All Purpose Analog Switch Design Hints

Introduction

The PI5A100/101 and PI5A3XXA families are all-purpose CMOS switches that can be used in a variety of applications. Because these switches exhibit very low on-resistance and flatness when the input is swinging rail-to-rail, they can often replace mechanical reed relays. These "all-purpose" switches can be used to switch digital bus data, analog signals, and in low-power applications.

This brief contains the following information:
1. Inverter, T, L, π, and Crosspoint configurations.
2. Multiplexing analog or digital signals.
3. General Design Hints...protection circuit, loading, distortion etc.
4. General Applications...integrator, clock signal switch, differential signal switch, low-power high-side driver/switch.

Switch Configurations

PI5A101 and PI5A391A are Quad Single-Pole Single- Throw (SPST) switches that can be arranged in numerous configurations, some of which are described below.

Inverter Switch

The quad PI5A101 and PI5A391A products are active low (enable) switches. But, by using the circuit shown in Figure 1, they can create an inverted logic signal. This circuit has many uses, some are explained below.
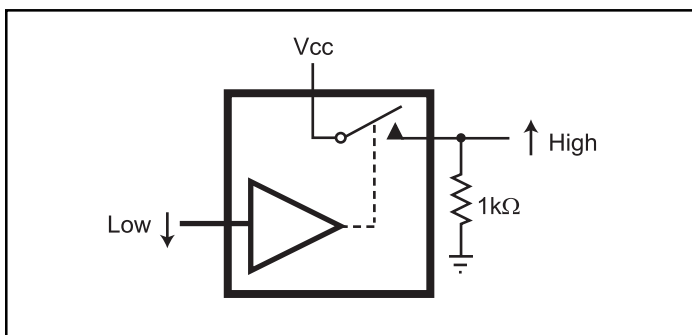

Figure 1. Inverter using PI5A101 & PI5A391A

"T" Switch

The "T" switch, shown in Figure 2, reduces crosstalk and improves off-isolation. When series switches are "off," the shunt switch is "on," steering any unwanted signal at either I/O to ground, thus isolating the input and output. Further isolation is created because there are two switches in series. This switch configuration is used in video and RF multiplexer and crosspoint applications.
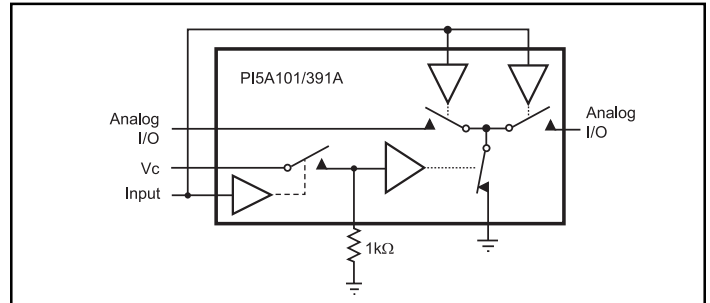

Figure 2. "T" Switch using PI5A101 & PI5A391A

"L" Switch

The inverting "L" switch, shown in Figure 3, is a simplified "T" switch that is also useful in helping crosstalk and off-isolation. Because there is only one series switch, the on-resistance is one-half that of the "T" switch.
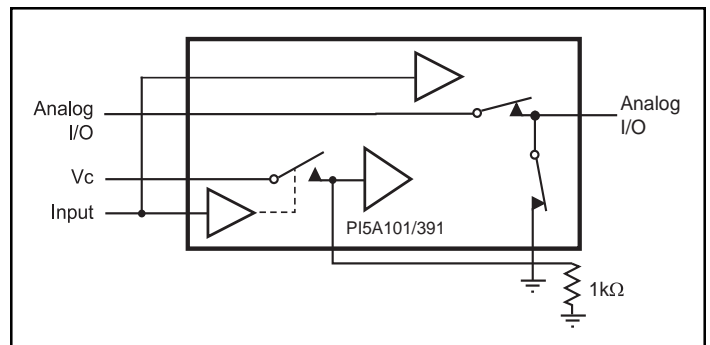

