

Introduction to Attribute Based Instrument Drivers

Application Note

Products:

R&S®FSW	R&S®CMW	R&S®ETL
R&S®FSV	R&S®RTM	R&S®ETH
R&S®FSVR	R&S®RTO	R&S®SFC
R&S®FSQ	R&S®ZNC	R&S®SFE
R&S®FSP	R&S®ZNB	R&S®SFU
R&S®FSU	R&S®ZVL	R&S®CLG
R&S®FSMR	R&S®ZVH	R&S®DVSG
R&S®FSUP	R&S®PR100	
R&S®FSL	R&S®EM100	
R&S®ESL		
R&S®FSC		
R&S®FSH4/8		

This application note introduces a novel attribute based architecture for VXIplug&play instrument drivers. The presented architecture uses the attribute based concept of IVI-C instrument drivers to introduce a two-layer design for VXIplug&play instrument drivers.

Table of Contents

1	VXIplug&play Instrument Drivers	3
1.1	Preface.....	3
1.2	The Definition of Instrument Drivers	4
2	Attribute Based Instrument Drivers.....	5
2.1	Attribute Access Functions.....	6
2.2	Attributes and its Data Types.....	6
2.2.1	Implementation of Attributes in C.....	7
2.2.2	Implementation of Attributes in LabVIEW	7
2.3	Range Table	8
2.4	Repeated Capabilities	8
2.5	Multithread Safety	9
2.6	Events.....	9
3	Use of Rohde & Schwarz Attribute Instrument Drivers	10
3.1	How to Use Attributes in LabVIEW	10
3.2	How to Use Attributes in LabWindows/CVI	10
3.2.1	Repeated Capabilities in LabWindows/CVI	13
3.2.2	Dynamic Repeated Capabilities in LabWindows/CVI	14
3.3	How to Use Attributes in Microsoft Visual Studio Using C#.....	15
3.3.1	Repeated Capabilities in C#	18
3.3.2	Dynamic Repeated Capabilities in C#	19
3.4	Tips and Tricks	19
3.4.1	Execution Speed: Disable Instrument Status Checking	19
3.4.2	How to Build Executables or Libraries in LabVIEW.....	19
3.4.3	Error Handling: "Instrument version not valid"	20
3.4.4	Error Handling: Range Checking.....	20
3.4.5	How to Minimize the Size of an Attribute-Based Instrument Driver.....	20
4	Related Documents.....	23
5	References.....	24

1 VXIplug&play Instrument Drivers

1.1 Preface

The task of programming instruments in a test system has always been a concern for end users and a major cost for the overall system development. Many users know that programming can often be the most time-consuming part of developing a system. The developer spends much valuable time learning the specific programming requirements of each instrument in the system. Almost all instruments are designed for interactive use through a physical front panel and also offer remote control capability via a communication port on the backside of the instrument. The details for how to program the instrument remotely are usually documented in the instrument manual in the form of ASCII command sets that cause the instrument to perform the desired operation. Documenting an instrument command set in the user manual, along with some example program listings, has traditionally been the standard method for an instrument vendor to assist the end user in programming the instrument. These documentation methods have served the industry well for many years, but this approach still places the responsibility for writing the program code on the user, many of whom may end up writing very similar application programs.

If the same command works for multiple instruments, regardless of the manufacturer, users can interchange or upgrade instruments and reduce the amount of changes to their application programs. In particular, many of the installed base of users who had substantial investments in their software environments, that did not easily lend themselves to software modularity, lobbied for this approach. Through the mid to late 1980s, many standard organizations, including the IEEE, worked on this objective with little progress. The IEEE 488.2 specification [ANSI/IEEE Std 488.1-1987], completed in 1987, more carefully defined the operation of instruments like the program message exchange protocol, but did not address the issue of standard command sets. In 1990, the SCPI¹ Consortium [The SCPI Consortium] was formed, which became part of IVI Foundation in 2002. This organization approved a specification for standardized commands for message-based programmable instruments. The SCPI Consortium is not active anymore and the last updated document was published in 1999 [The SCPI Standard]. While more and more companies continue to endorse the SCPI standard and use it in their new instrument designs, still instruments available today do not use this standard command set. In addition, while many users of SCPI instruments appreciated the progress and have experienced improvement in productivity once they learn the standard command set, instrument interchangeability is still not a reality because most instruments have different, often unique functionality and therefore a command set different to the SCPI standard command set. Moreover syntactically equal SCPI commands are a necessary, but not a sufficient condition for instrument interchangeability.

While the SCPI standard is certainly recognized by the entire industry as a step forward, the lack of progress on this issue encouraged both users and vendors to explore other approaches before SCPI was completed.

¹ Standard Commands for Programmable Instruments

They needed to decrease the time required to program instruments, facilitating instrument interchangeability and easing system maintenance. Rather than trying to solve the problems by standardizing the instruments from all suppliers, both users and vendors began to take advantage of new computer science technology to address the issues by making software more modular and flexible.

1.2 The Definition of Instrument Drivers

An instrument driver, in the simplest definition, is a set of software routines that handles the programmatic details of controlling and communicating with a specific instrument. The most successful instrument driver concepts have always distributed instrument drivers in source code and provided end users with access to the same tools developers use to write drivers. With this philosophy, new instrument drivers were often easily developed by end users through modifying an existing driver for another instrument. End users, in general, had come to view the availability of an instrument driver as an important factor in the choice of a particular instrument. However, users still had access to standard instrument driver development tools and source codes for other instruments.

VXIplug&play instrument drivers are defined by VXIplug&play Systems Alliance [VXIplug&play Systems Alliance], which is part of the IVI (Interchangeable Virtual Instrument) Foundation [Interchangeable Virtual Instrument Foundation] since 2002. These drivers offer a simple API (application programming interface) using non structured data types. This API is defined by a so called "function panel file" which contains graphical panels. Each of these panels is representing a function's prototype. Functions are designed to group several instrument's parameters which are logically tied one to each other. It allows the driver's user to make instrument setup or measurement in less steps compared to sending SCPI commands using low-level or VISA functions [Virtual Instrument Software Architecture]. On the other hand, there are cases where access to specific commands is needed.

Modern instruments capable of measuring, generating and analyzing advanced signals, such as WiMAX² or LTE³, are very complex and sometimes it may be necessary to configure only a single parameter of the instrument, usually because of speed (either speed of software execution or speed of instrument's internal reconfiguration and measurement). Formerly this contradiction was solved by sending SCPI commands directly using either VISA low level functions like the VISA Read/Write, or utilizing the function of the driver that is configuring this parameter. However, issues like instrument state synchronization or error checking needs to be solved by the user. To avoid mixing two different programming techniques new drivers have been designed with layered API consisting of low level and high level functions. Low level functions are usually using only one SCPI command. High level functions are then calling into several low level functions according to its parameters. While this API structure allows the user to benefit from both having well organized high level functions and having low level functions, it leads to high number of exported functions (and VIs in case of LabVIEW⁴ instrument drivers).

Rohde & Schwarz offers a new approach to balance the instrument driver's API called Attribute Based Instrument Drivers.

