



A New Generation of High-Speed Frequency Counters

A LITTLE over a decade ago the Hewlett-Packard Company introduced what subsequently proved to be one of the electronics field's most important measuring instruments. This was the high-speed frequency counter, the now well-known -hp- Model 524*. This counter automatically measured frequencies up to 10 megacycles and did so with an accuracy superior to that of any but the most elaborate methods of the time. During the ensuing decade, its all-around capabilities brought this counter to the stature of an instrument accepted by all as the standard of the industry.

Advances in the art have now permitted the development of a new generation of two high-speed frequency counters. These are shown in

Figs. 3 and 4. One of the new counters measures from 0 cps to 20 megacycles and the second from 0 cps to 50 megacycles. Using a plug-in, each counter will measure to 500⁺ megacycles. Both counters have a large, in-line readout and high input sensitivity. They are transistorized and use computer-type construction, giving a small physical size with a panel height of only 5¼". A full array of plug-ins has been designed to be compatible with this small panel size, as described later. Except for their different maximum counting rates of 20 and 50 Mc, the two counters have essentially the same electrical and mechanical characteristics and use the

*A. S. Bagley, "The High-Speed Frequency Counter—A New Solution to Old Problems," *Hewlett-Packard Journal*, Vol. 2, No. 5, Jan., 1951.



Fig. 1. New -hp- high-speed frequency counter (center) measures from 0 to 20 or 50 megacycles in two models, has accessory plug-ins to measure to 500 megacycles. Counters have very high stability time bases for high accuracy in demanding measurements. Counters can be used with many other data-handling devices.

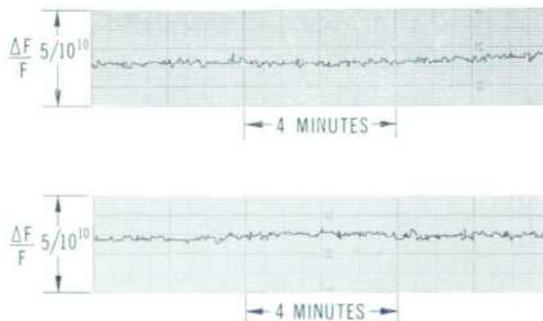


Fig. 2. Very high stability of time bases in new counters is indicated by above deviation curves of two production units. Rated short-term stability is 5 parts in 10¹⁰, so performance of these units is substantially above ratings. Deviations measured with one-second averaging.

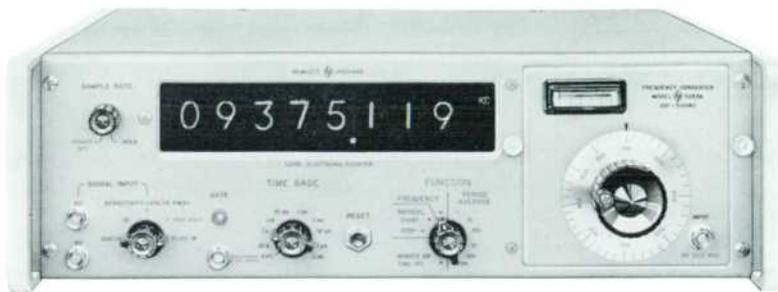


Fig. 3. New *hp*-Model 5245L 0-50 Mc Counter with Model 5253A 100-512 Mc Converter plug-in. Both new counters are identical in appearance and panel controls.

same plug-ins. Besides frequency, the counters will also measure period (including multiple-period averages), time intervals, frequency ratios, and phase angles; and will totalize random counts, or scale random or periodic counts. With other *hp*-equipment such as transfer oscillators, the counters will measure frequencies up to 18 gc (kmc) with full counter accuracy. The counters are also useful with much other data-handling equipment and provide binary-coded decimal (BCD) outputs to facilitate such applications.

TIME BASE STABILITY

Of the many new measuring capabilities that the counters embody, one of great interest and assistance to engineers working in today's advanced technology is the increased measuring accuracy provided by the high stability in the counters' time bases. These time bases are rated to have stabilities of within ± 5 parts in 10^{10} short term (1-second averaging) and an aging rate of within ± 3 parts in 10^9 per day. Such very high stabilities are extremely valu-

able since they permit precise measurements of up to 8 and 9 places in narrow-band VHF telemetry or communications work. Such stabilities also permit the counters to be used as an in-house frequency standard having a stability not commercially available until recently.

Actually, as might be expected on the basis of *hp*-engineering practice, the measured stabilities of these time bases are typically considerably better than even the above specifications. This can be seen in Figs. 2, 5 and 6 which show the short- and long-term deviations measured on several production instruments. In the curves of Fig. 2 the short-term deviations of two of the counters are shown as measured against a standard of even higher stability, so that the curves show mainly the deviations of the time bases themselves. The measurements are made with 1-second averaging. The full vertical scale shown is the rated short-term stability; that is, the short-term deviations are rated not to exceed the vertical portion shown of the chart. The portion shown represents 5

parts in 10^{10} . The curves show that these instruments exceeded ratings by more than 5 times.

