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Stereo-amplifier IC's outputs drive multiple loads

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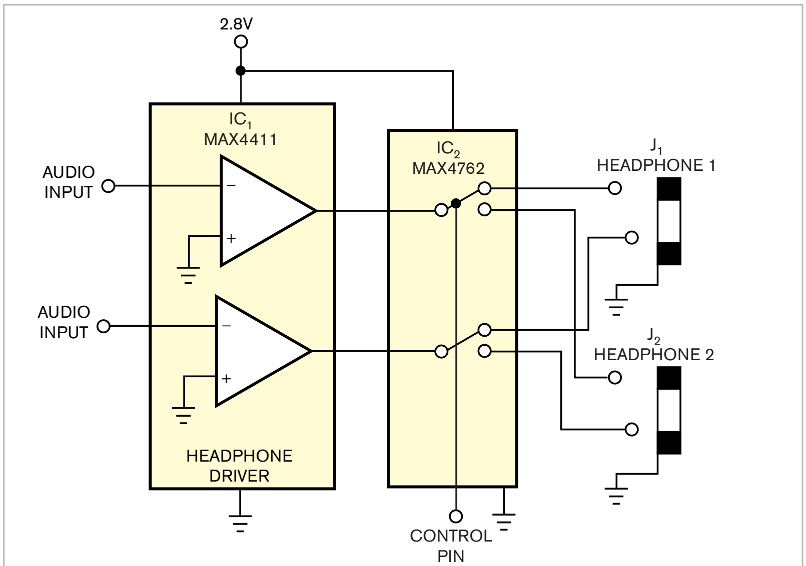

Figure 1 For low values of power-supply voltage, 2.8V maximum, use an analog switch at IC_2 that handles signal amplitudes to $V_{DD}-5.5V$ to direct IC_1's bipolar outputs to the headphone loads.

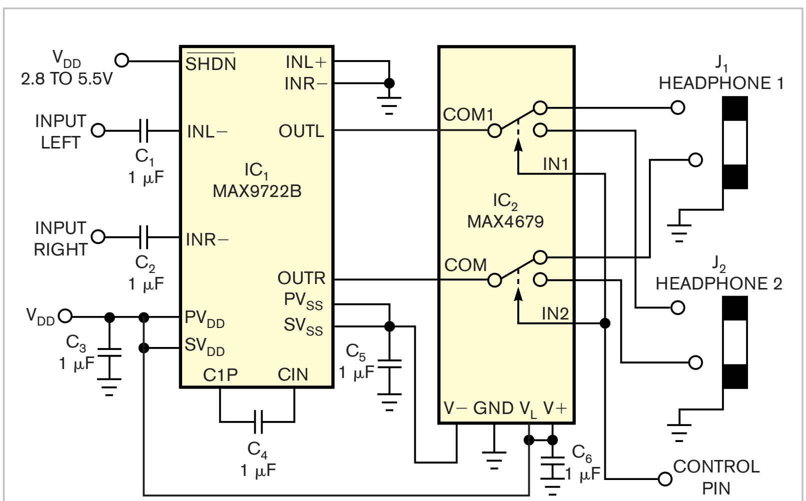

Figure 2 Higher values of V_{DD}, 2.8 to 5.5V, require a different amplifier and a dual-supply-voltage switch at IC_2.

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Newer generation, directly coupled stereo-amplifier ICs can directly drive headphones and speakers and thus eliminate bulky and expensive output-coupling capacitors. Many of these amplifiers also include a charge pump for generating an internal negative-supply-voltage rail to produce a bipolar-output swing while operating from one positive-supply voltage. However, if your applications require switching the amplifier's output between two or more headphones or other loads, you cannot necessarily use a simple electronic analog switch. Many analog switches can't handle a signal that makes excursions above the positive-power-supply voltage, V_{DD}, or below ground. Depending on V_{DD}'s maximum value, you can apply one of two approaches.

