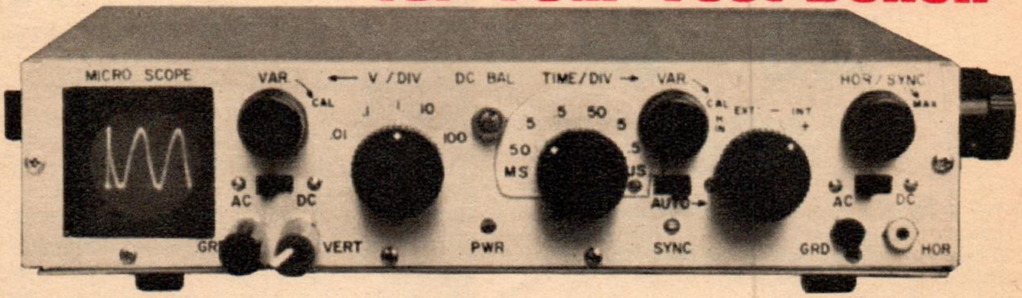
Build the Micro Oscilloscope for Your Test Bench



By WALT HENRY ONE of the more important test instruments to a service technician or serious hobbyist is an oscilloscope, a word which in itself is likely to bring to mind a large and cumbersome chunk of equipment.

But do oscilloscopes *have* to be the elephants of their world? Wouldn't it be nice to have a 'scope that required not much more bench space than a voltmeter and could be slipped into a drawer or tool kit? We thought it would so, we set out to do something about shrinking a 'scope. You can see the results above and on the cover.

Reducing size, however, did not mean a reduction in performance. Our Micro 'Scope shows figures actually superior to many general-purpose instruments. It also features the latest solid-state circuits. Along with a handful of conventional transistors and diodes, it uses four high-performance (yet inexpensive) integrated circuits and five field-effect transistors. The only tube in the 'scope is the CRT. It is a 1EP1 flat-face type with a viewing diameter of 1⅛ in. If size is not important the identical circuitry can be used to drive a 2-in. 2BP1 CRT or a 3-in. 3AQP1. With appropriate modification to the power supply to get the voltage up to about −1,500

SPECIFICATIONS

Vertical Amplifier

AC or DC input
Input impedance: 1 megohm shunted by 20 $\mu\mu$f
Calibrated vertical attenuator: .01, 0.1, 1, 10, 100 V/div.
Bandwidth: DC to better than 1 mc. AC—8 cps to 1 mc

Horizontal Amplifier

AC or DC input
Input impedance: 50,000 ohms
Sensitivity: 120 mv/div., AC and DC
Bandwidth: DC to 150 kc. AC—20 cps to 150 kc

Sweep Circuits

Triggered type with automatic trace-selector switch
Blanked retrace
Trigger level control
Selectable trigger on INT +, INT − or EXT.
Sync indicator to show sweep properly locked to input signal
Six sweep ranges calibrated for 50 ms, 5 ms, 0.5 ms, 50 μs, 5 μs and 0.5 μs/div. Variable control allows rates down to 0.5 sec/div.

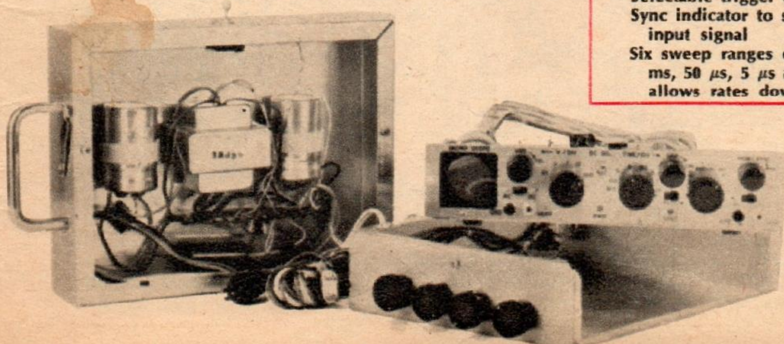


Fig. 1—At far left is scope's power supply which can be tucked away under your bench. At top, right is scope—built on 7 x 9-in. chassis bottom plate. The scope is sitting on 2 x 9 x 7-in. chassis in which focus, intensity, positioning controls are mounted.

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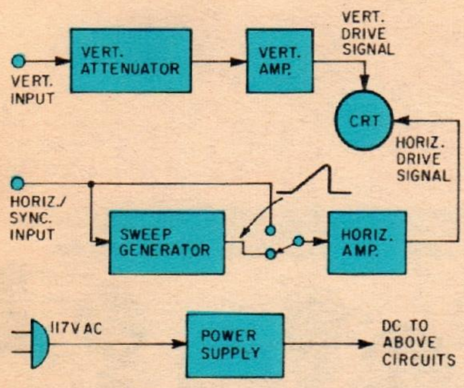


Fig. 2—Block diagram of the scope shows major circuits. The schematic showing each circuit in detail will be published in our March 1970 issue.

VDC, a 5-in. 5UP1 CRT may be used. Everything that can be shown on a 5-in. tube, however, can be displayed on the 1⅛-in. type. It's smaller but you just move closer to it.

Features

The usefulness of our Micro 'Scope is enhanced by DC-coupled vertical and horizontal amplifiers and a triggered sweep. What's triggered, sweep? Before we can explain it, let's talk briefly about the more familiar recurring sweep that is used in simpler general-purpose scopes. Recurring sweep is a continuous horizontal sweeping of the CRT's electron beam that goes on and on whether there's a signal to the vertical input or not.

A triggered sweep is just the opposite. That is, the electron beam is not swept horizontally until either a trigger signal (external to the 'scope) or a portion of the signal to be viewed is applied to the sweep generator. Triggered sweep enables you to view irregular wave shapes or non-recurring one-shot signals. A triggered sweep can be adjusted to start at any point of the signal being viewed.

A unique feature of the 'scope's sweep circuit is the synclock-indicator neon lamp, NL2. When an input signal is not present, NL2 is off. When the sweep circuit is properly triggered, however, NL2 comes on. Switch S3 will cause the sweep generator to run continuously when in the *auto* position even though an input signal is not present. When S3 is closed there is no sweep unless the sweep generator is triggered by an input signal. The 'scope's specs are listed in detail on the first page of this article.

Construction

To build the 'scope the size shown here, we used subminiature switches and pots which cost more than conventional-size components. For example, the switch we specify for S6, a four-pole four-position non-shorting rotary switch, costs about $6. A larger switch costs about $3. The choice is yours and depends on your budget and the size instrument you want.

