High-Speed Scanning with the Agilent 34980A Multifunction Switch/Measure Mainframe and Modules

Optimizing Your Scanning Speed

Application Note

Introduction

The Agilent 34980A multifunction switch/measure unit provides the core switching functionality, stimulus/measurement capabilities, and performance necessary for low- to medium-density switching/measurement applications from design verification to functional test. You can choose from more than 14 switch modules for the 34980A to get the capabilities you need. The modules offer multiple switch topologies such as multiplexers (MUX), matrices, and general-purpose switches with a built-in 6½ digit digital multimeter (DMM) that can make measurements at up to 3000 readings per second.

Engineers typically use one of three measurement models when they use the 34980A: the transactional model, the scanning model, or the sequencing model. The transactional model uses individual commands orchestrated by the main controller. This model is very dependent on the instrument I/O. For example, you need to send a total of three commands to perform a measurement on a channel:
1. A “close” command to close the relay on the specific channel of the configured DMM.
2. A “measure” command to have the DMM measure the channel.
3. An “open” command to open the channel and stop the measurement.

Notice that this is only one channel measurement and it takes three commands. Imagine the number of commands you would need to measure 100 channels. The scanning model works with the multiplexer modules where the 34980A internal CPU manages the setup and measurements. With the scanning model, the 34980A manages the open/measure/close process with a single command. The sequencing model can work with both the multiplexer and matrix modules where the 34980A internal CPU manages the setup and the commands reside in the 34980A. This model is typically used when users do not want to interact with a computer to control the instrument. In this application note, we will focus on the frequently used scanning model with multiplexer modules.

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For high-speed testing applications, users often ask how to set up the instrument for the fastest scanning speed. Achieving high scanning speeds and the accuracy necessary for your specific application with the 34980A requires an understanding of how the instrument works and which factors affect the speed. This application note explores components that affect the speed in a system. In addition, it gives a breakdown of each component with SCPI language examples of how to set up the instrument for fast measurements that best fit your specific application.

Factors that Affect System Speed

As shown in Figure 1, a typical system consists of input signals from the device under test (DUT) connected to the 34980A for measurements. Readings are transferred through the I/O interface and monitored by a computer. All of these components can affect the system speed.

Most of the time, the computer processing speed is much faster than all of the other components so it is not a major component that will affect system speed. We will not talk about the effect of the computer’s speed in this application note. Also, since the DUT provides the signals to be measured and we cannot change the speed of its behavior, we will not talk about this component’s effect on speed either. The two main components that we will discuss are the 34980A scanning speed and the data transfer rate within the 34980A as well as over the I/O interface.

Different types of switch MUX modules are used in scanning applications for the 34980A. The type of module you choose affects the scanning speed. In the next section, we will look at which switch MUX module to use for your application. You will gain an understanding of how the DMM works and how to set it up for the fastest reading speed during a scan. You will learn how to configure the DMM to fit your application needs, including example code. We will also take a look at additional 34980A mainframe features that can affect scanning speed.

Understanding what these features can do and how they affect speed will help you decide whether or not you should use them.

There are three different paths to store and transfer data after readings are taken. The path to transfer data and the I/O interface (GPIB, LAN, and USB) used, also affect the system speed. In the “Optimizing the Data Transfer Rate” section, we discuss the different paths and which to use for the fastest transfer rate.

Optimizing 34980A Scanning Speed

To create a scan, the 34980A combines a DMM (either internal or external) with multiplexer channels. During a scan, the instrument connects the DMM to the configured multiplexer channels one at a time and makes a measurement on each channel. With the 34980A, you can perform a scan by sending one command. Data acquisition (DAQ) instruments from
other vendors typically require you to use a transactional model to perform scans. Using the scanning model is much faster than using the transactional model because it takes less time to parse and execute the commands.

Figure 2 shows how the components required for a scan are connected together. Scanning speed is affected by:

A. The speed of the switch on the MUX modules
B. The speed of the DMM
C. Additional mainframe considerations (will be discussed in detail later)

A. The speed of switch MUX modules
The 34980A allows you to combine a DMM with multiple switch topologies. The three types of switches used in the 34980A switch modules are armature, reed, and solid state optically isolated FET. Each offers distinct advantages and disadvantages, and each works best for certain applications. In addition to paying attention to switching speed, it is a good idea to investigate the longevity of your switches. For fast scanning applications, you will need to choose a type of switch module that will hold up well in your signal environment and one that can switch fast enough to meet your goals.

