# High-Speed Remote Control of R&S®SGMA RF Sources
# Application Note

**Products:**

| R&S®SGT100A

| R&S®SGS100A

This application note describes how to remotely control the R&S SGMA RF sources SGT100A and SGS100A with a special focus on their high-speed remote control capabilities via LAN based FAST Socket or FAST PCI Express (PCIe) connections which allow round trip setting times of only 100µs.

It therefore provides a brief introduction into the general remote control capabilities, explains the interaction of the different SW protocol layers and drivers, and in detail describes how to establish a high-speed remote control connection. Finally, a comparison of the measured setting time performance of the different remote control approaches is provided.

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ROHDE&SCHWARZ

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The following abbreviations are used in this application note for Rohde & Schwarz products:
- The R&S®SGT100A vector RF source is referred to as SGT
- The R&S®SGS100A RF source is referred to as SGS
- The R&S®SGMA100A RF (vector) source family is referred to as SGMA

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# 1 Introduction

State of the art Automated Test Equipment (ATE) must **guarantee consistent and highly accurate testing** combined with a **maximum test speed**.
Only this kind of test equipment allows efficient testing with an optimized throughput and high yield.

The **R&S SGMA** (vector) **RF sources** have been designed to exactly fit these needs. They offer highly accurate RF signals (CW and/or vector modulated) especially tailored for RF ATE systems in combination with a minimized remote control setting time.

This application note describes how to remotely control the R&S SGMA RF sources **SGT100A** and **SGS100A** with a special focus on their high-speed remote control capabilities via LAN based **FAST Socket** or **FAST PCI Express (PCIe)** connections which allow round trip setting times of only 100µs.
It therefore provides a brief introduction into the general remote control capabilities, explains the interaction of the different SW protocol layers and drivers, and in detail describes how to establish a high-speed remote control connection.
Finally, a comparison of the measured setting time performance of the different remote control approaches is provided.

Refer to the SGMA user manuals [1] and [2] for further remote control basics and the SGMA specific SCPI remote control commands.

# 2 Remote Control

Instead of controlling the SGMA RF source manually via the **R&S SGMA-GUI** software [11], [12]
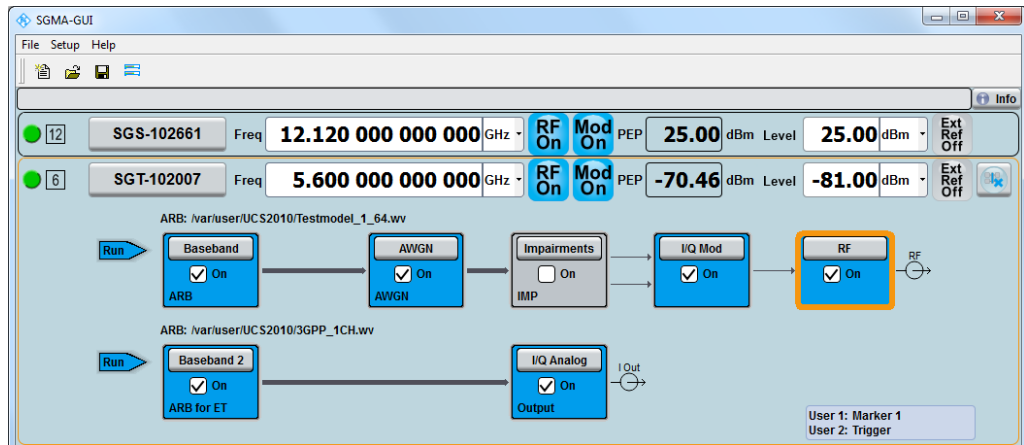


*Figure 1: Manual Control – SGMA-GUI*

ATE host controllers require remote control access to the SGMA RF sources to allow a flexible and fast alteration of the RF signal parameters based on the underlying test procedure.
In order to offer ATE developers with the highest possible flexibility for the integration of SGMA RF sources into their test systems both SGT and SGS provide several remote control hardware interfaces and support most of the common remote control protocols.

The following paragraphs summarize all essential information required to successfully establish a remote control connection between a **Microsoft**®**Windows based host controller** PC and an SGMA RF source via any of the available interfaces/protocols.

## 2.1 Interfaces

The SGMA RF sources provide a variety of remote control interfaces in order to allow and simplify the integration into nearly any kind of remote control architecture (①: **LAN**, ②: **USB**, ③: **PCI Express**).

**SGT:**
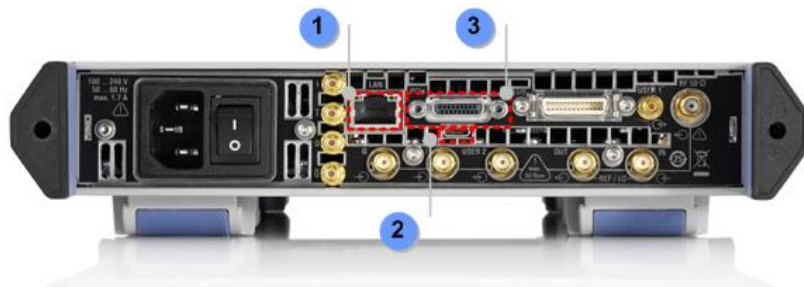
**SGS:**



*Figure 2: Interfaces – SGMA Remote Control*

## 2.1.1   LAN

All of the SGMA RF sources are equipped with a **1GBit/s Ethernet (TCP/IP) 10/100/1000BASE-T LAN interface** accessible via a standard **RJ45 connector**.

In order to establish an HW interconnection to a host controller both entities have to be interconnected directly or via additional network components like hubs, switches or routers by using CAT5 RJ45 cables.

For the purpose of a further minimization of the remote control setting times it is recommended to:
- Keep the physical dimensions of the used remote control network as small as possible.
- Remove all network components which are not absolutely required and which may cause undesired bus latencies.
- Use only reliable network components which guarantee a 1GBit/s physical layer data rate.
- Refer to chapter 3.1.1 for a further remote setting time minimization.

## 2.1.2   USB

In addition to the LAN interface a **USB 2.0 compliant USB interface** is onboard of any SGMA RF source. This interface is accessible via an **USB 2.0 micro connector** (jack).

In order to allow remote control of the SGMA via this interface the SGT/SGS has to behave like an **USB device**. It is therefore crucial to connect the host controller via a **USB 2.0 micro Type-B connector** (plug) to the SGMA.

In order to maximize the reliability of a USB based remote control connection it is recommended to:
- Use an active USB 2.0 hub to interconnect SGMA and host controller, especially in case of USB cables longer than 1.5 m.
- Only use reliable USB components and cables which comply with the USB 2.0 specification.
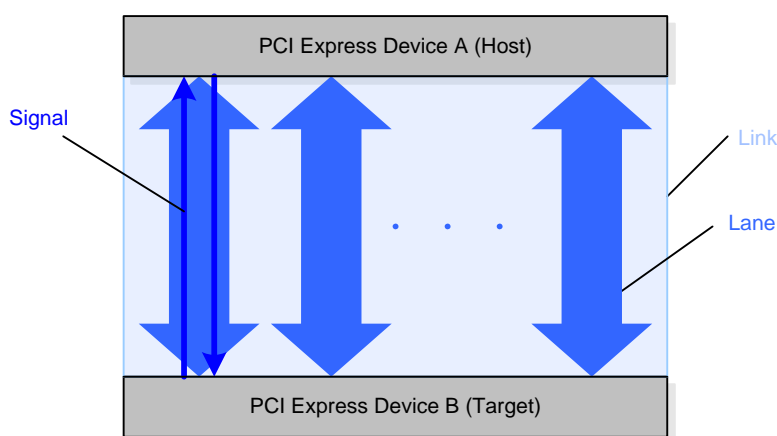
### 2.1.3 PCI Express (PCIe)

Since **PCI Express (PCIe)** interfaces are not as widely available as LAN or USB interfaces for remote control applications the following paragraphs are intended to provide a brief overview about PCI Express in general and its implementation on the SGMA RF sources and the host controller with a special focus on the HW interconnection setup.

#### 2.1.3.1 Overview

Formed in 1992, the Peripheral Component Interconnect Special Interest Group (PCI-SIG) with currently nearly 800 members is committed to the development and enhancement of the PCI specification(s) as open industry standards.

The **Peripheral Component Interconnect (PCI)** bus which was first introduced in the early 1990s provides I/O functionality for any kind of computer (e.g. servers, PCs workstations and also mobile devices). It is also a standard to transfer data between a CPU and its peripherals. Although PCI has enjoyed great success, it faces a series of challenges, including bandwidth limitations, lack of real-time data transfer services and others.

