MAXIM
Engineering journal
Volume Twenty-Seven

News Briefs

MAXIM REPORTS INCREASED BUSINESS ACTIVITY IN Q397

Maxim Integrated Products, Inc., reported net revenues of $111 million for the third quarter of fiscal 1997 ending March 31, 1997. Net income for Q397 was $35.4 million and income per share was $0.48. Sequentially, the results for Q397 showed an increase over Q297 net revenues of $104.7 million, net income of $33.3 million, and earnings per share of $0.46.

During the quarter, the Company increased cash and short-term investments by $24 million after paying $11 million for capital equipment and repurchasing $29 million of its common stock. Accounts receivable days decreased slightly from Q297 levels. Inventory declined $1.0 million from Q297.

During Q397, backlog shippable within the next twelve months grew to $124 million from the $103 million reported at the end of Q297. Orders requested for delivery in Q497 remained high, representing 76% of the beginning Q497 backlog.

Turns orders received in Q397 increased by more than 17% over those received in Q297 to a record $45.4 million. (Turns orders are customer orders that are for delivery within the same quarter and may result in revenue within the quarter if the Company has available inventory that matches those orders.)

Net bookings were up 30% from Q297 levels. The Company experienced sequential quarter over quarter growth in net bookings across all geographic regions and across all of Maxim's business units. Customer cancellations were $12.5 million, continuing the decline experienced over the last three quarters.

Bookings for Maxim's high-frequency products were up over 50% from last quarter. Customer inventories of high-frequency products that hampered bookings in Q197 and Q297 appear to be returning to normal levels.

Gross margins for the third quarter of 1997 were 66.3%, compared to 66.1% in Q297. R&D expenses increased by $1.6 million to 11.8% of net revenues due to continued investments in product development efforts.

Jack Gifford, Chairman, President and CEO, commented on the quarter: "Maxim is performing very well. Once again we did a good job of predicting and responding to significant turns orders. We are pleased with the sequential quarter over quarter growth in gross and net bookings across all of our business units and geographic territories. These improved business conditions should enable us to have further sequential growth next quarter. As of today, we have introduced twice the number of products in fiscal 1997 that we did in the comparable period in fiscal 1996."

Safe harbor statement under the Private Securities Litigation Reform Act of 1995: Forward-looking statements in this news release involve risk and uncertainty. Important factors, including overall economic conditions, demand for electronic products and semiconductors generally, demand for the Company's products in particular, availability of raw material, equipment, supplies and services, unanticipated manufacturing problems, technological and product development risks, competitors' actions and other risk factors described in the Company's filings with the Securities and Exchange Commission could cause actual results to differ materially.

MAXIM'S ENGINEERS HONORED BY EDN

Congratulations to Maxim's Dave Bingham and Charlie Allen, who have been honored by *EDN* Magazine as Innovators of the Year for 1996. They were recognized for their patented AutoShutdown/ AutoWakeup technology, which is featured in a variety of Maxim RS-232 ICs. One of these RS-232 products, the MAX3238, was awarded EDN Innovation of the Year in the analog IC and semiconductor category. The MAX3238 eliminates the need for shutdown software and cuts RS-232 serial-port supply current to 1µA.

Winners of EDN's Innovator and Innovation Awards are elected by EDN readers; these awards are a prestigious recognition from a cross-section of design engineers.

New developments in battery chargers

Electronic equipment is increasingly becoming smaller, lighter, and more functional, thanks to the push of technological advancements and the pull from customer demand. The result of these demands has been rapid advances in battery technology and in the associated circuitry for battery charging and protection.

For many years, nickel-cadmium (NiCd) batteries have been the standard for small electronic systems. A few larger systems, such as laptop computers and high-power radios, operated on “gel-cell” lead-acid batteries. Eventually, the combined effects of environmental problems and increased demand on the batteries led to the development of new battery technologies: nickel-metal hydride (NiMH), rechargeable alkaline, and lithium ion (Li+). These new battery technologies require more sophisticated charging and protection circuitry.

NiCd and NiMH batteries

NiCd has long been the preferred technology for rechargeable batteries in portable electronic equipment, and in some ways, NiCd batteries still outperform the newer technologies. NiCd batteries have less capacity than Li+ or NiMH types, but their low impedance is attractive in applications that require high current for short periods. Power tools, for example, will continue to use NiCd battery packs indefinitely.

Though similar to NiCd types, NiMH batteries have greater capacity. This advantage is offset somewhat by the NiMH battery’s higher self-discharge rate—approximately double that of the NiCd, which is relatively high to begin with (about 1% of capacity per day). Thus, NiMH batteries are not suitable for applications in which the battery is expected to hold its charge for a long time.

NiMH batteries also differ from NiCd batteries in the method required to fast charge them. Both types can be fast charged with a current equal to or greater than the capacity (C) in ampere hours. This technique allows you to charge a battery in about an hour or less. Because of internal losses, a battery charged at C for one hour cannot reach full capacity. For full capacity, you must either charge for an hour at more than C, or charge at C for more than an hour. Charging losses vary with the charging rate and from battery to battery.

When charging a NiCd battery, its terminal voltage peaks and then declines as the battery reaches capacity. An applied fast charge should therefore terminate when this voltage starts to drop (when $\Delta V/\Delta t$ becomes negative). Otherwise, the charging current delivers excess energy, which acts on the battery’s electrolyte to dissociate water into hydrogen and oxygen gases. This results in a rise in internal pressure and temperature and a decrease in terminal voltage. If fast charging continues, the battery can vent (explode).

As a secondary or backup measure, NiCd and NiMH chargers often monitor the battery’s temperature (in addition to its voltage) to ensure that fast charging is terminated before the battery is damaged. Fast charging should stop when a NiCd’s $\Delta V/\Delta t$ becomes negative. For NiMH batteries, fast charging should stop when the terminal voltage peaks (when $\Delta V/\Delta t$ goes to zero).

Trickle charging is simple for NiCd and NiMH batteries. As an alternative to fast charging, the use of a small trickle current produces a relatively small rise in temperature that poses no threat of damage to the battery. There is no need to terminate the trickle charge or to monitor the battery voltage. The maximum trickle current allowed varies with battery type and ambient temperature, but C/15 is generally safe for typical conditions.

Lithium-ion batteries

The most popular innovation in battery technology over the past few years has been the introduction of Li+ batteries. Li+ batteries have a higher capacity than other rechargeable types now in mass production, such as NiCd and NiMH. The advantage of Li+ over NiMH is only 10% to 30% when measuring capacity as energy per unit volume, but volumetric capacity is not the only property to consider; weight is also important in a portable device. When measuring capacity as energy per unit mass, Li+ batteries are clearly superior (NiMH batteries are relatively heavy). Because they are lighter, Li+ batteries have nearly twice as much capacity per unit mass.

Li+ batteries also have many limitations. They are highly sensitive to overcharging and undercharging. You must charge to the maximum voltage to store maximum energy, but excessive voltage can cause permanent damage to a Li+ battery, as can excessive charge or discharge current. Discharging the battery also carries a caveat: repeated discharges to a sufficiently low voltage can cause a loss of capacity. Therefore, to protect the battery, you must limit its current and voltage when discharging as well as when charging. Most Li+ battery packs include some form of undervoltage- and overvoltage-disconnect circuitry. Other typical features include a fuse to prevent exposure to excessive current and a switch that open circuits the battery if high pressure causes it to vent.

Unlike NiCd and NiMH batteries, which require a current source for charging, Li+ batteries must be charged with a combination current-and-voltage source. To achieve the maximum charge without damage, most Li+ chargers maintain a 1% tolerance on the output voltage. (The slight additional capacity gained with a tighter tolerance is generally not worth the extra difficulty and expense required to achieve it.)

For protection, a Li+ battery pack usually includes MOSFETs that open circuit the battery in the presence of undervoltage or overvoltage. These protection MOSFETs also enable an alternative charging method (applying a constant current with no voltage limit) in which the MOSFETs are turned on and off as necessary to maintain appropriate battery voltage. The battery's capacitance helps to slow the rise of battery voltage, but use caution: battery capacitance varies widely over frequency, as well as from battery to battery.

In some applications, intermittent loads can exceed the main battery's power capability. A solution to this problem is to provide an additional, rechargeable battery to supply the excess current during a high-load transient. The main battery then recharges the auxiliary battery in preparation for the next transient. Two-way pagers are a good example of this arrangement. Pagers generally run from a single AA alkaline battery, but the load during transmission is too high for an AA battery to handle. An additional NiCd battery powers the transmitter, and it can be recharged when the transmitter is off, which is most of the time.

Cradle chargers

For cell phones and many other devices, the preferred battery-charging method involves the use of a separate "cradle charger" into which you place the device or the battery pack (like a baby in its cradle). Because the charger unit is separate, its generated heat is less of a concern than it would be if the charger were integrated into the device.

The simplest circuit for use in a cradle charger is usually a linear-regulator charger. Linear regulators drop the difference voltage (between the dc power source and the battery) across a pass transistor operating in its linear region (hence the name linear regulator). However, the dissipated power (the charging current times the drop across this transistor) can cause overheating if the charger is confined to a small space without airflow.

For example, consider a four-cell NiCd battery charged at 1A. NiCd batteries usually terminate charging at approximately 1.6V or 1.7V per cell, but the voltage can be as high as 2V per cell, depending on the battery's condition and its charging rate. The dc-source voltage must therefore be greater than 4 x 2V = 8V. The voltage level of cells in a fully discharged battery can measure as low as 0.9V each; in this case, the battery voltage is 4 x 0.9V = 3.6V. If the dc source is 8V, the pass transistor sees 8V - 3.6V = 4.4V.

When charging a fully discharged battery, the dissipated power is 4.4W in the charger and 3.6W in the battery—an efficiency of only 45%! The actual efficiency is even lower, because the dc source voltage must be higher than 8V to account for dropout voltage in the pass transistor and tolerance in the source.

A linear, single-cell Li+ charger is suitable for use in a cradle charger **(Figure 1)**. It drives an external power transistor (Q1) that drops the source voltage down to the battery voltage. The external transistor accounts for most of the circuit's power dissipation; therefore, the controller temperature remains relatively constant. The result is a more stable internal reference, yielding a more stable battery-voltage limit.

R1 and R3 determine the output current. R1 senses the charging current, and R3 sets the level at which the current is regulated. Current out of the ISET terminal is equal to 1/1000 of the voltage between CS+ and CS-. The current regulator controls the ISET voltage at 2V; in this case, the current limit [2000 / (R3 + R1)] is 1A.

Control loops for the voltage and current limits have separate compensation points (CCV and CCI), which simplifies the task of stabilizing these limits. The ISET and VSET terminals allow for adjustment of the current and voltage limits.

