Scope Sweep Generator

By ROBERT G. TEETER / RF Communications, Inc.

Construction details on an inexpensive time-mark generator for calibrating the horizontal sweep of an oscilloscope.

MEASURING time or frequency accurately with an oscilloscope is impossible if the scope's horizontal sweep (trace) is uncalibrated. The horizontal sweep can be calibrated by a time-mark generator. Although a professional time-mark generator costs about $300, the simple time-mark generator covered in this article can be built for substantially less than this amount.

This time-mark generator has outputs at known frequencies and when the frequency is accurately known, the period in microseconds along the scope trace can be calculated. Table 1 indicates the relationship between frequency and time for this generator.

A scope's horizontal sweep can be calibrated in one of three ways. The first and most useful is in microseconds-per-centimeter. Other, less-common markings, are microseconds-per-inch, or frequency, which is uncalibrated. With a known frequency signal any scope's horizontal sweep can be calibrated with great accuracy by merely adjusting the variable sweep speed until a known number of timing intervals occupies a specific distance on the screen. Any scope sweep non-linearity will also be displayed.

In this time-mark calibrator, thirteen transistors are used to provide accurate calibration points of 1, 5, 10, 100, 1000, and 10,000 microseconds duration.

As shown in Fig. 1, a 1-MHz crystal oscillator (*Q*1) furnishes an accurate 1-microsecond timing output *via* *Q*2 to point "A". A one-shot multivibrator (*Q*3-*Q*4), adjusted for a division of five, furnishes an accurate 5-μsec output at point "B". Division-by-two is accomplished in flip-flop *Q*5-*Q*6 to produce a 10-μsec output at point "C". Division-by-ten can now be accomplished with unijunction transistor stage *Q*7 to produce a 100-μsec output at point "D". Two more divide-by-ten circuits, *Q*8 and *Q*9, have outputs of 1000 μsecs at point "E" and 10,000 μsecs at point "F", respectively.

Accuracy is inherent in this design. The crystal provides the primary accuracy and any error is too small to be observed on a scope. All of the other outputs are obtained by division from this stable source. A word of caution—division in the last three stages will be correct only if the loading of the unijunction emitters remains constant. For this reason, an emitter follower, *Q*12 and *Q*13, has been added.

Table 1. The relationship between frequency and time for the various output waveforms of the simple scope sweep calibrator.

TEST POINT	FREQUENCY	TIME
"A"	1 MHz	1 μsec
"B"	200 kHz	5 μsecs
"C"	100 kHz	10 μsecs
"D"	10 kHz	100 μsecs
"E"	1 kHz	1000 μsecs
"F"	100 Hz	10,000 μsecs

If your scope does not have a 10-megohm vertical amplifier input impedance, then the emitter follower should be used as part of the testing procedure. The emitter follower is a Darlington configuration with a calculated input impedance of about 14 megohms. It exhibits no measurable loading to any of the circuits.

Parts required to build this generator are standard but a high-*beta*, high-f_t transistor should be used for the higher frequency circuits. Placement of the parts is not critical although short leads should be used.

