# 1801

# Nanovolt Preamp Option

## For Model 2001 and 2002 DMMs


- **<600pV p-p DCV noise**
- **10nV/day voltage stability**
- **1GΩ isolation and 175dB CMRR**
- **Rise times from 500µs to 10s**
- **Chopper-based design cancels flicker noise**
- **Extends low-level measurement ranges and amplifies the voltage sensitivity of the Model 2001 and 2002**

## Ordering Information

**1801** Nanovolt Preamp for the Model 2001 or Model 2002 DMM

Requires a Model 2001 or 2002 DMM for operation.

**This product is available with an Extended Warranty.**

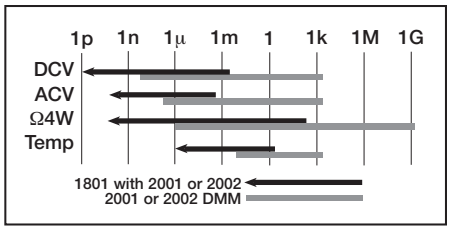
### Accessories Supplied

**Instruction manual, 3m of SC-93 low thermal cable (shielded twisted pair, solid copper wires, unterminated), thermal isolation enclosure, user's manual.**

With just 0.6nV p-p noise, the Model 1801 Nanovolt Preamp for the Model 2001 and 2002 is the most sensitive room temperature digital nanovoltmeter available. But it's equally suitable for a wide range of low-level AC voltage, 4-wire ohms, frequency/period, and differential temperature measurement applications. It extends the low-level measurement ranges and amplifies the voltage sensitivity of the Model 2001 and 2002 DMMs by 1000 times.

The Model 1801 is specifically designed for connection to these DMMs via the option slot on the instrument's back panel. The 1801 takes advantage of the DMM's flexible user interface and measurement and display capabilities, while isolating the preamp from the noisy electrical environment surrounding the test rack.

### Remote Preamp Architecture

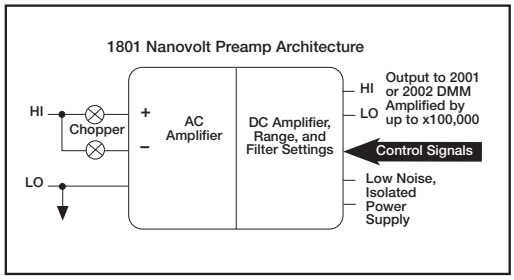



The Model 1801's remote preamp architecture isolates its sensitive amplification circuitry, allowing system builders to locate the unit near the test setup and keep leads short. This physical isolation also helps minimize noise degradation due to thermal gradients, magnetic interference, EMI/RFI, vibration, etc. A 3-meter cable links the preamp unit to a low-noise power supply card, which installs in the option slot in the DMM. Common mode current is reduced to <15nA p-p at 50 or 60Hz, for the highest isolation available in an instrument of this type.

On power-up, the DMM is automatically reconfigured with functions specific to the Model 1801 and additional measurement ranges.

### Applications

The Model 1801 is well suited for applications such as making pulsed measurements of superconducting samples with high source current levels. When using the Model 1801 for 4-wire ohms measurements, the full-scale input voltage is <2mV so users can employ "dry circuit" testing techniques when making contact resistance measurements. A user-supplied external clamp is required to limit the open circuit voltage. For more information, see Application Note 313, "Using the 1801 for Dry Circuit Testing." The nanovolt preamp's extremely low power dissipation minimizes DUT heating, which can be critical when characterizing temperature-sensitive devices such as RTDs.




The Model 1801 can measure temperature differentials accurately using a variety of sensors, including type J, K, T, E, R, S, and B differential thermocouples. Users may also enter a specific µV/°C value, making it possible to measure temperature using thermopiles. Thermistor measurements can be made by inputting a constant current to the sensor, then calculating temperature from the resulting µV/°C output.

