



A New DC-300 KC High-Sensitivity Oscilloscope with Triggered Sweep

A new dc-300 kc general-purpose oscilloscope has been designed with a number of valuable features usually found only in the more expensive, high-frequency type oscilloscopes. These features have been specifically selected to make the oscilloscope a true measuring instrument capable of accurate measurements not only of voltage but of time and phase shift as well.

Since one of the important uses for an oscilloscope is as a highly flexible voltmeter, considerable care has been taken for an oscilloscope of this class to make it suitable for measuring voltage. Its amplifiers have been designed to have a high order of stability in both a-c and d-c operation over the range from d-c to 300 kc and are provided with

direct-reading frequency-compensated attenuators. In addition, the instrument incorporates an accurate calibrator for both the vertical and horizontal systems. These features are such as to enable the instrument to measure voltages accurately within 5% over the amplitude range from 1 millivolt peak-to-peak to 500 volts peak-to-peak and over the frequency range from d-c to 300 kc.

Accurate measurements of time (i.e., durations, periods, or intervals) are made possible by designing the instrument so that it uses a triggered type sweep with a linear sweep generator. A triggered sweep is distinguished from the more common synchronized sweep in that it offers a method of obtaining high linearity in the sweep, in that the speed of the

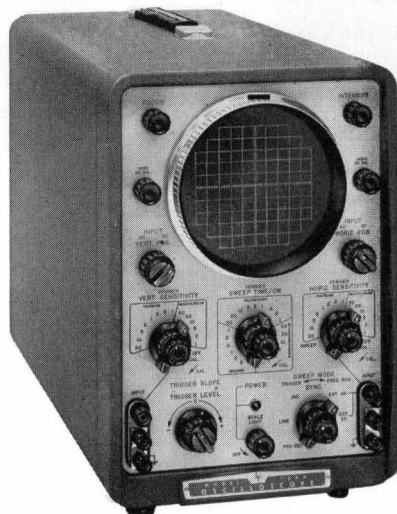


Fig. 1. New -hp- Model 130A DC-300 KC Oscilloscope has been designed with special emphasis on its suitability for measuring voltage, time, and phase shift. Special features include high sensitivity and stability, triggered type sweep with automatic triggering, identical vertical and horizontal amplifiers.

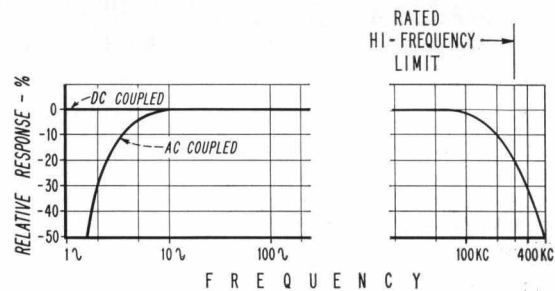


Fig. 2. Typical bandwidth characteristic of -hp- 130A Oscilloscope. Although rated at 300 kc, high-frequency 3 db point is typically much higher as shown in above curve. Curve applies to all sensitivity ranges but will be reduced about 10% at high end if sensitivity vernier is used.

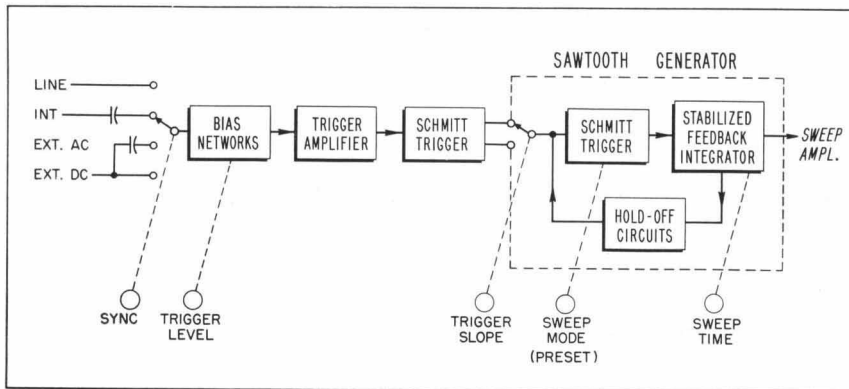


Fig. 3. Basic arrangement of trigger and sweep generator circuits. Use of triggered type sweep has many advantages as described in text.

sweep can be accurately known, in that the point on the trigger waveform at which triggering occurs can be selected, and in that a wide range of sweep speeds can be obtained. Time-wise, the new oscilloscope can be used to make measurements over the wide range from 1 microsecond to 150 seconds.

Measurements of phase shift in external devices have been facilitated by designing the oscilloscope so that its vertical and horizontal amplifiers are identical. No differential phase shift thus occurs between the vertical and horizontal amplifiers until frequencies are reached where differences in stray capacities become significant. As a result the oscilloscope can readily be used to measure phase shifts in external devices up to 50 kc and with care to much higher frequencies.

