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A New Frequency Counter Plug-In Unit for Direct Frequency Measurements to 510 MC

ONE of the significant steps in extending the usefulness of the high-speed frequency counter was the development of the plug-in frequency converter.* This converter enabled the accuracy, speed, and convenience of the basic 10-

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New microwave
frequency doublers, p. 3

megacycle counter to be extended by several decades. Now, an additional converter has been developed that enables frequency measurements to be made from 100 megacycles to above 500 megacycles. Like the other converters, the new unit enables these measurements to be made with the full accuracy of the basic counter. This is achieved

because the action of the converter is to subtract a selected, known harmonic of the counter's precision time base frequency from the frequency being measured, leaving a difference frequency in the range from 0 to 10 megacycles to be measured by the counter itself.

Despite the increase in the operating frequency range, the new converter's operation is even simpler than previous converters. To measure a frequency with the new unit, it is only necessary to tune one control until a reading is obtained on the panel meter.

*Dexter Hartke, "Measurements to 100 Megacycles with the -hp- Frequency Counter," Hewlett-Packard Journal, Vol. 4, No. 11-12, July-Aug., 1953.

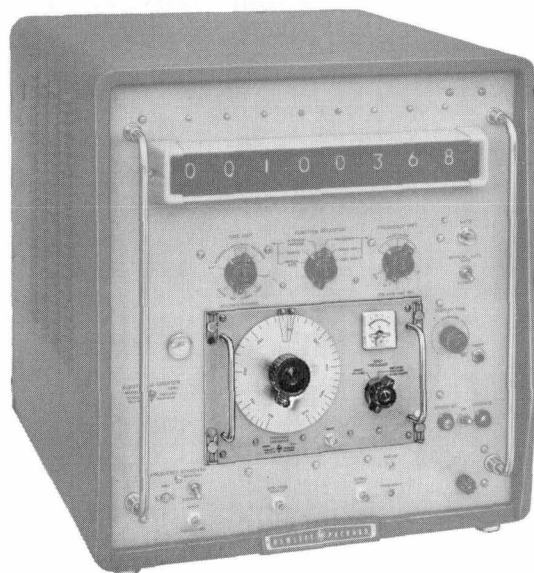


Fig. 1 (at left). New -hp- Model 525C Frequency Converter panel plug-in unit operates with -hp- 524B/C/D counter to measure frequencies from 100 to 510 megacycles with accuracy of counter itself. Converter unit is fully transistorized.

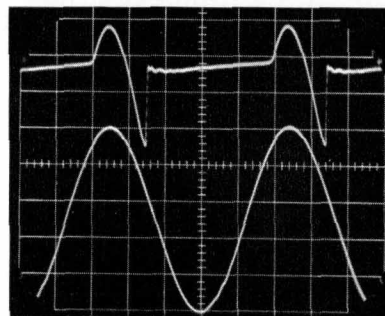


Fig. 2 (above). Oscillogram showing mechanism used to achieve high conversion efficiency in semiconductor diode used as harmonic generator. Lower trace is 10-megacycle driving voltage; upper trace shows abrupt turn-off of diode reverse current that generates high order of harmonics. Time scale is 20 millimicroseconds/cm.

