Introduction

The digital electronic frequency counter has come a long way since the first versions appeared over two decades ago. Once the luxury of large meterology labs and some crystal manufacturers, the frequency counter is now common-place in laboratories, on production lines, as a service tool and in automatic instrumentation systems. Moreover, counters have become increasingly more versatile and more powerful in the measurements they perform, thereby finding much wider applications. When Hewlett-Packard introduced the 524A in 1952 it was considered a milestone; the counter could measure frequencies up to 10 MHz, or the time between two electrical events to a resolution of 100 ns. Twenty-seven years later, HP's product lines feature counters that can measure the frequency of a 40 mV signal at 24 GHz completely automatically, or can resolve time to 20 ps, the same time it takes light to travel about 6 mm.

Basic counter measurements

The basic measurements which counters are capable of performing are described in this section.

Frequency

This fundamental measurement is performed by totalizing the number of input cycles or events for a precisely known period of time. The total count that results is proportional to the unknown frequency, and logic circuits internal to the counter position the decimal point such that the display directly indicates the input frequency. The time reference is usually derived from a precision quartz oscillator internal to the counter.

Using this basic technique allows measurements to 500 MHz to be made. Several methods are available, however, to extend this frequency range to 24 GHz and more. These are described in more detail below.

Period

This inverse of frequency capability is sometimes offered to provide the user with high resolution, low frequency measurements. In digital systems a period measurement represents the average bit to bit time of the input signal.

Totalize

The measurement is similar to frequency except that the user now controls the time over which the measurement takes place. With digital systems becoming more prevalent, this fundamental measurement assumes considerable importance. The HP 5345A, with its ability to totalize at a 500 megabit rate, represents the state of the art at this time.

Ratio

The ratio between two input frequencies is a measurement that is also offered by some counters. The major application for ratio is measurement of harmonically related signals.

Scaling

Some counters offer the capability of providing a digital output signal whose frequency is a scaled or divided version of the input frequency.

Time interval

The measurement of the time between two events or the time between two points on a common event, commonly referred to as time interval, is of major importance and is used in a wide variety of applications.

The ±20 pS single shot resolution of the 5370A represents today's state of the art. This unit utilizes a new concept of phase locked vernier interpolation which eliminates quantization errors. HP also pioneered the concept of time interval averaging, whereby for repetitive inputs substantial improvement in resolution over the single shot measurement can be obtained.

Time interval averaging is offered in five HP counters (5370A; 5345A; 5328A; 5315A/B and 5308A). Also available for precision time interval measurements is the 5363B Time Interval Probes box usable with any time interval counter. The 5363B has a wide dynamic range as well as a built in calibration feature and digitally set trigger voltages to eliminate the major uncertainties associated with TI measurements. The 5363B is fully programmable via the HP Interface Bus for systems applications.

All manner of time interval measurements are discussed in detail in Application Note AN 200-3 "Precision Time Interval Measurements Using an Electronic Counter" available on request from any Hewlett-Packard sales office.

Application Note 200: Fundamentals of the Electronic Counters

This forty-four page application note describes in detail the measurements mentioned above. In addition, the key considerations in making frequency and time measurements, plus the major characteristics required of a counter for certain applications are also described. For those readers who require more than the brief resumé above, this application note is available on request at any Hewlett-Packard sales office.

The contents of AN 200 are as follows:

Introduction
Fundamentals of the Conventional Counters
- Functions
- Input Considerations
- Time Base Oscillator Considerations
- Main Gate Requirements
- Sources of Measurement Error

Reciprocal Counters
Time Interval Measurement
- Input Considerations
- Trigger Level
- Increasing Accuracy and Resolution
- Use of Time Interval Probes

Automatic Microwave Frequency Counters
- Down-Conversion Techniques
- Comparison of Performance of the Down-Conversion Techniques

The major types of electronic counters

While counters can potentially offer all the measurement capabilities described above, they essentially fall into three classes: frequency counters; universal counters; and microwave counters. These are described below.

Frequency counters

These counters offer the basic capability of frequency measurement and in addition sometimes provide some or all of the other measurements described above except time interval. HP has a wide range of counters that fall into this class including: a) the 5380 low cost bench series, a family of three counters featuring 80 MHz—7 digit, 225 MHz—8 digit and 520 MHz—9 digit instruments; b) the 5300 portable, battery operated snap-on series with the 5303B snap-on covering 525 MHz and the 5305B 1300 MHz counter.

Table 1. Frequency counters summary

Model No.	Frequency Range	Number of Digits	Time Base	Other Functions*
5300/5301A	10 MHz	6	3×10^{-7}	T
5381A	80 MHz	7	3×10^{-7}	
5382A	225 MHz	8	3×10^{-7}	
5383A	520 MHz	9	3×10^{-7}	
5300/5303B	525 MHz	8	3×10^{-7}	
5300/5305B	1300 MHz	8	3×10^{-7}	
5341; Opt. 003	1500 MHz	10	1×10^{-7}	
5341A	4500 MHz	10	1×10^{-7}	
5340A	23000 MHz	8	3×10^{-7}	
5342A	24000 MHz	11	1×10^{-7}	A, Fo, Ao

*See legend next page

Table 2. Universal counter summary

Model No.	Frequency Range	Time Interval Resolution		Time Base	Other Functions*
		Single Shot	Averaging		
5300A/5304A	10 MHz	100 ns	—	3×10^{-7} per Month	MPA, T, R
5300/5302A	50 MHz	100 ns	—	3×10^{-7} per Month	P, MPA, T, R
5300A/5308A	75 MHz	100 ns	100 ps	3×10^{-7} per Month	P, MPA, T, R
5314A	100 MHz	100 ns	—	3×10^{-7} per Month	P, MPA, T, R
5315A/B	100 MHz	100 ns	10 ps	3×10^{-7} per Month	P, MPA, T, R, E
5328A	100 MHz	100 ns or 10 ns	10 ps	3×10^{-7} per Month	P, MPA, T, R, E, V**
5370A	100 MHz	±20 ps	1 ps	1×10^{-7} per Month	P, MPA, E
5345A	500 MHz	2 ns	2 ps	5×10^{-10} per Day	P, MPA, T, R
5328A Opt 030	512 MHz	100 ns or 10 ns	10 ps	3×10^{-7} per Month	P, MPA, T, R, E, V**
5328A Opt 031	1300 MHz	100 ns or 10 ns	10 ps	3×10^{-7} per Month	P, MPA, T, R, E, V**

*See legend next page
**Optional function

Universal counters

These instruments provide time interval capability in addition to the other measurements provided by the frequency counter.

The new 5314A is a perfect example of such an instrument featuring 100 MHz frequency, 100 ns time interval plus period, ratio and totalize. The new 5315A/B provides all these functions plus time interval average and reciprocal frequency measurements. The 5302A features 50 MHz frequency, 100 ns time interval plus period, ratio and totalize. Another member of the same family, the 5308A is ideally suited as a general purpose bench instrument, for in addition to the 5302A capabilities the 5308A offers time interval averaging, totalizing (with electronic start and stop) and frequency to 75 MHz. The 5304A snap-on is especially oriented towards time interval featuring adjustable hold-off. The 5328A (100 MHz) and 5328A Opt 031 (1300 MHz) are high performance rack mount instruments programmable (Opt 011) via the HP Interface Bus. Time interval averaging gives resolution to 10 ps on repetitive signals and Opt 040 also has 10 ns one shot resolution. The 5345A offers a 500 MHz bandwidth, with totalizing, ratio and period capability to this speed (500 MHz), plus 2 ns single shot time interval and 2 ps time interval averaging. This extremely powerful instrument features plug-in flexibility (see page 289), and a reciprocal frequency measurement mode (see next page).

Finally, the 5370A offers the ultimate in time interval measurement resolution with 20 ps single shot and 1 ps time interval averaging!

Microwave counters

These instruments provide high accuracy frequency measurements into the microwave spectrum. The 5342A harmonic heterodyne microwave counter automatically measures frequencies to 24 GHz under microprocessor control, and features 1 Hz resolution and wideband FM tolerance. The keyboard controls allow the user to program his own frequency offsets. The amplitude option will simultaneously display input frequency and input level for readily monitoring microwave devices and equipment. The 5340A automatic transfer oscillator counter can measure frequency from 10 Hz to 23 GHz via a single input at –35 dBm sensitivity! The 5341A automatic heterodyne counter provides coverage to 4.5 GHz using the switchable filter technique for super fast acquisition times. The 5354A is a 4 GHz heterodyne converter that plugs into the 5345A mainframe and provides extremely high resolution automatic measurements for CW and pulsed RF down to pulse widths of 20 ns. Application Note 173 discusses automatic pulsed RF measurements in detail. Application Note 190 discusses making frequency measurements to 40 GHz with counter accuracy using a 4 GHz Microwave Counter together with readily available microwave generators and mixers.

Application Note 200-1 deals with the fundamentals of microwave frequency counters and compares the various techniques.

Table 3. Microwave counter summary

Model No.	Frequency Range	Technique	Time Base	Sensitivity	Number of Digits
5354A*	4 GHz	Auto Heterodyne	5×10^{-10}/Day	−10 dBm	11
5341A	4.5 GHz	Auto Heterodyne	1×10^{-7}/Month	−20 dBm	10
5254C/5255A/5256A**	to 18 GHz	Manual Heterodyne	3×10^{-9}/Day	−13 dBm	8
5257A**	18 GHz	Manual Transfer Osc	3×10^{-9}/Day	− 7 dBm	8
5340A	23 GHz	Auto Transfer Osc	3×10^{-7}/Month	−35 dBm	8
5242A	24 GHz	Auto Harm Heterodyne	1×10^{-7}/Month	−25 dBm	11

*Plug-in to 5345A Counter
**Plug-in to 5245 Series Counter or 5345A with adapter

Reciprocal Counting Technique

The extremely powerful reciprocal counting technique is employed in several counters available from Hewlett-Packard. The distinction between this and the conventional technique is that the latter provides 1 Hz resolution in one second, whereas the resolution of the reciprocal technique is proportional to the frequency of the internal counted clock. The four instruments available are summarized in Table 4 below. Note that the 5345A is a plug-in instrument and hence the high mainframe resolving power offered applies to any of the compatible plug-ins. It has pulsed RF measurement capability via an external gate mode. In addition the 5345A includes a unique frequency averaging mode that allows high resolution measurements on repetitive pulses even if pulse width is 50 nsecs. The 5370A extends the reciprocal technique by means of phase locked vernier interpolation to give the ultimate in resolution. Frequency measurements to better than 10 digits may be made in 1 sec.

