MAXIM

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NEWS BRIEFS

IN-DEPTH ARTICLES

NEW PRODUCTS

News Briefs

MAXIM REPORTS RECORD REVENUES AND EARNINGS FOR ITS FOURTH QUARTER AND ITS FISCAL YEAR

Maxim Integrated Products, Inc., (MXIM) reported record net revenues of $159.5 million for the fourth quarter of fiscal 1999 ending June 26, 1999, compared to $155.2 million for the same quarter in fiscal 1998. Net income increased to a record $52.6 million in Q499, compared to $49.2 million for the fourth quarter of fiscal 1998. Diluted earnings per share were $0.34 for Q499, compared to $0.33 for the same period a year ago.

For the fiscal year ending June 26, 1999, Maxim reported net revenues of $607.0 million, an 8.3% increase over the $560.2 million reported for fiscal 1998. Net income increased to $196.1 million in fiscal 1999, compared to $178.1 million in fiscal 1998. Diluted earnings per share increased 9.3% to $1.29 in fiscal 1999 from $1.18 in the prior fiscal year.

During the quarter, the Company increased cash and short-term investments by $49.9 million after paying $43.4 million for 775,000 shares of its common stock and $14.2 million for capital equipment. For the year, the Company increased cash and short-term investments by $191.8 million after paying $113.9 million for 2,915,000 shares of its common stock and $38.7 million for capital equipment.

Gross margin for the fourth quarter increased to 69.7%, compared to 69.1% in Q399. During the quarter, the Company recorded a writedown of equipment of $2.7 million and increased inventory reserves by $2.5 million. The Company also recorded a charge to selling, general and administrative expenses of $1.0 million related to technology licensing matters.

Bookings on the Company were approximately $198 million in Q499, a 16% increase over the Q399 level of $171 million. Turns orders received in Q499 were $81 million, a 17% increase over Q399 levels (turns orders are customer orders that are for delivery within the same quarter and may result in revenue within the same quarter if the Company has available inventory that matches those orders).

End-market bookings increased 9% over Q399 levels (end-market bookings are end-user customer bookings received by both Maxim and the Company's distributors during the quarter). This increase is attributable mainly to strength in the U.S. OEM, U.S. distribution, and Japanese sales channels. Bookings on Maxim by U.S. distributors were $49.3 million and exceeded customer bookings on those distributors by $11.5 million. Bookings for the Pacific Rim decreased in Q4, while bookings in Europe were flat with the prior quarter.

There was continued strength in the notebook and communications end markets during the quarter. In addition, there was a considerable increase in demand for the Company's products that target its more traditional broad-based industrial end markets.

Fourth quarter ending backlog shippable within the next 12 months was approximately $176 million, including $144 million requested for shipment in the first quarter of fiscal 2000. Last quarter, the Company reported third quarter ending backlog shippable within the next 12 months of approximately $148 million, including $120 million requested for shipment in Q499. Order cancellations during Q499 were approximately $13 million, compared to $10 million in Q399.

Jack Gifford, Chairman, President, and Chief Executive Officer, commented on the quarter: "Q4 was a record bookings quarter for Maxim. We saw particularly strong growth in U.S. OEM bookings. Turns orders continued to constitute approximately 40% of total bookings, extending the trend of near-term ordering. As we mentioned last quarter, we believe that bookings will adjust to our predicted growth levels of 5% to 7% per quarter, and that as inventories recover from previously depleted levels, turns will constitute a smaller percentage of total orders.

"While our fourth quarter revenues increased 8.4% over last quarter, our profits increased 10.3% because of greater manufacturing efficiencies, resulting in higher gross margins. I think it's impressive that during the 1999 fiscal year, Maxim was able to generate over $190 million in cash, buy back 2.9 million shares of its stock, and spend less than $40 million on capital equipment, given that we are not a software company!"

Gifford continued: "Although two of our six business units significantly missed their fourth quarter product introduction plans, causing us to miss by approximately 5 percent our goal of introducing over 300 products in the product year ending in July, we executed well overall both for the quarter and the year, significantly surpassing last year's product introduction level. I am encouraged by the excitement with which engineers are greeting many of our new product offerings, particularly in the communications area."

ADC Captures 1Gsps

[This article appeared in the March 1999 *Microwaves and RF* magazine]

The MAX104 processes analog input bandwidths that exceed 2.2GHz with 8-bit resolution. It sets a new standard for performance in high-frequency, high-bandwidth digital communications receivers, digital oscilloscopes, and high-speed data-acquisition systems.

The MAX104 is a fast silicon monolithic analog-to-digital converter (ADC) that integrates a high-bandwidth track/hold (T/H) amplifier **(Figure 1)** with a high-speed quantizer that supports accurate digitizing of wideband analog input signals from DC to 2.2GHz. It is based on Maxim's GST-2 Giga-Speed silicon-bipolar process technology. This high-speed, self-aligned double-polysilicon process has been developed for high-density, high-performance circuits. It employs many of the features, such as trench isolation, that are incorporated in Maxim's lower performance GST-1 process.

Although many of the outstanding performance parameters of the MAX104 are possible with the integrated-circuit process (such as a transition frequency of 27GHz for NPN transistors, a three-metal interconnect system, small geometry, and precision laser-trimmed nickel-chrome (NiCr) thin-film resistors), additional credit goes to the MAX104's design team for creating an efficient and effective ADC architecture.

Most high-speed ADCs that sample more than several hundred megahertz have input bandwidths that are limited to no more than their maximum sampling frequency to improve noise performance. One example is the signal-to-noise ratio (SNR). This limited input bandwidth may rule out use in applications where bandwidths of interest in the input spectrum are higher, and an undersampling approach is needed. Also, if the input signal is changing rapidly during conversion, the effective number of bits (ENOB) and SNR will be reduced. The MAX104's on-chip 2.2GHz full-power-bandwidth T/H amplifier **(Figure 2)** increases dynamic performance significantly and supports more precise capture of fast analog data at extremely high conversion rates.

Bandgap reference

The MAX104 features an on-board +2.5V precision bandgap reference, which can be activated by connecting the bandgap reference's output contact (REFOUT) to the in-phase input (REFIN) of the internal reference amplifier. The negative input of this amplifier is internally tied to the reference ground (GNDR).

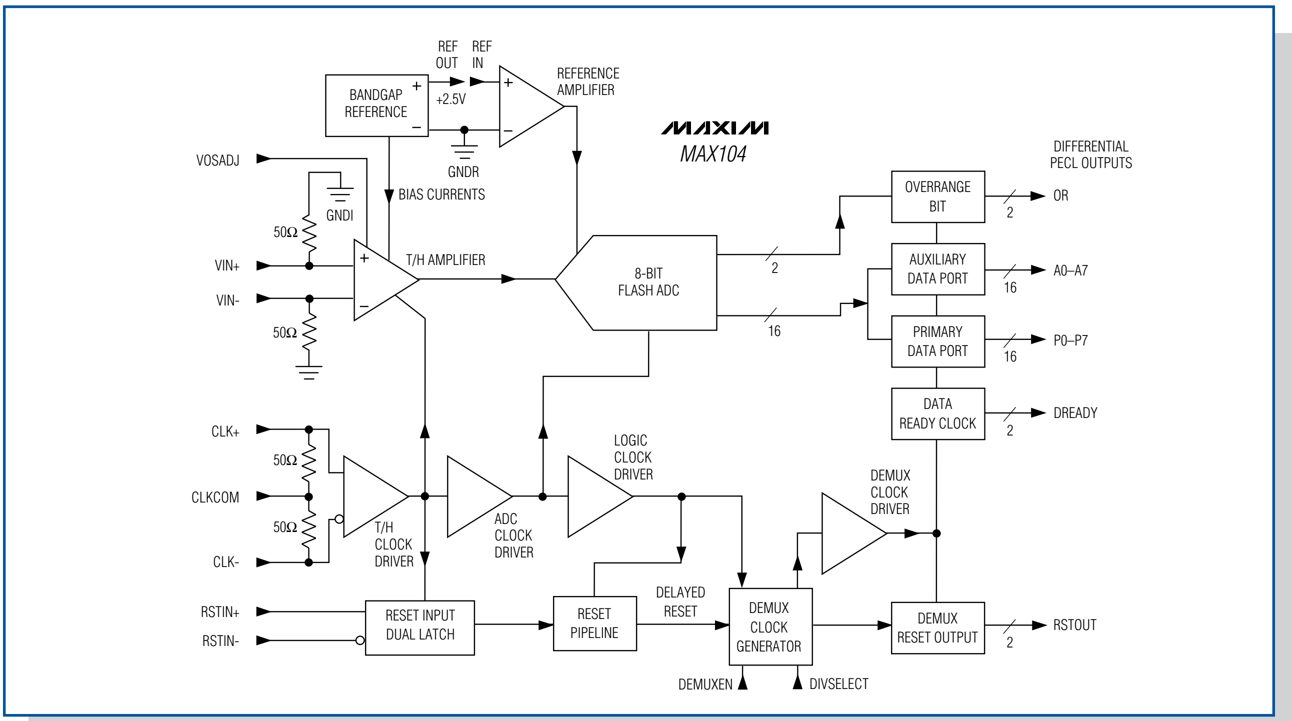


Figure 1. This simplified block diagram shows how the MAX104 integrates a high-bandwidth T/H amplifier with a high-speed quantizer.

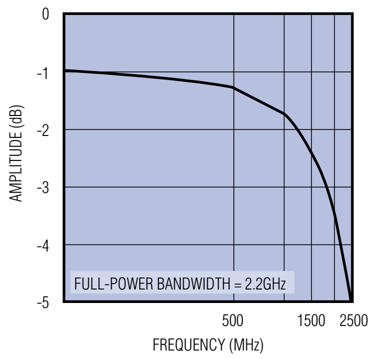


Figure 2. The MAX104's full-power bandwidth is shown as a function of input amplitude.

The REFOUT port can provide a current of up to 2.5mA for external devices. This is enough drive for two MAX104s configured for interleaved operation (to achieve a sampling rate of 2 gigasamples per second, or 2Gsps). Since the bandgap reference source is internally compensated, external bypass components are not needed with REFOUT connections.

To overdrive the internal reference, an external precision reference can be connected to the REFIN pin with REFOUT left floating. The external reference may then be used to adjust the full-scale range of the MAX104.

The MAX104's T/H amplifier input circuit design reduces the input signal requirement and supports a full-scale signal input range of 500mV peak-to-peak. Obtaining a full-scale digital output with a differential input requires 250mV applied between the positive (VIN+) and the negative input (VIN-) pins. Midscale digital output codes occur at an input of 0V.

For a zero-scale digital output code, the negative input (VIN-) must be 250mV above the positive input (VIN+). The high-performance differential T/H amplifier enables the MAX104 to be used in single-ended input configurations without any degradation in dynamic performance. For a typical single-ended configuration, the analog input signal is coupled to the T/H amplifier stage at the in-phase input pad (VIN+), while the inverted phase input (VIN-) pad is referenced to ground. Single-ended operation supports an input amplitude of 500mV peak-to-peak, centered at approximately 0V. For minimizing reflections and improving performance, the MAX104 inputs feature impedance-matched, on-chip, laser-trimmed 50Ω NiCr termination resistors.

Demonstrating almost identical dynamic performance at analog input frequencies of 125MHz **(Figure 3)**, 250MHz, 500MHz **(Figure 4)**, and 1GHz **(Figure 5)** with a sampling rate of 1Gsps for differential and single-ended analog input operation, the MAX104 solves one of the most perplexing problems in high-speed ADC applications—the need for costly, space-consuming, single-ended-to-differential signal-conversion circuitry. Now, applications requiring single-ended signal sources can just feed this signal into the VIN+ pin and terminate the VIN- pin through a 50Ω resistor connected to ground.

Similar to its analog input structure, the MAX104 features clock inputs designed for either single-ended or differential operation with very flexible input-drive requirements. Each clock input is terminated with an on-chip, laser-trimmed, 50Ω precision NiCr resistor to the clock-termination return. This termination may be connected anywhere between ground and -2V for compatibility with standard emitter-coupled-logic (ECL) drive levels.