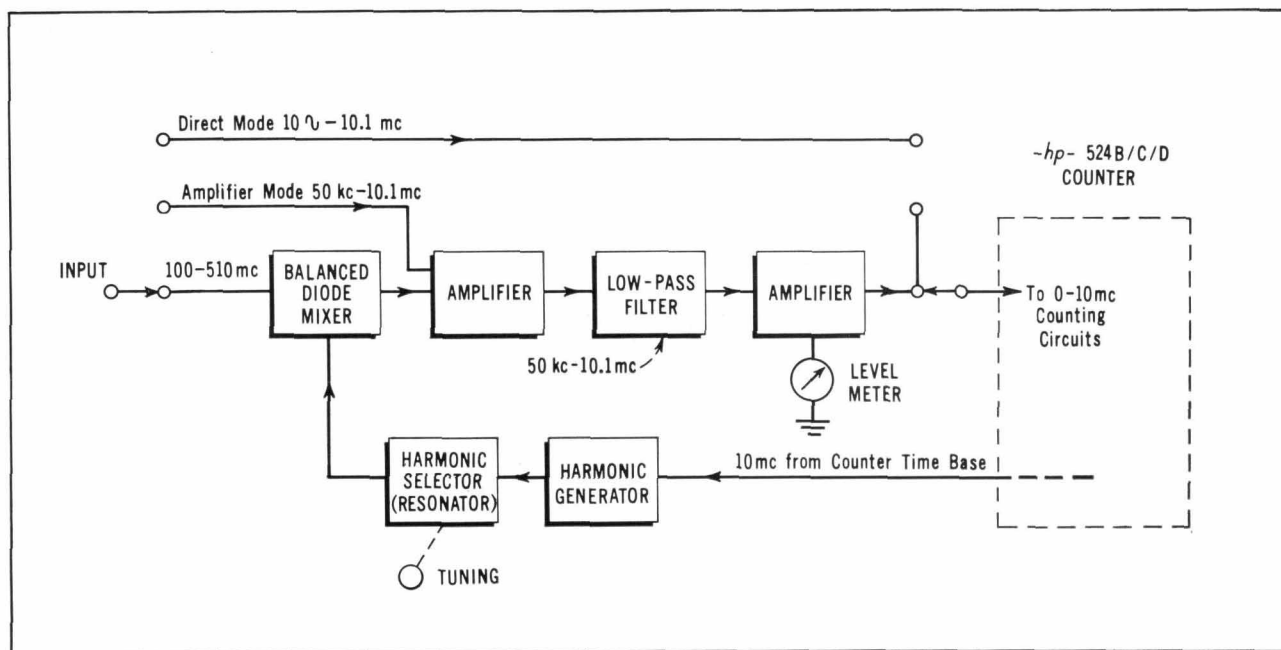


Fig. 3. Circuit arrangement of new converter unit. Besides operating as frequency converter, unit can be used as amplifier for measurements from 50 kc to 10.1 megacycles.

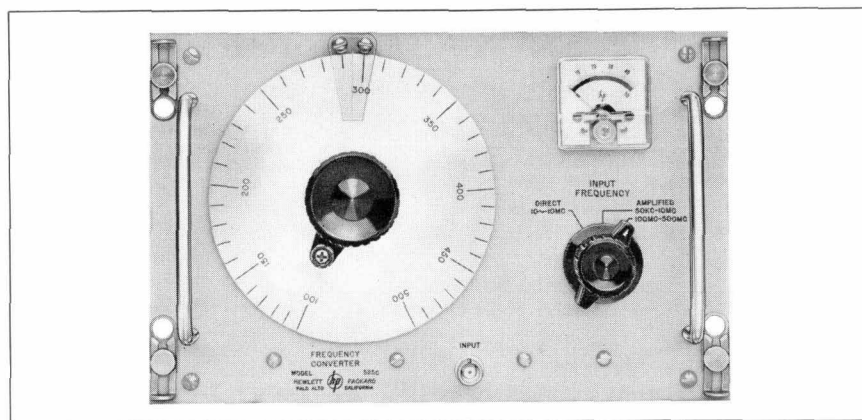


Fig. 4. Panel view of -hp- Model 525C Frequency Converter Unit. Panel control tunes internal resonator to integral multiple of 10-megacycle precision frequency from counter time base.

The frequency being measured is then merely the sum of the reading of the tuning control (which is always a simple multiple of 10 megacycles) added to the reading of the counter itself.

In addition to acting as a converter, the new plug-in also operates as an amplifier for measurements in the 50 kc–10.1 megacycle range, increasing the sensitivity of the counter to 20 millivolts for these frequencies. As a further convenience, the

plug-in will act as a direct feed-through unit so that all basic counter measurements in the 0–10 megacycle range can be made with the unit in place.