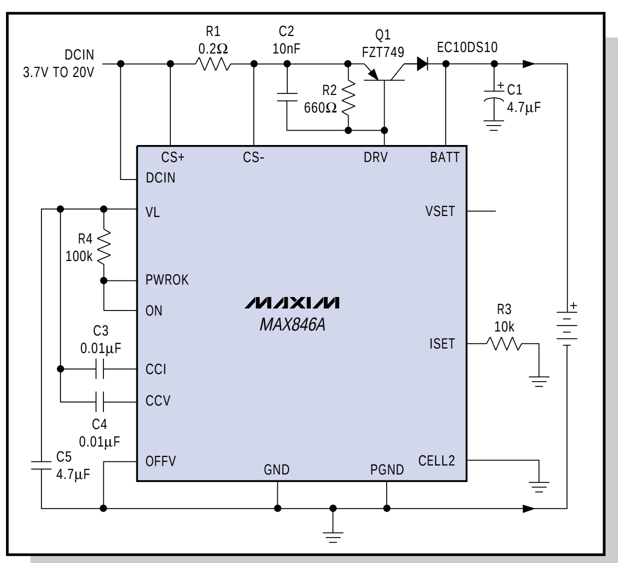


Figure 1. Designed for single lithium-ion cells, this battery-charging circuit is ideal for use in a stand-alone cradle charger.

Built-in battery chargers

For some larger systems, including laptop computers, the battery charger is built in as part of the system. The charger's efficiency in this arrangement is critical—not to ensure maximum energy transfer, but simply to minimize heat generation. Heat elevates temperature, and operation at elevated temperatures shortens a battery's life. Because this application requires high efficiency over the entire battery-voltage range, the charger should rely on a switching regulator, whose power dissipation is relatively low and independent of the input-to-output voltage drop.

The main drawback of switching regulators is the need for a passive inductor/capacitor filter, which converts the switched output voltage to a dc level suitable for the battery. In some cases, the battery capacitance is sufficient to replace the capacitor in this filter; however, as mentioned earlier, a battery's capacitance can vary greatly with frequency. Characterize it carefully before committing to a design.

Another drawback of switching regulators is the noise generated by their switching action. This problem can usually be avoided with proper layout techniques and shielding. For applications in which certain frequencies should be avoided, many switching chargers can be synchronized to an external signal—a capability that allows you to shift the charger's switching noise away from sensitive frequency bands.

A linear regulator is generally larger than an equivalent switching regulator because it dissipates more power and requires a larger heatsink. Consequently, the extra time necessary to design a smaller, more efficient switching charger is usually justified. One such design is the 4-cell NiCd/NiMH charger shown in **Figure 2**. It has no provision for terminating the charge; it operates in conjunction with a controller that monitors voltage across the battery and shuts off the charger when conditions are met. Many systems already include a controller suitable for this purpose. If your system does not have one, you will need a low-cost, stand-alone microcontroller (µC) that includes an on-board analog-to-digital converter. A number of such µCs are available.

The charger IC (MAX1640) chops the input voltage using a switching transistor (N1A) and a synchronous rectifier (N1B). This chopped voltage is placed across the inductor to form a current source. When the charger is turned off, diode D2 prevents current flow from the charged battery back into the voltage source.

In addition to "off," the MAX1640 operates in one of three modes as determined by the digital inputs D0 and D1: fast charge, pulse-trickle charge, and top-off charge **(Table 1)**. In fast-charge mode, the charging current is

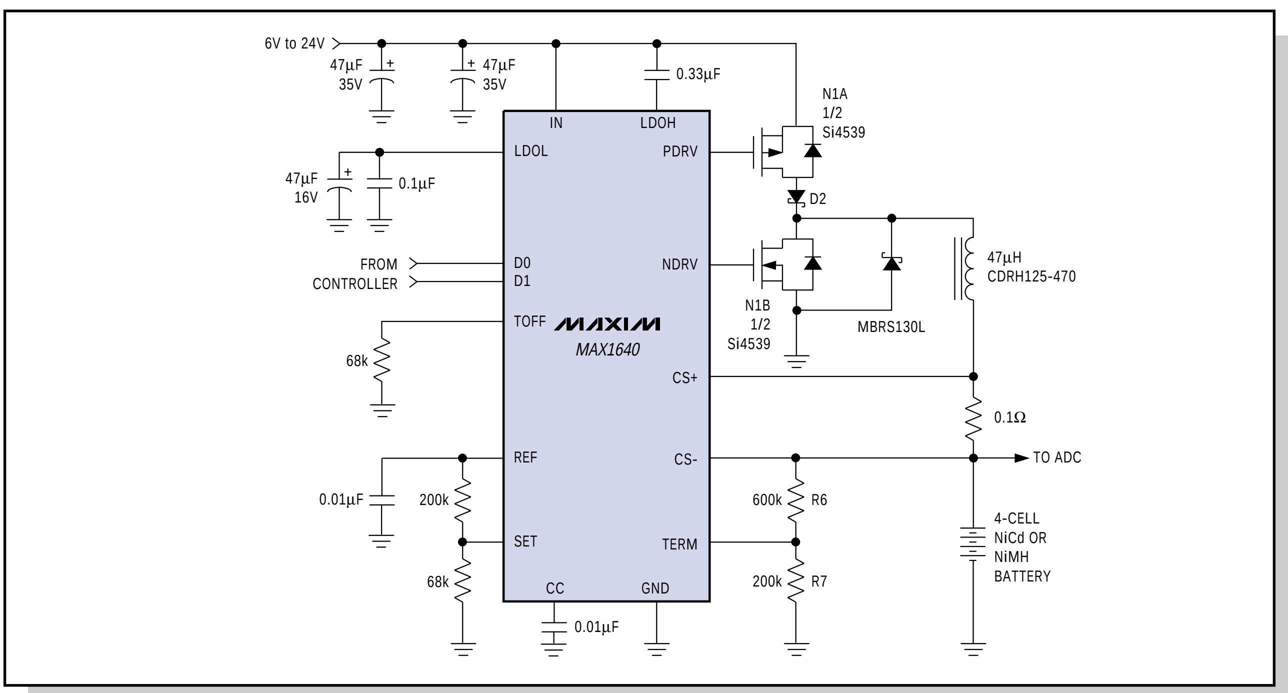


Figure 2. This four-cell NiCd or NiMH battery charger can be incorporated into a larger system.

Table 1. Charging states for the MAX1640

D0	D1	MODE	OUTPUT CURRENT
0	0	Off	—
0	1	Top-off charge	V_{SET} / (13.3R_{SENSE})
1	0	Pulse-trickle charge	V_{SET} / (13.3R_{SENSE}) (12.5% duty cycle)
1	1	Fast charge	V_{REF} / (13.3R_{SENSE})

150mV divided by the current-sense resistor value (0.1Ω), or 1.5A in this case. In top-off-charge mode, the voltage at SET produces 24.5% of the fast-charge current, or 381mA in this case. The current in pulse-trickle-charge mode is the same as in top-off mode, but it is pulsed with a 12.5% duty cycle. Frequency is determined by the resistor connected at TOFF (68kΩ). In this case, the frequency is 3.125MHz / R3 = 46Hz. The average pulse-trickle current is therefore 0.125 x 381mA = 47.6mA.

The circuit in Figure 2 should terminate a charge when ΔV/Δt equals zero or becomes negative (according to whether a NiMH or NiCd battery is being charged). However, if termination fails to occur, the circuit imposes a secondary voltage limit to prevent the battery voltage from rising too high. As an absolute maximum, the charging voltage for NiCd and NiMH batteries should not exceed 2V per cell, or 8V for the 4-cell battery in this circuit. R6 and R7 establish this voltage limit as $V_{LIMIT} = V_{REF}$ [(R6 + R7) / R7].

A similar circuit charges two Li+ cells in series **(Figure 3)**. It differs mainly in the accuracy of its charging voltage, which is better than the 1% required by Li+ batteries. Also unlike the Figure 2 charger, this one employs an n-channel MOSFET for the high-side switching transistor. When turned on, this transistor's source and drain voltages are approximately equal to V_{IN}, but the gate voltage must be higher than V_{IN} to allow the use of inexpensive n-channel MOSFETs. This elevated gate drive is achieved by charging C7 and adding its voltage to V_{IN}.

Charging current for the circuit shown in Figure 3 is determined by current-sense resistor R1: 185mV / R1 = 925mA for the 200mΩ value shown. This current can be adjusted linearly to lower values by varying the voltage at the SETI terminal. Similarly, you can adjust V_{OUT} by varying the voltage at the VADJ terminal. Because varying VADJ over its full range (0V to 4.2V) changes V_{OUT} by only 10% (0.4V per cell), you can achieve better than 1% output accuracy using 1% resistors. (One-percent-accurate resistors degrade the output accuracy by only 0.1%.)

Terminals CELL0 and CELL1 set the battery's cell count as shown in **Table 2**. (VL indicates the 5V level that powers the chip.) The charger can handle as many as four Li+ cells in series. Though not shown in Figure 3, the MAX745 can also terminate charging upon reaching a

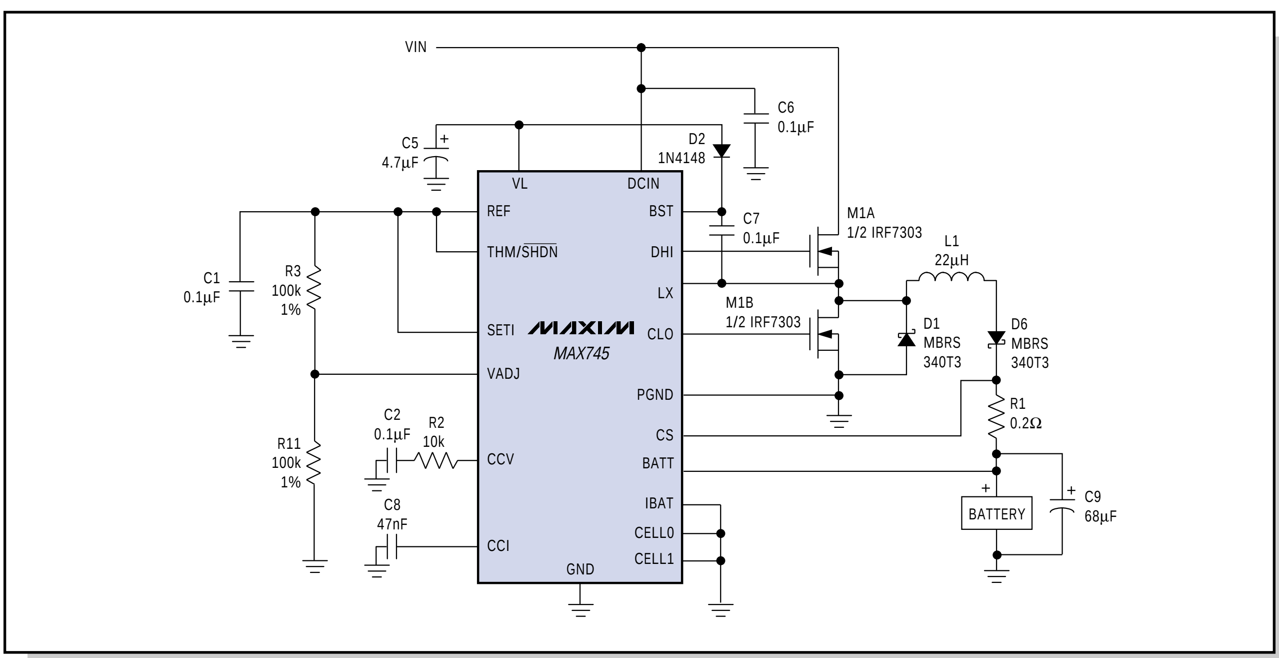


Figure 3. This charger generates a 1%-accurate charging voltage suitable for charging two lithium-ion batteries in series.

