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Improved Bias Supply for Tunnel-Diode Picosecond Pulse Generators

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***Abstract*—An improved bias supply for tunnel-diode (TD) picosecond-pulse generators is described. The supply is stable with temperature and, in a commercial 35-ps (nominal) risetime tunnel-diode pulse generator/sampling oscilloscope system, has produced a 4:1 reduction in time-base jitter and 2:1 reduction in time-base drift. Also described is a tunnel-diode pulse generator, which, when used with the bias supply, produces a stable pulse having a flat-top sag of no more than 2 percent in 1 μs.**

Introduction

In tunnel-diode pulse generator/sampling oscilloscope systems, display jitter and drift introduce uncertainties that are particularly troublesome for picosecond measurements. In a nominal 35-ps (10–90 percent) risetime pulse generator/oscilloscope system (Fig. 1), it is not unusual to encounter 10–20 ps of time-base jitter and a time-base drift of the order of 12 ps in a 1-minute interval. A significant portion of the jitter and drift originates in the tunnel-diode bias supply as a result of noise and long-term thermal variations in the biasing current.

This paper describes a temperature-stable tunnel-diode bias supply, which, when used with a commercial 35-ps (nominal) risetime tunnel-diode pulse generator/sampling oscilloscope system, produced a 4:1 reduction in time-base jitter and a 2:1 reduction in time-base drift. The supply was designed as a replacement for a commercial bias supply used to bias a 20-ps (nominal) risetime tunnel-diode pulse generator. The bias supply features include

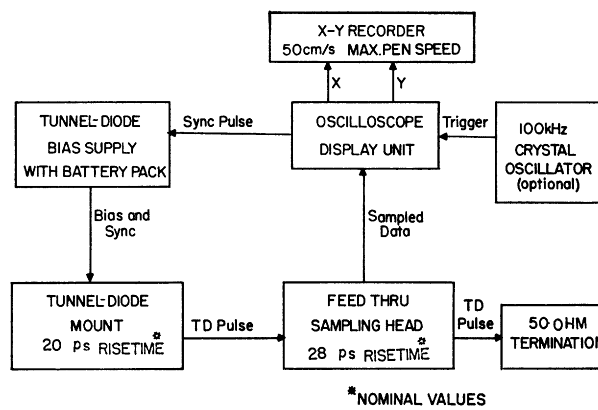

Fig. 1. Tunnel-diode pulse generator/sampling oscilloscope system.

1) bias voltage continuously adjustable from 0 to 500 mV and 2) an external trigger input to couple positive or negative trigger pulses onto the bias line.

Circuit Description

The tunnel-diode bias supply consists of two major sections, namely, the TD bias-control circuit (Fig. 2) and the series regulators (Fig. 3).

The bias-control circuit consists of a differential amplifier ($Q1$, $Q2$, $Q3$) and a Darlington pair ($Q4$, $Q5$) operated as an emitter–follower. The emitter–follower provides the low source impedance bias voltage for the tunnel diode. To maintain close control over this bias voltage, it is compared by the differential amplifier ($Q1$, $Q2$, $Q3$) to the voltage set by the bias-level control $R3$. The resultant error signal present at the collector of $Q3$ is coupled back to the emitter–follower ($Q4$, $Q5$) base to correct the bias

Manuscript received April 9, 1970.
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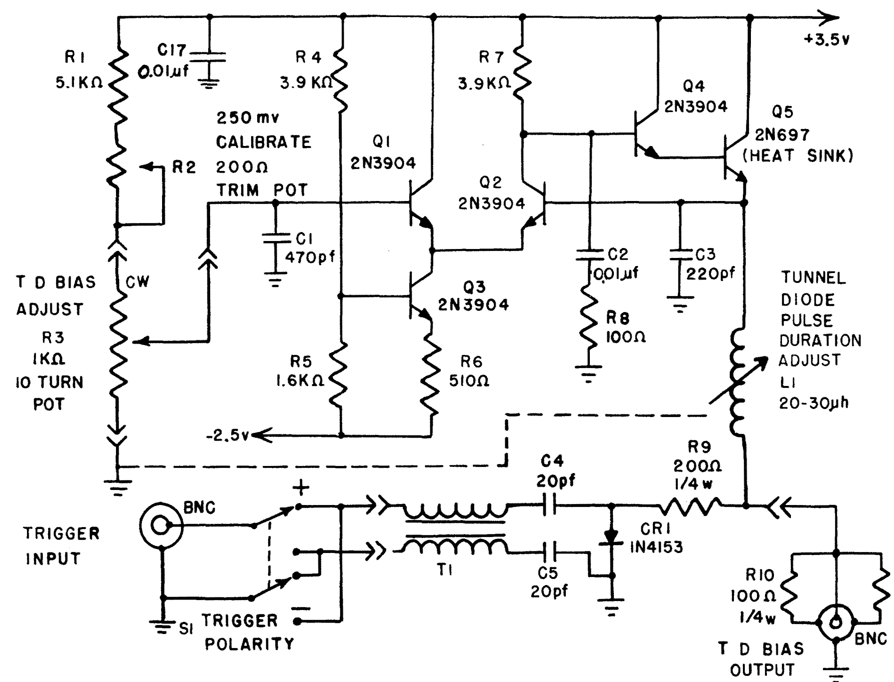