To overcome these challenges **PCI Express (PCIe)**, an evolutionary version of PCI, was introduced in 2004. Today, most PCs are shipped with a combination of PCI and PCI Express slots. PCI Express maintains the PCI software usage model and replaces the parallel physical bus with a high-speed serial bus, composed of point-to-point serial connections between two devices. It offers a scalable bandwidth performance based on the number of signal Lanes implemented on the PCI Express interconnects. The following figure highlights the used PCIe terminology:



*Figure 3: PCI Express – Interconnection Terminology*

The main features and advantages of PCIe are:
- High-speed point-to-point (serial) connection which results in viewer pins compared to the predecessor PCI with its parallel interface architecture
- Dual simplex connection (independent differential signals from/to the host device)
- Scalable: x1, x2, x4, x8, x12, x16, x32 lanes
- Packet based transaction protocol
- 2.5 (Rev. 1.x) ... 16.0 GT/s (Rev. 4.0)

The PCIe technology is constantly evolved and improved. As of 2015 the PCIe specification has reached version 4 (draft only). The following table provides an

overview about the link performance based on the different PCIe versions and the number of active lanes:

| PCI Express Link Performance | | | |
|---|---|---|---|
| **PCIe Version** | **Transfer Rate** | **Nominal Bandwidth/Throughput** | |
| | | **Per Lane[1] (x1)** | **16-Lane[1] (x16)** |
| **1.x** | **2.5 GT/s** | **8/10 x 2.5 GT/s: 2 Gbit/s (250 MB/s)** | 32 Gbit/s (4 GB/s) |
| 2.x | 5.0 GT/s | 8/10 x 5.0 GT/s: 4 Gbit/s (500 MB/s) | 64 Gbit/s (8 GB/s) |
| 3.0 | 8.0 GT/s | 128/130 x 8.0 GT/s: ≈ 8 Gbit/s (1.0 GB/s) | ≈ 128 Gbit/s (16 GB/s) |
| 4.0 | 16.0 GT/s | 128/130 x 16.0 GT/s: ≈ 16 Gbit/s (2.0 GB/s) | ≈ 256 Gbit/s (32 GB/s) |

1) In each direction

*Table 1: PCI Express – Link Performance*

Whereas PCIe was initially intended to be used to interconnect IO devices within a PC/server it may also be used to add external hardware to a computer system. The so-called **cabled PCIe** which was approved by PCI-SIG in 2007 provides a fully transparent, high throughput link which allows external modules/components to appear like internal computer modules. Cabled PCIe currently supports link widths from x1, x4, x8 to x16 lanes and specifies connectors and cables fully supporting PCIe V2.x. The serial bus technology and the embedded clocking of PCIe allow it to be used at full speeds (see *Table 1*) over a cable of a maximum length of 7 meters.

Therefore with cabled PCIe, users can apply this technology to take advantage of the high bandwidth/speed of PCIe to interconnect for example a host controller PC system with external state of the art test and measurement equipment/instruments like the SGMA RF sources.

The following paragraphs summarize the SGMA specific PCIe interface hardware details and describe how a SGMA RF source has to be interconnected with a PCIe enabled host controller PC.

### 2.1.3.2 SGT/SGS PCIe Interface

The SGT and the SGS PCIe interface are compliant with **PCIe V1.x** and **support hot plugging**. It provides a **single lane (x1) connector** which is accessible on the rear panel of the instruments (see *Figure 2*).

### 2.1.3.3 Host Controller PCIe Interface

The host controller which is normally a desktop PC or sometimes a notebook has to be equipped with a PCIe x1 cable adapter to allow the interconnection with the SGT or the SGS via a PCIe standard compliant interconnection cable.

**PCIe x1 cable adapter**:
A PCIe x1 cable adapter provides an interface from a standard PCIe single lane slot to a PCIe cable and has to conform with the:
- PCI SIG PCIe Base Specification 1.x [10] and the companion specification
- PCI SIG PCIe External Cabling Specification 1.0 [10]

These adapters which are available from different vendors are mostly completely transparent to PCIe but include signal repeating functionality, allowing cables up to 7 meters in length to be reliably used.
Nearly all of them do not require any kind of software (adapter card specific drivers) for operation.
On desktop PCs the host cable adapter has to be installed in a PCIe expansion slot. Notebooks with available Express Card slots can be extended by an Express Card cable adapter:



*Figure 4: PCI Express – PCIe x1 Cable Adapters*

The following paragraph provides a guideline how to establish a HW interconnection between an SGMA device and a host controller.

### 2.1.3.4   PCIe Interface HW Connection Setup

In the following it is assumed that the host controller PC does not provide PCIe hot-plugging capabilities and that both the SGMA RF source and the host controller are switched off.

1. SGS only: It has to be evaluated prior to the PCIe connection setup via the SGMA-GUI if the PCIe interface is configured to the compelling interface mode 'Endpoint' (Default mode): Setup → Maintenance → Operation → PCIe Interface Mode.
2. At first, an interconnection between both entities has to be established by using a suitable PCIe single lane cable.



*Figure 5: PCI Express – PCIe x1 Cable*

3. Power-on the SGMA RF source and wait until the power on/standby button on the front side of the instrument becomes green (permanent non-blinking) which indicates that the startup process has been finished and the instrument is thus ready for operation.
4. Finally switch on the host controller PC.

Perform the steps described above in reverse order to shut down the SGMA source and an interconnected host controller.

To maximize the reliability of a PCIe based remote control connection it is essential to notice that most of the shelf **host controller PCs do not provide PCIe hot plugging** capabilities. It is therefore strictly recommended:

- Not to interconnect the SGMA PCIe interface with the cable adapter during operation.
- Not to switch off an SGMA RF source if it is interconnected to an operating host controller via the PCIe interface.

## 2.2  Protocol Layers

Remote control interfaces come to life only with the availability of the related software protocol stacks. They enable the host control to interact with the SGMA RF sources in a well-defined manner.

The SGMA RF sources offer a bunch of different protocols for a remote control interaction fitting nearly any ATE test system requirements and/or preferences of the ATE developer(s):
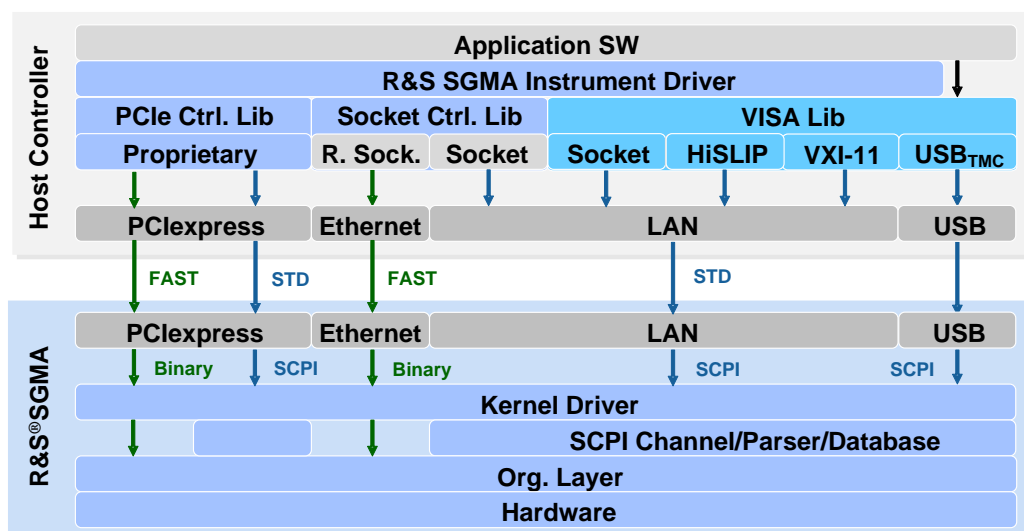


*Figure 6: Protocol Layers – Overview*

The following paragraphs intend to explain this protocol layer overview and to properly highlighting the different remote control approaches (VISA or Instrument-driver based). Additionally some light is shed on the required libraries, the drivers and their interaction.

## 2.2.1 Virtual Instruments Software Architecture (VISA)

**VISA**, a standardized software library, acts as a kind of I/O HW abstraction layer maintained and evolved by the IVI foundation. It allows simplified remote control communication via a variety of interfaces and protocols.
It is available free of charge from R&S [15] or may be purchased from other vendors.

