MAXIM

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MAXIM REPORTS RESULTS FOR THE THIRD QUARTER OF FISCAL 1999

Maxim Integrated Products, Inc., (MXIM) reported net revenues of $147.2 million for the third quarter of fiscal 1999 ending March 27, 1999, compared to $145 million for the same quarter in fiscal 1998. Net income was $47.7 million in Q399, compared to $46.1 million for the third quarter of fiscal 1998. Income per share was $0.31 for Q399, compared to $0.31 for the same period a year ago.

During the quarter, the Company increased cash and short-term investments by $72.4 million after paying $18.2 million for 400,000 shares of its common stock and $6.9 million for capital equipment. Inventories declined slightly during the quarter. Accounts receivable declined $2.7 million during the quarter. Annualized return on average stockholders' equity during the quarter was 24.8%, one of the highest in the industry today.

Bookings on the Company were $171 million in Q399, a 21% increase over the Q299 level of $141 million. During the quarter, customers continued their trend of ordering for near-term delivery. Turns orders received during the quarter were $69.2 million, a 33% increase over the Q299 level (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). Order cancellations during the quarter were approximately $10 million, the lowest level since Q496. Third quarter ending backlog shippable within the next 12 months was approximately $148 million, including $120 million requested for shipment by the end of Q499.

During Q399, bookings grew in the Pacific Rim, United States, and Japan. Growth was strongest in the Pacific Rim, primarily related to Korean OEM customers. In the U.S., there was double-digit bookings growth across a broad cross section of OEM and distribution customers, product lines, and end markets. While market conditions in Japan improved slightly during the quarter, bookings in that region are still not reaching prior business levels. Bookings in Europe during Q399 were down slightly from a strong bookings quarter in Q299. Bookings continued to improve in the communications-related end markets during Q399. In addition, bookings for the Company's computer-related (primarily notebook) product lines and those products that traditionally sell into the industrial markets increased from Q299.

Gross margins for Q399 were 69.1%, an increase from the 68.7% reported in Q299. During the quarter, the Company expensed $1.6 million of costs that were in excess of the costs achieved by the Company's lowest cost wafer fabrication facility (Beaverton). In addition, the Company increased inventory reserves by $0.8 million and increased its reserve by $1.3 million for the closure of a 4-inch wafer fabrication facility, further increasing cost of sales in Q399. The Company also recorded a charge to selling, general and administrative expenses of $1.5 million related to technology licensing matters.

Jack Gifford, Chairman, President and Chief Executive Officer, commented on the quarter: "Q399 was an excellent quarter. Our sales and profits grew sequentially, we increased cash and short-term investments by over $72 million, and our bookings grew to near record levels. Q199 now appears to have been the low point of a three-quarter trend of declining bookings. We hope the current trend continues. In addition, we remain on plan to introduce over 300 new products during our product announcement year ending in July."

Mr. Gifford continued: "Although turns and bookings grew by 33% and 21%, respectively, we believe our Q399 booking level now approximates our estimates of the current quarter's consumption of products by our customers. Accordingly, assuming that market conditions remain positive, we would expect the average sequential growth rate in bookings to be more consistent with a growth model of 5% to 6% per quarter."

During the quarter, Maxim was named by *The Wall Street Journal* as the 15th best performing company of the past 10 years, with an average compound annual return of 49% per year. Maxim was the top semiconductor company on the list. In addition, in a recent *San Jose Mercury News* listing of the largest 150 companies in the Silicon Valley, Maxim was listed as the 13th most profitable and the 16th most valuable of all the companies on the list and ranked 2nd with regard to profit as a percentage of sales.

Source resistance: the efficiency killer in DC-DC converter circuits

The DC-DC converter is very commonly used in battery-operated equipment and other power-conserving applications. Like a linear regulator, the DC-DC converter can regulate to a lower voltage. Unlike linear regulators, however, the DC-DC converter can also boost an input voltage or invert it to V_{IN-}. As an added bonus, the DC-DC converter boasts efficiencies greater than 95% under optimum conditions. However, this efficiency is limited by dissipative components, and the main cause is resistance in the power source.

Losses in source resistance can lower the efficiency by 10% or more, exclusive of loss in the DC-DC converter! If the converter has adequate input voltage, its output will be normal and there may be no obvious indication that power is being wasted. Fortunately, testing the input efficiency is a simple matter (see the *Source* section).

A large source resistance can cause other, less obvious effects. In extreme cases, the converter's input can become bistable, or its output can decrease under maximum load conditions. Bistability means that the converter exhibits two stable input conditions, each with its own efficiency. The converter output is normal, but system efficiency may be drastically affected (see *How to Avoid Bistability*).

Should this problem be solved simply by minimizing the source resistance? No, because the practical limits and cost/benefit trade-offs posed by the system may suggest other solutions. A prudent selection of power-supply input voltage, for example, can considerably minimize the need for low source resistance. Higher input voltage for a DC-DC converter limits the input current requirement, which in turn lessens the need for a low source resistance. From a systems standpoint, the conversion of 5V to 2.5V may be far more efficient than the conversion of 3.3V to 2.5V. Each option must be evaluated. The goal of this article is to provide analytic and intuitive tools for simplifying the evaluation task.

A systems view

As shown in **Figure 1**, any regulated power-distribution system can be divided into three basic sections: source, regulator(s) (a DC-DC converter in this case), and load(s).

The source can be a battery or a DC power supply that is either regulated or unregulated. Unfortunately, the source also includes all the dissipative elements between the DC voltage and load: voltage-source output impedance; wiring resistance; and the resistance of contacts, PC-board lands, series filters, series switches, hot-swap circuits, etc. These elements can seriously degrade system efficiency.

Calculation and measurement of the source efficiency is very simple. EFF_{SOURCE} equals (power delivered to the regulator)/(power provided by V_{PS}) multiplied by 100%:

$$\begin{aligned} EFF_{SOURCE} &= \frac{(I_{IN})(V_{IN})}{(I_{IN})(V_{PS})}(100\%) \\ &= \frac{V_{IN}}{V_{PS}}(100\%) \qquad [1] \end{aligned}$$

Assuming that the regulator draws a negligible amount of current when unloaded, you can measure source efficiency as the ratio of V_{IN} with the regulator at full load to V_{IN} with the regulator unloaded.

The regulator (DC-DC converter) consists of a controller IC and associated discrete components. Its characterization is described in the manufacturer's data sheet. Efficiency for the DC-DC converter (EFF_{DCDC}) equals (power delivered by the converter)/(power delivered to the converter) multiplied by 100%:

$$EFF_{DCDC} = \frac{(I_{OUT})(V_{OUT})}{(I_{IN})(V_{IN})}(100\%) \qquad [2]$$

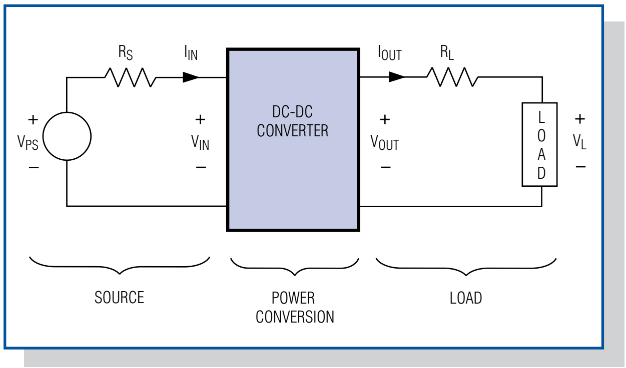

Figure 1. A regulated power-distribution system has three basic sections.

As specified by the manufacturer, this efficiency is a function of input voltage, output voltage, and output load current. It's not unusual for the efficiency to vary no more than a few percent over a load current range exceeding two orders of magnitude. Because the output voltage is fixed, we can say the efficiency varies only a few percent over an "output-power range" exceeding two orders of magnitude.

DC-DC converters are most efficient when the input voltage is closest to the output voltage. If the input variation is not extreme with respect to the data sheet specifications, however, the converter's efficiency can usually be approximated as a constant between 75% and 95%:

$$P_{IN,\ DCDC} = \frac{P_{OUT,\ DCDC}}{EFF_{DCDC}} \qquad [3]$$

This discussion treats the DC-DC converter as a two-port black box. For those interested in the nuances of DC-DC converter design, see **References 1–3**.

The load includes the device to be driven and all dissipative elements in series with it, such as PC-trace resistance, contact resistance, cable resistance, etc. Because the DC-DC converter's output resistance is included in the manufacturer's data sheet, that quantity is specifically excluded. Load efficiency (EFF_{LOAD}) equals (power delivered to the load)/(power delivered by the DC-DC converter) multiplied by 100%:

$$\begin{aligned} EFF_{LOAD} &= \frac{(I_{OUT})(V_{LOAD})}{(I_{OUT})(V_{OUT})}(100\%) \\ &= \frac{V_{LOAD}}{V_{OUT}}(100\%) \qquad [4] \end{aligned}$$

The key to optimum system designs is in analyzing and understanding the interaction between the DC-DC converter and its source. To do this we first define an ideal converter, then calculate the source efficiency, then test our assumptions against measured data from a representative DC-DC converter—in this case, the MAX1626 buck regulator.

The ideal DC-DC converter

An ideal DC-DC converter would have 100% efficiency, operate over arbitrary input- and output-voltage ranges, and supply arbitrary currents to the load. It would also be arbitrarily small and available for free! For this analysis, however, we assume only that the converter's efficiency is constant, such that input power is proportional to output power:

$$(V_{IN})(I_{IN}) = \frac{P_{OUT,\ DCDC}}{EFF_{DCDC}} \qquad [5]$$

For a given load, this condition implies that the input current-voltage (I-V) curve is hyperbolic and exhibits a negative differential-resistance characteristic over its full range **(Figure 2)**. This plot presents I-V curves for the DC-DC converter as a function of increasing input power. For real systems with dynamic loads, these curves are also dynamic. That is, the power curve moves farther from the origin as the load demands more current.

Considering a regulator from the input port instead of the output port is an unusual point of view. After all, regulators are designed to provide a constant-voltage (sometimes constant-current) output. Their specifications predominantly describe the output characteristics (output-voltage range, output-current range, output ripple, transient response, etc.). The input, however, displays a curious property: within its operating range it acts as a constant-power load **(Reference 4)**. Constant-power loads are useful in the design of battery testers, among other tasks.

Calculating source efficiency

We now have enough information to calculate the source's power dissipation and therefore its efficiency. Because the open-circuit value of source voltage (V_{PS}) is given, we need only find the DC-DC converter's input voltage (V_{IN}). From equation [5], solving for I_{IN}:

$$I_{IN} = \frac{P_{OUT,\ DCDC}}{(V_{IN})(EFF_{DCDC})}$$

(DC-DC characteristic) [6]

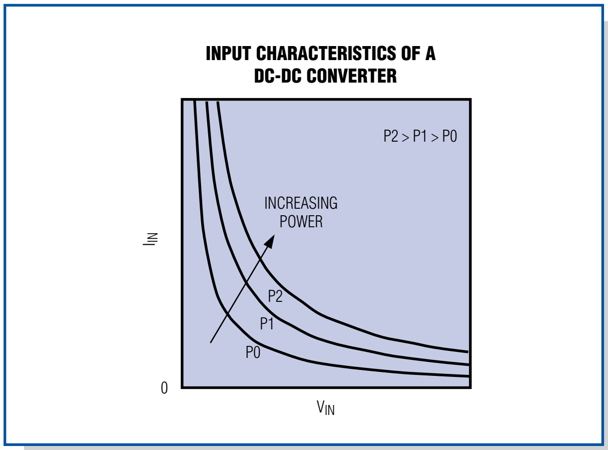

Figure 2. These hyperbolas represent constant-power input characteristics for a DC-DC converter.

