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A New DC-10 MC Oscilloscope with Dual-Trace and High-Gain Preamplifiers

THE second of the new *-hp-* oscilloscopes is designed as a wide-range dc-10 megacycle measuring instrument with many electrical and mechanical features that give it a high order of performance and ease of use. In addition, flexibility has been assured by designing the instrument to use plug-in vertical preamplifiers which increase the variety of measurements that the oscilloscope can make. Two such preamplifiers are presently available: a dual-channel dc-10 megacycle 50 millivolt/cm preamplifier which is arranged to permit either simultaneous or single display of its two channels; and a high-gain dc-10 megacycle 5 millivolt/cm single-channel preamplifier.

Other leading features of the new design are:

- Controls are functionally grouped and are unusually simple for an oscilloscope of this class.
- The sweep is *automatically triggered* by common waveforms so that sweep adjustments are reduced to a minimum.
- Trigger level and slope controls permit selection of trigger point.
- The sweep can be expanded 100 times to give an effective sweep length of 1,000 cm. A multi-turn positioning control permits any 10-cm portion of the expanded sweep to be displayed.
- Panel lamps automatically indicate when the sweep magnifier is used and when the fastest calibrated sweep is exceeded.
- The oscilloscope has a single-sweep provision which is further designed so as to be electronically re-armable from an external delay generator to obtain a delayed triggered sweep.
- The probes supplied have a slim, penholder style design which makes them especially easy to use.

Fig. 1. *(At left.) New -hp- Model 150A DC—10 Mc Oscilloscope has been designed with such special features as a 100x magnifier, automatic triggering, electronically re-armable single sweep, and plug-in preamplifiers. Many mechanical features are also included.*

Fig. 2. *Probes for new oscilloscope have slim easy-to-use shape and flange-operated alligator clips. Probe capacity can be adjusted without tools merely by loosening finger-operated nut at right of second flange.* *See description on p. 5.*

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- The dual-channel preamplifier is arranged to permit single, alternate, or chopped presentations.
- The dual-channel preamplifier has a trace-blanking feature in chopped operation to blank switching transients.
- The horizontal amplifier is calibrated directly in voltage and has a bandwidth in excess of 500 kc.
- Eighteen square-wave calibrating voltages from 0.2 millivolt to 100 volts peak-to-peak are available at a panel terminal to provide a convenient calibrating arrangement.
- A type 5AMP- flat-face monoaccelerator tube is used and is operated so as to give generous light output.
- An access compartment provides for direct connection to deflecting plates for very fast pulse applications, etc.
- Gate voltage is direct-coupled to the cathode-ray tube grid to maintain constant bias during the sweep.
- Gate voltage and sweep waveform are available at special terminals.
- The delay line in the main vertical amplifier is a distributed type which requires no adjustment.
- The cathode-ray tube bezel can be removed by a simple 15° twist so that filters or tubes can be quickly interchanged.
- The cathode-ray tube socket is provided with a lever to permit rapid and accurate angular positioning of the tube.
- The horizontal amplifier and sweep circuits are constructed on swing-out panels to give a high degree of accessibility to parts.
- Sub-chassis type construction is used with each sub-chassis generally confined to a single type of circuitry.

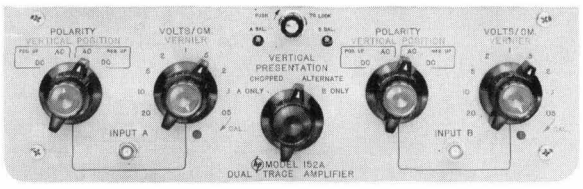


Fig. 3. *Preamplifiers have convenient drawer style construction. DC—10 mc dual-trace unit shown above.*

10 MC DUAL TRACE PREAMPLIFIER

The dual-trace preamplifier is provided with two identical channels, each of which is designed with a bandwidth extending from dc to 10 megacycles. This bandwidth is an overall bandwidth and includes the effect of the vertical amplifier in the main part of the oscilloscope.

