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Broader Information Capabilities in the Clip-On DC Milliammeter

ABOUT three years ago the Hewlett-Packard Company introduced a notable new instrument: a dc milliammeter that measured current merely by *clipping around* the conductor under test.* Because of its clip-on feature this instrument eliminated the inconvenience of opening the circuit under test to measure current. Further, the new milliammeter *reflected no dc resistance* into the measured circuit—current could be conveniently measured in all sorts of previously-impractical or difficult cases such as low impedance transistor circuits. Current could even be measured in the absence of conventional conductors as in electrolytes or by clipping around small composition resistors. Finally, the milliammeter is virtually burn-out proof; overloads of *hundreds of amperes* do not harm it.

SEE ALSO:
"Automatic measurement of microwave frequencies," p. 5

Needless to say, the Clip-On DC Milliammeter has been a tremendously useful and popular instrument. Now, however, its information-gathering abilities have been made even broader in a new alternate version of the instrument. The new model differs from the former by the addition of a wider dc-current measuring range and by the addition of the ability to sense low-frequency ac currents in the measured circuit. For dc measurements the sensitivity of the instrument has been increased from 3 milliamperes full scale to 1 milliampere full scale. At the same time the largest current-

*Arndt Bergh, Charles O. Forge, and George S. Kan, "A Clip-On DC Milliammeter For Measuring Tube And Transistor Circuit Currents," *Hewlett-Packard Journal*, Volume 9, No. 10-11, June-July, 1958.

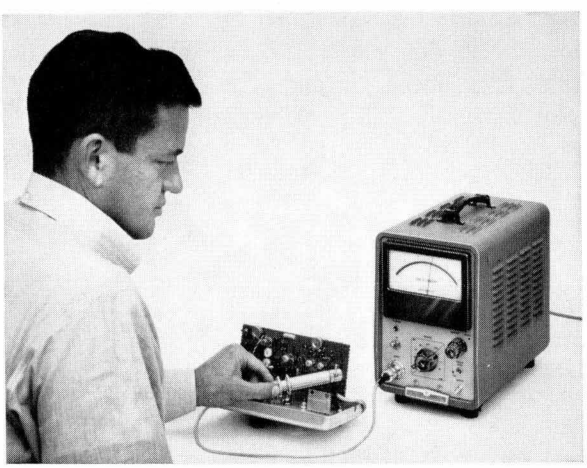


Fig. 1. *New -hp- Model 428B Clip-on DC Milliammeter measures dc currents merely by clipping probe around current conductor. Instrument also has proportional output for alternating currents up to 400 cps, permitting a-c up to several amperes to be measured readily in heretofore difficult cases.*

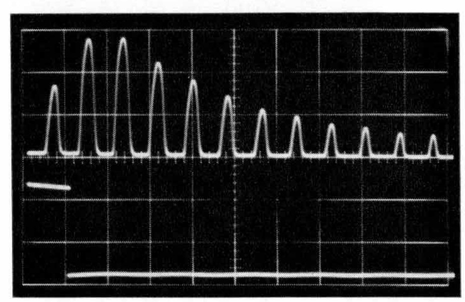


Fig. 2. *Oscillogram illustrating type of information obtainable with new Milliammeter. Shown are 120-cps current pulses in semiconductor power rectifier (upper trace) measured with Milliammeter and oscilloscope. Exponential envelope of pulses occurs because rectifier load is a dc pulse, shown by first part of lower trace.*

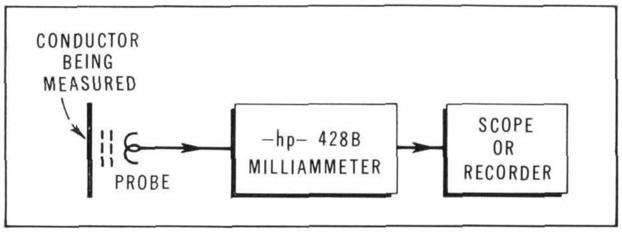


Fig. 3. *Proportional output from Model 428B Clip-On Milliammeter can be used to view and measure conductor currents from dc to 400 cps and from below 1 ma up to several amperes.*

measuring range has been increased from 1 ampere full scale to 10 amperes full scale. Hence, the usability of the instrument in measuring both low-power and high-power transistor circuits is significantly increased.

The low-frequency sensing feature in the new instrument is provided in the form of an output that has a response from dc to 400 cps. By means of this output low-frequency currents from a fraction of a milliampere to 4 amperes peak* in the measured circuit will result in a proportional voltage from the Milliammeter. This voltage is calibrated and can be applied to an oscilloscope for observation and measurement of the current under test. For obtaining such information as the peak value of the current pulses in power supply rectifiers, this output is unparalleled for convenience. A specific example of the value of the proportional output in measuring a rectifier current is shown in Fig. 2 (front page).

Since the frequency response of this output extends down to dc, it is also of value when it is desirable to observe or plot dc current phenomena. In such cases it can be used to operate an analog recorder. For dc, currents up to 10 amperes can be observed.