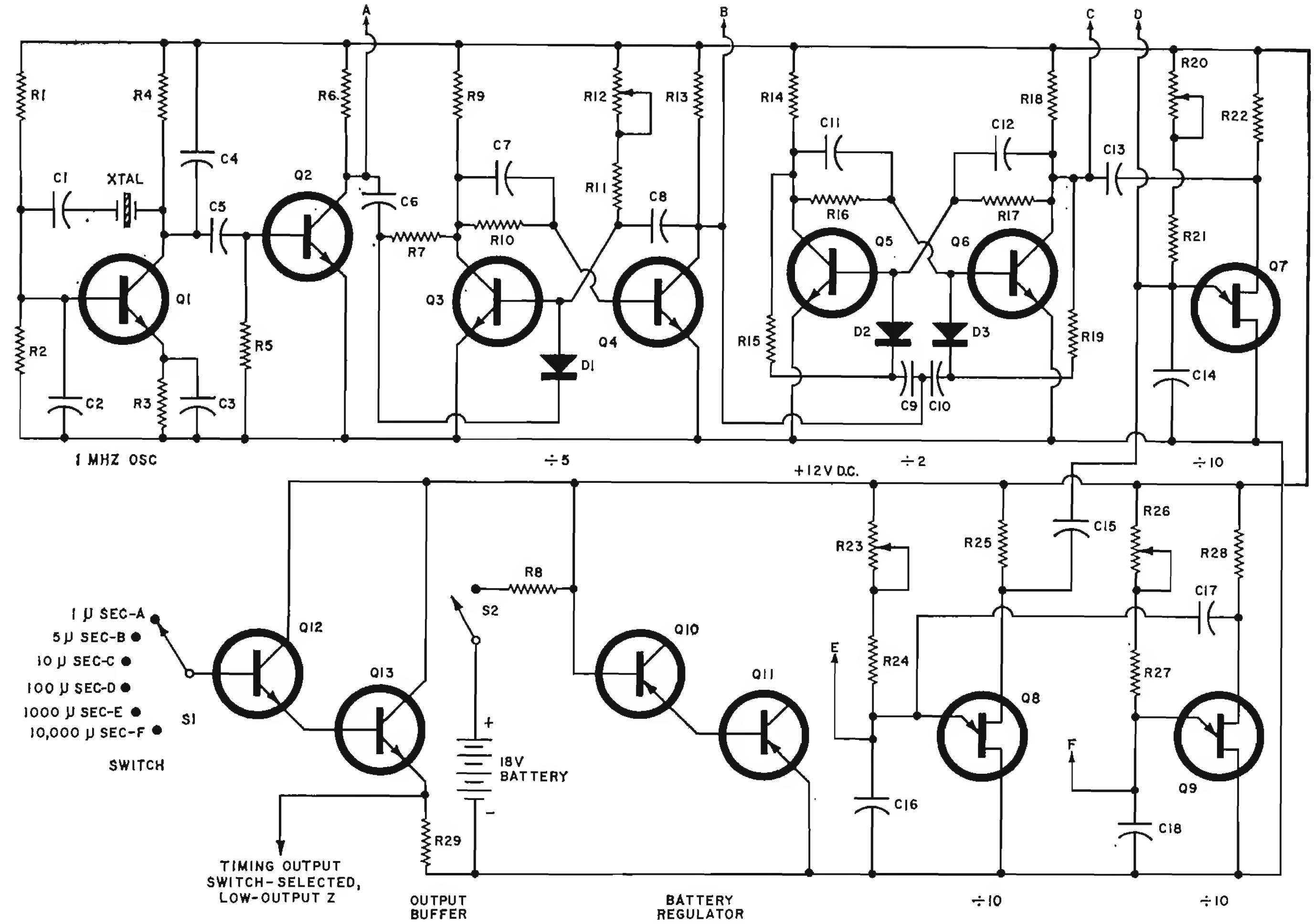
The addition of regulator *R*8 and *Q*10 and *Q*11 will result in greater stability. The emitter-base junctions of the 2N3638's are used as a low-cost zener diode. If a regulated supply or a mercury battery is used, the regulator would not be required, and could be omitted.

Waveforms

When power is applied, the waveform of Fig. 2A will be present at the collector of *Q*1. The purpose of buffer *Q*2 is to provide a sharp falling edge for triggering the following divide-by-five counter. The waveform of Fig. 2B will be present at the collector of *Q*2 and point "A". The trailing edges of this waveform are 1 μsec apart. Transistors *Q*3 and *Q*4 make up a one-shot, divide-by-five circuit. *Q*3 is normally "on" ("on" is defined as the transistor in conduction while "off" is when it is not). A negative pulse coupled through *C*6 and *D*1 turns *Q*3 "off" causing *Q*4 to go "on". Since the voltage across capacitor *C*8 cannot change instantaneously, the base of *Q*3 is forced approximately 10 volts below the emitter. Capacitor *C*8 is charged by *R*11 and *R*12 in series and, when approximately +0.6 volt is reached, *Q*3 turns "on" removing the base drive from *Q*4. Control *R*12 is adjusted so that the time required for this complete cycle is five pulses of the input. Fig. 2C shows the collector waveform of *Q*4 at point "B", while Fig. 2D shows the waveform at the base of *Q*3. The waveform at the collector of *Q*4 is 5 μsec per cycle.

