MAXIM

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News Briefs

Forbes Rates Maxim Among America's Best Small Companies

For the fifth consecutive year, Maxim Integrated Products is among America's most prosperous small companies. We are one of only 14 "top tier" companies on *Forbes* magazine's list of America's Best Small Companies to have achieved top 200 status at least four times in the past five years.

We announced 36 new products during the first quarter and 31 products during the second quarter, for a total of 795 new products introduced since the company was formed—the most of any company in the industry.

Maxim reports 35th consecutive quarter of increased earnings

Maxim Integrated Products, Inc., reported record net revenues of $56,184,000 for the second quarter of fiscal 1995, compared to $36,143,000 for the same period a year ago. This represents a 55.4% gain in net revenues from the same quarter a year ago. Net income of $8,930,000 (or $0.27 per share) for the quarter marked the 35th consecutive increasingly profitable quarter for Maxim and compared to net income of $5,686,000 (or $0.18 per share) for the same quarter in fiscal 1994.

Operating income for the quarter was 23.5% of net revenues, again one of the industry's highest. Gross margins increased to $32,868,000 (58.5% of net revenues) from $21,166,000 (58.6% of net revenues) for the same quarter in fiscal 1994.

During the quarter, cash and short-term investments increased $8,707,000 ($0.26 per share). Accounts receivable levels were 31 days outstanding, and inventory days declined to 63 days from 66 days in the prior quarter. The Company continued its stock repurchase program, repurchasing stock for $2,126,000 during the quarter. The Company also purchased for cash $6,635,000 of capital equipment.

Maxim effected a two-for-one stock split during the second quarter in the form of a stock dividend. At the annual meeting in November, shareholders approved a substantial increase in Maxim's stock option plan, confirming the Company's philosophy that people make the difference in great organizations.

New products developed and announced during the quarter were consistent with our model for 3-year sales and profit growth. New product announcements increased 13% per year from 1990 to 1993, and they are expected to increase 30% per year from 1993 to 1996. Based on past performance, we foresee that products developed during the 1993–1996 time frame will strongly influence sales and profits growth during 1996–1999.

We have now substantially completed integration of the operation acquired from Tektronix last year, and our emerging high-frequency businesses are growing on plan. To date, we have announced eight new standard products based on the acquired high-frequency bipolar technology. The existing high-frequency business has not declined as our worst-case plan allowed. Ramp-up of the manufacturing capability in Oregon is on track. In the second quarter, 30% of our wafers were manufactured in the acquired 0.8 micron facility. Wafer output from this facility has increased 25% quarter-to-quarter. By the end of Q495, we anticipate that 50% of our wafers will be produced in Beaverton. Over the next several quarters, if required, production can be increased to three times our current total wafer consumption with additional capital expenditures of less than $20 million.

Also during the quarter, Maxim began a three-quarter program to modernize its manufacturing facilities, including upgrading wafer fabrication from 4" to 6" wafers and replacing outdated test equipment and handlers in all of our facilities. Second quarter results included a $5.6 million charge related to this program.

Energy management for small portable systems

Numerous diverse and conflicting constraints burden the designer of small hand-held products. Aside from the customary restrictions on size and weight, these constraints include cost limitations, strict time schedules, battery-life goals measured in weeks instead of hours, and host computers that are (sometimes) overtaxed with the demands of power management.

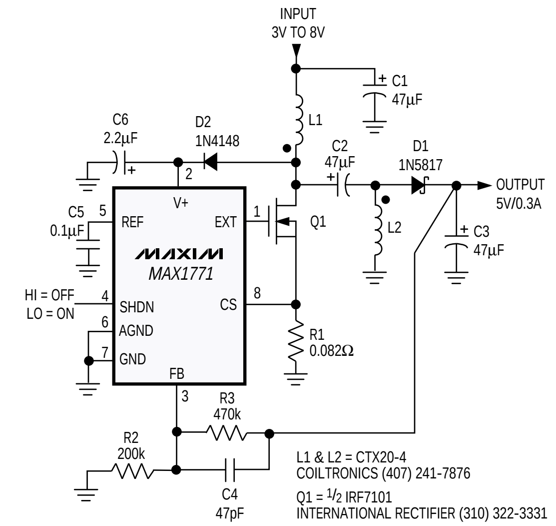
Because power requirements for hand-held applications vary widely with product use, no single "best" power source exists for these applications. A device used intermittently is more concerned with no-load quiescent current than with full-load efficiency, and so may operate satisfactorily with alkaline batteries. Cell phones, on the other hand, must contend with high peak loads and frequent use. This mode of operation emphasizes conversion efficiency over quiescent current, so cell phones are better served with a rechargeable battery.

In hand-held product design, size limitations often dictate the number of battery cells early in the process. This is frustrating to the electrical engineer, and a substantial constraint, since the number (and type) of cells allowed determines the operating-voltage range, which in turn strongly affects the cost and complexity of the power supply. High cell counts enable the use of linear regulators and simple circuitry at the cost of extra weight and limited efficiency. Low cell counts compel the use of a more costly switching regulator, but the low cost of the battery may justify this expense.

Four-cell designs

Four-cell batteries often provide an attractive compromise between weight and operating life. That number is particularly popular for alkaline batteries because they are commonly sold in multiples of four. Four-cell power for 5V circuitry presents a design challenge, however. As the battery discharges, the regulator must first step down, and then step up. This requirement precludes use of the simpler, one-function regulator topologies that can only step down, step up, or invert.

One effective solution to this problem is the SEPIC (single-ended primary inductance converter), in which



EFFICIENCY AT I_{LOAD}

INPUT VOLTAGE	10mA	100mA	200mA	300mA
3.5V	81%	83%	84%	84%
4.0V	82%	84%	84%	85%
5.0V	82%	84%	85%	86%
6.0V	82%	84%	86%	86%

Figure 1. This regulator topology supplies 5V for inputs ranging from 3V to 8V. The operation shifts smoothly between step-up and step-down conversion without steps or mode changes. During shutdown, the output turns off completely and sources no current.

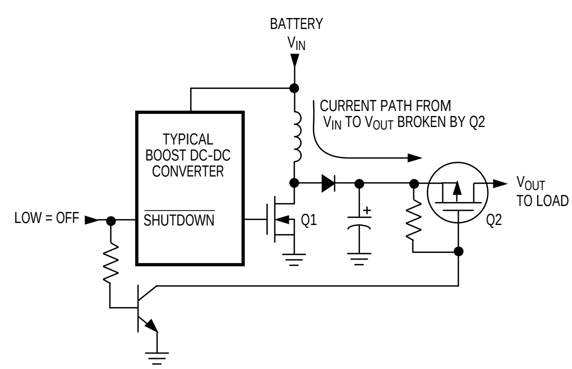


Figure 2. Typical dc-dc boost converters provide a current path from input to output, even when powered down. To interrupt this path, you must add a disconnect switch (Q2).

V_{OUT} is capacitively coupled to the switching circuitry (**Figure 1**). The absence of a transformer is one of several advantages this configuration has over flyback-transformer regulators and combination step-up/linear regulators.

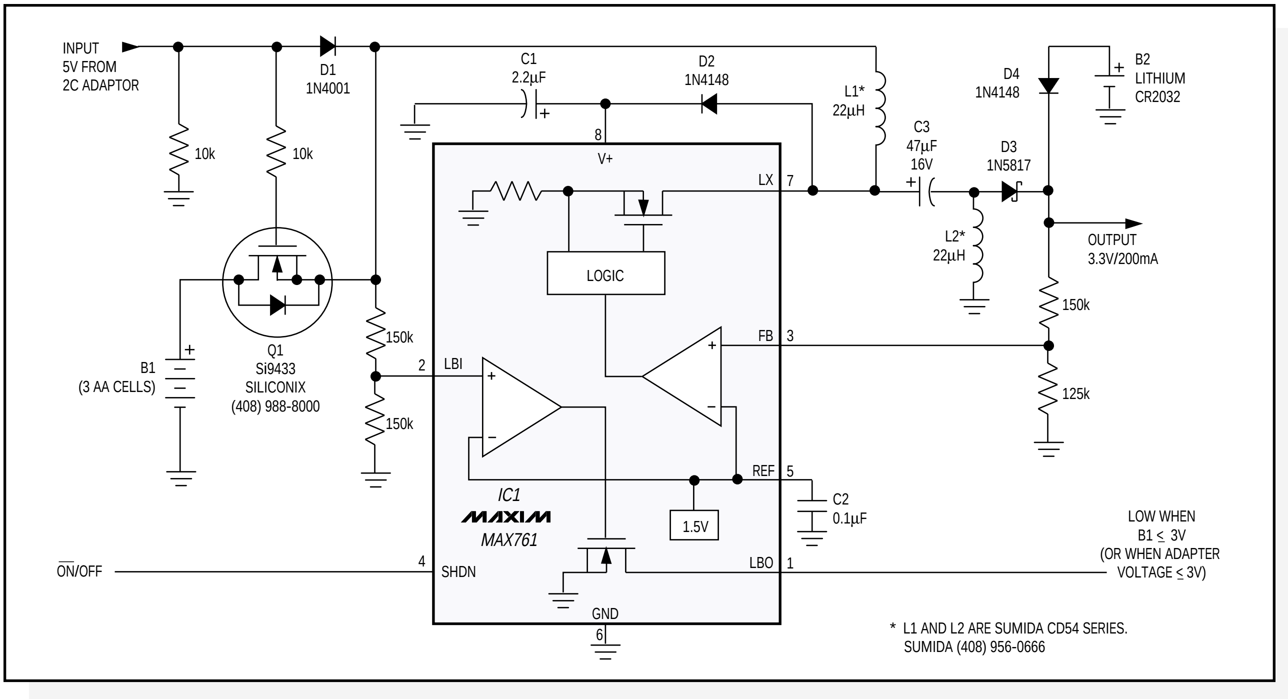


Figure 3. This low-current step-up/step-down regulator supplies 3.3V at 200mA. Q1 automatically disconnects the B1 battery when you connect an ac adapter, and a diode-OR circuit allows B2 to back-up the 3.3V output.

As another improvement over boost designs (in which current drains from the battery during shutdown unless you add a cut-off switch—see **Figure 2**), the SEPIC output fully turns off in response to a shutdown command. As V_{IN} falls during normal operation, the SEPIC circuit smoothly regulates V_{OUT} without shifting its mode of operation as V_{OUT} approaches V_{IN}. Its power-conversion efficiency peaks at 86%, near 200mA (Figure 1).

Coils L1 and L2 (Figure 1) should be the same type and have the same value, but coupling between them is not required. They can be wound on the same core for convenience, but the circuit works equally well if they are completely separate. Each coil passes only one half of the peak switching current (I_{PEAK} = 100mV/R1 = 1.22A), so each can be rated accordingly.

Capacitor C2 couples energy to the output and requires low ESR to handle high ripple currents. A low-ESR Sanyo OS-CON capacitor, for instance, offers 3% more efficiency than does a less expensive 1µF ceramic capacitor. Tantalum capacitors are not recommended because high ESR causes them to self-heat at high ripple currents.

Diode D2 provides a supply voltage for the IC (pin 2) by capturing switching pulses at the drain of Q1. Although this voltage (approximately the sum of V_{IN} and V_{OUT}) limits the maximum V_{IN} to 8V, it improves the start-up capability under full load and improves the low-V_{IN} efficiency by boosting gate drive to the external MOSFET. If V_{IN} does not fall below 4V, you can substitute a 3V-threshold FET for Q1 and omit D2. In that case, pin 2 connects directly to V_{IN}, which assumes an upper limit of 16.5V.

Three cells to 3.3V

The circuit of **Figure 3** employs the same principles as that of Figure 2, but adds battery-backup capability. It also foregoes the external FET for a lower-current internal one. Separate coils for L1 and L2 (vs. a single transformer) allow the use of a 22µH coil for each of multiple versions of the circuit—such as you would need in a product that required power supplies of 3.3V, 5V, 12V, and 30V, for example. The input-voltage range is 3V to 13V.