This article describes the 'scope's features

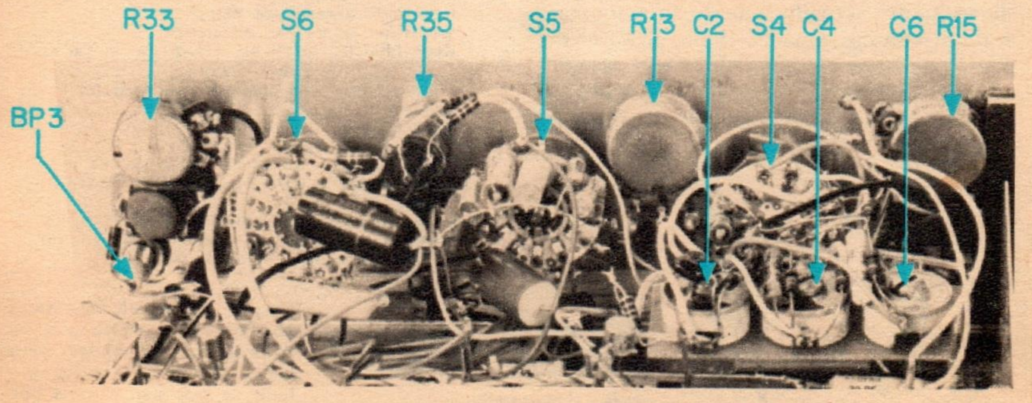
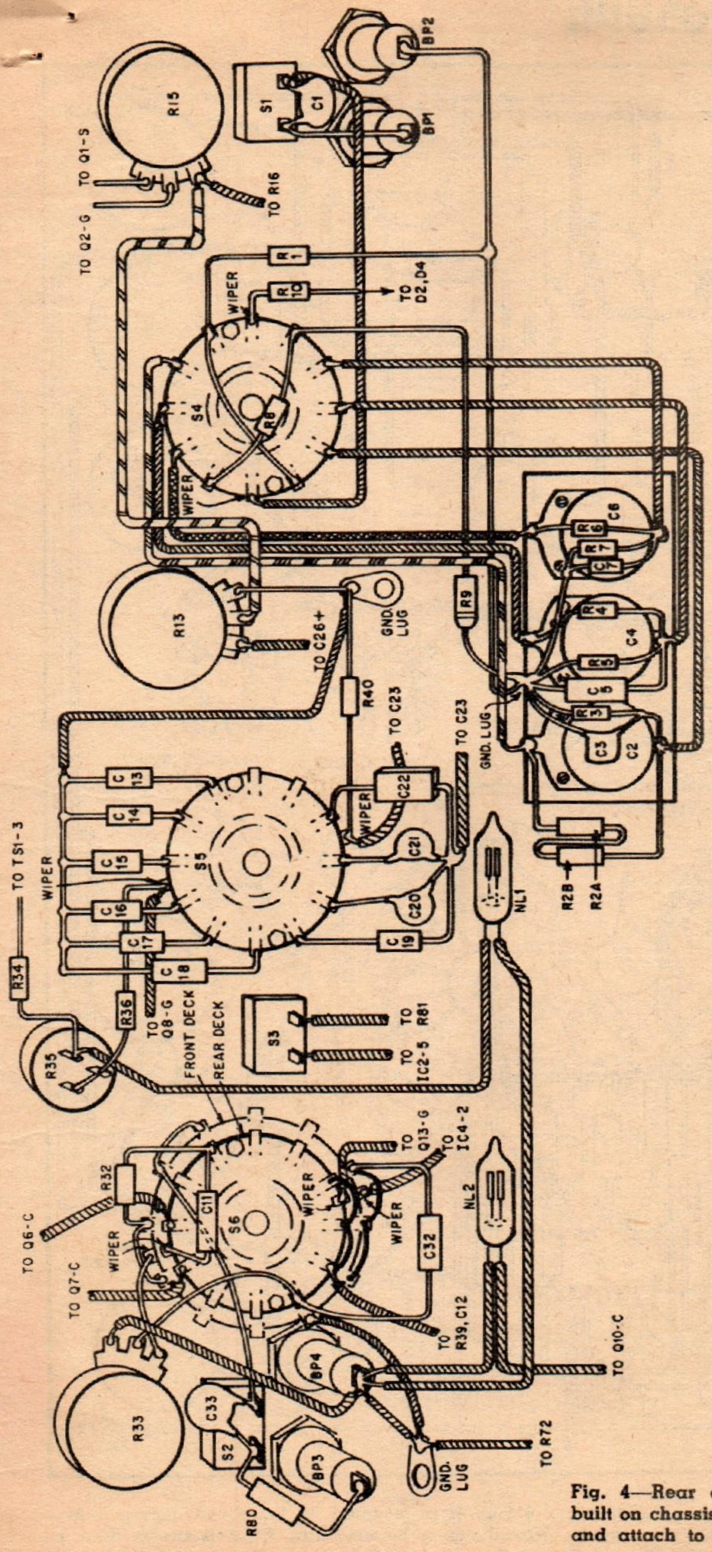


Fig. 3—Photo of rear of left side of front panel. Notice how capacitors are installed perpendicular to switch S5. Trimmer capacitors C2,C4 and C6 are mounted on a 1 x 2¼-in. piece of phenolic board behind vertical-attenuator switch S4. Board is held above chassis bottom plate by small aluminum bracket.



and includes the Parts List; enough information for you to start construction. The second part of the article, which will appear in our March 1970 issue will include the schematics and explanations of how the 'scope works, the calibration procedure and operating instructions.

The 'scope is built in two 2 x 9 x 7-in. aluminum chassis boxes. The power supply is in one box and all other components and operating controls are in the other box. The 'scope is built in two units to keep the main section as small and light as possible. The power transformer and filter capacitors are by far the largest and heaviest components and are in the power supply box which can be tucked away under a workbench or on a shelf out of the way. The main section is small enough to set atop other test equipment or on a shelf.

Of course all parts could be built in one larger case. If you do this be sure to keep the power transformer as far as possible from the CRT since 60-cps noise from the transformer's stray magnetic field may show up as a ripple on the CRT. In our two-cabinet construction some 60-cps ripple shows up on the CRT when the 'scope unit sits directly on top of the power supply.

The interconnecting cable can be made as long as desired. Unused cable length can be coiled up and tucked inside the power supply. We attached a car-

Fig. 4—Rear of front panel. Because 'scope is built on chassis bottom plate, make 2 x 9-in. panel and attach to bottom plate with angle brackets.

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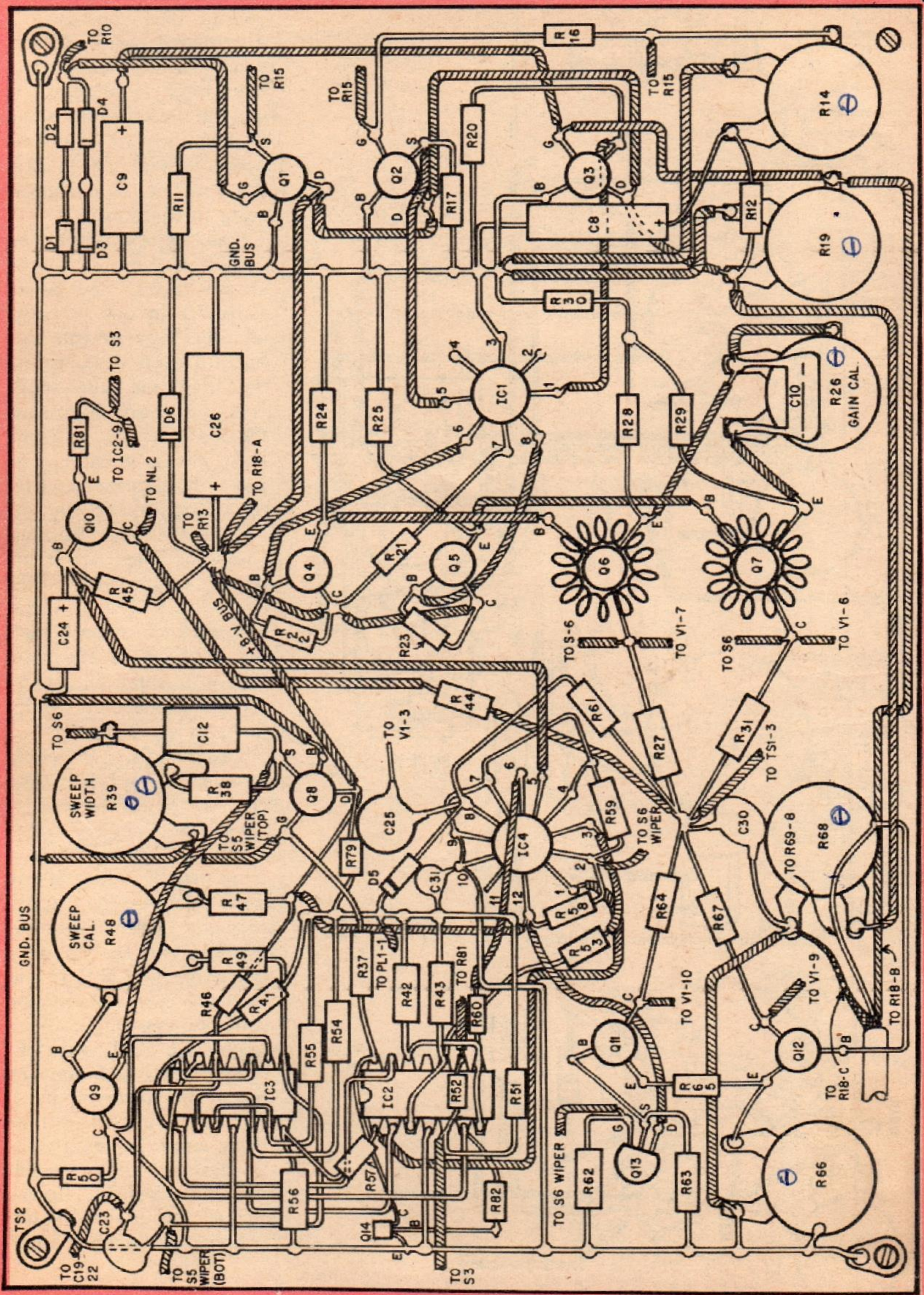

Fig. 5—Board on which parts are mounted is 4⅝ x 6½-in. It is mounted ⅜ in. above chassis bottom plate with spacers; mounting screws connect the ground bus to bottom plate. All pots shown here are screwdriver-adjust type. Loops around Q6 and Q7 are heat sinks. Wiring around IC2,IC3 is very tight.

