



A DC-500 KC Oscilloscope with Extended Measurement Capabilities

IN THE day-to-day use of present oscilloscopes, it is interesting to recall the enormous advances that have occurred in general-purpose oscilloscopes in just a few years' time. Prior to the introduction of the Hewlett-Packard Model 130 Oscilloscope in 1956*, for example, typical general-purpose oscilloscopes were decidedly limited in their measurement capabilities. Usually, they had a low sensitivity in the order of a tenth of a volt, while their frequency ranges or effective bandwidths were expressible in tens of kilocycles. Sweep circuits were normally of the synchronizing rather than triggered types and were rather inconvenient to use. Accuracies on important characteristics were low.

By contrast, the new "C" version of the -hp- Model 130 Oscilloscope shown below has measurement capabilities of a very advanced

character indeed. The sensitivity in the vertical and horizontal amplifiers is each 200 microvolts/cm, while the bandwidth of each extends beyond 500 kc at the high end and to dc at the low end. The sweep circuit is of the -hp- automatic type which gives automatic triggering from a viewed signal and, in the absence of a signal, automatically displays a base line as a convenience in general measurement work. The sweep system also has the capability for single sweeping and includes a magnifier that gives up to $\times 50$ magnification. The overall design includes many other measuring conveniences such as identical vertical and horizontal amplifiers, an amplitude calibrator, and the -hp- internal-graticule cathode-ray tube.

*Duane Dunwoodie and Dick Reynolds, "A New DC-300 KC High-Sensitivity Oscilloscope with Triggered Sweep," Hewlett-Packard Journal, Vol. 7, No. 7, March, 1956.



Fig. 1. New -hp- Model 130C Oscilloscope has a high sensitivity of 200 microvolts/cm and many conveniences to permit measurements to be made in presently-difficult situations. Scope uses new -hp- internal-graticule cathode-ray tube which avoids mirroring and parallax.

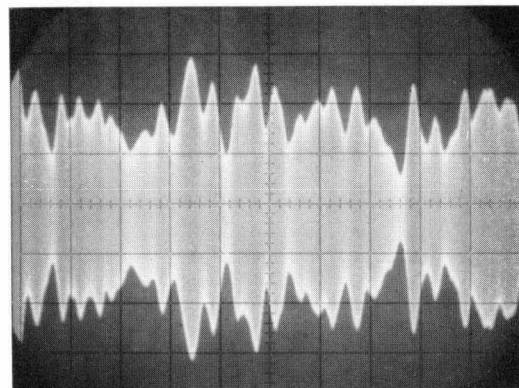


Fig. 2. Several capabilities of new oscilloscope are demonstrated by above oscillogram of modulated carrier of regular a-m broadcast station. Oscillogram was made at -hp- using short tuned antenna connected to scope input. Carrier frequency is about 700 kc. Scope's single-sweep feature was used to permit single trace to be photographed.

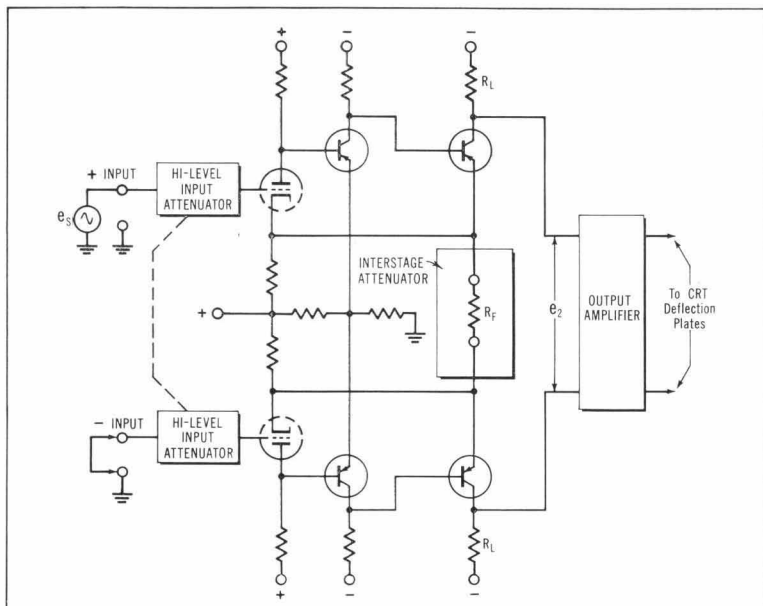


Fig. 3. Basic circuit arrangement used to achieve high-sensitivity, high-stability deflection amplifiers.

