HEWLETT hp PACKARD

APPLICATION NOTE 190

40 GHz FREQUENCY MEASUREMENT WITH STANDARD HP INSTRUMENTS

Continuous coverage to 40 GHz • Wide phase-lock range tolerates 0.1% FM, facilitates tuning • Calibrated local oscillator for faster set-up • High L.O. frequency avoids crowded lock points • Typical sensitivity -30 dBm • Uses standard HP instruments—each useful in many other applications.

CHOICE OF COUNTERS

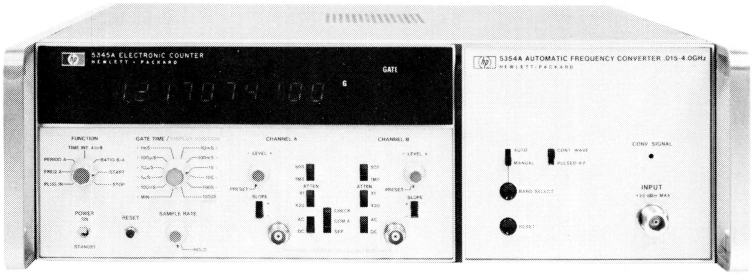
5340A

- **FULL COVERAGE, 10 Hz TO 40 GHz**

5341A

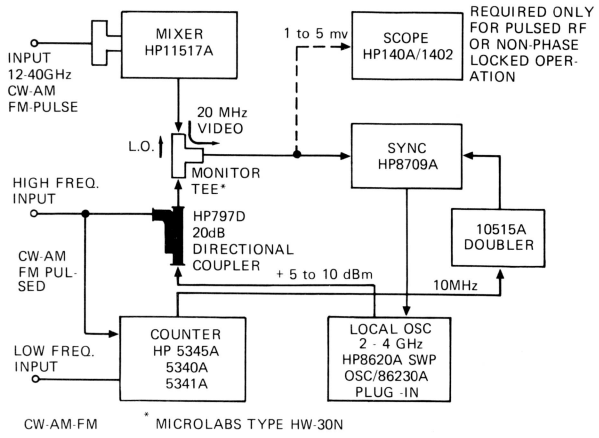
- **PERFORMANCE**
- **ECONOMY**

5345A/5354A



- **GENERAL PURPOSE**
- **HIGH PERFORMANCE**

This versatile 40 GHz instrument grouping, which consists of standard HP instruments and a commercially available monitor tee, gives superior performance and easier operation than previously available special-purpose microwave frequency measuring instruments. The standard HP instruments built into the system are fully usable as the general-purpose instruments they were originally designed to be, giving the instrument grouping additional versatility. Owners of some or all of these standard instruments can build up the grouping as shown in Figure 1.



Measurements are made as follows: Low frequency measurements and microwave measurements made with proper input on selected counter. From 12 to 40 GHz a "transfer oscillator" technique is used to read the frequency of the HP 8620A Sweep Oscillator with 86230A Plug-in which is used as a 2 to 4 GHz local oscillator. Also used is an 8709A Synchronizer for phase-locking to CW signals, HP 11517A Mixer and a Microlab Type HW-30N Monitor Tee. For pulsed RF input signals the 8709A is not required, but an external oscilloscope is required to display the zero beat pattern.

HIGH LOCAL OSCILLATOR FREQUENCY

The high local oscillator frequency used in the system, 2 to 4 GHz, permits making all measurements from 20 to 40 GHz using a harmonic number of 10, a number that facilitates mathematical manipulation. For equipment set-up and other purposes, CW signals can also be rapidly read to 1% accuracy direct from the 8620A Sweep Oscillator dial by tuning it for phase-lock, then mentally shifting the decimal point one place to the right, without using the counter to measure the 8620A Sweep Oscillator output.

The high local oscillator frequency also facilitates tuning by keeping the system phase-lock points well spread out instead of crowded together.

SENSITIVITY

The local oscillator power level influences, to a large extent, the magnitude of the mixer output and therefore the system sensitivity. In obtaining the sensitivity curves of Figure 2, an optimum power level on a broad band basis was used. For very weak input signals, however, adjusting the local oscillator power level while tuning for phase-lock, will increase system sensitivity even further.

