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MAXIM REPORTS RECORD REVENUES AND EARNINGS FOR THE THIRD QUARTER OF FISCAL 2000

Maxim Integrated Products, Inc., (MXIM) reported record net revenues of $226.5 million for its fiscal third quarter ending March 25, 2000, a 53.9% increase over the $147.2 million reported for the same quarter a year ago. Net income increased to a record $74.7 million in the third quarter, compared to $47.7 million last year, a 56.7% increase. Diluted earnings per share were $0.23 for the third quarter, a 53.3% increase over the $0.15 reported for the same period a year ago.

During the quarter, the Company increased cash and short-term investments by $97.7 million after paying $33.9 million for capital equipment and repurchasing 100,000 shares of its common stock for $5.0 million. The Company generated higher than normal cash balances principally due to lower than normal stock repurchases. Accounts receivable increased by $21.7 million in the third quarter to $125.1 million, and inventories increased $7.0 million to $51.4 million during the quarter.

Gross margin for the third quarter increased slightly to 69.9%, compared to 69.8% in the second quarter. Research and development expense was $36.4 million or 16.1% of net revenues in the third quarter, compared to $32.3 million or 16.0% of net revenues in the second quarter. During the quarter, the Company recorded a writedown of equipment of $8.8 million to cost of goods sold and recorded a charge to selling, general and administrative expenses of $4.5 million related to technology licensing. Due to recent accounting changes, the Company recorded an expense in the third quarter of approximately $5.7 million in medicare taxes on employees' realized stock option gains. The tax payments were previously recorded within Stockholders' Equity as an offset against the proceeds received from the exercise of stock options. Included in interest income and other, net, was a $4.5 million gain from the cash sale of the Company's 50% interest in its high-frequency packaging and assembly business. This business was jointly owned with Tektronix and was set up to facilitate the 1994 acquisition of the Tektronix integrated circuit operation.

Bookings in the quarter were approximately $304 million, an 8% increase over the previous quarter's level of $283 million, and a 78% increase over the third quarter of last year. Turns orders received in the quarter were $95 million, a 3% increase over the $93 million received in the prior quarter (turns orders are customer orders that are for delivery within the same quarter and may result in revenue within the same quarter if the Company has available inventory that matches those orders). The bookings increase is primarily attributable to strength in the U.S. distribution channels and Europe. There was significant growth in bookings for the Company's products targeted for the high-frequency end markets and products with broad-based industrial applications. Bookings on Maxim by U.S. distributors were $78.8 million during the quarter and exceeded customer bookings on those distributors by $17.6 million. Bookings on distributors by their customers were up by $14.3 million, a 30% increase over the previous quarter.

Third quarter ending backlog shippable within the next 12 months was approximately $345 million, including approximately $271 million requested for shipment in the fourth quarter of fiscal 2000. The Company's second quarter ending backlog shippable within the next 12 months was approximately $285 million, including approximately $231 million that was requested for shipment in the third quarter. All of these backlog numbers have been adjusted to be net of cancellations and estimated future U.S. distribution ship and debit pricing adjustments.

Jack Gifford, Chairman, President, and Chief Executive Officer, commented on the quarter: "This was another strong quarter for Maxim, with record bookings, revenues, and earnings. Relative to many younger technology companies, Maxim continues to offer investors a finite price to earnings ratio. Our annualized bookings rate was over $1 billion. Turn orders as a percentage of total bookings were in line with historical levels, at approximately 31%. We continue to believe that bookings and turns growth will moderate to reflect our short-term forecasted end-market consumption levels. During the past 12 months, we have increased our manufacturing capacity to support current and projected consumption trends."

Gifford continued: "I have never been more encouraged about the broad acceptance of Maxim's products in the global marketplace. Clearly our products, and the engineering value they represent, are helping to fuel the worldwide growth in digital communications and microprocessor-based electronics. It is my opinion that worldwide economies depend on state-of-the-art technologies, including Maxim's, that are dominated by U.S. corporations. I believe this to be a long-term growth engine for Maxim and other U.S. corporations offering these enabling technologies."

Gifford concluded: "During the quarter, our professional recruiting efforts were highly successful, indicating Maxim's continuing appeal to world-class technologists in all disciplines."

Implementing a trimless IF VCO (Part 1)

Part 1 of this two-part article explores the design fundamentals needed to implement a trimless, fixed-frequency, IF voltage-controlled oscillator (VCO) and points out the challenges in guaranteeing proper circuit operation. VCOs are essential components in the architecture of most wireless systems. In dual-conversion approaches, a fixed-frequency IF VCO is required to control the frequency translation from IF to baseband and/or baseband to IF.

Dual-conversion systems require two oscillators. Typically, the first (RF VCO) tunes over the full range of input channel frequencies, and the second (IF VCO) operates at a single frequency established by the frequency plan. The RF VCO is available as a module, IC, or discrete-component circuit, with modules and ICs being more common. For IF VCOs, small, cost-effective modules are nearly absent from the market. Probable reasons include the need for many arbitrary IF frequencies and the need for large-valued inductors that cannot be laser-trimmed (adjusted) in production. As a result, the IF VCO is usually implemented as a discrete circuit or as part of an IC.

Maxim has pioneered a new VCO IC intended for use in wireless systems whose other board-level RF/IF ICs lack that function. Part 2 of this article will introduce the IC, discuss its development, and detail the simple and cost-effective applications it makes possible.

A discrete-component VCO offers sufficient degrees of freedom to meet the performance objectives of most systems (tuning range, output power, phase noise, current consumption, cost, etc.). For higher volume, cost-sensitive modern products, however, production-line adjustment of the oscillation frequency is not acceptable. The RF engineer is therefore compelled to devise a VCO that requires no adjustments during assembly, i.e., a trimless VCO. The design is not trivial. In addition to an understanding of VCO design fundamentals, it requires substantial RF engineering effort to ensure that the design is properly centered and that the oscillator tunes to the desired frequency over all allowed variations in component values, temperature, and supply voltage. The following discussion, while explaining pertinent issues in the design of a trimless IF VCO, seeks to develop an appreciation for the magnitude of the task.

VCO topology

While several oscillator topologies are viable for construction of a practical RF VCO, the one that has proven successful in many commercial VCO modules and countless discrete VCO circuits is the Colpitts common-collector topology (**Figure 1**). This topology is useful for a wide range of operating frequencies, from IF to RF.

A flexible, low-cost, and reasonably high-performance VCO may be constructed with an inductor-capacitor (LC) tank circuit consisting of a low-cost surface-mount inductor and varactor diode. The oscillator tank is a parallel-resonant circuit controlling the oscillation frequency; any change in the inductor or capacitor changes the oscillation frequency. The inductor and varactor can implement the variable resonance as a parallel- or series-mode network.

The parallel-mode network may be used at lower frequencies where large-value varactors are impractical and the inductor value can be made larger. The parallel-mode configuration also permits a straightfoward analysis of the oscillator. For the remainder of this article, the trimless IF VCO will be illustrated with a Colpitts-style oscillator, using a parallel-mode LC tank (**Figure 2**).

The Colpitts oscillator is discussed in several textbooks (Clarke and Hess 1978, Hayward 1994, Rohde 1998), and various equations have been derived to predict the behavior of oscillators in general and the Colpitts topology in particular. The oscillator is generalized with a feedback-amplifier model of the circuit. Expressions for the exact oscillation frequency may be derived by equating

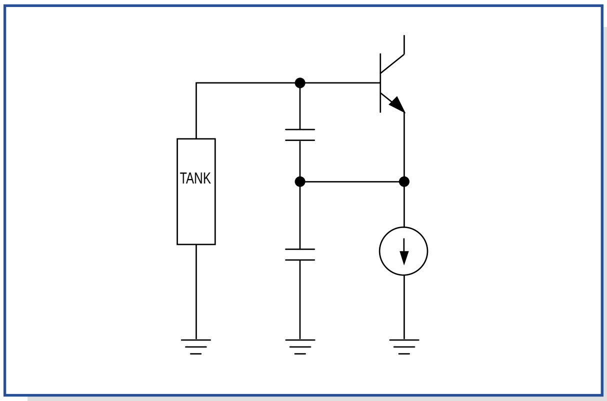

Figure 1. The basic Colpitts oscillator

impedances in that model, but those expressions are cumbersome and provide little insight into the design process.

Alternatively, the Colpitts oscillator can be analyzed in a simpler but less accurate manner, which provides a set of design equations that are clearer, more insightful, and useful for first-order oscillator design. First, the Colpitts oscillator may be redrawn as an LC amplifier with positive feedback (**Figure 3**). This view is useful in calculating the loop gain, oscillation amplitude, and phase noise. To predict startup behavior and oscillation frequency, the original circuit can also be redrawn as a negative impedance plus resonator structure (**Figure 4**). Equations from these two views are combined as a set of governing equations for the Colpitts oscillator (Meyer 1998).

Basic design equations for the Colpitts oscillator

Ignoring parasitic elements, the basic equations for this analysis assume that $C_C >> C_1$ and C_2, and $C_1 > C\pi$ ($C\pi$ is the base-emitter capacitance). Calculate the oscillation frequency (f_O) as follows:

$$f_O = \frac{1}{2\pi\sqrt{L \times C_T}},\ C_T = C_V + C_{12},$$
$$C_V = \frac{C_{VAR} \times C_O}{C_{VAR} + C_O},\ C_{12} = \frac{C_1 \times C_2}{C_1 + C_2} \qquad (1)$$

Calculate the quality factor of the resonant tank circuit (Q_T) as follows:

$$Q_V = \frac{1}{2\pi \times C_V \times R_S \times f_O},\ R_{QC} = Q_V{}^2 \times R_S,$$
$$Q_T = \frac{R_{EQ}}{2\pi \times L \times f_O},\ R_{EQ} = R_{QL} \| R_{QC} \qquad (2)$$

Estimate the oscillation amplitude as follows:

$$V_O \cong 2 \times I_Q \times R_{EQ} \times \frac{J_1(\beta)}{J_0(\beta)},$$
$$V_O \cong I_Q \times R_{EQ} \times\ 1.4 \qquad (3)$$

Calculate the loop gain and startup criteria as follows:

$$\text{Loop gain} = g_m \times R_{EQ} \times \frac{1}{n},\ \text{where } n = \frac{C_1 + C_2}{C_2} \qquad (4)$$

Startup criteria :

$$\frac{gm}{(2\pi \times f_O \times C_1)(2\pi \times f_O \times C_2)} >> \frac{R_{EQ}}{Q_T{}^2}, \qquad (5)$$

$\int$ minimum 2 : 1 ratio

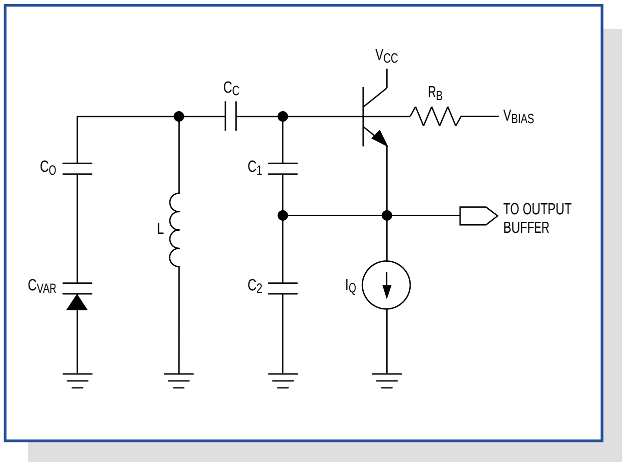

Figure 2. Use of the Colpitts topology in a VCO

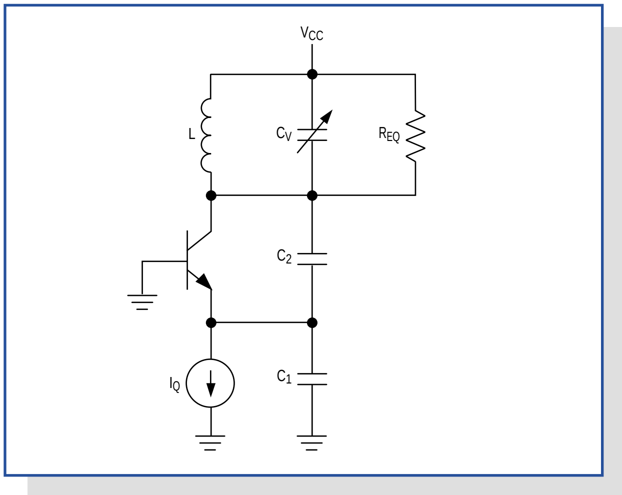

Figure 3. LC amplifier model

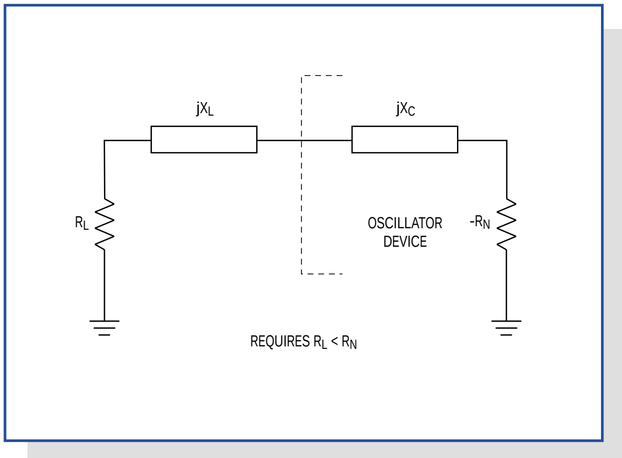

Figure 4. Reflection amplifier model

Calculate the Colpitts oscillator phase noise (PN) at an offset frequency (f_m) from the carrier as follows:

$$PN = i_n^{\,2} \times \frac{1}{V_O^{\,2}} \times \left(\frac{f_O}{2Q_O}\right)^2 \times \frac{R_{EQ}^{\,2}}{f_m} \qquad (6)$$

