mV

La **Figura 3a** indica como hacer las conexiones de termocupla y señal de 0-50mV. Ambos tienen polaridad que debe ser observada durante la instalación. Cuando haya necesidad de extender la longitud del termocupla, utilice cables de compensación apropiados.

- RTD (Pt100):

Es utilizado el circuito a tres hilos, conforme la **Figura 3b**. El cable utilizado debe tener hilos con la misma sección, para evitar errores de medida en función de la longitud del cable (utilice conductores del mismo calibre y longitud). Si el sensor posee 4 hilos, deje uno desconectado junto al controlador. Para Pt100 a 2 hilos, haga un cortocircuito entre los terminales 11 y 12.

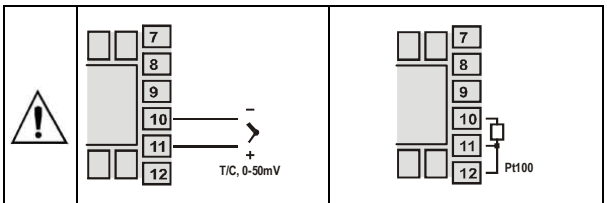


Figura 3a – Conexión T/C, 0-50mV **Figura 3b** - Conexión de Pt100 a 3 hilos

- 4-20 mA:

Las conexiones para señales de corriente 4-20 mA deben ser realizadas conforme la **Figura 4a**.

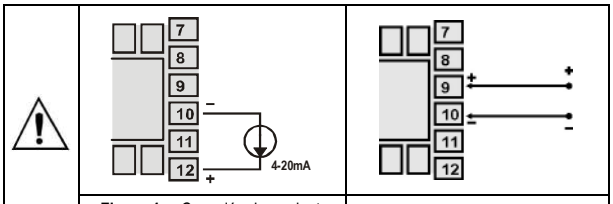


Figura 4a - Conexión de corriente 4-20 mA

Figura 4b - Conexión para 5V y 10 V

- 5 V y 10 V

Las conexiones para siñales de tensión deben ser realizadas conforme la **Figura 4b**.

Setpoint Remoto

Recurso disponible en los terminales 9 y 10 del controlador. Cuando la señal de SP Remoto es 0-20 mA o 4-20 mA, un resistor *shunt* de **100Ω** debe ser montado externamente junto a los terminales del controlador y conectado conforme **Figura 4c**.

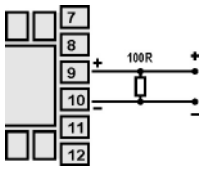


Figura 4c - Conexión para SP remoto

Conexiones de Entrada Digital

Para accionar los canales I/O 3, I/O 4 o I/O 5 como Entrada Digital conecte una llave o equivalente (contacto seco (*Dry Contact*)) a sus terminales.

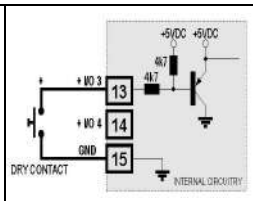


Figura 5a – I/O3 como Entrada Digital

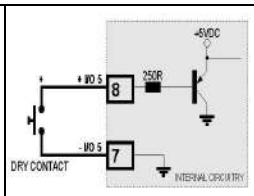


Figura 5b – I/O5 como Entrada Digital

Conexión de Alarmas y Salidas

Los canales de I/O, cuando configurados como salida, deben tener sus límites de capacidad de carga respetados, conforme las especificaciones.

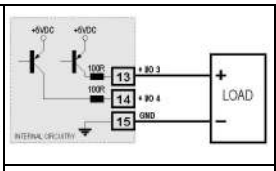


Figure 6a – I/O3 o I/O4 con salida pulso para SSR.

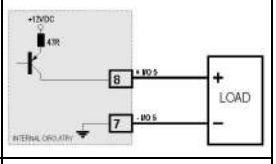


Figure 6b – I/O5 con salida pulso para SSR.

OPERACIÓN

El panel frontal del controlador, con sus partes, puede ser visto en la **Figura 7**:

Figura 7 - Identificación de las partes del panel frontal

Display de PV / Programación: Presenta el valor actual de la PV (*Process Variable*). Cuando en configuración, muestra los mnemotécnicos de los diversos parámetros que deben ser definidos.

Display de SP / Parámetros: Presenta el valor de SP (*Setpoint*). Cuando en configuración, muestra los valores definidos para los diversos parámetros.

Señalizador COM: Parpadea toda la vez que el controlador intercambia datos con el exterior vía RS485.

Señalizador TUNE: Permanece conectado mientras el controlador esté en proceso de sintonía.

Señalizador MAN: Señaliza que el controlador está en el modo de control manual.

Señalizador RUN: Indica que el controlador está activo, con la salida de control y alarmas habilitados.

Señalizador OUT: Para salida de control Relé o Pulso, el señalizador OUT representa el estado instantáneo de esta salida. Para salida de control analógica (0-20 mA o 4-20 mA) este señalizador permanece constantemente encendido.

Señalizadores A1, A2, A3 y A4: señalizam la ocurréncia de situación de alarma.

P **Tecla P**: Tecla utilizada para avanzar a los sucesivos parámetros del controlador.

◀| **Tecla Back**: Tecla utilizada para retroceder parámetros.

▲ **Tecla de aumento y** ▼ - **Tecla Disminución:** Estas teclas permiten alterar los valores de los parámetros.

Al ser energizado, el controlador presenta durante 3 segundos el número de su versión de *software*, pasando luego a operar, mostrando en el visor superior la variable del proceso (PV) y en el visor de parámetros / SP el valor del *Setpoint* de control (pantalla de indicación).

Para operar adecuadamente, el controlador necesita de una configuración que es la definición de cada uno de los diversos parámetros presentados por el controlador. El usuario debe entender la importancia de cada parametro y para cada uno determine una condición válida o un valor válido.

