

Fig. 1. *This new all solid state –hp– Model 3410A AC Microvoltmeter will measure signals even when frequency and amplitude are unknown. A panel light helps in determining the proper setting of the range switch. Adjusting the front panel tuning control to within 1% of the signal frequency enables the phase-lock circuitry to lock on and track the input signal within the specified limits.*

How to Recover Weak Signals Buried in Noise

A new phase-lock synchronous detector enables this ac microvoltmeter to lock on to signals obscured by noise.

By Raymond C. Hanson

MEASURING LOW-LEVEL SIGNALS nearly obscured by noise or other nonrelated signals is required in many applications. Some general areas in which this condition is encountered include instrument calibration, communications and medical research.

The broadband, average responding voltmeter is limited in sensitivity by inherent noise and spurious signals. An extension of the average-responding voltmeter for very low level signals obscured by noise uses the synchronous rectifier. When driven at the fundamental frequency of a known waveform, the filtered output of a synchronous rectifier is proportional to the average value of that waveform. Noise and spurious signals are rejected.

Voltmeters using this technique require a clean, high-level reference signal input from the test signal source, or that the system under test use the local oscillator output of the voltmeter. In many cases such a hook-up is not convenient or is impossible.

A new ac microvoltmeter, Fig. 1, has been designed that uses a phase-lock oscillator to drive a synchronous rectifier, thus eliminating the need for a reference input. It operates at any frequency from 5 Hz to 600 kHz and has a high input impedance of 10 megohms. Sensitivity is 3 microvolts full scale on the most sensitive range. Noise and spurious signals up to 20 dB above full scale are rejected.

Operation of the Microvoltmeter

The circuit of the –hp– Model 3410A AC Microvoltmeter, Fig. 2, consists of four major sections: The input or signal conditioning circuit, the phase lock loop, an inhibit circuit, and a meter circuit. When tuned to any discrete frequency between 5 Hz and 600 kHz, the meter indicates the rectified average value of the signal. All noise and nonharmonically related signals are filtered out.

Rejection of Submultiple Frequencies. The synchronous rectifier will respond to any odd harmonic of its drive frequency in inverse proportion to its harmonic number. Thus, if an input signal is at a frequency of 5000 Hz with a level of 5 mV, and the drive frequency is at 1000 Hz, the output dc of the synchronous rectifier will pro-

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Typical Applications of -hp- Model 3410A

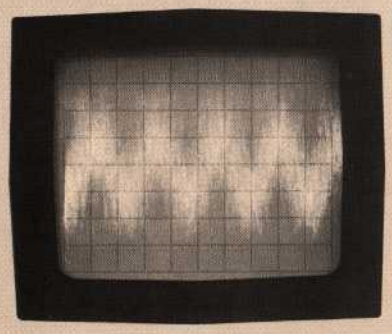
Measuring Frequency of Signals in Noise

A low-level signal in the microvolt region can easily be obscured by noise (a). Direct reading of frequency with a counter is not possible, even with a high-gain preamplifier. In addition, a counter may give erroneous readings if the amplitudes of the measured signals are fluctuating.

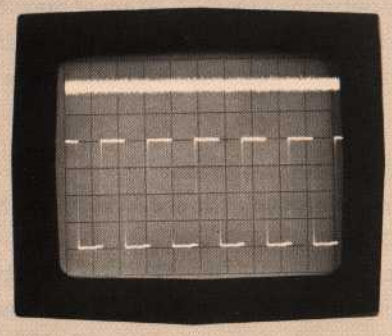
The ac microvoltmeter may be used as a preamplifier for a counter. When it locks to a signal, its local oscillator output (a 5 V square wave) is constant amplitude and at the input signal frequency (b).

It is very difficult to synchronize an oscilloscope to a low-level repetitive signal in noise. The ac microvoltmeter can be used as a sync source by locking it to the repetitive signal and applying its local oscillator output to the external sync terminals of the oscilloscope (c). Thus it is possible to see the repetitive nature of the noisy signal on the CRT.

