

DMM Voltage Zeroes and SelfCal Offsets

Introduction

Voltage offsets of the DMM-12 and DMM-16 are measured and stored for use with applications code. They tend to change with time and temperature, so it is important to measure them periodically as well as after changes in the operating temperature of the DMM. Offsets are measured and stored for subtraction from subsequent measurements to enhance accuracy at low voltages. DMM voltage offsets are measured during execution of the SelfCal.exe utility program, but are stored separately from those updated more often. For convenience, DMM voltage offsets that are updated independent of SelfCal are called DMM zeroes.

Stored DMM offsets won't be correct if they are measured before sufficient system or module warm-up had occurred. Nor will they be correct if the facility temperature changes dramatically since the last set of offsets were stored. Because true offsets cannot be determined quickly, they are only measured when necessary for optimum system performance:

- During initialization, which occurs automatically when starting the Reedholm shell.
- In certain calibration routines.
- As part of error recovery.

DMM zeroes are not always used. Certain maintenance and calibration routines disable automatic offset correction entirely. For example, SelfCal offsets are not measured with DMM zeroes applied since SelfCal offsets are subtracted before DMM zeroes are.

Current offsets for DMM's are measured during SelfCal, but there is no separate tracking of them. That is because DC offset current is not as well behaved as voltage offset and because what is often termed offset current is actually a point in a long dielectric absorption decay function caused by previous test conditions. Applying current offset correction usually reduces system accuracy instead of improving it.

This document describes measuring and applying DMM zeroes and the relationship between SelfCal DMM voltage offsets and DMM zeroes.

Connection Topology for Offsets

As of July 2005, the same low-level code is used to connect the DMM for offset measurements, regardless of the application or system type. Figure 1 is a simplified schematic showing the node 1 high and low relays shorting the DMM signal inputs and the node 0 low relay connecting the inputs to node 0.

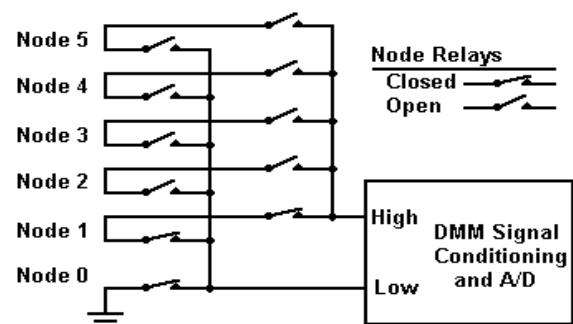


Figure 1 - DMM Connections for Offset Measurement

Offsets are measured in this configuration for each voltage range on each DMM.

Settling Time Considerations

When connected as shown above, the voltage going into the A/D, after being conditioned, will move toward zero volts at maximum speed. If only bandwidth factors were involved, the DMM would respond to the zero connection and settle to within a fraction of an LSB in <1msec regardless of prior test conditions. Thus, even if the DMM input had been at 100V prior to a zero command, it would be possible to make a measurement, and trust the 7.8µV resolution on the 250mV range, in <1msec. However, limitations unrelated to bandwidth of the DMM amplifiers and passive components govern response time when settling times involve very large dynamic ranges. That is, dielectric properties of pcb's, relays, and capacitors ultimately determine how long a wait time is required to obtain accurate offset measurements.

Experimentation to Determine Wait Times

To simulate a worst-case scenario, the DMM input was connected to 100V for 20 seconds followed by a recovery period during which the DMM is connected to 0V before making the offset measurement shown in figure 1. Various recovery periods were used as shown in table 1.

To eliminate systemic effects not related to voltage, data was taken using 0V for pre-conditioning, and that day was subtracted from that taken with 100V pre-conditioning. Each pass was repeated three times for the five delays shown in table 1, and a fourth pass was taken with a delay of 1110 msec.

Delay (ms)	Offset After 100V Presoak (DMM-16 lsb's)			
	Test 1	Test 2	Test 3	Test 4
300	0.92	4.32	3.32	-
1110	0.60	0.97	2.46	2.42
2000	0.40	3.30	-0.49	-
3000	-0.17	0.14	-0.41	-
20000	-1.67	-0.43	-0.16	-

Table 1 - Change in 250mV Range Offset

Table 1 data is not definitive due to its variability, but suggests that a recovery time >2 seconds is required to reasonably expect accurate offset measurements on the order of a few lsb's. The following data was obtained for a fixed recovery time of 3 seconds.

Offset After 100V (DMM-16 lsb's)	
Test 1	-3.08
Test 2	0.78
Test 3	1.47
Test 4	-1.09
Test 5	-0.42
Test 6	-0.18
Test 7	-1.60
Test 8	-1.39
Average	-0.68

Table 2 - Change in Offset after 3 Seconds

The rattle apparent in the foregoing data is due to shot noise in the DMM front-end amplifiers. Shot noise is known to be ~30µV, or 3.8 lsb's peak-to-peak, on the 250mV range. It represents the limiting factor in how effective offset corrections can be made.

