



A New 3 CPS-100 KC Electronic Frequency Meter with Discriminator Output and Expandable Scale

ELECTRONIC frequency meters, as distinguished from electronic frequency counters, are instruments that indicate the frequency of an applied waveform on a calibrated meter scale. The current that operates the indicating meter is also usually made available for operating an external d-c recorder.

Besides indicating an applied frequency and providing a recorder output, however, the new -hp- Model 500B Electronic Frequency Meter is designed to be valuable in two other types of measurements. First, it is designed to be able to expand its scale readings by factors of 3 or 10 times, an arrangement that facilitates measurements of frequency changes such as might be caused by line voltage changes on frequency-generating circuits. Second, the instrument is designed to provide an output voltage which is proportional to the applied frequency. This

enables the instrument to be used as a wide band discriminator in applications where the measured signal contains very rapid frequency changes or frequency modulation. The discriminator voltage, when filtered, can be used in measuring the amount of deviation in the signal as well as the rate and components of the deviation.

Frequency-wise, the new instrument will directly measure frequencies from 3 cps to 100 kc in nine ranges to a full scale accuracy of within $\pm 2\%$. The applied voltage can have nearly any of the common waveforms. Random as well as equally-spaced signals can be measured.

The instrument further provides a d-c supply for operating the -hp- 506A Optical Pickup, a device that detects even the fastest rotary motions and supplies an appropriate signal to be measured by the frequency meter.

EXPANDABLE SCALE

The 3 or 10 times expandable scale feature enables frequency changes to be measured with increased accuracy. If the frequency shift encountered in a 2 kc frequency were to be measured, for example, 10 times expansion will permit 10% of the meter scale placed in the vicinity of 2 kc to occupy the entire meter swing. In expanded operation the absolute reading of the meter will not be indicative of the applied frequency, but the calibrations of the meter, in addition to being expanded or magnified, are still direct-reading as far as the differential frequency is concerned. Expanded operation is further facilitated by a panel control that permits the meter pointer to be positioned to any arbitrary point on the meter scale



Fig. 1. New -hp- Model 500B Electronic Frequency Meter measures frequencies from 10 cps full scale to 100 kc full scale in 9 ranges. Special features include a discriminator output for measuring f-m and the ability to expand its scale for increased accuracy in frequency change measurements.

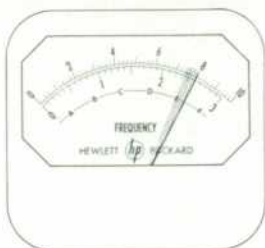


Fig. 2. In normal operation a 600-cps shift in an 8 kc frequency causes pointer change shown by shaded arc.



Fig. 3. Same shift as in Fig. 2 will cause pointer change shown when measured in $\times 10$ expanded operation.

for the initial reading. In such measurements a zero, half, or full-scale position for the meter pointer is most often preferred for the initial reading.

To further illustrate the expandable scale feature, assume that a 600-cps downward shift in an 8 kc frequency were to be measured. If this shift were measured in normal operation on the most suitable range (10 kc) of the instrument, the meter pointer would move through the shaded arc shown in Fig. 2.

To make such a measurement with expanded operation, the meter pointer might initially be positioned to full scale in this example, since the shift is known to be downward. The meter pointer would then be shown as in Fig. 3. When the frequency being measured now changes as before, the meter pointer will move through the 10 times larger arc indicated in Fig. 3. Since 10 times expansion is used with the 10 kc range, the full swing of the meter represents 1 kc. Since the needle has dropped 60% of the meter scale, the frequency has dropped 600 cps.

Three times expansion operates in an analogous manner.

Expanded operation offers two advantages over unexpanded operation for the measurement of frequency

changes. Besides the obvious advantage of having a magnified motion of the meter pointer for the frequency shift, expanded operation gives increased accuracy to the differential measurement. Where a measurement of a frequency change in conventional operation could be construed to have an error of 4% (i.e., the difference between two measurements each accurate within $\pm 2\%$), 10 times expansion gives an accuracy of within $\pm 0.7\%$ and 3 times expansion an accuracy of within $\pm 1.4\%$ of the frequency applied to the input terminals. It is of interest to note that most frequency change measurements will be made to even better accuracy than these figures indicate, because the figures are cited for the worst possible case, i.e., where the line voltage changes from $\pm 10\%$ to $\mp 10\%$ of its nominal 115-volt value between the first and second measurements.

Expanded operation does not affect the discriminator output but does expand the recorder output in the same manner as the meter reading is expanded. More detailed records with higher accuracy can thus be obtained for differential measurements if expanded operation is used while recording.

