

**Keithley Instruments**

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**DC CHARACTERISTICS**
**CONDITIONS: MED (1 PLC)<sup>1</sup> or SLOW (5 PLC)**

FUNCTION	RANGE	RESOLUTION	TEST CURRENT ±5% OR BURDEN VOLTAGE	INPUT RESISTANCE OR CLAMP VOLTAGE	ACCURACY: ±(ppm of reading + ppm of range) ppm = parts per million) (e.g., 10ppm = 0.001%)				TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C
					24 Hour <sup>2</sup> 23°C ±1°	90 Day 23°C ±5°	1 Year 23°C ±5°	2 Years 23°C ±5°	
Voltage	100.00000 mV <sup>3</sup>	10 nV		> 10 GΩ	10+9	25+9	37+9	50+10	2 + 6
	1.0000000 V	100 nV		> 10 GΩ	7+2	18+2	25+2	32+2	2 + 1
	10.000000 V	1 μV		> 10 GΩ	7+4	18+4	24+4	32+4	2 + 1
	100.00000 V	10 μV		10 MΩ ±1%	10+4	25+5	35+5	52+5	5 + 1
	1000.0000 V <sup>4</sup>	100 μV		10 MΩ ±1%	17+6	31+6	41+6	55+6	5 + 1
Resistance <sup>5</sup>	10.000000 Ω <sup>6</sup>	1 μΩ	10 mA		15 + 9	40+9	60+9	100+10	8 + 6
	100.00000 Ω <sup>6</sup>	10 μΩ	1 mA		15 + 9	36+9	52+9	90+10	8 + 6
	1.0000000 kΩ <sup>6</sup>	100 μΩ	1 mA		15 + 2	33+2	50+2	80+2	8 + 1
	10.000000 kΩ <sup>6</sup>	1 mΩ	100 μA		15 + 2	32+2	50+2	80+2	8 + 1
	100.00000 kΩ	10 mΩ	10 μA		15 + 4	40+4	70+4	120+4	8 + 1
	1.0000000 MΩ <sup>7</sup>	100 mΩ	10 μA		20 + 3	50+4	70+4	125+4	8 + 1
	10.000000 MΩ <sup>7,8</sup>	1 Ω	640 nA // 10 MΩ		150 + 4	200+4	400+4	500+4	70 + 1
	100.00000 MΩ <sup>7,8</sup>	10 Ω	640 nA // 10 MΩ		800 + 4	1500+4	1500+4	1800+4	385 + 1
Dry Circuit Resistance <sup>6</sup>	10.00000 Ω	10 μΩ	1 mA	20 mV	25 + 90	50 + 90	70 + 90	120 + 90	8 + 60
	100.0000 Ω	100 μΩ	100 μA	20 mV	25 + 90	50 + 90	70 + 90	120 + 90	8 + 60

<sup>1</sup> For the following ranges, add 4 ppm to the range accuracy specification: 100 mV, 10 Ω, 100 Ω, 10 mA, 100 mA, and 1 A. Dry Circuit function add 40 ppm.

<sup>2</sup> Relative to calibration accuracy.

<sup>3</sup> When properly zeroed using REL function.

<sup>4</sup> For signal levels >500 V, add 0.02 ppm/V uncertainty for the portion exceeding 500 V.

<sup>5</sup> Specifications are for 4-wire ohms. For 2-wire ohms, add 1 Ω to "ppm of range" uncertainty. 10 Ω range is for 4-wire only.

<sup>6</sup> Offset compensation on.

<sup>7</sup> For rear inputs, add the following to Temperature Coefficient "ppm of reading" uncertainty: 1 MΩ 25ppm, 10 MΩ 250ppm, 100 MΩ 2500 ppm. Operating environment specified for 0 °C to 50 °C 50 % RH at 35 °C.

<sup>8</sup> Must have 10 % matching of lead resistance in Input HI and LO.

