BUILD THIS

TRIGGERED OSCILLOSCOPE

This easy-to-follow design lets you keep cost low by using a CRT of your choice. Its operational feature is a continuous zero baseline.

DANIEL METZGER and DENNIS PERRY

ONCE A TECHNICIAN HAS EXPERIENCED troubleshooting with a calibrated DC lab scope, he'll probably want to keep that scope probe close at hand most of the time he's at the service bench. Transistor base-emitter voltages, collector saturation voltages, and IC logic levels can be checked as easily as power-supply lines while the operating signals are present. No other instrument provides that simultaneous readout of bias and signal conditions.

Two factors have conspired to keep that scope probe out of the hands of most experimenters. The first is cost, which approaches \$200—even for a kit. That problem is easily solved by simplified design. The scope described here can be built from standard parts for \$100, and considerably less if the junk box is well stocked. Yet it boasts a 2-MHz bandwidth and 10 mV-per-division vertical sensitivity.

The second factor is the annoyingly frequent need to lay down the probe, reach over to the scope, throw the input switch from DC to GROUND, check the position of the zero-volt baseline, and throw the switch back to DC. That problem is handled by incorporating a circuit that provides a continuous display of the DC ground level at a brightness level lower than that of the signal display.

How it works

The operation of the scope as a whole is best understood from the block diagram, Fig. 1. The vertical attenuator and amplifier provide a replica of the input signal, both AC and DC, at the approximately 100-volt level needed at the deflection plates of the CRT. The electronic baseline switch interrupts the signal and grounds the amplifier input for approximately 3 ms each 15 ms, thus providing a 1/5 duty-cycle baseline display at a rate of about 60 Hz—too fast for the eye to perceive the flicker.

A separate trigger amplifier is fed from a point ahead of the electronic baseline switch to preserve continuity of sweep triggering. A Schmitt trigger produces squarewaves in sync with the input signal, and a differentiator produces sharp spikes from the edges of the squarewaves. The negative spikes initiate a linear ramp that always starts at the same selected point on the input AC wave-

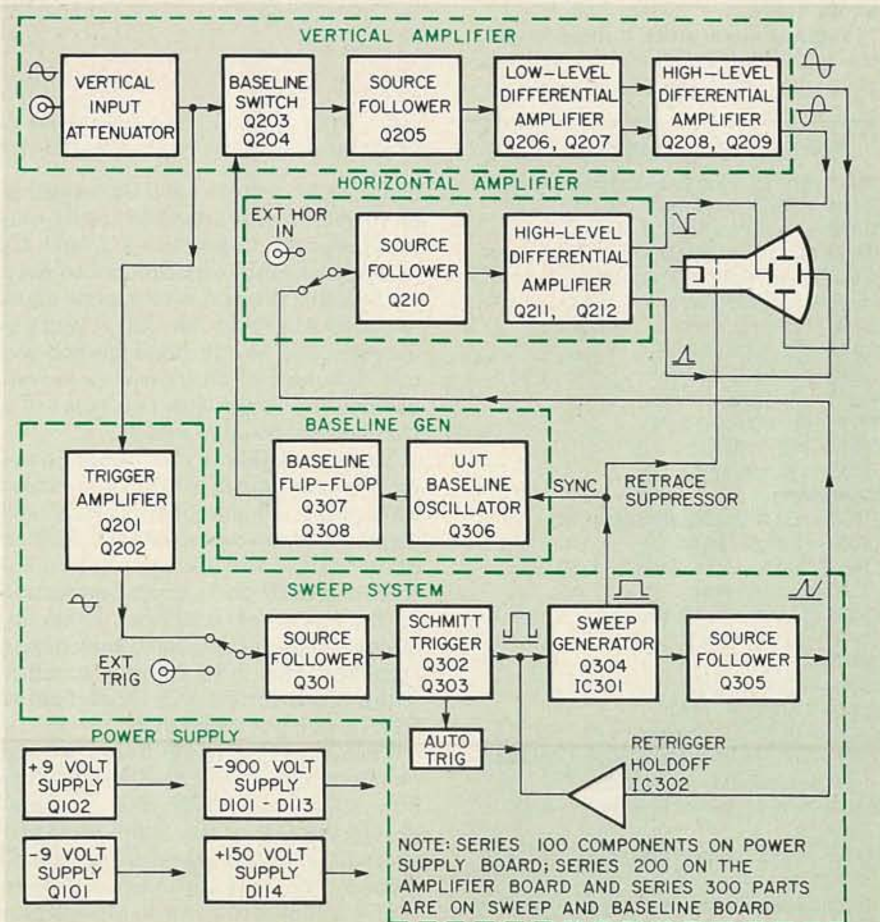


FIG. 1—BLOCK DIAGRAM of the zero-baseline scope. Operation is somewhat similar to a dual-trace scope with the baseline considered as the second trace.

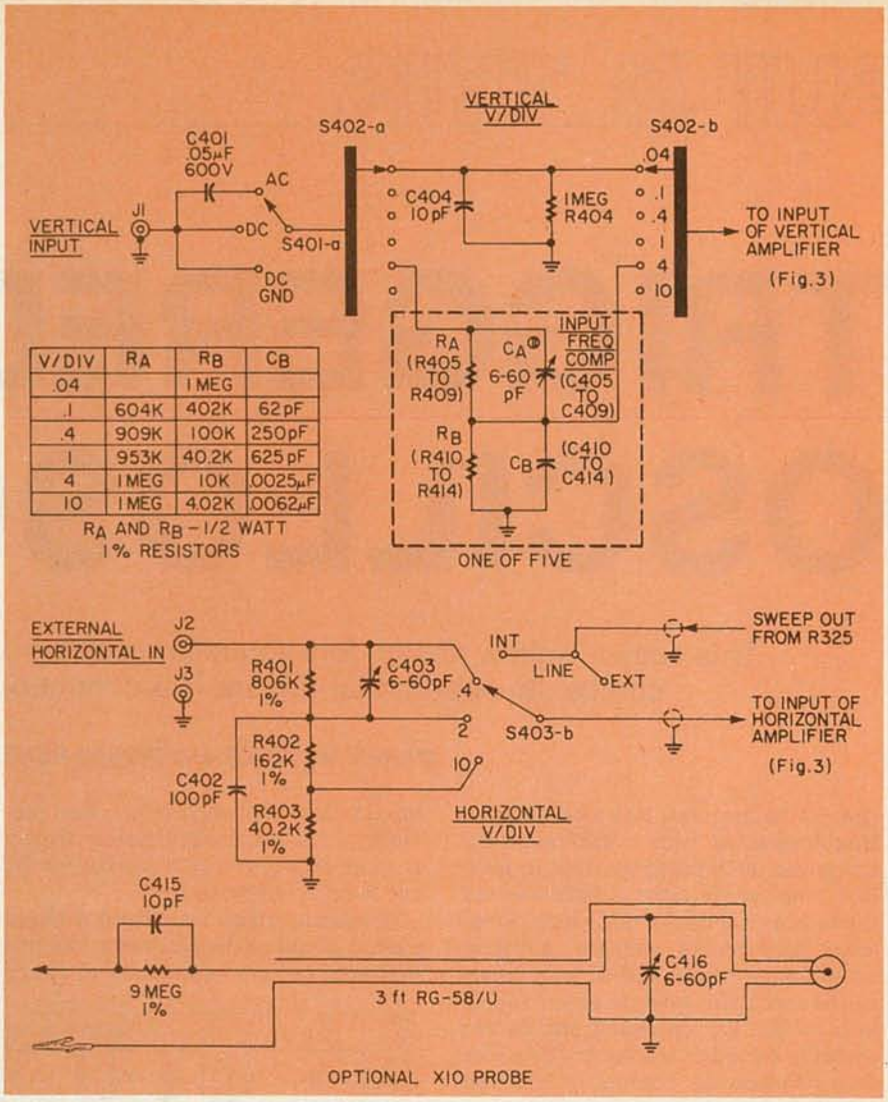
form. That ramp is applied to the horizontal amplifier to produce the calibrated time sweep. A source-follower provides a low output impedance for the ramp, and an op-amp comparator holds off further triggering signals until the ramp voltage returns to zero.

An auto-trigger circuit senses when the Schmitt trigger is not switching and immediately applies a voltage to the ramp genrator commanding continuous ramps, thus providing sweeps for the display of DC voltages.

