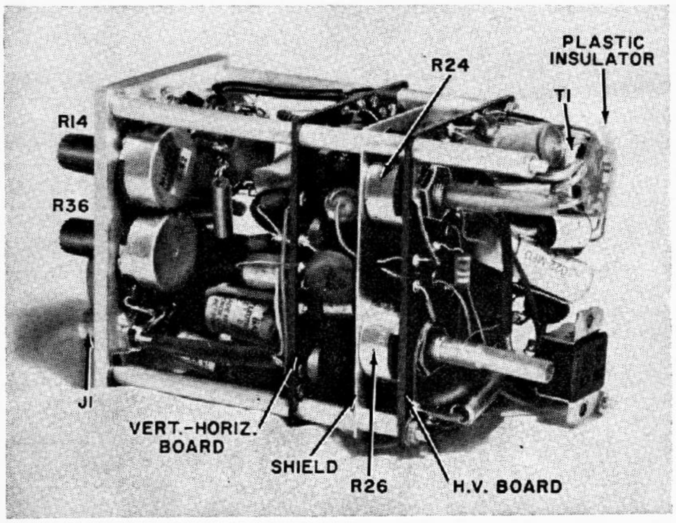
A MINIATURE, TRANSISTORIZED OSCILLOSCOPE

By **THOMAS J. BARMORE**



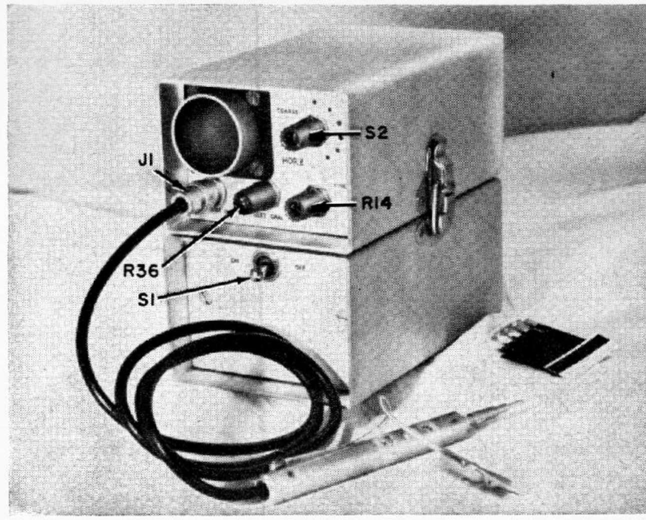


Fig. 1. Greatest dimension of the handy unit complete with power pack, its depth, is less than the width of this page.

Fig. 2. Shown out of its housing, the complete scope chassis is lying on one side, with its front facing left. Note the mounting and spacing of the two chassis boards and the shield.

Look at this portable's specifications before you let its size, weight, cost, and operation from self-contained, low voltage deceive you.

A COMMONLY used instrument today, the versatile oscilloscope has been extended to many functions beside that of merely examining waveforms. Considering its potential, it would be handy to carry one wherever testing may be needed. Unfortunately, size, weight, and the need for line voltage have limited use to the fixed test bench.

The scope described here is the author's answer to the problem. About the size of two boxes of kitchen matches, using transistors and self-powered by batteries, it is lightweight and fully portable. Operating controls (Fig. 1) as well as size have been cut to a minimum. Vertical gain (R_{36}) and horizontal frequency (S_2, R_{14}) are adjusted at the front; brightness and focus at the rear. Sweep width and centering are fixed without controls. Synchronization is also automatic, without external control. The instrument obviously falls short of deluxe laboratory instruments, but it meets or exceeds the modest capabilities one might expect in a carry-about unit.

Vertical-channel response is only 1 db down from 10 cps to 1 mc., 3 db down from 5 cps to 1.5 mc. (See Fig. 5.) Sensitivity is excellent (.004 volt r.m.s./inch at 1 kc.); input impedance is 1 megohm at 1 kc.; and rise time is .25 microsecond. Sweep frequency, provided in six overlapping, switched steps and a vernier control, ranges from 5 cps to 50 kc. The 1½-inch scope tube is a 913 or equivalent. A 45-volt battery and 4 flashlight cells provide the necessary power.

