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1-μV Resolution in a Low-Cost 4½ Digit Multimeter

Model 3465A/B Digital Multimeter has a 20-mV full-scale dc voltage range that gives a resolution of 1 μV, very useful for measuring the outputs of strain gages and thermocouples or drift in precision voltage sources. The maximum resolution on ac voltage measurements is 10 μV, on measurements of current (ac or dc) it is 10 nA, and on resistance measurements, 10 mΩ. Open-circuit voltage on the most sensitive ohms range does not exceed 5 volts to prevent damage to most semiconductor devices.

Midrange dc accuracy is ±0.02% ± 1 digit. The frequency range for ac measurements is 40 Hz to 20 kHz.

Model 3465A/B is manual ranging with autopolarity and autozero. Like Model 3435A, it can work with the optional "touch-hold" probe to retain a measured value on display whenever the pushbutton on the probe is pushed.

This multimeter is available in two versions. Model 3465A is in a modular cabinet that is readily combined with other modules for rack mounting or bench stacking. It has a variety of power options, including rechargable Nicad batteries with internal charger, throw-away type-D dry cells (alkaline cells give 60 hours continuous operation), or ac line. The dry-cell version can also operate on dc supplied from hand-held calculator battery chargers.

Model 3465B is housed in a streamlined plastic case with carrying handle. It is powered by ac line and rechargable Nicad batteries.

Like Models 3476A and 3435A, Model 3465A/B achieves quality performance at low cost by extensive use of computer-aided testing, laser-trimmed fine-line resistors in the attenuator, and a single-reference bipolar A-to-D converter.







Roy D. Barker

Roy Barker graduated with a BSEE degree from the University of Oklahoma in 1962 and worked in satellite-tracking instrumentation and microwave data links before joining Hewlett-Packard in 1967. At HP, Roy was initially involved in production engineering, then became involved in IC design and production before becoming section manager for digital voltmeters. In his off hours, Roy likes to go cross-country skiing, often with his wife and 8-year-old son, and he also enjoys woodworking.



Virgil L. Laing

Virgil Laing first worked in IC development upon joining HP in 1968, subsequently becoming project leader for the NMOS process used for the 9800-series Calculator ROMs. He then designed a major part of the IC used in the 970A Probe Multimeter. Then he became project manager for the Model 3435A Multimeter. He has bachelor's, master's, and PhD degrees in electrical engineering, all from the University of Minnesota. Virgil enjoys the Colorado outdoors, going pheasant hunting and taking his family on hiking and camping trips.

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SPECIFICATIONS

HP Model 3476A/B Digital Multimeter

DC VOLTMETER

RANGE	ACCURACY (90 days, 20 to 30°C)
±0.110V	±(0.3% of reading + 2 digits)
±1.10V ±11.0V	±(0.3% of reading + 1 digit)
±110V ±1100V (1000V max)	±(0.4% of reading + 1 digit)

TEMPERATURE COEFFICIENT: ±(0.05% of reading + 0.2 digit)/°C.
COMMON MODE REJECTION (1kΩ unbalance): >100 dB at 50 Hz, 60 Hz.
INPUT RESISTANCE: 10 MΩ±5%.
INPUT PROTECTION: 1100V peak.

AC VOLTMETER

RANGE*	ACCURACY (90 days, 20 to 30°C; % of reading + no. of digits)		
	45 Hz to 2 kHz	2 to 5 kHz	5 to 10 kHz
0.110V	±(2% + 6)	±(5% + 6)	±(18% + 10)
1.10V ↓ 1100V (700V rms max)	±(1.5% + 4)	±(3% + 6)	±(8% + 10)

*Ranges usable above 3% of full scale.

TEMPERATURE COEFFICIENT: ±(0.05% of reading + 0.5 digit)/°C.
COMMON MODE REJECTION (1kΩ unbalance): >80dB @ 50 Hz, 60 Hz.
INPUT RESISTANCE: 10 MΩ±5%.
INPUT CAPACITANCE: <30 pF.
INPUT PROTECTION: <1100V peak.

DC AMMETER

RANGE	ACCURACY (90 days, 20 to 30°C)
±0.110A ±1.10A	±(0.8% of reading + 2 digits)

TEMPERATURE COEFFICIENT: ±(0.05% of reading + .2 digit)/°C.
IMPEDANCE: 1—1.5 ohm constant.
CURRENT PROTECTED: 1.5A fuse.