The minimum input curve of Figure 2 was established on the basis of at least 3 consecutive lock points being available across the entire local oscillator band. Two of these lock frequencies find N, the subharmonic of the unknown input signal, and the third checks the spacing between these two. When the input frequency is approximately known, only one lock point is required; then, a more practical sensitivity would be the absolute minimum curve, where at least one lock point exists. Again, it should be noted that the curves were established on a broad band basis, and significant improvement in sensitivity can be expected if the local oscillator power level is adjusted while tuning for phase-lock.

To avoid mixer damage, keep the input signal below 1 mW. To avoid phase-lock on spurious signals, keep input power below the maximum input curve of Figure 2. Excessive input power can also bias the mixer out of its operating range.

PHASE-LOCK

The system phase-locks to CW or FM inputs, resulting in greater accuracy and easier tuning than in systems having automatic frequency control. Since the system only locks to the input frequency minus the 20 MHz IF frequency, there's no ambiguity—one always adds 20 MHz to the answer. A lamp on the 8709A Synchronizer indicates phase-lock and a meter indicates phase error, if any.

Lock range is independent of the input frequency and varies linearly from approximately 100 MHz at the low end of the local oscillator range to 40 MHz at the high end. Capture range is approximately 20% of the lock range. Set the 8709A MOD SENS switch to 6 MHz/volt and use HELIX OUTPUT for the 8620A plug-in phase lock input.

Since the local oscillator (sweeper) is phase locked to the counter with the 8709A synchronizer, the system accuracy is determined by the time base stability of the counter being used.

PULSED RF MEASUREMENTS

Pulsed RF measurements can also be made. Common to all other transfer oscillator techniques, the phase-locked mode cannot be used for pulsed inputs. The system arrangement is identical to that shown in Figure 1, except that the 8709A is not required, and should be disconnected. The input to the synchronizer

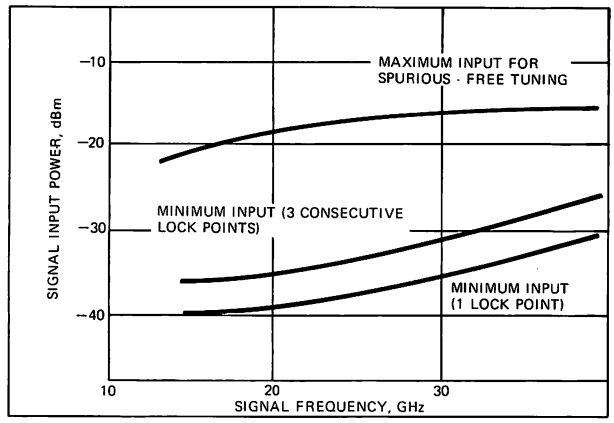


Figure 2. Typical Sensitivity Using Constant Local Oscillator Power (Between +5 and +10 dBm)

is instead applied to an oscilloscope with at least 5 mV sensitivity. The local oscillator is tuned for a zero beat pattern on the oscilloscope in the same fashion as with any transfer oscillator. There is no 20 MHz IF frequency ("offset") to add to the answer.

Using a signal generator such as the HP 8616A (in place of the sweeper) can increase pulsed RF measurement accuracy by at least one order of magnitude, due to the 8616A's low residual FM. The 8616A is not desirable for accurate, convenient CW measurement because it cannot be phase-locked, while the 8620A can. System sensitivity is identical for both pulsed RF and CW signals.

CHOICE OF COUNTERS

Any of three microwave counters manufactured by HP can be used for 40 GHz measurements:

The 5340A Frequency Counter (pictured on front page) performs CW measurements to 18 GHz. Using this counter, the instrument grouping has a continuous CW measurement capability from 10 Hz to 40 GHz. The H10-5340A (frequency range extended to 23 GHz) allows the convenience of always operating the instrument grouping at a harmonic number of 10, since the basic counter can measure over 20 GHz.

The 5341A Frequency Counter is a 4.5 GHz CW counter. Using this counter significantly reduces the price of the instrument grouping, but frequency measurements from 4.5 GHz to 12.4 GHz are not possible.

The 5345A Electronic Counter with 5354A Frequency Converter is an exceptionally high performance instrument for frequency measurements to 4 GHz. The 5345A mainframe is a universal counter which fulfills many applications in the R&D laboratory. The 5345A/5354A combination is also capable of automatic frequency measurement within RF pulses up to 4 GHz. As with the 5341A above, using this counter in a 40 GHz instrument grouping does not allow frequency measurements from 4 GHz to 12.4 GHz.