Fig. 2. Tunnel-diode bias control and trigger circuit. $T1$ balun transformer consists of 8 turns of twisted pair no. 24 nyclad wire, 4 twists/inch, wound on a ferrite toroid. Toroid is of $Q2$ material, 0.375 inch OD, 0.187 inch ID and 0.125-inch thick.

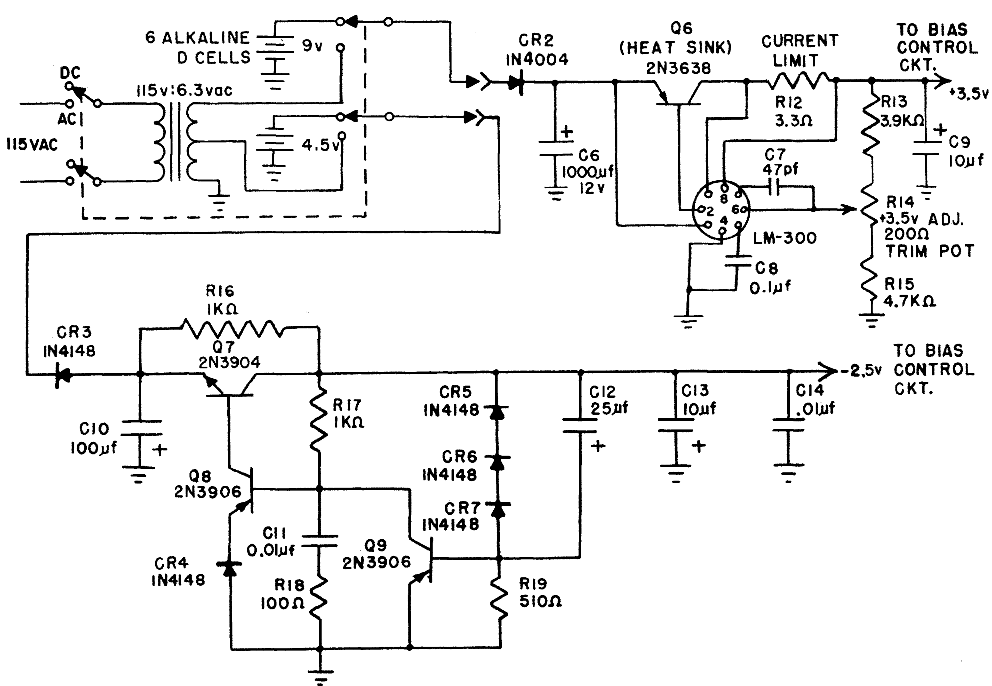


Fig. 3. Tunnel-diode bias-supply voltage regulators.

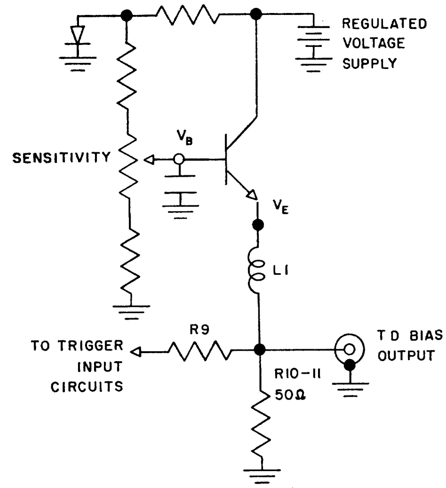


Fig. 4. Emitter-follower circuit used in commercial tunnel-diode bias supply. $L1$, $R9$, $R10$ and $R11$ are the same as those used in Fig. 2.

voltage. The use of the differential amplifier greatly improves the thermal stability of the bias voltage as compared to the simple emitter–follower (Fig. 4) used in the commercial bias supply. The bias voltage from the emitter–follower circuit is sensitive to temperature changes due to the variations in the base–emitter voltage with temperature. A matched transistor pair for $Q1$ and $Q2$ would be an additional improvement. Table I compares the thermal stability of the two bias supplies.

