



Application Note AN-1801: Switching in the Real World

How do I connect my Product to standard test equipment?

Let's look at a set of examples to understand how to connect the Product being tested to standard test equipment. These examples use the TAMS 18xx USB Controlled Switches.

Product connection and test requirements

For the sake of example, consider a Product that has the following requirements for connection to test equipment:

Power needs to be applied in a particular sequence, and then current flow needs to be monitored.

+5 VDC at 8 Amps
Then +12 VDC at 1 Amp

The Product has certain "control inputs" which need to be stimulated with sources, arbitrary waveform generators, DACs, etc.

The Product has certain "control outputs" which need to be measured with multimeters, timers/counters, etc.

The Product controls certain high current loads such as motors or solenoids. The V/I characteristics of these outputs need to be measured.

In other words, the Product needs stimulus/response testing, where sources provide signals to stimulate the Product, and analyzers measure the Product's response.

Power supply and high current load connections

Figure 1 shows the connections from the two power supplies to the Product, and from the Product to the two high current loads. Using the TAMS 1805A 5 Channel Switch allows us to switch the power in a particular sequence (channels 3 and 4), allows us to switch the

loads so they are connected only when they are being tested (channels 1 and 2), and allows us to measure the current through each path by using a high impedance Digital Voltmeter (DVM) connected to Analog Bus terminals A-1 and A-2.