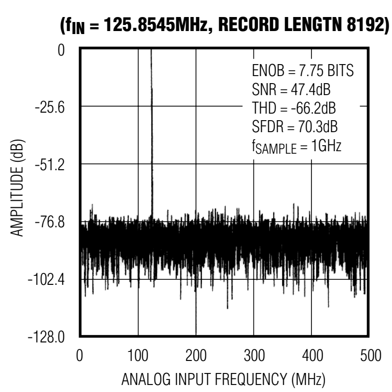


Figure 3. This fast Fourier transform (FFT) demonstrates the over-sampled performance of the MAX104 at a sampling rate of 1Gsps and an analog input frequency of 125MHz.

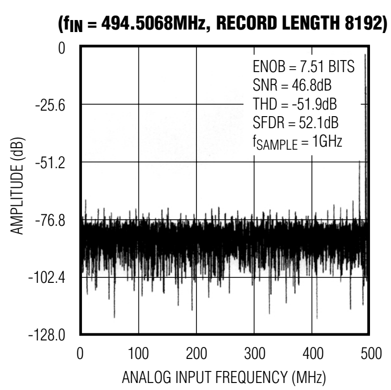


Figure 4. This FFT was taken at a Nyquist frequency of 500MHz and a sampling rate of 1Gsps.

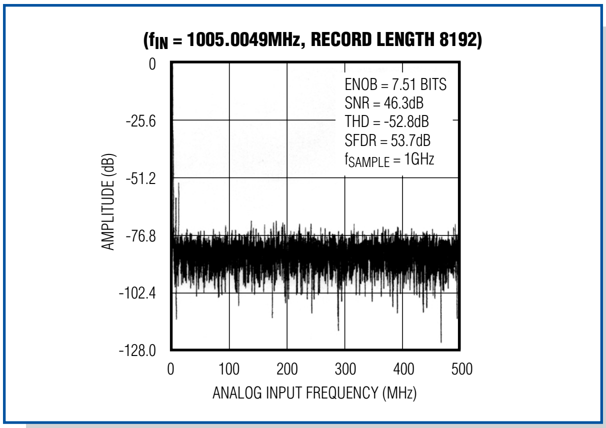


Figure 5. This FFT was measured with the MAX104 undersampling an analog input frequency of 1GHz at a sampling rate of 1Gsps.

The clock inputs are internally buffered with an amplifier to ensure proper operation of the ADC even with small-amplitude sine-wave sources. The MAX104 was designed for single-ended operation, maintaining superior dynamic performance when using low-phase-noise sine-wave clock input signals with as little as 100mV amplitude.

To obtain the lowest jitter clock drive, a low-phase-noise sine-wave source can be AC- or DC-coupled into a single clock input. The MAX104 can accommodate clock amplitudes up to 1V (2V peak-to-peak) with the clock-termination return connected to ground. The dynamic performance of the ADC is essentially unaffected by clock signal amplitudes from 100mV to 1V.

The ADC can be driven from a standard differential ECL clock source by simply setting the clock-termination voltage to -2V. To maintain the best performance, a very-high-speed differential ECL driver should be used.

Clock inputs CLK+ and CLK- may also be driven with positive referenced ECL (PECL) logic levels if the clock inputs are AC coupled. A single-ended ECL drive can also be used if the undriven clock input is connected to the ECL V_{TT} voltage (nominally -1.3V).

Another useful feature of the MAX104 may be its internal output demultiplexer (demux) circuitry. This circuitry provides three different modes of operation. The demux operation is controlled by two transistor-transistor-logic (TTL)/complementary-metal-oxide-semiconductor (CMOS)-compatible digital inputs: DEMUXEN, which activates or deactivates the internal demux, and DIVSELECT, which selects one of three demux modes (DIV1, DIV2, or DIV4).

The DIV2 (demux) mode reduces the output data rate to one-half the sample clock rate. The demuxed outputs are presented in dual 8-bit format with two consecutive samples in the primary and auxiliary output ports on the rising edge of the data-ready clock. The DIV1 nondemultiplexed (nondemux) mode supports operation of the MAX104 at sampling speeds up to 500 megasamples per second (Msps). In this mode, the internal demux is disabled and the sampled data are presented to the primary output port only. To consume less power, the auxiliary port can be shut down by two separate inputs (AUXEN1 and AUXEN2). To save additional power, the external 50Ω termination resistors connected to the logic PECL power supply (V_{CCO} at -2V) can be removed from all auxiliary output ports.

In a special decimated, demuxed output mode (DIV4), the MAX104 discards every other input sample and outputs data at one quarter of the input sampling rate. This mode is particularly useful for system debugging using the resulting slower output data rates. With an input clock of 1GHz, the effective output data rate will be reduced to 250MHz in this mode.

Along with the on-chip demux, the MAX104 provides internal demux reset circuitry that enables multiple ADCs to be synchronized for proper interleaving operation. In addition, the reset signal appears as an external demux reset output for synchronizing external demuxes.

Furthermore, the MAX104 provides latched, differential PECL outputs, which make the ADC ideal for driving controlled low-impedance lines. The PECL outputs can be powered from +3V to +5.25V DC supply voltages. PECL outputs on the MAX104 are typically terminated with a parallel 50Ω termination resistor into $V_{TT} = V_{CCO}$ - 2V (the PECL termination voltage).

Primary port outputs are labeled P0–P7 (LSB to MSB), while the auxiliary ports are labeled A0–A7. Outputs DREADY+ and DREADY- are data-ready true and complementary outputs, supplying the data clock.

These signal lines are used to latch the output data from the primary to the auxiliary output ports, as well as supplying a synchronous clock for downstream digital circuitry, such as demuxes or high-speed memory devices. Data changes are triggered on the rising edge of the DREADY clock.

Outputs OR+ and OR- are overrange true and complementary outputs. Outputs RSTOUT+ and RSTOUT- are the reset-out true and complementary outputs provided to reset downstream circuitry.

The MAX104 is supplied in a 192-contact enhanced-super-ball-grid-array (ESBGA) package from Amkor/Anam

(Chandler, AZ) that measures 25mm x 25mm. The MAX104 provides an on-board 1:2 demux function, slowing data rates to 500Mbps supplied on two ports. The package features 50Ω microstrip interconnects from the solder balls to the bond wires, which support high input/output (I/O) operating frequencies. In addition, the package enables a large number of solder balls to be dedicated to power supplies and ground. With a thickness of only 1.4mm, this 1.27mm pitch ESBGA package saves circuit-board space while providing excellent thermal performance. In many applications, the MAX104 can be used without a heat sink.

The MAX104 is ideal for many applications where high sampling rates are required to either capture an instantaneous value from a fast-moving signal, such as in a high-speed data acquisition (DAQ) application, or to digitize a complex high-frequency, high-bandwidth signal. One example of this is in wideband digital receivers for digital base stations. In this case, signal bandwidths that exceed 300MHz are allowed to pass through the receiver intermediate-frequency (IF) stages to the demodulator. At this point, the information bandwidth may be filtered and amplified before being presented to the ADC front end. This approach, known as block or direct downconversion, requires that the input bandwidth of the ADC be sufficiently flat to prevent distortions and nonlinearities in the resulting digital representation. The high-speed data stream thus created is then presented to a digital demodulator which separates the individual channels and extracts the modulated information.

Applying the ADC

The exceptional SNR and spurious-free dynamic-range (SFDR) performance of the MAX104 at input frequencies below (e.g., at 125MHz and 250MHz) and well above the Nyquist frequency (e.g., operating at 1GHz) make the MAX104 the converter of choice for oversampled as well as undersampled 8-bit digital communications applications. For instance, the MAX104 delivers a 47.4dB SNR and 68.9dB SFDR at an analog input frequency of 125MHz. The two-tone performance is an impressive -57.7dB at the same test frequency.

Another ideal application is in DAQ instruments and systems. These are systems that are designed to sample, analyze, and display signal waveforms detected at various nodes within a circuit under analysis (e.g., high-speed, multichannel digital oscilloscopes). ADCs are used in the front-end circuitry of digital sampling oscilloscopes (DSOs). Often, multiple converters are time interleaved to increase an effective sampling frequency. Maxim's new 600Msps/1.5Gsps converter, the MAX106, provides designers with the options of lower and even higher sampling speeds.

Important data-converter specifications in DAQ applications include an analog signal input bandwidth, gain flatness, ENOB performance, and low occurrence of metastable states. A differential comparator design and its decoding circuitry reduce out-of-sequence code errors, such as thermometer bubbles or sparkle codes, and provide excellent metastable performance of less than one error per 10^{16} clock cycles. Unlike other ADCs, which may have errors that result in false full-scale or zero-scale outputs, the MAX104 keeps its error magnitude to no more than 1LSB.

Furthermore, this fast ADC accomplishes outstanding numbers for integral-nonlinearity (INL) and differential-nonlinearity (DNL) parameters, ensuring monotonic operation. After trimming, the MAX104 displays parameters as low as ±0.25LSB **(Figures 6, 7)**.

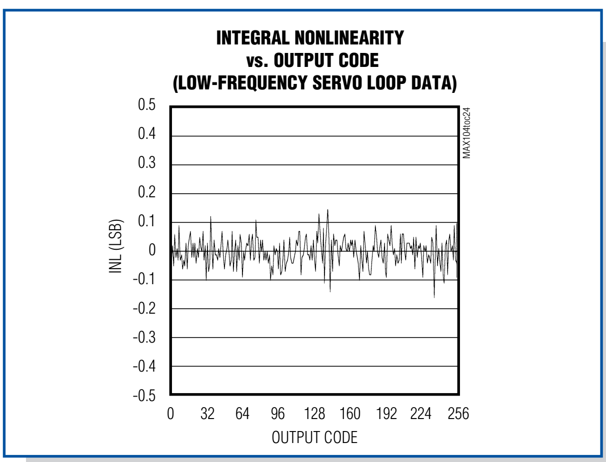


Figure 6. The MAX104's typical integral nonlinearity

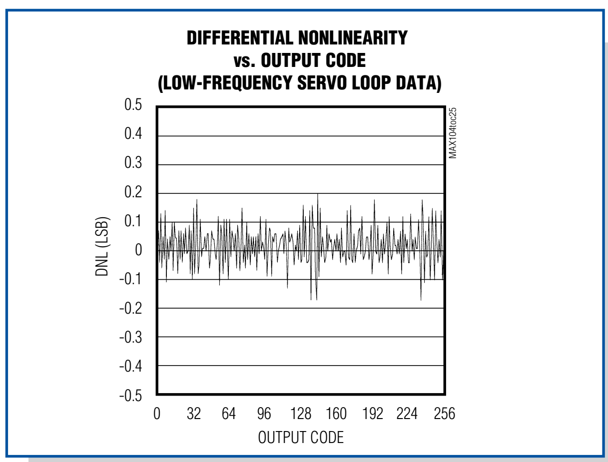


Figure 7. The MAX104's typical differential nonlinearity

How to select the right CMOS analog switch

Integrated analog switches often form an interface between a digital controller and analog signals. This article gives the theoretical background for analog switches and describes some common applications for standard types. It also discusses the special features of calibration multiplexers (cal-muxes), fault-protected switches, and force-sense switches.

In recent years, integrated analog switches have offered better switching characteristics, lower supply voltages, and smaller packages. Because so many performance options and special functions are now available, the well-informed product designer has a good chance of finding the ideal part for a particular application.

Although CMOS analog switches are often taken for granted because they are easy to use, don't overlook their ability to solve certain engineering problems. Conventional analog switches such as the early CD4066 or MAX4066 are now offered by many manufacturers; their basic structure 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. 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 single or dual.

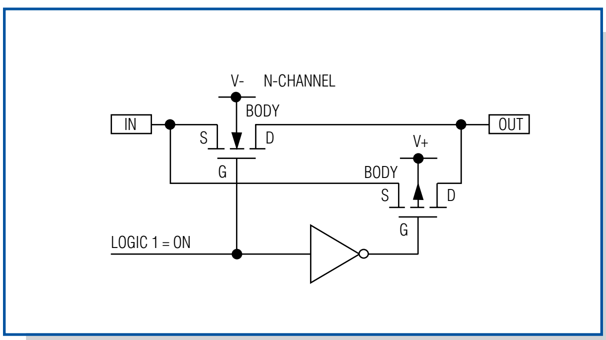


Figure 1. The internal construction of a typical analog switch features parallel N- and P-channel MOSFETs.

