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MAXIM REPORTS INCREASED REVENUES AND EARNINGS

Maxim Integrated Products, Inc., reported record net revenues of $110 million for the fourth quarter of fiscal 1996 ending June 30, 1996, compared to $76 million for the same period a year ago. This represents a 44.7% increase in net revenues from the same quarter a year ago. Net income increased to $34.7 million for the current quarter, compared to net income of $11.5 million for the same quarter in fiscal 1995. Income per share increased to $0.49 per share for Q496 from $0.17 per share in Q495, a 188% increase. Operating income was 47.1% of net revenues, compared to 22.1% for Q495.

Maxim ended fiscal 1996 with net revenues of $421.6 million, a 68.1% increase over fiscal 1995 net revenues of $250.8 million. Operating income for fiscal 1996 was $185.9 million, a 225% increase over the $57.2 million reported in 1995. Income per share for fiscal 1996 was $1.74, compared to $0.59 in fiscal 1995, an increase of 195%. Stockholders' equity grew to $325.4 million at June 30, 1996 from $178.7 million at June 30, 1995, an increase of 82%. Return on equity increased to 48.9% for the year, compared to 25.2% for fiscal 1995. Total assets increased to $417.8 million.

Jack Gifford, Chairman, President and CEO commented on the quarter and the year, "1996 was a year of challenges for Maxim and its employees. We ended fiscal 1995 with shippable backlog equal to 2.6 times our Q495 revenues, including unsatisfied customer requests of $69 million (which, with the benefit of hindsight, proved not to reflect actual consumption levels). Production capacity increased by 100% over Q495 and the Company increased revenues by 68% over 1995 levels. As the Company began shipping against that backlog, customers began adjusting their internal inventories and ordering strategies to reflect their reduced anxiety levels due to shorter lead times and the improved availability of product. As a result, net order rates for the second half of 1996 declined from the abnormally high levels of 1995. As recently reported by the U.S. Department of Commerce, the demand for end-market communication, computer and instrumentation equipment continues to grow at an annual rate of 15–20%. Since the end-market demand for electronic equipment remains brisk, we believe integrated circuit bookings growth will resume when lead times stabilize such that our customers can accurately determine the level of integrated circuit inventory and order coverage required to support their ongoing production run rates."

Mr. Gifford commented further, "Maxim is well positioned for the future. Our current level of product design resources has increased to the point that we were able to introduce 57 new products in the fourth quarter alone and we are planning on introducing 50% more new products in 1997 than in 1996. If we can carry out that plan, that level of success should be more than sufficient to sustain our historical growth in revenues. Today over 90% of our revenues come from products we have invented. During the current period of uncertainty regarding bookings and backlog growth, we believe we are micromanaging our spending levels without compromising our growth potential. We believe our ability to have responded to a broader customer base in 1996 allowed us to gain market share. The manufacturing infrastructure purchased with cash in 1996 is in place and is capable of supporting a material part of our growth in 1997. We have emerged from this year a stronger company, and we are optimistic about our potential for long-term growth."

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.

Charge pumps shine in portable designs

New-generation ICs have combined with passive-component improvements to make charge-pump voltage conversion a favored approach in most applications. In many cases, the earlier charge pumps were considered either unsuitable or acceptable only with compromise. For example, an application that had relaxed accuracy, low load current, high noise tolerance, and minimal need for efficiency could benefit from a charge pump's lower cost, smaller size, simpler circuitry, and—of course—inductor-free operation.

Today's charge-pump ICs meet the demanding requirements of portable systems with improved precision, higher output current, output noise levels acceptable to sensitive RF applications, and battery life comparable to that of some inductor-based designs. The following discussion compares several IC charge-pump designs, presents "inductorless" power-supply applications, and offers guidelines for component selection.

A short primer

The term "charge pump" refers to a type of dc-dc voltage converter that uses capacitors rather than inductors or transformers to store and transfer energy. Charge pumps (often called switched-capacitor converters) include a switch or diode network that charges and discharges one or more capacitors. The most compelling advantage of a charge-pump circuit is the absence of inductors.

Why avoid inductors? Compared with capacitors, they have fewer purchasing sources, fewer standard specifications and dimensions, greater component height, more EMI, greater layout sensitivity, and higher cost. (Otherwise, they're great.) The newer generation of charge-pump ICs offers satisfactory operation even with the low-cost ceramic capacitors commonly used to bypass power supplies.

The basic charge pump can be implemented in an IC with analog switches, or in a discrete-component circuit with diodes (**Figure 1**). In the IC version, the switch network toggles between charge and discharge states, and in the discrete version, the clock waveform drives the charge and discharge states via diodes. In both cases the "flying capacitor" (C1) shuttles charge, and the "reservoir capacitor" (C2) holds charge and filters the output voltage. You can expand and modify this scheme as required to add regulation, reduce noise, obtain higher output voltage, etc.

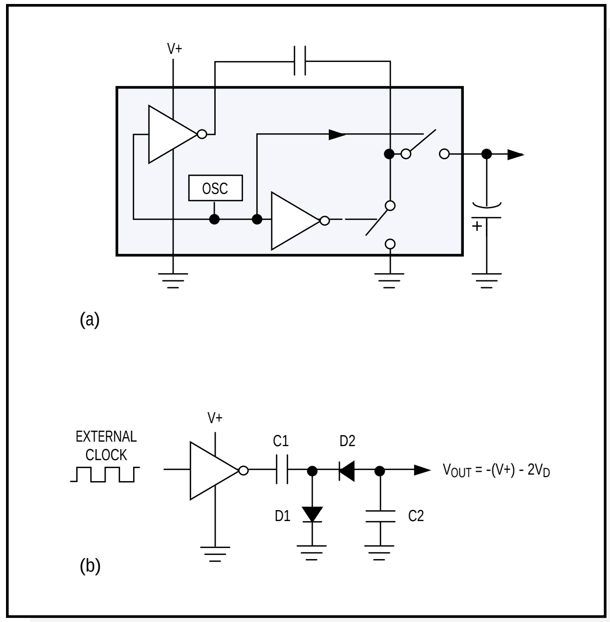


*Figure 1. A basic charge pump provides voltage doubling or inversion. It can be implemented with on-chip switches (**a**) or discrete diodes (**b**).*

Though charge pumps often serve as power sources for small circuit blocks or individual components such as interface ICs, they have not been widely used as system power supplies. This usage is changing, however: the output-current capability of charge pumps is increasing while the supply current required in portable designs is decreasing. In **Figure 2**, for example, the IC1 charge pump can generate 100mA at 3.3V when powered from a 2-cell battery of AA or AAA alkaline, NiCd, or NiMH cells, or a single primary lithium cell.

The Figure 2 circuit can maintain its 3.3V output for inputs as low as 2.2V. For inputs ≥2.4V, it can supply short-term loads exceeding 200mA. For 5V systems with inputs as low as 3V, a similar design plus a 5V linear regulator supplies 150mA when powered from a 3-cell alkaline, NiCd, or NiMH battery, or one rechargeable lithium cell. The efficiency in both circuits varies from almost 80% (with low V_{IN}) to slightly more than 50% when the battery voltage is high (3.2V for two cells, or 4.8V for three cells).

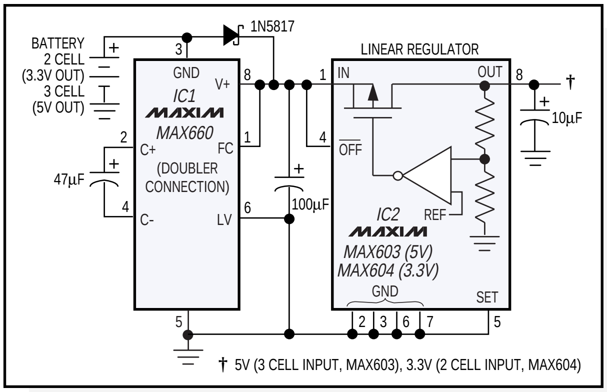


Figure 2. This charge-pump boost converter with linear regulator supplies 200mA at 3.3V with a 2-cell input, and 150mA at 5V with a 3-cell input.

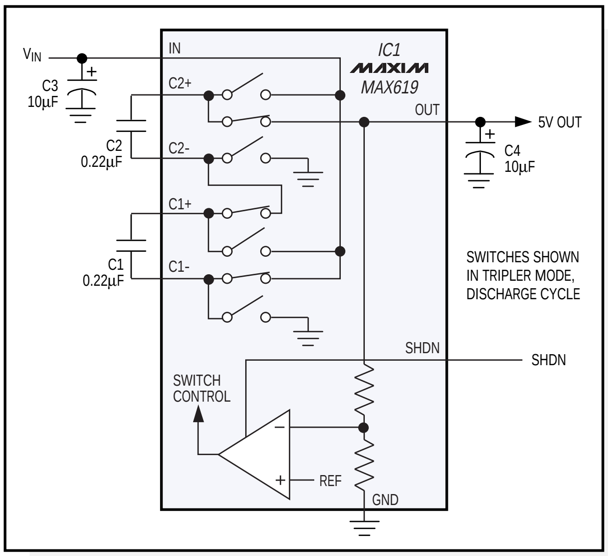


Figure 3. This IC contains a multi-switch boost converter with output regulation. The circuit either doubles or triples V_{IN} to maximize efficiency. Switch-control information is fed back to maintain the output regulation.

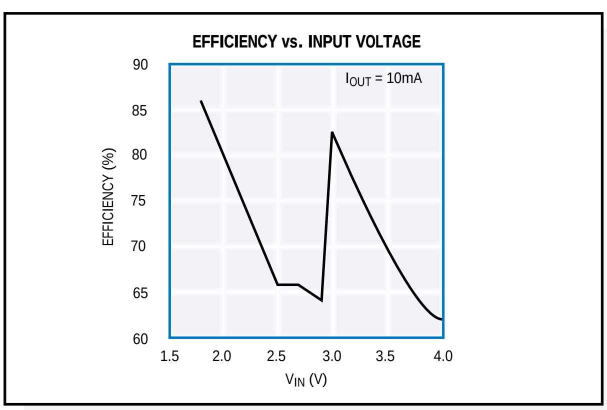


Figure 4. Discontinuities in the efficiency/V_{OUT} profile for Figure 3 occur when the internal charge pump shifts between voltage doubling and tripling.

Internally regulated charge pumps

The Figure 2 circuit overcomes the charge pump's lack of regulation by adding a regulator externally. Another option—if load currents are modest—is to add regulation on the chip. Regulation in a monolithic chip is generally accomplished either as linear regulation or as charge-pump modulation. Linear regulation offers the lowest output noise, and therefore provides better performance in (for example) a GaAsFET-bias circuit for RF amplifiers. Charge-pump modulation (which controls the switch resistance) offers more output current for a given die size (or cost), because the IC need not include a series pass transistor.

The circuit of **Figure 3** is useful both in main supplies and in backup supplies. It generates a regulated 5V output for load currents to 20mA and inputs ranging from 1.8V to 3.6V. For input voltages no lower than 3V, the output current can reach 50mA. The conversion efficiency (**Figure 4**) approaches that of an equivalent low-cost, inductor-based circuit. Note the variation with input voltage: efficiency exhibits a step change near V_{IN} = 3V, where the charge pump shifts automatically between its voltage-tripler and voltage-doubler modes of operation. For each "zone" of doubler or tripler operation, the highest efficiency occurs at the lowest V_{IN}. Within each zone, the efficiency declines as the losses increase with V_{IN}:

$$\text{Power lost} = I_{OUT} \times [(2 \text{ or } 3)V_{IN} - V_{OUT}].$$

The Figure 3 circuit accomplishes regulation without a linear pass element, but its losses are the same as those of an unregulated doubler or tripler feeding into a linear regulator! This surprising result is a consequence of the unavoidable loss that occurs whenever the pump capacitors change voltage within a switching cycle. Consider two 1µF capacitors, one charged to 1V and one to 0V. Their total stored energy is:

$$\tfrac{1}{2}CV^2 = \tfrac{1}{2}(1\mu F)(1V^2) + \tfrac{1}{2}(1\mu F)(0V^2) = 0.5\mu\text{Coulombs}.$$

Connecting them in parallel recharges each to 0.5V, so the new total is:

$$\tfrac{1}{2}(1\mu F)(0.5V^2) + \tfrac{1}{2}(1\mu F)(0.5V^2) = 0.25\mu\text{Coulombs}.$$

Thus, the energy lost in going from 1V to 0.5V (50%) is the same as that expected from a fixed-V_{OUT} doubler or tripler followed by a linear regulator. In Figure 3, efficiency is optimized by automatic shifts between doubler and tripler operation, which minimize the ΔV changes.

