

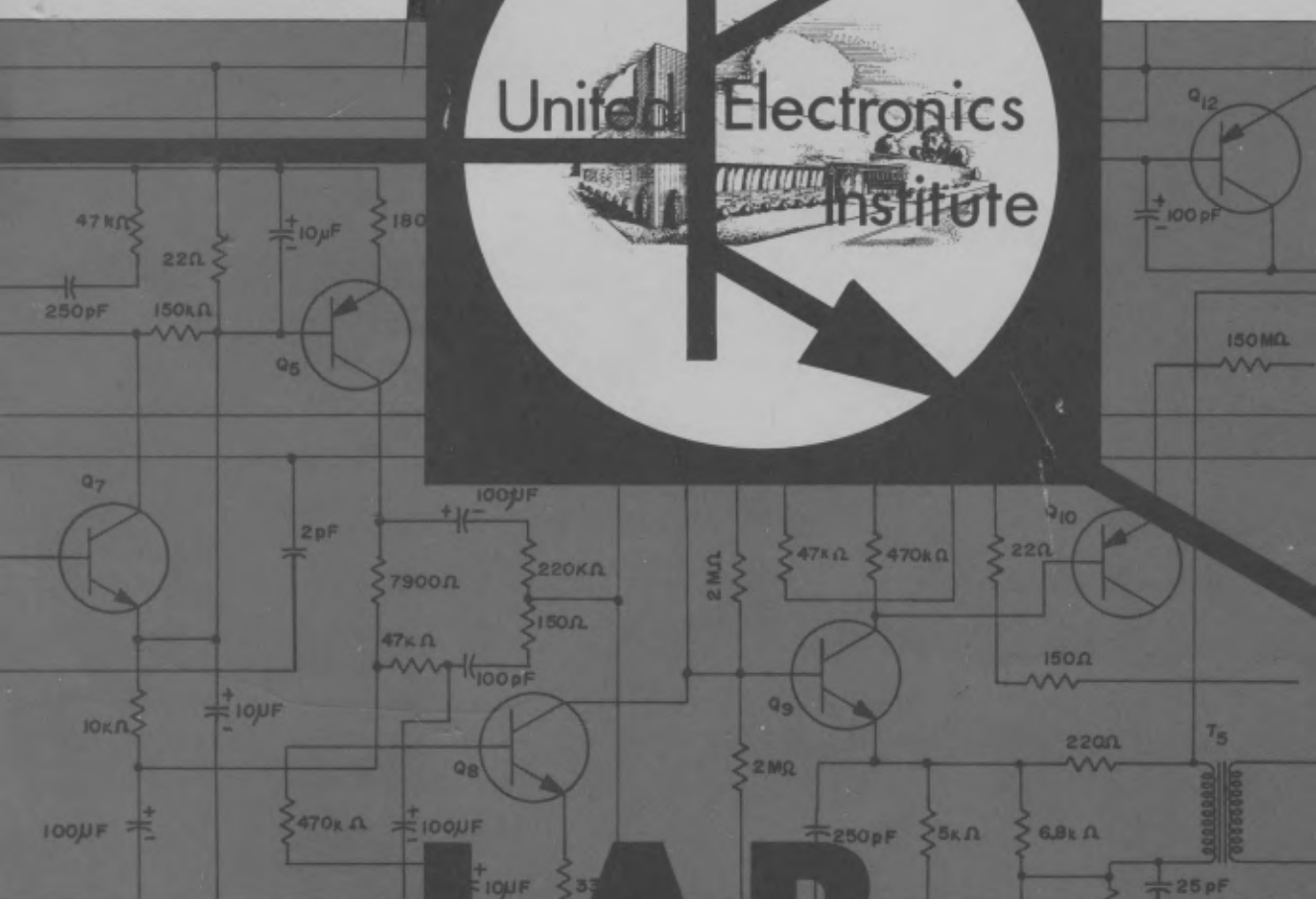
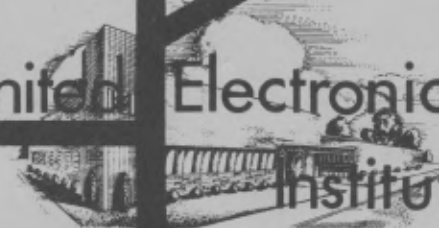
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EXPERIMENT NO. 16

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**U E I**  
**LABS**

**THE CATHODE-RAY OSCILLOSCOPE**

## LABORATORY EXPERIMENT NO. 16

### THE CATHODE-RAY OSCILLOSCOPE

The cathode-ray oscilloscope, as you have learned, provides a **visual** presentation of an electrical signal. Thus it makes it possible to actually “see” the electrical occurrences at various points within a circuit. As a consequence, the cathode-ray oscilloscope is probably the most valuable service tool available for a technician’s use. The more complex a piece of electronics equipment is, the greater is the value of the CRO when servicing it. To illustrate; a CRO can be used when a four- or five-transistor radio is being serviced, but will probably not be of great assistance. On the other hand, when analyzing a computer, or a radar unit, an oscilloscope is an absolutely essential service instrument.

In addition to their use as test instruments, CRO’s are often used as the **indicating devices** in many different kinds of equipment. For example, in the medical electronics field, a heartbeat may be picked up by a transducer, amplified, and **displayed** on a CRO. Similarly, the tiny voltages generated by nerves may be “picked up”, and observed on a scope. CRO’s are the indicating devices in radar units, in many industrial electronics applications, and in auto-diagnostic equipment. In fact, any electrical signal, or any other phenomenon which can be converted to an electrical signal by a transducer, may be analyzed through the use of a scope. Thus, it is obvious that an electronics technician needs to have a **thorough** understanding of cathode-ray oscilloscopes.

The cathode-ray oscilloscope which you will build in this experiment employs four triodes, one pentode, and a cathode-ray tube (CRT). Two solid-state power supplies provide the operating voltages. Each circuit will be analyzed before being assembled on the chassis. Circuit resistance measurements will be made as each section of the CRO is completed. When the wiring is completed, voltage measurements and circuit waveforms will be taken.

### Instructions For Performing The Experiment

1. Review Assignment Number 47.
2. Read through each Part of the Experiment before performing the assembly steps.

3. Perform each Step, in each Part, in the order given, and record your measurements.
4. Study and analyze your results.

### PRECAUTION

The d-c voltages used in this CRO range up to a potential difference of approximately 1240 volts. A negative 800-volt and a positive 440-volt power supply is employed. You may have let yourself become careless in regard to touching circuit parts while working on your transistor radio. **DO NOT BECOME CARELESS IN THIS EXPERIMENT**, rather **BE CAREFUL**. Do not make circuit changes, or work on a circuit while the power supply is energized. Employ a great degree of caution in making voltage measurements. Do not move the chassis about with power applied.

In addition to the danger of shock from high-voltage d-c circuits, it should be borne in mind that the 110-volt a-c input circuit, and the a-c voltage at the secondary of the power transformer, constitute sources of danger since it is possible to be subjected to a serious shock from such sources. In brief: **BE VERY CAREFUL!**

## Parts Supplied With Laboratory Experiment 16

The parts and equipment supplied with this Laboratory Experiment are listed in Figure 1(A). Check the parts which you receive against the list to be sure you have all of them. If any part which you receive is obviously defective or damaged, return it immediately for replacement.

In addition to the parts supplied with this Laboratory Experiment, you will use those parts which were issued with the preceding Laboratory Experiments, except those used in Laboratory Experiment 15. You should make such parts ready for your use at this time. The complete Bill of Material for the CRO is given in Figure 1(B).