STABILIZED HIGH-SENSITIVITY DEFLECTION AMPLIFIERS

One of the objectives in the design of this new oscilloscope was to incorporate the advantages of solid-state devices wherever such devices would contribute significantly to the performance of a particular circuit. An important instance in which this objective was realized occurred in the identical vertical and horizontal deflection amplifiers, where the extra-high sensitivity of the oscilloscope was achieved by using a hybrid tube-transistor circuit. This circuit uses a dual frame-grid triode in the input and output stages and transistors in the two intermediate stages, as shown in Fig. 3.

Besides having extra-high sensitivity and despite its use of transistors, the hybrid circuit has a high inherent gain stability, regardless of the differences between tube and transistor characteristics either initially or with age. This stability is achieved by a large amount of degenerative feedback from the third stage emitters to the cathodes of the input stage. The feedback factor for the amplifier is thus large, and the voltage gain with feedback is independent of the gain without feedback.

The feedback arrangement is also used as a means to adjust the net gain

or sensitivity of the deflection amplifiers. Since the feedback factor is large and the net voltage gain independent of the gain without feedback, the gain of the first three stages of the amplifiers can be written as

$$A = \frac{e_2}{e_s} = \frac{2R_L}{R_F}$$

This expression shows that varying the value of R_F in the third stage of the amplifiers is an accurate and effective means of varying the overall gain. This has permitted the oscilloscope to use an accurate adjustable attenuator for R_F to vary the oscilloscope input sensitivity from 200 $\mu\text{V}/\text{cm}$ to 0.2 V/cm . The remaining range of sensitivities from 0.2 to 20 V/cm is obtained by a frequency

compensated attenuator at the input of the amplifier.

At the maximum sensitivity of 200 $\mu\text{V}/\text{cm}$ for the amplifiers, the feedback factor typically has the substantial value of 85 or 38.6 db. This value increases with lesser sensitivities to a typical maximum of 85,000 or 98.6 db of feedback for sensitivities of 0.2 V/cm . On higher ranges the feedback varies somewhat with the range setting but does not go below a typical value of 82 db.

In the horizontal amplifier, this same technique of varying R_F is used to accomplish stable sweep magnification when the internal sweep generator is used.

DC STABILITY

Another characteristic of prime importance to the user and thus to the designer of a direct-coupled deflection amplifier is dc stability. In the new oscilloscope the following measures have been taken to minimize dc drift in both the vertical and horizontal deflection amplifiers: (a) the amplifiers are differential from input to output; (b) the power supplies are highly regulated; (c) the input amplifier tubes operate with very low voltages and currents and have regulated dc on the heater; (d) the first transistors are a silicon type with very low leakage current; (e) the input stages use wirewound resistors having a small temperature coefficient; (f) the input tubes are mounted to resist shock and vibration; and (g) all components that might influence dc stability are operated at a small fraction of rated dis-

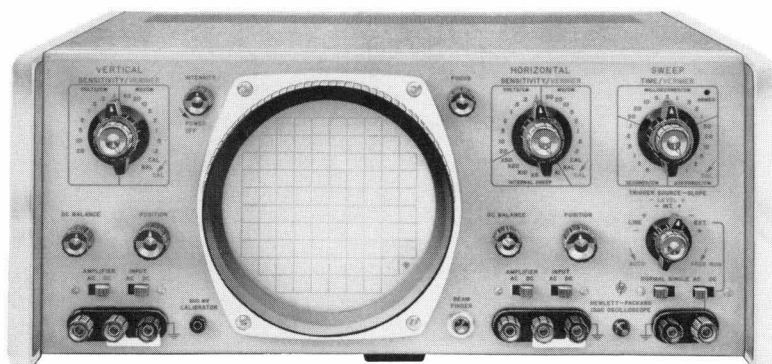


Fig. 4. Panel view of new hp-Model 130C Oscilloscope. Instrument can also be rack-mounted with special end brackets supplied.