In another interesting case, the stabilities of these particular production instruments were measured against one another (Fig. 5). Fig. 5 thus shows the sum of two deviations, usually considered to be $\sqrt{2}$ of the deviation of one frequency where the two frequencies have equal deviations. Here, too, the sum of the two deviations is far within the ratings of one counter.

LONG TERM STABILITY

The long-term stability also typically exceeds ratings by a considerable amount. While optimum utilization of any precision frequency instrument calls for a calibration program for the individual instrument, it is informative to examine the long-term curves presented in Fig. 6, since these are representative of the long-term stability experienced with the counters. The curves show the stabilities of the time base oscillators after the quartz crystals in the time bases have passed their initial several-week run-in period. It is plain that the time bases typically have an aging rate much below that specified. Also, since the data still indicate some run-in effect typical of a "green" crystal, the future aging rate can be expected to have the small slope exhibited by the final portions of the curve.

CIRCUIT ARRANGEMENT

The basic circuit arrangement of the new counters is indicated in Fig. 7. The frequency to be measured is



Fig. 4. New *hp*-Model 5243L 0-20 Mc Counter with Model 5253A 100-512 Mc Converter plug-in.

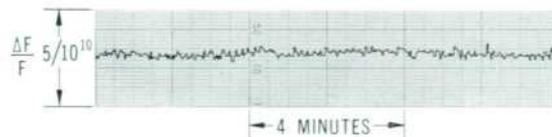


Fig. 5. Short-term deviation record obtained when time bases of Fig. 2 were compared with one another. Measurement made with one-second averaging.

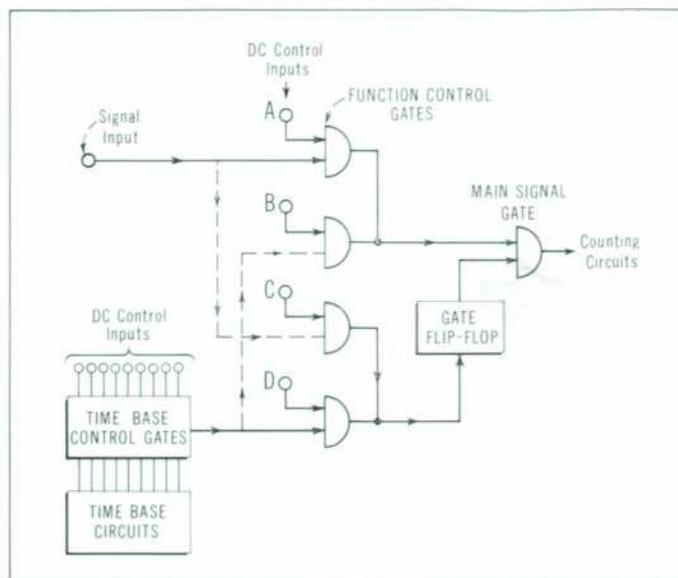
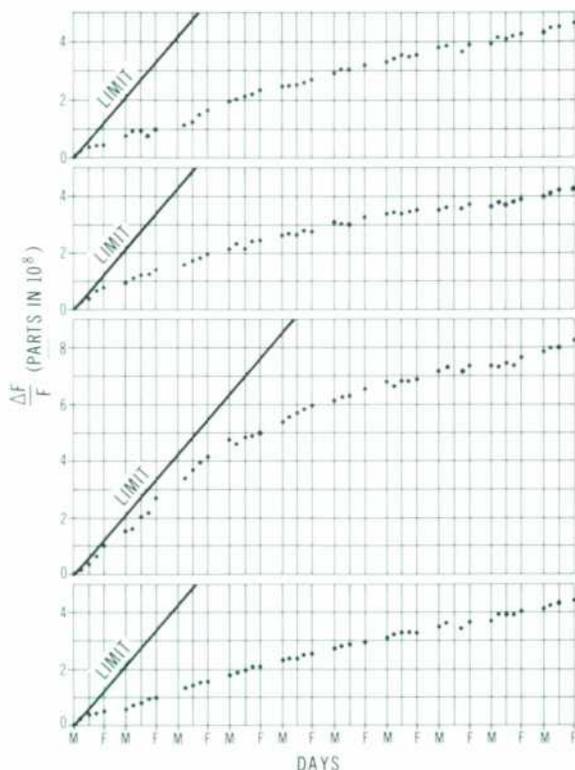


Fig. 8. (above). Use of AND gates permits functions of new counters to be selected by dc signals, giving remote function control capability.

Fig. 6 (at left). Aging curves typical of experience with time bases in new counters. Solid lines at left show rated maximum slope of $2/10^8$ /week. Curves still include some "run-in" effect but are well below rating.

passed through a time-base-controlled gate and then counted by decade counting circuits. Since the gate is held open by the time base for discrete, precise intervals of 10 seconds or a decade sub-multiple thereof, the count obtained by the counting circuits can be read out directly in frequency merely by appropriately positioning the decimal point. The counting circuits are followed by a digital readout system which directly displays the measured frequency and in which the illuminated decimal point is auto-

matically positioned.