² For details on WiMAX please visit <http://www.rohde-schwarz.com/appnote/1MA96.html>

³ For details on LTE please visit <http://www.rohde-schwarz.com/appnote/1MA111.html>

⁴ For details on National Instrument LabVIEW please visit <http://www.ni.com/labview/>

2 Attribute Based Instrument Drivers

An attribute can be defined as an element of a hardware configuration of an instrument or a software configuration of an instrument driver. Thus each instrument setting is associated with a hardware configuration attribute.

In general an attribute based driver is a standard VXIplug&play instrument driver. It can be used as a traditional single layer instrument driver. However, if the user needs to configure or measure a single parameter which is part of complex high level function. He does not have to directly use a SCPI command or if available, a low level function, but can use the appropriate attribute access function. For instance the high level function of the Rohde & Schwarz spectrum analyzer instrument driver (*rsspecan*⁵) for configuring the sweep coupling sets three parameters: the resolution- and the video bandwidth, as well as the sweep time. So for example to configure only the resolution bandwidth, the corresponding attribute can be used (illustrated in the figure below step a) and step aa)).

Attribute based drivers are leveraging the best from both VXIplug&play instrument drivers and IVI-C instrument drivers. Low level functionality is implemented in the same way as in IVI-C drivers via attributes. The high level driver functions are similar to the IVI standard, but not limited to the restrictions of the IVI class definition, like strict definition of function names, number of arguments and its names of functions which are following the IVI class specification.

Most high level functions are implemented using attributes as well. In this case also the shown steps a) and aa) are executed when calling one of these high level functions. However, not all instrument commands can be implemented as attributes, thus some functions are not using attributes, but are implemented in the traditional way, as already mentioned above. In that case the shown step b) is executed. For instance all functions, which have arrays as part of their API, fall into this category, for example a recorded trace of a spectrum.

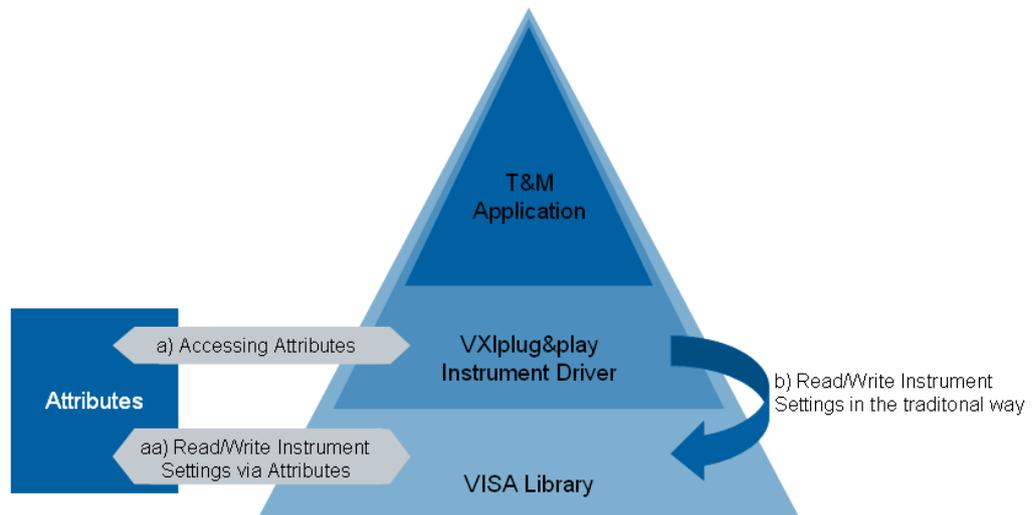


Figure 1: Architecture of Rohde & Schwarz attribute based instrument drivers: Example of instrument hardware configuration setting, e.g. a)-aa) frequency setting or b) reading trace data

⁵ The *rsspecan* instrument driver is available at <http://www.rohde-schwarz.com/drivers>.

2.1 Attribute Access Functions

When a high level function in an instrument driver queries or modifies the current setting of an attribute, it does so by calling one of the `Rs_GetAttribute` or `Rs_SetAttribute` functions. Each driver contains five *prefix*⁶ `GetAttribute` functions and five *prefix* `SetAttribute` functions, one for each possible attribute data type. These are called typesafe functions.

Each driver also exports five⁷ typesafe *prefix* `CheckAttribute` functions. Instrument drivers can call these functions to verify that a particular value is valid for an attribute. This allows users to bypass the high level functions in instrument drivers and directly query and modify the values of instrument attributes. The *prefix* `GetAttribute`, *prefix* `SetAttribute`, and *prefix* `CheckAttribute` functions are merely wrappers around calls to the `Rs_GetAttribute`, `Rs_SetAttribute`, and `Rs_CheckAttribute` functions.

This instrument driver contains high-level functions that set most of the instrument attributes. It is best to use the high-level driver functions as much as possible, because they handle order dependencies.

2.2 Attributes and its Data Types

Attributes can be grouped into two categories – hardware configuration attributes and software control attributes. Generally, each instrument setting is associated with a hardware configuration attribute, e.g. a frequency setting. Hardware configuration attributes allow the user to set and query values of the associated instrument settings. Software control attributes control how the instrument driver works rather than representing particular instrument settings. Those allow users to enable and disable features such as range checking and instrument status checking. For more information about that, please refer to chapter 3.4.

⁶ *prefix* stands for a corresponding attribute based instrument driver, e.g. `prefix_SetAttributeBoolean(...)` stands for `rsspecan_SetAttributeBoolean(...)` in case of the *rsspecan* attribute based instrument driver.

⁷ Five type safe functions are available for following data types: `ViBoolean`, `ViInt32`, `ViReal64`, `ViString` and `ViSession`.

Attributes are used in conjunction with the following data types:

- ViBoolean
- ViInt32
- ViReal64
- ViString
- ViSession

SCPI commands with enumerated string argument, e.g.

[SENSe<1|2>:]AVERAge:TYPE VIDEo | LINear ...) are realized by an attribute of data type *ViInt32* and proper range table (see image below). The SCPI command itself is implemented in the attribute data structure which is encapsulated by the instrument driver.

For instance a SCPI command with more than one argument can't be implemented as attributes, but instead are implemented as high level functions. The same is also true for SCPI commands which are dealing with data sets. In the Rohde & Schwarz spectrum analyzer for example, the function for reading a Y-trace of a spectrum analyzer is implemented in that way.

2.2.1 Implementation of Attributes in C

Attributes are implemented as global data structures defined in file '*prefix_attributes.c*'. Because all drivers are distributed in source code, users can freely modify, remove or add any attribute, range table and repeated capabilities. Data structures are interpreted by the core, which is implemented in files '*rsidr_core.c*' and '*rsidr_core.h*'. These two files are always the same for all Rohde & Schwarz attribute drivers, thus when combining source codes of two different drivers these two files need to be added to the project once. Using attributes in the C-based LabWindows/CVI⁸ environment is described in chapter 3.2.

