Following the SCPI Learning Process and Using the Tool

Many instruments use the SCPI programming language which is designed to be self-explanatory and quite intuitive. Agilent requires that its products use SCPI as the native programming language. SCPI is supposed to reduce the programming efforts substantially, which it can once you become familiar with it and are using multiple instruments that utilize SCPI. Even if you are familiar with SCPI, instruments today have so much functionality built in that it can be time consuming to understand the many subsystems, parameters, and interrelations between commands. Since direct SCPI programming is used in over 50% of test systems, you need a plan for learning it quicker. If you can get your hands on any tools to help you learn quicker, you'd likely be happy to use them. Time is of the essence.

What is SCPI?

Part of the process is to understand how SCPI commands are organized and what they do. The SCPI (Standard Commands for Programmable Instruments) Consortium evolved to standardize the control language used between programmable instruments. Its aim has been to promote a common language and syntax suitable for all programmable instruments. Today, SCPI is supported by most of the manufacturers of programmable instruments including Agilent (HP), Tektronix, Keithley, Fluke, and Racal. More information can be found at www.ivifoundation.org, now supporting the original SCPI Consortium information.

SCPI can be sent to an instrument over many interfaces such as LAN, GPIB, RS-232, and USB. All of these interfaces are directly supported by Agilent VISA or NI VISA I/O Libraries which make programming in the environment of your choice relatively easy, efficient, reliable, and fast. Many instruments from Agilent, for example, include several interfaces: LAN, GPIB, and USB, so you have programming flexibility for a particular environment.

SCPI is an ASCII language that consists of configuration and query commands that are specific to the instrument and a set of IEEE 488.2 operations and commands that are common to all SCPI-based instruments. SCPI commands have long and short forms, where the long form is very descriptive, and the short form is an abbreviation: "TRIGGER:COUNT" can be "TRIG:COUN".

Every instrument has a state, and that state determines what it is going to do next. It might be configured for DCV, 5 volt range, 100usec aperture, take 10 readings on a trigger from an external source, etc. That state can be changed with commands, and it can be queried with commands. Some commands change multiple state parameters and some queries only return dynamic data that has been captured by the measurement engine. SCPI commands can be broadly categorized as follows:

Configuration Commands

These commands are “write-only” and are essentially a “preset” which completely sets up the instrument for a particular function, range, etc. Whatever state the instrument was in, that is now changed, and many state parameters may have changed. Once used, all you typically need is to trigger the instrument and read results back. Here are two examples that show parameters and no parameters. Manuals that describe these commands often have tables to show all the state changes of the instrument.

```
CONF:VOLT:DC 5.00, 0.1
CONF:ACPower
TRIG IMMEDIATE
```

Configure – Query Commands

These commands are single-state operations where only a single state variable is changed and can be queried. For example, you can change the range of the instrument, and you can read it back. It is a command that looks the same for configure or query, except for the addition of a “?” at the end of the text to signify a query.

```
SENSE:VOLT:NPLC 1
SENSE:VOLT:NPLC?
SENSE:VOLT:RANGE 10
SEND:VOLT:RANGE?
TRIG:COUNT 10
TRIG:COUNT?
```

The query form of the previous command actually reads the state variable for that configuration of the instrument. The previous examples showed the CONF command, where many state variables are affected. It may take a number of queries to determine what changed in the instrument to determine what the CONF command changed.

Query Only Commands

These commands tend to be related to reading data from a buffer or actually causing measurements to be made. Other commands set up the instrument for these to work properly. These are the final commands you use in acquiring the data you want from the instrument.

```
FETCH?
READ?
MEAS:VOLT:DC?
```

Common Commands

These are the required commands in SCPI, according to the IEEE 488.2 standard. Since they are common to all instruments, they tend to do common things such as read commonly defined status registers, clearing error conditions, clearing reading buffers, reset, instrument model number, stored states, etc. Since these are common to all SCPI compliant instruments, once you learn them on one instrument, you know them for all.

*CLS
*IDN?
*RST

Reading the Instrument State Variables

As stated earlier, the instrument is a collection of state variables representing the state of the instrument. If you press buttons on the front panel, you are changing the state of the instrument as surely as you will when sending commands. And, this is the key to learning the instrument's SCPI – you make changes and see how the state of the instrument is affected. You use the query forms of commands to determine the state variable changes.

A properly designed instrument will have a configure command to change every state variable and have an associated query of that state variable. This is the Configure-Query combination of SCPI commands. These are the commands we use to learn the SCPI of the instrument. You need to acquire all the SCPI commands of the instrument and separate these commands from all the other commands. This can be done quite easily for modern day instruments which have electronic manuals. Every well written manual or on-line help tool such as 34410A_SCPI_Reference.chm, provides a listing of all the SCPI commands of the instrument. You simply weed out all the commands that are not of this form. The following is an excerpt from an electronic manual to illustrate:

[SENSe:]RESistance:APERture {<seconds>|MIN|MAX|DEF}
[SENSe:]RESistance:APERture? [{MIN|MAX}]

[SENSe:]RESistance:APERture:ENABled?

