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News Briefs

MAXIM REPORTS RECORD REVENUES FOR THE FOURTH QUARTER 1993

Maxim reported record net revenues of $30,100,000 for the fourth quarter of fiscal 1993, compared to $23,300,000 for the same period a year ago. This represents a 29.2% gain in net revenues from the same quarter a year ago. Net income of $4,730,000 (or $0.31 per share) for the quarter marked the 29th consecutive increasingly profitable quarter for Maxim compared to net income of $3,680,000 (or $0.25 per share) for the same quarter in fiscal 1992.

Operating income for the quarter was 23.2% of net revenues, again one of the industry's highest. Gross margins increased to $17,338,000 (57.6% of net revenues) from $13,608,000 (58.4% of net revenues) for the same quarter in fiscal 1992.

Net revenues for the fiscal year ending June 30, 1993 were $110,184,000, up 26.7% from fiscal 1992. Fiscal 1993 net income rose 26.4% to $17,282,000 compared with $13,673,000 in fiscal 1992. Earnings per share for fiscal 1993 increased $0.21 to $1.15. Gross margins increased to $63,343,000 (57.5% of net revenues) from $49,119,000 (56.5% of net revenues) in fiscal 1992. Cash was up $15,393,000 during the year.

Jack Gifford, Chairman, President and Chief Executive Officer, commented, "Effectively managing a 6,000 line item, highly fragmented, niche oriented inventory is a difficult goal we set for ourselves every year. We are particularly proud of the fact that while net revenues finished 26.7% higher than fiscal 1992, inventories increased only 2.1%."

"Maxim announced 23 new products during the quarter. This makes 87 products introduced in fiscal 1993, compared to 76 products introduced in fiscal 1992 and 62 products in fiscal 1991. Each year, our target marketing for each product has improved, and the value-added in each product has increased. Both factors continue to increase the annual revenues of the new products introduced during the year."

"Our reputation for solving tough analog design problems has grown steadily over the last 10 years, as Maxim has continued to introduce more new products than any other analog company (596 to date). Of the 225 products introduced in the last three years, 187 (or 83%) were proprietary! I believe Maxim's reputation in the design community is largely attributable to our proprietary products. Companies of all sizes, worldwide, are looking to us for the valuable solutions these products provide. This has created a repository of financial strength for Maxim that we plan to continue to build by investing in R&D and Marketing (up 27.0% this quarter over the same quarter in fiscal 1992). These proprietary products generally generate higher gross margins and comprise the cornerstone of Maxim's competitive position in the marketplace."

1994 NEW RELEASES DATA BOOK

Over 200 of Maxim's newest products are included in the 1994 New Releases Data Book–available now! This up-to-date data book is your easy reference to Maxim's latest products: it contains new product data sheets, plus cards for free samples. Don't go without it. Contact Sheila Lolli at (408) 737-7600, ext 6087 to order your copy today.

Fault-tolerant CMOS multiplexers offer "best-buy" protection

All analog multiplexers act as the solid-state equivalents of digitally controlled rotary switches. But multiplexers at the interface between an electronic system and its environment have an additional function—they act as insurance policies against malfunction and damage.

Designers may control the system, but input multiplexers contend with everything outside the system—poor installation, careless operators, and electrical noise. They must operate correctly in the presence of ground loops, electrical interference from motors and engines, and unintentional inputs such as 240VAC.

In the following discussion, a particular design (the serial-MOSFET switch) emerges as the most economical choice in overcoming these problems. Other designs offer overvoltage protection alone, but only the serial-MOSFET approach combines overvoltage and fault tolerance without the need for external components. Serial-MOSFET multiplexers are available from Maxim.

Multiplexer construction

The switches in common multiplexers have been designed the same way for nearly twenty years: each consists of an n-channel and p-channel MOSFET connected in parallel on a silicon substrate, and driven with opposite-polarity gate-drive voltages (**Figure 1a**). This connection provides a symmetrical signal path through the parallel source-to-drain resistances, producing a characteristic double hump in the curve of on-resistance vs. input voltage (**Figure 1b**). (Many designs minimize this effect by driving the body connection of the n-channel MOSFET with signal voltage.)

The presence of each device polarity guarantees that at least one of the two MOSFETs will conduct for any input voltage between the supply rails. Thus, the multiplexers can handle any signal level that falls between the rails.

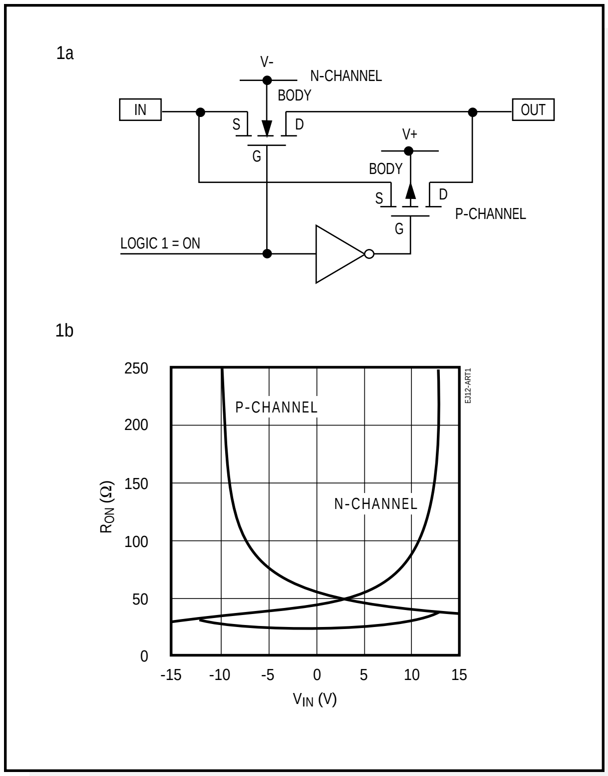


Figure 1**. The traditional CMOS analog switch is a transmission gate* **(a), whose on-resistance vs. signal voltage characteristic exhibits a double hump as shown* **(b)**.

A multiplexer switch ceases to be a switch, however, when signal voltage exceeds either supply rail. Each switch includes two parasitic diodes, intrinsic to the MOSFET source and drain structures, which provide current paths to the rails (**Figure 2**). Both diodes are reverse-biased during normal operation, but any signal excursion beyond the rails applies forward bias to one of the diodes, clamping the signal at 600mV beyond the rail. Because the diodes are present when power is removed, they also clamp (at ±600mV) when the rails are at zero volts.

Parasitic diodes provide a useful clamping function, but they also introduce problems. Excessive current in the diodes can cause overheating and damage in the signal source as well as the multiplexer (**Figure 3**). Somewhat lower levels of current (below that of overheating and damage) can still cause latchup in the multiplexer. And once it crosses a diode junction, the fault current becomes a flow of injected minority carriers that "spray" into the silicon substrate. Collected by other switching devices, this current can induce an error voltage in every channel.

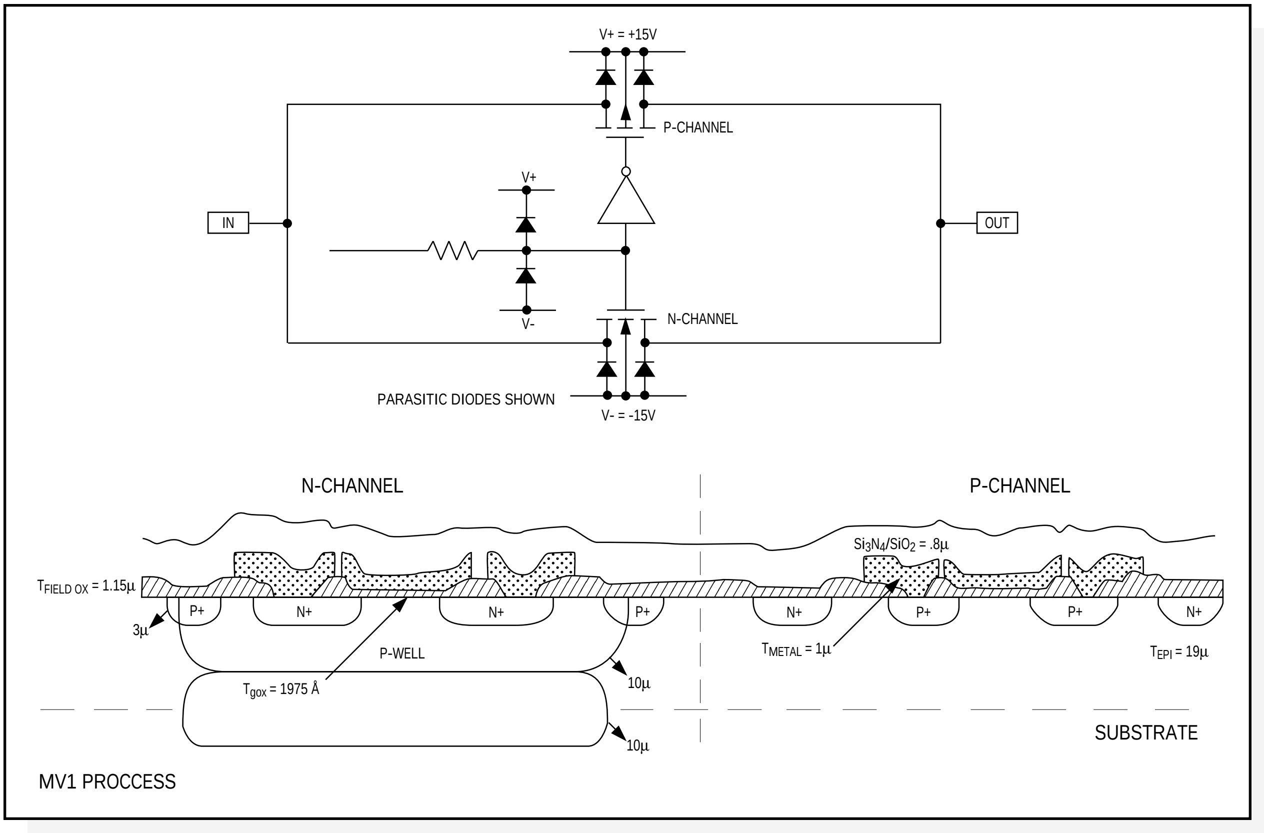


***Figure 2**. A closer look at the transmission-gate MOSFETs shows parasitic diodes tied to the supply rails.*

Turning on a parasitic diode clamps the multiplexer output to one supply rail—an action that can damage external circuits connected to that output. The cause of damage may not be obvious, but an output transient (to the rail) caused by momentary overvoltage at the multiplexer can destroy an A/D converter's input, or cause differential overload and long settling times in an op amp.

