
RF Cogs™ Operation Manual

Version 1.0



Applied Instruments, Inc.

RF Cogs™
RF Cogs™ Series Operation Manual

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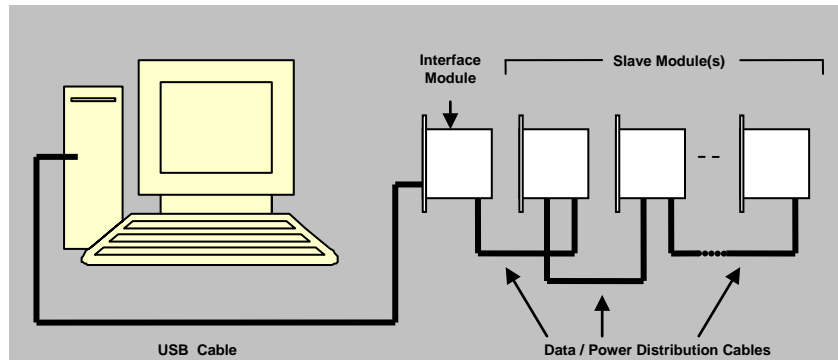
1 Description

This manual describes the operation of the *RF Cogs™* family of products manufactured by Applied Instruments.

2 Overview

RF Cogs™ modules can be used either together or alone to accomplish a variety of tasks commonly associated with RF testing. The modules are remotely controlled using either a personal computer or an embedded micro-controller, allowing them to operate under software control.

These versatile modules fall into two general categories: “interface modules” and “slave modules”. Slave modules perform the actual test functions. Interface modules connect a controlling device such as a PC to one or more slave modules.



2.1 **Slave Modules**

Slave modules accomplish gain, switching, attenuation, and other test support functions. Individual modules are uniquely addressable, allowing directed communications with each one over an I²C 2-wire bus. The unit's address is set on an easily accessed DIP switch located on each slave module.

In general, up to eight slave devices may be connected to one interface module. The exact number may be reduced due to current load if amplifier modules are used or may be more if some modules are configured at the same address.

A 12 VDC source is required to power the slave modules. A few types of slave modules may also support use of an interrupt line and a single bit I/O line.

A typical slave module will have a number of RF connectors that serve as the RF inputs and outputs as required by the module's function.

One edge of every slave module also has a pair of 20-pin connectors which are electrically interchangeable. You may connect to either one. Two are provided to allow the slave modules to be daisy-chained. The first module in the chain plugs into the second, the second module plugs into the third, etc.

Each slave module is shipped with a mating cable which enables that module to be added to the chain. If needed, both longer and shorter cables can be ordered. These cables distribute all of the power, I²C, interrupt, and I/O signals required by the RF Cogs™ modules.

2.2 Interface Modules

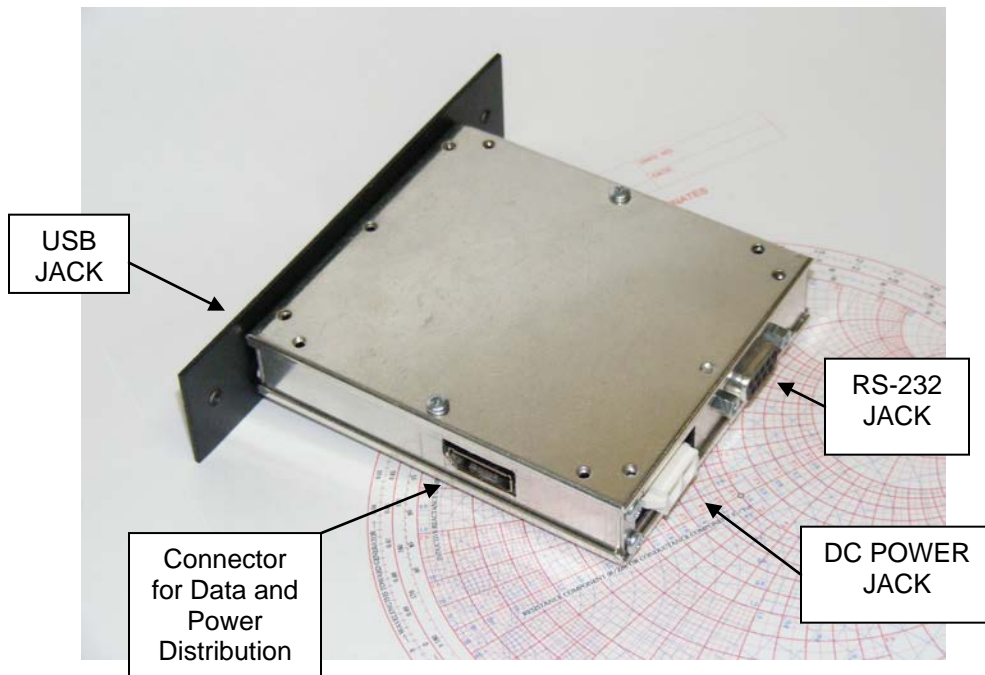
Interface modules, such as the *RFC-INTF*, provide the DC power required by the slave modules and a communications interface between an intelligent control device (such as a PC) and the slave modules. The interface module translates simple text commands received from the controller into I²C signals required by the slave modules and provides status and error data to the controller.

3 RFC-INTF Interface Module

The RF Cogs™ Interface Module is an intelligent interface between a controlling device (typically a personal computer) and one or more RF Cogs™ slave modules. Examples of slave modules are attenuator modules, switch modules, and amplifier modules.

