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READERS SOLVE DESIGN PROBLEMS

Audio-test accessory isolates and matches loads

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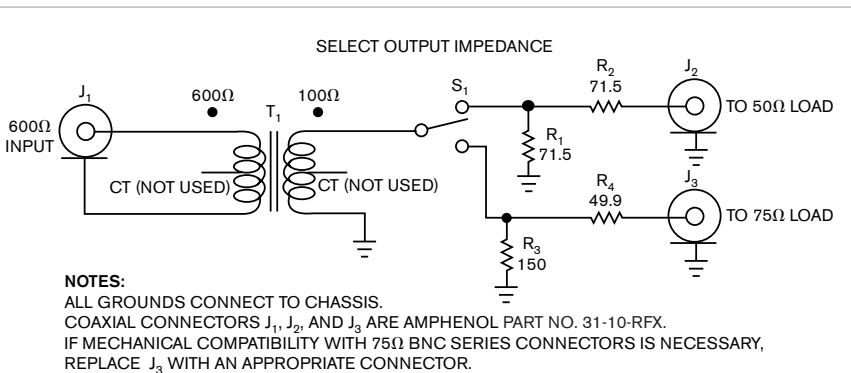
Connecting a 600Ω audio circuit to a 50 or 75Ω circuit or test instrument requires an impedance-matching circuit or, when isolation of the circuits is necessary, a transformer. Both approaches offer advantages and disadvantages. A conventional transformer can match impedances with low typical losses of 1.5 dB, provide dc isolation, and operate from either a balanced or an unbalanced, 600Ω primary circuit. A high-quality transformer's pass-

band can accommodate an audio-frequency range of 300 Hz to 15 kHz with minimal amplitude variation. However, transformers that can match 600 to 50 or 75Ω may not be readily available or may command a cost premium.

A minimum-loss, fixed-value impedance-matching circuit, or pad, provides frequency-invariant audio-impedance transformation and can comprise as few as two resistors. Although a pad can provide useful impedance

TABLE 1 INSERTION LOSS VERSUS FREQUENCY

Frequency (kHz)	Insertion loss (dB) 600 to 50Ω	Insertion loss (dB) 600 to 75Ω
0.1	11.7	8.7
0.3	10	7
0.5	9.5	6.7
1	9.2	6.5
2	9	6.3
5	8.9	6.1
10	8.8	6.1
20	8.8	6
50	8.9	6.1
100	9.5	6.7



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matching, it introduces a significant insertion loss of 14.8 dB for a 600-to-75Ω transformation or 16.6 dB for a 600-to-50Ω transformation, either of which might impose an unacceptable loss of dynamic range.

Part of a suite of test accessories, this low-cost, switchable, dual-impedance transformation circuit comprises a single conventional transformer and two minimum-loss pads (Reference 1). A single inexpensive, conventional transformer steps down the 600Ω primary input impedance to an intermediate impedance level of 100Ω (Figure 1). Switch S₁ selects a 100 to 50Ω or a 100 to 75Ω minimum-loss pad. Construction of the unit involves noncritical point-to-point wiring, although this design uses a Hammond 1590LB die-cast-aluminum box to provide shielding and a rugged enclosure to support three Amphenol (www.amphenolrf.com) RFX series BNC panel-mounted, insulated-frame input and output jacks. T₁ is a Mouser Electronics (www.mouser.com) 42TM031 audio transformer, and the resistors are 0.5W, metal-film units with ±1% tolerances. With quantity discounts, the overall bill-of-materials cost is less than \$20.

To verify frequency response and

Figure 1 A handful of passive components creates a handy test fixture for matching impedances in audio-test circuits.

attenuation in a 600 Ω test setup, connect two identical units back to back through their 50 or 75 Ω terminals. You obtain the measured data (Table 1) for a single unit by halving the 600-to-600 Ω transmission-loss measurements.

