

# Digitizing oscilloscopes (digital storage oscilloscopes – DSO)

## Digitizing oscilloscope KEYSIGHT MSO-X 2022 A

### Specification overview

		2002A	2004A	2012A	2014A	2022A	2024A
Bandwidth <sup>1</sup> (–3 dB)		70 MHz		100 MHz		200 MHz	
Calculated rise time (10 to 90%)		≤ 5 ns		≤ 3.5 ns		≤ 1.75 ns	
Input channels	DSOX	2	4	2	4	2	4
	MSOX	2 + 8	4 + 8	2 + 8	4 + 8	2 + 8	4 + 8
Maximum sample rate <sup>1</sup>		2 GSa/s half-channel interleaved, 1 GSa/s per channel					
Maximum memory depth		1M points per channel (standard)					
Display size and type		8.5-inch WVGA with 64 levels of intensity grading					
Waveform update rate		200,000 waveforms per second					

### Vertical system analog channels

Input coupling		AC, DC
Input sensitivity range		1 mV/div to 5 V/div <sup>2</sup>
Input impedance		1 MΩ ± 2% (11 pF)
Vertical resolution		8 bits (measurement resolution is 12 bits with averaging)
Dynamic range		± 8 divisions from center screen
Maximum input voltage		135 Vrms; 190 Vpk
		Probing technology allows testing of higher voltages. For example, the included N2841A or N2842A 10:1 probe supports testing up to 300 Vrms Use this instrument only for measurements within its specified measurementcategory (not rated for CAT II, III, IV). No transient overvoltage allowed
DC vertical accuracy		± [DC vertical gain accuracy + DC vertical offset accuracy + 0.25% full scale] <sup>2</sup> DC
vertical gain accuracy <sup>1</sup>		± 3% full scale (≥ 10 mV/div); ± 4% full scale (< 10 mV/div) <sup>2</sup>
DC vertical offset accuracy		± 0.1 div ± 2mV ± 1% of offset setting
Channel-to-channel isolation		≥ 40 dB from DC to maximum specified bandwidth of each modelPosition/offset
range	1 MΩ	1 mV to 200 mV/div: ± 2 V, > 200 mV to 5 V/div: ± 50 V Hardware
bandwidth limits		Approximately 20 MHz (selectable)

## Horizontal system analog channels

		2002A	2004A	2012A	2014A	2022A	2024A
Time base range		5 ns/div to 50 s/div				2 ns/div to 50 s/div	
Time base accuracy <sup>1</sup>		25 ppm ± 5 ppm per year (aging)					
Time base delay time range	Pre-trigger	Greater of 1 screen width or 200 μs (400 μs in interleaving mode)					
	Post-trigger	1 s to 500 s					
Channel-to-channel deskew range		± 100 ns					
Δ Time accuracy (using cursors)		± (time base accuracy <sup>1</sup> reading) ± (0.0016 <sup>1</sup> screen width) ± 100 ps					

## Acquisition modes

### Normal

Peak detect	Capture glitch as narrow as 500 ps at all timebase settings
Averaging	Select from 2, 4, 8, 16, 64... to 65,536
High resolution mode	12 bits of resolution when $\geq$ 20 $\mu$ s/div
Segmented	Re-arm time= 19 $\mu$ s (minimum time between trigger events)

### Trigger system

Trigger modes	<ul style="list-style-type: none"> <li>• Normal (triggered): Requires trigger event for scope to trigger</li> <li>• Auto: Triggers automatically in absence of trigger event</li> <li>• Single: Triggers only once on a trigger event, press [Single] again for scope to find another trigger event, or press [Run] to trigger continuously in either Auto or Normal mode</li> <li>• Force: Front panel button that forces a trigger</li> </ul>
Trigger coupling	Coupling selections: AC, DC, noise reject, LF reject and HF reject
Trigger source	Each analog channel, each digital channel (MSO models or DSOX2MSO upgrade, Ext, WaveGen, line)
Trigger sensitivity (internal) <sup>1</sup>	< 10 mV/div: greater of 1 div or 5 mV; $\geq$ 10 mV/div: 0.6 div
Trigger sensitivity (external) <sup>1</sup>	200 mV (DC to 100 MHz); 350 mV (100 to 200 MHz)
External trigger input	Included on all models

## Trigger type selections

### All 2000 X-Series models

Edge	Trigger on a rising, falling, alternating or either edge of any source
Edge then edge (B trigger)	Arm on a selected edge, wait a specified time, then trigger on a specified count of another selected edge
Pulse width	Trigger on a pulse on a selected channel, whose time duration is less than a value, greater than a value, or inside a time range <ul style="list-style-type: none"> <li>Minimum duration setting: 2 to 10 ns (depends on bandwidth)</li> <li>Maximum duration setting: 10 s</li> </ul>
1. Denotes warranted specifications, all others are typical. Specifications are valid after a 30-minute warm-up period and from $\pm 10^{\circ}\text{C}$ firmware calibration temperature. 2. 1 mV/div and 2 mV/div is a magnification of 4 mV/div setting. For vertical accuracy calculations, use full scale of 32 mV for 1 mV/div and 2 mV/div sensitivity setting.	
Pattern	Trigger when a specified pattern of high, low, and don't care levels on any combination of analog, digital, or trigger channels is [entered   exited]. Pattern must have stabilized for a minimum of 2 ns to qualify as a valid trigger condition.
Video	Trigger on all lines or individual lines, odd/even or all fields from composite video, or broadcast standards (NTSC, PAL, SECAM, PAM-M)
Runt Trigger	on a position runt pulse that fails to exceed a high-level threshold. Trigger on a negative runt pulse that fails to exceed a low-level threshold. Trigger on either polarity runt pulse based on two threshold settings. Runt triggering can also be time-qualified (< or >) with a minimum time setting of 6~10 ns (depending on bandwidth) and maximum time setting of 10 s.
Rise/fall time	Trigger on rise-time or fall-time edge speed violations (< or >) based on user-selectable threshold. Select from (< or >) and time settings range between 3-5 ns (depending on bandwidth) and 10 s

## Cursors

Types	Amplitude, time, frequency (FFT), manual, tracking, binary, HEX
Measurements	$\Delta T$ , $1/\Delta T$ , $\Delta V/X$ , $1/\Delta X$ , $\Delta Y$ , Phase and Ratio
Cursors <sup>2</sup>	<ul style="list-style-type: none"> <li>Single cursor accuracy: <math>\pm [\text{DC vertical gain accuracy} + \text{DC vertical offset accuracy} + 0.25\% \text{ full scale}]</math></li> <li>Dual cursor accuracy: <math>\pm [\text{DC vertical gain accuracy} + 0.5\% \text{ full scale}]</math> <sup>1</sup></li> </ul>

## Automatic waveforms measurements

Voltage	Snapshot all, maximum, minimum, peak-to-peak, top, base, amplitude, overshoot, preshoot, average- N cycles, average-full screen, DC RMS- N cycles, DC RMS- full screen, AC RMS- N cycles, AC RMS- full screen (std dev)
Time	Period, frequency, rise time, fall time, + width, – width, duty cycle, delay A→B (rising edge), delay A→B (falling edge), phase A→B (rising edge,) and phase A→B (falling edge), bit rate

## Waveform math

Operators	Add, subtract, multiply, divide, FFT, $Ax + B$ , Square, Absolute, Common Log, Natural Log, Exponential, Base 10 Exponential, LP Filter, HP Filter, Magnify, Measurement Trend, Chart Logic Bus (Timing or State)
FFT	Windows: Hanning, flat top, rectangular; Blackman-Harris - up to 64 kpts resolution
Sources	Math functions available between any two channels

## MSO (digital channels)

Upgradable from DSO	Yes
MSO channels	8 channels (D0 to D7)
Maximum sample rate	1 GSa/s
Maximum record length	500 kpts per channel (digital channels only) 125 kpts per channel (analog and digital channels)
Threshold selections	TTL (+1.4 V), CMOS (+2.5 V), ECL (-1.3 V), User-definable ( $\pm 8.0$ V in 10 mV stops)
Threshold accuracy <sup>1</sup>	$\pm (100 \text{ mV} + 3\% \text{ of threshold settings})$
Maximum input voltage	$\pm 40$ V peak CAT I
Maximum input dynamic range	$\pm 10$ V about threshold
Minimum voltage swing	500 mVpp
Input impedance	100 k $\Omega$ $\pm$ 2% at probe tip, ~8 pF
Minimum detectable pulse width	5 ns
Channel-to-channel skew	2 ns (typical), 3 ns (maximum)

1. Denotes warranted specifications, all others are typical. Specifications are valid after a 30-minute warm-up period and from  $\pm 10$  °C firmware calibration temperature.
2. 1 mV/div and 2 mV/div is a magnification of 4 mV/div setting. For vertical accuracy calculations, use full scale of 32 mV for 1 mV/div and 2 mV/div sensitivity setting.

## Digitizing oscilloscope HP 54600 A

**Type** 2-channel oscilloscope with digital signal acquisition, automatic setup of the front panel, automatic and cursor measurements of frequency, time, and voltage, waveform storage, save and recall of 16 front-panel setups, peak detect

### Vertical system

<b>Bandwidth</b> (CH1, CH2)	0 - 100 MHz (-3 dB) DC 10 Hz - 100 MHz (-3 dB) AC
<b>Rise time</b>	3.5 ns
<b>Sensitivity</b>	2 mV/div. to 5 V/div. in 11 ranges
<b>Accuracy</b>	±1.5 %
<b>Verniers</b>	50 (75) steps, accuracy ± 3 %
<b>Coupling</b>	Ground, AC, DC
<b>Input impedance</b>	1 MΩ    13 pF
<b>Maximum input voltage</b>	(DC + peak value): 400 V

### Horizontal system

<b>Sweep speeds</b> (main and delayed)	5 s/div. to 2 ns/div. in 29 steps
<b>Accuracy</b>	±0.01 %
<b>Vernier: Accuracy</b>	±0.05 %
<b>Horizontal resolution</b>	100 ps
<b>Pretrigger delay</b> (negative time)	max. 10 div.
<b>Posttrigger delay</b> (from trigger point to start of sweep)	at least 2560 div. or 50 ms, not to exceed 100 s
<b>Delayed sweep operation</b>	main sweep 5 s/div. to 10 ms/div. ....delayed sweep up to 200 times main sweep 5 ms/div. and faster..... up to 2 ns/div.

### Trigger system

<b>Internal trigger</b>	
<b>Sensitivity</b>	DC to 25 MHz      0.35 div. or 3.5 mV DC to 100 MHz      1 div. or 10 mV
<b>Sources</b>	CH1, CH2, line, and external
<b>Coupling</b>	AC, DC, LF reject, HF reject, and noise reject
<b>Modes</b>	Auto, Autolevel, Normal, Single, and TV
<b>Holdoff</b>	Adjustable from 200 ns to 13 s

**External trigger**

<b>Range</b>	$\pm 18\text{ V}$	
<b>Sensitivity</b>	DC to 25 MHz	50 mV
	DC to 100 MHz	100 mV
<b>Coupling</b>	DC, HF reject, and noise reject	
<b>Input impedance</b>	$1\text{ M}\Omega \parallel 13\text{ pF}$	
<b>Maximum input voltage</b>	400 V (DC + peak AC)	

**X - Y operation**

<b>Sensitivity and bandwidth</b>	Same as vertical system
<b>Phase difference</b>	$\pm 3^\circ$ at 100 kHz

**Display system**

<b>Display</b>	7-inch raster CRT
<b>Resolution</b>	255 vertical by 500 horizontal points
<b>Controls</b>	Front-panel intensity control
<b>Graticule</b>	$8 \times 10$ grid or frame

**Acquisition system**

<b>Maximum sample rate</b>	20 MSa/s
<b>Resolution</b>	8 bits
<b>Simultaneous channels</b>	CH1 and CH2
<b>Record length</b>	4,000 points (2,000 single shot)
<b>Maximum update rate</b>	1,000,000 points/s
<b>Single-shot bandwidth</b>	2 MHz single channel, 1 MHz dual channel
<b>Peak detect</b>	50 ns glitch capture (100 ns dual channel) from 5 s/div. to 50 $\mu$ s/div.
<b>Average</b>	number of averages selectable at 8, 64, and 256

**Advanced functions****Automatic measurements** (measurements are continuously updated)

<i>Voltage</i>	Vave, Vrms, Vp-p, Vtop, Vbase, Vmin, Vmax
<i>Time</i>	frequency, period, +width, -width, duty cycle, rise time, and fall time
<i>Cursors</i>	manually or automatically placed
<i>Setup functions</i>	Autoscale: Sets vertical and horizontal deflections and trigger level for signals with frequency min. 50 Hz, duty cycle > 1 % and voltage level > 20 mVp-p external trigger > 100 mVp-p
<i>Save/Recall</i>	16 front-panel setups
<i>Trace memory</i>	Two volatile pixel memories

## Digitizing oscilloscope Agilent (HP) 54621A

**Type** Series Portable 2-channel Oscilloscope

### Scope Channels

<b>Bandwidth (CH1, CH2)</b>	DC to 60 MHz
<b>AC coupled</b>	3.5 Hz to 60 MHz
<b>Max. Sample Rate</b>	200 MSa/s
<b>Max. Input</b>	400 V (DC + peak AC)
<b>Range</b>	1 mV/div to 5 V/div
<b>Vertical Resolution</b>	8 bits
<b>DC Vertical Gain Accuracy</b>	$\pm 2.0\%$ full scale
<b>DC Vertical Offset Accuracy</b>	$< 200 \text{ mV/div: } \pm 0.1 \text{ div } \pm 1.0 \text{ mV} \square \pm 0.5 \text{ offset}$ $\geq 200 \text{ mV/div: } \pm 0.1 \text{ div } \pm 1.0 \text{ mV} \square \pm 1.5 \text{ offset}$
<b>Single Cursor Accuracy</b>	$\pm \{\text{DC Vertical Gain Accuracy} + \text{DC Vertical Offset Accuracy} + 0.2\% \text{ full scale}\}$
<b>Peak Detection</b>	5 ns
<b>Averages</b>	selectable from 2, 4, 8, 16, 32, 64, ... 16383
<b>High Resolution Mode</b>	12 bits of resolution when $> 500 \mu\text{s/div}$ , average mode with average = 1
<b>Max. Memory Depth</b>	4 MB interleaved, 2 MB each channel
<b>Input Resistance</b>	$1 \text{ M}\Omega \pm 1\%$
<b>Input Capacitance</b>	14 pF
<b>Coupling</b>	ac, dc, ground

### Horizontal system

<b>Range</b>	5 ns/div to 50 s/div
<b>Resolution</b>	25 ps
<b>Vernier</b>	1-2-5 increments when off, 25 minor increments between major settings when on
<b>Reference Positions</b>	Left, Center, Right
<b>Delay Range</b>	Pre-trigger (negative delay) Greater of 1 screen width or 10 ms Post-trigger (positive delay) 500 seconds
<b>Channel-to-Channel</b>	$\pm 0.01\%$ reading $\pm 0.1\%$ screen width $\pm 80 \text{ ps}$

