Specifications and Operating Characteristics

19

Chapter Contents

- specifications of the HP 54121T
- operating characteristics

Specifications

Channels (Vertical)[1]

	20 GHz Bandwidth Mode[2]	12.4 GHz Bandwidth Mode
Bandwidth (−3 dB)	dc to 20 GHz, Channels 2, 3, & 4 (Channel 1 is -3.5 dB @ 20 GHz) dc to 18 GHz, Channel 1	dc to 12.4 GHz
Transition Time (10% to 90%) (calculated from $T_r = 0.35/BW$)	≤ 17.5 ps, Chs 2, 3, & 4 ≤ 19.4 ps, Ch 1	≤ 28.2 ps
Maximum Noise (RMS)	≤ 2 mV	≤ 1 mV
Scale Factor (full-scale is 8 divisions)		
Minimum	1 mV/div	1 mV/div
Maximum	80mV/div	80mV/div
dc Accuracy Single Voltage Marker[3]		
Average mode:	±0.4% of full-scale or marker reading (whichever is greater) ±2 mV	±0.4% of full-scale or marker reading (whichever is greater) ±2 mV
Persistence mode:	±0.4% of full-scale or marker reading (whichever is greater) ±2 mV ±3.0% of (reading minus channel offset)	±0.4% of full-scale or marker reading (whichever is greater) ±2 mV ±1.5% of (reading minus channel offset)

dc Difference Voltage Accuracy Using Two Voltage Markers On The Same Channel[3]		
Average mode	± 0.8% of full-scale or delta marker reading (whichever is greater)	± 0.8% of full-scale or delta marker reading (whichever is greater)
Persistence mode	± 0.8% of full-scale or delta marker reading (whichever is greater) ± 3.0% of delta marker reading	± 0.8% of full-scale or delta marker reading (whichever is greater) ± 1.5% of delta marker reading

Programmable dc Offset[4]	Channel offset: ± 500 mV

Inputs:	
Number	Four
Dynamic Range	± 320 mV relative to channel offset
Maximum Safe Input Voltage	± 2 V dc ± ac peak (16 dBm)
Nominal Impedance	50 Ω
Percent Reflection	≤ 5% for 30 ps risetime
Connectors	3.5 mm (m)

1. When operated within ± 5° C (± 9° F) of the temperature of the last front panel calibration.
2. The input samplers are biased differently for increased bandwidth in the 20 GHz bandwidth mode.
3. When driven from a 0 Ω source
4. An effective offset of ± 820 mV can be achieved by using the ± 500 mV of channel offset and adding ± 320 mV of offset with the waveform math offset scaling function.

TDR System

	Combined Oscilloscope and TDR Performance	Normalized Characteristics[1]
Risetime[2]	≤ 45 ps[3]	Adjustable-allowable values based on timebase setting Minimum: 10 ps or 0.08 X Time/div, whichever is greater Maximum: 5 X Time/div
Flatness[2]	≤ ± 1% after 1 ns from edge; ≤ ± 5%, − 2% to 1 ns from edge	± 0.1%
Levels: Low High	0 V ± 2 mV + 200 mV ± 2 mV	0 V ± 2 mV + 200 mV ± 2 mV

[1] Normalized information is a characteristic not a specification. The information is presented here for comparison purposes only. Normalization characteristics are achieved only with the use of the normalization calibrations and firmware routines.

[2] Measured in the 12.4 GHz Bandwidth and Average Display Modes.

