Model 7707 32-Channel Digital I/O Module

Instructions for use with DAQ6510

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Introduction

The Model 7707 32-Channel Digital I/O Module with 10-channel Differential Multiplexer offers ten channels of 2-pole or five channels of 4-pole multiplexer switching that can be configured as two independent banks of multiplexers. The 7707 also provides 32 digital input/output channels (four 8-bit ports) for I/O control. The 7707 connects to industry standard solid-state relays to switch up to 125 VA.

Figure 1: Model 7707

Item shipped may vary from model pictured here.

The 7707 includes the following features:

- 300 V, 1 A capacity; 60 W, 125 VA maximum (analog)
- 33 V, 100 mA capacity (digital)
- Digital outputs are short circuit protected
- Relay closures stored in onboard memory

The 7707 switching module can be used with the DAQ6510 Data Acquisition and Multimeter System.

NOTE

If you are using this switching module with the 2700, 2701, and 2750 instruments, please see *Model 7707 User's Guide*, Keithley Instruments document number PA-770.

Connection information

NOTE

The 7707 is shipped with plastic connector covers installed on the D-shell connectors. Each cover is secured to the connector by two screws. After removing a connector cover, retain it and the screws for future use. Any unused D-shell connector must have the connector cover installed.

The 7707 is supplied with one 50-pin female IDC ribbon cable connector and one 25-pin male IDC ribbon cable connector. These ribbon cable connectors mate to the D-shell connectors of the switching module.

⚠ WARNING

When using IDC ribbon cable connections on the DB-25 (analog inputs), do not exceed 42 V on any analog input in the test system (including the front panel inputs of the instrument). For higher voltage applications (up to 300 V), use wire rated for the application and add supplementary insulation to the wire harness, as shown in Solder cup cable connections (on page 13).

The DB-50 connector is used for digital I/O connections. Do not exceed 40 V on any digital terminal in the test system.

There are two connector kits that have connectors that can be used with the 7707:

- **Model 7790 ribbon cable adapter kit:** Contains one female DB-50, one male DB-50, and one male DB-25 IDC ribbon cable connector. The female DB-50 and the male DB-25 mate to the D-shell connectors on the 7707.
- **Model 7789 50/25-pin solder cup connector kit:** Contains one male DB-50 and one male DB-25 solder cup connector. The male DB-25 mates to the 25-pin D-shell on the 7707.

Simplified schematic

The following figure shows a simplified schematic diagram of the 7707 switching module. As shown, the 7707 has channels that are grouped into two banks of five channels (10 channels total). Backplane isolation is provided for each bank. The first bank contains channels 1 to 5, while the second bank contains channels 6 to 10. Each channel of the 10-channel multiplexer card is wired with separate inputs for HI/LO, providing fully isolated inputs.

NOTE

Although the 7707 relays are latching type (relays hold their state even after power has been removed), all relay states are set to open a few seconds after either a power cycle or an *RST command is issued.

Connections to DMM functions are provided through the card backplane connector for INPUT connections and SENSE (4-wire Ω) connections.

Channel 15 (2-wire/4-wire configuration), channel 16 (sense isolation), and channel 17 (input isolation) are automatically configured during normal channel operation. When channel 15 is closed, channels 1 to 5 are isolated from channels 6 to 10. When a 4-wire function is selected, the channels are paired as follows:

- CH1 and CH6
- CH2 and CH7
- CH3 and CH8
- CH4 and CH9
- CH5 and CH10

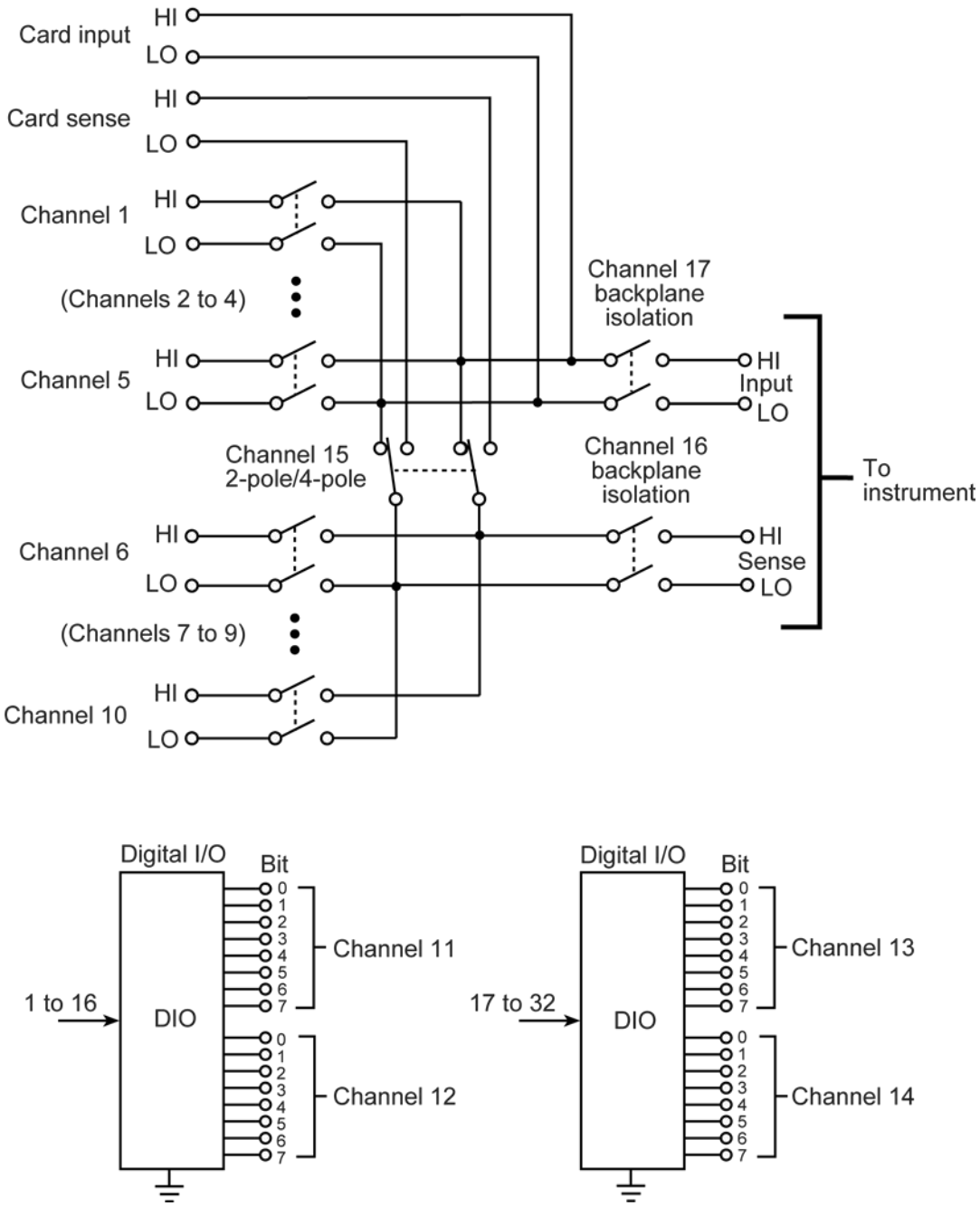
The 7707 has four digital input/output channels (11, 12, 13, and 14). Each I/O channel can be set as either a digital input port or a digital output port. Each port has eight lines (bits 0 to 7).

When an I/O channel is used as an input port, you can read the high or low state of each input line (bit). When an I/O channel is used as an output port, you can set each line high or low to control external circuitry.

NOTE

In the following schematic, channels 15 to 17 refer to the designations used for control and are not available channels.

Figure 2: Simplified schematic for the 7707



Installation

WARNING

Before operating an instrument with a switching module, verify that the switching module is properly installed and the mounting screws are tightly fastened. If the mounting screws are not properly connected, an electrical shock hazard may be present.

If you are installing a 7707 and a 7708, the 7707 must be installed in slot 1 and the 7708 in slot 2 to reduce measurement uncertainty. If you are installing two switching modules, it is easier to install one switching module into slot 2 first, then install the second switching module into slot 1.

NOTE

If you have a Keithley Instruments Model 2700, 2701, or 2750 instrument, you can use your existing switching module in the DAQ6510. Follow the instructions in your original equipment documentation to remove the module from the instrument, then use the following instructions to install it in the DAQ6510. You do not need to remove wiring to the module.

NOTE

For inexperienced users, it is recommended that you do not connect a device under test (DUT) and external circuitry to the switching module. This allows you to exercise close and open operations without the dangers associated with live test circuits. You can also set up pseudocards to experiment with switching. Refer to "Pseudocards" in the *Model DAQ6510 Data Acquisition and Multimeter System Reference Manual* for information on setting up pseudocards.