Importante:
Siempre el primer parámetro a ser definido es el tipo de entrada

Los parámetros de configuración están reunidos en grupos de afinidades, llamados ciclos de parámetros. Los 7 ciclos de parámetros son:

CICLO	ACCESO
1- Operación	Acceso libre
2- Sintonía	Acceso reservado
3- Programas	
4- Alarmas	
5- Entrada	
6- I/Os	
7- Calibración	

Tabla 05 – Ciclos de Parámetros

El ciclo de operación (1º ciclo) tiene acceso fácil a través de la tecla P. Los demás ciclos necesitan de una combinación de teclas para ser accesados. La combinación es:

◀| (BACK) y P (PROG) presionadas simultáneamente

En el ciclo deseado, se puede recorrer todos los parámetros de ese ciclo presionando la tecla P (o ◀| , para retroceder en el ciclo). Para retornar al ciclo de operación, presione P hasta que todos los parámetros del ciclo sean recorridos o presione la tecla ◀| durante 3 segundos.

Todos los parámetros configurados son almacenados en memoria protegida. Los valores alterados son guardados cuando el usuario avanza para el siguiente parámetro. El valor de SP también es guardado en el intercambio de parámetro o cada 25 segundos.

DESCRIPCIÓN DE LOS PARÁMETROS

CICLO DE OPERACIÓN

Indicación de PV (Visor Rojo) Indicación de SP (Visor Verde)	**Pantalla Indicación de PV y SP** - El visor superior indica el valor actual de la PV. El visor inferior indica el valor de SP de control adoptado.
CtrL *Control*	**Modo de Control:** **AUto** - Significa modo de control automático. **mAn** – Significa modo de control manual. Transferencia *bumpless* entre automático y manual.
Indicación de PV (Visor Rojo) Indicación de MV (Visor Verde)	**Valor de MV** - Presenta en el visor superior el valor de la PV y en el visor inferior el valor **porcentual** aplicado a la salida de control (MV). En modo de control automático, el valor de MV sólo puede ser visualizado. En modo de control manual, el valor de MV puede ser alterado por el usuario. Para diferenciar esta pantalla de la pantalla de SP, el valor de MV parpadea constantemente.
E Pr *Enable Program*	**Ejecución de Programa** - Selecciona el programa de rampas y mesetas que será ejecutado. **0** - no ejecuta programa **1** a **20** - número del programa a ser ejecutado Con salidas habilitadas (**run= YES**), el programa seleccionado entra en ejecución inmediatamente.
P.SEG	Pantalla apenas indicativa. Cuando un programa está en ejecución, muestra el número del segmento en ejecución de este mismo programa. De 1 a 9.
t.SEG	Pantalla apenas indicativa. Cuando un programa está en ejecución, muestra el tiempo restante para el fin del segmento en ejecución. En la unidad de tiempo adoptada en la Base de Tiempo de los Programas (**Pr.tb**).
run	Habilita salidas de control y alarmas. **YES** - Salidas habilitadas. **no** - Salidas no habilitadas.

CICLO DE SINTONÍA

AtUn *Auto-tune*	Define la estrategia de control a ser tomada: **oFF** – Apagado. **FASt** – Sintonía automática rápida. **FULL** – Sintonía automática precisa. **SELF** – Sintonía precisa + auto-adaptativa **rSLF** – Fuerza una nueva sintonía automática precisa + auto-adaptativa. **tUnE** Fuerza una nueva sintonía automática precisa + auto-adaptativa cuando Run= YES o controlador es encendido.
Pb *Proporcional Band*	Banda Proporcional - Valor del término **P** del modo de control PID, en porcentual del rango máxima del tipo de entrada. Ajusta de entre 0 y 500.0 %. **Cuando en 0.0 (cero), determina modo de control ON/OFF.**
Ir *Integral Rate*	Tasa Integral - Valor del término **I** del modo de control PID, en repeticiones por minuto (Reset). Ajustable entre 0 y 99.99. Presentado si la banda proporcional ≠ 0.
dt *Derivative Time*	Tiempo Derivativo - Valor del término **D** del modo de control PID, en segundos. Ajustable entre 0 y 300.0 segundos. Presentado si la banda proporcional ≠ 0.
Ct *Cycle Time*	Tiempo del Ciclo PWM - Valor en segundos del período del ciclo PWM do control PID. Ajustable entre 0.5 y 100.0 segundos. Presentado si la banda proporcional ≠ 0.
HYSt *Hysteresis*	Histéresis de control - Valor de la histéresis para control ON/OFF. Ajustable entre **0** y el ancho del rango de medición del tipo de entrada seleccionado.
Act *Action*	Lógica de Control: **rE** Control con Acción reversa. Propia para **calentamiento**. Conecta la salida de control cuando PV está abajo de SP. **dir** Control con Acción directa. Propia para **refrigeración**. Conecta salida de control cuando PV está arriba de SP.
Lbdt *Loop break detection time*	Intervalo de tiempo de la función LBD. Intervalo de tiempo máximo para la reacción de PV a comandos de la salida de control. En minutos.
bIAS	Función Bias - Permite alterar el valor porcentual de la salida de control (MV), sumando un valor entre -100 % y +100 %. El valor 0 (zero) inhabilita la función.
ouLL *Output Low Limit*	Límite inferior para la salida de control - Valor porcentual mínimo asumido por la salida de control cuando en modo automático y en PID. Típicamente configurado con **0.0 %**.
ouHL *Output High Limit*	Límite Superior para la salida de control - Valor porcentual máximo posible asumido por la salida de control cuando en el modo automático y en PID. Típicamente configurado con **100.0 %**.
SFSt *Softstart*	Función *SoftStart* – Intervalo de tiempo, en segundos, durante el cual el controlador limita la velocidad de subida de la salida de control (MV). Valor cero (0) inhabilita la función Softstart.
SP.A1 **SP.A2** **SP.A3** **SP.A4**	SP de Alarma: Valor que define el punto de actuación de las alarmas programados con funciones "**Lo**" o "**Hi**". Para las alarmas programados con funciones tipo **Diferencial**, este parámetro define desvío. Para las demás funciones de alarma no es utilizado.