[3] The risetime of the generator is less than 35 ps, as calculated by

$(Tr\ system)^2 = (Tr\ generator)^2 + (Tr\ Scope)^2$

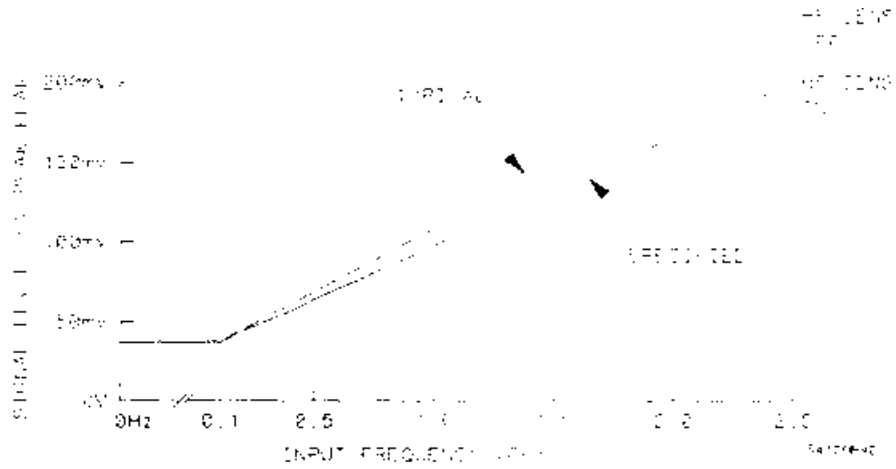
Timebase (**Horizontal**)

Scale Factor (full-scale is 10 divisions)	
Minimum	10 ps/division
Maximum	1 s/division
Delay (time offset relative to trigger)	
Minimum	16 ns
Maximum	1000 screen diameters or 10 seconds, whichever is smaller
Time Interval Accuracy (Dual marker measurement)	≤ 10 ps ± 0.1% of reading
Time Interval Resolution	0.25 ps[1] or 0.02 division whichever is greater

[1] At 10 ps/division, data points are plotted at 0.2 ps intervals to match the display pixel resolution.

Trigger-External Input Only

Sensitivity (With HF Sensitivity ON)	40 mV peak-to-peak from dc to 100 MHz increasing linearly to 200 mV peak-to-peak at 2.5 GHz.



Pulse Width	200 ps for pulses ≥ 200 mV
Trigger Level Range	± 1 V
Jitter (Trigger and timebase combined) (one standard deviation)	≤ 2.5 ps + 5E-5 x delay setting tested using a 2 GHz synthesized source at 200 mV peak-to-peak with High Frequency Sensitivity ON and High Frequency Reject OFF
Trigger Input:	
Maximum Save Input Voltage	± 2 V dc + ac peak (16 dBm)
Nominal Impedance	50 Ω
Percent Reflection	≤ 10% for 100 ps risetime
Connnector	3.5 mm(m)

Operating Characteristics

Channels (Vertical)

Scale Factors : Adjustable from 1 mV/div to 80 mV/div in a 1-2-5-10-20-50-80 sequence from the RPG control or the increment decrement keys. Also adjustable over the range in 1 mV increments from the numeric keypad.

Attenuation Factors : Factors may be entered to scale the oscilloscope for external attenuators connected to the channel inputs.

Noise: Averaging reduces noise by $1/\sqrt{n}$, where n is the number of averages, until a system limitation of approximately 35 μV is reached. Typical noise is:

Display Mode	Noise (RMS)
20 GHz bandwidth, Avg = 1	1.2 mV RMS
20 GHz bandwidth, Avg = 256	80 μ V RMS
20 GHz bandwidth, persistence	1 mV RMS
12.4 GHz bandwidth, Avg = 1	500 μ V RMS
12.4 GHz bandwidth, Avg = 256	35 μ V RMS
12.4 GHz bandwidth, persistence	400 μ V RMS

Channel-to-channel Isolation : 60 dB

Timebase (Horizontal)

