

# RedLab 1808

Eight-Channel Simultaneous-Sampling Multifunction Device

## User's Guide

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# Introducing the RedLab 1808

The RedLab 1808 is a multifunction data acquisition device providing the following features:

- Eight 18-bit simultaneous-sampling differential (DIFF) or single-ended (SE) analog input channels – software-selectable per channel as DIFF or SE
- Sample rate of 50 kS/s per channel maximum
- Analog input ranges of  $\pm 10$  V,  $\pm 5$  V, 0 V to 10 V, and 0 V to 5 V – software-selectable per channel
- Two 16-bit analog outputs
- Four individually-configurable digital I/O channels
- Two high-speed general purpose counters
- Two quadrature encoder inputs
- Two timer outputs
- One external digital trigger for data acquisition and one external digital trigger for data generation
- Two external clock inputs and two clock outputs for synchronous input and output operations with more than one device.
- Screw terminals for field wiring connections

The device is powered by the +5 V USB supply from the computer, requiring no external power.

The RedLab 1808 is a USB 2.0 high-speed device that is fully compatible with both USB 1.1, USB 2.0, and USB 3.0 ports.

## Functional block diagram

RedLab 1808 functions are illustrated in the block diagram shown here.

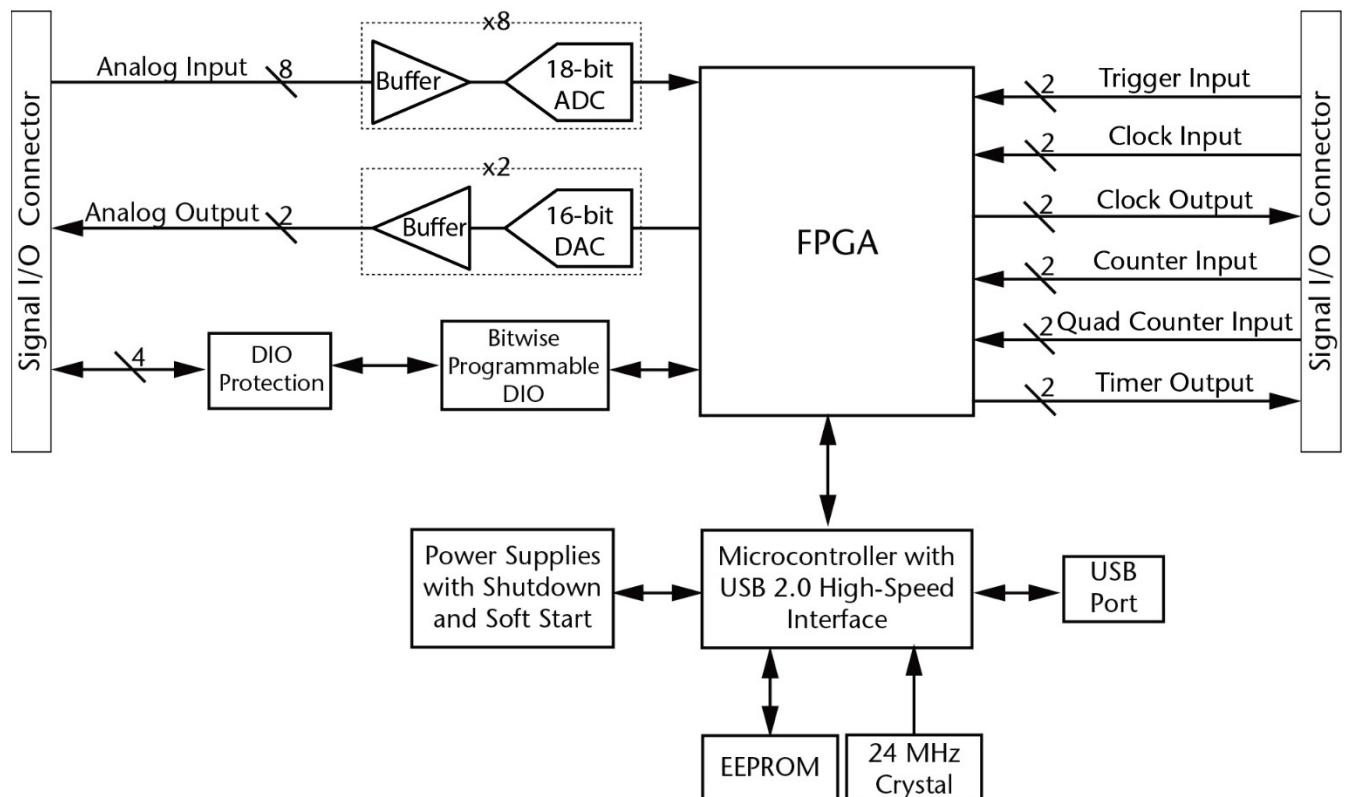


Figure 1. Functional block diagram

# Installing the RedLab 1808

## Unpacking

As with any electronic device, you should take care while handling to avoid damage from static electricity. Before removing the device from its packaging, ground yourself using a wrist strap or by simply touching the computer chassis or other grounded object to eliminate any stored static charge.

If any components are missing or damaged, contact us immediately using one of the following methods:

- Phone: +49 (0) 8141/5271-0
- Fax: +49 (0) 8141/5271-129
- E-Mail: [support@meilhaus.com](mailto:support@meilhaus.com)

## Installing the hardware

To connect the RedLab 1808 to your system, connect the USB cable to an available USB port on the computer or to an external USB hub connected to the computer. Connect the other end of the USB cable to the USB connector on the device. No external power is required.

When connected for the first time, a **Found New Hardware** dialog opens when the operating system detects the device. When the dialog closes, the installation is complete. The **Status** LED turns on after the device is successfully installed.

### **If the Status LED turns off**

If communication is lost between the device and the computer, the device LED turns off. To restore communication, disconnect the USB cable from the computer and then reconnect it. This should restore communication, and the LED should turn on.

## Calibrating the hardware

The Meilhaus Electronic Manufacturing Test department performs the initial factory calibration. Return the device to Meilhaus Electronic when calibration is required. The recommended calibration interval is one year.

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# Functional Details

## External components

The RedLab 1808 has the following external components (see Figure 2 through Figure 4 on pages 7-8):

- USB connector
- LEDs
- Screw terminals

### USB connector

The USB connector provides +5 V power and communication. No external power supply is required.

### Screw terminals

The screw terminals provide the following connections:

- Eight DIFF analog inputs (**CH0H/CH0L** to **CH7H/CH7L**) or eight SE analog inputs (**CH0H** to **CH7H**)  
Refer to Figure 2 and Figure 3 on page 7 for DIFF and SE pinouts.
- Two analog outputs (**AOUT0** and **AOUT1**)
- Four digital I/O lines (**DIO0** to **DIO3**)
- Two general-purpose counter inputs (**CTR0** and **CTR1**)
- Two quadrature encoder inputs (**ENC0A**, **ENC0B**, **ENC0Z** and **ENC1A**, **ENC1B**, **ENC1Z**)
- Two timer outputs (**TMR0** and **TMR1**)
- An external trigger input (**ITRIG**) and an external trigger output **OTRIG**)
- Two external clock inputs (**ICLK1** and **OCLK1**) and two external clock outputs (**ICLKO**, **OCLKO**)
- One +5 V power output (**+VO**) connection
- Ten analog ground (**AGND**) and seven digital ground (**GND**) connections

Use 16 AWG to 30 AWG wire when making connections to the screw terminals.