Operating current

Many capacitor-based voltage converters offer extremely low operating current—a useful feature in systems for which the load current is either uniformly low, or low most of the time. Thus, for smaller hand-held products the light-load operating currents can be much more important than full-load efficiency in determining battery life. In such products, the "off" state is not completely off, but rather a suspend or sleep state in which the supply current required (for µP and memory, for instance) may be 100µA or less. Battery life is affected directly if a comparable current is drawn by the power supply itself.

The supply current for a charge-pump IC is generally proportional to its operating frequency. You can minimize the current draw by running at the lowest possible frequency, but the penalty (for older charge-pump ICs) is higher ripple voltage, less I_{OUT} capability, and the need for larger valued pump capacitors. Some ICs provide a pin-settable operating frequency to assist in making this tradeoff.

Newer charge-pump ICs employ another technique (on-demand switching), which enables low quiescent current and high-I_{OUT} capability at the same time. Thus, the Figure 3 system incorporates on-demand circuitry that lowers the no-load supply current to 75µA (typical).

Although Figure 3's full-load efficiency (shown in Figure 4) is less than that found in most inductor-based designs, its very low operating current may allow a longer battery life. The effect of operating current on battery life depends on the fraction of operating time spent in the suspend or sleep state. The MAX619 in Figure 3, for instance, includes an on-demand oscillator that runs only when the output voltage falls below 5V. The resulting no-load quiescent current is only 75µA, and the device delivers output currents to 50mA using 0.22µA pump capacitors. Low operating current is also of interest when generating a backup voltage for lithium coin cells.

Flash memory

An application well suited for charge-pump conversion is the generation of a programming voltage for flash memory chips. The charge-pump approach provides a nearly ideal solution for credit-card-sized products in which the component height is severely restricted—particularly if it lowers the number of electrolytic capacitors or eliminates them altogether. An IC designed for this purpose (**Figure 5**) supplies a 12V "V_{PP}" voltage suitable for programming 2-byte words of flash memory. Another IC (the MAX619, mentioned earlier) supplies a 5V V_{PP} for 5V flash devices.

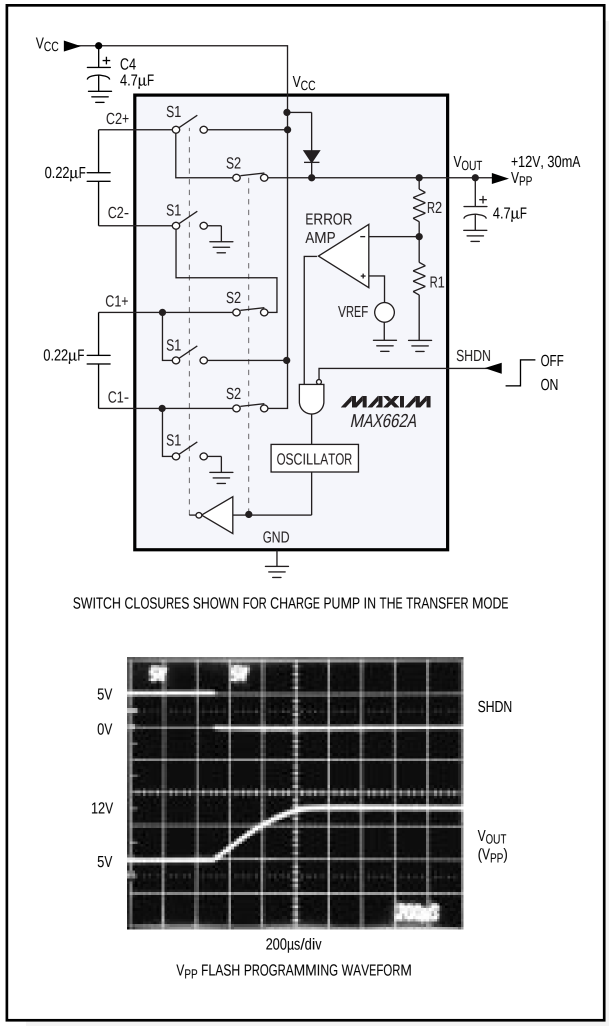


Figure 5. This IC generates the V_{PP} programming voltage required for a 12V flash memory (12V). V_{OUT} is fully regulated for loads of 30mA.

Compared with other types of voltage converters, the charge pump can provide superior performance in applications that process low-level signals or require low-noise operation. In some cases, the charge pump now allows voltage conversion in applications for which the only feasible solution had been a linear regulator. Note that these advantages don't apply to all charge pumps. When compared with inductor-based circuits, some disadvantages become apparent as well.

The most direct advantage is elimination of the magnetic fields and EMI that come with an inductor or transformer. One EMI source remains in a charge-pump circuit—the high charging current that flows to a "flying capacitor" when it connects to an input source or another capacitor with a different voltage. The instantaneous current flow is limited only by the associated capacitor ESR and switch

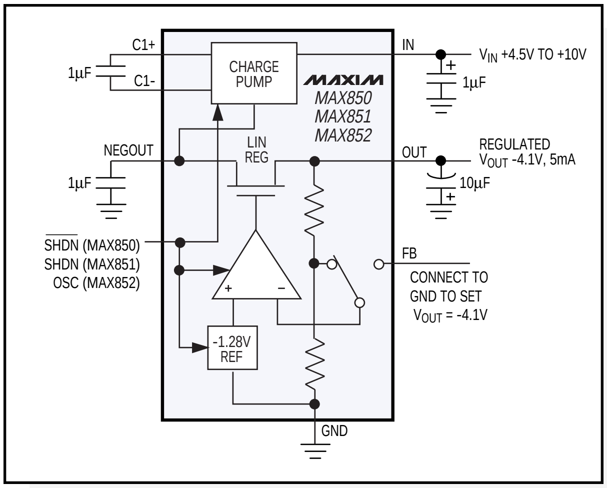


Figure 6. This GaAsFET-bias power supply contains a linear regulator that limits the output noise to 2mVp-p.

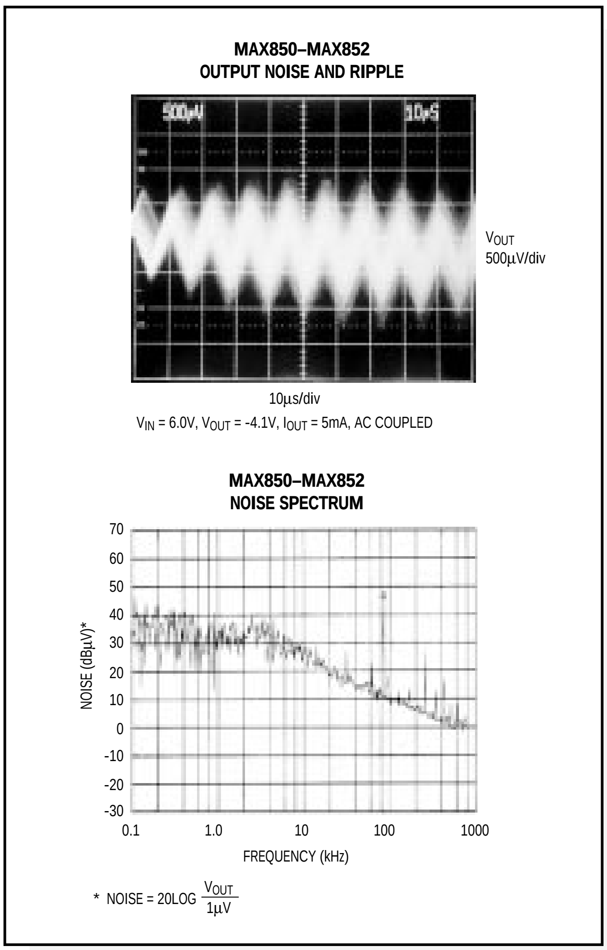


Figure 7. This noise plot for the Figure 6 circuit shows noise below 2mVp-p.

resistance, which can be as low as 5Ω. Unless the charge pump is tailored for low-noise operation, the noise produced by these high-$\Delta I/\Delta t$ events can be eliminated only by post filtering or a large capacitance.

One example of a low-noise charge-pump converter is the MAX850 (**Figure 6**). Designed to generate very quiet negative bias voltages for GaAsFET RF power amplifiers, it combines an inverting charge pump with a low-noise, negative-output linear regulator. The MAX850 operates from 5VDC and has a high switching frequency (100kHz) that enables the use of small-valued external capacitors. An on-chip regulator lowers the output ripple and noise to only 2mVp-p. This noise (**Figure 7**) is remarkably low for a switching power supply.

A similar approach taken in higher-current applications supplies a low-noise bias for the magneto-resistive read-write head in a high-capacity (2Gbytes and up) hard-disk drive. Such drives typically require -3V at 100mA, with no more than 10mVp-p of output noise and ripple. The pump output's switching transients again preclude a direct connection to the MR head preamp, but you can interpose a cheap yet serviceable linear regulator fashioned from three transistors (**Figure 8**). This arrangement is adequate for most uses. Its output accuracy, however, depends on the V_{IN} tolerance because (for simplicity) V_{IN} serves as a reference for the regulator. The output ripple and noise are about 5mVp-p.

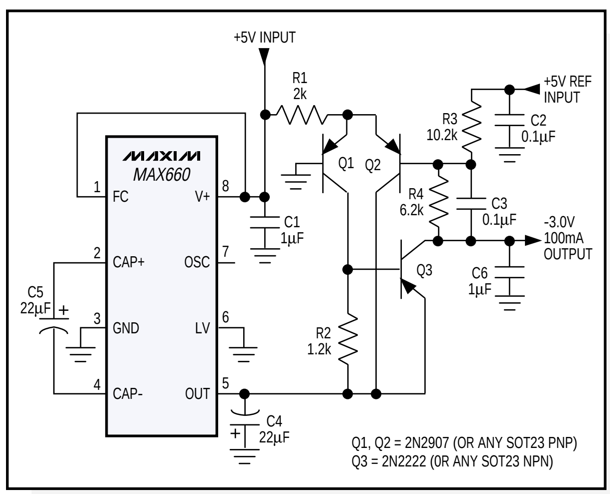


Figure 8. A cheap but serviceable three-transistor circuit adds a regulated 100mA, -3V output to a charge-pump IC.

Capacitor selection

A sometimes elusive bit of information relating to charge-pump designs is the minimum capacitor value needed for a particular load current. For most charge-pump ICs, the data sheet recommends only one or two capacitor values, yet (usually) the chip can operate with a wide range of values—especially when load currents are low. In most designs you should specify the smallest capacitor value that provides acceptable levels of output voltage, current, and ripple. These quantities depend on switching frequency and switch resistance as well as capacitance.

The effect of capacitance value on ripple and output current is illustrated by the eight graphs shown in **Figure 9** (and summarized in **Table 1**). Each graph includes five curves that supplement data-sheet information for three common charge-pump dc-dc converters from Maxim—the MAX660, MAX860, and MAX861:

1) MAX660, high-frequency mode (FC = V+), approximately 40kHz

2) MAX860, high-frequency mode (FC = OUT), approximately 100kHz

3) MAX860, medium-frequency mode (FC = GND), approximately 40kHz

4) MAX861, high-frequency mode (FC = OUT), approximately 200kHz

5) MAX861, medium-frequency mode (FC = GND), approximately 90kHz

These graphs show that lower load currents can often be supported by small ceramic capacitors. Evolving ceramic capacitor technology is producing higher values at lower costs, so you can now obtain ceramic capacitors to 10µF, at volume prices in the $0.30 range, from manufacturers such as United Chemicon (formerly Marcon), Tokin, TDK, and Murata Erie.