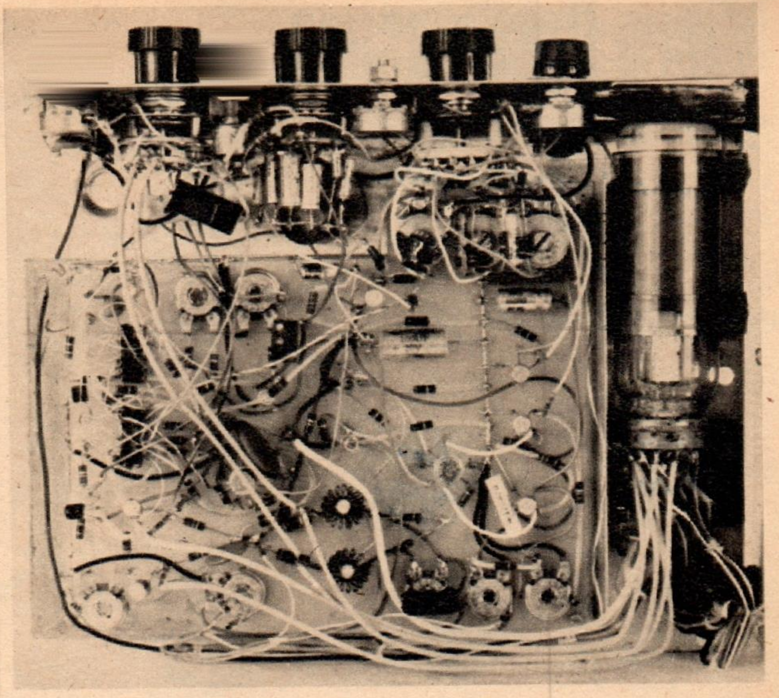

Fig. 6—Looking right down into guts. It's difficult to see here but there's a metal shield between right side of board and CRT. It's necessary to keep AC field of CRT away from vertical-input circuit.

rying handle and clips to hold the two units together for carrying.

The appearance of your 'scope will depend greatly on panel layout and markings. We sanded the aluminum surface then put the lettering on with a Leroy lettering set and India ink. The panel was then sprayed with a heavy coat of clear Krylon to give it durability. Other methods such as transfer lettering will work just as well.

Neon lamps NL1 and NL2 can be cemented to the inside of the case with transparent silicon-rubber adhesive. Circuit layout in the scope unit is important especially in the vertical amplifier section.

Most components in our model are mounted on a 4⅝ x 6½-in. glass-epoxy circuit board. However, perforated circuit board and flea clips may also be used. The vertical attenuator is built on a separate 1 x 2½-in. board and mounted behind vertical-attenuator switch S4. *Focus, intensity,* vertical- and horizontal-position controls R73, R75, R18 and R69 are mounted on the side of the chassis box. All other controls are mounted on the front panel. The chassis was modified by cutting one side (2 x 9 in.) away and attaching a new side (the front panel) to the chassis bottom plate. This allows good access to all parts. The CRT is mounted with two large nylon cable clamps.

Note in Figs. 6 and 7 that a metal shield is installed between the CRT and the circuit board. It provides electrostatic and thermal shielding between the CRT and sensitive vertical-amplifier input stages. The circuit lay-

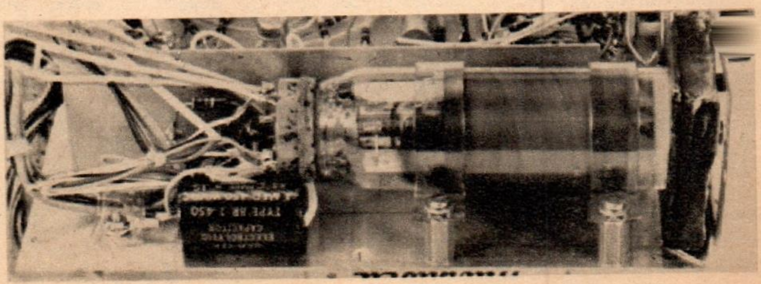

Fig. 7—Closeup of CRT shows how it's mounted on ½-in. spacers with cable clamps. Wood frame at right holds graticule. Note 5½-in. long x 1½-in. high shield behind CRT.

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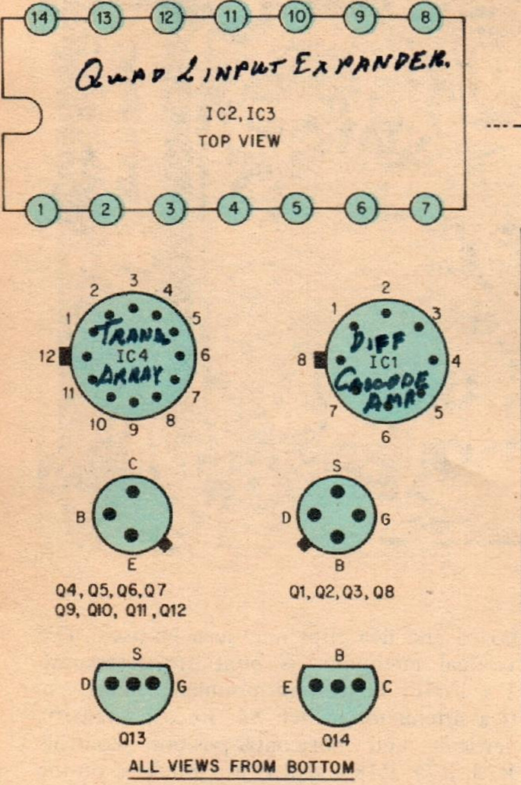


Fig. 8—Use these diagrams to identify semiconductor leads. Note that views of IC2 and IC3 are of top. View is of bottom of other semiconductors.

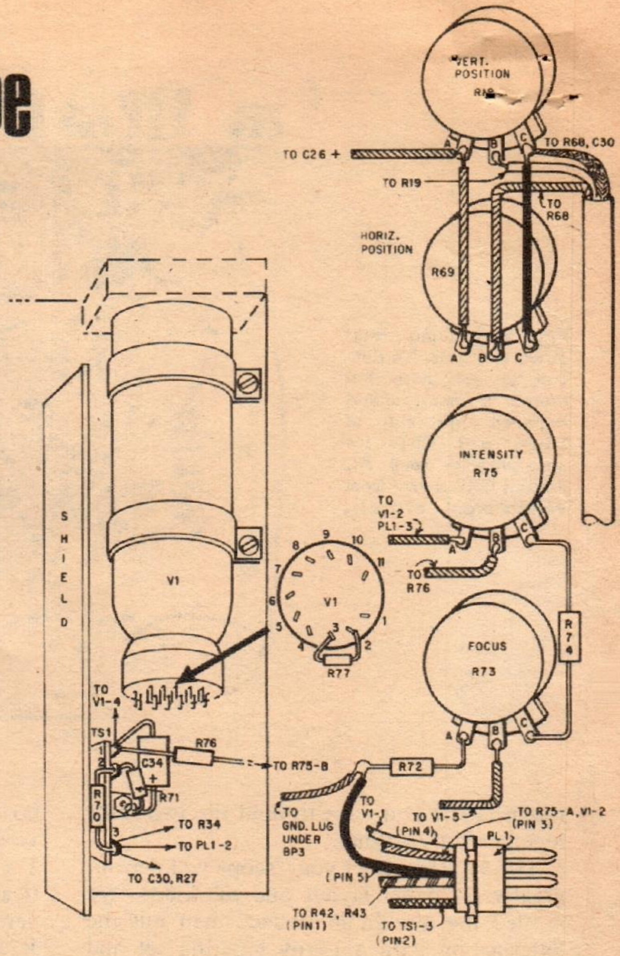


Fig. 9—Left sketch shows parts near CRT's base. Positioning, intensity, focus controls (right) go on side of chassis (cover). PL1 goes to power supply.

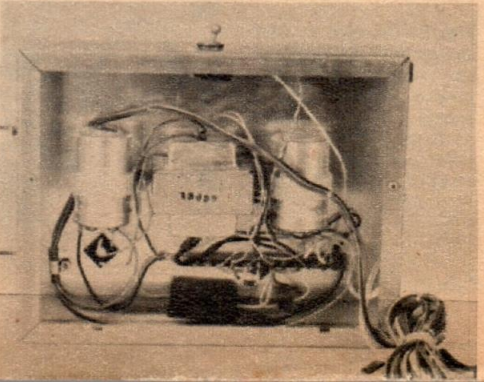
out should be similar to the one shown. It is necessary to keep the vertical amplifier output well away from the input to prevent oscillation.