Figure 3. Inverting "L" Switch using PI5A101 & PI5A391A

"π" (Pie) Switch

The pie switch, shown in Figure 4, is ideal for terminating a cable even when the switch is open. In this example, an RG58 50Ω cable impedance can be matched and switched.
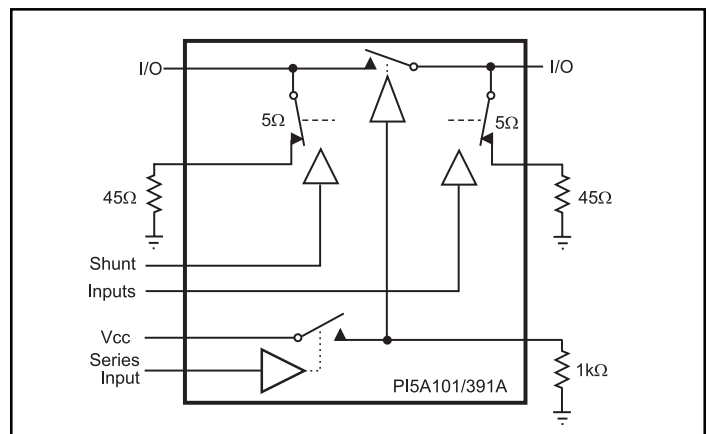

Figure 4. π (pie) Switch using PI5A101/391A

Crosspoint Switch

As shown in Figure 5, PI5A101 & PI5A391A can be used as crosspoint switches using the "T" configuration shown in Figure 2.
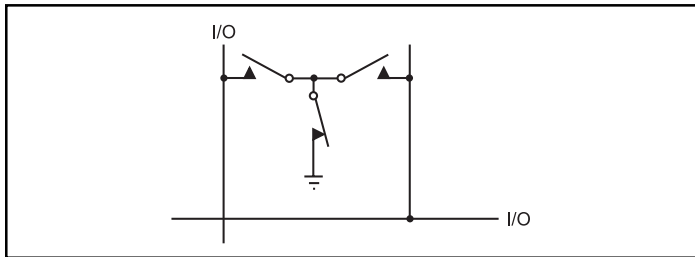

Figure 5. Crosspoint Using PI5A101 & PI5A391A

Multiplexing Both Analog and Digital Signals

The PI5A100 & PI5A319A are SPDT switches (PI5A100 is a quad). These parts perform muxing and demuxing for rail-to-rail digital or analog signals.

Break-Before-Make Switch Action

A consideration in muxing signals (selecting 1 of 2 or more channels) is when a make-before-break action occurs. This is not desirable because channels are connected at the same time. A good multiplexer has a break-before-make switch action, this guarantees only one channel is selected at the same time. Both the PI5A100 and PI5A319A are break-before-make multiplexers. The data sheet shows a turn-on (t_{ON}) time of generally 10ns and a turn-off (t_{OFF}) of 5ns. This 5ns difference indicates a break-before-make action. The t_{ON} time must always be longer than t_{OFF} time. If t_{OFF} becomes longer than t_{ON}, two channels can conduct simultaneously. This can occur when RC time increases.

Assuming a load resistance of 50W and a load capacitance of 100pF, the RC time is 5ns. So with t_{OFF} = 5ns and the additional discharge time of C_L (see Figure 6) equal to 5ns, the new turn-off time is 10ns. Since t_{ON} is 10ns and the new t_{OFF} is 10ns, a break-before-make can no longer be guaranteed.
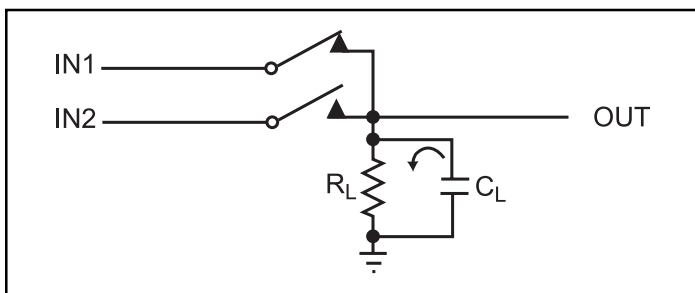

Figure 6. Discharge Time of C_L Helps Determine t_{OFF}

Mux Or Demux?

The PI5A100 & PI5A319A are true bidirectional mux-ing switches that can easily be used in the reverse direction as a demux, i.e., to send one common signal to two possible destinations.