The VISA library enables the ATE developer to access the SGMA RF sources via the LAN and the USB interface by using the Socket, HiSLIP, VXI-11 and USBTMC protocol:
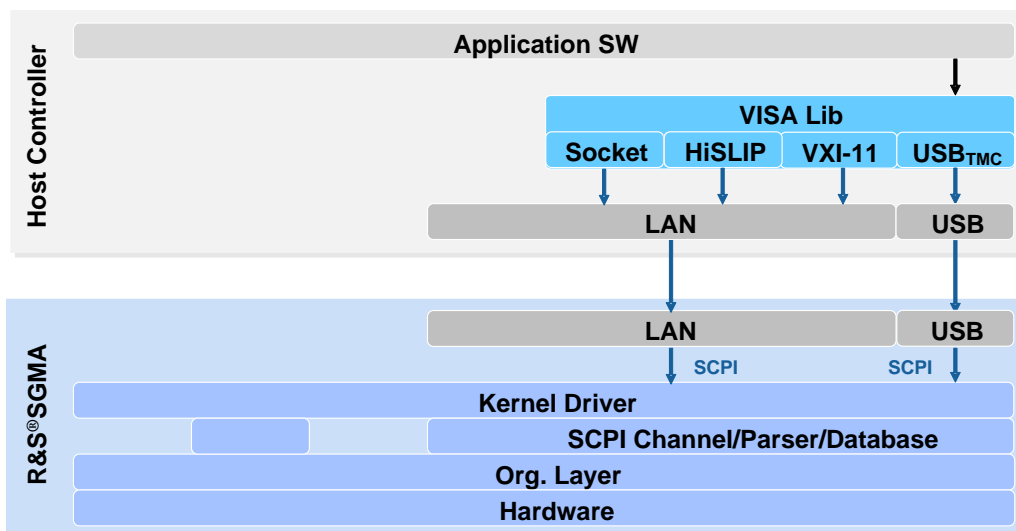
*Figure 7: VISA based SGMA remote control – Protocol Layers*

For this reason the VISA library exports functions which allow ATE developers to:

- establish a remote control connection to a certain instrument based on a unique interface/protocol specific identifier, the so-called 'VISA Resource String' (see chapter 2.3 for further details on the connection setup)
- send/write instrument specific SCPI commands (see [1] and [2]) to the SGMA device under control
- receive/read data from the test instrument
- maintain and parameterize the remote connection (e.g. timeouts)

The following table provides a first overview and informs about the required SW libraries which have to be installed on the host controller PC to support VISA based remote control via a certain interface and protocol:

| SGMA VISA based Remote Control – Libraries | | |
|---|---|---|
| **Interface** | **Protocol** | **Libraries** |
| | | **HW Abstraction** |
| **LAN (Ethernet)** | TCP/IP VXI-11 | VISA |
| | TCP/IP HiSLIP | |
| | TCPIP Socket | |
| **USB** | USBTMC | |

*Table 2: VISA based SGMA remote control – Libraries*

## 2.2.2 R&S Instrument Drivers

**R&S Instrument Drivers** may be used optionally in combination with the VISA library. Instrument drivers are the means of choice if ATE developers are not interested in plain SCPI-command-based remote control but prefer to use more abstract functions/methods in combination with online help functions. The R&S instrument drivers can easily be integrated into various Integrated Development Environments (IDE).

R&S offers instrument drivers for all SGMA RF sources free of charge:

| Instrument Driver based SGMA control – Instrument Drivers | | |
|---|---|---|
| **Driver Title** | **SGT** [13] | **SGS** [14] |
| VXI Plug&Play x64 | `rssgt-vxipnp_x64` | `rssgs-vxipnp_x64` |
| VXI Plug&Play x86 | `rssgt-vxipnp_x86` | `rssgs-vxipnp_x86` |
| LabWindows/CVI | `rssgt-cvi`[1] | `rssgs-cvi`[1] |
| Linux/OSX | | |
| LabVIEW 2010 x86 | `rssgt-lv_x86` | `rssgs-lv_x86` |

1) Driver source code which may be integrated and compiled with different IDEs

*Table 3: Instrument Drivers based SGMA control – Instrument Drivers*

Related application notes and programming language specific application examples are available as well [3], [4], [5], [6], [7].

The SGMA instrument drivers in combination with the VISA library enable the ATE software developer to access the SGMA RF sources via all available HW interfaces by using the Socket, HiSLIP, VXI-11, USBTMC and an R&S proprietary PCIe protocol:
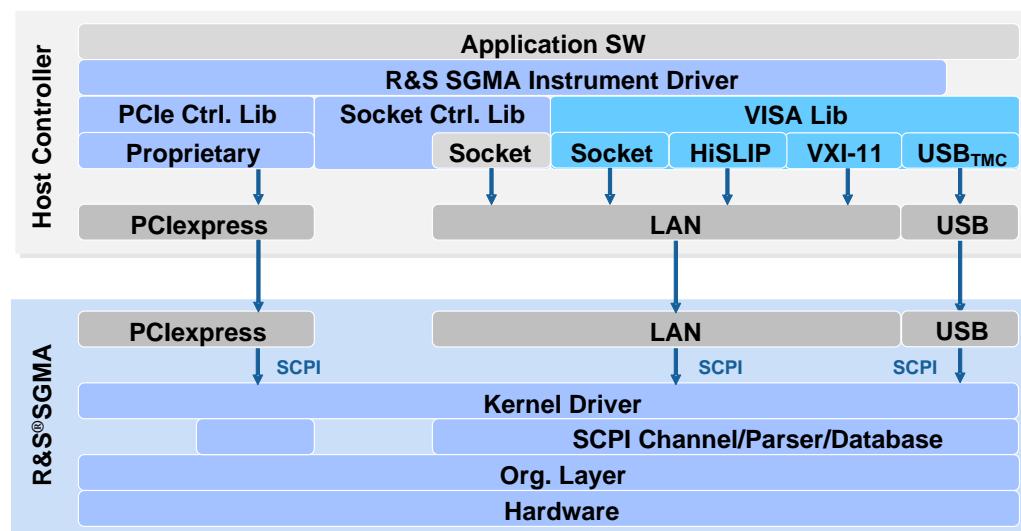


*Figure 8: Instrument Drivers based SGMA control – Protocol Layers*

As illustrated in the above figure SGMA instrument drivers not only encapsulate SCPI commands but also have to take care about the driver and protocol specific I/O hardware abstraction layer.
LAN based interconnections via HiSLIP, VXI-11 or USBTMC are setup using the underlying VISA library. LAN based Socket connections will either be established via the VISA library (LabVIEW) or by using the **R&S Socket Controller** library as an I/O

HW abstraction layer (VXI Plug&Play/CVI). All PCIe connections are established via the **R&S PCIe Controller** library. The following table summarizes these dependencies:

| Instrument Driver based SGMA control – I/O Hardware Abstraction | | | | | |
|---|---|---|---|---|---|
| **Driver Title** | **HiSLIP** | **VXI-11** | **USBTMC** | **Socket** | **PCIe** |
| VXI Plug&Play | VISA | | | Socket Controller | PCIe Controller |
| LabWindows/CVI | | | | | |
| LabVIEW 2010 x86 | | | | VISA | - |

*Table 4: Instrument Drivers based SGMA control – I/O Hardware Abstraction*

**Note**: In the following, it is assumed that either **VXI Plug&Play** or **LabWindows/CVI** drivers are used since only these drivers support:
- Interconnections via all SGMA interfaces (also the PCIe interface)
- FAST remote control connections (see chapter 3 for details)

The instrument drivers export functions which allow ATE developers to
- establish/initialize a remote control connection to a certain instrument based on a unique interface/protocol specific identifier, the so-called 'Resource String', which is identical or at least similar to the 'VISA Resource String'
- send/write instrument specific SCPI commands to the device under control by using dedicated functions (e.g. `rssgt_SetFrequencyAndLevel`) or attributes (e.g. `RSSGT_ATTR_BB_PATH_GAIN`)
- receive/read data from the test instrument
- maintain and parameterize the remote connection (e.g. timeouts)

The following table provides a first overview and informs about the required SW libraries which have to be installed on the host controller PC to support instrument driver based remote control via a certain interface and protocol:

| Instrument Driver based SGMA control – Libraries | | | |
|---|---|---|---|
| **Interface** | **Protocol** | **Libraries** | |
| | | **HW Abstraction** | **Instrument Driver** |
| **USB** | USBTMC | `VISA` | `VXIPlug&Play` or `LabWindows/CVI` |
| **LAN (Ethernet)** | TCP/IP VXI-11 | | |
| | TCP/IP HiSLIP | | |
| | TCPIP Socket | `SocketController`[1] | |
| **PCIe** | PCIe | `PCIeController`[1] | |

1) Comes with the SGMA-GUI software

*Table 5: Instrument Driver based SGMA remote control – Libraries*

The **Socket Controller** and the **PCIe Controller** are R&S proprietary libraries. Both don't have to be installed manually but will be automatically installed in parallel with the SGMA-GUI software [11] [12] which has to be used for manual operation of any SGMA RF source (see *Figure 1*). They will be installed by default in the following directories:
**32 Bit Version (x86)**:
*C:\Program Files (x86)\Common Files\Rohde-Schwarz\SGMA-GUI*
*C:\Program Files (x86)\IVI Foundation\VISA\WinNT\Bin*

**64 Bit Version**:
*C:\Program Files\Common Files\Rohde-Schwarz\SGMA-GUI*
*C:\Program Files\IVI Foundation\VISA\Win64\Bin*

## 2.3 Remote Connection Setup

This chapter summarizes relevant aspects for properly setting up a remote control interconnection between an SGMA RF source and a host controller PC.

