MAXIM Engineering journal

Volume Twenty-Five

News Briefs

MAXIM REPORTS EARNINGS AND RECORD NEW PRODUCT INTRODUCTIONS FOR Q197

Maxim Integrated Products, Inc., reported net revenues of $101 million for the first quarter of fiscal 1997 ending September 30, 1996, compared to $96.4 million for the same period a year ago. Net income was $31.4 million for the current quarter, compared to net income of $22.6 million for the first quarter of fiscal 1996. Income per share was $0.45 per share for Q197, compared to $0.32 per share in Q196. Operating income was 45.7% of net revenues, compared to 36.1% for Q196.

During the quarter, the Company increased cash and short-term investments by $8.9 million after paying $10 million for capital expenditures and repurchasing $16.3 million of its common stock. Accounts receivable increased $1.3 million over Q496 levels. Inventory increased $4.1 million as a result of turns and forecast mismatches. Accounts payable declined $5.0 million during the quarter as a result of lower capital equipment spending.

Jack Gifford, Chairman, President and CEO commented on the quarter: “Our first quarter, while difficult from a revenue perspective, went well. The inventory correction that we predicted in 1995 did occur and now appears to be subsiding. First quarter gross margins remained excellent at 67.3% of sales, reflecting the high number of proprietary products in our product line. We have reduced lead times on 85% of our product lines to historical levels for analog products, which are normally longer than lead times for most digital products.

“Although Q1 manufacturing levels were slightly lower than those of Q4, our manufacturing productivity remained high. Overall operating expenses declined in Q1. Research and development spending continued to increase. During this period of uncertainty for the semiconductor industry, we have managed our resources well and have remained committed to investing in our future.

“We are pleased with the market acceptance of Maxim’s products introduced in FY95 and FY96. They are contributing materially to our current revenue base. Over 90% of our revenues today are from products invented by Maxim. Q1 was a record quarter for Maxim new product development, with 59 products announced. We are well on our way to achieving our goal of introducing 50% more new products than in FY1996.”

Maxim has been recognized by *Fortune* Magazine as one of America’s fastest growing companies. Maxim was ranked 42nd out of the top 100, with a revenue growth rate of more than 60% over the past year.

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.

ESD protection for I/O ports

*Electrostatic discharge (ESD) can threaten an electronic system when someone replaces a cable or even touches an I/O port. Discharges that accompany these routine events can disable the port by destroying one or more of its interface ICs (**Figure 1**). Such failures can also be costly—they raise the cost of warranty repairs while diminishing the product's perceived quality.*

ESD has another way of causing trouble. Manufacturers may soon be barred from selling to the European community unless their equipment meets minimum levels of ESD performance. These two factors, coupled with the increasing amount of electrical communication between computers and computer-related equipment, lend emphasis to the need for engineers to understand ESD.

A proper understanding of ESD requires an awareness not only of the voltage levels involved, but also of the voltage and current waveforms, IC-protection structures, test methods, and application circuits. These matters are discussed in the following sections.

ESD generation

Electrostatic charge appears when two dissimilar materials come together, transfer charge, and move apart, producing a voltage between them. Walking on a rug with leather soles, for example, can generate voltages as high as 25kV. The level of electrostatic voltage induced depends on the relative charge affinity between rug and shoe leather, the humidity, and other factors.

The triboelectric series (**Table 1**) describes this charge affinity between various materials. Charge transfer occurs when any two items on the list are brought into contact. Materials higher in the series acquire positive charge, and those lower in the series acquire negative charge.[1] The net charge and resulting electrostatic voltage is greater for items farther apart on the list.

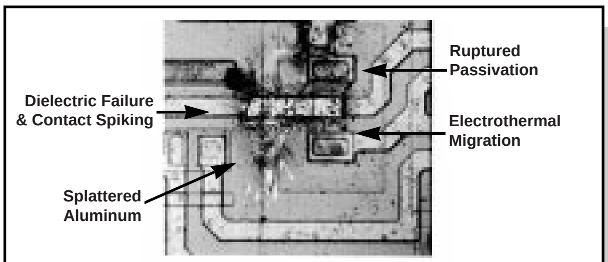


Figure 1. ICs with inadequate ESD protection are subject to catastrophic failure—including ruptured passivation, electrothermal migration, splattered aluminum, contact spiking, and dielectric failure.

[1]*Electrostatic Discharge, Protection Test Handbook, 2nd Edition,* KeyTek Instrument Corporation, 1986, p. 7.

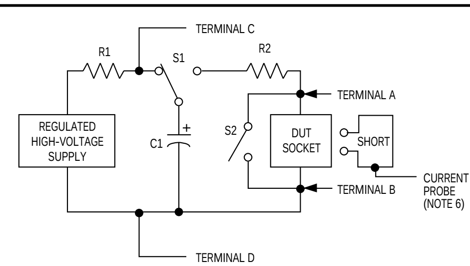
Table 1. Triboelectric series

AIR (MOST POS.)	FUR	SEALING WAX	ORLON
HANDS	LEAD	HARD RUBBER	SARAN
ASBESTOS	SILK	NICKEL, COPPER	POLYURETHANE
RABBIT FUR	ALUMINUM	BRASS, SILVER	POLYETHYLENE
GLASS	PAPER	GOLD, PLATINUM	PVC
MICA	COTTON	SULFUR	KEL-F (CTE)
HUMAN HAIR	STEEL	ACETATE, RAYON	SILICON
NYLON	WOOD	POLYESTER	TEFLON (MOST NEG.)
WOOL	AMBER	CELLULOID	

ESD test methods

Two methods are commonly used for testing the ESD susceptibility of integrated circuits. The oldest, MIL-STD-883 Method 3015.7, was developed as an aid in understanding the precautions necessary for packaging and handling ICs. This method tests each package pin against other groups of pins, and classifies the device according to the lowest voltage for which failure occurs.

The applied signal in this test is a current waveform derived from a circuit called the human body model (**Figure 2**), which simulates the capacitance and source impedance typical of a human body. (Circuit layout is critical, because the actual waveform delivered at the IC



COMPONENT	HUMAN BODY MODEL (MIL-STD 883, METHOD 3015.7)	MACHINE MODEL (IC-121, EIAJ)	IEC 1000-4-2
R1 (Ω)	1M–10M	1M	50M–100M
R2 (Ω)	1500 ± 1%	0Ω	330
C1 (pF)	100 ± 10%	200 ± 5%	150

Figure 2. Substituting different component values as shown yields discharge circuits known as the human body model, the machine model, and the IEC 1000-4-2 model (human holding a metallic object).

depends also on parasitic inductance and capacitance associated with the test connections and PC board.) The resulting current waveform represents the ESD that occurs when a person touches an object, such as an IC.

The other method, which differs from the above only in the values for R and C, was developed by the Electronic Industries Association of Japan (EIAJ). Called IC-121 and based on a circuit called the machine model (**Figure 2**), it applies a current waveform similar to that produced when an IC makes contact with its handling machinery. By mimicking the ESD events caused by charges that accumulate on moving parts, the waveform simulates static discharges seen during machine assembly.

The two methods are complementary, so you shouldn't choose one over the other. Because ESD can affect ICs during manufacturing, during PC board assembly, and after the end product is put into service, a test based on the human body model and the machine model together provides adequate assurance regarding the IC's tolerance for the rigors of manufacturing and insertion.

Some ICs, whose pins are exposed to the outside world through connectors, can encounter ESD even when mounted on a PC board within an enclosure. ESD exposure is less likely for the other pins, which are connected to circuitry on the board. For this class of IC, a test method such as Method 3015.7 (which tests pin combinations) does not provide an adequate representation of ESD susceptibility for the input/output (I/O) pins.

Both offer ratings according to the lowest-voltage failure on *any* pin—an approach that may not do justice to the higher levels of internal ESD protection required by the I/O pins (and provided by some manufacturers). A device might have I/O pins that withstand ±15kV, for example, and non-I/O pins that fail at ±2kV. With the above methods, the device's ESD rating would be less than ±2kV. Fortunately, however, better test methods are now available for rating the I/O pins.

New ESD tests for I/O ports

An I/O port allows communication with other pieces of equipment. I/O ports for ICs comprise logical groups of pins that give access to equipment external to the system that contains the IC. These pins are subject to static discharge and other abuse as operators connect and disconnect cables from the system. For the I/O pins of an RS-232 or RS-485 interface IC, an ideal test method for ESD susceptibility should:

- Test the I/O pins only in ways that simulate exposure to ESD events in actual equipment.
- Apply test waveforms that model electrostatic discharges produced by the human body. Different circuit models specify different values of amplitude, rise/fall time, and transferred power.
- Test the IC with and without power applied.
- Define IC failures to include latchup (a momentary loss of operation), as well as catastrophic or parametric failure. Latchup is considered a failure mechanism because if left undetected, it can lead to reliability problems and system malfunctions.

