Command-line Instrument Control and Measurement Tools

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Abstract

The main purpose of this thesis is to automate laboratory instruments with command lines. The created commands allow users to control instruments and record measured values into a file, by using industrial standards, these commands can communicate to the instruments through different interfaces. The users may utilize these commands to execute an experiment remotely and records values automatically. These commands made experiments flexible in location, reduce the time spent for recording experiment values, and reduce any possible human errors. The recorded values can be accepted by well-known analysis software packages such as MATLAB, for further processing as a file. These commands provide the users with convenience and personal safety, when executing laboratory experiments with modern laboratory instruments.

The target of this thesis is producing a set of commands that allow users to control, read, and record, the common instruments used on an electronics workbench. These devices include power supplies, digital multimeters, function generators, and oscilloscopes. The produced commands allow users to establish two workbenches with these common laboratory instruments. The created commands were written in C language in combination with the test and measurement industrial standard to ensure the compatibility with instruments from different vendors. This thesis also provides the readers with required background knowledge that is related to the usage and development of these commands. The target readers of this thesis are the graduates of Bachelor of Electrical and Electronics Engineering or higher.

With these command sets, researchers do not need to spend a long time controlling instruments and recording results from instrument manually. Apart from setting up the hardware, they can simply enter the command, to get the result they require.

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1. Overview

1.1. Purpose and Target

Laboratory experimentation and testing often requires personnel to be operating laboratory measurement equipments for the full length of the experiment. Errors could potentially occur when a long period experiment is performed. These errors can be small, which do not affect the overall experimental results or they can be significant enough to compromise the entire experiment, or they can be potentially dangerous. It may be inconvenient, potentially unreliable, and dangerous, to execute manually for a long period an experiment. It is possible to solve these problems with custom made programmes that are based on the communication standard used in the test and measurement industry. These programmes are aimed to automate, and control laboratory instruments, that support the communication standard used in the industry.

There are two popular user machine interface development approaches, one is using LabVIEW software from National Instruments Ltd, to produce graphical user interfaces. Another is developing custom made software by using C or C++ programming language. It is relatively simple to produce a LabVIEW programme to control the instruments; however, the LabVIEW programmes cannot run in command prompt. The compatibility of LabVIEW programmes could be a potential problem if the programmes required running on different computer platforms. The LabVIEW programmes have problems executing speed which is slower than script commands. The cost of LabVIEW software is expensive, and is not an ideal option for the development of academic software. Where the development of the custom made script commands may be free or of little cost, the script commands require less software and hardware resources to run by avoiding using the graphical user and machine interface. Therefore, the custom-made script commands are the appropriate approach to develop the instrument control software for the University of Waikato.

The purpose of this thesis is to simplify the experimental procedures, reduce research workload, accelerate experimental progress, and reduce any possible human errors by automation using an instrument communication standard. The target is to produce a command set that can control instruments and record values from the instruments on a workbench. These targeted instruments include power supplies, digital multimeters, function generators, and oscilloscopes. The recorded values are required to be in human and software readable file format, which can be further processed in other analysis software, such as MATLAB. The produced commands with this thesis can be divided into three main categories; firstly, the set up commands is responsible of setting up the instrument parameters. Secondly, reading commands that are responsible for downloading experimental values and writing these values into a file. Finally, the specific commands that can be seen as a combination of first and second groups to achieve a specific goal. Because these commands are used for a specific application, they are called custom-made commands for specialized applications. The read and write commands are in separate chapters by instrument categories with a single chapter for the specific command. This thesis will introduce the background knowledge of the test and measurement communication standard, approach method, and assist readers to use the commands produced with this thesis as a user manual.

1.2. VISA Introduction

Virtual Instrument Software Architecture (VISA) is a specification of the test and measurement industrial communication standard, which is implemented by the VXIplug&play alliance made by major test and measurement companies such as Agilent and National Instruments [3, 4]. The objective of the alliance is to reduce the barriers of hardware and system-level software produced by different test and instrument vendors. They define and implement standards at system-level that is followed by vendors in the alliance.

VISA is therefore an I/O library that provides a unified platform for the test and measurement industry. The common library allows software from different vendors to run on the same platform and interoperable. The VISA software from any vendor should be installed and running properly in order to use the VISA commands produced with this thesis to control the instruments.

1.3. Approach and Connection Structures

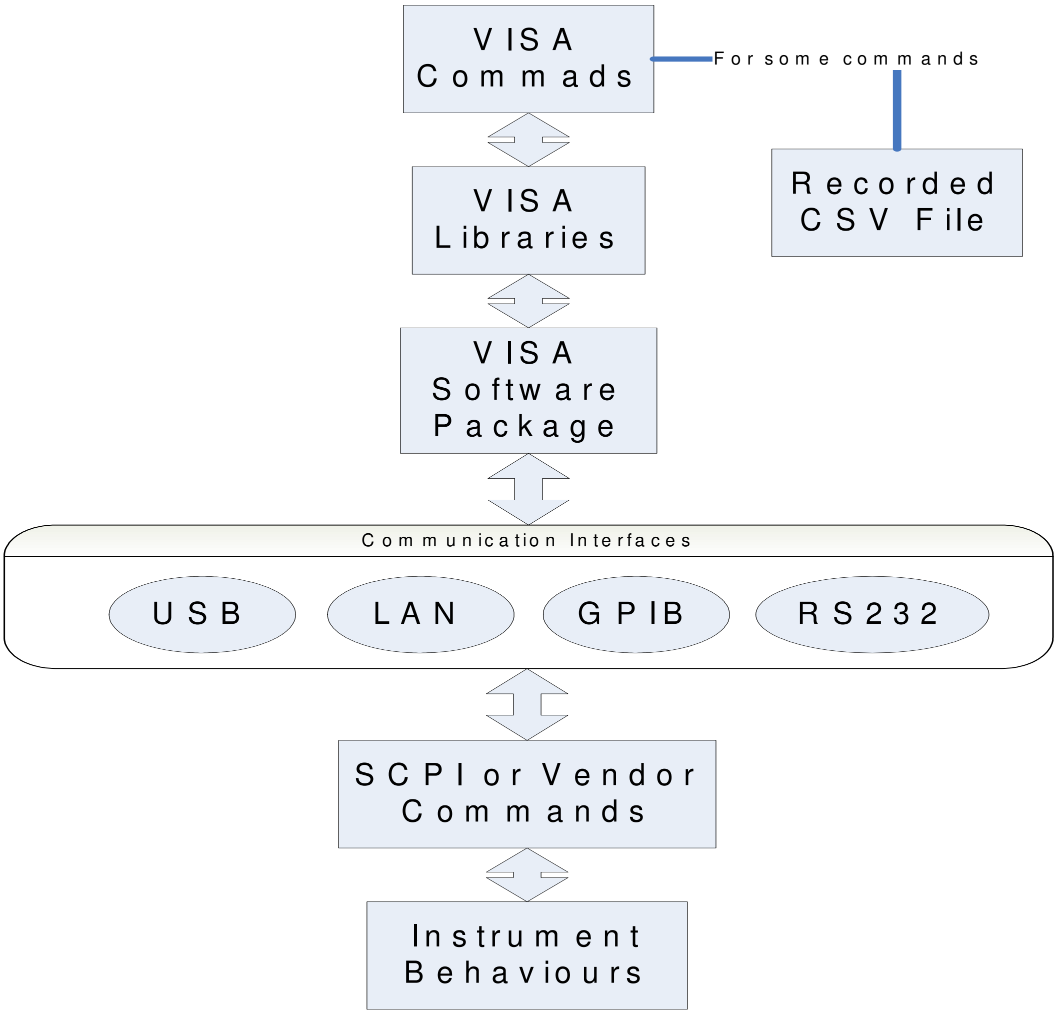

Figure 1.1 *Main structure of the approach in this thesis. Virtual Instrument Software Architecture (VISA) is a specified standard to manage instrument communication. The target of this thesis is the top VISA commands that allows the user to control instrument and record value read by instruments. The VISA libraries provide a link between the command development and the software package, acting as a universal bridging between different communication interfaces. Standard Commands for Programmable Instrumentation (SCPI) is the standard built in lower commands in devices that control behaviours of the device.*

The approach of this thesis is using GNU software to develop the custom-made VISA commands in C language. The tools used in the development of the VISA commands are DEV-CPP as C, C++ IDE, and MinGW C library with GCC complier. The VISA software can be obtained from Agilent home web page freely with registration[1]. Any VISA software from other vender is compatible with the commands created, but users should follow the installation and the user guide came with the VISA software. This thesis will only use Agilent VISA IO Library as the example.

Figure 1.1 shows the basic relationships between the products of this thesis, VISA commands, and the instrument. Please refer to Appendix for details on VISA, SCPI and GPIB if the reader is interested. The VISA commands are using VISA software such as Agilent IO Library as a bridge to communicate with the instrument. The SCPI or vendor commands are the actual commands that control the instrument. Some hardware vendors have their own command set instead of SCPI commands to control the instruments. The SCPI or vendor commands are embedded in the VISA commands in order to control the instruments. The main purpose for the VISA commands are sending instrument control commands such as SCPI and download the readings from the instruments into a formatted human and software readable record file. Comma Separated Values (CSV) file format is readable to human and accessible to most of text editor software, and it is also acceptable by many common analysis software today such as MATLAB. Its format can be easily produced by few command programme lines. Therefore, CSV file is the chosen format for file recording approach.

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[1] Agilent IO Library, http://adn.tm.agilent.com/index.cgi?CONTENT_ID=26

For example, the user may enter a command with parameters as following to obtain the battery-charging characteristic. The instrument used is HAMEG HM8143 dual outputs power supply:

“bc8143 GPIB0::1 c 12 2 >12vchg.csv”

“bc8143” is the name of the command. “GPIB0::1” is the address of the HM8143. “c” is the charging function. “12” is the voltage level. “2” is the current limit. “>12vchg.csv” is the output file name and file type.

The user may connect the instruments directly to a PC, a network or to a LAN and GPIB interface gateway. Normally using Agilent E5810A LAN/GPIB gateway is a more convenient way to accomplish the task since GPIB interface is capable of connecting multiple instruments and the E5810A allows users to control these connected instruments via LAN. Figure 1.2 illustrates three typical connections with Agilent E5810A.

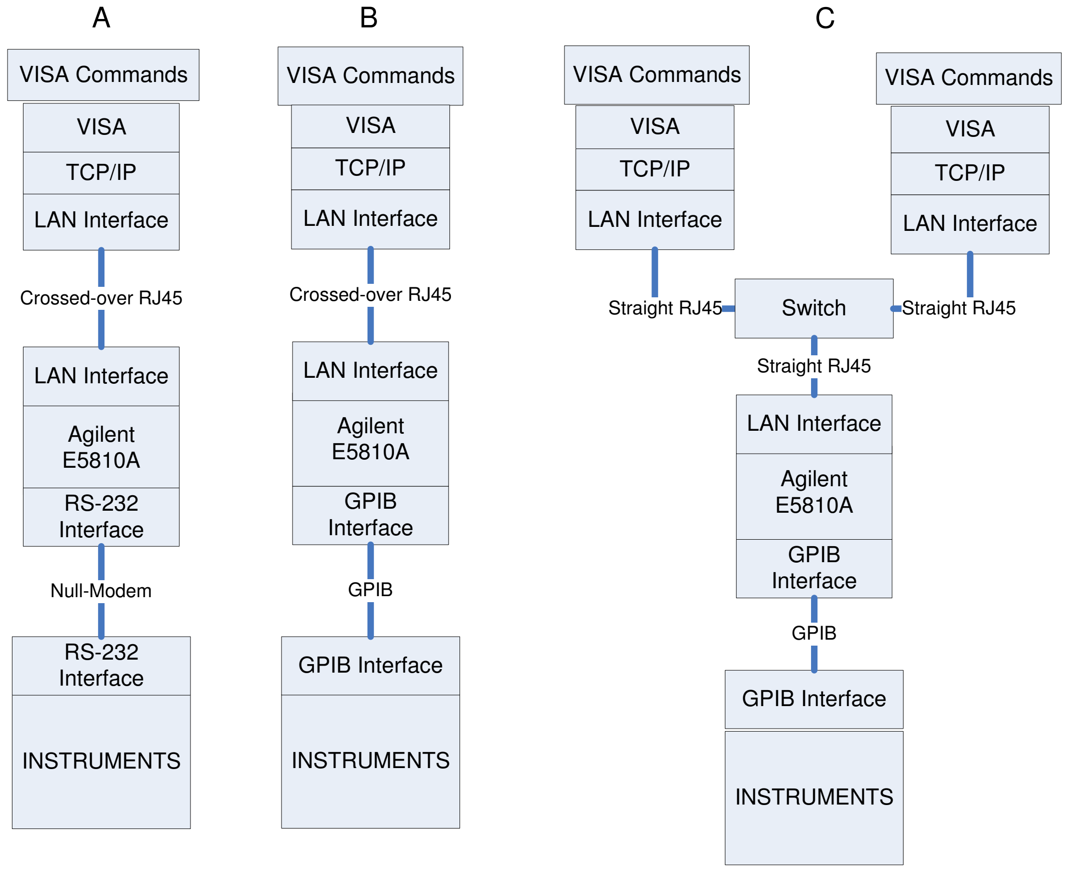

Figure 1.2 *Connections with Agilent E5810A. (A) E5810A can be connected directly to a PC with a crossed-over RJ45 cable with single connection to a RS-232 interface capable device through a null-modem. (B) The connected device can also be GPIB interface capable. (C) E5810A is also capable connecting to a network device such as a switch and allows multiple access to users in the network. [Source: PH50 System The user Manual, Professor J. Scott, 2000, Ref 5]*

In figure 1.2 A, the E5810A can connect to one instrument with its single RS-232 port and allowing user to access the instrument via LAN. Figure 1.2 B is the most common connection by using GPIB cable to connect the instrument. The E5810A can also connect to a network switch or any layer 2 function capable of network devices and allow other network users to use the instruments through the E5810A as shown in figure 1.2 C. Therefore, the application can be very flexible when using Agilent E5810A. The users can control any instruments that are connected to the E5810A either remotely or locally. For example, a demonstrator can easily demonstrate an experiment in the US with the equipment in NZ without shipping the equipment to USA and avoiding set up time. Another useful application is avoiding injuries in a dangerous experiment, where the operator can remotely control from a safe distance rather than close to the testing area.

For some instruments that only have the interfaces that are not supported by the E5810A such as LAN, USB and multiple RS-232 connection requirement. Figure1.3 shows the common direct connections to RS-232, USB and LAN capable instruments.

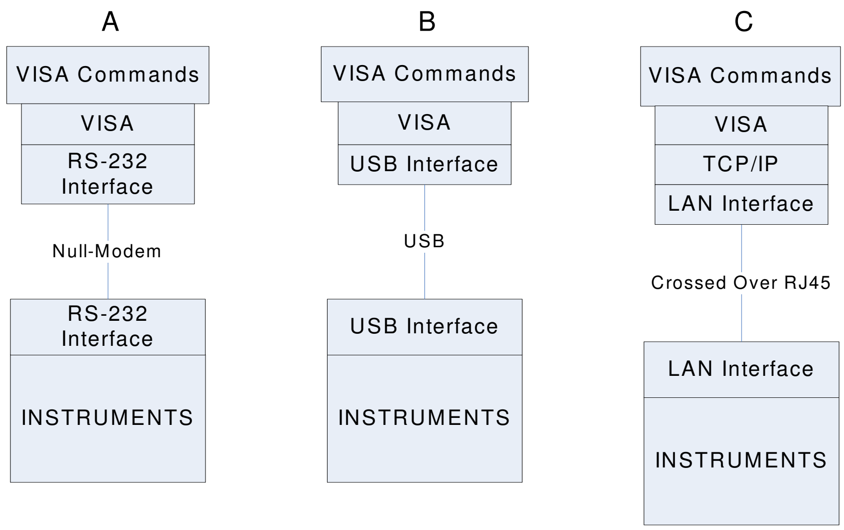

Figure 1.3 *Direct instruments connection diagrams. (A) Direct connections require a null-modem for RS-232 interfaces. (B) A USB type A to USB type B cable is required for direct USB connection. (C) The direct LAN interface connection requires a crossover RJ45 cable. [Source: PH50 System The user Manual, Professor J. Scott, 2000, Ref 5]*

Among the connection interface shown in figure 1.3 only those instruments that have LAN interface can be connected through a local LAN for multiple user access. Other instruments that only support RS-232 or USB interface will require a PC to be connected.

Most of the instruments in the laboratory at the University of Waikato can be connected to E5810A. Therefore, our workbench can be set up in a fixed room or as a mobile bench which allows users to move around.

1.4. Software Requirements

The essential software packages in order to execute the VISA commands are:

1. Any VISA Software.
2. Microsoft Windows 98 / ME / 2000 / XP, Linux, Mac OS X.

The most important software is the VISA, the operating system will be based on the requirement of the VISA software you have. Apart from Agilent VISA software, the user may choose the VISA software from other vendors. National Instrument VISA software has better compatibility. The VISA software used in this thesis is Agilent IO Library Suite, it is Microsoft Windows based software, which requires at least MS Windows 98 (SE) or MS Windows ME for Agilent IO Library Suite version 14.0. The latest version 15.0 requires MS Windows 2000 Professional, MS Windows XP Home, or Professional with service pack 2 or MS Windows Vista 32 bits Business or Ultimate or Enterprise version. All operating system versions listed above have command prompt, that is capable of running the VISA commands produced in this thesis. The installation of the Agilent IO Library Suite is a straightforward process for the user. Be aware of the hardware driver for USB interface on the instrument must be installed before the user can see the instrument appear in the Agilent IO Library Suite window. Only MS Windows 98 (SE) and MS Windows ME might require manual installation of the

USB interface driver. Most of other versions of MS Windows should be able to detect the newly installed USB interface with its plug and play capability.

Other operating system users may use either virtual machine with MS Windows installed or remotely controlled a PC that is installed with MS Windows and connected to the instruments.

1.5. Hardware Requirements

The general hardware limits of the approach of the thesis are:

1. The instruments must support SCPI or the instrument vendor's control commands.
2. The instruments must have one of more of LAN, USB, RS-232 or GPIB interfaces.
3. The user's PC must have a processor better than 450MHz Intel Pentium class, 128MB RAM, 280MB hard disk space, 800x600 256 colours display, a mouse, and communication ports such as LAN, RS-232 and a USB.

The basic hardware requirement, is the instruments must support SCPI commands and have either one or more USB, LAN, RS2-232 or GPIB interfaces. The PC requirements listed are for the Agilent IO Library Suite to execute properly, but the requirements of the PC might be differ when using the VISA software from other vendors.

In the setup procedures in this thesis, users are required to prepare cables for connection, the cable are USB type A to USB type B cable for USB connection, null-modem for RS-232 connection, IEEE-488 GPIB cable for GPIB connection, straight RJ45 for computer network connection and crossover RJ45 for direct PC connection. Hardware set up procedures in each chapter will explain the connection in details for each device model used in that chapter.

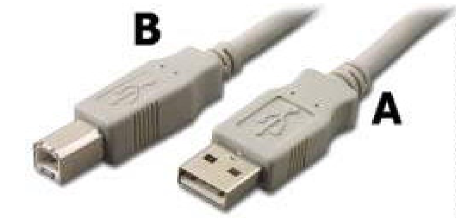

Figure 1.4 *USB A to USB B cable. USB A is usually connected to PC side and USB B is connected to the device.*

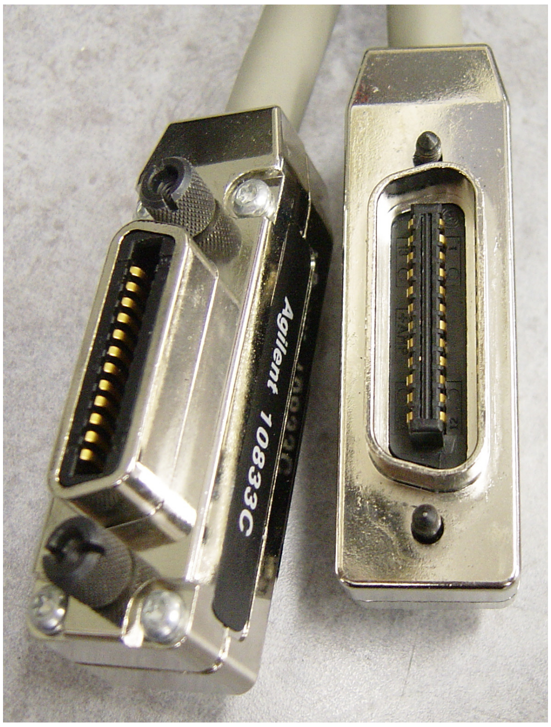

Figure 1.5 *GPIB cable. GPIB has one side is male head and female on other side. Total 24 pins in one connector head.*

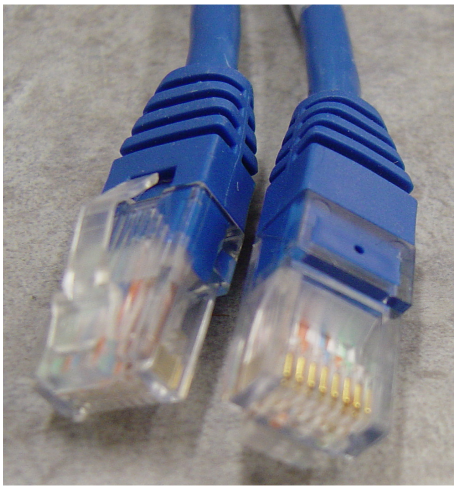

Figure 1.6 *RJ45 cable. RJ45 has total eight pins on both ends. The crossed over is simply swapping pin 1, 3 and pin 2, 6.*

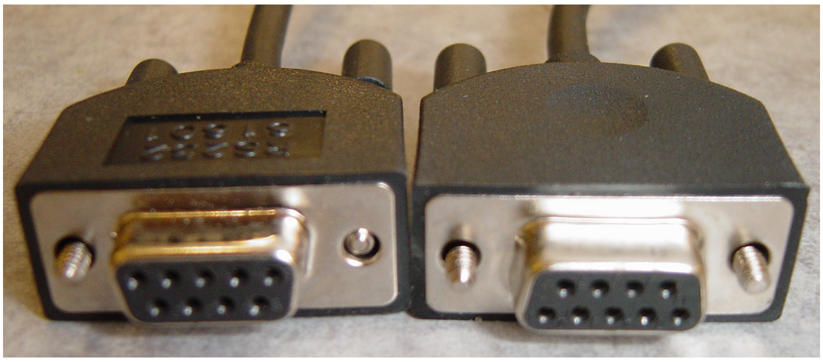

Figure 1.7 *RS-232 Cable. The DB9 RS-232 cable has nine pins on both ends. This cable is supplied along with Agilent device. The part number is 61601. Refer to figure 1.9 for crossover links details.*

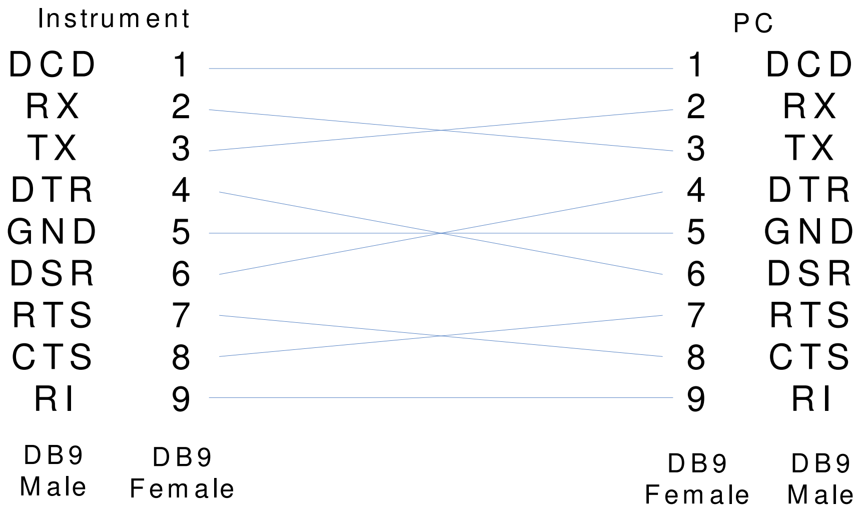

Figure 1.8 *RS-232 crossover diagram. The DB9 null-modem cable is crossover for direct link from PC to the device. All read and write lines must be crossover to ensure the communication. The best way to test is either using a serial cable tester or using a multimeter to measure the conductivity for each line.*

1.6. VISA Address HOWTO

In many sections later in the thesis, the user is required to provide the VISA address of the device in order to run the VISA commands. Different interfaces have different VISA address names and parameters, so these cannot be organized and used in a general way. Therefore, the only way is allowing the user to input the VISA address according to the interface for each instrument. This section will introduce the general instruction to obtain the VISA address from Agilent IO Library Suite version 14.0 and apply the VISA address in the command prompt with the VISA commands. (Different versions of the Library might be slightly different from the instruction provided in the thesis.)

Step 1: Double click on the IO icon in the tool icon section at lower right hand side of the screen as show in figure 1.9. The icon should show up automatically after VISA installation.

Figure 1.9 *Agilent IO Library Suite icon location. Open up the software package by double clicking on the icon.*

Step 2: The Agilent IO Library Suite window should show up after step 1 and then expand all sub-level in the "Instrument I/O on this PC" column.

Step 3: Single left click on the button "Refresh All" and check the model name of desired device when it appears in the window.

Step 4: Selecting the desired device to copy VISA address. The green tick mark indicates the interface or device is working properly, and the red cross indicates the interface or device is not working correctly. For our example, in figure 1.10, we can see all interfaces on this PC is ready to be connected and there is only one available device, MSO4054. The connection information will appear after the user clicks on MSO4054 once.

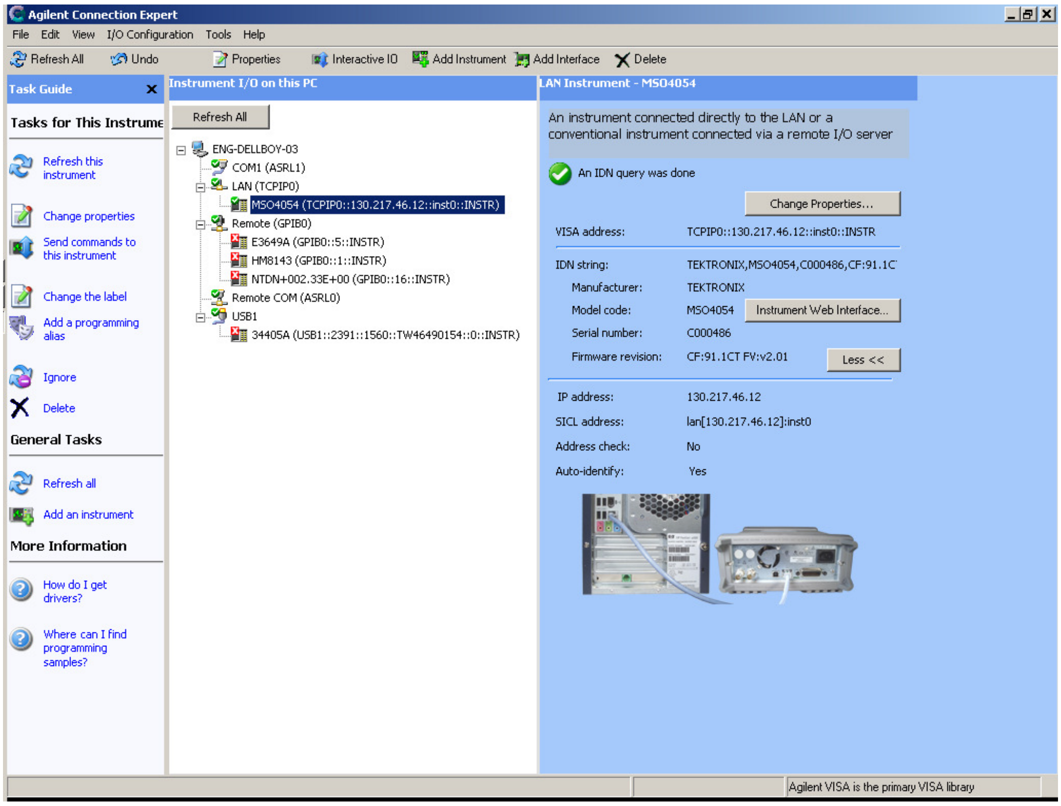

Figure 1.10 *VISA address example. MSO4054 connection properties on the right hand side shows the connection interface, manufacturer, model, serial number, firmware version, and other information related to the specified instrument. The required VISA address is located in the upper right hand side of the window just below the Change Properties button. Select all characters before "::INSTR" and press CTRL + C.*

Step 5: Locating and copying VISA address. On the right hand side, the user should locate a property named "VISA address". Select the address up to the "::INSTR" and press CTRL + C. For example, you should have copied the address as "TCPIP0::130.217.46.12::inst0".

Step 4: To paste the VISA address. Move to a command window (such as the Windows command shell) to run the command set, right click on the window and select "paste." The user should see the VISA address pasted into the command line window as shown in figure 1.11.

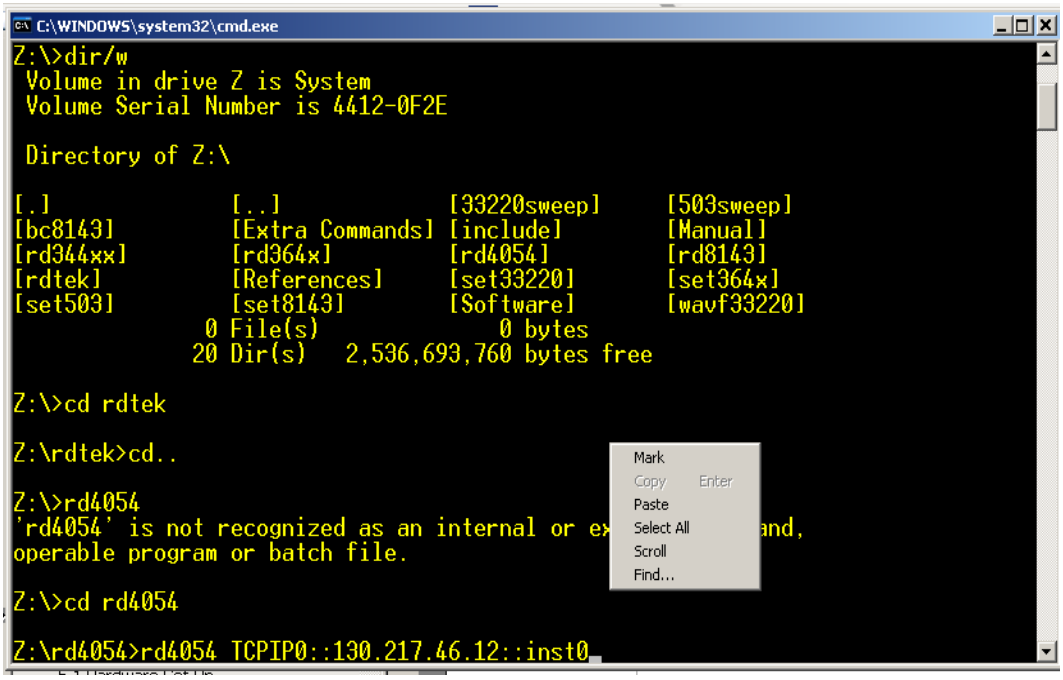

Figure 1.11 *Pasting VISA address in command. Single right clicks on the command window triggers the small grey window, which allows the user to paste the copied VISA address in the current cursor position. In this screen the address is already pasted after the command rd4054.*

2. Power Supply Unit

This chapter introduces the basic hardware set up steps and the VISA commands used. The power supplies involved in this chapter are HAMEG HM8143, Agilent E3646A, E3647A, E3648A, and E3649A. These power supply units are all dual channel outputs. The HM8143 can output 0~30v VDC with up to 2A current supply and have the capability of measuring the actual voltage and current. Agilent E3646A can output 0~20.6V DC voltage, 0~1.545A DC current and 1~22V over voltage protection level. Agilent E3647A can output 0~61.8V DC voltage, 0~0.515A DC current and 1~66V over voltage protection level. Agilent E3648A can output 0~20.6V DC voltage, 0~2.575A DC current and 1~22V over voltage protection level. Agilent E3649A can output 0~61.8V DC voltage, 0~0.824A DC current and 1~66V over voltage protection level.

Be aware the devices may have minor differences in the set up procedures. Please refer back to the individual device user manual for more details if the set up procedures are insufficient in this chapter.

There are two types of commands in this chapter, the first, command is responsible for setting up the voltage, current, protection, and other parameters of the power supplies they are set8143 and set364x. Second, commands responsible for measuring actual sensed values are rd8143 and rd364x. Please refer to individual sections in this chapter for more details of the VISA commands listed above.

2.1. Hardware Set Up

HAMEG HM8143

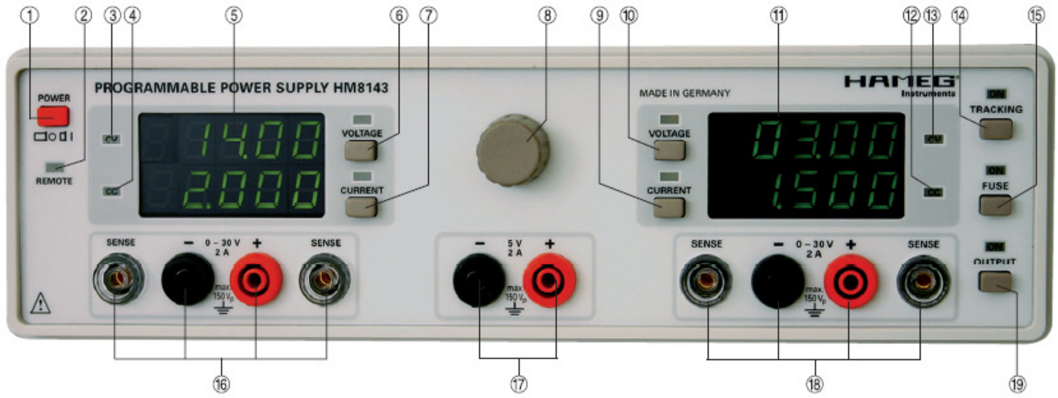

Figure 2.1 *The front panel of HAMEG HM8143. Number 1 is the main power of HM8143, number 19 is the output power switch. The power will not output power until the output switch has been turned on. The user may confirm the connection and power settings by just turning the main power on without turning the output on. In number 16 and 18 the sense connectors are those transparent connectors. [Source: HAMEG HM8143 Arbitrary Power Supply The user Manual, HAMEG Ref: 6]*

Figure 2.2 *The back panel of HAMEG HM8143. The connector at the upper left hand side is the GPIB connector in this case, or it could also be a RS-232 connector. [Source: HAMEG HM8143 Arbitrary Power Supply The user Manual, HAMEG Ref: 6]*

Step 1: Connect GPIB according to connector at the back of HM8143.

Step 2: Turn on the main power and confirm for any abnormal errors.

Step 3: Following the steps in Appendix A accordingly to complete and confirm the device is added correctly.

Step 4: Follow the steps in section 1.6 VISA Address HOWTO in the thesis and copy the VISA address.

Step 5: Open the command prompt and go the VISA commands folder, at this stage, everything should be set up properly and ready to use the VISA commands to control the HM8143.

