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Tunnel Diode–Transistor Twisted Ring Counter

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A new tunnel diode–transistor twisted ring counter is described. Each stage of the counter consists of a tunnel diode controlling a long tailed pair which switches current into the following stage. Rectangular input pulses are "differentiated" by a shorted delay cable and the tunnel diodes are progressively switched to high voltage states by the positive pulses and then progressively reverse switched to low voltage states by the negative pulses. The scaling capacity of the counter for rectangular input pulses is $(2n-1)$ where n is the number of stages. A maximum scaling rate of 450 MHz was observed for a practical three stage quinary counter.

INTRODUCTION

WHEN a tunnel diode is biased as shown in Fig. 1 it can be switched from the low voltage state A to the high voltage state B by a positive current pulse and from B to A by a negative current pulse. With triggering pulses of limited amplitude it is possible by controlling I_b to allow the tunnel diode to switch only when it is biased close to the peak or close to the valley of the tunnel diode static characteristic. The bias current I_b can thus be employed as a gate control. These properties of the tunnel diode are exploited in a twisted ring counter which is an improvement on an earlier ring counter.[1] The positive and negative triggering pulses of the counter are obtained from rectangular input pulses by means of a shorted delay cable.

PRINCIPLE OF OPERATION

Figure 2 shows the circuit of a three stage counter. Each tunnel diode is biased by the constant current I_L and an additional current I_{on} depending on the state of the previous tunnel diode. The long tailed pair current switches S_1 and S_2 supply I_{on} to tunnel diodes TD2 and TD3 when the controlling tunnel diodes are in high voltage states. The current switch S_3 which is in antiphase with S_1 and S_2 supplies I_{on} to TD1 when TD3 is in a low voltage state. The antiphase arrangement of S_3 introduces the "twist" in the ring.

Initially all the tunnel diodes are arranged to be in low voltage states (e.g., by means of a manual reset). With reference to the notation in Fig. 3, TD1 is in a O_H state and TD2 and TD3 are in O_L states. If alternately positive and negative triggering pulses are applied to all the tunnel diodes and the amplitudes I_1 and I_2 are such that forward switching can only occur when the tunnel diode is in a O_H state and reverse switching when the tunnel diode is in a 1_L state, the tunnel diodes will be progressively switched by the first three positive pulses. The next three negative pulses will then progressively reverse switch the tunnel diodes to O_L states and return the counter to its initial condition. If each pair of positive and negative triggering pulses is obtained from a rectangular input pulse (say, by "differentiation" with a shorted delay cable),

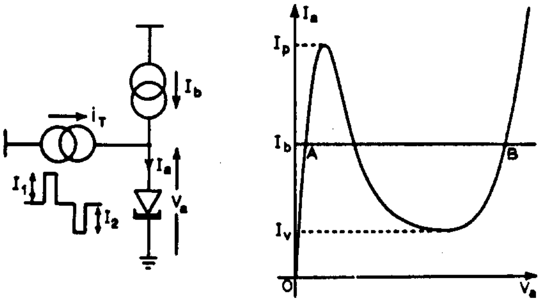

FIG. 1. Basic biasing arrangement.

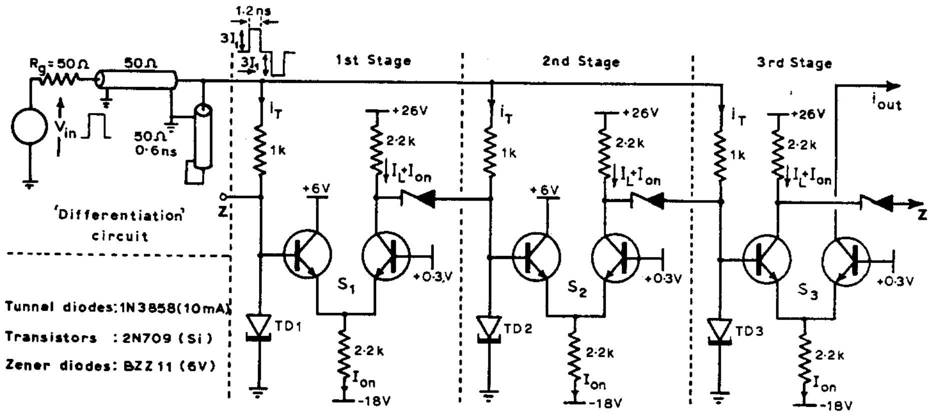

FIG. 2. Three stage twisted ring counter.

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[1] Z. C. Tan, Rev. Sci. Instrum. 38, 1415 (1967).