WARNING

To prevent electric shock that could result in injury or death, never handle a switching module that has power applied to it. Before installing or removing a switching module, make sure the DAQ6510 is turned off and disconnected from line power. If the switching module is connected to a DUT, make sure power is removed from all external circuitry.

WARNING

If a card slot is unused, you must install slot covers to prevent personal contact with high voltage circuits. Failure to install slot covers could result in personal exposure to hazardous voltages, which could cause personal injury or death if contacted.

CAUTION

Before installing or removing a switching module, make sure the DAQ6510 power is turned off and disconnected from line power. Failure to comply may result in incorrect operation and loss of data in the memory.

Required equipment:

- Medium flat-blade screwdriver
- Medium Phillips screwdriver

To install a switching module into the DAQ6510:

1. Turn off the DAQ6510.
2. Disconnect the power cord from the power source.
3. Disconnect the power cord and any other cables that are connected to the rear panel.
4. Position the DAQ6510 so you are facing the rear panel.
5. Use the screwdriver to remove the slot cover screws and the cover plate. Retain the plate and screws for future use.
6. With the top cover of the switching module facing up, slide the switching module into the slot.
7. Press the switching module in firmly to make sure the switching module connector is connected to the DAQ6510 connector.
8. Use the screwdriver to tighten the two mounting screws to secure the switching module to the mainframe. Do not overtighten.
9. Reconnect the power cord and any other cables.

Remove a switching module

NOTE

Before you remove a switching module or begin any testing, make sure that all the relays are open. Since some relays may be latched closed, you must open all the relays before removing the switching module to make connections. Additionally, if you drop your switching module, it is possible for some relays to latch closed.

To open all channel relays, go to the CHANNEL swipe screen. Select **Open All**.

⚠ WARNING

To prevent electric shock that could result in injury or death, never handle a switching module that has power applied to it. Before installing or removing a switching module, make sure the DAQ6510 is turned off and disconnected from line power. If the switching module is connected to a DUT, make sure power is removed from all external circuitry.

⚠ WARNING

If a card slot is unused, you must install slot covers to prevent personal contact with high voltage circuits. Failure to install slot covers could result in personal exposure to hazardous voltages, which could cause personal injury or death if contacted.

CAUTION

Before installing or removing a switching module, make sure the DAQ6510 power is turned off and disconnected from line power. Failure to comply may result in incorrect operation and loss of data in the memory.

Required equipment:

- Medium flat-blade screwdriver
- Medium Phillips screwdriver

To remove a switching module from the DAQ6510:

1. Turn off the DAQ6510.
2. Disconnect the power cord from the power source.
3. Disconnect the power cord and any other cables that are connected to the rear panel.
4. Position the DAQ6510 so you are facing the rear panel.
5. Use the screwdriver to loosen the mounting screws that secure the switching module to the instrument.
6. Carefully remove the switching module.
7. Install a slot plate or another switching module in the empty slot.
8. Reconnect the power cord and any other cables.

Connections and wiring overview

WARNING

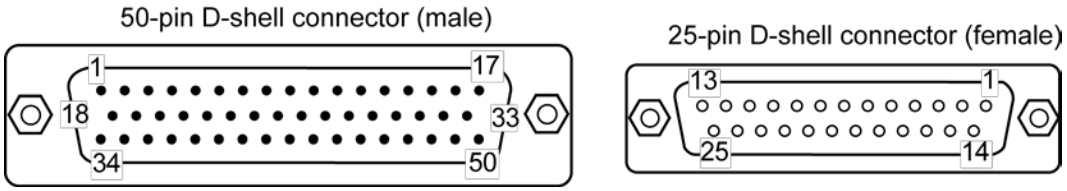
Connection and wiring procedures in this document are intended for use by qualified personnel only, as described by the types of product users in the Safety precautions (on page 33). Do not perform these procedures unless qualified to do so. Failure to recognize and observe normal safety precautions could result in personal injury or death.

To prevent electric shock that could result in serious injury or death, adhere to the following safety precautions:

- Before removing or installing the switching module in the mainframe, make sure the mainframe is turned off and disconnected from line power.
- Before making or breaking connections to the switching module, make sure power is removed from all external circuitry.
- Do not connect signals that may exceed the maximum specifications of the 7707.

The following figure shows the pin numbers for the 7707 rear-panel connectors. Use the 50-pin D-shell to access digital input/output channels. Use the 25-pin D-shell to access analog input channels. Terminal identification for the D-shell connector pins is provided in the following table.

Figure 3: 7707 rear panel D-shell connector pinouts



50-pin D-shell (DB-50)

Pin	7707 terminal
1	Gnd
2	Ch 11 Bit 2
3	Ch 11 Bit 5
4	Protection K1
5	Gnd
6	Ch 12 Bit 1
7	Ch 12 Bit 4
8	Ch 12 Bit 7
9	Gnd
10	Ch 13 Bit 0
11	Ch 13 Bit 3
12	Ch 16 Bit 6
13	Gnd
14	Gnd
15	Ch 14 Bit 2
16	Ch 14 Bit 5
17	Protection K4
18	Ch 11 Bit 1
19	Ch 11 Bit 4
20	Ch 11 Bit 7
21	Gnd
22	Ch 12 Bit 0
23	Ch 12 Bit 3
24	Ch 12 Bit 6
25	Gnd

Pin	7707 terminal
26	Gnd
27	Ch 13 Bit 2
28	Ch 13 Bit 5
29	Protection K3
30	Gnd
31	Ch 14 Bit 1
32	Ch 14 Bit 4
33	Ch 14 Bit 7
34	Ch 11 Bit 0
35	Ch 11 Bit 3
36	Ch 11 Bit 6
37	Gnd
38	Gnd
39	Ch 12 Bit 2
40	Ch 12 Bit 5
41	Protection K2
42	Gnd
43	Ch 13 Bit 1
44	Ch 13 Bit 4
45	Ch 13 Bit 7
46	Gnd
47	Ch 14 Bit 0
48	Ch 14 Bit 3
49	Ch 14 Bit 6
50	Gnd

25-pin D-shell (DB-25)

Pin	7707 terminal
1	Ch 1 Hi
2	Ch 2 Hi
3	Ch 3 Hi
4	Ch 4 Hi
5	Ch 5 Hi
6	Ch 6 Hi
7	Ch 7 Hi
8	Ch 8 Hi
9	Ch 9 Hi
10	Ch 10 Hi
11	Sense Hi
12	Input Hi
13	—

Pin	7707 terminal
14	Ch 1 Lo
15	Ch 2 Lo
16	Ch 3 Lo
17	Ch 4 Lo
18	Ch 5 Lo
19	Ch 6 Lo
20	Ch 7 Lo
21	Ch 8 Lo
22	Ch 9 Lo
23	Ch 10 Lo
24	Sense Lo
25	Input Lo

Fifty-pin ribbon cable connections

WARNING

The DB-50 connector is used for digital I/O connections. Do not exceed 40 V on any digital terminal in the test system.

Connect an appropriate length of 50-conductor IDC ribbon cable to a 50-pin female D-shell IDC connector. The following table and figure provides terminal identification for the 50-pin ribbon cable connections.

The connectors of the prepared ribbon cable assembly mates to the 50-pin D-shell connectors of the 7707. Make sure an unused D-shell connector has the connector cover installed.

50-conductor IDC ribbon cable is available from Keithley.

