



Two New Transistorized Frequency Counters with Increased Readout and Low-Frequency Capabilities

THE accuracy, speed and simplicity with which measurements can be made with the electronic frequency counter have made it one of the most useful and popular instruments available. In the ten years since it was first offered commercially, considerable industry effort has been devoted to further refinement of digital counting techniques and to expanding the versatility of equipment employing these techniques. Drawing from the experience of its years of leadership in this field, Hewlett-Packard has recently introduced the electronic counters shown below as the first of a new generation of digital frequency and time-measuring instruments.

Of the two new counters one operates over the frequency range from 2 cps to 1.2 megacycles and the other from 2 cps to 300 kilocycles. Both will measure frequency, period, and the average of up to 10^5 periods as well as the ratio of two frequencies, and both will operate on signals down to 0.1 volt rms. The higher frequency counter presents its measurements on a 6-digit display system, while the 300

kc counter has a 5-digit display system. Each counter is available with either an in-line readout or with an improved arrangement of the familiar column readout. Both counters are fully transistorized and are packaged in cabinets only $3\frac{1}{2}$ " high. The cabinet style is such that the standard bench-type instrument can also be used in a relay rack, if desired, by adding a pair of simple brackets supplied with the instrument.

NEW READOUT FEATURES

In addition to these basic specifications, the new counters have several unusual operating conveniences. One of the most apparent of these is that the readout is steady and continuous, changing only when the measured count changes. This display storage feature is in contrast to the usual arrangement wherein the continuity of the display is interrupted during the interval in which the counter is counting. As is known, display storage requires that each flip-flop in the counting circuitry be duplicated



Fig. 1. New -hp- 1.2-megacycle and 300-kilocycle general-purpose frequency counters are designed to display measurements in a non-intermittent type readout that eliminates usual visual interruptions in readings. Counters are also arranged to measure low frequencies by averaging up to 10^5 periods,

thus giving much increased low-frequency accuracy. Instrument panel is $3\frac{1}{2}$ " high or less than height of 5U4GB tube shown in scale for comparison. Besides in-line type of readout shown, counters also have a new arrangement of column-type readout (Fig. 8).

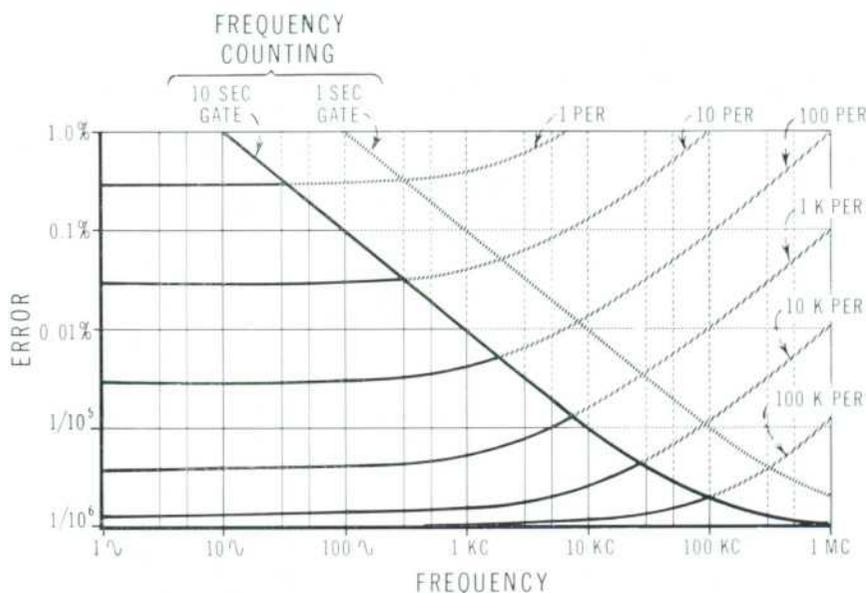


Fig. 2. Curves relating period- and frequency-measuring accuracy of new 1.2-megacycle counter. Frequencies for which counter will give better accuracy on period measurements than on direct-frequency measurements is shown by solid portion of curves. Curves assume time base error of 1×10^{-6} and trigger error of 0.3%/number of periods averaged. Using external time base, accuracies of 1×10^{-8} can be achieved with 10^5 period measurements.

in a storage flip-flop to control the display. This feature together with the code conversion from binary-coded decimal to decimal output at the high voltage required for indicator tubes is achieved by the use of a special photoconductor matrix developed at *hp*. In decoding alone this single solid-state matrix replaces many semiconductor elements per decade.