INSTRUMENT ARRANGEMENT

The Milliammeter consists of a small penholder style probe for clipping around the conductor and a small cabinet that contains the amplifying circuitry and indicating meter. The probe is equipped with tong-like jaws which are conveniently operated by means of flanges on the probe body (Fig. 4). Within the probe jaws are magnetic sensing elements that sample the magnetic field of the current being measured. These elements are part of a magnetic amplifier which produces an ac signal which is further amplified and, after rectification, used to operate the indicating meter. The overall circuit including the probe sensing elements is connected in a feedback loop to insure high stability. The output which is provided has a response from dc to 400 cps, although the indicating meter itself responds only to the average value of the dc current measured.

NON-LOADING MEASUREMENTS

One of the special features of the Milliammeter is that it does not load the circuit being measured. This very desirable characteristic occurs because the Milliammeter extracts no actual dc energy from the circuit, the energy needed for a measurement being supplied by the Milliammeter itself. Measurements can thus normally be made in even the lowest-impedance circuits without difficulty.

The presence of the probe introduces into the measured circuit a very slight inductance of about 0.5 microhenry and a slight shunt capacity of about 2 mmf, but these are not of consequence in most circuits. Often, too, a measurement can be made at a circuit point which is bypassed with a capacitor for minimal effect from these factors.

The probe does couple into the measured circuit a small ac voltage of up to 15 millivolts peak. The Milliammeter has been designed so that this voltage occurs at a little-used frequency, 20 kc and its harmonics, for minimum measurement inconvenience. In rare cases where this small voltage might prove undesirable, it, too, can usually be avoided by selection of the measurement point.

PROPORTIONAL OUTPUT

The proportional output feature provided on the new Milliammeter has proved very valuable and has been designed to drive high-impedance devices such as oscilloscopes and potentiometric recorders as well as low-impedance galvanometer recorders. The output jack has associated with it a screwdriver type control (Fig. 5) which has a switch position at one end of its rotation but is otherwise adjustable in the usual fashion. When the control is set to the switch position, the Milliammeter produces an output of 1 volt across high-impedance loads of several tens of kilohms and more for a full-scale reading. This output is

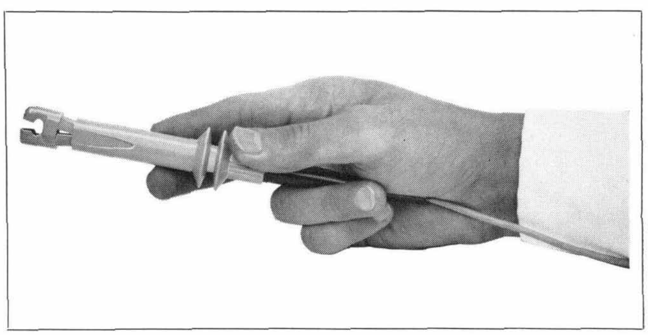


Fig. 4. *Clip-On probe operates by flanges on probe body.*

*This is the maximum rating at 120 cps. At lower frequencies the rating is as high as 10 amperes peak, while at higher frequencies it decreases from 4 amperes.

Fig. 5. *New -hp- Model 428B Clip-On Dc Milliammeter measures dc current without loading measured circuit, thus enabling dc and low-frequency ac to be measured in previously difficult cases.*

calibrated and is accurate within a few percent. It thus permits accurate recording of dc current information and also permits oscilloscopes to be used to measure low-frequency ac currents in the range from dc to 400 cps.

When the output control is switched out of its calibrated position, it adjusts the output voltage up to a maximum of about 1.5 volts so that 1 milliampere will be available to operate 1400-ohm galvanometer type recorders.

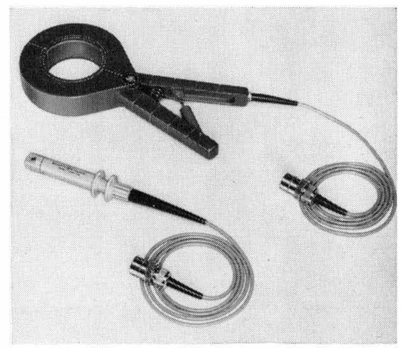
INCREASED SENSITIVITY

It is often practical to increase the effective sensitivity of the instrument by looping additional turns of the measured conductor through the aperture in the Milliammeter's probe. This technique increases the sensitivity of the measurement in direct proportion to the number of loops through the probe. The reverse-coupled voltage of 15 mv peak maximum will also increase proportionately, but this can often be minimized by measuring at a point bypassed with a capacitor. At -*hp*- the sensitivity of the instrument has been experimentally increased one thousand times to 1 microampere full scale by clipping onto a coil consisting of 1000 turns of #40 wire. The reverse-coupled noise was then held to less than 15 millivolts peak by bypassing this coil with an .027-mf capacitor.