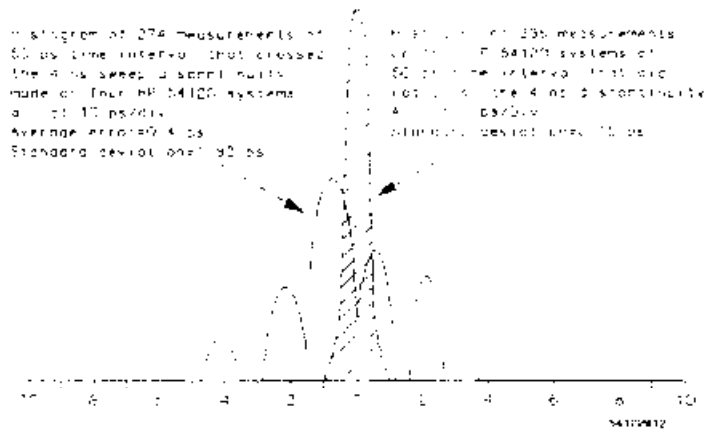
Delay Between Channels: The difference (up to 100 ns) in delay between channels can be nulled out in 1 ps increments to compensate for differences in input cables or probe length.

Reference Location: The reference point can be located at the left edge or center of the display. The reference point is that point where the time is offset from the trigger by the delay time.

Triggered Mode: Causes the oscilloscope to trigger synchronously to the trigger input signal.

Free Run Mode: Causes the scope to generate its own triggers at a user specified rate (between 15.3 Hz and 500 kHz). Used with the Channel 1 step generator for TDR and transmission measurements. The channel 1 step may also be used to trigger a device under test to view information prior to the trigger.

Typical Accuracy: The timebase consists of a series of 4 ns blocks. Small discontinuities across these blocks is a major contribution to the 10 ps accuracy specification. The graph below is the result of many measurements on 8 instruments.



Trigger

Attenuation Factors: Factors may be entered to scale the oscilloscope for external attenuators connected to the trigger input.

Edge Trigger: Triggers on the positive or negative edge of the trigger source.

HF Sensitivity: When on hysteresis is suppressed for increased sensitivity at high frequencies. When off, hysteresis is added to the trigger comparator to reduce the effect of noise.

High Frequency Reject: Limits Trigger Bandwidth to approximately 100 MHz

Display

Data Display Resolution: 501 points horizontally X 256 points vertically.

Data Display Formats

Full screen: All channel displays are superimposed and are eight divisions high.

Split screen: With four graphs, channels are displayed separately and are two divisions high; or with two graphs, channels 1 and 3 are superimposed and channels 2 and 4 are superimposed and are four divisions high.

Display Modes

Persistence: The time that each data point is retained on the display can be varied from 300 ms to 10 seconds, or it can be displayed infinitely.

Averaging: The number of averages can be specified as powers of 2, up to 2048. On each acquisition, 1/n times the new data is added to (n-1)/n of the previous value at each time coordinate. Averaging operates continously, except over HP-IB where it terminates at the specified number of averages.

Graticules : The user may choose full grid, axes with tic marks frame with tic marks, or no graticule.

Bandwidth: When in the Average or Persistence display modes, the user may select between 20 GHz and 12.4 GHz bandwidth. The 12.4 GHz bandwidth reduces noise. See channel characteristics for bandwidths and noise levels.

Display Colors: Users may choose a default color selection or select their own colors from the front panel, or over HP-IB. Different colors are used for display background, channels, functions, background text, highlighted text, advisories, markers, overlapping waveforms and memories.

Programmability

Instrument settings and operating modes, including automatic measurements, may be remotely programmed via HP-IB (IEEE-488). The HP 54121T can be programmed to take data only at specified time points, or to return only measurement results (i.e., tr, tf frequency, etc.) to speed up data acquisition.

Data Transfer Rate: 115 kbytes/s maximum (data output only)

Typical Measurement Times: 200-700 ms

Data Record Lengths:

Timebase Setting/Histogram Type	# of points/record
10 ps/div < time/div < 20 ps/div	100, or 400
20 ps/div < time/div < 50 ps/div	100, 400, or 800
50 ps/div < time/div < 200 ps/div	100, 500, or 1000
200 ps/div < time/div < 1 s/div	128, 256, 500, 512, or 1024
Voltage Histogram	256
Time Histogram	501

Measurement Aids

Markers: Dual voltage or time markers can be used for a variety of time and voltage measurements. Voltage markers can be assigned to channels, memories, or functions.