Armature switches – Because of their ruggedness and ability to handle higher currents and voltages, armatures are the most commonly used relays. They generally have slower switch times because the mechanical switch is bigger and takes longer to move. Armature switches are somewhat more susceptible to arcing than the other types.

Reed switches – When you need to switch at high speeds, reed relays typically are a good choice. In general, reed relays switch much faster than armature relays, have low contact resistance and offer the added benefit of being hermetically sealed, which minimizes failures due to contamination. They do not have the capacity to carry as high voltages and currents as armature relays.
Solid state optically isolated FET switches – These switches are used for switching lower-power circuits. Solid-state switches have no moving parts and are arc-free. However, they generally have a higher “on resistance” than is acceptable in low-level signal switching applications. Of all the switches available with the 34980A, FETs switch the fastest.

Refer to Table 1 for a summary of the general characteristics of the different switch modules. Please also refer to the 34980A data sheet for more detailed specifications on each switch MUX module.

Table 1. Typical 34980A switch MUX module characteristics

<table>
<thead>
<tr>
<th>Switch type</th>
<th>Armature 34921A and 34922A</th>
<th>REED 34923A and 34924A</th>
<th>FET 34925A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact resistance</td>
<td>&lt; 1.5 Ω</td>
<td>&lt; 1.5 Ω</td>
<td>&lt; 700 Ω</td>
</tr>
<tr>
<td>Switch speed</td>
<td>100 ch/sec</td>
<td>500 ch/sec</td>
<td>1000 ch/sec</td>
</tr>
<tr>
<td>Life (10 V, 100 mA)</td>
<td>10 M</td>
<td>10 M</td>
<td>unlimited</td>
</tr>
<tr>
<td>Typical failure mode</td>
<td>Fails open</td>
<td>Fails open/shorted</td>
<td>Fails shorted</td>
</tr>
<tr>
<td>Typical max. input</td>
<td>± 300 V/1 A switch current</td>
<td>± 150 V/0.5 A switch current with input resistors bypassed</td>
<td>± 80 V/0.02 A switch current</td>
</tr>
<tr>
<td>Use for</td>
<td>High-power circuits</td>
<td>Medium-level switching</td>
<td>High-speed, low-level switching</td>
</tr>
</tbody>
</table>

B. DMM configuration speed

During a scan, the 34980A connects the DMM to the configured channels one at a time and makes a measurement on each channel. With fast scanning applications, you will also need the DMM to make fast measurements. The speed of the DMM measurement depends on its configuration. First we will explore how the DMM works, and then we will explain how to set it up for fast reading rates.

How the DMM works:

You can use an external DMM or the internal DMM to perform measurements with the 34980A. The internal DMM includes signal conditioning, amplification (or attenuation), and a high-resolution (up to 26 bits) analog-to-digital converter (ADC). As shown in Figure 3, the ADC takes a pre-scaled voltage from the signal-conditioning circuitry and converts it to digital data for output. The ADC is the component that affects the DMM speed the most. The ADC governs some of the most basic measurement characteristics, including resolution, reading speed, and the ability to reject spurious noise. Depending on how the DMM is configured, these characteristics can affect how fast it can take readings.

The 34980A’s internal DMM uses an integrating ADC technique, which means it measures the average input value over a defined time interval. This integrating technique rejects power-line related noise present with DC signals on the input. This is
called normal mode rejection or NMR. Normal mode noise rejection is achieved when the internal DMM measures the average of the input by “integrating” it over a fixed period. If you set the integration time to a whole number of power line cycles (PLCs) of the spurious input, these errors (and their harmonics) will average out to approximately zero, thus rejecting these noise sources. Depending on the requirements of your application, the fastest rate may not achieve the desired performance. For example, if measurements are made with an aperture less than 1 PLC and in the presence of significant power-line frequency interference, there is no NMR at those frequencies. Any rejection of such interference would have to occur through averaging readings in the computer, and many samples must be taken over the period of the noise to reject it. To sample faster than 1 PLC in the presence of noise, the typical solution is to add passive filtering to the sensors before they are measured by the DMM.