The preamplifier is arranged with a selector switch that permits any one of four presentations to be obtained. Two of the presentations provide for exclusive display of either of the two independent channels. The third presentation provides for alternate display of the two channels, i.e., one sweep presents the input to one channel while the next sweep presents the other channel in a continuing process. This arrangement gives the effect of a dual trace and permits two phenomena to be compared directly on the face of the cathode-ray tube. A typical example of this usage is indicated in Fig. 4, where the upper trace shows a gate waveform while the lower trace shows pulses that have been passed through the gate. These time comparisons are essentially errorless, since the sweeps that present the two inputs are identical and since the time delays in the two channels are equal within 2 millimicroseconds. On the fastest sweep of 0.02 microsecond/cm any horizontal displacement is thus less than 1 mm or the same order as the trace resolution. In other words if, using the fastest possible sweep, two identical signals are applied to the two inputs and the traces superimposed with the vertical controls, it is usually difficult to determine that the dual trace feature is used. On slower sweeps, of course, any displacement is accordingly less.

As the alternate presentation feature is extended to lower and lower frequencies, a point is eventually reached where the comparison of two phenomena is limited by insufficient persistence of the cathode-ray tube screen. For this case and for the case where a single long-duration transient is to be compared with a second waveform, a "chopped" type presentation is incorporated in the preamplifier. This is useful for comparing two phenomena that are longer than a millisecond or so. In this arrangement the sweep is alternately switched between the outputs of the two channels by a 100 kc switching circuit. For phenomena that are slow compared to 100 kc, the switching effect becomes unobservable, so that

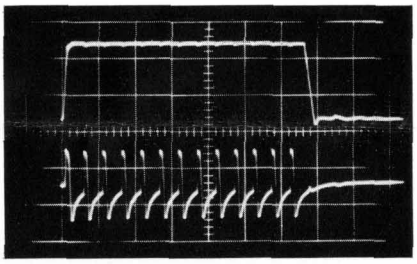


Fig. 4. *Use of dual-trace preamplifiers enables accurate comparison of two simultaneous waveforms. Above oscillogram compares gate waveform with pulses passed through gate.*

the presentation on the screen is that of the inputs to the two channels. By this means the dual-trace effect is extended to much lower frequencies for a given tube persistence.

An important feature of "chopped" operation in this instrument is that the switching transients are blanked. This feature avoids the trace thickening and intensity gradations which otherwise occur. Fig. 6 is an oscillogram of a 1 kc triangular waveform viewed in chopped operation which illustrates the trace resolution that such blanking produces.

Typical transient response of the vertical system using either channel of the dual-trace preamplifier is shown in Fig. 7. Rise-time is approximately 0.035 microsecond and the response is essentially free from overshoot or initial ripple.

Fig. 5. *-hp- Model 150A Oscilloscope with Model 152A Dual-Trace Preamplifier. Functionally-grouped panel controls are unusually simple for an oscilloscope of this class leading to considerable convenience in use.*

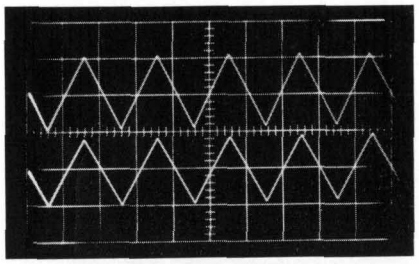


Fig. 6. *One kc triangular wave viewed in "chopped" operation. Switching-transient blanking feature permits high trace resolution in this type of operation.*

To permit complete viewing of the leading edge of pulses, as is done in Fig. 7, $\frac{1}{4}$-microsecond delay lines are included in the vertical amplifier in the main part of the oscilloscope. Their delay is sufficient to permit the sweep to be internally triggered from the signal applied to the vertical system and yet display the leading edge of the signal. An important feature of the delay lines is that they are a distributed type which have essentially no distortion and which do not need to be adjusted.

Each channel of the preamplifier is arranged so that the polarity of its output can be inverted by a panel switch so as to further facilitate comparing the phenomena appearing on the tube face in some cases. Polarity inversion has no effect on the sensitivity of the channel. Separate vertical positioning controls are also provided for each channel.

The maximum sensitivity of each channel is 0.05 volts/cm. A nine-position attenuator reduces sensitivity in a 5-10-20 sequence to a minimum of 20 volts/cm. The attenuator is provided with a $2\frac{1}{2}$:1 vernier to permit any desired intermediate sensitivity to be obtained and to extend the minimum sensitivity to 50 volts/cm.

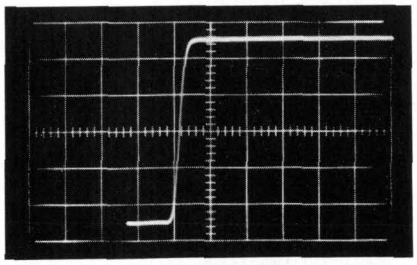


Fig. 7. *Typical transient response of dual-trace preamplifier. Sweep is 0.1 microsecond/cm.*

A-c or d-c input coupling is provided. With a-c coupling the low-frequency response extends down to approximately 2 cps.