Specifications are subject to change without notice.

FUNCTION	RANGE	RESOLUTION	TEST CURRENT ±5% OR BURDEN VOLTAGE	INPUT RESISTANCE OR CLAMP VOLTAGE	ACCURACY: ±(ppm of reading + ppm of range) ppm = parts per million) (e.g., 10ppm = 0.001%)				TEMPERATURE COEFFICIENT 0°–18°C & 28°–50°C
					24 Hour <sup>2</sup> 23°C ±1°	90 Day 23°C ±5°	1 Year 23°C ±5°	2 Years 23°C ±5°	
Current	10.000000 mA	1 nA	< 0.15 V		60 + 30	300+80	500+80	740+80	50 + 5
	100.000000 mA	10 nA	< 0.18 V		100+300	300+800	500+800	740+800	50 + 5
	1.00000000 A	100 nA	< 0.35 V		200 + 30	500+80	800+80	1200+80	50 + 5
	3.0000000 A	1 µA	< 1 V		1000+15	1200+40	1200+40	1800+40	50 + 5
Continuity 2W	1 kΩ	100 mΩ	1 mA		40 + 100	100+100	120 + 100	190 + 10	8 + 1
Diode Test	10.000000 V	1 µV	1 mA		20 + 6	30 + 7	40 + 7	55 + 7	8 + 1
	4.400000 V	1 µV	100 µA		20 + 6	30 + 7	40 + 7	55 + 7	8 + 1
	10.000000 V	1 µV	10 µA		20 + 6	30 + 7	40 + 7	55 + 7	8 + 1
DCV: DCV Ratio <sup>9</sup>	100 mV to 1000 V				Ratio accuracy = accuracy of selected sense input range + accuracy of selected input range.				

## DC OPERATING CHARACTERISTICS<sup>10</sup>

FUNCTION	DIGITS	READINGS/s	PLCs <sup>11</sup>
DCV (all ranges),	7½ <sup>12</sup>	4 (3)	5
DCI (all ranges), and	6½ <sup>12, 13</sup>	30 (27)	1
Ohms (<10 M range)	6½ <sup>12, 14</sup>	50 (44)	1
	5½ <sup>12, 14</sup>	260 (220)	0.1
	5½ <sup>14</sup>	490 (440)	0.1
	5½ <sup>14</sup>	1000 (1000)	0.04
	4½ <sup>14</sup>	2000 (1800)	0.01

<sup>9</sup> Sense LO input must be referenced to Input LO. Sense HI input must not exceed 125% (referenced to Input LO) of range selected. Sense input has 100 mV, 1 V, and 10 V ranges.

<sup>10</sup> Speeds are for 60 Hz (50 Hz) operation using factory default operating conditions (\*RST). Autorange off, Display off, Trigger delay = 0.

<sup>11</sup> 1 PLC = 16.67 ms @ 60 Hz, 20 ms @ 50 Hz/400 Hz. The frequency is automatically determined at power up.

<sup>12</sup> Speeds include measurement and binary data transfer out the GPIB.

<sup>13</sup> Ohms, 17 (15) readings/second.

<sup>14</sup> Sample count = 1024, auto zero off.

Specifications and characteristics are subject to change without notice.

## DC NOISE PERFORMANCE

RATE	DIGITS	RMS NOISE 100 mV RANGE		RMS NOISE 10 V RANGE		NMRR <sup>15</sup>	CMRR <sup>16</sup>
		10 s	2 minute	10 s	2 minute		
5 PLC	7½	100 nV	110 nV	1.1 µV	1.2 µV	60 dB	140 dB
1 PLC	6½	135 nV	165 nV	1.3 µV	1.4 µV	60 dB	140 dB
0.1 PLC	5½	1.9 µV	1.9 µV	11 µV	11.5 µV	—	80 dB
0.01 PLC	4½	3.0 µV	2.9 µV	135 µV	139 µV	—	80 dB