Table 2. Cell-count setting for the MAX745

CELL0	CELL1	NUMBER OF CELLS
GND	GND	1
VL	GND	2
GND	VL	3
VL	VL	4

temperature limit monitored by a thermistor. When the battery temperature exceeds this limit (determined by an external resistor and thermistor connected to the THM/$\overline{\text{SHDN}}$ terminal), the charger shuts off. Hysteresis associated with this threshold enables the system to resume charging when a declining battery temperature causes the THM/$\overline{\text{SHDN}}$ voltage to fall 200mV below its 2.3V threshold.

Smart-battery chargers

Smart batteries represent a new technology that is helping designers and consumers alike. Smart-battery packs include a controller that can "talk" through its serial port to tell an external charger what kind of charging routine the battery requires. This arrangement helps designers, because they can design a single charger that handles all batteries compliant with the smart-battery standard.

Smart batteries also benefit consumers, who can replace a given battery without regard to its type, as long as the replacement is smart-battery compliant. The smart-battery specification allows any manufacturer to participate in the market, and the resulting competition leads to standard products and lower prices.

The smart-battery specification was defined by a consortium of companies that manufacture batteries, computers, and related products. It defines the way the battery pack connects to the host system and the way it communicates with the host. It communicates via a two-wire serial interface known as the System Management Bus (SMBus™), which is derived from the I^2C protocol. A large base of I^2C-compliant µCs capable of controlling peripherals on the SMBus is already available.

Smart batteries also provide an elegant solution to the problem of fuel gauging. In a system run by ordinary non-communicating batteries, the host knows the state of the battery only when it has been fully charged or discharged. Smart batteries, on the other hand, remember their charge state. When such batteries are switched in and out of the host, the fuel gauge is able to maintain the same level of accuracy as it would under continuous operation.

In the smart-battery-compliant charger shown in **Figure 4**, the controller IC includes an SMBus interface that allows it to communicate with the host computer and the smart battery under charge. Because the switching regulator and its small, power-efficient current-sense resistor cannot achieve a 1mA (min) resolution in charging current, the first 31mA (five LSBs) of output current are supplied by an internal linear current source.

To preserve high efficiency (89%), the system activates a switch-mode current source when programmed for output currents of 32mA or more. However, the linear source remains on to ensure monotonicity in the output current regardless of the current-sense resistor's value or offset in the current-sense amplifier. Transistor Q1 off-loads an otherwise heavy power dissipation in the internal linear regulator, which occurs when the input voltage is much greater than the battery voltage. Q1's base is held approximately 5V below the input voltage. Voltage across the internal current source is less than 5V; therefore, power dissipation in the current source remains below 160mW.

A diode (D3) is placed in series with the inductor to prevent a flow of reverse current out of the battery. IC2's high switching frequency (250kHz) permits the use of a small inductor. The circuit accepts inputs as high as 28V, and provides pin-selectable maximum output currents of 1A, 2A, and 4A.

SMBus is a trademark of Intel Corp.

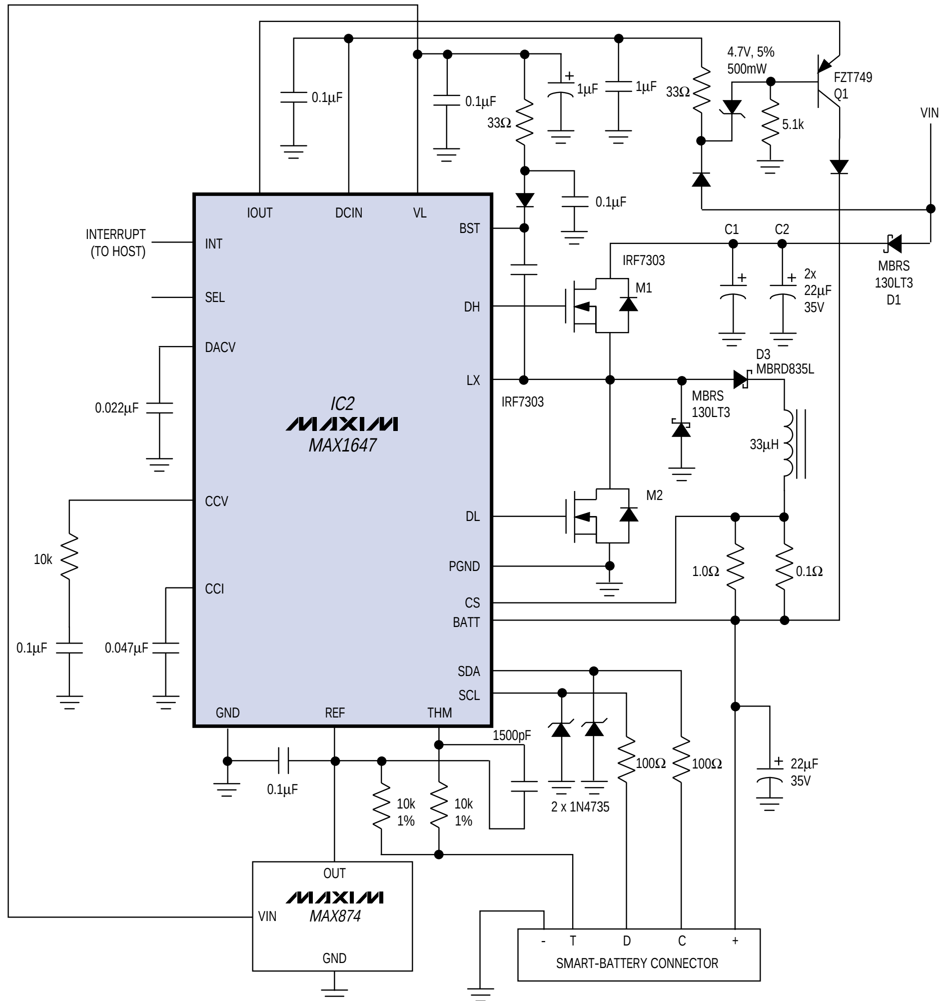


Figure 4. This charger is compliant with the smart-battery specification, and communicates with the host computer and a smart battery via the SMBus interface.

Load switcher draws only 6µA

Figure 1's circuit draws only 6µA, but it enables a small signal of ±1mV or more to switch relatively large load currents. It takes advantage of the IC's very low quiescent current—1.2µA (max) per amplifier (less than a typical battery's self-discharge)—which is able to flow through R1 without turning on Q1. When operated with a sensing coil (as shown) and stimulated by a magnet, the circuit performs the function of a reed switch, but with greater sensitivity. Other applications include alarm systems, bipolar threshold sensing, and audio volume switching.

Inducing a signal of either polarity in the coil (by passing a magnet near it, for example) causes the dual op amp to draw more current from its V_{CC} terminal. The increase produces a voltage across R1 that exceeds Q1's V_{BE} threshold, activating the complementary monostable multivibrator consisting of Q1, Q2, and associated components. As a result, Q1 connects battery voltage to the load. For many applications, you can replace the monostable with a simple pnp output stage.

A similar idea appeared in the 7/4/96 issue of EDN.

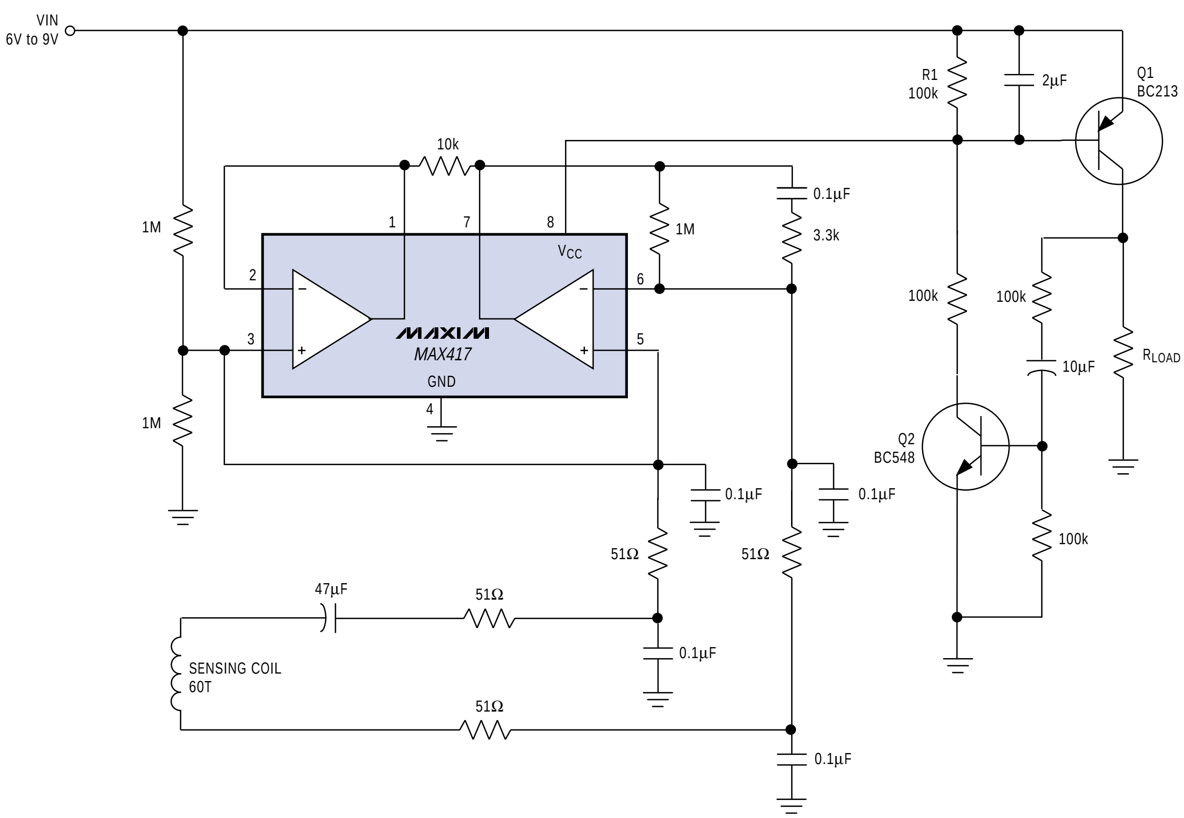


Figure 1. This load switcher enables a small signal to turn on a much larger load current.

DESIGN SHOWCASE

Single-cell boost converter generates auxiliary bias for LCD

The circuit of **Figure 1** generates two supply voltages commonly required in pagers and other portable instruments that have small, graphic liquid-crystal displays: a regulated 3.3V at 100mA, and a regulated negative output suitable for use as an LCD bias voltage. Overall efficiency is about 80%.