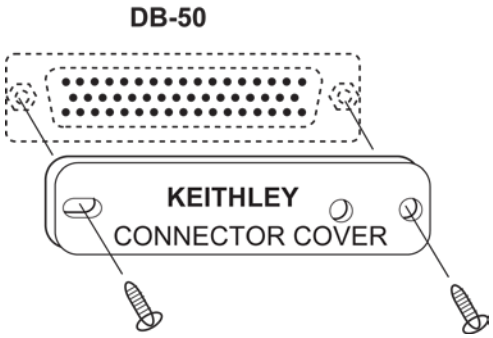
Terminal identification for 50-conductor IDC ribbon cable and 7707 DB-50 connector

Ribbon cable		7707 terminal	DB-50 pin #
Conductor	Color		
1	Brown	Gnd	1
2	Red	Ch 11 Bit 0	34
3	Orange	Ch 11 Bit 1	18
4	Yellow	Ch 11 Bit 2	2
5	Green	Ch 11 Bit 3	35
6	Blue	Ch 11 Bit 4	19
7	Violet	Ch 11 Bit 5	3
8	Gray	Ch 11 Bit 6	36
9	White	Ch 11 Bit 7	20
10	Black	Protection K1	4
11	Brown	Gnd	37
12	Red	Gnd	21
13	Orange	Gnd	5
14	Yellow	Gnd	38
15	Green	Ch 12 Bit 0	22
16	Blue	Ch 12 Bit 1	6
17	Violet	Ch 12 Bit 2	39
18	Gray	Ch 12 Bit 3	23
19	White	Ch 12 Bit 4	7
20	Black	Ch 12 Bit 5	40
21	Brown	Ch 12 Bit 6	24
22	Red	Ch 12 Bit 7	8
23	Orange	Protection K2	41
24	Yellow	Gnd	25
25	Green	Gnd	9

Ribbon cable		7707 terminal	DB-50 pin #
Conductor	Color		
26	Blue	Gnd	42
27	Violet	Gnd	26
28	Gray	Ch 13 Bit 0	10
29	White	Ch 13 Bit 1	43
30	Black	Ch 13 Bit 2	27
31	Brown	Ch 13 Bit 3	11
32	Red	Ch 13 Bit 4	44
33	Orange	Ch 13 Bit 5	28
34	Yellow	Ch 13 Bit 6	12
35	Green	Ch 13 Bit 7	45
36	Blue	Protection K3	29
37	Violet	Gnd	13
38	Gray	Gnd	46
39	White	Gnd	30
40	Black	Gnd	14
41	Brown	Ch 14 Bit 0	47
42	Red	Ch 14 Bit 1	31
43	Orange	Ch 14 Bit 2	15
44	Yellow	Ch 14 Bit 3	48
45	Green	Ch 14 Bit 4	32
46	Blue	Ch 14 Bit 5	16
47	Violet	Ch 14 Bit 6	49
48	Gray	Ch 14 Bit 7	33
49	White	Protection K4	17
50	Black	Gnd	50

If the connector is not used, install a connector cover as shown in the following figure. Use two #4-40 screws.

Figure 4: Connect DB-50 ribbon cable assembly



Twenty-five-pin ribbon cable connections

WARNING

When using IDC ribbon cable for analog inputs (DB-25), do not exceed 42 V on any analog input (including front panel terminals of the instrument). When using IDC ribbon cable for the digital I/O (DB-50), do not exceed 40 V on any digital terminal.

Connect an appropriate length of 25-conductor IDC ribbon cable to a 25-pin male D-shell IDC connector. The following table and figure provide terminal identification for the 25-pin ribbon cable connections.

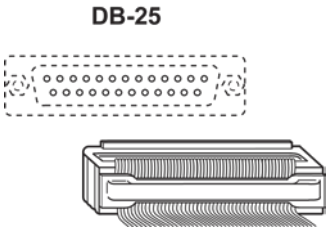
Terminal identification for 25-conductor IDC ribbon cable and 7707 DB-25 connector

Ribbon cable		7707 terminal	DB-25 pin #
Conductor	Color		
1	Brown	Ch 1 Hi	1
2	Red	Ch 1 Lo	14
3	Orange	Ch 2 Hi	2
4	Yellow	Ch 2 Lo	15
5	Green	Ch 3 Hi	3
6	Blue	Ch 3 Lo	16
7	Violet	Ch 4 Hi	4
8	Gray	Ch 4 Lo	17
9	White	Ch 5 Hi	5
10	Black	Ch 5 Lo	18
11	Brown	Ch 6 Hi	6
12	Red	Ch 6 Lo	19
13	Orange	Ch 7 Hi	7

Ribbon cable		7707 terminal	DB-25 pin #
Conductor	Color		
14	Yellow	Ch 7 Lo	20
15	Green	Ch 8 Hi	8
16	Blue	Ch 8 Lo	21
17	Violet	Ch 9 Hi	9
18	Gray	Ch 9 Lo	22
19	White	Ch 10 Hi	10
20	Black	Ch 10 Lo	23
21	Brown	Sense Hi	11
22	Red	Sense Lo	24
23	Orange	Input Hi	12
24	Yellow	Input Lo	25
25	Green	—	—

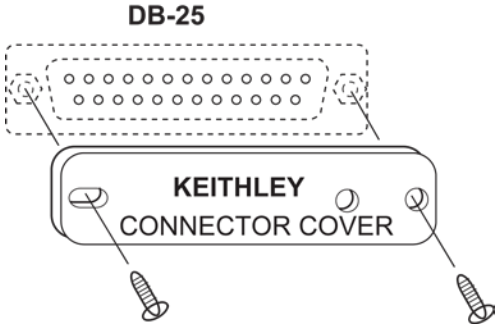
The connectors of the prepared ribbon cable assemblies mate to the 25-pin D-shell connectors of the 7707, as shown in the following figure. 25-conductor IDC ribbon cable is available from Keithley.

Figure 5: Connect 25-pin ribbon cable assembly



If a D-shell connector is not used, make sure the connector has the connector cover installed, as shown in the following figure.

Figure 6: DB-25 connector cover



Solder cup cable connections

Make all connections to D-shell male solder cup connectors using the correct wire size, up to 20 AWG. When using a solder cup cable on the DB-25, use supplementary insulation around the harness for voltages above 42 V_{PEAK}, as shown in the following figure.

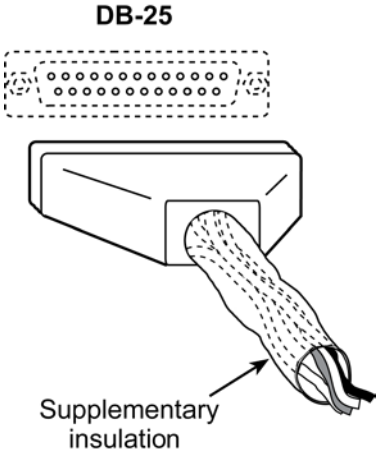
⚠ WARNING

For analog inputs (DB-25), all solder cup wiring must be rated for the maximum voltage in the system. For example, if 300 V is applied to the front terminals of the DMM, all wiring for analog inputs must be rated for 300 V.

For the digital I/O (DB-50), wiring must be rated for the maximum voltage applied to a digital terminal (up to 40 V).

A connector cover must be installed on an unused 50-pin D-shell connector. If the connector is left open, an electrical shock hazard may be present.

Figure 7: Connect the solder cup cable assembly



Connection log

You can use the following tables to record connection information and channel descriptions as needed.

Channel		Color	Description
INPUT	H		
	L		
SENSE	H		
	L		
CH1	H		
	L		
CH2	H		
	L		
CH3	H		
	L		
CH4	H		
	L		
CH5	H		
	L		
CH6	H		
	L		
CH7	H		
	L		
CH8	H		
	L		
CH9	H		
	L		
CH10	H		
	L		

I/O line	Ch 11			Ch 12		
	In	Out	Color	In	Out	Color
Bit 0	(B0)	0 1		(B8)	0 1	
Bit 1	(B1)	0 1		(B9)	0 1	
Bit 2	(B2)	0 1		(B10)	0 1	
Bit 3	(B3)	0 1		(B11)	0 1	
Bit 4	(B4)	0 1		(B12)	0 1	
Bit 5	(B5)	0 1		(B13)	0 1	
Bit 6	(B6)	0 1		(B14)	0 1	
Bit 7	(B7)	0 1		(B15)	0 1	

0 = low, 1 = high

I/O line	Ch 13			Ch 14		
	In	Out	Color	In	Out	Color
Bit 0	(B16)	0 1		(B24)	0 1	
Bit 1	(B17)	0 1		(B25)	0 1	
Bit 2	(B18)	0 1		(B26)	0 1	
Bit 3	(B19)	0 1		(B27)	0 1	
Bit 4	(B20)	0 1		(B28)	0 1	
Bit 5	(B21)	0 1		(B29)	0 1	
Bit 6	(B22)	0 1		(B30)	0 1	
Bit 7	(B23)	0 1		(B31)	0 1	

0 = low, 1 = high

Analog inputs

The following 7707 channels are used to measure analog inputs:

- Channels 1 to 10: Measurement channels
- Channel 15: 2-pole/4-pole selection relay
- Channels 16 and 17: Backplane isolation relays for sense and input

Typical analog input connections

The following examples show typical connections for the following types of measurements:

- Two-wire resistance and thermistor
- Four-wire resistance and RTD
- DC or AC voltage

