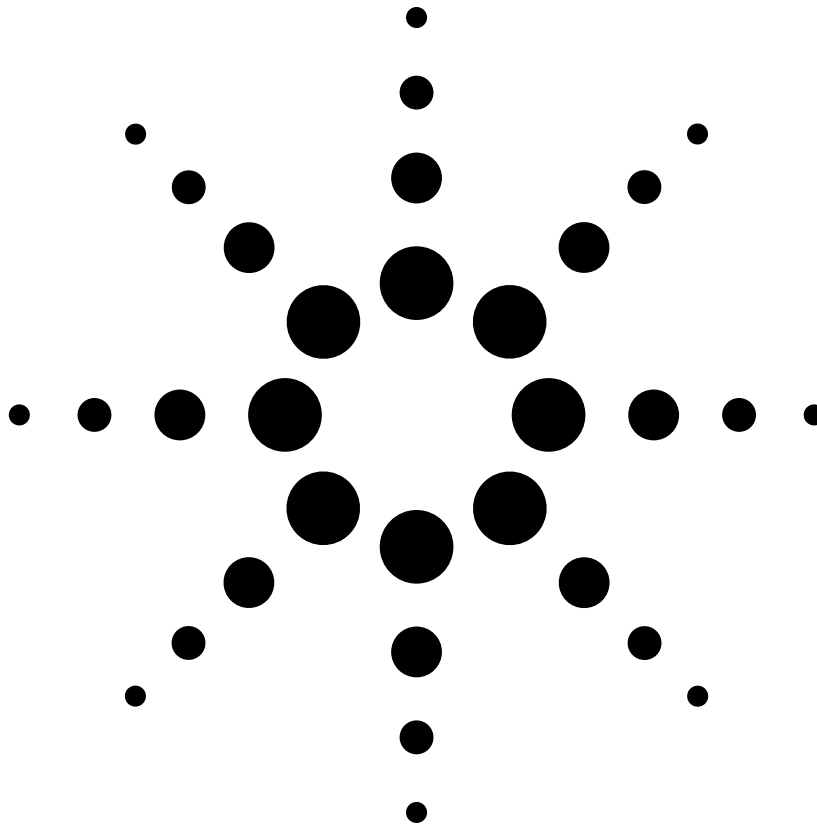


# Techniques to minimize overall test time when using a DMM and switch system

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## Introduction

The expectation of an automated test system is that it takes accurate measurements and collects data from a device under test (DUT). In most cases, automated tests must execute in the shortest time possible, without compromising measurement accuracy to minimize per unit cost and capital investment. This application note discusses techniques to minimize automated test time while maintaining measurement accuracy. One of the most efficient ways to make automated measurements quickly is to use bi-directional instrument triggering since it reduces the number of commands that must be sent to individual instruments. Bi-directional triggering is explained in detail using the 3499A/B/C Switch system and the 34401A DMM as an example. Other ways to reduce test time include using scan lists, and configuring settling time, aperture, auto zero, data transfers and more.

## Bi-directional trigger technique

Relative to the actual measurement, a great deal of test time is spent sending individual commands to different instruments for configuration, measurement initialization, and data reads. To save test time, you can replace a sequence of individual instrument commands with a much smaller set of commands and use bi-directional triggering to make many measurements. This can be achieved by setting two instruments, such as a Switch system and DMM, to trigger each other (bi-directional triggering) as they connect to the DUT and make measurements. The bi-directional trigger process for the 3499A/B/C switch system and 34401A proceeds like this; The switch system closes selected relay(s) then, triggers the DMM to take a reading. The DMM triggers the switch system when the reading is complete. The switch system progresses to the next selection of relay(s) and repeats this process until complete. The bi-directional trigger process enables successive multiple readings with the same DMM function.

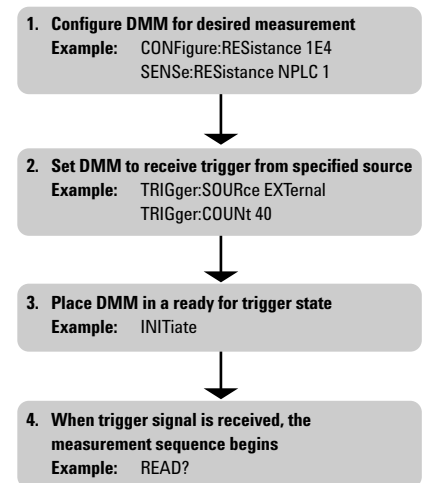
The first step to integrating instruments for bi-directional triggering is to understand the trigger sub-systems of the instruments. The instrument trigger sub-systems will help determine what pre-trigger configuration is required, and how the instruments expect to send and receive triggers.