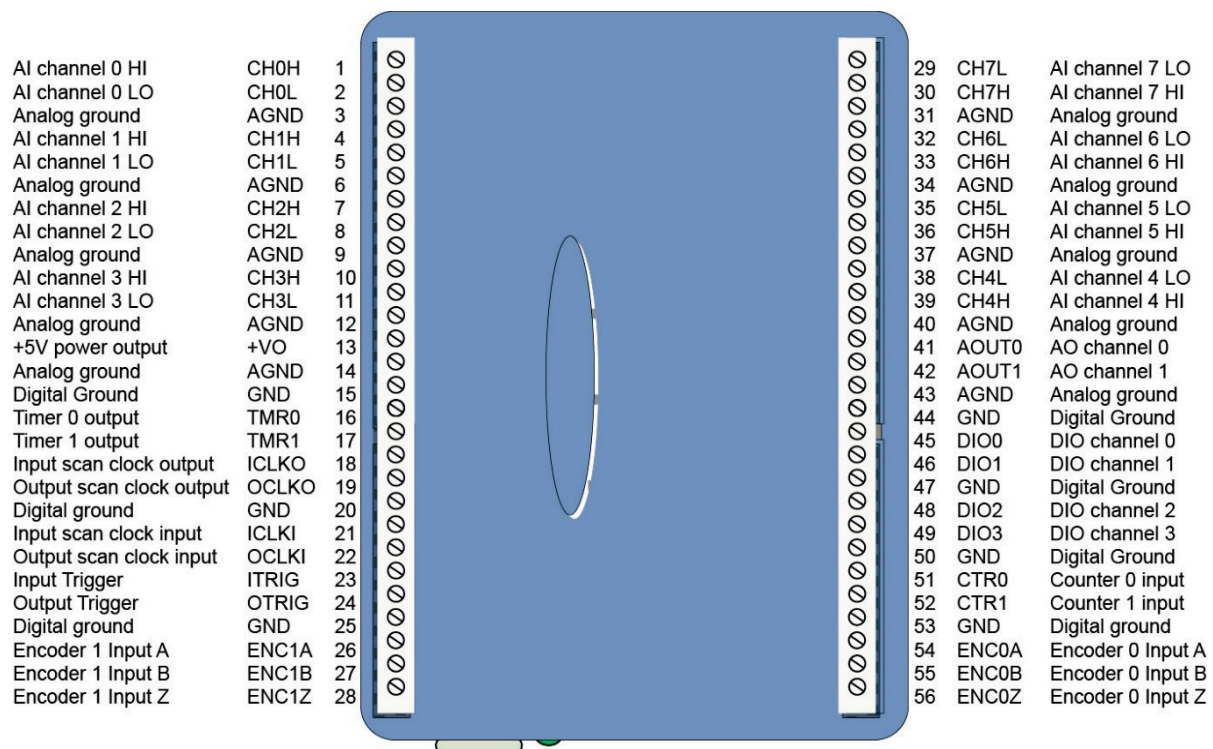


Figure 2. DIFF mode pinout

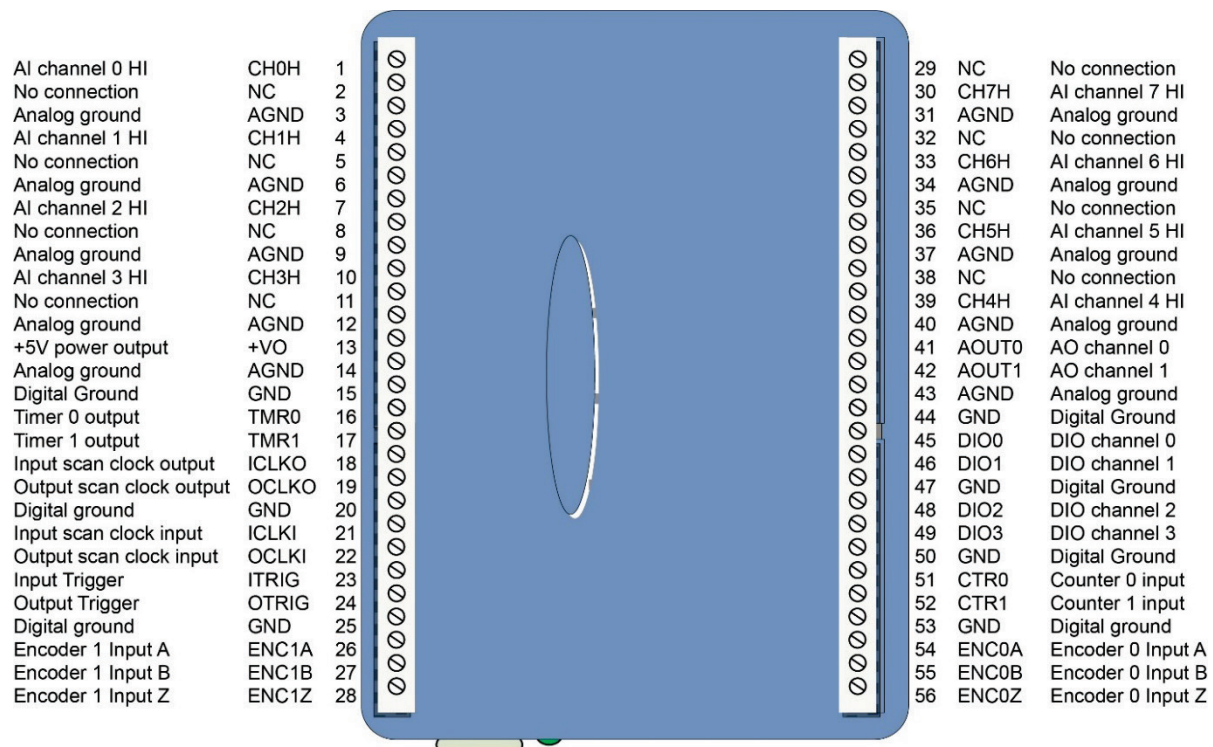


Figure 3. SE mode pinout

## LEDs

The RedLab 1808 has two LED indicators that indicate the status of power and data. The LEDs are stacked one above the other, as shown in Figure 4.

- The **Status** LED turns on when the device is detected by the computer.
- The **Activity** LED blinks when data is transferred, and is off otherwise.

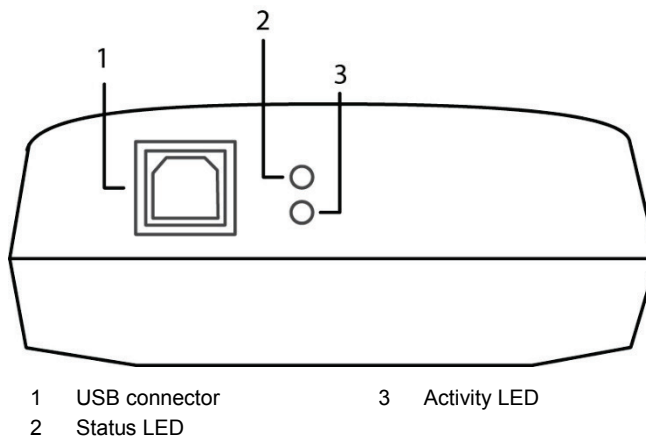


Figure 4. LED indicators

## Analog input

You can configure each analog input channel for either SE or DIFF mode. We recommend connecting unused analog input terminals to analog ground terminals during operation. For example, if you are not using **CH7L**, connect this terminal to an available **AGND** terminal.

The input voltage range is software-selectable per channel for  $\pm 10$  V,  $\pm 5$  V, 0 V to 10 V, or 0 V to 5 V.

Analog input operations can be paced by the internal clock or by an external clock (**ICLK1** – refer to *Clock I/O* on page 13). They can be initiated by a digital trigger (*Digital triggering* on page 13) or a pattern trigger (*Pattern triggering* on page 13).

Refer to *Synchronous I/O – mixing analog, digital, and counter scanning* on page 12 for information on running analog input scans at the same time as other subsystem scans.