**Unique Circuit Design.** The 1801's chopper-based design offers several advantages over traditional preamps designed for high-frequency amplification. For example, most DMMs and lock-in amplifiers are designed to filter out random noise by averaging. However, low-level measurements are also subject to (1/f) noise, which cannot be filtered out in this way. The chopper design cancels out (1/f) noise completely, which lock-in preamps and most DMMs can't. By continuously inverting the DC input and amplifying the resulting AC waveform, the 1801's chopper measures the DC input amplitude precisely, exclusive of voltage offsets and (1/f) noise in the amplifier circuitry. Carefully designed feedback circuitry makes the 1801 capable of rise times as fast as 500µs 10–90% and DC input resistance of up to 1GΩ. A one-eighth-inch-thick steel shield and an internal mu-metal shield prevent magnetic coupling of noise to the amplifier.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LOW V/LOW R PRODUCTS

# 1801 Nanovolt Preamp Option

## For 2001 and 2002 DMMs

| FUNCTION | RANGES AVAILABLE |
|---|---|
| DC Volts | 20μV, 200μV, 2mV |
| DC Volts Peak Spikes | Not available. |
| AC Volts Low Frequency rms | 500μV rms. |
| AC Volts Normal rms Average Peak, Crest Factor | Not available. |
| DC Current | Not available. |
| DC In-Circuit Current | Not available. |
| AC Current | Not available. |
| 2-Wire Ohms | Not Available. |
| 4-Wire Ohms | 2mΩ, 20mΩ, 200mΩ, 2Ω, 20Ω, 200Ω. |
| Frequency | Available for limited frequency range. |
| Temperature | Only differential thermocouple temperature is specified. RTD not available. |

### GENERAL NOTES

1. The Model 1801 Nanovolt Preamp consists of a power-supply card that plugs into the Model 2001 or 2002 scanner slot, the remote nanovolt preamp, and a 3-meter cable to connect the two.
2. The Model 1801 Nanovolt Preamp is specified only for use with the Model 2001 or 2002 Multimeter. Specifications are based on the published Model 2001/2002 performance and are referenced to the Model 1801 Nanovolt Preamp input. It is assumed the Model 2001/2002 used with the nanovolt preamp is properly calibrated.
3. Model 1801 specified calibration interval is 1 year.
4. The Model 2001/2002 checks for the presence of the nanovolt preamp on power up. If the nanovolt preamp is detected, the front panel menu tree is adjusted accordingly. An additional subset of the 2001/2002 functions are active with ranges as follows:

## DC VOLTS (with 2001 or 2002) DCV ACCURACY[1]

| RANGE | FULL SCALE | 7½-DIGIT RESOLUTION | DEFAULT RESOLUTION | ACCURACY[2] ±(ppm of reading+ppm of range) 24 Hours[3] | 90 Days[4] | 1 Year[4] | 2 Years[4] | TEMPERATURE COEFFICIENT ±(ppm of reading+ ppm of range)/°C Outside $T_{CAL}$ ±5°C |
|---|---|---|---|---|---|---|---|---|
| 20 μV | ±21.000000 | 1 pV | 10 pV | 300 + 60 | 450 + 60 | 460 + 60 | 470 + 60 | 40 + 13 |
| 200 μV | ±210.00000 | 10 pV | 100 pV | 200 + 20 | 250 + 20 | 260 + 20 | 270 + 20 | 40 + 2 |
| 2 mV | ±2.1000000 | 100 pV | 1 nV | 200 + 6 | 250 + 6 | 260 + 6 | 270 + 6 | 40 + 2 |

**DC VOLTAGE UNCERTAINTY** = ± [ (ppm of reading) × (measured value) + (ppm of range) × (range used) ] / 1,000,000.

**% ACCURACY** = (ppm accuracy) /10,000.

**1PPM OF RANGE** = 2 counts at 6½ digits.

**INPUT CHARACTERISTICS (HI to LO):**

**Input Bias Current:** Adjustable at preamp to <20pA. Temperature drift less than 25pA/°C.

**Zero Drift:** Typical variation of zero reading with low thermal short (see Instruction Manual) is less than 10nV, 5nV/°C. (24 hours, TREF±1°C, 1 PLC, 10-reading digital filter).

