MAXIM
Engineering Journal
Volume Thirty-Eight

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# News Briefs

## MAXIM REPORTS RECORD REVENUES AND EARNINGS FOR THE SECOND QUARTER OF FISCAL 2000

Maxim Integrated Products, Inc., (MXIM) reported record net revenues of $201.7 million for the second quarter of fiscal 2000 ending December 25, 1999, compared to $145.0 million for the same quarter in fiscal 1999. Net income increased to a record $64.6 million in Q200, compared to $46.5 million for the second quarter of fiscal 1999. Diluted earnings per share were $0.20 for Q200, compared to $0.16 for the same period a year ago.

During the quarter, the Company repurchased approximately 2.1 million shares of its common stock for $68.7 million and paid a total of $28.0 million for capital equipment. Accounts receivable increased by $10.3 million in Q200 to $103.4 million due to the increase in net revenues, while inventories declined by $0.5 million to $44.4 million during the quarter.

Gross margin for the second quarter increased slightly to 69.8%, compared to 69.7% in Q100. Research and development expense was $32.3 million (16.0% of net revenues) in Q200, compared to $28.3 million (15.7% of net revenues) in Q100. During the quarter, the Company recorded a writedown of equipment of $3.9 million, primarily to cost of goods sold, and recorded a charge to selling, general and administrative expenses of $3.0 million related to technology licensing matters.

Bookings on the Company were approximately $283 million in Q200, a 17% increase over the Q100 level of $242 million. Turns orders received in Q200 were $93 million (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 11% over Q100 levels (end-market bookings are end-user customer bookings received by both Maxim and the Company’s distributors during the quarter). This increase was fueled by growth in all geographic areas and all product market areas.

Second quarter ending backlog shippable within the next 12 months was approximately $300 million, including $242 million requested for shipment in the third quarter of fiscal 2000. Last quarter, the Company reported first quarter ending backlog shippable within the next 12 months of approximately $225 million, including $192 million that was requested for shipment in Q200. Order cancellations remained low during Q200 at approximately $13 million, compared to $11 million in Q100.

Jack Gifford, Chairman, President, and Chief Executive Officer, commented on the quarter: “We were very pleased to have another record-breaking quarter. Over the past two quarters, we have booked $525 million, a higher level than we had forecasted for the first half of the year. During Q200, 55% of our bookings were from markets outside the U.S. We consider this international balance to be a positive factor that tends to support a more stable growth pattern over the long term. Our bookings have continued to grow as a result of increased demand for our customers’ products and design wins by Maxim in new equipment and applications, which were beyond our product planning assumptions and projections. Both of these factors are good news for our future. Although general market conditions remain favorable, we continue to anticipate that bookings and bookings growth rates for the second half of our fiscal year will moderate from the levels we experienced during the first 6 months. We continue to feel comfortable with our longer term projections and plan.”

Gifford continued: “The reduction in turns orders is not a surprise and turns levels should, in the next 6 months, be more reflective of historic percentages of total bookings. While lead times have increased industry wide, we believe that Maxim is doing a good job of meeting our commitments to our customers.

“Our fiber and wireless revenue levels remain relatively small as a percentage of our total revenues, but we are comfortable that our 3- to 4-year projections for these businesses will be realized.

“At the beginning of January 2000, Maxim sold its interest in its 50%-owned high-frequency packaging and assembly subsidiary back to Tektronix for cash. This subsidiary was set up to be jointly controlled by Maxim and Tektronix as a result of the 1994 acquisition by Maxim of IC technology and foundries from Tektronix.”

*Fortune* Magazine recently measured and highlighted Maxim as having achieved the 11th largest stock appreciation of the decade, with an 8,735% increase in stock price from 1990 through 1999.

# Distributed temperature sensing improves reliability

*To prevent damage or loss of performance, many electronic systems include temperature sensors for monitoring thermal conditions. Systems with more than one potential "hot spot" require multiple, distributed temperature sensors.*

**Figure 1** illustrates the concept for a chassis in which three locations pose a potential for thermal trouble. Two are high-speed chips such as microprocessors (µPs), DSPs, or graphics controllers operating at power levels capable of generating dangerous temperatures. Another thermal generator is the power device mounted on a heatsink at the rear of the chassis.

A temperature sensor can be placed at each location to monitor each temperature individually. If any temperature exceeds its safe operating range, the system can avoid problems by turning on a cooling fan, reducing clock speed, or disabling the system power. To verify that the fan is working properly and that external ambient air is cool enough to keep internal temperatures within the safe range, a fourth sensor at the air intake monitors incoming air from the cooling fan.

Most temperature-sensor ICs sense their own die temperature, which is virtually identical to that of the package leads. Placed very close to a hot device, such ICs provide a good indication of temperature for the heat source. Because the heat source is warmer than the circuit board on which it is mounted, the measured temperature will be somewhat lower than that of the source.

To minimize this temperature difference, mount the sensor as close to the heat source as possible. Connect the sensor and heat source together at their ground pins and (if practical) at the supply pins. Make sure the copper area is large enough for good heat transfer. Some sensor packages have tabs that are easily mounted to other objects with bolts. Such packages offer an excellent thermal path from the mounting tab to the die, making them useful for measuring heat sink or chassis temperature.

## Analog vs. digital transmission

Once you locate temperature sensors in the proper places, their temperature information must be conveyed to the point of use—typically a microcontroller (µC). The approach taken depends on the purpose for sensing temperature in the first place. If you simply need to know the temperature at each location from time to time, one approach is to deploy analog temperature sensors (ICs or thermistor/resistor combinations) and measure their output voltages periodically with an analog-to-digital converter (ADC). The ADC can be a stand-alone device or integrated on the µC. Such ADCs typically include a multiplexer (mux). If not, you must add one (**Figure 2**).

If the sensor signal lines are long and the system produces a significant amount of electrical noise, a sensor with relatively high sensitivity will minimize noise pickup and improve accuracy. The sensor ICs

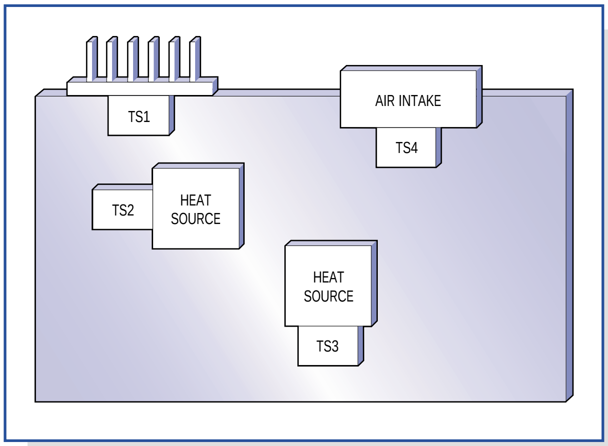

Figure 1. This distributed-sensing system monitors temperature at a heatsink, at two ICs on the circuit board, and at an air inlet.

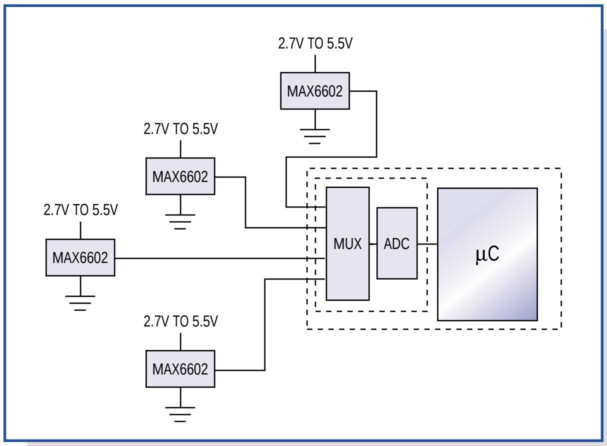

Figure 2. This simple approach to distributed temperature sensing is cost effective if the ADC resides on the µC and the mux has enough analog input channels to accommodate all sensors in the system.

shown specify an output sensitivity of 25mV/°C, which is enough to allow use of low-resolution ADCs in most applications. For applications with a wide temperature range, the linear temperature-sensor IC offers a major advantage over thermistors by producing consistent temperature resolution over the full range.

Sometimes a µC lacks sufficient analog inputs to accommodate all of the system sensors and other analog signals. In that case, consider a sensor that communicates temperature to the µC in other ways.

Temperature sensors that include an ADC and a standard serial interface provide an easy way to sense multiple temperatures when analog inputs are in short supply. The MAX6625*, for example, communicates with the µC using a 2-wire interface that is I$^{2}$C™/SMBus™ compatible. It has a pin that sets the sensor's address to one of four values by connecting to ground, the supply voltage, the SDA pin, or the SCL pin. As many as four MAX6625s can be connected to a single 2-wire bus (**Figure 3**).

You can accommodate even more digital temperature sensors by adding sensors with different addresses. As many as eight MAX1617s, for example, can be added to the four MAX6625s. Because the MAX6625 system connection is digital, it offers an excellent alternative to analog-output sensors when the sensors are widely separated or in systems that generate large amounts of electrical noise.

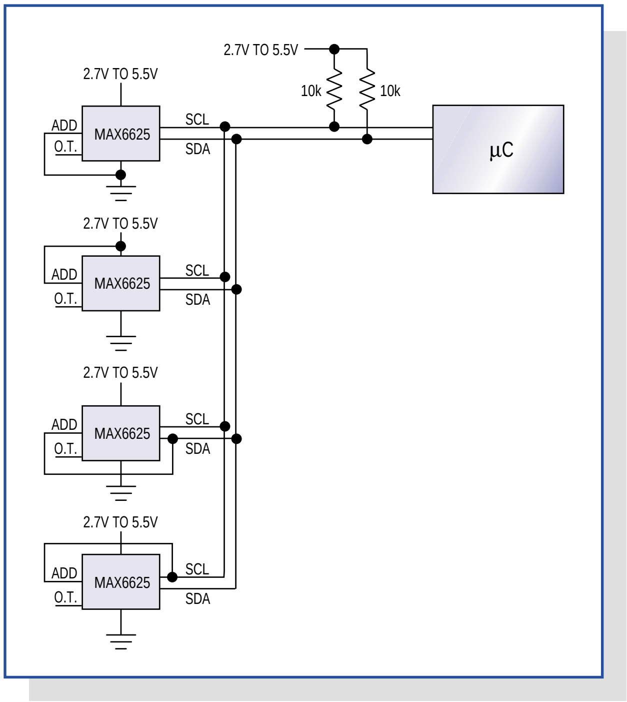

*Figure 3. As many as four MAX6625s in various locations can share a 2-wire bus by setting different addresses on their ADD pins. If necessary, you can add up to eight more MAX1617s or MAX1619s, yielding a total of 12 thermal-monitoring locations on the bus.*

The MAX6625 measures temperature continuously and updates its 8-bit-plus-sign output every 133ms. The host processor can read temperature over the 2-wire bus at any time. When temperature exceeds a host-programmed threshold, the MAX6625 can generate an interrupt on an open-drain output (the O.T. terminal). The hysteresis on this comparator function can also be programmed, enabling the MAX6625 to ignore small temperature variations. To monitor potential thermal problems at several locations without constant reading by the host, connect the interrupt lines from several MAX6625s on a single trace with a common pull-up resistor. The MAX6625's tiny 6-pin SOT23 package allows close proximity to heat sources, even on tightly packed boards.

A standard serial interface is not the only way for multiple sensors to transmit data. The MAX6575, for instance, produces a logic output whose time delay is proportional to temperature. A simple time-delay-based multiplexing scheme lets you connect as many as eight MAX6575s to a single µC I/O pin.

