User Guide

USB/I²C/SPI/TTL High Isolation Solid State RF Switch Modules

Mini-Circuits®

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Chapter 1 – General Information

1.1 *Scope of the User Guide*

This user guide provides general introduction, installation instructions and operating information for Mini-Circuits USB high isolation (H-series) solid state switch modules. For information on Mini-Circuits USB/Ethernet mechanical switches please see:
https://www.minicircuits.com/app/AN49-002.pdf
For information on USB-SP4T-63 solid state switch see:
https://www.minicircuits.com/app/AN49-009.pdf

1.2 *Warranty*

See Mini-Circuits website http://www.minicircuits.com/support/ordering.html for warranty information.

1.3 *Definitions*

Note: A note advises on important information you may need to ensure proper operation of the equipment. There is no risk to either the equipment or the user.

CAUTION **A caution advises about a condition or procedure which can cause damage to the equipment (no danger to users).**

WARNING **A warning alerts to a possible risk to the user and steps to avoid it. DO NOT proceed until you are sure you understand the warning.**

1.4 *General safety precautions*

Please observe the following safety precautions at all times when using Mini-Circuits USB RF switch modules.

WARNING **Ensure that all instruments using mains power supply are properly grounded to prevent risk of electrical shock.**

CAUTION

1. **Do not attempt to switch signals of greater power than the switch is rated for in its datasheet.**
2. **Safe power input degrades below specified frequency range. Do not input signals below the specified frequency range.**

1.5 *Introduction*

Mini-Circuits has developed a new series of solid state USB RF switch modules in rugged, low profile cases. Switches covering DC to 8GHz with up to 4 switches in a unit of various types from SPDT to SP16T are available. Despite being solid state switches with the high speed and reliability expected from such switches Mini-Circuits' USB solid state switch modules also provide very high isolation (80 - 110 dB depending on model) and can handle up to 4 W power terminated internally.
The switches can be controlled via the supplied GUI, or most common lab test software using supplied DLLs. Mini-Circuits even provides the command codes for direct control (See programming guide for details) and also have additional control methods from direct parallel control at TTL voltage to SPI allowing many units to be connected in a daisy chain.

1.6 *Service and Calibration*

The solid state switch modules do not require any periodic service or calibration. The only user service possible for the switch is external cleaning of the case and connectors as needed. Do not use any detergents or spray cleaning solutions to clean the switch. To clean the connectors use an alcohol solution, and to clean the case a soft, damp cloth.

1.7 *Contact Information*

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For regional offices and tech support see http://www.minicircuits.com/contact/offices.html

1.8 *Technical description*

1.8.1 **Features of Mini-Circuits Switch modules**

- Absorptive solid state switch
- Wide band frequency range (model dependant).
- High speed switching
- Electronic switching; high isolation; high reliability, life not related to switching cycles.
- High power handling (model dependent)
- All RF ports SMA(F)
- Programmable, timed switching sequence
- Easy GUI installation and operation, simplifies complex switching and timing setups
- USB HID ”plug & play” device
- ActiveX com object and .Net class library for use with other software: C++, C#, CVI®, Delphi®, LabVIEW® 8 or newer, MATLAB® 7 or newer, Python, Agilent VEE®, Visual Basic®, Visual Studio® 6 or newer, and more(see programming manual and application note AN-49-001 for details)
- User friendly Graphical User Interface for any Windows® 32 or 64 bit computer command line support for Linux® computers
- All power via USB

For Additional details, performance data and graphs, outline drawing, ordering information and environmental specifications, see our catalog at:
https://www.minicircuits.com/WebStore/PortableTestEquipment.html

1.8.2 **Model Selection Guide**

Model Name	Frequency Range (MHz)	Switch Type	Number of switches in module	Max Input Power (W)	Control Protocols
U2C-1SP2T-63VH	10 - 6000	SPDT	1	2	USB, SPI & I^2C
USB-2SP2T-DCH	DC* - 8000	SPDT	2	3.15	USB
USB-4SP2T-63H	1 - 6000	SPDT	4	1	USB
U2C-1SP4T-63H	1 - 6000	SP4T	1	1	USB & I^2C
USB-2SP4T-63H	1 - 6000	SP4T	2	1	USB
USB-1SP8T-63H	1 - 6000	SP8T	1	1	USB
USB-1SP16T-83H	1 - 8000	SP16T	1	1	USB & TTL(parallel)

* True DC, passes DC current up to 60mA.

1.8.3 **Intended Applications**

Mini-Circuits solid state high isolation switches are intended for indoor use in:
- Lab and test equipment setups for both manual and automated measurements
- Control systems
- Automated switching of signal paths in a complex system

The models can be used by anyone familiar with the basics of electronics measurements or electronic control systems.

1.8.4 **Conformity**

Mini-Circuits USB solid state switches conform to all requirements for the following international standards**:**

RoHS – The model complies with EU directive for Restriction of Hazardous Substances for 6 substances.

USB 2.0 – The model meets the specifications of the Universal Serial Bus Ver. 2.0 communication standard as described by USB-IF.

USB HID – The model meets the requirements for Universal Serial Bus Human Interface Devices according to USB-IF's Device Class Definition for Human Interface Devices firmware rev. 1.11.

I^2C – Models with U2C prefix also meet requirements for an I^2C slave device as defined in Rev 6 of the I^2C bus specification and user manual.