Taking the P- and N-channel on-resistances (R_{ON}) in parallel (product over sum) for each level of V_{IN} yields a composite on-resistance characteristic for the parallel structure (**Figure 2**). This plot of R_{ON} vs. 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. Be aware, however, that these effects represent disadvantages, and that minimizing them is often the primary purpose of new products.

The first analog switches operated on ±20V supply voltages and had several hundred ohms of R_{ON}. The latest products (Maxim's MAX4601, for instance) achieve 2.5Ω max R_{ON} with a much lower supply voltage. Supply voltage has a significant effect on R_{ON} (**Figure 3**). The MAX4601 specifies signal and supply voltages from +4.5V to +36V or from ±4.5V to ±20V. As you can see, R_{ON} increases for lower supply voltages. The max R_{ON} is about 8Ω at +5V, 3Ω at +12V, and only 2.5Ω at +24V. Some new analog switches specify low-voltage operation for supplies as low as +2V. **Figure 4**

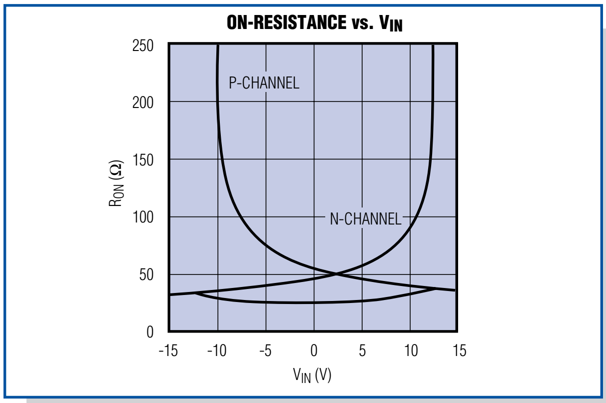


Figure 2. The N-channel and P-channel on-resistances of Figure 1 form a low-valued composite on-resistance.

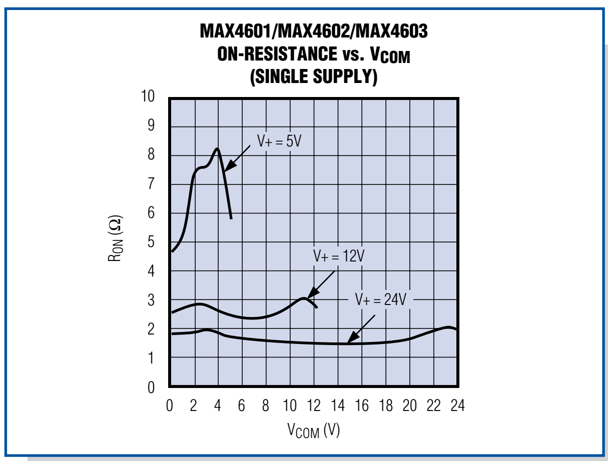


Figure 3. Higher supply voltage causes lower on-resistance.

compares the performance of the new Maxim switches with older switch types for +5V supplies.

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. That pin connects to the system logic voltage, which is usually 5V or 3.3V. Having the input logic signals referenced to the actual logic levels increases the noise margin and prevents excessive power dissipation.

Signal handling

A second look at Figure 3 shows the value of R_{ON} vs. signal voltage. These curves fall within the specified supply range, because analog switches can only handle analog signal levels between the supply voltages. Under- or overvoltage input signals 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) as high as ±2kV.

R_{ON} for a typical CMOS analog switch causes a linear reduction of signal voltage that is proportional to current passing through the switch. This might not be a disadvantage for modest levels of current, or if the design accounts for R_{ON} effects. If, however, you accept a certain level of R_{ON}, then channel matching and R_{ON} flatness can become significant. Channel matching describes the variation of R_{ON} for the channels of one device, and R_{ON} flatness describes the variation of R_{ON} vs. signal range for a single channel. Typical values for these parameters are 2Ω to 5Ω; very low-R_{ON} switches (i.e., the MAX4601) have only 0.5Ω max. The smaller the ratio of matching/R_{ON} or flatness/R_{ON}, the more accurate the switch.

Charge-injection effects

Low on-resistance is not necessary in all applications. Lower R_{ON} requires greater chip area, and the result is a greater input capacitance whose charge and discharge currents dissipate more power in every switching cycle. Based on the time constant t = RC, this charging time depends on load resistance (R) and capacitance (C).

Maxim offers both types, each with the same pinout in the same miniature SOT23 package. The MAX4501 and MAX4502 specify higher on-resistance but shorter on/off times. The MAX4514 and MAX4515 have lower on-resistance but longer switching times. Another negative consequence of low on-resistance can be the higher charge injection caused by 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 5**). For switches connected to high-impedance outputs, this action can cause significant changes in the expected output signal. A small parasitic capacitor (C_L) (and no other load) adds a variation of ΔV_{OUT}, so charge injection can be calculated as $Q = \Delta V_{OUT}(C_L)$.

A track/hold amplifier, which maintains a constant analog output during conversion by an analog-to-digital converter (ADC), offers a good example (**Figure 6**). 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

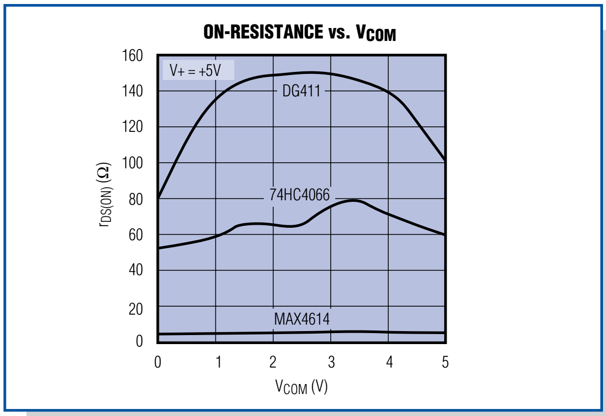


Figure 4. At +5V supply voltage, later generation analog switches have lower on-resistance.

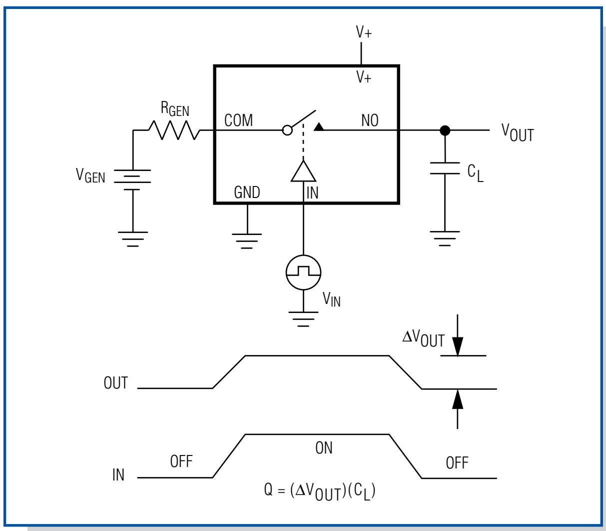


Figure 5. Charge injection from the switch-control signal causes a voltage error at the analog output.

remains stored on C when S1 opens. The high-impedance buffer then maintains V_H constant over the ADC's conversion time. For short acquisition times, the track/hold's capacitor must be small, and S1's on-resistance must be low. On the other hand, charge injection can cause V_H to change by $\pm\Delta V_{OUT}$ (a few millivolts), thereby affecting the accuracy of the following ADC.

Having reviewed these fundamentals, we now focus on new and innovative switches for special applications.

T-switches for higher frequencies

The T-switch is suitable for video and other frequencies above 10MHz. It consists of two analog switches in series, with a third switch connected between ground and their joining node. This arrangement provides higher off-isolation than does a single switch. The capacitive crosstalk for an off T-switch typically rises with frequency due to the parasitic capacitances in parallel with each of the series switches **(Figure 7)**. The problem in operating a high-frequency switch is not turning it on, but turning it off.

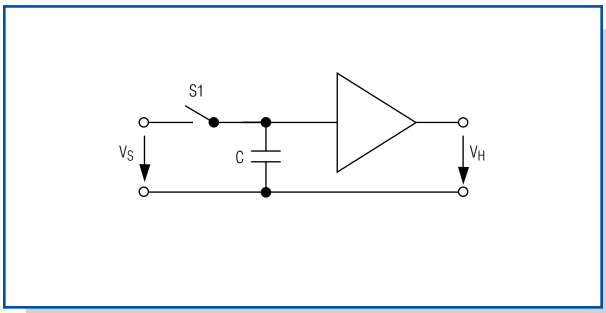


Figure 6. A typical track/hold function requires precise control of the analog switches.

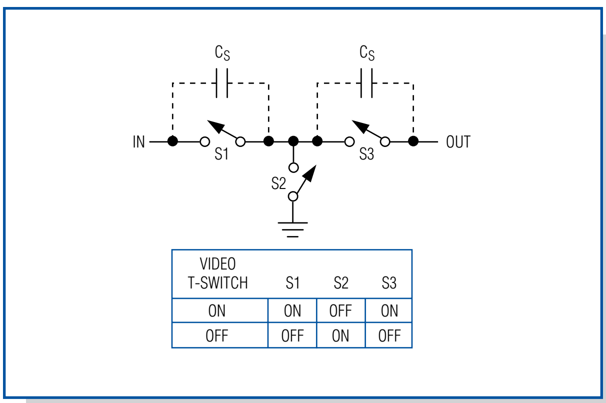


Figure 7. The T-switch configuration attenuates RF frequencies that couple through the stray capacitance between the source and drain of an open (off) switch.

When the T-switch is on, S1 and S2 are closed and S3 is open. In the off state, S1 and S2 are open and S3 is closed. In the off state, the signal tries to couple through the off-capacitance of the series MOSFETs, but is shunted to ground by S3. Comparing off-isolation at 10MHz for a video T-switch (MAX4545) vs. a standard analog switch (MAX312), the result is dramatic: -80dB vs. -36dB for the standard switch.

Smaller packages

Other advantages of CMOS analog switches are small packages and no mechanical parts (unlike reed relays). Maxim offers a small video switch (MAX4529) as well as a standard, low-voltage SPDT switch (MAX4544). Both come in 6-pin SOT23 packages and operate from supply voltages in the +2.7V to +12V range. The MAX4544 is the smallest SPDT analog switch available.

As mentioned earlier, Maxim offers many variations of popular analog switches like the CD4066. For example, a new family of low-cost quad analog switches has been released (MAX4610/MAX4611/MAX4612). The MAX4610 is a pin-compatible upgrade to the industry-standard CD4066, but with lower supply voltage (as low as +2V) and higher accuracy: channel matching to within 4Ω max, and channel flatness to within 18Ω max. These parts offer three different switch configurations, and their lower on-resistance (<100Ω at 5V) suits low-voltage applications. A tiny 14-pin TSSOP package (6.5 x 5.1 x 1.1mm3 max) saves board space.

ESD-protected switches

Based on the success of Maxim's ESD-protected interface products, ±15kV ESD protection was added to some of its new analog switches. Maxim now offers the first switches with ±15kV ESD protection per IEC 1000-4-2 Level 4 (the highest level). All analog inputs are ESD tested using the Human Body Model, as well as the Contact and Air-Gap Discharge Methods specified in IEC 1000-4-2. The MAX4551/MAX4552/MAX4553 switches are pin compatible with many standard quad-switch families such as the DG201/DG211 and MAX391. To round out standard multiplexer families like the 74HC4051 and MAX4581, Maxim has also released ESD-protected multiplexers: the MAX4558/MAX4559/MAX4560. From now on, you need not use costly TransZorbs™ to protect your analog inputs.

TransZorb is a trademark of General Semiconductor Industries, Inc.

Fault-protected switches

The supply-voltage rails for an analog switch restrict the allowed range for input signal voltage. Although normally this restriction is not a problem, in some cases the supply voltage can be turned off with analog signals still present. That condition can permanently damage the switch, as can transients outside the normal range of the power supply. Maxim's new fault-protected switches and multiplexers guarantee an overvoltage protection of ±25V and a power-down protection of ±40V, along with Rail-to-Rail® signal handling and the low on-resistance of a normal switch. Also, the input pin assumes a high impedance during fault conditions, regardless of the switch state or load resistance. Only nanoamperes of leakage current can flow from the source **(Figure 8)**.