CICLO DE PROGRAMAS

Pr.tb *Program time base*	Base de tiempo de los Programas - Define la base de tiempo adoptada por los programas en edición y también los ya elaborados. **SEC** - Base de tiempo en segundos; **Min** - Base de tiempo en minutos;
Pr n *Program number*	Programa en edición - Selecciona el programa de Rampas e Mesetas a ser definido en las siguientes pantalla de este ciclo. Son 20 programas posibles.
PtoL *Program Tolerance*	Desvío máximo admitido entre la PV y SP. Si es excedido, el programa es suspenso (para de contar el tiempo) hasta que el desvío se encuadre dentro de esta tolerancia. El valor 0 (cero) inhabilita la función.

PSP0 PSP9 *Program* SP	SP's de Programa, 0 a 9: Conjunto de 10 valores de SP que definen el perfil del programa de rampas y mesetas.
Pt 1 Pt9 *Program Time*	Tiempo de los segmentos del programa, 1 a 9: Define el tiempo de duración, en segundo o minutos, de cada uno de los 9 segmentos del programa en edición.
PE 1 PE9 *Program event*	Alarmas de Evento, 1 a 9: Parámetros que definen cuales alarmas deben ser accionadas durante la ejecución de un determinado segmento de programa. Las alarmas adoptados deben aún ser configuradas con la función Alarma de Evento "rS".
LP *Link Program*	Enlace de Programas: Al final de la ejecución de este programa, un otro programa cualquiera puede iniciar su ejecución inmediatamente. **0** - no conecte a ningúm otro programa.

CICLO DE ALARMAS

FuA1 FuA2 FuA3 FuA4 *Function Alarm*	Funciones de Alarma. Define las funciones de las alarmas entre las opciones de la **Tabla 3**. oFF, lErr, rS, rFAIL, Lo, HI, dIFL, dIFH, dIF
bLA1 bLA2 bLA3 bLA4 *Blocking Alarm*	Bloqueo inicial de Alarmas. Función de bloqueo inicial para alarmas 1 a 4. YES - habilita bloqueo inicial no - inibe bloqueio inicial
HYA1 HYA2 HYA3 HYA4 *Histeresis of Alarm*	Histéresis de Alarma. Define la diferencia entre el valor de PV en que la alarma es conectada y el valor en que ella es apagada. Un valor de histéresis para cada alarma.
A1t1 A2t1 A3t1 A4t1 *Alarm Time* **t1**	Define intervalo de tiempo **t1** para la temporización en los accionamientos de las alarmas. En segundos. El valor 0 (cero) inhabilita la función.
A1t2 A2t2 A3t2 A4t2 *Alarm Time* **t2**	Define intervalo de tiempo **t2** para la temporización en los accionamientos de las alarmas. En segundos. El valor 0 (cero) inhabilita la función.
FLSh *Flash*	Permite señalizar la ocurrencia de condiciones de alarma haciendo parpadear la indicación de PV en la pantalla de indicación. El usuario selecciona los números de las alarmas que desea que presenten esta característica.

CICLO DE ESCALA

tYPE *Type*	Tipo de Entrada. Selección del tipo entrada utilizada por el controlador. Consulte la **Tabla 1**. **Obligatoriamente el primer parámetro que será configurado**.
FLtr *Filter*	Filtro Digital de Entrada - Utilizado para mejorar la estabilidad de la señal medida (PV). Ajustable entre 0 y 20. En 0 (cero) significa filtro apagado y 20 significa filtro máximo. Cuanto mayor el filtro, más lenta es la respuesta del valor medido.

dPPo *Decimal Point*	Define la presentación del punto decimal.
unit *Unit*	Define la unidad de temperatura que será utilizada: Celsius " °C " o Farenhart " °F " Parámetro presentado cuando son utilizados los sensores de temperatura.
root *Square Root*	Función Raíz Cuadrada. Aplica la función cuadrática sobre la señal de entrada, dentro de los límites programados en "SPLL" y "SPHL". YES Habilita la Función no No habilita la Función La indicación asume el valor del límite inferior cuando la señal de entrada es inferior a 1% de su excursión. Parámetro disponible para entradas lineales.
OFFS *Offset*	Parámetro que permite al usuario hacer correcciones en el valor de PV indicado.
E.rSP *Enable Remote SP*	Habilita SP remoto. YES Habilita la Función no No habilita la Función Parámetro no presentado cuando la seleción de SP remoto es definida por las Entradas Digitales.
rSP *Remote SP type*	Define o tipo de señal para SP remoto. 0-20 corriente de 0-20 mA 4-20 corriente de 4-20 mA 0-5 tensión de 0-5 V 0-10 tensión de 0-10 V Parámetro presentado cuando es habilitado el SP remoto.
rSLL *Remote SP Low Limit*	Define la escala de valores de SP remoto. Determina el valor mínimo de esta escala. Parámetro presentado cuando el SP remoto es habilitado.
rSHL *Remote SP High Limit*	Define la escala de valores de SP remoto. Determina el valor máximo de esta escala. Parámetro presentado cuando el SP remoto es habilitado.
SPLL *Setpoint Low Limit*	Define el límite inferior para ajuste de SP. - Entradas Lineales: Define el valor mínimo para el ajuste del SP y para la indicación de PV. - Entradas termocupla y Pt100: Define el valor mínimo permitido para ajuste del SP.
SPHL *Setpoint High Limit*	Define el límite superior para ajuste de SP. - Entradas Lineales: Define el valor máximo para ajuste del SP y el fondo de escala para la indicación de PV. - Entradas termocupla y Pt100: Define el valor máximo permitido para ajuste del SP.
IEou	Valor porcentual a ser aplicado a MV cuando se aplica la función de **Salida Segura**. Si el valor es 0 (cero), la función se deshabilita y las salidas se apagan ante la ocurrencia de falla en el sensor.
rtLL	Define el límite mínimo del rango de retransmisión analógica del controlador. Parámetro presentado cuando la retransmisión analógica es habilitada.
rtHL	Define el límite máximo del rango de retransmisión analógica del controlador. Parámetro presentado cuando la retransmisión analógica es habilitada.

bAud *Baud Rate*	*Baud Rate* de la comunicación serial. En kbps **1.2**, **2.4**, **4.8**, **9.6**, **19.2**, **38.4**, **57.6** y **115.2**
PrtY *Parity*	Paridad de la comunicación serial. **nonE** Sin paridad **EUEn** Paridad par **Odd** Paridad impar
Addr *Address*	Dirección de Comunicación. Número que identifica el controlador en la red de comunicación serial, entre 1 y 247.