Two methods—both compliant with the requirements listed—have seen increasing use by equipment manufacturers in testing the ESD susceptibility of I/O ports. The first is a modification of Method 3015.7, MIL-STD-883. It makes use of the same circuit model and waveform as the original method, but applies ESD pulses only to the I/O pins of a device. Its intent is to simulate the fault currents seen by an IC installed on a board and operating in the target system. The waveform (**Figure 3**) is generated by the test circuit of Figure 2 using the same component values as originally specified in Method 3015.7.

Like the original Method 3015.7, the modified method defines only an ESD waveform and the criteria for failure: after exposure to the waveform, a failed IC must either exhibit latchup or fail one or more data sheet specifications. The modified method stipulates no particular operating mode for the IC during test, but Maxim recommends that all possible modes be exercised: power on/off, transmitter outputs high/low, standby/normal operation, etc.

Similarly, the modified method 3015.7 does not compel products to withstand particular levels of ESD; it only defines classes of protection. New transceivers from Maxim, however, generally provide protection levels to ±15kV (**Tables 2** and **3**). This level allows some users to eliminate costly TransZorbs™ and other external protection circuitry.

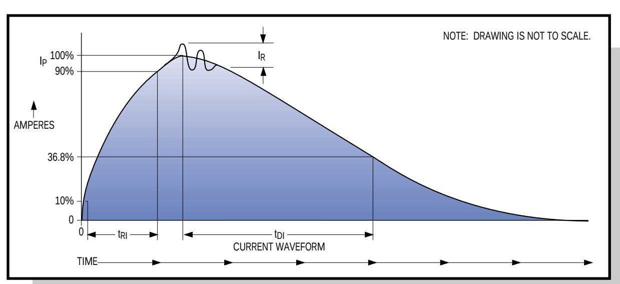


Figure 3. This ESD waveform's parameters (rise time, peak current, ringing, and decay time) are specified in MIL-STD-883 method 3015.7.

TransZorb is a trademark of General Semiconductor Industries, Inc.

Table 2. RS-232 interface ICs with high-level ESD protection

PRODUCT	Rx/Tx	ESD LEVELS			CAPACITORS (µF)	DATA RATE (kbps)	ACTIVE Rx IN SHDN	SHDN I_{CC} (µA)
		HUMAN BODY MODEL	IEC 1000-4-2					
			CONTACT	AIR				
MAX1406	3/3	±15kV	±8kV	±15kV	None	230	0	N/A
MAX1488E	4/0	±15kV	±8kV	±15kV	None	120	0	N/A
MAX1489E	0/4	±15kV	±8kV	±15kV	None	120	0	N/A
MAX202E	2/2	±15kV	±8kV	±15kV	0.1	120	0	N/A
MAX203E	2/2	±15kV	±8kV	±15kV	None	120	0	N/A
MAX205E	5/5	±15kV	±8kV	±15kV	None	120	0	1
MAX206E	4/3	±15kV	±8kV	±15kV	0.1	120	0	1
MAX207E	5/3	±15kV	±8kV	±15kV	0.1	120	0	N/A
MAX208E	4/4	±15kV	±8kV	±15kV	0.1	120	0	N/A
MAX211E	4/5	±15kV	±8kV	±15kV	0.1	120	0	1
MAX213E	4/5	±15kV	±8kV	±15kV	0.1	120	2	15
MAX232E	2/2	±15kV	±8kV	±15kV	1.0	120	0	N/A
MAX241E	4/5	±15kV	±8kV	±15kV	1.0	120	0	1
MAX3185	5/3	±15kV	±8kV	±15kV	None	230	0	N/A
MAX3186	5/3	±15kV	±8kV	±15kV	None	230	0	N/A

Table 3. RS-485/RS-422 interface ICs with high-level ESD protection

PRODUCT	Rx/Tx	ESD VOLTAGE (HUMAN BODY MODEL)	DATA RATE (kbps)	SHDN I_{CC} (µA)	SUPPLY CURRENT (µA)	MAXIMUM No. TRANSCEIVERS ON BUS
MAX1487E	1/1	±15kV	2500	300	250	128
MAX481E	1/1	±15kV	2500	1	500	32
MAX483E	1/1	±15kV	200	1	350	32
MAX485E	1/1	±15kV	2500	300	500	32
MAX487E	1/1	±15kV	250	1	250	128
MAX488E	1/1	±15kV	250	N/A	350	32
MAX489E	1/1	±15kV	250	1	350	32
MAX490E	1/1	±15kV	2500	N/A	500	32
MAX491E	1/1	±15kV	2500	300	500	32

IEC 1000-4-2 model

The second, more stringent method for testing ICs that include I/O pins is IEC 1000-4-2. This equipment-level test was developed by the International Electrotechnical Commission. Originally intended as an acceptance condition for equipment to be sold in Europe, it is rapidly gaining acceptance as a standard ESD criterion in the United States and Japan as well. Though not originally intended as an IC specification, it now does extra duty as an ESD test for ICs. Like the modification to 3015.7, it tests only the I/O pins.

The model for IEC 1000-4-2 is again the circuit of Figure 2, but with different component values. The resistance R2 (330Ω) represents a human holding a screwdriver or other metallic object, and C1 (150pF) represents another estimate of human-body capacitance. This circuit produces a current waveform (**Figure 4**) with a rise time steeper than that produced by Method 3015.7.

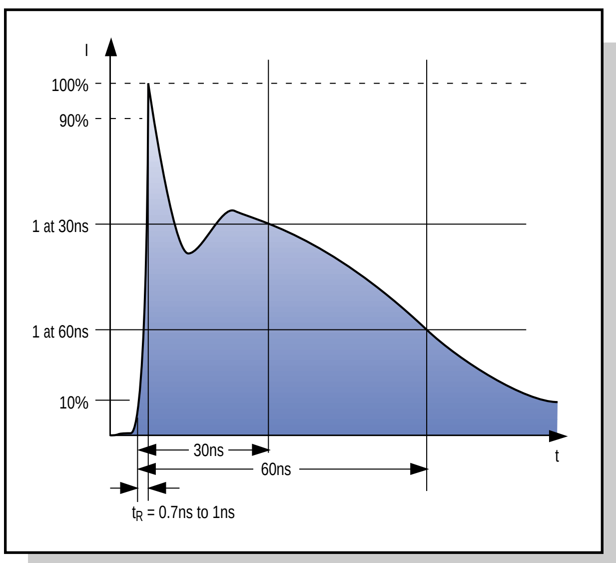


Figure 4. Parameters for this ESD waveform (rise time, peak current, amplitude at 30ns, and amplitude at 60ns) are specified by IEC 1000-4-2.

Table 4. IEC 1000-4-2 compliance levels

IEC 1000-4-2 COMPLIANCE LEVEL	MAX TEST VOLTAGE, CONTACT DISCHARGE (kV)	MAX TEST VOLTAGE, AIR DISCHARGE (kV)
1	2	2
2	4	4
3	6	8
4	8	15

Table 5. ESD current vs. model and applied voltage

APPLIED VOLTAGE (kV)	PEAK CURRENT (A)	
	IEC 1000-4-2	HUMAN BODY MODEL
2	7.50	1.33
4	15.0	2.67
6	22.5	4.00
8	30.0	5.33
10	37.5	6.67

IEC 1000-4-2 specifies ESD testing both by contact discharge and by air discharge. ESD events caused by actual contact are more repeatable but less realistic, and air discharge is more realistic but subject to wide differences in waveform shape—according to variations in temperature, humidity, barometric pressure, distance between IC and electrode, and rate of approach to the IC pin. (This change of shape can have a significant effect on the measured level of tolerance for ESD.)

IEC 1000-4-2 defines four levels of compliance (**Table 4**) according to the lowest maximum voltage withstood by the I/O pins. The table defines these levels both for contact discharge and for air discharge.

Contact or air discharge?

Testing ICs for ESD ruggedness per IEC 1000-4-2 requires the use of an ESD "gun," which allows testing with either contact discharge or air discharge. Contact discharge requires physical contact between the gun and the I/O pin before test voltage is applied by a switch internal to the gun. Air discharge requires the gun to be charged with test voltage before it approaches the I/O pin (from the perpendicular, and as quickly as possible). The second technique produces a spark at some critical distance from the test unit.

ESD produced by air discharge resembles actual ESD events. But, like actual ESD, the air-discharge variety is not readily duplicated. It depends on many variables that are not easily controlled. Thus, attesting to the general importance of repeatability in testing, IEC 1000-4-2 recommends contact discharge, and the modified 3015.7 method requires contact discharge only. In either case, the test procedure calls for at least 10 discharges at each test level.