In the following it is assumed that:
* the HW interconnection to a certain remote control interface was properly established and
* all relevant and latest libraries/drivers are installed on the host controller.

### 2.3.1 VISA Resource String

To open a remote control session to a certain SGMA device via the:
* VISA function **`viOpen`** or the
* Instrument driver functions **`rssgt_init`** or **`rssgs_init`**

an address string has to be passed to these functions which uniquely identifies the device/resource.

The resource strings supported by a certain SGMA RF source may be retrieved via the SGMA-GUI software: SGS/SGT → Setup → Remote:
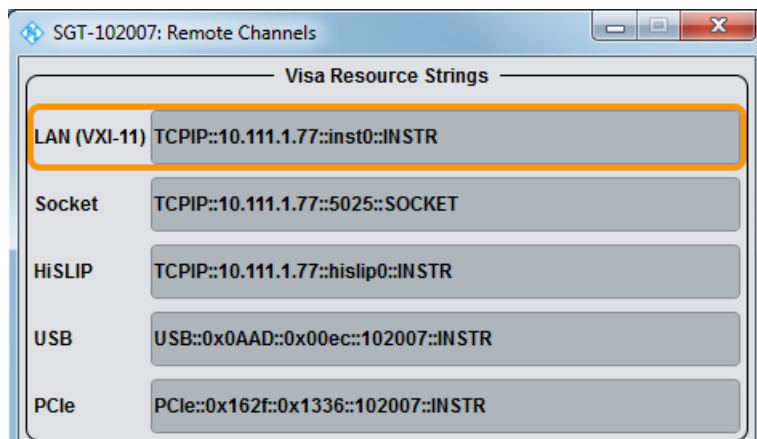


*Figure 9: Remote Connection Setup – VISA Resource Strings (SGT)*

In the following, the resource string syntax is described in detail (SGS/SGT resource strings). Optional string segments are shown in square brackets:

**VXI-11 resource string:**

```
TCPIP[board]::host address[::LAN device name][::INSTR]
```

| | |
|---|---|
| *board* | Host controller LAN interface index. Only relevant in case of several installed LAN interfaces. Default: 0 |
| *host address* | Assigned IP address or hostname (e.g. rssgt100a102661) |
| *LAN device name* | `inst0` in case of VXI11 |

Example: `TCPIP::rssgt100a102661::inst0::INSTR`

**Socket resource string**:

```
TCPIP[board]::host address::port::SOCKET
```

*board*            Host controller LAN interface index. Only relevant in case of
                   several installed LAN interfaces. Default: 0
*host address*     Assigned IP address or hostname (e.g. 10.111.1.77)
*port*             The registered TCP/UDP port for socket based remote
                   control communication is port **5025**

Example: TCPIP::10.111.1.77::5025::SOCKET

**HiSLIP resource string**:

```
TCPIP[board]::host address::hislip0[::INSTR]
```

*board*            Host controller LAN interface index. Only relevant in case of
                   several installed LAN interfaces. Default: 0
*host address*     Assigned IP address or hostname (e.g. rssgt100a102661)

Example: TCPIP::rssgs100a102661::hislip0::INSTR

**USBTMC resource string**:

```
USB::vendor ID::product ID::serial number[::INSTR]
```

*vendor ID*        The [registered R&S USB vendor ID](#) is **0x0AAD**
*product ID*       The SGMA USB product IDs are:
                   SGS: **0x0088**
                   SGT: **0x00EC**
*serial number*    SGMA serial number

Example: USB::0x0AAD::0x00EC::102007::INSTR

**PCIe resource string**:

```
PCIe::vendor ID::product ID::serial number[::INSTR]
```

*vendor ID*        The [registered R&S PCIe vendor ID](#) is **0x162F**
*product ID*       The SGMA PCIe product IDs are:
                   SGS: **0x132E**
                   SGT: **0x1336**
*serial number*    SGMA serial number

Example: PCIe::0x162F::0x132E::102661::INSTR

# 3 High-Speed Remote Control

The remote control setting speed of nearly all R&S instruments and especially of the SGMA RF sources is fully sufficient for most standard test applications in R&D.

Nevertheless, in case of demanding test applications which require a high test throughput (e.g. extensive characterization tests or tests performed in a production line) a further reduction of the overall test time per DUT in the end leads to an earlier time to market and will thus result in significant financial savings and offers a noticeable competitive advantage.
It has to be considered in this context that even setting time reductions of only 100 µs per remote control command may sum up over all commands per test run, the number of tested devices and all parallel running test systems to total test time savings per day of several minutes up to hours.

Therefore **R&S has significantly improved the efficiency of the used algorithms and the remote control setting time of the SGMA RF sources**.
These improvements resulted in a new remote control mode for the SGMA RF sources, the so-called **FAST Mode**, which is part of the SGMA firmware by default (no additional option required).
It allows R&S to increase the setting speed for commands which are used frequently and repeatedly in common test procedures by a factor of up to 8 in comparison with a standard remote control LAN connection (VXI11).
In principle, this significant increase in remote control performance is achieved by an optimized transfer of the control commands.
The standard/legacy remote control mode (see chapter 2) is based on a sent SCPI string which has to be intensively parsed and transformed into the required HW adjustments by the controlled instrument. The FAST mode in contrast is based on a much more hardware related (memory mapped) approach which allows broadly speaking direct access of the SGMA RF source to the memory (where the command resides) of the host controller which allows bypassing of time consuming protocol layers (e.g. the SCPI parser).

To benefit from these remote setting speed improvements only some prerequisites have to be fulfilled:
- the remote control connection has to be established via **LAN Socket** or via **PCIe**
- **VXI Plug&Play** or **LabWindows/CVI instrument drivers** have to be used

It has to be considered also that the FAST mode is focusing on those parameters/functions which are of major interest for high-speed ATE applications. The following table provides an overview about the operations which are currently supported by the FAST mode of SGT and SGS. Just for reference, also the related SCPI commands are shown which have to be sent to the SGMA RF source instead if the standard mode is used:

| High-Speed Remote Control – Operations | | | |
|---|---|---|---|
| **Operation** | **Description** | **Supported** | |
| | | **SGT** | **SGS** |
| RF Frequency | Sets the RF frequency at the RF output connector [:SOURce]:FREQuency[:CW\|FIXed] <Cw>[1] | yes | yes |
| RF Level | Sets the RF level at the RF output connector [:SOURce]:POWer[:LEVel][:IMMediate] [:AMPLitude] <Amplitude>[1] | yes | yes |

| High-Speed Remote Control – Operations | | | |
| --- | --- | --- | --- |
| **Operation** | **Description** | **Supported** | |
| | | **SGT** | **SGS** |
| RF State | Activates/ deactivates the RF output<br>:OUTPut[:STATe]:PON <Pon>[1] | yes | yes |
| Modulator State | Switches the I/Q modulation on and off<br>[:SOURce]:IQ:STATe <State>[1] | yes | yes |
| Wideband State | Selects optimized settings for wideband modulation signals<br>[:SOURce]:IQ:WBSTate <State> | yes | yes |
| Baseband Trigger | Executes a baseband (ARB) trigger<br>[:SOURce<hw>]:BB:ARBitrary:TRIGger:EXECute[1] | yes | n.a. |
| Digital Attenuation | Sets a relative attenuation value for the baseband signal<br>[:SOURce]:POWer:ATTenuation:DIGital <AttDigital>[1] | yes | n.a. |
| Next Segment | Triggers a switchover to the subsequent segment in a multi segment ARB waveform<br>[:SOURce<hw>]:BB:ARBitrary:WSEGment:NEXT:EXECute[1] | yes | n.a. |
| Delib. Segment | Deliberately selects the segment of a multi segment ARB waveform to be output<br>[:SOURce<hw>]:BB:ARBitrary:WSEGment:NEXT <Next>[1] | yes | n.a. |
| Frequency Offset | Sets the frequency offset for the baseband signal (relative to the RF frequency)<br>[:SOURce]:BB:FOFFset <Foffset>[1] | yes | n.a. |
| Phase Offset | Sets the phase offset for the baseband signal<br>[:SOURce]:BB:POFFset <Phoffset>[1] | yes | n.a. |

1) Corresponding SCPI command. Optional string segments are shown in square brackets.

***Table 6: High-Speed Remote Control – Operations***

Further details regarding this new remote control approach and how to establish this kind of high-speed remote control connection will be discussed in the following paragraphs.

## 3.1 Interfaces

The SGMA RF sources provide a variety of remote control interfaces to allow and simplify the integration into nearly any kind of remote control architecture. Two of these interfaces (①: **LAN**, and ③: **PCI Express**, see *Figure 2*) support the FAST Mode.