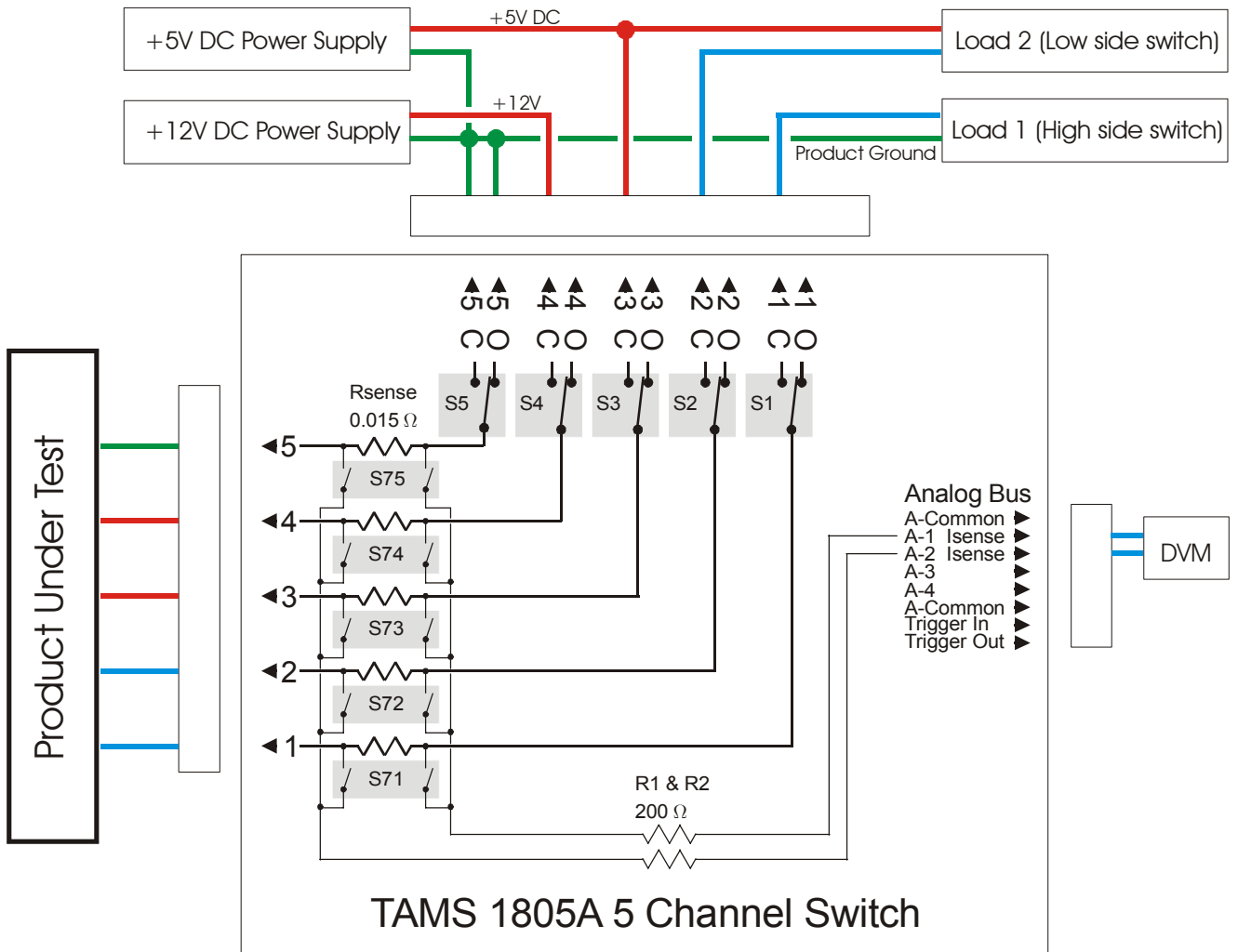


Figure 1 -- Product connections for power and high current loads

TAMS 1805A Configuration

The TAMS 1805A is a USB-controlled 5-channel switch. Each channel is capable of switching 8 Amps at 30DVC or 125VAC. See Figure 1. These high current switches are shown as S1 through S5. Each switch has two positions: a “CLOSE” command causes the switch to move to the “C” position, and an “OPEN” command causes the switch to move to the “O” position.

The current through each channel can be calculated by measuring the voltage across a 0.015 Ohm resistor, shown as Rsense. This Isense signal is routed through switches S71 through S75 to the Analog Bus connections on the rear of the device. A DVM connected to Analog Bus pins A-1 and A-2 allows measuring the voltage across Rsense to compute the current. Resistors R1 and R2 provide isolation between the analog bus and the power connections.

Example TAMS 1805A SCPI commands to apply power to the Product in Figure 1:

```
CLOSE (@3);*WAI          -- Connect +5V supply to Product
CLOSE (@4)               -- Connect +12V supply to Product
```

The *WAI is a standard IEEE 488.2 command which causes the switch box to wait until the relay is done debouncing before executing another command. This ensures that +5V is connected before +12V is applied.

Loads can be switched on the “high side” or “low side”. A “high side” load, for example Load 1 in Figure 1, is connected directly to ground, meaning that the Product must control the “high side”, in this case via channel 1 of the TAMS 1805A. Load 2 is a “low side” load, with a direct connect to the power supply, and the switching operation on the “low side”, here shown as channel 2.

Example commands to connect Load 1 to the Product and measure the current flowing through Load 1:

```
CLOSE (@1)               -- Connect Load 1 to the Product output pin 1
CLOSE (@71)              -- Connect Rsense for channel 1 to A-1 and A-2
```

The current can be computed as

$$I = \frac{V}{0.015}$$

where V is the voltage read by the DVM. For a high impedance voltmeter, R1 and R2 can be ignored when calculating the current.

Higher current switching: Parallel Channels can be used for higher currents beyond 8 Amps. See Figure 2.

