



 **Mini-Circuits**[®]

ISC-2425-25+ Industrial System Controller Quick Start Guide

AN-50-001

www.minicircuits.com



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1. Introduction

The ISC-2425-25+ Industrial System Controller and Small Signal Generator board is a powerful device with many capabilities.

This document guides the user through the recommended steps to get a quick start with generating the output signals for an RF energy application.

First, the hardware setup will be explained, then the software setup and interactions will be covered for both a graphical user interface (GUI) and for a text-based serial terminal interface directly to the application programming interface (API) of the controller.

Note: The commands used in this manual will not be explained in detail. This information can be found in the “command set manual” available for download here:

www.xxxx.com/comand_set_manual_ISC-2425-25+

2. Quick Start (GUI)

The following instructions will enable the user to exercise a quick start with the ISC-2425-25+ signal generator and system control board.

The following load scenario will be used:

- The RF signal generator and power amplifier (the ISC-2425-25+ and the ZHL-2425-250X+, respectively) are connected to a suitable microwave cavity. (Note: there are many other applicator examples that could be used e.g., plasma sources etc.)
- The load inside the cavity is a material that needs to be processed with microwave energy.
- A Windows or Linux PC is used to communicate with the ISC-2425-25+ board through the Mini-Circuits GUI. The goal is to heat the chosen material, which presents a challenging load situation to the genertorsystem.

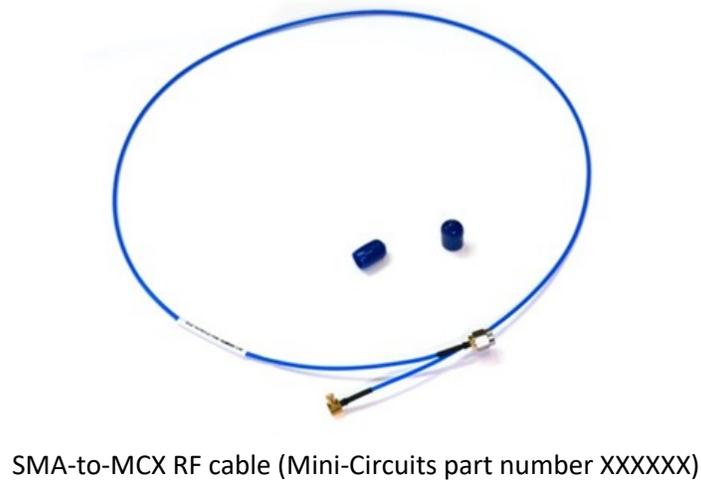
2.1 Step 1 – Assemble the hardware

The ISC-2425-25+ controller is delivered in a box with the following accessories:

- USB A – USB mini 1m cable
- I2C bus cable (Molex to Molex) assembly
- DC power supply connector



The ZHL-2425-250X+ power amplifier is connected to the ISC-2425-25+ with an SMA-to-MCX RF cable (Mini-Circuits part number XXXXXX, to be defined).



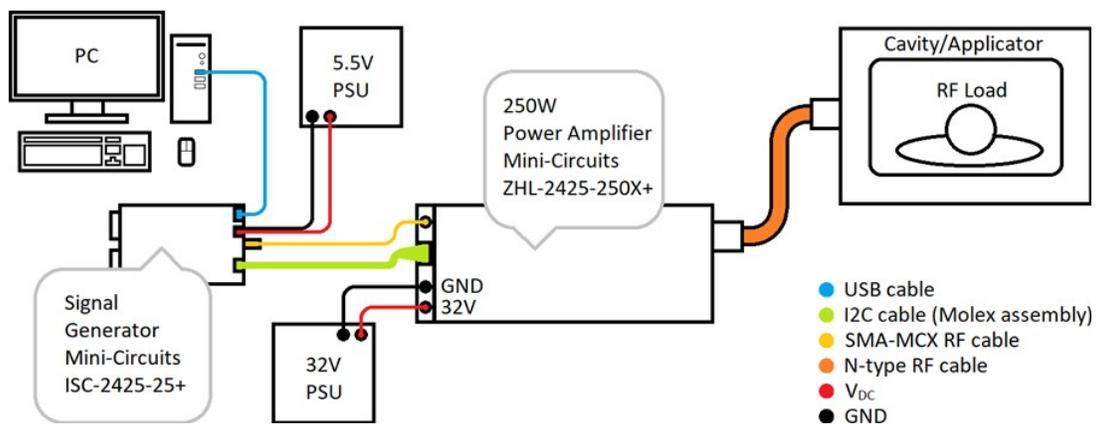
In addition to the ISC-2425-25+ controller and ZHL-2425-250X+ amplifier, the following components are needed:

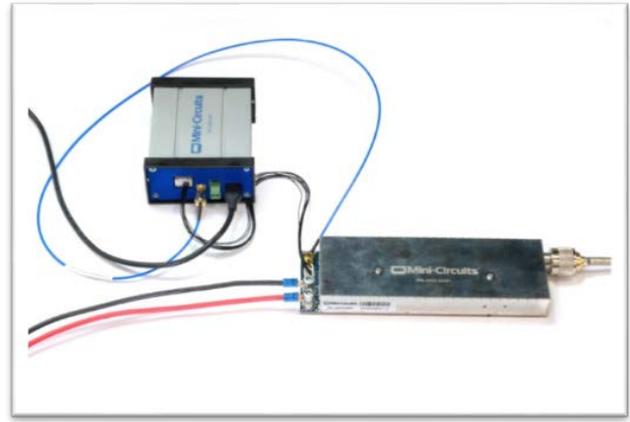
- A power supply for the ZHL-2425-250X+ power amplifier 32V, 16Amp for the power amplifier;
- Note: a power supply for the ISC-2425-25+ is optional since it is by default powered by USB. (for RF out-put power values up to 23dBm)
For applications where the full RF output power (25dBm) of the ISC-2425-25+ is needed, a dedicated 5.5V supply is required. (5.5V, 1 Amp);
- An appropriate microwave cavity with the chosen material as the load
- Additional Cables Required:
DC supply cable (32V, 16A, wire diameter $\geq 2.5\text{mm}^2$ or $\leq 14\text{AWG}$) to connect the main power supply to the amplifier. These are connected to the ZHL-2425-250X+ using Mating M5 screw (Mcmaster P/N92095A308), Belleville washer (Mcmaster P/N 90895A027), Ring Terminal (Mcmaster P/N7113K29), please refer to the ZHL-2425-250X+ datasheet.

