SCTA Documentation

Release 1.0

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May 18, 2022

Contents

Warning: This documentation is under construction. Please check regularly for updates.

Imagine all the manual configuration it takes to accurately measure something as simple as channel power on a spectrum analyzer like the Rhode & Schwarz FSW:

Now you don't have to! In the time it takes to make one manual measurement, this automation script can make 20:

With these automation libraries you can spend less time making repetitive signal measurements and more time analyzing the data. You can even automate trivial monitoring tasks anytime, anywhere.

Contents

CHAPTER 1

Installation & Network Setup

Note: You must have Administrator priveleges to do the following installations.

Warning: Most of the installation can be done on either Linux or Windows. However, the SNMP drivers we use only support Windows machines. So, if you want to interact with any equipment over SNMP, you must use a Windows machine. Our sincerest apologies.

Prerequisites We expect some familiarity with using your computer's command prompt/ terminal utility.

Hardware Requirements The SCTA libraries have only been tested with the following environment:

- Intel i5-4590 CPU @ 3.30GHz
- 8GB RAM
- 64-bit OS
- Windows 7 Professional

Tips

- none

Contents

1.1 VISA Drivers

The SCTA libraries use the Virtual Instrument Software Architecture (VISA) standard I/O commands to control our lab equipment. The VISA standard is widely accepted by the Test & Measurement Industry, such as National Instruments, Rhode & Schwarz, and Keysight Technologies. We will be installing VISA equipment drivers provided by National Instruments.

1.1.1 Installing NI-VISA

Hint: Search your programs for `NI-VISA`. If you already have NI-VISA installed, skip this section.

If you do not have NI-VISA installed, go to the downloads page at the National Instruments website.

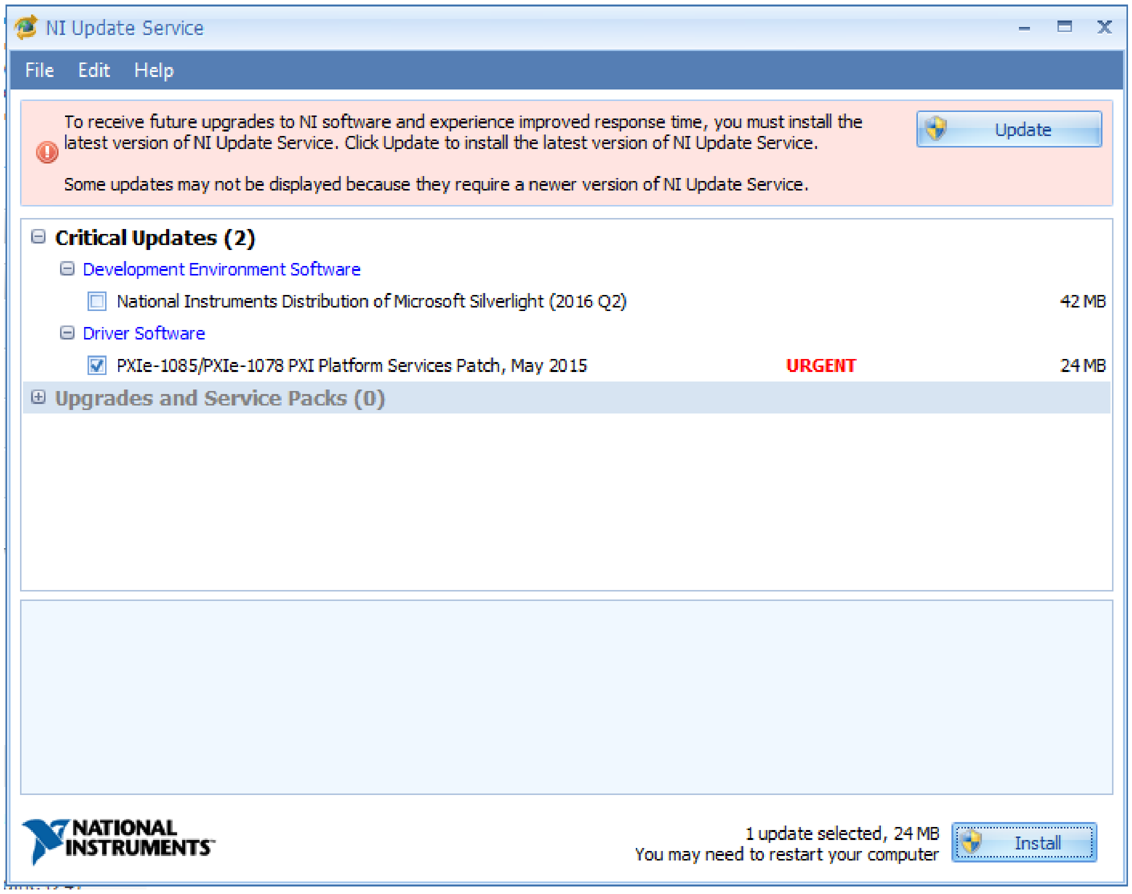
You may have to login with an existing National Instruments account. Download the latest NI-VISA Run-Time Engine.

Note: The SCTA libraries have been tested with NI-VISA version 16.0

1.1.2 Updating NI-VISA

In programs, open the NI Update Service.

If you see a red banner telling you to update the NI Update Service, click the Update button.



To receive future upgrades to NI software and experience improved response time, you must install the latest version of NI Update Service. Click Update to install the latest version of NI Update Service.

Some updates may not be displayed because they require a newer version of NI Update Service.

Critical Updates (2)

Development Environment Software

☐ National Instruments Distribution of Microsoft Silverlight (2016 Q2) 42 MB

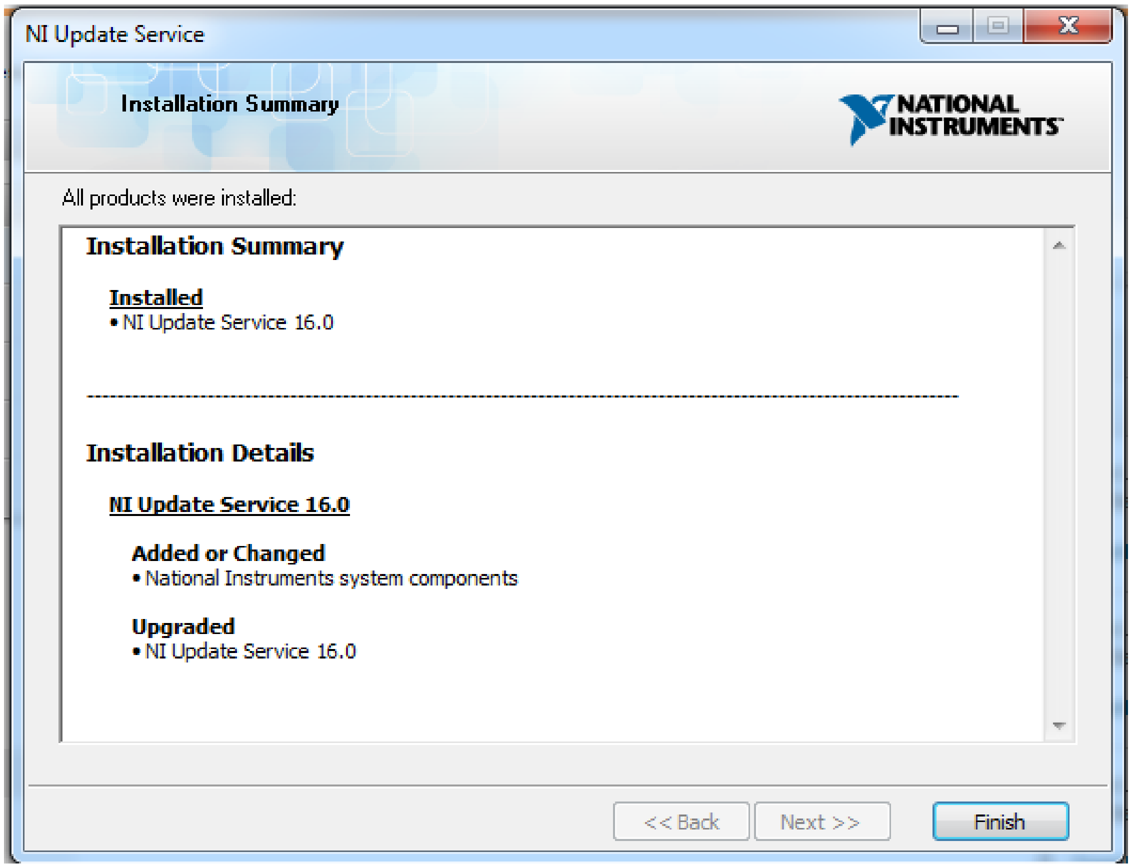
Driver Software

☑ PXIe-1085/PXIe-1078 PXI Platform Services Patch, May 2015 URGENT 24 MB

Upgrades and Service Packs (0)

1 update selected, 24 MB
You may need to restart your computer

Click Yes when asking to allow changes to the computer. When prompted, accept all license agreements. When the update is complete, you will be prompted to restart the computer.



All products were installed:

Installation Summary

Installed
• NI Update Service 16.0

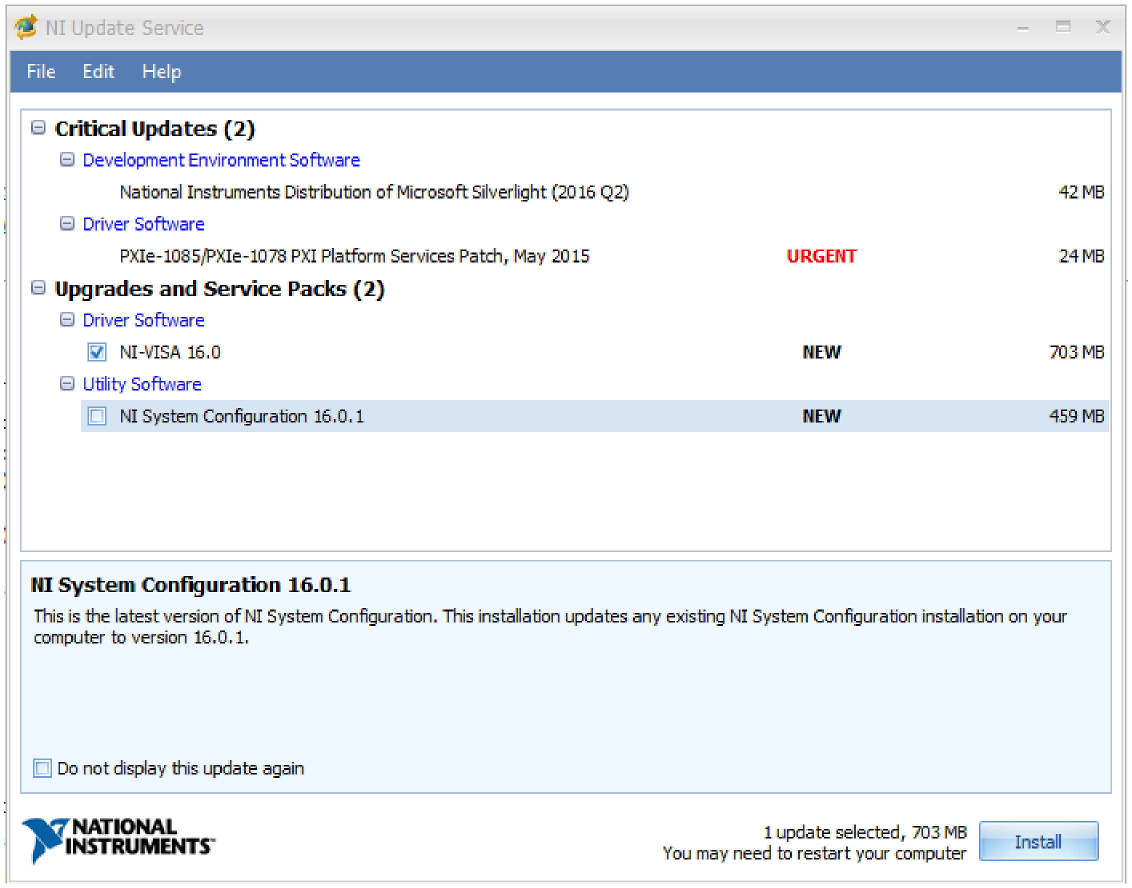
Installation Details

NI Update Service 16.0

Added or Changed
• National Instruments system components

Upgraded
• NI Update Service 16.0

After restarting, open NI Update Service again. The red banner should be gone. The `Critical Updates` section should already be expanded, but also expand the `Upgrades and Service Packs` section. Check anything related to `NI-VISA` under the `Driver Software` sections.



Critical Updates (2)

Development Environment Software

National Instruments Distribution of Microsoft Silverlight (2016 Q2)		42 MB

Driver Software

PXIe-1085/PXIe-1078 PXI Platform Services Patch, May 2015	URGENT	24 MB

Upgrades and Service Packs (2)

Driver Software

[✓] NI-VISA 16.0	NEW	703 MB

Utility Software

[ ] NI System Configuration 16.0.1	NEW	459 MB

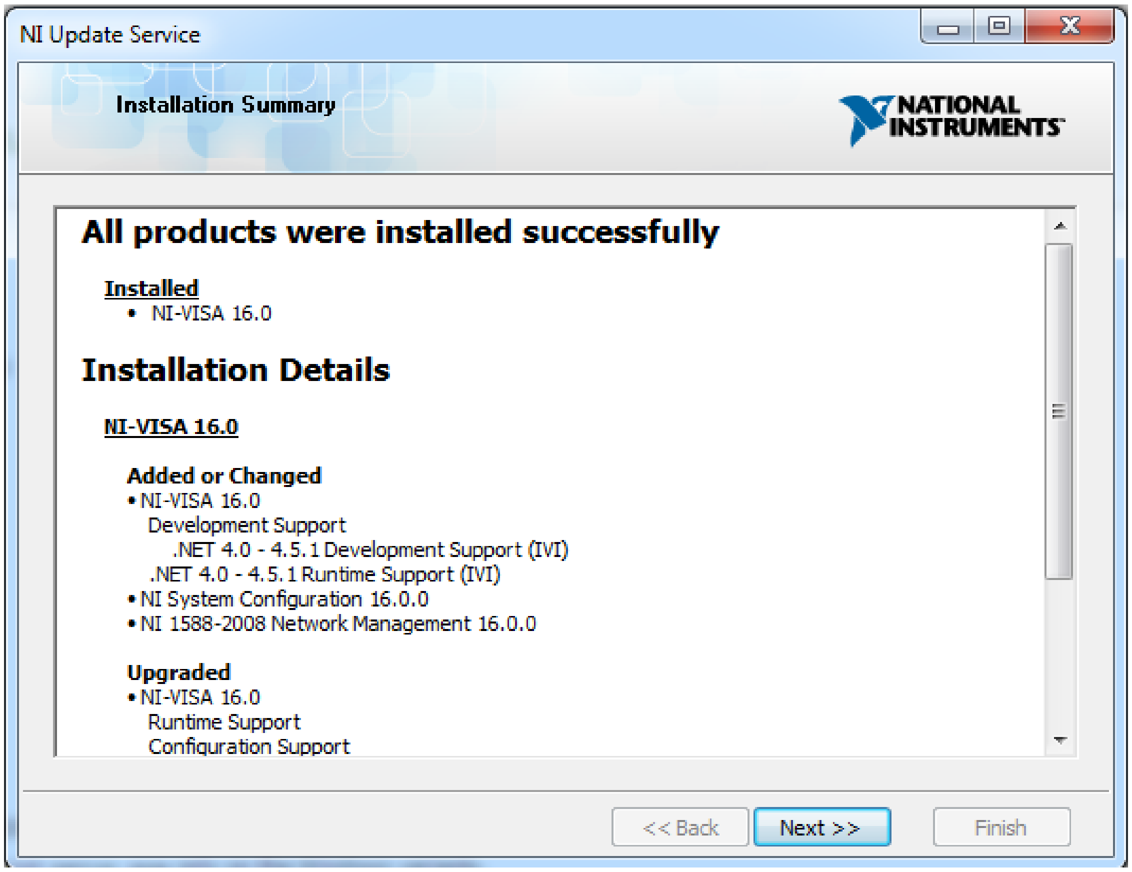
NI System Configuration 16.0.1

This is the latest version of NI System Configuration. This installation updates any existing NI System Configuration installation on your computer to version 16.0.1.

