MAXIM Engineering journal

Volume Thirteen

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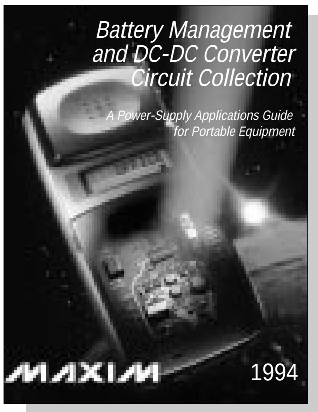

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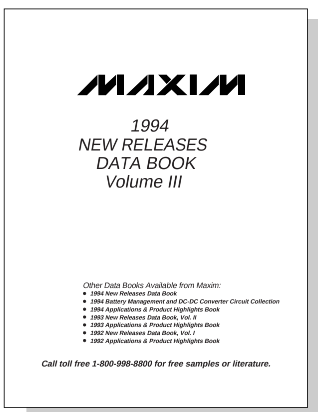

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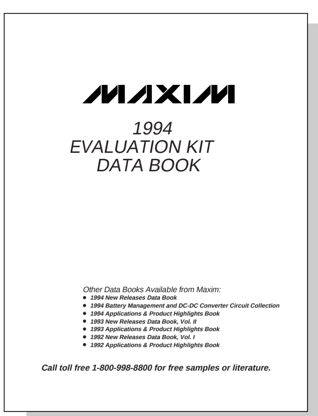

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Power-supply IC accommodates dual-voltage portable systems

A portable system's power supply is a complicated beast. It not only includes numerous sophisticated subsystems for voltage monitoring and power management, it may also generate dual V_{CC} levels (3.3V and 5V) and support the voltage switching required by new PCMCIA cards (**Figure 1**).

Other factors add complexity: the constant pressure to miniaturize, the need for increased battery life, and the noise-suppression measures made necessary in portable equipment by internal radio modems and pen digitizers. The result is an unprecedented challenge in power-supply design.

This article discusses the capabilities of a new IC that greatly simplifies power-supply design for notebook computers, handy-terminals, and other portable systems. The chip's sophisticated architecture and high level of integration address many of the main-supply requirements. Their usual order of importance is the following:

- Include necessary voltages and functions
- Improve efficiency and extend battery life
- Reduce costs
- Miniaturize
- Minimize EMI
  (for radios and pen-based computers)

These points will be examined in detail and related to the new chip's construction. The main supply in a notebook computer, for example, is deceptively simple. It should generate 12V at 120mA and 3.3V/5V at approximately 3A each, from a battery voltage ranging between 7V and 20V. As we shall see, the computer's required operating modes and the various constraints on size and efficiency complicate things tremendously.

Similar considerations apply to power supplies for other portable equipment as well, such as bar-code readers, pH meters, and medical instruments.

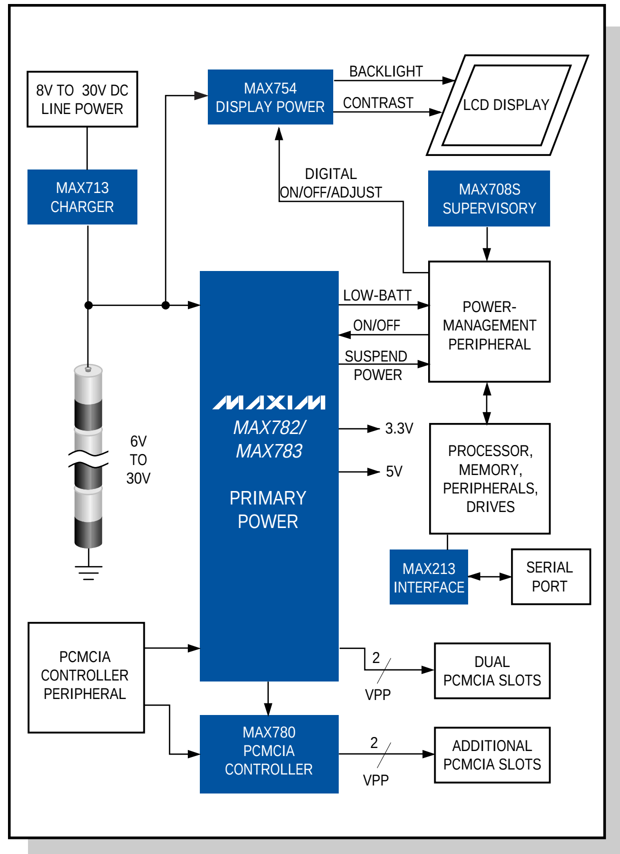


Figure 1. *This block diagram shows the power supply in a typical notebook computer, highlighting the key controller ICs.*

Generate needed voltages, with accuracy

Supply-voltage accuracy is a key requirement in portable systems. Logic-board designers often ask for ±3% accuracy in place of the usual ±5%. And in some applications, these voltages must be slightly offset from the nominal values. Higher voltages compensate for drops across the downstream load switches, and lower voltages extend battery life by minimizing power in the load.

Output accuracy is an unsung aspect of the power-supply designer's art. Tight accuracy must be maintained in spite of sharp line transients when the ac adapter is plugged in, and in spite of equally sharp load transients when the computer shifts from suspend mode to run mode. The skilled designer must balance loop gain, loop compensation, switching frequency, and filtering to maintain the required accuracy despite numerous ac and dc perturbations. Cost and efficiency goals, often in conflict with the above, must also be satisfied.

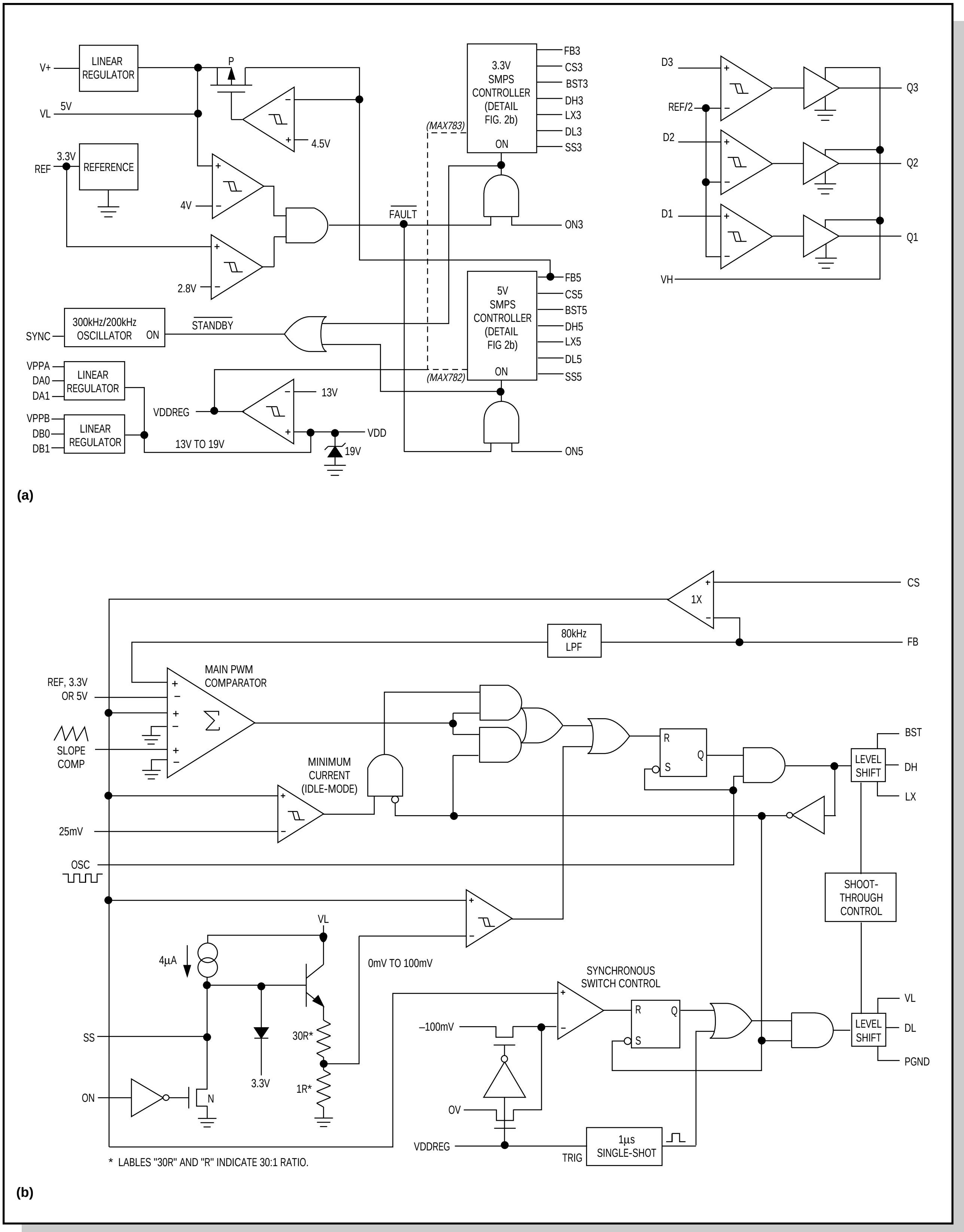


Figure 2. *These block diagrams show the MAX782 internal functions* ***(a)****, and details of the SMPS (switch-mode power supply) function* ***(b)****.*

A new buck-regulator IC from Maxim (MAX782) achieves excellent dc accuracy and ac-transient behavior while generating the required output voltages 3.3V, 5V, and 12V (**Figure 2**). It includes control circuitry for two pulse-width modulated (PWM) buck regulators. Its novel, current-mode PWM control (patent pending) produces a high unity-gain crossover frequency (60kHz) that allows quick recovery from line and load transients—within four or five cycles of the internal 300kHz clock. The new control architecture compares low-level signals directly instead of adding gain first.

By feeding correctly weighted values of output error, reference voltage, inductor-current ramp, and slope-compensation ramp directly into a proprietary summing comparator, the circuit dispenses with conventional integrating error amplifiers and their associated phase shift and stability problems. This approach also allows the use of smaller filter capacitors.

Another way to reduce filter capacitance is by lowering the PWM loop gain. A deliberately controlled loop gain enables relatively low values of capacitance to establish ac stability, by producing a gain rolloff that reaches unity before the next pole or zero frequency. Setting the initial dc loop gain low allows this gain attenuation to be realized with only 30µF per ampere of load current. The low gain introduces a load-regulation error of about 1.5%, but tight initial accuracy on the output voltages (achieved through laser trimming) holds the overall accuracy to within ±3%.

Another basic concern is the input-voltage range. The low end is determined by the specified minimum battery voltage. At the high end, the regulator must withstand open-circuit output voltages from ac adapters and battery chargers. (The worst-case high voltage usually occurs with batteries removed and ac power applied.) The resulting input-range requirement for 6-cell systems is 6V to 24V. Standard analog-CMOS processes break down at 16V or so, but a new CMOS process from Maxim withstands 30V. Developed specifically for the ICs in battery-powered supplies, it eliminates the need for inelegant hybrid devices and power-hungry bipolar ICs.