Trimless VCO approach

Developing a trimless VCO is relatively simple in concept. Oscillator-frequency adjustments can be eliminated if the oscillator has sufficient extra tuning range to overcome all the error sources (e.g., component tolerances) that produce shifts in frequency. At first glance, it may seem intuitive and simple enough just to provide plenty of oscillator tuning range and tune out all the error sources. For a given tuning-voltage range, however, finite variable capacitance imposes a fundamental limit on the frequency-tuning range, and the VCO's electrical-performance requirements often constrain the tuning range before that limit is reached.

Unfortunately, several negative consequences attend an oscillator with excessive tuning range. Very wide ranges require heavy capacitive coupling of the varactor to the tank, which substantially reduces the tank-circuit Q. The result is greater phase noise (reduced tank amplitude vs. transistor noise), greater sensitivity to tuning-line noise (which translates directly into frequency modulation), the possibility of too much voltage swing across the varactor, potential startup problems, and greater challenge in designing the loop filter. These factors lead to the conclusion that excessive tuning range is undesirable. Indeed, it should be no greater than the minimum necessary to absorb all error sources.

Glossary

C_O = varactor coupling capacitance

C_T = total tank capacitance

C_{VAR} = varactor capacitance

f_m = offset frequency of PN in Hz

f_O = frequency of oscillation

g_m = bipolar transistor (oscillator) transconductance

i_n = collector shot noise

I_Q = oscillator transistor bias current

Q_L = inductor Q

Q_T = tank Q

Q_V = effective varactor Q

R_{EQ} = equivalent tank parallel resistance

R_S = varactor series resistance

V_O = RMS tank voltage

A wider tuning range causes greater oscillator phase noise through two well-understood phenomena: a reduction in the tank-circuit Q and noise on the tuning line. To achieve a wider tuning range, the varactor must be coupled more heavily into the tank circuit. This coupling reduces the Q of C_V (the effective variable capacitance) as shown in Equation 2. Lower Q for C_V reduces the net Q of the tank and, consequently, increases the phase noise, per Equation 6.

The second factor in reducing phase noise is thermal noise on the tuning input, which creates FM-sideband noise. This noise increases with tuning range, and it can exceed the oscillator's inherent phase noise. The phase noise induced by thermal noise is given by:

$$PN = 20\log\left(\frac{\sqrt{2} \times K_V \times V_n}{2 \times f_m}\right), \text{ where } K_V = \text{VCO gain in } \frac{\text{Hz}}{\text{V}}, V_n = \text{noise density at } V_{TUNE} \text{ input at } f_m \text{ in } \frac{\text{V}}{\sqrt{\text{Hz}}} \qquad (7)$$

It is evident in both cases that phase noise degrades with increasing tuning range. To preserve low phase noise in a trimless VCO, therefore, it is critically important to provide *just enough* tuning range to meet the guaranteed bandwidth and accommodate the expected error sources.

As the varactor is coupled-in more heavily, more tank-voltage swing appears across the varactor, and the varactor voltage swing must be limited to avoid forward-biasing the varactor. This sets a limit on signal power in the tank and, consequently, on the oscillator's phase noise. Finally, startup problems may occur if the tank-circuit equivalent series resistance (ESR) becomes too high (refer to the equations). A VCO with very wide frequency-tuning range may not start up properly, especially over the extremes of temperature. With the goal of providing just enough tuning range, the question is—how much?

Error sources in the oscillation frequency

The trimless VCO's frequency tuning range is increased to accommodate error sources in the oscillation frequency. These error sources fall in two categories: error in the component values and error from design centering. The LC components that set the oscillation frequency are not ideal, of course. They contribute the following:

- Part-to-part variations (tolerance)
- Non-ideal performance (limited frequency response due to inductance, capacitance, and series resistance in the leads)

- Error induced by parasitic capacitance and inductance in the circuit layout

On the other hand, design-centering errors result from uncertainty in centering the VCO tuning range during the design process.

Component-tolerance error

Each capacitive and inductive component affecting the oscillation frequency in an LC oscillator has only limited part-to-part accuracy, and this tolerance error contributes to error in the oscillation frequency. **Table 1** lists the typical tolerances for the frequency-setting components in the oscillator.

Table 1. Oscillator frequency-setting component tolerances

Component	Tolerance
Varactor	±15% at V_{TUNE} = 0.4V, ±10% at V_{TUNE} = 2.4V
Inductor	±5%
Capacitors	±5%
Parasitic Capacitance	±10%
Parasitic Inductance	±6%
Oscillator-Device Impedance	±15%

Design-centering error

Design centering is often overlooked as a source of error in establishing the oscillation frequency. To maximize use of the available frequency-tuning range, the tuning limits must be symmetric with respect to the desired oscillation frequency. Any error in establishing this center point, caused by inaccuracies in modeling the components' initial or mean values, reduces the tuning range available to absorb error sources. To guarantee the oscillation frequency over all conditions of temperature, supply voltage, component tolerances, etc., the tuning range must be wide enough to accommodate this error.

You can calculate total frequency error using the frequency-of-oscillation formula, by multiplying each element by a variation scaling factor:

$$f_O = \frac{1}{2\pi\sqrt{L \times C_T}},\ C_T = C_V + C_{12},$$
$$C_V = \frac{C_{VAR} \times C_O}{C_{VAR} + C_O},\ C_{12} = \frac{C_1 \times C_2}{C_1 + C_2} \quad (8)$$

The quickest way to compute net frequency skew due to the various errors is to utilize a spreadsheet program that contains the detailed formula for oscillation frequency, based on L and C values in the circuit.

Frequency shifts and tuning range

The frequency-tuning range, obtained by varying the tuning voltage from $V_{TUNE(LOW)}$ to $V_{TUNE(HIGH)}$, has high- and low-frequency endpoints (f_{HIGH} and f_{LOW}) with a "center" frequency (f_{CENTER}) defined as the midpoint between f_{HIGH} and f_{LOW} (**Figure 5**). Ideally, the tuning range should be positioned with f_{CENTER} at the desired oscillation frequency (Figure 5a). However, component errors and design-centering errors can shift the frequency-tuning limits.

The desired oscillation frequency cannot be reached if the system provides inadequate tuning voltage over the worst-case conditions, which results in insufficient frequency range (Figure 5b). Clearly, a careful determination of the required tuning range is necessary. That is accomplished by calculating the frequency skew caused by all error sources, and verifying that $f_{LOW} < f_{OSC}$ and $f_{HIGH} > f_{OSC}$ under the worst-case conditions (Figure 5c).

Verification of the design

Once circuit-board layout and component value selection are complete, the design requires verification and measurements (even more than most RF circuits). Nominally, you must check the tuning range, startup behavior, phase noise, etc., for compliance with design targets. In addition, measurements must be made over a statistically significant number of manufacturing runs to determine the tuning range and the mean center frequency, and its location with respect to the desired oscillation frequency.

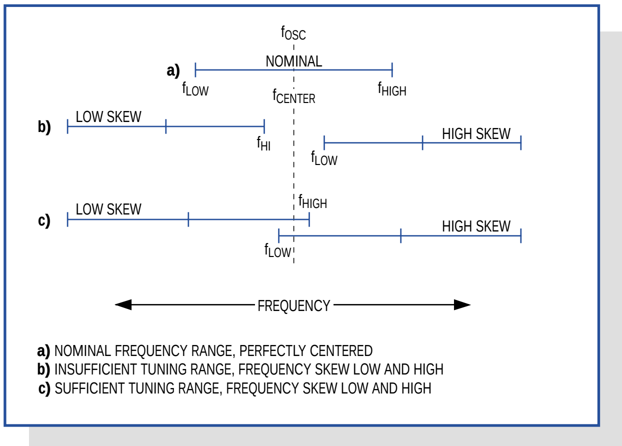

Figure 5. Tuning range and frequency shifts

All this work is necessary to produce a robust, reproducable design with the desired electrical performance. Because the tasks usually require several iterations, you can easily take months to achieve a discrete-component design that is acceptable and production worthy. Development of a trimless IF VCO requires a detailed circuit design, inclusion of all error sources, verification on the circuit board, and monitoring over production to ensure a viable result. Maxim has met this challenge with a new IC (to be described in Part 2), which solves the VCO design problems while dramatically reducing the time necessary to implement a trimless IF VCO.

Part 2 of this article will introduce the IC, discuss its development, and present a detailed description and performance summary (*Engineering Journal Vol. 40*). An application that illustrates the simplicity, small size, and cost effectiveness of the device will also be included.

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Hayward, Wes. 1994. *Radio Frequency Design*. Chap. 7.

Meyer, Dr. Robert. 1998. Internal communication.

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Managing noise in cell-phone handsets

Modern cell phones must operate in the face of many unwanted signals. In a typical phone, the signal amplitude may be only 0.35µV—over 100dB below the amplitude of nearby noise. To amplify this signal to a level suitable for demodulation, cell phones often use intermediate frequency (IF) sections with over 80dB of gain.

To meet the required bit-error rate (BER), noise must be managed. Shielding and filtering are effective but add extra weight, size, and cost while shortening battery life. A better approach is to design for low noise from the start so that known noise spectra don't interfere with radio performance. Managing noise in this way requires an understanding of the following:

- Noise-propagation mechanisms
- Points of greatest noise sensitivity
- Noise-generating circuits.

Cell-phone handsets

A digital cell phone is a marvel of packaging, human interface, and power conservation. The RF sections consist of filters, low-noise amplifiers, mixers, a power amplifier (PA), and a frequency synthesizer. A mixed-mode ASIC connects transmit and receive sections to IF signals. Working in concert with a digital ASIC containing DSP and system-control processors, the mixed-mode ASIC contains data converters for modulating and demodulating the IF signals. The system-control processor also manages the human interface and power management.

A power-distribution subsystem manages the battery pack and distributes operating voltages within the handset **(Figure 1)**. Cell phones may also include a switch-mode power supply to boost the cell voltage to a level appropriate for the PA. New low-voltage ASICs can receive power from a small, step-down switch-mode supply, and remaining RF and analog circuits can be powered from linear low-dropout (LDO) regulators. The various regulators turn on under processor control, selecting operations demanded by the wireless protocol (GSM or IS-95, for example).

Noise-propagation mechanisms

Noise propagates by conduction and radiation. Conduction channels noise through a wire, printed-circuit trace, metal chassis, or electrical component. Radiation transfers noise energy through the air or other dielectric such as circuit-board material. Conducted noise can be filtered with traditional circuit techniques. Radiated noise, if not reduced at the source, requires shielding. Conducted noise that finds an efficient antenna becomes radiated noise. Although radiated noise is often controlled with shielding, conductive coatings, and gaskets, these measures may be unnecessary if noise is confined to the conductive mode by proper PC layout and filtering. It is best, if possible, to keep noise conductive and not let it radiate.