CICLO DE I/OS (ENTRADAS Y SALIDAS)

io 1	Función del canal I/O 1: Selección de la función utilizada en el canal I/O 1, conforme la **Tabla 2**.
io 2	Función del canal I/O 2: Selección de la función utilizada en el canal I/O 2, conforme la **Tabla 2**.
io 3	Función del canal I/O 3: Selección de la función utilizada en el canal I/O 3, conforme la **Tabla 2**.
io 4	Función del canal I/O 4: Selección de la función utilizada en el canal I/O 4, conforme la **Tabla 2**.
io 5	Función del canal I/O 5: Selección de la función utilizada en el canal I/O 5, conforme la **Tabla 2**.

CICLO DE CALIBRACIÓN

Todos los tipos de entrada y salida son calibrados en la fábrica. Si es necesaria una recalibración, esta debe ser realizada por un profesional especializado. Si este ciclo es accesado en forma accidental, pase por todos los parámetros sin realizar alteraciones en sus valores.

PASS *Password*	Entrada de la Contreseña de Acceso. Este parámetro es presentado antes de los ciclos protegidos. Vea el tópico Protección de la Configuración.
inLC *Input Low Calibration*	Vea el capítulo MANTENIMIENTO / Calibración de la entrada. Declaración de la señal de calibración de inicio del rango aplicado en la entrada analógica.
inHC *Input High Calibration*	Vea el capítulo MANTENIMIENTO / Calibración de la entrada. Declaración de la señal de calibración de final del rango aplicado en la entrada analógica.
rSLC *Remote SP Low Calibration*	Vea el capítulo MANTENIMIENTO / Calibración de la entrada. Declaración de la señal de calibración de inicio del rango aplicado en la entrada de SP remoto.
rSHC *Remote SP High Calibration*	Vea el capítulo MANTENIMIENTO / Calibración de la entrada. Declaración de la señal de calibración de final del rango, aplicada en la entrada de SP remota.
OuLC *Output Low Calibration*	Vea el capítulo MANTENIMIENTO / Calibración de la salida analógica. Declaración del valor presente en la salida analógica.
OuHC *Output High Calibration*	Vea el capítulo MANTENIMIENTO / Calibración de la salida analógica. Declaración del valor presente en la salida analógica.
CJ *Cold Junction*	Ajuste de la temperatura de junta fría del controlador.
HtYP *Hardware Type*	Parámetro que adapta el controlador al opcional de *hardware* disponible. No debe ser alterado por el usuario, excepto cuando un accesorio es introducido o retirado. **0** – Modelo básico. Sin opcionales **1** – 485 **2** – 3R **3** – 3R + 485 **4** – DIO **5** – DIO + 485 **8** – HBD **9** – HDB + 485
PASC *Password*	Permite definir una nueva contraseña de acceso, sempre diferente de zero.
Prot *Protection*	Estabelece el Nivel de Protección. Vea **Tabla 06**.
FrEQ *Frequency*	Frecuencia de la red eléctrica local.
rStr *Restore*	Resgata las calibraciones de fábrica de entrada, salida analógica y SP remoto, eliminando toda y cualquier alteración realizada por el usuario.

CICLO DE OPERACIÓN	CICLO DE SINTONÍA	CICLO DE PROGRAMACIÓN	CICLO DE ALARMA	CICLO DE CONFIGURACIÓN	CICLO DE I/OS	CICLO DE CALIBRACIÓN
PV y SP	AtUn	tbAS	FuA1 - FuA4	tYPE	Io 1	PASS
Auto	Pb	Pr n	bLA1 - bLA4	FLtr	Io2	inLC
PV y MV	hYSt	PtoL	HYA1 - HYA4	dPPo	Io3	inHC
Pr n	Ir	PSP0 – PSP9	A It 1	un It	Io4	rSLC
run	dt	Pt 1 – Pt9	A It2	oFFS	Io5	rSHC
	Ct	PE 1 – PE9	A2t 1	SPLL		OuLC
	ACt	LP	A2t2	SPHL		OuHC
	b tAS			rSLL		CJ
	Lbdt			rSHL		HtYP
	ouLL			bAud		PASC
	ouHL			Addr		Prot
	SFSt					FrEQ
	SPA1 - SPA4					rStr

Tabla 06 – Todos los Parámetros del Controlador

CICLO EXPRESO – CONFIGURACIÓN RÁPIDA

El Ciclo Expreso da al operador acceso rápido y fácil a los principales parámetros del controlador, permitiendo una configuración mínima, más suficiente para dejar el controlador apto a operar. Los parámetros son:

CICLO EXPRESO
tYPE
* dPPo
* un It
* SPLL
* SPHL
AtUn
ACt
FuA 1
SPA 1
FuA2
SPA2
Io 1
Io2
IoS
* rSP
* rSLL
* rSHL
* rtLL
* rtHL
* Ct

* La apresentación de estos parámetros depende de la configuración de otros.

Para acceder este ciclo presione simultáneamente las teclas:

▲ y ◄

PROTECIÓN DE CONFIGURACIÓN

El controlador permite la protección de la configuración elaborada por el usuario, impidiendo alteraciones indebidas. El parámetro **Protección** (**Prot**), en el ciclo de Calibración, determina el nivel de protección a ser adoptado, limitando el acceso a los ciclos, conforme la siguiente tabla.