When the signal to be measured is low in frequency, improved measuring accuracy can normally be achieved (Fig. 11) by measuring the period of the signal instead of measuring its frequency as described above. For period measurements the basic measuring circuit is reconnected by the panel selector switch as indicated by the dashed lines in Fig. 7. The instrument then counts suitable clock signals from the time base for 1, 10, . . . or 100,000 periods of the low frequency. The read-

out is thus direct-reading in seconds, milliseconds or microseconds. Time intervals are also measured by this same basic approach of counting clock signals from the time base, although a plug-in is used to provide start and stop signals to the measurement gate circuit.

Frequency ratios are measured in a manner similar to that used for period measurements, except that the clock frequency from the time base is replaced by the higher of the two frequencies in question.

REMOTE CONTROL/ PROGRAMMABILITY

While the above circuit arrangement is conventional, it embodies some new approaches that give the counters the ability to make measurements in previously troublesome applications. One of the circuit innovations, for example, is the use of AND gates to establish the signal paths in the circuit, where previously the selection of these paths was made with conventional mechanical switches. The arrangement of the gates is shown in Fig. 8. The AND

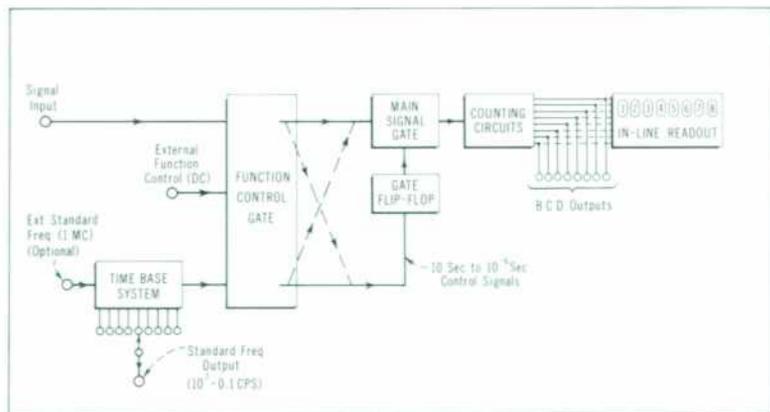


Fig. 7. Basic circuit plan of new counters.

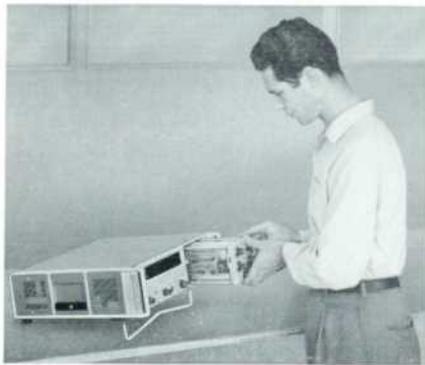


Fig. 9. All plug-ins can be used with either counter. Counter top and bottom plates are easily removed, being secured with coin-slotted screws.

gates pass a signal only when they see both a signal input and a control input. Since the control input can be, and is, a dc signal, the use of the AND gates has the advantage that the instrument's measuring functions can be remotely controlled by means of dc signals. To accommodate remote control operation, the

instrument's time base signals also are selected by a group of AND gates.

The ability to remotely control the functions of the counters strictly by dc signals should prove valuable to many engineers working with systems. For example, the counters can be used for a sequence of measurements in a missile or other check-out system. Measurements of telemetry transmitter frequency, of a telemetry subcarrier frequency (or period), of the interval between two timing pulses (using time-interval plug-in) could be made in sequence under the control of a central console.

To facilitate remote control, connectors are provided at the rear of the instrument for operation of the AND gates. A dc supply voltage for operating the gates is also provided at a rear connector terminal so that

it is only necessary for the applications engineer to arrange for simple external contact closures to obtain remote and/or programmed operation of the counter. All functions of the basic counters are remote-controllable except for sensitivity and sampling rate.

READOUT CONVENIENCES

As shown in Fig. 10, the counting circuits feed storage circuits which in turn drive the readout system. This arrangement makes possible the *hp display storage* feature which has two characteristics that are of assistance in making most measurements. One is that the displayed count is retained on the readout system while a new count is being made. The display is thus continuous, and changes only if the new count changes from the previous. If only the last places change from one count to another, the other places in

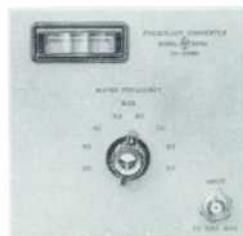
To enable a variety of measurement problems to be solved with the counters, four plug-in units have been designed. Two of these jointly permit measuring frequencies to above 500 megacycles. The third is an amplifier that increases the sensitivity of the counters to 1 millivolt over the full 10 cps to 50 Mc range. The fourth plug-in enables time intervals to be measured and can also serve as an amplitude discriminator, accepting for counting only signals that exceed a selected amplitude level.

Each of the plug-ins can be used with either of the counters.

The plug-ins fit into a recess in the right side of the panels of the counters. When no plug-in is used, a panel plate covers the recess opening.