A UJT baseline oscillator running at approximately 60 Hz is synchronized to the sweep generator to insure that the switching from signal to baseline will always occur during a retrace of the sweep. The baseline flip-flop drives the baseline-switching FET's at the input of the vertical amplifier.

The CRT cathode is operated at −900 volts to accelerate the electron beam toward the CRT face. Deflection sensitivity and hence calibration depend upon that voltage, so it is regulated by a string of 180-volt Zener diodes. Vertical and horizontal position and sweep time depend upon the 9-volt supplies, so they are transistor-regulated. The +150-volt supply serves only differential amplifiers, and their inherent common-mode rejection makes regulation of that supply unnecessary. We shall now proceed to a detailed description of each functional block.

Vertical attenuator: Voltage dividers R_A and R_B (Fig. 2) reduce the input signal to a maximum of 0.32 volt (8 divisions at 0.04 volt-per-division) or a minimum of 0.01 volt (1 division at 0.01 volt-per-division). Capacitors C_A and C_B swamp out stray capacitances to keep the reactive division ratio exactly equal to the resistive division ratio at high frequencies. A 1—4—10 step-sequence permits coverage of the 10-mV to 10-volt-per-division range with two poles of a standard six-position switch.



V/DIV	RA	RB	CB
.04		1MEG	
.1	604K	402K	62pF
.4	909K	100K	250pF
1	953K	40.2K	625pF
4	1MEG	10K	.0025μF
10	1MEG	4.02K	.0062μF

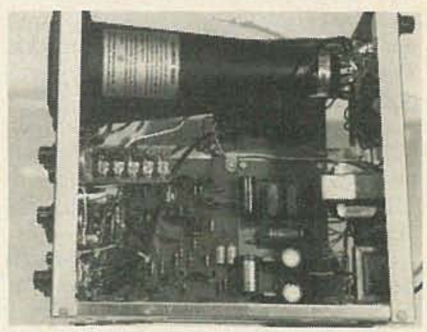
FIG. 2.—THE ATTENUATORS. Components for the vertical attenuator are mounted on a special circuit board. Also shown in the diagram of the optional multiplier probe.

PARTS LIST (Attenuators, Fig. 2)

Resistors 1% tolerance or better, ½ watt
R401—806,000 ohms
R402—162,000 ohms
R403, R412—40,200 ohms
R404, R408, R409—1 megohm
R405—604,000 ohms
R406—909,000 ohms
R407—953,000 ohms
R410—402,000 ohms
R411—100,000 ohms
R413—10,000 ohms
R414—4,020 ohms
R415*—9 megohms
Capacitors
C401—.05 μF, 600 volts, ceramic
C402—100 pF, Mylar
C403, C405—C414, C416*—6-60 pF ceramic trimmer
C404, C415*—10 pF, ceramic
C410—62 pF, mica
C411—250 pF, mica
C412—620 pF, mica
C413—.0022 μF, Mylar
C414—.0062 μF, Mylar
S401—miniature double-pole 3-position toggle switch (Alco MST205T)
S402—3-pole, 6-position rotary wafer switch
R403—2-pole, 6-position rotary wafer switch
Miscellaneous: printed circuit board
*Note: Components required for optional ×10 probe

Vertical amplifier: The overall gain of the vertical amplifier (Fig. 3) is about 2000 in the full-gain (÷4) position, and about 500 in the calibrated (×1) position of the vertical variable control. Resistor R201 and D201 provide input protection in the event of accidental overload. Source-follower Q201 and common-base amplifier Q202 form a trigger amplifier with a non-inverting AC gain of about 40 and a high input impedance.

Transistors Q203 and Q204 are switched on alternately by the zero-baseline flip-flop (Q307 and Q308, Fig. 4), connecting the base of source-follower Q205 alternately to the signal input and to ground. The stray capacitance of these FET's amounts to about 10 pF, and produces switching transients of about 10 μS duration on the 1-megohm input line.



TOP VIEW of the scope. The amplifier board is beneath the CRT. The power-supply board is at the rear near the transformers mounted on the back panel. The sweep board is up front near the controls. The attenuator board, with its five trimmers, is on a bracket held by the vertical-sensitivity control. Astigmatism control is on rear panel near base of the CRT.

The switching frequency must therefore be held below a few hundred hertz to prevent those transients from being frequent enough to be seen on the CRT display.

Transistors Q206 and Q207 are wired as a variable-gain differential amplifier. Potentiometer R213 is the 10-mV calibrator and sets the gain to four times the indicated vertical sensitivity with R214

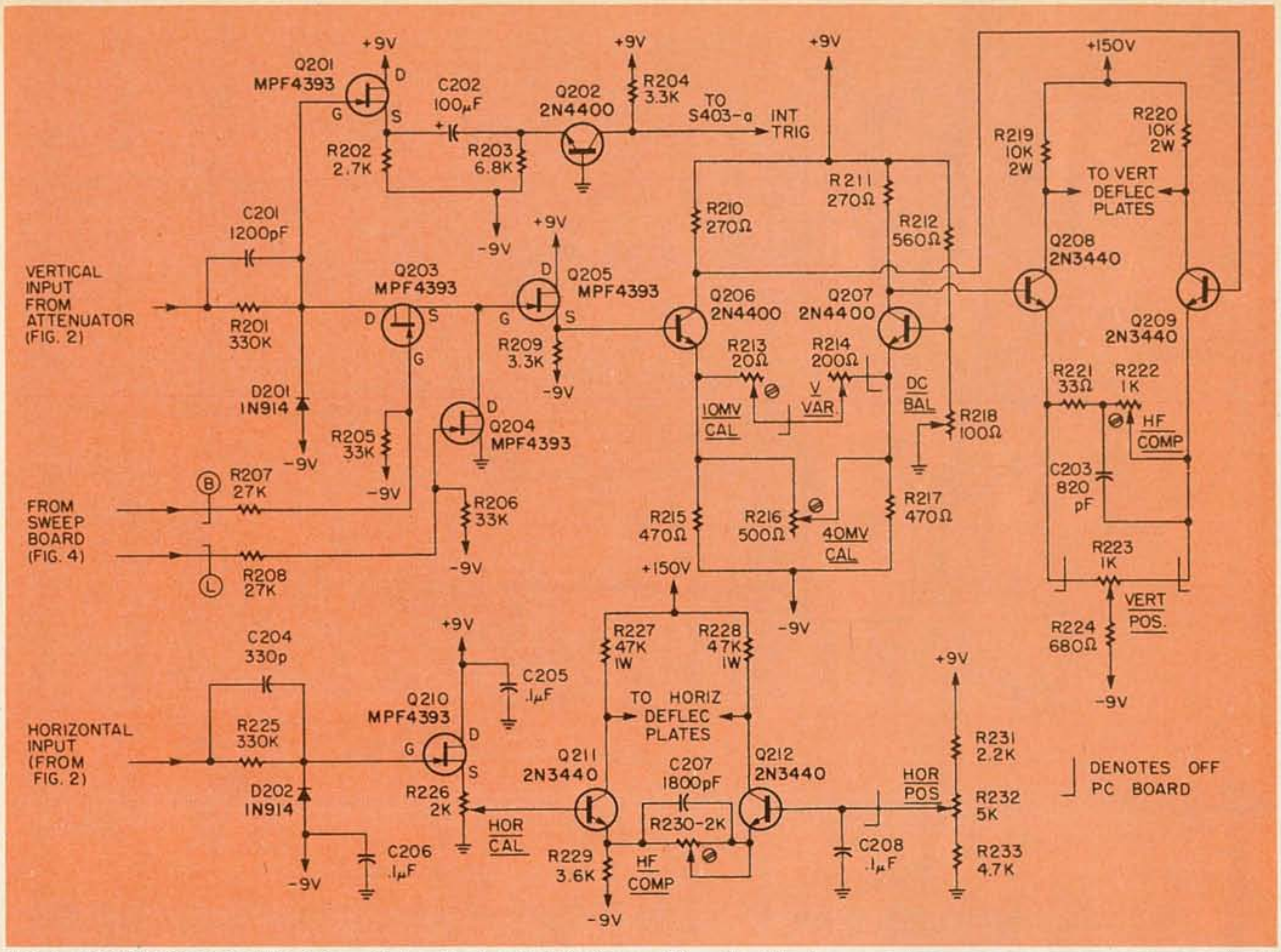
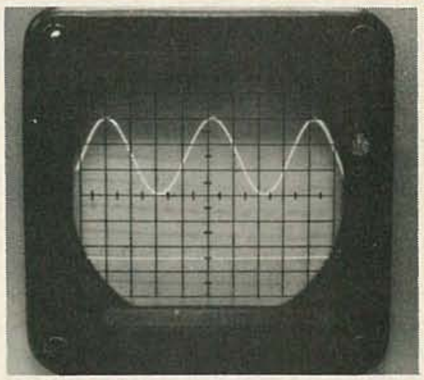


FIG. 3—SCHEMATIC DIAGRAMS of the vertical and horizontal deflection amplifiers. The latter is comparatively simple because its response is limited to the sweep frequencies.

at minimum resistance. Pot R216 is the 40-mV calibrator. It adjusts the indicated sensitivity with R214 at maximum resistance. Pot R218 is the DC balance control; it sets zero voltage between the two emitters at zero input in order that the gain control will not shift the vertical position.