HP Interface bus

The more recently introduced counters (and other HP digital instruments) have a digital input/output structure which is compatible with the interface bus which is Hewlett-Packard's implementation of the IEEE Digital Interface Standard 488-1975. HP Desktop Calculators in the 9825/30 Series and Minicomputers in the HP 2100/21MX Series are also compatible with the interface bus, making it possible to expand the capabilities of the individual instruments even into areas of real time data reduction and control. Interfacing is available for interconnecting up to 14 compatible devices on one I/O slot. The HP 59310B Computer Interface serves for minicomputers and the HP 98034A or 59405A HP-IB Calculator Interface interconnects up to 14 devices using one I/O slot and one ROM. At this time, compatible instruments are the 5345A, 5370A, 5340A, 5341A, 5342A, 5328A, and 5312A (for 5300B system).

Table 4. Reciprocal frequency counters

Model No.	Frequency Range	Measurement Resolution	Number of Digits	Time Base	Sensitivity
5300A/5307A	2 MHz	3×10^{-5}	6	3×10^{-7} per Month	10 mV rms
5315A/B	100 MHz	1×10^{-7}	8	3×10^{-7} per Month	10 mV rms
5370A	100 MHz	1×10^{-10}	16	3×10^{-7} per Month	20 mV rms
5345A	500 MHz	2×10^{-9}	11	5×10^{-10} per Day	20 mV rms

Table 5. Counter selection guide

Classification	Description	Frequency	Functions*	Time Base	Price	Page
5381A, 5382A & 5383A Low Cost	Traditional HP quality and reliability at low prices.	To 520 MHz	F	3×10^{-6}/Mo. Optional 1×10^{-7}/Mo.	From $295	313
5314A Low Cost Universal Portable	Traditional HP quality and reliability at new low price	100 MHz	F, P, MPA, TI, T, R	3×10^{-7}/mo. Optional 1×10^{-7}/mo.	From $375	303
5315A/B Economic Reciprocal Portable	A new high performance micro-processor controlled universal counter with sub nanosecond time interval averaging capability and optional high frequency coverage. 5315B offers rack/stack package and improved RFI.	100 MHz Optional higher frequency	F, P, MPA, TI TI AVG, T, R, E	3×10^{-7}/mo. Optional 1×10^{-7}/mo.	From $800	304
5300 Series Economic Portable	Select from 8 plug-ons to meet present needs. Move up in functions or frequency range when needed. Battery pack, D to A converter and HP Interface Bus output module extend versatility.	To 1300 MHz	F, P, MPA, TI TI AVG, T, R V, E	3×10^{-7}/Mo. Optional 1×10^{-7}/Mo.	From $685	306
5328A Universal Counter	A high performance universal counter with sub nanosecond time interval averaging capability that can include high frequency measurement, DVM or HP Interface Bus options.	To 1300 MHz	F, P, MPA, TI TI AVG, T, R, V, E	3×10^{-7}/Mo. Optional 1.5×10^{-8}/Mo.	From $1300	298
5245 Series General Purpose Plug-in Counters	A mainframe and 6 plug-ins provide unmatched versatility. Plug-ins provide up to 18 GHz frequency and 100 nsec time interval capabilities.	To 18 GHz	F, P, MPA, TI T, R	1×10^{-7}/Mo. ($<3 \times 10^{-9}$/Day)	From $5000	296
5345 Series High Performance Plug-in Counters	A series of high performance mainframe and plug-ins, providing 500 MHz direct count, 2 nsec time interval, and 4 GHz automatic pulsed RF measurements.	To 18 GHz	F, P, MPA, TI, TI AVG, T, R E	1.5×10^{-8}/Mo. ($<5 \times 10^{-10}$/Day)	From $4400	289
5340, 5341, 5342A Automatic Counters	Broad band, high sensitivity, microwave frequency measurements 10 Hz–1.5 GHz; 10 Hz–4.5 GHz and 10 Hz–24 GHz.	To 24 GHz	F, Fo, A, Ao	Optional to 1.5×10^{-8}/Mo. ($<5 \times 10^{-10}$/Day)	From $4500	314
5370A	Highest resolution frequency measurements and time interval measurements to ±20 ps resolution	100 MHz	F, P, MPA, TI, TI AVG	3×10^{-7}/Mo. Optional 1.5×10^{-8}/mo.	$6500	294

***Legend for Functions**

F = Frequency
P = Period
MPA = Multiple Period Average
TI = Time Interval
A = Amplitude
TI AVG = Time Interval Average
T = Totalize
R = Ratio
V = Voltage
E = Electronically Controlled Totalize
Fo = Frequency Offsets
Ao = Amplitude Offsets

ELECTRONIC COUNTERS

500 MHz plug-in counter

Model 5345A

- 500 MHz Direct Counting
- 20 mV Sensitivity DC to 500 MHz
- 2 ns Single Shot T.I. Resolution
- Averaging to 2 ps resolution
- Pulsed RF and Microwave Measurements
- Programmable for systems applications via HP-IB

The 5345A Electronic Counter represents the most advanced general purpose instrument in the Hewlett-Packard Counter Product line. Utilizing state of the art monolithic bipolar integrated circuit technology especially designed and manufactured at Hewlett-Packard, this instrument provides unsurpassed power, versatility and flexibility in frequency and time measurements.

Major mainframe features

Frequency: direct from DC to 500 MHz—Reciprocal technique provides high measurement resolution.
Time interval: resolution of 2 ns single shot.
Averaging: new modulated clock technique gives true averages under all conditions. T.I. resolution extended to 2 ps. Frequency averaging improves RF pulse measurements similarly.
Totalize: to 500 megabit rate on both A and B inputs. A ± B functions also available.
Ratio: from DC to 500 MHz on both inputs.
Fully programmable: provides great flexibility when used with calculators and computers.
Plug-in versatility: two plug-ins presently available (see page 292) with an on-going R&D program to extend this number. In addition the 10590A plug-in adapter allows most existing 5245 plug-ins to be used.

Signal input circuits

Signal conditioning: fully optimized front end includes switchable

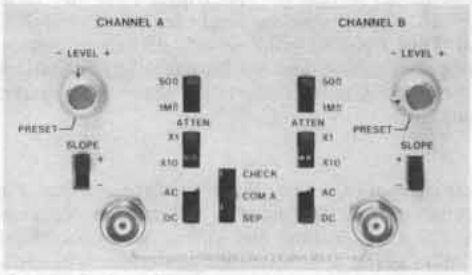


Figure 1. Input Switches

50Ω/1 MΩ input impedances, DC/AC coupling, and slope selection that assures triggering on any waveform.
Sensitivity, dynamic range: highly sensitive wideband amplifiers assure measurements on even the lowest level sinusoidal and digital signals. The inputs also feature an extremely wide linear dynamic range of −2 to +5 V DC that greatly increases measurement versatility, especially on digital input signals.

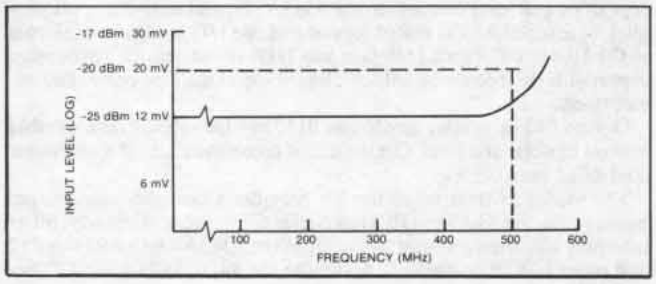


Figure 2. Typical Amplifier Sensitivity

Frequency measurements

Reciprocal capability: one of the advantages of measuring period

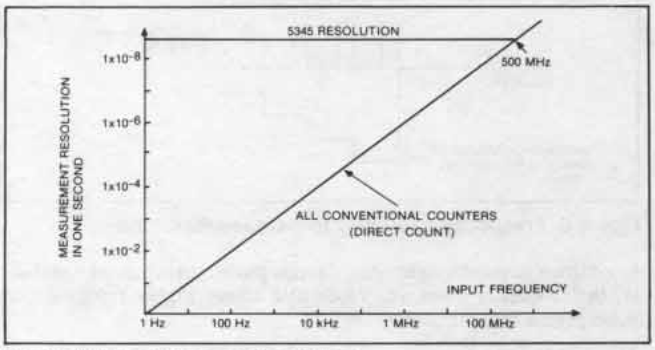


Figure 3. Measurement Resolution

and computing the frequency is that measurement resolution is independent of input frequency and at the maximum to which the instrument is capable of resolving. Thus for example, a 1 MHz input can be resolved to 2×10^{-9} (=0.002 Hz) in one second, whereas the conventional counter provides 1 Hz resolution, some 500 times less.

Measurement speed

Mode of Operation	Readings per Second
Normal Operation (Max sample rate)	10
Externally armed	500
Externally gated	500
Computer dump	9,000

The extremely high resolution obtained in one second can be traded for measurement speed. For example of 100 μs gate time provides a resolution of 2×10^{-5} yet the measurement can now be made 5000 times a second, thus making the 5345A an invaluable tool in high speed data acquisition systems.
Ext. gated capability: via the rear panel gate control input; this capability allows the operator to determine at what point in real time and for how long the measurement is to be made. This capability essentially replaces the front panel "sample rate" and "gate time" controls.

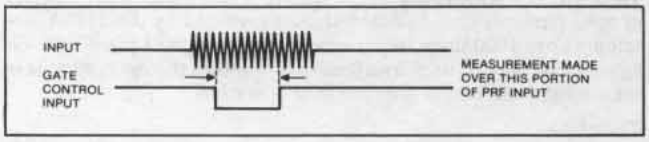


Figure 4. External Gate Control

The major application is in the measurement of pulsed RF signals.
Frequency averaging: the minimum pulse width for which the input frequency can be measured is 20 ns. The single shot measurement resolution is 2×10^{-9} divided by the GATE TIME. This resolution can be improved up to 1000 times by a unique mode of operation known as frequency averaging that is built into the mainframe. The only requirement for this mode is that the signal is repetitive.