Nivel de protección	Ciclos protegidos
1	Apenas el ciclo de Calibración es protegido.
2	Ciclos de I/Os y Calibración.
3	Ciclos de Escala, I/Os y Calibración.
4	Ciclos de Alarma, Escala, I/Os y Calibración.
5	Ciclos de Programas, Alarma, Escala, I/Os y Calibración.
6	Ciclos de Sintonía, Programas, Alarma, Escala, I/Os y Calibración.
7	Ciclos de Operación (excepto SP), Sintonía, Programas, Alarma, Escala, I/Os y Calibración.
8	Ciclos de Operación (inclusive SP), Sintonía, Programas, Alarma, Escala, I/Os y Calibración.

Tabla 07 – Niveles de Protección de la Configuración

Contraseña de Acceso

Los ciclos protegidos, cuando son accesados, solicitan al usuario la **Contraseña de Acceso** que, si es insertada correctamente, da permiso para alteraciones en la configuración de los parámetros de estos ciclos.

La contraseña de acceso es insertada en el parámetro **PASS** que es mostrado en el primero de los ciclos protegidos. Sin la contraseña de protección, los parámetros de los ciclos protegidos pueden ser apenas visualizados.

La Contraseña de Acceso es definida por el usuario en el parámetro *Password Change* (**PASC**), presente en el ciclo de Calibración.

Los controladores nuevos salen de fábrica con la contraseña de acceso definida como 1111.

Protección de la contraseña de acceso

El controlador prevé un sistema de seguridad que ayuda a prevenir la entrada de innumerables contraseñas en el intento de acertar la contraseña correcta. Una vez identificada la entrada de 5 contraseñas inválidas seguidas, el controlador deja de aceptar contraseñas durante 10 minutos.

Contraseña Maestra

En el caso de un olvido eventual de la contraseña de acceso, el usuario puede utilizar el recurso de la Contraseña Maestra. Esta contraseña cuando es insertada, da acceso con posibilidad de alteración al parámetro Password Change (**PASC**) y permite al usuario la definición de una nueva contraseña de acceso para el controlador.

La contraseña maestra está compuesta por los tres últimos dígitos del número de serie del controlador **sumados** al número 9000.

Como ejemplo, para el equipo con número de serie 07154321, la contraseña maestra es 9321.

PROGRAMA DE RAMPAS Y MESETAS

Característica que permite la elaboración de un perfil de comportamiento para el proceso. Cada programa está compuesto por un conjunto de hasta **9 segmentos**, llamado PROGRAMA DE RAMPAS Y MESETAS, definido por valores de SP e intervalos de tiempo.

Pueden ser creados hasta **20 diferentes programas** de rampas y mesetas. La siguiente figura muestra un modelo de programa:

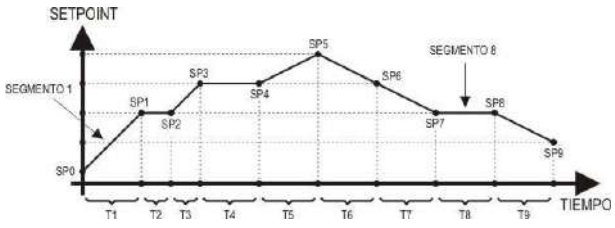


Figura 8 - Ejemplo de programa de rampas y mesetas

Una vez definido el programa y colocado en ejecución, el controlador pasa a generar automáticamente el SP de acuerdo con el programa elaborado.

Para la ejecución de un programa con menor número de segmentos, basta programar 0 (cero) para los valores de tiempo de los segmentos que suceden el último segmento a ser ejecutado.

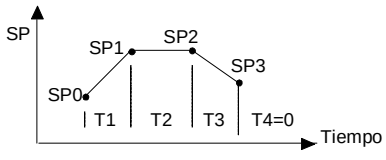


Figura 9 - Ejemplo de programa con pocos segmentos

La función tolerancia de programa "**PtoL**" define el desvío máximo entre PV y SP durante la ejecución del programa. Si este desvío es excedido, el conteo de tiempo es interrumpido hasta que el desvío quede dentro de la tolerancia programada (da prioridad al SP). Si programado cero en la tolerancia, el controlador ejecuta el programa definido sin considerar eventuales desvíos entre PV y SP (da prioridad al tiempo).

LINK DE PROGRAMAS

Es posible elaborar un gran programa, más complejo, con hasta 180 segmentos, conectando los 20 programas. De esta manera, al final de la ejecución de un programa el controlador inicia inmediatamente la ejecución de otro.

En la elaboración / edición de un programa se define en la pantalla "**LP**" si habrá o no conexión a otro programa.

Para que el controlador ejecute continuamente un determinado programa o programas, basta conectar un programa a él mismo o el último programa al primero.

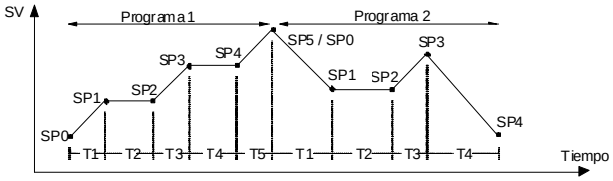


Figura 10 - Ejemplo de programas interconectados

ALARMA DE EVENTO

La función Alarma de Evento permite programar el accionamiento de las alarmas en segmentos específicos de un programa.

Para que esta función opere, las alarmas a ser accionados deben tener su función definida como **rS** y son configuradas en los parámetros **PE1** a **PE9**.

Notas:

1- Antes de iniciar el programa el controlador espera que PV alcance el *setpoint* inicial ("**SPO**").

2- Al retornar de una falta de energía el controlador retoma la ejecución del programa a partir del inicio del segmento que fue interrumpido.