Other salient features of the new Model 130A oscilloscope are as follows:

- The vertical and horizontal amplifiers both have maximum sensitivities of 1 millivolt/cm and bandwidths of at least 300 kc.
- The oscilloscope has a feature that gives automatic triggering on common waveforms.
- The trigger point on the trigger waveform can be selected by panel polarity- and level-selecting controls.

- The vertical and horizontal amplifiers are electrically identical to facilitate phase shift measurements (Fig. 11).
- The sweep voltage is generated by a feedback integrator which gives excellent sweep linearity and stability.
- Sweep speed, vertical sensitivity and horizontal sensitivity are all selected by single directly-calibrated controls (Figs. 6 and 8).
- Bandwidth is essentially constant and does not decrease at high sensitivities (Fig. 2).
- The amplifiers have a high order of stability, being virtually free of line voltage effects (Fig. 10).
- The vertical and horizontal amplifiers can each be operated from balanced signals on the five most sensitive ranges to suppress common mode signals.
- To facilitate accurate voltage measurements, an internal calibrator for both the vertical and horizontal amplifiers is included.
- The 5-inch mono-accelerator type 5AQP- cathode-ray tube is operated with a 3,000-volt accelerating potential to achieve high light output.
- The crt bezel is designed as a

standard camera mount but can be removed by a simple 15° twist so that filters or tubes can be changed rapidly (Fig. 13).

- The crt is provided with a lever so that angular positioning of the tube can be adjusted very easily (Fig. 14).
- The graticule is of the adjustable edge-lighted type.
- Etched circuit construction is used to achieve clean layout and to simplify maintenance.

SIMPLIFIED TRIGGERING

One of the special objectives in the design of the new oscilloscope was not only to use the more technically refined triggered type sweep generally found only in high-frequency type oscilloscopes but to achieve greater simplicity of use than has been available heretofore. This objective has been realized in the form of a *Sweep Mode* control which is provided with a *Preset* position. Using the *Preset* feature, the instrument will *automatically trigger* from any displayed waveform which is such that it has a peak-to-peak deflection of $\frac{1}{2}$ cm or more (or $\frac{1}{2}$ volt peak-to-peak when triggering is obtained from an external trigger).

Another feature of the internal triggering and sweep system is that it uses an advanced type of circuitry. The basic arrangement is indicated in Fig. 3. The trigger voltage, which can be obtained either from an external source or from the signal applied to the vertical amplifier, is applied through bias networks and a trigger amplifier to a Schmitt trigger circuit which in turn triggers a feedback type sawtooth generator. The function of a Schmitt circuit is to produce a trigger whenever the input signal passes a certain voltage level (in this case approximately $+\frac{1}{4}$ volt). The Schmitt circuit is restored when the input signal level passes approximately $-\frac{1}{4}$ volt. Any signal