GENERAL DESIGN HINTS

Fault Protection

These analog switches should not be operated more than 0.7V above the positive rail. Generally a 1N914 or any signal diode can be used to protect against overvoltage. Actually these analog switches are not recommended for input signals that exceed either rail by more than 0.7V. Doing so can cause an internal parasitic diode to turn on. If more than 20mA is drawn by the forward biased diode, damage can occur.
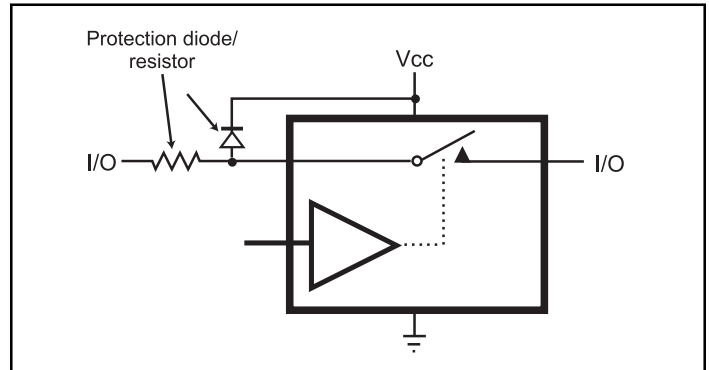

Figure 7. Fault Protection Against Overvoltage

The current limiting resistor can also be placed in series with Vcc.

Distortion

These switches have very low distortion because the typical change in R_{ON} is only 2Ω. Increasing resistive loads also reduces distortion as seen here:

$$\text{Distortion} = 20\text{Log}\Delta R_{ON}/R_L$$
$$\text{or}$$
$$\%\text{Distortion} = \Delta R_{ON}/R_L$$

The R_{ON} flatness is critical to low distortion. Since the rail-to-rail on-resistance change is only 2Ω, minimal signal distortion is expected in most applications.

Loading

Both resistive and capacitive loads are critical to video switch performance. Increasing resistive loads also increases the crosstalk (X_{TALK}) and negatively affects off-isolation (OIRR).

$$X_{TALK} \text{ or OIRR} = 20\text{Log } V_O/V_{IN}$$

GENERAL APPLICATIONS
Analog Integrator - Filter - Sample/Hold

Make-before-break switch action is needed in an active integrator otherwise severe glitches can occur when switching various capacitance in and out of the loop. These switches normally are break-before-make at lower capacitance but change to make-before-break as the capacitance increases.

The circuit shown in Figure 8 can be used as a selectable integrator or a sample/hold amplifier or even a low pass filter. R2/R1 sets a DC gain when S2 is enabled. S3 and S4 select two capacitance values. S1 can be used for a sample/hold application.
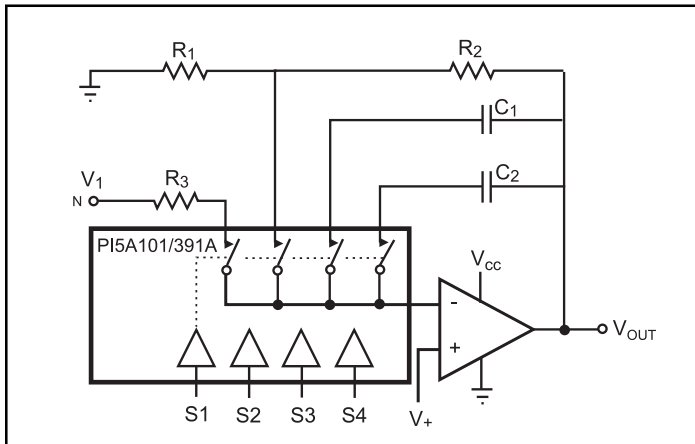
Figure 8. Single-Supply Integrator/Filter/Sample-Hold

Bus Switch...Switching a Clock Signal

These analog switches also make very good bus switches. Typically a bus switch is considered a zero delay device because its channel resistance, when the switch is closed, is about 5Ω. But since on-resistance (R_{ON}) increases with an increasing input voltage level, the propagation delay also increases. Propagation delay is directly proportional to:

$$R_{ON} \text{ x } C_L.$$

A system clock is designed for a 50 percent duty cycle. A TTL clock signal propagating through a bus switch will trigger at about 1.5V on the rising edge of the signal. The R_{ON} of the switch is relatively low at about 6Ω. But on the falling edge, because the level is higher, the edge is pushed out owing to the increase in propagation delay (see Figure 9). Because of the unequal propagation delay on the edges, the duty cycle can degrade from 50 percent to 60/40 percent.
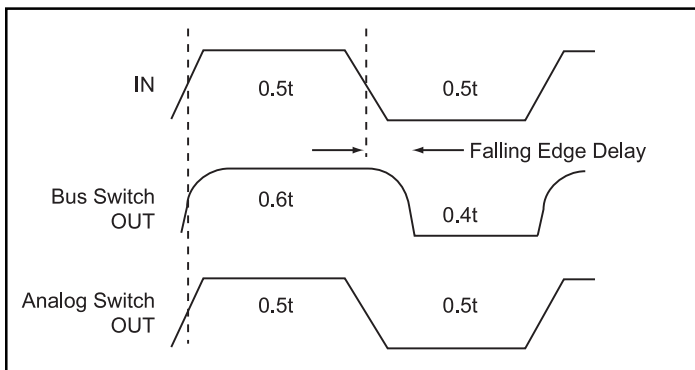

Figure 9. Analog Switch Improves Duty Cycle

The analog switch has a constant R_{ON} even with rail-to-rail changes in amplitude. This means that both the rising and falling edge propagation delays are the same. The duty cycle then remains 50 percent.

High-Side Driver /Switch

Actually these analog switches can switch in excess of 100mA per channel. The PI5A101 & PI5A391A can switch close to half an ampere (don't exceed package maximum) when the four switches are placed in parallel. Figure 9 shows a typical position of the switch.
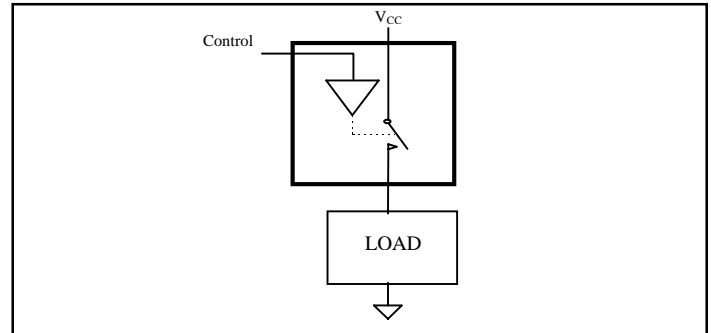

Figure 10. High-Side Driver/Switch

Figure11 shows the parallel connection of the switches such that each channel can divide the current and keep internal power dissipation spread across the chip. I^2R_{ON} gives the power dissipated in each channel. If the channel current is 100mA and R_{ON} is 6Ω, this results in 60mW power dissipation per channel. It should be noted that the **parallel connection** reduces R_{ON} from 6Ω to 1.5Ω.
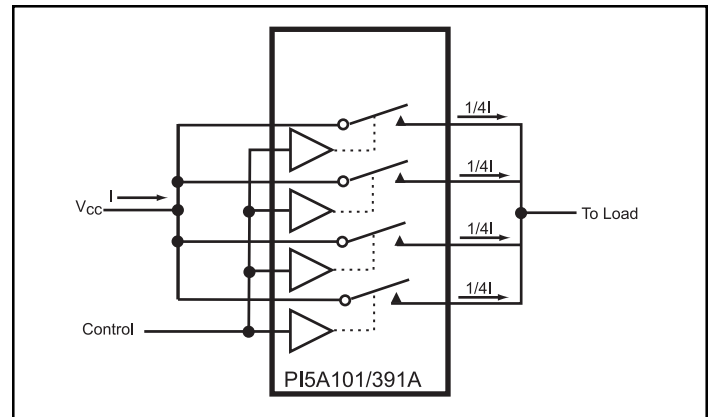

Figure 11. PI5A101 & PI5A391 Low Power Parallel Operation

Differential Applications

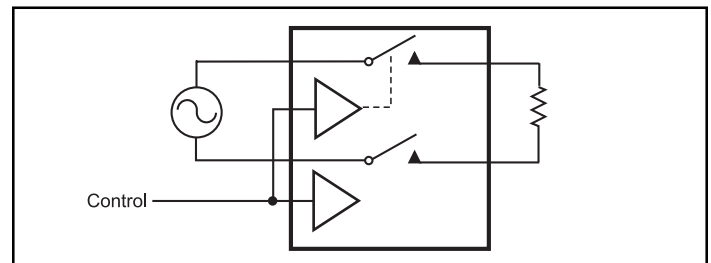These analog switches can be used in differential circuits if input signals stay within the rails. No other precautions need be taken (see Figure 12).

Figure 12. Differential Signals