There are applications that require faster measurement speed than is possible to achieve with the internal DMM. For these types of applications, we recommend using the Agilent 34410A/34411A or 3458A as an external DMM. Please refer to the “Scanning With External Instruments” section in the 34980A User’s Guide for details on how to set up the 34980A to scan with an external DMM. These DMMs use different ADC techniques that can read at a much faster speed than the 34980A internal DMM. Please also refer to the user guides on these instruments for details on how they work. The 34410A can measure up to 10 k readings/second. The 34411A can make 50 k readings/second. And the 3458A can make 100 k readings/second. When you set them up to scan through a list of channels, the switch and DMM communicate without any intervention from the PC. This process is much faster than trying to sequence channels using software commands. With an external DMM such as the 34410A/34411A or 3458A, you can nearly double the scan speed compared to using the 34980A’s internal built-in DMM.

How to set up the DMM for fast reading rates

DC measurements setup:

There are four key features that control the measurement speed for DC measurements on a DMM:

• Autozero
• Autorange
• Integration time
• Automatic trigger delay

When autozero is enabled (default), the instrument internally disconnects the input signal following each measurement and takes a zero reading. It then subtracts the zero reading from the preceding reading. This prevents offset voltages present on the instrument’s input circuitry from affecting measurement accuracy. So, when this feature is enabled, two readings are taken for every measurement. When autozero is disabled, the instrument takes one zero reading and subtracts it from all subsequent measurements. It takes a new zero reading each time you change the function, range, or integration time. Turning autozero off will accelerate your reading speeds for temperature, DC voltage, resistance and DC current functions because you make only a single measurement compared to two when it is enabled.

Autorange makes pre-measurements of the applied signal to try and determine the best range to select in order to achieve the highest-resolution measurement. Autorange will also take longer when transitioning from the 10-V or 10-Mohm ranges to higher ranges. You can allow the instrument to automatically select the measurement range using autoranging or you can select a fixed measurement range using manual ranging. Autoranging is convenient because the instrument automatically decides which range to use for each measurement based on the input signal, but it requires additional time to select the range. For fastest scanning, use manual ranging for each measurement.

Integration time is the period of time the internal DMM’s ADC samples the input signal for a measurement. Integration time affects the measurement resolution (for better resolution,
AC measurements setup:

There are 3 key elements that control the measurement speed for AC measurements:

- Autorange
- Automatic trigger delay
- AC filter setting

The autorange and automatic trigger delay elements work the same way we described in the “DC measurements setup” section above.

AS for the AC filter setting, the DMM AC voltage and AC current functions implement three different low-pass filters. These filters allow you to trade-off low-frequency accuracy for faster reading speed. The fast filter settles in 0.12 seconds and is useful for frequencies above 200 Hz. The medium filter settles in 1 second and is useful for measurements above 20 Hz. The slow filter settles in 7 seconds and is useful for frequencies above 3 Hz. See Table 2 for more detail on the reading rate.

Table 2. AC default settling delay and maximum reading rate

<table>
<thead>
<tr>
<th>Input frequency</th>
<th>Default settling delay</th>
<th>Maximum reading rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Hz - 300 kHz (slow)</td>
<td>7 seconds/reading</td>
<td>0.143 reading/second</td>
</tr>
<tr>
<td>20 Hz - 300 kHz (medium)</td>
<td>1 second/reading</td>
<td>1 reading/second</td>
</tr>
<tr>
<td>200 Hz - 300 kHz (fast)</td>
<td>0.12 second/reading</td>
<td>100 readings/second</td>
</tr>
</tbody>
</table>

1. With 34925A FET module located in slot 1 of 34980A mainframe
2. Refer to “Single channel measurement rates” table on page 24 in the 34980A data sheet for spec (5989-1437EN)
3. Autozero cannot be turned off when making four-wire ohms measurements. Temperature measurements are all resistive and can be two- or four-wire measurements.
4. The NPLC/aperture settings are set to MIN; this would be 300 μs. The same commands can be used for DC, ohms, or temperature – but you have to change the VOLTage to CURRent, RESistance, FRESistance, or TEMPerature.
5. Maximum limit with default settling delays defeated
With a few precautions, you can perform AC measurements at speeds up to 100 readings per second (use manual ranging to eliminate auto-ranging delays). By setting the preprogrammed channel settling delays to zero, each filter will allow up to 100 channels per second. However, the measurement might not be very accurate since the filter is not fully settled. In scanning applications where sample-to-sample levels vary widely, the medium filter (20 Hz) will settle at 1 reading per second and the fast filter (200 Hz) will settle at 10 readings per second.