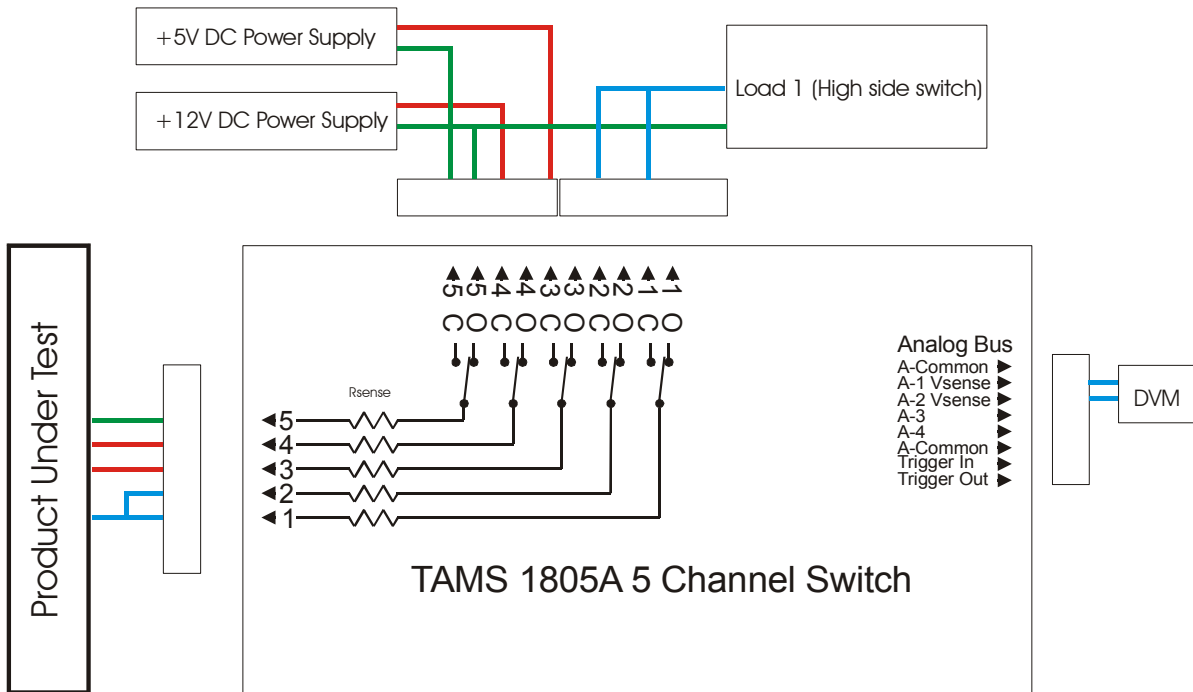


Figure 2 -- Higher current loads use multiple parallel channels. Switches S71 through S75 omitted for clarity.

In Figure 2, Load 1 is a high current load, and is therefore routed through channels 1 and 2 in parallel. Always operate the relays simultaneously:

CLOSE (@1,2)	-- Connect Load 1 to the Product
OPEN (@1,2)	-- Disconnect Load 1 from the Product

Connecting sources and analyzers to the Product's control inputs and outputs

A multiplexer is the simplest way to connect Product control signals to instrumentation. The multiplexer allows sharing one instrument among a set of signals, by switching exactly one signal at a time to the instrument. See Figure 3.

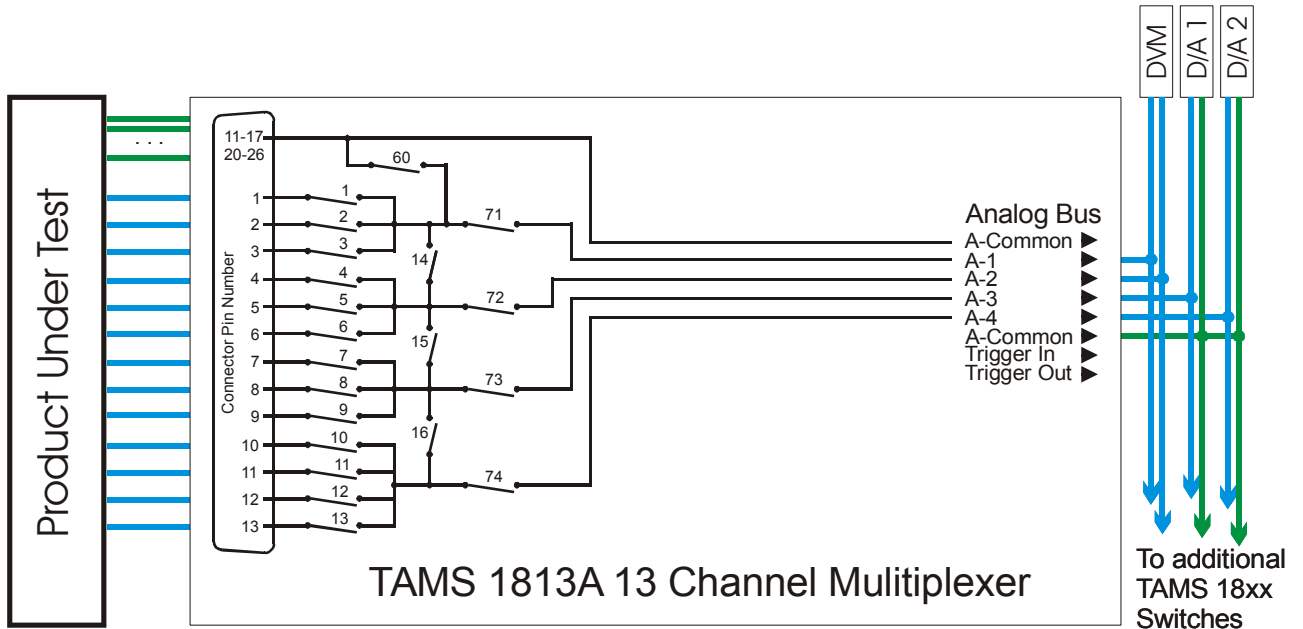


Figure 3 -- Product Under Test connections to a DVM and two Digital to Analog sources