## PART I

### The Cathode-Ray Oscilloscope

A schematic diagram of the CRO which you will assemble is given in Figure 2. Block diagrams appear in Figures 3 and 4. This scope employs one type-3RP1 cathode-ray tube, one type-12AT7 twin-triode tube (or industrial equivalent, 6211, 5963, 5965, etc.), one type-6BH11 twin-triode-pentode tube, and four silicon diode rectifiers. The vertical amplifier of the CRO uses one of the type 12AT7 triodes and the pentode section of the 6BH11. The other type 12AT7 triode and the two 6BH11 triodes are used in the horizontal sweep circuits. Two of the silicon diodes

are used in a full-wave-rectifier circuit in the +435-volt low-voltage power supply. The other two silicon diodes are used in a voltage-doubler circuit in the -800-volt high-voltage power supply.

The UEI Model 301 CRO provides three horizontal sweep ranges, with sweep frequencies of 30 Hz to 500 Hz, 500 Hz to 5 kHz, and 5 kHz to 100 kHz. Provisions are included for synchronizing the horizontal sweep with the vertical input signal, or an external synchronizing signal may be used if desired. A fourth sweep range position makes it possible to apply an external horizontal input signal to the horizontal deflection plates of the CRT.

### STEP 1. Analysis of the CRO Block Diagram, Internal Sweep

The block diagram of Figure 3 illustrates the circuit arrangement when the CRO is operated in the most widely used fashion - employing the internal sweep generator to produce horizontal deflection of the CRT beam. The vertical input signal is capacity-coupled to the vertical-gain-control potentiometer. This coupling capacitor has a 600-volt rating. It is important that the input signal to the CRO never exceed the 600-volt rating of this vertical-input coupling capacitor. The vertical input signal from the gain control is fed to the first vertical amplifier, thence to the second vertical amplifier. The amplified vertical input signal is then fed to one of the vertical deflection plates of the cathode-ray tube (CRT). The other vertical deflection plate is grounded, as far as the signal is concerned.

The horizontal sweep generator, a multivibrator, produces the horizontal sweep signals for the CRT. The sweep-range switch,  $S_2$ , is in this circuit. The multivibrator, in any sweep range, has a square wave generated at the plates of the two multivibrator triodes as shown in Figure 2. One part of the square wave is of longer duration than the other. The longer portion of that waveform is shaped into a sawtooth waveform at the cathode of  $V_{1B}$ , amplified and inverted by  $V_{2C}$ , and used as the CRT horizontal sweep signal. The sweep signal causes the CRT beam to move across the CRT from left to right (facing the tube). Of course, a portion of the sweep waveform also causes the beam to return to the left side of the CRT after each sweep. The shorter portion of the multivibrator square wave is coupled from the plate of  $V_{1B}$ , via  $C_{13}$ , to the grid of the CRT to blank the retrace signal. Positioning controls are provided for positioning the beam on the face of the CRT.

As the beam is deflected, vertically by the signal from the vertical amplifier, and horizontally by the signal from the horizontal sweep circuit, a graph of the vertical input signal with respect to time appears on the face of the CRT.

Provisions are included for synchronizing the horizontal sweep generator with a portion of the vertical input signal, or with an external signal. Selection is made by a choice of the two positions of  $S_3$ , the sync switch.

The CRO is most commonly used in the mode illustrated in the block diagram

of Figure 3. When it is desired to use an external sweep signal, instead of the internally generated sweep signal, another operating mode, as indicated in Figure 4 is employed.

### **STEP 2. Analysis of the CRO Block Diagram With An External Horizontal Signal As Sweep**

Under some conditions it is desirable to use an external sweep signal. The block diagram of Figure 4 shows the CRO switched to the "Horizontal Input" mode, selected by the sweep range switch  $S_2$ .

In this mode the vertical amplifier operates as before, but the horizontal circuit operates differently.  $V_{2B}$  is now a voltage amplifier and amplifies the horizontal input signal, applying it to  $V_{1B}$ , which operates as a cathode follower.  $V_{2C}$  further amplifies the signal for application to the horizontal deflection plates of the CRT.

The operation of the positioning controls is unchanged in either mode of operation.

## **PART II Preliminary Assembly And Wiring**

In this Part of the experiment the power transformer, filter choke, filter capacitors for the low-voltage power supply, tube sockets, terminal strips, and four resistors are installed on the chassis. The transformer, choke and capacitor wires are connected to their proper tie points. Some additional parts and wiring are installed at this time, since it is most convenient to do so.

Throughout this entire Experiment, make a concerted effort to produce perfect solder joints and to dress your parts and wires so that you will be proud of the appearance of your scope, as well as its operation.

### **STEP 1. Wire Coding Notation**

A form of "shorthand" used by layout draftsmen in industry, when they make wire connection drawings of a piece of electronics equipment, is called "wire-coding notation". It saves a lot of lettering on the drawings, and it is quite easy to understand. The wire coding simply tells you where to connect a wire or a part. This method of notation has been explained previously, but will be reviewed at this time.

In the explanatory drawing of Figure 5 a terminal strip, TS-7, a potentiometer,  $R_9$ , a tube socket,  $V_2$ , a 220-k $\Omega$  resistor,  $R_{15}$ , and some inter-connecting wires are shown. In the drawing it may be seen that wire number 1 connects between terminal 5 of TS-7 and terminal 3 of potentiometer  $R_9$ . Coded, this becomes:

5TS7 to 3R9, or 5TS7-3R9

The terminal number 5 and the number of the terminal strip form the first group. The terminal number of the potentiometer and the circuit symbol of the potentiometer form the second group.

In describing where to connect  $R_{15}$  for example, notice the difference in the length of the following hookup directions: (1) Connect  $R_{15}$  from terminal 1 of TS-7 to pin 8 of the  $V_2$  socket. (2)  $R_{15}$  1TS7-8V2. Check the other connections in Figure 5 to make sure you are familiar with this method of wire connection notation.

This notation is especially useful when the point of connection of a wire is not included on the drawing, as is the case in the bottom view of a chassis where a wire is routed through a hole to the top of the chassis and connected to a part mounted on, or above, the top of the chassis.

In the case of wire number 3 in Figure 5, the free end of that wire, coded 2R25, connects to terminal 2 of potentiometer  $R_{25}$ . Terminal coding on the potentiometers is clockwise, looking at their back.

Wire number 2 connects to terminal 1 of switch  $S_3$ .

To assure that you understand the method of coding, complete the following sentence: Wire number 4 of Figure 5 connects between \_\_\_\_\_ of \_\_\_\_\_ and \_\_\_\_\_ of \_\_\_\_\_.

This notation is used in the assembly and wiring illustrations in this Experiment. Refer to Figure 6 which shows the hardware location and orientation for this Part of the Experiment. Can you find a length of high-voltage (HV) wire connected 3TS3-2TS4? \_\_\_\_\_.

## STEP 2. Mounting Hardware and Preliminary Wiring

Install the 9-pin tube socket, using 3-48 hardware. Install the 12-pin tube socket, the terminal strips, the power transformer, and the filter choke using 6-32 hardware.

Cut and dress the leads of the choke and transformer (as well as all other leads) as you see fit to make a neat wiring job with no large, lazy, loops in the wiring, nor with the wires stretched taut.

It is necessary in a piece of equipment of this type to keep lead lengths to a minimum and to arrange the lead placement so as to keep down distributed capacity and inter-lead coupling. Since the capacity present between the a-c leads and the chassis presents no problem, the usual procedure is to wire the a-c circuits first and to place these leads flat against the chassis. Where applicable, the a-c leads are usually twisted so that the magnetic fields produced by the current flowing through the two wires will counteract each other and thereby minimize the a-c coupling into other circuit components and leads of the equipment.

To create the desired results in the wiring of this oscilloscope you will have to apply yourself to doing a "neat" job. Neat in appearance generally means a good wiring job; not necessarily because it is pretty, but because of the fact that the wires are as short as possible, and components mounted smartly between two points tend to keep the aforementioned capacity to a minimum while, at the same time, providing a rigid mounting arrangement.