**Figure 4** illustrates the technique. As many as eight MAX6575s are connected to the µC through a single I/O line. The µC reads temperature by pulling that line low for a minimum of 1µs. After it releases the I/O line, one MAX6575 pulls the line low, holds it low for a period proportional to the absolute temperature (5µs/°K), and then releases it. The time interval between high-low transitions initiated by the µC and by any MAX6575 is proportional to absolute temperature and is pin-programmable as 5, 20, 40, or 80µs/°K (MAX6575L), or as 160, 320, 480, or 640µs/°K (MAX6575H). With the help of the µC's internal counter/timer, up to eight sensors can be placed in different locations, all read by a single I/O line. This technique offers excellent noise rejection because any skewing of transition edges by electrical noise is masked by the relatively long time delays.

For some applications, making the multiple sensors unique through addresses (MAX6625) or time delays (MAX6575) is not helpful. A card rack, for example, in which several identical cards are plugged into connectors on a backplane, cannot have unique sensor addresses or time delay selections because you must be able to replace any card with any other card.

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**The MAX6625 is a future product.*
*I$^{2}$C is a trademark of Philips Corp.*
*SMBus is a trademark of Intel Corp.*

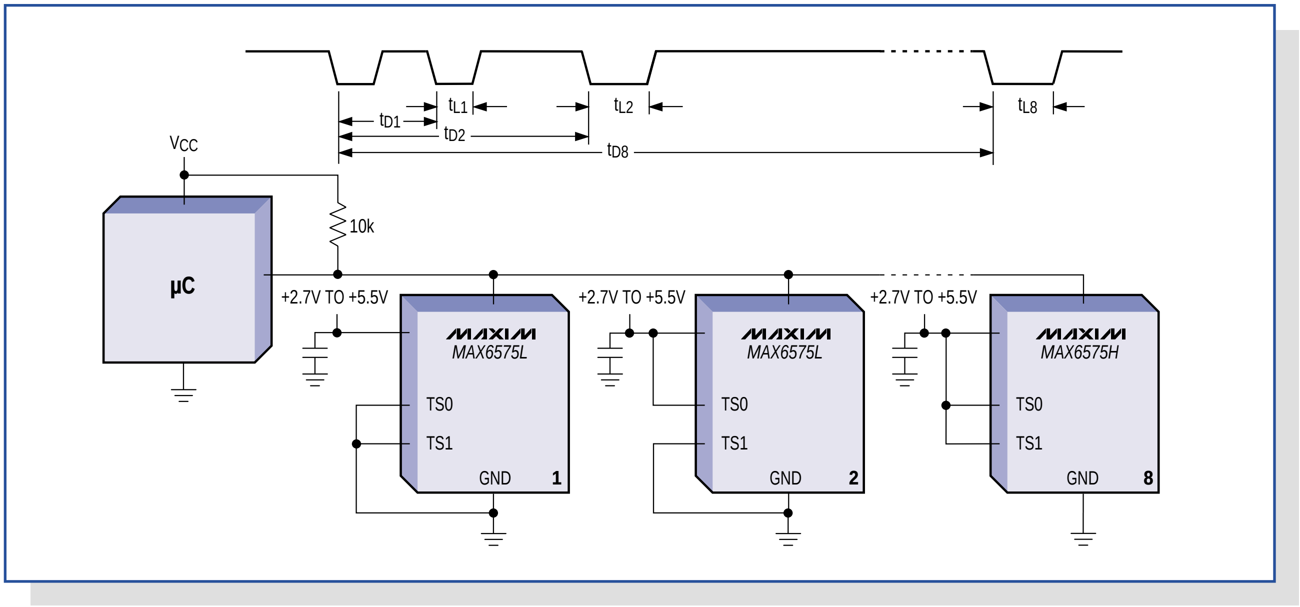

*Figure 4. Using a time delay scheme to encode temperature information, the MAX6575 can transmit as many as eight temperatures to a single digital I/O pin at the µC.*

The MAX6575 can monitor multiple interchangeable cards by sharing the outputs of several similar sensors. Its time-delay output allows you to measure temperatures for the hottest and coldest cards (**Figure 5**). This circuit is identical to Figure 4's, except all MAX6575Ls are set for the shortest available time delay (pins at TS0 = TS1 = GND). Thus, the delay before each MAX6575L pulls the I/O line low (T1) and the interval that it holds I/O low are both equal to 5Tµs, where T is the temperature in °K.

When several MAX6575Ls are connected together as shown in Figure 4, the sensor with the lowest temperature will be the first to pull I/O low. This action produces a T1 value proportional to the temperature of the coldest MAX6575. The hottest MAX6575 will be the last to release I/O (at time T2), after a period of 10Tµs from the falling edge of the start pulse. By measuring T1 and T2, the µC can calculate temperatures for the hottest and coldest cards.

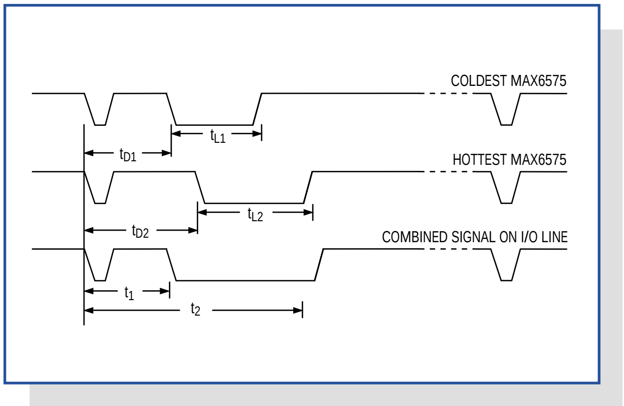

*Figure 5. Even when set with identical time delays to measure temperatures on interchangeable cards, multiple MAX6575s connected to a single I/O line can indicate temperatures for both the coldest and hottest boards in the system.*

## Thermal switch monitors threshold violations

If you need only an indication that a card temperature has exceeded its threshold, perhaps for the purpose of turning on a fan, the MAX6501 family of devices provides a simple solution. The MAX6501 "thermal switch" is a temperature comparator with a factory-set threshold, available in 10°C increments from -45°C to +115°C. Its open-drain output becomes active when the die temperature exceeds this preset threshold.

In the card rack, for example, each card would contain one or more MAX6501s, with all MAX6501 outputs connected to a common output line. If any card exceeds its temperature limit, it pulls the output line low, turning on a fan or initiating some other action to reduce the card's temperature (**Figure 6**). Because the open-drain outputs connect together, they generate an "overtemp" signal when any card is above its trip temperature. This arrangement can also monitor several temperatures on a single board. The MAX6501 is available in a 5-pin SOT23 package for board-mounted applications and in a 7-pin TO-220 package for applications that require mounting to a heatsink or chassis.

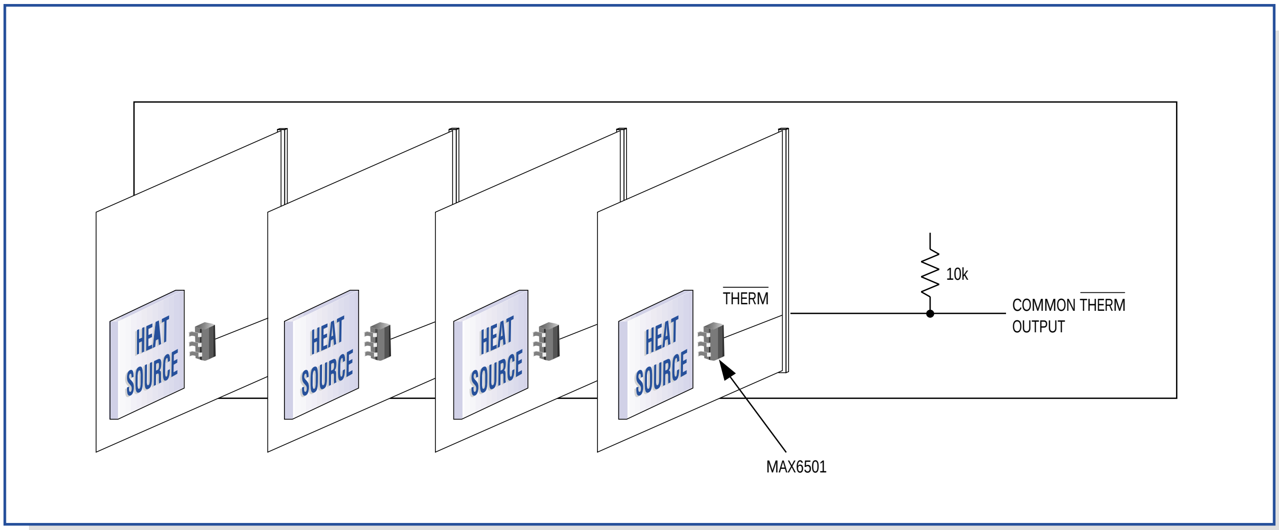

*Figure 6. When separate addresses are not practical, as in this system with multiple interchangeable cards, you can monitor multiple temperatures with a thermal comparator like the MAX6501. "Low" on the common THERM node indicates that at least one card has exceeded its threshold temperature.*

## Remote-junction sensors simplify design

The sensors discussed so far measure their own temperature. Sensors of another class measure the temperature of a remote PN junction, which can be part of a discrete transistor or part of a high-power IC such as a high-speed µP. This arrangement allows direct temperature measurement on an IC that might experience thermal problems only under unusual conditions—such as a blocked air path. Remote-junction temperature sensors (MAX1617/MAX1618/MAX1619) are used for this purpose in numerous systems. They operate by forcing two different current levels through the sense junction and measuring the voltage in each case. The difference in forward voltages caused by the two currents is proportional to absolute temperature.

In a system with several high-speed, high-power chips such as multiple processors, an alternative to using several remote-junction sensors is to use a single chip that measures multiple remote junctions (**Figure 7**). A single IC in Figure 7 (MAX1668) measures the temperatures of four external junctions: two µPs, a high-performance graphics controller, and a discrete npn transistor that senses the temperature of another nearby heat-generating IC. Besides these four remote junctions, the MAX1668 measures its own temperature to provide an indication of conditions on the local PC board.

As a single IC monitoring multiple temperatures, the MAX1668 enables more efficient designs. Because it resides at a single address instead of the multiple addresses required for separate sensor chips, the master controller can more easily read multiple temperatures or identify the location of a fault. Multiple measurement channels sharing the required analog signal-conditioning circuitry also reduce the cost and size of a system. The MAX1668 is available in the 16-pin QSOP package common to most remote-junction sensors.

One concern for system designers is the maximum usable distance between a remote-junction sensor and its target junction. So many variables affect this maximum, however, that a single numerical answer is meaningless. In electrically quiet environments, the remote junction can be quite far from the sensor (up to one meter) if the series resistance is below one or two ohms. As EMI increases, this trace length must be reduced. Most remote-junction sensors have good noise rejection, but if noise pickup on the traces is large enough to affect the sense junction's forward voltage, the measured temperature will be in error. A prudent approach for high-speed systems is to limit the trace length to a few inches.

