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APPLICATION NOTE 5299

Selecting the Right CMOS Analog Switch

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Abstract: With the large number of analog switches on the market today, there are many performance criteria for a product designer to consider. This application note reviews the basic construction of the standard CMOS analog switch and describes some common analog-switch parameters. It also discusses the improved performance offered by the latest analog switches.

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Introduction

Integrated analog switches often form the interface between analog signals and a digital controller. With the large number of analog switches on the market today, there are many performance criteria for a product designer to consider. There are also many application-specific switch circuits that have evolved from the standard CMOS switch developed over 35 years ago.

This article reviews the basic construction of the standard CMOS analog switch and describes some common analog-switch parameters such as on-resistance (R_{ON}), R_{ON} flatness, leakage, charge injection, and off-isolation. It discusses the improved performance offered by the latest analog switches: better switching characteristics, lower supply voltages, and smaller packages. Application-specific features such as fault protection, ESD protection, calibration multiplexers (cal-muxes), and force-sense capability are explained. Application-specific switches for video, Hi-Speed USB, HDMI®, and PCIe® applications are presented.

Basics of a Standard Analog Switch

The structure of a conventional analog switch is shown in **Figure 1**. Connecting an n-channel MOSFET in parallel with a p-channel MOSFET allows signals to pass in either direction with equal ease. The n-channel device carries signal current that is dependent on the ratio of input voltage to positive supply voltage, while the p-channel device carries signal current that is dependent on the ratio of input voltage to negative supply voltage (or ground in single-supply designs). Because the switch has no preferred direction for current flow, it has no preferred input or output. The two MOSFETs are switched on and off by internal inverting and noninverting amplifiers. These amplifiers level shift the digital input signal as required, according to whether the signal is CMOS- or TTL-logic compatible and whether the analog supply voltage is a single or dual supply.

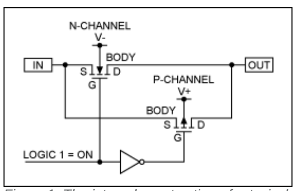

Figure 1. The internal construction of a typical analog switch features parallel n- and p-channel MOSFETs.

Conventional analog switches like the early CD4066 are now offered by many semiconductor manufacturers. Maxim also offers devices such as the MAX4610, which is pin-for-pin compatible with these earlier switches, but provides better performance. For example, there are now CD4066 pin-for-pin compatible parts that provide lower R_{ON} and higher accuracy than the original CD4066.

There are also some functional variations to the basic analog switch construction. Some low-capacitance analog switches use only n-channel MOSFETs in the signal path (e.g., the MAX4887) and eliminate the larger p-channel MOSFETs that significantly reduce the bandwidth of the analog switch.

Other analog switches operating from a single positive supply rail use charge pumps to allow negative signal voltages. For example, the MAX14504 audio switch operates from a single $+2.3V_{CC}$ to $+5.5V_{CC}$ supply and an internal charge pump allows signal capability from $-V_{CC}$ to $+V_{CC}$ to pass without distortion. In addition to improved functionality, many of the industry's latest analog switches are offered in smaller packages than earlier generation parts.

Low On-Resistance (R_{ON}) Switches Reduce Signal Losses

The combined p- and n-channel R_{ON} in parallel for each level of V_{IN} yields a composite R_{ON} characteristic for the parallel structure (**Figure 2**). This plot of R_{ON} versus V_{IN} can be described as linear if you exclude the effects of temperature, power-supply voltage, and R_{ON} variation with analog input voltage. Ideally, R_{ON} would be as low as possible in order to keep the signal losses and propagation delays small. However, reducing R_{ON} involves increasing the width/length (W/L) ratio of a MOSFET's silicon, which results in higher parasitic capacitance and a larger silicon area. This larger parasitic capacitance reduces the bandwidth of the analog switch. Apart from W and L, R_{ON} is a complex function of electron and hole mobility (μ_n and μ_p), oxide capacitance (C_{OX}), threshold voltage (V_T), and signal voltage, V_{GS} (V_{IN}), of the n- and p-MOSFETs as shown in Equations 1a and 1b below.

Minimizing R_{ON} and the parasitic capacitance, along with improving the linearity of R_{ON} versus V_{IN} over temperature and voltages, are often the primary purposes for designing new products.

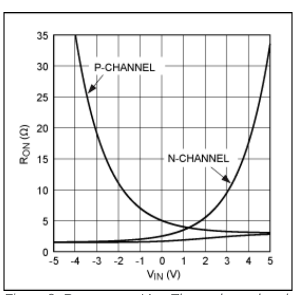

Figure 2. R_{ON} versus V_{IN}. The n-channel and p-channel R_{ON} of Figure 1 form a low-valued composite R_{ON}.

n-channel $$R_{ON} = \frac{L_n}{\mu_n \times C_{OX} \times W_n \times (V_{GS} - V_T)}$$ (Eq. 1a) p-channel $R_{ON} = \frac{L_p}{\mu_p \times C_{OX} \times W_p \times (V_{GS} - V_T)}$ (Eq. 1b)

Table 1. Low-Resistance Switches*

Part	Function	$R_{DS(ON)}$ (Ω, max)	$I_{L(OFF)}$ (nA, max)	R_{ON} Match (Ω, max)	R_{ON} Flatness (Ω, max)	t_{ON}/t_{OFF} (ns, max)	Charge Injection (pC, typ)	Supply Voltage Range (V)	Package
MAX14535E	1 DPDT; NO	0.35	10	—	0.003**	90000/40000	—	2.4 to 5.5	10-UTQFN
MAX4715/MAX4716	1 SPST; NO/NC	0.4	1	—	0.09	18/12	20	1.6 to 3.6	5-SC70
MAX4735	4 SPDT	0.4	20	0.03	0.75	200/180	100	1.6 to 3.6	16-TQFN/TSSOP
MAX14504	2 SPDT; bidirectional	0.5	50	—	0.001**	60000/3000	—	2.3 to 5.5	12-WLP
MAX4626	1 SPST; NO	0.5	2	—	0.1	50/30	40	1.8 to 5.5	5-SOT
MAX4742	2 DPST; NC	0.8	1	0.08	0.18	24/16	28	1.6 to 3.6	8-µDFN/µMAX®/SOT
MAX4754	4 DPDT	0.85	3	0.35	0.4	140/50	300	1.8 to 5.5	16-TQFN/UCSP
MAX4758/MAX4759	4 DPDT/8 SPDT	0.85	5	0.35	0.45	140/50	40	1.8 to 5.5	36-TQFN; 32-UCSP/WLP
MAX4751/MAX4752	4 SPST; NO/NC	0.9	2.5	0.12	0.1	30/25	21	1.6 to 3.6	16-QFN/14-TSSOP
MAX4855	2 SPDT	1	2	0.12	0.275	60/40	170	2 to 5.5	16-TQFN
MAX4783	3 SPDT	1	2	0.4	0.2	25/15	-40	1.6 to 3.6	16-QFN/TQFN/TSSOP
MAX4680/MAX4690/MAX4700	2 SPST; NC/NO/NO-NC	1.25	0.5	0.3	0.3	275/175	550	±4.5 to ±20	16-PDIP(N)/SOIC(W)/SSOP
MAX4677/MAX4678/MAX4679	4 SPST; NC/NO/NO-NC	1.6	1	0.3	0.4	350/150	85	±2.7 to ±5.5	16-PDIP(N)/TSSOP
MAX4688	1 SPDT	2.5	0.5	0.4	1	30/12	40	1.8 to 5.5	6-UCSP
MAX4661/MAX4662/MAX4663	4 SPST; NC/NO/NO-NC	2.5	0.5	0.5	0.5	275/175	300	±4.5 to ±20	16-PDIP(N)/SOIC(W)/SSOP
MAX4667	2 SPST; NC	2.5	0.5	0.4	0.4	275/175	450	±4.5 to ±20	16-PDIP(N)/SOIC(N)
MAX4706/MAX4707	1 SPST; NC/NO	3	1	—	0.85	20/15	5	1.8 to 5.5	6-µDFN/SC70; 5-SC70
MAX4675/MAX4676	1 SPST; NO/NC	3	1	—	0.7	300/110	87	±2.7 to ±5.5	6-SOT
MAX4674	4 SPDT	4	0.5	0.4	0.8	18/6	10	1.8 to 5.5	16-QSOP/SOIC/TQFN/TSSOP
MAX4664/MAX4665/MAX4666	4 SPST; NC/NO/NO-NC	4	0.5	0.5	0.5	275/175	300	±4.5 to ±20	16-PDIP(N)/SOIC(N)
MAX4739	4 SPST; NO-NC	4.5	0.5	0.4	1.2	80/40	5	1.8 to 5.5	14-TSSOP/UCSP
MAX4621/MAX4622/MAX4623	2 SPST; NO/2 SPDT/2 DPST; NO	5	0.5	0.5	0.5	250/200	480	±4.5 to ±20	16-PDIP(N)/SOIC(N)
MAX4947/MAX4948	6 SPDT; bidirectional	5.5	3	0.5	1	800/800	10	1.8 to 5.5	24-TQFN/25-UCSP
MAX4729/MAX4730	1 SPDT	5.5	2	0.15/0.34	1.5/0.95	45/26	3	1.8 to 5.5	6-µDFN/SC70
MAX4670	8 SPDT; NO-NC	9	1000	0.15	0.18	400/200	20	2.7 to 3.6	32-TQFN
MAX14756/MAX14757/MAX14758	4 SPST; NC/NO/NO-NC	10	2.5	0.5	0.004**	60000/3000	580	±10 to ±35	16-TSSOP