Protecting the multiplexer

Several design measures offer protection for a CMOS multiplexer and its associated external circuits. These measures include connecting a resistor in series with each channel input, connecting diode-resistor networks to control the fault effects, and choosing a multiplexer whose architecture and process technology provide fault-tolerant properties.

The simplest form of protection adds series resistors that work in conjunction with the internal protection diodes (**Figure 4**). The resistor values are critical because they present a tradeoff: larger values give more protection but introduce greater signal errors.

Leakage current into the multiplexer also flows through the series resistors, causing an error voltage that worsens with temperature (the leakage doubles for each 8°C increase above ambient). Lowering the resistor values can reduce this error to an acceptable level, but the lower value may allow too much diode current, threatening latch-up in the multiplexer. As a rule, unless otherwise specified in the data sheet section on absolute maximum ratings, you should limit the diode current to 20mA continuous or 40mA peak.

Low leakage currents can offset this drawback of large protection resistors. New, ultra-low-leakage multiplexers from Maxim (MAX328 and MAX329) have extended the design limits for series-resistor protection over those for earlier-generation multiplexers. The new devices' low leakage (±1pA at 25°C; ±20nA at 125°C) allows very high-valued protection resistors. Resistors of 150kΩ, for example, admit fault currents of only 1mA while withstanding ±150V inputs. At ±1500V, they admit fault currents of only ±10mA. The resistors produce only ±3mV of additional error at 125°C.

Note that ±1500V protection resistors require 15W ratings for continuous duty. But, in most applications you can scale this thermal rating considerably because the overvoltage has a much lower duty cycle. External resistors thus offer flexibility—you can choose different resistor values for different channels in the same device, and scale their power ratings as required. Integrated resistors, on the other hand, are constrained by their package power rating; this rating may limit the number of channels that can withstand overvoltage at the same time.

The series-resistor approach protects the multiplexer, but it doesn't prevent corruption of signals in the selected channel. These signals are at the mercy of overvoltage in any of the unselected channels. But the direct cause isn't overvoltage; it's fault current (the injected minority carriers mentioned earlier) flowing into the substrate via one or more protection diodes. Eliminate that substrate current and you eliminate the gross signal errors.

One way to handle the fault current is to divert it into an external network (**Figure 5**). Two zener diodes produce ±12V clamp levels, centered within the multiplexer's ±15V supply rails. Then, instead of flowing through an internal protection diode, the fault current due to overvoltage on any channel flows through one of the two external protection diodes for that channel.

Though it offers excellent protection, this technique requires a large number of external components. And, the external diodes produce additional leakage current that precludes use of the high-valued series resistors discussed earlier. The external components represent extra board space, not to mention the cost of purchase, test, through-hole assembly, and inventory. A better solution is to integrate this protection with the multiplexer, on a single chip.

Fault-tolerant multiplexers

Fault-tolerant multiplexers require no external components, yet are capable of withstanding high levels of overvoltage without corresponding high levels of fault current. They achieve this protection with an internal design that is quite different from that of conventional multiplexers.

Each switch in a fault-tolerant multiplexer is actually a series connection of three MOSFETs, in the order n-channel/p-channel/n-channel (**Figure 6a**). Internally generated drive voltages turn the switch on by simultaneously driving the n-channel gates to the

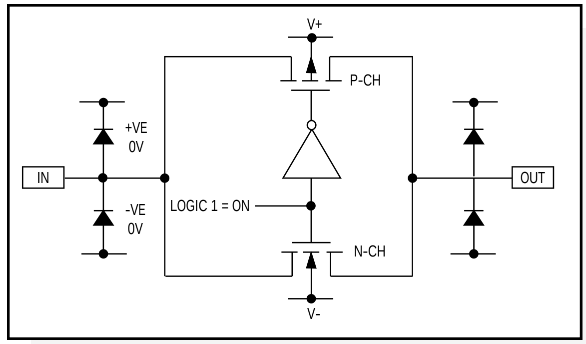


Figure 3. *Parasitic diodes provide a path for fault current when a conventional analog switch is exposed to overvoltage.*

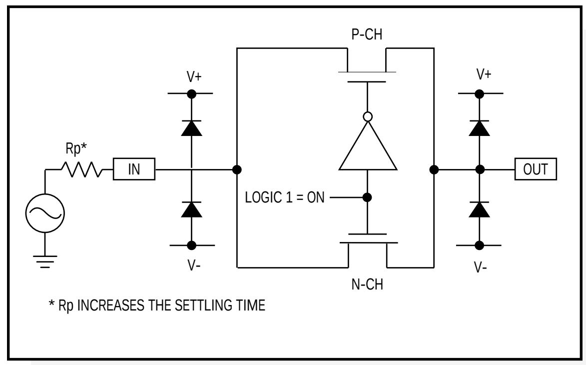


Figure 4. *Adding a series resistor to the switch of Figure 4 limits fault current, but it also adds to the switch resistance and lengthens settling time.*

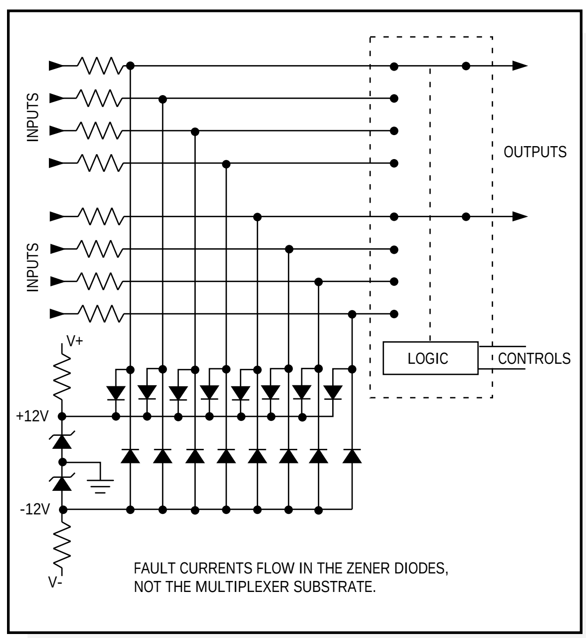


Figure 5. *Fault protection for a conventional multiplexer entails current-limiting resistors, two zener diodes for a bipolar clamp-voltage network, and dual clamp diodes for each channel.*

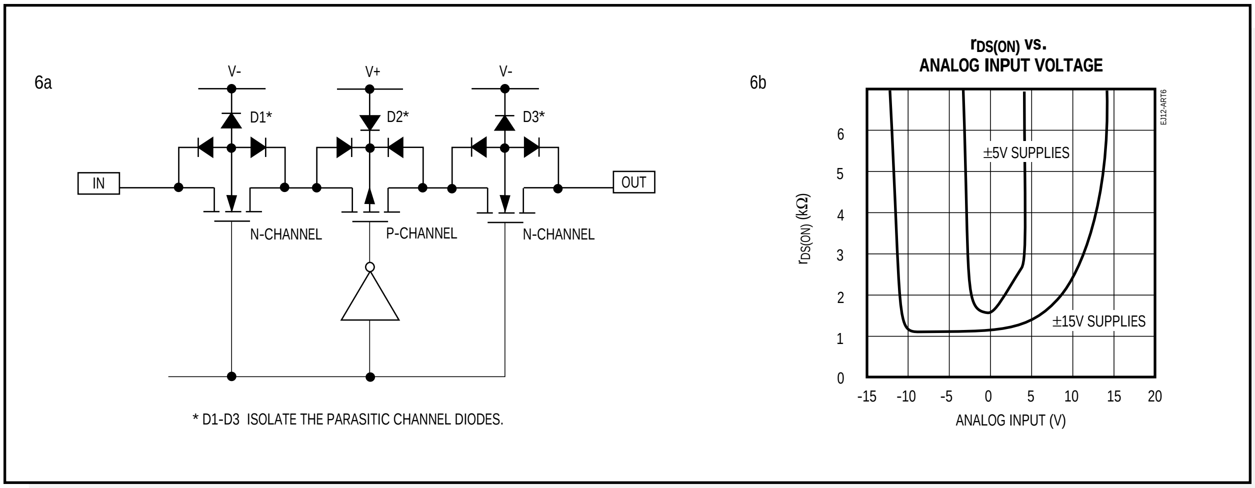


***Figure 6**. The 3-MOSFET switch element of a fault-tolerant multiplexer **(a)** has an on-resistance characteristic shaped like a bathtub **(b)**.*

positive rail and the p-channel gate to the negative rail. The switch then remains on for as long as the analog signal (which modulates the gate-source voltages) remains within limits set by the n- and p-channel gate-source thresholds.