Layouts of the horizontal amplifier and sweep generator are not so critical but all signal leads should be kept well separated both on the board and to the various front-panel controls and CRT. Leads to the four controls on the chassis side should be tightly cabled together. Note that the horizontal-position control's wiper lead (center terminal of R69) is shielded. The shield provides ground connection to both horizontal- and vertical-position controls.

We soldered all integrated circuits and transistors directly into the circuits. You may want to use sockets, especially since part of the checkout and calibration procedure requires that transistors Q4, Q5, Q6 and Q7 to be removed. If you do not use sockets leave these transistors out until told to put them in.

The RCA type 40468A transistor must be handled carefully to prevent it from being

Fig. 10—Power supply is also built in 2 x 9 x 7-in. aluminum chassis. Pictorial and schematic will appear in article in our March 1970 issue.



destroyed by electrostatic charges. The transistor comes with the leads shorted together with a small eyelet. Before removing the eyelet wrap a fine wire around the leads just under the case to keep the four leads shorted together. Don't remove this lead until after the transistor has been installed in the circuit board.

Values of electrolytic capacitors are not important except for C13, 14 and 15. Others may be the nearest available value. Be sure that power decoupling capacitors C26 and C30 are mounted on the circuit board close to the amplifier stages.

The graticule for the CRT may be made by stretching fine wire across a piece of stiff clear or green plastic. Use a drop of glue on each edge to hold that wire taut. Spray the plastic and wires with a heavy coat of clear Krylon to hold the wires in place.

Sockets for the 1EP1 CRT are not readily available. If you have trouble locating one just solder the leads directly to the CRTs pins.

PARTS LIST

BP1-BP4—Insulated phone-tip jack
BR1—Bridge rectifier; minimum ratings: 2 A, 250 PIV (Varo VS 248, Allied 49 D 34 VS248-VA. $2.15 plus postage. Not listed in catalog)
Capacitors:
C1,C30,C31—.02 µf, 1,000 V disc
C2,C4,C6—1.5-20 µµf midget trimmer (Elmenco 402, Allied 43 D 7088, 23¢ plus postage. Not listed in catalog)
C3,C23—100 µµf, 500 V dipped silver mica
C5—1,000 µµf, 500 V dipped silver mica
C7—.01 µf, 200 V (Sprague 192P10392, Allied 43 C 0347)
C8—120 µf, 6 V electrolytic
C9—70 µf, 20 V electrolytic
C10—680 µµf, 500 V dipped silver mica
C11—.05 µf, 500 V disc
C12—150 µµf, 500 V dipped silver mica
C13—22 µf, 15 V miniature tantalum electrolytic
C14—2.2 µf, 20 V miniature tantalum electrolytic
C15—.22 µf, 35 V miniature tantalum electrolytic
C16—.022 µf, 50 V tubular
C17—2,200 µµf, 500 V dipped silver mica
C18—220µµf, 500 V dipped silver mica
C19,C32—.33 µf, 50 V tubular
C20—.033 µf, 50 V tubular
C21—.0033 µf, 500 V disc
C22—330 µµf, 50 V disc
C24—15 µf, 6 V electrolytic
C25—.1 µf, 1,000 V disc
C26—100 µf, 10 V electrolytic
C27—450 µf, 100 V electrolytic (Sprague 451F100AA, Allied 43 C 5091)
C28—4,600 µf, 15 V electrolytic (Sprague 462GO15AA, Allied 43 D 5032, $2.31 plus postage. Not listed in catalog)
C29—8 µf, 500 V electrolytic
C33—.2 µf, 600 V tubular
C34—1 µf, 450 V electrolytic
D1-D5—1N914 diode
D6—8.5 V, 1 watt, 5% zener diode (Sarkes Tarzian VR8.5A or equiv.)
IC1—CA3028 integrated circuit (RCA)
IC2,IC3—MC785P integrated circuit (Motorola)
IC4—CA3018 integrated circuit (RCA)
NL1—NE-86 neon lamp
NL2,NL3—NE-2 neon lamp
PL1—five-prong miniature cable connector (Amphenol 91-MPM5L, Allied 47 A 0570 or equiv.)
Q1,Q2,Q3,Q8—40468A transistor (RCA)
Q4,Q5—2N5183 transistor (RCA)
Q6,Q7,Q10,Q11,Q12—2N5184 transistor (RCA)
Q9—2N963 transistor (Motorola)
Q13—2N5459 field-effect transistor (Motorola)
Q14—MPS3646 transistor (Motorola)
Resistors: ¼ watt, 10% unless otherwise indicated. Values are in ohms unless otherwise indicated.
R1,R4,R6,R8—1 megohm (5%)
R2A—430,000 (5%)
R2B—470,000 (5%)
R3—100,000 (5%)
R5—10,000 (5%)
R7,R10,R12,R47,R49,R52,R80,R81—1,000 (R7, 5%)
R9—100 (5%)
R11,R21,R50—3,900
R13,R18—1 megohm linear-taper pot
R14,R26,R39,R48,R66—1,000 ohm printed-circuit pot (Mallory MTC-4, Lafayette 33 E 16718)
R15—5,000 ohm linear-taper pot
R16,R71—56,000
R17,R38,R63—5,600
R19,R68—10,000 ohm printed-circuit pot (Mallory MTC-4, Lafayette 33 E 16783)
R20,R41,R56—4,700
R22,R23,R24,R25—2,200
R27,R31—8,200, ½ watt
R28,R29—180
R30,R53,R57—470
R32—220,000
R33,R69—50,000 ohm linear-taper pot
R34—24,000 (5%)
R35—500,000 ohm linear-taper pot
R36,R70,R74—47,000
R37—22
R40—2,700
R42,R43,R51,R54,R55—6,800
R44,R78—150,000
R45,R64,R67—18,000
R46,R76—39,000
R58—270,000
R59—62,000 (5%)
R60,R82—390
R61—27,000
R62,R77—470,000
R65—47
R72—560,000
R73—250,000 ohm linear-taper pot
R75—100,000 ohm linear-taper pot
R79—200 (5%)
S1,S2,S3—SPST miniature slide switch
S4—two-pole, five-position non-shorting miniature rotary switch (Centralab PS-105, Allied 56 D 5352. $5.04 plus postage, not listed in catalog)
S5—two-pole, six-position non-shorting miniature rotary switch (Centralab PSA-203, Newark Electronics Corp., 500 N. Pulaski Rd., Chicago, Ill. 60624. $4.80 plus postage)
S6—four-pole, four-position non-shorting miniature rotary switch (Centralab PS-111, Allied 56 D 5355. $6.30 plus postage, not listed in catalog)
S7—SPST toggle switch
SO1—five-prong miniature socket (Amphenol 78-PCG5, Allied 47 A 0332)
SR1—Silicon rectifier; minimum ratings: 1 A, 400 PIV
SR2—Silicon rectifier; minimum ratings: 1.5 A, 1,000 PIV (International Rectifier 1N5054 or equiv.)
T1—Power transformer. Available from Universal Transformer Co., Wylie, Texas. $7.50 plus postage, part No. 13699.
V1—1EP1 cathode ray tube (RCA)
Misc.—2 x 9 x 7-in. aluminum chassis (Bud AC406), 7 x 9-in. bottom plate (Bud BPA-1593), two of each required

Build the Micro Oscilloscope for Your Test Bench

Part II: Calibration and Opera[redacted]

By WALT HENRY

IN our January '70 issue we described features and construction of the Micro Oscilloscope. In case you missed that article, here is what the 'scope is all about. It's a really compact instrument with a 1⅛-in. screen-dia. CRT. The vertical amplifier is DC coupled and its response is flat out to 1 mc. Except for the CRT, it is completely solid state and includes four integrated circuits. It has triggered sweep, a calibrated vertical attenuator and measures 2 x 7 x 9 in. (The separate power supply is the same size.) This article covers checkout and calibration procedures and includes the theory of operation.

After you are satisfied your wiring is correct you can adjust and calibrate the 'scope. The following step-by-step procedure should be followed in sequence. If a voltage is out of range or an adjustment will not give the proper result the trouble should be located and corrected before proceeding. You will need a 20,000 ohms-per-volt VOM and a signal generator to properly adjust and calibrate the 'scope.