AC AMMETER

RANGE*	ACCURACY (90 days, 20 to 30°C; % of reading + no. of digits)	
	45 Hz to 2 kHz	2 to 5 kHz
1.1A	±(2% + 4)	±(3.5% + 6)
0.11A	±(2.5% + 6)	±(5.5% + 6)

*Ranges usable above 3% off full scale.

TEMPERATURE COEFFICIENT: ±(0.05% of reading + 0.5 digit)/°C.
IMPEDANCE: 1—1.5 ohm constant.
CURRENT PROTECTED: 1.5A fuse.

OHMMETER

RANGE	ACCURACY (90 days, 20 to 30°C)
1.1 kΩ 11 kΩ	±(0.5% of reading + 1 digit)
110 kΩ 1100 kΩ	±(0.3% of reading + 1 digit)
11,000 kΩ	±(0.5% of reading + 1 digit)

TEMPERATURE COEFFICIENT: ±(0.05% of reading + 0.2 digit)/°C.
OPEN CIRCUIT VOLTAGE: <4V.
INPUT VOLTAGE PROTECTION: <30 Vrms continuous, fuse protected from 30V to 250Vrms.

General

RANGING: Automatic, Range Hold.
OVERLOAD INDICATION: Horizontal bars.
COMMON TO GROUND: <500 V (peak).
SAMPLE RATE: ~3/second.
OPERATING ENVIRONMENTAL CONDITIONS: 0 to 40°C, <95% RH.
POWER: 3476A and 3476B ac line, <6 VA.

STANDARD	104-127V; 54-66 Hz
OPTION 001	86-106V; 54-66 Hz
OPTION 002	86-106V; 48-54 Hz
OPTION 003	190-230V; 48-54 Hz
OPTION 004	208-250V; 48-54 Hz

3476B BATTERIES: 4 rechargeable nickel cadmium sub-C size. Typical continuous operating time using fully charged batteries: 8 hours at 25°C.
Typical battery charging time: 14 hours at 25°C with instrument turned off. Trickle charge with instrument on.

WEIGHT: 3476A, 0.77kg (1 lb. 11 oz.); 3476B, 0.97kg (2 lb. 2 oz.).
DIMENSIONS: 58 mm high × 168 mm wide × 206 mm deep (2.3 03302 6 6 03302 8.1 inches).
PRICES IN U.S.A.: 3476A, $225; 3476B, $275.

HP Model 3435A Digital Multimeter

DC Voltmeter

Ranges	Maximum Display
±200mV	±199.9mV
±2V	±1.999V
±20V	±19.99V
±200V	±199.9V
±1200V	±1199V

SENSITIVITY: 100μV on 200mV range.
MAXIMUM INPUT: 1200V (dc + peak ac).
RANGING: Automatic or manual.
POLARITY: Automatically sensed and displayed.
ACCURACY (1 year, 15 to 30°C at 95% RH):

Range	Specifications
200mV	±(0.1% of reading + 2 digits)
2V to 1200V	±(0.1% of reading + 1 digit)

TEMPERATURE COEFFICIENT (0 to 15°C and 30 to 55°C):
±(.018% reading + 0.1 digit)/°C.
INPUT RESISTANCE: 10 MΩ ± 1%.
INPUT TYPE: Floating; 500V maximum, common to ground.
NORMAL MODE REJECTION: 40dB at 50/60 Hz ±.1 Hz.
EFFECTIVE COMMON MODE REJECTION (1kΩ unbalance): >120 dB at 50/60 Hz ±0.1%.
RESPONSE TIME: <0.7 seconds to within 1 digit of final value on one range. Add 1 second for each range change.

DC Current

Ranges	Maximum Display
±200μA	±199.9μA
±2mA	±1.999mA
±20mA	±19.99mA
±200mA	±199.9mA
±2000mA	±1999mA

SENSITIVITY: 100nA on 200μA range.
MAXIMUM INPUT: Current, 2A (fuse protected); voltage, 250V.
RANGING: Manual only.
POLARITY: Automatically sensed and displayed.
ACCURACY (1 year, 15 to 30°C at 95% RH):

Range	Specifications
200μA to 20 mA	±(0.3% of reading + 2 digits)
2000mA	±(0.6% of reading + 2 digits)

TEMPERATURE COEFFICIENT (0 to 15°C and 30 to 55°C): ±(.028% of reading + 0.1 digits)/°C
VOLTAGE BURDEN:

Range	Maximum at Full Scale
200μA to 20mA	<220mV
200mA	<240mV
2000mA	<400mV

RESPONSE TIME: 0.7 seconds on any range to within 1 digit of final value.

AC Voltmeter

AC CONVERTER: Average responding, rms calibrated.