### 3.1.1 LAN

All of the SGMA RF sources are equipped with a **1GBit/s Ethernet (TCP/IP) 10/100/1000BASE-T LAN interface** accessible via a standard **RJ45 connector**.

To establish an HW interconnection to a host controller both entities have to be interconnected directly or, if indispensable, via additional network components like hubs or switches by using CAT5 RJ45 cables.

To minimize the remote control setting times and thus to fully benefit from the FAST mode setting speed advantages, the general guidelines for LAN based remote control interconnections apply (see chapter 2.1.1) but have to be extended by the following requirements/recommendations:

- Only Ethernet layer 2 network components (hubs or switches) must be used if that. **No layer 3 or 4 TCP/IP routers** are allowed in general.
- For further setting speed optimizations of < 100 µs, one has to consider the performance of the used host controller network interface card.
  It may be worth adding an additional high performance network adapter which allows to optimize certain interface properties (e.g. disabling of interrupt coalescing).

### 3.1.2 PCI Express (PCIe)

The SGT and the SGS PCIe interface are compliant with **PCIe V1.x and support hot plugging**. It provides a **single lane (x1) connector** which is accessible on the rear panel of the instruments (see *Figure 2*).

To maximize the reliability of a PCIe based remote control connection the guidelines for PCIe based remote control interconnections apply (see chapter 2.1.3.4).

For further information about the PCIe interface, see chapter 2.1.3.

## 3.2   Protocol Layers

Unlike standard remote control operations (see chapter 2.2) which use instrument drivers optionally in parallel with the VISA library, **R&S VXI Plug&Play** or **LabWindows/CVI Instrument Drivers** are compelling for **FAST Socket** and **FAST PCIe** protocol based remote control connections. The VISA based hardware abstraction layer is not at all required for this kind of connection.

### 3.2.1   R&S Instrument Drivers

Only the **R&S VXI Plug&Play** and the **LabWindows/CVI Instrument Drivers** allow access to the Socket Controller and the PCIe Controller library which are crucial to establish and maintain the high-speed remote control connections:
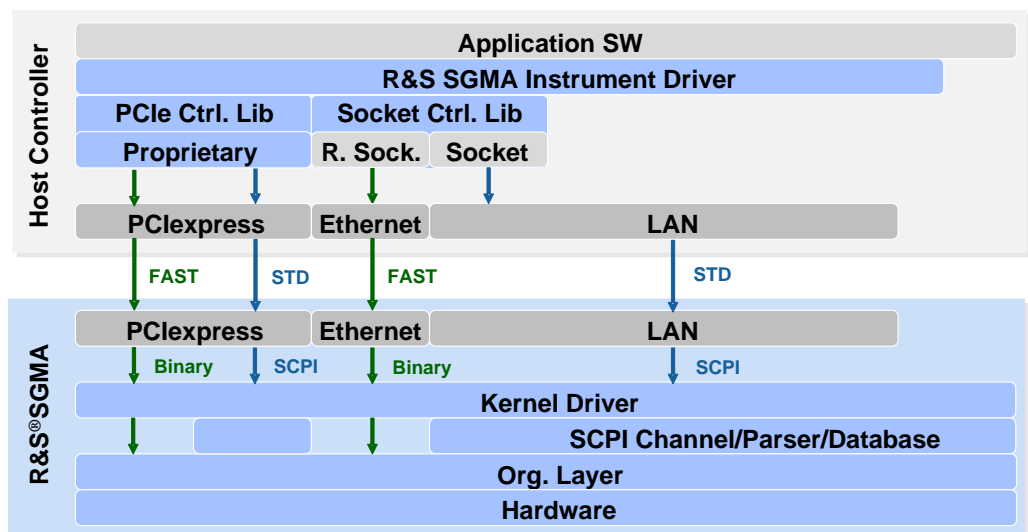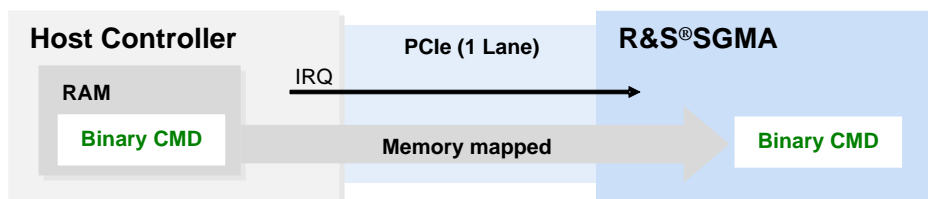


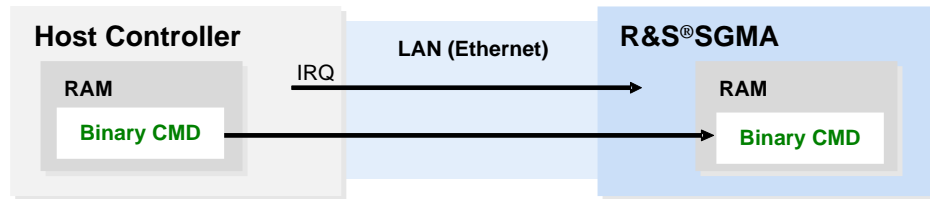*Figure 10: Instrument Drivers based (FAST) SGMA control – Protocol Layers*

In principle the instrument drivers operate as a kind of shunt/router for the remote control commands which have to be sent by a test application.
When the FAST mode is activated, all commands/operations supported by this mode (see *Table 6*) are sent via the speed optimized FAST channel of the PCIe- or Socket Controller I/O hardware abstraction layer, respectively.
As highlighted by the following figures, the FAST commands are transferred in a binary format to the SGMA RF source and become active within the SGMA hardware almost instantly bypassing the SCPI parser:

**FAST PCIe:**

**FAST Socket:**



*Figure 11: Instrument Drivers based (FAST) SGMA control – Binary Commands*

All other commands/operations not supported by the FAST mode are sent to the SGMA RF sources using the standard/legacy (STD) SCPI based mode. The same applies to all commands when the FAST mode is deactivated.

The following table shows the required SW libraries which have to be installed on the host controller PC to support instrument driver based remote control via any FAST mode capable interface and protocol:

| Instrument Driver based FAST SGMA control – Libraries | | | |
|---|---|---|---|
| **Interface** | **Protocol** | **Libraries** | |
| | | **HW Abstraction** | **Instrument Driver** |
| **LAN (Ethernet)** | TCP/IP Socket | `SGMA NDISPROT`[1], `SocketController`[1] | `VXIPlug&Play` or `LabWindows/CVI` |
| | **FAST Socket** | | |
| **PCIe** | PCIe | `PCIeController`[1] | |
| | **FAST PCIe** | | |

1) Comes with the SGMA-GUI software

*Table 7: Instrument Driver based (FAST) SGMA remote control – Libraries*

**Note**: To double check if the SGMA NDISPROT kernel driver is properly installed on a certain host controller:
- just enter the command 'driverquery' in a command prompt dialog to show all installed kernel drivers or
- have a look into the Local Area Connection Properties (Networking)

## 3.3 Remote Connection Setup and Configuration

This chapter summarizes relevant aspects for properly setting up a high-speed remote control interconnection between an SGMA RF source and a host controller PC by using the FAST mode.

It is assumed in the following that:
- the HW interconnection to a certain remote control interface was properly established and
- all relevant and actual libraries/drivers are installed on the host controller.

The connection setup is in principle exactly the same as that for legacy remote control connections (see chapter 2.3 for details) but requires some additional configuration steps.

In the following, a connection setup from a Windows based host controller to a SGT is illustrated:

1. In case of FAST Socket connections it is essential to ensure that the **SGMA NDIS protocol driver service** (OS Kernel driver) is properly started manually or by the application software. Keep in mind that both alternatives require administrator rights:

Manually: Open a command prompt dialog as administrator and type:

```
net start SGMANDISPROT
```

Application software:

```
ServiceHandle = OpenSCManager
(NULL, NULL, SC_MANAGER_ALL_ACCESS);


OpenService
(ServiceHandle, "SGMANDISPROT", SC_MANAGER_ALL_ACCESS);
```

2. Establish **instrument driver session** to certain SGT (via LAN Socket or PCIe):

```
rssgt_init
(ResourceString, idQuery, resetDevice, &SGTHandle);
```

A handle is returned by this function which has to be used to properly address this certain remote control session.

3. **Enable FAST Mode** and **disable asynchronous command processing** (each parameter setting function call returns not until the completion of the SGT hardware settings):

```
rssgt_UseFastSettings
(SGTHandle, enableFast, disableAsync);
```

The synchronous mode of operation is comparable with a SCPI command terminated with *OPC? in case of the standard/legacy remote control mode.