If the sample-to-sample levels are similar, little settling time is required for each new reading. Under this specialized condition, the medium filter (20 Hz) will provide reduced accuracy results at 5 readings per second, and the fast filter (200 Hz) will provide reduced accuracy results at 50 readings per second. Additional settling time may be required when the DC level varies from sample to sample. One final consideration: the internal DMM’s DC blocking circuitry has a settling time constant of 0.2 seconds. This settling time only affects measurement accuracy when DC offset levels vary from sample to sample.

### SCPI command example to achieve maximum measurement speed for ACV6, 7, 8:

```plaintext
CONFigure:VOLTage:AC (@1001)
SENSe:VOLTage:AC:BANDwidth 200,(@1001)
SENSe:VOLTage:AC:RANGe 1.0,(@1001)
TRIGger:DELAY:AUTO OFF
TRIGger:DELAY 0
```

### C. Additional mainframe considerations that affect speed

There are other functions and features in the 34980A mainframe that can affect the speed of the instrument. Scanning speed is affected when:

- Switching between banks
- Functions are changed between channels
- The front panel displays the readings from the DMM
- Alarms and scaling are turned on

### Switching between banks:

The multiplexer modules have two banks of switches to connect a particular channel to the DMM. This includes the channel switch and the bank analog bus switch. See Figure 4 for details on the location of these switches in the MUX module.

The channel switch type is dependent on the multiplexer module you use. The bank analog bus switch is an armature non-latching relay. The armature relay needs a longer time (~4 ms) to settle after switching. This switch does not switch until the DMM needs to connect to another bank in the scan. So if you can group all of your channels into one bank, you will save time in the scanning process because the bank analog bus switch is not switched.

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6. With 34925A module located in slot 1 of a 34980A mainframe
7. Refer to “AC Operating Characteristics” table on page 26 in the 34980A data sheet for spec (5989-1437EN)
8. ACI will use the same commands – except for specifying CURRent instead of VOLTage. For frequency, the FREQ:APER command specifies a gate time of 0.01, 0.1, or 1 second, which will also affect reading rates in addition to the AC filter selection.
Functions are changed between channels:
When the function is changed from one scan channel to another (for example, from DCV to 2-wire ohms), the processor needs time to change the range and measurement method before it can perform the measurement on the next channel. To save time, try to group the channels with the same function together in the scan order before changing to another group of functions (for example, configure CH1001:1004 for DCV and CH1005:1008 for 2-wire ohm and scan in the order of 1001:1008).

The front panel displays the readings from the DMM:
It takes time for the processor to display the measured reading on the front panel. For applications where you don’t need the front panel display (for example, when you are recording readings directly to the PC so you can view the data later), it is a good idea to turn the display off to save processing time. To turn display off, use the command “DISPlay:STATe OFF”.

Alarms and scaling are turned on:
The 34980A has four TTL alarm output lines that you can configure to alert you when a reading exceeds specified limits on a channel during a scan. You can assign a high limit, a low limit, or both to any configured channel in the scan list. You can assign multiple channels to any of the four available alarms (numbered 1 through 4). When you set up the scanned channels to alert you when a condition is met, the processor needs time to make the comparison between the alarm state and the actual reading. For faster operation, it is a good idea to turn off this feature if you don’t need it.

Figure 4. The location of switches on a 34921A MUX module
The scaling function allows you to apply a gain and offset to all readings on a specified multiplexer channel during a scan. In addition to setting the gain ("M") and offset ("B") values, you can also specify a custom measurement label for your scaled readings (RPM, PSI, etc.). You can apply scaling to any multiplexer channels and for any measurement function. As with the alarm feature, it takes time for the processor to make the calculation after every channel that has scaling set up in the scan. Again, for faster operation, it is a good idea to turn off this feature if you don’t need it.

**Optimizing the Data Transfer Rate**

The data transfer rate consists of the system readings and throughput rates. There are three different paths to store and transfer the data for simulation in a 34980A system. The paths are described in the system reading architecture diagram shown in Figure 5:

Path A is the reading rate into the reading storage. This is called readings to memory or “measurement into memory” in the 34980A data sheet. The fastest reading rate is 3000 readings/second, which is a function of the A-to-D sampling rate\(^9\). The fastest scanning rate is 1000 channels/second into memory\(^{10}\).

