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 sweep is uniform and independent of the signal amplitude.
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 +1 cm or more (or +5 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 +1 volt). The Schmitt circuit is restored when the input signal level passes approximately −1 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.
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 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-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 ±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-
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, 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.

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-tube 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.
(b) D-c balance controls are provided
con-Phase shift at 100 kc with amplifier
corntrols at identical settings.

on the panel to adjust the d-c volt-
ages at the ends of the amplifier at-
tenuator so that the sensitivity con-
trols do not affect the beam position.

DIFFERENTIAL PHASE SHIFT

The twin design of the vertical and horizontal amplifiers is of con-
siderable value in many applications
where phase shift measurements are
to be made because very little dif-
ferential phase shift occurs in the
scope. This is especially true
when the vertical and horizontal
sensitivity controls are at identical
settings. Fig. 11 (a, b, c) show typi-
cal differential phase shifts at fre-
quencies 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 differ-
ent 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. 11. Typical differential phase shift between vertical and horizontal amplifiers.

In addition to these factors, how-
ever, 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. Conse-
quently, the filament supply for the
amplifier tubes has been fully regu-
lated 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 inde-
pendent 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 oscillo-
scope. Each major division of the
record is then equal to 1 cm of de-
fection on the crt or the equivalent
of 1 millivolt applied to the oscillo-
scope 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 scarce-
detachable. In addition, for each of
the first four reductions in the set-
ting of the amplifier Sensitivity con-
trol, 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 mini-
mize thermal changes, resulting in a
good long-term stability rated as
drifting not more than the equiva-
 lent of a change at the input termi-
nals of 1 millivolt/hour. No data are
presented on this characteristic be-
cause of the considerable space re-
quired.

D-c balance controls are provided
on the panel to adjust the d-c volt-
ages at the ends of the amplifier at-
tenuator so that the sensitivity con-
trols do not affect the beam position.
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 parallactic 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 phospher (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. 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...
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 (\(\frac{3}{8}\)" 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 oscillographic 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 -hp- 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 balls 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 subassemblies, 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 -hp- engineering departments. The electrical team included Norman B. Schroek, 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 \(\mu\)sec/cm to 15 sec/cm.
- CALIBRATED: 21 calibrated sweeps in 1-2-5-10 sequence, 1 \(\mu\)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 some characteristics.
- SENSITIVITY RANGE: 1 mv/cm to 50 v/cm.
- INPUT ATTENUATOR: 14 calibrated ranges, in a 1-2-5-10 sequence, 1 \(\mu\)v/cm to 20 \(\mu\)v/cm. Vernier permits continuous adjustment between ranges.
- PASS BAND: D-c to 300 kc independent of attenuator setting.
- COUPLINGS: A-c and d-c.
- BALANCED INPUT: On 1, 2, 5, 10 and 20 mv/cm ranges. Input impedance 2 megohms shunted with 25 \(\mu\)f.
- SINGLE ENDED INPUT: On all ranges, input impedance 1 megohm shunted with 50 \(\mu\)f.
- 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 removable by a 13° 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 \(\mu\) 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-93\(\frac{1}{8}\)"; Height-151\(\frac{1}{8}\)"; 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.