1.8.5 **Supported Software environments**

Mini-Circuits USB solid state switches have been tested in the following operating systems:
32 bit systems: Windows 10, Windows 8, Windows 7, Windows Vista, Windows XP Windows 98
64 bit systems: Windows 10, Windows 8, Windows 7, Windows Vista, Linux
The switches will work with almost any software environment that supports ActiveX or .Net including: C++, C#, CVI®, Delphi®, LabVIEW® 8 or newer, MATLAB® 7 or newer, Python, Agilent VEE®, Visual Basic®, AutoIT, Visual Studio® 6 or newer, and more

For more information see the Solid State Switch modules Programming Manual and application note AN-49-001 on our website.

1.8.6 **Included Accessories and Options**

The solid state switches are supplied with a 2.6 ft' USB cable, additionally the following accessory options are available:

- Software (Windows GUI program, .net and ActiveX DLL, and codes for direct control in Linux environment) can be downloaded from: https://www.minicircuits.com/softwaredownload/solidstate.html
- 6.6 ft (2m) USB cable
- Control cables for secondary control methods (see model datasheet for details)
- For additional details and ordering information, see: https://www.minicircuits.com/WebStore/PortableTestEquipment.html

Chapter 2 – Installation and Setup

System requirements for the switch are a computer (Pentium II or better) with support for USB HID. To run the GUI program a Windows operating system for either 32 or 64 bits is also required. For secondary control methods (I^2C, SPI, etc) a master unit supporting those control methods may be needed.

2.1 *Software Setup*

If you have had any problems installing the software, we're here to help.
Try following these complete step-by-step instructions. If you still experience problems, give us a call at Mini-Circuits Worldwide Technical support. It's (718) 934-4500 or e-mail apps@minicircuits.com for North America, or go to minicircuits.com/contact/worldwide_tech_support.html for other regional numbers and addresses.

2.1.1 ***First*** save all work in progress and close any other programs that may be running.

2.1.2 ***Next,*** Insert the *Mini-Circuits* CD into the CD-ROM drive, or download the full CD software from minicircuits.com. If installing from files downloaded from the web - unzip the downloaded files to a temporary folder on your desktop or C: drive, then open the file folder you created and double-click the "Install" icon.

2.1.3 ***If installation from the CD does not start automatically, run install.exe*** from the <CD drive> root directory.

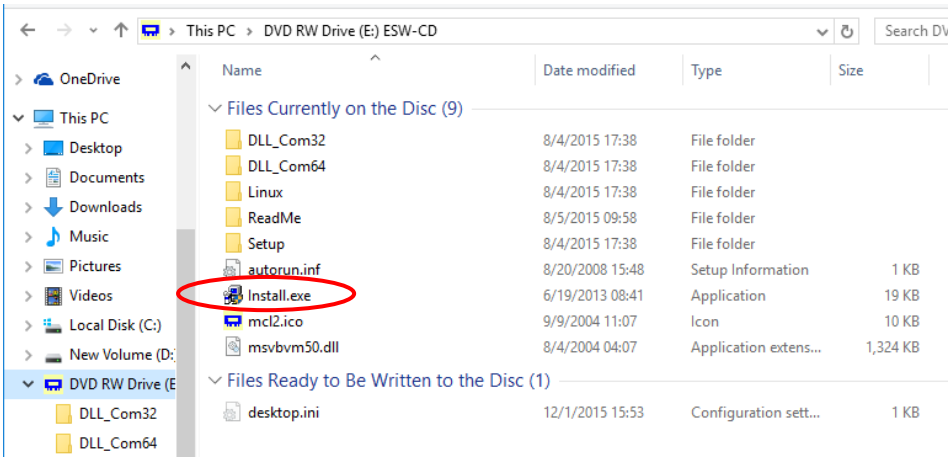

Figure 2.1.3 *CD file listing window*

2.2 *Installation*

2.2.1 ***The installer window*** should now appear. Click the “Install Now” button.

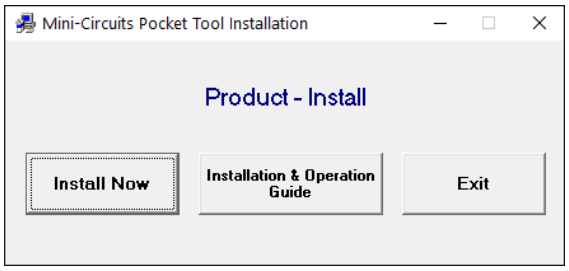

Figure 2.2.1 *Installation window*

2.2.2 ***The license agreement*** should now appear. To proceed, click “I Agree” and the “Continue” button.

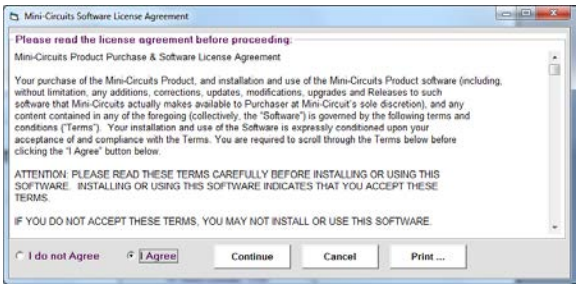

Figure 2.2.2 *License agreement*

2.2.3 ***The installation program will launch***. Click the “OK” button to continue.