FREQUENCY CONVERTERS

Of the two frequency converters, one provides for measuring frequencies from 20 to 100 megacycles, and the second from 100 to 512 megacycles. Both converters have a high sensitivity and permit signals down to at least 50 millivolts to be measured at all frequencies. To assure the operator of adequate signal level, panel meters with a green-colored "go" area on their scales are provided. The meters also indicate proper settings of the mixing frequency selector control, the only operating control on the converters. In the lower-frequency converter this control is a selector switch. In the higher-frequency converter it is a con-



MODEL 5251A
CONVERTER

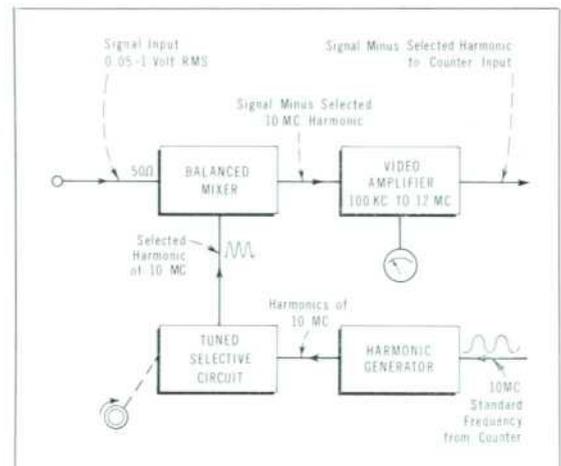


MODEL 5253A
CONVERTER

tinuous-tuning control, but one in which a mixing signal is obtained only at discrete frequencies.

The circuit arrangement of the converters is indicated in the accompanying diagram. Using the precision 10-mc frequency from the counters' time bases, the converters generate harmonics at 10-Mc intervals. The harmonic lying immediately below the

COUNTER



frequency to be measured is then selected by a tuned circuit and subtracted from the frequency to be measured. When the appropriate harmonic is used, the difference frequency will lie within the range of the counter itself and will be measured by it. The frequency being measured is thus the sum of the harmonic frequency, as shown by the panel control, and the

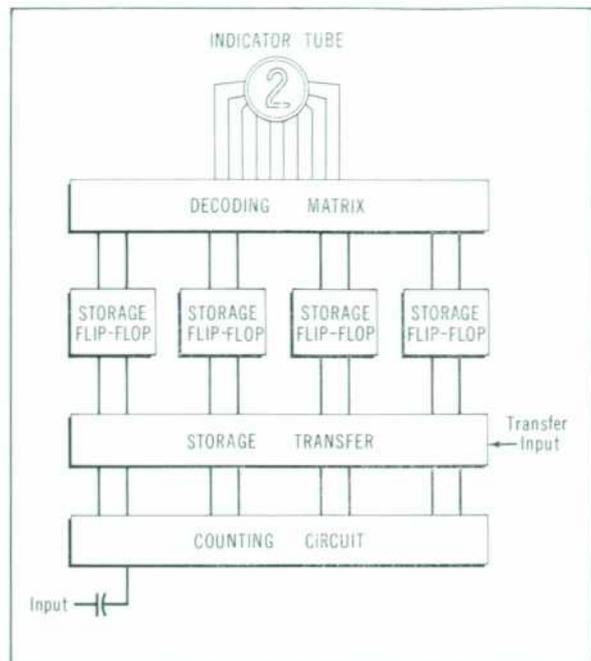
the display remain fixed and only the changed numbers change. Such a storage type display is obviously much easier to read and less susceptible to reading error.

The display storage feature, in turn, leads to the second measurement convenience which is that the readout time is independent of the gate (counting) time. This is especially convenient when the longer gate times of 1 and 10 seconds are used, because it is not necessary to await the completion of a "display time" before a new measuring time can begin. If the *Sample Rate* control is turned to its maximum setting, a new count will begin as soon as (100 ms) the previous count is completed. A higher sampling rate is thus achieved.

Gating of the instruments is indicated by a panel lamp.

(Continued on page 6)

Fig. 10. *Circuit arrangement used in new counters to achieve Display Storage feature which gives continuous display of readouts with no interruption during measurement.*



PLUG-INS

reading on the counter. Since the harmonic frequency is always an integral multiple of 10 megacycles, it is an easy number to add mentally to the counter reading, which will lie in the range between 0.1 and 12 megacycles. The overall measurement has the same accuracy as the rating for the counter itself, since the subtracted frequency is obtained directly from the counter time base.

TIME INTERVAL PLUG-IN

The Time Interval Plug-In enables measurements to be made of the interval between desired points on two separate signals or between two desired points on one signal. Intervals from

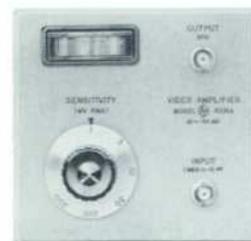


MODEL 5262A
TIME INTERVAL UNIT

10^{-6} to 10 seconds can be measured at 0.1 microsecond resolution and to 10^8 seconds at lesser resolution. The plug-in has a "start" and a "stop" channel with separate controls that permit measurements to begin or end on either positive or negative voltages and on either positive or negative slopes, as desired. In counting applications the input controls can also be used to cause the plug-in to operate as an amplitude discriminator where signals of a variety of amplitudes may be present.

