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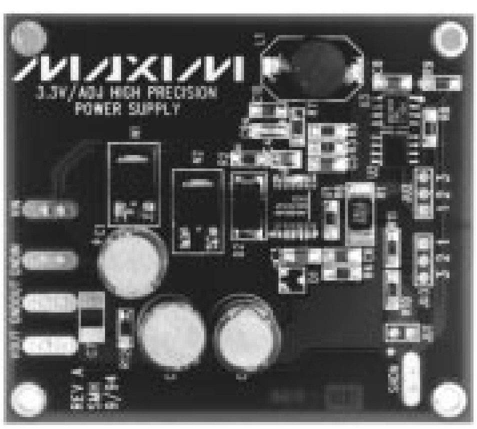
News Briefs

MAXIM INTEGRATED PRODUCTS AND LINEAR TECHNOLOGY CORPORATION SETTLE LAW SUIT

Maxim Integrated Products and Linear Technology Corporation have settled their patent litigation that commenced on August 13, 1993. While both parties have agreed to keep specific terms of the settlement confidential, the agreement provides for cross licenses for existing patents in the RS-232 interface area, with Linear paying a nominal paid-up license fee. Maxim will not use Linear patents relating to step-down switching regulators, and will discontinue using the LTC product name prefix.

1995 NEW RELEASES DATA BOOK

Maxim's *1995 New Releases Data Book* introduces over 130 analog products—all released within the last year. This catalog of new data sheets guides you through your design with detailed specifications and applications information on the latest analog solutions. This book will be mailed by October 30, 1994 in the U.S.



Pentium™, PowerPC™ Power Supply Evaluation Board

This fully assembled evaluation board is available from Maxim. Among other applications, it assists in evaluating the circuits of Figures 5 and 6 in the following article.

™ *Pentium is a trademark of Intel Corp. PowerPC is a trademark of IBM.*

Power supplies for Pentium™, PowerPC™, and beyond

The latest microprocessors to emerge from Intel, Motorola, and others are forcing fundamental changes in the power supplies for desktop and portable computers. Not only do the µPs demand lower and more precise supply voltages, but their main clocks also exhibit start/stop operation that causes ultra-fast load transients. As a result, the relatively simple 5V/12V supply has been transformed into a system with five or more outputs, featuring unprecedented accuracy and 50A/µs load-current slew rates.

These characteristics present a problem: it appears that the classic, centralized power-supply architecture cannot provide the accuracy and transient response needed by coming generations of computer systems. The more effective approach will be a distributed architecture in which local, highly efficient dc-dc converters are located on the motherboard next to the CPU. Expect power-supply manufacturers to respond with smaller, higher-frequency ICs and modules that feature improved dynamic response and better synchronous rectifiers. The PC's offline (silver box) power supply won't disappear; it will remain to generate the main bus for small dc-dc converters on the motherboard.

This article examines the power-supply architectures proposed for next-generation computers, and takes a close look at solutions for the problems currently facing designers of board-level computers.

Voltage proliferation

The most significant trend associated with CPU power supplies is that of lower and lower supply voltages. The race downward to new voltage levels proceeds in jumps, as each major CPU manufacturer brings successive new fab processes on line. Currently, the lowest voltage mentioned around Maxim is 1.1V—rumored as the V_{CC} required for certain CPUs yet to be released.

It seems likely that core-logic chips, which will probably make use of the fab capacity vacated by CPUs as they graduate to finer-lithography fabs, will follow the CPUs in supply voltage. DRAM voltages, on the other hand, will probably remain at 3.3V for some time to come because of the large investments in 3.3V fabs. Five volts should remain for a long time as well, even if used only to support audio and the existing customer base for PCMCIA cards and other 5V-only peripherals. The result is a list of likely voltages (**Table 1**) that apply to ICs ranging from the present to more than a year away.

Table 1. Current and projected operating voltages

Supply	Imminent	1.5 Years Out	3 Years Out
CPU	2.XV	2.5V or less	1.XV
Core Logic	3.3V	3.3V	2.XV
DRAM	3.3V	3.3V	3.3V
I/O and Analog	5V	5V	5V
PCMCIA, ISA 12V	12V	12V	?
Bus Termination	none	1.5V	1V
Total Supply Voltages	4	5	5–6

In addition to the standard CPU, I/O, and core-logic supplies, future systems will need a power supply for terminating high-speed data buses such as the 66MHz Gunning Transceiver Logic (GTL) bus (**Figure 1**). Invented by Bill Gunning at Xerox, it consists of 144 or more open-drain transistor drivers, each with a 50Ω resistive pull-up to a low-voltage source (typically 1.5V).

Special CPU voltages

In addition to the trend toward lower voltages, another factor is proliferating the levels of supply voltage: the tendency for manufacturers to specify special levels for certain models or clock-speed variants of a given CPU. This "voltage du jour" practice, conducted to enhance manufacturing yields at high clock speeds, includes 4V (Cyrix), 3.6V (Power PC), and 3.45V (Intel).

A good example of special supply voltage is the "VR" version of Intel's P54C Pentium, which requires a supply voltage between 3.30V and 3.45V including noise and transients. This spec gives headaches to power-supply designers, who must worry about noise, transient response, and the minute voltage drops in connectors and wiring, as well as fundamental dc accuracy. Their complaints about layout difficulty and extra cost, however, are rightly outweighed by savings in the CPU itself. Paying 20% less for a $500 CPU can finance a lot of power-supply stuff, so don't expect CPU makers to avoid non-standard supply levels—especially for their latest and "hottest" models.

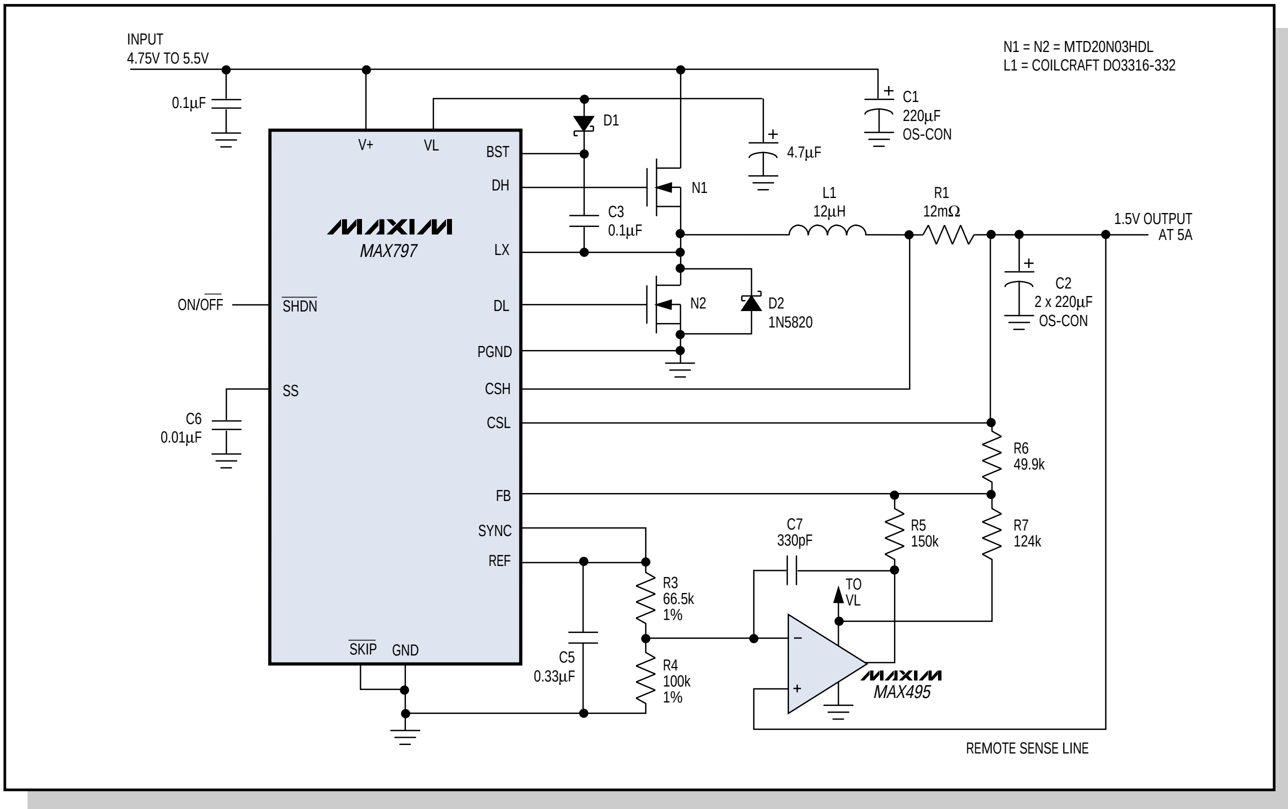


Figure 1. This highly accurate, 1.5V step-down dc-dc converter powers the termination resistors in a Gunning Transceiver Logic (GTL) bus. The converter's architecture—buck topology with synchronous rectifier—is by far the best choice for low-voltage, high-efficiency distributed power systems.

Cross-regulation error

Another challenge for power-supply designers is cross-regulation error—the variation at one regulated output caused by load-current variation at another—which is common in classic, low-cost, multi-output offline supplies. This error, produced in "green PCs" governed by load-switching power-management techniques, is actually caused by a power-saving measure—the absence of minimum loads on the regulated outputs.

The standard low-cost power supply for PCs generates multiple output voltages by including extra transformer windings on a flyback or forward off-line supply. A minimum load on the main output is necessary for maintaining regulation on the secondary outputs. But, this technique causes problems in the new computers (Green PCs), which employ load-switching and clock-halting schemes to reduce power consumption. The resulting wild fluctuations of load current at each output can produce severe cross-regulation errors in conventional supplies. Along with fast load transients and tight output-accuracy specs, the cross-regulation problem is one reason why future systems will probably adopt a distributed power-supply architecture.

Another reason is parasitic inductance in the high-current paths. For systems in which the CPU clock starts and stops abruptly, even a few inches of wire contributes enough inductance to cause excessive ringing or sagging (or both) at the V_{CC} pins. For the many cases in which IR drops and unwanted inductance completely rule out a centralized power supply, you must adopt a distributed-power architecture. It usually consists of small, local dc-dc converters or linear regulators on the CPU motherboard, fed with 5V or 12V from the familiar silver-box power supply in the PC.

Once you decide on a distributed architecture, the next step is to decide between linear and switch-mode regulators. The issue is usually clear-cut: if you can tolerate the heat and efficiency loss, go with a linear supply; if not, choose a switch-mode supply with a step-down (buck) topology. Future desktop systems will probably distribute a power bus of 5V or 3.3V (or both), and generate the lower CPU voltages with local linear regulators (**Figures 2 and 3**). Portable systems, in which efficiency is always paramount, often distribute their battery voltage to switch-mode converters located on the motherboard.

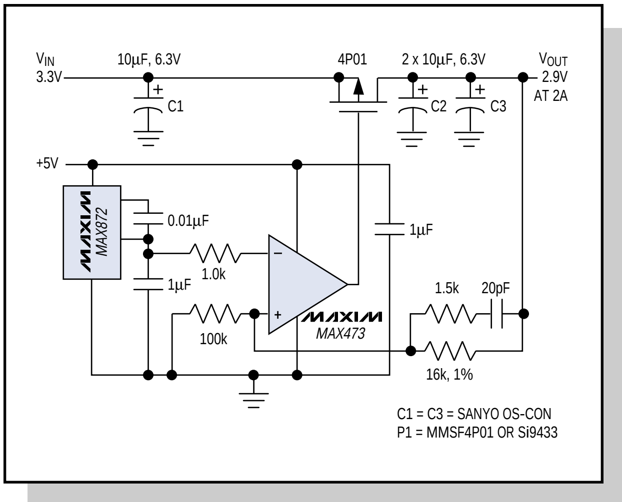


Figure 2. This linear-regulator circuit includes a fast, low-power op amp for excellent dynamic response to fast-load transients caused by the latest dynamic-clock CPUs. The low-threshold, p-channel MOSFET (vs. a bipolar transistor) provides an ultra-low dropout voltage and minimum quiescent current.