<u>Agilent 364xA</u>

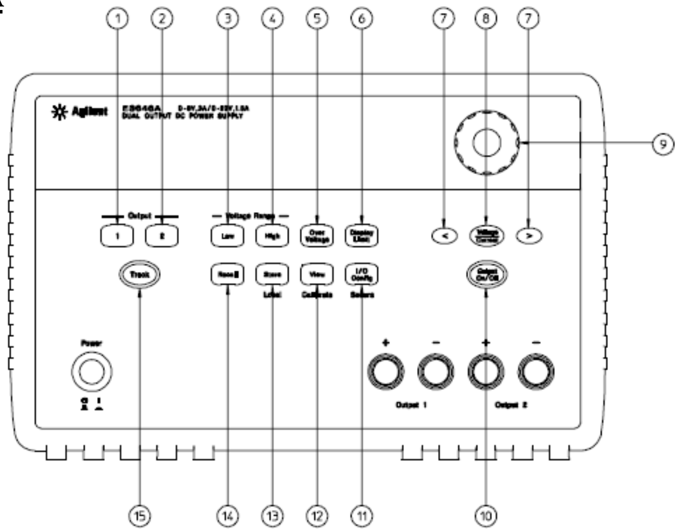

Figure 2.3 *The front panel of Agilent E364xA model series. The user can configure settings and view the current settings from the front LCD display. The 364x series have one manual power switch for turning the instrument on and the software and front panel control output switch for outputting power to the object circuit. [Source: Agilent E364xA Dual Outputs Power Supplies, Agilent Ref: 7]*

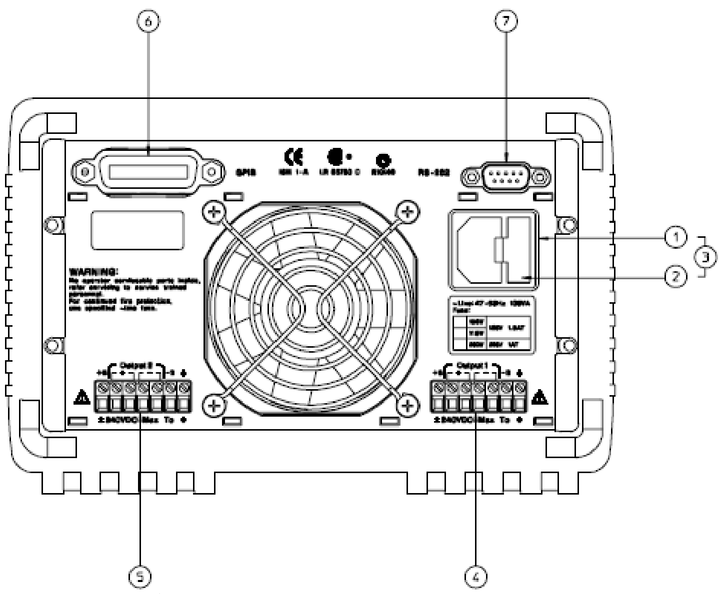

Figure 2.4 *The back panel of Agilent E364xA model series. Number 3 is the AC power input and the fuse for E364xA, number 7 is the male serial connector, number 6 is GPIB connector. [Source: Agilent E364xA Dual Outputs Power Supplies, Agilent Ref: 7]*

r PC according to user's requirement.

Step 2: Following steps in Appendix A accordingly to complete and confirm the device is added correctly.

Step 3: Follow steps in section 1.6 VISA Address HOWTO in the thesis and copy the VISA address.

Step 4: Open up the command prompt and go to the VISA commands folder.

By now, it is ready for users to use the VISA commands to control the 364xA model series.

2.2. Set8143

This command sets up the voltage and the current of HM8143, then output power to the user desired channel. The user are required to input VISA address of HM8143 (1.6 VISA Address HOWTO), desired output channel, output voltage, current limitation, electronic fuse, and output switch status. Entering the command name only will activate the quick help for the command. The parameters in this command must be entered and cannot be ignored.

Addr – The VISA Address of the desired instrument. Please refer to steps in section 1.6 VISA Address HOWTO.

Ch - Output channel can be 1, 2 or ALL. When channel sets to 1 or 2, only the specified channel number will be set up but both channels will be updated with the new settings. When the channel sets to ALL, both 1 and 2 channels will be set up and outputting the power simultaneously.

Volt - The applicable voltage range is from 0V to 30V.

Current - Valid current range is from 0A to 2A. Over all power available on HM8143 is 60W (DC).

Fuse - If electronics fuse is activated, the output power will automatically terminate when current drawn excess the limitation you set. If the electronics fuse is deactivated, constant current mode will be activated automatically when actual current drawn excess the limitation you set.

SW - The output switch status allows you to turns on or off the output power manually by the command.

Related Sections: 1.6 VISA address HOWTO, 2.2 rd8143

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: SET8143 1.00 by DH, Jan 2008
Hardware: HAMEG HM8143.
Software Description: Set HM8143 voltage and current.

USE FORMAT:
set8143 Addr Ch Volt Current Fuse SW

Addr:	The address of the desired device. e.g.USB1::1689::869::C020200::0
Ch:	Desired Channel. Range: 1, 2, ALL
Volt:	Set voltage. Range: 0 ~ 30V
Current:	Set current. Range: 0 ~ 2A
Fuse:	Activate electronic fuse. Range: ON, OFF
SW:	Power switch. Range: ON, OFF

2.3. Rd8143

This command reads the voltage and current from the user specified channel on HAMEG HM8143 and records the value at the user's request. The user has to enter the VISA address, desired channel, and punctuation mark. Entering only the command name will activate the quick help.

Addr - VISA address can be obtained by following the steps in the related section, 1.6 VISA Address HOWTO.

Ch – The user is allowed to select 1, 2 or ALL as a channel input parameter, and when the user input is either 1 or 2, the command will read the voltage and current from the corresponding channel output. When the user selects ALL, the command will read voltage and current on both channels in sequence.

Punc – The user may also specify a punctuation mark for command comment lines in the recorded file. When the punctuation mark is not specified, the command output reading will be directly onto the screen without recording into a file. When the punctuation mark is specified, rd8143 will activate the file recording function. The recorded file name is data.csv and is located under the same path of rd8143.exe. The format of the recorded file is in CSV format, and the user should be aware of the size of the recorded file. The output file will accumulate the user's command echo, and detected values in the recorded file.

If the channel parameter is 1 or 2, the output file content will be in the format of:

Time, Set Volt (1 or 2), Read Volt (1 or 2), Set Current (1 or 2), Read Current (1 or 2)

The Set Volt and Set Current are the voltage and current limits of the previous settings in the HM8143. Read Volt and Read Current is the actual measured figure by HM8143.

If the channel parameter is ALL, file content will be:

Time, Set Volt 1, Read Volt 1, Set Current 1, Read Current 1, Set Volt 2, Read Volt 2, Set Current 2, Read Current 2

Related Sections: 1.6 VISA Address HOWTO, 2.2 set8143

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: RD8143 V1.00 by DH, Jan 2008
Hardware: HAMEG HM8143.
Software Description:
Read HM8143 voltage and current.

USE FORMAT:
rd8143 Addr Ch Punc

Addr:	The address of the desired device. e.g.USB1::1689::869::C020200::0
Ch:	Desired Channel. e.g. 1, 2, ALL
Punc (optional):	Set punctuation mark. This optional function will enable recording function. Recorded file named data.csv e.g. /, *...etc DEF=#

2.4. Set364x

Set364x will set up the voltage and current for Agilent E3646A, E3647A, E3648A, and E3649A. The user is required to enter the VISA address, output, voltage, current, over voltage protection (OVP) and power switch status. Entering only the command name will activate the quick help. The user may use lower or upper case of X to ignore the parameter. The ignored parameter will not change from the previous setting.

Addr – The VISA address of the instrument. Steps in section 1.6 will lead you to VISA address.

Output - Output is the user desired output channel, available choices are 1, 2, or ALL. When either 1 or 2 is selected, only the correspondent output will be updated with new settings. When ALL is selected, both output 1 and 2 will be updated with same settings.

Volt - Volt is setting the maximum allowable voltage supplied from E364xA series. Refer to table 2.1 for range. Key in x or X in this parameter for not changing this particular setting.

Current - Current is the maximum allowable current supplied from E364xA series. When current limit is reached, E364xA will switch to constant current mode automatically. Please refer to table 2.1 for the parameter range. Key in x or X in this parameter will not change this particular setting.

OVP - OVP is over-voltage protection, which will cause power output shortening to internal SCR when peak voltage exceeds the OVP limit in voltage. As a result, the power will not be delivered to the output channel. Each channel has individual OVP settings. When the channel parameter is ALL then the OVP for both channels will be updated with the same status. The OVP parameter can be OFF, CLR and the range is in table 2.1. When the OVP is set to CLR, the OVP trigger will be clear and the output power will no longer short to internal SCR. When voltage limit is reached and OVP is deactivated, E364xA will go to constant voltage mode or else E364xA will perform as described above. Key in x or X in this parameter to not change this particular setting.

SW – The software and the push button at the front panel can control the output function. The user may select "ON" for output power to the object circuit or "OFF" to disable the power output. This is the main power output switch. Turning off this switch will not terminate the communication with the power supply unit.

Table 2.1 indicates the maximum voltage, current and OVP range available for different models.

	E3646A	E3647A	E3648A	E3649A
VOLT (V)	0 ~ 20.6	0 ~ 61.8	0 ~ 20.6	0 ~ 61.8
CURRENT (A)	0 ~ 1.545	0 ~ 0.515	0 ~ 2.575	0 ~ 0.824
OVP (V)	1 ~ 22	1 ~ 66	1 ~ 22	1 ~ 66

Table 2.1 *Agilent E364xA series power supply range [7]*

Related Sections: 1.6 VISA Address HOWTO, 2.5 rd364x

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: SET364x 1.00 by DH, Jan 2008
Hardware: Agilent 364xA series.
Software Description:
Set up 364xA voltage and current.

USE FORMAT:
set364x Addr Output Volt Current OVP SW

Addr: The address of the desired device.

e.g.USB1::1689::869::C020200::0

Output: Desired output.

e.g. 1, 2, ALL

Volt: Set voltage. x=ignore

Current: Set current. x=ignore

OVP: Over voltage protection. x=ignore

Range: OFF, CLR, 1~22(3646(7) A), 1~66(3647(9) A)

SW: Power switch.

Range: ON, OFF

2.5. Rd364x

Rd364x allows the user to measure the voltage and current values from one or both output channels of the Agilent 364xA series power supply. It requires the user to enter the VISA address, output channel, and punctuation mark. Entering only the command name will activate the quick help.

Addr – The VISA address of the desired instrument. Please refer to steps in section 1.6 VISA Address HOWTO.

Output – The output channel that the user wishes to measure from. The user is allowed to select 1, 2, or ALL. When either 1 or 2 is selected, only the corresponding output channel is measured. When ALL is selected, both channel 1 and 2 will be measured.

Punc – The user may specify a punctuation mark for the command comment lines in the recorded file. When the punctuation mark is not specified, the command will output the reading directly onto screen without recording into the file, data.csv. When punctuation mark is specified, rd364x will activate the file recording function. The recorded file name is data.csv and located under the same path of rd364x.exe. The format of the recorded file is in

CSV format, and the user should be aware of the size of the recorded file. The output file will accumulate the user's command echo and detect values in the recorded file.

If channel parameter is 1 or 2, output file content will be in the format of:

Time, Volt (1 or 2), Current (1 or 2)

If the channel parameter is ALL, file content will be:

Time, Volt1, Current1, Volt2, Current2

Related Sections: 1.6 VISA Address HOWTO, 2.4 set364x

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: RD364x V1.00 by DH, Jan 2008
Hardware: Agilent 364xA series.
Software Description:
Read 364xA voltage and current.

USE FORMAT:
rd364x Addr Output Punc (Optional)

Addr: The address of the desired device.
e.g.USB1::1689::869::C020200::0
Output: Desired output.
e.g. 1, 2, ALL
Punc (Opt): Set punctuation mark.
e.g. #, *...etc. DEF = #

---

3. Digital Multimeters

The digital multimeters used in this chapter are Agilent 34401A, 34405A, 34410A, 34411A. Generally, the read command should accommodate required general reading. However, the communication bus and few advanced functions might be different between different models. Advanced functions for these devices are not provided with this reading measurement command. Command rd344xx is capable to read common measurements available in Agilent 344xxA model series such as DC, AC voltage, DC, AC current, resistance, temperature, frequency, capacitance, continuity and diode voltage. 34401A have a GPIB and a RS-232 bus interface, where 34405A has only one full speed USB interface. Both 34410A and 34411A have LAN, USB and GPIB interfaces. The user is not able to specify the name of the recorded file, because the command will accumulate the command echo and measured value in order to let the user to process data and logging command history.

3.1. Hardware Set Up

Apart from RS-232, other connections are relatively simple to establish. GPIB, LAN, and USB connections only require related cable and simply connect to related interface. The reader should refer to the Appendix A for the installation details for each interface.

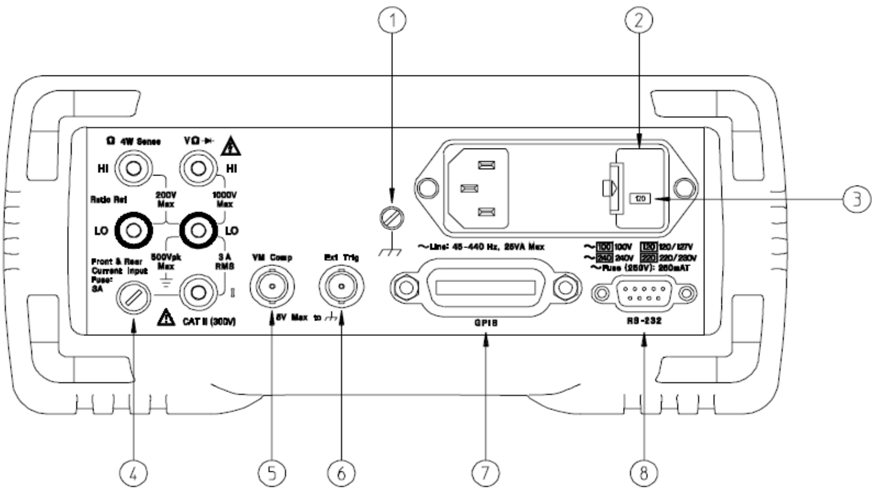

Figure 3.1 *The back panel of Agilent 34401A. Number 7 is the GPIB interface and number 8 is RS-232 interface. Number 2 and 3 are the power fuse and AC line rating setting. [Source: Agilent 34401A 6.5 Digit Multimeter The user's Guide, Agilent, Ref 8]*

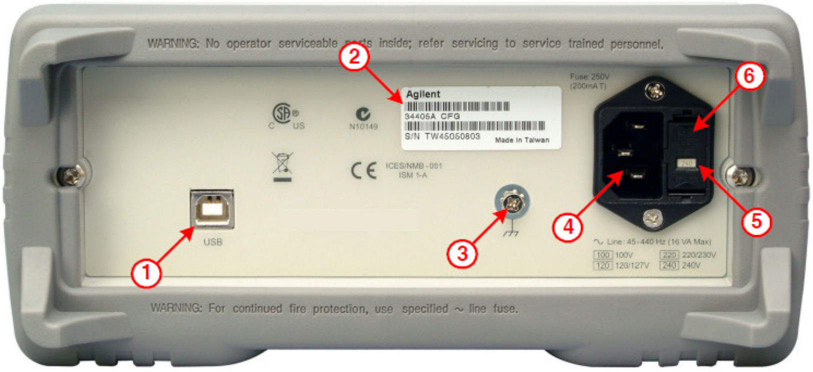

Figure 3.2 *The back panel of Agilent 34405A. Number 1 is the USB interface. Number 6 and 5 are the AC line fuse and setting. [Source: Agilent 34405A 5.5 Digit Multimeter The user's and Service Guide, Agilent, Ref 9]*

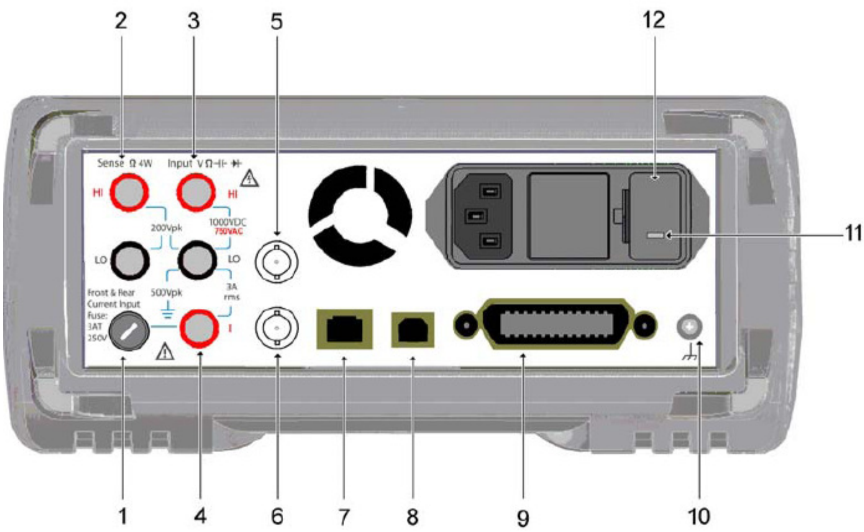

Figure 3.3 *The back panel of Agilent 34410A & 34411A. Number 9 is GPIB connector, number 8 is USB B connector, number 7 is LAN connector and number 11 is the power supply voltage rating. [Source: Agilent 34410A/11A 6.5 Multimeter the user's Guide, Agilent, Ref 10]*

USB & GPIB Connection

Step 1: Prepare a USB or a GPIB cable as described in section 1.5 Hardware Requirements.

Step 2: Connect the USB cable to the device (34405A, 34410A, 34411A), or make connection with GPIB cable to Agilent E5810A and the device (34401A, 34410A, 34411A)

Step 3: Following steps in Appendix A accordingly to complete and confirm the device is added correctly.

Step 4: Follow steps in section 1.6 VISA Address HOWTO in the thesis and copy the VISA address.

LAN connection

Step 1: Prepare a straight RJ45 cable for connection to computer network or a crossed over RJ45 for direct connection to the PC.

Step 2: Make required connection based on user's requirement.

Step 3: Following steps in Appendix A accordingly to complete and confirm the device is added correctly.

Step 4: Follow steps in section 1.6 VISA Address HOWTO in the thesis and copy the VISA address.

RS-232 Connection

Step 1: Prepare one DB9 null-modem as described in section 1.5 Hardware Requirements in this thesis and connect the cable accordingly.

Step 2: Following steps in Appendix A accordingly to complete and confirm the device is added correctly.

Step 3: Follow steps in section 1.6 VISA Address HOWTO in the thesis and copy the VISA address.

3.2. rd344xx

Rd344xx reads the value of the current activated function from Agilent 344xxA series multimeters. Available readings are DC voltage, DC current, AC voltage, AC current, resistance, capacitance, temperature, diode, frequency and continuity. In continuity, the programme shows high or low resistance reading in ohms to indicate the connectivity. For example, value 46999E999 ohms for not conductive or 2.34E-8 ohms for conductive. Continuity reading only gives either extremely high or extremely low impedance in ohms, where resistance measurements are not extreme to high or low values. The programme requires user to input device VISA address and punctuation mark. It will identify the current function setting on 344xxA automatically and obtain required reading. On the other hand, this programme does not provide function switching ability. The user must change the desired function to read manually on the front panel of the instrument. Entering only the command name will activate the quick help.

Addr – VISA address. Refer back to chapter 1.6 VISA Address HOWTO.

Punc – The punctuation mark for comment lines in the recorded file. The user may specify desired punctuation mark to comment out lines unwanted for analysis software to process. Enabling this function will activate recording file else, the command will not record the value into the file. The read value will be output to data.csv along with measurement time stamp.

The recorded file format as following:

Time, Function (Unit)

Where time is hour:mins:secs and function is the function selected by user from the front panel such as Freq (Hz), VDC (V), IAC (A)…etc.

Related Sections: 1.6 VISA Address HOWTO

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007

Software Info: RD344xx V1.00 by DH, Jan 2008

Hardware: Agilent 3344xx series.

Software Description:

Read Agilent 344xx series.

USE FORMAT:

rd344xx Addr Punc

Addr: The address of the desired device.

e.g.USB1::1689::869::C020200::0

Punc (optional): Set punctuation mark.

This optional function will enable recording function.

Recorded file named data.csv

e.g. /,%,&,$,#...etc DEF=#

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4. Function Generators

Function generator chapter involves 2 generators, Agilent 33220 and MOTECH FG503. The FG503 supports GPIB and RS-232 interface and capable of outputting sine, square, triangle, ramp up, ramp down and DC waveforms. The output impedance is fixed at 50 ohms with 5% variation. The over voltage protection of FG503 cannot exceed 20V peak. Agilent 33220 can output sine, square, ramp, negative ramp, noise, DC, exponential rise, exponential fall, sinc, cardiac and arbitrary waveforms. Agilent 33220A allows LAN, USB and GPIB communication interfaces. Majority commands in Extra Command section of this thesis is involved with set up in details for Agilent 33220A. The identification of the commands is command name starting with 33220.

4.1. Hardware Set up

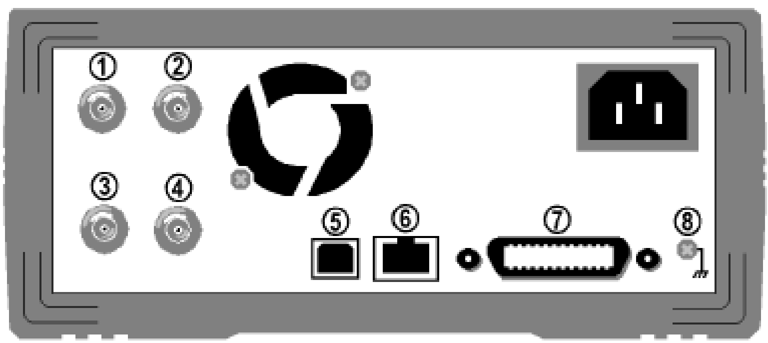

Figure 4.1 *The back panel of Agilent 33220A. Number 7 is the GPIB interface, number 6 is the LAN interface and number 5 is the USB B interface. [Source: Agilent 33220A 20MHz Function / Arbitrary Waveform Generator, Agilent, Ref 11]*

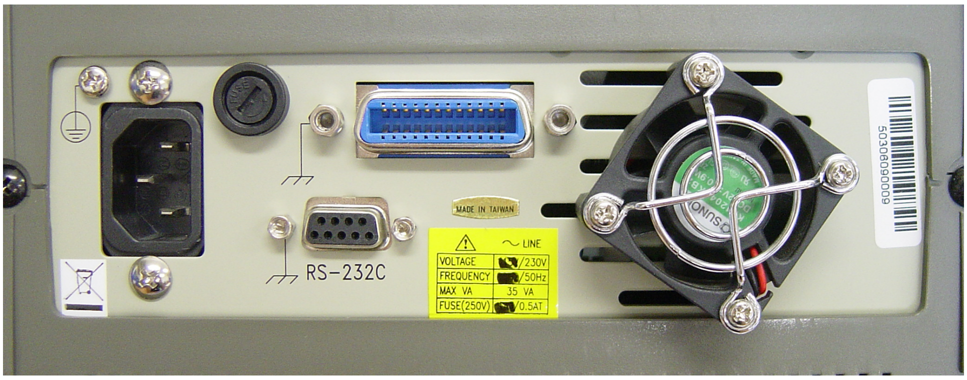

Figure 4.2 *The back panel of MOTECH FG503. The blue connector is the GPIB connector and the black 9 pins connector is the RS-232 interface.*

Step 1: Connect USB, LAN, RS-232 or GPIB cable to correspondent connector on the FG503 and the E5810A gateway. The RS232 and the USB cable may also connect direct to the user's PC.

Step 2: Follow steps in Appendix A accordingly to complete and confirm the device has added properly.

Step 3: Follow steps in section 1.6 VISA Address HOWTO in the thesis and copy the VISA address.

By now, the instrument should be ready to use with the VISA commands introduced in this chapter.

4.2. set33220

This command allows user to set up and output desired waveform with user specified frequency, amplitude, offset, duty-cycle and symmetry. The user can also use the internal built arbitrary functions as well as user defined arbitrary function. With user defined arbitrary function, user must use command wavf33220 before applying command set33220 in order to output defined waveform properly. All parameters in this command can be ignored by entering lower or upper case of X. The ignored parameters will be remaining the same from last change. All parameters must are compulsory. Quick command help can be obtained by just entering the command and then press Enter. The quick help will indicates the exact applicable parameters followed by a simple parameter description.

Addr – VISA address. Refer to 1.6 VISA Address HOWTO.

Wavf – The desired waveform function. Available choices are sine, square, ramp, pulse, noise, DC, exponential rise, exponential fall, negative ramp, sinc, cardiac, arbitrary 1, arbitrary 2, arbitrary 3, arbitrary 4. The arbitrary 1 to 4 waveform is the user-defined waveform, which is required to run wavf33220.exe before set33220.exe in order to work properly, else error will occur and warning message will show on the screen of 33220A. Other waveform functions do not need pre-run command.

Freq – The desired frequency of the waveform. Each waveform allows different applicable frequency range. The following table 4.1 shows the applicable frequency range for different waveform functions.

Function	Min Freq (Hz)	Max Freq (Hz)
Sine	1E-6	20E6
Square	1E-6	20E6
Ramp	1E-6	200E3
Pulse	500E-6	5E6
Noise, DC	N/A	N/A
Arbitrary	1E-6	6E6

Table 4.1 *The frequency range of Agilent 33220A.*

Amplitude – the desired peak-to-peak voltage of the waveform with unit V. Set33220 only provides peak-to-peak voltage setting. The user may use commands of 33220 in Appendix D Extra Commands section for other amplitude settings such as RMS. The limit of amplitude is in relation of offset setting as shown in equation 4.1 below.

$$|Voffset| + \frac{Vpp}{2} \leq V\max$$

Equation 4.1 *The relation equation between Vpp & Voffset for Agilent 33220A.*

Offset – the desired offset level in V. Offset parameter is the amplitude when waveform is in DC function. For other waveform functions, the limit of offset is in relation with Vpp as shown in Equation 4.1. If the offset made the Vpp exceeds Vmax, 33220A will reduce offset for complete waveform shape to be inside the Vmax limit.

Dcyc/Symm – the desired duty-cycle or symmetry depends on the selection of waveform function. When the waveform functions is in square or pulse waveform, this parameter acts as the duty-cycle of the function. When waveform function is in ramp, this parameter acts as symmetry of ramp function. This parameter is ignored if the chosen function is not square or ramp and the previous setting will remain. The range of this parameter is in percentage of a cycle of the waveform. For square waveform, the range is show in Table 4.2. For ramp waveform function, the range is from 1 to 100. For pulse waveform, the range is from 0 to 100. Command set33220 is only a general command to set up all waveform provided by 33220A. Detailed set up command for pulse can be found in Appendix D Extra Commands section.

	Freq <= 10E6	Freq > 10E6
Min %	20	40
Max %	80	60

Table 4.2 *The range of square waveform duty-cycle for Agilent 33220A.*

Pwr – the power switch allows user to turn on or off 33220A manually via command. Selections are ON or OFF.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

---

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: set33220 V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set and output desired waveform signal.

USE FORMAT:
set33220 Addr Wavf Freq Amp Offset Dcyc/Symm Pwr

Addr: The address of the desired device.
Wavf: Desired waveform function.
Range:SIN,SQU,RAMP,PULS,NOIS,DC,ERIS,EFAL,NRAMP,SINC,CARD,ARB1,ARB2,ARB3,ARB4
Freq: The waveform frequency.
Amplitude: Set desired amplitude.
Offset: Waveform offset value. (Offset=Amp when Wavf=DC)
Dcyc/Symm: Desired Duty cycle (Pulse/Square)
or Symmetry (Ramp)
Range: 0~100
Pwr: Power switch.
Range: ON, OFF

4.3. 33220sweep

This command allows the user to perform frequency sweeping with Agilent 33220A. The 33220A will output signal from the start frequency towards the end frequency when the preset trigger is met. First seven parameters are compulsory and cannot be ignored by entering low or upper case of X. The desired waveform function must be pre-selected by using set33220 or detailed commands in Appendix D Extra Commands section before using 33220sweep. The command 33220sweep only set up and activate the sweeping function rather than setting up the waveform. The user may write script file to run specific task. Quick command help can be obtained by just entering the command and then press Enter.

Addr – VISA address. Refer to 1.6 VISA Address HOWTO.

Startf – The desired start frequency for sweep. The range for ramp waveform is from 1E-6 to 200E3. The range for arbitrary function is from 1E-6 to 6E6. Range for other waveform is from 1E-6 to 20E6. The user may also enter MIN or MAX to select the minimum and maximum of the frequency range of each waveform function.

Stopf – The desired stop frequency for sweep. The range is the same as the start frequency. If the start frequency is large than stop frequency, the sweeping is downwards. If the start frequency is smaller than stop frequency, the sweeping is upwards.

Mode – The desire type of sweeping. The user may choose LIN, linear spacing sweeping or LOG, logarithmic spacing sweeping. Other enters are not applicable.

Dur – The duration of the sweep. The user may control the length in time for the sweep. 33220A will automatically adjust the interval of the sweep evenly. The unit of this parameter is in second. The range is from 1E-3 to 500E0. The user may also enter MIN or MAX to select minimum or maximum duration.

Trgsou – The user uses this parameter to choose the desired trigger source for sweep to activate. INT is using internal trigger, which will cause continuous sweeping. EXR is using external rising edge for triggering signal. The sweeping function will not be activated until 33220A received a rising edge from external source. EXF is using external falling edge for triggering signal. The sweeping function will not be activated until 33220A received a falling edge from external source. MAN is using manual triggering, which user may send the manual trigger signal by using 33220trg in Extra Commands section. Sweeping function will not be activated until the manual trigger signal is received either by the command 33220trg.exe or from the trigger button at the front panel.

Trgout – This parameter allows user to output the trigger out signal when the sweeping starts from the Trig-Out connector at back panel of 33220A. The choice can be rising edge or falling edge signal.

Markerf (Optional) – The frequency limit to put logic low at Sync during sweeping. Therefore, the Marker frequency must be between the start and stop frequencies.

Related Sections: 1.6 VISA Address HOWTO, 4.2 set33220, 4.4 wavf33220, Appendix D: Extra Commands

---

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220sweep V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set & enable frequency sweep function.

USE FORMAT:

33220sweep Addr Startf Stopf Mode Dur Trgsou Trgout Markerf (optional)

Addr: The address of the desired device.
e.g.USB1::1689::869::C020200::0
Startf: Start frequency. Startf < Stopf = Sweep up
E.g. MAX, MIN, 1E-6 ~ 20E6 (200E3 for Ramp, 6E6 for Arbitrary).
Stopf: Stop frequency. Stopf > Startf = Sweep down.
E.g. MAX, MIN, 1E-6 ~ 20E6 (200E3 for Ramp, 6E6 for Arbitrary).
Mode: Choose linear/log sweep.
E.g. LIN, LOG
Dur: Set sweep duration time. (Seconds)
E.g. MAX, MIN, 1E-3 ~ 500E0
Trgsou: Choose trigger source. MAN uses 33220trg.exe to send trigger signal.
E.g. INT, EXR, EXF, MAN
Trgout: Turn on trigger output.
E.g. OFF, RISE, FALL
Markerf (Optional): Select frequency triggers SYNC to low in sweep.
E.g. MAX, MIN, 1E-6 ~ 20E6 (200E3 for Ramp, 6E6 for Arbitrary).

4.4. wavf33220

This command allows user to upload user-defined waveform from a file to Agilent 33220A as an arbitrary waveform and store in non-volatile memory in 33220A. The user is required inputting device VISA address, waveform file with file type and desired non-volatile memory slot. The waveform file is just defining the shape of the waveform, user may very the period, amplitude and offset by using set33220 or using 33220arb in Extra Commands section. The values of the waveform file are in percentage from 0 to 100 without the percentage mark. These values must be separated by comma, any other punctuation mark might cause problem. The user can enter up to 65536 points in the waveform file. It is not necessary to repeat the same sequence of point levels, because 33220A will cycle user's waveform setting automatically. Therefore, user only required entering only one period of desired waveform in the waveform file. All parameters in this command are compulsory, and cannot be ignored by enter lower or upper case of X.

Addr – VISA address of device. Refer to 1.6 VISA Address HOWTO.

File.type – The name and type of the file, which contain the user defined waveform. The content value is in percentage and must be separated by comma.

ARB# - The name of the non-volatile memory in the 33220A for storing uploaded waveform. Available choices are 1, 2, 3 and 4. The user may also use the front panel of 33220A to check. The display name should be ARB1, ARB2, ARB3 or ARB4.

Related Sections: 1.6 VISA Address HOWTO, 4.2 set33220, 4.3 33220sweep, Appendix D: Extra Commands

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```
Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: wavf33220 V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
  Read arbitrary waveform from file and set up 33220A.