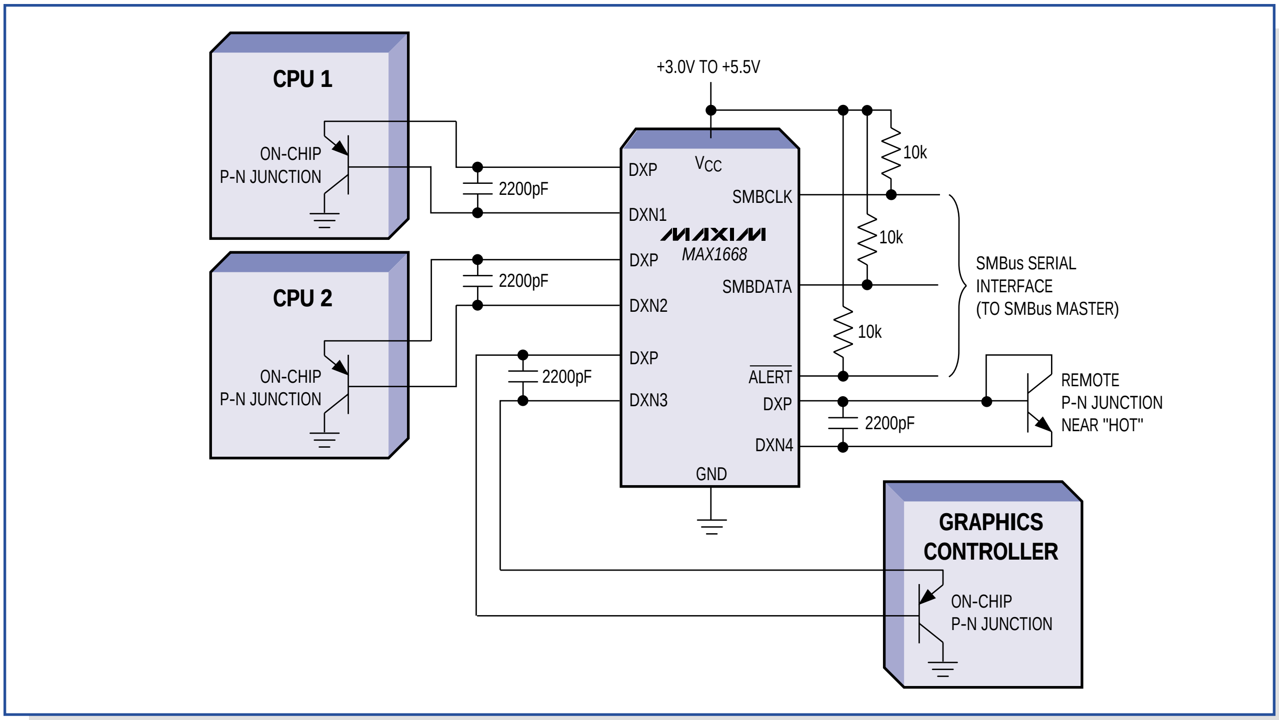

*Figure 7. In addition to its own die temperature, this multiple-junction sensor measures temperature at four external P-N junctions.*

# High-voltage PWM controller yields small, efficient telecom/ datacom supplies

*The available power-bus voltage for many of today's telecommunication and data communication systems is -48V*$_{DC}$*. Aside from its historical roots in the telephone network, this supply-voltage level remains a good compromise among several important considerations. It is high enough to produce low line currents when powering remote equipment at the end of long copper loops and low enough to be intrinsically safe (not a shock hazard to personnel). Unfortunately, the design of such isolated, high-voltage power supplies poses numerous challenges. Meeting stringent performance requirements while reducing costs and reducing the form factor of a power supply over succeeding generations can be a daunting task.*

This article describes the use of a MAX5003 controller in designing a power supply with -48V input and +5V/1A output. It demonstrates that such power supplies can be designed with small form factors and at lower cost while optimizing their design for best performance.

These high-input-voltage power supplies are found in PABX gear and telecommunication applications (base stations and central offices) as well as data communication applications such as switches, routers, and hubs. Typically, a high-power (-48V) backplane power supply feeds various line cards in a rack-mounted cabinet. Each card converts -48V to an isolated supply voltage and also generates other supply voltages as required on the secondary side of the isolation transformer.

Such schemes make the line cards modular, allowing you to expand a system by adding more line cards instead of redesigning the main power-supply bus. Likewise, you can replace a defective board without affecting system performance. Isolated power supplies prevent noise coupling between the line-card outputs, and they also prevent a single shorted line-card output from causing catastrophic failure in the system.

Although backplane voltages are nominally -48V, the power supplies designed for that environment should operate with inputs as low as -36V and as high as -72V and tolerate transients as high as -100V. As you add more cards to a rack-mounted cabinet without increasing its size, the closer spacing between cards necessitates the use of lower profile components on each board. Similarly, the greater functionality of line cards such as xDSL compels designers to squeeze the power-supply circuitry into less PCB real estate. Greater packing density also raises thermal-management issues.

Many line cards are on standby 90% of the time, so to keep light-load efficiency high, a power supply should have low quiescent current in the standby mode as well as high efficiency at full load. Powering the PWM controller from a high-input-voltage supply makes light-load efficiency difficult. A good source of low voltage is available after the supply is running (the output), but only the high voltage is available during startup.

Many PWM controllers use an external bleeder resistor and capacitor for startup. After the external capacitor charges to a preset undervoltage lockout voltage, the PWM controller begins operating, taking its power from a low voltage derived from an auxiliary winding in the transformer. No provision is made to turn off the bleed resistor, so it continues to waste power during normal operation. A larger resistor value conserves power but lengthens the power supply's startup time.

An alternative solution replaces the resistor-capacitor combination with a zener diode and current-limiting resistor. This approach solves the startup problem, but the bleed current remains, serving no purpose after startup but to heat up the power resistor. The MAX5003 includes a high-voltage startup FET transistor and preregulator (**Figure 1**), which restricts the quiescent power dissipation during normal operation by disconnecting the high voltage after startup. The IC withstands input voltages as high as 110V, and an external resistor divider at the input helps program the system's undervoltage lockout (UVLO) voltage.

At power-up, the internal FET transistor is biased on, providing power to an internal low-dropout linear regulator (LDO1). In turn, LDO1 powers the linear regulator LDO2, generating a $V_{CC}$ supply for the device. Once the input voltage exceeds the preset UVLO threshold, the internal high-voltage FET transistor turns off, disconnecting high voltage from the device. Power for the MAX5003 now derives from an auxiliary winding connected to the $V_{DD}$ pin. Biasing the $V_{DD}$ pin between 10.75V and 18.75V disables LDO1, allowing LDO2 to bias the device by generating a regulated $V_{CC}$ supply voltage.

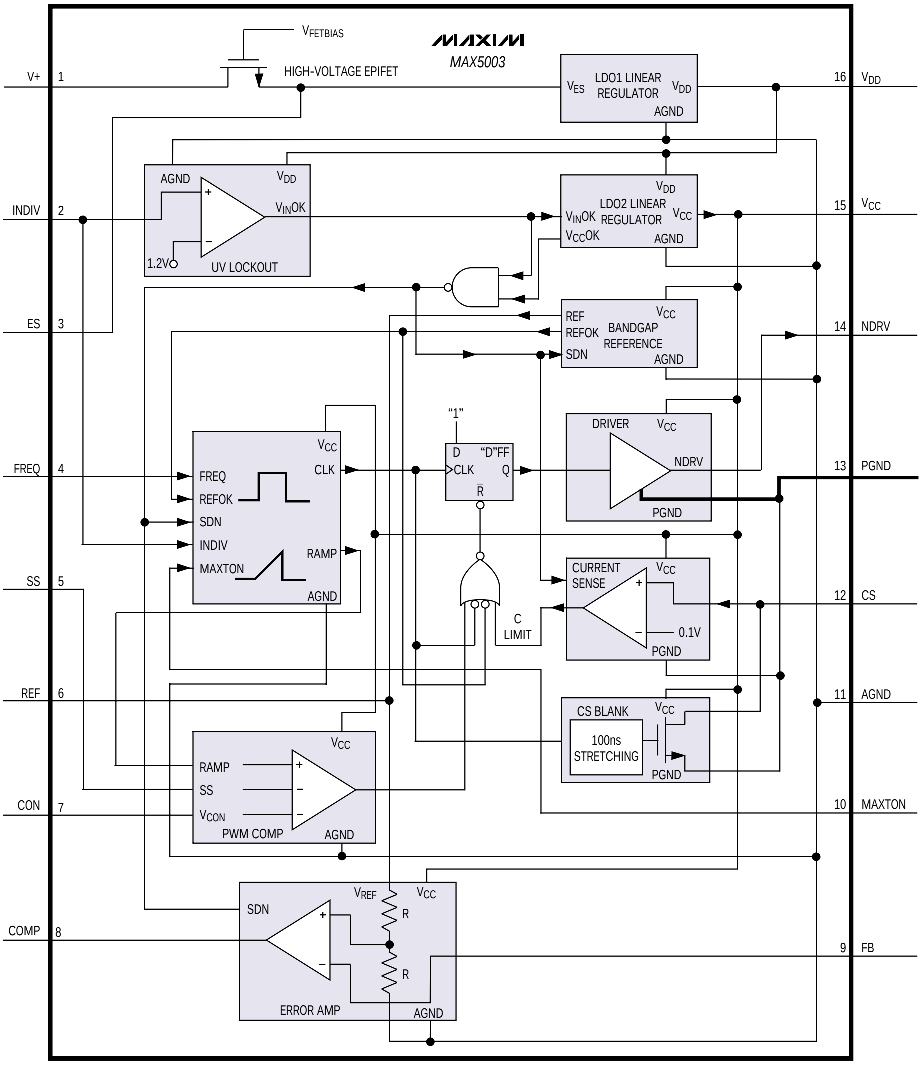

*Figure 1. This functional diagram of the MAX5003 PWM controller contains all the functions necessary for designing cost-effective flyback and forward-mode DC-DC converters.*

Because its high-voltage input is disconnected after power-up, the MAX5003 draws only leakage current (µA) from the high-voltage supply. With a typical supply current (2mA) and $V_{DD}$ bias voltage (12V), the MAX5003 quiescent power dissipation in normal operation is only 24mW (vs. 200mW if the current were drawn from a 100V source). The MAX5003 is designed to operate from input voltages in the 25V to 110V range (connected to its V+ pin). For lower voltage operation, bypass the internal high-voltage FET by connecting the V+ and ES pins together and leaving the $V_{DD}$ pin unconnected. In this case, the external supply voltage at the V+ and ES pins is limited to an 11V to 36V range.

The MAX5003 is a very flexible PWM voltage-mode controller. It can operate in continuous- or discontinuous-current modes and in the flyback or forward-converter topology. Flyback is a versatile, low-cost topology that allows multiple outputs, input-to-output isolation, and simple design. The MAX5003 with flyback topology is recommended for low- to medium-power applications (under 20W). At higher output power levels, the flyback topology becomes less desirable because large peak currents can develop in the external switch transistor and rectifying diode. This action can cause high ripple (especially in discontinuous-current mode) that requires a large and expensive output capacitor. Finally, the flyback-converter stability can be problematic, especially in continuous-mode operation.

For these reasons, the forward-mode topology is recommended for use with the MAX5003 at higher power levels (20W to 50W). Forward mode allows higher power capability than the flyback topology, and it also produces lower ripple due to its output LC filter and lower peak-to-average current ratios. Trade-offs (vs. the use of a flyback topology) include a more complex magnetics design, a higher component count, and an external switch with a voltage rating twice the input voltage (due to the use of an extra clamp-reset winding). When compared with earlier generation devices, the MAX5003 offers features with better customer benefits (**Table 1**).

## Design example:
## +48V to +5V/1A flyback supply

This section describes the design of a flyback power supply using the MAX5003, resulting in a very compact, low-cost and efficient circuit (**Figure 2**). (For greater detail on the design steps, see the MAX5003 data sheet.) This design has a nonisolated output for the sake of simplicity and straightforward description. Maxim offers a power supply with similar specifications and an isolated output, already assembled and tested for easy evaluation (MAX5003EVKIT) (**Figure 3**). Briefly, the design methodology for Figure 2 is as follows:

1) Determine the requirements: $V_{IN}$, $V_{OUT}$, $I_{OUT}$, ripple, and settling time.
2) In free-running mode, choose the programming resistor for the FREQ pin. In synchronized mode, choose the external $f_{CLK}$ frequency.
3) Determine the transformer turns ratio, and check the maximum duty cycle.
4) Determine the transformer primary inductance.
5) Complete the transformer specifications by listing the primary maximum current, the secondary maximum current, and the minimum duty cycle at full power.
6) Choose the programming resistor for the MAXTON pin.
7) Choose a filter capacitor.
8) Determine the compensation network.

