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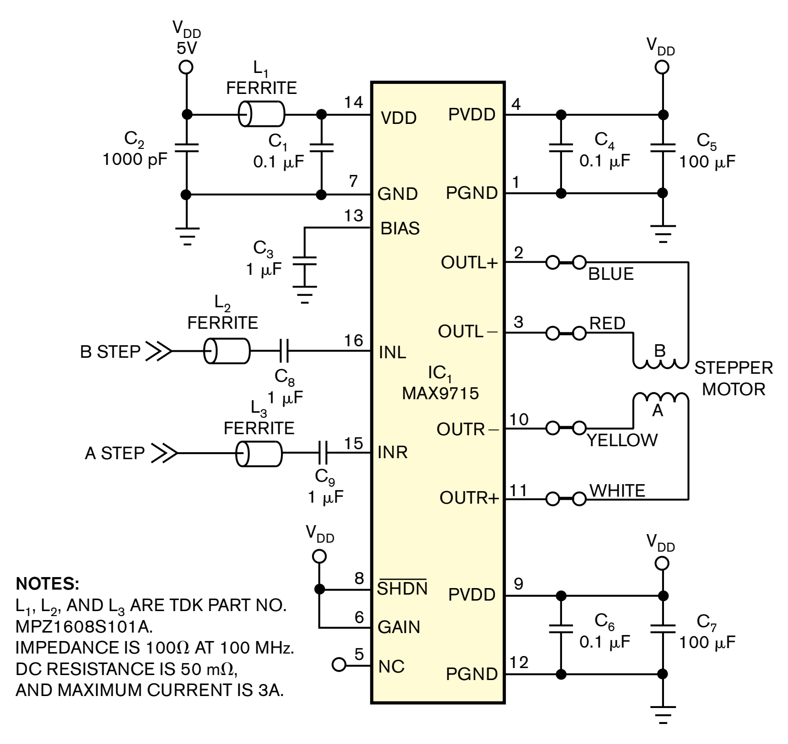
Two-channel audio amplifier drives stepper motor

Phill Leyva and Bill Quach, Maxim Integrated Products, Sunnyvale, CA

Although relatively expensive, monofilar-wound, bipolar stepper motors provide strong torque for a given physical size. However, each of the motor's two windings requires eight driving transistors connected in groups of four in an H-bridge configuration. Each transistor must withstand and quickly recover from overloads and short-circuit conditions, and a driver must consequently include complex and large discrete-component protective circuitry.

As an alternative, **Figure 1** shows a motor-driver circuit based on Maxim's (www.maxim-ic.com) MAX9715, a tiny, surface-mount, 2.8W Class D audio amplifier, which typically drives 4 or 8Ω speakers. Each of IC_1's two outputs consists of a MOSFET H-bridge that drives a pair of output lines, OUTR+ and OUTR− and OUTL+ and OUTL−, that connect to the stepper motor's A and B windings, respectively. Each pair delivers a differential-pulse-width-modulated signal with a nominal switching frequency of 1.22 MHz. The circuit's low-interference design eliminates the requirement for output-line filters.



NOTES:
L_1, L_2, AND L_3 ARE TDK PART NO. MPZ1608S101A.
IMPEDANCE IS 100Ω AT 100 MHz.
DC RESISTANCE IS 50 mΩ,
AND MAXIMUM CURRENT IS 3A.

Figure 1 A single surface-mount circuit and a few passive components can drive a bipolar, monofilar-wound stepper motor.