CIRCUITRY

The usual design arrangement for an electronic frequency meter uses a series of limiting amplifiers to reduce the effect of waveform on the measured frequency. While such an arrangement gives moderate freedom from waveform effects, greater

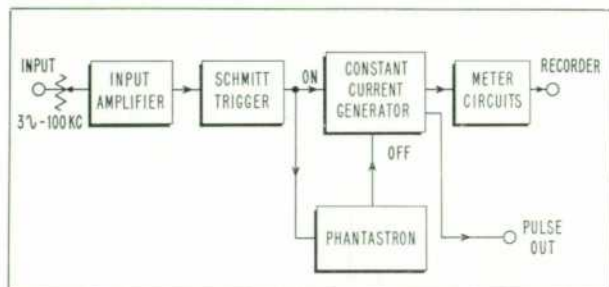


Fig. 4. Basic circuit arrangement of new frequency meter.

freedom, including the ability to measure pulse frequencies, can be obtained by using the design approach indicated in Fig. 4.

In Fig. 4 the frequency to be measured is passed through the input amplifier and applied to a Schmitt trigger circuit. For each cycle of the applied waveform the trigger circuit generates a fast pulse which switches on a constant current generator and at the same time triggers a phantastron. The purpose of the phantastron is to turn off the constant-current generator after a pre-determined time interval. The time constants in the phantastron circuit are changed by the range switch for each frequency range so that a current pulse of known duration is obtained for each cycle of the input frequency.

The current pulses generated by the constant-current generator are applied to a meter circuit which averages their value. The resulting meter deflection is thus proportional to frequency and independent of the waveform applied to the instrument's input terminals. The current pulses applied to the meter circuit are also used to derive the voltage pulses made available at the "Pulse Out" terminal. The latter pulses are provided as negative from ground at an amplitude such as to give a d-c output of -20 volts for a full scale meter reading. The averaged current through the meter is made available at the "Recorder" terminal for operating a d-c recorder. The meter indication, discriminator output, and recorder output are all thus derived

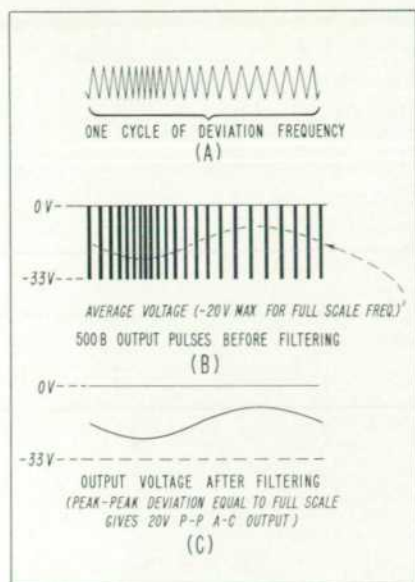


Fig. 5. Diagram indicating how discriminator output of frequency meter can be used to measure amount of f-m in applied frequency.

from the current pulses generated in the constant current generator.

Scale expansion is accomplished by an arrangement that increases the sensitivity of the meter circuit and simultaneously allows a bucking current to be applied to the meter. The bucking current is adjusted by a panel "Offset" control. The arrangement is such that any meter reading that occurs as a partial scale reading in unexpanded operation can be adjusted to any point on the meter scale in expanded operation. Expanded operation also expands the current-frequency characteristic at the recorder output jack in the same way that the meter reading is expanded.

DISCRIMINATOR OUTPUT

How the discriminator output of the new frequency meter proves valuable in measurements can be described by assuming that a frequency of 50 kc is to be measured. Assume further that this frequency contains a ± 5 kc frequency modulation swing at a 1 kc rate and that it is desired to investigate this f-m.

When the frequency-modulated waveform is applied to the fre-

quency meter, the panel meter will indicate the average frequency of 50 kc. For each cycle of the applied frequency, a voltage pulse will be available at the "Pulse Out" terminal as indicated in Fig. 5(a) and (b). Since the amplitude and width of these pulses are constant, and since the pulses are negative from ground, their short-time average value will vary, as in Fig. 5(c), in exact accordance with the frequency modulation they contain. The original deviation waveform can therefore be recovered if the pulses are averaged with a suitable low-pass filter.

Not only can the waveform be recovered, but the amount of deviation in the signal can readily be measured, because the peak-to-peak amplitude of the variations in the short-time average level will be exactly proportional to the deviation. Since the amplitude and width of the output pulses is such as to give a d-c output level of -20 volts for a full-scale reading on the meter, the applied frequency of 50 kc in this example would cause a half-scale reading on the 100 kc range and therefore an average d-c output of -10 volts or -0.2 volt d-c/kc. By now measuring the peak-to-peak amplitude of the varying component of the d-c output with an oscilloscope or a-c voltmeter, the ± 5 kc deviation in the signal will be found to cause a measured value of 2 volts peak-to-peak.