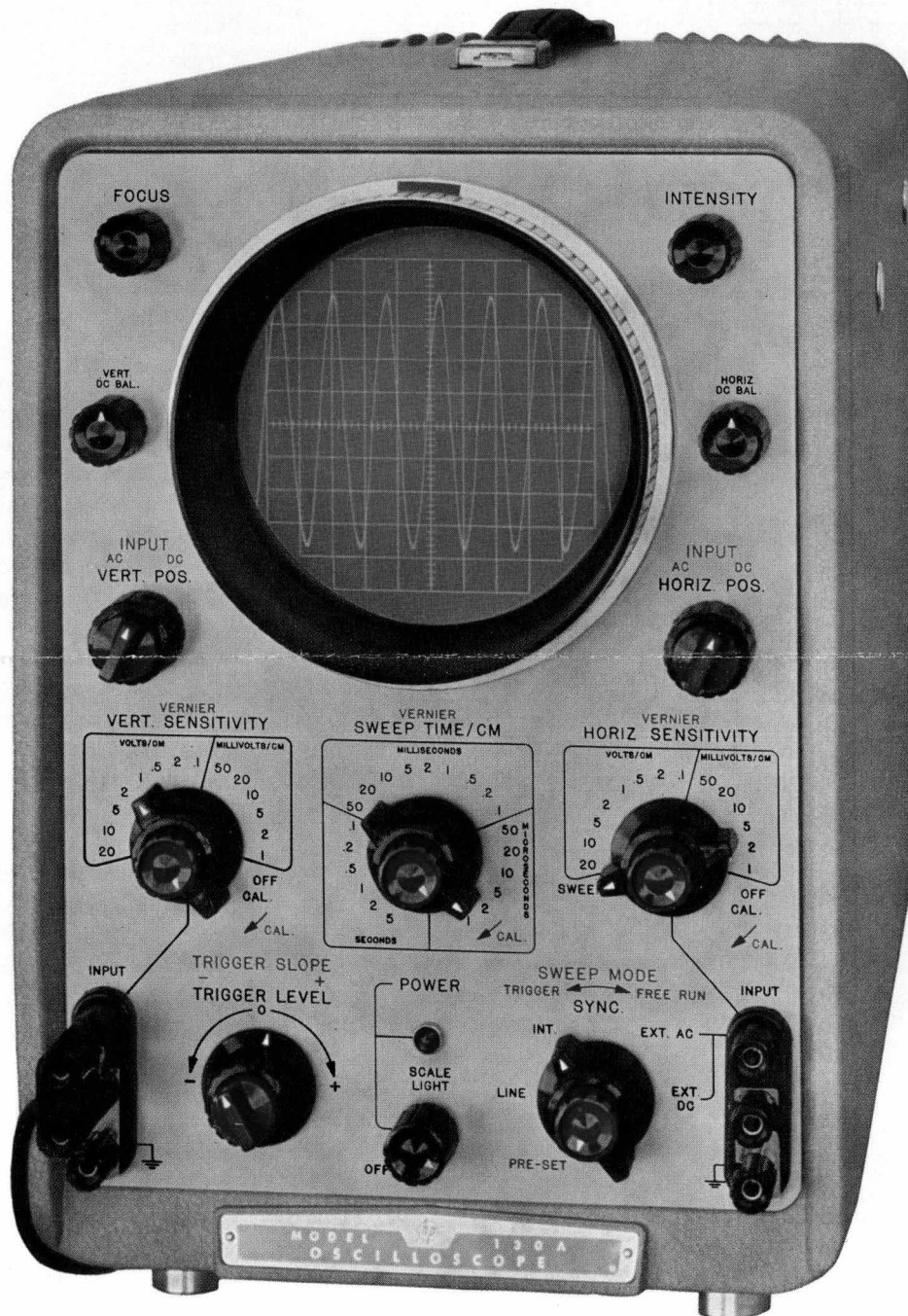


Fig. 4. New -hp- Model 130A has been designed with especially pleasing color scheme. Panel controls are functionally grouped and convenient bar knobs are used on all rotary switches. Pattern on screen is 300 kc sine wave with sweep triggered automatically using Preset feature.

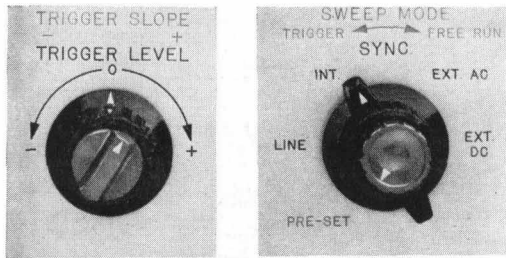


Fig. 5. Trigger controls on new *hp-Model 130A*. Concentric level- and slope-selecting controls are at left. Sync control at right selects source of trigger voltage. Sweep Mode adjusts sweep for free-running or triggered operation with Preset automatic triggering position at ccw end.

which is such as to cross the trigger levels will thus actuate the sweep circuit. The d-c bias networks ahead of the Schmitt circuit shift the d-c levels so that operation of the circuit will be initiated at any desired point on the trigger waveform. A switch at the output of the Schmitt circuit determines whether the sawtooth generator is actuated by the negative or positive slope of the trigger voltage.

The foregoing trigger arrangement has a number of advantages. It obviates the need in most cases for experimentally setting trigger controls and at the same time gives positive, jitter-free operation of the sweep circuit and a choice of triggering from nearly any point on the input waveform.

TRIGGER CONTROLS

The trigger controls on the panel are reproduced in Fig. 5. At the left in Fig. 5 are the concentric *Trigger*

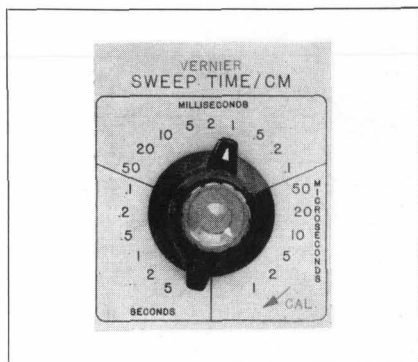


Fig. 6. Sweep Time control is direct-reading. Concentric knob is 3:1 vernier for selecting intermediate sweep times.

Level and *Trigger Slope* controls. *Trigger Slope* selects the slope of the applied trigger from which triggering is to occur. *Trigger Level* selects the voltage point on the input trigger waveform at which triggering will occur. The range of selection offered by this control is from at least -30 to $+30$ volts using external triggers

or at any level of a displayed waveform when triggering is obtained from the vertical system.

On the right are the concentric *Sync* and *Sweep Mode* controls. The *Sync* control selects (reading ccw) whether triggering is to be obtained from d-c coupling of an external trigger, from a-c coupling, internally from the signal applied to the vertical system, or from the power line.