CIRCUIT APPROACH

Circuitwise, the new converter has the form indicated in Fig. 3. While the circuit approach is substantially that of the previous converters, the development of this unit was made possible by the discovery of a new mechanism for obtaining higher

conversion efficiency in semiconductor diodes used as harmonic generators.*

In the new converter a 10-megacycle precision frequency from the counter's time base is applied to a harmonic generator in the form of a semiconductor diode. This diode is specially designed to have a fast rise time in its reverse current turn-off, thereby providing a mechanism for increased efficiency of harmonic generation. In operation the diode is biased so that forward current will flow for somewhat less than half of a cycle of the applied 10-megacycle voltage. This forward current builds

*A. F. Boff, J. Moll, and R. Shen, "A New High-Speed Effect in Solid-State Diodes," 1960 International Solid-State Circuits Conference."

(concluded on p. 6)

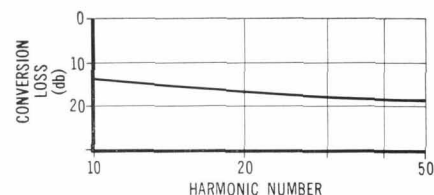


Fig. 5. Typical conversion efficiency of harmonic generator used in new converter unit.

TWO NEW MICROWAVE FREQUENCY DOUBLERS FOR EXTENDING SIGNAL SOURCES TO THE 18-40 KMC RANGE



Fig. 1. New Microwave Frequency Doubler enables existing lower-frequency signal sources to provide signals in the 18-26.5 kmc or 26.5-40 kmc ranges.

IN the range above about 20 kilomegacycles there has been a lack of convenient and economical signal sources, especially for broadband work. To meet this situation, two new frequency doubler sets have been developed. These sets double the output frequency of existing lower-frequency signal sources and thus make them usable for higher frequency work. The two doubler sets jointly extend the frequency of generators in the 9 to 20 kmc range to frequencies of 18 to 40 kmc. In this range they will produce a maximum of about 2 milliwatts.

Since the new sets double the output frequency of existing sources, they can be used with several *hp*-signal generators (Table I) to obtain an 18-40 kmc signal that has all the flexibility of the basic generator. If the basic generator is a swept oscillator, such as the *hp*- 686A or 687A, then a swept signal will be produced at the doubled frequency. Similarly, pulsed, f-m or c-w sources can be used just as readily. Measurements at the higher frequency are thus often considerably simplified. When used with either the *hp*- 686A or 687A swept oscillators, the doublers

will typically provide one-half to one milliwatt, which will meet most applications.

Each doubler is further provided with its own metering circuit and attenuator so that the output level at the doubled frequency can be measured and adjusted. The output attenuator is calibrated and has a range from 0 to 100 db so that, with the *hp*- 686A or 687A sweep oscillators, the sets will typically produce an output from about 0 to -100 dbm. Aside from the output attenuator control, there are no tuning controls or adjustments and the sets are wholly passive in character.

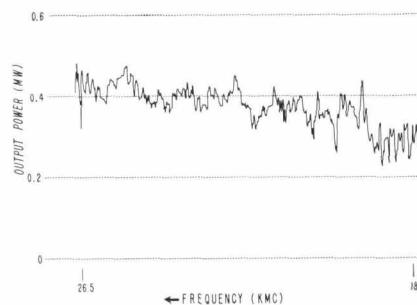


Fig. 2. Typical power output characteristic of new *hp*- Model 938A Frequency Doubler when driven with 10 milliwatts from *hp*- Model 686A voltage-tuned sweep oscillator.

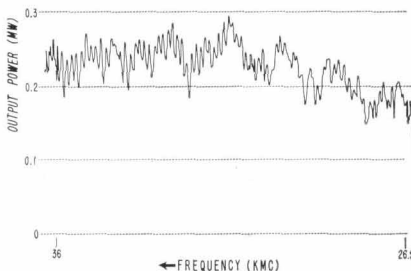


Fig. 3. Typical power output characteristic of new *hp*- Model 940A Frequency Doubler when driven with 10 milliwatts from *hp*- Model 687A voltage-tuned sweep oscillator.