Capacitors C_1, C_3, C_4, and C_6 provide bypassing for IC_1's power input and bias pins, and C_5 and C_7 provide bulk-holdup capacitance for the Class D power amplifiers' outputs. Capacitors C_8 and C_9 limit the amplifiers' input bandwidth to 16 Hz, and L_2 and L_3 suppress electrical-noise pickup by the long input cables. Comprising C_1, C_2, and ferrite bead L_1, a pi-section noise filter suppresses noise on IC_1's power-sup-

TABLE 1 A_STEP AND B_STEP PULSE SEQUENCE

Step	A_Step	B_Step
0	H	L
1	L	L
2	L	H
3	H	H
4	H	L

ply input. A suitable controller feeds digital pulses to IC$_1$'s A_Step and B_Step inputs, which respectively drive the motor's right and left channels. Internal short-circuit and thermal protection guards the amplifier against overcurrent and short circuits caused by the stepper motor or its connecting leads.

Table 1 illustrates the A_Step and B_Step pulse sequence that rotates a typical stepper motor in one direction by continuous application of steps 0 through 4. Step 4 returns the motor's shaft to its starting position and completes its 360° rotation. To reverse the motor, begin at the bottom of the **table** to reverse the pulse pattern and work upward. You can disable both of the amplifier's channels by applying a logic-low signal to Pin 8, IC$_1$'s active-low $\overline{\text{SHDN}}$ input. **Figure 2** illustrates the circuit's input and output waveforms. **EDN**

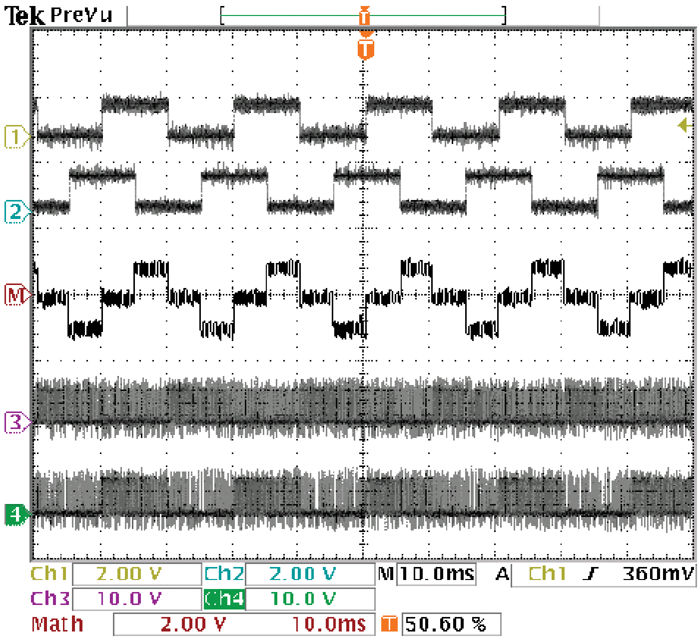


Figure 2 Waveforms from the circuit in Figure 1 include the A_Step input (Channel 1), B_Step input (Channel 2), outputs OUTR+ (Channel 3) and OUTR− (Channel 4), and the signal that arrives at the motor's windings (OUTR+ minus OUTR−, middle trace), which the oscilloscope's math function computes.

Get power from a telephone line without disturbing it

Yongping Xia, Navcom Technology, Torrance, CA

An idle telephone line tempts designers to use its 48V potential as a power source. However, Part 68 of the US Federal Communications Commission's telecommunications regulations states that any device that connects to the phone line and is not actively communicating must present a resistance of at least 5 MΩ (**Reference 1**). To meet this requirement, a device's continuous-current drain must not exceed 10 μA. Fortunately, many devices that connect to the phone line do not require continuous power and can remain off for long intervals, awakening only for a short time before relapsing into power-off mode. Providing power for these applications from the phone line presents obvious advantages by eliminating the need for a battery or another power source and the cost of battery maintenance.