Transistors Q208 and Q209 provide a second stage of amplification, producing a maximum differential output of about 180 volts P-P. Capacitor C203 lowers the impedance between the emitters to track the decrease in impedance between the collectors caused by CRT plate capacitance at high frequencies. Since gain is essentially the ratio of those impedances, C203 tends to preserve a constant gain as frequency increases. Because an 820-pF trimmer would be large and unstable, we adjust the associated resistor (R202) to suit the capacitor, instead of vice-versa. Capacitor C203 thus determines the stage gain, and should be altered if necessary to produce a stage gain of about 50.

Horizontal amplifier: This amplifier (Fig. 3) is similar to the vertical amplifier except that the low-voltage differential stage is omitted and the entire gain (about 70) is achieved in the high-voltage stage. The differential output voltage required is about 250 volts P−P because the second (less sensitive) set of CRT deflection plates is used. Bandwidth is about 500 kHz.



ZERO-BASELINE DISPLAY permits reading the DC component of this waveform. Scale factor is 1 V/div and the sinewave is 3 volts peak-to-peak riding on a 4-volt DC level.

PARTS LIST (Amplifiers, Fig. 3)

Resistors ½ watt, 10%, carbon composition, unless otherwise noted
R201, R225—330,000 ohms
R202—2700 ohms
R203—6800 ohms
R204, R209—3300 ohms
R205, R206—33,000 ohms
R207, R208—27,000 ohms
R210, R211—270 ohms
R212—560 ohms
R213—20 ohms, trimmer, vertical mount
R214—200 ohms, potentiometer
R215, R217—470 ohms
R216—500 ohms, trimmer, vertical mount
R218—100 ohms, trimmer, vertical mount
R219, R220—10,000 ohms, 2 watts
R221—33 ohms
R222—1000 ohms, trimmer, vertical mount
R223—1000 ohms, potentiometer
R224—680 ohms
R226, R230—2000 ohms, trimmer, vertical mount
R227, R228—47,000 ohms, 1 watt
R229—3600 ohms
R231—2200 ohms
R232—5000 ohms, potentiometer
R233—4700 ohms

Capacitors
C201—1200 pF, Mylar
C202—100 µF, 15 volts, radial-lead electrolytic
C203—820 pF, mica
C204—330 pF, mica
C205, C206, C208—0.1 µF, ceramic disc
C207, 1800 pF, Mylar

Semiconductors
D201, D202—1N914 or similar silicon diode
Q201, Q203, Q204, Q205, Q210—MPF4393 or similar N-channel FET (Motorola)
Q202—2N4402 or similar
Q206, Q207—2N4400 or similar
Q208, Q209, Q211, Q212—2N3440 or similar

Miscellaneous: PC or perforated circuit board, hookup wire, mounting hardware, transistor sockets, etc.

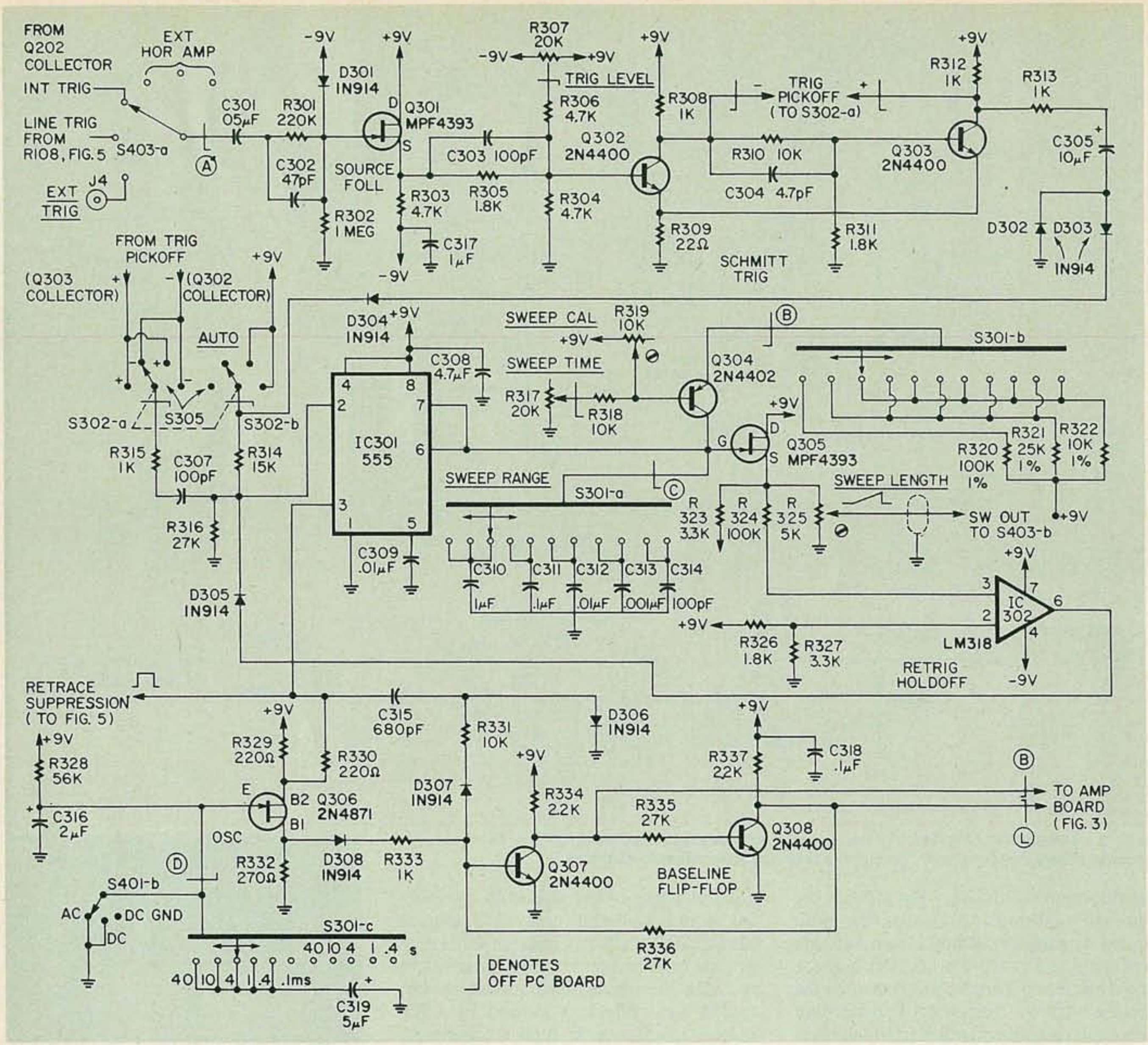


FIG. 4—THE SWEEP and zero-baseline generator circuits comprise the most complex sections of the instrument.