[ ] Do not display this update again

1 update selected, 703 MB
You may need to restart your computer

When prompted, accept all license agreements. When the drivers are installed, you will be prompted to restart the computer.



All products were installed successfully

Installed
- NI-VISA 16.0

Installation Details

NI-VISA 16.0

Added or Changed
- NI-VISA 16.0
  Development Support
    .NET 4.0 - 4.5.1 Development Support (IVI)
  .NET 4.0 - 4.5.1 Runtime Support (IVI)
- NI System Configuration 16.0.0
- NI 1588-2008 Network Management 16.0.0

Upgraded
- NI-VISA 16.0
  Runtime Support
  Configuration Support

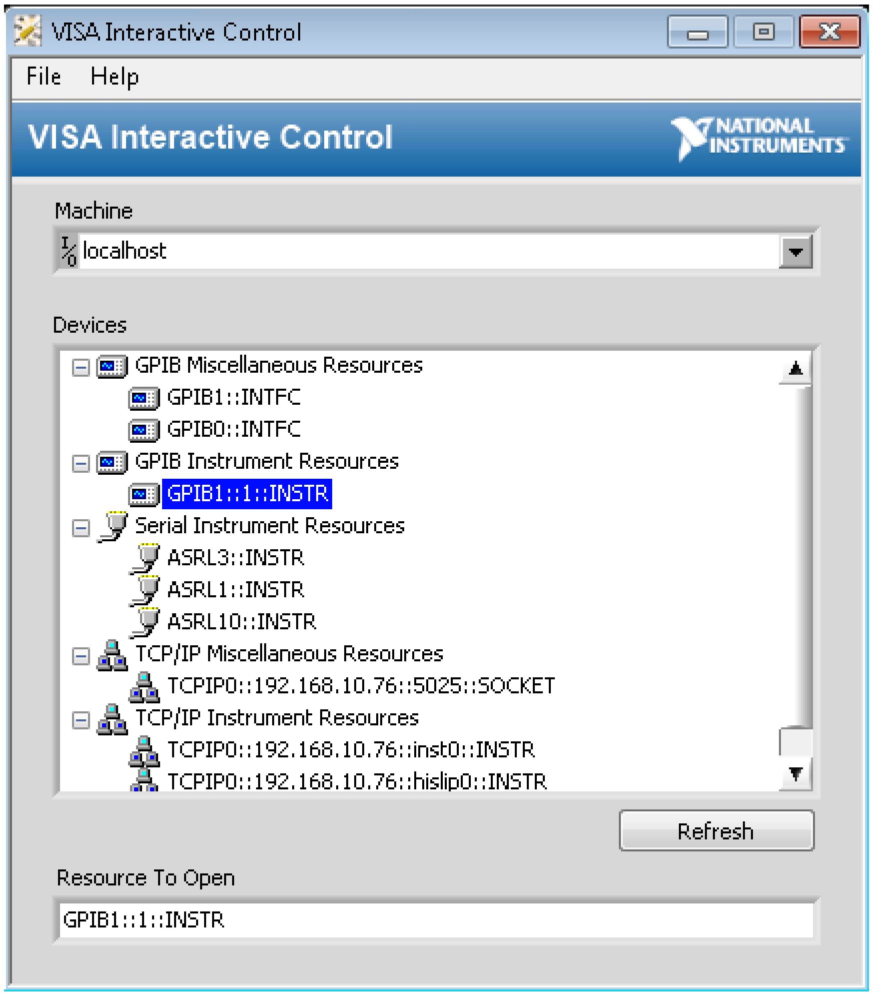
1.1.3 Installing GPIB drivers

Warning: Please ask Luis to fill out this section!

1.1.4 VISA Interactive Control

In programs, open the VISA Interactive Control.

Any equipment connected to the network should be listed under the `Devices` section.



Machine
localhost

Devices
GPIB Miscellaneous Resources
GPIB1::INTFC
GPIB0::INTFC
GPIB Instrument Resources
GPIB1::1::INSTR
Serial Instrument Resources
ASRL3::INSTR
ASRL1::INSTR
ASRL10::INSTR
TCP/IP Miscellaneous Resources
TCPIP0::192.168.10.76::5025::SOCKET
TCP/IP Instrument Resources
TCPIP0::192.168.10.76::inst0::INSTR
TCPIP0::192.168.10.76::hislip0::INSTR

Resource To Open
GPIB1::1::INSTR

1.2 SNMP Drivers

Simple Network Management Protocol (SNMP) is an Internet-standard protocol for collecting and organizing information about managed devices on IP networks and for modifying that information to change device behavior. SNMP exposes management data in the form of variables called management information base (MIB) objects which describe the system status and configuration. These variables can then be remotely queried and manipulated.

Some RF equipment, like the DM240XR, VTM, and VTR strictly use SNMP for remote interaction.

Instead of using proper Python libraries for interacting over SNMP, we use Windows batch files that implement the SNMP `set` and `get` commands. Unfortunately, this restricts our automation libraries to Windows only if you want to interact with equipment over SNMP. The batch files `SnmpSet` and `SnmpGet` can be found under `SCTA_repo\install\`. Copy the batch files to the `C:` drive on your Windows machine.

1.3 Git Version Control

The SCTA libraries are stored on the AMCLAB server in the form of a Git repository. Git is a Version Control System that developers use to store historical snapshots of code throughout its lifetime. We use

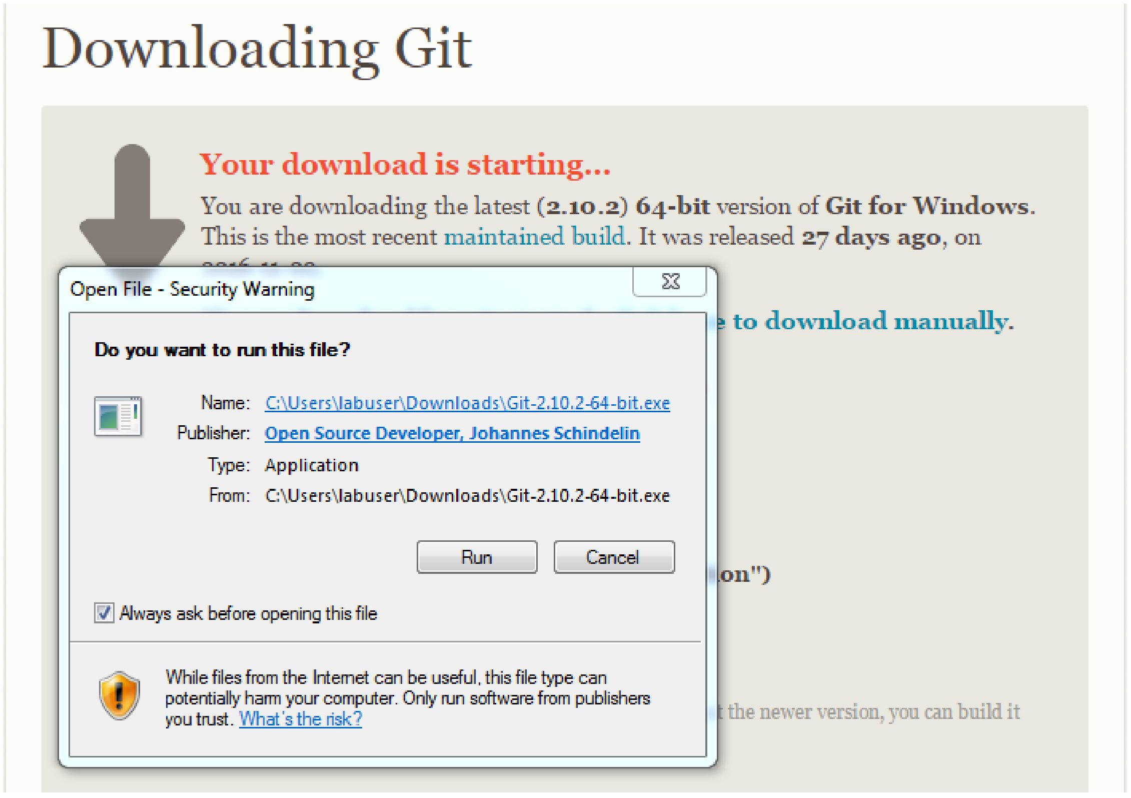
Git to store the most updated version of the SCTA libraries as well as previous working versions. In this tutorial, you will be downloading the most recent version of SCTA through Git.

Note: The following installation instructions are for Windows PCs only! Installing Git on Ubuntu should be as simple as an `apt-get install git` command.

1.3.1 Installing Git

Go to the downloads page at the Git website.

Choose the appropriate installer for your OS. For Windows, it should download an executable. Run it, and click Yes when asking to allow changes to the computer.


Downloading Git

Your download is starting...

You are downloading the latest (2.10.2) 64-bit version of Git for Windows. This is the most recent maintained build. It was released 27 days ago, on

Open File - Security Warning

Do you want to run this file?

Name: C:\Users\labuser\Downloads\Git-2.10.2-64-bit.exe
Publisher: Open Source Developer, Johannes Schindelin
Type: Application
From: C:\Users\labuser\Downloads\Git-2.10.2-64-bit.exe

Run Cancel

☑ Always ask before opening this file

While files from the Internet can be useful, this file type can potentially harm your computer. Only run software from publishers you trust. What's the risk?

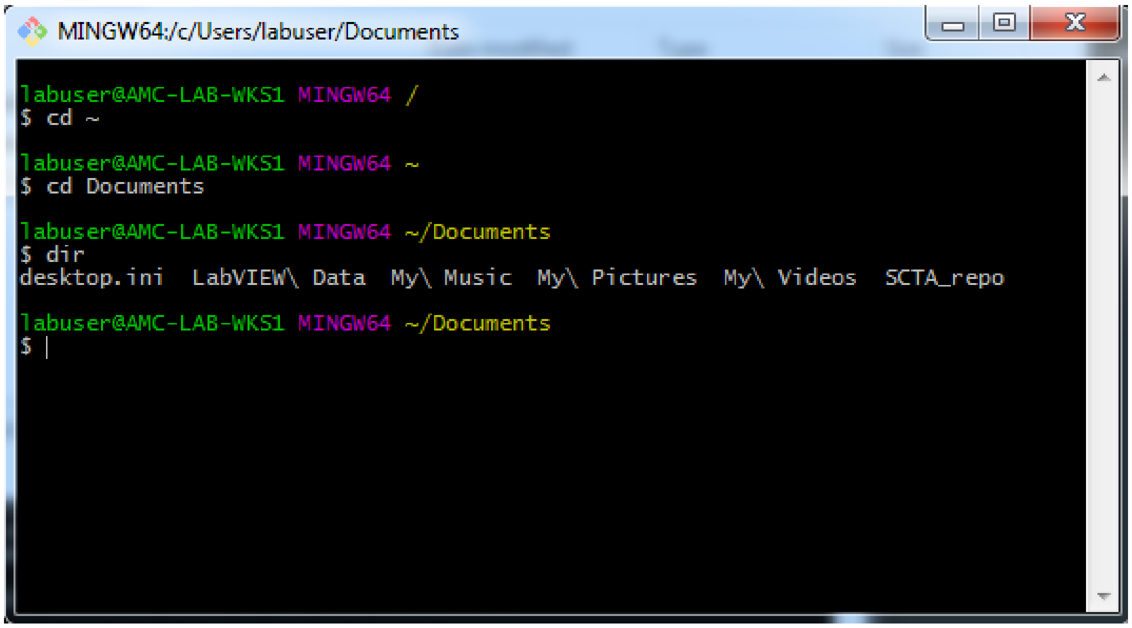
In the Git Setup service, use the default installation destination, components, start menu shortcuts, PATH environment, line ending conversions, terminal emulator, and extra options. The installation should be quick.

1.3.2 Cloning the SCTA Libraries

In programs, open Git Bash.

Use Git Bash like any other Command Prompt or Terminal application. It defaults to the computer's root directory, but you can change directories using `cd` and list directory contents using `dir`. For example, change to your Documents directory:

```
cd ~\Documents\
```



```
labuser@AMC-LAB-WKS1 MINGW64 /
$ cd ~

labuser@AMC-LAB-WKS1 MINGW64 ~
$ cd Documents

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents
$ dir
desktop.ini  LabVIEW\ Data  My\ Music  My\ Pictures  My\ Videos  SCTA_repo

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents
$ |
```

Beyond the default shell commands, Git Bash also has Git commands built-in. To see a list of all available commands run:

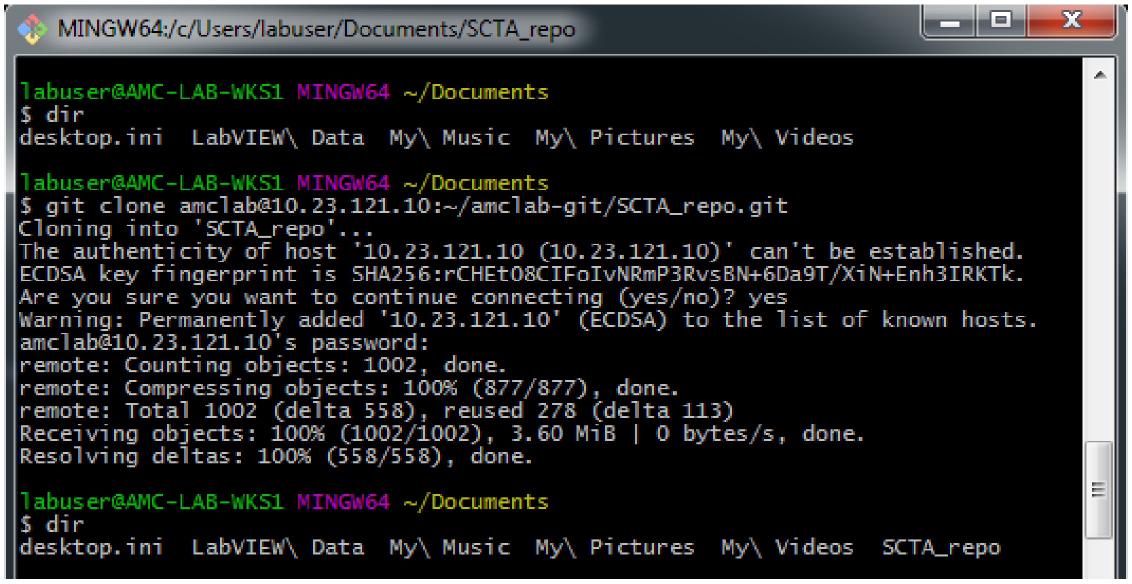
```
git --help
```

Note: To run the following commands, you must be on the same network as the AMCLAB server. You must also know the AMCLAB server password. Ask someone from the lab for access.