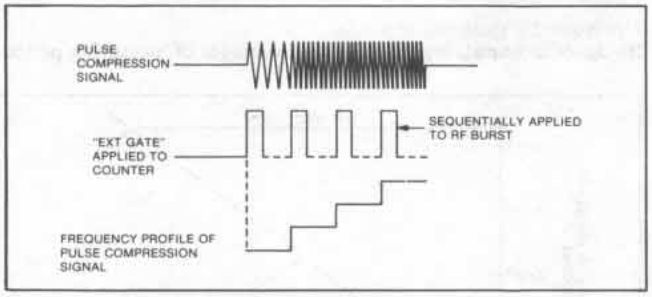


Figure 5. Frequency Averaging to Increase Resolution

In addition to greatly enhancing narrow pulse measurement capability, the frequency averaging mode also allows higher resolution on pulse profile measurements.

Time Interval

Precision measurement: the single shot time interval measurement resolution of the 5345A is 2 ns, which is the time it takes light to travel approximately 2 Ft—the 5345A is an extremely high resolving time measuring device.
Trigger level: quantitative high speed time interval measurements are provided by the 5345A since the user can simply determine where triggering occurs even on complex waveforms. The method of determination involves measuring the DC levels at which triggering occurs. These DC levels are available at rear panel BNC's.

The ability to determine trigger level, together with high sensitivity and wide dynamic range of the inputs greatly enhances the versatility and power of the 5345A in time interval measurements.

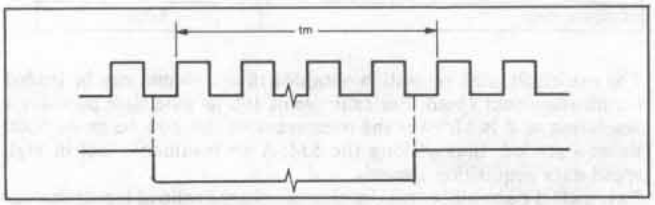


Figure 6. Using EXT GATE to Measure Tm

Ext. gate capability: external gating adds even more versatility to the time interval measurements of the 5345A, as measurements such as that shown in figure (6) indicate.
Time interval averaging: for repetitive inputs a successive number of measurements may be automatically averaged by the 5345A, obtaining up to 1000 times improvement in resolution (2 ps). This averaging mode may be used irrespective of whether the instrument is in the conventional or ext. gate mode of operation.

Totalize

High speed: the 5345A has the ability to totalize to a 500 megabit rate through either or both A and B inputs. Coupled with the high sensitivity and full signal conditioning of both channels, this capability enables measurements to be made on most modern digital systems.

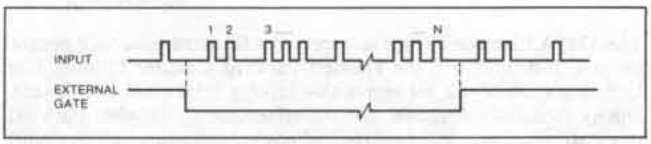


Figure 7. Selecting a Portion of a Pulse Train

Ext. gate capability: using the external gated mode allows the user to select only the desired portion of the input pulse train for measurement.

A ± B Modes

The A—B mode is used for comparison tests between high speed reference and test signals applied to the two mainframe inputs.

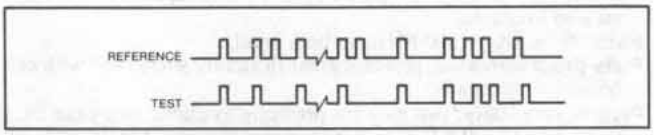


Figure 8. Comparison Measurements

Any difference between the total number of events accumulated in each channel is indicated by the 5345A display after the measurement is completed.

The primary application for the A + B mode is in the measurement of NRZ signals. By setting the "A" trigger slope to "+" and the B slope to "−" allows all transitions and hence bits of the NRZ signal to be counted. Thus 1 gigabit NRZ waveforms can be measured.

This mode of operation does not introduce any limitations—maximum input rate is 500 megabits on either channel and external gating may be used.

Ratio

This measurement represents the ratio of the number of events occuring through channel B divided by the number occuring through channel A. The major features are: a) that the measurement or comparison (similar to the A ± B totalize modes); and, b) the frequency or bit rate of either channel can vary from DC to 500 MHz. These features allow this measurement to be extremely useful in digital systems and synthesizer check out.

Digital I/O

Option 011 provides complete digital input-output capability (except slope and level control) to the 5345A. Digital output is a bit parallel, byte serial ASCII coded format and the I/O structure conforms to the Hewlett-Packard Interface Bus (HP-IB) standard. This option is particularly recommended for a bench top calculator controlled environment.

Option 012 is similar to Option 011, but includes programmable control of slope and level. Option 012 is recommended for a computer controlled environment.

The model 59310B Interface Kit provides a complete operational package for use with the HP 2100 Series Computers. Similarly, other interface kits allow the user to interface the 5345A Option 011 or 012 and other HP-IB compatible devices to the 9820, 9825 and 9830 Series HP Desktop Computers.

5345A Condensed specifications

Frequency/period measurements

Range: 0.00005 Hz to 500 MHz.

Accuracy: $\frac{\pm 2 \times 10^{-9}}{\text{gate time}}$ ± trigger error* ± time base error.

Gate time: 1000 seconds to 100 nanoseconds in decade steps; <50 ns in MIN position.

Time interval/time interval average

Range: 10 nsec to 20,000 sec.
Minimum dead time: 10 nsec.
Trigger pulse width: 1 nsec minimum width input at minimum voltage input.
Accuracy
Time interval: ± trigger error** ± 2 ns ± time base error.
Time interval averaging:

$$\pm \frac{\text{trigger error ** } \pm 2 \text{ nsec}}{\sqrt{\text{intervals averaged}}} \pm 0.7 \text{ nsec} \pm \text{time base accuracy}$$

Not affected by harmonics of clock frequency.
Resolution:
Time interval: 2 nsec.
Time interval average:

$$\pm \frac{2 \text{ nsec}}{\sqrt{\text{intervals averaged}}} \pm 2 \text{ picoseconds.}$$

Ratio B/A

Range: both channels accept dc to 500 MHz.
Accuracy: ± L.S.D. ± trigger error*.

Start/stop

Range: both inputs dc to 500 MHz.
Modes: A, A ± B determined by rear panel switch.

Scaling

Range: dc to 500 MHz.
Scaling factor: selectable by GATE TIME setting. Scaling factor equals GATE TIME setting/10^{-9} seconds.
Input: input signal through channel A.
Output: output frequency equals input frequency divided by scaling factor. Rear panel BNC supplies 80% duty cycle TTL compatible pulses.

Input channels A and B

Range: 0 to 500 MHz dc coupled 50Ω and 1 MΩ; 4 MHz to 500 MHz ac coupled, 50Ω; 200 Hz to 500 MHz ac coupled, 1 MΩ.
Impedance: selectable, 1 MΩ shunted by less than 30 pF or 50Ω (nominal).
Sensitivity: X1, 20 mV rms sine wave and 60 mV peak-to-peak pulse. X10, 250 mV rms sine wave and 750 mV peak-to-peak pulse.
Dynamic range: 50Ω & 1 MΩ: 20 mV to 250 mV rms sine wave (X1); 250 mV to 2.0 V rms (X10).
Trigger level: adjustable over ±1.3 V dc.
Output: rear panel BNC connectors bring out CHAN A TRIG LEVEL and CHAN B TRIG LEVEL for convenient DVM monitoring. Accurate to ±15 mV.

Common input

In this mode the signal is applied to channel A.
Range: ac coupled 50Ω, 4 MHz to 400 MHz; ac coupled 1 MΩ, 300 Hz to 400 MHz.
Impedance: 50Ω remains 50Ω; 1 MΩ becomes 500 kΩ shunted by <60 pF.
Sensitivity: 50Ω: 40 mV rms; 1 MΩ: No change.
Dynamic range: 50Ω: 40 mV to 500 mV rms (X1); 500 mV to 4 V rms (X10); 1 MΩ: No change.

*Trigger error for sinewaves of 40 dB signal-to-noise amplitude ratio is <[±0.3% of one period ÷ number of periods averaged]. If peak noise amplitude is greater than 10 millivolts, additional miscounting may occur (this situation can arise when measuring high-level outputs of broadband synthesized signal sources).

**For any wave shape, trigger error is less than

$$\pm \frac{0.0025}{\text{Signal Slope in V/}\mu\text{s}} \ \mu\text{s}$$

General

Display: 11 digit LED display and sign. Annunciator displays ksec to nsec, k to n, μHz to GHz. Decimal point is positioned with DISPLAY POSITION control or positioned after the first, second or third most significant digit if DISPLAY POSITION is in AUTO. Leading zeros are suppressed.
Overflow: asterisk is illuminated when display is overflowed.
Sample rate: continuously variable from <0.1 sec to >5 sec with front panel control. In HOLD positon the last reading is maintained until the counter is reset.
External arm input: counter can be armed by a −1.0 V signal applied to the rear panel 50Ω input.
External gate input: same conditions as for EXT ARM.
Gate output: >1 volt into 50Ω.

Time base

Standard high stability time base: crystal frequency, 10 MHz (10544A).
Stability
Aging rate: $<5 \times 10^{-10}$ per day.
Short term: $<1 \times 10^{-11}$ for 1 sec average.
Temperature: $<7 \times 10^{-9}$, 0°C to 55°C.
Opt 001: crystal frequency, 10 MHz.
Stability:
Aging rate: $<3 \times 10^{-7}$ per month.
Short term: $<2 \times 10^{-9}$ rms for 1 sec.
Temperature: $<2 \times 10^{-6}$, 25°C to 35°C.
$<5 \times 10^{-6}$, 0°C to 55°C.
Line voltage: $<1 \times 10^{-8}$, ±10% from nominal.
Self test: a 100 MHz signal is internally applied.
External frequency standard input: input voltage >1.0 V rms into 1 kΩ required from source of 1, 2, 2.5, 5 or 10 MHz $\pm 5 \times 10^{-8}$ ($\pm 5 \times 10^{-6}$ for opt. 001). Input can be sine or square wave.
Frequency Standard Output: >1 V rms into 50Ω at 10.0 MHz sine wave.
Operating temperature: 0°C to 55°C.
Power requirements: 100/120/220/240 V rms +5% −10% 48 to 66 Hz, maximum power 250 VA.
Weight: 17 kg (37 lb).
Size: 132.6 H x 425 W x 495 mmD (5 7/32" x 16 3/4" x 19 1/2").