Ranges	Maximum Display
200mV	199.9mV
2V	1.999V
20V	19.99V
200V	199.9V
1200V	1199V

SENSITIVITY: 100μV on 200mV range.
MAXIMUM INPUT: 1700V (dc + peak ac), 10^7 volt-Hz max.
RANGING: Automatic or manual.
ACCURACY (with display of >20 digits; 1 year, 15 to 30°C at 95% RH):

Range	Specifications
30 Hz—50 Hz	±(1.5% of reading ± 3 digits)
50 Hz—20 kHz	±(0.3% of reading ± 3 digits)
20 kHz—100kHz	±(1.5% of reading ± 10 digits)

TEMPERATURE COEFFICIENT (0 to 15°C and 30 to 55°C):
±(0.04% of reading + 0.2 digit)/°C.
INPUT IMPEDANCE: 5 MΩ//50 pF.

RESPONSE TIME: 1.6 seconds to within 3 digits of final value on one range. Add 1.2 seconds for each range change.
INPUT TYPE: Floating, 500V maximum common to ground.

AC Current

Ranges	Maximum Display
200μA	199.9μA
2mA	1.999mA
20mA	19.99mA
200mA	199.9mA
2000mA	1999mA

MAXIMUM INPUT: Current, 2 A (fuse protected); voltage, 250V.
RANGING: Manual only.
SENSITIVITY: 100nA on 200μA range.
ACCURACY (with display of >20 digits; 1 year, 15 to 30°C @ 95% RH):

Range	Specification (% of reading + no. of digits)	
2000mA	±(2% +4)	±(1.2% +4)
200mA	±(1.7% +4)	±(0.9% +4)
200μA		
	30 Hz	50 Hz — 10 kHz

Frequency of Input Signal

TEMPERATURE COEFFICIENT (0 to 15°C and 30 to 55°C):
±(0.05% of reading + 0.2 digits)/°C.
VOLTAGE BURDEN:

Range	Maximum at Full Scale
200μA to 20mA	<220mV rms
200mA range	<240mV rms
2000mA range	<400mV rms

RESPONSE TIME: 1.6 seconds on any range to within 3 digits of final value.
INPUT TYPE: Floating, 500V maximum common to ground.

Ohmmeter

Ranges	Maximum Display
20Ω	19.99Ω
200Ω	199.9Ω
2 kΩ	1.999 kΩ
20 kΩ	19.99 kΩ
200 kΩ	199.9kΩ
2MΩ	1.999MΩ
20MΩ	19.99MΩ

SENSITIVITY: 10 milliohm on 20Ω range.
INPUT PROTECTION: 250V rms.
RANGING: Automatic or manual.
ACCURACY (1 year, 15 to 30°C @ 95% RH):

Range	Specifications
20Ω	±(0.5% of reading + 10 digits)
200Ω—2MΩ	±(0.2% of reading + 2 digits)
20MΩ	±(0.8% of reading + 2 digits)

TEMPERATURE COEFFICIENT (0 to 15°C and 30 to 55°C):

Range	Specifications
20Ω—2MΩ	±(0.04% of reading + 0.2 digits)/°C
20MΩ	±(.18% of reading + 0.2 digits)/°C

CONFIGURATION: 2 wire.
OPEN CIRCUIT VOLTAGE: <5V.
CURRENT THROUGH UNKNOWN:

Range:	20Ω	200Ω	2 kΩ	200 kΩ	2 MΩ	20 MΩ
Current:	5mA	5mA	500μA	5μA	500nA	50nA

RESPONSE TIME: 0.8 seconds to within 1 digit. Add 0.8 seconds for each range.

General

CALIBRATION: Data sheet specifications guaranteed for 1 year.
READING RATE: 2.4—4.7/sec, depending on input level.
OPERATING TEMPERATURE: 0 to 55°C.
HUMIDITY: 95% RH, +15 to +40°C.
POWER: AC line: 48-440 Hz; 86-250V
BATTERY: rechargeable lead-acid 10 hours minimum continuous operation with full charge. Recharge time: 16 hours operating, 12 hours nonoperating.
TOTAL INSTRUMENT POWER DISSIPATED: ac only: 3 watts; with charger, 8 watts.
DIMENSIONS: 238.1 mm wide × 98.4 mm high × 276.2 mm deep (9-3/8 × 3⅞ × 10⅞ inches). Opt 002, 210 × 85.7 × 26.7 mm (8¼ × 3⅜ × 10½ in).
WEIGHT: 2.41 kg (5 lb., 5 oz); Opt 001, 1.84 kg (4 lb., 1 oz).
PRICES IN U.S.A.: 3435A, $400; without batteries (Opt. 001), less $65. Rack-and-stack case Opt 002 (ac line power only), less $35. 34112A Touch-Hold Probe, $40.