## Channel-Gain queue

The channel-gain queue feature allows you to configure a different gain setting for each channel. The gain settings are stored in a channel-gain queue list that is written to local memory on the device.

The channel-gain queue list can contain up to eight unique elements. The channel list must be in increasing order. An example of a five-element list is shown in the following table.

Sample channel-gain queue list

| Element | Channel                 | Range       |
|---------|-------------------------|-------------|
| 0       | <b>CH0H/CH0L</b> (DIFF) | $\pm 10$ V  |
| 1       | <b>CH2H/AGND</b> (SE)   | $\pm 5$ V   |
| 2       | <b>CH3H/AGND</b> (SE)   | 0 V to 5 V  |
| 3       | <b>CH6H/CH6L</b> (DIFF) | 0 V to 10 V |
| 4       | <b>CH7H/CH7L</b> (DIFF) | $\pm 5$ V   |

Carefully match the gain to the expected voltage range on the associated channel or an over range condition may occur. Although this condition does not damage the device, it does produce a useless full-scale reading, and can introduce a long recovery time due to saturation of the input channel.



## Analog output

The two 16-bit analog outputs (AOUT0 and AOUT1) can be updated simultaneously at a rate of 250 kS/s per channel. Each output can be updated at a rate of 250 kS/s. The output range is fixed at  $\pm 10$  V. The outputs default to 0 V at power up, or when a reset command is issued to the device.

Analog output operations can be paced by the internal clock or by an external clock (**OCLKI** – refer to Clock I/O on page 13). They can be initiated by a digital trigger (*Digital triggering* on page 13) or a pattern trigger (*Pattern triggering* on page 13).

Refer to *Synchronous I/O – mixing analog, digital, and counter scanning* on page 12 for information on running analog output scans at the same time as other subsystem scans.

## Digital I/O

You can connect four digital I/O lines to **DIO0** through **DIO3**. Each digital channel is individually configurable for input or output. During initial power on or reset, the digital pins are set for input.

The digital I/O terminals can detect the state of any TTL-level input. Refer to the schematic shown in Figure 5.

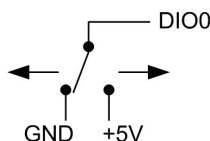


Figure 5. Schematic showing switch detection by digital channel DIO0

If you set the switch to the +5 V input, DIO0 reads TRUE (1). When set to GND, DIO0 reads FALSE (0).

## Digital input scanning

Digital input operations can be paced by the internal clock or by an external clock (**ICLKI** – refer to *Clock I/O* on page 13). They can be initiated by a digital trigger (*Digital triggering* on page 13) or a pattern trigger (*Pattern triggering* on page 13).

If no analog inputs are being scanned, the digital inputs can sustain rates up to 200 kHz. Digital input ports can also be read asynchronously before, during, or after an analog input scan.

Refer to *Synchronous I/O – mixing analog, digital, and counter scanning* on page 12 for information on running digital input scans at the same time as other subsystem scans.

## Pull-up/down configuration

All digital I/O lines are pulled down to 0 V (LO) with a 47 k $\Omega$  resistor (default). You can change the pull-up/down configuration using the internal jumper labeled **DIO**. You must remove the device housing to access the jumper on the circuit board.

To set the jumper for pull-up or pull-down, complete the following steps.

1. Unplug the device from the computer.
2. Turn the device over and rest the top of the housing on a flat, stable surface.

**Caution!** The discharge of static electricity can damage some electronic components. Before removing the RedLab 1808 from its housing, ground yourself using a wrist strap or touch the computer chassis or other grounded object to eliminate any stored static charge.

3. Remove the rubber fee from the bottom of the device, and the four screws using a #1 Philips head screwdriver.
4. Hold both the top and bottom sections together, turn the device over and rest it on the surface, then carefully remove the top section of the case to expose the circuit board.

Figure 6 shows the location of the **DIO** jumper on the circuit board.

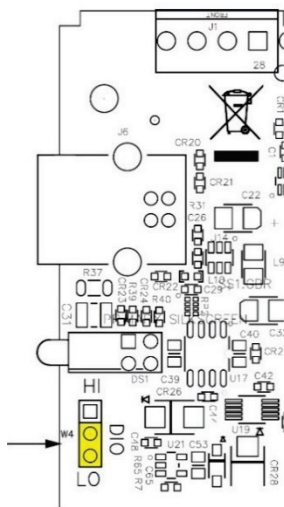


Figure 6. Pull-up/down jumper location

5. Configure the **DIO** jumper for pull-up or pull-down, as shown in Figure 7.

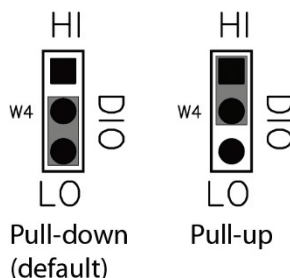


Figure 7. Pull-up/down jumper configuration

6. Replace the top section of the housing, and fasten it to the bottom section with the four screws.

## Counter input

Counter inputs can be read asynchronously under program control, or synchronously as part of a digital scan group.

The **CTR0** and **CTR1** terminals are 32-bit general-purpose counters that can accept frequency inputs up to 50 MHz.

The RedLab 1808 supports the following counter input modes:

- Totalize
- Period measurement
- Pulse-width measurement

Counter input modes are programmable with software. Each mode supports additional counter operation options.

Typically, when data is acquired with no counter operation options set, the count of each counter channel is set to 0 and latched at the beginning of the acquisition.

When counter options are set the counters can concurrently monitor time periods, frequencies, pulses, and other event-driven incremental occurrences directly from pulse-generators, limit switches, proximity switches, and magnetic pick-ups.

Counter input operations can be paced by the internal clock or by an external clock (**ICLKI** – refer to *Clock I/O* on page 13). They can be initiated by a digital trigger (*Digital triggering* on page 13) or a pattern trigger (*Pattern triggering* on page 13).

Refer to *Synchronous I/O – mixing analog, digital, and counter scanning* on page 12 for information on running counter input scans at the same time as other subsystem scans.

## Totalize counter mode

The RedLab 1808 can be used as a high-speed pulse counter for general counting applications. The internal counter increments when the TTL levels transition from low to high or from high to low.

Each option supported in Totalize mode is explained in following table:

Totalize counter mode options

| Counter option | Description                                                                                                                                                                                                                                                                             |
|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Clear on read  | The counter is cleared after each read (synchronous or asynchronous). The value of the counter before it was cleared is latched and returned.                                                                                                                                           |
| Range limit    | When counting up: The counter rolls over to MINLIMIT (or stops if Non-recycle is set) when the maximum count (specified by the MAXLIMIT value) is reached.<br>When counting down: The counter counts down to MINLIMIT and then rolls over to MAXLIMIT (or stops if Non-recycle is set). |
| Non-recycle    | The counter stops if a count overflow or underflow occurs (or, if Range limit is set, the MAXLIMIT or MINLIMIT value is reached). Counting resumes if direction is reversed or the counter is reloaded.                                                                                 |

## Period measurement mode

Use period mode to measure the period of a signal at a counter channel's input. You can measure x1, x10, x100 or x1000 periods for 32-bit values. Four resolutions are available — 20 ns, 200 ns, 2000 ns, or 20,000 ns. All period measurement mode options are software-selectable. The 100 MHz system clock is used as the timing source. Periods from sub-microsecond to many seconds can be measured.

## Pulse width measurement mode

Use pulse width mode to measure the time from the rising edge to the falling edge, or vice versa, on a signal on a counter input. Four resolutions are available — 20 ns, 200 ns, 2000 ns, or 20,000 ns. All pulse width measurement mode options are software selectable. The 100 MHz system clock is used as the timing source. Pulse widths from sub-microsecond to many seconds can be measured.