The main difference between the two ESD standards just discussed—the modified 3015.7 method and the air- or contact-discharge version of IEC 1000-4-2—is in the peak currents they produce in the device under test. Different component values can cause these peak currents to differ by a factor greater than five (**Table 5**). Because peak currents produce the unwanted power that an IC must dissipate, IEC 1000-4-2 is usually the more demanding test method for ESD.

High current can damage an IC in various ways:

- Excessive local heating
- Melted silicon
- Spiked junctions, caused by a short that dissolves aluminum in the silicon (**Figure 5**)
- Damaged metal lines
- Gate-oxide failure due to excessive voltage
- Transistor damage due to electrothermal migration (**Figure 6**)

Protection methods

To protect against ESD, a designer can either add the protection externally or choose ICs with high levels of

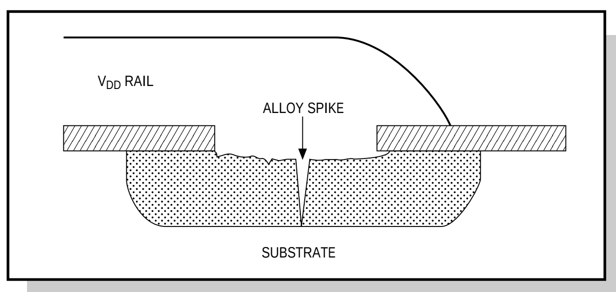


Figure 5. High-ESD current in an IC can "spike" a junction by partially dissolving the aluminum contact in silicon, causing a permanent short to the layer below.

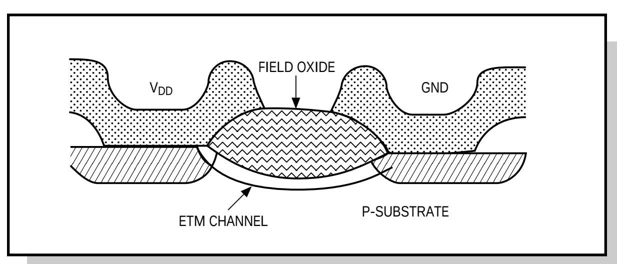


Figure 6. Electrothermal migration (ETM) in an IC can set the stage for damage in the presence of an ESD event. The resulting high current and high voltage can cause a short circuit or low-impedance path between the terminals of a transistor.

protection built in. Protection circuitry includes metal-oxide varistors and silicon avalanche suppressors such as the TransZorb. These devices are effective but expensive (silicon avalanche protectors cost as much as $0.30 per line). External ESD protection also consumes valuable board area and adds capacitance to the I/O line.

To overcome these limitations, manufacturers have repeatedly raised the level of ESD protection in their ICs. Maxim, for example, now provides ±15kV protection for RS-232 ICs, whether tested in accordance with IEC 1000-4-2 or the human body model.

Maxim's approach to ESD protection

An ESD current waveform is characterized by extremely fast rise times, so its progress through an IC is strongly affected by the circuit's distributed parasitic impedances. Therefore, attention to the external layout will ensure maximum performance by the IC's internal protection networks. Maxim recommends the following practice with respect to its interface ICs:

- Follow standard analog-layout techniques, placing all bypass and charge-pump capacitors as close to the IC as possible.
- Include a ground plane on the PC board.
- Minimize trace inductance and capacitance.
- Place the IC as close to the I/O port as possible.

To characterize an RS-232 transceiver or other interface IC for reliability in the presence of ESD, Maxim recommends use of the modified 3015.7 method and the IEC 1000-4-2 model as well, following a similar procedure in each case: step through the specified ESD range in increments of 200V, and at each level, zap the device 10 times with each polarity of voltage, approximately once per second.

Because the intent of these tests is to assess the ESD performance of an IC installed in end equipment, the test setup should cause ESD currents to flow along the same paths as they would in that equipment. Zaps should be administered with respect to the IC's ground pin. (As stated in IEC 1000-4-2, circuit ground usually connects to the equipment chassis.) Maxim recommends the model NSG 435 ESD gun by Schaffner Instruments (Switzerland) for the IEC 1000-4-2 method, and the model 4000 ESD tester by IMCS (a division of Oryx Technology Corporation, Fremont, CA) for the modified 3015.7 method.

You should check for failures by monitoring three parameters after each zap. First, the supply current should remain constant (an increase may indicate latchup or internal damage). Second, the transmitter output voltage should continue to meet the ±5V minimum levels for RS-232 transmission. Third, the receiver input resistance should remain between 3kΩ and 7kΩ (ideally, it should remain at a constant level in that range). Be sure to zap and test the device in all its modes: normal operation, shutdown, power off, transmitter high/low, etc.

Guidelines for selecting ICs with high resistance to ESD

Here are some questions to resolve before choosing an IC (particularly an RS-232 transceiver) that must withstand high levels of ESD:

- *What level of ESD voltage is the IC guaranteed to withstand, and by what test method was that level established?* Different test methods yield different voltage ratings. Currently, the recommended approach includes both IEC 1000-4-2 and the modified 3015.7 method.
- *Will ESD cause latchup in the IC?* Latchup is a critical problem. The IC might stop functioning if ESD causes latchup in the circuit. The resulting supply current (as much as 1A) may destroy the IC.
- *Does the IC's ESD protection affect normal operation?* Normal operation can cause latchup in the internal protection structure if it is poorly designed.
- *Must you observe special precautions when applying the IC?* Bipolar ICs might require expensive, low-ESR capacitors or a ground plane with low ac impedance. It's best to learn of these requirements at the outset.
- *What is the IC's maximum specified slew rate?* An IC susceptible to latchup because of its ESD-protection structure might specify an unusually low maximum slew rate to avoid triggering the latchup condition.
- *How does the IC respond to an ESD test that covers the entire range for which voltage protection is guaranteed?* Trigger mechanisms for an ESD-protection structure can kick in at different voltage ranges, leaving open "windows" with no protection. (Such a device might survive ±10kV but fail at ±5kV, for instance.) Maxim recommends that an ESD test cover the entire range in 200V increments.

DESIGN SHOWCASE

Add-on circuit preconditions battery before charging

If left undisturbed, the microcrystalline cadmium in a NiCd battery's anode slowly changes. Tiny crystals in the metal coalesce into larger ones, producing an increase in battery resistance that lowers the terminal voltage. This effect can become noticeable when repeated partial discharges leave the lowest layers of cadmium unaffected. On the other hand, an occasional complete discharge converts the entire cadmium anode to cadmium hydroxide, which allows the anode to revert (during recharge) to the desired microcrystalline state.

Thus, a full discharge eliminates the reduction in terminal voltage sometimes (erroneously) called the memory effect. The circuit of **Figure 1** "preconditions" a battery by fully discharging it (to approximately 1V per cell) before initiating a charge cycle. The preconditioner is within the dashed line (it also operates with other battery-charge ICs or as a stand-alone circuit), and the remaining circuitry is a conventional NiCd battery charger based on IC1.

Until preconditioning is initiated by a momentary depression of S1, the charger circuit operates normally: the 5-cell battery has a capacity (C) of 500mAhr, and R4 configures IC1 for a fast-charge rate of C/2 (250mAhr for two hours). Following a fast charge, the circuit delivers a trickle charge of about 33mA.

Depressing S1 turns on Q3, which initiates battery discharge by turning on the preconditioning load Q2. Current through R9 produces a control voltage for the shunt regulator IC2. For values above 2.5V (battery above 5V), IC2 remains on and sinks current, holding Q3 on when S1 is released. When the battery voltage discharges to 5V (1V per cell), IC2 turns off and ends the preconditioning cycle. The circuit requires about 10 hours to precondition (fully discharge) a fully charged battery. It then recharges the battery automatically, in about 2 hours.

