

**Optimizing System Throughput with the
NI PXI-4070 6 ½-Digit FlexDMM™**

Introduction

“How do I maximize my system throughput?” is a common question posed by many engineers and scientists. For years, engineers and scientists have employed numerous strategies to extract more speed from DMM-based systems in both R&D laboratories and on the manufacturing floor. These optimization techniques have often included brute force procedures, such as cutting down the number of tests, purchasing several DMMs, or purchasing very accurate DMMs and running them at much lower resolution. This paper describes how to achieve superior throughput with the National Instruments PXI-4070 6 ½ -digit FlexDMM, NI switch modules, and NI LabVIEW software, without having to make such sacrifices.

DMM Optimization

Optimizing both measurement and system speed is the easiest way to improve a DMM-based system throughput. Measurement speed is how fast a DMM can take a measurement. System speed includes how fast a DMM can scan with an external switch, and change ranges (1 V to 10 V) and functions (VDC to VAC), in addition to taking measurements. Addressing both of these speeds can dramatically increase automated test system throughput.

Measurement Speed

Every application has different requirements. For example, some may require the highest level of accuracy, while others require you to maximize throughput. Consequently, DMMs have selectable features or parameters so you can tweak the DMM to your specific requirements. But before you can make the appropriate tradeoffs, you must first understand how these features and parameters affect measurement speed and accuracy.

Resolution

The highest resolution of a DMM (i. e. 6 ½-digits) will always correspond to its slowest measurement rate. As you reduce the resolution of your DMM, you achieve faster and faster measurement rates. A very common scenario is for a DMM user to purchase a 6 ½ digit DMM, but primarily use it at 5 ½ digits to achieve higher measurement speeds with respectable accuracy.

The unique architecture of the NI FlexDMM delivers superior measurement performance by taking full advantage of both LabVIEW and the high-speed PXI bus. The FlexDMM offers a continuously variable DC reading rate from 5 S/s at 7 digits to 5 kS/s at 4 ½-digits, as shown in Figure 1. With the NI-DMM driver software, you can fine-tune the FlexDMM to meet your exact requirements.

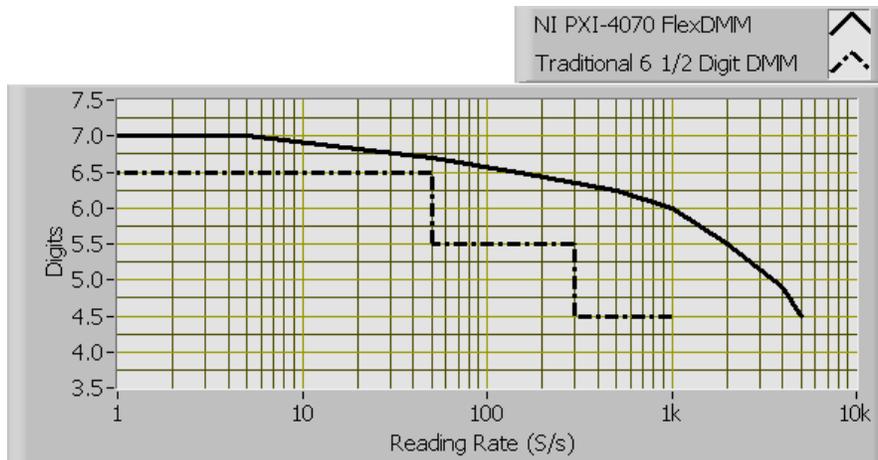


Figure 1. FlexDMM DC Measurement Speed

Autoranging

Autoranging is used for measuring a signal when you do not know which range to select. The DMM takes a series of measurements and adjusts the range until the measurement falls within the smallest range appropriate for that measurement. If you know the approximate value of the input signal, it is advantageous to use a fixed range because the FlexDMM will only take one measurement.

With the FlexDMM, you can also select Autorange Once. Autorange Once performs an autorange and stores the range value for use in all subsequent measurements, as long as Autorange Once remains selected.

Autozero

Autozero is a technique that removes the effect of several kinds of drift, such as temperature-related drift, long-term drift, and low-frequency drift. The process of autozeroing involves disconnecting the external signal from the input of the DMM, internally connecting zero volts to the DMM instead, and taking a measurement. Ideally, this internal value should be zero volts, but real components can create an offset. While measuring this offset value, autozeroing automatically reduces this error. Autozero requires the FlexDMM to take additional measurements, reducing system speed.

Similar to autoranging, you can enable Autozero Once. Autozero Once performs an autozero and stores the value for use in all subsequent measurements, as long as Autozero Once remains selected.