TYPICAL SPECIFICATIONS 12.4 to 40 GHz

INPUT SIGNAL CAPABILITY: CW signals. Signals with high FM content. Pulsed RF signals (using external oscilloscope).
CW MEASUREMENT ACCURACY: "Refer to counter timebase"
INPUT SENSITIVITY: Better than -30 dBm at 12 GHz, -20 dBm at 40 GHz (see Figure 2 for typical sensitivity).
INPUT IMPEDANCE: 50 ohms nominal
MAXIMUM INPUT: 1 mW
AUTO PHASE-CONTROL LOCK RANGE: Better than 0.1% of input signal frequency
CAPTURE RANGE: Approximately 20% of Lock Range
LOCK INDICATION: Lamp turns off when system phase-locks to CW or FM signals; meter indicates phase error
VFO FREQUENCY RANGE: 2 GHz to 4 GHz
INPUT CONNECTOR: Input is to HP 11517A Mixer. The waveguide adapter required is governed by the user's waveguide system.

ORDERING INFORMATION

COUNTER

5340A Frequency Counter (18 GHz)

or

H10-5340A Frequency Counter (23 GHz)

or

5341A Frequency Counter (4.5 GHz)

or

5345A Electronic Counter, with 5354A Automatic Frequency Converter (4 GHz)

SWEEPER

8620A Sweeper Mainframe
86230A 1.8 to 4.2 GHz Plug-in

SYNCHRONIZER

8709A Phase Lock Synchronizer

HARDWARE

10515A Frequency Doubler
11517A 40 GHz Harmonic Mixer
11518A W/G Adapter 12.4—18 GHz
11519A W/G Adapter 18—26.5 GHz
11520A W/G Adapter 26.5—40 GHz
797D Directional Coupler
HW-30N Monitor Tee*

*Available from Microlab/Fxr. Inc. 10G Microlab Road, Livingston, New Jersey, 07039

FULLERTON

SCHOENY DON

FROM: HOLLY COLE
JIM SORDEN

TO: DISTRIBUTION
DATE: MAY 1975
SUBJECT: 5345A NEWS NOTE, VOL. TWO

COUNTING UP . . . 5345

COUNTING TO 40 GHz

Your comments at the Senior Sales Seminars have not gone unheeded. Several of you mentioned that your customers wanted to count millimeter microwave signals but did not want to wait until we could develop a dedicated new product. The enclosed AN 190 gives you something you can offer your customer now.

AN 190 describes how to use your 5345A/5354A, 5340A or 5341A and other standard, unmodified hardware to measure all the way to 40 GHz with counter timebase accuracy. The application note is pretty concise and self explanatory but if you have any questions—or need more copies let us know.

THAT FAST TALKING COUNTER

The rest of this issue is divided into two sections. The first section reviews the available output options, what they do and won't do and should help you decide which one will be best suited for your customer.

The second half reviews output data speed with plenty of examples. You may want to file this part with your data sheet for future reference.

5345A OPTION 012

5345A Option 012 is here (almost). Price is $1450, but delivery is currently a rather lousy 20 weeks. Confused as to which I/O option is ideal for a given application? Read on!

NEWS FLASH!!

RELEASED JUST IN TIME FOR YEAR END GOVERNMENT SPENDING...
NATIONAL STOCK NUMBER
5345 = 6625 00531 4752
10590A = 6625 00544 3971

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OPTION 010 DIGITAL OUTPUT ONLY

Fully compatible with HP Interface Bus. Outputs data in the standard display format. Option can be addressed (commanded) to talk or it will operate in the talk only mode for controller-less operation, i.e., for use with 59301A bus to parallel converter, 59303A DAC or 5150A Thermal Printer. Field installation is practical but not recommended——see 5345A Operating and Service Manual, HP Part No. 05345-90013, paragraph 7-8.

Option 010 was designed primarily for the customer who wants to go directly to a Digital Printer (5150A) as cheaply as possible. Sales have been very low as most customers feel the powerful Option 011 gives much greater value for their investment.

OPTION 011 DIGITAL INPUT/OUTPUT

Fully compatible with HP Interface Bus. Provides standard display format output. Computer dump format output is also available under programmer control. Programming input provides complete digital control of 5345A, except input amplifiers. If the 5345A has been commanded to be in *"remote"* control, pushing the reset pushbutton will return control to front panel operation (all other front panel controls except the input amplifiers are locked out in *"remote"* operation).