Calculated insertion loss for the 100 to 50 Ω minimum-loss pad is 7.7 dB, and insertion loss for the 100 to 75 Ω minimum-loss pad is 4.8 dB. Subtracting these values from the measured losses indicates that the transformer con-

tributes a midband loss of 1.3 to 1.5 dB. Insertion loss due to stray coupling from the selected output port to an unused output exceeds 40 dB. Combining a conventional transformer with two minimum-loss pads takes advantage of the best of both techniques.

The low-cost transformer contributes moderate insertion losses and provides dc isolation and good frequency response. In addition, the transformer's low-frequency roll-off

helps reduce 60-Hz hum and low-frequency noise. The electrically isolated input jack allows connection of the transformer's input to balanced or grounded 600 Ω sources. **EDN**

REFERENCE

■ Kurzrok, Richard M, "Simple Lab-Built Test Accessories for RF, IF, Baseband, and Audio," *High Frequency Electronics*, May 2003, pg 60.

One oscillator drives multiple solid-state relays

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Thanks to a combination of low initial cost and low on-resistance, a conventional electromechanical relay often makes sense for switching large amounts of load current on and off and when proportional control of the load's current or voltage is unnecessary. Low cost and low on-resistance represent the main reasons that relays still enjoy widespread use in the industry. In addition, a relay remains useful for switching high-voltage ac under the control of low-voltage electronics, due to the high degree of isolation between the control and the load circuits.

However, although relay technology has matured and offers proven performance, the relay remains a mechanical device that suffers from wearing out and other failure modes. Electrical endurance of the relay's contacts imposes a limit on the number of switching cycles. When a relay's contact opens, interruption of the current in an inductive load causes a spark that deteriorates the contact's performance. When switching high currents, a relay may reach the end of its operating lifetime in as few as 100,000 actuation cycles.

As an alternative to a conventional relay, a series-connected pair of MOSFETs can replace a contact in an ac circuit (Figure 1). A pair of IRF530 devices switches loads in circuits with peak maximum voltages as high as $\pm 100\text{V}$. Based on the well-known 555 timer, an astable oscillator, IC₁, provides a source of square-wave voltage to drive the MOSFET pairs' gate. Resistors R₁ and R₂ provide charge and discharge paths for timing capacitor C₁. The 555's output stage can sink and source several tens of milliamperes and provide enough current to drive as many as 10 stages' simultaneously operating switch gates, each consuming 5 mA of peak current; the 555's output sinks a maximum of 50 mA at an on-state maximum voltage of 0.75V. The 555's output drives a distribution bus that provides power to an array of pulse transformers, T₁ and T₂. Capacitor C₃ in series with the transformers' primary removes the dc offset voltage that would otherwise appear across the winding.

Selection of the transformer is not critical, and any ferrite-core pulse transformer that can provide gate voltage to the MOSFETs and maintain a

safe level of voltage isolation can function in the circuit. For example, you can use C&D Technologies' (www.cdtech.com) 76601/3, which provides a 1-to-1 turns ratio at a primary inductance of 219 μH with 500V-dc interwinding isolation.

Applying a control signal to the base of general-purpose NPN switching transistor Q₃ allows collector current to flow through the primary of its associated transformer. Diode D₂ provides a reverse-current path through the winding. On the secondary side, diode D₁ rectifies the secondary voltage and charges capacitor C₄, which filters the rectified voltage to improve noise immunity and reduce voltage ripple at the MOSFETs' gates. Removing the control signal switches off Q₁ and Q₂. Resistor R₃ provides a discharge path for C₄, allowing the MOSFETs to switch off in approximately 3 msec. For faster turn-off, you can reduce the value of either C₄ or R₃ at the expense of increased ripple on the rectified gate voltage.

Using two series-connected MOSFETs allows bidirectional ac conduction through the pair. When the MOSFETs are off, their parasitic diodes connect in series opposition and thus block conduction. You can select from among a range of MOSFETs to match your application's requirements, but make sure that the voltage you apply to the gates of Q₁ and Q₂ is sufficient to fully switch

both devices into full conduction. The IRF530 has a gate threshold voltage of 3V, but applying a gate-source voltage of 10V ensures low on-resistance. You can adjust the gate-source voltage by altering the transformer's turns ratio or IC₁'s power-supply volt-

age within its 4.5 to 16V rating (references 1 and 2).**EDN**

REFERENCES

1 "Transformer-isolated gate driver provides very large duty cycle ratios," Application Note 950, International

Rectifier Co, www.irf.com/technical-info/appnotes/an-950.pdf.