The main 3.3V supply is provided by a boost converter (IC1) operating in its standard configuration. The auxiliary bias voltage is provided by an extra flyback winding (the T1 secondary) and is regulated via Q1 and the low-battery detector internal to IC1.

As the battery discharges, its declining terminal voltage causes a decline in the voltage induced in the flyback winding. At minimum battery voltage (0.8V), the T1 primary sees 3.3V - 0.8V = 2.5V; thus, the 6:1 turns ratio produces 6(2.5) = 15V in the secondary. At maximum battery voltage (1.65V), the primary sees only 1.65V, producing 9.9V in the secondary. MOSFET Q1 stabilizes this output by interrupting the secondary current, introducing the regulation necessary to generate a constant (and therefore useful) negative output.

The regulator employs IC1's low-battery detector (a comparator/reference combination) as an on/off controller for Q1. Normally, the input (LBI) monitors a positive battery voltage and drives the output (LBO) low when LBI drops below 1.25V. In this circuit, the

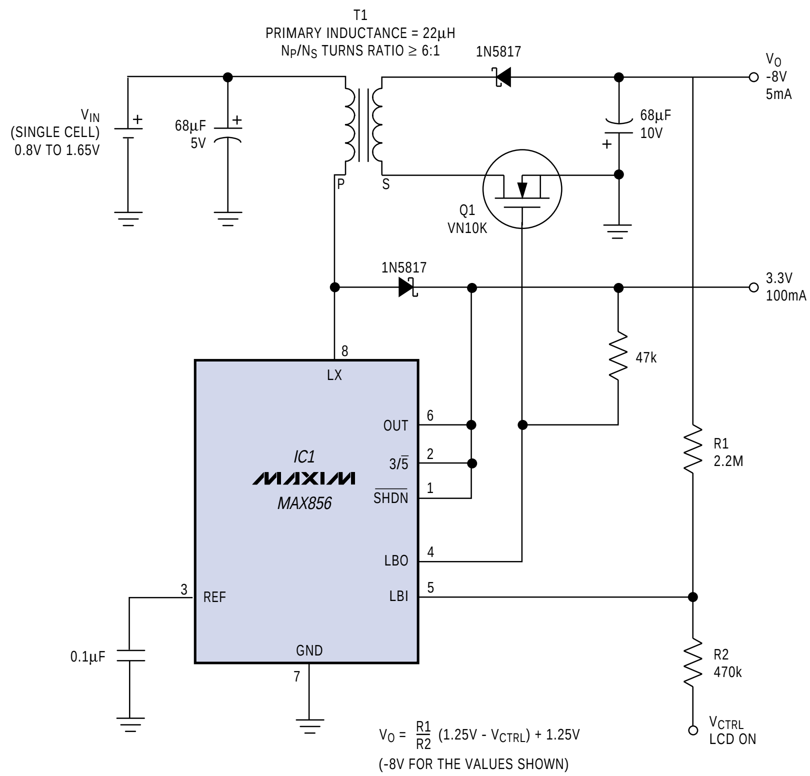


Figure 1. This circuit establishes a regulated V_{CC} (3.3V or 5V) and a regulated, negative, LCD-bias voltage (-8V in this case).

R1/R2 divider holds LBI between V_{CTRL} (normally 3.3V) and the LCD bias output (normally -8V). The R1 and R2 values are chosen such that LBO turns Q1 off when the LCD bias becomes too negative (and pulls the LBI voltage below 1.25V). Load current then causes the LCD bias to drift upward (toward 0V) until LBI exceeds 1.25V, which causes Q1 to turn on again.

The bias output makes excursions above and below its nominal value, producing a ripple voltage whose frequency depends on the size of the output filter capacitor, the output load, and the hysteresis in IC1's low-battery comparator. This frequency is about 150Hz for the circuit shown, and the hysteresis (about 25mV) dominates ripple magnitude. Multiplied by the R1/R2 ratio, the hysteresis results in a ripple amplitude (for -8V/1mA output) of about 100mV. Because ripple is essential to operation in this hysteretic converter, it cannot be reduced directly. Most LCDs are very forgiving of bias ripple. Otherwise, ripple can be minimized by adding an RC network or linear regulator at the negative output.

A logic signal at the LCD ON terminal provides a means to enable and disable the negative output. This signal voltage also sets the feedback level, and therefore should have a full CMOS swing. In addition, you can apply a variable voltage at LCD ON to make the output variable. Voltages below 1.25V turn the output off, and voltages greater than 1.25V change the output with a slope of $-R1/R2(V_{IN} - 1.25V)$, with an offset of 1.25V. This variable input, generated by a low-power digital-to-analog converter or the filtered pulse-width-modulator output from a microcontroller, can vary the LCD contrast in response to a change in temperature or viewing conditions. (See the output voltage equation in Figure 1.)

The main voltage can be changed from 3.3V to 5V by grounding the $3/\overline{5}$ terminal on IC1. In that case, the turns ratio should also be reduced to 3:1 because the highest battery voltage will induce 3.35V in the T1 primary. Then adjust the R1 and R2 values to obtain the desired negative-output level.

A similar idea appeared in the 11/4/96 issue of Electronic Design.

DESIGN SHOWCASE

Supply generates 5V from solar-cell power

Applications powered by solar cells often require a +5V power supply, but the cells typically provide only a 0.8V to 1.4V terminal voltage, with a 3A to 4A current capacity. Most dc-dc converters cannot start at such low voltages, nor can they start under full load. A two-step approach **(Figure 1)** enables the system to start up and produce the 5V rail under full load.

IC1 operates in bootstrapped mode (powered by its own output) and boosts the input voltage from 0.8V (min) to 5V. Powered by 5V, the second converter (IC2) then delivers as much as 0.5A. IC2's output voltage (5V) is programmed by R2 and R3. IC1 thus enables IC2 to start regardless of load conditions. Providing IC2 with a full +5V supply also minimizes $R_{DS(ON)}$ in the external n-channel MOSFET by providing a 0V to 5V (max) gate drive (voltage swing).

To suppress input ripple due to power-supply switching, specify C1 as a 220µF, low equivalent series resistance (ESR) capacitor. This input capacitor also minimizes supply-voltage fluctuations by lowering the solar cell's output impedance. The 330µH inductor (L1) enables a low start-up voltage for IC1. IC1's 15µF, low-ESR output capacitor (C2) minimizes supply-voltage ripple for IC2.

Make sure that the output-stage inductor (L2) is properly rated for maximum peak inductor current and maximum saturation current. The current-sense resistor (R1) limits peak current in this inductor to 100mV/R3. IC2's 470µF, low-ESR output capacitor (C3) reduces output ripple to less than 80mVp-p for load currents as high as 600mA. Smaller output load-current values permit smaller values for C1 and C3.

Figure 2 shows the overall conversion efficiency for different input voltages versus load current. The circuit delivers 200mA or more for V_{IN} = 0.8V, and 450mA or more for V_{IN} = 1.5V.

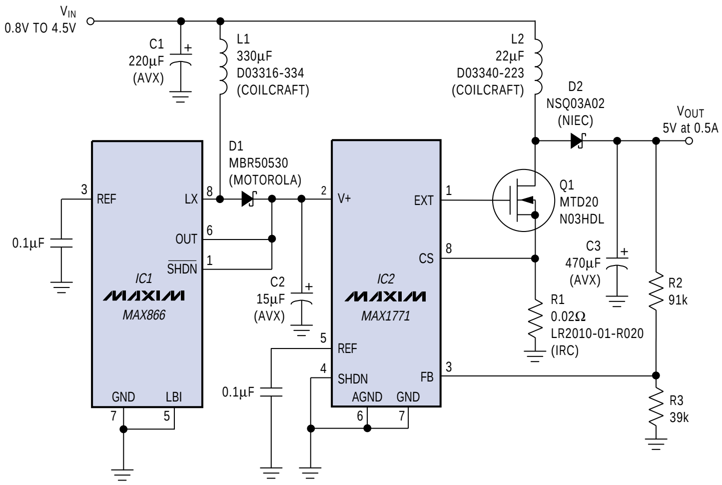


Figure 1. This two-stage step-up converter derives 0.5A at 5V from a typical solar-cell array, and guarantees start-up under full load.

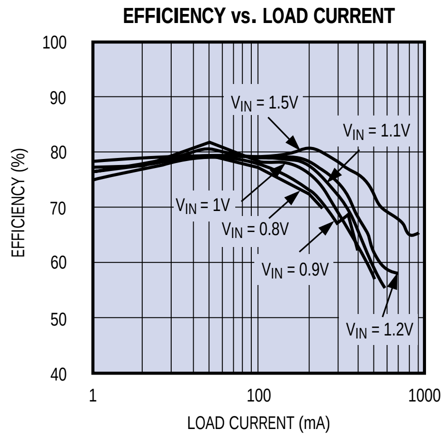


Figure 2. Efficiency for the Figure 1 circuit varies with input voltage and load current.

DESIGN SHOWCASE

Battery-switchover circuit accommodates 3V systems

Portable systems often offer the flexibility to operate either from an internal battery or from an ac-to-dc wall adapter. Many such systems include circuitry that switches automatically between the internal battery and an external source as the user connects and disconnects the wall adapter. The circuit shown in **Figure 1** implements this idea with a dual linear regulator, one side of which is preset for a 2.84V regulated output. (Other versions of the IC offer 2.8V and 3.15V outputs.)

The other side of the dual regulator is configured to allow user-adjustable outputs, and in this case monitors the wall-adapter voltage. When you remove that voltage by unplugging the adapter, the regulator's pass transistor routes battery current into the IC to support the 2.84V output. (Current flow in this transistor is counter to that of most applications.) The input bypass capacitor (C1) provides enough holdup time for seamless transitions between the battery and adapter voltages.

Resistors R1 and R2 sense the wall-adapter voltage and determine the switchover threshold (V_{SW}):

$$V_{SW} = V_{SET}\left(\frac{R1 + R2}{R2}\right) = 1.25V\left(\frac{130k + 100k}{100k}\right) = 2.875V$$

Diode D1 isolates the wall-adapter voltage so the battery cannot cause limit cycling by retriggering the switchover. D2 holds the IC's Dual Mode™ input in external-feedback mode by maintaining a minimum voltage at the SET2 input.

Battery operation interposes two pass transistors in series between the battery and the regulated output, doubling the regulator's dropout voltage. These transistors each have about 1.1Ω on-resistance. To prevent battery current from bleeding through the OUT2 transistor's intrinsic body diode when operating from the wall adapter, the wall-adapter voltage should be equal to or greater than the maximum battery voltage.

If you turn the regulators on and off with the shutdown inputs $\overline{\text{SHDN1}}$ and $\overline{\text{SHDN2}}$, choose the MAX8865 rather than the MAX8866, whose auto-discharge feature will attempt to discharge the battery. As shown, the MAX8865S with a 5V wall adapter and 3-cell battery provides up to 100mA at 2.84V.