Maximum battery life

After basic needs are met, the next goal for a portable-system supply is ultra-high efficiency and maximum battery life. But battery life can't be inferred from snapshots of efficiency under fixed load. Instead, you must maximize efficiency over a broad range of load currents, representing shutdown, suspend, and run-state load conditions.

During shutdown, when a portable system's load often consists only of static RAM, real-time clock, and power-management logic, the supply current is a few hundred microamps. This current must be supplied either from the backup battery or from the main battery, if present. (Drawing shutdown current from the main battery saves the backup until it's really needed.) Such keep-alive supplies are usually implemented with a linear regulator operating from the main battery.

For the suspend state, in which the main processor runs at a greatly reduced clock rate, the system's supply currents range from 3mA to 10mA. This current range is above the comfort level for linear regulators, so the preferred circuit is a switching regulator with reasonably high efficiency at light loads. The moderate to high currents drawn in the run state, on the other hand, demand the highest possible efficiency (>90%).

A single MAX782 accommodates each of these distinct operating modes. For shutdown operation, the chip includes two low-dropout, micropower linear regulators that maintain 3.3V and 5V outputs while drawing only 70µA of battery current. The critical 3.3V output connects either to the main 3.3V bus or to a separate back-up/keep-alive bus.

For suspend-state operation, the IC brings two circuit innovations to bear. A pulse-skipping mode allows the 3.3V and 5V buck regulators to shift smoothly between variable-frequency operation and the normal fixed-frequency PWM operation. This shift occurs automatically as load currents vary above and below 27% of full load, resulting in optimum efficiency for the regulators. The 5V regulator, for example, is 95% efficient at heavy loads, and more than 80% efficient for load currents ranging from full scale down to 1% of full scale (**Figure 3**).

Switching noise is unavoidable, but the frequencies and control algorithms employed by the MAX782 insure that the frequency bands of interest for common applications are noise-free. Operation at 300kHz, for instance, leaves a quiet band around the sensitive 455kHz IF of commercial radio (**Figure 4a**). The harmonics shown (at 300kHz, 600kHz, and 900kHz) remain fixed at those locations as the MAX782's pulse-width modulation responds to changes in load current.

The LT1148, on the other hand, is a similar power-controller IC that responds to load-current changes by

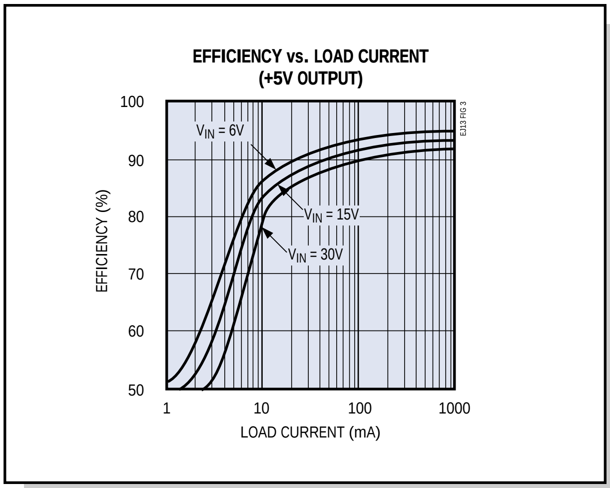


Figure 3. *For high currents, the MAX782's 5V output is more than 90% efficient.*

varying its nominal 100kHz switching frequency. This frequency and its variation combine to fill the 455kHz region with noise (**Figure 4b**). At lower load currents, the LT1148 maintains regulation by issuing 100kHz pulses in a variable-burst mode whose spectral components contaminate the audio band (**Figure 5b**). The MAX782 also shifts to variable frequency at low load currents, but at 50mA its 40kHz frequency remains above the audio band (**Figure 5a**).

Another MAX782 innovation—fast, precise current sensing—allows the device to turn off its synchronous-rectifier switch as the inductor's discharge current passes through zero. The synchronous rectifier thus continues operating even for light loads, allowing the inductor current to become discontinuous. With both switching regulators operating, the entire 25W MAX782 application circuit draws only 470µA of quiescent battery current.

Competitive chips either disable the synchronous rectifier completely at light loads, or leave it on and pay a big penalty in quiescent supply current. (With the rectifier on, the reversal of inductor current after discharge causes a transfer of energy from the output capacitor back to the battery. Supply current rises because the losses associated with this transfer must be replenished from the battery.)

For run-state operation, the MAX782's balanced design and 300kHz switching frequency provide 95% efficiency without the use of superconductors, solid-gold wires, or large magnetic cores. The circuit's n-channel MOSFET switches and bootstrapped operation enable high efficiency, even with standard surface-mount components (**Figure 6**).

Both buck regulators employ logic-level n-channel MOSFETs in place of the p-channel MOSFETs normally used as high-side switches. The n-channel devices' higher majority-carrier mobility results in much lower values of gate capacitance and reverse-transfer capacitance. For devices of equivalent on-resistance, the n-channel types cost 50% less. And for available devices in small SOIC packages, the n-channel parts exhibit only half as much on-resistance.

Gate drive for the high-side MOSFETs is obtained via "bootstrap" capacitors (**Figure 7**). When the synchronous switch is on, two 0.1µF capacitors (connected to the BST pins) are charged to 5V via two small-signal diodes.

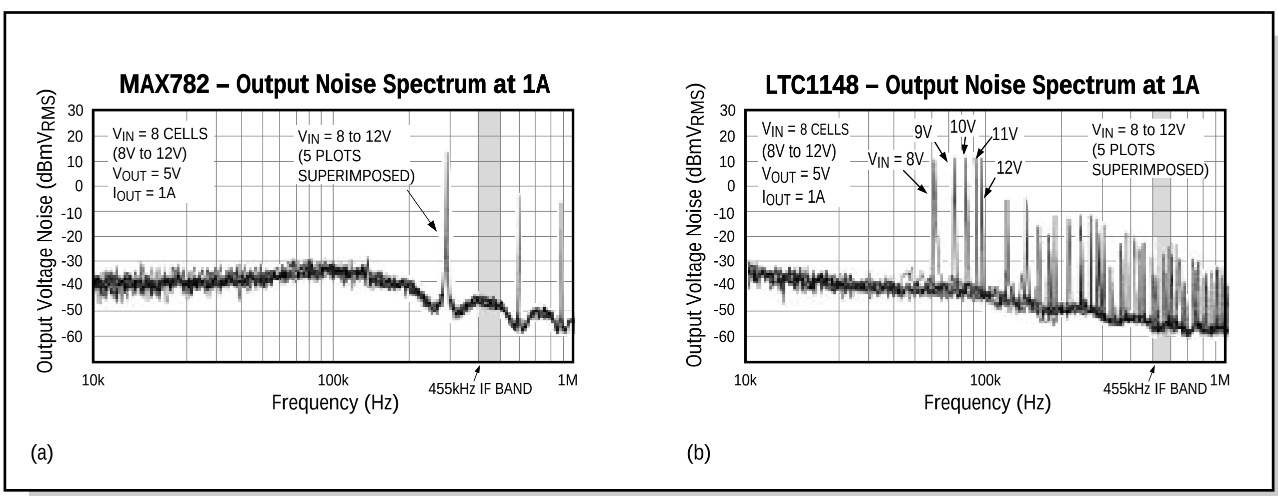


Figure 4. *At 1A load currents, the MAX782's 300kHz fixed-frequency PWM control produces no spectral components near the 455kHz IF band **(a)**, but the LT1148's nominal 100kHz variable-frequency control floods that band with noise **(b)**.*

Internal switches then turn on either MOSFET by connecting a charged capacitor across gate and source.

Start-up power to the MAX782 is delivered by a linear regulator operating on battery voltage. When the 5V output achieves regulation, an internal switchover circuit automatically connects the chip's internal supply rail (via the FB3 pin) to the 5V output. Power for the chip and the gate drivers then comes from the 95%-efficient 5V supply, rather than the inefficient combination of battery and linear regulator. What's more, an adjustable soft-start capability precludes the battery-voltage transients that would otherwise occur each time a buck regulator turns on.

Another efficiency-enhancing feature is the chip's relatively low-voltage threshold for the output-current limit, established by 100mV across a 25mΩ sense resistor. Other, less-precise designs require a larger drop of 150mV to 200mV across the same resistor, dissipating as much as 400mW in additional power.

Cost-saving architecture

The next priority in portable-system power supplies is cost reduction. Higher switching frequency in the MAX782 already saves costs through reduced pc area, cheaper magnetic cores, and all-surface-mount construction (which eliminates through-hole assembly steps). The chip's 12V output offers further economy. Derived from an extra winding on the 5V buck inductor, this output is almost free. Though the trick is widely known (it's often called a "coupled-inductor" or "buck with flyback winding" design), the MAX782 circuit's independent 12V regulation provides an extra twist.

When a conventional circuit's high-side switch is on, the flyback circuit stores energy in the inductor core and then discharges a portion of that energy through the secondary winding to the 14V output. During discharge, the primary voltage is $V_{OUT} + V_{SW}$, where V_{SW} is the synchronous rectifier's saturation voltage. (The secondary output equals the primary output times the turns ratio.) A linear regulator then drops the 14V to 12V.

Unfortunately, if the primary load is removed and the synchronous rectifier turns off at zero current (when no energy is stored), the 14V output in this conventional circuit sags to ground. If the synchronous rectifier remains on, the primary current reverses and the transformer operates in the forward mode. Its output-current capability (theoretically infinite) prevents the 14V output from sagging, but quiescent supply current remains high.

The MAX782, however, achieves excellent cross-regulation with no penalty in quiescent supply current. A second feedback loop in the 5V buck regulator senses the 14V output (V_{DD}). When V_{DD} is in regulation, the rectifier operates normally and turns off at zero current. But if V_{DD} falls below 13V, the loop holds the synchronous rectifier on for an extra microsecond after the primary current reaches zero, causing the transformer to deliver energy in the forward mode (Figure 2b). V_{DD} can therefore deliver hundreds of milliamps, even with the 5V output unloaded.

