Three-transistor modulator-amplifier circuit works with swept-control frequencies

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Many applications require a circuit to perform pulse modulation and voltage amplification to drive a load with a train of impulses. A typical application is driving a piezoelectric generator in a robot. Other applications include driving small motors or LEDs. Echolocation and ultrasound visualization use a sweeping-frequency, or chirp, signal. Nonlinear distortion is not important in these applications. When you drive a piezoelectric load, its natural resonance removes any frequency components other than the fundamental. This circuit combines a modulator and an amplifier into a single stage. The compactness of the circuit makes it appropriate for portable-system applications.

The load is in series with two switches (**Figure 1**). The input signal controls S_2, S_3 controls S_1, and the modulating signal controls S_3. This circuit's mod-

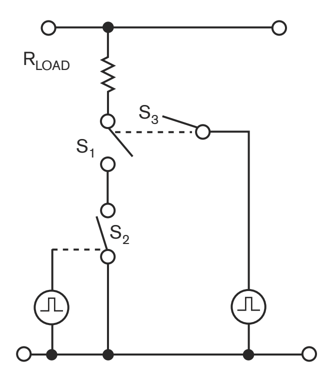

Figure 1 This simple modulator uses three switches.

ulation operation is similar to that of an AND gate. The switches must have internal resistance to dissipate the harmonics that the resonant load reflects. This circuit uses transistors Q_1 and Q_2 as switches, although they operate in the active region (**Figure 2**). Their operation resembles that of controlled resistors, and they perform voltage and current amplification. You drive Q_2 with a 42-kHz signal that matches the load's resonance. You modulate the Q_3 transistor with a periodic low-frequency impulse signal. These impulses open Q_3, which drives Q_1 and Q_2 toward saturation. When Q_3 opens, it drops the voltage across the base of Q_1, blocking the state of Q_2. Q_1 and Q_2 operate conjointly; Q_1 conducts only when Q_2 is conducting. You can view this scheme as a differential amplifier in which the signal in one branch controls the load of another branch.

Q_2 and Q_3 operate over large signals yet remain in the active region most of the time. The resistor values in the base and collector of Q_1 are critical. When the frequency of the signal is higher than the load's resonant frequency, D_1 protects Q_1 from the effects of L_1 and of harmonics on the LC circuit. The collector voltage has a spectrum rich in harmonics due to the nonlinear behavior of transistors. This characteristic is not a serious disadvantage because the resonant load removes the harmonics.

The value of R_1 is critical to the current and voltage amplification of the Q_1/Q_2 stage. The swing of voltage in the collector of Q_1 is sensitive to the value of R_1 (**Figure 3**). Q_1 operates in the active mode because its collector voltage increases slowly toward the maximal value. The significant glitch at small collector voltages shows that the blocking process partly occurs in the active regions of Q_2 and Q_3. If the load impedance varies, the circuit does not degrade the impulse shape. This situation is true even at twice the load's resonant frequency. The circuit functions with input voltages of 4.5 and 11V. This voltage range allows you to drive the circuit with a 5V microcontroller (**Reference 1**).EDN

IF THE LOAD IMPEDANCE VARIES, THE CIRCUIT DOES NOT DEGRADE THE IMPULSE SHAPE.

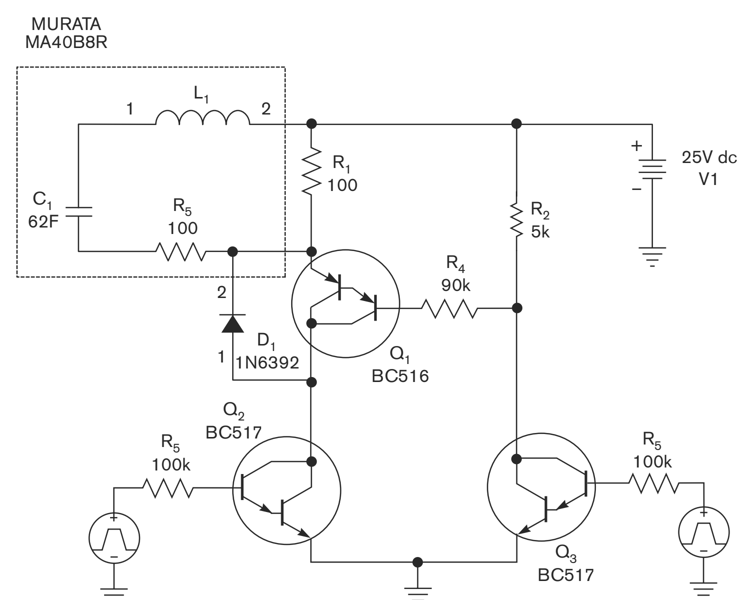

Figure 2 A three-transistor modulator with a resonant load works over a large input range.

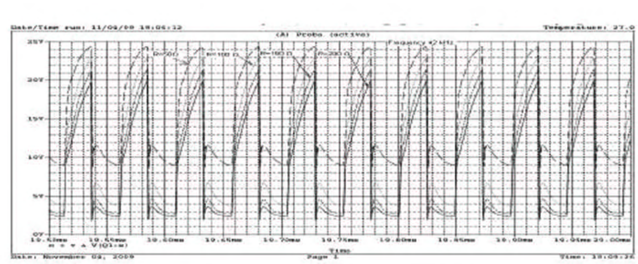

Figure 3 Changing the value of R_1 yields different response waveforms.

REFERENCE

1 Teodorescu, Horia-Nicolai L, "Algorithm for Adaptive Distance Estimators for Echolocation in Air," International Solid-State Circuits Conference, 2009, www.adbiosonar.ugal.ro/ad/content/funding.