ACCURACY

The Clip-On Milliammeter measures dc currents with a very desirable order of accuracy: $\pm 3\% \pm 0.1$ ma. Furthermore, the dc indication is virtually unaffected by the presence of ac currents. In a typical case the presence of ac in the measured circuit will usually produce no observable effect on the meter. In any case the instrument is rated such that ac with a peak value equal to the full scale value to which the Milliammeter is set will have less than $\pm 2\%$ effect on the dc reading. In general this is not a serious limitation, since in electronics work the dc current is generally larger than the peak ac. An exception to this, however, occurs when measuring rectified currents such as those illustrated in Fig. 2. Here, the peak ac is considerably larger than the average dc current so that a range should be used where the meter indication is sufficiently downscale to maintain the peak ac value within the full-scale value of the range. In case of doubt the output provided on the Milliammeter can be applied to an oscilloscope for observation of the ac waveform. The possibility of an erroneous reading will be indicated by limiting of the waveform peak.

When measuring pulse currents such as those shown in Fig. 2, the finite high frequency response (400 cps) of the instrument can diminish the apparent peak value of the pulse. The amount of this effect will vary,



LARGE-APERTURE CLIP-ON PROBE

The accompanying photograph shows a new probe which has been designed to enable the -*hp*- Clip-On Milliammeter to be used to measure dc currents in large conductors. Alongside the large probe is shown one of the regular Milliammeter probes for comparison. The large probe accommodates conductors up to $2\frac{1}{2}''$ in diameter so that measurements can be made in a variety of applications including even the corrosion-producing currents in pipes and cable sheaths.

Planned for production in the spring, the large probe will be known as the -*hp*- Model 3528A. It will be usable with both the 428A and 428B Milliammeters and is interchangeable with the existing probes. Performance specifications have not been finalized, but it is expected that range of measurement and accuracy with the large probe will approach that obtainable with the regular probe.

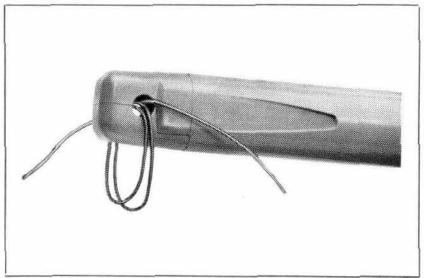


Fig. 6. *Sensitivity of measurements can be increased by looping additional turns of measured conductor through probe. See details in text.*

but in the case of 120 cps pulses the amount will typically be in the vicinity of —5% and will seldom exceed —10%.

Ac currents located within a few cycles of 20 kc and its harmonics can cause a beat in the meter reading but this has not been found to be a problem in practice because of the remote location of this frequency.

Two additional ratings apply to insure the accuracy of measurements involving ac currents in "fringe area" cases. One is that the maximum ac that the instrument will accommodate without affecting the dc reading is 4 amperes peak. The second is that the instantaneous sum of dc and ac below 5 cps in frequency should not exceed the full scale value of the range used.

The probe is well shielded and uses a balanced type of construction so that external magnetic fields seldom affect the measurements. It is good practice, however, to avoid strong magnetic fields.

GENERAL

The variety of uses to which the Clip-On Milliammeter has been and can be put is remarkable. It can be used to sum, subtract, and balance currents. It can be used to search for short—and for open—circuits. It can be used to check power supply ratings and to insure proper current drain by load circuits. As mentioned previously, it has even measured current in the absence of metallic conductors.

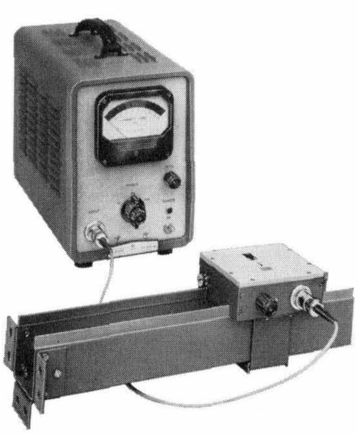
The possibility of current measurements in a number of other unusual applications has also been suggested and these are under investigation.

Because of its sheer usefulness and convenience, the Clip-On Milliammeter has won a place as one of the principal instruments in the electronics laboratory. Now, with the addition in this alternate version of the instrument of wider current capabilities and the ability to extract dc and low-frequency information from the measured current for external use, the instrument becomes even more valuable.

—Donald E. Barkley and Arndt Bergh

MAGNETIC INK TESTING

An interesting application of the Clip-On Milliammeter described in this issue has occurred in an unusual place for electronic equipment—the banking field. There, to use the new style checks which are magnetic-ink encoded for computer processing, it is necessary to quality-control the magnetic properties of the ink impression placed on the checks during printing. To do this, a modified form of the Milliammeter has come into use in check printing.



In essence, the ink tester consists of one of the Milliammeters with a special form of probe that can sample the magnetic field of the ink impression on the printed check. Included in the arrangement is a permanent magnet which is used to magnetize the imprinted ink prior to a measurement with the tester. The tester is provided with a special meter face which shows the operator whether the ink impression is within acceptable limits.