Figure 8: Two-wire resistance and thermistor connections

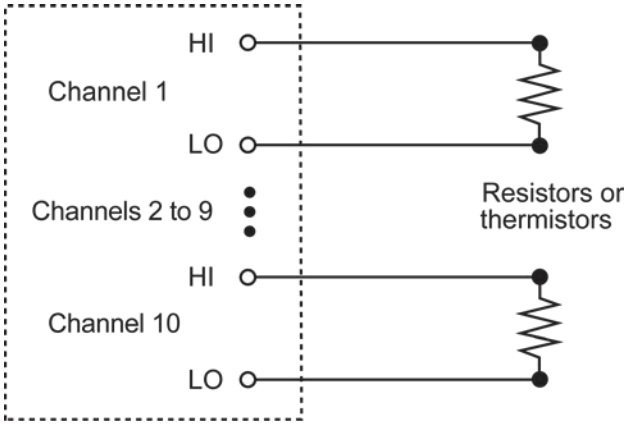


Figure 9: Four-wire resistance and RTD connections

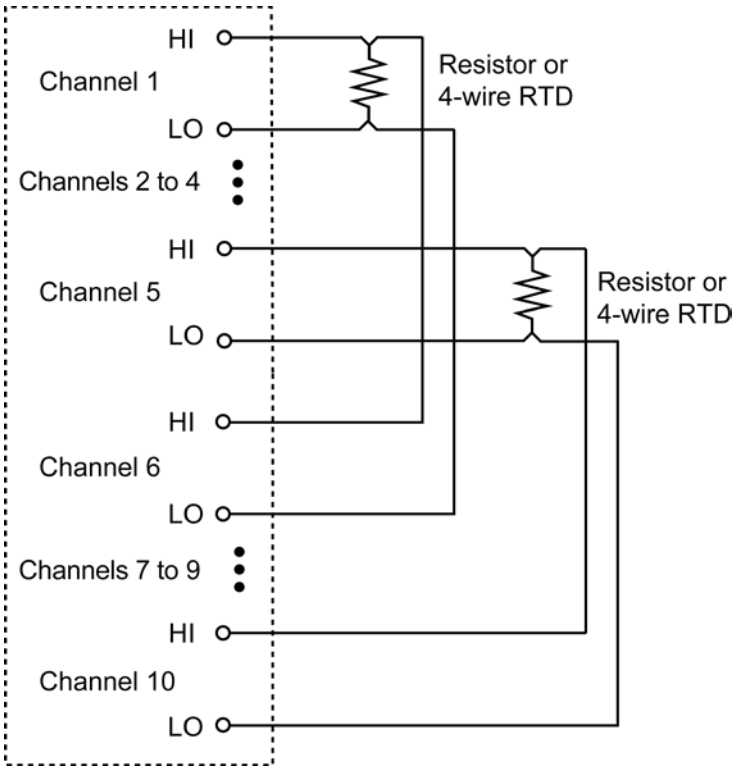
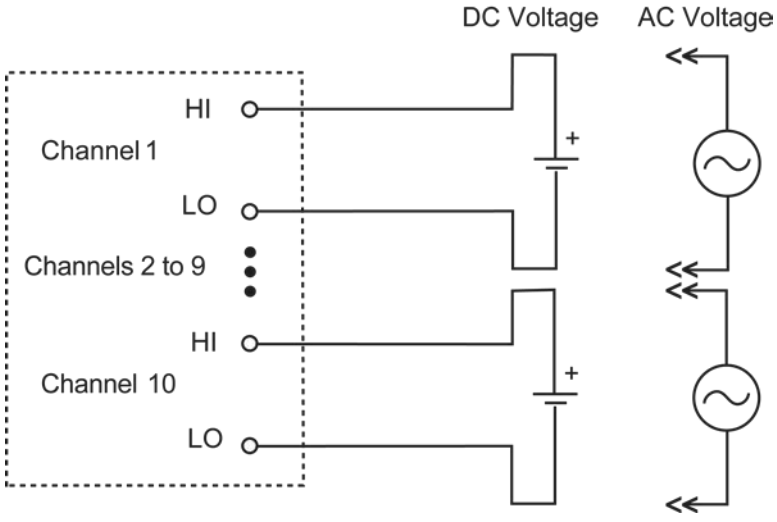


Figure 10: Voltage connections (AC or DC)

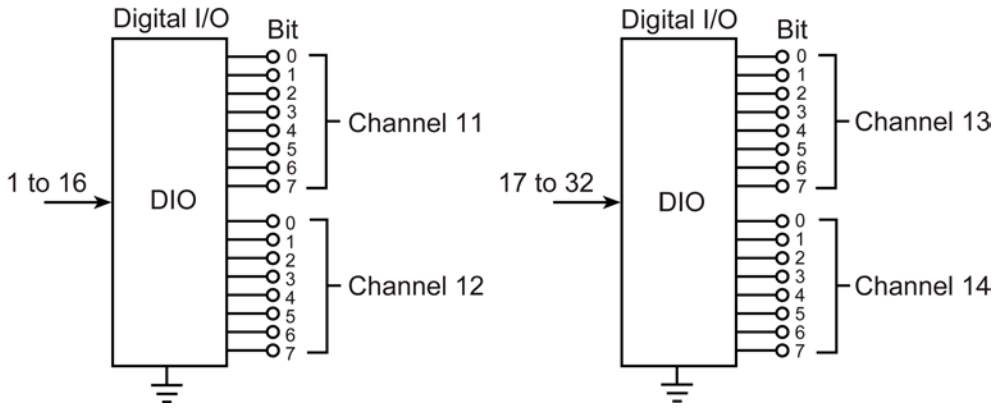


Digital I/O

The 7707 has four digital input/output channels (11, 12, 13, and 14). Each I/O channel can be set as either a digital input port or a digital output port. Each port has eight lines (bits 0 through 7).

When an I/O channel is used as an input port, you can read the state (high or low) of each input line (bit). When an I/O channel is used as an output port, you can set each line high or low to control external circuitry.

Figure 11: 7707 Digital I/O



Digital outputs

You can use digital outputs to control devices such as logic devices, indicators, fixtures, switches, solenoids, loads, and relays. With one I/O channel set as an output port, eight output lines (bits) are available. With two channels set as output ports, 16 output lines are available. With three channels set as output ports, 24 output lines are available. With all four channels set as output ports, 32 output lines are available.

An output line can be set high to ≈4.3 V or low to 0 V (digital ground). Output lines are set as follows:

- Logic 0 sets output line low to 0 V (digital ground).
- Logic 1 sets output line high to ≈4.3 V.

NOTE

You must configure a digital I/O channel as an output port before its output lines can be set high or low.

Sink or source

You can use a digital output line as a sink for an external source up to 40 V or as a ≈4.3 V source for a low-current device.

Sink mode

As a sink, current provided by an external source flows into the module when the output line is set low (logic 0). Using an output line as a sink provides control for high voltage (up to 40 V) or high current (up to 100 mA) devices, such as relays, solenoids, and other loads. The following figures show how to use an output line as a sink.

CAUTION

Do not apply more than +40 V to the K1, K2, K3, and K4 pins of the module. For the output lines, do not exceed the maximum sink current. The maximum sink current for an output line is 100 mA. Exceeding these limits may cause damage to the instrument that is not covered by the warranty.