Options and accessories

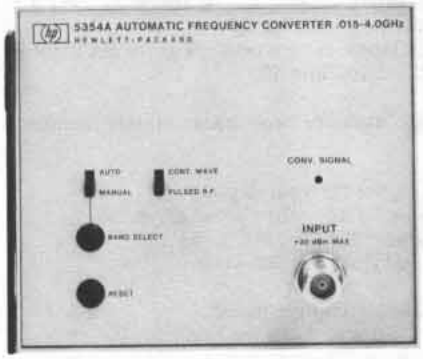
	Price
001: Room Temperature Time Base	less $350
010: Digital output only. HP Interface Bus format, talk only. Useful with 59301A ASCII-to-Parallel Converter and 5050B or 5055A Digital Printers	add $250
011: Digital Input/Output same as Opt 010, Compatible with HP Interface Bus and allows 5345A to be remotely programmed.	add $800
012: Digital I/O similar to Opt 011. Includes slope and level control	$1450
908: Rack flange kit	add $10
K13-59992A: includes state machine tester as an aid for trouble-shooting the arithmetic processor	$2340
10595A Board extender kit: useful for troubleshooting plug-in boards while in operation	$575
10590A Plug-in adapter: adapts 5245 series plug-ins to 5345 (see next page)	$700
K15-59992A Standby power unit: plug-in to maintain oscillator operation for prolonged periods without line voltage	$1200

Available reference material

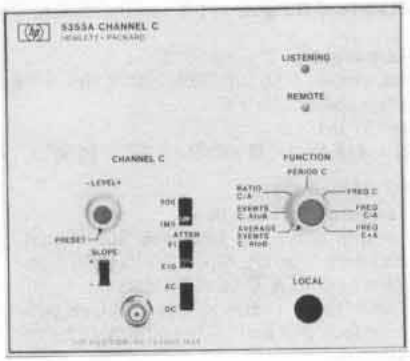
5345A Data Sheet
5345A Users Handbook
AN-173 Recent Advances in Pulsed RF and Microwave Measurements
AN-173-1 Dynamic Measurement of Microwave VCO's
AN-174 Applications Series on Counter/Calculator Instrument Groupings
AN-190 40 GHz Frequency Measurements
AN-200-3 Precision Time Interval Measurements
HP Journal June 1974
I.D. #90337D Color Video Tape Applications and Demonstrations

5345A Plug-In Counter **$4400**

- Fully automatic to 4 GHz
- Pulse Measurements
- Frequency averaging
- Count a group of events between A and B
- Frequency sum and difference measurements



5354A



5353A

10590A

5354A Automatic frequency converter

The 5354A translates not only the microwave signal but all its modulation directly to the 500 MHz window of the counter (via the heterodyne technique). It allows signals with a large amount of FM to be easily characterized.

Perhaps even more powerful is its ability to take direct measurements on the carriers of very narrow microwave pulses. Pulse measurements can be easily automated.

Range: 15 MHz to 4 GHz.

Sensitivity: −10 dBm (70 mV rms) auto mode, −20 dBm typical (22 mV rms) Manual/Pulse mode to 20 dBm (2.2 V rms).

Input signal capability: CW signals. Pulsed microwave signals. Signals with very high FM content.

RF Pulse width: determined by counter GATE TIME setting.

FM Sensitivity: overlap at band edges ±10 MHz. Maximum deviation at band center

±250 MHz, above 1 GHz and below 500 MHz.

±125 MHz, between 500 MHz and 1 GHz.

Operating modes: Automatic and Manual.

Automatic: measures lowest frequency signal of sufficient amplitude to trigger counter.

Manual: measures signal within selected band. Signals of sufficient amplitude between 15 MHz and 525 MHz will also be counted.

Acquisition time:

Automatic mode: CONT. WAVE, <2 ms; PULSED R.F., <1s.

Manual mode: when proper band has been selected CONT. WAVE <5 μs; PULSED R.F. <20 ns.

Options	Price
011: remote control via HP Interface Bus and L.O. ± I.F.	add $200

5354A Automatic Frequency Converter **$3400**

5353A Channel C plug-in

The 5353A Channel C Plug-In consists of a third input to the 5345A Counter. When the plug-in counting capability is combined with the mainframe gating capability it becomes quite easy to make frequency sum and frequency difference measurements.

For high speed digital applications, the greatest benefit the plug-in offers is the ability to count a specific group of events while ignoring others. This measurement is required in many applications such as computer peripheral testing and digital communications systems. It is accomplished in the events C between A and B mode by applying a start signal to CHAN A and a stop signal to CHAN B while applying the data to be counted to CHAN C.

Range: dc coupled: 0 to 500 MHz; ac coupled: 1 MΩ: 200 Hz to 500 MHz; 50Ω: 4 MHz to 500 MHz.

Impedance: 50Ω; (nominal), or 1 MΩ shunted by less than 30 pF.

Sensitivity: variable to 20 mV rms sine wave and 60 mV peak-to-peak pulse. Attenuator settings are X1 and X10.

Modes of operation: Frequency C + A; Frequency C − A; Period C; Frequency C; Ratio C/A; Average Events C, A to B; Events C, A to B.

Events accuracy: Plus or minus one count worst case.

Options	Price
011: Digital Input. Full compatibility with HP Interface Bus. Provides for digital control over all functions excluding amplifier.	add $250

5353A Channel C plug-in **$1250**

10590 Plug-in adapter

The 10590A allows the user to interface any of the 5245 series of plug-ins (except the 5264A) to the 5345A (see page 297 for details on these plug-ins). The major application is to extend the frequency range to 18 GHz via the 5255A, 5256A and 5257A plug-ins. In addition the adapter is "intelligent" in that it detects the plug-in being used and automatically adjusts the 5345A accordingly.

10590A Plug-in adapter **$700**

Frequency and Time Data Acquisition System
Model 5391A

- Capable of 100,000 measurements/second

5391A Frequency and Time Data Acquisition System

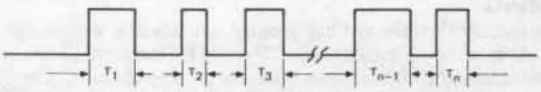
GENERAL

The HP5391A Frequency and Time Data Acquisition System combines the power of the HP5345A Universal Counter with the speed and storage capability of the HP5358A Measurement Storage Plug-In to allow you to make and store frequency or time measurements at rates as high as 100,000 measurements per second. The 5391A can help you characterize pulse width jitter by measuring and storing each pulse width and then computing statistical parameters such as min, max, mean, and standard deviation. Other application areas include nuclear time of flight studies, explosive testing and characterization, and frequency profile measurements.

The 5391A is a compact HP-IB system consisting of the 5345A Universal Counter with the 5358A Measurement Storage Plug-In, the 9825A Option 001 Computing Controller, and a versatile software package providing utility application routines and diagnostic service routines.

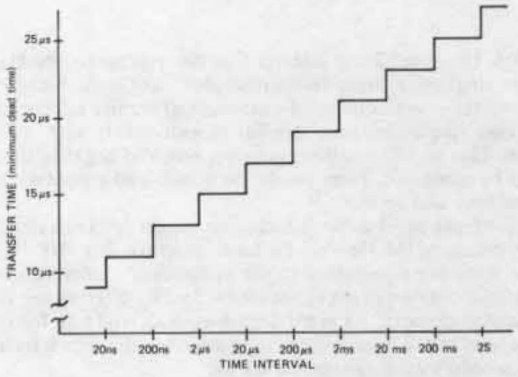
APPLICATION EXAMPLE

Frequencies, periods, ratios, and time intervals may be measured and stored by the 5391A. A typical application, shown in the figure, is to measure and store every pulse width in a burst of pulses:



The 5345A counter makes a single shot time interval measurement (2 nanosecond resolution) for each pulse width. During the dead time between successive time intervals, the 5345A transfers the data to the 5358A Measurement Storage Plug-In. The time required for this transfer is 7 μs + 1 μs/digit transferred. The graph plots transfer time required versus the time interval measured. If the dead time immediately following a measured time interval is greater than the required transfer time, the 5391A can make the measurement.

The number of measurements which can be consecutively made at this high rate is limited in most cases by the size of the 9825A memory. For the standard 5391A with 9825A Option 001, 700 measurements can be consecutively made and stored for time intervals less than 200 seconds. For the 5391A Option 102 (which has a 9825 Option 002), 1200 consecutive measurements may be made for time intervals less than 2 milliseconds. Above 2 milliseconds, the 8K memory size of the 5358A is limiting.



When the desired number of measurements in a run exceeds the maximum allowable, the maximum is taken and then stored as a block on the 9825A cassette. Subsequent blocks of measurements are taken and stored on cassette until the total desired number of measurements has been accumulated. The time required to transfer the measurement data from the 5358A to the 9825A and store it on cassette is on the order of seconds. During this time, no measurements can be made. The total number of measurements is program selectable from 1 to 9999.