Remote operation of this plug-in is also possible, i.e., the unit can be activated or de-activated by means of external contact closures, as described in the main text. The measurements will be made in terms of the settings of the plug-in's panel controls.

The time interval readout obtained on the counter is given directly in time units. Alternatively, the readout can be obtained directly in other desired units such as fps, mph, or rpm by applying an appropriate external frequency for the counter to count in place of the time base frequency. For example, the phase difference between two 10 kc signals will be displayed directly in degrees if a 3600 kc signal is supplied as the counted frequency. For measuring phase difference, the trigger level controls would usually be set at the zero axis crossing of the input waveforms for both the start and stop channels.



MODEL 5261A
VIDEO AMPLIFIER

VIDEO AMPLIFIER

The video amplifier plug-in increases the input sensitivity of the counters over the 10 cps to 50 Mc range. At the same time the amplifier raises the input impedance of the amplifier-counter combination to a high value of 1 megohm shunted by 15 pf. If desired, this impedance level can be further increased to 10 megohms shunted by 10 pf by using the -hp-AC-21M oscilloscope probe. This increase will change the sensitivity of the amplifier to 10 millivolts, however.

The amplifier has two outputs. One of these operates the counter, and the second is available at the amplifier panel for other uses such as oscilloscope observation of the input signal. The amplifier is also useful in this way in non-counting applications as a high-sensitivity pre-amplifier.

MULTIPLE-PERIOD AVERAGING

A feature new in high-speed counters is the feature known as *multiple-period averaging*. This feature permits increased accuracy in measuring the period of a signal, because it *averages* the periods of from 1 to 10^5 cycles of the frequency being measured. In cases where the signal has noise that obscures the precise duration of a single cycle, the resulting ambiguity in a cycle can be reduced by the number of periods over which the measurement is averaged. Similarly, the influence of instability in the signal or the ± 1 count ambiguity inherent in a counter can be reduced by this same factor.

SCALING

Another provision new in *-hp-* counters is the provision for scaling input signals, i.e., providing one output signal for, in this case, each decade multiple count of the input signal. The signals can be random or periodic and can have any repetition rate up to the maximum counting rates of the counters. This results in much faster scaling capabilities than are found even in most specially-designed scaling equipment.

The scaling capability is often convenient in many measuring situations for such purposes as frequency-dividing or obtaining accurate time intervals which can, if

desired, be very long, such as 1000 seconds or more.

The counters are arranged to scale in selectable decade steps between 10^1 and 10^5 for the 20 Mc counter or 10^1 to 10^6 for the 50 Mc counter. To facilitate scaling, the dc-coupled inputs on the counters can be used to prevent base-line shifting on aperiodic or unequal signals. The scaled output is provided in the form of positive pulses at the rear panel.

The double-pulse resolution of the 20 mc counter is about 40 ns for 15 ns-wide pulses. The 50 mc counter will resolve 5 ns pulses spaced 20 ns apart.

(Continued on page 8)

SPECIFICATIONS

-hp-

MODEL 5243L

20 MC ELECTRONIC COUNTER

Same as Model 5245L except as follows:

FREQUENCY MEASUREMENTS

RANGE: 0-20 mc.

RATIO MEASUREMENTS

RANGE: f_1 : 0 to 20 mc. (f_2 same as 5245L).

SCALING

FREQUENCY RANGE: 0 to 20 mc.
FACTOR: By decades from 10 up to 10^5 .
PRICE: \$2,950.

-hp-

MODEL 5245L

50 MC ELECTRONIC COUNTER

FREQUENCY MEASUREMENTS

RANGE: 0 to 50 mc.
GATE TIME: 1 μ sec to 10 sec in decade steps.

ACCURACY: ± 1 count \pm time base accuracy.

READS IN: kc or mc with positioned decimal point.

SELF CHECK: Counts 10 mc for gate time chosen by time base selector.

PERIOD AVERAGE MEASUREMENTS

RANGE:

Single Period: 0 to 1 mc.

Multiple Period: 0 to 300 kc.

PERIODS AVERAGED: 1 to 10^5 periods in decade steps.

ACCURACY: ± 1 count \pm time base accuracy \pm trigger error¹ \div periods averaged.

COUNTED FREQUENCY:

Single Period: 10^7 to 1 cps in decade steps.

Multiple Period: 10^7 cps to 0.1 times number of periods averaged in decade steps.

READS IN: Sec, ms or μ s with positioned decimal point.

SELF CHECK: Gate time of 10 μ s to 1 sec; counts at 100 kc rate.

RATIO MEASUREMENTS

DISPLAYS: (f_1/f_2) times period multiplier.
RANGE: f_1 : 0 to 50 mc, f_2 : 0 to 1 mc in single periods.

PERIODS AVERAGED: 1 to 10^5 in decade steps.

ACCURACY: ± 1 count of $f_1 \pm$ trigger error¹ of f_2 divided by number of periods averaged. One count of f_1 is f_2/nf_1 where n is number of periods averaged, f_1 is frequency applied to counting binaries (enters Time Base Ext. jack), f_2 is frequency applied to decade dividers (enters Signal Input jack).