If the switch is on, the COM output is clamped to the supply by two internal "booster" FETs (N2, P2 in Figure 8). 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. The fault-protected switches MAX4511/MAX4512/MAX4513 are pin compatible with the DG411/DG412/DG413 and DG201/DG202/DG213 types. Note that signals pass equally well in either direction through an ESD- and fault-protected switch, but these protections apply only to the input side.

Force-sense switches

Recently, Maxim released a new family of analog switches in which different switch types reside in the same package. The MAX4554/MAX4555/MAX4556 devices, for instance, are configured as force-sense switches for Kelvin sensing in automated test equipment. Each part contains low-resistance, high-current switches for forcing current, and higher-resistance switches for sensing voltage or switching guard signals. On-resistance is only 6Ω for the current switches, and only 60Ω for the sensing switches at ±15V supply voltages. The MAX4556 contains three SPDT switches with break-before-make action.

Typical force-sense applications are found in high-accuracy systems and in measurement systems that involve long distances **(Figure 9)**. For 4-wire measurements, 2 wires force a voltage or current to the load, and 2 other wires connected directly to the load sense and the load voltage.

A 2-wire system senses load voltage at the ends of the force wires opposite the load. Load voltage is lower than the source voltage because the forcing voltage or current causes a voltage drop along the wires. The longer the distance between source and load, the larger the load current; the higher the conductor resistance, the larger the degradation. The resulting signal reduction can be overcome by using a 4-wire technique, in which the two additional voltage-sensing conductors carry negligible current.

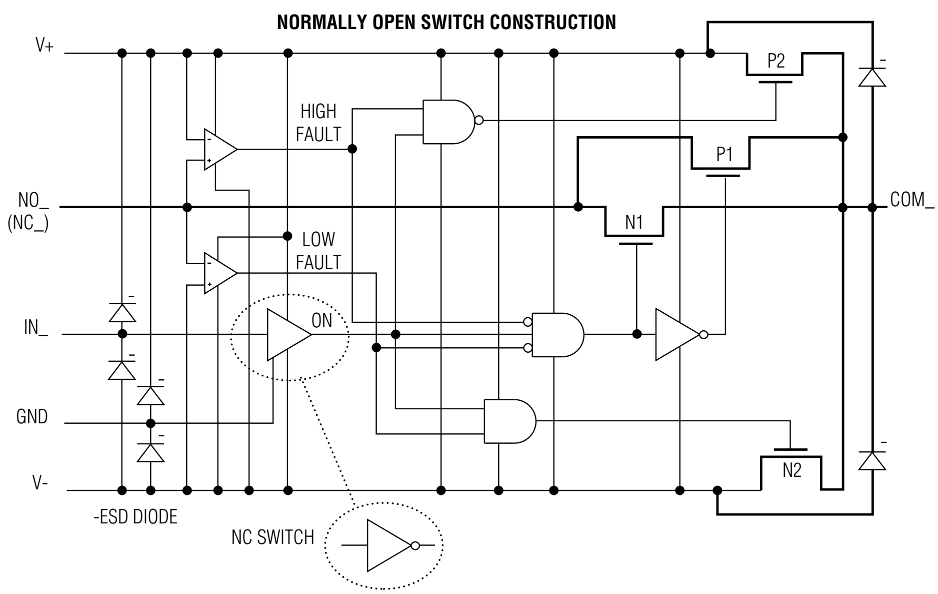


Figure 8. This internal structure shows the special circuitry in a fault-protected analog switch.

Rail-to-Rail is a registered trademark of Nippon Motorola, Ltd.

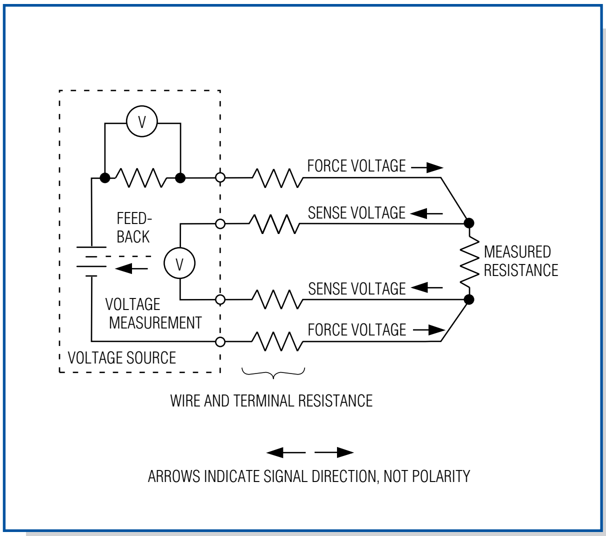


Figure 9. In this four-wire resistance measurement (constant voltage) technique, two wires force and two other wires sense the measured voltage.

The new force-sense switches simplify many applications, such as switching between one source and two loads in a 4-wire system. They are suitable for use in high-accuracy measurement systems such as nanovoltmeters and femto-ammeters, and for 8- or 12-wire force-and-sense measurements using the guard wires of triax cables. For more information, please see the MAX4554/MAX4555/MAX4556 data sheet.

Calibration multiplexers

Calibration multiplexers (cal-muxes) are used in precision ADCs and other self-monitoring systems. Their combination of different components in one package has not been offered before: analog switches for generating accurate voltage ratios from an input reference voltage, internal precision resistor-dividers, and a multiplexer for selecting between different inputs.

Two of these devices (the MAX4539/MAX4540) can balance two major errors associated with an ADC system: offset and gain error. Using the internal precision voltage dividers, these devices measure gain and offset in just a few steps, controlled through the serial interface of a microcontroller. The reference ratios 15/4096 and 4081/4096 (with respect to the external reference voltage) are accurate to 15 bits. The ratios (5/8)(V+ - V-) and V+/2 are accurate to 8 bits.

The cal-mux first applies half the supply voltage to verify that power is present. The system then measures zero offset and gain error and forms an equation to correct the subsequent readings. Zero input voltage, for example, should produce a digital zero output. The cal-mux calibrates for offset error by applying a very small input voltage of 15/4096 referred to (V_{REFHI} - V_{REFLO}). For a 12-bit ADC with 4.096V reference, 15/4096 equals 15mV and also 15LSB. The digital output, therefore, should be binary 000000001111. To measure offset error, the microcontroller simply records the difference between binary 000000001111 and the ADC's actual output.

To measure gain error, the cal-mux applies a voltage of 4081/4096 referred to (V_{REFHI} - V_{REFLO}). The microcontroller then records the difference between binary 111111110000 and the ADC's digital output. Knowing the ADC's offset and gain error, 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 capability to periodically recalibrate the system.

How to simplify the interface between microcontroller and temperature sensor

Temperature is an analog quantity, but digital systems often use temperature to implement measurement, control, and protection functions. If you apply the right techniques and components, the necessary conversion of analog temperature to digital information won't be difficult.

Reading temperature with a microcontroller (µC) is simple in concept. The µC reads the output code of an analog-to-digital converter (ADC) driven by a thermistor-resistor voltage divider, analog-output temperature sensor, or other analog temperature sensor (**Figure 1**). The ADC built into some controllers can simplify this design. ADCs require a reference voltage, which can be generated by an external device. For example, the reference voltage for a thermistor sensor is usually the same as that applied to the top of the resistor-thermistor voltage divider. However, the following complications can arise in these systems:

- **The sensor's output-voltage range is significantly smaller than the ADC's input-voltage range.** A typical ADC for this purpose might have 8-bit resolution and a 2.5V reference voltage, which is normally equivalent to the input-voltage range. If the sensor's maximum output for the temperature range of interest is only 1.25V, the effective resolution drops to 7 bits. To achieve 8-bit resolution, either add gain via an external op amp or lower the ADC's reference voltage (which may reduce the accuracy of some ADCs).
- **The error budget is tight.** Combining the error from the thermistor-resistor combination or analog-sensor device with those contributed by the ADC, the amplifier offset voltage, the tolerance of gain-setting resistors, and the voltage reference error may be more error than your system can tolerate.
- **You want a linear temperature-to-code transfer function and you're using a thermistor.** The transfer function for thermistors is very nonlinear, but it may be sufficiently linear over the narrow temperature range required in many applications. You can compensate for the nonlinearity with a look-up table, but this approach requires resources that may not be available.
- **ADC inputs are limited.** If the number of temperatures you want to measure exceeds the number of ADC inputs available, you may need to add a multiplexer, which will increase the cost and development time.
- **The number of µC I/O pins is limited.** This won't be an issue for an internal ADC, but an external serial ADC will require two to four I/O pins as an interface to the µC.

The design problems are simplified if you use a temperature sensor with a digital interface. Similarly, temperature sensors with time- or frequency-based outputs can alleviate the measurement problem when ADC inputs and µC I/O pins are in short supply (**Figure 2**). The MAX6576 temperature sensor, for example, produces an output square wave whose period is proportional to absolute temperature. It comes in a 6-pin SOT23 package that requires very little board space. A single I/O pin interfaces this device to a µC; after its internal counter measures the period, the µC calculates the temperature.

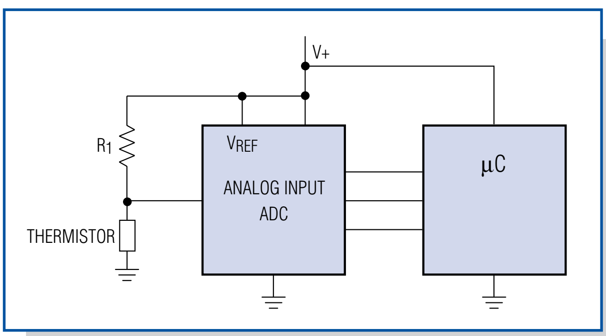


Figure 1. In this simple interface, the ADC's reference voltage is derived from the power-supply voltage. An analog temperature sensor can replace the thermistor-resistor voltage divider. In that case, the ADC (which can be internal to the µC) requires a reasonably accurate voltage reference.

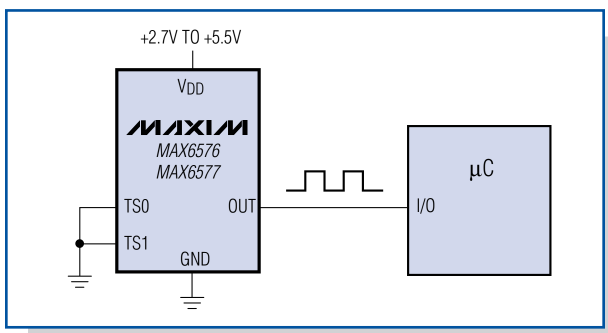


Figure 2. The MAX6576 produces a square wave with period proportional to absolute temperature; the MAX6577 produces an output frequency proportional to temperature. The resulting proportionality constant is set to one of four values by the TS0 and TS1 pins. No external components are necessary.

Applying either ground or the positive supply voltage to each of two logic inputs selects one of four period/temperature proportionality constants between 10µs/°K and 640µs/°K.

A related temperature sensor (MAX6577) generates an output square wave whose frequency/temperature factor is programmable between 0.0675Hz/°K and 4Hz/°K. Both devices simplify temperature acquisition by reducing the required PC board real estate, component count, and analog/digital I/O resources. They transmit temperature data to the µC through a single digital I/O pin, and the addition of a single optical isolator makes them ideal for applications that require electrical isolation between the sensor and the CPU.

For measuring multiple temperatures at various locations, the choices become more complicated. Thermistors or conventional analog sensors can be placed in appropriate locations and connected to the ADC inputs, provided the ADC has sufficient inputs available. As an alternative, the MAX6575 transmits temperature data directly to the µC; as many as eight MAX6575s can be connected to a single µC I/O input. A single I/O trace connects the µC to these eight MAX6575s (**Figure 3**). To measure temperature, the µC briefly pulls the I/O line low, and after a short delay the first MAX6575 also pulls the I/O line low. This time delay is proportional to absolute temperature, with a proportionality constant programmed using two pins on the MAX6575.

