

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.

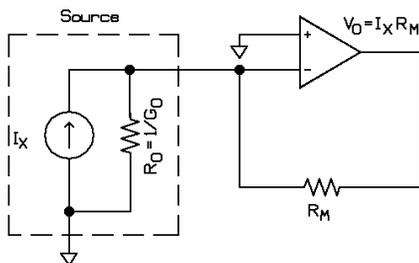


Figure 1 - Feedback Ammeter with Non-Ideal Source

		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.reedholm.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 $\pm 100V$ span. Because the common mode rejection ratio (CMRR) is 106dB in voltage mode, small differences between two voltages near 100V are measured with $<500\mu V$ uncertainty. Differences between lower voltages are proportionally smaller. Thus, diode-matching measurements would have $<5\mu V$ 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 $10\mu A$.

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 $\pm 600V$ 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 $<10\mu V$.

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 $<40\mu sec$.
- Digital register transfers to set range/mode or retrieve measurement results take $<10\mu sec$.

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.

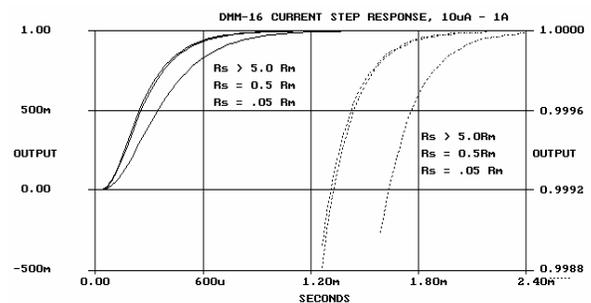


Figure 2 - Current Step Response, $10\mu A - 1A$ Ranges

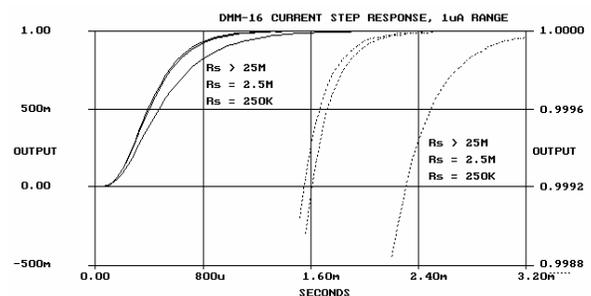


Figure 3 - Current Step Response, $1\mu A$ Range

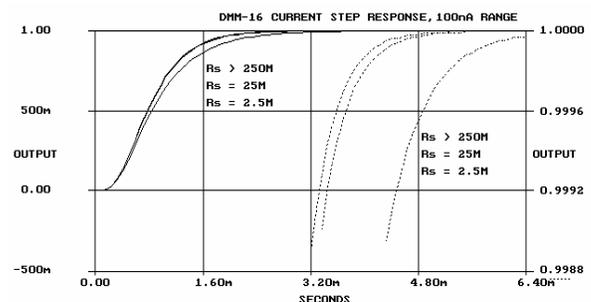


Figure 4 - Current Step Response, $100nA$ Range