USE FORMAT:
wavf33220 Addr File.type ARB#

Addr:           The address of the desired device.
File.type:    Name of waveform file. Include file type.
ARB#:          The waveform number to store waveform on 33220A.
                      Range: 1,2,3,4.
```

4.5. set503

This command allows user to set up MOTECH FG503 3MHz DDS function generator. The FG503 does not provide software switch to turn on or off the instrument, nor the set503 command. The user must be cautious before changing the settings of the FG503 while experiment object is connected. The FG503 does not provide arbitrary waveform, therefore the set503 command will not support as well. The FG503 does not provide changeable detailed settings such as duty-cycle and symmetry. The output impedance of FG503 is 50 ohms with 5% variation range. The set503 command allows the user to ignore the parameter by inputting lower or upper case of X. Set503 will not change the ignored parameter. The user can enter only the command name to activate the quick help.

Addr – Device VISA address. Refer to 1.6 VISA Address HOWTO.

Func – The user desired waveform function. The available choices are sine, square, triangular, ramp up, ramp down and DC.

Freq – The desired frequency for the waveform. Each waveform has certain range limit for user to use. Table 4.3 below shows the range of frequency for different waveforms.

Function	Min Freq (Hz)	Max Freq (Hz)
Sine	10E-3	3E6
Square	10E-3	3E6
Triangule	10E-3	20E3
Ramp	10E-3	20E3

Table 4.3 *The frequency characteristics of FG503.*

Amp – The user desired peak-to-peak voltage of the waveform. FG503 can outputs 40mVpp to 20Vpp without load. The limit of amplitude is in relation with offset level. Equation 4.2 shows the relation of the amplitude and offset level for FG503. When amplitude (Vp) is between 1V to 10V, the sum of offset level and amplitude cannot be larger than 5V. When amplitude (Vp) is between 100mV to 1V, the sum of offset level and amplitude cannot be larger than 1V. When amplitude (Vp) is lower than 100mV, the sum of offset level and amplitude cannot be larger than 100mV.

$$|Voffset| + Vp \leq 5V \, (1V \leq Vp \leq 10V)$$
$$|Voffset| + Vp \leq 1V \, (100mV \leq Vp < 1V)$$
$$|Voffset| + Vp \leq 100mV \, (Vp < 100mV)$$

Equation 4.2 *The relation between offset and peak-to-peak voltage of FG503.*

Offs – The desired offset level. The offset level shares the same relation with amplitude above in equation 4.2.

Related Sections: 1.6 VISA Address HOWTO, 4.6 503sweep

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: SET503 V1.00 by DH, Jan 2008
Hardware: MOTECH FG503.
Software Description:
 Set up & output desired waveform on FG503.

USE FORMAT:
set503 Addr Func Freq Amp Offs

Addr: The address of the desired device.
 e.g.USB1::1689::869::C020200::0
Func: Desired function output. x=no change
 Range: SIN, SQU, TRI, RUP, RDW, DC
Freq: Desired frequency. x=no change
 Range: 10E-3~3E6 (SIN, SQU), 10E-3~20E3 (TRI, RUP, RDW)
Amp: VPP amplitude. x=no change

Range: 40E-3~20V

Offs: Waveform offset. x=no change

4.6. 503sweep

503sweep allows user to perform frequency-sweeping function on the FG503. The instrument is capable of sweeping range set up by user or sweeping the audio frequency range. Similar to 33220sweep, 503sweep requires user to enter device address, start, stop frequencies, sweep type and sweep duration. The users have to use set503 to setup the waveform function desired and than run 503sweep in order to output desired waveform with sweeping function. Parameters in 503sweep can be ignored by entering lower or upper case of X. Ignored parameters will not be changed from last settings. Entering only the command name will activate the quick help.

Addr – The device VISA address. Refer to 1.6 VISA Address HOWTO.

Mode – Desired sweep mode. The user can enter NOR for user defined sweeping range or AUD for audio frequency sweeping. In AUD mode, only Addr and Mode are required, other parameters are not necessary and will be ignored. The audio sweeping mode will outputs sine wave with user defined amplitude and 0V offset. The start frequency is 100Hz and stop frequency is 100 KHz with logarithm sweeping. Sweeping duration will be 20 seconds and cycling.

Startf – The start frequency of the sweeping function. The range of start frequency is shown in Table 4.3 in previous page. This parameter will be ignored when sweep mode is in audio.

Stopf – The stop frequency of the sweeping function. The range of stop frequency is shown in Table 4.3 in previous page. This parameter will be ignored when sweep mode is in audio.

Type – The desired sweep type. The user may choose either linear (LIN) of logarithm (LOG) sweeping.

Time – The desired sweep duration in seconds. This parameter will be ignored automatically when sweeping mode is in audio.

Related Sections: 1.6 VISA Address HOWTO, 4.5 set503

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 503SWEEP V1.00 by DH, Jan 2008
Hardware: MOTECH FG503.
Software Description:
Sweep a frequency range on FG503.

USE FORMAT:
503sweep Addr Mode Startf Stopf Type Time

Addr: The address of the desired device.
e.g.USB1::1689::869::C020200::0
Mode: Desired sweep mode. x=no change
Range: NOR, AUD
Startf (Mode=NOR): Desired start frequency. x=no change
Stopf (Mode=NOR): Desired stop frequency. x=no change
Type (Mode=NOR): Sweep type. x=no change
Range: LIN, LOG
Time (Mode=NOR): Sweep duration.

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5. Oscilloscopes

The devices used in this chapter are Tektronix TDS, TPS and 4000 series oscilloscopes. The VISA commands in this chapter can download the waveform form the oscilloscopes and store the values into a user named file. In the Appendix D Extra Commands section, there are few more commands that allow the user to set up vertical, horizontal and triggering scale.

The rdtek command is designed for Tektronix TDS and TPS series, the rd4054 command is designed for Tektronix 4000 series. The user is not advised to download a long length in time waveform, due to the embedded software design in these instruments the longer time length to record the longer time will require. The PC resources such as RAM and hard drive will be in high demands if the user requires very long downloaded waveform.

5.1. Hardware Set Up

In order to use the commands in this chapter properly, the user is required to have USB, straight RJ45, crossed over RJ45 and RS-232 cables ready depends on user's connection. TDS2004B only supports USB connection, TPS2024 only supports RS-232 and MSO4054 supports both USB and LAN. For MSO4054 users may connect the device through local LAN or direct to PC. Therefore, user have to refer back to section 1.5 Hardware Requirements for details of LAN cable.

1. **Trigger Out**. Use the trigger signal output to synchronize other test equipment with your oscilloscope. A LOW to HIGH transition indicates that the trigger occurred. The logic level for Vout (HI) is ≥2.5V open circuit; ≥1.0 V into a 50Ω load to ground. The logic level for Vout (LO) is ≤0.7 V into a load of ≤4 mA; ≤0.25 V into a 50Ω load to ground.

2. **XGA Out**. Use the XGA Video port (DB-15 female connector) to show the oscilloscope display on an external monitor or projector.

3. **LAN**. Use the LAN (Ethernet) port (RJ-45 connector) to connect the oscilloscope to a 10/100 Base-T local area network.

4. **Device**. Use the USB 2.0 High speed device port to control the oscilloscope through USBTMC or GPIB with a TEK-USB-488 Adapter. The USBTMC protocol allows USB devices to communicate using IEEE488 style messages. This lets you run your GPIB software applications on USB hardware.

5. **Host**. Use the USB 2.0 Full speed host ports (three) to take advantage of USB flash drives and printers.

6. **Power** input. Attach to an AC power line with integral safety ground. (See page 7, *Operating Considerations*.)

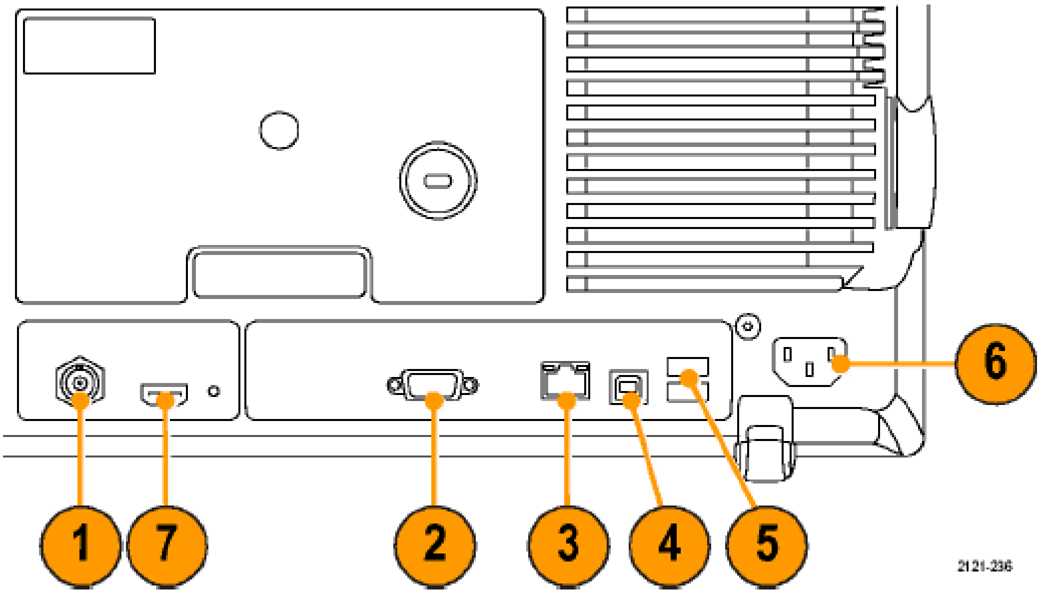


Figure 5.1 *The back panel of Tektronix MSO4054. The MSO4054 is capable of connecting USB and LAN cable, but LAN cable must be crossover when connecting direct to PC. Straight LAN cable should be applicable for other connections. [SOURCE: Tektronix 4000 Series Digital Phosphor Oscilloscopes The user Manual, Tektronix, Ref: 17]*

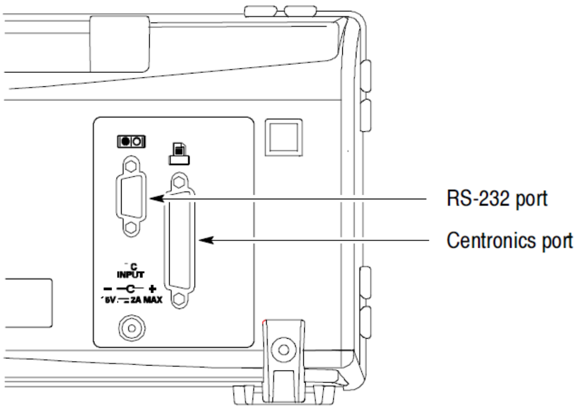


Figure 5.2 *The back panel of Tektronix TPS2024. The TPS2024 only supports RS-232 communication interface that can connect direct to the PC or the RS232 port on Agilent E5810A. [SOURCE: Tektronix TPS2000 Series Digital Storage Oscilloscope The user Manual, Tektronix, Ref: 13]*

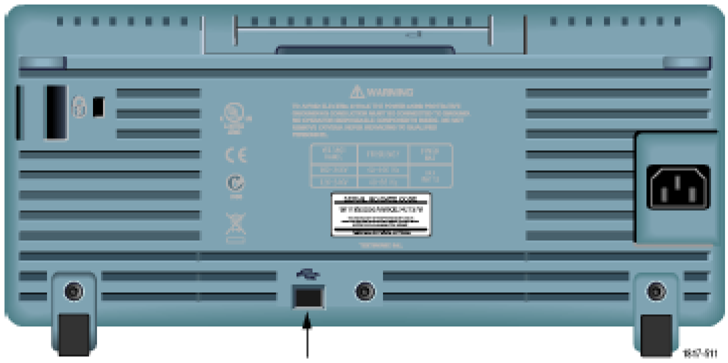


Figure 5.3 *The back panel of Tektronix TDS2004B. The TDS2004B can only connect direct to the PC through the USB cable. [SOURCE: Tektronix TDS1000B and TDS2000B Series Digital Storage Oscilloscope User Manual, Tektronix, Ref: 14]*

Step 1: Connect USB, LAN, RS232 or GPIB cable as required accordingly.

Step 2: Following steps in Appendix A accordingly to complete and confirm the device is added correctly.

Step 3: Follow steps in section 1.6 VISA Address HOWTO in the thesis and copy the VISA address.

5.2. Rdtek

This command allows user to read waveform figures from most of Tektronix TDS and TPS series oscilloscope and store the data into a user named file. The purpose of this command is letting user to download the waveform automatically. This command assumes the proper settings have applied to the device by using front panel control. The user may also use the commands in Appendix D Extra Commands section to tune the device by command. The device in the series group has a pre-set real-time sampling rate of 2 G sample per second. The maximum data points in a screen shot is 2500 points. The points are sampled evenly across the screen of the scope. The waveform figure in the recorded file will be the same when user re-plots the graph. The user is required to input device VISA address, channel number, start time, end time, punctuation mark and recording file name and file type. The only potential problem of this programme is that the longer waveform to record will take longer time and more PC resource to operate. If the required length is extremely long, the programme is very likely to crash due to out of hard disk and RAM resources. As the waveform shift further away from the 0 point in seconds will take longer time to display the waveform. It is because the device is always plotting the waveform graph from the zero point to the user's current position in time axis. This default hardware design is also the reason for the longer processing time of the programme. The more practical way is dividing a long waveform into smaller waveforms for rdtek to record. The comment lines in the recorded file are marked with the default or user defined punctuation mark to avoid other software compatibility problems later. The comments in the recorded file are time, device model, command ran, warning messages and units. All parameters in this command are compulsory; none can be ignored by entering lower or upper case of X.

Device_Address – The VISA address of the device. Refer to 1.6 VISA Address HOWTO.

Channel_Number – The desired channel to record. The user may choose 1, 2, 3, 4 or all. When the selection is a number, only the relevant channel will be recorded. Only when the selection is ALL, the programme will record all 4 channels. The user should understand that more channels to record would increase the demand of time and resources to run the programme successfully. The length of recording should also take into consideration alone with requested number of channels. This parameter will automatically turns on required channel for recording.

Start_Time – The start point in time axis for recording. The start time must not lesser than the stop time and must bigger than the minimum time for the current time scale. Different time scale will have different minimum time on the waveform graph. The format of this parameter can be normal or engineering format.

Stop_time – the stop point in time axis for recording. The stop time must be larger than the start time and smaller than 50 seconds. All model series has 50 seconds as the maximum in time axis. Both start and stop time are ignored if the scope is in scan mode, which occurs when the time scale is larger than 100mS. However, punctuation mark may not be changed if either start or stop time is not entered. The user may enter any number for start and stop time in order to change the punctuation mark in scan mode.

Punc (Optional) – The defined punctuation mark for comment lines in recorded file. The user may define the punctuation mark to suit different mathematic and plotting software for further data process. The default punctuation mark is # when not entered by the user. The punctuation mark allows user to read the comments in the recorded file while preventing incompatible with other process with other software.

Related Sections: 1.6 VISA Address HOWTO

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007

Software Info: RDTEK V1.00 by DH, Nov 2007

Hardware: Tektronix Oscilloscope.

Software Description:

1. Read values of the current displaying waveform.
2. Organize and record the waveform figures into a file with CSV format.

USE FORMAT:
rdtek Device_Address Channel_Number Start_Time End_Time Punc (Optional) >File_Name.CSV

Device_Address: The address of the desired device.
e.g.USB1::1689::869::C020200::0
Channel_Number: Desired channel to measure.
Format: 1(CH1), 2(CH2), 3(CH3), 4(CH4), all (all ch)
Start_Time: Start point on time axis.
Format: #E#. Eg.-2E-6
End_Time: Stop point on time axis.
Format: #E#. eg.1E6
Punc (Optional): Desired punctuation maker. (4 characters max.) e.g./,#...etc
File_Name.CSV: The file name of the recorded figures.
E.g. abc.csv (File type is fixed in CSV format.)
File location = same place where the command is located.
Caution !!! Shorter Start-Stop time interval is recommended.
Longer interval requires longer process time.

5.3. Rd4054

This command allows users to download waveform figures from Tektronix 4000 series and store them into a file. The user may use these figures for further process such as plotting the graphs or mathematics process. The requirement of this command is similar to the rdtek command. The user must tune the scope to the desired settings such as time scale, vertical scale, trigger scale and sample rate. The zoom functions for Tektronix 4000 series are not recommend using with this command. The best approach for using this command is utilizing horizontal scale and horizontal position rather than zooming. By re-plotting the waveform with the figures obtained, the output graph should be identical to what user seen on the screen of the scope. The user must be aware that it is only possible to obtain long waveform when user’s PC has sufficient of memory and hard drive resources.

Tektronix MSO4054 allows user to set its waveform resolution from 10K to 10M points. For normal usage, 10K to 100K points should be enough. Rd4054 can easily complete its task within reasonable time when resolution is from 10K to 100K. However, as the record length increases or as the sample resolution increases the duration for rd4054 to run increases as well. The increased above requirements might also lead to failure of running rd4054 since the hardware resource is limited. Rd4054 requires minimum of 128MB RAM to run the command properly. The hard drive storage should be larger than 1GB. Some higher resolution fetch operations will store up to 1GB for one single file. For example, the recorded file size is usually around 75MB for 1mS duration single channel recording with 250ms per division and resolution of 10M points. The size of the recorded file will be between 100MB to 150MB for complete 10M points of one channel at scan mode. Scan mode, which is when the horizontal scale above 40mS per division. In scan mode, rd4054 will write the warning in the recorded file. The duration of recording is recommended to be as short as possible since longer recorded file will also take more PC resources to run further process on the recorded data. The users should make their own judgment on the usage balance of the PC resources wisely. The user is required to input VISA address of the device, starting point in time, stop point in time, punctuation mark and the redirect sign (>) followed by the file name and file type.

Device_Address – VISA address of the device. Refer to 1.6 VISA Address HOWTO.

Channel_Number – Desired channel to measure. The user may select 1,2,3,4 or ALL channel. When selection is 1 to 4, rd4054 will only turns on the relevant channel. Only when selection is ALL, multiple 4 channels will be turned on and recorded.

Start_Time – Start point on time axis. The user desired starting point in time for recording. Start time must not be larger than stop time and smaller than the minimum time in different time scale. The minimum time is typically time scale times -10. The start time may by enter in normal or engineering form.

End_Time – Stop point of time axis. The stop time is the desired stop point for recording on time axis. Stop time should never be smaller than start time. For MSO4054, the maximum stop time is 50 seconds. The stop time may be entering in normal or engineering form. It is highly recommended that the duration between start and stop time is not too long. The longer duration will cost more time and PC resources to process. It is highly possible that the PC resources will be insufficient to run long recording such as over 100mS duration at 10M points of resolution at micro seconds time scale level.

Punc (Optional) – the punctuation mark for record comments. The default punctuation mark is #, but user may change to other marks with maximum length of 4 words. The usage of punctuation mark is allowing other software to process the figure and avoid the marked lines while providing understandable description to readers.

File_Name.CSV – The file contains the downloaded waveform figures. The user may use different file type, but the content of the file will always remain as CSV (Comma Separated Values) file format. Most mathematics and plotting software such as MS Excel, MATLAB and GNUPLOT accept CSV file format.

Related Sections: 1.6 VISA Address HOWTO

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: RD4045 V1.00 by DH, Nov 2007
Hardware: Tektronix 4000 Series.
Software Description:
1. Read values of the current displaying waveform.
2. Organize and record the waveform figures into a file with CSV format.

USE FORMAT:
rd4045 Device_Address Channel_Number Start_Time End_Time Punc (Optional) >File_Name.CSV

Device_Address: The address of the desired device.
e.g.TCPIP0::130.217.46.16::inst0
Channel_Number: Desired channel to measure.
Format: 1(CH1), 2(CH2), 3(CH3), 4(CH4), all (all ch)
Start_Time: Start point on time axis.
Format: #E#. Eg.-2E-6
End_Time: Stop point on time axis.
Format: #E#. eg.1E6
Punc (Optional): Desired punctuation maker. (4 characters max.) e.g./,#...etc
File_Name.CSV: The file name of the recorded figures.
E.g. abc.csv (File type is fixed in CSV format.)
File location = same place where the command is located.
Caution!!! Shorter Start-Stop time interval is recommended.
Longer interval requires longer process time.

6. Usage Examples

This chapter will provide basic examples for the users to understand how to use the VISA commands and what results would be expected. The examples will be in sections, the first section is an example of the power supply units, and also the digital multimeters, and the second section is an example of the function generators and oscilloscopes. Each section will have 2 sets of functional identical instruments connected for testing. The connection will allow each command to cross-examine each other. Please read each section for more details.

6.1. Power Supply Unit and Digital Multimeter

This example will use HAMEG HM8143, Agilent 3649A dual output power supply units and Agilent 34401A, Agilent 34405A multimeters as testing instruments. Agilent E5810A is used as the communication gateway for most of the instruments used in the example. Only Agilent 34405A digital multimeter is connected directly to the user’s PC, because the 34405A only support USB interface.

6.1.1. HAMEG HM8143 and Agilent 34401A

Hardware Configurations

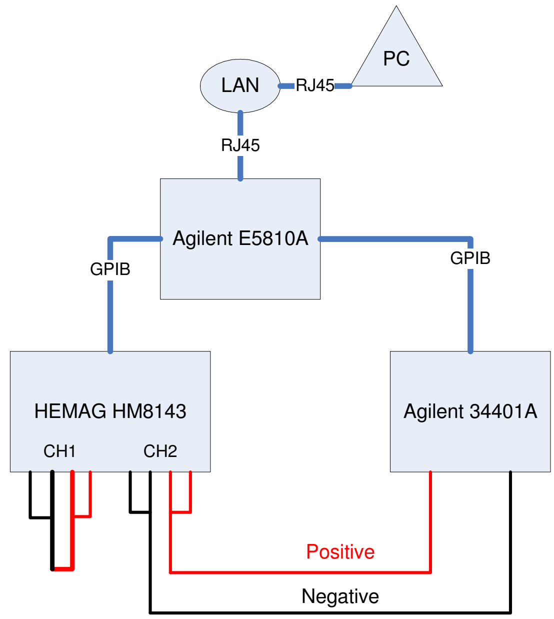


Figure 6.1 *The connection example using HAMEG HM8143 and Agilent 34401A. The 34401A is connected to channel 2 (CH2) of HM8143 and in parallel to the sense ports on HM8143. Channel 1 (CH1) on HM8143 is connected directly from positive to negative port and in parallel with the sense ports of the channel 1. Both 34401A and HM8143 are connected to Agilent E5810A and controlled by the remote PC. Note: the positive port is in red and negative port is in black.*

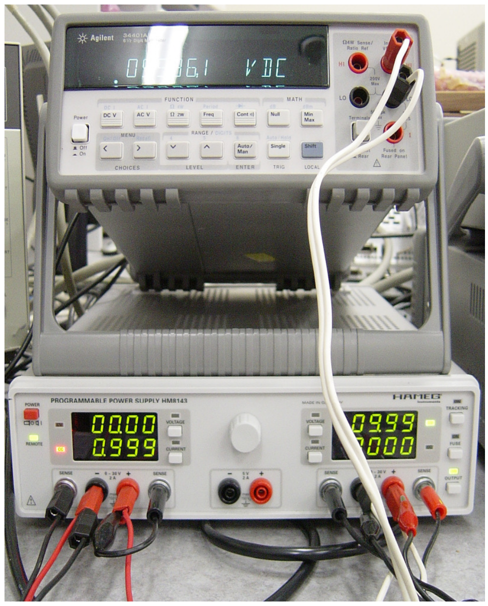


Figure 6.2 *The actual connection photo of HAMEG HM8143 and Agilent 34401A. The channel 1 is short-circuited and channel 2 is connected to Agilent 34401A. All sense ports are connected in parallel with the output channels.*

This example is using HAMEG HM8143 power supply unit to deliver and measure the voltage and current on both channels 1 and 2. The Agilent 34405A digital multimeter is measuring the DC voltage from the HM8143 to confirm the reading is close to what the HM8143 is measured. In order to ensure the readings are as expected, the short-circuited channel 1 will cause the current drawn to the limit, and channel 2 will read the voltage set up by using the set8143 command. The rd8143 command will measure the voltage and current from the sense ports. The rd344xx command will measure the DC voltage from Agilent 34401A multimeter.

In figures 6.1 and 6.2 34401A is connected to the channel 2 of the HM8143 in parallel with the sense ports of the channel 2. The channel 1 on the HM8143 is short-circuited from the positive to negative port in parallel to the sense ports of channel 1. We will set up the HM8143 by using the set8143 command and measuring values by using the rd8143 command for channel 1 and the rd344xx command for channel 2. The HM8143 will activate the constant current mode on channel 1; therefore, it is safe to perform the task.

Commands and Parameters

```
Command Prompt

USE FORMAT:
set8143 Addr Ch Volt Current Fuse SW

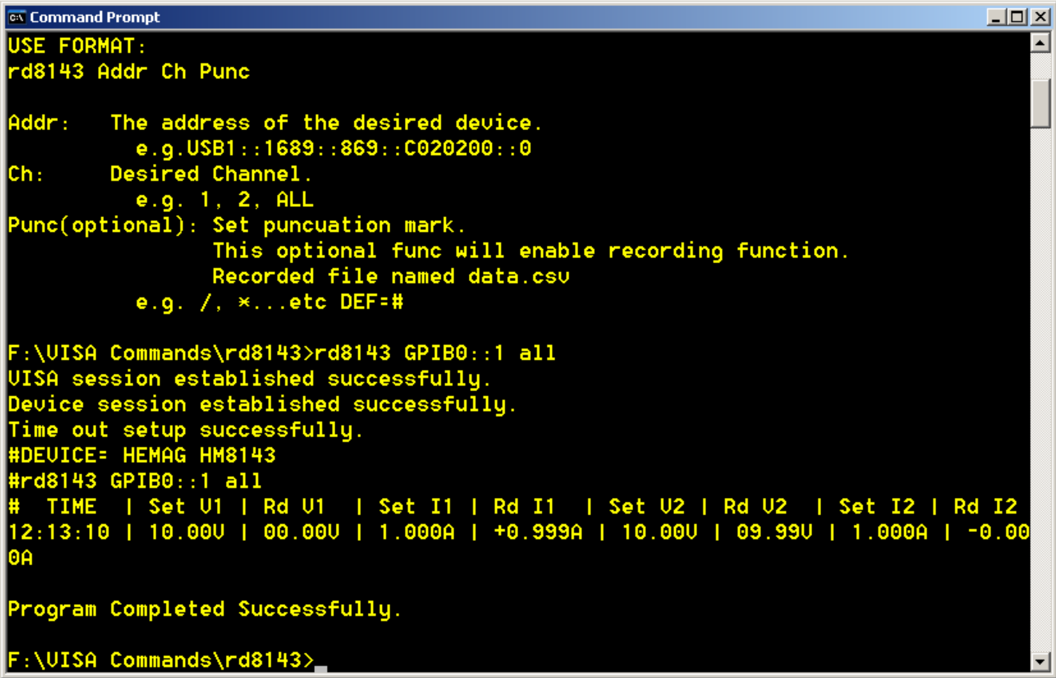
Addr:     The address of the desired device.
             e.g.USB1::1689::869::C020200::0
Ch:       Desired Channel.
             Range: 1, 2, ALL
Volt:     Set voltage.
             Range: 0 ~ 30V
Current:  Set current.
             Range: 0 ~ 2A
Fuse:     Activate electronic fuse.
             Range: ON, OFF
SW:       Power switch.
             Range: ON, OFF

F:\VISA Commands\set8143>set8143 GPIB0::1 all 10 1 off on
VISA session established successfully.
Device session established successfully.
Time out setup successfully.

Program Completed Successfully.

F:\VISA Commands\set8143>
```

Figure 6.3 *The set8143 command sent. The set8143 command sets the HM8143 power supply to 10V and 1A for both channels, disable the electronics fuse and enable the output switch.*



```
Command Prompt
USE FORMAT:
rd8143 Addr Ch Punc

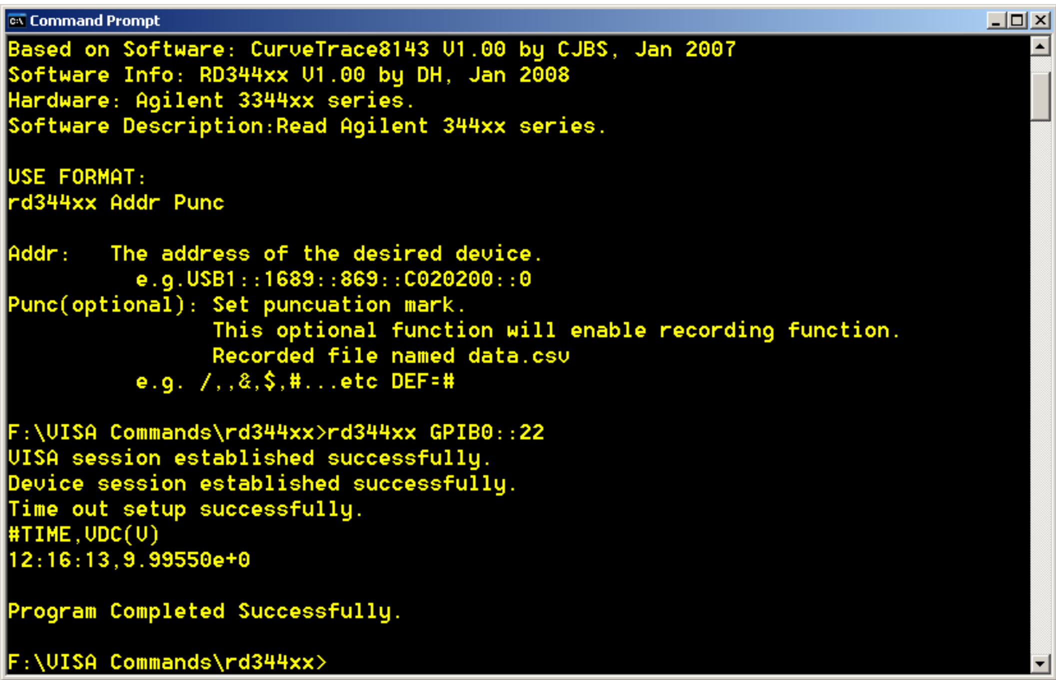
Addr:   The address of the desired device.
          e.g.USB1::1689::869::C020200::0
Ch:     Desired Channel.
          e.g. 1, 2, ALL
Punc(optional): Set puncuation mark.
                This optional func will enable recording function.
                Recorded file named data.csv
          e.g. /, *...etc DEF=#

F:\VISA Commands\rd8143>rd8143 GPIB0::1 all
VISA session established successfully.
Device session established successfully.
Time out setup successfully.
#DEVICE= HEMAG HM8143
#rd8143 GPIB0::1 all
#  TIME   | Set V1 | Rd V1  | Set I1 | Rd I1   | Set V2 | Rd V2  | Set I2 | Rd I2
12:13:10 | 10.00V | 00.00V | 1.000A | +0.999A | 10.00V | 09.99V | 1.000A | -0.00
0A

Program Completed Successfully.

F:\VISA Commands\rd8143>_
```

Figure 6.4 *The rd8143 command sent. The rd8143 command reads voltage and current values from both channel 1 and channel 2 with the time stamp.*



```
Command Prompt
Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: RD344xx V1.00 by DH, Jan 2008
Hardware: Agilent 3344xx series.
Software Description:Read Agilent 344xx series.

USE FORMAT:
rd344xx Addr Punc

Addr:   The address of the desired device.
          e.g.USB1::1689::869::C020200::0
Punc(optional): Set puncuation mark.
                This optional function will enable recording function.
                Recorded file named data.csv
          e.g. /,,&,$,#...etc DEF=#

F:\VISA Commands\rd344xx>rd344xx GPIB0::22
VISA session established successfully.
Device session established successfully.
Time out setup successfully.
#TIME,VDC(V)
12:16:13,9.99550e+0

Program Completed Successfully.

