DATA SHEET

# 53200A Series
# RF/Universal Frequency Counter/Timers

## 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.




KEYSIGHT TECHNOLOGIES

## 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).

## Keysight BenchVue Software (Now Included)

Keysight BenchVue software for the PC makes it simple to connect, control instruments, and automate test sequences so you can quickly move past the test development phase and access results faster with just a few clicks.

### The Universal Counter Control & Automation App within BenchVue is now included with your instrument purchase.

- Access the most commonly used universal counter controls using an intuitive interface.
- Quickly display single measurements, charts, tables, or histograms from a single instrument or multiple counters simultaneously to correlate trends you might otherwise miss
- Conveniently log and export data in only few clicks to popular tools, such as MATLAB and Microsoft Excel or Word for documentation or further analysis
- Rapidly develop custom test procedures or sequences with Test Flow
- Deeper instrument controls with Command Expert integration
- KeysightCare software support subscription included
- License included with new instrument purchase

Download BenchVue software at no cost today
www.keysight.com/find/benchvue

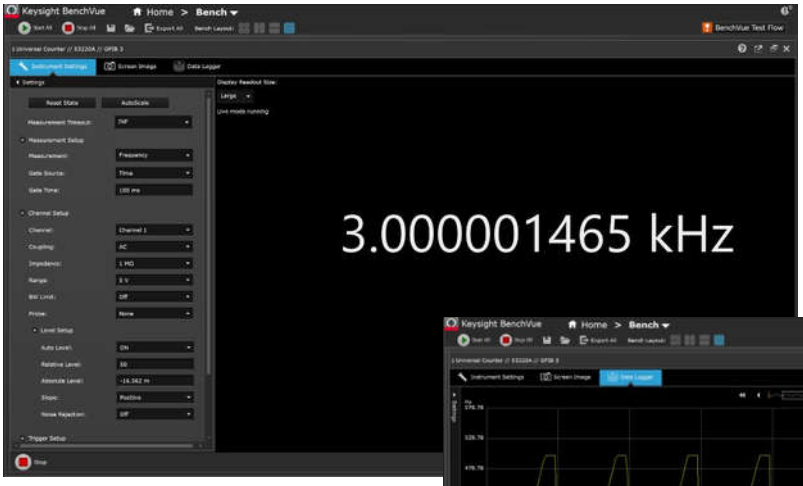



Figure 1: Remote control of instrument within BenchVue App.



Figure 2: Log Data remotely within BenchVue App.

## 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<br>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<br>> 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<br>On: Sets auto-level (% of Vpp) operation<br>Occurs once for each INIT or after a timeout.<br>Measures signal Vpp and sets Trigger level to 50%<br>Off: Selectable user set level (Volts) | | |

| | 53210A | 53220A | 53230A |
|---|---|---|---|
| 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<br>50 Ω internal termination auto-protects by switching to 1 M Ω | | |
| 1 M Ω damage level | DC - 5 kHz: 350 Vpk (AC + DC)<br>5 kHz - 100 kHz: Derate linearly to 10 Vpk (AC + DC)<br>>100 kHz: 10 Vpk (AC + DC) | | |
| **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)<br>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)<br>15 GHz (Opt 115):<br>< 3 GHz: -23 dBm<br>3 – 11 GHz: -27 dBm<br>> 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)<br>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)<br>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 |