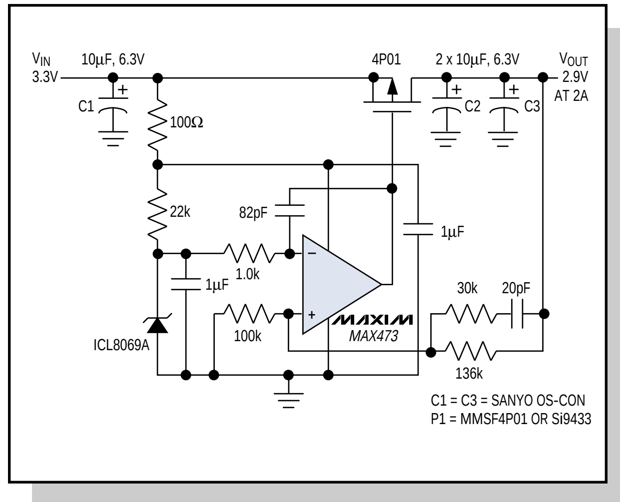


Figure 3. For systems in which 5V is unavailable for the op amp, this stand-alone linear regulator operates entirely from the 3.3V bus, generating 2.9V with only a minor degradation in transient response.

Linear regulators cost $2 to $3, vs. $6 to $7 for a switch-mode type. Faster loop response lets the linear types handle load transients with less output capacitance. And in many cases, the linear regulator's efficiency is acceptably high even for portable applications.

Discounting the losses due to quiescent and base currents, the efficiency of a low-dropout linear regulator equals V_{OUT}/V_{IN}. A 5V-to-3.3V converter, for example, has an efficiency of 66%—which means that a maximum load of 3A will produce 5W of heat dissipation. That amount of power is easily handled with a heatsink, but for multiprocessor LAN servers with four or more CPUs, the required dissipation jumps to 20W. That power level is hard to disperse in a system that is already blazing hot. For 5V-to-3.3V desktop systems, the load-current crossover point at which heatsinking problems outweigh the extra cost of a switch-mode supply is about 5A.

Step-down switching regulators exhibit typical efficiencies of 90% or better, almost independently of V_{IN}. But, compared with linear regulators they are more expensive, require a more careful pc layout, and generate more ripple and EMI. The classic buck topology (**Figure 4**) is by far the best choice; it is simple, has very high efficiency, and has the smallest magnetic components of all the competing topologies (forward, flyback, Cuk, etc.). Buck regulators are also compatible with synchronous rectifiers—a feature of increasing importance as CPU voltages fall, causing the power loss in a forward-biased rectifier to become a larger portion of the output power.

Low-voltage, high-accuracy supplies

At lower levels of supply voltage, the logic swings decrease and produce a corresponding shrinkage in noise margins. Power supplies for future systems must therefore have very good dc and ac accuracy to avoid noise-margin problems. A 5%, 1.5V supply, for instance, has an output tolerance of just ±75mV. Small voltage drops across the resistance of a connector, power-MOSFET switch, or wiring harness can so degrade accuracy as to render this supply unusable.

The dominant term affecting overall accuracy in a power supply is that of the internal reference-voltage accuracy. Reference accuracy is therefore a key parameter in power-supply ICs for the next generation of low-voltage systems. The question for IC designers is, how much manufacturing cost do you allow for the reference? The issue is not so much silicon area as the cost of laser trimming, testing, and yields.

The reference in today's typical power-supply IC represents 20% to 25% of the IC's manufacturing cost, and has a ±2% output tolerance. The ±2% error band allows the manufacturer to test at room temperature only, and screen for temperature extremes by sample testing only. But at ±0.5%, all the parts must be tested over temperature, and the the laser trimming must be more precise. Costs increase accordingly. Thus, the decision to include a precision, data-acquisition-grade reference in a power-supply IC is not to be made lightly.

Two circuit configurations provide high-accuracy supply voltages, each with a different tradeoff between cost and

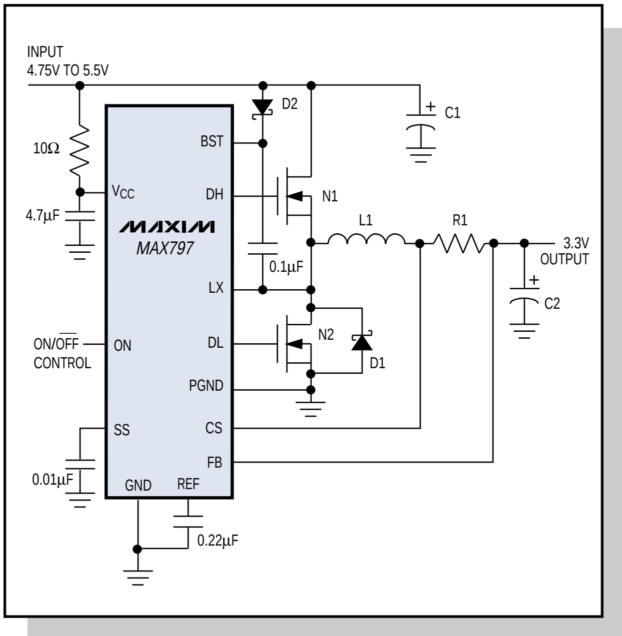


Figure 4. This step-down (buck) switching regulator employs all n-channel MOSFETs to save cost, and operates at 300kHz to minimize the physical size of its inductor.

accuracy (**Figures 5 and 6**). Both reduce the load-regulation error (to 0.1%) by increasing the dc-loop gain with an external integrator amplifier (MAX495). The first circuit achieves low reference error with a screened ("T" grade) version of the MAX767, whose reference tolerance is ±1.2% maximum. This Pentium P54C-VR application circuit is available from Maxim as an evaluation kit. The second circuit achieves still lower error with an external reference (MAX872), whose contribution to output uncertainty is only ±0.38% over temperature.

Both circuits have low output ripple and excellent dynamic response. Step changes from zero to full load produce output excursions of less than 40mV. In particular, each circuit supports the VR (voltage regulator) version of Intel's P54C Pentium CPU, whose supply voltage (including noise and transients) must remain between 3.30V and 3.45V. **Table 2** lists the components recommended for different levels of output current in these two circuits.

Note: To prevent over-voltage at the CPU when the remote-sense line connects at the far side of a connector (which could be disconnected during supply operation), connect 10kΩ from the sense line to the connector's near (power-supply) side.

(Circle 1)

Table 2. Component recommendations for Figures 5 and 6

Part	1.5A Circuit	3A Circuit	5A Circuit	7A Circuit	10A Circuit
L1	10µH Sumida CDR74B-100	5µH Sumida CDR125 DRG# 4722-JPS-001	3.3µH CoilCraft DO3316-332	2.1µH, 5mΩ Coiltronics CTX03-12338-1	1.5µH, 3.5mΩ Coiltronics CTX03-12357-1
R1	0.04Ω IRC LR2010-01-R040 or Dale WSL-2512-R040	0.02Ω IRC LR2010-01-R020 or Dale WSL-2512-R020	0.012Ω Dale WSL-2512-R012 or 2 x 0.025Ω IRC LR2010-01-R025 (in parallel)	3 x 0.025Ω IRC LR2010-01-R025 or Dale WSL-2512-R025 (in parallel)	3 x 0.020Ω IRC LR2010-01-R020 or 2 x 0.012Ω Dale WSL-2512-R012 (in parallel)
N1, N2	International Rectifier IRF7101, Siliconix Si9936DY or Motorola MMDF3N03HD (dual n-channel)	Siliconix Si9410DY, International Rectifier IRF7101 or Motorola MMDF3N03HD (both FETs in parallel)	Motorola MTD20N03HDL	Motorola N1: MTD75N03HDL N2: MTD20N03HDL	Motorola MTD75N03HDL
C1	47µF, 20V AVX TPSD476K020R	2 x 47µF, 20V AVX TPSD476K020R	220µF, 10V Sanyo OS-CON 10SA220M	2 x 100µF, 10V Sanyo OS-CON 10SA100M	2 x 220µF, 10V Sanyo OS-CON 10SA220M
C2	220µF, 6.3V Sprague 595D227X06R3D2B	2 x 150µF, 10V Sprague 595D157X0010D7T	2 x 220µF, 10V Sanyo OS-CON 10SA220M	2 x 220µF, 10V Sanyo OS-CON 10SA220M	4 x 220µF, 10V Sanyo OS-CON 10SA220M
D2	1N5817 Nihon EC10QS02, or Motorola MBRS120T3	1N5817 Nihon EC10QS02, or Motorola MBRS120T3	1N5820 Nihon NSQ03A02, or Motorola MBRS340T3	1N5820 Nihon NSQ03A02, or Motorola MBRS340T3	1N5820 Nihon NSQ03A02, or Motorola MBRS340T3
Temp. Range	to +85°C	to +85°C	to +85°C	to +85°C	to +85°C

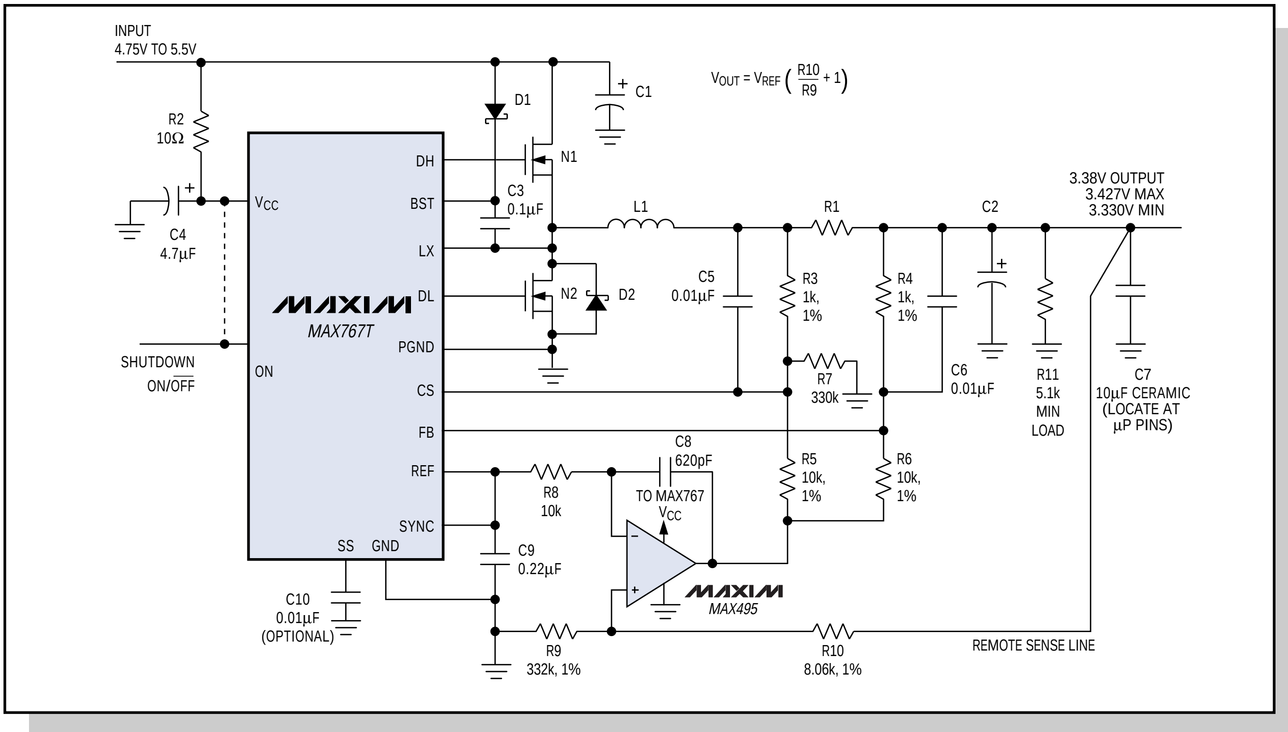


Figure 5. This high-precision, step-down dc-dc converter is intended for Pentium P54C-VR desktop applications with stringent requirements for dc and ac accuracy. An evaluation kit for this Pentium VR application is available to speed designs (see page 2).