The *Sweep Mode* control adjusts the sensitivity of the sweep circuits so as to permit either free-running or triggered operation. Although the preset feature will automatically accept trigger signals as described previously, the free-running feature has also been included in the instrument since free-running operation is often useful in determining base lines when establishing set-ups. Reading ccw, the *Sweep Mode* control varies the bias on the sweep circuits from that which gives free-running operation through a region where the circuits are receptive to triggers to a region where the circuits are insensitive to triggers. At the extreme ccw end is a switch position which adjusts the circuits for preset operation.

In most conditions when using the preset feature, the *Trigger Level* control is set to 0 and the *Trigger Slope* control to either $+$ or $-$ as desired. In this condition the oscilloscope automatically triggers at the levels described previously. Triggering at other levels can be obtained by re-

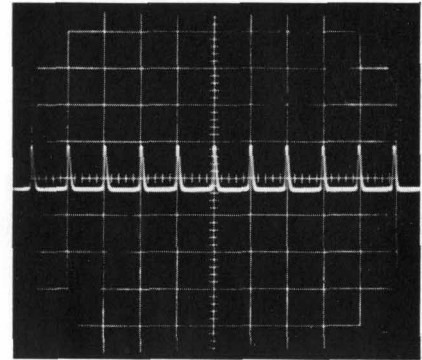


Fig. 7. Sweep linearity is illustrated by above timing comb consisting of 10-microsecond spaced pips.

adjusting the *Trigger Level* control as required.

SWEEP CIRCUITS

The actual sweep waveform is generated by a feedback type sawtooth generator which gives the sweep circuits a high order of performance with respect to linearity, accuracy of sweep time, and range of sweep speeds. A special feature of the sweep generator is that it is stabilized when in the rest condition to achieve a fixed starting point as well as to give good linearity to the first portion of the sweep where unstabilized sweep generators usually introduce significant non-linearity. A further sweep feature is that the gate voltage which unblanks the cathode-ray tube during the sweep is d-c coupled to the crt grid so as to maintain constant grid bias regardless of sweep duty cycle.

The oscilloscope is provided with 21 calibrated sweep speeds ranging from 1 microsecond/cm to 5 seconds/cm. A 3:1 sweep speed vernier permits continuous adjustment of sweep speed between steps and extends the slowest sweep to 15 seconds/cm with vernier fully ccw. These speeds are rated as being accurate within $\pm 5\%$.

Linearity-wise, the use of the stabilized feedback-type sawtooth generator coupled with the uniformity of the crt deflection factor gives excellent sweep linearity as demon-

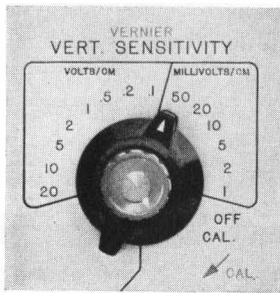


Fig. 8. Sensitivity of vertical and horizontal amplifiers is controlled by single, direct-reading switches. Sensitivity verniers are concentric with switch knob.

strated by the timing comb reproduced in Fig. 7. This linearity is typical of all of the sweep ranges except that the fastest 1 microsecond/cm range may have somewhat less linearity.

SIMPLIFIED AMPLIFIER CONTROLS

In further conformance with specified design objectives, an improved degree of simplicity of use has been achieved for the vertical and horizontal amplifiers as well as the sweep circuits just described. In place of the rather standard arrangement which requires adjustment of two or more controls and a mental calculation of two or more factors, the sensitivity of each amplifier in the new oscilloscope is determined by single direct-reading controls (Fig. 8). Except for their nomenclature, the calibrations on the sensitivity controls are identical, a factor which further simplifies use of the instrument. It will be seen in Fig. 8 that the controls always give a direct indication of sensitivity, either in millivolts-per-centimeter or volts-per-centimeter.

The positions of the controls are related in a 1-2-5-10 sequence to give an arrangement convenient to use with a 10-division graticule. Concentric with the range selector is a Vernier control with a 2½:1 range which permits continuous adjustment of sensitivity so that any desired sensitivity in the 1 millivolt-500 volts peak-to-peak overall measuring range of the instrument can be obtained.

VERTICAL AND HORIZONTAL AMPLIFIERS

The vertical amplifier has been designed to give especially fine performance for an oscilloscope of this class. In addition, the horizontal amplifier has been made the full equal and, in fact, twin of the

vertical amplifier so as to facilitate phase shift measurements and to give equal capacity to the vertical and horizontal systems. The following discussion of bandwidth and d-c stability thus applies to both amplifiers.