I_{IN} can also be solved in terms of V_{PS}, V_{IN}, and R_S:

$$I_{IN} = \frac{(V_{PS} - V_{IN})}{R_S}$$

(resistive load-line characteristic) [7]

Equate the expressions from equations [6] and [7] and solve for V_{IN}:

$$V_{IN} = \frac{V_{PS} \pm \sqrt{V_{PS}^2 - \frac{4(R_S)(P_{OUT})}{EFF_{DCDC}}}}{2} \qquad [8]$$

To understand their implications, it is very instructive to visualize equations [6] and [7] graphically **(Figure 3)**.

The resistor load line is a plot of all possible solutions of equation [7], and the DC-DC I-V curve is a plot of all possible solutions of equation [6]. The intersections of these curves, representing solutions to the pair of simultaneous equations, define stable voltages and currents at the DC-DC converter's input. Because the DC-DC curve represents constant input power, $(V_{IN+})(I_{IN+}) = (V_{IN-})(I_{IN-})$. (The + and – suffixes refer to the two solutions predicted by equation [8], and correspond to the ± signs in the numerator.)

The optimum operating point is at V_{IN+}/I_{IN+}, which minimizes $I_{IN}^2R_S$ loss by drawing minimum current from the power supply. The other operating point causes large power dissipation in any dissipative components between V_{PS} and V_{IN}. System efficiency drops dramatically. But you can avoid such problems by keeping R_S low enough. The source efficiency $[(V_{IN}/V_{PS}) \cdot 100\%]$ is simply equation [8] divided by V_{PS}:

$$EFF_{SOURCE} = \frac{V_{PS} \pm \sqrt{V_{PS}^2 - \frac{4(R_S)(P_{OUT})}{EFF_{DCDC}}}}{2V_{PS}}(100\%)$$

$$= \frac{1}{2} \pm \sqrt{\frac{1}{4} - \frac{(P_{OUT})(R_S)}{EFF_{DCDC}(V_{PS}^2)}}(100\%) \qquad [9]$$

It's easy to get lost in the equations, and therein lies the value of the load-line analysis plot of Figure 3. Note, for example, that if the series resistance (R_S) equals zero, the resistor load-line slope becomes infinite. The load line would then be a vertical line passing through V_{PS}. At this point $V_{IN+} = V_{PS}$ and the efficiency would be 100%. As R_S increases from 0Ω, the load line continues to pass through V_{PS} but leans more and more to the left. Concurrently, V_{IN+} and V_{IN-} converge on $V_{PS}/2$, which is also the 50% efficiency point. When the load line is tangent to the I-V curve, equation [8] has only one solution. For larger R_S, the equation has no real solution and the DC-DC converter no longer functions properly.

DC-DC converters—theory vs. practice

How do these ideal-input curves compare with those of an actual DC-DC converter? To examine this question, a standard MAX1626 evaluation kit **(Figure 4)** was configured for an output voltage of 3.3V and a load resistor of 6.6Ω. We then measured the input's I-V curve **(Figure 5)**. Several nonideal characteristics were evident immediately. Note, for example, that for very low input voltages the input current is zero. A built-in undervoltage lockout (denoted as V_L) ensures that the DC-DC converter is off for all input voltages below V_L. Otherwise, large input currents could be drawn from the power supply during start-up.

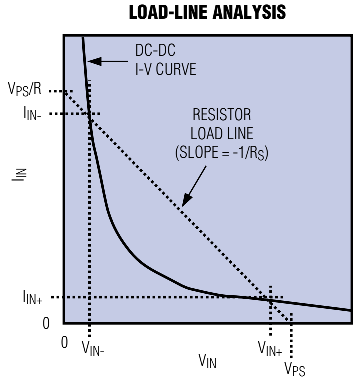

Figure 3. This plot superimposes a load line for source resistance on the DC-DC converter's I-V curve.

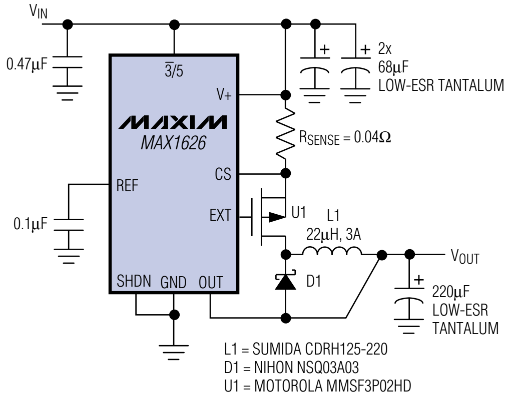

Figure 4. A standard DC-DC converter circuit illustrates the ideas of Figure 3.

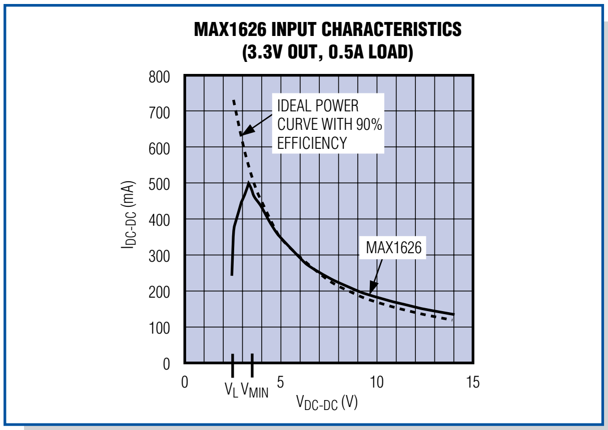

Figure 5. Above V_{MIN}, the MAX1626 input I-V characteristic closely matches that of a 90%-efficient ideal device.

When V_{IN} exceeds V_L, the input current climbs toward a maximum that occurs when V_{OUT} first reaches the preset output voltage (3.3V). The corresponding input voltage (V_{MIN}) is the minimum required by the DC-DC converter to produce the preset output voltage. For $V_{IN} > V_{MIN}$, the constant-power curve for 90% efficiency closely matches the MAX1626 input curve. Variations from the ideal are caused primarily by small variations in DC-DC converter efficiency as a function of its input voltage.

How to avoid bistability

The power-supply designer must also guarantee that the DC-DC converter never becomes bistable. Bistability is possible in systems for which the load line intersects the DC-DC converter curve at or below V_{MIN}/I_{MAX} **(Figure 6)**.

Depending on the load line's slope and position, a system can be bistable or even tristable. Note that a lower V_{PS} value can allow the load line to intersect at a single point between V_L and V_{MIN}, resulting in a system that is stable, but nonfunctional! As a rule, therefore, the load line must not touch the cusp of the DC-DC converter curve and must not move below it.

In Figure 6, the load-line resistance (R_S, which has a value of -1/slope) has an upper limit called $R_{BISTABLE}$:

$$R_{BISTABLE} = \frac{V_{PS} - V_{MIN}}{I_{MAX}} \qquad [10]$$

where $$I_{MAX} = \frac{P_{OUT}}{EFF_{DCDC}(V_{MIN})} \qquad [11]$$

therefore,

$$R_{BISTABLE} = \frac{EFF_{DCDC}(V_{MIN})(V_{PS} - V_{MIN})}{P_{OUT}} \qquad [12]$$

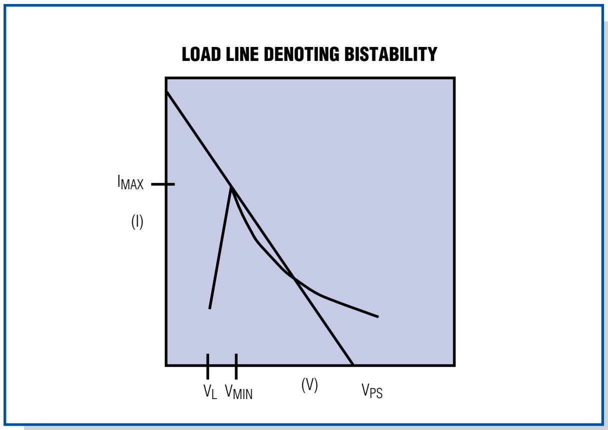

Figure 6. A closer look at the intersection points indicates a possibility of bistable and even tristable operation.

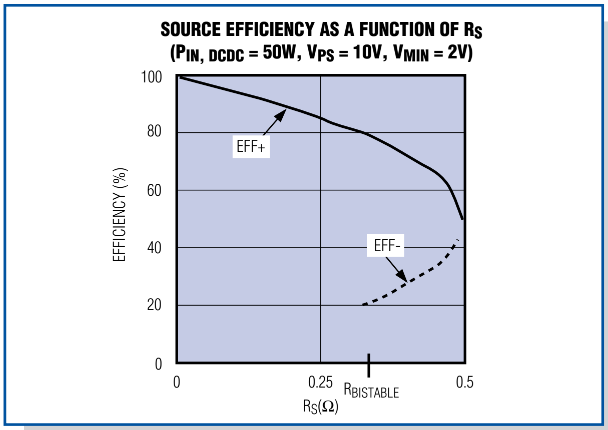

Figure 7. This plot of source efficiency vs. source resistance indicates multiple values of efficiency for a given R_S.

The source resistance (R_S) should always be smaller than $R_{BISTABLE}$. If this rule is broken, you risk highly inefficient operation or a complete shutdown of the DC-DC converter.

An actual case

It might be helpful to plot, for an actual system, the relationship shown in equation [9] between source efficiency and source resistance **(Figure 7)**. Assume the following conditions:

V_{PS} = 10V Open-circuit power-supply voltage

V_{MIN} = 2V Minimum input voltage that ensures proper operation

P_{IN} = 50W Power to the DC-DC converter's input (P_{OUT}/EFF_{DCDC}).

Using equation [12], $R_{BISTABLE}$ can be calculated as 0.320Ω. Subsequently, a plot of equation [9] shows that source efficiency drops as R_S increases, losing 20% at $R_S = R_{BISTABLE}$. *Note*: this result cannot be generalized. You must perform the calculations for each application. One component of R_S is the finite output resistance found in all power supplies, determined by the load regulation and usually defined as:

Load Regulation =

$$\frac{100\%\left(V_{NO-LOAD} - V_{FULL-LOAD}\right)}{V_{NO-LOAD}} \qquad [13]$$

Power-Supply Output Resistance =

$$\frac{\left(V_{NO-LOAD} - V_{FULL-LOAD}\right)}{I_{FULL-LOAD}} \qquad [14]$$

Therefore,

Power-Supply Output Resistance =

$$\frac{\text{Load regulation}\left(V_{NO-LOAD}\right)}{I_{FULL-LOAD}\ (100\%)} \qquad [15]$$

A 5V/10A power supply with 1% load regulation, for example, would have only 5.0mΩ of output resistance—not much for a 10A load.