Joe E. Marriott

A 1969 graduate of the University of Utah (BSEE), Joe Marriott joined HP that same year, going to work on the Model 3403A True-rms Voltmeter. Returning to HP following a tour of duty with the National Guard, Joe contributed to the 970A and 3465A Voltmeters. While working on the 3476A/B Joe became project manager. Along the way, he earned an MSEE degree at Colorado State University in the HP Honors Co-op program. Married, and with a 2-year-old daughter, Joe cross-country skis, hikes, plays volleyball, and occasionally does some photography.



H. Mac Juneau

Mac Juneau joined HP in 1967, going to work on the Model 3480A Digital Voltmeter and then on high-speed A-to-D converters as project manager. For three years, Mac was product assurance manager with time out as project manager for the Model 3476A Multimeter. He is now manager of the HP Loveland facilities IC lab. He has a BSEE degree from Swarthmore College (Philadelphia) and MSEE and PhD degrees from the University of Minnesota. With children 8 and 5, Mac contributed to a school playground design. He also does some woodworking and creates welded sculptures.

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SPECIFICATIONS

HP Model 3465A/B Digital Multimeter

DC Voltmeter

Ranges	Maximum Display
±20mV	19.999
±200mV	199.99
±2V	1.9999
±20V	19.999
±200V	199.99
±1000V	1000.0

SENSITIVITY: 1 microvolt on lowest range.
MAXIMUM INPUT: 1000V max dc and peak ac.
POLARITY: Automatically sensed and displayed.
ACCURACY (1 year, 23°C ±5°C at 95% RH):

Range	Specifications
20mV	±0.03% of reading ± 2 digits
200mV thru 200V	±0.02% of reading ± 1 digit
1000V	±0.025% of reading ± 1 digit

TEMPERATURE COEFFICIENT (0°C to 50°C):
±0.003% of reading/°C.
INPUT RESISTANCE:

Range	Specifications
20mV thru 2V	$>10^{10}\Omega$
20V thru 1000V	10MΩ ± 1%

INPUT TYPE: floating, 500V maximum common to ground.
NORMAL MODE REJECTION: >60 dB at 50/60 Hz ± .1%.
EFFECTIVE COMMON MODE REJECTION (1 kΩ unbalance): >120 dB at 50/60 Hz ± .1%.
RESPONSE TIME: 1 second to within 1 digit.

DC Current

Ranges	Maximum Display
±200μA	199.99
±2mA	1.9999
±20mA	19.999
±200mA	199.99
±2000mA	1999.9

SENSITIVITY: 10nA on lowest range.
MAXIMUM INPUT: 2A from <250V source (fuse protected).
POLARITY: Automatically sensed and displayed.
ACCURACY (1 year, 23°C ±5°C at 95% RH):

Range	Specifications
200μA, 2mA	±0.07% of reading ± 1 digit
20mA	±0.11% of reading ± 1 digit
200mA, 2000mA	±0.6% of reading ± 1 digit

TEMPERATURE COEFFICIENT (0°C to 50°C):

Range	Specifications
200μA	±0.006% of reading/°C
2mA, 20mA	±0.004% of reading/°C
200mA, 2000mA	±0.01% of reading/°C

VOLTAGE BURDEN
HIGHEST RANGE: <700mV FS.
ALL OTHER RANGES: <250mV FS.
RESPONSE TIME: 1 second to within 1 digit.

Ohmmeter

Ranges	Maximum Display
200Ω	199.99
2 kΩ	1.9999
20 kΩ	19.999
200 kΩ	199.99
2000 kΩ	1999.9
20 MΩ	19.999

SENSITIVITY: 10 milliohm on lowest range.
INPUT PROTECTION: 350V (dc + peak ac)/250V rms.
ACCURACY (1 year, 23°C ± 5°C @ 95% RH):

Range	Specifications
200Ω	±0.02% of reading ± 2 digits
2 kΩ thru 2 MΩ	±0.02% of reading ± 1 digit
20 MΩ	±0.1% of reading ± 1 digit

TEMPERATURE COEFFICIENT (0°C to 50°C):

Range	Specifications
200Ω thru 2 MΩ	±0.0015% of reading/°C
20 MΩ	±0.004% of reading/°C

CONFIGURATION: 2 wire.
OPEN CIRCUIT VOLTAGE: <5V max.
CURRENT THROUGH UNKNOWN:

Range	Current
200Ω	1mA
2 kΩ	1mA
20 kΩ	10 μA
200 kΩ	10 μA
2000 kΩ	1 μA
20 MΩ	0.1 μ

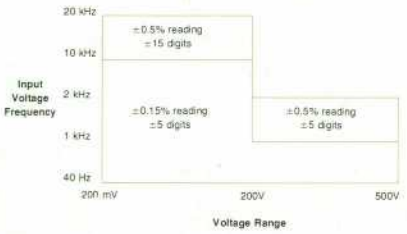
RESPONSE TIME: 2 seconds to within 1 digit.

