Multiplier Improves the Dynamic Range of Echo Systems (HA-2556, HA-5177)

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Introduction

In an echo system the returned signal amplitude is a function of the distance to the target, and it can be expressed mathematically as function of time. An echo system with a fixed gain preamp has poor dynamic range because close targets (short return times) have high signal amplitudes while distant targets (long return times) have much lower signal amplitudes. In fixed gain systems, the biggest signals establish the upper preamp gain limit based on not saturating the system, and this gain may not be high enough to process small returns properly.

The solution is a preamplifier which has a gain proportional to time, such that the gain will be small for close targets and large for distant targets. The preamp still has to meet all the other normal preamp criteria such as bandwidth and noise performance, and the added time dependent gain function must not degrade the signal. The circuit shown in the figure implements the variable gain preamp with the Intersil HA-2556 multiplier. This IC establishes the signal bandwidth and noise figure because it is the only component in the signal path. The equation for the multiplier gain, as shown in the accompanying figure, is given below:

$$V_{OUT} = \frac{V_X V_Y}{5}\left(\frac{R_7}{R_8} + 1\right) = 10 V_X V_Y$$

The HA-5177 and its associated circuitry comprise a constant current source whose current is $V_{D1}/R_2 = I = 51\mu A$. If S_1 is in the L_{IN} position with Q_2's gate held high, the current source is shorted to ground by Q_2 and the multiplier gain is set to zero. When the received signal from the closest target can be present, Q_2's gate is brought low forcing it into a very high drain resistance state (almost an open circuit) allowing the HA-5177 current to charge C_1 in a linear manner. The voltage across C_1 ramps up from 0V to 5V in 1ms which is the time it takes sound to travel approximately one foot through air. During the first portion of the ramp, when the returned signal is very large, the multiplier gain is small because V_X is small. As time increases V_X also increases providing more gain through the multiplier as the expected echo decreases in amplitude. Thus, the output voltage swing of the multiplier tends to stay constant for large changes in input signal, and the dynamic range is improved to the amount of the ramp change, which is more than 60dB with the values shown in Figure 1.

Often the returned signal is a nonlinear function and it may be desirable to linearize it. An inverse nonlinear ramp can be employed to linearize the overall function. R_3, R_4 and C_1 generate a logarithmic ramp when S_1 is in the Log position thus yielding a logarithmic gain function adequate for linearizing some transducers. Many other time-gain transfer functions can be generated by employing different types of ramps.

It is important to eliminate the multiplier offsets with the adjustments [1] provided because offsets will appear in the output signal, reduce the dynamic range and contribute errors. As the circuit is configured it will sweep from a gain of 0.01, as the ramp begins, to 10 as the ramp ends. Returned signal amplitude is usually small but should not exceed $100mV_{P-P}$ unless distortion can be tolerated. The circuit bandwidth can be as high as 57MHz in low gain applications, and is 5MHz as configured.

References

[1] Wideband Four Quadrant Voltage Output Analog Multiplier Data Sheet HA-2556, File Number 2477, Intersil Corporation, Melbourne, Florida.

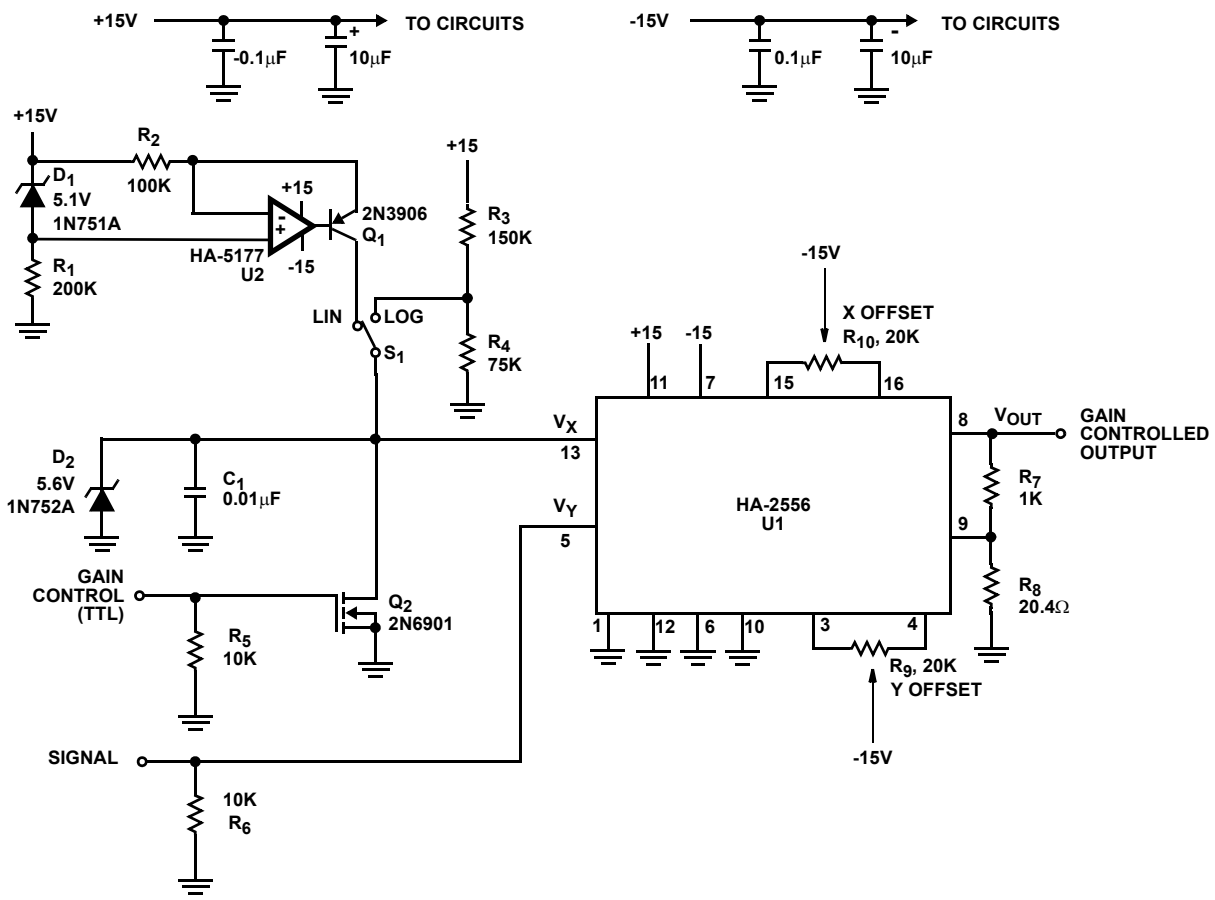

FIGURE 1. MULTIPLIER IMPROVES DUAL RANGE OF ECHO SYSTEMS

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