The circuit in **Figure 1** charges a 1.5F supercapacitor, C$_1$, from the phone line through a diode bridge and a 5.6-MΩ resistor. A Maxim (www.maxim-ic.com) MAX917 nanopower comparator, IC$_1$, consumes only 0.75 μA from its power supply. Resistors

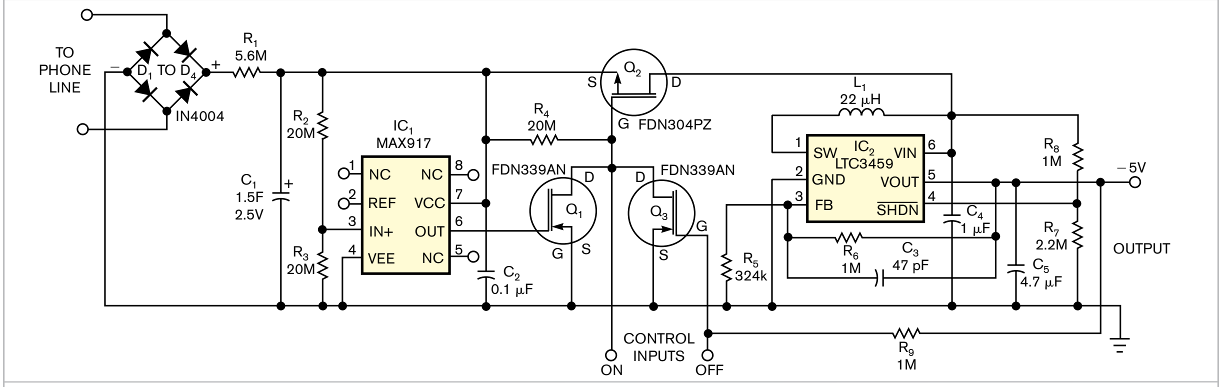


Figure 1 This power-conversion circuit delivers intermittent bursts of regulated voltage from a supercapacitor charged by a trickle of current from a telephone line.

R_2 and R_3 halve the voltage across C_1 and apply it to IC_1's positive input voltage at Pin 3 for comparison with its built-in 1.245V reference. For voltages across C_1 that do not exceed 2.49V, IC_1's output at Pin 6 remains low. When C_1's voltage reaches 2.5V, Pin 3's voltage exceeds the reference voltage, and IC_1's output goes high, turning on Q_1 and Q_2.

Several days must elapse before C_1 becomes fully charged, given its huge capacitance and a charging current of less than 10 μA. The voltage on C_1 can never exceed 2.5V because, once it reaches 2.49V, Q_1 and Q_2 turn on, connecting C_1 to a switched-mode-power-supply circuit. Because the power-supply current exceeds the charging current, the voltage across C_1 starts to decrease when Q_2 turns on. Transistor Q_3 holds Q_2 on when C_1's decreasing voltage causes Q_1 to turn off.

The switched-mode-power-supply circuit comprises a Linear Technology (www.linear.com) LTC3459 micropower boost converter, IC_2, and its associated components, which deliver 5V at 10 mA. A fully charged C_1 can supply power to a 10-mA load for approximately 40 sec. With no load, the circuit can sustain its 5V output for more than 10 hours. For greater output current and shorter operating time, select another boost converter that can operate at a low input voltage.

Mechanical switches, open-drain MOSFETs, open-collector transistors, or a microcontroller's open-drain output pins can drive two external control inputs to force the circuit on and off. Pulling the On input low forces Q_2 to turn on and deliver power from C_1 to the power converter, and pulling the Off input low turns off Q_2 and removes power from the converter. Note that the power converter's output-return line connects to the telephone line and thus should not connect to an earth ground or to grounded equipment. **EDN**

REFERENCE

1. "Part 68," Federal Communications Commission, www.fcc.gov/wcb/iatd/part_68.html.