PARTS LIST (Sweep and zero-baseline generators, Fig. 4)

Resistors ½ watt, 10% unless otherwise noted
R301—220,000 ohms
R302—1 megohm
R303, R304, R306—4700 ohms
R305, R311—1800 ohms
R307, R317—20,000 ohms, potentiometer
R308, R312, R313, R315, R333—1000 ohms
R309—22 ohms
R310, R318, R331—10,000 ohms
R314—15,000 ohms
R316, R335, R336—27,000 ohms
R319—10,000 ohms, trimmer, vertical mount
R320—100,000 ohms, 1%
R321—25,000 ohms, 1%
R322—10,000 ohms, 1%
R323, R327—3300 ohms
R324—100,000 ohms
R325—5000 ohms, trimmer, vertical mount
R326—18,000 ohms
R328—56,000 ohms
R329, R330—220 ohms
R332—270 ohms
R334, R337—2000 ohms

Capacitors
C301—.05 µF, 600 volts, ceramic disc
C302, C304—47 pF, ceramic disc
C303, C307—100 pF, ceramic disc
C305, C306—10 µF, 25 volts, axial-lead electrolytic
C308—4.7 µF, 25 volts, axial-lead electrolytic
C309—.01 µF, ceramic disc
C310*—1 µF, Mylar
C311*—0.1 µF, Mylar
C312*—.01 µF, Mylar
C313*—.001 µF, Mylar
C314**—100 pF, ceramic trimmer
C315—680 pF, ceramic disc
C316—2 µF, 25 volts, axial-lead electrolytic
C317, C318—0.1 µF, ceamic disc
C319—5 µF, 25 volts, axial-lead electrolytic
*Note: select to keep ratios within ±1%
**Note: In prototype, C314 was made by connecting a 47-pF disc in parallel with a 6–60-pF ceramic trimmer

Semiconductors
D301–D308—1N914 or similar silicon diode
IC301—555 timer
IC302—LM318 op-amp (National)
Q301, Q305—MPF4393 or similar N-channel FET (Motorola)
Q302, Q303, Q307, Q308—2N4400 or similar
Q304—2N4402 or similar
Q306—2N4871 or similar unijunction transistor
S401, S403—see attenuator parts list
S301—3-pole, 11-position rotary wafer switch (Centralab PA-10009 or equal)
S302—2-pole, 4-position rotary switch

Miscellaneous: PC or perforated circuit board, shielded cable, transistor and IC sockets, mounting hardware, knobs, etc.

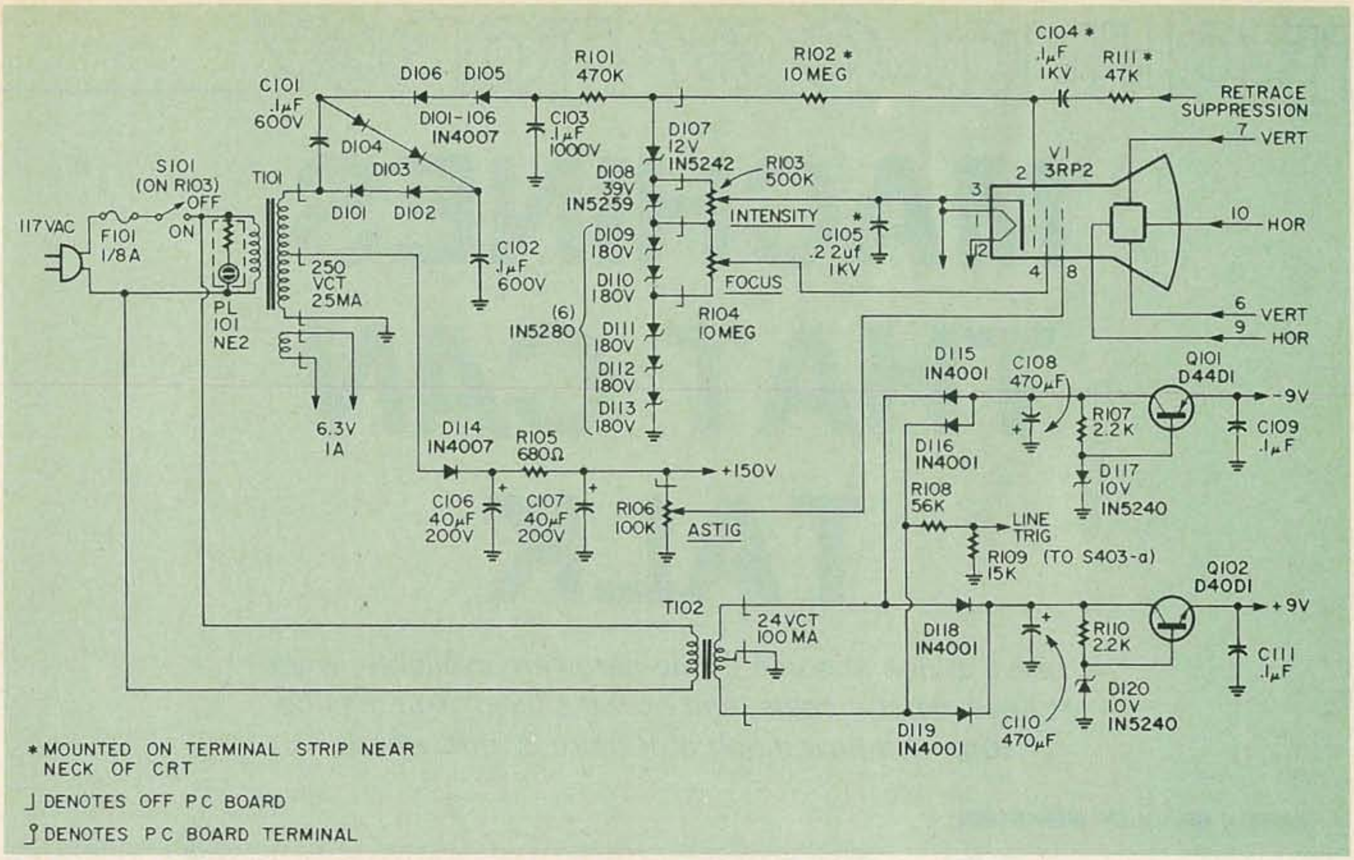


FIG. 5—THE POWER SUPPLY is simple and inexpensive to build. The voltage-tripler replaces the expensive and dangerous high-voltage power transformer used in many scopes. The string of Zener diodes replaces a high-resistance voltage-divider string.

Trigger circuits: Source-follower Q301 (Fig. 4) provides the high input impedance required during external triggering, and the low driving impedance necessary for good sensitivity of the Schmitt trigger, Q302 and Q303. The trigger will operate with 0.1 volt P-P input, and trigger up to 5 MHz with 0.3-volt P-P input. The edges of the Schmitt-trigger output (inverted or non-inverted) are coupled through switch S302-a capacitor and C307 to the trigger input of the NE555, IC 301; that is where the negative edges are used to initiate the sweep ramps.

In the DRIVEN mode, the trigger input is held high by the +9-volt supply through R314 and triggering occurs only by negative pulses from C307. In the AUTO mode, AC detectors D302, D303, and C306 furnish the positive supply as long as the Schmitt trigger is switching. However, if the trigger remains inoperative for longer than about 150 ms, C306 discharges and R316 pulls the trigger input low, resulting in automatic triggering with no input signal.

Sweep circuit: Transistor Q304 is a variable-current source that charges the selected timing capacitor (C310 through C314) at a linear rate depending on the sweep variable control and the selected timing resistor (R320 through R322). Pin 7 of the NE555 automatically discharges the capacitor whenever pin 6 rises to +6 volts. A source-follower Q305 buffers the ramp since any current drawn from it would destroy its linearity. Pot R325 reduces the ramp to 4.4 volts, thus providing 11 divisions of sweep to the 0.4 volt-per-division horizontal amplifier.

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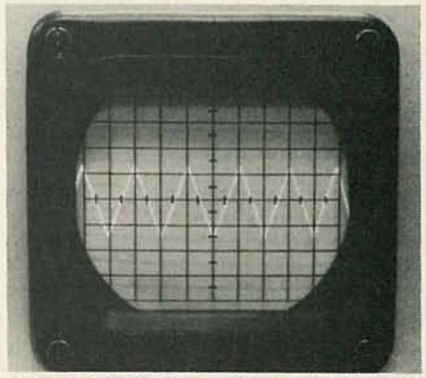

SWEEP LINEARITY is evident in this photo of a 500-kHz triangle waveform at 1 mV/div.

PARTS LIST (Power supplies, Fig. 5)

Resistors ½ watt, 10% carbon composition unless otherwise noted
R101—470,000 ohms
R102—10 megohms
R103—500,000 ohms potentiometer with SPST switch
R104—10 megohms, potentiometer
R105—680 ohms
R106—100,000 ohms, potentiometer
R107, R110—2200 ohms
R108—56,000 ohms
R109—22,000 ohms
R111—47,000 ohms

Capacitors
C101, C102—0.1 uF, 600 volts, tubular
C103, C104—0.1 uF, 1000 volts, tubular
C105—.22 uF, 1000 volts, tubular
C106, C107—40 uF, 200 volts, axial-lead electrolytic
C108, C110—470 uF, 25 volts, radial-lead electrolytic
C109, C111—0.1 uF ceramic disc
V1—CRT, 3RP2 was used in prototype. 3EP1, 3RP1, 3BP1 and 3ACP11 can be used. See text.