## DMM trigger system

When you configure a system DMM, like the Agilent 34401A, to respond to an external trigger there are a number of steps that must be taken. The steps include; configuring the DMM for a specified measurement, identifying the trigger source, verifying the DMM is ready to receive a trigger, then, once the DMM receives a trigger signal, begin making measurements. The flow chart in Figure 1 shows the DMM configuration steps including example instrument commands.

Figure 1. DMM trigger configuration

### DMM external trigger steps



### 3499A/B/C switch/control trigger system

The 3499A/B/C trigger system is different from the 34401A DMM, in that it is comprised of three trigger layers, idle, arm, and trigger as seen in the flow chart in Figure 2. The switch system is in the idle state at all times that it is not operating in the arm or trigger state. The trigger process begins when a command (SCAN, GET or \*trg) is sent to the switch system and the instrument proceeds into the arm layer. The

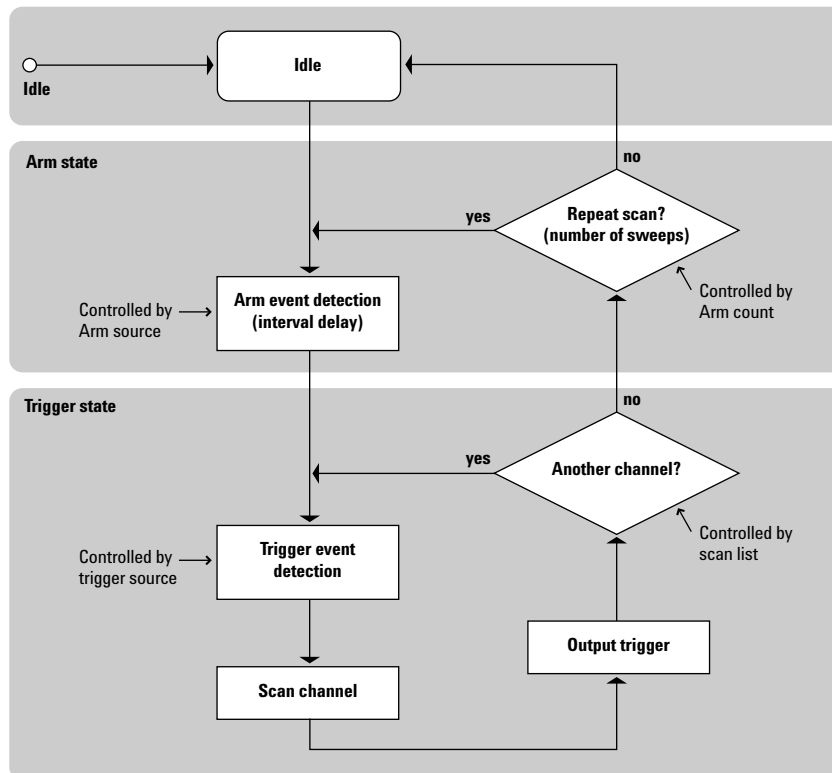
switch's arm subsystem allows an event control, such as a scan or delay, to be added to the trigger process. For example, it allows a scan list to be scanned multiple times with one INITiate command, and/or sets the timer for delay intervals between scan sweeps. When an arm source is detected, the instrument leaves the arm state and proceeds to the trigger state. In trigger state, when a trigger source is detected, it executes the specified switch settings and the instrument returns to the idle state.

### Using scan lists

Scan lists can increase the speed of the test tremendously by eliminating many individual instrument commands sent to the switch system and the DMM and replace them with a few commands that make many measurements. The switch system will scan the specified channels automatically in the same order of the scan list. To configure a scan procedure you start by specifying an arm source, a trigger source, the number of sweeps through the scan list and, if needed, any interval delays between scans. In trigger state, when a trigger signal is detected from the source, the switch system advances one step within the defined scan list. After scanning through all the channels in the scan list and reaching the arm count, the scan is terminated and the instrument returns to the idle state.