During normal operation, the ac adapter's 5V output powers the circuit and turns off Q1. Disconnecting the adapter removes 5V, turns on Q1, and allows the three AA cells to provide power. If the input voltage drops below 3.0V, a low-battery comparator in IC1 alerts the system by driving LBO low. And for backup, a diode-OR connection allows the optional lithium battery (coin cell B2) to maintain the 3.3V output. To simplify the switchover circuit from adapter to main battery, this design requires the ac adapter's 5V output to be somewhat regulated—to between 4V and 5.5V.

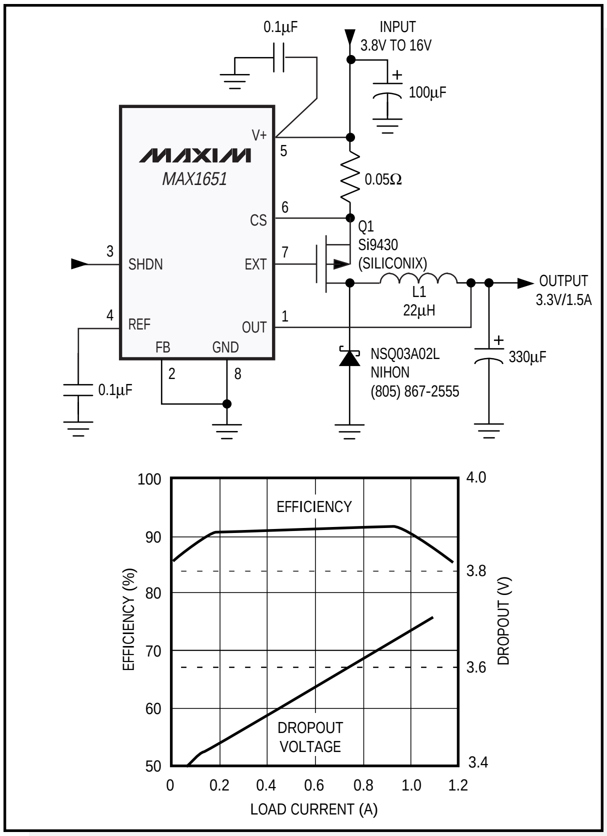


Figure 4. A low-dropout switch-mode controller and p-channel MOSFET supply 3.3V at 1.5A with inputs as low as 3.8V. Efficiency exceeds 90% for most of the operating range.

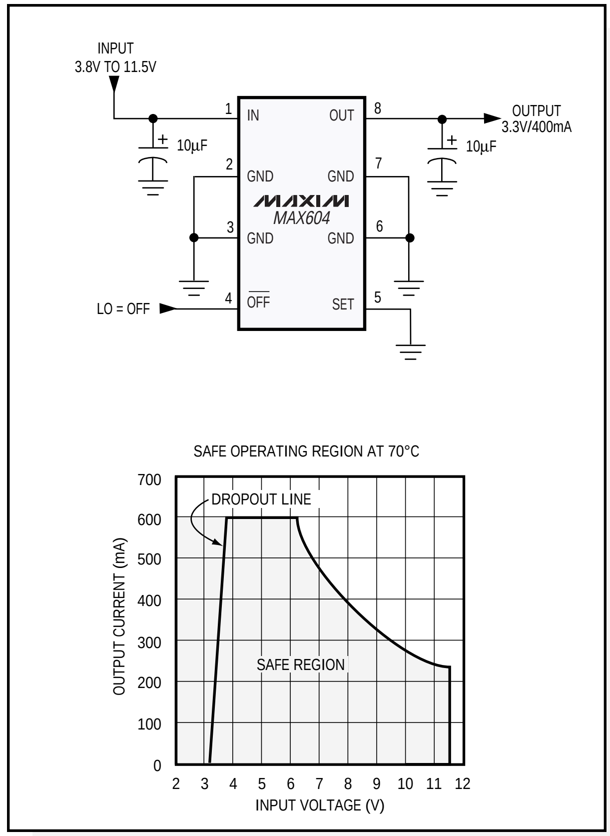


Figure 5. This combination of internal MOSFET pass transistor and high-power SO-8 package provides a linear regulator with low dropout, an operating current of 15µA, and an output capability of over 400mA.

Low-dropout, step-down converter

Low-voltage logic, such as that powered from 3.3V, now enables the use of 4-cell inputs for simple step-down configurations that optimize efficiency and cost. For 3.3V outputs, the key specification is dropout voltage—the minimum allowable difference between V_{IN} and V_{OUT}. "End-of-life" voltage for the battery varies according to cell type and the product's pattern of use, but (for all but lithium batteries) it falls in the range of 0.8V to 1V per cell. As a result, it's not uncommon for 3.3V regulators to operate with input voltages as low as 3.6V.

The design of **Figure 4** offers an uncomplicated means for delivering intermediate current loads at 3.3V from four cells. The IC drives a low-threshold p-channel MOSFET, and minimizes current-sense losses with a low current-sense voltage of 110mV. For best performance, the MOSFET on-resistance should be specified in conjunction with the circuit's lowest operating voltage—about 3.6V in this case.

Linear regulators

Still the lowest-cost approach for many step-down applications (short of no regulator at all) is linear regulation, provided its efficiency and battery-life limitations are acceptable, and its power dissipation at higher V_{IN} is manageable.

For portable designs, even a simple linear regulator can provide some twists. As an example, dropout voltage (the low-V_{IN} level at which output regulation is lost) should often be regarded as a part of normal operation rather than a fault. That is, to extend operating time it may be advisable to allow the regulator to fall out of regulation without shutting down. The regulator's behavior during dropout (especially its quiescent current) is important in these designs.

The simple linear regulator of **Figure 5** offers exceptional dropout behavior with little effect on operating current. Essentially an 8-pin surface-mount package, it delivers more than 400mA. Because the internal pass element is a MOSFET instead of a bipolar transistor, the circuit's dropout voltage is nearly zero at light loads.

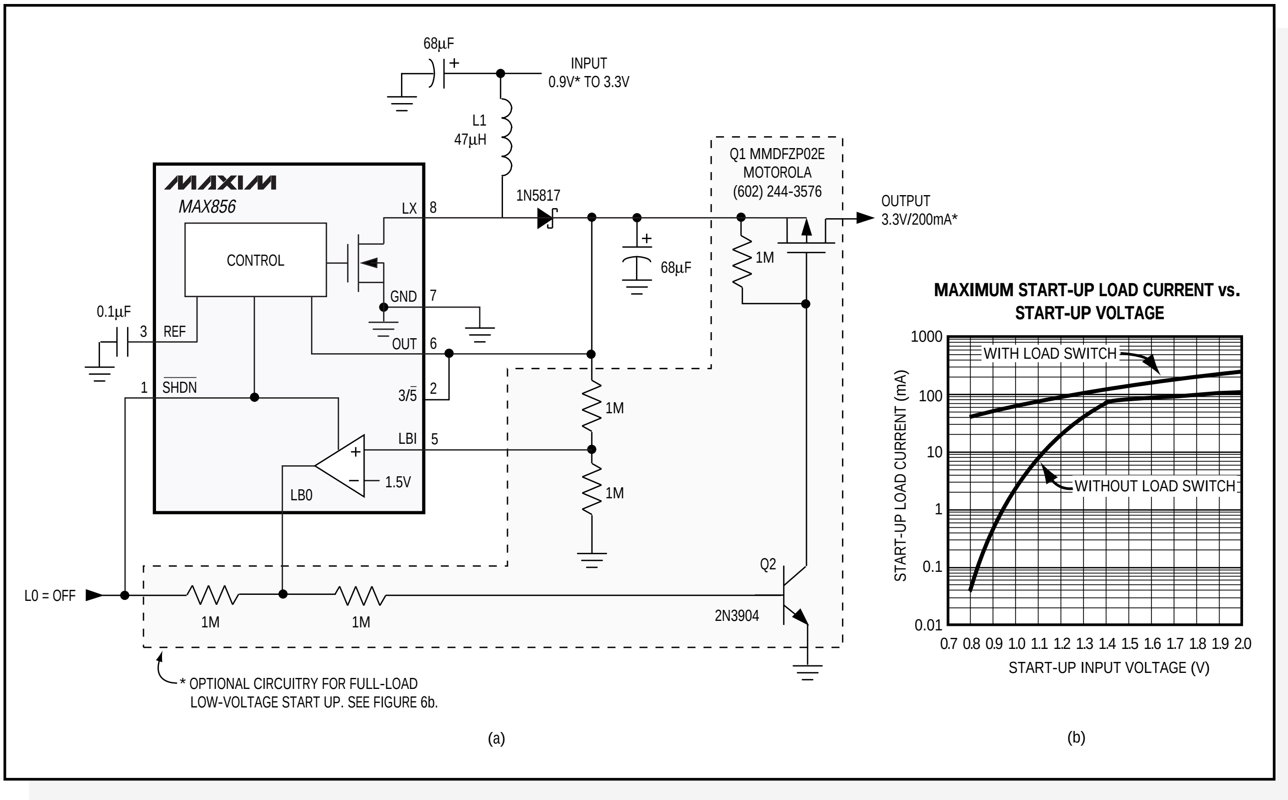


Figure 6. This low-power, CMOS step-up converter (a) generates 3.3V from 1-cell and 2-cell inputs. The optional load-disconnect circuitry (dashed lines) enables the circuit to start with inputs as low as 0.8V (b).

And, its quiescent current does not rise as V_{IN} approaches V_{OUT}.

This last characteristic is especially important for small portables whose steady-state load is no greater than 100µA. In such designs, the milliamp or more of quiescent-current rise (typical of a low-dropout regulator with bipolar pass transistor) accelerates the battery discharge at a time when the battery can least afford it: near the end. Typically, the IC in Figure 5 draws 15µA of operating current whether in or out of dropout.

Boosting from low-cell-count batteries

The cell count for batteries in earlier-generation designs was high—not to provide more energy, but rather to allow generation of the system voltages with low-cost linear regulators (or even with no regulator at all). The latest generation of voltage-conversion ICs, on the other hand, lets you reduce the cell count while adding a minimum number of external parts. Usually, this extra cost is more than offset by the benefits of lower cell count: smaller size, less weight, and (sometimes) longer battery life. To illustrate, the 4.5Whrs of available energy in two AA cells exceeds the 3Whrs in a 6-cell, 9V alkaline battery by 50%, even though the two batteries are comparable in size and weight.

The step-up regulator of **Figure 6a** provides high, 88% efficiency for 2-cell and 1-cell inputs, and its high, 500kHz switching frequency enables the use of very small inductors. The IC's quiescent current is only 60µA at light or zero loads—an attractive feature for portable products whose supply voltage must remain active when the product is turned "off." As the product enters such an idle or suspend mode, load current falls to microamps and must not be dominated by current into the regulator IC. For equipment that truly shuts down, the IC provides a very low-current shutdown mode in which it draws less than 1µA.

One-cell regulators

It makes sense to operate from a 1-cell battery when size is of prime importance. Reasonable efficiency and cost is now possible when operating with inputs below one volt, so many hand-held applications have become new candidates for 1-cell operation. The switching frequency for

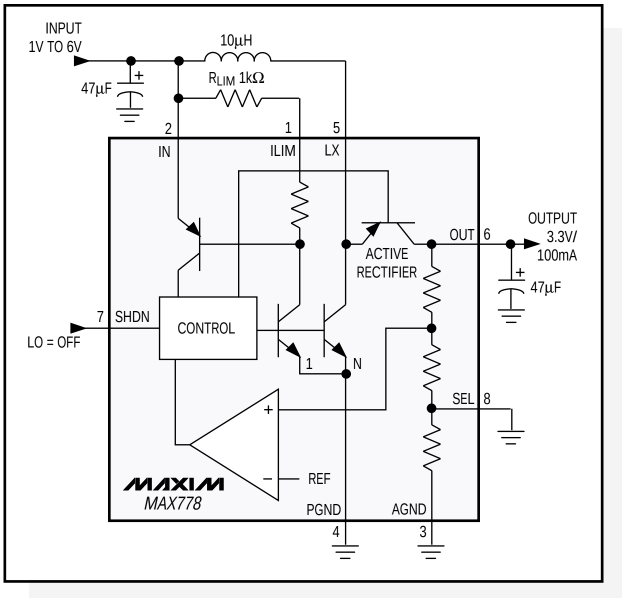


Figure 7. This single-IC boost converter has an internal synchronous rectifier. It maintains a regulated 3.3V output for inputs ranging from 1V to 6V.

low-cost ICs now approaches 1MHz, which permits the use of small magnetic components available from multiple sources. It's not unusual, therefore, for the dc-dc circuitry to occupy less space than the battery it replaced.