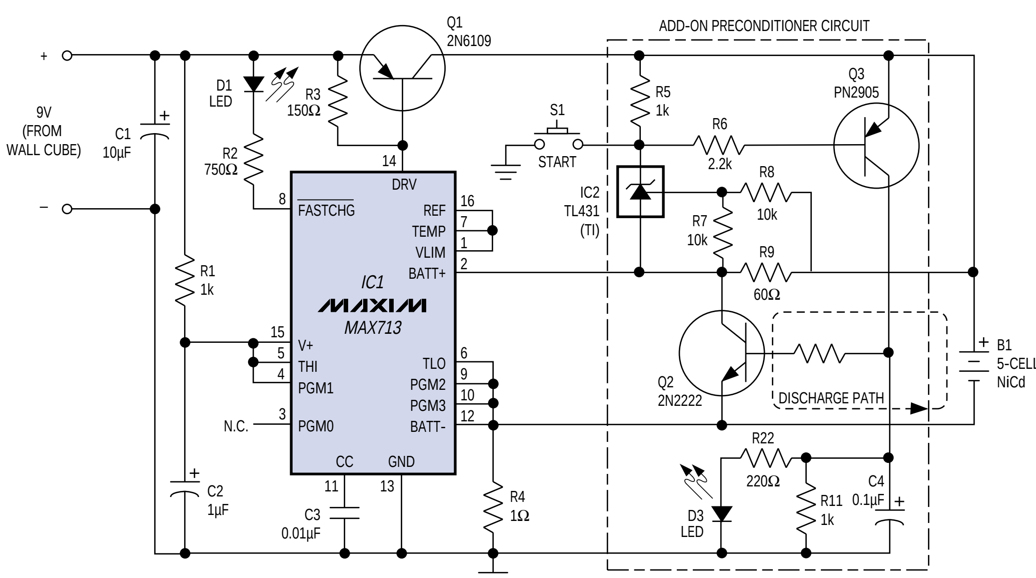


Figure 1. This add-on preconditioner circuit for NiCd battery chargers eliminates the so-called "memory effect" by fully discharging a battery before recharging it.

The IC normally enters fast-charge mode when you apply power or install a battery, but (as a safety measure) it does not begin or continue the fast charge if the battery voltage is below 0.5V per cell. Note that fast charging is disabled during the preconditioning cycle, because the battery-sense terminals (pins 2 and 12) are clamped by the $V_{CE(SAT)}$ of Q2. IC1 maintains a trickle charge during the preconditioning cycle, so you must account for the 33mA trickle current when calculating the value for R9.

As shown, the 60Ω value for R9 draws 83mA at 5V. Nearly 33mA of that is trickle current, so at 5V, only 50mA comes from the battery. (As mentioned, this 50mA discharges a fully charged 500mAhr battery in about 10 hours.) Thus, when modifying the circuit for other cell counts, preconditioning times, or trickle rates, you must account for trickle-charge current in the calculation of R9.

Shunt regulator IC2 includes a 2.5V bandgap reference that limits the circuit to applications of three cells or more. For lower cell counts (with some sacrifice of accuracy and temperature performance), you can substitute an npn transistor for IC2 and set the R8/R7 divider to produce one base-emitter drop.

A similar idea appeared in the 1/22/96 issue of Electronic Design.

DESIGN SHOWCASE

Current-sense IC prevents overcurrent damage

CMOS interface ICs serve as gateways to the wired connections between electronic systems. If those external connections are mishandled, the interface ICs can be damaged by a short to ground or by applied voltage that causes them to latch up. For short periods, however, short circuits and latchups are generally safe. (Latchups can be triggered by pulling the gate terminal below ground or above V_{CC}.)

In **Figure 1**, IC1 monitors supply current to the interface circuitry (I_S), and quickly removes current and voltage from the interface if I_S exceeds a programmed threshold. During normal operation, IC1's OUT current (1/2000 of I_S) flows through R3 to a logic-low level—the output of IC2's lower NOR gate.

During a fault condition (defined as $I_S \geq 50mA$ by the R3 value shown), the rising OUT current develops 1.2V across R3, causing the set/reset flip-flop (IC2) to produce a low-to-high transition at pin 4. This action shuts down the interface: Q1 blocks the interface supply current, and Q2 "crowbars" the interface supply to prevent overvoltage. Without the crowbar, an external overvoltage fault could act through parasitic diodes in Q1 and the interface IC to lift the main supply voltage. (A positive supply voltage tends to rise if the supply is asked to sink current.)

R3's connection to the flip-flop output instead of ground (as in most MAX471 circuits) introduces hysteresis in the control of Q1 and Q2. Otherwise, oscillation can result: turning off Q1 removes fault current, and the circuit tries to resume normal operation. R2 and D1 provide a break-before-make action that prevents Q1 and Q2 from shorting the supply rails. Once tripped, the circuit remains latched until manually reset with S1.

An LED with current-limiting resistor can be connected as a fault indicator between the main supply and the Q1-Q2 node. Other add-on features include a capacitor across R3 to provide a "slow-blow effect," and the use of a precision reference and comparator (such as the MAX931) for greater accuracy in sensing the R3 voltage.

A similar idea appeared in the 4/25/96 issue of EDN.

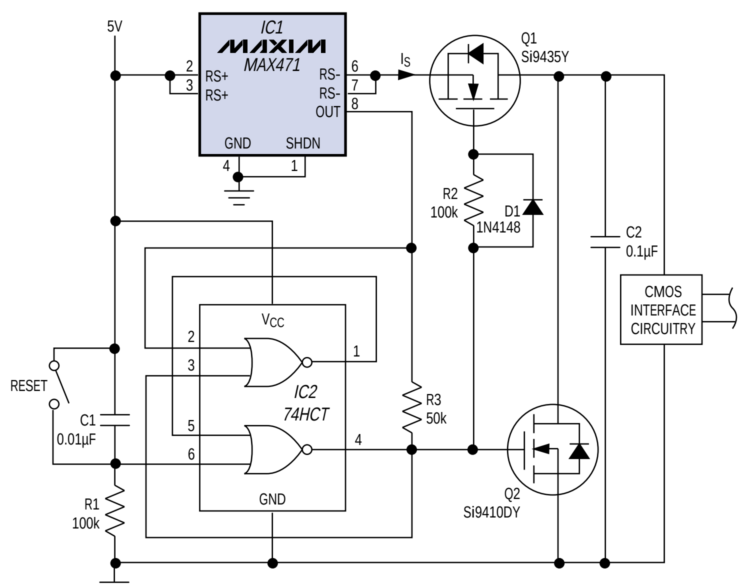


Figure 1. By blocking the supply current and crowbarring the supply voltage, this circuit protects the interface circuitry against faults involving the external lines.

Power-boost circuit powers cellular handset

Powering the RF power amplifier in a European GSM or DCS1800 cellular-telephone handset presents some challenges. Circuitry other than the RF PA operates on 3V, but the PA usually needs 5V minimum to produce the 1W-to-2W peak antenna power required.

Also, the difficulty in designing the necessary boost regulator usually dictates a bulky 5-cell battery in place of the preferred 3-cell NiCd or NiMH battery. The PA connects to the 5-cell battery directly, and the 3V components connect either to a step-down regulator or to a high-dissipation linear regulator (the inefficient but technically simpler approach).

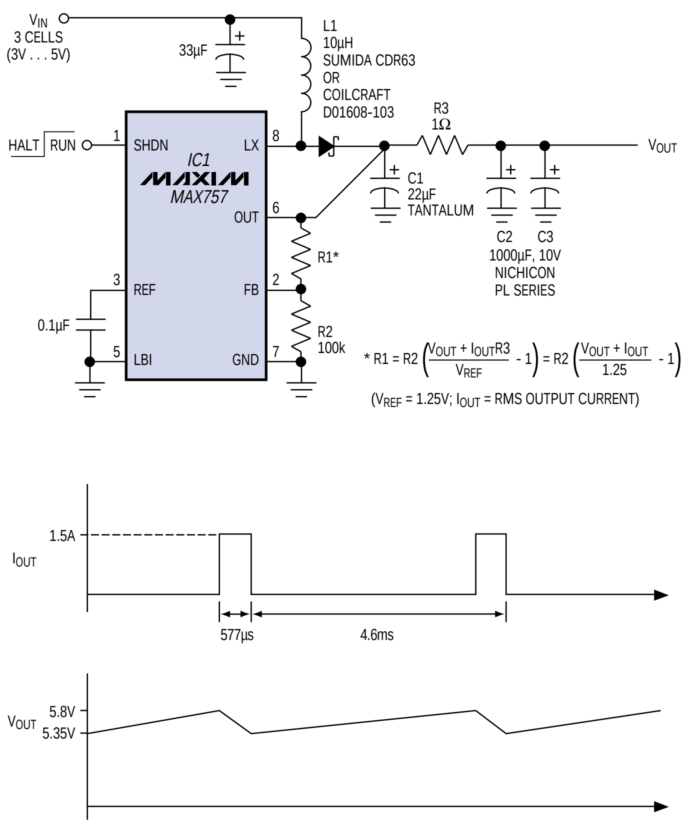


Figure 1. This boost converter's large output capacitor (C2-C3) enables it to supply 1.5A peak currents to the power amplifier in a GSM or DCS1800 cellular handset.