Figure 3 shows the TAMS 1813A 13 Channel Multiplexer in a simple application. The TAMS 1813A is organized as a series of small multiplexers, which can be programmatically combined via configuration switches to form larger multiplexers. The first multiplexer is switches 1-3, which can be connected to the Analog Bus pin A-1 via switch 71 and can be connected to the second multiplexer via switch 14. The second multiplexer is switches 4-6, and so on. There are three “3 to 1” multiplexers, and one “4 to 1” multiplexer. Each multiplexer can be connected to one line on the Analog Bus, and adjacent multiplexers can be connected together to form larger multiplexers.

A number of different scenarios can be tested with the solution shown in Figure 3.

To measure the voltage across two Product pins, route those pins to the DVM. For example, to measure the voltage between connector pins 1 and 4:

```

OPEN ALL                                -- open all relays
CLOSE (@1, 71, 4, 72)                  -- connect pin 1 to A-1 (channels 1, 71)
                                         connect pin 4 to A-2 (channels 4, 72)

```

Half of the front connector pins are “A-common”, an Analog Ground for the product being tested. A-Common runs as a ground plane beneath the switching section of the TAMS 1813A. “A-Common” is completely separate from the USB ground.

To drive connector pin 9 with D/A 1 and connector pin 13 with D/A 2:

CLOSE (@9, 73, 13, 74)

-- connect pin 9 to A-3; connect pin 13 to A-4

Relay 60 allows grounding the A-1 bus to Product ground. To measure connector pin 4 voltage with respect to Product ground, using the DVM:

OPEN ALL

-- open all relays

CLOSE (@4, 72, 60, 71)

In a pure multiplexer, only one channel should be closed at any one time. The TAMS 1813A does not enforce a pure multiplexer – the user closes and opens switches explicitly, unless the scanning commands are used. The “OPEN ALL” command opens all relays.

What about scanning?

In many applications, the Product needs to be tested by quickly measuring a series of voltages across each channel. For the example in figure 3, we can set up a scan list of channels 1 through 13, and instruct the switches and the voltmeter to measure each channel and then move to the next channel. This scanning can proceed at hardware triggered pacing, with optional timer or software triggering as well. For the full details, see the TAMS 1805A manual.

Figure 3 can test with many scenarios, but notice some limitations. For example, Product pins near the top (1, 2, 3, ...) cannot be routed to D/A 3 if Product pins near the bottom need to be routed to the DVM. For such an application, the matrix switch provides an excellent solution.

What if I need more flexibility than the multiplexer provides?

The matrix switch provides the most flexibility to connect your Product to the test equipment, at a cost of consuming more relays per Product pin connection. See Figure 4.