Automatic Level Set: Voltage markers may be preset to 10%-90%, 20%-80%, 50%-50%, or to user specified levels.

Automatic Edge Find: The time markers can be assigned automatically to any displayed edge of either polarity on any channel. The voltage markers establish the reference, on the edge for the time markers in this mode.

Automatic Pulse Parameter Measurements: The HP 54121T automatically takes ten pulse parameter measurements, (as defined by IEEE standard 194-1977, "IEEE Standard Pulse Terms and Definitions"). The standard measurement thresholds are 10%, 50% and 90%.

Automatic Pulse Parameter Measurements

Frequency	Risetime
Period	Falltime
Positive pulse width	Preshoot
Negative pulse width	Overshoot
Duty cycle	Vp-p voltage

Waveform Math: Any two of seven waveform math operations may be assigned to two displayable math functions. The available operations are Plus, Minus, Invert, Versus, Max, Min, and Only. Max and Min, which define an envelope about the waveform, are only available in the Persistence mode. The vertical channels or any of the waveform memories, can be used as operands for the waveform math. Function sensitivity and offset may be adjusted independently of the channel display settings.

Waveform Save: Four waveforms may be stored and displayed in four non-volatile waveform memories. Waveform memories are typically used in the Average display mode. Screen displays may be stored in two volatile pixel memories. Pixel memories are typically used in the Persistence display mode.

Networks

Reflection Measurements

Source: Measurements are made using the Channel 1 step source or a user-supplied external source.

Calibration: A reference plane is defined by calibrating the reflection channel with a short placed at the point where the device under test will be connected. The short calibration is followed with a 50 Ω calibration. These calibrations are used to derive the normalization filter.

Cursor : Reads out the percent reflection, impedance, time, and distance from the reference plane to the cursor. (See Note 2.)

Percent Reflection: Automatically calculates the maximum and minimum percent reflection of the waveform shown on screen.

Normalization Filter: Applies a firmware digital filter to the measured data and puTS the resulting waveform in memory 1. The risetime of the filter may be varied to allow the user to simulate the edge speeds, which would be seen by the device under actual operation. See TDR output specifications for allowable risetime values. Normalization also removes errors caused by discontinuities prior to the reference plane.

Note 1

Normalization utilizes the Bracewell Transform, which is under license from Stanford University.

Note 2

Percent reflection measurements** should be used to quantify reactive peaks and valleys of the TDR display. Impedance measurements are valid only for resistive horizontal flat line TDR displays. **Because the accuracy depends on the** measurement being made, percent reflection and impedance accuracies **are not specified. Percent reflection and** impedance measurements are ratios of voltage measurements whose accuracies **are specified.

$$\text{Percent Reflection (Rho)} = \frac{(\text{Vcursor} - \text{Vtop})}{(\text{Vtop} - \text{Vbase})}$$

$$\text{Impedance (Z)} = 50\,\Omega \times \frac{(1 + \text{Rho})}{(1 - \text{Rho})}$$

Where:

Vcursor = voltage at the cursor
Vtop = high level of calibration reflected step
Vbase = low level of calibration reflected step and are determined during the reflection calibration.

Distance measurements are subject to the accuracy of the velocity factor or dielectric constant entered by the user. Since the HP 54121T has no control over the accuracy of these numbers distance accuracy is not specified. Distance is derived from time interval measurements whose accuracies are specified.

$$\text{Distance (d)} = 1/2 \text{ X } \frac{\Delta t}{\text{Velocity Constant}} =$$

Where Δt = time from the reference plane to the cursor.

Dielectric Constant = $(3 \times 10^8 \text{ m/s})^2$ (Velocity Constant)^2

Where the user enters either a relative Dielectric Constant or a Velocity Constant.