Since the time available for read-out with storage includes the gate time, sample rate is no longer limited by the need to provide enough time between counts for a readable display. Thus more readings per second can be obtained.

Another improvement has to do with the interval between counting times—usually called "display time". Where the minimum display time

was previously equal to the gate time, the interval between gate times in the new counters can be considerably shorter. Thus, for the longer count times of 1 and 10 seconds, the new counters can operate at nearly double the previous maximum sampling rates if the minimum display time is used. The between-count interval can be adjusted by a panel control up to 5 seconds, and an infinite display position is also provided.

INCREASED-ACCURACY PERIOD MEASUREMENTS

Each of the new counters is capable of making multiple-period average measurements up to 10^5 periods. For low and mid-range frequencies the periods-average technique can greatly increase measurement resolution and accuracy over that possible with direct-frequency counting. Consider, for example, measuring a 400-cps sine wave, first by direct frequency-counting and then by period and multiple-period average measurement with the new 1.2-megacycle counter. Since in the period measurement modes the counter is gating a 1-mc count frequency, each period of the 400-cps input signal results in 2500 counts being registered. In the 1000-period



Fig. 3(a). Long-term accuracy curve measured of time base in 1.2-megacycle counter. Excellent long-term stability for a counter of this class has been achieved by operating time-base crystal near room temperature. Short-term variations in curve are largely due to ambient temperature variations.

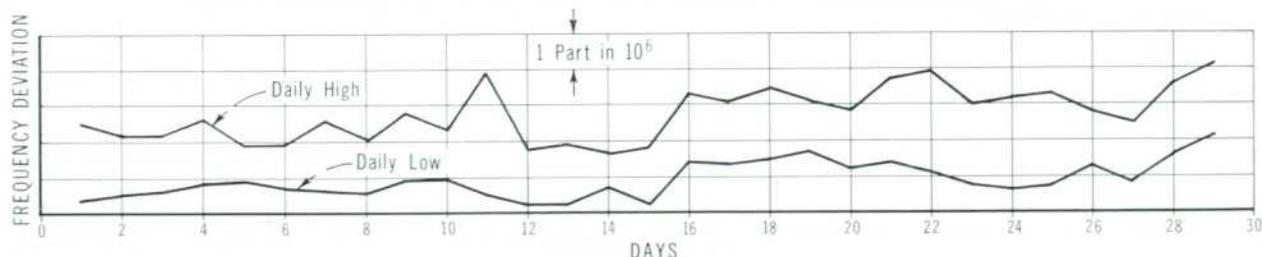


Fig. 3(b). Long-term accuracy curve measured of time-base in 300-kilocycle counter.

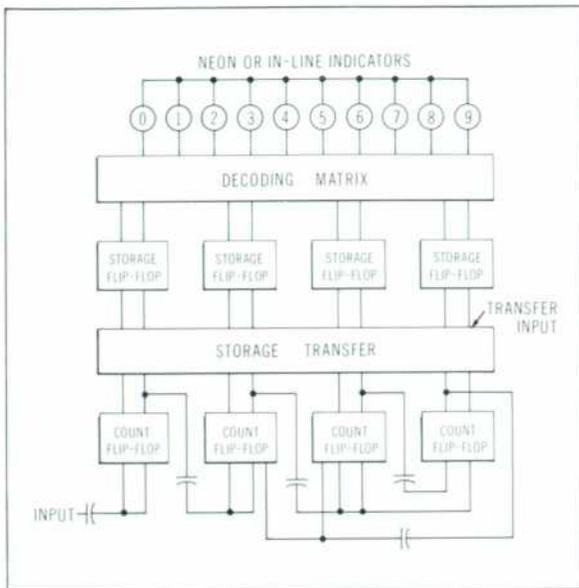


Fig. 4. Basic circuit arrangement used to obtain continuous readout feature.