Initial Turn-On

1) Turn all controls including the screwdriver-adjust trimpots to the center of their rotation. Set S1 and S2 to *AC* (open) and close S3 (non-*auto.* position). Set S4 to 100 V/div., S5 to 0.5 ms/div. and S6 to *hor./trig. in.*

2) Turn on power switch S7 and look

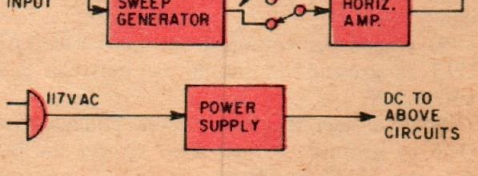


Fig. 1—Block diagram of the 'scope shows the six major sections. The schematics of each are shown in this article and are decribed in complete detail.

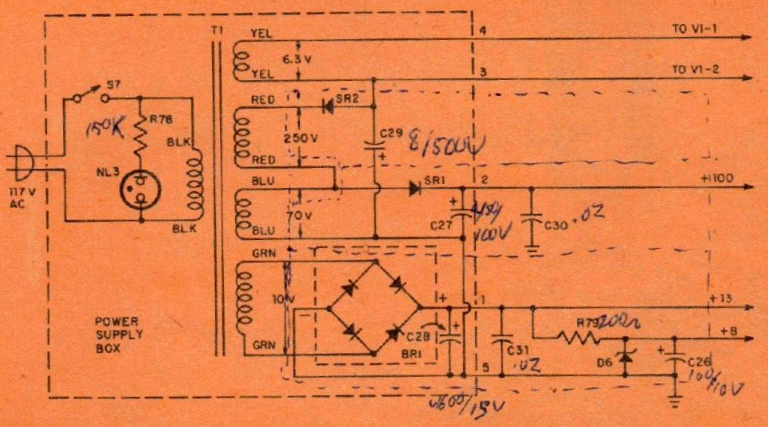


Fig. 2—Power supply furnishes operating voltages to all circuits. —450 VDC for CRT is produced by series connection of 250-V and 70-V windings. If voltage at junction of C29, SR2 is considerably less than —450 V, interchange red leads. Numbers at right of box are the pin numbers of SO1.

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to see if NL3 is on and if heater of the CRT is glowing.

Power-Supply Check

3) Check the DC voltage from the positive end of C28 to ground. It should be between 13 and 16 V.

4) The voltage from C26 to ground should be between 7.8 and 8.6 V.

5) The voltage from C27 to ground should be 90 to 100 V.

6) The voltage from the negative terminal of C29 to ground should be between —420 and —480 V. If the voltage is only about —200 V. the transformer phase is incorrect. Reverse the two red leads and the voltage should be in range.

7) *Power on* lamp NL1 should be on.

Horizontal Amplifier

8) Connect the voltmeter between the collectors of Q11 and Q12. Turning R68 should make the voltage go through zero and reverse polarity. Set it as close to zero as you can.

9) Check the voltage from source lead of Q13 to ground. It should be between 3.5 and 5.5 V.

10) Connect the meter from collector of Q11 to ground. Adjust R66 to get an indication of 45 to 50 V.

11) Recheck the voltage between collector of Q11 and Q12 and readjust R68 to get within 2 V of zero. It may be necessary to alternately adjust R66 and R68 two or three times to get both indications within range.

Vertical Amplifier

12) Remove Q4, Q5, Q6 and Q7 from their sockets. Turn R26 to maximum resistance and R15 to maximum gain (wiper to Q1 end). Make sure R15 stays set this way and that R13 remains centered until step 22. The voltage from the source lead of Q1 to ground should be 1.7 to 2.4 V.

13) Now connect the meter between the source lead of Q1 and the wiper of R14 and adjust R14 to get a zero indication.

14) The voltage from the source lead of Q2 to ground should be 3.4 to 5 V.

15) Connect the meter between the source leads of Q2 and Q3 and adjust R19 for zero volts.

16) Connect the meter between pins 6 and 8 of IC1. Readjust R19 for a zero indication. This is a sensitive adjustment. Get the indication as close to zero as you can with R19, then bring it as close as possible with *vert. pos.* control R18.

17) The voltage from IC1 pin 6 to ground should be from 5.5 to 6.5 V. If it is not in this range select a new value of R21 to bring it in. A further adjustment of the value of R21 may be necessary in step 20.

18) Plug Q4 and Q5 into their sockets. The voltages from each emitter to ground should be identical, and should be between 5 and 6 V.

19) Plug in Q6 and Q7. Connect the meter between their collectors and adjust R18 for a zero indication.

20) The voltage from collectors of Q6

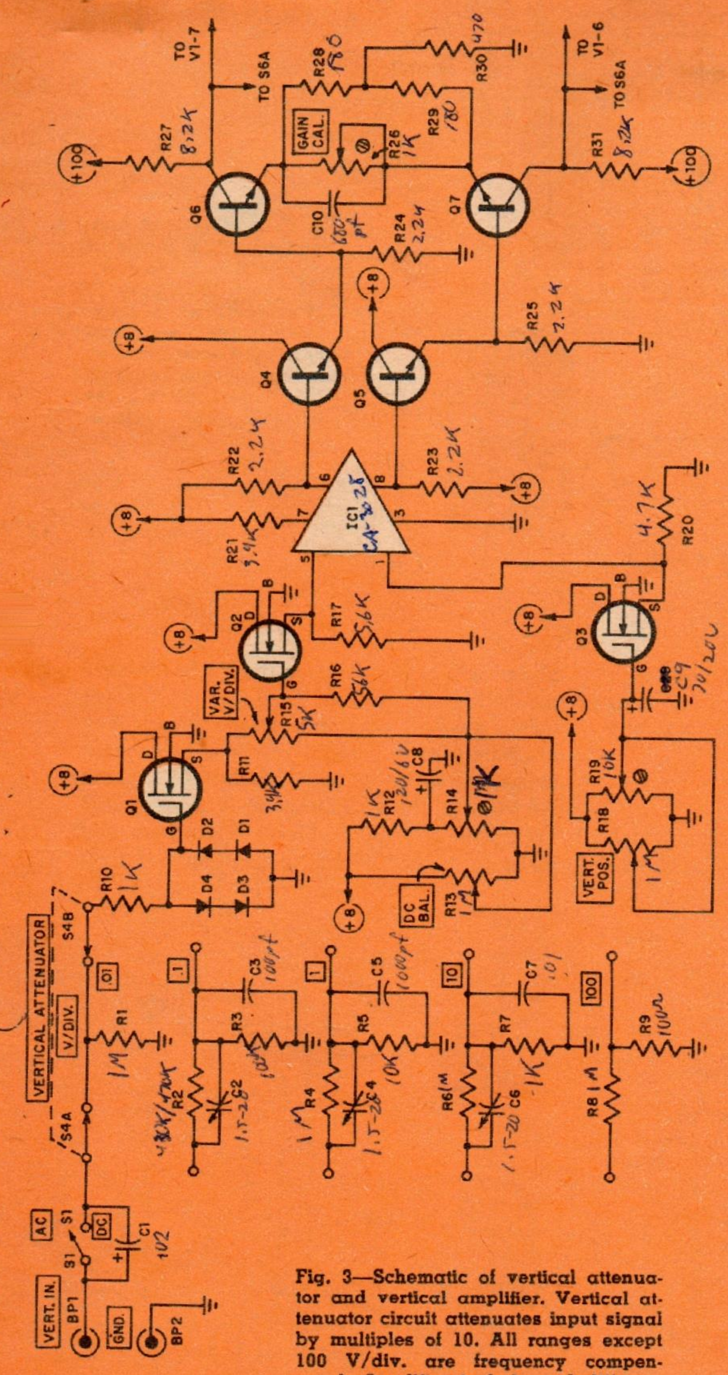

Fig. 3—Schematic of vertical attenuator and vertical amplifier. Vertical attenuator circuit attenuates input signal by multiples of 10. All ranges except 100 V/div. are frequency compensated. Amplifier is balanced differential type and is DC coupled throughout. Diodes D1-D4 protect input against overload. Amplifier output goes to CRT.

and Q7 to ground should be between 45 and 55 V. If it falls outside this range select a new value of R21 to set the voltage near 50 V.

