SPARKS: A LANGUAGE FOR TEST PROCESS SCRIPTING FOR INSTRUMENTATION SYSTEMS

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MAHDI SAEEDI NIKOO

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SPARKS: A LANGUAGE FOR TEST SCRIPTING FOR INSTRUMENTATION SYSTEMS

submitted by **MAHDI SAEEDI NIKOO** in partial fulfillment of the requirements for the degree of **Master of Science in Computer Engineering Department, Middle East Technical University** by,

Prof. Dr. Gülbin Dural Ünver
Dean, Graduate School of **Natural and Applied Sciences** _____

Prof. Dr. Adnan Yazıcı
Head of Department, **Computer Engineering** _____

Assoc. Prof. Dr. Halit Oğuztüzün
Supervisor, **Computer Engineering Dept., METU** _____

Examining Committee Members:

Prof. Dr. Ali Hikmet Doğru
Computer Engineering Dept., METU _____

Assoc. Prof. Dr. Halit Oğuztüzün
Computer Engineering Dept., METU _____

Assoc. Prof. Dr. Murat Manguoğlu
Computer Engineering Dept., METU _____

Assoc. Prof. Dr. Uluç Saranlı
Computer Engineering Dept., METU _____

Assoc. Prof. Dr. Umut Sezen
Electrical and Electronics Engineering Dept., Hacettepe U. _____

Date: 28.04.2015

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: Mahdi Saeedi Nikoo

Signature :

ABSTRACT

SPARKS: A LANGUAGE FOR TEST PROCESS SCRIPTING FOR INSTRUMENTATION SYSTEMS

Saeedi Nikoo, Mahdi

M.S., Department of Computer Engineering

Supervisor: Assoc. Prof. Dr. Halit Oğuztüzün

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Calibration of test and measurement equipment is an important requirement in industry to ensure that the measurements they perform are reliable. Developing automated calibration procedures with existing tools requires considerable programming expertise. In this thesis, we introduce the initial version of SparkS, a domain specific language that aims to make development and maintenance of automated calibration procedures much easier for workers in the field of calibration. We present the design and implementation of SparkS, and demonstrate its use on an example test process. The SparkS interpreter runs on Metrology.NET, a new generation platform for calibration automation, developed by Cal Lab Solutions, Inc., Aurora, CO, USA.

Keywords: calibration, test and measurement equipment, domain specific language

ÖZ

SPARKS: ENSTRÜMANTASYON SİSTEMLERİNİN TEST SÜREÇ BETİKLERİ İÇİN BİR DİL

Saeedi Nikoo, Mahdi

Yüksek Lisans, Bilgisayar Mühendisliği Bölümü

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Test ve ölçüm ekipmanlarının kalibrasyonu, endüstride yapılan ölçümlerin güvenilir olduğundan emin olmak için önemli bir gerekliliktir. Mevcut araçlar ile otomatik kalibrasyon prosedürleri geliştirmek önemli ölçüde programlama uzmanlığı gerektirir. Bu tezde, otomatik kalibrasyon prosedürlerinin geliştirilmesini ve bakımını kolaylaştırmayı amaçlayan, alana özel bir dil olan SparkS'ın ilk sürümü sunulmaktadır. Bu tezde SparkS'ın tasarım ve gerçekleştirimi anlatılmakta ve kullanımı örnek bir test süreci üzerinde gösterilmektedir. SparkS yorumcusu, Metrology.NET üzerinde çalışmaktadır; bu Cal Lab Solutions, Inc. (Aurora, CO, ABD) tarafından geliştirilen kalibrasyon otomasyonu için yeni nesil bir platformdur.

Anahtar Kelimeler: Kalibrasyon, test ve ölçüm ekipmanı, alana özel dil

To My Mother

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LIST OF ABBREVIATIONS

AJAX	Asynchronous JavaScript And XML
ANSI	American Standard Code for Information Interchange
ANTLR	Another Tool For Language Recognition
API	Application Programming Interface
CSS	Cascading Style Sheets
CMS	Calibration Management Software
CVI	C for Virtual Instrumentation
CW	Synthesized Sweeper
DLL	Dynamic Link Library
DSL	Domain Specific Language
DUT	Device Under Test
EBNF	Extended Backus–Naur Form
ETE	Electronic Test Equipment
GPIB	General Purpose Interface Bus
HP	Hewlett-Packard
HTML	HyperText Markup Language
IDE	Integrated Development Environment
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
MSB	Metrology Service Bus
NI	National Instruments
PC	Personal Computer
QA	Quality Assurance
REST	Representational State Transfer
RF	Radio Frequency

SCPI	Standard Commands for Programmable Instruments
SDE	Software Development Environment
SQL	Structured Query Language
TME	Test Management Environment
UoM	Unit of Measure
UUT	Unit Under Test
VB	Visual Basic
VI	Virtual Instrument
VEE	Visual Engineering Environment
XML	Extensible Markup Language

CHAPTER 1

INTRODUCTION

This chapter introduces the motivation and scope of the work, summarizes the related works and further outlines the organization of the thesis.

1.1 Aim and Scope of the Work

Electronic Test Equipment such as signal and power generators, signal and power analyzers, and oscilloscopes, are to be tested in predefined time intervals or for the purpose of repair. Testing and calibration is important in that these instruments play a critical role in product testing and development in industry.

Calibration [6][8] for such instruments is done either manually or through automation software. Manual testing, being time and energy consuming, error prone, and tedious, is a costly option. On the other hand, the same task can be performed automatically through a client computer connected to the instrument that needs to be calibrated.

There are several software systems available in the market to be used to perform testing and calibration for testing equipment. Some of these software systems such as Agilent TME [11][26] are automation systems to be used in the labs directly by technicians to run the preloaded tests on equipment while others such as Agilent VEE [4] and NI(National Instruments) LabView [9] allow domain experts to write and add their own test modules. These tools all have their own pros and cons but the main downside that they all have in common is the difficulty of developing test scripts for technicians and even experts in the domain who do not have a programming background.

In this thesis, we present a Domain Specific Language (DSL) that is aiming to fill up this gap between test manuals that are quite understandable for their readers who are usually technicians at labs who are in charge of the calibration tasks, and the developed test scripts executable by computers. Test manuals, such as [10], are calibration manuals for a specific instrument or a family of instruments, along with their options, that cover all the steps (with variations) to be taken by a technician for a manual calibration.

The proposed DSL, named SparkS, is aimed to sit on top of an automated calibration platform. The language syntax and semantics are designed to be independent of any underlying platform while the interpreter, that is the backend of the language processor, will be based on the platform on which to run the tests, namely Metrology.NET, a new platform for calibration automation developed by Cal Lab Solutions, Inc., Aurora, CO, USA [12]. There also is not any dependency of the language and its processor to any equipment, whether it be Device Under Test (DUT) or Electronic Test Equipment (ETE). Besides the ease of writing the language provides, test script reading and tracking program flow is also an important capability that our language provides for especially technicians and QA (Quality Assurance) people who need to understand and audit a test script.

As a comparison, you can see in table 1.1, at one side, the two main competitors, Agilent VEE and NI LabView, and at the other side, the composition of the Metrology.NET system and our language SparkS. The main effect of SparkS appears in the features number 1, 2 and 8. For the feature number 1, the language provides transparency to the end user to read/write and inspect test procedures in an easier way. In the two mentioned graphical development environments, as experience shows, as the size of a program gets bigger, complexity level increases which lowers the readability. Also, as it is obvious from the feature number 8, we have complete customization on our system to adapt it to our needs. A complete description for each of the features will be given in the next chapters.

Table 1.1 - Comparison of Product Features

No	Product features	Agilent VEE / LabVIEW	Metrology.NET + SparkS
1	Transparent, meaning it is easy to read, understand, and inspect the automated process by non-programmers	No	Yes
2	Complexity level as program size gets bigger	High	Low
3	Usage of multiple functions of units for different purposes for a better efficiency	No	Yes
4	Optimization of test setups through client/server relationship	No	Yes
5	Remote User Interface of test process over the internet by smart phones or laptops	No	Yes
6	Taking advantage of service-oriented architecture	No	Yes
7	Uncertainty calculation tools	No	Yes
8	Customization ability for our needs	No	Yes
9	Aids the operator when selecting the best reference to use for a calibration	No	Yes

1.2 Organization of the Thesis

The remaining chapters in this study will be as follows:

- Chapter 2 will cover the related domain concepts that will help readers have a background on the related metrology domain concepts, a brief introduction to Domain Specific Languages and the related works that have already been done in the domain. In this section, Metrology.NET, the underlying platform for our language implementation will also be discussed.
- Chapter 3 will discuss the language requirements and SparkS language syntax (grammar, lexical conventions) while the complete presentation of the grammar used for parsing is in Appendix A.
- In chapter 4, language implementation issues, including the front-end and back-end, use of the visitor pattern in the interpreter and how the interpreter binds to the underlying platform, Metrology.NET will be discussed.

- Chapter 5 covers a case study with a sample script and a detailed account of how it runs to show the language in use.
- Chapter 6 will conclude the study, what has been achieved, and what else is being planned as future work.

CHAPTER 2

DOMAIN CONCEPTS

In this chapter, we summarize the Metrology domain concepts, platform-related concepts and the domain-specific language approach used in our work.

2.1 Metrology Domain Concepts

Metrology, the science of measurement, is an extensive domain both in research and industry [8][13]. In this work, our focus is over measuring instruments used in electrical and electronic systems. Signal Generators, Signal Analyzers, Frequency Generators, Frequency Analyzers, Network analyzers, Spectrum Analyzers are some examples of the types of these instruments. Uncertainty analysis [29] is delegated to the underlying platform; thus, it is outside the scope of this work. Below come the main concepts that we will be dealing with throughout our study:

Electronic Test Equipment or Standard

In every test configuration we have a UUT on one side and Electronic Test Equipment (ETE) or standard on the other side. Depending on what the UUT is, we will have appropriate ETE(s) to perform a test. In order to test if our instrument functions accurately, we need to test it against some ETE(s) that we are sure of their performance accuracy. So this way we can make sure that the device fulfills its job appropriately as expected. In the figure shown above the Synthesized Sweeper takes an ETE role to test the Spectrum Analyzer's performance.

Device/Unit Under Test

Device Under Test (DUT) or Unit Under test (UUT) is the manufactured equipment that is supposed to undergo tests. In Figure 2.1 the Spectrum Analyzer is our UUT on which tests are performed.

Performance Test

Performance Tests are performed to test the electrical performance of the device and make sure the Unit Under Test (UUT) fulfills the expected functions. All the required equipment to perform a test and all the details including test configuration are described in this part for customers who want to perform the tests. These tests are mostly done by calibration laboratories which have the required tools and equipment and standard and high quality settings for this purpose.

Test Point

A performance test is typically comprised of cycles in which a series of parameters for both the UUT and ETE change. Each cycle in a test refers to a test point in test manual. In the following table you can see the test points for Frequency Readout Accuracy Performance Test of Agilent PSA Series Spectrum Analyzers as an example:

Table 2.1 – Test Points for Frequency Readout Accuracy Performance Test [14]

Synthesized Sweeper CW Frequency (MHz)	**Analyzer Span (MHz)**	**Analyzer Center Frequency (GHz)**	**Measured Frequency**
517.59	1.98	517.59	
832.50	1.98	832.50	
1505	2000	1505	
1505	127.2	1505	
1505	54.1	1505	
1505	7.95	1505	
1505	0.106	1505	

Each row in the table is a test point to be tested. The rightmost column is left to be filled after the test is applied. The first column contains the parameter values for the ETE used in this test configuration (Synthesized Sweeper) while the second and the third columns are for the UUT.

Test Manual

Test manual, calibration guide or calibration procedure is the document that is provided by the manufacturer of an instrument. The guide usually contains all the required information about the instrument for customers, including safety information, equipment required for performance tests and calibration, specifications, performance test procedures, basic maintenance, and some other material.

Test Configuration

In order to perform a correct measurement, most performance tests require specific connections to be made before the test is started. This information is provided in each test which often involves a graphical figure as the one shown below:

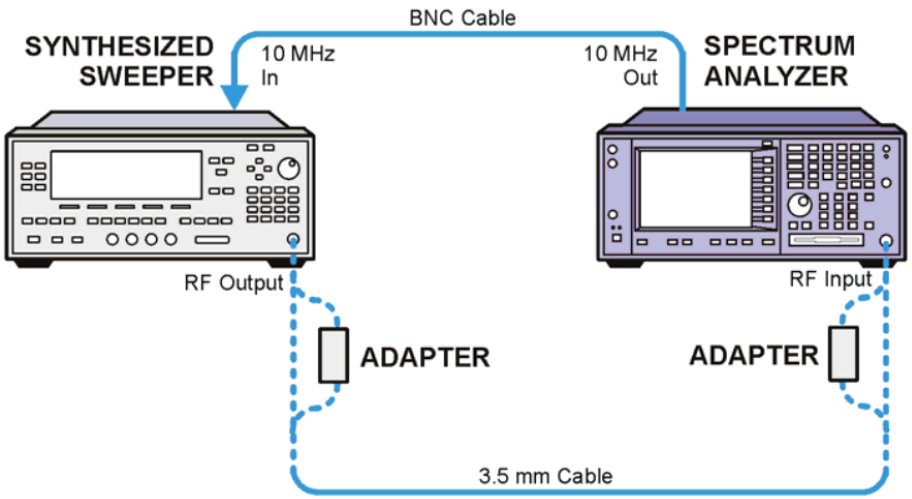


Figure 2.1 Frequency Readout Accuracy Performance Test Configuration [14]

The configuration shown in Figure 2.1 is for the Frequency Readout Accuracy Performance Test of Agilent PSA Series Spectrum Analyzers [14].

Test Procedure

Test Procedure is the set of steps that need to be done either manually or automatically for both UUT and ETE(s) in order to perform a test. The procedures in test manuals are arranged for manual testing on the instruments involved. The

counterpart SCPI commands are also provided in the Command Reference of UUT for programmers to control the equipment remotely through a computer.

Command Reference

Manufacturers also provide another document named Command Reference that includes all the commands (SCPI Commands [14]) that one needs to control equipment through a computer. In calibration automation these commands are used to communicate with the instrument. One step in a Test Procedure is equivalent to one or several commands in the Command Reference.

Testing Terminal

In manual testing, the technician who performs a calibration goes through Test Procedures one by one as indicated in instrument's test manual. But if we want to automate the calibration process, we have two options. Either available automation tools are used or appropriate test scripts are written to perform the same task as manual calibration. In either case this is done through a terminal computer that connects to all the equipment that are involved in a test and controls them by sending and receiving commands.

GPIB/IEEE-488

IEEE-488 is a digital communication bus specification [16]. IEEE-488 was created as HP-IB (Hewlett-Packard Interface Bus) but is commonly called GPIB (General Purpose Interface Bus). GPIB is the standard bus that is mostly used in calibration labs for communication between instruments. A very useful feature provided by this bus is the ability to connect several instruments to each other to form a network of equipment.

SCPI/IEEE488.2

Standard Commands for Programmable Instruments (SCPI), which is mostly pronounced as "skippy", is standard that defines syntax and commands to be used in controlling programmable test and measurement devices. It was defined in IEEE488.2 specification [14]. The language was defined to be a standard among all

instruments but later was customized by different vendors. It is still the dominant instrument language used for programming instruments.

Metrology Technician

The person at a calibration lab, who gets work orders and is responsible for running tests on UUTs and does adjustments and fixes if necessary and finally produces reports for customers.

Metrology Engineer

The person who is usually responsible for developing calibration automation programs to be used at calibration labs by technicians.

2.2 Metrology.NET

The Metrology.NET automated calibration system, produced by Cal Lab Solutions, Inc., Aurora, CO, USA [12], touted as the new generation platform for the testing and calibration process. The main features of the Metrology.NET™ framework are highlighted below [20].

The system is in a client/server configuration. The main server hosts the Metrology.NET application service. Each client workstation will be configured as Calibration Agents. Technicians will interact with the calibration agents using the local workstation or remotely using Metrology.NET Application Services. The Metrology.NET automated calibration system is designed using an open standard Service Oriented Architecture. It is built on REST communications [17] using AJAX calls [18] to securely exchange data between system agents.

Metrology.NET views a calibration job as a set of test points related to a specific instrument. The calibration process is abstractly viewed as the process of obtaining and collecting the results for all the required test points. Once all the test points have been completed the calibration job will be considered complete and the calibration

activity can then review the data and certify the instrument by generating reports that comply to ISO 17025 and ISO 900x standards.

Collection of the data can be accomplished in a number of ways. Metrology.NET will allow for manual data collection, fully automated data collection and several hybrid methods of data collection between manual and fully automated. The overall goals of Metrology.NET are to simplify the process of data collection, storage, data analysis and reporting in to a single calibration system.

For many labs fully automated calibration procedures will increase productivity, accuracy and repeatability. Metrology.NET offers flexibility with regard to automation. Every calibration task can be broken down into smaller reusable test modules to test specific sections of a UUT (Unit Under Test) using specified ETE configurations. Automated calibration can be accomplished by passing a subset of test points to an autonomous test module. As the test module completes the test point(s) it will send the test results to the Metrology.NET application service.

Technicians are allowed a level of autonomy with executing a calibration procedure. Metrology.NET allows them to select what test groups to perform, in what order and on what test stations they will be performed. They will be able to start, stop, and retest each section of the procedures as needed. Metrology.NET allows the technicians to halt a calibration process and restart it overnight or for weeks later after it has been repaired.

Additionally, Metrology.NET stores important data about the calibration process at every test result. Common elements like as-found, as-left along with the measured value and the uncertainty are stored. Furthermore, Metrology.NET also stores information like technicians, calibration work station used, standards used, time stamps, and other customized parameter data. Such information is stored at every test result record to enhance repeatability.

Once the calibration is complete, Metrology.NET provides a report of the calibration data meeting the industry standards and requirements, such as ISO 17025 and ISO 900x.

A distinguishing functionality offered by the Metrology.NET is the use of multiple functions of units for different purposes for better efficiency. Typically, calibration automation systems limit the usage of equipment functions to specific brands or models and this does not allow users to use other equipment they might have at hand instead of the one supported by the tool.

Remote User Interface of testing process over the internet is another distinguishing feature that is provided by the Metrology.NET. The user is able to initiate the test and follow the process through the end so that when there is a need for the user to interfere physically, s/he could come in and configure the testing setup appropriately or if there is no need for a physical reconfiguration, s/he could do the right action remotely through his/her PC or smart phone to move forward the process. This feature will be very useful and time saving for the technicians because they do not need to stay in the lab for long periods of time to follow the testing process.

The web based user interface is designed in such a way that enables the technician to manually upload the test points to the server. After all the data for a test package is ready, the technician is able to create work orders in which s/he can choose which tests to put into the work order. A work order is equivalent to a calibration task that is supposed to be done by a technician on the customer's equipment. It includes all the tests that are supposed to be performed on a UUT.

A useful feature of the server side of Metrology.NET is that it can be placed in different locations. As it is considered, in most cases there will be a local version of the server for a lab to work with the testing agents in the same lab. The testing agents are like worker bees that do the calibration process in a collaborative manner that are all controlled by the local server. Another option is a remote server which does the same thing as the local one. If we ignore the distance, security or other issues that might be caused by a remote server instead of a local one, it might still have some

advantages. We envision the metrology server as a centralized source to keep all the calibration related data and a place to have shared jobs and communications among different labs. Another choice for the Metrology.NET server is a cloud based database which is close in concept to the remote server while it also will take advantage of the cloud computing benefits.

Metrology.NET has been designed in an extendible way based on the driver-based approach. There are some preloaded drivers for some instruments to do their testing and calibration while it is open for any third party drivers to be added onto the platform to be used accordingly. This is done by the API that is provided by the Metrology.NET to the end users. So as long as a new driver matches the provided interface, it will be ready to go on and run the test.

In the following section some modeling for the Metrology.NET is presented which gives an overview for understanding of the main concepts and functionalities that are dealt with in the system. Figure 2.2 shows an overview of the whole system and how the interactions occur among the system components. The Metrology engineer will be the one in charge of the server control. The Testing Agent is the computer in the lab that connects directly to the customer and standard equipment and performs the test. The complete conceptual model (class diagram) for the Metrology.NET system can be found in Appendix D. Also, a data dictionary for the Metrology.NET platform is given in Appendix C.

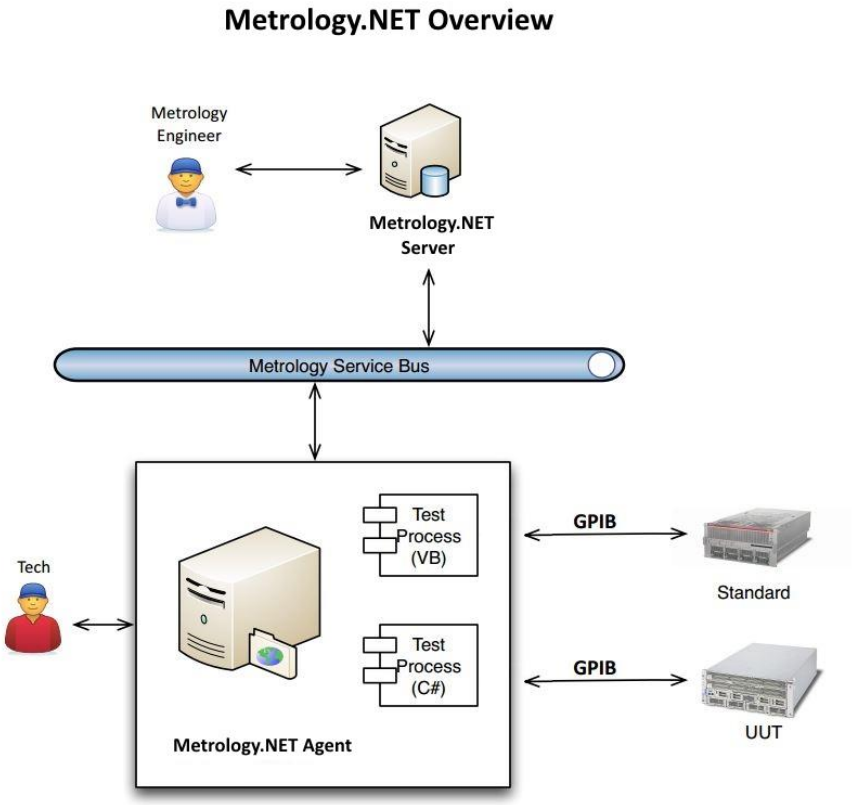


Figure 2.2 Metrology.NET System Overview

Equipment are connected to each other and to the agent that runs the test through General Purpose Interface Bus (GPIB) [16] which is the most commonly used port type in such settings. Test Processes which include the test scripts can be written in any Microsoft .NET language, such as VB or C#.

The system functionalities are elaborated by three major steps which will be shown below.

Step 1: Create a test package and put it in the library.

The test package Library is the source in which to keep all the data needed for tests to be done. Test package, test group and test point form the hierarchy in which Test package is the container to keep the other two, and the test group is the container to keep test points. A test package corresponds to one or a family of equipment with

different models and options. A test group comes down to a single test and a test point includes the data needed for one iteration of the related Test Process.

Metrology.NET is designed in such a way to allow users to choose from a test process list the one that best fits their purpose. This can be applied for any test group in the library. Test process link inside the test package Library in Figure 2.3 shows this connection.

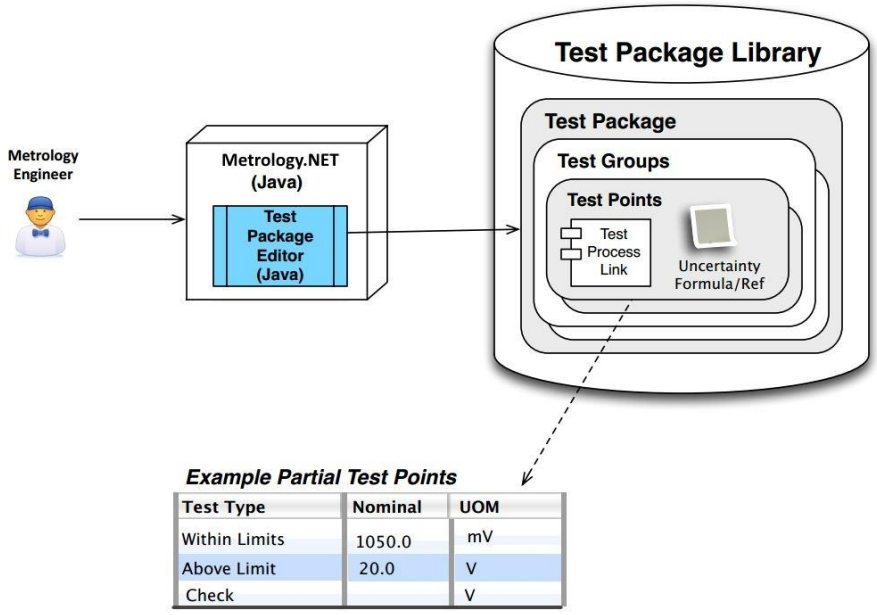


Figure 2.3 Metrology.NET data handling overview

Step 2: Create a work order using the test package library and assign it to a specific piece of test equipment.

Work orders are test plans that are initiated by the technicians at the lab. After all the data are put together and uploaded to the server (this could also be done manually through the web based interface for the server), work orders get created after which a calibration job can be started. In creating a test package, the user enters all the data which could be for a family of instruments with different options, while in creating work orders a subset of a test package is extracted and cloned to be passed to the appropriate Test Process which is chosen by the technician through the

Metrology.NET web based service bus. Figure 2.4 helps to show the work order concept visually. “Test process link” and “test equipment link” in Figure 2.4 show the concept that a test group can be configured to be run with a chosen test process and test equipment out of a list each.