SYSTEMS OPTIONS

102: Expands 9825A memory to 23,228 bytes — add $800
325: Deletes 9825A Controller (as well as ROMS and HP-IB Interface) — less $7,950

Ordering Information

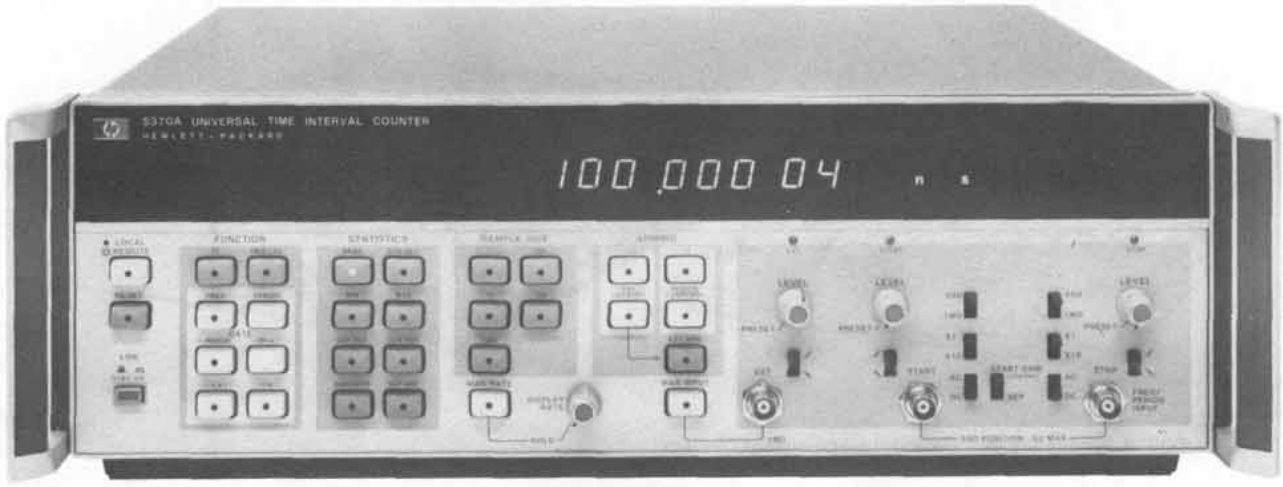
	Price
5391A basic system includes:	
5345A Option 011 Electronic Counter	
5358A Measurement Storage Plug-In with 8K bytes of memory	
9825A Option 001 Computing Controller with 15,036 bytes of memory	
98034A HP-IB Interface	
98210A Adv. Prog., String Variable ROM	
98213A Gen. Purpose I/O, Extended I/O ROM	
System Software Cartridge	
System and Instrument Manuals	
5391A Basic System	17,900

ELECTRONIC COUNTERS

UNIVERSAL TIME INTERVAL COUNTER

MODEL 5370A

- 20 ps single shot time interval counter
- Statistics
- Automatic calibration of systematic errors
- Positive or negative time intervals
- Frequency and period to 100 MHz



5370A

HP-IB

The 5370A Universal Time Interval Counter represents the highest resolution single-shot time interval counter available today. The counter utilizes a new concept of phase locked vernier interpolation, which allows single-shot time interval measurements with ±20 pS resolution. This technique allows positive, zero and negative time intervals to be measured. High resolution period and frequency measurements may also be made.

All major front panel controls including trigger level are programmable by means of the Hewlett-Packard Interface Bus (HP-IB).

User convenience is increased by the inclusion of a microprocessor, which extends the usefulness of the instrument by offering the statistical functions of mean, standard deviation, max, and min for repetitive time intervals. A user-defined time interval reference is included for the cancellations of systematic errors.

The high resolution time interval capability makes the instrument ideal for IC testing, radar and laser ranging, digital communications, ballistics and nuclear measurements.

FUNCTIONS

TI: Time Interval function measures time difference from the START to the STOP channel. In the ±TI mode, the counter will measure the time from the first event in either channel to the first event in the other channel. The microprocessor affixes a negative sign to the display if the stop channel event occurred first.

The negative time feature allows applications like differential phase measurement between two waveforms to be continuously monitored even though the phase changes from a positive to a negative drift. Statistical functions are available in both TI modes.

Trig Lev: *Measures the trigger levels of* START and STOP channels and displays both levels simultaneously with 10 mV resolution. Additional equipment like oscilloscopes or DVM's is not required.

Freq: Measures the frequency of the STOP channel signal by taking the reciprocal of a period average. Both timed gates and single period gates are available. In the single period mode, resolution may be improved by using a larger sample size. Statistics are available in the single period mode.

The exceptionally high resolution (11-12 digits per second) of the 5370A makes the instrument ideal for directly measuring the drift of oscillators and other applications requiring exceptionally high frequeny resolution.

Period: Measures the period average of STOP channel events. Statistics are available in the single period mode, but not with timed gates.

STATISTICS

Statistical functions allow much more complete characterization of time intervals. In addition to the mean, both the max and min within a selected sample size are available and also the standard deviation. In many cases, these parameters are of more interest than the mean. For example, in a digital communications system, the limits of pulse jitter as described by the max and min could be of primary interest. For a normal distribution of jitter, the standard deviation gives the rms jitter directly.

Sample size: push-button selectable to 1,100, 1K, 10K, and 100K samples.

Mean: displays the mean estimate which is the average for the selected sample size.

Std dev: displays a standard deviation estimate for the selected sample size.

Min: displays the minimum time interval measured within the selected sample size.

Max: displays the maximum time interval measured within the selected sample size.

ARMING

Extremely flexible arming greatly extends the usefulness of the 5370A into new applications. "Hold-off" features allow complex pulse trains to be measured by preventing "stop channel" arming until the removal of an external "gating" signal. An example could be the measurement of time from a radar or laser send pulse to the return pulse, where depending on the range of the object, several return pulses may occur before the return pulse of interest.

Other methods of arming allow the counter to be externally gated by an input waveform which very precisely controls both measurement duration and the time position at which the measurement occurs. Applications are in the frequency profiling of VCO's, pulsed rf bursts, or sweep linearity investigations.

The following modes of arming are available:

+TI
Internally armed – no hold-off
Externally armed – no hold-off
Externally armed – external hold-off

±TI
External arming
Internal arming

Programming

All major controls are programmable as standard by means of the HP-IB making the 5370A an economical, versatile unit for systems applications.

Data Output Rate

1) HP-IB 10-20 readings per second.
   Dead time between measurements within a sample is 330 μs.
2) Fast Binary: 6 KHz
   Dead time between measurements is 165 μs.

5370 Specifications

Sensitivity: 100 mV p-p, 35 mV rms sine wave times attenuator setting.
Impedance: Selectable 1 M ΩII30 pF or 50 Ω nominal.
Trigger Level: Adjustable from −1.3V to 0.5V with 10 mV displayed resolution.
Trigger Slope: Independent selection of + or − slope.
Attenuators: X1 and X10 nominal.
Dynamic Range (preset):

50Ω X1 100 mV to 1V p-p pulse
X10 1V to 7V p-p pulse
1MΩ X1 100 mV to 1V p-p pulse
X10 1V to 10V p-p pulse

Dynamic range for rms sine wave is one-third of the above values.

Signal Operating Range:

50Ω X1 −2.5V to 1V
X10 −7V to 7V
1 MΩ X1 −2.5 to 1V
X10 −25V to 10V

Coupling: AC or DC switch selectable.

Minimum Pulse Width: 5 ns

Maximum Input:

50Ω X1 ±7V DC
7V rms below 5 MHz
3.5V rms (+24 dBm) above 5 MHz
X10 ±7V DC, 7V rms (+30 dBm)
1MΩ X1 ±350V DC
250V rms to 20 KHz decreasing to 3.5V rms above 5 MHz
X10 ±350V
250V rms to 20 KHz decreasing to 35V rms above 5 MHz

Common Input

All specifications are the same as for separate operation with the following differences:
Impedance: 1 M Ω becomes 500 K Ω shunted by <60pF. 50 Ω same as in separate.
Sensitivity: (preset)

50Ω X1 200mV p-p, 70 mV rms
X10 2V p-p, 700 mV rms
1M Ω same as in separate

Dynamic Range: (preset)

50 Ω X1 200mV to 2V p-p pulse
X10 2V to 5V p-p pulse
1M Ω Same as in separate

Maximum Input:

50 Ω ±5V DC or 5V rms
1MΩ same as in separate

Attenuators: Becomes X2 and X20 for 50

Frequency and Period Measurements

Frequency Range: 0 to 100 MHz
Period Range: 10 ns to 10 seconds
Resolution: $\frac{20\text{ ps}}{\text{Gate Time}}$
Internal Gate Time: 1 period 0.01, 0.1, 1 seconds
Accuracy: $\frac{100\text{ ps rms} \pm \text{trigger error}}{\text{Gate Time}} \pm \text{time base}$
Period/Frequency Statistics: (1 period gate only) mean, standard deviation, maximum, minimum
Sample Size: 1, 100, 1000, 10,000, 100,000
External Gate Input: 20 ns to 10s/sample size
Time Interval Measurements
Time Interval Range:

± Mode −10 seconds to +10 seconds
+ Only Mode 10 ns to 10 seconds

Time Interval Statistics: Mean, Standard deviation, maximum, minimum
Sample Size: 1, 100, 1000, 10,000, 100,000
Minimum Time Between Measurements: 330 μs
Resolution: $\frac{\pm 20\text{ ps}}{\sqrt{\text{sample size}}} \pm 2\text{ ps}$
Accuracy: jitter ±700 ps systematic ± time base † ± trigger error/$\sqrt{N}$
Jitter: $\frac{35\text{ ps rms}}{\sqrt{N}}$ typical $\frac{100\text{ ps rms}}{\sqrt{N}}$ maximum
Trigger Error: $\frac{\pm 2 \times \text{noise peak voltage}}{\text{Signal Slope V}/\mu\text{s}}\ \mu\text{s}$

Trigger error due to input signal noise is usually the limiting factor in high resolution frequency measurements at low frequencies. If peak noise amplitude is greater than 10 mV, additional miscounting may occur. (This situation can arise when measuring high-level outputs of broadband synthesized signal sources.)

Timebase
Frequency: 10 MHz
Aging: $<3 \times 10^{-7}$/month
Temperature: $<2.5 \times 10^{-6}$, 0°C to 50°C
Display: 16 digits, suppressed leading zeros.
Size: 133 H x 426 W x 521 mm D (5¼" x 16¾" x 20 ½").
Weight: 32 lbs.