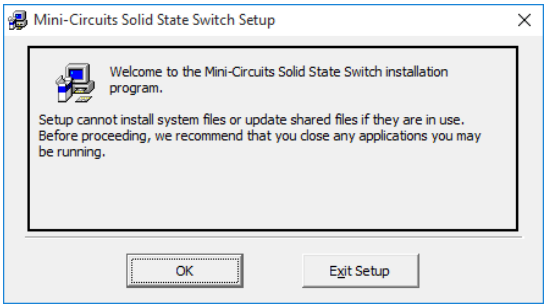

Figure 2.2.3 *Installation Program window*

2.2.4 ***The destination directory window*** will appear. At this point it's a good idea to take a second and confirm the full destination address for the software. In most cases, the default will be your computer's hard drive (C:)\Program Files (x86)\Mini-Circuits Solid State Switch\. Or Change it then click the large button at the top to continue.

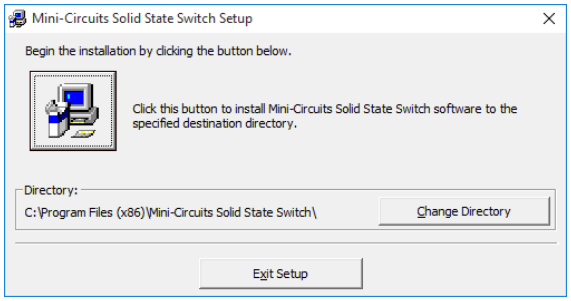

Figure 2.2.4: *Destination Directory window*

2.2.5 ***The Program Group window*** will appear. This window allows you to select the program group under which the link for the switch controller program in the Start Menu will be created. If you change the Program Group for this software, be sure to record that information together with your destination address. Click on "Continue" to proceed.

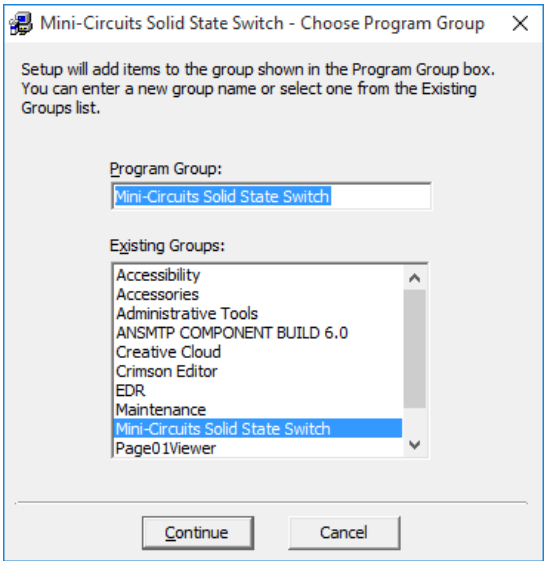

Figure 2.2.5: *Program Group Window*

2.2.6 ***In a second or two, your installation will be complete.*** Click "OK" to close the installer.

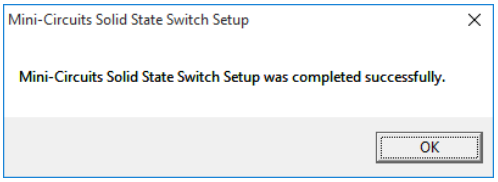

Figure 2.2.6: *Installation complete*

2.3 *Switch control and power Setup*

2.3.1 *USB Control*

2.3.1.1 *Set up instructions*

Connect the switch to the computer using the provided MUSB-CBL-3+ USB cable or equivalent, and then connect the required RF connections.

CAUTION **Note the maximum rating power input in the datasheet and the conditions specified for it. Exceeding these values may damage the switch.**

2.3.1.2 *USB communication*

USB communication for all H-Series is available

- via provided GUI
- via provided dll files for ActiveX and .Net (see programming manual for details)
- direct access as described in programming manual.

2.3.2 *I^2C Control (for U2C models)*

2.3.2.1 *Set up instructions*

- Connect the address lines in the control cable (varies by model, see model datasheet for details) you wish to set to '0' to GND, address bits which are to be '1' can be left unconnected – this will set the unit's I^2C address.
- Connect the control cable to the I^2C master device.
- Power to the switch when controlled via I^2C can be provided either via the I^2C port (see model datasheet for details) or via USB port to either a USB device or a power adaptor such as USB-AC/DC-5+.

2.3.2.2 *I^2C communication (U2C models)*

The I^2C is a short-range synchronous communication protocol for simple 2-wire communication with slave devices using clock (SCL) and data (SDA) connections. The U2C models interface also include 3 address pins (A0, A1 and A2), allowing up to 8 switches to be controlled independently from a single master with shared SDA and SCL connections.

All I^2C pins are connected to an internal pullup resistor so will float to logic '1' when disconnected. This sets a default address of 111 for all units (decimal 7). Addresses from 0 to 7 can be set by externally grounding the relevant address pins (A0, A1 and A2).

The I^2C functionality is limited to setting or reading switch states. Control sequences are sent to the switch in several bytes on the data connection, enclosed by a start and stop signal, and clocked at up to 400 kHz. The switch will acknowledge each byte received with a single "ACK" bit (logic 1) on the same data connection.