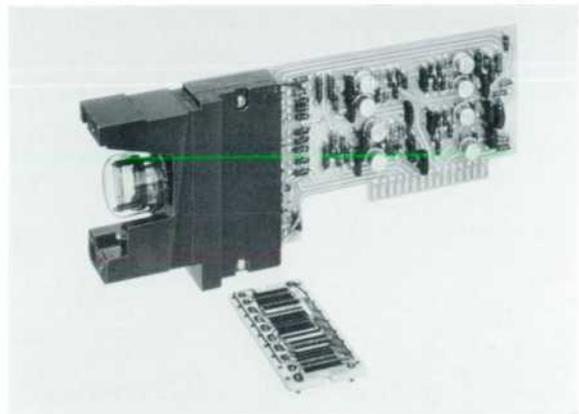


Fig. 5. Counter assembly corresponding to circuit shown in Fig. 4. Photoconductive matrix on small plate in front fits inside assembly and greatly simplifies circuitry needed to achieve decoding and other circuit features.

average position, however, 2.5×10^6 counts are taken in $2\frac{1}{2}$ seconds, and measurement resolution is several hundred times greater than in the direct frequency mode where the longest gate time of 10 seconds permits a total of only 4000 counts.

In addition to storage and multiple-period average, other unusual features which add to the versatility of these instruments are binary-coded decimal output, wide operating temperature range, and advanced mechanical construction. Four-line BCD output, suitable for systems use or direct measurement recording, is a standard feature on the new counters. The code is 1-2-2-4. It is available through a rear connector along with print-command and hold-off circuit access.

The operating ambient temperature range over which counter performance is specified is -20°C to $+65^\circ\text{C}$. Over this range the time base frequency remains constant within ± 100 parts in 10^6 for the lower-frequency counter and within ± 20 parts in 10^6 for the higher-frequency counter. Over narrower temperature ranges, of course, the time bases remain within much narrower limits than these.

It is important to note that the time base oscillators of the new counters achieve this high stability without the use of an oven. Besides the significant savings in terms of space and power requirements for the instruments, the following functional advantages result:

First, no warmup time is required. The first readings obtained on the counter after turn-on meet the full specified accuracy. Secondly, high long-term stability is achieved. The aging rate of a crystal at or near room temperature is considerably less than that of a crystal at the usual elevated oven temperature. See Fig. 3. Close control over the angle of cut of quartz crystals results in a minimum frequency change over a wide temperature range. These crystals are a product of the Hewlett-Packard Precision Components Division.

DISPLAY STORAGE

The functional block diagram of Fig. 4 illustrates how display storage is accomplished. The counting flip-flops are driven in the ordinary manner by pulses from the trigger unit. The outputs of these flip-flops are then coupled through diode transfer

gates to storage flip-flops which, in turn, control the displayed readout through the decoding matrix. When a count is completed, the transfer gate opens and the information present in the count flip-flops is transferred to the display, where it is stored until the completion of the next count. In the meantime, the transfer gate has closed, allowing the counting flip-flops to accumulate new information without disturbing the displayed reading. Display storage is thus achieved and reading changes occur only when the storage flip-flops are presented with information different from the previous count.

PHOTOCONDUCTIVE DECODING MATRIX

The fact that it has been possible to incorporate such features as display storage without excessive cost or circuit complexity arises from the development and use of decoding matrices composed of simple photoconductive elements. Each display decade includes an hermetically-sealed unit containing special neon lamps and a matrix composed of a photoconductive film in a suitable pattern. This unit replaces many semiconductor elements otherwise

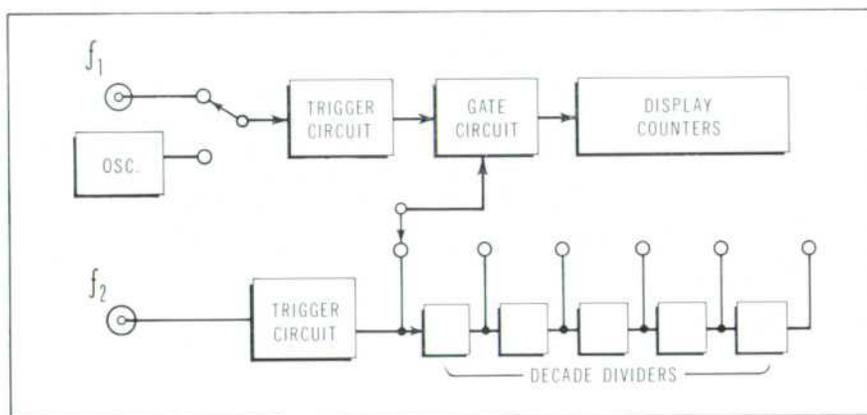


Fig. 6. Block diagram of counter circuit arrangement for ratio and period measurements.

needed to provide the following three functions:

(1) Storage: To achieve count information storage, the photoconductive matrix is excited by 4 pairs of neon lamps. Each pair is connected through transfer diodes to a counting flip-flop in such a manner that one and only one lamp is on when the transfer gate is closed. The lamp pairs thus act as storage elements for the information gathered by the counting flip-flops.