2.2.2 Implementation of Attributes in LabVIEW

Similarly to C implementation, in the latest version attributes and range tables in LabVIEW are implemented as global structures, which are accessed via global variables. Search for attributes and range tables uses pre-generated sorted hash tables and binary search instead of linear search. A global variable containing attribute definition is unique for each instrument driver as well as the driver core, which is distributed as LabVIEW library. This is the same for all Rohde & Schwarz attribute-based LabVIEW drivers. As speaking of attribute based driver which are shipped as project based LabVIEW code, here the same implementation of the functional global variable is realized, the only difference are different file names of the related files. Using attributes in LabVIEW is described in chapter 3.1.

⁸ For details on National Instrument LabWindows/CVI please visit <http://www.ni.com/lwcvl/>

2.3 Range Table

An Attribute can have its range table which defines the attribute's valid values. There are three types of range tables:

- *Ranged* - valid values are defined as a closed interval of integer or floating point values (according to the range table's data type). The number of marker available on a spectrum analyzer can be named as example.
- *Coerced* - valid values are defined as a discrete set of numbers. If this range table is associated with an attribute, then the attribute values are coerced to the nearest value listed in the coerced range table. For example the number of sweep points of a spectrum can be limited to an increment of 100 for number of points equal or greater than 201.
- *Discrete* - valid values are defined as a discrete set of numbers. No coercion applies. This range table is also used for mapping of integer constant values to enumerated string command arguments. For instance the string 'VIDeo', which needs to be sent to the instrument can be mapped to the symbolic constant `PREFIX_VAL_AVERAGE_TYPE_VIDEO` with integer value (0 for instance).

2.4 Repeated Capabilities

Many instruments contain multiple instances of the same type of functionality. For example, many instruments have multiple channels, windows or traces with independent settings. The general term for functionality that is duplicated in an instrument is repeated capability. Repeated capabilities can be complex. An instrument may have multiple sets of repeated capabilities, such as windows and traces, or markers. Also, repeated capabilities may be nested within other repeated capabilities, for example traces within displays.

Repeated capability instances are specified by a string parameter to each function that accesses the repeated capability or by a function that selects the active instance. Attribute access functions are provided with a string parameter which selects the capability to be used by function. To define the usage of a particular capability fill the string with a proper value. To use more than one repeated capability in one attribute, separate them with comma.

The attribute access functions include a repeated capability selector parameter for use with channel-based attributes or attributes of repeated capabilities. When using attribute access functions on attributes (see chapter 2.1) that do not apply to repeated capabilities, application programs pass `VI_NULL` or an empty string for the parameter.

Dynamic Repeated Capabilities

Some instruments, for instance R&S®ZNB, require user to create own identification strings for repeated capabilities (traces, channel, windows, etc.). In this case the multiplicity and the formatting of the so called dynamic repeated capabilities is defined by the user in the run time. In general this implies that the user must allow the driver to track the creation and the deletion of such repeated capabilities.

Even dynamic repeated capabilities are statically predefined with default values, which can be found on the instrument after its reset. For instance there's always after reset one trace, one window and one channel defined in network vector analyzer. These capabilities are statically predefined in instrument driver. However, these can be deleted or replaced afterwards during run time of the software.

Examples for this topic are presented in chapter 3.2.1 and chapter 3.3.1.

2.5 Multithread Safety

Rohde & Schwarz attribute drivers are multithread safe. Multithread safety means that multiple threads in the same process can use the same driver session and that different sessions of the same driver can run simultaneously on different threads. To access a driver session from multiple threads, the application initializes the driver in one thread and then shares the session handle or object with other threads. If an application wants to treat several calls to a driver as a single operation that other threads must not interfere with, the application must block other threads during the sequence of calls. The application can do this by using synchronization functions provided by the operating system or programming environment. Locking inside of a driver has not yet been implemented.

Multithread safety does not provide any mechanism to allow multiple processes to share the same session. It also does not provide any mechanism to synchronize between multiple threads or processes that open multiple sessions on the same physical instrument. To synchronize access to the same physical instrument from multiple processes, applications must use its own resource locking.

2.6 Events

Events are basically attributes with no data. This is different to IVI driver specification which does not allow implementation of events via attribute engine. Events in Rohde & Schwarz drivers are realized using *prefix_SetAttributeViString* with `VI_NULL` or an empty string in place of the string argument.

3 Use of Rohde & Schwarz Attribute Instrument Drivers

The following example is referring to the *rsspecan* and the *rsvna* instrument driver. The described procedures are all adaptable to other attribute based Rohde & Schwarz instrument drivers, only the naming of the files can be different. The naming convention is *PREFIX*, where the *PREFIX* is the abbreviation of a specific instrument driver.

3.1 How to Use Attributes in LabVIEW

For LabVIEW instrument drivers please refer to a separate document extensively dealing with this topic <http://www.rohde-schwarz.com/appnote/1MA228>. Chapter 4.2 describes using the attributes in LabVIEW.

3.2 How to Use Attributes in LabWindows/CVI

This section explains how to use attributes in the *rsspecan* instrument driver. This is necessary, for instance, if the driver does not support the functionality via high level functions (API).

Please use the *Driver Attribute Help* chm file. This help file is accessible via the *Instrument Driver Help* file (e.g. *rsspecan_vxi.chm*).

The *rsspecan.sub* file has to be added to the project. This file is mandatory for browsing attributes.

Example: How to set the *Frequency Start* value by attributes

To select an attribute, use the provided function panels, which are included in the instrument driver package. These instrument driver function panels can be found in:
Instruments=>ROHDE & SCHWARZ SpecAn=>Configuration=>Set/Get/Check Attribute/Repeated Capabilities

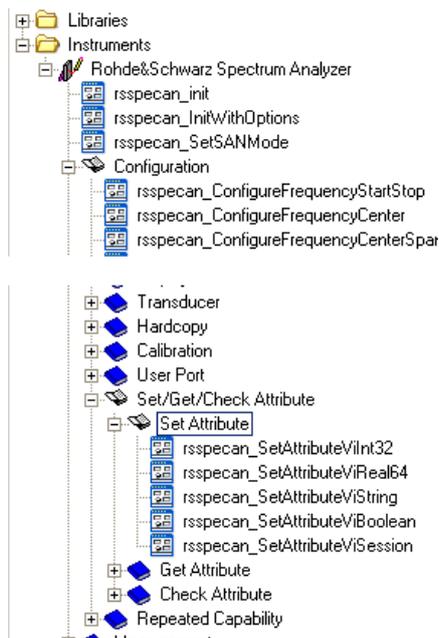


Figure 2: Function panel for rssipecan driver attributes.

To open the function panel, double-click on the desired function. Fig. 9 shows the function panel of "rssipecan_SetAttributeViReal64". Clicking on the "Attribute ID" text box opens the "Select Attribute Constant" window.

Now you can select the desired attribute from the tree structured list. Each attribute can have a different access type (*read only*, *write only* or *read/write*). Proper *read/write* operation can be selected by the proper function panel, either *Set Attribute*, *Get Attribute* or *Check Attribute*.

