CHAPTER 4

ELECTRONIC TEST EQUIPMENT

A Tradevman must be able to test, adjust, and repair equipments containing electronic circuits such as power supplies, voltage and power amplifiers, phase detectors, amplitude modulators, and servomechanisms. He must be capable of testing these circuits for continuity, shorts, and grounds; and measuring electrical quantities such as voltage, current, power, frequency, and phase angles. This chapter discusses the application of electronic test equipment as well as some of the equipment circuits.

Many of the general-purpose electronic test instruments are described in detail in the Navy Training Courses Basic Electricity, NavPers 10086-A, Basic Electronics, NavPers 10087-A, and Tradevman 3 & 2, NavPers 10376-A. However, this chapter provides information on the selection of proper test instruments and their operating limitations.

USE OF METERS

Maintenance shops are equipped with various types of meters. They range in complexity from a simple plug-in ammeter to an electronic volt-ohm ammeter. The repairman must exercise judgment in the selection of the proper test instrument to insure the desired results. He must not only base his selection on the type of meter and its operating ranges, but must also consider the effect the meter will have on the circuit being tested.

AMMETER

The ammeter used for routine alinement and adjustment of a trainer is normally specified by the Maintenance Instructions Manual for the trainer. Since the ammeter has to be connected in series with the current path, circuits, requiring frequent current readings or adjustments normally provide current jacks for use with a plug-in meter. Some equipments have a meter installed as part of the equipment, with a meter switch to provide the necessary ranges.

OHMMETER

The Navy does not normally supply its maintenance facilities with an instrument consisting solely of an ohmmeter (an ohmmeter, AN/USM-21A is available for special applications). The ohmmeter is incorporated with the voltmeter to form a multimeter. Therefore, the choice of ohmmeter should be determined by the resistance ranges available in the various multimeters. Small multimeters, such as the TS-297/U, have a high range of R x 100; larger multimeters, such as the PSM-4, have a high range of R x 10,000. The VTVM TS-505A/U has a high range of R x 1,000,000 and should be used where high values of resistance must be measured.

D-C VOLTMETERS

The selection of a d-c voltmeter is normally based on the sensitivity of the meter movement and its effect on the circuit being tested. Meter sensitivity is discussed in Basic Electricity, NavPers 10086-A, Basic Electronics, NavPers 10087-A, and Tradevman 3 & 2, NavPers 10376-A.

A multimeter having low sensitivity may be used for quick, rough readings where approximations are adequate. When a high degree of accuracy is desired, a meter having high sensitivity is required. Such a meter has wide application in the maintenance of medium- and high-impedance electronic circuits.

A vacuum tube voltmeter, because of its high input impedance, is the ideal instrument for measuring low voltage in oscillators, automatic gain control, automatic frequency control, and other electronic circuits sensitive to loading. When measuring voltages in excess of 500 volts, a multimeter having a sensitivity of 20,000 ohms per volt will have an input impedance equal to or greater than most vacuum tube voltmeters. This can be proven by comparing input impedances of the two types of meters. The input impedance of most vacuum tube voltmeters is between 3 and 10 megohms. A 20,000-ohm-per-volt meter, when reading a voltage of 500 volts, would have an input impedance of 500 x 20,000 or 10 megohms. Therefore, on the 500-volt scale a multimeter of this sensitivity would have an input impedance at least equal to the vacuum tube voltmeter. For voltage readings over 500 volts, a 20,000-ohms-per-volt multimeter offers an input impedance higher than the vacuum tube voltmeter.

Any multirange voltmeter, though its sensitivity may not exceed 1,000 ohms per volt, can be used in an emergency to obtain reliable readings in a d-c circuit. If the impedance of the circuit being tested is not known, a comparison of two voltage readings—one on the lowest usable range and the other on the next higher range—will indicate if the meter is having a loading effect on the circuit. If the two readings are approximately the same, the meter is not causing appreciable voltage variations and the higher reading may be accepted as the true voltage. If the two readings differ considerably, the true voltage may be found by the use of the following formula:

$$E = \frac{E_2 - E_1}{\frac{E_1 R}{E_2} - 1} + E_2$$

where E is the true voltage

E_1 is the lower of the two voltage readings.

E_2 is the higher of the two voltage readings.

R is the ratio of the higher voltage range to the lower voltage range.

To illustrate the application of the correction formula, the following conditions are assumed:

1. A reading of 82 volts was obtained between two terminals with the meter on the 0-300 volt scale.

2. A reading of 22 volts was obtained between the same two terminals with the meter on the 0-30 volt scale.

The true voltage may be found as follows:

$$E = \frac{82-22}{\frac{22 \times 10}{82} - 1} + 82$$

$$E = 119 \text{ volts.}$$

A-C VOLTMETERS

The selection of an a-c voltmeter is more difficult in that frequency and waveform of the voltage being measured must be taken into consideration. Although some a-c voltmeters react to the peak value and others to the average (of one alternation) value, most a-c voltmeters are calibrated to indicate effective (rms) values of voltage. This is because effective values are generally more useful. (Rms is explained in Basic Electricity, NavPers 10086-A.)

Multimeters capable of measuring a-c voltages utilize conventional d-c meter movements and multipliers plus metallic oxide rectifiers to change the a.c. to d.c. Most multimeters have an accuracy of 2 to 5 percent at low frequencies. However, the shunt capacity of the metallic oxide rectifiers affects the accuracy of the multimeter as the frequency of the voltage being measured increases. When the frequency is above the audio range, the voltage reading is no longer usable. However, for rough readings the multimeter may be sufficiently accurate for most equipments. Where accuracy at the higher frequencies is desired, an a-c vacuum tube voltmeter should be used. Although many d-c vacuum tube voltmeters have an a-c voltage function, many circuits use the conventional metallic rectifier circuits mentioned above.

For measuring a-c voltages such as the trainer's power supply, the electrodynamometer or iron vane meter gives the most accurate measurement. Though the electrodynamometer and the iron vane meters are extremely accurate, their low input impedance makes their use prohibitive in most electronic circuits. Their use should be restricted to low-frequency applications and to circuits that are not affected by meter loading.

POWER SUPPLY

The Power Supply PP-106/U (fig. 4-1) is designed to supply various voltages for electronic

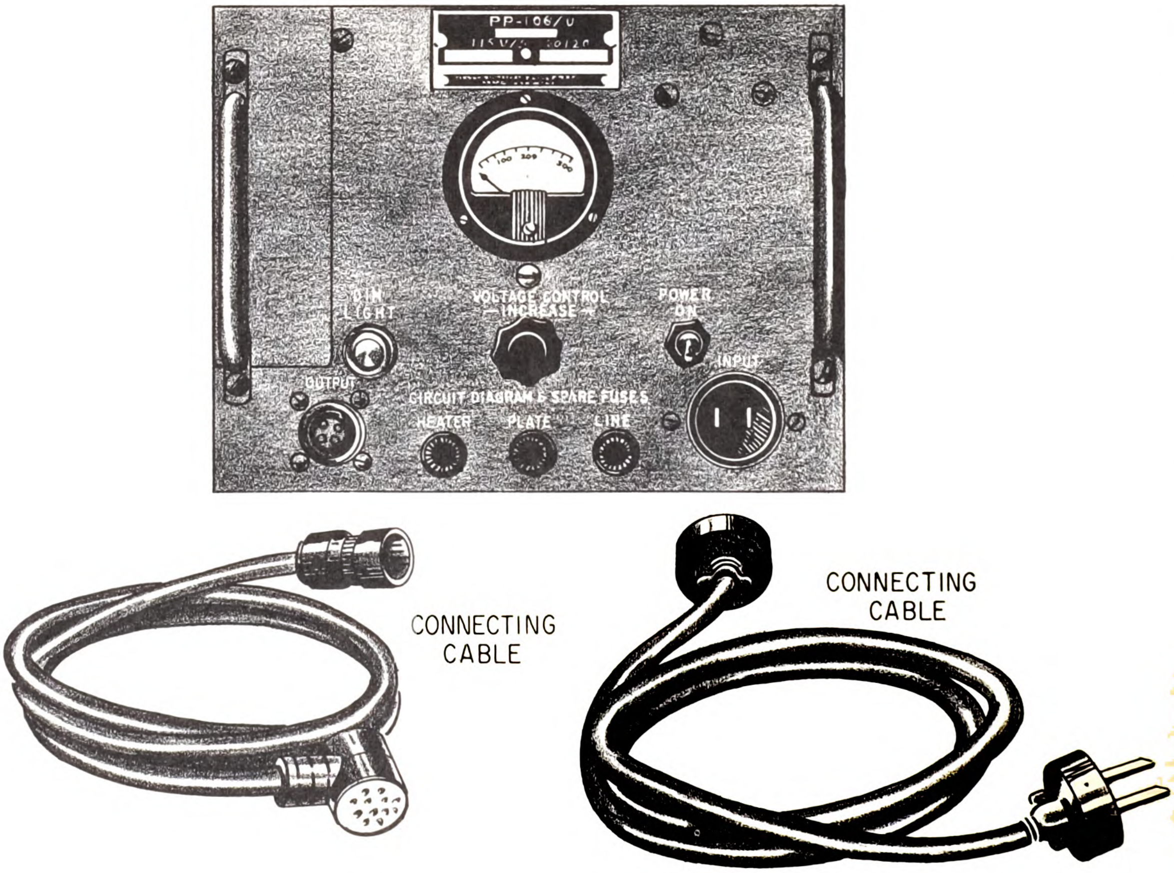

Figure 4-1.—Power supply PP-106/U.

equipments. Some test sets and frequency meters require voltages from an external source for their operation. Voltages and currents supplied are as follows:

1. 90 to 270 volts d.c. at 0.08 amp.
2. 270 to 300 volts d.c. at 0.06 amp.
3. 6.3 volts a.c. at 5 amp.
4. 12.6 volts a.c. at 2.5 amp.
5. 28 volts a.c. at 2.5 amp.

The PP-106/U contains a front panel meter and voltage control. The voltage control is used for setting the output d-c voltage. The a-c voltages are fixed and no adjustment is necessary.

Two connecting cables are required to operate the power supply. The input cable carries external power (115 a.c.; 60 cycles) to the power supply. The output cable is fitted with a seven-pin connector for connection to the electronic equipment requiring the voltages supplied by the power supply.

The a-c output voltages are obtained from a tapped secondary winding of a power transformer. The d-c output voltages are obtained from a full-wave rectifier using beam power amplifier tubes for voltage stabilization. Further stabilization is provided by the action of a VR tube.