(2) Decoding: Each lamp-pair with its associated photoconductive segments acts as a multi-contact relay equivalent to one branch of a relay-tree matrix. Thus the photoconductive matrix provides 10 distinct output connections from the four bits of binary information stored in the lamp pairs.

(3) Amplification: The total resistance change in the matrix output

results in ample power gain for driving the associated Nixie® indicator tube.

Fig. 5 is a picture of an *-hp-* decimal counter assembly showing the molded lamp block assembly, the readout display tube, and the associated counting circuitry.

MULTIPLE-PERIOD AVERAGE

With the function switch in one of the multiple-period average positions, the gate circuitry is controlled by the input signal and the count frequency is the frequency of the time base oscillator (100 kc for the 300 kc counters and 1 mc for the 1.2 mc counters). The number of periods to be averaged is determined by the number of decade dividers through which the input signal passes before being sent to the gate control circuitry. The count displayed on the readout then repre-

sents the time interval between like-polarity zero crossings of the input wave-form times the number of periods averaged.

Multiple-period-average measurements also give an improvement in measuring accuracy in cases where a low-frequency sine wave signal is accompanied by noise. This occurs because the trigger error caused by noise is also divided by the number of periods measured.

RATIO MEASUREMENTS

Ratio measurements are also made with the counter in the period or multiple-period average function modes. To make direct ratio measurements it is necessary only to apply the frequency representing the ratio numerator to the external counted frequency connector at the rear of the instrument and the frequency representing the ratio denominator to the signal input jack. In this way, the counter reads $f_1/f_2 \times$ the period multiplier factor as determined by the position of the function selector switch. Again, the accuracy is improved directly as the number of periods of f_2 averaged. The block diagram of Fig. 6 shows the input arrangement for ratio measurements.

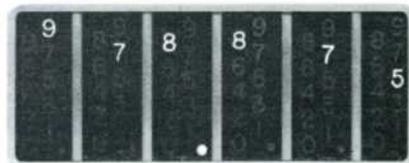


Fig. 8. New arrangement of column-type readout is shorter vertically and easier to read.

DECADE DIVIDERS

The gate timing circuitry has been designed using digital decade dividers capable of operating over a wide frequency range.

Besides eliminating any need for time-base divider adjustment, these dividers improve the accuracy of multiple-period average and ratio measurements by several orders of magnitude.

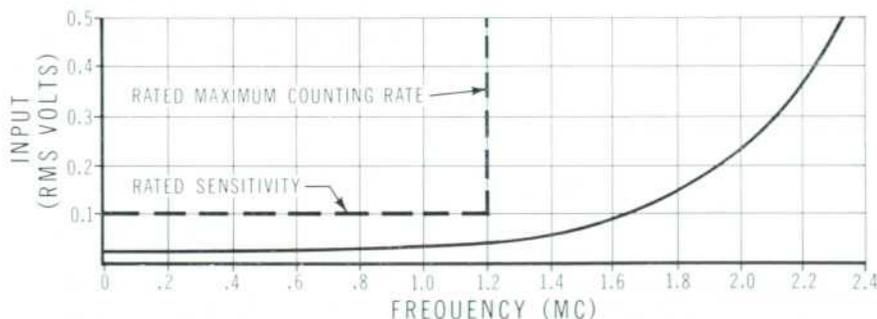


Fig. 7. Sine-wave sensitivity measured on new 1.2-megacycle counter compared with rated values. With some increase in drive counter measured to well above ratings. Similar improved performance over ratings is exhibited by 300-kc counter.

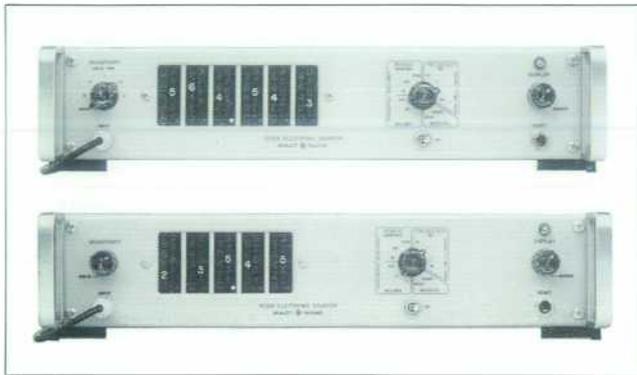


Fig. 9. New 1.2-megacycle and 300-kilocycle counters in column-readout versions.