The frequency for each curve in Figure 9 is somewhat less than the typical found in the data sheet, because V_{IN} is specified on the low side: 4.5V = 5V - 10%, and 3.0V = 3.3V - 10%. Some of the graphs depict higher current at 2.0µF than at 2.2µF. That occurs because the 1µF and 2µF values are ceramic chips (with Z5U dielectric), and the values from 2.2µF up are tantalum types (AVX TPS series). Current and ripple data was collected by loading the outputs until V_{OUT} reached the value shown in Table 1. (Ripple improvement is negligible at higher values of capacitance.) V_{OUT} is higher at lower load currents, but $-(V_{OUT})$ never exceeds V_{IN}.

Charge-pump tricks

Power conversion by integrated charge pumps is, of course, predated by the use of discrete capacitors for that purpose. Charge-pump techniques have been used in 50Hz/60Hz ac-line supplies for many years, and also in high-voltage multipliers to achieve outputs of several kV. The use of CMOS analog switches has enabled the integration of complex functions with very few parts. As another advantage, CMOS switches exhibit a virtual zero drop at low current, versus the minimum 0.6V drop across a diode switch. But, in some cases, the addition of discrete components can add performance, even in applications employing the latest charge-pump ICs.

A low-power converter of 5V to ±20V can be made surprisingly small by enhancing a dual-output charge-pump IC with an extra boost stage composed of discrete diodes. Such supplies are useful for CCD power supplies, LCD bias, and varactor tuners. The MAX864 on its own can generate ±10V (minus load-proportional losses) from a 5V input, or ±6.6V from a 3.3V input. Using additional diode-capacitor stages (**Figure 10**), these outputs can be doubled again to approximately $\pm 4V_{IN}$, or multiplied by 1.5 to approximately $\pm 3V_{IN}$. Note that the external diode/capacitor network connects to C1 for ±15V outputs, or to C2 for ±20V outputs.

Figure 11 illustrates the output voltage versus load current for each circuit in Figure 10, using both silicon diodes (for lowest cost) and Schottky diodes (for highest output). These circuits can supply as much as 20mA, and the 1µF filter capacitors yield less than 100mV of output ripple. If desired, you can lower that level considerably with slightly larger capacitors. The ICs in Figure 10 are set for 100kHz operation to allow use of 1µF capacitors, which results in a no-load supply current of 7mA. You can pin-program a lower frequency that lowers the supply current to 600µA, but to achieve the output currents shown in Figure 11 you'll need larger capacitors of 10µF.

Normally, a single-stage charge-pump converter cannot generate negative outputs greater than its positive input voltage. To achieve negative outputs of -8V or more from inputs of 2.5V to 5.5V, add discrete diodes as shown in **Figure 12**. Peak-to-peak noise is the same as shown in Figure 7, and the available output current for a given regulated output voltage is shown at five discrete input voltages in **Figure 13**.

To avoid the need to supply battery or line voltage to low-power computer peripherals, you can siphon off a few milliwatts from the serial port. The common PC

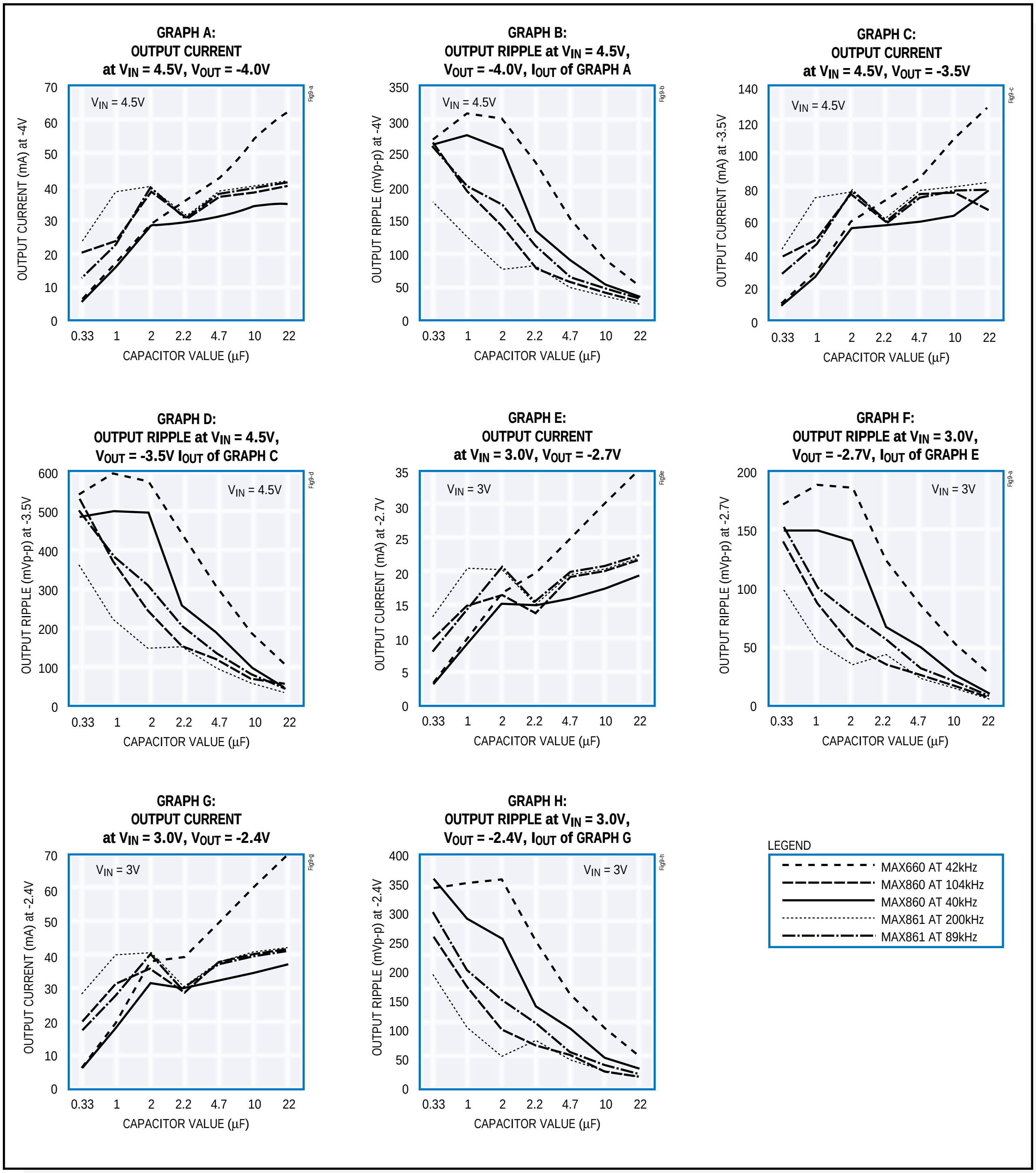


*Figure 9. These graphs (**A–H**) show the relationships among operating frequency, capacitance value, operating current, and output voltage for a charge-pump voltage converter. For a given load, the data enables selection of the minimum capacitance value and operating current.*

Table 1. Summary of graphs in Figure 9

GRAPH	V_{IN} (V)	V_{OUT} (V)	PLOTTED DATA	GRAPH	V_{IN} (V)	V_{OUT} (V)	PLOTTED DATA
A	4.5	-4.0	I_{OUT} vs. cap. value (0.33µF to 22µF)	E	3.0	-2.7	I_{OUT} vs. cap. value
B	4.5	-4.0	Ripple vs. cap. value, at I_{OUT} from "A"	F	3.0	-2.4	Ripple vs. cap. value, at I_{OUT} from "E"
C	4.5	-3.5	I_{OUT} vs. cap. value	G	3.0	-2.4	I_{OUT} vs. cap. value
D	4.5	-3.5	Ripple vs. cap. value, at I_{OUT} from "C"	H	3.0	-2.7	Ripple vs. cap. value, at I_{OUT} from "G"

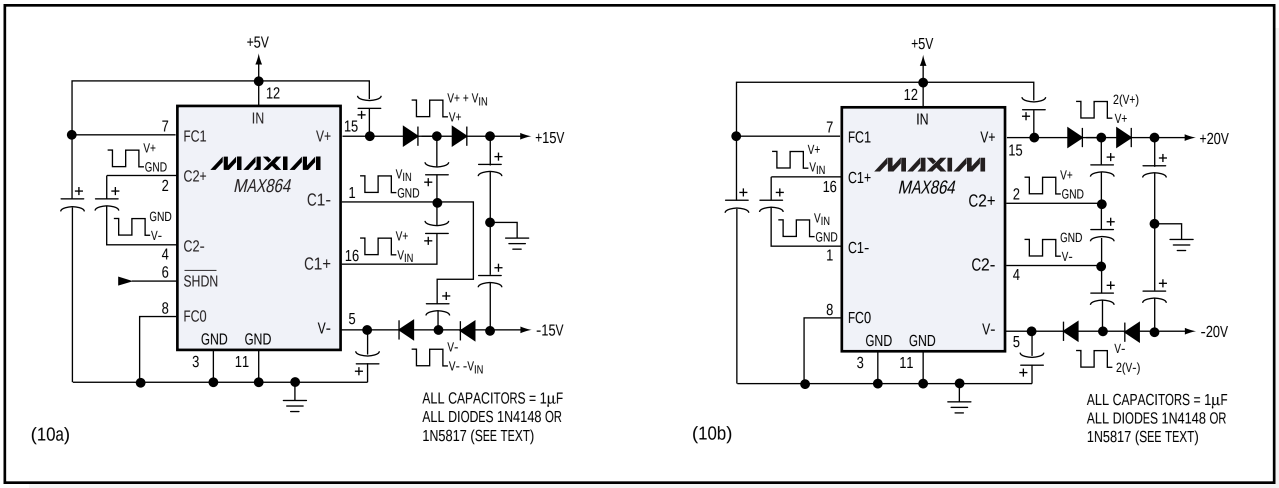


Figure 10. You can obtain higher output voltage from many charge-pump ICs by augmenting the circuit with external diodes and capacitors. These circuits supply up to ±20V.

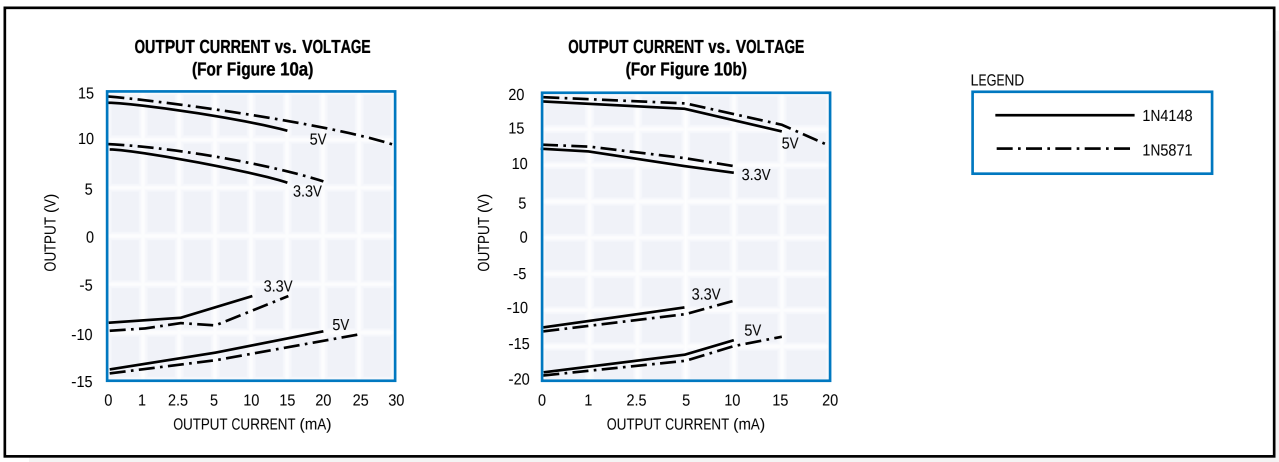


Figure 11. These graphs show V_{OUT} vs. I_{OUT} for the two circuits of Figure 10.