If V_{DD} falls below 2.8V (**Figure 1**), choose a switch for IC_2 such as Maxim's MAX4762, which handles negative signals down to V_{SS} of −5.5V, where V_{DD} can range from 1.8 to 5.5V with a typical on-resistance of 0.6Ω. If V_{DD} falls between 2.8 and 5V, use a dual-supply, low-on-resistance switch, such as Maxim's MAX4679 at IC_2 (**Figure 2**), along with a different stereo amplifier, such as the MAX9722B, IC_1, to handle the higher V_{DD}. For the switch's negative supply, you can use the negative voltage generated within the MAX9722B to eliminate the need for an additional charge-pump-power-supply circuit.

To enhance a mobile-telephone design, you can use a stereo-headphone jack to accommodate a hands-free combination earphone and microphone. You use the stereo jack's tip connection as the headphone contact, the ring contact for the microphone, and the shell contact as the common connection to ground (**Figure 3**). When you connect the hands-free combination, you must also turn off one channel of headphone amplifier IC_1. Although the MAX4411 amplifier offers an individual-channel-shutdown feature, the device's outputs present an impedance of 2 kΩ to ground when you switch it off.

An electret microphone capsule typically includes an open-drain JFET-output circuit that typically requires a 2-kΩ resistor, R_1, which connects to a low-noise, positive-supply voltage of approximately 2V. The resistor provides dc bias to the JFET and allows the microphone capsule's audio-output signal to appear on the output terminal. In most applications, the microphone's output connects directly to a high-impedance, low-noise amplifier, IC_3, by ac coupling of capacitor C_1.

The amplifier's 2-kΩ-to-ground off-impedance would heavily load the microphone and halve its dc bias, moving it out of its optimum operating range and reducing its output and SNR. Adding analog switch IC_2 between the microphone and the headphone amplifier's output maintains the microphone's bias and resistive load. EDN

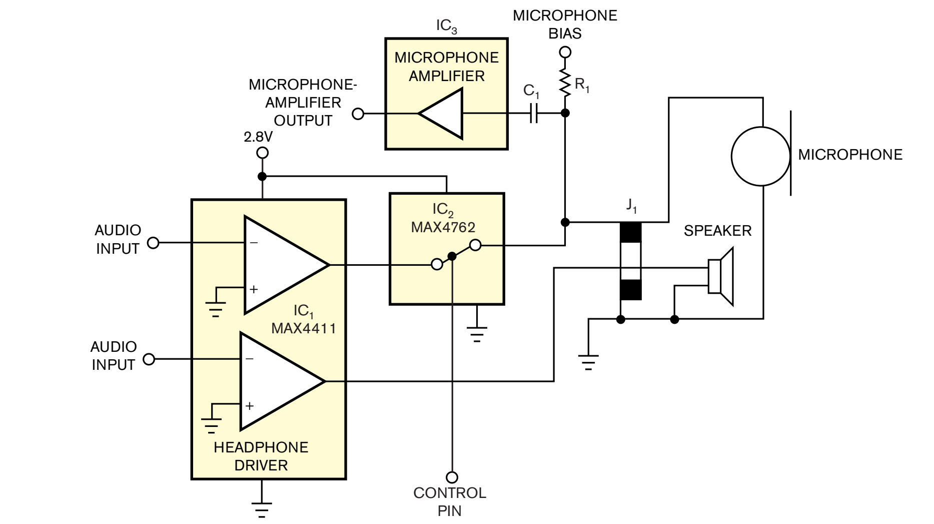

Figure 3 When using a hands-free microphone/earphone kit as an alternative to stereo headphones, add the circuitry shown to avoid loading the microphone's output with the headphone-driver amplifier's output.

Muscle power drives battery-free electronics

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Recent developments in electric-double-layer-capacitor technology have made it possible to replace rechargeable batteries in certain secondary-power-storage applications (**Reference 1**). Capacitors offer significant advantages over rechargeable batteries, including a practically unlimited number of charge/discharge cycles, survival of short circuits, and simple charging circuits that require only overvoltage protection. In addition, storage capacitors recharge quickly and pose no toxic-waste-disposal problems when the product reaches the end of its service life.