The following example was designed using the above procedure:

1) *Requirements*: $36V < V_{IN} < 72V$, $V_{OUT} = 5V$, $I_{OUT} = 1A$, ripple < 50mV, settling time ≈ 0.5ms.
2) *Operating frequency*: In general, higher frequency means a smaller transformer. Higher frequency also provides a higher system bandwidth and faster settling time. The trade-off is somewhat lower efficiency. In this case, we chose 300kHz to allow a small transformer. One external resistor programs the internal oscillator for 300kHz: $R_{FREQ} = 66.7k\Omega$.
3) *Determine the transformer turns ratio, and check the maximum duty cycle*. The trade-off here is between low peak currents in the primary winding or a lower primary voltage. A good starting point is the nominal $V_{IN}/V_{OUT}$ ratio. To simplify compensation, we also want to avoid the continuous-conduction mode of operation. These two considerations lead to a choice of 8:1 turns ratio. The duty cycle for which continuous conduction occurs is 55%, a good value for the MAX5003.
4) *Determine the transformer primary inductance*. If we assume 80% efficiency, the system requires 6.25W input power. The frequency chosen and a conservative

## Table 1. Selected MAX5003 features

| FEATURES | BENEFITS |
|---|---|
| Input voltage range 11V to 110V | Direct high-voltage operation |
| Voltage-mode control with current limiting | Easy compensation, good input-transient response, and good noise immunity |
| High-voltage startup circuit with shutoff | High efficiency even at light loads, and a low thermal profile for the system |
| Programmable switch-current limit | Flexibility and lower cost FETs |
| Adjustable frequency to 300kHz and external-frequency synchronization | Flexibility, reduced EMI, smaller magnetics, and smaller overall designs |
| Adjustable soft-start and undervoltage lockout | Flexibility, reliability, and simpler bus-distribution design |
| Input feed-forward | Fast line-transient response |
| Precision internal reference, ±2.5% over temperature | Voltage accuracy and stability |
| Modern 16-pin QSOP package | 43% smaller footprint than comparable ICs in 14-pin SO packages |

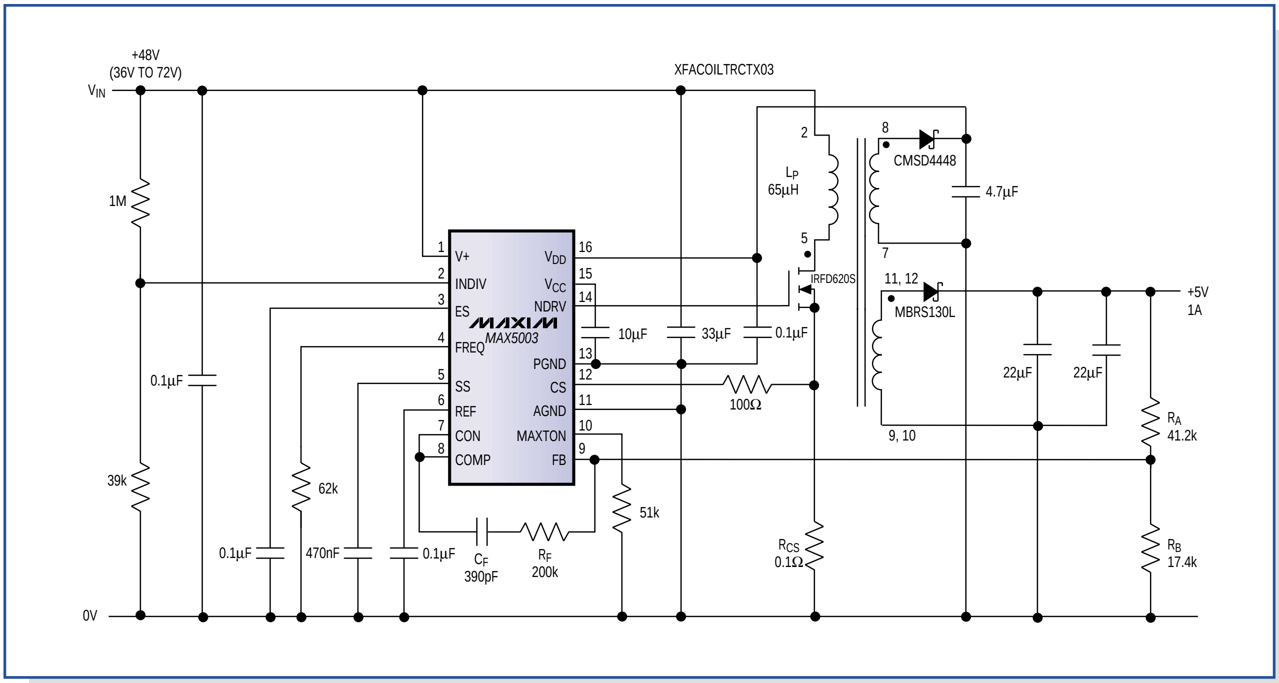

*Figure 2. This nonisolated power supply derives 5V/1A from +48V (see the design example on page 10).*

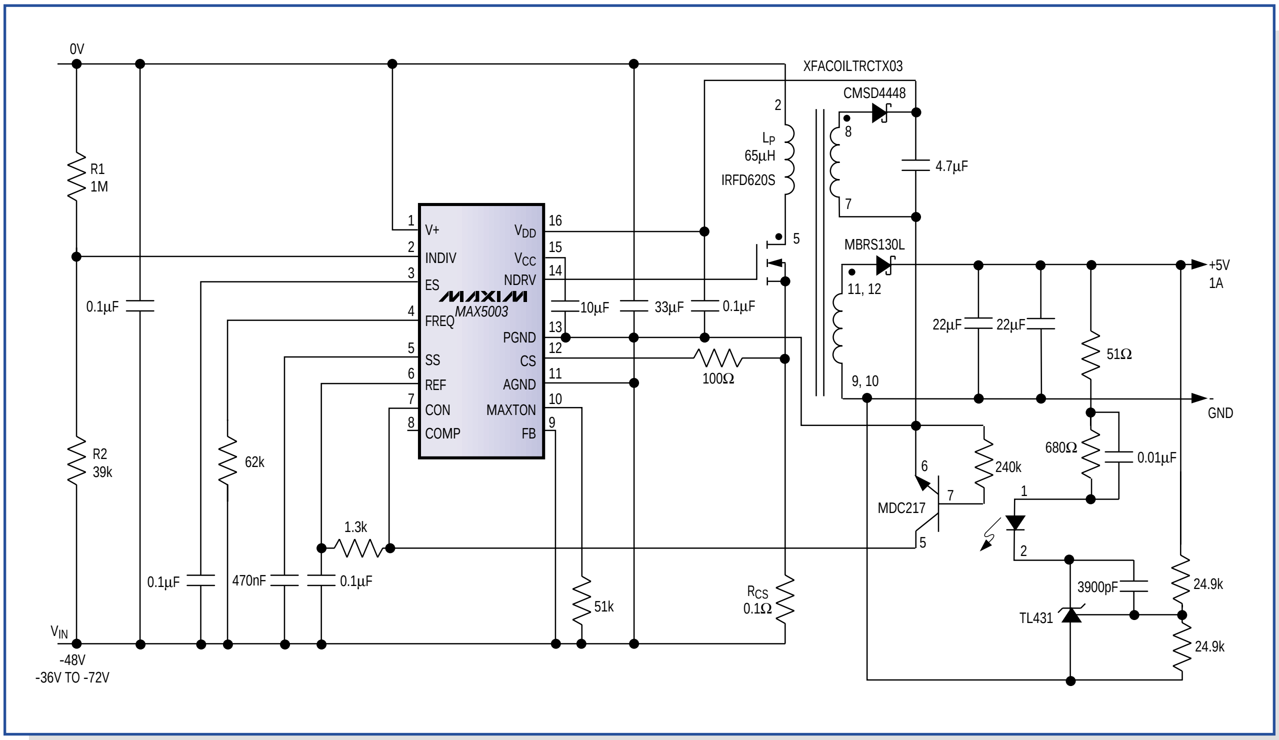

*Figure 3. With specifications similar to Figure 2's circuit, this isolated-output supply (-48V to 5V/1A converter) is available from Maxim as a preassembled evaluation kit (MAX5003EVKIT).*

duty cycle (43%) result in a nominal primary inductance of 65µH.

5) *Complete the transformer specifications by listing the primary maximum current, the secondary maximum current, and the minimum duty cycle at full power*. Using methods similar to those above for input power, frequency, and primary inductance, the maximum primary current is 0.8A, the secondary current equals this current times the transformer turns ratio, or 6.4A, and the minimum duty cycle at 72V input and maximum output is 21.5%. This information completes the specifications required for the transformer.

6) *Choose a programming resistor for the MAXTON pin*. To avoid continuous-mode operation, the duty cycle must be less than 55% at 36V. The MAX5003 automatically adjusts this value as the input voltage changes, so the duty cycle is 27.5% for a 72V input. Thus, the resistor value required for $R_{MAXTON}$ is 55kΩ.

7) *Choose a filter capacitor*. Of two factors to consider (equivalent series resistance (ESR) and capacitance value), ESR is not an issue in the calculation of ripple. A 44µF ceramic filter capacitor allows less than 50mV ripple with a 50% maximum duty cycle.

8) *Determine the compensation network*. With a few simple formulas and some bench optimization, the compensation components (three resistors and one capacitor) were initially determined and then optimized. $R_A$ and $R_B$ determine the output voltage, $R_F$ determines the feedback amplifier's midband gain, and $C_F$ creates a rolloff for this gain: $R_A$ = 41.2kΩ, $R_B$ = 17.4kΩ, $R_F$ = 200kΩ, and $C_F$ = 400pF.

# Intelligent IC conditions pressure-sensor signals

*While writing this article I often stopped to* take a breather, *and while waiting to see if it would be accepted I was* breathless with anticipation. *I hope I don't* choke *while presenting it. When finished, though, I can* breathe easy. *These metaphors show the close connection between the physical act of breathing and the mental states of anxiety and their opposite—relaxation* (Fesmire 1994).

Anxiety isn't the only influence on breathing patterns; it may be that every feeling affects our respiration. Psychologists investigate these links between emotion and breathing patterns in a number of research areas (Boiten, et al. 1994). Most such investigations require some form of electronic patient-monitoring equipment, partially because the very act of watching one's breathing changes its pattern.

## A respiration monitor with smart-sensor technology

The respiration monitor of **Figure 1** displays breathing patterns while giving a rough idea of the respiration amplitude. The monitor displays several important parameters used to detect anxiety: rate of breathing, regularity of breathing pattern, and the duration of pauses after expiration and before inspiration. Because calm, positive emotions usually produce a pattern of longer expiration than inspiration, the ratio of inspiration to expiration time can serve as an additional indicator of anxiety. A relatively higher level of thoracic breathing (vs. abdominal breathing) also indicates anxiety. Thus, an observation of increased thoracic breathing can augment the monitor's visual information.

Figure 1's monitor uses a silicon piezoresistive transducer (PRT) to detect the decrease and increase of pressure corresponding to inhalation and exhalation. The PRT output is fed to a signal-conditioning IC that corrects for errors inherent in the PRT and then passes a compensated voltage signal to the ADC. The ADC output (a digitized version of the pressure signal) is then fed to a PC interface and converted to RS-232 levels. These in turn are passed to a PC, which displays the respiration waveform and allows analysis of the parameters mentioned above.