Three fuses, mounted on the front panel of the power supply, protect the main circuits of the equipment. Spare fuses are mounted on the back (inside the cabinet) of the front panel.

SIGNAL GENERATORS

As indicated in Basic Electronics, NavPers 10087-A, a signal generator is a test equipment which generates an a-c signal which is suitable for test purposes. Most signal generators are constructed to generate a signal of any desired frequency. The signal may be modulated or unmodulated. If you have not recently reviewed the fundamentals of signal generators in Basic Electronics, you should do so before continuing with the present discussion.

AF SIGNAL GENERATOR

Tests and measurements made on many types of electronic equipment, such as amplifiers, modulators, and other voice-frequency apparatus, require a source of controlled audio-frequency oscillation usually with very little or no harmonic content. The frequency range required generally covers 20 to 20,000 cycles per second; however, some audio oscillators have ranges up to 200,000 cycles per second.

Several types of audio-oscillator stages are used to provide signals for the required amplitude and frequency. These circuits generally utilize resistance-capacitance (RC) oscillators and beat-frequency oscillators (BFO).

The RC oscillator provides audiofrequencies which are more easily controlled by varying the capacitance rather than the resistance. The change of frequency which can be produced by this method is limited; therefore, it is often necessary to cover the desired frequency range in several steps. This is accomplished by changing either, or both, the resistance and capacitance values.

A typical audio oscillator, often used for electronic maintenance, is the TS-382B/U. It should be remembered that the discussion to follow, although based on the use of a specific test equipment, is generally applicable to other signal generators of its type.

It should also be noted that AN/USM-30 is the overall nomenclature for the TS-382B/U, its transit case, and all its accessories.

The Audio Oscillator TS-382B/U (fig. 4-2) is a laboratory or shop device which generates a-c voltages ranging from 20 to 200,000 cycles per second at amplitudes which may be varied continuously from 0 to 10 volts. Its output frequency and amplitude are very accurate, making the instrument suitable for the measurement of gain and distortion in electronic circuits such as servoamplifiers.

Principles of Operation

The block diagram in figure 4-3 shows the following units:

1. The oscillator section which generates the audio voltage.
2. An amplifier which isolates the o[...] from the external circuit and amplifies [...] voltage.
3. An output level metering circ[...] an attenuator.
4. A power supply.
5. An electronic voltage regulating [...]
6. A frequency meter.
7. A cathode follower which isol[...] meter from the remainder of the circu[...]

The oscillator section (fig. 4-4) [...] tubes V101 and V102. It is a Wier[...] oscillator consisting basically of a tw[...] resistance coupled amplifier which is[...] to oscillate by the use of positive fe[...] (See Basic Electronics, NavPers 10087[...] detailed discussion of Wien bridge osci[...] An RC network in the positive feedbac[...] controls the frequency of oscillation[...] system. Any one of four ranges may be [...] by means of the range switch S1. Eac[...] four frequency ranges has a potentiom[...] calibration. The ganged capacitors, C[...] connected to the main dial and provide [...] of varying the frequency over the range [...] by S1. The trimmer capacitors, C102 a[...] are for tracking adjustments.

The output section consists of a tw[...] resistance coupled amplifier, V103 a[...] Negative feedback is used to minimize[...] tion and provide uniform output.

The output system consists of an [...] level meter (M101), a gain control (R1[...] a six-section ladder type attenuator. Th[...] meter operates from a full-wave type [...] circuit in which germanium crystals a[...] The gain control sets the voltage leve[...] input of the ladder attenuator. The at[...] is calibrated on the basis of the ins[...] working into its rated load of 1,000 ohm[...]

The voltage regulator (V106, V107, a[...] supplies a constant output of 230 volts to [...] circuits of the various tubes.

The voltage regulating system oper[...] follows: Assume that the voltage acros[...] R147, and R148 rises due to variation[...] voltage or changes in the load. The vo[...] the control grid of V107 then increases. [...] fore, the plate current increases, and [...] creased current causes the plate vo[...] decrease. Since the control grid of [...] connected to the plate of V107, the vo[...] this control grid also decreases. The [...] through V106 then decreases, restor[...] proper voltage across R146, R147, an[...]

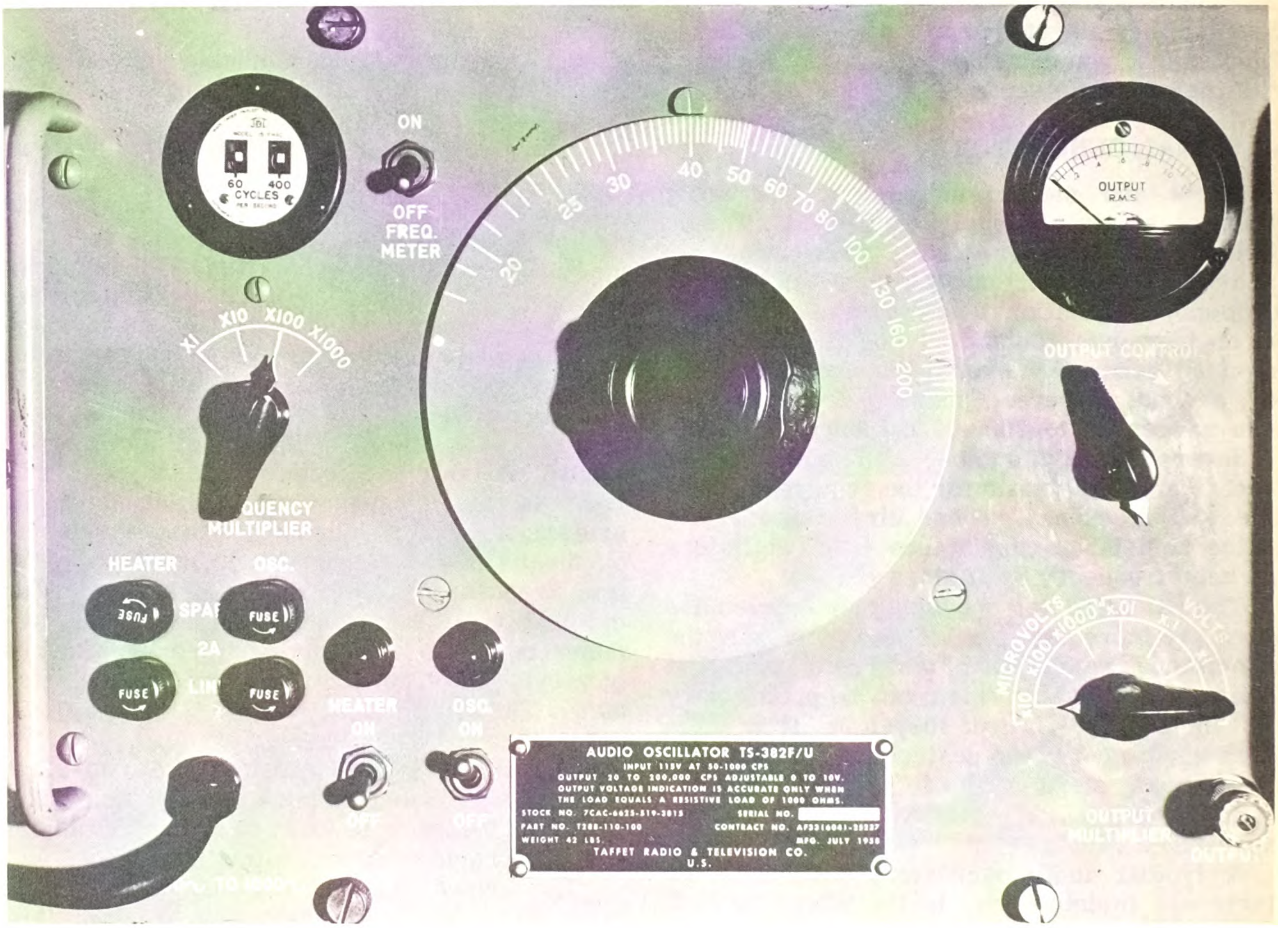

Figure 4-2.—Audio Oscillator TS-382B/U.

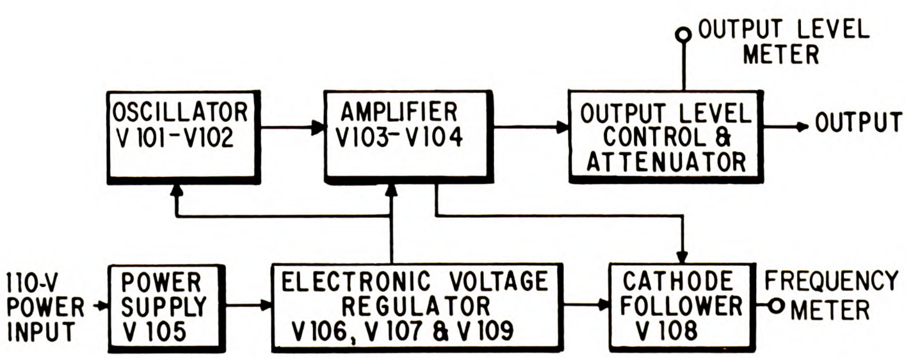

Figure 4-3.—TS-382B/U, block diagram.