Repeated capabilities are set by using identifier or identifier names within the function panel called *rssipecan_GetAttributeRepeatedCapabilityId[s|Names]*.

For example, in Basic Operation use the *Set Frequency Start* value:

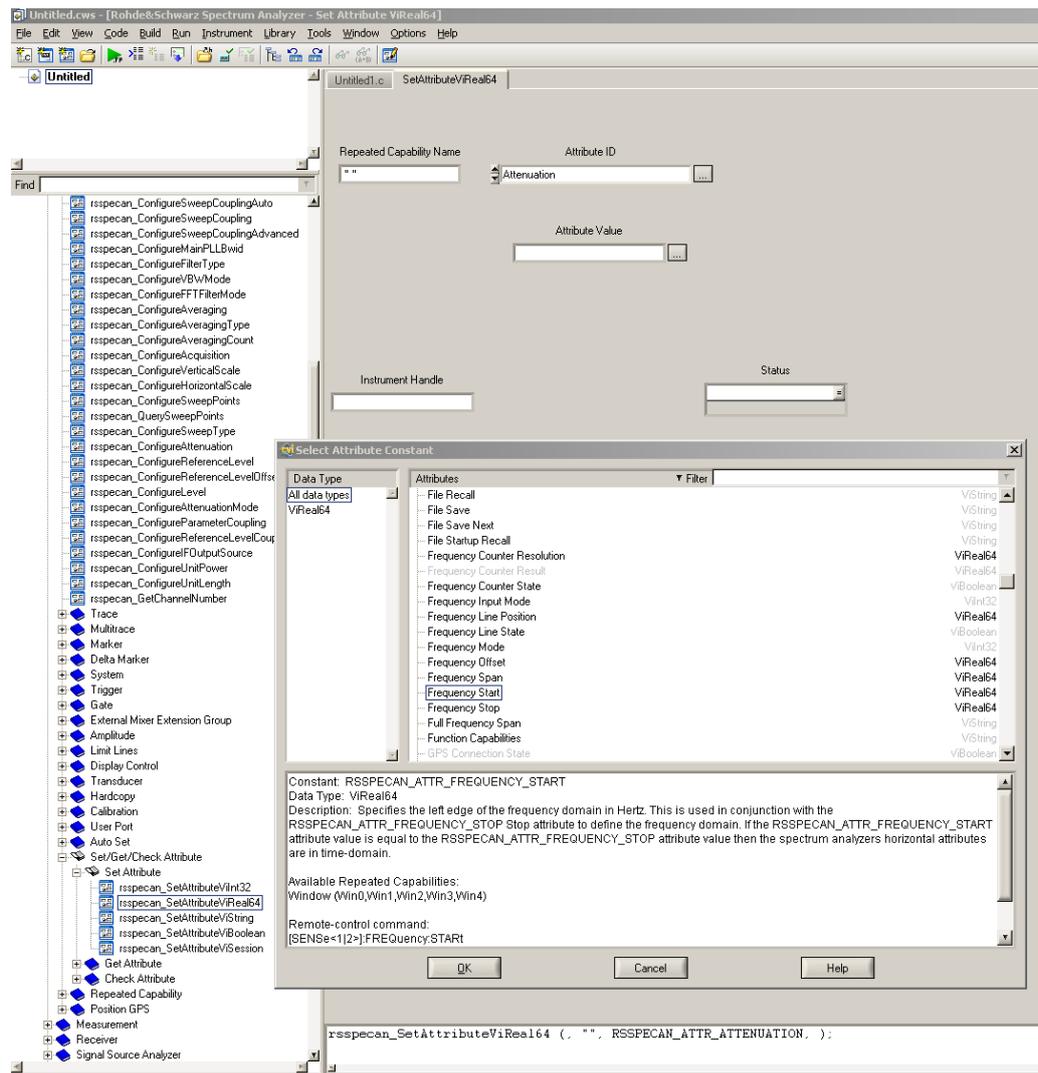


Figure 3: Selecting an attribute in the "SetAttributeViReal64" function panel.

1. Please select the desired attribute. To find the designated attribute easily the *rsspecan.chm* help file can be used to look for it. Be aware of the fact that the tree structures in the help file and the Express VI are the same.
2. Fill the *Repeated Capabilities* text box according to the documentation, e.g. "Win0".
3. Type the desired frequency value in the *Attribute Value* text box, e.g. "1e+9".
4. Enter a valid instrument handle in the *Instrument Handle* text box.
5. It is strongly recommended to evaluate the return value of your function, if you type the name of a declared integer variable in the *Status* text box.
6. To include the function into your source code, you can copy the created function string out of the window on the button of the function panel and insert it into the source code.

The result of this procedure is shown in Fig. 10.

```
rsspecan_SetAttributeViReal64 (io, "Win0", RSSPECAN_ATTR_FREQUENCY_START, 1e+9);
```

Figure 4: Building a function string on the button of the "rsspecan_SetAttributeViReal64" function panel.

The attribute and its features can be changed at any time later by right-clicking the function and recalling the function panel. See Fig. 11:

```
rsspecan_SetAttributeViReal64(io, "Win0", RSSPECAN_ATTR_FREQUENCY_START, 1e+9);
```

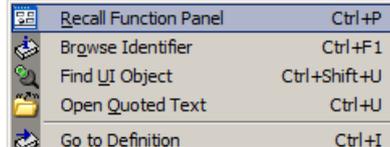


Figure 5: Recalling the function panel to modify the attributes.

3.2.1 Repeated Capabilities in LabWindows/CVI

Repeated capability instances are specified by a string parameter for each property. They can also be specified by a function which selects the active instance.

To define the usage of particular capability, enter the proper value in the *Repeated Capability* text box in the function panel. If more than one repeated capability is required for one attribute, separate them with a comma.

A marker example using repeated capabilities is shown in the figure below:

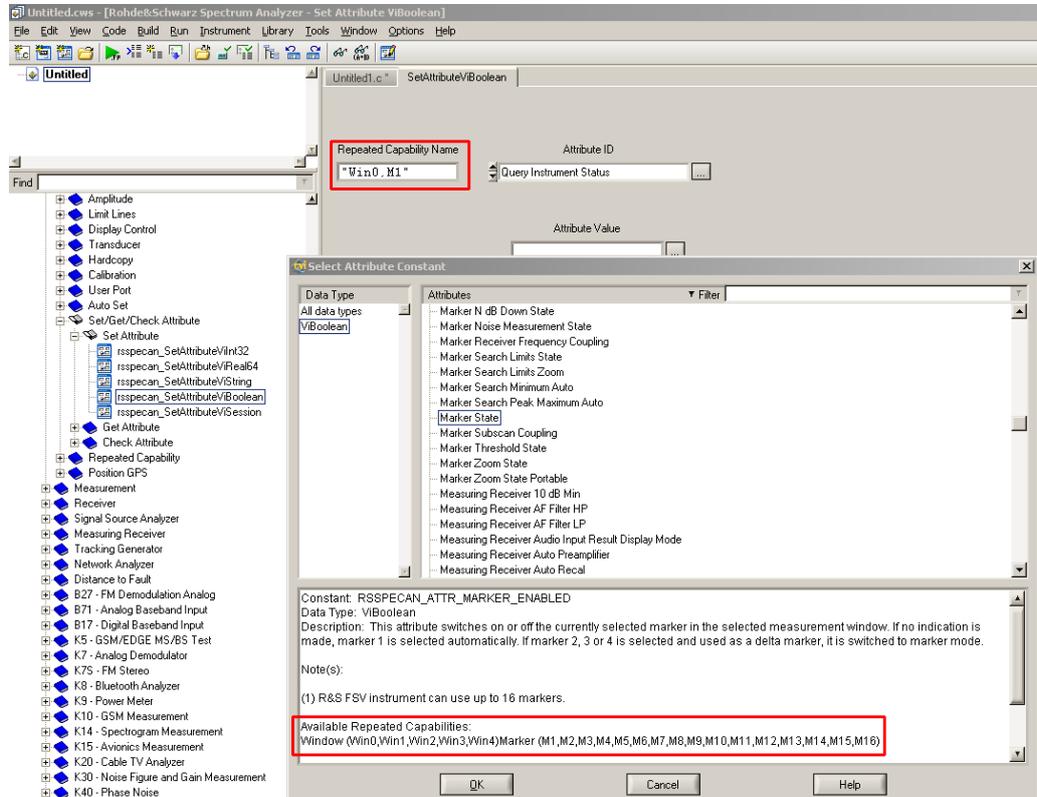


Figure 6: Example of "Repeated Capabilities" in LabWindows/CV.

The attribute and its features can be changed at any time later by recalling the function panel, which recalls the shown panel.

3.2.2 Dynamic Repeated Capabilities in LabWindows/CVI

In comparison to the previously described repeated capabilities, the so called dynamic repeated capabilities are specified by a user defined string parameter for each property in run time. For example, a property can be a channel or a trace of vector network analyzer. The instrument driver stores and tracks this user defined string parameter each time a new parameter is created. For this reason it is important to create new using the provided high level functions (e.g. `rsvna_TraceAddDiagramArea (...)`). Creating new parameters using attribute access functions would not allow the instrument driver to trace this newly created dynamic repeated capability accordingly. How to use a high level function is shown in the picture below.

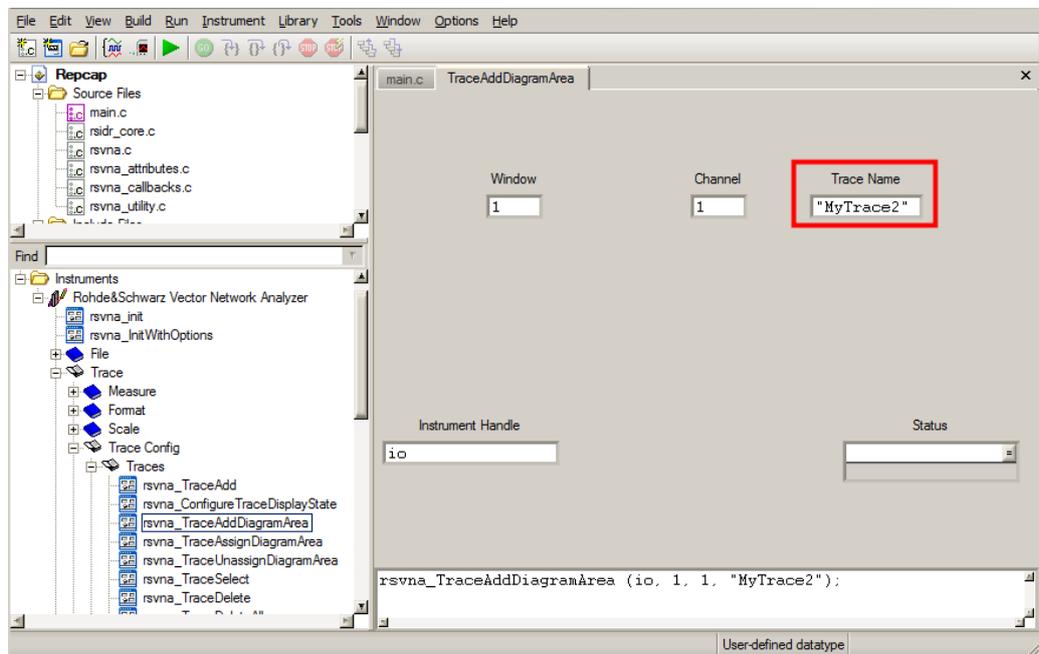


Figure 7: Example how to create a dynamic repeated capability using a high level function

This example outlines how to use dynamic repeated capabilities, here `MyTrace2`, in combination with an high level function as well as using it with a front panel. Furthermore the default channel setup of the Rohde & Schwarz ZNB network analyzer is required.

For the following example the dynamic repeated capability is fed into the driver attribute access function via a constant string parameter.

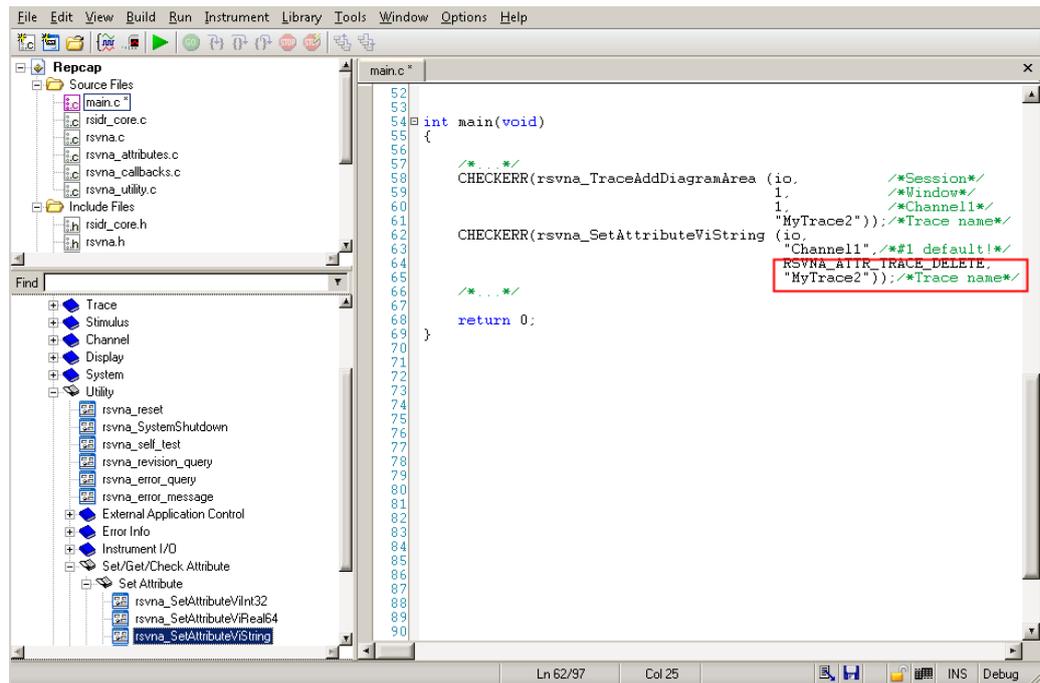


Figure 8: Example how to use a dynamic repeated capability using the attribute-access functions

After running this sequence a new channel and trace has been added on the instrument and is stored in the instrument driver for future use. To access this new trace the dynamic repeated capability “*MyTrace2*” has to be used. In this case the new trace can be addressed by other high level functions, as well as using the attribute-access functions directly. This attribute-access function is deleting the trace. The showed sequence is deleting the repeated capability “*MyTrace2*” again.