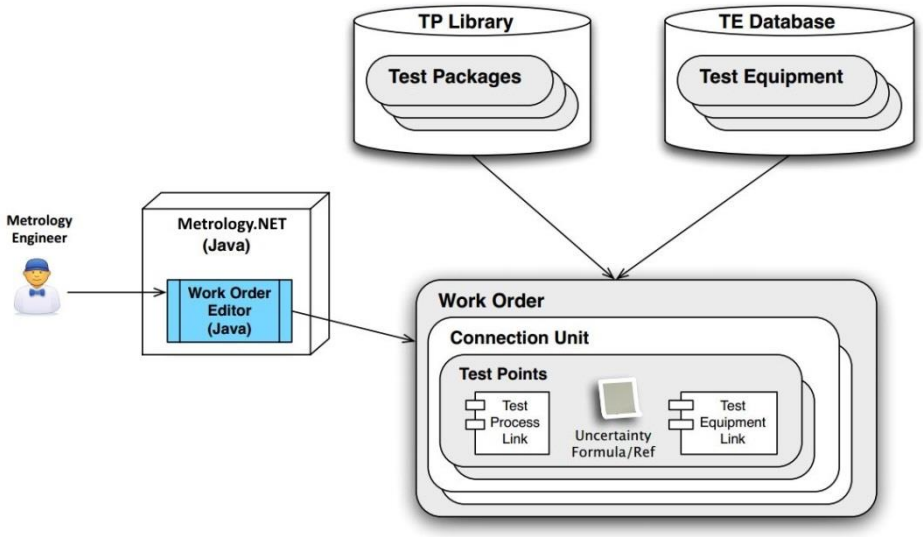


Figure 2.4 Metrology.NET work order concept overview

Step 3: Use an IDE with the Metrology Specific Language (in our case SparkS) to develop test process software modules.

This is the place where SparkS takes the role. The SparkS language will be used by the end users (typically domain engineers) to develop test scripts. Instead of using a programming language based on the Microsoft.NET platform, they will use SparkS scripting language, a high level language that consists of metrology terms that is quite friendly for the target developers. The overall process is sketched in Figure 2.5.

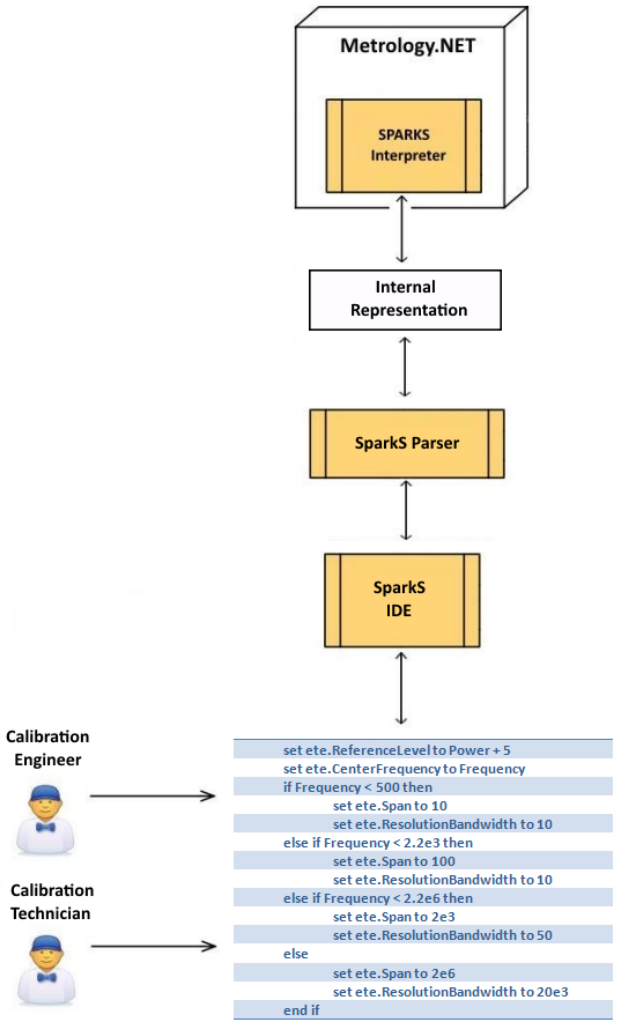


Figure 2.5 How SparkS interpreter embeds into Metrology.NET

2.3 Metrology.NET Test Process Software Hierarchy

Metrology.NET has separated the Unit Under Test (UUT) and Electronic Test Equipment (ETE) control mechanisms. The UUT controls are mainly done through the parsing of commands that are provided in test points as parameters. The UUT command parameters can be added as test package or as test group parameters, depending on the availability preferences. If the parameters are at test package level, then all the test groups of that test package can see those parameters, while if you put them in test group level, only that specific test group will be able to see them.

As can be seen in figure 2.6, Metrology.NET separates instrument calibration logic into several abstract layers. A calibration procedure developed on Metrology.NET is not tied to follow the architecture proposed, since it is also possible for a function at the top layer in the hierarchy to directly call functions from each of the lower layers. For example, you can directly send commands to a device from a test process class (MSB layer). However, if a calibration procedure complies with this hierarchy, it will lead to several reusable layers that will help in lowering the calibration procedure development costs.

At the highest level of the abstraction layers is the Metrology Service Bus (MSB) layer or Interchangeable Driver Interface. It is both language and platform independent. It is a layer for driver interchangeability that basically deals with a set of test points (a test group) at a time and passes down the test points with their parameters one by one to the underlying layer, the Measurement Process Driver layer. This layer is responsible for the measurements for ETEs. By getting the parameters for a test point at a time, this layer calls the services provided by its underlying layer. All the calls are based on string parameters to omit direct calls and increase flexibility. Since the calls are string-based, there is no need for a code modification for a change in the lower layer, as long as the same service names are provided.

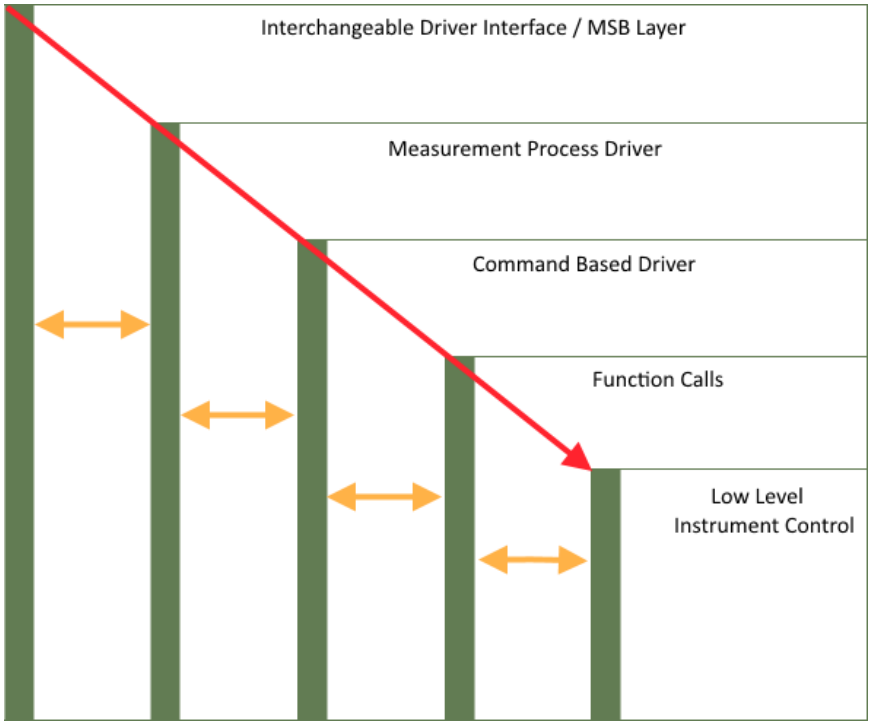


Figure 2.6 Metrology.NET Calibration Software Layers [19]

The underlying layer, Command Based Driver, is where the instrument control string commands or IEEE SCPI (Standard *Commands* for Programmable Instruments) commands reside. This layer is completely dependent on and specific to an instrument. The string commands that are sent to the instrument are analyzed by the firmware inside it which then it uses the corresponding function calls internally to perform that operation. A simple example is "*RST" SCPI command that leads to a Reset() function call, which does a reset on the equipment. Finally the function calls would internally do low level reads and writes to set up the equipment.

In developing a test procedure based on the mentioned software abstraction layering, the three top layers can be seen and accessed for a developer. Below comes a general description for each of these layers:

1) **Interchangeable Driver Interface** or Test Process Drivers are designed to process test points controlling both the UUT and all the standards (ETEs). They are designed to be the worker bees of the calibration lab. They pull test points from a service, execute them and save the results back to the service.

2) **Measurement Process Drivers** are designed to perform specific measurement tasks. They receive commands through a message, perform the task and then return the results to the calling tool via message. Each driver is designed to perform high level metrology functions, controlling one or more standards.

3) **Command Drivers** are the low level drivers that interact directly with the hardware. They are implemented with command messaging and operate similar to the measurement drivers.

2.4 Domain Specific Languages

The world of programming languages possesses great variety. From one point of view, there are two types of programming languages. One is general purpose languages like C++ and Java, which are aimed to target a wide range of application domains, and the other is Domain Specific Languages (DSLs), which include language constructs designed to be used within a specific application domain, so they are focused to address problems of that domain. DSLs have been around for a long time and they are extensively used in many different fields. DSLs do not have to be programming languages in the sense of being computationally universal. Some very popular examples include HTML, SQL, XML, and CSS[1].

DSLs generally fall into two groups, so called external and internal (Embedded) DSLs. External DSLs have their own custom syntax instead of being built on top of an existing language. Thus, the language implementer needs to write a full interpreter that interprets the language or a compiler that translates the source language to another one that is interpretable or executable. Moreover, all the tools such as editors, debuggers and those others that come handy in developing programs should be developed specifically for that language.

Internal DSLs on the other hand are not stand-alone languages. Here, we tweak a host language to make it feel like a different language for the application programmer. This means that we are able to take advantage of all the tools and services available for the host language, while we are limiting the programmer to the

syntax of the host language. If the host language is DSL-friendly, i.e. extensible and flexible, language, DSL implementation will be smooth [1][2].

CHAPTER 3

SPARKS LANGUAGE DESIGN

In this chapter, language design issues including the language grammar in EBNF, language components, the constructs used in the language and lexical characteristics will be discussed. The complete ANTLR grammar for the language can be found in Appendix A.

In our language design, simplicity was an overriding concern in all design decisions. Particularly in this initial version of the language we aimed at the essentials needed for test procedures to be run. As will be discussed in this chapter, dynamic typing and dynamic type checking were included in the language design to provide a more flexible language. Another point considered in the language design was the independence concept, and that the language should be independent from any instrument and any particular test process.

3.1 SparkS Grammar in EBNF

The SparkS grammar is produced using the standard EBNF notation [29].

```
program
    = 'testProcess', ID,
       {header,}
       body,
         'testProcess', ID,
       EOF
    ;
header
    = require {, require}
    | bind {, bind}
    | testPoint {, testPoint}
    | testGroup {, testGroup}
    ;
body
    = stmt {, stmt}
    ;
require
    = 'require', ID, 'as', 'linkerType', externalDesignator, ['testType',
externalDesignator]
```

```
    ;
externalDesignator
    = externalName
    | 'prompt'
    ;
externalName
    = STRINGLITERAL
    ;
bind
    = 'bind', ID, 'to', externalDesignator
    ;
testPoint
    = 'testPoint',  tpId
        'provide',
             paramID
             {paramID},
        'measure', ID,
     END, tpId
    ;
tpId
    = ID
    ;
paramID
    = ID
    ;
testGroup
    ='testGroup', ID, 'testPoint', tpId
    ;
//the possible statements
stmt
    = for_stmt
    | ifThenElseStmt
    | set_stmt
    | const
    | functionCall
    | error
    ;
functionCall
    = ID, '.', ID, ['(', [STRINGLITERAL, {',', STRINGLITERAL}], ')']
    ;
const
    = 'constant', ID, '=', constVal
    ;
constVal
    = (INT | DOUBLELITERAL)
    | ID
    ;
//a subset of the possible statements
sub_stmt
    = for_stmt
    | ifThenElseStmt
    | set_stmt
    | functionCall
    | error
    ;
//if-then-else structure
```

```
ifThenElseStmt
    = 'if', condition_block, {'else if', condition_block}, ['else',
stat_block], 'end if'
    ;
condition_block
    = boolExpr, 'then',
        stat_block
    ;
stat_block
    = [block]
    ;
//block
block
    = sub_stmt, {sub_stmt}
    ;
//bool expression rules
boolExpr
    = 'not', boolExprSub
    | boolExprSub, 'and', boolExprSub
    | boolExprSub, 'or', boolExprSub
    | boolExprSub, 'xor', boolExprSub
    | boolExprSub1
    ;
boolExprSub
    = '(', boolExpr, ')'
    | boolExprSub1
    ;
boolExprSub1
    = arithExpr, ('<=' | '>=' | '<' | '>'| '=' | '/='), arithExpr
    | ('TRUE' |  'FALSE')
    ;
//arithmetic expression rules
arithExpr
    = arithExprSub, ('*' | '/'), arithExprSub
    | arithExprSub, ('+' | '-'), arithExprSub
    | arithExprSub1
    ;
arithExprSub
    = '(', arithExpr, ')'
    | arithExprSub1
    ;
arithExprSub1
    = (INT | DOUBLELITERAL)
    | ID
    ;
//for loop variations
for_stmt
    = 'for',  'each',  ID,  'in',  ID,  'do',
            [block]
      'end',  'for',

    | 'for',  'each',  ID, 'in',  '[', limitVar, ',', limitVar, ']',
'do',
            [block]
      'end',  'for'
    ;
```

```
limitVar
    = ID
    | INT
    ;
//set statement
set_stmt
    = 'set', ID, 'to', setExpr
    | 'set', ID, '.', ID,  'to',  setExpr
    | 'set', 'UNCERTAINTY', 'to', setExpr
    ;
setExpr
    = arithExpr
    | STRINGLITERAL
    | ID, '.', ID
    ;
error
    = 'error', STRINGLITERAL
    ;

// LEXER TOKENS //

INT = ? a signed integer value with scientific E support ?
DOUBLELITERAL = ? a signed double value with scientific E support ?
STRINGLITERAL = ? anything inside quotation marks("") except for new
line character ?
ID = ? it starts with an English alphabetic character and a sequence
containing digits, English alphabetic characters and underscore ?
```

3.2 Syntax

A script written in SparkS basically consists of two parts. The header section that comes first and a body section which follows the header part. Roughly speaking, the header prepares the stage and the body does the acting.

For the interpreter to operate, some properties such as the resources that are involved in testing, and some test specific features are supposed to be set first. All these come in the header part. Header part is actually providing the binding of the interpreter to the underlying platform, presently Metrology.NET. One important aspect of SparkS scripts is the push based mechanism for data handling, instead of a pull based mechanism. This means that, instead of declaring the specific data to be pulled at runtime, the data type is declared and at runtime, the user chooses what data (test group) they want the test procedure to operate on. This is basically the mechanism used in the underlying platform, Metrology.NET.

After the binding is done, the execution of the test process begins. All the communications or send/receives and calculations take place inside the body. After the processing for the test is done, the result is sent back to the server.

The language grammar for parsing is developed using ANTLR 4 [5] [7]. For this, AntlrWorks [21] a NetBeans [3] based standalone editor and ANTLR's IntelliJ IDEA plugin were used that also support live syntax diagrams. Both Parser Rules and Lexical Tokens are put in the same file as comes in Appendix A.

3.3 Arithmetic and Boolean expressions

For the expressions, outermost parentheses will not exist in a main expression, but a sub-expression with a binary operator must be parenthesized. This provides a forced precedence that ought to be applied by the programmer. There are no precedence and association rules for arithmetic and Boolean operators in SparkS. An arithmetic sub-expression of a logical expression (including comparisons) will be regarded as a main expression (after all, it is not a part of an arithmetic expression) so will not be parenthesized. So, the following expressions are well-formed:

```
a + b
-(a + b)
a + (b * c)
```

Also,

```
if a + b > c + d then ...
if a + b > c + d or a + (b * d) > 0 then …
```

But not the following ones:

```
(a+b)
((a+b)*c)
```

3.4 SparkS Statements

Below is an informal presentation of SparkS constructs and statements with examples and the description for each construct or statement.

3.4.1 The *require* Statement

The *require* statement declares the general type of equipment that can be used in the test. For example, a family of equipment could be declared as the type. The general format is as below:

```
require identifier as linkerType resourceType testType resourceInterface
example:
require ete as linkerType “Measure.Device” testType “iSpectrumAnalyzer”
```

3.4.2 The *bind* Statement

There are some fixed attributes that belong to every test script, which include test name, test type, description, unit of measure, etc. The *bind* statement is used to define these properties. The *prompt* keyword that is used in *bind* statements is used to assist late binding, so that the user can choose at runtime the appropriate value for the parameter. Below come some examples:

```
bind property to ExternalName
bind property to prompt
example:
bind TestName to ”TestProcess.Measure.Harmonics (Agilent_E44xxA)”
bind TestType to prompt
```

3.4.3 The *testProcess* Statement

The *testProcess* construct is used to mark the textual beginning and end points of a script, in which both identifiers must be the same. So in fact the script goes between these two lines. Following is the overall structure and an example to clarify:

```
testProcess identifier
//statements
end identifier
example:
testProcess measureHarmonics
//statements
end measureHarmonics
```

3.4.4 The *testPoint* Statement

For the test script to be compatible with variable data types that come in at runtime, a *testPoint* structure is defined, in which the parameters that may be available in the data with the to-be-measured parameter are listed. For the coming data, its type is checked with the one defined in here to make sure if it meets the test requirements. The ordering of the parameters to be provided is not important. At the end of the test, the value that is set to measure parameter is counted as the test result and uploaded back to the server for more processing. Below comes the overall structure followed by an example:

```
testPoint identifier
        provide
                parameter1
                parameter2
                …
        measure
                parameter
end identifier
example:
testPoint tp
        provide
                Frequency
                Power
                ReferenceSource
                HarmonicToMeasure
                NumberOfHarmonics
        measure
                harmonics
end tp
```

3.4.5 The *testGroup* Statement

The *testGroup* keyword refers to a group of test points for a performance test, with some additional parameters that belong to the group. After the test point type is declared, we need an identifier to refer to the collection of test points ($identifier_1$) that come from the server as a part of work order. The *testGroup* structure does this by binding an identifier to the test point type declared already ($identifier_2$). This way we could have several test point types and different test group identifiers which would allow us to bind a test group identifier to each of the defined test point types to support a better data variation.

The important point here is the data handling mechanism used in the Metrology.NET and SparkS accordingly. They use a push-based approach for the data to be used in test procedures. So, instead of pulling data from the test procedure by providing a

reference to it, the data is pushed into the process through the Metrology.NET service bus, the web based user interface. The *testGroup* statement is used to provide a global identifier in the script to refer to the incoming data.

The overall structure of the statement and an example follow:

```
testGroup identifier1 testPoint identifier2
example:
testGroup tgCollection testPoint tp
```

3.4.6 Function Call

Since drivers for the equipment used in testing also include functions to call, we need a structure to support this. Basically, most of the functions in drivers get a list of parameters belonging to the test point which operation is done. This is done by the interpreter if needed. For a function to be recognized, the equipment identifier must be present in the statement as in the following example:

```
identifier.functionName
identifier.functionName(param1, param2, …)
example:
uut.reset
Dialog.ConnectionPicture("ImageName", "Message")
```

3.4.7 The *constant* Declaration

There are cases we want to keep the value set for a variable fixed along the program execution. For example, we might set and fix the uncertainty value for a test and based on the different results that may be produced as the program proceeds, just use it to embed into the final measurement result. The *constant* keyword is used for such a variable declaration. The overall statement structure and a simple example follow:

```
constant identifier = value
example:
constant UNC = 3.0
```

3.4.8 The *set* Statement

For assignment, *set* keyword is used which provides a strong structure for different types of assignments. Each type of the possible assignments and an example for each is presented below:

In the first following *set* statements, the first identifier can be either an already defined identifier or one that is implicitly defined for the first time in this statement, which from this point can be used anywhere in the code.

Here in this *set* statement, $identifier_2$ must be already defined, as it has a value to set to $identifier_1$.

```
set identifier1 to identifier2
example:
set Harmonics to MeasureVal
```

In the statement below, as it is obvious from the name, the result of an arithmetic expression is set to the identifier.

```
set identifier to arithmeticExpr
example:
set Harmonics to max + 1
```

In this statement, *stringLiteral* refers to a quoted string as also shown in the example which may contain a numeric or a string value based on the usage type.

```
set identifier to stringLiteral
example:
set Power to "100"
```

In this statement, in the *to* part of the assignment, $identifier_2$ depends on $identifier_1$. $Identifier_1$ can be a test point or an instrument identifier. If it is a test point identifier, then the $identifier_2$ must refer to a parameter in the test point. While, if $identifier_1$ is

an instrument identifier, then *identifier2* must refer to a function or a property in the regarding instrument driver.

```
set identifier1 to identifier2.identifier3
example:
set MaxFrequency to ete.MaxFrequency
```

In the next four types of *set* statements, in the *set* part of the assignment, $identifier_2$ depends on $identifier_1$. $Identifier_1$ can be a test point or an instrument identifier. If it is a test point identifier, then $identifier_2$ must refer to a parameter in the test point. While, if $identifier_1$ is an instrument identifier, then $identifier_2$ must refer to a property in the regarding instrument driver.

```
set identifier1.identifier2 to identifier3
example:
set ete.frequency to Freq
```

As the name suggests, the value from the *to* part comes from the result of the evaluation of the arithmetic expression in the statement.

```
set identifier1.identifier2 to arithmeticExpr
example:
set ete.frequency to 100 + index
```

In this statement, *stringLiteral* refers to a quoted string as also shown in the example which may contain a numeric or a string value based on the usage type.

```
set identifier1.identifier2 to stringLiteral
example:
set ete.frequency to "100"
```

In this statement, also, in the *to* part of the assignment, $identifier_2$ depends on $identifier_1$. $Identifier_1$ can be a test point or an instrument identifier. If it is a test point identifier, then $identifier_2$ must refer to a parameter in the test point. While, if $identifier_1$ is an instrument identifier, then $identifier_2$ must refer to a function or a property in the regarding instrument driver.

```
set identifier1.identifier2 to identifier3.identifier4
example:
set uut.frequency to tp1.Frequency
```

3.4.9 The *for each* Statement

Looping is one of the important control structures that is needed in almost every test procedure. The *for* construct provides the Iterator design pattern [23] [34]. We came across two general types of looping structures that were needed to be supported by our language. A looping that would go through an ordered collection of items, which in our case is mostly a collection of test points. There is also a looping structure that goes through a defined range, from the lower limit up to the upper limit in the range.

The first looping structure as comes below is designed looping through a collection of test points. The $identifier_1$ is the loop variable that refers to the current test point along looping, which is used inside the structure to recognize which parameter we are referring to.

```
for each identifier1 in identifier2  do
        //statements
end for
example:
for each tp1 in tgCollection  do
        //statements
end for
```

The second type of looping structure as described above supports a range of values defined with *lowerLimit* and *upperLimit* inside brackets. The limits can be either a number or an identifier. The overall structure and an example follow:

```
for each identifier in [lowerLimit, upperLimit] do
        //statements
end for
example:
for each index in [2, NumHarm] do
        //statements
end for
```

3.4.10 The *if-then-else* Statement

Another essential control structure in SparkS was a conditional structure. It follows almost the same structure used in the Visual Basic. The overall structure and an example follow:

```
if booleanExpr then
        //statements
else if booleanExpr then
        //statements
else
        //statements
end if
example1:
if Frequency < MinFrequency or Frequency > MaxFrequency then
        set ete.CenterFrequency to Frequency
end if
example2:
if Frequency < 2.2e3 then
        set ete.Span to 10
        set ete.ResolutionBandwidth to 100
else if Frequency < 2.2e6 then
        set ete.Span to 500
```

```
        set ete.ResolutionBandwidth to 50
else
        set ete.Span to 500e3
        set ete.ResolutionBandwidth to 10e3
end if
```

3.5 Lexical Elements

Whitespace:

Any number of spaces or non-visible characters and comments are considered as whitespace and will be ignored by the parser.

Comments:

For single line comments // is used. The rest of the line is considered as comment.

Example:

```
set a to b //this is a comment
set b to c
```

For single line or multiline comments /*…*/ is used.

```
example1:
set a to b /*this is a comment*/
example2:
set a to b /*this is
a comment
and ends here*/
```

Variable Names:

Variable Names must start with a letter, and may contain nothing but underscores, letters and digits. Variable names are not case sensitive.

Valid variable names:

frequency
Power50
unir_of_measure

Invalid variable names:

0frequency
_frequency
Frequency#

External Name:

The names that belong to outside resources, known by the underlying testing platform, Metrology.NET, to be used as a reference along test process.

Examples:
iSpectrumAnalyzer
iOscilloscope
iPowerMeter
Measure.Device

Integers:

Any sequence of digits of 0 to 9.

Floating point numbers:

Any sequence of digits of 0 to 9 and containing a decimal point or a scientific notation symbol (“e” or “E”). In scientific notation, the exponent must start with a + or – sign followed by one or more digits.

Statement Terminator:

We do not use a semicolon or any printable character as a statement terminator. As in VB, carriage return is the statement terminator.

3.5.1 Operators

Operator	Definition
(	Open function parameter list and subexpression designation operator
)	Close function parameter list and subexpression designation operator
+	Addition or positive sign operator
-	Subtraction or negative sign operator
*	Multiplication operator
/	Integer or floating point division operator
.	Identifier after '.' refers to a member of the identifier before '.'
and	Logical AND operator
or	Logical (inclusive) OR operator
xor	Logical exclusive OR operator
not	Logical negation operator
>	Greater than
>=	Greater than or equal to
<	Less than
<=	Less than or equal to
=	Equals
/=	Does not equal

3.5.2 Reserved Words

All keywords consist mostly of lowercase letters; uppercase is used only for separation for two-word keywords. The full list of keywords is given in Appendix E.

3.5.3 Paired keywords

The keywords that go together are listed below:

No	Keyword
1	as linkerType
2	for each
3	else if
4	end if
5	end for

These pairs are treated effectively as a single keyword.

3.5.4 Helper Functions

There are times you want to communicate with the user along a test run. For example, you want to show an image representing the test setup to the user and that how the equipment must be connected to each other before the test is run. Or you might need to ask for some input data from the user. For this purpose, helper functions were developed to support user interaction. The complete list of helper functions appear in Appendix F.

3.6 Mapping of Domain Concepts

Any DSL must address domain concepts at a satisfactory level [31]. In fact, there are at least two domains (or technical spaces) to be concerned with. One is the domain of application (a.k.a. problem space), which is Metrology, in particular, test and calibration, in our case. The other one is the domain of execution platform (a.k.a solution space), Metrology.NET, in our case. The DSL is situated between these two domains or spaces and connects them.