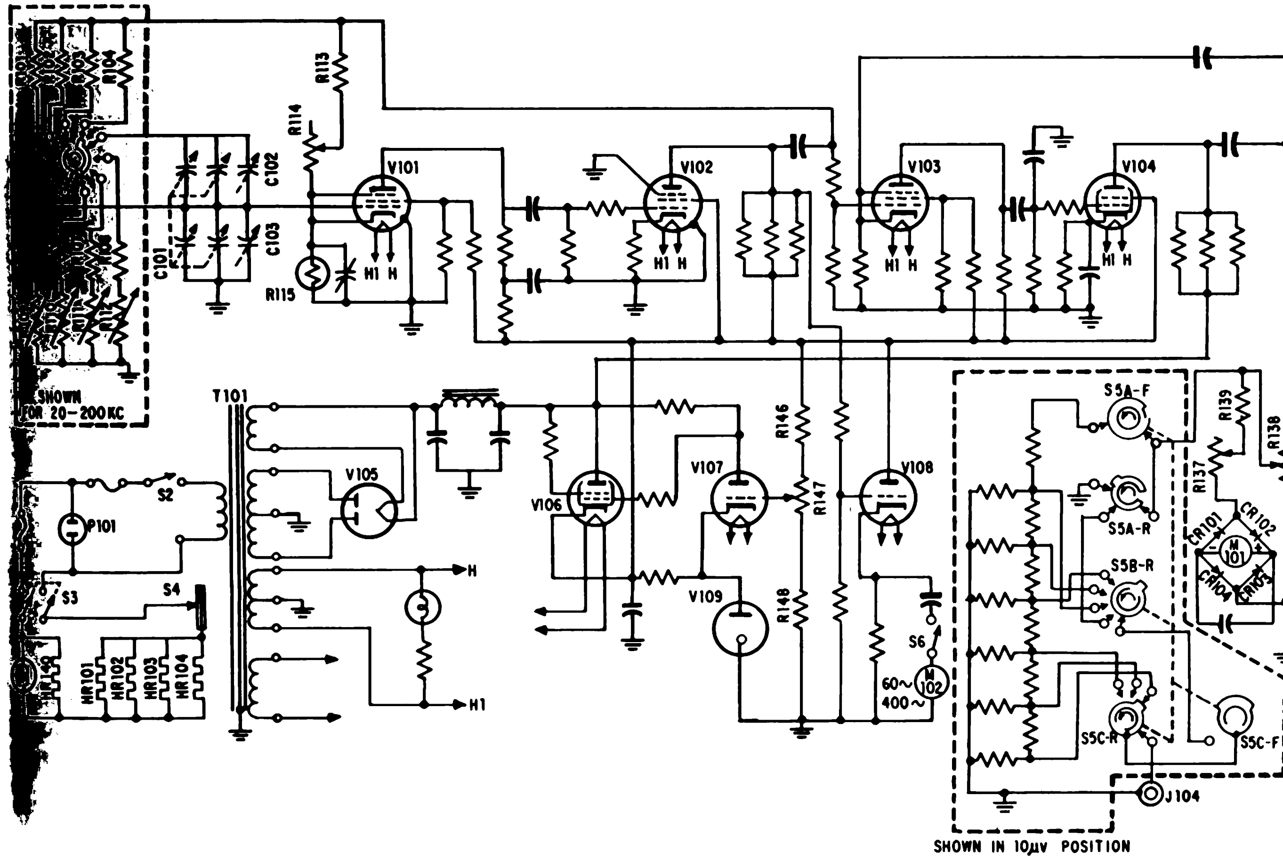

Figure 4-4.—TS-382B/U, simplified schematic diagram.

A vibrating reed type frequency meter (M102) permits an accurate check of the output frequency of the oscillator at 60-cycles per second and 400 cycles per second. The meter has been factory adjusted to an accuracy of three-tenths of one percent. This meter is isolated from the second oscillator tube (V102) by a cathode follower stage (V108) to prevent shifts in frequency when the frequency meter is in operation.

Five strip heaters are used to decrease the time required for the unit to reach stable operation and to permit satisfactory operation in colder climates. These strip heaters are regulated by a thermostat control switch on the front panel. An on-off switch and an indicator light are included in the circuit.

There are, at present, seven variations of the basic TS-382B/U. The latest model is known as the TS-382F/U. These are all basically the same with minor changes in circuitry, controls, cases, or accessories.

Details of operating procedure for the TS 382B/U may be found in the Operation Instruc tion Manual for the instrument.

Maintenance and Repairs.

Maintenance consists primarily of checkin for security of knobs and accessories. Car should be exercised to preclude the possibilit of the main tuning dial from becoming loos as this will affect the calibration of th instrument.

Proper operation of the audio oscillator ma be ascertained by checking its output at 6 cycles per second and at 400 cycles per secon against the built-in frequency meter. The mai dial is adjusted until the appropriate ree vibrates with maximum amplitude. The mai dial should read 60 cycles per second or 40 cycles per second within one or one and one half divisions, respectively.

Replacement of any tube other than those in the power supply involves recalibration of the instrument. Do not disturb any of the alinement adjustments as these will affect the frequency calibration.

Output Applications

The sine-wave of the signal generator is utilized in electronic maintenance. The TD will find sine-wave AF signals useful in checking gain and distortion in servoamplifiers and measuring output power.

SQUARE-WAVE OUTPUT.—Square waves have a wide use in the fast and accurate determination of the reproductive faithfulness of AF and video amplifiers. The use of square waves in checking amplifier frequency response reveals information about the phase characteristics of the amplifier which a sine-wave response check does not disclose.

To make an AF amplifier frequency-response check, connect the amplifier as shown in part (A) of figure 4-5. With the square-wave generator set to deliver the lowest frequency the amplifier is required to pass, throw switch S so that the generator output waveform appears on the screen of the oscilloscope. Adjust the oscilloscope controls to provide the best wave shape. Throw switch S to the amplifier output. The resulting pattern viewed on the oscilloscope may be distorted in several different ways, depending on which harmonic components of the input square wave are discriminated against either in amplitude or in time (phase). Part (B) of figure 4-5 shows several common response patterns encountered in checking amplifier response.

Next, increase the output frequency of the square-wave generator, and repeat the procedure listed above until the complete bandpass of the amplifier has been covered and the resulting patterns examined.

The frequency response of a video amplifier is checked in the same manner as an AF amplifier with the exception that only square-wave output frequencies of 30 cycles and 300 kc are used. If the response patterns show negligible distortion, the response of the video amplifier may be considered to extend as high as 15 times the fundamental frequency of the square wave.

RF SIGNAL GENERATORS

Radiofrequency signal generators comprise a rather large and very useful class of test equipments. Because of the extremely wide frequency range in the RF region of the spectrum, many signal generators with different RF ranges, as well as other instrument refinements, are available to the TD. The following general analysis of RF signal generators provides the principal circuits that are used in these generators.

In addition to the required power supply, the circuits common to most RF signal generators are the oscillator circuit, the modulator circuit, and the output circuit.

Oscillator Circuit

The oscillator has as its function the emission of a signal the frequency of which can be accurately set to any point in the designed frequency range. The type of oscillator used depends on the range of frequencies required. It may have as its resonant circuit a simple coil and capacitor (LC), a tuned line, a tuned cavity, or any of the various specialized types designed for microwave frequencies.

Modulator Circuit

The modulating circuit functions to change the RF output in accordance with the successive instantaneous voltage values of the audio or video modulating signal. For a particular generator the modulating signal may be provided by an internal source, by an external source, or by both, depending upon the design of the instrument. A meter is often included to indicate (and to permit control of) the percentage of modulation. The form the modulating signal may take depends upon the application of the particular signal generator. It may be a sine wave, a square wave, or a pulse.

Some instruments have special provisions for pulse modulation, which permits the RF signal to be pulsed over a wide range of pulse repetition frequencies (PRF) and at various pulse widths. An external synchronizing pulse may be used to initiate a generator pulse which, in some cases, may be delayed as long as 300 microseconds after initiation. In an AM signal generator, and audio oscillator is generally employed to modulate an RF oscillator. Frequency shift of the RF oscillator may occur

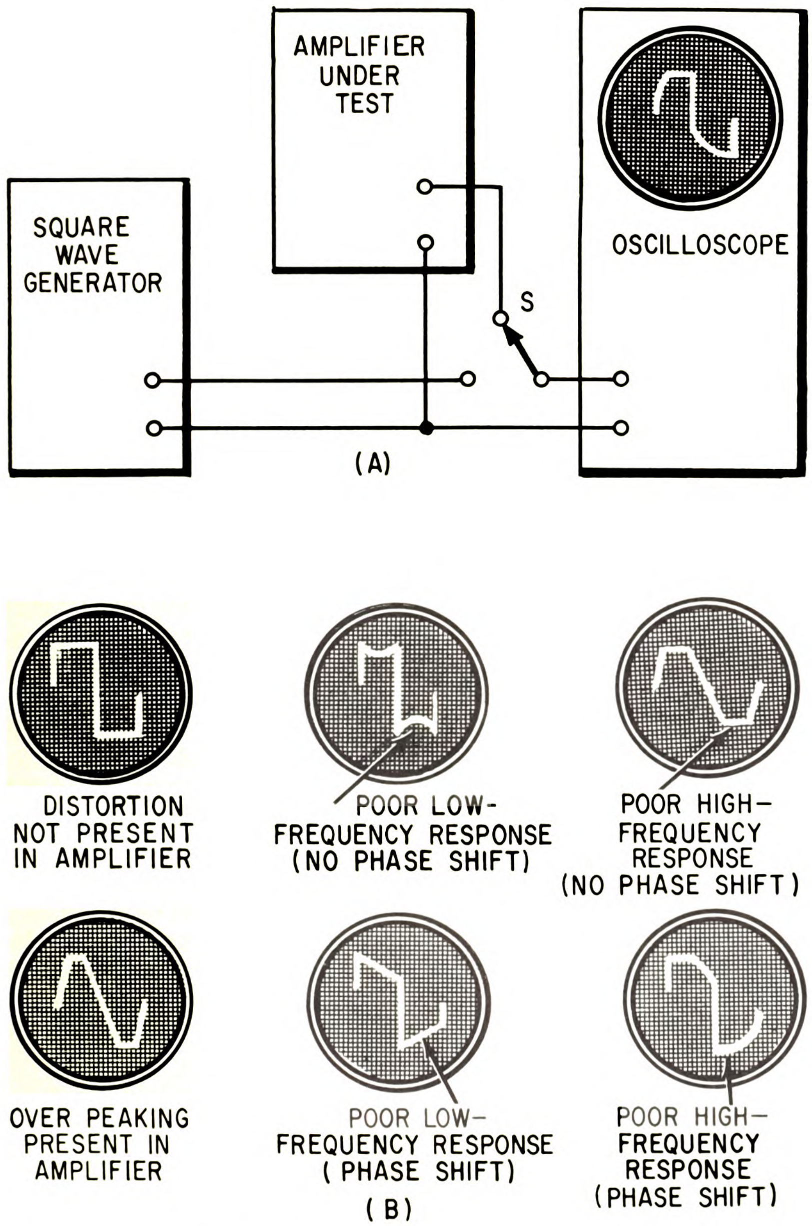

Figure 4-5.—Checking an amplifier using a square wave. (A) Test setup; (B) response patterns.

when an oscillator is directly modulated. For this reason the modulation percentage is generally kept at a low figure, usually about 30 percent. In FM or sweep generators, excessive frequency deviation (sweep) may produce a type of AM modulation of the RF signal. Although not always the case, this type of modulation may not be noticeable when the FM signal is fed to a receiver with limiter action. For this reason, and to avoid distortion in scope presentations, only sufficient deviation (sweep) should be provided to accomplish the purpose.