READS IN: Dimensionless; decimal point positioned for number of periods averaged.

SELF CHECK: Same as Period Average self check above.

SCALING

FREQUENCY RANGE: 0 to 50 mc.
FACTOR: By decades from 10 up to 10^5 , switch-selected on rear panel.
INPUT: At front panel Signal Input jack.
OUTPUT: At rear panel, in place of time base output frequencies.

TIME BASE

FREQUENCY (internal): 1 mc.
STABILITY: Aging rate: less than ± 3 parts in 10^6 per 24 hours, after 72 hours of continuous operation. As a function of temperature: less than ± 2 parts in 10^{10} per $^\circ$ C from -20 to $+55$ $^\circ$ C. As a function of line voltage: less than ± 5 parts in 10^{10} for $\pm 10\%$ change in line voltage from 115v or 230v rms. Short term stability: better than ± 5 parts in 10^{10} with measurement averaging time of one second under constant environmental and line voltage conditions.

ADJUSTMENT: Fine frequency adjustments covering range of approximately 4 parts in 10^6 and medium frequency adjustments covering range of approximately 1 part in 10^6 available from front panel through plug-in compartment. Coarse frequency adjustment covering range of approximately 1 part in 10^5 is available at rear of instrument.

OUTPUT FREQUENCIES (rear panel): 0.1 cps to 10 mc in decade steps, switch-selected on rear panel; all frequencies available in manual function without interruption at reset; 10 kc to 10 mc available continuously in all functions; 1 kc available continuously for all functions except 100K period av-

erage; stability same as internal time base; 5 volt p-p rectangular wave with 1000 ohm source impedance at 1 mc and lower; 1 volt rms sine wave with 1000 ohm source impedance only at 10 mc.

OUTPUT FREQUENCIES (front panel): 0.1 cps to 1 mc in decade steps, selected by Time Base switch; availability as defined under Output Frequencies above; stability same as internal time base; 1 volt peak-to-peak.

EXTERNAL STANDARD FREQUENCY: 1 mc, 1 volt rms into 1000 ohms required at rear panel BNC connector.

GENERAL

REGISTRATION: 8 digits in-line with Nixie[®] tubes and display storage; 99,999,999 maximum display; total width of 8 digit display including illuminated units, annunciator and auto-positioned decimal point indication is 7 inches.

SAMPLE RATE: Time following gate closing during which gate may not be reopened is adjustable from approximately 0.1 sec to 5 sec for any gate time; display of a single measurement can be held indefinitely.

INPUT: Maximum sensitivity: 100 mv rms. Coupling: ac or dc, separate BNC connectors. Attenuation: step attenuator provides ranges of 0.1, 1, and 10 volts. Impedance: 100K ohms/volt (10K ohms at 100 mv); approximately 40 pf on 0.1 v range, 15 pf on 1 and 10v ranges. Overload: 50 v rms signal on 0.1v range tolerable; 150 v rms on 1v range; 500 vrms on 10v range; ac coupling capacitor, 1 μ f, 600 v.

OPERATING TEMPERATURE RANGE: -20 to $+65$ $^\circ$ C.

CONNECTORS: BNC type, except for remote programming and BCD output.

BCD OUTPUT: Four-line BCD code output with assigned weights of 1-2-2-4 ("1" state positive with respect to "0" state). This output includes decimal point position and measurement units, suitable for systems use or output devices such as *-hp-* model 562A Digital Recorder, 580A, or 581A Digital-to-Analog Converter. Impedance is 100K each line with "0" state level approximately -8 v, "1" state level approximately $+18$ v.

¹ Trigger error for sine wave input is $\pm 0.3\%$ for signals with 40 db signal-to-noise ratio.

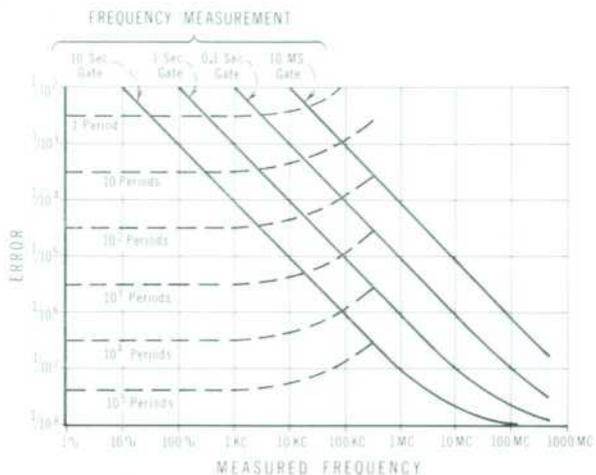


Fig. 11. Typical measurement accuracy obtainable with new counters for frequency and period measurements. Curves assume a time base error of $1/10^8$ and a period noise-error of $3/10^3/N$ where N is periods averaged of a 0.1 vrms sine wave of 100:1 signal-to-noise ratio.



Fig. 12. Circuitry in counters is built up on removable computer-type circuit boards to achieve compact overall size and high accessibility.