In practice, these voltages will all be affected by the impedance of the filter used. The voltage per cycle or per kilocycle out of the filter can easily be determined by dividing the measured d-c voltage out of the filter by the reading on the frequency meter.

MEASURING RESIDUAL F-M IN A KLYSTRON

Fig. 6 is an oscillogram of a demodulated f-m signal recovered by using the discriminator output of

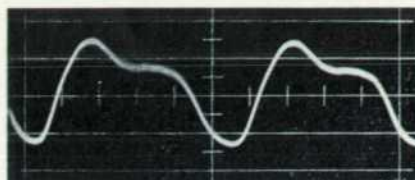


Fig. 6. Oscillogram of residual f-m in klystron oscillator as recovered by use of new frequency meter (see text).

the new frequency meter in the method described above. The waveform itself is the residual f-m modulated into a klystron oscillator, mainly from the heater circuit. The residual f-m in the klystron output was translated to the range of the frequency meter by mixing the klystron output with the *-hp-540A* Transfer Oscillator*. This Oscillator was then tuned to produce a difference frequency of 70 kc which also contained the incidental f-m.

The amplitude of the deviation was measured by adjusting the oscilloscope gain so that each major division on the graticule was equal to 5 kc of deviation. Total deviation represented by the waveform can thus be seen to be 15 kc peak-to-peak.

The fundamental component of the modulation is 60 cps which is combined with a large amount of second harmonic. If desired, an accurate measurement of each of the components could be made by applying the waveform to a harmonic wave analyzer (Fig. 8). If deviations larger than the 100 kc peak-to-peak that the frequency meter can accommodate are encountered, the *-hp-520A* 100:1 scaler can be connected ahead of the frequency meter (Fig. 9). This will allow deviations of up to 10 mc peak-to-peak to be measured.

DISCRIMINATOR LINEARITY

Care has been taken to maintain a good order of linearity for the discriminator circuits. Discriminator

*Dexter Hartke, "A Simple Precision System for Measuring CW and Pulsed Frequencies Up to 12,400 MC," *Hewlett-Packard Journal*, Vol. 6, No. 12, August, 1955.

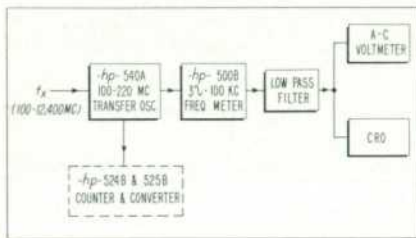


Fig. 7. Set-up for measuring *f-m* in frequencies from 100 to 12,400 mc.

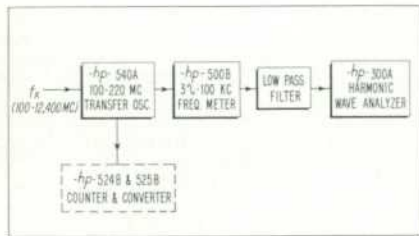


Fig. 8. Set-up for measuring components of *f-m* modulating waveform in frequencies from 100 to 12,400 mc.

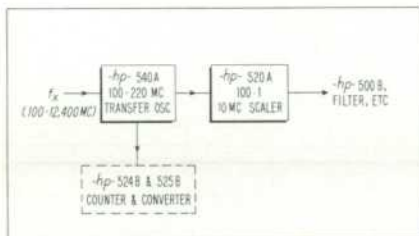


Fig. 9. Set-up for measuring deviations up to 10 mc peak-to-peak.

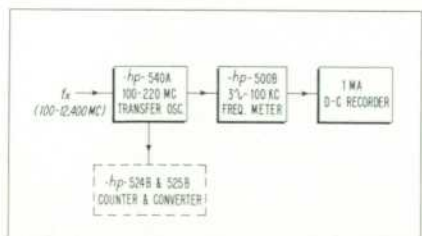


Fig. 10. Set-up for recording drifts in frequencies in 100-12,400 mc range.

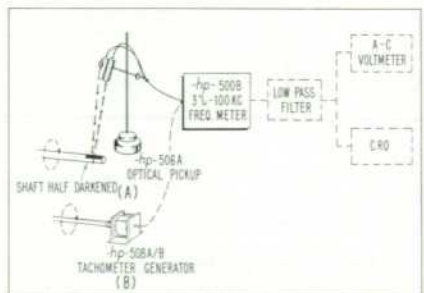


Fig. 11. Set-ups for measuring torsional vibration in rotating equipment. (A) shows use of *hp*-optical pickup, (B) use of *hp*-tachometer generator for converting mechanical effect to electrical signal.

linearity is of sufficient quality that not more than 1% harmonic distortion is introduced into a demodulated sine-wave signal for a peak-to-peak excursion of 100% of the meter range used (a peak-to-peak excursion of 30 kc, for example, when the 30 kc range is used).