HARMONIC GENERATOR

The heart of the new doubler sets is a crystal diode harmonic generator (Fig. 4). Broadband performance for this generator has been achieved

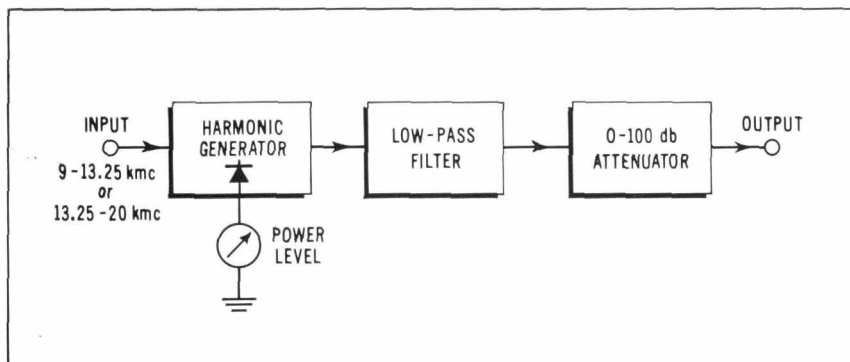


Fig. 4. Circuit arrangement of Models 938A and 940A Frequency Doublers.



Fig. 5. New Frequency Doubler can be used with several -hp- signal sources, is shown with -hp- Model 626A 10 - 15.5 kmc signal generator.

by locating the diode directly in the waveguide in a special wafer and by matching impedances through the use of ridged guide. A lead is brought from one terminal of the crystal through the guide to a dc meter on the panel of the set. The meter reading that occurs is a valid indication of the second harmonic power being generated, since the same non-linearities that produce a second harmonic also produce the dc component.

Since the harmonic generator produces higher harmonics in addition to the second, a suitable low-pass filter has been incorporated. The filter keeps higher harmonics generally about 40 db below the main output, except for the case of the third harmonic of the lowest input frequency. These harmonics lie quite close to the top of the main output range, i.e., to the top of the filter pass band. This factor reduces the degree of suppression of third

harmonics in this narrow area, but they are still at least 8 db below the main output. This amount of suppression in combination with the wide frequency separation is adequate for most situations.

The low-pass filter is then followed by the precision 0-100 db rotary attenuator. This unit is di-

rect-reading, being calibrated over the full 100 db range.

SWEPT REFLECTOMETER

The new Frequency Doublers can be used with the -hp- Models K422A and R422A Broadband Crystal Detectors (see inset) to form a practical swept reflectometer set-up, as shown in Fig. 6. A typical measurement made with this set-up on a broadband device is shown in Fig. 7.

A reflectometer using this new equipment will differ slightly from a set-up at lower frequencies because of the smaller power available. The main difference is that a 10-db rather than a 20 db directional coupler must usually be used to sample the incident power. In addition, the "Excess Coupler Loss" switch associated with the incident channel on the -hp- Model 416A Ratio Meter should be set as if a 20 db coupler were being used (i.e., set the switch to "10 db" excess loss). This procedure is necessary to provide enough signal amplitude in the incident channel to operate the internal circuitry of the Ratio Meter. The Ratio Meter can then be used normally if the range switch is treated as if the 30% range were 100%, the 10% range 30%, etc. It can be seen that these procedures provide more gain in both the incident and reflected channels than is achieved by

TABLE I

| -hp-SOURCE | BASIC FREQUENCY RANGE | FREQ. RANGE WITH 938A/940A DOUBLER |
|----------------------------------------|-----------------------|------------------------------------|
| 686A Voltage-tuned Sweep Oscillator | 8.2 — 12.4 KMC | 18 — 24.8 KMC |
| 687A Voltage-tuned Sweep Oscillator | 12.4 — 18 KMC | 26.5 — 36 KMC |
| 626A Signal Generator | 10 — 15.5 KMC | 20 — 26.5 KMC 26.5 — 31 KMC |
| 628A Signal Generator | 15 — 21 KMC | 30 — 40 KMC |