3.3 How to Use Attributes in Microsoft Visual Studio Using C#

This section explains how to use attributes in the *rsspecan* instrument driver in Microsoft Visual Studio 2008. This is necessary, for instance, if the driver does not support the functionality via high level functions (API).

In the following examples the programming language C# is used.

The *rsspecan.cs* (or the *rsspecan64.cs*⁹) file has to be added to the project. This file comes together with the VXIplug&play driver and is a prerequisite for using the driver in C#. **Please note, that for the instruments that in the meantime have a IVI.NET – a native .NET instrument driver available, the *.cs C# wrapper file is no more available in the VXIplug&play driver installation. We encourage the user to switch to the native .NET instrument driver.**

To control an instrument via an attribute, use one of the provided *get* and *set* functions of the C# wrapper. The available functions can be found in the following list:

- SetInt32 (*rsspecan_SetAttributeViInt32*)
- GetInt32 (*rsspecan_GetAttributeViInt32*)
- SetDouble (*rsspecan_SetAttributeViReal64*)
- GetDouble (*rsspecan_GetAttributeViReal64*)
- SetBoolean (*rsspecan_SetAttributeViBoolean*)
- GetBoolean (*rsspecan_GetAttributeViBoolean*)
- SetString (*rsspecan_SetAttributeViString*)
- GetString (*rsspecan_GetAttributeViString*)
- SetSession (*rsspecan_SetAttributeViSession*)
- GetSession (*rsspecan_GetAttributeViSession*)

The respective functions and their documentation can be found in the *Instrument Driver Help* file in *Instrument Driver Tree Structure=>Configuration=>Set/Get/Check Attribute/Repeated Capabilities* referring to listed function names in the brackets above.

Example: How to set the *Center Frequency* value by attributes

This example shows how to use attributes without repeated capabilities. The use of repeated capabilities is described in section 3.3.1.

To find the proper attributes for specific configurations, the *rsspecan_vxi.chm* help file can be used. All available attributes are listed in the *Instrument Driver Help chapter* under *Driver Attribute Help*; see figure below.

⁹ It is important to distinguish between 32-bit and 64-bit remote control software applications. These files are wrapper files for bitness dependent dynamically loaded libraries. Please always configure your Microsoft Visual Studio project to be 32-bit or 64-bit as target. The default setup “Any CPU” must not be enabled. For further information please refer to Application Note 1MA153, available on <http://www.rohde-schwarz.com/appnote/1MA153>.

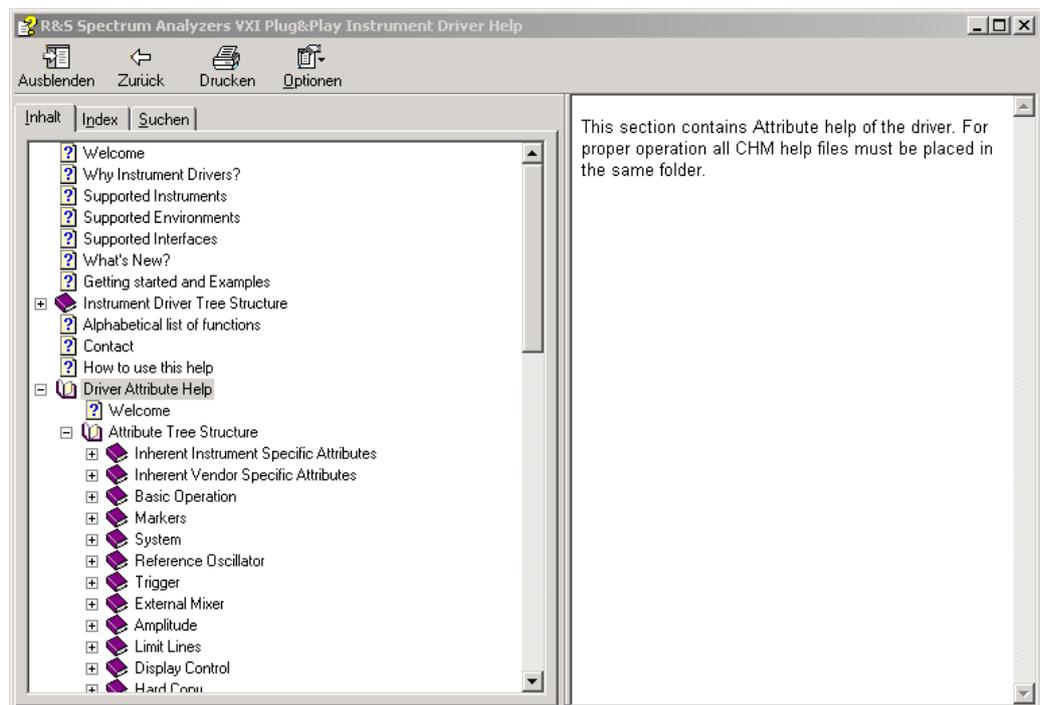


Figure 9: Documentation of available attributes in the *rsspecan* instrument driver.

C# attributes are accessible through the enum `rsspecanProperties` which is defined in the namespace `InstrumentDrivers` of the wrapper file `rsspecan.cs`.

For example, in Basic Operation use the *Center Frequency* attribute `rsspecanProperties.FrequencyCenter` (called `RSSPECAN_ATTR_FREQUENCY_CENTER` in the VXIplug&play chm help file) for configuring the center frequency as shown in the listing below:

```
using InstrumentDrivers;

namespace rsspecan_Application_Example
{
    class Program
    {
        static void Main(string[] args)
        {
            string resourceName = "TCPIP::FSP7-100894::INSTR";
            bool idQuery = true;
            bool resetDevice = true;

            //Open driver session
            rsspecan m_specAn = new rsspecan(resourceName, idQuery,
                resetDevice);

            //center frequency 1GHz
            double centerFrequency = 1e9;
            m_specAn.SetDouble(rsspecanProperties.FrequencyCenter,
                centerFrequency);

            //...insert more configuration and measurements here

            //Close driver session
            m_specAn.Dispose();
            m_specAn = null;
        }
    }
}
```

}

3.3.1 Repeated Capabilities in C#

Repeated capability instances are specified by a string parameter for each property. They can also be specified by a function which selects the active instance.