AC Voltmeter

AC CONVERTER: average responding, rms calibrated.

Ranges	Maximum Display
200 mV	199.99
2V	1.9999
20V	19.999
200V	199.99
500V	500.0

SENSITIVITY: 10μV on lowest range.
MAXIMUM INPUT: Full scale to 10 kHz decreasing linearly to 50% of full scale at 20 kHz except 500V range which has 2-kHz maximum frequency.
ACCURACY (1 year, 23°C ± 5°C @ 95% RH):

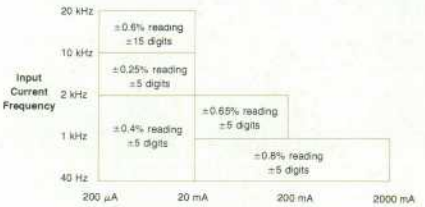


TEMPERATURE COEFFICIENT (0°C to 50°C): ±0.005% of reading ± .2 digit.
INPUT IMPEDANCE: 1 MΩ//<100 pF.
INPUT TYPE: floating, 500V maximum common to ground.
OVERLOAD PROTECTION: dc, 600V max; ac, 500V rms, 800V peak.
RESPONSE TIME: 5 seconds to within 1 digit.

AC Current

Range	Maximum Display
200μA	199.99
2mA	1.999
20mA	19.999
200mA	199.99
2000mA	1999.9

SENSITIVITY: 10nA on lowest range.
MAXIMUM INPUT: 2A from <250V source (fuse protected). Full scale to 10 kHz decreasing linearly to 50% full scale at 20 kHz on lowest 3 ranges, 2 kHz max on 200mA range; 1 kHz max on 2000mA range.
ACCURACY 1 year, 23°C ± 5°C @ 95% RH):



TEMPERATURE COEFFICIENT (0°C to 50°C): ±0.01% of reading/°C.
VOLTAGE BURDEN:
1A RANGE: <700mV fs.
ALL OTHER RANGES: <250mV fs.
RESPONSE TIME: 5 seconds to within 1 digit.

General

READING RATE: 2½ readings per second.
OVERLOAD INDICATION: display blanks.
HUMIDITY RANGE: 95% at 40°C
OPERATING TEMPERATURE: 0°C to +55°C (nickel-cadmium batteries, 0°C to +40°C).
WEIGHT: 2.04 kg (4 lbs., 8 oz.).
DIMENSIONS: 101.6 mm high × 212.7 mm wide × 279.4 mm deep (4 × 8-3/8 × 11 in.).
POWER: ac line, 86-127V, 176-250V; 48-440 Hz.
BATTERIES: rechargeable nickel cadmium standard.
Continuous operating time from full charge is 6 hours. Recharge time is 8 hours with instrument off. Trickle charge with instrument on.
OPTION 002: type D alkaline dry cells (U-2 cells in Europe). 60 hours continuous use at 23°C. Includes receptacle to use Model 82002A battery eliminator (82002A not included).
PRICE IN U.S.A.:
3465A, $530; Opt. 001: ac line only, −$20; Opt. 002, −$105.
3465B, $500. 34112 Touch-Hold Probe, $40.
MANUFACTURING DIVISION: LOVELAND INSTRUMENT DIVISION
815 Fourteenth Street S.W.
Loveland, Colorado 80537 U.S.A.

Hewlett-Packard Company, 1501 Page Mill Road, Palo Alto, California 94304

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Technical information from the Laboratories of Hewlett-Packard Company

Hewlett-Packard Central Mailing Department
Van Heuven Goedhartlaan 121
Amstelveen-1134 The Netherlands
Yokogawa-Hewlett-Packard Ltd., Shibuya-Ku
Tokyo 151 Japan

Editorial Director • Howard L. Roberts
Managing Editor • Richard P. Dolan
Art Director, Photographer • Arvid A. Danielson
Illustrator • Susan E. Wright
Administrative Services, Typography • Anne S. LoPresti
European Production Manager • Tina Eysten

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