USB-6451 Specifications

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Contents

USB-6451 Specifications

Definitions

Warranted specifications describe the performance of a model under stated operating conditions and are covered by the model warranty.

Characteristics describe values that are relevant to the use of the model under stated operating conditions but are not covered by the model warranty.

- ***Typical*** specifications describe the performance met by a majority of models.
- ***Nominal*** specifications describe an attribute that is based on design, conformance testing, or supplemental testing.

Specifications are ***Typical*** unless otherwise noted.

Conditions

Specifications are valid at 25 °C unless otherwise noted.

USB-6451 AI Connector Pinout

Use the pinout to connect to analog input terminals on the USB-6451.

Figure 1. USB-6451 AI Connector Pinout

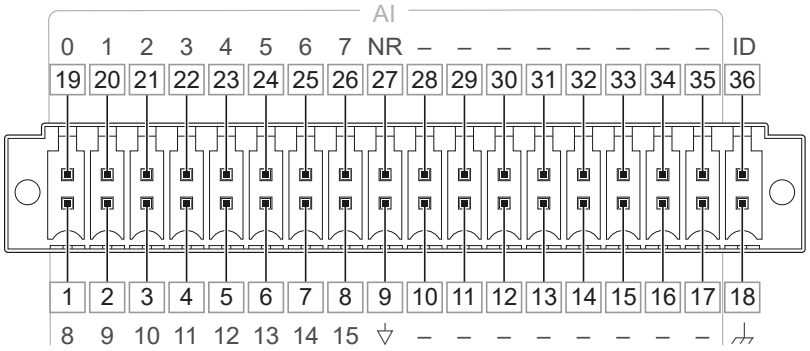


Table 1. USB-6451 AI Connector Pin Assignments

Pin	Signal
1	AI 8
2	AI 9
3	AI 10
4	AI 11
5	AI 12
6	AI 13
7	AI 14
8	AI 15
9	AI GND
10	No connect
11	No connect
12	No connect
13	No connect
14	No connect
15	No connect
16	No connect
17	No connect
18	CHSGND
19	AI 0
20	AI 1
21	AI 2
22	AI 3
23	AI 4
24	AI 5
25	AI 6
26	AI 7

Pin	Signal
27	NR (AI SENSE)
28	No connect
29	No connect
30	No connect
31	No connect
32	No connect
33	No connect
34	No connect
35	No connect
36	ID 0

Table 2. USB-6451 AI Connector Signal Descriptions

Signal	Function	Reference	Direction	Description
AI <0..7>	Analog input channels	Varies	Input	Supports differential or single-ended measurement modes. The default configuration is differential mode. In differential mode, these channels are the positive input for the differential pair. The negative input of the differential pair is located directly beneath the positive input. In single-ended

Signal	Function	Reference	Direction	Description
				mode, each signal is a separate analog input voltage channel. The ground reference in single-ended mode is configurable. In referenced single-ended (RSE) mode, AI GND is the reference for the voltage measurement. In non-referenced single-ended (NRSE) mode, the NR pin is the reference. **Note** You can configure the input mode per channel.
AI <8..15>	Analog input channels	Varies	Input	Supports single-ended measurements only. The default configuration is RSE mode. In RSE mode, AI GND is the reference for the voltage measurement. In NRSE mode, the NR

Signal	Function	Reference	Direction	Description
				pin is the reference. For differential measurements, refer to the descriptions for AI <0..7>.
AI GND	Analog input ground	—	—	The reference point for single-ended measurements in RSE mode and the bias current return point for differential measurements. AI GND, AO GND, D GND, and CHSGND are all connected internally.
NR (AI SENSE)	AI SENSE for NRSE mode	—	Input	The AI SENSE pin is labeled "NR" because it is used when the input terminal is configured to NRSE mode. In NRSE mode, AI SENSE acts as a remote sense of a reference voltage that can be at a different voltage potential than AI GND.
CHSGND	Chassis ground	—	—	Connects directly to the chassis ground of the USB-6451 enclosure. It can be

Signal	Function	Reference	Direction	Description
				used as a termination point for shielded cables to help improve measurement quality.
ID 0	—	—	—	This feature is not supported yet.

USB-6451 AO/DIO Connector Pinout

Use the pinout to connect to analog output and digital input/output terminals on the USB-6451.

