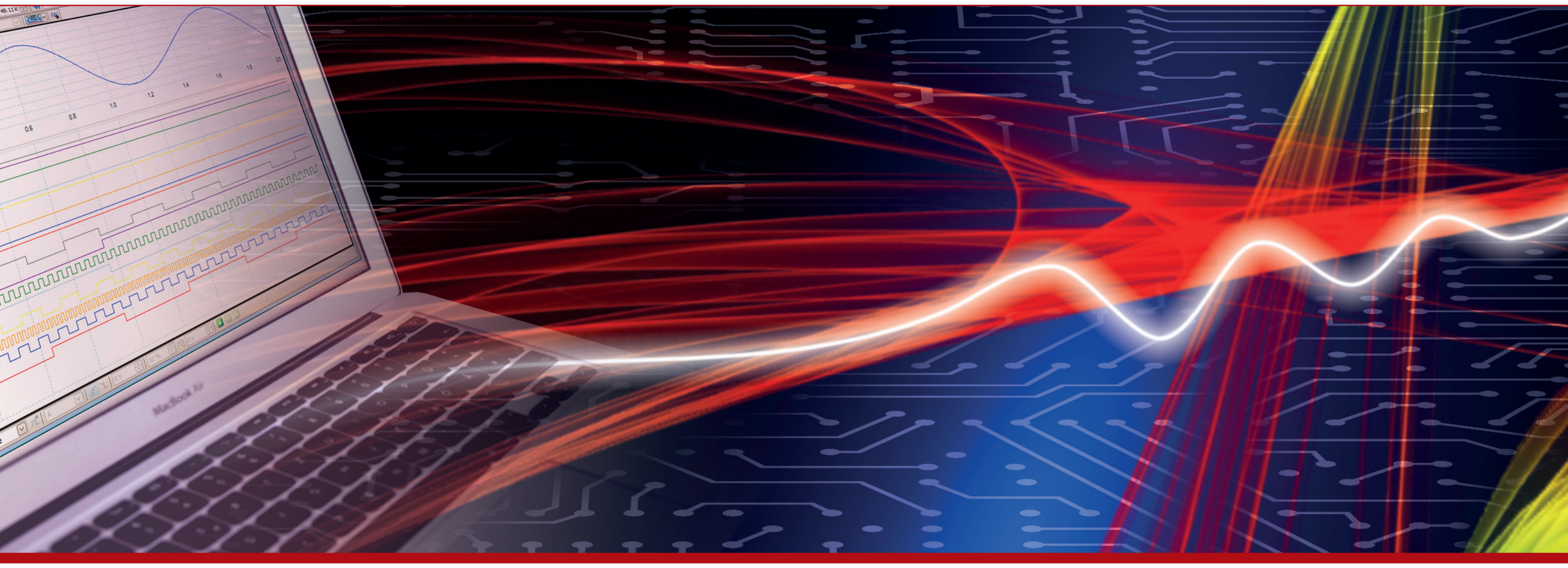
Product Datasheet - Technical Specifications



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DATA SHEET

53200A Series

RF/Universal Frequency Counter/Timers

KEYSIGHT
TECHNOLOGIES

Imagine Your Counter Doing More!

Introduction

Frequency counters are depended on in R&D and in manufacturing for the fastest, most accurate frequency and time interval measurements. The 53200 Series of RF and universal frequency counter/timers expands on this expectation to provide you with the most information, connectivity and new measurement capabilities, while building on the speed and accuracy you've depended on with Keysight Technologies, Inc. time and frequency measurement expertise.

Three available models offer resolution capabilities up to 12 digits/sec frequency resolution on a one second gate. Single-shot time interval measurements can be resolved down to 20 psec. All models offer new built-in analysis and graphing capabilities to maximize the insight and information you receive.

More bandwidth

- 350 MHz baseband frequency
- 6 or 15 GHz optional microwave channels

More resolution & speed

- 12 digits/sec
- 20 ps single-shot time resolution
- Up to 75,000 and 90,000 readings/sec (frequency and time interval)

More insight

- Datalog trend plot
- Cumulative histogram
- Built-in math analysis and statistics
- 1M reading memory and USB Flash storage

More connectivity

- LXI-C/Ethernet LAN, USB, GPIB
- Optional battery for unstable AC power or timebase accuracy

More measurement capability (53230A only)

- Continuous gap-free measurements
- Basic measurement and timestamps for modulation domain analysis (MDA)
- Pulse/burst microwave measurement

Measurement by model

Measurements	Model	Standard 350 MHz Input Channel(s)	Opt MW Inputs (53210A: Ch 2, 53220A/30A: Ch 3)
Frequency	53210A, 53220A, 53230A	•	•
Frequency ratio	53210A, 53220A, 53230A	•	•
Period	53210A, 53220A, 53230A	•	•
Minimum/maximum/ peak-to-peak input voltage	53210A, 53220A, 53230A	•	
RF signal strength	53210A, 53220A, 53230A		•
Single period	53220A, 53230A	•	
Time interval A to B, B to A, A, B	53220A, 53230A	•	
Positive/negative pulse width	53220A, 53230A	•	
Rise/fall time	53220A, 53230A	•	
Positive/negative duty	53220A, 53230A	•	
Phase A to B, B to A	53220A, 53230A	•	
Totalize (continuous or timed)	53220A, 53230A	•	
Continuous/gap-free	53230A	•	•
Timestamp	53230A	•	•
Pulse/burst measurement software[1]	53230A		•

[1] Burst carrier frequency, pulse repetition frequency (PRF), pulse repetition interval (PRI), burst positive width ("on" time), burst negative width ("off" time).