The assembly and wiring of your scope should reflect your ability as a technician to do a professional-like job of planning and executing the construction of a piece of test equipment. Such things as loose or sagging wires, splices where wires were cut too short, or helter-skelter components indicate poorly-planned slipshod construction.

You should plan to proceed with this project as if this piece of equipment were going to be inspected by an electronics supervisor who was considering hiring you. Do a job on this scope that would recommend you to anyone in the electronics field. With these suggestions in mind — proceed with the wiring.

Note in Figure 6 that the remnant piece of green-yellow wire from the transformer is cut into two pieces of equal length and used for 5V1-12V2, and 9V1-1V2.

After you have wired the transformer, choke, and capacitor leads, install resistors  $R_{11}$ ,  $R_{17}$ ,  $R_{18}$ , and  $R_{34}$  as follows:

$R_{11}$ , 1 M $\Omega$ , 4V2-GTS4

$R_{17}$ , 2.2 M $\Omega$ , 6V2-GTS4

$R_{18}$ , 2.7 k $\Omega$ , 5V2-GTS4

$R_{34}$ , 47 $\Omega$ , 4TS5-GTS2

Check your work carefully against Figure 6 to be certain that all of your connections are correct. Wiring errors made during assembly are much more difficult to correct later in the experiment. Make sure that you double check each step of the construction and make any corrections necessary at that time.

### **STEP 3. Upper Potentiometer Bracket Sub-assembly**

The upper potentiometer bracket will be built as a sub-assembly. In manufacturing plants you will find that equipment is usually produced by building a number of sub-assemblies, then putting them together to form the complete equipment.

The location and orientation of the four potentiometers,  $R_{25}$ ,  $R_{27}$ ,  $R_{32}$ , and  $R_{33}$  are illustrated in Figure 7. The potentiometers furnished may be either the bushing-mount type, or the tab-mount type. Provisions are made on the brackets for either type. If you have tab-mounted potentiometers, seat them against the bracket, with the tabs extending through the bracket. Bend the tabs out and away from the potentiometer shaft so that they lock the potentiometer solidly to the bracket.

Install the potentiometers and wire the sub-assembly as illustrated in Figure 7. Cut your leads to the lengths given in that figure. Use high-voltage wire for the leads which connect to  $2R_{25}$ ,  $3R_{25}$ , and  $2R_{27}$ . Use hookup wire for the remainder of the leads. Twist the pair of leads connected to  $S_1$ .

#### **STEP 4. Installing Potentiometers on the Lower Bracket**

Install the potentiometers on the bracket as shown in Figure 9(A) or 9(B). Orient the potentiometers as shown in Figure 9(C). These potentiometers will not be wired at this time.

#### **STEP 5. Installing the Potentiometer Brackets and Potentiometers**

The sub-assembly completed in Step 3, and the lower potentiometer bracket are attached to the main chassis in this Step. Assemble the two potentiometer brackets as illustrated in Figure 8 and mount with 6-32 x 3/8" hardware. Route the wires through the chassis holes as illustrated in Figure 8 and connect the wires to  $1TS_1$ ,  $2TS_1$ ,  $2TS_6$ ,  $1TS_5$ ,  $4TS_7$ , and  $5TS_3$  as indicated in Figure 8 and illustrated in Figure 10.

Connect a 2.2-M $\Omega$  resistor  $R_{28}$ , from  $3R_{27}$  to  $GTS_8$ . Also connect the wire from  $3R_{33}$  to  $GTS_8$  (do not solder the connections at  $GTS_8$  as yet). Note you will still have the wires connected to  $2R_{27}$  and  $2R_{32}$  free at one end at this time.

## **PART III Completing And Checking The Power Supply**

The power supply produces the following voltages for use in the CRO; 6.3-V ac for the heaters of  $V_1$  and  $V_2$ ; another 6.3-V ac source for the heater of the CRT,  $V_3$ ; and d-c voltages of +435, +280, +235, and -800 volts.

Two power supplies, using the same power transformer, produce the positive and negative d-c voltages. Solid-state rectifiers are employed in these supplies.

#### **STEP 1. Analysis of the Low-Voltage Power Supply**

Refer to the schematic diagram of Figure 2. The low-voltage power supply employs the center-tapped high-voltage secondary of transformer  $T_1$ , diodes  $D_1$  and



$D_2$ , capacitors  $C_{16}$  and  $C_{17}$ , choke  $L_1$ , and resistors  $R_{20}$  and  $R_{21}$ . It is a full-wave power supply with capacitor input filter. The voltage at the output of the pi-filter, comprised of  $C_{16A}$ ,  $L_1$ , and  $C_{16B}$ , is a nominal +435 volts d-c. Resistors  $R_{20}$  and  $R_{21}$  provide voltage drops to yield the nominal voltages of +280 and +235 volts. Each of those resistors has an 8- $\mu$ F filter capacitor,  $C_{17A}$  and  $C_{17B}$ , on its output side to provide decoupling of their load circuits from the power supply.

The 47- $\Omega$  1/2-watt resistor,  $R_{34}$ , connected between the center tap of the high-voltage winding and ground is for over-current protection. If, because of a shorted filter capacitor, the output current exceeds 100 mA, this resistor will over-heat, burn-out, and disconnect the load. This will prevent overload damage to the power transformer.

### STEP 2. Analysis of the High-Voltage Power Supply

The high-voltage power supply provides a -800-volt output for use in the CRT cathode, grid, and focusing circuits. The circuit, as seen in the schematic diagram of Figure 2, is composed of diodes  $D_3$  and  $D_4$ , resistors  $R_{22}$  and  $R_{23}$  and capacitors  $C_{18}$ ,  $C_{19}$ , and  $C_{20}$ . The circuit arrangement is that of a conventional half-wave voltage doubler, and provides a negative output voltage. A large filter resistor, and small filter capacitors are employed because of the low current drawn from this supply. Resistor  $R_{22}$  limits the surge currents through diodes  $D_3$  and  $D_4$ . A voltage-divider network, across the output of this negative voltage supply consists of resistors  $R_{24}$ ,  $R_{25}$ ,  $R_{26}$ ,  $R_{27}$ , and  $R_{28}$ , and serves to provide proper operating potentials for the CRT. The voltage from the intensity potentiometer,  $R_{25}$ , varies from approximately -625 to -760 volts, depending upon the setting. The voltage from the focus potentiometer,  $R_{27}$ , varies between -260 to -530 volts. The voltage at the grid of the CRT is approximately -785 volts.

### STEP 3. Completing the Wiring of the Power Supplies

A pictorial drawing of the power-supply wiring, and other parts and wiring to be installed at this time, may be seen in Figure 10. (The power transformer  $T_1$ , filter capacitors  $C_{16}$  and  $C_{17}$ , filter choke  $L_1$ , filament wiring, resistors, and interconnecting leads 1TS4-4TS2 and 2TS4-3TS3 shown in Figure 6 are not shown in Figure 10.) Capacitor  $C_{18}$  has a 600-volt rating. Capacitors  $C_{19}$  and  $C_{20}$  have a 1000-volt rating.

Install the parts and wiring shown in Figure 10. Parts and leads not included in the power-supply schematics, but which are shown in Figure 10, are included since it is most convenient to install them at this time. Be sure to use a heat sink when soldering the diodes. Also be sure the diodes are installed in the proper direction.

Check your power-supply circuits against the schematic diagram of Figure 2.

### STEP 4. Making Resistance Measurements

To serve as a further check on your power-supply wiring compile the data for

Table 1 by measuring the resistance from the 5 terminals of TS-2 and TS-3 to ground. Make the measurements first with the positive lead of your VOM (remember that this lead is connected to the negative side of the battery supply inside the VOM) to chassis ground and the negative test lead to the various terminals. Next reverse the test leads and repeat the measurements.