A similar idea appeared in the 2/3/97 issue of Electronic Design.

Dual Mode is a trademark of Maxim Integrated Products.

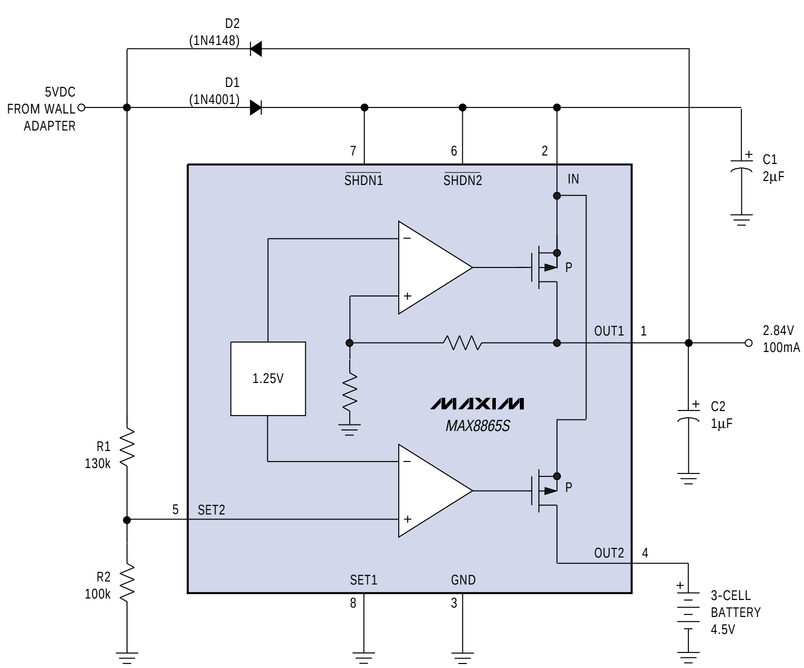


Figure 1. This linear voltage regulator with automatic-switchover circuitry maintains a 2.84V regulated output as you connect and disconnect the wall-adapter voltage.

DESIGN SHOWCASE

Off-the-shelf transformer adapts controller for SLIC applications

A new multiwinding transformer (configurable by the user for a variety of applications) enables an inverting controller to produce the high negative voltages required by an ISDN board or other telephone-line card **(Figure 1)**.

Such line cards employ a subscriber-line interface circuit (SLIC) such as the 79R79 ringing SLIC from AMD. This IC generates the off-hook and on-hook signal transmission, ring-tone generation, and ring-tip detection that constitute an analog telephone interface. For off-hook signal transmission, it requires a tightly regulated -24V or -48V; for generating ring tones, it requires a loosely regulated -70V. The five-ringer-equivalent requirement demands 9W to 10W from the -70V output, which translates to a full-load I_{OUT} of about 150mA.

IC1 is an inverting switching regulator that normally converts a 3V to 16V input to a fixed output of -5V or an adjustable output. In the circuit shown, three pairs of windings in series (provided by a single, off-the-shelf, multiwinding transformer) enable IC1 to generate the high voltages needed by a SLIC IC.

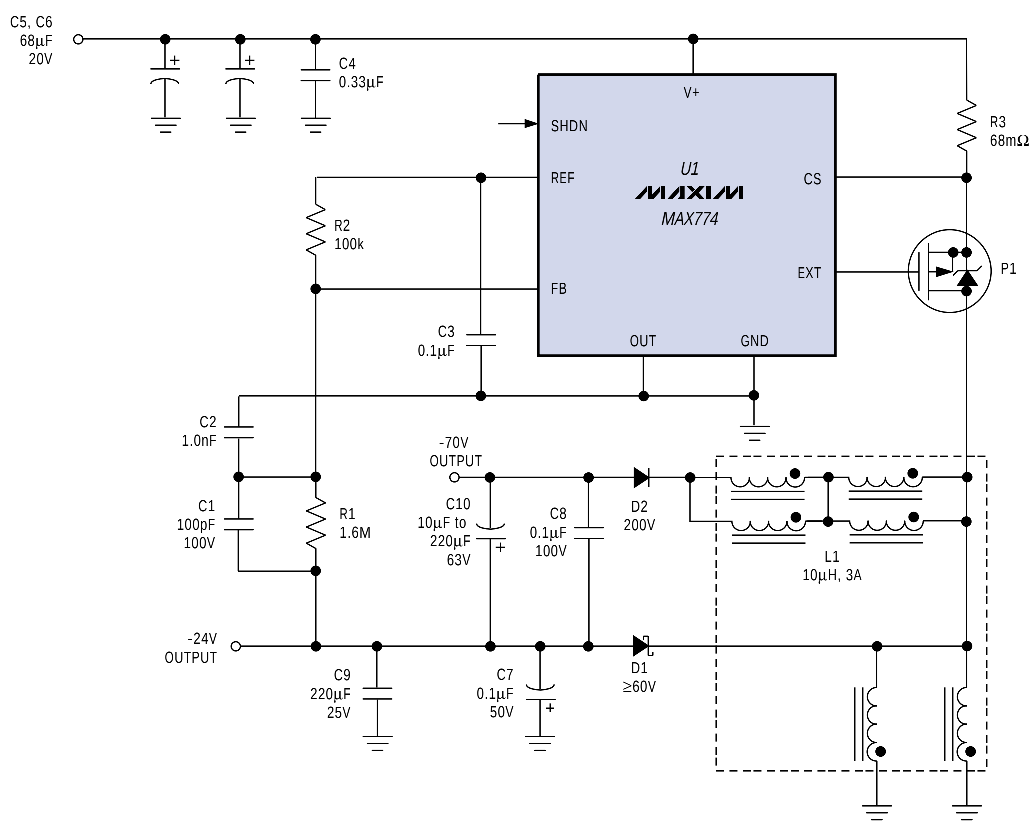


Figure 1. Dual power-supply outputs for a ringing SLIC IC (not shown) can be derived from a single inverting controller (IC1) by connecting several windings in an autotransformer configuration.

Connecting a diode and output capacitor (D1 and C7/C9) at the first or second pair of windings produces -24V (as shown) or -48V, respectively. Feedback to the IC via R1 and R2 achieves tight regulation at this output. The transformer turns ratios establish a loose regulation at the -70V output.

The circuit shown can service a five-telephone load (10W) from an input of 12V ±10%. It operates down to 3V, and produces about 2.4W at 3.3V and 3.9W at 5V. The -70V output depends on cross regulation with respect to the -24V output, and is therefore affected by relative loading on the two outputs (i.e., whether one is heavily loaded and the other lightly loaded, or vice-versa).

Multifilar transformer windings improve cross regulation by increasing the voltage coupling between outputs and by reducing the voltage spiking caused by leakage inductance. Cross regulation is also improved by connecting the -70V output's filter capacitor (C8/C10) to the -24V output instead of to ground. This connection also simplifies board layout and enhances stability.

The circuit shown in Figure 1 is optimized for compact surface-mount applications, and produces a worst-case ripple voltage at the -24V output of approximately 200mVp-p. To reduce this ripple, increase the capacitor values and use through-hole filter capacitors with low equivalent series resistance, such as the Sanyo MV-GX series. To prevent interference, place the dc-dc converter on a corner of the board opposite the sensitive audio circuitry. Cross-regulation graphs (as a guide to the preloading performance) and a tested pc board layout are available on request from Maxim's applications department.

A similar idea appeared in the 11/4/96 issue of Electronic Design.

NEW PRODUCTS

Low-power 8-bit DACs offer voltage output in a tiny package

The MAX548A/MAX549A†/MAX550A† digital-to-analog converters (DACs) are 8-bit, voltage-output serial devices available in single and dual versions. They offer low voltage, low power, and the tiny, proprietary 8-pin µMAX package (50% smaller than an 8-pin SO).

The dual MAX548A operates from a single +2.5V to +5.5V supply. Its low operating current, including current for the internal voltage reference (V_{REF} is internally connected to V_{DD}), is 150µA at V_{DD} = 2.5V and 300µA at V_{DD} = 5V. The MAX548A features a double-buffered input, independent software control of each DAC, a 1µA power-down mode, and an asynchronous load-DAC input pin. Its 3-wire serial interface is compatible with SPI™/QSPI™ and Microwire™ standards.

As upgrades to the existing dual MAX549B and single MAX550B, the software-compatible MAX549A/MAX550A have double-buffered inputs and an enhanced set of programming commands. The MAX550A also has an asynchronous load-DAC input pin.

The MAX548A/MAX549A/MAX550A are available in 8-pin DIP and µMAX packages specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $1.65 (1000 up, FOB USA).

†Previously announced.

SPI and QSPI and trademarks of Motorola, Inc.

Microwire is a trademark of National Semiconductor Corp.

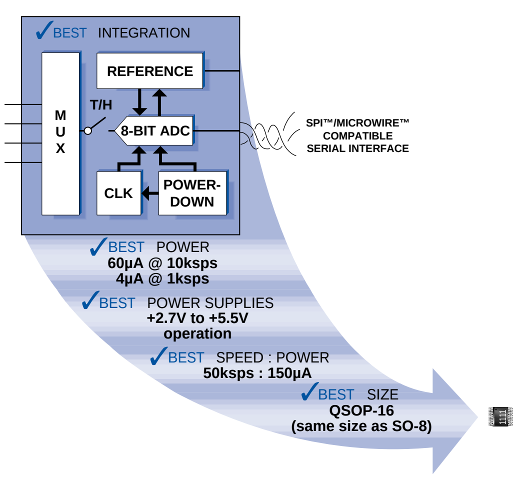
Low-cost, 3V, multichannel 8-bit ADCs are the smallest available

The MAX1110/MAX1111 analog-to-digital converters (ADCs) are complete, low-power, 3V, 8-bit devices that include an analog-input multiplexer, internal 2V reference, serial interface, and internal clock. The 4-channel MAX1111 comes in a 16-pin QSOP (same size as an 8-pin SO), and the 8-channel MAX1110 comes in a small 20-pin SSOP.

Operating from a single +2.7V to +5.5V supply, these low-power ADCs sample to 50ksps, yet draw only 120µA from the supply. For battery-operated applications, a 2µA power-down mode reduces power consumption at lower sampling rates.

The MAX1110/MAX1111 can be programmed to power down at the end of each conversion and power up when the 2MHz serial interface is accessed. The serial interface is SPI/QSPI and Microwire compatible. The analog inputs are software configurable for unipolar/bipolar and single-ended/differential operation. Other features include a hard-wired $\overline{SHDN}$ input, an internal/external clock and reference, and a serial strobe that provides the end-of-conversion signal.

The MAX1111 comes in 16-pin DIP and QSOP packages, and the MAX1110 comes in 20-pin DIP and SSOP packages. Both are available in versions specified for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), or military (-55°C to +125°C) temperature range. Prices start at $2.45 for the MAX1111 and $2.70 for the MAX1110 (1000 up, FOB USA).



