Application Note

Design Guide to Replace Relays with High-Voltage Analog Switches on ATE Boards

ABSTRACT

Analog switches offer many advantages over relays for use on Automated Test Equipment (ATE) boards but have been underutilized due to the limited power supply resources available on automated testers. This document discusses how to supply switches on ATE boards and shares example layouts and schematics, as well as key considerations for selecting the right switch for ATE board needs.

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1 Introduction

Relays are common on ATE boards, but have many disadvantages – large size, high power consumption, slow rise time, and poor long-term reliability. Analog switches can be used to combat these disadvantages of relays but may have a perceived limitation due to the finite power supply options available on ATE boards. Relays can pass through high voltage signals with only a 5V supply, whereas analog switches most often require a power supply in the same range as the signal going through the switch, thus limiting their use for high voltage applications on an ATE board. After discussing key differences between relays and switches, this application note details the options available for powering analog switches under such limitations, while still shrinking the total system design.

Mechanical relays, photorelays, and analog switches all perform a similar function, but in different ways. Mechanical relays typically consist of an inductive coil and a physical switch. When current excites the coil, this becomes magnetic and pulls two pieces of metal together. Photorelays have a similar operation except instead of a coil, an LED is used to drive the gate of a MOSFET on/off. An analog switch integrates multiple drivers and MOSFETs onto the same chip and drives the gate with a constant voltage source. As a result, analog switches save PCB space compared to Photorelay and mechanical relays.[1]

The key advantages of analog switches over relays are:

- High channel density
- Lower power consumption
- Can be controlled by any power supply available on the tester, due to low current requirements
- Can be SPI controlled, allowing IO expanders to be removed
- High long-term reliability
- Cost-effective

For more details on when and why to use switches in place of relays, see *When to Replace a Relay With a Multiplexer*.

2 How to Power Analog Switches

To power an analog switch on an ATE board, any power supply innate to the tester that can support the required voltage can be used. Below are the most common options available on an ATE board.

- An instrument on the tester (for example, analog sources and supplies)
- Power rails of the tester

2.1 ATE Instruments

Consider the current range of the supply when using tester instruments as power supplies for analog switches. If the current range is too low, an over voltage event on the switch cannot be properly clamped. Excess voltage on the signal line (source or drain) forwards bias the internal ESD diodes connected to the switch supply pins (see Figure 2-1). If the current on the power supply clamps, then the driving voltage from the signal line can raise the voltage on the supply pins, possibly exceeding the absolute maximum voltage of the switch. To avoid damage, a TVS diode can be placed between the supply rails of the switch to clamp the voltage between the rails, and to discharge excess current. Note that one TVS diode can serve multiple switches. TI recommends managing the current ranges on the signal lines to avoid damage.