The first sensor holds the line low for a period proportional to temperature (5µs/°K) and then releases it. After a second time delay, selected by setting the programming pins for a larger proportionality constant, the second MAX6575 pulls the I/O low and holds it for an interval defined by 5µs/°K. Four MAX6575s can be connected to the I/O line this way. Four more MAX6575s of the other, longer-delay version can be added to the same I/O line. The MAX6575L has delay multipliers ranging from 5µs/°K to 80µs/°K, and the MAX6575H delay multipliers range from 160µs/°K to 640µs/°K. Thus, as many as eight MAX6575s can be located in different places around the system, connected to the µC by a single I/O line.

For some systems, the information needed is not the exact temperature, but whether the temperature is above or below a specific value. This information can trigger a cooling fan, air conditioner, heater, or other environmental-control element. In system-protection applications, an "overtemperature bit" can trigger an orderly system shutdown to avoid losing data when the system power is cut off. This single bit of information can be obtained by measuring temperature as in the examples above, but that approach requires more software and hardware than the function demands.

Replacing the ADC in Figure 1 with a voltage comparator produces a simple 1-bit output that can drive a single I/O pin on the µC (**Figure 4**). Again, the thermistor shown can be replaced by an analog voltage-output temperature

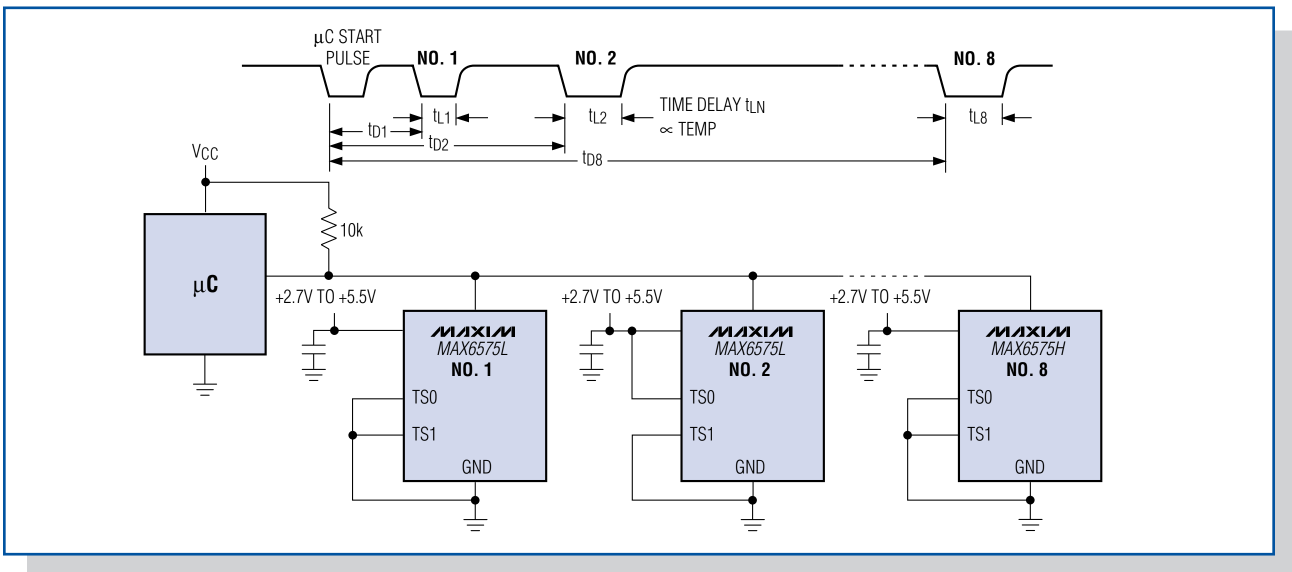


Figure 3. Using a delay scheme to encode temperature information, multiple MAX6575s transmit up to eight temperatures to the µC through a single digital I/O pin.

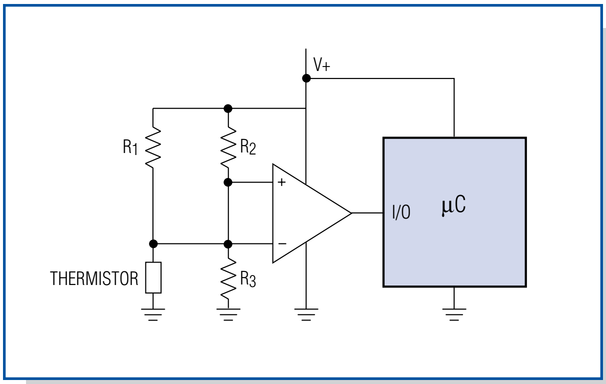


Figure 4. Combining a sensor with a comparator yields a 1-bit digital output that can warn the µC of temperature excursions beyond a predetermined threshold or trip point.

sensor. Most such devices have a relationship between temperature and output voltage that is unaffected by supply voltage. To preserve immunity from supply-voltage variations, connect the top of the comparator's resistor-divider to a voltage reference instead of the supply voltage.

The system can be simplified by replacing the sensor-comparator combination with a thermal switch like the MAX6501. This monolithic device combines the functions of a sensor, comparator, voltage reference, and external resistors. When temperature exceeds the preset trip level, the open-drain output goes low. Some devices in this family have open-drain outputs that go low when temperature falls below the trip point (MAX6503), and others have push/pull outputs that go high when temperature goes either above or below the trip point (MAX6502, **Figure 5**, or MAX6504). In addition, the hysteresis can be set to 2°C or 10°C by connecting a package pin to V+ or ground. The available trip temperatures range from -45°C to +115°C in 10°C increments.

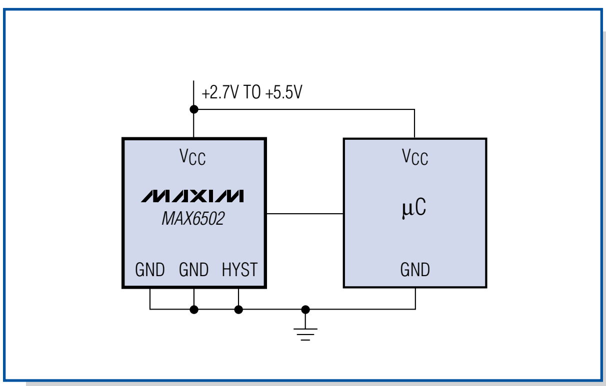


Figure 5. The MAX6502 produces a logic-high output when its temperature exceeds the preset threshold value.

As with the MAX6575, connecting several MAX6501s or MAX6503s to a single I/O trace enables the µC to be notified when temperature crosses the threshold at one or more locations. If the system must know which location has crossed the threshold, each switch output must be connected to a separate I/O pin.

These sensors measure their own die temperatures, and because die temperature closely tracks lead temperature, each sensor should be placed so its leads assume the temperature of the component being monitored. In some cases, however, you must measure a temperature not tightly coupled to the sensor—such as that of a power ASIC, whose die can be much hotter than the surrounding board. An internal temperature sensor may enable the ASIC to shut itself down in response to a temperature fault, but that capability alone lacks accuracy, and it seldom warns the system of an impending thermal overload.

By adding an externally accessible P-N junction to the ASIC die, you can measure die temperature directly by forcing two or more different forward currents through the sensing junction and measuring the resulting voltages. The difference between the two voltages is proportional to the absolute die temperature:

$$V2 - V1 = \frac{kT}{q}\left(1n\frac{I_2}{I_1}\right)$$

where I_1 and I_2 are the two current levels forced through the P-N junction, V1 and V2 are the resulting forward voltages across the junction, k is Boltzmann's constant, T is the absolute temperature of the junction in degrees Kelvin, and q is the electron charge.

This measurement, of course, requires precision circuitry for generating the accurate current ratios and measuring very small voltage differences while rejecting the noise produced by large transients on the power ASIC die. Fortunately, Maxim's remote-junction temperature sensors integrate these precision analog functions with a simple and versatile digital interface.

The MAX1618, for example, measures remote-junction temperatures with 8-bit (1°C) resolution and communicates the result to a µC over the SMBus **(Figure 6)**. Originally designed for monitoring the CPU temperature in PCs, this device has other features that remove some of the controller's overhead. For example, the MAX1618 monitors a remote-junction temperature with a window comparator and interrupts the µC when temperature goes

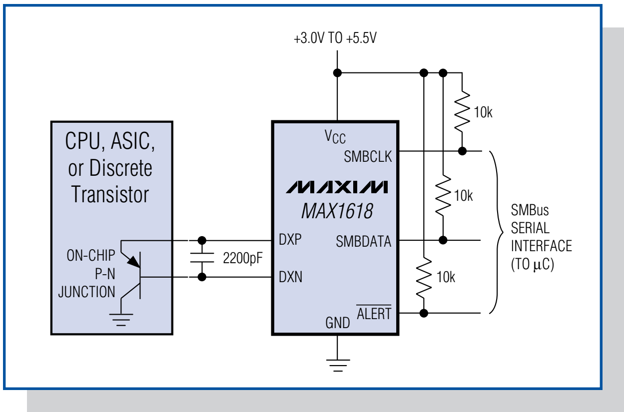


Figure 6. The MAX1618 measures the temperature of an external P-N junction (part of a discrete transistor, ASIC, or CPU) by forcing currents through the junction and measuring the resulting forward voltages.

above or below the limit thresholds previously downloaded to its registers by the µC. Rather than poll the MAX1618 continually, the µC can set the temperature thresholds on start-up and then ignore the MAX1618 until a thermal problem requires its attention.

Available in a 10-pin µMAX package, the MAX1618 can be placed close to the junction being measured. In turn, the resulting short trace lengths between the sense junction and MAX1618 help to avoid noise pickup.

NEW PRODUCTS

High-performance 8-bit ADC with track/hold converts at 600Msps

The MAX106 is an 8-bit, monolithic, bipolar analog-to-digital converter (ADC) with a 600Msps digitizing rate. Pin compatibility with the 1Gsps MAX104 allows easy upgrades. The MAX106 is ideal for high-speed communications, instrumentation, and data-acquisition applications that require wide bandwidth, good linearity, and a high level of dynamic performance at lower sampling rates.

Unlike other high-speed 8-bit ADCs, the MAX106 achieves a 47.8dB SINAD and 57.5dB SFDR at the 300MHz Nyquist frequency. It maintains this performance (within 0.1dB) for input frequencies to 600MHz, i.e., twice the Nyquist frequency.

The MAX106 achieves high performance through innovative design and the use of Maxim's proprietary 27GHz GST-2 bipolar process. A track/hold (T/H) with fully differential input employs Schottky diodes and laser-trimmed resistors to achieve 2.2GHz full-power bandwidth, aperture jitter less than 1ps, and typical integral nonlinearity (INL) and differential nonlinearity (DNL) values less than ±0.25LSB. As a further advantage, the proprietary decoding scheme ensures a low occurrence of metastable states (1 in 10^{15} clock cycles), with no error exceeding 1LSB.

Proper packaging is also critical to achieving good performance at these frequencies. The MAX106 comes in a 25mm x 25mm x 1.4mm, 192-contact Enhanced Super Ball-Grid Array (ESBGA™) package that minimizes parasitic effects, provides controlled-impedance signal paths, and eliminates the need for heatsinking in most applications.

A demultiplexer with 8 or 16 outputs (selectable) facilitates the digital interface by slowing the 600Msps data to only 300Mwords/second, ported to two parallel, differential, 8-bit, low-voltage PECL outputs. The MAX106 also supports single-port operation at 600Msps sampling rates. It presents data in offset-binary format and includes an output clock and overrange bit. The MAX106 operates from ±5V supplies and supports an output interface in the +3V to +5V range.

The MAX106 is specified for the commercial temperature range (0°C to +70°C). An evaluation kit is also available. Contact factory for availability.

ESBGA is a trademark of Amkor/Anam.

SOT temperature sensors have single-wire outputs

The MAX6576/MAX6577 temperature sensors have a single-wire digital interface that communicates temperature to a microprocessor over a single control line. The MAX6576 converts ambient temperature to a square wave with periods proportional to absolute temperature (°K). The MAX6577 converts ambient temperature to a square wave with frequency proportional to absolute temperature. Hard-wiring the two time-select pins to V_{DD} or GND selects this square-wave period or frequency range from one of four preset values.