Source efficiency for common applications

It's useful to know how much source resistance (R_S) can be tolerated and how this parameter affects system efficiency. R_S must be less than $R_{BISTABLE}$, as stated earlier, but how much lower should it be? To answer this question, solve equation [9] for R_S in terms of EFF_{SOURCE}, for EFF_{SOURCE} values of 95%, 90%, and 85%. R_S95 is the R_S value that yields a 95% source efficiency for the given input and output conditions. Consider the following four example applications using common DC-DC converter systems.

Example 1 derives 3.3V from 5V with a load current of 2A. For 95% source efficiency, be careful to keep the resistance between the 5V source and the DC-DC converter's input well under 162mΩ. Notice that $R_S90 = R_{BISTABLE}$, by coincidence. This value of R_S90 also implies that the efficiency could as easily be 10% as 90%! Note that system efficiency (as opposed to source efficiency) is the product of source efficiency, DC-DC converter efficiency, and load efficiency.

Example 1. Application Using a MAX797 or MAX1653 DC-DC Converter (I_{OUT} = 2A)

V_{PS}	V_{OUT}	I_{OUT}	V_{MIN}	EFF_{DCDC}	P_{OUT}	$R_{BISTABLE}$	R_S95	R_S90	R_S85
5V	3.3V	2A	4.5V	90%	6.6W	0.307Ω	0.162Ω	0.307Ω	0.435Ω

Example 2. Application Using a MAX797 or MAX1653 DC-DC Converter (I_{OUT} = 20A)

V_{PS}	V_{OUT}	I_{OUT}	V_{MIN}	EFF_{DCDC}	P_{OUT}	$R_{BISTABLE}$	R_S95	R_S90	R_S85
5V	3.3V	20A	4.5V	90%	66W	0.031Ω	0.016Ω	0.031Ω	0.043Ω

Example 3. Application Using a MAX1710 DC-DC Converter with Separate +5V Supply (V_{PS} = 4.5V)

V_{PS}	V_{OUT}	I_{OUT}	V_{MIN}	EFF_{DCDC}	P_{OUT}	$R_{BISTABLE}$	R_S95	R_S90	R_S85
4.5V	1.6V	5A	2.5V	92%	8W	0.575Ω	0.111Ω	0.210Ω	0.297Ω

Example 4. Application Using a MAX1710 DC-DC Converter with Separate +5V Supply (V_{PS} = 15V)

V_{PS}	V_{OUT}	I_{OUT}	V_{MIN}	EFF_{DCDC}	P_{OUT}	$R_{BISTABLE}$	R_S95	R_S90	R_S85
15V	1.6V	5A	2.5V	86%	8W	3.359Ω	1.149Ω	2.177Ω	3.084Ω

Example 2 is similar to Example 1 except for output-current capability (20A vs. 2A). Notice that the series-resistance requirement for 95% source efficiency is 10 times lower (16mΩ vs. 162mΩ). To achieve this low resistance, use 2oz. copper PC traces.

Example 3 derives 1.6V at 5A from a source voltage of 4.5V (i.e., 5V-10%). The system requirement of 111mΩ for R_S95 can be met, but not easily.

Example 4 is the same as Example 3, but with higher supply voltage (V_{PS} = 15V instead of 4.5V). Notice the useful trade-off: a substantial increase in the difference between input and output voltages has caused an efficiency drop for the DC-DC converter alone, but the overall system efficiency is improved. R_S is no longer an issue because the large R_S95 value (>1Ω) is easily met. A system with an input filter and long input lines, for example, can maintain a source efficiency of 95% or more without special attention to line widths and connector resistances.

Conclusion

When looking at DC-DC converter specifications, it is tempting to maximize efficiency by setting the supply voltage as close to the output voltage as possible. This strategy, however, can increase costs by placing unnecessary limitations on elements such as the wiring, connectors, and trace layout. System efficiency may even suffer. The analytic tools presented in this article should make such power-system trade-offs more intuitive and obvious.

References

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(2) Lenk, Ron. *Practical Design of Power Supplies.* IEEE Press & McGraw Hill, 1998.

(3) Gottlieb, Irving M. *Power Supplies, Switching Regulators, Inverters and Converters.* Second Edition, TAB Books, 1994.

(4) Wettroth, John. “Controller Provides Constant Power Load.” *EDN*, March 14, 1997.

DESIGN SHOWCASE

PC printer port controls I-V curve tracer

When connected to the printer port of a PC, the circuit shown in **Figure 1** enables you to determine the current-voltage (I-V) characteristics of an active component or integrated circuit. A short BASIC program* drives the port and displays the I-V characteristic as a graph on the monitor. The result is a very useful diagnostic tool for IC fault analysis.

The 12-bit digital-to-analog converter (DAC), IC4, is configured for bipolar outputs to ±2.048V. Op amp IC6A multiplies this signal with a gain of +2V/V, and op amp IC7 converts the result to a current that passes through the device under test (DUT). This current ranges from ±40µA to ±40mA, according to the resistor value selected for R_{SENSE}. For any combination of DUT and selected range, the maximum current available equals (approximately) the IC6A output (±4.096V max) divided by R_{SENSE}.

[continued]

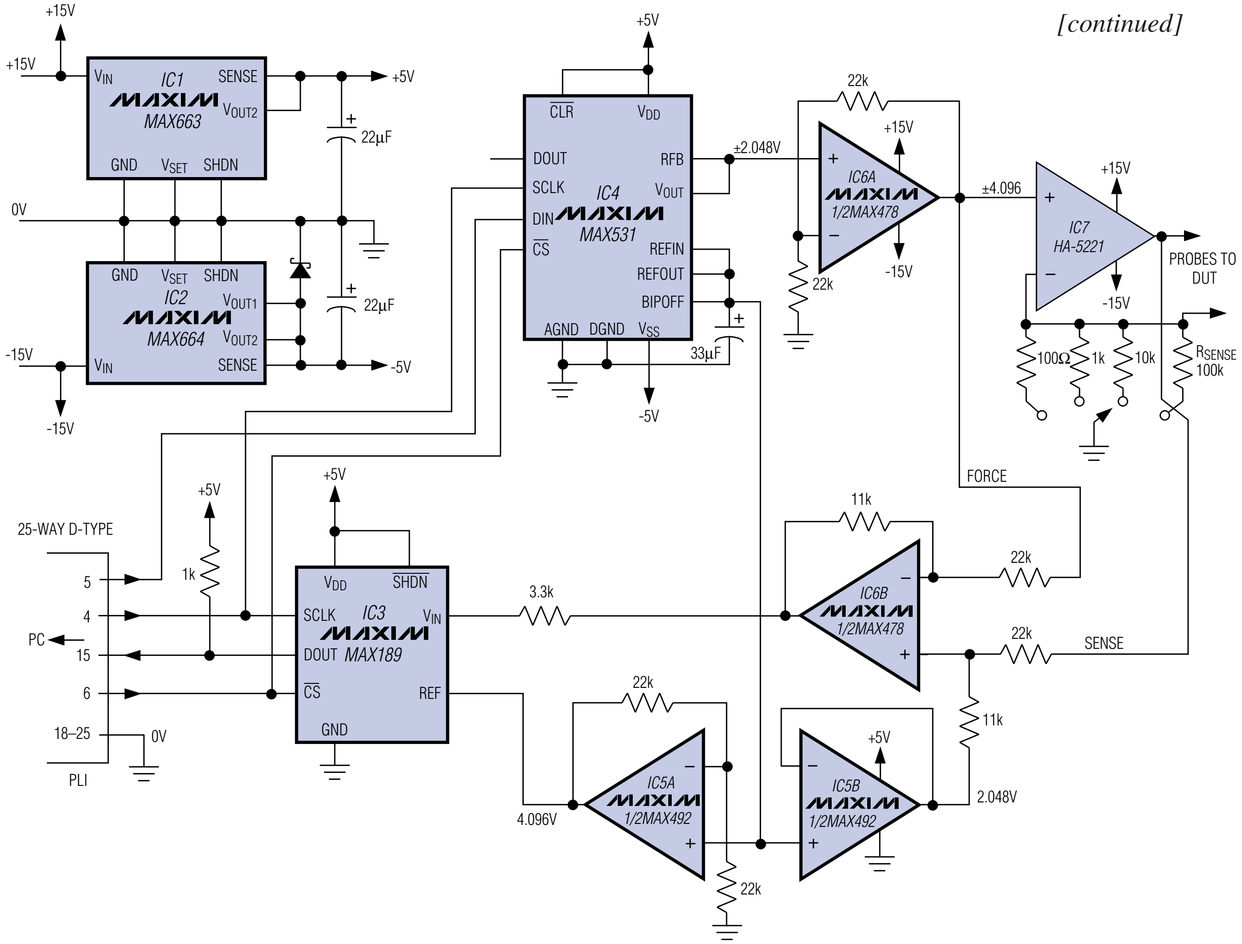

Figure 1. A 12-bit, serial-data DAC (IC4) and ADC (IC3) form an interface that enables the printer port of a PC to control this I-V curve tracer.

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[*] *The program, titled "I-V Curve Tracer," was written by Terry Millward, Maxim UK, and is available at Maxim's website (http://www.maxim-ic.com/othersoftware.htm).*

Current through the DUT produces a bipolar voltage that is sensed by the differential amplifier IC6B. To avoid the variable-offset error that would otherwise occur with a change in switch position, this amplifier's inverting-input signal is taken from the low-impedance, noninverting input of IC7 rather than its inverting input. The penalty for this choice is the fixed input-offset error of IC7.

The differential amplifier's gain plus the offset supplied to it result in a maximum output swing (0V to 4.096V) compatible with the unipolar input range of the 12-bit analog-to-digital converter (ADC), IC3. IC3's 3.3kΩ input resistor limits input current in the event of an applied overvoltage. IC7 requires ±15V supply rails to provide sufficient compliance voltage for its current-source function. To supply all the other ICs, IC1 and IC2 regulate these rails to ±5V.

During operation, the software drives the DAC to produce a current ramp, and the ADC measures the resulting voltage across the DUT. This voltage waveform is displayed on the PC monitor at 640x480 resolution, as shown in two examples (**Figure 2**). Twelve-bit converter resolution is excessive with respect to this display resolution, but 12 bits provides a margin for the use of higher resolution monitors, and also for examining the response with a software "zoom."

A similar idea appeared in the 11/97 issue of Electronic Engineering (UK).