Semiconductors
D101–D106, D114—1N4007
D107—1N5242 Zener diode, 12 volts, 500 mW
D108—1N5259 Zener diode, 39 volts, 500 mW
D109–D113—1N5280 Zener diode, 180 volts, 500 mW
D115, D116, D118, D119—1N4001
D117, D120—1N5240 Zener diode, 10 volts, 500 mW
Q101—D41D1 (GE) or similar PNP silicon transistor
Q102—D40D1 (GE) or similar NPN silicon transistor
F101—1/8-amp fuse
PL101—neon pilot-light assembly (NE-2 lamp with 68K resistor)
S101—SPST switch (part of R103)
T101—power transformer, 250 volts center-tapped, 25 mA; 6.3 volts, 1 amp. (Stancor PS-8416 or equivalent)
T102—power transformer, 24 volts center-tapped, 100 mA (Stancor P-8395 or equivalent)
Miscellaneous: Fuse holder, line cord, PC or perforated circuit board, hookup wire, terminal strip, MuMetal shield for CRT, CRT socket, transistor sockets, etc.

OSCILLOSCOPE

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The LM318 op-amp (IC302) is used as a voltage comparator, holding the trigger input of the 555 positive until the timing capacitor has completely discharged. Premature triggering during retrace is thus prevented. The 555 provides a squarewave output at pin 3 that goes to +9 volts while the ramp is rising and drops to ground during retrace and hold-off. That line is capacitively coupled to the CRT grid to suppress the beam except during the sweep.

Baseline generator: The retrace-suppression line is used via R330 to synchronize the zero-baseline oscillator Q306, insuring that the switch from baseline to signal display will always occur at the start of a retrace when the beam is suppressed. For the lower sweep speeds, synchronization requires a slower oscillator, and for that C319 is switched in.

Each time unijunction transistor Q306 fires, C316 discharges through R332, setting flip-flop Q307–Q308 through D308 and initiating a baseline sweep. After the baseline sweep (or several sweeps if C316 is not discharged after the first one) pin 3 of the 555 goes low, bringing the base of Q307 low through C315 and D307, thus resetting the flip-flop for a series of signal displays.

Power supplies: The power supplies (Fig. 5) are entirely conventional except for the −900-volt tripler. Diodes D105 and D106 charge C102 to the peak negative voltage of the transformer secondary on the negative half cycle. On the positive half-cycle, C102 and the secondary appear in series to charge C101 to twice the peak secondary voltage (negative on top), through D103 and D104. On the next negative half-cycle, C101 and the secondary appear in series to charge C103 to three times the peak secondary voltage through D101 and D102. The drain on that supply is about 200 uA, so the 0.1 μF Mylar filters are quite adequate. Some of those capacitors are used at 20% or so above their rated voltage, but many have been tested at four times rated voltage with no breakdowns. Any string of five to ten Zener diodes adding up to about 900 volts will do for D109 through D113 if 180-volt Zener diodes are hard to find. Capacitor C105 filters out the 60-Hz noise picked up from the power transformer by the CRT heater winding.

We must breakoff our discussion of the oscilloscope's power supplies now and will conclude it next month when we will also go into construction, checkout and calibration. R-E

TRIGGERED OSCILLOSCOPE

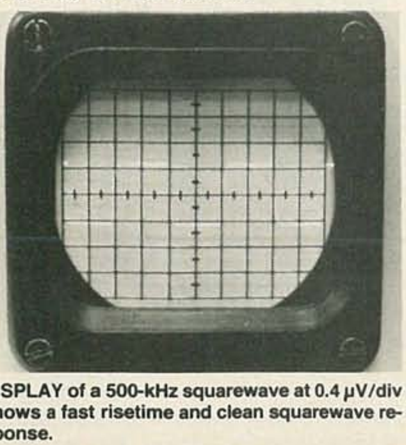
Part II—Construction details and calibration instructions for the low-cost scope that features a continuously displayed zero baseline.

DANIEL METZGER and DENNIS PERRY

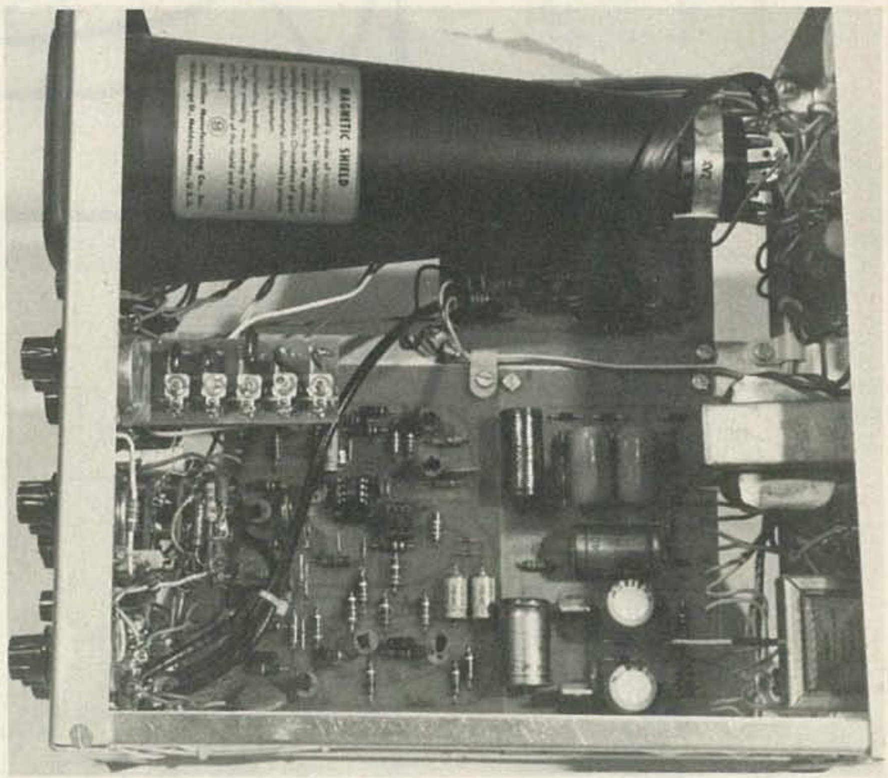
LAST MONTH WE DESCRIBED THE FEAtures of this inexpensive DC scope and went into detail on the operation of its various circuits. We continue this month by resuming our broken-off discussion with suggestions on selecting the CRT to meet your requirements.

Construction

Many types of CRT's have been used in this design, including 3BP1, 3EP1, 3ACP11, 3FP7, 3RP1, and 2AP1. Five-inch types can be used, but whatever is gained in screen size will be lost in sharpness of focus. The 3RP1A and 3WP1 are especially nice because they are flat-faced. The 3WP1 has about twice the deflection sensitivity of the others, and can be used to produce a scope with 5-mV sensitivity. The CRT must be shielded with MuMetal (nothing else will work) unless the power transformers can be located two feet from the CRT. Surplus houses that sell CRT's usually have fully formed shields.



DISPLAY of a 500-kHz squarewave at 0.4 μV/div shows a fast risetime and clean squarewave response.



TOP VIEW of the scope. The amplifier board is beneath the CRT. The power-supply board is at the rear near the transformers mounted on the back panel. The sweep board is up front near the controls. The attenuator board, with its five trimmers, is on a bracket held by the vertical-sensitivity control. Astigmatism control is on rear panel near base of the CRT.

The vertical and horizontal output wires must run straight to the CRT and be kept away from each other and from other wiring and the chassis. The vertical and horizontal inputs should be kept short and separate from other wire bundles. The wires to and from the TRIGGER LEVEL switch carry fast squarewaves and must be shielded to prevent coupling to other wires. The wires to the VERTICAL VARIABLE GAIN control should be kept reasonably short. Other wiring should be bundled and laced in the interests of neatness.