## The sensor

PRTs are commonly configured as a closed Wheatstone bridge. When pressure is applied to an active-bridge PRT (**Figure 2a**), resistances of the diagonally opposed legs change equally and in the same direction. As the resistances in one set of diagonally opposed legs increase with pressure, the resistances in the other set decrease, and vice versa. A half-active-bridge PRT (**Figure 2b**) exhibits resistance changes in only half of the bridge. Whether full- or half-active, the advantages of a PRT sensor include high sensitivity (>10mV/V), good linearity at constant temperature, and the ability to track pressure changes without signal hysteresis, up to the destructive limit (Konrad and Ashauer 1999).

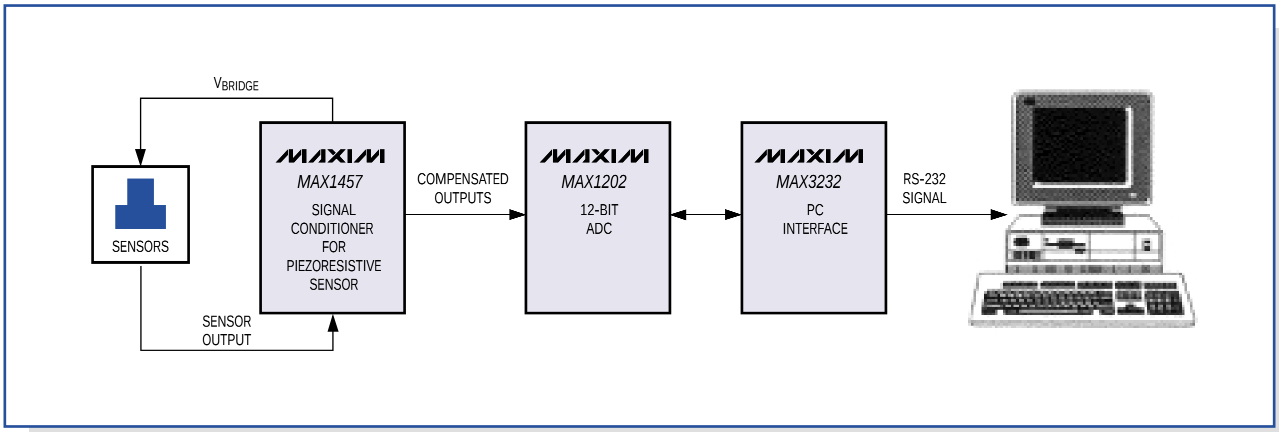

*Figure 1. This block diagram depicts a respiration monitor.*

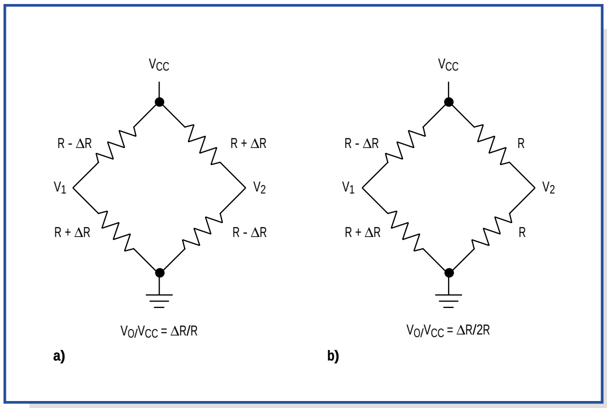

*Figure 2. All four legs of an active-bridge PRT (a) respond to pressure. For a half-active-bridge PRT (b), only two legs respond to pressure.*

Today’s engineers employ PRTs in low- and medium-accuracy applications, but high-end applications have traditionally forced designers to use strain gauges instead—despite their higher cost. New IC technologies that allow accurate PRT sensor correction, however, enable the use of these devices in high-end applications as well.

## Sensor errors

The chief obstacle in correcting PRT sensors is the wide range of error magnitude they exhibit. The variety of methods by which PRT sensors are manufactured produces various types of error and a range of error magnitudes. Even for a given model from one manufacturer, these error magnitudes vary appreciably from one transducer to the next.

PRT errors can include “. . . strong nonlinear dependence of the full-scale signal on temperature (up to 1%/°K), large initial offset (up to 100% of full scale or more), [and] strong drift of offset with temperature. Within limits, these disadvantages can be compensated with electronic circuitry” (Konrad and Ashauer 1999).

At a given temperature, both PRT types in Figure 2 maintain their bridge resistance (between $V_{CC}$ and ground) at a level that is fairly constant over a wide range of pressures. As temperature increases, however, the bridge resistance increases significantly. If the bridge is powered with a constant-current source, the result is an increasing bridge voltage.

PRT sensitivity increases as the bridge voltage gets larger with temperature. With bridge voltage held constant, however, a PRT’s sensitivity to pressure decreases with temperature. Thus, sensitivity is a function of two opposing factors: temperature and the temperature-dependent bridge voltage. This change in bridge resistance or bridge voltage can be exploited by modern signal-conditioning ICs to correct the sensitivity error over temperature in a PRT. These ICs use the change of bridge resistance to correct for variations in sensitivity vs. temperature.

## A traditional correction scheme

The **Figure 3** circuit compensates PRTs to a reasonable accuracy level. It allows adjustment of offset, offset drift with temperature, and sensitivity drift with temperature. Related to sensitivity drift is the full-span output drift over temperature; these two parameters change proportionally in response to temperature. **Figure 4** shows the relationship between offset and full-span output.

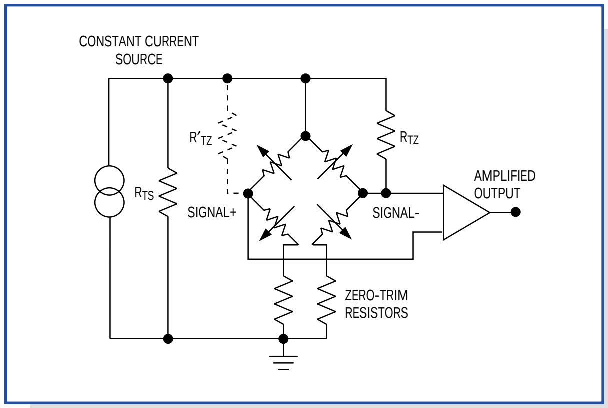

*Figure 3. A traditional correction scheme for PRTs features temperature-sensitive resistors.*

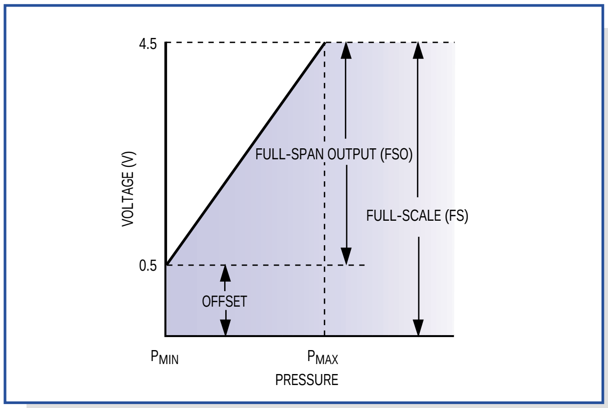

*Figure 4. A PRT’s offset and full-span output constitute the full-scale output.*

The circuit's zero-trim resistors compensate the sensor's offset voltage at room temperature, and resistors $R_{TS}$ and $R_{TZ}$ (or $R'_{TZ}$) correct for temperature errors. As described earlier, bridge resistance rises with increasing temperature, which increases the voltage across the sensor. That additional voltage increases the sensor's sensitivity; i.e., its output voltage is higher for a given pressure.

When the voltage across the sensor is held constant, however, the sensor's sensitivity decreases with increasing temperature. Because the positive-going sensitivity coefficient caused by increasing bridge resistance with temperature is greater than the negative-going sensitivity coefficient, the full-span output tends to increase with temperature. Resistor $R_{TS}$ negates this effect by shunting increasing amounts of bridge current as temperature rises. Similarly, $R_{TZ}$ or $R'_{TZ}$ correct the offset drift. Depending on the direction of the offset drift with temperature, either $R_{TZ}$ or $R'_{TZ}$ is added to the circuit.

The chief problem with this compensation scheme is circuit interaction among the compensation components, which makes calibration cumbersome and limits the achievable accuracy. Also, electronic trimming is not feasible when using this technique.

## A modern correction scheme

In **Figure 5**, a signal-conditioning IC (MAX1457) drives the respiration monitor's sensor and corrects the sensor errors. It contains a controlled current source that drives the sensor and an ADC that digitizes the sensor's bridge voltage. This voltage is a product of current from the current source and the temperature-dependent bridge resistance.

The MAX1457 also includes a programmable-gain amplifier (PGA) for amplifying the sensor's differential output and five digital-to-analog converters (DACs) for correcting various sensor errors. Because the sensor output is a low-level signal, the PGA output voltage is not sufficient to drive the ADC. For that reason, the MAX1457's internal op amp is used to boost the PGA output to a suitable level.

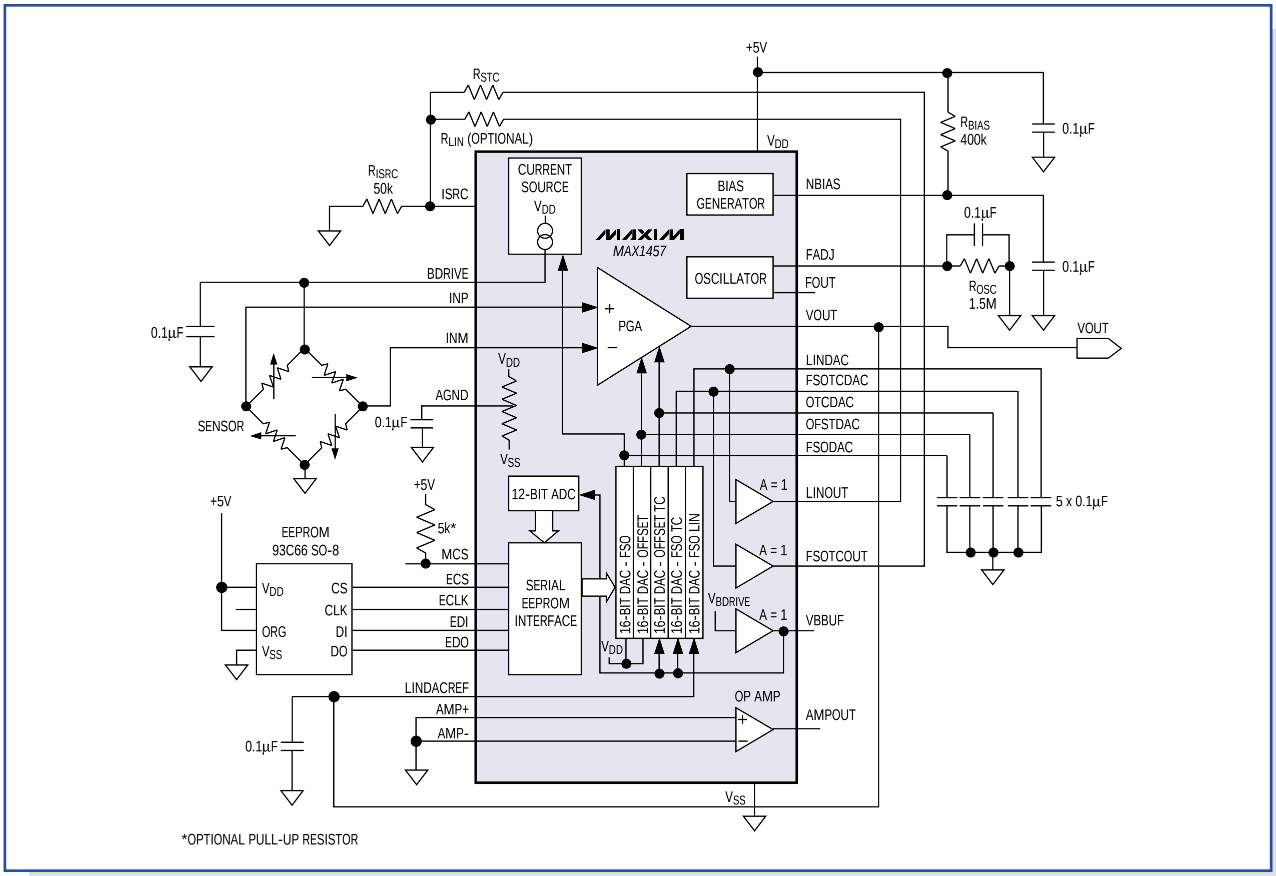

*Figure 5. A specialized IC (MAX1457) that provides current-source excitation and compensation for the pressure sensor yields 0.1% accuracy.*

Bridge voltage increases with temperature, and this temperature dependence can be used to compensate full-span temperature errors. With constant-voltage bridge excitation, the full-span output (FSO) decreases with temperature, resulting in a full-span output temperature coefficient (FSOTC) error. However, if the bridge voltage can be made to increase with temperature at a rate that compensates for the decrease in full-span sensitivity with temperature, the FSO will remain constant.