To "download" the SCTA libraries, we will use Git to `clone` the SCTA repository from the AMCLAB server to our local machine:

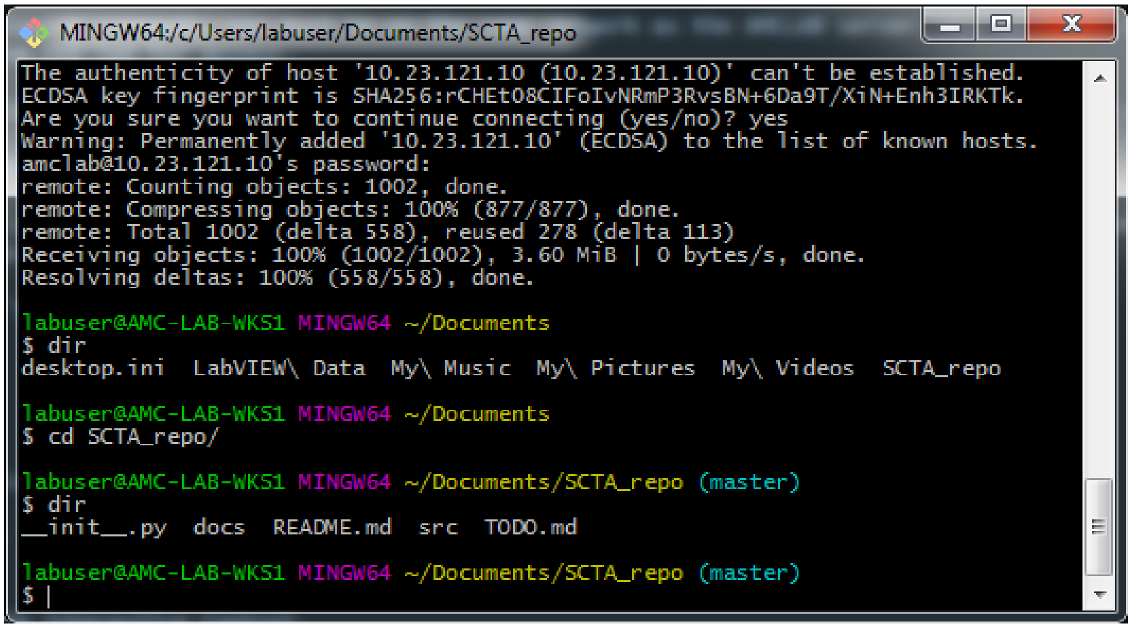
```
git clone amclab@10.23.121.10:~/amclab-git/SCTA_repo.git
```

If prompted to trust the authenticity of amclab, enter "yes". When prompted for a password, enter the password. After doing the `clone`, you should see a new directory called `SCTA_repo`.



```
labuser@AMC-LAB-WKS1 MINGW64 ~/Documents
$ dir
desktop.ini  LabVIEW\ Data  My\ Music  My\ Pictures  My\ Videos

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents
$ git clone amclab@10.23.121.10:~/amclab-git/SCTA_repo.git
Cloning into 'SCTA_repo'...
The authenticity of host '10.23.121.10 (10.23.121.10)' can't be established.
ECDSA key fingerprint is SHA256:rCHEt08CIFoIvNRmP3RvsBN+6Da9T/XiN+Enh3IRKTk.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '10.23.121.10' (ECDSA) to the list of known hosts.
amclab@10.23.121.10's password:
remote: Counting objects: 1002, done.
remote: Compressing objects: 100% (877/877), done.
remote: Total 1002 (delta 558), reused 278 (delta 113)
Receiving objects: 100% (1002/1002), 3.60 MiB | 0 bytes/s, done.
Resolving deltas: 100% (558/558), done.

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents
$ dir
desktop.ini  LabVIEW\ Data  My\ Music  My\ Pictures  My\ Videos  SCTA_repo
```

If you change into the SCTA_repo directory, you should see a README file that explains the contents of the repository. You should also see the prompt is "decorated" with (master). This refers to the current Git branch any of your commit s will be saved to. However, this is beyond the scope of this tutorial.



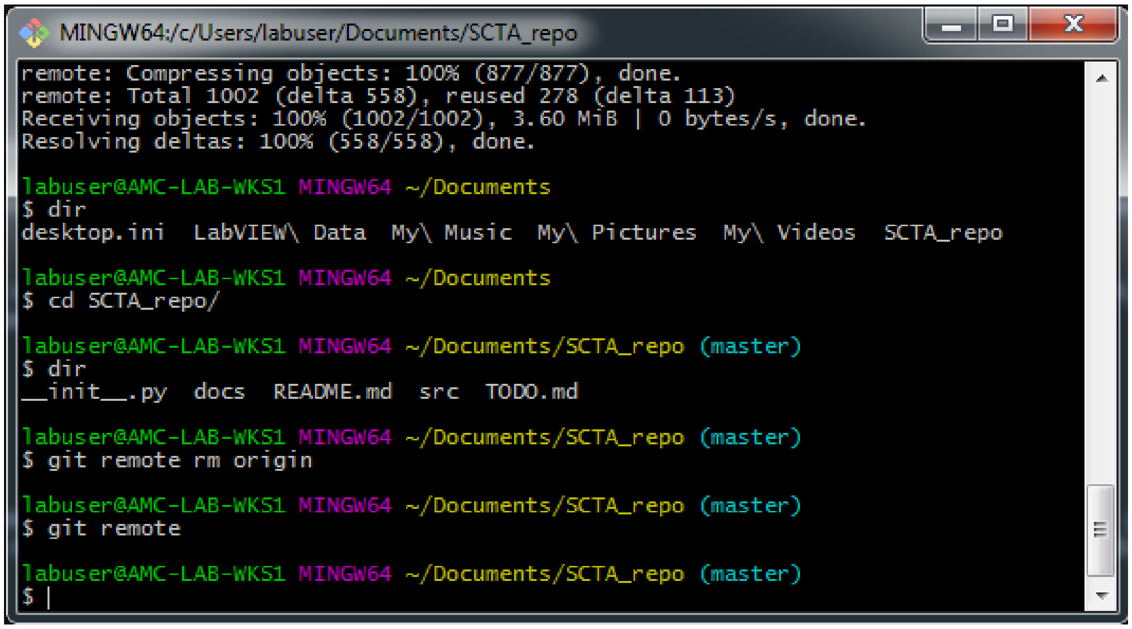
```
The authenticity of host '10.23.121.10 (10.23.121.10)' can't be established.
ECDSA key fingerprint is SHA256:rCHEt08CIFoIvNRmP3RvsBN+6Da9T/XiN+Enh3IRKTk.
Are you sure you want to continue connecting (yes/no)? yes
Warning: Permanently added '10.23.121.10' (ECDSA) to the list of known hosts.
amclab@10.23.121.10's password:
remote: Counting objects: 1002, done.
remote: Compressing objects: 100% (877/877), done.
remote: Total 1002 (delta 558), reused 278 (delta 113)
Receiving objects: 100% (1002/1002), 3.60 MiB | 0 bytes/s, done.
Resolving deltas: 100% (558/558), done.

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents
$ dir
desktop.ini  LabVIEW\ Data  My\ Music  My\ Pictures  My\ Videos  SCTA_repo

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents
$ cd SCTA_repo/

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents/SCTA_repo (master)
$ dir
__init__.py  docs  README.md  src  TODO.md

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents/SCTA_repo (master)
$ |
```

Hint: However, we **highly** recommend you come back to this later and use Git Version Control utilities when working on any serious programming project. There are several Git tutorials that show you how to view historical changes.

To be safe, remove the AMCLAB server's original repository address so that you won't ever accidentally write changes to the master copy of our SCTA libraries:

```
git remote rm origin
```

If you run the git remote command, nothing should be printed to the prompt.



```
MINGW64:/c/Users/labuser/Documents/SCTA_repo
remote: Compressing objects: 100% (877/877), done.
remote: Total 1002 (delta 558), reused 278 (delta 113)
Receiving objects: 100% (1002/1002), 3.60 MiB | 0 bytes/s, done.
Resolving deltas: 100% (558/558), done.

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents
$ dir
desktop.ini  LabVIEW\ Data  My\ Music  My\ Pictures  My\ Videos  SCTA_repo

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents
$ cd SCTA_repo/

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents/SCTA_repo (master)
$ dir
__init__.py  docs  README.md  src  TODO.md

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents/SCTA_repo (master)
$ git remote rm origin

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents/SCTA_repo (master)
$ git remote

labuser@AMC-LAB-WKS1 MINGW64 ~/Documents/SCTA_repo (master)
$ |
```

1.4 Anaconda v.s. Python

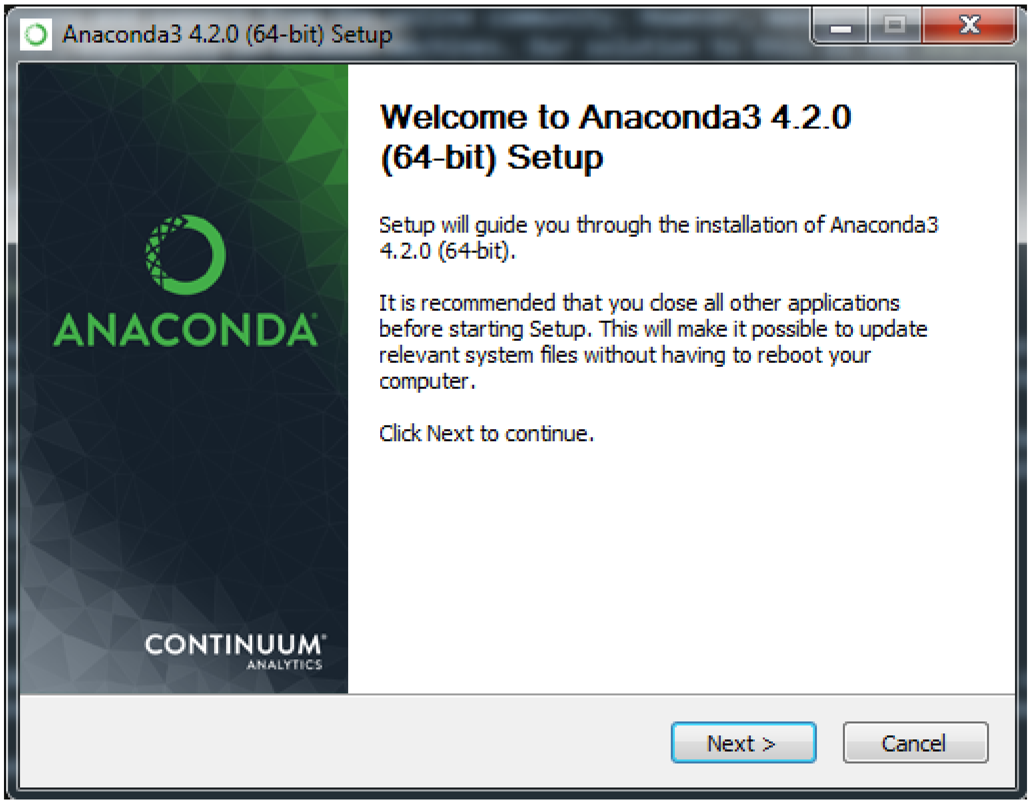
No, this is not an epic battle between the two largest snakes in the world.

The SCTA libraries form a Python package that you run using the Python programming language. Python is powerful for its wealth of open-source packages and support from the online community. However, managing these packages and their dependencies can be tedious and prone to error, especially on Windows machines. Our solution to this is the Anaconda package manager. Anaconda has servers dedicated to hosting Python packages, including PyVISA, which is a Python API to the *VISA Drivers*. Anaconda also provides command line tools for organizing our packages into `environments` that save the state of our packages for easy redeployment onto a new machine. All of this is explained in the following tutorial.

1.4.1 Installing Anaconda

Go to the downloads page at the Anaconda website.

Choose `Anaconda2-4.2.0-Windows-x86_64.exe` (Python 3.5 version, 64-bit installer). If it prompts you with an advertisement to email you more materials, click “No Thanks”. For Windows, it should download an executable. Run it, and click Yes when asking to allow changes to the computer.


Anaconda3 4.2.0 (64-bit) Setup

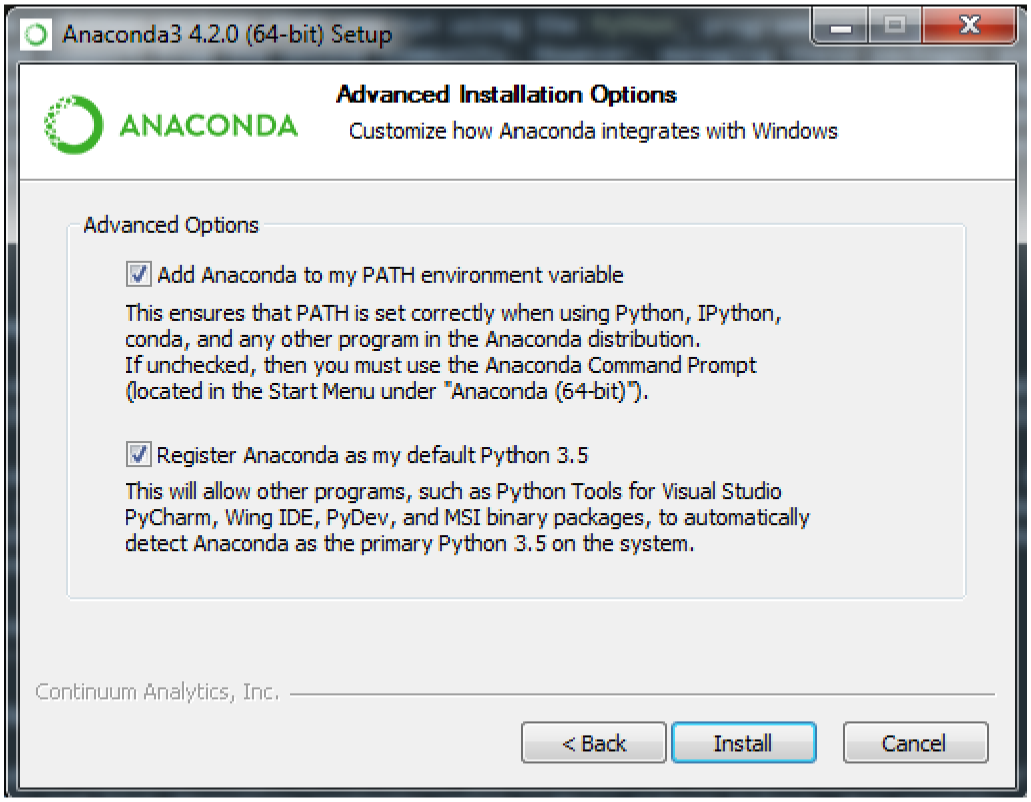
Welcome to Anaconda3 4.2.0 (64-bit) Setup

Setup will guide you through the installation of Anaconda3 4.2.0 (64-bit).

It is recommended that you close all other applications before starting Setup. This will make it possible to update relevant system files without having to reboot your computer.

Click Next to continue.

In the Anaconda Setup service, agree to the license agreement and use the default installation destination. In the "Advanced Installation Options", use the default options if you don't already have Python installed on your machine. If you already have Python installed, you can check or uncheck the options based on your preference. The installation should be quick.


Anaconda3 4.2.0 (64-bit) Setup

Advanced Installation Options

Customize how Anaconda integrates with Windows

Advanced Options

[✓] Add Anaconda to my PATH environment variable

This ensures that PATH is set correctly when using Python, IPython, conda, and any other program in the Anaconda distribution. If unchecked, then you must use the Anaconda Command Prompt (located in the Start Menu under "Anaconda (64-bit)").

[✓] Register Anaconda as my default Python 3.5

This will allow other programs, such as Python Tools for Visual Studio PyCharm, Wing IDE, PyDev, and MSI binary packages, to automatically detect Anaconda as the primary Python 3.5 on the system.