This Design Idea extends an earlier one by describing a muscle-power-driven capacitor charger. The combination of a muscle-powered electrical generator and a high-value capacitor provides a highly autonomous and environmentally clean power approach for emergency equipment and survival kits. Applications of such an alternative "renewable" energy source span a range of modern portable electrical and electronic devices, including cellular phones, MP3 players, AM/FM radios, PDAs, handheld PCs, and flashlights.

A muscle-powered capacitor charger contains only a few components: a storage capacitor, a bridge rectifier, and a voltage-limiting zener diode that protects the capacitor from excessive voltages (**Figure 1**). For practical energy-storage experiments, you can use 1 or 0.47F capacitors with 5.5V maximum ratings, such as those available from NEC-Tokin America (www.nec-tokin.com, **Figure 2**). For more storage, you can use higher capacitance capacitors, such as Elna's (www.elna.co.jp) 100F, 2.5V Dynacaps (**Figure 3**).

You can remove the lamp from an

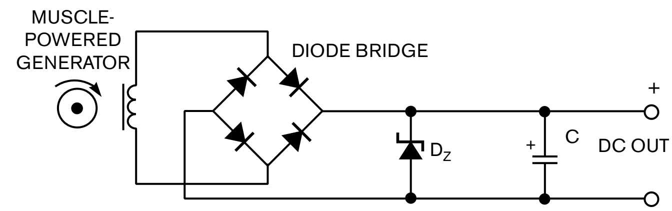

Figure 1 This charger circuit for storage capacitor C requires few additional components: a diode-bridge rectifier and an overvoltage-limiting zener diode.

Figure 2 Supercapacitors from NEC America provide 1F (left) and 0.5F of storage at 5.5V maximum and occupy little pc-board area.

Figure 3 These 100F, 2.5V Dynacaps from Elna approximate standard electrolytic capacitors in volume.

inexpensive, hand-powered flashlight and use its generator as a capacitor charger (**Figure 4**). Also, a variety of manually powered products now appearing on the market offer possibilities for experimentation. For higher outputs, you can use a stationary-bicycle-powered generator. Depending on the individual providing pedaling power, these generators can deliver average powers ranging from 20 to 100W. The hand-cranked flashlight in **Figure 4** originally lit a 2.5V, 0.15A, filament-type bulb, which consumes approximately 0.4W at full brightness. However, measurements show that the generator could deliver more power and could charge a 1F capacitor to 5V in approximately 10 sec. Thus, the following equation calculates the energy, E, stored in the capacitor of value C: $E=\frac{1}{2}C\times V_{MAX}^2=12.5J$, and the following equation calculates the average maximum muscle-generated electrical power over time, T: $T_{MAX}=E/T=12.5/10=1.25W$.

You can use the following equation to calculate the effective energy, E_{EFF}, that the capacitor can deliver during its discharge cycle while its terminal voltage changes from maximum to minimum voltage: $E_{EFF}=\frac{1}{2}C(V_{MAX}^2-V_{MIN}^2)$, where V_{MAX}^2 and V_{MIN}^2 represent the maximum and minimum operating voltages, respectively, applied to the powered devices. You can connect storage capacitors in parallel or in series. In both cases, make sure that the circuit includes proper overvoltage protection for the capacitors. To obtain additional voltages, you can add a dc/dc switched regulator to produce stable output voltages.

Important design considerations relate to the maximum voltage and current ratings of the diode-bridge rectifier and the zener diode, D_Z. Experimental measurements on the hand-cranked generator yield the following approximate values for its open-circuit voltage: maximum voltage of 10V rms, peak voltage of 14V, and maximum short-circuit current of 200 mA rms. For this application, an inexpensive bridge rectifier with 20V minimum peak-inverse voltage and 0.5A minimum forward current provide adequate margins. D_Z's breakdown-voltage rating should be slightly lower than the storage capacitor's maximum working voltage, and the diode's power rating—2W in this application—should exceed the product of the generator's maximum output current and the zener's conduction voltage.EDN