*For the latest information, please refer to the device's data sheet.
**Typical value

The first analog switches operated on ±20V supply voltages and had several hundred ohms of R_{ON}. Recent advances achieve 0.5Ω maximum R_{ON} with a much lower supply voltage. Supply voltage has a substantial effect on R_{ON} (**Figure 3A**), and the applied signal might also significantly affect R_{ON} (**Figure 3B**). In this example, the MAX4992 specifies signal and supply voltages from 1.8V to 5.5V and R_{ON} increases for lower supply voltages (Figure 3A). The maximum R_{ON} is approximately 0.38Ω at 1.8V, 0.3Ω at 2.7V, 0.28Ω at 3.3V, and only 0.25Ω at 5V. Many new analog switches specify low supply-voltage operation down to 1.6V. The MAX4992 achieves very low R_{ON} and R_{ON} flatness (1mΩ) with a single supply. Figure 3B compares R_{ON} of later-generation analog switches with older types for a 5V supply.

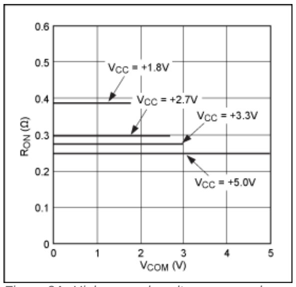

Figure 3A. Higher supply voltage causes lower R_{ON}. Here R_{ON} for the MAX4994 (single supply) is shown versus V_{COM}.

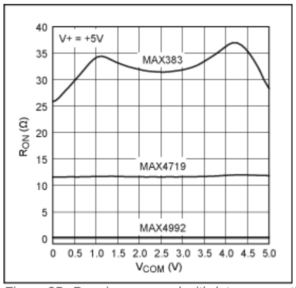

Figure 3B. R_{ON} is compared with later-generation analog switches.

When selecting switches for single-supply systems, it is best to choose from those designed specifically for single-supply use. Those devices save one pin because they do not require separate V- and ground pins. This economy of pins means that a single-pole/double-throw (SPDT) switch (e.g., the MAX4714) can fit into a miniscule 6-pin, 1.6mm² µDFN package. Similarly, low-voltage dual-supply applications call for dual-supply switches. These switches require both a V- pin and the ground pin, and typically specify a logic interface with standard CMOS and TTL levels.

Many high-performance analog systems still rely on higher-level bipolar supplies such as ±15V or ±12V. The interface to these voltages requires an additional supply pin commonly known as the logic supply voltage (e.g., the MAX14756). This pin (V_L) connects to the system logic voltage, which is usually 1.8V or 3.3V. Having the input logic signals referenced to the actual logic levels increases the noise margin and prevents excessive power dissipation.

The relationship between analog-switch input logic levels and their effect on supply current is often misunderstood. If the logic inputs are at ground or V_{CC} (or V_L, when available), analog switches have essentially no supply current. Applying TTL levels to a 5V switch, however, can cause the supply current to increase more than 1000 times. To avoid unnecessary power consumption, avoid TTL levels that are simply a legacy of the 1980s designs.

Designs for Signal Handling

Figure 3A also shows the value of R_{ON} versus signal voltage. These curves fall within the specified range of supply voltage, because typical analog switches that do not integrate internal charge pumps can only handle analog signal levels between the supplies. Under- or overvoltage inputs can permanently damage an unprotected switch by producing uncontrolled currents through internal diode networks. Normally, these diodes protect the switch against short-duration electrostatic discharge (ESD) up to ±2kV. (Refer to the section on ESD-Protected Switches below.)

R_{ON} for an analog switch causes a linear reduction of signal voltage that is proportional to the current passing through the switch. This voltage change might need to be considered, depending on the application and the level of currents.

Two other important parameters to be considered are channel matching and R_{ON} flatness. Channel matching describes the variation of R_{ON} for the channels of one device; R_{ON} flatness describes the variation of R_{ON} versus signal range for a single channel. The smaller the ratio of matching/R_{ON} or flatness/R_{ON}, the more accurate is the switch. Typical values for these parameters are 0.1Ω to 5Ω, respectively. Some switches are designed specifically to have low channel matching and flatness. The MAX4992, for example, can achieve channel matching of 3mΩ and R_{ON} flatness of 1mΩ. The MAX14535E has very good specifications for R_{ON}, channel matching, and R_{ON} flatness. It is ideal for AC-coupled audio or video portable devices and handling a negative signal swing down to -1.5V.

In most applications, you can avoid excessive switch currents by modifying the circuit design. For example, you might want to change the gain of an op amp by switching between different feedback resistances. In that case, it is best to choose a configuration that places the switch in series with a high-impedance input (**Figure 4A**). Here the value of R_{ON} and its temperature coefficient can be ignored because the switch currents are low. The design in **Figure 4B**, however, is less desirable because the switch current can be substantial, as it depends on the output voltage.

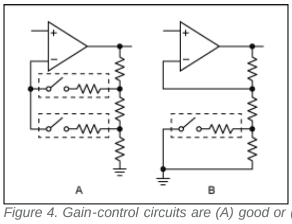

Figure 4. Gain-control circuits are (A) good or (B) bad depending on the amount of current through the switch.

Audio Switches and the Break-Before-Make Capability

A major performance requirement in all audio systems is the elimination of audible clicks and pops caused by transient pulses discharging through the speaker load. These transients usually occur during power on and off (turn-on and turn-off times, t_{ON} and t_{OFF}). Regardless of a device's audio quality during operation, if it makes a noisy click every time the system turns on or off, customers usually assume (or presume) that it is a poor quality audio device. Audible clicks and pops can be eliminated by increasing the t_{ON} and t_{OFF} of the analog switches. This step reduces the transient pulses discharging through the speaker load. The t_{ON} and t_{OFF} for most analog switches vary from below 15ns to as high as 1µs but can be in the millisecond range for other "clickless" switches.

Some clickless switches use shunt switches and a break-before-make feature to eliminate the clicks. In an audio application with the MAX4744, internal shunt switches are used to discharge any capacitance at the input. This action prevents a transient voltage from being switched into the speaker. The break-before-make feature guarantees that the switch breaks one connection before switching over to another connection. It also requires $t_{ON} > t_{OFF}$. Some alternate designs require a make-before-break switch where $t_{OFF} > t_{ON}$. The circuit in Figure 4A, for example, must take care in switching between the two gains. When changing the gain, it is important to avoid opening both switches at once; the second switch must close before the first switch opens. Otherwise, the op amp applies open-loop gain and drives its output to the rails.