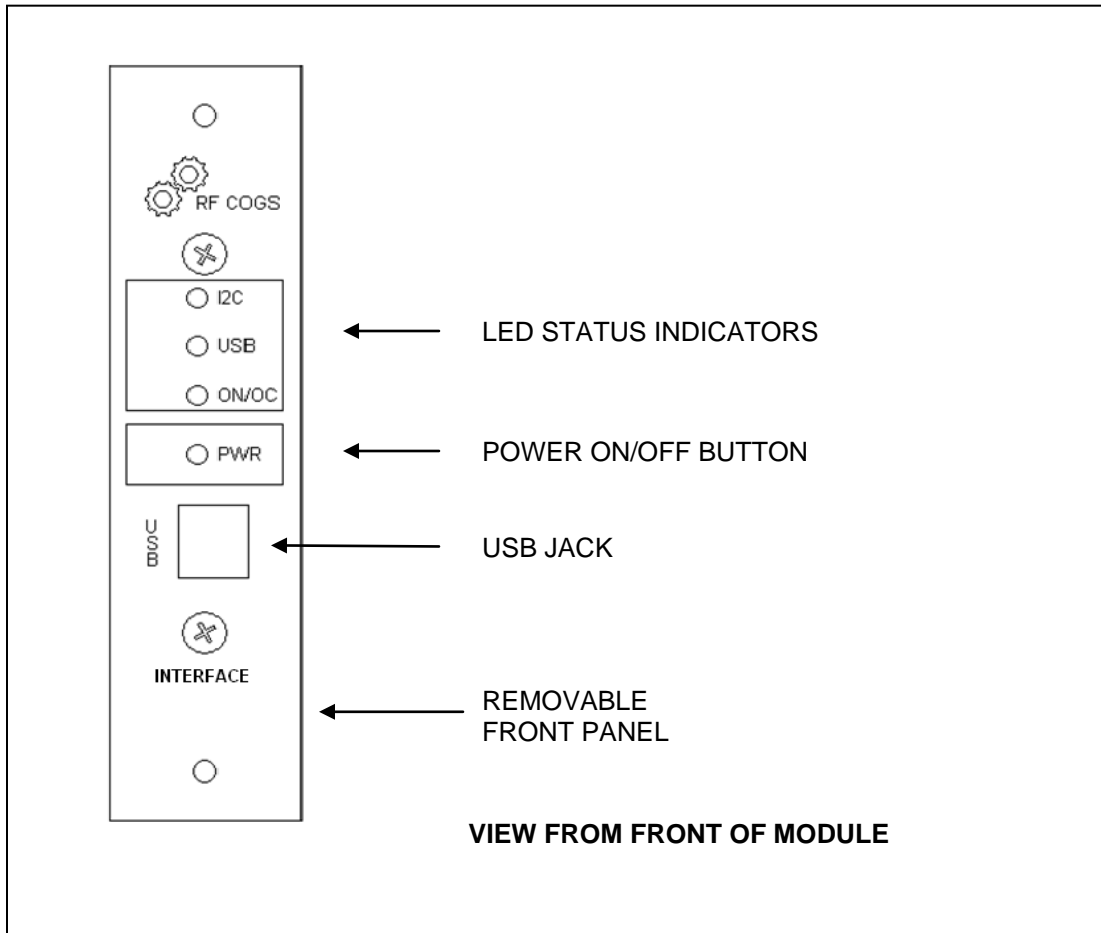
This module is required whenever a USB or RS232 interface to the system is desired. It also provides the DC power needed by the slave modules via an AC power adapter.

3.1 Connections



VIEW FROM REAR OF MODULE

3.2 Front Panel

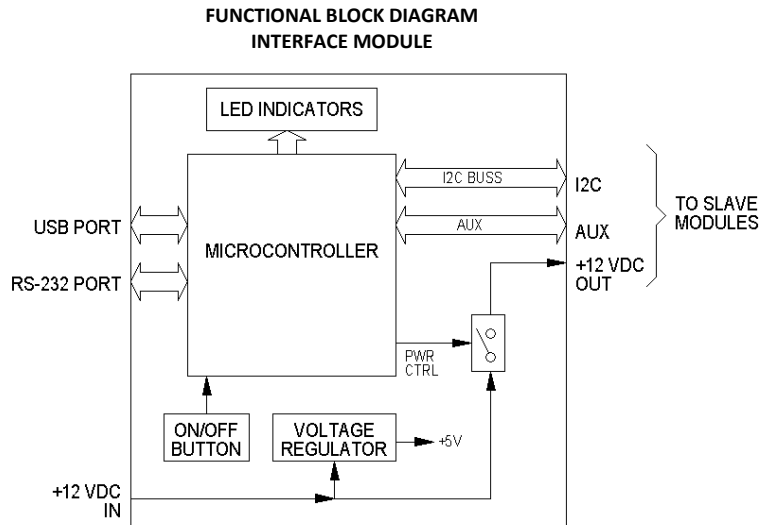


The front panel indicator LEDs operate as follows:

- **ON/OC LED**
 - OFF - Power to the slave modules is turned off.
 - GREEN - Power to the slaves is on, current is within normal limits.
 - RED – Over-current condition. Should an over-current condition occur, the Interface Module automatically shuts down power to the slave modules.
- NOTE:** The ON/OFF Power button must be pressed after the problem is cleared before slave power can be turned back on and sustained.
- **USB LED**
 - OFF - the USB cable is not plugged in or the PC is turned off.
 - GREEN - the USB cable is plugged in and the PC is turned on.
 - **I2C LED**
 - OFF - No problems with the operation of the I2C bus.
 - RED - The I2C bus is locked up and inoperable for some reason.

3.3 Power

The power for the Interface Module, as well as the power required by connected slave modules, is supplied by a universal AC to DC switching power supply adapter (external). The microcontroller used in the Interface Module is powered up whenever the adapter is plugged in. Power to the slaves is provided when the slave bus is turned on using the ON/OFF push button on the front panel. The Interface Module monitors the total current used by the slaves and shuts down if an over-current condition is sensed.



3.4 Communications

Communications between the controlling device and the Interface Module can be accomplished using either the USB or RS-232 ports provided. The Interface Module communicates as needed with the slave modules over an I²C bus. Since all slave modules have a user-settable address, communications can be directed to and from selected modules.