N-type male (on amplifier side) RF cable to microwave cavity connection

- Software:
- Mini-Circuits GUI:
Developed for integration with touch displays and with a PC and mouse. Available for download on Windows & Linux here: [Download link pending]

With the cables and other hardware ready, it is straightforward to connect it all together. See the diagram and photograph below:





2.2 Step 2 – Set up and run software

Download the software first (see above link).

Windows:

1. Simply unzip/extract the files to the desired destination folder.
2. In the extracted folder find the executable 'Toolkit_GUI' and double-click it to start the program.

Qt5PrintSupport.dll	24/01/2020 12:49	Application exten...	349 KB
Qt5SerialPort.dll	24/01/2020 13:06	Application exten...	90 KB
Qt5Svg.dll	24/01/2020 13:07	Application exten...	363 KB
Qt5Widgets.dll	24/01/2020 12:49	Application exten...	6,192 KB
theme.css	29/06/2021 10:35	CSS File	23 KB
Toolkit_GUI.exe	30/06/2021 08:06	Application	1,486 KB

Windows Defender may prevent the application from running. To grant permission to run the application do the following:
 a. Press "More Info".



- b. Press the "Run anyway" button that appears at the bottom.

Linux:

1. Simply unzip/extract the files to the desired destination folder on the Linux system.
2. Open a terminal (CTRL + ALT + T) and install the necessary dependencies.
 - Input the following lines:

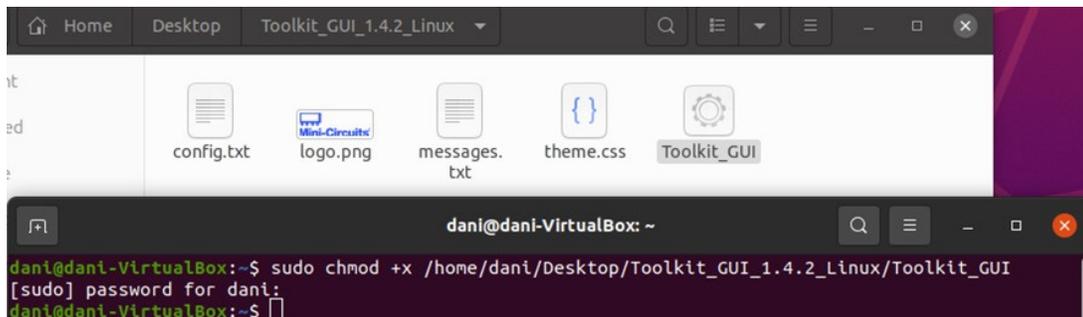

```
sudo apt-get update
sudo apt-get install qt5-default libqt5serialport5 libqt5serialbus5
```
 - **Note:** This step requires internet access.
 - **Note:** Linux may request permission to do these actions. Provide 'Y' to approve.
 - **Note:** Some Linux distributions may use a different packet manager than 'apt-get'.

```
dani@dani-VirtualBox: ~  
dani@dani-VirtualBox:~$ sudo apt-get update  
[sudo] password for dani:  
Hit:1 http://nl.archive.ubuntu.com/ubuntu focal InRelease  
Hit:2 http://nl.archive.ubuntu.com/ubuntu focal-updates InRelease  
Hit:3 http://nl.archive.ubuntu.com/ubuntu focal-backports InRelease  
Get:4 http://security.ubuntu.com/ubuntu focal-security InRelease [114 kB]  
Get:5 http://security.ubuntu.com/ubuntu focal-security/main amd64 DEP-11 Metadata [27,6 kB]  
Get:6 http://security.ubuntu.com/ubuntu focal-security/universe amd64 DEP-11 Metadata [61,0 kB]  
Get:7 http://security.ubuntu.com/ubuntu focal-security/multiverse amd64 DEP-11 Metadata [2,468 B]  
dani@dani-VirtualBox:~$ sudo apt-get install qt5-default libqt5serialport5 libqt5serialbus  
Reading package lists... Done  
Building dependency tree  
Reading state information... Done  
libqt5serialport5 is already the newest version (5.12.8-0ubuntu1).  
qt5-default is already the newest version (5.12.8+dfsg-0ubuntu1).  
The following packages were automatically installed and are no longer required:  
  chromium-codecs-ffmpeg-extra gstreamer1.0-vaapi libgstreamer-plugins-bad1.0-0 libva-wayland2  
Use 'sudo apt autoremove' to remove them.  
The following NEW packages will be installed:  
  libqt5serialbus  
0 upgraded, 1 newly installed, 0 to remove and 187 not upgraded.  
Need to get 94,6 kB of archives.  
After this operation, 337 kB of additional disk space will be used.  
Do you want to continue? [Y/n] Y
```

3. In the extracted folder locate the file 'Toolkit_GUI'.

In the terminal application use the 'chmod' function to grant run permission to the GUI application:

- `sudo chmod +x /path/to/Toolkit_GUI`



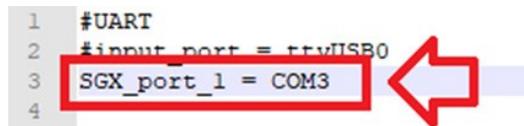
4. Double-click 'Toolkit_GUI' to start the program.