4. Disable automatic SGT status queries:

```
rssgt_SetAttributeViBoolean
(SGTHandle, "", RS_ATTR_QUERY_INSTRUMENT_STATUS, 0);
```

5. Configure any SGT parameter (e.g. RF frequency):

```
rssgt_SetAttributeViReal64
(SGTHandle, NULL, RSSGT_ATTR_RF_FREQUENCY, value);
```
...........
.....

6. Perform parameter queries (e.g. RF frequency):

```
rssgt_GetAttributeViReal64
(SGTHandle, NULL, RSSGT_ATTR_RF_FREQUENCY, &value);
```
..........
............

7. Close the established instrument driver session:

```
rssgt_close
(SGTHandle);
```

Further source code examples are provided by [13] and [14].

# 3.4  Setting Time Performance

With the information provided in the previous chapters a (high-speed) remote control connection to a SGMA RF source can be established.
The following paragraphs are focusing now on the setting time performance of these interconnections.
At first some essential questions regarding the **comparability of setting time numbers** and the potential impacts on the setting time performance are discussed.
Finally a **setting time comparison** of the legacy remote control approaches with a high-speed interconnection is provided.

## 3.4.1  Definitions

If it comes to discussions about remote control setting times it is essential to have an exact and clear understanding about:

- The different **types of setting times** (covered time intervals) and
- The **parameters and factors which may have an impact** on the measured/specified setting time

The following figure sheds some light on the setting time types/definitions:
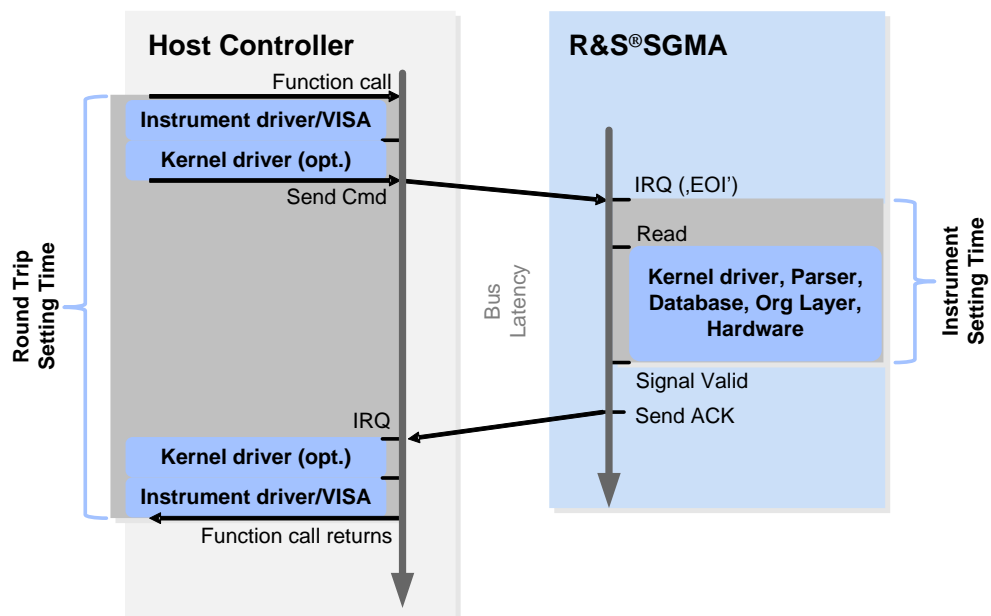


**Figure 12: Setting Time Performance – Definitions**

### 3.4.1.1  Setting Time Types

**Instrument Setting Time**:
This time interval includes all instrument internal processing steps which have to be performed to properly adjust a certain parameter based on a received remote control command. It starts directly after the command related interrupt service routine has been left (EOI, End Of Interrupt) and ends after the parameter has been settled within a well-defined tolerance/deviation window (see *Figure 13*).
The instrument setting time which comprises several sub time intervals (e.g. the HW

setting time) is normally specified by the instrument data sheets for some selected parameters (e.g. RF frequency/level) only.

**Hardware Setting Time**:
The time interval required to adjust a certain instrument parameter by altering the dedicated hardware units (e.g. FPGA registers) is called hardware setting time.
This time interval is accessible/measurable by the instrument design engineers only by using an especially instrumented firmware.

**Round Trip Setting Time**:
As shown by the figure above, the instrument setting time does neither consider the
- Bus latencies nor the
- Remote control command processing time consumed by the host controller PC

However if the overall settings time of a certain test application software has to be determined these setting time contributions must be considered, too.
In these cases, the so-called round trip setting time finds its application. This time interval accumulates all time contributions starting with the transmission of the settings command (e.g. instrument driver function call) and is ending with the acknowledgment of the controlled instrument received by the host controller (e.g. return of called instrument driver function).
In contrast to the instrument or hardware setting time, this time interval can be determined pretty easily by the test application software developer by just using the high precision timer functions provided by the Windows OS.

It has to be kept in mind that a round trip setting time may be significantly influenced by one of the included sub-time intervals:
- Physical dimensions of the remote control network (e.g. cable length)
- Network traffic/utilization
- Performance of the used network components (e.g. 100BaseT instead of 1000BaseT Ethernet hub)
- Performance and/or configuration of the used host controller network interface card
- Processing performance of the host controller PC

It is therefore crucial to get an impression of all these influencing factors and their respective share in the round trip setting time.

### 3.4.1.2 Setting Time Impacts

**Considered Time Interval**:
To prevent a comparison of apples with oranges during a discussion about setting times it is essential to have an eye on the setting time type(s) (see 3.4.1.1).

**Mode of Operation**:
Sometimes small setting time numbers are only feasible if a certain mode of instrument operation is used (e.g. list mode). Since this constraint may influence the overall configuration flexibility, be aware about these dependencies occurring.
Keep in mind that this kind of restrictions does not apply to the R&S FAST mode.

**Special Options required:**
Be aware that some other instruments are advertising a kind of high-speed setting but require a dedicated option to allow these competitive setting times.
In contrast, the R&S FAST mode comes free of charge with the base instrument not requiring any additional option.

**Endpoint of considered Time Interval**:

The endpoint of nearly any instrument parameter setting process is defined by the entering point to a defined tolerance window (which must not be left afterwards). It is therefore self-explanatory that a tight tolerance window will result in longer setting times than a wider tolerance window. This context is visualized by the following figure based on a performed RF level adjustment.
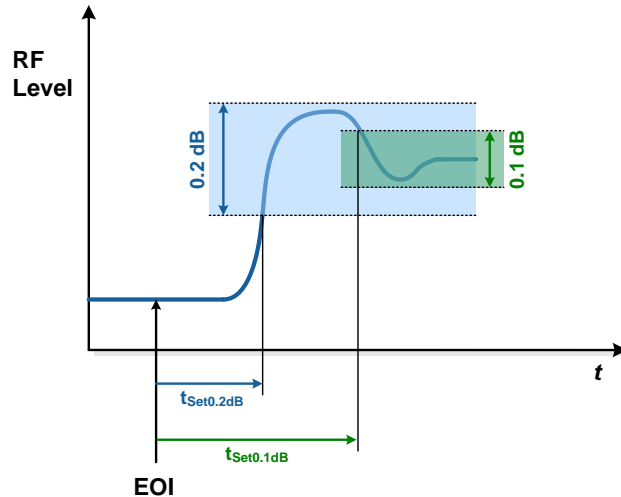


*Figure 13: Setting Time Performance – Impact of Settling Tolerance Window*

## 3.4.2   Comparison

The following tables and figures provide a comparison of interface specific measured SGT/SGS round trip setting time values (for a description of the performed operations refer to *Table 6*):

| SGT Round Trip Setting Time [ms] – Comparison[1] | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Operation** | **PCI Express** | | **LAN Socket** | | **LAN** | | **USB** |
| | **FAST** | **STD** | **FAST** | **STD** | **VXI-11** | **HiSLIP** | |
| RF Frequency | **0.34** (0.02) | 0.82 (0.04) | **0.33** (0.03) | 0.95 (0.05) | 1.15 (0.04) | 1.00 (0.05) | 0.87 (0.02) |
| RF Level | **0.28** (0.01) | 0.87 (0.04) | **0.28** (0.02) | 0.94 (0.05) | 1.18 (0.04) | 1.00 (0.05) | 0.88 (0.07) |
| RF State | **0.64** (0.03) | 1.47 (0.10) | **0.64** (0.05) | 1.66 (0.04) | 1.88 (0.17) | 1.72 (0.17) | 1.54 (0.40) |
| Modulator State | **0.29** (0.04) | 0.77 (0.06) | **0.27** (0.04) | 0.89 (0.07) | 1.13 (0.06) | 0.97 (0.05) | 0.82 (0.08) |
| Digital Atten. | **0.11** (0.02) | 0.43 (0.04) | **0.13** (0.01) | 0.48 (0.04) | 0.98 (0.04) | 0.55 (0.03) | 0.75 (0.01) |
| Next Segment | **0.09** (0.01) | 0.46 (0.03) | **0.12** (0.02) | 0.54 (0.05) | 0.99 (0.05) | 0.60 (0.04) | 0.75 (0.04) |
| Delib. Segment | **0.12** (0.02) | 0.56 (0.04) | **0.14** (0.02) | 0.63 (0.04) | 1.02 (0.05) | 0.73 (0.04) | 0.75 (0.03) |
| Frequency Offs. | **0.12** (0.02) | 0.51 (0.03) | **0.14** (0.02) | 0.60 (0.05) | 0.97 (0.06) | 0.67 (0.04) | 0.75 (0.03) |
| Phase Offset | **0.12** (0.02) | 0.51 (0.03) | **0.15** (0.02) | 0.60 (0.04) | 1.01 (0.06) | 0.66 (0.03) | 0.75 (0.05) |