The power amplifier

A PA generates noise by drawing large currents. A 3.6V, 50% efficient PA whose signal faces a 3dB loss before reaching the antenna can draw up to 800mA from a lithium ion (Li+) cell. This current flows through resistance in the battery connectors, PCB traces, and ground paths, producing noise on power-supply lines. The problem is compounded in phones that use burst transmission as specified by the GSM and IS-136 TDMA standards. Short PA bursts impose transients on the power supply and the distribution subsystem.

A popular method for powering the burst-mode PAs is to boost the supply voltage to reduce peak current, minimize noise, and allow less expensive PA technology. Still, the

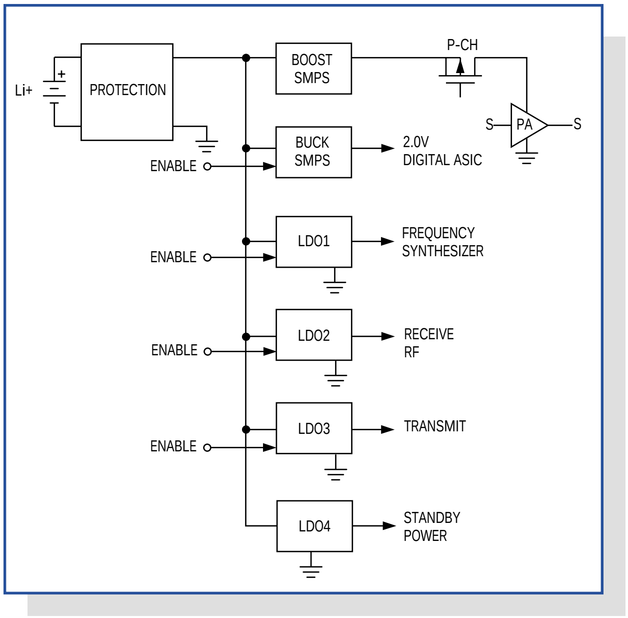


Figure 1. Switch-mode and linear regulators distribute power cleanly and efficiently.

need to supply a current peak often results in an over-specified boost converter. A better solution is to store the boosted energy on a capacitor; then the boost converter need only recharge the capacitor between transmitter bursts. A remaining problem occurs with a typical DC-DC converter when a capacitor voltage drop is sensed; it attempts to replenish the charge as quickly as possible, drawing a current surge from the Li+ cell that creates new noise. A solution incorporated into new ICs (MAX1687/MAX1688) limits the PA reservoir capacitor charge rate either with a user-set peak battery current or an automatically set adaptive current limit **(Figure 2)**. As a result, the capacitor and power converter work in concert to maintain efficient power conversion while minimizing the system disruptions that can accompany PA current surges. To further control noise, these chips can be disabled during transmit bursts.

PA bias

The bias voltage on a GaAs-FET PA controls the bias current, which sets PA gain and output impedance. Since the bias pin is an amplitude-modulated input, any bias noise appears at the RF output and is radiated from the antenna along with the desired signal. GaAs PAs use depletion-mode MOSFETs, which conduct maximum drain current without gate bias. To control drain current, the gate must be negative (below ground). To produce a bias voltage that's stable, quiet, and well defined, it's common practice to follow an inverting charge pump with an op amp regulator. Though flexible, this approach doesn't yield the physically smallest circuit.

The smallest available circuit for generating PA bias is the MAX881, which combines an inverting charge pump and negative regulator in a tiny 10-pin µMAX package. All bias needs for a GaAs PA are addressed in this IC. For normal operating conditions, output noise and ripple (~1mVp-p) are low enough to prevent unwanted noise sidebands at the RF output. The MAX881 also senses the negative bias voltage to ensure that drain current is controlled when the PA's main supply is applied. This safety interlock prevents PA damage **(Figure 3)**.

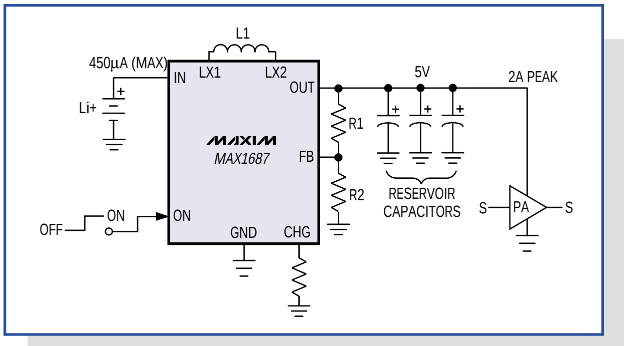


Figure 2. For burst systems such as IS-136 and GSM, large transients on the battery are minimized by reservoir capacitors and a boost converter.

PLL frequency synthesizer

In many cell phones, the first local oscillator (LO) is generated by a phase-lock loop (PLL) frequency synthesizer. In AMPS phones, the voltage-controlled oscillator (VCO) tunes in 30kHz steps over a ±12.5MHz range near 880MHz. (Actual VCOs generate frequencies offset by the first IF.) If you assume the PLL operates from 3V, the entire 25MHz tuning range should be covered with a 2V tuning voltage (control voltage). This provides a margin that ensures the PLL won't saturate in response to transients or temperature drift.

The VCO gain is 25MHz/2V or 12.5MHz/V. High gain makes the VCO sensitive to noise on the control line. If the phase detector and VCO are separated in a high-gain PLL, the VCO often picks up radiated noise, requiring a shielded cable to preserve the VCO noise spectrum. The following are other disturbances that can also modulate the VCO:

1) Power-supply noise, injected into the PLL phase detector
2) Power-supply noise injected into the VCO
3) Power-supply noise passed to the output of an active integrator or loop filter (watch op amp PSRR to minimize this)

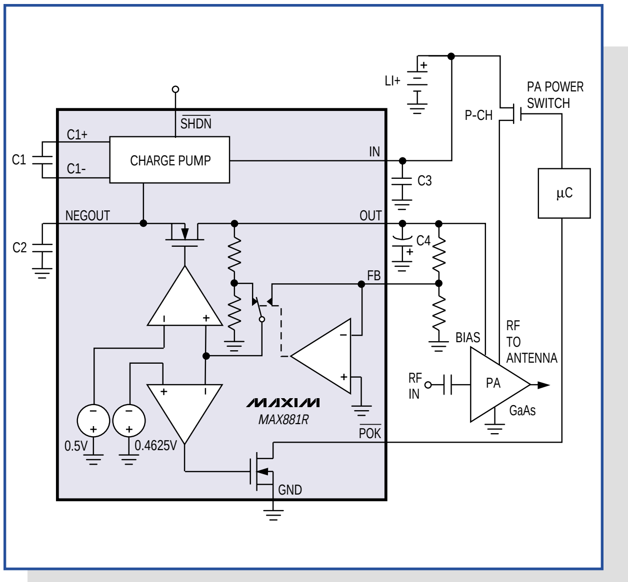


Figure 3. An interlock feature of the MAX881R protects the GaAs PA from damage.

4) Noise on the crystal oscillator (TCXO/VCTCXO). The oscillator signal in high-Q circuits should be clean and noise free, but excess power-supply noise can raise the oscillator's noise floor. Because the PLL multiplies noise within the loop bandwidth by the PLL division ratio (~30,000 for an AMPS handset), the frequency synthesizer is very sensitive to noise from the TCXO.

5) Noise caused by VCO output load impedance variations that reflect back into the VCO and pull its operating frequency

For systems where loop bandwidth shapes the noise spectrum to fall between DC and 500kHz, items 1 to 4 can be improved with passive filtering. The frequency synthesizer needs a separate LDO to avoid noise conducted from the power supply. Nevertheless, for digital phone systems, residual phase noise caused by modulation by the power supply is too great. An LDO provides a clean regulated supply voltage for the frequency synthesizer, but it also can produce noise.

Broadband noise source

An LDO regulator's voltage reference and error amplifier can have significant noise content. A low-noise device like the MAX8877 combats this by bringing the reference voltage out to a pin that allows bypassing the noise to ground with a capacitor. A 0.0μF capacitor, for instance, lowers output noise to $30\mu V_{RMS}$ over a 10Hz to 100kHz bandwidth **(Figure 4)**. This improvement lowers PLL noise at 900MHz by up to 20dB. LDOs also isolate handset sections from each other. Within the LDO bandwidth, the MAX8877 suppresses power-supply noise at 10kHz by 60dB. In terms of PCB area, this suppression is a bargain (the IC comes in a SOT23 package). Passive components that provide such filtering, especially at low frequencies, would be much larger.

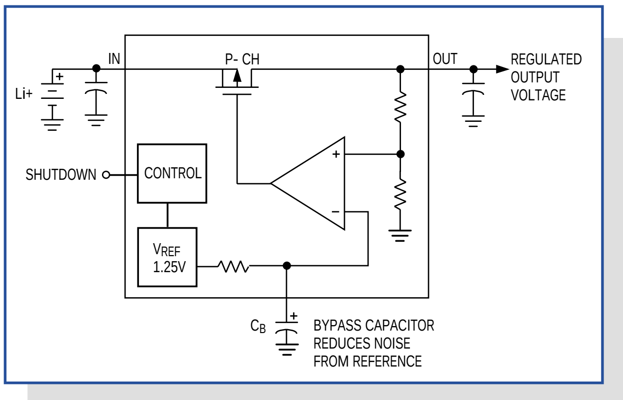


Figure 4. Output noise from an LDO regulator is reduced by adding a bypass capacitor (C_B) to the voltage reference.

Improved efficiency

The latest switch-mode power supplies (SMPS) designed for cellular phones offer small size, high efficiency, low-dropout voltage, small external components, and noise-control features. For example, the MAX1692 step-down power converter uses pulse-width modulation (PWM) and synchronous rectification to achieve over 90% efficiency with a low, predictable noise spectrum. Operating from a single Li+ cell ranging from 3V to 4.2V, it generates supply voltages down to 1.25V for large ASICs.

To control interference in high-gain RF sections such as the IF, the MAX1692 can be synchronized (at frequencies between 500kHz and 1MHz) with an external crystal-controlled clock such as that generated by the TCXO. High-frequency SMPS operation is crucial for the use of small external components and noise-spectrum planning.

Switch-mode supplies produce a noise spectrum in which the lowest frequency is the SMPS' fundamental switching frequency. The spacing between harmonics is equal to this fundamental, but other aspects of the spectrum are difficult to predict. Noise power distributed among the harmonics is a function of wave shape (vs. time), current level, inductor value, capacitor values, and PCB layout.

Switching noise can be conducted on the input, output, and ground lines, or radiated by the PCB traces. Always minimize the ripple and noise conducted from an SMPS, but also realize that adding filter networks to reduce conducted noise may actually increase radiated noise. Such noise radiates from the layout and then propagates efficiently throughout the system, appearing to come from everywhere.

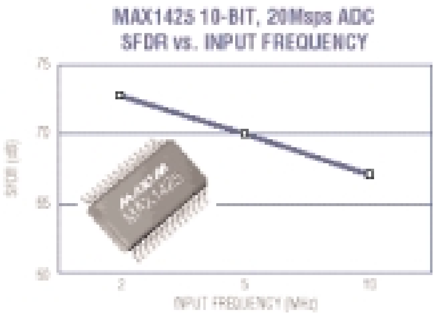
To best handle the problem of cell-phone noise, understand the phone's noise-coupling mechanisms, noise-sensitive circuit nodes, and noise-generating circuits. A boost power converter and a large capacitor can minimize the conducted noise from PA transients in a GSM/TDMA system. The radiated noise from an SMPS depends heavily on the PC layout, and a realistic schematic representation can guide the layout for first-time success. Small linear regulators provide active noise filtering and, with reference bypassing, can yield the very low noise levels required by frequency synthesizers. Finally, placing an IF in the quiet zone between noise harmonics of the power supply can eliminate the signal contamination that spoils bit-error rates in a digital cell phone. To allow the most effective trade-offs, these noise-planning steps should be considered early in the design.

10-bit ADC with track/hold converts at 20Msps

The MAX1425, a 10-bit, analog-to-digital converter (ADC) with 20Msps digitizing rate, targets imaging, high-speed communication, and instrumentation applications that require wide bandwidth, good linearity, and excellent dynamic performance. Unlike other high-speed 10-bit ADCs, this monolithic device achieves a full 61dB signal-to-noise plus distortion ratio (SINAD) and a 72dB spurious-free dynamic range (SFDR) at 2MHz input frequency. It achieves this performance over a ±2V input range, while operating from a single 5V supply, through use of a fully differential pipeline architecture and advanced 0.6µm CMOS process.