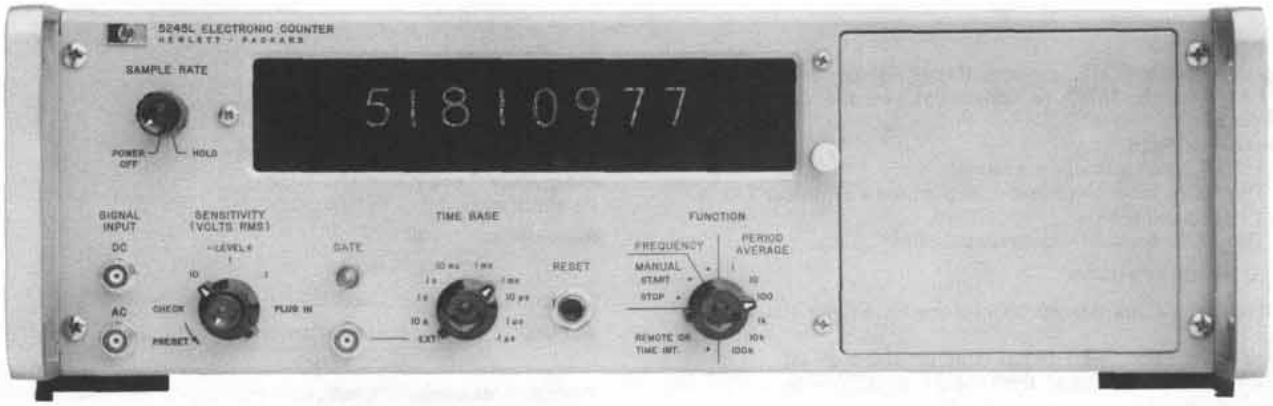
Options and Accessories	Price
001: High Stability Time Base	add $575
908: Rack Flange Kit	add $20
10870A: Service Kit	add $430
5370A Universal Time Interval Counter	**$6500**

ELECTRONIC COUNTERS

General purpose plug-in counters

Model 5245L

- High performance in a general purpose counter
- Wide selection of plug-ins provide wide versatility
- Extremely high reliability proven from over forty million hours of field operation



5245L

The 5245L has gained unprecedented popularity due to its high performance, flexibility and years of proven stability. Even though its performance has been recently upstaged by the 5345A, the 5245L is still considered the standard of the industry for instruments of this type with more 5245L counters in operation today than all other plug-in counters combined.

The 5245 series consists of a mainframe and a series of plug-ins. The plug-ins provide frequency measurement to 18 GHz and time interval capability. The wide choice of mainframes and plug-ins means that virtually any measurement task performable by counters can be accomplished by appropriate selection within this family.

The 5245 series counters are not only leaders in terms of performance and versatility, they are unsurpassed in the industry for ruggedness, wide operating temperature range, and field-proven reliability.

Specifications

5245L

Frequency measurements

Range: dc to 50 MHz.
Gate time: 1μs to 10 seconds in decade steps.
Accuracy: ±1 count ± time base accuracy.

Period average measurements

Range: dc to 1 MHz for single period; dc to 300 KHz for multiple period.
Periods averaged: 1 period to 10^5 periods in decade steps.
Accuracy: ±1 count ± 1 time base accuracy ± trigger error*

Mainframe measurement functions: frequency, period, period average, ratio, scaling.

Signal input

Sensitivity: 100 mV rms.
Coupling: AC and DC.
Impedance: 1 MΩ in parallel with approx. 25 pF all ranges.
Attenuation: step attenuator provides nominal sensitivities of 0.1, 1, and 10 V rms (SENSITIVITY switch).
Trigger Level: continuously adjustable over ±3 V multiplied by the setting of the SENSITIVITY switch.

Compatible 5245 series plug-ins: all.
Time base: 10 MHz oscillator, aging rate $<3 \times 10^{-9}$/day.
Display: 8 digits.
Operating temperature range: −20°C to +65°C.
Weight: net, 14.4 kg (32 lb) with blank plug-in panel.
Size: 133 H × 425 W × 416 mm D (5¼" × 16¾" × 16⅜").

Options	Price
908: Rack Flange Kit	add $35
5245L 50 MHz Electronic Counter	**$5000**

*Trigger error is <(±.3% of one period + number periods averaged) for signals with 40 dB signal-to-noise ratio and 100 mV rms amplitude; error decreases as signal to noise ratio increases.

ELECTRONIC COUNTERS

Plug-Ins for 5245L/M, 5246L, 5248L/M & 5345A

Models 5253B—5262A

The 5245 series of plug-ins adds greatly to the versatility of the 5245 series of plug-in counters. In addition, these plug-ins enhance the measurement capability of the 5345A Electronic Counter and the 5360A Computing Counter by the use of plug-in adapters which provide an interface between the plug-in and the 5345A and 5360A mainframes. A compatibility summary for presently available plug-ins is shown below, followed by brief descriptions of the individual plug-ins. Refer to the 5245 series data sheet for complete details and specifications for all the plug-ins.

Plug-in compatibility summary

5345A compatibility (using 10590A plug-in adapter): all except the 5264A.
5360A compatibility (using 10536A plug-in adapter): all except the 5262A, 5264A, 5265A, and 5267A.
5245L/M compatibility: all.
5248L/M compatibility: all.
5246L compatibility; all except the 5264A.

5253B

5262A

Specifications

5253B Heterodyne converter — $1350

Frequency range: 50 MHz to 512 MHz.
Sensitivity: −13 dBm to +13 dBm.
Mixing frequencies: 50 to 500 MHz in 10 MHz steps.
Input coupling: ac.
Accuracy: maintains counter accuracy.
Input impedance: 50Ω.

5254C Heterodyne converter — $2000

Frequency range: 150 MHz to 3 GHz.
Sensitivity: −13 dBm to + 13 dBm.
Mixing frequencies: 0.15 to 3 GHz in 50 MHz steps.
Input coupling: ac.
Accuracy: maintains counter accuracy.
Input impedance: 50Ω.
Auxiliary outputs: 1 MHz−50 MHz.

5255A Heterodyne converter — $2750

Frequency range: 3 GHz to 12.4 GHz.
Sensitivity: −7 dBm to + dBm.
Mixing frequencies: 2.8 to 12.4 GHz in 200 MHz steps.
Input coupling: dc.
Accuracy: maintains counter accuracy.
Input impedance: 50Ω.
Auxiliary input: 1 MHz−200 MHz at 5 mV sensitivity.
Auxiliary output: 1 MHz−200 MHz.

5256A Heterodyne converter — $3225

Frequency range: 8 GHz to 18 GHz.
Sensitivity: −7 dBm to +10 dBm.
Mixing frequencies: 8 to 18 GHz in 200 MHz steps.
Input coupling: dc.
Accuracy: maintains counter accuracy.
Input impedance: 50Ω
Auxiliary input: 1 MHz−200 MHz at 5 mV sensitivity.
Auxiliary output: 1 MHz−200 MHz.

5257A Transfer oscillator — $3500

Frequency range: 50 MHz to 18 GHz.
Input signal: CW, pulsed RF or FM modulated.
Sensitivity: −7 dBm, 50 MHz to 15 GHz; −4 dBm, 15 GHz to 18 GHz.
APC lock range: approximately ±0.2% of input frequency.
Pulse carrier frequency measurements: minimum pulse width: 0.5 μs. Minimum repetition rate: 10 pulses per second.
Input impedance: 50Ω.
VFO stability: typically 1 x 10^{-7} per minute after 2 hours.

5262A Time interval unit — $800

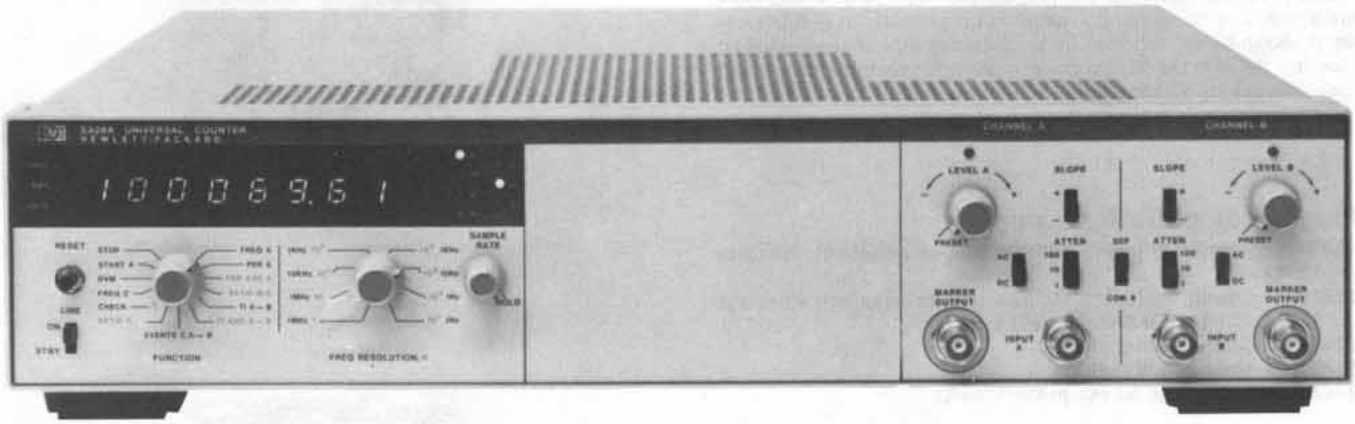
Range: 1μs to 10^8 s
Resolution: 0.1 μs.
Input sensitivity: 100 mV rms.
Start-Stop: independent or common channels.
Trigger slope: positive or negative on Start and Stop channels, independently selected.
Trigger amplitude: both channels adjustable from −250 to + 250 V peak.
Input repetition rate: better than 2 MHz.
Input impedance: from 10 kΩ/80 pF at x0.1 multiplier setting to 10 MΩ/20 pF at x 100 setting.

ELECTRONIC COUNTERS

100 MHz Universal counter

Model 5328A

- 100 MHz, 512 MHz and 1300 MHz
- 100 ns or 10 ns time interval
- T.I. averaging to 10 ps resolution
- "Armed" measurements
- DVM options
- HP-IB interface option



HP-IB Model 5328A

Description

The 5328A, thru the use of the latest technology (such as a ROM controlled measurement cycle) and a modular design, provides you with the optimum in universal counter price/performance. Optional modules allow you to tailor the performance of the 5328A to meet your particular measurement needs. In many instances, however, the standard 5328A offers all the capability you're ever likely to need.

Burst and CW measurements to 100 MHz: special gating circuits start a measurement only when the input signal is present, allowing burst frequencies to be measured as easily as CW signals. The option 030 channel C extends this capability to 512 MHz; option 031, to 1300 MHz.

Single shot time interval measurements: the standard universal module's 100 ns single shot resolution meets or exceeds the requirements for a wide range of applications such as mechanical and electromechanical device timing (relays), time of flight measurements (ballistics), sonar ranging, radio ranging and navigation

Time interval averaging: resolution better than 10 ps (10^{-11} seconds) for repetitive time intervals as short as 100 ps.