Two variations of the tester are in use. One is for sheet-fed presses and makes a test on a sheet of paper taken from the press. The second, which is the one shown in the accompanying photograph, is designed for presses that use a continuous roll of paper. In this arrangement the special probe attaches to the press where it continuously monitors a test impression printed at the paper edge.

SPECIFICATIONS
-hp-
MODEL 428B
CLIP-ON DC MILLIAMMETER

Current Range: Full scale readings from 1 ma to 10 amperes in 9 ranges. 1-3-10 sequence.

Accuracy: $\pm 3\%$ of full scale $\pm$ 0.1 ma.

Probe Inductance: Less than 0.5 μh. No noticeable loading, even up to 1 mc.

Probe Induced Voltage: Less than 15 mv peak (at 20 kc and harmonics).

Output: (a) Calibrated output: 1 volt $\pm 3\%$ across high-impedance loads or (b) Adjustable output: Adjustable up to approx. 1.5 volts maximum across loads of 1400 or more ohms.

Output Bandwidth: dc to 400 cps (min. 3 db point).

AC Rejection: AC with peak value less than full scale affects meter accuracy less than 2% at frequencies above 5 cps and different from the carrier (20 kc) and its harmonics. (On 10 ampere range, ac is limited to 4 amperes peak.) Below 5 cps total instantaneous current must not exceed full scale.

Probe Insulation: 300 volts, maximum.

Probe Tip Size: Approximately 1/2 in. by 9/32 in. Aperture diameter 3/16 in.

Power: 115 to 230 volts $\pm 10\%$, 50 to 60 cps, approximately 70 watts.

Dimensions:
Cabinet Mount: 7½ in. wide, 11½ in. high, 14¼ in. deep.
Rack Mount: 19 in. wide, 7 in. high, 13 in. deep behind panel.

Weight:
Cabinet Mount: Net 19 lbs. Shipping 24 lbs.
Rack Mount: Net 24 lbs. Shipping 35 lbs.

Price: -*hp*- Model 428B, Cabinet Mount, $550.00.
-*hp*- Model 428BR, Rack Mount, $555.00.

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

AN INSTRUMENT FOR AUTOMATICALLY MEASURING FREQUENCIES FROM 200 MC TO 12.4 GC

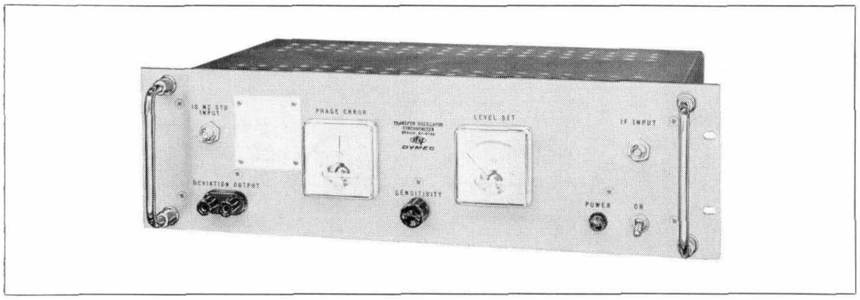


Fig. 1. *Model DY-5796 Synchronizer produced by -hp-'s Dymec division enables frequency measurements to be made automatically from 200 mc to 12.4 gc with -hp- transfer oscillator and frequency counter. Unit is particularly valuable when measured frequency is drifting or has residual f-m.*

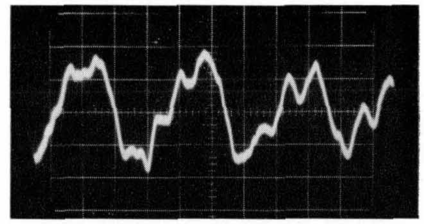


Fig. 3. *Oscillogram of residual f-m in a 10 kmc measured signal made using set-up of Fig. 2. Vertical sensitivity is 25 kc/division. Sweep time is 5 milliseconds/cm.*

In the microwave field the demands of doppler tracking, spectrum analyzing and similar work are resulting in signal sources of increased stability. Consequently, the ability to make precise frequency measurements in the microwave region has become increasingly important.

At present, measurements can be made up to 510 mc[1] with an accuracy of up to 3 parts in 10^8 using the -hp- Model 524 series Frequency Counter in conjunction with the -hp- Model 525 series Frequency Converter. Above 510 mc measurements are made using the Counter and Converter in combination with a transfer oscillator such as the -hp- Model 540A or 540B[2]. The Transfer Oscillator provides for manual zero-beating of one of its harmonics against the unknown signal to frequencies as high as 12.4 gc. Reading the Transfer Oscillator frequency on the Counter/Converter combination then yields the value of the unknown frequency with a high accuracy determined by the accuracy of zero-beating. On clean signals, accuracies of 1 part in 10^7 can be achieved. This arrangement is a convenient one and is currently in wide use. However, when the signal contains f-m or is drifting at a moderate rate, it becomes more difficult to obtain an accurate or meaningful reading.