Output Circuit

The output circuit contains a calibrated attenuator and often an output-level meter. The output-level meter, which permits accurate control of the output of the oscillator, indicates arbitrary values of oscillator output. The attenuator selects the amount of this output that is required, and is usually calibrated in terms of microvolts. When the output-level meter is adjusted to unity (1), the attenuator provides a direct reading in microvolts. At other output-level meter readings, the decimal value of the reading is multiplied by the attenuator reading to give the microvolt output.

There are three general types of RF signal generators. They are the AM, the FM, and the PM (pulse-modulated) types.

FM SIGNAL GENERATORS

Various types of frequency-modulated signal generators are available; however, these generators are restricted to specialized applications with the exception of that type known as a sweep generator. The following general analysis of FM signal generators is given to provide the technician with basic information pertinent to all types of FM generators. Sweep generators are discussed separately following the general analysis.

An FM signal is one in which the output frequency varies above and below a center frequency. The overall frequency variation is known as the frequency swing (or deviation), and the rate at which this swing recurs is controllable at any audio (or video) frequency rate for which the generator has been designed. The frequency change of the output may be accomplished by the mechanical variation of either the capacitance or inductance of the oscillator circuit, or the use of a reactance tube connected to the oscillator circuit. In the latter case, changes of the voltage impressed on the grid of the reactance tube change the amount of reactance introduced into the oscillator tuned circuit, and as a result cause the output frequency to change. The frequency of the signal on the grid of the reactance tube thereby controls the rate of frequency deviation, and the amplitude of the signal voltage controls the amount of the deviation.

Sweep Generators

A sweep generator is a form of an FM signal generator the carrier deviation of which is adjustable by means of a sweep-width control; however, the sweep generator differs from the ordinary FM signal generator in that the rate of carrier deviation is generally maintained at a fixed frequency. The voltage used to effect the deviation may be either a sine wave (very common) or a sawtooth waveform. Since an oscilloscope is used to observe the patterns which are formed when the bandpass of interest is swept by this type of generator, the oscilloscope time base must utilize (or be synchronized with) the same waveform used to produce the deviation. The horizontal (or time) axis of the pattern then represents the instantaneous frequency of the generator output, while the vertical axis shows the response characteristic of the circuit under test for each frequency. Sweep generators are widely used for the observation of response characteristics and the visual alinement of tuned circuits.

Deviation of the carrier may be accomplished either electromechanically or electronically. The electromechanical method consists of mechanically varying the capacitance or the inductance of the oscillator tank circuit, causing the frequency to vary accordingly. The electronic method makes use of a reactance-tube modulator.

A sweep generator produces patterns containing a considerable number of instantaneous frequencies. It is necessary to introduce marker signals, which are superimposed on the trace, in order to orient bandpass characteristics (or center frequency) of the circuit under test with respect to frequency. The circuit which produces the marker signals may be an integral part of the instrument, or the marker signals may be supplied from an external source such as an AM signal generator coupled to the circuit being tested.

Most modern frequency-swept signal generators use a reactance-tube method of modulation, since this results in greater flexibility and the equipment is lighter and more compact than would be possible with the rotating capacitor.

The reactance tube and its associated components are connected across the tank circuit of the oscillator in the signal generator. In many cases the a-c powerline, which provides an excellent oscilloscope synchronizing medium, is coupled to the grid of the reactance tube to control the rate of the sweep. The reactance-tube modulator has an advantage over electromechanical modulators in the respect that it can be excited by an external variable AF signal generator, whereas the electromechanical modulator is usually limited to single-frequency operation.

MARKER GENERATOR

The marker generator consists essentially of an oscillator, the tuned circuit of which is normally damped heavily by the conductance of a control (or clamping) tube. This tube is cut off by a pulse, which is supplied by the enabling pulse generator, thus initiating the timing marker oscillations in synchronism with each sweep. The marker generator includes amplifying and pulse-shaping circuits and a rotary ganged switch which is used to change the circuit constants that determine the marker-pulse intervals, and also to shut off the marker generator. These sharp negative pulses are applied to the cathode of the cathode-ray tube. Each pulse makes the cathode more negative with respect to the control grid, and therefore intensifies the electron beam; hence, a series of bright timing dots is produced on the screen as the beam sweeps across. Since the marker generator is controlled by the enabling pulse, the first of each series of markers nearly coincides with the start of the sweep.

Synchronizing pulses which are obtained either internally (from vertical amplifier or trigger generator) or externally, enter the sweep channel by means of a sync selector switch and then pass through an amplifier to the enabling-pulse generator. This generator supplies square waves to energize the sweep and marker generators, and also supplies positive pulses to unblank the electron beam, which up to this time has been blanked by the negative voltage on the control grid of the cathode-ray tube. The enabling pulse passes to the sweep generator, where the basic voltage waveform (sawtooth) that sweeps the electron beam horizontally across the screen originates. The stability control is a screwdriver adjustment used to control the oscillating point of the enabling-pulse generator.

The trigger-pulse generator consists of a rate-governing continuous oscillator, an amplifier, and a pulse-generating circuit similar to a blocking oscillator but operating only (1 cycle at a time) under control of the rate-governing oscillator. When desired, this trigger generator supplies positive 25-volt 4-microsecond pulses for triggering external circuits at the rate of 300, 800, or 2,000 times per second. Simultaneously, through an internal connection, the trigger generator also provides similar pulses of lower amplitude for synchronizing the sweep circuit of the oscilloscope.

CATHODE-RAY OSCILLOSCO

The operation and operating con general-purpose oscilloscope are di Tradevman 3 & 2, NavPers 10376-A strument is suitable for observation forms in circuits involving low fr However, as your work advances to complex equipment involving much h quencies, it becomes necessary to complex test equipment.

OSCILLOSCOPE AN/USM-24C

An oscilloscope capable of display forms found in the more complex equipments is the AN/USM-24C. USM-24C is a portable test set for a luminous plot of time variations o pulse or wave with self-contained measuring its duration, displacemen stantaneous magnitude. The test se of Oscilloscope OS-51/USM-24C, accessories, and case cover CW-268/ The case cover has provisions for mo accessories, and contains a schemati of the instrument and storage spa instruction book.

All operating controls and termi OS-51/USM-24C oscilloscope are l the oscilloscope's front panel and in of the combination case as shown 4-6. The figure should be studied in order to become familiar with the va trols and terminals.

Voltage Limitations

Before using any oscilloscope, portant that the repairman know the mate voltage amplitude of the signal served and the d-c voltage (steady s of the test point. The maximum voltag an oscilloscope is connected should ne that recommended by the Operation I Manual for the particular test instru voltage limitations listed in table 4 OS-51/USM-24C are typical for osc of this type. The figures indicated voltages which include not only the si ponent but the steady state (d.c.) as v

In noting the figures in table 4-1 be remembered that the exact voltage may be found in the appropriate ma important to remember that by usin

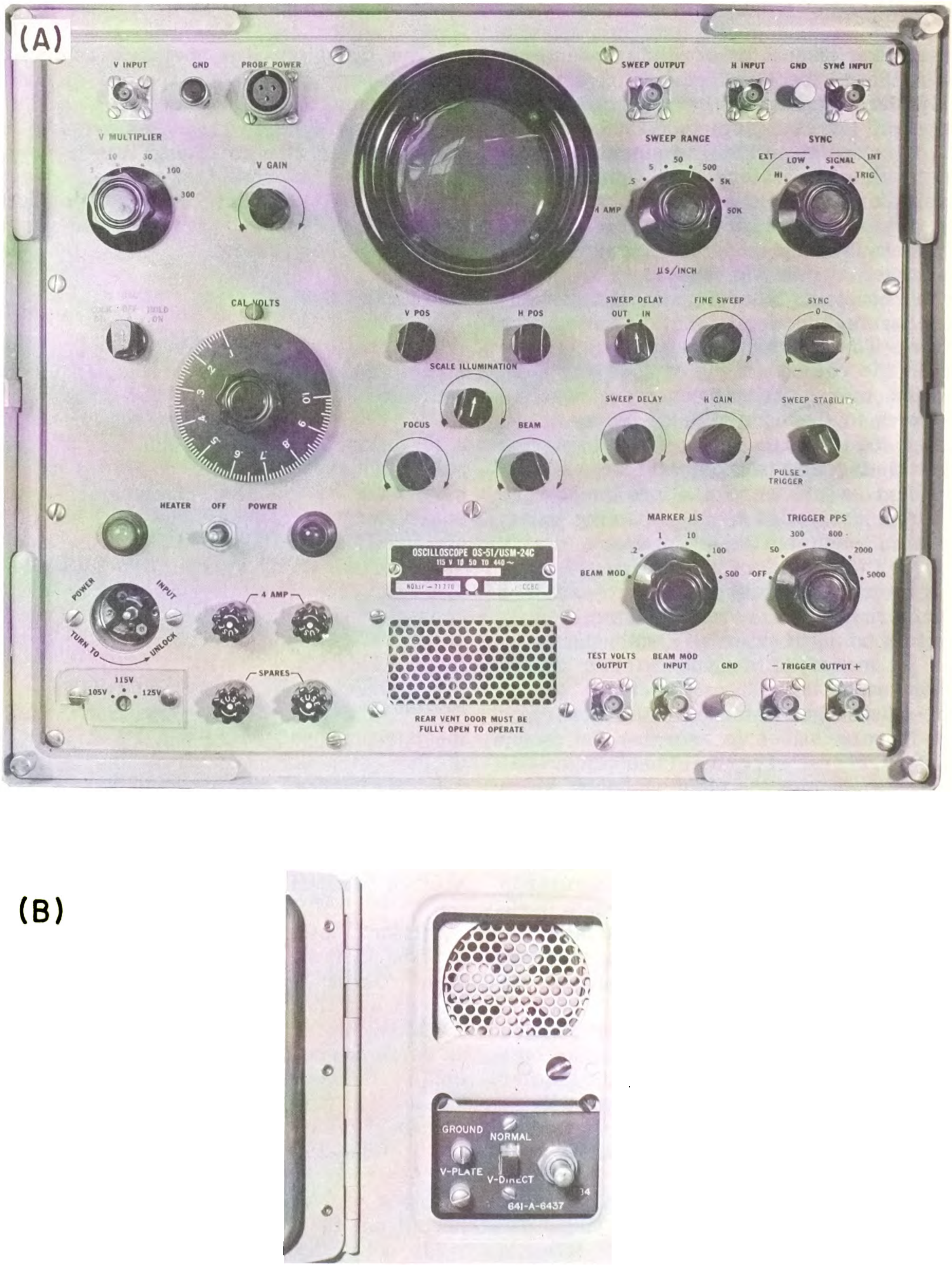

Figure 4-6.—Oscilloscope OS-51/USM-24C. (A) Front panel; (B) rear view.