A fully differential track/hold amplifier (T/H) ensures wideband dynamic performance with a low 5pF input capacitance and 150MHz full-power bandwidth. The MAX1425 includes a precision, 2.5V bandgap reference that also generates additional reference voltages. This capability provides input-range options and automatically ensures the correct DC-bias level for AC-coupled applications.

A 5V analog supply powers the MAX1425, with a separate digital supply to support an output interface of 3V to 5V. Output data is presented in the two's complement format. The device is packaged in a space-saving 28-pin SSOP specified for the industrial temperature range (-40°C to +85°C). Prices start at $3.95 (1000-up, FOB USA). An evaluation kit (MAX1425EVKIT) is available to save design time.

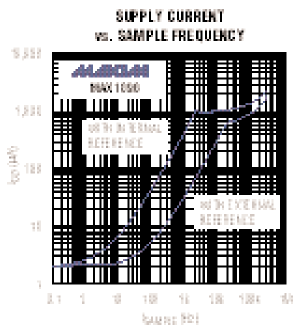


10-bit, multichannel, parallel I/O ADCs fit in QSOP packages

The MAX1090–MAX1093 10-bit, 400ksps, parallel-interface ADCs feature an 8-bit interface, 3V or 5V single-supply operation, an internal reference, and four or eight input channels. The devices' small footprint and low supply current are well suited for battery-powered applications.

The analog inputs are software-configurable for unipolar/bipolar and single-ended/differential operation. The full-scale analog-input range is determined by the internal +2.5V reference or by an externally applied reference in the 1V to V_{DD} range. Each ADC is powered by a single analog supply of 3V (MAX1091/MAX1093) or 5V (MAX1090/MAX1092). A V_{LOGIC} pin allows a direct interface with digital supplies in the 1.8V to 5V range, without additional circuitry.

Quiescent current is only 1.5mA at a sample rate of 100ksps, and software power-down modes further reduce the supply current to less than 10µA at lower sampling rates. The MAX1090–MAX1093 are available in 24-pin and 28-pin QSOP packages, with prices starting at $3.92 (1000-up, FOB USA).



Lowest power, 3V/18mW, 40MHz I/Q DACs deliver 70dB SFDR

The MAX5180 family of monolithic CMOS digital-to-analog converters (DACs) is capable of 40MHz update rates while operating from supply voltages in the 2.7V to 3.3V range, consuming only 18mW at 3.0V. With the addition of four new dual DACs (two 8-bit and two 10-bit), the family now has 12 devices: 8- and 10-bit, dual and single, voltage- and current-output, each with a 50ppm/°C, low-noise reference.

Guaranteed monotonic, the DACs of this family deliver ±0.5LSB INL and DNL. The dual versions provide ±1% FSR gain and 0.15° phase matching in I/Q reconstruction (transmit) applications. When operating on 3V, their power consumption is four-times less than that of comparable devices. Two selectable idle modes lower the supply current to 1µA (max) when the application is inactive.

The four new dual devices include the current-output MAX5188 (8-bit) and MAX5182 (10-bit), and the voltage-output MAX5191 (8-bit) and MAX5185 (10-bit). Intended for applications that require less precise DAC timing, the new devices update their outputs *alternately* rather than simultaneously. Specifications and packages for the alternate and simultaneous parts are otherwise identical.

Single 8- and 10-bit DACs are also available. The 10-bit MAX5181 (current output) and MAX5184 (voltage output), for example, deliver the same dynamic performance as the corresponding dual versions at just 14mW power dissipation. Specified for the extended-industrial temperature range (-40°C to +80°C), the singles come in 24-pin QSOP packages and the duals in 28-pin QSOPs. Prices range from $2.73 for the single 8-bit MAX5187/MAX5190 to $4.41 for the dual 10-bit MAX5180/MAX5183 and MAX5182/MAX5185 (1000-up, FOB USA). Evaluation kits are available for $49.50.

Dual 12-bit V_{OUT} DACs have serial interface

The MAX5104 is a dual 12-bit DAC with serial input and voltage output. It operates on a single 5V supply, draws only 500µA of supply current, and features Rail-to-Rail® output swings. The output amplifiers maximize dynamic range with an internal gain of 2V/V. Settling time is 12µs.

The 3-wire serial interface is SPI™/QSPI™/MICROWIRE™ compatible. Each double-buffered DAC input consists of an input register followed by a DAC register, which allows the DAC to be updated with 16-bit serial words independently or simultaneously.

Other features include programmable power-down (2µA), hardware power-down lockout (PDL), a separate reference-voltage input (AC or DC) for each DAC, and an active-low clear input (CL) that resets all registers and DACs to zero. Each device includes an input for adjusting the digital-logic thresholds and a serial-data output pin for daisy-chaining.

The MAX5104 comes in a 16-pin QSOP package. Prices start at $3.75 (1000-up, FOB USA).

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

SPI and QSPI are trademarks of Motorola, Inc.

MICROWIRE is a trademark of National Semiconductor Corp.

Low-cost 14/16-bit DACs have serial inputs and voltage outputs

The 16-bit MAX5541 and 14-bit MAX5544 are serial-input, voltage-output DACs that operate on a single 5V supply and provide full-resolution performance without adjustments. The serial-data inputs are SPI/QSPI/MICROWIRE compatible, and the unbuffered voltage outputs are capable of driving 60kΩ loads. Ranging from 0V to the applied V_{REF}, the unbuffered outputs also allow low offset error (1LSB) and low supply current (0.3mA). Settling time is 1µs.

The double-buffered inputs consist of an input register followed by a DAC register and accept 16-bit digital words. Each device includes a power-on reset circuit that clears the DAC output to zero in the unipolar mode. For applications requiring galvanic isolation, the Schmitt-trigger inputs allow a direct interface to optocouplers.

The MAX5541/MAX5544 come in 8-pin SO packages, with prices starting at $4.20 (1000-up, FOB USA).

40µA rail-to-rail op amps sustain 95dB A_{VOL} with 10kΩ load

The MAX4076/MAX4077/MAX4078 single/dual/quad rail-to-rail op amps are open-loop versions of Maxim's low-power GainAmp™ amplifiers. Unlike other rail-to-rail op amps, these have a patented output architecture capable of driving a 10kΩ load while maintaining 95dB open-loop gain. They feature 230kHz gain-bandwidth products and draw 40µA supply currents. Operating from a single supply voltage between +2.5V and +5.5V, these op amps suit micropower applications that require wide output swings while maintaining excellent distortion and gain accuracy.

MAX4076/MAX4077/MAX4078 devices are unity-gain stable for load capacitance up to 100pF. They achieve 84dB total harmonic distortion at 1kHz. The dual and quad versions exhibit 90dB of crosstalk at 100kHz.

The MAX4076 comes in space-saving 5-pin SOT23 and 8-pin SO packages, the MAX4077 in 8-pin µMAX and SO packages, and the MAX4078 in 14-pin SO and 16-pin QSOP packages. Prices start at $0.60 (1000-up, FOB USA).

GainAmp is a trademark of Maxim Integrated Products.

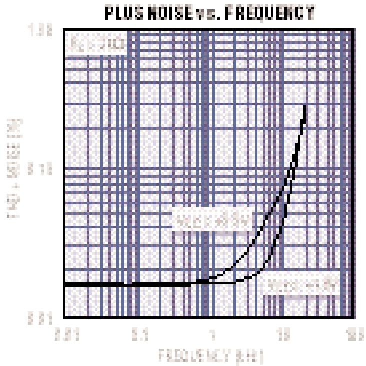
1.8V op amps deliver 120dB A_{VOL} and drive 2kΩ loads

The MAX4291/MAX4292/MAX4294 single/dual/quad op amps have rail-to-rail inputs and outputs. Operating from a single +1.8V to +5.5V supply, these op amps are ideal for 2-cell, low-power portable applications. A 100dB power-supply rejection ratio allows these devices to be powered directly from a single Li+ cell or from two to three NiCd, NiMH, or alkaline cells, without producing excessive output error as the cell voltage decays. Their robust three-stage design makes no compromise between specifications, size, and power.

The MAX4291/MAX4292/MAX4294 draw only 100µA of supply current per amplifier while achieving an open-loop gain of 120dB, even with a 2kΩ load. They exhibit a 500kHz gain-bandwidth product and are unity-gain stable for capacitive loads up to 100pF. Superior open-loop gain, excellent load-driving capability, and 400µV input offset voltage make these amplifiers well suited for buffering references.

The MAX4291 is offered in the tiny 5-pin SC70 and space-saving SOT23 packages. The MAX4292 is offered in space-saving 8-pin µMAX and SO packages. The MAX4294 is offered in miniature 14-pin TSSOP and SO packages. Prices start at $0.23 per amplifier (quad, 50,000-up, factory direct, FOB USA).

TOTAL HARMONIC DISTORTION PLUS NOISE vs. FREQUENCY

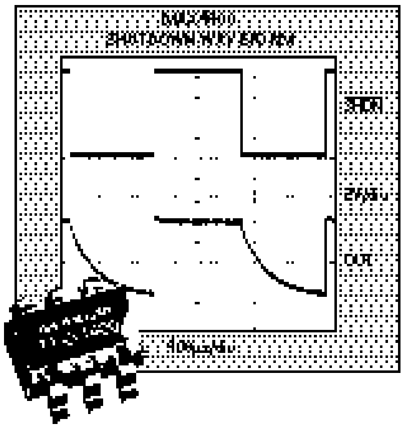


Rail-to-rail, 800kHz, SC70 op amp has 1µA shutdown

The MAX4400/MAX4401/MAX4402 rail-to-rail op amps draw only 320µA per amplifier while achieving an 800kHz gain-bandwidth product. The MAX4401 includes a low-power shutdown mode that reduces supply current to 1µA (max) and places its output in a high-impedance state. Ideal for portable and battery-powered applications, these op amps operate from a single +2.5V to +5.5V supply.

Applications that require wide output swings with good gain accuracy and low distortion benefit from the patented output architecture of the MAX4400/MAX4401/MAX4402. These op amps are capable of driving a 2kΩ load to within 55mV of each rail while maintaining a 110dB open-loop gain. They achieve 0.009% total harmonic distortion (THD) and are unity-gain-stable with capacitive loads up to 400pF.

The MAX4400 single op amp is available in 5-pin SC70 and SOT23 packages. The MAX4401 single op amp with shutdown is available in a 6-pin SC70 package. The MAX4402 dual op amp is available in 8-pin SOT23 and SOIC packages. All are specified over the automotive temperature range (-40°C to +125°C). Prices start at $0.33 (1000-up, FOB USA).



200MHz single-supply op amps in ultra-small, 5-pin SC70 packages

The MAX4450/MAX4451 are single/dual, low-power, 200MHz single-supply op amps in ultra-small SC70-5 and SOT23-8 packages, respectively. Combining single-supply operation, rail-to-rail outputs, wide bandwidth, and tiny footprints, they are ideal for a variety of wideband consumer applications, including set-top boxes, surveillance video systems, digital video cameras, and DVDs.

The MAX4450/MAX4451 operate from a single +4.5V to +11V supply or from dual ±2.25V to ±5.5V supplies. They achieve -3dB bandwidths of 200MHz and 485V/µs slew rates while drawing only 6.5mA of quiescent supply current per amplifier. In addition, they offer 0.1dB gain flatness to 55MHz, low differential gain/phase of 0.02%/0.08°, and an SFDR of -65dBc at 5MHz. The common-mode range includes ground, and their outputs swing rail-to-rail, making them highly suitable for low-voltage, single-supply applications.

The single MAX4450 is offered in 5-pin SC70 and SOT23 packages, and the dual MAX4451 is offered in 8-pin SOT23 and SO packages. Prices start at $0.41 per amplifier (dual, 50,000-up, FOB USA).

10V/µs, rail-to-rail I/O op amps in ultra-small packages

MAX4490/MAX4491/MAX4492 op amps—in miniature 5-pin SC70, 8-pin SOT23, and 14-pin TSSOP packages, respectively—are ideal for applications demanding the smallest possible board area. For single-supply applications (+2.7V to +5.5V), their rail-to-rail input/output (I/O) provides flexibility and dynamic range while simplifying circuit design. The combination of high slew rate (10V/µs), miniature packaging, and low-voltage operation makes these op amps ideal for portable applications such as RF power-amp control and audio amplification.