2 Balogh, Laszlo, "Design and application guide for high speed MOSFET gate drive circuits," Texas Instruments, 2002, focus.ti.com/lit/ml/slup169/slup169.pdf.

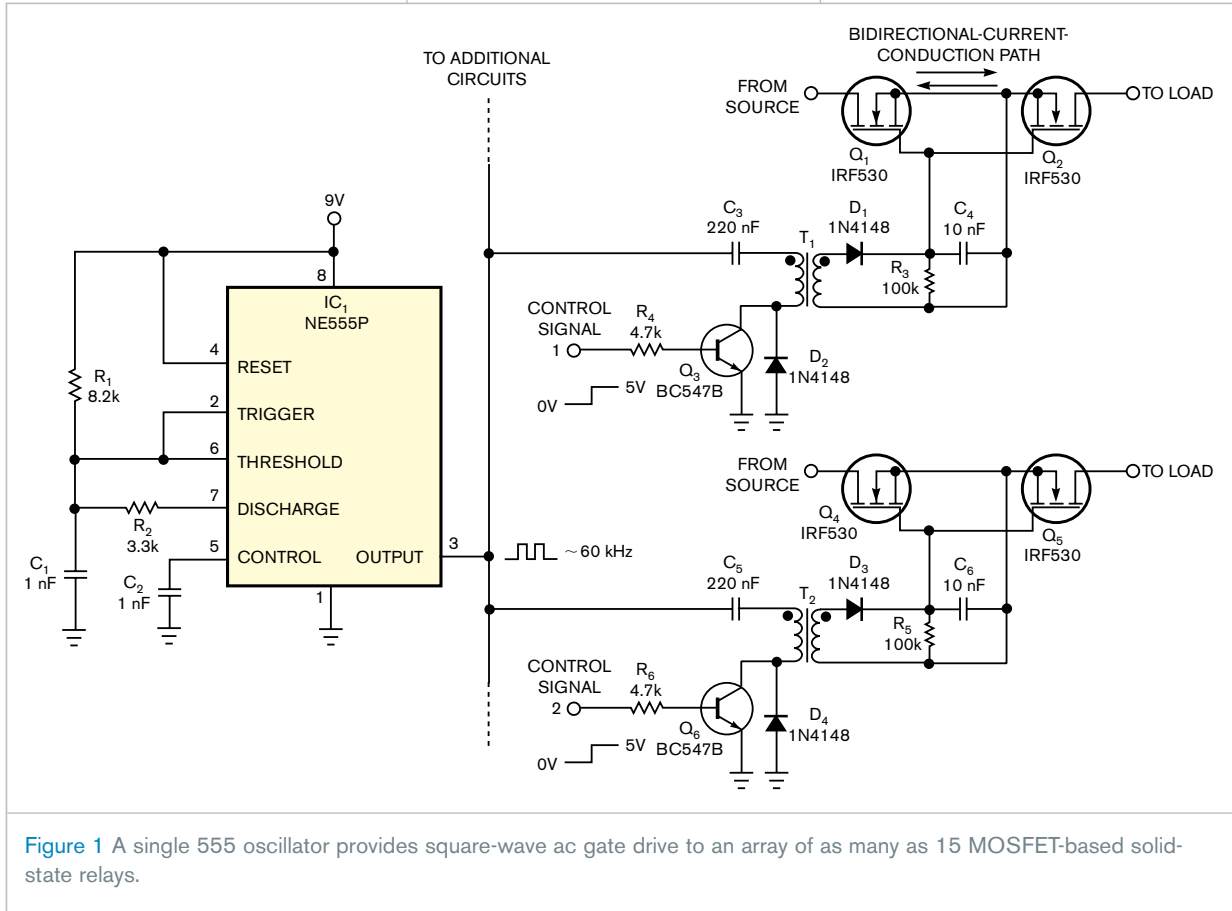


Figure 1 A single 555 oscillator provides square-wave ac gate drive to an array of as many as 15 MOSFET-based solid-state relays.