Input Channel Characteristics

Input characteristics (nom)	53210A	53220A	53230A
Channels			
Standard (DC - 350 MHz)	Ch 1	Ch 1 & Ch 2	
Optional (6 or 15 GHz)	Ch 2	Ch 3	
Standard inputs (nom)			
Frequency range			
DC coupled	DC (1 mHz) to 350 MHz (2.8 ns to 1000 sec)		
AC coupled, 50 Ω1 or 1 MΩ	10 Hz - 350 MHz		
Input			
Connector	Front panel BNC(f). Option 201 adds parallel rear panel BNC(f) inputs[2]		
Input impedance (typ)	Selectable 1 MΩ ± 1.5% or 50 Ω ± 1.5% || <25 pF		
Input coupling	Selectable DC or AC		
Input filter	Selectable 100 kHz cut-off frequency low pass 10 Hz (AC coupling) cut-off frequency high pass filter		
Amplitude range			
Input range	±5 V (±50 V) full scale ranges		
Sensitivity[3,4] (typ)	DC - 100 MHz: 20 mVpk > 100 MHz: 40 mVpk		
Noise[3]	500 µVrms (max), 350 µVrms (typ)		
Input event thresholds			
Threshold levels	±5 V (±50 V) in 2.5 mV (25 mV) steps		
Noise reject[4]	Selectable On/ Off		
Slope	Selectable Positive or Negative		
Auto-scale	Acquires signal for current measurement channel, selects range (5 V or 50 V), sets auto-level 50%		
Auto-level	Selectable On or Off On: Sets auto-level (% of Vpp) operation Occurs once for each INIT or after a timeout. Measures signal Vpp and sets Trigger level to 50% Off: Selectable user set level (Volts)		
Minimum signal frequency for auto level	User selectable (Slow (50 Hz), Fast (10 kHz))		
Minimum signal for auto level	300 mVpp		
Maximum input			
50 Ω damage level	1 W		
50 Ω protection threshold	Will not activate below 7.5 Vpk 50 Ω internal termination auto-protects by switching to 1 M Ω		
1 M Ω damage level	DC - 5 kHz: 350 Vpk (AC + DC) 5 kHz - 100 kHz: Derate linearly to 10 Vpk (AC + DC) >100 kHz: 10 Vpk (AC + DC)		

Input Channel Characteristics (continued)

	53210A	53220A	53230A
Optional microwave inputs (nom)			
Frequency range			
Option 106	100 MHz - 6 GHz		
Option 115	300 MHz - 15 GHz		
Input			
Connector	Front panel precision Type-N(f) Option 203 moves the input connector to a rear panel SMA(f)		
Input impedance (typ)	50 Ω ± 1.5% (SWR < 2.5)		
Input coupling	AC		
Continuous wave amplitude range			
Option 106	Autoranged to +19 dBm max. (2 Vrms)		
Option 115	Autoranged to +13 dBm max. (1.0 Vrms)		
Sensitivity (typ)[5]	6 GHz (Opt 106): -27 dBm (10 mVrms) 15 GHz (Opt 115): < 3 GHz: -23 dBm 3 – 11 GHz: -27 dBm > 11 GHz: -21 dBm		
Input event thresholds			
Level range	Auto-ranged for optimum sensitivity and bandwidth		
AM tolerance[6]	50% modulation depth		
Maximum input			
Damage level	6 GHz (Opt 106): > +27 dBm (5 Vrms) 15 GHz (Opt 115): > +19 dBm (2 Vrms)		

1. AC coupling occurs after 50 Ω termination.
2. When ordered with optional rear terminals, the standard/baseband channel inputs are active on both the front and rear of the universal counter though the specifications provided only apply to the rear terminals. Performance for the front terminals with rear terminals installed is not specified.
3. Multiply value(s) by 10 for the 50 V range.
4. Stated specification assumes Noise Reject OFF. Noise Reject ON doubles the sensitivity minimum voltage levels.
5. Assumes sine wave.
6. CW only. Assumes AM Rate > 10/gate. For Option 106, spec applies for input powers > -20 dBm; use a tolerance of 15% modulation depth for frequencies less than 900 MHz. For Option 115, spec applies for input powers > -10 dBm.

Measurement Characteristics

	53210A	53220A	53230A
Measurement range (nom)			
Frequency, period (average) measurements			
Common			
Channels	Ch 1 or optional Ch 2	Ch 1, Ch 2 or optional Ch 3	
Digits/s	10 digits/s	12 digits/s	12 digits/s
Maximum display Resolution[1]	12 digits	15 digits	15 digits
Measurement technique	Reciprocal	Reciprocal and resolution enhanced	Reciprocal, resolution-enhanced or continuous (gap-free)
Signal type	Continuous Wave (CW)		CW and pulse/burst
Level & slope	Automatically preset or user selectable		
Gate	Internal or external		
Gate time[2]	1 ms to 1000 s in 10 µs steps	100 µs to 1000 s in 10 µs steps	1 µs to 1000 s in 1 µs steps
Advanced gating[3]	N/A	Start delay (time or events) and stop hold-off (time or events)	
FM tolerance	± 50%		
Frequency, period			
Range[9]	DC (1 mHz) to 350 MHz (2.8 ns to 1000 s)		
Microwave input (optional)	Option 106 - 100 MHz to 6 GHz (166 ps to 10 ns) Option 115 - 300 MHz to 15 GHz (66 ps to 3.3 ns)		
Frequency ratio[4]			
Range	10^{15} Displayable range		
Timestamp/modulation domain			
Sample rate[5]	N/A	N/A	1 MSa/s, 800 kSa/s, 100 kSa/s, 10 kSa/s
#Edges/timestamp	N/A	N/A	Auto-acquired per acquisition
Acquisition length	N/A	N/A	up to 1 MSa or 100,000 s (max)
Time interval (single-shot) measurements[11]			
Common			
Channels	N/A	Ch 1 or 2	
Single-shot time resolution	N/A	100 ps	20 ps
Gating	N/A	Internal or external gate Start delay (time or events) and stop hold-off (time or events)	
Slope	N/A	Independent start, stop slopes	
Level	N/A	Independent start, stop slopes	
Channel-to-channel time skew (typ)	N/A	100 ps	50 ps

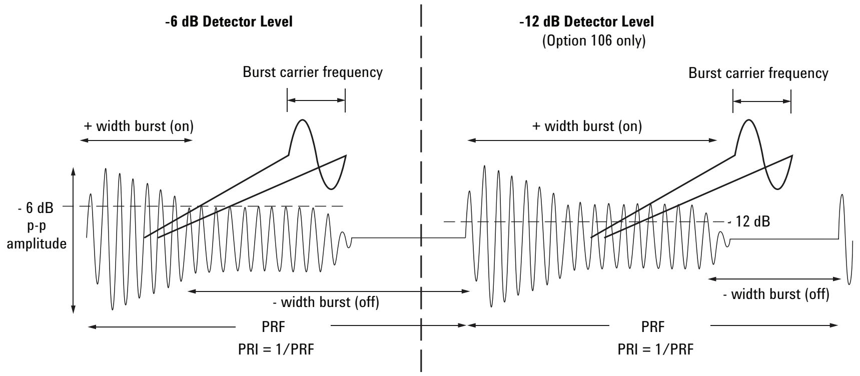
Measurement Characteristics (continued)