Figure 2. USB-6451 AO/DIO Connector Pinout

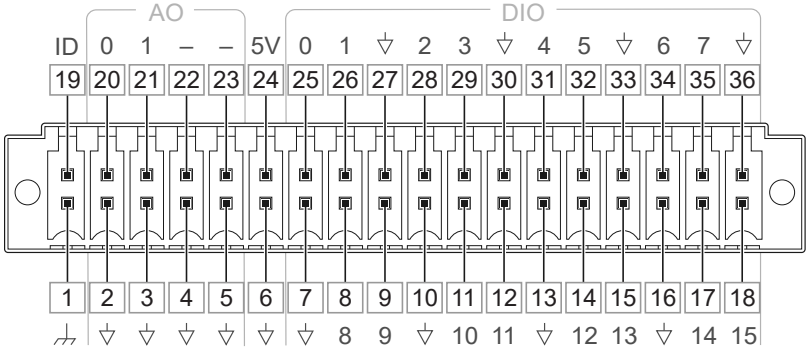


Table 3. USB-6451 AO/DIO Connector Pin Assignments

Pin	Signal
1	CHSGND
2	AO GND
3	AO GND
4	AO GND
5	AO GND
6	D GND
7	D GND
8	PFI 8/P0.8 (port0/line8)

Pin	Signal
9	PFI 9/P0.9 (port0/line9)
10	D GND
11	PFI 10/P0.10 (port0/line10)
12	PFI 11/P0.11 (port0/line11)
13	D GND
14	PFI 12/P0.12 (port0/line12)
15	PFI 13/P0.13 (port0/line13)
16	D GND
17	PFI 14/P0.14 (port0/line14)
18	PFI 15/P0.15 (port0/line15)
19	ID 1
20	AO 0
21	AO 1
22	No connect
23	No connect
24	+5 V
25	PFI 0/P0.0 (port0/line0)
26	PFI 1/P0.1 (port0/line1)
27	D GND
28	PFI 2/P0.2 (port0/line2)
29	PFI 3/P0.3 (port0/line3)
30	D GND
31	PFI 4/P0.4 (port0/line4)
32	PFI 5/P0.5 (port0/line5)
33	D GND
34	PFI 6/P0.6 (port0/line6)
35	PFI 7/P0.7 (port0/line7)

Pin	Signal
36	D GND

Table 4. USB-6451 AO/DIO Connector Signal Descriptions

Signal	Function	Reference	Direction	Description
AO <0..1>	Analog output channels	AO GND	Output	Supplies the voltage output of the AO channels.
AO GND	Analog output ground	—	—	AO GND is the reference for the AO channels. AI GND, AO GND, D GND, and CHSGND are all connected internally.
+5 V	+5 V power source	D GND	Output	Provides current limited +5 V power output that can be used to power external circuitry. Refer to the ***+5 V Power Source*** section for more information. Leave this pin open if you do not use it.
PFI <0..15>/P0.<0..15>	Port 0 digital I/O channels	D GND	Input or output	Digital channels that can be individually configured as input or output. These channels

Signal	Function	Reference	Direction	Description
				are referred to as port0/line0:15 in software when used as digital I/O. They are referred to as PFI 0:15 when used for other purposes, like timing I/O. Can also be individually configured for the following uses. • Digital I/O • Counter/ timer input • Counter/ timer output • External timing or trigger signal input for AI, AO, DI, DO, counter, or timers. • Timing or trigger signal output from AI, AO, DI, DO, counter, or timers.
D GND	Digital ground	—	—	Supplies the reference for the P0.<0..15> pins and +5 V pin. AI GND, AO GND, D

Signal	Function	Reference	Direction	Description
				GND, and CHSGND are all connected internally.
CHSGND	Chassis ground	—	—	Connects directly to the chassis ground of the USB-6451 enclosure. It can be used as a termination point for shielded cables to help improve measurement quality.
ID 1	—	—	—	This feature is not supported yet.

Related information:

- +5 V Power Source

Analog Input

Number of channels	16 single-ended or 8 differential
Number of ADC	8
Simultaneous sampling channels	Up to 8 channels

ADC resolution	20 bits
DNL	No missing codes guaranteed
INL	Refer to ***AI Absolute Accuracy***

Sample rate	
Simultaneous sampling	1 MS/s/ch for all 8 differential channels 1 MS/s/ch for up to 8 single-ended channels
Single-ended channel scan sampling[1]	500 kS/s per channel
Minimum	No minimum
Timing resolution	10 ns
Timing accuracy	50 ppm of sample rate

Input coupling	DC
Input range	±0.2 V

1. Pairs of single-ended channels are connected to a single ADC. (For example, AI0 and AI8, AI1 and AI9, etc.). When sampling any two single-ended channels connected to the same ADC, the channels are scanned in banks, and the maximum rate decreases to 500 kS/s/ch. In this case, AI0:7 are sampled simultaneously, then AI8:15 are sampled later after a delay controlled by the AIConv.Rate property.