Typical gate-source thresholds are 1.5V for n-channel devices and 3V for p-channel devices. Therefore, with ±15V supplies the thresholds confine a multiplexer's input signals to the range -12V to 13.5V. Because one of the three MOSFETs in a switch begins to turn off as the signal exceeds either limit, the switch on-resistance versus input voltage assumes a characteristic "bathtub-shaped" curve (**Figure 6b**).

The resulting high impedance in the off state is very convenient: the switch is off, blocking the overvoltage, and fault current is virtually zero. Substrate (fault) current flows only as a result of avalanche, which occurs when the overvoltage exceeds a limit set by the MOSFETs' geometry and doping levels.

Below the avalanche limit, signals in the selected channel remain unaffected because the overvoltage produces no substrate current (**Figure 7**). The series-connected switch also turns off when power is removed. This behavior simplifies the design of redundant systems, because multiplexers connected to common signal lines can be powered down without loading the lines.

Maxim offers several series-structure multiplexers: The MAX358 and MAX359 devices (1-of-8 and dual 1-of-4) withstand overvoltages to ±35V, and the MAX378 and MAX379 are similar devices that withstand overvoltages to ±75V. MAX368 and MAX369 add latched address inputs to the basic 35V-tolerant models, and the new MAX388 and MAX389 are latched models that withstand ±100V. The non-latched devices are pin compatible with industry-standard multiplexers DG508/509; the latched devices are pin compatible with the latched models DG528/529.

As shown earlier in Figure 5, conventional multiplexers such as the DG508/509 require numerous external components to duplicate the fault-tolerant capabilities mentioned in this article. MAX3XX devices not only save the cost and board area associated with external components, they offer capabilities not available in discrete-component circuits: MAX3XX devices always turn off when overvoltage is applied, but the switches of Fig. 5 remain on in the presence of overvoltage whether power is applied or not. The following (TABLE I) shows the cost advantages of fault-tolerant multiplexers vs. the non-protected DG508/509 alternatives:

TABLE I——Nonlatched multiplexers

	DG528/ DG529	MAX368/ MAX369	MAX388/ MAX389
Inherent O/V protection	NONE	±35V	±100V
Resale cost, 1k pcs	$1.78	$3.25	$3.75
External component cost and assembly	$2.15*	0.0	0.0
TOTAL SYSTEM COST	$3.93	$3.25	$3.75

**28 External components (x) .03 (+) 28 (x) 2 leads (x) .007*

Cost of the 10 resistors, 16 diodes, and two zeners in Figure 5 is about $0.92, based on purchases of 1k pieces or more. Plated-through holes are about $0.007 each, and the assembly cost for axial-leaded parts is about $0.03 per component. The resulting total for multi-component protection exceeds that of the simpler, single-IC protection offered by Maxim. External components also require five times more board area than the IC alone. The cost in Figure 5's circuit is even greater if you consider the cost of troubleshooting, reliability effects, and other hidden expenses.

All of TABLE I's ICs have an Absolute Maximum rating of 44V between the V+ and V- terminals, but increasing die sizes from left to right necessarily escalate the 1k-pc prices. To achieve reasonable on resistance, for example, the series MOSFETs in a 358/359 switch must be larger than the parallel MOSFETs in a 508/509 switch. And to achieve higher O/V protection, the series MOSFETs of the 378/379 must be larger still. Similar comments apply to the multiplexers that incorporate address latches (TABLE II):

TABLE II——Latched multiplexers

	DG528/ DG529	MAX368/ MAX369	MAX388/ MAX389
Inherent O/V protection	NONE	±35V	±100V
Resale cost, 1k pcs	$2.55	$3.75	$4.50
External component cost and assembly	$2.15	0.0	0.0
TOTAL SYSTEM COST	$4.70	$3.75	$4.50

The tables above show the actual cost of protected vs. unprotected multiplexers. In each case, a Maxim part with its built-in protection is more economical than the alternative—an inexpensive, unprotected multiplexer with a handful of discrete external components.

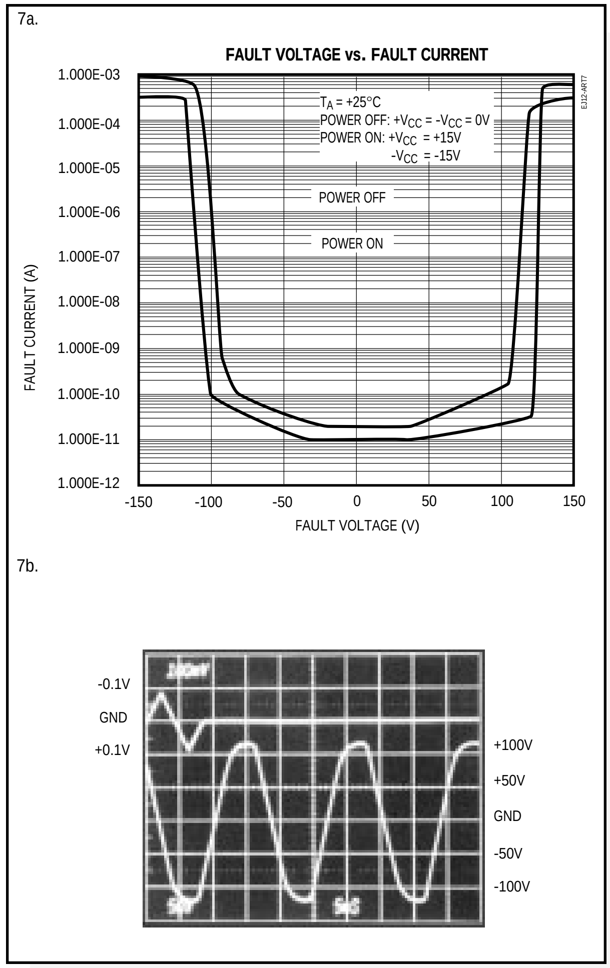


__Figure 7.__ The onset of avalanche (fault) current in a MAX388 multiplexer defines a fault-tolerant region of approximately ±100V (__a__). A 0V signal in the selected channel (__b__, top trace) is unaffected by ±100V applied to an off channel.

DESIGN SHOWCASE

48V-to-5V dc-dc converter borrows power from phone lines

The **Figure 1** circuit is not battery-powered in the usual sense—its power comes from a -48V lead-acid battery in a remote central office of the telephone system. The circuit is handy, though, for use in modems, telephone test sets, and other portable systems connected to subscriber (household) telephone lines.

For systems operating on 250mW or less, the circuit eliminates need for battery packs or ac adapters by drawing power from ordinary phone jacks. Built into peripheral equipment such as PCMCIA modem cards, the circuit can spare the main battery in a portable computer.

The current available from subscriber lines in the on-hook state is virtually zero. In the off-hook state, however, current is limited only by the sum of impedances in the central-office battery and the intervening telephone wires. Regulations such as Part 68 of the FCC rules do not restrict the current a subscriber can draw; you can even short out the line (which is what the hold button does). There is one condition: the off-hook current must exceed 20mA to ensure activation of a network-access relay in the central office.

For maximum power transfer, your impedance should match that of the line, but line impedance varies greatly, according to distance from the central office. Impedance matching is also in conflict with the need to draw at least 20mA. The 12V zener clamp, however, provides a termination that works well for line impedances up to 1700Ω. This line impedance sharply restricts the power available to you (**Figure 2**).

Because the circuit allows normal telephone communications while drawing power, it must block the switching noise (generated by IC1) from entering the hybrid transformer (not shown). Q1 and C1 perform this function by simulating an inductor that chokes off the noise currents. And, because the circuit sinks about 35mA regardless of the 5V load current, a "wet" hybrid transformer (one able to sink loop current) is not required. Instead, the hybrid can be a "dry" type with a smaller, lighter core.

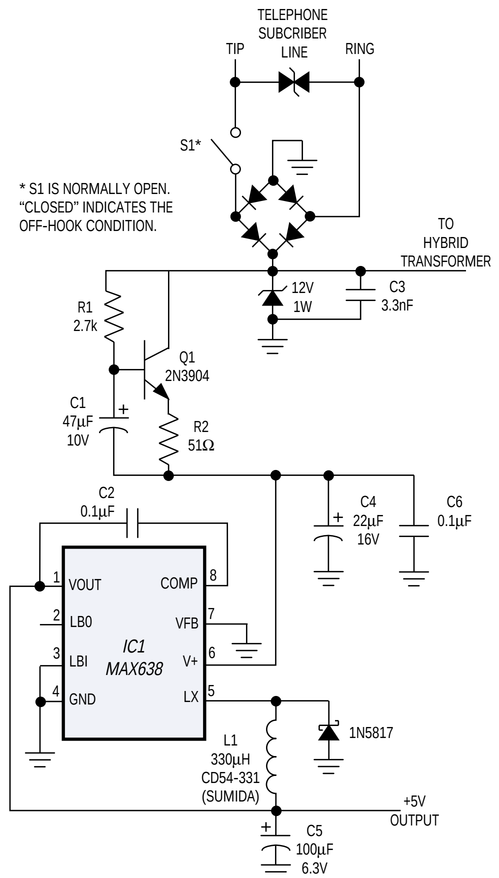


Figure 1. *This circuit draws line power in the off-hook condition and delivers as much as 250mW at the 5V output, while maintaining normal voice (or data) communications over the phone lines.*

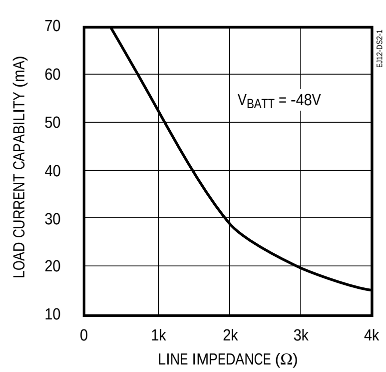


Figure 2. *Available power from the Figure 1 circuit declines steeply with line impedance.*

DESIGN SHOWCASE

Switch-mode battery charger delivers 5A

The fast-charge controller IC3 (**Figure 1**) normally directs current to the battery via an external pnp transistor. In this circuit, the transistor is replaced with a 5A switching regulator (IC1) that delivers equivalent power with higher efficiency.