	53210A	53220A	53230A
Time interval A to B, B to A			
Range[9]	N/A	-1 ns to 100,000 s (nom) -0.5 ns to 100,000 s (min)	
Time interval A or B			
Range	N/A	2 ns to 100,000 s (min)	
Minimum width	N/A	2 ns	
Minimum edge repetition rate	N/A	6 ns	
Level & slope	N/A	Auto-level or user selectable	
Single-period, pulse-width, rise time, fall time			
Range	N/A	0 s to 1000 s	
Minimum width	N/A	2 ns	
Minimum edge repetition rate	N/A	6 ns	
Level & slope	N/A	Auto-level or user selectable	
Duty			
Range	N/A	.000001 to .999999 or 0.0001% to 99.9999%	
Minumim width	N/A	2 ns	
Level & slope	N/A	Auto-level or user selectable	
Phase A to B, B to A			
Range[6]	N/A	-180.000° to 360.000°	
Totalize measurements			
Channels	N/A	Ch 1 or Ch 2	
Range[9]	N/A	0 to 10^{15} events	
Rate	N/A	0 - 350 MHz	
Gating	N/A	Continuous, timed, or external gate input Gate accuracy is 20 ns	
Level measurements			
Voltage level - standard input channels	±5.1 Vpk with 2.5 mV resolution or ±51 Vpk with 25 mV resolution		
Microwave power level (microwave channel option)	0 to 4 relative signal power		

Measurement Characteristics (continued)

	53210A	53220A	53230A	
			6 GHz (Option 106)	15 GHz (Option 115)
Pulse/burst frequency and pulse envelope detector [12]				
Pulse/burst measurements	N/A	N/A	Carrier frequency, carrier period, pulse repetition interval (PRI), pulse repetition frequency (PRF), positive and negative width	
Pulse/burst width for carrier frequency measurements[10]	N/A	N/A	> 200 ns Narrow: < 17 µs Wide: > 13 µs	> 400 ns Narrow: < 17 µs Wide: > 13 µs
Minimum pulse/burst width for envelope measurements	N/A	N/A	> 50 ns	> 100 ns
Acquisition	N/A	N/A	Auto, Manual[7]	
PRF, PRI range	N/A	N/A	1 Hz – 10 MHz	1 Hz - 5 MHz
Pulse detector response time (typ)[8]	N/A	N/A	15 ns rise/fall	40 ns rise/fall
Pulse width accuracy	N/A	N/A	20 ns + (2*carrier period)	75 ns
Power ratio (typ)	N/A	N/A	> 15 dB	
Power range and sensitivity (sinusoidal) (typ)	N/A	N/A	+13 dBm (1 Vrms) to -13 dBm (50 mVrms)	< 3 GHz: +7 dBm (500 mVrms) to -6 dBm (115 mVrms) 3 - 11 GHz: +9 dBm (630 mVrms) to -8 dBm (90 mVrms) > 11 GHz: +7 dBm (500 mVrms) to -6 dBm (115 mVrms)

1. Maximum display resolution for frequency and period. Totalize display resolution is 15 digits, time interval based measurements are 12 digits.
2. Continuous, gap-free measurements limits the gate time setting to 10 µs to 1000 s in 10 µs steps.
3. Refer to the gate characteristics section for more details on advanced gate capabilities.
4. Measurements on each input channel are performed simultaneously using one gate interval. The actual measurement gate interval on each channel will be synchrounous with edges of each input signal.
5. Maximum sample rate. Actual sample rate will be limited by the input signal edge rate for signals slower than the selected sample rate. Maximum timestamp rate offers minimal FM tolerance. If high FM tolerance is required, use lower timestamp rates.
6. Assumes two frequencies are identical, only shifted in phase.
7. Manual control of gate width and gate delay are allowed only for wide pulsed mode.
8. For pulsed signals > -7 dBm (100 mVrms) while gated on.
9. For totalize, time interval and frequency measurements, you may get measurement readings beyond the range stated, but the accuracy of those readings is not specified.
10. Applies when burst width * Carrier Freq > 80.
11. Specifications apply if measurement channels are in 5 V range, DC coupled, 50 Ω terminated and at fixed level for: time interval single and dual channel, pulse width, duty, phase, single period and rise/fall time measurements.
12. Microwave pulse/burst measurement descriptions:



Gate, Trigger and Timebase Characteristics

	53210A	53220A	53230A
Gate characteristics (nom)			
Gate			
Source	Time, external	Time, external or advanced	
Gate time (step size) [1]	1 ms - 1000 s (10 µs)	100 µs - 1000 s (10 µs)	1 µs - 1000 s (1 µs)
Advanced: gate start			
Source	N/A	Internal or external, Ch 1/Ch 2 (unused standard channel input)	
Slope	N/A	Positive or negative	
Delay time[1]	N/A	0 s to 10 s in 10 ns steps	
Delay events (edges)	N/A	0 to 10^8 for signals up to 100 MHz	
Advanced: gate stop hold-off			
Source	N/A	Internal or external, Ch 1/Ch 2 (unused standard channel input)	
Slope	N/A	Positive or negative	
Hold-off time[1]	N/A	Hold-off Time settable from 60 ns to 1000 s	
Hold-off events (edges)	N/A	0 to 10^8 (minimum width (positive or negative) > 60 ns)	
External gate input characteristics (typ)			
Connector	Rear panel BNC(f) Selectable as external gate input or gate output signal		
Impedance	1 kΩ when selected as external gate input		
Level	TTL compatible		
Slope	Selectable positive or negative		
Gate to gate timing	3 µs gate end to next gate start		
Damage level	< -5 V, > +10 V		
Gate output characteristics (typ)			
Connector	Rear panel BNC(f) Selectable as external gate input or gate output signal		
Impedance	50 Ω when selected for gate output		
Level	TTL compatible		
Slope	Selectable positive or negative		
Damage level	< -5 V, > +10 V		

Trigger and Timebase Characteristics (nom)

	53210A	53220A	53230A
Trigger characteristics (nom)			
General			
Trigger source	Internal, external, bus, manual		
Trigger count	1 to 1,000,000		
Trigger delay	0 s to 3600 s in 1 µs steps		
Samples/trigger	1 to 1,000,000		
External trigger input (typ)			
Connector	Rear panel BNC(f)		
Impedance	1 kΩ		
Level	TTL compatible		
Slope	Selectable positive or negative		
Pulse width	> 40 ns min		
Latency[2]	Frequency, period: 1 µs + 3 periods time interval, totalize: 100 ns		
External trigger rate	300/s max	1 k/s max	10 k/s max
Damage level	< -5 V, > +10 V		
Timebase characteristics (nom)			
Timebase reference	Internal, external, or auto		
Timebase adjustment method	Closed-box electronic adjustment		
Timebase adjustment resolution	10^{-10} (10^{-11} for Option 010 U-OCXO timebase)		
External timebase input (typ)			
Impedance	1 kΩ AC coupled		
Level (typ)	100 mVrms to 2.5 Vrms		
Lock frequencies	10 MHz, 5 MHz, 1 MHz		
Lock range	±1 ppm (±0.1 ppm for Option 010 U-OCXO timebase)		
Damage level	7 Vrms		
Timebase output (typ)			
Impedance	50 Ω ± 5% at 10 MHz		
Level	0.5 Vrms into a 50 Ω load 1.0 Vrms into a 1 kΩ load		
Signal	10 MHz sine wave		
Damage level	7 Vrms		

1. Continuous, gap-free measurements limits the Gate Time setting to 10 µs to 1000 s in 10 µs steps.
2. Latency does not include delays due to auto-leveling.