## Quadrature encoder input

The RedLab 1808 can simultaneously decode signals from up to two encoders. Quadrature encoders, 50 MHz maximum pulse frequency, and X1, X2, and X4 count modes are supported.

The RedLab 1808 provides A, B, and Z inputs – ENCxA, ENCxB, and ENCxZ – for each connected encoder. A typical encoder generates the A and B signals at a 90° phase shift with respect to each other. These signals are used to determine system position (counts), velocity (counts per second), and direction of travel or rotation. The Z signal can be programmed to latch the current count or reload the counter with the MINLIMIT value (counting up) or the MAXLIMIT value (counting down).

The Z signal may be used to establish an absolute reference position within one count of the encoder travel or rotation. This signal can be used to reload the position counter, which is useful at system startup when the incremental encoder cannot determine the starting position.

Encoder input operations can be paced by the internal clock or by an external clock (**ICLKI** – refer to *Clock I/O* on page 13). They can be initiated by a digital trigger (*Digital triggering* on page 13) or a pattern trigger (*Pattern triggering* on page 13).

Refer to *Synchronous I/O – mixing analog, digital, and counter scanning* on page 12 for information on running quadrature encoder scans at the same time as other subsystem scans.

Each supported quadrature encoder option is explained in following table:

## Quadrature encoder options

| Encoder option | Description                                                                                                                                                                                                                                                                                                                                                      |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Count mode     | Select X1, X2, or X4. Count modes provide different levels of accuracy with respect to the encoder position. <ul style="list-style-type: none"> <li>■ X1: counts rising edges on input A.</li> <li>■ X2: counts rising edges and falling edges on input A.</li> <li>■ X4: count rising and falling edges on both inputs A and B.</li> </ul>                      |
| Range limit    | When counting up: The counter stops when the maximum count (specified by the MAXLIMIT value) is reached. Counting resumes if direction is reversed or the counter is cleared.<br>When counting down: The counter stops when the minimum count (specified by the MINLIMIT value) is reached. Counting resumes if direction is reversed or the counter is cleared. |

Quadrature encoder options that are specific to the Z signal (ENCxZ) are explained in following table.

## Z input quadrature encoder options ( )

| Counter mode | Description                                                   |
|--------------|---------------------------------------------------------------|
| Clear on Z   | The counter is cleared by the Z signal.                       |
| Latching     | Latching mode allows the count to be latched by the Z signal. |

## Timer output

You can use **TMR0** through **TMR1** as 32-bit timer outputs. Each timer can generate a programmable width pulse of up to 100 MHz.

The timer output rate and pulse width can be updated asynchronously at any time, however, doing so results in a pulse stream that is not seamless.

The following timer output options are software-selectable:

- pulse frequency
- duty cycle (pulse width divided by the pulse period)
- number of pulses to generate
- time delay before starting the timer output after it is enabled
- idle state of the output (idle high or idle low)

The time delay can range from 0 seconds to 42.94 seconds.

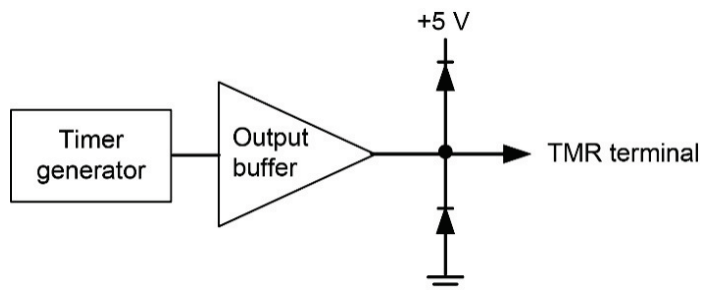


Figure 8. RedLab 1808 PWM timer channel

Timer output operations can be paced by the internal clock or by an external clock (**OCLKI** – refer to *Clock I/O* on page 13). They can be initiated by a digital trigger (*Digital triggering* on page 13).

## Synchronous I/O – mixing analog, digital, and counter scanning

The RedLab 1808 can read analog, digital, and counter inputs, and generate up to two analog outputs and one digital pattern output at the same time. Digital and counter inputs do not affect the overall A/D rate because these inputs use no time slot in the scanning sequencer.

For example, one analog input channel can be scanned at the full 50 kS/s A/D rate along with digital and counter input channels. Each analog channel can have a different gain, and counter and digital channels do not need additional scanning bandwidth as long as there is at least one analog channel in the scan group. Digital input channel sampling is done during the *dead time* of the scan period when no analog sampling is being done.

## Clock I/O

The RedLab 1808 provides one external clock input (**ICLKI**) and one clock output (**ICLKO**) for input operations.

- Connect an external clock signal to **ICLKI**.
- The pacer clock is available at **ICLKO**.

The RedLab 1808 provides one external clock input (**OCLKI**) and one clock output (**OCLKO**) for output operations.

- Connect an external clock signal to **OCLKI**.
- The pacer clock is available at **OCLKO**.

## Digital triggering

The **ITRIG** (for triggering input operations) and **OTRIG** (for triggering output operations) terminals are external digital trigger inputs. The trigger mode is software-selectable for edge or level sensitive. Edge sensitive mode is selectable for rising or falling. Level sensitive mode is selectable for high or low.

## Pattern triggering

You can also start an input or output scan with a digital pattern trigger using DIO0 – DIO3. The pattern represents the state of up to four bits on the port.

You specify the pattern and the trigger type with software. Supported trigger types are Above Pattern, Below Pattern, Equal Pattern, and Not Equal Pattern. The scan begins when the trigger conditions are met.

The base clock is fixed at 100 MHz (10 ns). The trigger pattern must be held for five base clock cycles (50 ns) to ensure that it is properly detected. The trigger latency is 1 scan clock period + 8 base clock cycles (80 ns).

### Mask option

Use a bitmask to specify which bits to include or exclude from the pattern to detect. To include a bit in the pattern, sets its value to 1. To exclude a bit from the pattern, sets its value to 0. Refer to the pattern and mask values shown in Figure 9 and Figure 10.

In Figure 9 all mask bits are set to 1, so all of the bits are included in the pattern to detect.

|         |            |     |
|---------|------------|-----|
|         | Bit        | Bit |
|         | 3          | 0   |
| Pattern | 1010       |     |
| Mask    | 1111 (AND) |     |
|         | 1010       |     |

Figure 9. Trigger mask with all bits included

In Figure 10 all mask bits are excluded except bit 3. The result of this operation is that only bit 3 is included in the pattern to detect.

|         |            |     |
|---------|------------|-----|
|         | Bit        | Bit |
|         | 3          | 0   |
| Pattern | 1010       |     |
| Mask    | 1000 (AND) |     |
|         | 1000       |     |

Figure 10. Trigger mask with some bits excluded

## Ground

The analog ground (**AGND**) terminals provide a common ground for all analog channels.

The digital ground (**GND**) terminals provide a common ground for the digital, trigger, counter, and encoder terminals.

## Power output

The **+VO** terminal can output up to 10 mA maximum. You can use this terminal to supply power to external devices or circuitry.