1.4.2 Anaconda Basics

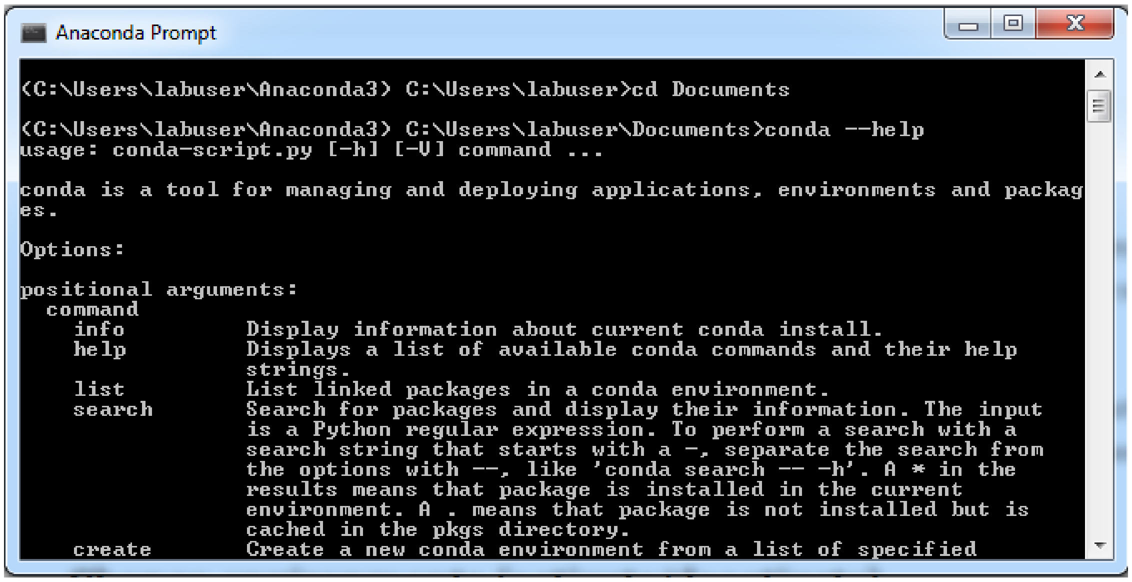
In programs, open Anaconda Prompt.

Use Anaconda Prompt like any other Command Prompt or Terminal application. It defaults to the user home directory, but you can change directories using cd and list directory contents using dir. For example, change to your Documents directory:

```
cd Documents
```

Beyond the default shell commands, Anaconda Prompt also has conda commands built-in. To see a list of all available commands run:

```
conda --help
```



```
(C:\Users\labuser\Anaconda3) C:\Users\labuser>cd Documents

(C:\Users\labuser\Anaconda3) C:\Users\labuser\Documents>conda --help
usage: conda-script.py [-h] [-V] command ...

conda is a tool for managing and deploying applications, environments and packag
es.

Options:

positional arguments:
  command
    info         Display information about current conda install.
    help         Displays a list of available conda commands and their help
                 strings.
    list         List linked packages in a conda environment.
    search       Search for packages and display their information. The input
                 is a Python regular expression. To perform a search with a
                 search string that starts with a -, separate the search from
                 the options with --, like 'conda search -- -h'. A * in the
                 results means that package is installed in the current
                 environment. A . means that package is not installed but is
                 cached in the pkgs directory.
    create       Create a new conda environment from a list of specified
```

Note that the prompt is "decorated" with `<C:\Users\labuser\Anaconda3>`. This refers to the default Anaconda `environment` any of your Python code will be running in. To see which packages are in this environment:

```
conda list
```

Later in the tutorial, we will be creating a much more slimmed down `environment` specifically for running our SCTA code.

Update the conda package manager for good measure:

```
conda update conda
```

Hint: For more advanced commands and environment management, try this tutorial.

1.4.3 The Easy Way: Cloning our SCTA Environment

Note: To run the following commands, you must first complete the *Git Version Control* Installation. After cloning the Git repository, you should have the `SCTA_repo` directory.

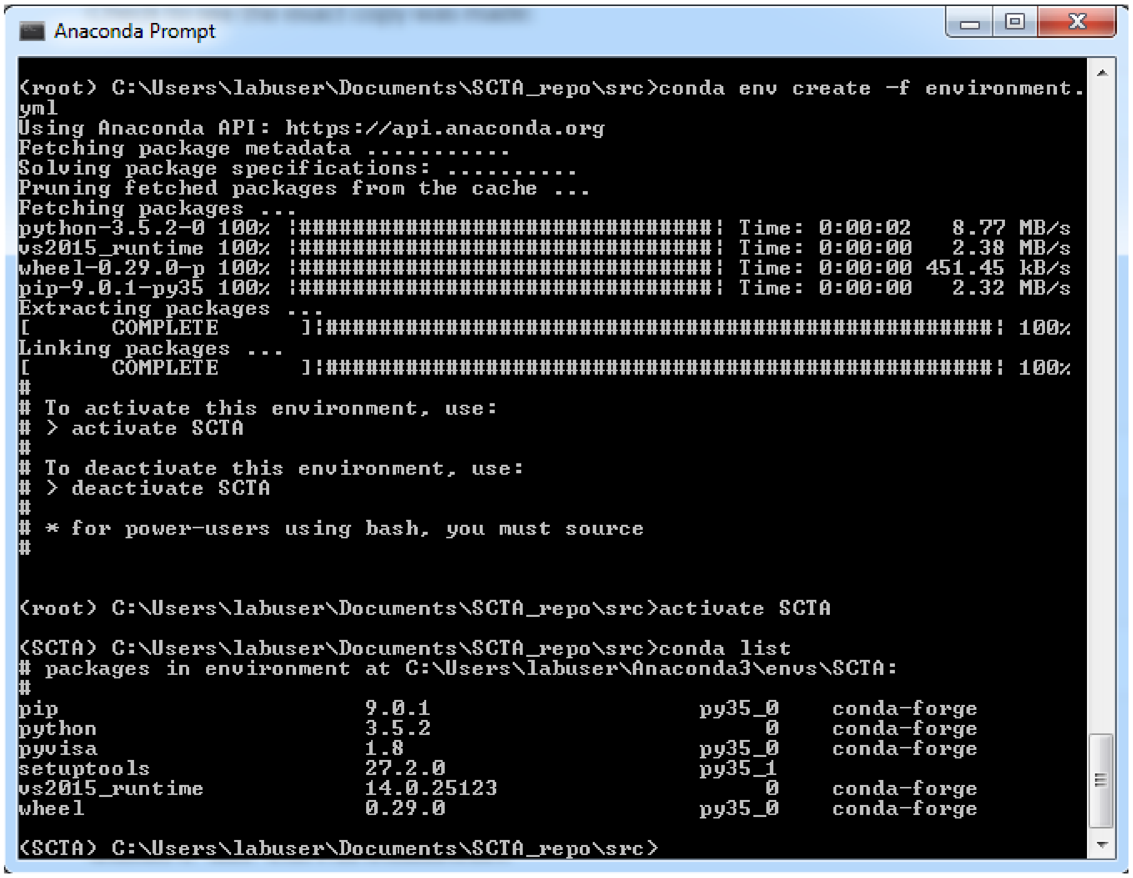
To clone our SCTA Environment:

```
cd SCTA_repo\install\Anaconda3\envs
conda env create -f SCTA-environment.yml
```

Once the environment is created, `activate` it and check that `pyvisa` v. 1.8 was linked to the environment:

```
activate SCTA
conda list
```

The output should look something like this.



```
(root) C:\Users\labuser\Documents\SCTA_repo\src>conda env create -f environment.
yml
Using Anaconda API: https://api.anaconda.org
Fetching package metadata ...........
Solving package specifications: ..........
Pruning fetched packages from the cache ...
Fetching packages ...
python-3.5.2-0 100% |###############################| Time: 0:00:02   8.77 MB/s
vs2015_runtime 100% |###############################| Time: 0:00:00   2.38 MB/s
wheel-0.29.0-p 100% |###############################| Time: 0:00:00 451.45 kB/s
pip-9.0.1-py35 100% |###############################| Time: 0:00:00   2.32 MB/s
Extracting packages ...
[      COMPLETE      ]|##################################################| 100%
Linking packages ...
[      COMPLETE      ]|##################################################| 100%
#
# To activate this environment, use:
# > activate SCTA
#
# To deactivate this environment, use:
# > deactivate SCTA
#
# * for power-users using bash, you must source
#


(root) C:\Users\labuser\Documents\SCTA_repo\src>activate SCTA

(SCTA) C:\Users\labuser\Documents\SCTA_repo\src>conda list
# packages in environment at C:\Users\labuser\Anaconda3\envs\SCTA:
#
pip                       9.0.1                    py35_0    conda-forge
python                    3.5.2                         0    conda-forge
pyvisa                    1.8                      py35_0    conda-forge
setuptools                27.2.0                   py35_1
vs2015_runtime            14.0.25123                    0    conda-forge
wheel                     0.29.0                   py35_0    conda-forge

(SCTA) C:\Users\labuser\Documents\SCTA_repo\src>
```

Note: To run any SCTA code, you **MUST REMEMBER** to `activate SCTA`. This is how you "link" the `pyvisa` package that we use extensively in the SCTA libraries.

1.4.4 The Hard Way: Creating your own SCTA Environment

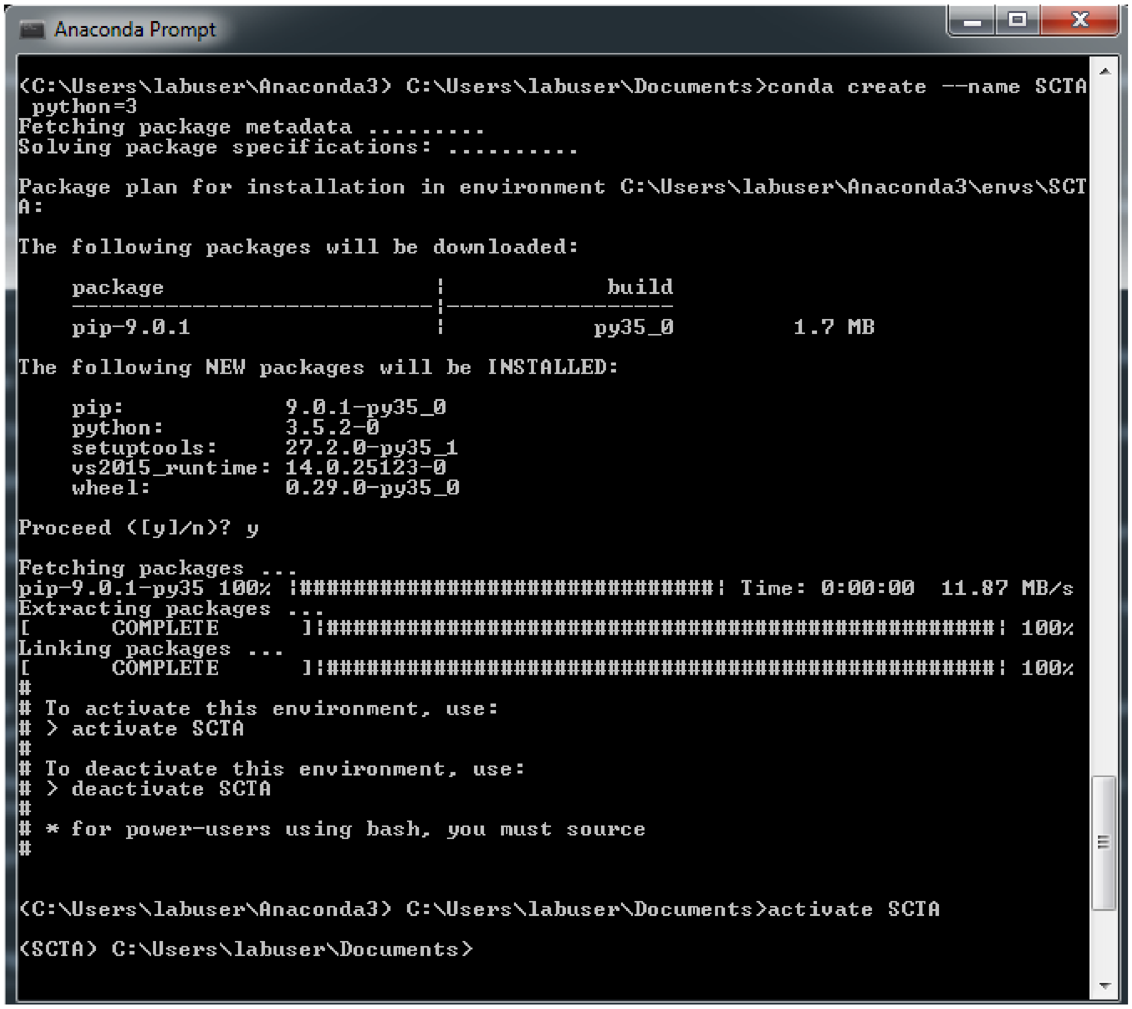
If you wish to create your own SCTA environment, first create an environment with Python 3:

```
conda create --name SCTA python=3
```

This will include Python 3's package manager and other base Python 3 packages. When prompted to proceed, enter "y". After it is complete, `activate` the environment:

```
activate SCTA
```

You should see that the prompt is now "decorated" with `<SCTA>`.



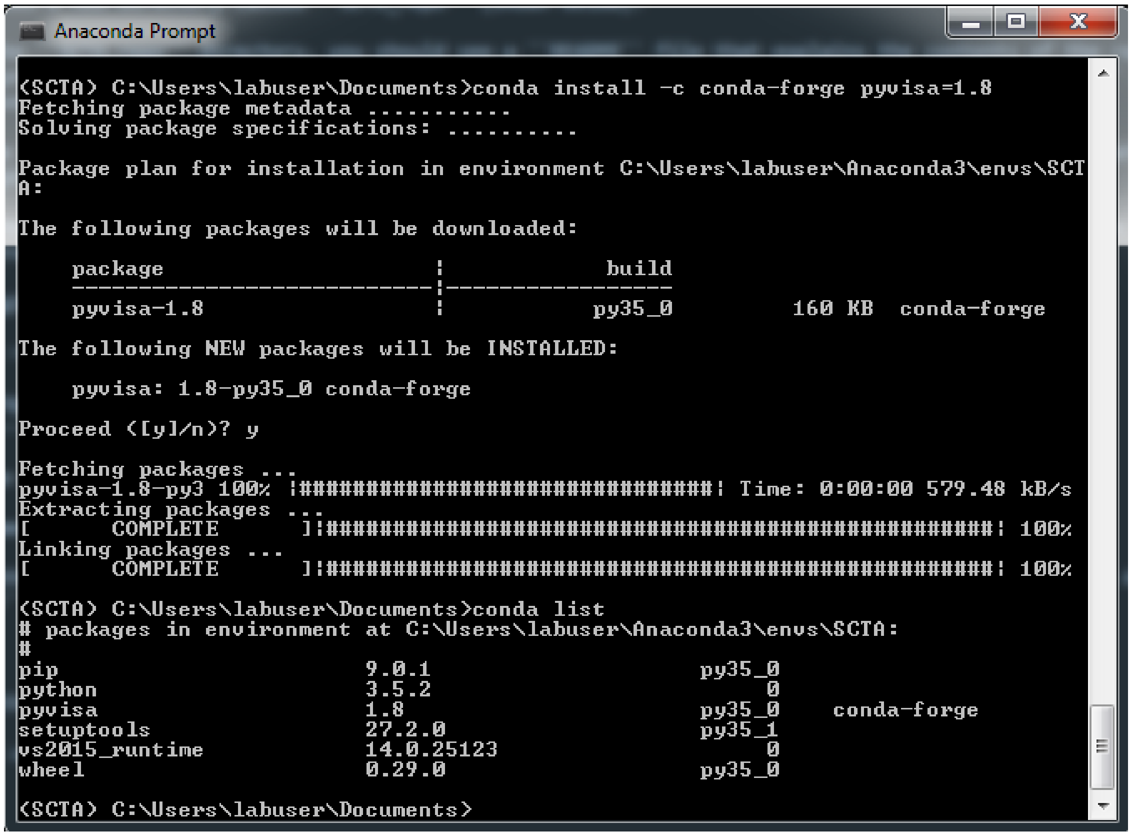
```
(C:\Users\labuser\Anaconda3) C:\Users\labuser\Documents>conda create --name SCTA
 python=3
Fetching package metadata .........
Solving package specifications: ..........

Package plan for installation in environment C:\Users\labuser\Anaconda3\envs\SCT
A:

The following packages will be downloaded:

    package                    |            build
    ---------------------------|-----------------
    pip-9.0.1                  |           py35_0         1.7 MB

The following NEW packages will be INSTALLED:

    pip:            9.0.1-py35_0
    python:         3.5.2-0
    setuptools:     27.2.0-py35_1
    vs2015_runtime: 14.0.25123-0
    wheel:          0.29.0-py35_0

Proceed ([y]/n)? y

Fetching packages ...
pip-9.0.1-py35 100% |###############################| Time: 0:00:00  11.87 MB/s
Extracting packages ...
[      COMPLETE      ]|##################################################| 100%
Linking packages ...
[      COMPLETE      ]|##################################################| 100%
#
# To activate this environment, use:
# > activate SCTA
#
# To deactivate this environment, use:
# > deactivate SCTA
#
# * for power-users using bash, you must source
#


(C:\Users\labuser\Anaconda3) C:\Users\labuser\Documents>activate SCTA

(SCTA) C:\Users\labuser\Documents>
```