Table 2. Clickless Analog Switches*

Part	Function	$R_{DS(ON)}$ (Ω, max)	$I_{L(OFF)}$ (nA, max)	R_{ON} Match (Ω, max)	R_{ON} Flatness (Ω, max)	t_{ON}/t_{OFF} (ns, max)	Charge Injection (pC, typ)	Supply Voltage Range (V)	Package
MAX4992	2 SPDT; bidirectional	0.5	100	0.003	0.001	150000/2000	—	1.8 to 5.5	10-UTQFN
MAX4744/MAX4746H	2 SPDT	0.95	15	0.1	0.55	560/540**	450	1.8 to 5.5	10-µDFN
MAX4910	4 SPDT	0.8	—	0.1	0.35	150/1000	300	1.8 to 5.5	16-TQFN
MAX4764/MAX4765	2 SPDT	0.85	2	0.1	0.4	80/70	150	1.8 to 5.5	10-TDFN-EP/UCSP
MAX4908/MAX4930	2 SP3T	0.8	50	0.1	0.35	—	—	1.8 to 5.5	14-TDFN-EP
MAX4901/MAX4902	2 SPST; NO	1	6	—	0.25	100/100	125	1.8 to 5.5	8-TDFN-EP; 9-UCSP
MAX4571/MAX4573	11 SPST; NO	35	0.2	3	6	8000/300**	—	2.7 to 5.25	28-QSOP/SOIC(W)/SSOP
MAX4562/MAX4563	2 SPST + 2 SPDT	30	1	5	5	12000/3000**	—	2.7 to 5.5	16-QSOP

*For the latest information, please refer to the device's data sheet.
**Typical value

A changing signal level can modulate the R_{ON}, causing a variation in the insertion loss of the switch. This increases the total harmonic distortion (THD) of the analog switch. THD is a critical parameter in audio applications as it indicates the quality or fidelity of a signal passing through a switch. THD is defined as the ratio of the square root of all squared harmonic components divided by its fundamental harmonic component (Equation 2). **Figure 5** compares the THD for different switches.

$$\text{THD (\%)} = \frac{\sqrt{a_2^2 + a_3^2 + \cdots a_n^2}}{a_1} \times 100\% \qquad \text{(Eq. 2)}$$

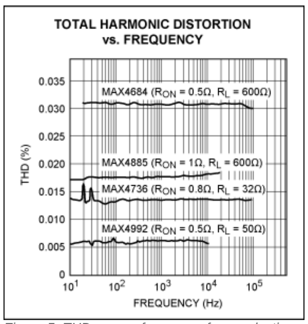

Figure 5. THD versus frequency for a selection of analog switches.

Low R_{ON} and Managing Charge-Injection Effects

Low R_{ON} is not necessary in all applications. When an application needs lower R_{ON}, however, there are several design requirements to consider. The circuit requires greater chip area and the design introduces a greater input capacitance whose charge and discharge currents dissipate more power in every switching cycle. The charging time of this input capacitance depends on load resistance (R) and capacitance (C); its time constant is given by t = RC. This charging time normally lasts a few tens of nanoseconds, but higher R_{ON} switches have shorter-duration t_{ON} and t_{OFF} periods. Some analog switches have different combinations of R_{ON}/input capacitance in the same package types with the same pinouts. The MAX4501 and the MAX4502 specify relatively high R_{ON} with short t_{ON}/t_{OFF}; the MAX4514 and the MAX4515 have lower R_{ON} but longer switching times.

There is another negative consequence of low R_{ON}: A higher charge injection can result from higher levels of capacitive gate current. A certain amount of charge is added to, or subtracted from, the analog channel with every on or off transition of the switch (**Figure 6A**). For switches connected to high-impedance outputs, this action can cause significant changes in the expected output signal. A small parasitic capacitor (C_L) with no other load adds a variation of ΔV_{OUT}, so charge injection can be calculated as $Q = (\Delta V_{OUT})(C_L)$. A track-and-hold amplifier, which maintains a constant analog output during conversion by an analog-to-digital converter (ADC), offers a good example of this (**Figure 6B**). Closing S1 charges the small buffer capacitor (C) to the input voltage (V_S). The value of C is only a few picofarads and V_S remains stored on C when S1 opens. The held voltage (V_H) is applied to the buffer by closing S2 at the beginning of a conversion. The high-impedance buffer then maintains V_H constant over the ADC's conversion time. For short acquisition times, the track-and-hold's capacitor must be small and S1's R_{ON} must be low. Note, moreover, that charge injection can cause V_H to change by $\pm\Delta V_{OUT}$ (a few millivolts), thereby affecting the accuracy of the following ADC.

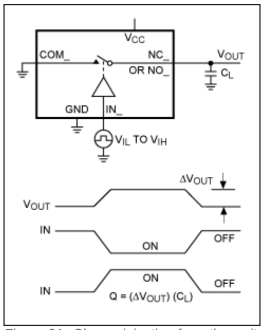

Figure 6A. Charge injection from the switch-control signal causes a voltage error at the analog output.

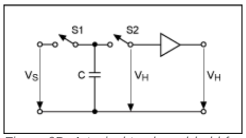

Figure 6B. A typical track-and-hold function in an ADC requires precise control of the analog switches.

Leakage Currents and Their Impact on Voltage Error

Leakage current affects the output voltage of an analog switch. **Figures 7** and **8** show the simplified small-signal models of an analog switch in the on and off states. In both cases, most of the leakage current flows through the internal parasitic diodes, and this contributes to the output voltage error. The leakage current is also a function of temperature and doubles approximately every 10°C. ESD protection diodes (e.g., in fault-protected switches) increase the leakage currents.

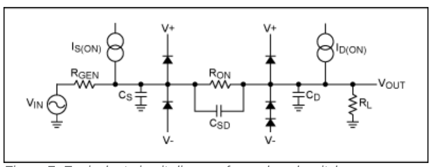

Figure 7. Equivalent circuit diagram for a closed switch.

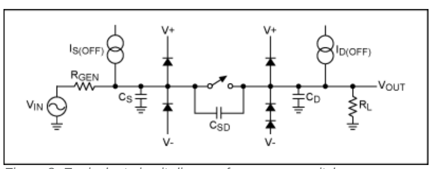

Figure 8. Equivalent circuit diagram for an open switch.

The output voltage for the on-state is calculated in Equation 3 and is a function of leakage current, R_{ON}, R_{ON} variation over the applied input signal, load resistance, and source resistance. For bidirectional analog switches I_{LKG} is equal to I_S or I_D (shown in Figures 7 and 8) depending on whether the drain or source side of the switch is configured as the output.

$$V_{OUT} = V_{IN} \times \left(\frac{R_L}{R_{GEN} + R_{ON} + R_L}\right) + I_{LKG} \times \left(\frac{(R_{GEN} + R_{ON}) \times R_L}{R_{GEN} + R_{ON} + R_L}\right) \quad \text{(Eq. 3)}$$

The output voltage for the off-state is principally affected by leakage current and is calculated by $V_{OUT} = I_{LKG} \times R_L$.

Many IC data sheets specify on/off leakage currents for worst-case scenarios: When the signal voltage approaches the supply voltage limits, this causes the parasitic diodes to inject higher currents into the substrate and results in current flow into adjacent channels. Consequently, a designer should be aware of the supply currents' absolute maximum rating for the part being used and should not exceed these limits. Exceeding the limits can permanently damage a device. Applications with operational amplifiers or ADCs that switch high-input impedances and require low-offset errors should use analog switches and multiplexers with low leakage currents.

Special Needs for Video and High-Frequency Switches

The trade-off between R_{ON} and parasitic capacitance is important for video signals. Traditional analog switches with large R_{ON} can require extra gain stages to compensate for the insertion loss. Meanwhile, low R_{ON} switches have larger parasitic capacitance that reduces bandwidth and degrades the video quality. Low R_{ON} switches require input buffers to preserve the bandwidth, but this increases the component count.

Employing only n-channel switches improves bandwidth, as parasitic components and package size become smaller and allow, in turn, more switches per unit area. However, n-channel switches suffer from limited rail-to-rail operation. When an applied video signal exceeds these limits, the output clamps and the video signal is distorted. When selecting an n-channel switch, ensure that the specified limits of the switch are sufficient for passing through the full input-signal range.