Division-by-two is most easily accomplished with a flip-flop. Transistors *Q*5 and *Q*6 make a simple flip-flop, with *D*2 and *D*3, the triggering diodes. Since *R*16 and *R*17 form direct paths from opposite collectors to opposite bases, the flip-flop will remain stable until a change is triggered by the falling edge of the *Q*4 output waveform. The waveforms of this flip-flop will be affected by subsequent loading, so *C*13 and *R*22 should be connected before testing. Fig. 2E shows the waveform present at the *Q*6 collector and point "C". This waveform is 10 μsec per cycle, or 100 kHz.

Division-by-ten can be accomplished at lower frequencies using a unijunction transistor. Capacitor *C*13 couples the pulses from *Q*6 into base-2 of *Q*7. The combination of *C*14 and *R*20 and *R*21 form a time constant equivalent to a fre-



R1—27,000 ohm, ½ W res.
R2, R6, R13, R14, R18—10,000 ohm, ½ W res.
R3, R4—2200 ohm, ½ W res.
R5—100,000 ohm, ½ W res.
R7—15,000 ohm, ½ W res.
R8—100 ohm, ½ W res.
R9, R29—4700 ohm, ½ W res.
R10—39,000 ohm, ½ W res.
R11, R21, R24, R27—47,000 ohm, ½ W res.
R12, R20, R23, R26—100,000 ohm pot
R15, R16, R17, R19—22,000 ohm, ½ W res.
R22, R25, R28—470 ohm, ½ W res.
C1—220 pF capacitor
C2—82 pF capacitor
C3, C18—0.1 µF capacitor
C4, C6, C9, C10, C11, C12—100 pF capacitor
C5, C13, C14, C15, C17—1000 pF capacitor
C7—330 pF capacitor
C8—33 pF capacitor
C16—0.01 µF capacitor
S1—S.p.6-pos. rotary switch
S2—S.p.s.t. switch
Xtal—1 MHz crystal
D1, D2, D3—1N277 diode
Q1, Q2, Q3, Q4, Q5, Q6, Q12, Q13—2N3394 transistor
Q7, Q8, Q9—2N2646 transistor
Q10, Q11—2N3638 transistor

Fig. 1. Schematic and parts list for scope sweep calibrator. Regulator transistors Q10 and Q11 can be omitted if a regulated power supply or mercury battery is used. Each lettered output is connected to the appropriate terminal of switch S1.

quency of 10 kHz. Both C15 and R25 should be connected since they present a load to Q7. Potentiometer R20 is adjusted until 10 pulses at the Q6 collector result in one sawtooth at the emitter of Q7, as shown in Fig. 2F. This sawtooth is 100 µsec per cycle or 10 kHz.

Division-by-ten is accomplished twice more in exactly the same way by unijunction oscillators Q8 and Q9. Outputs are 1000 µsecs per cycle (1 kHz) and 10,000 µsecs per cycle (100 Hz), respectively. The waveform is identical to Fig. 2F except the µsec/cm scale becomes 100 and 1000 respectively. Fig. 2G shows the waveform at base-2 of each unijunction transistor.

How to Use

The generator output is connected to the scope vertical input and the scope is set to trigger on negative peaks. If the scope has provisions for external triggering, then the generator output can also be connected (in parallel) to this terminal and the sweep set for negative triggering.

The scope graticule should be calibrated in centimeters along the horizontal axis (one centimeter equals 0.3937 inch).

Assume that it is desired to calibrate the scope to 1 µsec/cm. Set the generator S1 to position "A", and adjust the scope sweep until one complete waveform (Fig. 2B) occupies one centimeter division. This distance, and all equivalent marked distances along the sweep, are now calibrated at 1 µsec per centimeter. The same centimeter divisions can be used to set the sweep to any desired value as selected by S1, and the corresponding waveforms of Fig. 2. ▲

Fig. 2. Waveforms present in the generator. See text for explanation.