Period, period average, ratio, totalize, scale: extra problem solving power for your special requirements.

Armed measurements: versatile arming modes (controlled by a rear panel switch) allow real time control over when a measurement begins. Useful for measurements such as frequency burst profile and frequency sweep linearity.

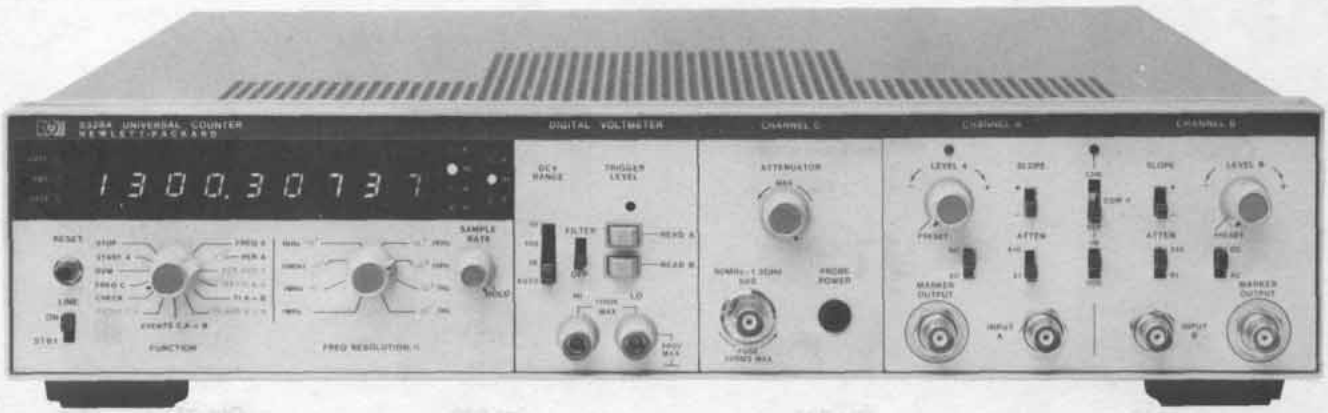
Trigger lights: trigger light blinks when channel is triggering; light is ON when input is above trigger level; OFF when input is below trigger level. Simplifies trigger level adjustments.

High performance marker outputs: marker outputs (operational to 100 MHz) indicate where channel is triggering in real time for oscilloscope monitoring applications. Provides measurement feedback to the operator for greatly simplified measurement set-ups.

These features and capabilities make the 5328A an excellent choice for general purpose lab use, electronic service, and production test. For more demanding applications, a variety of options offer extended performance at a modest increase in price.

Summary of characteristics

Model No.	Description	Features
5328A	Universal Counter	Frequency to 100 MHz; 100 ns single shot T.I.; T.I. averaging; Period; Period Avg; ratio; totalize
Opt. 010	High Stability Time Base	Oven oscillator with aging rate $<5 \times 10^{-10}$/day
Opt. 011	HP-IB Interface	Allows 5328A to output data and be controlled via the HP Interface Bus.
Opt. 020	DVM	Single ended DVM for trigger level and external voltage measurements
Opt. 021	High Performance DVM	Floating DVM for trigger level and high accuracy external voltage measurements.
Opt. 030	512 MHz Channel C	Frequency measurements to 512 MHz; 9 digit display.
Opt. 031	1300 MHz Channel C	Frequency measurements to 1300 MHz; 9 digit display.
Opt. 040	High Performance Universal Module	Same as standard 5328A but with 10 ns single shot T.I.; improved T.I. averaging; improved T.I. accuracy; measurements with delay; T.I.A→B marker; hysteresis compensation; switchable input impedance (1 MΩ/50Ω).
Opt. 041	Programmable Input Module	Full remote programming of all universal module controls thru opt. 011; 10 ns single shot T.I.; switchable 1 MΩ/50Ω input impedance.



5328A with Opt 021, 031, 041

5328A Option descriptions

High stability time base (Opt 010)

The standard time base for the 5328A is a room temperature 10 MHz crystal providing a long term aging rate of less than 3 parts in 10^7 per month. The option 010 oven oscillator offers excellent short term and temperature stability which can contribute to higher measurement accuracy. The low aging rate of $<5 \times 10^{-10}$/day permits longer intervals between time base calibrations.

HP Interface Bus for systems use (Opt 011)

The option 011 HP-IB Interface brings the full capability and power of the HP Interface Bus. The 5328A can accept program code words over the HP-IB which remotely program various front and rear panel controls. In addition, measurement results may be output over the bus to HP-IB compatible instruments, calculators, or computers.

Remotely programmable controls include FUNCTION selection, RESOLUTION selection, ARMING, SAMPLE RATE (max. or manual), RESET, measurement modes, output modes, and display modes. Option 041 adds programming of channel A and B input signal conditioning controls.

Digital voltmeters (Opt 020, 021)

The unique combination of an integrating digital voltmeter with a universal counter produces a superb general purpose measuring instrument. By using a voltage to frequency conversion technique, the incremental cost of adding DVM capability to the 5328A is very low.

Two DVM options are available; the option 020 DVM with single-ended input and the option 021 High Performance DVM with floating input. You can use these DVMs to measure channel A and B trigger levels and external voltages. Since a built-in DVM greatly simplifies time interval measurement set-ups, it is highly recommended that one of the DVM options be selected, particularly if time interval measurements are one of your major applications.

High frequency channel C (Opt 030, 031)

With a high frequency channel C module the 5328 is ideally suited for use in a wide variety of communications measurements. Option 030 gives direct count measurements to 512 MHz with 15 mV rms sensitivity; option 031 counts to a full 1300 MHz with 20 mV rms sensitivity. Typical applications include servicing, maintaining, calibrating, and monitoring communications trasmitters and receivers such as found in two-way radio, radio and television broadcasting, mobile radio, and common carrier multiplexing and transmission.

Extended capability universal modules (Opt 040, 041)

Options 040 and 041 give extended performance for time interval measurements. Option 040 is designed for bench use and includes "delay" capability for increased measurement versatility. Option 041 adds full programming of the input signal conditioning controls.

Both of these options generate a 100 MHz clock to give 10 ns single shot resolution for time interval measurements. This resolution is useful in applications such as computer/peripheral timing measurements, logic timing measurements, radar ranging, and optical ranging.

For improved time interval averaging performance, the options have input channels adjusted for delay matching to better than 2 ns. Additionally, options 040 and 041 use a jittered clock in T.I. AVG. function to give averaging even for those cases when the input repetition rate is synchronous with the counter's internal time base.

Selectable input impedance adapts the counter to the measurement environment: 50Ω for fast signals in a 50Ω environment, 1 MΩ to reduce circuit loading or to use with scope probes.

The "delay" feature of option 040 allows you to disable the inputs from triggering for selected periods of time (20 μs to 20 ms). Delay is useful for ignoring high amplitude noise such as from chattering relays or ignoring stop pulses in multiple stop T.I. measurements.

Option 041 allows remote programming of input trigger level, slope, coupling, and attenuator setting. Under remote control, the input impedance is independently selectable on the A and B channels. Also, a remote "Invert" function switches the A and B channel signals internally. "Invert" gives exceptional flexibility for two channel time interval measurements.

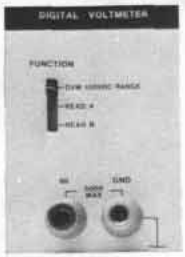
Retrofit kits

Retrofit kits, available for all options, allow you to upgrade the performance of your 5328A in response to your changing measurement requirements.

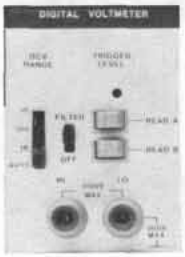
The condensed specifications on the following pages highlight some of the important performance characteristics of the 5328A and its options. Complete specifications and detailed applications information are available in the 5328A data sheet.

ELECTRONIC COUNTERS

Model 5328A (cont.)

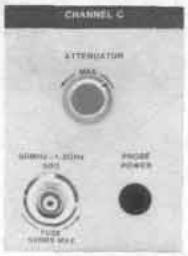


Opt 020
DVM



Opt 021
High Performance DVM

Opt 030
512 MHz
Channel C



Opt 031 1300 MHz
Channel C

10855A Preamp

Digital voltmeter modules

Digital voltmeter measurements†

DVM (Opt 020 and 021): trigger levels of input channels A and B and external voltages may be measured.

Maximum sensitivity	Opt 020	Opt 021
Meas. time: 10 s (N = 10^7) 1 s (N = 10^6) 0.1 s (N = 10^5) 10 ms (N = 10^4) 1 ms (N = 10^3)	 1 mV 1 mV 2 mV 20 mV 200 mV	 10 μV 100 μV 1 mV 10 mV 100 mV
Range	0 to ±125 V dc	±10, ±100, ±1000 V dc, and Autorange
Accuracy (20 min. warm-up)	±0.5% reading ±4 mV	±0.03% reading ±0.004% range; for 1000 V range: ±0.087% reading ±0.004% range
Input terminals	Single ended	Floating pair
Input impedance	10 MΩ	10 MΩ
Normal mode rejection ratio	>60 dB at 60 Hz (50 Hz) ±0.1%	>80 dB at 50 Hz or greater with filter on
Effective common mode rejection ratio (1 kΩ unbalance)		DC: >120 dB AC: >120 dB for multiples of 60 Hz (50 Hz) with filter on
Maximum input	±500 V	HI to LO: ±1100 V all ranges; LO to chassis ground: ±500 V
Trigger level measurements	2 mV display *resolution*	1 mV display resolution: trigger level reading automatically multiplied by setting of attenuator switch if using Opt 040 or 041 universal modules

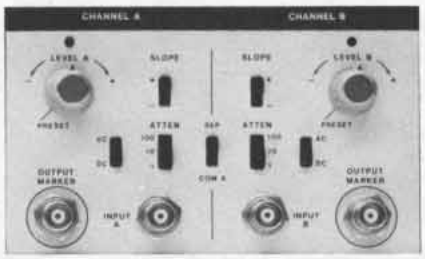
†Performance: 60 days at 23°C ±5°C and RH <80%