To send a command to the switch 3 bytes will be sent:

1. Control byte (**1010**$A_2A_1A_0$**R/W**)
   Where:
   1010 = Control code for U2C models
   $A_2A_1A_0$ = 3-bit address for the switch module
   R/W = Read / write select bit ('0' to write or '1' to read)
   Example:
   Control byte = **1010**1000
   Address = **100** (binary) = 4 (decimal)
   R/W = **0** (write to switch)
2. Switch selector byte - Currently all U2C models contain only a single switch so this byte is always 00000001.
3. Switch state byte (00000XYZ) - The switch state, represented by a binary string according to the individual model's truth table in the model datasheet.

2.3.3 *SPI Control (U2C-1SP2T-63VH only)*

2.3.3.1 *Set up instructions*

- Connect in series all the units you wish to control in SPI daisy chain (maximum 30 units)
- Connect the first unit to a suitable controller and 24V power supply such as USB-I/O-4D2R.

CAUTION **Be careful not to connect the 24V power to I^2C port, this could damage the unit.**

2.3.3.2 *SPI communication*

The serial interface is a 2-bit serial in, parallel-out shift register buffered by a transparent latch.
It is controlled by three-wire SPI protocol using Data, Clock, and Latch Enable (LE) and an additional Lock for added noise immunity and increased flexibility in controlling the units. All signal voltages are compatible with TTL and LVTTL. The Data and Clock inputs allow data to be serially entered into the shift register, a process that is independent of the state of the LE input. The dual input and output SPI ports allow up to 30 units to be connected in a "Daisy Chain" configuration, all controlled by a single controller.

The LE input controls the latch. When LE is HIGH, the latch is transparent and the contents of the serial shift register control the switch. When LE is brought LOW, data in the shift register is latched.

Lock is used to lock the current state of the switch regardless of LE state or shift register, while allowing the LE to pass to other switches in the chain. If Lock is at logic HIGH the switch will respond to LE normally, when Lock is at logic LOW the switch will not respond to LE. If Lock is not required it can be kept constantly at logic high.

The shift register should be loaded while LE is held LOW to prevent the switch state from changing as data is entered. If multiple units are connected in series, data for all units should be entered before raising the LE to prevent switches assuming unanticipated states. Thus for example if three units are connected in daisy chain all 6 bits of control should be entered before raising the LE.

The LE input should then be toggled HIGH and brought LOW again, latching the new data. The timing for this operation is defined in the model datasheet

2.3.4 *TTL Control (USB-1SP16T-83H only)*

2.3.4.1 *Set up instructions*

- Connect the control lines (5 bits) to a suitable I/O controller.
- Connect 5V power either using a power adaptor such as USB-AC/DC-5+ connected to the USB port, or supplying power to pin 1 of the D sub connector.

Note: The USB-1SP16T-83H will start up in disconnected state and assume any state defined by the TTL controls as long as there is no USB communication. Once USB communication is established commands via TTL will be disregarded until unit is shut down.

2.3.4.2 *TTL communication*

The USB-1SP16T-83H TTL control interface consists of 5 unlatched parallel control bits that select the desired switch state, see model datasheet for truth table. The parallel control does not have any latch and thus will respond immediately to any change.

Connecting the switch to USB control and establishing USB communication will disable the TTL control until the switch is reset by disconnecting and then reconnecting power.

All TTL controls are connected with internal pull-down resistors so the default state of the switch is disconnected state.
The TTL interface is input only providing no feedback on switch state.

Chapter 3 – Using Mini-Circuits' GUI

3.1 *USB interface*

Mini-Circuits' Solid State Switch controller GUI allows you to set manually the switch state or run a timed sequence of any configuration you can imagine.

3.1.1 ***Go to the Start menu*** and select All Programs>Mini-Circuits Solid State Switch (default), or go to the other destination address you selected earlier. The "Mini-Circuits Solid State Switch" icon should be waiting there for you. Click on it and get started!

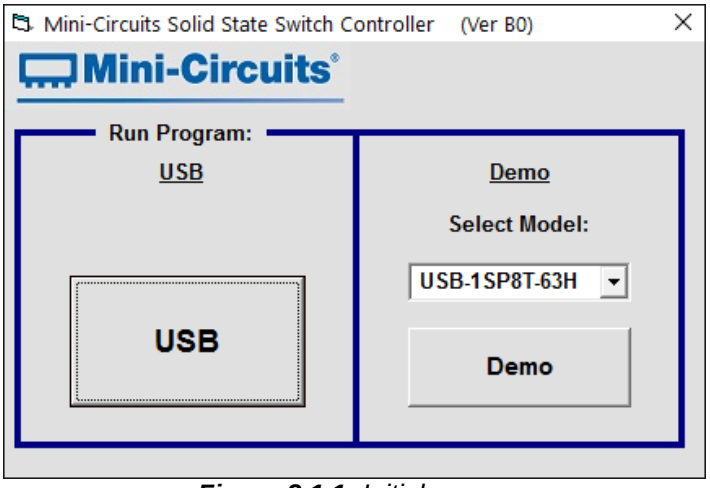

Figure 3.1.1: *Initial screen*

3.1.2 ***To run a demo of*** a solid state switch select the model from the drop down menu and click **DEMO**, otherwise click **USB** to start.

