Simple Tunnel Diode Circuit for Accurate Zero Crossing Timing

**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 TD₁ is biased in the high state well below the peak current. After TD₁ 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
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 Q2 and Q3. Quiescently TD1 is biased in the high voltage state at point A, with bias current I1 determined by R1 and P1. This biases Q2 off and I2 flows through Q3. The positive portion of the input drives TD1 to the low voltage state, causing Q2 to turn on and Q3 to turn off. Now the current I2 also flows through the tunnel diode. If the sum of I2 and the initial bias current I1 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, TD1 re-triggers and turns Q3 on again. The zero crossing timing information is obtained by clipping the waveform at Q3's collector and using the negative spike to trigger a fixed level discriminator.

The bias on the base of Q3 must be set properly to achieve optimum performance. If the negative voltage at Q3's base is too great, Q2 will begin to conduct before TD1 switches to the low state, resulting in a loss of sensitivity. If the bias voltage is too low, Q3 will not shut off completely after TD1 has switched to the low state. Therefore, I2 will split between Q2 and Q3 dropping point B below the peak, and TD1 will not retrigger at true zero unless I2 is increased.

P1 allows the sensitivity of TD1 to be adjusted over a limited range (~3:1). Each setting of P1 requires that P2 be adjusted to bring the sum of I1 and I2 to be equal to the peak current. The effect of capacity at the TD1 node can be partially compensated by making the sum of I1 and I2 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.
3. Inquiries concerning this innovation may be directed to:
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   Reference: B69-10116
   Source: A. J. Metz
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**Patent status:**
Inquiries about obtaining rights for commercial use of this innovation may be made to:

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