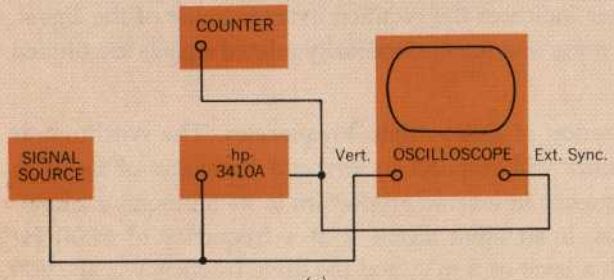
Because the *–hp–* Model 3410A is able to track a changing voltage and maintain voltage accuracy over a range of ±5% of the frequency range, it is possible to make measurements where the frequency of the input signal is changing. The input frequency can change as fast as 0.5% per second up to the 5% frequency range.



(a)



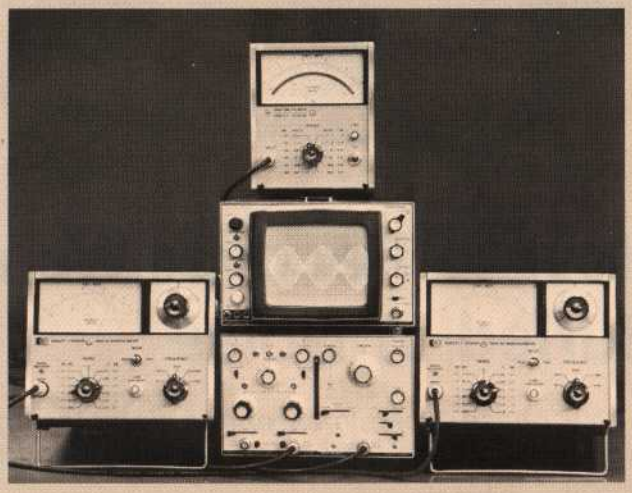
(b)



(c)

Separating Closely Spaced Coherent Signals

Two signals not related harmonically, but nearly the same amplitude and frequency can be measured independently. In this application, the microvoltmeter at the left is tuned to a 3000 Hz signal of 70 mV. At the right, the microvoltmeter is reading a 3100 Hz signal at a level of 90 mV. The sum of the two signals ($E = \sqrt{E_1^2 + E_2^2} = 114$ mV) is displayed on the true RMS voltmeter at the top. Displayed on the oscilloscope is the composite waveform illustrating the 100 Hz beat frequency.

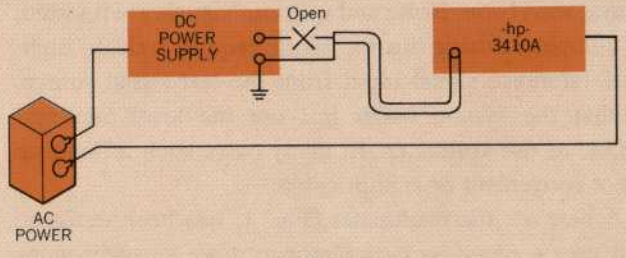


Measuring Power Supply Ripple

Ripple on a power supply of up to about 150 V dc can be measured with the *–hp–* Model 3410A Microvoltmeter. The instrument can measure microvolts at the usual ripple frequencies of 60, 120, 180 Hz and others.

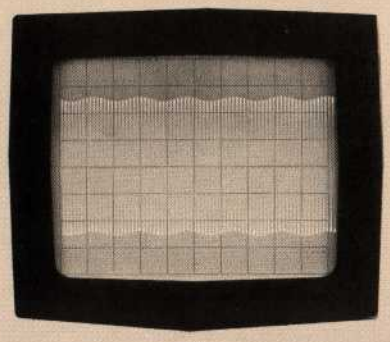
Every system has some ground loop problem and it is difficult or impossible to predict ground loop voltage. One method of determining ground loop voltage is shown in the block diagram (a). By disconnecting the input lead, but keeping the ground connection on, the ground loop voltage may be measured as shown. This voltage is subtracted from the ripple voltage reading to obtain the true ripple voltage.

Ripple on the 1 V, 400 Hz source (b) is of the order of 1 mV.



(a)

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(b)

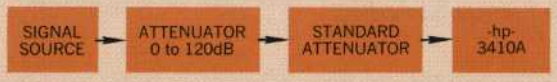
Measure Signal to Noise Ratio

Use an external variable attenuator to adjust the input level to the –*hp*– Model 3410A to be just sufficient to light the range indicator light. The range indicator light goes on when the postamplifier output is 10 dB or more above the amplitude required for a full-scale meter indication. The broadband input signal is then +10 ±1 dB above full scale for the particular range switch setting used. This procedure yields 1 dB resolution rather than 10 dB resolution provided by the range switch.