## Mechanical drawings

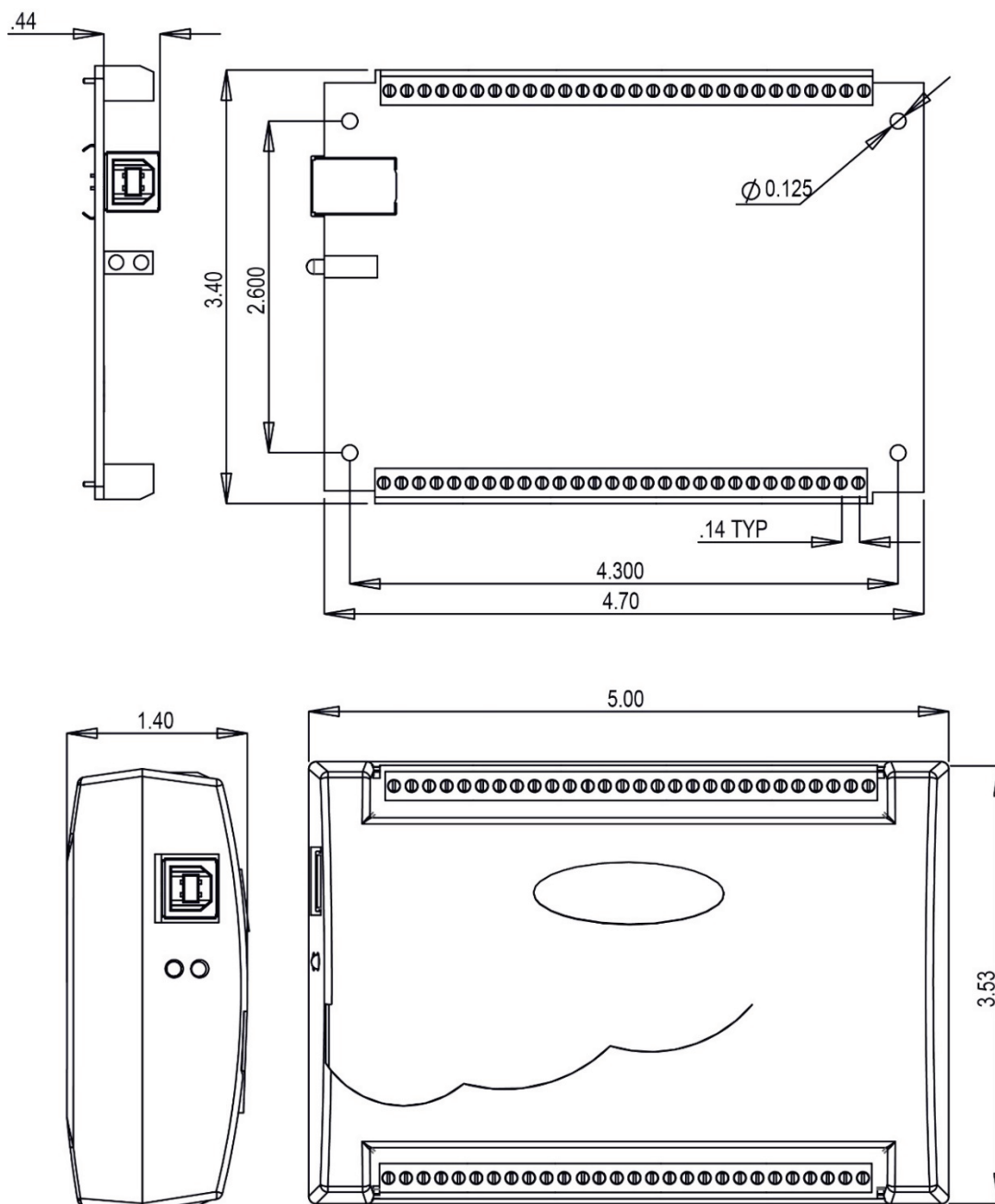


Figure 11. RedLab 1808 circuit board (top) and enclosure dimensions

# Specifications

All specifications are subject to change without notice.

Typical for 25 °C unless otherwise specified.

Specifications in *italic text* are guaranteed by design.

## Analog input

Table 1. General analog input specifications

| Parameter                         | Condition                                            | Specification                                                                                                                                                                   |
|-----------------------------------|------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| A/D converter type                |                                                      | Simultaneous                                                                                                                                                                    |
| ADC resolution                    |                                                      | 18 bits                                                                                                                                                                         |
| Number of channels                |                                                      | 8 differential (DIFF), 8 single-ended (SE); software-selectable per-channel for SE or DIFF                                                                                      |
| Input voltage range               |                                                      | $\pm 10\text{ V}$ , $\pm 5\text{ V}$ , $0\text{ V}$ to $10\text{ V}$ , $0\text{ V}$ to $5\text{ V}$<br>Software-selectable per channel                                          |
| <i>Absolute max input voltage</i> | <i>CHx relative to AGND</i>                          | <ul style="list-style-type: none"> <li>■ <math>\pm 25\text{ V max (power on)}</math></li> <li>■ <math>\pm 15\text{ V max (power off)}</math></li> </ul>                         |
| <i>Input impedance</i>            |                                                      | <ul style="list-style-type: none"> <li>■ <math>&gt; 1\text{ G}\Omega\text{ (power on)}</math></li> <li>■ <math>1000\text{ }\Omega\text{ (power off)}</math></li> </ul>          |
| <i>Input bias current</i>         |                                                      | $\pm 50\text{ pA}$                                                                                                                                                              |
| Input bandwidth                   | All input ranges, small signal ( $-3\text{ dB}$ )    | 2.0 MHz                                                                                                                                                                         |
| <i>Input capacitance</i>          |                                                      | $50\text{ pF}$                                                                                                                                                                  |
| Common mode voltage range         | $\pm 10\text{ V}$ range                              | $\pm 10.1\text{ V}$                                                                                                                                                             |
|                                   | $\pm 5\text{ V}$ range                               | $\pm 10.1\text{ V}$                                                                                                                                                             |
|                                   | $0\text{ V}$ to $10\text{ V}$ range                  | $\pm 10.1\text{ V}$                                                                                                                                                             |
|                                   | $0\text{ V}$ to $5\text{ V}$ range                   | $\pm 10.1\text{ V}$                                                                                                                                                             |
| Common mode rejection ratio       | $f/N \leq 1\text{ kHz}$ , all input ranges           | 90 dB                                                                                                                                                                           |
| Crosstalk                         | $\pm 10\text{ V}$ , adjacent channels, DC to 100 kHz | $-95\text{ dB}$                                                                                                                                                                 |
| Input coupling                    |                                                      | DC                                                                                                                                                                              |
| Sample rate                       |                                                      | 0.023 Hz to 50 kHz; software-selectable                                                                                                                                         |
| Scan clock source                 |                                                      | Internal input scan clock or external input scan clock (ICLKI pin)                                                                                                              |
| Trigger source                    |                                                      | <ul style="list-style-type: none"> <li>■ ITRIG (see <i>External trigger on page 21</i>)</li> <li>■ Digital pattern detection (see <i>Pattern trigger on page 21</i>)</li> </ul> |
| Channel gain queue                | Up to 8 elements                                     | Software-selectable. Queue list may contain up to eight elements of unique, consecutive channels paired with any valid range.                                                   |
| Warm-up time                      |                                                      | 15 minutes min                                                                                                                                                                  |

## Accuracy

### Analog input DC voltage measurement accuracy

Table 2. DC accuracy components and specifications. All values are ( $\pm$ )

| Range       | Gain error<br>(% of reading) | Offset error<br>(mV) | INL error<br>(% of range) | Absolute<br>accuracy at<br>Full Scale<br>(mV) | Gain<br>temperature<br>coefficient<br>(% reading/ $^{\circ}$ C) | Offset<br>temperature<br>coefficient<br>( $\mu$ V/ $^{\circ}$ C) |
|-------------|------------------------------|----------------------|---------------------------|-----------------------------------------------|-----------------------------------------------------------------|------------------------------------------------------------------|
| $\pm 10$ V  | 0.020                        | 1.5                  | 0.00076                   | 3.576                                         | 0.00023                                                         | 4                                                                |
| $\pm 5$ V   | 0.020                        | 1.0                  | 0.00057                   | 2.028                                         | 0.00023                                                         | 4                                                                |
| 0 V to 10 V | 0.020                        | 1.5                  | 0.00028                   | 3.528                                         | 0.00023                                                         | 4                                                                |
| 0 V to 5 V  | 0.020                        | 1.0                  | 0.00014                   | 2.007                                         | 0.00023                                                         | 4                                                                |