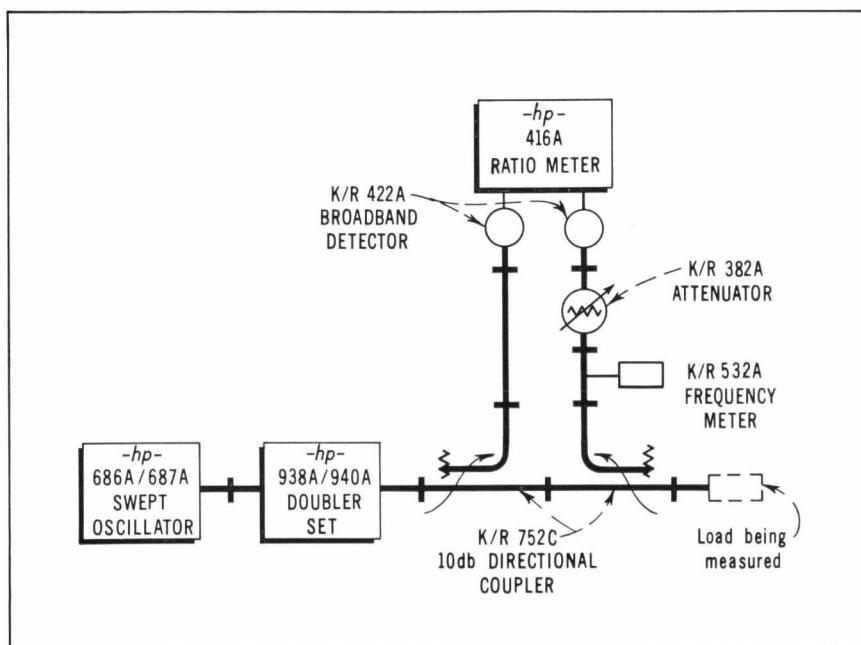


Fig. 6. Set-up for forming swept reflectometer using new frequency doublers.

the normal procedures used at lower frequencies. Using this procedure, reflection coefficients down to 3%

have been measured in the 26.5-40 kmc range on a swept basis at -hp-.
—Russell B. Riley

SPECIFICATIONS

-hp- MODEL 938A FREQUENCY DOUBLER SET

Frequency Range: 18-26.5 kmc.
Conversion Efficiency: Approximately 18 db at 10 mw input.
Output Power: Depends on input power supplied. Approximately .5 to 1.0 mw when used with typical -hp- Model 626 Signal Generator.
Input Power Required: 10 mw design center.
Maximum Input Power: 100 mw.
Output Monitor Accuracy: ± 2 db.
Output Attenuator Accuracy: $\pm 2\%$ of reading or $\pm .2$ db whichever is greater.
Attenuator Range: 100 db.
Output VSWR: Approximately 2 at full output. Less than 1.5 with attenuator set to 10 db or more attenuation.
Input Flange: M-Band flat cover flange for WR-75 waveguide.
Output Flange: UG-595/U flat cover flange for WR-42 waveguide.
Dimensions: 5 in. high, 19 in. wide, 18 in. deep.
Weight: 20 lbs.
Accessories Available: Waveguide Adaptors MP292A, MX292A.
Price: \$1500.00.

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

-hp- MODEL 940A FREQUENCY DOUBLER SET

Frequency Range: 26.5 - 40 kmc.
Conversion Efficiency: Approximately 18 db at 10 mw input.
Output Power: Depends on input power supplied. Approximately .5 mw when used with typical -hp- Model 626A and 628A Signal Generators.
Input Power Required: 10 mw design center.
Maximum Input Power: 100 mw.
Output Monitor Accuracy: ± 1.5 db.
Output Attenuator Accuracy: $\pm 2\%$ of reading or ± 0.2 db whichever is greater.
Attenuator Range: 100 db.
Output VSWR: Approximately 2 at full output. Less than 1.5 with attenuator set to 10 db or more attenuation.
Input Flange: N-Band flat cover flange for WR-51 waveguide.
Output Flange: UG-599/U flat cover flange for WR-28 waveguide.
Dimensions: 5 in. high, 19 in. wide, 18 in. deep.
Weight: 20 lbs.
Accessories Available: Waveguide Adaptor NP292A, MP292A, NK292A.
Price: \$1500.00.