Although the rated high-frequency 3 db point for the amplifier is 300 kc, a typical 3 db point in the new oscilloscope is in the vicinity of 400 kc, as indicated in Fig. 2 (front page). This order of bandwidth gives a theoretical rise time of approximately 1 microsecond for the amplifiers and this is confirmed in the oscillogram of Fig. 9. This oscillogram shows how the oscilloscope reproduces a high-quality 40 kc square wave. It can be seen that the rise time is just under 1 microsecond, while overshoot is small. The instrument is thus entirely suitable for observing the square-wave response of devices operating well into the ultrasonic range.

The amplifier has further been designed so as to make the bandwidth constant for all sensitivity ranges. This has been done by designing the amplifier so that its gain is basically controlled by frequency-insensitive attenuators. Although the vernier sensitivity controls reduce the bandwidth to some extent if

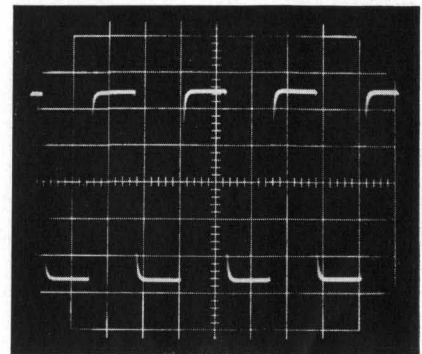


Fig. 9. Oscillogram of 40 kc square wave applied to vertical system. Sweep speed is 10 μsec/cm.

they are used, the basic arrangement is such that the full bandwidth is available even on the most sensitive 1 millivolt/cm range of the instrument.

D-C STABILITY

In any high-sensitivity d-c oscilloscope one of the major design considerations is achieving a high order of d-c stability. In the new Model 130A this consideration has been met by observing such precautions as the use of a balanced circuit with twin-type tubes, the use of low temperature coefficient wire-wound resistors and potentiometers in the first stage, and the use of a carefully-regulated plate supply.

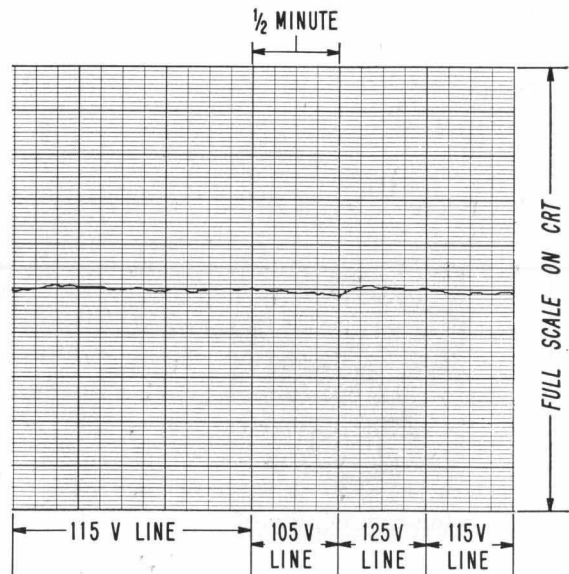
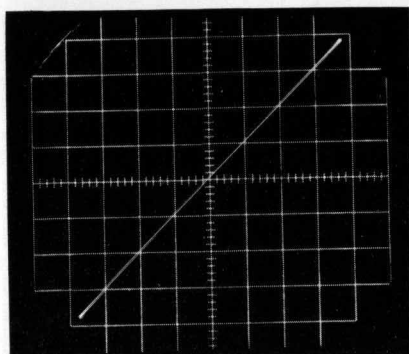
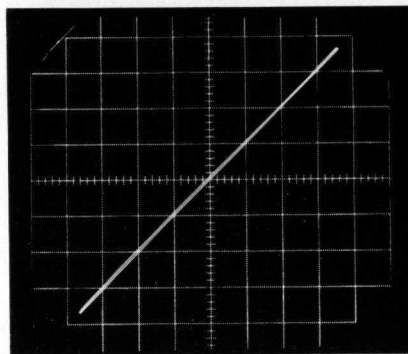


Fig. 10. Record of effect of line voltage changes on most sensitive range of oscilloscope. Height of chart is equal to full-scale deflection of oscilloscope.



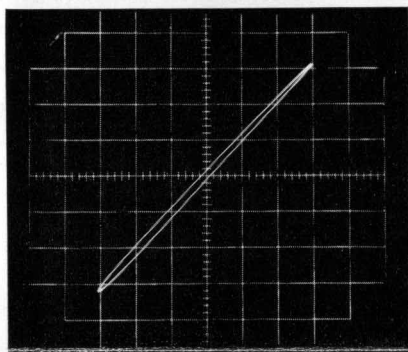
(a)

Phase shift at 50 kc with amplifier controls at identical settings.