TABLE 1

+ VOM TO GND. -VOM TO:	1TS2	2TS2	3TS2	4TS2	5TS2	1TS3	2TS3	3TS3	4TS3	5TS3
YOUR VALUES, OHMS	280	400k	220	420k	450k	700	15	155k	36	350k
UEI VALUES, OHMS	225	250k*	220	290k*	300k*	710	15	160k	40	290k*
-VOM TO GND. +VOM TO:	1TS2	2TS2	3TS2	4TS2	5TS2	1TS3	2TS3	3TS3	4TS3	5TS3
YOUR VALUES, OHMS	300	170	210	810	24k	690	$\infty$	$\infty$	$\infty$	810
UEI VALUES, OHMS	240	160	230	800	26k	700	$\infty$	$\infty$	$\infty$	800

\* THESE VALUES WILL VARY WIDELY, BUT ARE OK IN THE RANGE OF 20k $\Omega$  TO  $\infty$ .

To check your  $S_1$  circuit connect one VOM lead to 1TS1 and the other to 2TS1. With the switch in the off position you should measure infinity. With the switch in the on position you should measure zero.

## PART IV

### The Cathode-Ray Tube Circuits

A pictorial drawing of the 3RP1 cathode-ray tube, and a schematic of the d-c circuits associated with the CRT in your oscilloscope, are shown in Figure 11. The functions of the electron gun, the accelerating and focus anodes and the deflection plates are discussed in Assignment 47.

Refer to the CRO schematic diagram of Figure 2, and the drawing of Figure 11. Study both figures to fix in your mind the relationship between the CRT section of Figure 2 and the partial pictorial of Figure 11. In both figures you will find that the -800-volt supply is connected to the CRT grid through a 47-k $\Omega$  resistor. You can see that two potentiometers,  $R_{25}$  and  $R_{27}$ , in the bleeder network across the -800-volt supply to ground, supply variable control voltages to the cathode and the focusing anode.

A fixed d-c potential from the +280-volt source is applied, through 1-M $\Omega$  resistors  $R_{30}$  and  $R_{31}$ , to the deflection plates connected to pins 7 and 9. The horizontal-sweep signal, which is an a-c signal, is fed to pin 7. The vertical input signal, likewise an a-c signal, is fed to pin 9 of the CRT.

The d-c potentials applied to the deflection plates connected to pins 6 and 10, from the +435-volt source, may be varied by the adjustment of centering controls

R<sub>32</sub> and R<sub>33</sub> to position the beam as desired.

The opposite end connection points for all wires which connect to the CRT socket are identified in Figure 11 for your convenience.

### STEP 1. Attachment of CRT Socket Pins to Wires

You should have two high-voltage leads twisted and routed from 2TS4 and 3TS4 through the CRT lead hole, one high-voltage wire from 2R27, and one hookup wire from 2R32. These leads should have been cut to the lengths indicated in Figures 6 and 7.

Refer to Figure 12. An illustration of a lead soldered to a CRT socket pin appears in that Figure. Following this arrangement, solder CRT socket pins to the four leads mentioned in the preceding paragraph.

Refer to Figure 13. Install the six leads as shown in Figure 13. Solder CRT socket pins to the end of each lead. Make mechanically tight connections to the terminal strips, but do not solder these connections now. Solder them later when you make the other connections to these terminal strips.

Install the CRT socket pins in the CRT socket, dressing the leads as shown in Figure 14. When the CRT pins are properly seated in the CRT socket attach the back cover to the CRT socket using the two bolts and nuts furnished with the socket. The CRT socket should be in position so that it may be installed on the base of the CRT in a later Step.

### STEP 2. Making Continuity Checks at CRT Socket

Set your VOM to the Rx1 range. Measure continuity from each CRT socket pin to the lead at each point indicated in Table 2. If your socket connections are correct each reading will be zero. Record your measured resistance values in Table 2. A reading of infinity indicates an open circuit. This would occur if the CRT socket pins were not connected properly. Improper connections of the two wires from CRT socket pins 1 and 12 to 3TS4 and 2TS4 would be indicated by a value of 0.1 to 0.2 ohm, the resistance value of the CRT filament winding on transformer T<sub>1</sub>.

TABLE 2

CRT PIN NUMBER	1	2	3	4	5	6	7	8	9	10	11	12
TEST POINT	3TS4	3TS5	4TS7	2R27	/	2R32	5TS6	4TS6	3TS6	2TS6	/	2TS4
R IN OHMS					/						/	

## **PART V**

### **Front-Panel Assembly And Installation**

Parts are installed on the front panel as seen in Figures 15(A) and (B). The front panel and the sync switch,  $S_3$ , are then attached to the CRO chassis. Use care in handling the front panel to avoid scratching the panel or burring the heads of the front-panel screws.

#### **STEP 1. Installing Parts on the Front Panel**

The three input binding posts are attached using the "pop-rivet" tool furnished by your instructor. Refer to Figure 16(A), (B), and (C). First install the **black** input post at the GROUND position on the front panel. To do this, fully open the handles of the "pop-rivet" tool and place the stem of the "pop rivet", attached to the black input post, in the nosepiece of the tool as illustrated in Figure 16(A). Insert the other end of the black input post into the GROUND hole in the front panel, from the front of the panel as shown in Figure 16(B). Hold the shoulder of the input post snugly, and squarely against the panel. Squeeze the tool handles together until you feel the "pop-rivet" stem break away from the input post. If the stem does not break on the first squeeze, open the handles fully, moving the stem fully into the nosepiece of the tool. Squeeze the handles again. Repeat if necessary. As the pop-rivet tool pulls the stem into the post until it finally breaks away, the plastic portion of the other end of the input post expands tightly into and behind the panel hole as seen in Figure 16(C), to hold the post securely.

In a similar manner install one red binding post in the front-panel hole marked HORIZONTAL EXT. SYNC, and the other red binding post in the hole labeled VERTICAL, as seen in Figure 15(A).

Install the DP4T switch,  $S_2$ , and the four angle brackets as shown in Figures 15(A) and (B). Attach a 1" piece of pressure sensitive padding to each angle bracket as shown in Figure 15(B).

#### **STEP 2. Installing the Front Panel and Switch $S_3$**

Study Figure 17 for a moment and you will find that two 6-32 nuts and screws are used to hold the switch,  $S_3$ , and the front panel to the front of the CRO chassis. A third 6-32 nut and screw are used to help hold the front panel to the front of the chassis.

Attach the front panel and switch  $S_3$  to the front of the CRO chassis as illustrated in Figure 17. Install the third 6-32 screw and nut as also shown in that figure. Tighten the nuts snugly, but not so hard as to break the screws. Be careful not to let your screwdriver slip and scratch the finish of the front panel or burr the screw heads.

## PART VI

### The Vertical Amplifier

As the schematic diagram of Figure 2 reveals, the two-stage vertical amplifier employs a triode, (one half of a 12AT7 type tube)  $V_{1A}$ , as its first stage and the pentode section of a 6BH11,  $V_{2A}$ , as the second stage. The amplifier is resistance coupled. The cathodes are bypassed to improve high-frequency response. Amplifier output is fed to the vertical deflection plates of the CRT.

The vertical input signal is coupled by means of capacitor  $C_1$  to the vertical gain control,  $R_1$ . The signal is amplified in the triode stage of  $V_{1A}$  and coupled by  $C_3$  to the second stage where it is further amplified.

Two output signals are taken from the plate of the second stage amplifier. The signal to be displayed on the CRT is coupled by capacitor  $C_6$  to one of the vertical deflection plates, connected to pin 9 of the CRT. Another signal, used to synchronize the horizontal sweep, when  $S_3$  is in the internal-sync position, is coupled from the plate of  $V_{2A}$  via the series RC network composed of resistor  $R_8$ , capacitor  $C_7$ , potentiometer  $R_9$ , and resistor  $R_{10}$ , to the horizontal-sweep circuit.