Fortunately, the handset's TDMA (time-division multiple access) operation, which produces 577µs transmissions every 4.6ms and draws as much as 1.5A per burst, requires a much lower *average* current. The **Figure 1** alternative, therefore, combines a 3-cell battery with a relatively small, low-cost boost converter. A large reservoir capacitor of 2000µF (C2 and C3) stores the power needed during a transmission burst, and the boost converter delivers an average current of approximately 180mA for charging the capacitor. The capacitor supplies 1.5A peak loads at the 5.8V output with only 450mV of droop (Figure 1).

Though physically large, the output capacitor is smaller and cheaper than the two extra cells required to form a 5-cell pack. IC1 provides other advantages: its high switching frequency (500kHz) enables use of a small and inexpensive inductor (L1), and its internal switching MOSFETs minimize the number of external components. The 1Ω resistor (R1) isolates the regulator output from peak-load requirements.

The circuit shown produces 5.8V (adjustable) from inputs of 1.8V to 6V. The peak output current for this configuration is 1.5A. Power-up time is 20ms, and the minimum input voltage for startup is 2V. The quiescent supply current (60µA) drops to 20µA during shutdown. Power-conversion efficiency is 81% for 300mA peak currents, 80% for 800mA peaks, and 79% for the maximum 1.5A peaks.

This circuit produces the switching noise expected in a dc-dc converter. If necessary, you can eliminate the noise during critical periods of the TDMA frame by pulling $\overline{SHDN}$ low, temporarily halting the converter.

DESIGN SHOWCASE

LAN power supply generates isolated 9V

This low-power, isolated 9V supply for LAN applications (**Figure 1**) delivers more than 250mA (more than 2W of output power). For inputs of 10.8V to 13.2V combined with load currents of 1mA to 200mA, the nominal 8.78V output provides about ±1% of line and load regulation.

IC1's transformer-driver outputs (D1 and D2) normally drive each end of the primary directly—a configuration in which each driver terminal (on turnoff) sees a flyback voltage equal to twice the center-tap voltage. The flyback in this application (24V) exceeds the maximum rating for IC1 (12V), so two MOSFETs in cascode have been introduced to stand off the extra voltage while maintaining IC1's high switching frequency (typically 650kHz).

Surface-mount transformer T1 has a split primary, a single secondary, and a turns ratio of 1:1:1. This single-secondary approach requires fullwave-bridge rectification and a two-diode-drop reduction in output voltage, but the alternative—a split secondary, halfwave rectification at each end, and a one-diode drop in output voltage—adds an extra winding that increases the transformer cost.

The single-winding primary inductance should be high (about 250µH) to limit stored-energy losses. (The ideal is an infinite inductance, which would enable pure transformer action with no energy loss during the switching cycles.) The diode bridge is followed by a low-dropout linear regulator (IC3), which provides the 9V regulated output for inputs of 5V and 12V ±10%.

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

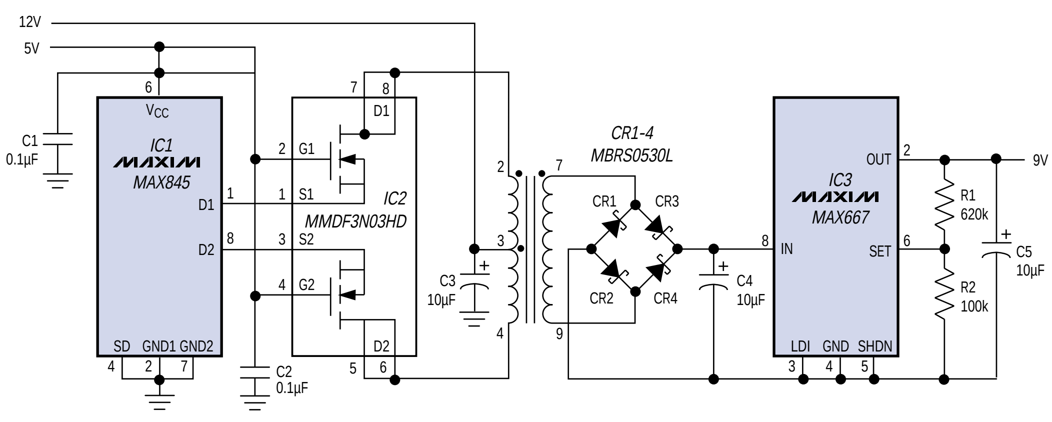


Figure 1. This regulator circuit provides an isolated 9V at 250mA for local area network (LAN) applications.

DESIGN SHOWCASE

Variable, linear current source operates on 5V

The current regulator of **Figure 1** features a low-dropout voltage regulator (IC2) whose voltage feedback is derived from the input current by a current-sense amplifier (IC1). This connection allows the regulator IC to oppose any change in output current. When powered from 5V, the current source has a compliance range of 0V to 4.7V.

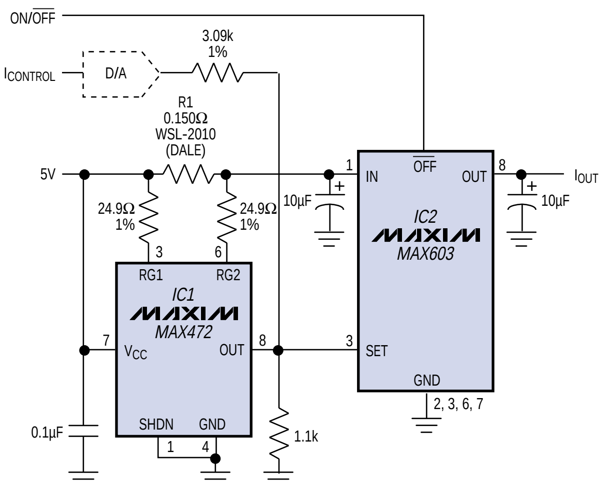


Figure 1. IC1 converts R1 current to a proportional output voltage, enabling the voltage regulator (IC2) to produce a regulated output current.

To set a specific, regulated I_{OUT} level between 0mA and 250mA, apply 0V to 5V at $I_{CONTROL}$: 0V sets I_{OUT} = 250mA, and 5V sets I_{OUT} = 0mA. Alternatively, a D/A converter can provide digital control of I_{OUT}. For 12-bit resolution (60µA per LSB), use a parallel-input MAX530 or a serial-input MAX531. For 10-bit resolution (250µA per LSB), use a parallel-input MAX503 or a serial-input MAX504.

You should take care not to exceed the package power-dissipation rating for IC2. At room temperature the rating is 1.8W, so a reasonable limit (with safety factor) is 1.5W. The internal dissipation is simply the programmed current times the voltage difference between the input (pin 1) and output (pin 8). Under worst-case conditions, therefore, (I_{OUT} = 250mA, output grounded, and a dissipation limit of 1.5W), the input voltage can be as high as 6V (i.e., 6V x 250mA = 1.5W).

A similar idea appeared in the 12/95 issue of Electronic Engineering (UK).

NEW PRODUCTS

14-bit, V_{OUT} serial DAC operates on 5V

The MAX545 D/A converter has 14-bit resolution, a 3-wire serial interface, a voltage output, and full 14-bit performance without adjustments. It operates on a single 5V supply and consumes only 1.5mW. Settling time (to within ½LSB of full scale) is approximately 1µs.

The MAX545 is guaranteed 14-bit monotonic, and meets ±1LSB integral and differential nonlinearity over the extended operating temperature range. For bipolar operation, it has internal scaling resistors that work with an external precision op amp such as the MAX400. The resistors are trimmed to provide $\pm V_{REF}$ bipolar voltage swings at the op amp's output.

Digital data is transmitted through a 3-wire serial interface that is compatible with SPI™/QSPI™, and Microwire™ synchronous-serial standards. These digital inputs can interface directly with a microcontroller or an optocoupler-driver circuit. An internal power-on reset circuit clears the DAC output to 0V (unipolar mode) when power is first applied, to prevent unwanted output voltages at power-up.

The MAX545 is available in 14-pin plastic DIP and SO packages, in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $7.90 (1000 up, FOB USA).

2.7V/5V, quad, 8-bit DACs have SO-8 footprints

The MAX533/MAX534 are serial-input, voltage-output, quad, 8-bit D/A converters. They come in tiny QSOP-16 packages that have the same board area as an SO-8. The MAX533 operates from a 2.7V to 3.6V single supply, and the MAX534 operates from 4.5V to 5.5V. Supply current for each device is approximately 200µA per DAC. In shutdown mode, the supply currents drop to 1µA (MAX533) and 2.5µA (MAX534). The reference input range includes ground and the positive rail, and the four output buffer amplifiers swing rail to rail.