Math, Graphing and Memory Characteristics (nom)

	53210A	53220A	53230A
Math operations			
Smoothing (averaging) [1]	Selectable 10 (slow), 100 (medium), 1,000 (fast) reading moving average Selectable filter reset .1% /1000 ppm (fast), .03%/300 ppm (medium), .01%/100 ppm (slow) change from average		
Scaling	mX-b or m(1/X)-b User settable m and b (offset) values		
Δ-change	(X-b)/b scaled to %, ppm, or ppb User settable b (reference) value		
Null	(X-b) User settable b (reference) value		
Statistics [1]	Mean, standard deviation, Max, Min, Peak-to-Peak, count	Mean, standard deviation, Allan deviation[2], Max, Min, Peak-to-Peak, count	
Limit test [3]	Displays PASS/ FAIL message based on user defined Hi/ Lo limit values.		
Operation	Individual and simultaneous operation of smoothing, scaling, statistics, and limit test		
Graphical display selections			
Digits	Numeric result with input level shown		
Trend	Strip chart (measurements vs. readings over time) Selectable screen time		
Histogram	Cumulative histogram of measurements; manual reset HI/LO limit lines shown Selectable bin and block size		
Limit test	Measurement result, tuning bar-graph, and PASS/FAIL message		
Markers	Available to read values from trend & histogram displays		
Memory			
Data log	Guided setup of # of readings/counts; automatically saves acquisition results to non-volatile memory		
Instrument state	Save & recall user-definable instrument setups		
Power-off	Automatically saved		
Power-on	Selectable power-on to reset (Factory), power-off state or user state		
Volatile reading memory	1 M readings (16 MBytes)		
Non-volatile internal memory	75 Mbytes (up to 5 M readings)		
USB file system	Front-panel connector for USB memory device		
Capability	Store/recall user preferences and instrument states, reading memory, and bit map displays		

Speed Characteristics[4] (meas)

	53210A	53220A	53230A
Measurement/IO timeout (nom)	no timeout or 10 ms to 2000 s, in 1 ms steps		
Auto-level speed	Slow mode (50 Hz): 350 ms (typ) Fast mode (10 kHz): 10 ms (typ)		
Configure-change speed	Frequency, Period, Range, Level: 50 ms (typ)		
Single measurement throughput[5]: readings/s **(time to take single measurement and transfer from volatile reading memory over I/O bus)**			
Typical (Avg. using READ?):			
LAN (VXI-11)	110	120	
LAN (sockets)	200	200	
USB	200	200	
GPIB	210	220	
Optimized (Avg. using *TRG;DATA:REM? 1, WAIT):			
LAN (VXI-11)	160	180	
LAN (sockets)	330	350	
USB	320	350	
GPIB	360	420	
Block reading throughput[5]: readings/s (Example uses: 50,000 readings) **(time to take blocks of measurements and transfer from volatile reading memory over I/O bus)**			
Typical (Avg. using READ?):			
LAN (VXI-11)	300	990	8700
LAN (sockets)	300	990	9700
USB	300	990	9800
GPIB	300	990	4600
Optimized (Avg. using *TRG;DATA:REM? 1, WAIT):			
LAN (VXI-11)	300	990	34700
LAN (sockets)	300	990	55800
USB	300	990	56500
GPIB	300	990	16300

Speed Characteristics[4] (meas) (continued)

	53210A	53220A	53230A
Maximum measurement speed to internal non-volatile memory[6]: (readings/s)			
Timestamp	N/A	N/A	1,000,000
Frequency, period, totalize	300	1000	75,000
Frequency ratio			44,000
Time interval, rise/fall, width, burst width	N/A		90,000
Duty cycle	N/A		48,000
Phase	N/A		37,000
PRI, PRF	N/A	N/A	75,000
Transfer from memory to PC via:			
LAN (sockets)	600,000 readings/sec		
LAN (VXI-11)	150,000 readings/sec		
USB	800,000 readings/sec		
GPIB	22,000 readings/sec		

1. *These Math operations do not apply for Continuous Totalize or Timestamp measurements.*
2. *Allan Deviation is only calculated for Frequency and Period measurements. Allan Deviation calculation is available on both 53220A and 53230A, it is only gap free on 53230A.*
3. *Limit Test only displays on instrument front panel. No hardware output signal is available.*
4. *Operating speeds are for a direct connection to a >2.5 GHz dual core CPU running Windows XP Pro SP3 or better with 4 GB RAM and a 10/100/1000 LAN interface.*
5. *Throughput data based on gate time. Typical reading throughput assumes ASCII format, Auto level OFF with READ? SCPI command. For improved reading throughput you should also consider setting (FORM:DATA REAL,64), (DISP OFF), and set fastest gate time available.*
6. *Maximum 53230A rates represent >= 20 MHz input signals with min gate times, no delays or holdoffs. Measurement rates for the 53210A & 53220A are limited by min gate time. Actual meas rates are limited by the repetition rate of the input being measured.*

General Characteristics (nom)