Path B is the time it takes to retrieve readings from reading storage into the PC. This is called “data out of memory to LAN, USB, or GPIB” in the 34980A data sheet. This speed is dependent on what you want to export and the interface you use to export the data. You will achieve the fastest transfer rate if you export just the readings without a timestamp or any extra format turned on. The interfaces include the physical interfaces of GPIB, USB 2.0, LAN with VXI 11, and LAN sockets. Using LAN sockets will give you the fastest throughput rate\(^{11}\).

Path C is the time it takes to programmatically trigger a reading (or readings) and retrieve the results into a computer. This is called “direct to I/O” in the 34980A data sheet. This operation is actuated by a “READ?” command, which is the same as the “INIT;:FETCH?” command. The scanning speed of this operation is faster when you use a LAN interface\(^{12}\).

Please refer to application note 5989-4376EN, *Migrating system software from GPIB to LAN/LXI*, for more detail on the read/write performance of each I/O interface. In summary, follow these guidelines to get the fastest data transfer rate:

- Store the readings into internal memory (path A) instead of using direct to I/O (path C) and retrieve the data (path B) later\(^{13}\).
- Use LAN sockets for retrieving data out of memory (path B)\(^{14}\).

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9. Refer to “Single channel measurement rates” table on page 24 of the 34980A data sheet for spec (5989-1437EN)

10. Refer to “Scanning measurement rates to bus or memory” table “Measurement into memory” column on page 24 of the 34980A data sheet for spec (5989-1437EN)

11. Refer to “Data out of memory to LAN, USB, or GPIB” table on page 24 of the 34980A data sheet for spec (5989-1437EN)

12. Refer to “Scanning measurement rates to bus or memory” table “Direct measurements – direct to I/O” column on page 24 of the 34980A data sheet for spec (5989-1437EN)

13. 34980A Internal memory is limited to 50 k readings.

14. Agilent instruments have standardized on using port 5025 for SCPI socket services. Once a connection is made you simply send the SCPI strings to the instrument and read back responses over the socket connection.
SCPI Example: Achieving the Fastest Scan Speed with the 34980A

The program to the right demonstrates how to setup for the fastest scan speed using the 34925A. This program assumes:

- A 34925A MUX module in SLOT 1
- The 34980A is connected through LAN with VXI 11

Go to www.agilent.com/find/34980VEE_fastscan to see a programming example using Agilent VEE that calculates the scan speed of measurement into memory (path A), data out of memory (path B), and direct to I/O (path C) paths. Notice that the program uses a VEE timestamp instead of the instrument’s timestamp so the value might be a little different from the specifications in the data sheet.

```plaintext
// Reset and clear the instrument
*RST
*CLS

// Configure channels 1001:1005 to measure DCV
// Setting range at a particular range instead of auto ranging
// Setting resolution to MAX for 4 ½ digits
CONFIGure:VOLTage:DC 10,MAX,(@1001:1005)

// Turning autozero off
SENSe:VOLTage:DC:ZERO:AUTO OFF,(@1001:1005)

// Setting channel delay to zero
ROUTe:CHANnel:DELay 0,(@1001:1005)

// Setting trigger delay to zero
TRIGger:DELAY:AUTO OFF
TRIGger:DELAY 0

// Turning display off
DISPlay:STATe OFF

// Setting up to trigger 1000 times and sample once
TRIGger:COUNt 1000
SAMPle:COUNt 1

// Setting up scan list
ROUT:SCAN (@1001:1005)

// Initiate scan and wait until it’s done
INIT
*OPC?
// Fetch the readings
FETCH?
```
Conclusion

As you can see, many different factors affect the 34980A measurement speed. Using the preceding recommendations for choosing which relay module to use, configuring the DMM, paying attention to the additional mainframe considerations, and choosing which path to take for data transfer will help you achieve the scanning speed you desire for your specific application. However, to reach the speed you want, you will have to make tradeoffs with the accuracy of the instrument. Remember to take these into account when you decide how fast you would like to scan using the 34980A.

Related Agilent Literature

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<th>Type</th>
<th>Publication number</th>
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<td>Data sheet</td>
<td>5989-1437EN</td>
</tr>
<tr>
<td>Agilent 34410A/34411A 6½ Digit High-Performance Multimeters</td>
<td>Application note</td>
<td>5989-4039EN</td>
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<tr>
<td>Migrating system software from GPIB to LAN/LXI</td>
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<tr>
<td>34980A User’s Guide</td>
<td>User’s guide</td>
<td>34980-90005</td>
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<tr>
<td>34410A/11A User’s Guide</td>
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