These op amps achieve 10MHz gain bandwidth products while drawing only 800µA of supply current per amplifier. Other features include low input bias current (50pA) and a 2kΩ output-drive capability. Sample/hold amplifiers and ADC predriver circuits benefit from the op amps' 300pF capacitive-load capability.

The single MAX4490 is available in ultra-small 5-pin SC70 and SOT23 packages. The dual MAX4491 is available in 8-pin SOT23 and SO packages, and the quad MAX4492 is available in the space-saving 14-pin TSSOP package. Prices start at $0.22/amplifier (100,000-up, FOB USA).

Tiny SOT23 package includes comparators and 6ppm/°C reference

The MAX9040/MAX9050 ICs include micropower comparators (with rail-to-rail inputs and outputs) and a precision reference in a 5-pin SOT23 package. Ideal for precision battery-voltage monitoring, these devices maximize battery life by eliminating the premature end-of-life readings common in low-accuracy voltage monitors. The MAX9040/MAX9050 also offer 0.4% initial accuracy ("A" grade only), 6ppm/°C temperature coefficients, and a fast (400ns) propagation delay while drawing only 40µA of supply current. The reference can drive 500µA and is stable with any capacitive load up to 4.7nF.

The MAX9040 operates from a single +2.5V to +5.5V supply and provides a +2.048V reference voltage, which produces a 500µV LSB in 12-bit systems. The MAX9050 operates from a single +2.7V to +5.5V supply and provides a +2.500V reference voltage. Both comparators feature internal hysteresis and crowbar current limiting, which lowers the supply current for high-frequency switching. Prices start at $0.82 for the "B" grade (50,000-up, FOB USA).

Analog switches guarantee 0.5Ω at +5V (world's lowest R_{ON})

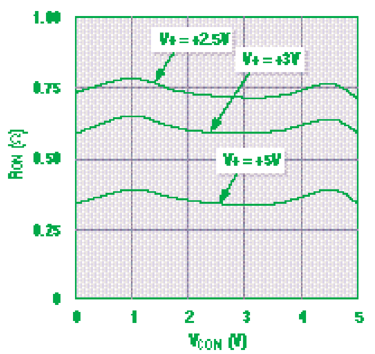
The MAX4624–MAX4628 low-voltage analog switches have the world's lowest on-resistance (R_{ON}). Maximum R_{ON} for the single-pole/single-throw (SPST) MAX4626/MAX4627/MAX4628 is only 0.5Ω at 5V. The single-pole/double-throw (SPDT) MAX4624/MAX4625 exhibit 1Ω max R_{ON} at +5V. R_{ON} flatness is 0.10Ω for the SPST devices and 0.15Ω for the SPDT parts. Because they operate from a single +1.8V to +5.5V supply, all are suitable for use in portable equipment.

These switches are also ideal as low-voltage relay replacements. Maximum continuous current through the SPST switches is ±400mA, with a peak of ±800mA (pulsed at 1ms, with a 10% maximum duty cycle). Overcurrent protection prevents damage from short circuits and excessive loads.

The MAX4626 is normally open (NO), the MAX4627 is normally closed (NC), and the MAX4628 has one NO and one NC switch. The MAX4624 is break-before-make, and the MAX4625 is make-before-break. For 5V operation, all feature TTL/CMOS-logic compatibility and fast switching (50ns t_{ON} and 50ns t_{OFF}).

The MAX4624/MAX4625/MAX4628 are available in 6-pin SOT23 packages, and the MAX4626/MAX4627 are available in 5-pin SOT23 packages. Prices start at $0.95 for the MAX4624/MAX4625/MAX4628 and $0.90 for the MAX4626/MAX4627 (2500-up, FOB USA).

ON-RESISTANCE vs. COM VOLTAGE



Single 4-to-1/ dual 2-to-1 muxes feature rail-to-rail fault protection

The MAX4534 (single 4-to-1) and MAX4535 (dual 2-to-1) fault-protected multiplexers operate with dual ±4.5V to ±20V supplies or a single 9V to 36V supply. All analog inputs are protected to ±40V with power off and to ±25V with ±15V supply voltages applied. The typical fault-response time is 20ns.

All on-resistances are 400Ω (max), matched (within a device) to within 10Ω (max). Each channel has rail-to-rail signal-handling capability, with overvoltage clamping (to the appropriate supply rail) at 150mV beyond the rails. All channels are open (off) when power is off, and all digital inputs guarantee TTL/CMOS compatibility for +12V or ±15V supplies.

Available packages include the 14-pin TSSOP, narrow SO, and plastic DIP. MAX4534/MAX4535 prices start at $1.70 (1000-up, FOB USA).

Single-supply SPDT analog switch in tiny SC70 package

The MAX4599 is a single-pole/double-throw (SPDT) analog switch that operates on a single +2.0V to +5.5V supply. It offers 60Ω (max) R_{ON} at 5V and fast switching (t_{ON} = 30ns max, t_{OFF} = 25ns max).

R_{ON} is flat to within 4Ω (max) and matches to within 1Ω (max) for channels within a device. Other specifications include 5pC maximum charge injection, a -3dB bandwidth of 200MHz, ±5nA leakage at +25°C, break-before-make switching, -76dB off-isolation at 1MHz, and 0.12% THD.

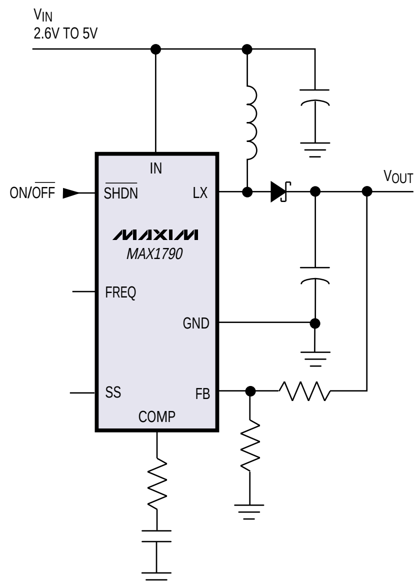
Package options include the tiny 6-pin SC70 and SOT23. Prices start at $0.56 (2500-up, FOB USA).

Low-noise step-up converter is 90% efficient

The MAX1790 DC-DC boost converter is a 90% efficient regulator with fast response. It includes fixed-frequency, current-mode, PWM circuitry, and a 0.21Ω, 1.6A/14V N-channel MOSFET.

High switching frequency (pin-selectable as 640kHz or 1.2MHz) allows easy filtering and faster loop performance. This feature, combined with an external compensation pin that provides flexibility in determining loop dynamics, enables the use of small, low-ESR ceramic output capacitors. The MAX1790 derives output voltages as high as 12V from inputs as low as 2.6V.

Soft-start capability is programmed with an external capacitor that sets the input-current ramp rate, and shutdown mode lowers supply current to 0.1μA. The MAX1790 comes in a space-saving 8-pin μMAX package. The ultra-small package and high switching frequency allow the total solution to be less than 1.1mm high. Prices start at $2.79 (1000-up, FOB USA).



High-efficiency current source drives white-LED backlighting

The MAX1698 is a switch-mode step-up controller that regulates LED current at power levels up to 5W. It's the most efficient driver available for the chains of white or colored LEDs used in backlit displays for PDAs, digital cameras, and laptop computers. When combined with white LEDs, the MAX1698 offers greater simplicity, lower cost, higher efficiency, longer bulb life, and greater reliability than is available in displays using fluorescent (CCFL) and electroluminescent (EL) lamps.

More than 90% efficient, the MAX1698 minimizes loss with a low, 300mV current-sense threshold. A sense resistor (15Ω typ) sets the current through a primary chain of LEDs. An equivalent resistor lets you add chains of matching LEDs that closely match the primary chain. Control and dimming of the LED current are accomplished with the adjust pin rather than high-value current-limiting resistors, which dissipate power and lower efficiency. The MAX1698 also includes a soft-start circuit that eliminates input-current surges at turn-on.

The MAX1698EUB comes in a small 10-pin µMAX package only 1.09mm high, which occupies half the area of an 8-pin SO, specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $1.40 (1000-up, FOB USA). A fully assembled evaluation kit (MAX1698-EVKIT) is available to help speed designs.

Dynamically adjustable synchronous step-down controller powers Intel's SpeedStep notebook CPUs

The MAX1717 buck controller features a dynamically adjustable output, ultra-fast transient response, ±1% DC accuracy, and the high efficiency needed to power leading-edge CPU cores. Maxim's proprietary, constant-on-time PWM control (Quick-PWM™) handles wide ratios of input/output voltage with ease and provides a 100ns instant-on response to load transients while maintaining a near-constant switching frequency. The MAX1717 has been optimized for ICs with two or more operational modes, e.g., CPUs with SpeedStep™ or Gemini™ technology.

Output voltage can be dynamically adjusted from 0.9V to 2V through the 5-bit DAC inputs, and the output slew-rate control minimizes battery and inductor surge currents. This slew-rate control can be tailored to a given application, providing a just-in-time arrival at the new DAC setting. An internal multiplexer uses only five digital input pins to accept two 5-bit DAC settings.

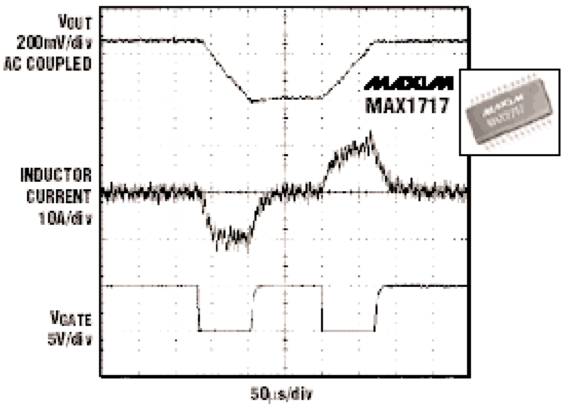
The MAX1717 comes in a 24-pin QSOP package specified for the extended temperature range (-40°C to +85°C). Prices start at $3.89 (1000-up, FOB USA). A preassembled evaluation kit with recommended external components (MAX1717-EVKIT) is available to reduce design time.

Quick-PWM is a trademark of Maxim Integrated Products.

SpeedStep is a trademark of Intel Corp.

Gemini is a trademark of Advanced Micro Devices.

DYNAMIC OUTPUT VOLTAGE TRANSITION



Ultra-high-efficiency dual buck controller powers next-generation notebook CPUs

The MAX1715 dual PWM step-down controller provides the high efficiency, excellent transient response, and high DC-output accuracy needed in stepping down from high battery voltage to the lower chipset and RAM voltages required in notebook computers.

The chip includes a free-running, constant-on-time, on-demand PWM controller with input feed-forward. Its control algorithm provides ultra-fast transient response, a wide differential input-output range, low supply current, and tight load regulation. The resulting IC is simple, easy to compensate, and not subject to the noise sensitivity of conventional fixed-frequency current-mode PWMs.

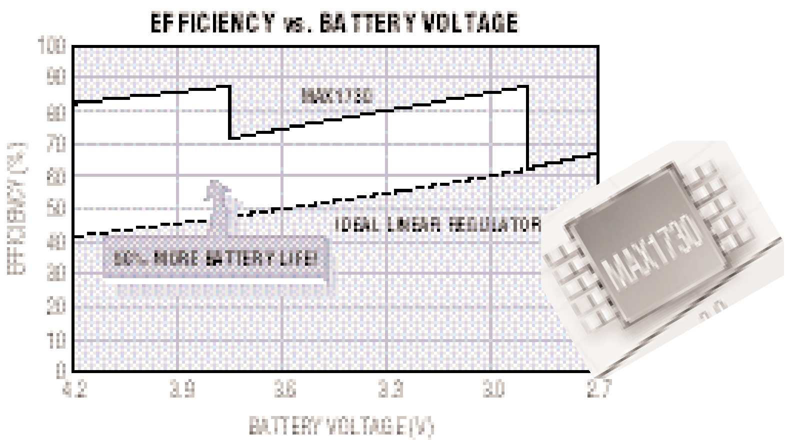
The MAX1715 was designed to generate the low supply voltages required for CPU core and I/O, or 1.8V chipsets and 2.5V RAM. It comes in a small 28-pin QSOP package specified for the extended temperature range (-40°C to +85°C). Prices start at $3.60 (1000-up, FOB USA). A preassembled evaluation kit (MAX1715EVKIT) with recommended external components is available to reduce design time.