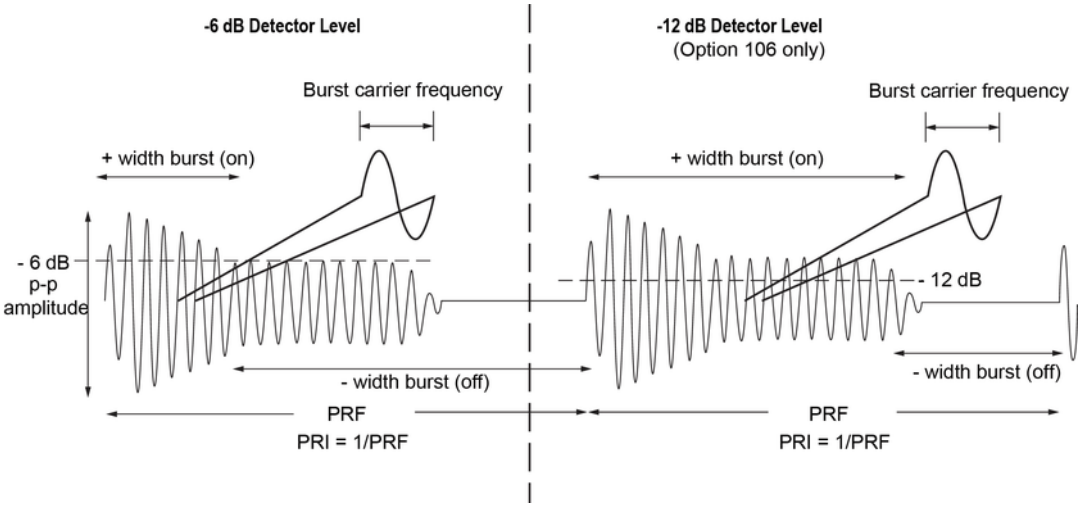
| | 53210A | 53220A | 53230A |
|---|---|---|---|
| #Edges/timestamp | N/A | N/A | Auto-acquired per acquisition |
| Acquisition length | N/A | N/A | up to 1 MSa or 100,000 s (max) |
| **Time interval (single-shot) measurements[11]** | | | |
| **Common** | | | |
| Channels | N/A | Ch 1 or 2 | |
| Single-shot time resolution | N/A | 100 ps | 20 ps |
| Gating | N/A | Internal or external gate<br>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 |
| **Time interval A to B, B to A** | | | |
| Range[9] | N/A | -1 ns to 100,000 s (nom)<br>-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% | |
| Minimum width | N/A | 2 ns | |
| Level & slope | N/A | Auto-level or user selectable | |

| | 53210A | 53220A | 53230A |
|---|---|---|---|
| **Phase A to B, B to A** | | | |
| Range[6] | N/A | -180.000º to 360.000º | |
| **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<br>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 | | |

| | 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<br>Narrow: < 17 µs<br>Wide: > 13 µs | > 400 ns<br>Narrow: < 17 µs<br>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)<br>3 - 11 GHz: +9 dBm (630 mVrms) to -8 dBm (90 mVrms)<br>> 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 synchronous 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) |

| | 53210A | 53220A | 53230A |
|---|---|---|---|
| **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<br>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 | |

| | 53210A | 53220A | 53230A |
|---|---|---|---|
| **Timebase output (typ)** | | | |
| Impedance | 50 Ω ± 5% at 10 MHz | | |
| Level | 0.5 Vrms into a 50 Ω load<br>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<br>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<br>User settable m and b (offset) values | | |
| Δ-change | (X-b)/b scaled to %, ppm, or ppb<br>User settable b (reference) value | | |
| Null | (X-b)<br>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)<br>Selectable screen time | | |

| | 53210A | 53220A | 53230A |
|---|---|---|---|
| Histogram | Cumulative histogram of measurements; manual reset<br>HI/LO limit lines shown<br>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;<br>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)<br>Fast mode (10 kHz): 10 ms (typ) | | |
| Configure-change speed | Frequency, Period, Range, Level: 50 ms (typ) | | |
| **Single measurement throughput[5]: readings/s<br>(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 | |

| | 53210A | 53220A | 53230A |
|---|---|---|---|
| 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 |
| **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 |

| | 53210A | 53220A | 53230A |
|---|---|---|---|
| **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)