5V, 12-bit/10-bit ADCs connect directly to 3V µPs

The 12-bit MAX1202/MAX1203 and 10-bit MAX1204 data-acquisition systems are designed for use in mixed-supply applications (5V analog; 3V or 5V digital). They combine a successive-approximation ADC converter with an 8-channel multiplexer, high-bandwidth track/hold, 4.096V reference (MAX1202/ MAX1204 only), and a serial-data interface.

Rather than adding external level translators, the user can set output logic levels to 3V, 3.3V, or 5V by simply applying the desired logic level to the VL input pin. In addition, the logic-high input levels are guaranteed down to 2V for compatibility with most 3V systems. The devices provide sampling rates to 133ksps and draw only 1.5mA from a single +5V or dual ±5V supply.

The MAX1202/MAX1203/MAX1204 have a 2MHz, 4-wire serial interface that connects directly to SPI and Microwire devices. They feature an internal clock and a serial-strobe output that allows direct connections to the TMS320 family of digital-signal processors. A $\overline{SHDN}$ input and two software-selectable modes are also included for powering down the devices.

The MAX1202/MAX1203/MAX1204 are available in 20-pin DIPs and 20-pin SSOPs, in versions specified for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), or military (-55°C to +125°C) temperature range. Prices start at $7.09 (1000 up, FOB USA).

NEW PRODUCTS

10-bit serial VOUT DACs available in 8-pin µMAX

The MAX5354/MAX5355 10-bit digital-to-analog converters (DACs) are available in small 8-pin µMAX packages (50% smaller than an 8-pin SO). Each includes a precision output amplifier. The MAX5354 operates from a single +5V supply, and the MAX5355 operates from a single +3.3V supply. Both draw 240µA in normal operation and only 2µA in shutdown mode.

Unlike other 10-bit DACs, these devices provide access to the amplifier's inverting input, allowing configuration for specific gains or high output current capability. The DAC output swings rail-to-rail and settles in 16µs. At power-up, the power-on-reset circuitry clears the DAC output to 0V.

The MAX5354/MAX5355 serial interface is SPI™/QSPI™ and Microwire™ compatible, and the input is double buffered. All logic inputs are TTL/CMOS compatible, and all are buffered with Schmitt triggers that allow a direct interface to opto-couplers.

MAX5354/MAX5355 are available in 8-pin DIP and µMAX packages, in versions specified for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), or military (-55°C to +125°C) temperature range. Prices start at $2.90 (1000 up, FOB USA).

SPI and QSPI are trademarks of Motorola, Inc. Microwire is a trademark of National Semiconductor Corp.

SOT23 rail-to-rail I/O op amps provide 200kHz GBW at 25µA ISUPPLY

The MAX4162/MAX4163/MAX4164 micropower op amps have Rail-to-Rail® input/output (I/O) and an exceptionally high bandwidth for their power consumption. Gain-bandwidth product is 200kHz, and typical quiescent current is only 25µA (40µA max). The single MAX4162 comes in a 5-pin SOT23 package. These devices operate from either a single +2.7V to +10V supply or dual ±1.35V to ±5V supplies.

These op amps are unity-gain stable for any capacitive load. Their outputs swing rail-to-rail, and their input common-mode range extends 250mV beyond the supply rails. A proprietary internal architecture ensures very high common-mode input rejection without the mid-swing nonlinearities found in other rail-to-rail op amps.

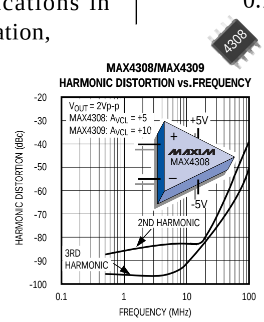
High bandwidth, low power consumption, and small packages make these op amps ideal for use in portable equipment and other low-power, single-supply applications. The MAX4162 comes in a tiny 5-pin SOT23 or 8-pin SO, and the MAX4163 comes in an 8-pin µMAX or SO. Both are specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $0.85 (1000 up, FOB USA).

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

400MHz voltage-feedback op amps have ultra-low -93dB distortion

The MAX4308/MAX4309 voltage-feedback op amps' high speed and ultra-low distortion make them ideal for use in low-level, 12-bit to 16-bit applications in medical imaging, instrumentation, and RF-signal processing.

Decompensated versions of the MAX4108/MAX4109, the MAX4308 requires a +5V/V (min) closed-loop gain, and the MAX4309 requires a +10V/V (min) gain. The MAX4308 delivers a 220MHz -3dB bandwidth, 1200V/µs slew rate, and a spurious-free dynamic range (SFDR) of -83dBc at 5MHz with R_L = 100Ω. The MAX4309 delivers a -3dB bandwidth of 200MHz and an SFDR of -83dB at 5MHz with R_L = 100Ω. Other features include wide output-voltage swings, high output-current capability (90mA), ultra-low differential gain/phase (0.004%/0.008°), and fast settling times (8ns to within 0.1%, and 12ns to within 0.01%, respectively).



The MAX4308/MAX4309 are available in 8-pin SO packages specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $3.88 (1000 up, FOB USA).

Small, low-power, 12-bit VOUT DACs have configurable outputs

The MAX5352/MAX5353 12-bit DACs include precision output amplifiers, and are available in small 8-pin DIP or µMAX packages. The MAX5352/MAX5353 operate from single supplies of +5V and +3.3V, respectively. Both draw 240µA in normal operation and only 10µA in shutdown mode.

Access to the amplifiers' inverting input allows the user to configure either device for specific gains and high output current capability. The DAC output swings rail-to-rail and settles in 14µs. At power-up, the power-on-reset circuitry clears the DAC output to zero.

The MAX5352/MAX5353 serial interface is SPI/QSPI and Microwire compatible, and the input is double buffered. All logic inputs are TTL/CMOS compatible, and all are buffered with Schmitt triggers, allowing a direct interface to opto-couplers.

The MAX5352/MAX5353 are available in 8-pin µMAX packages (50% less area than an 8-pin SO) and 8-pin DIPs, in versions specified for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), or military (-55°C to +125°C) temperature range. Prices start at $4.95 (1000 up, FOB USA).

NEW PRODUCTS

Ultra-low-power amplifiers offer SOT23 packaging and Hi-Z shutdown

The MAX4180–MAX4187 current-mode amplifiers combine high speed, low distortion, and excellent video specifications with ultra-low power consumption. They operate from a single +5V supply or from dual ±2.25V to ±5.5V supplies, and require only 1mA of supply current per amplifier while delivering output currents up to ±60mA.

Optimized for applications with +2 (6dB) or greater closed-loop gains, the MAX4180/MAX4182*/MAX4183*/MAX4186* provide a 240MHz -3dB bandwidth and a 90MHz 0.1dB bandwidth. The MAX4181/MAX4184*/MAX4185*/MAX4187*, optimized for +1V/V (0dB) or greater gains, provide a 270MHz -3dB bandwidth and a 60MHz 0.1dB bandwidth.

The MAX4180–MAX4187 amplifiers are ideal for high-performance video applications. They feature differential gain/phase errors of 0.08%/0.03°, -73dBc SFDR (f_C = 5MHz), a fast settling time to 0.1% of 20ns, and a 400V/µs slew rate. The MAX4180/MAX4181/MAX4183/MAX4185 have an additional feature: a low-power shutdown mode that lowers the supply current to 120µA (max) and places the outputs in a high-impedance state (useful in multiplexing applications).

The following package options are available: a space-saving 6-pin SOT23 or 8-pin SO for the single MAX4180/MAX4181, an 8-pin SO for the dual MAX4182/MAX4184, a 14-pin SO or 10-pin µMAX for the dual MAX4183/MAX4185, and a 14-pin SO or 16-pin QSOP for the quad MAX4186/MAX4187. All are specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $1.80 (1000 up, FOB USA).

**Future product—contact factory for availability.*

3MHz, low-power op amps with rail-to-rail I/O available in SOT23

The MAX4330–MAX4334 are a new family of wideband, low-power, single-supply, Rail-to-Rail® input/output (I/O) op amps. Available in single (MAX4330/MAX4331), dual (MAX4332/MAX4333), and quad (MAX4334) versions, these devices operate from a single +2.3V to +6.5V supply or dual ±1.15V to ±3.25V supplies. Each op amp achieves 3MHz gain-bandwidth from a supply current of only 245µA per amplifier (330µA max).

The MAX4330–MAX4334's outputs swing within 100mV of the rails (with a 2kΩ load), and their common-mode input voltage range extends 250mV beyond each rail. This rail-to-rail I/O makes them ideal for use in battery-powered equipment and other low-power, low-voltage, single-supply applications. In addition, their low offset voltage (250µV typical) and high speed (3MHz gain-bandwidth product) are ideal for signal-conditioning stages in precision, low-voltage data-acquisition systems. For space-critical applications, the MAX4330 comes in a tiny 5-pin SOT23 package.

Each output is capable of driving a 2kΩ load, and all amplifiers are unity-gain stable for capacitive loads to 150pF. The MAX4331/MAX4333 have a low-power shutdown mode that places the outputs in a high-impedance state and lowers the supply current to only 9µA per amplifier.

The MAX4330 comes in a 5-pin SOT23 package; the MAX4331 comes in an 8-pin µMAX and SO; the MAX4332 comes in an 8-pin SO; the MAX4333 comes in a 10-pin µMAX or 14-pin SO; and the MAX4334 comes in a 14-pin SO. All are specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $0.85 (1000 up, FOB USA).

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

Micropower, rail-to-rail I/O comparators come in 5-pin SOT23

The MAX985 family of single/dual/quad micropower comparators are specified for single-supply operation in the +2.5V to +5.5V range, making them ideal for use in both 5V and 3V systems. They also operate from dual supplies in the ±1.25V to ±2.75V range.

MAX985 devices typically exhibit 300ns propagation delays with 100mV overdrive while drawing 13µA quiescent supply currents. Each output stage's unique design limits supply-current surges while switching, virtually eliminating the supply glitches typical of other comparators. This design also minimizes overall power consumption under dynamic conditions.

Common-mode input voltage for the MAX985 family extends 250mV beyond each supply rail (V_{EE} - 0.25V to V_{CC} + 0.25V), and large output drivers enable rail-to-rail output swings with loads as high as 8mA. Typical input specifications include 0.5mV offset voltage and 1pA input bias current. Internal hysteresis ensures clean output switching, even with slow-moving input signals. The MAX985/MAX989*/MAX993* have push/pull outputs that sink as well as source current. The MAX986/MAX990*/MAX994* have open-drain outputs that can pull up to V_{CC} or to any level not exceeding V_{EE} + 6V.

Package options include a 5-pin SO or SOT23 for the single MAX985/MAX986, an 8-pin SO or µMAX for the dual MAX989/MAX990, and a 14-pin SO for the quad MAX993/MAX994. All are specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $0.66 (1000 up, FOB USA).

**Future product—contact factory for availability.*

NEW PRODUCTS

1GHz current-mode amplifiers offer SOT23 packaging and Hi-Z shutdown

The MAX4223–MAX4228 family of current-feedback amplifiers combine ultra-high speed, low distortion, and excellent video specifications with low power consumption. Operating from dual, ±3.0V to ±5.5V power supplies, they produce output currents as high as 80mA and draw only 6mA of supply current per amplifier.