To permit not only measuring the frequency of these difficult signals more accurately and conveniently than previously but also to permit more information to be obtained about the signal than is obtainable with the manual-visual link method, an automatic zero-beating process or equivalent effect is needed. This has now been designed in the form of a closed-loop phase control system provided by the Dymec DY-5796 Transfer Oscillator Synchronizer shown in Fig. 1. The Synchronizer connects to the Transfer Oscillator as shown in Fig. 2. In operation it controls the frequency of the Oscillator so that a harmonic thereof is phase-locked to the frequency being measured. The Oscillator frequency is then measured by the Counter/Converter in the regular way. If desired, the Counter readings can be recorded in digital and/or analog form so that a continuous record of the Oscillator frequency (and hence the drift in the initial measured signal) can be obtained, as indicated in Fig. 5.

[1] "A New Frequency Counter Plug-In Unit for Direct Frequency Measurements to 510 mc", *Hewlett-Packard Journal*, Vol. 12, No. 5, Jan., 1961.
[2] Dexter Hartke, "A Simple Precision System for Measuring CW and Pulsed Frequencies up to 12,400 mc", *Hewlett-Packard Journal*, Vol. 6, No. 12, Aug., 1955.

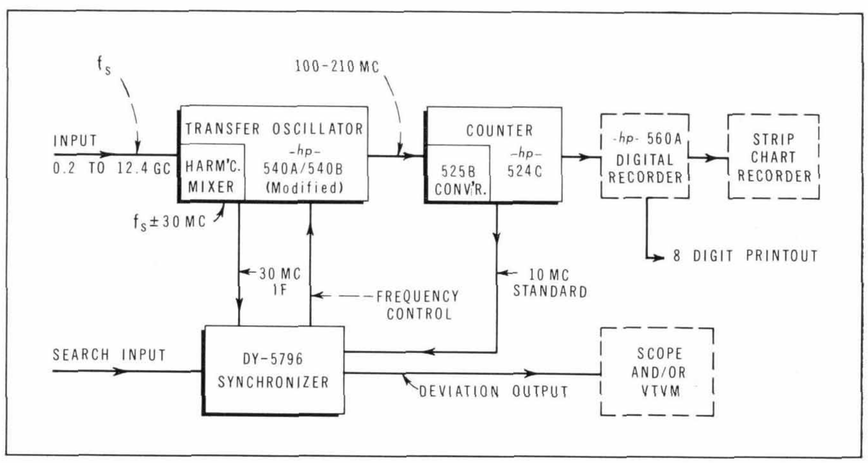


Fig. 2. *Synchronizer locks harmonic of transfer oscillator to measured signal; transfer oscillator frequency is then measured by counter in usual way. Visual records of measurement can be made as shown. Residual f-m in measured signal can be examined via output provided on Synchronizer.*

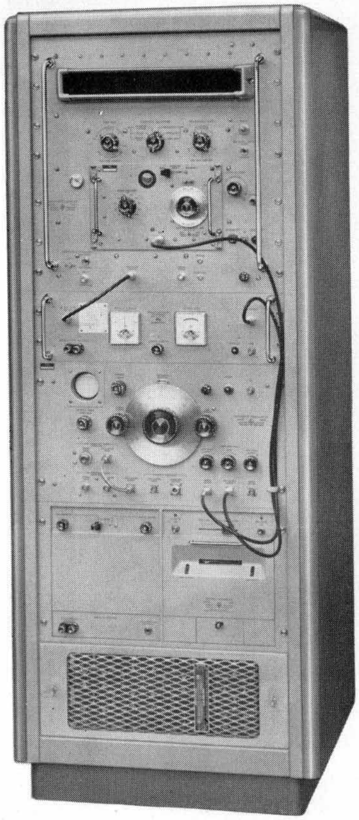


Fig. 4. *Synchronizer-transfer oscillator-counter system packaged in cabinet. System measures frequencies with accuracy of parts in 10^8. System shown is known as Dymec 5854 Frequency Measuring System.*

EXTRACTING RESIDUAL F-M

In addition to frequency and drift measurements, useful information about the f-m present on the signal can be obtained as a result of the tight lock between the signal and the Transfer Oscillator. This occurs because frequency variations are converted to voltage in the Synchronizer phase detector and applied to the Transfer Oscillator to correct its frequency. This voltage is thus a useful analog of frequency —its ac component indicates the presence of f-m on the signal. Hence, a pair of front panel terminals labeled *Deviation Output* are provided on the Synchronizer to make this voltage externally available. These terminals then enable an oscilloscope or vtvm to be connected for measuring both the amount and the components of f-m in the initial signal. A typical example of f-m information extracted by this technique is shown in Fig. 3.