1) Mean value (500 random repetitions), Standard deviation shown in brackets

*Table 8: SGT Round Trip Setting Time – Comparison (Measured values)*

Based on the performed measurements it becomes obvious that **FAST Socket** connections are **as fast as FAST PCIe** and up to **8 times faster** than legacy connections:
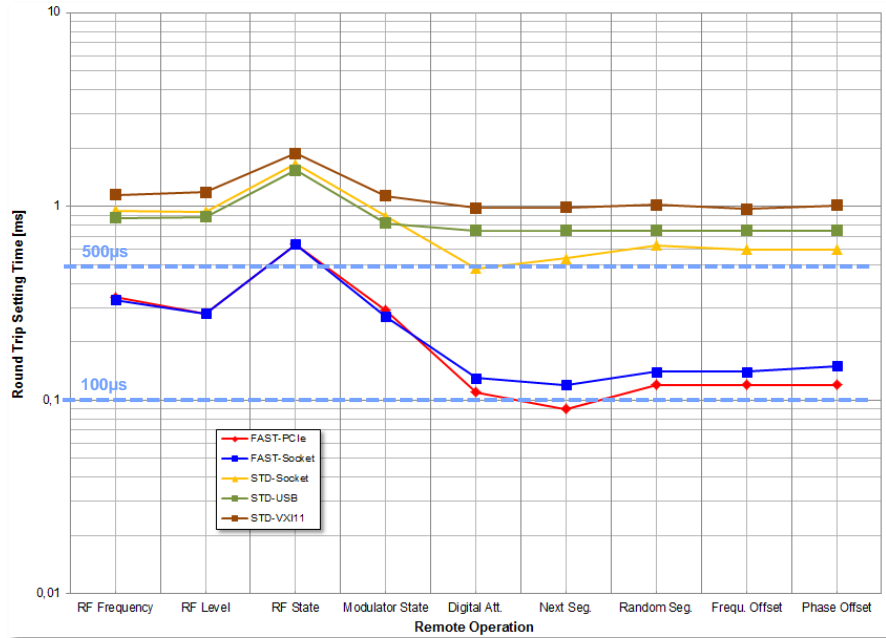


*Figure 14: SGT Round Trip Setting Time – Comparison (Measured values)*

The following figure visualizes the high setting speed based on a random variation of the digital attenuation. It also indicates the extraordinary fast hardware setting speed performance:
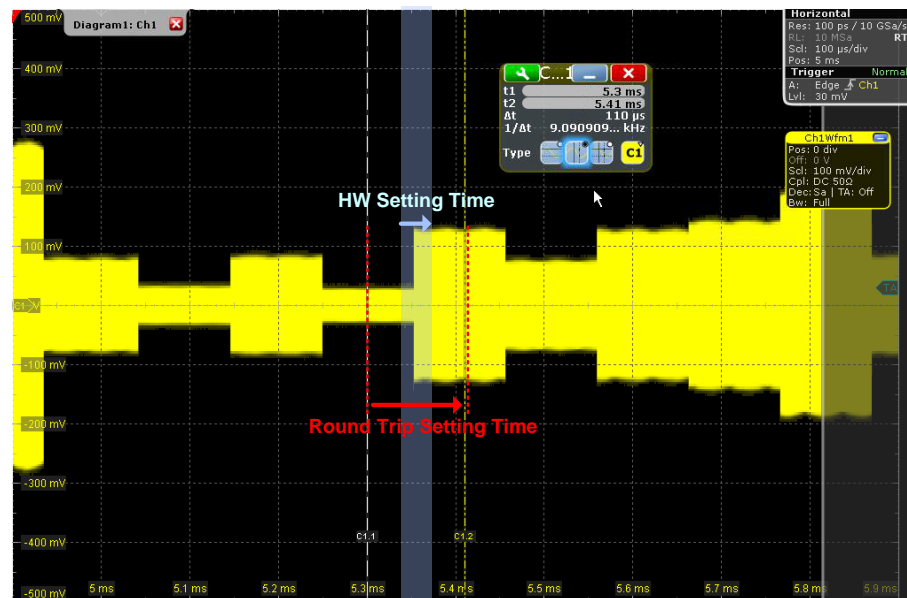


*Figure 15: SGT Round Trip Setting Time – Digital Attenuation*

The SGS is not as fast as the SGT but it yet reaches a competitive setting speed performance in case of FAST mode usage:

| SGS Round Trip Setting Time [ms] – Comparison[1] | | | | | | | |
|---|---|---|---|---|---|---|---|
| Operation | PCI Express | | LAN Socket | | LAN | | USB |
| | FAST | STD | FAST | STD | VXI-11 | HiSLIP | |
| RF Frequency | **0.59** (0.04) | 2.63 (0.08) | **0.66** (0.03) | 2.99 (0.11) | 5.03 (0.07) | 3.33 (0.06) | 2.99 (0.07) |
| RF Level | **0.53** (0.03) | 2.56 (0.09) | **0.60** (0.03) | 2.96 (0.07) | 5.03 (0.08) | 3.23 (0.06) | 2.79 (0.07) |
| RF State | **1.41** (0.05) | 3.51 (0.16) | **1.44** (0.04) | 3.93 (0.11) | 6.02 (0.09) | 4.26 (0.10) | 4.49 (0.68) |

1) Mean value (500 random repetitions), Standard deviation shown in brackets

*Table 9: SGS Round Trip Setting Time – Comparison (Measured values)*

All provided SGT/SGS round trip setting time values include/consider:
- Host controller command processing
- Bus latency
- SGT protocol and HW processing time
- Command synchronization
  - Legacy/STD mode:   Operation Complete (*OPC?) guard interval
  - FAST mode:            Synchronous operation

They therefore allow the test application developer to properly determine the cumulated setting time required for a certain measurement task which may consist of several, sometimes repeated operations/commands.

The measurements have been performed by using the **Speed Test Excel worksheet** (see chapter 6.1) with the following boundary conditions:

| SGMA Round Trip Setting Time – Measurement Boundary Conditions | |
|---|---|
| Parameter | Value |
| SGS/SGT FW: | V3.20.347.26 |
| Host controller: | Dell OptiPlex 790 (Intel i7-2600; 64-bit) |
| - LAN network adapter: | Intel Gigabit CT Desktop Adapter |
| - LAN network: | R&S network (1 GBit/s) Interconnection via Gigabit switch and 4m cable |
| - PCIe cable adapter: | One Stop Systems - OSS-PCIe-HIB25-x1-H Interconnection via 1m cable |
| - SGMA GUI SW: | V3.20.347.26 |
| - Instrument drivers: | `rssgt-vxipnp_x86` and `rssgs-vxipnp_x86` V1.5.0 |

*Table 10: SGMA Round Trip Setting Time – Measurement Boundary Conditions*

# 4 Abbreviations

| | |
|---|---|
| ATE | Automated Test Equipment |
| EOI | End Of Interrupt |
| GT/s | GigaTransfers per second |
| HiSLIP | High-Speed LAN Instrument Protocol |
| IDE | Integrated Development Environment |
| IRQ | Interrupt ReQuest |
| IVI | Interchangeable Virtual Instrument |
| LAN | Local Area Network |
| n.a. | not applicable |
| NDIS | Network Driver Interface Specification |
| OPC | OPeration Complete |
| PCI | Peripheral Component Interconnect |
| PCIe | Peripheral Component Interconnect Express |
| PCI-SIG | Peripheral Component Interconnect Special Interest Group |
| SCPI | Standard Commands for Programmable Instruments |
| STD | Standard |
| USB | Universal Serial Bus |
| VISA | Virtual Instruments Software Architecture |
| VME | Versa Module Eurocard-bus |
| VXI | VME Extensions for Instrumentation |