Low-dropout linear regulators double as voltage-supervisor circuits

William Lepkowski, On Semiconductor, Tucson, AZ

Many low-dropout voltage regulators include an enable-input pin that can also serve as an inexpensive alternative to a voltage-supervisor IC. Although the enable pin normally serves as a means of shutting down the regulator's output to save power, a

few discrete components ensure that the regulator's output will turn on and off at appropriate input voltages. Thus, you can use the circuit as a voltage supervisor or as a controlled-characteristic linear-voltage regulator.

A typical low-dropout regulator's

internal enable circuit comprises a voltage comparator that determines whether the voltage at the enable pin is either larger or smaller than an internal reference voltage, V_{REF} . Although you can create a low-dropout voltage supervisor by directly connecting the enable pin to the unregulated input voltage, this circuit's turn-on and turn-off voltages equal the reference voltage, which typically falls below the minimum operating voltage that most ICs powered by the regulator's output require.

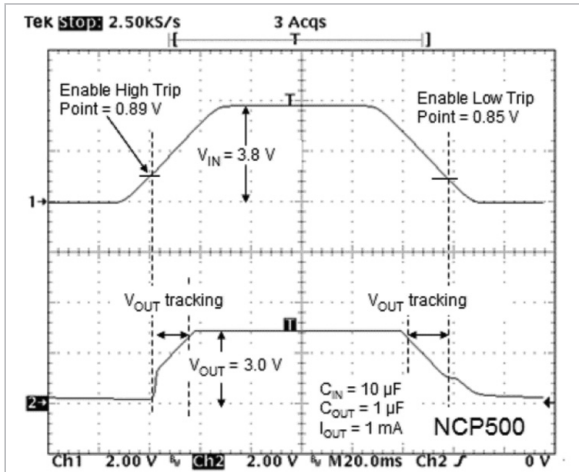


Figure 1 Connecting a low-dropout regulator's enable pin directly to the unregulated voltage input forces the output voltage to track the input voltage during the regulator's turn-on and turn-off intervals.

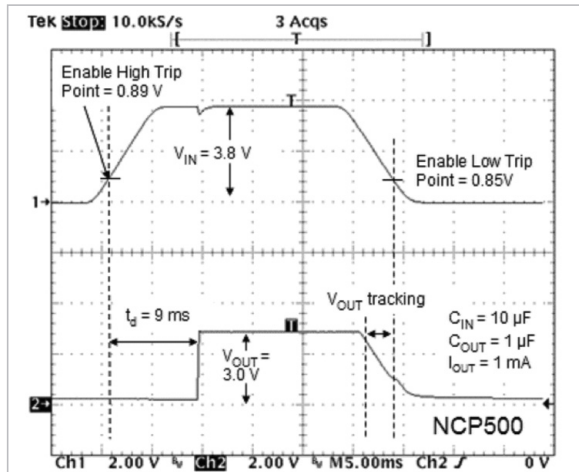


Figure 3 The added components in Figure 2 eliminate the problem of rising-edge output-voltage tracking. However, the falling-edge output voltage still tracks the input voltage.

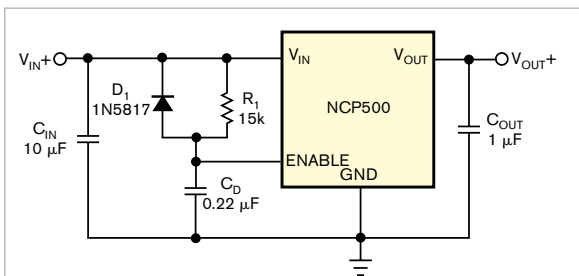


Figure 2 An alternative to directly connecting the regulator's input and enable pins, this "conventional" modification uses a resistor and a capacitor to delay the regulator's turn-on time. The diode eliminates the power-down delay interval.