CRT Check

21) Make sure *hor.-pos.* control R69 and *vert.-pos.* control R18 are set so that voltages between collectors of Q11 and Q12, and between collectors of Q6 and Q7 are zero. By adjusting *intensity* control R75 and *focus* control R73 you should get a small sharp dot on the CRT. *Vert.-pos.* control R18 should make the dot move up and down and R68 should make it move left and right. You will probably have to rotate the CRT to get it oriented properly. Don't leave a small extremely bright dot in one spot on the CRT face for a length of time as the phosphor coating may become burned at that spot, permanently damaging the CRT.

22) Set the dot to the center of the CRT with R18 and R69. Now turn *var. V/div.* control R15 and the dot will move up and down. With R13 centered, set R14 to get as little movement of the dot as possible. Adjustment of *DC-bal.* control R13 should then yield a stationary dot when R15 is turned.

23) Turn *vertical-attenuator* switch S4 to each position and make sure the dot remains stationary. Note at this point if you touch *vert. in.* terminal BP1 when S4 is on the sensitive ranges a vertical line will appear on the CRT. Rotate *hor./sync.* control R33

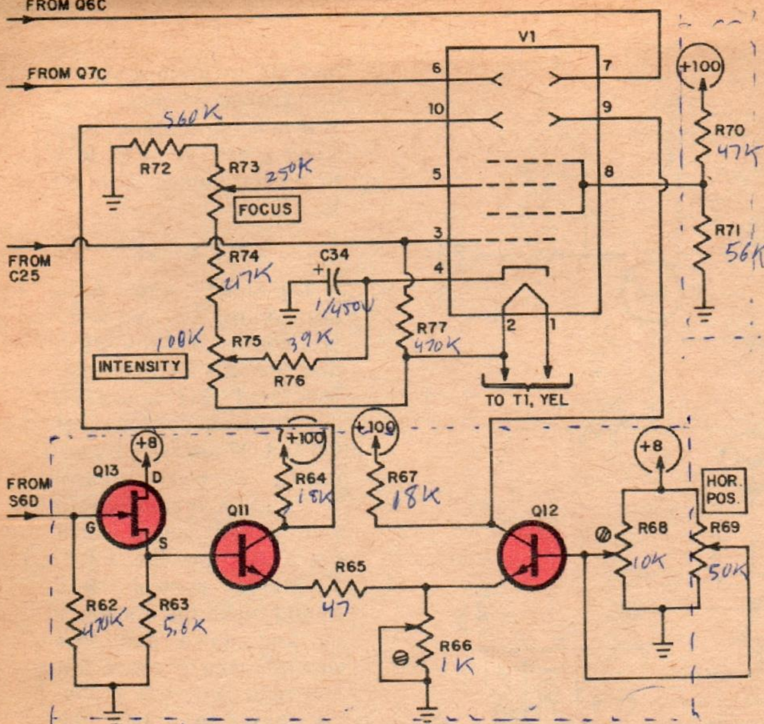

Fig. 4—Schematic of horizontal amplifier. Inputs at top come from vertical amplifier and go directly to CRT's vertical plates. Other inputs are from sweep generator and function selector switch S6. Pots whose names are in boxes are front-panel controls.

through its range and note if the dot stays stationary. Touching the *hor./trig. in.* input terminal (BP3) will cause a horizontal line to appear on the CRT.

Sweep Generator

24) Make sure horizontal-selector switch S6 is in the *hor. in.* position and S3 is closed. From each of the points in the Table measure the voltage to ground. An incorrect voltage means a wiring error or a defective part. Any discrepancies in step 24 should be corrected before going on to step 25. Before making the voltage checks momentarily ground IC2 pin 5 and IC3 pin 3. Don't leave them tied to ground—just touch to ground and then

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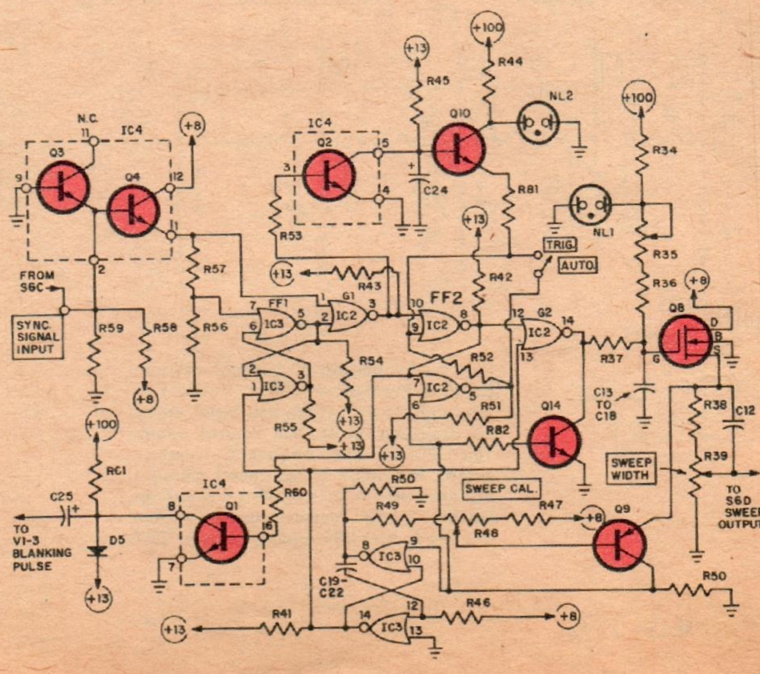

Fig. 5—Sweep generator. This schematic is an expansion of schematic in Fig. 6. Here, ICs are opened up to show functions of different sections. Configurations of FF1, FF2, G1, G2, and one shot (two IC3s at bottom) are shown in further detail in Fig. 7.

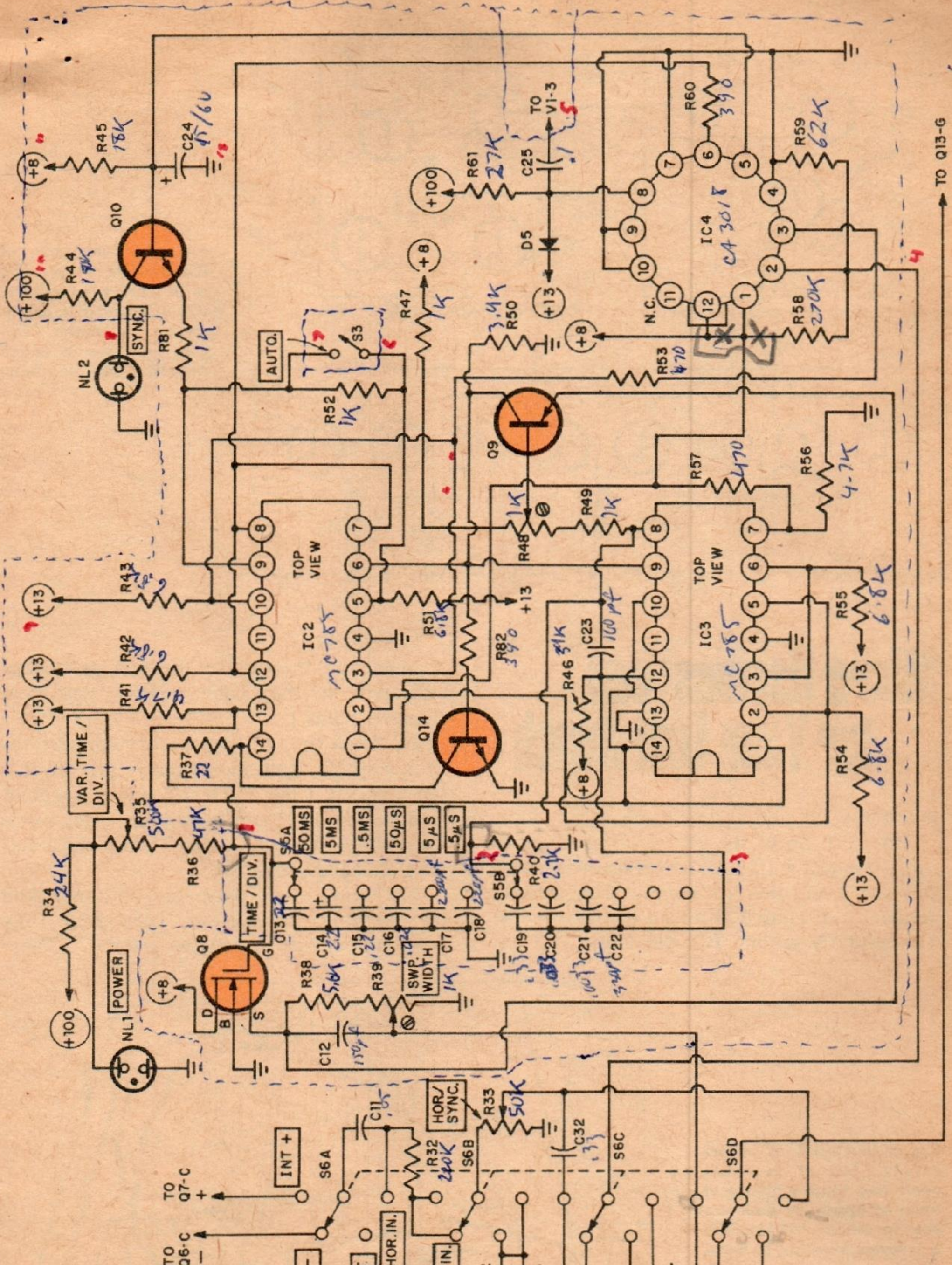

Fig. 6—Sweep generator. IC2 and IC3 are identical digital ICs used in computer-type sequential logic circuit. Sync-lock indicator NL2 is always off when there's no input signal to 'scope. When circuit is properly triggered, NL2 comes on. When S3 is in auto. position the sweep generator will run continuously.