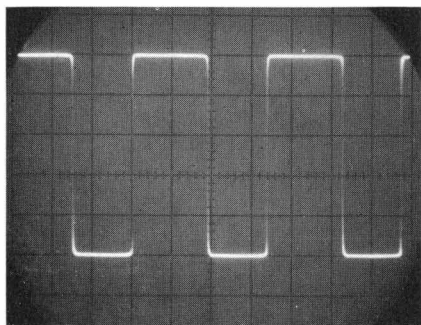


Fig. 5. Oscillogram of calibrator waveform. -hp- internal-graticule crt gives easily-read display having high trace-graticule contrast.

sipations to minimize temperature effects.

The result of these measures is that the deflection amplifiers have a very satisfactory stability which is at least equal if not superior to that achieved in much lower sensitivity oscilloscope amplifiers. The stability of the amplifiers, for example, is such that drift typically does not exceed approximately 1 millivolt per hour after warmup.

INTERSTAGE COUPLING

For cases where overall dc coupling is not required and where high sensitivity operation is desired, the oscilloscope is provided with a front panel switch that gives zero dc transmission to the deflection amplifiers. The arrangement is equivalent to conventional ac coupling and thus eliminates essentially all trace drift even over extended periods of operation. When this equivalent interstage ac coupling is used, the lower cut-off frequency of the amplifiers is approximately 25 cps at the highest sensitivity of 200 $\mu\text{V}/\text{cm}$. As sensitivity is reduced, the cut-off frequency decreases proportionally, becoming 0.25 cps at sensitivities of 20 mV/cm . Above this range, the basic dc stability of the oscilloscope, because of the measures described above, is such that dc drift is essentially undetectable. Consequently, the higher ranges are arranged to be always dc-coupled.

INPUT COUPLING

A choice is also available at the vertical and horizontal inputs to the oscilloscope as to whether dc or ac coupling is desired. The choice of

input coupling permits measurements to be made with or without dc from an external circuit. The input coupling capacitor is rated to withstand voltages up to 600 volts peak. The low-frequency 3 db point using ac input coupling is 10 cps or lower.

AUTOMATIC AND SINGLE-SWEEP OPERATION

The oscilloscope has been designed with a sweep system that is equal in flexibility to the systems used in the most sophisticated present-day oscilloscopes. With the *Level* control in the *Auto* position, automatic sweeping will occur as desired from any one of the three general sources of triggers, i.e., from the waveform being viewed, from a separate external signal, or from the power line waveform. Automatic triggering occurs at the zero-crossing of the trigger waveform and at the slope to which the trigger selector is set (Fig. 4). On the waveform being viewed, triggering will occur whenever the waveform provides one-half centimeter or more of deflection. On external waveforms, a minimum amplitude of one-half volt is required. External signals are ac-coupled in automatic operation to permit the circuitry to sense the zero-crossing point. The trigger *Level* control has an override provision in the *Auto* position so that external triggers will be ac-coupled in automatic operation even if the trigger-coupling switch (lower right of front panel) is set for dc coupling.

Single-sweep operation is combined with a front-panel indicator lamp which shows when the sweep is armed for a trigger. When armed, the sweep will trigger whenever the circuit receives a signal that crosses the level and slope for which the trigger controls are set. After being triggered, the sweep remains insensitive until the *Normal - Single* switch is momentarily returned to the *Normal* position, when the *Armed* indicator light (upper right of panel) will relight.

Free-run operation of the sweep can be obtained at any time by setting the *Level* control to the clockwise end of its range. Intermediate positions of the *Level* control give a

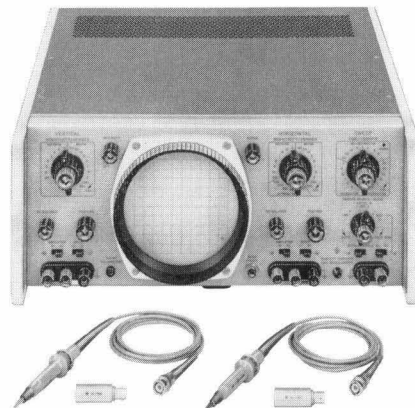


Fig. 6. Special -hp- AC-76B adapters (foreground) have been designed to enable -hp- penholder style x10 probe to be used with 130C Oscilloscope.

choice of polarity and level up to ± 10 volts at which the sweep circuit will trigger. In these positions the automatic sweeping feature is overridden.