The MAX4223/MAX4224/MAX4226*/MAX4228* have a shutdown mode (useful in multiplexing applications) that lowers the supply current to 350µA and places the outputs in a high-impedance state. The MAX4223/MAX4225*/MAX4226 are optimized for +1V/V (0dB) closed-loop gains, and have 1GHz -3dB bandwidths. The MAX4224/MAX4227*/MAX4228 are optimized for +2V/V (6dB) closed-loop gains, and have 600MHz -3dB bandwidths (a 1.2GHz gain-bandwidth product).

Low differential gain/phase errors (0.01%/0.02°), 0.1% gain flatness to 300MHz, and slew rates up to 1700V/µs make these amplifiers ideal for use in professional video applications. Their low total harmonic distortion (-60dBc) and fast settling time (8ns to 0.1%) make them ideal for data communications or for driving the inputs of high-speed analog-to-digital converters.

Package options are as follows: a tiny 6-pin SOT23 or 8-pin SO for the single MAX4223/MAX4224, an 8-pin SO for the dual MAX4225/MAX4227, and a 10-pin µMAX or 14-pin SO for the dual MAX4226/MAX4228. All these devices are specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $2.15 (1000 up, FOB USA).

**Future product—contact factory for availability.*

Ultra-low-voltage micropower comparators include 1.235V ±1.5% references

The MAX965–MAX970 family of micropower comparators includes single, dual, and quad versions; all have Rail-to-Rail® input/output (I/O). Their operating voltage range is fully specified down to 1.6V, making them ideal for 2-cell battery-powered applications. Typical quiescent supply currents are less than 3µA per comparator.

For ultra-low-voltage operation, the input common-mode voltage range for each device extends to each supply rail. The open-drain outputs simplify voltage translation in multirail systems, and they also provide rail-to-rail output swings when operating with an external pull-up resistor. All inputs and outputs can withstand a continuous short circuit to either supply rail.

The single MAX965, dual MAX967/MAX968, and quad MAX969 include a 1.235V ±1.5% bandgap voltage reference for use in threshold-detector and window-comparator applications. This reference makes it possible to include adjustable hysteresis.

The MAX965–MAX968 comparators are available in 8-pin SO and µMAX packages. The MAX969 is available in a 16-pin SO or QSOP, and the MAX970 is available in a 14-pin SO or 16-pin QSOP. All devices are specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $1.05 (1000 up, FOB USA).

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

Precision, single-supply op amps have rail-to-rail I/O

The MAX4165–MAX4169 family of precision, high-output-drive op amps includes single, dual, and quad versions. Each op amp combines low power consumption, high output current capability (80mA minimum), and rail-to-rail operation with exceptional DC accuracy. These qualities provide excellent performance in portable audio and other low-voltage, battery-powered applications.

All amplifiers guarantee single-supply operation from +2.7V to +6.5V, as well as dual-supply operation in the ±1.35V to ±3.25V range. Quiescent supply currents are only 1.2mA (1.4mA max) per amplifier. The MAX4166/MAX4168 have a shutdown mode that lowers their supply current to 38µA (per amplifier) and places each output in a high-impedance state.

Each amplifier is unity-gain stable, with a 5MHz gain-bandwidth product and a 2V/µs slew rate. Input offset voltages are only 250µV. PSRR is 88dB, and voltage gain with a 100kΩ load is 120dB.

Package options include a 5-pin SOT23 for the single MAX4165; an 8-pin µMAX, SO, or plastic DIP for the single MAX4166; an 8-pin SO or plastic DIP for the dual MAX4167; a 10-pin µMAX or a 14-pin SO or plastic DIP for the dual MAX4168; and a 14-pin SO or plastic DIP for the quad MAX4169. All are specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $0.95 (1000 up, FOB USA).

NEW PRODUCTS

Quad, wideband current-mode amplifiers have 0.1dB gain flatness to 90MHz

The MAX4119/MAX4120 are quad, low-power amplifiers with current-mode feedback. They combine high speed with low-power operation, operate from ±5V supplies, and draw only 5mA of supply current per channel. The MAX4119, optimized for +2V/V or greater closed-loop gains, delivers a 350MHz -3dB bandwidth and 0.1dB gain flatness to 90MHz. The MAX4120, optimized for +8V/V or greater closed-loop gains, has a 300MHz -3dB bandwidth and 0.1dB flatness to 115MHz.

These amplifiers exhibit high slew rates (1200V/µs at +2V/V and 1800V/µs at +8V/V) and exceptional full-power bandwidths, making them excellent choices for use in high-performance pulse and RGB-video applications. They offer wide output swings (±3.5V into a 100Ω load) and a high 80mA current-drive capability.

Other devices in this family include the single MAX4112/MAX4113 and the dual MAX4117/MAX4118. The MAX4119/MAX4120 are available in a 14-pin SO and a 16-pin QSOP; the MAX4112/MAX4113/MAX4117/MAX4118 are available in an 8-pin SO; and the MAX4112 also comes in an 8-pin µMAX. All are specified for the extended-industrial temperature range (-40°C to +85°C). Prices for the MAX4119/MAX4120 start at $1.95 (1000 up, FOB USA).

16-channel/dual 8-channel CMOS muxes feature ultra-low leakage

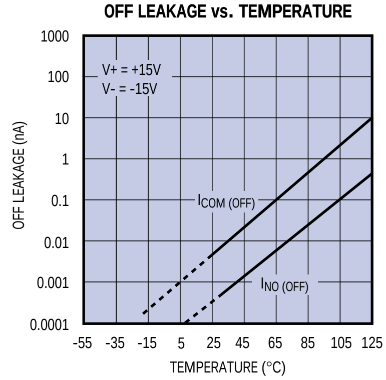
The MAX336/MAX337 are CMOS analog multiplexers (muxes). The MAX336 has four digital inputs that select one of 16 single-ended channels, and the MAX337 has three digital inputs that select one of 8 differential channels. Both devices are capable of demultiplexing as well as multiplexing, because the on-resistances (400Ω max, matched to within 10Ω) conduct equally well in both directions. Transition times are less than 500ns.

Leakage currents are extremely low: off leakages are less than 20pA at +25°C, and on-channel leakages are less than 50pA at +25°C. The MAX336/MAX337 have a new design that guarantees low charge injection (1.5pC typical), and protection (per Method 3015.7 of MIL-STD-883) against electrostatic discharge (ESD) to 2000V. The MAX336/MAX337 are improved, pin-compatible upgrades for the industry-standard DG506A/DG507A muxes.

The MAX336/MAX337 handle Rail-to-Rail® signals while operating from single +4.5V to +30V or dual ±4.5V to ±20V supplies. The digital enable and channel-address inputs remain TTL/CMOS-logic compatible (0.8V and 2.4V switching thresholds) over the full operating temperature range and over the ±4.5V to ±18V power-supply range. These parts are fabricated with Maxim's 44V silicon-gate process.

The MAX336/MAX337 are available in 28-pin DIP, wide-SO, SSOP, and PLCC packages, in versions specified for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), or military (-55°C to +125°C) temperature range. Prices start at $3.69 (1000 up, FOB USA).

MAX336/MAX337
OFF LEAKAGE vs. TEMPERATURE



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

Dual SPST/SPDT analog switch fits in 6-pin SOT23

The MAX4541–MAX4544 are a family of dual, low-voltage analog switches. The MAX4541/MAX4542/MAX4543 have dual single-pole/single throw (SPST) configurations: two normally open (NO) switches (MAX4541), two normally closed (NC) switches (MAX4542), and one NO with one NC (MAX4543). The MAX4544 offers an all-new single-pole/double-throw (SPDT) configuration in a 6-pin SOT23 package.

Low power consumption (5µW) makes these switches ideal for use in battery-powered equipment. They offer low leakage current (100pA maximum at +25°C and 2.5nA maximum at +85°C) and fast switching: t_{ON} is 150ns (max), and t_{OFF} is 100ns (max). Low charge injection is guaranteed at 5pC (max), and all switches offer 2kV protection against ESD per Method 3015.7 of MIL-STD-883.

All switches operate from a single +2.7V to +12V supply. When operating from a +5V supply, they exhibit 60Ω (max) on-resistances (33Ω typical), 2Ω (max) between-channel matching, and 6Ω (max) R_{ON} flatness over the analog input range. All control inputs are TTL/CMOS compatible, and the MAX4543/MAX4544 guarantee break-before-make switching.

For dual-supply operation, see the MAX320/MAX321/MAX322 (pin compatible with the MAX4541/MAX4542/MAX4543). For similar, quad versions of these dual-supply switches, see the MAX391/MAX392/MAX393. The MAX4541–MAX4544 are available in 8-pin DIP, µMAX, and SO packages; the MAX4544 also offers a 6-pin SOT23 option. All are available in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $0.41 (1000 up, FOB USA).

NEW PRODUCTS

Multiple-output notebook power-supply controllers are 96% efficient

The MAX1630–MAX1635 switch-mode power-supply controllers have step-down (buck) topologies to generate logic supply voltages in battery-powered systems. They produce dual and triple outputs plus many other functions: power-up sequencing, power-good signal with delay, digital soft-start, secondary winding control, low-dropout circuitry, internal frequency-compensation networks, and automatic bootstrapping.

Synchronous rectification and Maxim's proprietary Idle Mode™ control scheme help to achieve conversion efficiencies as high as 96%. High efficiency (>80%) over a 1000:1 load-current range extends battery life in suspend mode, idle mode, and other low-load conditions. The MAX1630–MAX1635's excellent dynamic response corrects (to within five clock cycles at 300kHz) the output load transients caused by the latest dynamic-clock CPUs. In addition, the internal gate drivers' robust 1A output capability ensures fast switching for external n-channel MOSFETs.

Input voltage range is 4.2V to 30V. At 12V, quiescent current is 250µA, dropping to 4µA in shutdown mode. Each device features a logic-controlled pulse-width-modulation (PWM) mode that reduces noise and RF interference in mobile communications, pen-entry devices, and other sensitive applications. The PWM switching frequency can be synchronized to an external signal, if necessary.

The MAX1630/MAX1632/MAX1633/MAX1635 contain 12V/120mA linear regulators. The MAX1631/MAX1634 lack the 12V regulator, but include a secondary-feedback input (SECFB) and a control pin (STEER) that selects which PWM loop (3.3V or 5V) receives feedback from the secondary. SECFB allows you to adjust the secondary winding's regulation point with an external resistor divider, and helps generate output voltages other than 12V.

The MAX1633/MAX1634/MAX1635, which lack the output undervoltage shutdown and overvoltage protection on the MAX1630/MAX1631/MAX1632, make it simpler to troubleshoot prototype boards. They also serve applications in which the outputs are supported by external keep-alive supplies that would otherwise interfere with the overvoltage-protection circuitry.

The MAX1630–MAX1635 are available in a 28-pin SSOP, in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $5.22 (1000 up, FOB USA).