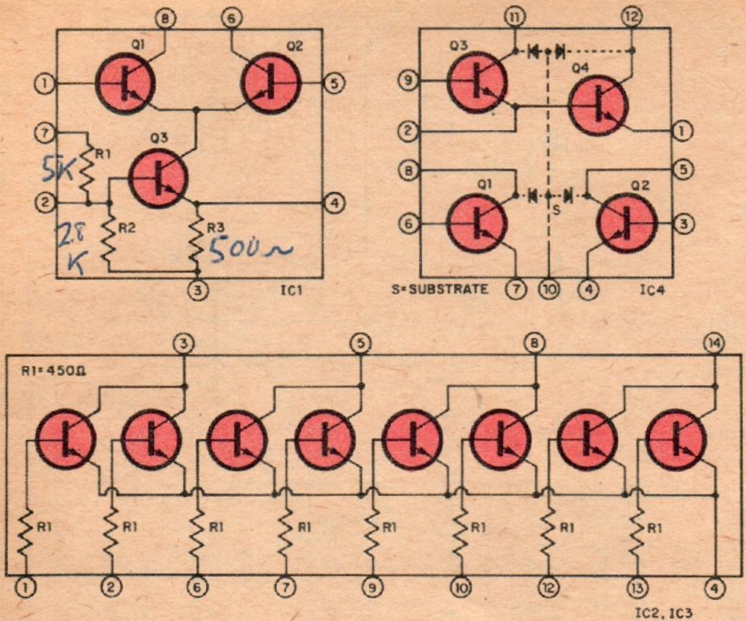

Fig. 7—Schematic of ICs used in 'scope. IC1 is in vertical amplifier. IC2, IC3 and IC4 are in sweep generator. Circled numbers at edges are IC's pin numbers.

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take away the wire.

25) Turn S6 to the *ext.* position. Temporarily connect a 10,000-ohm resistor between IC4 pin 2 and the 8-V supply. Temporarily connect a grounded clip-lead to IC2 pin 14. Momentarily ground IC2 pin 5 and IC3 pin 3 again and then make the voltage checks indicated in the Table. (FF1 has now changed states.)

26) With the same temporary connections as in step 25, again momentarily ground IC2 pin 5 and IC3 pin 3. Then connect a ground lead to IC4 pin 2 and leave it on. Now make the voltage checks in the Table. (FF2 has now changed states.)

27) Remove all temporary grounds and the 10,000-ohm resistor. Turn R33 fully counterclockwise (wiper to ground). There

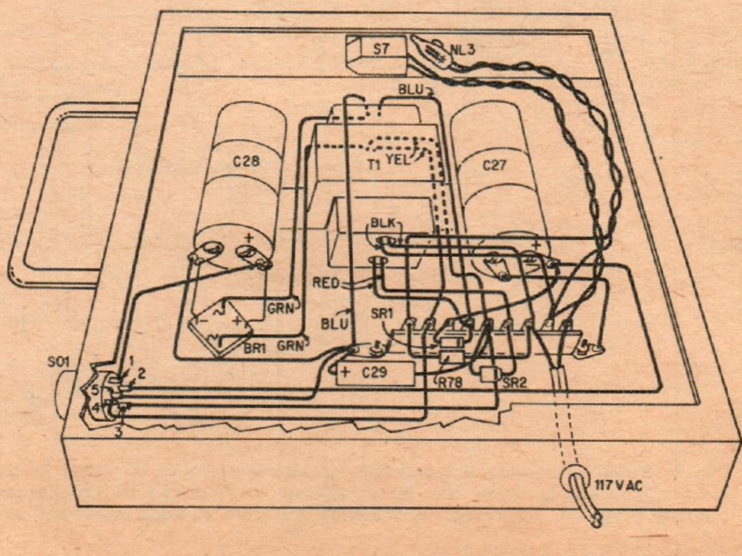

Fig. 8—Pictorial of power supply. Layout is wide open and there's plenty of room to spare as you can see in photo in Fig. 10. It is even possible to build supply in a smaller cabinet.

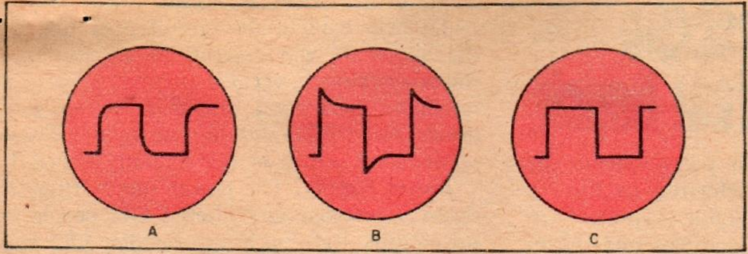

Fig. 9—'Scope patterns reveal adjustment of vertical-attenuator-compensation trimmer capacitors C2, C4, C6. A indicates undercompensation. B shows overcompensation. C shows correct compensation.

should be no sweep on the CRT. Now set S3 to the *auto.* (open) position. A trace should now appear on the CRT. Adjust *swp.-width* pot R39 to get the proper length trace. Turn S5 to each position and see that the trace stays put. On each range turn R35 through its full range and make sure the trace stays put and that NL1 remains on. If NL1 goes off when R35 is turned, the value of R34 should be lowered slightly.

TEST	STEP 24	STEP 25	STEP 26
Sync. lamp NL2	off	off	on
IC2-1, IC4-1	0	4.5-6.7	4.5-6.7
IC2-2, IC3-2, 5	0.9-1.3	LT 0.2	LT 0.2
IC2-3, 10	LT 0.2	LT 0.2	0.9-1.3
IC2-4	gnd.	gnd.	gnd.
IC2-5	LT 0.2	LT 0.2	1.3-1.7
IC2-6, IC3-9	0	0	0
IC2-7, 8, 12	0.8-1.1	0.8-1.1	LT 0.2
IC2-9	LT 0.2	LT 0.2	1.3-1.7
IC2-13, IC3-1, 10, 14	LT 0.2	LT 0.2	LT 0.2
IC2-14	0	gnd.	gnd.
IC3-3, 6	LT 0.2	1.3-1.7	1.3-1.7
IC3-4	gnd.	gnd.	gnd.
IC3-7	0	2.0-3.3	2.0-3.3
IC3-8	3.5-4.5	3.5-4.5	3.5-4.5
IC3-12	0.6-0.8	0.6-0.8	0.6-0.8
IC3-13	gnd.	gnd.	gnd.
IC4-2	gnd.	6-8	gnd.
IC4-3	LT 0.2	LT 0.2	0.6-0.8
IC4-4, 7, 9, 10	gnd.	gnd.	gnd.
IC4-5	0.5-1	0.5-1	LT 0.2
IC4-6	0.6-0.8	0.6-0.8	LT 0.2
IC4-8	LT 0.2	LT 0.2	+13 supply plus 0.7
IC4-12	+8 supply	+8 suppl	+8 supply
Q8-S	1.5-2.5	1.5-2.5	1.5-2.5

Notes: 1) LT means less than
2) 1.5-2.5 means voltage is between 1.5 and 2.5 V
3) Number after IC designation is pin no.