IC1 is a 5A buck switching regulator whose output is configured as a current source. Its internal power switch (an npn transistor) is relatively efficient because $V_{CE(SAT)}$ is small in comparison with the 15V-to-40V inputs. (For applications that require 2A or less, the low-saturation, non-Darlington power switch of a MAX726 offers better efficiency.)

R6 senses the battery-charging current and enables IC3 to generate an analog drive signal at DRV. The signal is first attenuated by the op amp to assure stability by reducing gain in the control loop. It then drives IC1's compensation pin (VC), which gives direct access to the internal PWM comparator. IC3 thus controls the charging current via the PWM duty cycle of IC1. The Q1 buffer provides current to the DRV input.

Loop stability is also determined by the feedback loop's dominant pole, set by C4 at the CC terminal of IC3. If you increase the value of the battery filter capacitor (C5), you should make a proportional increase in the value of C4. Lower values, however, assure good transient response. If your application produces load transients during the fast-charge cycle, check the worst-case response to a load step. To assure proper termination of the charge, battery voltage should settle within 2msec to 5mV times N (where N is the number of battery cells).

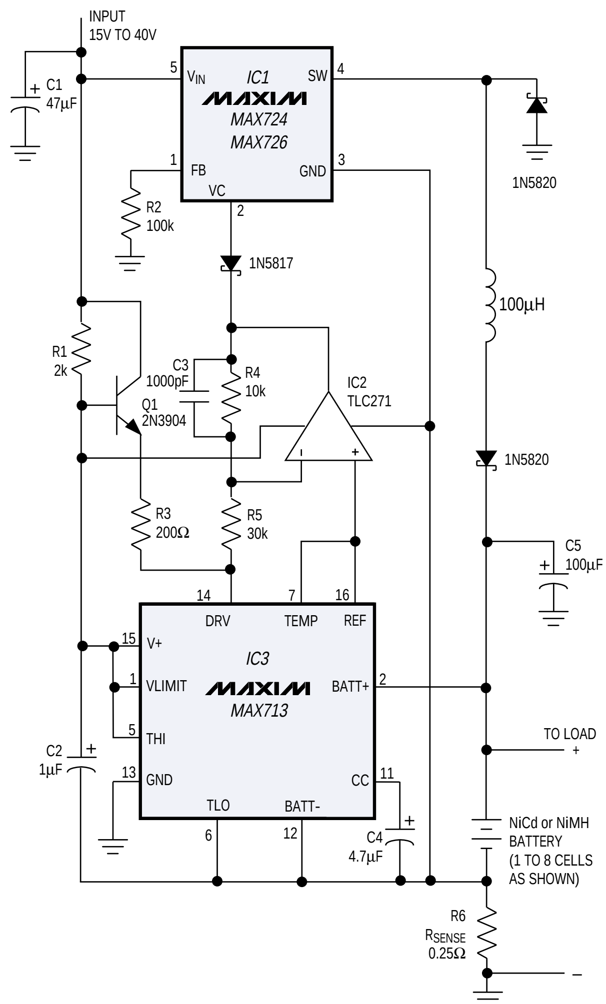


Figure 1. *By controlling the PWM duty cycle of switching regulator IC1, the fast-charge controller (IC3) makes efficient delivery of the battery's charging current.*

WTAs provide wideband, bidirectional drive for coaxial cable

Wideband coaxial systems can borrow a technique from the telephone network: telephones incorporate “hybrid circuits” based on transformers, which halve the cost of cable by enabling transmission and reception on the same twisted pair. You can build such voice-band circuits with op amps, but for megahertz bandwidths you need high-speed amplifiers and well-controlled impedances.

Programmable wideband transconductance amplifiers can provide such a wideband, bidirectional coaxial interface (**Figure 1**). This circuit is similar to the telephone interface and provides the same benefit—it saves the cost of a return cable. Though shown with 50Ω cables and terminations, the circuit applies equally well for inexpensive 75Ω video and other impedance levels.

Identical circuits terminate each end of the cable. Line-driver amplifiers IC_2 and IC_4 drive the coax, and return amplifiers IC_1 and IC_3 receive signals from the other end. Each return amplifier also cancels any signal originating at its end of the cable. Signal IN1, for example, drives the inverting input of IC_1 and the non-inverting input of IC_2. It passes unchanged through IC_2 but is inverted in passing through IC_1. Ideally, therefore, IN1 gets cancelled within IC_1 while IN2 comes through the coax and appears unaffected at OUT1. To achieve this cancellation, the amplifier transconductances (g_M) must be set for unity voltage gain throughout the system.

Several factors can degrade the cancellation. First, phase shift in the line driver prevents the return

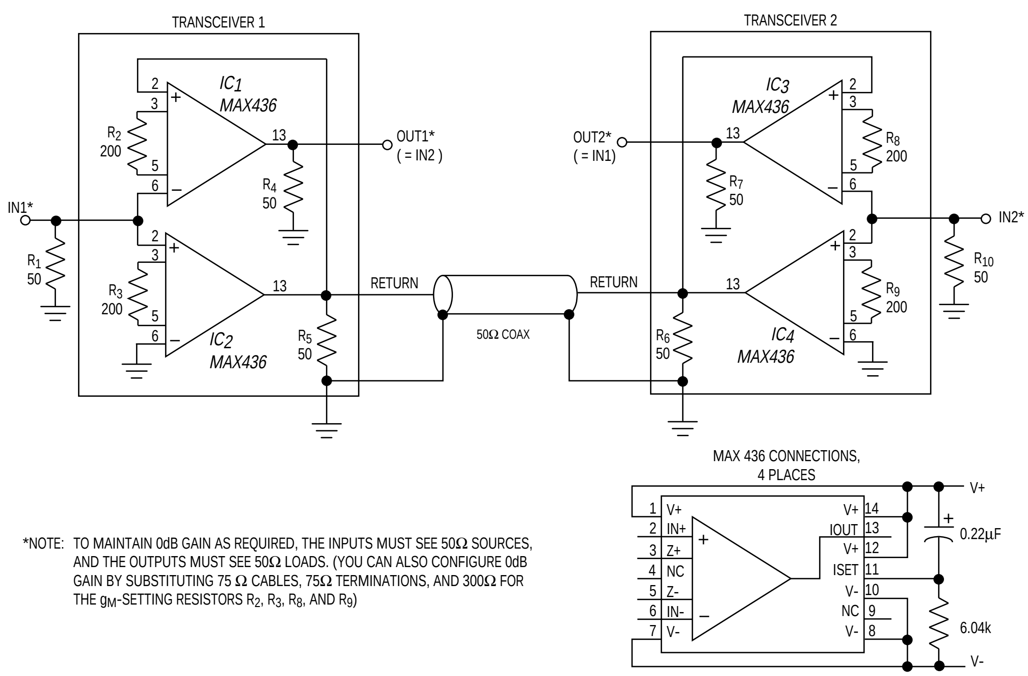


Figure 1. *Two transconductance amplifiers form a high-frequency coaxial-cable interface similar to the hybrid-circuit interface found in telephones.*

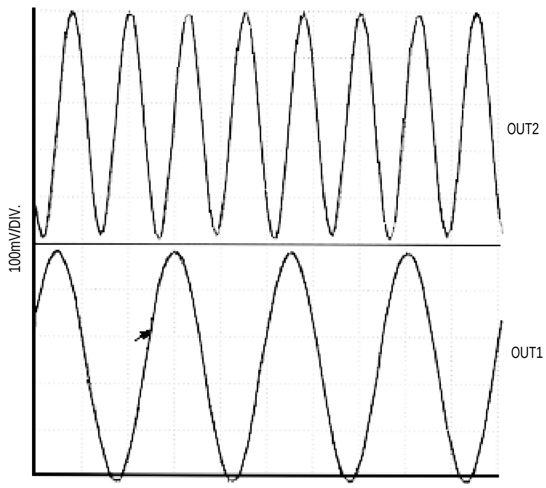


Figure 2. Outputs produced by driving Figure 1's IN1 and IN2 inputs at 2MHz and 1MHz.