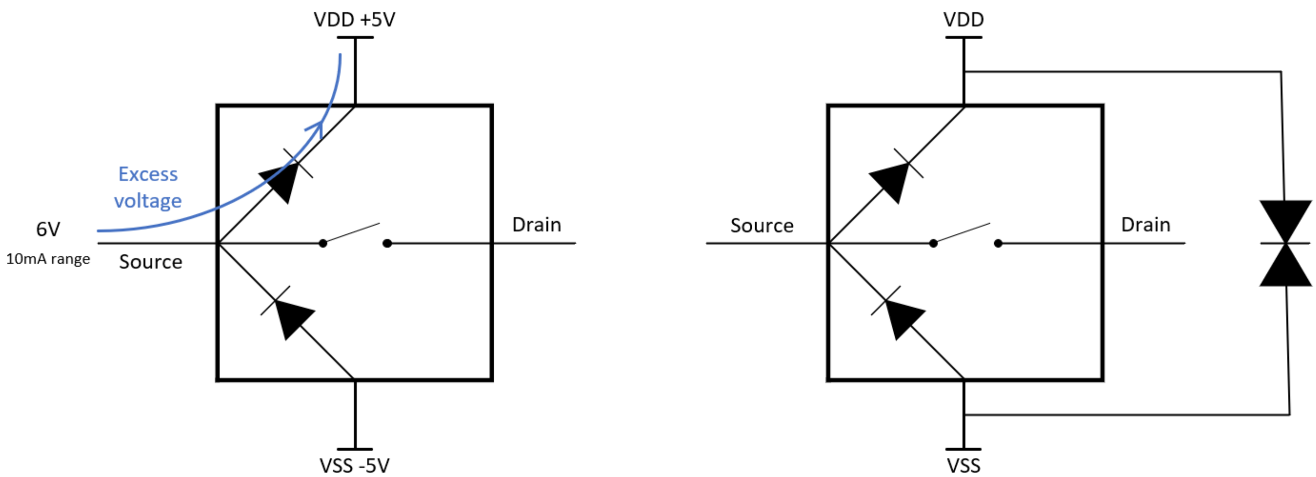

Figure 2-1. Preventing Overvoltage to VDD

2.2 Power Rails of the Tester

DC supplies in the tester can be used to power switches, even if the voltages are greater than the signals that are switching. The 5V and 12V DC supplies are commonly used in ATE boards, often to power the diodes and coils of relays. There are also often additional supplies, such as 15V or 24V, that can effectively supply a wider voltage range for your analog switches. When using these supplies, consider fault handling, as these supplies can often drive multiple amps of current. In the event of a damaged switch or electrical short, the heat generated can cause further damage. This can be managed with appropriately sized fuses, which can be divided by test site or zones if there are a large number of switches being used on the board (see Figure 2-2). This protects the PCB and components from over current damage, and this can aid in debug efforts by isolating the short to a given zone. Note that if a fuse isolates the supplies for a given zone, then signals carried by the switches in that zone can forward bias the internal ESD diodes, causing a back power scenario. TVS diodes across the supply rails inside each zone and signal line current management must be used to prevent damage to the switches.

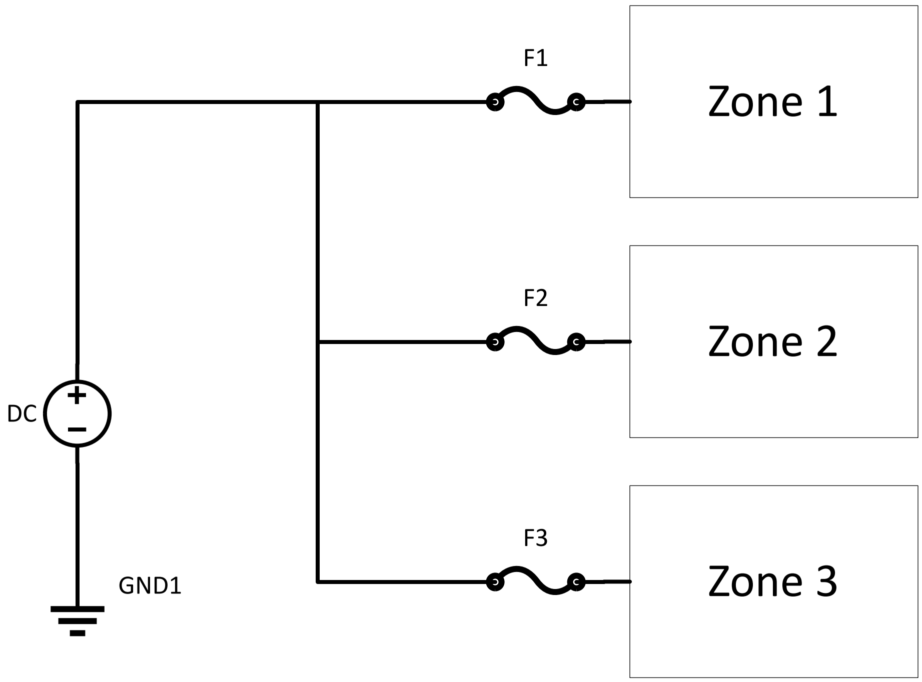

Figure 2-2. Fuse Feed Block Diagram

2.3 Power Supply Design and Considerations

Most analog switches require a power supply up to or greater than the signal that is being passed. Therefore, in the case of a high voltage signal, a high voltage supply is also needed. While most automated testers do not have high voltage supplies, TI has provided power supply design reference designs below for simplicity. Included in this section are schematic and layout designs for ±35V, ±50V, and 100V supplies.