	±2.5 V ±5 V ±10 V
Power on state	Differential Mode at 10 V Range

Maximum working voltage for analog inputs (signal + common mode)	
Input range ±2.5 V, ±5 V, ±10 V	±10.5 V to AI GND
Input range ±0.2 V	±3.5 V to AI GND

Table 5. Input Impedance

Device on	AI+ to AI GND	>10 GΩ in parallel with 35 pF
	AI- to AI GND	>10 GΩ in parallel with 35 pF
Device off	AI+ to AI GND	1,290 Ω
	AI- to AI GND	1,290 Ω

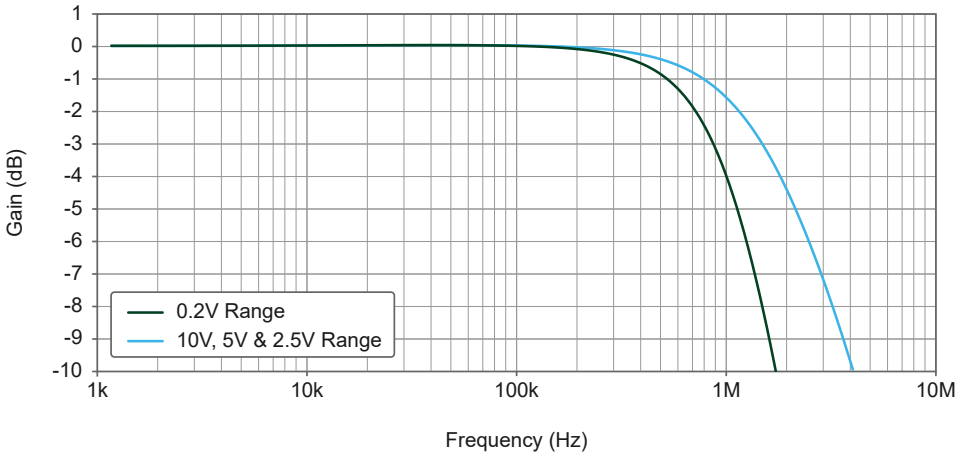
Input bias current	±10 pA typical ±2 nA maximum over full temperature range

Crosstalk (at 100 kHz)	
Differential channels	-75 dB

Single-ended channels	-63 dB

Small signal bandwidth (-3 dB)	
Input range ±2.5 V, ±5 V, ±10 V	1.3 MHz
Input range ±0.2 V	800 kHz

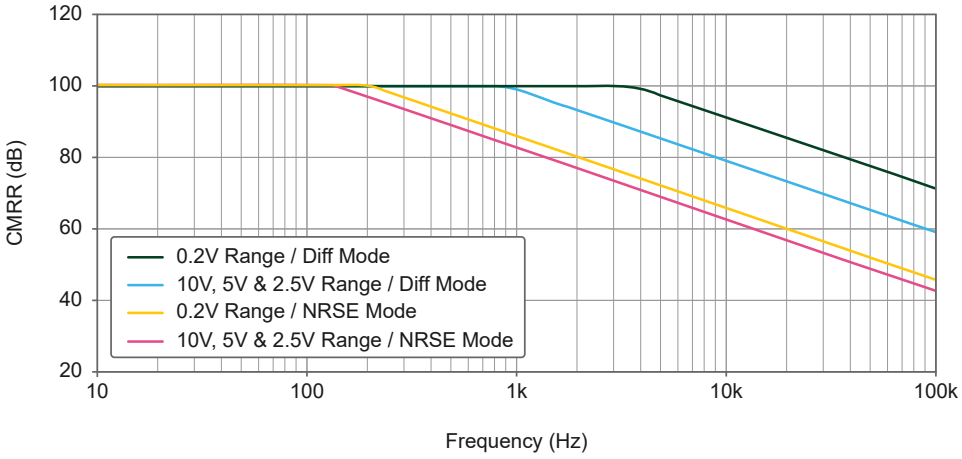
Figure 3. USB-6451 Small Signal Bandwidth versus Frequency



CMRR (DC to 60 Hz)[2]	
Differential mode	100 dB
Non-referenced single-ended (NRSE) mode	100 dB

2. CMRR is >90 dB on the ±0.2 V range when the common-mode voltage is above +2 V and >95 dB on the ±5 V range when the common-mode voltage is above +7 V.