	53210A	53220A	53230A
Warm-up time	45-minutes		
Display	4.3" Color TFT WQVGA (480 x 272), LED backlight		
User interface and help languages	English, German, French, Japanese, Simplified Chinese, Korean		
USB flash drive	FAT, FAT32		
Programming language			
SCPI	532xx Series and 53131A/53132A/53181A Series compatibility mode		
Programming interface			
LXI-C 1.3	10/ 100/ 1000 LAN (LAN Sockets and VXI-11 protocol)		
USB 2.0 device port	USB 2.0 (USB-TMC488 protocol)		
GPIB interface	GPIB (IEEE-488.1, IEEE-488.2 protocol)		
Web user interface	LXI Class C Compatible		
Mechanical			
Bench dimensions	261.1 mm W x 103.8 mm H x 303.2 mm D		
Rack mount dimensions	212.8 mm W x 88.3 mm H x 272.3 mm D (2U x 1/2 width)		
Weight	3.9 kg (8.6 lbs) fully optioned 3.1 kg (6.9 lbs) without Option 300 (battery option)		
Environmental			
Storage temperature	- 30 °C to +70 °C		
Operating environment	EN61010, pollution degree 2; indoor locations		
Operating temperature	0 °C to +55 °C		
Operating humidity	5% to 80% RH, non-condensing		
Operating altitude	Up to 3000 meters or 10,000 ft		
Regulatory			
Safety	Complies with European Low Voltage Directive and carries the CE-marking Conforms to UL 61010-1, CSA C22.2 61010-1, IEC 61010-1:2001, CAT I		
EMC	Complies with European EMC Directive for test and measurement products. IEC/EN 61326-1 CISPR Pub 11 Group 1, class A AS/NZS CISPR 11 ICES/NMB-001 Complies with Australian standard and carries C-Tick Mark This ISM device complies with Canadian ICES-001 Cet appareil ISM est conforme a la norme NMB-001 du Canada		
Acoustic noise (nom)	SPL 35 dB(A)		
Line power			
Voltage	100V - 240V ± 10%, 50-60 Hz ±5% 100 V - 120 V, 400 Hz ±10%		
Power consumption	90 VA max when powered on or charging battery; 6 VA max when powered off/standby		

General Characteristics (nom) (continued)

	53210A	53220A	53230A
Battery (Option 300)			
Technology	Internal lithium ion battery with integrated smart battery monitor & charger Use for maintaining timebase accuracy or environments with unstable AC power		
Operating temperature limits	0 to 55 °C. Battery will only charge under 35 °C. Instrument running on battery power above 50 °C will turn off to minimize battery capacity degradation.		
Storage temperature limits	-10 °C to 60 °C. Extended exposure to temperatures above 45 °C could degrade battery performance and life		
Operating time (typ)	3 hours when operated below +35 °C		
Standby time - OCXO powered (typ)	24 hours		
Recharge time (typ) [1]	4 hours to 100% capacity; 2 hours to 90% capacity		
Accessories included			
CD	User's guide, SCPI/programmers reference, programming examples, drivers (IVI-COM, LabView), IO library instructions		
Cables	Power line cord, 2 m USB 2.0		

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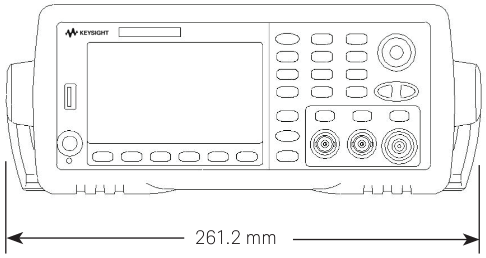
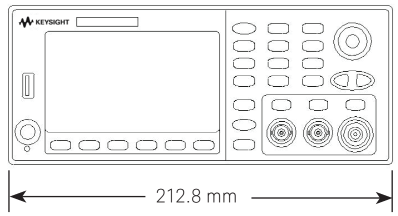
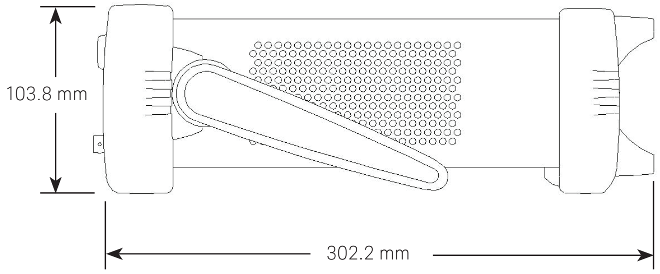
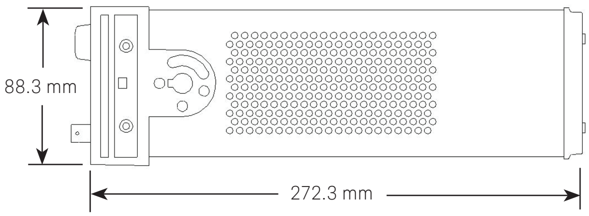
1. Assumes calibrated battery.









Dimensions apply to all three models: 53210A, 53220A, 53230A.

Timebase

Timebase Uncertainty = (Aging + Temperature + Calibration Uncertainty)

Timebase	Standard TCXO	Option 010 Ultra-High Stability OCXO
Aging [1] (spec)		
24-hour, T_{CAL} ±1 °C		± 0.3 ppb (typ)
30-day, T_{CAL} ±5 °C	± 0.2 ppm (typ)	± 10 ppb
1-year, T_{CAL} ±5 °C	± 1 ppm	± 50 ppb
2-year, T_{CAL} ±5 °C	± 0.5 ppm	± 25 ppb
Temperature (typ) [2]		
0 °C to T_{CAL} - 5 °C and T_{CAL} + 5 °C to 55 °C	± 1 ppm	± 5 ppb
Calibration uncertainty [3]		
Initial factory calibration (typ)	± 0.5 ppm	± 50 ppb
Settability error	± 0.1 ppb	± 0.01 ppb
Supplemental characteristics (typ)		
5-min. warm-up error [4]	± 1 ppm	± 10 ppb
72-hour retrace error [5]	< 50 ppb	< 2 ppb
Allan deviation τ = 1s	1 ppb	0.01 ppb

1. All Timebase Aging Errors apply only after an initial 30-days of continuous powered operation and for a constant altitude ±100 m. After the first 1-year of operation, use ½ x (30-day and 1-year) aging rates shown.
2. Additional temperature error is included in the time base uncertainty equation if the temperature of the operating environment is outside the T_{CAL} ± 5 °C (calibration temperature) range. The error is applied in its entirety, not per °C.
3. Initial factory calibration error applies to the original instrument calibration upon receipt from the factory. This error is applied until the first re-calibration occurs after shipment. Settability error is the minimum adjustment increment (resolution) achievable during electronic adjustment (calibration) of the instrument. It is added to the uncertainty of your calibration source.
4. Warm-up error applies when the instrument is powered on in a stable operating environment.
5. When moved between different operating environments add the Temperature error during the initial 30-minutes of powered operation
6. Retrace error may occur whenever the instrument line-power is removed or whenever the instrument is battery operated and the battery fully discharges. Retrace error is the residual timebase shift that remains 72-hours after powering-on an instrument that has experienced a full power-cycle of the timebase. Additional frequency shift errors may occur for instrument exposure to severe impact shocks > 50 g.

