# DATA SHEET

**DS-11049**

# Digital Multimeter Module-16 [DMM-16]

- **Differential Voltage Measurements**
  - **Common mode rejection > 106dB**
  - **Low thermal emf relays**
  - **Nine ranges: 250mV to 100V**
  - **Resolution: ±7.8125µV on 250mV range**
- **Floating Current Measurements**
  - **Feedback ammeter**
  - **Stable with bipolar transistors**
  - **Eight ranges: 100nA to 1A**
  - **Resolution: 3.125pA on 100nA range**
- **High Input Impedance**
- **True 16-Bit A/D Conversion in <40µsec**
- **Protection to ±600V**

## Precise and Stable

Voltage is measured using a differential input stage with each input terminal having an effective input resistance of 100GΩ. Current burden is virtually zero. Bias current into either input is typically <±20pA.

Current is measured using an active metering technique, sometimes called a feedback ammeter, providing virtually zero voltage burden while measuring currents up to ±200mA. This means that the DMM-16 can be assumed to be an ideal zero ohm and zero volt short on all ranges until current limiting occurs. Used in conjunction with current sources, currents to ±500mA can be measured. The feedback ammeter block diagram is shown in Figure 1.

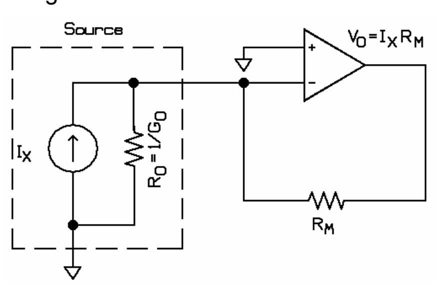


*Figure 1 - Feedback Ammeter with Non-Ideal Source*

**Specifications**

| Mode | Range | Source Error | | Resolution |
|---|---|---|---|---|
| | | Offset | % of Value | |
| Voltage | 250mV | 250µV (50µV) | 0.05 | 7.8125µV |
| | 500mV | 250µV (50µV) | 0.03 | 15.625µV |
| | 1V | 300µV (75µV) | 0.02 | 31.25µV |
| | 2.5V | 500µV (100µV) | 0.01 | 78.125µV |
| | 5V | 1mV (200µV) | | 156.25µV |
| | 10V | 2mV (400µV) | | 312.5µV |
| | 25V | 5mV (1mV) | | 781.25µV |
| | 50V | 10mV (2mV) | | 1.5625mV |
| | 100V | 20mV (4mV) | | 3.125mV |
| Current | 100nA | 100pA | 0.04 | 3.125pA |
| | 1µA | 300pA | 0.02 | 31.25pA |
| | 10µA | 2nA | | 312.5pA |
| | 100µA | 20nA | | 3.125nA |
| | 1mA | 200nA | | 31.25nA |
| | 10mA | 2µA | | 312.5nA |
| | 100mA | 20µA | 0.04 | 3.125µA |
| | 1A | 200µA | 0.05 | 31.25µA |

**Comments:**

1) Range offset errors shown in parentheses () apply for an eight-hour period after auto zero and for changes <±1C°. Otherwise, offsets apply for <±5C° and <90 days after calibration.
2) Gain factor (% of value) errors apply after running SelfCal with an ideal (<±10ppm uncertainty) transfer DMM. Actual performance is calculated using http://www.reedholmsystems.com/SuppNote/SN-115.pdf.
3) Maximum output current on 1A range is ±350mA. On other ranges, the maximum is 125% of range.
4) Settling time to 0.01%:
   - 4.0ms, 100nA Range
   - 2.3ms, 1µA Range
   - 1.7ms, 10µA-1A Ranges
   - 1.6ms, 250mV-100V Ranges
5) CMRR Voltage:
   - 5µV/V (106dB)
6) CMRR Current:
   - 1 ppm of range per volt, 10µA -1A
   - 2 ppm of range per volt, 1µA
   - 6 ppm of range per volt, 100nA
7) Accuracy of the lowest three current ranges is determined with digital averaging approximating line cycle integration.
8) Accuracy of current measured on a given range is proportional to range and a percentage of current being measured. For example, measuring 50µA on the 100µA range would have uncertainty of:
   - 50µA ± (20nA + 0.02% of 50µA) = 50µA ± 30nA
9) When measuring currents from sources with non-zero output conductance, the following is added to the error specifications:
   - ±(830 ppm of value +151µA)/mho

The digital averaging feature of the instrumentation drivers provides repeatable sensitivities of ±4µV and ±2pA. However, over long periods of time, shot noise produces larger variations. Current mode sensitivity is useful for occasional picoampere measurements, but the picoammeter matrix module should be used if currents below 500pA are measured routinely.