[SENSe:]RESistance:NPLC {<PLCs>|MIN|MAX|DEF}
[SENSe:]RESistance:NPLC? [{MIN|MAX}]

[SENSe:]RESistance:NULL[:STATe] {ON|OFF}
[SENSe:]RESistance:NULL[:STATe]?

[SENSe:]RESistance:NULL:VALue {<value>|MIN|MAX}
[SENSe:]RESistance:NULL:VALue? [{MIN|MAX}]

You will note there are 4 Configure-Query pairs and one that is a query only. In this case, we throw out the singleton, since it is returning a state variable that is not directly controlled by a command. This singleton is valid only if you use one of the instrument's APER configure commands. We also throw out the non-query versions of the 4 pairs, and we eliminate all the parameters. Finally, we eliminate all optional SCPI command nodes that are denoted by the brackets "[]". Much of this can be done with text editor Replace and Replace ALL functions. There is no need to convert from long form SCPI to short form. The commands are valid either way. Here is the result:

RESistance:APERture?
RESistance:NPLC?
RESistance:NULL:STATe?
RESistance:VALue?

This may seem tedious, but I have taken instruments like the Agilent 34410A DMM or Agilent 33220A Function Generator and extracted all the valid queries in 15-30 minutes each. Once you have all these queries, you are ready to use the SCPI Learning Process.

SCPI Learning Process

To learn the instrument, you simply read all the instrument state variables, change the state of the instrument, and read all the state variables again. That's it! Those weird CONF commands can be executed in between, and you can see how it changed the instrument. Those 15 button pushes on the front panel changed state variables, and you can see the SCPI command changes. It really does not matter how you change the instrument, as long as you first capture the state, make the changes, and then capture the state again, you have the means for learning what happens. Here is the process in a sequence:

1. Bring the instrument to some initial state - typically Reset or power ON
2. Send every extracted query to the instrument and read the results from the queries
3. Change the state of the instrument – front panel, driver call, Web interface
4. Send every extracted query to instrument again
5. Compare the results and show which commands changed parameters

With sometimes 100 or more queries, you probably want this automated somehow. With a tool like Excel, it is pretty easy to run through all the queries and dump them into columns that can later be compared. If any two columns are different, you note those changes, and those are the state variables you need to change to get the instrument to that new state. With the Command-Query commands as the basis, you now have the new state variable result, and you know the original command (without the "?"). All you need to do is send that command with that result concatenated to it to change the instrument to that state.

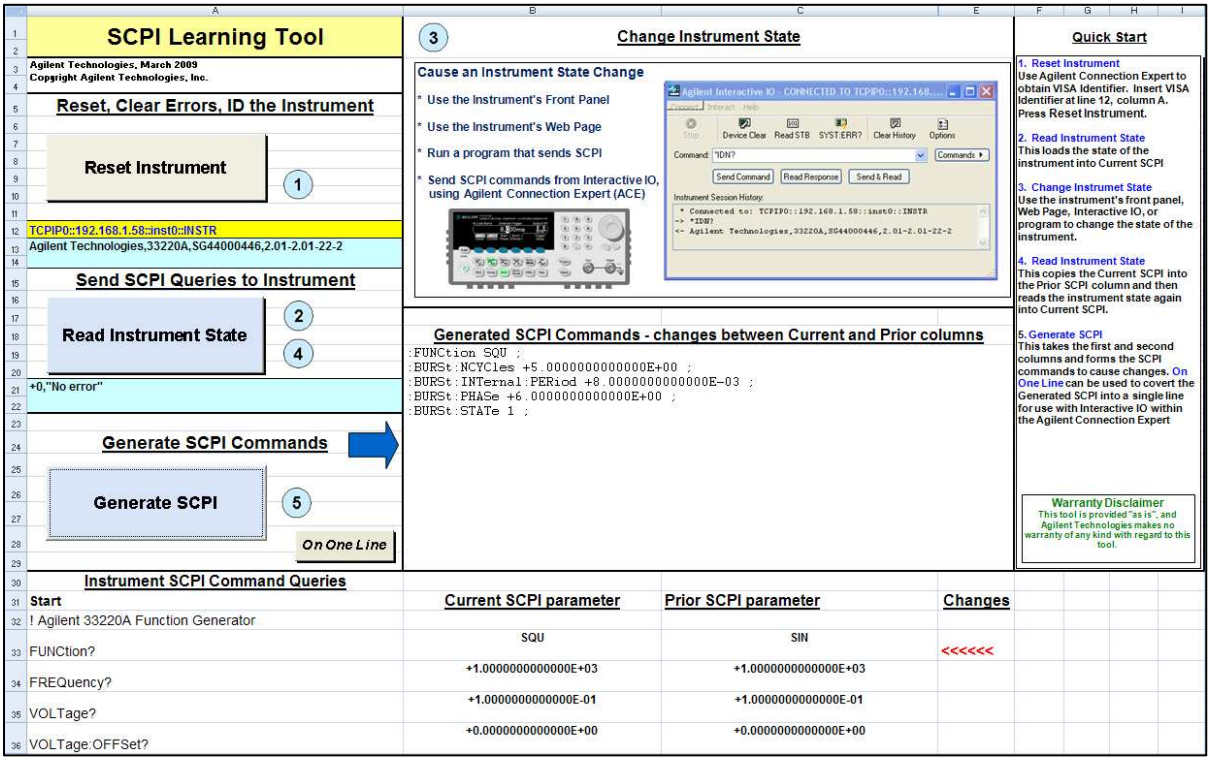
For learning how to program the instrument, this technique is perfect. For using the commands to reprogram the instrument directly, you need to be aware of a peculiarity of