**DC Input Resistance:** >1GΩ.

**Transient Input Resistance:** >1kΩ 1ms after step input. >10MΩ 4s after step input.

**Linearity:** <4ppm of range non-linearity, exclusive of zero offset and noise.

**Isolated Polarity Reversal Error:** <2ppm of range, exclusive of zero offset and noise.

**Maximum Input Levels:** 1V or 100mA peak.

**Overload Recovery:** 1s for <10mV overload, 1 minute for ≥10mV overload.

**COMMON MODE ISOLATION (input LO to 2001 or 2002 chassis ground):**

**Isolation Impedance:** 1GΩ in parallel with 1nF.

**Maximum Common Mode Voltage:** 42V peak.

**Common Mode Current:** <15nA p-p at 50 or 60Hz.

**NOISE REJECTION:**

**CMRR[1]:** 175dB for DC, 50 or 60Hz ± 0.1%, common mode signals up to 5V p-p AC, 42V p-p AC+DC.

**NMRR (at 50 or 60Hz ± 0.1%, NPLC > 1, Line Sync OFF):**

| FILTER | SLOW | MEDIUM | FAST |
|---|---|---|---|
| 20 μV Range | 90 dB | 80 dB | 60 dB |
| 200 μV Range | 90 dB | 80 dB | 60 dB |
| 2 mV Range | 90 dB | 60 dB | 60 dB |

Effective noise is reduced by a factor of 10 for every 20dB of noise rejection (60dB reduces effective noise by 1,000:1).

CMRR is rejection of undesirable AC or DC signal between LO and earth with a 1Ω imbalance in the LO lead.

NMRR is rejection of undesirable AC signal between HI and LO.

### PREAMP SETTLING CHARACTERISTICS (nominal, ±20%):

| FILTER | 10% to 90% Rise Time SLOW | MEDIUM | FAST |
|---|---|---|---|
| 20 μV Range | 10 s | 1 s | 10 ms |
| 200 μV Range | 1 s | 100 ms | 2 ms |
| 2 mV Range | 100 ms | 10 ms | 500 μs |

**ZERO SUPPRESSION:** Adjustable ±100μV at preamp. 2001 front panel suppression using REL.

**INPUT NOISE (with low thermal short):** Equivalent noise resistance of 20Ω. There is no 1/f component, 1PLC integration.[5]

| FILTER | Input Noise SLOW | MEDIUM | FAST |
|---|---|---|---|
| 20 μV Range | 0.6 nV p-p | 2 nV p-p | 30 nV p-p |
| 200 μV Range | 2 nV p-p | 9 nV p-p | 40 nV p-p |
| 2 mV Range | 6 nV p-p | 20 nV p-p | 90 nV p-p |

**MAXIMUM SOURCE RESISTANCE:** 10kΩ.

### DC VOLTS NOTES:

[1] Specifications are for 1 PLC, Auto Zero on, 10-reading digital filter, Preamp on SLOW filter.

[2] When properly zeroed (using zero adjustment initially then REL according to procedure in Instruction Manual) every 20 minutes or whenever the ambient temperature changes by more than 1°C.

[3] For $T_{CAL}$ ±1°C, following 15-minute preamp warmup. $T_{CAL}$ is ambient temperature at calibration which is 23°C from factory.

[4] For $T_{CAL}$ ±5°C, following 15-minute preamp warmup. Specifications include factory traceability to US NIST.

[5] For source resistance $R_S$ above 1Ω multiply noise by

$$\sqrt{\frac{20 + R_S}{20}}$$

## GENERAL

**INPUT CONNECTOR:** 3mm studs and nuts of pure copper.

**POWER:** Supplied through scanner slot of the Model 2001 or 2002.

**PREAMP WARMUP:** 15 minutes.

**ENVIRONMENT:**

**Operating Temperature:** 0°C to 35°C.

**Storage Temperature:** –40°C to 70°C.

**Humidity:** <80% R.H., 0°C to 35°C.

**Magnetic Field Density:** <0.1Tesla.

**NORMAL CALIBRATION:**

**Type:** Software. No manual adjustments are required. Adjustments for voltage and current offset are provided for use during measurement setup.