Smallest step-down DC-DC for 1.8V logic achieves 87% peak efficiency with no inductor

The MAX1730 regulated charge-pump step-down converter generates a fixed 1.8V or 1.9V output voltage from a +2.7V to +5.5V input. Typical applications generate a 1.8V core logic supply from a 3.6V Li+ battery. The MAX1730 needs no inductor. Its fractional-conversion technique performs DC-DC conversion with efficiency much greater than that of a linear regulator, yet with minimal increase in package size. Maximum efficiency for an ideal linear regulator in this application can be less than 50%, but the MAX1730 extends battery life with an efficiency exceeding 80%.

Switching frequencies up to 2MHz not only enable the use of small flying capacitors (0.22µF), they allow the entire circuit to fit in just $0.05in^2$ ($32mm^2$). Quiescent supply current is a low 75µA. In shutdown, the supply current drops to less than 1µA, and the output disconnects from the input. A proprietary soft-start circuit prevents excessive inrush current from the input supply during startup, making the MAX1730 compatible with sources of higher output impedance, such as alkaline and Li+ batteries.

The MAX1730EUB comes in a small 10-pin µMAX package only 1.09mm high and half the area of an 8-pin SO, specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $1.45 (1000-up, FOB USA).



Li+ battery-pack protector blocks voltage and charge faults

The MAX1665 provides complete protection for Li+ battery packs (with 2, 3, or 4 cells in series) against overvoltage, undervoltage, cell shorts, overcharging, and overdischarge current. By controlling external N-channel MOSFETs, the internal power-MOSFET drivers reliably disconnect the cells from the pack terminals when a fault condition occurs, simplifying the design of battery-pack safety circuitry; you just select the power MOSFETs and connect the Li+ cells.

The MAX1665 connects directly to battery voltages as high as 20V without an external linear regulator and features a ±1% accurate, factory-trimmed, 4.3V overvoltage threshold limit. It is also a “micropower” device, drawing less than 1µA in shutdown and only 15µA in operation. MAX1665 applications do not require an external current-sense resistor. Instead, overcurrent detection is accomplished by monitoring the voltage drop across both N-channel protection MOSFETs.

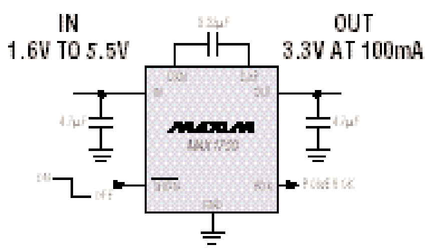
The MAX1665S protects two series cells, the MAX1665V three series cells, and the MAX1665X four series cells. All are available in 8-pin narrow SO packages specified for the extended industrial temperature range (-40°C to +85°C). Prices for the 4-cell protector start at $1.55 (1000-up, FOB USA).

3.3V, $0.05in^2$ buck/boost charge pump delivers 100mA

The MAX1759 regulated charge-pump converter generates an adjustable or fixed (3.3V) output voltage from a +1.6V to +5.5V input. This capability is useful for Li+ battery inputs, which can be at 4.2V when fully charged and below 2.9V when nearly discharged. The MAX1759’s ability to maintain its regulated output voltage whether the input is above or below that level is unique among charge-pump converters. It guarantees 100mA output currents without an inductor, with only three small ceramic capacitors. The entire circuit fits in $0.05in^2$ ($32mm^2$).

Quiescent supply current is a low 50µA and drops to 1µA in shutdown. Unlike more typical step-up converters, the load is completely disconnected from the input during shutdown. The MAX1759 operates up to 1.5MHz, allowing high output current with very small external capacitors. An open-drain power-OK output signals when the output is out of regulation.

Foldback short-circuit protection limits output current when the output is shorted to ground. The chip also includes soft-start circuitry that limits the inrush current during power-up. The MAX1759EUB is specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $2.45 (1000-up, FOB USA).



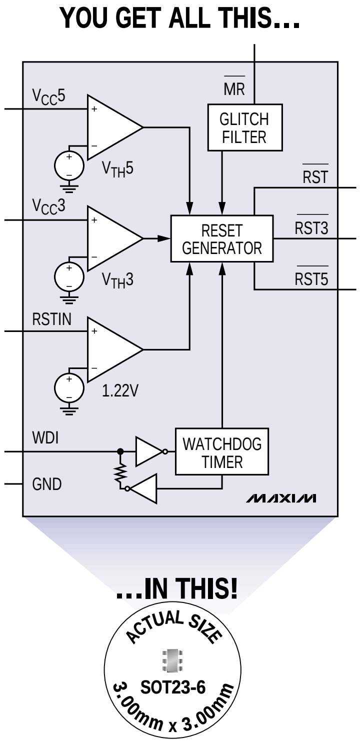
µP supervisors monitor three supply voltages

The MAX6351–MAX6360 microprocessor (µP) supervisors each monitor two to three supply voltages simultaneously. These IC supervisors provide substantial improvements in accuracy and system reliability over comparable discrete-component circuits. They draw supply currents of only 20µA and maintain valid outputs for as long as any monitored voltage remains above 1V.

Each IC asserts its reset outputs (3V logic, 5V logic, or both) when any monitored voltage falls below its reset threshold. (The user selects from a variety of factory-set, precision threshold voltages associated with 2.5V, 3V, 3.3V, or 5V power supplies.) Available in small 5- or 6-pin SOT23 packages, all devices include an active-low, TTL/CMOS-compatible, debounced manual-reset input.

The MAX6358/MAX6359/MAX6360 include a watchdog timer for monitoring software execution. They provide a 46.4s timeout at startup and 2.9s timeouts thereafter. The MAX6355/MAX6356/MAX6357 provide a third user-adjustable voltage monitor in place of the watchdog timer. The available reset outputs include 3V and 5V active-low push-pull and active-low open-drain. The MAX6351 provides two reset outputs.

All devices operate over the extended-industrial temperature range (-40°C to +85°C). Prices start at $1.38 (2500-up, FOB USA).



Industry-standard power-on reset ICs now in SC70 packages

MAX803/MAX809/MAX810 µP-supervisory circuits are designed to monitor +2.5V to +5.0V supply rails in digital and µP systems. Besides reducing cost and eliminating external components and adjustments, these devices are the first fully integrated power-on reset ICs available in a 3-pin SC70 package, which is half the size of the SOT package. Supply current (12µA) is 30% lower than that of existing devices.

These ICs offer ±2.5% reset threshold accuracy over temperature. When supply voltage falls below the preselected threshold, the IC asserts and maintains a reset signal for at least 140ms after V_{CC} returns above the threshold. The available reset outputs (guaranteed valid to 1.0V) are open-drain active-low (MAX803), push-pull active-low (MAX809), and push-pull active-high (MAX810).

The MAX803/MAX809/MAX810 come in a 3-pin SC70 package, with prices starting at $0.94 (2500 or 10,000 minimum, FOB USA).

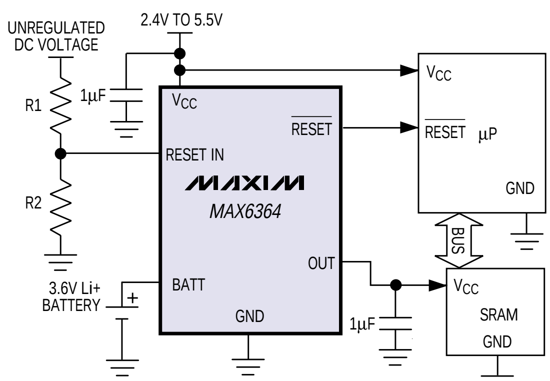
Backup-battery reset ICs offered in SOT packages

MAX6361/MAX6363/MAX6364 µP-supervisory circuits are designed to monitor +2.5V to +5.0V supply rails in digital and µP systems. Besides reducing cost and eliminating external components and adjustments, these devices are the first ICs to combine reset and backup-battery switchover in SOT packages, which are ≈70% smaller than currently available alternatives.

The MAX6361/MAX6363/MAX6364 ICs feature ±2.5% reset threshold accuracy over temperature. They automatically switch RAM memory to the backup power when V_{CC} falls below the reset threshold and the backup battery voltage. When the supply voltage declines below the reset threshold, a reset signal is asserted and maintained for at least 150ms after V_{CC} returns above the reset threshold.

Each device is offered with a push-pull active-low, push-pull active-high, or open-drain active-low reset output guaranteed valid to 1.0V. Other available features include a manual reset input (MAX6361), a battery-on output indicator (MAX6363), and an auxiliary user-adjustable reset input (MAX6364). Supply current for all three devices is only 10µA.

MAX6361/MAX6363/MAX6364 devices are available in a 6-pin SOT package, with prices starting at $1.50 (2500 minimum, FOB USA).



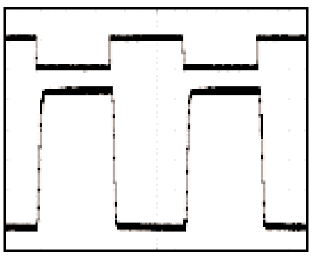
±15kV ESD-protected RS-232 transmitters in SOT packages

The MAX3188E/MAX3189E single RS-232 transmitters are designed for space and cost-constrained applications requiring minimal RS-232 communications. To ensure component compliance with strict European ESD standards, the transmitter input is protected to ±15kV using IEC 1000-4-2 Air-Gap Discharge, to ±8kV using IEC 1000-4-2 Contact Discharge, and to ±15kV using the Human Body Model.

Power consumption and heat dissipation are minimized by the devices' low supply current (only 1µA from a ±4.5V to ±6.0V supply). They guarantee RS-232 compliant performance for data rates up to 250kbps for the MAX3188E, and up to 1Mbps for the MAX3189E. The MAX3188E/MAX3189E have three-state transmitter outputs and can be run off the charge pump of more than 50 RS-232 devices from Maxim. To save space and increase design flexibility, the transmitters can be combined with a SOT receiver from Maxim's MAX3180E line, forming a complete SOT-package RS-232 transceiver.

The MAX3188E/MAX3189E are available in a 6-pin SOT23 package specified for the extended temperature range (-40°C to +85°C). Prices start at $0.55 (1000-up, FOB USA).

True RS-232 Operation at 1Mbps



2.5V/1µA RS-232 devices protect against ESD to ±15kV

The MAX3316E–MAX3319E RS-232 transceivers are designed for low-voltage systems, delivering RS-232 performance from a single +2.5V supply. To ensure compliance with strict European ESD standards, the RS-232 inputs and outputs are protected to ±15kV using IEC 1000-4-2 Air-Gap Discharge, to ±8kV using IEC 1000-4-2 Contact Discharge, and to ±15kV using the Human Body Model.

To minimize power and heat dissipation, the devices employ Maxim's revolutionary AutoShutdown Plus™ to draw only 1µA of supply current from a +2.25V to +3.0V source. They guarantee RS-232 performance for data rates up to 460kbps. The MAX3318E/MAX3319E feature a logic-level output (READY) that asserts when the charge pump is regulating and the device is ready to begin transmitting.

The MAX3316E family is available in TSSOP and SSOP packages specified for the commercial or extended temperature ranges. Prices start at $2.24 (100-up, FOB USA).

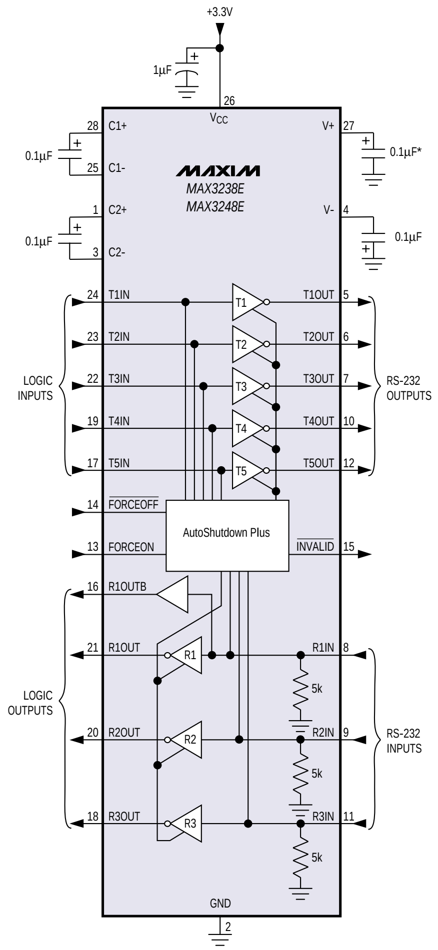
AutoShutdown Plus is a trademark of Maxim Integrated Products.