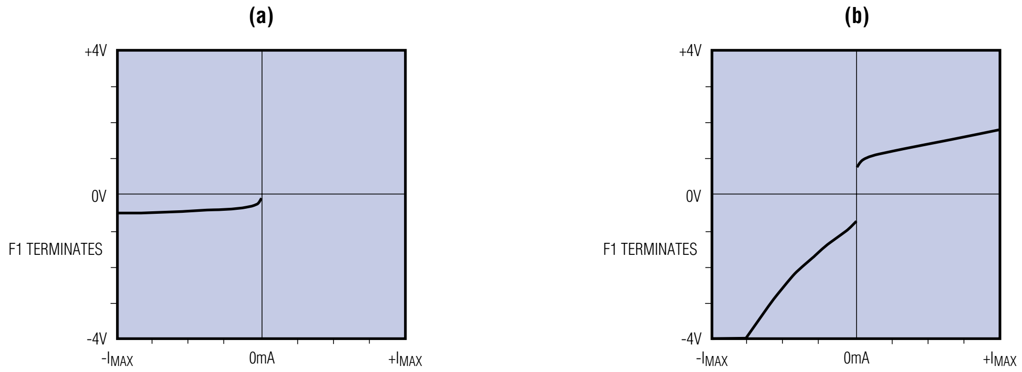


Figure 2. Examples of output from the Figure 1 circuit include a Schottky diode (a) and a more complex analog IC (b).

Switch-mode converter starts with full load connected

Operating from a 2-cell or 3-cell battery, the boost converter shown in **Figure 1** delivers as much as 500mA from its regulated 5V output. Following a start-up or brownout condition, however, the output and load remain disconnected until the output achieves regulation.

IC1's V+ terminal (pin 2) provides power as well as feedback to the chip. This "bootstrapped" operation (in which the chip is powered from its own output) enables start-up from input voltages as low as +1.8V, unless a heavy load prevents start-up altogether.

Proper operation requires a gate-drive voltage sufficient to provide low on-resistance in the switching MOSFET, but at start-up this drive is limited to the battery voltage. The resulting high on-resistance in the MOSFET can prevent the converter output from rising to its specified level. On the other hand, connecting the output and load only after V_{OUT} is within tolerance allows the MOSFET to turn on fully with minimum on-resistance.

The N-channel MOSFETs of IC2 are each rated for 3.5A, 12V, and a 0.05Ω on-resistance in the "fully on" state. Device #2 (on the left) is the switching transistor, and Device #1 is a high-side load switch. Gate drive for the load switch comes from a charge pump (C4 and the dual diode D2) that is driven by the switching node at the bottom of L1. At start-up the µP supervisor (IC3) issues a reset (low output at pin 2) that prevents charging of C4.

When IC3's pin 3 rises above 4.65V, however, pin 2 goes high, enabling C4 to charge via the right-hand diode each time the switching node goes low. Each time it returns high, the C4 voltage adds to the output voltage, boosting the MOSFET gate (G1) to about 9.5V. This level is maintained by a charge on the gate-source capacitance. On start-up, therefore, the

[continued]

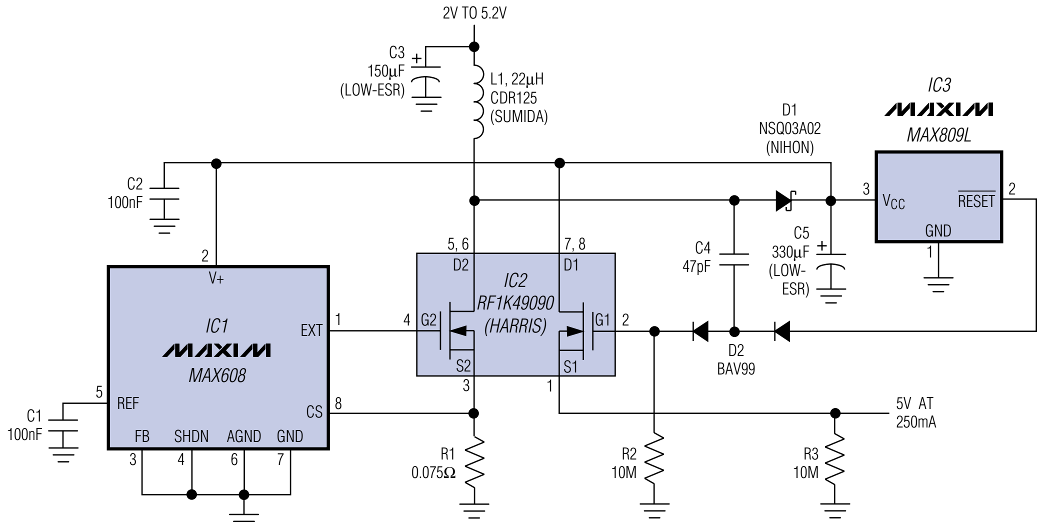


Figure 1. To ensure a full-load start-up, the extra circuitry in this regulated boost converter disconnects the load until the output voltage achieves regulation.

charge-pump output ramps up to about 4.5V, and then jumps to 9.5V when IC3's RESET output goes high. Only then does the high-side switch turn on and connect the load.

If IC3's 240ms power-up delay is too long, you can replace IC3 with another µP supervisor (MAX821) that lets you select the delay as 1ms, 40ms, or 200ms max. This boost converter circuit features pulse-frequency modulation (PFM), and therefore requires a minimum load of approximately 5µA to ensure that the converter (and therefore the charge pump) continues to switch occasionally. In practice, this minimum load is provided by reverse leakage in the Schottky rectifier (D1), but if D1 is replaced by a low-leakage non-Schottky rectifier (or if you just want to guarantee the load), reduce the value of R3 to 1MΩ.

The circuit shown provides efficiencies greater than 80% while supplying 250mA with an input of 2.0V, or 500mA with an input of 2.7V. The Harris MOSFETs have a $V_{GS(TH)}$ of 2.0V max, but by substituting a switch with lower $V_{GS(TH)}$ (such as the Temic Si6946DQ) you can modify the circuit to start from battery voltages as low as 1.8V. (The Temic part, however, has a higher $R_{DS(ON)}$.)

A similar idea appeared in the 9/98 issue of Electronics World & Wireless World.

Two AA cells power step-down regulator

DC-DC conversion is particularly challenging when both the input and output voltages are low. Step-up ICs that operate from less than +1V are available, but step-down ICs that accept input voltages near +2V are not. Thus, providing efficient power for the low-voltage CPU core in a hand-held product can be a problem if the power source is a 2-cell AA battery. This battery output can drop to 1.8V as the battery discharges.

The upper switch-mode DC-DC converter in **Figure 1** (IC1) generates over 600mA at 1.5V, from a 2-AA-cell input that varies from +3.4V to +1.8V. The 3.3V rail that powers this step-down controller is taken from a high-current, synchronous-rectified boost controller (IC3), which is otherwise included to provide power for external logic and the CPU's I/O blocks. Note that IC1 is biased by 3.3V, but power for the 1.5V output comes directly from the battery.

When the 3.3V rail is too low to properly operate IC1, the switching power MOSFET (Q1) is forced off by Q2, D2, and a SOT23 reset (IC2). Without these components, the conditions at power-up (battery voltage present but 3.3V momentarily absent, pulling the Q1 gate low) may cause the 1.5V output to overshoot to the battery voltage.

The 1.5V output's buck-conversion efficiency (about 85%) is quite good for the circuit's extra-small components: a 3-pin SOT23 power MOSFET (Q1) and 5mm-diameter surface-mount inductors. For the 3.3V output, IC3's on-chip synchronous rectification yields a boost efficiency higher than 90%.

A similar idea appeared in the 1/7/99 issue of EDN.

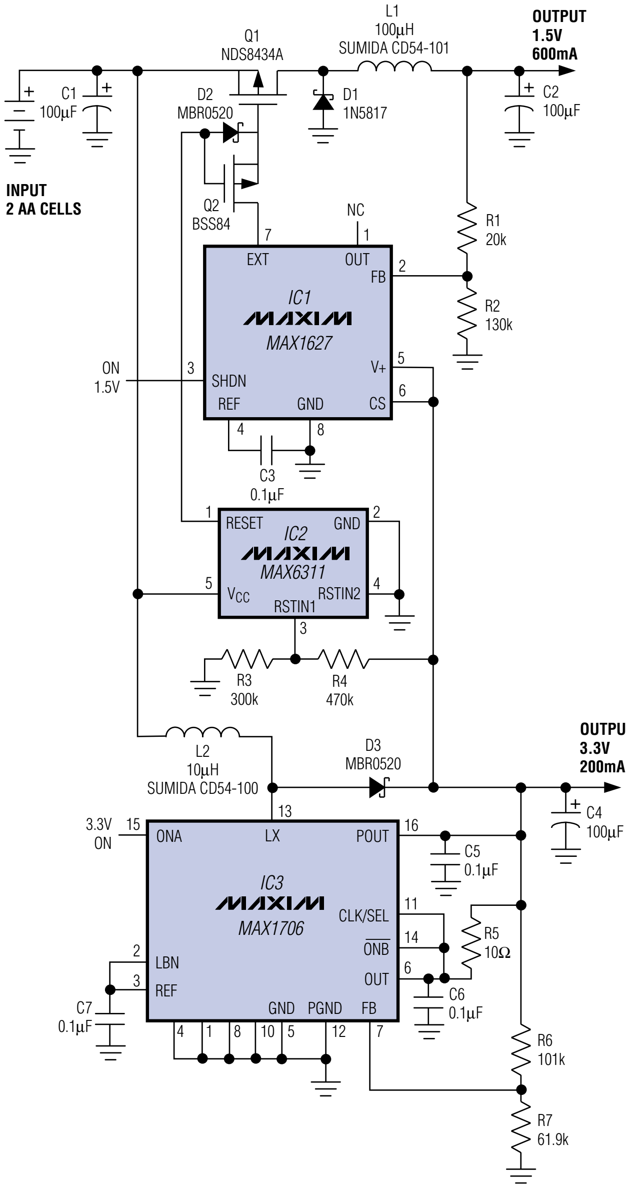


Figure 1. Powered by the 3.3V boost controller IC3, this step-down controller (IC1) generates 1.5V from inputs as low as 1.8V. If the 3.3V rail dips below the allowed minimum, IC2 and Q2 shut down the circuit by turning off Q1.

Miniature temperature monitors drive 3-speed fan controller

Combining a switch-mode DC-DC controller with two low-cost temperature-monitor ICs produces a 3-speed fan controller (**Figure 1**). Useful in many applications, this circuit cuts noise and power consumption in computers, temperature controllers, and alarm systems.

The idea is made possible by IC3's pin-selectable shutdown and output-voltage capabilities. The logic levels applied to those inputs ($\overline{3}/5$ and SHDN), along with properly valued feedback resistors (R2 and R3) set the output-voltage levels (available one at a time) at 0V, 8V, and 12V. In general, the lower voltage (V_{OUT1}, which equals 8V in this case) is determined by the R2/R3 divider, and the higher voltage (V_{OUT2}) (which equals 12V in this case) is determined by the product of V_{OUT1} and an internal ratio:

$$V_{OUT1} = 3.3[(R2+R3)/R3]$$

$$V_{OUT2} = V_{OUT1}(5/3.3)$$

The temperature monitors (IC1 and IC2) have open-drain outputs ($\overline{\text{TOVER}}$) that are pulled low when the ambient temperature exceeds a factory-programmed internal threshold. The monitors come in tiny SOT23-5 packages, with dedicated thresholds in the +35°C to +115°C range. When the temperature exceeds the threshold of IC2 (+45°C in this example), that device turns on IC3 by pulling its SHDN terminal low. IC3's $\overline{3}/5$ input remains low, producing 3.3V at OUT (and 8V at the fan), until the temperature rises to +65°C. At that time, the IC1 output pulls low, turning off Q2 and allowing R6 to pull the $\overline{3}/5$ input high, which applies 12V to the fan. Q2 is necessary for signal inversion and for meeting the $\overline{3}/5$ input's logic-high threshold (V+ - 0.5V).