In applications where a monitor displays video from many sources as in a security and surveillance system, off-isolation and crosstalk are key parameters. With a switch in the off state, the amount of feedthrough from an applied input signal determines the off-isolation. At high frequencies, which are typical in video and VHF applications, the signal is coupled through the drain-to-source capacitance (C_{DS}) that reduces off-isolation. The higher circuit impedances associated with the switch also contribute to reducing off-isolation.

The T-switch topology is suitable for video and other frequencies above 10MHz. It consists of two analog switches in series, with a third switch connected between their common connection and ground (**Figure 9A**). This arrangement provides higher off-isolation than a single switch. The capacitive crosstalk for a T switch that is turned off typically rises with frequency because of the parasitic capacitances in parallel with each of the series switches (Figure 9A). In multiple-channel switches, the parasitic capacitances between channels capacitively couples the signal into the adjacent channels, thereby increasing crosstalk.

When the T-switch in Figure 9A is turned on, S1 and S2 are closed and S3 is open. In the off state, S1 and S2 are open and S3 is closed. In this off state the signal tries to couple through C_{DS} of the series MOSFETs, but it is shunted to ground by S3. The difference between off-isolation at 10MHz for a video T-switch (e.g., the MAX4545) and a standard analog switch (e.g., the MAX312) is dramatic: -80dB versus -36dB (**Figure 9B**).

Finally, you can consider buffered and unbuffered video switches. The standard video switches, known as passive video switches, might require an additional circuit.[1] The integrated approach, known as active video switches, combines the switch and buffer into one package and reduces signal interferences. The integrated multiplexer-amplifiers (e.g., the MAX4310) have significant off-isolation for use in high-frequency applications.

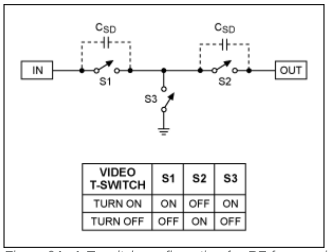

Figure 9A. A T-switch configuration for RF frequencies.

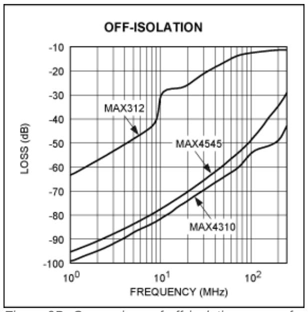

Figure 9B. Comparison of off-isolation versus frequency for standard (MAX312) and video (MAX4545, MAX4310) switches.

Smaller Packages

Maxim offers analog switches in very small packages. For example, the MAX4696/MAX4697 (1 SPDT) and the MAX4688/MAX4698 (1 SPST) are available in tiny 6-bump UCSP packages (1.5mm²). The UCSP packaging technology eliminates the traditional plastic package used to encapsulate integrated circuits, thus saving space. See **Table 3** for some other analog switches offered in small packages.

Table 3. Analog Switches in Small Packages*

Part	Function	$R_{DS(ON)}$ (Ω, max)	$I_{L(OFF)}$ (nA, max)	R_{ON} Flatness (Ω, max)	t_{ON}/t_{OFF} (ns, max)	Charge Injection (pC, typ)	Off-Isolation (dB)/Frequency (MHz)	Supply Voltage Range (V)	Package	Package (mm²)
MAX4698	1 SPDT	35	0.5	13	80/25	8	-750	2 to 5.5	6-UCSP	1.5
MAX4688	1 SPDT	2.5	0.5	1	30/12	40	-900	1.8 to 5.5	6-UCSP	1.5
MAX4594	1 SPST; NO	10	0.5	1.5	35/40	2	-80	2 to 5.5	6-µDFN	1.6
MAX4706/MAX4707	1 SPST; NC/NO	3	1	0.85	20/15	5	-82/1; -62/10	1.8 to 5.5	6-µDFN	1.6
MAX4729/MAX4730	1 SPDT	5.5	2	1.5/0.95	45/26	3	-67/1; -45/10	1.8 to 5.5	6-µDFN	1.6
MAX14508E/MAX14509AE/MAX14510E	1 DPDT; bidirectional	5	10000	—	60000/5000	—	—	2.7 to 5	10-UTQFN	2.5
MAX14535E/MAX14536E	1 DPDT; NO	0.35	10	0.001**	90000/40000	—	—	2.4 to 5.5	10-UTQFN	2.5
MAX4992/MAX4993	2 SPDT/1 DPDT	0.5	100	0.001	150000/2000	—	-4500	1.8 to 5.5	10-UTQFN	2.5
MAX4719	2 SPDT	20	0.5	1.2	80/40	18	-80/1; -55/10	1.8 to 5.5	10-UCSP	3.3
MAX14531E/MAX14532E	2 SP3T	2	2000	0.1	250000/6000	—	—	2.7 to 5.5	12-WLP	3.3
MAX14504/MAX14505A	2 SPDT; bidirectional	0.5	50	0.001**	60000/3000	—	—	2.3 to 5.5	12-WLP	3.3
MAX4906/MAX4906F	2 SPDT; NO-NC	7	1000	1**	60/30	5	-60/10; -26/500	3 to 3.6	10-µDFN	4.2
MAX4754	4 DPDT	0.85	3	0.4	140/50	50	-650	1.8 to 5.5	16-UCSP	4.3
MAX4501/MAX4502	1 SPST; NO/NC	250	1	—	75/10	10	-1000	2 to 12	5-SC70	5.3
MAX4624/MAX4625	1 SPDT	1	2	0.12	50/50	65	-57	1.8 to 5.5	6-TSOT	8.3
MAX4514/MAX4515	1 SPST; NO/NC	20	1	3	150/100	2	-900	2 to 12	5-SOT	9
MAX14550E	2 SP3T	6.5	250	0.1	100000/5000	—	—	2.8 to 5.5	10-TDFN-EP	9.6

MAX4908/MAX4930	2 SP3T	0.8	-/50	0.35	—	—	-4000	1.8 to 5.5	14-TDFN-EP	9.6

*For the latest information, please refer to the device's data sheet.
**Typical value

ESD-Protected Switches

ESD protection is an important feature for most analog-switch applications. Standard analog switches are designed to be protected up to ±2kV. A designer can add additional ESD protection externally, but this consumes valuable board area and adds capacitance to the input/output line. Some switches are, however, now designed with internal diodes to withstand ESD as high as ±15kV. They are tested using the Human Body Model (±15kV), and the Contact (typically ±8kV) and Air-Gap Discharge (±15kV) methods specified in IEC 61000-4-2.[2]

Table 4. ±15kV ESD Protected Analog Switches per IEC 61000-4-2/IEC 1000-4-2 Standard*

Part	Function	$R_{DS(ON)}$ (Ω, max)	$I_{L(OFF)}$ (nA, max)	R_{ON} Match (Ω, max)	R_{ON} Flatness (Ω, max)	t_{ON}/t_{OFF} (ns, max)	Charge Injection (pC, typ)	Off-Isolation/Crosstalk (dB)	Supply Voltage Range (V)
MAX14535E/MAX14536E	1 DPDT; NO	0.35	±10	—	0.0003**	90000/40000	—	—	2.4 to 5.5
MAX4983E/MAX4984E	1 DPDT; bidirectional	10	±250	1	0.1	100000/5000	—	-48/-73 (at 10MHz)	2.8 to 5.5
MAX4927	7 4:1 mux; NO	5.5	±1000	1.5	0.01**	50/50	—	—/-50 (at 25MHz)	3 to 3.6
MAX4575/MAX4577	2 SPST; NO/NO-NC	70	±0.5	2	4	150/80	4	-75/-90 (at 1MHz)	2 to 12
MAX4620	4 SPST; NO	70	±0.5	2	4	150/80	5	-75/-90 (at 1MHz)	2 to 12
MAX4561	1 SPDT	70	±0.5	2	4	150/80	17	75/— (at 1MHz)	1.8 to 12
MAX4568/MAX4569	1 SPST; NO/NC	70	±0.5	2	4	150/80	6	75/— (at 1MHz)	1.8 to 12
MAX4558/MAX4559/MAX4560	1 8:1 mux/2 4:2 mux/3 SPDT	160	±1	6	8	150/120	2.4	-96/-93 (at 0.1MHz)	±2 to ±6 or 2 to 12
MAX4551/MAX4552/MAX4553	4 SPST; NC/NO/NO-NC	120	±1	4	8	110/90	2	-90/-90 (at 0.1MHz)	±2 to ±6 or 2 to 12