Physically, the preamplifier has an especially convenient drawer-like construction and is designed to fit into a recess at the bottom of the front panel (Fig. 13). All power and internal signal paths are automatically connected when the preamplifier is inserted.

HIGH GAIN PREAMPLIFIER

The second preamplifier is a single-channel preamplifier which has the same bandwidth but ten times the sensitivity of one of the channels in the dual-trace preamplifier. The single-channel unit can be directly interchanged with the dual-channel unit with no adjustments whatever and is useful in applications where the dual-channel feature is not needed or where higher sensitivity is required.

The panel controls of the single-channel unit are much like those of one channel of the dual-trace unit, except that the sensitivity control is provided with three additional ranges which extend the sensitivity to 5 millivolts peak-to-peak/cm.

For convenience of use the preamplifier is arranged with two inputs. A panel switch selects the input desired. The same switch also switches in a d-c blocking capacitor in the input circuit for applications where an ac-coupled input is desired.

The transient response of the single-channel preamplifier is essentially identical to that of one of the channels of the dual-trace preamplifier (Fig. 7).

AUTOMATIC TRIGGERING SYSTEM

Like the *-hp-* Model 130A 300 kc oscilloscope described in the last issue, the new Model 150A 10 mc oscilloscope has a simple, flexible trigger system which further includes the *-hp-* automatic triggering feature. This feature is such that the oscilloscope triggers automatically on common waveforms. In many applications the oscilloscope can be used with no adjustment whatsoever of any of the trigger

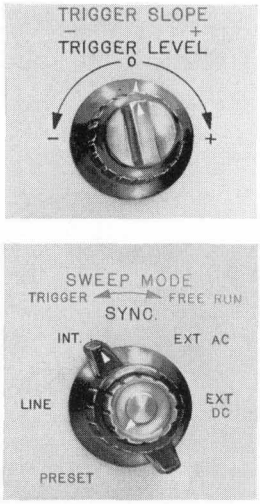


Fig. 8. Trigger Level *and* Slope *controls (above) with* Sync *and* Sweep Mode *controls (below). When* Sweep Mode *control is in* Preset *position, sweep triggers automatically on most waveforms.*

controls. At most the only resetting usually required of the trigger controls is when different trigger points are desired.

The trigger controls themselves are reproduced in Fig. 8. They consist of only two sets of concentric controls and of these one set selects the desired trigger point over a range from −30 to +30 volts of either positive or negative slope on external triggers or on any point of a displayed signal.

The lower set of trigger controls in Fig. 8 includes a *Sync* switch which selects the source from which the trigger voltage is obtained. As indicated by the calibrations on the control, the trigger voltage can be either d-c or a-c coupled from an external source, taken internally from the signal applied to the vertical system, or taken from the power line.

The center control of the lower set is the *Sweep Mode* control. Electrically, this control adjusts the bias level to which the triggers produced by the initial trigger-shaping circuitry are added. Proceeding counterclockwise around the control, this bias level ranges from that which gives free-running operation of the sweep generator through a region which gives triggered operation to a region where the sweep generator is insensitive to triggers. At the extreme counterclockwise

Fig. 9. Sweep Time *selector consists of single direct-reading control with concentric 3:1 vernier.*

end is a switch position which is labelled *Preset.* When the *Sweep Mode* control is in this position, the level at which the sweep generator triggers is pre-adjusted for optimum sensitivity to triggers. As a result, the sweep generator will automatically be triggered at the level and slope selected on any signal applied to the vertical system which is such as to cause only one minor graticule division of deflection. If triggering is obtained from an external source, the circuits will automatically trigger from most waveforms which have a peak-to-peak amplitude of at least 0.5 volt.

The automatic triggering system operates on trigger signals from d-c well up into the megacycle region—usually above 5 megacycles. For still higher frequencies the *Sweep Mode* control can be turned to the free-run region where the sweep then operates as a synchronized free-running sweep. In this mode the sweep will synchronize from waveforms up to the 20-megacycle vicinity.

SWEEP

Special care has been taken in the design of the sweep circuits to assure a high order of performance. The sweep voltage is generated by a feedback type sawtooth generator which provides high linearity (±3% including crt deflection and sweep amplifier non-linearities) and a wide range of sweep times.