IC3's ability to produce 100% duty cycles enables a very low dropout voltage for this application—about 150mV at 1A load. The conversion efficiency is independent of output voltage but varies with output current, ranging from 85% and 96% for currents between 10mA and 1A. The average efficiency is 90%. At low temperatures for which a fan is not required (below +45°C), the switching regulator shuts down and lowers the supply current in this circuit to about 100µA.

A similar idea appeared in the 2/22/99 issue of Electronic Design.

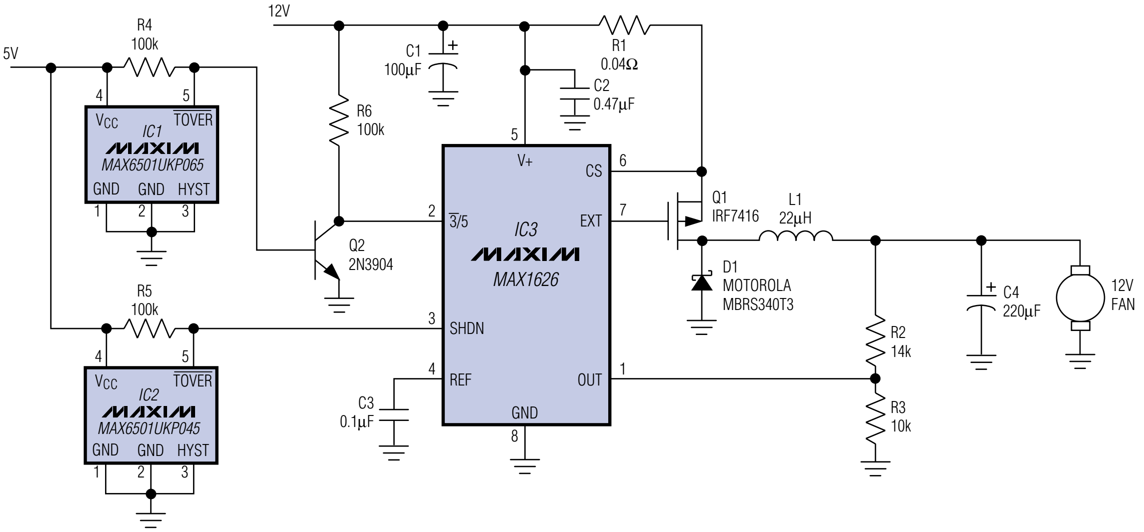


Figure 1. Controlled by the temperature monitors IC1 and IC2, this switch-mode DC-DC controller (IC3) applies either 0V, 8V, or 12V to the fan.

NEW PRODUCTS

8-bit ADC with 2.2GHz T/H converts at 1Gsps

The MAX104 is an 8-bit, monolithic, bipolar analog-to-digital converter (ADC) with a 1Gsps digitizing rate. The MAX104 is ideal for high-speed communication, instrumentation, and data-acquisition applications where wide bandwidth, good linearity, and high dynamic performance are required.

Unlike other gigahertz sampling 8-bit ADCs, the MAX104 achieves a full 47dB SINAD and 52dB SFDR at a 500MHz input (Nyquist) frequency. For both these parameters, the MAX104 maintains the same performance levels, within 1dB, out to twice the Nyquist (i.e., 1GHz) input frequency.

The MAX104 achieves this high performance through both innovative design and the use of Maxim's proprietary 27GHz GST-2 bipolar process. An integrated, fully differential input track/hold (T/H) employs Schottky diodes and laser-trimmed resistors to achieve a typical integral nonlinearity (INL) and differential nonlinearity (DNL) of less than ±0.25LSB, a full-power bandwidth of 2.2GHz, and less than 0.5ps aperture jitter. The MAX104's performance is further enhanced through the use of a proprietary on-chip decoding scheme, ensuring a low 1-in-10^{15} clock cycle occurrence of metastable states with no error exceeding 1LSB.

Proper packaging is also critical to achieving good performance at these frequencies. The MAX104 uses a 25x25x1.4mm, 192-contact ESBGA™ (Enhanced Super Ball-Grid Array) package to minimize parasitic effects, provide controlled impedance signal paths, and eliminate the need for heatsinking in most applications.

To facilitate digital interface, the MAX104 features an on-chip, selectable 8:16 output demultiplexer that slows the 1Gsps data to 500 mega-words per second ported to two parallel, differential 8-bit, low-voltage (PECL) outputs. Data is presented in offset binary format and includes an output clock and an overrange bit. The device operates from ±5V supplies and supports 3V to 5V output interfaces.

The MAX104 comes specified for the commercial temperature range (0°C to +70°C) and is priced from $398.00 (1000-up, FOB USA). An evaluation kit, which includes the MAX104, is available ($650.00).

ESBGA is a trademark of Amkor/Anam.

Serial, 8-bit, pseudo-differential ADCs fit in 10-pin µMAX package

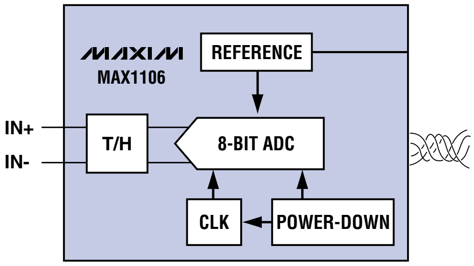
The MAX1106/MAX1107 8-bit ADCs include a track/hold, voltage reference, clock, and serial interface. As the industry's smallest pseudo-differential 8-bit ADCs, they come in a 10-pin µMAX package half the size of an 8-pin SO. Their small size, low-power operation, excellent dynamic performance, and ease of use make them well suited for use in battery-powered portable applications.

The MAX1106 operates from a +2.7V to +5.5V supply, and the MAX1107 operates from a +4.5V to +5.5V supply. Both draw only 130µA at their maximum conversion rate (50ksps). Their full-scale analog-input range is determined either by the internal reference voltage (2.048V for the MAX1106, 4.096V for the MAX1107) or an externally applied reference in the 1V to V_{DD} range.

When the MAX1106/MAX1107 devices are not in use, a software-controlled power-down can lower their supply currents to 0.5µA. The 4-wire serial interface connects directly to SPI™, QSPI™, and MICROWIRE™ devices without external logic. Prices start at $1.55 (1000-up, FOB USA).

SPI and QSPI are trademarks of Motorola, Inc.

MICROWIRE is a trademark of National Semiconductor Corp.



$0.35 digital pots offered in SOT23 package

The MAX5160/MAX5161 linear-taper digital potentiometers (pots) each have a fixed end-to-end resistance and a 32-tap wiper contact. Miniature size and a low price tag ($0.35) make them good replacements for mechanical potentiometers. (Mechanical pots become dirty and unreliable over time, but digital pots were previously too costly to use as replacements.) The MAX5160/MAX5161 offer an excellent way to adjust the LCD bias in hand-held equipment.

The MAX5161, in a 3x3mm SOT23-6 package, requires 70% less board space than similar devices offered in 8-pin SO packages. A low ratiometric temperature coefficient (5ppm/°C) allows the MAX5161 to serve in programmable-gain amplifiers that require stable gain over temperature.

The MAX5160, with 3-wire digital control, comes in a space-saving 8-pin µMAX package. The MAX5161, with 2-wire digital control, comes in a 6-pin SOT23 package. Both are available from stock in three options for end-to-end resistance: 50kΩ, 100kΩ, and 200kΩ. Prices start at $0.35 (50,000-up, factory direct, FOB USA).

NEW PRODUCTS

3V, 18-bit sigma-delta ADCs guarantee 0.0015% INL

The MAX1401/MAX1403 18-bit ADCs guarantee 16-bit performance (0.0015% INL) at 480sps. Coarse measurements at 12-bit accuracy (0.024% INL) can be performed 10 times more quickly, at conversion rates as high as 4800sps. This high level of accuracy is ideal for pressure transducers, industrial process control, and other applications requiring a wide dynamic range.

The MAX1401/MAX1403 operate from both +3V analog and +3V digital supplies. The low operating power consumption (1.5mW) drops below 50µW during shutdown. The MAX1403 provides matched 200µA current sources for sensor excitation, and the MAX1401 provides direct access to the multiplexer output and ADC input for inserting additional signal-conditioning circuitry.

These devices save board space and design time by combining a switching network, programmable-gain amplifier (PGA), and two buffers with an internal oscillator, on-chip digital filter, modulator, system-offset-correction digital-to-analog converter (DAC), and bidirectional serial interface. System offsets as high as 117% of the selected full-scale range can be corrected through the on-board offset-correction DAC. The analog inputs can be configured as five fully differential channels or as five pseudo-differential plus two differential channels. Other features include user-configurable automatic channel scanning, continuous data-output mode, and convert-on-command mode.

The MAX1401/MAX1403 are available in 28-pin SSOP packages with prices starting at $8.95 (1000-up, FOB USA).

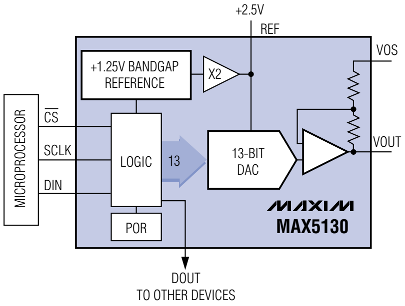
12- and 13-bit DACs guarantee 10ppm/°C reference

Devices in the MAX5120/MAX5130 family of serial-input/voltage-output, 12- and 13-bit DACs feature an internal Rail-to-Rail® output amplifier and a precision bandgap reference. Unlike comparable internal-reference DACs, these devices guarantee temperature coefficients (tempcos) of <10ppm/°C over the extended-industrial temperature range (-40°C to +85°C). They also guarantee 13-bit monotonicity, ±1LSB max DNL and ±1/2LSB INL.

Devices in this low-power DAC family operate on single supplies of +3V or +5V, drawing supply currents of 500µA (operating) or 3µA (power-down). Power-up reset reduces output glitches during power-up, allowing a user-selectable initial output state of either zero or midscale. The internal amplifier's user-accessible output and inverting input allow specific gain configurations, remote sensing, and high output-drive capability for a wide range of force/sense applications. The buffered outputs drive loads of 5kΩ||100pF or 4–20mA.

Each device has a serial interface compatible with SPI™, QSPI™, and MICROWIRE™ serial-data standards. Offered in space-saving 16-pin QSOP packages, the series features voltage-output versions (12-bit MAX5120/MAX5121 and 13-bit MAX5130/MAX5131) and force/sense versions (12-bit MAX5122/MAX5123 and 13-bit MAX5132/MAX5133). Prices start from $3.80 (1000-up, FOB USA).