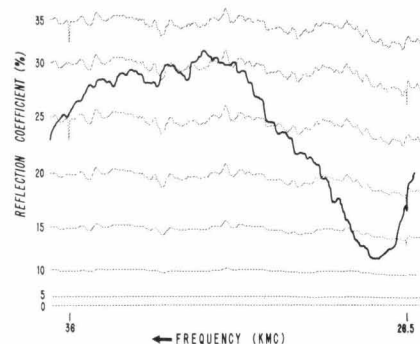


Fig. 7. Typical swept measurement made using reflectometer set-up shown in Fig. 6.

BROADBAND CRYSTAL DETECTORS FOR THE 18 - 40 KMC RANGE

The Models K422A and R422A Detector Mounts specified in the reflectometer set-up (Fig. 6) of the accompanying article are newly-developed crystal mounts which can be used for swept-frequency reflectometer measurements or for other applications where broadband detectors are useful. In these detectors sensitivity is a remarkably smooth function of frequency, the maximum deviation over their 1.5:1 bands being ± 2 db. This constant sensitivity is attained by integrally locating the crystal in a short section of waveguide. The optimum load resistance for best square-law response is determined during manufacture, and the detector can be used with this load resistance as a square-law detector or without it for maximum sensitivity.

The K422A Mount operates from 18 to 26.5 kmc, and the R422A Mount from 26.5 to 40 kmc. Specifications are given in the table below.

SPECIFICATIONS

-hp- MODELS K/R422A WAVEGUIDE CRYSTAL DETECTORS

Frequency Range:
Model K422A: 18 to 26.5 kmc.
Model R422A: 26.5 to 40 kmc.
VSWR: 2.5:1.
Sensitivity: Better than 0.05 volt per milliwatt.
Frequency Response: ± 2 db.
Square Law Response: ± 1 db (-3 to -40 dbm).
Matched Pair: ± 2 db. Includes frequency response and square law characteristics combined but excludes basic crystal sensitivity.
Price: \$200 each. Matched pair \$420.
Price f.o.b. factory
Data subject to change without notice