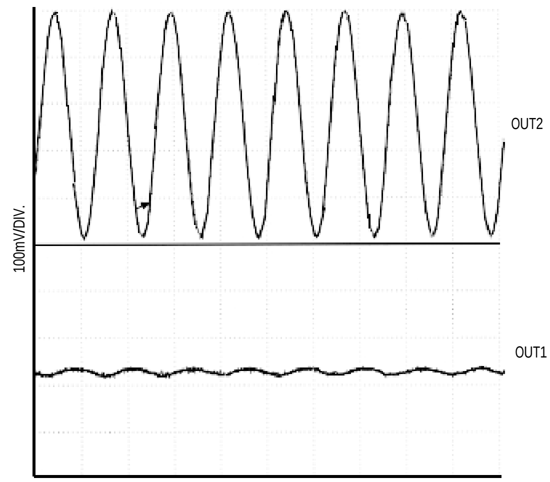


Figure 3. Replacing the IN2 generator of Figure 2 with a 50Ω terminator eliminates 1MHz at OUT1, leaving only the cancellation error due to 2MHz at IN1.

amplifier from subtracting identical signals. Second, any transconductance mismatch in the amplifiers causes the signals to have different amplitudes, again disturbing the output null. Third, any impedance mismatch along the cable causes signal reflections, and the non-adaptive circuits of Figure 1 cannot distinguish between such echoes and the desired incoming signal.

Signal cancellation depends on the tolerance of termination resistors R_1, R_5, R_6, and R_{10}, and their degree of mismatch with the cable impedance. Similarly, the g_M for each amplifier is affected by the g_M-setting resistors R_2, R_3, R_8, and R_9, where $g_M = 8/R$. The "8" factor is a property of the IC, and has a guaranteed tolerance of ±2.5%.

Figure 2 shows the system outputs with 50Ω generators driving IN1 at 2MHz and IN2 at 1MHz. The resulting large output signals (2MHz at OUT2 and 1MHz at OUT1) mask any cancellation errors that may be present. To see them, replace the IN2 generator with a 50Ω terminator and observe OUT1 (**Figure 3**). Similarly, to observe the IOUT2 leakage signal, replace the IN1 generator with a 50Ω terminator. In the circuit shown, 1% resistors provide an attainable cancellation of about 30dB for the low-megahertz range.

DESIGN SHOWCASE

Negative-output boost regulator has high efficiency

The circuit of **Figure 1** converts 5V to an adjustable output of -12V to -22V, suitable for use as a backplane-bias supply for LCDs. The circuit includes a switching regulator that boosts the input voltage to a high positive voltage (top of Q3), and a charge pump that converts this level to the negative output voltage. The scheme provides good load regulation and allows use of an economical, low-side, n-channel MOSFET switch (Q3). Efficiency (90% or so for the entire output range) surpasses that of most inverting-topology converters (**Figure 2**).

Q1 and Q2 form an SCR that turns on as the internal power switch (between the VS and LX terminals) turns off. The SCR action discharges the gate capacitance of Q3 so it can turn off quickly. Potentiometer R1 adjusts the output voltage.

If battery voltage exceeds the absolute value of output voltage, the output does not track the input as a normal boost regulator would do. Instead, the charge pump and feedback loop maintain the the correct output value, the cost being high noise and low efficiency (lower than that of an equivalent linear regulator).

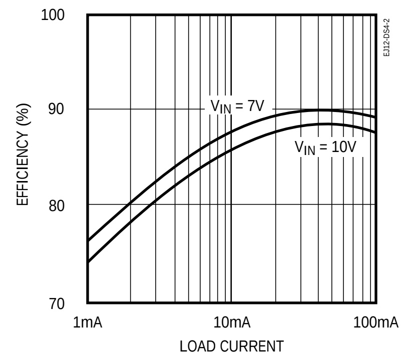


Figure 2. *The Figure 1 circuit exhibits excellent efficiency at higher load currents.*

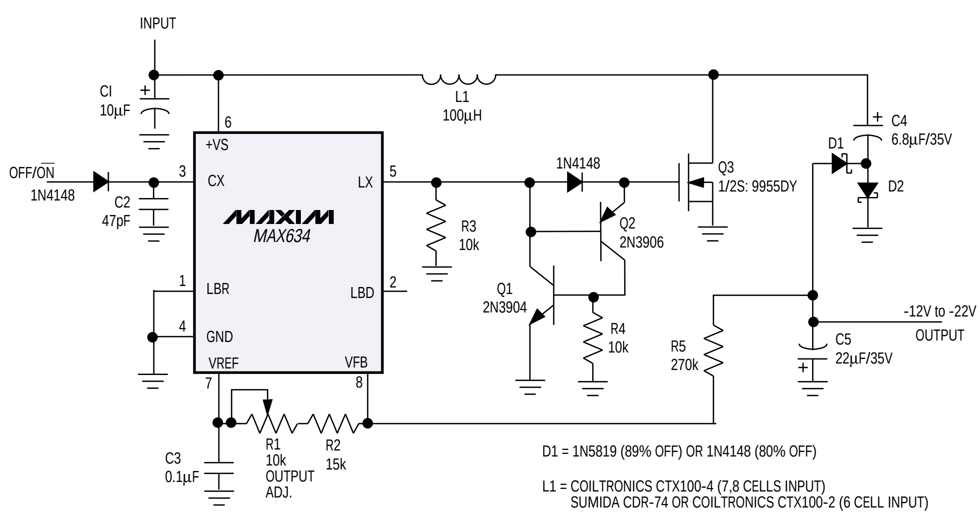


Figure 1. *This switching regulator operates with a discrete-component charge pump (D1, D2, C4, and C5) to produce an adjustable, regulated, negative output voltage.*

Negative buck regulator produces positive output

Though the step-down regulator of **Figure 1** normally converts a negative voltage to a lower negative voltage, this circuit's ground reference allows the output to be positive. The configuration works only if the battery terminals can float—a requirement that generally excludes systems in which multiple supply voltages are derived from the same battery.

Transistor Q1 translates the 5V feedback signal down to the level of CC (1.23V above the negative input voltage). The circuit's power switching transistor is on the low side rather than the high side, giving it an advantage over conventional buck regulators. N-channel power transistors are preferred in this application, and the low-side connection makes them easier to drive. (The MAX752 in this circuit, operating with an internal n-channel MOSFET, provides the same performance as a MAX738 with its equivalent but larger and more expensive p-channel MOSFET.)

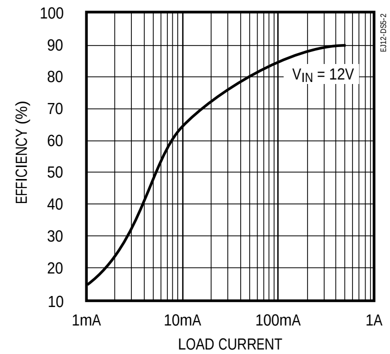


Figure 2. *Efficiency for the Figure 1 circuit increases with load current.*

The Figure 1 circuit supplies 500mA at 5V with excellent efficiency at higher currents (Figure 2). Quiescent supply current is 1.5mA, and the input-voltage range is -6V to -15V. The chip's 170kHz fixed-frequency oscillator allows small external components, and its current-mode PWM control provides precise regulation with low subharmonic noise.

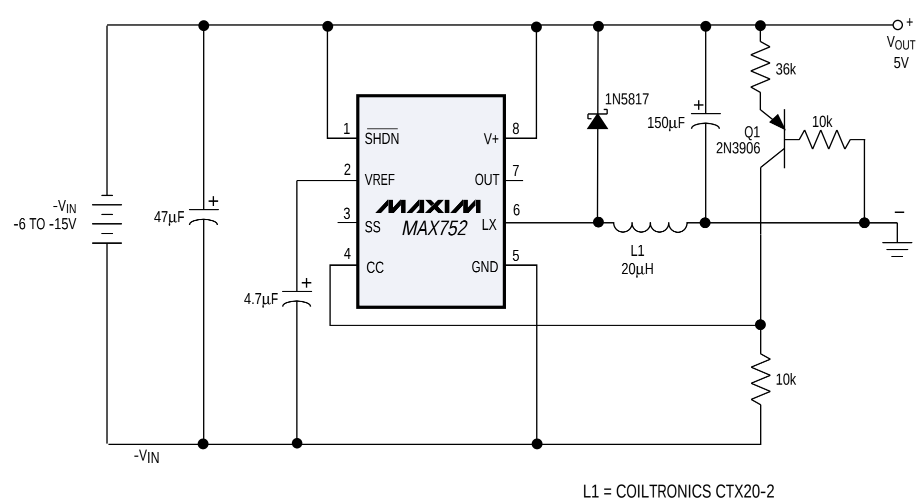


Figure 1. *A floating battery allows this negative buck regulator to produce a positive (5V) output.*

NEW PRODUCTS

QUAD, 8-BIT D/A CONVERTERS HAVE SERIAL INPUTS AND RAIL-TO-RAIL OUTPUTS

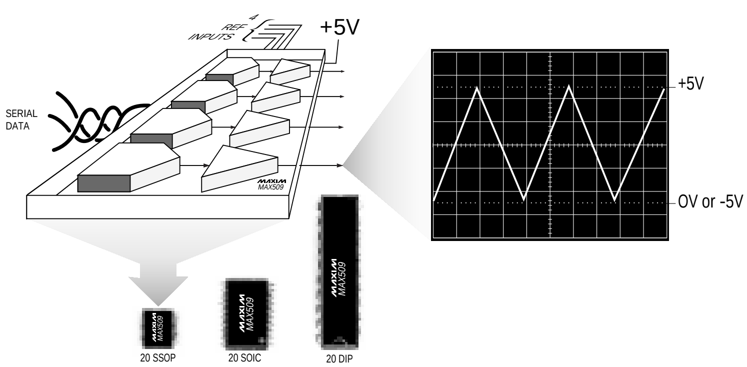
The MAX509 and MAX510 quad 8-bit D/A converters operate on 5V or ±5V supplies. Their voltage outputs swing rail to rail, and the input range for each reference includes both rails. The MAX509 has separate reference inputs for each of the four D/A converters, allowing the user to set a different full scale for each. The MAX510 has two reference inputs, each serving a pair of converters.