Of the problems involved, an important one was the requirement of most CR tubes for a higher deflection potential than can be obtained reasonably with transistors. This was solved by substantially lowering accelerating voltage. Satisfactorily bright traces were nevertheless obtained, and deflection sensitivity went up significantly. For the rest, nine transistors, not expensive, are used in conventional configurations. See Fig. 4.

Vertical Amplifier

Vertical-input stage V_1 uses a 2N170 as an emitter-follower to keep input impedance reasonably high; the latter ranges from 1 megohm at 20 cps to 50,000 ohms at 100 kc. V_1 output, developed across R_1, is coupled through C_2 to driver V_2, whose base bias is furnished by R_2. High-frequency compensation is obtained by bypassing R_3 with a smaller capacitor (C_3) than is normally used. This capacitor's reactance,

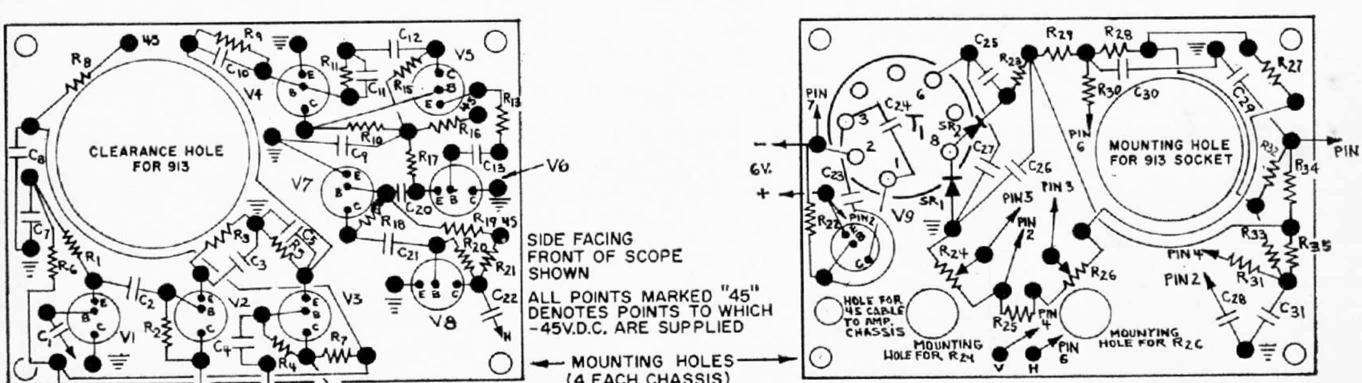


Fig. 3. Two chassis boards, drawn to scale here, contain most of the circuitry.

high at low frequencies, becomes a few oh[illegible] at higher frequencies, permitting [illegible] gain to increase. V_2 output is developed across vertical-gain control R_{36}, from which signal is tapped off and applied through C_4 to the vertical-output stage.

Output stage V_3 is operated like its preceding driver. A synchronization signal, developed across R_5, is applied to the horizontal oscillator. Two decoupling networks (R_6-C_7 and R_8-C_8) serve to isolate the driver and output stages from other circuits.

Horizontal Circuits

The horizontal oscillator (V_4 and V_5) is a multivibrator, with R_{10}, R_{15}, and C_{12} furnishing the operational mode for the generated pulse. The time constant is varied by the resistors R_{12} and R_{14} in conjunction with capacitors C_{14} through C_{19}, which form the integrated, saw-tooth waveforms. Synchronization is furnished by applying a signal from V_3, as already noted, to the base of V_4 through the network consisting of R_9 and C_{10}. C_9 and R_{16} form a decoupling

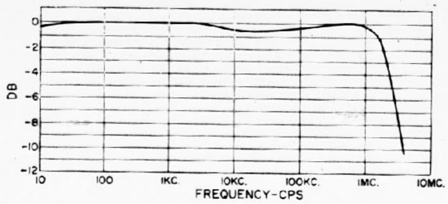


Fig. 5. Response of the vertical channel.

network to isolate the oscillator from other circuits. Oscillator output from V_5 is coupled through R_{13} and C_{13} to the base of V_6.

Since impedance of the oscillator output is relatively high, the first stage in the horizontal amplifier, V_6, is a 2N170 employed in a grounded-collector configuration to give the necessary high input impedance. The signal, developed with unity gain across R_{17}, is coupled through C_{20} to driver V_7.