The trigger circuit is a commercial design that will accept either positive or negative trigger pulses (Fig. 2). The trigger polarity switch $S1$ and the balun transformer $T1$ provide for trigger inversion if necessary. The trigger pulse is differentiated by capacitors $C4$ and $C5$. Diode $CR1$ and resistor $R9$ limit the level of the trigger signal applied to the tunnel diode. Resistors $R10$ and $R11$ form a 50-ohm termination to prevent the reflection of tunnel-diode pulses back down the coaxial cable connecting the bias supply and the tunnel diode.

Series regulators (Fig. 3) are used to supply the +3.5 volts and −2.5 volts required by the control circuit. The +3.5-volt supply uses an LM300 integrated-circuit linear voltage regulator. The input to the LM300 is a sample of the output voltage as determined by the setting of $R14$. The output of the LM300 then drives the series regulator transistor $Q6$. The −2.5-volt supply is a different type of series regulator circuit. The output voltage is first dropped through silicon diodes $CR5$, 6, and 7, and then is compared to the base–emitter drop in $Q9$. The error signal is sensed by $Q9$ and amplified by $Q8$, which drives the series regulator $Q7$.

Performance

Several precautions are necessary to minimize display jitter and horizontal drift. Imperfect filtering by the bias supply and/or ground loops introduce 60-Hz signals on the tunnel-diode bias voltage. For repetitive sweep operation or when using an X–Y recorder, this 60-Hz signal is a major source of jitter. To avoid the 60-Hz problem a battery pack is used as the source of primary power for the TD bias supply. The bias supply includes an ac power option for noncritical applications. The use of a 100-kHz crystal oscillator as a clock (Fig. 1) instead of allowing the oscilloscope time base to free-run, gives a slight decrease in jitter. It is also necessary to allow the equipment to warm up thoroughly and stabilize before taking data.

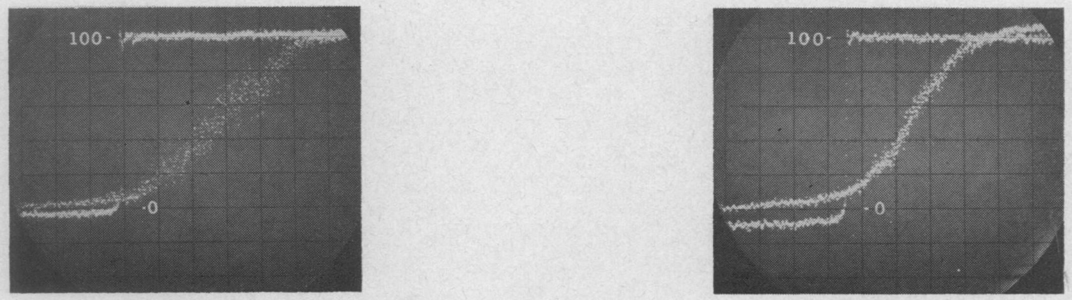
TABLE I
Thermal Stability Comparison of Bias Supplies

Oven Temperature (°F)	Bias Voltage Commercial Supply (mV)	Bias Voltage Improved Supply (mV)
74	250.3	250.8
100	265.5	250.4
130	280.5	248.0

Fig. 5 shows the reduction in display jitter for a single-sweep photograph when using the improved supply as compared to the commercial bias supply. Time-position jitter of ~15 ps was observed when using the commercial supply. With the improved supply ~4 ps of jitter was observed. Of the 4 ps, a sizable portion can be attributed to random vertical amplitude noise.