Sweep time is selected by a single direct-reading control (Fig. 9) which provides 24 calibrated sweeps from 0.1 microsecond/cm to 5 seconds/cm. A 3:1 vernier is also provided so that any intermediate sweep time can be obtained. This control also permits times as long as 15 seconds/cm to be obtained. Located below the control is a panel lamp which reminds the operator when the magnifier is in use.

Although the minimum sweep time provided by the *Sweep Time/Cm* control is 0.1 microsecond/cm, the minimum sweep time of which

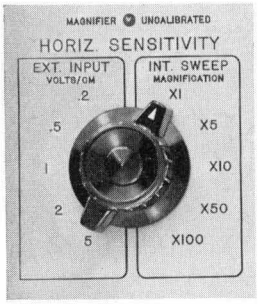


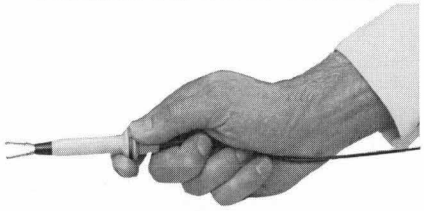
Fig. 10. *Horizontal amplifier sensitivity is determined by direct-reading control which also selects magnification factor when internal sweep is used.*

the instrument is capable is 0.02 microsecond/cm. This is achieved when the magnifier is put into use with fast sweeps.

100x MAGNIFICATION

One of the special features of the new oscilloscope is that it has been designed with a sweep magnifier that gives as much as 100 times magnification of the sweep. This results in an effective sweep length of 1000 cm—33 feet. Such an extremely long effective sweep is valuable in such applications as examining pulse trains. In this work the magnified sweep performs much the same function as the delayed type sweep found in more expensive oscilloscopes and at the same time is considerably more convenient to use.

PENHOLDER STYLE PROBES



The probes supplied with the Model 150A Oscilloscope are of an especially convenient design. Their most apparent feature is probably their slim, penholder shape which permits them to reach relatively inaccessible locations.

Besides shape, however, the probes have several other features of interest. One of these is the manner in which the alligator clips are operated. The clips themselves are a heavy-duty stainless steel type. They are operated by the insulated flanges provided on the probe body. The arrangement is such that a secure electrical and mechanical connection can be made while the hand is removed from the region where shock hazard may be involved.

The clips are opened by squeezing together the flanges on the probe body. This operation can be performed with one hand as indicated in the accompanying illustration. A spring in the probe body closes the clips when the flanges are released and insures a strong connection to whatever the clips are closed on.

Tuning the capacity of the probe has also been made simple and requires no tools whatsoever. The probe capacity can be adjusted by loosening the finger-operated nut behind the rear flange. When this has been done, the rear flange can be rotated with respect to the rear part of the probe, thus adjusting the capacity. A convenient method of checking the capacity adjustment is to connect the probe to the square-wave calibrator voltage available on the oscilloscope panel.

The probe body is molded from gray nylon. At the rear of the probe is a polyvinyl chloride sheath which tapers from the probe body to the attaching cable. This sheath, although semi-flexible, is sufficiently strong to prevent undue flexing of the cable at the point where it enters the probe. The cable itself is an extra-slim, high-flexibility type.

Two probes are provided with each oscilloscope and each has a different-colored cable so that they can easily be distinguished in use. They can be used with either the vertical or horizontal systems, since the input impedance of the systems is nominally the same. Capacity differences between the systems can be compensated by the tuning adjustment described previously.

Electrically, the probes increase the input impedance of the oscilloscope to 10 megohms shunted by only 10 mmf, and reduce the overall sensitivity by a factor of 10. To achieve the low 10 mmf input capacity, care has been taken in the probe design to isolate the input circuit from ground planes. In particular, an arrangement has been developed which shields the input circuit from the ground plane by the input shunting capacitor itself.

Sweep magnification is put into effect by the right-hand positions of the *Horiz. Sensitivity* control (Fig. 10). Four degrees of magnification are available: 5, 10, 50, or 100 times. When the sweep magnifier is in use, a lamp located just below the *Sweep Time/Cm* control (Fig. 9) glows as a reminder to the operator.

The portion of the magnified sweep displayed on the screen at any one time is selected by the *Horiz. Position* control. Often this is done by centering on the screen the portion of interest before the magnifier is turned on, but for applications where a sequential examination of a train is to be made a high order of resolution has been assured by selecting a three-turn wirewound potentiometer as the horizontal control.