Channel C modules

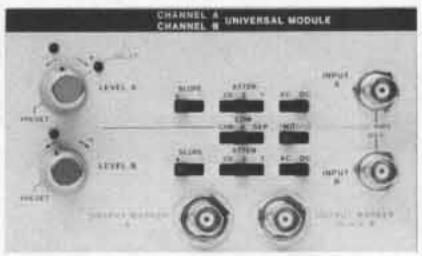
Input characteristics	Opt 030	Opt 031
Sensitivity	15 mV rms	20 mV rms
Coupling	dc	ac
Trigger level	0 V, fixed	0 V, fixed
Impedance	50Ω	50Ω
Maximum input	5 V rms	5 V rms, ±5 V dc
Input protection	fused	fused
Attenuator	No	Variable for optimum noise suppression on signals to 5 V rms
Frequency C measurements		
Range	5-512 MHz (direct count)	90-1300 MHz (prescaled, ÷4)
Resolution	1 MHz to 0.1 Hz in decade steps	1 MHz to 0.1 Hz in decade steps
Accuracy	±1 count ± time base error	±1 count ± time base error
Ratio C/A measurement		
Range: A C	0-10 MHz 5-512 MHz	0-10 MHz 90-1300 MHz
General		
Probe power	No	*Power to operate* 10855A Preamp or HP active probe

Events C, A to B (with Opt 030 only)

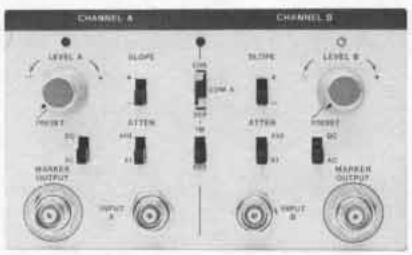
The number of events at the C input are totalized during the synchronized time interval defined by inputs to channels A and B. The synchronized time interval is a multiple of 100 ns with the standard universal module; a multiple of 10 ns with Opt 040 or 041 universal modules.



Standard
Universal Module



Opt 040
High Performance
Universal Module



Opt 041
Programmable Input
Universal Module

Accessories

10855A Preamp: (for use with Opt 031): gives >22 dB gain with ±1 dB flatness over the entire frequency range of the Opt 031 1300 MHz Channel C. For more details see page (14.30).

Universal modules, channels A and B

Input characteristics	Standard	Opt 040, Opt 041
Sensitivity:		
0–40 MHz (dc coupled)	25 mV rms	25 mV rms
20 Hz–40 MHz (ac coupled)	25 mV rms	25 mV rms
40–100 mHz	50 mV rms	50 mV rms
Min pulse width	5 ns, 140 mV p-p	
Coupling	ac or dc, switchable	
Impedance	1 MΩ, 40 pF shunt	1 MΩ or 50Ω, switchable
Trigger level	variable ±2.5 V times atten. setting	
Trigger slope	independent selection of + or − slope	
Attenuators	X1, X10, X100	Opt 040: X1, X2, X20 Opt 041: X1, X10
Dynamic range	25 mV to 1 V rms times attenuator setting for 0–40 MHz; 50 mV to 500 mV times attenuator setting for 40–100 MHz	
Channel input	Separate or Common A	Separate, Common A, or Check
Delay	No	Opt 040 only: 20μs to 20 ms
Programmable Controls	No	Opt 041 only: level, slope coupling, atten, impedance SEP-COM-CHK

Frequency A measurement

Range	0–100 MHz, direct count
Resolution	1 MHz to 0.1 MHz in decade steps
Accuracy	±1 count ± time base error

Period A measurement

Range	0–10 MHz	
Resolution	100 ns to 1 s in decade steps	10 ns to 0.1 s in decade steps
Accuracy	±1 count ± time base error ± trigger error*	

Period Average A measurements

Range	0–10 MHz	
Resolution	100 ns to 0.01 ps in decade steps	10 ns to 0.01 ps in decade steps
Accuracy	±1 count displayed ± time base error ± $\frac{\text{trigger error*}}{N}$	

Time interval A to B measurements

Range	100 ns to 10^8 s	10 ns to 10^7 s
Resolution	100 ns to 1 s in decade steps	10 ns to 0.1 s in decade steps
Accuracy	±1 count ± time base error ± trigger error*	

Time interval average A to B

Range	0.1 ns to 10 s	0.1 ns to 1 s
Resolution	$\pm\frac{100\text{ ns} \pm \text{trigger error*}}{\sqrt{N}} \pm 10$ ps	$\pm\frac{10\text{ ns} \pm \text{trigger error*}}{\sqrt{N}} \pm 10$ ps
Accuracy	± resolution ±4 ns ± time base error	± resolution ±2 ns ± time base error
Min. pulse width	25 ns	10 ns
Min. dead time (from each stop event to next start event)	150 ns	40 ns

Ratio B/A measurement

Range: A	0–10 MHz
B	0–100 MHz

Totalizing and scaling, Start A

The number of counts at the A input are totalized for N = 1 on the resolution switch. For N>1, A/N is totalized and the scaled output (A/N) is available at the Time Base Out rear panel connector.

Range: N = 1	0–100 MHz
N>1	0–10 MHz

* Trigger error is <0.3% of one period for sinewaves of 40 dB S/N or better and amplitude equal to sensitivity of counter. For any waveshape, trigger error is less than

$$\frac{\pm 2 \times \text{peak noise voltage}}{\text{signal slope}}$$

$$\left(\text{or } \frac{\pm 0.025\mu s,}{\text{signal slope in V}/\mu s} \text{ for 40 dB S/N.}\right)$$

ELECTRONIC COUNTERS

Model 5328A (cont.)

Measurements with delay (Opt 040)

Delay mode is activated by the inner concentric knob on Level A control of option 040 Universal Module. A red LED indicates delay is activated. In delay mode, Channel A triggers and is then disabled from triggering again until the delay times out (disabled state occurs within 1 μs after triggering.) Channel B is continuously disabled until the delay times out. After the delay, both A and B are enabled. The delay time may be measured by placing the counter in T.I.A→B and the Universal Module in check (CHK).

Delay range: 20 μs to 20 ms continuously adjustable.

Minimum dead time: 1 μs between stop and next start (T.I. average measurements only).

General

Display: 9 digit LED display, ninth digit used only with channel C functions (FREQ. C, Ratio C/A, Events C, A→B).

Blanking: suppresses display of unwanted zeros to left of most significant digit.

Storage: holds reading between samples; can be overriden by rear panel switch.

Sample rate: variable from less than 2 ms between measurements to HOLD which holds display indefinitely.

Gate output: rear panel output, TTL levels; high when counter gate open.

Time base output: rear panel output: TTL levels.

Check signal: with function switch in CHECK, counter should display 10 MHz ±1 count. With options 040 and 041, place function switch in FREQ A and universal module in CHECK (CHK). Counter should display 100 MHz ±1 count.

Trigger lights: light is ON when input is above trigger level; OFF when input is below trigger level; BLINKING when channel is triggering. Operate over full frequency range of 0-10 MHz.

Marker outputs: indicate actual change of state of input Schmitt trigger for channels A and B with <20ns delay. Output levels into 50Ω are 0 to −100 mV for the standard universal module, 0 to −50 mV for option 040, and 0 to +1 V for option 041. Outputs are protected from inadvertently applied voltage to ±5 V dc.

Arm: rear panel switch turns arming ON or OFF. With arming ON the measurement is armed by an input other than the input involved in the measurement. The following are armed by an event at B: Freq A, Period A, Period Avg A, Freq C, DVM, Ratio C/A; the following are armed by an event at C: T.I. A→B, Ratio B/A.

Operating temperature: 0° to 50°C.

Power requirements: 100/120/220/240 V rms, +5%, −10% (switch selectable), 48-66 Hz; 150 VA max.

Time base oscillators

Standard crystal oscillator

Frequency: 10 MHz.
Aging rate: $<3 \times 10^{-7}$/month.
Temperature: $<2.5 \times 10^{-6}$, 0° to 50°C.
Line voltage: $<1 \times 10^{-7}$ for 10% change.

Opt 010 oven oscillator

Frequency: 10 MHz.
Aging rate: $<5 \times 10^{-10}$/day after 24-hour warm-up.
Short term: $<1 \times 10^{-10}$ rms/s.
Temperature: $<7 \times 10^{-9}$, 0° to 50°C.
Line voltage: $\pm 5 \times 10^{-9}$ for 10% variation.
Warm-up: within 5×10^{-9} of final value in 20 min.

Ext. freq. std. input: 30 kHz to 10 MHz signal of amplitude >1.0 V rms into 1 kΩ. Maximum input: 5 V p-p. With options 040 and 041 the following constraints apply: ext. freq. std. must be 10 MHz for Period Avg., T.I. Avg., Period (N = 1), and T.I. (N = 1).

HP-IB Interface (Opt 011)

Option 011 provides digital output of measurement data ("talker") as well as input for remote program control ("listener").

Programmable features: function, resolution, sample rate (max or manual control), arming, display modes, measurement cycle modes, output modes, and reset commands. Option 041 adds control of channel A and B trigger level, slope, attenuator, coupling, input impedance, and SEP-COM-CHECK selection.

HP-IB commands: responds to the following bus commands (see HP-IB Users Guides for definitions)—Unlisten, Untalk, Local Lockout, Device Clear, Serial Poll Enable, Serial Poll Disable, Go to Local, Selected Device Clear, and Group Execute Trigger.

Service request (SRQ): if enabled, indicates end of measurement.

Maximum data output rate: 500 readings/sec.

Accessories

5363A Time Interval Probes: solve many of the "hidden" problems of precision time interval measurements. The 5363A Time Interval Probes minimize circuit loading, give calibrated trigger level settings, increase input dynamic range, and allow diffential channel delay calibration. See page 318 for more details.

Options and accessories	Price
010: High Stability Time Base	$525
011: HP-IB Interface	$350
020: DVM	$200
021: High Performance DVM	$500
030: 512 MHz Channel C	$400
031: 1300 MHz Channel C	$600
040: High Performance Universal Module	$350
041: Programmable Input Controls Module	$950
907: Front Handle Kit	$15
908: Rack Flange Kit	$10
909: Rack Flange and Front Handle Combination Kit	$20
10855A Preamp	$225
5363A Time Interval Probes	$2250
5328A Universal Counter	**$1300**