### Trigger system

<b>Internal trigger</b>	
<b>Sources</b>	CH1, CH2, line, and external
<b>Coupling</b>	AC, DC, LF reject, HF reject, and noise reject
<b>Modes</b>	Auto, Autolevel, Triggered (normal), Single
<b>Holdoff Time</b>	from 60 ns to 10 s
<b>Selections</b>	Edge, Pattern, Pulse Width, CAN, Duration, I <sup>2</sup> C, LIN, Sequence, SPI, TV, USB, Autoscale

**External trigger**

<b>Range</b>	$\pm 10$ V
<b>Sensitivity</b>	DC to 25 MHz, < 75 mV 25 MHz to max bandwidth, < 150 mV
<b>Coupling</b>	AC, DC, noise reject, HF reject and LF reject
<b>Input impedance</b>	1 M $\Omega$    14 pF
<b>Maximum input voltage</b>	400 V (DC + peak AC)

**X - Y operation**

<b>Sensitivity and bandwidth</b>	Same as vertical system
<b>Phase difference</b>	$\pm 1.8$ degrees at 100 kHz

**Display system**

<b>Display</b>	7-inch raster monochrome CRT
<b>Resolution</b>	255 vertical by 1000 horizontal points
<b>Throughput of Analog Channels</b>	25 million gray scale vectors/sec per channel 32 levels of gray scale
<b>Controls</b>	Waveform intensity on front panel 8 $\times$ 10 grid with continuous intensity control

**Measurement Features**

<b>Automatic Measurements</b>	Measurements are continuously updated Cursors track current measurement
<b>Voltage</b>	Peak-to-Peak, Maximum, Minimum, Average, Amplitude, Top, Base, Overshoot, Preshoot, RMS (DC)
<b>Time</b>	Frequency, Period, +Width, -Width, and Duty Cycle on any channels, Rise time, Fall time, X at Max (Time at max volts), X at Min (Time at min volts), Delay, and Phase
<b>Threshold Definition</b>	Variable by percent and absolute value: 10 %, 50 %, 90 % default for time measurements
<b>Cursors</b>	Manually or automatically placed readout of Horizontal (X, $\Delta X$ , 1/ $\Delta X$ ) and Vertical (Y, $\Delta Y$ )
<b>Waveform Math</b>	1-2, 1*2, FFT, differentiate, integrate Source of FFT: differentiate, integrate, analog channels 1 or 2, 1-2, 1+2, 1*2



## Digitizing oscilloscope HP 54645D (Mega Zoom)

**Type** DSO with 2 analog channels (A1, A2) and 16 digital channels

### Analog Channels

**Range** 1 mV/div to 5 V/div  
**Vernier calibrated**  $\pm 3 \%$   
**Position (offset) range**  $\pm 8$  divisions minimum  
 $\pm 2$  V on ranges  $< 200$  mV/div  
 $\pm 40$  V on ranges  $> 200$  mV/div

#### DC Vertical Gain Accuracy

1, 2, 5 sequences  $\pm 1.5 \%$  of full scale  
Vernier  $\pm 3 \%$  of full scale

**DC Vertical Offset Accuracy**  $\pm 1 \%$  of full scale  $\pm 0.5 \%$  of position value  
 $(\geq 10$  mV/div)  
 $\pm 2 \%$  of full scale  $\pm 0.5 \%$  of position value  
 $(< 10$  mV/div)

**Single-Cursor Accuracy** DC vertical gain accuracy + DC vertical offset accuracy  $\pm \frac{1}{2}$  LSB (LSB = 0.4 % of full scale)

**Dual-Cursor Accuracy** DC vertical gain accuracy  $\pm 1$  LSB

#### Bandwidth (3 dB)

Repetitive 100 MHz ( $\geq 10$  mV/div); 75 MHz ( $< 10$  mV/div)  
Single shot 50 MHz

**Max. Input** 400 V (DC + peak AC)

**Input Resistance**  $1 \text{ M}\Omega \pm 1 \%$

**Input Capacitance**  $\sim 13$  pF

**Coupling** AC, DC, GND

**XY Bandwidth** 100 MHz; Phase error (1 MHz) .... 1.8 degrees

### Digitizing System

**Vertical Resolution** 8 bits on all settings except 7 bits on  $< 2$  mV/div to 1 mV/div

**Horizontal Resolution** 500 (displayed points)

**Sample Rate** 200 Msa/s maximum per channel

**Sample Rate Accuracy** 0.01 %

**Peak Detection** 5 ns digital

**Averages** 4, 8, 16, 32, 64, 128, 256, Smoothing-selectable

**Memory Depth** 1 M maximum

**Data Throughput** Up to 3.0 million samples per second with sufficient trigger rate, and not using averaging, time base vernier, waveform math, or vectors

### Logic Channels

**Vertical Resolution** 1 bit

**Max. Horizontal Resolution** 500 (displayed points)

**Sample Period** 2.5 ns maximum

**Glitch Detection** 8 channels ... 2.5 ns; 16 channels ... 5 ns

**Memory Depth per Channel** 2 M maximum

etc.

# Voltmeters and Multimeters

<b>TVT-321</b> (Troneer)
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**Type** Electronic analog voltmeter, frequency 5 Hz to 1 MHz

**Specifications - Meter Section:**

**Ranges:** 300  $\mu$ V, 1 mV, 3 mV, 10 mV, 30 mV, 100 mV, 300 mV, 1 V, 3 V, 10 V, 30 V, 100 V  
- 70 ... + 40 dB (0 dB = 1 V)  
- 70 ... + 42 dBm (0 dBm = 1 mW, 600  $\Omega$ )

**Error:**  $\pm 3$  % of full scale at  $f = 1$  kHz

**Frequency response:**  $\pm 10$  % at  $f = 5$  Hz to 1 MHz,  
 $\pm 5$  % at  $f = 10$  Hz to 500 kHz,  
 $\pm 3$  % at  $f = 20$  Hz to 200 kHz as referenced to 1 kHz response

**Input impedance:** 1 M $\Omega$   $\pm 5$  % with less than 45 pF parallel capacitance

**Durable input voltage:** 500 V (DC + AC peak) at 1 V ... 100 V range,  
100 V (DC + AC peak) at 300  $\mu$ V ... 100 mV range

**Stability:** Within  $\pm 0,5$  % of full scale for  $\pm 10$  % line voltage fluctuation

**Residual voltage:** Within 2 % of full scale by shorting input

**Amplifier Section:**

**Gain:** Approx. 60 dB  
**Output voltage:** 0.1 V<sub>rms</sub> (Full scale)  $\pm 20$  %  
**Output impedance:** 600  $\Omega$   $\pm 20$  %  
**Distortion:** Less than 1 % at full scale  
**Frequency response:** Within  $\pm 3$  dB at 5 kHz to 200 kHz

## DMM 7001

<b>Type</b>	4 1/2 - digit table digital multimeter with integration A/D converter ICL 7135 (Maxim) and true RMS to DC converter AD 636 (Analog Devices)
<b>DC voltage</b>	
<b>Ranges</b>	200 mV, 2 V, 20 V, 200 V, 1000 V
<b>Accuracy</b>	± 0.01 % of f.s. ± 0.05 % of rdg
<b>AC voltage</b>	
<b>Ranges</b>	200 mV, 2 V, 20 V, 200 V, 400 V
<b>Accuracy</b>	± 0.15 % of f.s. ± 0.5 % of rdg
<b>Input resistance</b>	1 MΩ for all ranges
<b>DC and AC current</b>	
<b>Ranges</b>	20 μA, 200 μA, 2 mA, 20 mA, 200 mA, 2000 mA, 20 A
<b>Accuracy</b>	± 0.01 % of f.s. ± 0.2 % of rdg - DC current ± 0.15 % of f.s. ± 0.5 % of rdg - AC current
<b>Voltage drop</b>	200 mV for full scale and all current ranges
<b>AC measurements:</b>	True RMS value of voltage and current to frequency 5 kHz

## V 553

**Type** 4-digit table digital multimeter with the integration A/D converter and the precision rectifier for AC measurements

### DC voltage

**Ranges** 100 mV, 1 V, 10 V, 100 V (manual switching or autoranging)  
**Accuracy**  $\pm 0.01\%$  of f.s.  $\pm 0.05\%$  of rdg  
**Input resistance**  $>1000\text{ M}\Omega$  for ranges 100 mV to 10 V  
 $10\text{ M}\Omega \pm 1\%$  for ranges 100 V, 1000 V

### AC voltage

**Ranges** 100 mV, 1 V, 10 V, 100 V (manual switching or autoranging)  
**Accuracy**  $\pm 0.05\%$  of f.s.  $\pm 0.2\%$  of rdg (20 Hz to 40 Hz)  
 $\pm 0.05\%$  of f.s.  $\pm 0.1\%$  of rdg (40 Hz to 20 kHz)  
 $\pm 0.2\%$  of f.s.  $\pm 0.2\%$  of rdg (20 kHz to 50 kHz)  
 $\pm 0.5\%$  of f.s.  $\pm 0.5\%$  of rdg (50 kHz to 100 kHz)

**Input impedance**  $1\text{ M}\Omega \pm 1\% \parallel 100\text{ pF}$   
(Measures rectified mean value multiplied by 1.1107.)

### Resistance

Range	Accuracy
100 m $\Omega$ - 1 k $\Omega$	$\pm 0.01\%$ of f.s. $\pm 0.05\%$ of rdg
1 $\Omega$ - 10 k $\Omega$	$\pm 0.01\%$ of f.s. $\pm 0.05\%$ of rdg
10 $\Omega$ - 100 k $\Omega$	$\pm 0.01\%$ of f.s. $\pm 0.05\%$ of rdg
100 $\Omega$ - 1 000 k $\Omega$	$\pm 0.01\%$ of f.s. $\pm 0.1\%$ of rdg
1 k $\Omega$ - 10 000 k $\Omega$	$\pm 0.02\%$ of f.s. $\pm 0.2\%$ of rdg

## DM-441B (LG Precision)

**Type** A portable, bench type digital multimeter with a 4 ½ - digit light- emitting diode; it can make hFE measurements, diode measurements, frequency measurements and continuity measurements in addition to the usual DMM measurement – AC/DC volts, AC/DC current and resistance; true RMS measurement of AC signals (AC voltage frequencies up to 50 kHz)

### Resolution and accuracy

Function	Range	Resolution	Accuracy	Frequency Range
<b>DC voltage</b>	200 mV 2 V 20 V 200 V	10 μV 100 μV 1 mV 10 mV	± (0.1 % of rdg + 4 dgt)	
	1000 V	100 mV	± (0.15 % of rdg + 4 dgt)	
	<b>Input resistance</b> 10 MΩ approximately			
<b>AC voltage</b>	200 mV	10 μV	± (0.5 % of rdg + 20 dgt)	45 Hz ...1 kHz
	2 V	100 μV	± (0.5 % of rdg + 20 dgt) ± (0.8 % of rdg + 10 dgt) ± (1.0 % of rdg + 20 dgt) ± (3.0 % of rdg + 30 dgt)	45 Hz ...1 kHz 1 kHz ...10 kHz 10 kHz ...20 kHz 20 kHz ...50 kHz
	20 V	1 mV	± (0.5 % of rdg + 20 dgt) ± (1.5 % of rdg + 20 dgt) ± (2.5 % of rdg + 20 dgt) ± (5.0 % of rdg + 20 dgt)	45 Hz ...1 kHz 1 kHz ...10 kHz 10 kHz ...20 kHz 20 kHz ...50 kHz
	200 V	10 mV	± (0.5 % of rdg + 10 dgt) ± (2.0 % of rdg + 10 dgt)	45 Hz ...1 kHz 1 kHz ...10 kHz
	750 V	100 mV	± (1.0 % of rdg + 20 dgt) ± (3.5 % of rdg + 20 dgt)	45 Hz ...1 kHz 1 kHz ...10 kHz
<b>DC current</b>	2 mA	0.1 μA	± (0.5 % of rdg + 1 dgt)	
	20 mA	1 μA		
	200 mA	10 μA		
	2 A	100 μA		
	10 A	1 mA	± (0.75 % of rdg + 3 dgt)	
<b>Max. fullscale burden voltages</b>	0.3 V ... for the 2 mA, 20 mA, 200 mA ranges; 0.9 V ... for the 2 A and 10 A ranges			
<b>AC current</b>	2 mA	0.1 μA	± (1.0 % of rdg + 10 dgt) ± (2.0 % of rdg + 20 dgt)	45 Hz ...10 kHz 10 kHz ...20 kHz
	20 mA	1 μA	± (1.0 % of rdg + 10 dgt) ± (2.0 % of rdg + 20 dgt)	45 Hz ...10 kHz 10 kHz ...20 kHz
	200 mA	10 μA	± (1.0 % of rdg + 10 dgt) ± (2.0 % of rdg + 20 dgt)	45 Hz ...10 kHz 10 kHz ...20 kHz
	2 A	100 μA	± (1.0 % of rdg + 10 dgt)	45 Hz ...2 kHz
	10 A	1 mA	± (1.0 % of rdg + 10 dgt)	45 Hz ...20 kHz

Function	Range	Resolution	Accuracy
<b>Resistance</b>	200 $\Omega$	0.01 $\Omega$	$\pm (2.0 \% \text{ of rdg} + 5 \text{ dgt})$
	2 k $\Omega$	0.1 $\Omega$	$\pm (0.2 \% \text{ of rdg} + 2 \text{ dgt})$
	20 k $\Omega$	1 $\Omega$	$\pm (0.2 \% \text{ of rdg} + 2 \text{ dgt})$
	200 k $\Omega$	10 $\Omega$	$\pm (0.2 \% \text{ of rdg} + 2 \text{ dgt})$
	2 M $\Omega$	100 $\Omega$	$\pm (0.5 \% \text{ of rdg} + 2 \text{ dgt})$
	20 M $\Omega$	1 k $\Omega$	$\pm (0.5 \% \text{ of rdg} + 2 \text{ dgt})$
<b>Frequency</b>	20 kHz	1 Hz	$\pm (1.0 \% \text{ of rdg} + 3 \text{ dgt})$
	200 kHz	10 Hz	$\pm (2.0 \% \text{ of rdg} + 3 \text{ dgt})$
<b>hFE</b>	Base current: 3.5 $\mu\text{A}$ ; $V_{\text{CE}} = 4.5 \text{ V}$ approx.		
<b>Diode</b>	Test voltage: 4.5 V approx., maximum test current: 1 mA		
<b>Continuity</b>	Threshold: 200 $\Omega$ or less		

## Summit 45 (Brighton Electronics)

**Type** An autoranging digital multimeter with a 4 digit LCD display (2 time per second update). Measurement capabilities include AC/DC voltage, AC/DC current (the rectifier for AC measurements), resistance, diode test and continuity, the model 45 also has record and hold features.