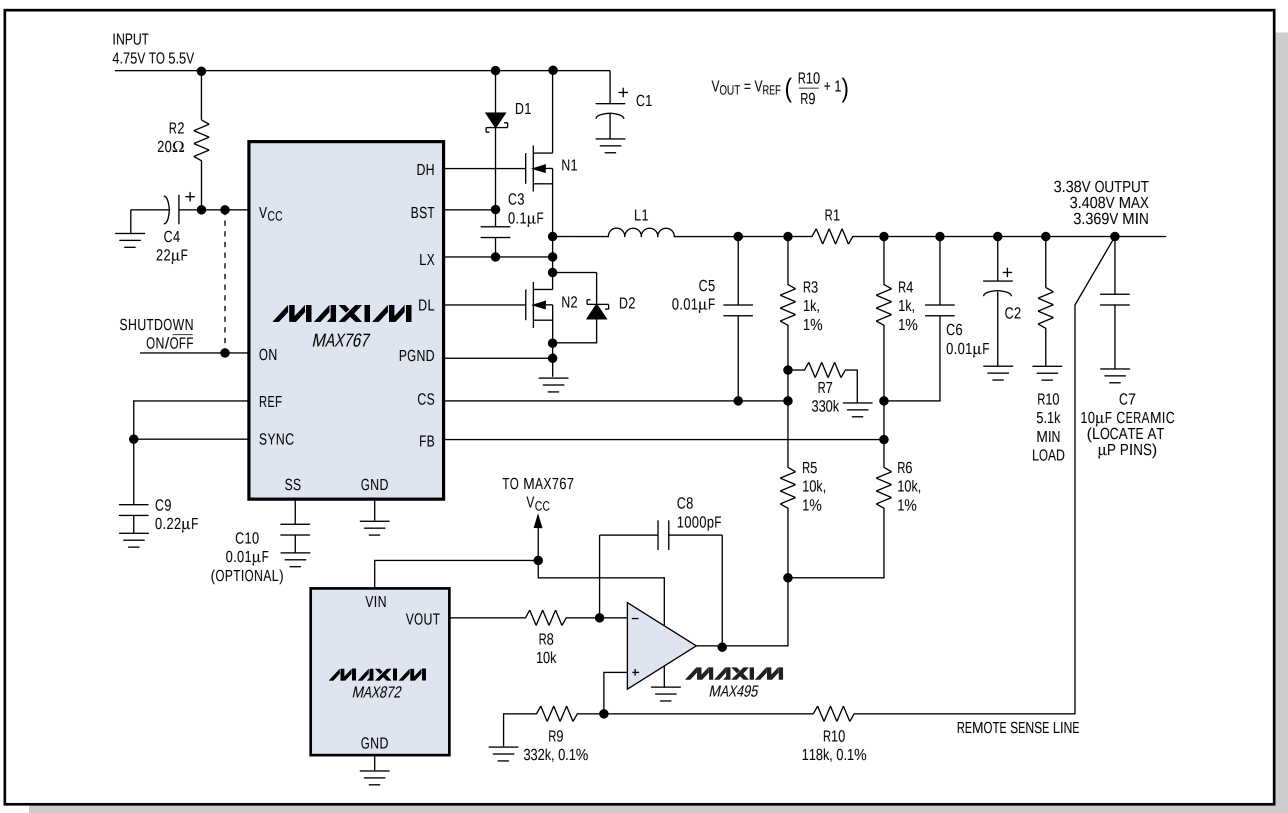


Figure 6. Otherwise similar to the step-down converter of Figure 5, this circuit adds a data-acquisition-grade voltage reference to further improve dc accuracy.

New ICs boost video performance

*By integrating the functions once implemented with discrete components, new video ICs are making life easier for the design engineer (**Table 1**). The new products not only cost less and save space on the pc board, they offer better performance because the proximity of video functions on the IC reduces parasitic capacitance and its detrimental effect on bandwidth and other parameters. This article introduces basic video technology along with new, state-of-the-art video switches and their applications.*

Switching is a common requirement in video systems. Video editors must select one of several input signals on command, and other systems (broadcast studios, security and surveillance networks) must be capable of displaying multiple input signals on multiple monitors.

Traditional video switches are followed by a buffer amplifier in a separate package. Some applications include an input buffer as well, to isolate the signal sources and preserve bandwidth (**Figure 1a**). The resulting circuits require at least two or three packages, but recent video-switch ICs have absorbed the output buffer while precluding the need for an input buffer. This integration of functions lowers the package count to one, and by minimizing certain parasitic capacitances it also improves the electrical performance.

Monolithic vs. discrete switch/buffers

Distributed capacitance associated with the package, board, and switch make bandwidth preservation a difficult job in the traditional, discrete-IC video switch (**Figure 1b**). Switch capacitance C_{DS} causes feedthrough that reduces OFF isolation. C_{pb} and C_{pp}, also associated with the switch, combine with source impedance R_{SOURCE} (usually 75Ω) to produce a bandwidth-limiting pole. The finite source impedance also causes C_{pp} to produce coupling (crosstalk) between the two channels. Adding an input buffer as shown in Figure 1a eases the effect on bandwidth and crosstalk by substituting a low impedance for R_{SOURCE}.

Referring again to Figure 1b, note that the switch output capacitance consists of C_{pb} and C_{CM} in parallel, plus a differential-mode value (C_{DM}) between the pins. These capacitances charge rapidly when the switch closes (turns on), but they discharge through a rapidly increasing switch resistance when the switch turns off. The resulting slow turn-off can produce unwanted artifacts at the boundary between images in a graphics display.

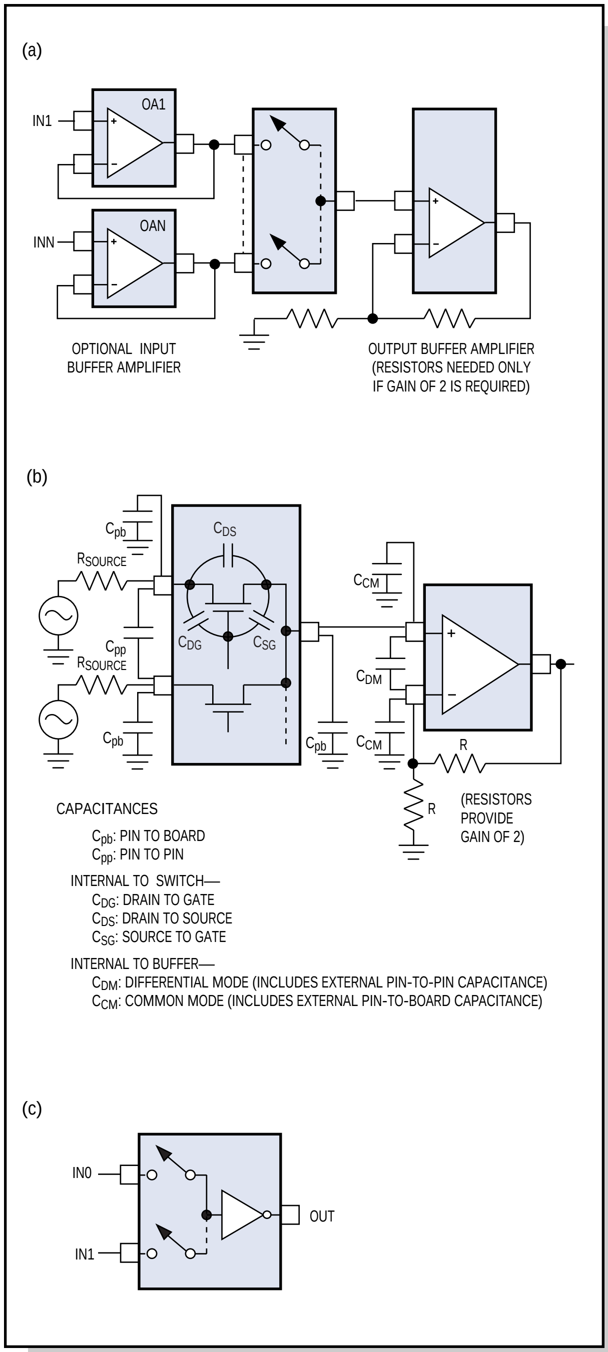


Figure 1. For a traditional video switch, the switch and buffers reside in separate ICs (a). Parasitic capacitances in the traditional switch limit bandwidth and provide paths for unwanted feedthrough and crosstalk (b). The integrated approach (c) improves performance by minimizing parasitics.

Table 1. Video/High-Speed Products

Part Number	Unity GBW (MHz)	Slew Rate (V/µs)	V_{OS} (mV max)	Output Current (mA min)	Supply Voltage (V)	I_{BIAS} (nA max)	Features	Price† 1000-up ($)
VIDEO AMPLIFIERS								
MAX404	80 ($A_V \geq 2$)	500	8	50	±5	3µA	Broadcast-quality video op amp, 0.01°/0.05% diff phase/gain, symmetrical inputs, 70dB CMRR, 66dB A_{VOL}	2.68
MAX408/428/448	100 ($A_V \geq 3$)	90	6 to 12	50/op amp	±5	1.1µA	Single/dual/quad op amp, high-output drive	3.02/4.06/6.74
MAX435/436	275	800	3	10	±5	3µA	Ultra high-speed differential input/output transconductance amp, no feedback required	2.75
MAX445	200	2.5ns (typ)	–	140	+10, -10.5, +75	10µA	CRT video display driver for ultra-high resolution monitors, single IC pre-amp and high-voltage (+75V) output stage	6.83
MAX452	50	300	5	14	±5	10	Unity-gain stable, drives 75Ω coax cable	2.40
MAX457	70	300	5	15	±5	1	Dual, unity-gain stable, drives 75Ω coax cable	4.45
MAX476	300	3000	2	100	±5	5µA	Gain of +1 or +2 buffer, 0.01°/0.01% diff phase/gain error	††
BB3554	90	1200	1	125	±15	50pA	Fast-settling (150ns), differential JFET input	56.99
VIDEO BUFFERS								
MAX4005	950	1000	3	75Ω output	±5	1	FET input buffer with 75Ω output to minimize reflections, 0.03°/0.11% diff phase/gain, 60MHz gain flatness (0.1dB), 28dBm IP_3 (100MHz)	2.75
MAX405	180	650	5	60	±5	2µA	Broadcast quality, 0.99V gain guaranteed over temp, 0.01°/0.03% diff phase/gain error	4.25
MAX460	140	1500	5 to 10	100	±15	0.05 to 0.1	FET input, EL2005/LH0033 upgrade	19.78
MAX467	100	200	10	20	±5	–	Triple (RGB) video buffer, 0.03°/0.01% diff phase/gain error	3.70
MAX468	100	200	10	20	±5	–	Quad, unity-gain video buffer, 0.03°/0.01% diff phase/gain error	4.20
MAX469	90	300	10	20	±5	–	Triple (RGB), gain of +2 video buffer, 0.03°/0.01% diff phase/gain error	3.70
MAX470	90	300	10	20	±5	–	Quad, gain of +2 (6dB) video buffer, 0.03°/0.01% diff phase/gain error	4.20
MAX477	500	3000	4	100	±5	5µA	Ultra high-speed amplifier, 0.01°/0.01% diff phase/gain error	††
LH0033	100	1400 to 1500	5 to 20	100	±15	0.1 to 0.5	FET input, improved industry standard	13.67
LH0063/BB3553	300	2000	25 to 50	200	±15	0.2 to 0.5	FET input, industry standard	23.51/24.99
VIDEO MULTIPLEXERS/AMPLIFIERS								
MAX440	160 110 ($A_V \geq 2$)	370	10	35	±5	2µA	Video amp with 8-channel mux, 0.03°/0.04% diff phase/gain error,15ns switch time, high-Z output state	8.95
MAX441	160 110 ($A_V \geq 2$)	370	10	35	±5	2µA	Video amp with 4-channel mux 0.03°/0.04% diff phase/gain error, 15ns switch time	5.90
MAX442	140	250	5	35	±5	2µA	Video amp with 2-channel mux, 15ns switch time, 8-pin DIP/SO	4.45
MAX453	50	300	5	14	±5	10	Video amp with 2-channel video mux	3.94
MAX454	50	300	5	14	±5	10	Video amp with 4-channel video mux	5.25
MAX455	50	300	5	14	±5	10	Video amp with 8-channel video mux	8.75

Part Number	Unity GBW (MHz)	Slew Rate (V/µs)	Switching Time (ns)	Number of Inputs	Number of Outputs	Buffer Amp Gain (V/V)	Output Current (mA)	Features	Price† 1000-up ($)
RGB VIDEO SWITCHES									
MAX463/465	100	300	20	6 (RGB_A, RGB_B)	3 (RGB)	+1, +2	20	RGB switch with 75Ω cable drivers	6.97
MAX464/466	100	300	20	8 (RGB_A + Sync, RGB_B + Sync)	4 (RGB + Sync)	+1, +2	20	RGB + sync switch with 75Ω cable drivers	7.97

Part Number	Unity GBW (MHz)	Slew Rate (V/µs)	Diff Phase/Gain Error	Off Isolation (dB typ)	Crosstalk (dB typ)	Features	Price† 1000-up ($)
VIDEO CROSSPOINT SWITCHES							
MAX456	35	250	1°/0.5%	80 (5MHz)	70 (5MHz)	8 x 8 crosspoint switch array with 8 output buffers, high-Z output capability	19.98
MAX458/459	100	300	0.05°/0.01%	60 (10MHz)	55 (10MHz)	8 x 4 crosspoint switch array with four 75Ω cable drivers, high-Z output capability.	22.00

† Prices provided are for design guidance and are FOB USA. International prices will differ due to local duties, taxes, and exchange rates.