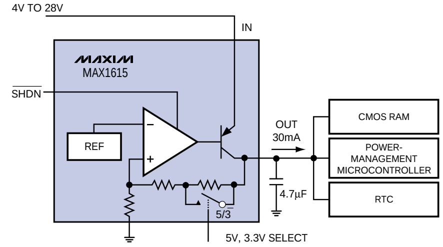
Idle Mode is a trademark of Maxim Integrated Products.

Micropower linear regulator accepts inputs to 28V

The MAX1615 micropower linear regulator is useful in all battery-powered systems. It is designed to provide a pin-selectable keep-alive supply of 5V or 3.3V (with ±2% initial output accuracy) for CMOS RAM in a notebook computer. The 4V to 28V input range allows direct connection to high-voltage batteries.

Despite a miserly 8µA (max) no-load supply current, the MAX1615 has excellent AC PSRR and line-transient response, providing clean 5V or 3.3V outputs even when subjected to the fast supply-voltage changes that occur when switching between the battery and an AC adapter. The 30mA (max) output current is guaranteed by design. Dropout voltage is 350mV (max), and shutdown supply current is less than 1µA.

Fault protection includes internal foldback-current limiting and thermal-shutdown circuitry. The MAX1615 is specified for the extended-industrial temperature range (-40°C to +85°C), and comes in a tiny 5-pin SOT23 package, whose excellent thermal characteristics tolerate power dissipation to 571mW Prices start at $0.79 (1000 up, FOB USA).



Dual, step-up DC-DC controller is smallest available

The MAX863 includes two independent, step-up DC-DC controllers on a single IC in a 16-pin QSOP (same board area as an 8-pin SO). Each controller generates a high-power output by driving a low-cost external n-channel MOSFET. The main output uses Maxim's proprietary Dual Mode™ feature to provide 3.3V or 5V (or an adjustable output) to power the system logic and microprocessor. The second output, ideal for powering PCMCIA cards or driving an LCD, is adjustable with external resistors.

Input voltage range extends down to 1.5V to allow start-up and operation from two or three battery cells (required in organizers, translators, and other low-power hand-held products). A current-limited, pulse-frequency-modulated (PFM) control mode reduces start-up surges; for output loads from 20mA to over 1A, it provides efficiencies as high as 90%. With both controllers operating, quiescent supply current is 50µA. The MAX863 provides independent 1µA shutdown controls for system flexibility and long battery life.

For applications in which the input voltage extends above and below the main output voltage, the MAX863 can be configured in a buck/boost SEPIC topology. For complex systems, two MAX863s can generate 3.3V, 5V, 12V, and 28V.

The MAX863 is available in a 16-pin QSOP specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $2.80 (1000 up, FOB USA). An evaluation kit (MAX863EVKIT) is also available; it includes the MAX863, an assembled printed circuit card, and all other external components required.

Dual Mode is a trademark of Maxim Integrated Products.

NEW PRODUCTS

Step-up DC-DC converter supplies ±28V for LCDs and varactors

The MAX629 high-efficiency boost converter produces a positive or negative high-voltage output from low-voltage inputs. It can drive the LCD in a small hand-held system or the varactor tuner in a set-top box. Its 30V internal switch (vs. an external switch) saves space and cost. The MAX629's internal switch, low supply current, small package, and tiny external components provide an extremely compact and efficient high-voltage supply for LCDs.

A polarity-select pin, which inverts the polarity of the feedback-error amplifier and shifts the set point from V_{REF} to ground, allows the circuit to be configured for a high positive or negative output voltage. Typical input voltages (3.3V or 5V) enable the MAX629 to generate output voltages as high as ±28V with 10mA output capability. V_{OUT} can be set with a resistor divider, potentiometer, or digital-to-analog converter (DAC). This device requires a +2.7V to +5.5V power supply, but power for the step-up inductor can come directly from a battery or any other voltage between 0.8V and V_{OUT}.

The MAX629's current-limited, pulse-frequency-modulation control scheme achieves efficiencies as high as 93% over a wide range of load conditions. Its low supply current (80µA during operation and 1µA during shutdown) is ideal for battery-powered applications. High switching frequencies (to 300kHz) and a pin-selectable 500mA or 250mA current limit allow the use of tiny, inexpensive inductors.

The MAX629 is available in a small, 8-pin SO package specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $2.85 (1000 up, FOB USA).

High-performance step-down controllers power high-end CPUs

The MAX1624/MAX1625 step-down controllers are intended for demanding applications in which output voltage precision and good transient response are essential for proper operation. Powered by single +5V ±10% supplies, they deliver more than 100W. Output accuracy over line and load is better than ±1%.

Two external resistors program the MAX1625 output voltage, and an internal 5-bit DAC enables the MAX1624 to provide a digitally programmable output, adjustable in 100mV increments from 1.1V to 3.5V. Both devices employ synchronous rectification to achieve efficiencies greater than 90%. Flying-capacitor bootstrap circuitry generates gate-drive voltages higher than V_{CC}, enabling the use of inexpensive n-channel MOSFETs for both external switching transistors.

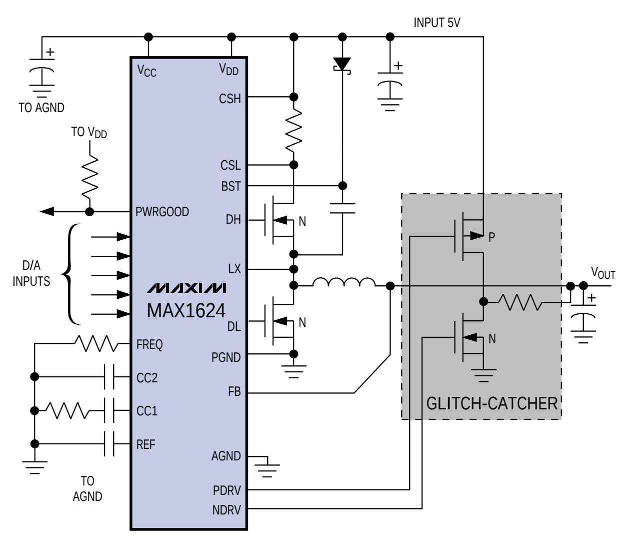
Excellent dynamic response minimizes the output transients otherwise induced by the latest dynamically clocked CPUs, and external resistors program the switching frequency from 100kHz to 1MHz. High frequencies eliminate the need for large surface-mount inductors and output filter capacitors, reducing board area and system cost. Other features common to both devices include an internal digital soft-start, a power-good output, and a 3.5V ±1% reference output.

When dynamically clocked CPUs toggle their internal circuitry on and off to save power, they can generate load steps that are several amperes within a few tens of nanoseconds. To minimize transients on the supply rails for these CPUs, the MAX1624 provides dedicated high-speed outputs (NDRV and PDRV) for driving external p-channel and n-channel MOSFETs. These MOSFETs form a Glitch-Catcher™ that quickly restores regulation at V_{OUT} by providing a brief short to V+ or ground, bypassing the inductor's lowpass-filter effect.

The MAX1624 also allows user control of the loop gain, to trade output accuracy against the output filter-capacitor requirement. AC-load regulation can be set to 0.5%, 1%, or 2% by connecting the LG input to ground, REF, or V_{CC}.

The MAX1625 is available in a 16-pin narrow-SO package, and the MAX1624 is available in a 24-pin SSOP. Both are specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $3.85 (1000 up, FOB USA).

Glitch-Catcher is a trademark of Maxim Integrated Products.



NEW PRODUCTS

Boost 2-cell batteries to 3.3V; no inductor needed

The MAX679 DC-DC converter is a charge-pump step-up device that provides a regulated 3.3V (±4%) from 1.8V to 3.6V input voltages (as produced by two alkaline, NiCd, or NiMH cells).

Operating in regulated doubler mode, the MAX679 provides regulation by gating the internal oscillator on and off, increasing the number of cycles as the load increases or the input supply voltage decreases. As a limiting case, the charge pump operates continuously at a pin-selectable frequency (330kHz or 1MHz) that allows a trade-off between quiescent current and capacitor size. The MAX679's low operating current (50µA) provides high efficiency (just under 90%) for the following conditions: V_{IN} = 2V, V_{OUT} = 3.3V, and I_{OUT} = 20mA.

The MAX679 comes in an ultra-small µMAX package and requires no external inductor. Its low operating voltage and high switching frequency (to 1MHz) enable the use of very small surface-mount components: a small flying capacitor (0.33µF), a 4.7µF input capacitor, and a 10µF output capacitor. The entire circuit fits in less than $0.05in^2$. To prevent battery drain, the MAX679 features a logic-controlled shutdown that lowers the supply current to 1µA and disconnects the load. Special soft-start circuitry prevents the flow of excessive battery current during start-up.

The MAX679 is available in an 1.11mm-high, 8-pin µMAX package (half the size of an 8-pin SO), specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $1.55 (1000 up, FOB USA).

Dual, 230kbps RS-232 serial port (6 Tx/10 Rx) withstands ±15kV ESD

The MAX3187 RS-232 transceiver includes six drivers and ten receivers, forming two complete DTE serial ports. Each meets the European Community's stringent electrostatic-discharge (ESD) requirements: all transmitter outputs and receiver inputs are protected to ±15kV using the Human Body Model or IEC 1000-4-2 Air-Gap-Discharge method, and to ±8kV using the IEC 1000-4-2 Contact-Discharge method. The chip remains latchup free during ESD events.

The MAX3187 is optimized for use in motherboards and desktop PCs. Compatible with popular PC-communications software, it is guaranteed for data rates as high as 230kbps. It operates on +5V and ±12V nominal supply voltages, and draws less than 3mA (I_{CC}) and 1mA (I_{DD} and I_{SS}).

The MAX3187 comes in a space-saving 36-pin SSOP with flow-through pinout, in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $1.85 (100,000 up, FOB USA).

Low-noise, precision voltage references guarantee 1ppm/°C tempcos

The MAX6325/MAX6341/MAX6350 precision voltage references feature low noise and extremely low temperature coefficients (tempcos). Excellent line/load regulation and low output impedance at high frequencies make them ideal for use in systems with digital resolution to 16 bits. The MAX6325 features a buried-zener technology that provides a very low output noise of 1.5µVp-p (0.1Hz to 10Hz).

Each reference exhibits the ultra-low tempco (0.5ppm/°C typ, 1ppm/°C max) normally associated with costly, power-hungry heated references while consuming relatively small amounts of power (18mW typ). These devices achieve their exceptional temperature stability with a low-power compensation scheme.

Output voltages are fixed at 2.500V (MAX6325), 4.096V (MAX6341), and 5.000V (MAX6350); with initial accuracies of ±0.02%. Each reference guarantees its load-regulation specification for source/sink currents to ±15mA. All three devices include options for external voltage trimming and noise reduction.

The MAX6325/MAX6341/MAX6350 come in 8-pin DIPs and SOs, in versions screened for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), or military (-55°C to +125°C) temperature range. Prices start at $6.70 (1000 up, FOB USA).