Now, we will install all other necessary packages to run our SCTA code. Install them using:

```
conda install -c conda-forge pyvisa=1.8
```

When prompted to proceed, enter “y”. Check that `pyvisa` v. 1.8 was linked to your environment:

```
conda list
```



```
(SCTA) C:\Users\labuser\Documents>conda install -c conda-forge pyvisa=1.8
Fetching package metadata ...........
Solving package specifications: ..........

Package plan for installation in environment C:\Users\labuser\Anaconda3\envs\SCT
A:

The following packages will be downloaded:

    package                    |            build
    ---------------------------|-----------------
    pyvisa-1.8                 |           py35_0         160 KB  conda-forge

The following NEW packages will be INSTALLED:

    pyvisa: 1.8-py35_0 conda-forge

Proceed ([y]/n)? y

Fetching packages ...
pyvisa-1.8-py3 100% |###############################| Time: 0:00:00 579.48 kB/s
Extracting packages ...
[      COMPLETE      ]|##################################################| 100%
Linking packages ...
[      COMPLETE      ]|##################################################| 100%

(SCTA) C:\Users\labuser\Documents>conda list
# packages in environment at C:\Users\labuser\Anaconda3\envs\SCTA:
#
pip                       9.0.1                    py35_0
python                    3.5.2                         0
pyvisa                    1.8                      py35_0    conda-forge
setuptools                27.2.0                   py35_1
vs2015_runtime            14.0.25123                    0
wheel                     0.29.0                   py35_0

(SCTA) C:\Users\labuser\Documents>
```

Repeat the procedure for `paramiko` and `scipy` packages.

Note: You can follow a similar process to install `pyvisa`, `paramiko`, and `scipy` into a Python virtualenv using `pip install` commands.

1.4.5 Adding SCTA to your PYTHONPATH Environment Variable

If you want `import SCTA` to work in your Python scripts out-of-the-box, you will need to modify your PYTHONPATH environment variable. This is because Python searches the PYTHONPATH for any libraries you import.

One way to do this is to configure Anaconda to modify PYTHONPATH for you every time you `activate SCTA`. To do this, you need to add special batch files to your Anaconda installation directories. The batch files `env_vars` can be found under `SCTA_repo\install\Anaconda3\etc\conda\activate.d\` and `SCTA_repo\install\Anaconda3\etc\conda\deactivate.d\`.

Follow this guide to place these batch files in the appropriate Anaconda installation directories, and modify the `SCTA_repo\install\Anaconda3\etc\conda\activate.d\env_vars` batch file to add the correct path to `SCTA_repo\src` on your own machine.

Hint: For me, the location of my Anaconda environment was `C:\Users\labuser\Anaconda3\envs\SCTA`. It may not be the same for you.

CHAPTER 2

Getting Started

Prerequisites Basic knowledge of how to run python scripts through commandline

I recommend running the interactive Jupyter Notebook tutorials:

```
cd SCTA_repo\src\tutorials
jupyter notebook
```

Note: You need to install `jupyter` in your SCTA environment to run the interactive tutorials.

If you are new to scripting in Python, walk through the `Python-Basics.ipynb` to get a quick intro to concepts important for using the SCTA libraries.

Walk through the `SCTA-Basics.ipynb` to help you start writing a simple automation script.

If you do not have `jupyter` installed or do not want an interactive tutorial, there are equivalent tutorials as python scripts in `SCTA_repo\src\tutorials\`. The `Python-Basics.py` script introduces Python programming and `SCTA-Basics.py` script introduces the SCTA libraries. You can run the scripts to see the output:

```
cd SCTA_repo\src\tutorials
python SCTA-Basics.py
```

After walking through the tutorials, browse `SCTA_repo\src\examples\` for real examples of automation scripts. You can use these as templates for your own scripts. For example, check out `NetAnDemo.py` for a common frequency sweep test.

CHAPTER 3

User's Guide to SCTA

Prerequisites People reading this document should have an understanding of basic Python objects:

- lists
- dictionaries
- classes

Contents

3.1 Summary

The Space & Communications Test Automation (SCTA) libraries form a **general purpose** satellite test API. It can be used for any kind of Communications Lab/ ODU **testing**, **monitoring** and **evaluation**.

Our goal is to build **reusable**, **modular** code that makes any kind of testing or monitoring **easy to do** in code that satellite communications engineers can *understand*.

3.1.1 Simple test script

Imagine you want to measure the signal-to-noise ratio (SNR) of a satellite transponder generated by a Rhode & Schwarz RF modulator (BTC) across all operating frequencies of a coaxial cable (L-band). Perhaps your lab setup might look like this.

Here is an example of an automation script that is very easy to read, understand, and **modify** for your own custom tests.

```
# Initialize equipment and output file
mod = BTC()
dut = VTR()
csv = DataLogger("measurements.csv")

```

(continues on next page)

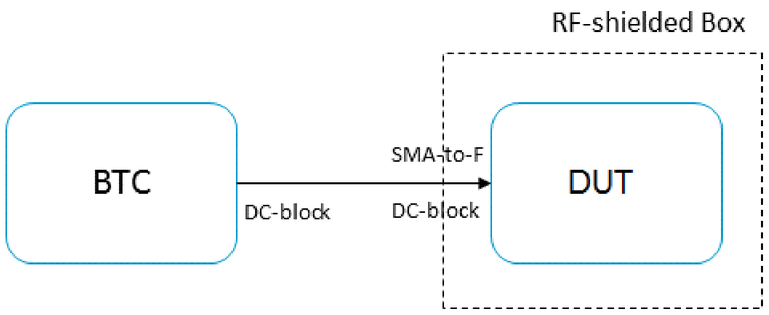


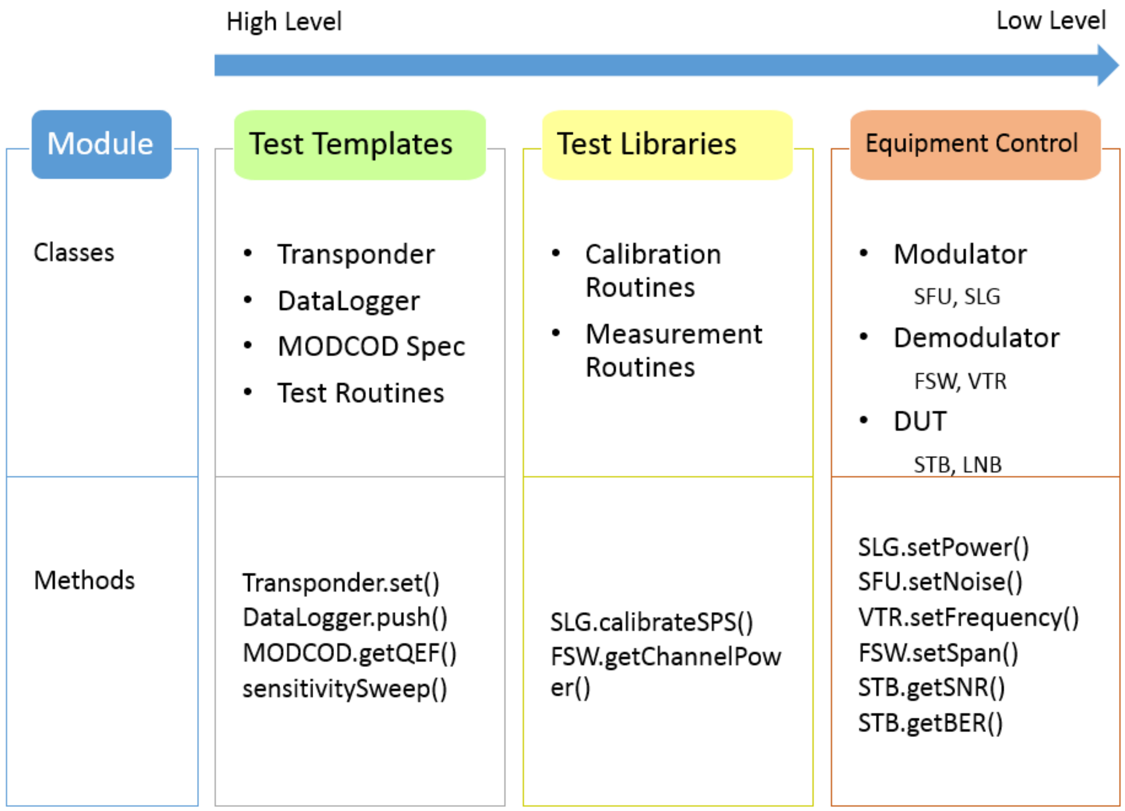
Fig. 1: Block diagram of a SNR measurement setup. The DUT is tuned to a noisy transponder generated by the BTC. The SNR is measured across L-band frequencies.

(continued from previous page)

```
# Test DUT on a DVB-S2 MODCOD 13 transponder, i.e. 8PSK 2/3
txpdr = Transponder(mode=13)
mod.setTransponder(txpdr)
dut.setTransponder(txpdr)

# Test performance across L-band frequencies, i.e. 250 - 2150 MHz
Lband = list(range(250e6, 2150e6, 10e6))

# Take SNR measurement at each frequency
for freq in Lband:
    mod.setFrequency(freq)
    dut.setFrequency(freq)
    snr = dut.getSNR()
    csv.push(snr)
```

3.1.2 Software architecture

This is a basic breakdown of the software modules. At the highest level, the user will interact with test templates that automate common calibration and measurement routines. The user can specify what to log and where to save it. At the lowest level are the equipment specific functions to control the most common test instruments.



3.2 Specification Libraries

Warning: This must be updated regularly! Always read through these libraries before writing any test script. Make sure they contain the most updated specifications relevant to your test.

The Specification Libraries contain all the up-to-date specifications and pass/fail criteria. This includes the *MODCOD Specification Table* , *Scrambling Code Table* , and *ODU Specification Table* . All test procedures use these libraries to determine the correct test conditions and evaluation, so it is **imperative** that all updates to the DVB-S2 Specification are reflected here.

More importantly, the Specification Libraries provide one simple interface to reconfigure all existing automation scripts for your own test spec. Adapting these libraries is as simple as modifying or adding a CSV file. Feel free to modify or add specifications that are relevant to your own tests.

3.2.1 MODCOD Specification Table

The MODCOD Specification Table stores the C/N Threshold for Quasi-Error Free (QEF) performance for each MODCOD specified in the DVB-S2 Specification (EN 302 307-1). It is implemented as a `dictionary` of MODCOD Spec Entries addressed by mode number. These values are extracted from the `raw/DVBS2_Spec.csv` file, and thus the values can be easily modified by making changes to this file.

All values are sourced from EN 302 307-1 V1.4.1 Table 12 (p.32) and Table 13 (p.36). Also see the DVB-S2 Implementation Guidelines (ETSI TR 102 376) for typical transponder settings.

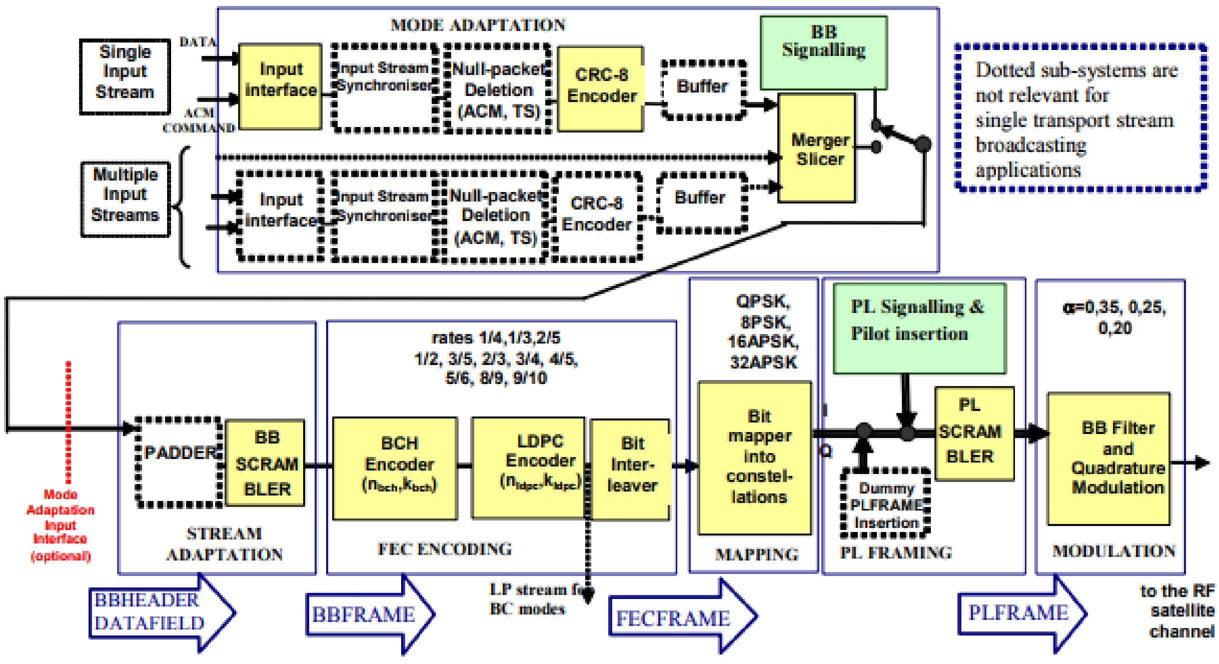

MODE ADAPTATION
Single Input Stream
DATA
ACM COMMAND
Input interface
Input Stream Synchroniser
Null-packet Deletion (ACM, TS)
CRC-8 Encoder
Buffer
BB Signalling
Merger Slicer
Dotted sub-systems are not relevant for single transport stream broadcasting applications
Multiple Input Streams
Input interface
Input Stream Synchroniser
Null-packet Deletion (ACM, TS)
CRC-8 Encoder
Buffer
Mode Adaptation Input Interface (optional)
PADDER
BB SCRAM BLER
STREAM ADAPTATION
rates 1/4,1/3,2/5 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, 9/10
BCH Encoder (n_{bch},k_{bch})
LDPC Encoder (n_{ldpc},k_{ldpc})
Bit Inter-leaver
FEC ENCODING
QPSK, 8PSK, 16APSK, 32APSK
Bit mapper into constel-lations
MAPPING
PL Signalling & Pilot insertion
I
Q
PL SCRAM BLER
Dummy PLFRAME Insertion
PL FRAMING
α=0,35, 0,25, 0,20
BB Filter and Quadrature Modulation
MODULATION
BBHEADER DATAFIELD
BBFRAME
LP stream for BC modes
FECFRAME
PLFRAME
to the RF satellite channel

Figure 1: Functional block diagram of the DVB-S2 System

Fig. 2: DVB-S2 modulation and coding system block diagram. Physical Layer Scrambling is performed before modulation for efficient energy dispersal.