In Figure 6a, the addition of Q1 and Q2 within the dashed lines allows the regulator to start with lower input voltages and higher load currents. Q1 also disconnects the load and battery from each other during shutdown, and the on-chip comparator does not allow Q1 to turn on again until V_{OUT} has risen to at least 3V. **Figure 6b** illustrates this circuit's loaded-start capability and its remarkably low typical start-up voltage (0.8V).

Figure 7 shows a low-parts-count step-up regulator that also starts under load and operates with inputs down to 0.8V. Its 500kHz switching frequency and adjustable peak coil current (set by R_{LIM}) allows use of a tiny, low-cost surface-mount coil. The on-board active (synchronous) rectifier not only eliminates the external diode, it also enables the shutdown input to turn off the output completely—a useful feature not common in boost designs, and one that requires an external FET in Figure 6.

The active rectifier and control circuitry in the IC of Figure 7 maintain regulation for inputs to 6.2V—an achievement which, if not of benefit in single-cell designs, may be useful elsewhere. The price for these improvements is higher quiescent current: 190µA for Figure 7 vs. 30µA for Figure 6.

Inductorless conversion suits tight spaces

Despite the advances made in inductor-based switching regulators, most designers would regard the ideal converter circuit as one that has no inductor. The capacitor-based alternatives (charge-pump converters) were hampered in the past by their lack of regulation and limited output current. Though still low compared to that of switching regulators, their output current is now adequate for many designs. And in some cases, the charge-pump advantages are compelling—low cost, small size, and reduced EMI. Charge pumps are particularly useful in PCMCIA systems and other "credit-card" products in which the component height is limited.

Figures 8, 9, and 10 illustrate three inductorless voltage converters. In **Figure 8**, the output of a 2-cell battery or other low-voltage source is converted to a regulated 5V ±4%. The IC changes its operational mode with input voltage, producing a tripler at low V_{IN}, a doubler at high V_{IN}, and a tripler-doubler at mid-range that changes modes every switching cycle. Efficiency ranges from 85% to 65%. Low supply current—typically 75µA for no-load operating conditions and 1µA in shutdown—makes the circuit useful as a coin-cell-powered backup supply for DRAM or PSRAM.

The optional diode-capacitor network in Figure 8 generates an unregulated negative voltage between -1.4V and -3V. Acting as a negative supply, this output simplifies analog designs by allowing the use of inexpensive op

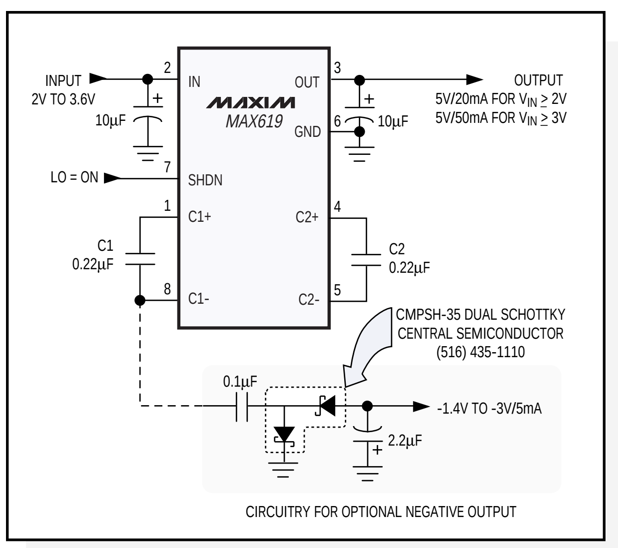


Figure 8. With a few external capacitors, one IC boosts a 2-cell or 3-cell input to 5V, and delivers 50mA (for 3V inputs) with only 75µA of quiescent current. With an additional SOT-23 dual diode and two capacitors, it also produces a small negative output.

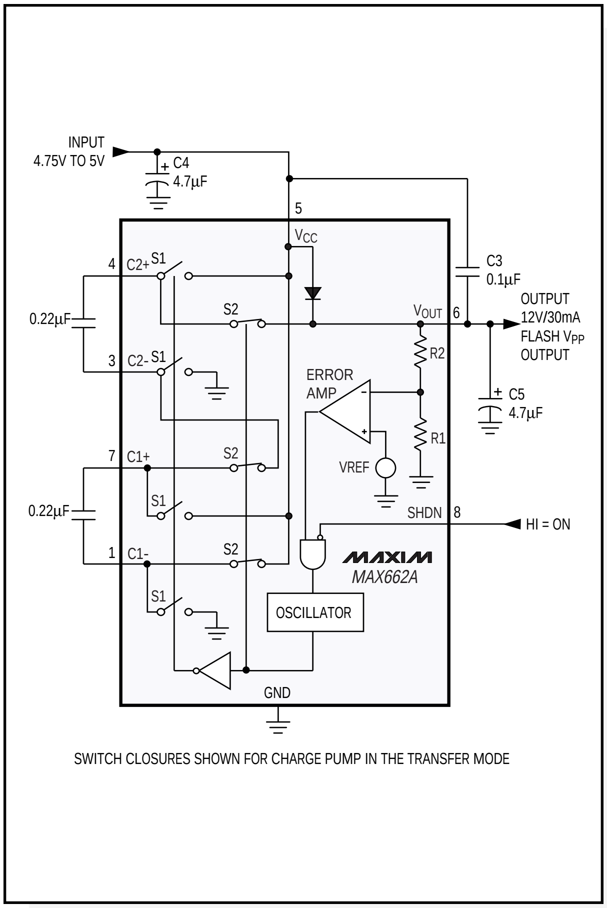


Figure 9. For programming flash memory, this circuit generates a regulated 12V/30mA programming voltage without inductors. It's small enough to fit into "smart cards" the size of a credit card.

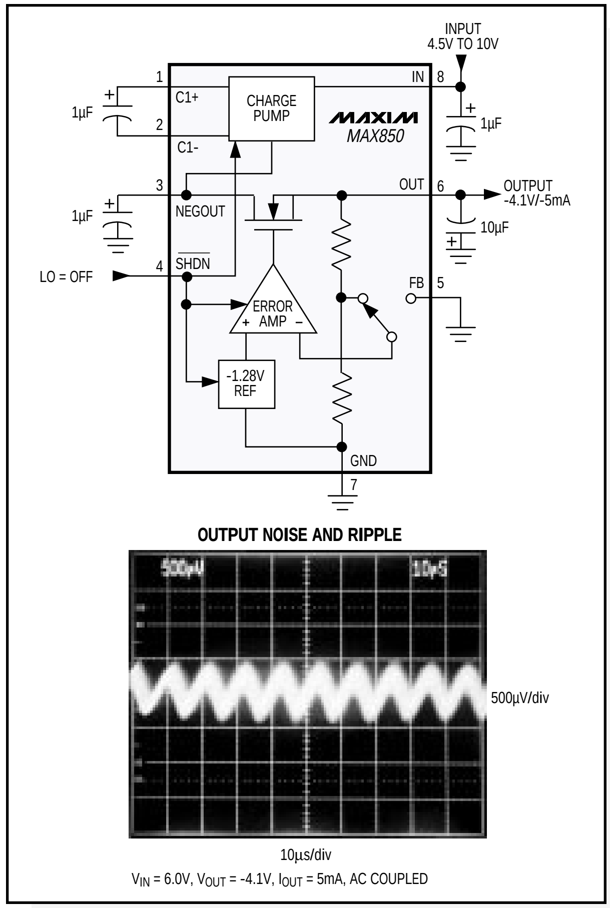


Figure 10. Intended for biasing efficient GaAsFET RF power amplifiers, this charge-pump voltage inverter includes a super-quiet linear regulator that limits output ripple and noise below 1mVp-p.

amps. The negative rail assures that such op amps can swing completely to ground.

Another charge-pump circuit, built in less than $0.1in.^2$ of board area, converts 5V to the 12V level required for programming "flash" memory chips (**Figure 9**). Common in PCMCIA cards, flash memory is popular for compact portable applications because it provides large amounts of nonvolatile storage in a small space, and because it needs power only for read and write operations. Some flash ICs operate on 5V, but those with the highest memory densities require 12V for programming.

A third application that benefits from the use of charge pumps is the optimization of RF-transmitter efficiency in cellular and other voice/data wireless transceivers. "Talk time" in these transceivers is extended by the use of power amplifiers based on gallium-arsenide FETs (GaAsFETs), which are more efficient than those based on bipolar transistors.

Though more efficient, a GaAsFET costs more and requires a small negative bias voltage. Typical charge pumps generate too much noise for this application, but an output voltage regulator in the chip of **Figure 10** holds the output noise and ripple to 1mVp-p. Tying the FB terminal to ground sets the regulated output to -4.1V (you can set other output levels with two external resistors). Regulation and low noise are achieved with an output linear regulator—unlike the circuits of Figures 8 and 9, which regulate by gating the charge pump's switching action.

Intermittent high-current loads

A second requirement in many hand-held wireless designs is a quick response to abrupt load changes. The power supply may idle at milliamp levels for most of the time, but to handle short RF transmissions or bursts of CPU activity it must also deliver high-amplitude currents for short intervals. Especially demanding is the RF trans-

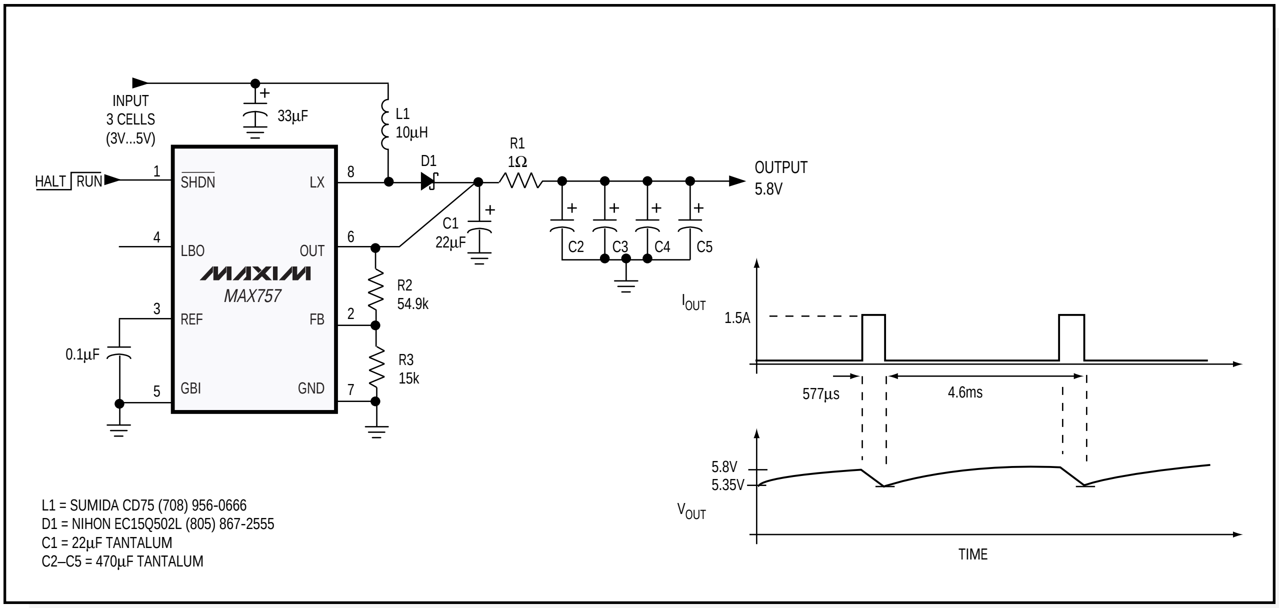


Figure 11. This circuit includes a large capacitive reservoir that supplies 1.5A transient loads in a GSM cellular telephone. The average load is only 200mA, so the 8-pin, surface-mount, boost-regulator IC requires no external MOSFET.

mitter in a GSM cellular telephone or other digital wireless system employing TDMA (time-division multiple access) techniques.