## DC SYSTEM SPEEDS<sup>10,17</sup>

**RANGE CHANGE<sup>12</sup>:** 50/s (42/s).

**FUNCTION CHANGE<sup>12</sup>:** 45/s (38/s).

**AUTORANGE TIME<sup>12,18</sup>:** <30 ms (<35 ms).

**ASCII READINGS TO RS-232 (19.2K BAUD):** 55/s (55/s).

**MAXIMUM INTERNAL TRIGGER RATE:** 2000/s (2000/s).

**MAXIMUM EXTERNAL TRIGGER RATE:** 480/s (480/s).

**RATIO SPEED<sup>12,10</sup>:** 10/s (8/s).

## DC GENERAL

**LINEARITY OF 10VDC RANGE:** ±(2 ppm of reading + 1 ppm of range).

**DCV, Ω, TEMPERATURE, CONTINUITY, DIODE TEST INPUT PROTECTION:** 1000 V, all ranges.

**MAXIMUM 4WΩ LEAD RESISTANCE:** 5 % of range per lead for 10 Ω, 100 Ω, and 1 kΩ ranges; 1kΩ per lead for all other ranges.

**DC CURRENT INPUT PROTECTION:** 3 A, 250 V fuse.

**SHUNT RESISTOR:** 0.1 Ω for 3 A and 1 A ranges. 1 Ω for 100 mA range. 10 Ω for 10 mA range.

**CONTINUITY THRESHOLD:** Adjustable 1 Ω to 1000 Ω.

**OVERRANGE:** 120 % of range except on 1000 V, 3 A, and Diode.

**OFFSET COMPENSATION:** Available for 10 kΩ and lower ranges only.

<sup>15</sup> For line frequency ±0.1 %.

<sup>16</sup> For 1kΩ unbalance in LO lead.

<sup>17</sup> Auto zero off, NPLC = 0.01.

<sup>18</sup> Add 120 ms for ohms.

## TRUE RMS AC VOLTAGE AND CURRENT CHARACTERISTICS

ACCURACY<sup>19</sup> 1:  $\pm$ (% of reading + % of range), 23 °C  $\pm$ 5 °C

VOLTAGE RANGE	RESOLUTION	CALIBRATION CYCLE	3 Hz–10 Hz <sup>20</sup>	10 Hz–20 kHz	20 kHz–50 kHz	50 kHz–100 kHz–	100 kHz–300 kHz
100.0000 mV	0.1 $\mu$ V						
1.000000 V	1.0 $\mu$ V	90 Days	0.35 + 0.03	0.05 + 0.03	0.11 + 0.05	0.60 + 0.08	4 + 0.5
10.00000 V	10 $\mu$ V						
100.0000 V	100 $\mu$ V	1 Year	0.35 + 0.03	0.06 + 0.03	0.12 + 0.05	0.60 + 0.08	4 + 0.5
750.000 V	1 mV						
<b>TEMPERATURE COEFFICIENT/°C</b> <sup>21</sup>			0.035 + 0.003	0.005 + 0.003	0.006 + 0.005	0.01 + 0.006	0.03 + 0.01

CURRENT RANGE	RESOLUTION	CALIBRATION CYCLE	3 Hz–10 Hz	10 Hz–3 kHz	3 kHz–5 kHz
1.000000 A	1 $\mu$ A	90 Day/1 Year	0.30 + 0.04	0.10 + 0.04	0.14 + 0.04
3.00000 A <sup>22</sup>	10 $\mu$ A	90 Day/1 Year	0.35 + 0.06	0.15 + 0.06	0.18 + 0.06
<b>TEMPERATURE COEFFICIENT/°C</b> <sup>21</sup>			0.035 + 0.006	0.015 + 0.006	0.015 + 0.006