Offset-Compensated Ohms

Offset-Compensated Ohms (OCO) is a technique that eliminates the thermal offsets in low-level resistance measurements. OCO requires the DMM to take two resistance measurements. The first measurement includes the voltage drop across the resistor created by the current source and any thermal EMFs that may be present caused by dissimilar metal connections in the measurement path.

During the second measurement, the current source is turned off so the voltage drop across the resistor becomes zero volts. The DMM subtracts the second measurement from the first, giving you the correct resistance value. Similar to Autozero, this feature requires the DMM to take additional measurements.

ADC Calibration

ADC Calibration is a feature exclusive to the FlexDMM, with which you can appropriately trade off measurement speed for long-term accuracy. The NI PXI-4070 ADC is designed for precision, linearity, and stability. By doing routine calibration of the ADC back to a single well-controlled component, you can ensure absolute accuracy of the conversion.

With ADC Calibration disabled, the measurement speed increases by a factor of up to two, but you need to add a temperature coefficient error of 3 ppm/°C to the appropriate range specification. Although this error is small, you should still consider the effects. If you need to turn off ADC Calibration, as you might when you want optimum speed in 6½ digit resolution, you can recover the specified accuracy by running self-calibration periodically.

DC Noise Rejection

DC Noise Rejection (DCNR) is another feature exclusive to the FlexDMM that suppresses the noise coupled onto a DC measurement. There are three types of noise rejection – normal, second-order, and high-order. Normal emulates the behavior of most traditional DMMs. Second-order provides improved protection against high-frequency interference. High-order enables unprecedented immunity from interfering signal, >46 Hz.

How DCNR affects your measurement speed depends on the level of noise you have on your measurement. For example, if you have a very noisy power line frequency, you can run faster using the High-Order DCNR because it only requires you to take a single measurement due to the high level of noise rejection. In Normal DCNR, you would have to average several points to get the same level of noise rejection, thus reducing your overall throughput.

With LabVIEW, you can quickly adjust each parameter by simply adding a subVI or a property node, as shown in Figure 2.

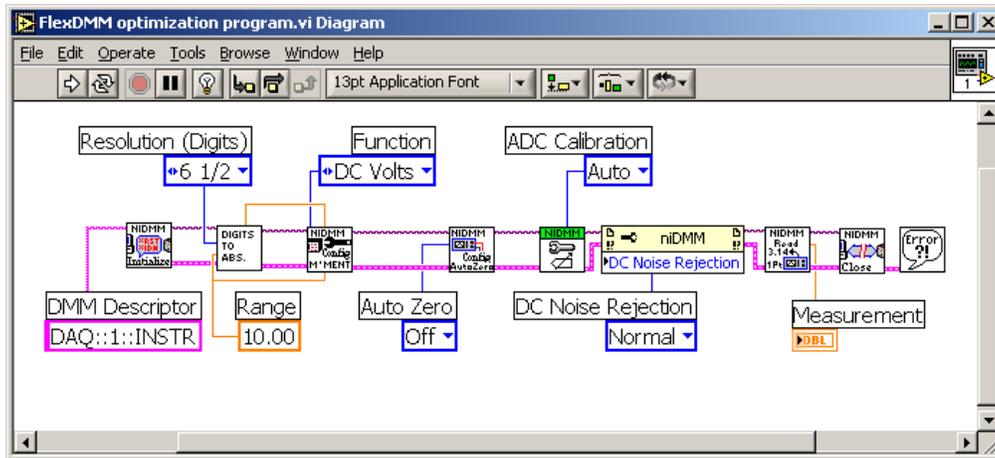


Figure 2. FlexDMM Optimization Program

To simplify the optimization process, the NI-DMM driver software provides an auto mode, which implements features only when appropriate, as shown in Table 2.

Function	Aperture	Autozero	ADC Calibration	DC Noise Rejection
DC				
6 1/2 digits	100 ms	ON	ON	High-Order
5 1/2 digits	500 μ s	ONCE	OFF	Second-Order
4 1/2 digits	20 μ s	ONCE	OFF	Second-Order
Autorange	500 μ s	OFF	OFF	Second-Order
AC				
6 1/2 digits	Max (100 ms or 4/minFreq)	OFF	OFF	N/A
Autorange	Max (500 μ s or 4/minFreq)	OFF	OFF	N/A

Table 1. Auto Mode Setting

System Speed

Optimizing the order of your measurements to minimize the number of reconfigurations is the simplest way to increase system speed because every function change (DCV to 2-wire Ω) or range change within a function (1 V to 10 V) requires a DMM reconfiguration. The reconfiguration time can be on the order of a few milliseconds, which can substantially slow down many automated test applications. The reconfiguration overhead consists of both hardware and software latencies.