# 5 References

**Manuals:**

[1]    R&S, SGT100A Operating Manual
[2]    R&S, SGS100A Operating Manual

**Application Notes:**

[3]    R&S, 1MA153,  Development hints and best practices for using instrument drivers
[4]    R&S, 1MA170,  Introduction to attribute based instrument drivers
[5]    R&S, 1MA171,  Control R&S instruments directly from MATLAB
[6]    R&S, 1MA196,  Interactive remote control or Phython scripts automation
[7]    R&S, 1MA228,  How to use R&S instruments with LabVIEW
[8]    R&S, 1GP79,    Top Ten SCPI Programming Tips for Signal Generators
[9]    R&S, 1GP72,    Connectivity of Rohde & Schwarz Signal Generators

**Standards and Specifications:**

[10]   PCI-SIG, PCI Express Specifications

**Miscellaneous:**

[11]   R&S, SGT Software download area (e.g. SGMA-GUI)
[12]   R&S, SGS Software download area (e.g. SGMA-GUI)
[13]   R&S, SGT Instrument driver download area (drivers and application examples)
[14]   R&S, SGS Instrument driver download area (drivers and application examples)
[15]   R&S VISA software library

# 6 Appendix

## 6.1 SGMA Speed Test Excel Worksheet

The SGMA Speed Test Excel worksheet which comes with this application note allows round trip setting time measurements for SGS and SGT RF sources. It supports all available remote control interfaces and protocols including the FAST mode. It is therefore the method of choice to evaluate and demonstrate the setting time performance of the SGMA RF sources.
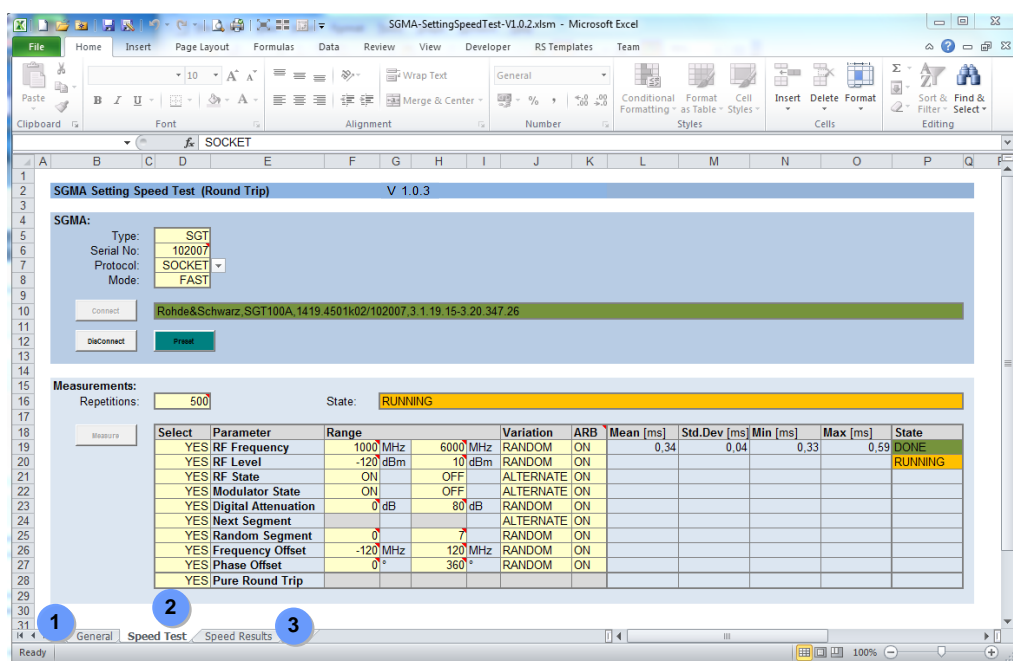


*Figure 16: SGMA Speed Test Excel Worksheet – Overview*

The overall functionality of the worksheet is split up into 3 tabs.
On first use of the worksheet it is recommended to familiarize with it by studying the information provided by the ① '**General**' tab. It includes helpful background information about the SGMA Speed Test Excel worksheet like:

- Version control information
- Summary of prerequisites (see also chapter 6.1.1)
- Overview about the supported speed tests including information about the done pre-settings in advance of a certain test
- Hints to visualize the test performance by using an R&S RTO
- Test examples

The ② '**Speed Test**' tab provides the main functionality of the worksheet. It is used to control a certain SGMA interconnection and allows the configuration and performance of round trip setting time measurements. See chapter 6.1.2 for further details.

The ③ '**Speed Results**' tab contains detailed results of the performed tests which include the set parameter values and the required/measured round trip setting times. See chapter 6.1.3 for further details.

### 6.1.1 Prerequisites

The following prerequisites have to be fulfilled by the SGMA RF sources and the host controller PC to allow the usage of the Speed Test Excel worksheet to its full extent:

| SGMA Speed Test Excel Worksheet – Prerequisites[1] | |
|---|---|
| **Parameter** | **Requirement** |
| SGMA Options | SGS: none<br>SGT: K510 (Arbitrary waveform generator) |
| SGMA FW | Release version |
| SGMA Waveform file | SGS: none<br>SGT: 'PowStepsMSeg.wv'[2] |
| Host Controller SW | SGMA-GUI [11], [12]<br>SGT/SGS VXI Plug&Play instrument drivers (32bit, x86) [13], [14] |
| PCIe | A PCIe cable adapter has to be installed on the host controller PC<br>(e.g One Stop Systems OSS-PCIe-HIB25-x1-H)<br>**Attention**: Take care about required power on/off sequence (see chapter 2.1.3.4) |
| FAST Socket | The LAN interconnection between the host controller PC and the SGMA must not include routers (TCP/IP routing is not supported) |

1) See also 'General' tab of the SGMA Speed Test Excel worksheet
2) Comes with the SGMA Speed Test Excel worksheet and has to be saved in the same directory

***Table 11: SGMA Speed Test Excel Worksheet – Prerequisites***

The SGMA Speed Test Excel worksheet can be opened when all these prerequisites have been considered and a hardware interconnection via any of the available SGMA remote control interfaces has been established.

### 6.1.2 Speed Test Performance

The 'Speed Test' tab of the SGMA Speed Test Excel worksheet allows the:
- Configuration and establishment of a remote control interconnection to a certain SGMA RF source
- Definition and start of a round trip setting time measurement sequence
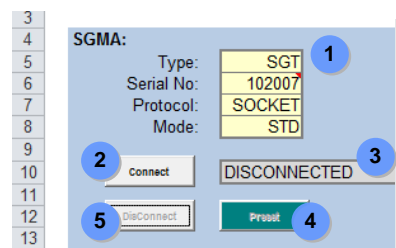


***Figure 17: SGMA Speed Test Excel Worksheet – SGMA Interconnection***

Any round trip setting time measurement has to be started with ① the configuration of some indispensable parameters which determine the interconnected SGMA RF source

and the tested interface/protocol. After all of these parameters have been set thoroughly the ② interconnection can be established by just pressing the 'Connect' key. The ③ status of any connection attempt is instantly shown.
To reset an interconnected SGMA source just press the ④ 'Preset' key.
The ⑤ 'Disconnect' key has to be pressed if a certain interconnection has to be released because a new one (e.g. via another protocol or to another SGMA RF source) has to be established.

The desired measurement sequence has to be configured after an interconnection has been established successfully.
It is required to specify the ① number of repetitions for any remote parameter setting to allow the calculation of several statistical parameters (e.g. arithmetic mean and standard deviation).
Further on, each subtest could be ② individually parameterized. The subtest may be selected/deselected, the variation range of a certain parameter value can be adapted, the kind of parameter value variation may be changed and for some parameters it is possible to run the test with activated/deactivated ARB (SGT only).



**Figure 18: SGMA Speed Test Excel Worksheet – Measurement Configuration**

The configured measurement sequence is started by pressing the ③ 'Measure' key. A permanently updated measurement status is also displayed.
Some statistical parameters (e.g. arithmetic mean) of the subtests performed are shown after a certain measurement sequence has been finished.



**Figure 19: SGMA Speed Test Excel Worksheet – Result Statistics**

### 6.1.3   Speed Test Detailed Results

In certain cases it may be useful to have a closer look into the performed measurements, the set parameter values and/or the derived round trip setting time values. This kind of detailed results is available via the 'Speed Result' tab:



***Figure 20: SGMA Speed Test Excel Worksheet – Result Details***

## 6.2   Code Examples

Remote control code examples are provided with the SW archives (Low-level drivers) for SGT [13] and SGT [14].

# 7 Ordering Information

Please visit the Rohde & Schwarz product websites at www.rohde-schwarz.com for ordering information on the following Rohde & Schwarz products:

- R&S®SGT100A vector signal generator
- R&S®SGS100A vector signal generator

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## Sustainable product design

- Environmental compatibility and eco-footprint

- Energy efficiency and low emissions

- Longevity and optimized total cost of ownership

Certified Quality Management
**ISO 9001**

Certified Environmental Management
**ISO 14001**

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