Each IC includes a 3-wire, 10MHz serial interface compatible with SPI™, QSPI™, and Microwire™ synchronous-serial standards, and each includes an input shift register that receives 12-bit words consisting of four control bits and eight data bits. Each DAC is double buffered, enabling a single software command to update the DAC outputs independently or simultaneously. In addition, the asynchronous control pins $\overline{\text{CLR}}$ and $\overline{\text{LDAC}}$ allow external control signals to clear or update the DAC outputs simultaneously. A buffered data output (D_{OUT}) allows daisy-chaining of multiple MAX533/MAX534s, and a software-programmable logic output (UPO) provides control for external devices.

The MAX533/MAX534 are available in 16-pin DIP and QSOP packages, in versions specified for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), or military (-55°C to +125°C) temperature range. Prices start at $2.80 (1000 up, FOB USA).

Low-power, 8-bit DAC comes in 8-pin µMAX package

The MAX550B 8-bit D/A converter operates from a 2.5V to 5.5V single supply, and draws only 75µA of operating current (including external reference current). This low-power, voltage-output device comes in an ultra-small, 8-pin µMAX package that is 50% smaller than an 8-pin SO. TUE is guaranteed at ±1LSB over temperature.

Operating at clock rates to 10MHz, the 3-wire serial interface is compatible with SPI/QSPI and Microwire synchronous-serial standards. An internal power-on reset initializes the DAC by setting all internal registers to zero. In 1µA shutdown mode, the reference input exhibits high impedance and the DAC output goes to zero.

The MAX550B is available in 8-pin DIP and µMAX packages, in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $1.45 (1000 up, FOB USA).

Quad, serial, 12-bit V_{OUT} DAC offers lowest power and smallest size

The MAX525 is a monolithic, quad, 12-bit D/A converter. It combines a dual bank of input registers with four 12-bit DACs, four precision output amplifiers, control logic, and a serial interface. Package options include the space-saving 20-pin SSOP.

The MAX525 operates on just 6mW (the next-lowest power for comparable devices is 37mW) and occupies only 0.09 in^2 of board area (the next-smallest package is 0.173 in^2). Accessible feedback connections enable a force-and-sense capability (remote sensing) that enables each output amplifier to drive a wide range of resistive loads. Each amplifier provides rail-to-rail output swings.

Other features include a low-power shutdown mode that lowers the normal 0.9mA quiescent current to 20µA, and an internal power-on reset that guarantees all outputs to be 0V when power is applied. Also included is a general-purpose logic output that is user-programmable for the serial control of external devices.

Each DAC input is double buffered by an input register and a DAC register. A 16-bit serial word for each DAC (two address bits, two control bits, and 12 data bits) is loaded via a 3-wire interface that is compatible with the SPI™/QSPI™ and Microwire™ synchronous-serial standards. The DAC registers can be updated independently or simultaneously, and all logic inputs are TTL/CMOS compatible.

The MAX525 comes in a 20-pin DIP or SSOP, in versions specified for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), or military (-55°C to +125°C) temperature range. Prices start at $11.95 (1000 up, FOB USA).

SPI and QSPI are registered trademarks of Motorola, Inc.

Microwire is a registered trademark of National Semiconductor Corp.

NEW PRODUCTS

Low-power, 3V/5V, 4-channel, 8-bit ADCs feature 1µA power-down

The MAX113/MAX114 A/D converters are low-power, 8-bit, 4-channel devices designed for data-processing and data-acquisition applications. Each includes an internal track/hold and a parallel-data interface that is compatible with many microprocessors and microcontrollers.

The MAX113 operates on 3V, converts in 1.8µs, and offers sample rates to 400ksps. The MAX114 operates on 5V, converts in 660ns, and offers sample rates to 1Msps. Both offer a 1µA power-down mode that is ideal for battery-powered applications. Their fast turn-on times (the MAX114 exits from power-down in only 200ns and the MAX113 in 900ns) enable them to minimize power consumption by shutting down between conversions. For instance, at 1ksps, the MAX113/MAX114's power consumption is only 12µW and 40µW, respectively.

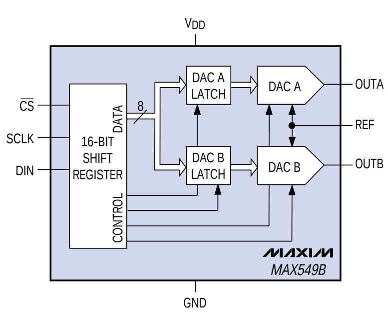
The MAX113/MAX114 come in 24-pin DIP and SSOP packages, in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $3.30 (1000 up, FOB USA).

Dual, 8-bit, 1µA DAC comes in 8-pin µMAX package

The MAX549B is a dual, low-power, 8-bit D/A converter that features two voltage-output DACs in an ultra-small, 8-pin µMAX package (50% smaller than an 8-pin SO). Operating from a 2.5V to 5.5V single supply, it draws less than 1µA (excluding the reference current). TUE is guaranteed at ±1LSB over temperature.

The 3-wire serial interface operates at clock rates to 10MHz and is compatible with SPI™/QSPI™ and Microwire™ synchronous-serial standards. In shutdown mode, the reference input exhibits high impedance and the DAC outputs go to zero. The internal power-on reset initializes both DACs by setting all internal registers to zero.

The MAX549B is available in 8-pin DIP and µMAX packages, in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $1.65 (1000 up, FOB USA).



Low-power, 16-bit V_{OUT} DAC operates on 5V

The MAX542 16-bit D/A converter is designed for industrial and instrumentation applications that require high resolution and low power. Operating from a single 5V supply, it features 16-bit performance yet dissipates only 1.5mW. It provides 38µV resolution with an external 2.5V reference, is guaranteed monotonic, and exhibits ±1LSB maximum integral and differential nonlinearity over the extended temperature range.

The MAX542 provides a unipolar voltage output. Bipolar operation is made possible by an external precision op amp and the internal scaling resistors, which are trimmed to provide bipolar swings of $\pm V_{REF}$ at the op-amp output. The 3-wire serial-data interface is compatible with SPI™ and Microwire™ synchronous communications standards, and allows a direct connection to microcontroller and optocoupler-driver circuits. When power is first applied, the internal power-on reset clears the DAC output to 0V (unipolar mode).

The MAX542 is available in 14-pin DIP and SO packages, in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $9.95 (1000 up, FOB USA).

SPI and QSPI are registered trademarks of Motorola, Inc.

Microwire is a registered trademark of National Semiconductor Corp.

Low-cost, dual linear regulator has only 200mV dropout at 250mA I_{OUT}

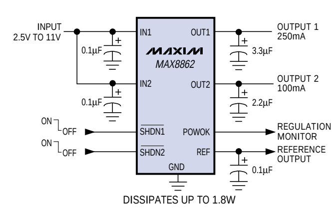
The MAX8862 dual linear regulator is ideal for portable, battery-powered applications. It includes two separate circuits with independent shutdown and supply-voltage inputs, and each input range is 2.5V to 11.5V. The P-channel MOSFET pass transistors maintain low quiescent current in the IC, particularly during dropout, when a pnp-bipolar pass transistor saturates and draws excessive base current.

MAX8862 regulators make ideal power supplies for the radio and microcontroller in a PCS or digital cordless telephone. The main regulator delivers 250mA for digital circuitry, and is optimized for transient and dynamic response; the secondary regulator delivers 100mA for analog circuitry and exhibits a low level of wideband output noise. At 250mA load currents, dropout voltage is a low 200mV.

This regulator features Dual Mode™ (fixed/adjustable) operation: V_{OUT} is either preset to 4.95V (L), 3.175V (T), or 2.85V (R), depending on the part number's suffix letter; or adjusted by the user, with external resistors, between 2V and 11V. It maintains a low supply current, even in dropout: 250µA in operation, and <1µA in shutdown. It also features power-good indicator, short-circuit and reversed-battery protection, and thermal-overload protection. The SO package includes a lead frame in which multiple ground pins act as heatsinks for additional power dissipation.

The MAX8862 is available in a 16-pin SO package, specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $2.09 (1000 up, direct FOB USA).

Dual Mode is a trademarks of Maxim Integrated Products.



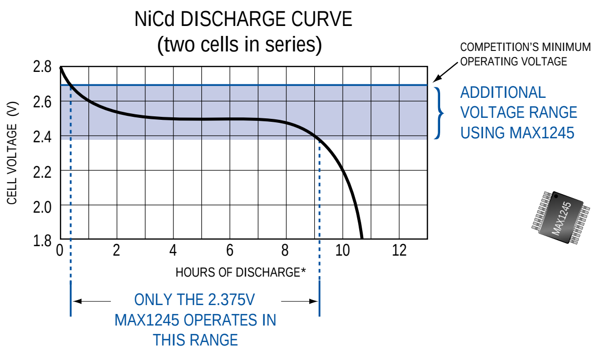
NEW PRODUCTS

12-bit ADC is first to operate at 2.375V

The MAX1245 is a 2.375V, low-power, 12-bit, monolithic data-acquisition system. The lowest-voltage 12-bit ADC available, it guarantees performance specifications from 3.3V down to 2.375V. Combining an 8-channel multiplexer and high-bandwidth track/hold with a serial interface, it offers high conversion speed (to 100ksps) and ultra-low power consumption. It draws less than 1mA during operation and 1µA in power-down mode.