Electrically, sweep magnification is achieved by reducing attenuation and feedback in the sweep amplifier. Even when x10 magnification is used, however, feedback is still more than 20 db. In addition, stage currents have been stabilized, a general Model 150A practice.

Besides having a good order of stability precautions have been taken to minimize jitter. Hum and noise are kept at a low order by use of d-c on critical heaters and by use of deposited carbon type resistors. As a result, even when 100 times magnification is used, jitter in the sweep is negligible.

The sweep circuits are designed with a maximum calibrated rate of 0.02 μsec/cm. When high magnification factors are used with the fastest sweeps of the instrument the controls will be set for speeds exceeding the rated maximum. For this case and for a few possible control settings where the reduced feedback in the sweep amplifier prevents the full sweep speed from being realized, a reminder lamp glows just above the *Horiz. Sensitivity* control.

SINGLE SWEEP ARRANGEMENT

Another feature of the new instrument is the provision for single sweeps. This is arranged by providing a selector switch which permits the sweep circuits to be armed manually with the *Sweep Mode* control. When the sweep is armed, a lamp glows as an indication to the operator. The sweep can then be triggered by any one of three methods. First, the sweep can be triggered by the signal applied to the vertical system. Secondly, it can be triggered by a separate trigger applied to the *External Sync Input* terminals. Or thirdly the sweep can be triggered manually by turning the *Sweep Mode* control to the *Free Run* region. As in conventional operation, the point on the signal applied to the vertical system or on the external trigger at which the sweep is initiated can be selected with the *Trigger Level* and *Trigger Slope* controls.

After the sweep has occurred it is locked out until again re-armed.

ELECTRONIC RE-ARMING FOR TRIGGERED DELAYED SWEEPS

Besides being arranged so that the single sweep feature can be re-armed manually, the oscilloscope is further arranged so that single sweeps can be re-armed electronically. This feature makes the oscilloscope valuable in cases where it is desired to examine in detail the individual pulses in pulse trains which have too much jitter to permit them to be examined with the magnified sweep.

A typical situation where the electronically re-armed single sweep is valuable is indicated in Fig. 11 which shows a pulse train with jitter. Since the sweep in the oscilloscope is not triggered after re-arming until a trigger signal occurs, it is possible to use the electronically re-armed single sweep feature of the oscilloscope in conjunction with a laboratory type delay generator to examine any arbitrary pulse in the train. This is done by using the initial reference pulse of the train to trigger the delay generator. The delay generator is then adjusted to produce its delayed pulse at a time just preceding the occurrence of the pulse to be examined. This delayed pulse is used to re-arm the oscilloscope sweep which will then be susceptible to a trigger. The triggering is then accomplished internally by the signal itself. Even if the signal has jitter, the presentation of the signal on the oscilloscope will be jitter-free.

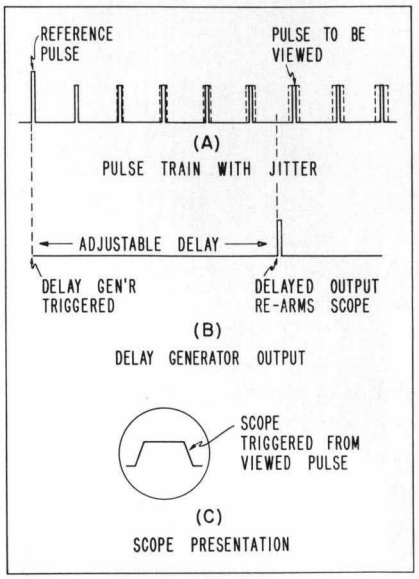


Fig. 11. *Electronic re-armed single sweep feature of new oscilloscope can be used with external delay generator to obtain jitter-free presentation of pulses in trains that have jitter.*

Electronic re-arming can be accomplished by a positive pulse of 15-20 volts amplitude and 1 - 5 microseconds duration.

AMPLITUDE CALIBRATOR

The oscilloscope is provided with an amplitude calibrator which makes available eighteen different 1000-cycle square-wave voltages ranging from 0.2 millivolt to 100 volts peak-to-peak. In addition, a special position on the calibrator makes available a line-frequency signal.

Calibrating voltages are selected by a single direct-reading switch (Fig. 12) and are available at a terminal adjacent to the switch.