Fig. 10. Circuitry in new counters is built in plug-in modules.

IN-LINE AND COLUMN READOUTS

Each of the new counters has been designed with two styles of readout systems. One is the popular in-line style shown in Fig. 1. This style uses 1"-size Nixie® tubes of the long-life

type arranged behind a light-polarizing window which greatly reduces reflections from internal surfaces and thus provides high contrast for ease of viewing.

The second readout style is a newly-designed arrangement of the

familiar column-type readout using neon lamps. In the new arrangement (Fig. 8) the numerals in each column have been staggered to achieve a shorter vertical dimension for the column. As a result the vertical span over which the eye must

DIGITAL OR ANALOG RECORDING OF COUNTER MEASUREMENTS

Two useful output devices for obtaining records of counter readings or other digital data are the -hp- 562A Digital Recorder and the -hp- 580A Digital-Analog Converter. Although designed primarily for use with the new family of -hp- transistor counters, Models 562A and 580A are extremely flexible and can be used in a wide variety of individual applications. Output kits are available for -hp- and Dymec vacuum tube counters.



MODEL 562A DIGITAL RECORDER

This 11-column digital recorder will print a paper tape record of digital input data at rates up to five lines per second. Unlike other recorders which must inhibit the driving source during the print cycle to prevent a change in input data, Model 562A makes use of input flip-flops for buffer storage. Because of this, data transfer can be accomplished in just 2 ms as compared to 160 ms or more for non-storage printers.

Printing is accomplished with a mechanism similar to that of the -hp- 560A and 561B Digital Recorders by striking a print bar against prepositioned print wheels. Each print wheel representing an input digit has associated with it a printed circuit module containing the circuitry needed for data storage and for selecting the proper print wheel position for that particular column. These modules are arranged in the standard recorder configuration to accept the 1-2-2-4 weighted BCD code as provided by the new -hp- counters discussed in this article. Modules for other codes may also be obtained.

Internal plug-in connectors are provided for each of the columns. These connectors are readily accessible and provide the means for routing the input information to any desired sequence of print wheels.

Another important feature of the 562A Digital Recorder is the provision for dual input coupling. At a small additional cost, another rear input connector may be added to the instrument to permit data entry and simultaneous printing from two unsynchronized counters or other sources.

An analog voltage, similar to that provided by the -hp- Model 580A discussed below is also an available option for the 562A Digital Recorder.

The standard Model 562A is equipped for six-column operation from one input source.

MODEL 580A DIGITAL-ANALOG CONVERTER

This converter is designed to accept digital input data, such as is available from the new -hp- counters, and provide an analog output suitable for strip chart or X-Y recorders of both potentiometer and galvanometer types. Any three successive digits for analog conversion may be chosen by the front panel selector switch. This information is transferred to storage flip-flops within the 580A after receipt of the counter print command. The stored data is then translated and weighted to provide the proper analog output voltage or current.



Since input data is stored and changes only when the input changes, accuracy of conversion is maintained at high sample rates. Specified accuracy is 0.5% full scale or better with a resolution of 0.1% full scale.

Since the data in three successive columns can range only from 000 to 999, automatic zero-shifting is inherent in Model 580A output, which keeps the record on scale at all times.

range has been reduced by 50%, making the new type of readout considerably easier to read.

MECHANICAL DESIGN

In order to take full advantage of the comparatively small space requirements and low heat dissipation of semiconductors, the over-all mechanical design of the counters was integrated into the development program at an early stage. In this way it was possible to design the counters for maximum utilization of space and ease of instrument maintenance without sacrifice of operational capability or convenience.

Circuits are functionally grouped into plug-in modules supported by a slotted guide strip. Removal of two screws releases the top cover and its hold-down arrangement for these modules. All circuitry is then accessible in place or may be vertically extended for trouble-shooting by the adapter board included in each instrument. Finally, modular construction permits a high degree of manufacturing standardization which, in turn, reduces costs and helps assure a uniform high level of quality.