For cellular handsets, a desirable battery combination for minimal size and weight is three NiCd cells. The lowest-cost RF transmitters for this application operate at or near 6V. You might expect the expense of a switching regulator capable of delivering 2W at 6V to force the use of a five-cell battery. But, the high current is drawn only for 600µs or so at a 10% duty cycle, so a small step-up IC can supply the load.

In **Figure 11**, a reservoir capacitor powers both the TDMA logic and the RF circuitry. The capacitor supplies an average 200mA, but at 1.5A its output drop is less than 500mV after 577µs. A 1Ω resistor (R1) isolates the RF load from the dc-dc converter IC. While 4 x 470µF is certainly a lot of buffer capacitance in a hand-held device, the four surface-mount capacitors are far smaller and cheaper than two additional battery cells. The circuit's average power-conversion efficiency is 80%, and its quiescent supply current is only 60µA.

LCD bias supplies

The bias requirements for LCD panels in portable gear cover broad ranges of voltage and current, depending on the display's technology, screen size, and cost. Bias voltages may be positive or negative and as high as ±30V. The boost converter in **Figure 12**, for example, produces an output range of 20V to 30V, adjusted either by digital control or by an external potentiometer. This circuit's high switching frequency and adjustable inductor-current limit enable the use of small surface-mount inductors and output-filter capacitors. For loads below 10mA, for instance, the Murata-Erie LQH4 coil shown is only 2.6mm high.

Note that the potentiometer's configuration is not arbitrary (see the optional circuit in Figure 12). Connecting the pot between FB and ground (rather than FB and V_{OUT}) ensures that an open or noisy pot wiper will produce a low output voltage rather than a maximum (and possibly destructive) output. Moreover, connecting the pot and its wiper to ground minimizes the trace area at FB; if you swap R8 and R9 the V_{OUT} noise will likely increase.

In 2- or 3-cell applications you can optimize efficiency by biasing the IC from 5V (if available) instead of the battery voltage. The inductor still draws current from the battery, but higher voltage at the chip's V+ pin improves efficiency by providing more gate drive to Q1, which lowers its on-resistance. On the other hand, if battery voltage exceeds 5V then V+ should connect directly to the battery. V_{OUT} can be adjusted by a 4-bit, 3.3V CMOS digital code or by the optional potentiometer, as shown.

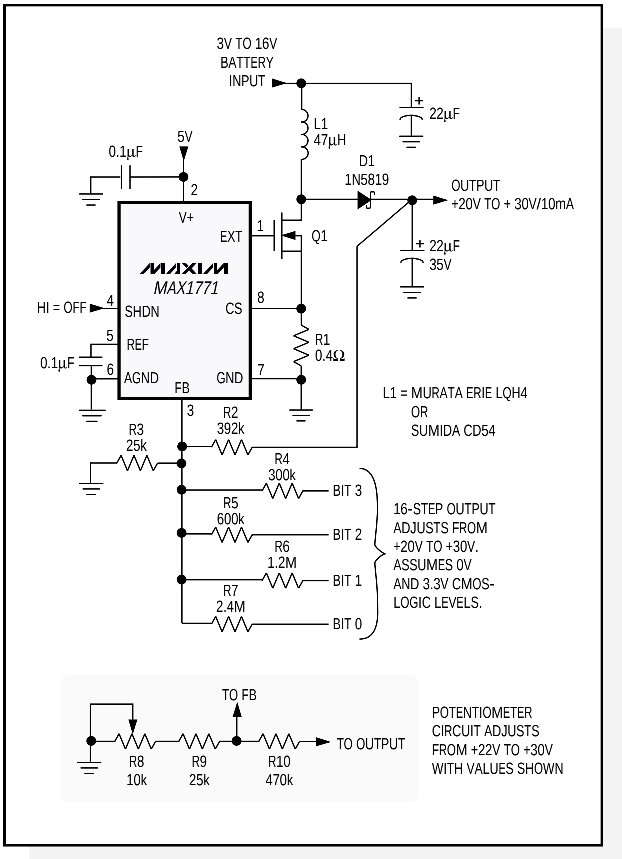


Figure 12. This circuit produces a bias (contrast) voltage for LCD panels that can be adjusted either with a potentiometer or digitally with a 4-bit homemade D/A converter.

Multiple supply voltages

Many portable designs require more than one supply voltage. Even as IC manufacturers add to the list of functions that can be powered from standard 3.3V and 5V levels, the need to optimize performance, weight, battery life, and cost continues to justify additional voltages. Fortunately, the use of multi-output ICs minimizes the number of components needed to create these voltages. These ICs minimize the board area and the number of “glue” components required, while improving the system’s low-load efficiency and other performance parameters.

With two ICs you can design a four-output power supply for hand-held organizers, computers, or data terminals (**Figure 13**). The output voltages are 5V for PCMCIA slots and analog circuitry, 3.3V for CPU and RAM, 12V for flash memory, and -17V for LCD backplane bias.

A fifth regulator—a micropower boost circuit—is included for backup during battery replacement. It sits idle until the main battery dies or is removed, then supports the 3.3V rail by boosting the output of a lithium coin cell. The 5V and 3.3V main outputs are also overridden by pnp linear regulators (Q2 and Q4), which become active when you plug in an external unregulated dc supply. This action also unloads the main battery. The two ICs include several control and supervisory lines in addition to the four output voltages.

Simple battery charging

For small hand-held products, a lack of space and a limited budget often preclude sophisticated schemes for battery monitoring and charging. The goal in these cases is to squeeze the maximum performance from “bare bones” hardware. If available, though, CPU resources (combined with low-cost analog circuitry) offer a convenient means for charge control.

The 8-pin, step-down, switching regulator IC of **Figure 14** is configured as a high-efficiency 1A current source, activated via a logic-level signal. The op amp (IC2) monitors the charging current with a sense resistor (R10) and applies feedback to the regulator chip. This “high side” current sensing lets the negative battery terminal connect directly to ground.

Switch-mode battery charging offers advantages, even for low-cost applications; it dissipates less power and makes full use of an ac adapter as a power source. Linear-regulator designs typically require wall cubes with twice the power rating, after you consider high- and low-amplitude extremes for the ac-line voltage. Linear designs also require heatsinks to implement fast charging.

The circuit shown generates a regulated current for charging a 3-cell battery. A 5.1V zener diode (D3) clamps the output at approximately 6.3V when the battery is removed. You can adjust for other battery voltages and currents by changing R5, R10, and D3. The operating-voltage range is 5V to 16V, but surges to 24V are allowed (with some output error).

If a fast charge is desired but no CPU resources are available, an “all-in-one” controller may solve the problem (**Figure 15**). IC1 is a low-cost NiCd charge controller operating in a low-loss, switch-mode charging configuration. The DRV pin drives a p-channel MOSFET (Q1) via the bipolar-transistor buffer Q1–Q2. The cell count (2 to 16), charge rate, and trickle-charge current are pin programmed via the IC’s PGM0–PGM3 inputs.

The circuit terminates a fast charge automatically by detecting a negative slope in the curve of battery voltage

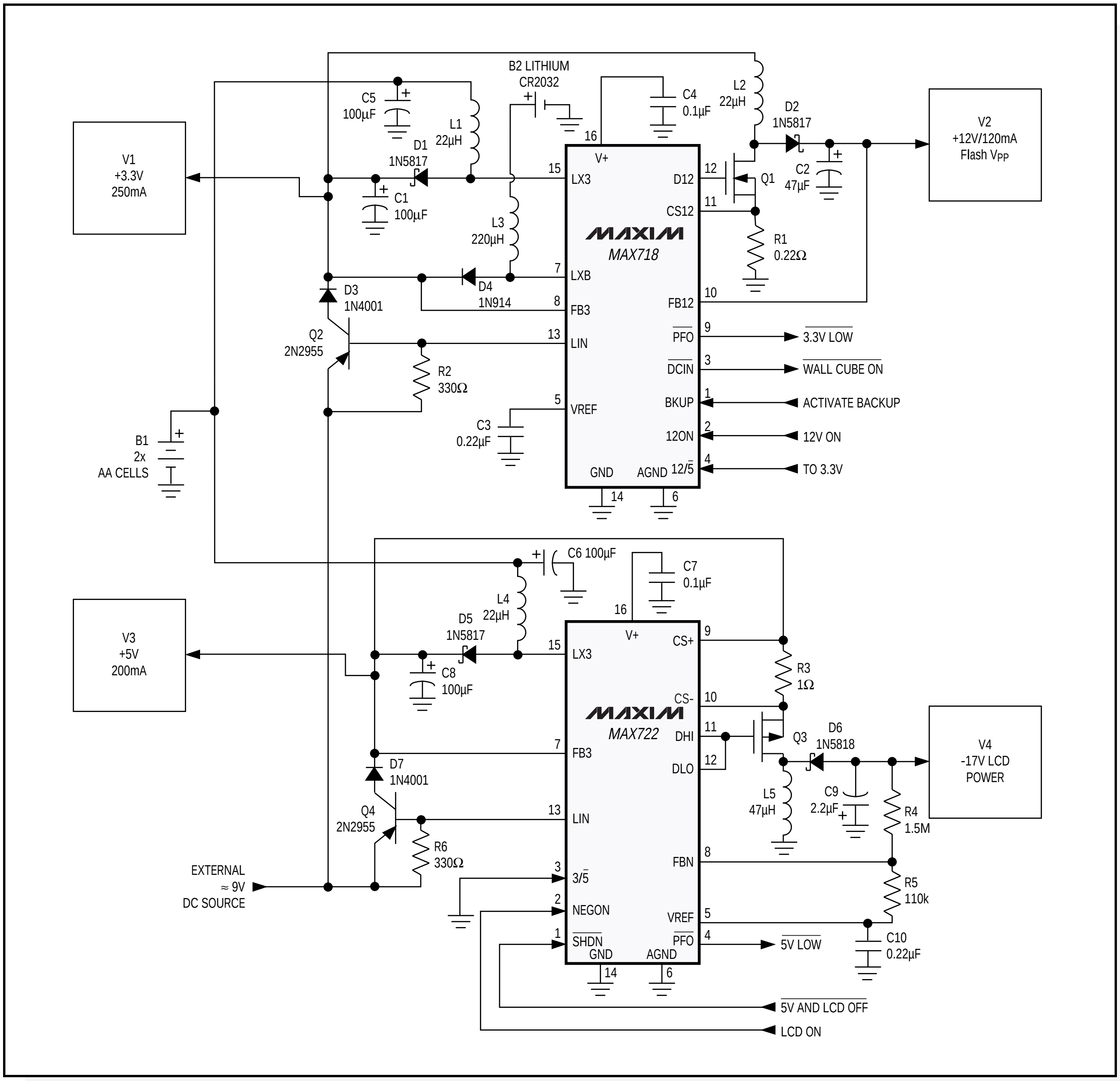


Figure 13. These two ICs perform a multitude of power-related tasks in a system powered by two AA cells. They generate four supply voltages, supervise the system power, control a lithium backup battery, and provide a switchover between battery and wall-adapter outputs.

vs. time. For safety, it also provides an adjustable timeout as backup for terminating the charge. Note that NiMH batteries require termination at zero slope rather than negative slope. For NiMH batteries, replace the MAX713 with the pin-compatible MAX712.

Figure 15 accommodates nominal 12V inputs such as a car battery, and is therefore limited to charging batteries of six cells or less. As shown, the PGM0–PGM3 connections set the fast-charge rate at one ampere and the trickle-charge rate at 1/16 of that. The backup timer is set for 90 minutes. **(Circle 1)**

Reference:

1. *High Frequency Power Converters*, Sevens and Wittlinger, Harris.