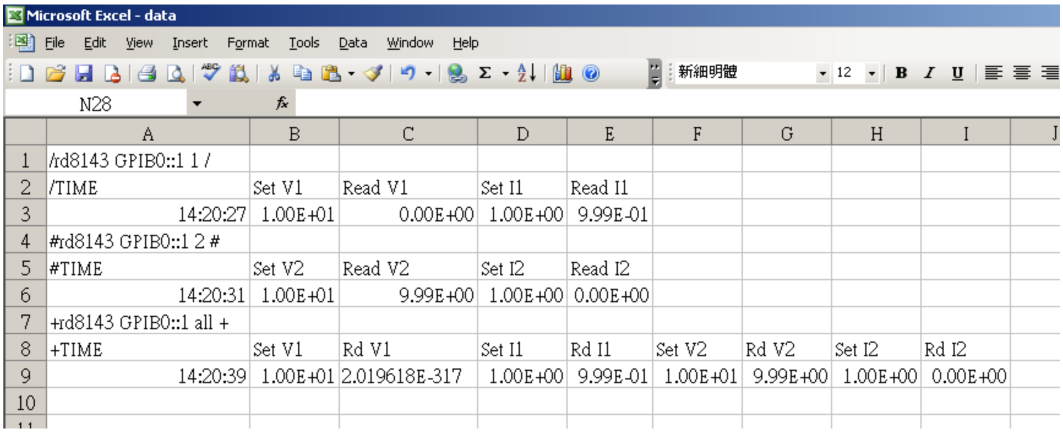
F:\VISA Commands\rd344xx>
```

Figure 6.5 *The rd344xx command sent. The rd344xx command reads 9.9955VDC from its probe.*

In figure 6.3, the set8143 command sets up both output channels on the HM8143 to 10V and 1A. The command disables the electronic fuse in order to avoid the HM8143 shut off when the current limit is reached. In figure 6.4, the rd8143 the command reads the limits of the voltage and current settings, and measures the actual voltage and current on each channel with a time stamp. The "Set V1" means the voltage limit setting and "Set I1" means the current limit setting for channel 1. "Rd V1" and "Rd I1" are the actual measured values of voltage and current from channel 1. Channel 2 values are named as "V2" and "I2" for voltage and current. In figure 6.2 the reading shows that channel 1 is in constant current mode since the channel 1 voltage dropped to 0V and the current rose to its current limit.

Figure 6.5 shows the reading from Agilent 34401A by using the rd344xx command. The reading on channel 2 of HM8143 is 9.9955VDC, which is almost equal from what the HM8143 measured on the channel 2 voltage in figure 6.4.

Results

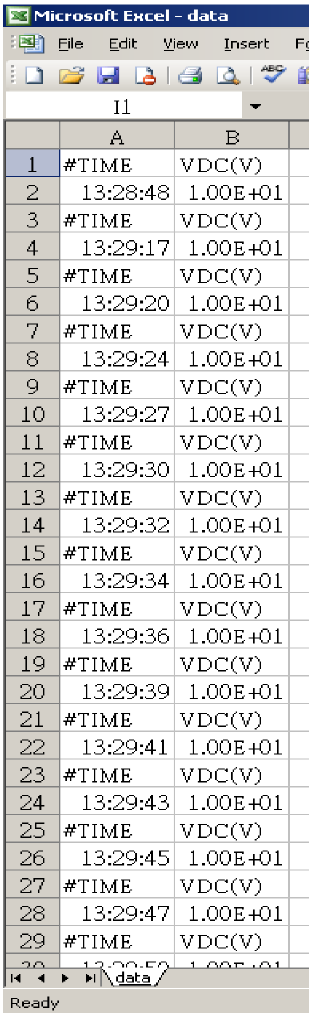


Microsoft Excel - data

	A	B	C	D	E	F	G	H	I
1	/rd8143 GPIB0::1 1 /								
2	/TIME	Set V1	Read V1	Set I1	Read I1				
3	14:20:27	1.00E+01	0.00E+00	1.00E+00	9.99E-01				
4	#rd8143 GPIB0::1 2 #								
5	#TIME	Set V2	Read V2	Set I2	Read I2				
6	14:20:31	1.00E+01	9.99E+00	1.00E+00	0.00E+00				
7	+rd8143 GPIB0::1 all +								
8	+TIME	Set V1	Rd V1	Set I1	Rd I1	Set V2	Rd V2	Set I2	Rd I2
9	14:20:39	1.00E+01	2.019618E-317	1.00E+00	9.99E-01	1.00E+01	9.99E+00	1.00E+00	0.00E+00
10									

Figure 6.6 *The contents of the data.csv file recorded by the rd8143 command. The data.csv file shows the HM8143 has voltage and current limit of 10V and 1A on both channel 1 and 2. The measured voltage and current is nearly 0V and nearly 1A on the channel 1. The measured voltage and current are 10V and 0A on the channel 2.*

Figure 6.6 shows the recorded values in the data.csv when the user specifies a punctuation mark in the rd8143 command line. The overall format is the same as what the reader has seen in previous figures, when the punctuation mark is not assigned. The extra information shows in the data.csv file is the command and parameters sent by the user. Every command echo begins with a specified punctuation mark to avoid processing by other analysis software. The data.csv file accumulates the information each time the user records the values. This data.csv file is the accumulation of the command executed in sequence. The file shows that the user is measuring channel 1 with the punctuation mark "\" and then measures channel 2 with the punctuation mark "#" and then measures both channels with the punctuation mark "+".



	A	B
1	#TIME	VDC(V)
2	13:28:48	1.00E+01
3	#TIME	VDC(V)
4	13:29:17	1.00E+01
5	#TIME	VDC(V)
6	13:29:20	1.00E+01
7	#TIME	VDC(V)
8	13:29:24	1.00E+01
9	#TIME	VDC(V)
10	13:29:27	1.00E+01
11	#TIME	VDC(V)
12	13:29:30	1.00E+01
13	#TIME	VDC(V)
14	13:29:32	1.00E+01
15	#TIME	VDC(V)
16	13:29:34	1.00E+01
17	#TIME	VDC(V)
18	13:29:36	1.00E+01
19	#TIME	VDC(V)
20	13:29:39	1.00E+01
21	#TIME	VDC(V)
22	13:29:41	1.00E+01
23	#TIME	VDC(V)
24	13:29:43	1.00E+01
25	#TIME	VDC(V)
26	13:29:45	1.00E+01
27	#TIME	VDC(V)
28	13:29:47	1.00E+01
29	#TIME	VDC(V)

Figure 6.7 *The content of the data.csv file recorded by the rd344xx command. Each measurement came with the time stamp. The voltage readings are around 10VDC.*

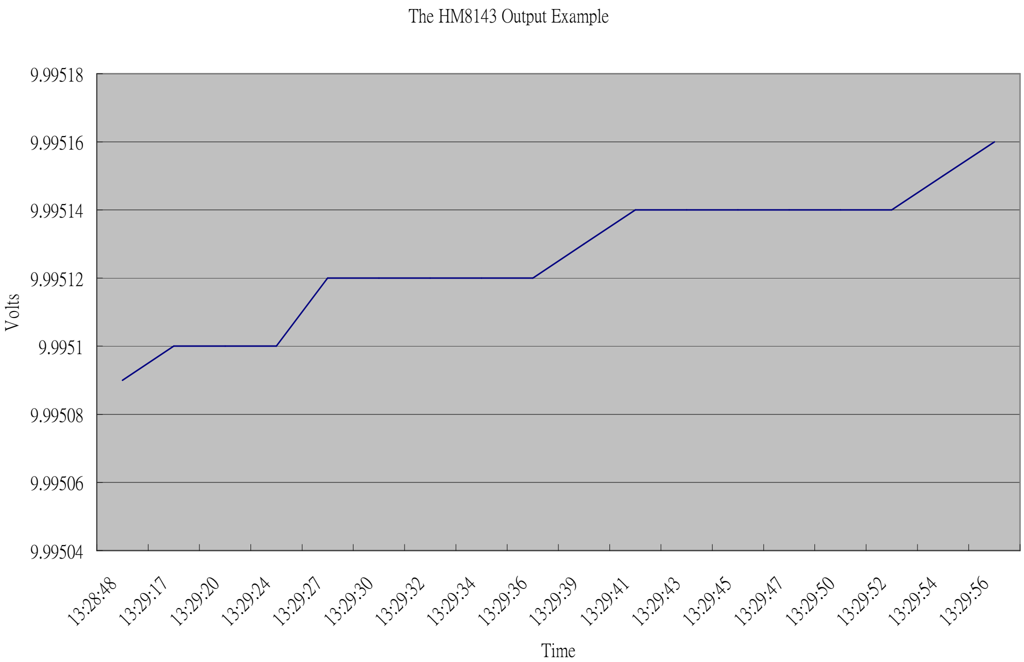


Figure 6.8 *The graphical result of the data.csv file. This graph shows the 10 voltage readings on the channel 2 on the HM8143.*

Figure 6.7 and 6.8 show the output results of measuring the voltage on channel 2 of HM8143 by using Agilent 34401A multimeter. We can see that the rd344xx command has been running a few times for data accumulation in figure 6.9. The user may write a batch file to run the rd344xx command for repeating measurements. By comparing figure 6.6 and 6.7, the voltage and current readings on channel 2 of theHM8143 are very close. The voltage and current readings on channel 1 also match the short circuit signs, high current drawn, and voltage drops to near zero volts. The output voltage and current readings from the rd8143 and the rd344xx command are about the same as expected initially.

6.1.2. Agilent 3649A and Agilent 34405A

Hardware Configurations

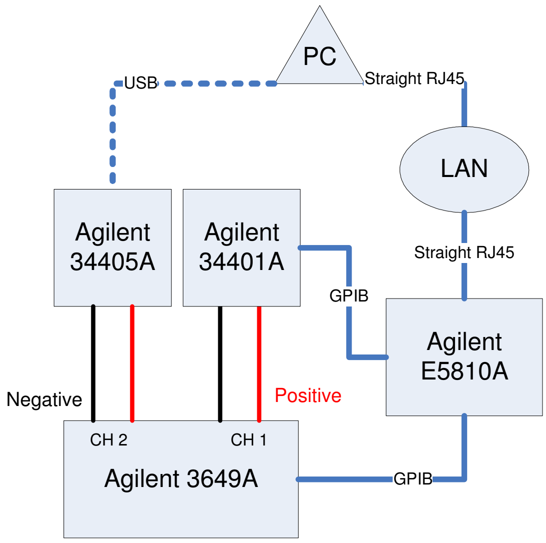


Figure 6.9 *The connection example using Agilent 3649A and Agilent 34405A. The connection on channel 1 is short-circuited in series with Agilent 34401A. The channel 2 is connected in parallel to Agilent 34405A. The 3649A is communicating with the PC via the E5810A and the local LAN.*

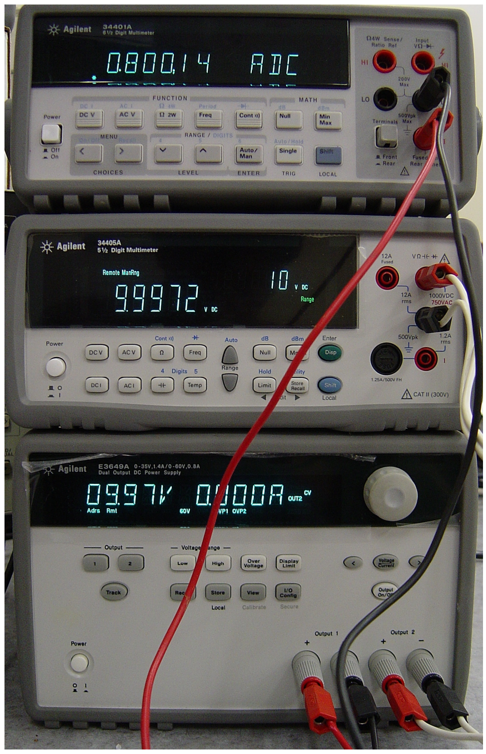


Figure 6.10 *The actual connection of Agilent 3469A and Agilent 34405A. The channel 1 of the 3649A at the bottom is short circuited in series with Agilent 34401A on top and the channel 2 is connected in parallel to the 34405A at the middle.*

This example uses Agilent 34401A, 34405A multimeter, and Agilent 3649A power supply unit. Channel 1 of the 3649A is short-circuited in series with the 34401A to measure current and channel 2 is connected to the 34405A to measure voltage. This configuration allows 34401A to cross-examine the current drawn measured by the 3649A and the 34405A to confirm the voltage measured by the 3649A.

In figure 6.9 and 6.10 channel 1 on the 3649A power supply is short-circuited in series with 34401A to measure the current and channel 2 is connected in parallel to 34405A multimeter to measure the voltage. The 3649A and the 34401A are communicating to the user's PC through E5810A gateway, but the 34405A is connected directly to the user's PC because it only supports USB interface, which is not supported by the E5810A gateway. The 3649A automatically changes its channel 1 to constant current mode since the output is short-circuited.

Commands and Parameters

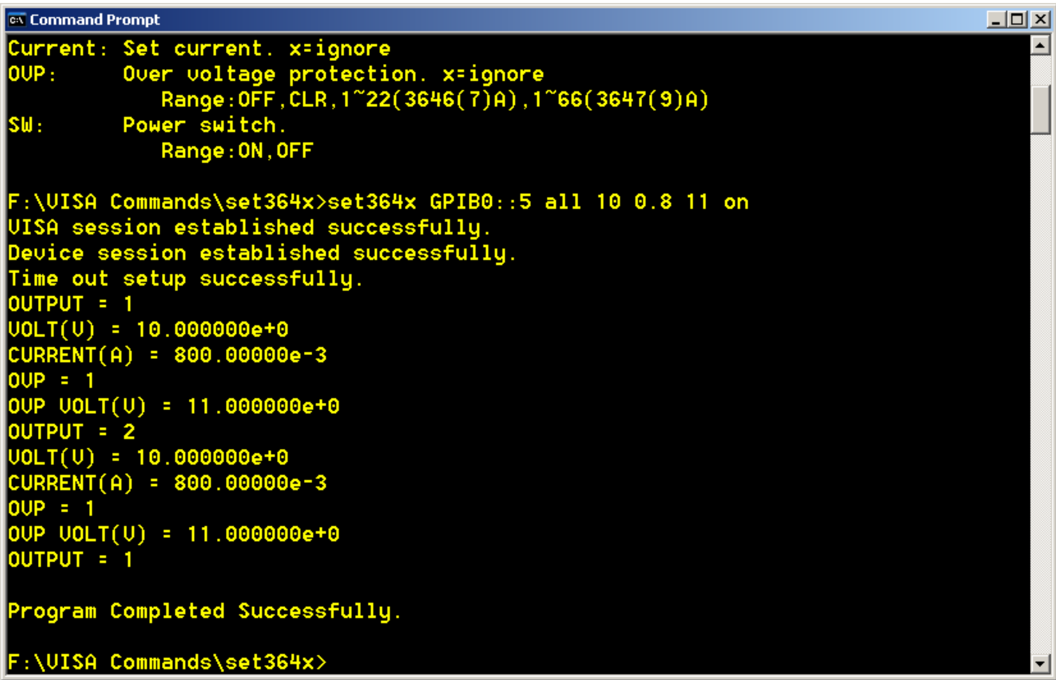


Figure 6.11 *The set364x command sent. The set364x command configures both channel to 10V and 1A with 11V of OVP. The command returns the settings confirmed on instrument.*

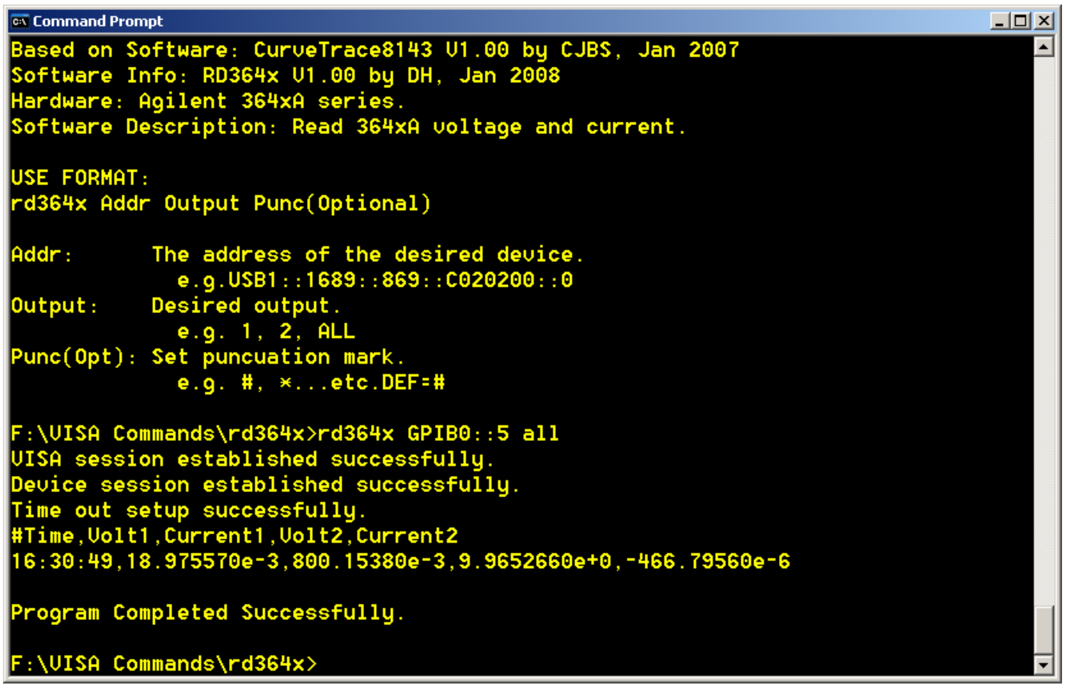


Figure 6.12 *The rd364x command sent. The rd364x command reads the actual measured values of voltage and current from channel 1 and 2 on the instrument with the time stamp.*

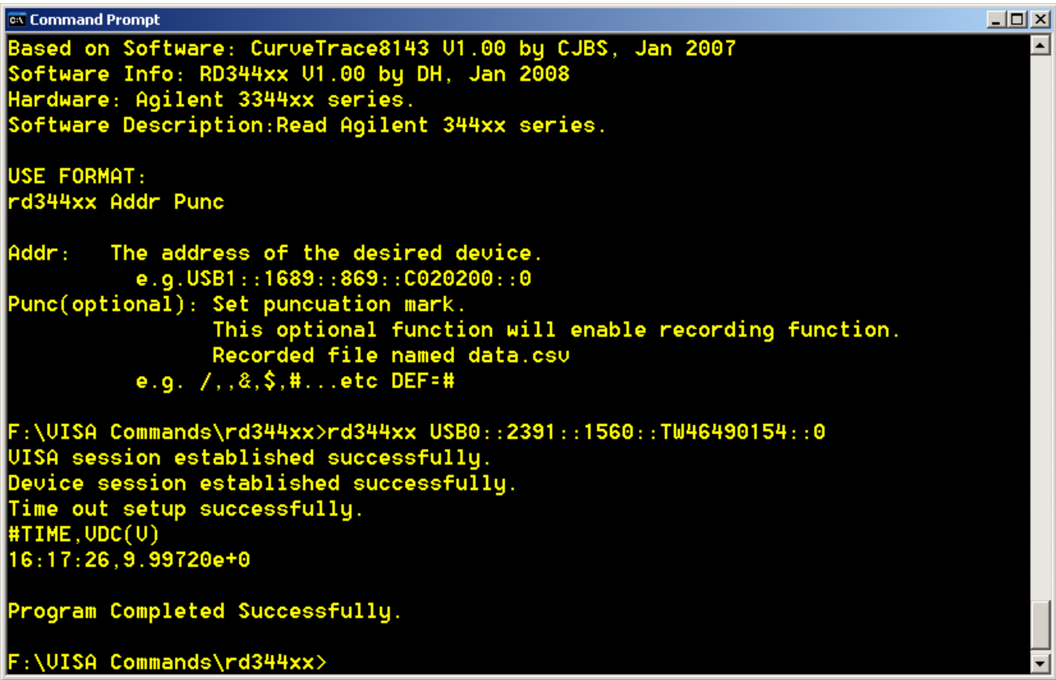


Figure 6.13 *The rd344xx command sent to the 34405A. The rd344xx command reads 9.9972VDC from the channel 2 of the 3649A power supply.*

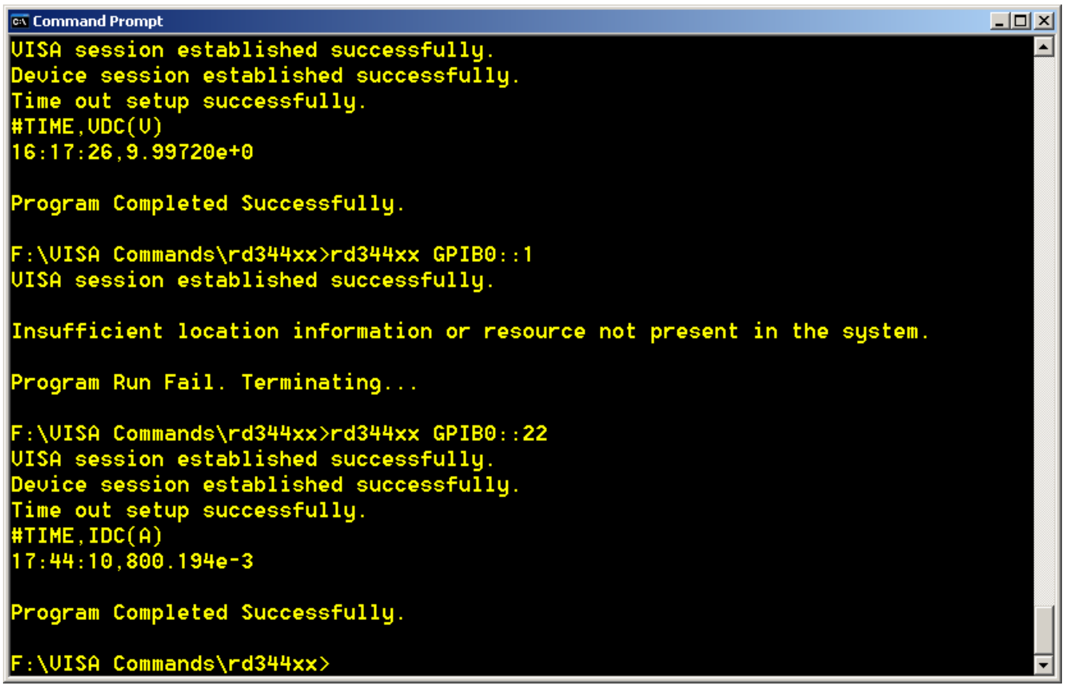
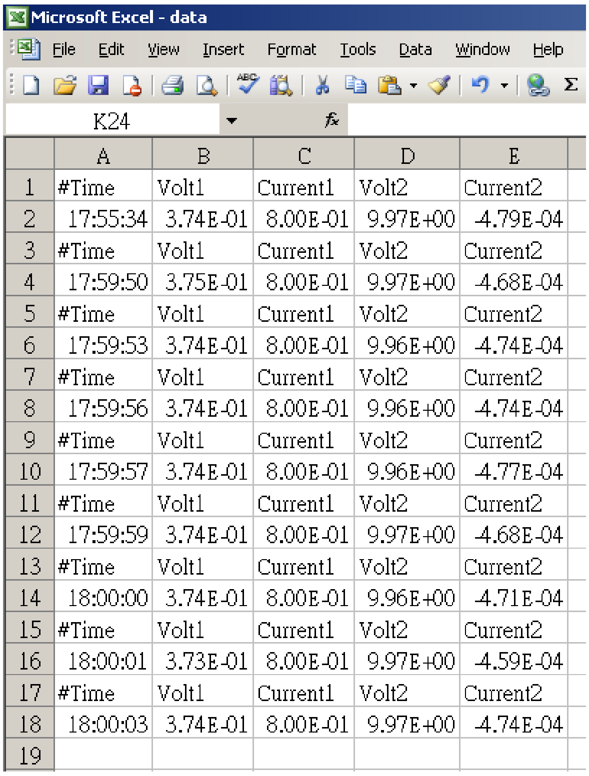


Figure 6.14 *The rd344xx command sent to the 34401A. The rd344xx command reads 800.194mA current drawn from the channel 1 of the 3649A power supply.*

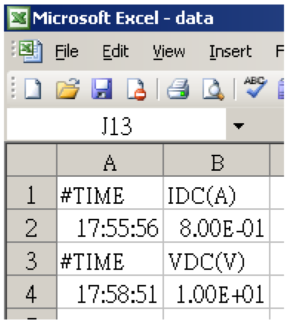
In figure 6.11 the 3649A is configured with 10V and 800mA output with 11V of the OVP settings by using the set364x command. The command also returns confirmation for each setting on the instrument. In figure 6.12 the rd364x command reads the actual measure voltage and current on the output channels. It indicates that channel 1 is short-circuited and it is in constant current mode since the voltage decreased to near zero and the current increased to the limit. The channel 2 on 3649A measures around 9.96V and an almost zero current is drawn with the 34405A multimeter connected. In figure 6.13 the voltage reading on the 34405A is around 9.97V, which is close to the reading from figure 6.12 measured by the 3649A. In figure 6.14 the 34401A measures around 800.194mA current drawn from the channel 1 on the 3649A that is almost equal to the value obtained by the rd364x command in figure 6.12.

Results



	A	B	C	D	E
1	#Time	Volt1	Current1	Volt2	Current2
2	17:55:34	3.74E-01	8.00E-01	9.97E+00	-4.79E-04
3	#Time	Volt1	Current1	Volt2	Current2
4	17:59:50	3.75E-01	8.00E-01	9.97E+00	-4.68E-04
5	#Time	Volt1	Current1	Volt2	Current2
6	17:59:53	3.74E-01	8.00E-01	9.96E+00	-4.74E-04
7	#Time	Volt1	Current1	Volt2	Current2
8	17:59:56	3.74E-01	8.00E-01	9.96E+00	-4.74E-04
9	#Time	Volt1	Current1	Volt2	Current2
10	17:59:57	3.74E-01	8.00E-01	9.96E+00	-4.77E-04
11	#Time	Volt1	Current1	Volt2	Current2
12	17:59:59	3.74E-01	8.00E-01	9.97E+00	-4.68E-04
13	#Time	Volt1	Current1	Volt2	Current2
14	18:00:00	3.74E-01	8.00E-01	9.96E+00	-4.71E-04
15	#Time	Volt1	Current1	Volt2	Current2
16	18:00:01	3.73E-01	8.00E-01	9.97E+00	-4.59E-04
17	#Time	Volt1	Current1	Volt2	Current2
18	18:00:03	3.74E-01	8.00E-01	9.97E+00	-4.74E-04
19					

Figure 6.15 *The data.csv file of the rd364x command. The values for the channel 1 indicate it is short-circuited. The channel 2 reads 9.96V and almost zero current drawn.*



	A	B
1	#TIME	IDC(A)
2	17:55:56	8.00E-01
3	#TIME	VDC(V)
4	17:58:51	1.00E+01

Figure 6.16 *The data.csv file of the rd344xx command. The first value is in current measured by the 34401A and the second value is in voltage measured by the 34405A.*

In figure 6.15, the data.csv file recorded by the rd364x command shows the voltages and current for both channel 1 and 2 with time stamps. In figure 6.16, the data.csv file recorded by the rd344xx command shows the current measured on the channel 1 by the 34401A as the first value in amp and the second value in voltage is measured on channel 2 by the 34405A. By comparing figure 6.15 and 6.16 the high current drawn and high voltage drop on channel 1 is about the same as expected from a short circuit. The voltage and current are around 10V and 0A from both figure 6.15 and 6.16. The result proves the VISA commands are working as required and expected.

6.2. Function Generator and Oscilloscope

6.2.1. Agilent 33220 and Tektronix TDS2004B

Hardware Configurations

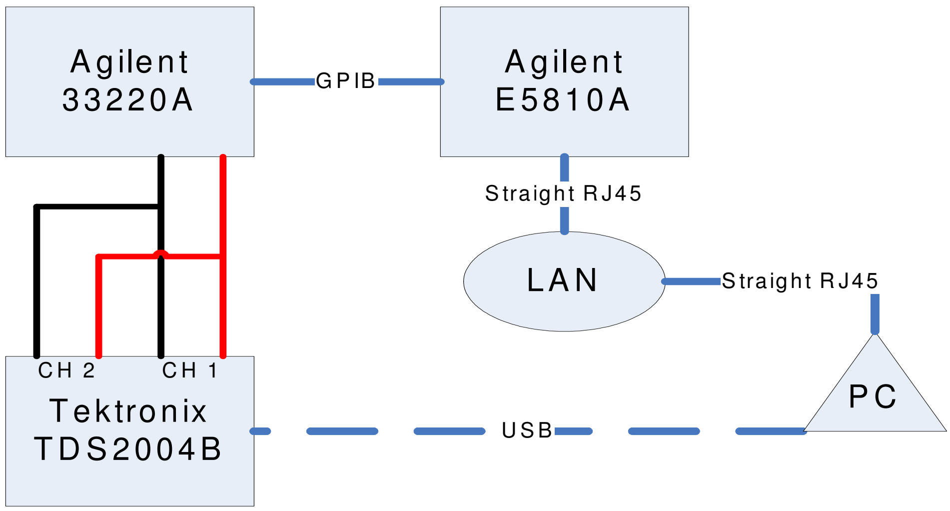


Figure 6.17 *The connection example using Agilent 33220A and Tektronix TDS2004B. The 33220A function generator outputs the waveform to the TDS2004B oscilloscope. The 33220A is connected through the E5810A and local LAN to the user's PC. The TDS2004B oscilloscope only supports USB; therefore, it is connected directly to the user's PC.*

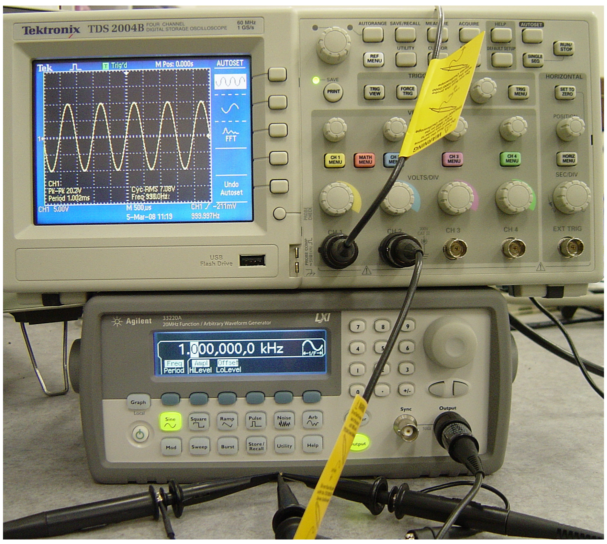
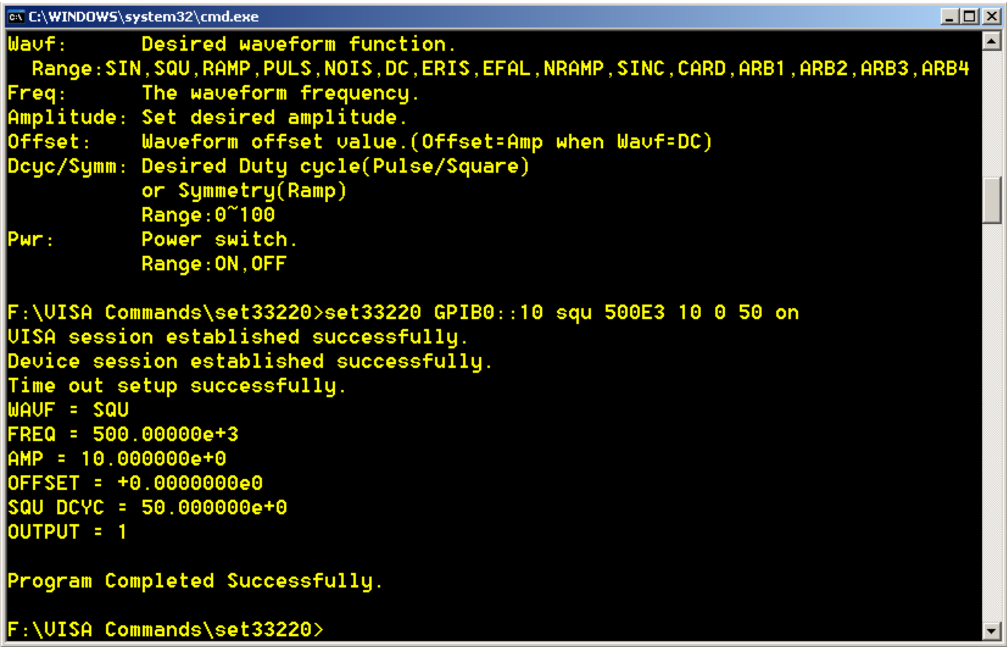


Figure 6.18 *The actual connection photo of Agilent 33220 and Tektronix TDS2004B. The channel 1 and 2 of the TDS2004B are connected in parallel from the output of the 33220A function generator.*

This example uses the Agilent 33220 function generator and Tektronix TDS2004B oscilloscope to cross-examine the VISA commands applied by the results. The 33220A will output a 500 KHz, 10V peak voltage of square wave with 0V offset and 50% duty cycle. The TDS2004B will download the signal from all 4 channels to allow the user to re-plot the waveform.

In figure 6.17 and 6.18 channel 1 and 2 are connected in parallel to the output of the 33220A. Channel 2 is inverted in order to illustrate both channel 1 and 2 values in the graph clearly. All probes used are Tektronix probes and set to 1x measuring scale. The 33220A function generator is connected to the user's pc through the E5810A and the local LAN. The TDS2004B is connected directly to the user's PC since the instrument only supports USB interface.

Commands and Parameters



```
C:\WINDOWS\system32\cmd.exe
Wavf:       Desired waveform function.
  Range:SIN,SQU,RAMP,PULS,NOIS,DC,ERIS,EFAL,NRAMP,SINC,CARD,ARB1,ARB2,ARB3,ARB4
Freq:       The waveform frequency.
Amplitude:  Set desired amplitude.
Offset:     Waveform offset value.(Offset=Amp when Wavf=DC)
Dcyc/Symm:  Desired Duty cycle(Pulse/Square)
            or Symmetry(Ramp)
            Range:0~100
Pwr:        Power switch.
            Range:ON,OFF

F:\VISA Commands\set33220>set33220 GPIB0::10 squ 500E3 10 0 50 on
VISA session established successfully.
Device session established successfully.
Time out setup successfully.
WAVF = SQU
FREQ = 500.00000e+3
AMP = 10.000000e+0
OFFSET = +0.0000000e0
SQU DCYC = 50.000000e+0
OUTPUT = 1

Program Completed Successfully.

F:\VISA Commands\set33220>
```

Figure 6.19 *The set33220 command sent in 6.2.1. The set33220 command setup the 33220A to output 500 kHz 10V peak voltage square wave with 0V offset and 50% duty cycle.*

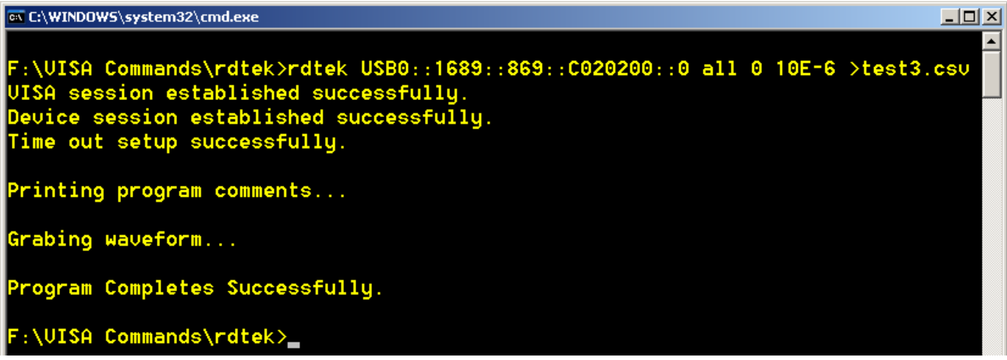
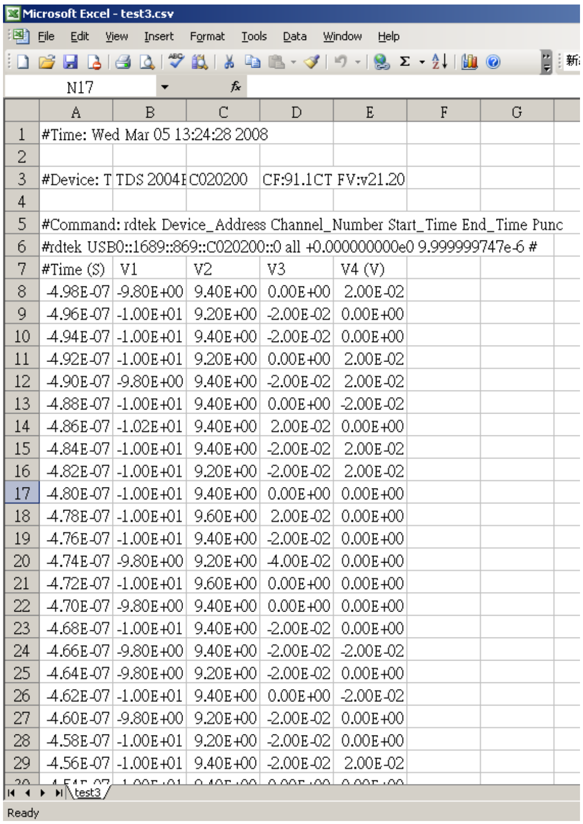


Figure 6.20 *The rdtek command sent to the TDS2004B. The rdtek command reads the waveform values for all four channels from 0 to 10 microseconds and stores the values in test3.csv file. The location of the test3.csv file is in the same path of the rdtek command.*

In figure 6.19 the set33220 command makes the 33220A function generator output 500 kHz, 10V peak voltage of square wave with 0V offset and 50% duty cycle. The set33220 command returns the effective confirmed settings on the 33220A after sending the settings to the instrument. In figure 6.20 the rdtek command sent with the VISA address of the TDS2004B reads all four channels from 0 to 10 microseconds and stores the values in the test3.csv file. The test3.csv file is under the same path of the rdtek command.

Results



Microsoft Excel - test3.csv

	A	B	C	D	E	F	G
1	#Time: Wed Mar 05 13:24:28 2008						
2							
3	#Device: T	TDS 2004I	C020200	CF:91.1CT	FV:v21.20		
4							
5	#Command: rdtek Device_Address Channel_Number Start_Time End_Time Punc						
6	#rdtek USB0::1689::869::C020200::0 all +0.000000000e0 9.999999747e-6 #						
7	#Time (S)	V1	V2	V3	V4 (V)		
8	-4.98E-07	-9.80E+00	9.40E+00	0.00E+00	2.00E-02		
9	-4.96E-07	-1.00E+01	9.20E+00	-2.00E-02	0.00E+00		
10	-4.94E-07	-1.00E+01	9.40E+00	-2.00E-02	0.00E+00		
11	-4.92E-07	-1.00E+01	9.20E+00	0.00E+00	2.00E-02		
12	-4.90E-07	-9.80E+00	9.40E+00	-2.00E-02	2.00E-02		
13	-4.88E-07	-1.00E+01	9.40E+00	0.00E+00	-2.00E-02		
14	-4.86E-07	-1.02E+01	9.40E+00	2.00E-02	0.00E+00		
15	-4.84E-07	-1.00E+01	9.40E+00	-2.00E-02	2.00E-02		
16	-4.82E-07	-1.00E+01	9.20E+00	-2.00E-02	2.00E-02		
17	-4.80E-07	-1.00E+01	9.40E+00	0.00E+00	0.00E+00		
18	-4.78E-07	-1.00E+01	9.60E+00	2.00E-02	0.00E+00		
19	-4.76E-07	-1.00E+01	9.40E+00	-2.00E-02	0.00E+00		
20	-4.74E-07	-9.80E+00	9.20E+00	-4.00E-02	0.00E+00		
21	-4.72E-07	-1.00E+01	9.60E+00	0.00E+00	0.00E+00		
22	-4.70E-07	-9.80E+00	9.40E+00	0.00E+00	0.00E+00		
23	-4.68E-07	-1.00E+01	9.40E+00	-2.00E-02	0.00E+00		
24	-4.66E-07	-9.80E+00	9.40E+00	-2.00E-02	-2.00E-02		
25	-4.64E-07	-9.80E+00	9.20E+00	-2.00E-02	0.00E+00		
26	-4.62E-07	-1.00E+01	9.40E+00	0.00E+00	-2.00E-02		
27	-4.60E-07	-9.80E+00	9.20E+00	-2.00E-02	0.00E+00		
28	-4.58E-07	-1.00E+01	9.20E+00	-2.00E-02	0.00E+00		
29	-4.56E-07	-1.00E+01	9.40E+00	-2.00E-02	2.00E-02		

test3

Ready

Figure 6.21 *The contents of the test3.csv file. The test3.csv file contains the execution time, device used and the command echo. The time column is seconds and used as the x-axis in the plot in figure 6.22. The values for each channel are listed in V1 to V4 with unit of voltage. These values are the actual measured values.*

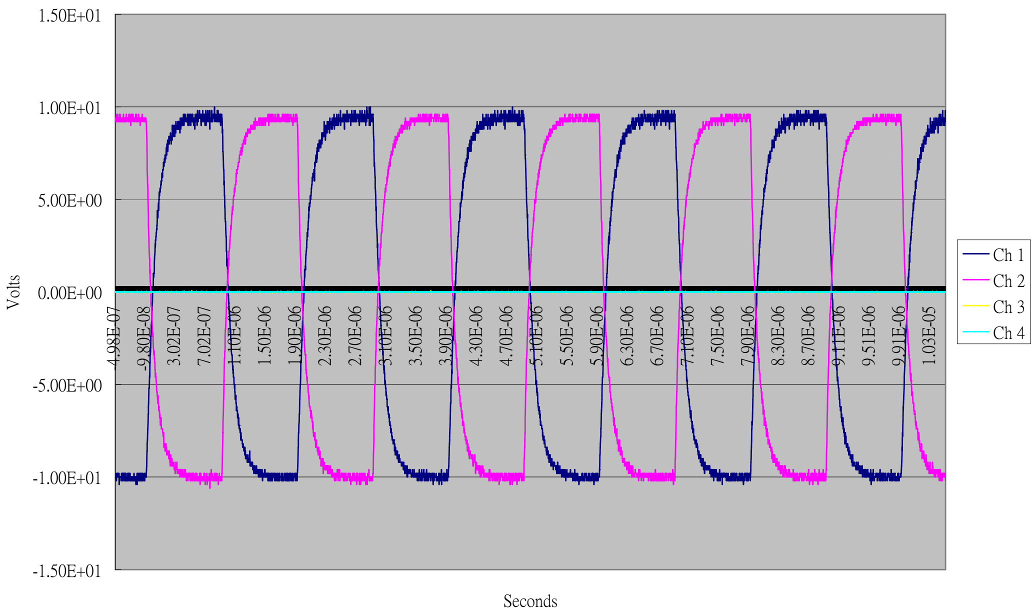


Figure 6.22 *The graphical result of the test3.csv file. Both channel 1 and 2 are the same square waveform from the 33220A, but the channel 2 signal is inverted by the TDS2004B. Channel 3 and 4 do not have any signals. The 10V peak voltage of square wave is around 500 KHz.*

In figure 6.21, the test3.csv contains the execution time of the rdtek command, the device used, the command echo, and measured results. The time column is sampled time in seconds on the x-axis on the oscilloscope screen, which is shown in figure 6.22. The y-axis values are the values below V1 to V4, where V1 is the value in voltage of the reading of channel 1 and V4 is the measured voltage from channel 4 on the TDS2004B. Both figures indicate that channel 3 and 4 do not have any signals and confirmed with the hardware configuration. The square waveform from the 33220A function generator is outputting to only channel 1 and 2. The signal at channel 1 is normal, but channel 2 signal is inverted by TD2004B for the graphical purpose as shown in figure 6.22. The frequency of the 10V peak voltage of square waveform in the figure 6.22 is around 500 KHz, which is close to what the 33220A outputs.

6.2.2. MOTECH FG503 and Tektronix TPS2024

<u>Hardware Configurations</u>

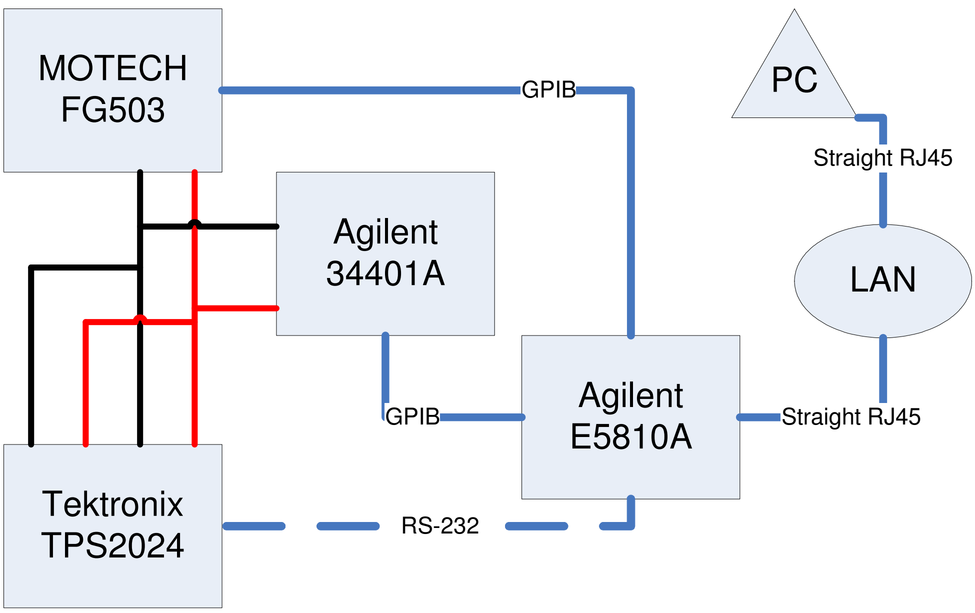


Figure 6.23 *The connection example using MOTECH FG503 and Tektronix TPS2024. Both the FG503 and the TPS2024 are connected to the user's PC through the E5810A. The FG503 is using GPIB cable and the TPS2024 is using RS-232 cable connected to the E5810A.*

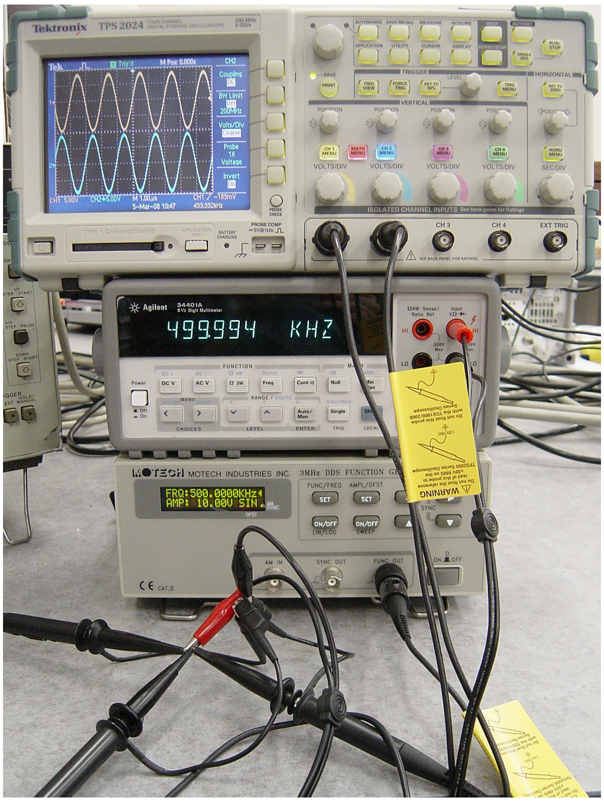


Figure 6.24 *The actual connection of Tektronix TPS2024, Agilent 34401A and MOTECH FG503. The channel 1 and 2 of the TPS2024 are connected in parallel with the 34401A and FG503. The FG503 function generator outputs the 500 KHz sine wave to TPS2024 oscilloscope and the 34401A multimeter.*

This example uses MOTECH FG503 function generator, Agilent 34401A digital multimeter and Tektronix TPS2024 oscilloscope to cross-examine the VISA commands by the results. The FG503 will output a 500 KHz, 10V peak voltage of sine wave with 0V offset to the 34401A and the TPS2024 in parallel. The 34401A will read the sine wave frequency and the TPS2024 will download the waveform and allow the user to re-plot the waveform.

In figure 6.23 and 6.24 channel 1 and 2 of the TPS2024 oscilloscope are connected in parallel with the output of the FG503 function generator and the input of the 34401A multimeter. The FG503 outputs 500 KHz, 10V peak voltage sine wave with 0V offset to both the TPS2024 and the 34401A. The 34401A is measuring the frequency of the signal and the TPS2024 is recording the waveform into the file. The channel 2 signal is inverted by the TPS2024 setting for graphical result purpose. All instruments are connected to the E5810A for the remote PC to access the instruments across the local LAN.

Commands and Parameters