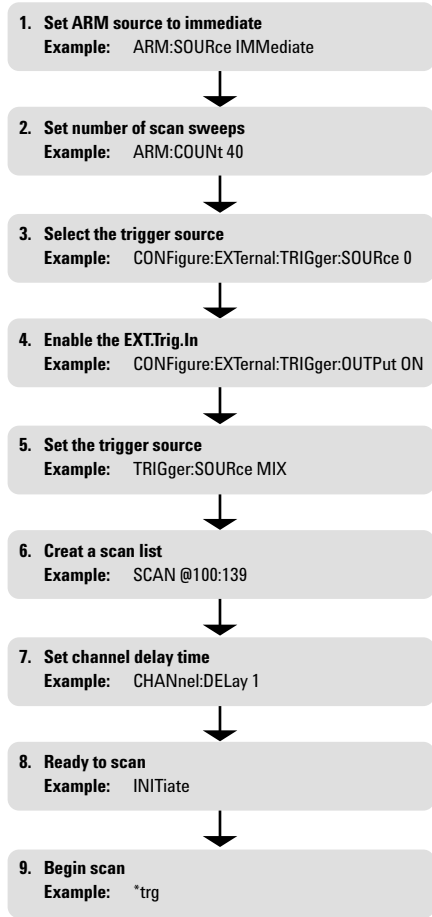
Figure 2. Switch systems' trigger sub system

#### 3499A/B/C trigger operation process



**Figure 3.**  
Switch systems' trigger configuration

**3499A/B/C scan list trigger steps**



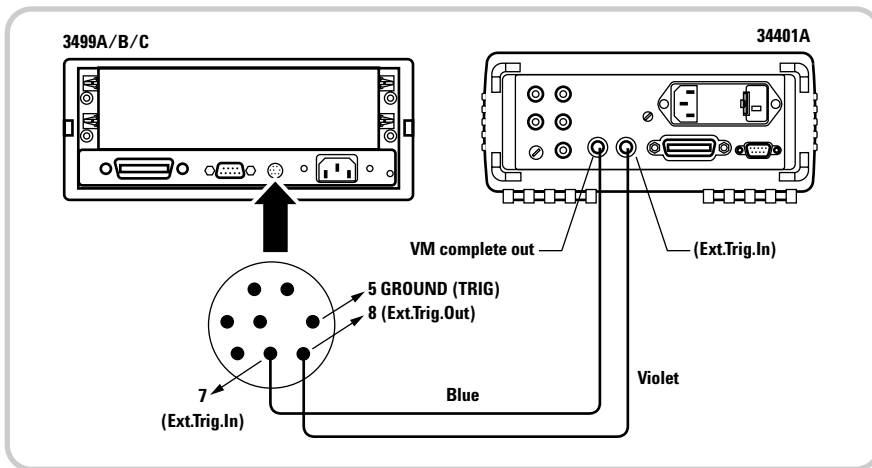
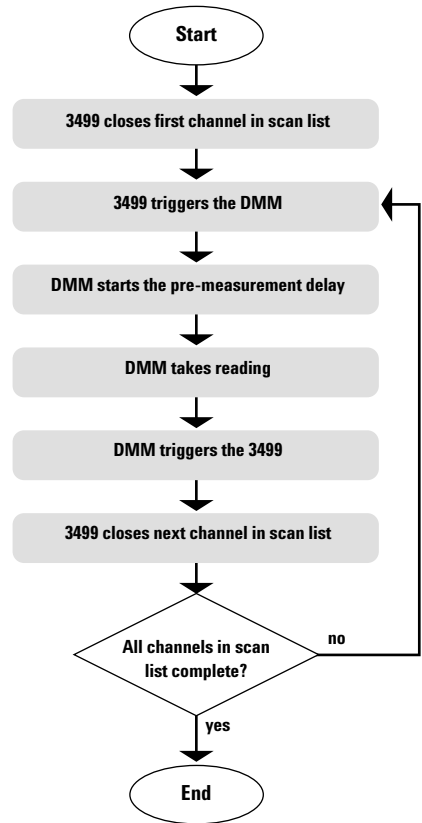
To configure the switch system for bi-directional triggering the external trigger lines, and the trigger out must be enabled (see Figure 3). Also, the arm should be set to IMMEDIATE, and trigger configured for MIX. The flow chart in Figure 3 includes example instrument commands for configuring the 3499A/B/C switch system. You can see the advantage and flexibility of the scan list. Any number of sequential channels can be selected with the option to repeat the scan sequence with an interval delay all within these few configuration commands sent to the switch system.