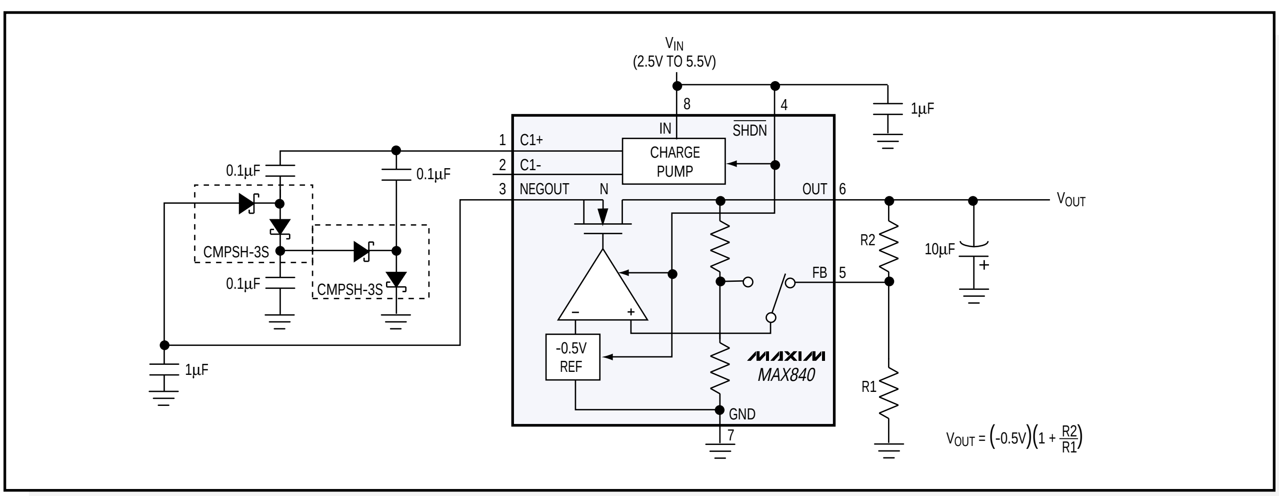


Figure 12. The diode-capacitor network external to this low-noise regulated charge pump lowers the minimum input voltage from 4.5V to 2.5V.

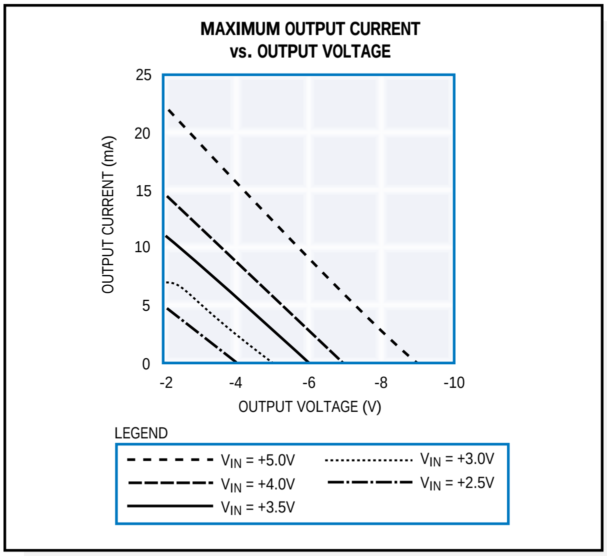


Figure 13. These curves show I_{OUT} vs. regulated V_{OUT} for the Figure 12 circuit.

mouse and other such designs rely on the modem control signals DTR and RTS, but the circuit of **Figure 14** gets power from the TX line of a 3-wire port. Its output capability (8mA) is sufficient for a CMOS microcontroller and some support electronics. The TX line idles at a negative voltage, so the IC's normal input polarity is reversed (the negative input voltage applied between the OUT pin and ground enables the IC to pump backward from its normal direction). Zener diode D1 provides shunt regulation for a 4.7V output.

Charge-pump ICs can help shrink the power supply in a portable system, so it pays to monitor the new technologies and new IC designs constantly being introduced by manufacturers. Maxim, for instance, offers a variety of charge-pump ICs, listed in **Tables 2–4**.

(Circle 1)

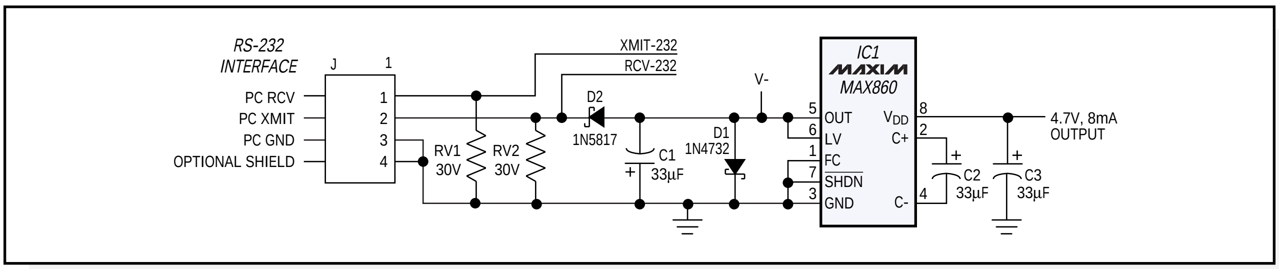


Figure 14. Operating in a voltage-doubler mode, this charge pump converts a negative input voltage (from the TX line of an RS-232 port) to a semi-regulated 5V output at 8mA.

Table 2. Single-output charge pumps

PARAMETER	MAX828	MAX829	MAX860	MAX861	MAX660	MAX1044	ICL7662	ICL7660
PACKAGE	SOT23-5	SOT23-5	SO-8, µMAX	SO-8, µMAX	SO-8	SO-8	SO-8	SO-8, µMAX
OUTPUT CURRENT (mA typ)	0.06	0.15	0.2 @ 6kHz, 0.6 @ 50kHz, 1.4 @ 130kHz	0.3 @ 13kHz, 1.1 @ 100kHz, 2.5 @ 250kHz	0.12 @ 5kHz, 1 @ 40kHz	0.03	0.25	0.08
OUTPUT (Ω typ)	20	20	12	12	6.5	65	125	55
PUMP RATE (kHz)	12	35	6, 50, 130	13, 100, 150	5, 40	5	10	10
INPUT (V)	1.25 to 5.5	1.25 to 5.5	1.5 to 5.5	1.5 to 5.5	1.5 to 5.5	1.5 to 10	1.5 to 20	1.5 to 10

Table 3. Regulated charge pumps

PARAMETER	MAX619	MAX662A	MAX840/843/844	MAX850/1/2/3
PACKAGE	SO-8	SO-8	SO-8	SO-8
OUTPUT CURRENT (mA typ)	0.075	0.185	0.75	2
OUTPUT (V)	5 ±4%	12 ±5%	-2, or set -0.5 to -9.4	-4.1, or set -0.5 to -9
GUARANTEED I_{OUT} (mA)	50	30	4	5
PUMP RATE (kHz)	500	500	100 ±20	100 ±20
INPUT (V)	2 to 3.6	4.5 to 5.5	2.5 to 10	4.5 to 10
SHUTDOWN	Yes	Yes	Yes	Yes
FEATURES/COMMENTS	—	Flash memory V_{PP}	Low-noise GaAsFET bias	Low-noise GaAsFET bias

Table 4. Multi-output charge pumps

PARAMETER	MAX680	MAX865	MAX864
PACKAGE	SO-8	µMAX	QSOP
OUTPUT CURRENT (mA typ)	1	0.6	0.6 @ 7kHz, 2.4 @ 33kHz, 7.0 @ 100kHz, 12 @ 185kHz
OUTPUT (V)	±10V (5V in)	±10V (5V in)	±10V (5V in)
POSITIVE Z_{OUT} (Ω typ)	150	150	55
NEGATIVE Z_{OUT} (Ω typ)	90	75	34
PUMP RATE (kHz)	8	24	7, 33, 100, 185
INPUT (V)	2 to 6	2 to 6	1.75 to 6
SHUTDOWN	No	No	Yes

Turnkey power-supply solutions power Pentium Pro® µPs

The latest microprocessors to emerge from Intel and other manufacturers have forced fundamental changes in the design of personal-computer power supplies. Recent-vintage microprocessors (µPs) demand supply rails of lower voltage and greater accuracy than did those of earlier generations. What's more, they feature a start/stop clock operation that demands a fast response to load transients. Thanks to highly integrated power-supply ICs, all these requirements can be met with miniature-component circuitry on a small PC board.

As a result of these developments, the earlier and relatively simple 5V/12V power supply has been transformed into a power-supply system that generates multiple low-voltage outputs with high accuracy and high efficiency. Such systems must also respond quickly to changes in load current. The Pentium Pro® µP, for example, can produce 0.5A to 10A load-current steps that require the power supply to respond within 350ns, at 30A/µs.

Desktop and notebook computers require several different low-level supply voltages to operate their internal memory, logic, and disk-drive circuitry. These computers employ a combination of 5V, 3.3V, and 2.XV in most cases. Two key requirements for this task are high-efficiency dc-dc converters and synchronous rectifiers.

The synchronous rectifier in a switch-mode power supply consists of a low-resistance conduction path across the Schottky diode, for the purpose of improving power-conversion efficiency. MOSFETs usually provide this low-resistance path, but bipolar transistors and other semiconductor switches are also suitable. The forward-voltage drop across a switch-mode rectifier degrades efficiency in proportion to the V_{IN}/V_{OUT} ratio. As standard supply voltages have been revised downward repeatedly, the drop has become an increasing fraction of V_{OUT}, producing an efficiency loss that calls for closer attention to rectifier design.

The following discussion develops a complete power-supply design that meets the Pentium Pro specifications for accuracy and fast transient response. It occupies only 3.1" x 1.5" of board area. A second, higher current board offers output currents to 15A and an option for moderate- or high-accuracy output voltage. Also presented is the design of a 1.5V power supply used to terminate the Gunning Transceiver Logic (GTL) bus and other high-speed buses associated with processors such as the Pentium Pro.

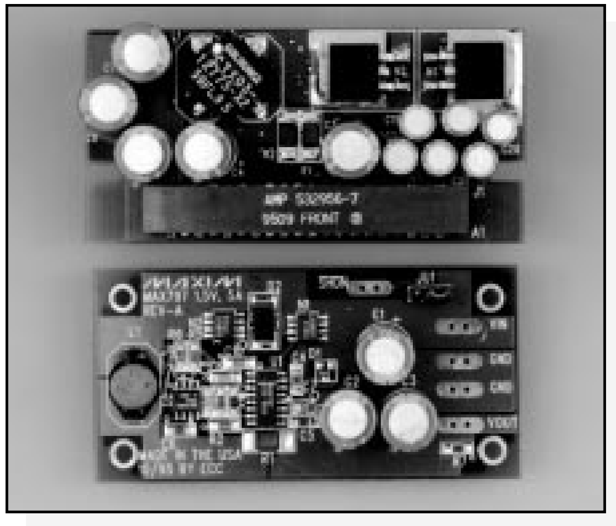


Figure 1. A power-supply module for Pentium Pro microprocessor systems (top) and a bus-termination supply for Gunning Transceiver Logic (bottom) both depend on the MAX797 step-down PWM controller.

To meet Intel's Pentium Pro power requirement, Maxim designed a plug-in power-supply module with a standard connector that plugs into a mating socket on the motherboard. This dc-dc converter module is based on the MAX797 BiCMOS controller U1 (See photo, top of **Figure 1**, and **Figure 2**). Configured in the fixed-frequency PWM mode, U1 operates with a synchronous rectifier (N2) that improves efficiency at low output voltages.