*For the latest information, please refer to the device's data sheet.
**Typical value

Fault-Protected Switches for Overvoltage Protection to ±36V

The supply-voltage rails for an analog switch restrict the allowed input-signal voltage range. (Refer to the Designs for Signal Handling section above.) If the input signal exceeds the supply-voltage rails, the device can latch up or be permanently damaged. Normally this restriction is not a problem, but in some cases, the input signal might be present while the supply voltage to the analog switch is turned off. (This can happen if the system supply-voltage sequencing causes the input signal to be present before the supply-voltage rail comes up.) Transients outside the normal range of the power supply can also cause latchup or permanent damage. New fault-protected switches and multiplexers guarantee overvoltage protection of up to ±36V and power-down protection of ±40V, along with rail-to-rail signal handling and the low R_{ON} of a normal switch. The input pin, moreover, assumes high impedance during fault conditions, regardless of the switch state or load resistance, and only nanoamperes of leakage current can flow from the source.

Figure 10 shows the internal structure of a fault-protected analog switch. If the switch (P2 or N2) is on, the COM output is clamped to the supply by two internal "booster" FETs. Thus, the COM output remains within the supply rails and delivers a maximum of ±13mA, depending on the load, but without a significant current at the NO/NC pin. Note that signals pass equally well in either direction through an ESD- and fault-protected switch, but the fault protections apply only to the input side.[3]

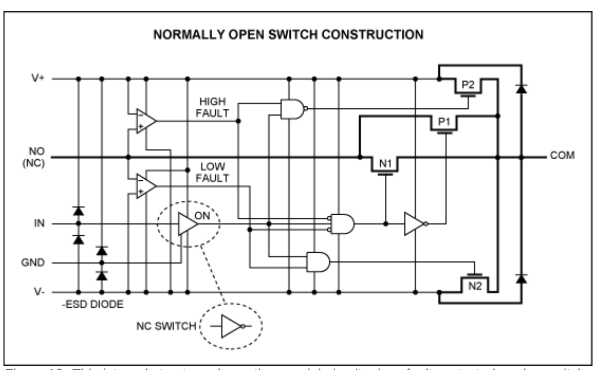

Figure 10. This internal structure shows the special circuitry in a fault-protected analog switch.

Many dual-rail analog switches require the positive rail to be applied before the negative rail to avoid latchup or damage. If this is an issue, there are switches available that do not require power-supply sequencing, e.g., the MAX14752 multiplexer. The MAX14752 is pin-compatible with the industry-standard DG408/DG409, and internal diodes at the inputs protect the switch from over/undervoltages.

Table 5 shows some of Maxim's fault-protected switches. The MAX4511/MAX4512/MAX4513 fault-protected switches are pin-compatible with the DG411–DG413 and the DG201/DG202/DG213 industry-standard switches.

Table 5. Fault Protection with Rail-to-Rail Signal Swings*

Part	Function	$R_{DS(ON)}$ (Ω, max)	$I_{L(OFF)}$ (nA, max)	R_{ON} Match (Ω,max)	Overvoltage Supplies ON/OFF (V)	t_{ON}/t_{OFF} (ns, max)	Charge Injection (pC, typ)	Supply Voltage Range (V)	Package
MAX9940	1 line protector	77.5	—	—	±28	—	—	2.2 to 5.5	5-SC70
MAX4505	1 line protector	100	±0.5	—	±36/±40	—	—	8 to 18 or ±9 to ±36	5-SOT; 8-µMAX
MAX4506	3 line protector	100	±0.5	—	±36/±40	—	—	8 to 18 or ±9 to ±36	8-CDIP(N)/PDIP(N)/SOIC(N)
MAX4507	8 line protector	100	±0.5	—	±36/±40	—	—	8 to 18 or ±9 to ±36	18-PDIP(N)/SOIC(W); 20-SSOP
MAX4510/MAX4520	4 SPST; NC/NO	75	±0.5	—	±36/±40	500/175	1.5	9 to 36 or ±4.5 to ±20	8-µMAX; 6-SOT
MAX4633	2 DPST; NO	85	±0.5	6	±36/±40	500/400	10	9 to 36 or ±4.5 to ±18	16-PDIP(N)/SOIC(N)
MAX4511/MAX4512/MAX4513	4 SPST; NC/NC/NO-NC	160	±0.5	6	±36/±40	500/400	1.5	9 to 36 or ±4.5 to ±20	16-CDIP(N)/PDIP(N)/SOIC(N)
MAX4708/MAX4709	1 8:1 mux/2 4:1 mux	400	±0.5	15	±25/±40	275/200	0	9 to 36 or ±4.5 to ±20	16-PDIP(N)/SOIC(N)
MAX4534/MAX4535	1 2:1 mux; 2 4:1 mux	400	±2	10	±25/±40	275/200	1	9 to 36 or ±4.5 to ±18	14-PDIP(N)/SOIC(N)/TSSOP
MAX4533	4 SPDT	175	±0.5	6	±25/±40	250/150	1.5	+9 to +36 or ±4.5 to ±18	20-PDIP(N)/SOIC(W)/SSOP
MAX4508/MAX4509	1 8:1 mux/2 4:1 mux	400	±0.5	15	±25/±40	275/200	2	9 to 36 or ±4.5 to ±20	16-CDIP(N)/PDIP(N)/SOIC(N)
MAX4632	2 SPDT	85	±0.5	6	±25/±40	500/400	5	9 to 36 or ±4.5 to ±18	16-PDIP(N)/SOIC(N)
MAX4711	4 SPST; NC	25	±0.5	1	±7/±12	125/80	25	2.7 to 11 or ±2.7 to ±5.5	16-PDIP(N)/SOIC(N)/TSSOP

*For the latest information, please refer to the device's data sheet.

Force-Sense Switches Impact System Accuracy

There are a number of wiring techniques employed in voltage- and current-measurement systems. These wiring techniques, known as 2-, 3-, and 4-wire systems, differ in their accuracy and complexity. The 2-wire system shown in **Figure 11** is used when high accuracy is not a primary factor. This technique senses the load voltage at the *source end* of the force wires. The load voltage can be significantly lower than the source voltage. This happens because the voltage can drop along the wires if a relatively large force current is flowing through the resistance of the wires. Longer wires, larger load current, and higher wire resistance all contribute to this degradation and introduce significant measurements errors. A 3-wire system improves the accuracy, but best results are achieved with a 4-wire force-sense technique.

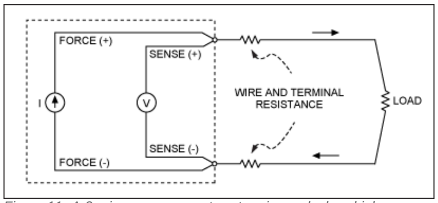

Figure 11. A 2-wire measurement system is used when high accuracy is not critical.

The 4-wire force-sense technique (**Figure 12**) uses two wires for the force voltage or current, while two other sense wires connect directly across the load to measure the load voltage. Some analog force-sense switches have different switch types residing in the same package. The MAX4554 device family, for example, is configured as force-sense switches for Kelvin sensing in automated test equipment (ATE). Each device contains low-resistance high-current switches for the forcing current wires and higher-resistance switches for sensing voltage or switching guard signals. The R_{ON} for the high-current switches is only 6Ω, and 60Ω at ±15V supply voltages for the sensing switches. Force-sense switches are suitable for use in high-accuracy measurement systems such as nanovoltmeters and femtoammeters. They also simplify many applications, such as switching between one source and two loads in a 4-wire system, as shown in **Figure 13**.