Another device—the MAX783—derives V_{PP} in the same way, but from 3.3V instead of 5V. It generates V_{PP} with an auxiliary winding on the 3.3V inductor, and regulates V_{PP} via the 3.3V synchronous rectifier. This

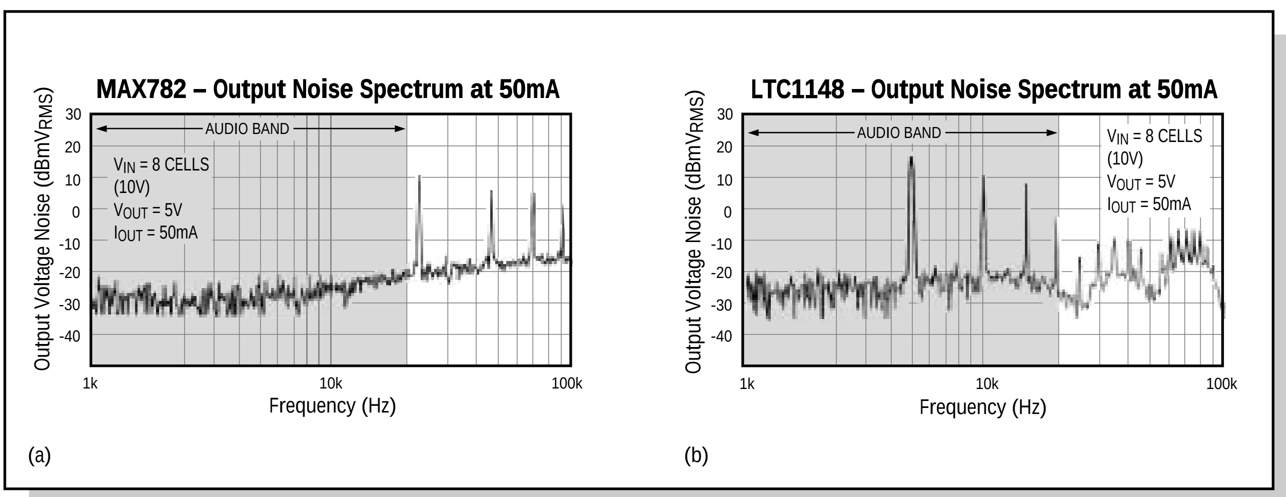


Figure 5. *At 50mA load currents, both the MAX782* ***(a)*** *and the LT1148* ***(b)*** *have switched automatically to variable-frequency operation, but the LT1148's lower frequency contaminates the audio band.*

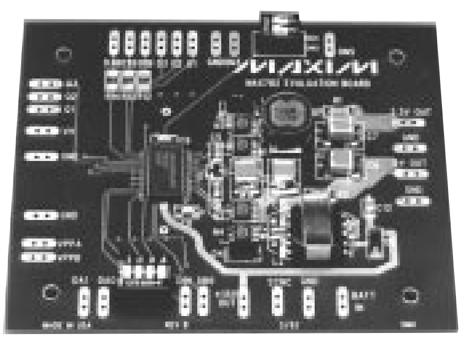


Figure 6. *All components in the MAX782 evaluation kit are surface mount.*

makes the MAX783 more suitable for systems powered by 6-cell NiCd batteries. Otherwise, the MAX782 and MAX783 are almost identical.

Another cost-saving feature is the inclusion of two linear regulators with outputs switchable to 0V, 5V, or 12V. They provide V_{PP} switching for two memory-card sockets as specified by the PCMCIA memory-card standard. Normally, this switching function is implemented with a 12V supply and a rat's nest of MOSFET switches. The MAX782, however, substitutes two linear-regulator pass transistors for the expensive low-r_{ON} MOSFETs. The internal pass transistors are cheap because they occupy little die area.

Decoding logic is also eliminated, because the MAX782 accepts V_{PP} programming code directly from popular PCMCIA controllers such as Intel's 82365SL or Cirrus Logic's CL-PD6720. The MAX782 includes level translators that implement 3.3V/5V PCMCIA switching for V_{CC}. As an alternative, the level translators (which remain alive in the standby mode) can serve as 1%-accurate comparators in circuits that warn of low battery voltage.

Miniaturization

Size and weight constraints usually have a slightly lower priority in the design process than does cost. But "creeping featuritis" can be a headache for the power-supply designer, who may be asked at the last minute to supply an extra half ampere, or to confine his circuit to a tiny L-shaped area of pc board.

The MAX782's high switching frequency (300kHz) lowers the necessary primary inductance to only 10µH—one-fifth of that required in competing IC circuits. The lower inductance means smaller cores, fewer turns, and less power loss in the wire resistance.

The 36-pin monolithic MAX782 also supports miniaturization through its high level of integration, having absorbed the functions of 12V generation, linear regulation, PCMCIA switching, and control for two independent V_{CC} buck regulators. To achieve further size reduction, a shrink small-outline package (SSOP) with tight lead pitch (32 mil) replaces conventional PLCC and SOIC packages.

Noise and ripple reduction

Low-noise/low-EMI power supplies are often required by personal communicators and pen-based personal digital assistants (PDAs). Though poised to scale new heights in personal computing, these devices have yet to prove themselves to the FAA. Supposedly, EMI from a laptop computer was the cause of a recent disruption in the navigation system of an airliner bound for New York.

PDAs and similar devices often include radio modems or RF/electromagnetic-actuated pen-entry digitizers powered directly from the battery. Current switching within the radio can produce voltage ripple, which, reflected from the battery back into the radio, can interfere with the IF signal. As discussed earlier, radio designers are therefore likely to specify suppression of all fundamental and harmonic interference in the vicinity of the IF—near 455kHz, for example.

The MAX782's fixed-frequency PWM architecture provides the predictable frequency spectrum required in such applications. Its free-running oscillator, operating at 200kHz or the pin-strap option of 300kHz, is factory-trimmed to ±10% tolerance and requires no external capacitor.

For demanding applications, you can further reduce noise by synchronizing the internal oscillator to an external clock. Even in its low-power pulse-skipping mode, the MAX782's switching pulses, triggered by the fixed-frequency clock, are more predictable than those of a chaotic burp-mode controller.

The MAX782 has been system-engineered as the main component in portable-system power supplies. One of a family of new power-supply ICs, it leapfrogs the performance of earlier devices by combining high-frequency generation and high efficiency—features that once were mutually exclusive. Other devices in the family are intended either as resonant-mode CCFT/LCD supplies (MAX753/MAX754), or as main supplies for sub-notebook computers (MAX781/MAX782).

(Circle 1)

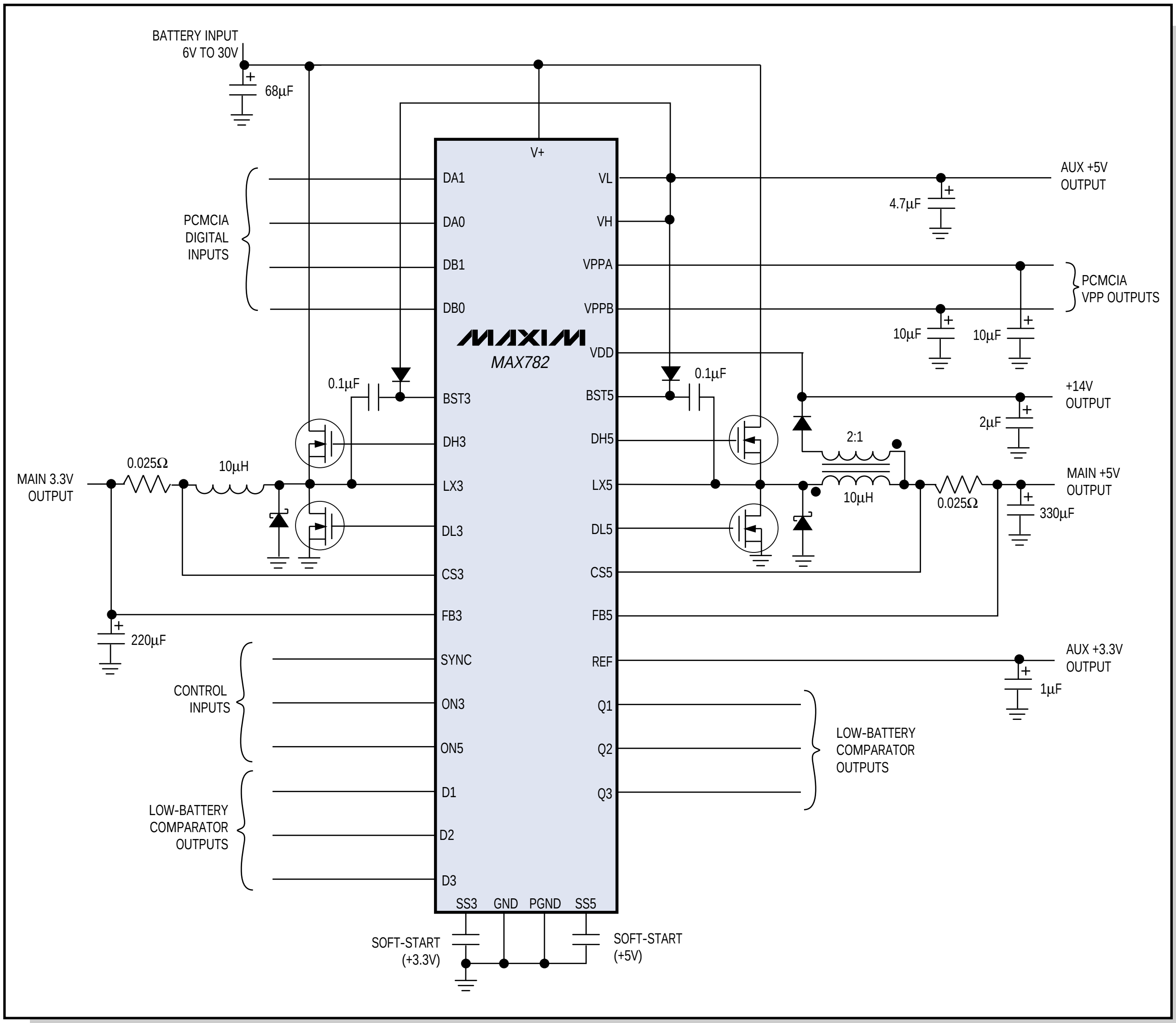


Figure 7. *The multi-function MAX782 generates high-side gate-drive voltages for the external power MOSFETs.*

Convert 3V to 5V without inductors

Charge-pump ICs can either invert or double an input voltage (3V to -3V or 6V, for example). The charge pump operates without inductors, but it doesn't regulate the output and it doesn't easily boost 3V to an intermediate level such as 5V. By adding a comparator and reference (IC2 in **Figure 1**) you can generate arbitrary outputs (such as 5V) and regulate them as well.

The charge pump (IC1) has an internal oscillator whose 45kHz operation transfers charge from C1 to C2, causing the regulated output to rise. When the feedback voltage (pin 3 of IC2) exceeds 1.18V, the IC2 comparator output goes high and turns off the oscillator via Q1.

Comparator hysteresis—easily added at IC2—is set to zero because the control loop requires no hysteresis. The oscillator generates only two cycles after turn-on, which is always enough to drive V_{OUT} slightly above the desired level before feedback turns the oscillator off again. The resulting output ripple depends mainly on the input voltage and the output load current (**Figure 2**).

You can reduce output ripple at the expense of circuit efficiency by adding a small resistor of about 1Ω (not shown) in series with C1. Ripple also depends on the value and ESR associated with C1; smaller values of C1 transfer less charge to C2, producing smaller jumps in V_{OUT}.

For those not afflicted with inductorphobia, Maxim offers various inductor-based switching regulators for boosting 3V to 5V. They include the MAX731, MAX741, MAX756, MAX856, and others.