2.3 Step 2.1 – (Optional) Configure communication port

By default, the application should automatically detect the hardware communication port at which the signal generator is plugged in. If for whatever reason the application cannot find the signal generator board, it can be forced to use a specific port by editing the program's configuration file.

1. In the folder where the software was extracted find and open the file 'config.txt'.
2. Inside the config.txt file find the entry 'SGX_port_1' and uncomment it by removing the '#' in front, then provide a valid port name for the signal generator board.

```
1 #UART
2 #input_port = ttyUSB0
3 SGX_port_1 = COM3
4
```



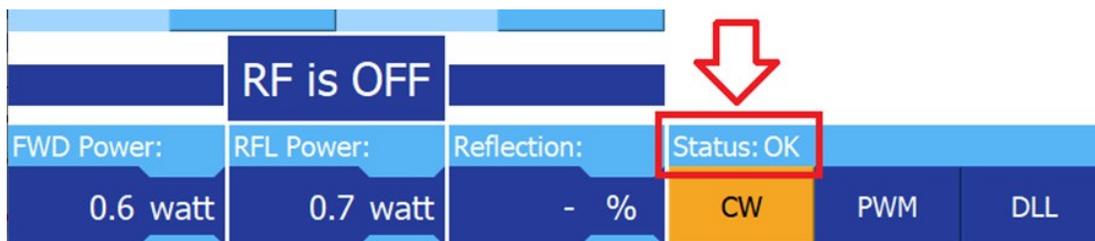
Note: The device's port name can be found using Window's Device Manager or by looking at the Linux' / dev/ directory. For detailed instructions see Chapter 3.2 Step 2 – Set up communication.

Automatic port detection can be re-enabled again by commenting out the line with a '#'.

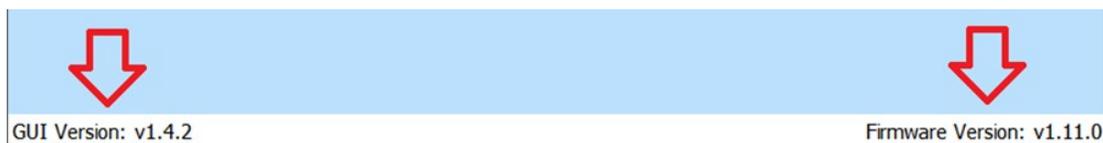
2.4 Step 3 – Check system status

Before continuing to the RF application activity, take a moment to become familiarized with some of GUI's features.

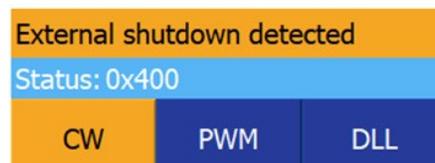
- In the 'Home' menu take a look at the status bar in the lower right area of the GUI to see if there are any errors.



- In the 'Settings' menu take a look at the bottom row to see the version of the signal generator board's firmware as well as the version of the GUI software.



In this case the firmware version on the ISC-2425-25+ is v1.11.0 and there are no pending errors. If there were an error, it would be displayed on the GUI like so:



The GUI automatically attempts to clear errors. If any errors persist, that means there is an ongoing problem with the setup that must be resolved before continuing.

2.5 Step 4 – Find the best frequency for RF energy delivery

Now you have the GUI installed you will want to run your first application. During an RF heating process, the user wants to make sure that the available RF energy is used optimally to heat up the load (the chosen material). In a typical application, this is not a trivial thing to do: The frequency where energy is effectively transferred into the load is called the “match” and needs to be determined. A good match means most of the RF energy is absorbed by the load, whereas a bad match means a large portion of the energy is reflected back into the RF generator system.

A match can be expressed in different ways depending on the units used to measure RF power. When measuring the power using dBm, the match is expressed as ‘S11’:

$$S11 = (P_{RFL} - P_{FWD})$$

Here, S11 is expressed in dB, and the powers PFWD and PRFL are expressed in dBm.

A lower value of S11, the better. For example, a value of about -13dB would indicate that more than 95% of the forward RF power is used in the cavity.

When measuring the power using watts the match is expressed as “Reflection”:

$$Reflection = (P_{RFL} / P_{FWD})$$

The reflection has a value typically between 0 and 1, and is expressed as a percentage (%); The powers PFWD and PRFL are expressed in watt. The closer the reflection is to 0%, the better.

The GUI displays forward power, reflected power and reflection (%) or S11 (dB) in the lower left corner. Switching units (watt <-> dBm) is done by clicking the ‘unit’ button of any of the three displayed parameters:



Though this information is very useful, it alone is not sufficient to properly optimize the process. To find out the frequency at which to heat (i.e., the match), a frequency sweep should be performed to assess the S11 parameter across a pre-defined frequency band. This is done by briefly using low RF power and determining the S11 parameter at various frequencies over a given frequency range. The resulting data can be formatted into a graph that provides insight into the possible match within the tested frequency range. See figure 1 below.

In the example graph below, a 'minimum' S11 point can be seen around the 2450MHz range, this is the frequency where the reflection is closest to 0 and the RF energy delivery into the load/process would be the most efficient.