When using one of the power supply reference designs provided by TI, consider the following:

- Keep the power and analog components separate
- Feedback and compensation pins of buck or boost converters are sensitive
  - Make sure traces to these pins are short
  - Keep these pins far from any power components or traces

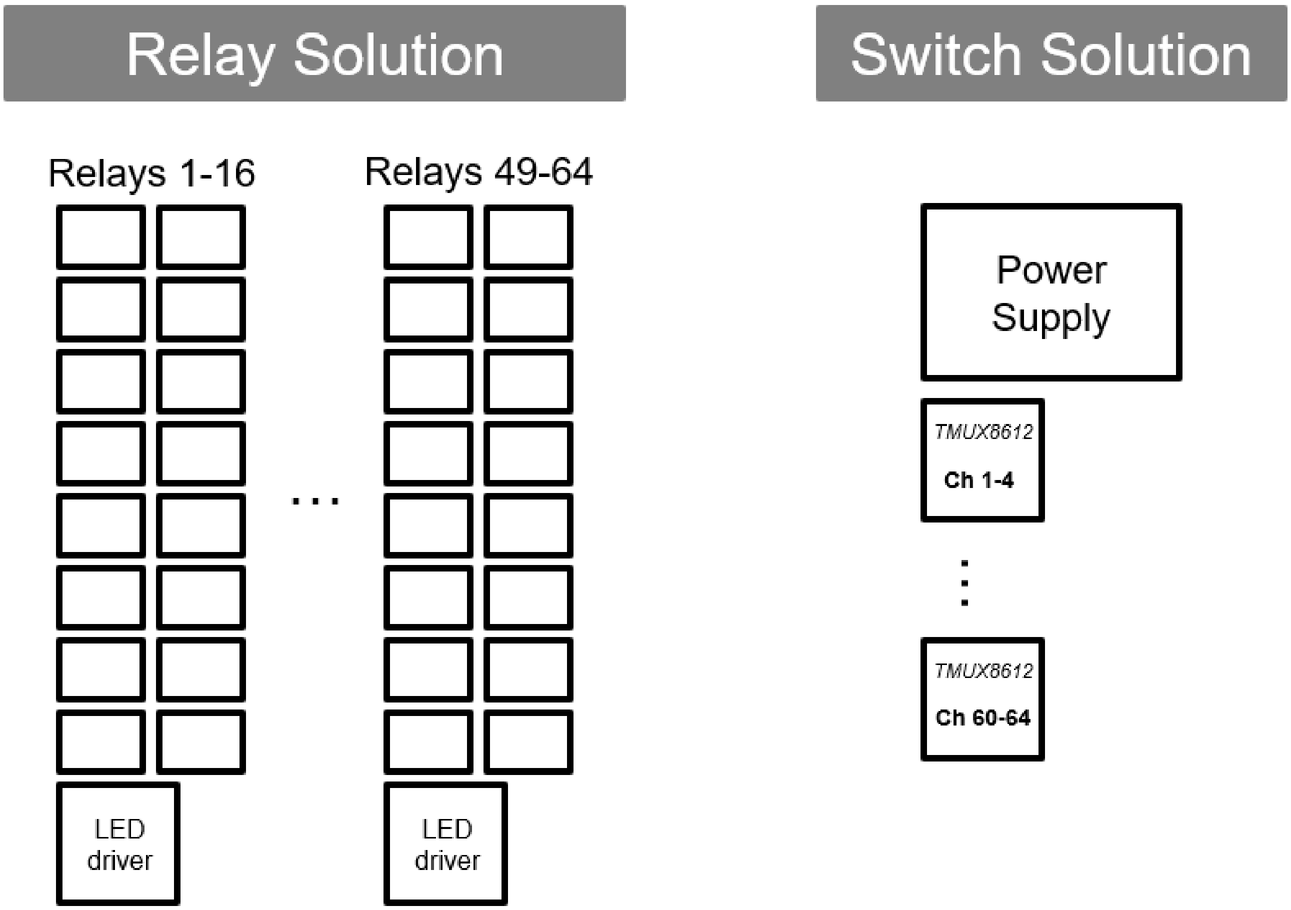

Figure 2-3. Relay vs TMUX8612 64-Channel Solution Block Diagram

While there is extra circuitry involved in powering a high voltage analog switch, Figure 2-3 shows that this 64-channel design is smaller than most alternative relay-based designs.

Table 2-1. TMUX8612 vs Relay 64-Channel Total Design Size

	±35V	±50V	100V
TMUX8612	$1065mm^2$	$1318mm^2$	$995mm^2$
PhotoRelay	$1508mm^2$	$1508mm^2$	$1508mm^2$
Analog Switch Size Savings	$443mm^2$	$190mm^2$	$513mm^2$