The vertical amplifier of your CRO is essentially the same circuit for which you plotted a response curve in Figure 17 of Laboratory Experiment No. 10. However with proper component layout, lead length and lead dress used in this assembly the frequency response upper limit should increase considerably compared to that obtained in Laboratory Experiment No. 10. A complete explanation of the amplifier may be found in Laboratory Experiment No. 10.

#### STEP 1. Wiring the Vertical Amplifier

In the pictorial drawing of Figure 18 the wire and parts connections, routing and orientation are indicated. Install the parts and wiring as illustrated in that figure. When installing capacitor  $C_1$  (which has a 600-volt rating), make the lead from the capacitor to the vertical-input post as short as practical, and leave the lead from  $C_1$  to 3R1 long, as shown in Figure 18. This places  $C_1$  as far toward the outer edge of the chassis as possible, and will minimize stray coupling between  $C_1$  and circuit wiring to be added later.

There are a number of bare lead wires connected to the pins of the  $V_1$  and  $V_2$  tube sockets. Pay particular attention to the drawing of Figure 18 to the routing of the wires, to which lead is closest to the chassis and to see which lead crosses over the top of the other. Resistors  $R_3$ ,  $R_6$ , and  $R_7$  have their leads bent at the sockets to provide wiring clearance as does capacitor  $C_6$ . Capacitor  $C_{22}$  (.1  $\mu$ F) is installed at this time for convenience in soldering at GTS6.

When you complete the wiring of the vertical amplifier check your circuit against the schematic diagram of Figure 2.

## STEP 2. Making Resistance Measurements

Turn the vertical control,  $R_1$ , fully clockwise. Turn all other potentiometers fully counterclockwise. Make those point-to-point resistance measurements indicated in Table 3 and record your results.

TABLE 3

BLACK TEST LEAD TO GND. RED TO:	RESISTANCE IS IN OHMS, $R_1$ FULLY CLOCKWISE								3TS6 TO 9V3
	1V1	2V1	3V1	8V2	9V2	10V2	11V2	2TS5	
YOUR VALUES	75K	8M	325	2.2M	120K	50K	470	40K	0
UEI VALUES	75k	1M	330	2.2M	220k	56k	470	40k	0

## STEP 3. Installing the CRT Support Assembly

Refer to Figure 18 to locate chassis hole "I". Install the CRT support assembly at hole "I" as illustrated in Figure 19. Tighten the 8-32 nut snugly, but not so tight as to crack the CRT cradle mount.

## PART VII The Horizontal-Sweep Circuits

The horizontal-sweep circuits include three triodes,  $V_{2B}$ ,  $V_{1B}$ , and  $V_{2C}$ , as indicated in the schematic diagram of Figure 2. In this drawing, in the 30-Hz to 500-Hz range,  $V_{2B}$  and  $V_{1B}$  operate as a free-running multivibrator. With  $S_2$  in this position, a .05- $\mu$ F capacitor,  $C_{10}$ , and the resistance,  $R_{15}$ , and potentiometer  $R_{16}$  establish the sweep range. The sweep frequency is adjusted through its range as  $R_{16}$  is varied. In the 500-Hz – 5-kHz sweep range, capacitor  $C_{11}$  (.005  $\mu$ F) is placed in series with  $C_{10}$  by contacts 3 and 4 of the  $S_{2A}$  section of the sweep-range switch. In the 5-kHz – 100-kHz sweep range, capacitor  $C_{12}$  (220 pF) is placed in series with  $C_{11}$  to ground through contacts 2 and 3 of  $S_{2A}$ . In each case the frequency may be varied by adjustment of the sweep-range potentiometer  $R_{16}$ . The waveform at the cathode of  $V_{1B}$  is a linear sawtooth which is amplified and inverted by triode  $V_{2C}$  and coupled to pin 7 of the CRT by capacitor  $C_{15}$  to cause horizontal deflection of the CRT beam.

The multivibrator may be synchronized with the vertical signal taken from the sync potentiometer  $R_9$  and coupled by means of the  $R_{10}$ - $C_8$  network to the grid of  $V_{2B}$  by placing the sync switch  $S_3$  in the INT position. If desired, an external-sync signal may be used for synchronization of the sweep by placing  $S_3$  in the EXT position.

With the sweep-range switch,  $S_2$ , in the fourth, or horizontal input position, and the sync switch,  $S_3$ , in the external position, the external signal fed to the horizontal-input connector is applied to  $V_{2B}$  which acts as a resistance-coupled

amplifier. The signal is then coupled to  $V_{1B}$  which now operates as a cathode follower. The signal is further amplified by triode  $V_{2C}$  and fed via capacitor,  $C_{15}$ , to the horizontal deflection plate of the CRT to cause horizontal deflection of the CRT beam.

### STEP 1. Wiring the Sweep-Range Switch

The sweep-range switch, a double-pole four-throw (DP4T) switch, has two sections,  $S_{2A}$  and  $S_{2B}$ , each with five terminals. This produces four positions of the switch as may be seen in the schematic diagram of Figure 2. A pictorial of the sweep-range switch wiring may be seen in Figure 20. One of the 2.2-M $\Omega$  resistors,  $R_{28}$ , is a part of the negative high-voltage divider network. It is connected, 3R27 - GTS8, at this time for convenience.

Wire the sweep-range-switch circuit as shown in Figure 20.

### STEP 2. Wiring the Horizontal-Sweep Circuit

Resistors  $R_{11}$ ,  $R_{17}$ , and  $R_{18}$  and potentiometers  $R_{16}$  and  $R_{19}$ , which are part of the horizontal-sweep circuit, were installed in earlier steps. The wiring diagram of Figure 21 shows the horizontal-sweep circuit wiring which appears below the chassis. Capacitor  $C_{21}$ , .01  $\mu$ F at 1000 volts, is connected at this time for convenience. Wire the remainder of your horizontal-sweep circuit as illustrated in Figure 21. **Be Sure to Route the Leads Running Through Hole "D" and Connecting to 1S3 and 2S3 So That They Are at Least 1/2" From  $C_1$ , to Minimize Feedback.**

This completes the wiring of the horizontal-sweep circuit. Check your circuit wiring against the schematic diagram of Figure 2.

### STEP 3. Making Resistance Measurements

Turn the horizontal-gain potentiometer,  $R_{19}$ , fully clockwise. Turn all other potentiometers fully counterclockwise. Select the 30-Hz - 500-Hz sweep range and internal sync. Make the point-to-point resistance measurements indicated in Table 4, and record your values.

TABLE 4

BLACK TEST LEAD TO GND. RED TO:	RESISTANCE IN OHMS, $R_{19}$ CLOCKWISE										
	6V1	7V1	8V1	2V2	3V2	4V2	5V2	6V2	7V2	5TS5	
YOUR VALUES, OHMS	265K	30K	7.7M	650	30K	1M	26K	2.2M	200K	25K	
UEI VALUES, OHMS	28k	30k	7.7M	680	30k	1M	2.7k	2.2M	200k	25k	
RED TEST LEAD TO:	1S3		2S3		3S3		4TS6		3V2		3TS5
BLACK TEST LEAD TO:	1S2B		2S2B		2R9		7V3		7V1		2V3
YOUR VALUES, OHMS	0		1M		0		1M		0		0
UEI VALUES, OHMS	0		1M		0		1M		0		0

## **PART VIII**

### **Completing The Oscilloscope**

In this Part of the Experiment the a-c line cord is connected to the oscilloscope, the tubes are installed, the oscilloscope is given a final visual inspection, and then energized from the a-c line.