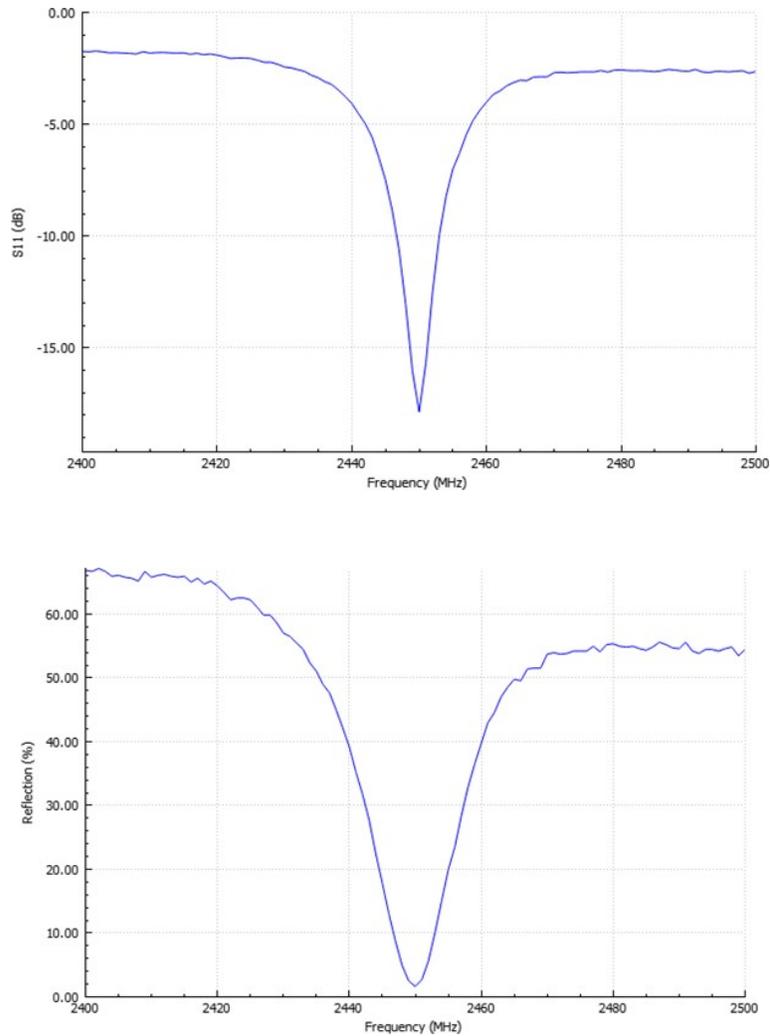


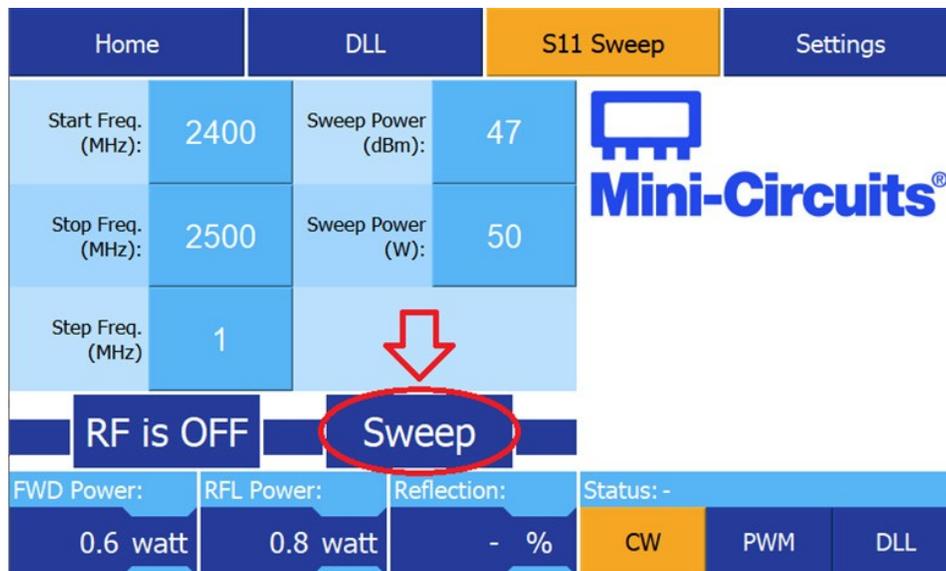
Figure 1: S11 (dB) vs frequency & Reflection (%) vs Frequency

Note: During the execution of a frequency sweep, reflected power will be generated at all mismatched frequencies; it is therefore best to perform the frequency sweep at a lower power than what is intended to be used for the actual heating process to avoid stressing the RF generator. Another reason to use low power is that the user does not want to already process the load during this characterization phase. Typical values of 5-10% of the intended processing power are recommended to be used for the characterization sweep(s).

The ISC-2425-25+ signal generator supports frequencies in the 2400 – 2500 MHz range.

In the example below, an S11 frequency sweep is performed at 50 watts, in the 2400 – 2500 MHz range, with a step size of 1MHz:

- Perform the sweep at 50 watts, in the 2400 – 2500 MHz range, with a step size of 1MHz
 1. Go to the Sweep menu.
 2. Configure the sweep parameters appropriately.
 - a. Press the button for each parameter.
 - b. Provide input values using the numpad that appears on the right side.
 - c. Press 'OK' to confirm inputs.
 3. Press the Sweep button to perform the S11 frequency sweep.



After performing a Sweep, the GUI visualizes the sweep data as a graph (see figure 2 below). The lowest point in the graph represents the best match. In this case that is at 2470MHz, where the reflection amountsto roughly 12%.

Note: To return to previous page of the sweep menu, press the 'back' button in the top left.