### Dynamic performance

Table 3. Dynamic performance specifications

| Range       | Condition                                    | Specification |
|-------------|----------------------------------------------|---------------|
| $\pm 10$ V  | Signal-to-noise ratio (SNR)                  | 94 dB         |
|             | Signal-to-noise-and-distortion ratio (SINAD) | 94 dB         |
|             | Total harmonic distortion (THD)              | -108 dB       |
|             | Spurious free dynamic range (SFDR)           | 112 dB        |
|             | Effective number of bits (ENOB)              | 15.3 bits     |
| $\pm 5$ V   | SNR                                          | 91 dB         |
|             | SINAD                                        | 91 dB         |
|             | THD                                          | -105 dB       |
|             | SFDR                                         | 107 dB        |
|             | ENOB                                         | 14.8 bits     |
| 0 V to 10 V | SNR                                          | 87 dB         |
|             | SINAD                                        | 87 dB         |
|             | THD                                          | -104 dB       |
|             | SFDR                                         | 109 dB        |
|             | ENOB                                         | 14.5 bits     |
| 0 V to 5 V  | SNR                                          | 83 dB         |
|             | SINAD                                        | 83 dB         |
|             | THD                                          | -103 dB       |
|             | SFDR                                         | 103 dB        |
|             | ENOB                                         | 13.6 bits     |

### Noise performance

For the peak-to-peak noise distribution test, a differential input channel is connected to AGND at the input terminal block, and 32,000 samples are acquired at the maximum rate available at each setting.

Table 4. Noise performance specifications

| Range       | Counts | LSBrms |
|-------------|--------|--------|
| $\pm 10$ V  | 11.6   | 1.77   |
| $\pm 5$ V   | 18.0   | 2.73   |
| 0 V to 10 V | 23.3   | 3.54   |
| 0 V to 5 V  | 36.1   | 5.47   |



## Analog output

Table 5. Analog output specifications

| Parameter                       | Condition                                                                                 | Specification                                                                                                                                                                   |
|---------------------------------|-------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Number of channels              |                                                                                           | 2                                                                                                                                                                               |
| Resolution                      |                                                                                           | 16 bits                                                                                                                                                                         |
| Output ranges                   | Calibrated                                                                                | $\pm 10$ V                                                                                                                                                                      |
| Output transient                | Host computer is reset, powered on, suspended, or a reset command is issued to the device | Duration: 5 ms<br>Amplitude: 2 V p-p                                                                                                                                            |
|                                 | Powered off from 0 V output                                                               | Duration: 20 ms<br>Amplitude: 5 V p-p                                                                                                                                           |
| Differential non-linearity      |                                                                                           | $\pm 0.25$ LSB typ<br>$\pm 1$ LSB max                                                                                                                                           |
| Output current                  | AOUTx pins                                                                                | $\pm 3.5$ mA max                                                                                                                                                                |
| Output short-circuit protection | Single AOUTx channel connected to AGND                                                    | Unlimited duration                                                                                                                                                              |
| Output coupling                 |                                                                                           | DC                                                                                                                                                                              |
| Power on and reset state        |                                                                                           | DACs cleared to zero-scale: 0 V, $\pm 50$ mV                                                                                                                                    |
| Output noise                    |                                                                                           | 100 $\mu$ Vrms                                                                                                                                                                  |
| Trigger source                  |                                                                                           | <ul style="list-style-type: none"> <li>■ OTRIG (see <i>External trigger</i> on page 21)</li> <li>■ Digital pattern detection (see <i>Pattern trigger</i> on page 21)</li> </ul> |
| Scan clock source               |                                                                                           | Internal output scan clock or external output scan clock (OCLKI pin)                                                                                                            |
| Output update rate              |                                                                                           | 0.023 Hz to 125 kHz per channel                                                                                                                                                 |
| <i>Slew rate</i>                |                                                                                           | 15 V/ $\mu$ S                                                                                                                                                                   |
| Throughput                      | Software paced                                                                            | 33 S/s to 8,000 S/s typ, system-dependent                                                                                                                                       |
|                                 | Hardware paced                                                                            | 250 kS/s max, system-dependent                                                                                                                                                  |

**Note 1:** Leave unused AOUTx output channels disconnected.

**Note 2:** AOUTx defaults to 0 V whenever the host computer is reset, powered on, suspended, or a reset command is issued to the device.

Table 6. Calibrated absolute accuracy specifications

| Range      | Absolute accuracy ( $\pm$ LSB) |
|------------|--------------------------------|
| $\pm 10$ V | 16                             |

Table 7. Calibrated absolute accuracy components specifications

| Range      | % of reading | Offset ( $\pm$ mV) | Offset tempco ( $\mu$ V/ $^{\circ}$ C) | Gain tempco (ppm of range/ $^{\circ}$ C) |
|------------|--------------|--------------------|----------------------------------------|------------------------------------------|
| $\pm 10$ V | 0.0183       | 1.831              | 4.7                                    | 9.4                                      |

Table 8. Relative accuracy specifications ( $\pm$ LSB)

| Range      | Relative accuracy (INL) |
|------------|-------------------------|
| $\pm 10$ V | 1.0                     |

## Analog input/output calibration

Table 9. Analog I/O calibration specifications

| Parameter            | Specification              |
|----------------------|----------------------------|
| Warm-up time         | 15 minutes recommended min |
| Calibration method   | Factory calibration        |
| Calibration interval | 1 year                     |

## Digital input/output

Table 10. Digital I/O specifications

| Parameter                                              | Specification                                                                                                                                                                                                                        |
|--------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Digital type                                           | CMOS                                                                                                                                                                                                                                 |
| Number of I/O                                          | 4                                                                                                                                                                                                                                    |
| Configuration                                          | Each bit may be configured as input (power on default) or output                                                                                                                                                                     |
| Pull-up configuration                                  | The port has 47 k $\Omega$ resistors configurable as pull-up or pull-down (default) via internal jumper (DIO).                                                                                                                       |
| Digital I/O transfer rate (system-paced, asynchronous) | 33 to 8,000 port reads/writes or single bit reads/writes per second typ, system dependent.                                                                                                                                           |
| Digital I/O transfer rate (synchronous)                | 0.023 Hz to 50 kHz input, 125 kHz output, based on the internal clock speed of 100 MHz                                                                                                                                               |
| Scan clock source for input                            | Internal input scan clock or external input scan clock (ICLKI pin)                                                                                                                                                                   |
| Scan clock source for output                           | Internal output scan clock or external output scan clock (OCLKI pin)                                                                                                                                                                 |
| Trigger source                                         | <ul style="list-style-type: none"> <li>■ ITRIG for inputs, OTRIG for outputs (see <i>External trigger</i> on page 21)</li> <li>■ Digital pattern detection for inputs and outputs (see <i>Pattern trigger</i> on page 21)</li> </ul> |
| Input high voltage                                     | 2.0 V min<br>5.5 V absolute max                                                                                                                                                                                                      |
| Input low voltage                                      | 0.8 V max<br>−0.5 V absolute min<br>0 V recommended min                                                                                                                                                                              |
| Output high voltage                                    | 4.4 V min (IOH = −50 $\mu$ A)<br>3.76 V min (IOH = −2.5 mA)                                                                                                                                                                          |
| Output low voltage                                     | 0.1 V max (IOL = 50 $\mu$ A)<br>0.44 V max (IOL = 2.5 mA)                                                                                                                                                                            |
| Output current                                         | ±2.5 mA max                                                                                                                                                                                                                          |