### Some characteristics

Function	Range	Resolution	Accuracy	Input impedance
<b>DC voltage</b>	400 mV	0,1 mV	$\pm (0.3 \% \text{ of rdg} + 2 \text{ dgt})$	10 M $\Omega$
	4 V	1 mV		
	40 V	10 mV		
	400 V	100 mV		
	1000 V	1 V		
<b>AC voltage (45 Hz ... 450 Hz)</b>	4 V	1 mV	$\pm (0.8 \% \text{ of rdg} + 3 \text{ dgt})$	10 M $\Omega$
	40 V	10 mV	$\pm (0.8 \% \text{ of rdg} + 3 \text{ dgt})$	
	400 V	100 mV	$\pm (1.2 \% \text{ of rdg} + 3 \text{ dgt})$	
	750 V	1 V	$\pm (1.2 \% \text{ of rdg} + 3 \text{ dgt})$	
<b>DC current</b>	400 $\mu$ A	0.1 $\mu$ A	$\pm (0.5 \% \text{ of rdg} + 2 \text{ dgt})$	
	4 mA	0.001 mA	$\pm (0.5 \% \text{ of rdg} + 2 \text{ dgt})$	
	40 mA	0.01 mA	$\pm (0.5 \% \text{ of rdg} + 2 \text{ dgt})$	
	400 mA	0.1 mA	$\pm (0.5 \% \text{ of rdg} + 2 \text{ dgt})$	
	4 A	1 mA	$\pm (1.2 \% \text{ of rdg} + 2 \text{ dgt})$	
	10 A	0.01 A	$\pm (1.2 \% \text{ of rdg} + 2 \text{ dgt})$	
<b>AC current</b>	400 $\mu$ A	0.1 $\mu$ A	$\pm (0.8 \% \text{ of rdg} + 3 \text{ dgt})$	
	4 mA	0.001 mA	$\pm (0.8 \% \text{ of rdg} + 3 \text{ dgt})$	
	40 mA	0.01 mA	$\pm (0.8 \% \text{ of rdg} + 3 \text{ dgt})$	
	400 mA	0.1 mA	$\pm (0.8 \% \text{ of rdg} + 3 \text{ dgt})$	
	4 A	1 mA	$\pm (1.5 \% \text{ of rdg} + 3 \text{ dgt})$	
	10 A	0.01 A	$\pm (1.5 \% \text{ of rdg} + 3 \text{ dgt})$	
<b>Resistance</b>	400 $\Omega$	0.1 $\Omega$	$\pm (0.5 \% \text{ of rdg} + 2 \text{ dgt})$	
	4 k $\Omega$	1 $\Omega$	$\pm (0.5 \% \text{ of rdg} + 2 \text{ dgt})$	
	40 k $\Omega$	10 $\Omega$	$\pm (0.5 \% \text{ of rdg} + 2 \text{ dgt})$	
	400 k $\Omega$	100 $\Omega$	$\pm (0.5 \% \text{ of rdg} + 2 \text{ dgt})$	
	4 M $\Omega$	1 k $\Omega$	$\pm (1 \% \text{ of rdg} + 2 \text{ dgt})$	
	40 M $\Omega$	10 k $\Omega$	$\pm (1 \% \text{ of rdg} + 2 \text{ dgt})$	
<b>Diode Test</b>	Test voltage 3 V, max. test current 30 $\mu$ A, approx.			
<b>Continuity</b>	Test voltage 3 V, threshold < 50 $\Omega$			

**Max. voltage between any input and ground:** 1000 V

**Fuse protection:** mA: 0.5 A/600 V<sub>AC</sub>; A: 10 A/600 V<sub>AC</sub>

**Power supply:** 2 each 1.5 V „AA“ batteries

**Size:** 33 mm  $\times$  86 mm  $\times$  187 mm

**Weight:** 340 g

**MY64 (Mastech)**

**Type** A series handheld professional measuring instrument with dual- slope integration A/D converter; and a 4 digit LCD display (2-3 time per second update). A rotary switch is used to select functions as well as ranges. Measurement capabilities include: DC voltage and current, AC voltage and current (with the rectifier – average value, calibrated in RMS of sine wave), resistance, capacitance, temperature, frequency. Diode and transistor test, audible continuity test.

**Some characteristics**

Function	Range	Resolution	Accuracy	Input impedance
<b>DC voltage</b>	200 mV	0.1 mV	$\pm (0.5 \% \text{ of rdg} + 1 \text{ dgt})$	10 M $\Omega$
	2 V	1 mV	$\pm (0.5 \% \text{ of rdg} + 1 \text{ dgt})$	
	20 V	10 mV	$\pm (0.5 \% \text{ of rdg} + 1 \text{ dgt})$	
	200 V	100 mV	$\pm (0.5 \% \text{ of rdg} + 1 \text{ dgt})$	
	1000 V	1 V	$\pm (0.8 \% \text{ of rdg} + 2 \text{ dgt})$	
<b>AC voltage (40 Hz ... 400 Hz)</b>	200 mV	0.1 mV	$\pm (1.2 \% \text{ of rdg} + 3 \text{ dgt})$	10 M $\Omega$
	2 V	1 mV	$\pm (0.8 \% \text{ of rdg} + 3 \text{ dgt})$	
	20 V	10 mV	$\pm (0.8 \% \text{ of rdg} + 3 \text{ dgt})$	
	200 V	100 mV	$\pm (0.8 \% \text{ of rdg} + 3 \text{ dgt})$	
	750 V	1 V	$\pm (1.2 \% \text{ of rdg} + 3 \text{ dgt})$	
				Resistance of shunt
<b>DC current</b>	2 mA	0,001 mA	$\pm (0,8 \% \text{ of rdg} + 1 \text{ dgt})$	110 $\Omega$
	20 mA	0,01 mA	$\pm (0,8 \% \text{ of rdg} + 1 \text{ dgt})$	15 $\Omega$
	200 mA	0,1 mA	$\pm (1,5 \% \text{ of rdg} + 1 \text{ dgt})$	5 $\Omega$
	10 A	10 mA	$\pm (2,0 \% \text{ of rdg} + 5 \text{ dgt})$	0,03 $\Omega$
<b>AC current (40 Hz ... 400 Hz)</b>	400 $\mu$ A	0,1 $\mu$ A	$\pm (1,0 \% \text{ of rdg} + 3 \text{ dgt})$	110 $\Omega$
	4 mA	0,001 mA	$\pm (1,0 \% \text{ of rdg} + 3 \text{ dgt})$	15 $\Omega$
	40 mA	0,01 mA	$\pm (1,8 \% \text{ of rdg} + 3 \text{ dgt})$	5 $\Omega$
	400 mA	0,1 mA	$\pm (3,0 \% \text{ of rdg} + 7 \text{ dgt})$	0,03 $\Omega$
<b>Resistance</b>	200 $\Omega$	0,1 $\Omega$	$\pm (0,8 \% \text{ of rdg} + 3 \text{ dgt})$	
	2 k $\Omega$	1 $\Omega$	$\pm (0,8 \% \text{ of rdg} + 1 \text{ dgt})$	
	20 k $\Omega$	10 $\Omega$	$\pm (0,8 \% \text{ of rdg} + 1 \text{ dgt})$	
	200 k $\Omega$	100 $\Omega$	$\pm (0,8 \% \text{ of rdg} + 1 \text{ dgt})$	
	2 M $\Omega$	1 k $\Omega$	$\pm (0,8 \% \text{ of rdg} + 1 \text{ dgt})$	
	20 M $\Omega$	10 k $\Omega$	$\pm (1,0 \% \text{ of rdg} + 2 \text{ dgt})$	
	200 M $\Omega$	100 k $\Omega$	$\pm 5,0 \% \text{ of } (rdg - 10 \text{ dgt}) \pm 10 \text{ dgt}$ On 200 M $\Omega$ range, if short input, display will read 1 M $\Omega$ , this 1 M $\Omega$ should be subtracted.	
<b>Frequency</b>	20 kHz	10 Hz	$\pm (1,5 \% \text{ of rdg} + 5 \text{ dgt})$	
<b>Temperature</b>	-20 $^{\circ}$ C to 0 $^{\circ}$ C	1 $^{\circ}$ C	$\pm (5,0 \% \text{ of rdg} + 4 \text{ dgt})$	
<b>-20 <math>^{\circ}</math>C to 1000 <math>^{\circ}</math>C</b>	0 $^{\circ}$ C to 400 $^{\circ}$ C		$\pm (1,0 \% \text{ of rdg} + 3 \text{ dgt})$	
	400 $^{\circ}$ C to 1000 $^{\circ}$ C		$\pm 2,0 \% \text{ of rdg}$	
<b>Capacitance</b>	2 nF	1 pF	$\pm (4,0 \% \text{ of rdg} + 3 \text{ dgt})$	
	20 nF	10 pF	$\pm (4,0 \% \text{ of rdg} + 3 \text{ dgt})$	
	200 nF	100 pF	$\pm (4,0 \% \text{ of rdg} + 3 \text{ dgt})$	
	2 $\mu$ F	1 nF	$\pm (4,0 \% \text{ of rdg} + 3 \text{ dgt})$	
	20 $\mu$ F	10 nF	$\pm (4,0 \% \text{ of rdg} + 3 \text{ dgt})$	

**Maximum voltage between terminals and earth ground:** 1000 VDC or 700 VRMS (sine)

**Fuse protection:** mA: 200 mA/250 V; A: bez jištění

**Power supply:** 9 V battery

**Display:** LCD, 1999 counts

**Weigh :** 310 g (including battery)



## GDM-8145 (GW Instek)

**Type** Portable, bench-type digital multimeter with a 4 ½ digit LED display; it can measure: AC/DC voltage, AC/DC current, and resistance. Some special advantages of the instrument: TRUE RMS measurement of AC or AC+DC signals (true RMS measurement is the only accurate way to directly measure AC or AC+DC signals that are not noise-free pure sinewaves). This instrument measures AC voltage frequencies up to 50 kHz.

### Resolution and accuracy

Function	Range	Resolution	Accuracy	Frequency Range
DC voltage	200 mV	10 μV	± (0.03 % of rdg + 4 dgt)	
	2 V	100 μV		
	20 V	1 mV		
	200 V	10 mV		
	1000 V	100 mV		
Input impedance	10 MΩ in parallel with < 100 pF, all ranges			
AC voltage (TRUE RMS responding, AC or AC+DC)	200 mV	10 μV	± (1 % of rdg + 15 dgt) ± (0.5 % of rdg + 15 dgt) ± (1 % of rdg + 15 dgt) ± (2 % of rdg + 30 dgt) ± (5 % of rdg + 30 dgt)	20 Hz ... 45 Hz 45 Hz ...2 kHz 2 kHz ...10 kHz 10 kHz ...20 kHz 20 kHz ...50 kHz
	2 V	100 μV	± (1 % of rdg + 15 dgt) ± (0.5 % of rdg + 15 dgt) ± (1 % of rdg + 15 dgt) ± (2 % of rdg + 30 dgt) ± (5 % of rdg + 30 dgt)	20 Hz ... 45 Hz 45 Hz ...2 kHz 2 kHz ...10 kHz 10 kHz ...20 kHz 20 kHz ...50 kHz
	20 V	1 mV	± (1 % of rdg + 15 dgt) ± (0.5 % of rdg + 15 dgt) ± (1 % of rdg + 15 dgt) ± (2 % of rdg + 30 dgt) ± (5 % of rdg + 30 dgt)	20 Hz ... 45 Hz 45 Hz ...2 kHz 2 kHz ...10 kHz 10 kHz ...20 kHz 20 kHz ...50 kHz
	200 V	10 mV	± (1 % of rdg + 15 dgt) ± (0.5 % of rdg + 15 dgt)	20 Hz ... 45 Hz 45 Hz ...1 kHz
	1000 V	100 mV	± (1 % of rdg + 15 dgt) ± (0.5 % of rdg + 15 dgt)	20 Hz ... 45 Hz 45 Hz ...1 kHz

Function	Range	Resolution	Accuracy	Frequency ranges
<b>DC current</b>	200 $\mu$ A 2 mA 20 mA 200 mA	0.01 $\mu$ A 0.1 $\mu$ A 1 $\mu$ A 10 $\mu$ A	$\pm (0.2 \% \text{ of rdg} + 2 \text{ dgt})$	
	2000 mA 20 A	100 $\mu$ A 1 mA	$\pm (0.3 \% \text{ of rdg} + 2 \text{ dgt})$	
<b>Max. fullscale burden voltages</b>	0.3 V ... for the 200 $\mu$ A, 2 mA, 20 mA, 200 mA ranges; 0.9 V ... for the 2 A and 20 A ranges			
<b>AC current</b>	200 $\mu$ A	0.01 $\mu$ A	$\pm (1 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (0.5 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (1 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (2 \% \text{ of rdg} + 15 \text{ dgt})$	20 Hz ... 45 Hz 45 Hz ...2 kHz 2 kHz ...10 kHz 10 kHz ...20 kHz
	2 mA	0.1 $\mu$ A	$\pm (1 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (0.5 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (1 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (2 \% \text{ of rdg} + 15 \text{ dgt})$	20 Hz ... 45 Hz 45 Hz ...2 kHz 2 kHz ...10 kHz 10 kHz ...20 kHz
	20 mA	1 $\mu$ A	$\pm (1 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (0.5 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (1 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (2 \% \text{ of rdg} + 15 \text{ dgt})$	20 Hz ... 45 Hz 45 Hz ...2 kHz 2 kHz ...10 kHz 10 kHz ...20 kHz
	200 mA	10 $\mu$ A	$\pm (1 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (0.5 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (1 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (2 \% \text{ of rdg} + 15 \text{ dgt})$	20 Hz ... 45 Hz 45 Hz ...2 kHz 2 kHz ...10 kHz 10 kHz ...20 kHz
	2000 mA	100 $\mu$ A	$\pm (1 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (0.5 \% \text{ of rdg} + 15 \text{ dgt})$	20 Hz ... 45 Hz 45 Hz ...2 kHz
	20 A	1 mA	$\pm (1 \% \text{ of rdg} + 15 \text{ dgt})$ $\pm (0.5 \% \text{ of rdg} + 15 \text{ dgt})$	20 Hz ... 45 Hz 45 Hz ...2 kHz

				Full scale voltage across unknown resistance
Resistance	200 $\Omega$	0.01 $\Omega$	$\pm$ (0.1 % of rdg + 4 dgt)	0.2 V
	2 k $\Omega$	0.1 $\Omega$	$\pm$ (0.1 % of rdg + 2 dgt)	2 V
	20 k $\Omega$	1 $\Omega$		2 V
	200 k $\Omega$	10 $\Omega$		0.2 V
	2000 k $\Omega$	100 $\Omega$	$\pm$ (0.25 % of rdg + 2 dgt)	2 V
	20 M $\Omega$	1 k $\Omega$	2 V	
Diode Test	These three ranges have enough voltage to turn on silicon junctions to check for proper forward-to-back resistance. The 2 k $\Omega$ range is preferred and is marked with a large diode symbol on the front panel of the instrument.			