## Accurate Floating Measurements

The DMM-16 provides truly differential measurements because both inputs operate linearly over the full ±100V span. Because the common mode rejection ratio (CMRR) is 106dB in voltage mode, small differences between two voltages near 100V are measured with <500μV uncertainty. Differences between lower voltages are proportionally smaller. Thus, diode-matching measurements would have <5μV uncertainty. Similarly, because CMRR is so high, current measurements made at high voltages have little additional uncertainty. For example, the CMRR induced error from a 100V bias is <1nA when measuring 10μA.

## Minimum Effects from Thermal EMF's

The DMM-16 is connected to other instrumentation by reed relays, which exhibit low resistance, low leakage currents, and ±600V isolation from other instrumentation. Unfortunately, reed relays generate small thermally induced voltages. Joining two metals creates a thermocouple, which produces an electromotive force (emf) if the junction is heated or cooled. Reed relays have at least two types of metals, so several thermocouples can be present in a single relay package.

Heat from relay drive coils plus other heat generators result in reed relay thermal emf's. In addition to minimizing relay self-heating, DMM components are placed to neutralize the impact of other heat sources on reed relays handling low-level voltages. Also, relays with guaranteed low thermal performance are used to keep thermal emf's <10μV.

## Full 16-Bit Quality

The monolithic, 16-bit sampling A/D converter is based on a successive-approximation algorithm, but instead of relying on film resistors, which limit linearity, the converter uses inherently stable silicon dioxide capacitors. A self-linearizing calibration routine automatically executes during system initialization producing full 16-bit linearity. In comparison, resistor based 16-bit converters are often limited to 14-bit linearity.

## High Throughput

In addition to being extremely linear, the DMM-16 is fast. A sampling aperture time of 30ns allows rapidly changing inputs to be sampled accurately. Bandwidth of the DMM-16 provides rapid settling to within 0.01% of a change in current or voltage. A/D conversion and bus communication speeds are also fast.

- A/D conversions take <40μsec.
- Digital register transfers to set range/mode or retrieve measurement results take <10μsec.

## Preventing Bipolar Device Oscillation

When measuring emitter current, the device under test (DUT) becomes part of the feedback ammeter because the base capacitance is multiplied by current gain. If current gain is high enough, the combination will oscillate. The DMM-16 was designed to be stable with current gains up to a superbeta $H_{FE}$ = 1000.

## Speed with Real World Devices

Ideally, currents from semiconductor devices behave like ideal current sources. When they do not, measurement speeds are affected. As illustration, output resistance $R_O$ shown in Figure 1 reduces the ammeter loop gain by the ratio $R_O/R_M$ where $R_M$ is the metering resistor. Step response times are dependent on $R_O$ as shown in Figures 2 through 4.

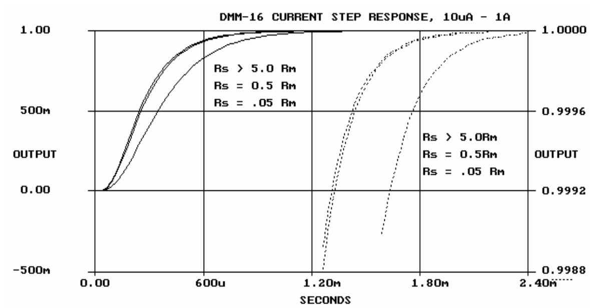


*Figure 2 - Current Step Response, 10μA - 1A Ranges*

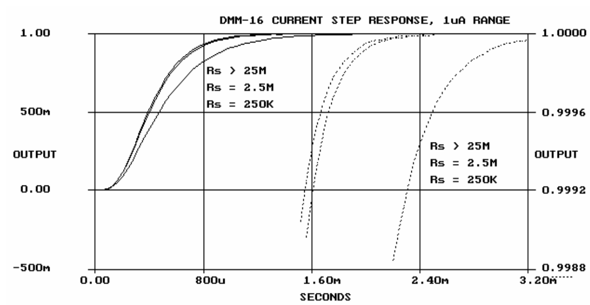


*Figure 3 - Current Step Response, 1μA Range*

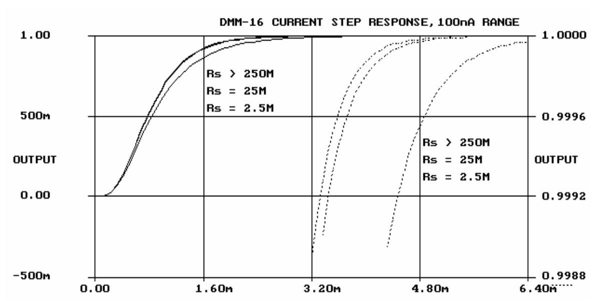


*Figure 4 - Current Step Response, 100nA Range*