The CRT is then aligned and the operation of the INTENSITY, FOCUS, POSITIONING, HORIZONTAL, VERTICAL, SWEEP and SYNC controls is checked. Voltage measurements are then taken.

#### **PRECAUTION**

In this Part of the Experiment the CRO will have a-c voltages of about 340 volts, and d-c voltages of approximately +440 volts, and -800 volts. The maximum voltage exists between the +440-volt and -800-volt points, a potential difference of approximately 1240 volts. **The fact that a great deal of caution should be observed cannot be overemphasized. Be sure that at all times the power supply is deenergized when changes are being made in the circuit or when meter test leads are being changed.** When the oscilloscope is in operation the hand should not be placed anywhere on the scope, except on the front side of the front panel. High voltages are applied to the various potentiometers which are mounted behind the front panel. The 110-volt a-c input power is applied to the switch on the intensity control even when the switch is in the off position.

High voltages are also present under the chassis, and at the cathode-ray-tube socket. You should observe these precautions yourself. You should prevent others, particularly children, from accidental contact with the high voltages present in your oscilloscope.

#### **STEP 1. Installing the A-C Line Cord**

Connect the a-c line cord as illustrated in Figure 22, tying an overhand knot in the line cord next to the grommet. This should complete the wiring of your CRO.

#### **STEP 2. Installing the Tubes**

You should handle your CRT as carefully as you would handle an egg, to prevent breakage. Loosen the top two angle bracket screws. Carefully slip the CRT in place. Position pin 1 of the CRT at 3 o'clock. Place the neoprene retainer clip over the neck of the CRT, slipping each end of the clip over the hooked ends of the CRT cradle to hold the CRT in position. The face of the CRT should be very close to, but not touching, the front panel.



Carefully push the CRT socket on the base of the CRT matching up the socket keyway with the key on the base of the CRT.

Tighten the screws of the two top angle brackets only enough to keep them from slipping. The CRT will, in all probability, have to be rotated slightly to align the horizontal-sweep trace with the horizontal plane in Step 5.

Install a type 12AT7 tube and the 6BH11 tube.

### **STEP 3. Final Inspection of Your Oscilloscope**

You should give your completed oscilloscope a most critical final inspection. Check all of your connections against the pictorials of Figure 23. **Check each connection to make sure you have completed all soldering**, and to assure that you have made good solder joints. Check the bare wire leads to make certain that there is adequate clearance between leads and between leads and chassis. Check your four diodes to see that they are properly polarized and correctly connected.

### **STEP 4. Energizing Your Oscilloscope**

Set the controls of your oscilloscope as indicated:

SWEEP RANGE: 30-500 Hz	SWEEP: Middle of Range
SYNC SWITCH: INT	HORIZONTAL: Middle of Range
CENTERING: Middle of Range	FOCUS: Middle of Range
VERTICAL: C.C.W.	INTENSITY: C.C.W.
SYNC: C.C.W.	POWER: OFF

Place the CRO on the bench in its normal, upright position. Connect the line cord to the 110-volt, 60-Hz line. Turn the power switch on. Turn the intensity control fully clockwise. About 10 seconds are required for the CRT to illuminate.

After light is seen on the screen adjust the vertical- and horizontal-centering controls to move the sweep trace to near the center of the screen. Reduce intensity to a reasonable brightness. Adjust the focus control for best focus. Adjust the horizontal-gain control until the sweep just fills the CRT. Readjust the positioning controls as necessary to position the sweep in the center of the CRT.

Use a ball-point pen to mark the position of the CRT trace about one-half inch in from each edge of the trace. Turn the power switch off. Disconnect the line cord.

### **STEP 5. Aligning the CRT**

Loosen the screws which hold the two top angle brackets at the front panel. Remove the neoprene retainer clip from the CRT support cradle. Rotate the CRT until the two one-half-inch lines, which you marked on the face of your CRT, are in a horizontal plane. Hold the CRT in this plane with one hand while reinstalling the neoprene retainer clip with your other hand. The marks on the CRT should now be aligned in the horizontal plane. Tighten the two top screws, holding the foam-padded angle brackets.

Energize your CRO and check the horizontal-sweep alignment now. If not satisfactory, repeat this step.

### **STEP 6. Initial Operational Checks**

With the sweep-range switch in the 30–500-Hz range, and the trace centered as in Step 5, advance the vertical gain until the pickup pattern on your CRT is about one inch in height. (The vertical amplifier is so sensitive it is amplifying, and the scope is displaying, the stray electrical signal from the electrical circuits in the classroom.) Adjust the sweep control until the pattern is almost completely stopped while displaying a single distorted cycle. Now, adjust the sync control until the sweep is locked in synchronization at 60 Hz.

Remove one of the test leads from your VOM. Touch one end of the test lead, the other end remaining free, to the vertical-input post of your CRO. The increase in the amplitude of the pattern should be such that the pattern goes off the screen. Remove the test lead.

Switch the sweep-range switch to the “Horiz In” position. Switch the SYNC switch to its external, EXT, position. Touch one end of the test lead to the HORIZONTAL/EXTERNAL SYNC input post, leaving all front panel adjustments untouched. A pattern similar to a slightly distorted “O” should now be displayed on the face of your CRT.

If your CRO has checked out thus far, you can feel reasonably sure that it will operate satisfactorily. Turn the power switch off. Disconnect the line cord.

### **STEP 7. Making Voltage Measurements**

Turn your CRO on its side with the transformer and choke closest to the bench and with the front panel to your right.

Make the measurements indicated in Table 5, changing your meter scales as necessary and entering your values in the spaces provided. Observe the precautions discussed at the beginning of this Part of the Experiment. In making measurements at the  $V_1$  and  $V_2$  tube sockets you may find it convenient to measure from the lead of a part attached to a particular pin rather than at the pin.

TABLE 5

TEST POINT	YOUR VALUES IN VOLTS	UEI VALUES IN VOLTS	TEST POINT	YOUR VALUES IN VOLTS	UEI VALUES IN VOLTS	TEST POINT	YOUR VALUES IN VOLTS	UEI VALUES IN VOLTS
1TS2	350uAC	340 AC	2TS6	+275	+240	7V2	+355	+350
2TS2	+455	+452	3TS6	+250	+245	8V2	0	0
3TS2	350uAC	340 AC	4TS6	+275	+278	9V2	+125	+145
4TS2	+450	+442	5TS6	+250	+245	10V2	+265	+235
5TS2	+280	+267	1TS7	+235	+225	11V2	+2.7	+3
1TS3	350uAC	340 AC	4TS7	-760	-762	2R16	+235	+220
2TS3	-425	-435				1R32	+445	+440
3TS3	-780	-810	1V1	+78	+103	2R32	+270	+250
4TS3	-820	-830	2V1	0	0	1R33	+445	+445
5TS3	+445	+443	3V1	+1.4	+1.25	2R33	+260	+240
1TS4	+445	+443	6V1	+275	+270	1R25	-640	-630
2TS4	-780	-810	7V1	+235	+230	2R25	-760	-785
3TS4	-780	-810	8V1	+250	+240	3R25	-760	-805
1TS5	-760	-805	2V2	+4.9	+4.8	1R27	-570	-345
2TS5	+220	+215	3V2	+235	+230	2R27	-520	-285
3TS5	-770	-805	4V2	0	0	3R27	-375	-145
5TS5	+280	+267	5V2	+11.5	+10.5			
1TS6	+210	+195	6V2	0	0			

When you have completed your measurements turn the power switch off and disconnect the line cord from the power line.

## PART IX

### Checking CRO Performance

#### STEP 1. Checking the Vertical Amplifier

A source of signal, 100 mV at 1000 Hz, is needed for this step. This can be obtained from a CRO calibrator, or from an audio signal generator, whichever is available. If an audio generator is used it will be necessary to use a divider as shown in Figure 24.