Below comes the traceability matrix that provides links to the concepts that are dealt with in the metrology, specifically calibration domain, the features provided by the underlying platform, Metrology.NET, and their equivalent language constructs/features in SparkS language.

Metrology Domain Concept	SparkS Language Construct/feature	platform (Metrology.NET) property/ feature/ functionality
testing machine	A developed SparkS script resides on an agent/machine for a test to be run	testing agent/machine
Unit Under Test (UUT)	The UUT is defined using the require statement. This is declared in the header section of a SparkS script.	Unit Under Test (UUT)
Electronic Test Equipment (ETE) or Standard	The ETE is defined using the require statement. This is declared in the header section of a SparkS script.	Electronic Test Equipment (ETE) or Standard
model family	A SparkS script is written in a generic way, which may cover several models for a family of instruments.	model group
model	A SparkS script is written in a generic way, which may cover several models for a family of instruments.	model
model option	As there are different test procedures for different options for an instrument, there can be different SparkS scripts developed for them.	model option
measure device	An instrument declared using the require statement in a script, can be either a measure device or a source device.	measure device
	SparkS scripts are single flat files for its first version. For the next version, it is supposed to support script calls from within scripts. This way, we could provide a better script reusability.	measure driver
source device	An instrument declared using the require statement in a script, can be either a measure device or a source device.	source device
	SparkS scripts are single flat files for its first version. For the next version, it is supposed to support script calls from within scripts. This way, we could provide a better script reusability.	source driver
measurement result	The measure section for a testPoint statement defines the variable for the measurement result.	measurement result

test manual data	A SparkS script includes a single test among the several tests in a test manual.	test package
a group of test points	The test group, on which a test script performs actions, is referred through the variable declared in the testGroup statement. A SparkS script works on a single test group at a time. For looping through the test points of a test group, for loop construct is used.	test group
test point	A test point type is declared using testPoint struct. The list of parameters to come with test points are listed in the provide section, and the parameter to be measured is declared in the measure section.	test point
work order	The test group that is fed into a SparkS script comes from a work order already created by the user. The work order concept, however, is not directly supported by SparkS.	work order
test procedure	A test script developed in SparkS is intended to execute a test procedure for a performance test. The identity for a test procedure is declared in the header section of a SparkS script.	test process
	The test type defines the generic type for a written SparkS script. It is declared using the bind statement.	test type
uncertainty	Uncertainty is defined as a predefined word in SparkS.	uncertainty computation library
unit of measure	This is declared in the header section of a SparkS script using the bind statement.	unit of measure
instrument setting	All the settings (send/receive commands) for instruments are handled through the set construct.	instrument setting
	All the interactions with the user are handled through the Dialog library.	user interaction
	This is hidden in the SparkS interpreter.	Post Office mechanism (for inter-object communication)

CHAPTER 4

LANGUAGE IMPLEMENTATION

In this chapter, the language implementation issues including the front-end, back-end, and a detailed description of all the steps taken in developing the language will be covered.

Before elaborating on the implementation details, an overall picture showing the major parts of the language implementation and the overall view of the language processor is shown in figure 4.1. As can be seen in figure 4.1, it shows that after a script is developed in SparkS, how ANTLR tool handles the front-end issues and where the parse tree is generated for the back-end. You can see the language interpreter embedded into the Metrology.NET, and the two passes used in the interpretation of the provided parse tree from the front-end. It also shows the interaction done between the agent on which the interpreter operates and the Metrology.NET server that holds the data for running tests. The test equipment involved in a calibration and their communications with the system is shown as well.

For traversing the parse tree from the front-end, two passes (tree visits) were added to the interpreter. In the first pass, an error checking is done for the semantics of the language. As an example, for the designed loop construct that iterates through a range of numbers, in the first pass, it is checked to make sure if the lower limit and upper limit are in the right order. In the second pass, we focus on the logics and execution of the desired operation for the language constructs.

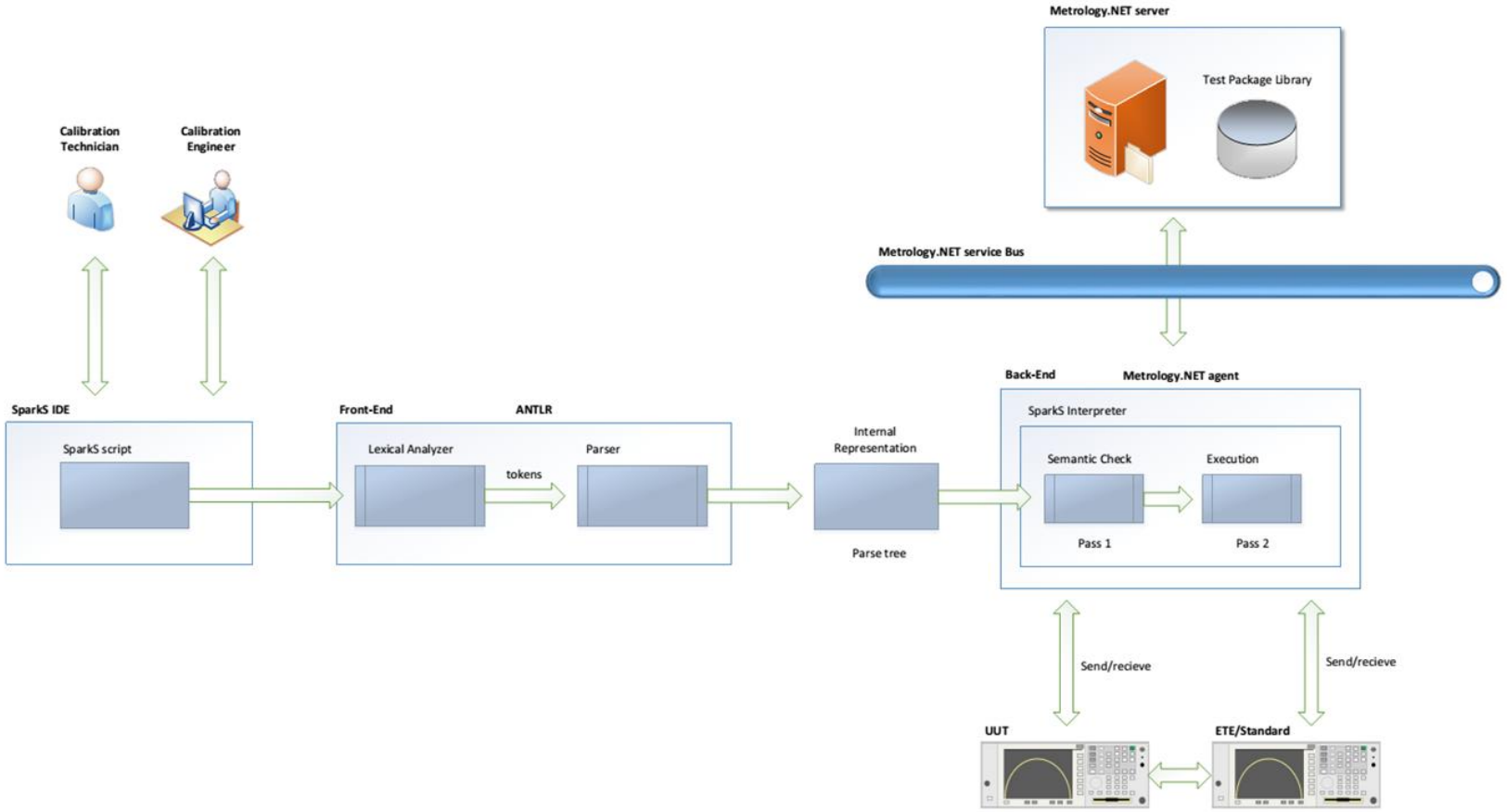


Figure 4.1 Embedding SparkS interpreter into Metrology.NET system

4.1 SparkS Front-End

For our language development, ANTLR (ANother Tool for Language Recognition) tool was considered to be used along the whole process [5]. ANTLR is a powerful parser generator that is used for reading, processing, executing, or translating structured text. It's widely used to build languages, tools, and frameworks. From the grammar given as input, ANTLR generates a parser and also parse tree listeners which are used for walking the generated parse tree. The lexicon used in ANTLR tool is similar to C with some extensions to support grammatical descriptions. ANTLR-generated parsers build a data structure called parse tree or syntax tree which is also called as internal representation. An example parse tree and how it is created from the input is shown in figure 4.2. The front-end development of the language which is generating a parser is handled by the ANTLR tool. The back-end which embodies the semantics behind grammar rules can be developed using two different approaches in ANTLR, either by using Listener or by Visitor patterns.

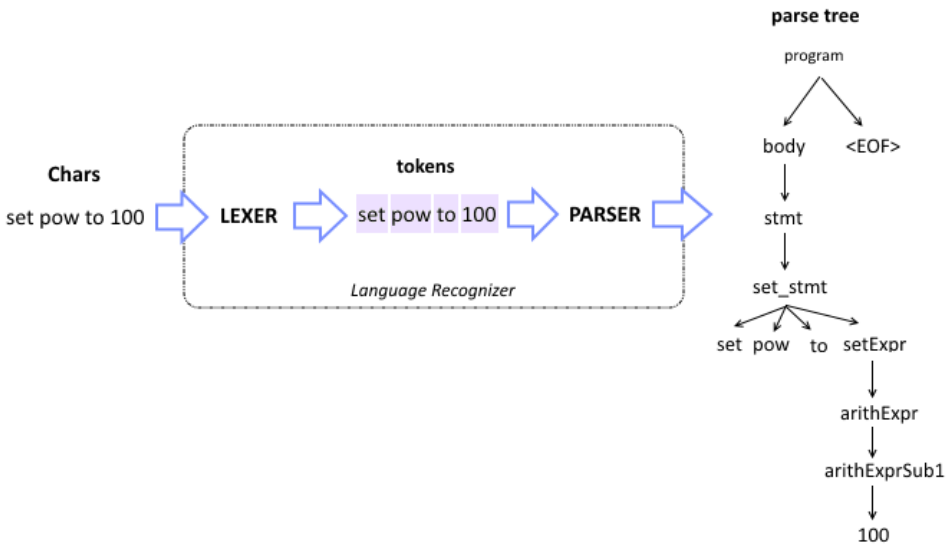


Figure 4.2 An example parse tree generated by the front-end

Listeners and visitors are useful in that they keep application-specific code out of grammars, making grammars easier to read and preventing them from being coupled

with a particular application. The biggest difference between the listener and visitor approaches is that listener methods are called independently by a tree walker provided by the ANTLR, whereas visitor methods must walk their children with explicit visit calls. Forgetting to invoke visitor methods on a node's children, means that those subtrees will not be visited.

Since Visitor pattern provides a better control on the generated parse tree over the listener pattern, we chose this mechanism. With the Visitor pattern, you get separate functions for each of the rules and labels in your grammar. The function provides the language implementer with the context parameter that allows him to access the parser and lexer rules of the current rule.

4.1.1 Interpretation *vs* Compilation

For the implementation of the language, basically there are two approaches, one is to develop a compiler and the other is to develop an interpreter. A compiler for a language translates the source code into the target machine which then will be used by the computer to run the machine code. On the other side, using interpretation, the source code is not run directly by the target machine, but a program called interpreter reads and executes the source code. There are some advantages and disadvantages for either of these approaches [22].

- Compiled code has higher running speed compared to interpreters because the code can be optimized for the target platform and there is no interpretation overhead.
- Interpreters tend to be more portable than compilers.
- Interpreted implementations of a language usually are easier to develop than compilers.

For SparkS, we chose to develop an interpreter for the language. Also, in calibration automation, computer systems are always interacting with equipment along a test, and this leads to a shared work load between the computer and equipment. Therefore, speed gained by compilation is not required in our targeted application area.

4.1.2 Communication Mechanism in Metrology.NET

Based on loosely-coupled software architecture, Metrology.NET relies on a mechanism called PostOffice. The Metrology.NET PostOffice System serves a role in Metrology.NET that is very similar to the role that the Windows Message Pump and Windows Messages serve in the Microsoft Windows Operating System [24]. The PostOffice system is intended to simplify the implementation of the Reactive Programming Model [25]. The PostOffice system sends messages in the form of PostOffice.Mail objects to PostOffice.Box objects [32]. A PostOffice.Box object will direct incoming Mail messages to a list of standard events as well as custom definable events that the box can define and subscribe to.

For every object that is instantiated, a thread is created, so objects resides on different threads at runtime, and as the job with an object is done, its thread exits at that point. For the communication between two objects, there is no direct call from one object to the other. Instead, the PostOffice mechanism is used. The PostOffice system, on its basic form provides calls of the following form:

```
PostOffice.Send(SenderAddress, RecieverAddress, MessageType, Message)
```

In which the first parameter refers to the sender's PostBox address, the second is for the receiver's PostBox address, the third parameter shows the message type that is defined by the user and the message itself.

Metrology.NET offers a wrapper mechanism called MessageLinker to cover the PostOffice system, which leads to an easier to use programming interface for the objects to be called. Different operations that can be done on the target class are put into the wrapper to provide Intellisence for the programmer. As an example, the following code can be used to call different functions through the same interface provided by the wrapper, sending the function name as the parameter. Here Analyzer has the reference to the target class MessageLinker object. MarkerAmplitude is the function to be called.

```
Dim Measured As Double = Analyzer.FunctionCall("MarkerAmplitude")
```

Based on the architectural choices of Metrology.NET such as the fact that the communication among objects takes place through the use of PostOffice system or the wrapper for it, MessageLinker mechanism, we decided to embed our interpreter into the platform as shown in figure 4.3. Basically, the main logic for the interpretation resides inside the implemented visitor class which is shown in red in the diagram. The green boxes represent the MessageLinker classes used by different system resources to communicate. The gray box at the top shows the SparkS script loaded by the TestProcessScript which will be used in the visitor class. The blue box shows the agent class that is actually the main class on an agent to manage calibration tasks on the agent.

Testing agent, the executable that sits on the terminal and runs the tests knows has interface only with the TestProcess class and initiates the process through this class. So, all the pretest settings and configurations are done before this call and the data (test group) for the chosen test inside the work order comes into the called test process as a parameter. Our visitor class or SparkS script engine uses the messageLinker of TestProcessScript class to talk to other resources in the platform as indicated in figure 4.3. TestProcessScript itself inherits TestProcess base class that is known by the agent.

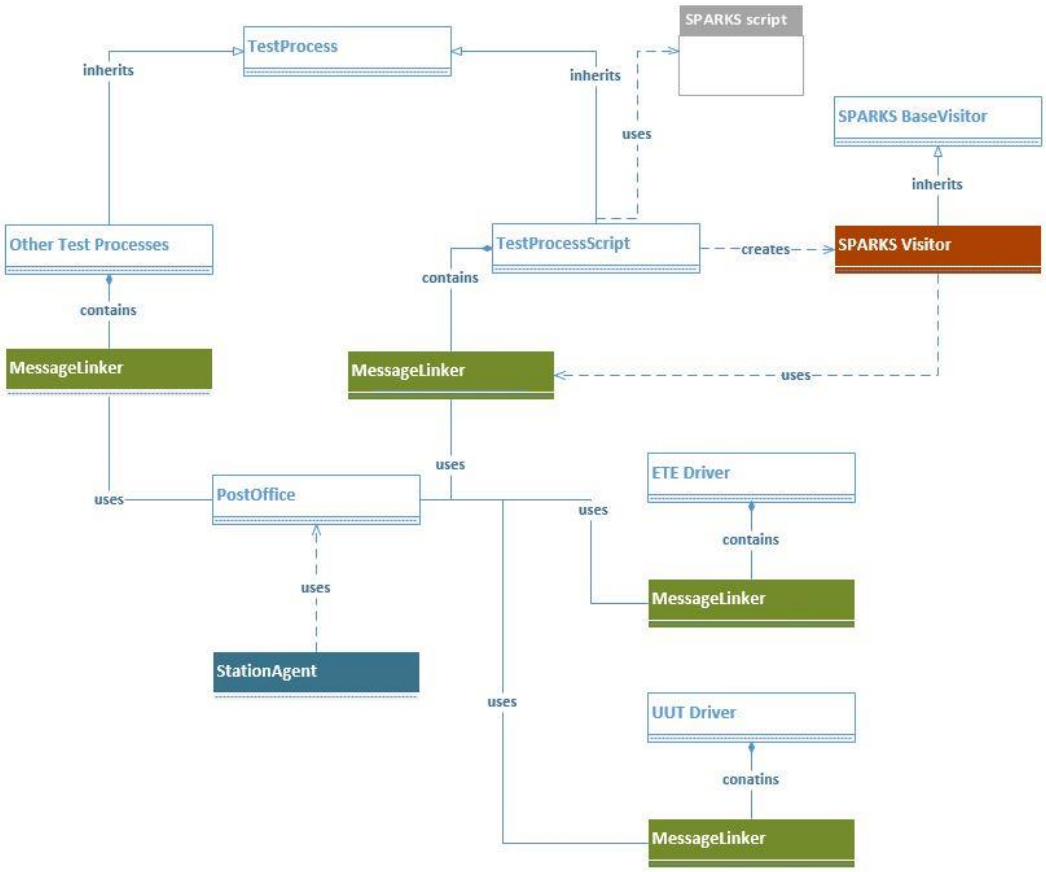


Figure 4.3 Metrology.NET and SparkS interpreter

ANTLR tool, reading the supplied grammar, if chosen, also generates a baseVisitor class as a result, beside the lexer and parser classes. The generated visitor class provides a tree walker mechanism for the parse tree generated by the tool. Based on how you want to implement a rule in your grammar, you may override the regarding visit method in the baseVisitor class. If you do not put any implementation for the rules in grammar, the tree will be walked with no specific result at the end. SparkS Visitor shown in figure 4.3 refers to the class that is extending the baseVisitor generated by the tool.

4.2 SparkS Back-End

In this section a detailed description of the language processor back-end or in our case the interpreter and its parts will be discussed. Basically, the interpretation job is done through the use of a visitor class that is supplied by the ANTLR tool. For each of the rules in the SparkS grammar a regarding visit method is generated that can be overridden. Depending on how complicated a rule might get, there may be several choices to be made with the parser. For each of the choices for a rule, you can add labels to the grammar to access to sub-rules.

As we had discussed in 2.3, Metrology.NET follows a specific software hierarchy. Figure 4.4 shows how SparkS interpreter replaces the two topmost layers. In SparkS we merge the two layers, MSB layer (Test Process layer) and Measurement Process Driver, and this is basically because we had a significant reduction in the amount of code needed to be written for a test procedure. Having a single layer seems to work well, but extending the interpreter to support a modular structure should be considered as a future plan too.

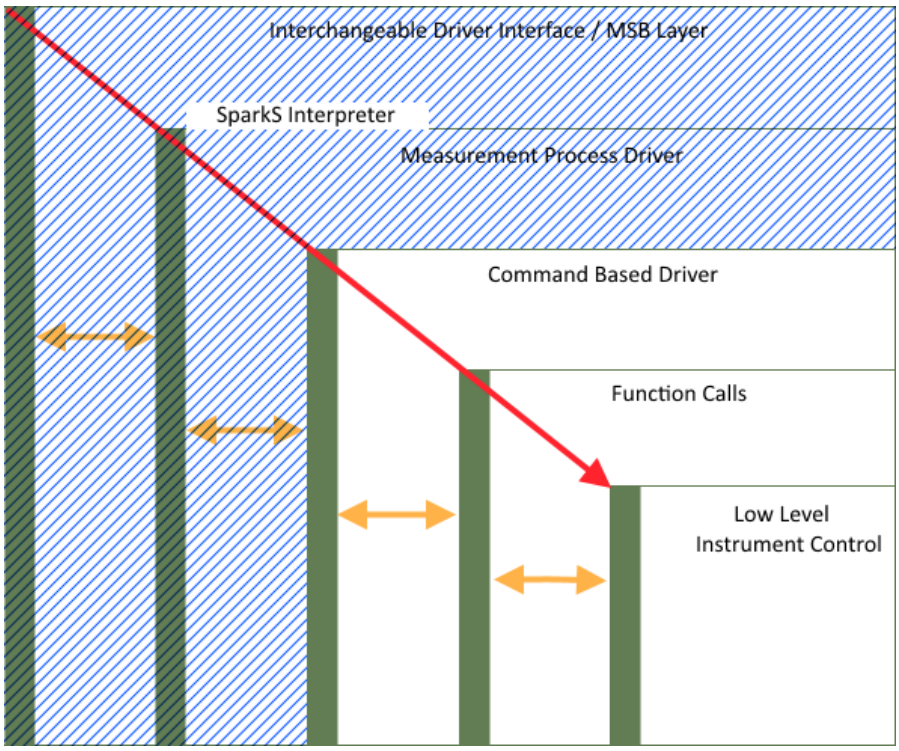


Figure 4.4 SparkS Interpreter position in the Metrology.NET software hierarchy

4.2.1 Return Type

The first step to take in implementing the visitor class is defining the global return type for your methods which goes in the header of the class definition. By this definition, all the visit methods must return values of the specified type.

Since there were different types that could be returned back by different rules, for handling the return values uniquely we designed the Value class to be our return type that plays as a wrapper for the different types such as String, Double and Boolean used in our grammar. This way, methods return values wrapped with this type and the caller method, using the casting functions provided inside the Value class, converts the received value into the appropriate type based on the context that is used. In the following code sample you can see how this is done:

```
Value left = this.Visit(context.boolExprSub(0));
Value right = this.Visit(context.boolExprSub(1));
return new Value(left.asBoolean() || right.asBoolean());
```

As can be seen in the first two lines, the result of visiting the two sub expressions result in left and right values that also are of Value type. The variables are then converted into the appropriate type, which is Boolean in this case, and after the calculation is done, then again the result is wrapped by the Value type to be returned to the calling method.

4.2.2 Bindings

For a test to run, there are some preparation steps that must be taken in order to be able to initiate the test. For example, the equipment on which test will be run or UUT, and all the other equipment that play role in evaluating the performance of UUT, namely ETE(s), the test point type to be used in the test, and the test group that will be used as the data for the test process. For this purpose, we defined a header section for SparkS scripts that covers these preparations.

4.2.3 The *require* Statement

The require statement is the starting point for a header. It will include the list of all the equipment that will be used along the test as resources. By providing the two parameters in this statement, Metrology.NET provides us with the messageLinker reference to use to talk to that resource.

It has two forms in general. One including the linker type and test type, whose parse tree can be seen in figure 4.5. Resource type is a conventional name used by Metrology.NET to classify its resources. The test type contains the interface implemented by the driver of that resource.

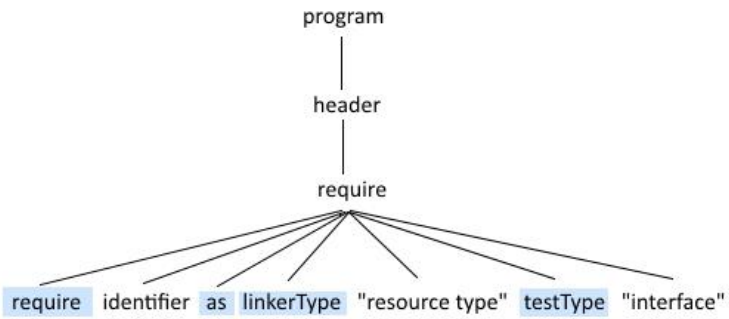


Figure 4.5 require statement type-1 parse tree

The second type of require statement only includes the linker type as shown in figure 4.6. This is used to define the UUT. By this, we can get the reference to the UUT resource we want to communicate with through the Metrology.NET platform.

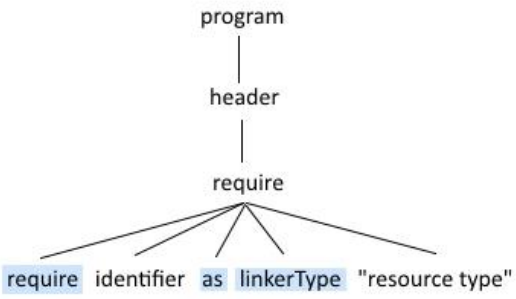


Figure 4.6 require statement type-2 parse tree

In the code block provided below, you can see how a list of different member types, namely methods, functions and properties, for the interface types provided in the script header as resources are created. In the code below, the list is created for the *iSpectrumAnalyzer* interface.

```
eteCallableMembers = new List<KeyValuePair<string, string>>();

List<string> interfaceList = new List<string>();
var driver = typeof(Driver);

Type[] list = driver.GetInterfaces();
foreach (Type t in list)
{
    if(t.FullName.Contains("CLS_V1")&&
t.Name.Equals("iSpectrumAnalyzer"))
        interfaceList.Add(t.AssemblyQualifiedName);
}

foreach (string interf in interfaceList)
{
    //add the method list
    foreach(var m in
Type.GetType(interf).GetMethods(BindingFlags.Instance |
BindingFlags.Static | BindingFlags.Public |
BindingFlags.NonPublic).Where(m => !m.IsSpecialName))
    {
        if(m.ReturnType.Name == "Void")
            eteCallableMembers.Add(new
KeyValuePair<string,string>(m.Name, "method"));
        else
            eteCallableMembers.Add(new
KeyValuePair<string,string>(m.Name, "function"));
    }

    //add the property lis
    foreach (var m in Type.GetType(interf).GetProperties())
    {
        eteCallableMembers.Add(new KeyValuePair<string, string>(m.Name,
"property"));
    }
}
```

4.2.4 The *bind* Statement

The bind statement is used to assign test specific properties and make a binding to the Metrology.NET. The binding can be done either to a string literal, statically, or to prompt, dynamically. In the case of prompt, the binding is delayed to runtime to be

selected or entered by the user. Figure 4.7 shows the general format for the parse tree of a bind statement using prompt keyword.

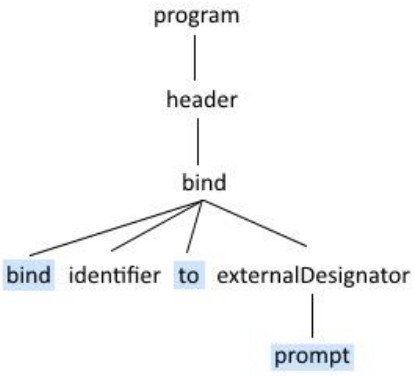


Figure 4.7 bind statement type-1 parse tree

The other form of binding is done with a string literal as shown in figure 4.8.