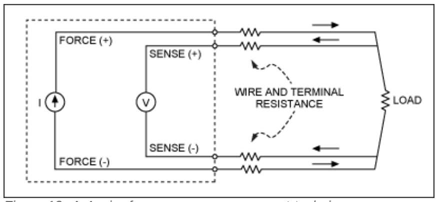

Figure 12. A 4-wire force-sense measurement technique.

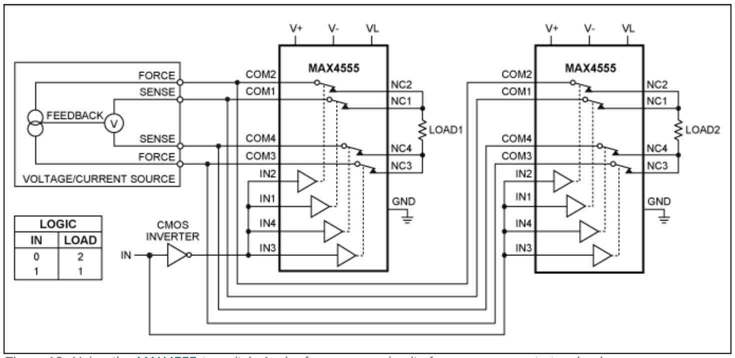

Figure 13. Using the MAX4555 to switch 4-wire force-sense circuits from one source to two loads.

Multiplexers and Crosspoint Switches for Multichannel Applications

A multiplexer (mux) is a special version of an analog switch in which two or more inputs are selectively connected to a single output. A mux can be a simple SPDT switch or come in many combinations for a larger number of selectable channels (**Figure 14**). With digital inputs required to select the appropriate channel (e.g., three digital inputs in the case of an 8-channel mux), the digital control for these higher-order multiplexers is similar to a binary decoder.

A demultiplexer is basically a mux used in reverse. Here, one input connects to two or more outputs based on the decoded address data. Many multiplexers can be used as demultiplexers.

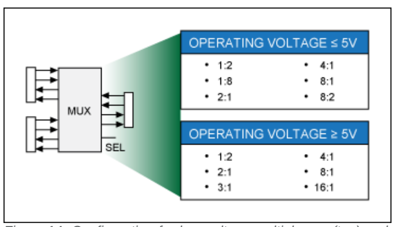

Figure 14. Configuration for low-voltage multiplexers (top) and midvoltage multiplexers (bottom).

Some of Maxim's crosspoint switches are listed in **Table 6**. Many have enhanced features over the older generation. For example, the MAX4360 is a replacement product for the MAX458.

Table 6. Crosspoint Switches*

Part	Function	Off-Isolation (dB)	Crosstalk (dB)	-3dB Bandwidth (MHz)	Supply Voltage Range (V)	Package	Package (mm²)
MAX4989	2 2-of-4; bidirectional	-43dB (at 10MHz)	-50dB (at 50MHz)	1000	2.7 to 5.5	14-TDFN-EP	9.6
MAX4548/MAX4549	3 × 3:2	-72dB (at 10MHz)/-85dB (at 20kHz)	-55dB (at 10MHz)/-85dB (at 20kHz)	250	2.7 to 5.5	36-SSOP	163.4
MAX4550/MAX4570	2 × 4:2	-78dB (at 4MHz)	-54dB (at 4MHz)	—	2.7 to 5.5 or ±2.7 to ±5.5	28-SOIC(W)/SSOP	192.8
MAX4359	4 × 4	-80 (at 5MHz)	-70 (at 5MHz)	35	±5	24SOIC(W)/36-SSOP	163.4
MAX4360	8 × 4	-80 (at 5MHz)	-70 (at 5MHz)	35	±5	36-SSOP	163.4
MAX9675	16 × 16	-110dB (at 6MHz)	-62dB (at 6MHz)	110	±5	100-TQFP	262.4
MAX4356	16 × 16	-110dB (at 6MHz)	-62dB (at 6MHz)	110	5 or ±3 or ±5	128-LQFP	359.6
MAX4357	32 × 16	-110dB (at 6MHz)	-62dB (at 6MHz)	110	5 or ±3 or ±5	128-LQFP	359.6

*For the latest information, please refer to the device's data sheet.

Crosspoint switches are employed in audio/video routing, video-on-demand, and security and surveillance systems. A crosspoint switch is usually an M × N device, whereby any or all of M inputs can be connected to any or all of N outputs (and vice versa). These devices are capable of implementing larger matrixes.[4]

Calibration Multiplexers Balance ADC Offset and Gain Error

Calibration multiplexers (cal-muxes) are used in precision ADCs and other self-monitoring systems. They combine different components in one package: analog switches for generating accurate voltage ratios from an input reference voltage; internal precision resistor-dividers; and a multiplexer for selecting between different inputs.

Cal-muxes can balance two major errors associated with an ADC system: offset and gain error. Using internal precision voltage-dividers, these devices measure gain and offset in a few steps controlled through the serial interface of a microcontroller. Knowing the ADC's offset and gain errors, the system software constructs calibration factors that adjust the subsequent outputs to produce correct readings. The cal-mux then serves as a conventional multiplexer, but with the ability to recalibrate the system periodically.[5] **Figure 15** shows the MAX4539 cal-mux block diagram.

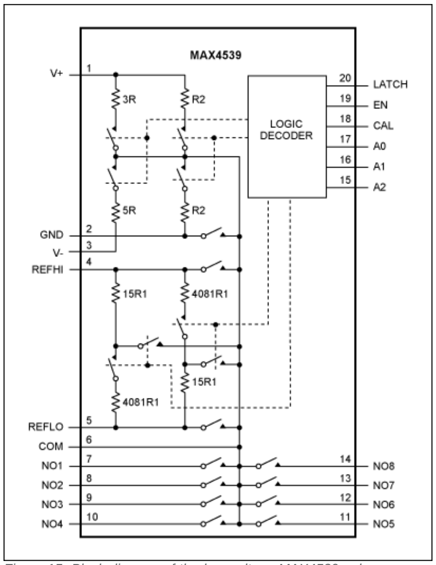

Figure 15. Block diagram of the low-voltage MAX4539 cal-mux.

The MAX4539 and the MAX4540 cal-muxes are pin-for-pin compatible with the MAX4578 and the MAX4579, respectively. The MAX4539 and the MAX4540 operate from a single supply of 2.7V to 12V or a dual supply in the range ±2.7V to ±6V. The MAX4578 and the MAX4579 are exemplified by their high voltage supply; they operate from a single 4.5V to 36V supply or from dual supplies of ±4.5V to ±20V. Application note 5036, "Calibration Circuit Library" outlines many calibration circuits with the MAX4539 used in one solution. See also application note 261, "Calibration-Multiplexers Ease System Calibration" for more information on cal-muxes.

USB Switches Enable Systems to Communicate

The universal serial bus (USB) is a high-speed interface that enables devices to communicate over a standard interface. It can also be used to supply power to a slave device from a USB host. Multiple USB devices can be connected to a computer, and analog switches are used to route the USB signal to different devices.[6] Most of the latest USB applications also require charging the portable devices over the USB interface.[7] The USB 2.0 specification is for high-speed signals that require high-bandwidth/low-capacitance analog switches like the MAX14531E. Maxim offers a good selection of USB 2.0-compliant switches (**Table 7**), ideal for USB 2.0 high-speed (480Mbps) applications.