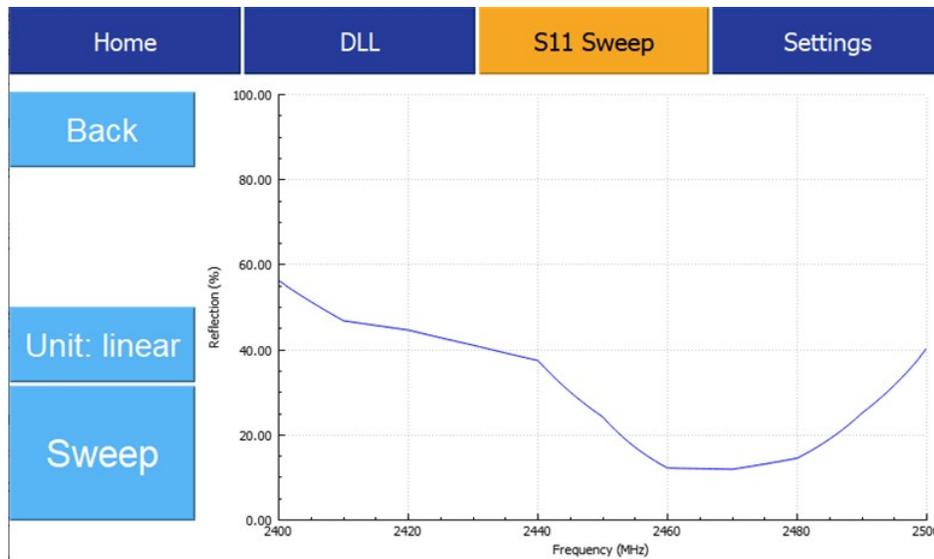
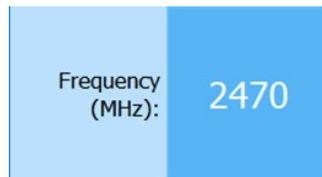


Figure 2: Resulting reflection (%) graph from the sweep just defined

Now that the best match frequency has been found, the frequency of the ISC-2425-25+ board needs to be changed to 2470MHz.

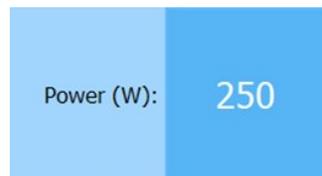
- Go to the home menu and set the frequency to 2470MHz.



2.6 Step 5 – Configure power

For this example, the chosen material will be heated with maximum available power. The Mini-Circuits ZHL-2425-250X+ PA is a 250W model, so 250W output power will be used.

- Set the power to 250W.



2.7 Step 6 – Start heating

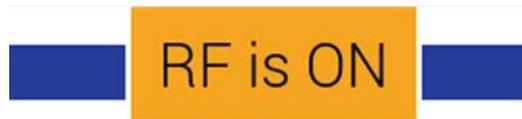
With the right frequency and power configured, the RF output may now be switched on.

Note: Before turning on the RF output, ensure the RF cannot leak from the cavity. Press the RF ON/OFF button to enable RF.

2.8 Step 7 – Use the digital locked loop (DLL) to track the best match frequency real time

With the right frequency and power configured, the RF output may now be switched on.

Note: Before turning on the RF output, ensure the RF cannot leak from the cavity. Press the RF ON/OFF button to enable RF.



The material in the cavity is now being heated at the optimized frequency.

FWD Power:	RFL Power:	Reflection:
250.0 watt	29.9 watt	12 %

The GUI displays a forward power of 250W, a reflected power of 30W and a reflection value of 12%, meaning the material is absorbing some 220W of RF energy. This is in line with the earlier sweep measurement.

2.9 Step 7 – Use the digital locked loop (DLL) to track the best match frequency

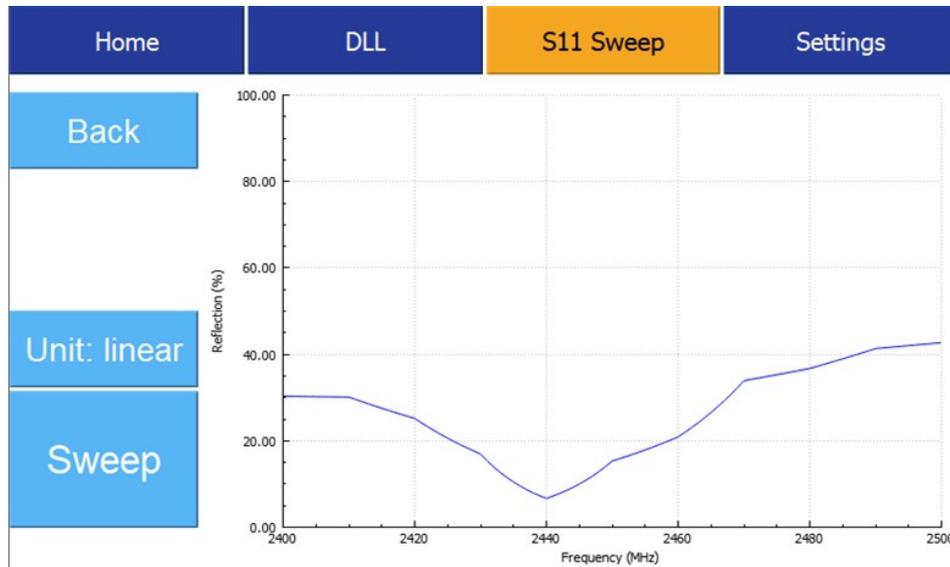
As the material continues to heat, its physical properties may start changing. Changes to the load can affect the quality of the match: the best match frequency will shift to a different value. It is more than likely that after a while the match is no longer optimal, and the load reflects too much energy back into the system. Obviously, this is not a desirable situation.

- To avoid straining the system with a poor match, turn off RF output for the time being.