**Figure 6** shows how the MAX1457 implements this scheme for correcting FSO errors due to temperature. Using the digitized bridge voltage from the ADC output, the chip determines which previously calculated correction coefficient (stored in EEPROM) should be applied to the FSOTC DAC. The resulting DAC output voltage then changes the current level feeding the bridge. This new current level compensates the FSO by adjusting the bridge voltage to compensate the change in sensor sensitivity at a particular temperature. To smooth this correction, the chip applies analog bridge voltage to the FSOTC DAC's reference input, thereby providing an additional correction between each successive pair of digital numbers (supplied by the ADC to the EEPROM).

The same technique compensates offset over temperature, except the OFFSETTC DAC voltage is fed to a summing junction at the PGA output (instead of the MAX1457 current source).

Calculate temperature coefficients and store them in EEPROM in the following sequence: in most instances, take sensor data at various pressures with the sensor and MAX1457 at the lowest temperature, then take the same data with the sensor and MAX1457 at the highest temperature. Using this data from the temperature extremes, software written for the MAX1457 then calculates the four correction coefficients (FSO, FSOTC, Offset, and OffsetTC). These four coefficients correct the PRT's first-order errors. (For the accuracy level this respiration monitor requires, a fifth coefficient to correct pressure nonlinearity is considered unnecessary.)

To achieve 0.1% accuracy, the MAX1457 allows compensation at specific temperatures, with recalculation of FSOTC and OffsetTC at each temperature. The user determines the number of such calibration points (up to 120). If sensor output error were perfectly repeatable, the accuracy of a sensor-MAX1457 combination would be better than 0.1%.

The MAX1457 compensation technique has a significant advantage over the traditional approach shown in Figure 3. The MAX1457 eliminates interaction between compensation components by separating the offset and span adjustments: it compensates offset at the PGA and separately adjusts the FSO through the current source. Another advantage is the extra accuracy made available by specific adjustments at various temperatures. This method is inherently more accurate than one based on external resistors, whose values cannot compensate the sensor precisely at specific temperatures.

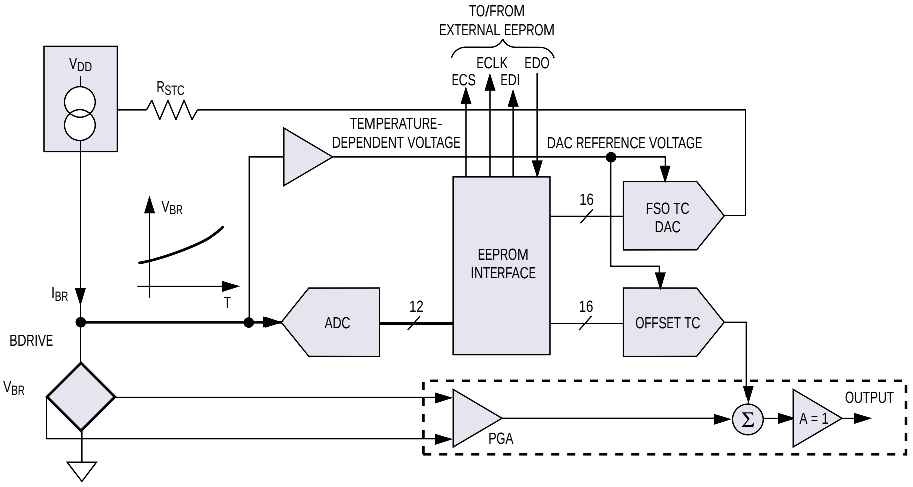

*Figure 6. This circuitry within the MAX1457 compensates for offset and full-span temperature errors.*

## Simpler compensation ICs

The MAX1457 provides more precision than necessary for a respiration monitor; i.e., the 16-bit resolution of its correction DACs is more than required. The part was chosen, however, because it includes the extra op amp needed to boost the respiration monitor's low-level sensor signals.

Although the MAX1457 offers greater precision than needed for this application, its ability to compensate for temperature error is needed even for modest variations of temperature: a change of 10°C commonly produces a 3% change in the FSO of a PRT. Because the MAX1457 enables the respiration monitor to operate over a wide temperature range, the monitor's potential applications could include space exploration and scuba diving.

The functions performed by a MAX1450 signal conditioner (**Figure 7**) are essentially those of a MAX1457, but resistors rather than DACs are used to set the error correction. Because the MAX1450 uses far fewer calibration points than the MAX1457, its accuracy is 1% instead of 0.1%. MAX1450 chips are commonly included in hybrids, where the combination of a MAX1450 and laser-trimmed resistors provides a low-cost solution.

A third IC (the MAX1458/MAX1478 of **Figure 8**) provides the same basic compensation techniques as the other two, but includes 12-bit (vs. 16-bit) compensation DACs. MAX1458/MAX1478 devices also include an EEPROM for on-board storage of the compensation coefficients. Like the MAX1450, they provide 1% accuracy.

MAX1450/MAX1458/MAX1478 devices compensate a sensor by calculating four correction coefficients (mentioned above), using pressure data measured at two temperatures—usually the extremes of the operating-temperature range. Unlike these devices, the MAX1457 allows additional temperature-error correction at user-selected temperature levels (as many as 120). For a more detailed discussion of these compensation schemes, refer to Konrad and Ashauer 1999, and Dancaster, et al. 1997.

*A similar article was presented at the Sensors Expo in Cleveland, Ohio, September 14–16, 1999.*

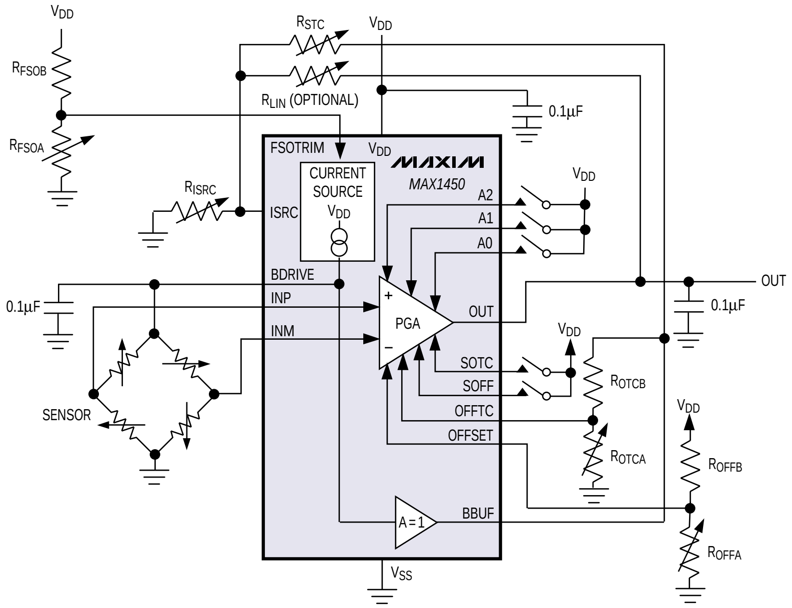

*Figure 7. A MAX1450 signal conditioner operating with external laser-trimmed resistors provides 1% accuracy.*

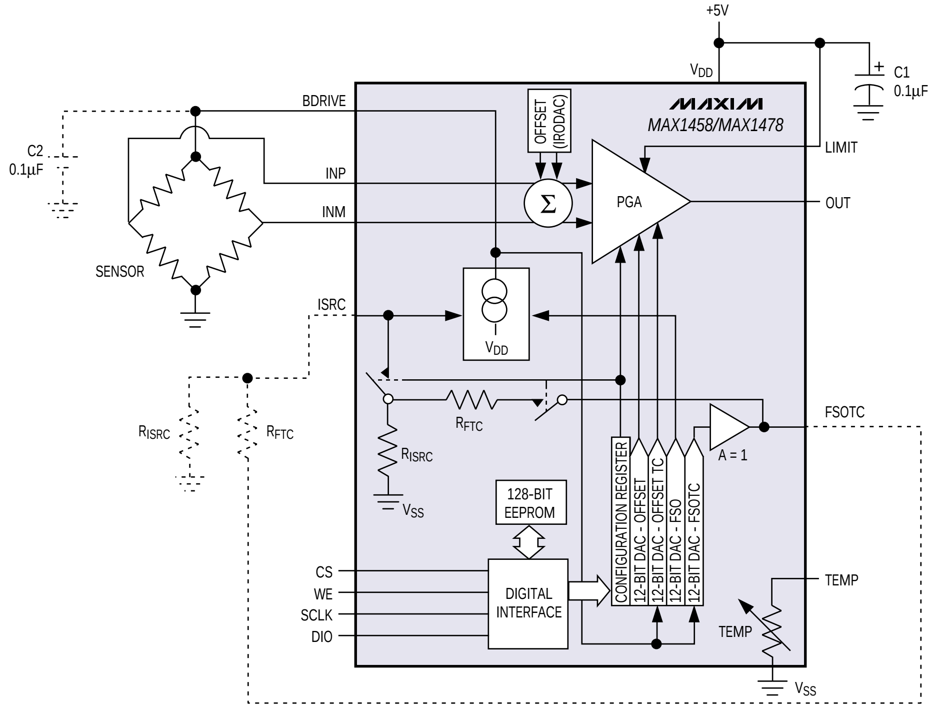

*Figure 8. A MAX1458/MAX1478 signal conditioner operating with internal 12-bit DACs provides 1% accuracy.*

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Fesmire, Steven A. 1994. Aerating the mind: the metaphor of mental functioning as bodily functioning. *Metaphor and Symbolic Activity* 9 (1): 31–44.

Konrad, Bernhard, and Martin Ashauer. 1999. Demystifying piezoresistive pressure sensors. *Sensors* 16 (7): 12–25.

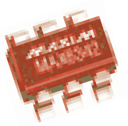
# NEW PRODUCTS

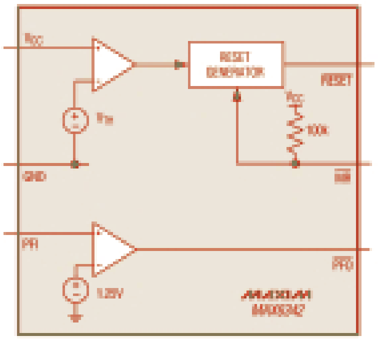
## First reset + power-fail comparator in SOT23 package

The MAX6342–MAX6345 µP supervisory circuits save board space and reduce cost in 2.5V/3V/3.3V/5V systems while also increasing reliability and lowering the number of adjustments and external components. Each device asserts a reset whenever the supply voltage drops below a preset value. Each includes a power-fail comparator that can be used for power-fail warning, low-battery detection, or for monitoring another power supply. Comparable circuits require 50% more power and 70% more board space.