The input attenuator and sweep-timing resistors must be held to 1% if good

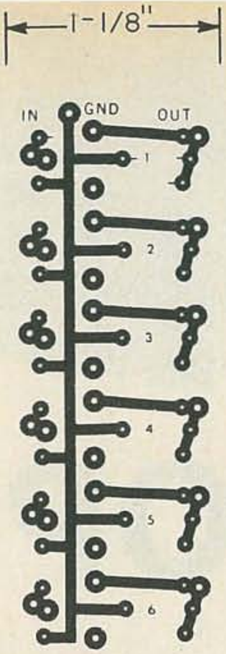


FIG. 6—FOIL PATTERN for the attenuator used in the vertical-sweep circuit.

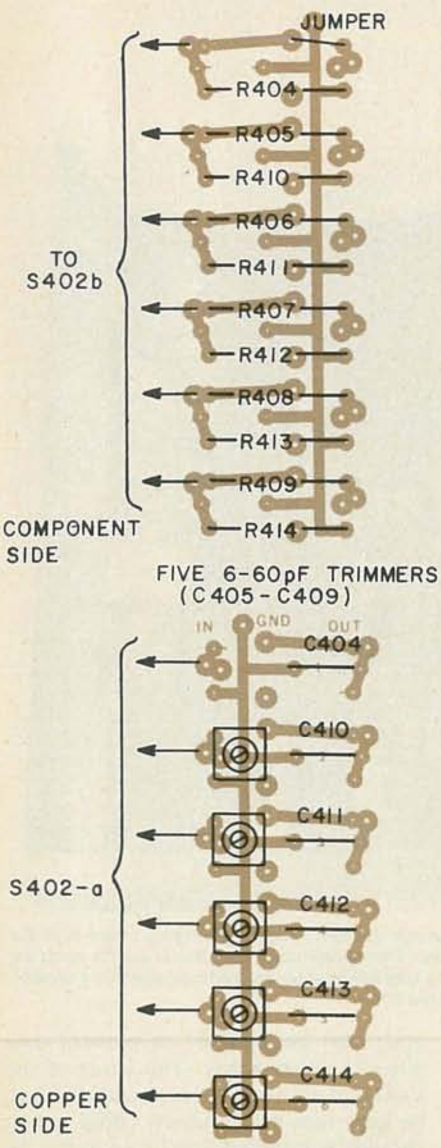


FIG. 7—COMPONENT PLACEMENT GUIDE for the vertical-input attenuator. The precision resistors are on one side and the frequency-compensating capacitors are on the other.

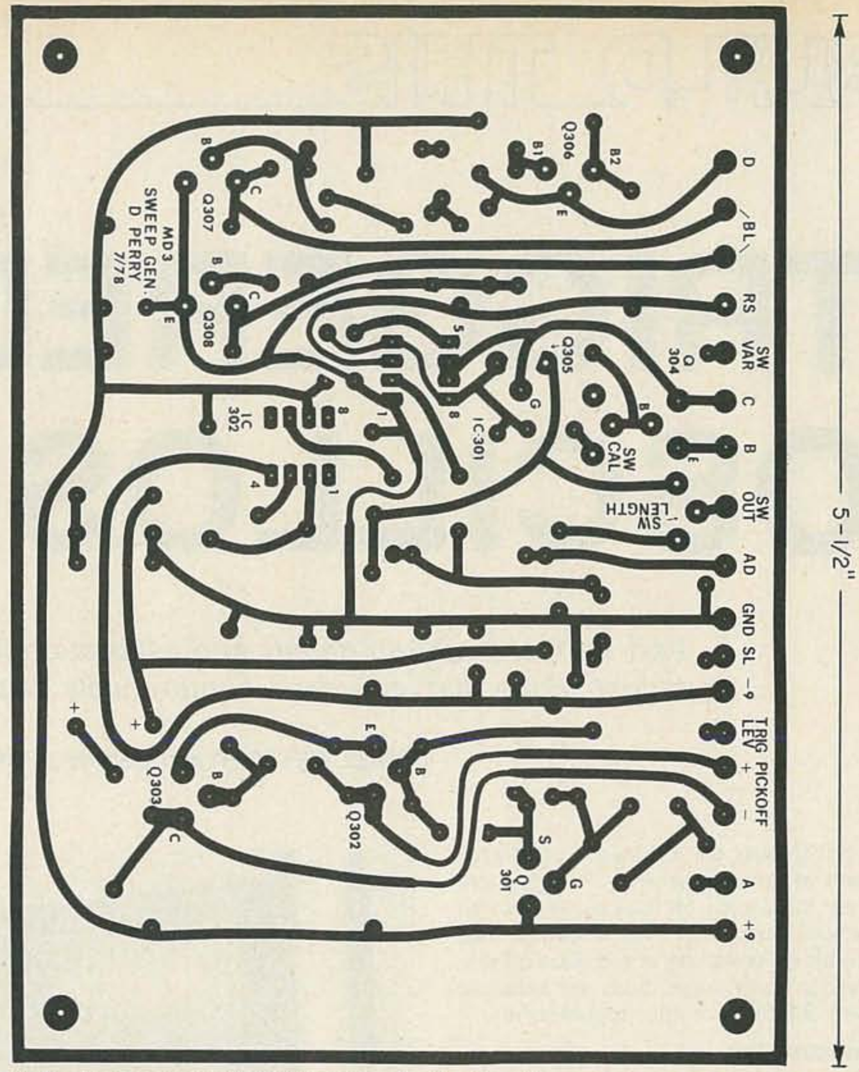


FIG. 8—THE SWEEP-GENERATOR PC-board foil pattern. The pads along the top edge are for connections to off-the-board components and leads to other circuit boards.

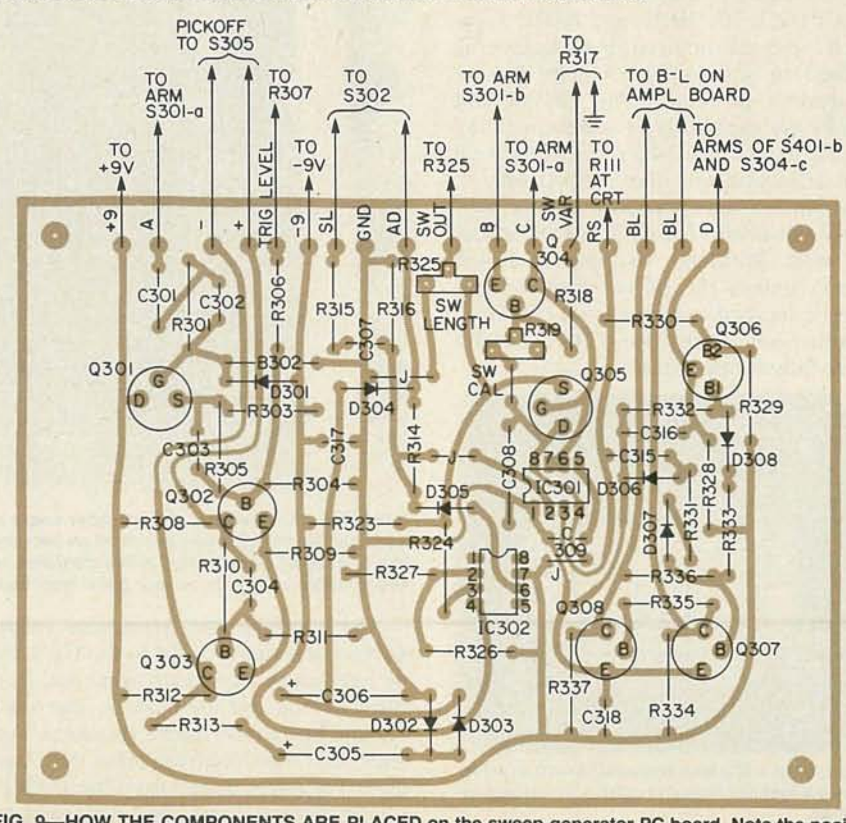


FIG. 9—HOW THE COMPONENTS ARE PLACED on the sweep-generator PC board. Note the positions of the three jumpers.