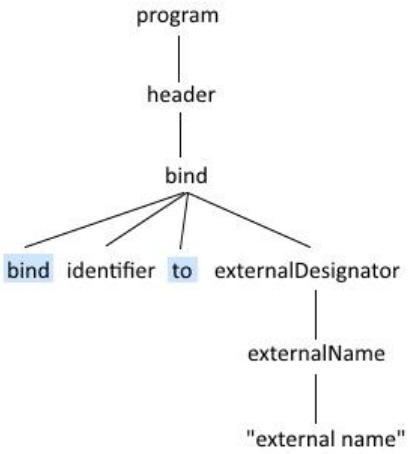


Figure 4.8 bind statement type-2 parse tree

TestProcessScript class has all the properties, such as test name, test type, unit of measure, etc. for each script to be assigned. For each script an object of TestProcessScript class is instantiated, whose properties are assigned according to the ones provided in the script.

4.2.5 The *testPoint* Declaration

A test point contains all the data needed for a cycle of test to be done. The parameters that are needed for both UUT and ETE along the test are put into a test point. This means that for running a test, there must be a match between the test point as input data and the test process that includes the test procedure for a test. Based on this fact, we designed a structure as test point type. A test point type structure consists of two parts: One is the *provide* part that contains the parameters that are expected to come in test points. The other is the *measure* part that contains the only parameter that the test will measure. The *provide* ids are compared against the ones in the provided test points as they come from the Metrology.NET server and then added to the memory for later access. In the parse tree shown in figure 4.9, you can see the three parameters in the *provide* section and the one *resultParam* in the *measure* part.

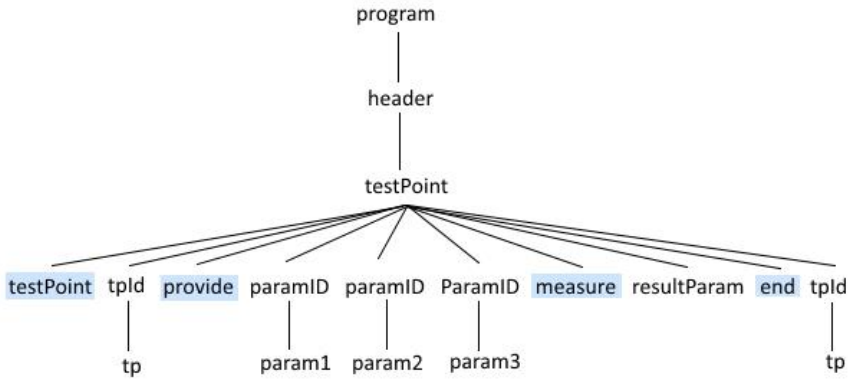


Figure 4.9 testPoint statement parse tree

Below, you can see some code snippet from the implementations done for this construct. As can be seen in Figure 4.9, *tpId* identifiers refers to the begin/end identifiers that comes in the type declaration. They're checked at the first pass to make sure they match. Also, in the first tree visit, the type checking of the coming test points against the ones in the *provide* section in the declared test point type is done. In the second pass, since the checks are already done, it is now safe to add the provided variables into the memory as shown below:

```
string beginID = context.tpId(0).ID().GetText();
string endID = context.tpId(1).ID().GetText();

int paramIDCount = context.paramID().Length;

string[] provIDlist = new string[paramIDCount];

for (int i = 0; i < (paramIDCount); i++)
{
       provIDlist[i] = context.paramID(i).ID().GetText();
}

//add the 'provide' data to memory
tPointProvide.Add(beginID, provIDlist);

//add the 'measure' data to memory
string measureID = context.ID().GetText();
tPointMeasure.Add(beginID, measureID);
```

4.2.6 The *testGroup* Statement

After the test point type is declared, we can define test group variables with different test point types. These variables are used in the looping for test points to access the test points in the collection. In the parse tree in figure 4.10, *tgCollection* refers to a list of test points of type defined by tp. The *testGroup* keyword in this context has the meaning of a test group concept in Metrology.NET.

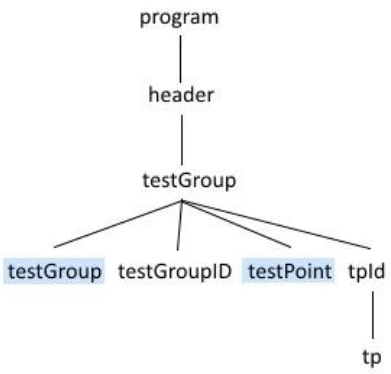


Figure 4.10 testGroup statement parse tree

In the code block given below, it is shown that after the regarding identifiers are extracted from the input script, they are added to the memory, in a way that they can be accessed at other parts of the interpreter. For the *testGroup* construct, the *testPoint* type identifier is checked to make sure it has been declared already.

```
string tGroupID = context.ID().GetText();
string tPointTypeID = context.tpId().ID().GetText();

//add the test group, test point ID to memory
tGroup_tPointType.Add(tGroupID, tPointTypeID);

//add the test group, test point array list to memory
tGroup_tPoints.Add(tGroupID, tpArray);
```

4.2.7 The *set* Statement

The *Set* statement is one of the most variant structures in SparkS, since it can support different forms of assignments. Figure 4.11 shows an example *set* statement of the following form:

```
set id to value
```

Where, *id* is an identifier that might not exist which gets defined here. The value is set from a string value or from an arithmetic expression.

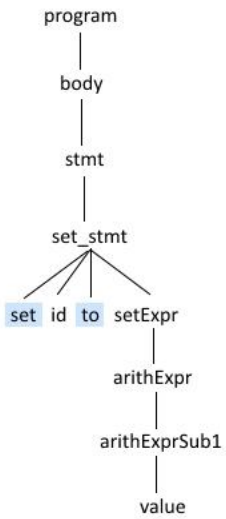


Figure 4.11 set statement parse tree type-1

The value to be set in set statements are defined as a sub-rule in the grammar. You can find the complete grammar in Appendix A. In the code below, you can see that

after visiting the sub-rule *setExpr*, its returned value is set to a local variable. The ID refers to the only id in the rest of the statement.

```
//extract value form the setExpr
Value value = this.Visit(context.setExpr());

//extract the ID name
String id = context.ID().GetText();
```

Since the test result is also set through the use of set statement, we should check that in the rule implementation. The unit of measure is checked in the first tree visit for its existence. Here in the second visit, after the parameter for the *measure* section of the test point type is extracted, it is checked against the identifier in the *set* statement. If they match, the measurement result for the current test point is sent back to the server.

```
//check if you're inside a test point loop
if (testPointLoopVar.Key != string.Empty && testPointLoopVar.Key !=
null)
{
    //read the top of stack to find tpCollectionID
    string tpCollectionID = testPointLoopVar.Value;

    //using tpCollectionID, get test point type ID
    string tpTypeID = tGroup_tPointType[tpCollectionID];

    //using test point type ID, get its 'measure' var
    string tpMeasure = tPointMeasure[tpTypeID];

    //compare the ID name with 'measure' param to see if it's the test
result
    //if they're the same, save the test result back to the server
    if (id.Equals(tpMeasure))
    {
        MeasurementResult measResult = new
MeasurementResult(value.asDouble(), UnitOfMeasure, uncertainty);

        result.Measured = measResult.Value;

        //upload the result to the server
        tProcess.SaveTestResults(result);
    }
}
```

In the code block given below, you can see that how the identifier is looked for inside the global memory. If it does not exist in the memory, it is implicitly defined here and added to the memory.

```
//if variable exist in memory
if (memory.ContainsKey(id))
{
    //put the value
    memory[id] = value;
}
else // if variable not exist in memory, implicit declaration
{
    //add the id with the value
    memory.Add(id, value);
}
```

Another form of *set* statement is of the form:

```
set id.member to value
```

Where *id* can refer to an equipment variable that is used in the test as a resource. The value is set from a string value or from an arithmetic expression.

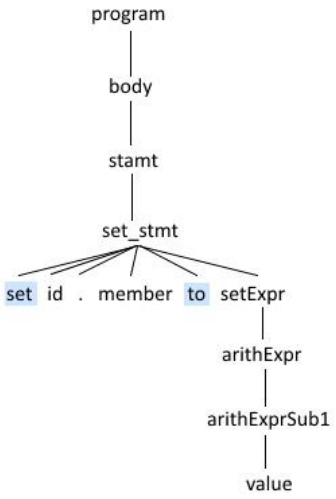


Figure 4.12 set statement parse tree type-2

Based on what user defines in the *require* statement in the script header as the required resources for the test, a list of members for that resource is generated, so that in the assignments it is checked against this list to find out to which category the member in the *set* statement belongs. The member in this type of statement can only be a property of that resource. This is checked in the first pass in the interpreter. The code snippet given below shows the action that takes place in the second pass:

```
//extract value form the setExpr
Value value = this.Visit(context.setExpr());

// ID(0) must be an instrument value, since the value for a test point
can not be set.

String id = context.ID(0).GetText();

//set the value that comes from setExpr to ID.ID in the rule

string attrName = context.ID(1).GetText();

bool wasSet = Analyzer.SetProperty(attrName, value.asString());

//if the property was not set
if (!wasSet)
    throw new Exception("property was not set!");
```

Another form of *set* statement is of the form:

```
set id1 to id2.member
```

Where, the id_1 is an identifier that might not exist which then gets defined here. The id_2 can be either a test point variable, which then the interpreter will check for its parameters, or may be an id belonging to a resource. In this case, the member is either a property or a function in the resource driver. The interpreter gets lists of functions, methods and properties for the driver of all the resources at the beginning of the execution. This is done through the use of Reflection [35] and reading the interface that is provided in the *testType* filed of the require keyword for every resource that is added to the test script. The lists are used here to check to which list the member in the statement belongs to. If it belongs to none of them, then it gives an error.

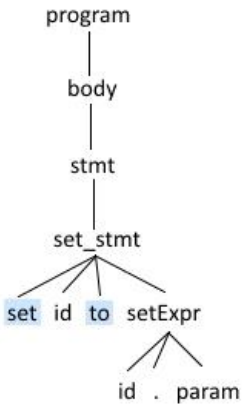


Figure 4.13 set statement parse tree type-3

In the code block below, it is checked to see if the id_2 is the test point identifier in the for loop statement. If that is the case, then it is checked for the member in the test point parameters. If the parameter is found, its value is set as indicated in the last if statement.

```
//ID(1) can be a test point or an equipment attribute
string attrName = context.ID(1).GetText();

//check if ID(0) is a test point
string IDName = context.ID(0).GetText();

string idValue = null;
//if ID(0) is equal to the test point loop ID
if (testPointLoopVar.Key != string.Empty && testPointLoopVar.Key !=
null)
{
    if (testPointLoopVar.Key.Equals(IDName))
    {
        //check if ID(1) is a test point parameter
        if (tPoint != null)
        {
            foreach (Parameter p in tPoint.ParameterArray)
            {
                if (attrName.Equals(p.Name))
                {
                    //get the value from the test point parameter
                    idValue = p.Value;
                    break;
                }
            }
        }
    }
}
```

It is also possible for the id_2 in the set statement to be an instrument property or function. Here again, as can be seen in the code block given below both of the property and function categories in the memory for the resource are checked to see which one is the right match.

```
//define variables
string propertyValue = null;
string funcValue = null;

//check if ID(1) is an ETE property
if (eteCallableMembers.Contains(new KeyValuePair<string,
string>(attrName, "property")))
{
    propertyValue = Analyzer.GetProperty(attrName);
}
//check if ID(1) is an ETE function
else if (eteCallableMembers.Contains(new KeyValuePair<string,
string>(attrName, "function")))
{
    funcValue = Analyzer.FunctionCall(attrName);
}
```

The last form for the *set* statement is as follows:

```
set id1.member to id2.member
```

The general form of how a parse tree for this statement looks like is shown in figure 4.14. Both of the parts in this statement type were explained in the other set statement types.

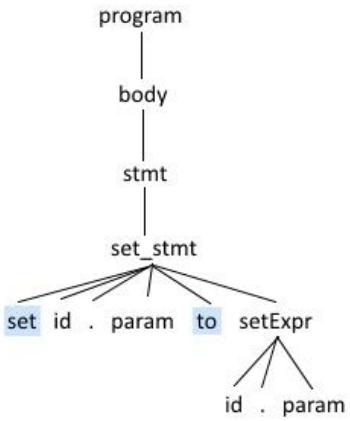


Figure 4.14 set statement parse tree type-4

4.2.8 The *constant* Declaration

The concept of constant variables seemed to be useful in the context of test procedures, since you always encounter variables that you want to keep their values fixed along the test process, so it was added to the language. The main task is to put the variable that comes in the statement into memory for later access, but with the difference that it won't be allowed in set statements. The general form of how a parse tree for this statement looks like is shown in figure 4.15.

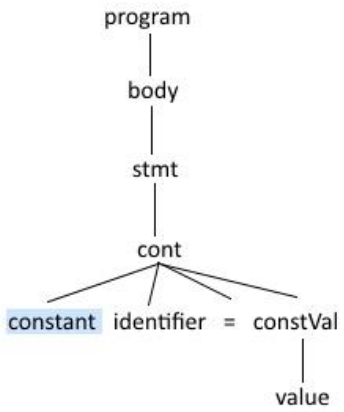


Figure 4.15 constant statement parse tree

Below, you can see how a constant variable is defined and added to the memory. Also, you can see the return type here, which is used for those rules that there is no expecting return value for them.

```
string ID = context.ID().GetText();
Value constValue = this.Visit(context.constVal());

//add the value to the list
constList.Add(ID, constValue);

//return base.VisitConst(context);
return Value.VOID;
```

4.2.9 The Function Call Statement

Function calls are usually done for either UUT or ETE in a test. Since the driver for UUT has pushed the variation into test points, that's why there are fixed number of operations to call from a UUT driver. The general form of how a parse tree for this statement looks like is shown in figure 4.16.

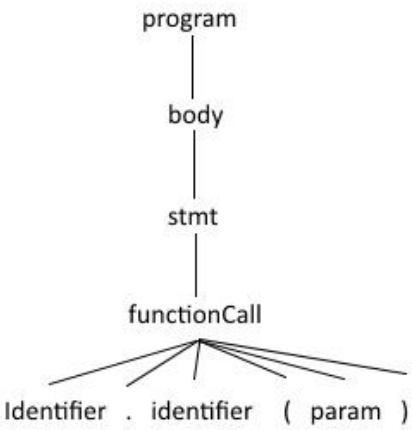


Figure 4.16 function call statement parse tree

As explained already, at the beginning of the interpretation we prepare a list of members for instrument drivers. Since a function call can be either of type function or method, the string that comes in the script as a function is checked against these lists to find a match. The code snippet below shows this.

```
if (eteCallableMembers.Contains(new KeyValuePair<string,
string>(attrName, "function")))
{
    //treat ID(1) as an ete function call
    string returnValue = Analyzer.FunctionCall(attrName);
}
else if (eteCallableMembers.Contains(new KeyValuePair<string,
string>(attrName, "method")))
{
    //treat ID(1) as an ete method call
    bool wasCalled = Analyzer.MethodCall(attrName);
}
```

Also, as explained, we have a fixed number of functions for UUT to call as shown below:

```
//check to see if ID(1) is a uut call
if (attrName.ToUpper().Equals("reset".ToUpper()))
    msg = UUT_Source.Reset();
else if (attrName.ToUpper().Equals("enable".ToUpper()))
    msg = UUT_Source.Enable();
else if (attrName.ToUpper().Equals("disable".ToUpper()))
    msg = UUT_Source.Disable();
```

4.2.10 The *for each* Loop

4.2.10.1 The *testPointLoop* Statement

We have looping for two different data types: One is to support looping on the collection of test points of a test group, and the other is to support looping in a range from a lower to an upper limit which is shown in the next statement. Since we do not support nested looping for test points, we keep a single global memory to store loop variables which comes in a *keyValuePair*. There are times user wants to halt the test execution through the Metrology.NET user interface, so we have to frequently check for the halt flag from the *TestProcess* class to make sure if it is ok to continue the process. The general form of how a parse tree for this statement looks like is shown in figure 4.17.

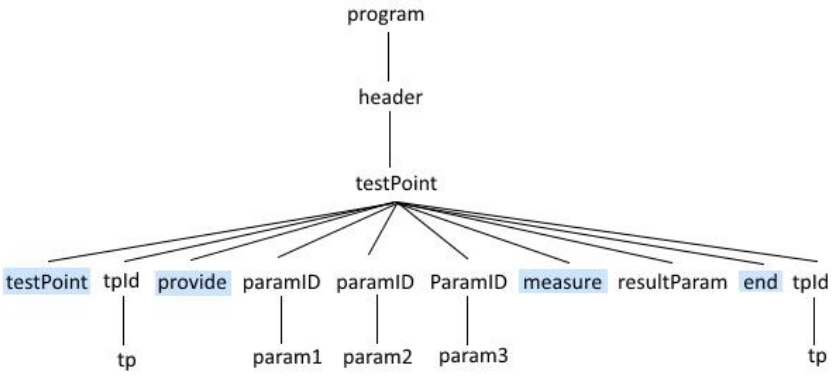


Figure 4.17 *testPointLoop* construct parse tree

As can be seen in the code given below, first the identifiers are extracted from the loop statement. The test point collection must have already been declared, which otherwise we would've encountered an error in the first visit of the parse tree. Here in the second visit, the *foreach* loop goes through all the test points in the list registered with the defined test point collection. For the result to be created for a test point, we must define a *TestResult* object passing the test point reference to it. After that, UUT setup is completed here by passing the test point object to it. There, inside the UUT driver, all the related parameters for the received test point are extracted and sent to the defined UUT. The last line in the *if* construct is used to ask the visitor class to process that rule.

```
//get the ID(0), the variable of the loop
string tpID = context.ID(0).GetText();

//check that the test-point-collection has value
string tpCollectionID = context.ID(1).GetText();

//set the test point Loop variable
testPointLoopVar = new KeyValuePair<string, string>(tpID, tpCollectionID);

foreach (TestPoint tp in tGroup_tPoints[tpCollectionID])
{
    if (tProcess.HaltFlag == false)
    {
        //set the global test point to the current tp
        this.tPoint = tp;

        iTestPoint itp = tp;
        result = new TestResult(ref itp);

        //set up the UUT
```

```
        if (tProcess.HaltFlag == false)
        {
            UUT_Source.Setup(tp);
        }

        // evaluate the code block
        this.Visit(context.block());
    }
}

//empty the testpointLoopVar when done.
testPointLoopVar =new KeyValuePair<string,string>(string.Empty,
string.Empty);
```

4.2.10.2 The *rangeLoop* Statement

Looping on ranges follows almost the same structure as looping on test points, except the fact that here, instead of using a collection of test points to loop through, there is a range defined as [*lowerLimit*, *upperLimit*] that goes from the lower to the *upperLimit* inclusively. A general form of this looping construct is shown in figure 4.18.

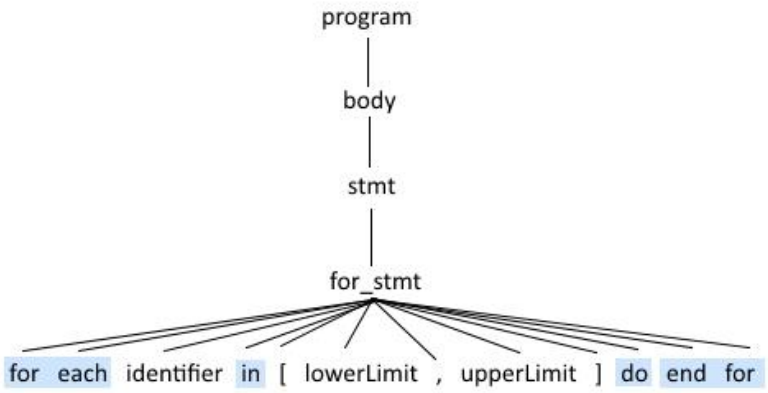


Figure 4.18 *rangeLoop* construct parse tree

As can be seen in the code block given below, after the looping variables are extracted from the script, the loop index is added to the global memory so that it can be accessed to, from the statements inside the loop block. Inside the loop, the index gets updated in the memory as index moves from the defined lower to upper limit.

Then the statement block for the loop is processed by visiting the block sub-rule. Before this pass of the interpretation, in the check pass, the limits have been checked to see if the lower and upper limits are in the right order.

```
//extract loop index
string index = context.ID().GetText();
//get the lower limit for range
Value lowerLimit = this.Visit(context.limitVar(0));
//get the upper limit for range
Value upperLimit = this.Visit(context.limitVar(1));

int lowerLimitValue = lowerLimit.asInt();
int upperLimitValue = upperLimit.asInt();

//add loop index into memory
memory.Add(index, lowerLimit);

for (int i = lowerLimitValue ; i <= upperLimitValue ; i++)
{
    //update for index in the memory
    memory[index] = new Value(i);

    this.Visit(context.block());

}

//remove the for loop value from the memory when done.
memory.Remove(index);
```

4.2.11 The *if-then-else* Statement

For the conditional *if* statement, the conditions for if clause and each of the else if clause(s) are checked and if one meets, its statement block will be run. At the end, a control is done to see if any condition before the else clause resulted in true. If there was none and there exist an else clause, then its statement block is called. You can see a general form of an *if* statement with no statements in the clauses in figure 4.19.

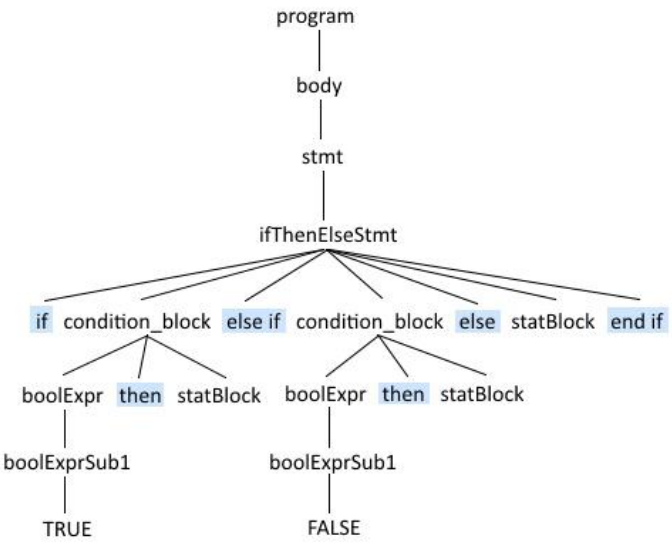


Figure 4.19 *if-then-else* statement parse tree

And below comes the code snippet implemented for the *if* construct.

```
SparkS_v1Parser.Condition_blockContext[] conditions =
context.condition_block();

bool evaluatedBlock = false;

foreach(SparkS_v1Parser.Condition_blockContext condition in conditions)
{

    Value evaluated = this.Visit(condition.boolExpr());

    if(evaluated.asBoolean()) {
        evaluatedBlock = true;
        // evaluate this block whose expr==true
        this.Visit(condition.stat_block());
        break;
    }
}

if(!evaluatedBlock && context.stat_block() != null) {
    // evaluate the else-stat_block (if not null)
    this.Visit(context.stat_block());
}
```

For the Boolean operators, the below code is used for processing the two operands that exist in the statement. Since, the operator has been checked in the first

interpretation pass, it is then assumed to be one of the cases mentioned in the *if* statement.

```
Value left = this.Visit(context.arithExpr(0));
Value right = this.Visit(context.arithExpr(1));

string op = context.op.Text;

if (op.Equals("<"))
{
    return new Value(left.asDouble() < right.asDouble());
}
else if (op.Equals("<="))
{
    return new Value(left.asDouble() <= right.asDouble());
}
else if (op.Equals(">"))
{
    return new Value(left.asDouble() > right.asDouble());
}
else if (op.Equals(">="))
{
    return new Value(left.asDouble() >= right.asDouble());
}
else if (op.Equals("="))
{
    return new Value(left.asDouble() == right.asDouble());
}
else if (op.Equals("/="))
{
    return new Value(left.asDouble() != right.asDouble());
}
```

And for the four arithmetic operators supported by the language, the code below shows how the processing for addition and subtraction operators is handled. The same logic is used for the multiplication and division operators.

```
Value left = this.Visit(context.arithExprSub(0));
Value right = this.Visit(context.arithExprSub(1));

string op = context.op.Text;

if (op.StartsWith("+"))
{
    return new Value(left.asDouble() + right.asDouble());
}
else if (op.StartsWith("-"))
{
    return new Value(left.asDouble() - right.asDouble());
}
```

CHAPTER 5

SPARKS IN USE

This chapter is dedicated to the discussion of the calibration process based on the Metrology.NET platform, using SparkS. First, it will be shown how data for a test is added to the Metrology.NET server. We also will present our tool for data uploading to the server which is much more efficient. Then, we will discuss how the developed test processes are used at the agent side and how an agent registers itself at the server with the list of test processes it can perform. After that, operations involving work order creation and start and how tests are run will be demonstrated. We will have a brief discussion on a programming editor for SparkS with a reference to the Geany editor. At the end, a detailed case analysis of a sample script written in SparkS will be presented.

5.1 Calibration process based on Metrology.NET

From one point of view we can look at a calibration automation process take place in two phases: One is procedure development and data gathering for a test. The other is running the test and producing report for customer. On the manuals that accompany testing equipment, all the performance tests for the product are listed. Basically, these manuals are prepared for a manual testing of the product. They include all the data to be used during testing of these equipment in the provided procedures. They also include the testing procedure to be applied by technician to run the test.

First of all, the data needed for a test is added to the Metrology.NET server. This can be done through the web based user interface provided by Metrology.NET to support data manipulation and test control. As can be seen in Figure 5.1, you have to insert test points one by one to the database.