The MAX6576/MAX6577 feature an accuracy of ±3°C max (±0.8°C typ) at +25°C, and ±5°C max at +125°C. They operate from a +2.7V to +5.5V supply and draw supply currents of only 140µA typ, making them ideal for use in portable, battery-powered equipment. Available in space-saving 6-pin SOT23 packages, they are specified for operation over the automotive temperature range (-40°C to +125°C). Prices start at $0.74 (2500-up, FOB USA).

12- and 14-bit DACs with 1LSB INL eliminate power-up glitch

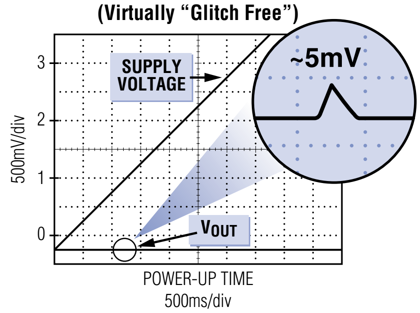
The MAX5170–MAX5177 serial-input/voltage-output, 12- and 14-bit digital-to-analog converters (DACs) feature proprietary circuitry for eliminating power-up glitches. Unlike DACs with undesirable output glitches of 2V to 3V at power-up, these outputs are virtually "glitch free," with excursions less than 5mV. These devices also guarantee monotonicity, with ±1LSB INL and ±1LSB max DNL at 14-bit resolution.

These low-power devices operate from a single supply voltage of +3V or +5V, and draw supply currents of only 350µA max. This current drops to 1µA in the power-down mode. A power-up reset allows the user to select an initial output state of either zero or midscale. The amplifier's user-accessible output and inverting input allows remote sensing, specific gain configurations, and high-output-drive capability for a wide range of force-sense applications. The buffered output is capable of driving 5kΩ | | 100pF or 4–20mA loads.

These eight SPI™-, QSPI™-, and MICROWIRE™-compatible serial interface devices are available in space-saving 16-pin QSOP packages. The 12-bit MAX5174/MAX5176 and 14-bit MAX5170/MAX5172 are voltage-output versions. The 12-bit MAX5175/MAX5177 and 14-bit MAX5171/MAX5173 are force-sense versions. Prices start at $3.15 (1000-up, FOB USA).

SPI™/QSPI™ are trademarks of Motorola, Inc. MICROWIRE™ is a trademark of National Semiconductor Corp.

MAX5170 FAMILY
(Virtually "Glitch Free")



NEW PRODUCTS

2.7V rail-to-rail instrumentation amplifiers achieve 115dB CMRR

The MAX4194–MAX4197 family of micropower instrumentation amplifiers have Rail-to-Rail® capability and a three-op-amp topology that combines precision specifications with operation from a single supply voltage in the +2.7V to +7.5V range. Supply current is just 93µA in normal operation and 8µA in shutdown. Enable time is 500ms, and the unity-gain settling time to 0.1% is 85µs.

These devices conserve battery life in low-voltage, battery-powered systems by pulsing the amplifier on and off with a low duty cycle. In addition to low power consumption, the devices have an excellent DC common-mode rejection rate (CMRR) of 95dB to 115dB, depending on the gain. The unity-gain-stable MAX4194 is configurable for gains up to +1000V/V. The CMRR is 115dB at the highest gain. The MAX4195/MAX4196/MAX4197 are internally configured for gains of unity, +10V/V, and +100V/V, respectively.

The MAX4195 exhibits 95dB CMRR and achieves a 220kHz bandwidth. The MAX4196/MAX4197 achieve bandwidths of 34kHz and 3.2kHz, and exhibit 115dB CMRR. All parts feature rail-to-rail outputs that can drive a 5kΩ load to within 100mV of each rail. The MAX4194–MAX4197 amplifiers are available in 8-pin SO packages. Prices start at $1.60 (1000-up, FOB USA).

Rail-to-Rail is a registered trademark of Nippon Motorola, Ltd.

Hot-swap controller speeds start-up and improves fault response

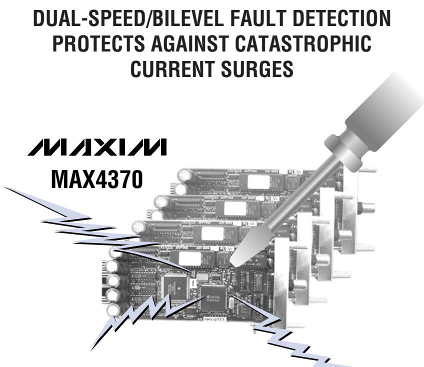
The MAX4370 is a Hot-Swap™ controller for 3V to 12V systems. Upon insertion into a live backplane, it regulates the inrush current while monitoring two types of fault condition: low-amplitude/long-duration current transients, and fast high-amplitude current transients. Hot Swap controllers that don't regulate this start-up current introduce long delays that vary with component tolerances. The MAX4370 reduces this variation and eliminates start-up delays without collapsing the backplane supply.

After the start-up period expires, two comparators in the DualSpeed/BiLevel™ protection circuitry (one fast, one slow) operate simultaneously to detect the two power-supply overcurrent faults (fast, high-amplitude transients or long-duration, low-amplitude transients). If either fault occurs, the MAX4370 asserts a latched output alert and disconnects the main supply by turning off the external MOSFET. Because this proprietary scheme (patent pending) more easily differentiates faults that are disruptive and catastrophic from those that are benign, the controller is less prone to false triggering than are other Hot Swap devices.

The start-up timeout period and the slow-comparator response time are programmed separately with external capacitors, and the overcurrent thresholds are programmed with an external current-sense resistor. The MAX4370 is available in an 8-pin SO package, with prices starting at $1.95 (1000-up, factory direct, FOB USA).

Hot Swap is a trademark of Linear Technology Corp.

DualSpeed/BiLevel is a trademark of Maxim Integrated Products.



Rail-to-rail SOT23 op amps include gain-setting resistors

Rail-to-Rail op amps in the low-cost GainAmp™ family (MAX4174/MAX4175 and MAX4274/MAX4275) include precision gain-setting resistors and V_{CC}/2 bias networks. The factory-trimmed internal resistors provide fixed inverting gains from -0.25V/V to -100V/V and fixed noninverting gains from +1.25V/V to +101V/V. They also yield 0.1% gain accuracy while minimizing layout size and cost.

GainAmps draw only 300µA, operating from a single supply in the +2.5V to +5.5V range. Optimal compensation of each device yields exceptional gain-bandwidth products (as high as 23MHz for A_V between +25V/V and +101V/V). High-voltage fault protection at each input allows the devices to withstand up to ±17V without drawing excessive current.

The GainAmp family includes three versions: single/dual/quad open-loop and unity-gain stable (MAX4281/MAX4282/MAX4284), single/dual fixed-gain (MAX4174/MAX4274), and single/dual fixed-gain with internal V_{CC}/2 bias at the noninverting input (MAX4175/MAX4275). (Internal V_{CC}/2 bias simplifies single-supply circuitry.)

The input common-mode voltage range for the open-loop amplifiers extends from 150mV below the negative supply to within 1.2V of the positive supply. Each output swings rail-to-rail and maintains excellent DC accuracy while driving a 1kΩ load. The amplifiers maintain stability for capacitive loads up to 470pF, without need for an external isolation resistor. GainAmps come in 5-pin SOT23 packages with prices starting at $0.60 (1000-up, FOB USA).

GainAmp is a registered trademark of Maxim Integrated Products.

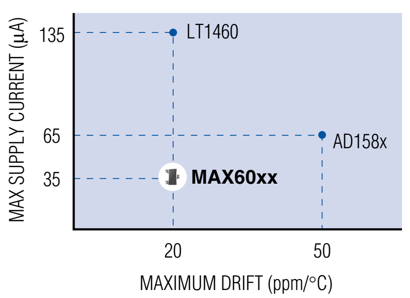
NEW PRODUCTS

Precision, low-dropout voltage references offer 15ppm/°C stability

A family of low-dropout micropower voltage references (MAX6012/MAX6021/MAX6025/MAX6030/MAX6041/MAX6045/MAX6050) offers a low temperature coefficient of 15ppm/°C over the commercial temperature range (0°C to +70°C). Available in tiny 3-pin SOT23 packages, their respective voltage outputs are 1.250V, 2.048V, 2.500V, 3.000V, 4.096V, 4.500V, and 5.000V. A proprietary curvature-correction circuit and laser-trimmed thin-film resistors provide the low tempco and tight initial accuracy.

Unlike conventional shunt-mode (2-terminal) references whose external resistor wastes supply current, Maxim's series-mode devices require no external resistor. Drawing a quiescent supply current of 27µA, they can sink or source load currents as high as 500µA.

Because these internally compensated references require no external compensation capacitor, either, they save valuable board area in space-critical applications. Line regulation is <8µV/V, load regulation is <15µV/µA, and the operation remains stable for load capacitance up to 2.2nF. Low dropout voltage (200mV) and very low supply current make these references ideal for low-voltage, battery-operated systems. Prices start at $1.35 (1000-up, FOB USA).



4/8-channel video mux-amps operate from single +5V supply

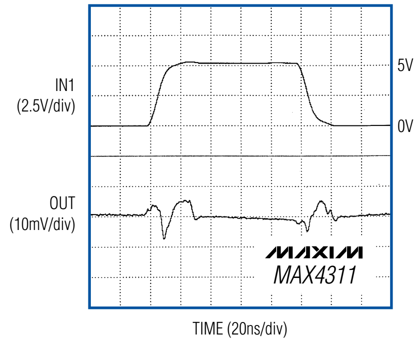
The MAX4311/MAX4312/MAX4314/MAX4315 are single-supply, 4- and 8-channel multiplexer-amplifiers (mux-amps). Their video output buffers have bandwidths as high as 345MHz (MAX4311). Unlike mux-amps that require ±5V bipolar supplies, these guarantee operation from a single supply voltage in the +4.0V to +10.5V range. They also operate between ±2.0V to ±5.25V in dual-supply applications.

Rail-to-rail outputs, ground-sensing inputs, and low (6.1mA) quiescent supply currents suit these mux-amps for video switching in portable, battery-powered applications. In addition, their low cost, ultra-low switching glitch (10mVp-p), and excellent video specifications make them suitable for consumer applications including video teleconferencing equipment, set-top boxes, and video surveillance systems.

The MAX4311/MAX4312/MAX4314/MAX4315 offer 0.1dB gain flatness to 78MHz, slew rates to 430V/µs, low differential gain/phase (0.06%/0.08°), and a spurious-free dynamic range (SFDR) of -95dBc (MAX4314/MAX4315). Their optional disable mode reduces supply currents to 560µA and places the outputs in a high-impedance state, making these devices useful in multiplexing applications that require larger switch matrices.

The MAX4311/MAX4314 are offered in 14-pin SO and 16-pin QSOP packages, and the MAX4312/MAX4315 are offered in 16-pin SO and QSOP packages. Prices start from $0.44 per channel (100,000-up, factory direct, FOB USA).

ULTRA-LOW SWITCHING GLITCH



Rail-to-rail, quad SPDT analog switch has ±40V fault protection

The MAX4533† is the new member of Maxim's family of fault-protected switches. A quad, single-pole/double-throw (SPDT) device, it is pin compatible with the nonprotected industry-standard MAX333 and MAX333A.

The fault-protected MAX4533 provides ±40V of input protection with power off, and as much as ±25V of overvoltage protection during power-up and power-down. The input terminals become open-circuited during a fault condition, allowing only nanoamperes of leakage into the source. To ensure unambiguous outputs, the switch output clamps to the appropriate supply voltage during a fault condition and delivers as much as 13mA of proper-polarity load current.

The MAX4533 also features rail-to-rail signal handling capability, low on-resistance of 175Ω max, and channel-to-channel on-resistance matching to 6Ω max. The fault-protected input leakage is 0.5nA at +25°C and 10nA at +85°C. The switch operates from a single supply voltage of +9V to +36V, or from dual supplies in the ±4.5V to ±18V range. The digital-input thresholds (+0.8V and +2.4V) ensure compatibility with TTL/CMOS logic. The MAX4533 is available in 20-pin plastic DIP, SO, and SSOP packages, with prices starting at $2.32 (1000-up, FOB USA).

† Patent pending.