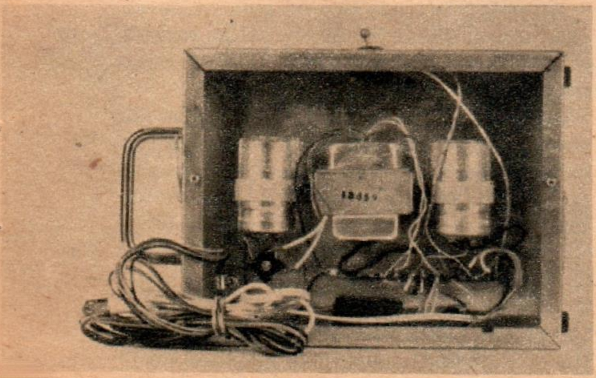

Fig. 10—Inside of power supply. Electrolytics at right and left are mounted with large cable clamps. Our model had cable which connected to 'scope.

28) Set S3 to the closed position. Connect a signal generator to the *hor. in.* and *vert. in.* terminals and adjust for 2 or 3 V amplitude at 1,000 cps. Set S4 to an appropriate range. Turn R33 clockwise until a trace appears on the CRT and locks in as indicated by NL2. Set S5 to an appropriate range and note if turning R35 simply expands or contracts the waveform. Changing the frequency of the signal generator has the same effect.

Sweep Generator Calibration

29) Set the signal generator to 2,000 cps. Set S5 to 0.5 ms/div. and turn R35 full clockwise. Adjust trimmer pot R48 so that one cycle on the CRT occupies exactly one division. Readjust trimmer pot R39 for the proper sweep length. You may also have to readjust the horizontal position. Check calibration of the other sweep ranges using the signal generator.

Vertical-Amplifier Calibration

30) Set S5 to 10 V/div. and connect the signal generator. Set it for about 500 cps and using the voltmeter set the generator amplitude to 7.07 VAC. Make sure R15 is set for maximum gain. Adjust R26 for a two division (peak-to-peak) sine wave on the CRT.

Vertical-Attenuator Calibration

31) Connect a 5,000-ohm carbon potentiometer between IC2 pin 3 and ground, and connect the wiper to *vert. in.* terminal BP1. Connect a signal generator to the *hor. in.* terminal and set it for about a 1,000 cps square-wave output at about a 2-V amplitude. Set S6 to *ext.* and adjust R33 for a stable sweep with NL2 on. Adjust S5 and R35 to get about 1½ cycles of the square wave on the CRT. Set R15 to maximum and

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S4 to 10 V/div. Turn the potentiometer for maximum amplitude. Referring to Fig. 9, adjust compensating capacitor (trimmer) C6 to obtain the properly compensated waveform of Fig. 9C.

32) Repeat the process for the 1 V/div. and 0.1 V/div. ranges adjusting C4 and C2 respectively. Adjust the potentiometer for a convenient amplitude on the CRT for each trimmer adjustment. The 0.01 and 100 V/div. ranges require no compensating adjustment. Frequency response on the 100 V/div. range is somewhat less than the other ranges.

Operating Hints

The 'scope has all necessary controls to serve as a very versatile service or lab instrument. The DC amplifier coupling and triggered sweep are features usually found on 'scopes in the several-hundred-dollar price range. Learning to use these features effectively will greatly enhance the usefulness of your 'scope.

The vertical and horizontal amplifiers are both DC coupled. In general, DC coupling is used only when you wish to view low-frequency waveforms or complex waveforms where you need to know the DC level as well as the amplitude of the AC component of it. Experience is the best teacher and with some practice you will find the DC coupling is often very handy in circuit measurements. *DC bal.* control R13 may need occasional readjustment to keep the CRT trace from moving when R15 is turned.

The most important feature of this 'scope is the triggered sweep. Triggered sweep is locked to the input signal and will not go out of sync if the input frequency changes. Choose the desired sync source, *int.+*, *int.−*, or *ext.* and set R33 for a locked sweep as indicated by *sync.* lamp NL2.

A continuous trace will appear on the CRT even with no trigger signal if S3 is in the *auto.* position. When S3 is closed a trace will not appear on the CRT until there's an input signal. When viewing low-frequency waveforms S3 should be in the closed (non-auto) position for the most stable display on the face of the CRT.

How It Works

To help explain the circuit operation of the 'scope we will describe its six sections: the power supply, vertical attenuator, vertical amplifier, horizontal amplifier, sweep generator and CRT (cathode ray tube). These sections are shown in the diagram in Fig. 1.

Power Supply. The power supply (Fig. 2) delivers rectified and filtered DC power to the circuits. Refer to bridge rectifier BR1 and filter capacitor C28 provide +13 V to power the logic circuits in the sweep generator. The +13 V is regulated down to about 8 V by zener diode D6 to power low-level amplifier stages and other parts requiring a stable DC voltage. Capacitor C26 provides further filtering.

The +100 V supply derived from SR1 and C27 is necessary for the transistor stages that drive the CRT and which require large voltage swings for full-scale deflection. A negative high-voltage DC is required for the CRT. Two windings of power transformer T1 are series connected to SR2 and C29 to develop −450 V. One side of the 6.3-V filament winding is connected to −450 V to keep the CRT heater near the cathode potential.

Vertical Amplifier. This amplifier (Fig. 3) is a balanced differential type and is DC coupled throughout. Transistor Q1, an MOS field-effect transistor, provides the amplifier with an extremely high input impedance. Diodes D1 through D4 protect Q1 from overload. The high input impedance of Q2 prevents amplifier bias change when vertical gain control R15 is turned. Transistor Q3 gives the necessary low impedance to the differential input of IC1 and also reduces circuit drift caused by temperature changes.

Amplifier IC1 has two outputs which are 180° out of phase. These signals go to emitter followers (Q4, Q5) that increase high-frequency response.

Gain cal. Potentiometer R26 varies the amplifier gain for calibration. Capacitor C10 increases the frequency response of the output stages. *DC bal.* control R13 is for occasional front panel adjustment of amplifier balance. Proper adjustment keeps the CRT trace from moving up or down when vertical gain control R15 is turned.

Vertical Attenuator. Switch S4 and associated components attenuate the input signal by factors of 10 for sensitivities of 0.01, 0.1, 1, 10 and 100 V per division on the CRT,

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a division being ¼ in. All ranges except 100 V/div. are frequency compensated. Switch S1 allows selection of AC or DC input signal coupling.

Horizontal Amplifier. Junction FET Q13 (Fig. 4) gives high input impedance. Transistors Q11 and Q12 are emitter coupled to give two signals 180° out of phase to drive the CRT's horizontal plates. Bias of these stages is set by R66. The horizontal amplifier input is either connected to the sweep generator (C25) or to the front-panel horizontal-input terminal (BP3) depending on position of switch S6 (Fig. 6). Switch S2 allows either AC or DC coupling from horizontal input terminal BP3.

Sweep Generator (Fig. 6). Two identical digital integrated circuits IC2 and IC3 are used in a computer type sequential logic circuit. The sweep generator circuit is illustrated in detail in Fig. 5. The gates in IC2 and IC3 are interconnected to form two flip-flops, a one-shot multivibrator and the required signal gating. Another integrated circuit, IC4, contains four transistors; It is shown in Fig. 7. Refer back to Fig. 5 now. Transistor Q4 operates as an emitter follower to maintain high input impedance. The base-emitter junction of Q3 has a reverse zener breakdown of about 7 V, to protect Q4 from large input-voltage swings.

Flip-flops FF1 and FF2 and gates G1 and G2 are interconnected so that FF1 triggers on the positive slope of an input signal and FF2 triggers on the following negative slope. Thus C13 through C18 (switched by S5A) can begin to charge only on the negative slope of an input signal. Control R35 controls the charging rate of C13 through C18. Neon lamp NL1 serves as a voltage regulator for the charging circuit and also as the power-on indicator on the scope panel.

When the sweep voltage reaches sufficient amplitude, Q9 turns on and triggers the one-shot (IC3). Sweep-calibration control R48 sets the voltage at which Q9 turns on and thus controls the amplitude of the peak voltage reached on C13 through C18. The one-shot keeps the input signal from triggering the circuit again until C13 through C18 has time to fully discharge.

The CRT is blanked while C13 through C18 is discharging (retrace time). Transistor Q1 (in IC4) is driven by FF2 and supplies a 13-V blanking pulse through C25 to the control grid of the CRT.

A unique feature of the sweep circuit is sync-lock indicator NL2. With no input signal present NL2 is off. When the circuit is properly triggered, however, Q2 (in IC4) discharges C24 turning off Q10 and NL2 comes on. When in the *auto.* position switch S3 will cause the sweep generator to run continuously even though an input signal is not present. When S3 is closed there is no sweep unless the circuit is triggered by an input signal.