Active-filter circuit and oscilloscope inspect a Class D amplifier's output

John Guy, Maxim Integrated Products Inc, Sunnyvale, CA

The increasing acceptance of Class D amplifiers has helped them gain market share from their linear Class AB brethren. That acceptance is no surprise; the advantages of Class D amplifiers are legion, but such amplifiers also require new techniques for evaluation. For example, consider a basic sine-wave test of a linear amplifier. You apply power, apply a sine wave of suitable amplitude to the input, and connect an oscilloscope probe to the output. You'll see a replica of the input, usually offset by about half the power-

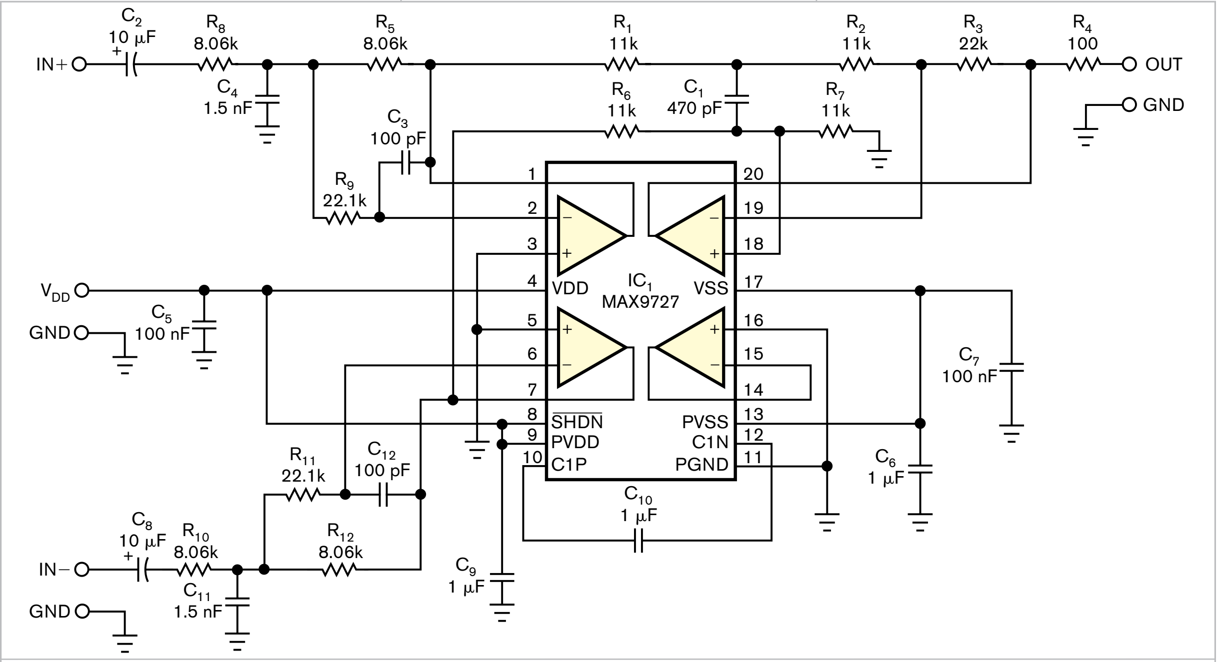


Figure 1 Use this third-order, 30-kHz filter circuit to observe a Class D amplifier's output signal on an oscilloscope.

supply voltage. Even if the linear amplifier drives a BTL (bridge-tied load), you'll still see a recognizable replica of the input at either end of the load, albeit at half of the output signal that's available.

Testing a Class D amplifier poses more difficulties. The amplifier's output comprises a PWM (pulse-width-modulated) signal that swings between ground and the supply voltage at a frequency that's usually 200 kHz to 2 MHz. However, when you view this PWM output on an oscilloscope, you'll see no resemblance to the sine-wave input.

You can observe a Class D audio amplifier's output if you introduce the filter circuit in **Figure 1**. Based on Maxim's (www.maxim-ic.com) MAX-9727 quad-audio-line driver, IC_1, the circuit combines separate single-ended filters—one for each of the BTL outputs' phases—with a third amplifier that provides a difference signal with additional filtering. The first stage of each single-ended-filter section contributes the complex-conjugate pole pair of a third-order, 30-kHz multiple-feedback Butterworth filter, for which many design guidelines and equations are available. Each third-order-filter section comprises a complex-conjugate pole-zero pair and one real pole.