NEW PRODUCTS

Triple audio/visual crosspoint switches have serial control

The MAX4548/MAX4549 programmable crosspoint switches are well suited for multimedia (audio/video) applications. Each switch includes three 3-input/2-output (triple 3x2) crosspoint matrices, and each matrix has a shunt input to improve off-isolation. Each output is programmable for regular mode or for a selectable soft-switching mode that provides "clickless" audio operation. Typical on-resistances (22Ω with a +5V supply) are flat to within 2Ω and matched (between channels) to within 5Ω.

The MAX4548/MAX4549 operate on a single supply voltage in the +2.7V to +5.5V range. Each includes a set of resistive voltage dividers that are independently selectable via the serial interface, which provides a DC bias for each output when the inputs are AC-coupled. Other specifications include 0.07% THD (with 600Ω load), off-isolation of -85dB at 20kHz (-72dB at 10MHz), and crosstalk of -85dB at 20kHz (-55dB at 10MHz).

The MAX4548 2-wire serial interface is compatible with the I²C™ standard, and the MAX4549 3-wire serial interface is compatible with the SPI/QSPI/MICROWIRE standards. Both devices are available in 36-pin SSOP packages specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $3.12 (1000-up, FOB USA).

I²C™ is a trademark of Philips Corp.

Low-voltage analog mux/switches have ±15kV ESD protection

The MAX4558/MAX4559/MAX4560 are low-voltage CMOS analog devices configured as an 8-to-1 multiplexer (MAX4558), dual 4-to-1 multiplexer (MAX4559), and triple SPDT switch (MAX4560). These parts withstand electrostatic discharge (ESD) without latchup or damage, to ±15kV (Human Body Model), ±12kV (IEC 1000-4-2 Air-Gap-Discharge Method), and ±8kV (IEC 1000-4-2 Contact-Discharge Method).

Pin compatible with the industry-standard 74HC4051/74HCH052/74HC4053 switches, these devices operate from a single supply in the +2V to +12V range or from dual supplies in the ±2V to ±6V range. On-resistances are guaranteed to ≤220Ω with a +5V supply, to ≤160Ω with ±5V supplies, and are matched within 2Ω (typ) for a single device.

Each switch handles rail-to-rail input signals. The off-leakage current is only 1nA at +25°C, and only 10nA at +85°C. To ensure TTL/CMOS compatibility with single 5V or dual ±5V supplies, all digital inputs guarantee 0.8V/2.4V thresholds. Other specifications include low (<0.02%) distortion with 600Ω loads, low (-93dB) crosstalk with 50Ω loads, and high (-96dB) off-isolation with 50Ω loads.

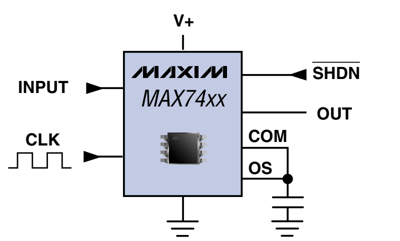
The MAX4558/MAX4559/MAX4560 come in 16-pin QSOP, DIP, and narrow-SO packages, with prices starting at $1.59 (1000-up, FOB USA).

Lowpass switched-capacitor filters have 8th-order elliptic response

The MAX7400/MAX7403/MAX7404/MAX7407 are 8th-order elliptic, lowpass switched-capacitor filters. Whether operating from +5V (MAX7400/MAX7403) or +3V (MAX7404/MAX7407), they provide corner frequencies from 1Hz to 10kHz and draw supply currents of only 2mA, making them ideal for low-power anti-aliasing and post-DAC filtering applications. Shutdown mode lowers the supply current to just 0.2µA.

The MAX7400/MAX7404 provide a sharp rolloff with a 1.5 transition ratio and 80dB of stopband rejection, and the MAX7403/MAX7407 provide a sharper rolloff (1.2 transition ratio) with 58dB of stopband rejection. The low output offset (±4mV) can be further minimized via an offset-adjustment pin (OS) in all four filters.

The filters' internal switching can be self-clocked with an external capacitor or clocked externally for tighter control of the corner frequency. Their fixed output response reduces the design task to simply selecting a corner frequency by setting the clock frequency. The parts are available in 8-pin plastic DIP and SO packages, with prices starting at $1.98 (1000-up, FOB USA).



Single chip drives pager-vibrator motor

The MAX1749 is a buzzer/vibrator motor driver for pagers and wireless handsets. Unlike conventional approaches in which the motor strength decays with battery voltage, this device enables the motor to deliver constant force by producing a constant output voltage throughout its input range (+2.5V to +6.5V).

Acting as a regulator and logic-controlled switch, the MAX1749 draws just 1nA in its off state. Its fixed output is designed to drive inexpensive single-cell annunciators. The output is also adjustable, which lets you customize the buzzer strength for load currents up to 120mA. Other features include output-current limiting, thermal-overload protection, and reverse-battery protection.

The MAX1749EUK is available in an ultra-small 5-pin SOT23 package specified for the extended-industrial temperature range (-40°C to +85°C). Prices start from $0.74 (1000-up, FOB USA).

NEW PRODUCTS

Boost converters drive 2A Tx burst with 6x-lower battery current

The MAX1687/MAX1688 step-up DC-DC converters minimize peak battery current and prevent battery glitches during the transmit cycle of GSM phones and wireless LANs. To drive the RF power amplifier (PA) in a typical cell phone, these DC-DC converters boost the output of three NiCd cells or a single 3.6V lithium-ion (Li+) cell to 5V.

For pulsed load currents such as that drawn during the transmit burst of a GSM phone (which operates with a 1:8 duty cycle), the MAX1687/MAX1688 have a proprietary control scheme (patent pending) that lowers the battery drain by recharging a reservoir capacitor during the off-time. During the transmit pulse, the DC-DC converters turn off to eliminate switching noise at the PA and isolate the battery from load transients.

A typical 5V PA draws as much as 2A while transmitting, and a conventional DC-DC converter pulls nearly 3A from the battery: 2A times (5V/3.6V), plus efficiency losses. The MAX1687/MAX1688 reduce this current to zero during the transmit burst, and to less than 0.5A (a 6-times improvement) when recharging the reservoir capacitor during the off-time. The MAX1687 lets you set maximum battery current; the MAX1688 samples the output voltage droop, automatically adjusting the peak inductor current to minimize battery drain while charging the output capacitor within the GSM timing cycle.

The MAX1687/MAX1688 require no external FET, and their internal synchronous rectifier eliminates a Schottky diode while boosting efficiency to more than 90%. They are available in standard 8-pin SO packages and in small 16-pin TSSOP packages less than 1.1mm high. Prices start from $2.20 (1000-up, FOB USA). A preassembled evaluation kit with recommended external components (MAX1688EVKIT) is available to reduce design time.

Synchronous, switch-mode buck regulator has 3A internal switches

The MAX1623 buck regulator provides CPU and bus-termination power in notebook and desktop computers. The output voltage is either pin selectable as 3.3V or 2.5V, or adjustable down to 1.1V. Output accuracy including line and load regulation is ±1%.

An internal PMOS power switch and an NMOS synchronous-rectifier switch, both rated at 3A/0.1Ω, minimize the external component count and enable the device to deliver (for example) 2A at 3.3V from a +5V supply, with 93% efficiency. The input-voltage range is +4.5V to +5.5V, and the typical operating supply current is 450µA.

Load current causes the MAX1623 to shift smoothly between operating modes. Above 1A it assumes current-mode pulse-width modulation (PWM) control, in which constant off-times for the power switch are followed by on-times proportional to the load current required. Below 1A, it accommodates lower load currents by turning off both switches to skip entire cycles.

PWM operation allows switching frequencies as high as 350kHz. Other MAX1623 features include thermal protection (T_j = +150°C) and a logic-controlled shutdown mode that lowers the supply current below 1µA (10µA max).

The MAX1623 is available in a space-saving 20-pin SSOP package specified for the extended-industrial temperature range (-40°C to +85°C). Prices start from $4.78 (1000-up, FOB USA).

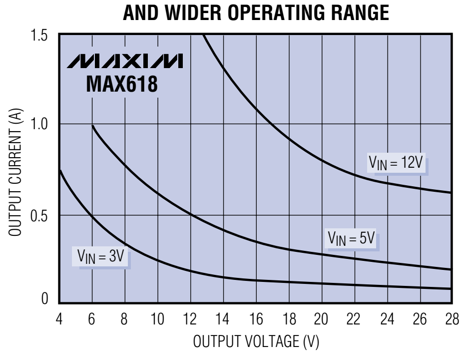
28V PWM step-up DC-DC converter delivers high voltage and current

The MAX618 is a CMOS, PWM, step-up DC-DC converter that generates output voltages to 28V and accepts inputs from 3V to 28V. An internal 2.2A/0.3Ω switch eliminates the need for external power MOSFETs and delivers 50% more output current than comparable 1.5A devices. Typical applications include LCD displays, telecom devices, industrial 24V and 28V systems, and buck-boost (SEPIC) converters for automotive-powered systems.

A fixed-frequency PWM control scheme with Maxim's Idle Mode™ operation minimizes noise and ripple at light loads while maximizing efficiency over a wide range of load current. Low levels of no-load operating current (500µA) allows efficiencies to 93%, and the supply current in shutdown drops to only 3µA. Fast switching (250kHz) allows use of small surface-mount inductors and capacitors. Adaptive-slope compensation and a single compensation capacitor lets the MAX618 accommodate wide ranges of input and output voltage.

The MAX618EEE is available in a thermally enhanced 16-pin QSOP package (same size as a standard 8-pin SO) that dissipates up to 1W. The parts are specified for the extended-industrial temperature range (-40°C to +85°C), with prices starting at $3.25 (1000-up, FOB USA). A preassembled evaluation kit with recommended external components (MAX618EVKIT) is available to reduce design time.

STEP-UP DC-DC DELIVERS 50% MORE OUTPUT CURRENT AND WIDER OPERATING RANGE



Idle Mode is a trademark of Maxim Integrated Products.

NEW PRODUCTS

Small, high-frequency step-down converter has internal switches

The MAX1644 DC-DC converter is suited for use in PC cards, CPU daughter cards, and bus-termination boards. It is the smallest, highest frequency, and most efficient device available among 2A DC-DC converters with internal switches. To minimize external components and improve efficiency (to 95%), the MAX1644 includes 0.1Ω typ internal N- and P-channel MOSFETS for switching and rectification.

The MAX1644's current-mode PWM control scheme features a programmable constant-off time with switching frequencies as high as 350kHz. To maintain high efficiency during light-load operation, it also includes a pulse-frequency-modulation (PFM) mode (Idle Mode). The MAX1644 produces a preset output voltage of 3.3V or 2.5V, or an adjustable output of 1.1V to 3.8V. The input voltage range is +3V to +5.5V. Other features include 1% output accuracy, adjustable soft-start for limiting inrush current, and supply currents of 240µA typ during operation and 1µA max during shutdown.

The MAX1644 is available in a space-saving 16-pin SSOP package specified for the extended-industrial temperature range (-40°C to +85°C). Prices start from $4.08 (1000-up, FOB USA). A preassembled evaluation kit (MAX1644EVKIT) with recommended external components is available to reduce design time.

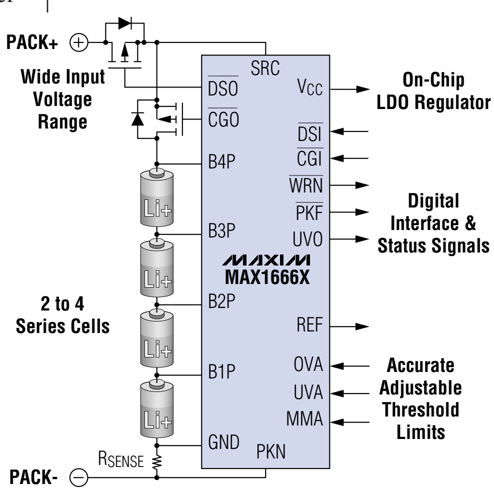
Li+ cell protector is ±0.5% accurate

The MAX1666 is the first Li+ cell protector to offer ±0.5% accuracy for the cell-overvoltage threshold. Its accuracy (vs. that of other protectors) allows the use of charge voltages much closer to the cell's design limits, increasing the amount of charge stored in a typical 4-cell battery pack by as much as 2%. The MAX1666 is also the first to closely monitor cell-to-cell voltage mismatches and automatically shut down the pack when a mismatch exceeds the user-adjusted limit.