Table 7. USB 2.0 Switches*

Part	Function	$R_{DS(ON)}$ (Ω, max)	$I_{L(OFF)}$ (nA, max)	R_{ON} Match (Ω, max)	R_{ON} Flatness (Ω, max)	t_{ON}/t_{OFF} (ns, max)	C_{ON}/C_{OFF} (pF, typ)	Charge Injection (pC, typ)	Bandwidth (MHz)	Supply Voltage Range (V)
MAX14578E	2 SPST; NO	—	—	—	—	—	—	—	—	2.8 to 5.5
MAX14508E/MAX14509AE/MAX14510E	1 DPDT; bidirectional	5	10000	—	0.02**	60000/5000	8/8	—	950	2.7 to 5
MAX14550E	1 DP3T	6.5	250	—	0.1	100000/5000	5.5/2	—	1000	2.8 to 5.5
MAX14531E/MAX14532E	1 DP3T	2	2000	—	—	250000/6000	8/5	—	800	2.7 to 5.5
MAX4999	8 8:1 mux	12	1000	0.8	—	10000/10000**	6/5	—	1200	3 to 3.6
MAX4983E/MAX4984E	1 DPDT; bidirectional	10	250	1	0.1**	100000/5000	6.5/5.5	—	950	2.8 to 5.5
MAX4906/MAX4906F	2 SPDT; NO-NC	7	1000	1.2	1**	60/30	6/2	5	1000	3 to 3.6
MAX4907/MAX4907F	2 SPST; NO	7	1000	1.2	1**	60/30	4/2	5	1000	3 to 3.6
MAX4906EF	2 SPDT; NO-NC	5	1000	0.8	0.5**	1.4/35**	10/9	20	500	3 to 3.6
MAX4899AE/MAX4899E	4:1 mux/3:1 mux	5	1000	0.8	1.1	2800/3	15/10.5	25	425	2.7 to 3.6

*For the latest information, please refer to the device's data sheet.
**Typical value

HDMI Switches Enable Digital Audio/Video Signaling

A high-definition multimedia interface (HDMI) is a high-speed interface for uncompressed digital audio/video signaling. This interface can interconnect high-definition TVs (HDTVs), DVD players, and other HDMI-compatible devices with PCs, notebooks, and tablets.

The HDMI consists of four low-voltage differential signal (LVDS) pairs for the red, green, blue (RGB) video channels and a dedicated clock signal. An ideal HDMI switch contains four differential pairs of 1:2 or 2:1 switches, and employs an n-channel architecture for low capacitance and R_{ON} (e.g., the MAX4886).[8]

Table 8. HDMI Switches*

Part	Function	$R_{DS(ON)}$ (Ω, typ)	R_{ON} Match (Ω, max)	R_{ON} Flatness (Ω, max)	Off-Isolation (dB)	Crosstalk (dB)	Bandwidth (MHz)	Supply Voltage Range (V)
MAX14886	4 2:1 switch; NO-NC	—	—	—	—	—	5000	3 to 3.6
MAX4814E	1 2:4 switch; bidirectional	12**	—	2.5**	65 (at 1MHz)	75 (at 1MHz)	190	4.5 to 5.5
MAX4929E	2 2:1 mux; NO-NC	10	8	13	70 (at 1MHz)	75 (at 1MHz)	40	5 or ±5
MAX4886	4 2:1 switch; NO-NC	11	0.4	0.6	58 (at 50MHz)	-49 (at 50MHz)	2600	3 to 3.6

*For the latest information, please refer to the device's data sheet.
**Typical value

DisplayPort and PCIe Switches Improve Performance for Pint-to-Point Connections

The peripheral component interconnect express is a serial interface (PCI Express® interface) that enables greater performance with Accelerated Graphics Port (AGP) applications. PCI Express switches interconnect different sources from single or multiple buses. Common applications of PCI Express switches are switching DisplayPort graphics, PC and laptop expansion card interfaces, and servers.

Some PCI Express switches are designed to route data between two possible destinations. The MAX4928A and the MAX4928B, for example, support signal routing between a Graphics and Memory Controller Hub (GMCH) and a DisplayPort or PCIe connector.[9]

Table 9. PCIe Switches*

Part	Function	$R_{DS(ON)}$ (Ω, max)	$I_{L(OFF)}$ (nA, max)	R_{ON} Match (Ω, max)	t_{ON}/t_{OFF} (ns, max)	Off-Isolation (dB,typ)	Crosstalk (dB, typ)	Bandwidth (MHz, typ)	Supply Voltage Range (V)	Package
MAX4928A/MAX4928B	6 1:2 switch; bidirectional	8**	1000	2	120/50	-22 (at 3GHz)	-40 (at 3GHz)	10000	3 to 3.6	TQFN/56
MAX4888B/MAX4888C	2 1:2 mux; bidirectional	8.4	1000	1.5	65/7**	-12 (at 8GHz)	-35 (at 3GHz)	8000	3 to 3.6	TQFN/28
MAX4889B	1:2 switch; bidirectional	8.4	1000	0.5	80/1**	-12 (at 5GHz)	-25 (at 5GHz)	5000	3 to 3.6	TQFN/42
MAX4888A/MAX4889A	4 SPDT/8 SPDT; bidirectional	7**	1000	2	250/50	-56 (at 10MHz)	-53 (at 50MHz)	5000	1.6 to 3.6	TQFN/28
MAX4888/MAX4889	4 SPDT/8 SPDT; NO-NC	7**	1000	2	250/50	-56 (at 10MHz)	-53 (at 50MHz)	1250	1.6 to 3.6	TQFN/28

*For the latest information, please refer to the device's data sheet.
**Typical value

High-Voltage Switches for Industrial and Medical Applications

High-voltage (HV) analog switches are ideal for many industrial and medical applications. For example, in ultrasound applications, HV pulses (±100V) are applied to transducers to generate ultrasonic waves. HV analog switches are required for routing these pulses between the transducers and the main systems. These switches typically feature low on-capacitance and flat equivalent R_{ON} over the entire input range. HV switches typically have low-charge-injection specifications to avoid spurious transmissions and the associated image artifacts. Many HV switch parts can be programmed using either the SMBus or SPI interface.[10, 11] **Table 10** shows a selection of Maxim's HV switches.

Table 10. High-Voltage Switches*

Part	Function	Single V_{SUPPLY} (min, V)	Single V_{SUPPLY} (max, V)	Dual V_{SUPPLY} (min, ±V)	Dual V_{SUPPLY} (max, ±V)	Bandwidth (MHz)	$I_{L(OFF)}$ (nA, max)	t_{ON}/t_{OFF} (ns, max)	C_{ON}/C_{OFF} (pF, typ)
MAX14802/MAX14803/MAX14803A	16 SPST; NO	—	200	40	160	50	2000	5000/5000	36/11
MAX4800A/MAX4800B	8 SPST; NO	40	200	40	100	20	2000	5000/5000	36/11
MAX4802A	8 SPST; NO	40	200	40	100	50	2000	5000/5000	36/11

*For the latest information, please refer to the device's data sheet.

Conclusion

This tutorial is a basic narrative about the many types of analog switches available today. With recent advances, integrated analog switches offer better switching characteristics, lower and higher supply voltages, and application-specific designs. Because so many performance options and special functions are available, the well-informed product designer can usually find the right part for a particular application.

References

1. Application note 3823, "Switching Video Using Analog Switches."
2. Application note 764, "Interfacing Switches and Relays to the Real World in Real Time."
3. Application note 2854, "Low-Voltage Fault Protection."
4. Application note 795, "Designing Large Video-Crosspoint Systems Just Got Easier."
5. Application note 261, "Calibration-Multiplexers Ease System Calibration."
6. Application note 4372,"Implementing an Eight-to-One USB Switch for KVM Applications."
7. Application note 3607, "Charging Batteries from USB."
8. Application note 4056, "Using the MAX4929E for HDMI/DVI Low-Frequency Switching."
9. Application note 4191, "New Switch Facilitates DisplayPort/PCIe Switching."
10. Application note 5131, "Maxim Addresses High-Voltage Needs in Industrial Ultrasound Applications."
11. Application note 4696, "Overview of Ultrasound Imaging Systems and the Electrical Components Required for Main Subfunctions."