**PHYSICAL:**

**Remote Preamp Case Dimensions:** 35mm high × 70mm wide × 140mm long (1.38 in × 2.76 in × 5.5 in). Add 6mm (0.25 in) to height to include terminals.

**Thermal Isolation Enclosure Dimensions:** 127mm wide × 279mm high × 102mm deep (5 in × 11 in × 4 in).

**Remote Preamp Weight:** 0.5kg (1.1 lbs).

**Shipping Weight:** 2.2kg (4 lbs 15 oz).

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## For 2001 and 2002 DMMs

## ANALOG OUTPUT

**CONNECTION:** Screw terminals on power supply card.

**OUTPUT:** ±2V full scale, maximum 1mA load.

**GAIN:** 1000 on 2mV range, 10000 on 200μV range, 100000 on 20μV range.

**NOISE:** Input noise times gain plus modulation products.

**MODULATION PRODUCTS:** Up to 40mV p-p at 288Hz.

**ACCURACY:** ±(2% of output + 1mV) when properly zeroed at preamp.

## DIFFERENTIAL TEMPERATURE

**TEMPERATURE SENSOR:** Differential thermocouple of type J, K, T, E, R, S, B, or user-entered μV/°C value.

Differential temperature reading is DCV reading × the °C/μV slope.

Default resolution (0.1m°C).

Maximum differential temperature reading 50°C.

| Differential Thermocouple Type | Range |
|---|---|
| J | –200°C to + 760°C |
| K | –200°C to + 1372°C |
| T | –200°C to + 400°C |
| E | –200°C to + 1000°C |
| R | 0°C to + 1768°C |
| S | 0°C to + 1768°C |
| B | +350°C to + 1820°C |

## AC VOLTS RMS (with 2001 or 2002)

**AC MAGNITUDE:** Low Frequency rms.

Normal rms, Average, rms, and Peak measurements are not available using the 1801.

**RMS RANGE:** 500μV.

**PEAK INPUT:** 2mV.

**FULL SCALE RMS:** 500.00.

**7½-DIGIT RESOLUTION:** 100pV.

**DEFAULT RESOLUTION:** 1nV.

**ACCURACY[1,2]:** 6 + 0.1.

**SIGNAL FREQUENCY:** 1–100Hz.

**TEMPERATURE COEFFICIENT[2], ±(% of reading + % of range)/°C, Outside $T_{CAL}$ ±5°C:** 1 + 0.03.

**AC VOLTAGE UNCERTAINTY =** ± [ (% of reading) × (measured value) + (% of range) × (range used) ] / 100.

**SETTLING CHARACTERISTICS:** <5s to 0.1% of final value.

**ACV NOTES:**

1. Specifications apply for a sinewave input, crest factor = 1.4, AC+DC coupling, 1PLC, digital filter off. Accuracy specification applies for 90 days, 1 year or 2 years, $T_{CAL}$ ±5°C for 5% to 100% of range. Low frequency rms only, AC+DC coupling. All ACV measurements are made with a preamp gain of 1000 and the fast filter.