Hardware Latencies

The types of relays used in traditional DMMs primarily cause hardware latencies. Each function change and sometimes range change requires switching an

electromechanical relay inside a traditional DMM. Electromechanical relays have switching times of several milliseconds, which can hinder your overall throughput. The FlexDMM reduces this hardware latency by using solid-state relays, which have switching times less than one millisecond. Even the random measurement sequence, shown in Table 2, will execute much faster due the solid-state relays on the FlexDMM.

The recommended method is to take similar measurements contiguously, which limits the number of function and range changes. A well-constructed measurement sequence is depicted in Table 2.

A Random Measurement Sequence:

Switch Channel	Function	Range
1	DC volts	10 V
2	2-wire ohms	1 k Ω
3	DC current	1 A
4	DC volts	300 V
5	AC current	100 mA
6	2-wire ohms	100 k Ω
7	2-wire ohms	1 k Ω
8	DC volts	300 V
9	AC current	100 mA
10	AC current	1 A
11	2-wire ohms	100 k Ω
12	AC current	100 mA

Function changes: 9
 Range changes within a function: 2
 Total DMM reconfigurations: 11

An Optimized Measurement Sequence:

Switch Channel	Function	Range
1	DC volts	10 V
2	DC volts	300 V
3	DC volts	300 V
4	2-wire ohms	1 k Ω
5	2-wire ohms	1 k Ω
6	2-wire ohms	100 k Ω
7	2-wire ohms	100 k Ω
8	DC current	1 A
9	AC current	100 mA
10	AC current	100 mA
11	AC current	100 mA
12	AC current	1 A

Function changes: 3
 Range changes within a function: 3
 Total DMM reconfigurations: 6

Table 2. Correct Sequencing of Measurements

Software Latencies

The reconfiguration cycle requires you to an open a session with the DMM, configure the DMM to the correct state, and close the session with DMM. However, that doesn't mean you have open and close a session with the DMM each time a range or function change is needed. A more efficient approach is to implement all the range and function changes inside a LabVIEW loop structure, as shown in Figure 3. You can make all of your measurements in a loop, and then close the single session after the measurement sequences are complete. This technique will greatly reduce the software latencies.