†† Future product—contact factory for pricing and availability. Specifications are preliminary.

Switch on-resistance must be low enough to prevent distributed capacitance from limiting the signal bandwidth. A 75Ω switch with 10pF, for example, produces a rolloff to -3dB at $\frac{1}{2}\pi RC$ = 212MHz. But, switches with low on-resistance are physically large structures with unavoidably large values of junction capacitance C_{DG}, C_{DS}, and C_{SG}. C_{DS} undermines the isolation between source and output, and the other parasitics undermine the bandwidth. An input buffer can compensate for these effects, but (as mentioned) it adds a third package to the circuit.

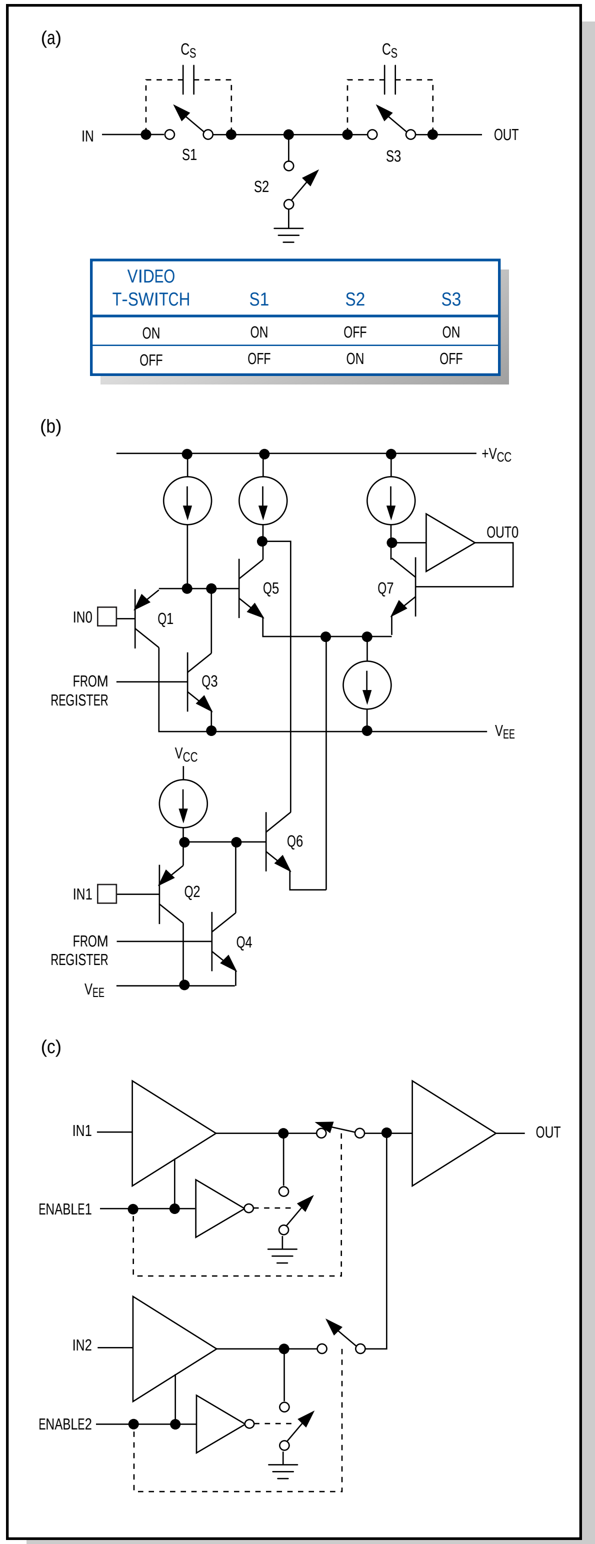
The integrated approach combines switch and buffer in one package (**Figure 1c**). The switch can have higher on-resistance because the switch-to-amplifier capacitances (C_{pb}, C_M, and C_D) are smaller. In turn, the higher-resistance switch is physically smaller, and its lower-valued C_{DG}, C_{DS}, and C_{SG} may eliminate the need for an input buffer. As a further advantage, switching transients and other performance parameters are specified for the switch/buffer combination as a single subsystem. Integration thus improves performance while saving board space.

Circuit topology

A major concern in multiplexing video signals is the degree of isolation between the output and the non-selected input signals. Data sheets specify this isolation as “adjacent-channel crosstalk” and “all-hostile crosstalk.” Integrated multiplexer-amplifiers perform well in this respect—most such devices provide isolation in excess of -60dB, which is sufficient for most NTSC and PAL systems.

A popular method for providing high isolation is the “T” switch (**Figure 2a**). Used in all CMOS “mux-amps” from Maxim, the T-switch preserves isolation by shorting to ground the feedthrough capacitance of S1: when the T-switch is on, S1 and S3 are closed and S2 is open; when the T-switch is off, S1 and S3 are open and S2 is closed. Thus, signals that would otherwise couple through C_S are shorted to ground before reaching the output. The disadvantage—higher on-resistance due to S1 and S3 in series—is usually not a problem for the IC because intra-chip capacitances at the output of S3 can be kept very low.

An implementation of the T-switch in bipolar technology includes parallel npn transistors on one side of the buffer amplifier’s differential input pair (**Figure 2b**). Turning on Q3 steers emitter current from Q1 and robs Q5 of base current. Q1 and Q5 turn off, disconnecting IN0 from the output stage. This action is similar to that of the T-switch, in which two off transistors (Q1 and Q5) are shorted to ground via Q3.



VIDEO T-SWITCH	S1	S2	S3
ON	ON	OFF	ON
OFF	OFF	ON	OFF

Figure 2. By shunting feedthrough currents to ground (through S2), the T-switch provides improvements of 6dB to 12dB in feedthrough and crosstalk (a). Implemented in bipolar technology, the T-switch configuration offers high input impedance and low input capacitance (b). Make-before-break action in the integrated T-switch minimizes glitches (c).

Definitions

"Video" in this article refers to the approximate 4MHz to 6MHz analog signals that emanate from a video camera—i.e., baseband video in the context of broadcast television. "Graphics" refers to the resulting CRT display. (Note that the video signals for high-performance workstations and other graphics systems, generated by a computer and reconstructed with a D/A converter, can exceed 100MHz.) Other video terms are defined as follows:

NTSC (National Television Standards Committee) is the US agency that developed standard monochrome and composite-color waveforms for the US. NTSC signals are now used in the US, Japan, Canada, Mexico, and many other countries of the western hemisphere. Because these systems are sensitive to errors of differential gain and phase, Europeans once referred to NTSC as "Never The Same Color." Today's high-performance circuits have largely eliminated these problems.

PAL (Phase Alternate Line) is a transmission standard for color television developed by the Telefunken Company in Germany, partly as an answer to the shortcomings of NTSC. Though similar to NTSC, it includes a line-by-line alternation in phase for one of the two color-signal components, which minimizes the distortion due to differential phase error between the luminance and chrominance signals. PAL is used by the United Kingdom and most of Western Europe, except France.

SECAM (Sequential Couleur Avec Memoire) was developed in France, also as an alternative to NTSC. Luminance signals have the same format as those of NTSC and PAL, but the color-difference signals modulate two separate carriers that are transmitted on alternate lines. To restore the missing color information for a given line, SECAM receivers include a one-line memory element (1H delay). Today, SECAM is used in France and in some countries of the former USSR.

IRE (Institute of Radio Engineers) was a forerunner of today's IEEE. Today, the term represents an arbitrary unit for measuring relative amplitudes on a video signal. One hundred IRE units represents full scale (i.e., 1V on a monochrome signal or 0.714V on a color signal).

RGB (Red, Green, Blue) is a term that refers to the primary colors. A video camera resolves light into its RGB components and generates the corresponding analog voltages E_R, E_G, and E_B. After gamma correction (which minimizes the visual effect of noise by assuring a logarithmic relation between signal amplitude and CRT brightness) the signals become E_R', E_G', and E_B'. These are encoded to produce the luminance component "E_Y" ($0.30E_R' + 0.59E_G' + 0.11E_B'$), and the chrominance components "E_U" ($E_R' - E_Y$) and "E_V" ($E_B' - E_Y$).

Component video refers to individual signal components such as the three found in an RGB or YUV system.

Composite video is an analog waveform suitable for transmission on a single channel. It is obtained by combining the chrominance and luminance signals with sync and blanking pulses.

Saturation is a term of perception (not subject to quantitative measurement) that refers to the intensity of a primary color. It corresponds to purity, which is an objective, measurable quantity.

Hue is a term of perception (not subject to quantitative measurement) that corresponds to a color's dominant wavelength, which is an objective, measurable quantity.

Color burst is a brief reference pulse of RF energy that is transmitted with every line of an NTSC signal. Because the color subcarrier (phase and amplitude modulated according to hue and saturation) and the color burst derive from the same signal, phase and amplitude distortion affect burst and subcarrier equally, and tend to cancel.

Differential gain and **differential phase** errors result from nonlinear characteristics in a video amplifier. Because the amplifier's gain and phase responses change slightly with signal level, variations in luminance affect the color subcarrier's gain and phase modulation. Differential gain error (DG) is a change in gain as the amplifier's dc output level swings from 0V to 1V, and differential phase error (DP) is a change in phase over the same range. DG (expressed in dB or %) affects color saturation in the CRT display, and DP (expressed in degrees) affects the hue.

Similarly, turning off Q4 allows Q2 to act as an emitter follower, connecting IN1 to the output via Q6. The high input impedance and low input capacitance of this pnp emitter follower (Q2) negates the need for an input buffer amplifier. It also isolates the input signal from switching transients. The circuit's make-before-break action minimizes glitches (**Figure 2c**). Note that a break-before-make action would open both switches at the same time, floating the inputs to the output stage and causing a high-amplitude glitch as the output slews toward a supply rail.

Mechanical switches usually avoid make-before-break action, because shorting the inputs together would disrupt the signals on those channels (the signals may be routed to other destinations besides the switches). This problem can't occur with bipolar switches from Maxim, because each switch is preceded by an internal unity-gain buffer.

T-switches are found in integrated-circuit multiplexers as well as IC switches. Maxim's MAX442, for example, combines a 2PST switch with an uncommitted, unity-gain-stable output amplifier in an 8-pin DIP or SO package. It switches one of two composite video signals to a single output, as required in a video editor or tape recorder. T-switches in the MAX442 assure -76dB minimum isolation and crosstalk, which is 6dB to 12dB lower than that of conventional switches.

Composite video vs. RGB

In video systems, "RGB" refers to the three electrical signals corresponding to the red, green, and blue components of an image. After correction and shaping, the RGB signals are encoded to produce chrominance (color) and luminance (brightness) signals. Then, combining the chrominance and luminance with sync and blanking signals produces a "composite" video signal (see **sidebar**). Thus, combining all video information in a single signal makes a convenient input for monitors, VTRs, and broadcast transmitters.

Composite signals allow single-channel transmission (especially convenient for broadcasting), but their complex encoding of chrominance and luminance information carries disadvantages. System nonlinearities, for instance, degrade the image by producing unavoidable crosstalk between the luminance and chrominance components. To control this problem, engineers seek to develop signal-processing electronics with minimal errors of differential gain (which affects color saturation) and differential phase (which affects hue).