REFERENCE LEVELS: Approximately +17.5 v, 350 ohm source; approximately -6.9 volts, 1000 ohm source; print command step, +13 v to 0 v, dc coupled; hold-off requirements from 1000 ohm source, chassis ground to +15 v (min) +25 v (max).

REMOTE OPERATION: All front panel functions may be programmed from remote location except for Sample Rate and Sensitivity control setting. Instrument provides all voltages necessary for remote control through rear panel connectors. Programming voltages for digital display are low level, -15v dc maximum with approximately 5K ohms looking into counter on signal control leads. Control may also be achieved by using external -15 vdc supply. Decimal point and measurements unit may be illuminated from remote location at +170 vdc using internal or external supply.

DIMENSIONS: 16 $\frac{3}{4}$ in. wide, 5 $\frac{1}{4}$ in. high including plug-in, 16 $\frac{1}{2}$ in. deep. Hardware furnished converts unit to 19-inch wide by 5 $\frac{1}{4}$ inch high rack mount.

WEIGHT: Net, 32 lb. with blank plug-in; shipping 48 lb.

POWER SUPPLY: 115 or 230 volts $\pm 10\%$, 50 to 60 cps; approximately 80 watts.

ACCESSORIES FURNISHED: -hp- AC-16K cable, 4 ft. long, male BNC connectors. -hp- 8120-0078 Power Cord, 7 $\frac{1}{2}$ ft. long, NEMA plug. Circuit board extender.

PRICE: \$3,250.

**-hp-
MODEL 5251A
FREQUENCY CONVERTER**

RANGE: 20 to 100 mc using mixing frequencies of 20 to 90 mc in 10 mc steps.

ACCURACY: Retains accuracy of counter.

INPUT VOLTAGE: 50 mv to 2 volts rms.

INPUT IMPEDANCE: Approximately 50 ohms.

LEVEL INDICATOR: Meter aids frequency selection, indicates usable voltage level.

REGISTRATION: Converter reading adds to counter reading.

ACCESSORY FURNISHED: AC-16K cable, 4 ft. long, male BNC connectors.

NET WEIGHT: Net 2 $\frac{1}{2}$ lbs., shipping 7 lbs.

PRICE: \$300.00.

**-hp-
MODEL 5253A
FREQUENCY CONVERTER**

RANGE: 88 to 512 mc, using mixing frequencies of 100 mc to 500 mc in 10 mc steps.

ACCURACY: Retains accuracy of counter.

INPUT VOLTAGE: 50 mv to 1 v rms for optimum operation under worst-case conditions. Typical signal drop-out level is 10 mv rms.

INPUT IMPEDANCE: Approximately 50 ohms.

OVERLOAD: AC signals in excess of 2 v rms may damage converter. DC to ± 100 v is tolerable.

LEVEL INDICATOR: Meter aids frequency selection; indicates acceptable voltage level.

REGISTRATION: Counter display is added to or subtracted from converter dial reading depending on whether mixing frequency is below or above measured frequency.

ACCESSORY FURNISHED: AC-16K cable, 4 ft. long, male BNC connectors.

WEIGHT: Net 5 lbs., shipping 9 lbs.

PRICE: \$500.00.

**-hp-
MODEL 5261A
VIDEO AMPLIFIER**

SENSITIVITY: 1 mv rms.

INPUT: BNC connector, ac coupled.

INPUT IMPEDANCE: 1 megohm shunted by 15 pf (nominal).

BANDWIDTH: 10 cps to 50 mc.

ATTENUATOR RANGES: 1, 3, 10, 30, and 100 mv rms; meter shows when signal to counter is within acceptable amplitude range.

AUXILIARY OUTPUT: Separate BNC front panel output for oscilloscope monitoring or for driving external equipment; 50 Ω source impedance. On amplifier's most sensitive attenuator range, 1 mv rms at input results in at least 100 mv rms at auxiliary output into 50 Ω load. Max. undistorted output is 300 mv rms into 50 Ω load.

ACCESSORIES AVAILABLE: AC-21M high impedance, 10:1 voltage-divider probe.

WEIGHT: Net 2 lbs., shipping 6 lbs.

**-hp-
MODEL 5262A
TIME INTERVAL UNIT**

RANGE: 1 μ sec to 10^6 sec.

ACCURACY (pulse): ± 1 period of standard frequency counted \pm time base accuracy.

REGISTRATION: On -hp- Model 5243L or 5245L counter.

INPUT VOLTAGE: 0.3 volt, peak-to-peak minimum, direct coupled input.

INPUT IMPEDANCE: 10K ohms, less than 80 pf, on $\times 1$ and $\times 2$ multiplier positions; constant up to ± 40 volts times multiplier position; 100K ohms times multiplier position on $\times 3$ to $\times 100$ positions, less than 40 pf on $\times 3$ and less than 20 pf on $\times 1$ to $\times 100$; constant up to ± 40 volts times multiplier position.

OVERLOAD: 50 volts rms, or ± 150 volts peak on $\times 1$, $\times 2$ and $\times 3$ multiplier positions is tolerable; 150 volts rms or ± 250 v peak, on $\times 1$ and $\times 3$; ± 250 volts peak, on $\times 10$, $\times 30$ and $\times 100$.