Figure 4. USB-6451 CMRR versus Frequency



Input FIFO size	8,191 samples shared among channels used
Data transfers	USB Signal Stream, programmed I/O

Overvoltage protection for AI<0..15> and NR (AI Sense) pins	
Device on	±30 V for up to two AI pins
Device off	±20 V for up to two AI pins
Input current during overvoltage condition	±14 mA maximum per AI pin ±45 µA maximum per NR pin

Table 6. Settling Time to Accuracy for Single-Ended Scan Multi-Channel Measurements at Full Scale Step

Input Range	**±450 ppm**	**±90 ppm**	**±30 ppm**	**±15 ppm**	**±4 ppm**
±2.5 V, ±5 V, ±10 V	1.0 µs	2.7 µs	6.2 µs	11.0 µs	40 µs
±0.2 V	1.7 µs	2.1 µs	2.5 µs	4.0 µs	50 µs

Note The ***AI Absolute Accuracy*** table excludes the settling error from this Scan Mode measurement.

Note For applications that require a settling time greater than 10 µs, configure the AIConv.Rate property.

Figure 5. USB-6451 Settling Error versus Time for Different Source Impedances at 10 V, 5 V, and 2.5 V Input Ranges

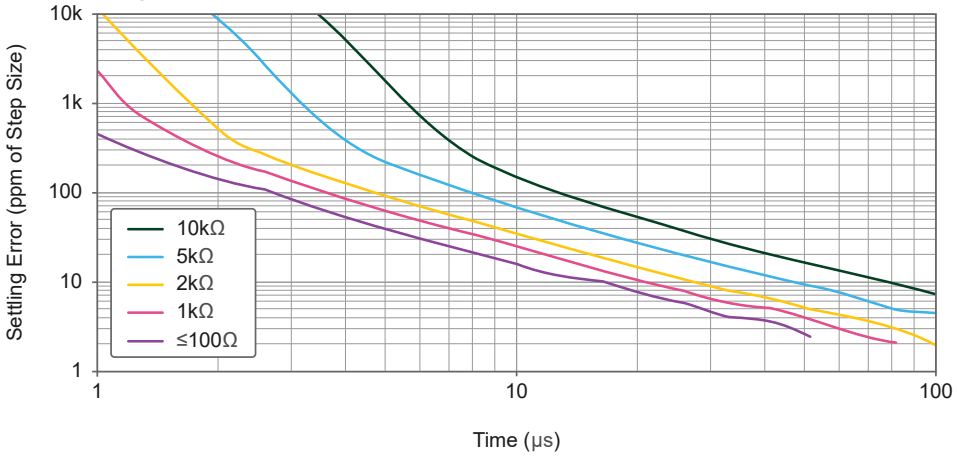


Figure 6. USB-6451 Settling Error versus Time for Different Source Impedances at the 0.2 V Input Range

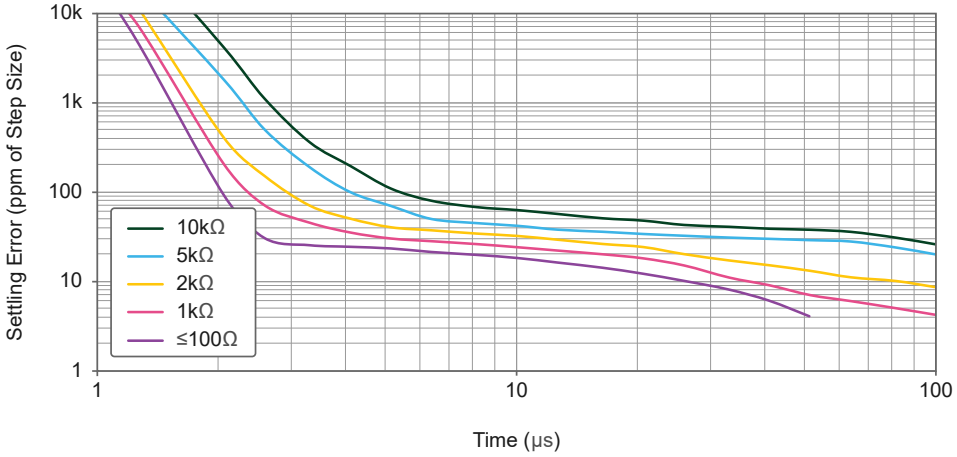


Table 7. Total Harmonic Distortion (THD) at 1 MSps

Input Level	Input Range	1 kHz	10 kHz	100 kHz
-1 dBFS	±10 V	-102 dBc	-82 dBc	-62 dBc
	±5 V	-106 dBc	-88 dBc	-68 dBc
	± 2.5 V	-106 dBc	-99 dBc	-79 dBc