ACKNOWLEDGMENT

The design and development of the new counters was a joint effort of several members of the *-hp-* Frequency and Time Engineering Department. The group leader for the electrical design was Blair H. Harrison, who was assisted by Ralph R. Reiser and John Skovholt. Marvin J. Willrodt and Robert P. James gave valuable assistance on the readout circuitry. Charles Reis and Irwin Wunderman were responsible for many of the basic techniques used in the display. Application and performance data were compiled by Dean Morton.

The mechanical design and production aspects were handled by Gladys Kinney, Rolf K. Murchison, Papken Der Torossian and Jess C. Valentine under the direction of Stephen D. Nemeth.

SPECIFICATIONS

-hp-

MODEL 5212A/5512A FREQUENCY COUNTER

Maximum counting rate: 300 kc.
Registration:
Number of digits: 5.
Display: Model 5212A: neon column; Model 5512A: long-life indicator tubes.
Input sensitivity: 0.1 v rms for sine waves; 1 v for negative pulses, 2 μ sec min. pulse width.
Input impedance: Approx. 1 megohm shunted by 50 pf.
Operating temperature range: -20° to $+65^{\circ}$ C.
Time base:
Long-term stability: ± 10 parts in 10^8 per week.
Short-term stability: ± 20 parts in 10^8 ($+15^{\circ}$ to $+35^{\circ}$ C); ± 100 parts in 10^8 (-20° to $+65^{\circ}$ C).
Frequency measurement:
Range: 2 cps to 300 kc.
Accuracy: ± 1 count \pm time base accuracy.
Reads in: kc with positioned decimal point.
Self check: Counts 10 kc.
Gate times: 10, 1, 0.1, 0.01 second.
Period measurement:
Range: 2 cps to 10 kc in single period; 2 cps to 100 kc in 10-period average; 2 cps to 300 kc in 100-period average and above.
Accuracy: ± 10 μ sec \pm time base accuracy \pm trigger error/periods averaged. (Trigger error for sine wave inputs at rated 0.1 v rms sensitivity may be stated as $\pm 0.3\%$ maximum for signals of 40 db signal-to-noise ratio.)
Reads in: Milliseconds with positioned decimal point.
Periods averaged: 1, 10, 10^2 , 10^3 , 10^4 , or 10^5 .
Self-check: Measures period of 100 kc.
Ratio measurement:
Reads: $f_1/f_2 \times$ period multiplier.
Range: f_1 : 100 cps to 300 kc (1v rms across 1000 ohms); f_2 : same as period.
Accuracy: ± 1 count of $f_1 \pm$ trigger error of f_2 .
Output: 4 line BCD (1-2-2-4).
Impedance: 100K ohms on each line.
Level: "0" state indicated by approximately -24 v; "1" state by -1 v.
Print Command: Consists of step from -29 to -1 v, dc coupled from 2700-ohm source.
Hold-Off Requirements: Positive voltage not exceeding $+12$ V. May be anywhere from ground to $+12$ V.
Dimensions: $16\frac{3}{4}$ " wide, $3\frac{1}{2}$ " high, $11\frac{1}{2}$ " deep.
Net weight: 13 pounds.
Power requirements: 115/230v $\pm 10\%$, 50/60 cps (50-1000 cps on special order); 35 watts.
Price:
Model 5212A (column readout): \$975.00.
Model 5512A (in-line readout): \$1175.00.

MODEL 5232A/5532A FREQUENCY COUNTER

Maximum counting rate: 1.2 mc.
Registration:
Number of digits: 6.
Display: Model 5232A: neon column; Model 5532A: long-life indicator tubes.
Input sensitivity: 0.1 v rms for sine waves; 1 v for negative pulses, 0.2 μ sec min. pulse width.
Input impedance: Approx. 1 megohm shunted by 50 pf.
Operating temperature range: -20° to $+65^{\circ}$ C.
Time base:
Long-term stability: ± 3 parts in 10^7 per month.
Short-term stability: ± 2 parts in 10^8 ($+10^{\circ}$ to $+50^{\circ}$ C); ± 20 parts in 10^8 (-20° to $+65^{\circ}$ C).
Frequency measurement:
Range: 2 cps to 1.2 mc.
Accuracy: ± 1 count \pm time base accuracy.
Reads in: kc with positioned decimal point.
Self check: Counts 100 kc.
Gate times: 10, 1, 0.1, 0.01 second.
Period measurement:
Range: 2 cps to 10 kc in single period; 2 cps to 100 kc in 10-period average; 2 cps to 1 mc in 100-period average and above.
Accuracy: ± 1 μ sec \pm time base accuracy \pm trigger error/periods averaged. (Trigger error for sine wave inputs at rated 0.1 v rms sensitivity may be stated as