Front/rear view of 53230A

Accuracy Specifications

Definitions

Random Uncertainty

The RSS of all random or Type-A measurement errors expressed as the total RMS or 1-σ measurement uncertainty. Random uncertainty will reduce as $1/\sqrt{N}$ when averaging N measurement results for up to a maximum of approximately 13-digits or 100 fs.

Systematic Uncertainty

The 95% confidence residual constant or Type-B measurement uncertainty relative to an external calibration reference. Generally, systematic uncertainties can be minimized or removed for a fixed instrument setup by performing relative measurements to eliminate the systematic components.

Timebase Uncertainty

The 95% confidence systematic uncertainty contribution from the selected timebase reference. Use the appropriate uncertainty for the installed timebase or when using an external frequency reference substitute the specified uncertainty for your external frequency reference.

Basic accuracy [1] = ± [(k * Random Uncertainty) + Systematic Uncertainty + Timebase Uncertainty]

Measurement Function	1-σ Random Uncertainty	Systematic Uncertainty	Timebase Uncertainty2
Frequency [3] Period (parts error)	$\frac{1.4*(T_{SS}^2+T_E^2)^{1/2}}{R_E * \text{gate}}$	If $R_E \geq 2$: 10 ps / gate (max), 2 ps / gate (typ)[4] If $R_E < 2$ or REC mode ($R_E = 1$): 100 ps / gate	•
Option 106 & 115: Frequency [3] Period (parts error)	$\frac{1.4*(T_{SS}^2+T_E^2)^{1/2}}{R_E * \text{gate}}$	If $R_E \geq 2$: 10 ps / gate (max), 2 ps / gate (typ)[4] If $R_E < 2$: 100 ps / gate	•
Frequency Ratio A/B (typ) [5] (parts error)	1.4* Random Uncertainty of the *worst case* Freq input	Uncertainty of Frequency A plus Uncertainty of Frequency B	
Single Period (parts error)[17]	$\frac{1.4*(T_{SS}^2+T_E^2)^{1/2}}{\text{Period Measurement}}$	$\frac{T_{accuracy}}{\text{Period Measurement}}$	•
Time Interval (TI)[17], Width [17], or Rise/Fall Time [7, 17] (parts error)	$\frac{1.4*(T_{SS}^2+T_E^2)^{1/2}}{\lvert\text{TI Measurement}\rvert}$	$\frac{\text{Linearity}^{6} + \text{Offset}^{8}}{\lvert\text{TI Measurement}\rvert}$ Linearity = $T_{accuracy}$ Offset (typ) = T_{LTE} + skew + $T_{accuracy}$	•
Duty [5, 9, 10, 17] (fraction of cycle error)	$2*(T_{SS}^2+T_E^2)^{1/2}$ * Frequency	$(T_{LTE} + 2*T_{accuracy})$*Frequency	
Phase [5, 9, 17] (Degrees error)	$2*(T_{SS}^2+T_E^2)^{1/2}$ * Frequency * 360°	$(T_{LTE}$+skew+$2*T_{accuracy})$*Frequency*360°	
Totalize[11] (counts error)	± 1 count[11]		
Volts pk to pk [12] (typ) 5 V range		DC, 100 Hz - 1 kHz: 0.15% of reading + 0.15% of range 1 kHz - 1 MHz: 2% of reading + 1% of range 1 MHz - 200 MHz: 5% of reading + 1% of range + 0.3 * (Freq/250 MHz) * reading	

Accuracy Specifications (continued)

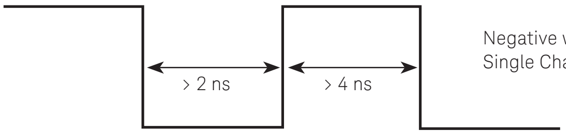
Measurement Function	1-σ Random Uncertainty	Systematic Uncertainty	Timebase Uncertainty[2]
6 GHz (Option 106): Pulse/Burst Measurements[3, 13]			
PRF, PRI (parts error)[14]	If $R_E > 1$: 200 ps / (R_E * gate) If $R_E = 1$: 500 ps / gate	$\frac{200\text{ ps}}{R_E * \text{gate}}$	•
Pulse/Burst Carrier Frequency[15] (Narrow Mode) (parts error)	$\frac{100\text{ ps}}{\text{Burst Width}}$	$\frac{200\text{ ps}}{\text{Burst Width}}$	•
Pulse/Burst Carrier Frequency[16] (Wide Mode) (parts error)	$\frac{40\text{ ps}}{R_E * \text{Burst Width}}$	$\frac{100\text{ ps}}{R_E * \text{Burst Width}}$	•

15 GHz (Option 115): Pulse/Burst Measurements3, 13			
PRF, PRI (parts error)[14]	$\frac{1\text{ ns}}{(R_E * \text{gate})}$	$\frac{200\text{ ps}}{R_E * \text{gate}}$	•
Pulse/Burst Carrier Frequency[15] (Narrow Mode) (parts error)	$\frac{100\text{ ps}}{\text{Burst Width}}$	$\frac{400\text{ ps}}{\text{Burst Width}}$	•
Pulse/Burst Carrier Frequency[16] (Wide Mode) (parts error)	$\frac{75\text{ ps}}{R_E * \text{Burst Width}}$	$\frac{200\text{ ps}}{R_E * \text{Burst Width}}$	•

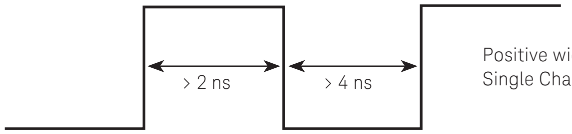
Accuracy Specifications (continued)