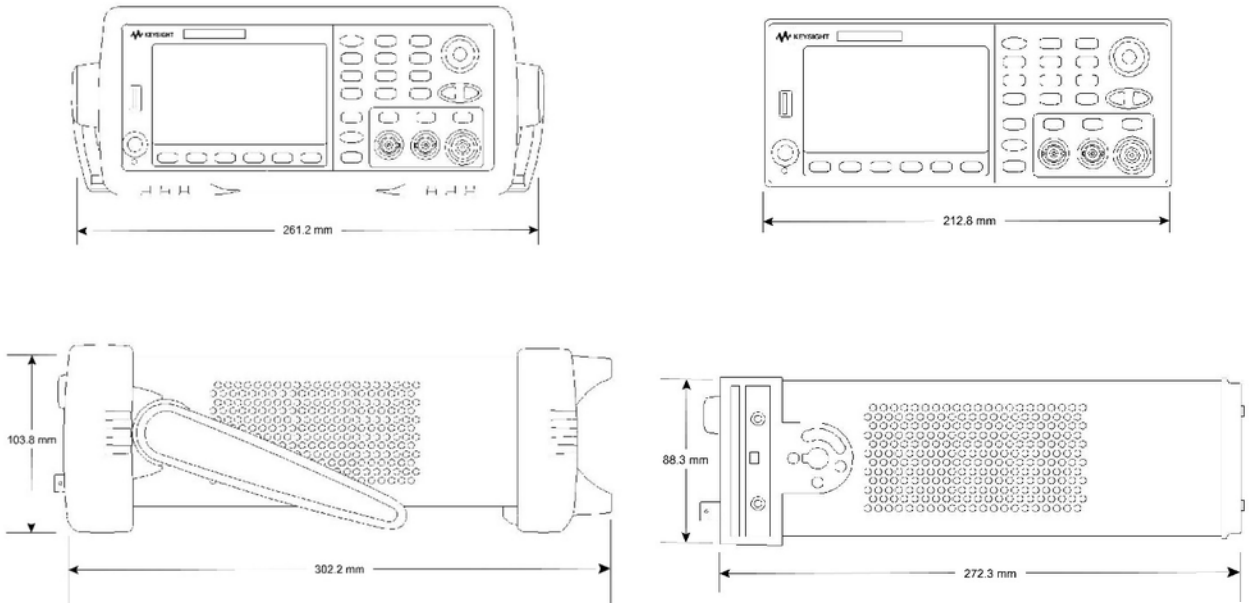
| | 53210A | 53220A | 53230A |
|---|---|---|---|
| Warm-up time | | 45-minutes | |
| Display | | 4.3" Color TFT WQVGA (480 x 272), LED backlight | |
| User interface and help languages | | English, German, French, Japanese, Simplified Chinese, Korean | |
| USB flash drive | | FAT, FAT32 | |
| **Programming 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 | |

| | 53210A | 53220A | 53230A |
|---|---|---|---|
| **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<br>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 & EMC | Refer to Declaration of Conformity for the latest revisions of regulatory compliance at: www.keysight.com/go/conformity | | |
| 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<br>6 VA max when powered off/standby | | |
| **Battery (Option 300)** | | | |
| Technology | Internal lithium ion battery with integrated smart battery monitor & charger<br>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.<br>Instrument running on battery power above 50 °C will turn off to minimize battery capacity degradation. | | |

| | 53210A | 53220A | 53230A |
|---|---|---|---|
| Storage temperature limits | -10 °C to 60 °C<br>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** | |
| Cables | Power line cord, 2 m USB 2.0 |

1. Assumes calibrated battery.




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

# Timebase

Timebase Uncertainty = (Aging + Temperature + Calibration Uncertainty)

| Timebase | Standard<br>TCXO | Option 010<br>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 TCAL ± 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]

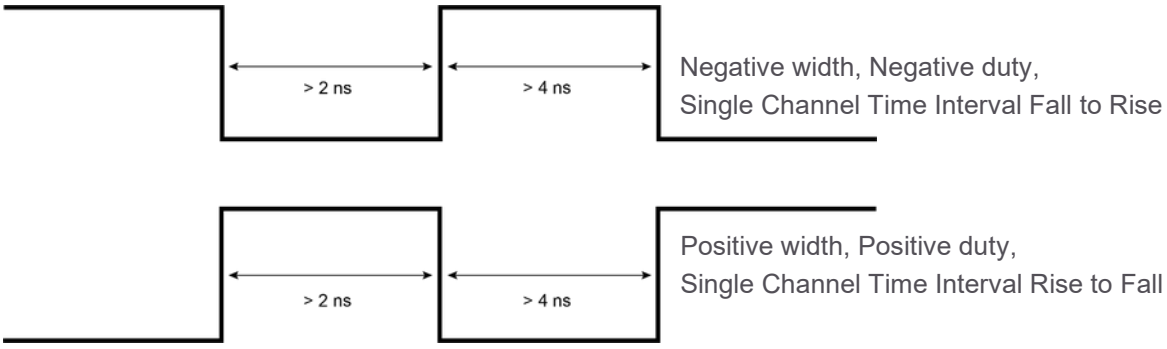
| Measurement Function | 1-σ Random Uncertainty | Systematic Uncertainty | Timebase Uncertainty[2] |
|---|---|---|---|
| Frequency [3]<br>Period (parts error) | $\frac{1.4^* (T_{SS}^2 + T_E^2)^{1/2}}{R_E * \text{gate}}$ | If $R_E \geq 2$: 10 ps / gate (max), 2 ps / gate (typ)[4]<br>If $R_E < 2$ or REC mode ($R_E = 1$): 100 ps / gate | • |
| Option 106 & 115:<br>Frequency [3]<br>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]<br>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 | |