Input Level	Input Range	1 kHz	10 kHz	100 kHz
	±0.2 V	-105 dBc	-97 dBc	-68 dBc
-10 dBFS	±10 V	-106 dBc	-92 dBc	-72 dBc
	±5 V	-106 dBc	-103 dBc	-84 dBc
	± 2.5 V	-103 dBc	-103 dBc	-83 dBc

AI Absolute Accuracy (Warranted)

Notice The input channels of the USB-6451 are sensitive to electromagnetic interference (EMI). As a result, you might experience reduced measurement accuracy or temporary performance degradation with cables routed through strong EMI environments. To ensure optimal performance, either avoid such environments, or carefully select and route cables or probes connected to the USB-6451.

Table 9. AI Absolute Accuracy

Nominal Range, Positive Full Scale (V)	Nominal Range, Negative Full Scale (V)	2 Years Residual Gain Error (ppm of Reading)	10 Years Residual Gain Error (ppm of Reading)	Gain Tempco (ppm of Range/°C)	Residual Offset Error (ppm of Range)	Offset Tempco (ppm of Range/°C)	Random Noise, σ (µV RMS)	2 Years Absolute Accuracy at Full Scale (µV)	10 Years Absolute Accuracy at Full Scale (µV)
10	-10	81	133	2	6	0.3	197	1,299	1,819
5	-5	86	138	2	9	0.6	138	692	952
2.5	-2.5	114	166	2	18	1.2	134	442	572
0.2	-0.2	152	204	16	96	9	22	63	74

Note Absolute accuracy at full scale on the analog input channels is determined using the following assumptions:

- ***Temp Change From Last External Cal*** = 10 °C
- ***Temp Change From Last Internal Cal*** = 1 °C
- ***Number of readings*** = 10,000
- ***Coverage Factor*** = 3σ

Note Accuracies listed are valid for up to 2 and 10 years from the device external calibration.

Reference Tempco	3 ppm/°C
INL error	10 ppm of range

AI Absolute Accuracy Equation

$$Absolute\ Accuracy = Reading * (Gain\ Error) + Range * (Offset\ Error) + Noise\ Uncertainty$$

- $Gain\ Error = Residual\ Gain\ Error + Gain\ Tempco * (Temp\ Change\ From\ Last\ Internal\ Cal) + Reference\ Tempco * (Temp\ Change\ From\ Last\ External\ Cal)$
- $Offset\ Error = Residual\ Offset\ Error + Offset\ Tempco * (Temp\ Change\ From\ Last\ Internal\ Cal) + INL\ Error$
- $Noise\ Uncertainty = \frac{Random\ Noise * 3}{\sqrt{10,000}}$

For a coverage factor of 3 σ and averaging 10,000 points

AI Absolute Accuracy Example

For example, on the 10 V range for 2 years calibration interval, the absolute accuracy at full scale is as follows:

- $Gain\ Error: 81\ ppm + 2\ ppm * 1 + 3\ ppm * 10 = 113\ ppm$
- $Offset\ Error: 6\ ppm + 0.3\ ppm * 1 + 10\ ppm = 16.3\ ppm$
- $Noise\ Uncertainty: \frac{197\ \mu V * 3}{\sqrt{10,000}} = 5.91\ \mu V$
- $Absolute\ Accuracy: 10\ V * (Gain\ Error) + 10\ V * (Offset\ Error) + Noise\ Uncertainty = 1,299\ \mu V$

Analog Output

Number of channels	2

DAC resolution	16 bits
DNL	±1 LSB
Monotonicity	16 bits guaranteed

Maximum update rate (simultaneous)	
All channels	250 kS/s
Timing accuracy	50 ppm of sample rate
Timing resolution	10 ns

Output range	±10 V
Output coupling	DC
Output impedance[3]	0.05 Ω
Output current drive	±2 mA
Overdrive protection during power on/off	±30 V