The TDR's ability to resolve the distance between two discontinuities is limited to 1/2 the system risetime. Without normalization, this is approximately 1/2 45 ps or 7 mm in air. For the distance resolution in your media, divide 7 mm by the $\sqrt{\varepsilon eff}$ of your media. With normalization the system risetime can be 10 ps yielding 1.5 mm of resolution in air.

The maximum length the TDR can measure is subject to media loss. For a lossless vacuum, and using a 15.3 Hz TDR repetition rate, the HP 54121T can measure 4900 km. Actual maximum lengths will generally be limited by the losses of the media under test.

Transmission Measurements

Source: Measurements are made using the Channel 1 step source or a user-supplied external source.

Calibration: A calibration with a straight-through path or through a user's standard device determines reference amplitude levels and reference time and distances of the signal path. These reference levels are used for gain and propagation delay measurements.

Cursor: Reads out time referenced to the calibration edge and gain referenced to the transmission calibration results. (See Note 4.)

Propagation Delay and Gain: Automatically calculates the difference in time and distance between the calibration signal path and the test signal path. Also calculates the ratio of the test signal amplitude to the calibration signal amplitude. (See Note 4.)

Normalization Filter: Applies a firmware digital filter to the measured data and puts the resulting waveform in memory 2. The risetime of the filter may be varied to allow the user to simulate the edge speeds, which would be seen by the device under actual operation. See TDR output specifications for allowable risetime values.

Note 3

Normalization utilizes the Bracewell transform, which is under license from Standard University.

Note 4

Δt = *Time of the cursor − Time of reference edge (50%)*

$$Gain = \frac{(Vtop - Vbase)\ signal}{(Vtop - Vbase)\ reference}$$

Prop Dly = Time of test edge (50%) - Time of reference edge (50%)
Distance (d) = Prop Dly / Velocity Constant
Where Vtop = High level of waveform
Vbase = Low level of waveform

Histograms

Time and voltage histograms may be taken with a user-specified number of samples (between 100 and 655,300,000) to be taken within a user-specified voltage window (time histogram) or time window (voltage histogram). To accelerate throughput when taking voltage histograms, samples are taken only in the user-specified time window.

Distribution markers: Two markers, labeled Upper and Lower Distribution Limits, indicate the cumulative occurrences of samples from the edge of the display to a given time (time histogram) or voltage (voltage histogram).

Mean and Standard Deviation: Calculates the mean and standard deviation of a distribution on screen, or between the distribution limits, assuming a Gaussian distribution.

Setup Aids

Auto-Scale: Pressing the AUTOSCALE key automatically adjusts the vertical and horizontal scale factors and the trigger level for a display appropriate to the signals applied to the inputs. The autoscale feature requires a signal with a duty cycle greater than 2% and a frequency greater than 50 Hz. Autoscale is operative only for relatively stable input signals.

Save/Recall: Up to ten front-panel setups may be saved in non-volatile memory.

Preset Reflection Channel: Sets up the instrument for making TDR measurements.

Documentation Aids

Waveforms, scaling information and measurement results can be transferred directly to HP-GL compatible digital plotters and HB-IB raster graphics printers, including the HP 2255A ThinkJet® printer and the HP 3630A printer.

Digitizer

Converter: 12-bit successive approximation A/D converter.

Resolution: The useable full-scale range of the A/D is 640 mV. One LSB of the A/D converter equals 250 μV. This gives one part in 2560 or slightly more than 11 bits of resolution. Averaging can extend the resolution to 32 μV. This increased resolution, of around 14 bits, can be seen at more sensitive ranges or over HP-IB.

Digitizing Rate: The signal is sampled and digitized at a rate dictated by the trigger repetition rate, the time base range, the display mode, and the number of channels turned on. If data acquisition is not trigger rate limited, the actual sampling and digitizing rate will vary within the following range:

a. Maximum of 10k samples per second at 10 ns/div or faster with one channel on while in infinite persistence display mode.

b. Minimum of 1k samples per second at timebase ranges of 46 m s/div or slower regardless of number of channels turned on or the display mode.