SEARCH PROVISION

The Synchronizer is also arranged to that it can cause the Transfer Oscillator to search for a signal to which it is only approximately tuned or to automatically resynchronize with a signal that has been interrupted. To accomplish this, the Synchronizer is provided with a set of *Search Input* terminals on the rear panel. An external voltage such as a 60 cps signal can be applied to these terminals to cause the Transfer Oscillator to sweep. If the signal is passed, a capture is made and the Oscillator locks onto the signal. The maximum search range varies from about 25 mc at 12.4 gc to 1 mc at 500 mc.

AUTOMATIC CONTROL ARRANGEMENT

The phase locking achieved by the Synchronizer provides absolute synchronization of the external signal and Transfer Oscillator harmonic and eliminates zero-beat errors. In order to give direction sense to the system, a reference or frequency offset of 30 mc is used. No measurement error is introduced by this technique, since the offset is obtained from the time base in the Counter by tripling its 10 mc standard frequency. Offset is accounted for by adding 30 mc to the indicated transfer oscillator frequency after multiplying by the harmonic number. Overall measurement accuracy of a direct frequency measurement is that of the Counter time base[3] (typically in the order of 5 parts in 10^8).

Fig. 6 shows a more detailed block diagram of the Synchronizer and associated instruments. The signal and Transfer Oscillator frequencies are compared in a harmonic mixer (which is part of the Transfer Oscillator circuitry*) in the same manner as a manual comparison. However, the mixer output, which is at 30 mc, is fed directly to the Synchronizer instead of to the video (output) amplifier in the Transfer Oscillator.

The mixer output is amplified in the Synchronizer in a wide band (4 mc) i-f amplifier and limiter and applied to a balanced cosine phase detector. The limiter eliminates any a-m that may be present, which would otherwise contribute to unwanted f-m on the Transfer Oscillator signal. Adequacy of limiting is indicated on the front panel LEVEL SET meter, which also provides an indication of proper signal level adjustment. A broad green area on the meter scale indicates the satisfactory level. A front panel control enables the i-f gain to be adjusted to correspond with associated signal coupling equipment.

[3] LaThare N. Bodily, Leonard S. Cutler, "5×10^{-8}/Week Time Base Accuracy in the 10 mc Frequency Counter." *Hewlett-Packard Journal*, Vol. 10, No. 3-4, Nov.-Dec., 1958.

*(NOTE: The mixer can be either of the two available in the *-hp-* Model 540B Transfer Oscillator. The low frequency mixer is used from 200 mc/s to approximately 5 gc/s. The high frequency unit, a combined harmonic generator and mixer, is used from 2 gc/s to 12.4 gc/s. If the *-hp-* Model 540A is used instead of a 540B, measurements above 5 gc/s may be made using an external *-hp-* Model 934A Harmonic Mixer.)

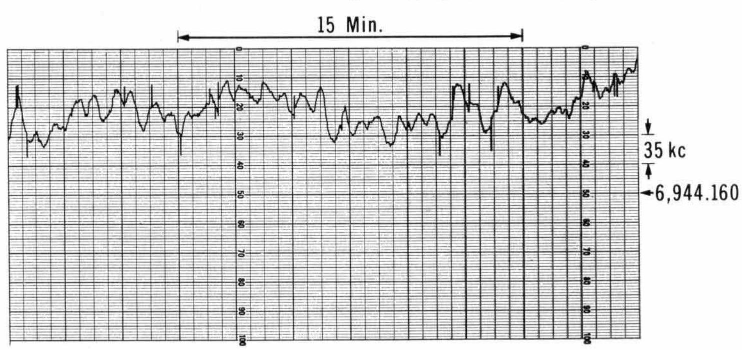


Fig. 5. *Typical curve of drift measured in 6 kmc oscillator with arrangement of Fig. 2. See also Fig. 3.*