Table 4-1.—Voltage limits.

Connector	Condition	Signal peak voltage	Total p volta
V INPUT		150	400
V INPUT	With Test Lead CG-883/USM-24C.	600	600
V INPUT	With Test Lead CG-944/AP.	2	400
V DIRECT		150	+600 -
H INPUT		40	400
SYNC INPUT		150	150
SYNC INPUT	With Test Lead CG-883/USM-24C.	450	600
BEAM MOD		50	400
BEAM MOD	With Test Lead CG-883/USM-24C.	450	600
TRIGGER PLUS			D-c cou
TRIGGER MINUS			+600 -

probes in connecting the inputs to the oscilloscope, voltages of a large range may be applied without damage to the equipment. In cases when it may become necessary to observe waveforms involving voltages in excess of those previously stated, a voltage divider may be used.

Waveform Observation

In the maintenance of electronic equipment, it is frequently necessary to observe waveforms at various test points within the equipment. First, in taking waveforms, it is necessary to prepare the oscilloscope and the equipment. The oscilloscope must be properly grounded to protect the operator from dangerous voltages that may result from a part breakdown. Next, the repairman must decide if the oscilloscope sweep is to be triggered or synchronized; if synchronized, he must decide whether to use external or internal sync.

To present a stationary pattern on screen of the oscilloscope, the time dura of the sawtooth sweep voltage must be equ or some multiple of the time duration of waveform to be observed. If this condition not exist, the observed waveform will ap to drift across the screen. The process which the beginning of the oscilloscope sv is adjusted to coincide with the beginnin the observed waveform is called sv synchronization.

Many times it is desired to observe r than 1 cycle of the input waveform. To do determine the time duration of the numbe cycles to be observed and adjust sweep duration accordingly (use μsec markers). example, to observe 4 cycles of a 500-kc sig the time duration of the sweep must be 8 μ

To observe waveforms utilizing the OS USM-24C, the controls must be set (assur that the oscilloscope has been adjusted for pr focus, beam position, and beam intensity, and the signal and sync test leads are connected to their respective connectors) as follows:

1. By means of the SWEEP RANGE switch and FINE SWEEP potentiometer, set the sweep time base to the proper range based on the number of cycles to be observed.
2. Set the SYNC selector switch to the desired synchronization source.
3. Set the H GAIN about halfway.
4. Rotate the SYNC control through its entire range and note the null point; set the control at this position. (NOTE: The null point is the point at which the horizontal sweep disappears.)

With the controls thus adjusted, the oscilloscope may be operated in the repetitive mode by rotating the SWEEP STABILITY control in a clockwise direction until a horizontal trace appears. To check your adjustment, slowly rotate the SYNC control through its null point. The horizontal trace should remain during this rotation.

To operate the oscilloscope in a triggered mode, set the SYNC control to the null point and rotate the SWEEP STABILITY control in a counterclockwise direction until the horizontal trace disappears. Check the adjustment by rotating the SYNC control away from the null point—the horizontal trace should reappear.

Once the mode of operation has been established by the proper setting of the SWEEP STABILITY control, the sweep can be controlled by the SYNC switch as indicated in table 4-2.

When it is necessary or desired to observe a particular portion of the trace, the SWEEP DELAY switch is turned to the IN position. This allows a 10 percent portion of the trace to be examined in detail. This 10 percent portion is expanded to occupy the full length of the screen which enables the SWEEP DELAY control to be adjusted until the desired portion of the trace appears on the screen of the CRT.

Table 4-2.—Sweep sync control settings.

SYNC switch position	Source of signal
INT-SIGNAL	Sweep internally synchronized or triggered by the signal.
EXT-LOW or EXT HI	Sweep externally synchronized or triggered. (NOTE: EXT-LOW is used if the synchronizing signal is less than 5 volts.)
INT-TRIG	Sweep synchronized or triggered from internal trigger generator. (NOTE: These pulses are highly accurate in frequency and are available at 50, 300, 800, 2,000, or 5,000 pulses per second as selected by the TRIGGER PPS switch.)

Voltage Measurements

The amplitude of any signal displayed upon the screen of the cathode-ray tube may be measured directly in peak-to-peak voltage by employing the calibration circuit contained in the oscilloscope. To measure the voltage amplitude of a signal, set the SWEEP RANGE switch to H AMP position to eliminate optical confusion in the horizontal plane. Turn the SCALE ILLUMINATION control clockwise until the scale divisions are plainly visible. Note the number of vertical divisions which the signal occupies. Hold the CAL switch in the ON position and adjust the CAL VOLTS control until the calibration signal occupies the same number of vertical divisions. The peak-to-peak voltage is the reading on the CAL VOLTS dial multiplied by the V MULTIPLIER switch setting. The waveform of the calibrating voltage is shown in figure 4-7.

It should be noted that the CAL VOLTS dial is calibrated in peak-to-peak voltage. If rms voltage is desired, the computed voltage must be divided by 2.83.

Time Measurements

The time duration of signals or portions of signals displayed on the cathode-ray screen may be measured by means of accurately timed marker pulses which appear as intensified dots along the trace as shown in figure 4-8. The marker pulses are generated in the oscilloscope and are available as follows: 0.2 μsec,

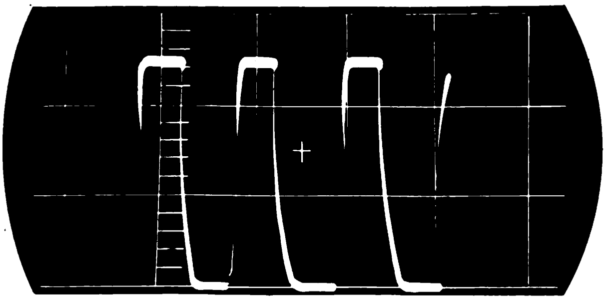

Figure 4-7.—Calibration voltage waveform.

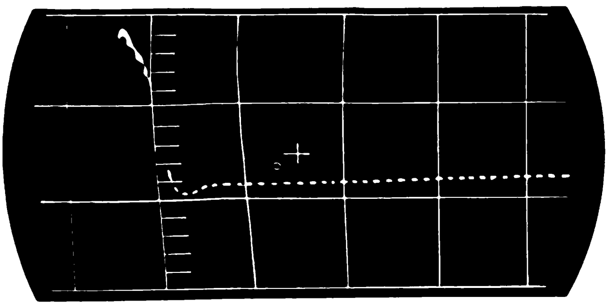

Figure 4-8.—Pulse and time markers.

1.0 μsec, 10 μsec, 100 μsec, and 500 μsec. However, the accuracy of time measurements is limited below 1.0 μsec. The markers are applied to the trace by setting the MARKER μS switch to the appropriate range and adjusting the BEAM control until the markers are clearly defined.

Accessory Probes

Two types of probes are furnished with the USM-24C. They are Attenuating Probe CG-883/USM-24 and Test Lead CG-944/AP. The attenuating probe is frequency-compensated, has a 10 to 1 attenuation which introduces a loss of 10 to 1, and increases the input impedance by 10. It is employed when the input signal to the vertical, horizontal, synchronization, or beam modulation channels is so large as to cause overdrive and distortion of the signal. The shunt capacity is 9 μμf (also called picofarad) and the input impedance is 3 megohms.

The tip may be replaced with a 6-32 screw for short connections. The probe may be used to reduce total capacitive effect on a circuit under test. When two of these probes are used together with connector UG-274/U (a T connector), sufficient isolation is provided to permit mixing 2 voltages at the oscilloscope in o to portray them simultaneously. The probe be connected to the V INPUT, H INPUT, S INPUT, CAL VOLTS, and BEAM MOD nectors. The ground clip should be conne to the chassis of the equipment under test the probe tip to the point to be measure to which voltage is being supplied.

If very high level signals are to be me ured which, when attenuated by the V MUL PLIER and probe combined, are still above voltage safety limit of the V INPUT, a vol divider such as Voltage Divider TS-89B/AP be used to decrease the signal. This wil effect, extend the oscilloscope range in cordance with the factors of attenuation prov by the voltage divider.

Test Lead CG-944/AP has an inte grounded plate amplifier with low loss. probe assembly has an input impedance megohm shunted by 8 μμf and can handle v ages up to 2 volts rms. Figure 4-9 sho schematic diagram of the probes. The tr

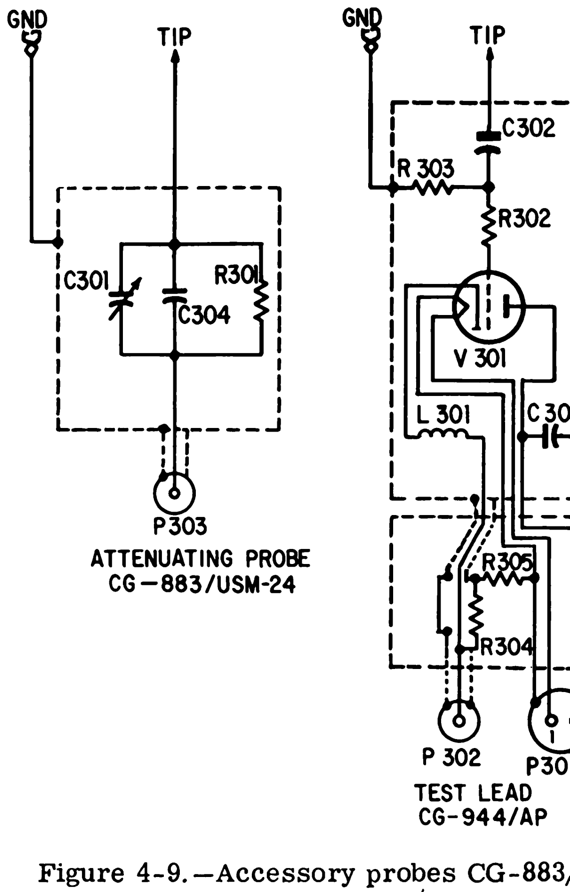

Figure 4-9.—Accessory probes CG-883/ USM-24 and CG-944/AP.