Wait Times with DMM-12

Surprisingly, the DMM-12 did not seem to be as sensitive to 100V pre-conditioning as the DMM-16. That apparent difference is due the DMM-12 having one-sixteenth of the DMM-16 sensitivity. In table 3, the peak-to-peak shot noise is too small to cause measurements to change by ≥0.5lsb peak-to-peak, so digital averaging did not respond to the noise. On the other hand, a slightly different offset on the 5V range shown in table 4 allowed the peak-to-peak noise to register during averaging.

Delay (ms)	Offset After 100V Presoak (DMM-12 lsb's)			
	Test 1	Test 2	Test 3	Test 4
10	0	0	-	-
100	-0.003	0	-0.006	-
300	0.017	0.006	0	0
1000	0	-	-	-
3000	0	-	-	-

Table 3 - Change in 250mV Range Offset

Delay (ms)	Offset After 100V Presoak (DMM-12 lsb's)			
	Test 1	Test 2	Test 3	Test 4
10	-0.096	-0.116	-	-
100	-0.117	-0.137	-0.152	-0.102
300	0.076	-0.070	-0.099	-
1000	-0.081	-	-	-
3000	0.026	-	-	-

Table 4 - Change in 500mV Range Offset

Control Over Offset Measurements

Because long periods might elapse between user invoked offset measurements, several calls to FindDMMzeroes are made automatically:

- Whenever >15 minutes has elapsed since the previous update.
- Start of the DMM NODE RELAY CONNECT – DISCONNECT TEST. This is the only DIAG test that uses offset correction, so that is the only FindDMMzeroes call in DIAG.
- Procedure TestVoltage within VF_CAL. This is the only calibration procedure that uses the DMM without invoking FindDMMzeroes.
- Start of an EMPAC/EMAGE test unless called from ACQUIRE or EMREL.
- Start of each new wafer in ACQUIRE.
- Start of each scan after infant scans in EMREL.

User Invoked Offset Measurements

Automatic updating of the DMM assures quality of low voltage measurements. However, there are ways for the user to generate a new set of offsets whenever desired by forcing instrument initialization.

Stored values for DMM offsets are updated when the driver procedure, FindDMMzeroes, is invoked. The system initialization procedure, RIinit, includes a call to FindDMMzeroes, so the user can invoke offset measurements by invoking RIinit these ways:

- By starting the Reedholm shell.
- Pressing <F4> in the Maintenance application before selecting the test.
- Pressing <F4> in the Calibration application before selecting the test.
- Pressing <Alt><F4> at an EMAGE test screen.
- Pressing <Alt><F4> at an EMPAC test screen.
- By entering the command string, "RIinit", as a HOOKUP command string.
- By selecting the system command, "RIinit", in the HOOKUP dialog box.

Limits of DMM Zero Adjustment

DMM zero correction is limited to $\pm 0.35\%$ of range. Measured values that exceed this indicate that the module likely is defective.

- In such cases, offset correction is set to zero rather than preventing operation of the system through an abort or user message.
- When SelfCal is run, excessive offsets are flagged in the report.

Applying DMM Zeroes

DMM zeroes are subtracted when the Boolean, DMMzeroOn is set TRUE. Thus, turning the Boolean on and off in Hookup while making measurements with the DMM inputs shorted is a way of manually determining if the zeroes are working as expected.

SelfCal Offset Measurements & Use

When SelfCal software is run, offset and scaling correction factors are stored in SELFCAL.INI.

If the SelfCalOn Boolean is TRUE, the voltage and current values are operated on by the SelfCal correction constants (Scaling and Offset) as follows:

- For all SelfCal instruments except the DMM:
Corrected Value = [Value-Offset]*Scaling
- For the DMM only:
Corrected Value = Value*Scaling

SelfCal Scaling Corrections

Except for the DMM, SELCAL.INI values are used to correct for both offset and scaling errors. For the DMM, only Scaling errors need to be corrected because the DMM offsets are under control of the DMMzeroOn Boolean.

The allowed scaling error tolerance is $\pm 2\%$ of range for all modules. If the error is larger, the range is flagged in the report and scaling factor is set to 1.0.

SelfCal Offset Corrections

Except for the DMM, which has error tolerance of $\pm 0.35\%$ of range, SelfCal Offset error tolerance is $\pm 0.8\%$ of range. Excessive offsets are flagged in the report and set to 0.

Summary

The DMMzero_Table is used to correct DMM measured values for voltage offset only when the Boolean variable, DMMzeroOn, is set TRUE. The maximum limit of offset correction is $\pm 0.35\%$ of range.

Most measured and sourced values are corrected by information from SelfCal.ini when the Boolean variable, SelfCalOn, is set TRUE.

- To prevent conflict with DMM zeroes that might have been taken subsequent to SelfCal.ini being populated, only scaling factors are used to adjust DMM measurements.
- DMM offsets are under control of the Boolean, DMMzeroOn.