Note: This table is used in the *Mode Class* to initialize MODCOD Mode instances.

Attributes

- Mode number
- Broadcast Standard
- Modulation
- Code Rate
- QEF Point
- SNR threshold

Code Example

This is how to access information about MODCOD Mode 1.

```
>>> MODCOD_Spec.getBroadcastStandard(1)
'DVB-S2'
>>> MODCOD_Spec.getConstellation(1)
'QPSK'
>>> MODCOD_Spec.getCodeRate(1)
```

(continues on next page)

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```
'1/4'
>>> MODCOD_Spec.getCNRThresh(1)
-2.35
>>> MODCOD_Spec.getQEFpoint(1)
1e-7
```

3.2.2 Scrambling Code Table

The Scrambling Code Table is a `dictionary` of Physical Layer (PL) Header Scrambling Sequences, Sequence IDs, and Gold Codes specified in the DVB-S2 Specification. There are 262,142 entries addressed by sequence ID.

All values are sourced from EN 302 307-1 V1.4.1 Section 5.5.4 Physical Layer Scrambling (p.34). Also see this ETRI Journal article for an algorithm for scrambling code estimation.

Attributes

- Sequence ID (decimal)
- PL Header Scrambling Sequence (octal)
- Gold Code index (decimal)
- Gold Code seed (hex)
- Concatenated Header + Gold Code (hex)

Code Example

Here is how to access information about Scrambling Code 0.

```
>>> Scrambling_Spec.getPLHeader(0)
'000000000000000000000000000000'
>>> Scrambling_Spec.getGoldCode(0)['index']
'0'
>>> Scrambling_Spec.getGoldCode(0)['seed']
'0x00001'
>>> Scrambling_Spec.getConcatenated(0)
'0x000000000000000000000000001'
```

3.2.3 ODU Specification Table

Warning: unimplemented

3.3 Transponders

What is a **Transponder**? Wikipedia says, “it is a *device* that gathers signals over a range of uplink frequencies and re-transmits them on a different set of downlink frequencies.”

However, in the SCTA Libraries, a Transponder is certainly *not a device*, or even a class that represents a device. It is an **interface between the RF modulated signal and the lab equipment**. It is a class that stores only the signal characteristics necessary for the equipment to generate, frequency translate, tune, and measure the signal.

There are many important signal characteristics to define, so the *Transponder Class* is broken down into sublasses: the *Mode Class* and *Local Oscillator Class*. There are also convenient ways to group together similar transponders using *Transponder Sets*.

Hint: For a quick example of creating a Transponder, jump to the *Transponder Constructor* method.

3.3.1 Mode Class

The Mode class stores the parameters associated with a mode in the MODCOD Specification. The *MODCOD Specification Table* uses Modes to define the 32 DVB-S2 operational mode configurations and their corresponding SNR and PWR thresholds required to close the satellite link. The *Transponder Class* defines transponders using modes, including, but not limited to, the ones defined in the MODCOD Spec.

Hint: You can easily create a custom mode or a predefined mode from the MODCOD Spec. See the *Mode Constructor* method for an example.

Attributes

- Broadcast Standard
- Modulation
- Code Rate

Methods

Contructor Description: A mode object can be initialized 2 different ways. One way is to individually specify broadcast standard, modulation, and code rate. The other way is to specify the MODCOD mode index as an integer in $\{1, 2, \ldots, 24\}$.

Inputs: all attributes

Outputs: instance of the Mode class

```
# Option 1
mode1 = Mode(bcstd="DTV", mod="QPSK", fec="1/2")

# Option 2
mode1 = Mode.fromMODCOD(1)

# Both definitions are equivalent
```

Class definition

```
class Mode(object):

    def __init__(self, bcstd='DTV', mod='QPSK', fec='1/2'):
        """Constructor.

        Default values create a MODCOD Mode 1

        ~~~~~ Possibilities ~~~~~
        bcstd:        "DTV", "DVB-S", "DVB-S2"
        mod: "QPSK", "8PSK"
        fec: "1/2", "3/5", "2/3", "3/4", "4/5",
             "5/6", "6/7", "7/8", "8/9", "9/10"

        """
        self.bcstd = bcstd           # BroadCast STandarD
        self.mod = mod               # Modulation
        self.fec = fec               # FEC Rate

    @classmethod
    def fromMODCOD(cls, index):
        bcstd = MODCOD_spec[index]["bcstd"]
        mod = MODCOD_spec[index]["mod"]
        fec = MODCOD_spec[index]["fec"]
        return cls(bcstd, mod, fec)
```

3.3.2 Local Oscillator Class

In a satellite broadcast system, a transponder goes through many frequency translations in its lifetime. The 3 main stages are upconversion at the broadcast center, translation at the satellite, and downconversion at the LNB. Each stage has its own local oscillator (LO) frequency. Furthermore, these LO frequencies are different depending on band: Ku, Ka, etc. The Local Oscillator Class stores this metadata for each transponder and provides convenient methods for calculating the transponder's uplink and downlink frequencies.

Attributes

- Band
- Upconverter LO frequency
- Satellite LO frequency
- Downconverter LO frequency

Methods

getDownconversion(inputFreq) Description: Calculates the down-converted frequency based on the input frequency and LO frequency.

Inputs: input frequency [MHz] (float)

Outputs: down-converted frequency [MHz] (float)

getUpconversion(inputFreq) Description: Calculates the up-converted frequency based on the input frequency and LO frequency.

Inputs: input frequency [MHz] (float)

Outputs: up-converted frequency [MHz] (float)

Class Definition

```
class LocalOsc(object):

    def __init__(self, id='LO', freq=0):
        """Constructor.

        ~~~~~ Possibilities ~~~~~
        id:  string
        freq:        positive (float) [MHz]

        """
        self.id = id          # identifier string
        self.freq = freq      # LO freq
```

3.3.3 Transponder Class

The Transponder class is defined by a mode, a local oscillator, and all the downlink signal parameters associated with a transponder.

Note: All of the *Equipment Classes* use transponders to generate lab signals and tune demodulators.

Hint: There is a useful predefined list of all DVB-S2 transponders, which you can pick and choose from using *Transponder Sets*.

Attributes

- ID
- Mode
- Frequency
- Symbol Rate
- Roll-off
- Scrambling ID
- Pilot Symbols
- Antenna Polarization
- Local Oscillator

Methods

Constructor Description: The transponder must be initialized with all of the above attributes. The mode can be either an integer Mode number or an instance of the *Mode Class*.

Inputs: all attributes

Outputs: instance of the Transponder class

```
# Create MODCOD Mode 1
mode1 = Mode.fromMODCOD(1)

# Input downlink parameters
txpdr1 = Transponder(id="anything-you-want", mode=mode1, freq=974e6,␣
↪symb=20e6, roll=20, scramb=0, pilot=True)

# Equivalent transponder
txpdr1 = Transponder(id="anything-you-want", mode=1, freq=974e6,␣
↪symb=20e6, roll=20, scramb=0, pilot=True)
```

Class definition

```
class Transponder(object):

    def __init__(self, id='txp', mode=1, freq=1074e6, symb=20e6, roll=20,␣
↪scramb=0, pilot=True, pol=None, LO=None):
        """Constructor.

        Default values Create a MODCOD Mode 1 Transponder @ 1074 MHz

        ~~~~~ Possibilities ~~~~~
        mode:         integer Mode number or Mode class instance
        freq:         float in Hz
        symb:         float in Baud
        roll:         [0, 100] %
        scramb:       [0, 2^18-1]
        pilot:        False, True (off, on)
        pol: "LHCP", "RHCP", "horizontal", "vertical"

        """
        self.id = id # human-readable identifier
        self.mode = mode      # Mode class instance
        self.freq = freq      # Center frequency
        self.symb = symb      # Symbol rate
        self.roll = roll      # roll-off
        self.scramb = scramb # Scrambling code
        self.pilot = pilot    # Pilot symbols
        self.pol = pol        # Antenna polarization
        self.LO = LO # Local Oscillator class instance
```

3.3.4 Transponder Sets

Sometimes you might want to group together several transponders that are related. Some predefined groups of transponders are subdivided by:

1. Orbital Slot

2. Satellite
3. Bands
4. Market (CONUS/ spot)
5. HD/ SD

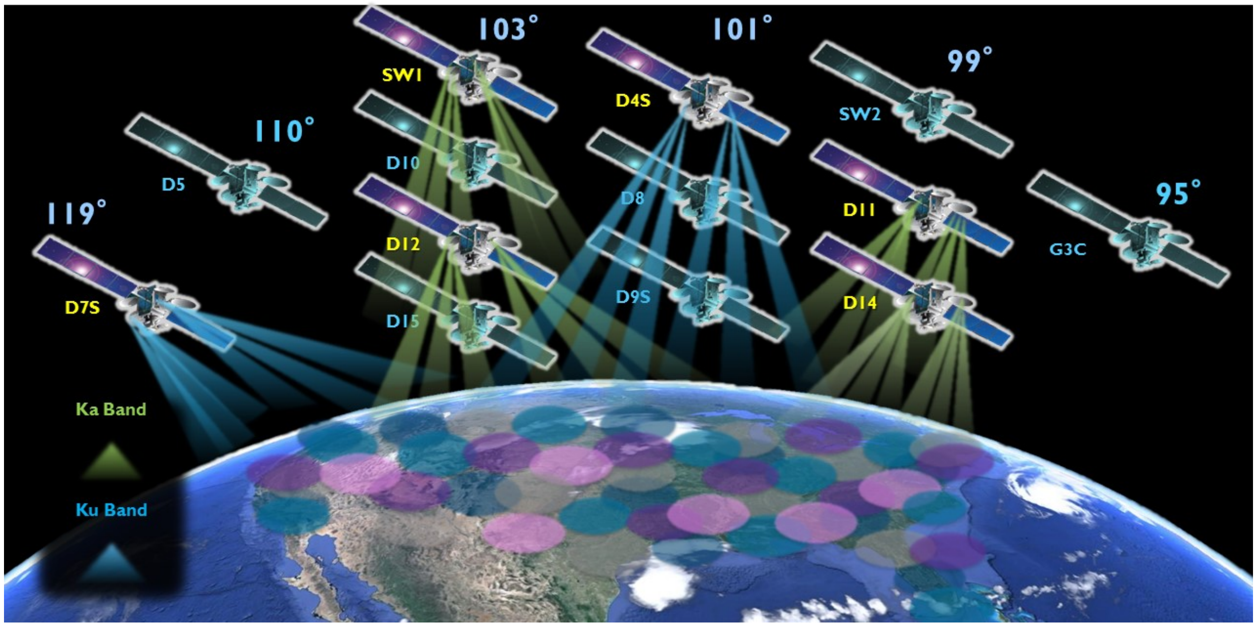

Fig. 3: Cartoon of satellite spot beams in Ku and Ka Bands. We can easily group transponders based on orbital slot, bands, market, etc.

For example, suppose we are given a group of all transponders from one satellite and a group of all spot-beam transponders across all satellites. Suppose we want *only* the spot-beam transponders from that one satellite. What we want is the *intersection* of these two groups. To accomplish this, we use python `sets`.

set In Python, a set is an unordered collection with no duplicate elements.

Hint: For example, say we have a list of transponders, and some of them are identical in mode and downlink parameters. If we create a `set` from this list, all the duplicate transponders would be filtered out, and the list's original order is not guaranteed.

set operations Python supports set operations like union, intersection, difference, and exclusive or.

For example, we might want to test only the LHCP transponders from satellites in Orbital Slot 101W. We could make a custom set of all LHCP transponders and intersect that with the predefined set of 101W transponders. The possibilities are endless.

Here is the corresponding pseudocode:

```
# Create 3 hypothetical transponders
txpdr1 = Transponder(id='101W-txpdr1', mode=1, freq=250e6, pol="RHCP")
txpdr2 = Transponder(id='101W-txpdr2', mode=1, freq=950e6, pol="LHCP")
txpdr3 = Transponder(id='99W-txpdr5', mode=1, freq=2150e6, pol="LHCP")
```

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```
# Group the transponders into hypothetical sets
slot101 = set([txpdr1, txpdr2])
lhcp = set([txpdr2, txpdr3])

# I want all slot 101 W, LHCP transponders
intersect = slot101 & lhcp
```

3.4 Equipment Classes

3.4.1 Comm Class

The comm class will obtain the protocol to communicate with the instruments (GPIB, IP, serial) and will also pass the resource manager which will be common to all instruments.

Additional methods will be needed to write and read using this class.

```
class Comm(object)

        def __init__(self, protocol, port, config={}, rm)
                """Constructor.

                ~~~ Valid ranges ~~~
                protocol: GPIB, serial, IP
                port: String of port of IP address

                """
                self.protocol=protocol
                self.port=port

                if protocol=GPIB then
                        port=GPIB::'+port+"::'INSTR'
                if protocol = IP then
                        port="TCPIP0::"+port+"::INSTR"

                self.instrument=rm.open_resource(port, kwargs=config)
```

Usage

```
comm = Comm_Class("IP","192.0.0.0")
mod1 = Modulator(comm)
mod2 = Modulator(comm)
mod_list = [mod1, mod2]
btc = BTC(mod_list)
```

3.4.2 Modulator Class

```
class Modulator(Transponder):

    def __init__(self, id="mod"):
        """Constructor.
```

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```
        ~~~ Valid ranges ~~~
        ip:             IP address
        power:          [-80, -10] dBm
        freq:           [250, 2150] MHz
        symrate:        [20, 45] MBaud
        pilots:         True, False

        """
        super(Modulator, self).__init__( id=id)
        self.power = -30
```

SFU Class

Warning: We have found that different SFUs use different commands for Broadcast Standard and Code Rate related functions. We have determined this to be caused by two different firmware versions: **fill in here** and have implemented a solution that works for both. We try our best to fix the bugs we find, but there may be more. If an SFU script is buggy, please contact us. If you are a developer, use the `VISA Interactive Control` to verify that the commands the script sends actually changes the settings correctly.

```
class SFU(Modulator):

    def __init__(self, id="SFU", type="GPIB", port="28", config={}):
        """Constructor.