The *RFC-INTF* serves as the I²C master and does not need a DIP switch to give it an address.

The *RFC-INTF* translates text commands received over the USB or RS-232 interface into the specific I²C message required for the desired function. You do not need to understand the I²C details when using the *RFC-INTF*.

4 Remote Commands

The following describes some of the commands used with the *RFC-INTF* Interface Module. Information on other commands which may be of interest may be found in the Data Sheet for the particular slave modules being used.

4.1 SCPI Language

The command set follows the SCPI language syntax and protocol. Note: SCPI is not strictly adhered to.

In the sections that follow, the commands are described using a syntax with the following conventions:

- 1) Required portions of a command word are shown in upper case.
- 2) Lower case denotes optional portions of the command word.
- 3) Square brackets denote optional words within the command.
- 4) Commands may be given in either case (both required and optional parts).
- 5) Commands are terminated with a carriage return.
- 6) Words within a command are separated by colons.
- 7) A command ending in a question mark is a query and the device should respond with the value for that command.
- 8) Some commands may be followed by one or more values separated by a space.
- 9) Values may be one of the following types:
 - a) Int
 - b) Float
 - c) String
 - d) Boolean
- 10) Angle brackets are used to enclose a keyword

For example, consider the following definition:

```
SWITCh[:SELEct] <int>
```

“Switch” is a required word and may be spelled as “switch”, “switc”, or “swit”, in any mixture of upper or lower case. “Select” is an optional word and may be spelled as “select”, “selec”, or “sele”. The command takes an integer value.

The following are all legal entries for this command:

```
SWITCH:SELECT 1  
Swit:sele 2  
swit 3
```

4.2 Error Reporting

The system error query command is supported for a few types of errors:

SYSTEM:ERRor?

Returns one of the following:

- 0, "No error"
- 100, "Command error"
- 101, "Invalid character"
- 222, "Invalid Value"
- 350, "Queue overflow"
- 100, "I2C Error"
- 200, "Serial Number/Version Number is already set"
- 300, "Module Type Error"

4.3 SCPI Required Commands

The following commands are implemented as required by the SCPI standard but have no real function in this product.

- *CLS Clear Status Command
- *ESE Standard Event Status Enable Command
- *ESE? Standard Event Status Enable Query
- *ESR? Standard Event Status Register Query
- *IDN? Identification Query
- *OPC Operation Complete Command
- *OPC? Operation Complete Query
- *RST Reset Command
- *SRE Service Request Enable Command
- *SRE? Service Request Enable Query
- *STB? Read Status Byte Query
- *TST? Self Test Query
- *WAI Wait to continue Command

The interface module has no overlapped commands, so the *OPC, *WAI and *OPC commands are not needed.

4.4 Multiple Commands

SCPI allows multiple commands to be strung together on the same line separated by semi-colons. This feature is not implemented.

4.5 Device Addresses and Names

Before sending a command, the address of the device to receive the command must be specified. To simplify use, each device in the system may be named.

4.5.1 Standard Addresses

The "address" command specifies the I²C bus address used for following commands. This address will be used for all un-named commands that follow until another address is given.

ADDRESS <int>

ADDRESS?

This query form returns the current value of the reference address.

4.5.2 Named Addresses

Devices may be named and the name associated with an I²C address. The names may then be used as a prefix to any command intended for that device.

NAME <string> <int>

This command defines the string value as a device name and associates it with the given I²C address.

Example:

```
NAME NOTCH 56
```

This command defines “notch” as the name for the device at I²C address 56 (0x38). This may then be used as follows:

```
Notch:switch:select 2
```

4.6 System Configuration Commands

IDN?

The “IDN?” command returns the model and serial number of the control unit.

Example: IDN?
Returns: 1.00, 1651234

SYSTem:DEVICES?

This command returns the number of currently attached slave devices.

Example:
Given there are two slave devices attached.

```
SYST:DEV?
```

Returns: 2

SYSTem:DEVIce:ID? <int>

The integer given in this command may vary from 1 to the number of attached devices. The command returns the address and module type for the indicated device number.

Example:
Given there is a switch module connected as the first device at address 56 (0x38).

```
SYST:DEV:ID? 1
```

Returns: 56, 0

The presently defined slave module types are:

Id	Model	Description
0	RFC-SW41	RF Switch, SP4T (1x4), relay
128	RFC-AT60	Step Attenuator, 0-60 dB, 15 dB/step

SYSTem:DEVIce:ADDRess? <int>

The integer given in this command may vary from 1 to the number of attached devices. The command returns the address for the indicated device number.

Example:

Given an attenuator module connected as the second device at address 58 (0x3A).

```
SYST:DEV:ADDR? 2
```

Returns: 58

SYSTem:DEVIce:TYPE? <int>

The integer given in this command may vary from 1 to the number of attached devices. The command returns the module type for the indicated device number.

Example:

Given an attenuator module connected as the second device at address 58 (0x3A).

```
SYST:DEV:TYPE? 2
```

Returns: 128

Note: For all the previous commands, when a slave device is attached or detached the power must be cycled to update the device list.

SYSTem:ADDRess:STATus? <int>

Indicates if a device is configured at the given address:

- 0 = No response
- 1 = Responding

Example:

Given no slave module currently attached at the address.

```
SYST:ADDR:STAT? 60
```

Returns: 0

[SYSTem:]STATus?

The current status of the slave bus is returned. The possible states are

- 0 = BUS OFF
- 1 = BUS ON
- 2 = OVERCURRENT
- 3 = I2C ERROR

[SYSTem:]POWER <bool>

The power condition of the slave bus can be set to either ON or OFF with this command.

[SYSTem:]POWER?

The present power status of the slave bus is returned. The possible states are:

- 0 = OFF
- 1 = ON

SYSTem:VERBoSe <bool>

This command turns the terminal messages ON or OFF. This allows for more readability when the user is working within a terminal window. These messages include error messages as they occur, command responses, and more descriptive returns to query commands.