The 10MHz serial input is compatible with Microwire and SPI/QSPI synchronous-serial standards. It accepts 8-bit words. Two consecutive words should contain an 8-bit data word, MSB first, preceded by two control bits and two address bits. After assembly in an internal 12-bit shift register, the data word is directed to one of four 8-bit input registers. Each input register feeds one of four DAC registers, providing a double buffer for each converter. The control bits provide a variety of ways to update the four D/A converters. $\overline{\text{CLR}}$ and $\overline{\text{LDAC}}$ inputs provide clear and load capability.

All digital inputs and outputs are TTL and CMOS compatible. An internal power-on reset clears the serial interface and sets all internal registers to zero, and a buffered data output lets you daisy-chain the quad-converter chips or provide readback to the microprocessor.

The MAX509 comes in 20-pin DIP and SSOP packages; the MAX510 comes in 16-pin DIP and SO packages. Both are screened for commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices (1000 up, FOB USA) start at $5.35 for the MAX509 and $5.19 for the MAX510.

(Circle 1)



SECOND-SOURCE, DUAL/QUAD OP AMPS OFFER LOWER OFFSET AND LOWER SUPPLY CURRENT

- ***Single-supply operation***
- ***Input range includes ground***

Maxim is now a source for four precision op amps: the low-supply-current dual/quad LT1178/LT1179 (17µA maximum per amplifier), and the dual/quad LT1013/LT1014. Though optimized for single-supply 5V operation, the four devices are characterized for ±15V operation as well. Their input ranges include ground, and their outputs swing within a few millivolts of ground.

Maxim's LT1013 and LT1014 are competitively priced equivalents for existing devices. The Maxim parts have typical precision specifications of 40µV V_{OS}, 0.4µV/°C V_{OS} drift, 117dB CMRR, and 120dB PSRR. They draw typical supply currents of 350µA per amplifier, and the outputs can sink or source more than 20mA.

LT1178/LT1179 op amps can operate from a single lithium cell (2.2V minimum) or two NiCd cells. They specify 70µV maximum V_{OS}, 0.5µV/°C V_{OS} drift, 250pA maximum I_{OS}, 103dB typical CMRR, and 104dB typical PSRR. Outputs can source and sink 5mA.

The LT1013 and LT1014 are screened for commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges; the LT1178 and LT1179 are screened for the commercial and extended-industrial ranges only. Packages are as follows: LT1013, 8-pin DIP and SO; LT1014, 14-pin DIP and 16-pin wide SO; LT1178, 8-pin DIP and SO; and LT1179, 14-pin DIP and 16-pin DIP and wide SO. Prices (1000 up, FOB USA) start at $1.57 for the LT1013, $3.06 for the LT1014, $2.58 for the LT1178, and $3.35 for the LT1179.

(Circle 2)

µPOWER 12-BIT ADCs DRAW ONLY 1.5mA

- ***Serial-data interface***
- ***Operates from single 5V supply***
- ***8-pin package saves space***

The MAX187/MAX189 micropower A/D converters feature 5V operation, ultra-low power consumption, and conversion rates to 90k samples per second (ksps). The MAX187 has an internal 4.096V reference; the MAX189 operates with an external reference.

A power-down function lowers the supply current to less than 1µA during shutdown. At maximum sampling rates, the supply current including reference current is only 1.5mA (2.5mA maximum). The 8MHz serial interface not only simplifies the addition of opto-isolation; it connects directly to SPI, QSPI, and Microwire ports without external logic. Both converters guarantee ±1/2LSB maximum offset and INL over temperature.

Available in 8-pin DIP and 16-pin wide SO packages, the MAX187 and MAX189 A/D converters are screened for commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges.

(Circle 3)

NEW PRODUCTS

70µV OFFSET, SINGLE-SUPPLY DUAL OP AMP IN 8-PIN SO PACKAGE OPERATES FROM 17µA

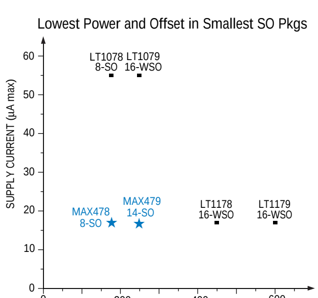
- ***Single-supply operation down to 2.2V***
- ***Input range includes ground***
- ***17µA max supply current***

The MAX478 and MAX479 are dual and quad precision micropower op amps. The MAX478's 8-pin SO is the smallest package available for such a device. The devices combine extremely low supply currents—less than 17µA per amplifier—with precision: input offset voltage is 30µV (70µV max); offset voltage drift is 2.2µV/°C max; input bias current is 5nA max; and input offset current is 250pA max.

Both amplifiers can operate from a single lithium cell or two NiCd cells, and their input-voltage ranges include ground. Because the output stages swing within a few millivolts of ground while sinking current, they save power by eliminating pull-down resistors. Though optimized and guaranteed for 3V and 5V operation, the MAX478/MAX479 guarantee ±15V operation as well.

Other specifications include $0.9\mu V_{p\text{-}p}$ voltage noise (0.1Hz to 10Hz), $1.5pA_{p\text{-}p}$ current noise (0.1Hz to 10Hz), and an 85kHz gain-bandwidth product.

The MAX478 dual op amp comes in 8-pin plastic DIP and SO packages, and the MAX479 quad op amp comes in 14-pin plastic DIP and narrow SO packages. Both are screened for commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $2.58 for the MAX478 and $3.35 for the MAX479 (1000 up, FOB USA).



(Circle 4)

LOW-POWER, PRECISION ANALOG SWITCHES HAVE 35Ω ON-RESISTANCE

The DG417, DG418, and DG419 precision CMOS analog switches offer low leakage (250pA maximum at 25°C), fast switching (175ns maximum for turn on; 145ns maximum for turn off), and low on-resistance (35Ω maximum).

The DG417 is a SPST normally open switch, the DG418 is a SPST normally closed switch, and the DG419 is a SPDT NO/NC switch. Each IC has a 44V maximum breakdown voltage that enables the switches to withstand applied voltages equal to the supply rails.

DG417/DG418/DG419 switches operate on ±15V and draw only 1µA supply currents at 25°C. They are well suited for use in battery-powered systems, sample/hold circuits, guidance and control systems, test equipment, and military radios.

Available in 8-pin DIP and narrow-SO packages, the DG417/418/419 switches are screened for extended-industrial (-40°C to 85°C) and military (-55°C to 125°C) temperature ranges. Prices (1000 up, FOB USA) start at $1.01 for the DG417/DG418, and $1.39 for the DG419.

(Circle 5)

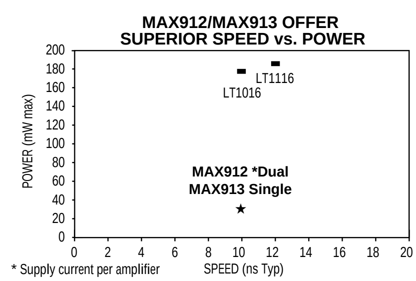
10ns, LATCHED TTL COMPARATORS HAVE COMPLEMENTARY OUTPUTS

The LT1016 and LT1116 are high-speed, complementary-output precision comparators that operate with +5V or ±5V supplies and specify 1mV (typical) offset voltages. The LT1116's input common-mode range includes the negative rail with single or dual supplies. The LT1116 also withstands input voltages to 15V, regardless of supply voltage.

High-speed operation suits the LT1016/LT1116 comparators for applications such as A/D converters, zero-crossing detectors, line receivers, and pulse-height discriminators. Propagation delays are 10ns typical, 14ns max (LT1016), and 12ns typical, 16ns max (LT1116). Both devices have TTL-compatible latch-enable inputs. Because they remain stable when outputs are in the active region, the comparators handle slow-moving input signals without oscillation or minimum-slew-rate limitations.

For lower power and higher performance, consider Maxim's MAX912 and MAX913 comparators. The MAX912 is a dual equivalent to the MAX913, which is an improved plug-in replacement for the LT1016 and LT1116. The MAX912/MAX913 comparators offer wider input-voltage ranges, and operate with equivalent speed at 1/4 the supply current.

Maxim's LT1016 and LT1116 come in 8-pin DIP and SO packages. The LT1016 is available in commercial (0°C to +70°C) and military (-55°C to +125°C) temperature ranges, and the LT1116 is screened for the commercial range only. Prices (1000 up, FOB USA) start at $2.75.

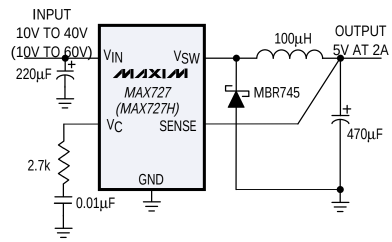


(Circle 6)

NEW PRODUCTS

FIXED-OUTPUT, STEP-DOWN SWITCHING REGULATORS GENERATE 2A

The MAX727 (5V output), MAX728 (3.3V output), and MAX729 (3.0 output) dc-dc switching regulators accept inputs from 8V to 40V (or 60V for the high-voltage "H" versions). Each has an internal, 2A power MOSFET whose 0.85Ω $r_{DS(ON)}$ contributes to 80% efficiency. Because the 100kHz oscillator and control circuitry are also on chip, few external components are required for standard operation.



STEP-DOWN CONVERTER

The regulators' buck topology and PWM control provide excellent dynamic characteristics and transient response. Cycle-by-cycle current limiting protects against overcurrent faults and output short circuits. (Seven-pin packages allow for micropower shutdown and adjustable current limiting as well.) Each device has an 8.5mA quiescent current and a 2.6A preset limit for output current.