Time-position drift is most objectionable when using an X–Y recorder to record data from the sampling oscilloscope. Fig. 6 shows the resolution that can be achieved using an X–Y recorder and manually scanning the trace in 5 seconds. A measure of the accuracy of a waveform recorded on an X–Y recorder is to determine the repeatability of the waveform. This is accomplished by recording several traces superimposed upon each other. When this is done the time-position drift becomes quite apparent. Fig. 7 compares the drift of the two supplies. The commercial supply has a time-position drift of ≈6 ps in a 30-second interval. The improved supply showed a drift of ≈3.6 ps in a 30-second interval.

Although the bias supply was designed to be compatible



(a) (b)

Fig. 5. Time-position jitter in the 35-ps (nominal) risetime tunnel-diode pulse generator/sampling oscilloscope system. (a) Commercial tunnel-diode bias supply. (b) Improved bias supply. Vertical scale adjusted so that 0–100 percent = 5 divisions. Horizontal scales are 1 ns/div. for the pulse and 10 ps/div. for the leading edge. Single-sweep photographs.

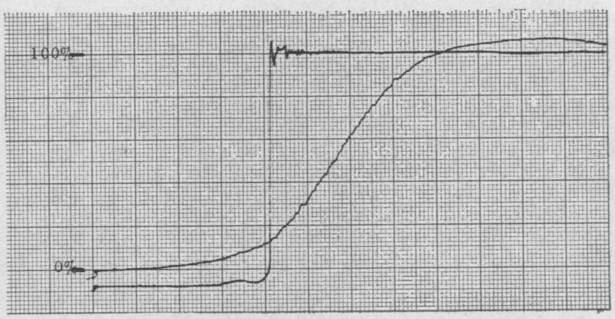
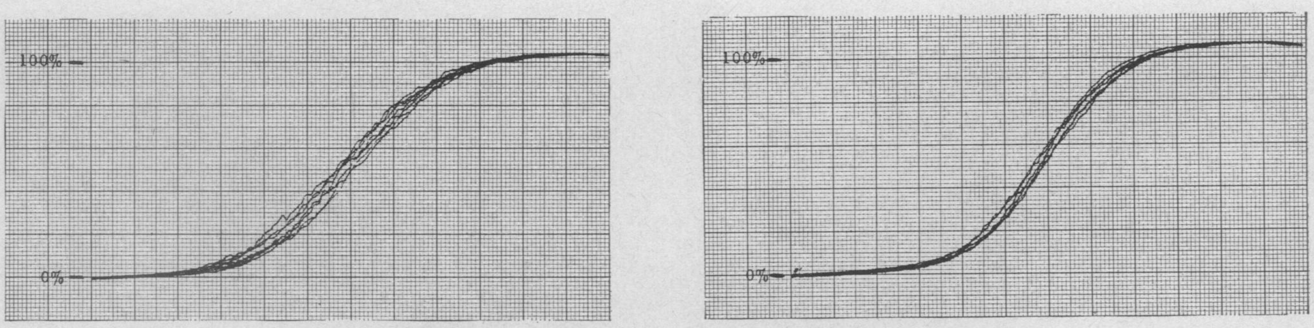


Fig. 6. *X–Y* recorder plot of the same pulse shown in Fig. 5 using the improved bias supply recorded using manual scan sweep of $\sim$ 5 seconds. Vertical scale adjusted so that 0–100 percent = 5 divisions. Horizontal scales are 1 ns/div. for the pulse and 10 ps/div. for the leading edge.



(a) (b)

Fig. 7. Time-position drift comparison. *X–Y* recorder plots of the same pulses as shown in Fig. 5. Recorded for a 30-second interval using continuous manual scan sweeps of $\sim$ 5 seconds. Vertical scale adjusted so that 0–100 percent = 5 divisions. Horizontal scale is 10 ps/div. (a) Obtained using commercial bias supply while (b) is obtained using improved bias supply.

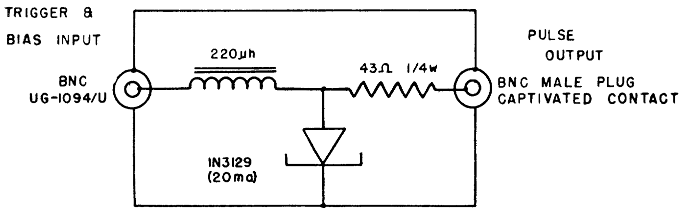


Fig. 8. Tunnel-diode pulse generator. The 43-ohm resistor is physically mounted within the output BNC connector. The pill-package tunnel diode is soldered directly to the cable-clamping nut of the output connector. The 220-μH choke is mounted as close as possible to the tunnel diode.