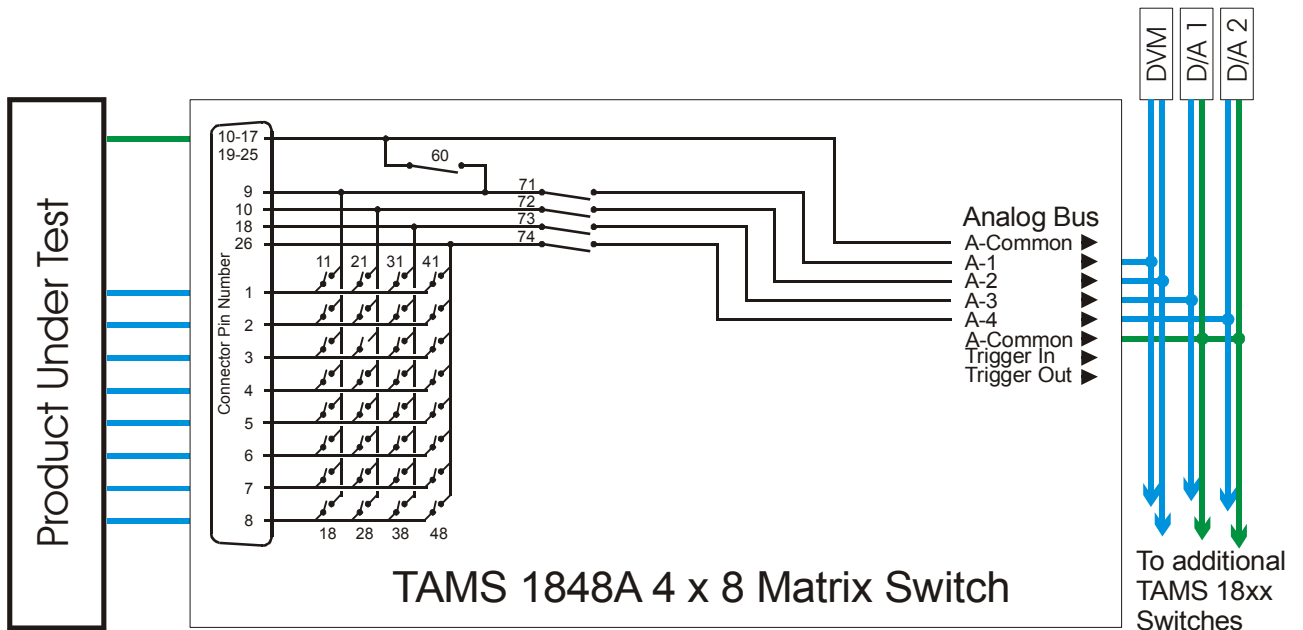


Figure 4 -- Product Under Test connections to a DVM and two Digital to Analog sources

The matrix switch in Figure 4 allows any Product pin to be connected to any Analog Bus pin. For example, to make a floating voltage measurement between pins 2 and 5:

OPEN ALL

CLOSE (@12, 71, 25, 72) -- connect pin 2 to A-1; connect pin 5 to A-2

To make a Product grounded measurement of pin 2:

OPEN ALL

CLOSE (@60, 71, 22, 72) -- connect A-1 to Product ground
connect A-2 to pin 2

What if I need to connect more Product pins?

The Analog Bus allows easy expansion of your switch system via simple daisy-chaining. You may connect as many units as needed. Figure 5 shows two 4 x 8 matrixes connected as a 4 x 16 matrix, allowing 16 Product pins to be tested.