MAGNIFIER

The sweep circuitry provides for sweep times from 5 seconds/cm down to 1 $\mu\text{second}/\text{cm}$ which are accurate within $\pm 3\%$. In addition the system has been designed with a magnifier which can be used to expand any portion of the sweep by up to 50 times for examination of waveform detail. The magnifier can also be used to obtain sweep times of up to 0.2 $\mu\text{second}/\text{cm}$ at a slight reduction in accuracy of $\pm 2\%$ from the normal sweep.

BALANCED OPERATION AND PROBE USAGE

To permit the differential configuration of the vertical and horizontal amplifiers to be usable for viewing and measuring balanced signals, a dual attenuator has been located at the input of each deflection amplifier. The resulting arrangement is such that the oscilloscope has a balanced input for all ranges and not just the most sensitive ranges. A convenient grounding strap is provided at the terminals of each amplifier to convert from single-ended to balanced operation and vice versa.

The input attenuators are designed to keep the input impedance of each deflection amplifier constant for all sensitivity settings. This factor enables the -hp- AC-21 penholder style

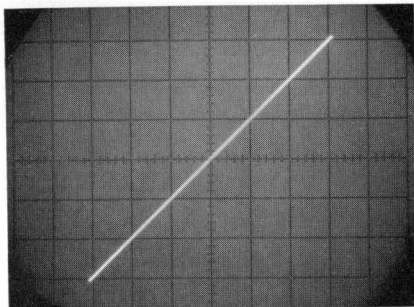


Fig. 7. Identical vertical and horizontal deflection systems have negligible phase difference below 100 kc as shown by above oscillogram of 100 kc signal on both systems.

probes to be used either to obtain an extra-high input impedance of 10 megohms in parallel with 10 mmf or to obtain the mechanical convenience that these probes offer in connecting to circuits under test.

INTERNAL-EXTERNAL CALIBRATOR

To permit the calibration of the vertical and horizontal deflection amplifiers to be checked when desired (Fig. 5), a square-wave type calibrator has been included in the oscilloscope. Each deflection amplifier's sensitivity switch has a *Calibrate* position which automatically connects the calibrator to the amplifier and disconnects the input terminals. A 5 cm-high calibrating waveform is provided. The amplitude of the calibrator waveform when internally connected is accurate within $\pm 3\%$.

Besides the internal connection, the calibrator waveform is also made available for external use at a terminal on the front panel. This arrangement permits the waveform to be used in adjusting the -hp- AC-21A oscilloscope probe for optimum response with the oscilloscope. The accuracy of the calibrator waveform at the panel terminal is $\pm 2\%$.

CATHODE-RAY TUBE

The oscilloscope uses the -hp- internal-graticule style cathode-ray tube which has now been widely used in other -hp- oscilloscopes and is proving very popular. In this tube the graticule is located on the back of the faceplate and is thus in the same plane as the tube's phosphor.

Because of this coplanar arrangement, there is no error from parallax when the tube is viewed from other than a perpendicular angle. Two or more observers simultaneously viewing the tube will all see the trace and graticule in the same relationship. The graticule itself is black instead of being a light source like the trace itself. Unlike the conventional case, there is thus no confusion in visually separating the trace from the graticule. Similarly, photographs of the trace are easier to read (Fig. 5).

An additional property and a continuing convenience of the internal-graticule crt is that the front of the tube is specially processed to make it non-reflective. Since there is no plastic graticule or filter in front of the tube, there is no mirroring and it is thus unnecessary to position the oscilloscope or one's head to avoid seeing reflections that obscure the trace.

The crt is produced by the -hp- cathode-ray tube plant and, aside from the internal-graticule feature, is essentially the same as the 5AQP mono-accelerator type.

GENERAL

In addition to their use in the deflection amplifiers, solid state devices have also been used exclusively in the power supply and regulator circuits including a regulated dc supply for the heaters of the deflection amplifier input tubes. This results in a high efficiency and keeps the instrument's power consumption at only 90 watts at a line voltage of 115 volts. The series transistors in the regulator circuits use the back panel of the instrument as a massive heat sink, thereby assuring conservative operation.

The cabinet for the oscilloscope is of the new -hp- type in which the top or bottom covers can be independently removed.

ACKNOWLEDGMENT

The design group for the new oscilloscope included Tom D. McLaughlin, Robert L. DeVries, and the undersigned.