The MAX727/MAX728 /MAX729 regulators come in 5-pin TO-220, 7-pin TO-220, and 4-pin TO-3 packages, screened for commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices (1000 up, FOB USA) start at $3.00.

(Circle 7)

MICROPOWER COMPARATOR/ REFERENCE HAS 3µA QUIESCENT CURRENT

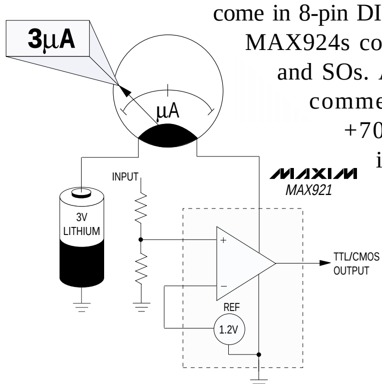
- ***Ideal for 3V micropower systems***

The MAX921/MAX922/MAX923/ MAX924 comparator/reference ICs feature single, dual, or quad micropower comparators. Supply currents (less than 4µA max over temperature for the MAX921) represent the lowest power consumption available for such devices. In addition to the voltage comparator(s) and the 1.18V ±1% reference, they offer programmable hysteresis, 40mA output source current, and TTL/CMOS-compatible outputs. The package is an 8-pin DIP or SO (16 pins for the MAX924).

As the lowest-power combination of comparator and reference available, the MAX921 is ideal for micropower 3V systems. And unlike conventional comparators, the MAX921 and MAX923 provide a HYST input that lets you add hysteresis without connections to the comparator inputs. Other comparators provide hysteresis—which prevents oscillation—via an external feedback connection and cumbersome equations.

Each IC operates on a single supply of 2.5V to 11V or a dual supply of ±1.25V to ±5.5V, and has an input voltage range that extends from the negative rail to within 1.3V of the positive rail. The MAX922 offers two comparators but no reference. The MAX923 has a reference and two comparators, each with an input tied to the reference, and a hysteresis pin. The MAX924 has four independent comparators and a reference.

The MAX921 excels in low-power applications. It draws less than 4µA quiescent current, yet it can source a continuous 40mA. It exhibits propagation delays of only 12µs with 10mV overdrive, and switches logic states without producing unwanted glitches in the supply voltage. MAX921/MAX922/MAX923 devices come in 8-pin DIP and SO packages; MAX924s come in 16-pin DIPs and SOs. All are available in commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55oC to +125°C) versions. Prices start at $1.50 (1000 up, FOB USA).



(Circle 8)

STEP-DOWN, VARIABLE-OUTPUT SWITCHING REGULATOR GENERATES 2A

- ***16-pin SOIC package***

The MAX726 step-down switching regulator, a monolithic bipolar device, is a classic buck regulator optimized for step-down applications. It accepts input voltages from 8V to 40V (to 60V for the MAX726HV), and produces outputs from 2.5V to 40V. You can also configure the MAX726 as an inverter, negative boost converter, or flyback converter, with input voltages as low as 5V.

The MAX726 has excellent dynamic and transient-response characteristics. Few external components are needed because the power switch, oscillator, and control circuitry are included on chip. The oscillator is preset to 100kHz (adjustable to 200kHz), and the power-switch current limit is preset to 2.6A. Cycle-by-cycle current limiting guards against overcurrent faults and output short circuits.

Packages include a 4-pin TO-3, a 5-pin TO-220, and a 16-pin SOIC. The MAX726 is available in commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices (1000 up, FOB USA) start at $3.00 for the MAX726 and $5.22 for the MAX726HV.

(Circle 9)

NEW PRODUCTS

35Ω, 250ns ANALOG SWITCHES HAVE INPUT LATCHES

The DG421, DG423, and DG425 dual analog switches (two SPST, two SPDT, and two DPST) have latched logic inputs that simplify the interface to microprocessors. The switches' fast operation (t_{ON} < 250ns), low on resistance ($r_{DS(ON)}$ < 35Ω), and low power consumption (< 35µW) make them ideal for use in battery-powered applications that require µP-compatible analog switches.

Maxim's high-voltage, silicon-gate CMOS process improves switching performance and enables the DG421/DG423/DG425 switches to specify absolute maximum ratings of 44V between the supply rails. An epitaxial layer prevents latchup. Each device operates on dual supplies of ±4.5V to ±20V.

The input latches are transparent when $\overline{WR}$ is low, and they latch the applied logic levels when $\overline{WR}$ goes high. $\overline{RS}$, when low, resets all switches to their default state (all control inputs low). Break-before-make switching is guaranteed by design in the DG423.

On switches conduct equally well in both directions, and off switches block voltages as high as $30V_{p-p}$. Switch on-resistance, nearly constant over the full ±15V input range, rivals the performance of JFETs while avoiding their inherent limitations in dynamic range and supply voltage.

Packages include 16-pin plastic and ceramic DIPs (the DG423 and DG425 also come in 20-pin PLCCs). All three devices are screened for commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices (1000 up, FOB USA) start at $1.77 for the DG421, $3.67 for the DG423, and $3.33 for the DG425.

(Circle 10)

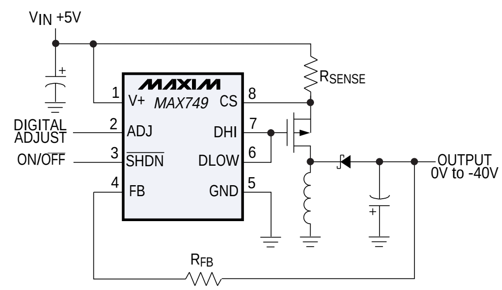
DIGITALLY ADJUSTABLE, HIGH-EFFICIENCY LCD SUPPLY FITS IN 0.5in.²

The MAX749 is an inverting switching regulator that generates negative voltages to -100V and more. It's particularly useful as a zero to -40V, variable-bias supply for LCDs. It operates with 83% efficiency and accepts input voltages from 2V to 6V.

An internal, digitally programmable D/A converter adjusts the regulated output voltage in 64 steps between 33% and 100% of full scale. The MAX749 simplifies applications by retaining this output setting during shutdown. Shutdown also reduces the supply current to only 15µA. An external feedback resistor adjusts the maximum output voltage to -100V or more: V_{OUT} (max) = $-R_{FB}$(20µA).

MAX749 circuits require only seven external surface-mount components, and occupy only 0.5in.² of pc-board area. The device can drive an external n-channel MOSFET or a pnp bipolar switching transistor. Available in 8-pin plastic DIP and SO packages, the MAX749 comes screened for commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $2.83 (1000 up, FOB USA).

(Circle 11)



ANALOG CONTROLLER POWERS TWO PCMCIA SLOTS

- ***0.09in² IC replaces more than 12 components***

Each member of the MAX780 family of dual-slot, PCMCIA power controllers provides the status and power-switching signals necessary to control two PCMCIA card slots (Personal Computer Memory Card International Association, Release 2.0).

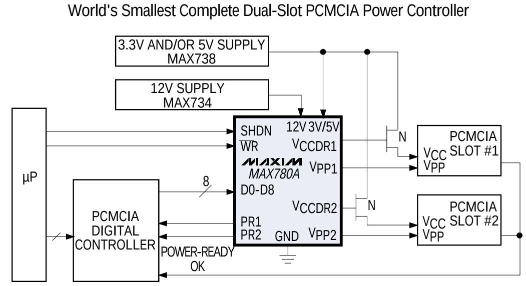
In conjunction with a PCMCIA digital controller, each MAX780 IC forms a complete, minimum-component-count PCMCIA interface for palmtop and notebook computers. MAX780 features are allocated among four versions (suffix A, B, C, and D). The SSOP package makes MAX780 devices the smallest such controllers available.

The MAX780 controls external MOSFETs that direct either 5V or 3.3V to the V_{CC} terminal of each card slot. Separate power-ready signals tell the external controller when the V_{CC} outputs are in regulation. Other internal circuitry directs 0V, 5V, 12V, or high impedance to the V_{p-p} terminal of each slot (for programming flash memories). Typical on-resistance for the internal V_{p-p} switches is 1.6Ω. Shutdown mode drops the 350µA quiescent supply current to only 10µA.

MAX780 devices come in 24-pin DIPs and SSOPs, screened for commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $1.80 (1000 up, FOB USA).

(Circle 12)

World's Smallest Complete Dual-Slot PCMCIA Power Controller



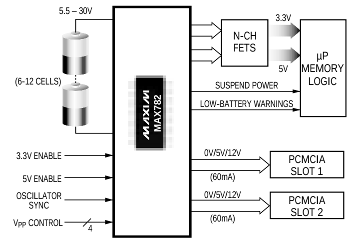
NEW PRODUCTS

TRIPLE-OUTPUT CONTROLLER POWERS NOTEBOOK COMPUTERS

The MAX782 power-supply controller is a systems-engineered device that provides regulated supply voltages for notebook computers and other battery-powered equipment. It includes dual PCMCIA (V_{PP}) outputs, and step-down regulators for 3.3V and 5V. It also includes three precision comparators for low-battery detection, and two low-dropout, micropower linear regulators useful as backup supplies for CMOS RAM and real-time clocks.

Efficiency for the main 3.3V/5V supplies is as high as 95% for 2A loads, and greater than 80% for loads from 3mA to 3A. Idle-Mode™ operation provides efficient regulation at light loads. At heavier loads, the operation shifts to synchronous rectification and pulse-width modulation (PWM). High operating frequency (200kHz or 300kHz) allows use of small-sized external components, and the current-mode PWM architecture allows filter-capacitor values as small as 30µF per ampere of load/current.