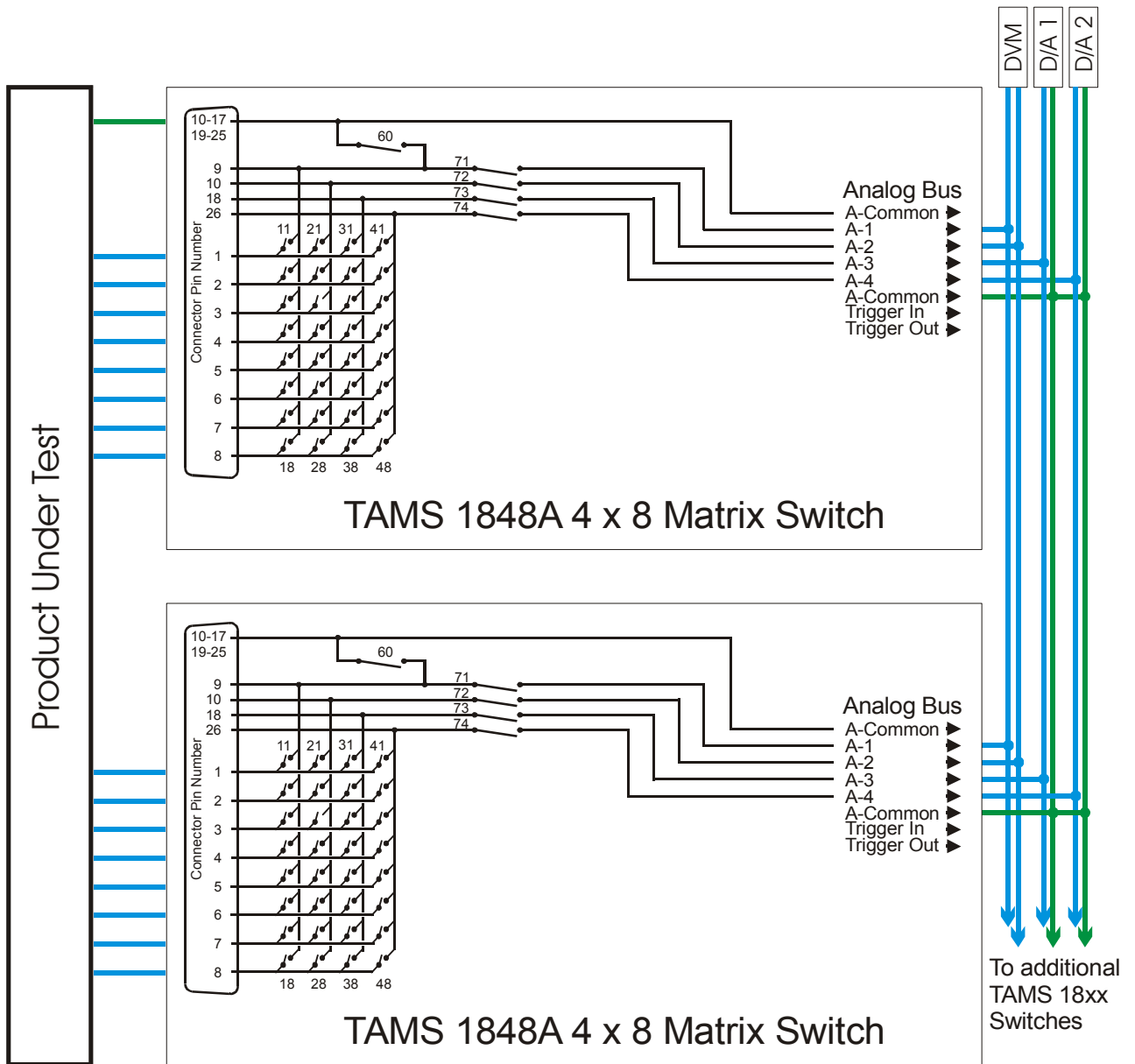


Figure 5 -- Expanding the matrix to connect more Product pins

This arrangement allows any of 16 Product pins to be connected to any instrument pin, in any combination. Connecting the instruments directly to the Analog Bus does, however, limit the number of instruments in this configuration.

What if I need to connect more instruments?

Additional instruments can be connected through matrix cards. See Figure 6.