3.1.3 ***If multiple switches are connected*** to the computer, the initial screen will show a list of S/N for connected units. Select the unit you wish to start with and click **OK**, or click **Cancel** to exit the program. The program can handle up to 24 units connected *simultaneously.*

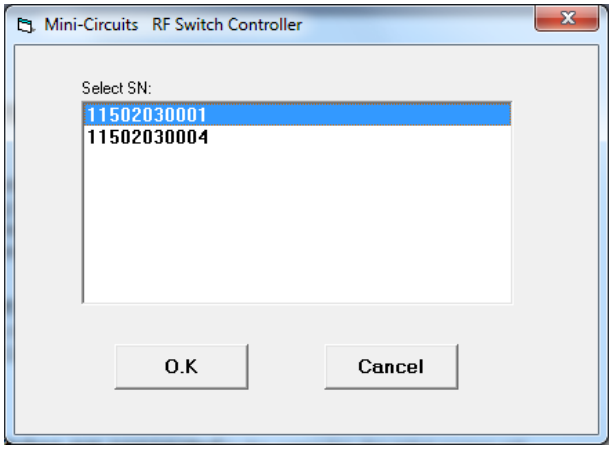

Figure 3.1.3: *Unit selection screen*

3.1.4 ***If no switch modules are connected*** to the computer via USB, or there is a problem with the power or USB connection of the unit an alert will pop up. Click OK, then check the power and USB connections of the unit before trying again.

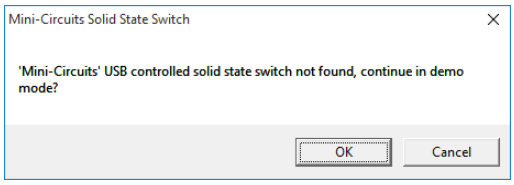

Figure 3.1.4: *No USB Unit found*

3.1.5 ***Once the GUI is started*** you can:

- Click on the switch setting you wish to use
- Use the Sequence mode to set a timed switching sequence (see **section 3.2**)
- Select the (fw) indicator to upgrade the firmware (See **section 3.3**)
- Update the unit address by entering an integer in the 1-255 range in the Address field below the S/N and clicking Set.

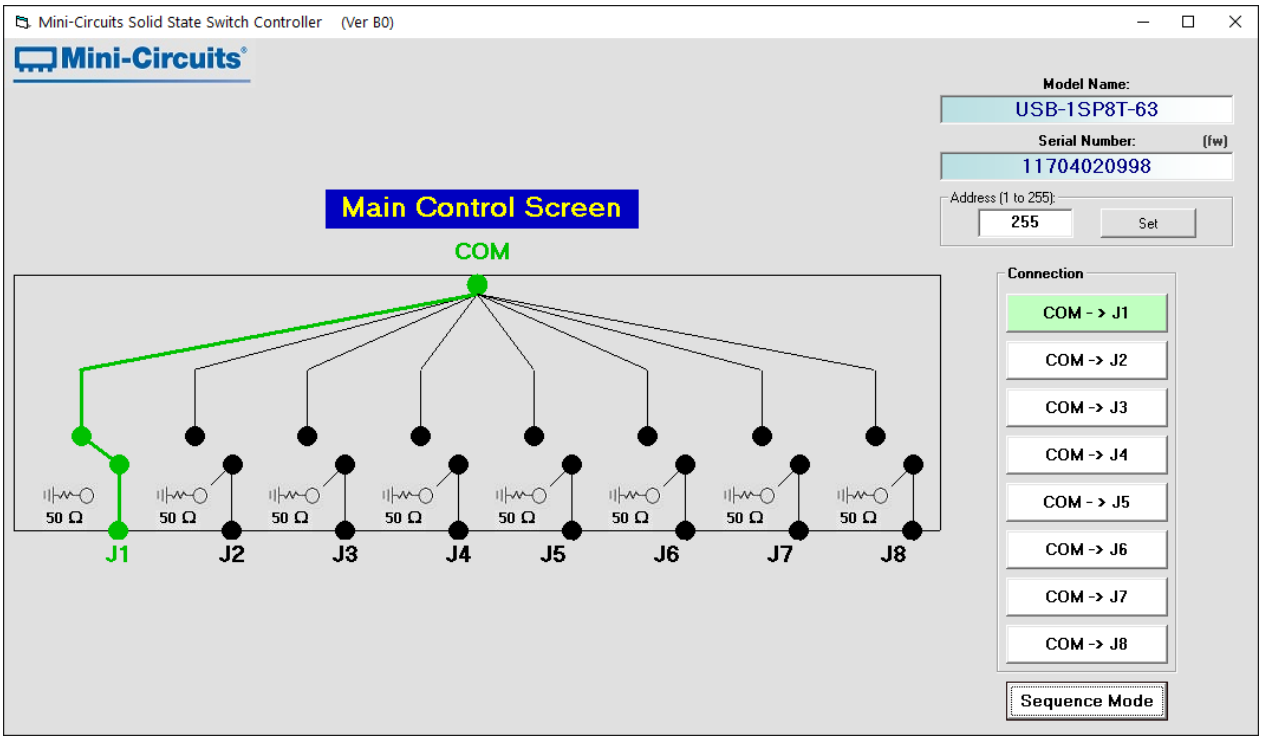

Figure 3.1.5 *Main screen*

3.2 *Sequence Mode*

The GUI supports a “Sequence Mode” which allows the user to program a timed sequence of switch states.

3.2.1 ***After clicking on the Sequence mode button, the*** User sequence window will open.