Conveniently, the ISC-2425-25+ board provides a method that tracks the processing frequency as the match changes over time: this is called the “digital locked loop” (DLL). The next few paragraphs describe the usage of this DLL feature. (see Apps Note: “appsNote DLL”)

- Perform an S11 frequency sweep to determine the starting frequency for the DLL algorithm



The sweep indicates the best match frequency has shifted towards 2440MHz, where the reflection value is a mere 6.6%. Please note that the reflection at the previously configured 2470 MHz has increased to almost 34% in the meantime.

To enable the real time tracking, we will enable the DLL algorithm to do the frequency tracking for us.

- Go to the DLL menu
- Configure the start frequency to 2440 MHz
- Press the DLL enable button in the bottom right corner of the GUI to turn on the DLL.
- Enable RF output.

Home		DLL		S11 Sweep		Settings	
Lower Freq. Limit (MHz):	2400	Power (dBm)	54				
Upper Freq. Limit (MHz):	2500	Power (W)	250				
Start Freq. (MHz)	2440	DLL Delay (ms):	0				
Step Freq. (MHz)	0.1	Threshold (dB):	0				
		RF is ON		DLL Freq. Lock:		2440.1 MHz	
FWD Power:	250.0 watt	RFL Power:	16.5 watt	Reflection:	7 %		
				Status: OK		CW PWM DLL	

The DLL is now enabled and is tracking the optimum S11 frequency as the material heats.

The currently used (locked-) frequency for the DLL can be viewed live on the right side of the GUI in the 'DLL Frequency Lock' bar (or alternatively at the frequency parameter in the home menu).

DLL Freq. Lock: 2440 MHz

Finish:

With the frequency optimized, the chosen material will be processed as per the user requirements. Of course, the exact timing of this process depends on the size of the material and the RF power used and needs to be determined in by the user.

3. Quick Start (Serial Terminal Interface)

The entire process of the quick start will be repeated now, but this time using the terminal emulator program 'PuTTY' instead. The scenario is the same as before (See chapter "2 Quick Start (GUI)") except for the software used.

When using the command language to control the ISC-2425-25+ the user has the option to create and save their own individual recipes to support their specific applications.

3.1 Step 1 – Assemble the hardware

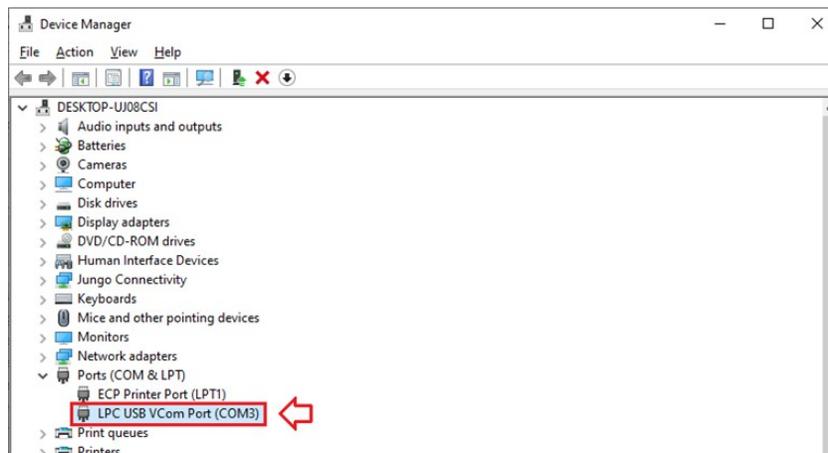
The physical requirements and the assembly of the components are the same as before (See chapter "2.1 Step 1 – Assemble the hardware"), however instead of the Mini-Circuits GUI, the ISC's command set is used to operate the generator. This is achieved by using the terminal emulator program PuTTY.

- PuTTY SSH and telnet client free open-source software
Windows download available here: <https://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html> Linux variants available through the package manager.
- Download example (Debian):
sudo aptitude install putty
Additional information available here: <https://www.ssh.com/academy/ssh/putty/linux>

3.2 Step 2 – Set up communication

1. Plug the ISC-2425-25+ board into the PC using a mini-USB cable.
2. Find the port name of the device

- **Windows:**
Open the 'Device Manager' in Windows and find the port name of your device. It will show up as an 'LPC USB VCOM Port', followed by the port name.