Next, the microvoltmeter is locked to the signal. The dB value of the signal as read on the meter minus 12 gives the signal-to-noise ratio.

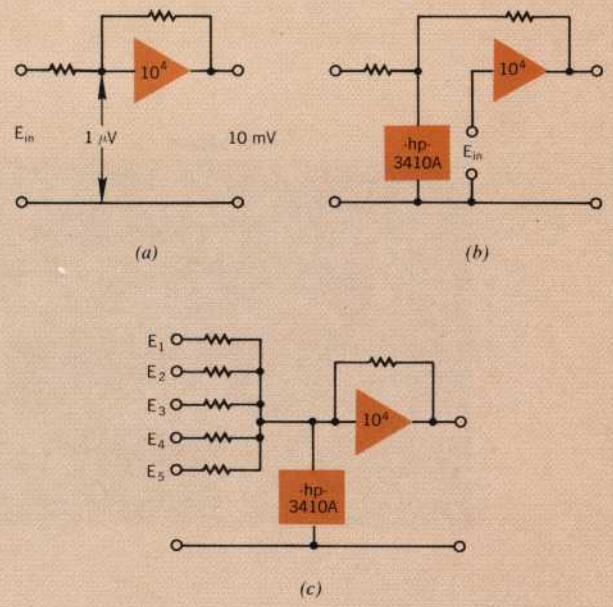
Calibrating Attenuators

Where an input power limitation restricts the input voltage to an attenuator, the output voltage at full attenuation will be low and likely buried in noise. For example, a coaxial attenuator such as the –*hp*– Model 355D has a total attenuation of 120 dB and a power limitation of 0.5 W. At 50 ohms, the maximum input signal is 5 volts, resulting in a 5 microvolt signal out at full attenuation. This 5 microvolt signal is smaller than the inherent input noise of broadband voltmeters. A typical attenuator calibration setup, uses the ac microvoltmeter to check deviation from the standard. The microvoltmeter can be used for calibration over a wide frequency range.



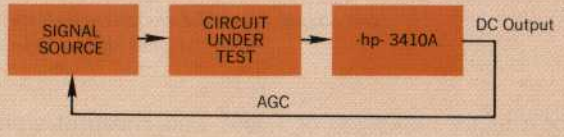
Measuring Summing Junction Voltages

Voltage measurements made at the summing junction of a typical operational amplifier (a), require an instrument with high sensitivity and high input impedance to avoid loading. The new ac microvoltmeter is ideally suited for this measurement with its 3 μV full scale sensitivity and input impedance of 10 megohms. By reconnecting the operational amplifier (b), a loop gain plot can be obtained by plotting the magnitude of the return voltage as a function of frequency. Where a number of voltages of different frequencies are summed at the input (c), they may be measured independently provided their frequencies are sufficiently separated.



Providing AGC to a Signal Source

The dc recorder output of the –*hp*– Model 3410A AC Microvoltmeter provides a dc level proportional to the amplitude of the input signal at its tuned frequency. The dc may be fed back to the source as an AGC voltage.