4.7 Switch Module Commands

Switch modules use the following command:

SWITCh[:SELEct] <int>

Where <int> is the switch position and depends on the switch type.

SWITCh[:SELEct]?

Returns the last given switch position.

If no switch command has been seen for this device since power up, -1 is returned.

If power is off, -1 is returned.

This command works for the 1x4 relay module and also the 1x2 solid state module.

4.8 Amplifier Commands

Amplifiers may be turned on or off using the following:

AMPLifier[:STATe] <bool>

Turns the amplifier ON or OFF.

AMPLifier[:STATe]?

Returns the present state of the amplifier.

4.9 Step Attenuator Commands

Attenuator modules use the following:

ATTENUator[:STEP] <int>

Sets the attenuator to the given step position. The possible positions depend on the attenuator model. For the RFC-AT60 they are 0, 15, 30, 45, and 60 dB.

ATTENUator[:STEP]?

Returns the present step position or -1 if unknown.

4.10 Other Slave Module Commands

As additional RF Cogs™ Modules are developed, the command set will be expanded to support them. Firmware updates will be available from our website, making it possible to update your RFC-INTF to support any new modules that become available.

5 I²C Communications

The information in this section is only needed if the RFC-TERM interface board is used. If using the RFC-INTF module to interface to a USB or RS232 port, this section may be skipped.

5.1 General Concept

Communications between modules use the I²C standard, defined by NXP (formerly Philips Semiconductor). I²C stands for Inter-Integrated Circuit Communications. Please refer to that standard if additional details are required; it can be obtained for no charge from their website.

The I²C bus can be used to transfer data simply and quickly from one device to another. It is a synchronous, serial interface which is bidirectional. Information is carried by two wires, serial data (SDA) and serial clock (SCL), between devices connected to the bus.

Devices have a unique address and can operate as either a transmitter or receiver, depending on the function of the device. Some devices only receive data, whereas others can both receive and transmit. In addition to transmitters and receivers, devices can also be considered as masters or slaves when performing data transfers. A *master* initiates a data transfer on the bus and generates the clock signals to permit that transfer. At that time, any device addressed is considered to be a *slave*.

5.2 Embedded OEM Applications

If you do not want to use USB or RS232 to communicate with the RF Cogs™ modules, but rather want to include the modules in a system that has an I²C bus of its own, you may use the RFC-TERM board instead of the RFC-INTF Interface Module. This board simply provides termination points to connect your I²C bus to the RF Cogs™ bus and provide 12V DC power to run the slave modules. In this case you need to know the structure of the I²C messages that implement the commands. This information is included in the datasheet for each module.

5.3 Electrical Characteristics

Both the SDA and SCL are bi-directional lines. They are each connected to a positive supply voltage through a pull-up resistor. When the bus is idle, both lines are HIGH. The output stages of devices connected to the bus must have an open-drain or open-collector to perform the wired-AND function.

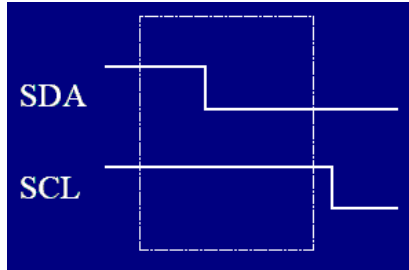
In the Standard-mode used by the RF Cogs™ devices, data on the I²C-bus can be transferred at a maximum rate of 100 Kbit/sec. Somewhat faster rates may be achievable though depending on the number of modules which are connected. This is because each module adds capacitance to the bus, limiting the speed.

One clock pulse is generated for each data bit transferred. Normally, the master device controls the clock line, SCL. This line dictates the timing of all transfers on the I²C bus. Other devices can manipulate this line, but they can only force the line low. This action means that item on the bus can not deal with more incoming data. By forcing the line low, it is impossible to clock more data in to any device.

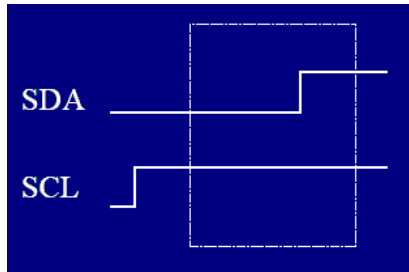
The data on the SDA line must be stable during the HIGH period of the clock. The HIGH or LOW state of the data line can only change when the clock signal on the SCL line is LOW.

There are two exceptions to this rule which are found within the procedure of the I²C-bus. These unique conditions are defined as START (S) and STOP (P) conditions.

- A HIGH to LOW transition on the SDA line while SCL is HIGH is one such unique case. This situation indicates START condition.

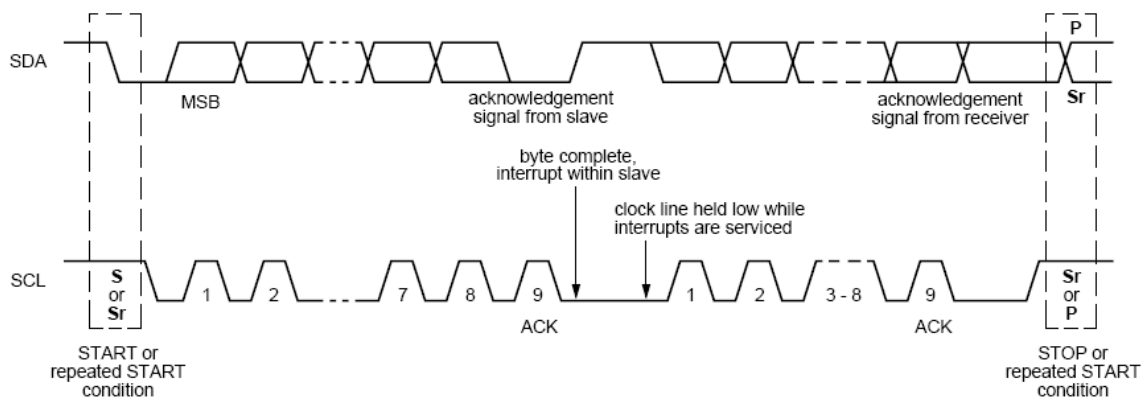


- A LOW to HIGH transition on the SDA line while SCL is HIGH defines a STOP condition.