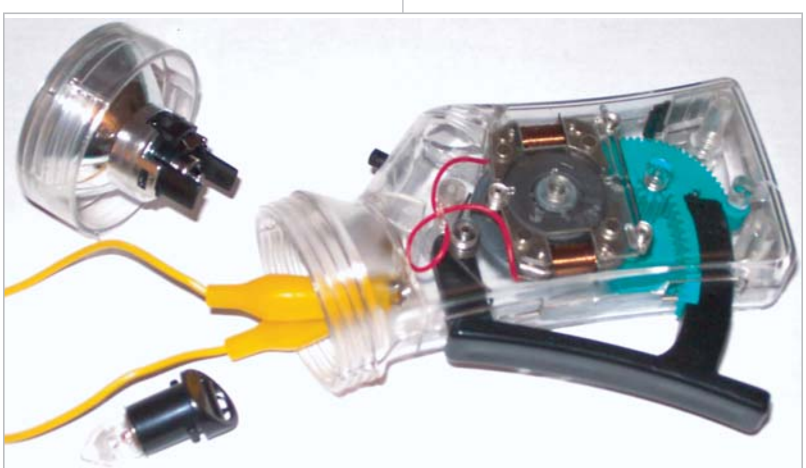

Figure 4 A hand-cranked flashlight's electrical generator serves as a muscle-powered charger for a high-capacity storage capacitor (lower left).

REFERENCE

1 Bell, Alexander, "Single capacitor powers audio mixer," *EDN*, March 14, 1997, pg 80, www.edn.com/archives/1997/031497/06DI_04.htm.

FET biasing targets battery-powered PWM applications

Steve Franks, Franks Development LLC, Tucson, AZ

Many PWM (pulse-width-modulated) applications, such as Class D audio amplifiers, require symmetric drive circuitry. Comprising complementary N- and P-channel FET devices with gates and sources connected, the textbook CMOS pair in **Figure 1** provides a low-impedance path to either the positive or the negative power supply and can directly drive a logic-level N-channel FET. Direct coupling of the CMOS pair to the logic driver works well in PWM systems in which the controlled devices operate at the same voltage as the logic circuits. However, raising the output FETs' power-supply voltage while driving the gates from lower voltage logic results in the P-channel device's remaining in conduction because of the difference between supply voltages.

To achieve an off-state, an amplifier's P-channel FET's gate must go to the positive-supply rail. Complementary-CMOS logic-level drivers can't accommodate the amplifier's high positive-supply voltage, and alternatives, such as using commercial FET drivers and operational-amplifier level-shift circuits, add cost and complexity. You can add an external high-voltage N-channel FET to drive the P-channel-amplifier FET's gate (**Figure 2**). However, capacitive loading imposes an exponential-rise characteristic on the drive waveform, leaving the P-channel FET in its linear operating region for an extended period and thus limiting switching frequency and causing significant power losses in the cascaded FETs.

Current-generation PWM systems can operate at relatively high switching frequencies and, as **Figure 3** shows, allow you to use a dc-blocking coupling capacitor, C_B, between the logic-level driver's output and the P-channel output FET's gate. Resistive divider R_1 and

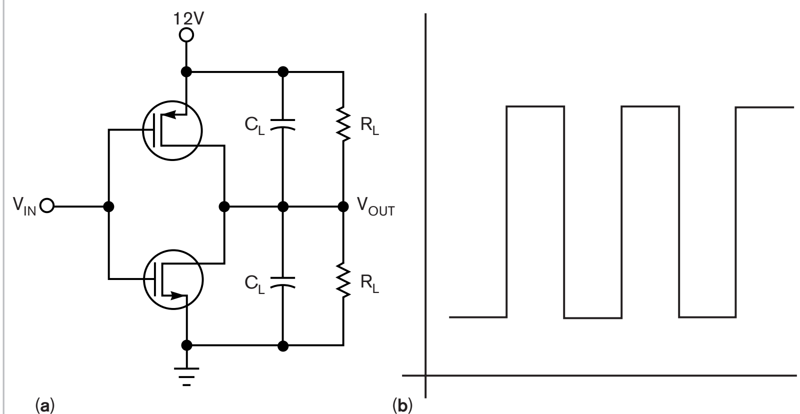

Figure 1 The textbook complementary-CMOS pair (a) produces a clean output waveform with fast on/off transitions (b).