2.3.1 ±35V Schematic & Layout Example

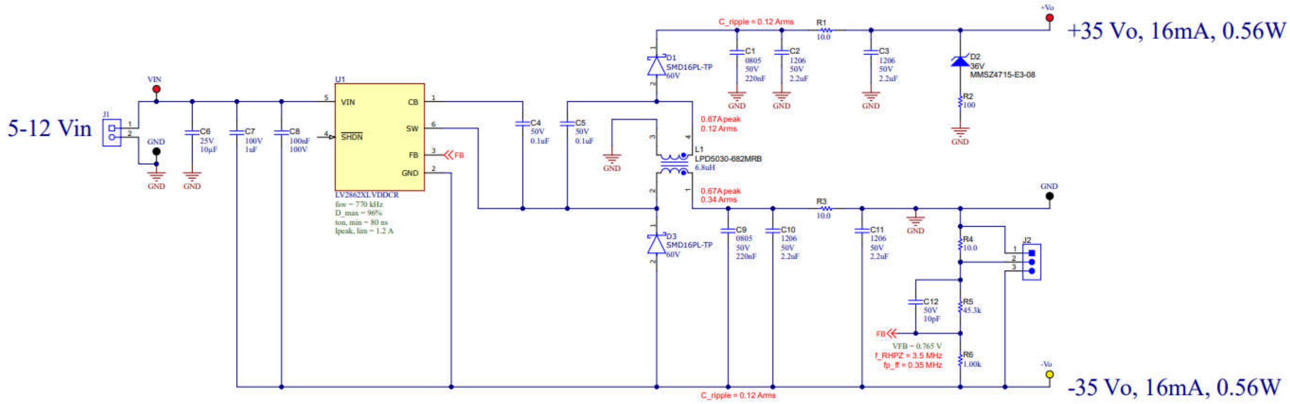

Figure 2-4. ±35V Power Supply Schematic

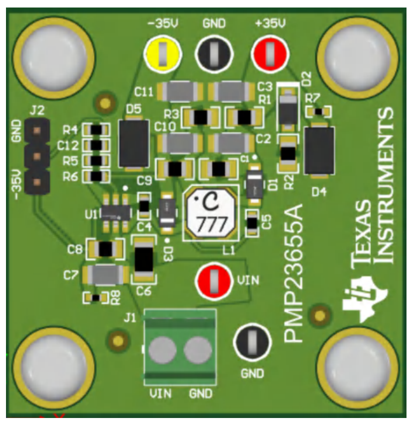

Figure 2-5. ±35V Power Supply Layout

2.3.2 ±50V Schematic & Layout Example

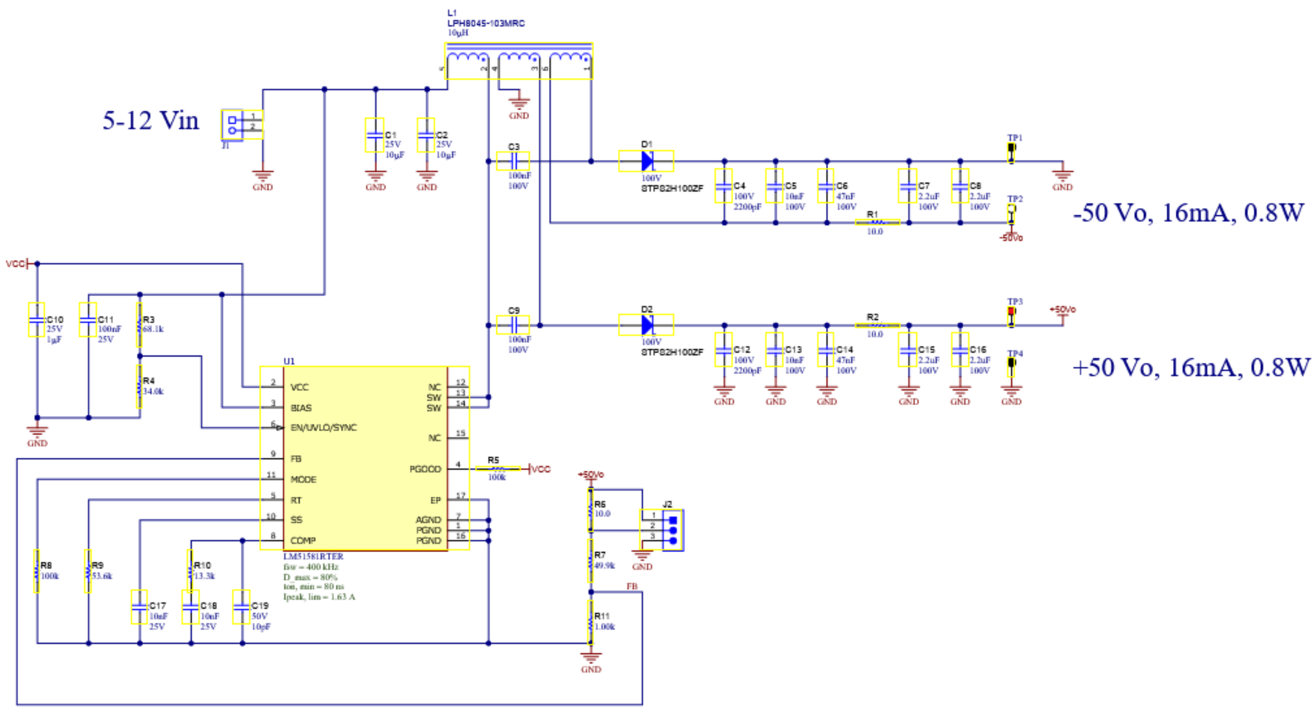

Figure 2-6. ±50V Power Supply Schematic

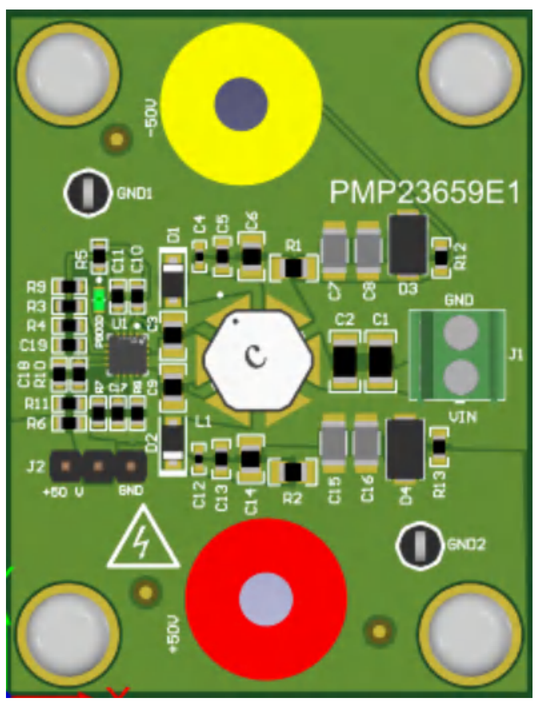

Figure 2-7. ±50V Power Supply Layout

2.3.3 100V Schematic & Layout Example

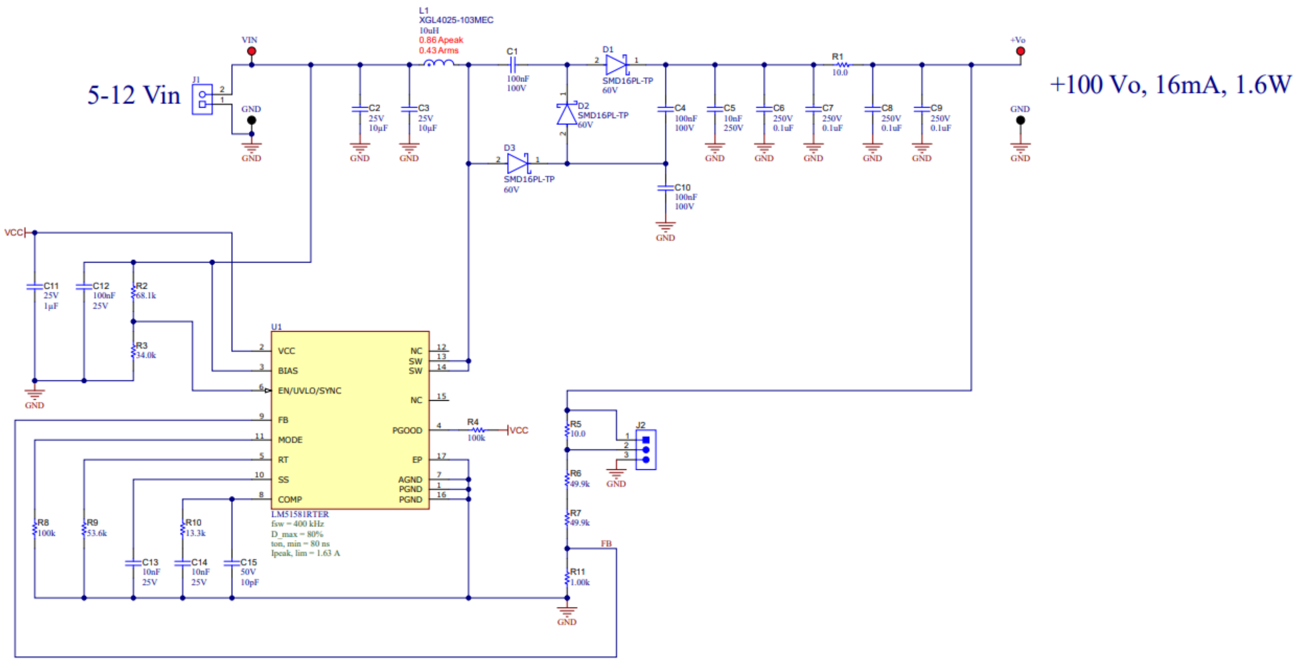

Figure 2-8. 100V Power Supply Schematic

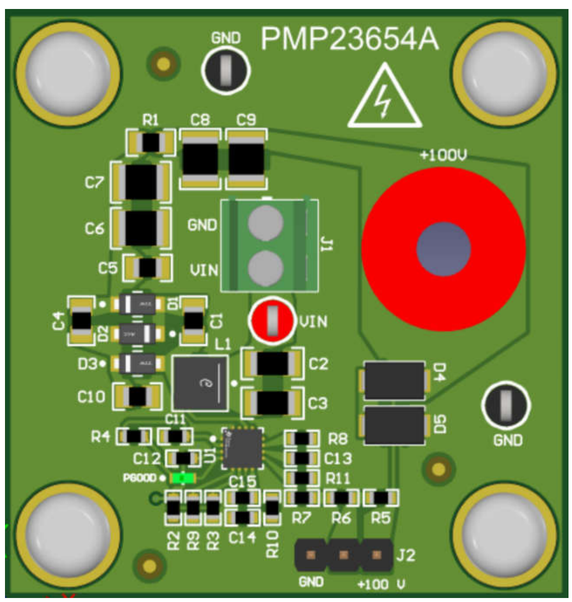

Figure 2-9. 100V Power Supply Layout

3 Controlling the Switch

3.1 CBITs

Unlike relays, analog switches require minimal current to control, allowing the option of using CBITs to control the switch with a direct connection. If selecting to control an analog switch with CBITs, it is helpful to pick a switch with logic that matches that of