(Circle 2)

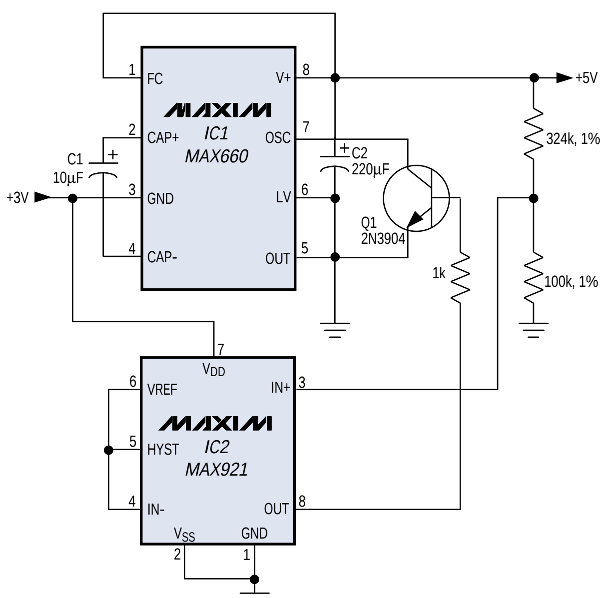


Figure 1. By configuring a comparator and transistor to control the oscillator in a charge pump, you enable the pump to generate a regulated output of any reasonable value.

LOAD RESISTANCE (Ω)	OUTPUT VOLTAGE (V)	OUTPUT RIPPLE (mVp-p)
∞	5.00	30
10k	5.00	35
1k	5.00	100
100	4.96	100
50	4.59	150

(a) Supply = +3.0V

LOAD RESISTANCE (Ω)	OUTPUT VOLTAGE (V)	OUTPUT RIPPLE (mVp-p)
∞	5.01	55
10k	5.01	55
1k	5.01	55
100	4.98	170
50	4.90	170

(b) Supply = +3.3V

LOAD RESISTANCE (Ω)	OUTPUT VOLTAGE (V)	OUTPUT RIPPLE (mVp-p)
∞	4.98	10
10k	4.98	25
1k	4.98	25
100	4.64	70
50	4.29	90

(c) Supply = +2.7V

Figure 2. Output ripple in the Figure 1 circuit depends on the input voltage and load current.

5V, non-interruptible power supply delivers 1A

The 5V output of **Figure 1** remains uninterrupted during loss of the main 5V supply. What's more, it maintains a ±5% output tolerance while delivering 1A for 80 minutes thereafter.

During normal operation, the main supply is monitored by the V_{CC} terminal of the supervisory circuit (IC1). This chip holds Q2 on by asserting $\overline{RESET}$ high. While on, Q2 holds the dc-dc controller (IC2) in shutdown mode, turns on Q1, and turns on Q3, which routes a trickle charge to the battery stack.

When the main supply voltage drops below IC1's reset threshold (typically 4.65V), $\overline{RESET}$ quickly turns off Q2 and Q3, bringing IC2 out of shutdown. IC2 then boosts the non-interruptible output back to 5V. After the main supply dips below threshold, $\overline{RESET}$ remains low for 200ms whether or not the voltage returns above threshold. This action assures an orderly completion of the switchover.

Q1 is a low-$r_{DS(ON)}$, p-channel MOSFET that drops only 60mV at 1A. Its connections—drain to the main supply and source to the uninterruptible 5V output—are backwards with respect to the usual configuration for p-channel high-side switches. The connections shown prevent Q1's body diode from draining the battery when the main supply fails. Also, this diode conducts when the main supply initially turns on, which assures a gate drive sufficient to turn the MOSFET fully on (approximately 4.5V).

The battery manufacturer (Ovonic) recommends that you apply a 230mA trickle charge to the 2300mAh nickel-metal-hydride (NiMH) cells. To avoid exceeding this recommended rate, you must select R2 according to the worst-case (highest) beta value for Q3. The beta range is 100 to 300. So, for a ±10% supply, R2 should be about 6kΩ. If a 12V supply is available, you can reduce the battery's recharge time by adding a battery-charger IC to control the charging rate.

(Circle 3)

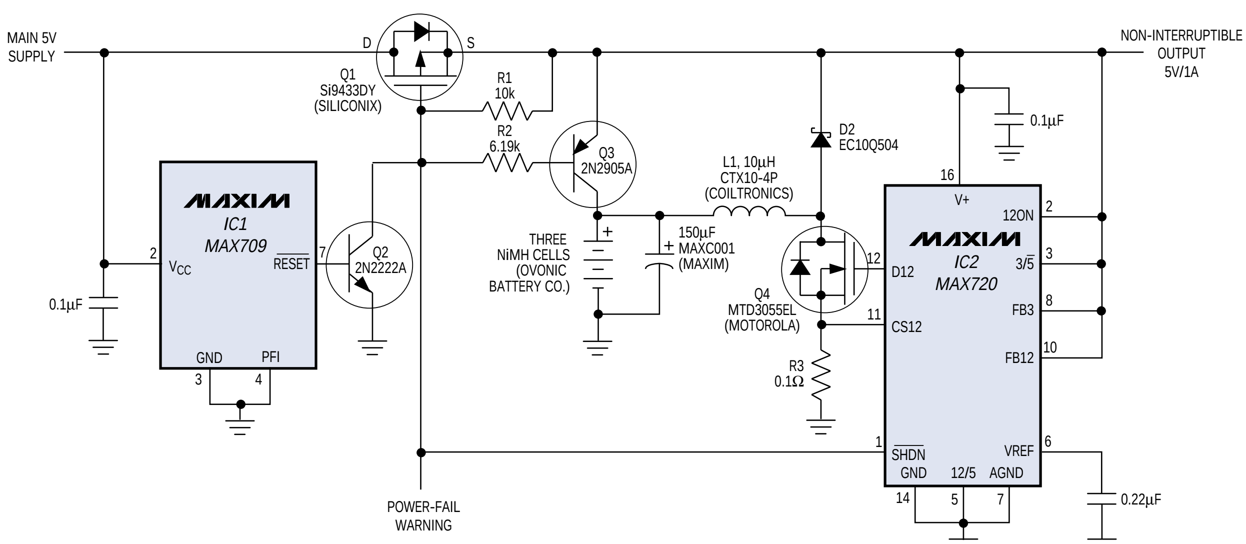


Figure 1. *Despite brownouts or loss of the main 5V supply, this non-interruptible power supply maintains the 5V output within ±5%. It supplies 1A at 5V for 80 minutes with the battery shown.*

DESIGN SHOWCASE

Dual boost regulator handles heavy surge currents

Among 2-cell boost regulators, five watts (5V at 1A) is “high power.” But, obtaining even 5W from a 2-cell or 3-cell battery is not a trivial problem. Peak currents exceed 2A, and the small voltage drops they produce in the power devices, battery, capacitors, and pc wiring can lead to poor efficiency and failure. The high internal impedance of alkaline AA batteries, for example, can support 5W loads only for short surges.

Combining the outputs of two simple boost regulators with a diode-OR connection (**Figure 1**) provides a surge-current capability for small systems that must support intermittent radio transmissions or disk spin-ups. The main regulator (controlled by the LX terminal) contributes high efficiency during normal operation and also guarantees start-up at low voltage (its internal power MOSFET has a gate-threshold voltage of 0.8V).

The auxiliary surge-current regulator, on the other hand, has an external MOSFET and is not limited to 5W. It can be tailored for heavier loads by substituting larger inductors and larger capacitors.

The chip offers a low-power mode that lowers the peak currents, which raises the light-load efficiency by 10% (**Figure 2**).

In most cases, it’s not a good idea to connect unsynchronized switching regulators in parallel: the oscillators can produce unwanted beat frequencies, and the load can monopolize current from one of the outputs. This circuit avoids such problems because the regulators differ greatly in switching frequency and output-current capability.

(Circle 4)

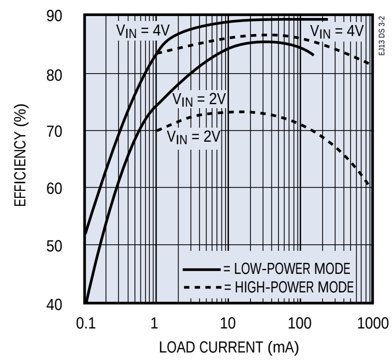


Figure 2. *Conversion efficiency in the Figure 1 circuit depends on the operating mode and the input voltage.*

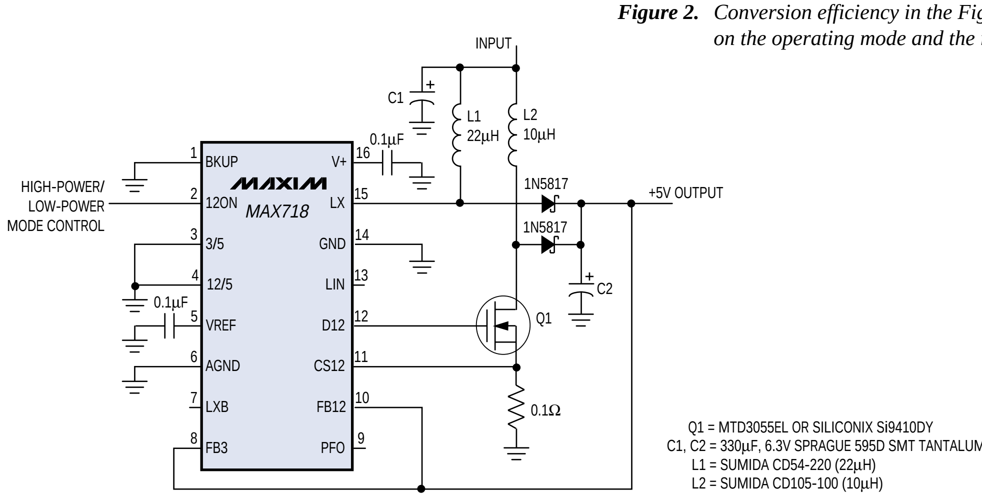


Figure 1. *This IC, designed as a power-supply controller for palmtop computers with flash memory, includes two switching regulators. Combining the outputs with a diode-OR connection and common feedback produces an efficient 5V output with surge-current capability.*

DESIGN SHOWCASE

Telephone tone generator requires no trimming

Many products that connect to phone lines (modems, for instance) incorporate a "call-progress monitoring" function known as CPM. CPM circuits "listen" to the lines as a human would, and respond according to what they "hear." You shouldn't dial a number unless you first hear a dial tone, for example. Neither should your computer.