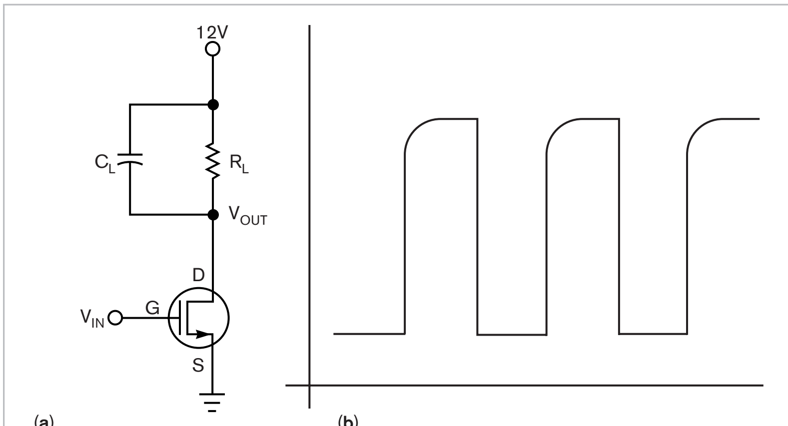

Figure 2 An N-channel FET driver (a) has output that exhibits an exponential rising edge on shutoff.

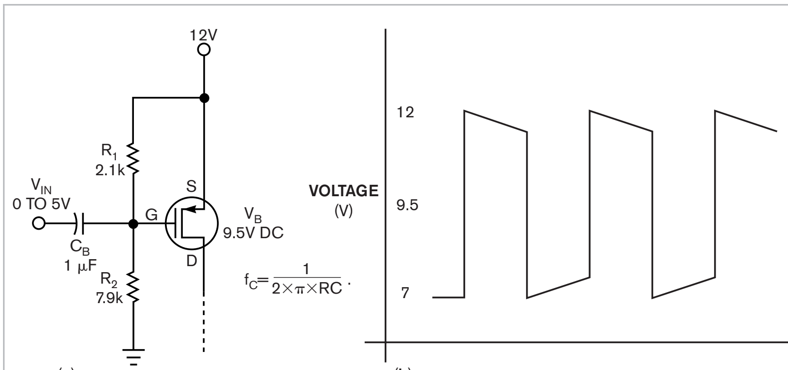

Figure 3 Adding resistive bias and capacitive coupling to an N-channel MOSFET (a) improves transition times but introduces waveform droop during on or off intervals (b).

R_2 applies a dc bias to the output FET's gate that's equal to the difference between the output power-supply voltage and the midrail logic voltage. For example, in a 12V Class D PWM audio amplifier driven from a 5V microcontroller, bias the P-channel FET's gate at 9.5V (12V−5V/2). Use the specified FETs for logic-level gate drive as output devices because other FETs don't exhibit nominal I_{DS} characteristics at gate drives of 5V or lower.

Battery-powered amplifiers with resistive-divider output-stage bias introduce an additional complication. As battery voltage decreases, so does bias. Instead, you can use a voltage-reference IC or a zener diode, D_1, to provide a constant bias voltage regardless of supply-voltage variations (**Figure 4**). This technique consumes less power than a purely resistive divider and offers more flexibility in coupling-capacitor selection to reduce waveform droop. Based on Texas Instruments' TPA2010 PWM power-amplifier IC (**Reference 1**), a Class D audio power amplifier boosts the TPA2010's 2.5W differential output to more than 200W rms into an 8Ω load (**Figure 5**).EDN

REFERENCE

1 TPA2101D1 data sheet, http://focus.ti.com/lit/ds/symlink/tpa2010d1.pdf.

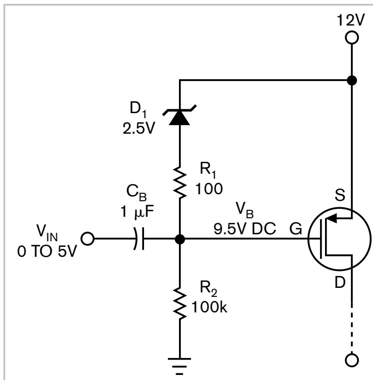

Figure 4 Inserting a zener diode into the bias divider allows optimization of the coupling capacitor's value and the P-channel device's bias voltage for logic-level drive.