3. Output impedance excludes cabling impedance.

Overdrive current	2.8 mA
Power on state	Less than ±5 mV
Output FIFO size	16,383 samples shared among channels used
Data transfers	USB Signal Stream, programmed I/O
AO waveform modes	Non-periodic waveform Periodic waveform regeneration mode from onboard FIFO Periodic waveform regeneration from host buffer, including dynamic update
Settling time, full-scale step, 15 ppm (1 LSB)	25 µs with 50 pF load
Slew rate	8 V/µs

AO glitch	
Device power up or reset	±0.8 V peak for 8 ms
Device power down	±0.8 V peak for 16 ms
USB cable hot unplug	-2.8 V peak for 4 ms

Glitch energy mid-scale code transition	±5 mV for 5 µs
Crosstalk (at 10 kHz)	< -100 dB

AO Absolute Accuracy (Warranted)

Notice The output channels of the USB-6451 are sensitive to electromagnetic interference (EMI). As a result, you might experience reduced measurement accuracy or temporary performance degradation with cables routed through strong EMI environments. To ensure optimal performance, either avoid such environments, or carefully select and route cables or probes connected to the USB-6451.

Absolute accuracy at full-scale numbers is valid immediately following internal calibration and assumes the device is operating within 10 °C of the last external calibration.

Table 9. AO Absolute Accuracy

Nominal Range, Positive Full Scale (V)	Nominal Range, Negative Full Scale (V)	2 Years Residual Gain Error (ppm of Reading)	10 Years Residual Gain Error (ppm of Reading)	Gain Tempco (ppm of Range/°C)	Residual Offset Error (ppm of Range)	Offset Tempco (ppm of Range/°C)	2 Years Absolute Accuracy at Full Scale (µV)	10 Years Absolute Accuracy at Full Scale (µV)
10	-10	77	129	4	21	1	1,640	2,160

Note Accuracies listed are valid for up to 2 and 10 years from the device external calibration.

Reference Tempco	3 ppm/°C

INL error	31 ppm of range

AO Absolute Accuracy Equation

$$Absolute\ Accuracy = Output\ Value * (Gain\ Error) + Range * (Offset\ Error)$$

- $Gain\ Error = Residual\ Gain\ Error + Gain\ Tempco * (Temp\ Change\ From\ Last\ Internal\ Cal) + Reference\ Tempco * (Temp\ Change\ From\ Last\ External\ Cal)$
- $Offset\ Error = Residual\ Offset\ Error + Offset\ Tempco * (Temp\ Change\ From\ Last\ Internal\ Cal) + INL\ Error$

Digital I/O (PFI)

Number of channels	16
Capabilities	Static Digital I/O, Waveform Digital I/O, PFI, Counter, or Timer
Direction control	Each terminal can be programmed individually as input or output
Logic Family	5 V (LVCMOS)

Electrical Characteristics

Ground reference	D GND
Direction control	Program each as input or output individually
Pull-down resistor	47 kΩ

Input voltage protection	±20 V per line, up to two lines simultaneously

Notice Stresses beyond those listed under the Input voltage protection specification may cause permanent damage to the USB-6451.

Static Digital I/O Capabilities

Channel names in software	Port0/line0:15

Waveform Digital I/O Capabilities

Channel names in software	Port0/line0:15
Port/sample size	Up to 16 bits
Waveform generation (DO) FIFO	8,191 samples
Waveform acquisition (DI) FIFO	1,023 samples
DO or DI sample clock frequency	0 MHz to 10 MHz, system and bus activity dependent
Data transfers	USB Signal Stream, programmed I/O

PFI Functionality

Channel names in software	PFI0:15
Functionality	Timing input Timing output
Timing output sources	Many AI, AO, counter, DI, and DO timing signals

Recommended Operating Conditions

Output high current (I_{OH})	
DIO<0..15>	-10 mA maximum per channel

Output low current (I_{OL})	
DIO<0..15>	10 mA maximum per channel

Note The maximum output current is shared between all channels and the +5 V power source.

Table 10. Digital Input Logic Levels

Logic Family	**Input Low Voltage (V_{IL})**		**Input High Voltage (V_{IH})**	
	Minimum	**Maximum**	**Minimum**	**Maximum**
5.0 V	-0.5 V	1.46 V	3.66 V	5.5 V

Table 11. Digital Output Logic Level

Logic Family	Current	Output Low Voltage (V_{OL}) Maximum	Output High Voltage (V_{OH}) Minimum
5.0 V	4 mA	0.30 V	4.59 V

Digital I/O Characteristics

I_{IL} input low current (V_{IN} = 0 V)	-1 µA maximum
I_{IH} input low current (V_{IN} = 5 V)	110 µA maximum