Tone accuracy is not very important when people monitor the call-progress tones, but the use of computers for this purpose has produced a need for tone-accuracy specifications to prevent errors in interpretation. Accordingly, CCITT has introduced the North American Precise Audible Tone Plan (the following data is from the CCITT Green Book, Volume VI-4):

USE	FREQUENCIES (Hz)				POWER (per tone, at exchange)	CADENCE
	350	440	480	620		
Dial	✓	✓			-13dBm0	Continuous
Busy			✓	✓	-24dBm0	0.5sec on; 0.5sec off
Re-Order			✓	✓	-24dBm0	0.2sec on; 0.3sec off' or 0.3sec on; 0.2sec off
Ringing		✓	✓		-19dBm0	2sec on; 4sec off
Call Waiting		✓			-13dBm0	0.3sec on, every 10sec

Figure 1 illustrates a simple circuit for generating single or dual tones. They must be ±0.5% accurate in frequency, and they must be gated as shown in the "Cadence" column (a µP can control the cadence). This generator suits applications such as the tone-generation portion of a test stimulus for CPM circuits.

Generating a sine wave is generally more difficult than generating a square wave of the same frequency. The simplest technique is to filter a square wave of the desired frequency; removing its harmonics leaves you with the fundamental sine wave—the desired signal. For a dual-tone generator you would seem to need two harmonic-removal filters, but a single filter will do if the two square waves are reasonably close in frequency.

Square waves contain only odd harmonics, so the lowest frequency component to be removed (the critical frequency) is the third harmonic of the lower-frequency square wave. The filter must pass the fundamental of the higher-frequency square wave. To avoid using two filters, each of these

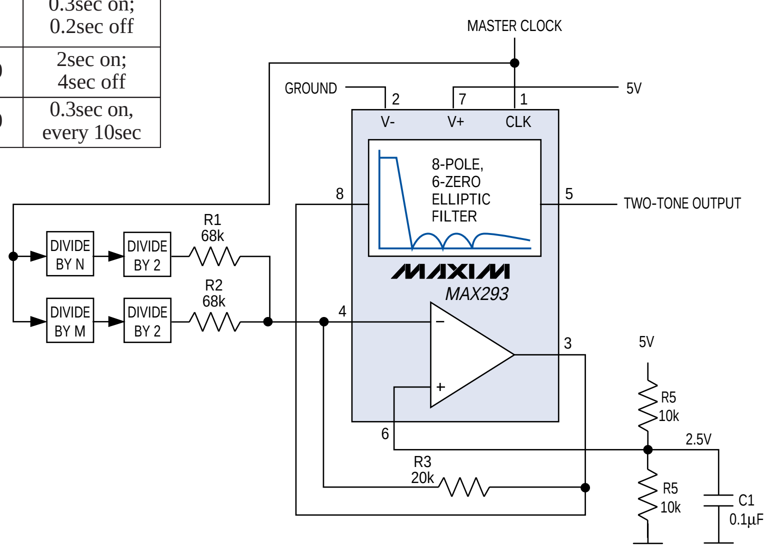


Figure 1. *In this tone generator, the uncommitted op amp of the lowpass filter IC1 acts as a summing amplifier. The amplifier's gain level assures that 5V-logic inputs will not cause clipping at the two-tone output.*

DESIGN SHOWCASE

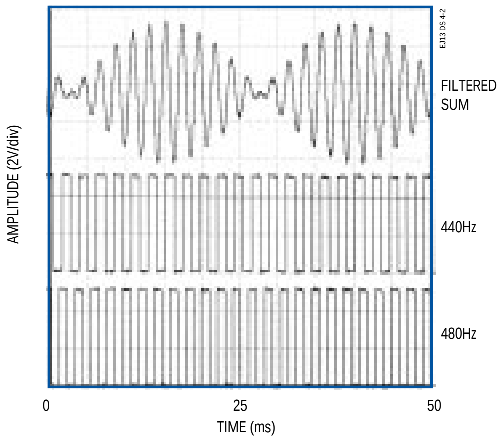


Figure 2. *These time-domain waveforms show the low and high square-wave tones for the "ringing" signal (lower traces), and the sinusoidal filtered sum (top trace).*

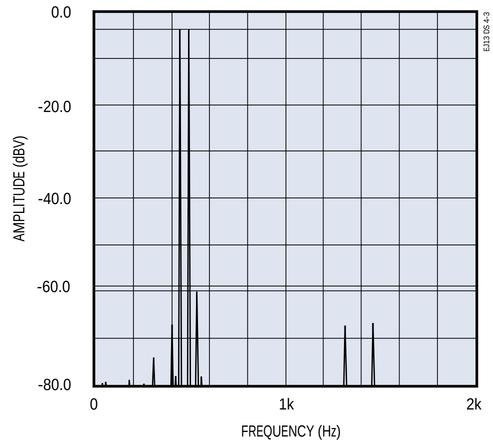


Figure 3. *In this frequency spectrum of the top trace in Figure 1, the highest-amplitude spur (spurious frequency) is at least 54dB down from the twin-tone level.*

square-wave frequencies must be an even-integer divisor of the filter's switched-capacitor clock. (This requirement forces the signal to be square—i.e., with a 50% duty cycle.)

As another requirement, the ratio of the lower tone's 3rd harmonic to the filter's corner frequency must be greater than the filter's transition ratio. (Transition ratio is the edge of the stopband divided by the edge of the passband.) The parameters necessary for generating each tone pair (or tone) are summarized in the table below.

The switched-capacitor lowpass filter (IC1), with a transition ratio of 1.5 and a clock-to-corner ratio of 100, meets each of these four sets of requirements. Setting the cutoff frequency to 528Hz, for example, allows 440Hz and 480Hz to pass. The resulting 792Hz stopband (528Hz times the 1.5 transition ratio) blocks the critical third harmonic of 440Hz (1320Hz), enabling generation of the ringing signal.

To generate low and high tones for the ringing signal, divide 52.8kHz by the divisors 120 and 110. The division scheme (left to the reader) can be implemented with simple logic, a PAL, or an up-counter/timer chip. If you use a programmable divider, you should follow it with a divide-by-two circuit to assure a 50% duty cycle. (The other CPM signals are produced in a similar way.)

Dual tones for the ringing signal are illustrated in the time domain (**Figure 2**) and the frequency domain (**Figure 3**). The frequency domain shows that the generator is free of spurious tones. In some CPM applications, tone detection involves a combination of frequency verification and guard margin. By verifying that tone energy is sufficiently above the remaining spectral energy, the tone margin ensures that voice and other signals won't fool the system into thinking a CPM tone is present.

(Circle 5)

USE	LOW TONE	HIGH TONE	CRIT. FREQ.	MINIMUM TRANSITION RATIO	CLOCK	LOW-TONE DIVISOR	HIGH-TONE DIVISOR
Dial	350	440	1050	1.70	61600	176	140
Busy/Re-Order	480	620	1440	1.61	89280	186	144
Ringing	440	480	1320	2.50	52800	120	110
Call Waiting	440	—	1320	2.50	52800	120	—

Note: The three master-clock frequencies have a common multiple of 34,372,800.

Third-order highpass filter has synthetic inductor

Inductors have a bad reputation as filter components—they not only transmit EMI, they act as antennas for receiving EMI as well. To avoid these problems, you can simulate the impedance of an inductor with the combination of two wideband transconductance amplifiers (WTAs) and a capacitor (**Figure 1**). The circuit acts as a synthetic inductor (L_{SYN}) with one end connected to ground.

By forcing a current at L_{SYN} and measuring the resulting voltage, you can determine the equivalent impedance Z_{EQ}:

$$Z_{EQ} = \frac{sC}{(gm1)(gm2)},$$

where gm ≡ transconductance.

The equivalent inductance, therefore, is:

$$L_{EQ} = \frac{C}{(gm1)(gm2)}.$$

This single-port network clearly offers the frequency-proportional impedance of an inductor, along with an advantage and a limitation: the inductance value can be large if (gm1)(gm2) << 1, but one end of the network must always connect to ground. Highpass, all-pole ladder filters make good applications because all their inductors connect to ground. Two WTAs and a capacitor must be substituted for each one, so you should choose a configuration with the minimum number of inductors.

To be cost-effective, your design should feature a series capacitor at each end of the filter, with the simulated inductor acting as a shunt between them (**Figure 2**). The input capacitor blocks any dc applied to the filter, and the output capacitor blocks any dc offset introduced by the synthetic inductor. Though constructed with active components, the filter thus retains some of the advantages of a passive filter.

In an actual circuit (**Figure 3**), C2 and C3 are bypass capacitors and C2 is part of the simulated inductor. The transconductance for each WTA is set by an external resistor (R1 or R3) according to the relationship gm = 8/R. Because the simulated inductance depends on the product of these transconductances, it may appear that you have a range of choices for each. But the optimum circuit for a given application allows the full range of output swing for each WTA, which restricts the gm values.

To determine these optimal gm values, start with equal transconductances and simulate the filter in Spice using "g" elements for the amplifiers. While sweeping the frequency at least one decade above and below the filter's corner frequency, observe each WTA output for its peak voltage magnitude (the two peaks may occur at different frequencies).

At the synthetic inductor's port (pin 13 of IC2), the peak value is demanded by the filter and cannot be

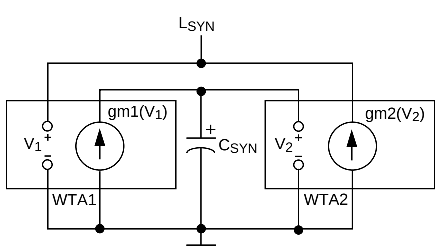


Figure 1. *This single-port network simulates an inductor with two wideband transconductance amplifiers and a capacitor.*

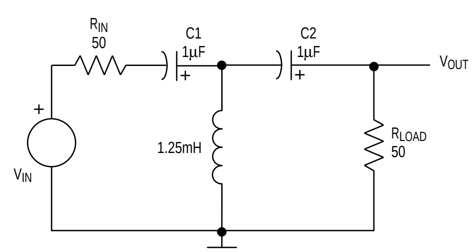


Figure 2. *This simple ladder filter is a good application for the simulated inductor, which must have one end connected to ground.*

DESIGN SHOWCASE

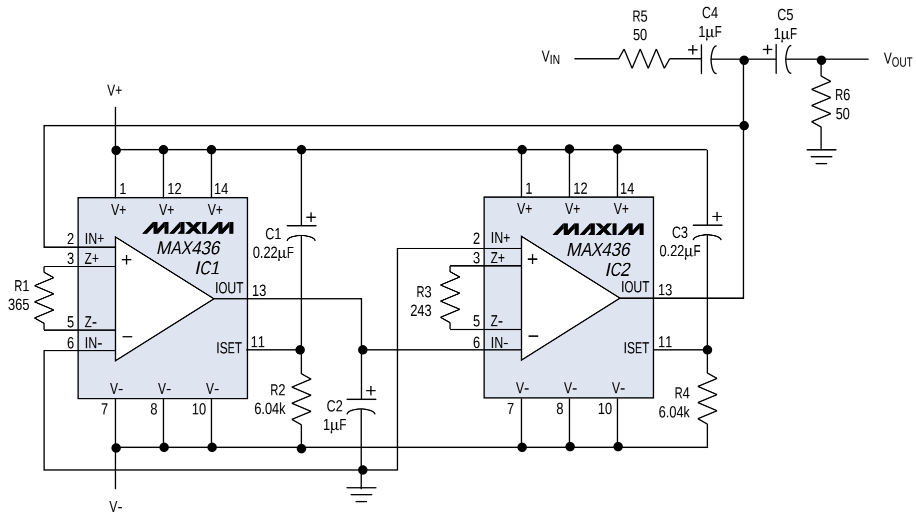


Figure 3. A 3rd-order Butterworth highpass filter is constructed by substituting the simulated inductor of Figure 1 in the ladder filter of Figure 2. The filter has a 3.2kHz corner frequency and a -6dB loss due to the source and load impedances.

changed; a real inductor would produce the same peak. You therefore adjust the other peak to match. Let K equal the ratio of gm2 to gm1. Gain is proportional to transconductance, so you divide gm1 by K and multiply gm2 by K. Finally, rerun the Spice simulation with these new gm values to verify that the peaks are equal and that the filter shape has not changed.