To improve the match between the signal paths, the two separate multiple-feedback filters share a real pole, which 470-pF capacitor C_1 and 11-kΩ resistors R_1 and R_6 provide. The circuit implements that pole as a difference amplifier, thereby producing a filtered output that presents a single-ended version of the BTL amplifier's outputs. The filters' signal paths present 5.5-kΩ impedances to each of the A and B amplifier sections' inputs. By inspection, the net 5.5-kΩ impedance from Section B's output to C_1 comprises the Thevenin-equivalent impedance of resistors R_6 and R_7. Similarly, the net impedance from Section A's output to C_1, also 5.5 kΩ, comprises the Thevenin impedance of resistors R_1 and R_2. Note that the virtual ground from Amplifier D's inverting input effectively grounds resistor R_2.

Matched resistors attenuate each of Amplifier D's differential inputs by 6 dB (IN+ by R_1 and R_2 and IN− by R_6 and R_7). A 22-kΩ feedback resistor, R_3, provides Amplifier D with a gain of two, which sets a unity-gain-transfer function in the circuit's passband. The circuit's single-ended output with respect to ground allows the oscilloscope's ground to also serve as the output signal's ground. A version of this circuit using conventional op amps would require a negative-power-supply-voltage source, but Maxim's MAX9727 already includes a negative-voltage source, which its internal charge-pump circuit generates. When you operate the circuit from a 5V supply, the circuit's output delivers more than 2.5V rms. Although its third-order filter is inadequate for precise measurements of distortion or noise, the circuit provides an excellent tool for troubleshooting and evaluating Class D-amplifier circuits and inspecting their outputs on an oscilloscope. **EDN**

Voltage-to-pulse-width converter spares microprocessor's resources

James Christensen, Kris Design Co, El Cajon, CA

Although not an ADC in the classic "stream-of-ones-and zeros" sense, this voltage-to-pulse-width converter produces a logic-level output pulse whose variable width represents an analog of the input voltage. Based on Atmel's (www.atmel.com) AT89LP4052 microprocessor, IC_1, this circuit makes efficient use of the target microprocessor's limited analog-port pinout and code space by using a modified version of the classic timed-discharge-RC (resistor-capacitor) ADC design.

The timed-RC ADC allows a capacitor to charge through a resistor while the microprocessor increments a counter. When a comparator detects that the capacitor voltage and analog- input voltage are equal, the count terminates, and its stored value represents the ADC's output. However, an RC network's exponential charging characteristic produces a nonlinear conversion. Various software and hardware techniques can partially correct the nonlinearities, but all entail adding code, increasing the circuit's development time, or consuming additional I/O-port pins required for other purposes.

To produce a linear-charging characteristic that needs no correction, the circuit in **Figure 1** uses an LM334 constant-current source, IC_2, to drive capacitor C_2, which connects to IC_1's AIN_0 analog-input port. An internal timer in the microcontroller measures the elapsed time from the charging ramp's start to the instant when the ramp voltage crosses the analog-input-voltage threshold at IC_1's AIN_1 port.

In this application, potentiometer RV_1 provides an analog-input voltage proportional to its position. The width of the positive-going pulse at the output, P1.5, varies in proportion to the analog-voltage input. Note that I/O-port pin AIN_1 serves a dual purpose as an analog input and as an open-drain output that discharges ramp-forming capacitor C_2 before the next conversion cycle.