Video signals in a broadcast studio may pass through many stages of editing and recording. To maintain fidelity in these applications, the studio video is best handled in a three-signal "component" format that eliminates the use of subcarriers with their crosstalk and noise problems. The original RGB can serve as component video, but advantages are realized by encoding RGB as YUV—i.e., the electrical analogs of luminance (Y) and the color differences B-Y (U) and R-Y (V) (see sidebar).

YUV requires less bandwidth than RGB: Equal amounts of picture detail reside in R, G, and B, but the YUV system conveys fine picture detail only in Y (U and V carry color information only). Bandwidths are approximately 4.2MHz for Y, 0.5MHz for U, and 1.5MHz for V, resulting in a lower overall bandwidth that can save costs. A video tape recorder, for example, needs three tracks to handle RGB video. For YUV, the VTR requires only two tracks—one for Y and one for U and V together.

YUV components have another advantage—the U and V signals are less subject to electronic gain error than are the RGB signals. Gain error in one RGB channel produces a wrong-colored image; gain error in the U or V channel produces only a small change in hue or saturation.

Many video cameras provide RGB outputs in addition to a composite output, and some commercial television monitors provide RGB inputs in addition to the composite input. YUV components are easily derived from RGB components with a resistive network called a matrix circuit.

Video editors

The substitution of video ICs for discrete-component circuitry, plus the growing importance of video for teleconferencing and related applications, has produced an expanding market for video ICs. One target for these products is the video editor.

Video editors accept one or more signals, which may be in different formats, from cameras, VTRs, computers, and other sources. After "editing" (rotating, translating, zooming, mixing, keying, wiping, etc.) the editor directs the signals to one or more VTRs or other systems. The video editor's electronics must pay close attention to dc as well as ac signal parameters.

In many cases, dc levels are unknown for the video editor's input signals. Each input, therefore, may include a dc-restore circuit that employs capacitive coupling to establish the zero (black) level. If this dc restoration is followed by switching, the subsequent amplifiers must have low dc offsets.

Two such devices—the MAX440 and MAX441 multiplexer/amplifiers (mux/amps)—illustrate the perfor-

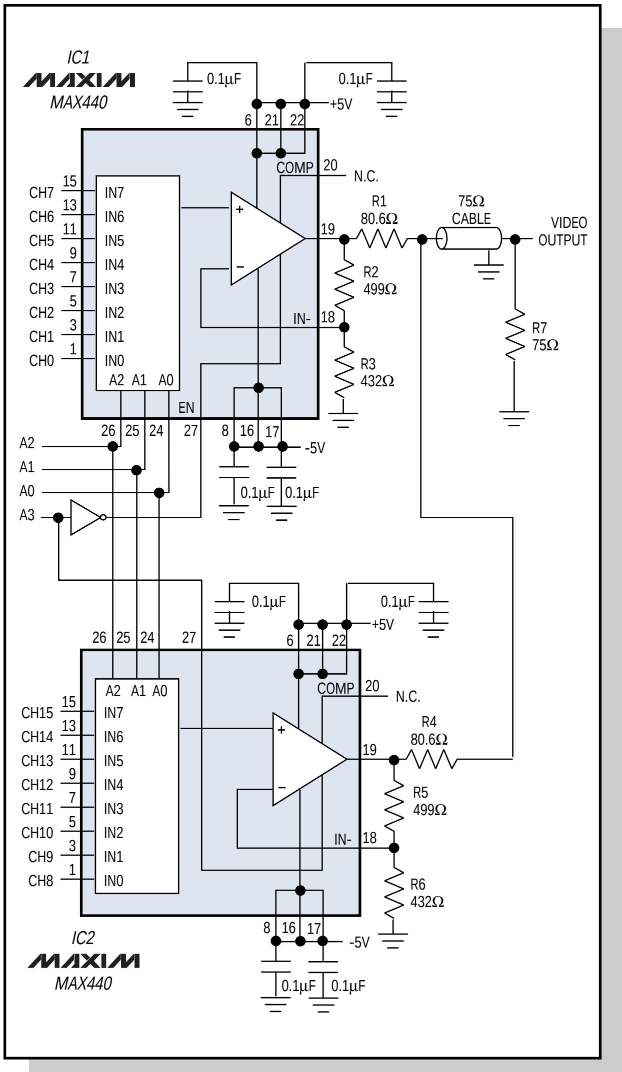


Figure 3. These mux/amp ICs can be combined as shown to form larger multiplex arrays.

mance available with T-configuration switches. Each combines a unity-gain-stable, wideband output buffer with an 8-channel (MAX440) or 4-channel (MAX441) video multiplexer. The parts offer low input-offset voltages of ±2.5mV typical ($\frac{1}{4}$IRE), low values of differential gain and phase (0.04% and 0.03° respectively), and low feedthrough and crosstalk (-66dB).

The ICs' output-disable capability enables their use in larger multiplex arrays (**Figure 3**). Each EN input serves as a fourth address bit (A3), and the inverters insure that two amplifiers are not enabled simultaneously. With proper selection of the R1–R6 values you can add more MAX440s in parallel, up to a limit imposed by parasitic capacitance and feedthrough from the de-selected channels.

Each back-termination resistor (R1 and R4) has been increased from 75Ω to 80.6Ω to compensate for the three resistors at the output of the disabled amplifier. In parallel with R1 or R4, these resistors produce the desired 75Ω termination value. The three resistors also form a divider with the active amplifier's output resistor. To compensate for this effect, the closed-loop gain of each amplifier is set slightly greater than 6dB. And to help minimize ringing, the amplifier outputs are joined at the cable end of R1 and R4—a connection that allows the resistors to isolate the enabled amplifier from the output capacitance of the disabled amplifier.

These circuits handle composite video, but many systems require switching of component video signals. To meet that need, Maxim has introduced the first switch/buffer ICs for RGB, YUV, YRGB, or RGB+SYNC applications (**Table 2**). MAX463–MAX466 devices switch from two sets of three inputs to one set of three outputs (3P2T) or from two sets of four inputs to one set of four outputs (4P2T). Each device contains an output driver with a fixed gain of one or two, which is capable of driving ±2V into a 75Ω back-terminated cable (150Ω load). And for buffering RGB, YUV, or other component video, the MAX467–MAX470 series includes triple and quad buffer amplifiers without the switches.

Table 2. Video switch/buffer ICs

Device	Description	Voltage Gain
MAX463	Triple switch & buffer	1
MAX464	Quad switch & buffer	1
MAX465	Triple switch & buffer	2
MAX466	Quad switch & buffer	2
MAX467	Triple video buffer	1
MAX468	Quad video buffer	1
MAX469	Triple video buffer	2
MAX470	Quad video buffer	2

The output buffers provide a combination of isolation and bandwidth that satisfies most video applications. By sandwiching each input and output pin between two ac-ground pins, the devices hold adjacent-channel crosstalk to 60dB at 10MHz. Their 100MHz bandwidths (90MHz for gain-of-two buffers) and 200V/µs slew rates (300V/µs for gain-of-two buffers) are difficult to achieve in discrete-component circuits. Wide bandwidth, low differential gain and phase error, and excellent gain and phase matching suit the MAX463–MAX470 devices for a wide range of component-video applications.

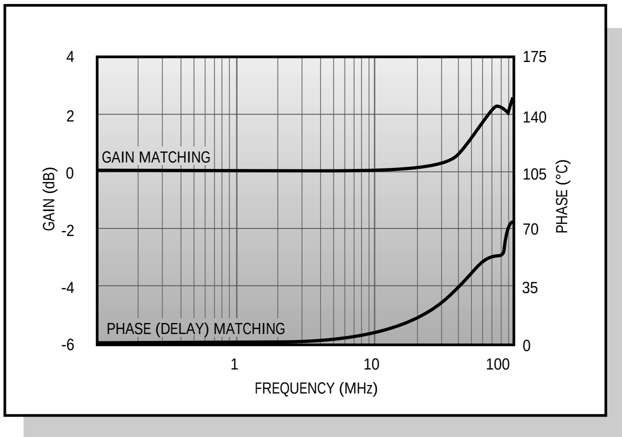


Figure 4. In the MAX463–MAX470 family of switch/buffer ICs, separate channels offer matched gain and phase over many megahertz of video bandwidth.

RGB video systems convey color information by amplitude only, so differential phase errors are unimportant. Gain and phase matching between channels, however, is important. **Figure 4** shows typical gain and delay matching for the MAX463–MAX470 devices.

Many functions in a video editor are handled by high-speed digital circuits, which require close attention to layout issues such as power-supply decoupling and the minimization of ground and power-supply transients. See the last section (*Layout, grounding, and bypassing*) for guidance in these matters.

Security and surveillance systems

Multiple inputs and outputs are a common feature of most security and surveillance systems, as is the need to make arbitrary connections between a given input and one or more outputs. Cost is a major issue for the "crosspoint switches" developed for this purpose.

Maxim is currently the only manufacturer of integrated crosspoint switches (**Table 3**). These devices really shine as space savers: a 16x16 array (16 inputs and 16 outputs) consisting of four MAX456 ICs (not including cable drivers) replaces 256 discrete switches and at least 32 buffer amplifiers. The same array constructed with MAX458 or MAX459 crosspoints requires eight packages, but those versions also include the cable drivers.

Table 3. Maxim crosspoint switches

Device	No. of Switches	Technology	Gain	Differential Phase/Gain	Cable Driver
MAX456	8 x 8	CMOS	1	1.0°/0.5%	No
MAX458	8 x 4	Bipolar	1	0.5°/0.01%	Yes
MAX459	8 x 4	Bipolar	2	0.14°/0.13%	Yes

MAX458 and MAX459 switches can be programmed either in parallel mode or in serial mode, which is fully compatible with SPI™, QSPI™, and Microwire™ standards for synchronous-data transmission. MAX458 and MAX459 outputs are disabled automatically at power-up. The disabled outputs assume a high-impedance state, except the MAX459's internal feedback (for achieving a gain of two) limits its output impedance to 1kΩ. Both devices can also be disabled on command, via software—a feature that enables the construction of switching arrays larger than 8x4.

CRT drivers

Moving up from the crosspoint switch to the CRT, we find another target for integration in video systems—the high-voltage CRT driver for high-resolution monitors. A new, monolithic variable-gain amplifier (**Figure 5a**) drives these monitors directly. Its internal preamp and high-voltage output driver provide a reliable, low-cost, and space-saving alternative to hybrids and discrete-component circuitry.

The IC's offset and variable-gain controls enable brightness and contrast adjustments. Its current-drive output provides for faster rise and fall times than those of a voltage-output device, and its TTL BLANK input disables the video signal by turning off the output current. The MAX445's 2.5ns rise time through 50V (**Figure 5b**) makes it ideal for driving the high-resolution displays (1280 x 1024 and 1530 x 1280) found in workstations and medical-imaging systems.

Layout, grounding, and bypassing

Layout on the printed-circuit board is important for all analog circuits, but it is especially crucial for video and other high-speed circuitry. A choice of surface-mount over feedthrough components, for example, may seriously affect performance by altering the layout.

To realize the full ac performance specified for high-speed amplifiers, you should provide a large, low-impedance ground plane and pay close attention to the pc layout and power-supply bypassing. Multilayer boards are preferred. Place an unbroken ground plane on a layer without signal traces, in a way that provides shielding for the traces. All inputs and outputs should be connected through lines of constant impedance, so you might consider a review of stripline techniques.

The input capacitance C_{IN+} can limit the bandwidth in a buffer amplifier by forming a pole with the signal-source

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Microwire is a trademark of National Semiconductor Corp.