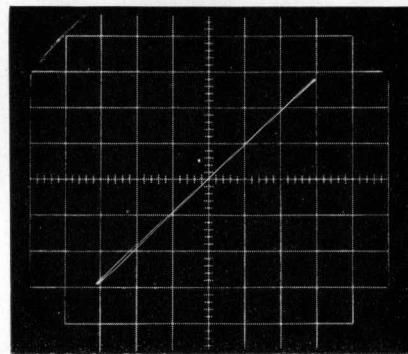
(b)

Phase shift at 100 kc with amplifier controls at identical settings.



(c)

Phase shift at 300 kc with amplifier controls at identical settings.



(d)

Phase shift at 300 kc with amplifier controls at equal settings but with verniers adjusted to minimize phase shift.

Fig. 11. Typical differential phase shift between vertical and horizontal amplifiers.

In addition to these factors, however, an unusual degree of care has also been taken with the filament supply, since the effect of filament supply variations on a d-c amplifier is even more critical than the effect of plate supply variations. Consequently, the filament supply for the amplifier tubes has been fully regulated with a high-control electronic type regulator in which the heater for the control tube is also regulated. These factors make the d-c stability of the oscilloscope essentially independent of line voltage changes as shown in Fig. 10. This illustration is a recording of the influence of line voltage on the stability of the most sensitive range of the oscilloscope. To make this record, the sensitivity of the recorder was adjusted so that the width of the recorder chart was

equal to full scale deflection for the most sensitive range of the oscilloscope. Each major division of the record is then equal to 1 cm of deflection on the crt or the equivalent of 1 millivolt applied to the oscilloscope input. Fig. 10 is thus a graphic representation of the shift of the crt beam as a function of line voltage changes for the most sensitive range. It will be seen that the shift in beam position for even a rapid ± 10 -volt change from a 115-volt line is scarcely detectable. In addition, for each of the first four reductions in the setting of the amplifier *Sensitivity* control, even this small effect will be halved, i.e., eventually being reduced by a factor of 20 times on the 20 mv/cm range and above, since the first four positions of the input at-

tenuator are located just following the first amplifier stage.

Care has also been taken to minimize thermal changes, resulting in a good long-term stability rated as drifting not more than the equivalent of a change at the input terminals of 1 millivolt/hour. No data are presented on this characteristic because of the considerable space required.

D-c balance controls are provided on the panel to adjust the d-c voltages at the ends of the amplifier attenuator so that the sensitivity controls do not affect the beam position.

DIFFERENTIAL PHASE SHIFT

The twin design of the vertical and horizontal amplifiers is of considerable value in many applications where phase shift measurements are to be made because very little differential phase shift occurs in the oscilloscope. This is especially true when the vertical and horizontal sensitivity controls are at identical settings. Fig. 11 (a, b, c) show typical differential phase shifts at frequencies of 50 kc, 100 kc, and 300 kc, respectively, for the condition of identical sensitivity positions. While the differential shift indicated in these oscillograms is typical of that obtained under these conditions, it is neither the best nor the worst of which the oscilloscope is capable. The worst condition occurs when the controls are set to widely different positions and is typically several times greater than indicated in the oscillograms. The best condition is obtained by adjusting the sensitivity verniers while the sensitivity switches are in identical positions. Fig. 11(d) shows how the differential phase shift at 300 kc can be improved with this technique in a typical case. In Fig. 11(c) the shift is about 3° , while in Fig. 11(d) it is less than 1° . Even at 600 kc the differential shift can be reduced to a few degrees in this manner. Below about 50 kc, of

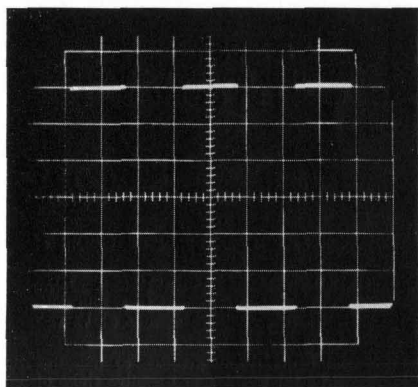


Fig. 12. Waveform of internal calibrator. Calibrator can also be applied to horizontal amplifier.

course, where the phase shift is small in any case, the settings of the controls have a relatively minor influence on phase shift.

BALANCED OPERATION

Many low-level devices such as are encountered in the electromechanical field naturally have balanced outputs or are designed with balanced outputs to minimize pick-up problems. Cognizance has been taken of this situation and the oscilloscope is arranged so that it can be used as a balanced input device on its five most sensitive ranges (20 mv/cm or 200 mv p-p full scale and lower). This range covers the region where pick-up is troublesome. The oscilloscope inputs are balanced to the extent that 45 to 60 db of suppression of a common mode signal will occur, depending on the sensitivity range used.

Balanced operation has the further advantage for some applications that it doubles the oscilloscope input impedance from 1 megohm in parallel with 50 mmf to 2 megohms in parallel with 25 mmf.