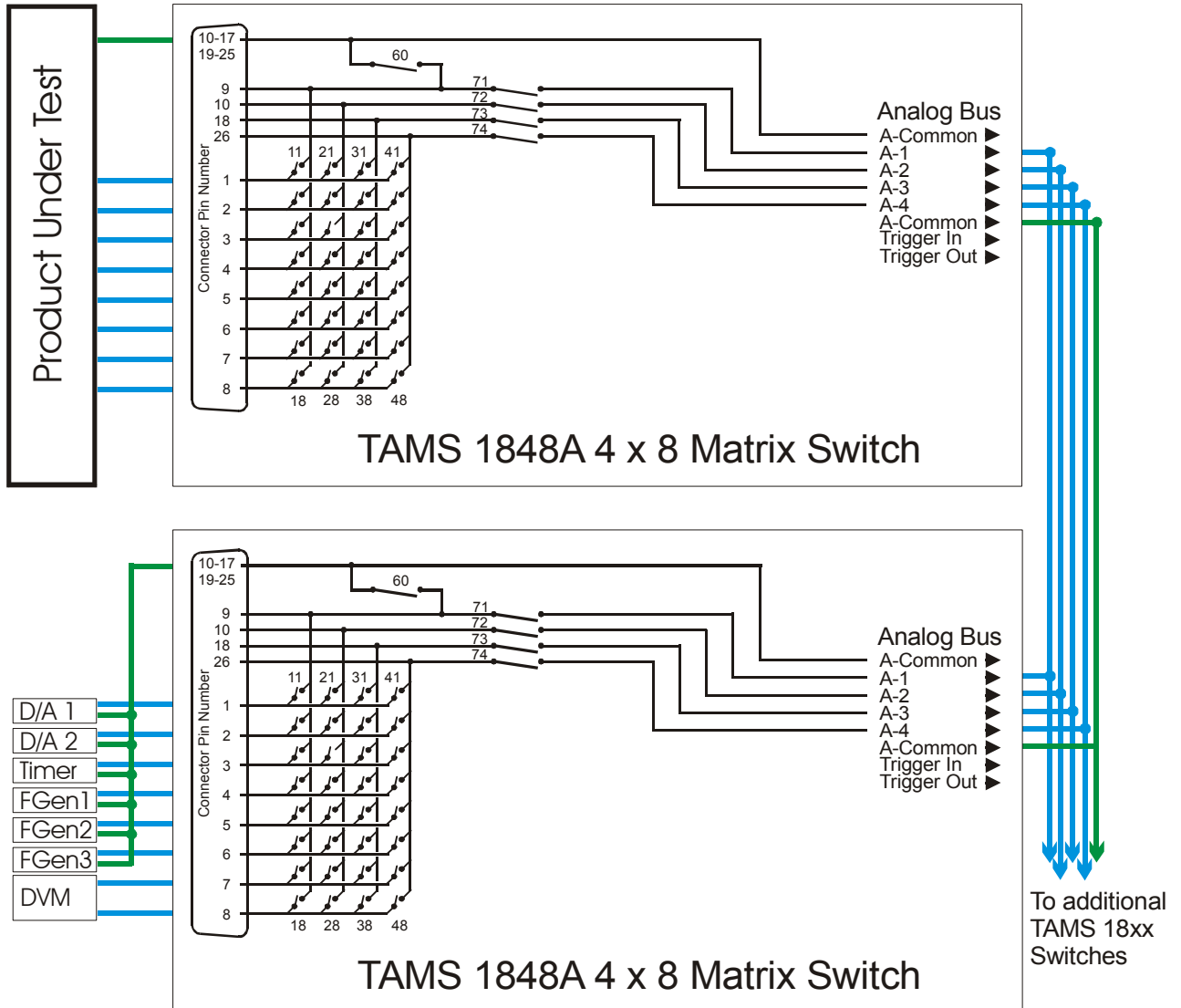


Figure 6 -- Additional instruments are added with matrix switches

Up to eight single ended instruments (or four floating 2 wire instruments) can be added with each additional matrix card. Figure 6 shows a mixture of single ended and floating instruments. In Figure 6, note that any combination of Product pins can be routed to any combination of instrument terminals. Also note that the number of Product pins and instrument terminals can be scaled up easily.

The full matrix switch is the most flexible arrangement, allowing any combination of measurement and stimulus on any set of Product pins.

Signal Integrity

Large matrix switches can suffer from stray capacitance and crosstalk, but these problems can be greatly reduced by opening relays 71 through 74 on each switch except the active one. This effectively reduces the size of the matrix back to 4 x 8 at any given time.

In addition, careful attention to grounding is required. The Product grounds are completely isolated from the USB and computer/controller ground. Each TAMS 18xx Switch provides multiple ground inputs to connect to A-Common on the Analog Bus. The A-Common trace runs as a wide ground plane underneath all the switching circuits. Twisted pair cabling between the Product and the switches will greatly increase signal integrity as well.

Reducing the size of the matrix

For some applications, a full matrix solution would require a prohibitive number of switches. Some Products can be tested with fewer switches if mutually exclusive sets of Product pins can be identified. These sets of pins can then be multiplexed together before the full matrix. For example, consider figure 7.