HORIZONTAL AMPLIFIER

The pass band of the horizontal amplifier is rated as being from d-c to more than 500 kc (3 db point). The basic sensitivity of the amplifier is 0.2 volts/cm. Lesser sensitivities are obtained by a calibrated attenuator-gain changing arrangement which reduces the sensitivity in four steps to 5 volts/cm. A 3:1 vernier permits the sensitivity to be varied continuously and also extends the

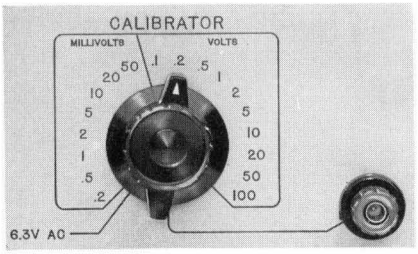


Fig. 12. *Calibrator voltage selector and terminal.*

minimum sensitivity to 15 volts/cm.

The input impedance of the horizontal amplifier is nominally the same as that of the vertical amplifier. This factor permits the probes supplied with the instrument to be used with the horizontal amplifier if desired.

CRT DATA

The cathode-ray tube used in the Model 150A is a type 5AMP-. This tube is one of the modern monoaccelerator designs which are especially suited to measurement work because of their reduced distortion. The tube provides a viewing area 6 cm high x 10 cm wide and has a flat face to reduce parallax. To make the tube deflection factor essentially independent of line voltage changes or intensity settings, the tube is operated from a regulated supply. The gate voltage which unblanks the tube is direct-coupled to make the grid bias independent of the duty cycle of the sweep voltage.

Accelerating voltage on the tube is 5,000 volts which, because the beam current is somewhat higher than is commonly used in other tube designs, gives considerably more light output than is usually associated with a 5,000-volt potential. Light output is thus ample even for high ambient intensity conditions.

The tube is available in any of four screen types: P1, P2, P7, or P11. A filter compatible with the designated screen type is provided.

For special-purpose work, connection to the vertical deflecting plates can be made at terminals which lead to the plates through short leads. Convenient access to these terminals is provided for by a door in the top of the instrument case.

OUTPUT WAVEFORMS

Two waveforms are made available from the oscilloscope for use with external equipment. One of these is the sweep waveform which is made available as a +20 to −20 volt sawtooth. The second waveform is a 20-volt positive gate which has the same duration as the sweep.

The waveforms are provided at terminals located in a special compartment which is reached through the access door in the top of the instrument case.

INTENSITY MODULATION

A third terminal is provided in the special compartment for use when intensity modulation is desired. At usual intensities a +20-volt pulse is required for blanking the trace.

MECHANICAL FEATURES

A number of convenient mechanical features have been included in the Model 150A, three of which are especially noteworthy. One of these is the physical layout of the instrument. As shown in Fig. 13, the instrument is constructed so that the horizontal amplifier and the sweep and trigger circuits are mounted on swing-out panels, an arrangement which gives a high order of accessibility to components and wiring. Many other circuits are also constructed in sub-assembly form and all of these sub-assemblies are interconnected with plug-in type wiring. As a result, it is possible to remove these sub-assemblies for servicing purposes or to keep on hand spare sub-assemblies for replacement purposes. Most sub-assemblies are constructed using etched circuit techniques.

TWIST-OFF BEZEL

Another of the special mechanical features of the instrument is that the bezel is arranged so that it can be removed merely by a 15° twist (Fig. 14). This arrangement simplifies replacing tubes and is especially convenient for changing filters.

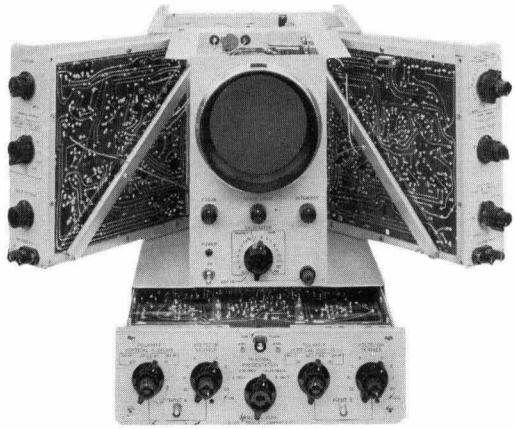


Fig. 13. *Model 150A has been designed to afford high degree of accessibility to parts as indicated by above view of instrument with cabinet removed.*

The bezel is also designed to offer a secure mechanical mount for an oscilloscope camera.