—John Strathman

SPECIFICATIONS

-hp- MODEL 130C DC — 500 KC OSCILLOSCOPE

VERTICAL AND HORIZONTAL AMPLIFIERS

Bandwidth:

DC Coupled: DC to 500 KC.

Input AC Coupled: 10 cps to 500 KC.

Amplifier AC Coupled: 25 cps to 500 KC at 0.2 mv/cm sensitivity. Lower cut-off frequency is reduced as sensitivity is reduced up to 20 mv/cm where fco is 0.25 cps. On higher input settings amplifier is automatically dc coupled.

Sensitivity: 0.2 mv/cm to 20 v/cm. 16 ranges in 1, 2, 5, 10 sequence with an attenuator accuracy within $\pm 3\%$. Vernier permits continuous adjustment of sensitivity between ranges and extends minimum sensitivity to at least 50 v/cm.

Internal Calibrator: Approximately 350 cps square wave. 5 mv $\pm 3\%$. Automatically connected for checking gain when the sensitivity is switched to CAL.

Input Impedance: 1 megohm shunted by 45 pf, constant on all sensitivity ranges.

Maximum Input: 600 v peak (DC + AC).

Balanced Input: On all sensitivity ranges.

Common Mode Rejection: At least 40 db from 0.2 mv/cm to 0.2 volts/cm sensitivity; common mode signal not to exceed 4 volts peak-to-peak. At least 30 db from 0.5 volts/cm to 20 volts/cm; common mode signal not to exceed 20 times the sensitivity setting from 0.5 volts/cm to 20 volts/cm.

Phase Shift: Within $\pm 1^\circ$ relative phase shift at frequencies up to 100 KC with verniers in CAL position and equal input sensitivities.

SWEEP GENERATOR

Internal Sweep: 21 ranges, 1 μ sec/cm to 5 sec/cm, accuracy within $\pm 3\%$. Vernier provides continuous adjustment between ranges and extends slowest sweep to at least 12.5 sec/cm.

Magnification: X2, X5, X10, X20, X50, overall sweep accuracy within $\pm 5\%$ for sweep rates which do not exceed a maximum rate of 0.2 μ sec/cm.

Automatic Triggering: Base line is displayed in the absence of an input signal.

Internal: 10 cps to 500 KC signal causing 0.5 cm or more vertical deflection and also from line voltage.

External: 20 cps to 500 KC, 0.5 volts peak-to-peak or more.

Trigger Point and Slope: Zero crossing, positive or negative slope of external sync signals or internal vertical deflection signals.

Amplitude Selection Triggering:

Internal: 0.5 cm or more vertical deflection signal.

External: DC or AC coupled, 0.5 volts peak-to-peak or more.

Trigger Point and Slope: Internally from any point of the vertical waveform presented on screen or continuously variable from +10 volts to -10 volts on either positive or negative slope of external signal.

Single Sweep: Front panel switch permits single sweep operation.

GENERAL

Calibrator: Approximately 350 cps, 500 mv $\pm 2\%$ available at front panel.

Cathode Ray Tube: -hp- Type G203E (P31) Internal Graticule, mono-accelerator, 3000 volts accelerating potential. P-2, P-7, and P-11 phosphors are available. Equipped with non-glare safety glass faceplate.

Internal Graticule: Parallax-free 10 cm x 10 cm, marked in cm squares. 2 mm subdivisions on major horizontal and vertical axis.

Beam Finder: Depressing Beam Finder control brings trace on crt screen regardless of setting of balance, position or intensity controls.

Intensity Modulation: Terminals on rear; +20 volt pulse blanks CRT at normal intensity.

Power: 115 or 230 volts $\pm 10\%$, 50 to 1000 cps.

Approximately 90 watts.

Dimensions: 16 $\frac{3}{4}$ inches wide, 7 $\frac{1}{2}$ inches high, 19 $\frac{3}{4}$ inches deep overall; hardware furnished for quick conversion to 7 in. x 19 in. rack mount. Rack mount depth 16 $\frac{1}{8}$ inches.

Weight: Net 32 lb. Shipping 45 lb.

Accessories Available:

AC-21A 10:1 Divider Probe.

AC-76B Adapter (see Fig. 6), \$7.00.

Rear input terminals wired in parallel with front terminals available on special order.

Price: -hp- Model 130C Oscilloscope, \$695.00.

Data subject to change without notice

Prices f.o.b. factory