The filter exhibits a maximum attenuation of 58.6dB/decade (**Figure 4**). The slope decreases at lower frequency because the synthetic inductor's Q is affected by its series resistance. (Comparable 1.25mH inductors also have an appreciable resistance of 53Ω or so.) At 10Hz, for instance, the attenuation for an ideal filter is -90dB. For this circuit, the attenuation is -80dB.

(Circle 6)

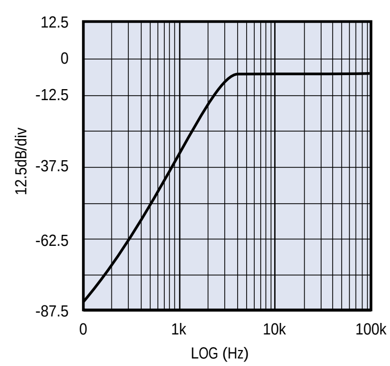


Figure 4. The Figure 3 filter has a maximum attenuation of 58.6dB per decade.

NEW PRODUCTS

12-BIT 5V DACs HAVE WORLD'S LOWEST POWER CONSUMPTION

- ***8-pin SOIC and DIP (MAX538/MAX539)***
- ***Internal voltage reference (MAX530/MAX531)***

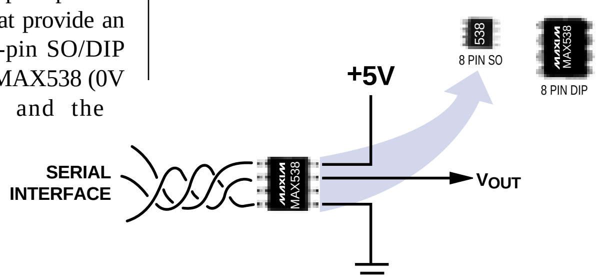
The MAX530, MAX531, MAX538, and MAX539 are 12-bit, voltage-output D/A converters well suited for portable and battery-powered applications. They operate on 5V supplies and draw supply currents as low as 300µA (maximum).

The MAX530 (parallel input) and MAX531 (serial input) have internal references and selectable output ranges of 0V to 2.048V, 0V to 4.096V, or ±2.048V. Each performs four-quadrant multiplication without external resistors or op amps. For space-sensitive applications that provide an external reference, choose 8-pin SO/DIP versions of the MAX531: the MAX538 (0V to 2.048V output range) and the MAX539 (0V to 4.096V output range).

The serial interface for MAX531/MAX538/MAX539 devices is compatible with SPI™, QSPI™, and Microwire™ serial-interface standards. These devices also provide serial-data outputs useful for daisy-chaining multiple D/A converters. The MAX530's double-buffered, parallel data inputs are compatible with 4-, 8-, and 16-bit microprocessors, and all data inputs are set to zero during power-up by an internal reset circuit. All devices offer low integral-nonlinearity errors of ±1/2LSB (maximum) over temperature.

The MAX530 comes in 24-pin narrow-DIP, wide-SO, and SSOP packages; the MAX531 comes in 14-pin DIP and SO packages; and the MAX538/MAX539 come in 8-pin DIP and SO packages. Each type includes versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices start at $4.85 (1000 up, FOB USA).

(Circle 7)



DUAL 12-BIT MULTIPLYING DACs HAVE BUFFERED VOLTAGE OUTPUTS

The MX7837 and MX7847 are dual 12-bit, multiplying D/A converters. Each includes feedback resistors and output amplifiers capable of developing ±10V across a 2kΩ load. Each achieves full 12-bit performance across the operating temperature range without external trims.

The fully parallel MX7847 has 12 data lines and a separate latch for each converter. The double-buffered MX7837, whose eight data lines accept eight bits followed by four bits, has separate 8-bit and 4-bit latches preceding each 12-bit DAC latch.

MX7837 and MX7847 devices are specified for operation with ±12V and ±15V supplies. All logic inputs are level-triggered and compatible with TTL and 5V-CMOS signals. Fast digital-timing characteristics (80ns minimum data-to-$\overline{WR}$ setup time) allow the devices to operate with most microprocessors. The output settling times (to within ±1/2LSB) are less than 4µs.

The MX7837 and MX7847 come in 24-pin narrow-DIP and wide-SO packages. Each incudes versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices start at $12.18 (1000 up, FOB USA).

(Circle 8)

LOW-POWER DUAL/QUAD OP AMPS CONSUME LESS THAN 1.2µA

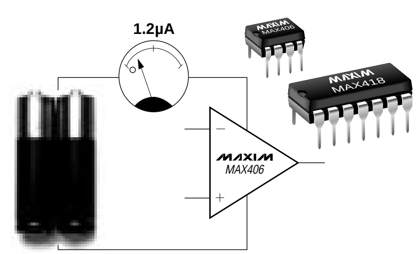
The dual MAX417 and the quad MAX418/MAX419 micropower precision op amps extend the existing series of MAX406/MAX407/MAX409 op amps. Supply currents for the new devices (1.2µA maximum per amplifier) are the lowest available—15 to 20 times lower than those for industry-standard micropower op amps. Rail-to-rail output swings and single- or dual-supply operation (to 2.5V) make the devices ideal for battery-powered systems.

MAX417/MAX418/MAX419 op amps maintain output linearity under load while operating with ultra-low supply currents, thanks to a unique design in the output stage. Each output swings rail-to-rail, sources as much as 2mA, and drives 1000pF capacitive loads without external components. Input bias current is less than 0.1pA. The input voltage range extends from the negative rail to within 1.1V of the positive rail.

The quad MAX418 is unity-gain-stable and has an 8kHz gain-bandwidth product. The dual MAX417 and quad MAX419, stable for gains greater than 10V/V, have 150kHz gain-bandwidth products and 80V/ms slew rates.

The dual MAX417 comes in 8-pin DIP and SO packages. The quad MAX418 and MAX419 come in 14-pin DIP and narrow-SO packages. Each device includes versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices (1000 up, FOB USA) start at $2.98 for the MAX417 and $3.98 for the MAX418 and MAX419.

(Circle 9)



NEW PRODUCTS

10ns, 5V COMPARATORS—70% LESS POWER THAN ALTERNATIVE DEVICES

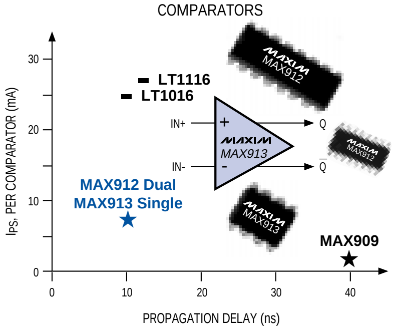
The MAX912/MAX913 dual/single, high-speed, low-power precision comparators feature 10ns propagation delays and 7mA supply currents (per comparator). Ideal for 5V and ±5V applications, the devices have wide input-voltage ranges that extend from below the negative supply rail to within 1.5V of the positive supply rail. This feature, available in few other single-supply comparators, eliminates the need for a negative supply in many applications.

The MAX913 is an improved plug-in replacement for the LT1016 and the LT1116. MAX912/MAX913 devices consume only 30% as much power as the LT1016 (which Maxim also second sources), yet they have equivalent speed and a wider input range. And unlike most other high-speed comparators, the MAX912 and MAX913 remain stable when driven by slow-moving input signals. Both devices have differential inputs, complementary TTL-compatible outputs, and independent latch-enable controls for each comparator.

The single MAX913 comes in 8-pin DIP and SO packages, and the dual MAX912 comes in 16-pin DIP and narrow-SO packages. Both include versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices (1000 up, FOB USA) start at $2.55 for the MAX913 and $3.90 for the MAX912.

(Circle 10)

LOWEST POWER, COMPLEMENTARY OUTPUT COMPARATORS



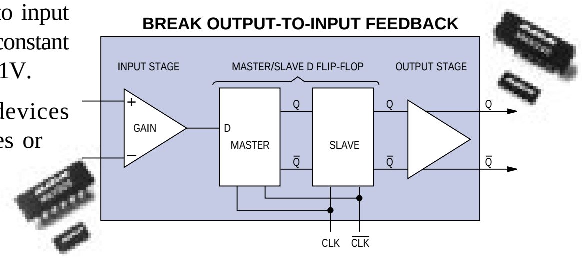
6ns COMPARATORS RESOLVE 2mV SIGNALS WITHOUT OSCILLATION—GUARANTEED

The MAX915/MAX916 (single/dual) edge-triggered comparators, unlike industry-standard TTL comparators, have unique master/slave architectures that allow resolution of input voltages as small as 2mV. This performance extends over the common-mode range, without oscillation. Propagation delay (only 6ns) is insensitive to input overdrive—the delay values are constant whether the overdrive is 3mV or 1V.

MAX915 and MAX916 devices operate from dual ±5V supplies or from single 5V-to-10V supplies. Power consumption is only 70mW per comparator. And, they suit 5V ground-sensing applications because the input common-mode range extends to the negative supply rail.

The MAX915 comes in 8-pin DIP and SO packages, tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. The MAX916 comes in 16-pin DIP and narrow-SO packages, screened for the commercial and extended-industrial ranges. Prices (1000 up, FOB USA) start at $2.55 for the MAX915 and $3.90 for the MAX916.

(Circle 11)



LOW-COST MICROPOWER COMPARATOR/REFERENCE HAS 4µA QUIESCENT CURRENT

- ***Ideal for 3V micropower systems***

The MAX931, MAX932, MAX933, and MAX934 comparator/reference ICs feature single, dual, or quad micropower comparators with 2%-accurate references. Each is a low-cost alternative to the corresponding part in the 1%-accurate MAX921-MAX924 series. (All but the MAX922/MAX932 pair have identical pinouts.)