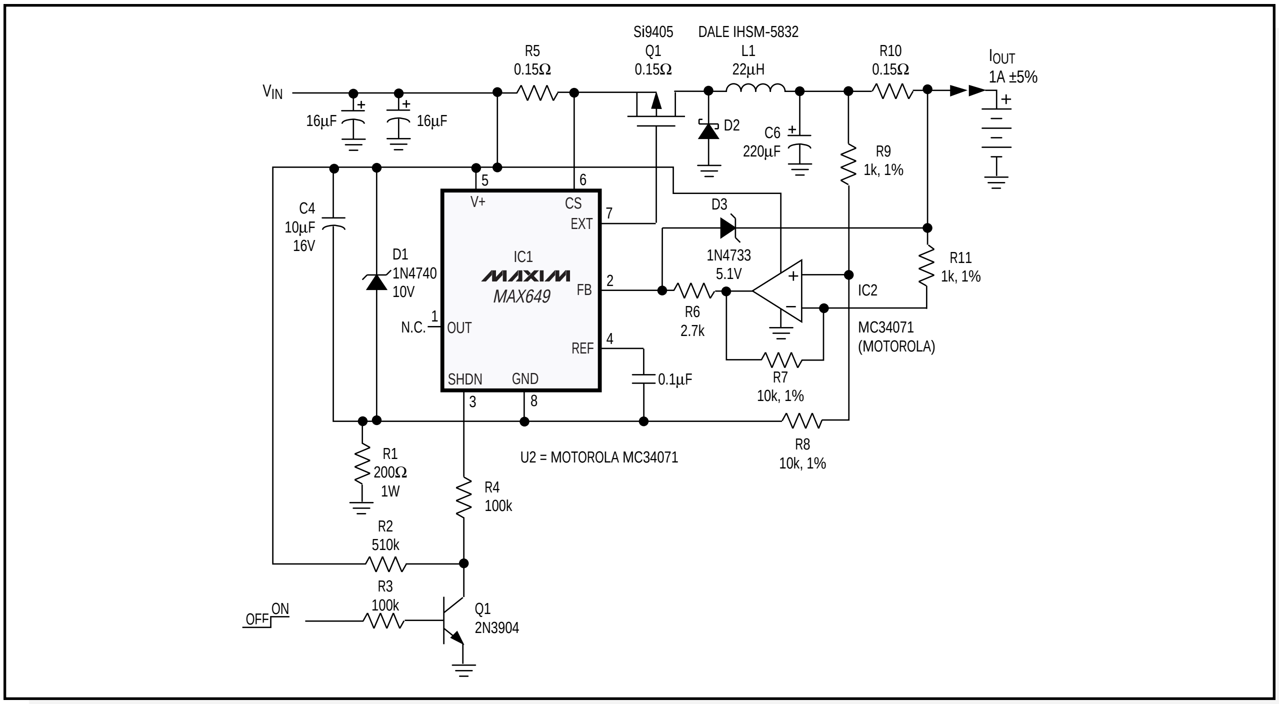


Figure 14. This 1A switch-mode current source supplies charging current to a grounded battery by sensing current on the "high side." An op amp senses the output current and supplies feedback to the dc-dc converter IC.

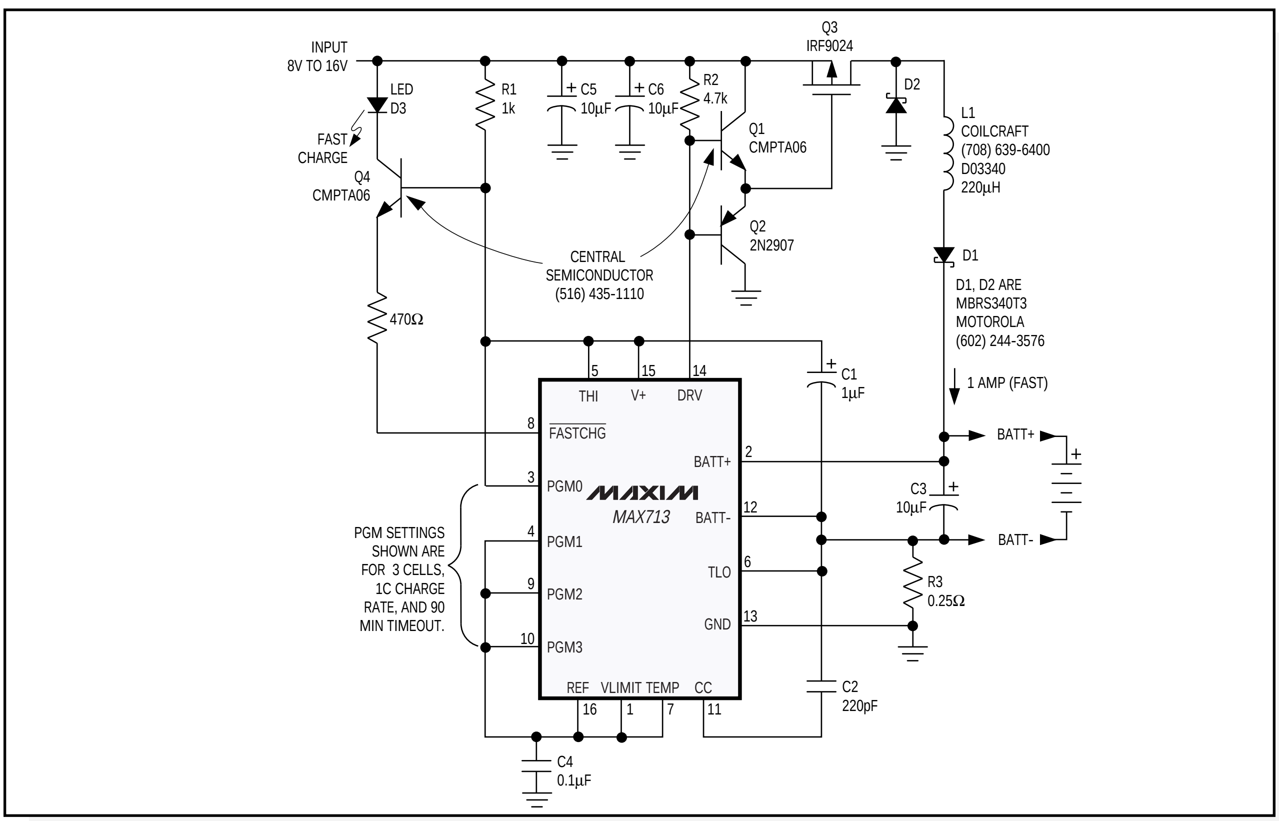


Figure 15. A low-cost battery-charge controller is the heart of a low-dissipation, fast-charge switch-mode circuit. When the battery is fully charged, the circuit shifts automatically to a C/16 trickle charge.

Switching regulator/transformer steps down from high voltage

Adding a transformer to a step-up dc-dc regulator enables the regulator to accept inputs of 20V and higher while operating in a flyback step-down mode (**Figure 1**). The circuit of Figure 1 handles inputs up to 30V (as shown), but is easily modified for higher specific voltages. It was developed for use in a small industrial controller whose non-ventilated case required close attention to power dissipation.

IC1 is well suited to the application because it drives an external switching transistor and derives its power from an internal shunt regulator—both of which can be made to accommodate a wide range of input voltages. IC1 includes internal feedback resistors for 5V, 12V, or 15V outputs (the connection shown is for 5V). To set output voltages other than these, connect a feedback divider between the circuit's regulated output and IC1's feedback terminal (pin 6).

Though not optimal for efficiency, the transformer's 1:1 turns ratio simplifies procurement by allowing the use of a standard product such as the Coiltronix CTX transformer shown. Its 1:1 ratio also enhances stability by producing a duty cycle well below 50%. An ideal 1:1 transformer would generate $V_{IN} + V_{OUT}$ at the bottom of the primary, but leakage inductance causes real transformers to produce a somewhat higher voltage. That voltage appears across Q1, so Q1's minimum breakdown voltage should be approximately $2V_{IN} + V_{OUT}$.

A snubber network across T1 reduces this breakdown-voltage requirement, at the cost of efficiency. The simplest snubber is the RC network shown in Figure 1. (A zener-diode type allows higher efficiency.) The amount of "snubbing" required depends on the output load, the circuit layout, and the parasitic elements present. For I_{OUT} = 250mA and V_{IN} between 20V and 30V, this circuit's efficiency is 66% (rising to 72% when you remove the snubber). R2 limits the peak current through Q1 and L1 to 0.33A.

The internal shunt regulator is a zener diode, biased by R1 at approximately 2mA (the allowed range is 1mA to 20mA). Replacing R1 with a constant-current source lets the circuit cope with a wider input voltage range. The shunt regulator's output is about 6V, which limits the gate drive to Q1; therefore, Q1 should have a logic-level gate threshold. (The VN88 MOSFET also works well, though its 2.5V maximum gate threshold is slightly high for this criterion.)

The SHDN input (pin 7, shown grounded) is a digital on/off switch for the load and the switching circuit. The shunt regulator remains active during shutdown and provides a useful supply voltage for backup memory, a real-time clock, or any general-purpose logic (including a latching on/off switch). The shunt regulator can supply 4000-series logic directly, or can supply 5V-specified devices via two "dropper" diodes.

(Circle 2)

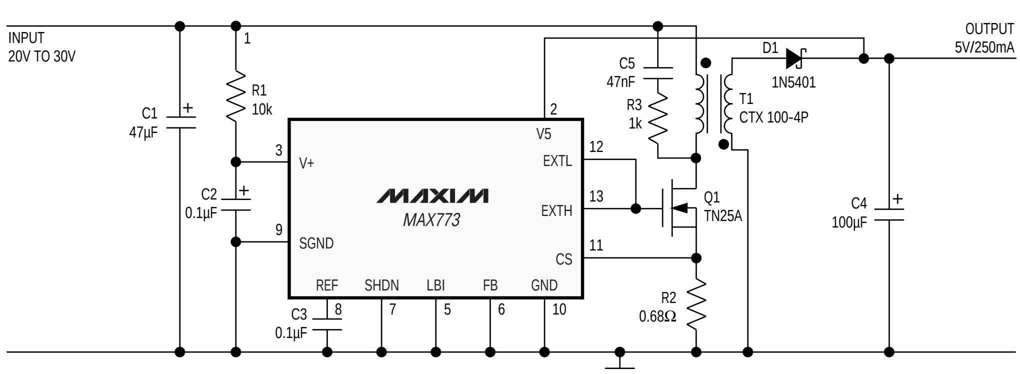


Figure 1. This step-up switching regulator and 1:1 transformer steps down to 5V from input voltages as high as 30V.

RS-485 data interface gives isolated, full-duplex operation

The simple RS-485 circuit of **Figure 1** provides full-duplex communications (simultaneous transmission and reception) with only two essential packages (IC2 and IC3). Its balanced and differential data lines are necessary for high-noise environments or for long-distance transmission between a computer and its peripherals. Such transmissions are difficult, if not impossible, with the single-ended circuitry of an RS-232 transceiver.

The RS-485 standard allows for bidirectional, multi-point, party-line communications, with data rates to 10M bits/second (10Mbps) and line lengths to 1200 meters. Differential transmission provides noise immunity. The circuit shown features controlled-slew-rate drivers that minimize EMI and the reflections caused by improperly terminated cables. It also enables error-free transmissions to 250kbps. To achieve data rates to 2.5Mbps, substitute a full-slew-rate MAX1480A for IC2, a MAX485 for IC3, and R2–R5 values per **Table 1**.