## ACV FREQUENCY

**FREQUENCY RANGE:** 1Hz–1kHz.

**PERIOD RANGE:** 1ms–1s.

**DEFAULT RESOLUTION:** 5 digits.

**MINIMUM SIGNAL LEVEL:** 400μV peak.

**ACCURACY ±(% of reading):** 2%.

## 4-WIRE OHMS (with 2001 or 2002)

| RANGE | FULL SCALE | 7½ DIGIT RESOLUTION | DEFAULT RESOLUTION | NOMINAL CURRENT SOURCE[1] | OPEN CIRCUIT VOLTAGE | MAXIMUM LEAD RESISTANCE[2] | MAXIMUM OFFSET COMPENSATION | MAX DUT POWER DISSIPATION |
|---|---|---|---|---|---|---|---|---|
| 2mΩ | ± 2.1000000 | 100pΩ | 1nΩ | 9.2 mA | 5 V | 1.7 Ω | ± 20 μV | 170 nW |
| 20mΩ | ± 21.000000 | 1nΩ | 10nΩ | 9.2 mA | 5 V | 1.7 Ω | ± 200 μV | 1.7 μW |
| 200mΩ | ± 210.00000 | 10nΩ | 100nΩ | 0.98 mA | 5 V | 1.7 Ω | ± 200 μV | 190 nW |
| 2 Ω | ± 2.1000000 | 100 nΩ | 1μΩ | 0.98 mA | 5 V | 1.7 Ω | ± 2 mV | 1.9 μW |
| 20 Ω | ± 21.000000 | 1μΩ | 10μΩ | 89 μA | 5 V | 1.7 Ω | ± 2 mV | 160 nW |
| 200 Ω | ± 210.00000 | 10μΩ | 100μΩ | 7 μA | 5 V | 1.7 Ω | ± 2 mV | 10 nW |

| RANGE | ACCURACY[3,4,5] ±(ppm of reading + ppm of range) 24 Hours[6] | 90 Days[7] | 1 Year[7] | 2 Years[7] | TEMPERATURE COEFFICIENT ±(ppm of reading + ppm of range)/°C Outside $T_{CAL}$ ±5°C |
|---|---|---|---|---|---|
| 2mΩ | 350 + 100 | 550 + 100 | 560 + 100 | 570 + 100 | 50 + 3 |
| 20mΩ | 250 + 30 | 350 + 30 | 360 + 30 | 370 + 30 | 50 + 3 |
| 200mΩ | 250 + 30 | 350 + 30 | 360 + 30 | 370 + 30 | 50 + 3 |
| 2 Ω | 250 + 10 | 350 + 10 | 360 + 10 | 370 + 10 | 50 + 3 |
| 20 Ω | 250 + 10 | 350 + 10 | 360 + 10 | 370 + 10 | 50 + 3 |
| 200 Ω | 270 + 10 | 350 + 10 | 360 + 10 | 370 + 10 | 60 + 3 |

**RESISTANCE VOLTAGE UNCERTAINTY** = ± [ (ppm of reading) × (measured value) + (ppm of range) × (range used) ] / 1,000,000.

**% ACCURACY** = (ppm accuracy) / 10,000.

**1PPM OF RANGE** = 2 counts at 6½ digits.

**OHMS NOTES:**

1. Current source nominal ±9%. Calibrated value available as a multiple display.
2. Maximum offset compensation plus source current × measured resistance must be less than source current × resistance range selected.
3. When properly zeroed (using zero adjustment initially then REL according to procedure in Instruction Manual) every 20 minutes or whenever the ambient temperature changes by more than 1°C.
4. Ohms specifications are derived from the 1801 DCV specifications and the Model 2001 ohms specifications. Specifications are guaranteed by verifying the 2001 ohms function and the 1801 DCV function separately.
5. Offset compensation on, SLOW filter, 10-reading digital filter, High accuracy mode, Auto zero on.
6. For $T_{CAL}$ ±1°C, following 15-minute preamp warmup. $T_{CAL}$ is ambient temperature at calibration which is 23°C from factory.
7. For $T_{CAL}$ ±5°C, following 15-minute preamp warmup. Specifications include factory traceability to US NIST.

## SETTLING CHARACTERISTICS

| FILTER | 10% to 90% Rise Time Nominal, ±20% SLOW | MEDIUM | FAST | Offset Compensated Ohms Settling Time to Rated Accuracy SLOW | MEDIUM | FAST |
|---|---|---|---|---|---|---|
| 2 mΩ Range | 1 s | 100 ms | 2 ms | 5 s | 1.5 s | 200 ms |
| 20mΩ–200Ω Range | 100 ms | 10 ms | 500 μs | 800 ms | 150 ms | 130 ms |

**OFFSET COMPENSATION:** Internal delay set for settling to rated accuracy.

**OHMS VOLTAGE DROP MEASUREMENT:** Available as a multiple display.