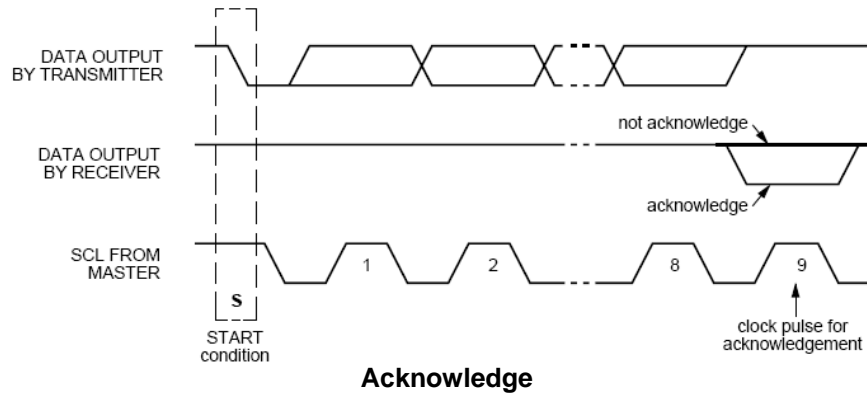


START and STOP conditions are always generated by the master. The bus is considered to be busy after the START condition. The bus is considered to be free again a certain time after the STOP condition.

When a master takes control of the bus in order to send data, it first sends a START condition, then clocks out 8 bits of data. The slave to which the communication is addressed provides an acknowledge bit (ACK) back to the transmitting device in response to a 9th clock pulse. The “ACK” is used to indicate that the data was received. This completes the transfer of an 8-bit byte of data. From there, the Master can either begin sending the next byte of data, or send a STOP condition to end the data transfer and free the bus (see diagrams below).



Data Transfer Process



This process is also used to transfer data from a slave to the master. Remember that data can flow in any direction on the I²C bus, but when it flows, it is controlled by the master device. The data that needs to be transferred is specific to the devices involved, but the 8 bits of data may be a control code, an address or data.

I²C Bus Details Specific to the RFC-AT60

The I²C device employed in the *RFC-AT60* is an 8-bit I/O port – specifically the PCA9554A made by NXP. A datasheet is available from that manufacturer with complete details on using it as an I²C device. You may refer to it for a more complete understanding of the device. Here, all of that has been summarized to include just what one is likely to need to know in order to talk successfully with the *RFC-AT60*. This summary includes not only the info needed about the PCA9554A, but also the information specific to the way it is being used to control the attenuators used in the module.

The PCA9554/PCA9554A consists of an 8-bit Configuration register (Input or Output selection); an 8-bit Input Port register, an 8-bit Output Port register and an 8-bit Polarity Inversion register (active HIGH or active LOW operation).

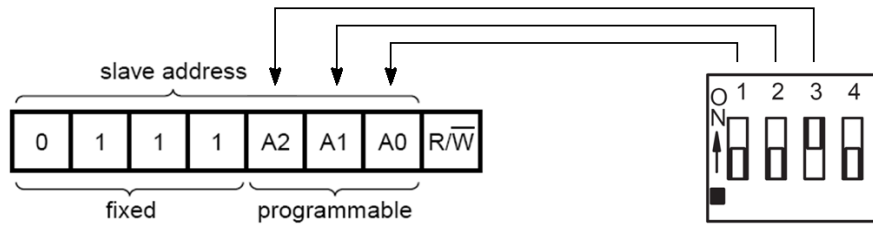
The system master can enable the I/Os as either inputs or outputs by writing to the I/O configuration bits. The data for each input or output is kept in the corresponding Input Port or Output Port register. The polarity of the read register can be inverted with the Polarity Inversion register. All registers can be read by the system master.

The polarities are not inverted when used as described here. Since this is the default condition on power-up, there is no need to write to the Polarity Inversion Register.

To control the attenuators used in the *RFC-AT60*, the 8-bit port needs to have bits 3, 2, 1 and 0 configured as outputs (the rest are not used and should be configured as inputs). This is accomplished through use of the Configuration register.

Note that it is possible to do a read of the *RFC-AT60* in order to read its Module-type ID. This is a fixed value that is characteristic of all RF Cogs™ modules of this type. Attenuator modules would return a different value, while an amplifier module would return a value unique to that type. This feature is used primarily to query the various I²C addresses to determine what type of module is located there. *It has nothing to do with controlling the attenuators used in the RFC-AT60.* In order to read the Module-type ID, it is necessary to use the Configuration register to make inputs of all eight bits of the PCA9554A port.

A6 through A3 are internally fixed inside the PCA9554A at 0111 respectively. Thus, the module's address can be set to xx38 thru xx3F (decimal 56 thru 62).



RFC-AT60 Address

DIP Switch

When the switch is in the “ON” position, the address bit is set high.

Section 1 of the DIP switch corresponds to A0, section 2 to A1, and section 3 to A2. The 4th section is not used on this module and has nothing to do with setting the I²C address. In the illustration above, the I²C address in binary would be 0111100 (xx3C, decimal 60).

*More devices can be used if some share the same address. Multiple RF Cogs™ Modules of the same type can be “ganged” together using this technique; all of them will then responding alike. This is most likely to be useful when one wants to combine several switch modules together to in effect increase the number of poles.