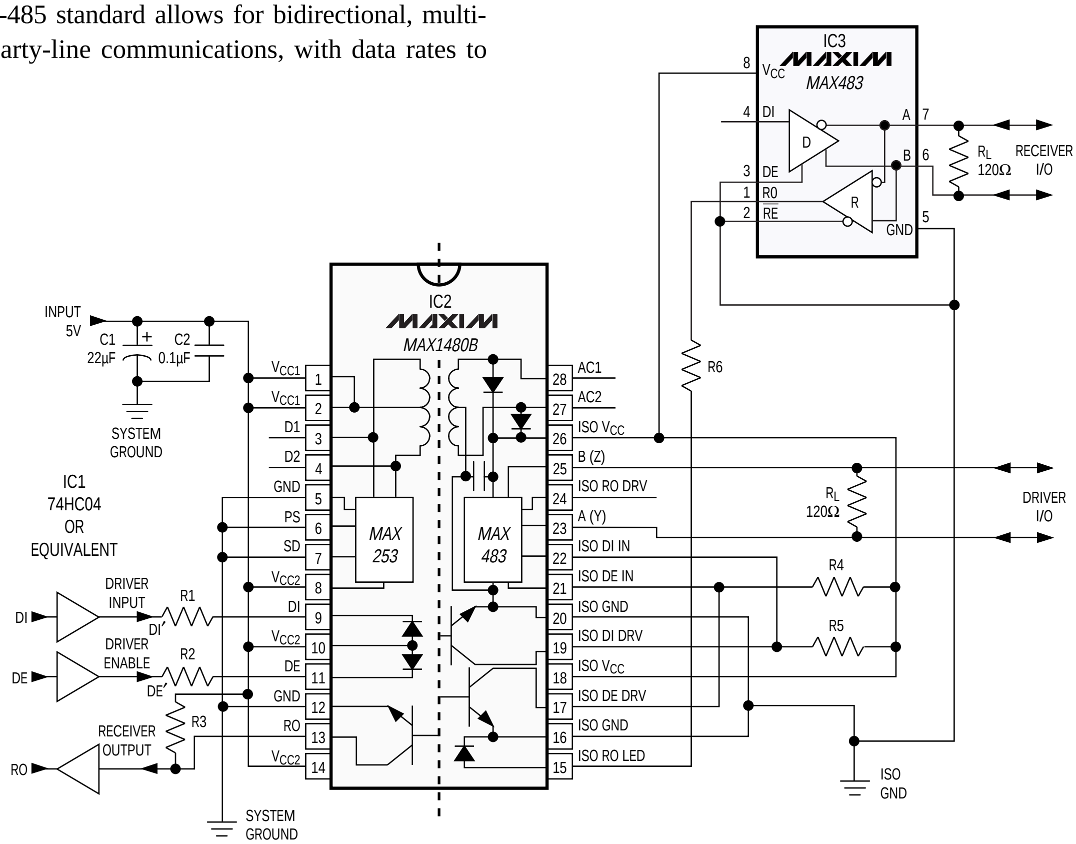


TABLE 1. PULL-UP AND LED DRIVE RESISTORS

IC2	IC3	R1 (Ω)	R2 (Ω)	R3 (Ω)	R4 (Ω)	R5 (Ω)	R6 (Ω)	MAX DATA RATE
MAX1480A	MAX485	200	200	360	3k	360	200	2.5Mbps
MAX1480B	MAX483	200	510	3k	2.2k	3k	200	250kbps

Figure 1. IC2 and IC3 provide full-duplex data communications for cable lengths as long as 1200 meters.

IC2 is a complete half-duplex interface that includes transceivers, optocouplers, a power driver, and a transformer. The optocouplers transmit digital signals across the internal isolation barrier, and the center-tapped transformer transmits power across the barrier from its logic (non-isolated) side to its isolated side.

IC3, powered by the isolated V_{CC}, upgrades the half-duplex operation of IC2 to full duplex using IC2's own dedicated optocouplers. Pin 3 must be tied low to disable IC3's driver, and pin 4 should be left floating. The driver outputs for IC2 and IC3 exhibit high impedance when $\overline{DE}$ is low; bringing $\overline{DE}$ high enables the outputs to function as line drivers.

The isolation barrier in IC2 typically withstands $1600V_{rms}$ for one minute or $2000V_{rms}$ for one second. Any TTL/CMOS-logic family can drive the IC2 digital inputs through a series resistor. With resistive pull-ups, the receiver outputs can drive any such logic as well. IC2's isolated outputs meet all RS-485 specifications.

(Circle 3)

Autotransformer boosts maximum V_{OUT}

Step-up dc-dc converters that operate from small input voltages often have correspondingly low maximum breakdown voltages of 5V to 6V, which limits the maximum output voltage available from such devices. Adding an autotransformer lets you double V_{OUT} without exceeding the IC's breakdown voltage.

A properly wound center-tapped inductor acts like a transformer with a 1:1 turns ratio. Combined with an IC that normally boosts single-cell inputs as high as 6V, it produces a regulated 9V output with no more than 4.5V across the IC (**Figure 1**). The circuit is suitable for use in smoke alarms and other battery-powered equipment. It delivers 30mA at 9V from a 1.1V input, and as much as 90mA at 9V from a 1.5V input.

A similar circuit for 2-cell inputs (**Figure 2**) delivers 30mA at 9V from 1.6V, and 80mA at 9V from 3.6V.

(Circle 4)

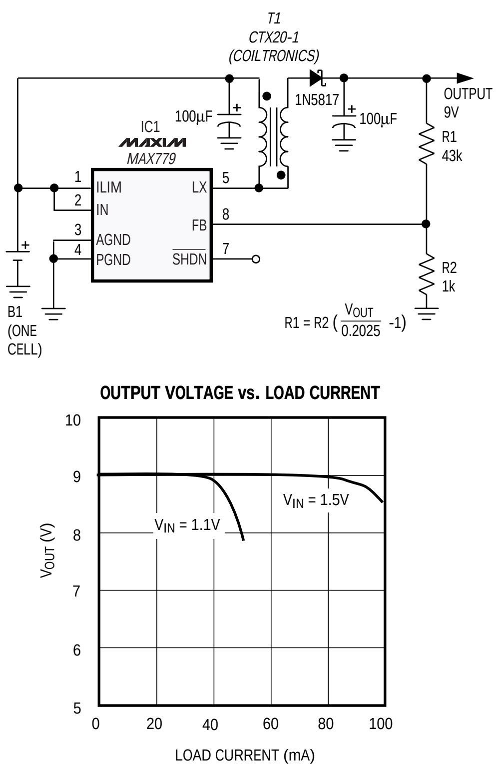


Figure 1. An autotransformer allows a low-voltage step-up converter to boost single-cell inputs as high as 10V.

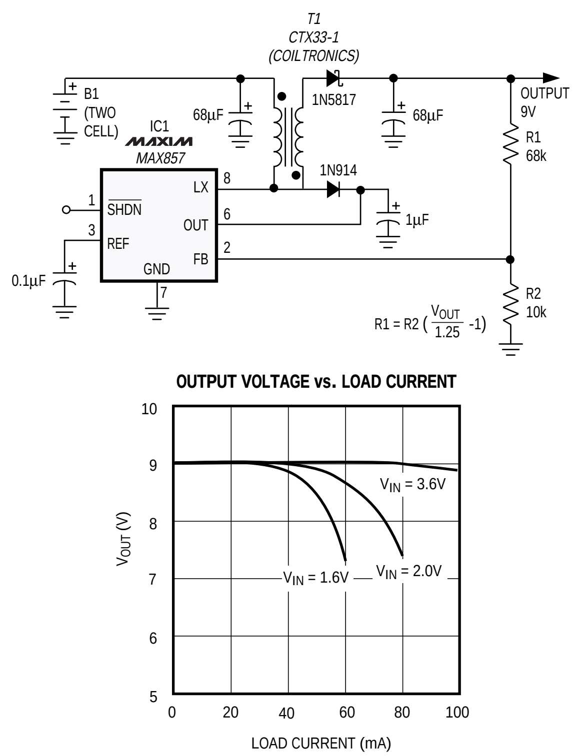


Figure 2. Similar to Figure 1, this circuit accepts 2-cell inputs and generates regulated outputs as high as 10V.

±5V regulator accepts inputs from 2V to 12V

Configured as in **Figure 1**, the step-up dc-dc converter IC1 and associated components produce ±5V from input voltages ranging from 2V to 12V. Input voltages are negative with respect to the output ground terminal. Transistor Q1 shifts the feedback voltage to a level compatible with the IC, which is about 1.5V relative to the chip's GND pin.

By taking V+ from the highest voltage in the circuit (V_{IN} + V_{OUT}), the chip minimizes internal loss by maximizing the gate drive to its internal switching MOSFET. When this MOSFET (between LX and GND) turns off, the energy stored in T1's primary flows to the V+ output, generating a voltage across the primary equal to V+ plus a diode drop.

The -5V output is generated similarly by the additional winding plus D2 and C6. Regulation is via T1's 1:1 winding ratio, which causes the -5V output magnitude to track that of the 5V output. This negative-output generation isn't possible with the standard step-up topology (**Figure 2**) because neither winding would see a V_{OUT}-proportional voltage.

Figure 1 offers two other advantages over the Figure 2 configuration. First, it remains in regulation when V_{IN} rises above the nominal output level. In Figure 2, the inductor-diode leakage path forces V_{OUT} to track V_{IN} for this condition. In Figure 1, V_{IN} is limited by IC1's absolute-maximum voltage rating: V+ to BATT- must not exceed 17V, so for V_{OUT} = 5V the input range is 2V to 12V. Second, the Figure 1 circuit has no leakage path from input to output during shutdown. With 50kΩ output loads and R1 = 100kΩ, the total shutdown current is only 26µA.

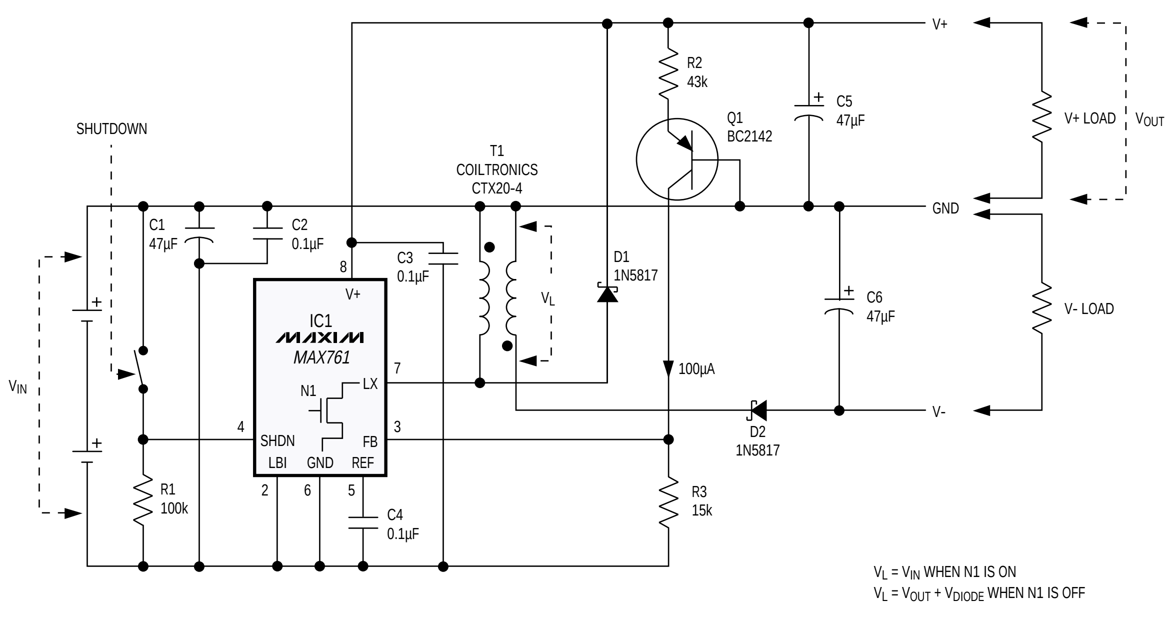


Figure 1. This regulator circuit produces ±5V from just two battery cells, whose terminal voltage may range above and below the positive output level.

The efficiency in Figure 1 is about 70%—a little lower than that of a standard step-up circuit (**Figure 3**). This efficiency data is based on V_{IN} = 2.5V, representing two AA cells at 50% discharge. The circuit can start with 50Ω loads and a 2.0V input, but it can't quite regulate with that combination of input and load—the V+/V- outputs will sag to 3.88V/-3.68V.

Output noise (mostly fast spikes) is nominally 200mVp-p for a wide range of output loads. In addition, IC1's current-limited PFM (pulse-frequency modulation) control causes a variation in the frequency of output ripple and noise. If this is undesirable, IC1 can be replaced with the MAX752 dc-dc converter, whose current-mode PWM (pulse-width modulation) control produces a constant switching frequency (and somewhat lower efficiency due to higher quiescent current).

(Circle 5)

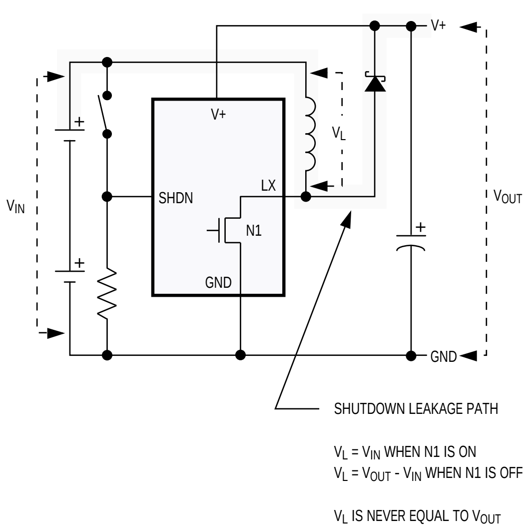


Figure 2. The leakage path (dotted line) in this conventional step-up switching regulator prevents regulation when V_{IN} exceeds V_{OUT}.