```
C:\WINDOWS\system32\cmd.exe
Software Info: SET503 V1.00 by DH, Jan 2008
Hardware: MOTECH FG503.
Software Description: Set up & output desired waveform on FG503.

USE FORMAT:
set503 Addr Func Freq Amp Offs

Addr: The address of the desired device.
         e.g.USB1::1689::869::C020200::0
Func: Desired function output.x=no change
         Range: SIN,SQU,TRI,RUP,RDW,DC
Freq: Desired frequency.x=no change
         Range:10E-3~3E6(SIN,SQU),10E-3~20E3(TRI,RUP,RDW)
Amp:  VPP amplitude.x=no change
         Range:40E-3~20V
Offs: Waveform offset.x=no change

F:\VISA Commands\set503>set503 GPIB0::1 sin 500E3 10 0
VISA session established successfully.
Device session established successfully.
Time out setup successfully.

Program Completed Successfully.

F:\VISA Commands\set503>
```

Figure 6.25 *The set503 command sent. The set503 command make the FG503 function generator outputting 500 KHz, 10V peak voltage of sine wave with 0V offset.*

```
C:\WINDOWS\system32\cmd.exe
Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: RD344xx V1.00 by DH, Jan 2008
Hardware: Agilent 3344xx series.
Software Description:Read Agilent 344xx series.

USE FORMAT:
rd344xx Addr Punc

Addr:   The address of the desired device.
          e.g.USB1::1689::869::C020200::0
Punc(optional): Set puncuation mark.
                This optional function will enable recording function.
                Recorded file named data.csv
          e.g. /,,&,$,#...etc DEF=#

F:\VISA Commands\rd344xx>rd344xx GPIB0::22
VISA session established successfully.
Device session established successfully.
Time out setup successfully.
#TIME,FREQ(HZ)
16:22:37,499.994e+3

Program Completed Successfully.

F:\VISA Commands\rd344xx>
```

Figure 6.26 *The rd344xx command sent to Agilent 34401A. The rd344xx command reads 499.993 KHz signal from the FG503 function generator.*

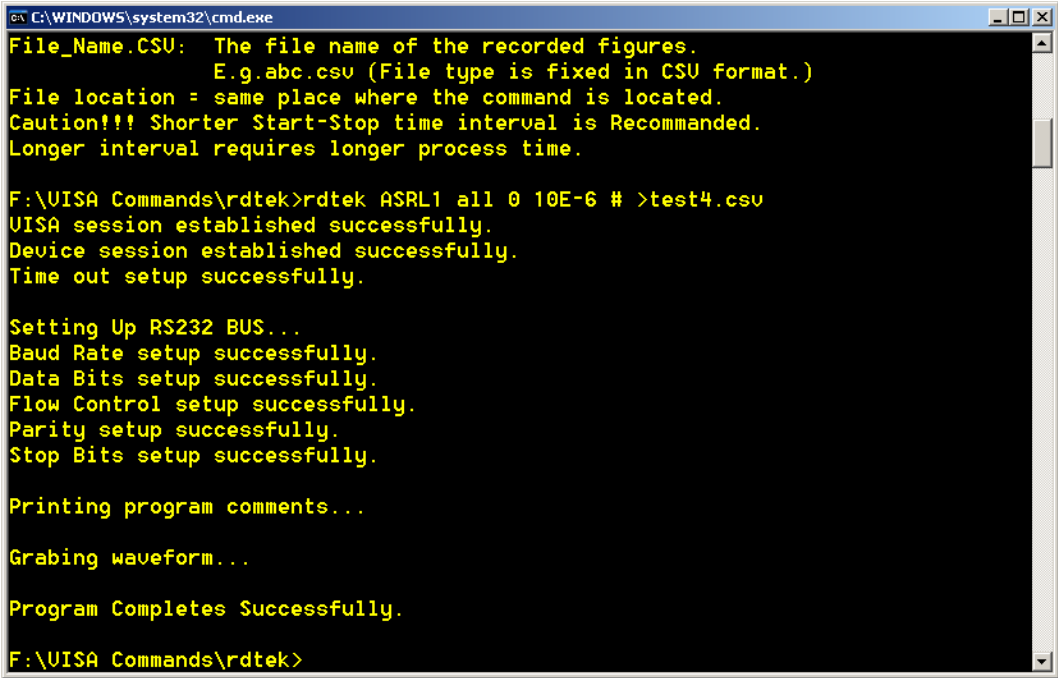
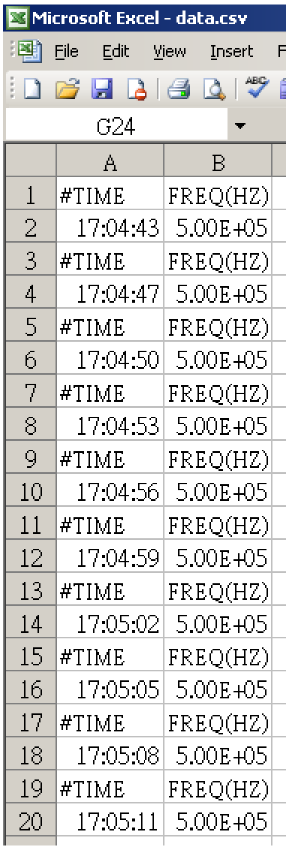


Figure 6.27 *The rdtek command sent to Tektronix TPS2024. The rdtek command sets up the RS232 interface parameter if the VISA address indicates a COM port. The rdtek command downloads the waveform from 0 to 10u seconds into test4.csv file.*

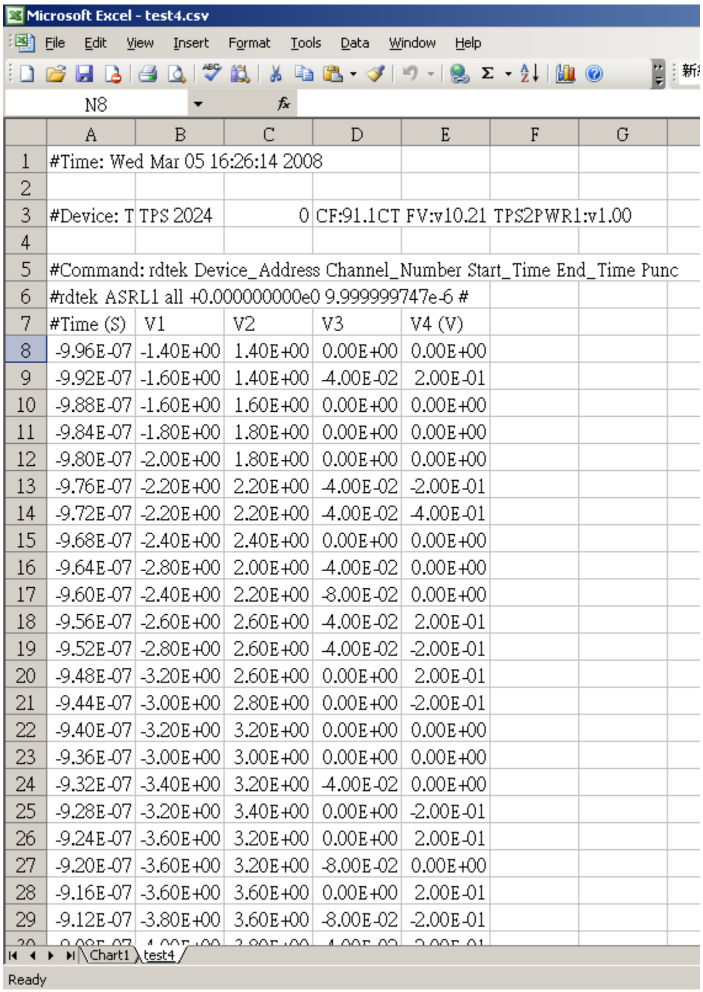
In figure 6.25 the set503 command make the FG503 outputs 500 KHz, 10V peak-to-peak sine wave with 0V offset to the 34401A and to channel 1 and 2 of the TPS2024. The set503 command only shows the progress of the command, because the FG503 did not respond to the queries while developing the set503 command. In figure 6.26, the rd344xx command reads the signal frequency is around 499 KHz from the FG503. In figure 6.27, the rdtek command sets up the RS232 interface parameter when it identify the VISA address is a COM port. The parameters are the same as shown in Appendix A.2 RS-232 Interface.

Results



	A	B
1	#TIME	FREQ(HZ)
2	17:04:43	5.00E+05
3	#TIME	FREQ(HZ)
4	17:04:47	5.00E+05
5	#TIME	FREQ(HZ)
6	17:04:50	5.00E+05
7	#TIME	FREQ(HZ)
8	17:04:53	5.00E+05
9	#TIME	FREQ(HZ)
10	17:04:56	5.00E+05
11	#TIME	FREQ(HZ)
12	17:04:59	5.00E+05
13	#TIME	FREQ(HZ)
14	17:05:02	5.00E+05
15	#TIME	FREQ(HZ)
16	17:05:05	5.00E+05
17	#TIME	FREQ(HZ)
18	17:05:08	5.00E+05
19	#TIME	FREQ(HZ)
20	17:05:11	5.00E+05

Figure 6.28 *The data.csv file of the rd344xx command. The file accumulates the downloaded value by using the rd344xx command.*



	A	B	C	D	E	F	G
1	#Time: Wed Mar 05 16:26:14 2008						
2							
3	#Device: T	TPS 2024	0	CF:91.1CT FV:v10.21 TPS2PWR1:v1.00			
4							
5	#Command: rdtek Device_Address Channel_Number Start_Time End_Time Punc						
6	#rdtek ASRL1 all +0.000000000e0 9.999999747e-6 #						
7	#Time (S)	V1	V2	V3	V4 (V)		
8	-9.96E-07	-1.40E+00	1.40E+00	0.00E+00	0.00E+00		
9	-9.92E-07	-1.60E+00	1.40E+00	-4.00E-02	2.00E-01		
10	-9.88E-07	-1.60E+00	1.60E+00	0.00E+00	0.00E+00		
11	-9.84E-07	-1.80E+00	1.80E+00	0.00E+00	0.00E+00		
12	-9.80E-07	-2.00E+00	1.80E+00	0.00E+00	0.00E+00		
13	-9.76E-07	-2.20E+00	2.20E+00	-4.00E-02	-2.00E-01		
14	-9.72E-07	-2.20E+00	2.20E+00	-4.00E-02	-4.00E-01		
15	-9.68E-07	-2.40E+00	2.40E+00	0.00E+00	0.00E+00		
16	-9.64E-07	-2.80E+00	2.00E+00	-4.00E-02	0.00E+00		
17	-9.60E-07	-2.40E+00	2.20E+00	-8.00E-02	0.00E+00		
18	-9.56E-07	-2.60E+00	2.60E+00	-4.00E-02	2.00E-01		
19	-9.52E-07	-2.80E+00	2.60E+00	-4.00E-02	-2.00E-01		
20	-9.48E-07	-3.20E+00	2.60E+00	0.00E+00	2.00E-01		
21	-9.44E-07	-3.00E+00	2.80E+00	0.00E+00	-2.00E-01		
22	-9.40E-07	-3.20E+00	3.20E+00	0.00E+00	0.00E+00		
23	-9.36E-07	-3.00E+00	3.00E+00	0.00E+00	0.00E+00		
24	-9.32E-07	-3.40E+00	3.20E+00	-4.00E-02	0.00E+00		
25	-9.28E-07	-3.20E+00	3.40E+00	0.00E+00	-2.00E-01		
26	-9.24E-07	-3.60E+00	3.20E+00	0.00E+00	2.00E-01		
27	-9.20E-07	-3.60E+00	3.20E+00	-8.00E-02	0.00E+00		
28	-9.16E-07	-3.60E+00	3.60E+00	0.00E+00	2.00E-01		
29	-9.12E-07	-3.80E+00	3.60E+00	-8.00E-02	-2.00E-01		

Figure 6.29 *The test4.csv file of the rdtek command. The test4.csv file contains time of execution of the rdtek command, device used, the command echo and the downloaded values.*

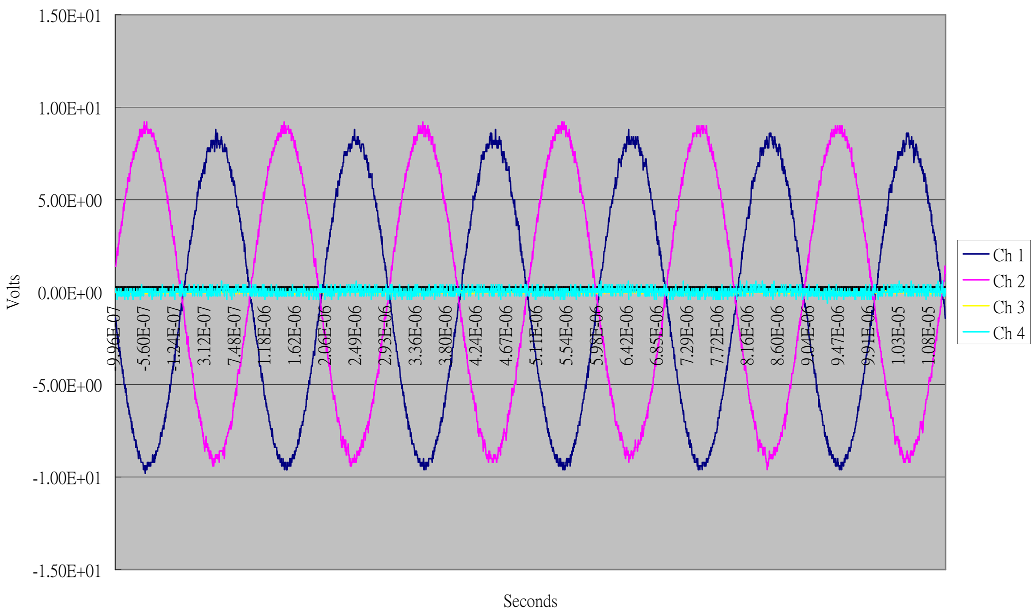


Figure 6.30 *The graphical of the test4.csv file. The graph shows a normal sine wave on the channel 1 and an inverted since wave on the channel 2 of the TPS2024. The channel 3 and 4 do not have signal. The peak voltage of the sine wave is around 10V with frequency around 499KHz.*

In figure 6.28 the data.csv file shows 10 accumulated reading in frequency around 499 KHz from the FG503 output. Figure 6.29 shows the contents of test4.csv file that are the downloaded values from the TPS2024. The file contains the execution time, device used, command echo and the actual waveform values. Figure 6.30 is the re-plotted waveform by using test4.csv file and MS Excel. The sine wave in channel 1 is normal, channel 2 is inverted, and channel 3 and 4 do not have any signals, which is the same as the configuration established initially. The peak voltage for the sine wave is around 10V with the signal frequency around 499 KHz, which is close to the reading from the 34401A and output from the FG503.

6.2.3. Agilent 33220 and Tektronix MSO4054

Hardware Configurations

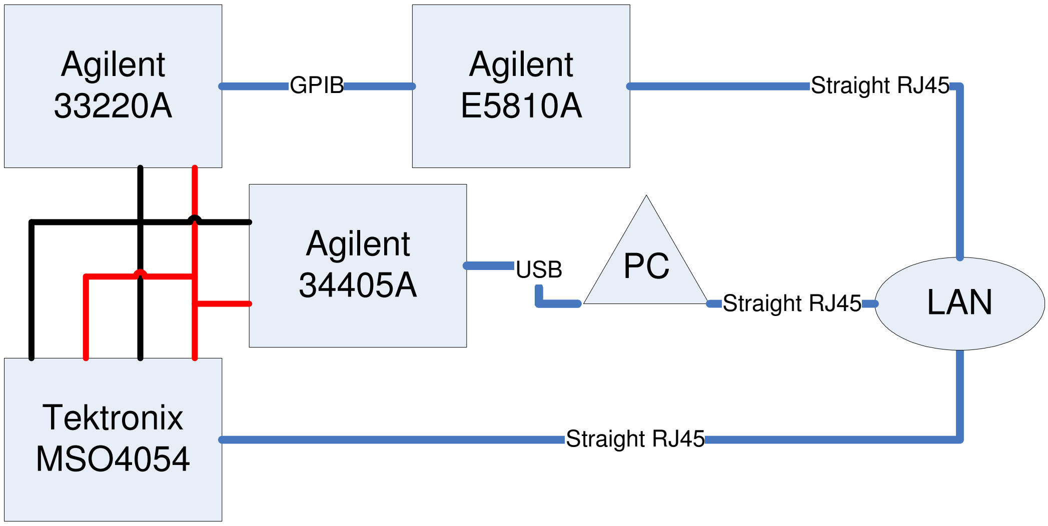


Figure 6.31 *The connection example using Agilent 33220A, Agilent 34405A and Tektronix MSO4054. The 33220A is connected the user's PC through the E5810A and the MSO4054 is connected to the user's PC through the local LAN. The channel 1 and 2 of the MSO4054 and the probe of the 34405A are connected in parallel with the output of the 33220A. The 34405A is directly connected to the user's PC through USB cable.*

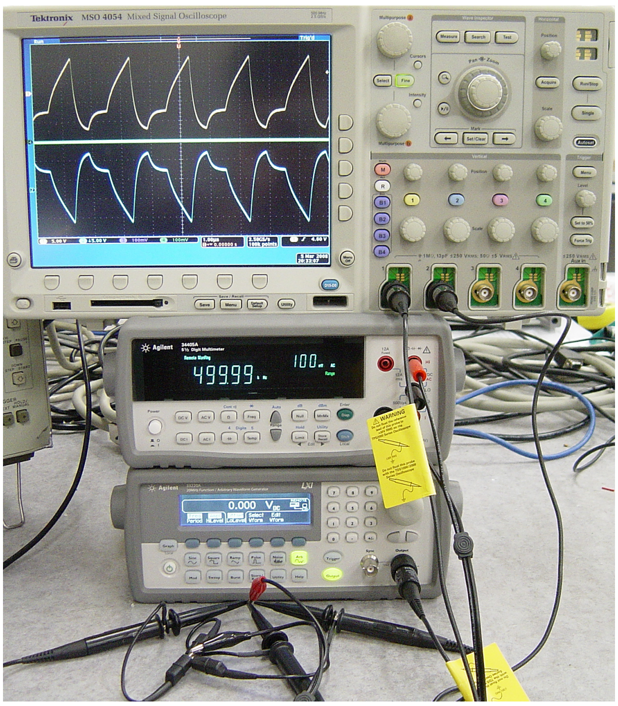


Figure 6.32 *The actual connection of the Agilent 33220A, Agilent 34405A and Tektronix MSO4054. The channel 1 and 2 of the MSO4054 and the probe of the 34405A are connected to the output of the 33220A in parallel. The screen of MSO4054 shows the user defined arbitrary waveform with frequency around 500 KHz measured by the 34405A.*

This example uses Agilent 33220A function generator, Agilent 34405A multimeter, and Tektronix MSO4054 to cross-examine the VISA commands with the results. The 33220A outputs a user defined waveform as shown in figure 6.22 to the 34405A and the MSO4054. The 34405A measures the frequency of waveform to confirm with the settings of the 33220A configured using the set33220 command. The MSO4054 downloads the waveform values and allows the user to re-plot the waveform and compare with the reading and settings of 34405A and 33220A.

From figure 6.31 and 6.32 the output of the 33220A is connected in parallel to channel 1 and 2 of the MSO4054 and the probe of 34405A. The 34405A is responsible for measuring the frequency and the MSO4054 is downloading the waveform from the 33220A. The 33220A is responsible for outputting the user defined arbitrary waveform as shown on the screen of the MSO4054 in figure 6.32. The signal in channel 1 is normal and the signal in channel 2 is inverted on the MSO4054 as shown in figure 6.32. The 33220A is connected to E5810A gateway and communicate with the user's PC via the local LAN. The MSO4054 is on the local LAN allowing the user access. The 34405A is connected with a USB cable directly to the user's PC.

Commands and Parameters

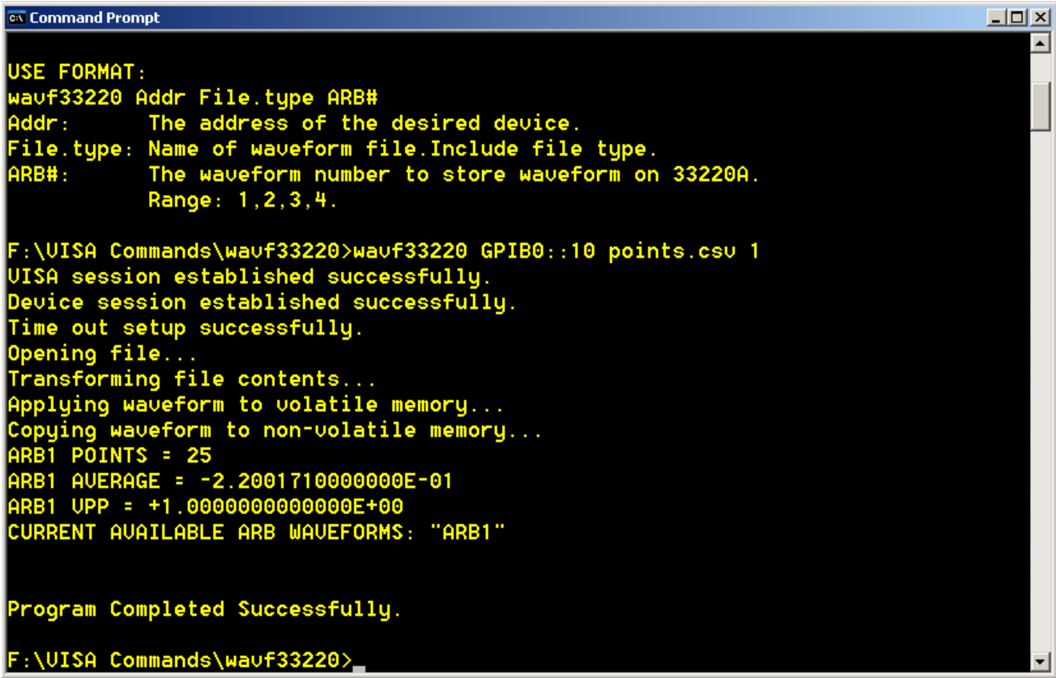


Figure 6.33 *The wavf33220 command sent to the 33220A. The wavf33220 reads the user defined waveform from the "points.csv" file and sends the waveform to the 33220A. The user-defined waveform is stored as "ARB1" in the 33220A.*

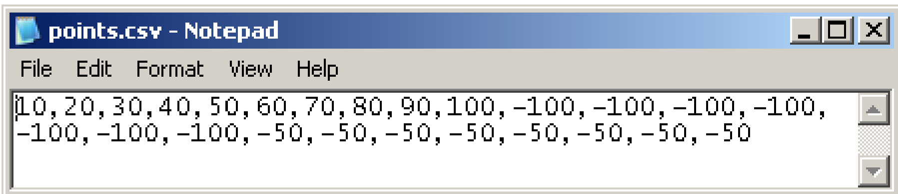


Figure 6.34 *The contents of the "points.csv" file. The value is in percentage and the users allow entering any number from 100 to 100 and separating every value with comma.*

In figure 6.33 the wavf33220 command uploads the user-defined waveform in "points.csv" file to the 33220A. The wavf33220 command only allows the user to upload the user-defined waveform rather than outputting the waveform, and the user should use set33220 to output the waveform. Figure 6.34 shows the contents of a valid user defined waveform file. Every number in the file can be a positive or negative percentage, separated by a comma without a space. The

33220A can accept up to 65535 percentage numbers. Any typing errors in this file will cause wavf33220 to malfunction. If the user does not see the return confirmation of ARB waveform returned by the wavf33220 command, then this means the user defined waveform file contents is invalid.

```
Command Prompt
Wavf:      Desired waveform function.
  Range:SIN,SQU,RAMP,PULS,NOIS,DC,ERIS,EFAL,NRAMP,SINC,CARD,ARB1,ARB2,ARB3,ARB4
Freq:      The waveform frequency.
Amplitude: Set desired amplitude.
Offset:    Waveform offset value.(Offset=Amp when Wavf=DC)
Dcyc/Symm: Desired Duty cycle(Pulse/Square)
           or Symmetry(Ramp)
           Range:0~100
Pwr:       Power switch.
           Range:ON,OFF

F:\VISA Commands\set33220>set33220 GPIB0::10 ARB1 500E3 10 0 x on
VISA session established successfully.
Device session established successfully.
Time out setup successfully.
WAVF = USER
ARB WAVF = ARB1
FREQ = 500.00000e+3
AMP = 10.000000e+0
OFFSET = +0.0000000e0
OUTPUT = 1

Program Completed Successfully.

F:\VISA Commands\set33220>_
```

Figure 6.35 *The set33220 command sent for user-defined waveform. The set33220 command setup the frequency, amplitude and offset of the user-defined waveform pre-loaded by the wavf33220 command previously. The set33220 command will return with waveform confirmation.*

```
Command Prompt
Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: RD344xx V1.00 by DH, Jan 2008
Hardware: Agilent 344xx series.
Software Description:Read Agilent 344xx series.

USE FORMAT:
rd344xx Addr Punc

Addr:   The address of the desired device.
          e.g.USB1::1689::869::C020200::0
Punc(optional): Set puncuation mark.
                This optional function will enable recording function.
                Recorded file named data.csv
          e.g. /,,&,$,#...etc DEF=#

F:\VISA Commands\rd344xx>rd344xx USB0::2391::1560::TW46490154::0
VISA session established successfully.
Device session established successfully.
Time out setup successfully.
#TIME,FREQ(HZ)
20:20:12,499.990e+3

Program Completed Successfully.