This module accepts, via the J1 connector pins, an input voltage of 4.5V to 6V and a 4-bit configuration code from the Pentium Pro (pins Vid0–Vid3). The code adjusts the module's output voltage to that required by the µP at its supply pins. Each bit is either 5V (logic 1) or ground (logic 0). The result is 16 available codes that set the output voltage in 100mV increments from 2.1V to 3.5V.

To minimize cost, the single D/A converter usually employed for output-voltage adjustment has been replaced with a strip of resistor divider and two MAX4051 (or CD4051) 8-1 multiplexers. U1's fixed 2.5V reference enables the circuit to regulate output levels below 2.5V. R6 and R7 divide down this voltage and feed it to an integrator formed by U2A, C14, C23, and R36. Reduced from 2.5V to 2.1V, this voltage is

Pentium Pro is a registered trademark of Intel Corp.

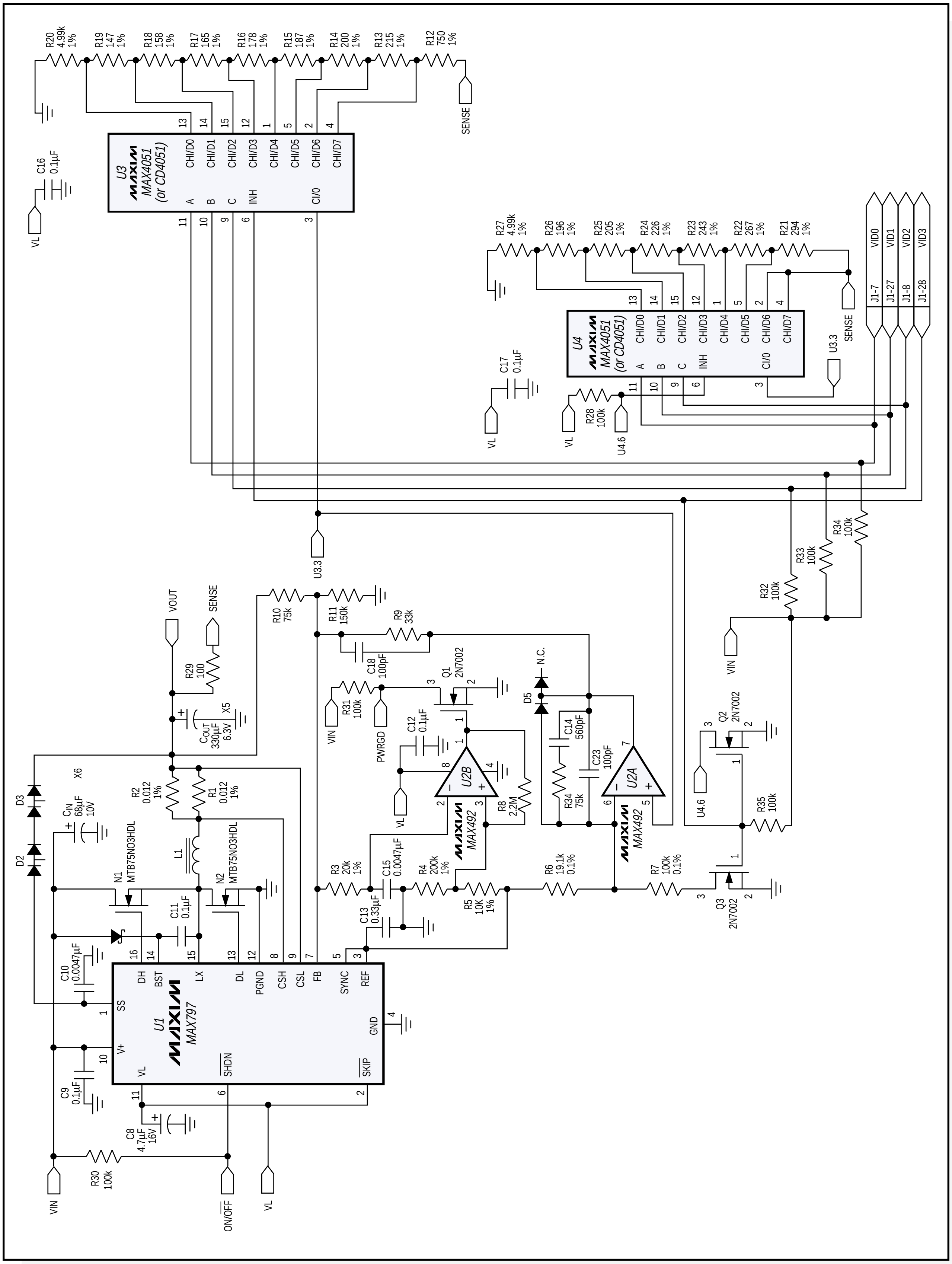


Figure 2. This power-supply circuit generates 2.1V to 3.5V at 11.2A, for Pentium Pro microprocessor systems.

summed with a directly coupled feedback signal (to ensure rapid response to transients), and fed to the main high-speed comparator at U1's FB terminal. The other half of U2, op amp U2B, generates an open-drain power-good signal (PWRGD) that goes low whenever the output voltage is out of tolerance.

During power-up, diode D5 (between U2A pins 6 and 7) limits the output overshoot, and capacitor C10 (U1, pin 1) reduces the input surge currents. An internal soft-start circuit holds C10 discharged to ground during shutdown (OUTEN = 0V). When OUTEN goes high, C10 is charged by an internal 4µA current source, and the main output capacitor, C_{OUT}, charges up slowly, depending on its value. The maximum current limit is reached within 5ms.

D2 and D3 protect the converter during a continuous short circuit. The input capacitor (C_{IN}) assists in decoupling load transients from the main input and in meeting the input-ripple requirement, which is approximately half the output current. C_{OUT} provides bulk capacitance and low ESR. For load steps of 0.2A to 11.2A (the module's maximum output current), the output transient is typically ±50mV and the output ripple is typically 15mV.

The controller IC in Figure 2 (MAX797) is also suitable for higher power 5V step-down applications in which efficiency, board space, and output-voltage accuracy are critical. One such circuit is the synchronous buck dc-dc converter of **Figure 3**. Designed to operate with a minimum number of small external components, it features a 300kHz switching frequency, 15A (or 20A) maximum output current, and a 2V to 3.5V output range. The low-cost, high-slew-rate, n-channel switching MOSFETs (N1 and N2) provide efficiencies (without a heat sink) that exceed 90% at high I_{OUT}.

The IC provides fixed-output connections for applications that tolerate ±4% output-voltage accuracy. Connecting the FB terminal (pin 7) as listed in the figure provides outputs of 2.5V, 3.3V, or 5.0V. For higher accuracy, you can add an op amp with rail-to-rail output capability (U2) that controls FB by comparing a scaled version of V_{OUT} with the controller's reference voltage. Resistors R9 and R10 then set the output level: V_{OUT} = 2.5(1 + R10 / R9). Either feedback arrangement enables the board to supply V_{CC} for multiple microprocessors.

U1 provides excellent line and load regulation, with a micropower shutdown that lowers the quiescent current to a maximum of 3µA. It also includes soft-start circuitry that limits the input surge current at start-up by gradually increasing the internal current limit. Soft-start causes the output capacitors to charge relatively slowly. In this case, the 0.01µF soft-start capacitor (C18) allows the output current to reach its maximum limit within 10ms. Table 1 lists component choices that enable the Figure 3 circuit to generate 2.5V at 15A or 20A.

Table 1. Component choices for Figure 3 with 2.5V output

COMPONENT	LOAD CURRENT	
	15 AMPERES	20 AMPERES
INPUT VOLTAGE	4.75V to 5.5V	4.75V to 5.5V
N1 MOSFET (HIGH SIDE)	MTB75N03HDL (MOT)	MTB75N03HDL (MOT)
N2 MOSFET (LOW SIDE)	MTB75N03HDL (MOT)	MTB75N03HDL (MOT)
INPUT CAPACITOR (C_{IN})	3 x 330µF (Sanyo 6SA330M or 10SA330M)	4 x 330µF (Sanyo 6SA330M or 10SA330M)
OUTPUT CAPACITOR (C_{OUT})	6 x 330µF (Sanyo 6SA330M)	8 x 330µF (Sanyo 6SA330M)
SENSE RESISTOR (R1)	2 in parallel (Dale WSL-2512-R009)	3 in parallel (Dale WSL-2512-R009)
POWER INDUCTOR (L1)	1.5µH, 20A (Coilcraft DO5022P-152HC)	1µH, 25A (Coilcraft DO5022P-102HC)

The new microprocessors not only demand lower voltage rails; they also require high-speed, low-voltage buses for the next generation of computers. These buses—GTL, Futurebus, and Rambus, for example—require low-voltage terminations that reduce the signal-voltage swings. Other buses, such as center-terminated transceiver logic (CTT) and high-speed transceiver logic (HSTL), have center terminations that require the terminating power supply to both sink and source current.

Thus, a bus-termination power supply must generate 1.5V for a GTL bus or 0.75V for a CTT or HSTL bus, and be able to sink and source current into the termination resistors. Providing 1.5V at 5A, the **Figure 4** circuit meets these requirements with a MAX797 controller that operates with synchronous rectification for high efficiency (**Figure 5**). The circuit's sink capability at low voltage is provided by the combination of synchronous switch N2 and a circuit topology that allows the inductor current to reverse. (See bottom of the Figure 1 photo.)

Pulling the $\overline{\text{SKIP}}$ logic input high enables continuous-conduction mode for the inductor current, and also allows this current to flow from the output back through the inductor and N2 switch to ground. You can easily change the output voltage from 1.5V to 0.75V by changing R5 from 66.5kΩ to 232kΩ. As in the Pentium Pro power supply, this circuit achieves regulated outputs

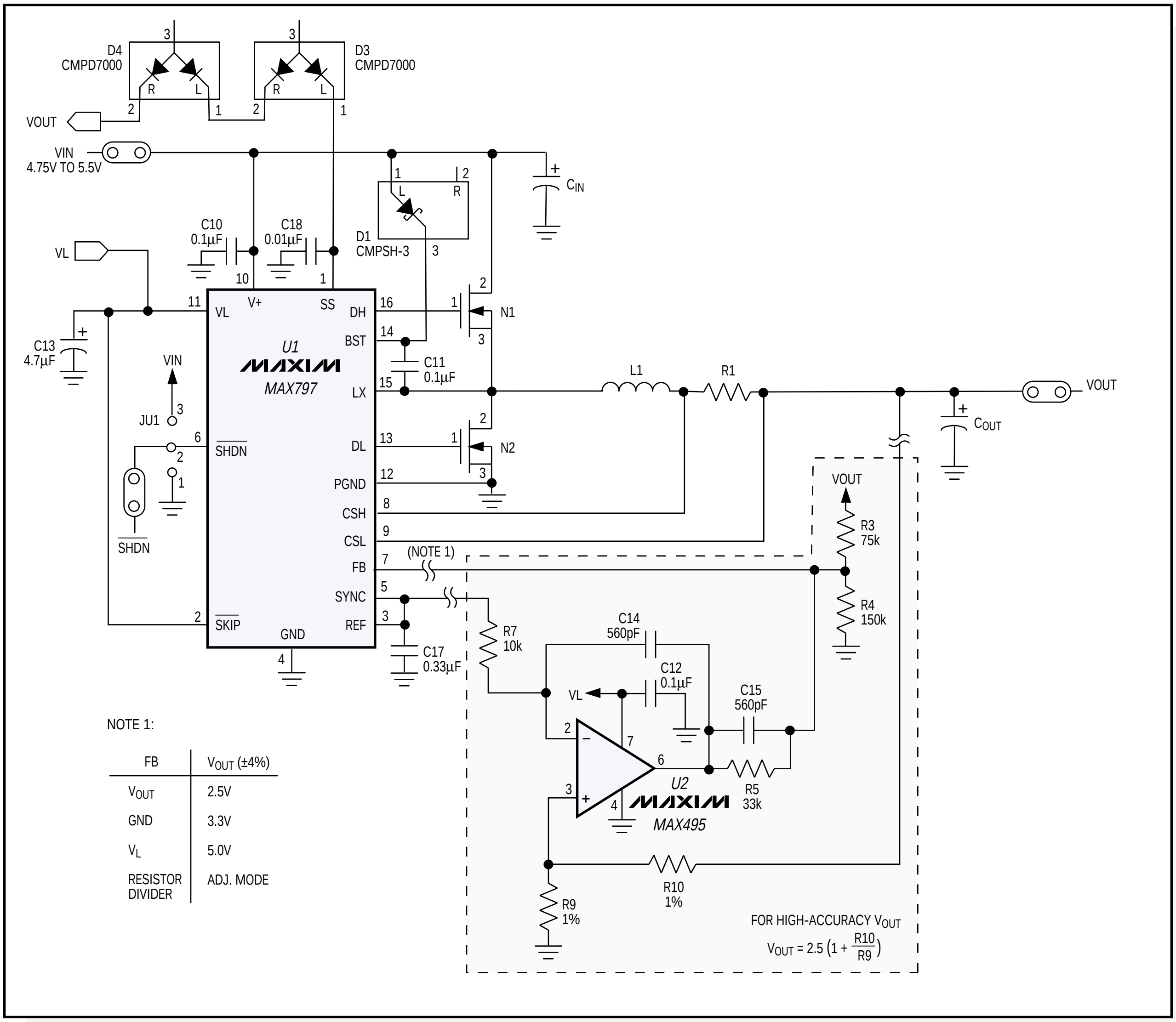


Figure 3. This high-I_{OUT} circuit can deliver maximum output currents of 15A or 20A (see text).

below 2.5V by dividing down the internal 2.5V reference (pin 3), integrating the result, and combining it with a directly coupled feedback signal.