### HIGH CREST FACTOR ADDITIONAL ERROR

$\pm$ (% of reading)<sup>23</sup>

Crest Factor:	1–2	2–3	3–4	4–5
Additional Uncertainty:	0.05	0.15	0.30	0.40

### AC OPERATING CHARACTERISTICS<sup>24</sup>

FUNCTION	DIGITS	READINGS/s	RATE	BANDWIDTH
ACV (all ranges) and ACI (all ranges)	6½ <sup>25</sup>	0.5 (0.4)	SLOW	3 Hz–300 kHz
	6½ <sup>25</sup>	1.4 (1.5)	MED	30 Hz–300 kHz
	6½ <sup>26</sup>	4.0 (4.3)	MED	30 Hz–300 kHz
	6½ <sup>25</sup>	2.2 (2.3)	FAST	300 Hz–300 kHz
	6½ <sup>26</sup>	35 (30)	FAST	300 Hz–300 kHz

<sup>19</sup> Specifications are for SLOW rate and sinewave inputs >5 % of range.

<sup>20</sup> Typical uncertainties. Typical represents two sigma or 95 % of manufactured units measure < 0.35 % of reading and three sigma or 99.7 % < 1.06 % of reading.

<sup>21</sup> Applies to 0 ° – 18 °C and 28 ° – 50 °C.

<sup>22</sup> For signal levels >2.2 A, add additional 0.4 % to “of reading” uncertainty.

<sup>23</sup> Applies to non-sine waves >5 Hz and <500 Hz. (Guaranteed by design for Crest Factors >4.3.)

<sup>24</sup> Speeds are for 60 Hz (50 Hz) operation using factory default operating conditions (\*RST). Auto zero off, Auto range off, Display off, includes measurement and binary data transfer out the GPIB.

<sup>25</sup> 0.01 % of step settling error. Trigger delay = 400 ms.

<sup>26</sup> Trigger delay = 0.

Specifications and characteristics are subject to change without notice.

## AC SYSTEM SPEEDS<sup>24,27</sup>

**FUNCTION/RANGE CHANGE<sup>28</sup>:** 4/s.

**AUTORANGE TIME:** <3 s.

**ASCII READINGS TO RS-232 (19.2 K BAUD)<sup>26</sup>:** 50/s.

**MAX. INTERNAL TRIGGER RATE<sup>26</sup>:** 300/s.

**MAX. EXTERNAL TRIGGER RATE<sup>26</sup>:** 300/s.

## ADDITIONAL LOW FREQUENCY ERRORS

±(% of reading)

	SLOW	MED	FAST
20 Hz – 30 Hz	0	0.3	–
30 Hz – 50 Hz	0	0	–
50 Hz – 100 Hz	0	0	1.0
100 Hz – 200 Hz	0	0	0.18
200 Hz – 300 Hz	0	0	0.10
>300 Hz	0	0	0

## AC GENERAL

**INPUT IMPEDANCE:** 1 M $\Omega$   $\pm$ 2 % paralleled by <100 pF.

**ACV INPUT PROTECTION:** 1000 V.

**MAXIMUM DCV:** 400 V on any ACV range.

**ACI INPUT PROTECTION:** 3 A, 250 V fuse.

**BURDEN VOLTAGE:** 1 A Range: <0.35 V<sub>rms</sub>.  
3 A Range: <1 V<sub>rms</sub>.

**SHUNT RESISTOR:** 0.1  $\Omega$  on all ACI ranges.

**AC CMRR:** >70 dB with 1 k $\Omega$  in LO lead.

**MAXIMUM CREST FACTOR:** 5 at full scale.

**VOLT HERTZ PRODUCT:**  $\leq 8 \times 10^7$  V·Hz.

**OVERRANGE:** 120 % of range except on 750 V and 3 A ranges.

<sup>27</sup> DETector: BANDwidth 300, NPLC = 0.01.

<sup>28</sup> Maximum useful limit with trigger delay = 175 ms.