The MAX782 has quick response, thanks to a high (60kHz) unity-gain crossover frequency that enables recovery from line and load transients within four to five clock cycles. High-level integration and the use of low-cost, external n-channel MOSFETs mean lower system costs. Also lowering costs is the high-side 15V output generated by an integral flyback-winding controller, which maintains regulation even in the absence of a main-output load.



Input range is 5.5V to 30V, and the quiescent current is 420µA, dropping to 70µA in standby mode (when only the linear regulators are active). Other features include low-noise, fixed-frequency PWM operation for moderate to heavy loads, and a synchronizable oscillator for noise-sensitive applications such as communicating computers and electromagnetic pen-based systems.

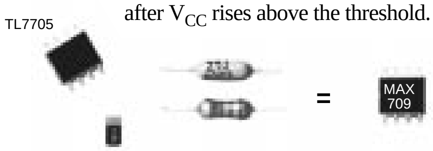
The MAX782 comes in 36-pin SSOPs, screened for commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $5.95 (1000 up, FOB USA).

(Circle 13)

SIMPLE 3V AND 5V RESET MONITORS REQUIRE NO EXTERNAL COMPONENTS

The MAX709 is an inexpensive µP-supervisor that issues system resets during power-up, power-down, and brownout conditions. It requires no external parts (unlike the TL7705) and comes in a small 8-pin SO package.

Five trip thresholds, identified by suffix, enable variants of the MAX709 to flag low V_{CC} voltages in 3V, 3.3V, and 5V systems: 4.6V ("L" suffix), 4.40V ("M"), 3.08V ("T"), 2.93V ("S"), and 2.63V ("R"). The outputs are guaranteed valid for V_{CC} as low as 1V. They go low when V_{CC} drops below the threshold, and remain low for a minimum of 140ms after V_{CC} rises above the threshold.



Supply currents are only 35µA (MAX709R/S/T) or 65µA (MAX709L/M).

MAX709s come in 8-pin DIP and SO packages, screened for commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $1.15 (1000 up, FOB USA).

(Circle 14)

TWO-CELL TO 5V STEP-UP CONVERTERS MAXIMIZE BATTERY LIFE

- ***3.3V & 5V output dc-dc converters have 150µA IQ and 20µA shutdown***
- ***Outputs deliver 10mA to 300mA (a 30:1 ratio) with efficiencies of 85% to 88%***

MAX756/MAX757 dc-dc converters extend battery life with the world's best combination of high efficiency and low quiescent current. Efficiency exceeds 85% while delivering 5V from 2.5V inputs, for loads from 10mA to 300mA. Quiescent current under these conditions is 150µA. For 3.3V outputs, the quiescent current is just 60µA. And in the logic-controlled shutdown mode, a further reduction lowers the quiescent current to only 20µA.

The internal MOSFET's high switching frequency—to 500kHz—allows operation with one small 22µH inductor, three capacitors, and a diode. MAX756/MAX757 circuits are guaranteed to start with inputs as low as 1.8V (two battery cells), and they continue operating with inputs ranging from 1.1V to V_{OUT}.

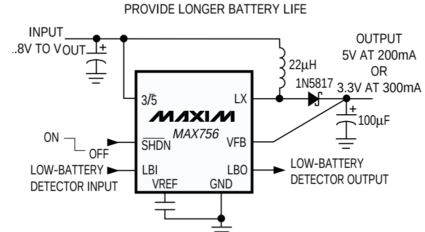
The MAX756 has a preset, pin-selectable output voltage of 3.3V or 5V, and the MAX757 output is adjustable from 2.7V to 5.5V. Output current extends to 500mA for 3.3V outputs, and to 700mA for 5V outputs. Each device has a built-in low-battery detector.

Applications include palmtop computers, 3.3V-to-5V converters, PCMCIA cards, personal digital assistants, and systems powered by 2- and 3-cell batteries.

MAX756/MAX757 converters are screened for commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Their 8-pin DIP and SO packages save space in portable equipment. Prices start at $1.95 (1000 up, FOB USA). A pre-assembled surface-mount evaluation kit is available for $25, FOB USA (MAX756EVKIT-SO).

(Circle 15)

3.3V & 5V STEP-UP CONVERTERS PROVIDE LONGER BATTERY LIFE

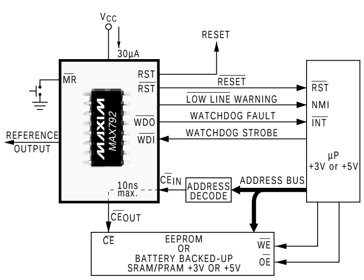


NEW PRODUCTS

SIX-FUNCTION µP SUPERVISORS INCLUDE WRITE PROTECTION FOR NONVOLATILE MEMORY

The MAX792/MAX820 microprocessor supervisors provide all basic µP-supervisory functions, and they prevent false writes to memory during power-supply faults. The MAX792 and MAX820 come in five versions, each dedicated to a different supply-voltage level. The five available trip thresholds, associated supply tolerances, and corresponding suffixes are as follows: 2.61V, 3V ±10%, (R suffix); 2.91V, 3.3V ±10%, (S); 3.06V, 3.3V ±5%, (T); 4.37V, 5V ±10%, (M); and 4.62V, 5V ±5%, (L). As an option, you can program arbitrary thresholds with an external resistor divider.

The ICs issue both RESET and $\overline{\text{RESET}}$ for all conditions of power-up, power-down,



brownout, and momentary power interruption. They also include manual-reset inputs (MR). An independent comparator monitors the input voltage, and a watchdog timer flags software hang-ups. A low-line output warns of power failure before the reset signal appears. For the MAX820, this low-line output has ±2% accuracy.

To protect nonvolatile memory against false write operations, the MAX792 and MAX820 provide gating for the memory's chip-enable signal (CE). The chips normally pass CE with a delay of only 6ns (10ns max), but during power failures they disable the memory by blocking CE. MAX792/MAX820 devices are intended either for nonvolatile-memory systems in which backup circuitry is already present, or for systems in which the memory requires no backup battery (EEPROMs).

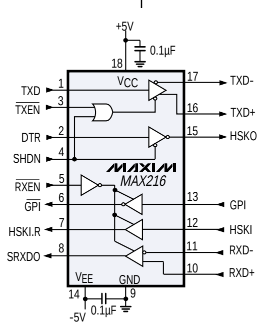
Finally, a watchdog timer monitors software execution, issuing a reset whenever 1.6 seconds elapses (or other interval, as set with an external capacitor) with no evidence of activity on a selected I/O line.

Available in 16-pin DIP and SO packages, the MAX792 and MAX820 are screened for commercial (0°C to +70°C), extended-industrial (-40oC to +85°C), and military (-55°C to +125°C) temperature ranges. Prices (1000 up, FOB USA) start at $3.48 for the MAX792 and $3.82 for the MAX820.

(Circle 16)

APPLETALK™ DATA TRANSCEIVER DRAWS 30µA DURING SHUTDOWN

The MAX216 is a data-communications transceiver designed especially for AppleTalk™ networks. Its differential-output driver, single-ended driver, differential-input receiver, and two single-ended receivers meet all AppleTalk™ specifications.



The device offers a complete data interface for printers and peripheral devices that communicate with Apple computers. It operates on ±5V and draws only 3mA (maximum) when fully active. During shutdown, the quiescent current drops to 30µA, and all driver outputs assume a high-impedance state. When active, each driver has a ±5V output range and provides thermal-shutdown protection against short circuits.

The MAX216's single-ended inputs and outputs are functionally compatible with EIA/TIA-562 and EIA/TIA-232E standards, and its differential inputs and outputs are functionally compatible with the RS-422 standard. With suitable external connections, the device can convert between RS-422 and EIA/TIA-562/232E signal levels.

One single-ended receiver is configured as a buffer and one as an inverter, each with TTL-compatible input thresholds and ±7V input-voltage ranges. The differential-input receiver has ±200mV input thresholds and a ±7V input common-mode range. Available in an 18-pin wide-SO package, the MAX216 is screened for the commercial (0°C to +70°C) temperature range. Prices start at $3.72 (1000 up, FOB USA).

(Circle 18)

µP SUPERVISORS GENERATE ACTIVE-HIGH RESETS FOR INTEL MICROCONTROLLERS

The MAX805L and MAX813L microprocessor-supervisory ICs generate active-high reset outputs (RESET) when V+ drops below 4.65V (5V ±5%), for all conditions of power-up, power-down, brownout, and momentary power interruption. Active-high resets are required by the 8051 series and many other Intel µPs. Predecessors to the MAX805L and MAX813L (the MAX690A and MAX705) produce active-low resets ($\overline{\text{RESET}}$).

The MAX805L's battery switchover accomodates backup-battery power for SRAM and real-time clocks, and a debounced manual-reset input (MR) allows resets on command. Reset pulses are 140ms minimum, guaranteed for V+ as low as 1V. Each device has an independent comparator/reference circuit that lets you monitor a battery, a regulator input, or any other voltage. Each includes a watchdog timer that monitors software execution by issuing a reset whenever 1.6 seconds elapses without evidence of activity on a selected I/O line.

The MAX805L and MAX813L come in 8-pin DIP and SO packages, screened for commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices (1000 up, FOB USA) start at $3.22 for the MAX805L and $1.61 for the MAX813L.

(Circle 17)