## Counter

Table 11. Counter specifications

| Parameter                     | Specification                                                                                                                                                                   |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Terminal names                | CTR0, CTR1                                                                                                                                                                      |
| Number of channels            | 2 channels                                                                                                                                                                      |
| Resolution                    | 32-bit                                                                                                                                                                          |
| Counter type                  | FPGA                                                                                                                                                                            |
| Counter input modes           | Totalize, Pulse width, Period                                                                                                                                                   |
| Input type                    | Schmitt trigger, 33 $\Omega$ series resistor, 47 k $\Omega$ pull-down to ground                                                                                                 |
| Input source                  | CTR0<br>CTR1                                                                                                                                                                    |
| Scan clock source             | Internal input scan clock or external input scan clock (ICLKI pin)                                                                                                              |
| Trigger source                | <ul style="list-style-type: none"> <li>■ ITRIG (see <i>External trigger</i> on page 21)</li> <li>■ Digital pattern detection (see <i>Pattern trigger</i> on page 21)</li> </ul> |
| Counter read clock            | Internal or external input scan clock up to 50 kHz                                                                                                                              |
| Period/pulse width resolution | 20 ns, 200 ns, 2 $\mu$ s or 20 $\mu$ s; software-selectable                                                                                                                     |
| Input high voltage            | 2.2 V min, 5.5 V max                                                                                                                                                            |
| Input low voltage             | 1.5 V max, -0.5 V min                                                                                                                                                           |
| Schmitt trigger hysteresis    | 0.4 V min, 1.2 V max                                                                                                                                                            |
| Input frequency               | 50 MHz, max                                                                                                                                                                     |
| Schmitt trigger hysteresis    | 0.76 V typ<br>0.4 V min<br>1.2 V max                                                                                                                                            |
| Input high voltage threshold  | 1.74 V typ<br>1.3 V min<br>2.2 V max                                                                                                                                            |
| Input low voltage threshold   | 0.98 V typ<br>0.6 V min<br>1.5 V max                                                                                                                                            |
| Input low voltage limit       | -0.5 V absolute min<br>0 V recommended min                                                                                                                                      |

## Quadrature inputs

Table 12. Quadrature input specifications

| Parameter                      | Specification                                                                                                                                                                   |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Terminal names                 | ENC0A, ENC0B, ENC0Z; ENC1A, ENC1B, ENC1Z                                                                                                                                        |
| Number of encoders             | 2                                                                                                                                                                               |
| Signals per encoder            | A, B and Z                                                                                                                                                                      |
| Resolution                     | 20 ns                                                                                                                                                                           |
| Maximum frequency              | 50 MHz                                                                                                                                                                          |
| Minimum pulse width            | 10 ns                                                                                                                                                                           |
| De-bounce function             | None                                                                                                                                                                            |
| Scan clock source              | Internal input scan clock or external input scan clock (ICLKI pin)                                                                                                              |
| Trigger source                 | <ul style="list-style-type: none"> <li>■ ITRIG (see <i>External trigger</i> on page 21)</li> <li>■ Digital pattern detection (see <i>Pattern trigger</i> on page 21)</li> </ul> |
| Input high voltage             | 2.2 V min, 5.5 V max                                                                                                                                                            |
| Input low voltage              | 1.5 V max, -0.5 V min                                                                                                                                                           |
| Absolute maximum input voltage | 5.5 V                                                                                                                                                                           |

## Timer

Table 13. Timer specifications

| Parameter                | Specification                                                                 |
|--------------------------|-------------------------------------------------------------------------------|
| Terminal name            | TMR0, TMR1                                                                    |
| Timer type               | PWM output with count, period, delay, and pulse width registers               |
| Output value             | Default state is idle low with pulses high, software-selectable output invert |
| Trigger source           | OTRIG (see <i>External trigger</i> on page 21)                                |
| Internal clock frequency | 100 MHz                                                                       |
| Register widths          | 32-bit                                                                        |
| High pulse width         | 10 ns min                                                                     |
| Low pulse width          | 10 ns min                                                                     |
| Output high voltage      | 4.4 V min (IOH = -50 $\mu$ A)<br>3.76 V min (IOH = -2.5 mA)                   |
| Output low voltage       | 0.1 V max (IOL = 50 $\mu$ A)<br>0.44 V max (IOL = 2.5 mA)                     |
| Output current           | $\pm$ 2.5 mA max                                                              |

## External clock input/output

Table 14. External clock I/O specifications

| Parameter                  | Specification                                                                                                                                                                               |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Terminal names             | ICLKI, ICLKO<br>OCLKI, OCLKO                                                                                                                                                                |
| Terminal types             | xCLKI: Input, active on rising edge<br>xCLKO: Output, power on default is 0 V, active on rising edge                                                                                        |
| Terminal descriptions      | xCLKI: Receives sampling clock from external source<br>xCLKO: Outputs the internal input scan or internal output scan clock, or the pulse generated from xCLKI when in external clock mode. |
| Input clock rate           | 125 kHz max                                                                                                                                                                                 |
| Clock pulse width          | xCLKI: 400 ns min<br>xCLKO: 400 ns min                                                                                                                                                      |
| Input type                 | Schmitt trigger, 33 $\Omega$ series resistor, 47 k $\Omega$ pull-down to ground                                                                                                             |
| Schmitt trigger hysteresis | 0.4 V to 1.2 V                                                                                                                                                                              |
| Input high voltage         | 2.2 V min<br>5.5 V absolute max                                                                                                                                                             |
| Input low voltage          | 1.5 V max<br>-0.5 V absolute min<br>0 V recommended min                                                                                                                                     |
| Output high voltage        | 4.4 V min (IOH = -50 $\mu$ A)<br>3.76 V min (IOH = -2.5 mA)                                                                                                                                 |
| Output low voltage         | 0.1 V max (IOL = 50 $\mu$ A)<br>0.44 V max (IOL = 2.5 mA)                                                                                                                                   |
| Output current             | $\pm$ 2.5 mA max                                                                                                                                                                            |

## External trigger

Table 15. External trigger specifications

| Parameter                  | Specification                                                                                                                                  |
|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------|
| Trigger source             | ITRIG for inputs, OTRIG for outputs                                                                                                            |
| Trigger mode               | Software programmable for edge or level sensitive, rising or falling edge, high or low level. Power on default is edge sensitive, rising edge. |
| Trigger latency            | 1 $\mu$ s + 1 clock cycle max                                                                                                                  |
| Trigger pulse width        | 100 ns min                                                                                                                                     |
| Input type                 | Schmitt trigger, 33 $\Omega$ series resistor and 49.9 k $\Omega$ pull-down to ground                                                           |
| Schmitt trigger hysteresis | 0.4 V to 1.2 V                                                                                                                                 |
| Input high voltage         | 2.2 V min<br>5.5 V absolute max                                                                                                                |
| Input low voltage          | 1.5 V max<br>–0.5 V absolute min<br>0 V recommended min                                                                                        |

## Pattern trigger

Table 16. Pattern trigger specifications

| Parameter         | Specification                                                       |
|-------------------|---------------------------------------------------------------------|
| Trigger source    | DIO0 – DIO3                                                         |
| Trigger types     | Above pattern, Below pattern, Equal pattern, or Not equal pattern   |
| Trigger stability | Digital port must be stable for 50 ns to be recognized as a pattern |
| Trigger bit width | Up to 4, adjustable through bitmask                                 |
| Trigger latency   | Up to 1 scan period                                                 |

## Memory

Table 17. Memory specifications

| Parameter           | Specification                                              |
|---------------------|------------------------------------------------------------|
| Data FIFO           | 4 kS analog input/2 kS analog output                       |
| Non-volatile memory | 32 KB (28 KB firmware storage, 4 KB calibration/user data) |

## Power

Table 18. Power specifications

| Parameter                              | Condition                     | Specification           |
|----------------------------------------|-------------------------------|-------------------------|
| Supply current (Note 3)                | Quiescent current             | 305 mA                  |
| +VO user output voltage range (Note 4) | Available at connector pin 13 | 4.5 V min to 5.25 V max |
| +VO user output current                | Available at connector pin 13 | 10 mA max               |

**Note 3:** This is the total quiescent current requirement for the device that includes up to 10 mA for the status LED. This does not include any potential loading of the digital I/O bits, +VO terminal, or the AOuTx outputs.