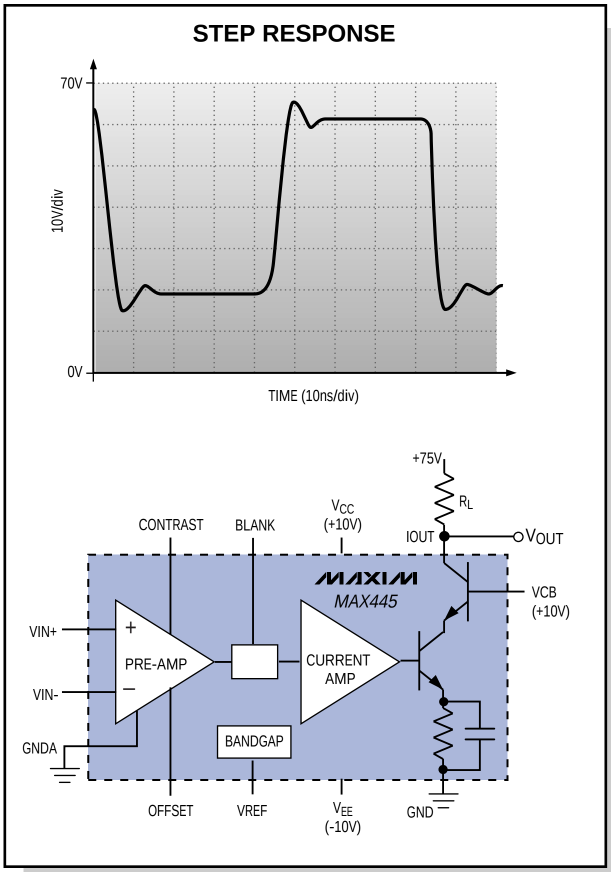

Figure 5. The current-drive output in this high-voltage amplifier drives high-resolution CRT monitors directly, with rise and fall times of 2.5ns.

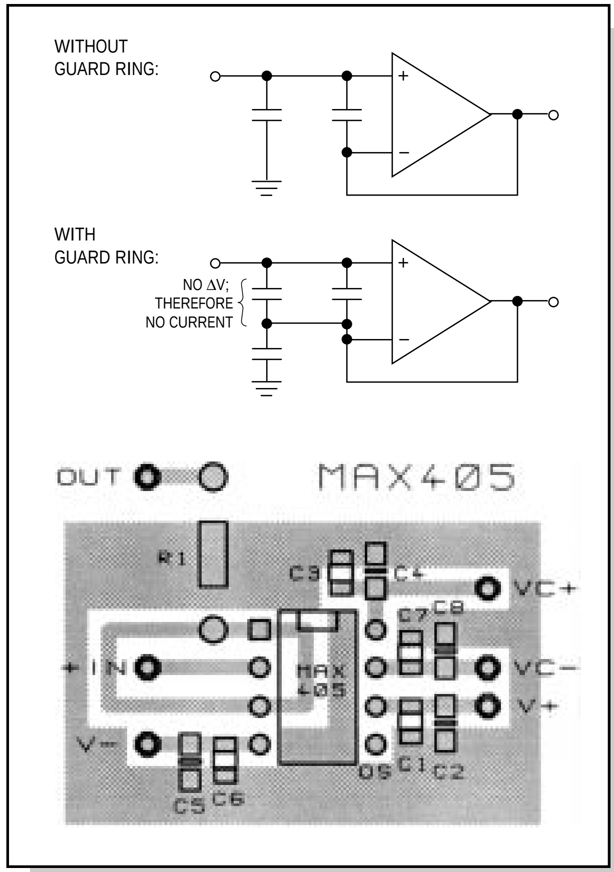

Figure 6. Surrounding this buffer amplifier's input (pin 2) with a guard ring driven by the output (pin 1) minimizes the effect of input capacitance on bandwidth.

impedance R_S. The pole can be defeated, however, by preventing current flow in C_{IN+}. Buffer operation maintains the IN+, IN-, and OUT terminals at the same potential. Thus, surrounding IN+ with an ac "guard ring" driven by the buffer's output eliminates the current flow in C_{IN+} by removing voltage variations across it. Adjacent positions for IN+, IN-, and OUT simplify the guard-trace layout (**Figure 6**).

You should bypass all power-supply pins directly to the ground plane with 0.1µF ceramic capacitors placed as close to the pins as possible, and keep the lead lengths as short as possible to minimize series inductance. For high-current loads, it may be necessary to include 10µF tantalum or aluminum electrolytic capacitors in parallel with the 0.1µF ceramics. Surface-mounted chip capacitors are ideal for this application.

To prevent unwanted coupling of signals, minimize the trace area at the circuit's critical high-impedance nodes, and surround each analog input with ac-ground traces. The analog inputs and outputs of Maxim switches are separated with such ac-ground pins (GND, V_{CC}, and V_{EE}), which minimize the parasitic coupling that causes crosstalk and amplifier instability. To further reduce crosstalk, connect the coaxial-cable shield to the ground side of the 75Ω termination resistor, at the ground plane.

Wherever possible, use Faraday shields that interpose the ground plane or another component between sensitive circuits and those that produce noise. Noise generators include the digital circuitry that operates as an interface to the systems processor and memory.

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(Circle 2)

Draw 150mW of isolated power from off-hook phone line

The power supply of **Figure 1** is useful in portable systems that connect to subscriber (household) telephone lines, such as modems and telephone test sets. For systems that require 150mW or less, this circuit eliminates the need for batteries and ac adapters by drawing power from ordinary phone jacks without interrupting the voice signal. Built into peripheral equipment such as PCMCIA modem cards, it can spare the battery in a host computer.

The line current available to a telephone in the off-hook state is limited not by regulations or code, but only by the sum of impedances in the central-office battery and intervening phone lines. These line impedances vary greatly (in proportion to distance from the central office), so the customary practice of matching impedances for maximum power transfer is impractical.

But, the zener-clamp termination (D1) works well for line impedances to 1000Ω and for worst-case conditions. It also meets the one condition imposed on line current by the phone system: off-hook current must exceed 20mA to ensure activation of a network-access relay in the central office.

D1 provides approximately 6.8V to the center tap of T1 and 5V to the V_{CC} terminal of IC1. IC1—a 400kHz oscillator driving an internal flip-flop—generates two push-pull, 50%-duty-cycle, 200kHz square waves that drive internal, ground-referenced switches connected to the primary of T1. Isolated power on the secondary side is first rectified by Schottky diodes D2 and D3, and then regulated to 5V by the low-dropout linear regulator IC2.

T1's primary is a center-tapped winding whose ET product (a voltage-time product of 25V-µs) is sufficient to prevent saturation under worst-case condi-

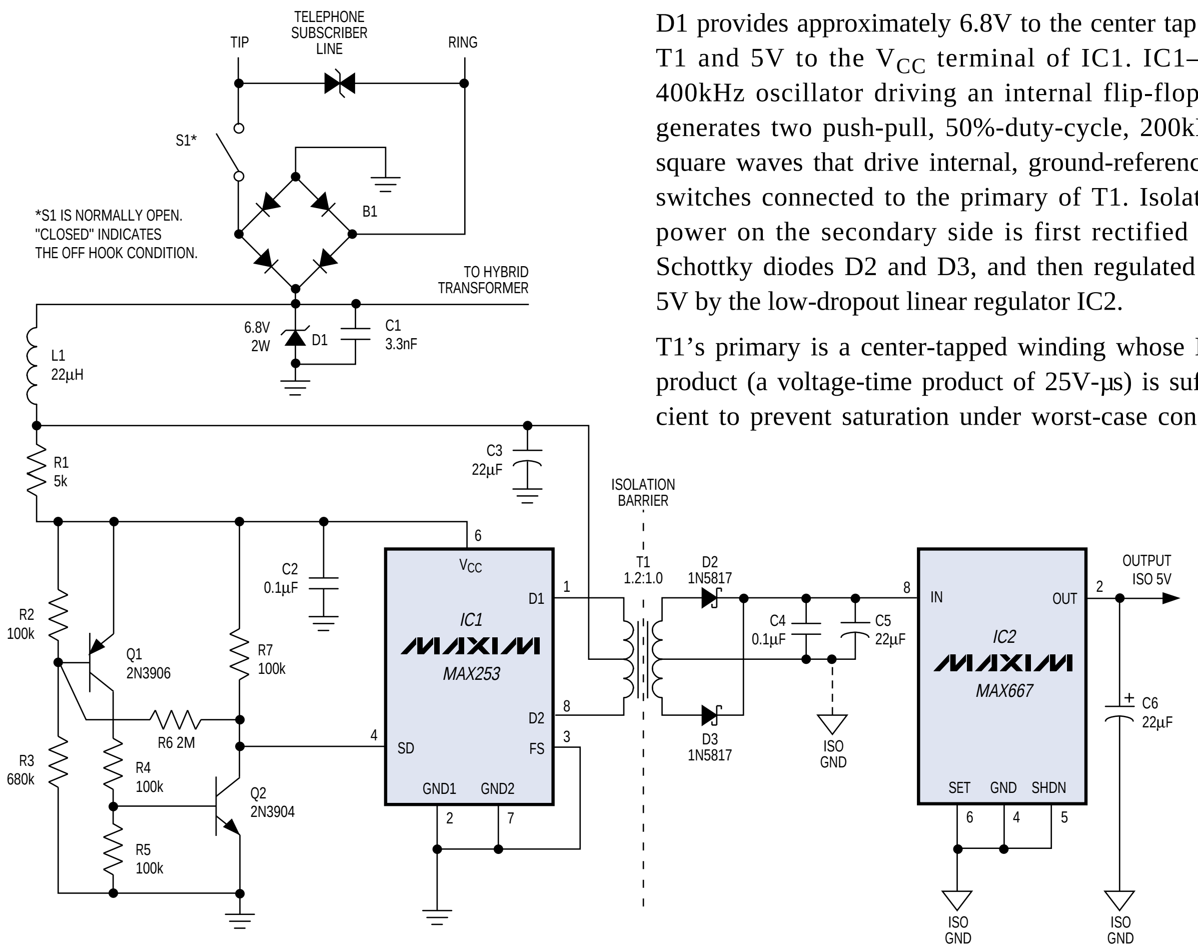


Figure 1. This circuit draws current in the off-hook condition, delivering as much as 150mW of isolated power while allowing normal voice or data communications over the phone line.

tions. Similarly, T1's turns ratio should provide the minimum-required output voltage for maximum load and minimum input voltage. This calculation should also assume worst-case losses in D2 and D3.

This turns ratio produces a much higher secondary voltage for best-case conditions, and for some applications that is acceptable. Otherwise, add the linear regulator (IC2) as shown. For isolated 5V outputs, the ideal turns ratio is 1.2CT:1.0CT (CT ≡ Center Tapped). The transformer should be wound on Magnetics Incorporated "W," Fair-Rite "76," or other high-permeability magnetic material. To minimize radiated noise, choose a pot core, E/I/U core, toroid, or other geometry with closed magnetic paths.

Consider a typical toroid such as the 40603-TC from Magnetics, Inc. (0.125" thick with a 0.230" outside diameter). For 6.8V inputs this core should have a 48-turn primary (24 turns on either side of the CT), which yields a nominal, end-to-end primary inductance of 8mH. The secondary can be scaled for any reasonable output voltage required. Forty turns, for example, (20 turns on either side of the CT) delivers 5.2V minimum as required by the linear regulator for maintaining a regulated 5V output.

For isolated 3.3V applications, the minimum voltage to IC2 is 3.5V. T1's turns ratio should be 2.0CT:1.0CT, with a primary ET product of at least 25V-µs. Using the same 48-turn primary as for 5V applications, the required number of secondary turns is 24 (12 on either side of the CT). In addition, you must add a resistive divider for setting IC2's regulated output to 3.3V.

Q1, Q2, and the associated resistors assure a low-power shutdown mode for IC1 until its supply voltage can sustain a full power-up. IC1's supply current is fairly constant, so light filtering (provided by L1 and C3) is sufficient to prevent noise from entering the hybrid transformer (not shown).

A related idea appeared in the 9/1/94 issue of EDN.

(Circle 3)

12-bit ADC upgrades µC's internal 8-bit ADC

The simple circuit of **Figure 1** (plus a software routine) lets you substitute a multi-channel, 12-bit A/D converter for the 8-bit A/D converter internal to an 87C752 microcontroller. Thus, a single assembly can implement both the low- and high-performance versions of a system. The software mentioned may be downloaded from EDN's free electronic bulletin board service (BBS)*.

A socket lets you plug in the external A/D converter when you need it; otherwise you plug in the network of ten 10Ω resistors. At power-up, the µC executes a routine that looks for the external converter. If present, it is used; if not, the internal 8-bit converter is used. (Internally, the chip handles all conversion results as 12-bit values.)

This idea relies on the fact that the 87C752's five A/D-input pins can also serve as the bidirectional pins of an 8051 port (port 1). The resistor network connects the internal A/D converter directly to the applied analog inputs. Or, replacing the network with the external A/D converter connects those inputs to corresponding channels on that converter, and the µC's A/D-input pins (now acting as a bidirectional port) serve as a digital interface to the converter. By fortune and design, the change from external to internal converter is effected by simple pin-for-pin jumpers across the socket.