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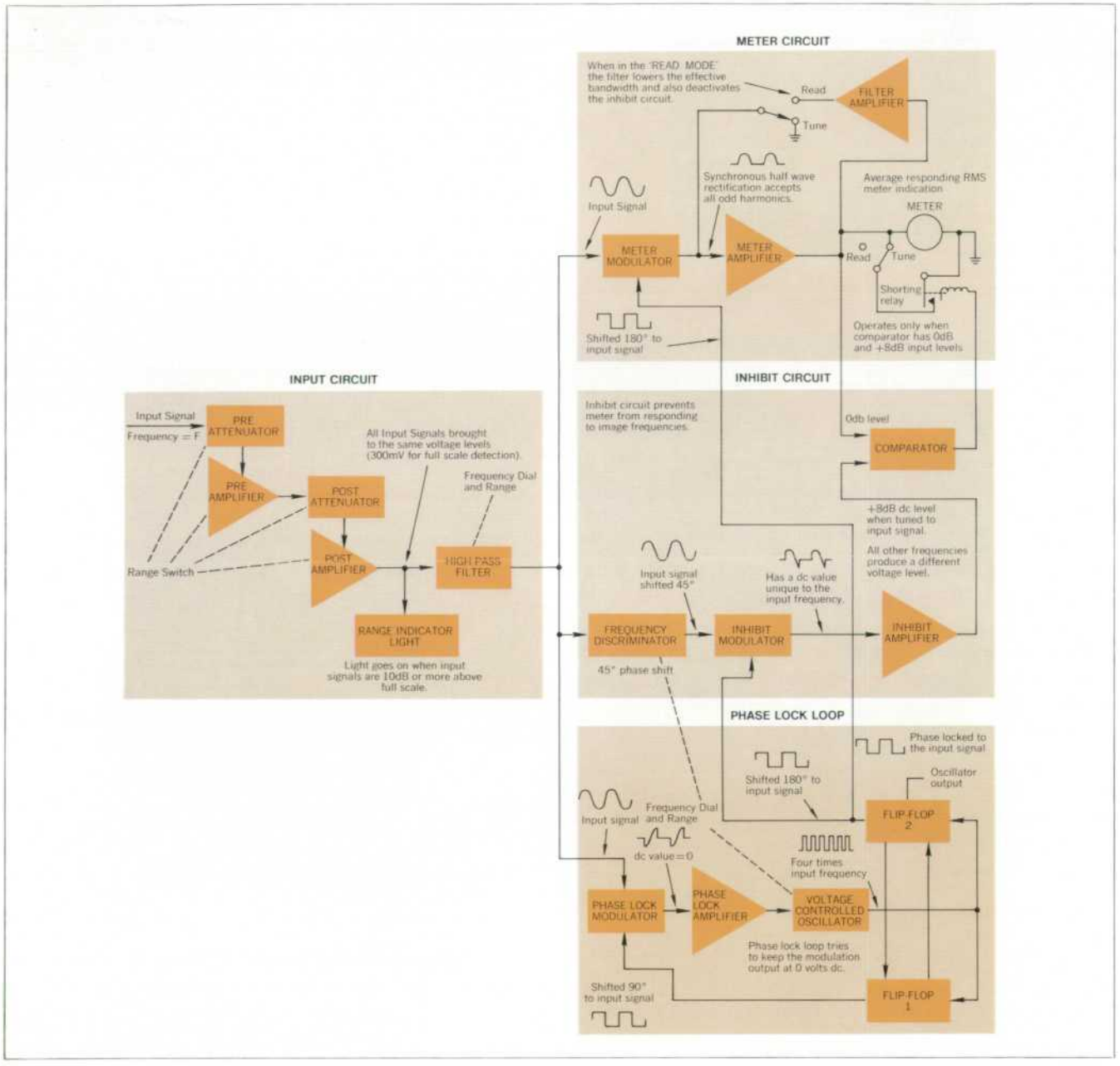


Fig. 2. *In the Model 3410A, the input signal is applied to the meter modulator which is driven by the square wave output of flip-flop 2 in phase with the input frequency. Thus the output from the meter modulator is a synchronous half-wave rectification of the input signal which rejects even, but not odd harmonics.*

duce a meter indication of 1 mV. This constitutes an erroneous response since there is no input signal at the tuned frequency of 1000 Hz. To prevent this type of error, the microvoltmeter has an inhibit circuit. The inhibit circuit consists of signal processing circuits similar to that of the metering circuit except that it is preceded by a tuned frequency discriminator. The output of the inhibit circuit and meter circuit are fed to a comparator which controls a reed relay connected across the meter. The reed relay shorts out the meter except when the input signal is at the tuned frequency of the local oscillator.

Response to Harmonics. The microvoltmeter does not respond to even harmonics of the signal to which it is

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Raymond C. Hanson

Ray Hanson received his Bachelor of Science in Electrical Engineering from the University of California in Berkeley in 1959, and his Master of Science in EE from New York University in 1961. While attending NYU and after graduation, he worked at Bell Laboratories on voice frequency test equipment.

Ray joined the Hewlett-Packard Loveland Division in 1963 and began investigation of low-level detection systems out of which grew the Model 3410A AC Microvoltmeter. He became project leader on the 3410A.

locked. It responds to odd harmonics in proportion to their amplitude and phase relationship to the fundamental as do all average-responding voltmeters. If the instrument is tuned to a harmonic of some signal, it will respond to the odd multiples of that harmonic in proportion to the amplitude and phase relationship of these odd multiples to the tuned harmonic.