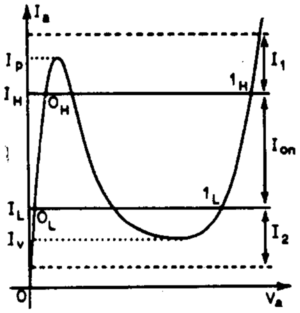

FIG. 3. Tunnel diode states.

the scaling capacity of the counter with an incorporated "differentiation" circuit is ($2n$-1) where n is the number of stages. Waveforms illustrating the operation of the counter are shown in Fig. 4.

In the operation of the counter, each tunnel diode has to be in a O_H state prior to forward switching by a positive pulse and in a 1_L state prior to reverse switching by a negative pulse. For this to be the case,

$$I_p - I_H < I_1 < I_p - I_L$$
$$I_L - I_v < I_2 < I_H - I_v.$$

The above conditions reduce to

$$I_p - I_H < I_1 < I_H - I_v$$

if $(I_p - I_H)$ is made equal to $(I_L - I_v)$ and if $I_1 = I_2$ (as is the case when a shorted delay cable is used to generate the positive and negative triggering pulses from rectangular input pulses). It should be pointed out that the triggering current is applied simultaneously to all the tunnel diodes, so that the driving source must be capable of supplying $3I_1$.

There is a restriction on the width of the triggering pulse. After having triggered a tunnel diode the triggering current must be removed before the next tunnel diode becomes "primed" by the gate current I_{on}. This restriction can be overcome by suitable choice of the length of the shorted delay cable employed in the "differentiation" of the input pulses.

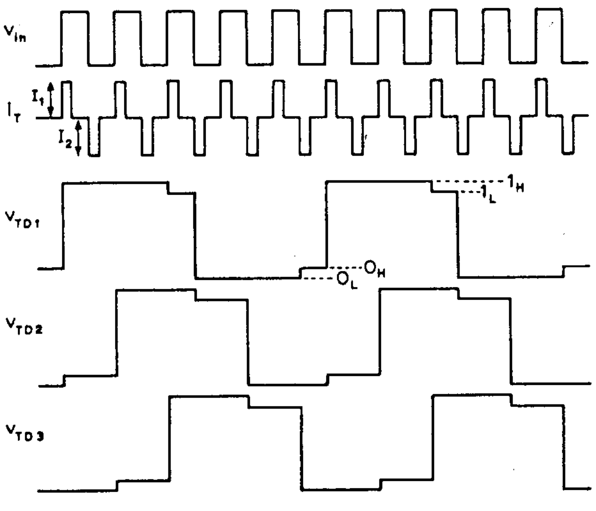

FIG. 4. Waveforms illustrating operation of counter.

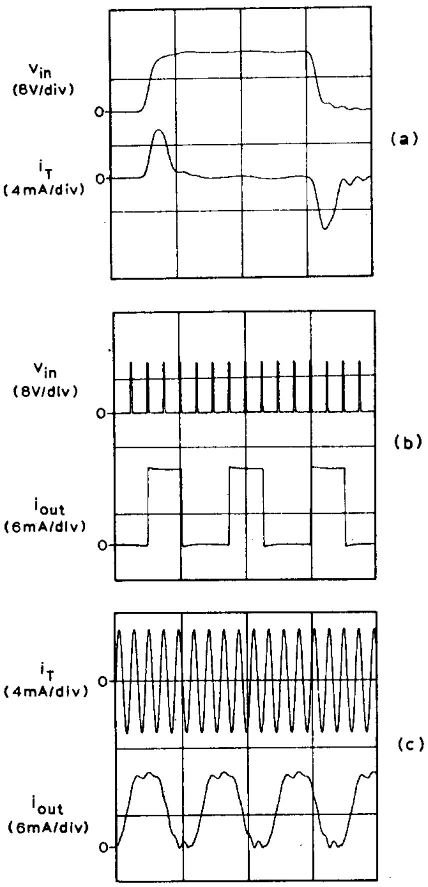

FIG. 5. Practical waveforms: (a) "Differentiation" of input pulse (4 nsec/div); (b) operation with 1 MHz rectangular pulses (4 μsec/div); and (c) operation with 450 MHz sinusoidal pulses (10 nsec/div).

PRACTICAL CIRCUIT

The counter is relatively simple to design. Having selected the tunnel diode, values can then be assigned to I_L and I_{on}. For maximum sensitivity to input pulses the "primed" states O_H and 1_L must be, respectively, as close as possible to the peak and valley of the tunnel diode. Ten milliampere tunnel diodes (RCA 1N3858) and n–p–n transistors[2] (2N709) were used in the practical test circuit. 1_H and 1_L were assumed to be approximately 0.5 mA below $I_{p\ \min}$ (9.5 mA) and 0.5 mA above $I_{v\ \max}$ (0.6 mA), respectively. The actual values of these currents are defined by the power supply levels and the standard value resistors used.