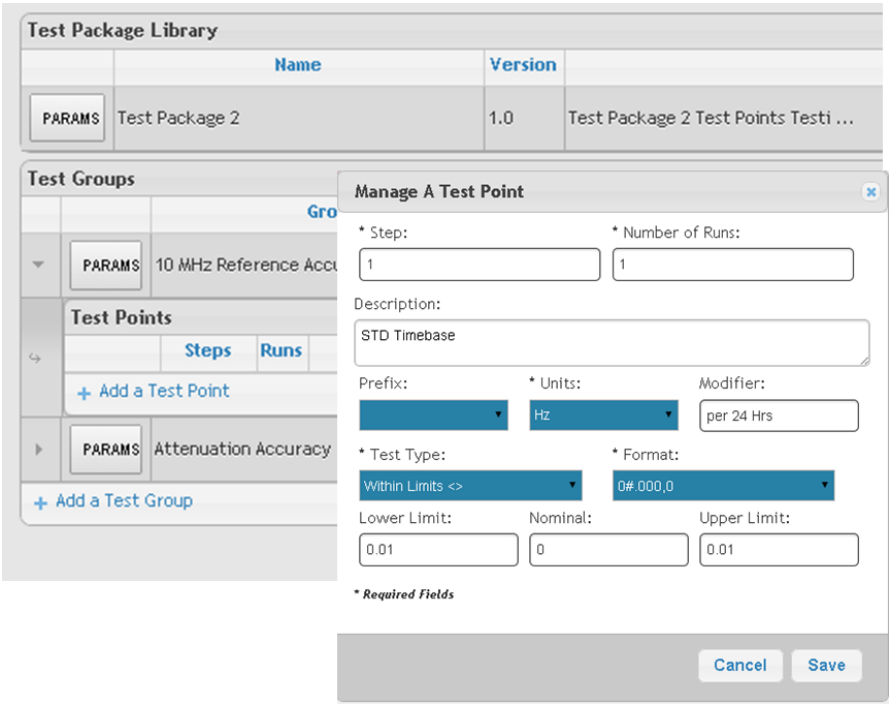


Figure 5.1 Adding a test point using Metrology.NET web interface

Test groups that consist of the data for a test may have hundreds of test points to be tested and manual adding of data to the system in the way offered by the Metrology.NET has a big time cost for the calibration personnel. To overcome this problem, a tool was developed that reads calibration data from Excel sheets and uploads to the server. A single Excel file is created for all the test groups for different tests for a test package, with separate sheets for each test group that contain test points for that test group. After the data is prepared in the format we have defined in Excel files, the tool is able to read all the data and upload it to the server which leads to a big time save for the user. A sample data sheet is shown partially in figure 5.2 that was filled based on the FM Accuracy performance test of the Agilent 8648X series [33].

TestGroupID	DF19ABF3-0A1C-499F-A948-11D0273610BF								
Name	FM Accuracy								
Description	FM Accuracy Performance Test Points								
IsLib	True								
TestType	TestProcess.Measure.FM.Modulation								
Command	Rate								
CommandID	1050CB1A-2254-4FA9-81E6-7A919FFE2FA9								
SCPI	FM:INT:FREQ [Value]								
Test Point Description	TestPoint ID	Sequence	Step Num	LowerLimit	Nominal	UpperLimit	Format	Modifier	TestType
1d	9A16A444-BAB1-4	1	1	4.82	5.00	5.18	#0.00		WithinLimits
2d	98CA779E-0897-4(	2	1	9.67	5.00	10.33	#0.00		WithinLimits
3d	1F967ED1-8A62-4(	3	1	9.67	5.00	10.33	#0.00		WithinLimits
4d	AB724F35-AF06-4	4	1	4.82	5.00	5.18	#0.00		WithinLimits
5d	909509AC-F83B-4,	5	1	4.82	5.00	5.18	#0.00		WithinLimits
6d	4BB69C27-65EC-4	6	1	9.67	5.00	10.33	#0.00		WithinLimits
7d	DBA2EDB0-D4A9-	7	1	9.67	5.00	10.33	#0.00		WithinLimits
8d	CBC46F91-E8BF-4,	8	1	4.82	5.00	5.18	#0.00		WithinLimits
9d	A43F1F58-C5D6-4	9	1	4.82	5.00	5.18	#0.00		WithinLimits
10d	E2322171-4606-40	10	1	9.67	5.00	10.33	#0.00		WithinLimits
11d	03D72494-30B2-4	11	1	9.67	5.00	10.33	#0.00		WithinLimits
12d	7BC83F76-4EEE-4	12	1	4.82	5.00	5.18	#0.00		WithinLimits
13d	CC5CBAF2-A018-4	13	1	4.82	5.00	5.18	#0.00		WithinLimits
14d	2AAC49D7-EFD7-4	14	1	9.67	5.00	10.33	#0.00		WithinLimits
15d	07050B34-75A3-4	15	2	4.79	5.00	5.21	#0.00		WithinLimits
16d	05A9D91E-5FA6-4	16	2	9.64	10.00	10.36	#0.00		WithinLimits
17d	B0377687-BE08-4	17	2	4.79	5.00	5.21	#0.00		WithinLimits
18d	5CD524CE-D2D9-4	18	2	9.64	10.00	10.36	#0.00		WithinLimits

Figure 5.2 An example Excel sheet showing partially a sample test group

Figure 5.3 shows a screenshot from the upload tool we developed in which it is shown that some of the test groups for a test package are chosen to be uploaded into the server whose identification is given in the lower part of the window.

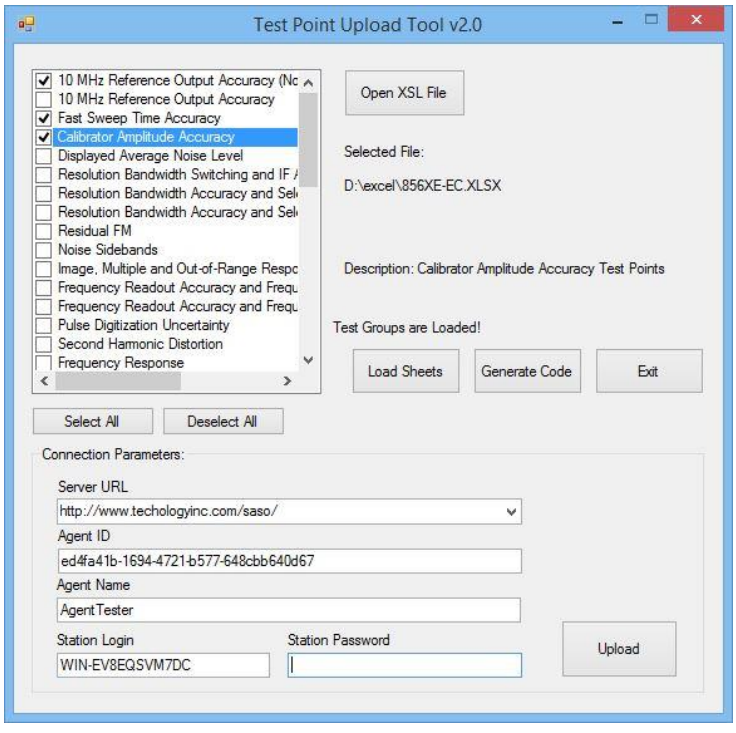


Figure 5.3 Our upload tool for selective test group uploading

After the test points got prepared and uploaded to the server, then test procedures should be prepared, which will use these data to run. Test procedures are developed based on Microsoft.Net framework in which test manuals are again used to extract the required steps to put into procedure. After the test procedures are programmed, they are compiled into class libraries to be used inside agents.

For each equipment or possibly a family of equipment, we will have separate class libraries that we put inside the agent machine on which tests will be run. Metrology.NET has an agent side executable that can read these libraries. A screenshot of the agent service interface is shown in figure 5.4. The user can choose the type of tests that are needed to be done and adds to the agent. The user then connects agent to the server. All the selected libraries for the agent are registered in the server so the server has knowledge about which tests an agent can run.

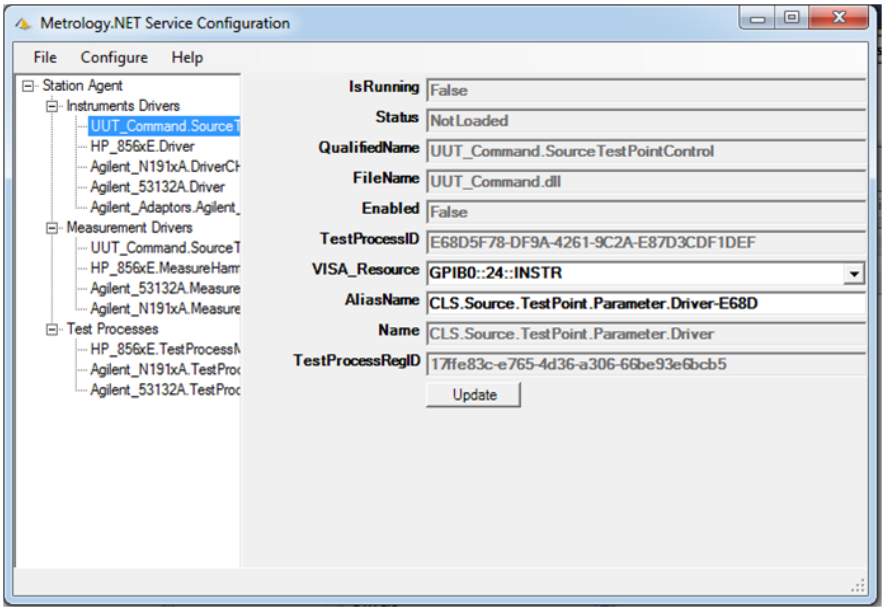


Figure 5.4 A screenshot of Metrology.NET agent service

As explained in 2.3, Metrology.NET follows a layered software hierarchy which basically consists of the three layers: Test process, measurement driver, and instrument driver. Each of these layers are independent from one another and they can be added separately through the Metrology.NET agent interface, as shown in figure 5.4. This is how developed test procedures operate in at the agent side of the

Metrology.NET. After the desired instances from different layers are added to the agent, they get registered each into the Metrology.NET server with that agent ID. This makes the server aware of the capabilities of the agent.

In the case of using SparkS on Metrology.NET, we have a single generic test process to be seen in this list, instead of different test instances from different layers. The variation is pushed into written scripts, so different scripts are developed for different testing purposes and are fed into the generic test process. A detailed scenario of how an agent is registered on the server is shown in figure 5.5.

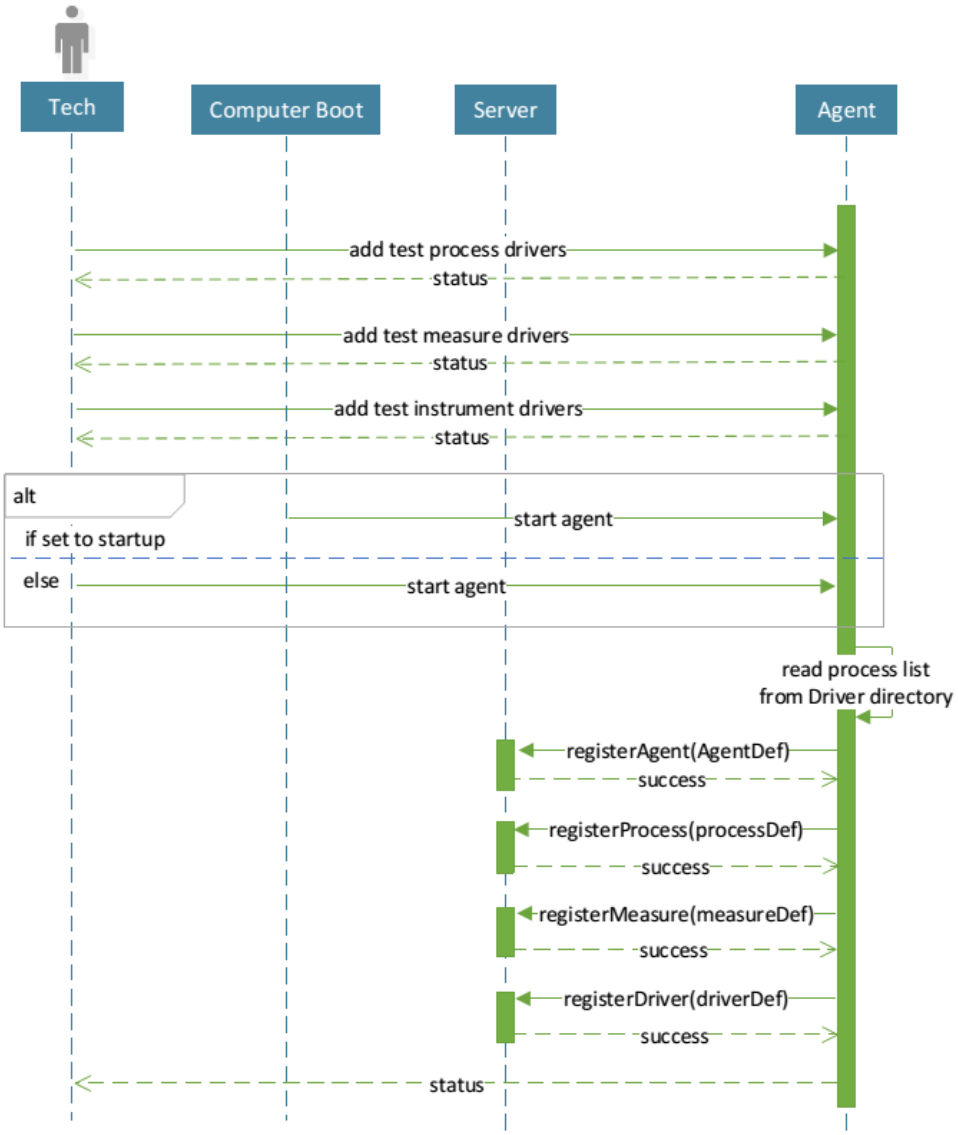


Figure 5.5 Register an agent in Metrology.NET

After the agent is registered on the server with its functionalities, it starts waiting for incoming job requests from the server. At the server side, using the service bus, user creates a work order out of the uploaded data for equipment. The user can choose which models and options he/she wants to include for testing. He/she then chooses the agent on which to run the test(s). There might be several different implementations for a test. The user can choose from a list of possible choices. A screenshot of open work orders screen shows performance test list created from HP 8648X series that can be seen in figure 5.6. By the ASSIGN button, the user is able

to assign the test process type that can be used to run this test. RUN button is used to start the test and the PARAMS button to show the parameter list for the selected test.

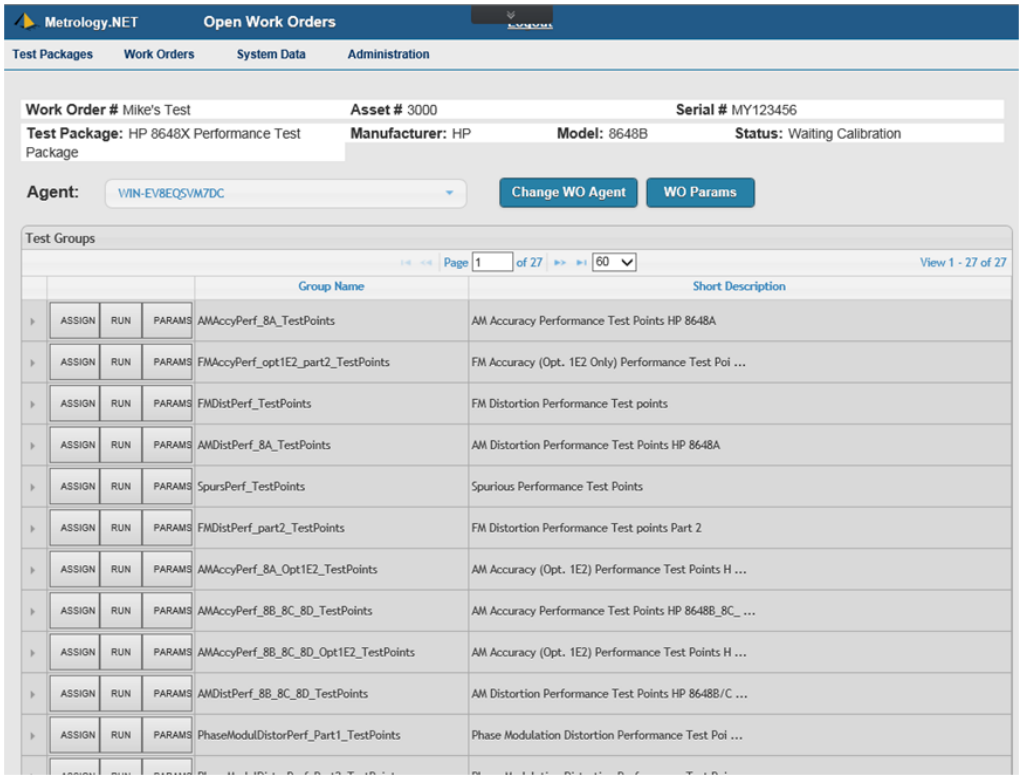


Figure 5.6 A screenshot from Metrology.NET web interface showing open work orders

Figure 5.7 shows the overall steps taken to create the data and work order for a test package.

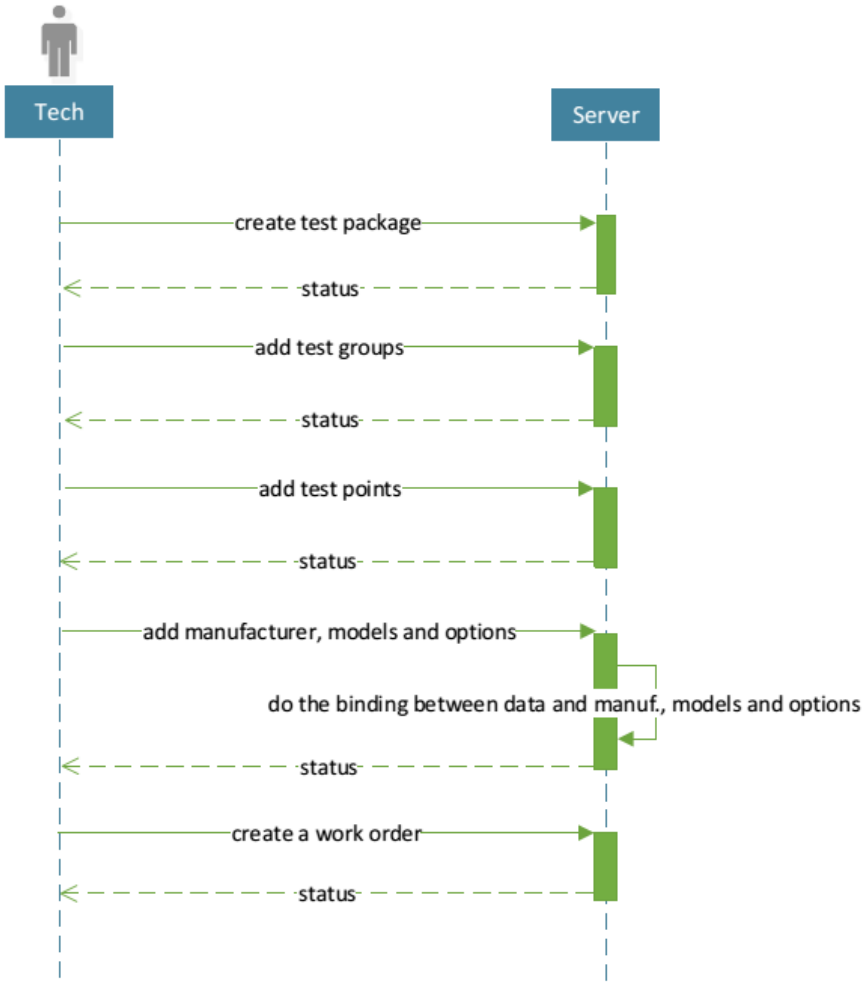


Figure 5.7 Create test package and work order

After all these are set, the user starts the calibration. At this point, server starts sending the required test points for that test to the agent. The agent then directs the coming test points to the target test process that will run the test. The test process will process the test points, sending the appropriate commands to the equipment involved in testing. The results coming back from the equipment are processed and the final result for a test point is sent back to the server as the test result for that test point. For the results received from the agent, the server decides if a test point passes or fails and records it into the database. The user can choose to produce a calibration report after all the test points are done testing. Figure 5.8 shows the sequence diagram that gives a detailed scenario of how a work order is started and a test is run.

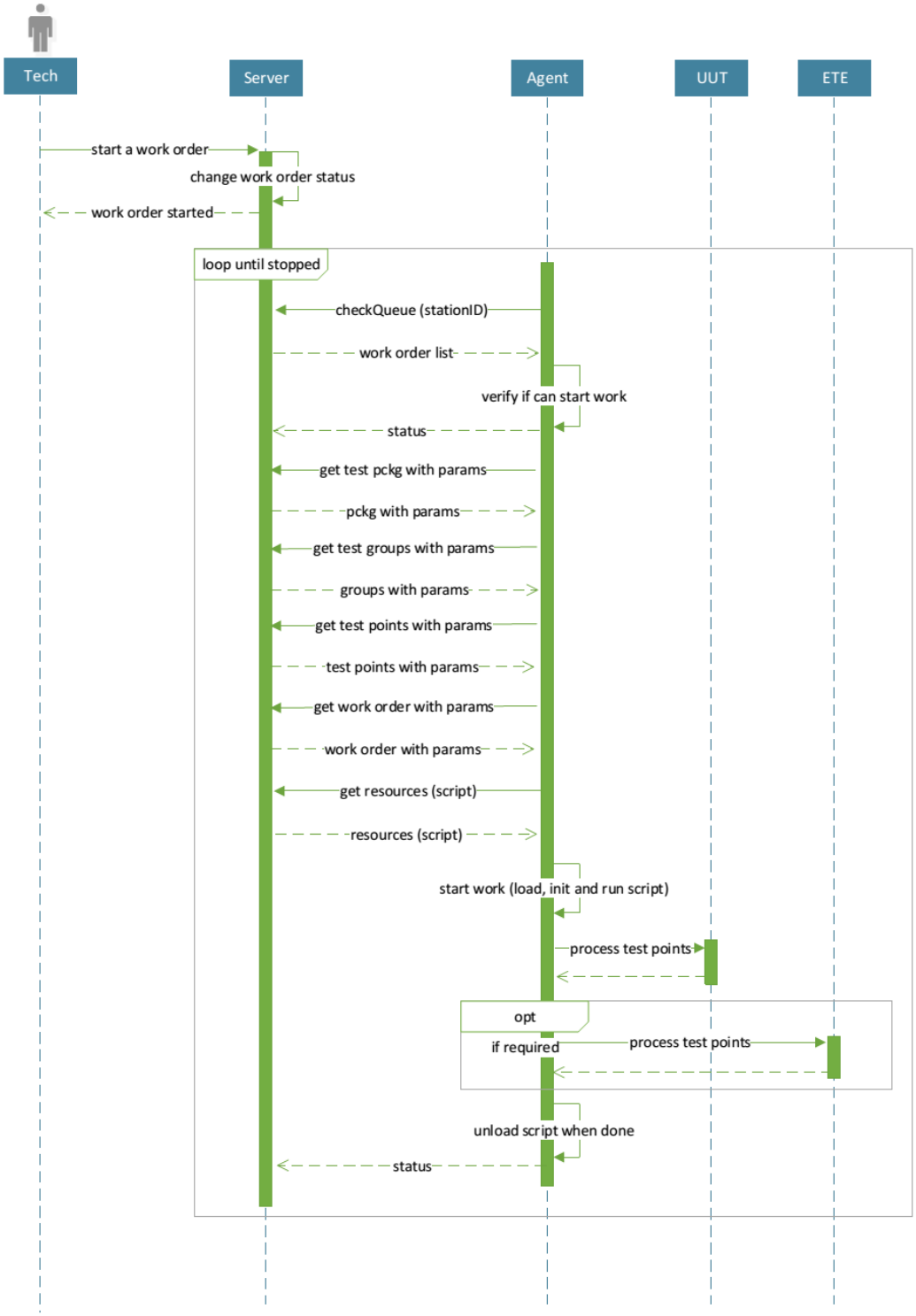
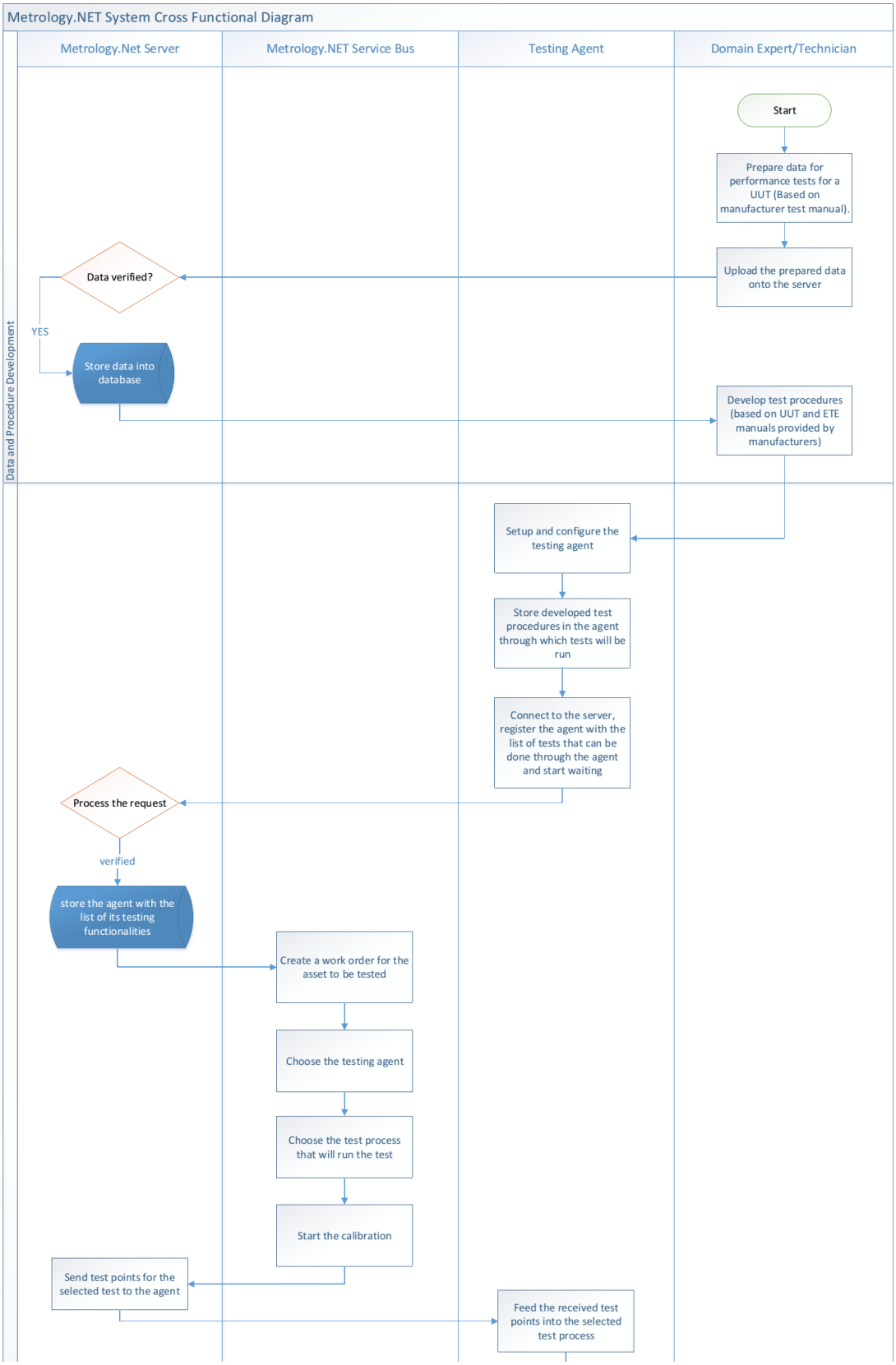


Figure 5.8 Start a work order and run a test

The overall picture with the steps taken in each phase is represented in figure 5.9.