An 8-bit voltage-to-pulse-width-conversion cycle completes in less than 4 msec. The code performs the conversion function and outputs a pulse train at IC_1's port P1.5 (Pin 17) with a period of 100 msec and a positive-going pulse width proportional to the analog-input voltage at Pin 13 (AIN_1). Programming connector J_1 provides access to IC_1 for uploading the compiled code. The AT89LP4052 microprocessor typically executes one instruction per clock cycle, and a 10-µsec timer routine can perform the required housekeeping functions with plenty of time left over for other program tasks, including a future application that requires a binary-coded analog-to-digital output. You can download **Listing 1**, which is written in C for the Keil Software (www.keil.com) compiler, from the online version of this Design Idea at www.edn.com/061201di1.**EDN**

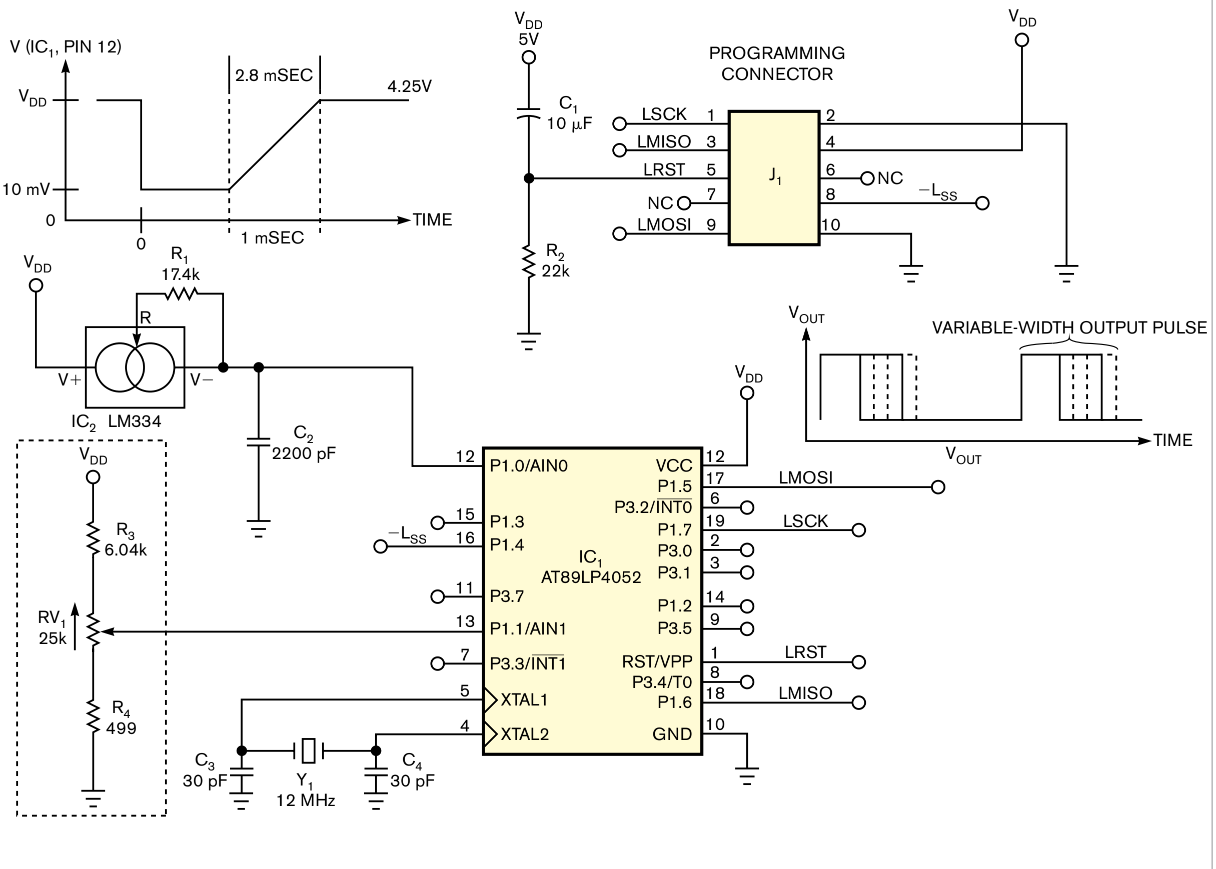


Figure 1 An analog-voltage-to-pulse-width converter features minimal parts. Subgraphs show timing-network and output-voltage waveforms. IC$_1$'s unlabeled pins are available for user functions.