F:\VISA Commands\rd344xx>
```

__Figure 6.36__ The rd344xx sent to Agilent 34405A. The rd344xx command reads 499.99 KHz.

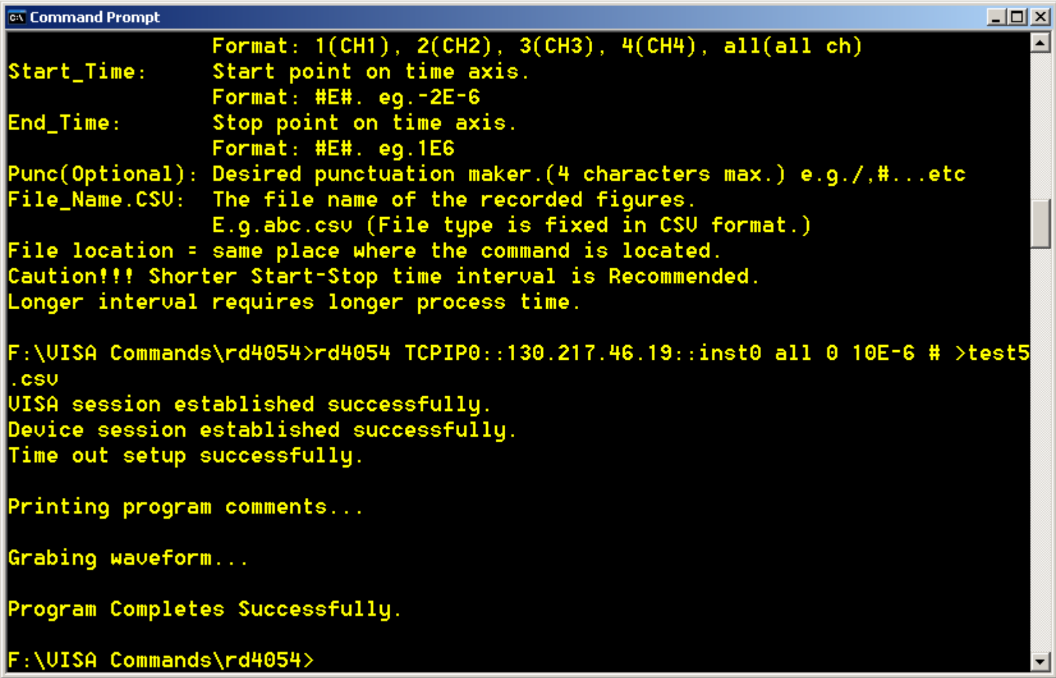


__Figure 6.37__ The rd4054 sent to Tektronix MSO4054. The rd4054 downloads the waveform from 0 to 10u seconds and stores to test5.csv file under the same path of the rd4054 command.

The user-defined waveform must be uploaded into the 33220A with the wavf33220 command, before the user can output the waveform by using the set33220 command. The set33220 command is responsible for setting up the waveform output parameters such as frequency, amplitude, offset, and so on. In figure 6.34 the set33220 command outputs the user defined waveform with 500 KHz in frequency, 10V peak in amplitude and 0V offset to the 34405A and the MSO4054 as shown in figure 6.32. Figure 6.35 show that the 34405A reads around 499.99 KHz in frequency by using the rd344xx command. This reading is very close to what the 33220A outputs. Figure 6.36 shows that the rd4054 command downloads the user-defined waveform from 0 to 10 microseconds and stores the values in the test5.csv file.

Results

Microsoft Excel - data.csv

	A	B
1	#TIME	FREQ(HZ)
2	17:04:43	5.00E+05
3	#TIME	FREQ(HZ)
4	17:04:47	5.00E+05
5	#TIME	FREQ(HZ)
6	17:04:50	5.00E+05
7	#TIME	FREQ(HZ)
8	17:04:53	5.00E+05
9	#TIME	FREQ(HZ)
10	17:04:56	5.00E+05
11	#TIME	FREQ(HZ)
12	17:04:59	5.00E+05
13	#TIME	FREQ(HZ)
14	17:05:02	5.00E+05
15	#TIME	FREQ(HZ)
16	17:05:05	5.00E+05
17	#TIME	FREQ(HZ)
18	17:05:08	5.00E+05
19	#TIME	FREQ(HZ)
20	17:05:11	5.00E+05

***Figure 6.38** The data.csv file of the rd344xx command. The records contain the 10 frequency readings with time stamp.*

Microsoft Excel - test5.csv

	A	B	C	D	E	F	G
1	#Time: Wed Mar 05 20:46:14 2008						
2							
3	#Device: T	MSO4054	C000486	CF:91.1CT FV:v2.01			
4							
5	#Command: rdtek Device_Address Channel_Number Start_Time End_Time Punc						
6	#rdtek TCPIP0::130.217.46.19::inst0 all +0.000000000e0 9.999999747e-6 #						
7	#Time (S)	V1	V2	V3	V4 (V)		
8	-1.00E-06	-6.90E+00	6.70E+00	0.00E+00	0.00E+00		
9	-1.00E-06	-6.90E+00	6.70E+00	0.00E+00	0.00E+00		
10	-9.99E-07	-6.90E+00	6.70E+00	0.00E+00	0.00E+00		
11	-9.99E-07	-6.70E+00	6.70E+00	4.00E-03	-8.00E-03		
12	-9.98E-07	-6.70E+00	6.90E+00	4.00E-03	-1.60E-02		
13	-9.98E-07	-6.70E+00	6.90E+00	0.00E+00	-4.00E-03		
14	-9.98E-07	-6.70E+00	6.90E+00	0.00E+00	-8.00E-03		
15	-9.97E-07	-7.10E+00	6.90E+00	8.00E-03	-4.00E-03		
16	-9.97E-07	-6.90E+00	6.70E+00	8.00E-03	-4.00E-03		
17	-9.96E-07	-6.50E+00	6.70E+00	4.00E-03	0.00E+00		
18	-9.96E-07	-6.70E+00	6.90E+00	4.00E-03	-8.00E-03		
19	-9.96E-07	-6.70E+00	7.10E+00	0.00E+00	4.00E-03		
20	-9.95E-07	-6.50E+00	6.90E+00	0.00E+00	-8.00E-03		
21	-9.95E-07	-6.70E+00	6.70E+00	8.00E-03	0.00E+00		
22	-9.94E-07	-6.70E+00	6.50E+00	8.00E-03	0.00E+00		
23	-9.94E-07	-6.70E+00	6.50E+00	0.00E+00	-4.00E-03		
24	-9.94E-07	-6.30E+00	6.50E+00	8.00E-03	-4.00E-03		
25	-9.93E-07	-6.50E+00	6.50E+00	8.00E-03	-4.00E-03		
26	-9.93E-07	-6.70E+00	6.70E+00	8.00E-03	-8.00E-03		
27	-9.92E-07	-6.70E+00	6.70E+00	4.00E-03	-1.20E-02		
28	-9.92E-07	-6.70E+00	6.90E+00	8.00E-03	-1.20E-02		
29	-9.92E-07	-6.70E+00	6.50E+00	8.00E-03	-4.00E-03		

***Figure 6.39** The contents of the test5.csv. The file contains the command execution time, device used, the command echo and the recorded waveform values. The time is the time point in seconds on the x-axis of the MSO4054 screen.*

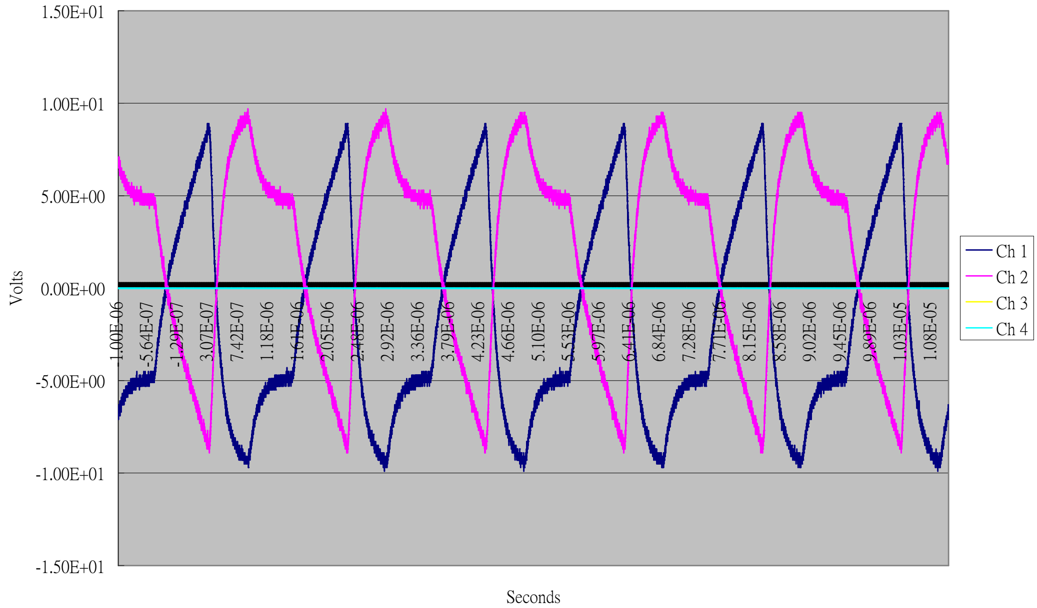


Figure 6.40 *The graphical result of the test5.csv file . The frequency of this waveform is around 460 KHz with around 10V peak voltage.*

Figure 6.37 shows that the frequency reading from the 34405A is about the same as the output frequency from the 33220A. Figure 6.39 indicates the output amplitude is about 10V peak, which is almost the same as the output amplitude form the 33220A. The frequency is about 460 KHz by calculating the period from the graph, but the graph is not showing point to point details and the original file is too large to include it here. The waveform shows in figure 6.39 as expected from the waveform in the "points.csv" file. The results matched to each other and the instruments are performing as required and expected originally.

7. Specific Command

7.1. Introduction

The purpose for this specific command is recording the 12V car battery capacity, charging, and discharging characteristics. The recorded value allows the user to analyze the charging and discharging characteristics in order to apply the battery to a suitable application for optimal performance. This command is capable of charging and discharging any voltage range of battery. It uses a constant current of 2A to charge and discharge the battery.

The typical composition of a 12 volt car battery is lead-acid with 6 serials connected to 2.1 volt cells to provide around 12.6V output. The battery is usually made up of lead and lead oxide plates, that are submerged in an electrolyte solution made of 35% sulphuric acid and 65% of water. Normally, the charging and discharging process will require about 2.5 days with a constant current of 2A. The programme will then calculate the time taken and display the battery performance in AH rating in the recorded file. There will be recorded file comments, such as starting time, completion time, command echo, and power supply status. The command is only compatible with the HAMEG HM8143 power supply. Table 7.1 below shows the typical charging state of a 12 volt car battery.

Open Circuit Voltage	~ State-of-charge
12.65 V	100 %
12.45 V	75 %
12.24 V	50 %
12.06 V	25 %
11.89 V	0 %

***Table 7.1** The typical 12V car battery capacity. 11.89V to 12.65V is the operational range for a 12V car battery. Any voltage below 11.89V is less likely to satisfy a 12V battery application.*

To avoid damage to the battery, this programme only charge and discharge the battery to the level according to figure 7.1. Any exceed charging will potentially causing hazard, which the user should be taking with extra care. Any over exceed discharging will shorten the life cycle of the battery.

7.2. Hardware Set Up

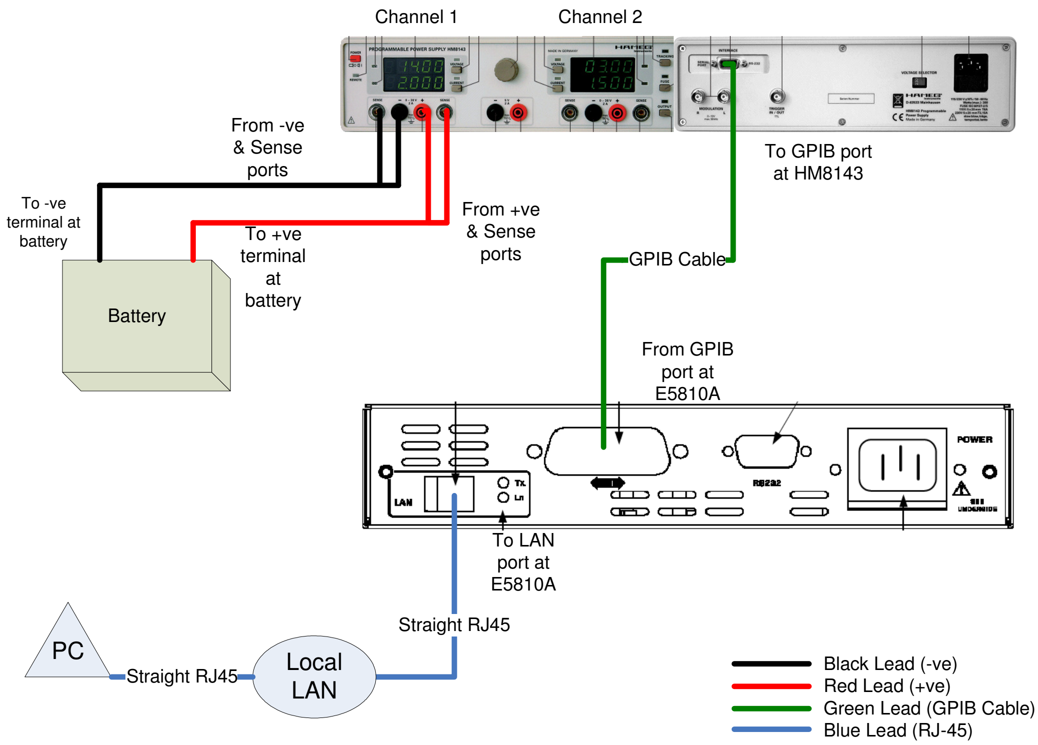


***Figure 7.1** The connection of bc8143 application. The connection starts from the battery to HM8143 with a parallel connection to power output and the two sense ports. GPIB cable connects the HM8143 from its back panel to the GPIB connector on the back panel of E5810A. Straight RJ45 cable connects from the LAN port of the E5810A to a computer network, or uses a crossover RJ45 cable to connect to a PC directly. [Source: Agilent E5810A LAN/GPIB Gateway for Windows User's Guide, Agilent, Ref: 18] [Source: HAMEG HM8143 Arbitrary Power Supply User Manual, HAMEG Ref: 6]*

Figure 7.1 Shows the typical hardware connection in order to use this command. The test object is a heavy-duty 12V car battery brought from the local automotive shop.

Step 1: Connect the GPIB and RJ45 cables according to figure 7.1.

Step 2: Connect the battery to the channel 1 and sense ports of the HM8143 as shown in figure 6.1

Step 3: Follow steps in Appendix A accordingly to complete and confirm the device has been added properly.

Step 4: Follow steps in section 1.5 VISA Address HOWTO in the thesis, and copy the VISA address.

At this stage the hardware should be ready for the user to use the bc8143 command to test the battery.

7.3. bc8143

This command allows the user to charge and discharge the rechargeable battery by using the HM8143 power supply with maximum 30V and 2A in DC voltage and current limits. The command uses a constant current charging and discharging method, to track and calculate the capacity of the battery at the end of the process. The capacity result of the battery is in ampere-hour unit. The user can also re-plot the charging and discharging characteristic graph by using the recorded values created by this command. The VISA address in this command is different from the commands in previous chapters. All parameters are compulsory and the punctuation mark is pre-set to "#." The user can read the 'quick help' by entering only the command name at the command prompt. The typical VISA address for a GPIB interface on the E5810A gateway is similar to the following:

GPIB0::1::INSTR

GPIB0 indicates the GPIB interface on the E5810A. The number "0" is the "VISA_Name#" parameter in this command and the number "1" is the "GPIB_Address" parameter in the command.

VISA_Name# - This is the number behind "GPIB" in the VISA address.

Func – The user desired function. The user can enter either "c" for charging or "d" for the discharging function, other enteries are invalid.

Vbatt – The output voltage from the HM8143. The voltage level should not exceed the battery voltage. Maximum available voltage is up to 30V.

Ibatt – The output current from the HM8143. The maximum current level is up to 2A.

GPIB_Address – The second number appears in the VISA address.

FileName.filetype – The file name and the file type of the recorded file. The format of the recorded file is always in CSV format.

BattCapa8143 V1.00 by DH Mar 2007 based on CurveTrace8143 V1.00 by cJBS Jan 2007
Uses Hameg HM8143 PSU to measure & record battery charging & discharging characteristic.

Usage Format= bc8143 VISA_Name# Func vbatt ibatt GPIB_Address >FileName.filetype

VISA_Name# is the VISA name#. No Unit. Format = XX (e.g. 1 for GPIB1 or 12 for GPIB12, etc) Range 0 ~ 255
Func is the function choice to discharge or charge the battery. Format = c (charge) / d (discharge)

vbatt is the maximum voltage of the battery. Format = 12 Range:00.00 ~ 30.00 V
ibatt is the maximum current of the battery. Format = 2 Range:0.000 ~ 2.000 A
GPIB_Address is the address of the HM8143 (Default = 1)
FileName.filetype is the file name of the recorded figures. Format = abc.csv (can be any file type based on user input.) File location = same place where batdschg8143.exe is located.

Note: Process will always set on constant current mode. Max Power output = 30V x 2A = 60W (DC) for HM8143.

7.4. Bc8143 Command Example

The user should follow steps in sections Appendix: B. Agilent E5810A Gateway set up and Appendix: A. Adding Instruments in Agilent VISA in this thesis to confirm the connection has been established properly. The example below is running a discharging function and then charging on the same 12V car battery. This section will only show the command example sent for the two functions.

The command bc8143 sent for discharging operation is as follows.

Charging Command – bc8143 0 d 12 2 1 >12vdschg.csv

This command locates the HM8143 at address GPIB0::1, the VISA number is the number after GPIB and the GPIB address is the last number in the line.

Command bc8143 will output a CSV file named “12vdschg” under the same path of the command location.

“bc8143” – command name

“0” – VISA number

“d” – Discharging function

“12” – 12 volts

“2” – 2 amps

“1” – First GPIB address

“>12vdschg.csv” – Output a CSV file named 12vdschg.

The command bc8143 sent for charging operation is as follows.

Charging Command – bc8143 0 c 12 2 1 >12vchg.csv

This command locates the HM8143 at address GPIB0::1, the VISA number is the number after GPIB and the GPIB address is the last number on the line.

Command bc8143 will output a CSV file named “12vchg” under the same path of the command location.

“bc8143” – command name

“0” – VISA number

“c” – Charging function

“12” – 12 volts

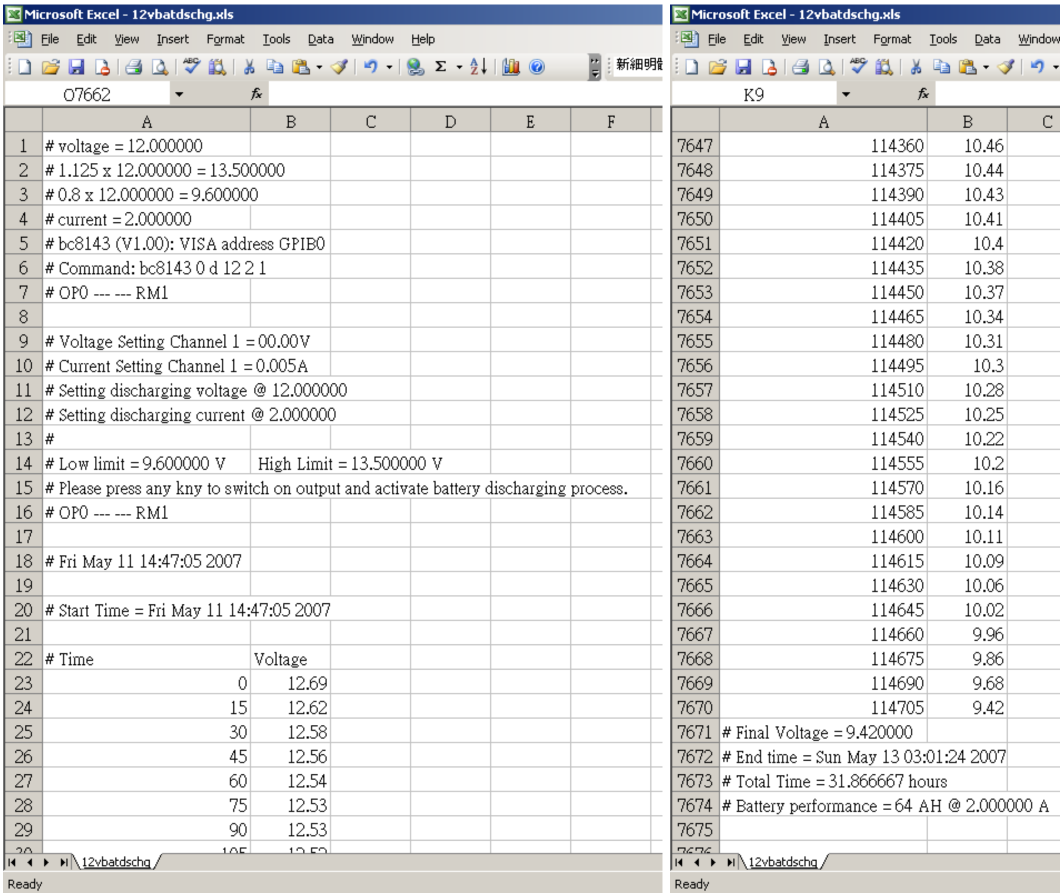
“2” – 2 amps

“1” – First GPIB address

“>12vchg.csv” – Output a CSV file named 12vchg.

7.5. Results

Discharging:



Microsoft Excel - 12vbatdschg.xls

	A	B	C	D	E	F
1	# voltage = 12.000000					
2	# 1.125 x 12.000000 = 13.500000					
3	# 0.8 x 12.000000 = 9.600000					
4	# current = 2.000000					
5	# bc8143 (V1.00): VISA address GPIB0					
6	# Command: bc8143 0 d 12 2 1					
7	# OP0 --- --- RM1					
8						
9	# Voltage Setting Channel 1 = 00.00V					
10	# Current Setting Channel 1 = 0.005A					
11	# Setting discharging voltage @ 12.000000					
12	# Setting discharging current @ 2.000000					
13	#					
14	# Low limit = 9.600000 V	High Limit = 13.500000 V				
15	# Please press any kny to switch on output and activate battery discharging process.					
16	# OP0 --- --- RM1					
17						
18	# Fri May 11 14:47:05 2007					
19						
20	# Start Time = Fri May 11 14:47:05 2007					
21						
22	# Time	Voltage				
23	0	12.69				
24	15	12.62				
25	30	12.58				
26	45	12.56				
27	60	12.54				
28	75	12.53				
29	90	12.53				

Microsoft Excel - 12vbatdschg.xls

	A	B	C
7647	114360	10.46	
7648	114375	10.44	
7649	114390	10.43	
7650	114405	10.41	
7651	114420	10.4	
7652	114435	10.38	
7653	114450	10.37	
7654	114465	10.34	
7655	114480	10.31	
7656	114495	10.3	
7657	114510	10.28	
7658	114525	10.25	
7659	114540	10.22	
7660	114555	10.2	
7661	114570	10.16	
7662	114585	10.14	
7663	114600	10.11	
7664	114615	10.09	
7665	114630	10.06	
7666	114645	10.02	
7667	114660	9.96	
7668	114675	9.86	
7669	114690	9.68	
7670	114705	9.42	
7671	# Final Voltage = 9.420000		
7672	# End time = Sun May 13 03:01:24 2007		
7673	# Total Time = 31.866667 hours		
7674	# Battery performance = 64 AH @ 2.000000 A		
7675			

***Figure 7.2** The contents of the 12vdschg.csv file. The Figure on the left hand side is the beginning of the file and contains comments of the instrument settings, the command echo, instrument status in programme progress, low and high operation limits, execution time and the actual readings. All comments are marked with "#" punctuation mark. The figure on the right hand side is the end of the file that contains the final voltage reading, end time, total time taken and the battery performance result in AH unit.*

The comment lines in the 12vdschg.csv file includes input voltage, current, fully charged point, fully discharged point, graph range, software version, VISA address, command sent, initial status of HM8143, standby voltage and current for channel 1, charging/discharging ratings, and start time. The fully charged point is 105% and the fully discharged point is 98% of user input voltage, pre-set in the command. The output graph range is the maximum charged or discharged point reached without damaging the battery. The high limit is 110% and low limit is 80% of the user input voltage. The current version of bc8143 is 1.00. The command line displays the exact user input without file output parameter. Status of HM8143 is always in the format of output_status channel1_status channel2_status control_mode. Output status can be either "OP1" for "output on" or "OP2" for "output off." Channel 1 status can be "CV1" for "constant voltage" or "CC1" for "constant current". Channel 2 status is same as channel 1. Control mode can be either "RM0" for "not remote controlled" or "RM1" for "remote controlled." Standby ch1 voltage and current are initialized by programme in order to clean the previous settings. The programme will then input the desired voltage and current into HM8143 and check the status again to ensure safety. Start time is recorded based on the software clock of the running PC with format of weekdays, month, date, hours, minutes, seconds, and year. At the end of the file, time start is the time recorded at 105% of the capacity, time end, is the time recorded at 92% of the capacity. Total time is calculated in hours in order to provide a battery performance in amp hour units, at the desired current rate. Finally, end time is the system time recorded when the programme finishes its operation. The format of end time is the same as the start time.

Charging:

Microsoft Excel - 12vbatchg.csv

	A	B	C	D
1	# Fully Charged Point=1.05x12.000000=12.600000	Fully Discharged Point=0.98x12.000000=11.760000	Graph Max V=1.125x12.000000=13.500000	Graph Min V=0.8x12.000000=9.600000
2	# current = 2.000000			
3	# bc8143 (V1.00): VISA address GPIB0			
4	# Command: bc8143 0 c 12 2 1			
5	# OP0 --- --- RM1			
6	# Voltage Setting Channel 1 = 00.00V			
7	# Current Setting Channel 1 = 0.005A			
8	# 1st step=3.000000V/0.500000A	2nd step=4.000000V/0.666667A	3rd step=6.000000V/1.000000A	4th step=12.000000V/2.000000A
9	# soft start commencing (1st step)...			
10	# 1st step power = 1.500000			
11	# soft start commencing (2nd step)...			
12	# 2nd step power = 2.666667			
13	# soft start commencing (3rd step)...			
14	# Actual 3rd step power = 6.000000			
15	# soft start commencing (4th step)...			
16	# Actual 4th step power = 24.000000			
17	# Start Time = Mon May 14 14:32:45 2007			
18				
19	# Time	Voltage		
20	0	10.73		
21	15	10.87		
22	30	10.9		
23	45	10.92		
24	60	10.94		
25	75	10.96		

12vbatchg

Ready

Figure 7.3 *The contents of the 12vchg.csv file. The file comments indicates the fully charge and discharge point in voltage, graph range, charge current, command echo, instrument status in programme progress, start time and the actual voltage values versus time in seconds.*

The contents for the charge record file is similar to the discharge records. It tells the reader of the fully charged point in voltage, the current for charging, instrument status in programme progress, and a soft-start progress to avoid impact of the sudden voltage change on the battery chemical, that could be potentially dangerous. The rest of the records are the voltage records versus time in seconds. The end of this file does not contain the battery performance calculation since it is a charging function.

The graphical results for the 12vdschg.csv and the 12vchg.csv files are below.

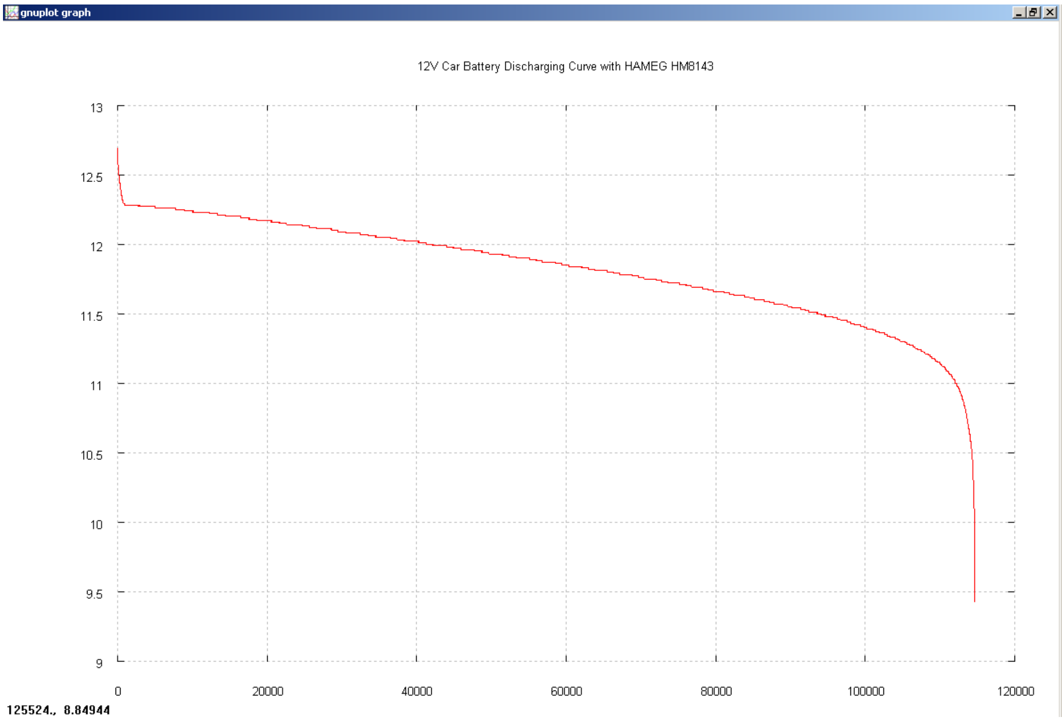


Figure 7.4 *The discharging characteristic of the 12V car battery. The total duration of this discharging process is around 114705 in seconds or 31.87 in hours. The battery starts discharging from 12.69V to 9.42V. According to the typical operation range of a 12V car battery, the operation time for this battery is around 60000 in seconds or 16.67 in hours.*

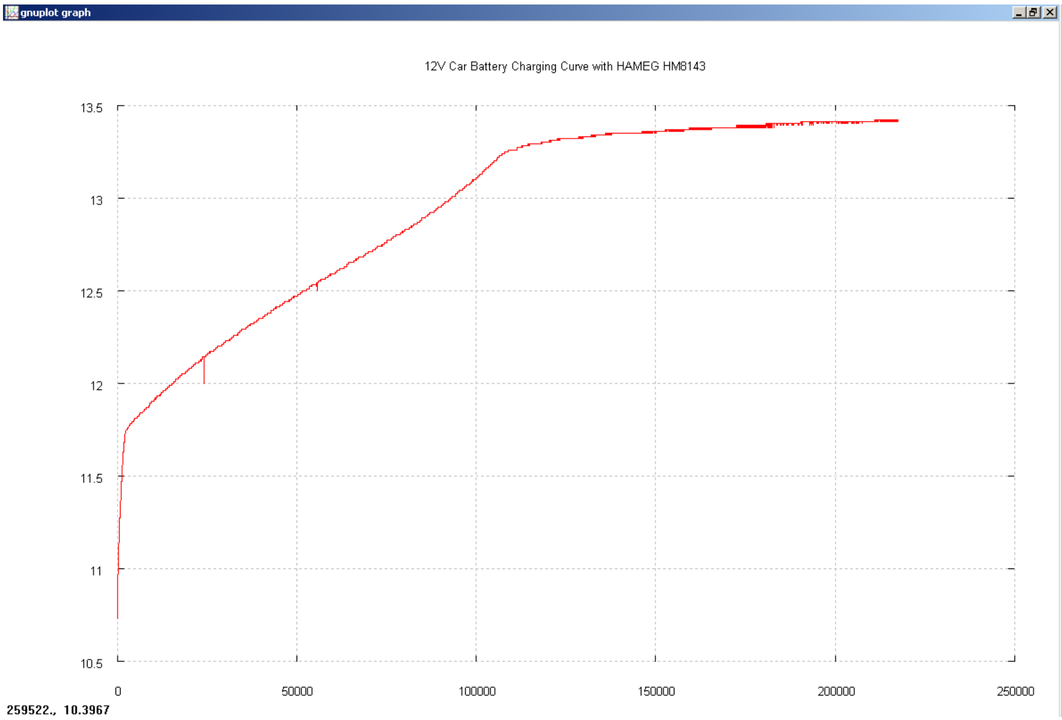


Figure 7.5 *The charging characteristic of the 12V car battery. The maximum charged voltage is around 13.42V with charging duration around 217665 in seconds or 60.46 hours. The starting point is from around 10.73V. The typical operation range for a 12V car battery is from 11.89V up to the top limit. The graph is drawn by GNUPLOT v4.2 from the CSV records file.*

Figures 7.4 and 7.5 are plotted by GNUPLOT 4.2, which is an open source software and allows the user to plot graphs in the command line environment. The command used in this case in order to plot a line graph is:

"plot <data location> using "%lf,%lf" with lines"

The "data location" is the path to the recorded output file from bc8143 command. "Using" function is applied to tell gnuplot the data is separated by a comma rather than a space. This parameter should be placed due to the default setting as a space not comma. The "with lines" parameter is necessary to plot the graph in line style, rather than the default cross style. Figure 7.4 shows a very clear battery discharge characteristic graph. The graph starts from around 12.75 volts to 9.49 volts with total duration of 114705 seconds, i.e. around 31 hours of discharging. However, a valid battery level is around 11.75 volts, which is around 80,000 seconds (about 22.22 hours) from 12.75 volts to 11.75 volts in figure 7.4. The valid battery performance is around 44.44 AH since the charging current is 2A. The charging characteristic graph in figure 7.5 is much sharper compared to the discharging graph. The graph shows it takes less time to charge from 9.49 volts to 12.75 volts than discharging from 12.75 volts to 9.49 volts. The time difference is around 38,000 seconds (about 10.56 hours). This indicates the battery uses less time to charge compared to discharging, which is an ideal rechargeable battery characteristic.

8. Conclusion and Future Work

8.1. Conclusion

Normally, users are required to sit in the laboratory to operate the experiment instrument, and recording the experiment results for the full length of the experiment. Such an operation takes time, and has a high chance after working long hours for human error. The command set produced in this thesis is providing users to control laboratory instruments remotely, and record the results automatically. With user friendly and public accessible features, the users can leave some repeatable experiments to run or record automatically, simply and remotely. The flexibility of the usage allows experiment instruments to become a mobile workbench or a fixed laboratory room. The commands can accelerate the electronic research progress in the engineering department, and perhaps other research in different departments in the future.

The commands produced in this thesis, are for the general functions of the common workbench instruments such as power supply units, digital multimeters, function generators, and oscilloscopes. In chapter 6 the applied commands cross-examine each other as expected at the beginning of the tests. The downloaded waveform values from the oscilloscopes allow the user to process the data with analysis software quickly. The user may see chapter 6 as a practical example, if not understanding the command explanations in the previous chapters. Chapter 7 shows how a specific long task can be easily done by using the bc8143 command. The task in chapter 7 took around two days to complete, which is not practical and can be unreliable if done manually. The battery type involved can also be potentially hazardous if the operation in not properly performed. The VISA commands provide an efficient and safe approach to assist the researchers in completing their tasks effortlessly.

8.2. Future Work

One of the future developments for this thesis is to create more VISA commands for academic users. Many instruments can be controlled with commands, these instruments are widely used in electronics, chemistry, and biological laboratories. Some software provided by the vendor may have certain limitations or unnecessary functions, where the user can use one simple command line to obtain the data or complete the task required. The more VISA commands developed the more flexible tools that the user may have. The software and license fees can also be reduced to a minimum by using the VISA commands.

Another future work is further developing any specific programme with batch file or graphical user interface. The VISA commands are possible to further develop into other programmes for specific tasks. The VISA commands can act like the basic blocks for different functions on different instruments. The future developers can use these blocks to build a programme for any specific task with graphical interface or automated batch files. Such a graphical interface programme will have a faster response than LabVIEW software, being more flexible rebuilt for other purposes.

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A. Appendix: Adding Instruments in Agilent VISA

In the Agilent Connection Expert window, the icon represents the connection status of the instrument. The green tick means the hardware device is connected properly, and identifies the device model by the Agilent Connection Expert.

The yellow warning mark indicates the hardware device is connected properly; however, the Agilent Connection Expert is not able to identify the model of the device nor the information. The red cross means the hardware device has not been connected properly.

A.1. GPIB Interface

Step 1: Open the Agilent Connection Expert window and expand all the sub instruments under each interface.

Step 2: Press "Refresh All" button and wait until the refresh finishes.

Step 3: Confirm the added device shows up under "Remote (GPIB)" interface.

A.2. RS-232 Interface

Direct Connection to the PC

Step 1: Open Agilent Connection Expert window and expand sub instruments under the COM (ASRL) interface.

Step 2: Figure A1 will appear after right clicking on the COM (ASRL) port and select "Change Properties."

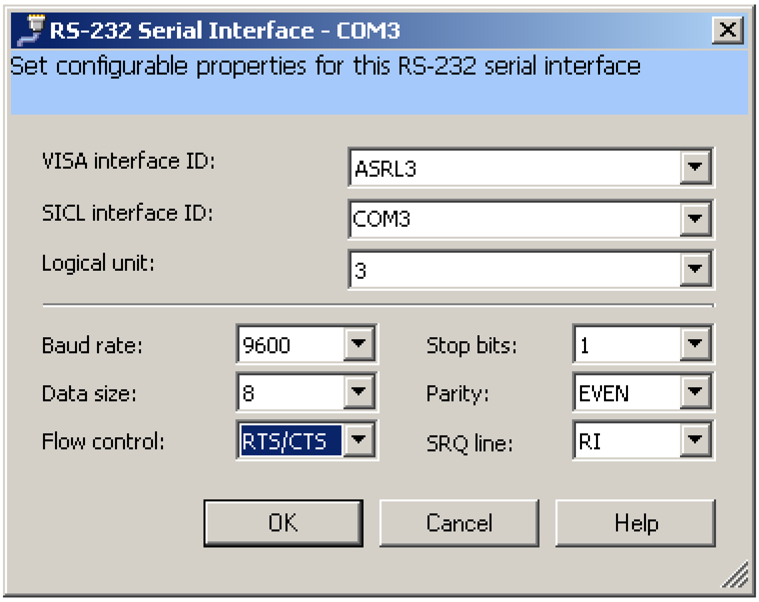

Figure A.1 *The RS-232 Interface properties. The RS-232 of PC should be the same configuration as the RS-232 settings of the device. In most cases, the configurations should be as shown above.*

Step 3: Configure the RS-232 according to figure A.1.

Step 4: Right click on COM (ASRL) and select "Add Instrument."

Step 5: Select COM (ASRL) in the "Add Instrument" window and click the "OK" button until it starts searching for a new instrument.

Step 6: The newly added instrument will show up under COM (ASRL) interface.

Connection through Agilent E5810A

Step 1: Open Agilent Connection Expert window.

Step 2: Click "Add Interface" at top of the Agilent Connection Expert window and the "Manually Add an Interface" window will appear.

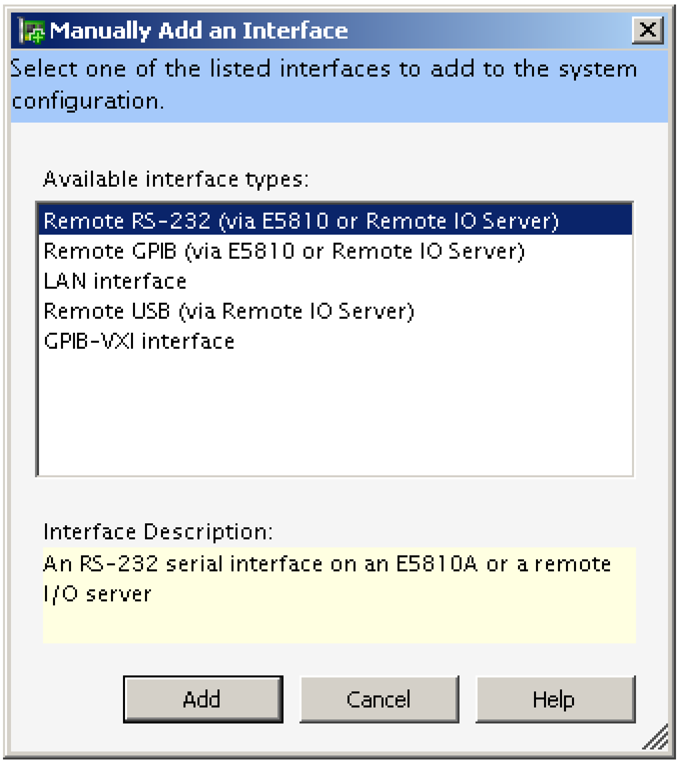

Figure A.2 *The Manually Add an Interface window. The E5810 have RS-232 and GPIB interfaces.*

Step 3: Select "Remote RS-232" option and click "Add" to add the RS-232 interface on the Agilent E5810A gateway. The "Remote Serial RS-232 Interface – Remote COM" window will appear.

Step 4: In the "Remote Serial RS-232 Interface – Remote COM" window click on "find the interface" and the "Find Remote ASRL Interfaces" window will appear.

Step 5: In the "Find Remote ASRL Interfaces" window, click "Find Now" and select the Agilent E5810A from the list and click "Ok" until all sub windows are closed. The list will not show the model name of the Agilent E5810A, but it will show the hostname and the IP address of Agilent E5810A. This search function will only find the test and measurement instruments. The user will see a new interface name "Remote COM (ASRL)" added in the Agilent Connection Expert window.

A.3. USB Interface

Step 1: Install the driver of the new "USB Test and Measurement Device" in Windows XP by letting Windows search for the hardware driver automatically.

Step 2: Open Agilent Connection Expert window and expand all sub instruments under each interface.

Step 3: Press "Refresh All" button and wait until the refresh finishes.

Step 4: Confirm the added device shows up under "USB" interface.

A.4. LAN Interface

Step 1: Open Agilent Connection Expert window and expand sub instruments under LAN (TCPIP) interface.

Step 3: Right click on the LAN interface in the Agilent Connection Expert window and select "Add Instrument."

Step 4: Select LAN (TCPIP) from the "Interface Name" column and press "OK."

Step 5: The window with title "LAN Instrument – TCPIP0::hostname.net.com::Inst0::INSTR" will appear.

Step 6: Click on the button "Find Instruments" and then click on "Find Now" button, and the "Search for Instruments on the LAN." window will come up.

Step 7: After search completed, select the desired device from the list and press "OK" button.

Step 8: Press "OK" button in the "LAN Instrument – TCPIP0::hostname.net.com::Inst0::INSTR" window and confirm the new device added under LAN (TCPIP) interface.

B. Appendix: Agilent E5810A Gateway Set Up

Some devices used in this thesis only have the GPIB or RS-232 interface, so they have to be connected to Agilent E5810A gateway, as there is no GPIB PCI adaptor card installed in the PCs at the University of Waikato. Hence, this section introduces the basic setting up and checking procedures to ensure a complete hardware environment.

Agilent E5810A is a LAN/GPIB gateway, which allows users to use any GPIB devices without the GPIB PCI adaptor card. Instead, users can access the device connected to E5810A through LAN and GPIB interface. In other words, E5810A it acts like an adapter for GPIB, RS-232 and LAN interfaces. As long as the PC fulfils the software requirements, users may use the commands immediately. The E5810A is operating similar to a network router but E5810A only establishes communication between LAN and GPIB or RS-232 buses. A user may use any GUI web browser to access the network and GPIB software settings inside E5810A. This method has been used to check and set up E5810A in this chapter. The instructions are in two parts, the first part is the hardware set up, and the second part is the software configuration. Both instruction parts must be correct before using the E5810A. Bearing in mind this chapter is a basic set up procedure. The users should refer back to the manual of Agilent E5810A for more details or trouble shooting.

Hardware Set Up

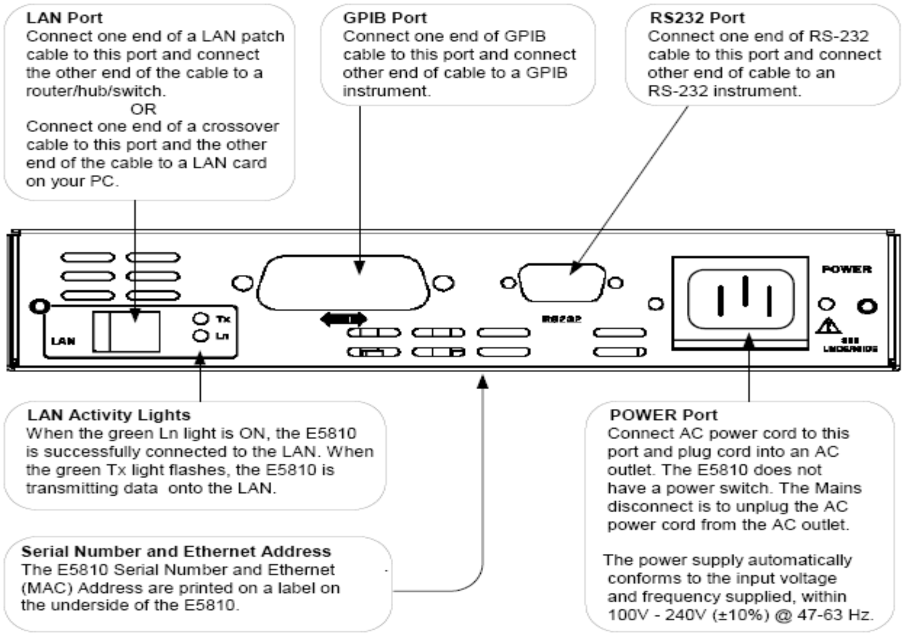

Figure B.1 *The back panel of Agilent E5810A. It has a GPIB, a RS232 and a LAN interfaces. GPIB interface can connect multiple instruments in either series or parallel connection, but RS232 port can only connect to one instrument at one time. The LAN port can be connected directly to a PC via a crossover RJ45 cable or connect to a computer network via a straight RJ45 cable. [Source: Agilent E5810A LAN/GPIB Gateway for Windows The user's Guide, Agilent, Ref: 18]*

The users should read through figure B.1 above to confirm the locations of each interface and power port at the back panel of the 5810A before continuing with the hardware set up.