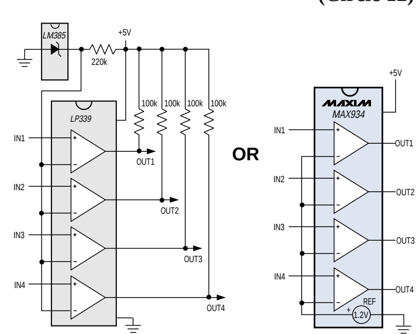
As the lowest-power combination of comparator and reference available, the MAX931 is ideal for micropower 3V systems. It draws less than 4µA maximum quiescent current over the operating temperature range, yet can source 40mA continuously. Its propagation delay is only 12µs, and it switches logic states without producing unwanted glitches in the supply voltage.

MAX931, MAX932, and MAX933 devices provide HYST inputs that let you add hysteresis with a simple connection of two external resistors. (Hysteresis—which prevents oscillation—is added to conventional comparators via external feedback connections and cumbersome equations.) MAX931-MAX934 devices offer 40mA output currents and TTL/CMOS-compatible outputs.

Each IC operates on a single supply of 2.5V to 11V, or a dual supply of ±1.25V to ±5.5V. Input voltage ranges extend from the negative rail to within 1.3V of the positive rail. Propagation delay (with 10mV overdrive) is 12µs. You can monitor voltages above or below the 1.18V reference by attenuating the input or reference voltage.

MAX931, MAX932, and MAX933 ICs come in 8-pin DIP and SO packages; the MAX934 comes in 16-pin DIPs and narrow SOs. All are available in commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) versions. Prices start at $0.98 (1000 up, FOB USA).

(Circle 12)



NEW PRODUCTS

PRECISION QUAD ANALOG SWITCH OFFERS 35Ω MATCHED ON-RESISTANCES

The MAX333A is a CMOS, precision, quad single-pole/double-throw (SPDT) analog switch. Its four independent switches have low on-resistance (35Ω maximum), close matching (<2Ω variation among the channels), and excellent flatness (<3Ω variation over the analog signal range).

Other improvements made possible by Maxim's new 44V silicon-gate process are lower charge injection (<10pC), break-before-make action (10ns typical), and fast switching (turn-off <145ns, turn-on <175ns). The MAX333A operates either with bipolar supplies (±4.5V to ±20V) or with a single supply (10V to 30V). Maximum quiescent power consumption is only 3mW.

Logic inputs are guaranteed TTL and CMOS compatible over the operating temperature range. Logic and analog signals may range between the supply voltages without damage to the MAX333A. One MAX333A provides upgraded performance for either two DG403 dual-SPDT switches or a DG211/DG212 pair used as a quad SPDT switch.

The MAX333A comes in 20-pin DIP and wide-SO packages, in versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices start at $3.60 (1000 up, FOB USA).

(Circle 13)

HIGH-SPEED ANALOG SWITCHES IMPROVE r_{ON} MATCHING AND CHARGE INJECTION

The MAX301, MAX303, and MAX305 are high-speed dual analog switches with the following configurations: MAX301—single-pole/single-throw (SPST), both normally closed (NC); MAX305—double-pole/single-throw (DPST), both NC; and MAX303—DPST, one normally open (NO) and one NC. Switch leakage is very low (<250pA).

Maxim's new 44V silicon-gate process improves performance. The MAX301/MAX303/MAX305 ICs have low charge injection (15pC), and their low on resistance (35Ω maximum) remains flat to within 3Ω over the analog-signal range. Within a device, on-resistances are matched to within 2Ω maximum.

Each device maintains CMOS-logic compatibility and fast switching (turn-on is <150ns, turn-off is <100ns) while operating either with a single supply of 10V to 30V, or with dual supplies of ±4.5V to ±20V. Quiescent current is only ±1µA maximum with ±15V supplies. A separate logic-supply terminal can implement TTL compatibility regardless of the power-supply levels. Off switches can block rail-to-rail voltages, and the digital inputs draw ±1µA maximum.

MAX301/MAX303/MAX305 switches come in 20-pin LCCs and 16-pin DIP and narrow-SO packages, in versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. (For MIL-STD-883 versions, please consult the factory.) Prices start at $1.23 for the MAX301, and $2.57 for the MAX303 and MAX305 (1000 up, FOB USA).

(Circle 14)

PRECISION CMOS ANALOG SWITCHES OFFER IMPROVED PERFORMANCE

The MAX317/MAX318/MAX319 are single-pole/single-throw monolithic CMOS analog switches. The MAX317 is normally closed (NC), the MAX318 is normally open (NO), and the MAX319 includes one NO and one NC switch. Each device consumes less than 35µW.

These devices are fabricated with a new silicon-gate process that yields significant design improvements: r_{ON} is low (<35Ω), flat to within 3Ω over the analog-signal range, and matched to within 2Ω between channels. Charge injection is extremely low, and guaranteed to be no greater than 10pC. Unlike their predecessors, the Maxim parts are guaranteed to withstand electrostatic discharge (ESD) in excess of ±2000V (per MIL-STD 883, Method 3015.7).

Digital inputs are TTL and CMOS compatible. The switches offer low leakage (less than 250pA) and fast operation (less than 175ns to turn on, less than 145ns to turn off). The 44V maximum breakdown voltage lets the switches withstand rail-to-rail analog voltages.

MAX317/MAX318/MAX319 devices come in 8-pin DIP and SO packages, in versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices start at $1.05 (1000 up, FOB USA).

(Circle 15)

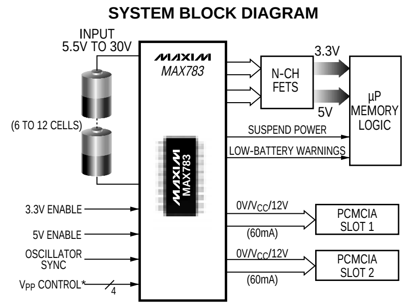
NEW PRODUCTS

TRIPLE-OUTPUT, 95%-EFFICIENT CONTROLLER POWERS NOTEBOOK COMPUTERS

The MAX783 power-supply controller is a system-engineered device that provides regulated supply voltages for notebook computers and other battery-powered equipment. It includes dual PCMCIA (V_{PP}) outputs, and step-down regulators for 3.3V and 5V.

The V_{PP} outputs may be programmed for 0V, 3.3V, 5V, or 12V. Two precision comparators perform low-battery detection, and two low-dropout, micropower linear regulators act as backup supplies for CMOS RAM and real-time clocks. (See page 3 for an in-depth discussion of the similar MAX782.)

Efficiency for the main 3.3V/5V supplies runs as high as 95% for 2A loads, and greater than 80% for loads from 3mA to 3A. Maxim's Idle-Mode™ operation governs the regulation at light loads. At heavier loads, the operation shifts automatically to synchronous rectification and pulse-width modulation (PWM). A high operating frequency (200kHz or 300kHz) allows use of physically small external components, and the current-mode PWM architecture permits filter-capacitor values as small as 30µF per ampere of load.



The MAX783 has fast ac response, thanks to a high (60kHz) unity-gain crossover frequency that enables recovery from line and load transients within four to five clock cycles. Low-cost, external n-channel MOSFETs, and high-level integration lower the system costs. Lowering costs even further is an integral flyback-winding controller, which generates a high-side 15V for the V_{PP} outputs.

The input range is 5.5V to 30V, and the quiescent current (420µA) drops to 70µA in standby mode (when only the linear regulators are active). Shutdown current is only 25µA. Other features include low-noise, fixed-frequency PWM operation for moderate to heavy loads, and a synchronizable oscillator for noise-sensitive applications such as communicating computers and electromagnetic pen-based systems.

The MAX783 comes in 36-pin SSOPs, in versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $5.95 (1000 up, FOB USA).

(Circle 16)

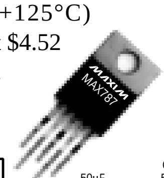
STEP-DOWN dc-dc CONVERTERS OFFER 5V/3.3V/3V OUTPUTS

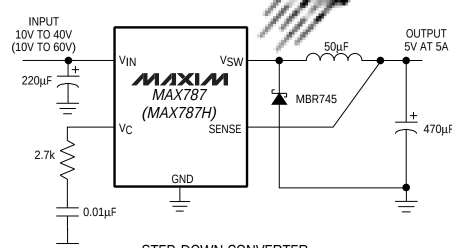
The MAX787/MAX788/MAX789 step-down dc-dc converters have output voltages of 5V (MAX787), 3.3V (MAX788), and 3V (MAX789). They require few external components because the oscillator, 5A power switch, and control circuitry are all on-chip. Quiescent supply currents (8.5mA each) drop to 140µA in the shutdown mode.

High operating frequencies (100kHz) allow each device to implement the standard "buck" topology with a small external inductor, Schottky diode, and output filter capacitor. Input voltages range from 8V to 40V (to 60V for the high-voltage "H" versions). Each regulator offers cycle-by-cycle current limiting to protect against overcurrent and short-circuit faults. Excellent dynamic characteristics provide a well-behaved transient response.

Available in 5-pin TO-220 packages, the MAX787/MAX788/MAX789 devices each offer a commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) version. Prices start at $4.52 (1000 up, FOB USA).

(Circle 17)





STEP-DOWN CONVERTER

PCMCIA CONTROLLERS MANAGE VPP AND VCC TERMINALS

MAX613 and MAX614 analog power controllers operate with standard PCMCIA digital controllers such as Intel's 82365SL and Vadem's VG-365, VG-465, and VG-468. The MAX613 and MAX614 control the V_{CC} and V_{PP} voltages applied to computer card slots—those complying with Release 2.0 of the Personal Computer Memory Card International Association (PCMCIA).

The MAX614 controls one or both V_{PP} terminals on a PCMCIA slot with a single V_{PP} output that asserts V_{PP}, V_{CC}, 0V, or high impedance according to codes generated by the digital controller. The MAX614 also includes a level shifter for its gate-drive output (DRV), which controls V_{CC} via an external MOSFET.

The MAX613 provides independent control of the two V_{PP} terminals via two V_{PP} outputs, each programmed by separate 2-bit codes. A third 2-bit code allows the DRV3 and DRV5 outputs, each with separate internal level shifters and driving separate external MOSFETs, to apply 3V or 5V to the V_{CC} terminal. MAX613 and MAX614 devices have 1.6Ω internal power switches and 50µA (maximum) quiescent supply currents.

The MAX613 comes in 14-pin DIP and narrow-SO packages; the MAX614 comes in 8-pin DIP and narrow-SO packages. Both include versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices (1000 up, FOB USA) start at $1.68 for the MAX613 and $1.48 for the MAX614.

(Circle 18)

NEW PRODUCTS

DUAL-OUTPUT, 95%-EFFICIENT CONTROLLER POWERS NOTEBOOK COMPUTERS

The MAX786 power-supply controller, suitable for use in notebook computers and other battery-powered equipment, includes separate step-down regulators for 3.3V and 5V. It also includes two precision comparators for low-battery backup, and two low-dropout, micropower linear regulators for supplying backup power to CMOS RAM and real-time clocks.