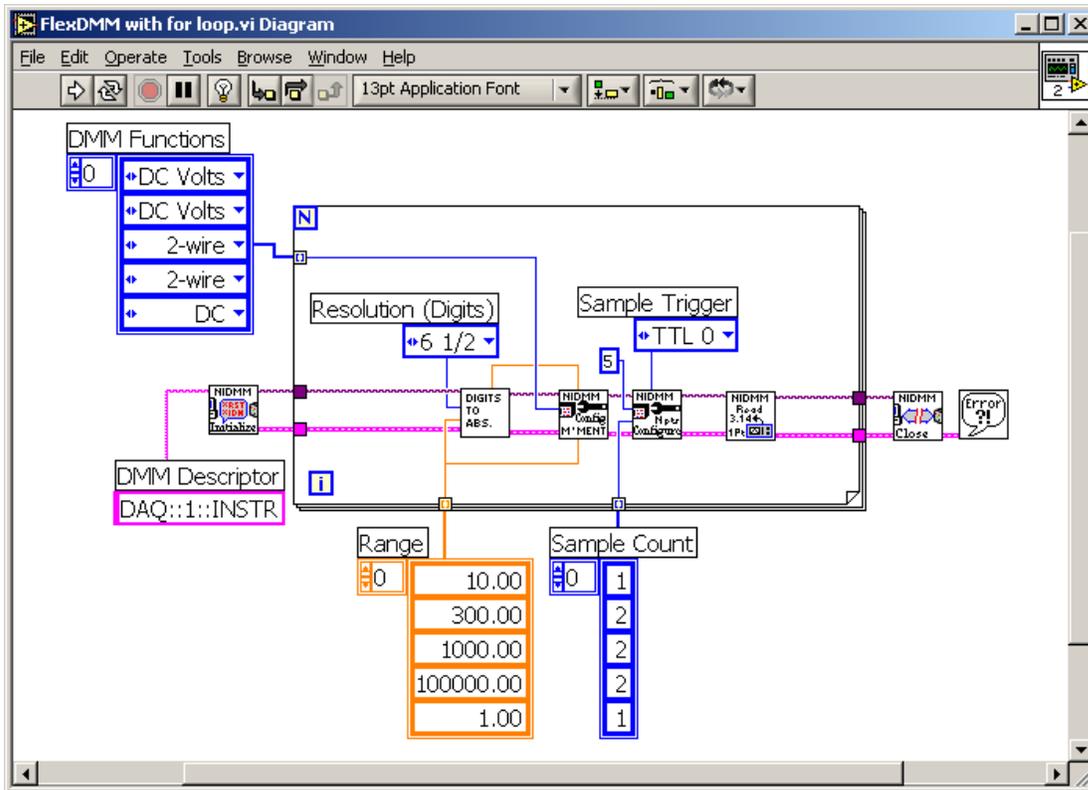


Figure 3. A LabVIEW Optimization Technique

DMM and Switch Scanning

Scanning is the key to maximizing your DMM and switch system throughput. The most efficient scanning method is hardware handshaking. With hardware handshaking, the switch and DMM communicate with each other when the device is ready, which ensures that the switch has settled completely. Note that you may need to add additional trigger delays if your unit under test hasn't completely settled (for reasons such as charging a capacitor). Hardware Handshaking requires both the DMM and switches to have hardware triggers. Table 3 lists the common hardware triggers and their functionality.

DMM Triggers	Function
Input Trigger	The DMM acquires measurement
Measurement Complete	The DMM emits pulse upon completion of measurement
Switch Triggers	
Input Trigger	Switch executes next connections in the scan list
Output Trigger/Scanner Advanced	Switch emits pulse when the connections have settled

Table 3. The Common Triggers Found on DMMs and Switches

To implement handshaking, you should connect the hardware triggers in the following manner:

- Input trigger of the DMM with the output trigger/scanner advanced of the switch.
- Measurement complete of the DMM with the input trigger of the switch

Hardware scanning also requires the switch modules to have a scan list. A scan list is a list of channels supplied to the switch that indicates the order in which channels will be scanned. This scan list is downloaded onto the switch module at run time. With National Instruments switches, you can execute the scan list once or continuously.

In your program, configure both devices and initiate the DMM. The DMM will wait for a trigger before taking first measurement. Then initiate the switch, which cause the switch to connect its first scan list entry and emit an output pulse. At that point, the DMM and switch start the handshaking process, as shown in Figure 4. This scanning method delivers improved system speed because all communication between the DMM and Switch is hardware timed and runs without host PC intervention.

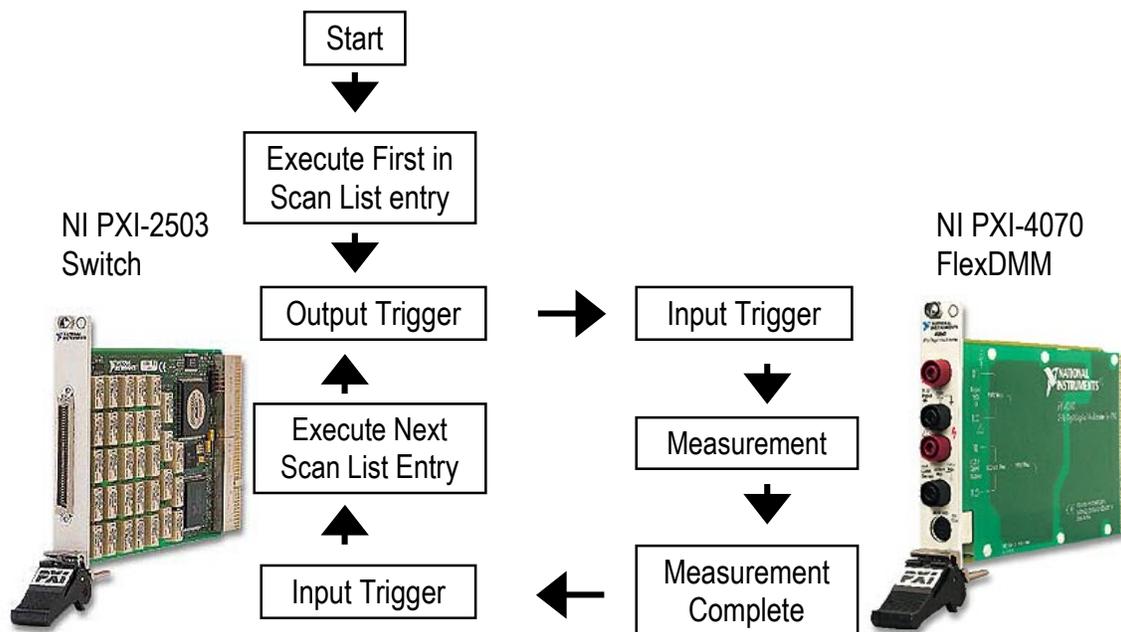


Figure 4. Hardware Handshaking

Conclusion

Understanding these techniques doesn't necessarily mean you need to use them in every application. Oftentimes, the FlexDMM provides higher throughput rates and accuracy, without disabling any functions. The FlexDMM achieves this performance because it's optimized for both measurement speed and system speed.