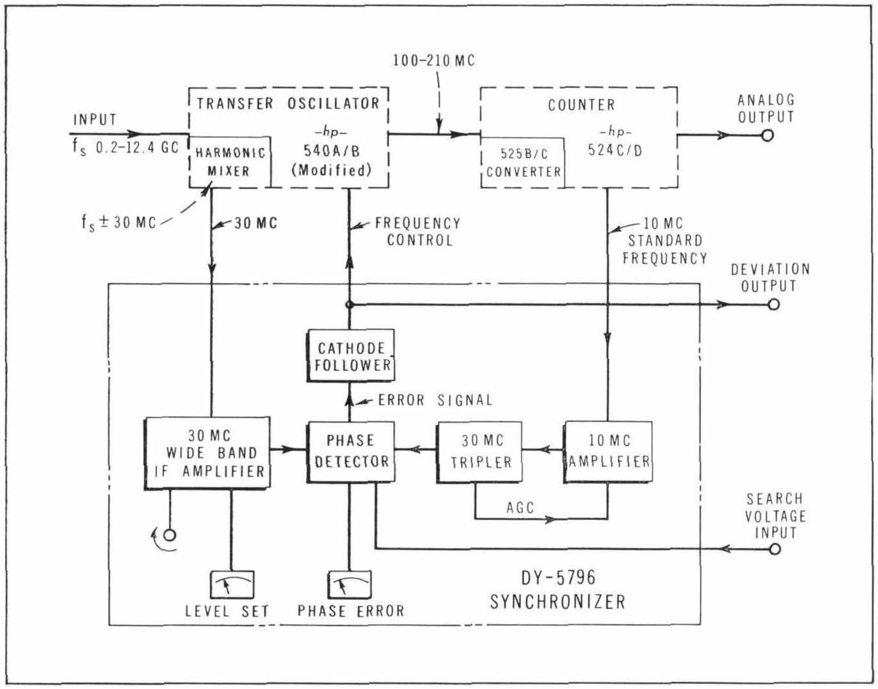


Fig. 6. *Detailed block diagram of Dymec 5796 Synchronizer.*

The 10 mc reference signal from the counter is amplified in a separate channel and tripled in frequency to generate a 30 mc signal reference. A delayed agc loop in this channel maintains a constant reference level into the phase detector. When sufficient i-f signal is also applied (as indicated by the *Level Set* meter) to produce limiter action, the detector sensitivity is constant and independent of signal and reference level variations.

Detector output is indicated on the meter and, after passing through a direct-coupled cathode follower, is available as a frequency control signal for the Transfer Oscillator. The output is a cosine function of phase difference and has a peak value of 7 volts. A dc adjustment of the cathode follower output enables setting the average output level at zero.

DETERMINING HARMONIC NUMBER

Since the transfer oscillator range is from 100 to over 200 mc, the possible number of harmonics that could be used to zero-beat with the signal frequency is at least equal to the signal frequency divided by 200 mc, e.g., at 12 gc/s there are more than 60 harmonics available. The number can be doubled because the Synchronizer can be locked with an oscillator harmonic either 30 mc above or below the signal frequency. This results in pairs of lock-in points separated by 60/N mc on the oscillator dial. *This "pairing" of lock-in points provides an easier means of determining the harmonic in use than is possible without the Synchronizer.* The operator notes the frequency reading on the counter at each of a pair of lock points, and divides their difference into 60 to obtain the harmonic number. The signal frequency is the counter reading multiplied by the harmonic number, plus or minus 30 mc/s depending on whether the upper or lower frequency is used.

TRANSFER OSCILLATOR FREQUENCY CONTROL

A minor modification to the automatic frequency control system of a standard -*hp*- 540A or 540B Transfer Oscillator provides an increased range of control for use with the DY-5796 Synchronizer. (A modification kit, available from Dymec, includes the necessary components and a new frequency dial that reflects the change in the upper frequency of the transfer oscillator from 220 mc to 210 mc.)

CAPTURE AND LOCK RANGE PARAMETERS

The ± 7 volt control voltage from the Synchronizer produces at least $\pm 0.05\%$ change at 100 mc and $\pm 0.2\%$ at 200 mc in a modified Transfer Oscillator. The reduction in control at the low frequency end is due to a swamping effect caused by the higher tuning capacity, and points out the desirability of using the highest possible dial setting to obtain the greatest control range. The control range, expressed as a percentage, also defines the signal frequency lock range; thus, $\pm 0.2\%$ at 12.4 gc corresponds to a 50 mc range. A typical curve of lock range versus dial setting is shown in Fig. 7.

Whenever feedback is employed in a control system, the effect of loop gain and bandwidth variations on stability must be considered by the designer. In this system, the loop gain is a function of the harmonic used, since the i-f frequency is obtained by comparing the signal with an oscillator harmonic. Stable control loop design requires the capture range to be less than the open-loop bandwidth of the system. However, the lock-in range f_1 can be made much greater than the open-loop bandwidth, and is expressed as follows:

$$f_1 = 2K_1 K_2 N$$

where K_1 is the detector sensitivity in volts per radian

K_2 is the oscillator control slope in mc per volt

N is the harmonic number

Typical values are

$K_1 = 7$ volts per radian

$K_2 = 0.1$ mc/s per volt (at 200 mc dial setting)

$N = 60$ (at 12.4 gc)

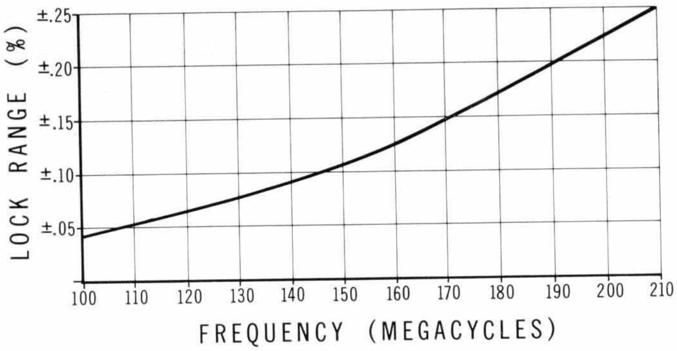


Fig. 7. *Curve of typical lock range of Dymec 5796 Synchronizer in terms of transfer oscillator frequency dial setting. At transfer oscillator harmonics lock range percentage applies to harmonic frequency.*

This results in a maximum lock-in range of about ±40 mc at 12.4 gc. Because of control slope non-linearity and conservative rating practices, a lock-in range of ±25 mc (±0.2%) is guaranteed at 12.4 gc. The capture range is limited to a value less than the system bandwidth, or typically 1 mc.