## FREQUENCY AND PERIOD CHARACTERISTICS<sup>29,30</sup>

ACV RANGE	FREQUENCY RANGE	PERIOD RANGE	GATE TIME	RESOLUTION ±(ppm of reading)	ACCURACY 90 Day/1 Year ±(% of reading)
100 mV to 750 V	3 Hz to 500 kHz	333 ms to 2 μs	1 s	0.3	0.01

## TEMPERATURE CHARACTERISTICS

### THERMOCOUPLE<sup>31,32,33</sup>

TYPE	RANGE	RESOLUTION	ACCURACY <sup>34</sup> 90 DAY/1 YEAR (23 °C ± 5 °C) RELATIVE TO SIMULATED REFERENCE JUNCTION	USING 2001-TCSCAN <sup>35</sup>
J	-200 to + 760 °C	0.001 °C	±0.5 °C	±0.65 °C
K	-200 to +1372 °C	0.001 °C	±0.5 °C	±0.70 °C
N	-200 to +1300 °C	0.001 °C	±0.5 °C	±0.70 °C
T	-200 to + 400 °C	0.001 °C	±0.5 °C	±0.68 °C

### 4-WIRE RTD<sup>31,32,36,37</sup>

RANGE	RESOLUTION	90 DAY/1 YEAR (23 °C ± 5 °C) ACCURACY <sup>38</sup>	2 YEAR (23 °C ± 5 °C) ACCURACY <sup>38</sup>
-100 °C to +100 °C	0.001 °C	±0.08 °C	±0.12 °C
-200 °C to +630 °C	0.001 °C	±0.14 °C	±0.18 °C

<sup>29</sup> Specifications are for square wave inputs only. Input signal must be >10 % of ACV range. If input is <20 mV on the 100 mV range, then the frequency must be >10 Hz. For sine wave inputs, frequency must be >100 Hz.

<sup>30</sup> 20 % overrange on all ranges except 750 V range.

<sup>31</sup> Temperature can be displayed in °C, K, or °F.

<sup>32</sup> Accuracy for all thermocouple types and the 100 Ω platinum, D100, and F100 RTD types based on ITS-90. Accuracy for the PT385 and PT3916 RTD types based on IPTS-68.

<sup>33</sup> Exclusive of thermocouple error.

<sup>34</sup> For temperatures ≤100 °C, add ±0.1 °C and >900 °C, add ±0.3 °C.

<sup>35</sup> Specifications apply to channels 2–6. Add 0.06 °C/channel from channel 6.

<sup>36</sup> 100 Ω platinum, D100, F100, PT385, PT3916, or user type.

<sup>37</sup> Maximum lead resistance (each lead) to achieve rated accuracy is 5 Ω.

<sup>38</sup> Exclusive of probe errors.

Specifications and characteristics are subject to change without notice.

## INTERNAL SCANNER SPEED

MAXIMUM INTERNAL SCANNER RATES: RANGE: CHANNELS/s<sup>39</sup>

### TRIGGER DELAY = 0

DCV <sup>40</sup>	ACV <sup>40,41</sup>	2 WIRE OHMS <sup>40</sup>	4 WIRE OHMS <sup>40</sup>	T/C TEMPERATURE <sup>40</sup>	RTD TEMPERATURE <sup>40</sup>
All: 105	All: 96	All: 102	<10 M $\Omega$ : 55	All: 70	All: 2

### TRIGGER DELAY = AUTO

DCV <sup>40</sup>	ACV <sup>40,41</sup>	2 WIRE OHMS <sup>40</sup>	4 WIRE OHMS <sup>40</sup>	T/C TEMPERATURE <sup>40</sup>	RTD TEMPERATURE <sup>40</sup>
0.1 V: 100	All: 1.8	100 $\Omega$ : 82	100 $\Omega$ : 42	All: 70	All: 2
1 V: 100		1 k $\Omega$ : 85	1 k $\Omega$ : 42		
10 V: 100		10 k $\Omega$ : 42	10 k $\Omega$ : 25		
100 V: 70		100 k $\Omega$ : 28	100 k $\Omega$ : 21		
1000 V: 70		1 M $\Omega$ : 8	1 M $\Omega$ : 7		
		10 M $\Omega$ : 5	10 M $\Omega$ : 5		
		100 M $\Omega$ : 3	100 M $\Omega$ : 3		