V301 is a subminiature tube, with the load appearing in the cathode circuit. L301 is a peaking coil to neutralize the effect of cable capacity in the bandpass. The signal is connected to the oscilloscope through P302, and power for the test lead is obtained through P301. This probe is employed where the signal under test is small and the circuit cannot stand the oscilloscope's shunting effect of 300,000 ohms and 37 $\mu\mu$f. The probe's 2 connectors are attached to the V INPUT and PROBE connectors of the oscilloscope. The main purpose of the probe is for observation in circuits without loading them unduly.

Maintenance

The useful life of this oscilloscope can be extended by using normal care when handling and operating it. Insofar as it is practicable, it should be protected from dust and extremes in temperature. When not in use, the power should be disconnected from the oscilloscope, unless climatic conditions require the use of the heater. (The unit should remain connected to the power source and the power switch left in the HEATER position when humidity conditions range from 75 to 95 percent.)

When storing the unit, replace the accessories in their proper locations and place the cover on the oscilloscope. When in use, the area behind the oscilloscope should be clear to permit the free flow of air through the rear ventilating door. If the rear ventilating door can be opened fully (approximately 4 inches), there will be enough air space in the rear of the oscilloscope for proper operation.

To insure proper ventilation the air intake grill on the front panel and air exhaust grill inside the rear vent door must be kept clean at all times. The grills may be kept clean by wiping the inner and outer surfaces with a damp, soft cloth.

Both the graph screen and cathode-ray-tube face must be kept free of dust, which tends to collect on charged surfaces. Clean the cathode-ray-tube face with a clean damp cloth and dry the tube thoroughly. The graph screen may be cleaned with any detergent. Do not use alcohol, acetone, kerosene, gasoline, carbon tetrachloride, or paint thinner.

No parts of the oscilloscope require periodic lubrication. The blower motor is lubricated at the factory for the life of the motor. Potentiometer shafts which bind may be lubricated sparingly with oil such as MS 2075.

Electronic maintenance of the USM-24C is straightforward and should present no unusual problems. A large percentage of maintenance will probably consist of replacement of tubes, calibration, and alinement. Instruction Book for Oscilloscope AN/USM-24C, NavShips AN16-30USM24-3, presents detailed operating and maintenance instructions.

Figure 4-10 is a simplified block diagram of the USM-24C oscilloscope. It is suggested that you become thoroughly familiar with the block diagram.

HIGH-PERFORMANCE OSCILLOSCOPES

The advent of higher operating frequencies and the ability to develop pulse waveforms of extremely short rise and fall times (10 nanoseconds (0.01 μsec) is not uncommon), have given rise to a need for an oscilloscope that can faithfully reproduce these waveforms. This requires an O-scope with a flat frequency response over a wide range of frequencies (d.c. to 14 megacycles or better). Figure 4-11 shows the AN/USM-105A which has been developed for the Navy to fulfill these needs.

This scope features simplicity of operation by the use of simplified, logically grouped controls and a high degree of flexibility with the use of plug-in units. It utilizes a 5-inch CRT with a calibrated-grid overlay (called a graticule). This graticule is 10 cm long by 6 cm high, marked in centimeter squares with 2 mm subdivisions on the horizontal and vertical axes. The horizontal sweep time control is calibrated in time per cm and the vertical sensitivity controls are calibrated in volts per cm. Thus, the display on the scope face may be read directly in volts and time. (Frequency is found by taking the reciprocal of time; that is, $f = 1/t$.)

Another important feature of the USM-105A is the dual trace vertical amplifier. This is a plug-in unit and enables the scope to present two signals simultaneously for easy comparison.

INTERPRETATION OF OSCILLOSCOPE PATTERNS

One of the most important steps in waveform analysis—the one which usually proves the most difficult for personnel inexperienced with oscilloscope work—is the proper interpretation of the patterns viewed on the oscilloscope screen. It should be borne in mind that

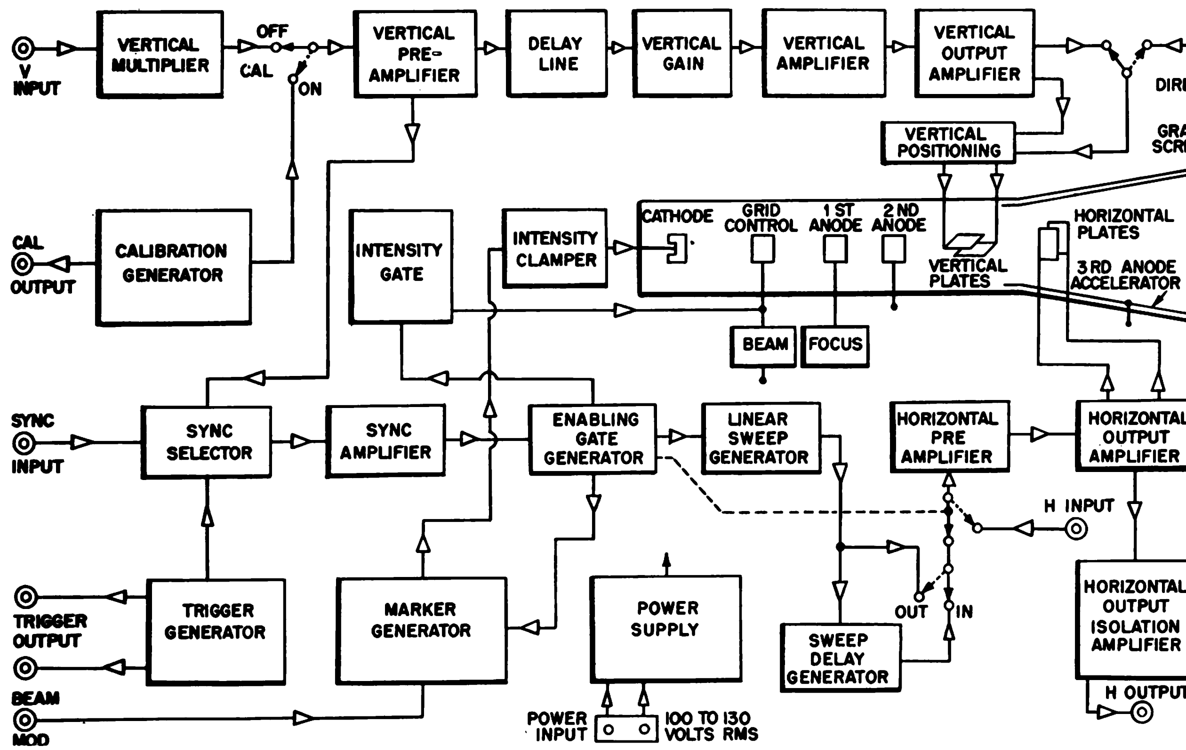

Figure 4-10.—USM-24C, block diagram.

the unknown signal is always plotted as a function of a signal whose characteristics are known. If the characteristics of the signal on one axis are not known, then it will be almost impossible to identify or interpret the signal under investigation on the other axis. For this reason, it is generally common practice to use on the horizontal axis a sawtooth (or sinusoidal) waveform of a known frequency which is synchronized with the fundamental or some integral submultiple of the frequency under test.

Since the sawtooth waveform gives horizontal deflection which is linearly proportional to time, it provides a plot of the wave shape of the unknown signal versus time. Whether the observed pattern is a true reproduction of the signal under test is largely determined by the limitations of the particular oscilloscope available for use. The basic oscilloscope is limited by the following circuit characteristics, which are inherent in the test equipment's frequency response and sensitivity of both the vertical and horizontal amplifiers; namely, phase distortion, input impedance, and the maximum permissible input signal.

Frequency Comparison

Measurement of frequency can be a plished with the oscilloscope by compa unknown frequency with a standard or frequency. The procedure involves the p tion of Lissajous patterns on the oscill These patterns, or figures, are traced screen when the linear sweep voltage is s off and sine-wave voltages are applied the horizontal and to the vertical de plates.

Waveform Distortion

For purposes of discussion, wavefor be considered, as simple (consistin fundamental sine wave) or complex harmonic content, such as a sawtooth or wave). When both simple and complex forms pass through an amplifying circui a definite frequency response, their outpu forms are affected (distorted) in a d manner. The sine wave can suffer only of amplitude, whereas the complex wa because of its harmonic content, can be di

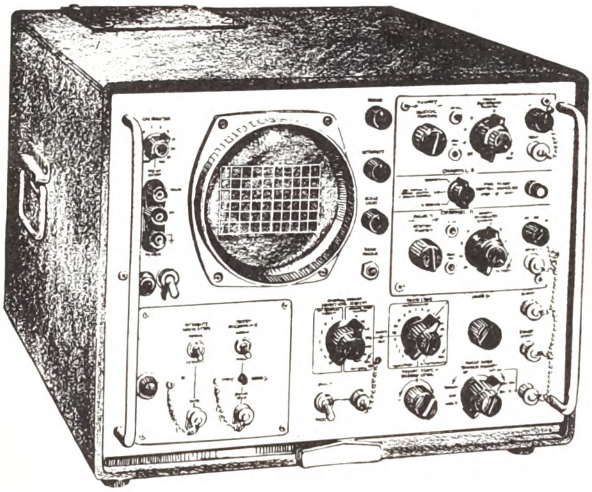

Figure 4-11.—AN/USM-105A oscilloscope.

in both amplitude and wave shape. Therefore, when viewing waveforms having harmonic content, the repairman must consider the frequency response of the amplifiers in the oscilloscope being used.

The horizontal amplifier is used to amplify a sawtooth waveform, the frequency of which varies broadly. Because of the harmonic content of this waveform, it is possible that a nonlinear (distorted) sweep may develop at the horizontal output, becoming more pronounced as the frequency increases. For this reason, signals under observation should be viewed on the fundamental and on several integral submultiples of the sweep voltage. The resultant single, double, triple, etc., presentations should be compared with each other, and the pattern which provides the best linearity should be used.

The frequency response of the vertical and horizontal amplifiers of the basic oscilloscope (OS-8/U) described in Basic Electronics, NavPers 10087-A, extends from about 5 cycles per second to 100 kc. Since this frequency response has proved inadequate for many test applications, an oscilloscope having a frequency response extending from 5 cycles per second to 2 megacycles is now considered as a general-purpose oscilloscope. For true reproduction and proper evaluation of complex waveforms, a synchroscope having special circuits for pulse analysis is used. This type of oscilloscope has a very broad frequency response, extending from about 3 cycles per second to 11 megacycles.