We recommend Option 011 for all bench top/lab instrumentation groupings. Option 011's great flexibility makes it ideal for calculator systems (see HP Application Note series 174-XX). Field installation is practical but not recommended——see 5345A Operating and Service Manual, HP Part No. 05345-90013, paragraph 7-8.

The powerful versatility of Opt. 011 has made it perhaps HP's most popular output option. Typical sales have run up to 40% of all orders. And don't forget, with the 5930XA HP-IB modules available for future sale, Option 011 is like selling your customer a counter with **two** plug-in holes!!!

OPTION 012 DIGITAL I/O WITH INPUT AMPLIFIER CONTROL

This I/O option contains all the programming and data output features of Option 011 plus slope and level control of the input amplifiers. For each amplifier (A and B), slope selection programming is controlled when 5345A is commanded to be in *"remote"*. In a like manner, input amplifier level control is programmed in 4 mV steps from -1.3 to +1.3 V. Specifications on the level control DAC's are similar to 59303A DAC specification.

Since the Opt. 012 programming steps are in 4 mV steps instead of 10 mV steps as in the 59303A, the 59303A accuracy should be multiplied by 0.4 when applied to Opt. 012. To summarize, the center of the 5345A hysteresis window can be programmed to an accuracy of better than ± 4 mV with Option 012.

An added programming feature of Option 012 is the local lockout BUS command (LLO). BUS command "LLO" locks out the 5345A front panel reset pushbutton which would otherwise return the 5345A to local operation. Thus *all* programmable front panel functions can be locked in *"remote"* operation. Option 012 responds to serial polling and all other universal commands on the BUS (such as Local Lockout, GET, DCL).

Switches not programmed with Option 012:

1. AC power switch
2. Input amplifier
   a. 50Ω/1 meg switch
   b. AC/DC switch
   c. X1/X20 attenuation switch
   d. SEP-COM
3. INT-EXT FREQ STD (rear panel). This switch is incorporated on all 5345A's manufactured after April, 1975. (S/N ≥ 1512A 00951)

The AC power and rear panel INT-EXT FREQ switches are not programmable. However, the user may be interested in input signal conditioning beyond slope and level. The 59307A 500 MHz switch was designed to be used in this application. With the 59307A, any arbitary attenuation, DC offsetting, etc., can be programmed using coaxial or barrel attenuators, capacitors, etc.

We recommend Option 012 for all turn key system applications. It is ideal for computer controlled or dedicated calculator based system use. Field installation is *not practical*. Option 012 is not intended to compete with Opt. 011. It is designed to get us some incremental system business that we would otherwise lose.

PROGRAMMING OPTIONS 010, 011, 012

Programming is similar but not identical for all options. Programs written for option 011 may not run properly with a 5345A option 012, etc. One of the reasons for this is that when Opt. 012 is in REMOTE the trigger levels *must* be programmed. While this is great in a dedicated application it can be a real pain in a versatile bench-top instrument grouping, i.e., AN-174. Please consult the programming section of the 5345A Operating Manual for specific details. Currently, Application Notes 174-1 to 174-4 and 174-6 to 174-13 will not work with Option 012. Any program written for Option 011 which puts the 5345A in *"remote"* will not run with Option 012 instruments and vica versa.

OUTPUT SPEEDS AND EXAMPLES

(You may want to read this section later when you need it.)

The 5345A is about the fastest TALKER in the West—thus the LISTENER's speed determines thru put rate.

Typical Thru Put Rate:

1. 5345A—Superfast Computer ..... ≃ 9 kHz
2. 5345A—Usual Computer I/O ..... ≃ 1 kHz
3. 5345A/98XXA Calculator ..... ≃ 25 Hz
4. 5345A/5150A Printer ..... ≃ 3 Hz

The measurement cycle of the 5345A is the sum of several events.

1. Measurement time (Gate Time)
2. Process (compute) time
3. Output time on the HP Interface bus
4. Arming time to next measurement

1. **Measurement time** for CW frequency signal can be from 20 ns to 20,000 s.
2. **Process time** for mainframe only (5345A), measurement will typically be 1 ms. For measurements involving plug-ins with complex arithmetic routine, the process time may be as long as 3 ms.
3. **Minimum output time** is a function the total number of digits outputted. Seven characters plus some number of displayed digits (1 to n) are outputted per measurement in (23 + 11 n) μs.
4. **Arming time** is variable from < 1 μs to infinite (hold).