Precision voltage reference delivers 80 mA

James Horste and Gary Staiman,
Maxim Integrated Products Inc, Sunnyvale, CA

Large analog systems that present many loads to a voltage-reference source can often demand more current than a single reference IC can deliver. However, if the reference IC includes force and sense terminals, you can easily add a buffer to the circuit's feedback loop without affecting the reference's accuracy. For example, the circuit in **Figure 1** provides the same 0.04% initial accuracy and 7-ppm/°C temperature coefficient as IC$_1$, a standalone MAX6033. The buffer circuit delivers as much as 80 mA.

When you design a buffer stage for a force/sense-control loop, the buffer must provide unity-voltage gain with no phase inversion. In addition, the circuit's power supply must provide head-room voltage to accommodate the reference voltage plus voltage drop across the buffer stage. The simplest buffer circuit comprises an NPN transistor that connects as an emitter follower, which requires a drive voltage that exceeds the reference's output voltage by one transistor base-emitter voltage drop. If you add the required minimum power-supply voltage plus the maximum allowable base-emitter voltage, the configuration runs out of head room. Using a PNP stage to drive the emitter drive stage solves the head-room problem but inverts the output voltage and prevents the force/sense loop from functioning. Adding a second PNP stage cancels the phase inversion but destabilizes the force/sense loop by adding excessive gain.

The modified complementary Darlington, or Sziklai, connection (**Reference 1**) in **Figure 1** solves both problems by providing an emitter follower's unity-voltage gain with no inversion. The output PNP stage provides plenty of head room, but the NPN stage does not. You can easily overcome this drawback by adding diode D$_1$ to shift the NPN transistor's emitter voltage downward by a diode drop. Thus, to a first approximation, the diode's voltage drop and the transistor's base-emitter voltage cancel one another, leaving plenty of voltage head room.

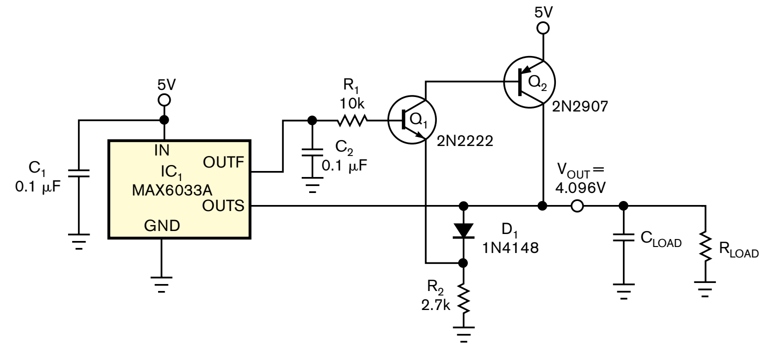


Figure 1 Add a two-transistor output buffer to a 4.096V, 15-mA reference IC to boost its output current to 80 mA or higher.

Transistor Q$_2$, a 2N2907, provides limited current gain, which in turn limits the circuit's maximum output current to 80 mA. Substituting a higher gain transistor can increase the output current to any reasonable level.

For stability, the MAX6033 requires 0.1-µF ceramic bypass capacitors on its In and OutF pins. Capacitor C$_2$ determines the circuit's response speed, but the buffer circuit exerts no significant effect on transient response. Most dc-reference-voltage ICs cannot accommodate a fast-changing load-current step; thus, the circuit's transient response and its ability to supply fast current spikes depend on the output capacitor, C$_{LOAD}$. Values of C$_{LOAD}$ as high as 10 µF do not affect the circuit's stability.**EDN**

REFERENCE

1 "Sziklai Pair," Wikipedia, http://en.wikipedia.org/wiki/Sziklai_pair.