## HP / Agilent 34401A

**Type** 6 1/2 -digit, high-performance portable digital multimeter with built-in math operations, continuity and diode test functions, HP-IB (IEEE 488) interface and RS-232 interface; standard programming languages (SCPI, HP 3478A, and Fluke 8840); reading rates up to 1000 readings per second, storage for up to 512 readings, limit testing with pass/fail signals.

### Some DC characteristics

**DC voltage** (measurement method: continuously integrating, multi-slope A/D converter)

Range	Accuracy (1 year, 23 °C ± 5 °C)	Input resistance
100.0000 mV	0.0050 % of reading + 0.0035 % of range	10 MΩ or > 10 GΩ
1.000000 V	0.0040 % of reading + 0.0007 % of range	10 MΩ or > 10 GΩ
10.00000 V	0.0035 % of reading + 0.0005 % of range	10 MΩ or > 10 GΩ
100.0000 V	0.0045 % of reading + 0.0006 % of range	10 MΩ ± 1 %
1000.000 V	0.0045 % of reading + 0.0010 % of range	10 MΩ ± 1 %

### DC current

Range	Burden voltage	Accuracy (1 year, 23 °C ± 5 °C)	Shunt resistor
10.00000 mA	< 0.1 V	0.05 % of reading + 0.020 % of range	5 Ω
100.0000 mA	< 0.6 V	0.05 % of reading + 0.005 % of range	5 Ω
1.00000 A	< 1 V	0.10 % of reading + 0.010 % of range	0.1 Ω
3.00000 A	< 2 V	0.12 % of reading + 0.020 % of range	0.1 Ω

**Resistance** (measurement method: 4-wire or 2-wire)

Range	Test current	Accuracy (1 year, 23 °C ± 5 °C)
100.0000 Ω	1 mA	0.010 % of reading + 0.004 % of range
1.000000 kΩ	1 mA	0.010 % of reading + 0.001 % of range
10.00000 kΩ	100 μA	0.010 % of reading + 0.001 % of range
100.0000 kΩ	10 μA	0.010 % of reading + 0.001 % of range
1.000000 MΩ	5 μA	0.010 % of reading + 0.001 % of range
10.00000 MΩ	500 nA	0.040 % of reading + 0.001 % of range
100.0000 MΩ	500 nA	0.800 % of reading + 0.001 % of range

### Diode Test

Range	Test current	Accuracy (1 year, 23 °C ± 5 °C)
1.0000 Ω	1 mA	0.010 % of reading + 0.02 % of range

## Some AC characteristics

**True RMS AC voltage** (measurement method: AC-coupled True RMS - measures the ac component of the input with up to 400 Vdc of bias on any range)

Range	Frequency	Accuracy (1 year, 23 °C ± 5 °C)
100.0000 mV	3 Hz to 5 Hz	1.00 % of reading + 0.04 % of range
	5 Hz to 10 Hz	0.35 % of reading + 0.04 % of range
	10 Hz to 20 kHz	0.06 % of reading + 0.04 % of range
	20 kHz to 50 kHz	0.12 % of reading + 0.05 % of range
	50 kHz to 100 kHz	0.60 % of reading + 0.08 % of range
	100 kHz to 300 kHz	4.00 % of reading + 0.50 % of range
1.000000 V to 750.000 V	3 Hz to 5 Hz	1.00 % of reading + 0.03 % of range
	5 Hz to 10 Hz	0.35 % of reading + 0.03 % of range
	10 Hz to 20 kHz	0.06 % of reading + 0.03 % of range
	20 kHz to 50 kHz	0.12 % of reading + 0.05 % of range
	50 kHz to 100 kHz	0.60 % of reading + 0.08 % of range
	100 kHz to 300 kHz	4.00 % of reading + 0.50 % of range

**Input impedance:** 1 MΩ ± 2 %, in parallel with 100 pF

**True RMS AC current** (measurement method: direct coupled to the fuse and shunt; AC-coupled True RMS measurement - measures the AC component only)

Range	Frequency	Accuracy (1 year, 23 °C ± 5 °C)	Shunt resistor
1.00000 A	3 Hz to 5 Hz	1.00 % of reading + 0.040 % of range	0.1 Ω
	5 Hz to 10 Hz	0.30 % of reading + 0.040 % of range	
	10 Hz to 5 kHz	0.10 % of reading + 0.040 % of range	
3.00000 A	3 Hz to 5 Hz	1.10 % of reading + 0.060 % of range	0.1 Ω
	5 Hz to 10 Hz	0.35 % of reading + 0.060 % of range	
	10 Hz to 5 kHz	0.15 % of reading + 0.060 % of range	

## Frequency and period characteristics

(measurement method: reciprocal-counting technique; AC-coupled input using the ac voltage measurement function; gate time: 10 ms, 100 ms, or 1 s)

Range	Frequency	Accuracy (1 year, 23 °C ± 5 °C)
100 mV to 750 V	3 Hz to 5 Hz	0.1 % of reading
	5 Hz to 10 Hz	0.05 % of reading
	10 Hz to 40 kHz	0.03 % of reading
	40 kHz to 300 kHz	0.01 % of reading

## Menu

In the local regime some functions of the multimeter can be set only by the use of MENU - see User's Guide HP 34401A.

## PK 430.1 (Metra Blansko)

**Type** Universal clamp meter with digital display; measurement capabilities of the meter include:  
AC current and voltage (True RMS), DC current and voltage, AC active and apparent power,  
DC power, lagging or leading power factor ( $\cos \phi$ ), frequency, resistance, temperature

### Some characteristics

Function	Range	Resolution	Accuracy
<b>AC, AC+DC current (A)</b> 0 to 1000 A	39.99 399.9 1000	0.01 0.10 1.00	1 % of range 1 % of range 1 % of range
<b>DC, AC+DC current (A)</b> 0 to 1000 A	39.99 399.9 1000	0.01 0.10 1.00	2 % of range 1 % of range 1 % of range
<b>AC, DC, AC+DC voltage (V)</b> 0 to 1000 V	39.99 399.9 1000	0.01 0.10 1.00	0.5 % of range 0.5 % of range 0.5 % of range
<b>Active power (kW)</b> 0,4 to 1000 kW (voltage 10 to 1000 V, current 10 to 1000 A)	3.999 39.99 399.9 1000	0.001 0.010 0.100 1.000	2 % of range <sup>1)</sup> 2 % of range 2 % of range 2 % of range
<b>Apparent power (kVA)</b> 0,1 to 1000 kVA (voltage 10 to 1000 V, current 0 to 1000 A)	3.999 39.99 399.9 1000	0.001 0.010 0.100 1.000	2 % of range 2 % of range 2 % of range 5 % of range for I < 40 A
<b>Power factor</b> (voltage 10 to 1000 V, current 40 to 1000 A, apparent power 1 to 1000 kVA)	-1.0 to 1.0 L -1.0 to 1.0 C	0.01 0.01	3 % of range 3 % of range
<b>Frequency (Hz)</b> 20 to 3999 Hz (voltage 10 to 1000 V) 20 to 399.9 Hz (current 15 to 1000 A)	399.9 3999	0.1 1.0	0.5 % of range 0.5 % of range
<b>Resistance (<math>\Omega</math>)</b> 0 to 399.9 k $\Omega$	399.9 3.999 k 39.99 k 399.9 k	0.1 0.001 k 0.010 k 0.100 k	0.5 % of range 0.5 % of range 0.5 % of range 0.5 % of range
<b>Temperature (<math>^{\circ}\text{C}</math>)</b>	-50 to +125.0	0.1	2.5 % of range

### Frequency range

**current:** to 400 A 30 Hz to 300 Hz, over 400 A 30 Hz to 100 Hz  
**voltage:** 30 Hz to 1000 Hz

**Input resistance:** 1 M $\Omega$

**Power supply:** 9 V battery, Function time: min. 30 hours, with a new battery  
insufficient value of power voltage is displayed by symbol "BAT"

## Keysight U3400 Series

### DC voltage

#### U3401A 4.5-digit DMM

Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C)	Typical input impedance <sup>1</sup>
500.00 mV	10 µV	510.00	0.02% + 4	10.0 MΩ
5.0000 V	100 µV	5.1000	0.02% + 4	11.1 MΩ
50.000 V	1 mV	51.000	0.02% + 4	10.1 MΩ
500.00 V	10 mV	510.00	0.02% + 4	10.0 MΩ
1000.0 V	100 mV	1200.0 <sup>2</sup>	0.02% + 4	10.0 MΩ

1. Input impedance is in parallel with capacitance <100 pF.
2. In VDC 1000 V range, 1200 V is readable with audio warning.

Rate	Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C)	Typical input impedance <sup>1</sup>
Slow	120.000 mV	1 µV	119.999	0.012% + 8 <sup>2</sup>	10.0 MΩ
	1.20000 V	10 µV	1.19999	0.012% + 5	10.0 MΩ
	12.0000 V	100 µV	11.9999	0.012% + 5	11.1 MΩ
	120.000 V	1 mV	119.999	0.012% + 5	10.1 MΩ
	1000.00 V	10 mV	1000.00 <sup>3</sup>	0.012% + 5	10.0 MΩ
Medium	400.00 mV	10 µV	399.99	0.012% + 5	10.0 MΩ
	4.0000 V	100 µV	3.9999	0.012% + 5	11.1 MΩ
	40.000 V	1 mV	39.999	0.012% + 5	10.1 MΩ
	400.00 V	10 mV	399.99	0.012% + 5	10.0 MΩ
	1000.0 V	100 mV	1000.0 <sup>3</sup>	0.012% + 5	10.0 MΩ
Fast	400.0 mV	100 µV	399.9	0.012% + 2	10.0 MΩ
	4.000 V	1 mV	3.999	0.012% + 2	11.1 MΩ
	40.00 V	10 mV	39.99	0.012% + 2	10.1 MΩ
	400.0 V	100 mV	399.9	0.012% + 2	10.0 MΩ
	1000 V	1 V	1000 <sup>3</sup>	0.012% + 2	10.0 MΩ

1. Input impedance is in parallel with capacitance <120 pF.
2. Relative (REL) operation is used.
3. In VDC 1000 V range, 1050 V is readable.

### AC voltage (true RMS, AC coupling mode)

#### U3401A 4.5-digit DMM

Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C) <sup>1</sup>			
			30 Hz to 50 Hz	50 Hz to 10 kHz	10 kHz to 30 kHz	30 kHz to 100 kHz
500.00 mV	10 µV	510.00	1% + 40	0.05% + 40	2% + 60	3% + 20
5.0000 V	100 µV	5.1000	1% + 20	0.35% + 15	1% + 20	3% + 50
50.000 V	1 mV	51.000	1% + 20	0.35% + 15	1% + 20	3% + 50
500.00 V	10 mV	510.00	Not specified	0.5% + 15	1% + 20 <sup>2</sup>	3% + 50 <sup>2</sup>
750.0 V	100 mV	1000.0	Not specified	0.5% + 15 <sup>3</sup>	1% + 20 <sup>2</sup>	Not specified

1. Accuracy specified at input >5% of full scale.
2. Input voltage <200 V RMS.
3. For 5 kHz to 10 kHz, accuracy is 0.7% + 15.
4. In VAC 750 V range, 1000.0 V RMS is readable with audio warning.

## U3402A 5½-digit DMM

Rate	Range	Resolution	Max. reading	Accuracy (1 year; 23 °C ± 5 °C) <sup>1</sup>			
				20 Hz to 45 Hz	45 Hz to 10 kHz	10 kHz to 30 kHz	30 kHz to 100 kHz
Slow	120.000 mV	1 µV	119.999	1% + 100	0.2% + 100	1.5% + 100	5% + 300 <sup>2</sup>
	1.20000 V	10 µV	1.19999	1% + 100	0.2% + 100	1% + 100	3% + 200 <sup>2</sup>
	12.0000 V	100 µV	11.9999	1% + 100	0.2% + 100	1% + 100	3% + 200 <sup>2</sup>
	120.000 V	1 mV	119.999	1% + 100	0.2% + 100	1% + 100	3% + 200 <sup>2</sup>
	750.00 V	10 mV	750.00 <sup>4</sup>	1% + 100 <sup>2</sup>	0.2% + 100	1% + 100	3% + 200 <sup>3</sup>
Medium	400.00 mV	10 µV	399.99	1% + 40	0.2% + 40	1.5% + 80	5% + 120 <sup>2</sup>
	4.0000 V	100 µV	3.9999	1% + 40	0.2% + 40	1% + 40	3% + 80 <sup>2</sup>
	40.000 V	1 mV	39.999	1% + 40	0.2% + 40	1% + 40	3% + 80 <sup>2</sup>
	400.00 V	10 mV	399.99	1% + 40 <sup>2</sup>	0.2% + 40	1% + 40	3% + 80 <sup>2</sup>
	750.0 V	100 mV	750.0	1% + 40 <sup>2</sup>	0.2% + 40	1% + 40	3% + 80 <sup>3</sup>
Fast	400.0 mV	100 µV	399.9	1% + 5	0.2% + 5	1.5% + 10	5% + 15 <sup>2</sup>
	4.000 V	1 mV	3.999	1% + 5	0.2% + 5	1% + 5	3% + 10 <sup>2</sup>
	40.00 V	10 mV	39.99	1% + 5	0.2% + 5	1% + 5	3% + 10 <sup>2</sup>
	400.0 V	100 mV	399.9	1% + 5 <sup>2</sup>	0.2% + 5	1% + 5	3% + 10 <sup>2</sup>
	750 V	1 V	750	1% + 5 <sup>2</sup>	0.2% + 5	1% + 5	3% + 10 <sup>3</sup>

1. Accuracy specified at input >5% of full scale.
2. Input voltage <200 V RMS.
3. Input voltage <500 V RMS.
4. In VAC 750 V range, 787.5 V RMS is readable.

## AC voltage (true RMS, AC+DC coupling mode)

### U3401A 4.5-digit DMM

Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C) <sup>1</sup>		
			50 Hz to 10 kHz	10 kHz to 30 kHz	30 kHz to 100 kHz
500.00 mV	10 µV	510.00	0.5% + 50	2% + 70	3% + 130
5.0000 V	100 µV	5.1000	0.5% + 25	1% + 30	3% + 60
50.000 V	1 mV	51.000	0.5% + 25	1% + 30	3% + 60
500.00 V	10 mV	510.00	0.5% + 25	1% + 30 <sup>2</sup>	3% + 60 <sup>2</sup>
750.0 V	100 mV	1000.0 <sup>3</sup>	0.5% + 25 <sup>4</sup>	1% + 30 <sup>2</sup>	Not specified

1. Accuracy specified at input >5% of full scale.
2. Input voltage <200 V RMS.
3. In VAC 750 V range, 1000.0 V RMS is readable with audio warning.
4. For 5 kHz to 10 kHz, accuracy is 0.7% + 25.