6 Mounting

The *RF Cogs™* modules are designed to be mounted in one of two ways. The first method is to mount them side-by-side into a 19" sub-rack that is an accessory item available from Applied Instruments (part RFC-RM). The second requires the removal of the two #6-32 screws which secure the module's front panel.

With the front panel removed, the module can then be mounted directly to another surface in one of two ways:

- With the two PEM nuts on the edge of the module vacated by removing the front panel
- With the four additional PEM nuts located on the bottom lid

7 RfcDemo Program

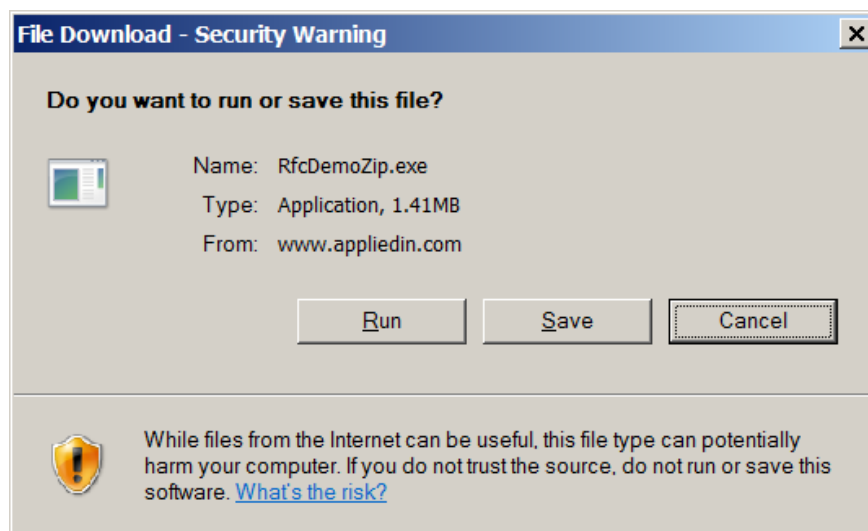
A Microsoft Windows™ application is available from our website for demonstration and exercising of the system.

7.1 Installation

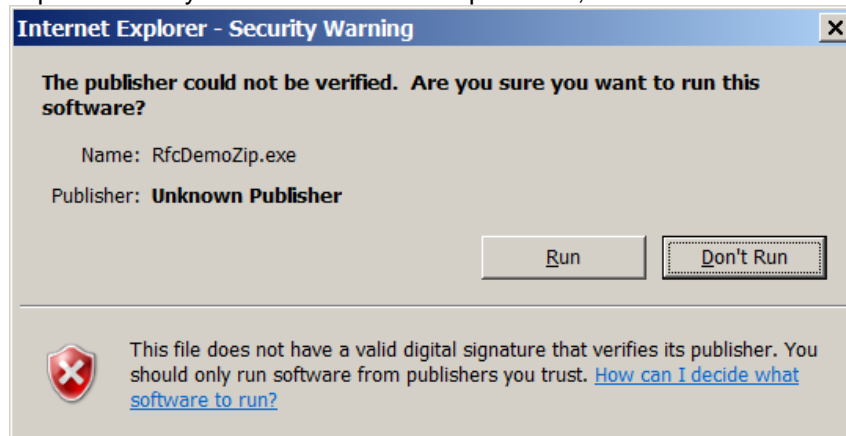
- 1) Download and run the RfcDemoZip program from the Applied Instruments website:
www.appliedin.com/downloads/RfcDemoZip.exe

This downloads an installation application program onto the computer. Running this installation application will unzip and install the program files into a specified folder.

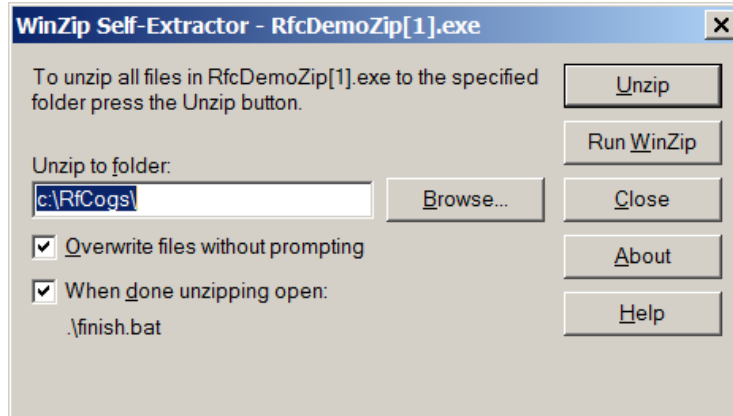
- 2) If your computer asks if you want to save or run this file, select RUN:



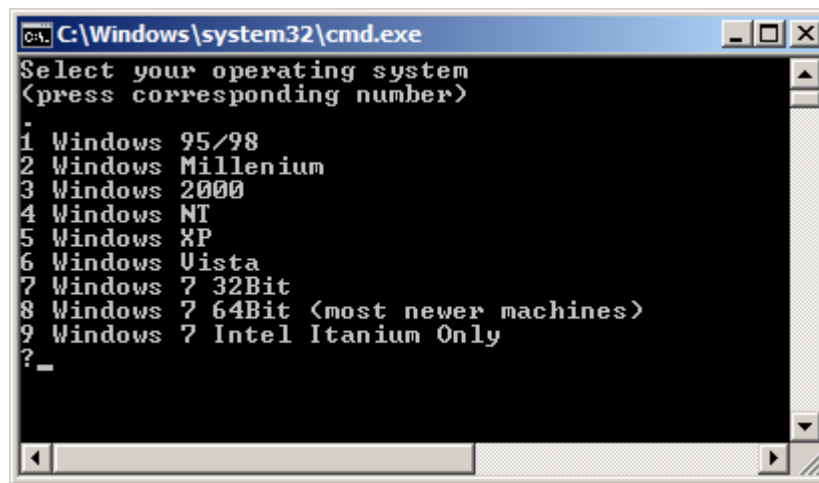
- 3) If your computer warns you about an unverified publisher, select RUN:



- 4) You should see a window asking you where to store the files. You may take the default folder or change to another folder, then click "Unzip". Note: if you change to another folder, the program shortcut icon installed on your desktop will not work without redirecting to the new folder.