Table 1. 43k and 15k FEEDBACK RESISTORS

V+ LOAD (Ω)	V- LOAD (Ω)	V_{IN} (V)	I_{IN} (mA)	V+ (V)	V- (V)	Eff (%)
50	Note 1	2.5	280	4.93		69.4
50	∞	2.5	280	4.93	7.17	69.4
50	10,000	2.5	283	4.93	5.38	69.1
50	1000	2.5	301	4.93	5.08	68.0
50	100	2.5	494	4.90	4.87	58.1
50	50	2.5	605	4.78	4.63	58.6
100	Note 1	2.5	138	5.00		72.5
100	∞	2.5	138	5.00	6.84	72.5
100	10,000	2.5	139	5.00	5.28	72.7
100	1000	2.5	151	5.00	5.06	73.0
100	100	2.5	273	4.96	4.86	70.7
100	50	2.5	469	4.93	4.73	58.9
1000	Note 1	2.5	14.6	5.00		68.5
1000	∞	2.5	14.3	5.00	6.27	69.9
1000	10,000	2.5	15.6	5.00	5.08	70.7
1000	1000	2.5	27.7	5.00	4.92	71.1
1000	100	2.5	137	5.00	4.66	70.7
∞	Note 1	2.5	0.803	5.00		
∞	∞	2.5	0.802	5.00	5.07	
Shutdown		2.5	26µA			

Measurements from veroboard prototype.
Efficiency would improve with ground plane PCB.
Note 1: V- components disconnected.

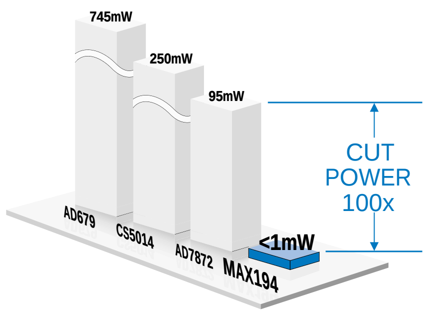
Figure 3. Conversion efficiency for the Figure 1 circuit is about 70%, depending on the input voltage and the output loads.

NEW PRODUCTS

14-bit, 85ksps serial ADC has 20µA shutdown

The 14-bit MAX194 analog-to-digital converter (ADC) has ultra-low power consumption, high accuracy, and high speed, making it ideal for medical, instrumentation, and industrial applications. As the low-power leader in 14-bit applications, it consumes only 80mW at the maximum operating speed of 85ksps. Because the MAX194 is the only device in its class with shutdown capability (to 10µA), its power consumption drops even further at lower sampling rates. At 1ksps, for instance, the consumption is only 1mW.

The MAX194's capacitive-DAC architecture provides an inherent track/hold function with a fast, 2.4µs acquisition time. Its internal calibration circuitry maintains true 14-bit accuracy over temperature by correcting for linearity and offset errors, and its separate analog and digital power-supply terminals minimize the effects of digital noise. The device has a serial data interface and pin-selectable unipolar/bipolar input ranges.



The MAX194 comes in 16-pin DIP and SO packages, in versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices start at $14.00 (1000 up, FOB USA).

(Circle 6)

10-bit, VOUT DACs operate from 5V

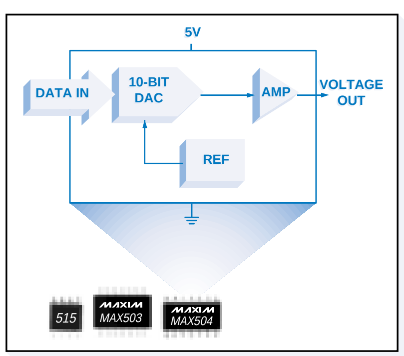
- *Draws only 140µA from 5V (MAX515)*
- *Buffered voltage outputs swing rail-to-rail*
- *Internal voltage reference (MAX503/MAX504)*
- *Small 8-pin SO footprint (MAX515)*

The MAX503/MAX504/MAX515 voltage-output digital-to-analog converters (DACs) combine ultra-low power consumption and small size with operation from a single 5V supply. These features make the devices ideal for a wide range of applications—especially portable and battery-powered systems. The serial-input MAX515 draws only 140µA of operating current. The parallel-input MAX503 and serial-input MAX504 include internal references, and draw only 260µA. Both include a shutdown mode that lowers the supply current to 40µA.

Besides power savings, the DACs save real estate on the pc board. They come in small packages, and their rail-to-rail output buffers eliminate the op amp and associated components required with a current-output DAC. The MAX503 and MAX504 are capable of 4-quadrant multiplication, and include true 10-bit accuracy, power-on reset, and configurable gains of 1 or 2. To simplify equipment upgrades, the MAX503/MAX504/MAX515 devices are both software and hardware (plug-in) compatible with Maxim's 12-bit MAX530/MAX531/MAX539 converters.

The MAX515 comes in an 8-pin DIP/SO package and the MAX504 comes in a 14-pin DIP/SO. The parallel-input MAX503 comes in a 24-pin DIP/SO or a shrink small-outline package (SSOP), which requires less board area than an 8-pin DIP. All are tested for operation over the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices for the MAX515 start at $2.50 (1000 up, FOB USA).

(Circle 7)



50V, 200MHz amplifier drives high-resolution monitors

The monolithic MAX445 is a low-cost, variable-gain transconductance amplifier that drives high-resolution CRT monitors directly. Combining a variable-gain preamp with a high-voltage (50Vp-p) open-collector output stage, it is suitable for workstation and medical-imaging displays with video resolutions as high as 1280 x 1024 and 1530 x 1280.

An internal bandgap reference enables external adjustments at the differential-input preamp for gain (contrast) and output offset. A control input (TTL/BLANK) turns off the output current regardless of input signal. With an external peaking network, the MAX445 delivers 2.5ns rise times at 45Vp-p into an external load of 200Ω and 8pF (including the CRT and parasitics).

The MAX445 comes in a 24-pin power-tab DIP, which requires additional heatsinking to maintain its internal junctions within the recommended range for operating temperature. The device is characterized for a case-temperature operating range of 0°C to +90°C.

(Circle 8)

NEW PRODUCTS

950MHz JFET video buffer includes 75Ω trimmed resistor

The MAX4005 is the first ultra-high-speed video buffer with a trimmed, 75Ω output resistor to minimize reflections produced by mismatched impedances on a transmission cable. The buffer's JFET input stage has an extremely low input current (10pA), making the MAX4005 ideal for high-speed applications that require isolation between a high-impedance signal source and a low-impedance 75Ω cable.

High-speed performance parameters include a 950MHz, -3dB bandwidth; gain flatness within ±0.1dB to 60MHz; a 1000V/µs slew rate; and 350ps rise/fall times. The MAX4005 also offers precision: 3mV maximum offset voltage, ±1nA maximum input current, a -28dB 3rd-order intercept at 100MHz, better than -60dB 3rd-harmonic distortion at 50MHz, and low differential gain and phase errors of 0.11% and 0.03°.

MAX4005 applications—for video, medical, test and measurement, diagnostic, and ATE systems—include video buffers and line drivers, impedance transformers, remote-sense amplifiers, and fanout multipliers for 75Ω signal distribution. The MAX4005 comes in an 8-pin SO package, tested for the commercial (0°C to +70°C) temperature range. Prices start at $2.75 (FOB USA).

(Circle 9)

CMOS analog multiplexers offer extremely low leakage

The MAX338/MAX339, 8-channel/dual 4-channel multiplexers exhibit extremely low leakage currents: $I_{NO(OFF)}$ is less than 20pA at +25°C, and $I_{COM(ON)}$ is less than 50pA at +25°C. The maximum channel on-resistance is 400Ω, and the on-resistances in a device match to within 10Ω. Because the channels conduct equally well in both directions, either device is suitable for use as a multiplexer or demultiplexer. Switching-transition times are less than 500ns.

These new ICs feature extremely low charge injection—only 1.5pC at +25°C (5pC maximum). Fabricated with Maxim's 44V silicon-gate process, they guarantee protection per MIL-STD-883, Method 3015.7 against electrostatic discharge (ESD) greater than 2000V. Each operates from a single supply of +4.5V to +30V or dual supplies of ±4.5V to ±20V. All control inputs remain TTL compatible over the specified ranges of temperature and supply voltage.

The MAX338 and MAX339 are improved, pin-compatible electrical upgrades that replace the industry-standard DG508A and DG509A at no additional cost. (For even lower leakage and charge injection at the expense of higher on-resistance, consider the MAX328 and MAX329 multiplexers.) MAX338/MAX339 devices come in 16-pin DIP and narrow-SO packages, in versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices start at $2.39 (1000 up, FOB USA).

(Circle 10)

Active, in-line circuit protectors guard signal lines

The MAX366 and MAX367 each contain multiple 2-terminal circuit protectors. Placed in series with signal lines, the protectors guard sensitive circuitry against fault conditions that produce line voltages near or beyond the supply voltages. During a fault, the line voltage can differ from the opposite-polarity supply voltage by as much as 40V. The protectors are active during power-up, during power-down, and when the supplies are off.

The MAX366 contains three protectors, and the MAX367 contains eight. Each protector is a series connection of two n-channel FETs and one p-channel FET, configured so the overall on-resistance is very high with power off and about 100Ω with power on. Leakage currents are less than 1nA at +25°C. The devices are suitable for analog or digital lines, and operate with unipolar supplies of +4.5V to +36V or bipolar supplies of ±2.25V to ±18V. Each protector is fully symmetrical, which allows the input and output terminals to be freely interchanged.

As the signal voltage approaches within 1.5V (approximately) of either supply voltage, the on-resistance increases dramatically and limits the output voltage and fault current. On the protected side, the signal voltage clamps approximately 1.5V below the supply rail, maintaining its polarity without polarity reversals or "glitches."

The MAX366 comes in 8-pin DIP and SO packages; the MAX367 comes in 18-pin DIP and SO packages. Both are available in versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices for the MAX366 start at $1.42 (1000 up, FOB USA).

(Circle 11)

NEW PRODUCTS

Analog switches and multiplexers guarantee matched, low on-resistances

The MAX381/MAX383/MAX385 dual analog switches and the MAX398/MAX399 (8-channel and dual 4-channel analog multiplexers) offer precision, high speed, and low-voltage operation. Ideal for 5V systems, these devices feature low on-resistances (<35Ω for switches, <100Ω for muxes) flat to within 4Ω (maximum) over the analog signal range. On-resistances are also matched between channels to within 2Ω for switches and 10Ω for muxes. Switch configurations are SPST, NO (MAX381); SPDT, NO (MAX385); and SPDT, NO/NC (MAX383).

These CMOS devices are fabricated with Maxim's low-voltage silicon-gate process. They maintain fast switching and CMOS-logic compatibility while operating with a single positive supply (+2.7V to +16.5V) or dual supplies (±2.7V to ±8V). Design improvements have guaranteed extremely low charge injection (<5pC) and low power consumption per package (<10µW for switches, <300µW for muxes). Switch leakage is low: <250pA at +25°C and <2.5nA at +85°C. For muxes at 5V and +85°C, the NO-off leakage is <1nA and the COM-off leakage is <2.5nA. Mux transition times are <100ns at 5V. The switches turn on in <175ns, turn off in <100ns, and guarantee ESD protection in excess of 2kV.

MAX398 and MAX399 multiplexers are pin compatible with the industry-standard DG408/DG409 and DG508A/DG509A, and they come in 16-pin DIP and SO packages. So do the MAX381/MAX383/MAX385 switches, which are pin-compatible with the industry-standard DG401/DG403/DG405. All are available in versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices start at $1.47 for the MAX381, $2.57 for the MAX383/MAX385, and $2.50 for the MAX398/MAX399 (1000 up, FOB USA).