The driver and succeeding horizontal-output stage, V_8, are conventional. Base bias is furnished respectively by R_{18} and R_{20}. V_8 output is then coupled to the horizontal deflection plate through C_{22}.

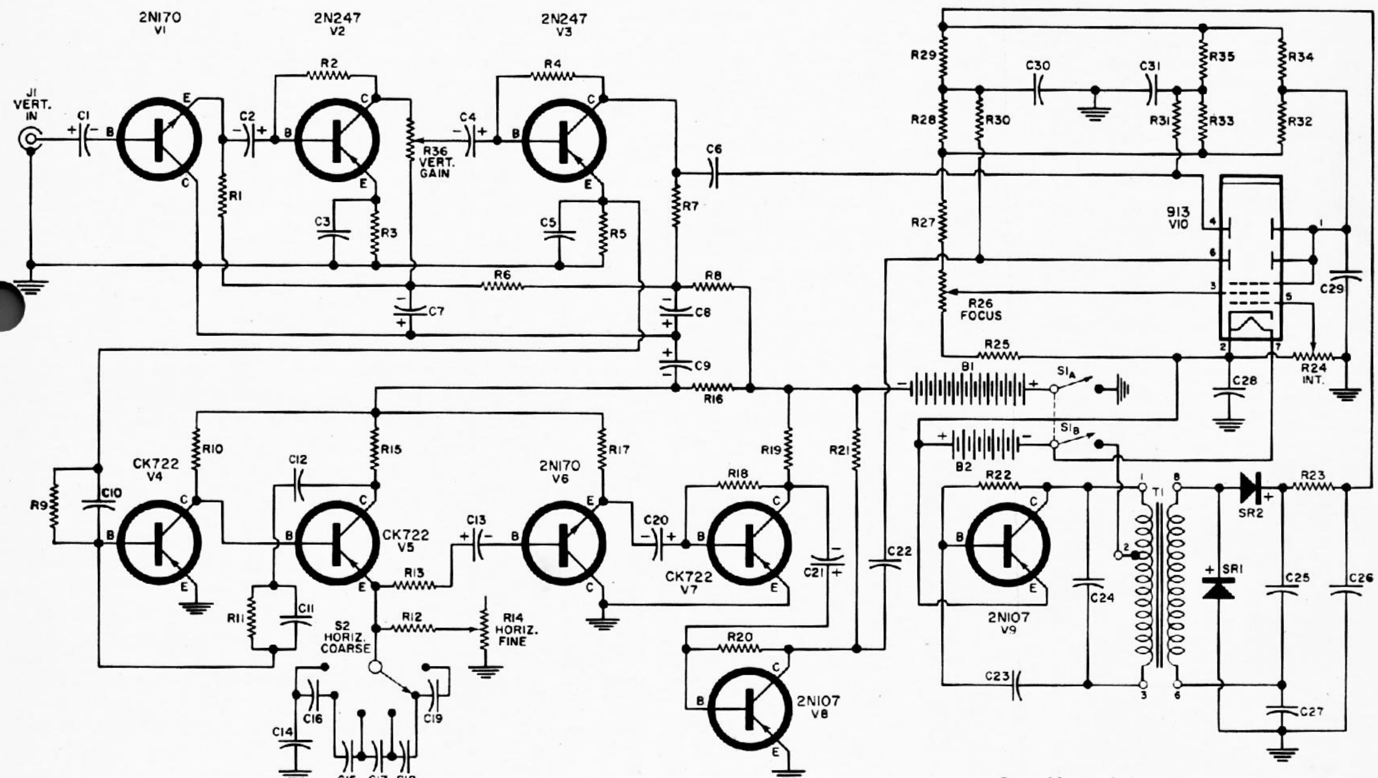
Note that gain of the horizontal amplifier is set to maximum by adjustment of the value of R_{18}. No gain control is used because output voltage of the amplifier must be as high as possible in order that horizontal sweep will be of sufficient amplitude.

The Power Supplies

The high-voltage supply uses a 2N107, V_9, as a Hartley oscillator, whose tuned circuit is made up of T_1 and C_{24}. Output voltage is controlled by the feedback loop consisting of R_{22} and C_{23}. The T_1 secondary feeds a voltage doubler that includes rectifiers SR_1 and SR_2 in conjunction with capacitors C_{25} through C_{27} and resistor R_{23}. The transformer is normally a line-to-grid audio unit, a *UTC* "Ouncer." This little supply develops about 300 to 400 volts d.c. at 100 microamperes, which is sufficient for good trace brightness.