When a complex waveform is passed through an RC network (usually coupling), some of the harmonic components may develop a time lead with respect to the other components. This change in the waveform is known as phase distortion, and is most pronounced at either end of the amplifier response curve. If the RC coupling network contains a variable resistor (gain control), the degree of phase distortion of a particular frequency varies, depending upon the setting of the control. At the lower frequencies the resistance of the potentiometer is the determining factor; at the higher frequencies the inherent distributed capacitance of the rotor affects the phase relationship of the harmonic components. Insofar as the oscilloscope is concerned, only complex waveforms are affected by phase distortion. While it is true that a simple (fundamental) waveform may develop a time lead or lag, the resultant wave shape is unaltered.

Stray pickup may be another cause of waveform distortion. To avoid such pickup, make the leads from the circuit under test as short as possible. In some cases the pickup may be so disturbing that it is almost impossible to use an oscilloscope. A few things can be done to reduce the effect of stray fields on the oscilloscope: First, the cathode-ray tube itself must be very carefully shielded. In most cases, this shielding is provided by the aquadag coating within the tube and also by a metallic shield surrounding the outside of the tube. Second, the common side of the oscilloscope circuit should be connected to a ground point in the circuit under test and also to a good external ground connection, to eliminate most of the stray voltages that are picked up by the leads. Third, a low-capacitance coaxial cable may be used to reduce still further the effect of stray fields.

Procedure for Waveform Observations

Use of the oscilloscope to observe wave shapes when tracing signals is especially indispensable when circuits contain more than one type of signal. This is true when observing composite signals which contain synchronizing pulses and video information on the same transmitted carrier. At different horizontal sweep frequencies the oscilloscope will allow the various composite signals to be displaced. A TD should be familiar enough with the equipment under test to know approximately what type of wave shape to expect, its approximate frequency, and at what point in the circuit.

The oscilloscope is one of the most valuable and dependable test instruments. However, you must be able to interpret the information before any use can be made of it. Use the oscilloscope and use it correctly. An Operation Instruction Manual is provided with each type of oscilloscope used by the Navy. Obtain one for the particular oscilloscope you are to use and study it thoroughly.

SPECIAL OSCILLOSCOPE CIRCUITS

Oscilloscopes designed for the analysis of pulse waveforms are calibrated in terms of time and voltage for the horizontal and vertical axes, respectively. Voltage calibrations are conducted by means of an attenuator at the input of the vertical amplifier and by a signal-generator circuit that produces a known level, or controlled levels of voltage which may be used for reference. The horizontal, or time, axis is marked for selected intervals of time by precisely spaced pulses that produce either vertical lines, or if injected into the cathode or grid circuit of the cathode-ray tube, cause intensification or deintensification of the trace at given time intervals.

Calibration Generator

The calibration generator uses a gas-filled VR type voltage-regulator tube in conjunction with an intermittently operated relay to provide a continuous square-wave output of relatively low frequency (approximately 100 cycles) and of controllable amplitude (0.1 volt to 1 volt). Whenever the multiplier switch (fig. 4-12) is turned to the calibration position, the chosen calibrating voltage is impressed on the signal input of the vertical amplifying system, so that the deflection per volt at this point can be determined for any setting of the gain control. Since this point of calibration is inside the oscilloscope at the output of the multiplier, the voltage of the signal at this point must be multiplied by the ratio of voltage increase back to the signal input. This ratio is a fixed quantity for each multiplier setting, and is marked beside the corresponding switch position. A probe containing an L-pad extends the voltage range to 450 volts, at the expense of a 10-to-1 reduction in sensitivity. Use of an external voltage divider will further extend the voltage range.

CRYSTAL TEST SET MODEL 390A

MIXER

The Mixer Crystal Test Set, Model 3 (fig. 4-13) is designed to give accurate ind tions of crystal quality. The accuracy and simplicity of this test set make it a valu aid in maintaining optimum performance of high-frequency equipments and especially t types which utilize balanced mixer crystals

Theory of Operation

The quality of a mixer crystal can be termined by measurement of its conversion and noise temperature. Conversion loss is fined as the ratio of the power available f the RF signal source to the power availabl the IF output of the crystal. Noise tempera is defined as the ratio of the IF noise po available from the crystal to the thermal n power available from a resistance (equa the IF resistance of the crystal) at r temperature.

The design of the mixer crystal test se based on the fact that the minimum conver loss and noise temperature can be determ from the degree of nonlinearity of the st voltage current (E-I) curve of a mixer crys The mixer crystal test set measures this n linearity by measuring the incremental cha in crystal current caused by an increme change in voltage applied to the crystal in "forward" direction. The adjustment tha made to variable resistor R101 (fig. 4-14) CAL-TEST switch S101 in the CAL posi is such that, if the E-I curve of the cry being tested were linear, a midscale rea would be obtained on meter M101 when S was switched to the TEST position. If the re ing obtained is below midscale, the E-I curv the crystal is nonlinear. The amount by wh the reading falls below midscale is a meas of the degree of nonlinearity; the lower meter reading is below midscale, the m nonlinear is the E-I curve of the crystal, the lower are its conversion loss and n temperature.

Figure 4-14 is a schematic diagram of mixer crystal test set. The initial adjustm of voltage V1 is made by variable resistor R with CAL-TEST switch S101 in the CAL posit Fixed resistors R102, R104, R105, and R determine the limits to which V1 can be adjus

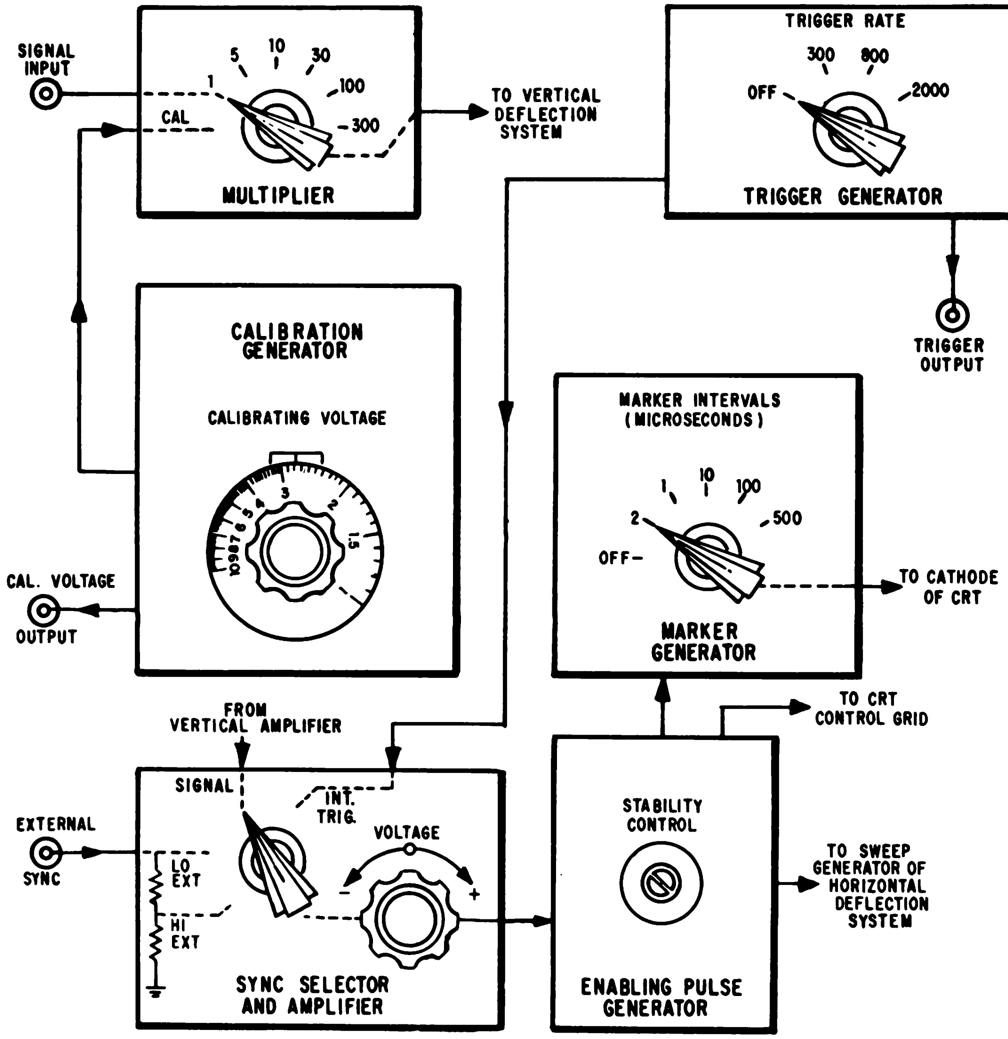

Figure 4-12.—Special oscilloscope circuits used for pulse analysis; block diagram.

The voltage increment (Δe) is established by resistors R103 and R107 when S101 is placed in the TEST position; it has the same value for all crystals.

When a crystal is to be tested, it is placed in crystal holder X101. (The crystal should be handled by the base, and any static charge should be removed by touching the base to the grounding spring on the crystal holder while inserting the crystal.) S101 is placed in the CAL position, and R101 is adjusted until the indication on microammeter M101 coincides with the calibration scale reading of R101. When S101 is placed in the TEST position, M101 indicates the quality of the crystal. With the aid of figure 4-15, the reading of M101 in the TEST position can be converted to actual conversion loss and noise temperature. Black-and-white block sections on the meter scale facilitate acceptance or rejection of crystals according to the type being tested.

An incorrect adjustment of variable resistor R101 may cause excessive voltage to be applied to microammeter M101, which in turn will damage the pointer. Therefore, before moving CAL-TEST switch S101 to the CAL position, set variable resistor R101 fully clockwise.

EQUIPMENT LIMITATIONS

The mixer crystal test set is used to determine the conversion loss and noise temperature

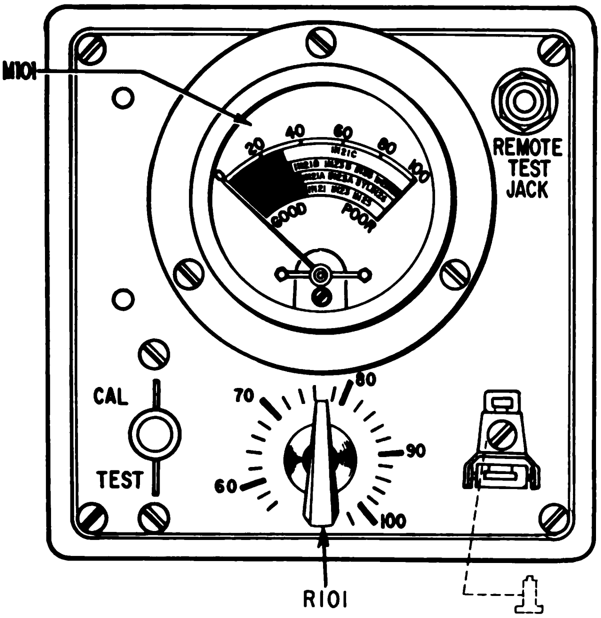

Figure 4-13.—Mixer Crystal Test Set, Model 390A.