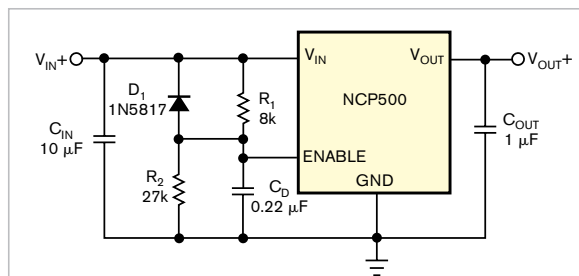


Figure 4 Resistor R_2 increases the enable pin's switching threshold voltage.

In addition, directly connecting the enable pin to the unregulated input doesn't provide a turn-on delay to ensure that the input voltage has reached a value higher than the low-dropout regulator's dropout voltage. The directly connected circuit has unsatisfactory power-up and power-down characteristics (**Figure 1**). As a first-order improvement, you can enhance the circuit's performance by adding R_1 , C_{IN} , and D_1 to provide a start-up delay for the voltage regulator's enable pin (**Figure 2**). Unfortunately, the external delay network improves the output's rising-edge characteristic, but its falling edge continues to track the input voltage (**Figure 3**).

You can solve the circuit's shutdown problem by replacing the single resistor with a voltage-divider network (**Figure 4**). Resistor R_2 raises the switching threshold of the regulator's enable pin and "tricks" the enable comparator into turning on at a higher voltage. The regulator's output then exhibits an adequate start-up delay and

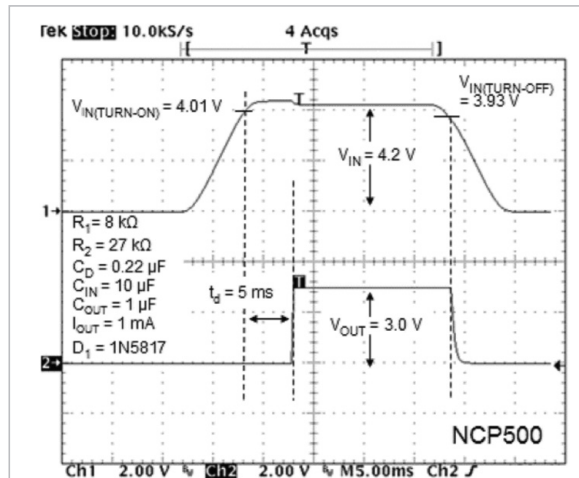


Figure 5 The addition of R_2 in Figure 3 solves the falling-edge problem, and shutdown occurs immediately after the input voltage drops too low. The regulator's output switches off only after sufficient voltage is present at its input.

clearly switches on and off (Figure 5).

You can use Equation 1 to calculate the values of resistors R_1 and R_2 to alter the enable pin's threshold voltage in the circuit in Figure 4.

$$V_{IN(TURN-ON)} \approx \left[\left(2 \times V_{EN(RISING)} \right) - V_{EN(FALLING)} \right] \times \left(1 + \frac{R_1}{R_2} \right) \quad (1)$$

where $V_{IN(TURN-ON)}$ is the user-defined turn-on voltage, $V_{EN(RISING)}$ is the enable pin's rising-edge trip-point voltage, and $V_{EN(FALLING)}$ is the enable pin's

falling-edge trip-point voltage. For example, $V_{IN(TURN-ON)} = 4V$, $V_{EN(RISING)} = 0.89V$, and $V_{EN(FALLING)} = 0.85V$. To prevent the regulated output voltage from tracking the input, set the minimum value of $V_{IN(TURN-ON)}$ to $V_{OUT} + V_{DROPOUT}$, where $V_{DROPOUT}$ is the dropout voltage.

$$\frac{R_1}{R_2} \approx \frac{V_{IN(TURN-ON)}}{\left[\left(2 \times V_{EN(RISING)} \right) - V_{EN(FALLING)} \right] - 1} - 1 \approx \frac{4}{\left[\left(2 \times 0.89 \right) - 0.85 \right] - 1} - 1 \approx 3.3 \quad (2)$$

If you select a value of $8\text{ k}\Omega$ for R_2 , then $R_1 = 3.3 \times R_2$, or approximately $27\text{ k}\Omega$.