the CBITs. CBITs use an open drain drive (see Figure 3-1) and CBITs are low when on and high when off. To avoid confusion during test program development, select an active low switch such that the switch turns on when the CBIT is turned on.

Remember the I_{IL} and I_{IH} of the analog switch being used, as multiple switches being controlled together can require more current. In cases such as these, TI recommends adding an additional pullup resistor to the CBIT line. This provides the CBIT with a stronger high drive to support more control pins, and to improve switching times. Without the use of an additional pullup, the control signal can be too slow or the voltage can not be high enough to trigger the switch reliably.

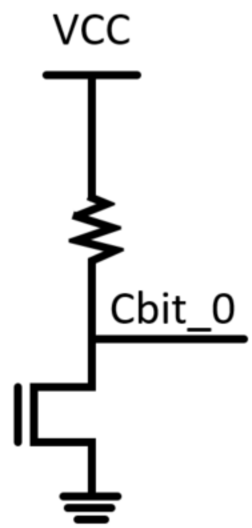

Figure 3-1. CBIT Architecture

3.2 Digital Instruments

Digital instruments can also be used to control switches by sending digital high or low signals. Note that the I_{IH} and I_{IL} current of the switch determines how many switches can be controlled by a single instrument.

4 Selecting the Correct Switch

There are many considerations in selecting the correct switch for an ATE board. Just like when selecting a relay, look at on-state resistance and leakage when selecting a switch. Table 4-1 lists some of TI's high voltage switches with low leakage and low RON.

Table 4-1. High Voltage Analog Switches

	TMUX7612	TMUXS7614D	TMUX8612
Configuration	4 channel, 1:1	8 channel, 1:1	4 channel, 1:1
Supply Voltage	5V to 50V ±4.5V to ±25V	4.5V to 42V ±4.5V to ±25V	10V to 100V ±10V to ±50V
Supply Current (ON)	435µA	840µA	65µA
RON	1.1Ω	1Ω	14Ω
COFF	24pF	24pF	7pF
Turn on time	2.1µS	2.1µS	28µS
IOFF	21pA	21pA	30pA
SPI Control	N/A	Yes	N/A
Size per channel	$4.0mm^2$	$2.5mm^2$	$4.0mm^2$

5 Summary

Replacing relays with analog switches on test boards can be a great cost-effective and space-effective selection. Switches require less power, and if SPI controlled, can allow IO expanders to be dropped. By using the examples provided in this application note, a user can replace relays with switches for a variety of signals from low to high voltage, allowing the user to take advantage of these benefits.

6 References

1. Texas Instruments, *When to Replace a Relay With a Multiplexer*, application note.
2. Texas Instruments, *TMUX7612 50V, Low-RON, 1:1 (SPST), 4-Channel Precision Switches with 1.8V Logic* datasheet.
3. Texas Instruments, *TMUXS7614D 50V, SPI Controlled, Low-RON, High Density, 1:1 (SPST), 8-Channel Precision Switches with 1.8V Logic* datasheet.
4. Texas Instrument, *TMUX861x 100V, Flat Ron, 1:1 (SPST), 4-Channel Switches with Latch-Up Immunity and 1.8V Logic* datasheet.

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