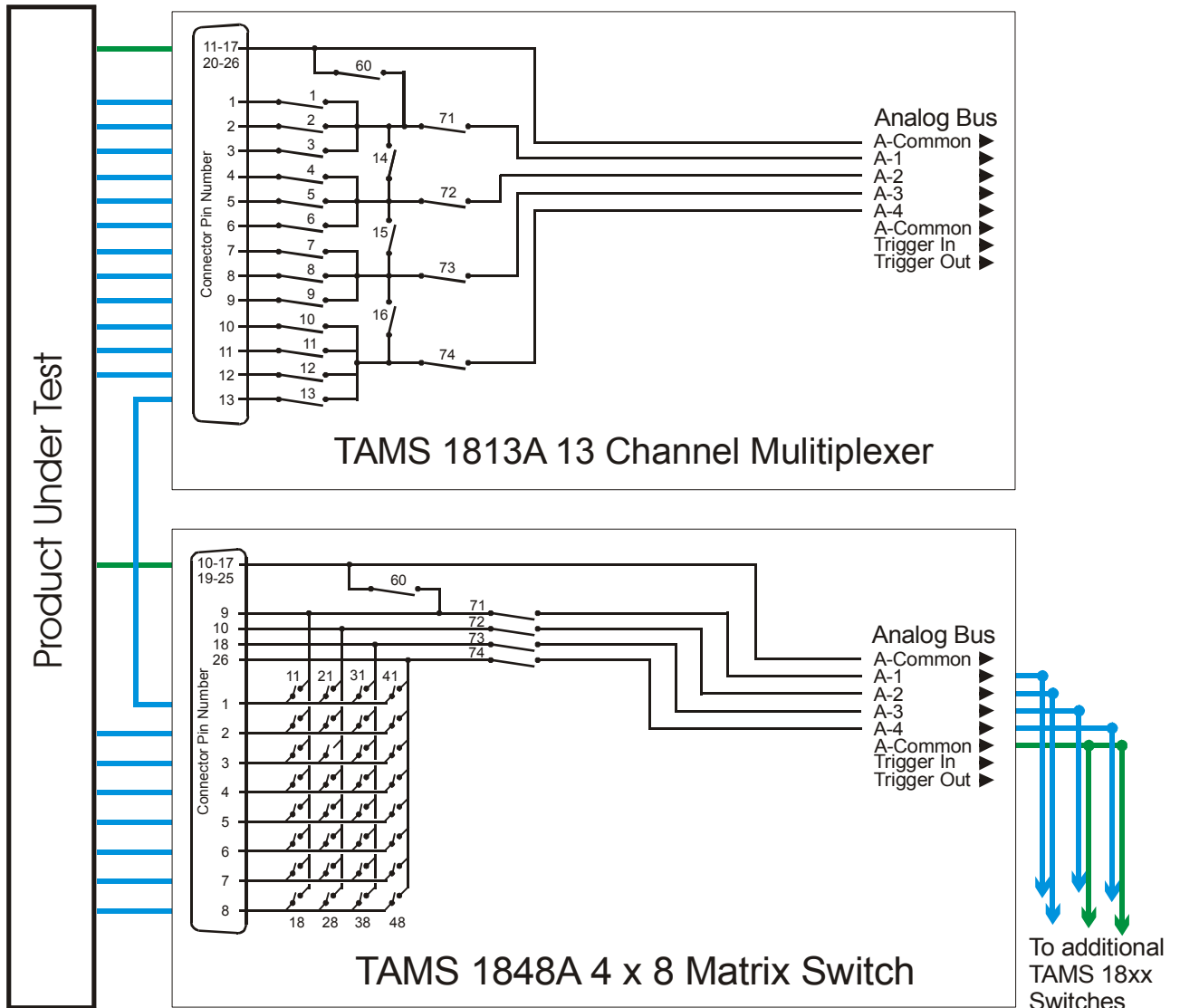


Figure 7 – A multiplexer expands the front end of the matrix

In Figure 7, the top 12 pins of the Product are multiplexed to the first pin of the matrix, meaning that each can be connected to an instrument one at a time.

Augmenting a matrix with multiplexers allows testing a large number of pins with only a modest increase in the number of switches, as long as only one pin at a time needs to be connected. The tradeoff of flexibility versus cost and complexity must be evaluated for each Product tested.

What about RF switching?

The Analog Bus is for baseband signals. RF switching is best accomplished by a dedicated RF switching topology, custom built to the application. The TAMS 1887A USB Switch Controller allows full control and readback of virtually any RF switch. This gives one consistent USB controlled framework for controlling the entire switching portion of your test system.

Putting it all together

Most test systems will require a combination of the building blocks presented here.

Dedicated Product pins whose use is mutually exclusive can be multiplexed for the most efficient connection solution. Product pins requiring simultaneous use will require matrix switching. Using multiplexing as a front end for the matrix can greatly reduced the size of the matrix. Instruments can be connected directly to the Analog Bus, or they can be multiplexed or matrixed from the Analog Bus. Loads and power can usually be switched with the same unit. A simple current sense multiplexed to the Analog Bus allows key parameters to be measured without field wiring or routing of high currents to the instruments.