**Note 4:** The +4.5 V min limit includes the +VO 10 mA load, it does not include any potential loading of the digital I/O bits or the AOuTx outputs.

## USB

Table 19. USB specifications

| Parameter            | Specification                                                                      |
|----------------------|------------------------------------------------------------------------------------|
| USB device type      | USB 2.0 (high-speed)                                                               |
| Device compatibility | USB 1.1, USB 2.0, USB 3.0                                                          |
| USB cable type       | A-B cable, UL type AWM 2725 or equivalent. (Min 24 AWG VBUS/GND, min 28 AWG D+/D-) |
| USB cable length     | 3 m (9.84 ft) max                                                                  |

## Environmental

Table 20. Environmental specifications

| Parameter                   | Specification                |
|-----------------------------|------------------------------|
| Operating temperature range | 0 °C to 55 °C max            |
| Storage temperature range   | –40 °C to 85 °C max          |
| Humidity                    | 0% to 90% non-condensing max |

## Mechanical

Table 21. Mechanical specifications

| Parameter              | Specification                                 |
|------------------------|-----------------------------------------------|
| Dimensions (L × W × H) | 127 × 89.9 × 35.6 mm (5.00 × 3.53 × 1.40 in.) |
| User connection length | 3 m (9.84 ft) max                             |

## Screw terminal connector

Table 22. Screw terminal connector specifications

| Parameter        | Specification    |
|------------------|------------------|
| Connector type   | Screw terminal   |
| Wire gauge range | 16 AWG to 30 AWG |

## Differential mode pinout

Table 23. 8-channel differential mode pinout

| Terminal |       |                          | Terminal |       |                   |
|----------|-------|--------------------------|----------|-------|-------------------|
| #        | Label | Use                      | #        | Label | Use               |
| 1        | CH0H  | AI channel 0 HI          | 29       | CH7L  | AI channel 7 LO   |
| 2        | CH0L  | AI channel 0 LO          | 30       | CH7H  | AI channel 7 HI   |
| 3        | AGND  | Analog ground            | 31       | AGND  | Analog ground     |
| 4        | CH1H  | AI channel 1 HI          | 32       | CH6L  | AI channel 6 LO   |
| 5        | CH1L  | AI channel 1 LO          | 33       | CH6H  | AI channel 6 HI   |
| 6        | AGND  | Analog ground            | 34       | AGND  | Analog ground     |
| 7        | CH2H  | AI channel 2 HI          | 35       | CH5L  | AI channel 5 LO   |
| 8        | CH2L  | AI channel 2 LO          | 36       | CH5H  | AI channel 5 HI   |
| 9        | AGND  | Analog ground            | 37       | AGND  | Analog ground     |
| 10       | CH3H  | AI channel 3 HI          | 38       | CH4L  | AI channel 4 LO   |
| 11       | CH3L  | AI channel 3 LO          | 39       | CH4H  | AI channel 4 HI   |
| 12       | AGND  | Analog ground            | 40       | AGND  | Analog ground     |
| 13       | +VO   | +5V power output         | 41       | AOUT0 | AO channel 0      |
| 14       | AGND  | Analog ground            | 42       | AOUT1 | AO channel 1      |
| 15       | GND   | Digital Ground           | 43       | AGND  | Analog ground     |
| 16       | TMR0  | Timer 0 output           | 44       | GND   | Digital Ground    |
| 17       | TMR1  | Timer 1 output           | 45       | DIO0  | DIO channel 0     |
| 18       | ICLK0 | Input scan clock output  | 46       | DIO1  | DIO channel 1     |
| 19       | OCLK0 | Output scan clock output | 47       | GND   | Digital Ground    |
| 20       | GND   | Digital ground           | 48       | DIO2  | DIO channel 2     |
| 21       | ICLKI | Input scan clock input   | 49       | DIO3  | DIO channel 3     |
| 22       | OCLKI | Output scan clock input  | 50       | GND   | Digital Ground    |
| 23       | ITRIG | Input Trigger            | 51       | CTR0  | Counter 0 input   |
| 24       | OTRIG | Output Trigger           | 52       | CTR1  | Counter 1 input   |
| 25       | GND   | Digital ground           | 53       | GND   | Digital ground    |
| 26       | ENC1A | Encoder 1 Input A        | 54       | ENC0A | Encoder 0 Input A |
| 27       | ENC1B | Encoder 1 Input B        | 55       | ENC0B | Encoder 0 Input B |
| 28       | ENC1Z | Encoder 1 Input Z        | 56       | ENC0Z | Encoder 0 Input Z |

## Single-ended mode pinout

Table 24. 16-channel single-ended mode pinout

| Terminal |       |                          | Terminal |       |                   |
|----------|-------|--------------------------|----------|-------|-------------------|
| #        | Label | Use                      | #        | Label | Use               |
| 1        | CH0H  | AI channel 0 HI          | 29       | NC    | No connection     |
| 2        | NC    | No connection            | 30       | CH7H  | AI channel 7 HI   |
| 3        | AGND  | Analog ground            | 31       | AGND  | Analog ground     |
| 4        | CH1H  | AI channel 1 HI          | 32       | NC    | No connection     |
| 5        | NC    | No connection            | 33       | CH6H  | AI channel 6 HI   |
| 6        | AGND  | Analog ground            | 34       | AGND  | Analog ground     |
| 7        | CH2H  | AI channel 2 HI          | 35       | NC    | No connection     |
| 8        | NC    | No connection            | 36       | CH5H  | AI channel 5 HI   |
| 9        | AGND  | Analog ground            | 37       | AGND  | Analog ground     |
| 10       | CH3H  | AI channel 3 HI          | 38       | NC    | No connection     |
| 11       | NC    | No connection            | 39       | CH4H  | AI channel 4 HI   |
| 12       | AGND  | Analog ground            | 40       | AGND  | Analog ground     |
| 13       | +VO   | +5V power output         | 41       | AOUT0 | AO channel 0      |
| 14       | AGND  | Analog ground            | 42       | AOUT1 | AO channel 1      |
| 15       | GND   | Digital Ground           | 43       | AGND  | Analog ground     |
| 16       | TMR0  | Timer 0 output           | 44       | GND   | Digital Ground    |
| 17       | TMR1  | Timer 1 output           | 45       | DIO0  | DIO channel 0     |
| 18       | ICLK0 | Input scan clock output  | 46       | DIO1  | DIO channel 1     |
| 19       | OCLK0 | Output scan clock output | 47       | GND   | Digital Ground    |
| 20       | GND   | Digital ground           | 48       | DIO2  | DIO channel 2     |
| 21       | ICLKI | Input scan clock input   | 49       | DIO3  | DIO channel 3     |
| 22       | OCLKI | Output scan clock input  | 50       | GND   | Digital Ground    |
| 23       | ITRIG | Input Trigger            | 51       | CTR0  | Counter 0 input   |
| 24       | OTRIG | Output Trigger           | 52       | CTR1  | Counter 1 input   |
| 25       | GND   | Digital ground           | 53       | GND   | Digital ground    |
| 26       | ENC1A | Encoder 1 Input A        | 54       | ENC0A | Encoder 0 Input A |
| 27       | ENC1B | Encoder 1 Input B        | 55       | ENC0B | Encoder 0 Input B |
| 28       | ENC1Z | Encoder 1 Input Z        | 56       | ENC0Z | Encoder 0 Input Z |



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