CRT POSITIONING LEVER

The third special mechanical feature of the new oscilloscope is that the cathode-ray tube socket is provided with a lever that simplifies angular positioning of the tube whenever tubes are changed. How this lever is used is shown in Fig. 15. The lever is attached to the socket for the cathode-ray tube. At the same time the socket is clamped with a simple circumferential clamp. All that is needed to position the tube is to loosen the clamp with one hand and position the socket lever with the other, after which the clamp can be tightened. The positioning can be done safely while the instrument is operating so that the oscilloscope trace can be readily aligned using the graticule as a reference. It can be seen that this adjustment requires only a few seconds, and greatly simplifies the matter of accurately positioning the tube.

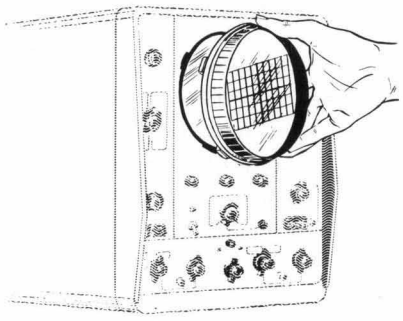


Fig. 14. *Bezel can be removed by 15° twist to facilitate filter or tube replacement but is also a firm camera mount.*

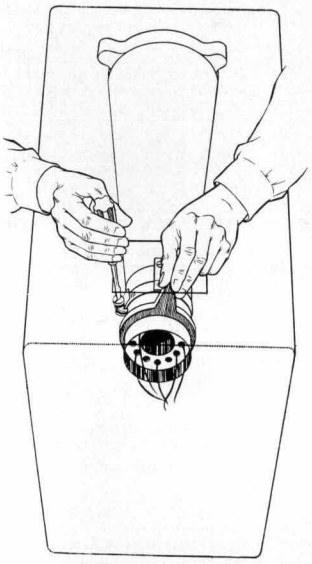


Fig. 15. *Angular positioning of crt is simplified by lever and clamp arrangement on socket.*

GENERAL

Many other features in addition to those described are included in the oscilloscope. The instrument is fan-cooled with filtered air so that components are operated at low temperatures. The air filter snaps into place and can be removed for cleaning without tools. A thermal cut-out supplements the cooling system to guard against accidental air stoppage. Protective devices are included for the power supply. The cabinet is provided with a tilting bail so that the panel can be tilted for convenient viewing. A channel and nylon-glide arrangement facilitates removing the instrument from its case. For convenience in low-frequency use, two special BNC-binding post adaptors are supplied so that patch cords can be used with the vertical input. The *Ext Sync* and *Horiz.* inputs have both BNC and binding-post type inputs. The graticule is edge-lighted from a variable light source.

DESIGN TEAM

Many members of the *-hp-* engineering departments have contributed to the design of the new oscilloscope. The electrical group included James A. Chesebrough, Lawrence W. Johnson, Herbert Shear, William L. Wise, and John Zevenbergen. The mechanical group included Donald K. Borthwick, Carl J. Clement, Jr., Gordon F. Eding, Harold Edmondson, Glenn Herreman, Calvin C. Larsen, and Donald L. Palmer.

—Robert A. Grimm and Norman B. Schrock

OSCILLOSCOPE PROJECT LEADER

Norman B. Schrock, group leader for the development of the new *-hp-* oscilloscopes, has also been instrumental in the design of a number of other important *-hp-* instruments. After obtaining his M.A. from Stanford University in 1943, Mr. Schrock joined *-hp-* where he initially worked on radar equipment, analog frequency meters and high-frequency signal generators. Subsequently, he was project engineer for the design of such *-hp-* instruments as the 335B FM Monitor, the 460 series 140-megacycle bandwidth distributed amplifiers, and much of the basic *-hp-* waveguide equipment such as the waveguide slotted lines, detector mounts, frequency meters, etc.

SPECIFICATIONS

-hp- MODEL 150A OSCILLOSCOPE

SWEEP

RANGE: 0.02 μsec/cm to 15 sec/cm.
CALIBRATED: 24 calibrated sweeps in 1-2-5-10 sequence, 0.1 μsec/cm to 5 sec/cm. Accuracy within 3%.
VERNIER: Permits continuous adjustment of sweep time.
TRIGGERING: Internally or with line voltage, and externally with 0.5 v or more.
TRIGGER POINT: Any positive or negative level on positive or negative slope of signal triggering sweep, +30 v to −30 v range for external trigger.
PRESET TRIGGERING: Switch position on sweep mode control automatically selects optimum setting for stable triggering for majority of conditions.
SINGLE SWEEP: Sweep circuits may be set for triggered single sweep operation. After being triggered, sweep remains locked out until reset. Resetting may be done manually or electronically. Indicator light glows when sweep is armed.