SENSITIVITY CALIBRATOR

For use in the many applications where it is desirable to use an oscilloscope to measure voltage, an amplitude calibrator accurate within 5% is incorporated into the oscilloscope. A special feature of the calibrator is that it is arranged so that it can be

used to calibrate both the vertical and horizontal sensitivities.

The calibrator is placed into operation by setting the vertical or horizontal *Sensitivity* controls to the extreme cw *Cal* position. This position automatically places a square wave on either the vertical or horizontal system, depending on which control has been set. The stability of the amplifiers is such that the day-to-day sensitivity of the amplifiers normally need not be adjusted, so no gain adjustment is included on the front panel.

The quality of the square wave that the calibrating system generates is indicated in Fig. 12. Special care has been taken to provide the square wave with a flat top to avoid introducing ambiguities in the calibration procedure.

CRT

The cathode-ray tube used in the new oscilloscope is a type 5AQP-. This is rather a new type of tube that offers several advantages for use in a general-purpose oscilloscope. For one thing, the tube has a flat face which tends to reduce parallax errors. In addition, it is a mono-accelerator type in which deflection occurs after full acceleration of the beam. This has the advantage that the focus of the beam is nearly the same over any part of the tube face and that spurious illumination is reduced for improved photographic use.

Each instrument is provided with a filter compatible with the type of phosphor (P1, P7, or P11) used in the crt supplied with the instrument.

Another unusual feature for an oscilloscope of this class is that the cathode-ray tube is operated with a relatively high accelerating potential of 3,000 volts on the 5-inch crt.

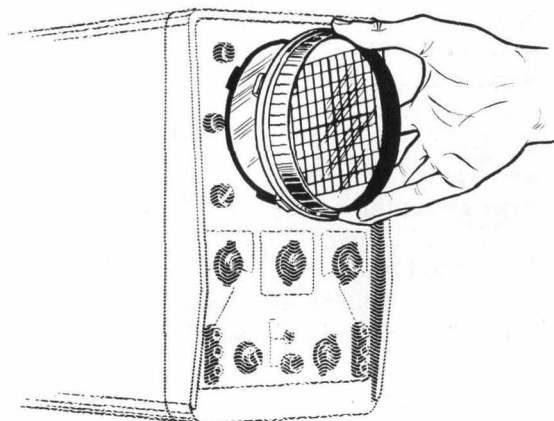


Fig. 13. Bezel can be removed or replaced by a 15° twist to facilitate filter or tube replacement.

This high level results in sufficient light output that even in high ambient light conditions the oscilloscope trace is generously above the visual threshold. The high-voltage supply is regulated to make the deflection factor of the tube independent of line voltage or intensity level.

TWIST-OFF BEZEL

Mechanically, a number of conveniences have been incorporated into the design. One of these is the

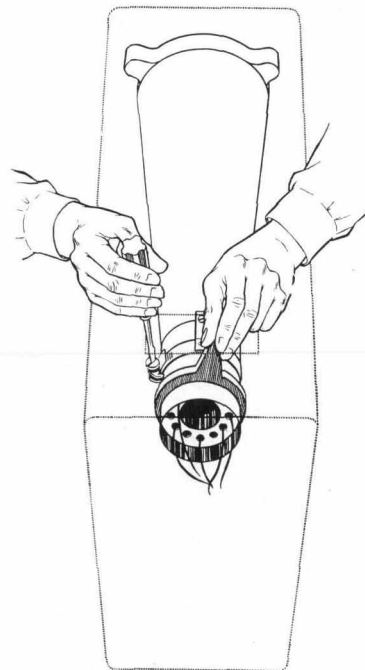


Fig. 14. Crt socket is provided with positioning lever to facilitate angular positioning of tube.

method used to attach the cathode-ray tube bezel to the panel of the instrument. Instead of the usual machine screw arrangement, the bezel in the new oscilloscope is removable merely by a 15° twist (Fig. 13). A simple spring-pin arrangement gives positive positioning of the bezel and prevents accidental loosening.

Despite its simple removal means, the bezel is designed to be usable as a mount for a camera without need of a special adapter. The bezel is of heavy die-cast construction and has sufficient flange depth ($\frac{5}{8}$ " or the same as the clamp width on a typical camera attachment) so that a secure mechanical connection can be made.

CRT POSITIONING LEVER

Anyone who has been faced with the problem of replacing a cathode-ray tube in an oscilloscope or making an oscilloscopic recording has found that aligning the axes of the crt is typically an inconvenient matter at best. This valid criticism has been recognized in the mechanical design of the new Model 130A and has been met by a simplified tube positioning and locking arrangement.

This arrangement is shown in Fig. 14. The tube socket is circumferentially clamped with a simple clamp which can be loosened or tightened by one hand with a screwdriver. In addition, a lever is provided on the crt socket so that the tube can be rotated easily with the other hand. This arrangement both simplifies accurate tube orientation and makes it possible to orient the tube in a matter of seconds. The procedure can be followed safely while the tube is turned on.