The 4-wire serial interface is compatible with SPI/QSPI, Microwire, and TMS320 synchronous-serial standards. Accessing the serial interface automatically powers up the MAX1245, and the resulting quick turn-on enables power-down between conversions as a practical power-saving technique. At reduced sampling rates, power-down cuts the supply current to less than 10µA. The serial interface also configures the analog inputs as unipolar/bipolar and differential/single-ended. A serial-strobe output allows direct connections to the TMS320 family of digital signal processors.

The MAX1245 is available in 20-pin plastic DIP or SSOP packages, in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. The SSOP occupies 30% less area than an 8-pin DIP. Prices start at $6.25 (1000 up, FOB USA).



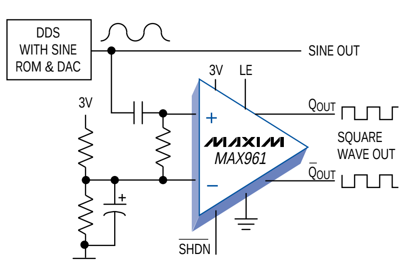
First 3V/7ns comparators accept rail-to-rail inputs

The MAX961–MAX964 (single/dual/dual/quad) high-speed, single-supply comparators are the first in the world to guarantee propagation delays below 7ns (typically 4.5ns) while operating from a single supply as low as 2.7V. The input common-mode range extends beyond the supply rails, and the outputs can sink or source 4mA to within 0.52V of V_{CC} and ground.

The single MAX961 and dual MAX963 feature complementary outputs that exhibit less than 300ps of propagation skew—an important consideration for digital communications. The MAX961/MAX963 also have a latch-enable function that holds the output on command, and a logic-controlled shutdown that lowers the supply current to 500µA max. Both come with hysteresis to ensure clean switching.

The MAX961/MAX962 come in 8-pin SO and µMAX packages. The MAX963* comes in 14-pin SO and 16-pin QSOP packages, and the MAX964* comes in a 16-pin SO or QSOP. All are specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $2.50 (1000 up, FOB USA).

**Future product—contact factory for availability.*



10MHz, single-supply op amps feature rail-to-rail I/O and SOT23 packages

The MAX4130/MAX4131 wideband op amps combine wide gain-bandwidth (10MHz) and excellent dc accuracy with rail-to-rail operation at input and output. The MAX4130 comes in a space-saving SOT23-5 package.

These op amps draw quiescent currents of only 1.05mA maximum, operating from a 2.7V to 6.5V single supply or ±1.35V to ±3.25V dual supplies. Each device is capable of driving 250Ω loads, and each exhibits a common-mode voltage range that extends beyond V_{CC} and V_{EE}. Each is unity-gain stable with a 10MHz gain-bandwidth product.

The MAX4131 features a shutdown mode that places the output in a high-impedance state and lowers the quiescent current to only 45µA.

Other features include 600µV maximum input-offset voltages, stability with capacitive loads to 250pF, and no output phase reversal when the inputs are overdriven. The rail-to-rail range for input and output voltage swings makes the MAX4130/MAX4131 op amps useful in low-voltage, single-supply applications. Also, their low offset voltage and high speed are well suited for signal-conditioning stages in precision, low-voltage data-acquisition systems.

The MAX4130 comes in a 5-pin SOT23-5; the MAX4131 comes in 8-pin SO and µMAX packages. Both are specified for the extended-industrial temperature range (-40°C to +85°C). Prices for the MAX4130 start at $0.85 (1000 up, FOB USA).

NEW PRODUCTS

Low-noise amplifier handles DC-to-microwave frequencies

The MAX2611 low-voltage, low-noise broadband amplifier operates on 5V and has a flat gain response from DC to 800MHz. Its low noise figure (3.5dB at 500MHz), high gain (18dB at 500MHz), and high drive capability (2dBm at 16mA bias current) make the MAX2611 suitable for transmit, receive, and buffer applications such as TV tuners, satellite receivers, ISM radios, set-top boxes, and global-positioning systems. Small size and simple bias circuitry make it ideal for space-limited applications.

The only external components required in a typical application are blocking capacitors at input and output, and a series bias resistor to V_{CC}. To improve gain and output power, you can also add an RF choke in series with the bias resistor.

The MAX2611 is a drop-in second source for Hewlett Packard's MSA-0611. It comes in a 4-pin SOT143 package specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $0.90 (1000 up, FOB USA).

Low-power limiting amplifiers ideal for 622Mbps ATM LAN applications

The MAX3761/MAX3762 limiting amplifiers are optimized for low-cost applications in 622Mbps or 155Mbps SONET/ATM fiber optic systems. They offer 4mV input sensitivity, 5V operation, and low power consumption (150mW). Data outputs are PECL compatible.

An integrated power detector senses the input signal amplitude and produces a received-signal-strength indicator (RSSI) (an analog indication of power level). Complementary loss-of-signal (LOS) outputs indicate when the input power level exceeds a user-programmed threshold. Adjust these LOS thresholds to detect signal amplitudes between 3mVp-p and 50mVp-p, which provides an LOS adjustment of 12dB for fiber optic receivers. The LOS outputs' 3.5dB hysteresis prevents chatter at low signal levels. When combined with the DISABLE input, the LOS outputs implement a squelch function that turns off the data outputs when the input signal is below the programmed threshold.

The MAX3761/MAX3762 come as dice, and in 20-pin QSOP packages specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $8.25 (1000 up, FOB USA).

Wideband, 2.7V op amps feature rail-to-rail I/O and SOT23 packages

Each member of the MAX4122–MAX4129 family of single, dual, and quad op amps combines wide bandwidth and excellent dc accuracy with a rail-to-rail common-mode input-voltage range and rail-to-rail output swings. Available packages are as small as the 5-pin SOT23-5. Each IC operates from a single supply of 2.7V to 6.5V, or a dual supply of ±1.35V to ±3.25V.

The op amps draw quiescent currents of only 725µA per amp from a 5V supply, yet provide large gain-bandwidth products: 25MHz for the decompensated, minimum-gain-of-10 MAX4124/MAX4125/MAX4128, and 5MHz each for the remaining unity-gain-stable devices. All are stable for capacitive loads to 500pF. The MAX4123/MAX4125/MAX4127 have an optional shutdown mode that lowers the maximum quiescent current to 45µA.

Other features include 600µV maximum input-offset voltages, the ability to drive 250Ω loads, and the ability to tolerate overdriven inputs without phase reversal at the output. MAX4122–MAX4129 op amps are recommended for portable, low-power, and battery-powered applications. In particular, their low offset voltage and high speed make them ideal for precision, low-voltage data-acquisition systems.

The MAX4122/MAX4124 come in SOT23-5 packages, the MAX4123/MAX4125/MAX4126/MAX4128 come in 8-pin SO and µMAX packages, and the MAX4127/MAX4129 come in 14-pin SO packages. All are specified for the extended-industrial (-40°C to +85°C) temperature range. Prices for the MAX4122 start at $0.85 (1000 up, FOB USA).

Quad, SPST analog switches operate on 2.0V

The MAX4521/MAX4522/MAX4523 quad, single-pole/single-throw (SPST) analog switches offer a cost/performance alternative that falls between the CD4066 and DG211/DG212 industry standards. These switches feature low on-resistance (100Ω max) and high speed (t_{ON}/t_{OFF} = 80ns/30ns at T_A = +25°C).

The MAX4521 has four normally closed (NC) switches, and the MAX4522 has four normally open (NO) switches. (MAX4521/MAX4522 pinouts are compatible with DG211/DG212 pinouts.) The MAX4523 has two NO and two NC switches. All can handle rail-to-rail analog signals, and all can operate continuously on dual supplies in the ±2.0V to ±6V range, or single supplies in the 2.0V to 12V range. Each device is fully specified to operate on a 2.7V supply. When operating on 5V or ±5V, the MAX4521/MAX4522/MAX4523 exhibit 0.8V and 2.4V TTL/CMOS-compatible logic thresholds.

On-resistances are flat to within 10Ω over the specified signal range, and matched to within 5Ω max between switches. Maximum off-leakage currents are 1nA at +25°C and 10nA at +85°C. Each device includes protection to 2kV against electrostatic discharge (ESD), per MIL-STD-883, Method 3015.7.