A typical sample rate is 4500 samples per second.

General Characteristics

Environmental Conditions

Temperature:
Operating: + 15° C to + 35° C (+ 59° F to + 95° F).
Non-operating: - 40° C to + 70° C (- 40° F to + 158° F)

Humidity:
Operating: Up to 90% relative humidity at + 35° C (+ 95° F)
Non-operating: Up to 95% relative humidity at + 65° C (+ 149° F)

Altitude:
Operating: Up to 4600 metres (15,000 ft)
Non-operating: Up to 15,300 metres (50,000 ft)

Vibration:
Operating: Random vibration 5-500 Hz 10 minutes per axis, ≈ 0.3 g (rms).
Non-operating: Random vibration 5-500 Hz, 10 minutes per axis, = 2.41 g (rms); and swept sine resonant search, 5-500 Hz, 0.75 g (0-peak), 5 minute resonant dwell @ 4 resonances per axis.

Power Requirements

Power requirements listed are for the combined HP 54121T system. The HP 54121A Four Channel Test Set draws its power over the provided interface cable from the HP 54120B Digitizing Oscilloscope Mainframe.

Voltage: 115/230 V ac, - 25% to + 15%, 48-66 Hz
Power: 200 watts, 400 VA maximum

Weight

HP 54120B Net: Approximately 20.5 kg (45 lb)
HP 54121A Net: Approximately 3.2 kg (7 lb)
Combined Shipping Weight: Approximately 28.2 kg (62 lb)

Dimensions

Refer to outline drawings below.

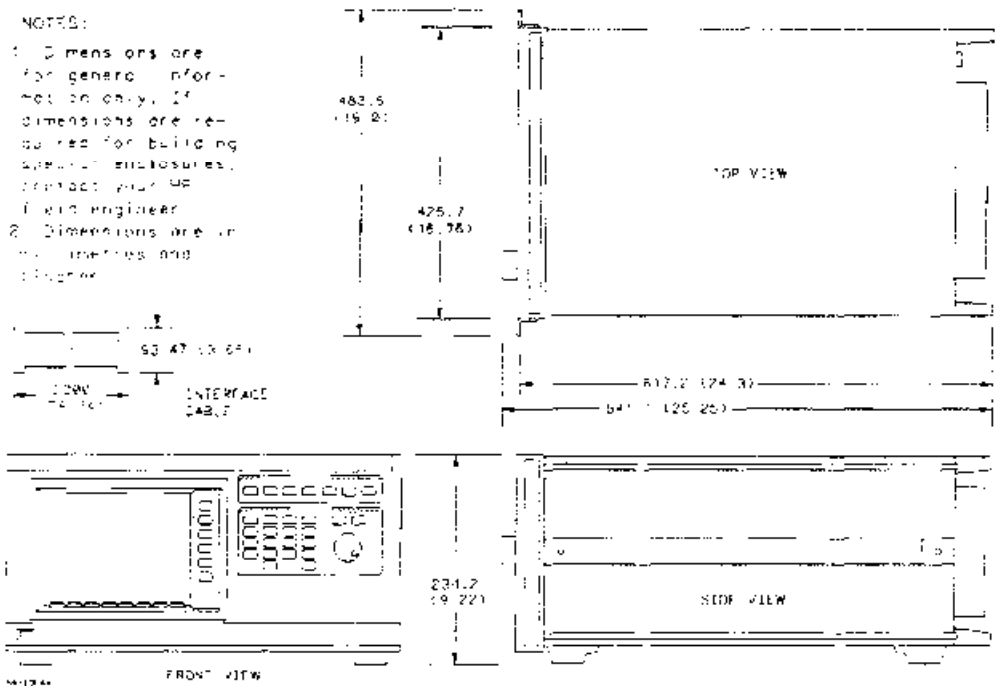


Figure 19-1. 54120B Dimensions