High voltage is then distributed through a divider network consisting of resistors R_{24} through R_{29}. Two of these are controls: R_{24} for intensity and R_{26} (*Continued on page* 72)

Fig. 4. The small CRT, two semiconductor rectifiers, nine common transistors, and a miniature transformer are the major components.



R_1, R_{17}, R_{23}—100,000 ohm, ½ w. res.
R_2, R_{32}, R_{34}—47,000 ohm, ½ w. res.
R_3, R_5—100 ohm, ½ w. res.
R_4—330,000 ohm, ½ w. res.
R_6, R_7, R_{16}—10,000 ohm, ½ w. res.
R_8—560 ohm, ½ w. res.
R_9—150,000 ohm, ½ w. res.
R_{10}—22,000 ohm, ½ w. res.
R_{11}—82,000 ohm, ½ w. res.
R_{12}—150,000 ohm, ½ w. res.
R_{13}—10 megohm, ½ w. res.
R_{14}—10 megohm pot.
R_{15}—6800 ohm, ½ w. res.
R_{18}—56,000 ohm, ½ w. res. (see text)
R_{19}—8200 ohm, ½ w. res.
R_{20}—820,000 ohm, ½ w. res.
R2[illegible],000 ohm, ½ w. res.
R[illegible] ohm, ½ w. res.
R2[illegible]0,000 ohm linear taper pot.
R_{25}—470,000 ohm, ½ w. res.
R_{26}—500,000 ohm linear taper pot.
R_{27}, R_{30}, R_{31}—2.2 megohm, ½ w. res.
R_{28}, R_{29}, R_{33}, R_{35}—1 megohm, ½ w. res.
R_{36}—10,000 ohm linear taper pot.
C_1, C_4—20 µf., 25 v. elec. capacitor
C_2—75 µf., 25 v. elec. capacitor
C_3—.002 µf., 200 v. capacitor
C_5, C_{17}—.005 µf., 200 v. capacitor
C_6—.01 µf., 400 v. capacitor
C_7, C_{29}—5 µf., 25 v. elec. capacitor
C_8—10 µf., 50 v. elec. capacitor
C_9—5 µf., 50 v. elec. capacitor
C_{10}, C_{18}—500 µµf., 200 v. capacitor
C_{11}—20 µµf., 200 v. capacitor
C_{12}—.02 µf., 200 v. capacitor
C_{13}—1 µf., 25 v. elec. capacitor
C_{14}, C_{28}—.1 µf., 200 v. capacitor
C_{15}—.01 µf., 200 v. capacitor
C_{16}, C_{24}—.03 µf., 200 v. capacitor
C_{19}—100 µµf., 200 v. capacitor
C_{21}—20 µf., 25 v. elec. capacitor
C_{22}—.1 µf., 400 v. capacitor
C_{23}—.22 µf., 200 v. capacitor
C_{25}, C_{27}—.01 µf., 600 v. capacitor
C_{26}—.03 µf., 600 v. capacitor
C_{29}, C_{30}, C_{31}—.005 µf., 400 v. capacitor
T_1—Line-to-grid trans. pri: 50-500 ohms, sec: 50,000 ohms (UTC 0-2 "Ouncer")
S_1—D.p.s.t. toggle switch
S_2—6-pos. non-shorting rotary switch
SR_1 SR_2—Silicon rectifier, 600 p.i.v. (Sarkes Tarzian F-6 or equiv.)
B_1—45-volt battery (Burgess XX30 or equiv.)
B_2—Four size "D" flashlight cells
J_1—BNC panel connector (Type UG-262/U)
V_1, V_6—"n-p-n" transistor (G-E 2N170)
V_2, V_3—"p-n-p" transistor (Sylvania 2N247)
V_4, V_5, V_7—"p-n-p" transistor (Raytheon CK722).
V_8, V_9—"p-n-p" transistor (G-E 2N107)
V_{10}—913 cathode-ray tube (or equiv. If unavailable, the electrically similar 2AP1 can be used with minor changes in a somewhat larger housing.)