The amplitude of the triggering current I_1 must satisfy the condition stated earlier. In this case I_1 must be less than 8.4 mA ($I_{v\ \max} = 0.6$ mA) but greater than 1.5 mA

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[2] p–n–p transistors can be used instead. The collector of the other transistor in each long tailed pair would then have to be coupled to the following tunnel diode.

($I_{\mathrm{p\,max}}=10.5$ mA). Triggering currents of 3 mA amplitude were used in testing the counter.

Figure 5(b) shows waveforms of the counter scaling 1 MHz input pulses from a H-P215A pulse generator. Actual triggering pulses (after "differentiation") are shown in Fig. 5(a). To measure the maximum repetition rate of the counter, sinusoidal current pulses can be used directly to trigger the tunnel diodes (i.e., the "differentiation" circuit can be bypassed). A maximum repetition rate of 450 MHz[3] was observed and waveforms showing the counter operating at this triggering frequency are shown in Fig. 5(c).

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[3] It should be pointed out that integrated circuits capable of operating at this speed are now commercially available. Since the submission of this paper Motorola has introduced their MECL III circuits, in particular their MC 1070S flipflops which can scale up to 300 MHz and which may be "tweaked" to operate up to 500 MHz.

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Computerized Acoustic Spectrometer for Polymeric Solids at Low Temperatures

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A force, flexural resonance spectrometer at acoustic frequencies with an automatic data acquisition system is designed to measure the dynamic mechanical properties of polymeric solids from 10 to 500 K. The sample is clamped at its nodal points and driven by a voltage-controlled oscillator through an electromagnetic transducer. Two small iron tabs are glued to either ends of the sample to provide magnetic coupling. A similar transducer is used to receive the response of the sample. The bandwidth method is employed to determine the internal friction. An electronic circuit is devised to measure the frequency at the maximum amplitude and those at the half-power points of the amplitude-frequency curve. These readings, as well as the voltage output from the thermocouple, are digitally recorded on a paper-tape punch. Data are then transferred onto cards and processed on a computer. Results are displayed in analog form via a CalComp plotter. Measurements for polyethyl methacrylate, polyethylene, and paraffin wax are reported.

INTRODUCTION

ALTHOUGH there has been considerable interest during the past decade in the investigation of dynamic mechanical properties of polymeric solids at low temperatures,[1,2] most of these works did not cover the temperature region below 77 K. Several authors have studied a number of polymers from 4 K upwards by torsion pendulum[3,4] and by forced resonance techniques.[5,6] Both free-decay[5,6] and bandwidth[5] methods have been employed in the latter. All of these, however, require considerable attention of the operator during the experiment and tedious calculations in subsequent data reduction. In this paper we wish to describe a forced flexural resonance spectrometer in the acoustic frequency range with an automatic data acquisition system. Data thus obtained can be directly fed to an electronic computer, which performs the programmed calculations and displays the results in both digital and analog forms.

DESCRIPTION OF THE SYSTEM

The polymeric sample, in the form of a bar with square cross section, is driven at its fundamental flexural mode of vibration by a low amplitude alternating stress. The applied frequency is varied through the resonant frequency of the sample to yield an amplitude-frequency curve. Internal friction is then calculated by[7]

$$Q^{-1}=\Delta f/f_0, \tag{1}$$

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[1] A. E. Woodward and J. A. Sauer, in *Physics and Chemistry of the Organic Solid State,* D. Fox, M. M. Labes, and A. Weissberger, Eds. (Interscience Publishers, Inc., New York, 1965).

[2] N. G. McCrum, B. E. Read, and G. Williams, *Anelastic and Dielectric Effects in Polymeric Solids* (John Wiley & Sons, Inc., New York, 1967).

[3] K. M. Sinnott, J. Polymer Sci. **35**, 273 (1959).

[4] C. D. Armeniades, I. Kuriyama, J. M. Roe, and E. Baer, J. Macromol. Sci. (Phys.) **B1**, 777 (1967).

[5] J. M. Crissman and R. D. McCammon, J. Acoust. Soc. Amer. **34**, 1703 (1962).

[6] M. Shen, J. D. Strong, and H. Schlein, J. Macromol. Sci. (Chem.) (in press).

[7] C. Zener, *Elasticity and Anelasticity of Metals* (University of Chicago Press, Chicago, 1948).