Metrology.NET System Cross Functional Diagram
Metrology.Net Server
Metrology.NET Service Bus
Testing Agent
Domain Expert/Technician
Data and Procedure Development
Start
Prepare data for performance tests for a UUT (Based on manufacturer test manual).
Upload the prepared data onto the server
Data verified?
YES
Store data into database
Develop test procedures (based on UUT and ETE manuals provided by manufacturers)
Setup and configure the testing agent
Store developed test procedures in the agent through which tests will be run
Connect to the server, register the agent with the list of tests that can be done through the agent and start waiting
Process the request
verified
store the agent with the list of its testing functionalities
Create a work order for the asset to be tested
Choose the testing agent
Choose the test process that will run the test
Start the calibration
Send test points for the selected test to the agent
Feed the received test points into the selected test process

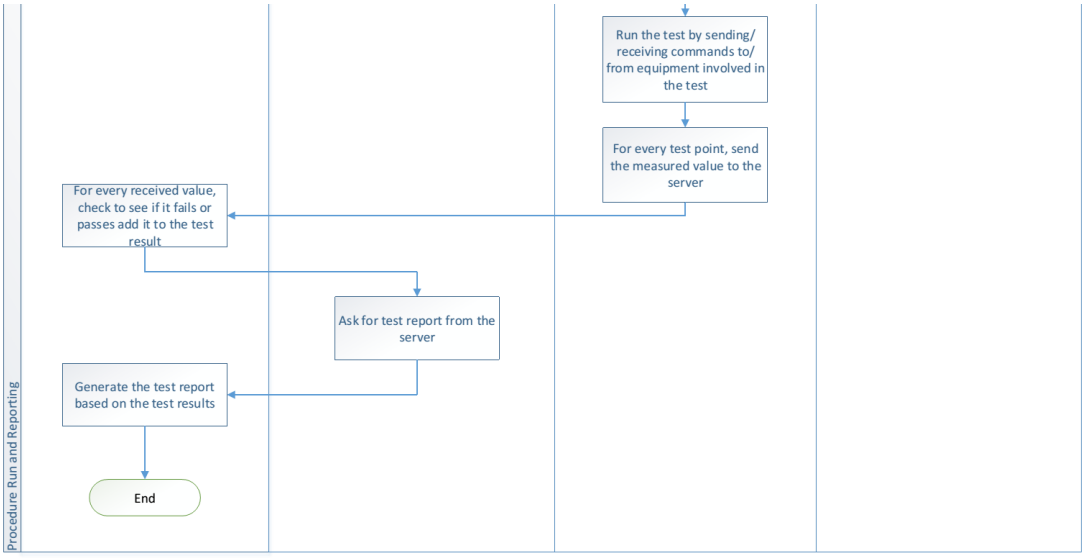


Figure 5.9 Overall calibration process based on Metrology.NET

5.2 Programming Editor

For providing a more convenient experience in programming in SparkS, Geany text editor was used to add support for our language syntax. Geany is a free, lightweight, cross-platform and fast text editor using the GTK2 toolkit (the GIMP Toolkit) [30] that has many of the basic features for an IDE (Integrated Development Environment) including syntax highlighting, code folding, symbol name auto-completion, construct completion/snippets, code navigation and build system to compile and execute your code.

Some of the features mentioned were added for SparkS in Geany. The editor now supports SparkS file extension (.ss). With the help of fileType mechanism you can define your language features in a configuration file that enables you to customize the settings such as styling, keywords for highlighting, indentation, etc. for your language. Also, code snippet support was added for SparkS, so that by entering a keyword, you can get the whole statement produced for you to reduce programming effort. Figure 5.10 shows a screenshot of the Geany editor with a sample script in it.

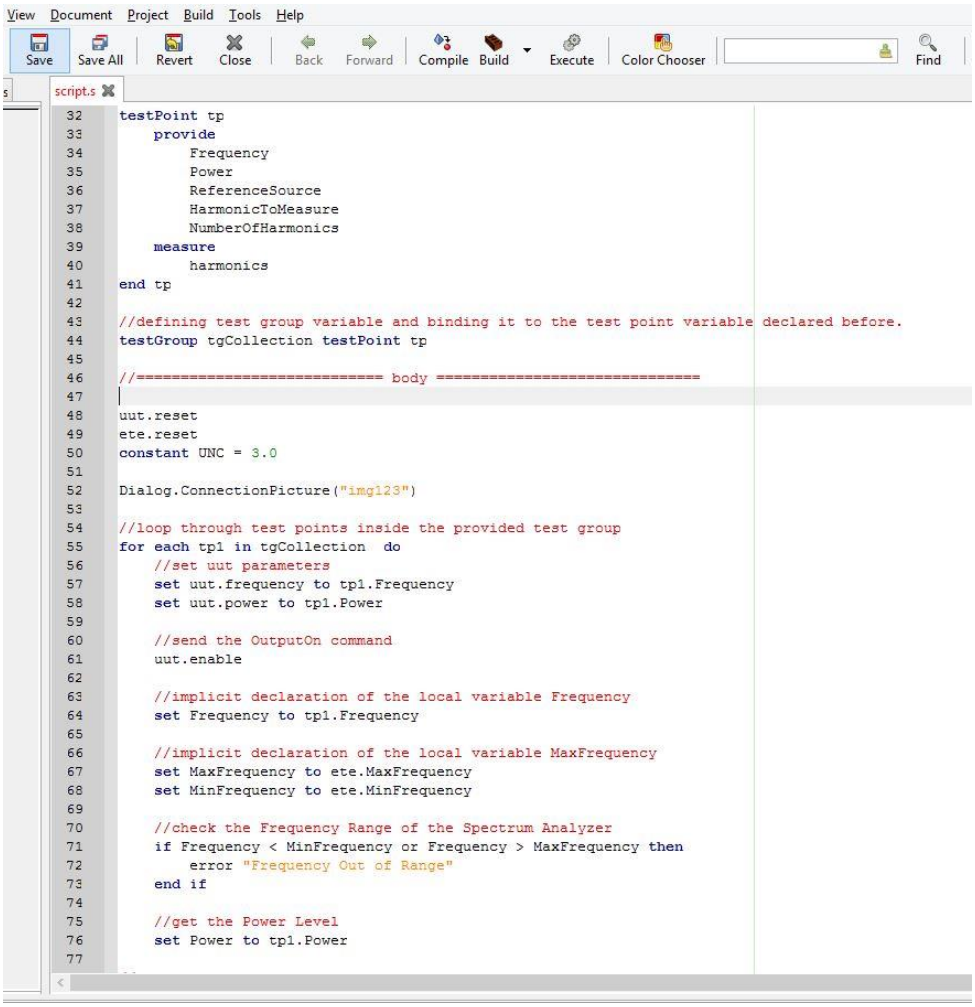


Figure 5.10 A snapshot of a SparkS script written in Geany

5.3 Case Study

In this section, a step by step discussion on an example script written in SparkS is presented to show a real world application for it. The test script is developed based on the Frequency Test for the Agilent E44xx ESG Signal Generator [14].

Every SparkS script starts and ends with the *testProcess* keyword and an identifier for the script. This was a design decision for language extensibility. If we think of a document similar to that of a test manual (calibration guide) such as [14] with several SparkS scripts here and there, then, there would be a need to mark the script blocks in the text.

```
testProcess measureFrequency
```

The *require* keyword is a part of the header. It is used to reference to the resources that will be used along the test. To get a reference to a resource we need two properties of that resource to be specified. These are its message linker type (*linkerType*) and its test type (*testType*). Message linker type specifies the type of resource based on the equipment that is used. As an example, a Signal Generator is classified as a source type and a Spectrum Analyzer is classified as a measure type which is based on the functionality of the equipment. The test type specifies the generic type that is used as an indicator of a family of instruments that can be used for this specific test script.

For this performance test, two resources are used, one for the ETE and another for the UUT. The names *uut* and *ete* here are names for the identifiers and can be anything.

```
require ete as linkerType "Measure.Device"  testType "iSpectrumAnalyzer"
require uut as linkerType "Source.Device"  testType "iSignalGenerator"
```

The *bind* keyword is a part of the header. Every script is supposed to have a test name and an optional description field. We must also set the unit of measure used in the test, for the value measured to be used in the test result.

```
bind TestName to "TestProcess.Measure.Frequency (Agilent_E44xxA)"
```

```
bind Description to "Measures the Frequency of a signal using an Agilent PSA (E44xxA)"
bind UnitOfMeasure to "Hz"
```

The *TestType* is a generic property assigned for a test script. For a single test type, there may be several implementations. This is to supply with the user who does calibration, to choose from a list of different implementations for a test type at runtime. The *prompt* keyword allows the property to be assigned at runtime.

```
bind TestType to prompt
```

Here we define a test point type which is similar to a data type in how it is applied. The *tp* is the identifier that will be used to refer to this type. We declare the parameter list that is expected to be provided in incoming test points, but these are not mandatory to exist among parameters. In the *measure* part, we have one parameter, that is *measuredFrequency*, the parameter to which the measurement result must be assigned.

```
testPoint tp
        provide
                Frequency
                Power
        measure
                measuredFrequency
end tp
```

The *tgCollection* is a test group identifier that is bound to the test point type declared already using the *tp* identifier. In the script we can have access to the input test point array through the use of *tgCollection*.

```
testGroup tgCollection testPoint tp
```

The following line will call the reset function on the declared UUT device.

```
uut.Reset
```

The following line will call the reset function on the ETE device.

```
ete.Reset
```

The following line will create a constant variable named *UNC* and assign it the value of 0.5. The value of *UNC* cannot be changed anywhere in the code.

```
constant UNC = 0.5
```

At this point, before taking any action, the test setup must be arranged by the user for the current test to run. This line of code will pop up a window on the Metrology.NET web interface, showing the user an image (with the name given in the parameter) as a guide on how to make the appropriate connections for the equipment involved in the test.

```
Dialog.ConnectionPicture("PSA_TO_UUT_RFIN")
```

The following two lines show a looping statement for test points. *tgCollection* refers to the test point list that is sent from the server to the agent, based on the selected test group out of a work order. The *tp1* will keep reference to the current test point as looping continues.

```
for each tp1 in tgCollection  do
end for
```

All the following statements go into the *for* loop just discussed. This statement sends the *OutputOn* command to the UUT, enabling the equipment to send output to the ETE.

```
uut.Enable
```

In the following statement, the *Frequency* variable (shown in green) shows an implicit variable declaration. It holds the value for the *Frequency* parameter of *tp1*.

```
set Frequency to tp1.Frequency
```

In the following statement, *MaxFrequency* variable shows an implicit variable declaration. It will hold the value for the *MaxFrequency* parameter extracted from the ETE driver. The same is about the *MinFrequency* variable.

```
set MaxFrequency to ete.MaxFrequency
set MinFrequency to ete.MinFrequency
```

In the following if statement, the local *Frequency* variable is checked against the local *MinFrequency* and *MaxFrequency* variable. If the condition is true, an error is given. This is an important check to be sure if the incoming frequency parameter falls within the predefined limits of the specified resource driver.

```
if Frequency < MinFrequency or Frequency > MaxFrequency then
        error "Frequency Out of Range"
end if
```

In the following *set* statement, the *Coupling* property of the ETE is set to *DC*. Coupling provides a mechanism to prevent or allow *DC* signals into the spectreum analyzer.

```
set ete.Coupling to "DC"
```

In this line, the *ReferenceLevel* property of the ETE is set to 10.

```
set ete.ReferenceLevel to 10
```

In this statement, the *CenterFrequency* parameter of ETE is set to the local variable *Frequency*. It refers to the center position on the horizontal line of the display.

```
set ete.CenterFrequency to Frequency
```

The *if-then-else* statement will execute based on the value of local variable *Frequency*. If it is less than 2.2e3 the first code block will be run, setting the *Span* and *ResolutionBandwith* of the ETE to 10 and 100 respectively. Another condition is for when the value is not less than 2.2e3 but less than 2.2e6. If none of the conditions are met, the *else* block will be run. Here, Span defines the frequency range which is subject to the measurement, and *ResolutionBandwidth* specifies the resolution (detail level) of the sweep. The less the *ResolutionBandwidth*, the higher the resolution.

```
if Frequency < 2.2e3 then

        set ete.Span to 10
        set ete.ResolutionBandwidth to 100

else if Frequency < 2.2e6 then
        set ete.Span to 500
        set ete.ResolutionBandwidth to 50

else
        set ete.Span to 500e3
        set ete.ResolutionBandwidth to 10e3

end if
```

In the following statement, the value for the *AverageSweep* parameter for the ETE is set to 1. *AverageSweep* is the average value for the average sweep number of spectrum analyzer sweeps.

```
set ete.AverageSweep to 1
```

The *TakeSweep* function of the ETE driver will be called two times by the following two statements. Taking a sweep consists of all the measurement through the spectrum analyzer span (the frequency range between the start and stop frequency)

```
ete.TakeSweep
ete.TakeSweep
```

The *MarkerPeakHi* function of the ETE driver will be called. Here, *MarkerPeakHi*, puts the display marker of the spectrum analyzer to the highest point of the signal.

```
ete.MarkerPeakHi
```

In the following line, the local variable *RefMarker* is defined implicitly and set to the value that comes as the return value from the *MarkerAmplitude* function of the ETE. *MarkerAmplitude* refers to the y coordinate of the marker (power level of the marker).

```
set RefLevel to ete.MarkerAmplitude
```

The following statement shows a simple conditional *if* statement. The value of the variable *RefLevel* is supposed not to be less than -40, and if that's the case, it is set to -40.

```
if RefLevel < -40 then
        set RefLevel to -40
end if
```

In the following statement, the *ReferenceLevel* parameter of the ETE is set to the local variable *RefLevel*.

```
set ete.ReferenceLevel to RefLevel
```

In this statement, local variable *Sum* is defined and set to 0.

```
set Sum to 0
```

The *for* loop statement that will loop through 1 to 5, keeping the current value in the *index* variable each time along the loop. Inside the loop, the value of the *MarkerFrequencyCount* parameter of the ETE is added to the last value of the *Sum* variable. Here, the *MarkerFrequencyCount* refers to the x coordinate of the marker (frequency value of the marker).

```
for each index in [1, 5] do
        set Sum to Sum + ete.MarkerFrequencyCount
end for
```

In this statement, the value for *Sum* is divided by 5 and put into the local variable *MeasureVal*.

```
set MeasureVal to Sum / 5
```

In the following statement, the value for the predefined variable *UNCERTAINTY* is set to the constant variable *UNC*. This value is used beside the measured value for a test point.

```
set UNCERTAINTY to UNC
```

In this statement, the measured value as the test result is set to the *measuredFrequency* parameter declared in the *measure* section of the test point type. Reading this, the interpreter will upload the result to up to the server for finalization.

```
set measuredFrequency to MeasureVal
```

In this statement, the *OutputOff* command for the UUT is set, which causes the output for the UUT to be disabled.

```
uut.Disable
```

And finally, the following line shows the end of the script.

```
end measureFrequency
```

The complete code for this sample script and another sample can be found in the Appendix B.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Contributions

In this thesis, we designed and implemented the initial version of a domain specific language, named SparkS, for developing calibration procedures for test and measurement equipment. The motivation behind this study was to propose a language to be used by domain workers who have a little programming knowledge.

The SparkS grammar was developed using ANTLR tool which produced the parser in C#, which is the front-end of the language processor. We had an elaborated discussion on the language constructs and presented a complete case study that was developed in SparkS. We developed an interpreter using the Visitor pattern for the implementation of the back-end. The interpreter was embedded into the Metrology.NET platform, the next generation of calibration automation systems developed by Cal Lab Solutions, Inc.

For adding test points, the data for running tests, into the database on the server, an upload tool was developed that reads test points in the format we defined, from Excel sheets, and uploads to the server. The developed tool offers a much higher speed compared to the ordinary way of adding test points one by one through the Metrology.NET web based interface, which resulted in a big time save in adding test points into the server.

For showing how a written SparkS script compares to a test procedure developed on Metrology.NET, a comparison matrix is presented for a complete test written both in SparkS and VB.Net. The table can be found in Appendix G.

6.2 Future Work

SparkS IDE

For a better programming experience, we are planning to add features to the Geany editor. Features such as code folding, and a stronger code completion (Intellisense) support will be added to the editor.

There are several language features that were postponed for the next version of SparkS. The following paragraphs elaborate on these features.

Multi-line Bind

In the current version of the language, we are using single line sets and binds. For the next version, the mentioned keywords will be factored out to make a block of statements with these common keywords.

For example use:

```
bind
   a to b
   b to c
end bind
```

instead of:

```
bind a to b
bind b to c
```

Space-delimited Strings

For the string literals used in some statements, the quotation marks can be ignored if there is no space character within the string (white space delimited string). This should make the writing of the external names cleaner.

For example use:

```
set ete to spectrumAnalyzer
```

instead of:

```
set ete to “spectrumAnalyzer”
```

Then-if ladder

For the conditional statement, we’re planning to introduce the following structure that leads to cleaner code:

```
if a>b
   then if b>c
      then if c>d then
            //statement…
end if
```

Instead of :

```
if a>b then
   if b>c then
      if c>d then
          //statement…
      end if
   end if
end if
```

More specific ordered collections

We are planning to extend the for loop structure, so that the ordered collection can be specified in more detail by setting the limits and also ordering for the collection in the statement. The example below shows how it would look like:

```
for each tp1 in tgCollection
where Frequency< ete.Maxfrequeny and Frequency > ete.MinFrequency
order by Frequency inccreasing , power decreasing)
// loop body
```

Interval notation

Another feature that we would like to have in our feature set is to take advantage of ranges in other statements. The example below shows a sample use:

```
if not Frequency in [MinFrequency,MaxFrequency] then
   //statements…
end if
```

Test Point Parameters

For the initial version of SparkS, we assumed the test point parameters to be all optional. Basically, there are parameters that are optional, but also parameters that must be present in a test point for a test to be run. The mandatory parameters will be added to the language as another feature.

Error Handling

For the first version of SparkS, a light exception handling was added. To make the language interpreter robust, a complete exception handling is supposed to be done for the next version of SparkS. Also, a better error handling for user input is considered to be added to the language.

Some other features, such as adding Proceed statement, for forward jump, Goto statement, for jumping over points in a script, and dynamic type checking mechanism are also considered to be added in the next version of SparkS.

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APPENDIX A

ANTLR GRAMMAR FOR SPARKS

```
grammar SparkS_v1;

options
{
    language = 'CSharp';
}

//////////////////
// PARSER RULES //
//////////////////

//starting rule
program
    : NEWLINE*
        TESTPROCESS ID
        NEWLINE+

      header*
      body

        NEWLINE*
        TESTPROCESS ID
      NEWLINE* EOF
    ;

header
    : require+
    | bind+
    | testPoint+
    | testGroup+
    ;

body
    :
      stmt (NEWLINE+ stmt)*
    ;

//======================= header rules ========================
require
    : REQUIRE ID AS LINKERTYPE externalDesignator (TESTTYPE
externalDesignator)? NEWLINE+
    ;

externalDesignator
    : externalName
    | PROMPT
```

```
    ;

externalName
    : STRINGLITERAL
    ;

bind
    : BIND ID TO externalDesignator NEWLINE+
    ;

testPoint
    : TESTPOINT tpId NEWLINE+
        PROVIDE NEWLINE+
           (paramID NEWLINE+)+
        MEASURE NEWLINE* ID NEWLINE+
     END tpId NEWLINE+
    ;

tpId
    : ID
    ;

paramID
    : ID
    ;

testGroup
    : TESTGROUP ID TESTPOINT tpId NEWLINE+
    ;

//the possible statements
stmt
    : for_stmt
    | ifThenElseStmt
    | set_stmt
    | const
    | functionCall
    | error
    ;

functionCall
    : ID DOT ID (LPAREN (STRINGLITERAL (COMMA STRINGLITERAL)*)? RPAREN)?
    ;

const
    : CONST ID EQ constVal NEWLINE+
    ;
constVal
    : (INT | DOUBLELITERAL)                 #numberConst
    | ID                                    #idConst
    ;

//a subset of the possible statements
sub_stmt
    : for_stmt
    | ifThenElseStmt
```

```
    | set_stmt
    | functionCall
    | error
    ;

//if-then-else structure
ifThenElseStmt
    : IF condition_block (ELSEIF condition_block)* (ELSE NEWLINE+
stat_block)? END_IF
    ;

condition_block
    : boolExpr THEN NEWLINE+
        stat_block
    ;

stat_block
    :
      (block NEWLINE*)?
    ;

//block
block
    : sub_stmt (NEWLINE+  sub_stmt)*
    ;

//bool expression rules
boolExpr
    : NOT boolExprSub                   #notExpr
    | boolExprSub AND boolExprSub       #andExpr
    | boolExprSub OR boolExprSub        #orExpr
    | boolExprSub XOR boolExprSub       #xorExpr
    | boolExprSub1                      #boolSub1Expr1
    ;

boolExprSub
    : LPAREN boolExpr RPAREN            #boolExprParen
    | boolExprSub1                      #boolSub1Expr2
    ;

boolExprSub1
    : arithExpr op=(LTEQ | GTEQ | LT | GT| EQ | NEQ) arithExpr
#arithmeticExpr
    | (TRUE |  FALSE)
#boolAtom
    ;

//arithmetic expression rules
arithExpr
    : arithExprSub op=(MULT | DIV) arithExprSub       #multiplicationExpr
    | arithExprSub op=(PLUS | MINUS) arithExprSub     #additiveExpr
    | arithExprSub1                                   #arithsub1Expr1
    ;

arithExprSub
    : LPAREN arithExpr RPAREN                         #arithExprParen
```

```
    | arithExprSub1                                #arithsub1Expr2
    ;
arithExprSub1
    : (INT | DOUBLELITERAL)                      #numberAtom
    | ID                                         #idAtom
    ;

//for loop variations
for_stmt
    : FOR  EACH  ID  IN  ID  DO NEWLINE+
             (block NEWLINE*)?
      END  FOR                                   #tPointLoop

    | FOR  EACH  ID  IN  O_BRAC limitVar COMMA limitVar C_BRAC  DO
NEWLINE+
             (block NEWLINE*)?
      END  FOR                                   #rangeLoop

    ;

limitVar
    : ID                                         #varID
    | INT                                        #varINT
    ;

//set statement
set_stmt
    : SET  ID TO  setExpr                        #setVar
    | SET  ID DOT ID  TO  setExpr                #setAttr
    | SET UNC TO setExpr                         #setUNC
    ;

setExpr
    : arithExpr                                  #setExprArith
    | STRINGLITERAL                              #setExprString
    | ID DOT ID                                  #setExprAttr
    ;

error
    : ERROR STRINGLITERAL NEWLINE+
    ;

//////////////////
// LEXER TOKENS //
//////////////////

NEWLINE     : '\r'? '\n';
WS          : [ \t] -> skip;

REQUIRE     :'require';
LINKERTYPE  :'linkerType';
TESTTYPE    :'testType';
BIND        :'bind';
TESTPROCESS :'testProcess';
TESTPOINT   :'testPoint';
TESTGROUP   :'testGroup';
```

```
PROMPT      :'prompt';
AS          :'as';
DO          :'do';
END         :'end';
IF          :'if';
ELSE        :'else';
FOR         :'for';
EACH        :'each';
IN          :'in';
SET         :'set';
TO          :'to';
THEN        :'then';
COMMA       :',';
DOT         :'.';
IS          :'IS';
NULL        :'NULL';
END_IF      :'end if';
ELSEIF      :'else if';
MEASURE     :'measure';
PROVIDE     :'provide';
ERROR       :'error';
CONST      :'constant';

TRUE: 'TRUE';
FALSE: 'FALSE';

// Control Chars
LPAREN : '(';
RPAREN : ')';
O_BRAC : '[';
C_BRAC : ']';

// Binary Arithmetic Operators
MULT    : '*';
DIV     : '/';
PLUS    : '+';
MINUS   : '-';

// Comparison Operators
EQ      : '=';
NEQ     : '/=';
GTEQ    : '>=';
LTEQ    : '<=';
GT      : '>';
LT      : '<';

// Logical Operators
NOT : 'not';
AND : 'and';
OR  : 'or';
XOR : 'xor';

// Literals and Identifiers
fragment DIGIT : [0-9];
fragment LETTER : [A-Za-z];
fragment CHARACTER : DIGIT | LETTER | '_';
```

```
INT: (PLUS|MINUS)? DIGIT+ ( ('e' | 'E') INT)*;
DOUBLELITERAL : (PLUS|MINUS)? DIGIT* '.' DIGIT+ ( ('e' | 'E')
(PLUS|MINUS)? ('0'..'9')+)*;
STRINGLITERAL : '"' (~["\r\n])* '"';

ID: LETTER CHARACTER*;

//Comments
COMMENT
    :   '/*' .*? '*/'  -> skip // match anything between /* and */
    ;
LINE_COMMENT
    : '//' ~[\r\n]* '\r'? '\n' -> skip
    ;
```