Related Parts		
MAX14578E	USB Battery Charger Detectors	Free Samples
MAX14752	8-Channel/Dual 4-Channel 72V Analog Mux	Free Samples
MAX14802	Low-Charge-Injection, 16-Channel, High-Voltage Analog Switches	Free Samples
MAX14803	Low-Charge-Injection, 16-Channel, High-Voltage Analog Switches	Free Samples
MAX14803A	Low-Charge-Injection, 16-Channel, High-Voltage Analog Switches	Free Samples
MAX14805	16-Channel (Two Banks of 8-Channel), High-Voltage Analog Switches	Free Samples
MAX14806	16-Channel (Two Banks of 8-Channel), High-Voltage Analog Switches	Free Samples
MAX14886	Dual DisplayPort Graphics Multiplexer with HDMI Level Shifter	
MAX312	10Ω, Quad, SPST, CMOS Analog Switches	Free Samples
MAX383	Precision, Low-Voltage, SPST CMOS Analog Switch	Free Samples
MAX391	Precision, Quad, SPST Analog Switches	Free Samples
MAX4066	Low-Cost, Low-Voltage, Quad, SPST, CMOS Analog Switch	Free Samples
MAX4310	High-Speed, Low-Power, Single-Supply Multichannel, Video Multiplexer-Amplifiers	Free Samples
MAX4356	16 x 16 Nonblocking Video Crosspoint Switch with On-Screen Display Insertion and I/O Buffers	Free Samples
MAX4357	32 x 16 Nonblocking Video Crosspoint Switch with I/O Buffers	Free Samples
MAX4359	Low-Cost 4x4, 8x4, 8x8 Video Crosspoint Switches	Free Samples
MAX4360	Low-Cost 4x4, 8x4, 8x8 Video Crosspoint Switches	Free Samples
MAX4505	Fault-Protected, High-Voltage, Signal Line Protector	Free Samples
MAX4506	Fault-Protected, High-Voltage Signal-Line Protectors	Free Samples
MAX4507	Fault-Protected, High-Voltage Signal-Line Protectors	Free Samples
MAX4508	Fault-Protected, High-Voltage Single 8-to-1/Dual 4-to-1 Multiplexers with Output Clamps	Free Samples
MAX4509	Fault-Protected, High-Voltage Single 8-to-1/Dual 4-to-1 Multiplexers with Output Clamps	Free Samples
MAX4510	Rail-to-Rail, Fault-Protected, SPST Analog Switches	Free Samples
MAX4511	Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches	Free Samples
MAX4512	Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches	Free Samples
MAX4513	Quad, Rail-to-Rail, Fault-Protected, SPST Analog Switches	Free Samples
MAX4520	Rail-to-Rail, Fault-Protected, SPST Analog Switches	Free Samples
MAX4533	Quad, Rail-to-Rail, Fault-Protected, SPDT Analog Switch	Free Samples
MAX4534	Fault-Protected, High-Voltage, Single 4-to-1/Dual 2-to-1 Multiplexers	Free Samples
MAX4535	Fault-Protected, High-Voltage, Single 4-to-1/Dual 2-to-1 Multiplexers	Free Samples
MAX4539	Low-Voltage, Single 8 to 1 and Dual 4 to 1 Cal Multiplexers	Free Samples
MAX4540	Low-Voltage, Single 8 to 1 and Dual 4 to 1 Cal Multiplexers	Free Samples
MAX4545	Quad/Dual, Low-Voltage, Bidirectional RF Video Switches	Free Samples
MAX4548	Serially Controlled, Triple 3x2 Audio/Video Crosspoint Switches	Free Samples
MAX4549	Serially Controlled, Triple 3x2 Audio/Video Crosspoint Switches	Free Samples
MAX4550	Serially Controlled, Dual 4x2, Clickless Audio/Video Analog Crosspoint Switches	Free Samples
MAX4551	±15kV ESD-Protected, Quad, Low-Voltage, SPST Analog Switches	Free Samples
MAX4552	±15kV ESD-Protected, Quad, Low-Voltage, SPST Analog Switches	Free Samples
MAX4553	±15kV ESD-Protected, Quad, Low-Voltage, SPST Analog Switches	Free Samples
MAX4554	Force-Sense Switches	Free Samples
MAX4555	Force-Sense Switches	Free Samples
MAX4556	Force-Sense Switches	Free Samples

MAX4560	±15kV ESD-Protected, Low-Voltage, CMOS Analog Multiplexers Switches	Free Samples
MAX4570	Serially Controlled, Dual 4x2, Clickless Audio/Video Analog Crosspoint Switches	Free Samples
MAX4578	High-Voltage, Single 8-to-1/Dual 4-to-1 Cal Multiplexers	Free Samples
MAX4579	High-Voltage, Single 8-to-1/Dual 4-to-1 Cal Multiplexers	Free Samples
MAX4581	Low-Voltage, CMOS Analog Multiplexers/Switches	Free Samples
MAX4632	Fault-Protected, High-Voltage, Dual Analog Switches	Free Samples
MAX4633	Fault-Protected, High-Voltage, Dual Analog Switches	Free Samples
MAX4684	0.5Ω/0.8Ω Low-Voltage, Dual SPDT Analog Switches in UCSP	Free Samples
MAX4696	35Ω, Low-Voltage, SPST/SPDT Analog Switches in UCSP Package	
MAX4697	35Ω, Low-Voltage, SPST/SPDT Analog Switches in UCSP Package	
MAX4708	Fault-Protected, Single 8-to-1/Dual 4-to-1 Multiplexers	Free Samples
MAX4709	Fault-Protected, Single 8-to-1/Dual 4-to-1 Multiplexers	Free Samples
MAX4711	Fault-Protected, Low-Voltage, Quad SPST Analog Switches	Free Samples
MAX4714	0.8-Ohm, Low-Voltage, Single-Supply SPDT Analog Switch in SC70	Free Samples
MAX4736	0.6 Ohm, Low-Voltage, Single-Supply, Dual SPDT Analog Switch	Free Samples
MAX4800	Low-Charge Injection, 8-Channel, High-Voltage Analog Switches	Free Samples
MAX4800A	Low-Charge-Injection, 8-Channel, High-Voltage Analog Switches with 20MHz Serial Interface	Free Samples
MAX4801	Low-Charge Injection, 8-Channel, High-Voltage Analog Switches	
MAX4802	Low-Charge Injection, 8-Channel, High-Voltage Analog Switches	Free Samples
MAX4802A	Low-Charge-Injection, 8-Channel, High-Voltage Analog Switches with 20MHz Serial Interface	Free Samples
MAX4814E	DVI™/HDMI 2:4 Low-Frequency Fanout Switch	Free Samples
MAX4886	Quad, High-Speed HDMI/DVI 2:1 Digital Video Switch	Free Samples
MAX4887	Triple Video Switch	Free Samples
MAX4888	2.5Gbps PCI Express Passive Switches	Free Samples
MAX4888A	5.0Gbps PCI Express Passive Switches	Free Samples
MAX4888B	Up to 8.0Gbps Dual Passive Switches	Free Samples
MAX4888C	Up to 8.0Gbps Dual Passive Switches	Free Samples
MAX4889	2.5Gbps PCI Express Passive Switches	Free Samples
MAX4889A	5.0Gbps PCI Express Passive Switches	Free Samples
MAX4889B	2.5/5.0/8.0Gbps PCIe Passive Switch	Free Samples
MAX4899AE	USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers	Free Samples
MAX4899E	USB 2.0 High-Speed, Fault-Tolerant 3:1, 4:1 Multiplexers	Free Samples
MAX4906EF	High-/Full-Speed USB 2.0 Switches with High ESD	Free Samples
MAX4907	High-/Full-Speed USB 2.0 Switches	Free Samples
MAX4907F	High-/Full-Speed USB 2.0 Switches	Free Samples
MAX4928A	DisplayPort/PCIe Passive Switches	Free Samples
MAX4928B	DisplayPort/PCIe Passive Switches	Free Samples
MAX4929E	HDMI 2:1 Low-Frequency Translating Switch	Free Samples
MAX4968	16-Channel, Linear, High-Voltage Analog Switches	Free Samples
MAX4968A	16-Channel, Linear, High-Voltage Analog Switches	
MAX4989	USB 2.0 Hi-Speed 2 of 4 Crosspoint Switch	
MAX4999	USB 2.0 Hi-Speed Differential 8:1 Multiplexer	Free Samples
MAX9675	110MHz, 16 x 16 Video Crosspoint Switch with Programmable Gain	
MAX9940	Signal-Line Overvoltage Protector for Low-Voltage Devices	Free Samples

More Information
For Technical Support: http://www.maximintegrated.com/support
For Samples: http://www.maximintegrated.com/samples
Other Questions and Comments: http://www.maximintegrated.com/contact

Application Note 5299: http://www.maximintegrated.com/an5299
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