To define the usage of particular capability, the following overloaded functions are provided by the C# wrapper file, for example the *rsspecan.cs*:

- SetInt32 (*rsspecan_SetAttributeViInt32*)
- GetInt32 (*rsspecan_GetAttributeViInt32*)
- SetDouble (*rsspecan_SetAttributeViReal64*)
- GetDouble (*rsspecan_GetAttributeViReal64*)
- SetBoolean (*rsspecan_SetAttributeViBoolean*)
- GetBoolean (*rsspecan_GetAttributeViBoolean*)
- SetString (*rsspecan_SetAttributeViString*)
- GetString (*rsspecan_GetAttributeViString*)

A marker example using repeated capabilities is shown in the following example:

```
//repeated capability example
//set a marker to a specific frequency
double freqPosition = 1.5e9;
m_specAn.SetDouble (rsspecanProperties.MarkerPosition, "Win0,M1", freqPosition);
```

The following figure outlines the “*Supported Repeated Capabilities*” of the attribute `rsspecanProperties.MarkerPosition` (called `RSSPECAN_ATTR_MARKER_POSITION` in the *rsspecan.chm* help file).

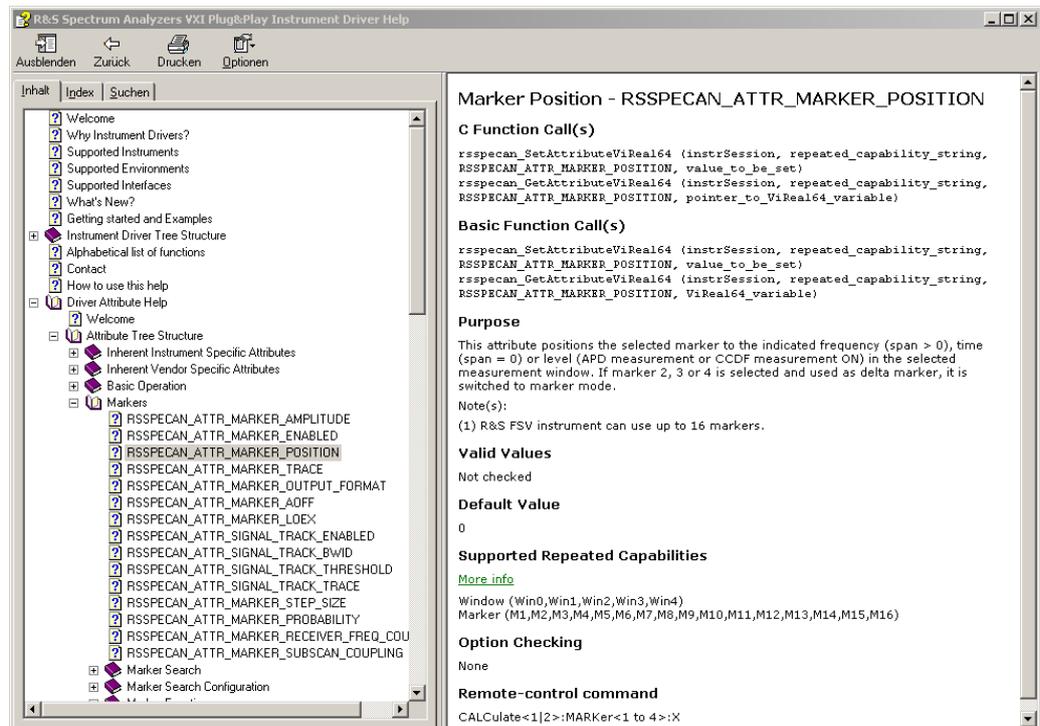


Figure 10: Marker example to explain repeated capabilities.

3.3.2 Dynamic Repeated Capabilities in C#

In comparison to previously described repeated capabilities, the so called dynamic repeated capabilities are specified by a user defined string parameter for each property in run time. For example, a property can be a channel, a trace or a window of vector network analyzer. The instrument driver stores and tracks this user defined string parameter each time a new parameter is created. For this reason it is important to create new using the provided high level functions (e.g.

`m_specAn.TraceAddDiagramArea(...)`). Creating new parameters using attribute access functions would not allow the instrument driver to trace this newly created dynamic repeated capability accordingly. How to use a high level function is shown below.

```
/* add a new trace "MyTrace2" into a new diagramm area */
m_VNA.TraceAddDiagramArea(winNumber, chanNumber, "MyTrace2");
```

This example outlines how to use dynamic repeated capabilities, here `MyTrace2`, in combination with high level function. To get this line of code executed, the default channel setup of the Rohde & Schwarz ZNB network analyzer is required.

For the following example the dynamic repeated capability is fed into the driver attribute access function via a string parameter.

```
/* delete the trace named "MyTrace2" */
m_VNA.SetString(rsVnaProperties.TraceDelete, "Channel1" /*default*/, "MyTrace2");
```

After running this code a new channel and trace has been added on the instrument and is stored in the instrument driver for future use. To access this new trace the dynamic repeated capability `MyTrace2` has to be used. In this case the new trace can be addressed by other high level functions, as well as using the attribute-access functions directly. This attribute-access function is deleting the trace. The showed sequence is deleting the repeated capability `MyTrace2` again.

3.4 Tips and Tricks

3.4.1 Execution Speed: Disable Instrument Status Checking

If instrument status checking is enabled, the driver automatically checks the status of the instrument after most operations. If the instrument indicates an error condition, the driver returns a special error code. The user then calls the error query function to retrieve the instrument specific error code from the instrument.

Instrument status checking is most useful during debugging. Once application development is complete, this feature can be disabled to maximize performance.

3.4.2 How to Build Executables or Libraries in LabVIEW

The driver core of the attribute-based instrument drivers is dynamically linked to any executed VI during runtime. This cannot be recognized by the LabVIEW application

builder. The LabVIEW application builder follows all static dependencies and includes them in the distributed package when building an executable.

To create an executable in LabVIEW, please manually add all VIs in the `<instr.lib>\PREFIX_utility\callbacks` folder to the LabVIEW project. In case of project based driver please add the *Private* folder to your project. With this manual reference, the driver core is included in the build and the driver core is accessible during runtime.

3.4.3 Error Handling: “Instrument version not valid”

If option checking is enabled, the driver checks first, if the following command is supported by the connected instrument. While the initialization of the driver the “ID Query” has to be enabled to correctly identify the connected instrument. Based on the installed instrument options, the driver is generating the error “Instrument version not valid” if the command is not supported by the instrument.

For extended debugging the option checking functionality can be disabled using the function/VI “Option Checking” and set the input variable to “False”. This can be found in the “Utility Functions” folder of the driver documentation

3.4.4 Error Handling: Range Checking

If range checking is enabled, the driver checks if the input parameters are within the valid range for the connected instrument. Range checking is most useful during debugging. After users have validated their programs, they can disable range checking to maximize performance.

Using the function/VI “Option Checking” and set the input variable to “False”. This can be found in the “Utility Functions” folder of the driver documentation.