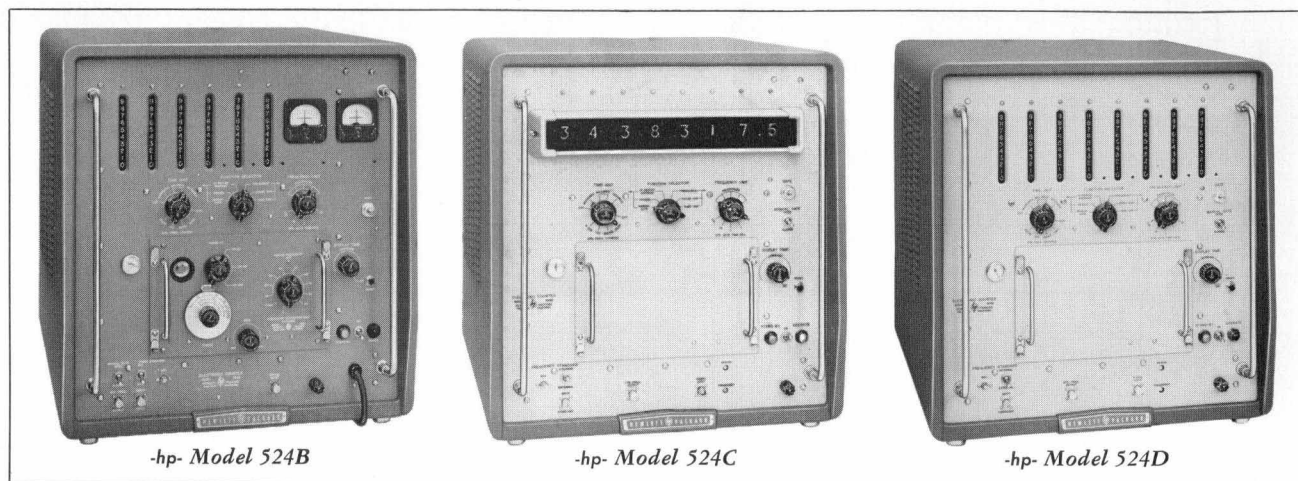


Fig. 6. New Converter can be used with above -hp- 10-megacycle frequency counters.

(Continued from p. 2)

up stored minority carriers at the diode junction. When the diode then becomes reverse-biased during the later part of the cycle, these carriers provide a reverse current for a time. When the stored carriers are depleted, however, the current falls rapidly to zero with a rise time that is typically less than a millimicrosecond. This abrupt change in the reverse current is responsible for the high order of harmonic generation that occurs.

Since the harmonics generated by the diode occur only at discrete 10-megacycle intervals, a desired individual harmonic can be selected by a suitable tuned circuit. Such a circuit is provided in the form of a high-Q coaxial cavity resonator which is tuned by the calibrated dial at the converter panel. The cavity drive system consists of a spring-loaded lead-screw and gear-reduction drive that provide a high order of tuning precision and stability. Resonator dimensions are minimized by capacitively-loading an otherwise higher-frequency resonator to bring its frequency to the desired 100-500 mc range. The resonator drive system is also arranged to provide a linear tuning calibration.

The output of the resonator is mixed with the frequency to be measured (100-510 mc) in a balanced

mixer and the resulting 0-10 mc difference frequency is amplified and applied to the counter proper. A meter in the difference-frequency amplifier indicates to the operator when the resonator is tuned to provide a difference frequency in the 0-10 mc range of the amplifier.

In the other positions of the input selector switch, the difference-frequency amplifier can be used to increase the sensitivity of the counter in the 50 kc-10.1 mc range from 1 volt to 20 millivolts. The switching arrangement also enables external signals to be applied directly to the counter.

SENSITIVITY

From a usage point of view the new converter has the desirable characteristic that its sensitivity is essentially constant over the full 100-500 mc range. Besides being constant, the sensitivity is high enough (100 millivolts) to meet most laboratory and production frequency-measuring situations.

The constant sensitivity characteristic is achieved by tailoring the tuning mechanism so that the orientation of the resonator input and output loops is changed as the resonator tuning is changed. This compensates for the variation in resonant harmonic amplitude which occurs in a predictable manner over the resonator tuning range. Because

of the constant sensitivity thus achieved, the need for controls other than the resonator tuning control is eliminated.

COMPATABILITY

The new converter can be used directly with any of the following models of 10-megacycle counters manufactured by -hp-: 524B, 524C, 524D or FR-38/USM-26.

ACKNOWLEDGMENT

The development and electrical design of the new converter were carried out by A. Frank Boff, while the mechanical design is due to Frank Berry.

SPECIFICATIONS

-hp- MODEL 525C

FREQUENCY CONVERTER UNIT

Range: As converter for counter, 100 MC to 510 MC. As amplifier for counter, 50 KC to 10.1 MC. Direct connection for 0 to 10.1 MC.

Accuracy: Retains accuracy of 524 Counter.
Registration: 9 places; first two places indicated on converter dial, next 7 displayed by counter.

Input Voltage: 20 mv rms minimum, 50 KC to 10.1 MC; 100 mv rms minimum, 100 MC to 510 MC.

Input Impedance: Approximately 700 ohms, 50 KC to 10.1 MC; Approximately 50 ohms, 100 MC to 510 MC.

Level Indicator: Meter aids frequency selection; indicates usable voltage level.

Weight: Net 6½ lbs. Shipping 11 lbs.

Price: \$425.00.

Price f.o.b. factory

Data subject to change without notice