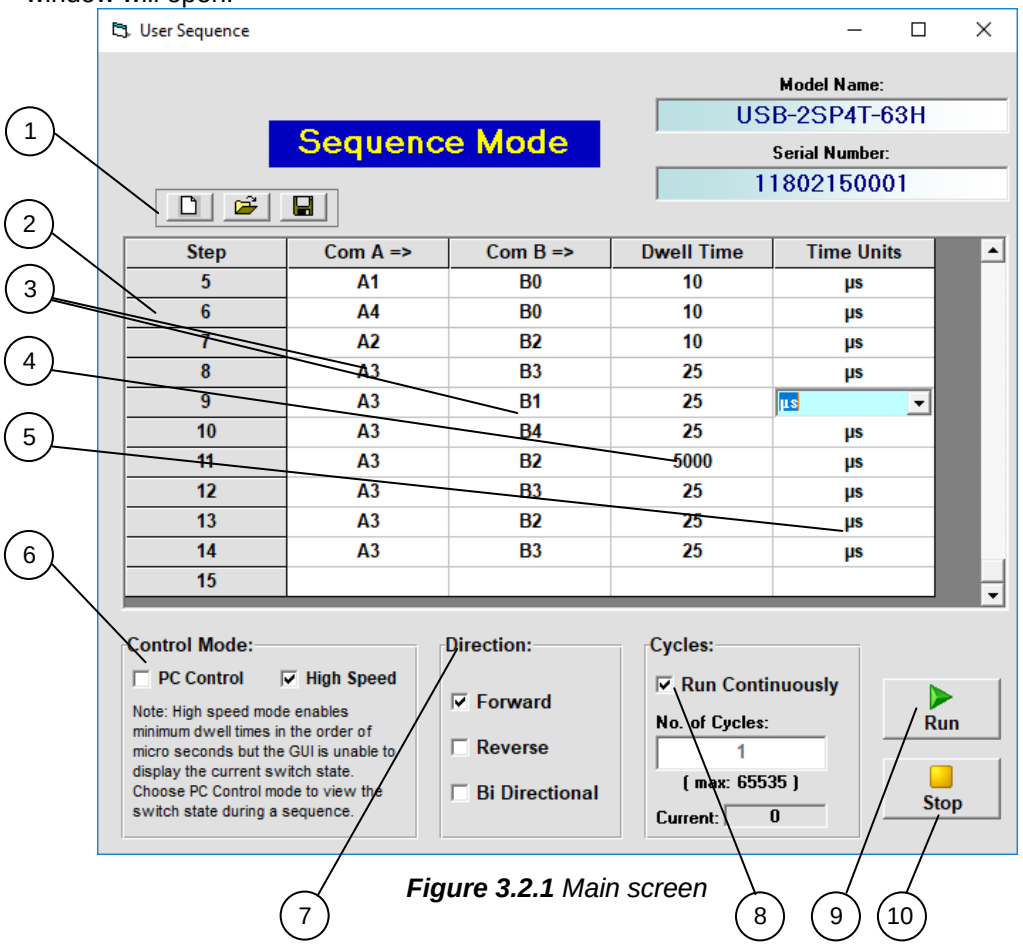

Figure 3.2.1 *Main screen*

3.2.2 ***The user sequence controls are:***

#	Name	Description
1	Icons	Allow clearing a current sequence, opening a previously saved sequence or saving the current sequence.
2	Step	Listing of the step number in the sequence. Up to 100 steps in a sequence are possible.
3	Com =>	The port to which the Com port connects in any given step, one column for each switch in unit. In models with multiple switches all columns need to be filled.
4	Dwell Time	The time the switch will hold at each step (must be an integer value). When operating in high speed mode, note that some models have an additional processing delay of a few microseconds, which should be subtracted from the desired value to get accurate timing. See 3.2.4 for details.
5	Time units	The time units of the dwell time set in each step. The time units can be set independently for each step to seconds, milliseconds or microseconds (in high speed mode).
6	Control mode	Select between PC control (Each command is send individually from the PC and status can be monitored) or High speed mode(the entire sequence is sent in a single block of commands and triggered with an execute command – allows for faster and more precise timing but status cannot be monitored from the PC).
7	Direction	Select direction the sequence will run. Forward is the sequence as shown, reverse will run the sequence from last step to first and bi-directional will run the sequence from first step to last, then from last step to first.
8	Cycles	Number of cycles to run, can be set from 1 to 65535. If “run continuously” is selected the sequence will keep repeating until stopped.
9	Run	Start running the sequence with the current settings.
10	Stop	Stop the switch in the current setting

3.2.3 ***To delete a line click on the relevant*** step number and press ‘delete’. To run only a single step, double click on the number of that step.

3.2.4 ***High speed mode is only available from certain*** firmware revision in each model. See below table of models with the earliest revision that supports high speed mode, and the typical processing delay for each model.