3.4.5 How to Minimize the Size of an Attribute-Based Instrument Driver

The Rohde & Schwarz attribute-based instrument drivers are by definition divided into different independent modules. These modules are based on the instrument’s hardware and software options. Consequently, it is possible to include only the instrument driver core modules and the other driver modules corresponding to the instrument options used. This allows you to avoid unused driver modules within your development project.

LabVIEW driver

To avoid unused VIs in a LabVIEW project, you can simply delete unused folders inside the *instr.lib* folder. The folders minimally needed for a correctly operating instrument driver are shown in the following, using the *rsspecan* LabVIEW instrument driver as an example.

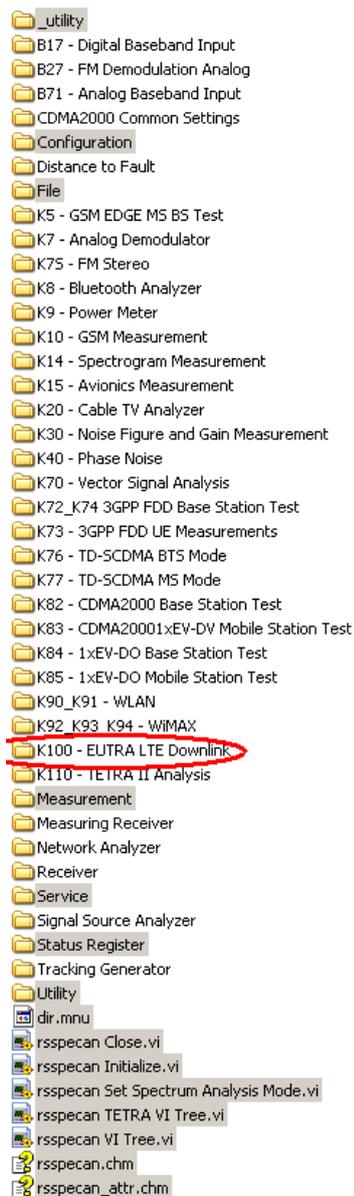


Figure 11: Possible configuration of the rssipecan instrument driver.

In the figure above, the minimal recommended configuration of the *rssipecan* LabVIEW instrument driver is highlighted in gray. For example, to have a proper setup for performing measurements on an LTE¹⁰ downlink signal, only the *K100- EUTRA LTE Downlink* folder needs to be preserved besides the folders highlighted in gray. The remaining folders can be easily deleted. The content of the LabVIEW *user.lib\express\rssipecan* folder is mandatory.

This procedure is also applicable to other attribute-based instrument drivers.

¹⁰ [UMTS Long Term Evolution \(LTE\) Technology Introduction](#)

LabWindows/CVI and VXIplug&play driver

For C/C++-based projects, there is also the possibility to easily eliminate unused source code. The source code files minimally needed for a correctly operating instrument driver are shown below, using the *rsspecan* LabWindows/CVI instrument driver as an example.

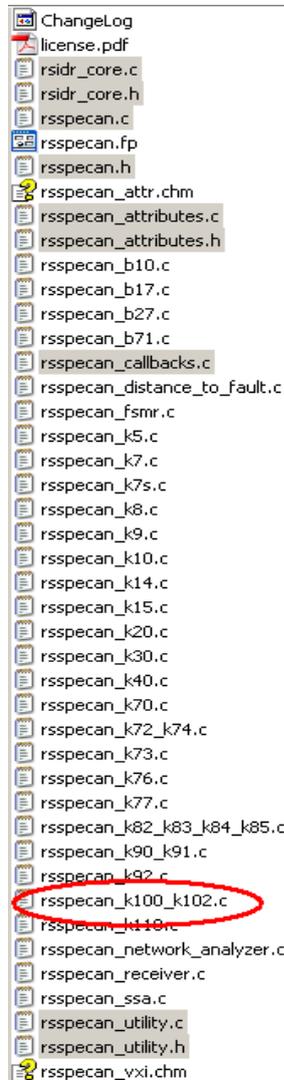


Figure 12: Possible configuration of the *rsspecan* instrument driver.

In the figure above, the minimal recommended configuration of the *rsspecan* LabWindows/CVI instrument driver is highlighted in gray. For example, to have a proper setup for performing measurements on an LTE¹¹ downlink signal, only the *rsspecan_k100_k102.c* file needs to be preserved besides the files highlighted in gray. The remaining folders can be easily deleted.

This procedure is also applicable to other attribute-based instrument drivers.

¹¹ [UMTS Long Term Evolution \(LTE\) Technology Introduction](#)

4 Related Documents

- Application Note 1MA153: Development Hints and Best Practices for Using Instrument Drivers <http://www.rohde-schwarz.com/appnote/1MA153.html>
- Automatic Measurement Control, A tutorial on SCPI and IEEE 488.2; John M. Pieper; Rohde & Schwarz GmbH & Co. KG
- IEEE Std 488.2-1992 IEEE Standard Codes, Formats, Protocols, and Common Commands for Use With IEEE Std 488.1-1987, IEEE Standard Digital Interface for Programmable Instrumentation
http://standards.ieee.org/reading/ieee/std_public/description/im/488.2-1992_desc.html

5 References

- [1] ANSI/IEEE Std 488.1-1987 IEEE Standard Digital Interface for Programmable Instrumentation
http://standards.ieee.org/reading/ieee/std_public/description/im/488.1-1987_desc.html

- [2] The SCPI Consortium
<http://www.ivifoundation.org/scpi/default.aspx>
Note: Became part of the IVI Foundation in 2002

- [3] The SCPI Standard
<http://www.ivifoundation.org/docs/SCPI-99.pdf>

- [4] VXIplug&play Systems Alliance
http://www.ivifoundation.org/VXIPlug_Play/default.aspx
Note: Became part of the IVI Foundation in 2002

- [5] Interchangeable Virtual Instrument Foundation (IVI Foundation)
<http://www.ivifoundation.org/>

- [6] Virtual Instrument Software Architecture (VISA)
<http://www.ivifoundation.org/specifications/default.aspx>

- [7] IVI Driver Architecture Specification
<http://www.ivifoundation.org/specifications/default.aspx>

About Rohde & Schwarz

Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

Environmental commitment

- Energy-efficient products
- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system



Regional contact

Europe, Africa, Middle East

+49 89 4129 12345

customersupport@rohde-schwarz.com

North America

1-888-TEST-RSA (1-888-837-8772)

customer.support@rsa.rohde-schwarz.com

Latin America

+1-410-910-7988

customersupport.la@rohde-schwarz.com

Asia/Pacific

+65 65 13 04 88

customersupport.asia@rohde-schwarz.com

China

+86-800-810-8228 /+86-400-650-5896

customersupport.china@rohde-schwarz.com

This application note and the supplied programs may only be used subject to the conditions of use set forth in the download area of the Rohde & Schwarz website.

R&S® is a registered trademark of Rohde & Schwarz GmbH & Co. KG; Trade names are trademarks of the owners.

Rohde & Schwarz GmbH & Co. KG

Mühlhofstraße 15 | D - 81671 München

Phone + 49 89 4129 - 0 | Fax + 49 89 4129 - 13777

www.rohde-schwarz.com