Figure 12: Typical digital output: Sink mode with K1 protection

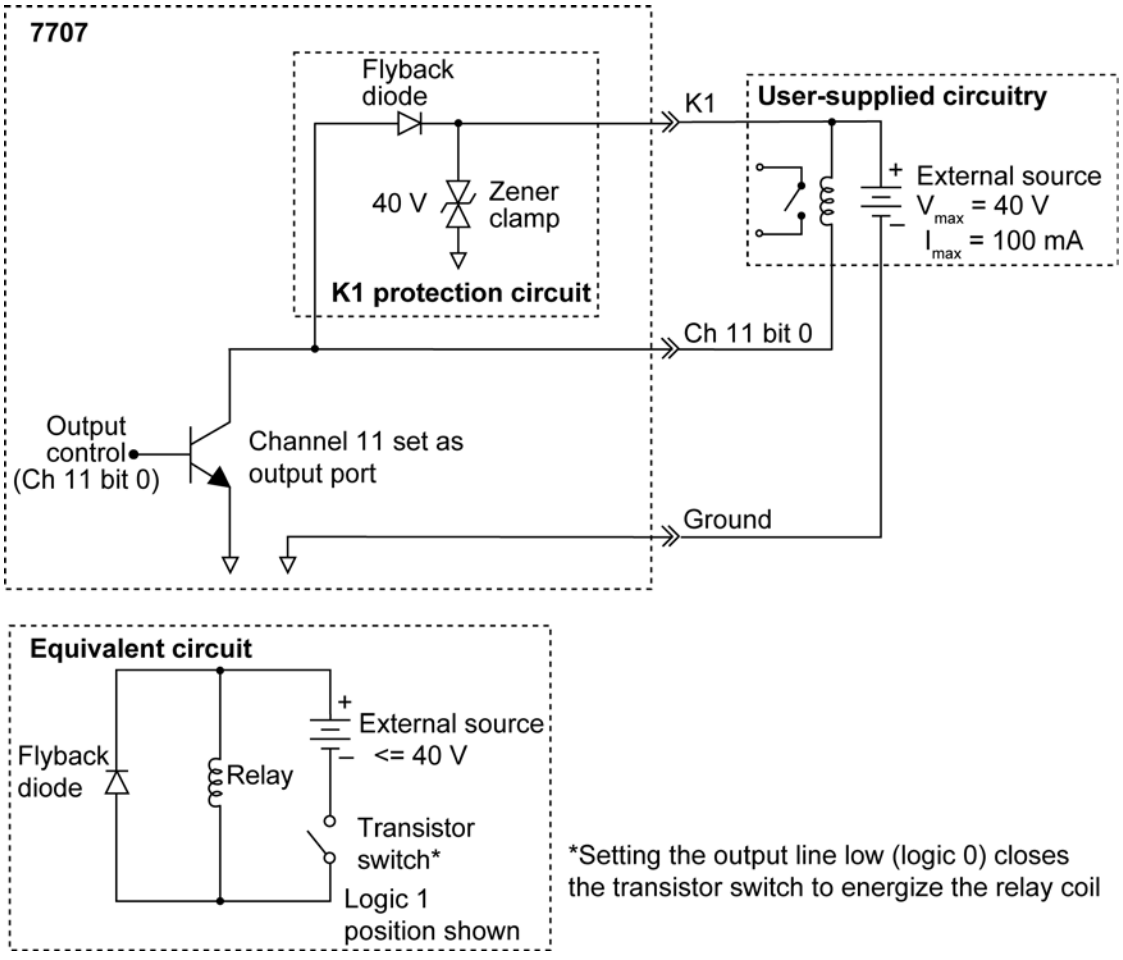
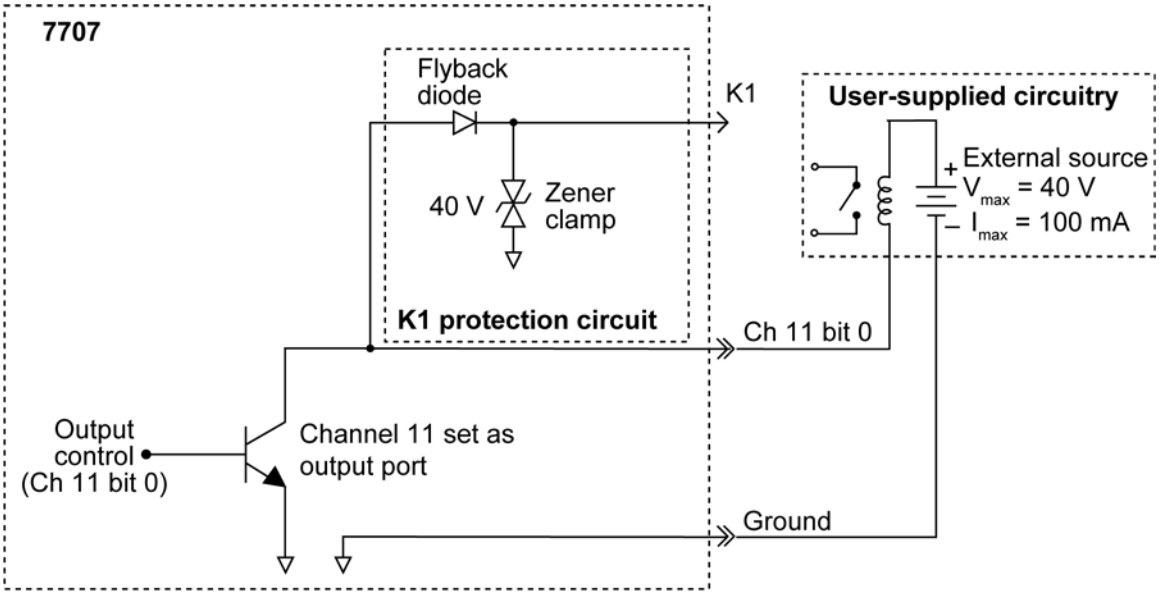
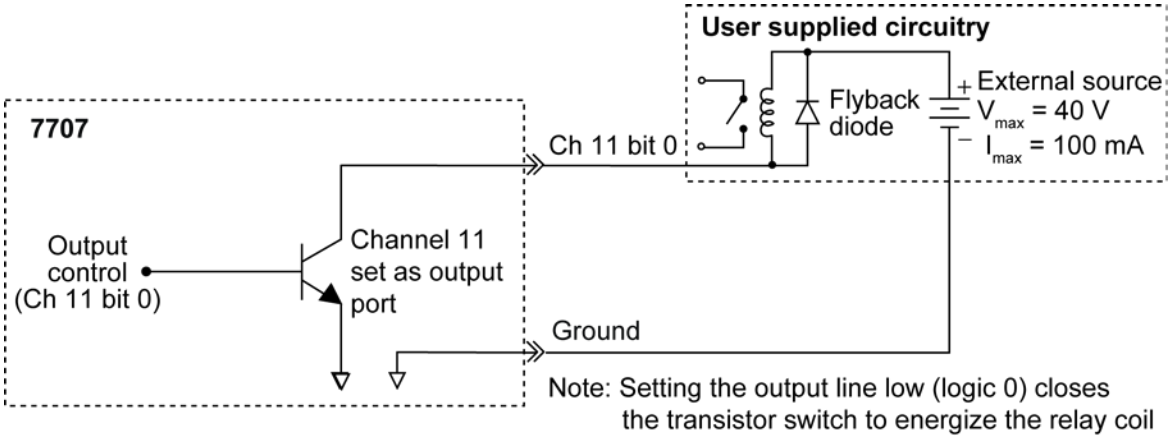


Figure 13: Typical digital output: Sink mode without K1 protection



Note: Setting the output line low (logic 0) closes the transistor switch to energize the relay coil.

Figure 14: Typical digital output: Sink mode using external flyback diode protection



Note: Setting the output line low (logic 0) closes the transistor switch to energize the relay coil

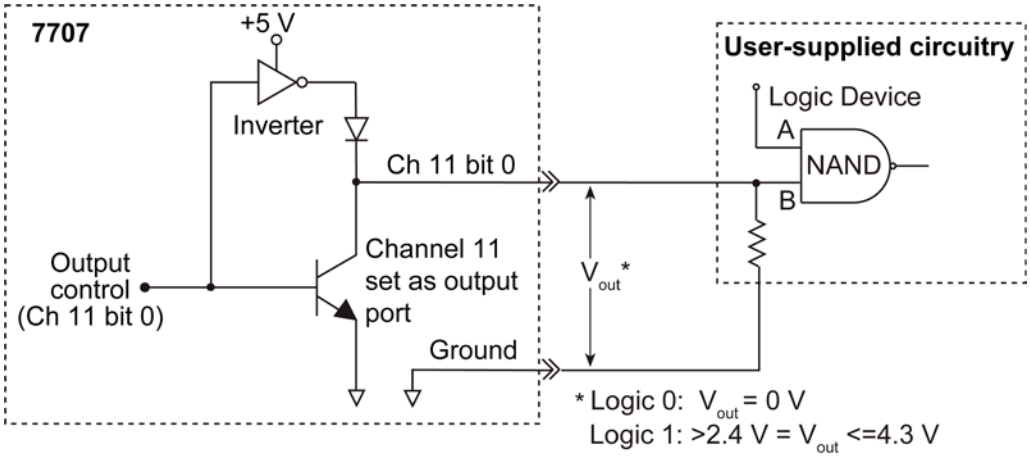
Source mode

When used as a source, current provided by the internal 5 V supply flows out of the module to a load when the output line is set high (logic 1). Using an output line as a source provides control for low voltage, low current (up to 1 mA) loads, such as logic devices and indicator lamps. The following figure shows how to use an output line to apply high and low logic levels to a NAND gate.

CAUTION

Each output line can source up to 1 mA. Exceeding 1 mA may cause damage to the 7707 switching module that is not covered by the warranty.

Figure 15: Typical digital output: Source mode



Note: Setting output line high (logic 1) opens the transistor switch to apply logic high (1) to the NAND gate.
Setting the output line low (logic 0) closes the transistor switch to apply logic low (digital ground) to the NAND gate.