To capture a signal and obtain synchronization, the Transfer Oscillator must be tuned so that the difference frequency is very close to 30 mc. Normally, it is tuned through the proper point in order to capture the signal and then settled back into the wide lock-in range. The lock-in range is centered by tuning the Transfer Oscillator to indicate center on the Phase Error meter. As the signal drifts, the phase error increases until the edge of the lock-in range is reached — the *Phase Error* meter needle enters the end areas of the scale. Synchronization on a drifting signal can be maintained without measurement interruption by retuning the oscillator to re-center or reverse the *Phase Error* meter indication whenever it nears the edge. Since phase lock is held during these adjustments, no frequency error occurs, and the counter reading is not disturbed.

An interesting example of how a drifting signal can be recorded with a Synchronizer system is the klystron oscillator drift record shown in Fig. 5.

F-M MEASUREMENTS

The amount and nature of incidental f-m in the measured frequency can be obtained from the oscillator control voltage made available at the *Deviation Output* terminals on the front panel. The sensitivity of this measurement is directly related to the slope of the oscillator frequency control circuit. At a dial setting of 200 mc, the slope is about 100 kc per volt. The signal deviation is determined by multiplying the oscillator deviation by the harmonic number. The oscillator control slope can easily be measured by using a variable voltage source and the -hp- 524/525 Counter/Converter at various dial settings.

One error source should be considered in applying this technique. The measured f-m is slightly less than the signal f-m, because the control loop gain is finite and a function of oscillator and modulating frequencies as well as harmonic number. The f-m, measured at dial settings around 200 mc, will be within 5% of the signal f-m for modulating frequencies below 7 kc and harmonics above the first. The 5% error limit increases to 50 kc as the harmonic number reaches 60. (This is approximately proportional to the root of the harmonic number.)

The maximum f-m deviation that can be handled without loss of synchronization is obtained when the oscillator is tuned for zero phase error indication, thus centering the f-m in the lock range. In this condition, f-m at rates up to 1000 cps can be measured to the full limits of the lock-in range of ±0.2%. Above 1000 cps, the maximum permissible deviation is reduced by 20 db per decade.

The minimum measurable f-m is limited by the residual f-m of the Transfer Oscillator itself. This is typically 150 cps peak deviation at dial settings around 200 mc, or less than ±.0001%. This occurs principally at a 60 cps rate.

ACKNOWLEDGMENT

The design of the Synchronizer was based on a technique developed by Duane Marshall in the -hp- Frequency and Time Engineering Department. The design group at Dymec included John Hasen, who performed the circuit development, and Kenneth G. Wright, who performed the mechanical design.

—Albert Benjaminson

OVERALL SPECIFICATIONS
(Transfer Oscillator plus Counter plus Synchronizer)

Frequency Range: 0.2 to 12.4 gc.
Sensitivity: —10 dbm minimum signal input at 12.4 gc, decreasing to —40 dbm at 200 mc.
Lock-On Range: ±0.2% of signal frequency maximum. (Depends on Transfer Oscillator setting, see Fig. 7 in text.)
Accuracy: ± Stability ± resolution; see following entries.
Stability: 3/10⁸ short term, 5/10⁸ per week. May be used with external frequency standard, e.g. -hp- 103AR for 5/10¹⁰ per day.
Resolution: ±1 count at transfer oscillator frequency, equivalent to 5/10⁹ with 1-second counter gate, or 5/10¹⁰ with 10-second gate (at 200 mc oscillator setting).
F-M Measurement: Deviations up to lock-on range at rates to 1 kc. Above 1 kc deviation limit reduced at 20 db/decade to maximum of 0.001% of 200 kc.

SPECIFICATIONS
DYMEC MODEL 5796 SYNCHRONIZER

Input Requirements:
30 mc Input: 150 μv rms minimum (front panel BNC).
10 mc Input: O.8v rms minimum (front panel BNC).
Error Signal Output: ±7v maximum for full lock-on range (rear panel BNC).
Deviation Output: 14v peak-to-peak at modulation rates up to 1 kc. Decreases at 20 db/decade at rates to 200 kc. (Available at front panel binding posts).
Search Voltage Input: Capture point may be varied over desired part of lock range by application of dc to 60 cps signal, ±7v peak maximum. (Rear panel binding posts.)
Power Required: 115/230v ±10%, 50-1000 cps, 35 watts.
Dimensions: 19″ wide, 5½″ high, 9½″ deep.
Weight: 14 lbs. net, 22 lbs. shipping.
Price: DY-5796 Transfer Oscillator Synchronizer (rack mount) $685.00.

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

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