START-STOP: Independent or common channels.

TRIGGER SLOPE: Positive or negative independently selected on both channels.

TRIGGER AMPLITUDE: Both channels continuously adjustable from -6 to +6 volts times multiplier position.

FREQUENCY RANGE: (When used as input signal discriminator) 0 to 2 mc.

STANDARD FREQUENCY COUNTED: 10^7 to 1 cps in decades from counter, or externally applied frequency.

MARKERS: Separate output voltage steps, 0.5 volts peak-to-peak from source impedance of approximately 7k ohms, 100 pf available at rear panel of counter; negative step coincident with trigger points on input waveforms for positive slope, and positive step coincident for negative slope.

READS IN: μ s, ms, or sec with measurements unit indicated and decimal point positioned.

ACCESSORIES FURNISHED: AC-16K cable, 4 ft. long, male BNC connectors.

WEIGHT: Net 2 $\frac{1}{2}$ lbs., shipping 7 lbs.

PRICE: \$300.00.

All prices f.o.b. Palo Alto, Calif. Data subject to change without notice



HIGH-READABILITY DISPLAY

Besides their compact size, perhaps the most conspicuous feature of the new counters is the ease with which their display can be read. This comes about because the previous wide spacing necessitated by tube diameter now has been considerably compressed as shown in the illustration. The numerals have the same large size as previously, but the spacing is reduced about 30%, which results in a display with a more readable span. The reduction is achieved by using new "rectangular" Nixie® readout tubes, which were de-

veloped by the Burroughs Corporation at the request of the Hewlett-Packard Company. Combined with the display storage feature which keeps the numerals visually readable at all times with no "count-time" effect, a very pleasing display indeed is obtained.

The display system includes an automatically-positioned and illuminated decimal point, as well as an automatic, illuminated readout of the units of measurement (kc, mc, μ sec, msec and sec.).

(Continued from page 6)

BCD OUTPUTS

The counters are also arranged to operate with recently-developed *-hp-* auxiliary equipment to provide a printed record of measurements on paper tape or to obtain strip-chart or X-Y recordings by use of the *-hp-* 580A Digital-to-Analog Converter. For such purposes, the counters provide a binary-coded decimal (1-2-2-4) output at special connectors at the rear panel. Using the *-hp-* printer Model 562A (with option 14), the printed record of measurements can be obtained complete with indication of decimal point multiplier and units of measurement.

The BCD outputs are also useful with Dymec equipment to permit the counter measurements to be fed into automatic systems.

TIME BASE OSCILLATOR

The heart of the time base circuitry is, of course, a crystal-controlled precision oscillator. To achieve an oscillator with the stability shown by the curves discussed earlier re-

quires an excellent crystal operating in a stable environment and maintained by a constant-amplitude drive. The crystal is one that has a high Q of about 2,000,000 to 5,000,000 and is exceptionally free from contaminants for good long-time stability. To achieve the needed environment, the crystal is operated in an oven with proportional-type temperature control to avoid cycling effects. The oven holds the crystal temperature constant within approximately 0.01°C over a -20° to $+55^{\circ}$ C ambient range. To keep the crystal's physical excursions at a constant amplitude, the amplifier that maintains the crystal is AGC-controlled.

The crystal oven circuitry is arranged so that the oven heater is always energized so long as the counters are connected to a power source and even though the panel power switch is turned to off. The crystal itself is thus kept at operating temperature which greatly reduces turn-on effects.

ENVIRONMENTAL DATA

It is part of their specifications that the new counters have an operating temperature range from -20° C to $+65^{\circ}$ C, i.e., to $+149^{\circ}$ F. This upper operating limit is well beyond the temperature where grasping the knobs will burn the fingers. Operation at such extremes will be unusual for most users, but a design that embraces this range of temperatures assures broad performance margins for the instrument.

Time base stability is specified from -20° C to $+55^{\circ}$ C (131° F), although the time base operates to $+65^{\circ}$ C. The narrower temperature range for specified stability occurs because the oven for the quartz plate in the time base operates at a temperature between 60° and 75° C, depending on the turnover temperature of the individual crystal. To allow some temperature differential between oven and ambient, time base stability is specified only to $+55^{\circ}$ C, although operation to $+65^{\circ}$ C is permissible.

Prototype samples of the instruments have been satisfactorily stored at temperatures ranging from -65° C to $+85^{\circ}$ C with no reduction in subsequent performance.

Prototype samples of the instruments have also been subjected without damage to severe mechanical tests such as the vibration test specified in MIL-E-16400D.

DESIGN GROUP

The electrical design group for the new counters and plug-ins included Robert L. Allen, Larry A. Amsden, LaThare Bodily, John H. Gliever, Dexter C. Hartke, Edgar G. Stromer, Jeffery J. Wolfington and the undersigned. The mechanical design group included Alfred Low, Charles S. Lowe, Stephen D. Nemeth, and David D. Smith. Valuable contributions were also made by Francis Berry, Leonard S. Cutler, Glen E. Elsea, Lawrence Lim, Rolf K. Murchison, and Irwin Wunderman.

*—Charles M. Hill
and Tracy S. Storer*