1. Apply the appropriate errors detailed for each measuring function.
2. Use Timebase Uncertainty in Basic Accuracy calculations only for Measurement Functions that show the • symbol in the Timebase Uncertainty column.
3. Assumes Gaussian noise distribution and non-synchronous gate, non-gaussian noise will effect Systematic Error. Note all optional microwave channel specifications (continuous wave and pulse/burst) assume sine signal.
4. Typical is achieved with an average of 100 readings with 100 samples per trigger. Worst case is trigger and sample count set to 1.
5. Improved frequency ratio, duty and phase specifications are possible by making independent measurements.
6. Minimum Pulse Width for using stated linearity is 5 ns; Pulse Widths of 2-5 ns use linearity=400 ps.
7. Residual instrument Rise/ Fall Time 10%-90% 2.0 ns (typ). Applies to fixed level triggering. Threshold can still be set based on % of auto-level detected peaks, but since these peak levels may contain unknown variations, accurate measurements need to be based on absolute threshold levels.
8. Input signal slew rates and settling time have effects on offset. Offset is calibrated with rise times < 100 ps.
9. Constant Duty or Phase are required during the measurement interval. Duty and Phase are calculated based on two automated sequential measurements - period and width or TI A to B, respectively.
10. Duty is represented as a ratio (not as a percent).
11. Additional count errors need to be added for gated totalize error, latency or jitter. If gated, add gate accuracy term (See Totalize measurements in the Measurement Characteristics section).
12. Volts pk error apply for signal levels between full range and 1/10th range. Spec applies to sine wave only. 50 V range reading accuracy is 2% at DC-1 KHz, 5% 1 KHz -1 MHz band. Accuracy above 200 MHz is not specified on both ranges.
13. For 6 GHz (Opt 106): Specifications apply to signals from ±13 dBm, operable to ±19 dBm. For 15 GHz (Opt 115): Specifications apply to input powers as listed under “Pulse/burst frequency and pulse envelope detector measurement characteristics”, operable from +13 dBm to -8 dBm.
14. Use the R_E equation, but use the input PRF for F_{IN}. Assume sharp envelope transition.
15. Applies when Burst Width * Carrier Freq > 80.
16. Specifications based on gate and width for automated detection. If in manual mode, delay and width selected will impact accuracy specification. For approximate accuracy for manual gate, use the R_E calculation, but F_{IN} is now 10^6 and use gate as burst width. For input signals where PRI < 250 µs, double the $1\text{-}\sigma$ Random Uncertainty specification, unless a Trigger Count of 1 and a large Sample Count acquisition method are used.
17. Specifications apply if measurement channels are in 5 V range, DC coupled, 50Ω terminated and at fixed level. The following minimum pulse width requirements apply:

Single-Period: < 250 MHz, 50% Duty
Phase, Dual Channel Time Interval: < 160 MHz, 50% Duty



Negative width, Negative duty,
Single Channel Time Interval Fall to Rise



Positive width, Positive duty,
Single Channel Time Interval Rise to Fall

Definition of Measurement Error Sources and Terms used in Calculations

	53210A	53220A	53230A
R_E	1	use R_E equation	use R_E equation
T_{SS}	100 ps	100 ps	20 ps
Skew		100 ps	50 ps
$T_{accuracy}$		200 ps	100 ps

Confidence Level (k)
For 99% Confidence use k= 2.5 in accuracy calculations.
For 95% Confidence use k= 2.0 in accuracy calculations.

Resolution enhancement factor (R_E)
The resolution enhancement (R_E) calculates the added frequency resolution beyond the basic reciprocal measurement capability that is achieved for a range of input signal frequencies and measurement gate times. The maximum enhancement factor shown is for input signals where $T_{SS} > T_E$ and is limited due to intrinsic measurement limitations. For signals where $T_{SS} << T_E$, R_E may be significantly higher than the specified levels. R_E will always be >=1.

For signals where $T_{SS} >> T_E$, $R_E = \sqrt{(F_{IN} * \text{Gate}/16)}$ R_E is limited by gate time as show below
Gate time > 1 s, R_E max of 6
Gate time 100 ms, R_E max of 4
Gate time 10 ms, R_E max of 2
Gate time < 1 ms, $R_E = 1$

Interpolation between listed gate times allowed.

Single shot timing (T_{SS})
Timing resolution of a start/stop measurement event.
Skew

Skew is the additional time error if two channels are used for a measurement. It is not used for width, rise/fall time, and single channel time interval.

$T_{accuracy}$
$T_{accuracy}$ is the measurement error between two points in time.

Threshold error (T_E)
Threshold error (T_E) describes the input signal dependent random trigger uncertainty or jitter. The total RMS noise voltage divided by the input signal slew rate (V/s) at the trigger point gives the RMS time error for each threshold crossing. For simplicity T_E used in the Random Uncertainty calculations is the worst T_E of all the edges used in the measurement. RSS of all edge's T_E is an acceptable alternative. Vx is the cross talk from the other standard input channel. Typically this is -60 dB. Vx = 0 on 53210A, and when no signal is applied to other standard input channel on 53220A/53230A. (Note: the best way to eliminate cross talk is to remove the signal from the other channel).

$$\text{For 5v} \quad \frac{(500\mu V^2 + E_N{}^2 + Vx^2)^{1/2}}{SR_{\text{-TRIG POINT}}}$$

$$\text{For 50v} \quad \frac{(5000\mu V^2 + E_N{}^2 + Vx^2)^{1/2}}{SR_{\text{-TRIG POINT}}}$$

Threshold level timing error (T_{LTE})
This time interval error results from trigger level setting errors and input hysteresis effects on the actual start and stop trigger points and results in a combined time interval error. These errors are dependant on the input signal slew rate at each trigger point.
V_H = 20 mV hysteresis or 40 mV when Noise Reject is turned ON. Double V_H values for frequencies > 100 MHz.

$$\pm \frac{T_{\text{LSE-start}}}{SR_{\text{-start}}} \pm \frac{T_{\text{LSE-stop}}}{SR_{\text{-stop}}} \pm \left[\frac{½\, V_H}{SR_{\text{-start}}} - \frac{½\, V_H}{SR_{\text{-stop}}} \right]$$

Definition of Measurement Error Sources and Terms used in Calculations (continued)

Phase Noise and Allan Deviation The input signal's jitter spectrum (Phase noise) and low-frequency wander characteristics (Allan variation) will limit the achievable measurement resolution and accuracy. The full accuracy and resolution of the counter can only be achieved when using a high-quality input signal source or by externally filtering the input signal to reduce these errors.	
Threshold level setting error (T_{LSE}) Threshold level setting error (T_{LSE}) is the uncertainty in the actual signal threshold point due to the inaccuracies of the threshold circuitry.	±(0.2%-of setting + 0.1%-of range)
Slew rate (SR) Slew rate (SR) describes the input signal's instantaneous voltage rate of change (V/s) at the chosen threshold point at customer BNC. For sine wave signals, the maximum slew rate $SR= 2\pi F*V_{0\text{ to }PK}$. For Square waves and pulses, the max slew rate = $0.8\ Vpp/\ t_{RISE\ 10-90}$ Using the 100 kHz low pass filter will effect Slew Rate.	V/s (at threshold point)
Signal noise (E_N) The input signal RMS noise voltage (E_N) measured in a DC - 350 MHz bandwidth. The input signal noise voltage is RSS combined with the instruments equivalent input noise voltage when used in the Threshold Error (T_E) calculation.	