certain instruments. Some instruments like commands in a particular order; otherwise, you can generate errors or warnings. You learn this quickly by sending the commands back to the instrument. It really is a function of the order in which you read the results, build the return command-parameter, and send the new command back to the instrument.

SCPI Learning Utility

The entire process above is illustrated in the free utility available on the Agilent web site at the following URL: www.agilent.com/find/learnSCPI

The figure below shows the tool's single page screen. You will note there are numbered sequences and buttons that are presented to perform the various operations.



These sequences follow the SCPI Learning Process discussed earlier. All you need do is determine the instruments VISA string by using the Agilent Connection Expert or NI's Measurement Automation Explorer and place that in the cell with sequence #1. You then press the Reset Instrument and Read Instrument State. After changes are made to the instrument, you press the Read Instrument State again, and then press the Generate SCPI button to see the SCPI commands and parameters required to move from one state to another. After seeing how things change and all the changes required, you can refer to the instrument's SCPI Reference manual to better understand the specific command.

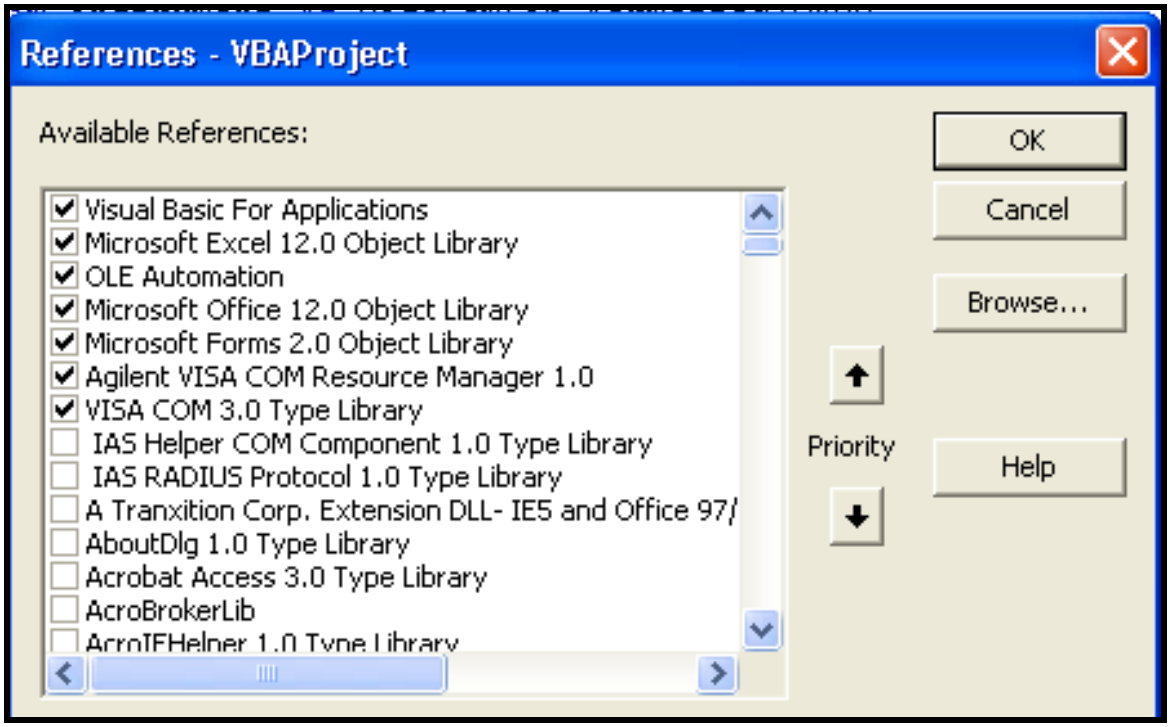
You can see the instrument's Query commands in the lower left hand corner, under Start. You need only supply all the valid Configure-Query commands in this column, and the tool does the rest of the work.

SCPI Learning Tool Setup and Use

The SCPI Learning tool is designed to work with Excel 2003 and beyond. You must have the Agilent IO Libraries installed and the appropriate References checked in the Excel program in order to communicate with instruments using VISA.

Install Agilent IO Libraries: http://www.agilent.com/find/iosuite

Once installed, you bring load the SCPI Learning Tool and enable Macros. Then, add the correct VISA libraries to the Microsoft Visual Basic Tools-References:



Next, read the Quick Start instructions on the SCPI Tool page to understand how to use the tool. To add new SCPI to the tool, select the Getting Instrument SCPI page and follow the instructions.