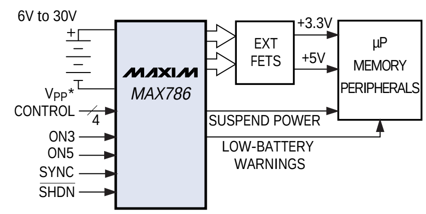
Efficiency for the 3.3V and 5V supplies runs as high as 95% for 2A loads, and greater than 80% for loads from 3mA to 3A. Maxim's Idle-Mode™ operation governs the regulation at light loads. At heavier loads, the operation shifts automatically to synchronous rectification and pulse-width modulation (PWM). High operating frequency (200kHz or 300kHz) allows the device to operate with small external components. The current-mode PWM architecture permits filter-capacitor values as small as 30µF per ampere of load.

The MAX786 has fast ac response, thanks to a high (60kHz) unity-gain crossover frequency that enables recovery from line and load transients within four to five clock cycles. High-level integration and low-cost, external n-channel MOSFETs lower the system costs.

The input range is 5.5V to 30V. The quiescent current (420µA) drops to 70µA in the standby mode (when only the linear regulators are active), and to 25µA in the shutdown mode. Other features include low-noise, fixed-frequency PWM operation for moderate to heavy loads, and a synchronizable oscillator for noise-sensitive applications such as communicating computers and electromagnetic pen-based systems.

The monolithic-BiCMOS MAX786, available in commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) versions, comes in a 28-pin, fine-pitch, surface-mount SSOP package. Prices start at $4.15 (1000 up, FOB USA).

(Circle 19)



µP-SUPERVISOR MODULE INCLUDES BACKUP BATTERY

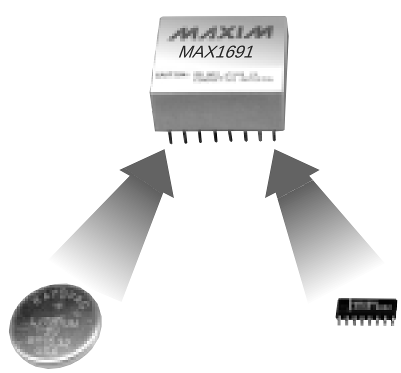
The MAX1691 µP-supervisor module combines an IC (MAX691A) with a 125mA lithium battery. It reduces complexity and lowers the component count associated with power-supply monitoring and battery control in microprocessor systems.

The internal battery remains unconnected until a user connects the BATT and BATTOUT terminals. MAX1691 features include backup-battery switchover, memory-write protection, and a watchdog function that monitors software execution by asserting a reset in the absence of normal digital activity on a selected I/O line.

The MAX1691 switches automatically to an alternate power source (the backup battery) when V_{CC} is below V_{BATT} and below its own reset threshold. RESET and $\overline{\text{RESET}}$ outputs assure that the controlling µP assumes a known state during power-up, power-down, and brownout conditions. Quiescent operating current is 35µA, and standby current is 1µA maximum.

To protect CMOS RAM from erroneous write operations during power failures, the MAX1691 gates the RAM's chip-enable signal. It disables RAM by blocking CE when reset is asserted, and delays CE no more than 10ns during normal operation. The MAX1691 comes in a 16-pin plastic DIP, tested for the commercial (0°C to +70°C) temperature range.

(Circle 20)



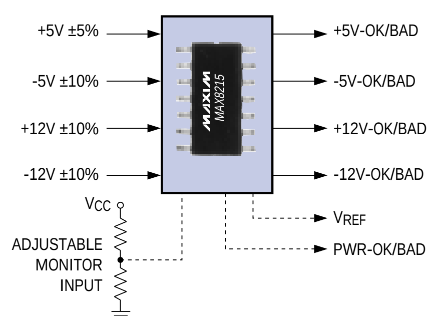
ICs MONITOR ±5V AND ±12V (OR ±15V) WITH ±1.3% ACCURACY

The MAX8215 and MAX8216 voltage monitors each include a 1.25V reference and five comparators, plus internal resistive dividers that dedicate four of the comparators to preset trip thresholds: 12V and -12V (MAX8215 only), 15V and -15V (MAX8216 only), 5V, and -5V. An external divider enables the fifth comparator to monitor any voltage in the range 2.7V to 11V.

The 5V-monitor circuit has 1.3% accuracy; all others have ±2% accuracy. The 1.25V reference is accurate to ±1%. All the comparators have open-drain outputs and built-in hysteresis. The maximum supply current (over temperature) for each device is 400µA.

The MAX8215/MAX8216 come in 14-pin DIP and narrow-SO packages, in versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices start at $1.98 (1000 up, FOB USA).

(Circle 21)



NEW PRODUCTS

SERIAL PORT REDUCES POWER BY FACTOR OF EIGHT

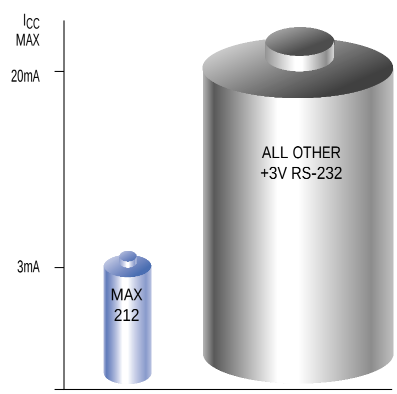
- ***Runs at 120kbits/sec***
- ***Drives mouse at 3V***

The CMOS MAX212 is a 3.3V-powered RS-232 transceiver. Compared with equivalent devices, it handles higher data rates (120kbits/ sec), and draws less no-load current (3mA at 3.3V). Only the MAX212 can drive a mouse at 3V V_{CC}. The MAX212 is the first 3V IC to guarantee 4V/µs slew rates, 120kbit/sec data rates, and ±5V minimum output swings. Its three transmitters and five receivers meet EIA/TIA-232E specifications.

Supply current drops to only 1µA in the low-power shutdown mode. To monitor external devices, all five receivers remain active while in shutdown (subject to logic control). To accommodate different standards, each receiver output has a three-state driver that lets you wire-OR the receivers at the UART. A flow-through pinout (all driver outputs and receiver inputs on the same side) simplifies the pc layout.

The MAX212 is compatible with EIA/TIA-232E, EIA/TIA-562 and V.28/V.24 serial-interface standards. An evaluation kit is available. The MAX212 comes in 24-pin wide-SO packages and tiny SSOP packages, in versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $3.12 (1000 up, FOB USA).

(Circle 22)



COMPLETE 3V SERIAL-DATA INTERFACE RUNS AT 230kbits/sec

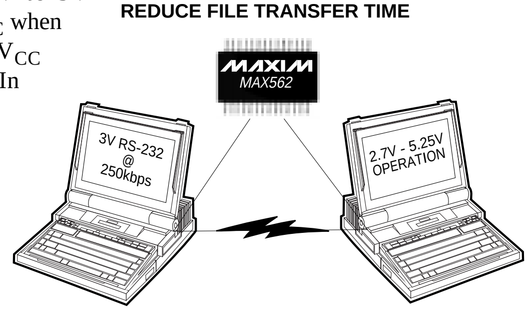
The MAX562 is a 3-driver/5-receiver serial-data transceiver capable of data rates to 230kbits/sec. Featuring a guaranteed-minimum slew rate of 4V/µs, the MAX562 is the fastest transceiver available among those designed specifically for notebook and palmtop computers. Its compliance with the EIA/TIA-562 standard guarantees compatibility with RS-232 ports.

Operation from 2.7V to 5.25V makes the MAX562 suitable for 3V-to-5V systems (which provide a 3V V_{CC} when running on batteries and a 5V V_{CC} when running on wall power). In low-power shutdown mode the device draws only 60µA of quiescent current, yet all five receivers remain active. The MAX562 can monitor five lines in this condition, each at data rates to 20kbits/sec. During normal operation, at 20kbits/sec with a 3kΩ/2500pF load on each output, it consumes about 100mW.

The MAX562 simplifies layout because its "flow-through" pinout places the three driver outputs and five receiver inputs on the same side of the IC. To reduce board space, it comes in 28-pin SO and SSOP packages (the SSOP is 60% smaller than the standard 28-pin SO). MAX562s are tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $3.12 (1000 up, FOB USA).

(Circle 23)

REDUCE FILE TRANSFER TIME



CALIBRATED, PRECISION VOLTAGE REFERENCES GUARANTEE 1ppm/°C DRIFT IN SO PACKAGE!

- ***10ppm/1khrs in SO package!***

The MAX676, MAX677, and MAX678 precision voltage references produce outputs of 4.096V, 5V, and 10V respectively. Each has an internal factory-calibrated "analog ROM" that guarantees unprecedented low temperature drifts of 1ppm/°C. Also guaranteed is a long-term drift of 10ppm/1000hrs.

The analog ROM—an internal network of fusable links that allows factory calibration by digital command—minimizes the output variation with temperature by making internal V_{OUT} adjustments at each of 16 temperatures. This calibration is performed on all units.

Each device guarantees excellent line and load regulation (12ppm/V and 3ppm/mA at +25°C, maximum) while sourcing as much as 5mA or sinking as much as 0.5mA. The output tolerance at +25°C (±0.01%) represents a maximum error of only ±1/2LSB for 12-bit data converters. Maximum output variation over the commercial and extended-industrial temperature ranges, respectively, is ±0.017% and ±0.022%.

Maximum input voltage is 18V. The MAX678 minimum is 12V, the MAX677 minimum is 8V, and the MAX676 minimum is 4.75V, allowing that device to operate on 5V ±5%. MAX676/MAX677/MAX678 references come in 20-pin DIP and wide-SO packages, screened for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges.

(Circle 24)

NEW PRODUCTS

5V RS-232 TRANSCEIVERS PROTECT AGAINST LARGE TRANSIENTS AND ESD

- ***±10kV protection (human body model)***

The MAX211E, MAX213E, and MAX241E are monolithic RS-232 transceivers. In many applications, these ESD-rugged ICs replace the more expensive and space-consuming Tranzorb devices currently used to protect against transient voltages and ESD.

The Maxim devices include four transmitters and five receivers. Operating from 5V, they meet all EIA/TIA-232E and CCITT V.28 specifications at data rates to 120kbits/sec (when loaded in accordance with EIA/TIA-232E).

Maxim's patented RS-232 charge-pump-converter technology produces internal voltages sufficient for generating output levels in full compliance with the EIA/TIA-232E specifications. Each transmitter output and receiver input can withstand ESD shocks as high as ±10kV (human body model). And unlike bipolar RS-232 ICs, Maxim's CMOS MAX211E, MAX213E, and MAX241E handle ESD without latchup.

During shutdown, the MAX213 maintains two receivers active (using only 15µA of current) for monitoring external signals, such as the ring indicator from a modem. MAX241E transceivers operate with 1.0µF external capacitors, while the MAX211E and MAX213E save cost and space with 0.1µF capacitors.

MAX211E/MAX213E/MAX241E devices come in 28-pin wide-SO and SSOP packages (which are 60% smaller than equivalent SO types), tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices (1000 up, FOB USA) start at $3.62.

(Circle 25)