Equation 1 calculates only approximate values for the voltage-divider resistors, which may vary slightly depending on the voltage regulator's characteristics. If the resistors' values are too low, the regulated output tracks the input, a problem that you can easily solve by increasing the value of R_1 . Also, R_1 and C_D determine the regulator's turn-on delay time, and C_D 's capacitance should ideally be 0.01 to $0.47\text{ }\mu\text{F}$. Too large a value increases the discharge time and reduces the circuit's effectiveness as a voltage supervisor. **EDN**

External components provide true shutdown for boost converter

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The step-up switching-converter circuit in Figure 1 presents a familiar problem: If you shut down boost converter IC_1 by pulling its $\overline{\text{SHDN}}$ input low, external inductor L_1 and forward-biased Schottky diode D_1 allow the load to continue drawing current. For battery-powered applications that present a heavy load— 300 mA , for example—this unwanted dc-current path may quickly drain the battery. Adding an N-channel MOSFET, Q_1 , and a $100\text{-k}\Omega$ resistor, R_1 , solves the problem by opening the unwanted current path during shutdown. The resulting circuit is suitable for battery-powered-system applications in which a microcontroller handles the power management.

Asserting a low logic level on the $\overline{\text{SHDN}}$ input simultaneously shuts down the switching converter, a MAX756, and turns off the MOSFET, thereby blocking load current by removing the load's ground connection. When the $\overline{\text{SHDN}}$ signal deasserts, the $100\text{-k}\Omega$ pullup resistor turns on the MOSFET by pulling the MOSFET's gate high. With its ground reconnected, the load then draws cur-

rent from the activated boost-converter circuit.

For optimum results at high load currents, select a logic-level MOSFET for

Q_1 that presents a reasonably low on-resistance. The MOSFET's drain-to-source breakdown voltage should also be able to withstand at least twice the maximum output voltage you expect from the boost converter. If necessary, you can reduce the MOSFET's effective on-resistance by connecting two or more MOSFETs in parallel. **EDN**

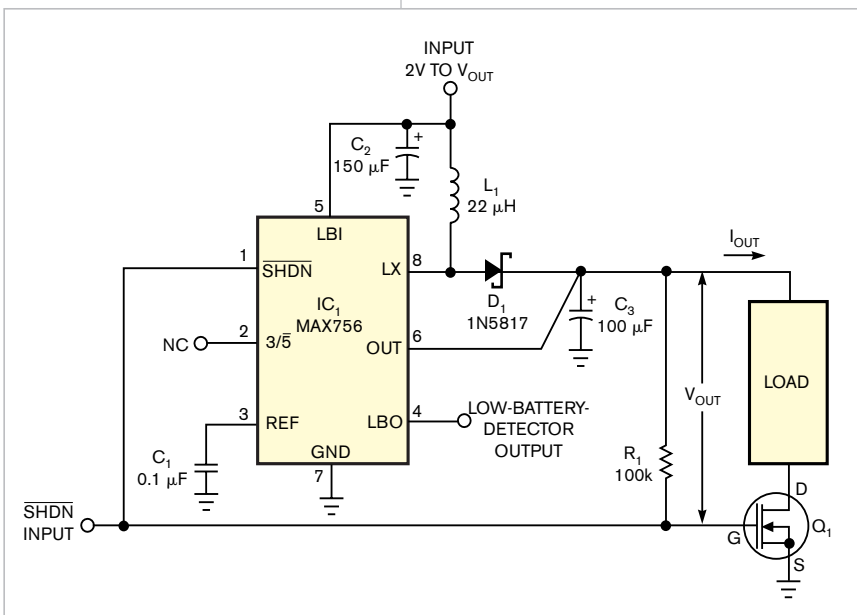


Figure 1 Adding R_1 and MOSFET Q_1 to this step-up-converter circuit enables the $\overline{\text{SHDN}}$ control to impose a “true” shutdown that blocks load current when boost converter IC_1 switches off.