        ~~~ Valid ranges ~~~
        type:           [GPIB, IP]
        port:           [28 or 192.10.10.10]
        cnr:            [0, 20] dB


        """
        super (SFU, self).__init__(id=id)
        self.comm = Comm(protocol=type, port=port, config=config)
        self.cnr=None
```

setTransponder(self, transponder) Description: This will set all the parameters of the transponder to the SFU.

inputs: Transponder attributes

outputs: none

setBroadcastStandard(self, bcstd) Description: Sets the desired broadcast standard

Inputs: (bcstd): DVB-S2, DVBS

Outupts: None

getBroadcastStandard(self): Description: Queries the current broacast standard set on the SFU.

Inputs: none

ouputs: Returns the broadcast standard as: DVB-S2, DVBS

setPower(self, double) Description: This function will set the SFU power level or it can also be set to the power level inherited.

inputs: power[double]: power level value in dB.

outputs: (none)

getPower(self) Description: This function will obtain the current power levelon the SFU.

inputs: (none)

outputs: SFU power

setFrequency(self, double) Description: This functions will set the SFU frequency in Hz.

inputs: freq(double): Frequency in Hz.

outputs: (none)

getFrequency(self) Description: This function will obtain the current frequency from the SFU.

inputs: (none)

outputs: (freq in Hz)

setAlpha(self, double) Description: This function will set the SFU symbol rate in S/s.

inputs: symrate(double): Symbol Rate in kS/s.

outputs: (none)

getAlpha(self) Description: This function will obtain the current symbol rate from the SFU.

inputs: (none) outputs: (symbol Rate in S/s)

setNoiseLevel(self, double) Description: This function will set the CNR level on the SFU, once set, the SFU automatically adjusts its noise level to obtained the input CNR desired.

Inputs: noiseLeveldB[double]: value of CNR level in dB. Range 0 - 20 dB.

Ouput: (none)

getNoiseLevel(self) Description: Queries the current noise level set on the SFU.

Inputs: none

outputs: returns the noise level in dB.

enableNoise(self, boolean) Description: This function will enable or disable noise output.

Inputs: Boolean

Outputs: none

Test code:

```
>>> import SFU from Equipment_Lib
>>> sfu = SFU(ip=10.23.121.1)
>>> sfu.setNoise(20)
(0/2) setNoise: method called
(1/2) setNoise: turned on bandwidth coupling
(2/2) setNoise: set CNR level
```

getNoise(self) Description: This function will get the current CNR level on the SFU

Inputs: (none)

Ouput: returns SFU SNR level (double)

setPilots(self, boolean) Description: Sets the Pilots on when True, pilots off when false. inputs: (boolean)

outputs: (none)

getPilots(self) Description: Queries the pilots status

inputs: none

outputs: (boolean) ON:true; OFF;false

setCW(self, boolean) Description: Enables, disables CW, based on boolean:

inputs: (boolean) True: Modulation off, False, Modulation ON

outputs: None

getCW(self) Description: Queries instrument whether CW is enabled or disabled

inputs none

outputs: True; CW enabled, False; CW disabled

setAlpha(self, alpha) Description: Sets roll off for the modulated signal.

inputs: (int) roll off 20, 30, 35

outputs: none

setPhaseNoise(self, boolean) Description: Sets Phase noise for Phase Noise Shape 1, magnitude 13

inputs (boolean): Enables or disables phase noise

outputs: none

getPhaseNoise(self) Description: Determines if Phase Noise is enabled or disabled:

inputs None

outputs:

setModulation(self, modulation) Description: Sets the Modulation type on the SFU for the desired tranponder

inputs DVB-S2, DVBS

outputs: none

getModulation(self) Description: Obtains the current modulation set on the SFU.

inputs: none

outputs: current modulation set on SFU.

setCodeRate(self, coderate) Description: Sets the desired code rate on the SFU

inputs: code rate, 2/3, 3/5, 6/7, 1/2, etc..

outputs: none

setScramblingCode(self, scramb) Description: Sets the scrambling code on the SFU.

input: (int): scrambling code ID

output: none

getScramblingCode(self) Description: Gets the scrambling code ID from the SFU.

inputs none

outputs: Scrambling code ID

BTC Class

```
class BTC(object):

    def __init__(self, id="BTC", type=GPIB, port=port, numMods=2):
        """Constructor.


        ~~~ Valid ranges ~~~
        cnr:            [0, 20] dB
        pilots:         True, False

        """
        self.modulator_list = []
        self.id=id
        self.cnr = 20
        for i in range(numMods):
                        mod=Modulator(id=id+"-output-"+str(i+1)
                        self.modulator_list.append(mod)
```

getCodeRate(self) Description: Sets the FEC code rate on the SFU.

Inputs: code rate 1/2, 2/3, 6/7, etc…

outputs: none

setPower(self, pwr, modNumber) Description: This function will set the BTC power level on the corresponding output. inputs: pwr (double): power level value in dB. modNumber (int): corresponding output port outputs: (none)

getPower(self, modNumber) Description: This function will obtain the current power level on the BTC from the output indicated.

inputs: modNumber (int)- corresponding output port

outputs: BTC power from specified port

setFrequency(self, freq, modNumber) Description: This functions will set the BTC frequency in Hz in the appropriate output port.

inputs: freq (double): Frequency in Hz. modNumber (int): specified output port

outputs: (none)

getFrequency(self, modNumber) Description: This function will obtain the current frequency from the BTC.

inputs: modNumber (int): specified output port

outputs: frequency in Hz

setAlpha(self, symb, modNumber) Description: This function will set the BTC symbol rate in MS/s.

inputs: symb(double): Symbol Rate in MS/s. modNumber (int): specified output port

outputs: (none)

getAlpha(self, modNumber) Description: This function will obtain the current symbol rate from the BTC on the specified port.

inputs: modNumber (int): specified output port

outputs: symbol Rate in MS/s from the specified port

setNoise(self, cnr, modNumber) Description: This function will set the CNR level on the BTC, once set, the BTC automatically adjusts its noise level to obtained the input CNR desired. Note: this need to set the bandwidth coupling ON to obtain an accurate measurement.

Inputs: cnr (double): value of CNR level in dB. Range 0 - 25 dB. modNumber (int): specified output port

Ouput: (none)

Test code:

```
>>> import BTC from Equipment_Lib
>>> btc = BTC(ip=10.23.121.1)
>>> btc.setNoise(20)
(0/2) setNoise: method called
(1/2) setNoise: turned on bandwidth coupling
(2/2) setNoise: set CNR level
```

getNoise(self, modNumber) Description: This function will get the current CNR level on the BTC

Inputs: modNumber (int): specifies output port to get noise from.

Ouput: returns BTC SNR level (double)

setPilots(self, boolean, modNumber) Description: Sets the Pilots on when True, pilots off when false.

inputs: (boolean): True; pilots ON, False; Pilots OFF modNumber (int):specifies output port to set pilots status.

outputs: (none)

getPilots(self, modNumber) Description: Queries the pilots status from the specified port.

inputs: modNumber (int): specifies output port to get pilots status.

outputs: (boolean) ON:true; OFF;false

SLG Class

```
class SLG(object):
        def __init__(self, id="SLG", type="IP", port=port, numMods=32)
                """Constructor.

                ~~~ Valid ranges ~~~



                """
                self.modulator_list = []
                self.id=id
                for i in range(numMods):
                        mod=Modulator(id=id+"-output-"+str(i+1)
                        self.modulator_list.append(mod)
```

loadScenario(self, Scen) Description: Loads the scenario specified

inputs: Scen[string]: Scenario name which needs to be available in the SLG

outputs: (none)

setPower(self, power, modNumber) Description: Description: This function will set the SFU power level. inputs: power[double]: power level value in dB.

outputs: (none)

getPower(self, modNumber) Description: This function will obtain the current power levelon the SFU.

inputs: (none)

outputs: SFU power

setFrequency(self, freq, modNumber) Description: This functions will set the SFU frequency in Hz.

inputs: freq(double): Frequency in Hz modNumber (int): specific output port

outputs: (none)

getFrequency(self, modNumber) Description: This function will obtain the current frequency from the SFU.

inputs: modNumber (int): specific output port

outputs: (freq in Hz)

setAlpha(self, symb, modNumber) Description: This function will set the SFU symbol rate in MS/s.

inputs: symb (double): Symbol Rate in MS/s. modNumber (int): specific output port

outputs: (none)

getAlpha(self, modNumber) Description: This function will obtain the current symbol rate from the SFU.

inputs: modNumber(int): specific output port

outputs: (symbol Rate in S/s)

setPilots(self, boolean, modNumber) Description: Sets the Pilots on when True, pilots off when false. inputs: (boolean) modNumber (int): specific output port

outputs: (none)

getPilots(self, modNumber) Description: Queries the pilots status

inputs: modNumber (int): specific output port

outputs: (boolean) ON:true; OFF;false

setAlpha(self, roll, modNumber): Description: Sets the roll-off value on the specified SLG modulator

inputs: roll: roll-off value as integer modNumber: SLG modulator number to set

outputs: none

getAlpha(self, modNumber): Description: Obtains thed current modulator roll-off/Alpha value:

Inputs: modNumber: SLG modulator number to query roll-off value set

outputs: returns roll off value on specified modulator output

setScramblingCode(self, scramb, modNumber) Description: Sets the scrambling code on the device.

inputs: scramb (int): Scrambing code number to set modNumber (int): specific output port

outputs: (none)

getScramblingCode(self, modNumber) Description: Queries the current scrambling code set on device on the indicated output modulator

inputs: modNumber (int): specific output port

outputs (int) returns the current scrambling code

setModulatorState(self, boolean, modNumber) Description: Enables or disables the desired modulator output

inputs: (boolean): True; enable output. False; disable output (modNumber): which modulator to turn on/off on the current SLG.

outputs: none

getModulatorState(self, modNumber) Description: Queries modulator status on SLG.

inputs: (modNumber) Modulator output to check

outputs: (boolean): True; modulator is on. False; modulator is off.

selectBand(self, band): Description: Selects band range based on the following

3.4.3 Demodulator Class

```
class Demodulator(Transponder):

    def __init__(self, id):
        """Constructor.

        ~~~ Valid ranges ~~~
        id: string

        """
        super(Demodulator, self).__init__(id=id)
```

FSW Class

```
class FSW(Demodulator)

        def __init__(self, id, protocol, port, config)
                """Constructor.

                ~~~ Valid Ranges ~~~
                protocol: GPIB, ethernet, serial
                freq: [20, 26.5] GHz

                """
                super (FSW, self).__init__(id=id)
                self.comm = Comm(protocol=type, port=port, config=config)
```

config(self, Transponder) Description: Configures the FSW to measure either Channel Power or MER and power using the Transponder objects.

Inputs: (Transponder): Uses the tranponder objects to configure the FSW

Outputs: none

getAllMeasurements(self) Description: Obtains all measurements from the VSA window.

inputs: (none)

outputs Returns MER, power, phase error, carrier frequency error from VSA.

getSpectrumChannelPower(self, freq, symrate) Description: Measures channel power and returns measurement inputs: (double) frequency (double) symrate

outputs: (double) channel power measurement

```
FSW.getchpwr(Demodulator)

        setfreq(freq)
        bw=symrate*1.2
        setsymrate(bw)

        #set RBW and VBW
        #set sweep time
        #getmeasurement

        return chpwr
```

setFrequency(self, freq) Description: Sets the input frequency in Hz

inputs: (double) frequency

outputs: (none)

getFrequency(self, freq) Description: obtains the frequency setting for the specified tuner.

inputs: (int): Tuner index

outputs: (double): frequency setting on current tuner

setBroadcastStandard(self) Description: Obtains the modulation and code rate for the tuner indicated.

inputs: (int): TunerIndex

outputs: (string): tuner modulcation and code rate

setAlpha(self, double) Description: This function will set the VTR symbol rate in MS/s.

inputs: (double): Symbol Rate in MS/s.

outputs: (none)

getAlpha(self) Description: This function will obtain the current symbol rate from the VTR.

inputs: (none) outputs: (symbol Rate in MS/s)

VTR Class

```
class VTR(Demodulator):

    def __init__(self, comm, power, freq, symrate, pilots):
        """Constructor.

        ~~~ Valid ranges ~~~
        comm:        GPIB, ethernet, serial...
        numTuners: number of tuners available
        power:       [-80, -10] dBm
        freq:        [250, 2150] MHz
        symrate:     [20, 45] MBaud
        pilots:      True, False

        """
```

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```
        super (VTR, self).__init__(id=id)
        self.comm = Comm(protocol=type, port=port, config=config)
```

setFrequency(freq, TunerIndex) Description: Sets the input frequency

inputs: (double) frequency (int): Tuner index

outputs: (none)

getFrequency(TunerIndex) Description: obtains the frequency setting for the specified tuner.

inputs: (int): Tuner index

outputs: (double): frequency setting on current tuner

setPower(pwr, TunerIndex) Description: Sets the power level on the appropriate tuner.

inputs: (double): frequency (int): tuner

getPower(TunerIndex) Description: Obtains the power level for the appropriate tuner.

inputs: (int): tuner number

getMode(TunerIndex) Description: Obtains the modulation and code rate for the tuner indicated.

inputs: (int): TunerIndex

outputs: (string): tuner modulcation and code rate

setAlpha(double) Description: This function will set the VTR symbol rate in MS/s.

inputs: (double): Symbol Rate in MS/s.

outputs: (none)

getAlpha() Description: This function will obtain the current symbol rate from the VTR.

inputs: (none) outputs: (symbol Rate in MS/s)

setPilots(boolean) Description: Sets the Pilots on when True, pilots off when false. inputs: (boolean)

outputs: (none)

getPilots() Description: Queries the pilots status

inputs: none

outputs: (boolean) ON:true; OFF;false

setScramblingCode(int, TunerIndex) Description: Sets the scrambling code on the device on the desired tuner.

inputs: (int): Scrambing code number to set

outputs: (none)

getScramblingCode(TunerIndex) Description: Queries the current scrambling code set on device.

inputs: (none)

outputs (int) returns the current scrambling code

DM240XR Class

Warning: This class is not being updated right now!!!

```
class DM240(Modulator):

    def __init__(self, ip, power):
        """Constructor.

        ~~~ Valid ranges ~~~
        ip:             IP address
        power:          [-80, -10] dBm
        freq:           [250, 2150] MHz
        symrate:        [20, 45] MBaud
        pilots:         True, False

        """
        Modulator.__init__(self, ip, power, freq, symb, pilots)
        self.power=power
```

setPower(power) Description: This function will set the DM240 power level. inputs: power[double]: power level value in dB. [0dBm to -20 dBm]

outputs: (none)

getPower() Description: This function will obtain the current power level on the DM240.

inputs: (none)

outputs: DM240 power

setFrequency(double) Description: This functions will set the DM240 frequency in Hz.

inputs: freq(double): Frequency in Hz. [950e6 Hz to 2050e6 Hz]

outputs: (none)

getFrequency() Description: This function will obtain the current frequency from the DM240.

inputs: (none)

outputs: (freq in Hz)

setAlpha(double) Description: This function will set the DM240 symbol rate in S/s.

inputs: symrate(double): Symbol Rate in S/s.

outputs: (none)

getAlpha() Description: This function will obtain the current symbol rate from the DM240.

inputs: (none) outputs: (symbol Rate in MS/s)

setPilots(boolean) Description: Sets the Pilots on when True, pilots off when false. inputs: (boolean)

outputs: (none)

getPilots() Description: Queries the pilots status

inputs: none

outputs: (boolean) ON:true; OFF;false

setScramblingCode(int) Description: Sets the scrambling code on the device.

inputs: (int): Scrambing code number to set

outputs: (none)

getScramblingCode() Description: Queries the current scrambling code set on device.

inputs: (none)

outputs (int) returns the current scrambling code

3.5 Test Templates

3.5.1 Frequency Sweep Test Template

Imagine you want to measure the Power or SNR measurement accuracy of a satellite receiver compared to a vetted RF test instrument like the Rhode & Schwarz FSW. Perhaps your lab setup might look like this.

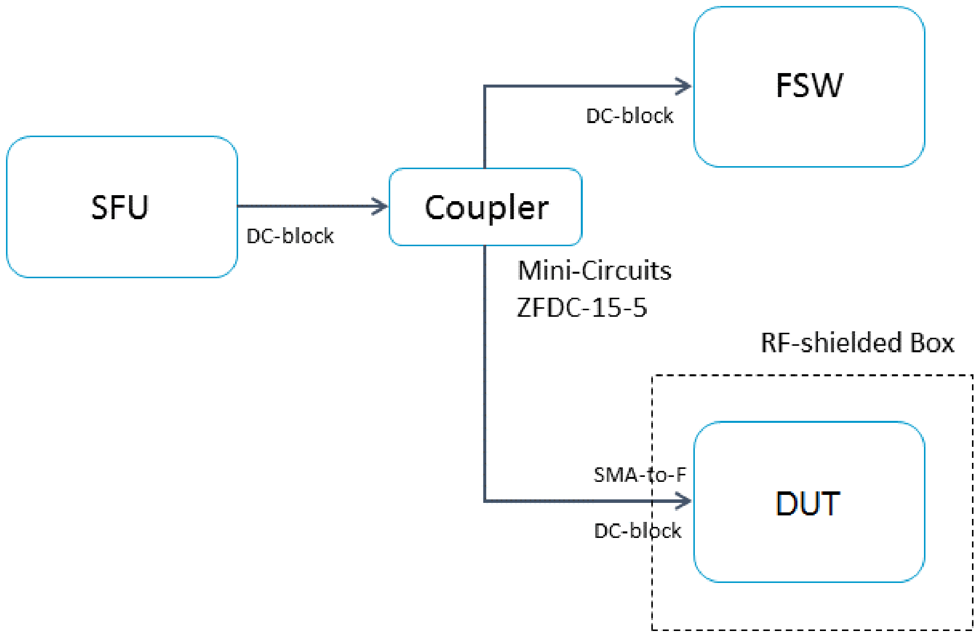

Fig. 4: Block diagram of a power accuracy test setup. Both the FSW and DUT are tuned to a transponder generated by the SFU. Since the input signal is split into different paths, the individual path losses to the FSW and the DUT should be properly accounted for in the data analysis.