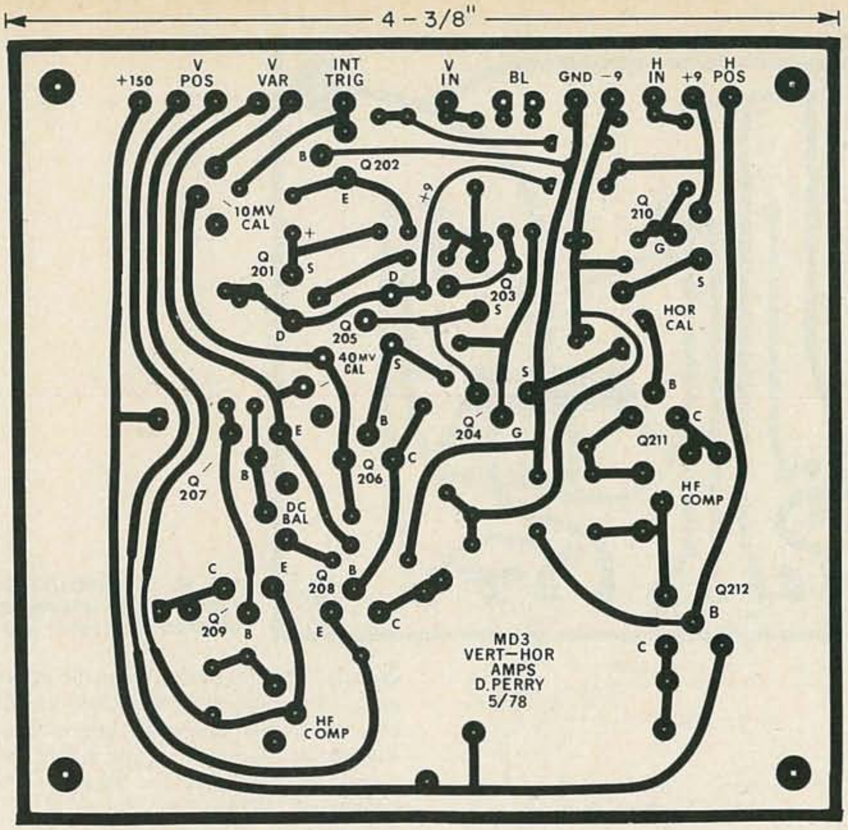
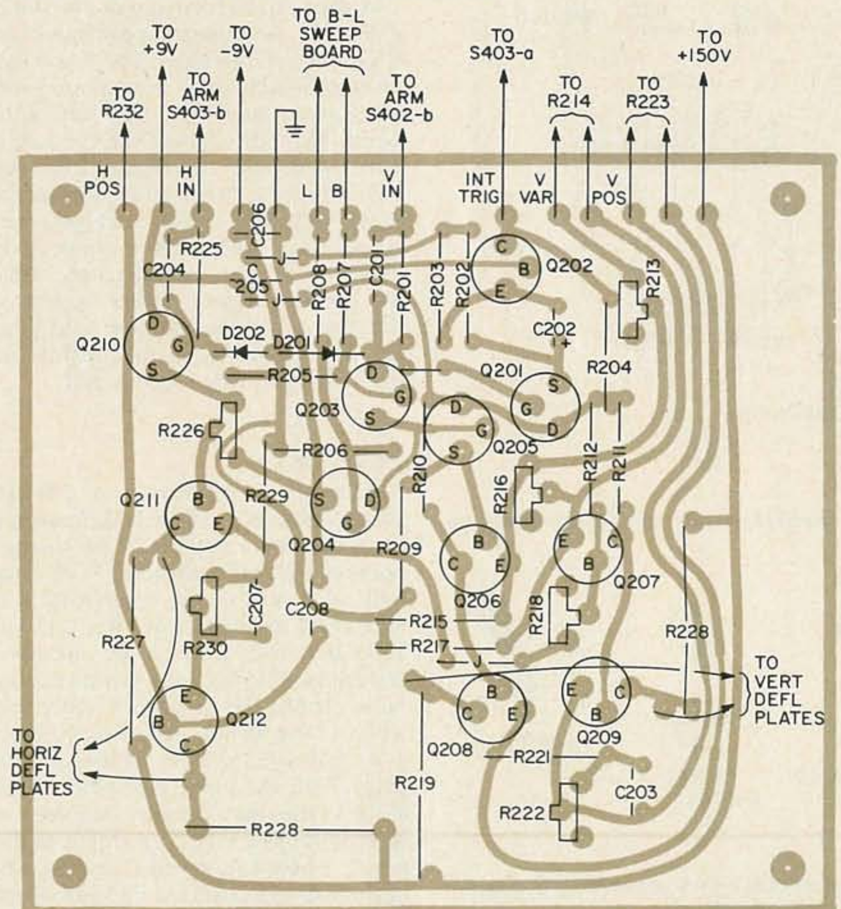


FIG. 10—PRINTED-CIRCUIT FOIL PATTERN for the board for the horizontal and vertical deflection circuits.



NOTE: CONNECTION TO HORIZONTAL DEFLECTION PLATE SHOULD BE MADE SO THAT BEAM SWEEPS FROM LEFT TO LIGHT; VERTICAL DEFLECTION PLATES SHOULD BE CONNECTED SO THAT POSITIVE INPUT TO VERTICAL AMPLIFIER PRODUCES UPWARD DEFLECTION OF BEAM.

FIG. 11—THE DEFLECTION-AMPLIFIER board has three jumpers and six trimmers for circuit calibration and adjustments. Leads to CRT deflection plates should be as short as practical to minimize stray capacitance.

TABLE 1 TROUBLESHOOTING CHART

Vertical: 50mV P-P, 1kHz sineware input; R214 at min resistance, S401 at DC

Horizontal: 2V P-P, 1kHz sineware to EXT HOR, S403 at 0.4V/DIV

Sweep: 2V P-P, 1kHz sinewave at EXT TRIG; + SLOPE, AUTO, 0.4ms/DIV, DC GND

TEST POINT	VOLTAGE DC	VOLTAGE AC P-P	POSSIBLE CAUSE
Power Supply - 100 Board			
C103	−1100	40	D101 thru D106
D107A	−950	<1	D107-D113 C105, T101, CRT
C107	+145	<1	D114, C106
C108	−19	0.6	D115, D116
C110	+18	1	D118, D119
Q101E	−9.4	<5m	D117, Q101
Q102E	+9.4	<5m	D120, Q102
Trig & Vert Amp - 200 Board			
Q201S	+1 to +2	=5m	
Q202C	+5	=2	
Q205G	0	50m	D201, Q205
Q205S	+1 to +2	45m	Q205
Q206E	Follows 0.6V below Q205S		
Q207E	+0.5 to +1.5	=0	R218
Q206C Q207C	=4	1.0	Q205, R215, R217
Q208C Q209C	75	50	Q208, Q209, R224
Horiz Amp - 200 Board			
Q210S	+1 to +2	1.5	Q210, D202
Q211C Q212C	+75	60	Q211, Q212, R229
Sweep - 300 Board			
Q301G	0	2	Q301, D301
Q301S	+1 to +2	1.8	Q301
Q302B	−1 to −3 Varied by R307		
Q302C Q303C	+1 to +9 SQR		Q302, Q303
C306	+8	0	D302, D303
Q304B	+7.3 to +8.5 Varied by R317		
R320-R322	+1.5 DC across R_T AT CAL		
IC301 pin 6	0 to +6 RAMP		Q304
Q305S	+1 to +7 RAMP		Q305
IC302 pin 6	+9 to −9 SQR		IC302, R327
IC301 pin 3	0 to +9 SQR		IC301
Q306E	0 to 7 RC Charge;		Q306, R278
Q306BI	+5 SPIKE		Q306
Q307C Q308C	0 to +9 SQR		Q307, Q308