Because of the wide range of applications to which the instrument may be put, the pulsed output is not filtered. For most applications either a low-pass or band-pass filter can be used.

OPERATING CHECKS

Two operating checks are provided on the new frequency meter. One of these permits the instrument to read the power line frequency. The other is an arrangement whereby the current level in the constant current generator can be monitored by the panel meter. By means of a special position on the frequency range switch, a predetermined fraction of the current generator's output is applied to the d-c indicating meter. The design is such that a full-scale meter reading should be obtained. A screwdriver-adjusting control is provided on the panel for adjusting the level if required, a feature that simplifies tube replacement.

MEASUREMENT SET-UPS

The new frequency meter is a valuable tool for investigating many frequency and stability phenomena. Figs. 7 to 11 indicate how the instrument can be combined with other *hp*- instruments to measure such quantities as peak-to-peak *f-m* deviation, components of *f-m* modulation, stability, torsional vibration, rotary mechanical speed, etc.

RPM CALIBRATIONS

As mentioned earlier, the new Model 500B Frequency Meter is calibrated directly in cycles per second. A second version of the instrument, the Model 500C, is calibrated directly in rpm for applications where the instrument is to be used

primarily to measure rotary speed. Except for calibration differences, the instruments are identical.

SUPERSEDES FORMER FREQUENCY METERS

The new Models 500B and 500C Electronic Frequency Meters supersede the former *hp*- Models 500A, 505A, and 505B.

—Duane Marshall

SPECIFICATIONS

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MODEL 500B

ELECTRONIC FREQUENCY METER

FREQUENCY RANGE: 3 cps to 100 kc. Nine ranges with full scale values of 10, 30, 100 and 300 cps; 1, 3, 10, 30, and 100 kc.

EXPANDED SCALE: Allows any 10% or 30% portion of a selected range to be expanded to full meter scale. (Not present on lowest range.)

INPUT VOLTAGE: Sensitivity: 0.2 volts rms minimum for sine waves, 1.0 volt minimum for pulses. Maximum: 250 v peak. Sensitivity control on front panel to reduce threshold sensitivity.

INPUT IMPEDANCE: Approximately 1 megohm shunted by 40 μ f. BNC connector for input.

ACCURACY: Better than $\pm 2\%$ of range selector setting. See text for expanded accuracy. Line voltage variations of nominal $\pm 10\%$ affect reading less than $\pm 1/2\%$ or less than $\pm 1/4\%$ on $\times 10$ expanded operation.

SELF CHECK: Allows calibration of internal constant current source and check against 60 cps line frequency.

RECORDER OUTPUT: Phone jack on panel for connection to 1 ma 1400 ohm ± 100 ohm Esterline-Angus Automatic Recorder.

PULSE OUTPUT: Provides negative pulses for use in detecting and measuring rapid frequency changes.

PHOTOCELL INPUT: Phone jack on panel provides bias for Type 1P41 Phototube. Allows direct connection of *hp*- 506A Optical Pickup.

POWER: 115/230 v $\pm 10\%$. 50/1000 cps, approx. 110 watts.

DIMENSIONS: Cabinet mount: 7 $3/8$ " wide, 11 $1/2$ " high, 12 $1/4$ " deep.

WEIGHT: Net 17 lbs.; shipping weight 35 lbs.

ACCESSORIES FURNISHED: *hp*- AC-16D Cable Assembly.

ACCESSORIES AVAILABLE: *hp*- Model 506A Optical Tachometer Pickup, \$100.00. *hp*- Model 508A/B Tachometer Generator, \$100.00 each. *hp*- Model 500B-95A Accessory Meter (identical to panel meter but operates from recorder jack for remote indication), \$21.00.

PRICE: *hp*- Model 500B Electronic Frequency Meter, \$285.00.

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MODEL 500C

ELECTRONIC TACHOMETER INDICATOR

Circuit and construction same as *hp*- 500B, except for meter calibration.

SPEED RANGE: 180 RPM to 6,000,000 RPM. Nine ranges with full scale values of 600, 2,000, 6,000, 20,000, 60,000, 200,000, 600,000, 2,000,000 and 6,000,000 RPM.

ACCESSORIES FURNISHED: *hp*- AC-16D Cable Assembly.

ACCESSORIES AVAILABLE: *hp*- Model 500C-95A Accessory Meter (see above), \$21.00. Also *hp*- 506A and 508A/B pickups (see above).

PRICE: *hp*- Model 500C Electronic Tachometer Indicator, \$285.00.

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