Figure 24 shows that the output of the generator connects across two resistors in series to obtain an approximate division of 10 to 1. The output of the generator is

measured with the multimeter on the 6ACV range. In Figure 24 the output of the generator is given as .35 V rms, this is 1 V peak-to-peak so the 10-1 divider gives an output to the CRO of approximately .035 V rms, or .1 V p-p (100 millivolts).

The 100-mV p-p signal should be connected to the vertical input of the scope. The vertical-gain control should be turned fully clockwise. Since your scope is designed to provide sensitivity of 100-mV-per-inch deflection, or better, the pattern on your CRT should have an amplitude of slightly more than one inch. If it does, okay. If not, check your vertical amplifier to determine the reason for the lower-than-normal gain.

### STEP 2. Checking the Horizontal-Sweep Circuits

Connect an audio signal generator to the vertical input of your CRO. Set the generator to a frequency of 30 Hz. Put the CRO sweep-range switch in the No. 1 position. With the sync control fully clockwise, adjust the sweep control until you stop one complete cycle on the CRO. Your CRO sweep frequency is the same as the generator frequency when there is one cycle on the CRT. Next feed a 500-Hz signal to the vertical input and see if your sweep circuit produces this frequency on the first range.

Using this technique, check for 500 Hz and 5 kHz in the second range, and 5 kHz and 100 kHz on the third range. Check your results in Table 6. If all readings are satisfactory, your sweep-range switch and sweep-oscillator wiring are okay.

TABLE 6

SWEEP RANGE	SWEEP FREQUENCY RANGE			
		CHECK		CHECK
30 - 500 Hz.	30Hz.	✓	500Hz.	✓
500 - 5 kHz.	500Hz.	✓	5 kHz.	✓
5 k - 100 kHz.	5 kHz.	✓	100 kHz.	✓

### STEP 3. Checking Horizontal-Amplifier Circuits, External Sweep

Feed a signal with 1.0-volt peak-to-peak amplitude (from a signal generator or CRO Voltage Calibrator) to the horizontal input of your CRO. Set the CRO sweep-range switch to HORIZ IN, set the sync switch to EXT. Turn the horizontal gain control fully clockwise. Your horizontal trace should be about one inch long.

### STEP 4. Checking Circuit Waveforms

In this Step you will observe the waveform at the grids and plates of the multivibrator tubes, at the cathode of  $V_{1B}$ , and the horizontal sweep waveform which is applied to pin 7 of the CRT, and which appears at terminal 5 of TS-6. Be sure that your CRO is deenergized before connecting or disconnecting test leads to its circuits.

Use two scopes to do this; one scope to observe waveforms on the other scope. By doing this you will be able to adjust the sweep on the scope you take waveforms with so that you can see more than one waveform.

Set your CRO to the 30–500-Hz sweep range with sweep control near full clockwise. Take those waveforms as indicated in Figure 25. Draw sketches of your waveforms in the spaces provided in Figures 25 (E) through (H). The amplitude of the waveforms shown in Figures 25(A) through (C) is approximately 25 volts peak-to-peak. The amplitude of the sweep waveform of Figure 25(D) is approximately 170 volts peak-to-peak when the horizontal trace of the CRO under test fills the CRT when the trace is centered.

## Summary

In this experiment you employed a number of the skills which you have developed in the training program. In assembling your oscilloscope you should have noticed that the parts were easier to attach, the leads were easier to form, the solder joints looked better, soldering was easier and wiring runs were neater, than was the case earlier in the training program.

In early stages of your training you were given specific instructions for connecting each part in the test circuits. You could have wired the oscilloscope directly from the schematic diagram, except for the fact that there are several wires and parts in the scope whose location is critical.

The vertical amplifier in your oscilloscope is more sensitive than in the majority of the scopes which you will encounter. That sensitivity, which is approximately 75 millivolts (.075 V) per inch, or about 30 millivolts per centimeter, makes it especially useful in observing low-level waveforms in solid-state circuits.

The practical experience which you have gained in this experiment and at other times working with oscilloscopes in the laboratory, and your understanding of the related material in the theoretical assignments have provided you with an excellent background in the use and operation of the CRO. You should now feel that you can successfully employ an oscilloscope as an effective service instrument.

A word of caution once again. There are voltages in your CRO which are hazardous. Take care to see that no one (especially children) is permitted to get into position to encounter any of those voltages.

## Test Questions

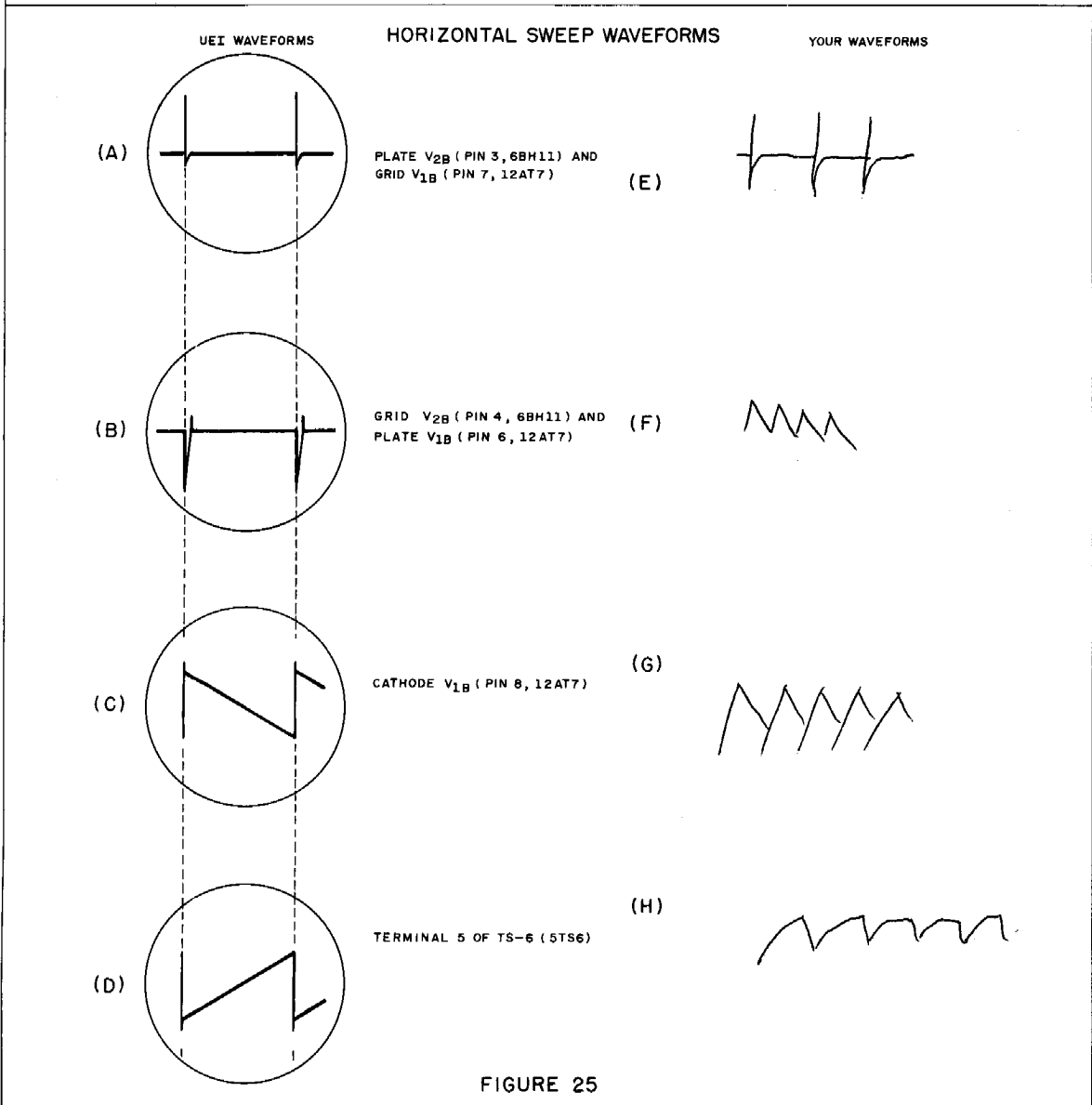
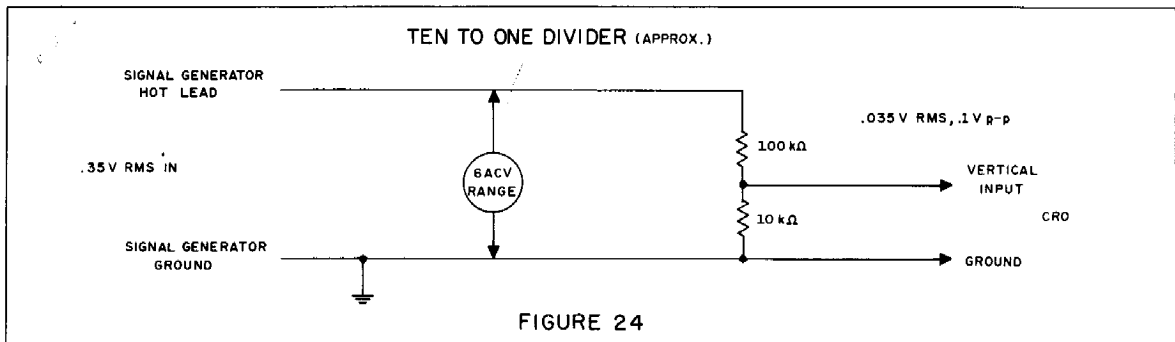
Answer these Test Questions on a regular Answer Sheet. Number your Answer Sheet L.E. No. 16 (Laboratory Experiment No. 16).