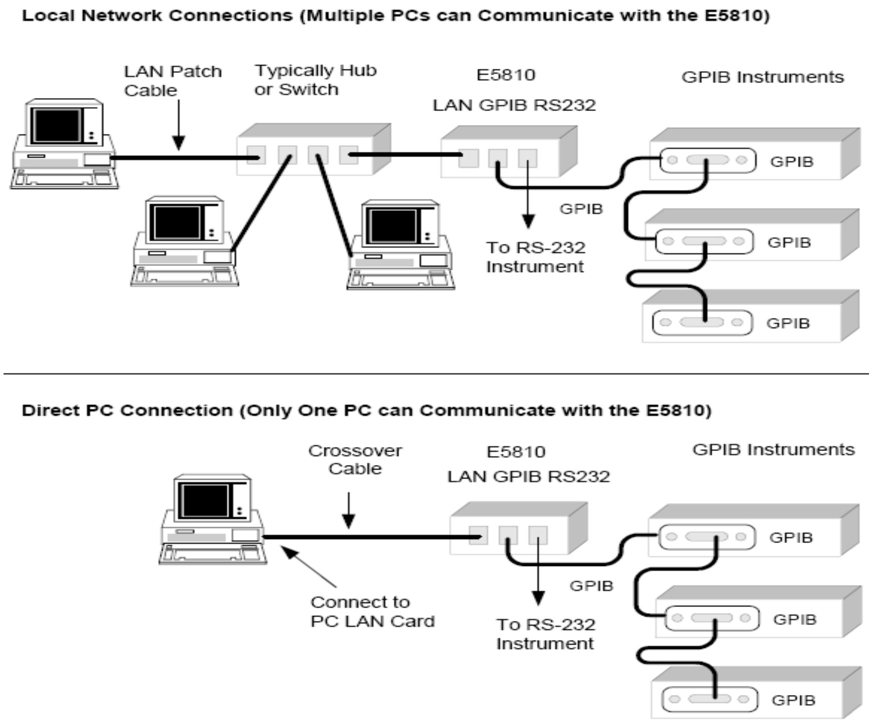

Figure B.2 *Possible Agilent E5810A connections. The GPIB cable can be connected bi-direction. The connection can be either parallel or series form E5810A. The RS-232 connector on E5810A can only connect to one device. The LAN of E5810A can connect to the computer network through a straight RJ45 cable or connect direct to the PC with a crossover RJ45 cable. [Source: Agilent E5810A LAN/GPIB Gateway for Windows The user's Guide, Agilent, Ref: 18]*

Step 1: Connect GPIB and RS-232 to E5810A according to the user's requirement, but LAN cable must present either connect to a PC network or direct to a PC as shown above in figure B.2 to access.

Step 2: Be mindful the E5810A does not have a power switch. The user should ensure safety first, before plugging in the power cable.

Step 3: Confirm the LEDs at front panel are flashing in order to check the hardware connections are done properly.

At this stage, the Agilent E5810A should be ready to set up the software settings. Before starting the software set up, the user should check whether the Fault LED at front panel is on, off, or flashing. If the fault LED is on, refer back to the user manual of E5810A for more detailed trouble shooting; or please follow the steps below to set up the software in E5810A.

Software Set Up

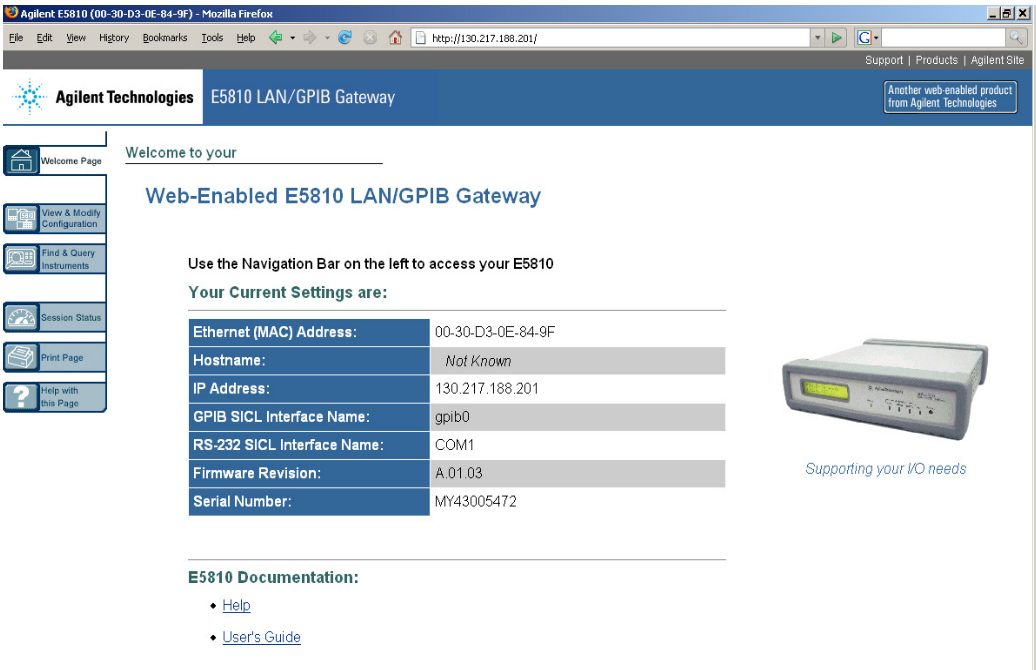

Figure B.3 *The welcome page of Agilent E5810A. Agilent E5810A welcome page shows the MAC address, IP address and host name, firmware version, and serial number of E5810A. It also indicates the GPIB interface and RS232 interface names . The user may check the details using the menu on the left hand side.*

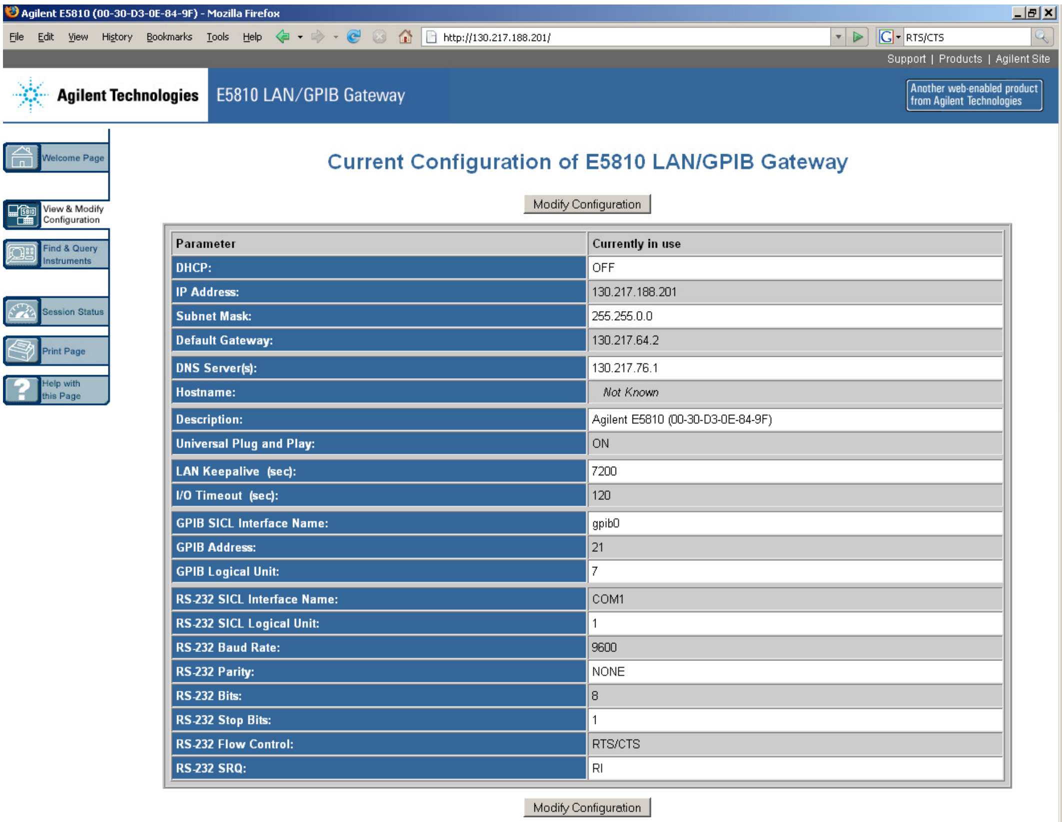

Figure B.4 *Agilent E5810A configuration page. The user should confirm the configurations of E5810A are the same as shown above before using the device. The configurations are setting up significant properties for the LAN, GPIB and RS232 interfaces.*

Step 1: Open up your GUI web browser, enter the IP address of E5810A in the address bar, and then press the enter key. The first welcome page looks like figure 1.6.

Step 2: On the left hand side of figure 1.4 click on the second tab from the top, “View & Modify Configuration” and confirm the configuration settings with figure 1.7.

If the configuration is not the same as shown in figure 1.4 please contact your network administrator or MIS professional before you modify these settings.

Setting Up Agilent E5810A in Agilent IO Library

Follow steps until Step 3 in section 1.7 later in the thesis and continue with following steps.

Step 1: Select “Add Interface” at the upper part of the window shown in figure 1.8.

Step 2: Select “Remote GPIB (via E5810 or Remote IO Server)” in the newly appeared window and press the “Add” button.

Step 3: Click the “Find Interfaces…” button in the “Remote GPIB interface – Remote” window.

Step 4: Click “Find Now” button in the “Find Remote GPIB Interfaces” window. Select the IP address that matches the IP address of the E5810A and press “OK” button.

Step 5: Click “OK” button and confirm a “Remote (GPIB#)” is shown in “Instrument I/O on this PC” column.

At this stage, the Agilent E5810A should be included into the Agilent Connection Expert as an interface that is capable of connecting instruments.

C. Appendix: The VISA Commands and References Location

The command set developed with this thesis are grouped by different file folders with the same name as the command. Each command should have a separated folder. Each file folder contains the source code of the command, the project file and the actual command. Some commands come with brief instruction. The instruction in this thesis is sufficient to support user for all commands. The user may also locate the relevant references for the used devices in this thesis, VISA and SCPI commands within the scope of the thesis topics. The relevant VISA software, Agilent Connection Expert and the software used during the development are all located in the software folder.

The location the information described above is in the folder with the path:

\\floyd\resources\visa command

D. Appendix: Extra Commands

This section will introduce other supportive commands that user may also use to set up function generator Agilent 33220A and oscilloscope Tektronix TDS and TPS series. For most 33220A commands can be substituted with set33220 in section 4.2, however one or two parameters are not support in set33220. Therefore, user may use these commands when necessary. Commands for TDS and TPS series do not have any substitutable commands. These commands are used to set up time and vertical axis and trigger level.

Agilent 33220A

33220sin:

This command allows users to output a user specified sine waveform. Like other commands, user is required to provide VISA address, frequency, amplitude and offset. The users may use this command to turn on the invert function and enable sync output at front panel of the 33220A. This command also allows users to choose the amplitude type and change the output impedance to match actual load and avoid attenuation.

Addr – The VISA address of device. Refer to 1.6 VISA Address HOWTO.

Freq – The frequency of the sine waveform. Refer to table 4.1 for the range available. The user may enter MAX to set to the maximum available frequency or MIN to the minimum frequency. The user may enter either normal or engineering format number.

Amplitude – The user desired amplitude. The limit of amplitude is in relation as shown in Equation 4.1. The range when the output impedance at 50 ohms is from 10E-3 to 10.

Unit – Desired amplitude type. VPP is peak-to-peak voltage. RMS is the amplitude in RMS value. DBM is the amplitude in DBM unit.

Offset – The offset value of the waveform. Refer to Equation 4.1 for the relation between Vpp and Offset voltage.

Invert – The user may invert the output waveform by entering ON or OFF to disable inverting function.

Sync – Enabling the sync output function by entering ON or OFF to disable sync output.

Load (Optional) – This is an optional parameter allows the user to chance the output impedance. The impedance will automatically set to 50 ohms when not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220sin V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set and output sinusoid signal.
USE FORMAT:
33220sin Addr Freq Amplitude Unit Offset Invert Sync Load (Optional)

Addr: The address of the desired device.
e.g.USB1::1689::869::C020200::0
Freq: Waveform frequency. 1E-6 HZ ~ 20E6 HZ

E.g. MAX, MIN, 10E0, 3E2...etc

Amplitude: Set Desired amplitude. VPP <= 2*(Vmax - |Voffset|).

E.g. 10E-3~10E0 @ 50ohm.

Unit: Desired amplitude unit.

E.g. VPP, RMS, DBM.

Offset: Waveform offset value. |VOffset| <= Vmax - VPP/2.

Vmax = 5V @ 50 ohm, Vmax = 10V @ >50 ohm

e.g. 0, 1E-6,-3E-6...etc

Invert: Enable the invert function.

E.g. ON, OFF

Sync: Enable sync.

E.g. ON, OFF

Load (Optional): Desired output impedance.

E.g. HIGH, MAX=10E3, MIN=1, 1 ~ 10E3

33220squ:

This command allows users to output square waveform with most identical parameters as in 33220sin. The users may change the duty cycle of the square waveform in this command.

Addr – VISA address of the device. Refer to 1.6 VISA Address HOWTO.

Freq – The desired frequency for the square waveform. Refer to table 4.1 for the frequency range. The user may use MAX or MIN to tune to maximum or minimum available frequency.

Amplitude – The desired waveform amplitude. The amplitude is in relation with the offset level. Refer to Equation 4.1. The range of amplitude is from 10E-3 to 10 when output impedance is 50 ohms.

Unit – Desired amplitude type. VPP is peak-to-peak voltage. RMS is the amplitude in RMS value. DBM is the amplitude in DBM unit.

Offset – The offset value of the waveform. Refer to Equation 4.1 for the relation between Vpp and Offset voltage.

Invert – The user may invert the output waveform by entering ON or OFF to disable inverting function.

Sync – Enabling the sync output function by entering ON or OFF to disable sync output.

Dcyc – The desired duty cycle of the waveform. The range is in percentage from 1 to 100. Enter MAX and MIN for maximum and minimum available duty cycle.

Load (Optional) – This is an optional parameter allows the user to change the output impedance. The impedance will automatically set to 50 ohms when not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220squ V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set and output square signal.

USE FORMAT:
33220squ Addr Freq Amplitude Unit Offset Invert Sync Dcyc Load (Optional)

Addr: The address of the desired device.
E.g.USB1::1689::869::C020200::0
Freq: Waveform frequency. 1E-6 HZ ~ 20E6 HZ
E.g., MAX, MIN, 10E0, 3E2...etc\n");
Amplitude: Set Desired amplitude. VPP <= 2*(Vmax - |Voffset|).
E.g. 10E-3~10E0 @ 50ohm.
Unit: Desired amplitude unit.
E.g. VPP, RMS, DBM.

Offset: Waveform offset value. |VOffset| <= Vmax - VPP/2.
Vmax = 5V @ 50 ohm, Vmax = 10V @ >50 ohm
e.g. 0, 1E-6,-3E-6...etc
Invert: Enable the invert function.
E.g. ON, OFF
Sync: Enable sync.
E.g. ON, OFF
Dcyc: Desired duty cycle in percentage.
E.g. MAX, MIN, 1~100
Load (Optional): Desired output impedance.
E.g. HIGH, MAX=10E3, MIN=1, 1 ~ 10E3. DEF=50

33220ramp:

This command allows users to output ramp waveform with most parameters identical to 33220sin. The users may change the symmetry of the ramp waveform in this command.

Addr – VISA address of the device. Refer to 1.6 VISA Address HOWTO.

Freq – The desired frequency for the square waveform. Refer to table 4.1 for the frequency range. The user may use MAX and MIN to tune to maximum and minimum available frequency.

Amplitude – The desired waveform amplitude. The amplitude is in relation with the offset level. Refer to Equation 4.1. The range of amplitude is from 10E-3 to 10 when output impedance is 50 ohms.

Unit – Desired amplitude type. VPP is peak-to-peak voltage. RMS is the amplitude in RMS value. DBM is the amplitude in DBM unit.

Offset – The offset value of the waveform. Refer to Equation 4.1 for the relation between Vpp and Offset voltage.

Invert – The user may invert the output waveform by entering ON or OFF to disable inverting function.

Sync – Enabling the sync output function by entering ON or OFF to disable sync output.

Symm – The symmetry percentage of the waveform. The user may ether from 1 to 100 or with MIN and MAX to tune to minimum and maximum available symmetry value.

Load (Optional) – This is an optional parameter allows the user to change the output impedance. The impedance will automatically set to 50 ohms when not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220ramp V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set and output square signal.

USE FORMAT:
33220ramp Addr Freq Amplitude Unit Offset Invert Sync Symm Load (Optional)

Addr: The address of the desired device.
E.g.USB1::1689::869::C020200::0
Freq: waveform frequency. 1E-6 HZ ~ 20E6 HZ
E.g. MAX, MIN, 10E0, 3E2...etc
Amplitude: Set Desired amplitude. VPP <= 2*(Vmax - |Voffset|).
E.g. 10E-3~10E0 @ 50ohm.
Unit: Desired amplitude unit.
E.g. VPP, RMS, DBM.
Offset: Waveform offset value. |VOffset| <= Vmax - VPP/2.
Vmax = 5V @ 50 ohm, Vmax = 10V @ >50 ohm
e.g. 0, 1E-6,-3E-6...etc
Invert: Enable the invert function.

E.g. ON, OFF

Sync: Enable sync.

E.g. ON, OFF

Symm: Desired symmetry in percentage.

E.g. MAX, MIN, 1~100

Load (Optional): Desired output impedance.

E.g. HIGH, MAX=10E3, MIN=1, 1 ~ 10E3

33220puls:

This command allows users to output pulse waveform with most parameters identical to 33220sin. The user may change the pulse duty cycle and the edge length of the pulse waveform in this command.

Addr – VISA address of the device. Refer to 1.6 VISA Address HOWTO.

Freq – The desired frequency for the square waveform. Refer to table 4.1 for the frequency range. The user may use MAX and MIN to tune to maximum and minimum available frequency.

Amplitude – The desired waveform amplitude. The amplitude is in relation with the offset level. Refer to Equation 4.1. The range of amplitude is from 10E-3 to 10 when output impedance is 50 ohms.

Unit – Desired amplitude type. VPP is peak-to-peak voltage. RMS is the amplitude in RMS value. DBM is the amplitude in DBM unit.

Offset – The offset value of the waveform. Refer to Equation 4.1 for the relation between Vpp and Offset voltage.

Invert – The user may invert the output waveform by entering ON or OFF to disable inverting function.

Sync – Enabling the sync output function by entering ON or OFF to disable sync output.

Dcyc – The desired duty cycle of the waveform. The range is in percentage from 1 to 100. Enter MAX and MIN for maximum and minimum available duty cycle.

Edge – The desired edge time of the rising and falling edge of the pulse signal. The available range is from 5E-9 to 100E-9.

Load (Optional) – This is an optional parameter allows the user to change the output impedance. The impedance will automatically set to 50 ohms when not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220puls V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
  Set and output pulse signal.

USE FORMAT:
33220puls Addr period Amplitude Unit Offset Invert Sync Dcyc Edge Load (Optional)

Addr: The address of the desired device.
             e.g.USB1::1689::869::C020200::0
Period: Pulse period. Period >= (Period*Dcyc/100) + (1.6*EdgeT)
             e.g., MAX, MIN, 200E-9 ~ 2E3
Amplitude: Set Desired amplitude. VPP <= 2*(Vmax - |Voffset|).
             E.g. 10E-3~10E0 @ 50ohm.
Unit: Desired amplitude unit.
             E.g. VPP, RMS, DBM.
Offset: Waveform offset value. |VOffset| <= Vmax - VPP/2.
                  Vmax = 5V @ 50 ohm, Vmax = 10V @ >50 ohm

E.g. 0, 1E-6,-3E-6...etc

Invert: Enable the invert function.

E.g. ON, OFF

Sync: Enable sync.

E.g. ON, OFF

Dcyc: Desired duty cycle in percentage.

E.g. MAX, MIN, 1 ~ 100

Edge: Desired edge time in seconds. 5E-9 ~ 100E-9

E.g. MAX, MIN, 5E-9 ~ 100E-9

Load (Optional): Desired output impedance.

E.g. HIGH, MAX=10E3, MIN=1, 1 ~ 10E3

33220nois:

This command allows users to output noise waveform with parameters identical to 33220sin.

Addr – VISA address of the device. Refer to 1.6 VISA Address HOWTO.

Freq – The desired frequency for the square waveform. Refer to table 4.1 for the frequency range. The user may use MAX and MIN to tune to maximum and minimum available frequency.

Amplitude – The desired waveform amplitude. The amplitude is in relation with the offset level. Refer to Equation 4.1. The range of amplitude is from 10E-3 to 10 when output impedance is 50 ohms.

Unit – Desired amplitude type. VPP is peak-to-peak voltage. RMS is the amplitude in RMS value. DBM is the amplitude in DMB unit.

Offset – The offset value of the waveform. Refer to Equation 4.1 for the relation between Vpp and Offset voltage.

Invert – The user may invert the output waveform by entering ON or OFF to disable inverting function.

Sync – Enabling the sync output function by entering ON or OFF to disable sync output.

Load (Optional) – This is an optional parameter allows the user to change the output impedance. The impedance will automatically set to 50 ohms when not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220nois V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set and output noise signal.

USE FORMAT:
33220nois Addr Amplitude Unit Offset Invert Sync Load (Optional)

Addr: The address of the desired device.
e.g.USB1::1689::869::C020200::0
Amplitude: Set Desired amplitude. VPP <= 2*(Vmax - |Voffset|).
E.g. 10E-3~10E0 @ 50ohm.
Unit: Desired amplitude unit.
E.g. VPP, RMS, DBM.
Offset: Waveform offset value. |VOffset| <= Vmax - VPP/2.
Vmax = 5V @ 50 ohm, Vmax = 10V @ >50 ohm
e.g. 0, 1E-6,-3E-6...etc
Invert: Enable the invert function.
E.g. ON, OFF
Sync: Enable sync.
E.g. ON, OFF
Load (Optional): Desired output impedance.
E.g. HIGH, MAX=10E3, MIN=1, 1 ~ 10E3

33220dc:

This command allows user to output DC waveform. The command contains less parameter among 32200A command set.

Addr – VISA address of the device. Refer to 1.6 VISA Address HOWTO.

Amplitude – The desired waveform amplitude. The amplitude is from -10 to +10. The user may enter MIN and MAX for minimum and maximum amplitude.

Sync – Enabling the sync output function by entering ON or OFF to disable sync output.

Load (Optional) – This is an optional parameter allows the user to chance the output impedance. The impedance will automatically set to 50 ohms when not entered.

Related Sections: 1.6 VISA Address HOWTO, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220dc V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
  Set and output DC signal.

USE FORMAT:
33220dc Addr Amplitude Sync Load (Optional)

Addr: The address of the desired device.
        E.g.USB1::1689::869::C020200::0
Amplitude: Set desired amplitude.
        E.g. MAX, MIN, -10 ~ 10.
Sync: Enable sync.
        E.g. ON, OFF
Load (Optional): Desired output impedance.
        E.g. HIGH, MAX=10E3, MIN=1, 1 ~ 10E3

33220arb:

This command allows user to output an arbitrary waveform. The user may use this command to output pre-defined arbitrary waveforms that stored in 33220A such as exponential rise (ER), exponential fall (EF), negative ramp (NEGR), sinc (SINC), cardiac (CAR), waveform in volatile memory (VOL), waveform in non-volatile memory 1 (A1), waveform in non-volatile memory 2 (A2), waveform in non-volatile memory 3 (A3) and waveform in non-volatile memory 4 (A4). Like other commands, user is required to provide VISA address, frequency, amplitude and offset. The user may use this command to turn on the invert function and enable sync output at front panel of 33220A. This command also allows user to choose the amplitude type and change the output impedance to match actual load and avoid attenuation.

Addr – The VISA address of device. Refer to 1.6 VISA Address HOWTO.

Freq – The frequency of the sine waveform. Refer to table 4.1 for the frequency range. The user may enter MAX to set to the maximum available frequency or MIN to the minimum frequency. The user may enter either normal or engineering format number.

Amplitude – The user desired amplitude. The limit of amplitude is in relation as shown in Equation 4.1. The range when the output impedance at 50 ohms is from 10E-3 to 10.

Unit – Desired amplitude type. VPP is peak-to-peak voltage. RMS is the amplitude in RMS value. DBM is the amplitude in DBM unit.

Offset – The offset value of the waveform. Refer to Equation 4.1 for the relation between Vpp and Offset voltage.

Wform – The desired arbitrary waveform. The user may select one of following.

ER, EF, NEGR, SINC, CAR, VOL, A1, A2, A3, A4.

Invert – The user may invert the output waveform by entering ON or OFF to disable inverting function.

Sync – Enabling the sync output function by entering ON or OFF to disable sync output.

Load (Optional) – This is an optional parameter allows the user to change the output impedance. The impedance will automatically set to 50 ohms when not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220arb V%.2f by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set and output arbitrary signal.

USE FORMAT:
33220arb Addr Freq Amplitude Unit Offset Wform Invert Sync Load (Optional)

Addr: The address of the desired device.
e.g.USB1::1689::869::C020200::0
Freq: waveform frequency. 1E-6 HZ ~ 20E6 HZ
e.g., MAX, MIN, 10E0, 3E2...etc
Amplitude: Set Desired amplitude. VPP <= 2*(Vmax - |Voffset|).
E.g. 10E-3~10E0 @ 50ohm.
Unit: Desired amplitude unit.
E.g. VPP, RMS, DBM.
Offset: Waveform offset value. |VOffset| <= Vmax - VPP/2.
Vmax = 5V @ 50 ohm, Vmax = 10V @ >50 ohm

e.g. 0, 1E-6,-3E-6...etc

Wform: Desired waveform.

e.g. ER,EF,NEGR,SINC,CAR,VOL,A1,A2,A3,A4

Invert: Enable the invert function.

E.g. ON, OFF

Sync: Enable sync.

E.g. ON, OFF

Load (Optional): Desired output impedance.

E.g. HIGH, MAX=10E3, MIN=1, 1 ~ 10E3

33220bc:

This command allow user to output burst cycle waveform for certain period and with selectable starting phase of the waveform.

Addr – VISA address. Refer to 1.6 VISA Address HOWTO.

#cyc – The number of burst cycle. The number of burst cycle must be smaller than the burst period times the waveform frequency. This parameter will be ignored when the trigger source is INT.

Trgsou – The desired trigger source. The user may choose internal (INT) for continuous burst with certain period or external rising edge (EXR) or external falling edge (EXF) or manual trigger (MAN). Apart from INT, the rest trigger will only activate the burst waveform once received a trigger signal.

Trgout – The enable the trigger output from the trigger out connector at the back panel of 33220A. The user may choose to turn off the function (OFF) or output rising edge signal (RISE) or falling edge signal (FALL).

Angle – The user desired phase unit. The user may choose degree (DEG) or radian (RAD) as the starting phase unit.

Phase – The desired starting phase. The range for degree is from -360 to +360 degrees or -2 to 2 radians.

Period (Optional) – The user desired burst period for internal trigger. This parameter is only applicable when trigger is internal. Other triggering setting will ignore this parameter. The user may also not enter this parameter at the trigger setting other than INT. The range is from 1E-6 to 500. The user may enter MIN or MAX for minimum or maximum burst period.

Related Sections: 1.6 VISA Address HOWTO, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220bc V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set & enable burst (cycle) function.

USE FORMAT:
33220bc Addr #cyc Trgsou Trgout Angle Phase Period (optional)

Addr: The address of the desired device.
E.g.USB1::1689::869::C020200::0
#cyc: Number of burst cycle. #cyc < Period * Waveform Frequency (Trgsou=INT)
E.g. MAX, MIN, INF, 1~50E3.
Trgsou: Choose trigger source. MAN uses 33220trg.exe to send trigger signal.
E.g. INT, EXR, EXF, MAN
Trgout: Turn on trigger output.
E.g. OFF, RISE, FALL
Angle: Desired Phase unit.
E.g. DEG, RAD
Phase: Desired starting Phase.
E.g. -360~360(DEG), -2~2(RAD)
Period (Optional): Desired burst period ONLY when Trgsouc=INT.
E.g. MAX, MIN, 1E-6~500E0.

33220bg:

This command allow user to output gated burst waveform for certain period and with selectable starting phase of the waveform.

Addr – VISA address. Refer to 1.6 VISA Address HOWTO.

Polar – The desired polarity of the burst signal. The user may choose positive (POS) or negative (NEG). This parameter acts similar to inverting function.

Angle – The user desired phase unit. The user may choose degree (DEG) or radian (RAD) as the starting phase unit.

Phase – The desired starting phase. The range for degree is from -360 to +360 degrees or -2 to 2 radians.

Related Sections: 1.6 VISA Address HOWTO, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220bg V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set & enable burst (gated) function.

USE FORMAT:
33220bg Addr Polar Angle Phase

Addr: The address of the desired device.
e.g.USB1::1689::869::C020200::0
Polar: Set the polarity of burst.
E.g. POS, NEG.
Angle: Desired Phase unit.
E.g. DEG, RAD
Phase: Desired starting Phase.
E.g. -360~360(DEG), -2~2(RAD)

33220am:

This command allow user to enable amplitude modulation function on the current waveform set up previously.

Addr – VISA address. Refer to 1.6 VISA Address HOWTO.

Modwav – The desired modulating waveform. The user may choose waveform from external source (EXT) or sine wave (SIN) or square wave (SQU) or ramp wave (RAMP), negative ramp (NRAM), triangular wave (TRI), noise (NOIS), or arbitrary waveform (ARB). With arbitrary waveform, user should use 33220arb to set up the waveform before using any modulation commands.

Depth – The modulation depth is in percentage. The range is from 1 to 120. The user may enter MIN or MAX for minimum or maximum available depth.

Modf (Optional) – The modulating waveform frequency. This parameter is not required when Modwav is external source. The range is from 2E-3 to 20E3 Hz. The user may enter MIN or MAX for minimum or maximum available frequency. Default is 2E-3 Hz if not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220am V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set and output AM signal.

USE FORMAT:
33220am Addr Modwav Depth Modf (Optional)

Addr: The address of the desired device.
e.g. USB1::1689::869::C020200::0
Modwav: select desired modulating waveform.
E.g. EXT, SIN, SQU, RAMP, NRAM, TRI, NOIS, ARB
Depth: Modulation depth in percentage.
E.g. MAX, MIN, 0~120
Modf (Optional): Modulating waveform frequency.
Only required when Modwav is not EXT.
E.g. MAX, MIN, 2E-3 ~ 20E3, DEF=2E-3

33220fm:

This command allow user to enable frequency modulation function on the current waveform set up previously.

Addr – VISA address. Refer to 1.6 VISA Address HOWTO.

Modwav – The desired modulating waveform. The user may choose waveform from external source (EXT) or sine wave (SIN) or square wave (SQU) or ramp wave (RAMP), negative ramp (NRAM), triangular wave (TRI), noise (NOIS), or arbitrary waveform (ARB). With arbitrary waveform, user should use 33220arb to set up the waveform before using any modulation commands.

Dev – The desired frequency modulation deviation. The user may enter MIN or MAX for minimum or maximum available depth. The range is from 1E-6 to 150E3 (RAMP & NRAM), 3.05E6 (ARB) and 10.05E6 for other waveforms.

Modf (Optional) – The modulating waveform frequency. This parameter is not required when Modwav is selected to external source. The range is from 2E-3 to 20E3 Hz. The user may enter MIN or MAX for minimum or maximum available frequency. Default is 2E-3 Hz if not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220fm V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set and output FM signal.

USE FORMAT:
33220fm Addr Modwav Dev Modf (Optional)

Addr: The address of the desired device.
e.g. USB1::1689::869::C020200::0
Modwav: select desired modulating waveform.
E.g. EXT, SIN, SQU, RAMP, NRAM, TRI, NOIS, ARB
Dev: Desired FM Deviation.
E.g. MAX, MIN, 1E-6~10.05E6 (150E3, RAMP & NRAM), (3.05E6, ARB)
Modf (Optional): modulating waveform frequency.
Only required when Modwav is not EXT.
E.g. MAX, MIN, 2E-3 ~ 20E3, DEF=2E-3

33220pm:

This command allow user to enable pulse modulation function on the current waveform set up previously.

Addr – VISA address. Refer to 1.6 VISA Address HOWTO.

Modwav – The desired modulating waveform. The user may choose waveform from external source (EXT) or sine wave (SIN) or square wave (SQU) or ramp wave (RAMP), negative ramp (NRAM), triangular wave (TRI), noise (NOIS), or arbitrary waveform (ARB). With arbitrary waveform, user should use 33220arb to set up the waveform before using any modulation commands.

Dev – The desired pulse modulation deviation in degree. The user may enter MIN or MAX for minimum or maximum available depth. The range is from 0 ~ 360 degrees.

Modf (Optional) – The modulating waveform frequency. This parameter is not required when Modwav is selected to external source. The range is from 2E-3 to 20E3 Hz. The user may enter MIN or MAX for minimum or maximum available frequency. Default is 2E-3 Hz if not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220pm V1.00 by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
  Set and output PM signal.

USE FORMAT:
33220pm Addr Modwav Dev Modf (Optional)

Addr: The address of the desired device.
  E.g. USB1::1689::869::C020200::0
Modwav: select desired modulating waveform.
  E.g. EXT, SIN, SQU, RAMP, NRAM, TRI, NOIS, ARB
Dev: Desired PM Deviation in degree.
  E.g. MAX, MIN, 0~360
Modf (Optional): modulating waveform frequency.
  Only required when Modwav is not EXT.
  E.g. MAX, MIN, 2E-3 ~ 20E3, DEF=2E-3

3322fsk:

This command allow user to enable frequency shift keying modulation function on the current waveform set up previously.

Addr – VISA address. Refer to 1.6 VISA Address HOWTO.

Source – The desired modulating waveform source. The user may select external (EXT) or internal source (INT).

Hopf – The desired hopping frequency. The user can enter MIN or MAX for minimum or maximum available frequency. The range is from 1E-6 to 200E3 (RAMP & NRAM) or 6E6 (ARB) or 20E6 for other waveforms.

Rate (Optional) – The desired FSK rate. This parameter is only applicable when using internal source (INT). The user may enter MIN or MAX for minimum or maximum available rate. The range is from 2E-3 to 100E3. The default rating is 10 if not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220fsk V%.2f by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
  Set and output FSK signal.

USE FORMAT:
33220fsk Addr Source Hopf Rate (Optional)

Addr:        The address of the desired device.
          e.g. USB1::1689::869::C020200::0
Source:      Select modulating waveform source.
          E.g. EXT, INT
```