DETERMINACIÓN DE LOS PARÁMETROS PID

La determinación (o sintonía) de los parámetros de control PID en el controlador puede ser realizada de forma automática y auto-adaptativa. La **sintonía automática** es iniciada siempre por requisición del operador, mientras que la **sintonía auto-adaptativa** es iniciada por el propio controlador siempre que el desempeño de control empeora.

Sintonía automática: En el inicio de la **sintonía automática** el controlador tiene el mismo comportamiento de un controlador Enciende/Apaga (control ON/OFF), aplicando actuación mínima y máxima al proceso. A lo largo del proceso de sintonía la actuación del controlador es refinada hasta su conclusión, encontrándose en el control PID optimizado. Inicia inmediatamente después de la selección de las opciones FAST, FULL, RSLF o TGHT, por el operador, en el parámetro ATUN.

Sintonía auto-adaptativa: Es iniciada por el controlador siempre que el desempeño de control es peor que el encontrado después de la sintonía anterior. Para activar la supervisión de desempeño y **sintonía auto-adaptativa**, el parámetro ATUN debe estar ajustado para SELF, RSLF o TGHT. El comportamiento del controlador durante la **sintonía auto-adaptativa** dependerá del empeoramiento del desempeño encontrado. Si el desajuste es pequeño, la sintonía es prácticamente imperceptible para el usuario. Si el desajuste es grande, la **sintonía auto-adaptativa** es semejante al método de **sintonía automática**, aplicando actuación mínima y máxima al proceso en control enciende / apaga.

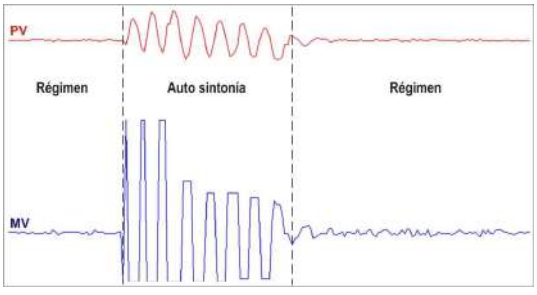


Figura 11 – Ejemplo de una auto sintonía

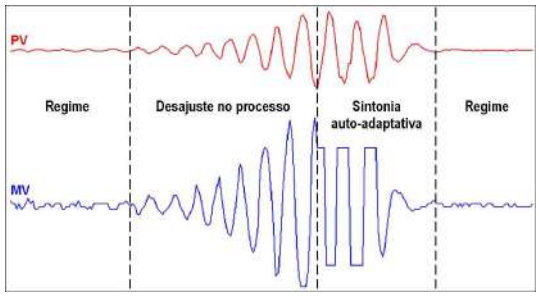


Figura 12 – Ejemplo de una sintonía auto-adaptativa

El operador puede seleccionar, a través del parámetro ATUN, el tipo de sintonía deseada entre las siguientes opciones:

- OFF: El controlador no ejecuta **sintonía automática** y ni **auto-adaptativa**. Los parámetros PID **no** serán automáticamente determinados y **ni** optimados por el controlador.
- FAST: El controlador realiza el proceso de **sintonía automática** una única vez, retornando al modo OFF cuando concluida. La sintonía en este modo es concluida en menor tiempo, pero no es tan precisa cuanto en el modo FULL.
- FULL: Incluso que el modo FAST, pero la sintonía es más precisa y demorada, resultando en mejor desempeño del control P.I.D.
- SELF: El desempeño del proceso es monitoreado y la **sintonía auto-adaptativa** es automáticamente iniciada por el controlador siempre que el desempeño empeora.

  Una vez completa la sintonía, se inicia una fase de aprendizaje donde el controlador colecta informaciones pertinentes del proceso controlado. Esta fase, cuyo tiempo es proporcional al tiempo de respuesta del proceso, es indicada con el señalizador TUNE destellando. Después de esta fase el controlador puede evaluar el desempeño del proceso y determinar la necesidad de nueva sintonía.

  Se recomienda no apagar el equipamiento y no alterar el SP durante esa etapa de la sintonía.
- rSLF: Realiza la **sintonía automática** y retorna para el modo SELF. Típicamente utilizado para forzar una **sintonía automática** inmediata de un controlador que estaba operando en el modo SELF, retornando a este modo en el final.
- TGHT: Semejante al modo SELF, pero además de la **sintonía auto-adaptativa**, también ejecuta la **sintonía automática** siempre que el controlador es colocado en RUN=YES o el controlador es encendido.

Siempre que el parámetro ATUN es alterado por el operador para un valor diferente de OFF, una sintonía automática es inmediatamente iniciada por el controlador (si el controlador no esté en RUN=YES, la sintonía se iniciará cuando pase para esta condición). La realización de esta sintonía automática es esencial para la correcta operación de la sintonía auto-adaptativa.

Los métodos de **sintonía automática** y **sintonía auto-adaptativa** son adecuados para la gran mayoría de los procesos industriales. Sin embargo, pueden existir procesos o incluso situaciones específicas donde los métodos no son capaces de determinar los parámetros del controlador de forma satisfactoria, resultando en oscilaciones indeseadas o incluso llevando el proceso a condiciones extremas. Las propias oscilaciones impuestas por los métodos de sintonía pueden ser intolerables para determinados procesos.

Estos posibles efectos indeseables, deben ser considerados antes de iniciar el uso del controlador, y medidas preventivas deben ser adoptadas para garantizar la integridad del proceso y usuarios.

El sieñalizador "**TUNE**" permanecerá encendido durante el proceso de sintonía.

En el caso de salida PWM o pulso, la calidad de la sintonía dependerá también del tiempo de ciclo previamente ajustado por el usuario.

Si la sintonía no resulta en control satisfactorio, la **Tabla 7** presenta orientación en como corregir el comportamiento del proceso.