| Measurement Function | 1-σ Random Uncertainty | Systematic Uncertainty | Timebase Uncertainty[2] |
|---|---|---|---|
| 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) | $\frac{1.4*(T_{SS}^2 + T_E^2)^{1/2}}{\lvert\text{TI Measurement}\rvert}$ | $\frac{\text{Linearity}^{6} + \text{Offset}^{8}}{\lvert\text{TI Measurement}\rvert}$<br>Linearity = $T_{accuracy}$<br>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 * 360º | $(T_{LTE}+skew+2*T_{accuracy})$*Frequency*360º | |
| Totalize[11] (counts error) | ± 1 count[11] | | |
| Volts pk to pk [12] (typ)<br>5 V range | | DC, 100 Hz - 1 kHz: 0.15% of reading + 0.15% of range<br>1 kHz - 1 MHz: 2% of reading + 1% of range<br>1 MHz - 200 MHz: 5% of reading + 1% of range<br>+ 0.3 * (Freq/250 MHz) * reading | |
| **6 GHz (Option 106): Pulse/Burst Measurements[3, 13]** | | | |
| PRF, PRI (parts error) [14] | If $R_E$ > 1: 200 ps / ($R_E$ * gate)<br>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 Measurements[3, 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) | $\frac{75\text{ ps}}{R_E * \text{Burst Width}}$ | $\frac{200\text{ ps}}{R_E * \text{Burst Width}}$ | • |

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
3. Uncertainty column.
4. Assumes Gaussian noise distribution and non-synchronous gate, non-gaussian noise will affect Systematic Error. Note all optional
5. microwave channel specifications (continuous wave and pulse/burst) assume sine signal.
6. Typical is achieved with an average of 100 readings with 100 samples per trigger. Worst case is trigger and sample count set to 1.

7. Improved frequency ratio, duty and phase specifications are possible by making independent measurements. Minimum Pulse Width for using stated linearity is 5 Neila Stewart. Pulse Widths of 2-5 ns use linearity=400 ps. 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 RE equation, but use the input PRF for FIN. 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 RE calculation, but FIN is now 106 and use gate as burst width. For input signals where PRI < 250 µs, double the 1-σ 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




## 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 $T_{SS} >> T_E$, $R_E = \sqrt{(F_{IN} * Gate/16)}$ $R_E$ 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).

For 5v $\frac{(500\mu V^2 + E_N^2 + Vx_2)^{1/2}}{SR_{\text{-TRIG POINT}}}$ For 50v $\frac{(5000\mu V^2 + E_N^2 + Vx^2)^{1/2}}{SR_{\text{-TRIG POINT}}}$

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 dependent 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.

$$\pm \frac{T_{LSE\text{-}start}}{SR_{\text{-}start}} \pm \frac{T_{LSE\text{-}stop}}{SR_{\text{-}stop}} \pm \left[ \frac{\frac{1}{2} V_H - \frac{1}{2} V_H}{SR_{\text{-}start} \quad SR_{\text{-}stop}} \right]$$

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/ $t_{RISE\ 10\text{-}90}$
Using the 100 kHz low pass filter will affect 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

## 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

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 $T_{CAL}$ ± 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 =

$$\frac{1.4 * (T_{SS}^2 + T_E^2)^{1/2}}{R_E * \text{Gate Time}} = \frac{1.4 * (100ps^2 + .159ps^2)^{1/2}}{6 * 1\ s} =$$

23.3 E-12 parts error

$T_{SS}$ = 100 ps

$T_E$ (for 5 V)

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

$E_N$ = 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= $2\pi F * V_{0 \text{ to PK}}$ = 2π(100 MHz)*5 V = 3.14*109 Volts/Hz
Since $T_{SS}$ >> $T_E$, we use the $R_E$ equation. Value is much greater than 6. So we limit $R_E$ 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) = 2 E-12 parts error

4. Timebase uncertainty = aging = 0.2 ppm = 0.2 E-6 parts error
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.

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