The MAX4521/MAX4522/MAX4523 come in 16-pin DIP, narrow-SO, and QSOP packages, in versions specified for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), or military (-55°C to +125°C) temperature range. Prices start at $0.69 (1000 up, FOB USA).

NEW PRODUCTS

DC-DC step-up converters deliver 200mA from one NiCd cell

The MAX848/MAX849 step-up dc-dc converters are recommended for use in portable phones, small systems with RF data links, and other portable products. Each regulator generates an output of 3.3V (fixed) or 2.7V to 5.5V (adjustable) from an input of one lithium-ion cell or one to three NiCd/NiMH cells. Either IC enables a portable phone to operate on one cell instead of two. I_{OUT} capabilities are 200mA with one NiCd cell and 750mA with two.

The synchronous rectification used in these regulators provides a 5% efficiency gain over comparable devices that operate with simple diode rectifiers. The MAX848/MAX849 differ only in the current capability of the internal N-channel-MOSFET power switch: 0.7A for the MAX848, and 1.3A for the MAX849. Input voltages range from 5.5V down to 0.7V.

Dual Mode™ operation maximizes efficiency by offering pulse-frequency-modulation (PFM) or pulse-width modulation (PWM) operation as selected by the CLK/SEL input: in standby (CLKSEL low), a pulse-skipping mode allows the device to maintain V_{OUT} while drawing only 150µA of quiescent current. Driving CLK/SEL high activates a fixed-frequency PWM at 300kHz. PWM operation limits switching noise to the 300kHz fundamental and its harmonics—a spectrum that allows easy noise reduction with a post filter. For even greater control of the noise spectrum, synchronize the internal switch to a 200kHz to 400kHz external clock.

The MAX848/MAX849 each include a 2-channel, serial-output A/D converter for monitoring battery voltages. One channel monitors single-cell voltages between 0.625V and 1.875V, and the other covers a 0V to 2.5V range. A single digital input selects between them. The output is a V-to-f bit stream that can be measured using external hardware or a µP's counter/timer capability. In addition, each IC's internal comparator monitors the converter's output voltage and generates a power-good output (PWROK).

The MAX848/MAX849 come in 16-pin narrow-SO packages specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $2.50 (1000 up, FOB USA).

Dual Mode is a trademark of Maxim Integrated Products.

230kbps RS-232 serial ports withstand ESD to ±15kV

The MAX3185/MAX3186 are complete, monolithic, RS-232 serial ports designed to meet the European community's stringent ESD requirements. All transmitter outputs and receiver inputs are protected to ±15kV using the Human Body Model or the IEC 1000-4-2 Air-Gap Discharge model, and to ±8kV using the IEC 1000-4-2 Contact Discharge model. The ICs are guaranteed latchup-free during ESD events.

Each device contains five transmitters and three receivers. The MAX3185 DTE port is optimized for use in desktop PCs and motherboards; the MAX3186 DCE port is optimized for use in modems. Other MAX3185/MAX3186 applications include printers and portable computers. The transceivers' data-rate capability (230kbps minimum) guarantees compatibility with popular PC-communications software. Power-supply currents are less than 300µA each for V_{DD} (nominally 12V) and V_{SS} (nominally -12V), and less than 1mA for V_{CC} (nominally 5V).

The MAX3185 is compatible in pinout and function with the industry-standard 75185 transceiver, so the user can upgrade a system for EMC compliance simply by substituting the MAX3185 for that device.

MAX3185/MAX3186 transceivers come in 20-pin SSOP or SO packages, in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $1.23 (1000 up, FOB USA).

Digitally controlled CCFL power supplies provide flicker-free display

The MAX1610/MAX1611 power-supply ICs drive cold-cathode fluorescent lamps (CCFL). Each high-efficiency device maintains constant CCFL brightness, despite V_{IN} changes, by regulating the lamp current. The V_{IN} range is 4.5V to 28V.

Each IC includes a high-frequency, power-switching MOSFET that enables the use of small, thin external magnetic components. (Driving the CCFL from an isolated transformer-secondary winding improves efficiency and prevents flicker at dim tube settings.) The MAX1610/MAX1611 protect themselves against open or shorted lamps, and they also accommodate floating-lamp designs. Both include a linear regulator, eliminating the need for a separate logic supply. Maximum supply currents are 3mA during operation and 20µA in shutdown.

To adjust brightness, either scale the lamp current or operate with fixed current and chop the CCFL on and off at a rate faster than the eye can detect. The MAX1610 provides digital inputs that allow brightness adjustment by incrementing, decrementing, or clearing an internal 5-bit up/down counter. The MAX1611 has a 2-wire serial interface—the System Management Bus (SMBus™)—to allow CCFL brightness to be set directly. During shutdown, the digital interface remains active to preserve the brightness setting.

The MAX1610/MAX1611 are available in 16-pin narrow-SO packages specified for the commercial temperature range (0°C to +70°C). Prices start at $3.85 (1000 up, FOB USA).

SMBus is a trademark of Intel Corp.

NEW PRODUCTS

500µA RS-232 transceiver operates on 3.0V to 5.5V; runs at 1Mbps

The MAX3237 high-speed data transceiver includes internal dual charge pumps and a proprietary, low-dropout output stage that ensures true RS-232 output levels for data rates to 1Mbps and above. The charge pumps require only four small, external 0.1µF capacitors.

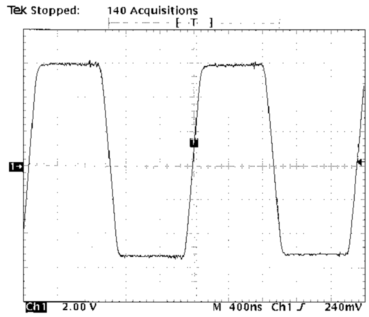
In normal operating mode, with a worst-case load of 3kΩ in parallel with 1000pF, the MAX3237's guaranteed 250kbps data rate makes it compatible with PC-to-PC communications software such as LapLink™. In megabaud operating mode (MBAUD terminal connected to V_{CC}), with a maximum load of 3kΩ in parallel with 250pF, the guaranteed data rate is 1Mbps. Slew rates are guaranteed to be 24V/µs minimum in megabaud mode.

The MAX3237 contains five drivers and three receivers, and is ideal for fast-modem applications. It offers a 1µA shutdown mode in which all three receivers remain active. This capability enables the MAX3237 to monitor external devices without the danger of heavy current flow. (When V_{CC} for an external device is turned off, current can flow as the result of forward bias on one of its protection diodes.)

The MAX3237 is available in a 28-pin SSOP, in versions specified for the commercial (0°C to +70°C) or extended-industrial (-40°C to +85°C) temperature range. Prices start at $3.29 (1000 up, FOB USA).

LapLink is a trademark of Traveling Software.

1MBPS RS-232 OPERATION WITH V_{CC} = 3.0V!



300MHz differential line driver delivers 160mA with only -87dBc distortion

The MAX4147 is a differential line driver and the MAX4144/MAX4146* are wideband receivers. Connected by a twisted-pair line, the MAX4147 and one instrumentation amplifier form a complete differential transmission link, ideal for digital subscriber lines (DSLs) in video and telecom applications. The MAX4144/MAX4146/MAX4147 replace existing circuits that include multiple high-speed, high-power op amps.

The MAX4147 is optimized for high-I_{OUT}, low-distortion, differential applications such as transformer drivers. Loaded with 50Ω, it produces ±5.6V differential or 2.8V single-ended output swings. It operates on ±5V, consumes 110mW, and has a 2V/V closed-loop gain. The MAX4147 features a 300MHz -3dB bandwidth, a 70MHz -0.1dB bandwidth, and ultra-low, 0.008%/0.03° differential gain/phase errors. Low distortion (-87dBc at 3kHz with R_L = 33Ω) makes the MAX4147 suitable for DSL applications.

The MAX4144/MAX4146 wideband receivers have fully symmetrical differential inputs and a single-ended output capable of driving ±2.6V into a 150Ω load. The MAX4144's gain is internally set at 2V/V, and the MAX4146's gain is set between 10V/V and 100V/V with a single external resistor. Each device has matched and laser-trimmed internal thin-film resistors that achieve common-mode rejection of 60dB at 10MHz. The MAX4144 employs current-feedback techniques to achieve a 130MHz bandwidth, 110MHz full-power bandwidth, and 1000V/µs slew rate.

The MAX4144/MAX4146/MAX4147 come in 14-pin SO packages specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $3.35 for the MAX4144, and $2.50 for the MAX4147 (1000 up, FOB USA).

**Future product—contact factory for availability.*

TWISTED-PAIR TO COAXIAL-CABLE CONVERTER