World's first 5Tx/3Rx RS-232 transceivers with ±15KV ESD protection on all I/O pins

MAX3237E/MAX3238E/MAX3248E RS-232 transceivers are complementary serial ports with five transmitters and three receivers, which makes them ideal for cell-phone data cables, modems, set-top boxes, and other devices requiring RS-232 compliant communications. All input and output pins (RS-232 and logic pins included) have integrated ESD structures that protect the device to ±15kV using the Human Body Model, to ±15KV using the IEC 1000-4-2 Contact Discharge method, and to ±4kV using the IEC 1000-4-2 Air-Gap Discharge method.

The devices' AutoShutdown Plus and low supply current (only 10nA from a 3.0V to 5.5V supply) minimize power and heat dissipation. The MAX3237E guarantees RS-232 compliant performance for data rates up to 1.0Mbps, and the MAX3238E/MAX3248E transmit RS-232 compliant data up to 250kbps. The MAX3248E operates with logic levels as low as 1.8V, which eliminates the need for level shifters in low-voltage logic systems.

MAX3237E receivers can be active or inactive in shutdown, but the MAX3238E/MAX3248E transceivers have a continuously active extra receiver for monitoring the ring indicator. All three devices come in an SSOP package, specified for the commercial (0°C to +70°C) or extended (-40°C to +85°C) temperature range. Prices start at $3.87 (1000-up, FOB USA).



*C3 MAY BE RETURNED TO EITHER V_{CC} OR GND.

Octal serial-parallel I/O expander suits SMBus systems

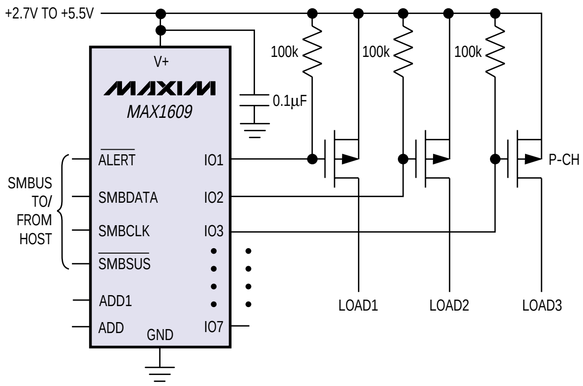
The MAX1608/MAX1609 I/O expanders are designed to provide remote I/O expansion through an SMBus™ serial interface. Each has eight high-voltage, open-drain outputs that also provide bidirectional capability by serving as TTL-compatible logic inputs. Typical applications include high-side MOSFET load-switch drivers in power-management systems, pushbutton switch monitors, and general-purpose I/Os.

The eight I/Os are continuously monitored and can be used as inputs. Two internal 8-bit latches allow the outputs to be toggled using the SMBus suspend input, without the inherent latency associated with reprogramming inputs and outputs through the serial bus.

The MAX1608 outputs, low at power-up, are intended for driving N-channel MOSFETs. MAX1609 outputs, in the high-impedance state at power-up, are intended for driving P-channel MOSFETs. These output conditions enable power-plane sequencing by ensuring that the MOSFETs are off at power-up.

Other features include thermal-overload and output-overcurrent protection, a wide supply voltage range (2.7V to 5.5V), and ultra-low supply current. An evaluation kit (MAX1608EVKIT) is available to speed the design cycle. The MAX1608/MAX1609 come in a space-saving 16-pin QSOP package, priced from $2.61 (1000-up, FOB USA).

SMBus is a trademark of Intel Corp.



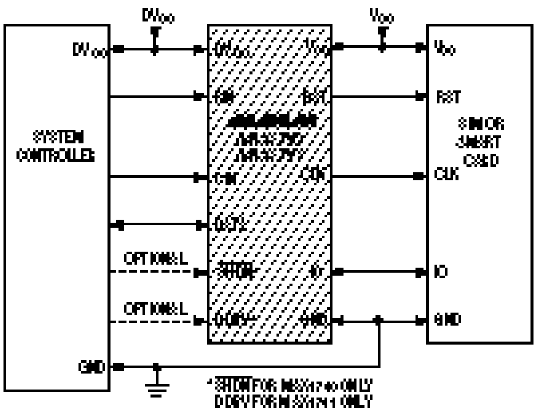
World's smallest SIM/smart-card interfaces operate below 1.5V

The MAX1740/MAX1741 SIM/smart-card level translators provide level shifting and ESD protection for smart-card and subscriber identification module (SIM) ports. The devices integrate two unidirectional level shifters for the reset and clock signals, a bidirectional level shifter for the serial data stream, and ±10kV ESD protection on all card contacts.

For maximum flexibility, the level shifters translate between any two logic voltages in the 1.425V to 5.5V range. The translators form an ideal interface between system controllers and plug-in cards with 1.8V, 2.5V, 3.3V, or 5V logic levels. To prolong battery life, the quiescent current is a low 1µA and drops to only 0.1µA during shutdown.

The MAX1740 includes a shutdown-control pin to aid card insertion and removal, and the MAX1741 includes a system-side data driver to support microcontrollers (µCs) without open-drain drivers. Both devices simplify power management by automatically shutting down when power for the system or card is removed. These devices may be combined with the MAX1686H regulated charge pump, which provides SIM/smart-card power by generating 0V/3V/5V from a +3V supply.

The MAX1740EUB/MAX1741EUB come in a small 10-pin µMAX package, which occupies half the area of an 8-pin SO and is only 1.09mm high, specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $1.45 (1000-up, FOB USA). An evaluation kit (MAX1741EVKIT) is available to help speed designs.



Signal conditioner enables highly accurate sensors and 4–20mA output

The MAX1459 signal conditioner compensates for the nonlinearities of piezoresistive transducers over a wide temperature range (-40°C to +125°C), using user-programmed compensation coefficients stored in the IC's internal EEPROM. The MAX1459 also features an uncommitted op amp that can be easily configured to provide a 4–20mA loop interface or the automotive diagnostic clip features required in today's automotive systems. In addition to piezotransducers, the MAX1459 can compensate nonbulk micromachined sensors, strain gauges, and similar resistive-based sensors.

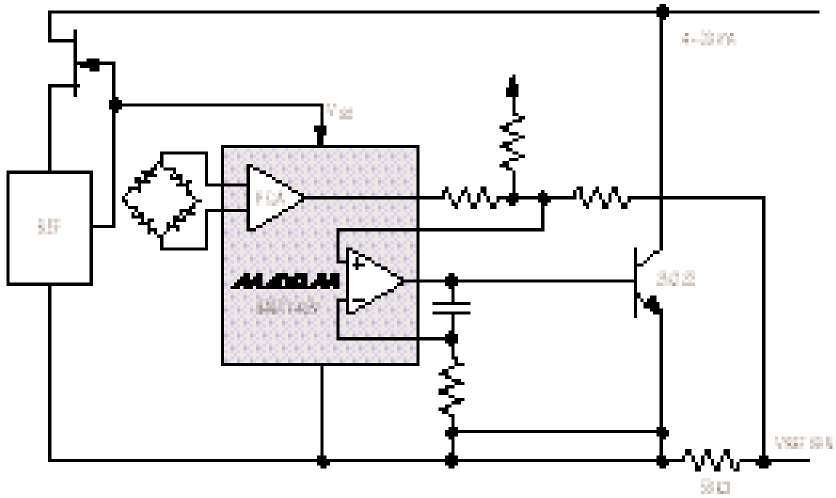
The MAX1459's electronic trimming simplifies sensor-module manufacturing by eliminating the need for laser trimming and other manual content in production. It also allows efficient production flow by consolidating the manufacturing steps of pretest, calibration, compensation, and final test. To speed development and improve time to market, the MAX1459 is supported by Maxim's Pilot Production System, which allows users to quickly set up a manufacturing line. Running under LabVIEW™, a single Pilot Production System can program up to 110 sensor modules simultaneously. This system is free to users who commit to the purchase of more than 10,000 units per year and is available for lease to lower-volume users.

The MAX1459 includes a complete analog signal path and four 12-bit DACs for integrated digital correction. The DACs are user-programmed to correct for span, span TC, offset, and offset TC. A fifth low-resolution DAC can adjust for course offset. All can be programmed through a digital interface, and the correction coefficients can be stored in the chip's internal EEPROM.

The MAX1459 was designed with a dedicated cell library of more than 200 sensor-specific functional blocks, including low-power op amps, integrated temperature sensors, and DSP engines. For high-volume applications, Maxim can quickly customize the MAX1459 to optimize price and performance. Please contact Maxim for more details.

The MAX1459 joins a family of sensor-conditioning circuits ranging from the low-cost, laser-trimmed MAX1450 to the fully digital MAX1460. The MAX1459 comes in a space-saving 20-pin SSOP package. Prices start at $2.95 (1000-up, FOB USA).

LabVIEW is a trademark of National Instruments.

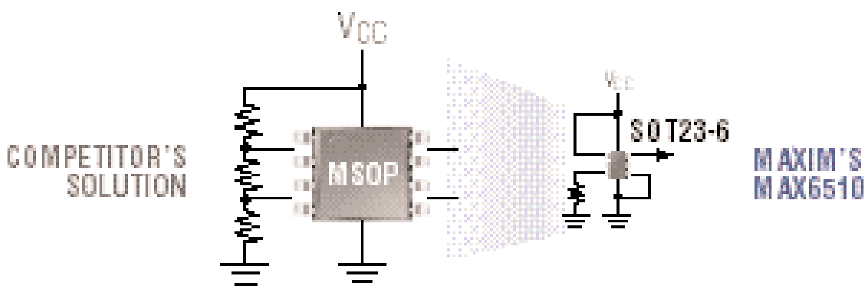


Resistor-programmable temperature switches combine flexibility with simplicity

The MAX6509/MAX6510 temperature switches are the newest additions to the most complete line of such devices in the industry. These two devices are the smallest resistor-programmable temperature comparators available today.

One external resistor sets the temperature threshold between -40°C and +125°C. Trip-point accuracy is ±0.5°C (typ) and ±4°C (max) over the -40°C to +125°C temperature range. Hysteresis is pin-selectable at 2°C or 10°C. These low-power devices operate from a +2.7V to +5.5V supply, making them ideal for use in portable and space-constrained environments.

The MAX6509 is available in a 5-pin SOT23 package and has an open-drain output. The MAX6510, available in a 6-pin SOT23 package, has an output programmable as active-high, active-low, or open-drain with internal pullup. Both have versions whose outputs become active as the temperature rises above its threshold (SET HOT) or falls below its threshold (SET COLD). Prices start at $0.70 for the MAX6509 and $0.72 for the MAX6510 (1000-up, FOB USA).

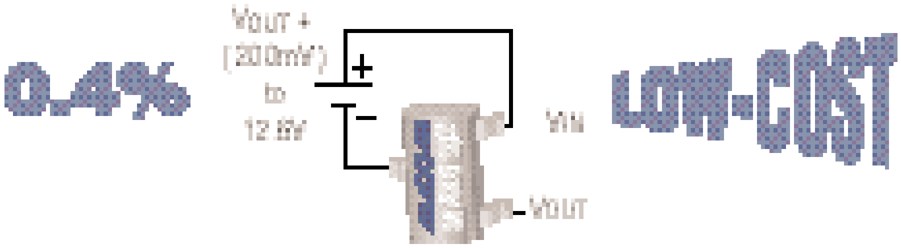


0.5%, SOT23 series references at shunt-reference prices

The MAX6101–MAX6105 family of low-cost, low-dropout, low-power, series-mode voltage references are available in a 3-pin SOT23 package. Intended for cost-sensitive portable power systems requiring precision and small size, their proprietary curvature-correction circuits and laser-trimmed thin-film resistors provide 0.4% initial accuracy along with a 75ppm/°C temperature coefficient over the extended-industrial temperature range (-40°C to +85°C).