APPENDIX B

SAMPLE SCRIPTS WRITTEN IN SPARKS

1. Sample 1

Frequency performance test for signal generators family.

```
testProcess measureFrequency
//==================== header ======================
//required types to be used in the test
require ete as linkerType "Measure.Device"  testType "iSpectrumAnalyzer"
require uut as linkerType "Source.Device"  testType "iSignalGenerator"

//set the test specific parameters
bind TestName to "TestProcess.Measure.Frequency (Agilent_E44xxA)"
bind Description to "Measures the Frequency of a signal using an Agilent PSA (E44xx)"
bind UnitOfMeasure to "Hz"

//value for some parameters can be assigned at runtime (using prompt keyword)
bind TestType to prompt

/*
test point type, including the expected parameters from test points (inside a test group)
and the to-be-measured parameter. test result will be assigned to this parameter at the end
of the test.
*/
testPoint tp
        provide
                Frequency
                Power
        measure
                measuredFrequency
end tp

//defining test group variable and binding it to the test point variable declared already.
testGroup tgCollection testPoint tp

//==================== body ======================
uut.Reset
ete.Reset

constant UNC = 0.5

//using the Dialog library, show the picture with the name given
Dialog.ConnectionPicture("PSA_TO_UUT_RFIN")
```

```
//loop through test points inside the provided test group
for each tp1 in tgCollection  do

        //send the OutputOn command
        uut.Enable

        //implicit declaration of the local variable Frequency
        set Frequency to tp1.Frequency

        //implicit declaration of the local variable MaxFrequency
        set MaxFrequency to ete.MaxFrequency
        set MinFrequency to ete.MinFrequency

        //check the Frequency Range of the Spectrum Analyzer
        if Frequency < MinFrequency or Frequency > MaxFrequency then
                error "Frequency Out of Range"
        end if

        //Set the Coupling
        set ete.Coupling to "DC"

        set ete.ReferenceLevel to 10
        set ete.CenterFrequency to Frequency

        //set the Span and Filters
        if Frequency < 2.2e3 then
                set ete.Span to 10
                set ete.ResolutionBandwidth to 100
        else if Frequency < 2.2e6 then
                set ete.Span to 500
                set ete.ResolutionBandwidth to 50
        else
                set ete.Span to 500e3
                set ete.ResolutionBandwidth to 10e3
        end if

        set ete.AverageSweep to 1

        //take a couple of sweeps
        ete.TakeSweep
        ete.TakeSweep

        //get the ref marker
        ete.MarkerPeakHi

        set RefLevel to ete.MarkerAmplitude

        if RefLevel < -40 then
                //adjust the refLevel
                set RefLevel to -40
```

```
        end if

        set ete.ReferenceLevel to RefLevel

        set Sum to 0

        for each index in [1, 5] do
                set Sum to Sum + ete.MarkerFrequencyCount
        end for

        set MeasureVal to Sum / 5

        set UNCERTAINTY to UNC

        //set the measured value as test result
        set measuredFrequency to MeasureVal

        //send the OutputOff command
        uut.Disable

end for

end measureFrequency
```

2. Sample 2

Harmonics performance test for signal generators family.

```
testProcess measureHarmonics
//==================== header ==========================
//required types to be used in the test
require ete as linkerType "Measure.Device"  testType "iSpectrumAnalyzer"
require uut as linkerType "Source.Device"  testType "iSignalGenerator"

//set the test specific parameters
bind TestName to "TestProcess.Measure.Harmonics (Agilent N9030A) "
bind Description to "Measures the Harminics of a signal using an Agilent PXA (N9030A)
Spectrum Analyzer"
bind UnitOfMeasure to "dBc"

//value for some parameters can be assigned at runtime (using prompt keyword)
bind TestType to "Measure.Harmonics"

/*
test point type, including the expected parameters from test points (inside a test group)
and the to-be-measured parameter. test result will be assigned to this parameter at the end
of the test.
*/
testPoint tp
        provide
                Frequency
                Power
                ReferenceSource
                HarmonicToMeasure
                NumberOfHarmonics
        measure
                Harmonics
end tp

//defining test group variable and binding it to the test point variable declared already.
testGroup tgCollection testPoint tp


//==================== body ==========================
uut.Reset
ete.Reset
constant UNC = 3.0

//using the Dialog library, show the picture with the name given
Dialog.ConnectionPicture("PXA_TO_UUT_RFIN")

//loop through test points inside the provided test group
for each tp1 in tgCollection  do

        //send the OutputOn command
```

```
uut.enable

//implicit declaration of the local variable Frequency
set Frequency to tp1.Frequency

//implicit declaration of the local variable MaxFrequency
set MinFrequency to ete.MinFrequency
set MaxFrequency to ete.MaxFrequency

//check the Frequency Range of the Spectrum Analyzer
if Frequency < MinFrequency or Frequency > MaxFrequency then
        error "Frequency Out of Range"
end if

//get the Power Level
set Power to tp1.Power

//get the Harmonic to Measure
set HarmToMeas to tp1.HarmonicToMeasure

//get the number of Harmonics to Measure
set NumHarm to tp1.NumberOfHarmonics

//error check the values
if HarmToMeas = 0 and NumHarm = 0 then
        error "Must Specify 'HarmonicToMeasure' or 'NumberOfHarmonics'"
end if

//error check the range of measurements
if Frequency * 2 > MaxFrequency then
        error "Harmonic Frequecy Out of Range!"
end if

//Set the Coupling
set ete.Coupling to "DC"

set ete.ReferenceLevel to Power + 5
set ete.CenterFrequency to Frequency

//set the Span and Filters
if Frequency < 500 then
        set ete.Span to 10
        set ete.ResolutionBandwidth to 10
else if Frequency < 2.2e3 then
        set ete.Span to 100
        set ete.ResolutionBandwidth to 10
else if Frequency < 2.2e6 then
        set ete.Span to 2e3
        set ete.ResolutionBandwidth to 50
else
        set ete.Span to 2e6
```

```
        set ete.ResolutionBandwidth to 20e3
end if

//take a couple of sweeps
ete.TakeSweep
ete.TakeSweep

//get the ref marker
ete.MarkerPeakHi

set RefMarker to ete.MarkerAmplitude

if HarmToMeas > 0 then
        //measure a single harmonic
        set ete.CenterFrequency to Frequency * HarmToMeas

        //take a couple of sweeps
        ete.TakeSweep
        ete.TakeSweep

        ete.MarkerPeakHi

        set Measured to ete.MarkerAmplitude
        set MeasureVal to Measured - RefMarker

        set UNCERTAINTY to UNC
        //set the measured value as test result
        set Harmonics to MeasureVal
else
        //measure the harmonics
        set Max to -999

        for each index in [2, NumHarm] do
                if Frequency * index < Maxfrequency then
                        //measure a single harmonic
                        ete.CenterFrequency to Frequency*index

                        //take a couple of Sweeps
                        ete.TakeSweep
                        ete.TakeSweep

                        ete.MarkerPeakHi

                        set Measured to ete.MarkerAmplitude
                        if Measured > Max then
                                set Max to Measured
                        end if
                end if
        end for

        set MeasureVal to Max - RefMarker
```

```
                set UNCERTAINTY to UNC
                //set the measured value as test result
                set Harmonics to MeasureVal

                //send the OutputOff command
                uut.disable

end for

end measureHarmonics
```

APPENDIX C

METROLOGY.NET SYSTEM DATA DICTIONARY

Name	Type	Definition
Agent	Class	An object of this class keeps data about a testing agent. Testing agent is the client that connects directly to the equipment and runs test processes.
AgentID	String	The unique ID given to a testing agent
Name	String	The name associated with an agent
OperatingSystem	String	The operating system running on the agent
Server_URL	String	The address of the machine on which the Meteology.NET server resides. It may be local, on a server.
State	String	The current state of the agent is kept here, whether it is running or stopped.
SystemLocation	String	The physical location of the agent
Asset	Class	An object of this class keeps the data about the asset that is under test, namely Unit Under Test.
assetID	String	The unique ID given to an asset
CalDate	Date	The date on which calibration is done
CalDue	Date	The due date for calibration
Manufacturer	String	The manufacturer of the asset
Model	String	The specific model associated with the asset
Options	String[]	All the options included in the asset
Serial number	String	The unique serial number of the asset
measureDriver	Class	All classes in the measure level of the test process hierarchy inherit from this class. The measure() method in this class does the measurements through device driver.
measureDeviceInstIO	Class	This class is a part of the test driver hierarchy that is used in measuring equipment.
measurementResult	Class	An object of this class keeps the measured value and the uncertainty value to be output as the return value for a test point.
ErrorFlag	Boolean	If an error occurs along a test process run, this flag is set to true.
ErrorMessage	String	If an error occurs along a test process run, this is set with the appropriate error message.
Uncertainty	Double	The uncertainty value to be applied onto the measured value from a test result.
UofM	String	The unit in which the measurement is performed
Value	Double	The value achieved as a result of the measurement
Model	Class	An object of this class keeps data about an equipment

		model associated with an asset.
Deleted	Boolean	Marks the entity as deleted to be applied later
Description	String	A description provided for a specific model
ModelID	String	The unique ID associated with a model
Name	String	The model name
OptionGroupID	String	The ID of the option group that belongs to this model
ProductLineID	String	The product line to which this model belongs
ModelGroup	class	An object of this class keeps data about the models included in an equipment model family.
AutoUpdateOnAdd	Boolean	If this option is true then every change applied to the object will be uploaded to the server
Delete	Boolean	Marks the object as deleted to be applied later
GroupName	String	The name of a model group
ModelGroupID	String	The unique ID associated with a model group
ModelIDs	String[]	The list of all model IDs in this group
Models	String[]	The list of all the models in a model group
ModelOption	class	An object of this class keeps data about a specific option for equipment.
Deleted	Boolean	Marks the object as deleted to be applied later
Description	String	A description for an option
ModelOptionID	String	The unique ID for an option
Opt	String	Option name
ModelOptionGroup	class	An object of this class keeps the relationship between a model and its associated options.
Deleted	Boolean	Marks the object as deleted to be applied later
ModelID	String	The model ID
ModelOptionID	String	The option ID
Parameter	Class	An object of this class keeps different types of data about other entities. For example, a parameter for a test point could tell to what model it applies.
Deleted	Boolean	Marks the object as deleted to be applied later
Editable	Boolean	Shows if this parameter is editable or not
eParentType	eParentTypes	Shows to what object it belongs: TestGroup, TestGroupLib, TestPkg, TestPkgLib, TestPoint, TestPointLib, TestProcess, TestResult, UserInterface, or WorkOrder
Format	String	The textual format of a parameter
Group	String	Parameter group
isLocalOnly	Boolean	If the parameter is used only as a local copy
LimitedToList	Boolean	Shows if we should only consider the items defined in the list of a parameter
List	String[]	The list of items that belong to a parameter
ListValues	String	The list of item values that belong to a parameter
Max	Double	The max value to be put into a parameter
Min	Double	The min value to be put into a parameter
Name	String	Name of a parameter
parameterID	String	The unique ID associated with a parameter
ParentID	String	The parent object ID to which this parameter belongs

ParentType	String	Parent type of a parameter
Sequence	Integer	The sequence of a parameter among several parameters
Type	String	The type of a parameter
Value	String	The value of a parameter
ProductLine	class	An object of this class keeps data about the manufacturer of equipment.
Deleted	Boolean	Marks the object as deleted to be applied later
Name	String	The name of a manufacturer
ProductLineID	String	The unique ID associated with a manufacturer
SourceDriver	Class	This class is a part of the test driver hierarchy that is used in source equipment.
SourceDeviceInstIO	Class	This class is a part of the test driver hierarchy that is used in source equipment.
SourceTpControler	Class	This class is a part of the test driver hierarchy that is used in source equipment.
TestPoint	class	An object of this class keeps the data about a test point.
AutoUpdateOnAdd	Boolean	If this option is true then every change applied to the object will be transferred to the server
Deleted	Boolean	Marks the object as deleted to be applied later
Description	String	A description for a test point
Format	String	The format of the data, e.g. #0.00 which has a 2 digit precision after the decimal point
isLocalOnly	Boolean	If this is used only as a local copy
LowerLimit	Double	The lower limit of the accepted range in which the measured value to appear
Modifier	String	Things that we want to appear on the reports for a specific test point
Nominal	Double	The median value between the lower and upper limit
ParameterArray	Parameter[]	The list containing test point parameters
ParameterList	ArrayList	The list containing test point parameters
Parameters	List<Parameter>	The list containing test point parameters
Prefix	String	The prefix used for a unit of measure. For example: K for KHz
Resolution	Integer	The resolution of the value for a test point
RunCount	Integer	The number of times this test point to be run for a test
Sequence	Integer	The sequence of a test point among test points of a test group
StepNum	String	The sequence of a test point in a calibration guide
TestGroupID	String	The unique ID of the test group to which this test point belongs
TestPkgID	String	The unique ID of the test package to which this test point belongs
TestPointID	String	The unique ID of a test point
TestProcessID	String	The ID of the process on which this test point will be used
TestProcessIDs	String[]	The ID of the processes on which this test point will be used

TestType	String	Either of BelowLimit, AboveLimit or WithinLimits
TestTypeVal	Integer	The numeric value for the test type.
UnitOfMeasure	String	Unit of measure for this test point
UoMID	Integer	The ID associate with a unit of measure
UpperLimit	Double	The upper limit of the accepted range in which the measured value to appear
TestGroup	Class	An object of this class keeps the data about a test group.
AutoUpdateOnAdd	Boolean	If this option is true then every change applied to the object will be transferred to the server.
Deleted	Boolean	Marks the object as deleted to be applied later
Description	String	A description for a test group
isLocalOnly	Boolean	If the parameter is used as local only
Name	String	The name of a test group
ParameterArray	Parameter[]	The list containing test group parameters
Parameters	List<Parameter>	The list containing test group parameters
Sequence	Integer	The sequence of the test group among other test groups specific to a test package
TestGroupID	String	The unique ID specific to a test group
TestPkgID	String	The unique ID of the test package to which a test group belongs
TestPoints	ArrayList	The list of the test points belonging to a test group
TestProcessID	String	The ID of the process on which this test group will be used
TestType	String	Showing the conventional type for a test group. E.g.: “Measure.Harmonics” for a test group used for a harmonics test.
TestPkg	class	An object of this class keeps the data about a test package.
AssetTypeID	String	The unique ID associated with the type of assets used in calibration
AutoUpdateOnAdd	Boolean	If this option is true then every change applied to the object will be transferred to the server.
Deleted	Boolean	Marks the object as deleted to be applied later
Description	String	A description for a test package
isLocalOnly	Boolean	If the parameter is used as local only
Name	String	The name assigned to a test package
Notes	String	optional notes about a test package
ParameterArray	Parameter[]	The list of parameters for a test package
ParameterArrayList	ArrayList	The list of parameters for a test package
ParameterCollection	Dictionary	The list of parameters for a test package
Parameters	List<Parameter>	The list of parameters for a test package
TestGroups	ArrayList	The test groups contained in this test package
TestPkgID	String	The unique ID assigned to the test package
Version	Double	The current version of a test package
TestProcess	Class	This class is a part of the test driver hierarchy. An object of this class keeps the data about a test

		process. This is a class of high level of abstraction that is used as the base class for every test process to be implemented.
RunFlag	Object	The flag showing if a test process is running
SortOrder	Parameter[]	This is to get or set the sort order for the parameters of a test process
TestGroup	TestGroup	The Test Group to be fed into this test process as the data to be processed.
TestPkg	TestPkg	The test package from which the corresponding test group was chosen
TestPoints	List<TestPoint>	The test points of the corresponding test group
WorkOrder	WorkOrder	The work order to which this test process object is assigned
UI	UserInteraction.MessageLinker	The object that is used for communication with the user running a test, through the web based interface for the server
_WorkOrder	WorkOrder	The work order from which the data for this test comes
TestProcessScript	Class	This is the class that was added to the Metrology.NET to support SparkS scripts. It extends TestProcess class with some additional members to be used by the SparkS interpreter, such as script loading and unloading functions.
Description	String	A description for the test process for scripts
ScriptDescription	String	A description for the loaded script
ScriptDir	String	The directory from which the script is loaded
ScriptTestName	String	The name of a written script
ScriptTestType	String	The conventional test type used for test processes. E.g.: “TestProcess.Measure.Harmonics (Agilent_E44xxA)”
ScriptUofM	String	The unit of measure used in a script
TestResult	Class	An object of this class keeps the data about a test result from a measurement.
AsFound	Boolean	The test result before calibration
AsLeft	Boolean	The test result after calibration is done
LowerLimit	Double	If available, the lower limit value for the test result to be considered as passed
Measured	Double	The measured value from an asset for a test point.
Nominal	Double	The median value between the lower and upper limit values for a test point
Note	String	Some optional notes about a test result
ParameterArray	Parameter[]	The variable number of parameters assigned for a test result to keep meta data about it.
ParameterArrayList	ArrayList	The variable number of parameters assigned for a test result to keep meta data about it.
ParameterCollection	Dictionary	The variable number of parameters assigned for a test result to keep meta data about it.
Pass	Integer	The value to show if the test has passed or failed at a test point

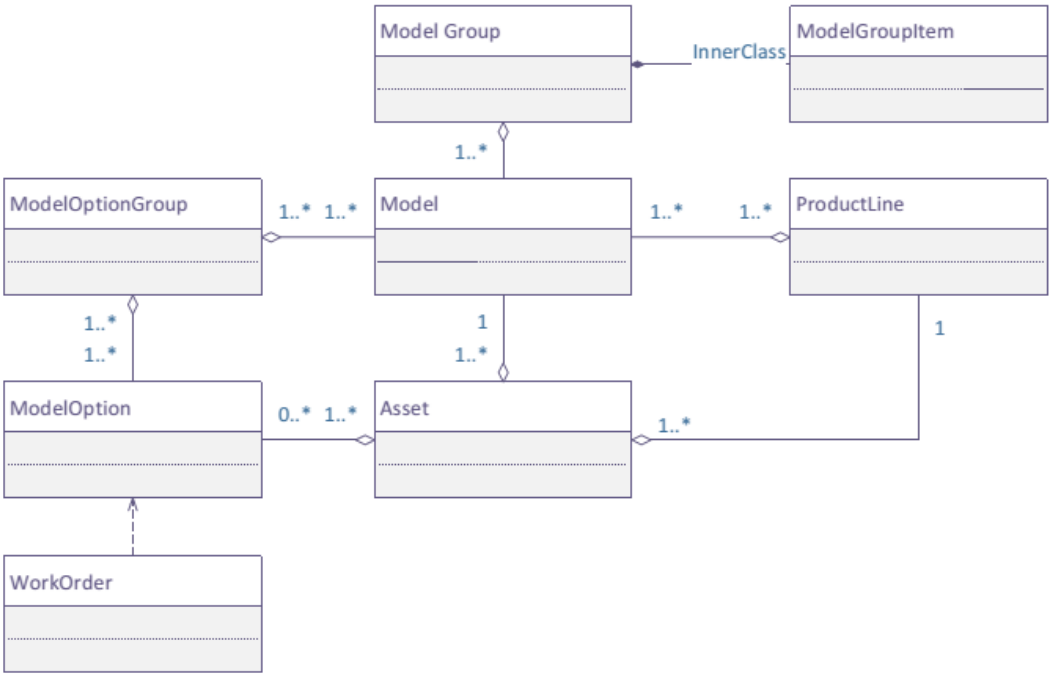
Run	Integer	Number of times the test was run
RunDate	Date	The date on which the calibration was done
Sequence	Integer	Sequence of the test result
StandardIDs	ArrayList	The ID's of the standards (ETEs) used in a test setup
Status	String	The current status for a test result
TestPointID	String	The ID of the test point to which this test result belongs
TestProcessID	String	The ID of the test process by which the test was done
TestResultID	String	The ID assigned to this test result
Uncertainty	Double	The uncertainty value for a test result
UncType	String	The uncertainty type used in the test result. It has two types: type A or type B. Type A is based on repeated measured values, while type B is based on already available data.
UpperLimit	Double	The upper limit for a result to be in. if the measured value passes this limit it is counted as failed
UserID	Integer	The ID of the user who did the calibration for this test point
TProcess	Class	An object of this class keeps the data about an activated and running test process.
ActivatedProcess	Object	The test process that is active now in an agent
AgentID	String	The ID for the testing agent
CreatedByID	String	The ID of the user who created the test process
DarwinLocation	String	The Metrology.NET server address
Description	String	The description of the test process
Name	String	Name of the test process
Revision	String	Current revision of the test process
State	String	Current state of the test process
TestProcessID	String	The ID for the active test process
TestProcessRegID	String	The registration ID assigned for the test process. This ID is used for binding two objects which need to communicate with each other.
TestProcessType	String	The type used in the test process
UnitOfMeasure	String	Unit of Measure used in the test process
Uncertainty	Class	An object of this class keeps the data about the measured uncertainty value.
ParameterArray	Parameter[]	The variable number of parameters assigned for an uncertainty to keep meta data about it.
Parameters	Double	The variable number of parameters assigned for an uncertainty to keep meta data about it.
Uncertainty	Double	The calculated uncertainty value
UncertaintyID	Double	The unique ID assigned to an uncertainty value
Version	Double	The current version for the calculated uncertainty value
UnitOfMeasure	Class	An object of this class keeps the data about the unit of measure used in a test.
User	Class	An object of this class keeps data about a user who runs calibration processes through the Metrology.NET service bus.
FirstName	String	First name of a user

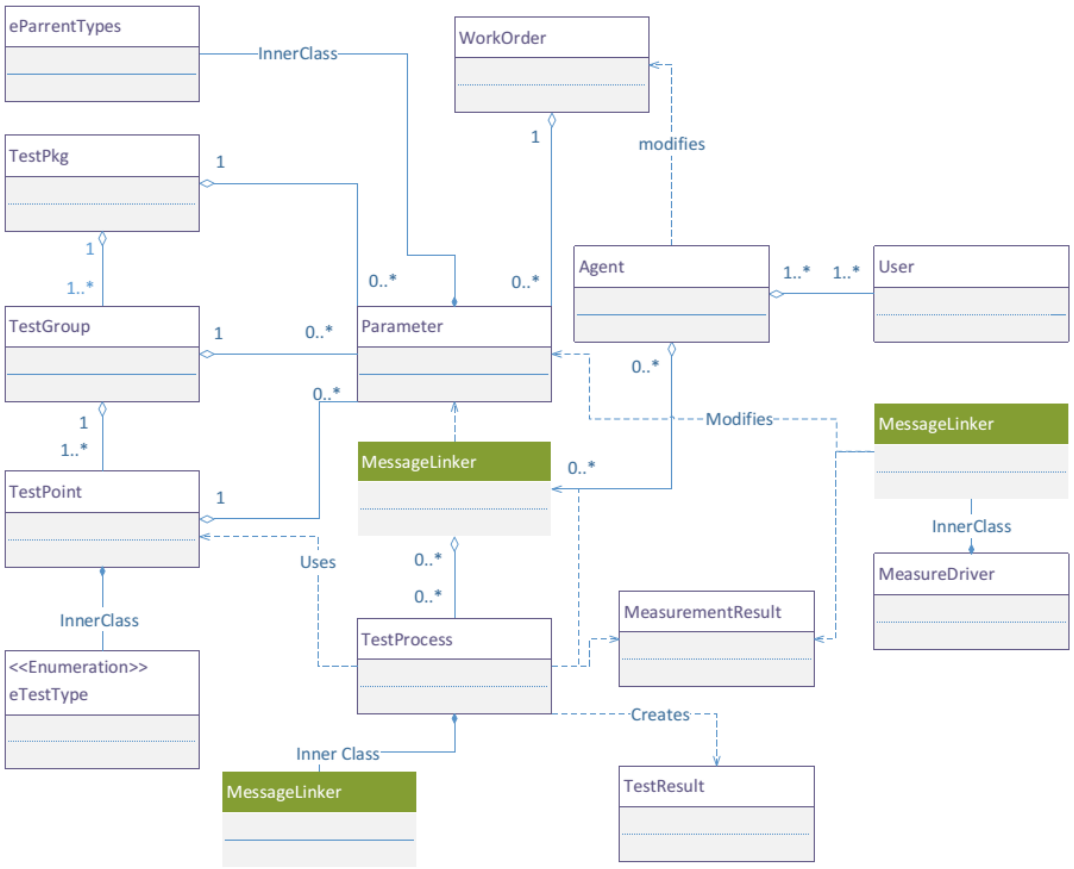
ID	String	the unique ID to be assigned to a user
Password	String	The password to be chosen by a user
Roles	String[]	The roles which are assigned to a user. A user can be chosen to be a technician, engineer, admin, QA, etc.
SurName	String	Surname of the user
UserName	String	The user name to be chosen by a user
WorkOrder	Class	An object of this class keeps data about a work order.
AgentID	String	The unique ID for the agent that initiates the work order
CreatedBy	String	Who created the work order
DueDate	Date	The due date to finish the work order
Notes	String	Some notes about the work order if there is any
ParameterArray	Parameter[]	The variable number of parameters assigned to a work order to keep some meta data about it.
ParameterArrayList	ArrayList	The variable number of parameters assigned to a work order to keep some meta data about it.
ParameterCollection	Dictionary	The variable number of parameters assigned to a work order to keep some meta data about it.
Parameters	List<Parameter>	The variable number of parameters assigned to a work order to keep some meta data about it.
RunBy	String	The user who runs the work order
RunDuration	String	The duration of the test
RunStart	Date	The date on which a work order was run
RunStop	Date	The date on which a work order was done
State	Integer	One of the several states a work order can be in: Start, Stop, Continue, and Close
TestPkgID	String	The unique ID of the test package from which the required data (Test Points) are pulled out
UutID	String	The unique ID of the UUT on which the work order will be run
WorkOrderID	String	The unique ID assigned to the work order
WorkOrderNumber	String	The number used to be seen and refer to a work order
TestProcessIdentity	Class	An object of this class keeps the data about a test process identity.
CreatedBy	String	Who created the test process
Description	String	Some description about the test process
Name	String	The name of the test process
OptionalParameters	List<Parameter>	Optional parameters
RequiredParameters	List<Parameter>	Required parameters
Revision	String	The revision of the test process
TestProcessID	String	The unique ID given to the test process
TestProcessRegID	String	The registration ID assigned for the test process. This ID is used for binding two objects which need to communicate with each other.
TestType	String	Showing the conventional type for a test group. E.g.: “Measure.Harmonics” for a test group used for a harmonics test.