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



1%-accurate sensor-signal conditioner is digitally trimmed

The MAX1478* is a highly integrated analog-signal processor optimized for the calibration and compensation of piezoresistive sensors. Requiring no external components, it includes a programmable current source (0.1mA to 2.0mA) for sensor excitation, a 3-bit PGA, a 128-bit internal EEPROM, and four 12-bit DACs. Accuracy is within ±1% of the sensor's repeatability error. The MAX1478 compensates silicon piezoresistive sensors for offset, offset temperature coefficient, full-span output (FSO), FSO temperature coefficient (FSOTC), and FSO nonlinearity.

By adjusting the input-signal offset and span through DACs, the MAX1478 compensates for 1st-order temperature error and eliminates quantization noise. Built-in features enable the MAX1478 to integrate three traditional sensor-manufacturing operations into one automated process:

Pretest: Host computer acquires sensor data.

Calibration and compensation: Host computer downloads calibration and compensation coefficients to the MAX1478's internal EEPROM.

Final test: Host computer verifies calibration and compensation without removing the MAX1478 from the test socket.

Although optimized for use with piezoresistive sensors, the MAX1478 with external components can operate with accelerometers, strain gauges, and other resistive sensors. For custom requirements, Maxim maintains a dedicated-cell library of more than 90 sensor-specific functional blocks. Contact the factory for further information.

The MAX1478 comes in die form and in 16-pin SSOP packages.

**The MAX1478 is a future product.*

NEW PRODUCTS

Complete high-side current-sense amplifier fits in a SOT23 package

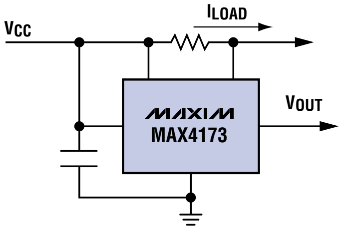
The MAX4173 is a high-side current-sense amplifier available in a small 6-pin SOT23 package that is only 3x3mm square. Unlike current-sensing techniques that disrupt the circuit ground plane, this tiny device employs a single high-side current-sense resistor between the power supply and the load. This external resistor allows the user to select a full-scale range for the measured current.

Three factory-trimmed gains are available:

+20V/V (MAX4173T)
+50V/V (MAX4173F)
+100V/V (MAX4173H)

The MAX4173 features a wide supply-voltage range, from +3V to +28V. Its circuit architecture allows an input common-mode voltage to range from 0 to +28V, independent of the supply voltage. Ground-sensing inputs maintain linearity. They also prevent phase reversal at the output when the input common-mode voltage is near ground. This feature is useful during power-up or power-down transients, and during some input-fault conditions. The MAX4173 achieves a full-scale accuracy of 0.5%. Its 1.7MHz bandwidth ($A_V = +20V/V$) makes it useful in closed-loop current-control applications.

The MAX4173 is offered in both 6-pin SOT23 and 8-pin SO packages. Prices start at $0.75 (1000-up, factory direct, FOB USA).



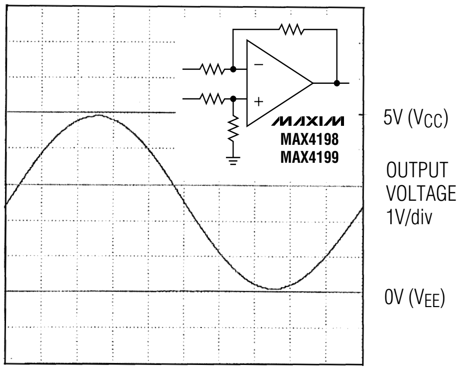
Differential amps draw only 42µA from a single +2.7V supply

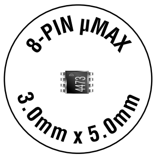
The MAX4198/MAX4199 are single-supply, micropower differential amplifiers with internal precision gain resistors and Rail-to-Rail® outputs. Unlike differential amplifiers that operate only from +5V supplies, these operate from single supply voltages in the +2.7V to +7.5V range and draw only 42µA. They are ideal for precision portable instruments and low-power equipment. To further prolong battery life, they feature a low-power shutdown mode that reduces the supply current to 6.5µA. Both amplifiers feature 110dB power-supply rejection and exhibit 0.001% total harmonic distortion at 1kHz.

The MAX4198, internally trimmed for unity gain, achieves a 175kHz -3dB bandwidth, 0.01% accuracy, 0.0003% nonlinearity, and 90dB common-mode rejection. The MAX4199, internally trimmed for a +10V/V gain, achieves a 45kHz -3dB bandwidth, 0.01% accuracy, 0.0003% nonlinearity, and 110dB common-mode rejection.

The MAX4198/MAX4199 are available in 8-pin SO and space-saving 8-pin µMAX packages (same dimensions as the industry-standard MSOP). Prices start at $1.25 (1000-up, factory direct, FOB USA).

SINGLE 2.7V SUPPLY,
RAIL-TO-RAIL OUTPUT





Rail-to-rail op amps sustain 115dB A_{VOL} with 1kΩ load

The MAX4281/MAX4282/MAX4284 single/dual/quad Rail-to-Rail® op amps have 2MHz gain-bandwidth products. Unlike most rail-to-rail op amps, they have a proprietary output architecture capable of driving 1kΩ loads to within 160mV of each rail, with no degradation of the 115dB open-loop gain. Operating from a single supply voltage of +2.5V to +5.5V, these unity-gain-stable op amps suit general-purpose, low-voltage applications that require wide output swings. They are open-loop versions of the new Gain-Amp™ amplifiers that feature factory-trimmed internal gain networks.

The MAX4281/MAX4282/MAX4284 draw only 300µA and are stable with loads up to 470pF. At 20kHz with 1Vp-p output swings, they achieve total harmonic distortion of 104dB. The dual and quad versions exhibit 90dB of crosstalk at 100kHz.

The MAX4281 comes in space-saving 5-pin SOT23 and 8-pin SO packages. The MAX4282 comes in 8-pin µMAX and SO packages, and the MAX4284 comes in 14-pin SO and 16-pin QSOP packages. Prices start at $0.60 (1000-up, factory direct, FOB USA).

Gain-Amp is a trademark of Maxim Integrated Products.

NEW PRODUCTS

Single chip controls ramp-up/down for GSM PAs

The MAX4473 IC controls power ramp-up and ramp-down for power amplifiers (PAs) as required by GSM and other TDMA cell-phone PAs. The tiny, 3x5mm 8-pin µMAX package replaces three discrete op amps and a handful of passive components, simplifying cell-phone layout and design by virtually eliminating the various RF noise and stability concerns. Optimized to meet strict GSM bandwidth and slew-rate requirements, the MAX4473 guarantees 1.5µs enable/disable times and a low supply current (1.2mA), which lowers power consumption without compromising the dynamic response. Three external gain resistors provide maximum versatility.

GSM and other TDMA cell phones pulse on while transmitting and then turn off. Typical bursts occur at 200Hz with a duty cycle of 1/8. The main challenge in designing these RF systems is ramping the power up and down per GSM specifications without producing extraneous RF splatter or radiation. To maintain stability and eliminate noise problems, the circuits currently require several op amps and a handful of passive components. The MAX4473 simplifies such systems by combining all necessary amplifiers in a single chip, and by optimizing the performance specifically for GSM applications.

The robust Rail-to-Rail® output, capable of driving 500Ω or 300pF loads (or both in parallel), is designed to drive the low-impedance gain-control inputs of a power amplifier. To allow accurate power control over a wide common-mode range and to prevent phase reversal at the outputs, the internal error amplifier also has rail-to-rail inputs. Other features of the MAX4473 include a rail-to-rail control-input buffer and a wide supply-voltage range of +2.7V to +6.5V. In shutdown, the device provides an active pull-down for the output and draws less than 1µA of supply current.

The MAX4473 is available in 8-pin SO and space-saving 8-pin µMAX packages (same dimensions as the industry-standard MSOP). Prices start at $0.75 (50,000-up, FOB USA).

Serially controlled audio/video switches offer clickless operation

The MAX4562/MAX4563 analog switches are controlled by a serial-data interface. Ideal for multimedia applications, they feature 30Ω max on-resistances matched to within 5Ω and guaranteed flat to within 5Ω over the analog signal range. Both devices offer selectable soft-switching, which provides a “clickless” mode of operation for audio applications. Crosstalk and off-isolation are -85dB at 20kHz for audio, and -55dB at 10MHz for video. Total harmonic distortion for audio is 0.007%.

The MAX4562/MAX4563 each contain two normally open SPDT switches and two normally open SPST switches, which (for example) are configurable as T-switches for video applications. The MAX4562 features a 2-wire, I^{2}C-compatible serial interface, and the MAX4563 features a 3-wire, SPI™/QSPI™/ MICROWIRE™-compatible serial interface. Both devices operate on a single supply voltage in the +2.7V to +5.5V range.

The MAX4562/MAX4563 come in 16-pin QSOP packages, with prices starting at $1.99 (1000-up, FOB USA).

I^{2}C is a trademark of Philips Corp.

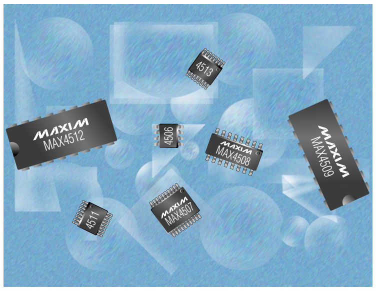
Fault-protected analog ICs offer rail-to-rail signal handling

A new circuit configuration designed to protect switches from transients outside the normal power-supply range has produced a variety of fault-protected products: quad single-pole/single-throw (SPST) switches (MAX4511/MAX4512/MAX4513), 8-channel and dual-4-channel multiplexers (MAX4508/MAX4509), and 3/8 in-line signal protectors (MAX4506/MAX4507). All devices feature Rail-to-Rail® signal-handling capability across the full range of supply voltage.

These devices provide ±40V of input protection with power off, and up to ±36V of overvoltage protection during power-up or power-down. The affected terminal becomes open-circuited during fault conditions, allowing only nanoamperes of leakage into the source. To ensure unambiguous outputs, the switch output clamps to the appropriate supply voltage and delivers as much as 10mA of proper-polarity load current during a fault condition.

Other features include low on-resistance (100Ω max) and on-resistance matching to within 6Ω maximum. The input off-leakage current is 0.5nA at +25°C and 10nA at +85°C. All parts operate from a single supply 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 and CMOS logic.

Parts are available in 8-pin DIP/SO, 16-pin DIP/narrow-SO/SSOP, 18-pin DIP/SO, and 20-pin SSOP packages. Prices start at $1.46 (1000-up, FOB USA).



NEW PRODUCTS

Low-cost, low-voltage, quad CMOS analog switches replace 74HC4066

The MAX4610/MAX4611/MAX4612 quad SPST analog switches are low-cost, pin-compatible replacements for the industry-standard 74HC4066 analog switch. On-resistances (65Ω max) are matched to within 4Ω max and flat to within 15Ω max over the specified signal range. Each switch accepts input voltages between V+ and ground, and the maximum off-leakage current is 1nA at T_A = +25°C and 6nA at T_A = +85°C.