Digital I/O protection

Short circuit protection

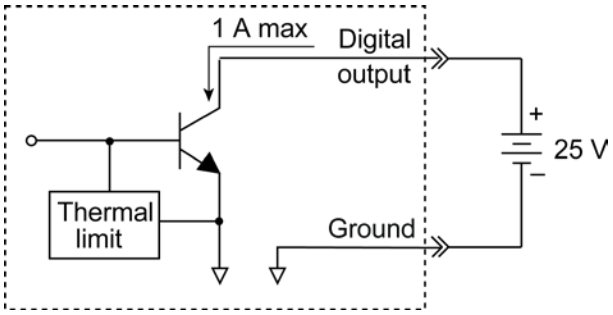
Each digital output line has internal short circuit protection up to 25 V. Overcurrent protection is tripped at approximately 1 A. The following figure is a simplified circuit showing thermal protection for a digital output.

A short circuit condition exists when the transistor switch for the digital output is closed (logic 0). When the current reaches 1 A, the driver for the digital output automatically reduces the current to a level that will not damage the digital I/O. If the short circuit condition is maintained, thermal limit circuitry senses the rise in device temperature and further decreases the current.

CAUTION

Short circuit protection is effective up to 25 V. To avoid damage to the DAQ6510, do not apply greater than 25 V directly to a digital I/O line.

Figure 16: Short circuit protection for digital outputs



K1, K2, K3, and K4 protection circuits

Each digital I/O channel has a circuit to protect it from high voltage. The figure in Sink mode (on page 19), "Typical digital output: Sink mode with K1 protection," shows the key components of the protection circuit for channel 11. It includes a Zener clamp to limit voltage to 40 V, and a flyback diode to provide a current discharge path for an inductive load (relay coil). Without a current discharge path, flyback voltage that occurs when the inductive load is switched could damage the digital I/O.

The figure in Sink mode (on page 19) shows how to connect an external circuit to the K1 protection circuit for channel 11. This circuit is shown connected to output line bit 0, but it is also connected to the other output lines (bits 1 through 7) in a similar fashion to protect those lines. As shown in the equivalent circuit, the flyback diode is placed across the relay coil to provide a discharge path for flyback voltage. There are similar protection circuits for the other three digital I/O channels: K2 protects channel 12, K3 protects channel 13, and K4 protects channel 14.

External protection circuits

For localized protection, an external flyback diode can be connected directly across the relay coil to provide a current discharge path for flyback voltage. The figure in Sink mode (on page 19), "Typical digital output: Sink mode using external flyback diode protection," shows how to connect the diode across the coil.

Even when using K1, K2, K3, or K4 protection, additional devices, such as fuses and current-limiting resistors, may be required to adequately protect the switching module from damage caused by reactive loads.

Output bit patterns

A binary bit pattern is a series of 0s and 1s that identifies the state of each line in the pattern. A bit with a logic 1 is effectively equal to a line high at approximately +4.3 V. A logic 0 is line low to 0 V.

You can use basic operation or advanced operation to set bit patterns.

Basic operation handles each channel as a single 8-bit pattern. An 8-bit pattern is a byte.

Advanced operation provides additional flexibility by allowing two digital output ports to be treated as a single 16-bit output pattern, or all four output ports to be treated as a 32-bit output pattern (double-word). Words and double-words can only be set using remote programming.

Basic operation: Writing bytes

Each I/O channel is set as an output port in an 8-bit output pattern. Bit 7 (B7) of each port is the most significant bit (MSB) and Bit 0 (B0) is the least significant bit (LSB).

An 8-bit output pattern for each port is set by entering a value that is the equivalent of the binary bit pattern. The entered value is in decimal format. The decimal (ASCII) format is the factory and `*RST` or `reset()` default.

The following table lists the decimal weights for the bits of an 8-bit pattern. To determine the decimal value for an output pattern, add the decimal weights for the bits set to `1`. As shown in the table, the decimal equivalent for output binary pattern `10100101` is the sum of the decimal weights for B7, B5, B2, and B0.

Channel 11, 12, 13, or 14

Digital I/O line:	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Bit position:	B7	B6	B5	B4	B3	B2	B1	B0
Binary bit pattern*:	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal weight:	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	2 (2^1)	1 (2^0)

* 0 = line set low, 1 = line set high.

Example: Determine decimal value for binary output pattern `10100101` (bits B7, B5, B2 and B0 to be set high to logic 1):

Bit position:	B7	B6	B5	B4	B3	B2	B1	B0
Binary bit pattern:	1	0	1	0	0	1	0	1
Decimal weight of bits set high:	128	—	32	—	—	4	—	1

Decimal value for bit pattern: = B7 + B5 + B2 + B0
= 128 + 32 + 4 + 1
= 165

For remote programming, the following SCPI commands set the channel as an input or output channel, set the width, and set the 8-bit output pattern for each output port:

- `ROUTe:CHANnel:MODE`
- `ROUTe:CHANnel:WIDth`
- `ROUTe:CHANnel:WRITe`

The equivalent TSP commands are:

- `channel.setmode()`
- `channel.setwidth()`
- `channel.write()`

The following examples demonstrate how to write the byte pattern 10100101 (165 decimal) to the ports of channel 11 in slot 1.

Using the front panel:

1. Press the **HOME** key.
2. On the NON-SWITCH swipe screen, select **Write**.
3. Select channel **111**.
4. Enter **165** and select **OK**.

Using SCPI commands:

```
ROUTe:CHANnel:MODE OUT, (@111)
ROUTe:CHANnel:WIDTH 1, (@111)
ROUTe:CHANnel:WRITe 165, (@111)
```

Using TSP commands:

```
channel.setmode("111", channel.MODE_OUTPUT)
channel.setwidth("111", 1)
channel.write("111", 165)
```

Advanced operation: Setting words (16-bits) or double-words (32-bits)

Sixteen-bit output patterns (words)

To set two output ports to form a 16-bit output pattern (word), you set the width of channel 11 or 13 to 2 and write to that channel. Setting the width to 2 combines channel 11 with channel 12 or channel 13 with channel 14 to form a second 16-bit output pattern.

The following example shows how to write the word pattern 0101010110101010 (21,930 decimal) to the channel 111 ports.

Using SCPI commands:

```
ROUTe:CHANnel:MODE OUT, (@111)
ROUTe:CHANnel:WIDTH 2, (@111)
ROUTe:CHANnel:WRITe 21930, (@111)
```

Using TSP commands:

```
channel.setmode("111", channel.MODE_OUTPUT)
channel.setwidth("111", 2)
channel.write("111", 21930)
```

When channel 11 is set as a word, bit 0 (B0) of channel 11 is the LSB, and bit 7 (B15) of channel 12 is the MSB. When channel 13 is set as a word, bit 0 (B0) of channel 13 is the LSB, and bit 7 (B15) of channel 14 is the MSB.

The decimal equivalent of the 16-bit output pattern is used to set the ports. The table below lists the decimal weights of the 16 bits.

Decimal weighting for 16-bit output pattern (word)

Channel 11 or 13 (B0 to B7)

Digital I/O line:	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Bit position:	B7	B6	B5	B4	B3	B2	B1	B0
Binary bit pattern:	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal weight:	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	2 (2^1)	1 (2^0)

Channel 12 or 14 (B8 to B15)

Digital I/O line:	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Bit position:	B15	B14	B13	B12	B11	B10	B9	B8
Binary bit pattern:	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal weight:	32768 (2^{15})	16384 (2^{14})	8192 (2^{13})	4096 (2^{12})	2048 (2^{11})	1024 (2^{10})	512 (2^9)	256 (2^8)

Thirty-two-bit output pattern (double-word)

To set the four output ports to form a 32-bit output pattern (double-word), you set the width of channel 11 to 4. Channel 11 is combined with channels 12, 13, and 14 to form the 32-bit output pattern. When channel 11 is set as a double-word, bit 0 of channel 11 (B0) is the LSB, and bit 7 of channel 14 (B31) is the MSB. Setting digital outputs (on page 27) lists the decimal weights of the 32 bits.

The following example shows how to write the double-word pattern 00001111000011110000111100001111 (252,645,135 decimal) to the channel 111 ports.

Using SCPI commands:

```
ROUTe:CHANnel:MODE OUT, (@111)
ROUTe:CHANnel:WIDTH 4, (@111)
ROUTe:CHANnel:WRITe 252645135, (@111)
```

Using TSP commands:

```
channel.setmode("111", channel.MODE_OUTPUT)
channel.setwidth("111", 4)
channel.write("111", 252645135)
```

Setting digital outputs

Before setting a digital output pattern, an I/O channel must first be set as an output port. This must be done using remote programming. You can set 8-bit patterns (bytes), 16-bit patterns (words), and a 32-bit pattern (double-word).