## TRIGGERING AND MEMORY

**READING HOLD SENSITIVITY:** 0.01 %, 0.1 %, 1 %, or 10 % of reading.

**TRIGGER DELAY:** 0 to 99 hours (1 ms step size).

**EXTERNAL TRIGGER DELAY:** <1 ms.

**EXTERNAL TRIGGER JITTER:** <500  $\mu$ s.

**MEMORY:** 1024 readings.

## MATH FUNCTIONS

Rel, Min/Max/Average/StdDev (of stored reading), dB, dBm, Limit Test, %, and mX+b with user-defined units displayed.

**dBm REFERENCE RESISTANCES:** 1 to 9999  $\Omega$  in 1  $\Omega$  increments.

## REMOTE INTERFACE

Keithley 199/196 Emulation

GPIB (IEEE-488.2) and RS-232C

SCPI (Standard Commands for Programmable Instruments)

<sup>39</sup> Speeds are for 60 Hz or 50 Hz operation using factory default operating conditions (\*RST). Auto Zero off, Auto Range off, Display off, sample count = 1024.

<sup>40</sup> NPLC = 0.01.

<sup>41</sup> DETector BANDwidth: 300.

Specifications are subject to change without notice.

## GENERAL

**POWER SUPPLY:** 100 V / 120 V / 220 V / 240 V.

**LINE FREQUENCY:** 50 Hz to 60 Hz and 440 Hz, automatically sensed at power-up.

**POWER CONSUMPTION:** 22 VA.

**COMMON MODE VOLTAGE AND ISOLATION:** 500 V<sub>peak</sub>, >10 GΩ and <150 pF.

**OPERATING ENVIRONMENT:** Specified for 0 °C to 50 °C. Specified to 80% R.H. at 35 °C. Altitude up to 2000 meters.

**STORAGE ENVIRONMENT:** -40 °C to 70 °C.

**SAFETY:** Conforms to European Union Directive 73/23/EEC EN61010-1, CAT II.

**EMC:** Complies with European Union Directive 89/336/EEC, EN61326-1.

**VIBRATION:** MIL-PRF-28800F Class 3 Random.

**WARMUP:** 2 hours to rated accuracy.

**DIMENSIONS:**

**Rack Mounting:** 89 mm high × 213 mm wide × 370 mm deep (3½ in. × 8-3⁄8 in. × 14-9⁄16 in.).

**Bench Configuration (with handle and feet):** 104 mm high × 238 mm wide × 370 mm deep (4-1⁄8 in. × 9-3⁄8 in. × 14-9⁄16 in.).

**SHIPPING WEIGHT:** 5 kg (11 lb).

**VOLT HERTZ PRODUCT:** ≤8 × 10<sup>7</sup> V·Hz.

**ACCESSORIES SUPPLIED:** Model 1751 Safety Test Leads, User Manual, Service Manual.

## ACCESSORIES AVAILABLE

2000-SCAN	10-Channel Scanner
2001-TCSCAN	9-Channel Thermocouple Scanner (includes 1-channel reference junction)
4288-1	Single Fixed Rack Mount Kit
4288-2	Dual Fixed Rack Mount Kit
5804	4-Terminal Test Lead Set
5805	Kelvin Probes
7007-1	Shielded GPIB Cable, 1m (3.2 ft)
7007-2	Shielded GPIB Cable, 2m (6.5 ft)
7009-5	Shielded RS-232 Cable 1.5m (5 ft)