HORIZONTAL AMPLIFIER

SWEEP MAGNIFICATION: Sweep may be expanded 5, 10, 50 or 100 times. Multi-turn horizontal positioning control provides a fine degree of adjustment, permits viewing any 10 cm portion of expanded sweep.
INDICATOR: "Reminder" lights glow when sweep magnifier is used, or when expanded sweep time exceeds fastest calibrated sweep time.
EXTERNAL INPUT: Pass band dc to more than 500 kc. Sensitivity range 200 mv/cm to 15 v/cm. Five calibrated ranges plus vernier.

VERTICAL AMPLIFIER

MAIN VERTICAL AMPLIFIER: Pass band dc to more than 10 mc. Optimum transient response and rise time less than 0.035 μsec.
SIGNAL DELAY: ¼-μsec delay permits viewing leading edge of signal triggering sweep.
INPUT: Through plug-in preamplifier.

GENERAL

AMPLITUDE CALIBRATOR: 18 calibrating voltages in 2-5-10-20 sequence, 0.2 mv to 100 v peak-to-peak, are available at a binding post to provide maximum flexibility. Accuracy within 3%. One kc square wave with rise and decay times of approx. 1 μsec.
SAWTOOTH OUTPUT: +20 to −20 v sawtooth waveform of sweep.
GATE OUTPUT: +20 v signal for duration of sweep.
ILLUMINATED GRATICULE: Edge-lighted graticule with controlled illumination, marked in centimeter squares with 2 mm subdivisions on major horizontal and vertical axes.
CRT BEZEL: CRT bezel readily removable by a 15° twist, providing rapid means of changing filters and replacing CRT if different phosphors are required. Bezel locks in place and thus provides firm mount for standard oscilloscope camera equipment.
CRT PLATES: Direct connection to deflecting plates via terminals in access compartment.
INTENSITY MODULATION: Terminals provided; 20 v positive signal blanks CRT at normal intensity.
CATHODE RAY TUBE: 5AMP- mono-accelerator flat face type with 5,000 v accelerating potential. Available with P1, P2, P7 or P11 screen.
TILT BAIL: Provided to elevate scope front panel for easy viewing.
SIZE: Width—13½"; Height—17¼"; Depth 25".
WEIGHT: Approximately 65 lbs. net.
POWER SUPPLY: 115/230 v ±10%, 50/60 cycles. Approximately 500 watts.
ACCESSORIES FURNISHED: 2 AC-21A probes. 1 filter compatible with screen phosphor. 2 AC-76A BNC to binding post adapters.
PRICE: $1,000.00 f.o.b. Palo Alto, Calif. (Normally supplied with P2 screen. For P1 screen, specify 150A-1; for P7 screen, specify 150A-7; for P11 screen, specify 150A-11.)

MODEL 151A HIGH GAIN AMPLIFIER

SENSITIVITY RANGE: 5 mv/cm to 50 v/cm.
INPUT ATTENUATOR: 12 calibrated ranges, in 0.5, 1, 2 and 5 sequence, from 5 mv/cm to 20 v/cm. Vernier permits continuous adjustment between ranges.
INPUT IMPEDANCE: 1 megohm shunted with 40 μμf.
PASS BAND: dc to 10 mc, 0.035 μsec rise time.
COUPLING: ac or dc.
DUAL INPUTS: Two signal inputs with Type BNC. Selection of either input by panel switch.
PRICE: $100.00 f.o.b. Palo Alto, Calif.

MODEL 152A DUAL CHANNEL AMPLIFIER

SENSITIVITY RANGE: 0.05 v/cm to 50 v/cm.
INPUT ATTENUATOR: 9 calibrated ranges, in 1, 2, 5 and 10 sequence, from 0.05 v/cm to 20 v/cm. Vernier permits continuous adjustment between ranges.
INPUT IMPEDANCE: 1 megohm shunted with 40 μμf.
PASS BAND: dc to 10 mc, 0.035 μsec rise time.
COUPLING: ac or dc.
ELECTRONIC SWITCHING: By alternate sweeps or chopped at approximately 100 kc.
VERTICAL POSITIONING: Individually adjustable.
POLARITY OF PRESENTATION: Input signal as applied or inverted.
INPUT CONNECTORS: Type BNC both channels.
PRICE: $200.00 f.o.b. Palo Alto, Calif.
Data subject to change without notice.