Ordering Information

Model numbers

53210A 350 MHz, 10-digits/s RF Frequency Counter
53220A 350 MHz, 12 digits/s, 100 ps Universal Frequency Counter/Timer
53230A 350 MHz, 12-digits/s, 20 ps Universal Frequency Counter/Timer

All models include:

- IEC Power Cord, USB cable
- CD including: Programming Examples, Programmer's Reference Help File, User's Guide, Quick Start Tutorial, Service Guide
- Keysight IO Library CD

Available options

Option 010	Ultra-high-stability OCXO timebase
Option 106	6 GHz microwave input
Option 115	15 GHz microwave input
Option 201	Add rear panel parallel inputs for baseband channels[1]
Option 202	Optional microwave input - front Type N (default if 106 or 115 ordered)
Option 203	Optional microwave input - rear panel SMA(f) connector
Option 300	Add internal lithium ion smart battery and charger for unstable AC power or timebase stability

Recommended accessories[2]

1250-1476	BNC(f) to type-N adapter
N2870A	Passive probe, 1:1, 35 MHz, 1.3 m
N2873A	Passive probe, 10:1, 500 MHz, 1.3 m
N2874A	Passive probe, 10:1, 1.5 GHz, 1.3 m
34190A	Rack mount kit; Use for mounting one 2U instrument by itself, without another instrument laterally next to it. Includes one rack flange and one combination rack flange-filler panel.
34191A	2U dual flange kit; Use for mounting two 2U instruments side-by-side. Includes two standard rack flanges. Note: Mounting two instruments side-by-side will require the 34194A Dual-lock link kit and a shelf for the instruments to sit on. 34194A Dual-lock link kit; for side-by-side combinations of instruments, and includes links for instruments of different depths.
34131A	Transit case

Support options

3-year Annual calibration service
5-year Annual calibration service

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1. When ordered with optional rear terminals, the standard/baseband channel inputs are active on both the front and rear of the universal counter though the specifications provided only apply to the rear terminals. Performance for the front terminals with rear terminal options is not specified.
2. All probes must be compatible with a 20 pf input capacitance.

Appendix A – Worked Example

Basic Accuracy Calculation for Frequency Measurement

Parameter assumptions:

- 53220A
- 95% confidence
- 100 MHz signal, 1 sec gate
- AUTO frequency mode
- Level: 5 V input signal amplitude
- TCXO standard timebase for unit plugged in for 30 days
- Assume operating temperature is within $T_{CAL} \pm 5\ °C$
- Instrument has been re-calibrated so Factory Calibration Uncertainty term is not required.

Process:

*Basic accuracy = ± [(k * Random Uncertainty) + Systematic Uncertainty + Timebase Uncertainty]*

1. Use k=2 for 95% confidence and k=2.5 for 99% confidence calculations)....................k = 2

2. Random uncertainty for frequency measurement = $\dfrac{1.4 * (T_{SS}{}^2 + T_E{}^2)^{1/2}}{R_E * \text{Gate Time}} = \dfrac{1.4 * (100\text{ps}^2 + .159\text{ps}^2)^{1/2}}{6 * 1\text{ s}} = \boxed{\begin{array}{l}\text{23.3 E-12}\\ \text{parts error}\end{array}}$

T_{SS} = 100 ps

T_E (for 5 V) $= \dfrac{(500\ \mu V^2 + E_N{}^2 + Vx^2)^{1/2}}{SR_{\text{-TRIG POINT}}} = \dfrac{(500\ \mu V^2)^{1/2}}{3.14 * 10^9} =$ .159 ps

E_N = Assume input signal RMS noise voltage is 0.
Vx = N/A (remove signal from other channel)
$SR_{\text{-TRIG POINT}}$ = maximum slew rate (sine)SR= $2\pi F * V_{0\text{ to PK}} = 2\pi(100\text{ MHz}) * 5\text{ V} = 3.14 * 10^9$ Volts/Hz
Since $T_{SS} >> T_E$, we use the R_E equation. Value is much greater than 6. so we limit RE to 6 due to gate time. $R_E = 6$
Gate time = 1 sec

3. Systematic uncertainty for frequency measurement = If $R_E >= 2$: 10 ps/gate max, 2 ps/gate (typ) = $\boxed{\text{2 E-12 parts error}}$

4. Timebase uncertainty = aging = 0.2 ppm = $\boxed{\begin{array}{l}\text{0.2 E-6}\\ \text{parts error}\end{array}}$
Aging: 0.2 ppm

Basic accuracy = ± [(k * random uncertainty) + systematic uncertainty + timebase uncertainty] = ± [(2 * (23.3 E-12)) + 2 E-12 + 0.2 E-6] = ± 0.2 E-6 parts error

Note: Using a higher accuracy timebase or locking to an external timebase standard will have the biggest impact on improvement to accuracy calculations.

Definitions

The following definitions apply to the specifications and characteristics described throughout.

Specification (spec)

The warranted performance of a calibrated instrument that has been stored for a minimum of 2½ hours within the operating temperature range of 0 °C - 55 °C and after a 45-minute warm up period. Automated calibration (*CAL?) performed within ±5 °C before measurement. All specifications were created in compliance with ISO-17025 methods.

Data published in this document are specifications unless otherwise noted.

Typical (typ)

The characteristic performance, which 80% or more of manufactured instruments will meet. This data is not warranted, does not include measurement uncertainty, and is valid only at room temperature (approximately 23 °C). Automated calibration (*CAL?) performed within ±5 °C before measurement.

Nominal (nom)

The mean or average characteristic performance, or the value of an attribute that is determined by design such as a connector type, physical dimension, or operating speed. This data is not warranted and is measured at room temperature (approximately 23 °C). Automated calibration (*CAL?) performed within ±5 °C before measurement.

Measured (meas)

An attribute measured during development for purposes of communicating the expected performance.

This data is not warranted and is measured at room temperature (approximately 23 °C).Automated calibration (*CAL?) performed within ±5 °C before measurement.

Stability

Represents the 24-hour, ±1 °C short-term, relative measurement accuracy.
Includes measurement error and 24-hour ± 1°C timebase aging error.

Accuracy

Represents the traceable measurement accuracy of a measurement for T_{CAL} ± 5 °C. Includes measurement error, timebase error, and calibration source uncertainty.

Random measurement errors are combined using the root-sum-square method and are multiplied by K for the desired confidence level. Systematic errors are added linearly and include time skew errors, trigger timing errors, and timebase errors as appropriate for each measurement type.

T_{CAL}
Represents the ambient temperature of the instrument during the last adjustment to calibration reference standards.

T_{CAL} must be between 10 °C to 45 °C for a valid instrument calibration.

T_{ACAL}
Represents the temperature of the instrument during the last automated calibration (*CAL?) operation.

1. All information in this document are subject to change without notice.

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