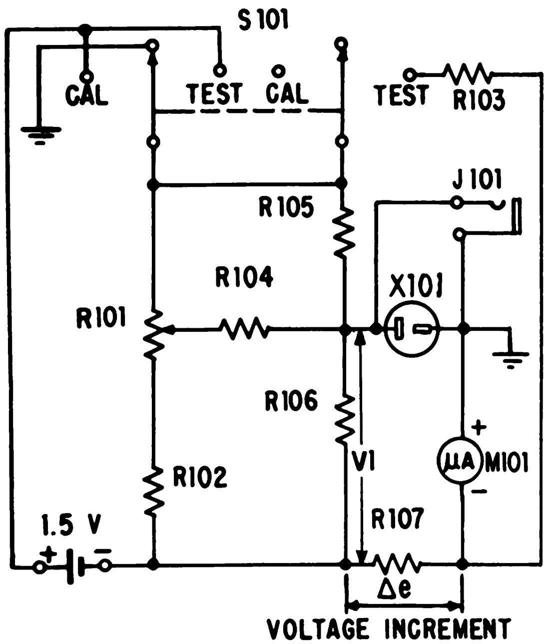

Figure 4-14.—Mixer crystal test set, schematic diagram.

of mixer crystals intended for use at 10,000 megacycles or below. For crystals used above 10,000 megacycles, the readings are still relative—that is, crystals can still be selected in the order of their quality.

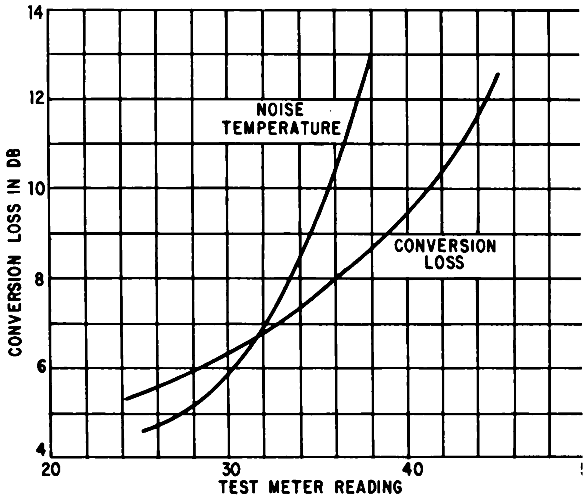

Figure 4-15.—Calibration chart.

TESTING CRYSTALS OF OPPOSITE POLARITY

Mixer crystals of opposite polarity car tested by using an adapter that reverses position of the crystal in the crystal holde the mixer crystal test set. Another metho to attach test leads to a telephone plug in remote test jack, and make connections to crystal by means of clips on the test lea observing proper polarity.

CHECKS AND ADJUSTMENTS

If it is not possible to obtain suffic pointer deflection, or if the meter pointer cre down-scale while the CAL-TEST switch is the CAL position, the dry-cell battery is proba exhausted and should be replaced. Always move the dry-cell battery from the equipm before it is stored for periods of more tha day or two.

If the meter pointer is positioned off-z at the leading edge of the scale, adjust the z corrector to return the pointer to zero.

If the meter pointer flickers back and fo while the CAL-TEST switch is in the CAL po tion, the crystal holder contacts may be b broken, or dirty. Clean the contacts or repl the crystal holder. Repairs other than th are generally considered beyond the scope operating personnel.

IN-CIRCUIT TRANSISTOR CHECKER

Test Set, Transistor TS-1100/U (fig. 4-16) is designed to measure the beta parameter of a transistor when the transistor is connected in a circuit, and to measure beta and I_{CO} parameters with the transistor removed from the circuit.

The characteristics of the test set are:

1. Range of beta: $10 < \beta < \infty$ in a single band.
2. Leakage current measurements: $0 < I_{CO} <$ 50 microamperes.
3. Temperature range: 0 C to +50 C.
4. Power supply: Battery operated.

The equipment contains two separate battery power supplies. One provides the power for the internal circuits, and the other furnishes the bias voltage required for the transistor under test. Either the mercury type or zinc-carbon batteries may be used for operation of the test set.

Low-impedance techniques are used for measurement to isolate the transistor under test from the surrounding circuity. The measurement accuracy of the tester is within ±20 percent provided that the loading of the emitter-base diode or the collector-base diode is not below 500 ohms, and the loading between the collector and the emitter is not below 500 ohms. If the emitter-base load contains a diode, the series impedance must not fall below 7,000 ohms to maintain this accuracy.

With the use of an appropriate shorting technique, the accuracy can be improved. The shorting technique consists of connecting a jumper wire between the emitter of the transistor under test and the far side of all components connected to the base electrode of the transistor. This technique is not universally applicable, and it should be employed only by skilled personnel.

The range of beta that can be measured is between 10 and ∞. A beta of infinity corresponds to zero microamperes on the readout meter scale. A transistor having a beta below 10 will cause the pointer of the meter on the tester to move off the scale. Because of the nonlinear characteristic of the meter scale, which causes crowding at the high end, the readout accuracy for betas above 100 is impaired.

The following controls, as seen on the front panel (fig. 4-16), are incorporated in the test set:

1. POWER switch (labeled ON-OFF): Turns the internal power source on or off.
2. PNP-NPN (transistor select) switch: Selects the proper collector bias polarity for the type transistor under test.
3. BETA switch: Permits readout of beta.
4. BIAS SELECT switch: Used to set the proper collector bias voltages (nominally 3, 6, or 12 volts). Also checks the condition of the internal battery when in the TEST position.
5. REDLINE SET control: Adjusts the amplitude of the test signal.
6. SHORT switch (labeled CB-CE, BE): Enables measurement of a short circuit or a low impedance in the collector-base (CB), collector-emitter (CE), or base-emitter (BE) circuits.
7. I_{CO} switch: Enables readout of transistor leakage.
8. SHORT indicator: The indicator lamp will light when a short circuit or low impedance exists in either the transistor under test or in the surrounding circuitry. If the lamp lights, this indicates a load of less than 500 ohms.
9. TEMPERATURE indicator: The indicator lamp will light when the ambient temperature surrounding the equipment exceeds +50 C. This indicates that the equipment is operating in an environment beyond that for which it has been designed, and that measurement inaccuracies will arise.
10. METER: Indicates magnitude of beta; indicates magnitude of I_{CO}; and indicates the condition of the internal battery. (The battery is good when the meter needle moves under the green band on the dial.)
11. PROBE connector: For connecting the cables (furnished with test set) to the transistor to be tested.
12. TRANSISTOR socket (labeled E-B-C): Enables direct connection between the test set and transistor to be tested.
13. BATTERY DISCONNECT switch (upper left corner of panel—not labeled): Disconnects the internal battery when the front cover is snapped in place.

For proper procedure in operating the test set, refer to Technical Manual for Test Set Transistor TS-1100/U, NavShips 93277.

OVERALL FUNCTIONAL DESCRIPTION

The block diagram (fig. 4-17) consists essentially of a reference oscillator, a tuned amplifier, and a variable bias supply. The oscillator is used to generate a test signal, the tuned amplifier is used to measure the second harmonic component of the current of

Figure 4-16.—Test Set, Transistor TS-1100/U.

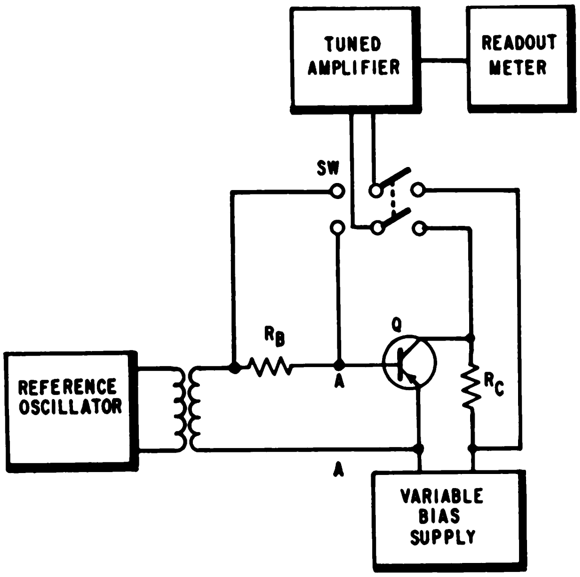

Figure 4-17.—TS-1100/U, block diagram.

the transistor under test, and the bias circuit furnishes the appropriate voltages to the transistor under test.

The reference signal source is a Hartley oscillator operating at a frequency of 1,125 cycles per second. The transistor under test is biased for approximately class B operation. Thus, the transistor conducts only when the input signal level exceeds the work function of the emitter-base diode. The input signal is adjusted until the average collector current is 1 milliampere. The current passes through the collector load resistor, and a voltage is developed across it. This signal is first coupled through a high-gain, narrowband amplifier, having a center frequency of 2,250 cycles per second, and then through a d-c microammeter. The amplifier gain has been adjusted so that the red line on the meter face corresponds to an average collector current of 1 milliampere.

The bandpass amplifier and meter are then switched across the base load resistor, and the meter then reads the magnitude of the average beta directly for a given transistor. Since the collector current is held constant for all transistors under test, the base current is inversely proportional to beta.

Direct measurement of the average collector and base current cannot be made on a d-c meter placed in series with these electrodes. This is because of the large errors which may result from the presence of "sneak paths" provided by the external network, since it is possible to have a direct current flow in these paths from the collector bias supply.

By making an a-c measurement, the problems of erroneous direct current are eliminated, but others are introduced. If the a-c components of the collector current and base current were measured without filtering, the readout meter would not be able to differentiate between the normally rectified signal of the transistor and a nonrectified signal caused by the a-c sneak paths. To eliminate these erroneous signals, the second harmonic component of the signal current is measured.