MAX6342–MAX6345 devices feature ±2.5% reset-threshold accuracy over the extended temperature range, and the available versions comprise six preset threshold voltages from 2.33V to 4.63V. When supply voltage declines below its threshold, the chip asserts a reset signal and maintains it for at least 100ms after $V_{CC}$ returns above the threshold (or until the manual reset is deasserted). These ICs draw only 25µA of supply current, and their reset outputs are guaranteed valid for supply voltages down to 1.0V.

The MAX6342 (push-pull) and MAX6343 (open-drain) feature active-low reset outputs, and the MAX6344 (push-pull) features an active-high reset output. The MAX6345 offers active-low and active-high push-pull reset outputs. MAX6342/MAX6343/MAX6344 devices also include a debounced manual reset. All are available in 6-pin SOT23 packages, with prices starting at $1.23 (2500–up, FOB USA).





## Low-power, rail-to-rail, 8-bit quad DACs operate on 370µA

The MAX5100–MAX5102 family of low-power, 8-bit, voltage-output DACs is intended for portable systems that require digital adjustment of gain and offset. Available in tiny TSSOP packages, the DACs operate from single-supply voltages in the +2.7V to +5.5V range, draw ultra-low supply currents, and provide a 1µA shutdown mode to further reduce power. Each includes Rail-to-Rail® precision buffer amplifiers.

The quad MAX5100 comes in a 20-pin TSSOP package and requires a maximum supply current of 720µA for all channels combined. The triple MAX5101 and dual MAX5102 come in 16-pin TSSOP packages, with maximum supply currents of 520µA and 360µA. The MAX5100's asynchronous control pin (LDAC) allows simultaneous updating of the DAC registers. Independent input latches prevent the DAC outputs from changing during a write operation, and a power-on reset restores all registers to zero.

Prices start at $2.09 (1000–up, FOB USA).

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

## Lowest power (18mW/DAC), 3V, 40MHz I/Q DACs deliver 70dB SFDR

The MAX5180 family of twelve monolithic-CMOS DACs are capable of 40MHz update rates while operating from a 2.7V to 3.3V supply. Available devices include 8- and 10-bit, dual and single, and voltage- and current-output versions, each with a 50ppm/°C low-noise reference. The DACs target applications in imaging, signal synthesis, and high-speed communications, which require low-power operation and high levels of dynamic performance.

Guaranteed monotonic, these devices deliver a typical integral and differential nonlinearity (INL and DNL) of ±0.5LSB. At 3V, the dual versions consume only one-fourth the power of the nearest competing part. They provide a ±0.5% typical FSR gain mismatch and 0.15° typical phase matching for I/Q reconstruction (transmit) applications. When the application is inactive, two user-selectable idle modes lower the supply current to 1.5mA (max) in standby and to 1µA (max) in shutdown mode.

The dual 10-bit current-output MAX5180 and voltage-output MAX5183 provide a 70dBc SFDR (at 2.2MHz $f_{OUT}$) while consuming only 21mW. These devices are intended for the I/Q baseband signal-reconstruction circuits found in portable digital-communications systems. The dual 8-bit current-output MAX5186 and voltage-output MAX5189 target lower-resolution applications in portable digital-communication systems. These DACs provide a 58dBC SFDR (at 2.2MHz $f_{OUT}$) while consuming only 21mW at +3V.

To simplify interfacing, the dual 8-bit and 10-bit versions accept interleaved (I/Q) data on a single digital-input bus from upstream logic and provide analog outputs in current or voltage formats. I and Q outputs update simultaneously on each clock cycle. These DACs come in 28-pin QSOP packages specified for the extended-industrial temperature range (-40°C to +85°C).

Single-DAC versions are also available. The 10-bit current-output MAX5181 or voltage-output MAX5184 and the 8-bit current-output MAX5187 or voltage-output MAX5190 deliver equivalent dynamic performance at just 18mW power dissipation.

These devices come in 24-pin QSOP packages, also specified for the extended-industrial temperature range. Prices start at $2.73 for the MAX5187/MAX5190 and at $4.41 for the MAX5180/MAX5183 (1000–up, FOB USA). An evaluation kit (MAX5180EVKIT) is available for $49.50 to shorten your design time.

# NEW PRODUCTS

## 16-bit smart ADC self-calibrates over temperature

The MAX1460 is a low-power, 16-bit ADC capable of digitally correcting its output over temperature. Highly integrated, it includes a RISC DSP, EEPROM, 16-bit ADC, 12-bit DAC, PGA, temperature sensor, and auxiliary op amp. The DSP produces the conditioned output by processing the digitized input signal, data from the temperature sensor, and user-programmed correction coefficients stored in the EEPROM. This feature is readily exploited by pressure sensors, smart batteries, and other automotive, industrial, and medical applications.

Built-in test circuitry integrates and automates the pretest, calibration, compensation, and final-test operations of traditional sensor manufacturing. By eliminating manual calibration methods, this test capability enables a substantial manufacturing cost reduction.

The conditioned output is available both as 12-bit digital words and as a ratiometric analog voltage from the internal 12-bit DAC. The uncommitted op amp can be used for filtering the analog output or for implementing a 2-wire, 4–20mA transmitter. The high-precision front end, which includes a 16-bit ADC, 2-bit PGA, and 3-bit coarse-offset DAC, provides submicrovolt resolution of the differential input signal.

Because the low-noise MAX1460 operates from a single +5V supply and draws only 400µA of supply current, it is ideal for low-power applications. In addition, a dedicated cell library of more than 90 sensor-specific functional blocks enables Maxim to quickly customize the MAX1460 for unusual or high-volume applications. It comes in a space-saving 9mm x 9mm 48-pin TQFP package, with prices starting at $6.50 (1000–up, FOB USA).

## Tiny SOT switches offer ±36V fault protection

The MAX4510/MAX4520 SPST switch inputs are fault-protected to ±36V with power on and to ±40V with power off. During fault conditions, the switch input becomes an open circuit that allows only nanoamperes of leakage current from the source, and the switch output continues to furnish up to 13mA (with appropriate polarity) to the load. This feature ensures unambiguous outputs at the beginning and end of a fault.

The normally closed MAX4510 and normally open MAX4520 protect signals originating from single (+9V to +36V) and dual (±4.5V to ±20V) power supplies. The switches feature low on-resistance (160Ω max) and low off-leakage current (only 0.5nA at +25°C and 10nA at +85°C). Both devices are available in tiny 6-pin SOT23 or 8-pin µMAX packages. Prices start at $0.92 (1000–up, FOB USA).

## 3V RS-232 transceiver provides power/bias to LCD

The MAX3325 integrates a 3V RS-232 transceiver (2Tx/2Rx) with an LCD supply and temperature-compensated contrast control. It generates +5V for a logic supply or LCD display, includes an internal sensor that compensates the LCD for changes in temperature, provides an adjustable bias for LCD contrast, and provides an RS-232 interface for serial communications. Data rates are guaranteed up to 250kbps. The +5V supply, composed of a regulated charge pump and low-dropout linear regulator, can deliver 11mA to the LCD.

Within the MAX3325, a 6-bit DAC provides 64 contrast levels, and a temperature sensor compensates the LCD contrast for changes in ambient temperature. Contrast can be adjusted for any voltage range between -5V and +2V. A proprietary, low-dropout stage at the transmitter output enables true RS-232 performance from a +3.0V supply. It includes a dual charge pump and consumes only 10µA supply current in shutdown mode. The charge pump operates with four small 0.22µF capacitors.

The MAX3325 is available in the commercial (0°C to +70°C) and extended (-40°C to +85°C) temperature ranges, in space-saving SSOP or narrow DIP packages. Prices start at $2.29 (1000–up, FOB USA).

## Complete current-sense amplifier in SOT23 draws only 30µA

The MAX4372, a micropower high-side current-sense amplifier with buffered output, comes in a space-saving 5-pin 3mm x 3mm SOT23 package. Unlike techniques that sense current on the low side of the supply voltage, this tiny device employs a single external resistor between the power supply and load, thereby avoiding disruption of the circuit ground plane. The combination of factory-trimmed gain and external sense resistor allows the user to select the full-scale range of the measured current. Three factory-trimmed gains are available: +20V/V (MAX4372T), +50V/V (MAX4372F), and +100V/V (MAX4372H).

The MAX4372 amplifier features a wide supply-voltage range (+2.7V to +28V) and achieves 275kHz bandwidths (for $A_V$ = +20V/V) while drawing only 30µA of supply current. The circuit architecture allows input common-mode voltages to range from 0V to +28V, independently of the supply voltage. Ground-sensing inputs maintain linearity and prevent output phase reversal when the input common-mode voltage is near ground. This feature is useful during power-up, power-down, and some input fault conditions. The MAX4372 achieves a full-scale accuracy of 0.18%. It comes in 5-pin SOT23 and 8-pin SO packages, with prices starting at $0.60 (50,000–up, FOB USA).

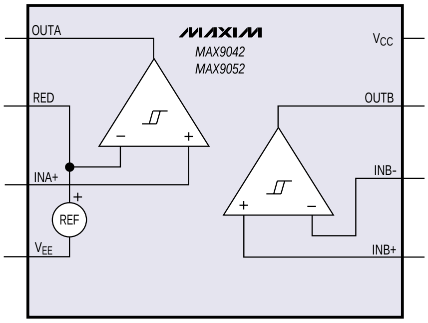
# NEW PRODUCTS

## Dual comparators with 6ppm/°C reference draw just 55µA

The MAX9042/MAX9043/MAX9052/MAX9053 dual comparators include rail-to-rail inputs and outputs and a precision reference in a single µMAX package (MSOP, 3.0mm x 5.0mm). Ideal for monitoring battery voltage, these devices maximize battery life by eliminating the large errors due to premature end-of-life readings common in some voltage monitors. The internal reference offers 0.4% initial accuracy (A-grade only) with a 6ppm/°C temperature coefficient. It can sink or source 500µA and is stable for capacitive loads up to 4.7nF. The comparator exhibits a fast propagation delay (400ns) while drawing only 55µA of supply current.

MAX9042/MAX9043 devices operate with supply voltages in the +2.5V to +5.5V range and provide a reference output of 2.048V (which represents a 500µV LSB in 12-bit systems). MAX9052/MAX9053 devices operate from +2.7V to +5.5V and provide a 2.500V reference. All comparators feature internal hysteresis and crowbar current limiting, which lowers the current drawn while switching at high frequencies.

The MAX9042/MAX9052 come in space-saving 8-pin µMAX and SO packages, and the MAX9043/MAX9053 come in 10-pin µMAX packages. B-grade prices start at $1.23 (1000–up, FOB USA).



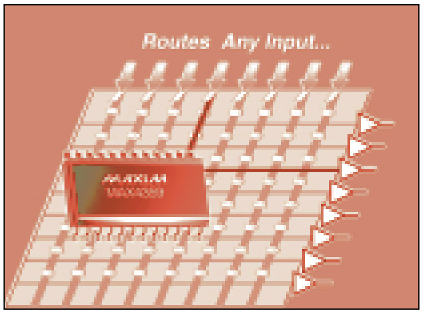
**MAXIM'S DUAL COMPARATORS PLUS PRECISION REFERENCE**

## Complete 8x4/4x4 video crosspoints simplify switching applications

The MAX4359/MAX4360 are complete 4x4 and 8x4 video crosspoint switches. They greatly simplify discrete-component designs by reducing the component count, board space, design time, and system cost. Ideal for security systems and teleconferencing applications, the MAX4359/MAX4560 offer a user-selectable serial or parallel digital interface that routes any of the four or eight inputs to any of the four outputs.