The MAX4610, with four normally open (NO) switches, is the 74HC4066 replacement. The MAX4611 has four normally closed (NC) switches, and the MAX4612 has two NO and two NC switches. All operate from a single supply voltage of +2V to +12V, and all digital inputs have logic thresholds of +0.8V and +2.4V, which ensures TTL/CMOS-logic compatibility when operating with a +5V supply. ESD protection exceeds 2kV per Method 3015.7.

The MAX4610/MAX4611/MAX4612 are available in 14-pin DIP and narrow-SO packages as well as 14-pin TSSOP packages. Prices start at $0.54 (1000-up, FOB USA).

Low-noise PWM buck converters accept 14V and deliver 1A

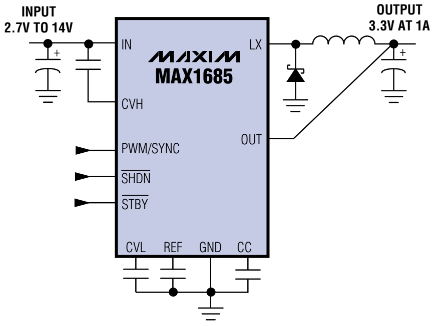
The MAX1684/MAX1685 are high-efficiency, step-down switching regulators intended for use in cellular phones, communicating personal digital assistants (PDAs), and handy-terminals. Each delivers a guaranteed 1A output current when driven by a 2-cell Lithium-Ion (Li-Ion) battery. The 3.3V preset output voltage can also be externally adjusted in the 1.25V to V_{IN} range. A wide input range (+2.7V to +14V) allows the ICs to operate from wall cubes as well as batteries.

Low on-resistance in the built-in power switch and synchronous rectifier enable efficiencies as high as 96%. Each converter offers four operating modes: normal, fixed-frequency, low-power, and shutdown. Normal mode (150µA quiescent current) maintains high efficiency for all loads; fixed-frequency pulse-width modulation (PWM) mode offers excellent noise characteristics; low-power mode (25µA quiescent current) conserves power during standby or when full-load capability is not required; and shutdown mode (2µA) turns off the IC.

The MAX1684 runs at 300kHz for maximum efficiency, and the MAX1685 runs at 600kHz to allow use of smaller external components. Both devices can be synchronized to an external clock. They also include a 100% duty cycle for low-dropout applications, a 1%-accurate voltage reference, and an auxiliary output of 3V/5mA.

For applications that allow lower input voltages (to +5.5V max), consider the smaller MAX1692 in a 10-pin µMAX package.

The MAX1684/MAX1685 come in space-saving 16-pin QSOPs with prices starting at $3.25 (1000-up, FOB USA). An evaluation kit is available to speed design efforts.



Six-output power-supply ICs power satellite phones

The MAX886*/MAX888 are high-efficiency, 6-output power supplies for wireless handsets such as satellite phones and private mobile radios. These highly integrated power-management systems include a 500mA step-down DC-DC converter, +5V regulated charge pump, power-on reset, start-up timer, and four low-dropout (LDO) low-noise linear regulators. Output voltages for the main converter and LDOs are set by an I^{2}C™/SMBus™-compatible serial interface.

The MAX886 main output voltage, programmable from 2.5V to 3.8V, is intended for systems powered by two Li-Ion batteries. The MAX888 main output voltage, programmable from 1.5V to 3.0V, is intended for systems powered by a single Li-Ion battery.

The main DC-DC converter supplies up to 500mA with efficiencies as high as 94%. The 200mA LDO powers the section for digital signal processing. Two 100mA LDOs power and isolate the Rx/Tx IF sections, and the 20mA LDO powers a +5V or +3V SIM card. The regulated charge pump supplies +5V for the LCD display.

Both devices operate in low-noise PWM mode with a programmable fixed frequency of 375kHz, 535kHz, 670kHz, or 925kHz. They can also be synchronized to an external clock. The quiescent current is a low 250µA, even with all devices on. A single on/off pushbutton controls the shutdown, reducing the supply current to only 5µA. The ICs also feature thermal shutdown and a low-battery detector with hysteresis.

Preassembled evaluation systems (MAX886EVSYS and MAX888EVSYS) are available with recommended external components to reduce design time. Also included with these systems is an I^{2}C/SMBus-compatible interface board with Windows software, which lets you control the programmable features via the parallel port of a PC. The MAX886ECJ and MAX888ECJ come in space-saving 32-pin TQFP packages only 9x9mm square, with prices starting at $4.70 (1000-up, FOB USA).

**Future product—contact factory for availability.*
SMBus is a trademark of Intel Corp.

NEW PRODUCTS

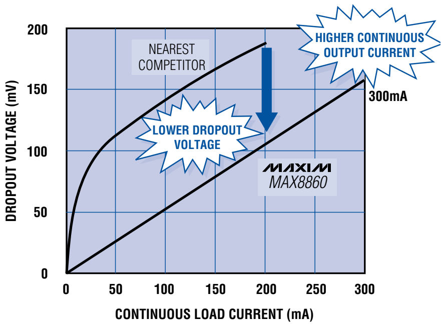
LDO regulator in µMAX guarantees 300mA output current

The MAX8860 is a low-dropout (LDO) linear regulator that guarantees up to 300mA output current when generating 1.8V to 3.0V from a +3.3V supply. This performance is needed by cell phones and other wireless communication systems to power DSP, baseband analog, and synthesizer/VCO sections. Less than 1.1mm high, the MAX8860 comes in a µMAX package that occupies only half the board area of an 8-pin SO.

A P-channel MOSFET output maintains low supply current (165µA) and low dropout voltage (105mV at 200mA) for any load up to 300mA. (For linear regulators with PNP outputs, the supply current at full load can be several milliamps.) To further conserve power, a logic-controlled shutdown reduces the supply current to less than 1µA.

The FAULT output indicates a loss of regulation due to dropout, current overload, or thermal shutdown. The internal FAULT threshold tracks dropout voltage with load current, extending battery life by allowing operation with a terminal voltage several hundred millivolts lower than is achievable with simple low-battery comparators. Other features include reverse-battery polarity protection and a very low noise of 60µV_{RMS}. The MAX8860EUA comes in a small 8-pin µMAX package, with prices starting at $0.89 (1000-up, FOB USA).

LOWEST DROPOUT AND HIGHEST OUTPUT CURRENT



SOT23 switched-capacitor voltage inverters have 1nA shutdown

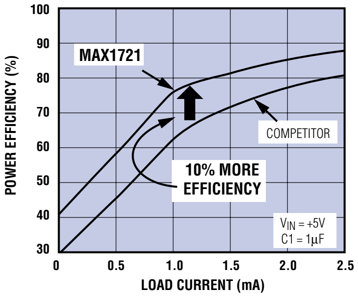
The MAX1720/MAX1721 charge-pump inverters are ultra-small monolithic CMOS devices that accept input voltages in the +1.5V to +5.5V range. High efficiency (to 99.9%), small external components, and a logic-controlled 1nA shutdown make these devices ideal for use in battery-powered and board-level voltage converters. In a typical MAX1720/MAX1721 application, the chip generates a -3.3V analog-supply voltage from a +3.3V logic supply.

The MAX1720 operates at 12kHz with a 50µA quiescent current, and the MAX1721 operates at 125kHz. Both include oscillator-control circuitry and four power-MOSFET switches. Both are capable of delivering 25mA continuous output currents.

For applications that don't require shutdown, consider the pin-compatible MAX828/MAX829 and MAX870/MAX871 voltage inverters, which come in 5-pin SOT23 packages. The MAX860/MAX861, which deliver up to 50mA and reside in tiny µMAX packages, can provide more power. The MAX868, also in a µMAX package, generates regulated outputs up to -2V_{IN}.

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

HIGHEST EFFICIENCY & SMALLEST CAPACITORS



3V/5V, ±15kV ESD-protected RS-232 transceivers don't need external components

The MAX3233E/MAX3235E are complete RS-232 dual transceivers with enhanced electrostatic discharge (ESD) protection. The MAX3233E/MAX3235E are +3.3V/+5V-powered EIA/TIA-232 and V.28/V.24 communication interfaces with automatic shutdown/wake-up features, high data-rate capabilities, and enhanced ESD protection. All transmitter outputs and receiver inputs are protected to ±15kV using IEC 1000-4-2 Air-Gap Discharge, ±8kV using IEC 1000-4-2 Contact Discharge, and ±15kV using the Human Body Model.

Both devices have internal dual charge pumps requiring no external capacitors. They have a proprietary low-dropout transmitter output stage, enabling true RS-232 performance from a +3.0V to +3.6V supply (MAX3233E) or from a +4.5V to +5.5V supply (MAX3235E). Both devices achieve a 1µA supply current using Maxim's innovative AutoShutdown Plus™ feature, and data transmission at 250kbps is guaranteed.

The MAX3233E/MAX3235E are available in both the commercial (0°C to +70°C) and extended industrial (-40°C to +85°C) temperature range, in 20-pin SO and DIP packages. Prices start from $3.59 (1000-up, FOB USA).

AutoShutdown Plus is a trademark of Maxim Integrated Products.

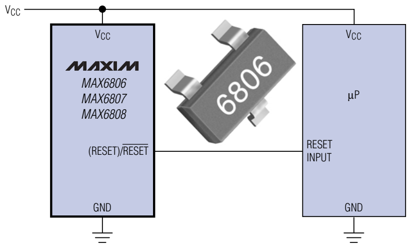
NEW PRODUCTS

First SC70 voltage monitors occupy virtually no board space

The MAX6806/MAX6807/MAX6808 are the first voltage monitors available in the miniature SC70 package. (This new package measures only 2.0x2.1mm, almost half the size of a SOT package.) By asserting a RESET output, the devices inform a microprocessor or microcontroller when the supply voltage drops below a preset value. A manual reset output, available in the 4-pin SOT143 package, enables system RESETs from an external source. Because they require no external components, these ICs improve the cost and reliability of a system.

These ±2%-accurate devices have built-in hysteresis that ensures stable switching. The MAX6806 features an active-low push-pull RESET, the MAX6807 features an active-high push-pull RESET, and the MAX6808 features an active-low open-drain RESET. All are available in versions with reset thresholds of 2.6V or 4.6V. The MAX6808 also has a 2.3V version.

Package options include the 3-pin SC70, 3-pin SOT23, and 4-pin SOT143 (with manual reset). Prices start at $0.87 for 3-pin devices and $0.94 for 4-pin devices (2500-up, FOB USA).



( ) ARE FOR MAX6807

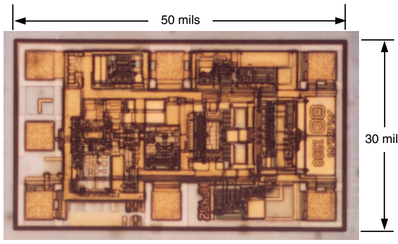
2.5Gbps SiGe TIAs slash power at 3.3V

The MAX3267 (2.5Gbps) and MAX3266 (1.25Gbps) transimpedance amplifiers (TIAs) were developed with SiGe process technology to address the need for high performance at low power (3.3V, 86mW) and low cost. They are the first SiGe transimpedance amplifiers available for the fiber optic marketplace. Used in gigabit ethernet and fibre-channel optical-receiver applications, these high-gain amplifiers convert photodetector output currents to usable output voltages.