TABLE II
TUNNEL-DIODE PULSE-GENERATOR PERFORMANCE

Voltage output	+225 mV pulse into 50 ohms
Generator impedance	~50 ohms
Risetime	325 ps
Maximum overshoot and ringing	< ±1 percent
Pulse sag	<2 percent in first microsecond
Pulse duration	13 μs
Maximum repetition rate	12.5 kHz
Bias voltage required	250 mV

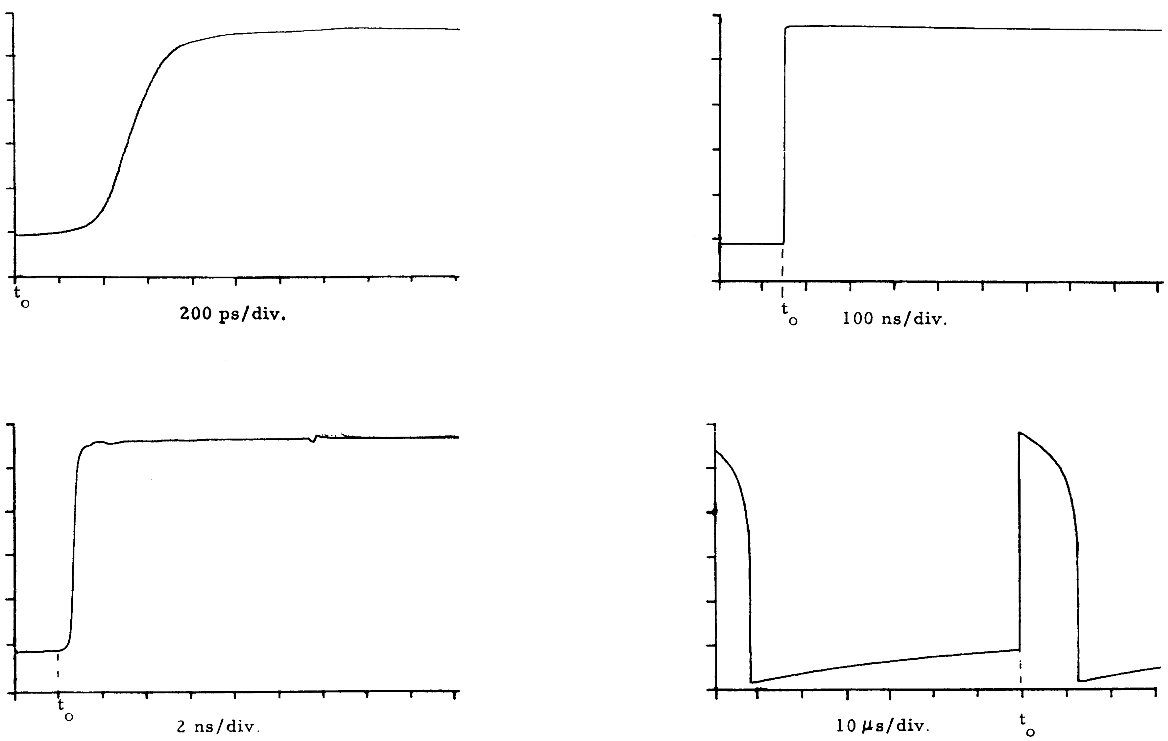


Fig. 9. IN3129 tunnel-diode pulse-generator output into 50-ohm 50-ps (nominal) risetime sampling oscilloscope. Vertical scale, 50 mV/div.

with a commercial 20-ps (nominal) risetime tunnel-diode generator, it may also be used with other generators such as the one shown in Fig. 8, which produces relatively flat topped pulses.

In some pulse measurements such as TDR measurements of small resistive discontinuities, it is more desirable to have a very flat pulse top than to have a fast risetime. The pulse generator shown in Fig. 8 is an inexpensive source of pulses having a relatively flat pulse top for the first microsecond and a nominal 325-ps risetime. Fig. 9 shows the pulse produced by the tunnel-diode generator. Several time scales are used to show the flatness of the pulse. The maximum overshoot and ringing amount to less than ±1 percent. It has a pulse sag of less than 2 percent for the first microsecond. Table II lists the performance specifications.