(Circle 12)

3V and 3.3V linear regulators have automatic shutdown

- *MAX687/MAX688/MAX689 for portable applications*

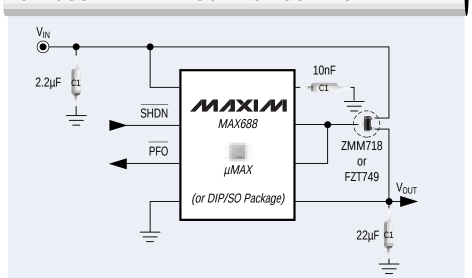
The MAX687/MAX688/MAX689 are low-dropout linear regulators whose input-to-output voltage is limited only by an external pnp pass transistor. Base-drive capability exceeds 10mA, enabling a high-gain pass transistor to supply more than 1A of load current.

The MAX687's output voltage is fixed at 3.3V, and the device shuts down automatically when V_{OUT} drops below 2.96V. Preceding the shutdown, an internal power-fail comparator issues an early warning of low output voltage. While in shutdown, the output is latched off and remains off until the ON input is pulsed. This procedure prevents the further discharge that can damage depleted battery cells in a portable telephone or other battery-powered equipment.

MAX687/MAX688/MAX689 devices are available in 8-pin DIP, SO, and µMAX packages, in versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $1.60 (1000 up, FOB USA).

(Circle 13)

LOW-COST LINEAR-REGULATOR CONTROLLER



3V and 3.3V linear regulators offer accuracy and low dropout

- *MAX688/MAX689 for 4A applications*
- *0.8V dropout with 4A I_{OUT}*

The MAX688 (3.3V) and MAX689 (3.0V) ICs form linear regulators in which an external pnp transistor determines the dropout voltage. The ICs can sink minimum-guaranteed base currents of 10mA, allowing high gain transistors (ß>100) to deliver load currents greater than 1A. Or, two external transistors in a quasi-Darlington configuration can boost the output current to 4A or more.

The MAX688 and MAX689 differ only in output voltage, and offer an active-low $\overline{SHDN}$ input in place of the automatic-shutdown feature. As $\overline{SHDN}$ falls, the chip first enters a <25µA standby mode in which the internal comparators and reference remain active, enabling the normal standby transition to occur at a well-defined level (specified to within ±2%). Thus, a declining battery voltage can be used to trigger the shutdown. Seventy millivolts of hysteresis prevents chatter between the normal and standby modes, and full shutdown (<1µA) occurs when $\overline{SHDN}$ falls below 200mV.

MAX688/MAX689 devices are available in 8-pin DIP, SO, and µMAX packages, in versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $1.60 (1000 up, FOB USA).

(Circle 14)

NEW PRODUCTS

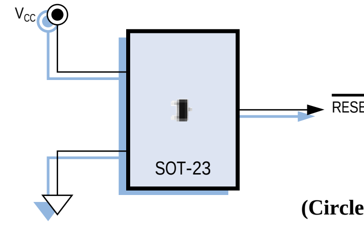
Smallest available µP supervisors come in SOT-23 packages

MAX809 and MAX810 microprocessor supervisors are the smallest such devices available. Fully specified over temperature, they assert a reset signal whenever V_{CC} falls below a preset threshold. When used in 3V or 5V systems, they provide excellent reliability and low cost by eliminating all external components and adjustments. Typical supply currents are only 24µA (L and M versions) and 17µA (R, S, and T versions).

The MAX809 and MAX810 differ only in the polarity of their reset outputs. The MAX809 issues an active-low $\overline{\text{RESET}}$ (valid for V_{CC} down to 1V), and the MAX810 issues an active-high RESET. Both ignore fast transients on the V_{CC} rail, but once a reset is asserted, it remains active for at least 140ms after V_{CC} returns above the trip threshold. The available thresholds are designated by letter suffix: 4.63V (L), 4.38V (M), 3.08V (T), 2.93V (S), and 2.63V (R).

Applications include computers, controllers, intelligent instruments, and portable/battery-powered equipment. The MAX809 and MAX810 come in 3-pin SOT-23 packages, with specifications guaranteed over the extended industrial temperature range (-40°C to +85°C). Prices start at $0.80 (3000 up, FOB USA).

MAX809
SMALLEST SIZE,
NO EXTERNAL COMPONENTS
LOWEST-COST SOLUTION



(Circle 15)

Multifunction µP supervisors monitor 3V and 3.3V systems

The MAX793/MAX794/MAX795* microprocessor supervisors monitor and control the activities of 3V and 3.3V µP-based applications, such as battery-powered computers and controllers, automotive systems, and portable equipment. Supervisory features include active-low and active-high reset outputs, low-line early warning, internal switch for the backup battery, internal switch for main power, driver for external FET or pnp switch, power-fail comparator, battery-OK output, software watchdog, isolation to guarantee battery freshness, manual-reset input, and chip-enable gating.

The MAX793 offers all the above features with four choices of reset-threshold range, as indicated by suffix letter: U (3.00V to 3.13V), T (3.00V to 3.15V), S (2.85V to 3.00V), and R (2.55V to 2.70V). The MAX794 is similar, but substitutes a user-programmable threshold for the battery-OK function. The 4-function MAX795 device offers the U/T/S/R ranges in an 8-pin package.

All three devices guarantee reliable resets for V_{CC} as low as 1V, on-board chip-enable gates with a maximum propagation delay of 10ns, and the capability to withstand backup-battery voltages higher than V_{CC} during normal operation. The MAX793 and MAX794 offer independent watchdog timers with 1.6 second timeouts, and an uncommitted voltage monitor for power-fail or low-battery warnings.

The MAX793 and MAX794 come in 16-pin DIP and narrow-SO packages; the MAX795 comes in 8-pin DIP and SO packages. All are available in versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges.

** Contact factory for availability.*

(Circle 16)

3.3V RS-485/RS-422 transceivers transmit to 10Mbps

Maxim's low-power 3.3V transceivers provide true RS-485 and RS-422 communications without the extra die size and extra pins associated with internal charge pumps. Instead, the devices include a proprietary output stage with low forward drop (patent pending) that delivers an industry first—2V minimum into 100Ω or 1.5V into 54Ω, while operating from supply voltages as low as 3.0V. Each IC (MAX3483, MAX3485, MAX3486, MAX3488, MAX3490, and MAX3491) contains one driver and one receiver. As many as 32 of these transceivers may connect to one bus.

Slew-rate-limited drivers in the MAX3483 and MAX3488 reduce EMI and reflections 100 times, compared with other RS-485 devices. These transceivers meet RS-485 and RS-422 specifications down to 3V, and guarantee error-free transmission at data rates to 250kbps. Partial slew-rate limiting in the MAX3486 allows transmission to 2.5Mbps, and the nonlimited MAX3485/MAX3490/MAX3491 transceivers run effortlessly at 10Mbps.

The full-duplex MAX3488 and MAX3490 are pin-compatible with the 75179 transceiver, and the full-duplex MAX3491 (with separate driver/receiver enables) is pin-compatible with the 75180. The half-duplex MAX3483/MAX3485/MAX3486 are pin-compatible with the 75176. All six Maxim transceivers operate with 1mA supply currents and dissipate only 3.3mW—100-times less than their 5V counterparts. All but the MAX3490 and MAX3491 have low-current 2nA shutdown modes.

Driver-overload protection includes foldback current limiting, which guards each output against short circuits and other fault conditions over the whole range of input common-mode voltage (-7V to 12V). Thermal-shutdown circuitry prevents excessive power dissipation by disabling the driver outputs. As a fail-safe measure, each receiver output guarantees a logic-high level when both inputs are open.

The MAX3483, MAX3485, MAX3486, MAX3488, and MAX3490 come in 8-pin DIP and SO packages; the MAX3491 comes in 14-pin DIP and SO packages. All are available in versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $1.75 (1000 up, FOB USA).

(Circle 17)

NEW PRODUCTS

AutoShutdown™ lowers RS-232 transceivers' supply current to 1µA

Maxim's new RS-232 transceivers include a proprietary AutoShutdown function (patent pending): except when actively in use, they automatically enter a low-power mode. As a result, the supply currents fall to 1µA when the input signals have non-valid RS-232 levels. The patent-pending internal circuitry saves power and extends battery life: between data transmissions, when the cable is disconnected, and when the transceiver at the far end of the cable is turned off. These power savings require no modification of the existing BIOS or operating system.

The MAX3212 and MAX3243* each contain three drivers and five receivers, providing complete serial ports ideal for notebook and subnotebook computers. The MAX3212 operates with a supply voltage of 2.7V to 3.6V (yet remains compatible with 5V logic), and the MAX3243 operates (with four small external capacitors) from 3.0V to 5.5V. Over their operating ranges of temperature and supply voltage, both transceivers meet all EIA/TIA-232E, EIA/TIA-562, and V.28/V.24 specifications. The guaranteed-minimum data rates (235kbps for the MAX3212 and 120kbps for the MAX3243) assure compatibility with popular data-communications software for personal computers.

To produce the ±5V-minimum transmitter outputs specified by RS-232, the MAX3212 employs an internal switch-mode controller that generates ±6.5V from a single, low-cost, external inductor. The MAX3243 generates the same levels with a capacitive doubler-inverter circuit followed by a proprietary low-dropout transmitter. Both devices drive serial mice, and both have convenient flow-through pinouts.

One receiver in each device maintains a second, complementary output active regardless of shutdown status. When V_{CC} is turned off, that output can monitor an external modem or other circuit without forward-biasing the circuit's protection diode. The MAX3212's receiver-enable input (EN) can three-state the receiver outputs or activate all five, with no effect on the shutdown current. (The MAX3223—a smaller, dual-transmitter/dual-receiver version of the MAX3243—offers an EN input in place of the always-active receiver output.) MAX3212/MAX3243 devices include FORCEON/$\overline{\text{FORCEOFF}}$ controls for overriding the AutoShutdown™ circuit if desired.

The MAX3212 and MAX3243 come in 28-pin wide-SO and SSOP packages, and the MAX3223 comes in a 20-pin DIP and SSOP. All are available in versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $1.85 for the MAX3223 and $3.29 for the MAX3212/MAX3243 (1000 up, FOB USA). **(Circle 18)**

** Contact factory for availability.*

™*AutoShutdown is a trademark of Maxim Integrated Products.*

Custom packaging accommodates high-frequency, high-power circuits

Maxtek's custom multichip modules (MCMs) contain circuits that comprise 20 to 200 separate components running at frequencies from 50MHz to 15GHz. Sampling heads and other specialized MCMs can operate at up to 50GHz. Maxtek's in-house laser-trimming capability enables adjustment of resistors to within 0.1%, capacitors to within 0.5pF, and time events to within picoseconds.

The MCM optimizes or tunes the performance of other circuitry in a typical application. At 50MHz and above, for example, the attenuator/preamp/ADC portion of a data-acquisition circuit may lack the gain necessary to flatten a step response. Substituting an MCM for the attenuator cures this problem by compensating the preamp's roll-off. The MCM undergoes final adjustment in an active laser-trimming jig, in which a test system flattens the step response by adjusting the operating circuit in 0.01% increments.

MCMs let you combine ICs and other components representing many different technologies. Prescalers and mixers, for example, may require a mixture of silicon and gallium-arsenide chips. Data-acquisition modules may require a mixture of high- and low-power components. An MCM can combine all of these in one package, along with crystals and other types of optical and electromechanical devices. The available MCM options include standard or custom surface-mount types, socketed daughter boards, flex circuits, hermetic packages, custom packages with integrated heatsinks, and JEDEC packages with more than 100 pins.

Maxtek is a new company formed by Maxim and Tektronix to perform design, testing, and manufacturing of complex, custom multichip modules and hybrids. As the descendent of Tektronix' internal MCM facility, Maxtek has produced more than 8,000,000 HF MCMs in the past 20 years.

Maxtek MCMs can operate from -15°C to +70°C. Prices range from $2,000 to $4 each on quantities of 50 to 500,000 per year, and prototype charges begin at $10,000 with deliveries as short as four weeks. For a limited time, Maxtek is offering free engineering consultations by telephone on the design of actual high-frequency MCMs. Please contact Maxtek for more information (1-800-4-MAXTEK).