Output time occurs in parallel with arming time and measurement time. Thus, if the sum of arming time and measurement time exceeds output time, the effective output time is zero.

For the fastest possible measurement cycle rates: process, output and arming are combined in the "computer dump" mode. **Total** minimum cycle time for the computer dump mode is

Computer Dump Min. = Measurement Time = 107 μs

For the standard output mode

Standard Output Time ≃ 1 ms

Remember that the output time is timeshared with arming and measurement time. Thus, if the 5345A is EXT ARM for the <1 μs arming time and if GATE TIME is >1 ms, cycle time will equal to GATE TIME.

Typically, system speed of outputting data from the 5345A is dictated by the receiver. DATA LISTENERS (receivers) are of two types:

1. Non-programmable, such as:
   a. 59303A Digital-to-Analog Converter
   b. 59301A HP Interface Bus to Parallel Converter
   c. 5150A Thermal Printer
2. Programmable Data Receivers, such as:
   a. 9820A Calculator
   b. 2105A Computer

The data rate between the 5345A and type 1, non-programmable receivers is fixed for any given word length of "n" bytes. For any pair of sender-receiver on the bus, the rate of transmission is approximately equal to the

rate of the slower machine. In fact, on the HP Interface bus one may have several LISTENERS (receivers). Of course, it is legal to have only one TALKER (sender). In this case the rate of information transmission is determined by the slowest instrument.

59301 Converter $\simeq$ 200—400 μs (25 μs/byte)
5150A Thermal Printer Cycle Rate $\simeq$ 300 ms

For programmable receivers, the input data rate is determined by three factors: the hardware constraint, system firmware and the programmers software. Typically the software and system firmware (pre-programmed internal software) is much more restrictive. The following example with 5345A minimum GATE TIME and minimum ARM TIME will illustrate this. Let 5345A talk address = J and listen address = *. Then:

1. 9820A — 5345A Operation
   a. For reference: 5345A TALK, nobody LISTEN

      CMD "J?"
      Cycle time $\simeq$ 1 ms (but useless because nobody listens)

   b. 5345A TALK, 9820A LISTEN with no 9820A storage of data. 9820A talk address = U, listen address = 5.

      ```
      Ø: CMD "J?5"
      1: RED 13,A; JMP Ø
      ```

      Cycle time $\simeq$ 19 ms (useless)

      The extra 18 ms represent firmware restriction of the 9820A.

   c. 5345A TALK, 9820A LISTEN and STORE DATA POINTS a minimum length program.

      ```
      Ø: CMD "J?5", 1 → C
      1: RED 13,R( )C; C +1 →C
      2: IF C> 300 GTO 4
      3: GTO 1
      4: STP
      ```

      Cycle time $\simeq$ 35 ms

      This program stores 300 readings in 300 9820A storage locations. The incremental 15 ms represent 9820A program execution line.

2. 9830A—5345A Operation
   5345A TALK, 9830A LISTEN with NO DATA STORAGE

   ```
   10 CMD "J?5"
   20 ENTER (13,*)A
   30 GO TO 20
   ```

   Cycle time $\simeq$ 18 ms (useless)

   Program execution time for a useful program is similar to the 9820A ($\simeq$ 35 ms).

3. Even faster operation can be obtained with a calculator (9820A, 21A, 30A) with the following trick. Since the calculator spends much of its 35 ms in program execution time, it is possible to shorten this program loop and reduce input time by telling the calculator where to put the data instead of letting it figure it out itself.

```
Ø:  CMD "J?5"
1:  RED 13, R1
2:  RED 13, R2
3:  RED 13, R3
      .
      .
      .
300:  RED 13, R300
301:  STP
```

This program stores 300 readings in almost twice the speed but with a program length of 302 steps vs. 5 steps in 1c, above.

4. 2100A, 59310A—5345A
   a. 5345A Computer Dump Mode — DMA LISTEN program Cycle time $\simeq$ 107 μs
   b. 5345A Standard Output — variable computer software Cycle times 1—10 ms

Your excellent sales efforts are greatly appreciated and if we can provide any assistance, please call or drop us a line.

Regards,

Holly Cole
Jim Sorden