Although they draw only 150µA of supply current, these internally compensated references can source 5mA and sink 2mA of load current. Unlike conventional shunt-mode (two-terminal) references, the MAX6101–MAX6105 have supply currents virtually independent of supply voltage, and they require no external resistor. Furthermore, they require no external capacitor and are stable for load capacitances up to 1µF.

MAX6101–MAX6105 references accept input voltages from (V_{OUT} + 200mV) to 12.6V and offer voltage options of 1.25V, 2.5V, 3V, 4.096V, and 5V. Prices start at $0.55 (1000-up, FOB USA).

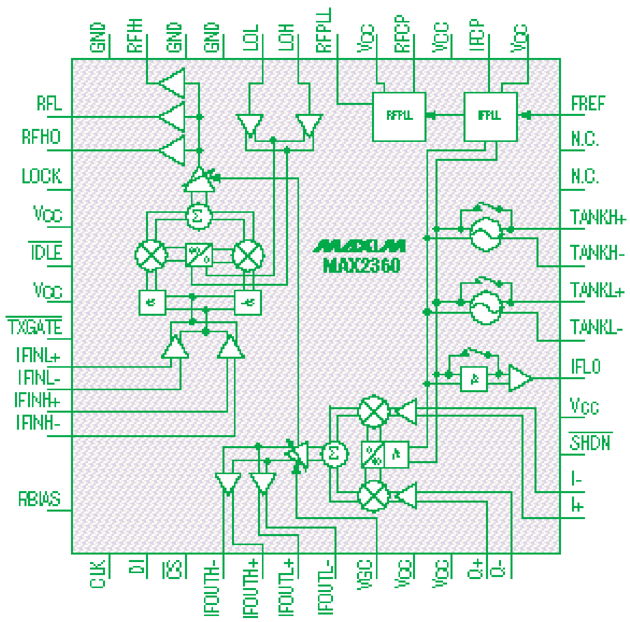


Highly integrated transmitter ICs serve dual-band cellular phones

The MAX2360/MAX2362/MAX2364 ICs contain complete baseband-to-PA transmitters for dual-band cellular phones. Designed for use in dual-band, tri-mode, and single-mode cellular phones, they are compatible with N-CDMA, TDMA, EDGE, and W-CDMA systems. High-level integration in these ICs dramatically reduces the size and number of components.

The MAX2360 includes an I/Q modulator, IF VGA, dual IF VCOs, upconverters, dual synthesizers, RF VGA, and three RF power-amplifier drivers. The MAX2360's high level of linear output power (+7dBm) allows it to drive the power amplifiers directly. Because of the image-reject upconverters, two SAW filters and two external PA drivers can be eliminated. These devices' wide frequency range and dual IF ports are ideal for a variety of dual-band and dual-mode radio architectures.

The MAX2360 dual-band transmitter fits applications such as CDMA, TDMA, and EDGE dual-band phones. The MAX2362 suits single-band PCS and W-CDMA applications, and the MAX2364 suits single-band, dual-mode cellular applications. All are available in a 48-pin TQFP package. Prices start at $5.85 (1000-up, FOB USA).



3.5GHz, SiGe active mixers deliver +11dBm IP3 performance

The MAX2683/MAX2684 SiGe mixers are the first active mixers to provide high IP3 performance. Until now, high IP3 performance has been achieved only with expensive and bulky passive mixers that exhibit 6dB insertion loss (typ) and require high-level drive for the LO inputs. The MAX2683/MAX2684 match the IP3 performance of passive mixers but reduce cost by 40% and board space by 80%. They deliver up to +11dBm IP3 at 3.5GHz, 10dB higher than other active mixers. To allow the setting of minimum IP3 performance without wasting supply current, the IP3 value is user-programmable with an external bias resistor.

An on-chip LO buffer and filter provide 37dB isolation between the LO and RF ports, 20dB better than that obtained in passive-mixer designs. The improved isolation helps to reduce front-end filter complexity and cost. These mixers are ideal for use in wireless local loop (WLL), wireless broadband access, and digital microwave radios.

Both devices operate with RF input frequencies between 3.4GHz and 3.8GHz. IF frequencies range from 100MHz to 400MHz (MAX2683) and from 800MHz to 1000MHz (MAX2684). At 3.5GHz, the conversion gain is 6dB for the MAX2683 and 1dB for the MAX2684. The LO input can be injected at full or half frequency. For the half-frequency input, a logic-enabled doubler increases the LO signal to full frequency. An internal LO filter reduces LO harmonics and mixer spurious products.

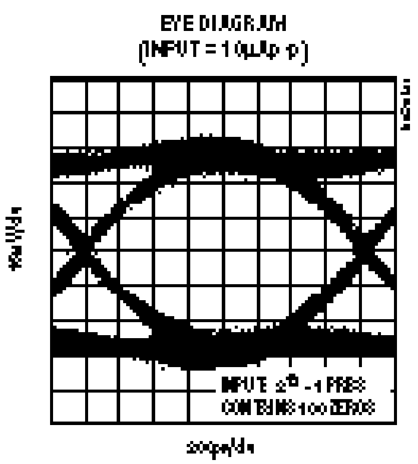
The MAX2683/MAX2684 operate from a single 2.7V to 5.5V supply. Both are available in a 16-pin TSSOP package, with an exposed paddle for optimum performance at 3.5GHz. Prices start at $1.90 (1000-up, FOB USA). Fully assembled evaluation kits (MAX2683-EVKIT/MAX2684EVKIT) are available to help reduce design time.

3V, 622Mbps, low-power transimpedance amplifier provides high sensitivity

The MAX3665 transimpedance amplifier for SDH/SONET applications features 3.3V, 622Mbps operation and ultra-low power consumption. It was designed for PIN-photodiode preamplifiers and receivers in SDH/SONET OC-12 transmission systems. When combined with the MAX3681 1:4 deserializer and the MAX3676 CDR and limiting amplifier, the MAX3665 forms a complete, high-performance 622Mbps receiver.

The MAX3665 converts small photodiode currents to a measurable differential voltage. Operating from a single +3.3V to +5.0V supply, it consumes only 70mW of power at 3.3V. The overall transimpedance gain is nominally 8kΩ, with a bandwidth of 470MHz. For 1300nm, 622Mbps receivers, the MAX3665's low input noise ($55nA_{RMS}$) provides a typical sensitivity of -33.2dBm. Its DC-cancellation circuit reduces pulse-width distortion by providing true differential output swings over a wide range of input current levels. Typical deterministic jitter is just 100ps. The differential outputs are back-terminated with 50Ω per side.

Available as dice and in an 8-pin µMAX package specified for the extended temperature range (-40°C to +85°C), the MAX3665E/D is priced from $5.80 (1000-up, FOB USA). Evaluation kits are available to reduce design time.



Direct I/Q transmitters for broadband wireless are highly integrated

The MAX2720/MAX2721 are the industry's most highly integrated direct I/Q transmitters for broadband wireless applications. Operating from 1.7GHz to 2.5GHz, they include differential amplifiers for modulation inputs, two matched double-balanced mixers, a selectable LO doubler, LO buffer, wideband 90° quadrature generator, RF variable-gain amplifier (VGA) with 35dB control range, and +13dBm PA driver amplifier.

Compared with traditional IF-based designs, the direct-conversion approach eliminates an IF SAW filter, VCO, PLL, and upconverter (i.e., one IF stage). This simplification reduces component costs by 35% and board space by 50%. The MAX2720/MAX2721 are ideal for applications in wideband CDMA systems, wireless local loops, PCS/DCS basestations, LMDS/MMDS, and 2.4GHz broadband ISM-band radios.

The MAX2720 converts baseband signals directly to RF outputs in the 1.7GHz to 2.1GHz frequency range. The MAX2721 output range is 2.1GHz to 2.5GHz. A logic-enabled frequency doubler allows the user to inject the LO signal at half frequency, resulting in a 33dB carrier suppression. The I/Q inputs are amplitude matched to within ±0.2dB and phase matched to within ±1°. Excellent amplitude and phase matching results in sideband suppression of 40dB at 1.9GHz (MAX2720) and 35dB at 2.3GHz (MAX2721).

To help reduce transmitter noise at the RF output, I/O pins are available for insertion of a bandpass filter between the VGA output and the PA driver input. The MAX2720/MAX2721 transmitters offer a low-power shutdown mode and 2.7V to 3.3V single-supply operation. Both devices are available in 20-pin TSSOP packages, with an exposed paddle. Prices start at $4.55 (1000-up, FOB USA). Fully assembled evaluation kits (MAX2720EVKIT/MAX2721EVKIT) are available to help reduce design time.

2.125Gbps, 3.3V Fibre Channel repeaters tolerate 0.7UI jitter

The MAX3770/MAX3771 repeaters serve Fibre Channel arbitrated-loop applications in storage systems, disk arrays, hubs, and switches. The 2.125Gbps MAX3770 and the 1.0625Gbps MAX3771 tolerate total input jitter of 0.7UI, and operate without need for a reference clock. The devices' outputs have only 0.10UI jitter.

All inputs and outputs have internally terminated current-mode logic that provides low jitter and is tolerant of mismatched circuit board traces and inductive connectors. The MAX3770/MAX3771 repeaters provide outputs for the recovered clock and a PLL lock indicator.

Both devices come in small 16-pin QSOP packages and operate from a +3.3V supply. The MAX3770 consumes 215mW, and the MAX3771 consumes 190mW. Prices start at $3.95 for the MAX3771 and at $8.55 for the MAX3770 (1000-up, FOB USA).

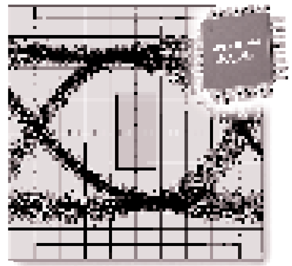
3.3V, 2.5Gbps laser driver includes current monitors and APC

The MAX3869 is a 3.3V, 2.5Gbps SDH/SONET laser driver with current monitors and automatic power control (APC). It is ideal for applications in 2.5Gbps SDH/SONET transmission systems such as add/drop multiplexers, digital cross-connects, section regenerators, and optical transmitters. When combined with the MAX3890 16:1 serializer, the MAX3869 forms a complete, low-power 2.5Gbps transmitter.

The MAX3869 requires only 211mW of power. It accepts differential PECL data and clock inputs while providing bias and modulation currents for driving a laser. An APC feedback loop is incorporated to maintain constant average optical power vs. temperature and lifetime. The chip includes bias- and modulation-current monitors that are directly proportional to the laser bias and modulation currents. The MAX3869 also provides enable control and a failure-monitor output to indicate when the APC loop is unable to maintain the average optical power. Ease of programming both the wide modulation-current range (5mA to 60mA) and the bias-current range (1mA to 100mA) make this device ideal for use in a variety of SDH/SONET applications.

The MAX3869 is available as dice and in a small (5mm x 5mm) 32-pin TQFP package specified for the extended-industrial temperature range (-40°C to +85°C). Prices start at $18.00 (1000-up, FOB USA). An evaluation kit is available to speed designs.

OPTICAL OUTPUT EYE DIAGRAM



3.3V, 2.5Gbps clock-and-data-recovery IC surpasses SDH/SONET regenerator specs

The MAX3876 compact, low-power, 3.3V clock-recovery and data-retiming IC with CML outputs is ideal for 2.488Gbps SDH/SONET applications. It is designed for section-regenerator, terminal-receiver, and switch core applications in OC-48/STM-16 transmission systems. In conjunction with the MAX3831 2.5Gbps interconnect mux/demux, the MAX3876 forms a complete backplane transceiver.

Operating from a single +3.3V to +5.0V supply, the MAX3876 consumes only 445mW at +3.3V. The fully integrated phase-locked loop recovers a synchronous clock signal from the serial NRZ data input, which is also retimed by the recovered clock. Low jitter generation in the MAX3876 surpasses the SDH/SONET specification by $6.3mUI_{RMS}$, and the typical jitter tolerance at 100kHz exceeds the SDH/SONET specification by 1.8UIp-p.

Differential CML outputs are provided for clock and data signals, and an extra 2.488Gbps serial input is available for system loopback diagnostic testing. The MAX3876 also includes a TTL-compatible loss-of-lock (LOL) monitor. Available as dice and in a 32-pin TQFP package specified for the extended temperature range (-40°C to +85°C), the MAX3876 is priced at $40.99 (1000-up, FOB USA). An evaluation kit is available to speed designs.