PARÁMETRO	PROBLEMA VERIFICADO	SOLUCIÓN
Banda Proporcional	Respuesta lenta	Disminuir
	Gran oscilación	Aumentar
Tasa de Integración	Respuesta lenta	Aumentar
	Grande oscilación	Disminuir
Tiempo Derivativo	Respuesta lenta o instabilidad	Disminuir
	Grand oscilación	Aumentar

Tabla 9 - Orientación para ajuste manual de los parámetros PID

MANTENIMIENTO

PROBLEMAS CON EL CONTROLADOR

Errores de conexión y programación inadecuada, representan la mayoría de los problemas presentados en la utilización del controlador. Una revisión final puede evitar pérdidas de tiempo y perjuicios.

El controlador presenta algunos mensajes que tienen el objetivo de ayudar al usuario en la identificación de problemas.

MENSAJE	DESCRIPCIÓN DEL PROBLEMA
----	Entrada abierta. Sin sensor o señal.
Err 1 Err6	Problemas de conexión y/o configuración. Revisar las conexiones hechas y la configuración.

Otros mensajes de errores mostradas por el controlador representan daños internos que implican necesariamente en el envío del equipo para el manntenimiento. Informar el número de serie del aparato, que puede ser conseguido presionándose la tecla ◄ por más de 3 segundos.

CALIBRACIÓN DE LA ENTRADA

Todos los tipos de entrada del controlador ya salen calibrados de la fábrica, siendo la recalibración un procedimiento imprudente para operadores sin experiencia. Si es necesaria la recalibración de alguna escala, proceda como lo descrito a seguir:

a) Configurar el tipo de entrada a ser calibrada.

b) Programar los límites inferior y superior de indicación para los extremos del tipo de entrada.

c) Aplicar a la entrada una señal correspondiente a una indicación conocida y poco superior al límite inferior de indicación.

d) Acceder al parámetro " InLc". Con las teclas ▲ y ▼, haga con que el visor de parámetros indique el valor esperado. Enseguida presione la tecla P.

e) Aplicar a la entrada una señal correspondiente a una indicación conocida y poco abajo del límite superior de la indicación.

f) Acceder al parámetro " InHc". Con las teclas ▲ y ▼, haga con que el visor de parámetros indique el valor esperado. Enseguida presione la tecla P.

Nota: Cuando son efectuadas comprobaciones en el controlador, observe si la corriente de excitación de Pt100 exigida por el calibrador utilizado es compatible con la corriente de excitación de Pt100 usada en este instrumento: 0,170 mA.

CALIBRACIÓN DE LA SALIDA ANALÓGICA

1. Configurar I/O 5 para salida de corriente que se desea calibrar, sea ella control o retransmisión.

2. En pantallla "ctrL", programar el modo manual (mAn).

3. Montar un miliamperímetro en la salida de control analógica.

4. Entrar en el ciclo de calibración con la contraseña correcta.

5. Seleccionar la pantalla "ouLc". Atuar en las teclas ▲ y ▼ para que el controlador reconozca el proceso de calibración de la salida de corriente.

6. Leer la corriente indicada en el miliamperímetro y indicarla en la pantalla de "ouLc" a través de las teclas ▲ y ▼.

7. Seleccionar la pantalla "ouHc". Actuar en las teclas ▲ y ▼ para que el controlador reconozca el proceso de calibración de la salida de corriente.

8. Leer la corriente indicada en el miliamperímetro y indicarla en la pantalla de "ouHc" a través de las teclas ▲ y ▼.

9. Presionar la tecla P o ◄ para salir de la pantalla y haga a calibración.

COMUNICACIÓN SERIAL

El controlador puede ser proporcionado opcionalmente con la interfaz de comunicación serial asíncrona RS-485 para comunicación con una computadora supervisora (master). El controlador actúa siempre como esclavo. La comunicación es siempre iniciada por el master, que transmite un comando para la dirección del esclavo con el cual se desea comunicar. El esclavo direccionado asume el comando y envía la respuesta al master. El controlador acepta también comandos tipo *broadcast*.

CARACTERÍSTICAS

- Señales compatibles con el estándar RS-485. Protocolo MODBUS (RTU). Conexión a 2 hilos entre 1 master y hasta 31 (pudiendo direccionar hasta 247) instrumentos en topología barra colectora. Las señales de comunicación son aislados eléctricamente del resto del aparato;
- Máxima distancia de conexión: 1000 metros.
- Tiempo de desconexión del controlador: Máximo 2 ms después del último *byte*.
- Velocidad seleccionable; 8 de bits de datos; 1 *stop* bit; paridad seleccionable (sin paridad, par o impar);
- Tiempo de inicio de transmisión de respuesta: máximo 100 ms después de recibir el comando.

Las señales RS-485 son:

D1	D	D +	B	Línea bidireccional de datos.	Terminal 16
D0	$\overline{D}$:	D -	A	Línea bidireccional de datos invertida.	Terminal 17
C				Conexión opcional que mejora el desempeño de la comunicación.	Terminal 18
GND					

CONFIGURACIÓN DE LOS PARÁMETROS DE LA COMUNICACIÓN SERIAL

Dos parámetros deben ser configurados para la utilización del serial:

bAud: Velocidad de comunicación.

PrtY: Paridad de la comunicación.

Addr: Dirección de comunicación del controlador.

TABLA RESUMIDA DE REGISTRADORES PARA COMUNICACIÓN SERIAL

Protocolo de Comunicación

Es soportado el protocolo MODBUS RTU esclavo. Todos los parámetros configurables del controlador pueden ser leídos y/o escritos a través de la comunicación serial. Se permite también la escritura en los Registradores en modo *broadcast*, utilizándose la dirección **0**.

Los comandos Modbus disponibles son los siguientes:

03 - *Read Holding Register*	06 - *Preset Single Register*
05 - *Force Single Coil*	16 - *Preset Multiple Register*

Tabla Resumida de Registradores Tipo Holding Register

A continuación se presentan los registradores más utilizados. Para informaciones completas consulte la **Tabla de Registradores para Comunicación Serial** disponible para download en la página del N1200 en el web site – www.novusautomation.com.