The assembly-language software routine "looks" for the external converter by triggering a conversion and noting whether the converter's busy flag (SSTRB) goes low. If it does, the µC sets an internal global flag (AD12) that tells it to use its external-converter routines for each subsequent conversion. This action is transparent to the calling routine. The conversion result, returned as bytes ADHI and ADLO, has the same format in either case except the four LSBs are zero for 8-bit-converter data.

Note that the µC's full scale is 5V, but the converter shown (MAX186) sets its full-scale input range with an internal reference of 4.096V. Software resolves the incompatibility in this example. Otherwise, you can replace the MAX186 with a MAX188 (a similar device with no internal reference) plus a separate 5V reference.

* *Set modem to 2400 baud, eight data bits, no parity, and one stop bit. Dial (617) 558-4241 and log on. (New users must set up an account; this is free.) Type **SS/DI_SIG** to select the Design Ideas section, **RK1554** to select this idea, and **D** for downloading the file. Select protocol, download the file, log off, and then "unzip" the file.*

A related idea appeared in the 7/7/94 issue of EDN.

(Circle 4)

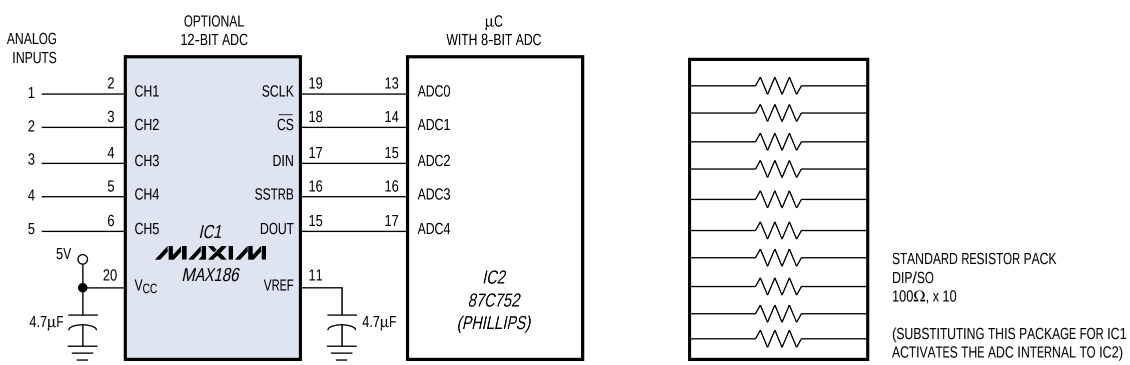


Figure 1. The connections shown enable this µC to substitute an external 12-bit A/D converter for its internal 8-bit converter. Replacing the external converter with the resistor network causes the µC to resume use of its internal converter.

Sine-wave generator is crystal accurate

Servos, test equipment, and telecommunications systems are among the applications that require stable, frequency-accurate sine-wave sources. Many such sine-wave oscillators are available, but finding one with a satisfactory level of absolute accuracy and drift can be a problem.

You can get greater accuracy and less drift by deriving the sine wave from a digital source. Because square waves comprise a fundamental at the square-wave frequency plus an infinite number of odd harmonics, you can obtain the desired fundamental sinusoid by removing the harmonics with a lowpass filter. Switched-capacitor filters suit this application (**Figure 1**). IC3 is an 8th-order, lowpass Butterworth type.

The sine-wave generator starts with an 8MHz signal and divides it by eight to obtain 1MHz at C1. (IC1's 2MHz and 500kHz outputs can serve as alternate drive signals.) Q1 level-shifts the 1MHz pulses so they can drive the bipolar circuitry necessary for producing a bipolar output. (For unipolar outputs, you can operate the circuit on a single supply voltage by biasing the IC3 ground terminal to mid-rail and adding a decoupling capacitor.) Synchronous counter IC2 divides 1MHz by 256 to give the desired output frequency (3906Hz), and IC3 filters the harmonic frequencies.

The filter's clock is taken from the first divide-by-2 tap of IC2, to assure a 50% duty cycle. IC2 further divides this signal by 128 to assure that the filter's

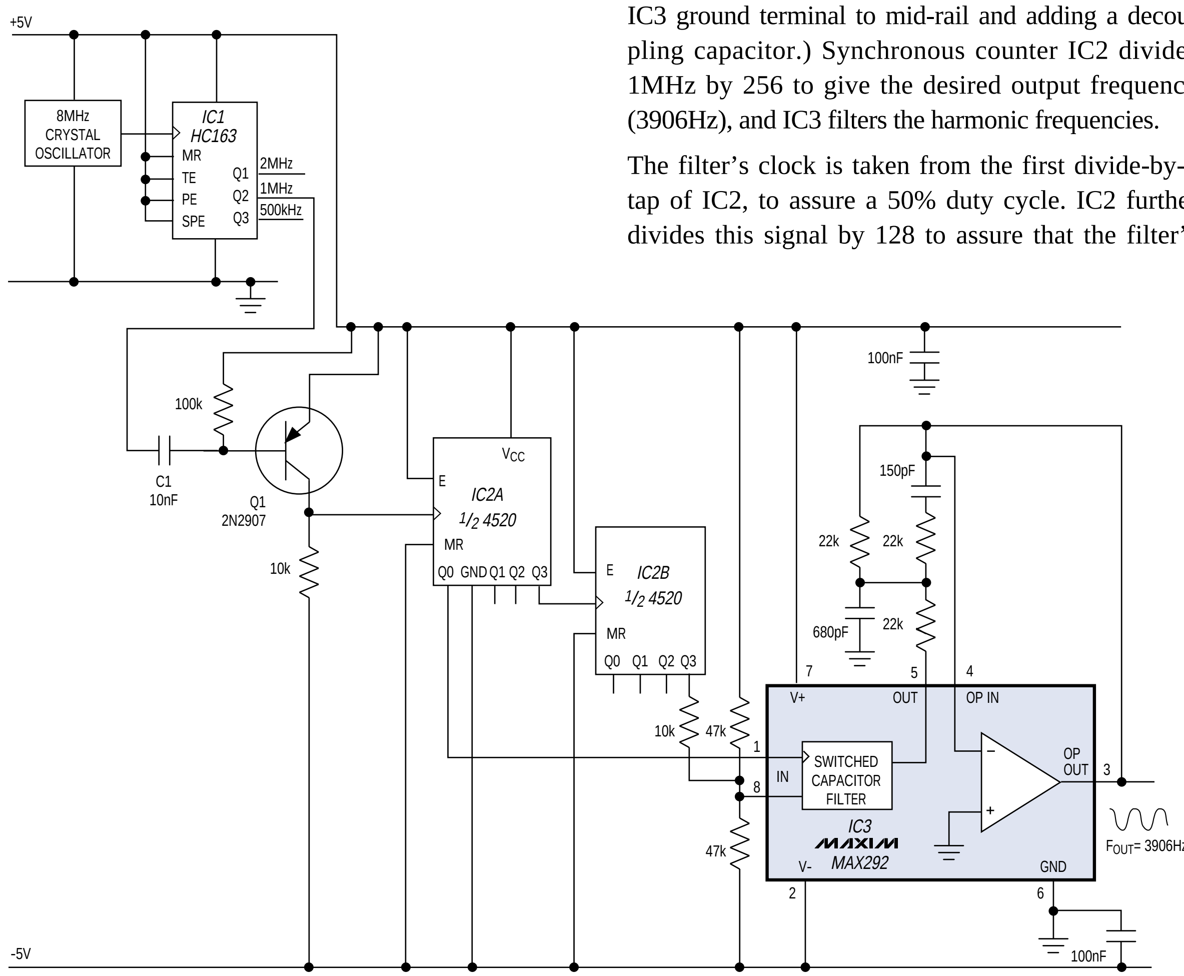


Figure 1. Filtering the harmonics from a square wave produces a sinusoidal output whose stability and flexibility derive from digital circuitry.

input signal (1MHz/256) falls within the flat portion of the filter response. Fifty-percent duty cycles on the IC2 outputs assure a symmetrical sine-wave output. The filter's major pole, or corner frequency, is fixed with respect to the clock and forms an internal clock-to-corner ratio of 100:1. Filter attenuation lowers the third-harmonic amplitude to -80dB.

The output of the switched-capacitor filter resembles a sampled sine wave; to smooth it you can build a 1st- or (as shown) a 2nd-order lowpass filter around the otherwise-uncommitted output op amp.

Because the filter's input and clock frequencies have a fixed ratio of 1:128, switching or sweeping the frequency applied at C1 has a proportional effect on the sine-wave generator output. Switching this frequency from 2MHz to 500kHz, for example, switches the output frequency from 7812Hz to 1953Hz. Output amplitude is not affected because this band is well below the smoothing filter's 25kHz corner frequency. Alias frequencies are not a problem, because the frequencies that represent a potential cause of aliasing in this circuit—the odd-numbered harmonics that exceed half the clock rate—have insignificant amplitudes.

A related idea appeared in the 7/25/94 issue of Electronic Design.

(Circle 5)

NEW PRODUCTS

500Msps, 8-bit flash ADC delivers 7.0 effective bits at Nyquist

- *1.2GHz input bandwidth*
- *2ps aperture uncertainty*

The MAX101, Maxim's first ultra-high-speed, ECL-compatible A/D converter, accurately digitizes analog signals from dc to the 250MHz Nyquist frequency. Fabricated with Maxim's proprietary and advanced bipolar process, it contains a high-performance track/hold amplifier (T/H) and two flash quantizers, which produce their outputs alternately at separate 8-bit ports.

Innovative T/H design assures an input bandwidth of 1.2GHz with an aperture uncertainty of less than 2ps, resulting in 7.0 effective bits of resolution at the Nyquist frequency. Special decoding circuitry and comparator-output design reduce the probability of erroneous codes due to metastability, resulting in less than one error per 10^{15} clock cycles (equivalent to 500Msps, 24 hours per day for 23 days).

The MAX101's analog input accommodates single-ended or differential signals in the range ±270mV. Sense pins for the reference voltage allow full-scale calibration and also aid in ratiometric operation. Other inputs let you adjust the converters' relative sampling times, and (by phasing the clock signals) you can interleave two or more devices to achieve higher sampling rates.

For less demanding applications, the MAX100 (containing one flash converter instead of two) guarantees a sampling rate of 250Msps.

MAX100/MAX101 converters are suitable for use in radar, high-speed imaging, instrumentation, and transient-event analysis. Both come in 84-pin ceramic flatpack packages, tested for operation over the commercial (0°C to +70°C) temperature range.

(Circle 6)

New spec guarantees boost performance of CMOS analog multiplexers

Guaranteed min/max limits assure unprecedented performance for Maxim's new CMOS analog multiplexers: MAX306/MAX307 (16-channel single-ended, 8-channel differential) and MAX308/MAX309 (8-channel single-ended, 4-channel differential). Each device guarantees on-resistances less than 100Ω, with no two channels differing by more than 5Ω maximum. In addition, each channel's on-resistance is guaranteed flat within 7Ω over the specified analog signal range.

Fabricated with Maxim's 44V silicon-gate process, the new multiplexers sport design improvements that enhance performance in other ways as well. For example, the guaranteed low charge injection of 10pC maximum yields excellent sample/hold circuits, and the low leakage over temperature minimizes source-resistance errors (MAX306/MAX307 $I_{NO(OFF)}$ at +85°C is less than 2.5nA, and $I_{COM(OFF)}$ at +85°C is less than 20nA).

Fast switching has not been sacrificed—the transition time for MAX306/MAX307 multiplexers is less than 250ns. All devices are guaranteed (per MIL-STD-883, Method 3015.7) to withstand electrostatic discharge (ESD) in excess of 2kV.

All four multiplexers guarantee fast switching and TTL/CMOS compatibility while operating with single supplies of 4.5V to 30V or bipolar supplies of ±4.5V to ±20V. The CMOS digital inputs reduce loading on digital control lines. These improved Maxim multiplexers are plug-in upgrades for industry-standard devices: the MAX306 and MAX307 replace DG406/DG407 and DG506A/DG507A multiplexers; the MAX308 and MAX309 replace DG408/DG409 and DG508A/DG509A multiplexers.