### U3402A 5.5-digit DMM

Rate	Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C) <sup>1</sup>		
				45 Hz to 10 kHz	10 kHz to 30 kHz	30 kHz to 100 kHz
Slow	120.000 mV	1 µV	119.999	0.2% + 100	1.5% + 300	5% + 300
	1.20000 V	10 µV	1.19999	0.2% + 100	1% + 100	3% + 200
	12.0000 V	100 µV	11.9999	0.2% + 100	1% + 100	3% + 200
	120.000 V	1 mV	119.999	0.2% + 100	1% + 100	3% + 200
	750.00 V	10 mV	750.000 <sup>2</sup>	0.2% + 100	1% + 100	3% + 200 <sup>3</sup>
Medium	400.00 mV	10 µV	399.99	0.2% + 45	1.5% + 83	5% + 125
	4.0000 V	100 µV	3.9999	0.2% + 43	1% + 43	3% + 83
	40.000 V	1 mV	39.999	0.2% + 43	1% + 43	3% + 83
	400.00 V	10 mV	399.99	0.2% + 43	1% + 43	3% + 83
	750.0 V	100 mV	750.00	0.2% + 43	1% + 43	3% + 83 <sup>3</sup>
Fast	400.0 mV	100 µV	399.9	0.2% + 7	1.5% + 12	5% + 18
	4.000 V	1 mV	3.999	0.2% + 7	1% + 7	3% + 12
	40.00 V	10 mV	39.99	0.2% + 7	1% + 7	3% + 12
	400.0 V	100 mV	399.9	0.2% + 7	1% + 7	3% + 12
	750 V	1 V	750.0	0.2% + 7	1% + 7	3% + 12 <sup>3</sup>

1. Accuracy specified at input >5% of full scale.
2. In VAC 750 V range, 787.5 V RMS is readable.
3. Input voltage <500 V RMS.

DC current

U3401A 4.5-digit DMM

Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C)	Burden voltage <sup>1</sup> and shunt resistor
500.00 µA	10 nA	510.00	0.05% + 5	<0.06 V/100 Ω
5.0000 mA	100 nA	5.1000	0.05% + 4	<0.6 V/100 Ω
50.000 mA	1 µA	51.000	0.05% + 4	<0.08 V/1 Ω
500.00 mA	10 µA	510.00	0.05% + 4	<0.8 V/1 Ω
5.0000 A	100 µA	5.1000	0.25% + 5	<0.3 V/0.01 Ω
10.000 A	1 mA	20.000 <sup>2</sup>	0.25% + 5	<0.6 V/0.01 Ω

1. Typical at full-scale reading and voltage across the input terminals.
2. In 10 A range, >10 to 20 ADC is readable for 20 seconds maximum with audio warning.

U3402A 5.5-digit DMM

Rate	Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C)	Burden voltage <sup>1</sup> and shunt resistor
Slow	12.0000 mA	0.1 µA	11.9999	0.05% + 15 <sup>2</sup>	<0.15 V/10 Ω
	120.000 mA	1 µA	119.999	0.05% + 5	<1.5 V/10 Ω
	1200.00 mA	10 µA	1199.99	0.2% + 5	<0.3 V/0.1 Ω
	12.0000 A	100 µA	11.9999	0.2% + 5	<0.6 V/0.01 Ω
Medium	40.000 mA	1 µA	39.999	0.1% + 6	<0.5 V/10 Ω
	120.00 mA	10 µA	119.99	0.1% + 3	<1.5 V/10 Ω
	1200.0 mA	100 µA	1199.9	0.2% + 3	<0.3 V/0.1 Ω
	12.000 A	1 mA	11.999	0.2% + 3	<0.6 V/0.01 Ω
Fast	40.00 mA	10 µA	39.99	0.1% + 2	<0.5 V/10 Ω
	120.0 mA	100 µA	119.9	0.1% + 2	<1.5 V/10 Ω
	1200 mA	1 mA	1199	0.2% + 2	<0.3 V/0.1 Ω
	12.00 A	10 mA	11.99	0.2% + 2	<0.6 V/0.01 Ω

1. Typical at full-scale reading and voltage across the input terminals.
2. Relative (REL) operation is used.

AC current (true RMS, AC coupling mode)

U3401A 4.5-digit DMM

Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C) <sup>1</sup>				Burden voltage <sup>2</sup> and shunt resistor
			30 Hz to 50 Hz	50 Hz to 2 kHz	2 kHz to 5 kHz	5 kHz to 20 kHz	
500.00 µA	10 nA	510.00	1.5% + 50	0.5% + 20	1.5% + 50	3% + 75 <sup>3</sup>	<0.06 V/100 Ω
5.0000 mA	100 nA	5.1000	1.5% + 40	0.5% + 20	1.5% + 40	3% + 60	<0.6 V/100 Ω
50.000 mA	1 µA	51.000	1.5% + 40	0.5% + 20	1.5% + 40	3% + 60	<0.08 V/1 Ω
500.00 mA	10 µA	510.00	1.5% + 40	0.5% + 20	1.5% + 40	3% + 60	<0.8 V/1 Ω
5.0000 A	100 µA	5.1000	2% + 40 <sup>4</sup>	0.5% + 20	Not specified	Not specified	<0.3 V/0.01 Ω
10.000 A	1 mA	20.000 <sup>5</sup>	2% + 40 <sup>4</sup>	0.5% + 30 (<1 kHz)	Not specified	Not specified	<0.6 V/0.01 Ω

1. Accuracy specified at input >5% of full scale and >1 A for 10 A range unless otherwise stated.
2. Typical at full-scale reading and voltage across the input terminals.
3. Input current >35 µA RMS.
4. Input current <3 A RMS.
5. In 10 A range, >10 to 20 ADC is readable for 20 seconds maximum with audio warning.



U3402A 5.5-digit DMM

Rate	Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C) <sup>1</sup>			Burden voltage <sup>2</sup> and shunt resistor
				20 Hz to 45 Hz	45 Hz to 2 kHz	2 kHz to 10 kHz	
Slow	12.0000 mA	0.1 µA	11.9999	1.5% + 100	0.5% + 100	2% + 200	<0.15 V/10 Ω
	120.000 mA	1 µA	119.999	1.5% + 100	0.5% + 100	2% + 200	<1.5 V/10 Ω
	1200.00 mA	10 µA	1199.99	1.5% + 100	0.5% + 100	2% + 200	<0.3 V/0.1 Ω
	12.0000 A	100 µA	11.9999	2% + 100 (<1.2 A)	1% + 100	Not specified	<0.6 V/0.01 Ω
Medium	40.000 mA	1 µA	39.999	1.5% + 40	0.5% + 40	2% + 80	<0.5 V/10 Ω
	120.00 mA	10 µA	119.99	1.5% + 12	0.5% + 12	2% + 30	<1.5 V/10 Ω
	1200.0 mA	100 µA	1199.9	1.5% + 12	0.5% + 12	2% + 30	<0.3 V/0.1 Ω
	12.000 A	1 mA	11.999	1.5% + 12 (<1.2 A)	1% + 12	Not specified	<0.6 V/0.01 Ω
Fast	40.00 mA	10 µA	39.99	1.5% + 5	0.5% + 5	2% + 10	<0.5 V/10 Ω
	120.0 mA	100 µA	119.9	1.5% + 2	0.5% + 2	2.2% + 5	<1.5 V/10 Ω
	1200 mA	1 mA	1199	1.5% + 2	0.5% + 2	2.2% + 5	<0.3 V/0.1 Ω
	12.00 A	10 mA	11.99	2% + 2 (<1.2 A)	1% + 2	Not specified	<0.6 V/0.01 Ω

1. Accuracy specified at input >5% of full scale.  
2. Typical at full-scale reading and voltage across the input terminals.

AC current (true RMS, AC+DC coupling mode)

U3401A 4.5-digit DMM

Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C) <sup>1</sup>			Burden voltage <sup>2</sup> and shunt resistor
			50 Hz to 2 kHz	2 kHz to 5 kHz	5 kHz to 20 kHz	
500.00 µA	10 nA	510.00	0.5% + 30	1.5% + 60	3% + 85 <sup>3</sup>	<0.06 V/100 Ω
5.0000 mA	100 nA	5.1000	0.5% + 30	1.5% + 50	3% + 70	<0.6 V/100 Ω
50.000 mA	1 µA	51.000	0.5% + 30	1.5% + 50	3% + 70	<0.08 V/1 Ω
500.00 mA	10 µA	510.00	0.5% + 30	1.5% + 50	3% + 70	<0.8 V/1 Ω
5.0000 A	100 µA	5.1000	0.5% + 30	Not specified	Not specified	<0.3 V/0.01 Ω
10.000 A	1 mA	20.000 <sup>4</sup>	0.5% + 40 (<1 kHz)	Not specified	Not specified	<0.6 V/0.01 Ω

1. Accuracy specified at input >5% of full scale and >1 A for 10 A range unless otherwise stated.  
2. Typical at full-scale reading and voltage across the input terminals.  
3. Input current >35 µA RMS.  
4. In 10 A range, >10 to 20 ADC is readable for 20 seconds maximum with audio warning.

U3402A 5.5-digit DMM

Rate	Range	Resolution	Maximum reading	Accuracy (1 year; 23 °C ± 5 °C) <sup>1</sup>		Burden voltage <sup>2</sup> and shunt resistor
				45 Hz to 2 kHz	2 kHz to 10 kHz	
Slow	12.0000 mA	0.1 µA	11.9999	0.5% + 100	2% + 200	<0.15 V/10 Ω
	120.000 mA	1 µA	119.999	0.5% + 100	2% + 200	<1.5 V/10 Ω
	1200.00 mA	10 µA	1199.99	0.5% + 100	2% + 200	<0.3 V/0.1 Ω
	12.0000 A	100 µA	11.9999	1% + 100	Not specified	<0.6 V/0.01 Ω
Medium	40.000 mA	1 µA	39.999	0.5% + 42	2% + 80	<0.5 V/10 Ω
	120.00 mA	10 µA	119.99	0.5% + 15	2% + 30	<1.5 V/10 Ω
	1200.0 mA	100 µA	1199.9	0.5% + 15	2% + 30	<0.3 V/0.1 Ω
	12.000 A	1 mA	11.999	1% + 15	Not specified	<0.6 V/0.01 Ω
Fast	40.00 mA	10 µA	39.99	0.5% + 7	2% + 12	<0.5 V/10 Ω
	120.0 mA	100 µA	119.9	0.5% + 4	2% + 7	<1.5 V/10 Ω
	1200 mA	1 mA	1199	0.5% + 4	2% + 7	<0.3 V/0.1 Ω
	12.00 A	10 mA	11.99	1% + 4	Not specified	<0.6 V/0.01 Ω

1. Accuracy specified at input >5% of full scale.  
2. Typical at full-scale reading and voltage across the input terminals.

Resistance

U3401A 4.5-digit DMM

Range <sup>1</sup>	Resolution	Maximum reading	Test current	Accuracy (1 year; 23 °C ± 5 °C)
500.00 Ω	10 mΩ	510.00	0.5 mA	0.1% + 5 <sup>2</sup>
5.0000 kΩ	100 mΩ	5.1000	0.45 mA	0.1% + 3 <sup>2</sup>
50.000 kΩ	1 Ω	51.000	45 μA	0.1% + 3
500.00 kΩ	10 Ω	510.00	4.5 μA	0.1% + 3
5.0000 MΩ	100 Ω	5.1000	450 nA	0.1% + 3
50.000 MΩ	1 kΩ	51.000	45 nA	0.3% + 3

1. To reduce noise interference that may be induced by the test leads, we recommend using a shielded test cable for measuring resistances above 500 kΩ.  
2. Relative (REL) operation is used.

U3402A 5.5-digit DMM

Rate	Range <sup>1</sup>	Resolution	Maximum reading	Test current	Accuracy (1 year; 23 °C ± 5 °C)	
					2-wire	4-wire
Slow	120.000 Ω	1 mΩ	119.999	0.5 mA	0.1% + 8 <sup>2</sup>	0.05% + 8 <sup>2</sup>
	1.20000 kΩ	10 mΩ	1.19999	0.5 mA	0.08% + 5 <sup>2</sup>	0.05% + 5 <sup>2</sup>
	12.0000 kΩ	100 mΩ	11.9999	100 μA	0.06% + 5 <sup>2</sup>	0.05% + 5
	120.000 kΩ	1 Ω	119.999	10 μA	0.06% + 5	0.05% + 5
	1.20000 MΩ	10 Ω	1.19999	1 μA	0.06% + 5	0.05% + 5
	12.0000 MΩ	100 Ω	11.9999	100 nA	0.3% + 5	0.3% + 5
	120.000 MΩ	1 kΩ	119.999	10 nA	3% + 8	3% + 8
Medium	400.00 Ω	10 mΩ	399.99	0.5 mA	0.1% + 5 <sup>2</sup>	0.05% + 5 <sup>2</sup>
	4.0000 kΩ	100 mΩ	3.9999	100 μA	0.08% + 3 <sup>2</sup>	0.05% + 3
	40.000 kΩ	1 Ω	39.999	50 μA	0.06% + 3	0.05% + 3
	400.00 kΩ	10 Ω	399.99	5 μA	0.06% + 3	0.05% + 3
	4.0000 MΩ	100 Ω	3.9999	500 nA	0.15% + 3	0.15% + 3
	40.000 MΩ	1 kΩ	39.999	50 nA	1.5% + 3	1.5% + 3
	300.00 MΩ	10 kΩ	299.99	10 nA	5.0% + 5	5.0% + 5
Fast	400.0 Ω	100 mΩ	399.9	0.5 mA	0.1% + 2 <sup>2</sup>	0.05% + 2
	4.000 kΩ	1 Ω	3.999	100 μA	0.08% + 2	0.05% + 2
	40.00 kΩ	10 Ω	39.99	50 μA	0.06% + 2	0.05% + 2
	400.0 kΩ	100 Ω	399.9	5 μA	0.06% + 2	0.05% + 2
	4.000 MΩ	1 kΩ	3.999	500 nA	0.15% + 2	0.15% + 2
	40.00 MΩ	10 kΩ	39.99	50 nA	1.5% + 2	1.5% + 2
	300.0 MΩ	100 kΩ	299.9	10 nA	5.0% + 2	5.0% + 2

1. To reduce noise interference that may be induced by the test leads, we recommend using a shielded test cable for measuring resistances above 100 kΩ.  
2. Relative (REL) operation is used.