Model Name	Firmware Revision	Processing delay	Typical Switch transition time
U2C-1SP2T-63VH	B9	No processing delay	0.7 µs
USB-2SP2T-DCH	A5	10 µs	10 µs
USB-4SP2T-63H	A5	25 µs	0.2 µs
U2C-1SP4T-63H	B9	No processing delay	0.2 µs
USB-2SP4T-63H	A5	12 µs	5 µs
USB-1SP8T-63H	A5	10 µs	0.2 µs
USB-1SP16T-83H	A5	10 µs	5 µs

3.2.5 *Typical transition speed plots:*

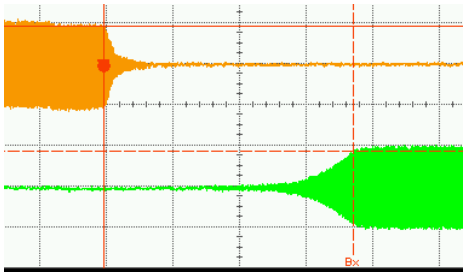

Figure 3.2.5a: Typ. Switching time for U2C-1SP2T-63VH with dwell time 5 µs

Ax = 614.308 µs
Bx = 614.683 µs
Δx = 375 ns

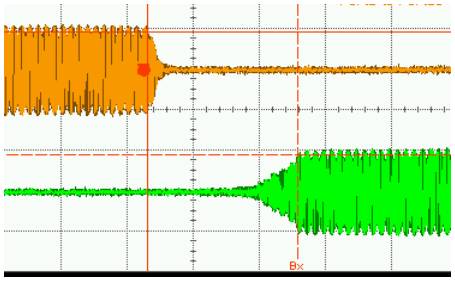

Figure 3.2.5b: Typ. Switching time for USB-1SP16T-83H Port 1-Port 16 with dwell time 15 µs

Ax = 609.676 µs
Bx = 614.221 µs
Δx = 4.545 µs

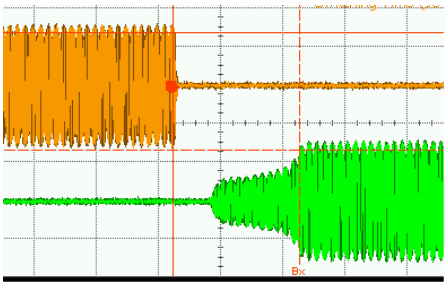

Figure 3.2.5c: Typ. Switching time for USB-2SP4T-63H Port1-Port4 with dwell time 15 µs

Ax = 625.747 µs
Bx = 629.820 µs
Δx = 4.073 µs

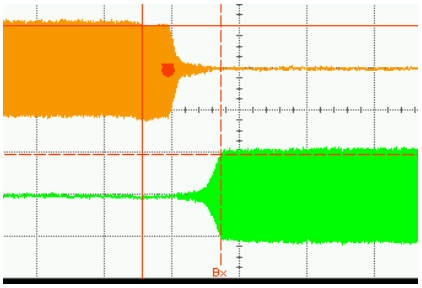

Figure 3.2.5d: Typ. Switching time for U2C-1SP4T-63H Port1-Port4 with dwell time 5 µs

Ax = 628.071 µs
Bx = 628.188 µs
Δx = 116 ns

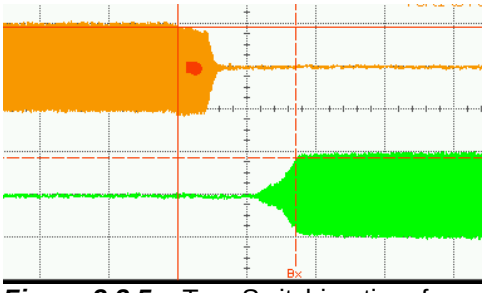

Figure 3.2.5e: Typ. Switching time for USB-1SP8T-63H Port1-Port8 with dwell time 25 µs

Ax = 634.592 µs
Bx = 634.763 µs
Δx = 171 ns

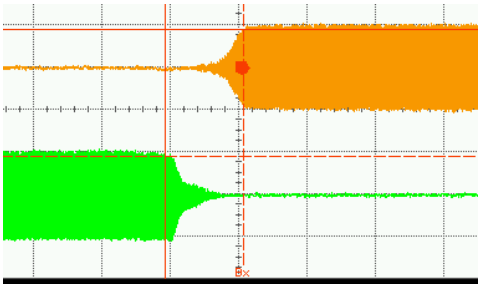

Figure 3.2.5f: Typ. Switching time for USB-1SP8T-63H Port1-Port2 with dwell time 25 µs

Ax = 642.124 µs
Bx = 642.239 µs
Δx = 115 ns

3.3 *Firmware update & recovery*

3.3.1 ***All units are shipped with*** the latest available firmware and an update is usually not required. Mini-Circuits occasionally makes firmware update files available as a courtesy to add additional features or correct known issues. Please contact testsolutions@minicircuits.com for details.

3.3.2 ***Once the switch controller GUI*** *i*s installed and started (see chapter 2) you will note an **(fw)** indicator in the upper right corner of the main screen.

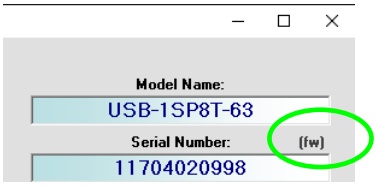

Figure 3.3.2 *Firmware indicator on main screen*

3.3.3 ***In order to update your switch firmware,*** you must have a Windows computer with Mini-Circuits' Switch Controller software installed.

CAUTION

The firmware update process has the potential to render the device inoperable in the event of communication failure. Updates should only be carried out with a stable PC and USB connection, and in-line with Mini-Circuits guidelines.
A recovery option is available to restore units rendered inoperable by an incorrect upgrade process. See section 3.3.8 for details

3.3.4 ***Click on the '(fw)' indicator,*** this will cause the firmware - info window to open (See **Fig. 3.3.4**). The 'Firmware' listed is the version of the firmware installed in your switch matrix. Click on "Update Firmware" to select a new firmware version to install or click 'Exit' to close the firmware – info window.