Place your Name and Associate Number on every Answer Sheet.

Be sure to perform all the Parts of the experiment before answering these test questions. Analyze your results carefully, and be sure that you are completely familiar with the entire Experiment before answering the test questions. Submit your answers for this experiment immediately after you finish it. This will give you the greatest benefit from our personal grading service.

1. What is the purpose of the sweep generator in a cathode-ray oscilloscope?  
*To cause horizontal deflection*
2. When the internal sweep generator of your CRO is being used, a portion of what signal is used to synchronize it? *Signal from the Vertical Amplifier*
3. What does this notation mean: 2T55-3S3? *a connection from the second terminal on terminas strips to the third terminal of switch S3*
4. Was the vertical sensitivity of your scope better than 100 millivolts per inch? *yes*
5. (A) What is the output voltage of your half-wave voltage-doubler power supply? (Indicate polarity.) *+820 volts*  
(B) What is the output voltage of your full-wave power supply at the output of the pi-type LC filter? *450 volts*
6. Explain how centering is accomplished — electrically — in your oscilloscope. *the charges on the deflection plates in the CRT the beam is attracted to at charac*
7. Draw a schematic diagram of the complete horizontal sweep generator, with the generator operating on the 5-kHz to 100-kHz range. (Don't just redraw that portion of Figure 2. Draw the circuit as if it were operating on this one frequency range only and wired to accomplish the result without switches.)
8. Explain the purpose of  $C_{13}$  in your scope. *Coupling cap*
9. Based on the information supplied relative to power supplies in theoretical assignments — and on information presented in preceding Laboratory Experiments — will the percentage of ripple be greater at the 435-volt point in your power supply where  $C_{16B}$  connects, or at the 235-volt point in the supply where  $C_{17B}$  connects?
10. If there is a vertical input signal applied to the oscilloscope, and  $R_{19}$  is adjusted so that the wiper arm is at the end of the potentiometer connected to B+, what sort of indication will appear on the face of the CRT?

+



COMPLETE BOTTOM OF CHASSIS WIRING

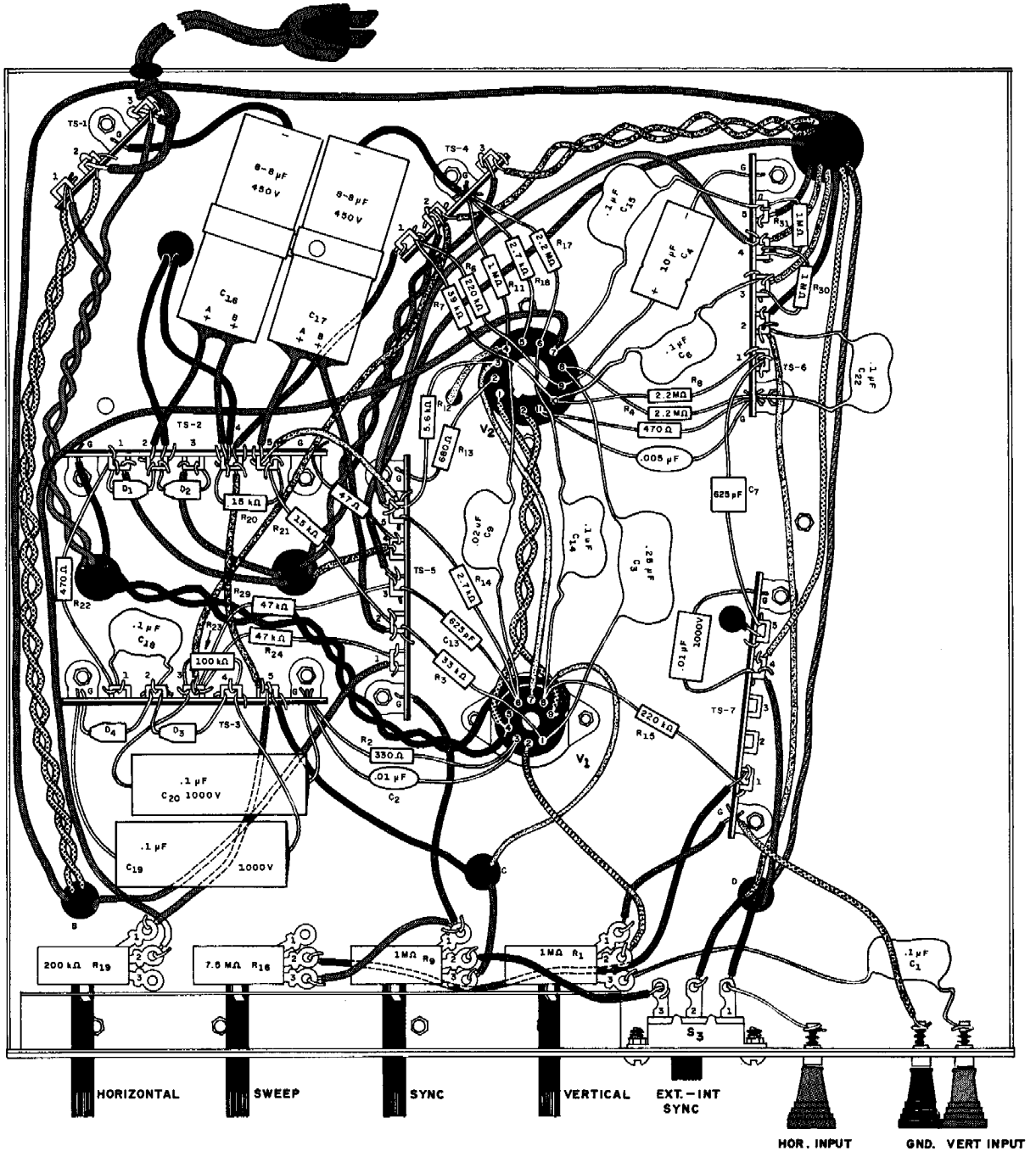


FIGURE 23(B)