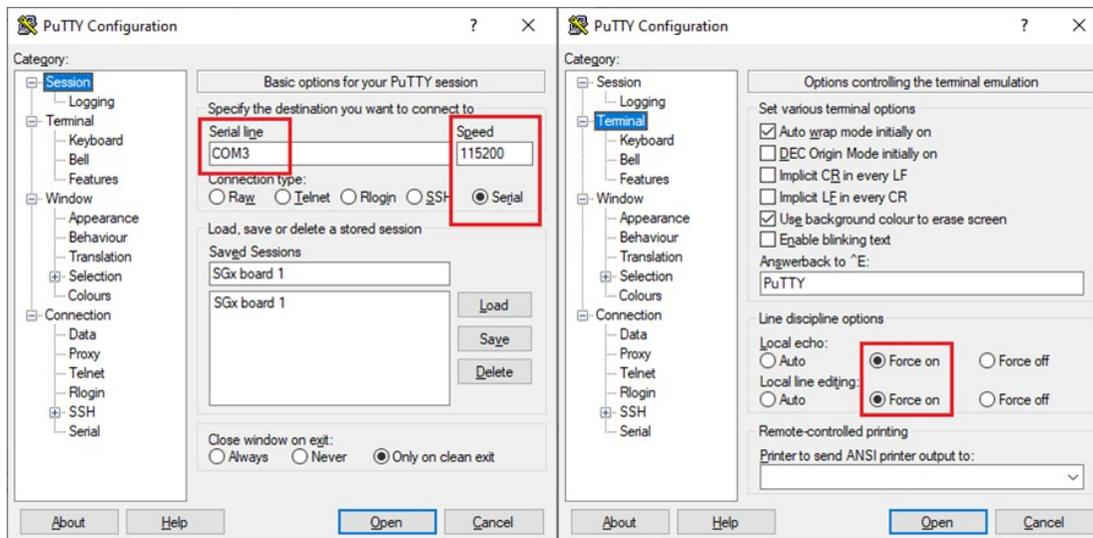
- **Linux:**

Open a terminal (CTRL + ALT + T) and use the “ls /dev” command to view available devices. The signalgenerator board should appear as a ‘ttyACM0’ device followed by a number.

```
pi@raspberrypi:~$ ls /dev
autofs          loop6           ram5            tty21           tty50           vcs3
block           loop7           ram6            tty22           tty51           vcs4
btrfs-control   loop-control    ram7            tty23           tty52           vcs5
bus             mapper          ram8            tty24           tty53           vcs6
cachefiles      mem             ram9            tty25           tty54           vcs7
char            memory_bandwidth random          tty26           tty55           vcsa
console         mmcblk0        raw             tty27           tty56           vcsa1
cpu_dma_latency mmcblk0p1      rfkill          tty28           tty57           vcsa2
cuse            mmcblk0p2      serial          tty29           tty58           vcsa3
disk            mmcblk0p5      serial0         tty3            tty59           vcsa4
fb0             mmcblk0p6      serial1         tty30           tty6            vcsa5
fd              mmcblk0p7      SGX            tty31           tty60           vcsa6
full            mmcblk0p8      shm            tty32           tty61           vcsa7
fuse            mqueue         snd             tty33           tty62           vcsm
gpiochip0       net            stderr          tty34           tty63           vcsm-cma
gpiochip1       network_latency stdin           tty35           tty7            vcsu
gpiochip2       network_throughput stdout          tty36           tty8            vcsu1
gpiomem         null           tty             tty37           tty9            vcsu2
hidraw0         ppp            tty0            tty38           ttyAMA0         vcsu3
hidraw1         ptmx           tty1            tty39           ttyAMA0         vcsu4
hidraw2         pts            tty10          tty4            ttyprintk       vcsu5
```

3. Open PuTTY on your PC and provide the necessary information for the connection with the device. It is highly recommended to configure the settings ‘Local echo’ and ‘Local line editing’ to ‘Force on’.

Note: Linux requires the full path to the port (e.g., “/dev/ttyACM0”).



Save the session, so that it won't need to be reconfigured again in the future and press 'Open' to start a connection with the ISC-2425-25+ board.

A blank terminal window will pop up.

3.3 Step 3 – Check system status

Before applying RF, take a moment to gather some data about the system to verify proper functioning:

- Send the \$VER command to view the firmware version of the ISC-2425-25+ board.
- Send the \$ST command to check if there are any errors.

```
$VER,1
$VER,1,PRF,1,10,4,SVN_REV,Feb 23 2021,14:47:38
$ST,1
$ST,1,0,0
```

In this case, the firmware version is v1.10.4 and there are no errors pending.

If the \$ST command were to return an error value (for example “\$ST,1,0,400”), use the \$ERRC command to reset errors, then send \$ST again to see if the errors did not reappear.

```
$ST,1
$ST,1,0,400
$ERRC,1
$ERRC,1,OK
$ST,1
$ST,1,0,0
```

If any errors persist, that means there is an ongoing problem with the setup that must be resolved before continuing. All error/warning codes are explained in the “Command set manual”.

3.4 Step 4 – Find the best frequency for RF energy delivery

During an RF heating process, the user wants to make sure that the available RF energy is used optimally to heat up the load (the chosen material). The frequency where energy is effectively transferred into the load is called a “match” and needs to be determined. A good match means most of the RF energy is absorbed by the load, whereas a bad match means a large portion of the energy is reflected back into the RF generators system.

To find out the best frequency at which to heat (i.e. a good match), a frequency sweep should be performed to assess the S11 parameter across a pre-defined frequency band.

The ISC-2425-25+ small signal generator supports frequencies in the 2400 – 2500 MHz range.

In the example below, an S11 frequency sweep is performed at 50 watts, in the 2400 – 2500 MHz range, with a step size of 10MHz:

- Use the \$SWP command to perform an S11 frequency sweep in watts.

```
$SWP,1,2400,2500,10,50,0
$SWP,1,2400.00,49.95,28.08
$SWP,1,2410.00,49.96,23.40
$SWP,1,2420.00,49.98,22.32
$SWP,1,2430.00,49.97,20.54
$SWP,1,2440.00,50.01,18.75
$SWP,1,2450.00,50.00,12.12
$SWP,1,2460.00,50.02,6.11
$SWP,1,2470.00,50.04,5.92
$SWP,1,2480.00,50.03,7.27
$SWP,1,2490.00,50.00,12.56
$SWP,1,2500.00,49.99,20.12
$SWP,1,OK
```

Input

Response

The command (\$SWP,1,2400,2500,10,50,0) returns forward and reflected RF powers in watts at 10MHz intervals, which show that the match is best around 2470MHz. At that frequency the reflection is only around 12% of the forward power ($5.92W / 50.04W = 0.118 \rightarrow 12\%$).

Note: For the sake of this guide, a large step size is used in the sweep to keep the resulting data easy to work with. Under normal circumstances a smaller step size like 1 MHz is recommended as it would yield a better resolution along the frequency axis.

Tip: In general, large loads will generate “broad”, generally well-matched S11 sweeps, whereas small loads will generate a more structured S11 spectrum with only few frequencies allowing efficient energy delivery.

Now that the best match frequency has been found, the frequency of the ISC-2425-25+ board needs to be changed to 2470MHz.