**Trigger connections between the switch system and DMM**

Now that the individual instruments are set-up we need to interconnect them so they can trigger each other. To control the 3499 Switch System scanning with an external instrument such as the 34401A DMM, external connections from/to the trigger control lines are required as shown in Figure 4. The switch system can be configured to output a trigger pulse to notify the DMM whenever a relay is closed. The switch system's trigger source must be configured as MIX to enable it to receive a bus trigger to

initiate the scan, then receive external trigger signals from the DMM to advance to each channel in the scan list. Now that the setup is entered in your automated program and hardware is connected for both the switch system and DMM, the code is executed and the following sequence takes place (see Figure 5).

**Figure 5.** Bi-directional trigger sequence



**Figure 4.** Trigger connection between DMM and switch system

## Other techniques

Bi-directional triggering for instruments is just one of many techniques to enable a test system to run faster and more efficiently. Now, let's talk about some other beneficial techniques that will help you fine tune your test system throughput.

### Group like measurements

The scan list concept can be used many times within a program for measurements that are the same. Avoiding multiple measurement changes can save test time that would be used for the DMM to change functions. Changing DMM functions requires reconfiguration of the hardware and the retrieval of different calibration constants.

#### RECOMMENDATION

Invest time during test development to organize test programs so that all like measurements are made at the same time to reduce overall test time.

### Measurement settling time

If a measurement is taken too quickly after an initial switch connection or range change, measurement errors may occur. The 34401A DMM is able to dynamically determine the needed delay for specific measurements based on the function, range, integration time, and AC filter. In most cases, the automatic delays are acceptable for the measurements being made.

In limited cases, cable capacitance and other devices create longer than expected settling times due to RC time constant effects. If your measurements require longer settling times, you are able to manually set the measurement trigger delay. However, if the 34401A trigger delay is set to a value other than automatic, the instrument applies the same delay to all functions and ranges.

#### RECOMMENDATION

Determine your measurement settling times and verify that the default measurement settling times of the DMM (or measuring instrument) are optimal for each individual signal of the device under test.

### Setting the measurement range versus auto-range

A DMM that auto-ranges can be helpful when you are unsure of the returned measurement values. The disadvantage of auto-ranging is that the multimeter requires additional time to determine which range to use for each measurement. For an automated test system it is optimal to determine a range that the returned measurements would best be measured in. Turn the instrument's auto-ranging off, and set specific measurement ranges. This saves the multimeter time it needs to determine which range to use for each measurement. When the DMM makes measurements on a fixed range, the results are fast and have predictable measurement times. Also, when more than one range is required for the measurements you will be making, organize the measurements within the same range and execute them together. This reduces the number of times you will need to reconfigure the measurement range of the DMM and save even more test time.

#### RECOMMENDATION

In a measurement test application, use fixed ranges and group similar measurements and measured values together.

## Signal filtering

Some instruments use automatic filters for input signals. These filters require a specific settling time before a measurement is made. The 34401A DMM, for example, uses filters for the AC voltage and AC current measurements. The chart shown in Figure 6 is an example of DMM filters available for different AC input signal frequencies.

**Figure 6.**  
Example filters for AC input signals

AC voltage input	Filter speed	Reading rate
3Hz & 300kHz	Slow filter	7 second/ reading
20Hz to 300kHz	Medium filter (default)	1 second/ reading
200Hz & 300kHz	Fast Filter	0.06 seconds/ reading

If you were measuring a 200Hz to 300kHz signal and were able to change the default filter without affecting the measurement accuracy to the fast filter you could make the measurements 10 times quicker.

### RECOMMENDATION

Know your AC signal inputs and use the faster DMM filters whenever possible.

## Resolution

Resolution is the number of digits an instrument can measure or display. To increase measurement accuracy and improve noise rejection, select the greatest resolution. This configuration is best used in product development and early test. However, to increase measurement speed, select the smallest resolution. It is common to reduce resolution and increase speed for production once the design is stabilized. The 34401A DMM offers a choice of 4, 5, or 6.5 digits for measurement resolution. The resolution can be selected and set for each measurement function. This gives you the flexibility to increase the speed of your automated test by reducing the resolution for the measurements that do not require the most highly accurate measurements and increasing the resolution for the measurements that must be measured very accurately.

### RECOMMENDATION

Use the smallest resolution required to make an accurate measurement. Adding resolution beyond the capability of the DUT will only increase test time.

## Integration time (aperture)

The integration time (aperture) is the amount of time an instrument's analog-to-digital (A/D) converter samples the input signal for a measurement. The integration time (aperture) directly effects measurement resolution and measurement speed. For more resolution, use a longer integration time. For faster measurements, use a shorter integration time. A disadvantage of too short of aperture is that increased noise may be seen in the measured values.