The MAX1666 provides accurate, user-adjustable threshold limits for cell overvoltage (4.0V to 4.4V at ±0.5%), cell undervoltage (2.0V to 3.0V at ±2.5%), cell-to-cell mismatch (0 to 500mV at ±10%), and charge/discharge current (set by the sense resistor at ±10%). When a fault condition occurs, the internal power-MOSFET drivers control external P-channel MOSFETs to reliably disconnect the cells from the pack terminals. The MAX1666 can operate as a stand-alone device or in conjunction with a pack microcontroller, using its digital interface and status signals.

The MAX1666's on-board 3.3V low-dropout (LDO) linear regulator alleviates the need for an external voltage regulator. This LDO regulator accepts inputs in the +4V to +28V range, and supplies up to 5mA for other circuitry. A true "micropower" device, it consumes only 30µA while operating and <1µA in shutdown.

The MAX1666 "S" version (16-pin QSOP) monitors 2-cell packs, the "V" version (20-pin QSOP) monitors 3-cell packs, and the "X" version (20-pin QSOP) monitors 4-cell packs. All parts are specified for the extended-industrial temperature range (-40°C to +85°C). Prices for the MAX1666X start from $2.75 (1000-up, FOB USA).



Single chip charges Li+ cells

The MAX1667 battery charger complies with Level 2 of the SBS IF Specification v1.0. Offering high efficiency and support for most battery chemistries, this one-chip charger for lithium-ion (Li+) cells contains independent circuitry for voltage and current regulation, enabling it to make automatic transitions between constant-current and constant-voltage modes during charging. The MAX1667 charges two to four series Li+ cells and regulates the programmed charging voltage to within ±0.8%.

By allowing the duty cycle to exceed 97%, the MAX1667's advanced synchronous-buck topology ensures a low input-to-output voltage differential while maintaining efficiencies greater than 95%. Its SMBus™-compatible 2-wire interface accepts programming commands for the charging voltage and current and reports status information for the charger and battery. The charging voltage is 11-bit programmable from 0 to 18.432V, and the charging current is 5-bit programmable from 0 to 1A, 3A, or 4A.

A thermistor in the battery and fail-safe protection logic in the MAX1667 inhibits charging if the battery temperature exceeds predetermined limits. The MAX1667 can signal the host controller when a battery is installed or removed, or when power is applied to the charger. A pin-compatible upgrade for the industry-standard MAX1647 (a Level 2 smart-battery charger), the MAX1667 connects directly to charge-voltage sources in the +7.5V to +28V range.

The MAX1667 is specified for the extended-industrial temperature range (-40°C to +85°C), and comes in a space-saving 20-pin SSOP package only 2mm high. Prices start at $4.95 (1000-up, FOB USA).

SMBus is a trademark of Intel Corp.

NEW PRODUCTS

Switched-capacitor voltage inverters offer shutdown

The MAX1719/MAX1720/MAX1721 charge-pump inverters are monolithic CMOS devices in tiny SOT23 packages. Accepting input voltages in the +1.5V to +5.5V range, they operate at 12kHz (MAX1720) or 125kHz (MAX1719/MAX1721). High efficiency (96%), small external components, and a logic-controlled 1nA shutdown make these devices suitable for battery-powered and board-level voltage-conversion applications—such as generating a -5V analog supply from the 5V digital supply.

Each part has oscillator-control circuitry and four power MOSFET switches. The MAX1720 quiescent current is a low 50µA, and all devices deliver continuous output currents up to 25mA.

For pin-compatible inverters without shutdown (allowing a 5-pin instead of a 6-pin package), see the MAX828/MAX829 and MAX870/MAX871. For higher power applications, the MAX860/MAX861 deliver output currents up to 50mA. For regulated outputs up to -2V_{IN}, see the MAX868. The MAX860/MAX861/MAX868 come in space-saving µMAX packages.

The MAX1719/MAX1720/MAX1721 come in 6-pin SOT23 packages, with prices starting at $1.30 (1000-up, FOB USA).

RS-232 receivers in SOT packages have ±15kV ESD protection

The MAX3180E family of single RS-232 receivers features ±15kV protection against electrostatic discharge (ESD). Each device is designed for space- and cost-constrained applications requiring minimal RS-232 communications. To ensure compliance with strict European ESD standards, the receiver inputs are protected to ±15kV using the IEC 1000-4-2 Air-Gap Discharge Method, to ±8kV using the IEC 1000-4-2 Contact Discharge Method, and to ±15kV using the Human Body Model.

Each device guarantees RS-232 performance up to 1.5Mbps, and minimizes power and heat dissipation by drawing only 0.5µA from a +3V to +5.5V supply. The MAX3180E/MAX3182E receivers have a three-state TTL/CMOS receiver output controlled by an EN logic output. For applications requiring automatic system wake-up, the MAX3181E/MAX3183E receivers feature an output ($\overline{\text{INVALID}}$) that indicates valid RS-232 signals at the receiver input.

The MAX3182E/MAX3183E have noninverting outputs, and the MAX3180E/MAX3181E have standard inverting outputs. All are specified for the extended temperature range (-40°C to +85°C). They come in 5-pin SOT23 packages, with prices starting at $0.66 (1000-up, FOB USA).

3V RS-485/RS-422 transceivers feature ±15kV ESD protection

To meet ±15kV ESD protection standards, Maxim offers the MAX3483E/MAX3485E/MAX3486E, MAX3488E/MAX3490E/MAX3491E 3V RS-485/RS-422 transceivers. These devices save space and cost by eliminating the need for TransZorbs™ and other external protection used to meet ESD standards. All transmitter outputs and receiver inputs are ESD-protected to ±15kV using the Human Body Model and the IEC 1000-4-2 Air-Gap Discharge Method, and to ±8kV using the IEC 1000-4-2 Contact Discharge Method.

Each part contains one driver and one receiver, and delivers RS-485/RS-422 performance down to V_{CC} = +3V. The MAX3483E/MAX3488E have slew-rate-limited drivers that minimize EMI and reduce reflections caused by improperly terminated cables, allowing error-free data transmissions to 250kbps. The partially slew-rate-limited MAX3486E transmits up to 2.5Mbps, and the MAX3485E/MAX3490E/MAX3491E can transmit at 12Mbps, making them ideal for high-speed industrial buses.

For full-duplex operation, use the MAX3488E/MAX3490E/MAX3491E; the MAX3483E/MAX3485E/MAX3486E offer half-duplex operation. The MAX3491E comes in 14-pin DIP and SO packages; all others come in 8-pin DIP and SO packages. Prices start at $1.91 (1000-up, FOB USA).

TransZorb is a trademark of General Semiconductor Industries, Inc.

IC combines UART and RS-485 transceiver

The MAX3140 combines a complete UART and RS-485 transceiver in a single 28-pin package. Its SPI/MICROWIRE-compatible serial interface saves additional board space and microcontroller I/O pins, and its pin-programmable network configurations simplify the installation of RS-485/RS-422 networks.

The MAX3140 includes a single RS-485/RS-422 driver and receiver with true fail-safe circuitry that guarantees a logic-high receiver output when the receiver inputs are open or shorted. This feature provides fault immunity without requiring complex terminations. The MAX3140 provides software-selectable control of the half/full-duplex, data-slew-rate, and phase-control functions. To control slew rate and minimize EMI, the transceiver data rate is programmable to 115kbps, 500kbps, or 10Mbps. Independent phase control in the transmitter and receiver enables software correction of polarity reversal in twisted-pair cables.

The UART includes an oscillator circuit derived from an external crystal, and a baud-rate generator with software-programmable divider ratios for common baud rates. It features an 8-word-deep receive FIFO that minimizes processor overhead, and provides a flexible interrupt with four maskable sources, including address recognition on 9-bit networks.

The MAX3140 operates from a single +5V supply, and has a 20µA shutdown mode (invoked by hardware or software) in which the receiver remains active. It is available in a space-saving 28-pin QSOP package, with prices starting at $4.07 (1000-up, FOB USA).

NEW PRODUCTS

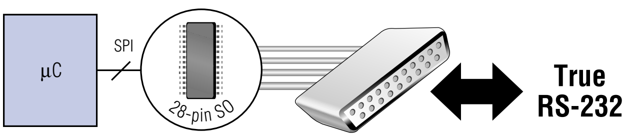
Integrated RS-232/UART saves space, power, and I/O pins

The MAX3110E/MAX3111E are the world's first ICs to integrate a UART and an RS-232 transceiver. Available in single 28-pin SO packages, they combine a full-featured universal asynchronous receiver/transmitter (UART) with an RS-232 transceiver (ESD-protected to ±15kV) and integrated charge-pump capacitors. The MAX3110E/MAX3111E SPI/ MICROWIRE-compatible serial interface minimizes the pin count while saving additional board space and microcontroller I/O pins.

A proprietary low-dropout (LDO) output stage allows the 2-driver/2-receiver interface to deliver true RS-232 performance down to V_{CC} = 3V (4.5V for MAX3110E), while drawing only 600µA. During shutdown, when the receivers remain active to allow monitoring of external devices, the ICs draw only 10µA of supply current. Each guarantees EIA/TIA-232 output-voltage levels for data rates as high as 230kbps.

The MAX3110E/MAX3111E UART includes an oscillator circuit derived from an external crystal, and a baud-rate generator with software-programmable divider ratios for all common baud rates from 300baud to 230kbaud. The UART features an 8-word-deep receive FIFO that minimizes processor overhead and provides a flexible interrupt with four maskable sources. One input and one output control line are included for hardware handshaking.

The MAX3110E/MAX3111E are available in 28-pin SO and DIP packages, with prices starting from $4.73 (1000-up, FOB USA).



Wideband buffer amps in SOT23-6

The MAX2472/MAX2473 are low-cost, wideband, high-isolation buffer amplifiers offering the most functionality available in a 6-pin SOT23 package. The MAX2472 provides dual open-collector outputs capable of delivering -5dBm while maintaining better than -25dBc harmonic suppression. Dual outputs are ideal for simultaneously driving two mixers, or one mixer and a PLL.

The MAX2473 has a single open-collector output, plus a bias-control pin that varies the output power as required to save current. It adjusts the output power from -10dBm to -2dBm while maintaining better than -25dBc harmonic suppression. Compared to discrete designs, each of these monolithic buffer amps saves board space by eliminating up to 15 components.

Both parts operate over a wide frequency range (500MHz to 2500MHz), providing 12dB gain and greater than 40dB isolation at 900MHz. High reverse isolation and low supply current make them ideal for high-performance, low-power applications. Both operate from a single supply in the +2.7V to +5.5V range and are available in tiny, 6-pin SOT23 packages. Prices start from $0.80 (1000-up, FOB USA).

900MHz, 1W silicon PA reduces output noise and spectral splatter

The MAX2235 is the first 900MHz, 1W silicon power amplifier (PA) to feature an autoramping output capability. During turn-on and turn-off, an external capacitor causes the RF output to ramp up and down gradually, thereby minimizing unwanted output-transient noise and spectral splatter found in FSK- and TDMA-based ISM-band applications. This unique feature is not available in existing GaAs MESFET and HBT PAs.

The MAX2235 delivers 30.3dBm of output power and 47% power-added efficiency while operating with a +3.6V supply. A power-control pin lets you adjust the gain over a 37dB range. The bias adjusts automatically to maintain optimum efficiency, even at lower output-power levels. To further decrease the system cost and increase battery life, a shutdown mode reduces the supply current to <10µA without the need for a supply switch.

The MAX2235 is designed for constant-envelope applications such as AMPS, 2-way pagers, and FSK-based systems in the 868MHz/900MHz ISM band. Its single supply voltage (+2.7V to +5.5V) eliminates the need for sequencing circuitry and the negative bias required in GaAs MESFET designs.

The MAX2235 is available in a thermally enhanced 20-pin TSSOP-EP (exposed paddle) package. Prices start from $3.23 (1000-up, FOB USA). A fully assembled evaluation kit (MAX2235 EVKIT) is available to help reduce design time.