## Keysight U1240 Series

### DC specifications for U1241C / U1242C

Function	Range	Resolution	Accuracy ± (% of reading + counts of least significant digit)	Test current / burden voltage
Voltage	100 mV <sup>1,3</sup>	0.01 mV	0.09 % + 2	—
	600 mV <sup>1,3</sup>	0.1 mV	0.09 % + 2	—
	1000 mV <sup>4</sup>	0.1 mV	0.09 % + 2	—
	10 V <sup>4</sup>	0.001 V	0.09 % + 2	—
	100 V <sup>4</sup>	0.01 V	0.09 % + 2	—
	1000 V <sup>4</sup>	0.1 V	0.09 % + 2	—
	Z <sub>LOW</sub> <sup>2,4</sup> (applicable to 1000 V range)	0.1 V	1 % + 4	—
Current <sup>5</sup>	1000 µA <sup>3</sup>	0.01 µA	0.1 % + 2	0.032 V (30 )
	10 mA <sup>3</sup>	0.001 mA	0.1 % + 2	0.32 V (30 )
	100 mA <sup>1,3</sup>	0.01 mA	0.2 % + 2	0.2 V (0.5 )
	600 mA <sup>1,3</sup>	0.1 mA	0.2 % + 2	0.88 V (0.5 )
	10 A <sup>2,4</sup>	0.001 A	0.3 % + 5	0.5 V (0.01 )
Diode test	—	0.001 V	0.5 % + 10	< 1.6 mA
Function	Range	Resolution	Accuracy ± (% of reading + counts of least significant digit)	Continuity threshold
Resistance / audible continuity	100 <sup>3,4,7</sup>	0.01	0.2 % + 5	28 ± 10
	1000 <sup>4</sup>	0.1	0.2 % + 2	28 ± 10
	10 k	0.001 k	0.2 % + 2	0.151 ± 0.05 k
	100 k	0.01 k	0.2 % + 2	1.38 ± 0.5 k
	1000 k	0.1 k	0.2 % + 2	13.8 ± 4.3 k
	10 M <sup>5</sup>	0.001 M	0.8 % + 2	0.12 ± 0.04 M
	100 M <sup>5,6</sup>	0.01 M	1.5 % + 3 (<50 M ) 3.0 % + 3 (>50 M )	0.12 ± 0.04 M

### Notes for DC specifications

#### A. Notes for voltage specification.

- 100 mV and 600 mV ranges available on Temperature T1 terminal. The accuracy is specified for 10 M (nominal) input impedance. The accuracy is specified after NULL function is used to zero out thermal effect (by shorting test leads).
- Only available in U1242C only. 1.8 k typical input impedance for Z<sub>LOW</sub> mode.
- Overload protection for 100 mV and 600 mV ranges: 1000 Vrms for circuits < 0.3 A short circuit current.
- Overload protection: 1000 Vrms.

#### B. Notes for current specification

- Current can be measured up to 440 mA continuously. Maximum of 20 hours for measuring current more than 440 mA and up to 600 mA. 100 mA and 600 mA ranges have thermal effect of 0.35 µA/mA to be offset after current applied to these ranges. Cool down the meter for at least 6 seconds if 100 mA was applied, and at least 3 minutes if 600 mA was applied; or alternatively use the NULL function to zero-out thermal effect with open test lead before measuring the signal.
- Current can be measured up to 10 A continuously. Maximum of 30 seconds for measuring current more than 10 A to 20 A, add 0.3 % to specified accuracy. The multimeter needs to be cool down after measuring current that is more than 10 A. Cool down the meter for twice the duration of the measured time and use NULL function to zero-out thermal effect before proceeding with lower current measurement.
- 1000 µA to 600 mA ranges (connection with mA terminal) overload protection by 10 x 35 mm, 440 mA/1000 V, and 10 kA minimum fast-acting

fuse.

- 10 A ranges (connection with A terminal) overload protection by 10 x 38 mm, 11 A / 1000 V, 20 kA minimum fast-acting fuse.
- Ensure good ventilation and no heat element close to the meter.

#### C. Notes for diode test specification

- Overload protection: 1000 Vrms for circuits < 0.3 A short circuit current.
- Built-in buzzer sounds when reading is below 0.05 V approximately, and single tone for normal forward-biased diode or semiconductor junction as 0.3 + 7 reading 7 0.8 +.
- The maximum threshold voltage display is less than +2 V.

#### D. Notes for resistance/audible Continuity specification

- Maximum open voltage: < +2.4 V
- Built-in buzzer sounds as transient when resistance less than 28 I 10 . It may capture the intermittent for longer than 1 ms.
- 100 range is for U1242C only
- The accuracy is specified after Math Null, which is used to subtract the test lead resistance and the thermal effect. Ensure good ventilation and no heat element close to the meter.
- For 10 M and 100 M ranges the R.H. is specified for <60 % at 30 °C.
- For 100 M range: temperature coefficient is 0.1 x (specified accuracy) / °C.
- Resistance range 100 is typical characteristic.

## AC voltage specifications for U1241C / U1242C

Function	Range	Resolution	Accuracy ± (% of reading + counts of least significant digit)	
			40 Hz to 1 kHz	1 kHz to 2 kHz
AC voltage <sup>1,4</sup> True RMS	100 mV <sup>2</sup>	0.01 mV	1.0 % + 3	1.5 % + 3
	600 mV <sup>2</sup>	0.1 mV	1.0 % + 3	1.5 % + 3
	1000 mV	0.1 mV	1.0 % + 3	1.5 % + 3
	10 V	0.001 V	1.0 % + 3	1.5 % + 3
	100 V	0.01 V	1.0 % + 3	1.5 % + 3
	1000 V	0.1 V	1.0 % + 3	1.5 % + 3
	Z <sub>Low</sub> <sup>3</sup> (applicable to 1000 V range)	0.1 V	2.0 % + 4	N/A
AC voltage <sup>1,4</sup> Averaging sense	100 mV <sup>2</sup>	0.01 mV	1.0 % + 5	1.5 % + 5
	600 mV <sup>2</sup>	0.1 mV	1.0 % + 5	1.5 % + 5
	1000 mV	0.1 mV	1.0 % + 5	1.5 % + 5
	10 V	0.001 V	1.0 % + 5	1.5 % + 5
	100 V	0.01 V	1.0 % + 5	1.5 % + 5
	1000 V	0.1 V	1.0 % + 5	1.5 % + 5

### Notes

1. Overload protection: 1000 Vrms.
2. 100 mV and 600 mV ranges available on Temperature T1 terminal. The accuracy is specified for 10 M (nominal) input impedance. The accuracy is specified after NULL function is used to Fero out thermal effect (by shorting test leads).
3. Only available in U1242C only. 1.8 k typical input impedance for Z<sub>Low</sub> mode.
4. The input signal is lower than the product of 20,000,000 V x Hz.

## AC current specifications for U1241C / U1242C

Function	Range	Resolution	Accuracy ± (% of reading + counts of least significant digit)	
			40 Hz to 1 kHz (True RMS)	40 Hz to 1 kHz (Averaging sense) <sup>6</sup>
AC current <sup>5</sup>	1000 µA <sup>3</sup>	0.1 µA	1.0 % + 3	1.2 % + 5
	10 mA <sup>3</sup>	0.001 mA	1.0 % + 3	1.2 % + 5
	100 mA <sup>3</sup>	0.01 mA	1.0 % + 3	1.2 % + 5
	1000 mA <sup>1,3</sup>	0.1 mA	1.0 % + 3	1.2 % + 5
	10 A <sup>2,4</sup>	0.001 A	1.2 % + 5 <sup>4</sup>	1.2 % + 5

### Notes

1. Current can be measured up to 440 mA continuously. Maximum of 20 hours for measuring current more than 440 mA and up to 600 mA. 100 mA and 600 mA ranges have thermal effect of 0.35 µA/mA to be offset after current applied to these ranges. Cool down the meter for at least 6 seconds if 100 mA was applied, and at least 3 minutes if 600 mA was applied; or alternatively use the NULL function to zero-out thermal effect with open test lead before measuring the signal.
2. Current can be measured up to 10 A continuously. Maximum of 30 seconds for measuring current more than 10 A to 20 A, add 0.3 % to specified accuracy. The multimeter needs to be cool down after measuring current that is more than 10 A. Cool down the meter for twice the duration of the measured time and use NULL function to zero-out thermal effect before proceeding with lower current measurement.
3. 1000 µA to 1000 mA ranges (connection with mA terminal) overload protection by 10 x 35 mm, 440 mA / 1000 V, 10 kA minimum fast-acting fuse.
4. 10 A ranges (connection with A terminal) overload protection by 10 x 38 mm, 11 A / 1000 V, 20 kA minimum fast-acting fuse.
5. Ensure good ventilation and no heat element close to the meter.
6. The averaging sense is calibrated for sine wave only. Add additional 0.05 counts / °C to accuracy from -20 °C to 18 °C or -28 °C to 55 °C.

## Temperature specifications for U1241C / U1242C

Thermal type	Range	Resolution	Accuracy ± (% of reading + as specified below)
K	-200 °C to 1372 °C	0.1 °C	1 % + 1 °C
	-328 °F to 2502 °F	0.1 °F	1 % + 1.8 °F
J <sup>7</sup>	-210 °C to 1200 °C	0.1 °C	1 % + 1 °C
	-346 °F to 2192 °F	0.1 °F	1 % + 1.8 °F

### Notes

1. The specification above is specified after 60 minutes of warm-up time.
2. The accuracy does not include the tolerance of the thermocouple probe.
3. Do not allow the temperature sensor to contact a surface that is energized above 30 Vrms or 60 V DC. Such voltages pose a shock hazard.
4. Ensure the stable (within ± 1 °C) ambient temperature, and that the Null function is used to reduce the test lead's thermal effect and temperature offset. Before using Null function, set the multimeter to measure temperature without ambient compensation (°C) and keep the thermocouple probe as close to the multimeter as possible (avoid contact with any surface that has a different temperature from the ambient temperature).
5. When measuring temperature with respect to any temperature calibrator, try to set both the calibrator and multimeter with an external reference (without internal ambient compensation). If both the calibrator and multimeter are set with internal reference (with internal ambient compensation), some deviations may show between the readings of the calibrator and multimeter, due to differences in ambient compensation between the calibrator and multimeter. Keeping the multimeter close to the output terminal of calibrator will help reduce the deviation.
6. The temperature calculation is specified according to the safety standards of EN/IEC-60548-1 and NIST 175.
7. Only for U1242C.

## Capacitance specifications for U1241C / U1242C

Range	Resolution	Accuracy ± (% of reading + counts of least significant digit)
1000 nF	0.1 nF	1.0 % + 5
10 µF	0.001 µF	1.0 % + 5
100 µF	0.01 µF	1.0 % + 5
1000 µF	0.01 µF	1.2 % + 5
10 mF	0.001 mF	1.2 % + 5

### Notes

1. Overload protection: 1000 Vrms for short circuits with < 0.3 A current.
2. The accuracy for all ranges is specified based on a film capacitor or better, and after the Null function is used to subtract the test lead resistance and thermal effect (by shorting the test leads).
3. The maximum display is 12000 counts selectable

## Frequency specifications for U1241C / U1242C

Range	Resolution	Accuracy ± (% of reading + counts of least significant digit)	Minimum input frequency
100.00 Hz	0.01 Hz	0.02 % + 1 <sup>1</sup>	
1000.0 Hz	0.1 Hz	0.02 % + 1	
10.000 kHz	0.001 kHz	0.02 % + 1	0.5 Hz
100.00 kHz	0.01 kHz	0.02 % + 1	
1000.0 kHz	0.001 kHz	0.02 % + 1	
10.000 MHz	0.001 MHz	0.02 % + 1, < 1 MHz	

### Notes

1. The frequency measurement is susceptible to error when measuring low-voltage, low-frequency signals. Shielding inputs from external noise pickup is critical for minimizing measurement errors. Turning on LPF (low pass filter) may help to filter out the noise and achieve a stable reading.

## U1241C / U1242C sensitivity for voltage measurement

Input range	Minimum sensitivity (RMS sine wave)		
Maximum input <sup>1</sup> for specified accuracy	0.5 Hz to 20 kHz	20 kHz to 50 kHz	50 kHz to 100 kHz
100 mV <sup>2</sup>	15 mV	7.2 mV	15 mV
600 mV <sup>2</sup>	15 mV	7.2 mV	15 mV
1000 mV	125 mV	60 mV	125 mV
10 V	1.25 V	0.6 V	1.25 V
100 V	12.5 V	6 V	12.5 V
1000 V	60 V	60 V	60 V

## U1241C / U1242C sensitivity for current measurement

Input range	Minimum sensitivity (RMS sine wave)	
Maximum input <sup>1</sup> for specified accuracy	0.5 Hz to 20 kHz	20 kHz to 30 kHz
100 µA	175 µA	60 µA
10 mV	1.75 mA	0.6 mA
100 mV	17.5 mA	6.0 mA
600 mV	100 mA	38 mA
10 A	N/A	1.15 A (< 10 kHz)

### Notes

1. Refer to 'AC specification' for specified accuracy of maximum input.
2. 100 mV and 600 mV ranges available on Temperature T1 terminal.

## Harmonic ratio for U1242C only

Range	Frequency	Voltage
0.0 % to 99.9 %	40 Hz to 1 kHz	100 mVAC to 1000 VAC

## Multimeter data refresh rate

Function	Slow (times/second)	Fast (times/second)
ACV (V or mV)	5	40
DCV (V or mV)	5	40
	5	40
Diode	5	40
Auto diode	1	
Capacitance	0.8 (<1000 µF)	-
DC µA, mA or A	5	40
AC µA, mA or A	5	40
Temperature	5	40
Frequency	1 (>10 Hz)	—

## UNI-T UT131B

### DC Voltage

Range	Resolution	Accuracy	Overload protection
200 mV	0.1 mV	$\pm(0.7\%+3)$	250 Vrms (AD/DC)
2000 mV	1 mV	$\pm(0.5\%+2)$	
20.00 V	0.01 V	$\pm(0.7\%+3)$	
200.0 V	0.1 V	$\pm(0.7\%+3)$	
250 V	1 V	$\pm(0.7\%+3)$	

Input impedance: about 10 M $\Omega$

### AC Voltage



Range	Resolution	Accuracy	Overload protection
200.0 V	0.1 V	$\pm(1.2\%+3)$	250 Vrms (AD/DC)
250 V	1 V		

Input impedance: about 10 M $\Omega$

### Resistance

Range	Resolution	Accuracy	Overload protection
200.0 $\Omega$	0.1 $\Omega$	$\pm(1.0\%+2)$	250 Vrms (AD/DC)
2000 $\Omega$	1 $\Omega$	$\pm(0.8\%+2)$	
20.00 k $\Omega$	0.01 k $\Omega$	$\pm(0.8\%+2)$	
200.0 k $\Omega$	0.1 k $\Omega$	$\pm(0.8\%+2)$	
20.00 M $\Omega$	0.01 M $\Omega$	$\pm(1.2\%+3)$	

### Diode and continuity measurement

Range	Resolution	Accuracy	Overload protection
	0.001 V	Open circuit voltage: 2.1 V, test current is about 1 mA, Silicon PN junction voltage is about 0.5–0.8 V.	250 Vrms (AD/DC)
		If the measured resistance is greater than 50 $\Omega$ , the measured circuit will be regarded as in open status, and the buzzer does not go off. If the measured circuit is in good conduction status, the buzzer goes off.	