Hopf: set Hop frequency.

E.g. MAX, MIN, 1E-6 ~ 20E6 (200E3, RAMP & NRAMP), (6E6, ARB)

Rate (Optional): FSK rate. (Source=INT only).

E.g. MAX, MIN, 2E-3 ~ 100E3, DEF=10

3322pwm:

This command allow user to enable pulse width modulation function on the current waveform set up previously.

Addr – VISA address. Refer to 1.6 VISA Address HOWTO.

Modwav – The desired modulating waveform. The user may choose waveform from external source (EXT) or sine wave (SIN) or square wave (SQU) or ramp wave (RAMP), negative ramp (NRAM), triangular wave (TRI), noise (NOIS), or arbitrary waveform (ARB). With arbitrary waveform, user should use 33220arb to set up the waveform before using any modulation commands.

Dcycdev – The PWM duty cycle deviation in percentage. The user may enter MIN or MAX for minimum or maximum available deviation. Range is from 0 to 100.

Modf (Optional) – The modulating waveform frequency. This parameter is not required when Modwav is selected to external source. The range is from 2E-3 to 20E3 Hz. The user may enter MIN or MAX for minimum or maximum available frequency. Default is 2E-3 Hz if not entered.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220pwm V%.2f by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Set and output PWM signal.

USE FORMAT:
33220pwm Addr Modwav Dcycdev Modf (Optional)

Addr: The address of the desired device.
e.g. USB1::1689::869::C020200::0
Modwav: select desired modulating waveform.
E.g. EXT, SIN, SQU, RAMP, NRAM, TRI, NOIS, USER
Dcycdev: PWM duty cycle deviation in percentage.
E.g. MAX, MIN, 0~100
Modf (Optional): modulating waveform frequency.
Only required when Modwav is not EXT.
E.g. MAX, MIN, 2E-3 ~ 20E3, DEF=10

3322pwm:

This command allows user to output a manual trigger signal to 33220A.

The user only required entering the VISA address of the device.

Related Sections: 1.6 VISA Address HOWTO, 4.3 33220sweep, 4.4 wavf33220, Appendix D: Extra Commands

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: 33220trg V%.2f by DH, Jan 2008
Hardware: Agilent 33220A.
Software Description:
Send *TRG trigger signal to 33220A.

USE FORMAT:
33220trg Addr
Addr: The address of the desired device.
E.g.USB1::1689::869::C020200::0

Tektronix TDS and TPS series:

setekt:

The command allows user to set up the time axis. All parameters are required and cannot be ignored.

Device_Address – The VISA address of the device. Refer to 1.6 VISA Address HOWTO.

Time_Scale – The desired time scale. Device will automatically adjust to closet value based on user's entry.

Time_Position – The desired center screen position. The user may select a time and make the time point as the center on the screen of the device.

Related Sections: 1.6 VISA Address HOWTO, 5.2 Rdtek, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: SETEKT V1.00 by DH, Jan 2008
Hardware: Tektronix Oscilloscope.
Software Description:
Set time scale and screen center position.

USE FORMAT:
setekt Device_Address Time_Scale Time_Position

Device_Address: The address of the desired device.
E.g.USB1::1689::869::C020200::0
Time_Scale: Desired time scale. Device will set to closest pre-set value
E.g. 1, 2.5,5...etc
Time_position: Desired center screen position.
E.g. 2E-3

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setekv:

This command allows user to set up the vertical settings of the Tektronix TDS and TPS series.

Device_Address – The VISA address of the device. Refer to 1.6 VISA Address HOWTO.

CH – The desired channel to set up. The user may choose 1, 2, 3, 4 or ALL. Each relevant channel chosen will be applied with the settings. All 4 channels will be set up with the settings when ALL is selected.

20MHz – Enabling the 20 MHz bandwidth setting. The user may enter ON or OFF.

Invert – The user may invert the waveform shown on the screen by enabling this parameter. The user may enter ON or OFF.

Coupling – To change the coupling setting. The user may enter AC, DC or GND (ground).

Attenuation – The desired channel attenuation value. If voltage is the selected unit, user may select one of 1, 10, 20, 50, 100, 500 or 1000 as the channel attenuation setting. If current is the selected unit, user may select one of 0.2, 1, 2, 5, 10, 50, 100 or 1000 as the channel attenuation setting.

Scale – The desired vertical scale. The unit is volt (amp) / division. The device will automatically adjust to the closest value based on user's entry.

Position – The vertical position of the waveform on the screen in divisions. The user may shift waveform up or down with this parameter.

Yunit (Optional) – Activate the current unit instead of voltage unit. The user may enter either "A" or "a" to activate the current unit. The default unit is volt if not entered.

Related Sections: 1.6 VISA Address HOWTO, 5.2 Rdtek, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: SETEKV V1.00 by DH, Jan 2008
Hardware: TDS1000B, TDS2000B, TPS2000.
Software Description:
Set voltage parameters.

USE FORMAT:
setekv Device_Address CH 20MHz Invert Coupling Attenuation Scale Position Yunit

Device_Address: The address of the desired device.
e.g.USB1::1689::869::C020200::0
CH: The desired channel.
e.g.1, 2, 3, 4, all
20MHz: Turn ON for 20MHz bandwidth or OFF for full-bandwidth.
E.g. ON or OFF
Invert: Turn ON for invert waveform or OFF for original waveform.
E.g. ON or OFF
Coupling: Change channel-coupling setting.
E.g. AC, DC, GND
Attenuation: Channel attenuation setting.
E.g. Yunit = V: 1, 10, 20, 50, 100, 500, 1000
E.g. Yunit = A: 0.2, 1, 2, 5, 10, 50, 100, 1000
Scale: Set vertical scale. Volt (amp)/div.
Device will adjust automatically.
E.g. 2E-3, 5E-3, 10E-3, 20E-3, 50E-3,100E-3,200E-3,500E-3, 1E0, 2E0, 5E0
Position: Position of the waveform in divisions.
e.g. +/-10 div ~ +/-1000 div
Yunit (optional): Activate current (A) instead of volt (V).
E.g. A or a
CAUTION!! Yunit only supported by TDS1000B, TDS200B, TPS2000.

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trige:

This command allows user to set up edge triggering.

Addr – The VISA address. Refer to 1.6 VISA Address HOWTO.

CH – The desired trigger channel. The user may choose 1, 2, 3, 4, AC (not supported by TDS2000), EXT (not supported by TDS224), EXT5 (not supported by TDS224) or EXT10 (only supported by TPS2000).

Mode – The desired trigger type. The user may choose AUTO or NORMAL.

Slope – The desired trigger edge. The user may select RISE or FALL for rising or falling edge triggering.

Coupling – The desired channel coupling setting. The user may enter AC, DC, HFREJ (high frequency rejection), LFREJ (low frequency rejection) or NOISEREJ (noise rejection).

Level – the desired triggering level. The user may enter "half" to trigger at middle of the waveform or any other value in volts.

Related Sections: 1.6 VISA Address HOWTO, 5.2 Rdtek, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: TRIGE V1.00 by DH, Jan 2008
Hardware: TDS1000B, TDS2000B, TPS2000.
Software Description:
 Set EDGE trigger parameters.

USE FORMAT:
trige Addr CH MODE SLOPE COUPLING LEVEL

Addr: The address of the desired device.
 e.g.USB1::1689::869::C020200::0
CH: The desired trigger channel.

e.g.1, 2, 3, 4, AC (not in TPS2000), EXT (not in TDS224) EXT5 (not in TDS224), EXT10 (TPS2000 only)

MODE: Desired trigger type.

E.g. AUTO or NORMAL

SLOPE: Desired slope edge type.

E.g. FALL or RISE

COUPLING: Desired channel-coupling setting.

E.g. AC, DC, HFREJ, LFREJ, NOISEREJ

LEVEL: Trigger level.

E.g. half=50% trigger, 1.4v, 2v...etc

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trigp:

This command allows user to set up pulse triggering.

Addr – The VISA address. Refer to 1.6 VISA Address HOWTO.

CH – The desired trigger channel. The user may choose 1, 2, 3, 4, AC (not supported by TDS2000), EXT (not supported by TDS224), EXT5 (not supported by TDS224) or EXT10 (only supported by TPS2000).

Mode – The desired trigger type. The user may choose AUTO or NORMAL.

Polarity – The desired polarity of the pulse triggering. The user may select POSITIVE or NEGATIVE.

Coupling – The desired channel coupling setting. The user may enter AC, DC, HFREJ (high frequency rejection), LFREJ (low frequency rejection) or NOISEREJ (noise rejection).

When – The trigger activate condition. The user may select EQUAL, NOTEQUAL, LESS, or GREATER than the width of the pulse width.

Width – The desired trigger pulse width in second. Range is from 33E-9 to 10.

Related Sections: 1.6 VISA Address HOWTO, 5.2 Rdtek, Appendix D: Extra Commands

Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: TRIGP V1.00 by DH, Jan 2008
Hardware: TDS1000B, TDS2000B, TPS2000.
Software Description:
  Set PULSE trigger parameters.

USE FORMAT:
trigp Addr CH MODE POLARITY COUPLING WHEN WIDTH

Addr: The address of the desired device.
E.g.USB1::1689::869::C020200::0
CH: The desired trigger channel.
E.g.1, 2, 3, 4, EXT (not in TDS224), EXT5 (not in TDS224), EXT10 (TPS2000 only)
MODE: Desired slope type.
E.g. AUTO or NORMAL
POLARITY: Desired polarity.\n");
E.g. POSITIVE, NEGATIVE
COUPLING: Desired channel-coupling setting.
E.g. AC, DC, HFREJ, LFREJ, NOISEREJ
WHEN: Trigger conditions
E.g. EQUAL, NOTEQUAL, LESS, GREATER
WIDTH: Trigger pulse width (s). Range = 33E-9 ~ 10E0
E.g. 2E-9, 8E0...etc

trigv:

This command allows user to set up video triggering.

Addr – The VISA address. Refer to 1.6 VISA Address HOWTO.

CH – The desired trigger channel. The user may choose 1, 2, 3, 4, AC (not supported by TDS2000), EXT (not supported by TDS224), EXT5 (not supported by TDS224) or EXT10 (only supported by TPS2000).

Polarity – The desired polarity of the pulse triggering. The user may select POSITIVE or NEGATIVE.

Sync – The desired sync pulse. The user may enter FIELD, LINE, ODD or EVEN.

Standard (Optional) – The video trigger standards. Only TDS1000, TDS2000, TDS1000B, TDS2000B and TPS2000 support this function. The user may enter NTSC or PAL.

Lin (Optional) – The desired line number. Only TDS1000, TDS2000, TDS1000B, TDS2000B and TPS2000 support this function.

Related Sections: 1.6 VISA Address HOWTO, 5.2 Rdtek, Appendix D: Extra Commands

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Based on Software: CurveTrace8143 V1.00 by CJBS, Jan 2007
Software Info: TRIGV V1.00 by DH, Jan 2008
Hardware: TDS1000B, TDS2000B, TPS2000.
Software Description:
 Set VIDEO trigger parameters.

USE FORMAT:
trigv Addr CH POLARITY SYNC STANDARD LINE

Addr: The address of the desired device.
 e.g.USB1::1689::869::C020200::0
CH: The desired trigger channel.
 e.g.1, 2, 3, 4, EXT (not in TDS224), EXT5 (not in TDS224),
EXT10 (TPS2000 only)
POLARITY: Desired polarity.
 E.g. INVERT, NORMAL
SYNC: Desired sync pulse.
 E.g. FIELD, LINE, ODD, EVEN
STANDARD (optional): VIDEO trigger standards.
 (TDS1000, TDS2000, TDS1000B, TDS2000B, TPS2000
only)
 E.g. NTSC, PAL
LINE (optional): Set line number.

(TDS1000, TDS2000, TDS1000B, TDS2000B, TPS2000 only)

E.g. 2E-9, 8E0...etc

E. Appendix: Details of GPIB Interface

General Purpose Interface Bus (GPIB) is a common communication medium used very widely in the test and measurement industry for over 30 years. It is capable of connecting multiple instruments in series or parallel configuration to the user's PC. The maximum connection length is up to 20 metres with a device connected every 4 metres. A single GPIB interface can connects up to 15 devices with at least two-thirds devices powered on. It was originally developed by Hewlett-Packard in 1965 for their programmable instruments and later accepted by the Institute of Electrical and Electronics Engineers (IEEE) organization as the IEEE 488 standard. IEEE 488 standard was then evolved into IEEE 488.1 for the physical standard and IEEE 488.2 for the programming command and syntax of the interface standard. [1, 2, 3]

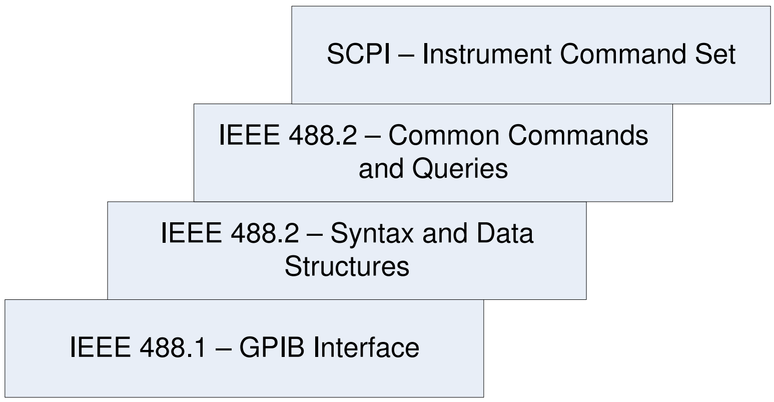

Figure E.1 *The GPIB interface structure. The lowest level is the physical GPIB interface, which is also called IEEE488.1 standard. The second level is the interface syntax and data structures that are specified by IEEE 488.2 standard. The Standard Commands for Programmable Instrumentation (SCPI) command set is the actual commands that control the behaviors of the instruments.*

Figure E.1 shows the communication structure of the GPIB interface. The other interfaces will have their own hardware and lower interface control structures, but the top level will always be SCPI in order to control the behaviors of the instruments.

The IEEE 488.1 standard specified that GPIB interface have 24 pins, which contains 8 data lines, 8 ground-return lines, 5 interface management lines and 3 handshake lines.

The handshake lines are responsible for communication handshaking before the transmission of the messages. The handshake lines contain data valid (DAV), not ready for data (NRFD) and not data accepted (NDAC); each handshake line is twisted with three separated ground wires to reduce possible interference with other lines.

The DAV is the valid signal to approve the sending data can be accepted by other devices in the network. The DAV signal is sent by either the controller or the talker when sending data messages.

The NRFD signal indicates a device is ready to or not ready to receive a message. The line can be driven by all devices. It is activated when receiving messages by the listeners or by the talkers when enabling HS488 protocol for high-speed communication on IEEE 488 network.

The NDAC signal indicates whether a device has received or not a message. The line can be driven by all devices when receiving messages as the listeners.

The interface management lines are responsible managing the communication roles and communication in between. The management lines contain attention (ATN), interface clear (IFC), remote enable (REN), service request (SRQ) and end or identify (EOI).

The ATN line is used by the controller in the network to allow or not allow a talker to send data messages.

The IFC line is used by the controller in the network to initialize the bus and obtains the CIC right.

The REN line is used by the controller to set the devices in the network in remote or local programming mode. In remote mode, the instrument will ignore the action of its front panel. In local mode, the instrument can be controlled by its front panel.

The SRQ line can be driven by any device in the network to asynchronously request service from the controller.

The EOI line is used by the talker and the controller with different purpose. The talker uses the EOI line to send the end mark of a message string. The controller uses the EOI line to identify the response of devices in parallel configuration.

The IEEE 488 standard has three parties in a running communication network. First is the listener, the device is waiting for receiving data. Second is the talker, the device who sends out data to the listener. Third is the controller, the device who controls the communication traffic in the network. The controller will enable a talker and listener before the communication starts. Multiple talker and listener pairs can be assigned by the controller in sequence. The talker can transmit the data to single or multiple listeners at one time. The controller is necessary in a GPIB network when the talker and the listener will switch their roles. A GPIB network can have multiple controllers, but only one controller will have the Controller-In-Charge (CIC) right to perform the tasks while other controllers are in standby. The CIC right can be handed over to any single controller by using the functions in the interface specific services group in VISA library described in section 1.3 VISA and Connection Structures previously in this thesis. A computer with appropriate hardware and software can satisfy the roles of a talker or a listener or a controller. A controller will not be required if a GPIB network has the role of a talker and a listener that will never change.

Table D.1 is showing the pin configurations of a GPIB interface.

Pin Number	Pin Name	Desciption	Pin Number	Pin Name	Desciption
1	DIO1	Data input/output pin	13	DIO5	Data input/output pin
2	DIO2	Data input/output pin	14	DIO6	Data input/output pin
3	DIO3	Data input/output pin	15	DIO7	Data input/output pin
4	DIO4	Data input/output pin	16	DIO8	Data input/output pin
5	EOI	End or identify	17	REN	Remote enable
6	DAV	Data valid	18	GND	(twisted with DAV)
7	NRFD	Not ready for data	19	GND	(twisted with NRFD)
8	NDAC	Not data accepted	20	GND	(twisted with NDAC)
9	IFC	Interface clear	21	GND	(twisted with IFC)
10	SRQ	Service request	22	GND	(twisted with SRQ)
11	ATN	Attention	23	GND	(twisted with ATN)
12	Shield		24	Logic ground	

Table E.1 *GPIB interface pin table. The management pins are pin 5, 9, 10, 11 and 17. The handshake pins are pin 6, 7, 8. The ground pins from 18 to 23 are twisted to three handshake pins and three management pins. The data pins are pin 1, 2, 3, 4, 13, 14, 15, 16.*

The IEEE 488.2 is the software protocol for IEEE 488.1 to provide a reliable communication channels by using the standard bus control functionalities described previously on the management lines. IEEE 488.2 enhanced the IEEE 488.1 standard by standardizing data formats, status reporting, controller functionality, error handling, and a defined common commands set that is compatible to all programmable instruments.

The data messages of a GPIB communication network have two types. Device-dependent messages are also called data or data messages; it contains the device-related information such as programming instructions and measurement results. Interface messages are the messages used to manage the interface bus. It is also called command messages, which is performs functions such as initializing the bus, addressing and un-addressing devices, setting device modes for remote or local programming. [1, 2]

F. Appendix: Details of SCPI Command Set

Standard Commands for Programmable Instrumentation (SCPI) is a defined hierarchy device-specific ASCII type command set that built on top of the IEEE 488.2 standard. The SCPI command set is responsible to control the behaviours of the instrument. For example, reading the voltage values, setting parameter and so on. Although IEEE 488.2 is capable to communicate to the instrument directly for device status or model information, but IEEE 488.2 is not responsible to control the behaviours of the instrument. The SCPI is a human and device readable command set that embedded into most of the programmable instruments in the current market. Some programmable instrument might not use SCPI as the control command set of the device such as HAMEG HM8143 dual channel power supply. In another word, the programme wrote for HM8143 is not compatible to any instruments that support SCPI only. The commands in SCPI are basically grouped by functions used in different type of devices such as function generators or oscilloscopes. For instance, the device memory functions to control a function generator might be the same as the memory functions applied on an oscilloscope that are from the same command subsystem of SCPI. There are many sub commands in a subsystem. The level of the subsystem is depended on how complex is the associated function. In another word, a major subsystem could have minor subsystems under it depends on the complexity of the function grouping. Most instrument manufacture usually follows the main structure of standard SCPI, but some minor sub functions might have different sequence or wording for each brand or even each model. For example, the Agilent MSO4054 has a line of SCPI command to query for the preamble values to calculate the display on the screen. One subsystem in the line of SCPI query command is named different from Agilent TDS, TPS series and the difference is due to the functionality and development concept difference between these model series even though they are produced by the same company.

This section will show the standard major subsystems of the SCPI commands and provide an example to give the reader an idea of how SCPI command is structured and used.

1. MEASurement Subsystem
2. CALCulate Subsystem
3. CALibration subsystem
4. CONTrol Subsystem
5. DIAGnostic Subsystem
6. DISPLAY Subsystem
7. FORMat Subsystem
8. HCOPy
9. INPut Subsystem
10. INSTrument Subsystem
11. MEMory Subsystem
12. MMEMory Subsystem
13. OUTPut Subsystem
14. Programme Subsystem
15. ROUTe Subsystem
16. SENSe Subsystem

17. SOURce Subsystem
18. STATus Subsystem
19. SYSTem Subsystem
20. TEST Subsystem
21. TRACe | DATA
22. TRIGger Subsystem
23. UNIT Subsystem
24. VXI Subsystem

A simple example of using SCPI command would be:

MEASure:FREQuency <parameter value>

This command is equivalent to:

MEAS:FREQ <parameter value>

This SCPI command line is reading the frequency value from the instrument. The upper case letters in the command are compulsory letters, other lower case letters can be ignored as shown above. The parameter value usually is the input of the scale in order to read the value correctly. Some model may have auto range selection as a parameter value to allow the instrument changing to the suitable scale to read the value required by the user. The MEASure is one of the major measurement subsystems that are responsible of measuring a value by the instrument. Under it, there are other functions that can be read such as frequency, DC, AC voltage and so on. Interchangeable Virtual Instrument Foundation (IVI Foundation) is an open organisation funded to promote specifications for programmable test instruments and currently in charge of maintaining SCPI command set.

G. Appendix: Details of VISA

VISA has its own data types such as size, integer variable and therefore reduces the affect on the VISA programme when transferring from one platform to another. VISA functions, data types and parameters are defined independently; the programme uses VISA can therefore run on any platform as long as the platform supports the language used by the programme. For instance, a C programme using VISA can be transferred from one platform to another by recompiling the same programme code on the destination platform.

VISA is an object-oriented language that can easily adapt to new instrument interfaces and flexible for upgrading old programmes that use VISA. The interface independency of VISA makes the programme capable of running on the same instrument with different hardware interface.

Because VISA was not available at first place, VXIplug&play alliance also produces a transition library also known as VISA Transition Library (VTL) that shares the advantages of VISA and compatible with VISA.

IVI foundation is currently in charge of maintaining the VISA specification, SCPI commands and shared VISA component to ensure the software compatibility between vendors. VISA component is the standard VISA software and compatible to any instruments produced by any vendor who follows VISA standard. Any user may download this software from IVI foundation[2]. The GPIB interface is directly

[2] VISA component at IVI foundation, http://www.ivifoundation.org/shared_components/Default.aspx

supported by VISA and other interface communication is achieved by protocol over PC standard I/O such as USB Test & Measurement Class (USBTMC) protocol over USB. USBTMC is a protocol that built on top of USB and allows GPIB-like communication with USB devices. Many other companies produce VISA software set. The user may download and install them according to the official procedures. IVI foundation web site also provides the shared VISA components for user to install. The software provides VISA functions for multi-interface communication control only. VISA is not responsible for instrument control, because instrument control is done by SCPI commands.

As an object-oriented language, VISA has resources, functions, and variables. In VISA, variables are called attributes but the original property of variables is still the same. Resources are the most significant objects in VISA language. An operation is called when a function used with an object. Each object associates with attributes that defines the parameters of an object.

There are five major resource groups in VISA. These resources have many attributes, which will be not explained in details. The mentioned VXI terminologies can be found in the earlier part of this section and the GPIB terminologies can be found in the later section of this thesis.

Instrument Control (INSTR)

Memory Access (MEMACC)

GPIB Bus Interface (INTFC)

VXI Mainframe Backplane (BACKPLANE)

TCPIP Socket (SOCKET)

The instrument control (INSTR) resource group defines the basic operations and attributes of the VISA resource. The INSTR allows the controller to interact with the device related to this resource, by providing the services such as request and send blocks of data, send device clear command to the device, trigger signal, the status information of the device. It also allows programmer to access registers of the devices that reside on memory-mapped buses.

The memory access (MEMACC) resource encapsulates the address space of a memory-mapped bus such as the VXI bus. The MEMACC resource also lets controller to interact with the interface associated with this resource. It provides the controller with the services to access the arbitrary registers and the memory addresses on the memory mapped buses.

The GPIB bus interface (INTFC) resource can encapsulate the operations and properties of a GPIB interface such as reading writing and so on. The INTFC resource allows the controller to interact with the resource associated the connected devices. It provides service such as sending, receiving blocks of data on the bus, trigger devices on the bus, send miscellaneous commands to any devices. The controller can also query and manipulate specific line on the bus directly and pass the controller right to other device.

The VXI mainframe backplane (BACKPLANE) resource is associated with the VXI-defined operations and properties of the backplane in the VXI bus system. The BACKPLANE resource allows the controller to query and control the specific line on the specific mainframe in the VXI system. It provides the services such as map, un-map, asserts and receives hardware triggers, and asserts utilities and interrupt signals. It includes some advanced functionalities that might not be found in all vendors' controllers.

The TCPIP socket (SOCKET) resource encapsulates the operations and properties of the network socket using TCPIP. The SOCKET resource exposes the capability of the network socket connection of TCPIP. The services provided are sending, receiving blocks of data. An attribute setting allows sending software triggers, querying the IEEE 488 status byte and sending a device clear signal if the device supports IEEE 488.2 string format.

VISA provides programmer with ten function groups. These function groups allow programmer to interact with the instrument, set up interfaces, manage events, trigger other operation, memory management, I/O control and so on.

The groups are:

Sessions Management

Control Mechanism

Event Handling

VXI Specific Series

Searching

Basic I/O

Formatted I/O

Memory I/O

Interface Specific Services

USB Specific Services

Sessions management group is responsible for establishing and terminating sessions. The resource manager session must be established before any other sessions to different resource can be made. The purpose of the default resource manager session is initializing the VISA system. This step allows VISA system to recognize the devices connected. A device will not be recognized if it is connected after a default resource manager session has been established. Any other VISA functions can then be invoked with resources available to use after the establishment of default resource manager session. Multiple sessions can be set up under one default resource manager. A device can accommodate multiple sessions at one time, but may cause potential operational problems between users. Each session must be terminated at the end of the programme, so the resources can be reused and updated accordingly for the next programme to run.

Control mechanism group is responsible for controlling and managing the miscellaneous operations between resources. It controls the software and hardware trigger, read and set attributes, allocate memory in devices, obtain the human readable VISA status messages, terminate asynchronous operations, access control to resources, mapping trigger lines. This group is important in a software platform that allows multiple users or software access to multiple instruments.

Event handling group is responsible for managing the events, interrupts and handlers. This group can assert an interrupt or signal by the given trigger condition, install and uninstall handlers in a session, enable, disable, discard and wait for events and programmer may construct their own event handler by the given prototype from the event handling group.

VME bus Extensions for Instrument (VXI) bus is an interface used in test and measurement industry that based on VERSAmodule Eurocard (VME) bus. VME bus was originally designed for the Motorola 68000 CPU communication. It uses 96 pins, DIN 41612 as the mechanical connector and using its own signaling system. The current VME64 bus protocol has average performance of 40MB/s, by using full 64-bits bus for both data and address lines. VXI bus was developed for portable instruments with an open standard modular architecture that can be integrated into GPIB bus system. The advantage of it uses high throughput capability of VME devices that are programmed and communicating in binary form. VXI Specific Series function group allows the user to send command and query and retrieve the response for devices with VXI bus.

The searching function group is responsible for searching device and obtains interface information. The user may use the functions in this group without establishing a session to resources before searching for resources. The search function in this group can find the device by the particular interface type and interface setting. However, the user cannot find the device by the model or serial number of the device unless the user establishes a session to the instrument and send a SCPI query for instrument information.

The basic I/O function group is responsible for reading and writing data from and to the device and clear sessions to the device. The operation can be either asynchronous or synchronous. The user may use the functions in this group to read the status byte of the service request, read data from a file and write it to a device or read data from device and write to a file synchronously. The requirement of this thesis is to output a formatted human and software readable file, direct read and write from and to file functions are not used in this thesis since the programme will not be able to lay out the format that satisfy the requirement of this thesis. The commands produced use the most basic read and write functions. These two functions only write and read the data to and from the device without any further automated process. By using these two commands, the programmer can then reorganize the data to the desired format.

The formatted I/O group is responsible to read and write data from and to the device in certain programmer-defined format or read and write unformatted data to formatted I/O buffers. The commands in this group behave very similar to sprintf and sscanf functions in C language. These commands allow the programmer to read and write multiple parameters in one programme line as long as the device supports such command format. The programmer may also use the functions to send and read formatted queries.

The memory I/O function group is responsible for reading and writing bits values between device and local memory or to specified memory space. The programmer may also use this function group to write bits value to certain memory address. The bits values can be 8, 16 or 32 bits. Each function in this group has a three version for three different bit number values. The function in the group can also map and un-map memory space. Most functions do not need memory mapping function to be called prior to their invocation.

The interface specific services function group is responsible for controlling the GPIB bus. Please find GPIB terminologies and knowledge later in this section of the thesis. This function group can send out REN signal to devices to set up the mode of the device in GPIB connection. The ATN signal can also be sent by the function in this group in order to all the controller of GPIB connection to send commands. The function in this group allows programmer to set the controller in charge (CIC) right to the specified controller in a multi-controller present network and send out interface clear (IFC) signal to initialize the bus.

The USB specific services function group is responsible for communicating the USB bus information. The programmer may send and request for the arbitrary data to and from a USB device, however programmer must be aware each parameter is based on USB class and base specification or a vendor-specific request definition.

Figure 1.2 below shows the brief structure of the function groups.

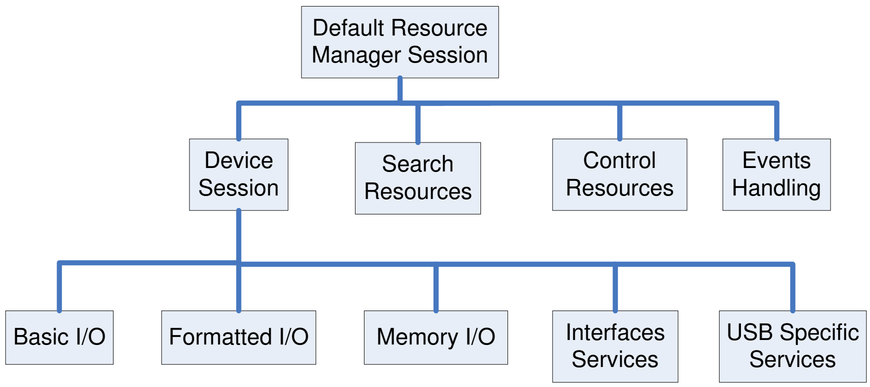

Figure G.1 *The structure of VISA functions. The default resource manager session must be present before using any VISA functions. The functions at level two do not require any more session to run apart from the default resource manager session. The functions level 3 are related to interface or instrument session, most of them require a specific interface or instrument session.*