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Simple Tunnel Diode Circuit for Accurate Zero Crossing Timing

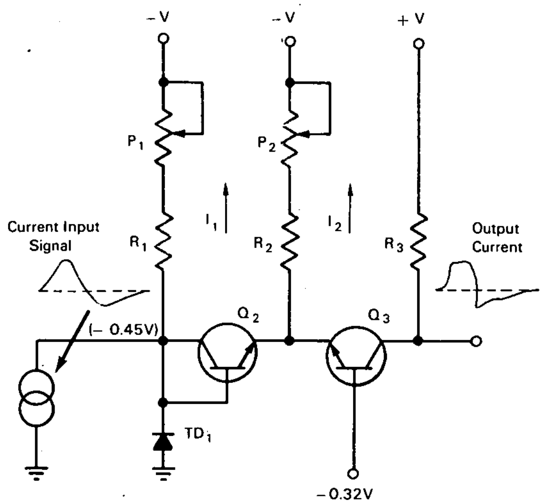

FIGURE 1
SIMPLIFIED SCHEMATIC OF ZERO CROSSING DETECTOR

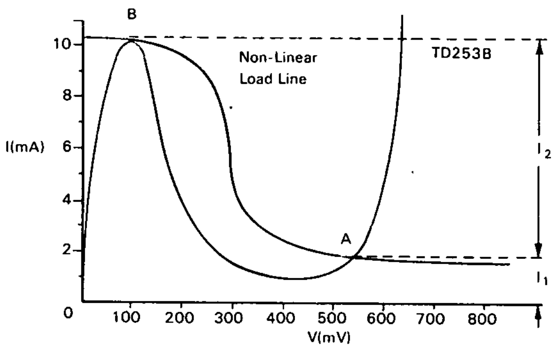

FIGURE 2
TUNNEL DIODE AND LOAD LINE CHARACTERISTICS

The problem:

To develop an effective circuit design for a fast zero crossing detector. A simple method uses a tunnel diode as a threshold device with the triggering level just above noise and of the same polarity as the second portion of a bipolar input. Considerable time slewing exists near threshold, however, because the triggering level is not at true zero. A leading edge side channel can be used to reduce time slewing, but this adds dead time to the system and introduces internal timing requirements. In addition, the circuit cannot respond to inputs which fall in the amplitude range between noise and the side channel threshold level.

The solution:

A simple tunnel diode circuit, capable of accurately timing the zero crossing point of bipolar pulses. The combination of a fast tunnel diode and a non-linear load line results in a circuit that can detect the zero crossing of a wide range of input waveshapes. This technique has been utilized in the design of a versatile, fast zero crossing discriminator. This instrument, which is compatible with existing logic systems, exhibits time slewing of less than 200 picoseconds for an input amplitude range of at least 1 to 70 times threshold. Direct coupling at critical points and extremely short recovery time enable the instrument to function well at high rates.

How it's done:

A simplified schematic of the zero crossing is shown in Figure 1. Quiescently TD_1 is biased in the high state well below the peak current. After TD_1 is switched to the low state, the bias current is increased to peak current by the action of the non-linear load line shown in Figure 2. This enables the circuit to

(continued overleaf)

detect the true zero crossing. Good resolution and sensitivity are achieved without sacrificing simplicity or versatility.

The non-linear load line is developed by the switching action of Q_2 and Q_3. Quiescently TD_1 is biased in the high voltage state at point A, with bias current I_1 determined by R_1 and P_1. This biases Q_2 off and I_2 flows through Q_3. The positive portion of the input drives TD_1 to the low voltage state, causing Q_2 to turn on and Q_3 to turn off. Now the current I_2 also flows through the tunnel diode. If the sum of I_2 and the initial bias current I_1 is equal to the peak current of the diode, the load line will pass through B as shown. Now when the input waveform crosses zero, TD_1 retriggers and turns Q_3 on again. The zero crossing timing information is obtained by clipping the waveform at Q_3's collector and using the negative spike to trigger a fixed level discriminator.

The bias on the base of Q_3 must be set properly to achieve optimum performance. If the negative voltage at Q_3's base is too great, Q_2 will begin to conduct before TD_1 switches to the low state, resulting in a loss of sensitivity. If the bias voltage is too low, Q_3 will not shut off completely after TD_1 has switched to the low state. Therefore, I_2 will split between Q_2 and Q_3 dropping point B below the peak, and TD_1 will not retrigger at true zero unless I_2 is increased.

P_1 allows the sensitivity of TD_1 to be adjusted over a limited range ($\sim$3:1). Each setting of P_1 requires that P_2 be adjusted to bring the sum of I_1 and I_2 to be equal to the peak current. The effect of capacity at the TD_1 node can be partially compensated by making the sum of I_1 and I_2 slightly greater than the peak current.

An important characteristic of this circuit is that all inputs in the threshold region are timed accurately; therefore, no additional circuitry is required to eliminate pulses near threshold. Also, the circuit requires no internal delays that would limit the circuit to inputs of a particular waveshape. These features allow the circuit to work well on inputs of widely differing shapes; for instance, it can time fast or slow inputs without modification.

Notes:

1. This innovation would be useful in timing, synchronizing, and counting applications. It may be of interest to circuit designers and instrument manufacturers.
2. Additional details are contained in the *Rev. of Scientific Instruments,* Vol. 38, No. 10, pp. 1445-1449, October 1967.
3. Inquiries concerning this innovation may be directed to:

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