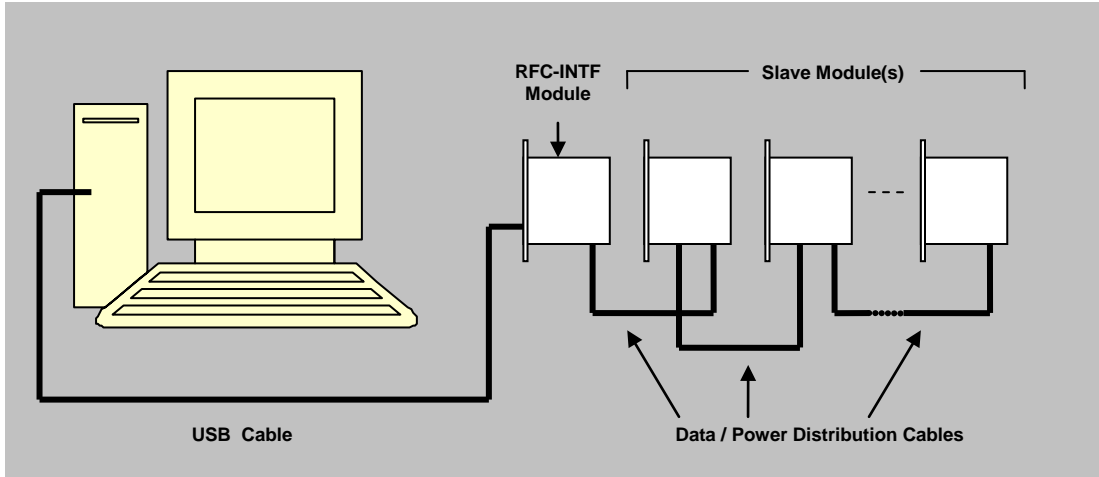


- 5) **Select the appropriate operating system** from the menu that is displayed to install the correct driver for the application (see Figure below). The RfCogs application within the specified folder can then be utilized to easily control the slave devices with the interface module.

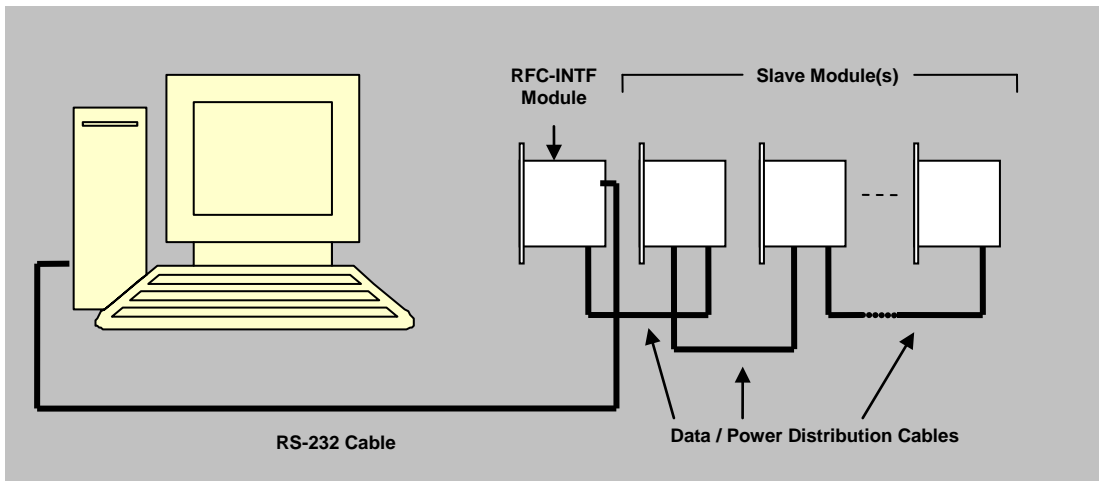


7.2 Running the Demo program

- 1) **Set DIP switches** to unique address for each module on bus (unless ganged operation is desired).
- 2) **Connect the RFC-INTF Interface Module to the PC and slave modules** as shown in one of the two diagrams below using the cables supplied with the modules.



Typical Connection Scheme using an RF Cogs™ Interface Module to Control Slave Modules from a PC using the USB Port

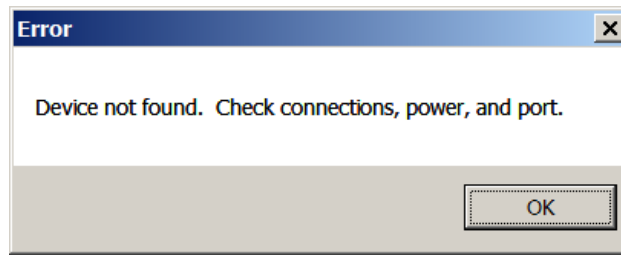


Typical Connection Scheme using an RF Cogs™ Interface Module to Control Slave Modules from a PC using the RS-232 port

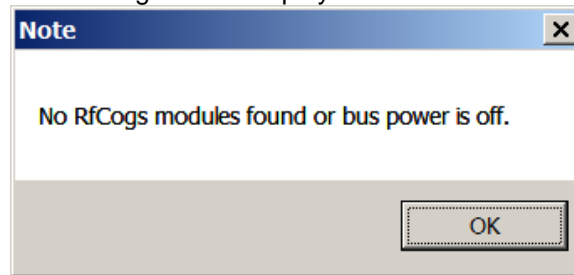
- 3) **Connect the DC Power Adapter** to the RFC-INTF. If the USB port is being used, the USB LED should light up green.
- 4) **Turn on slave modules** by pressing the PWR ON/OFF button located on the module's front panel. The ON/OC LED should light up green.