Figure 7. I_{OH} versus V_{OH}, 5.0 V Logic Family

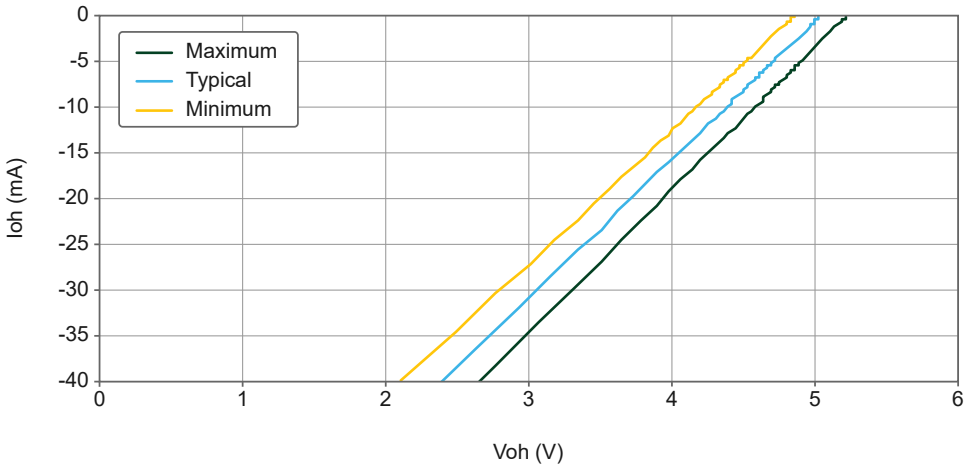
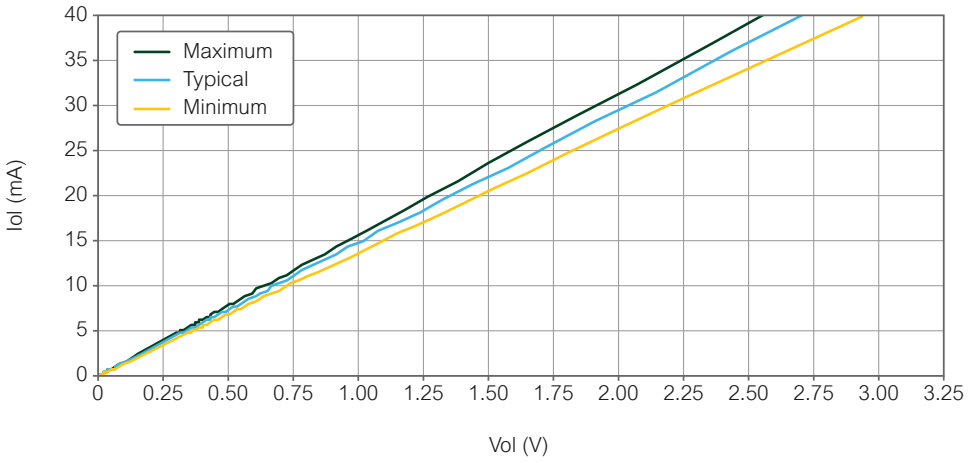


Figure 8. I_{OL} versus V_{OL}, 5.0 V Logic Family



General-Purpose Counters

Number of counters/timers	4
Resolution	32 bits
Counter measurements	Edge counting Pulse Pulse width Semi-period Period Two-edge separation
Position measurements	X1, X2, X4 quadrature encoding with Channel Z reloading Two-pulse encoding
Output applications	Pulse Pulse train Frequency division Equivalent time sampling
Internal base clocks	100 MHz 20 MHz 100 kHz

External base clock frequency	0 MHz to 25 MHz
Base clock accuracy	50 ppm
Inputs	Gate Source HW_Arm Aux A B Z Up_Down Sample Clock
Routing options for inputs	Any PFI, many internal signals
Data transfers	Programmed I/O

Frequency Generator

Number of channels	1
Base clocks	100 MHz 20 MHz

	100 kHz
Divisors	1 to 16
Base clock accuracy	50 ppm

Output can be available on any PFI terminal.