- Use the \$FCS command to set the frequency to 2470MHz.

```
$FCS,1,2470
$FCS,1,OK
```

3.5 Step 5 – Configure power

For this example, the material will be heated with the maximum available power. The Mini-Circuits ZHL-2425-250X+ PA is a 250W model, so 250W output power will be used.

- Use the \$PWRS command to set the power to 250W.

```
$PWRS,1,250
$PWRS,1,OK
```

3.6 Step 6 – Start heating

With the right frequency and power configured, the RF output may now be switched on. **Note:** Before turning on the RF output, ensure the RF cannot leak from the cavity.

- Use the \$ECS command to turn on RF output.

```
$ECS,1,1
$ECS,1,OK
```

The material is now being heated. According to the 12% reflection value calculated in the earlier step, the load is absorbing some 220W of RF energy and reflecting around 30W back into the RF system. This can be monitored on the fly using the \$PPG command:

- Use the \$PPG command to get live power measurements.

```
$PPG,1
$PPG,1,249.89000,29.76000
$PPG,1
$PPG,1,250.02000,29.92000
$PPG,1
$PPG,1,250.10000,30.32000
$PPG,1
$PPG,1,249.79000,29.78000
```

The measurements align with expectations: 250W forward power is emitted, 30W is reflected back, 220W is absorbed by the load.

3.7 Step 7 – Use the digital locked loop to track the best match frequency

As the material continues to heat, its physical properties will start changing. Changes to the load can affect the matching conditions: the best match frequency will shift to a different value. It is more than likely that after a while the match is no longer optimal, and the load reflects too much energy back into the RF generator. Obviously, this is not a desirable situation.

- To avoid straining the system with a poor match, turn off the RF output for the time being.

```
$ECS,1,0
$ECS,1,OK
```

The available DLL tracking algorithm resolves the issue.

- Perform an S11 frequency sweep to determine the starting frequency for the DLL algorithm.

```
$SWP,1,2400,2500,10,50,0
$SWP,1,2400.00,49.88,15.11
$SWP,1,2410.00,49.95,15.04
$SWP,1,2420.00,50.00,12.59
$SWP,1,2430.00,49.99,8.47
$SWP,1,2440.00,49.97,3.32
$SWP,1,2450.00,49.94,7.65
$SWP,1,2460.00,50.01,10.45
$SWP,1,2470.00,49.80,16.88
$SWP,1,2480.00,49.99,18.36
$SWP,1,2490.00,50.00,20.67
$SWP,1,2500.00,49.99,21.35
$SWP,1,OK
```

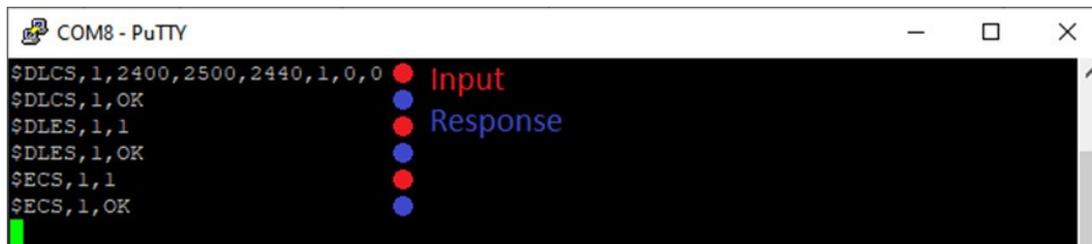
Input

Response

The sweep indicates the best match frequency has shifted towards 2440MHz, where the reflection value is a mere 6.6% ($3.32W / 49.97W = 0.066 \rightarrow 6.6\%$). Please note that the reflection at the previously configured 2470 MHz has increased to almost 34% in the meantime.

Going forward, the DLL algorithm will do the frequency tracking:

- Use the \$DLCS command to configure DLL to start tracking at 2440 MHz (at the best-known match).
- Use the \$DLES command to turn on DLL.
- Use the \$ECS command to turn on RF output again.

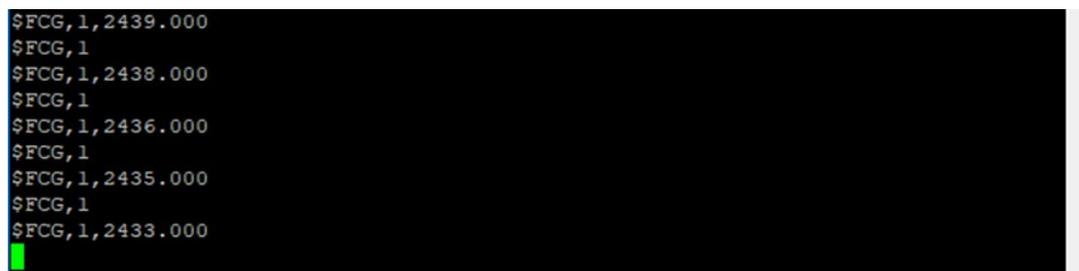


```
COM8 - PuTTY
$DLCS,1,2400,2500,2440,1,0,0
$DLCS,1,OK
$DLES,1,1
$DLES,1,OK
$ECS,1,1
$ECS,1,OK
```

The DLL is now enabled and is tracking the optimum S11 frequency as the material heats.

The momentarily used (locked-) frequency for DLL can be viewed using the frequency get command.

- Use the \$FCG command to view the frequency as it changes over time.



```
$FCG,1,2439.000
$FCG,1
$FCG,1,2438.000
$FCG,1
$FCG,1,2436.000
$FCG,1
$FCG,1,2435.000
$FCG,1
$FCG,1,2433.000
```

This shows the DLL is tracking the match downward in frequency as the best match frequency continues to shift over time.

Finish:

With the frequency optimized, the material will be processed as per the user requirements. Of course, the exact timing of this process depends on the size of the material and the RF power used and needs to be determined by the user.

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