A=anode B=base C=collector
E=emitter G=gate S=source

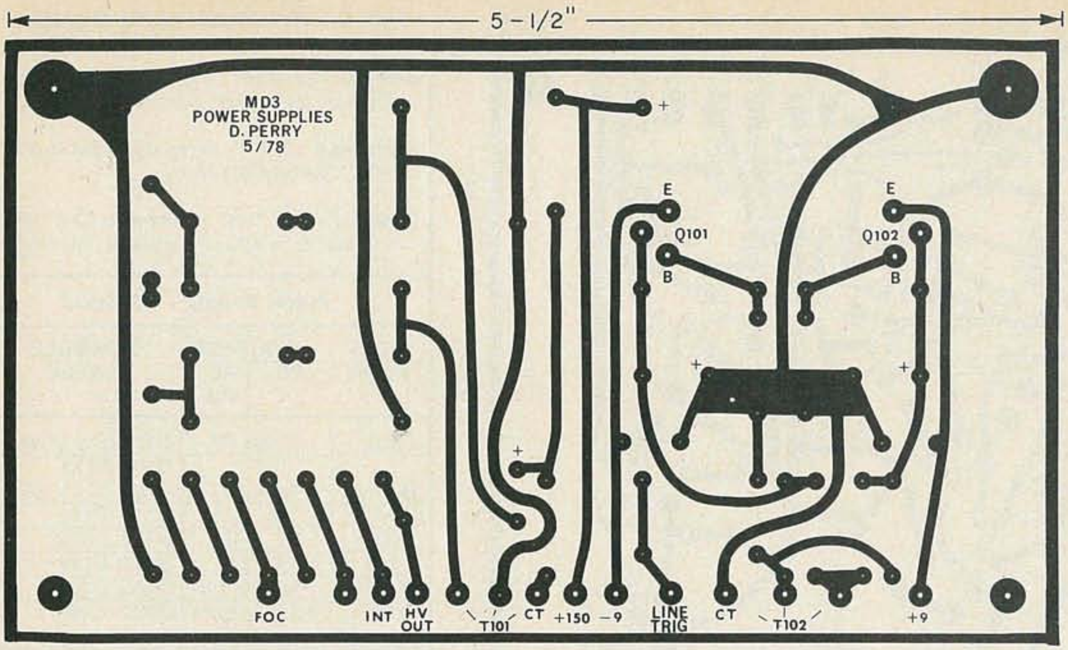


FIG. 12—THIS PRINTED-CIRCUIT PATTERN simplifies construction of the power supply.

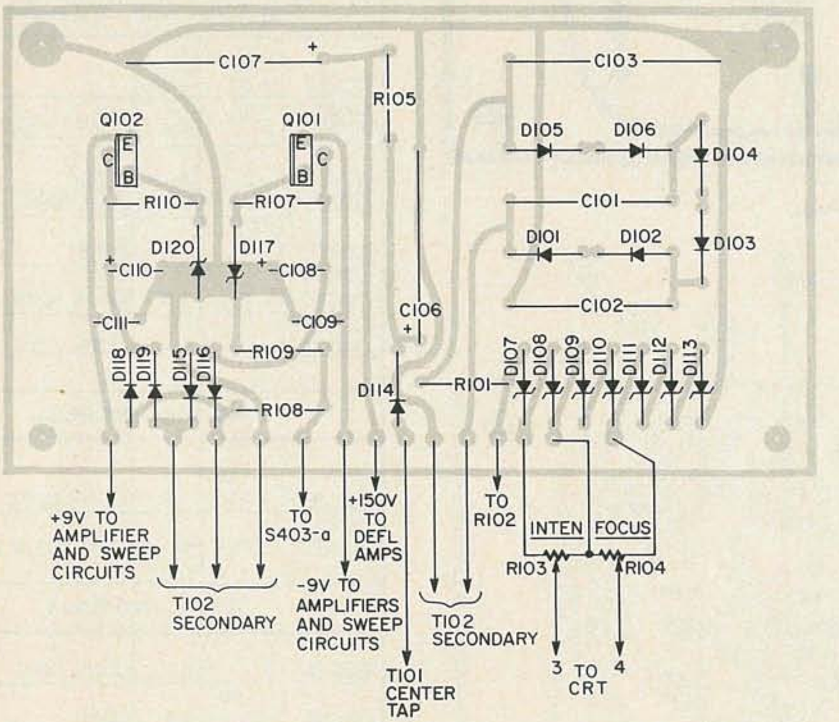
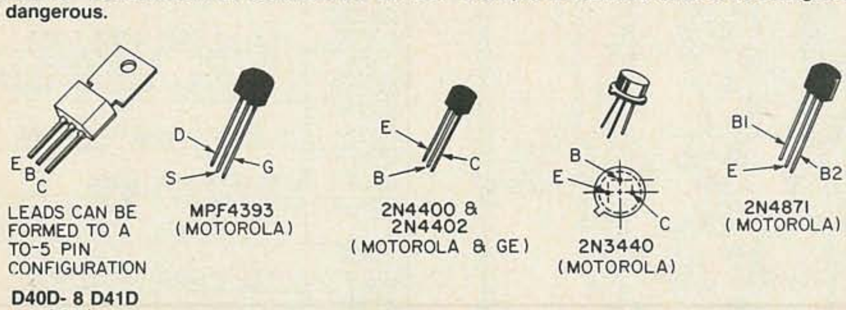


FIG. 13—POWER-SUPPLY COMPONENT LAYOUT is simple. Be careful; some of its voltages are dangerous.



PHYSICAL OUTLINES AND PINOUTS for the discrete devices used in the scope as active circuits. Be especially careful with the installation of the look-alike plastic devices.

calibration accuracy is expected. The timing capacitors must at least be in the same ratio, so if one is 7% high, strive to make them all 7% high. If a × 10 probe is to be used, the fixed frequency-compensating capacitors (C^B) must be held to 5% tolerance.

The scope is constructed on four PC boards. The foil patterns for the attenuator, sweep circuits, deflection amplifiers, and power-supply PC boards are in Figs. 6, 8, 10, and 12, respectively. The component layouts for those circuit boards are in Figs. 7, 9, 11, and 13.

Initial checkout

A spot can be focussed on the screen with only the power-supply board and CRT circuitry wired in. The 9-volt supplies will each need a temporary 470-ohm load if they are to be tested at this point. Now disconnect the primary of T101 to disable the high-voltage supplies while the sweep and low-level amplifiers are tested. The troubleshooting chart (Table 1) shows the voltages to be expected at various test points. Once the Schmitt trigger, sweep generator, baseline generator, and low-level amps are determined to be functioning, the high voltage can be reconnected.

Calibration

Vertical: First display a 200-kHz squarewave and adjust high-frequency compensation control R222 for sharpest corners with no overshoot. With range S402 at 1 V/div and variable R214 at maximum resistance, inject a 2.12 volt RMS (6.0 volts P-P) 100-Hz sinewave, and adjust R216 for a six-division display. Now change the range to 4 V/div and, with variable R214 at minimum resistance (÷4), adjust R213 for a six-division display. With the input grounded, adjust R218 so the trace remains stationary as R214 is rotated. The final step is to display a 1-kHz squarewave, and on each of the ranges from 0.1 to 10 V/div adjust the corresponding trimmer capacitor for the best squarewave with no rounding or overshoot.

Horizontal: With the horizontal atten-

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fixed and broadcast satellites that will be able to operate in the 12 GHz portion of the spectrum in the western hemisphere.

The 11.7- to 12.1-GHz band will be allocated to the Fixed Satellite Service (space-to-earth) shared with other services; the 12.0- to 12.7-GHz band will be allocated to broadcasting and broadcasing satellites, shared with other services. The specific frequencies to be assigned to the broadcasting satellite service will be allocated at a Conference scheduled to be held in 1983. That will be followed by a general satellite conference as mentioned above.

The overriding issue of the 80's will be the movement on the part of developing countries to plan the assignment and use of orbital slots and frequencies in such a way as to assure all countries an equal "slice of the pie." WARC-79 did not address that issue completely, but only deferred it to subsequent space conferences which will be held in this decade. Major battles on the issue of equal rights may loom ahead. **R-E**

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uator switch S403 at 0.4 V/div, connect a 20-kHz squarewave to the external horizontal input and adjust R230 so the display consists of two dots on the screen. Misadjustment will cause "tails" at the outside or inside of the dots indicating overshoot or rounding. Now apply a 1.41-volt RMS (4.0 V P-P) 100-Hz sinewave and adjust R226 for a ten-division horizontal line. Change S403 to 2 V/div and apply a 1-kHz squarewave, adjusting C403 for two dots with no tails as above.

Sweep: First set SWEEP LENGTH control R325 for an 11-division horizontal line. Then, with variable SWEEP TIME control R317 at minimum resistance and a 60-Hz line display, set SWEEP RANGE switch S304 to 4 ms/div and adjust SWEEP CALIBRATE control R319 so two complete cycles occupy 8.33 divisions. Now display a 100-kHz squarewave, set S304 to 1μs/div, and adjust C314 for one full cycle over ten divisions. Finally, vary the generator frequency slowly. If double traces appear at the right of the screen it will be necessary to lower the value of R327 to hold off trigger during retrace. If R327 is too low, the 555 will not trigger at all.

Now that the scope is calibrated, its ready to be put into active duty on your workbench. You should recalibrate the scope periodically to be sure of optimum performance, but the scope should provide years of trouble free service. **R-E**