Bus Interface

USB compatibility	USB 3.0/USB 3.1 Gen 1/USB 3.2 Gen 1 SuperSpeed
USB Signal Stream	8, can be used for analog input, analog output, digital input, or digital output
USB connector	USB Type-C

+5 V Power Source

Voltage accuracy	No load	+4.87 V to +5.22 V
	Maximum current	+4.76 V to 5.17 V

Maximum load current[4]	
Connected to USB 3.0 SuperSpeed Type-A port with 4.5 W power	50 mA
Connected to USB 3.0 SuperSpeed Type-C port with ≥7.5 W power	280 mA

4. The USB-6451 will self-detect the power capability of USB host to configure the current limit. If the

Power on state	Always on (no user control)
Overdrive protection during power on/off	±30 V

Power Requirements

Caution The protection provided by the USB-6451 can be impaired if it is used in a manner not described in the ***USB-6451 User Manual***.

Do not connect the USB-6451 to a USB 2.0 or lower port. The USB-6451 requires more than 2.5 W to power on.

USB power rating	4.5 W (900 mA at nominal 5 V)
Power input mating connector	USB Type-C plug for power and data

Related information:

- USB-6451 User Manual

Current Limit

DIO and +5 V terminals combined[5]	Connected to USB 3.0 SuperSpeed Type-A port with 4.5 W power	50 mA
	Connected to USB 3.0 SuperSpeed Type-C port with ≥7.5 W power	280 mA

USB-6451 is at 280 mA limit, it will lower the current limit to 50 mA if there is overdrive or fault condition. The current limit will be reset back to the default 280 mA limit when the fault or load is removed.

Maximum Working Voltage

Maximum working voltage refers to the signal voltage plus the common-mode voltage.

Channel to earth	10.5 V, Measurement Category I

Measurement Category

This product is rated for Measurement Category I.

Caution Do not connect the product to signals or use for measurements within Measurement Categories II, III, or IV.

Remarque Ne pas connecter le produit à des signaux dans les catégories de mesure II, III ou IV et ne pas l'utiliser pour effectuer des mesures dans ces catégories.

Measurement Category I is for measurements performed on circuits not directly connected to the electrical distribution system referred to as MAINS voltage. MAINS is a hazardous live electrical supply system that powers equipment. This category is for measurements of voltages from specially protected secondary circuits. Such voltage measurements include signal levels, special equipment, limited-energy parts of equipment, circuits powered by regulated low-voltage sources, and electronics.

Note Measurement Categories CAT I and CAT O are equivalent. These test and measurement circuits are for other circuits not intended for direct connection to the MAINS building installations of Measurement Categories CAT II, CAT III, or CAT IV.

5. The USB-6451 will self-detect the power capability of the USB host to configure the current limit. If the USB-6451 is at 280 mA limit, it will lower the current limit to 50 mA if there is an overdrive or fault condition. The current limit will be reset back to the default 280 mA limit when the fault or load is removed.

Physical Characteristics

I/O connector	2x 36-position spring terminals
Dimensions	116.7 mm x 177.0 mm x 30.4 mm (4.59 in. x 6.97 in. x 1.20 in.)
Weight	590 g (1.30 lb)

Field Wiring Specifications

Use copper wiring for all connections unless otherwise stated.

Gauge	0.14 mm^2 to 1.5 mm^2 (26 AWG to 16 AWG) copper conductor wire
Wire strip length	10 mm (0.394 in.) of insulation stripped from the end
Temperature rating	-25 °C to 120 °C
Wires per terminal	One wire per spring terminal; two wires per spring terminal using a 2-wire ferrule

Ferrules	
Single ferrule, uninsulated	0.14 mm^2 to 1.5 mm^2 (26 AWG to 16 AWG)

	10 mm barrel length
Single ferrule, insulated	0.14 mm^2 to 1.0 mm^2 (26 AWG to 18 AWG) 12 mm barrel length
Two-wire ferrule, insulated	2x 0.34 mm^2 (22 AWG) 12 mm barrel length

Connector securement	
Securement type	Screw flanges
Torque for screw flanges	0.2 N · m (1.80 lb · in.)

Environmental Characteristics

Temperature	
Operating temperature	0 °C to 55 °C
Storage temperature	-20 °C to 70 °C

Humidity	
Operating humidity[6]	10% RH to 90% RH, noncondensing

6. The USB-6451 will perform at the full accuracy specification up to 90% RH operating humidity at ≤40 °C.

Storage humidity	5% RH to 95% RH, noncondensing

Pollution Degree	2
Maximum altitude	2,000 m

Shock and vibration	
Operating vibration	5 Hz to 500 Hz, 0.3 g RMS
Non-operating vibration	5 Hz to 500 Hz, 2.4 g RMS
Operating shock	30 g, half-sine, 11 ms pulse

Calibration

Recommended warm-up time	15 minutes
Recommended calibration interval	2 years