$\pm 0.3\%$ maximum for signals of 40 db signal-to-noise ratio.)
Reads in: Milliseconds and microseconds with positioned decimal point.
Periods averaged: 1, 10, 10^2 , 10^3 , 10^4 , or 10^5 .
Self-check: Measures period of 1 mc.
Ratio measurement:
Reads: $f_1/f_2 \times$ period multiplier.
Range: f_1 : 100 cps to 1.2 mc (1v rms across 500 ohms); f_2 : same as period.
Accuracy: ± 1 count of $f_1 \pm$ trigger error of f_2 .
Output: 4 line BCD (1-2-2-4).
Impedance: 100K ohms on each line.
Level: "0" state indicated by approximately -24 v; "1" state by -1 v.
Print Command: $+28$ V, dc coupled from 2700 ohms source.
Hold-Off Requirements: Positive voltage not exceeding $+12$ V. May be anywhere from ground to $+12$ V.
Dimensions: $16\frac{3}{4}$ " wide, $3\frac{1}{2}$ " high, $11\frac{1}{2}$ " deep.
Net weight: 15 pounds.
Power requirements: 115/230v $\pm 10\%$, 50/60 cps (50-1000 cps on special order); 35 watts.
Price:
Model 5232A (column readout): \$1300.00.
Model 5532A (in-line readout): \$1550.00.

MODEL 562A DIGITAL RECORDER

Accuracy: Identical to input device used.
Printing rate: 5 lines per second, maximum.
Column capacity: To 11 columns (12 available on special order).
Print wheels: 12 positions, numerals 0 through 9, a minus sign, and a blank. Other symbols available (see *-hp-* Application Note 32).
Data input: Parallel entry 1-2-2-4 BCD, "1" state: 4 volts min. 75 v maximum, positive with respect to "0" state. Other codes and polarities available.
Reference voltages: Reference voltages required for both the "0" and "1" state voltage. Reference voltages not to exceed ± 150 volts to chassis.
Print command signal: Positive or negative pulse, 20 μ s or greater in width, 6 to 40 volts.
Transfer time: Approx. 2 ms.
Paper required: Standard 3 inch roll or folded paper.
Power requirements: 115/230 volts $\pm 10\%$, 50/60 cps (4 prints per second maximum at 50 cps).
Dimensions:
Cabinet mount: $20\frac{3}{4}$ in. wide, $12\frac{1}{2}$ in. high, $18\frac{1}{2}$ in. deep.
Rack mount: 19 in. wide, $10\frac{1}{2}$ in. high, $16\frac{7}{8}$ in. deep behind panel.
Weight:
Cabinet mount: Net 35 lbs. Shipping approx. 70 lbs.
Rack mount: Net 30 lbs. Shipping approx. 63 lbs.
Price: for 6-column operation: \$1600.00. Additional column modules: \$75.00 each. Analog output option: \$175.00. Additional input connector for input coupling: \$43.00. Additional interconnecting cable: \$35.00 each.

MODEL 580A DIGITAL-ANALOG CONVERTER

Resolution: 0.1% of full scale.
Accuracy: 0.5% of full scale or better.
Potentiometer Output: 0 to 100 mv. Minimum load resistance: 0.5 megohm. Calibrate control. Dual banana plugs front and rear.
Galvanometer Output: 0 to 1 ma into 5000 ohms or less. Zero and calibrate controls. Phone jack front and rear.
Data Input: Parallel entry 1-2-2-4 BCD (9 digits maximum); "1" state: 4 volts min., 75 v max., positive with respect to "0" state. Other codes and polarities available.
Reference Voltages: Reference voltages required for both the "0" and "1" state voltage. Reference voltages not to exceed ± 150 volts to chassis.
Command Pulse: Positive or negative pulse, 20 μ sec or greater in width, 6 to 40 volts amplitude.
Transfer Time: Approx. 2 milliseconds.
Power Requirements: 115/230 volts, 50/1000 cps.
Dimensions: $16\frac{3}{4}$ in. wide, $3\frac{1}{2}$ in. high, $11\frac{1}{2}$ in. deep.
Price: On request.

Prices f.o.b. factory
Data subject to change without notice