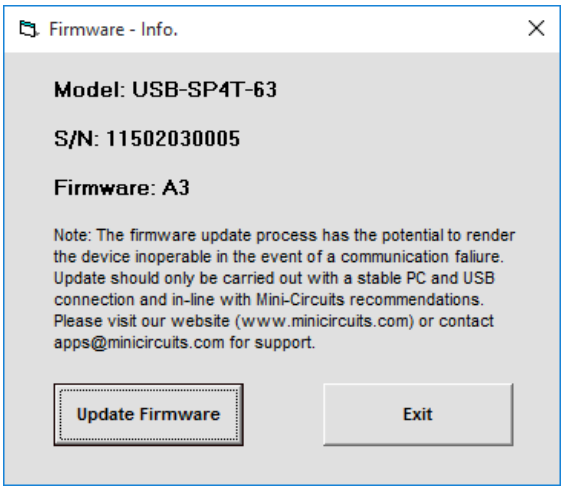

Figure 3.3.4: *Firmware Information Window*

3.3.5 ***A browse window will open to the firmware directory*** under the path you selected when installing the GUI program (See **Fig. 3.3.5**). Navigate to where you saved your firmware file, Select the firmware version you wish to install and click 'O.K'.

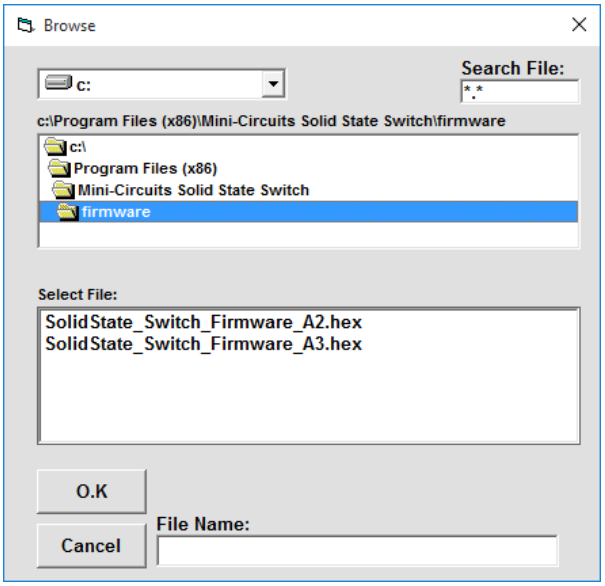

Figure 3.3.5: *Firmware - Browse Window*

3.3.6 ***The selected file will be installed in the switch*** **the process** will take up to a minute.

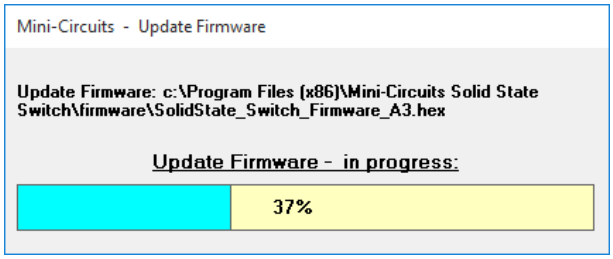

Figure 3.3.6: *Firmware - Progress Bar Window*

CAUTION **Attempting to start a second GUI session while the firmware is being updated may cause the firmware to be corrupted. It is therefore recommended not to attempt to start any additional GUI sessions until after the firmware upgrade has been completed.**

3.3.7 ***After the firmware has updated*** an alert will appear. Click 'OK' to shut down the Switch Controller program and then restart it normally.

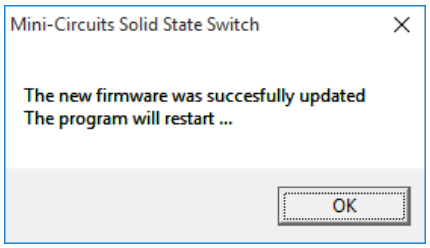

Figure 3.3.7: *Firmware - Successful Update*

3.3.8 ***If the firmware upgrade was interrupted*** this can result in partial installation rendering the device inoperable. When you attempt to connect a unit with damaged firmware an alert (See **Fig *3.3.8)*** will appear. Click 'Yes' to restart the firmware upgrade and repeat the attempt to install the firmware, or 'No' to cancel.

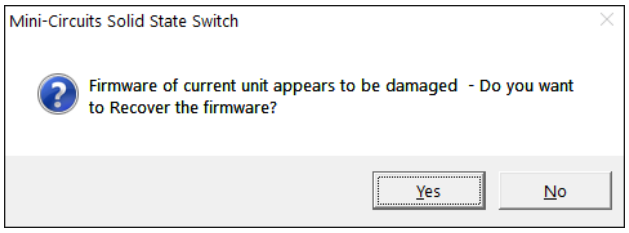

Figure 3.3.8 *Firmware recovery notice*

Chapter 4 – Revision history

August 31, 2017: Created user guide Rev OR.

June 05, 2018: Added USB-1SP16T-83H, U2C-1SP4T-63H, U2C-1SP2T-63VH. Added I^2C, SPI & TTL control methods.

January 10, 2019: Added USB-2SP4T-63H. Added description high speed switching mode and plots of switching time for various models.