Los registradores en la tabla abajo son del tipo *entero 16 bits con signo*.

Dirección	Parámetro	Descripción del Registrador
0000	SP activo	Lectura: *Setpoint* de Control activo (de la pantalla principal, de rampas y mesetas o del *setpoint* remoto). Escritura: *Setpoint* de Control en la pantalla principal. Rango máximo: desde **SPLL** hasta el valor seteado en **SPHL**.
0001	PV	Lectura: Variable de Proceso. Escritura: no permitida. Rango máximo: el mínimo es el valor seteado en **SPLL** y el máximo es el valor seteado en **SPHL** y la posición del punto decimal depende del valor de **dPPo**. En el caso de lectura de temperatura, el valor siempre será multiplicado por 10, independientemente del valor de **dPPo**.
0002	MV	Lectura: Potencia de Salida activa (manual o automático). Escritura: no permitida. Ver dirección 28. Rango: 0 a 1000 (0.0 a 100.0 %).

ESPECIFICACIONES

DIMENSIONES: ..... 48 x 48 x 110 mm (1/16 DIN)
..... Peso Aproximado: 150 g

RECORTE EN EL PANEL: ..... 45,5 x 45,5 mm (+0.5 -0.0 mm)

ALIMENTACIÓN: ..... 100 a 240 Vac/dc (±10 %), 50/60 Hz
Opcionalmente: ..... 24 Vac/dc ±10 %
Consumo máximo:..... 9 VA

CONDICIONES AMBIENTALES:
Temperatura de Operación: ..... 5 a 50 °C
Humedad Relativa: .....80 % máx. hasta 30 ºC
Para temperaturas mayores que 30 ºC, disminuir 3 % por ºC
Uso interno; Categoría de instalación II, Grado de contaminación 2; altitud < 2000 m

ENTRADA..... T/C, Pt100, tensión y corriente (conforme la **Tabla 1)**
Resolución Interna: ..... 32767 niveles (15 bits)
Resolución del Display: .... 12000 niveles (de -1999 hasta 9999)
Tasa de lectura de la entrada: .....hasta 55 por segundo
Precisión: ..... Termocuplas **J**, **K**, **T**, **E**: 0.25 % del *span* ±1 ºC
..... Termocuplas **N**, **R**, **S**, **B**: 0.25 % del *span* ±3 ºC
..... Pt100: 0.2 % del *span*
..... 4-20 mA, 0-50 mV, 0-5 Vdc: 0.2 % del *span*
Impedancia de entrada:0-50 mV, Pt100 y termocuplas: >10 MΩ
..... 0-5 V: >1 MΩ
.....4-20 mA: 15 Ω (+2 Vdc @ 20 mA)
Medición do Pt100: .....Tipo 3 hilos, (α=0.00385) con compensación de longitud del cable, corriente de excitación de 0,170 mA.

Todos los tipos de entrada calibrados de fábrica. Termocuplas conforme norma NBR 12771/99, RTD's NBR 13773/97;

SALIDA ANALÓGICA (I/O5): ..... 0-20mA o 4-20mA, 550Ω max.
..31000 niveles, aislada, para control o retransmisión de PV y SP

CONTROL OUTPUT:
..... 2 Relés SPST-NA (I/O1 y I/O2): 1,5 A / 240 Vac, uso general
.....1 Relé SPDT (I/O3): 3 A / 250 Vac, uso general
..... Pulso de tensión para SSR (I/O5): 10 V máx. / 20 mA
.....Pulso de tensión para SSR (I/O3 y I/O4): 5 V máx. / 20 mA

ENTRADA DE SP REMOTO: ..... Corriente de 4-20mA
Esta característica requiere un resistor externo de 100 R, conectado a los terminales 9 y 10 del panel trasero del controlador.

COMPATIBILIDADE ELETROMAGNÉTICA : ..... EN 61326-1:1997 y EN 61326-1/A1:1998

SEGURIDAD: .....EN61010-1:1993 y EN61010-1/A2:1995

CONEXIONES PROPIAS PARA TERMINALES TIPO HORQUILLA DE 6,3 mm;

PANEL FRONTAL: IP65, POLICARBONATO UL94 V-2; CAJA: IP30, ABS+PC UL94 V-0;

CICLO PROGRAMABLE DE PWM DE 0.5 HASTA 100 SEGUNDOS;

INICIA OPERACIÓN DESPUÉS 3 SEGUNDOS DE ENCENDIDA LA ALIMENTACIÓN;

IDENTIFICACIÓN

N1200 -	3R -	485 -	24V
A	B	C	D

A: modelo de controlador:
N1200;

B: Opcionales de I/O:
Nada mostrado (versión básica, sin los seguientes opcionales);
3R (versión con Relé SPDT disponible en I/O3);
DIO (versión con I/O3 e I/O4 disponibles);
HBD (versión con detección de Resistencia Quemada);

C: Comunicación Digital:
Nada mostrado (versión básica, sin comunicación serial);
485 (versión con serial RS485, Modbus *protocol*)

D: Alimentación Eléctrica:
Nada mostrado (versión básica, alimentación de 100 a 240 Vac);
24V (versión con alimentación de 24 Vac/dc);

GARANTÍA

El fabricante garantiza al propietario de sus equipos, identificados por la factura de compra, una garantía de 1 (un) año en los siguientes términos:

- El período de garantía inicia en la fecha de emisión de la Nota Fiscal.
- Dentro del período de garantía, la mano de obra y los componentes aplicados en las reparaciones de defectos ocurridos en uso normal, serán gratuitas.
- Para las reparaciones eventuales, envíe el equipo, juntamente con las facturas de remesa para reparación, para la dirección de nuestra fábrica.
- Los gastos y riesgos de transporte correrán por cuenta del propietario.
- Inclusive el período de garantía, serán cobrados las reparaciones de defectos causados por choques mecánicos o exposición del equipo a condiciones impropias para el uso.