INTENSITY MODULATION

Terminals are provided on the rear of the instrument to permit use of intensity modulation. A 20- to 30-volt positive signal is required to turn off the beam. Beam brightening thus requires a negative input.

ASTIGMATISM CONTROL

Because the 5AQP- crt is designed without post-deflection acceleration, there is no lens action at the deflecting plates and the focus of the beam is preserved over essentially the complete face of the tube. It has therefore been found unnecessary to provide the oscilloscope with a panel astigmatism control.

An internal screwdriver-operated astigmatism control is provided, however, for use in the event that an astigmatism adjustment becomes desirable.

ETCHED CIRCUITRY

In line with other recent *-bp-* designs, the new oscilloscope is constructed using etched circuit methods to achieve ready accessibility to parts. Considerable experience and investigation has been drawn on to insure that the etched laminate gives reliable performance under all conditions of temperature and humidity likely to be encountered.

MISCELLANEOUS

The new oscilloscope also includes such features as two tilting bails to tilt the front panel either up or down for easy viewing, an adjustable edge-lighted graticule calibrated vertically and horizontally in centimeters, internal functional layout of sub-assemblies, and a nylon glide and channel arrangement that simplifies cabinet removal and replacement.

DESIGN GROUP

Designing the new oscilloscope has been a joint effort on the part of many members of the *-bp-* engineering departments. The electrical team included Norman B. Schrock, leader, Don Broderick, Edward H. Daw, Duane Dunwoodie, and Dick Reynolds. The mechanical team included Donald K. Borthwick, Carl J. Clement, Jr., Gordon F. Eding, Calvin C. Larsen, Donald L. Palmer, and Harold C. Rocklitz.

—Duane Dunwoodie and Dick Reynolds

SPECIFICATIONS -hp- MODEL 130A DC-300 KC OSCILLOSCOPE

SWEEP

RANGE: 1 μ sec/cm to 15 sec/cm.

CALIBRATED: 21 calibrated sweeps in 1-2-5-10 sequence, 1 μ sec/cm to 5 sec/cm. Accuracy within 5%.

VERNIER: Permits continuous adjustment of sweep time.

TRIGGERING: Internally on signals giving $\frac{1}{2}$ cm or more deflection; from line voltage; or externally on signals of $\frac{1}{2}$ volt or more.

TRIGGER POINT: Any positive or negative level on the positive or negative slope of the signal triggering the sweep. +30 to -30 volt range for external trigger.

PRESET TRIGGERING: Switch position on sweep mode control automatically selects optimum setting for stable triggering.

INPUT AMPLIFIERS

Vertical and horizontal amplifiers have same characteristics.

SENSITIVITY RANGE: 1 mv/cm to 50 v/cm.

INPUT ATTENUATOR: 14 calibrated ranges, in a 1-2-5-10 sequence, 1 mv/cm to 20 v/cm. Vernier permits continuous adjustment between ranges.

PASS BAND: D-c to 300 kc independent of attenuator setting.

COUPLINGS: A-c or d-c.

BALANCED INPUT: On 1, 2, 5, 10 and 20 mv/cm ranges. Input impedance 2 megohms shunted with 25 μ mf.

SINGLE ENDED INPUT: On all ranges. Input impedance 1 megohm shunted with 50 μ mf.

UNDISTORTED DEFLECTION: Three screen diameters.

AMPLITUDE CALIBRATOR: Fixed amplitude, accuracy within 5%. Approximately 1 kc square wave.

GENERAL

ILLUMINATED GRATICULE: Edge lighted graticule with controlled illumination, 10 cm x 10 cm, marked in centimeter squares with 2 mm subdivisions on major horizontal and vertical axes.

CRT BEZEL: CRT bezel readily removed by a 15° twist, providing rapid means of changing filters and replacing cathode ray tube 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 on rear.

INTENSITY MODULATION: Terminals on rear; 20 v positive signal blanks CRT at normal intensity.

CATHODE RAY TUBE: 5AQP- mono-accelerator flat face type with 3000 volt accelerating potential. Available with P1, P7, or P11 screen.

SIZE: Width—9 $\frac{3}{4}$ "; Height—15 $\frac{1}{4}$ "; Depth—20".

WEIGHT: 39 lbs. net.

POWER SUPPLY: 115/230 volts \pm 10%, 50/400 cycles, approximately 175 watts.

FILTER: Color of filter compatible with screen phosphor.

PRICE: \$450.00 f.o.b. Palo Alto, California. (Normally supplied with P1 screen. When ordering with P7 screen, specify 130A-7. When ordering with P11 screen, specify 130A-11.)

Data subject to change without notice