The output sink current does not flow directly to ground as it would in a comparable linear design. Instead, the synchronous buck topology of this circuit works in reverse, becoming a boost topology that enables the sink current to constitute a net positive flow back into the 5V input supply.

For further information, including a bill of materials, please fax Nancy George-Adeh at (408) 737-7194.

(Circle 2)

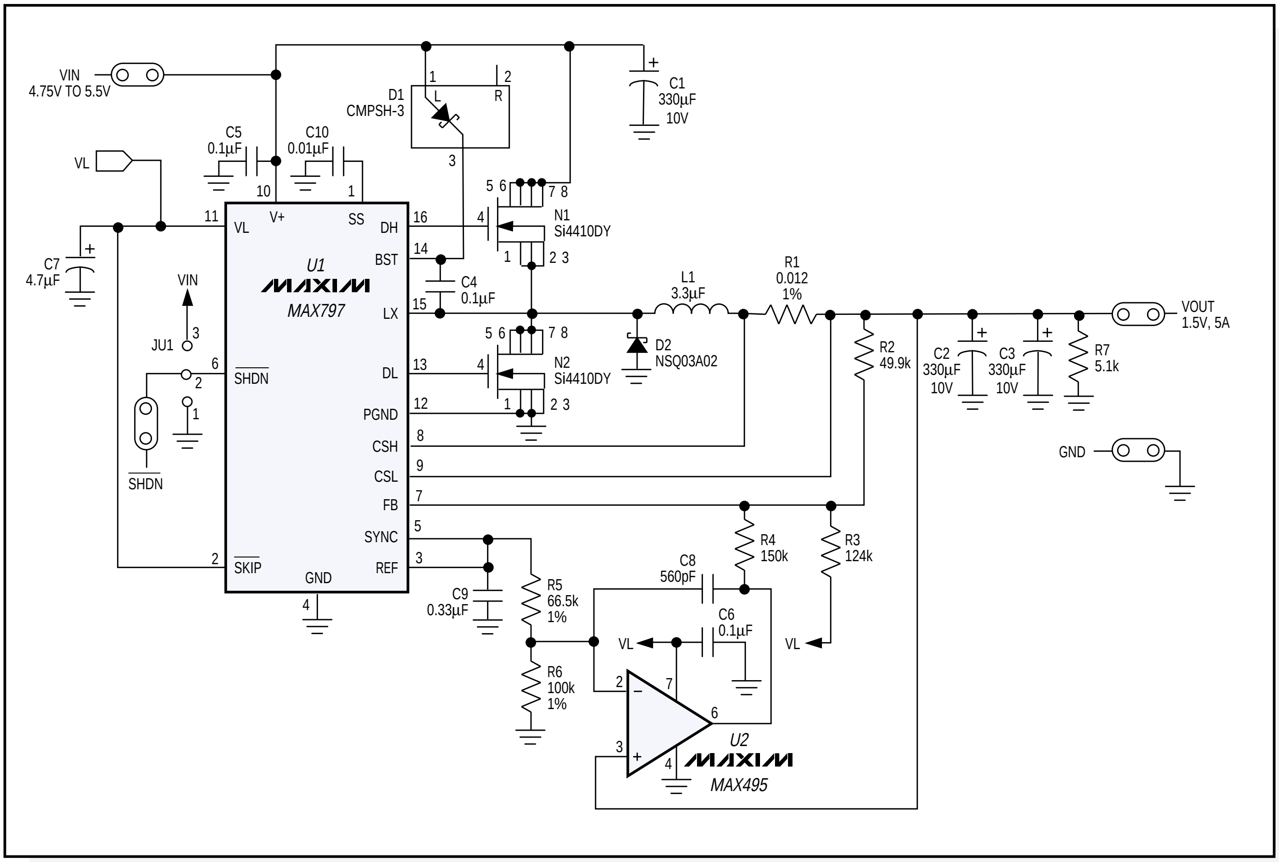


Figure 4. An accurate 1.5V step-down converter powers the termination resistors in a GTL data bus.

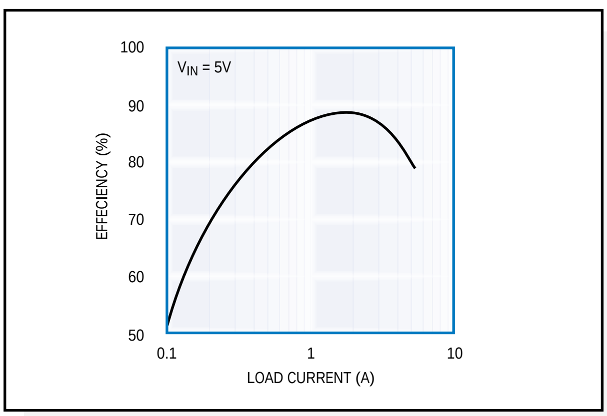


Figure 5. The low-V_{OUT} (1.5V) GTL-bus power supply of Figure 5 offers maximum efficiency for load currents between 1A and 2A.

Low-power circuit reduces V_{CC} audio ripple by 40dB

The **Figure 1** circuit reduces noise and ripple voltage by 40dB over the 100Hz to 20kHz audio range. It provides a clean source of 5V power for driving audio circuits in portable applications such as cellular phones and multimedia notebook computers. Most linear regulators reject noise only up to 1000Hz or so, and the bulk of a low-frequency passive filter is unwelcome in portable applications.

The circuit shown accepts noisy V_{CC} in the range 4.5V to 6V, and produces quiet V_{CC} at a dc level 7% lower. For example, it produces 4.65V at 1A from a nominal 5V source, with only 200µA of quiescent current. The physical layout is very small: one SOT23 transistor, one µMAX (shrink SO-8) op amp, and a few passive components. The largest capacitor is 10µF, and the resistors can be 0.1W or surface-mount 0805 size.

When operating, the circuit acts as a wide-bandwidth buffered voltage follower (not a regulator) whose dc output level is 7% below that of V_{IN}. R1 and R3 form a voltage divider that provides the 7% attenuation, and C4 helps to form a 93% filtered replica of V_{IN} at the op amp's inverting input. The op amp's small input bias current (25nA typical) allows large resistor values for R1 and R3, yet limits the maximum dc error to only 20mV. The result is a lowpass filter with 2Hz corner frequency that provides 20dB of attenuation at 20Hz.

Because the op amp's common-mode input range extends from rail to rail, its noninverting input can sample the output voltage directly. The op amp's supply voltage is filtered by R2 and C5, providing lower output impedance and better power-supply rejection for the op amp at high frequencies. This filter's 300Hz rolloff augments the op amp's PSRR (already impressive at 110dB).

A related idea appeared in the 1/18/96 issue of EDN.

(Circle 3)

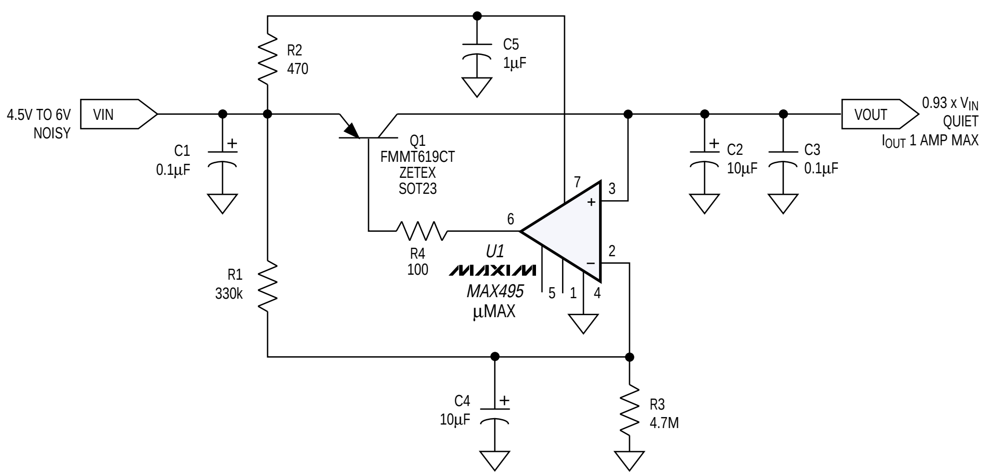


Figure 1. This compact circuit actively compensates for power-supply ripple and noise, providing 40dB of attenuation in the 100Hz to 20kHz audio band.

Single IC manages battery backup

Instruments powered by a "wall adapter" with battery backup typically diode-OR the battery and wall-adapter connections. That arrangement carries a penalty, however—the diode in series with the battery limits the minimum voltage at which the battery can supply power.

One alternative is a dual-comparator/reference IC, which monitors the battery and wall-adapter voltages with respect to its internal reference voltage (**Figure 1**). The open-drain output of comparator B (with pull-up to 3.3V) provides a low-battery warning in the form of a low-to-high transition when battery voltage drops to 3.6V. The open-drain output of comparator A (with pull-up to 9V) flags low wall-cube voltage in the same way, with a warning threshold of 3.9V.

Comparator A also controls the PMOS switch Q1, which replaces the OR-connection diode in a conventional circuit. When wall power is removed, Q1 turns on and provides a low-resistance path from battery to regulator.

A related idea appeared in the 5/1/96 issue of Electronic Design.

(Circle 4)

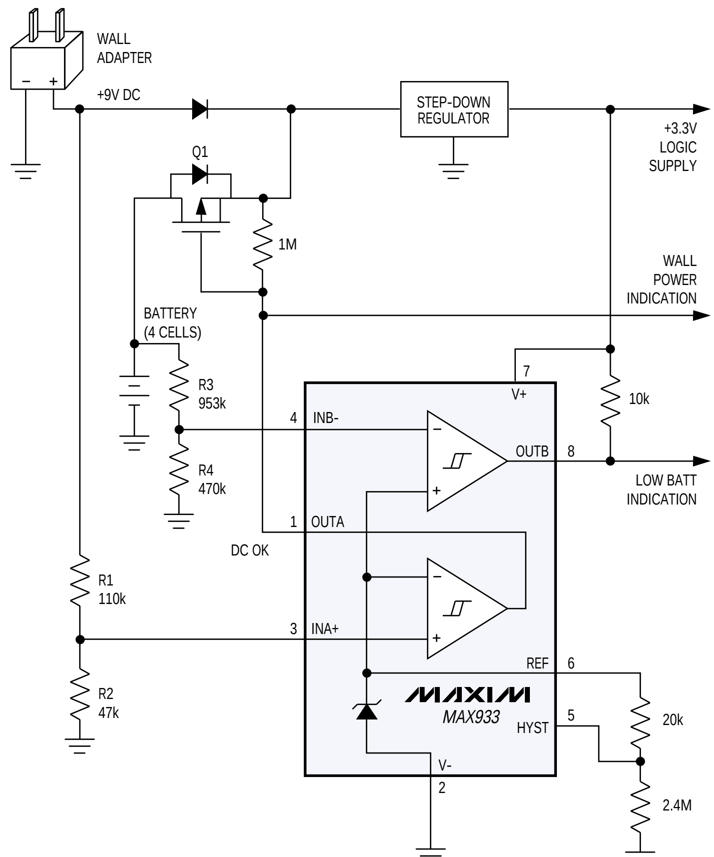


Figure 1. The MOSFET in this power supply (Q1) saves power and extends battery life by substituting for the diode otherwise required.