A Miniature Oscilloscope

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for focus. Vertical and horizontal positioning is fixed, centering being established by the values of R_{33}-R_{35} and R_{28}-R_{29} respectively. Normally the CRT is constructed symmetrically enough so that, if balanced voltage is applied to the deflection plates, the trace will be centered. If values of the resistors mentioned are adjusted to accomplish this, where necessary, controls can be eliminated.

Power for the high-voltage oscillator and the CRT filament is obtained by four flashlight cells in series, B_2. The other circuits draw on a small, 45-volt battery, B_1. Both sources are switched on and off simultaneously by S_1, a d.p.s.t. switch.

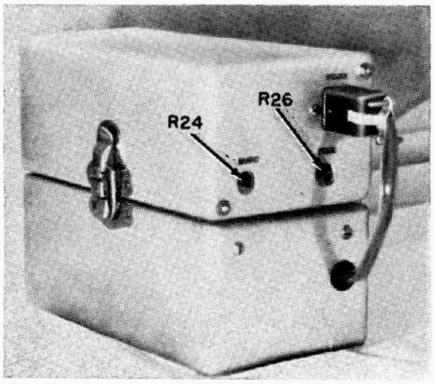

Fig. 6. Rear view of twin case assembly shows the intensity and focus controls.

Construction

Although it might appear a bit out of the ordinary, construction of the oscilloscope was chosen to accommodate standard components in small space. Most components and wiring were contained on two cloth-based phenolic boards, 1/16-inch thick, measuring 2½ by 3½ inches each. They are shown in Fig. 3 about three-quarters of life size, but drawn to scale. Hollow brass eyelets were used as tie points by the author. The horizontal and vertical channels were built on one chassis, with the high-voltage oscillator, divider, and positioning networks on the other. When mounted, the chassis boards are separated by an aluminum shield of the same size.

The case in which the scope is housed is simply an aluminum box measuring 2½ by 3½ by 6 inches, open at one end, with openings made at the rear (Fig. 6) for the brightness and focus controls and for mounting the power connector. Another case just like it is used to house the batteries.

The CRT bezel, horizontal coarse- and fine-frequency controls, vertical-input jack, and vertical-gain control (Fig. 1) are all mounted on the front panel, because these are the ones that will be most frequently used. The rear controls may be adjusted by shaft-extending plastic sleeves that protrude from the rear.

Once the chassis boards are wired, assembly is in the following order: front panel, horizontal-vertical chassis, shield, and high-voltage chassis, as shown in Fig. 2. The chassis and shield are held apart by aluminum spacers (the author cut sections of gas-burner pipe), through which four 6-inch lengths of threaded, aluminum welding rod are inserted. The straightforward arrangement in the battery case is shown in Fig. 8.

Since the instrument is very sensitive, the builder will probably want to construct an attenuator probe, as did the author. His, shown in Fig. 1 connected to the oscilloscope, includes a switch so that the probe may be used direct or with attenuation. In the latter position, of course, it increases input impedance of the instrument.

The probe circuit (Fig. 7) is quite simple. A resistor, bypassed with a small capacitor, is in series with the center conductor of about three feet of RG-59/U coaxial cable. About 10 megohms of resistance should be used for every 20 db (10 times) of desired attenuation. The capacitor is used for cable compensation. A small, variable unit may be used; the author employed a "gimmick" of five twists of #30 enamel wire. The probe housing should be metal for shielding.

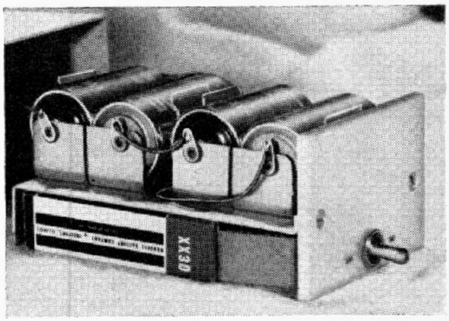

Fig. 8. Battery layout in bottom case.

The compensating capacitor is adjusted, once the scope is operating, by applying a 1000-cps square wave through the probe and working for waveform edges that show neither peaking nor rounding. The degree of attenuation built into the probe is best determined with some experimentation based on the amplitude of waveforms that the user is likely to be investigating. ▲

Fig. 7. Attenuator probe should be shielded. A gimmick may be used as compensating capacitor.