Also, you must be careful to minimize the number of times you change the aperture within a program. Aperture changes take additional time due to the instrument retrieving new calibration constants from memory. The best way to avoid inadvertently changing the aperture times is to directly specify it. This is done using the instrument command CONFigure to specify the aperture directly. Do not use the MEASure command because it does not allow you to configure the aperture. The integration time is specified in number of power line cycles (NPLC). The default integration time for the 34401A DMM is 10 NPLCs. The integration time can be set to as little as 0.02, 0.2, or 1 NPLC for test systems that are not susceptible to AC noise.

### RECOMMENDATION

Set the integration time to a value less than 10 for faster measurements and a value greater than 1 power line cycle to avoid problems with AC noise.

## Summary

### Auto-zero

Auto zero is used to prevent offset voltages present on the multimeter's input circuitry from affecting the measurement accuracy. Offset voltages can occur over lengths of time or if temperature changes are experienced between measurements. When the default auto-zero is enabled, the multimeter internally disconnects the input signal after each measurement and takes a zero reading. The multimeter subtracts the zero reading from the previous reading. If auto-zero is disabled the multimeter takes one zero reading and subtracts it from all the following measurements. The DMM will take a new zero reading each time the function, range, or integration time is changed. Functions such as DC volts, 2-wire resistance, and DC current can double the measurement speed when auto-zero is set to off.

#### RECOMMENDATION

For the same type of measurements made in close time and temperature proximity, increase the measurement speed by setting auto-zero to off.

### Data display

Another technique to reduced overall test time is to decrease the measurement time by limiting or disabling the 34401A front panel display. Updating the 34401A DMM front panel after each measurement can take between tens and hundreds of milliseconds. If a test is running automatically, you most likely will not need to view the measurements and can save time by turning off the front panel display.

#### RECOMMENDATION

Turn the front panel display off for automated tests.

### Data transfer time

Transferring data over a remote interface from a test instrument can cause a delay of approximately 2 milliseconds even when buffering is used. The 34401A DMM supports both RS-232 and GPIB but can also use USB/GPIB and LAN/GPIB converters. To achieve the best data transfer speed it is important to use a communications interface other than RS-232, such as GPIB, USB/GPIB, or LAN/GPIB. The GPIB interface is currently the fastest I/O method for individual measurements. USB and LAN are best used for large file transfers.

#### RECOMMENDATION

For faster data transfer use GPIB, USB/GPIB or LAN/GPIB I/O interfaces.

There are many easy ways to implement techniques to reduce automated test times. The use of bi-directional triggering with instruments similar to the 3499A/B/C Switch system and the 34401A DMM, where you are switching between a measuring instrument(s) and the DUT, can be a great advantage to automating and minimizing measurement test times.

Ensure measurement variables such as resolution, integration time, filtering and settling times are set to the optimal values. This will ensure quick and accurate measurements for your specific application. Use the front panel to display data only when it is necessary. Use a communication interface such as GPIB, USB and LAN that supports fast data transfer. The advantage of these techniques is they can be applied in many similar types of automated test systems.

## Glossary

**ARM state** – An instrument is in an ARM state when it is expecting and waiting for a trigger.

**IDLE state** – An instrument is in an idle state whenever it is not triggering or waiting to be triggered.

**TRIGGER state** – In the trigger state, when a trigger is detected the instrument performs the operation intended.

**Bi-directional trigger** – Bi-directional trigger uses a scan list and synchronizes the scanned channel closures with external measurement devices.

**Scan list** – a list of stored channel setups. When a scan starts, the first channel in a scan list is closed. The channel is then opened and the next channel in the list is closed. This process repeats for all channels in the scan list.

**MIX** – With mix arm source selected for the 3499A/B/C, the instrument will proceed to the trigger layer when a BUS event or EXTERNAL event occurs.

**BUS** – With bus arm source selected for the 3499, the instrument will proceed to the trigger layer when a GET or a \*TRG command is received.

**EXT** – With external (EXT) arm source selected for the 3499, the instrument will proceed to the trigger layer when an external trigger is received from the specified trigger-in line.

## Other Agilent Literature

### Data sheets

3499A/B/C Switch Family  
<http://www.agilent.com/find/3499>

34401A Digital Multimeter  
<http://www.agilent.com/find/34401a>

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