Phase Lock Oscillator. The purpose of the phase-lock oscillator is to develop a drive signal for the synchronous rectifier. This drive signal must be in phase with the input signal, while the nature of the phase-lock oscillator is to lock at 90 degree phase with respect to the input signal. Therefore, to drive the synchronous rectifier, the phase-lock oscillator must produce two signals phase shifted by 90 degrees. This is accomplished by operating the voltage-controlled oscillator at four times the frequency indicated on the frequency dial. The VCO provides a clock input for two flip-flops which are interconnected to divide by four and give two outputs with the proper 90 degree phase relationship.

The VCO is a free-running, multivibrator linearly tuned by means of voltage-controlled current sources. A low-pass filter in the phase-lock loop is changed each decade so that the frequency characteristic provides a capture range of 1% at full-scale frequency and full-scale meter deflection. Lock range is defined here to be the frequency range over which the oscillator will track a drifting signal while maintaining a sufficiently small phase error to maintain rated accuracy in the microvoltmeter meter reading. The lock range is ±5%.

Range Indicator. Selective voltmeters may give erroneous readings due to spurious signals overloading the input. To avoid this problem, a range indicator light tells the operator which range switch setting can be used with rated accuracy. It saves the operator time by indicating the range switch setting at which phase lock can be achieved, since the phase-lock loop has a finite dynamic range over which phase lock can be achieved. In the –*hp*– Model 3410A, this range is 20 dB above full-scale signal to −20 dB below full scale. For larger signals, the active filter in the phase-lock loop does not operate linearly. For smaller signals, the capture range is reduced to the point where phase lock cannot be achieved.

The range indicator is a broadband detector which responds to the average value of the composite input signal. It lights the range indicator light when the signal level is about 10 dB above full scale. If the input is a "clean" signal and the range switch is stepped down until the light comes on, the signal level will be between 10 dB and 20 dB above full scale and phase lock can be obtained. When phase lock is achieved by tuning, the meter will be pegged and it is necessary to up-range to obtain an on-scale indication. If spurious signals and/or noise exceeds the desired signal, then the meter indication may be less than full scale. If phase lock is not achieved, then the signal is too far below the noise to be recovered by the instrument.

Acknowledgment

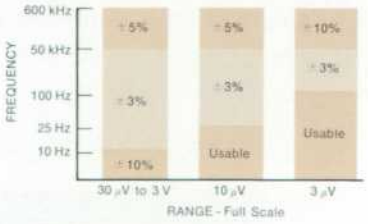
James L. Crooks was responsible for the product design of the –*hp*– Model 3410A AC Microvoltmeter. ■

SPECIFICATIONS

–*hp*–

Model 3410A AC Microvoltmeter

VOLTAGE RANGE: 3 μV full scale to 3 V full scale (−110 dBm to +10 dBm).
VOLTAGE ACCURACY: (% of full scale).



FREQUENCY RANGE: 5 Hz to 600 kHz in decade ranges.
FREQUENCY DIAL ACCURACY: ±10% full scale (unlocked). Linearly tuned over each decade (5 decades).
PHASE LOCK RANGE: Pull in ±1% of full scale frequency.
Track ±5% of full scale frequency.
Tracking speed ½% of full scale/s.
MAXIMUM NOISE REJECTION: 20 dB rms above full scale on all ranges for rated accuracy.
INPUT IMPEDANCE: 10 MΩ shunted by 20 pF.
METER: Reads rms value of sine wave; voltage indication proportional to average value of applied wave. Linear voltage scale 0 to 1, 0 to 3; dB scale −12 to +2 dB (0 dB = mW into 600Ω).
LOCAL OSCILLATOR OUTPUT: 5 V square wave, 1000Ω output impedance.
RECORDER OUTPUT: 1 mA into 1000Ω, ±0.5 V adjustable offset level.
AC POWER: 115 or 230 V ±10%, 50 to 1000 Hz, 22 W.
PRICE: –*hp*– Model 3410A, $800.00
MANUFACTURING DIVISION: –*hp*– *Loveland Division*
P. O. Box 301
Loveland, Colorado 80537

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