Simple circuit disconnects load from battery

To prevent battery damage, the **Figure 1** circuit disconnects the load at a predetermined level of load voltage. This level (V_{TRIP}, closely proportional to the battery voltage) is determined by R1 and R2 such that the voltage at pin 3 of IC1 equals 1.15V: $V_{TRIP} = 1.15V(R1 + R2)/R1$. The allowed range for V_{TRIP} is 2V to 16.5V.

The load-battery connection remains open until the system receives a manual reset command. Automatic reconnect circuitry is not always desired, and in any case it may not be effective because the battery voltage rises so much when the load is removed. If the load must be removed before full discharge, or if the difference in terminal voltage from charge to discharge is small, then the hysteresis required (including the effects of component tolerance) may be too great to ensure an automatic reconnection after the battery is recharged or replaced.

Pressing Reset (or pulling pin 3 above 1.15V with a transistor) reconnects the load after the battery is recharged or replaced. Battery drain with the load disconnected is only 5µA, so the circuit can remain in that state for an extended period without causing a deep discharge of the battery. Choose Q1 for a minimal voltage drop (source to drain) at the required load current.

A related idea appeared in the 3/14/96 issue of EDN.

(Circle 5)

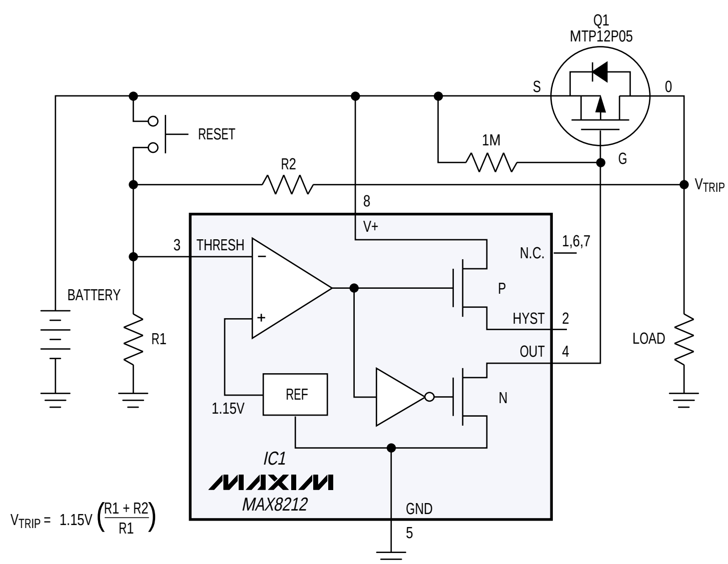


Figure 1. This circuit disconnects the load and battery (at a level of battery voltage determined by R1 and R2) and remains latched in that state until reset by the pushbutton switch.

NEW PRODUCTS

Low-power, 8-bit, 8-channel ADCs feature 1µA power-down

The MAX117 and MAX118 A/D converters are low-power, 8-bit, 8-channel devices designed for communications, data-processing, and data-acquisition applications. Each includes an internal track/hold and a parallel data interface compatible with many microprocessors and microcontrollers.

The MAX117 operates on a single supply of 3V to 3.6V, converts in 1.8µs, and offers sample rates to 400ksps. The MAX118 operates on 5V ±5%, converts in 660ns, and offers sample rates to 1Msps. Both offer a 1µA power-down mode that is ideal for battery-powered applications. The MAX118's fast turn-on time (exiting from power-down in only 200ns) enables it to minimize power consumption by shutting down between conversions.

The MAX117/MAX118 come in 28-pin DIP and SSOP 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 $3.40 (1,000 up, FOB USA).

(Circle 6)

4-channel, 10/12-bit, 2.7V ADCs come in tiny QSOPs

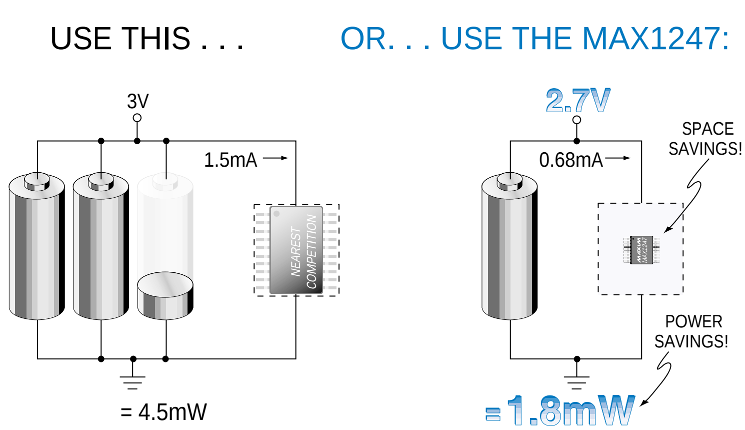
The MAX1247 and MAX1249 are monolithic data-acquisition systems of 12- and 10-bit resolution, respectively. Each combines a 4-channel multiplexer, high-bandwidth track/hold, and serial interface in a tiny, 16-pin QSOP. QSOPs require less height (1.73mm vs. 2.65mm) and only 28% as much area as a 16-pin wide-SO package. Both devices guarantee sampling rates to 133ksps.

The 4-wire serial interface is compatible with Microwire™, SPI™, QSPI™, and TMS320 synchronous-serial standards. Accessing the serial interface automatically powers up the MAX1247/MAX1249, and the resulting quick turn-on enables shutdown between conversions as a practical power-saving technique. At reduced sampling rates, these repeated power-downs can lower the supply current to less than 10µA. The serial interface also configures the analog inputs as unipolar/bipolar and 2-channel differential or 4-channel single-ended. A serial-strobe output allows direct connection to the TMS320 family of digital signal processors.

The MAX1247/MAX1249 draw 0.9mA supply currents while operating on a single supply of +2.7V to +5.25V. During shutdown, the supply currents are only 1µA (each part offers a $\overline{\text{SHDN}}$ terminal and software-selectable shutdown as well). Both devices operate with an external reference, performing successive-approximation conversions using either the internal clock or an external serial-interface clock. (For 8-channel versions of these ICs, please refer to the MAX147 and MAX148.)

The MAX1247/MAX1249 come in 16-pin DIPs and QSOPs, 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 $5.80 for the MAX1247 and $3.95 for the MAX1249 (1,000 up, FOB USA).

(Circle 7)



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

High-speed dual op amps feature current-mode feedback

The MAX4117 and MAX4118 dual current-mode-feedback amplifiers combine high speed with low-power operation. The MAX4117 delivers a 500MHz bandwidth with A_V = 2V/V, and the MAX4118 delivers 275MHz with A_V = 8V/V. High slew rates (1200V/µs and 1800Vµs respectively) and exceptional full-power bandwidths (300MHz and 250MHz) make these amplifiers an excellent choice for high-performance pulse and RGB-video applications. They operate on nominal ±5V supplies and draw quiescent currents of 5mA per amplifier.

The MAX4117 is optimized for closed-loop gains of 2V/V or more, and the MAX4118 for closed-loop gains of 8V/V or more. Each provides a ±3.5V output swing into 100Ω, and an output-current capability of 80mA. The MAX4117 provides 0.1dB gain flatness to 30MHz.

MAX4117/MAX4118 amplifiers come in 8-pin SO packages screened for the extended-industrial temperature range (-40°C to +85°C). Prices start at $2.65 (1,000 up, FOB USA).

(Circle 8)

NEW PRODUCTS

Video-distribution amps feature high speed and fast switching

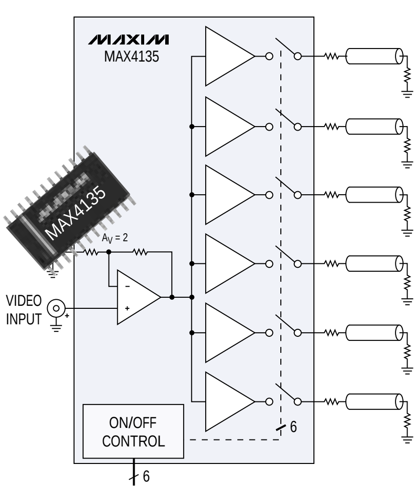
Combining high speed with fast video switching, the MAX4135–MAX4138 video-distribution amplifiers give excellent performance in video switching and distribution, high-resolution RGB monitors, high-speed analog bus drivers, RF signal processing, and composite-video preamplifiers.

All four products include an input amplifier plus an independently controlled unity-gain buffer for each output. On-board control logic allows selection of any combination of the different signal outputs. The MAX4135 and MAX4136 have one input and six outputs; the MAX4137 and MAX4138 have one input and four outputs.

Each device features an outstanding slew rate of 1000V/µs, gain flatness of 0.1dB to 40MHz, output-current capability of 70mA, and low differential gain/phase errors. Fast channel switching (a mere 25ns) enables rapid video multiplexing in applications that display a picture within a picture.

MAX4135–MAX4138 amplifiers come in 24-pin wide-SO packages, screened for the extended-industrial temperature range (-40°C to +85°C). Prices start at $5.29 (100 up, FOB USA).

(Circle 9)



Low-voltage, low-on-resistance analog switches come in 5-pin SOT23s

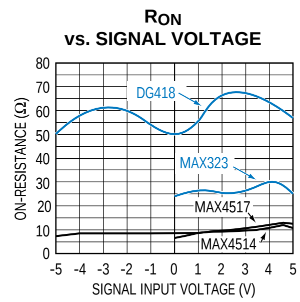
The MAX4501–MAX4504 and MAX4514–MAX4517 SPST CMOS analog switches come in 5-pin SOT23 packages. Guaranteed on-resistance at +25°C is 20Ω (10Ω typical) for the MAX4514–MAX4517, and 250Ω (90Ω typical) for the MAX4501–MAX4504.

The MAX4501/MAX4502 and MAX4514/MAX4515 switches (normally open/normally closed) operate with a single supply of +2V to +12V. The MAX4503/MAX4504 and MAX4516/MAX4517 switches (also NO/NC) operate with dual supplies of ±1V to ±6V. Off leakages are guaranteed 1nA at +25°C and 10nA at +85°C; on leakages are guaranteed 2nA at +25°C and 40nA at +85°C.

The t_{ON}/t_{OFF} switching speeds are fast: 75ns/50ns for the MAX4501/MAX4502, 100ns/75ns for the MAX4516/MAX4517, and 150ns/100ns for the MAX4503/MAX4504 and MAX4514/ MAX4515. The guaranteed maximum charge injection is only 10pC. Single-supply switches are guaranteed compatible with TTL/CMOS logic, and dual-supply switches are guaranteed compatible with CMOS logic.

MAX4501–MAX4504 and MAX4514–MAX4517 devices come in 8-pin SOICs, 8-pin DIPs, and 5-pin SOT23 packages, in versions tested 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 $0.47 for the MAX4514–MAX4517 and $0.42 for the MAX4501–MAX4504 (1,000 up, FOB USA).