Decimal weighting for 32-bit output pattern (double-word)

Channel 11 (B0 to B7)

Digital I/O line:	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Bit position:	B7	B6	B5	B4	B3	B2	B1	B0
Binary bit pattern:	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal weight:	128 (2^7)	64 (2^6)	32 (2^5)	16 (2^4)	8 (2^3)	4 (2^2)	2 (2^1)	1 (2^0)

Channel 12 (B8 to B15)

Digital I/O line:	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Bit position:	B15	B14	B13	B12	B11	B10	B9	B8
Binary bit pattern:	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal weight:	32768 (2^{15})	16384 (2^{14})	8192 (2^{13})	4096 (2^{12})	2048 (2^{11})	1024 (2^{10})	512 (2^9)	256 (2^8)

Channel 13 (B16 to B23)

Digital I/O line:	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Bit position:	B23	B22	B21	B20	B19	B18	B17	B16
Binary bit pattern:	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal weight:	8388608 (2^{23})	4194304 (2^{22})	2097152 (2^{21})	1048576 (2^{20})	524288 (2^{19})	262144 (2^{18})	131072 (2^{17})	65536 (2^{16})

Channel 14 (B24 to B31)

Digital I/O line:	**Bit 7**	**Bit 6**	**Bit 5**	**Bit 4**	**Bit 3**	**Bit 2**	**Bit 1**	**Bit 0**
Bit position:	B31	B30	B29	B28	B27	B26	B25	B24
Binary bit pattern:	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1
Decimal weight:	2147483648 (2^{31})	1073741824 (2^{30})	536870912 (2^{29})	268435456 (2^{28})	134217728 (2^{27})	67108864 (2^{26})	33554432 (2^{25})	16777216 (2^{24})

Digital inputs

You can read digital TTL inputs with the DAQ6510. With one I/O channel set as an input port, eight input lines (bits) are available. With two channels set as input ports, 16 input lines (bits) are available. With three channels set as input ports, 24 input lines (bits) are available. With all four channels set as input ports, 32 input lines (bits) are available.

TTL inputs are read as follows:

- TTL high (>2 V to 5 V) is read as logic 1.
- TTL low (<0.8 V) is read as logic 0.

NOTE

A digital I/O channel must first be configured as an input port before its input lines can be read. Use the SCPI command `:ROUTe:CHANnel:MODE` or TSP command `channel.setmode()` to configure the port. Refer to the *DAQ6510 Reference Manual* for detail on these commands.

Input bit patterns

You can use basic operation or advanced operation to read input bit patterns.

Basic operation handles each input channel as an input pattern.

Advanced operation provides additional flexibility by allowing two digital input ports to be treated as a single 16-bit input pattern (word) or all four input ports to be treated as a 32-bit input pattern (double-word).

Basic operation: Reading bytes

Each I/O channel that is set as an input port is an 8-bit binary input pattern.

The 8-bit output pattern for each port is read and returned as a decimal value. To determine the bit pattern, the value must be converted to its binary equivalent. For example, the binary equivalent of hexadecimal `F1` is `11110001`. For that bit pattern, bits 0, 4, 5, 6, and 7 are set to TTL high (logic 1). Bits 1, 2, and 3 are set to TTL low (logic 0).

The binary equivalent of the returned bit pattern value directly identifies the state of each line. For example, assume that the decimal value `240` is read. The binary equivalent for an 8-bit pattern is `11110000`.

The above bit pattern indicates that bits B0 through B3 are TTL low (logic 0) and bits B4 through B7 are TTL high (logic 1).

The following example reads an 8-bit input pattern for each input port (channels 11, 12, 13, and 14).

Using SCPI commands:

```
:ROUTe:CHANnel:MODE INPut, (@111:114)
:ROUTe:CHANnel:WIDTh (@111:114), 1)
:ROUTe:CHANnel:READ? (@111)
:ROUTe:CHANnel:READ? (@112)
:ROUTe:CHANnel:READ? (@113)
:ROUTe:CHANnel:READ? (@114)
```

Using TSP commands:

```
channel.setmode("111:114", channel.MODE_INPUT)
channel.setwidth("111:114", 1)
channel.read("111")
channel.read("112")
channel.read("113")
channel.read("114")
```

Advanced operation: Reading words (16-bits) or double-words (32-bits)

Sixteen-bit input patterns (words)

Sixteen bits of data (two bytes) is called a word. You can read 16-bit patterns (words) formed by two input ports. You can combine channels 11 with 12 and 13 with 14 to create two 16-bit patterns.

When channel 11 is read as a word, Bit 0 (B0) of channel 11 is the LSB, and Bit 7 (B15) of channel 12 is the MSB. When channel 13 is read as a word, Bit 0 (B0) of channel 13 is the LSB, and Bit 7 (B15) of channel 14 is the MSB.

The bit pattern is returned as a decimal value. The binary equivalent of the decimal value identifies the state of each line (bit). For example, if the decimal value 4,080 is read, the following is the binary equivalent:

```
00001111 11110000
```

The above bit pattern indicates that bits B4 through B11 are TTL high (logic 1). The other bits are TTL low (logic 0).

The following example reads a 16-bit pattern from the combined channels 11 and 12 in slot 1.

Using SCPI commands:

```
:ROUTe:CHANnel:WIDTh 2, (@111)
:ROUTe:CHANnel:MODE INPut, (@111)
:ROUTe:CHANnel:READ? (@111)
```

Using TSP commands:

```
channel.setwidth("111: 2)
channel.setmode("111", channel.MODE_INPUT)
channel.read("111")
```

Thirty-two-bit input pattern (double-word)

Thirty-two bits of data (two words) is called a double word. You can read a 32-bit pattern (double word) formed by four input ports.

Channel 11 is combined with channels 12, 13, and 14 to form the 32-bit pattern. When channel 11 is read as a double-word, bit 0 (B0) of channel 11 is the LSB, and bit 7 (B31) of channel 14 is the MSB.

The bit pattern is returned as a decimal value. The binary equivalent of the returned bit pattern value directly identifies the state of each line (bit). For example, assume that the decimal value 268,435,440 is read. The following is the binary equivalent:

```
00001111  11111111  11111111  11110000
```

The above bit pattern indicates that lines (bits) B4 through B27 are TTL high (logic 1). The other bits are TTL low (logic 0).

The following examples set up the 32-bit channel, set the digital I/O channel to an input, and read a double-word pattern.

Using SCPI commands:

```
:ROUTe:CHANnel:WIDTh 4, (@111)
:ROUTe:CHANnel:MODE INPut, (@111)
:ROUTe:CHANnel:READ? (@111)
```

Using TSP commands:

```
channel.setwidth("111, 4")
channel.setmode("111, channel.MODE_INPUT)
channel.read("111")
```

Scanning digital channels

Digital input channels can be included in the scan list of a scan set up using remote commands. When a digital channel is scanned, the input channel pattern is read.

Digital limit testing

You can configure an input channel to compare the input to a specified 8-bit digital pattern. There are two modes for the comparison; pattern or mask. When the input is compared to an exact pattern, the limit test fails for anything except an exact pattern match. For example, assume the set pattern is `00001111`. The digital limit test only passes if the 8-bit input pattern is `00001111`. The limit test fails for any other input pattern.

When compared to a mask, only 1s in the mask are used for the comparison. Any 0s in the mask are ignored. Assume the mask is set to `00001111`. When the limit test is performed, the limit test passes only if the four least significant bits of the input pattern are 1s.

For example, assume the mask = `00001111`:

- If input = `00001110`, the limit test fails.
- If input = `10101111`, the limit test passes.
- If input = `11111111`, the limit test passes.

NOTE

Like limit testing for analog inputs, there are two sets of limits available for each digital input channel; Limit 1 and Limit 2. However, for front panel operation, Limit 1 has precedence over Limit 2.

Measurement considerations (digital outputs)

The 7707 switching module provides thermal short circuit protection. That is, when a channel is programmed as an output, internal circuitry is protected from an inadvertent connection up to 1 A at 25 V.

The protection on the 7707 consumes power at approximately 80 mA per channel or 320 mA per 7707 with all four channels (11 to 14 set as 32 bits) programmed as outputs. Generated heat is dissipated within the 7707 switching module and the DAQ6510.

As a result of the power (current) consumption and heat dissipation, adhere to the following guidelines.

Capacity

The DAQ6510 can provide power, up to a total of 350 mA, for both module slots. This is sufficient power to properly operate a 7707 with any 770x module, except the 7706 switching module. The 7706 consumes power at approximately 180 mA. Power consumption of the 7706 is independent of the output state of the digital channels. Therefore, when the 7707 is used with the Model 7706, only two 7707 digital I/O channels can be programmed as outputs (16 bits).

CAUTION

Failure to adhere to these limitations will cause erratic operations, such as resetting the DAQ6510 internal microprocessors.