MAX306/MAX307 devices come in 28-pin 600-mil DIPs, PLCCs, and wide-SO packages; the MAX308/MAX309 devices come in 16-pin DIPs and narrow-SO packages. All are available in versions tested for the commercial (0°C to +70°C), extended-industrial (-40°C to +85°C), and military (-55°C to +125°C) temperature ranges. Prices start at $3.87 for the MAX306/MAX307 and $2.50 for the MAX308/MAX309 (1000 up, FOB USA).

(Circle 7)

Ultra-fast 12-bit DAC updates at 300Msps

The monolithic MAX555, an ECL-compatible 12-bit D/A converter, is fabricated with a proprietary, 9GHz, oxide-isolated bipolar process that guarantees minimum update rates of 300Msps. The converter's complementary 50Ω voltage outputs and low output capacitance (15pF) enable it to drive 50Ω transmission lines directly.

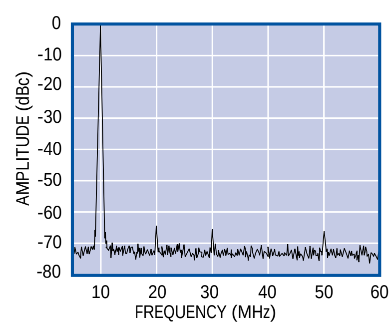
The MAX555 is suitable for direct digital synthesis, arbitrary waveform generation, instrumentation, and video reconstruction. Operating from a single -5.2V supply, it multiplies the applied digital input (interpreted as a fraction between 0 and 1) times the nominal 1V analog reference signal. Usable bandwidth for the reference input is 10MHz.

Precision laser trimming on the wafer yields 12-bit accuracy, with integral and differential linearity guaranteed to ±½LSB (±0.012% of full scale). Absolute gain error is 1% of full scale, and full-scale transitions occur in less than 0.5ns. Laser trimming also assures precision 50Ω complementary outputs.

On-chip registers and decoding circuitry assure a low glitch energy of 5.6pV-s. The MAX555 achieves precise RF performance over a spurious-free dynamic range of 70dBc (at 50Msps and f_{OUT} = 3.125MHz) or 54dBc (at 250Msps and f_{OUT} = 12.625MHz).

MAX555 devices are screened for the commercial temperature range (0°C to +70°C), and they come in 68-pin thermally enhanced PLCC packages capable of accepting a heatsink (the operating power dissipation is 900mW). Prices start at $68.00 (100 up, FOB USA).

(Circle 8)



NEW PRODUCTS

Low-dropout linear regulators deliver 500mA from 1.8W SO package

The MAX603 and MAX604 linear regulators generate 5V and 3.3V respectively for load currents to 500mA. Available in new, 1.8W, 8-pin SO packages, they feature low dropout voltages (320mV at 5V and 500mA, or 240mV at 3.3V and 200mA), and low quiescent currents (15µA typical, 35µA maximum). Shutdown mode reduces the supply currents to less than 2µA.

In addition to preset outputs, both devices allow the user to set any output voltage between 1.3V and 11V using two external resistors (Dual Mode™ operation). An internal protection scheme limits the reverse current when V_{IN} falls below V_{OUT}, and the regulator outputs are protected by foldback current limiting and thermal-overload circuitry. The input range is 2.7V to 11.5V.

The pass transistor in MAX603/MAX604 regulators (a p-channel MOSFET) allows them to draw less than 35µA over temperature regardless of output current. Supply currents remain low because the MOSFET—unlike the pnp pass transistor in a conventional regulator—requires no base current for operation. MAX603/MAX604 regulators also avoid the problem that plagues pnp regulators as V_{IN} approaches V_{OUT}, when the pass transistor saturates and draws excessive base current.

MAX603/MAX604 devices come in 8-pin DIPs and the new 1.8W SO packages, in versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $1.68 (1000 up, FOB USA).

(Circle 9)

™ Dual Mode is a trademark of Maxim Integrated Products.

Controller IC integrates core power-supply functions

The monolithic MAX781 controller integrates the core power-supply functions found in a PDA (personal digital assistant) or other wireless computer. It includes dual PCMCIA analog controllers, a 3.3V V_{CC} output, a programmable battery charger, five high-side gate drivers for external MOSFETs, and an SPI serial interface—all in a 36-pin SSOP. The MAX781 input range (5V to 18V) accommodates NiCd and NiMH battery stacks ranging from five to eight cells.

To produce 3.3V, the internal step-down dc-dc converter employs synchronous rectification in a PWM (pulse-width modulation) switching scheme. The circuit's all n-channel design saves space and cost. The PWM switching frequency is fixed at 300kHz to minimize noise in sensitive communications applications, and the synchronous rectification provides 92% conversion efficiency at full load. In shutdown, the device maintains an active 3.3V output while lowering the 1mA quiescent current to just 100µA.

The MAX781 provides control for the PCMCIA V_{CC} and dual V_{PP} outputs: V_{CC} can be switched between 0V, 3.3V, and 5V, and the V_{PP} outputs can be switched between 0V, V_{CC}, and 12V (also generated and regulated by the MAX781). Finally, the MAX781 includes a programmable current source for charging batteries. It operates in conjunction with a built-in multiplexer, which lets you implement custom charging algorithms by monitoring the battery's temperature, voltage, and charging current.

The MAX781 comes in a 36-pin SSOP, in versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $8.80 (1000 up, FOB USA).

(Circle 10)

10A synchronous step-down controllers are 95% efficient

The MAX796/MAX797/MAX799 step-down dc-dc converters provide the main power for latest-generation CPUs in notebook and subnotebook computers, PDAs, mobile communicators, cellular phones, and other battery-powered systems. The combination of synchronous rectification (an active MOSFET in place of a passive Schottky diode) and Maxim's proprietary Idle-Mode™ control scheme results in efficiencies as high as 95%. The outputs deliver as much as 10A.

Each device produces a main output of 5V or 3.3V, or an adjustable output of 2.5V to 6V set by two external resistors. The input-voltage range (4.5V to 30V) enables use of wall-adapter chargers and NiCd battery packs of up to 15 cells. For operation with 12V in and 5V out, the typical quiescent current is 375µA. The excellent dynamic response corrects output transients within five cycles of the 300kHz clock. In addition, the internal bootstrap circuits provide gate drive for inexpensive n-channel external MOSFETs.

For dual-output, external-transformer applications, the MAX796 and MAX799 have an extra feedback terminal (SECFB) that enables regulation of a second output voltage derived from the transformer's secondary. The MAX796 produces a positive auxiliary voltage and the MAX799 produces a negative one. These secondary outputs can be used to program flash memories, power 3.3V/5V systems, or provide an LCD-contrast supply. The independent secondary feedback path also minimizes cross-regulation problems for these auxiliary regulated voltages.

The MAX797 has a fixed-frequency PWM operating mode that reduces noise and RF interference in sensitive applications such as mobile communications and pen-entry systems. An override input ($\overline{SKIP}$) allows automatic switchover to Idle-Mode operation at light loads (for high-efficiency pulse skipping). As an alternative, $\overline{SKIP}$ can force the converter to the low-noise fixed-frequency mode for all load conditions.

All devices provide a precision 2.505V reference output, PWM operation at 300kHz or 150kHz, a synchronizing input, programmable soft-start capability, and 1µA typical shutdown currents. The data sheet includes component lists and recommended suppliers for applications ranging from 1A to 10A. And to speed designs, Maxim offers pre-assembled evaluation kits (MAX796 EVKIT-SO and MAX797EVKIT-SO).

MAX796/MAX797/MAX799 converters are available in 16-pin DIP and narrow-SO 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 $3.65 (1000 up, FOB USA).

(Circle 11)

™ Idle Mode is a trademark of Maxim Integrated Products.

NEW PRODUCTS

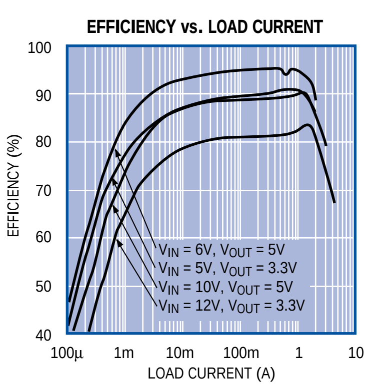
2A step-down controllers draw only 100µA

The MAX1649 and MAX1651 dc-dc step-down controllers are at least 90% efficient for loads between 10mA and 1.5A. They supply load currents as high as 2A, and they accept inputs from 3V to 16.5V. Their low quiescent and shutdown currents (100µA and 5µA maximum, over temperature) conserve battery life. Each device controls an external p-channel switching MOSFET capable of a 96.5% maximum duty cycle, which drops only 300mV for a 500mA load.

The controllers employ current limiting and pulse-frequency modulation (PFM) with switching frequencies as high as 300kHz. The resulting small inductor (47µH) and small external capacitors save space and cost. The devices offer fixed regulated outputs of 5V (MAX1649) and 3.3V (MAX1651). They also provide adjustable outputs in the range 1.5V to V_{IN}.

The MAX1649 and MAX1651 are suitable for hand-held computers, personal communicators, and any other application for which small size and long battery life are critical. An evaluation kit (MAX649 EVKIT-SO) is available to speed your designs. Both controllers are available in 8-pin DIP and SO packages, in versions tested for the commercial (0°C to +70°C) and extended-industrial (-40°C to +85°C) temperature ranges. Prices start at $1.60 (1000 up, FOB USA).

(Circle 12)



6-bit quadrature digitizer provides 5.3 effective bits at 60MHz

The monolithic, bipolar MAX2101 performs quadrature demodulation, 6-bit A/D conversion, and other functions for simple receiver subsystems. Applications include the recovery of PSK- and QAM-modulation, direct-broadcast satellite (DBS) systems, television receive-only (TVRO) systems, cable television (CATV) systems, and wireless local-area networks (WLANs). First developed as a custom integrated circuit for TV/COM, the MAX2101 provides an RF-to-bits function that bridges the gap between existing RF downconverters and CMOS digital signal processors (DSPs).

The MAX2101 accepts input signals in the range 400MHz to 700MHz, with a variable gain that provides up to 40dB of dynamic range. At f_{IN} = 15MHz and f_{SAMPLE} = 60MHz it produces an effective resolution greater than 5.3 bits. The internal local oscillator, phase-locked to an external crystal-stabilized standard, generates the 600MHz (nominal) signal from which quadrature components are derived. Mixed with the input signal, these components produce the internal baseband-video signals I and Q.

The baseband signals are fed to separate 5th-order Butterworth lowpass anti-aliasing filters, and then to separate 6-bit A/D converters. (Users can substitute external filters.) The 60Msps baseband sample rates can be varied by an on-chip programmable counter. Similarly, external control can vary the anti-aliasing filter bandwidths from 10MHz to 30MHz.

Other features include the auto-cancellation of dc offsets in the I and Q baseband-video signals, and an on-chip divide-by-16 prescaler for the phase-locked quadrature components. (Further division may be required to meet the external reference frequency; that division is performed externally to avoid on-chip feedthrough to the baseband.)

The MAX2101 comes in a 100-pin MQFP package, screened for the commercial (0°C to +70°C) temperature range. Prices start at $17.95 (1000 up, FOB USA).

(Circle 13)

12V/adjustable, step-up switching controller is 90% efficient

The MAX1771 step-up switching controller provides 90% efficiency for load currents ranging from 30mA to 2A. Its control scheme—pulse-frequency modulation with current limiting—delivers the benefit of PWM control (high efficiency with heavy loads) while drawing less than 110µA of supply current. (Typical PWM converters draw 2mA to 10mA.) The shutdown current is only 5µA.

High switching frequencies (to 300kHz) allow the MAX1771 to operate with miniature external components. The inductor, for example, is a surface-mount device only 5mm high and 9mm in diameter. The chip controls an external n-channel MOSFET that can deliver 24W to a load. For lower-power applications, consider a step-up switching regulator with on-board MOSFET, such as the MAX756, MAX757, MAX761, or MAX762.

MAX1771 output voltage is preset to 12V, but can also be adjusted with two external resistors. The input-voltage range is 2V to 16.5V. A single current-limit threshold of 100mV for all load conditions reduces noise and enhances efficiency at low input voltages.

The MAX1771 comes 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 $1.80 (1000 up, FOB USA). To speed your designs, request an evaluation kit (MAX770EVKIT-SO plus MAX1771CSA sample).

(Circle 14)