Remark: Make sure that the voltage level of calibrated equipment is less than 10 V to avoid damage to the meter.

### DC current

Range	Resolution	Accuracy	Overload protection
200.0 $\mu$ A	0.1 $\mu$ A	$\pm(1.0\%+2)$	250 Vrms (AC/DC)
200.0 mA	0.1 mA	$\pm(1.0\%+2)$	
10.00 A	0.01 A	$\pm(1.2\%+5)$	

Remark: At 10 A range: For continuous measurement  $\leq 10$  seconds and interval not less than 15 minutes

# Generators

## GOLDSTAR FG-8002

<b>Type</b>	function generator, pulse generator and sweep oscillator
<b>Frequency range</b>	0.02 Hz to 2 MHz in 7 decade ranges
<b>Output waveform</b>	sine, triangle, square, TTL-level square, pulse, ramp, screwed sine waves
<b>Accuracy of dial scale to output frequency</b>	$\pm 5\%$ (range: 1 Hz to 100 kHz), $\pm 8\%$ (range: 1 MHz)
<b>Frequency stability</b>	0.5 % of f.s. (18 °C to 28 °C)
<b>VCF input voltage</b> (= external voltage controlled frequency):	0 to 10 V (DC or AC peak)
<b>Frequency variable range</b>	100 : 1 or more
<b>Symmetry variable range</b>	10 : 1 to 1 : 10 or more
<b>DC offset</b>	$\pm 10$ V (open circuit) $\pm 5$ V (into 50 $\Omega$ )
<b>Sweep function control</b>	
Sweep width	1 : 1 to 100 : 1
Sweep ratio	20 ns to 2 s (0.5 Hz to 50 Hz)
Internal sweep	Linear
External sweep	Controlled by VCF input
<b>Output</b>	Max. output voltage: 20 Vp-p (open circuit); 10 Vp-p (into 50 $\Omega$ ) Output impedance: 50 $\Omega \pm 10\%$

## GOLDSTAR FG-2002C

<b>Type</b>	function generator
<b>Frequency range</b>	0.02 Hz to 2 MHz in 7 decade ranges
<b>Tuning range</b>	each range provides 100:1 frequency control
<b>Output waveform</b>	sine wave, triangle wave, square wave, TTL/CMOS square wave
<b>Dial accuracy</b>	4 digits $\pm 1$ count ( $\pm 8\%$ of full scale)
<b>Stability</b>	0.1 % after 30 minutes
<b>VCF input</b> (= external voltage controlled frequency):	Tunable by 0 to 10 V DC frequency increases with negative voltage, frequency may be programmed with DC voltages, FM-modulated with AC, or swept with ramp.
<b>Sweep function control</b>	
Sweep width	1 : 1 to 100 : 1
Sweep ratio	20 ns to 2 s (0.5 Hz to 50 Hz)
Internal sweep	Linear
External sweep	Controlled by VCF input
<b>Output</b>	Max. output voltage: 20 Vp-p (open circuit); 10 Vp-p (into 50 $\Omega$ ) Output impedance 50 $\Omega \pm 10\%$
<b>Counter</b>	4-digits, range 2 Hz to 4 MHz 6 ranges for external signals too



## GFG-8020H (GW Instek)

Type	digital function generator
Frequency range	0.2 Hz to 2 MHz (7 ranges), 4 digits display with coarse/fine tuning
Output waveform	Sine, triangle, square, ramp and pulse waveforms, plus a VCF input, variable DC offset and TTL or CMOS pulse
Amplitude	> 20 Vp-p open circuit, > 10 Vp-p into 50 $\Omega$
Attenuation	- 20 dB & continuously variable
DC offset	Variable +10 to -10 V open circuit, +5 to -5 V into 50 $\Omega$
Sine wave	Distortion: 0.2 Hz to 20 kHz < 1 % Response: 0.2 Hz to 100 kHz < 0.2 dB; 100 kHz to 2 MHz < 1 dB
Square wave	Rise Time < 120 ns
Pulse Output	Rise Time < 30 ns Level Amplitude Fixed > +3 V open circuit, CMOS Level (4 V $\pm$ 1 V)p-p to (14.5 V $\pm$ 0.5 V)
VCF input (= Voltage Controlled Frequency):	Approx. 0 to 10 V ( $\pm$ 1 V) input for 10 : 1 frequency ratio
Frequency Counter (INT only)	Accuracy: $\pm$ Time Base accuracy $\pm$ 1 count Time Base oscillation frequency 10 MHz Temp. stability (23 $^{\circ}$ C $\pm$ 5 $^{\circ}$ C) $\pm$ 1 $\times$ 10 <sup>-5</sup> Counting Capacity: 4 digit Resolution: 100 nHz, 1 mHz, 10 mHz, 100 mHz, 1 Hz, 10 Hz, 100Hz, 1 kHz

## AG-7001C (LG Precision)

Type	audio oscillator
Frequency range	10 Hz to 1 MHz in 5 decade steps, variable control 10 : 1 (overlapping ranges), accuracy $\pm$ 5 % of full scale
Sine wave characteristics	Output voltage 8 Vrms or more (open circuit) Output impedance approx. 600 $\Omega$ Freq. characteristics $\pm$ 0.2 dB for 10 Hz to 100 kHz; $\pm$ 0.5 dB for 100 kHz to 1 MHz Distortion factor 200 Hz - 100 kHz: 0.1 %, 50 Hz - 500 kHz: 0.5 %
Square wave characteristics	Output voltage 10 V p-p or more Overshoot 2 % or less (at 1 kHz, MAX. output) Rise and fall time 200 ns or less (at MAX. output) Duty ratio 50 % $\pm$ 5 % (at 1 kHz, MAX. output)
External synchronisation characteristics	Synchronizing range $\pm$ 1 % /Vrms; Max. input voltage 10 Vrms; Input impedance approx. 10 k $\Omega$
Output attenuator	4 step attenuator 0 dB, -10 dB, -20 dB, -40 dB, variable -60 dB or more
Frequency counter characteristic	Frequency range 0.2 Hz to 50 MHz with Auto Range Display 6 digit green LED, Gate time, MHz, kHz, Hz, mHz Input impedance 1 M $\Omega$    25 pF Max. input voltage 250 Vp-p Time base 10 MHz Accuracy Time base error $\pm$ 1 count

## GOLDSTAR AO-3001C

**Type** audio oscillator  
**Frequency range** 10 Hz to 1 MHz in 5 decade steps, variable control 10 : 1 (overlapping ranges)

**Frequency accuracy** 4 digits  $\pm 1$  count

### Sine wave characteristics

Output voltage 8 Vrms or more (open circuit)  
Output impedance approx. 600  $\Omega$  or 50  $\Omega$ , selectable ( $\pm 5\%$ ) (unbalanced)  
Freq. characteristics  $\pm 0.2$  dB for 10 Hz to 100 kHz  $\pm 0.5$  dB for 100 kHz to 1 MHz  
Distortion factor 500 Hz - 100 kHz: 0.1 %; 50 Hz - 500 kHz: 0.5 %  
10 Hz - 1 MHz: 1.5 %

### Square wave characteristics

Output voltage 10 V p-p or more  
Overshoot 2 % or less (at 1 kHz, MAX. output)  
Rise and fall time 200 ns or less (at MAX. output)  
Duty ratio 50 %  $\pm 5\%$  (at 1 kHz, MAX. output)

### External synchronisation characteristics

Synchronizing range  $\pm 1\%$  /Vrms  
Max. input voltage 10 Vrms  
Input impedance approx. 10 k $\Omega$

### Output attenuator (min. 100 dB)

4 step attenuator 0 dB, -10 dB, -20 dB, -40 dB (accuracy  $\pm 1$  dB)

### Frequency counter characteristic

Frequency range 10 Hz to 1 MHz  
Display 4-digit green LED display  
Sensitivity kHz range: 100 mV, MHz range: 300 mV  
Input impedance 1 M $\Omega$  || 25 pF  
Max. input voltage 150 Vrms (at 1 kHz)  
Time base 3.579545 MHz  
Accuracy Time base error  $\pm 1$  count

**Special function** 400 Hz, 1 kHz (usable in audio and modulation) Accuracy  $\pm 0.5\%$

# Agilent 33220A 20 MHz Function/Arbitrary Waveform Generator

**Type** A 20 MHz synthesized function generator with built-in arbitrary waveform and pulse capabilities.

## Convenient bench-top features

10 standard waveforms; built-in 14-bit 50 MSa/s arbitrary waveform capability; precise pulse waveform capabilities with adjustable edge time; LCD display provides numeric and graphical views, etc.

**Flexible system features** Four downloadable 64k-point arbitrary waveform memories; GPIB (IEEE 488), USB, and LAN remote interfaces are standard; SCPI compatibility.

**Waveforms** Standard: Sine, Square, Ramp, Triangle, Pulse, Noise, DC

Built-in Arbitrary: Exponential rise, Exponential fall, Negative ramp, Sin(x)/x, Cardiac

## Some waveform characteristics

<b>Sine</b>	Frequency Range:	1 $\mu$ Hz to 20 MHz
	Amplitude Flatness:	< 100 kHz ..... 0.1 dB (relative to 1 kHz)
		100 kHz to 5 MHz ..... 0.15 dB
		5 MHz to 20 MHz ..... 0.3 dB
	Total Harmonic Distortion:	DC to 20 kHz 0.04 %
<b>Square</b>	Frequency Range:	1 $\mu$ Hz to 20 MHz Rise/Fall Time: < 13 ns
	Overshoot:	< 2 %
	Variable Duty Cycle:	20 % - 80 % (to 10 MHz), 40 % - 60 % (to 20 MHz)
<b>Ramp, Triangle (Variable Symmetry)</b>		Frequency Range: 1 $\mu$ Hz to 200 kHz; Linearity: < 0.1 % of peak output
<b>Pulse</b>	Frequency Range:	0.0 % to 100.0 %, 500 $\mu$ Hz to 5 MHz
	Pulse Width (period $\leq$ 10 s):	20 ns minimum, 10 ns resolution Variable Edge Time: < 13 ns to 100 ns
	Overshoot:	< 2 %
	Jitter:	300 ps + 0.1 ppm of period
<b>Noise</b>	Bandwidth (-3 dB):	9 MHz, typical
<b>Arbitrary</b>	Frequency Range:	1 $\mu$ Hz to 6 MHz Waveform Length: 2 to 64 k points
	Amplitude Resolution:	14 bits (including sign)
	Sample Rate:	50 MSa/s
	Minimum Rise/Fall Time:	35 ns
	Typical Linearity:	< 0.1 % of peak output

## Some common characteristics

**Amplitude** Into 50  $\Omega$ : 10 mV<sub>pp</sub> to 10 V<sub>pp</sub>;  
Into open circuit: 20 mV<sub>pp</sub> to 20 V<sub>pp</sub>

**Accuracy (at 1 kHz)**  $\pm 1$  % of setting  $\pm 1$  mV<sub>pp</sub>

**Resolution** 4 digits

## INSTEK AFG 2225 Function/Arbitrary Waveform Generator

AFG-2225 models		CH1	CH2
Waveforms		Sine, Square, Ramp, Pulse, Noise, ARB	
Arbitrary Functions			
	Sample Rate	120 MSa/s	
	Repetition Rate	60 MHz	
	Waveform Length	4k points	
	Amplitude Resolution	10 bits	
	Non-Volatile Memory	4k points	
Frequency Characteristics			
Range	Sine, Square	1uHz~25MHz	
	Ramp	1MHz	
Resolution		1uHz	
Accuracy	Stability	±20 ppm	
	Aging	±1 ppm, per 1 year	
	Tolerance	≤1 mHz	
Output Characteristics			
Amplitude	Range	1mVpp to 10 Vpp (into 50Ω) 2mVpp to 20 Vpp (open-circuit) 1mVpp to 5 Vpp (into 50Ω) for 20MHz-25MHz 2mVpp to 10 Vpp (open-circuit) for 20MHz-25MHz	
	Accuracy	±2% of setting ±1 mVpp (at 1 kHz/into50Ω without DC offset )	
	Resolution	1mV or 3 digits	
	Flatness	±1% (0.1dB) ≤100kHz ±3% (0.3 dB) ≤5MHz ±5% (0.4 dB) ≤12MHz ±10%(0.9dB) ≤25MHz	
	Units	Vpp, Vrms, dBm	
Offset	Range	±5 Vpk ac +dc (into 50Ω) ±10Vpk ac +dc (Open circuit) ±2.5 Vpk ac +dc (into 50Ω) for 20MHz-25MHz ±5Vpk ac +dc (Open circuit) for 20MHz-25MHz	
	Accuracy	2% of setting + 20mV + 0.5% of amplitude	
Waveform Output	Impedance	50Ω typical (fixed); > 10MΩ (output disabled)	
	Protection	Short-circuit protected Overload relay automatically disables main output	
Sine wave Characteristics			
	Harmonic distortion	≤-55 dBc DC ~ 200kHz, Ampl > 0.1Vpp ≤-50 dBc 200kHz ~ 1MHz, Ampl > 0.1Vpp ≤-35 dBc 1MHz ~ 5MHz, Ampl > 0.1Vpp ≤-30 dBc 5MHz ~ 25MHz, Ampl > 0.1Vpp	
Square wave Characteristics			
	Rise/Fall Time	≤25ns at maximum output. (into 50 Ω load)	
	Overshoot	5%	
	Asymmetry	1% of period +5 ns	
	Variable Duty Cycle	1.0% to 99.0% ≤100kHz, 10% to 90% ≤ 1MHz, 50% ≤ 25MHz	

Ramp Characteristics		
	Linearity	< 0.1% of peak output
	Variable Symmetry	0% to 100% (0.1% Resolution)
Pulse Characteristics		
	Period	40ns~2000s
	Pulse Width	20ns~1999.9s
	Overshoot	<5%