(Circle 10)



Low-power µC-reset and watchdog ICs offer adjustable thresholds and timeouts

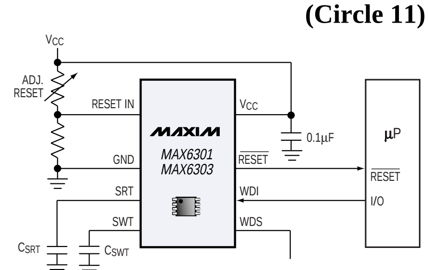
The MAX6301–MAX6304 µP supervisor ICs each draw a maximum 7µA supply current, and issue resets in response to power-up, power-down, or brownout conditions, or a failure in software execution. The models differ only in the reset output (active high vs. active low, and open drain vs. push-pull).

Trip thresholds are set with two external resistors, and each device issues a reset when the applied V_{CC} dips below its threshold. Resets are maintained until V_{CC} returns above the threshold, and for an interval thereafter determined by the user. This interval is set with an external capacitor, and (if desired) by an optional connection that extends the basic interval by a factor of 500. Resets are guaranteed for V_{CC} as low as 1V.

Internal watchdog timers enable each IC to issue a reset whenever the internal timeout elapses. The timer is cleared by any transition on the WDI input, so an absence of transitions (indicating a hang-up in software execution) allows the timeout to cause a reset. Like the reset interval, this timeout interval can be adjusted with an external capacitor. You can also disable it completely.

MAX6301–MAX6304 devices come in 8-pin DIP, SO, and µMAX packages, in versions tested for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $1.51 (1,000 up, FOB USA).

(Circle 11)



8-pin µP supervisors offer ±1.5% reset accuracy

The MAX801 and MAX808 µP-supervisory ICs are designed for battery-powered applications that require high-precision reset thresholds. They monitor and control 5V microprocessor systems by providing reset signals, backup-battery switchover, and low-line indicators. In addition, the MAX801 includes an independent software-watchdog capability, and the MAX808 includes write protection for the system's CMOS RAM.

Each device offers a choice of reset thresholds designated by suffix letter: 4.675V (L), 4.575V (M), and 4.425V (N). When power-down or brownout conditions cause V_{CC} to reach the threshold voltage, the ICs issue $\overline{RESET}$ (RESET as well, for the MAX801) and maintain it for 200ms (typical) after V_{CC} returns above the threshold. To exclude sub-spec V_{CC} levels while maximizing the battery-voltage range, the ICs' BiCMOS technology guarantees a tight tolerance of ±1.5% on the nominal threshold voltage. Resets are guaranteed valid for V_{CC} as low as 1V.

To warn the system processor of impending V_{CC} failure, the ICs issue a $\overline{LOWLINE}$ warning in advance of the reset signal. Also ±1.5% accurate, the $\overline{LOWLINE}$ threshold is 52mV above the reset threshold. Other features include 1µA standby currents, 2ns propagation delays for on-board gating of chip-enable signals (MAX808 only), and compatibility with charged MaxCap™ and SuperCap™ capacitors (as alternatives to the backup battery).

MAX801/MAX808 devices come in 8-pin DIP and SO packages, in versions tested 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 $3.17 (1,000 up, FOB USA).

(Circle 12)

MaxCap is a trademark of The Carborundum Corp.
SuperCap is a trademark of Baknor Industries.

Tiny, 4-pin SOT µP reset is 68HCXX compatible

The MAX6314 is a SOT µP-reset IC whose 68HCXX-compatible $\overline{RESET}$ output enables a direct interface to µPs with bidirectional reset pins, and also solves a problem common to those applications. The µP's method for determining whether a given reset originated externally or within itself can be foiled by stray capacitance associated with multiple devices on the reset line. To overcome the slow-down effect of this capacitance, the MAX6314 includes timing circuitry and an active pull-up for $\overline{RESET}$ (a p-channel MOSFET in parallel with 4.7kΩ), which enables rapid low-to-high output transitions. (See discussion in the data sheet.)

Small size, low supply current (6µA typical), and the simplicity of a single basic function make the MAX6314 an excellent choice for monitoring the supply voltage in digital systems. It has two patents pending. By eliminating external components and adjustments, the device saves cost and improves reliability.

The MAX6314 asserts a reset signal when V_{CC} falls below the preset internal threshold, and maintains the reset for a fixed, internally programmed interval after V_{CC} rises back above the threshold. Factory-trimmed threshold voltages are available in 100mV increments from 2.5V to 5V. Part number suffix codes also designate one of four minimum timeout intervals (1ms, 20ms, 140ms, or 1120ms). The MAX6314 is immune to short V_{CC} transients and guarantees resets for V_{CC} above 1V. It includes a debounced manual reset input ($\overline{MR}$), and is pin-compatible with the MAX811 voltage monitor.

MAX6314 devices come in 4-pin SOT143-4 packages configured for tape-and-reel assembly. All are screened for the commercial temperature range (0°C to +70°C). Prices start at $0.82 (10,000 up, FOB USA).

(Circle 13)

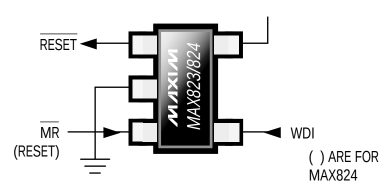
µP-reset/watchdog ICs in SOT packages operate on low current

The MAX823/MAX824/MAX825 are the first µP-reset and software-watchdog ICs in 5-pin SOT packages. Available in five versions distinguished by preprogrammed reset thresholds (4.63V, 4.38V, 3.08V, 2.93V, and 2.63V), these 5-terminal devices for 3V, 3.3V, and 5V systems provide an active-low RESET of 140ms minimum in response to a software malfunction or low V_{CC}. The MAX825 provides an active-high $\overline{RESET}$ output as well; RESET and $\overline{RESET}$ outputs are available simultaneously on this device. In addition, both the MAX823 and MAX825 offer a manual-reset input ($\overline{MR}$); while both the MAX823 and MAX824 feature a software-watchdog function. No external components are required.

The MAX823/MAX824 draw 5µA (12µA max) from a 3V supply or 10µA (24µA max) from a 5V supply. Their internal software watchdog monitors the activity on a selected I/O line, and issues a reset following any 1.6-second interval for which no logic transitions occur on the line. The MAX825 draws only 3µA (8µA max) from a 3V supply or 4.5µA (12µA max) from a 5V supply. Resets for all three devices are guaranteed for V_{CC} down to 1V. All are designed to ignore fast transients on V_{CC}.

The MAX823/MAX824/MAX825 come in 5-pin SOT23-5 packages screened for the extended-industrial temperature range (-40°C to +85°C). Prices (2,500 up, FOB USA) start at $1.20 for the MAX823/MAX824 or $1.15 for the MAX825.

(Circle 14)



NEW PRODUCTS

Tiny, 4-pin µP reset offers 26 thresholds and four reset-timeout delays

The MAX6315 SOT µP-reset IC asserts a reset signal when V_{CC} falls below the preset internal threshold, and maintains the reset for a fixed, internally programmed interval after V_{CC} rises back above the threshold. Factory-trimmed threshold voltages are available in 100mV increments from 2.5V to 5V. Part number suffix codes also designate one of four minimum timeout intervals (1ms, 20ms, 140ms, or 1120ms).

Small size, low supply current (6µA typical), and one-basic-function simplicity make the MAX6315 an excellent choice for supply-voltage monitoring in digital systems. By eliminating external components and adjustments, the device saves cost and improves reliability. Resets are guaranteed for V_{CC} above 1V. The MAX6315 is immune to short V_{CC} transients, and its simple open-drain $\overline{\text{RESET}}$ can pull up to voltages higher than V_{CC}. It includes a debounced manual-reset input ($\overline{\text{MR}}$).

MAX6315 devices come in 4-pin SOT143-4 packages configured for tape-and-reel assembly. All are screened for the commercial temperature range (0°C to +70°C). Prices start at $0.82 (10,000 up, FOB USA).

(Circle 15)

5V RS-232 transceivers are ESD protected to ±15kV

Devices in the 10-member MAX2XXE family of transceiver ICs are designed for RS-232 and V.28 communications in harsh environments. Typical applications include battery-powered or hand-held equipment such as notebook and palmtop computers. The transceiver models differ as shown in the table.

Each transmitter output and receiver input can withstand electrostatic discharge (ESD) to ±15kV without causing latchup in the IC. For RS-232 I/O pins, the ESD protection extends to ±15kV for the Human Body Model and IEC1000-4-2 air-gap-discharge model, and to ±8kV for the IEC1000-4-2 contact-discharge model.

When loaded in accordance with EIA/TIA-232E specifications, the transmitters and receivers of these devices meet all EIA/TIA-232E and CCIT V.28 specifications at data rates to 120kbps. Each IC is LapLink™ compatible, operates on 5V, and guarantees 3V/µs slew rates.

The MAX232E 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), or military (-55°C to +125°C) temperature range. The other nine transceivers come in 16-, 20-, 24, and 28-pin packages, screened for the commercial and extended-industrial ranges only. Starting prices for the newest members of this product family are as follows: $7.62 for the MAX205E and $3.79 for the MAX206E–MAX208E (1,000 up, FOB USA).

(Circle 16)

PART	NO. OF RS-232 DRIVERS	NO. OF RS-232 RECEIVERS	RECEIVERS ACTIVE IN SHUTDOWN	NO. OF EXTERNAL CAPACITORS	LOW-POWER SHUTDOWN	TTL THREE-STATE
MAX202E	2	2	0	4 (0.1µF)	No	No
MAX203E	2	2	0	None	No	No
MAX205E	5	5	0	None	Yes	Yes
MAX206E	4	3	0	4 (0.1µF)	Yes	Yes
MAX207E	5	3	0	4 (0.1µF)	No	No
MAX208E	4	4	0	4 (0.1µF)	No	No
MAX211E	4	5	0	4 (0.1µF)	Yes	Yes
MAX213E	4	5	2	4 (0.1µF)	Yes	Yes
MAX232E	2	2	0	4 (1µF)	No	No
MAX241E	4	5	0	4 (1µF)	Yes	Yes

LapLink is a trademark of Traveling Software.

PCMCIA/CardBus power-switching networks support two card slots

The MAX1600/MAX1603 and MAX1601/MAX1604 power-switching ICs support two PCMCIA or CardBus sockets—providing the control and low-resistance switching necessary (per PCMCIA specifications for 3V/5V switchover and rise/fall timing) to direct V_{CC} (3.3V or 5V) and V_{PP} (12V) to each socket. The package is a tiny 28-pin SSOP only 0.2" (5mm) wide. No external components are required.

Each device includes two 1A, ultra-low-resistance switches for sourcing 3.3V, and two 1A, 0.14Ω switches for sourcing 5V. Two 120mA, 1Ω switches source 12V to each socket. For the 3.3V switch, the MAX1600 and MAX1601—intended for CardBus applications—feature an extremely low $r_{DS(ON)}$ of 0.08Ω (max). In the MAX1603 and MAX1604, this switch measures 0.24Ω (max)—perfect for PCMCIA systems. All switches ensure enhanced reliability through thermal-overload protection, accurate current limiting, and undervoltage lockout. All switches operate with soft break-before-make action that lets you “hot swap” cards without causing an excessive inrush current.

Independent, internal charge pumps enable operation of the 3.3V switches when the 12V supply is disconnected or turned off to save power. Unlike switching ICs that feature separate shutdown-control inputs, these devices shut down automatically (lowering supply currents to 10µA max) when their control inputs are programmed to the high-Z or GND state.

The MAX1600 and MAX1603 digital interface is compatible with all popular PCMCIA digital controllers, including those from Cirrus Logic, Databook, Intel, and Vadem. MAX1601 and MAX1604 devices are compatible with the new, 2-wire serial System Management Bus (SMBus™), which provides complete power-status information while protecting the system from shorted or otherwise damaged cards.

MAX1600/MAX1603 and MAX1601/MAX1604 ICs come in 28-pin SSOP packages, screened for the extended-industrial temperature range (-40°C to +85°C). Prices for the MAX1600/MAX1601 start at $5.95; prices for the MAX1603/MAX1604 start at $5.25 (1,000 up, FOB USA).

(Circle 17)