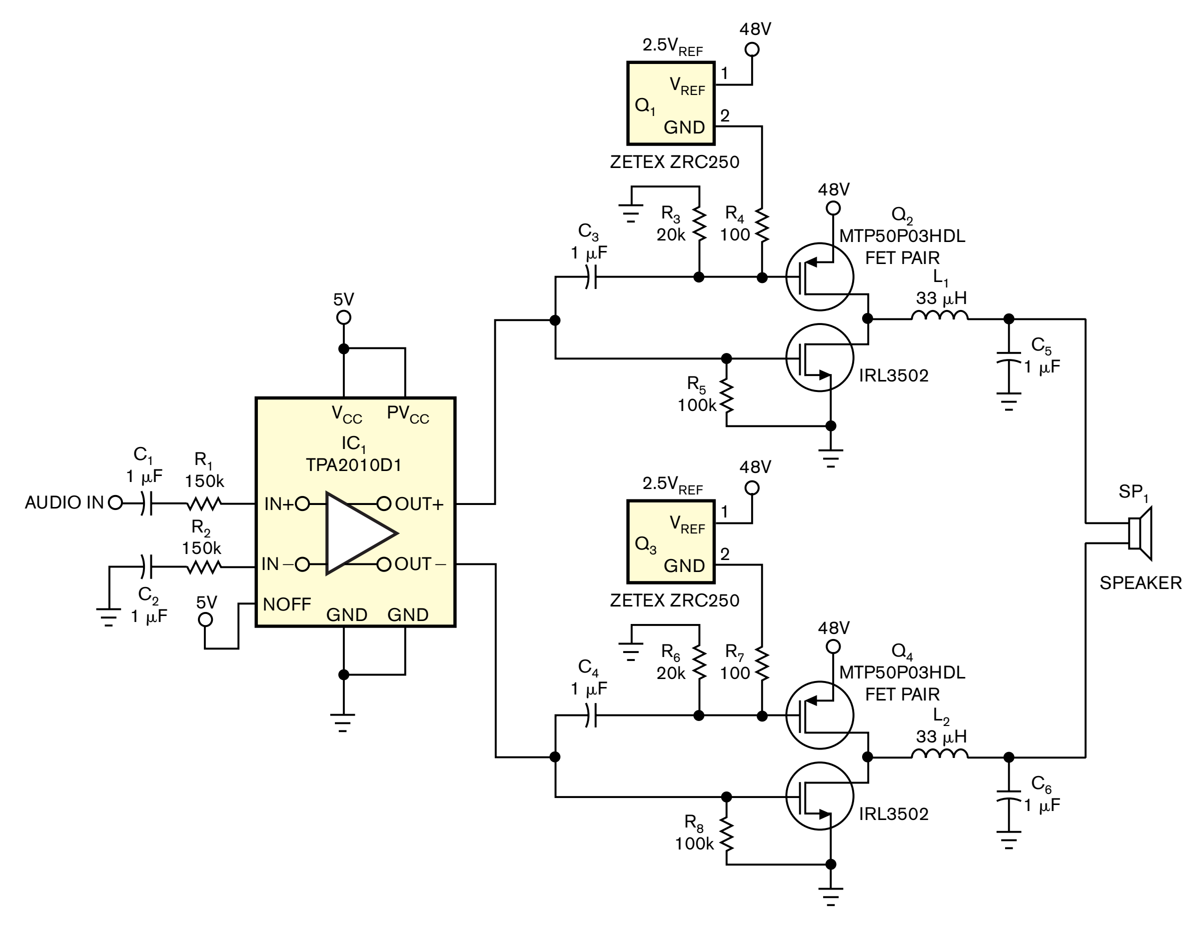

Figure 5 This Class D audio amplifier boosts its driver's output to 200W rms for a 48V power supply.