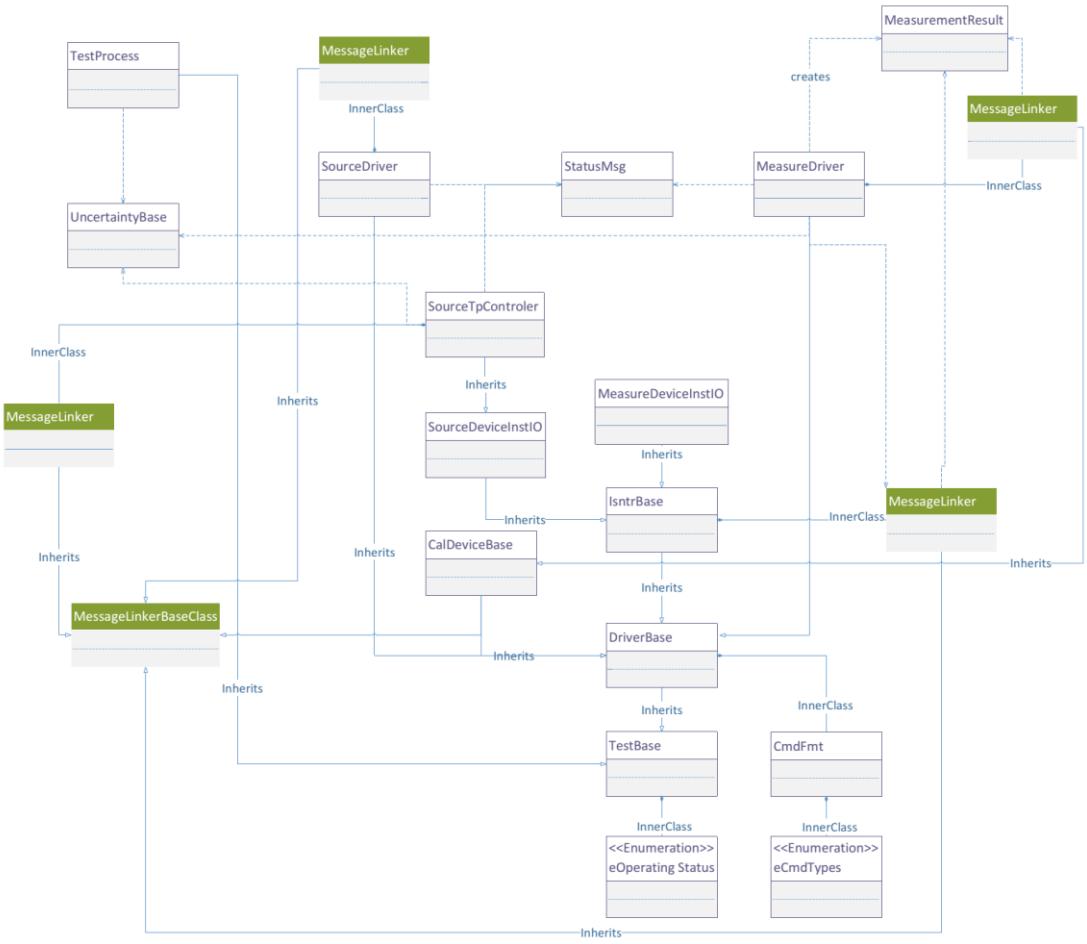
UnitOfMeasure	String	The unit of measure to be used in doing the measurements by the test process
InstrBase	Class	This is a class in the test process software hierarchy to keep data about some basic parameters of an instrument.
VISA_Resource	String	Reference to the GPIB address used to talk to an instrument
OptionalParameters	List<Parameter>	Optional parameters
RequiredParameters	List<Parameter>	Required parameters

APPENDIX D

METROLOGY.NET SYSTEM CONCEPTUAL MODEL




eParrentTypes
InnerClass
WorkOrder
TestPkg
1
modifies
1
1..*
0..*
0..*
Agent
1..*
1..*
User
TestGroup
1
0..*
Parameter
0..*
0..*
Modifies
MessageLinker
1
1..*
MessageLinker
0..*
InnerClass
TestPoint
1
Uses
0..*
0..*
MeasureDriver
InnerClass
MeasurementResult
TestProcess
<<Enumeration>>
eTestType
Creates
Inner Class
MessageLinker
TestResult


MeasurementResult
TestProcess
MessageLinker
creates
MessageLinker
InnerClass
SourceDriver
StatusMsg
MeasureDriver
InnerClass
UncertaintyBase
SourceTpControler
InnerClass
Inherits
MeasureDeviceInstIO
MessageLinker
Inherits
SourceDeviceInstIO
Inherits
IsntrBase
InnerClass
MessageLinker
Inherits
Inherits
CalDeviceBase
Inherits
Inherits
MessageLinkerBaseClass
DriverBase
Inherits
Inherits
Inherits
InnerClass
TestBase
CmdFmt
InnerClass
InnerClass
<<Enumeration>>
eOperating Status
<<Enumeration>>
eCmdTypes
Inherits

APPENDIX E

LIST OF SPARKS LANGUAGE KEYWORDS AND PREDEFINED WORDS

No	Keyword
1	and
2	as
3	bind
4	constant
5	do
6	each
7	else
8	end
9	for
10	if
11	in
12	measure
13	or
14	prompt
15	provide
16	require
17	set
18	testGroup
19	testPoint
20	testProcess
21	then
22	to
23	linkerType
24	testType
25	use
26	xor

No	Predefined words
1	Description
2	TestName
3	TestType
4	UNCERTAINTY
5	UnitOfMeasure

APPENDIX F

HELPER FUNCTIONS

Function Name
Dialog.ConnectionPicture(“ImageName”, “Message”) This function uses the web interface of Metrology.NET. Shows a Pop-up message box containing the image and the message provided.
Dialog.ConnectionMessage(“Message”) This function uses the web interface of Metrology.NET. Shows a Pop-up message box containing the message to be shown.
Dialog.EnterNumber(“Instructions”) This function uses the web interface of Metrology.NET. Shows a Pop-up message box containing a message and an input box for the user to enter a number.
Dialog.EnterText(“Instructions”) This function uses the web interface of Metrology.NET. Shows a Pop-up message box containing a message and an input box for the user to enter a string.
Dialog.MultipleChoice(“Questions”, “option1”, “option2”, …) This function uses the web interface of Metrology.NET. Shows a Pop-up message box containing the message to be shown.
Dialog.YesNo(“Question”) This function uses the web interface of Metrology.NET. Shows a Pop-up message box containing the question and Yes/No buttons to be shown.

APPENDIX G

COMPARISON OF A SAMPLE SPARKS SCRIPT WITH ITS EQUIVALENT ON METROLOGY.NET PLATFORM

	SparkS Script	Metrology.NET Code
1 2 3 4	The highest level class in the Metrology.NET abstract software model controlling an ETE (Electronic Test Equipment)	**Test Process Class**
5		Region "Header Information"
6 7 8 9 10	Handled by the interpreter	Public Overrides ReadOnly Property TestID As String Get Return "85B1282D-48D0-4CD1-A30C-C61B40B9D282" End Get End Property
11 12 13 14 15	**bind** TestType **to** "TestProcess.Measure.Frequency"	Public Overrides ReadOnly Property TestType As String Get Return "TestProcess.Measure.Frequency" End Get End Property
16 17 18 19 20 21	**bind** TestName **to** "TestProcess.Measure.Frequency (Agilent E44xxA)"	Public Overrides ReadOnly Property TestName As String Get Return "TestProcess.Measure.Frequency (Agilent E44xxA)" End Get End Property
22 23 24 25 26 27 28	**bind** Description **to** "Measures the Frequency of a CW signal using an Agilent PSA (E44xx) Spectrum Analyzer"	Public Overrides ReadOnly Property Description As String Get Return "Measures the Frequency of a CW signal using an Agilent PSA (E44xx) Spectrum Analyzer" End Get End Property
29 30 31 32 33 34 35 36	Handled by the interpreter	Public Overrides ReadOnly Property Revision As String Get Return System.Reflection.Assembly.GetExecutingAssembly().GetName().Version.ToString End Get End Property
37 38 39 40 41	**bind** UnitOfMeasure **to** "Hz"	Public Overrides ReadOnly Property UofM As String Get Return "Hz" End Get End Property
42 43 44 45 46	Handled by the interpreter	Public Overrides ReadOnly Property CreatedBy As String Get Return "9A42AF06-7467-4098-9607-476241D4CE11" End Get End Property

47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74	**testPoint** tp **provide** Frequency Power ReferenceSource **measure** measuredFrequency **end** tp	Public Overrides ReadOnly Property RequiredParameters As List(Of Parameter) Get Dim Params As New List(Of Parameter) Dim NewParam As Parameter NewParam = Parameter.NewParameter("Frequency", "") Params.Add(NewParam) NewParam = Parameter.NewParameter("Power", "") Params.Add(NewParam) Return Params End Get End Property Public Overrides ReadOnly Property OptionalParameters As List(Of Parameter) Get Dim Params As New List(Of Parameter) Dim NewParam As Parameter NewParam = Parameter.NewParameter("ReferenceSource", "") NewParam.LimitedToList = True NewParam.List = {"External", "Internal"} Params.Add(NewParam) Return Params End Get End Property
75		Region "Properties"
76 77 78 79 80 81 82 83 84 85 86 87 88	**require** ete **as linkerType** "Measure.Driver" **testType** "Agilent_PSA.MeasureFrequency"	Private MeasFreq As MeasureDriver.MessageLinker Private _MeasFreqID As String <TestTypeConfigParameter(TestType:="Agilent_PSA.MeasureFrequency")> Public Property MeasFreqID As String Get Return _MeasFreqID End Get Set(value As String) ' Need to Link this to the Mail Box of the Driver MeasFreq = MeasureHarmonics.MessageLinker.GetLinker(value) _MeasFreqID = value End Set End Property
89 90 91 92 93 94 95 96 97 98 99 100 101 102 103	**require** uut **as linkerType** "Source.Driver" **testType** "UUT_Command.SourceTpControlerDynamicUUT"	Private UUT_Source As SourceTpControler.MessageLinker Private _SourceID As String <TestTypeConfigParameter(TestType:="UUT_Command.SourceTpControlerDynamicUUT")> Public Property SG_DriverID As String Get Return _SourceID End Get Set(value As String) UUT_Source = SourceTpControler.MessageLinker.GetLinker(value) _SourceID = value End Set End Property
104 105 106 107 108	Handled by the interpreter	Public Overrides Function Run() As Boolean Try ' Set the UUT Information Me.UUT_Source.SetTestGroup(TestGroup) ' Me.UUT_Source.SetModel (MTestGroup)
109 110	**ete**.Reset	' Reset the System If Me.HaltFlag = False Then Me.MeasFreq.Reset()
111 112	**uut**.Reset	If Me.HaltFlag = False Then Me.UUT_Source.Reset()
113 114 115 116 117	Dialog.ConnectionPicture("PSA_TO_UUT_RFIN", "Connect both the UUT and PSA to the 10MHz Ref.")	' Connect the UUT Me.UI.ConnectionPicture(Me.GetEmbeddedPic("PSA_TO_UUT_RFIN.png"), "Connect both the UUT and PSA to the 10MHz Ref.")

118 119 120	**testGroup** tgCollection **testPoint** tp **for each** tp1 **in** tgCollection **do**	For Each Tp As TestPoint In Me.TestPoints
121 122 123 124 125 126 127 128 129 130	Handled by the interpreter	If Me.HaltFlag = False Then Try Tp.LoadParameters() Dim TestResult As New TestResult(Tp) TestResult.AsFound = True TestResult.AsLeft = True If Me.HaltFlag = False Then ' Check the Flag Again Me.UUT_Source.Setup(Tp)
131	uut.Enable	Me.UUT_Source.Enable(Tp.ParameterArray)

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137
	Handled by the interpreter	'Need to Pause Here
		Dim Result As MeasurementResult =
		Me.MeasFreq.Measure(Tp.ParameterArray)
		If Result.ErrorFlag = False Then
		TestResult.Measured = Result.Value
		Else

138 139 140 141	Not included in the interpreter	TestResult.AddParameter(Parameter.NewParameter("Error", Result.ErrorMessage)) End If End If
142	Handled by the interpreter	Me.SaveTestResults(TestResult)
143 144 145 146 147 148 149 150 151 152 153 154 155	Handled by the interpreter	Catch ex As HaltExecution Me.Halt() Catch ex As Exception Try Me.UUT_Source.Disable(Me.TestGroup.ParameterArray) Finally End Try Me.LogError(ex.Message) Me.UI.ConnectionMessage("Error Running Test Process! Please See the Error Logs") End Try End If Next
156 157	uut.disable	Me.UUT_Source.Disable(Me.TestGroup.ParameterArray)
158 159 160 161 162 163 164 165	Handled by the interpreter	Return True Catch ex As Exception LogError(ex) Me.UI.ConnectionMessage("Error Running Test Process! Please See the Error Logs") Throw (ex) End Try End Function
166 167 168 169 170	The middle level class in the Metrology.NET abstract software model for controlling an ETE	**Measure Driver**
171		Region "Header Information"
172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187	Since we have a single file SparkS script, a single header section is used for both a test process and measure driver.	Public Overrides ReadOnly Property TestID As String Get Return "BEE96ADD-C927-4215-BA57-23D67741A410" End Get End Property Public Overrides ReadOnly Property TestType As String Get Return "Measure.Frequency" End Get End Property Public Overrides ReadOnly Property TestName As String Get Return "Measure.Frequency (Agilent E44xxA)" End Get End Property

188		
189		Public Overrides ReadOnly Property Description As String
190		Get
191		Return "Measures the Frequency of a CW signal using an Agilent PSA
192		(E44xx) Spectrum Analyzer"
193		End Get
194		End Property
195		
196		Public Overrides ReadOnly Property Revision As String
197		Get
198		Return
199		System.Reflection.Assembly.GetExecutingAssembly().GetName().Version.ToS
200		tring
201		End Get
202		End Property
203		
204		Public Overrides ReadOnly Property UofM As String
205		Get
206		Return "Hz"
207		End Get
208		End Property
209		
210		Public Overrides ReadOnly Property CreatedBy As String
211		Get
212		Return "9A42AF06-7467-4098-9607-476241D4CE11"
213		End Get
214		End Property
215		Region "Parameters"
216	Already handled by the following	Private _SA_InstanceID As String
217	statement:	Dim Analyzer As InstrBase.MessageLinker
218	**require** ete **as linkerType**	<TestTypeConfigParameter(TestType:="Agilent_PSA.Driver")>
219	"Measure.Device" **testType**	Public Property SA_InstanceID As String
220	"iSpectrumAnalyzer"	Get
221		Return _SA_InstanceID
222		End Get
223		Set(value As String)
224		Analyzer = InstrBase.MessageLinker.GetLinker(value,
225		"iSpectrumAnalyzer")
226		_SA_InstanceID = value
227		End Set
228		End Property
229		Region "Measurment Process"
230	ete.Reset	Public Overrides Function Reset(Optional ByVal Parameters() As Parameter =
231		Nothing) As MetrologyNet.System.Interface.iStatusMsg
232		Try
233		Analyzer.MethodCall("Reset", Parameters)
234		
235		Return StatusMsg.SuccessMsg
236		Catch ex As Exception
237		LogError(ex)
238		Throw (ex)
239		End Try
240		End Function
241	ete.Setup	Public Overloads Overrides Function Setup(Parameters() As
242		MetrologyNet.Parameter) As MetrologyNet.System.Interface.iStatusMsg
243		Try
244		Analyzer.MethodCall("SelfCal", Parameters)
245		Return StatusMsg.SuccessMsg
246		Catch ex As Exception
247		LogError(ex)
248		Throw (ex)
249		End Try
250		End Function
251	Handled by the interpreter	Public Overloads Overrides Function Measure(Parameters() As
252		MetrologyNet.Parameter) As
253		MetrologyNet.System.Interface.iMeasurementResult
254		Try
255		Dim Frequency As Double
256		Dim RefLevel As Double
257		Dim MeasureVal As Double

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	Set Frequency To tp1.Frequency	' Get the Frequency
		If Parameter.Contans("Frequency", Parameters) = True Then
		Frequency = Parameter.GetParameterValue("Frequency", Parameters)
		Else
		Throw New Exception("Frequency Not Provided")
		End If

265 266 267	set MaxFrequency to ete.MaxFrequency	' Check the Frequency Range of the Spectrum Analyzer Dim MaxFrequency As Double = Val(Analyzer.GetProperty("MaxFrequency"))
268 269 270	set MinFrequency to ete.MinFrequency	' Check the Frequency Range of the Spectrum Analyzer Dim MinFrequency As Double = Val(Analyzer.GetProperty("MinFrequency"))
271 272 273 274 275 276	if Frequency < MinFrequency or Frequency > MaxFrequency then error "Frequency Out of Range" end if	If Frequency < MinFrequency Or _ Frequency > MaxFrequency Then Return MeasurementResult.MeasurementError("Frequency Out of Range") End If
277 278 279	set ete.Coupling to “DC”	' Set the Coupliing Analyzer.SetProperty("Coupling", "DC")
280 281	set ete.ReferenceLevel to 10	'Find the Fundimental Analyzer.SetProperty("ReferenceLevel", 10)
282 283 284	set ete.CenterFrequency to Frequency	Analyzer.SetProperty("CenterFrequency", Frequency)

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	if Frequency < 2.2e3 then
	set ete.Span to 10
	set ete.ResolutionBandwidth to 100
	
	else if Frequency < 2.2e6 then
	set ete.Span to 500
	set ete.ResolutionBandwidth to 50
	else
	set ete.Span to 500e3
	set ete.ResolutionBandwidth to
	10e3
	end if
		' Set the Span and Filters
		If Frequency < Val("2.2e3") Then
		Analyzer.SetProperty("Span", 10)
		Analyzer.SetProperty("ResolutionBandwidth", 100)
		ElseIf Frequency < Val("2.2e6") Then
		Analyzer.SetProperty("Span", 500)
		Analyzer.SetProperty("ResolutionBandwidth", 50)
		Else
		Analyzer.SetProperty("Span", Val("500e3"))
		Analyzer.SetProperty("ResolutionBandwidth", Val("10e3"))
		End If

297 298	set ete.AverageSweep to 1	Analyzer.SetProperty("AverageSweep", 1)
299 300 301 302	ete.TakeSweep ete.TakeSweep	' Take A couple Sweeps Analyzer.MethodCall("TakeSweep") Analyzer.MethodCall("TakeSweep")
303 304 305	ete.MarkerPeakHi	'Adjust the Level Analyzer.MethodCall("MarkerPeakHi")
306 307 308	set RefLevel to ete.MarkerAmplitude	RefLevel = Analyzer.FunctionCall("MarkerAmplitude")

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	if RefLevel < -40 then
	//measure a single harmonic
	set RefLevel to -40
	end if
		If RefLevel < -40 Then RefLevel = -40

313 314	set ete.ReferenceLevel to RefLevel	Analyzer.SetProperty("ReferenceLevel", RefLevel)

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	set Sum to 0
	
	for each index in [1, 5] do
	
	set Sum to Sum +
	ete.MarkerFrequencyCount
	end for
		Dim Sum As Double
		
		For i As Integer = 1 To 5
		Sum = Sum + Analyzer.FunctionCall("MarkerFrequencyCount")
		Next

323 324	set MeasureVal to Sum / 5	MeasureVal = Sum / 5
325 326 327	set UNCERTAINTY to UNC *//set the measured value as test result*	Dim Result As MeasurementResult = New MeasurementResult(MeasureVal, "Hz", "0.5")

328 329 330	**set** measuredFrequency **to** MeasureVal	
331 332 333 334 335 336 337	Handled by the interpreter	Return Result Catch ex As Exception LogError(ex) Throw (ex) End Try End Function
338 339 340 341	This is the main class that handles UUT settings. UUT parameters are passed through the test points upon a test run.	**UUT Driver**
342		Region "Test Process Identity"
343 344 345 346 347 348 349 350 351 352 353 354 355 356 357 358 359 360 361 362 363 364 365 366 367 368 369 370 371 372 373 374 375 376 377 378 379 380 381 382 383 384 385 386 387	UUT driver is embedded as-is into the interpreter	Public Overrides ReadOnly Property testID As String Get Return "B9A9401A-E142-4EC3-A65A-84B1B2212EF7" End Get End Property Public Overrides ReadOnly Property TestName As String Get Return "CLS.ParaCommand.Source" End Get End Property Public Overrides ReadOnly Property TestType As String Get Return "Source" End Get End Property Public Overrides ReadOnly Property UofM As String Get Return "N/A" End Get End Property Public Overrides ReadOnly Property Description As String Get Return "Generic Parameter based Driver for Sources" End Get End Property Public Overrides ReadOnly Property CreatedBy As String Get Return "9A42AF06-7467-4098-9607-476241D4CE11" End Get End Property Public Overrides ReadOnly Property Revision As String Get Return (System.Reflection.Assembly.GetExecutingAssembly().GetName().Version.To String) End Get End Property Region "Properties"

```
388                                 Private Commands As New Dictionary(Of String, Parameter)
389
390                                 Private Sub UpdateCommands(ByVal Parameters() As Parameter)
391                                     ' Update the Command Paramaters
392
393                                     If Parameters.Count > 0 Then
394                                         For Each Param As Parameter In Parameters
395                                             If Param.Name.StartsWith("Command:") Then
396                                                 Dim Key As String = Param.Name.Replace("Command:", "")
397                                                 If Commands.ContainsKey(Key) Then
398                                                     Commands(Key) = Param
399                                                 Else
400                                                     Commands.Add(Key, Param)
401                                                 End If
402                                             End If
403                                         Next
404                                     End If
405                                 End Sub
406
407                                 Public Overrides Function SetTestGroup(TestGroup As TestGroup) As Boolean
408                                     Try
409                                         TestGroup.LoadParameters()
410                                         MyBase.SetTestGroup(TestGroup)
411
412                                         Dim TPkg As TestPkg = TestPkg.GetByTestPkgID(TestGroup.TestPkgID)
413                                         TPkg.LoadParameters()
414
415                                         ' Build the Command library
416                                         Me.UpdateCommands(TPkg.ParameterArray)
417                                         Me.UpdateCommands(TestGroup.ParameterArray)
418
419                                         Return True
420                                     Catch ex As Exception
421                                         Return False
422                                     End Try
423                                 End Function
424                                 Region "Source Operations"
425 uut.Reset                       Public Overrides Function Reset(Optional ByVal Parameters() As Parameter =
426                                 Nothing) As iStatusMsg
427                                     Try
428                                         ' Update my Command list
429                                         Me.UpdateCommands(Parameters)
430
431                                         If Me.Commands.Keys.Contains("Reset") = True Then
432                                             Me.Write(Me.Commands.Item("Reset").Value)
433                                         Else
434                                             Me.Write("*RST")
435                                         End If
436                                         Return StatusMsg.SuccessMsg
437                                     Catch ex As Exception
438                                         Return StatusMsg.FailedMsg(-1, ex.Message)
439                                     End Try
440                                 End Function
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	This code is used by the interpreter	`Protected ReplacementValues() As String = {"[value]", "[Value]", "[VALUE]", "<value>", "<Value>", "<VALUE>"}`
		
		Public Overloads Overrides Function Setup(Parameters() As Parameter) As iStatusMsg
		  Try
		
		  ' Update my Command list
		  Me.UpdateCommands(Parameters)
		
		  'Process the Set Params
		  For Each Param As Parameter In Parameters
		  For seq As Integer = 0 To 1000
		  If Param.Sequence = seq Then
		  If Commands.ContainsKey(Param.Name) Then
		  Dim Command As String = Commands.Item(Param.Name).Value
		  For Each theToken As String In ReplacementValues
		  If Command.Contains(theToken) Then
		  Command = Command.Replace(theToken, Param.Value)
		  End If
		  Next
		  `Me.Write(Command)`
		  End If
		  End If
		  Next
		  Next
		
		  Return StatusMsg.SuccessMsg
		  Catch ex As Exception
		  Return StatusMsg.FailedMsg(-1, ex.Message)
		  End Try
		
		End Function
		
		Public Overrides Function SetupTestPoint(TestPoint As MetrologyNet.TestPoint) As MetrologyNet.StatusMsg
		  Return Setup(TestPoint.ParameterArray)
		End Function

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	uut.Disable	Public Overrides Function Disable(Optional Parameters() As MetrologyNet.Parameter = Nothing) As MetrologyNet.System.Interface.iStatusMsg
		  Try
		  Console.WriteLine("UUT disabled")
		  If Me.Commands.Keys.Contains("OutputOff") = True Then
		  Me.Write(Me.Commands.Item("OutputOff").Value)
		  End If
		  Return StatusMsg.SuccessMsg
		  Catch ex As Exception
		  Return StatusMsg.FailedMsg(-1, ex.Message)
		  End Try
		End Function

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	uut.Enable	Public Overloads Overrides Function Enable(Optional Parameters() As MetrologyNet.Parameter = Nothing) As MetrologyNet.System.Interface.iStatusMsg
		  Try
		  Console.WriteLine("UUT enabled")
		  If Me.Commands.Keys.Contains("OutputOn") = True Then
		  Me.Write(Me.Commands.Item("OutputOn").Value)
		  End If
		  Return StatusMsg.SuccessMsg
		  Catch ex As Exception
		  Return StatusMsg.FailedMsg(-1, ex.Message)
		  End Try
		End Function

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	This code is used by the interpreter	Public Function Output(Enabled As Boolean, Optional ByVal Parameters() As Parameter = Nothing) As iStatusMsg
		  Try
		  If Enabled = True Then
		  If Me.OperatingParam.Keys.Contains("Command:OutputOn") = True Then

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		VisaMsg.Send(Me.TestProcessID, Me.VISA_Resource, Me.OperatingParam.Item("Command:OutputOn").Value)
		End If
		Else
		If Me.OperatingParam.Keys.Contains("Command:OutputOff") = True Then
		VisaMsg.Send(Me.TestProcessID, Me.VISA_Resource, Me.OperatingParam.Item("Command:OutputOff").Value)
		End If
		End If
		Return StatusMsg.SuccessMsg
		Catch ex As Exception
		Return StatusMsg.FailedMsg(-1, ex.Message)
		End Try
		End Function

527 528 529 530 531 532 533	This code is used by the interpreter	Public Overrides Sub TearDown(Parameters() As Parameter) Try Me.Reset() Me.Output(False) Catch ex As Exception End Try End Sub