The MAX3266/MAX3267 consume only 86mW at 3.3V, which is 5 to 10 times less than that of competing ICs. The 2.5Gbps MAX3267 has a 1900MHz bandwidth, 485nA input-referred noise, and 1900Ω transimpedance. Its typical optical dynamic range is -21dBm to 0dBm in an 850nm shortwave configuration, and -24dBm to -3dBm in a 1300nm long-wave configuration.

The 1.25Gbps MAX3266 has a 920MHz bandwidth with 200nA noise and 2800Ω transimpedance. Its typical optical dynamic range is -24dBm to 0dBm in a shortwave configuration, and -27dBm to -3dBm in a long-wave configuration. The wide dynamic range of these parts provides 3dB to 6dB of design margin over gigabit ethernet requirements. This feature results in higher manufacturing yields for the optical-receiver assembly.

Both TIAs measure only 50x30mils, and their space-saving, on-chip compensation capacitors and photodiode filter resistors support assembly in TO-style headers. The MAX3266/MAX3267, available as die or in 8-pin SO packages, have identical pinouts for easy performance upgrades. Prices start at $4.00 (100,000-up, FOB USA). Assembled evaluation kits (MAX3266EVKIT and MAX3267EVKIT) are available to shorten the design cycle.



MAX3267

SDH/SONET 1:16 deserializer operates at 2.488Gbps

The MAX3880 1:16 deserializer provides clock recovery while converting 2.488Gbps serial data to 16-bit-wide, 155Mbps parallel data for SDH/SONET applications. Operating from a single +3.3V supply, it accepts high-speed serial data and delivers parallel clock and data outputs in low-voltage differential-signal (LVDS) format. The operating power is 920mW.

The MAX3880 includes a low-power clock-recovery and data-retiming function for 2.488Gbps applications, and an additional 2.488Gbps serial input for system-loopback diagnostic testing. Its fully integrated phase-locked loop recovers a synchronous clock signal from the serial-NRZ data input. The recovered clock then retimes the data signal. Jitter performance exceeds all SDH/SONET specifications. Also included is a TTL-compatible loss-of-lock monitor (LOL), and an LVDS-synchronization input that enables data realignment and reframing.

The MAX3880 is available in a 64-pin TQFP EP (exposed paddle) package.

NEW PRODUCTS

622Mbps SDH/SONET laser driver features auto power control

The MAX3668 is a complete laser driver for SDH/SONET applications up to 622Mbps. It operates on a single +3.3V to +5V supply, and draws only 38mA at 3.3V. It accepts differential PECL inputs, provides bias and modulation currents, and operates from -40°C to +85°C. The device complies with ANSI, ITU, and Bellcore SONET/SDH specifications.

Internal feedback for automatic power control (APC) maintains a constant average optical power over temperature and over lifetime. For ease of use, the modulation current is programmable from 5mA to 75mA, and the bias current is programmable from 1mA to 80mA. The MAX3668 also includes an ENABLE control and a FAIL output that indicates when the APC loop is unable to maintain the average optical power.

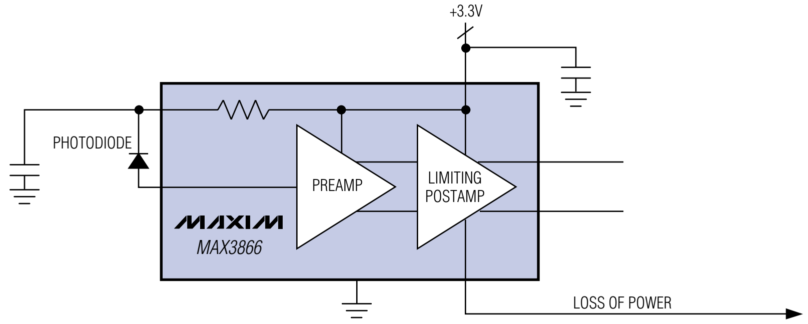
The MAX3668 is available in die form and in a 5mm-square TQFP package.

2.5Gbps, 3.3V transimpedance/ limiting amplifier runs on 165mW

The MAX3866 combines a transimpedance amplifier with a limiting amplifier, thereby eliminating one IC in SDH/SONET applications. Operating at 2.488Gbps, the device draws only 165mW with a +3.3V supply—less than half the power required in comparable discrete-component circuits. The device achieves an input sensitivity better than -22dBm. It also achieves an error rate of 10^{-10} bit, provided the input sensitivity is less than or equal to -22dBm.

The MAX3866 guarantees an overdrive capability of at least 1.4dBm. In conjunction with -22dBm input sensitivity, this wide input range suits the device for both long-haul and short-haul applications. Wide analog-input bandwidth (1.8GHz) optimizes the MAX3866 for 2.488Gbps applications without increasing noise. A TTL-programmable loss-of-power (LOP) indicator monitors line performance, and LOP hysteresis (3dB) eliminates false triggers.

The MAX3866 is available in die form, with performance guaranteed for junction temperatures in the -40°C to +120°C range.

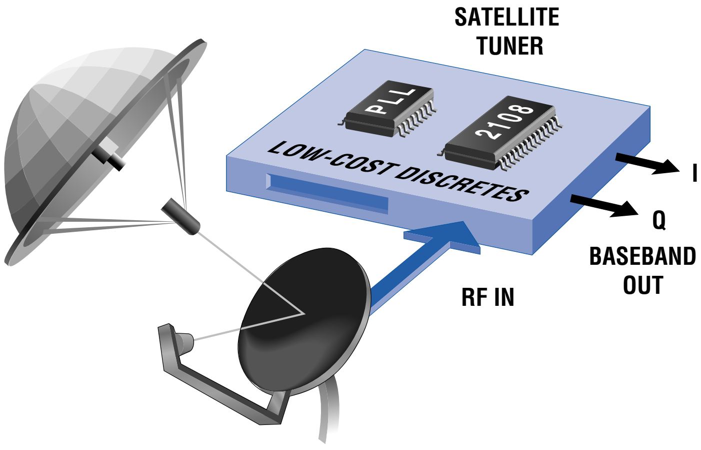


8dBm IIP3, zero-IF satellite tuner cuts system cost

The MAX2108 is a zero-IF digital satellite tuner IC that directly downconverts L-band signals to baseband I/Q channels. Compared with the traditional superhet approach, this device lowers the system cost dramatically by eliminating an IF local oscillator, IF mixer, and SAW filter.

The high 8dBm IIP3 at minimum gain allows the RF input to be directly connected through a matching network to the F-connector of a 75Ω cable, without the need for a pin-diode attenuator and amplifier.

Also included on-chip are a low-noise amplifier with automatic gain control, I/Q downconverting mixers, a 90° phase shifter, and baseband buffers. The MAX2108 is specified for the commercial temperature range (0°C to +70°C), and is available in a 24-pin QSOP package. Prices start from $4.00 (10,000-up, FOB USA).



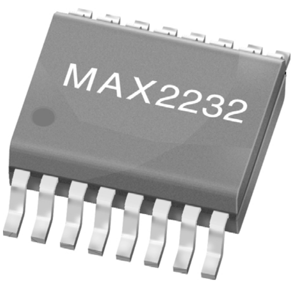
NEW PRODUCTS

900MHz, 250mW, silicon power amplifiers feature A/D gain control

The MAX2232/MAX2233 are 900MHz, 250mW, low-voltage, silicon power amplifiers (PAs) featuring analog and digital (A/D) gain control. The MAX2232 offers a continuously adjustable 24dB range; the MAX2233 offers two discrete 10dB steps via an internal, 2-bit, programmable gain control DAC. Both devices are capable of delivering 250mW (+24dBm) of output power at 915MHz from a single +3.6V supply, at a power-added efficiency (PAE) of 44%.

The MAX2232/MAX2233 also feature autoramping output capability. During turn-on and turn-off periods, the RF output is controlled by an external capacitor to gradually ramp up and down, minimizing unwanted output transient noise and spectral splatter. A low-power shutdown mode reduces the supply current to 0.2µA, saving power during “idle slots” in TDMA systems. In addition, a thermal-shutdown function protects the PA from excessive temperature conditions.

These PAs are designed for low-cost 868MHz/900MHz ISM band-applications. They operate from a single +2.7V to +5.5V supply, eliminating the need for the negative bias and sequencing circuitry required in GaAs MESFET designs. They are available in a space-saving, thermally enhanced 16-pin Power QSOP package. Prices start from $2.66 (1000-up, FOB USA). Fully assembled evaluation kits (MAX2232EVKIT/MAX2233EVKIT) are available to help reduce design time.



SOT temp sensor allows multidrop capability of up to eight ICs on a single wire

The MAX6575L/H temperature sensor features a unique single-wire digital interface that allows a microprocessor to interface with up to eight sensors using a single control line. Temperatures are sensed by measuring the time delay between the falling edge of an external triggering pulse and the falling edge of subsequent delays reported from the devices. Different sensors on the same I/O line use different timeout multipliers to avoid overlapping signals.

The MAX6575L/H features ±3°C accuracy max (±0.8°C typical) at +25°C and ±5°C accuracy max at +125°C. It operates from a +2.7V to +5.5V supply and features a low 150µA supply current, making the MAX6575L/H ideal for use in portable, battery-powered equipment.

The devices differ in that the MAX6575L version provides four delay ranges less than 50ms, and the MAX6575H version provides four delay ranges greater than 50ms. These delays are selectable by using the two time-select pins on each chip.

The MAX6575LZUT/MAX6575HZUT come in space-saving 6-pin SOT23 packages that are guaranteed to operate over the automotive temperature range (-40°C to +125°C). Prices start from $0.81 (2500-up, FOB USA).

Dual-alarm, remote/local temp sensor has SMBus interface

The MAX1619 is the first remote temperature sensor with remote dual-alarm outputs, one of which can be used to activate CPU fan control without system intervention. The MAX1619 is a precise digital thermometer (3°C remote accuracy, 2°C local accuracy) that measures the die temperature directly via an on-chip CPU thermal diode, replacing conventional thermistors or thermocouples. This allows the highest possible clock rates while keeping within the CPU thermal envelope. The remote overtemperature output is an unlatched, open-drain output that behaves as a thermostat; it can directly control a fan to reduce heat buildup, improve efficiency, and protect notebook computers against potentially destructive thermal overloads.

The 2-wire serial interface accepts standard SMBus™ Write Byte, Read Byte, Send Byte, and Receive Byte commands to program the alarm thresholds and read temperature data. Measurements can be taken automatically and autonomously, with the conversion rate programmed by the user or programmed to operate in a single-shot mode.

The MAX1619 is available in a space-saving 16-pin QSOP package and is guaranteed for the military temperature range (-55°C to +125°C). Prices start from $2.96 (1000-up, FOB USA). A preassembled evaluation kit (MAX1619EVKIT) is available with recommended external components to reduce design time.