NOTE

When a digital channel on the 7707 is programmed as an input or off, no power is consumed and capacity limitations do not apply.

Additional measurement uncertainty

On the 7707, additional heat is dissipated when the digital channels are programmed as outputs. This heat can cause additional uncertainty in thermocouple temperature measurements in the DAQ6510 and 7708 switching module when more than two digital channels are programmed as outputs.

The amount of uncertainty depends on slot number location of the 7707, the amount of time the channel is programmed as an output, and the other 770X switching module being used. The following table lists additional uncertainty to the published specification for the DAQ6510 and the 7708. Other modules, such as the 7700, are also affected by this heat, but are still within published specification.

NOTE

The listed uncertainty is with channels 11 to 14 programmed as outputs. The uncertainty is linear. That is, for each channel programmed as input or off, there will be approximately 25% reduction in the listed uncertainty.

Additional uncertainty for Model 7708

Thermocouple	Range (°C)	DAQ6510 front terminals	7708
J	–200 to 0 0 to +760	0.7 0.1	0.0
K	–200 to 0 0 to +1372	0.5 0.2	1.6

Thermocouple	Range (°C)	DAQ6510 front terminals	7708
N	–200 to 0 0 to +1300	0.8 0.2	3.0 0.5
T	–200 to 0 0 to +400	0.5 0.1	1.5
E	–200 to 0 0 to +1000	0.2 0.0	0.6
R	0 to +600 +600 to +1768	1.2 0.4	5.9
S	0 to +600 +600 to +1768	1.3 0.4	5.7
B	+350 to +1100 +1100 to +1820	1.8 0.5	9.4 2.4

Notes:

1. The above listed uncertainties are guaranteed by design for types J, K, N, T, E, R, S and B.
2. When the 7707 and 7708 are used together, 7707 must be installed in slot 1 and 7708 in slot 2.

Factory service

To return the switching module to Keithley Instruments for repair:

- Call the Repair Department at 1-800-833-9200 or send an email to `RMAREQUEST@tektronix.com` for a Return Material Authorization (RMA) number.
- Carefully pack the instrument in the original packing carton.
- Write `ATTENTION REPAIR DEPARTMENT` and the RMA number on the shipping label.

Safety precautions

The following safety precautions should be observed before using this product and any associated instrumentation. Although some instruments and accessories would normally be used with nonhazardous voltages, there are situations where hazardous conditions may be present.

This product is intended for use by personnel who recognize shock hazards and are familiar with the safety precautions required to avoid possible injury. Read and follow all installation, operation, and maintenance information carefully before using the product. Refer to the user documentation for complete product specifications.

If the product is used in a manner not specified, the protection provided by the product warranty may be impaired.

The types of product users are:

Responsible body is the individual or group responsible for the use and maintenance of equipment, for ensuring that the equipment is operated within its specifications and operating limits, and for ensuring that operators are adequately trained.

Operators use the product for its intended function. They must be trained in electrical safety procedures and proper use of the instrument. They must be protected from electric shock and contact with hazardous live circuits.

Maintenance personnel perform routine procedures on the product to keep it operating properly, for example, setting the line voltage or replacing consumable materials. Maintenance procedures are described in the user documentation. The procedures explicitly state if the operator may perform them. Otherwise, they should be performed only by service personnel.

Service personnel are trained to work on live circuits, perform safe installations, and repair products. Only properly trained service personnel may perform installation and service procedures.

Keithley products are designed for use with electrical signals that are measurement, control, and data I/O connections, with low transient overvoltages, and must not be directly connected to mains voltage or to voltage sources with high transient overvoltages. Measurement Category II (as referenced in IEC 60664) connections require protection for high transient overvoltages often associated with local AC mains connections. Certain Keithley measuring instruments may be connected to mains. These instruments will be marked as category II or higher.

Unless explicitly allowed in the specifications, operating manual, and instrument labels, do not connect any instrument to mains.

Exercise extreme caution when a shock hazard is present. Lethal voltage may be present on cable connector jacks or test fixtures. The American National Standards Institute (ANSI) states that a shock hazard exists when voltage levels greater than 30 V RMS, 42.4 V peak, or 60 VDC are present. A good safety practice is to expect that hazardous voltage is present in any unknown circuit before measuring.

Operators of this product must be protected from electric shock at all times. The responsible body must ensure that operators are prevented access and/or insulated from every connection point. In some cases, connections must be exposed to potential human contact. Product operators in these circumstances must be trained to protect themselves from the risk of electric shock. If the circuit is capable of operating at or above 1000 V, no conductive part of the circuit may be exposed.

Do not connect switching cards directly to unlimited power circuits. They are intended to be used with impedance-limited sources. NEVER connect switching cards directly to AC mains. When connecting sources to switching cards, install protective devices to limit fault current and voltage to the card.

Before operating an instrument, ensure that the line cord is connected to a properly-grounded power receptacle. Inspect the connecting cables, test leads, and jumpers for possible wear, cracks, or breaks before each use.

When installing equipment where access to the main power cord is restricted, such as rack mounting, a separate main input power disconnect device must be provided in close proximity to the equipment and within easy reach of the operator.

For maximum safety, do not touch the product, test cables, or any other instruments while power is applied to the circuit under test. ALWAYS remove power from the entire test system and discharge any capacitors before: connecting or disconnecting cables or jumpers, installing or removing switching cards, or making internal changes, such as installing or removing jumpers.

Do not touch any object that could provide a current path to the common side of the circuit under test or power line (earth) ground. Always make measurements with dry hands while standing on a dry, insulated surface capable of withstanding the voltage being measured.

For safety, instruments and accessories must be used in accordance with the operating instructions. If the instruments or accessories are used in a manner not specified in the operating instructions, the protection provided by the equipment may be impaired.

Do not exceed the maximum signal levels of the instruments and accessories. Maximum signal levels are defined in the specifications and operating information and shown on the instrument panels, test fixture panels, and switching cards.

When fuses are used in a product, replace with the same type and rating for continued protection against fire hazard.

Chassis connections must only be used as shield connections for measuring circuits, NOT as protective earth (safety ground) connections.

If you are using a test fixture, keep the lid closed while power is applied to the device under test. Safe operation requires the use of a lid interlock.

If a  screw is present, connect it to protective earth (safety ground) using the wire recommended in the user documentation.

The  symbol on an instrument means caution, risk of hazard. The user must refer to the operating instructions located in the user documentation in all cases where the symbol is marked on the instrument.

The  symbol on an instrument means warning, risk of electric shock. Use standard safety precautions to avoid personal contact with these voltages.

The  symbol on an instrument shows that the surface may be hot. Avoid personal contact to prevent burns.

The  symbol indicates a connection terminal to the equipment frame.

If this  symbol is on a product, it indicates that mercury is present in the display lamp. Please note that the lamp must be properly disposed of according to federal, state, and local laws.

The **WARNING** heading in the user documentation explains hazards that might result in personal injury or death. Always read the associated information very carefully before performing the indicated procedure.

The **CAUTION** heading in the user documentation explains hazards that could damage the instrument. Such damage may invalidate the warranty.

The **CAUTION** heading with the  symbol in the user documentation explains hazards that could result in moderate or minor injury or damage the instrument. Always read the associated information very carefully before performing the indicated procedure. Damage to the instrument may invalidate the warranty.

Instrumentation and accessories shall not be connected to humans.

Before performing any maintenance, disconnect the line cord and all test cables.

To maintain protection from electric shock and fire, replacement components in mains circuits — including the power transformer, test leads, and input jacks — must be purchased from Keithley. Standard fuses with applicable national safety approvals may be used if the rating and type are the same. The detachable mains power cord provided with the instrument may only be replaced with a similarly rated power cord. Other components that are not safety-related may be purchased from other suppliers as long as they are equivalent to the original component (note that selected parts should be purchased only through Keithley to maintain accuracy and functionality of the product). If you are unsure about the applicability of a replacement component, call a Keithley office for information.

Unless otherwise noted in product-specific literature, Keithley instruments are designed to operate indoors only, in the following environment: Altitude at or below 2,000 m (6,562 ft); temperature 0 °C to 50 °C (32 °F to 122 °F); and pollution degree 1 or 2.

To clean an instrument, use a cloth dampened with deionized water or mild, water-based cleaner. Clean the exterior of the instrument only. Do not apply cleaner directly to the instrument or allow liquids to enter or spill on the instrument. Products that consist of a circuit board with no case or chassis (e.g., a data acquisition board for installation into a computer) should never require cleaning if handled according to instructions. If the board becomes contaminated and operation is affected, the board should be returned to the factory for proper cleaning/servicing.

Safety precaution revision as of June 2017.