This automation script will perform a frequency sweep and measure MER/CNR and power at both the FSW and the DUT. An analysis of the measurement data can be found in `SCTA_repo\src\examples\RF-Validation-Presentation.ipynb`.

```
from SCTA.Instrumentation import SFU, VTR, FSW
from SCTA.System import Transponder
from SCTA.DataLogging import DataLogger

# Initialize equipment
```

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```
sfu = SFU(type="IP", port="192.10.10.7")
fsw = FSW(type="IP", port="192.10.10.8")
dut = VTR(type="IP", port="192.10.10.9")

# Format output file
header=['Frequency (Hz)', 'VTR SNR (dB)', VTR Power (dBm)', 'FSW SNR (dB)',␣
↪FSW Power (dBm)']
csv = Log(filename="FrequencySweep", format="csv", csv_header=header)

# Test DUT on a DVB-S2 MODCOD 13 transponder, i.e. 8PSK 2/3
txp = Transponder(id="101-txp1", mode=13, freq=974e6, symb=20e6, roll=20,␣
↪scramb=0, pilots=False)
sfu.setTransponder(txp)
fsw.setTransponder(txp)
dut.setTransponder(txp)

# Test performance across L-band frequencies, i.e. 250 - 2150 MHz
     for freq in range(250e6, 2150e6, 10e6):
     sfu.setFrequency(freq)
     dut.setFrequency(freq)
     fsw.setFrequency(freq)

   # Take measurements and write them to the output file
   fsw_meas = fsw.getAllMeasurements()
   vtr_meas = vtr.getAllMeasurements()
   sample = [freq, vtr_meas['mer'], vtr_meas['power'], fsw_meas['mer'], fsw_
↪meas['power']]
   csv.push(sample)
```

3.5.2 BER Test Template

Imagine you want to test the frequency sensitivity of a satellite receiver to low power conditions near the specified QEF point. Perhaps your lab setup might look like this.

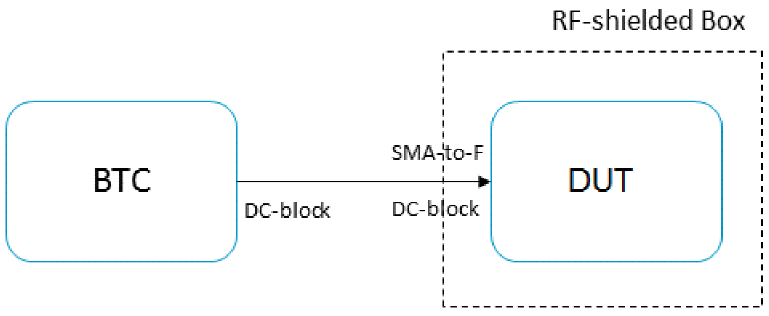


Fig. 5: Block diagram of a frequency sensitivity test setup. The DUT is tuned to a low-power transponder generated by the BTC. The DUT does not lock to the signal at first, so the BTC power is increased until the DUT locks and measures no bit errors. This QEF point is measured across frequency.

This automation will perform a frequency sweep and find the QEF point for the DUT. An analysis of the measurement data can be found in `SCTA_repo\src\examples\RF-Validation-Presentation.ipynb`.

```
from SCTA.Instrumentation import BTC, VTR
from SCTA.System import Transponder
from SCTA.DataLogging import DataLogger
from time import sleep

# Initialize equipment
btc = BTC(type="IP", port="192.10.10.7")
dut = VTR(type="IP", port="192.10.10.9")

# Format output file
header = ['Frequency (Hz)', 'BTC Power (dBm)', 'Bert Lock', 'Bit Error Rate']
csv = Log(filename="FrequencySweep", format="csv", csv_header=header)

# Test DUT on a DVB-S2 MODCOD 13 transponder, i.e. 8PSK 2/3
txp = Transponder(id="101-txp1", mode=13, freq=974e6, symb=20e6, roll=20,␣
↪scramb=0, pilots=False)
btc.setTransponder(txp)
dut.setTransponder(txp)

# Test performance across L-band frequencies, i.e. 250 - 2150 MHz
for freq in range(250e6, 2150e6, 10e6):
   btc.setFrequency(freq)
   dut.setFrequency(freq)

   # Reset power level on the BTC
   power = -85
   btc.setPower(power)

   # Run BERT for 5 seconds and check if the BERT is locked AND has no errors
   dut.restartBERT()
   sleep(5)
   dut_meas = dut.getMeasurements()

   # If not, then increase BTC input power by 0.1 dB
   while (dut_meas['Bert Total Bit Error'] != 0) or (dut_meas['Bert Lock'] !=␣
↪True):
      power = power + 0.1
      btc.setPower(power)
      dut.restartBERT()
      sleep(5)
      dut_meas = dut.getMeasurements()

   # Else, stop the test and log the BERT statistics
   sample = [freq, power, aim_meas['Bert Lock'], aim_meas['Bit Error Rate']]
   csv.push(sample)
```

3.6 Logging Measurements & Debug Messages

This page contains all you need to know about how to log measurements and debug messages in your scripts. It follows the life of a measurement from when you first take it using the equipment get methods to when you store it in your log file.

Note: Typically, logging debug messages is unnecessary unless you are developing low-level functions or need low-level information about equipment state.

Hint: For an example of typical measurement logging, jump to *Log Class*.

3.6.1 Measurement Object

The output of an equipment get measurement method should always be a Python `dictionary`. The measurement object stores the measurement value itself along with context about how the measurement was taken.

Attributes:

- Equipment ID
- Transponder tuning parameters
- Measurement ID, e.g. `snr`, `pwr`, etc.
- Measurement value

Here is an example measurement object:

```
{
    "timestamp": "2016-09-26T14:30:04",
    "equip_id": "fsw-1",
    "txpdr": {
        "id": "txpdr-1",
        "mode": {
            "bcstd": "DVB-S2",
            "mod": "8psk",
            "fec": "6/7"
        },
        "freq": 974,
        "symb": 20000,
        "roll": 20,
        "scramb": 1000,
        "pilot": "True",
        "pol": "None",
        "LO": "None"
    },
    "meas_id": "snr",
    "meas_val": 9.5
}
```

3.6.2 Log Class

The Log Class is an object used to configure what data to store and how to format the output.

Here is an example of typical configuration and use of the Log Class.

```
snr_log = Log(filename='FSW_SNR', format='csv')
measurement = fsw.getMeas()
snr_meas = measurement['snr']
snr_log.push(snr_meas)
```

Hint: Try creating a `Log` object specific to each equipment, and push measurements of that equipment to its individual `Log`. That way, you can save different equipment measurements to different files.

There are 2 possible formats for the output log file: CSV and JSON. If `csv` is selected, then a list of measurement values and time stamps are stored and written to separate column in a CSV file. If `json` is selected, then a list of *Measurement Object* s with time stamps are stored in the JSON file format.

Note: JSON stands for JavaScript Object Notation. It uses JavaScript syntax, but the format is text only. So, it can be read and used as a data format by any programming language. Python `dictionaries` lend themselves to JSON formatting due to structure similarities.

Attributes

Each Log includes a timestamp for each measurement object.

- List of time stamp
- List of corresponding measurement objects

Methods

Constructor Description: Configures where the measurements will be written to and what format. If no filename is specified, samples are not written to a file. If a filename is specified and the format is `csv`, then only the measurement value and timestamp will be written to a CSV file. If a filename is specified and the format is `json`, then the timestamp will be included in the *Measurement Object* and written to a JSON file.

Inputs: filename and format

Outputs: instance of the Log Class

Push(sample) Description: pushes measurement to the list of samples and writes sample to output file

Inputs: instance of *Measurement Object*

Outputs: Success/ Failure

Class Definition

```
class Log(object):

    def __init__(self, filename=None, format=None):
        """Constructor.

        ~~~~~ Possibilities ~~~~~
        filename: string with no '.'
        format: 'csv', 'json'

        """
        self.filename = filename
        self.format = format
        self.sample = []
        self.time_stamp = []
```

3.6.3 Debug Messages

Error Codes

Debug Class (Parent of all classes to set debug flag and print debug messages)

CHAPTER 4

Developer's Guide to Maintaining/ Extending SCTA

Prerequisites We recommend a development environment that includes package control and version control:

- git
- anaconda
- You should clone the `SCTA-dev` Anaconda environment. Follow *The Easy Way: Cloning our SCTA Environment* tutorial, but use the `SCTA-dev-environment.yml` file instead.

To contribute to the source code, you need a basic understanding of Python packages, debug tools, and test frameworks:

- import
- logging
- unittest
- nosetests

Most importantly, you need **VERY GOOD** documentation practices and naming conventions:

- docstrings
- naming

Contents

4.1 Unit Testing

4.1.1 Makefile

For Windows developers, make commands are stored in `make.bat`. For Linux developers, make commands are stored in `Makefile`.

To see available commands run:

```
cd SCTA_repo\src
make help
```

For example:

```
make SFU_Test
```

will run the SFU unit tests and output debug statements to the prompt, while:

```
make SFU_Progress
```

will output SFU unit test results to a `SFU_Test-log.txt` without any debug statements.

4.2 Simulating Instruments

Warning: This will not mimic real instrument output by any means. All instrument output will be the `string` "1".

4.2.1 Import Simulation Configuration

Simply add this import statement at the beginning of your automation script.

```
from SCTA.Simulation import RunAsSimulation
```

Run your script. You should notice that each instrument module will print `logging.INFO` statements simulating each command sent to the instrument, and each simulated query output received by the instrument.

4.3 Sphinx Documentation

4.3.1 Compiling HTML Documentation

Remember to **always clean any existing build** before recompiling (or else you might see broken links):

```
cd SCTA_repo\docs
make clean
make html
```

Then, open the `_build\html\index.html` to see the compiled HTML Documentation.

4.4 Advice from Previous Developers

4.4.1 Tips

- Update your `__init__.py` files whenever you add a new module
- Watch out for those Indent Errors

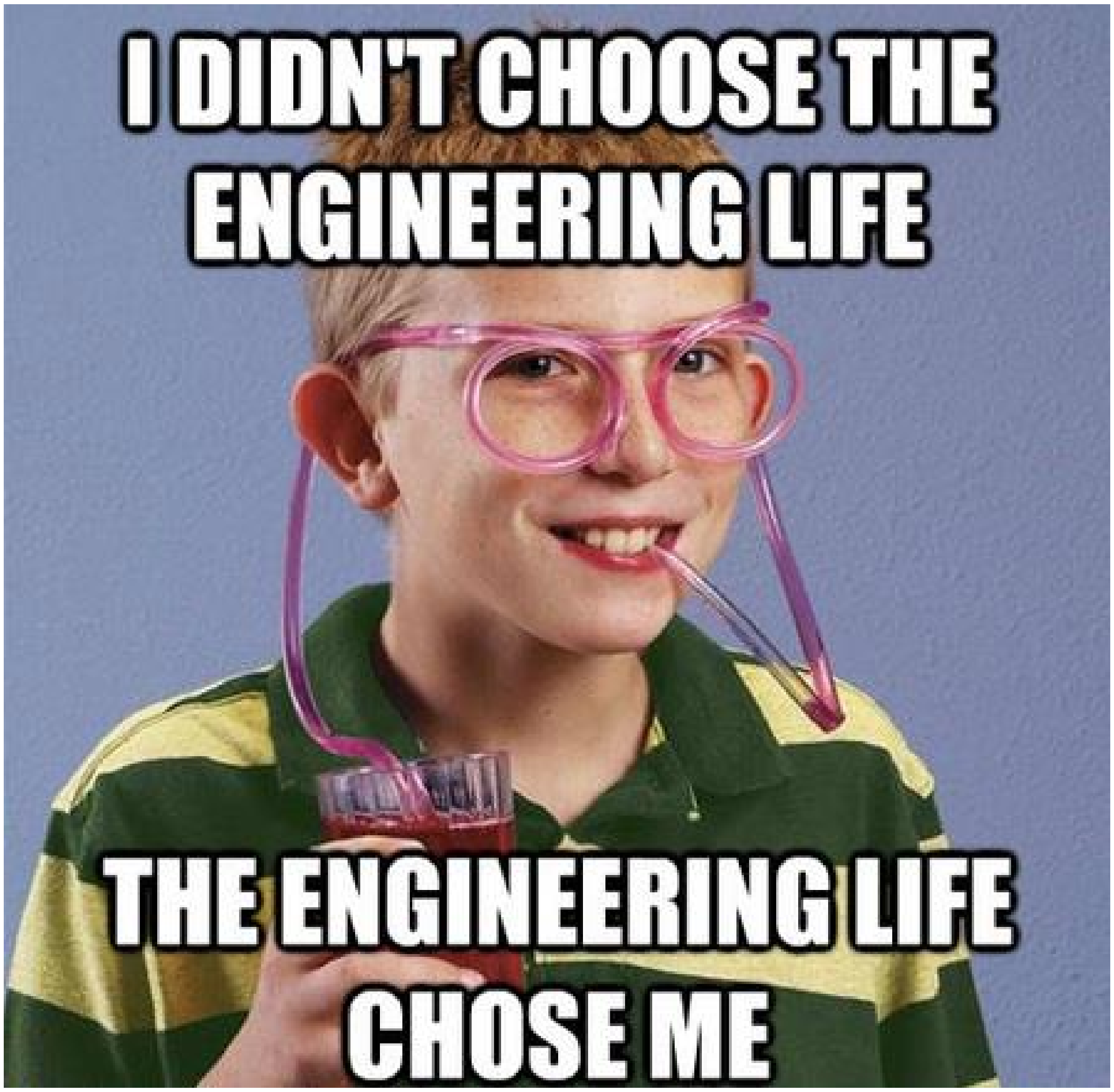
- Always check your import statements
- Be careful about querying instruments *too quickly*. Remember to always wait for operations to complete (OPC)
- If you see a `pyvisa` error about an "invalid resource handle" or "accessing a resource after it is closed", make sure you've implemented the `__del__()` function in your instrument class to `close` the `pyvisa` resource.
- If some data isn't being pushed properly to the DataLogger, check if your csv header and sample are equal length… Don't forget any commas between list entries…
- Be careful when operating on input lists by reference… Sometimes you only need a copy of it
- To enable Jupyter Notebook hide_cell extension, see https://github.com/kirbs-/hide_code/issues/23

4.4.2 Wishlist

- Please fix our import statements DDDD:
- Please figure out how to close our pyvisa resources gracefully during our unittests - Perhaps create another Manager with a `__del__` that closes all of pyvisa ResourceManager's resources

CHAPTER 5

Motivational Quotes


I DIDN'T CHOOSE THE ENGINEERING LIFE
THE ENGINEERING LIFE CHOSE ME

CHAPTER 6

Indices and tables

- genindex
- modindex
- search