These video crosspoints exhibit -3dB bandwidths of 65MHz, all-channel off-isolation of 80dB, and single-channel crosstalk of 70dB at 5MHz. The output buffers feature slew rates of 250V/µs. All outputs can be three-stated to allow wire-ORed configurations.

The MAX4359 (4x4) comes in 24-pin SO or space-saving 36-pin SSOP packages, and the MAX4360 (8x4) comes in a 36-pin SSOP package. Prices start at $4.98 (1000–up, FOB USA).



## Ultra-low-distortion, single-supply, 300MHz op amps offer -90dBc SFDR at 5MHz

The MAX4268–MAX4270 are dual, 300MHz, low-distortion op amps offering single-supply operation, wide bandwidth, low SFDR (-90dBc at 5MHz), $8nV/\sqrt{Hz}$ noise, and fast settling time (15ns to ±0.1%). They are ideal for use in preamps, ADC drivers, and other high-speed, single-supply applications in communications and instrumentation.

These amplifiers operate from a single +4.5V to +8V supply or from dual ±2.25V to ±4V supplies. They have full-power bandwidths of 200MHz, slew rates of 900V/µs, and can source and sink up to 45mA. A low-power disable mode lowers supply current to 1.6mA and places the outputs in a high-impedance state, making this family ideal for multiplexing applications.

The MAX4268–MAX4270 come in space-saving 16-pin QSOP or 14-pin SO packages. Prices start at $2.50 (1000–up, FOB USA).

## 3µA/580ns comparators fit ultra-small 5-pin SC70/8-pin SOT23 packages

MAX9075/MAX9077 micropower comparators reduce cost and board area without affecting your power budget, making them ideal for cost- and space-sensitive portable applications. The ultra-small MAX9077 is the world's only dual comparator in an 8-pin SOT23 package. The MAX9075/MAX9077 achieve fast 580ns propagation delays with only 3µA of supply current—an excellent speed/power ratio. Other features include rail-to-rail outputs, ground-sensing inputs, and +2.1V to +5.5V single-supply operation.

The single MAX9075 is packaged in an ultra-small 5-pin SC70 (about half the size of a 5-pin SOT23) and in a 5-pin SOT23. Prices start at $0.33 (100,000–up, FOB USA).

# NEW PRODUCTS

## Level 2 battery charger has input current limiting

The MAX1645 is a high-efficiency, Level 2 compliant battery charger that meets SBS IF Specification v1.0. Compatible with all battery chemistries, it contains independent voltage- and current-regulation circuitry that transitions automatically between the constant-current and constant-voltage modes during charging.

By limiting line input current, the MAX1645 also restricts current from the DC source to a predetermined level. It charges one to four lithium-ion (Li+) cells in series and regulates the programmed charging voltages to within ±0.8%.

An advanced synchronous buck topology allows duty cycles up to 99.99%, ensuring low input-to-output voltage differentials while maintaining efficiencies greater than 97%. The MAX1645 includes a 5.4V low-dropout linear regulator capable of delivering 15mA to an external load. An SMBus-compatible 2-wire interface conveys battery and charger status and receives the commands for charging voltage and charging current. If these commands fail to reach the MAX1645, a 175-second safety timer prevents runaway charging.

In response to a power-on reset and before applying full charging current, the MAX1645 delivers a 128mA “wake-up” current to condition deeply discharged cells. Charging voltage is programmable from 0V to 18.432V with 11-bit resolution, and charging current is programmable to 3A with 6-bit resolution.

MAX1645 fail-safe protection logic operates in conjunction with an external battery thermistor to inhibit charging when the battery temperature exceeds a predetermined limit. The device can also signal the host controller when power is applied to the charger or when a battery is installed or removed. It connects directly to charging sources from 8V to 28V and easily charges one to four Li+ cells in series.

The MAX1645 comes in a 28-pin QSOP package specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $5.31 (1000–up, FOB USA).

## Remote temperature sensor has SMBus serial interface

The MAX1618 precise digital thermometer reports the temperature of a remote sensor. The remote sensor is typically a discrete diode-connected transistor. It can also be a diode-connected transistor included on another IC such as a µP. This allows the MAX1618 to measure directly and report that IC’s temperature. Remote accuracy is ±3°C for multiple transistor manufacturers.

The MAX1618’s 2-wire serial interface programs the alarm thresholds and reads temperature data using standard Read Byte, Write Byte, Send Byte, and Receive Byte commands through the SMBus. With the 16kHz conversion rate programmed to operate in single-shot mode, measurements can be taken automatically and autonomously.

In thermostat mode, the MAX1618 configures its ALERT output as an interrupt or temperature reset that remains active only while the temperature is out of range. Configured as active high or active low, the ALERT output in thermostat mode can control a fan to reduce heat buildup, improve efficiency, and protect notebook computers against potentially destructive thermal overloads.

The MAX1618 is available in a space-saving 10-pin µMAX package and is guaranteed for the military temperature range (-55°C to +125°C). A preassembled evaluation kit including recommended external components (MAX1618EVKIT) is available to reduce design time. Prices start at $2.05 (1000–up, FOB USA).

## 150mA, SOT23 LDO regulators have power-OK flag

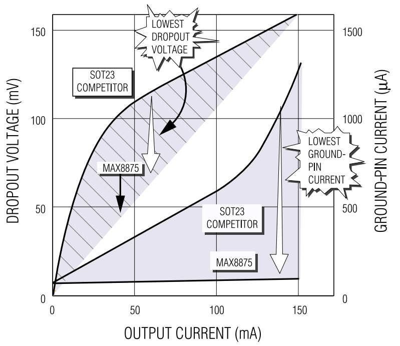
The MAX8875/MAX8885 low-dropout (LDO) linear regulators offer ±1% initial voltage accuracy, low dropout voltage, and a power-OK output that warns when the output voltage drops out of regulation by 5%. They include several features for extending battery life in cell phones, PCMCIA cards, modems, and other hand-held portable equipment.

P-channel MOSFETs allow the MAX8875/MAX8885 regulator outputs to maintain low dropout voltage (110mV at 100mA) and low supply current (100µA) at any load up to 150mA. (Linear regulators with pnp outputs can have several milliamps of supply current at full load.) To further conserve power, a logic-controlled shutdown reduces supply current to less than 1µA.

To guarantee stability for all loads up to 150mA, the MAX8875 requires only a tiny 1µF ceramic capacitor at the output. The MAX8885 is optimized, however, to operate with a low-cost, high-ESR tantalum output capacitor. Multiple versions of each IC provide preset output voltages with ±1% initial accuracy at 2.5V, 2.7V, 3.0V, 3.3V, and 5.0V. Other features provide protection against thermal overload, short circuits, and reverse-battery connections.

The MAX8875/MAX8885 come in ultra-small 5-pin SOT23 packages specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $0.77 (2500–up, FOB USA).

BEST COMBINATION OF LOW DROPOUT
AND LOW SUPPLY CURRENT GIVES
LONGEST BATTERY LIFE



# NEW PRODUCTS

## 3.3V, 622Mbps laser driver monitors current and output power

The MAX3669 +3.3V, 622Mbps SDH/SONET laser driver includes current monitors and automatic power control (APC). The device is ideal for 622Mbps SDH/SONET transmission systems such as add/drop multiplexers, digital cross-connects, section regenerators, and optical transmitters. Combining a MAX3669 and MAX3693 4:1 serializer forms a complete, low-power 622Mbps transmitter.

Consuming only 132mW of power, the MAX3669 exceeds by 60ps$_{P-P}$ the ITU/Bellcore specification for jitter generation (160ps$_{P-P}$). It accepts data and clock inputs in the differential-PECL format and provides bias and modulation currents for driving the laser. An APC feedback loop maintains constant average optical power over temperature and lifetime. The chip also includes bias- and modulation-current monitors that are directly proportional to the laser bias and modulation.

The MAX3669 provides enable control and a failure-monitor output that indicates when the APC loop is unable to maintain the average optical power. The ease of programming the wide ranges of modulation current (5mA to 75mA) and bias current (1mA to 80mA) suit this product for SDH/SONET applications.

The MAX3669 comes in a small (5mm x 5mm) 32-pin TQFP package specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $9.75 (1000–up, FOB USA). An evaluation kit is available to minimize design time.

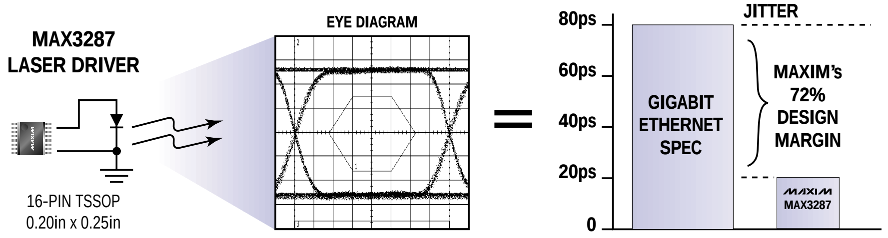
## 1.25Gbps and 2.5Gbps LAN laser drivers suit VCSEL, CD, and longwave applications

The 1.25Gbps MAX3286–MAX3289 LAN laser drivers target Gigabit Ethernet and Fibre Channel applications, and the 2.5Gbps MAX3296–MAX3299 devices target multigigabit applications. MAX3286–MAX3289 devices provide up to 30mA of laser-modulation current with only 22ps of deterministic jitter. MAX3296–MAX3299 devices provide up to 30mA modulation current with only 7ps of deterministic jitter.

All laser drivers in these families operate with a single 3.0V to 5.5V supply. For lasers with photodetector feedback, they include an automatic power-control circuit that adjusts the laser bias current to provide a constant optical-power output. For lasers without monitor diodes, they also provide a constant-current mode.

The low deterministic jitter of the MAX3286–MAX3289 (22ps) provides a 72% margin to the Gigabit Ethernet specification. Their single-point fault tolerance also supports laser safety requirements. Packaging options include bare die, 16-pin TSSOP-EP (exposed-paddle), and 32-pin TQFP packages that allow use in popular modules such as small form factor, 1x9, and GBIC. Prices start at $5.93 (1000–up, FOB USA).

**DRIVE VCSEL, CD, OR LONGWAVE LASERS WITH 30mA MODULATION CURRENT**



## Low-jitter limiting amplifiers handle 1.25Gbps and 2.5Gbps

MAX3264/MAX3265 and MAX3268/MAX3269 limiting amplifiers are well suited for Gigabit Ethernet and Fibre Channel applications. The 1.25Gbps MAX3264 and MAX3268 exhibit only 14ps of deterministic jitter, thereby providing a margin of 156ps to the Gigabit Ethernet specifications for robust, high-yield designs. Jitter for the 2.5Gbps MAX3265 and MAX3269 is even lower (11ps). Input sensitivity (the minimum input producing a fully limited output) is 5mV for the 1.25Gbps devices and 10mV for the 2.5Gbps devices.

The MAX3264/MAX3265 have PECL outputs, and the MAX3268/MAX3269 have CML outputs. All operate with a single 3.0V to 5.5V supply, allowing each to support both 3.3V and 5.0V designs. To prevent chatter in response to low input-signal levels, all devices have TTL-compatible LOS outputs with 2.5dB (min) hysteresis.

MAX3265/MAX3268/MAX3269 amplifiers come in tiny (3mm body) 10-pin µMAX packages that are ideal for low-cost, surface-mount applications in small modules. The MAX3264/MAX3265 are available in a small 16-pin TSSOP package with a 5mm body. Prices start at $5.93 (1000–up, FOB USA). These limiting amplifiers will also be offered as die; contact the factory for availability.