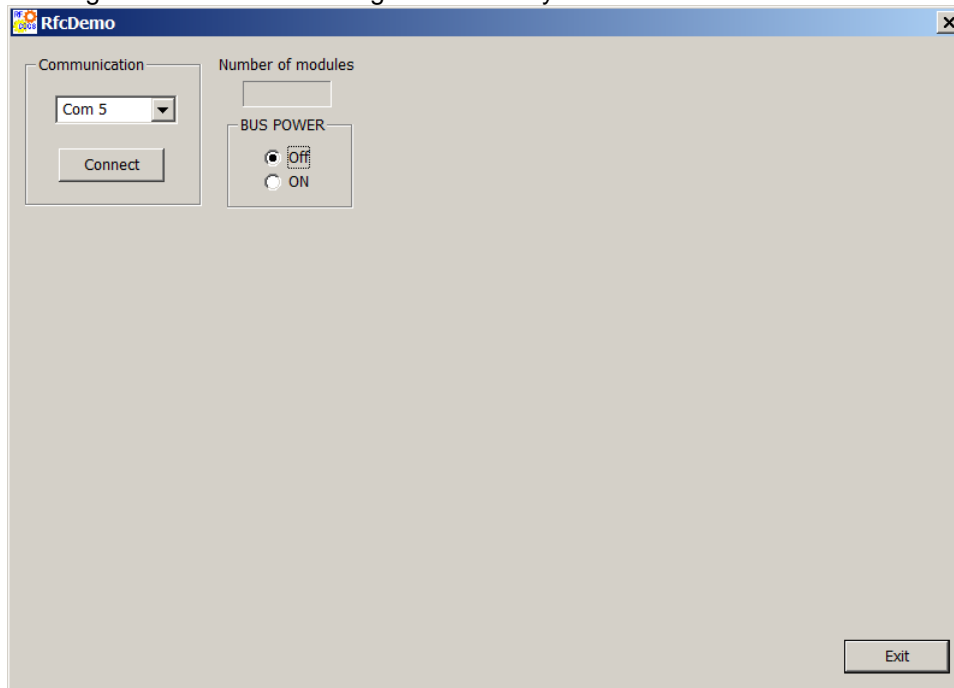
- 5) **Run the program RfcDemo.exe installed previously.** When the application is started, the communication ports on the computer are scanned for the interface module.
- a) If the interface module is not found, an error message will pop up informing the user of the error.



- b) If the communication port is known, a drop down menu is presented which can be used to choose the corresponding communication port.
- c) If the RFC-INTF interface is found, but the system bus power is off or no other modules are connected, the following error is displayed.



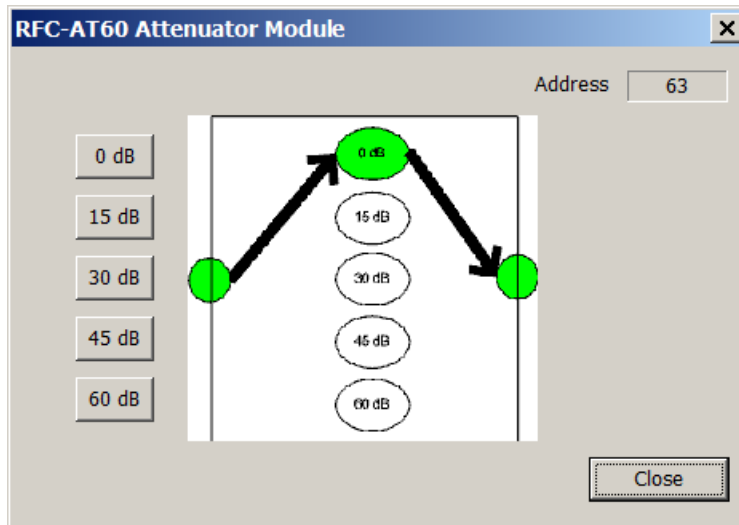
- d) Clicking OK to the error messages should let you view the main screen:



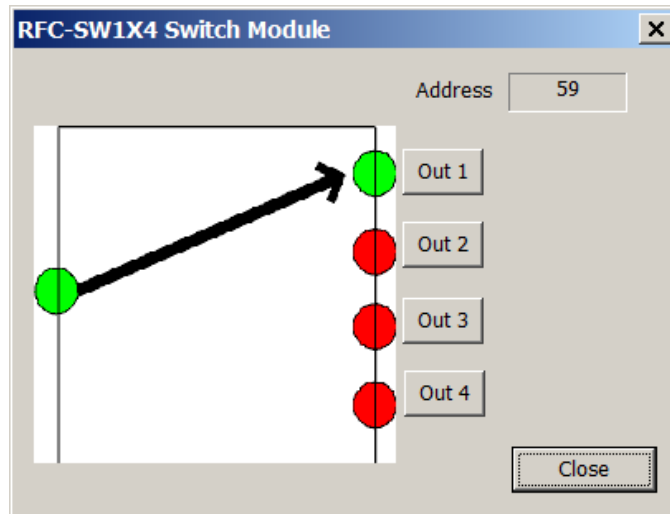
- e) This screen lets you select a different com port if necessary and lets you turn the bus power on or off. When you turn the bus power on with RF modules connected, the program will find the modules and display a pop-up window for each module. The pop-up

windows will probably lay on top of one another but may be dragged around the screen to be seen.

- 6) The RFC-AT60 will have a pop-up window like the following. You may click on the buttons on the left to select the desired attenuation.



- 7) The RFC-SW1X4 module will have a pop-up like the following. The arrow indicates the selected output port and may be changed by clicking the four buttons.



- 8) If more than one module of the same type is connected, they may be identified by the address displayed in the upper right of the windows.

Trademarks

I²C-bus — logo is a trademark of NXP B.V.
RF Cogs – is a trademark of Applied Instruments

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