Dual Channel Function			
	Phase	-180° ~180°	-180° ~ 180°
		Synchronize phase	Synchronize phase
	Track	CH2=CH1	CH1=CH2
	Coupling	Frequency(Ratio or Difference)	Frequency(Ratio or Difference)
		Amplitude & DC Offset	Amplitude & DC Offset
	DSOLink	√	√
Burst			
	Waveforms	Sine, Square, Ramp	Sine, Square, Ramp
	Frequency	1uHz~15MHz (Sine, Square); 1uHz~1MHz(Ramp)	1uHz~15MHz(Sine, Square); 1uHz~1MHz(Ramp)
	Burst Count	1 to 65535 cycles or Infinite	1 to 65535 cycles or Infinite
	Start/Stop Phase	-360 to +360	-360 to +360
	Internal Period	1ms to 500s	1ms to 500s
	Gate Source	External Trigger	External Trigger
	Trigger Source	Single, External or Internal Rate	Single, External or Internal Rate

## Tektronics AFG 3022B Function/Arbitrary Waveform Generator

### Basic parameters:

- 25 MHz Sine Waveforms

- 14 bits, 250 MS/s Arbitrary Waveforms, Amplitude up to 20 V<sub>p-p</sub> into 50 Ω Loads

- Pulse Waveform with Variable Edge Times, AM, FM, PM, FSK, PWM modulation

- Sweep and Burst

- Dual-channel Model

- USB Connector on Front Panel for Waveform Storage on Memory Device

- USB, GPIB, and LAN

*More details see in <https://www.testequipmenthq.com/datasheets/TEKTRONIX-AFG3022B-Datasheet.pdf>*

# Counters

## TF 930 3 GHz Counter

### INPUT SPECIFICATIONS

#### Input A

Input Coupling:	AC or DC
Input Impedance:	1M $\Omega$ /25pF (DC or AC coupled), or 50 $\Omega$ (AC coupled only) Attenuation: 1:1 or 5:1
Active Edge:	Rising or falling, or width high or low Low Pass Filter: 50kHz cut-off, or None
Frequency Range:	0.001Hz to > 125MHz (1M $\Omega$ , DC coupled) < 30Hz to > 125MHz (1M $\Omega$ , AC coupled) < 500kHz to > 125MHz (50 $\Omega$ , AC coupled).
Sensitivity:	Sinewave - 15mVrms 30Hz to 100MHz, 25mV to 125MHz at optimum threshold adjustment.
Signal Range:	1M $\Omega$ , DC - 0 to 3.3V (1:1) or 1 to 12V (5:1), 1M $\Omega$ , AC - up to 1Vrms (3Vpp) (1:1) or up to 4Vrms (12Vpp) (5:1) 50 $\Omega$ , AC - up to 1V rms above 300kHz
Trigger Threshold:	DC coupled - 0 to 2V (1:1) or 0 to 10V (5:1) AC coupled - Average $\pm$ 200mV (1:1) or $\pm$ 1V (5:1)

#### Input B

Input Impedance:	50 $\Omega$ (AC coupled) Frequency Range: <80MHz to >3000MHz
Sensitivity:	Sinewave - 25mVrms 2GHz to 6GHz
Signal Range:	<0dBm recommended, +13dBm (1Vrms) maximum

#### External Reference

Input Impedance:	>100k $\Omega$ , AC coupled Frequency: 10MHz
Signal Level:	TTL, 3Vpp to 5Vpp CMOS or 1 to 2Vrms sinewave

#### Maximum Input Voltage

Input A and Input B: 30Vdc; 30Vrms 50Hz/60Hz reducing to 1Vrms above 1MHz

*Note that the inputs will not be damaged if subjected to an accidental short-term connection to a 50/60Hz line voltage not exceeding 250V rms.*

### MEASUREMENT FUNCTIONS

#### Frequency

A Input Range:	0.001Hz (DC coupled) to >125MHz	B Input Range:	80MHz to >3000MHz
Resolution:	up to 10 digits (see Note) or 0.001Hz		

#### Period

A Input Range:	8ns to 100s (DC coupled)
B Input Range:	333ps to 12.5ns
Resolution:	up to 10 digits (see Note)

#### Pulse Width Mode (Input A only)

Functions: Width high, width low, ratio H:L (high time to low time) and duty cycle Pulse Width Range: 40ns to 1000s

Averaging: Automatic within measurement time selected, up to 50 pulses

Resolution: 20ns for one pulse; up to 1 ns or 10 digits with multiple pulse averaging

#### Total Count (Input A only)

Count Range:	1 to 9 999 999 999
Minimum Width:	8ns

### Frequency Ratio B:A

Resolution: Equal to the resolution of the two frequency measurements,

If the ratio exceeds 10 digits, 6 digits and the exponent are displayed

### Measurement Time

Selectable as 100s, 10s, 1s or 0.3s. The instrument displays the average value of the input signal over the measurement time selected, updated every 2s, 1s, 0.5s or 0.3s respectively. The hardware captures the count values and continues measuring without any dead time.

### Resolution

The displayed resolution depends upon measurement time and input frequency. The basic resolution of period is 8 digits for every 2 seconds of measurement time. Frequency resolution is the reciprocal of period resolution. Usable resolution can be reduced by noise at low frequencies.

### Accuracy

Measurement accuracy is timebase accuracy + measurement resolution + 2 counts.

## TIMEBASE

Measurement Clock: 50MHz

Internal Reference: 10MHz TCXO with electronic calibration adjustment ( $> \pm 8\text{ppm}$ );

Temperature Stability: Better than  $\pm 1\text{ppm}$  over rated temperature range

Initial Error:  $< \pm 0.2\text{ppm}$  at  $25^\circ\text{C}$

Ageing Rate:  $< \pm 1\text{ppm/year}$

## OPERATING FACILITIES

### Noise Filter

The Filter key controls a low pass filter, with a cut-off frequency of about 50kHz, to ensure more stable readings at low frequencies.

### Hold

Pressing the Hold key will stop further measurements being made and the current measured value will remain in the display, with the Hold indicator on, until the Hold key is pressed again. A long press on the Hold key clears old data and restarts the measurement.



# K 3-4 Školní čítač 100 MHz

	NAVOD K OBSLUZE A ÚDRŽBĚ	Vývojové laboratoře FEL ČVUT Poděbrady
18		typ: K 3-4
1		

## a/ Úvod:

Výrobce: Vývojové laboratoře ČVUT FEL Poděbrady

Název : Čítač 100 MHz

Typ : K 3-4

## b/ Rozsah použití:

Čítač je přístroj určený k použití v elektronických laboratořích, zvláště školních. Umožňuje stanovení frekvence, periody, šířky impulsu a časových intervalů signálů.

## c/ Popis vlastností, technické údaje:

### 1. Všeobecné údaje

Kapacita čítače:

$10^8$  / 8 dekád/

Indikace :

dvoumístné zobrazovače se  
světelnými diodami, číslicové  
s desetinou tečkou

Interval opakování měření:

0,5 s - 10 s

Frekvence interního krystalového oscilátoru :

10 MHz nastavitelné napětím  
- v rozsahu - 1 kHz

Stabilita v rozsahu  $-25^{\circ}\text{C} - +65^{\circ}\text{C}$ :  $2,5 \cdot 10^{-5}\%$  ( $\sigma_{f_0}$ )

Vnější oscilátor: frekvence:

10 MHz

napětí :

úroveň TTL

Vstup "HRADLO" : úroveň vstupního signálu: 0 - 5 V<sub>ss</sub>

blokování libovolné funkce: 0 V<sub>ss</sub>

Funkce "TEST" : automaticky po zapnutí, pokud není  
příslušným tlačítkem zvolena funkce  
jiná

### Režimy čítače:

základní - funkce zvolena příslušným tlačítkem, výsledek  
měření se zobrazí na displeji.

čítání - časově neomezené čítání, paměť vypnuta

paměť - vypnuta vnitřní paměť čítače, zobrazuje se  
obsah čítače během měrného intervalu

ručně - měření proběhne 1x po spuštění tlačítkem  
"START", trvalé zobrazení

Hmotnost : 7,2 kg

Rozměry přístroje: 435 x 370 x 135 mm

## Power supplies

### Agilent E3640A Single Output DC Power Supply

**Type** This power supply features a combination of programming capabilities and linear power supply performance that makes it ideal for power systems applications. The power supply may be programmed locally from the front panel or remotely over the GPIB and RS-232 interfaces. It has two ranges, allowing more voltage at a lower current or more current at a lower voltage. The output range is selected from the front panel or over the remote interfaces.

**Range** Low Range: 0 to +8 V / 0 to 3 A  
High Range: 0 to +20 V / 0 to 1.5 A

**Programming Accuracy** Voltage: < 0.05 % + 10 mV  
±( % of output + offset) Current: < 0.2 % + 10 mA

**Meter Accuracy** Voltage: < 0.05 % + dgt  
±( % of output + offset) Current: < 0.15 % + 5 mA

**Ripple and Noise** Normal mode voltage: < 0.5 mV<sub>rms</sub> and 5 mV<sub>p-p</sub>  
Normal mode current: < 1.5 µA<sub>rms</sub>

### Goldstar GP 305/3010/503/505 Single Output DC Power Supply

Model	GP-305	GP-3010	GP-503	GP-505
Output polarity	Positive & Negative			
Output current	0 ~5A	0 ~10A	0 ~3A	0 ~5A
Ripple Voltage	Less than 3mVpp			
Line Regulation	Less than 0.01% +2mV for power source voltage change of ±10%			
Load Regulation	Less than 0.01% +3mV for load variation of 0 to 100			
Voltmeter Monitor	0 ~ 30V (F.S)		0 ~50V (F.S)	
	Accuracy of 2.5% for full scale			
Ampermeter Monitor	0 ~ 5A	0 ~10A	0 ~ 3A	0 ~ 5A
	Accuracy of 2.5% for full scale			
Insulation between	More than 10MΩ at DC 500V chassis and output termin. More than 50MΩ at DC 500V chassis and AC plug.			
Compensation/ Protection circuit	Overload protection circuit of constant current self restoring type			
Ambient temperature	5°C ~ 40°C			
Operating Humidity	80% ~ 50%			

<b>UNI-T    UTP3313/3315/1303/1305    Single Output DC Power Supply</b>
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## ■ SPECIFICATIONS

	UTP3313TFL	UTP3315TFL	UTP1303	UTP1305
Output voltage	0~30V	0~30V	0~32V	0~32V
Output current	0~3A	0~5A	0~3A	0~5A
Load regulation	CV≤1x10 <sup>-4</sup> +2mV, CC≤2x10 <sup>-4</sup> +3mA		CV≤1x10 <sup>-4</sup> +3mV, CC≤2x10 <sup>-4</sup> +3mA	
Ripple and noise	≤0.3mVrms		≤1mVrms	
Output regulation resolution	CV: 100mV (typical), CC: 10mA (typical)			
Reliability	MTBF(e): ≥2000hrs			
Display mode	LED voltage and current dual display			
Feature	Auto conversion of constant voltage and current with current limit protection			

### 3. Technical data

Display	3.5 digit LCD display, max. display: 1999
Measuring rate	approximately 3 measurements per second
Test lead length	each approximately 80cm
Battery type	standard 9V battery
Overvoltage category	CAT III 300V (digital multimeter and test leads)
Hold function	yes
Automatic polarity indicator	yes
"Low Bat" indicator	yes
Auto power OFF function	yes
Operating temperature, air humidity	0°C to +40°C; max. 75% rel. humidity
Storage temperature, air humidity	-10°C to +50°C; max. 85% rel. humidity
Dimensions (W x H x D)	80 x 166 x 36.5mm (including range selector switch)
Weight	approx. 179g (without battery or test leads)

The technical data and design may be changed without notification.

#### DC voltage

Range	Resolution	Precision
200mV	0.1mV	$\pm (0.5\%+5)$
2V	1mV	$\pm (0.8\%+5)$
20V	10mV	
200V	0.1V	
300V	1V	$\pm (1.0\%+5)$

Input impedance: 10M $\Omega$

Overload protection: 300V DC/AC RMS

**AC voltage**

Range	Resolution	Precision
2V	1mV	$\pm (1.0\%+5)$
20V	10mV	
200V	0.1V	
300V	1V	$\pm (1.2\%+5)$

Input impedance: 10M $\Omega$

Frequency range: 40Hz to 400Hz

Overload protection: 300V AC RMS

Display: average value (RMS of the sine wave)

**DC current**

Range	Resolution	Precision
200 $\mu$ A	0.1 $\mu$ A	$\pm (1.0\%+5)$
2mA	1 $\mu$ A	
20mA	10 $\mu$ A	$\pm (1.2\%+5)$
200mA	0.1mA	
10A	10mA	$\pm (2.0\%+5)$

Overload protection: F1: F 250mA / 300V fuse

F2: F 10A / 300V fuse

Maximum input current: 10A (input current > 2A for continuous measurement < 10 seconds and interval > 15 minutes)

**AC current**

Range	Resolution	Precision
2mA	1 $\mu$ A	$\pm (1.2\%+5)$
20mA	10 $\mu$ A	$\pm (1.5\%+5)$
200mA	0.1mA	
10A	10mA	$\pm (3.0\%+7)$

Overload protection: F1: F 250mA / 300V fuse

F2: F 10A / 300V fuse

Maximum input current: 10A (input current > 2A for continuous measurement < 10 seconds and interval > 15 minutes)

Frequency range: 40Hz to 400Hz

Display: average value (RMS of the sine wave)

**Resistance**

Range	Resolution	Precision
200Ω	0.1Ω	± (1.0%+5)
2kΩ	1Ω	± (0.8%+3)
20kΩ	10Ω	
200kΩ	0.1kΩ	
2MΩ	1kΩ	
20MΩ	10kΩ	± (1.2%+3)

Overload protection: 300V

**Function generator**

Signal	Voltage Output impedance
1kHz square wave signal	approx. 3V peak-to-peak approx. 10kOhm

The specified precision in ± (% of the display + number of digits) is valid for 5% to 100% of the respective measuring range and is guaranteed for a period of one year at an ambient temperature from 18°C to 28°C and maximum air humidity of 75%. The accuracy is not guaranteed under different conditions.

**4. Safety instructions**

Before using this multimeter for the first time, always read the following instructions and pay attention to all warnings, even if you are familiar with handling electronic devices. Store these instructions in a safe place for future reference. If you sell the multimeter or pass it on, always include these instructions.



**WARNING!** This symbol indicates important information for safe operation of the multimeter and the safety of the user.



This symbol indicates other important information on the topic.



**DANGER!** Before opening it, the multimeter must be isolated or disconnected from the dangerous active voltage. There is a risk of an electric shock!



**DANGER!** This symbol warns against dangerous electrical voltage!



Electrical devices do not belong in the hands of children. Persons with disabilities should also only use electrical devices within the scope of their abilities. Never allow children or persons with disabilities to use electrical devices unsupervised. They may not recognise potential risks. Batteries and small parts may cause choking resulting in death or serious injury. Store the battery in a safe place. If a battery is swallowed, seek medical help immediately. Always keep plastic packaging out of reach. It poses a suffocation risk!