U3851A RF Microwave Circuit Design, Simulation, and Measurement Courseware, 5G NR n3

KEYSIGHT

GETTING STARTED GUIDE

Notices

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CAUTION

A CAUTION notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

WARNING

A WARNING notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Safety Symbols

The following symbols on the instrument and in the documentation indicate precautions which must be taken to maintain safe operation of the instrument.

	Caution, risk of danger (refer to this manual for specific Warning or Caution information)		Caution, hot surface

Safety Considerations

Read the information below before using the instrument.

The following general safety precautions must be observed during all phases of operation, service, and repair of this instrument. Failure to comply with these precautions or with specific warnings elsewhere in this manual violates safety standards for design, manufacture, and intended use of the instrument. Keysight Technologies assumes no liability for the customer's failure to comply with these requirements.

WARNING

To prevent fire or injury:

- Use only the designated AC/DC adapter with the instrument.
- Observe all ratings and markings on the instrument before connecting to the instrument.
- When performing measurements, ensure that the right safety and performance ratings of instrument and accessories are used.

CAUTION

Electrostatic discharge (ESD) can result in damage to the components at the exposed area of the educational kit. To prevent electrostatic discharge (ESD):

- Select a static-free work location when installing and removing sensitive component.
- Handle sensitive components to the minimum extent possible with ESD safe practices.
- Transport and store in ESD preventive bags or containers that protect sensitive components from static electricity.

CAUTION

- If the instrument is used in a manner not specified by the manufacturer, the instrument protection may be impaired.
- Always use a dry cloth to clean the instrument. Do not use ethyl alcohol or any other volatile liquid.

Environmental Conditions

The U3851A is designed for indoor use. The table below shows the general environmental requirements for this instrument.

Environmental condition	Requirement
Temperature	Operating condition – 5 to 50 °C Storage condition – -40 to 70 °C
Humidity	Operating condition – Up to 95% RH at 40°C (non-condensing) Storage condition – Up to 95% RH at 40°C (non-condensing)
Altitude	Up to 2000 m
Pollution Degree	2

Regulatory Information

The U3851A complies with the following Electromagnetic Compatibility (EMC) regulations:

- IEC 61326-1:2012/EN 61326-1:2013
- Australia/New Zealand: AS/NZS CISPR 11:2011
- Canada: ICES/NMB-001: ISSUE 4, June 2006

Regulatory Markings

CE	The CE mark is a registered trademark of the European Community. This CE mark shows that the product complies with all the relevant European Legal Directives.	**ICES/NMB-001**	ICES/NMB-001 indicates that this ISM device complies with the Canadian ICES-001. Cet appareil ISM est conforme a la norme NMB-001 du Canada.
CE ICES/NMB-001 ISM GRP 1-A	The CE mark is a registered trademark of the European Community. This CE mark shows that the product complies with all the relevant European Legal Directives. ICES/NMB-001 indicates thatthis ISM device complies with the Canadian ICES-001. Cet appareil ISM est conforme a la norme NMB-001 du Canada. ISM GRP.1 Class A indicates that this is an Industrial Scientific and Medical Group 1 Class A product.		The RCM mark is a registered trademark of the Spectrum Management Agency of Australia. This signifies compliance with the Australia EMC Frameworkregulations under the terms of the Radio Communication Act of 1992
	This symbol is a South Korean Class A EMC Declaration. This is a Class A instrument suitable for professional use and in electromagnetic environment outside of the home.		This instrument complies with the WEEE Directive (2002/96/EC) marking requirement. This affixed product label indicates that you must not discard this electrical or electronic product in domestic household waste.
40	This symbol indicates the time period during which no hazardous or toxic substance elements are expected to leak or deteriorate during normal use. Forty years is the expected useful life of the product.		

Waste Electrical and Electronic Equipment (WEEE) Directive 2002/ 96/EC

The crossed out wheeled bin symbol indicates that separate collection for waste electric and electronic equipment (WEEE) is required, as obligated by the EU DIRECTIVE and other National legislation.

Please refer to http://keysight.com/go/takeback to understand your Trade in options with Keysight in addition to product takeback instructions.

Sales and Technical Support

To contact Keysight for sales and technical support, refer to the support links on the following Keysight websites:

- www.keysight.com/find/u3851a
  (product-specific information and support, software and documentation updates)
- www.keysight.com/find/assist
  (worldwide contact information for repair and service)

Table of Contents

Overview

RF and microwave engineering covers the physical layer of wireless communication and are incorporated into almost everything that transmits or receives a radio wave, such as mobile phones, radios, and WLAN. The growth of 5G drives rapid innovations in the technology landscape and imposes new requirements on RF components, resulting in design challenges such as increased integration and exponential demands on performance. The increasing complexity brought by 5G means many companies will need additional expertise to execute the technology in the designs of their devices.

Keysight's RF and Microwave Lab Courseware focuses on end-to-end RF system design flow and integrates industry-oriented, real-world examples to prepare students for emerging technology trends. The lab courseware comes with a modular prototype kit utilizing a 1.8 GHz receiver module – a 5G New Radio n3 band – as well as lab sheets and assignments that focus on the complete physical design spectrum, from specifications and simulation to prototype building and validation.

The RF and Microwave Lab Courseware forms a core component of the Keysight RF and Microwave Teaching Solution. In addition to the lab courseware, this comprehensive solution includes Keysight PathWave Advanced Design System (ADS) and SystemVue software, as well as hardware instruments such as a network analyzer, RF signal generator and RF spectrum analyzer.

The RF Microwave Circuit Design, Simulation and Measurement Courseware, 5G NR n3 covers the following:

Courseware Contents

- Modular prototype kit
  - RF education hardware kit
  - Kit controller
  - RF adapters and splitter
  - Cables (RF, power, control, BNC)
  - Power adapter and carry case
- Editable lab sheets and model answers
- Problem-based assignments
- Covers 50 hours of lab sessions

List of Contents in the RF Microwave Kit Hardware

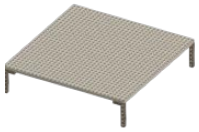
	Item	Quantity
1.	Assembled X-MWprotoplate Kit for Module 1	1
2.	X-MWcontroller RaspberryPi Kit	1
3.	GSG Placement Tool	1
4.	Hex Driver for 1-72 Socket Head Cap Screws	1
5.	Power adapter 13 W Plug In Power Supply 5.1 V, 2.5 A, Micro USB	1
6.	High Performance RF Cable SMA-M to SMA-M 0.9 m	2
7.	Adaptor, N-type to SMA-F	3
8.	Power Splitter SMA 1 GHz to 2.5 GHz	1
9.	SMA-F to SMA-F Thru Coaxial Adapter	1
10.	Carrying Case with Inner Foam	1
11.	Cable Assembly-Coaxial RG58C/U 50-Ohm BNC-Plug BNC-Plug PVC Black	1
12.	Connector-RF SMA Terminator Plug Straight 50-Ohm 18 GHz-MAX	1
13.	SMA-F to SMA-M 50 mm Cable	1
14.	Power Supply Cable from Kit to External Power Supply	1
15.	Cable Assembly-Coaxial RG-58/U 50-Ohm SMA-M BNC-M 1 m-LG	1
16.	LAN Crossover Cable, 2.13 m	1
17.	SMA-M to SMA-M 0.5 m RG316 Cable	2

NOTE

The LAN crossover cable facilitates direct peer-to-peer LAN device connection such as the Raspberry Pi to your computer. A regular “straight through” LAN cable may be adequate for devices that have Auto MDI-X ports that automatically choose the MDI or MDI-X configuration to properly match the other end of the link. The crossover cable should not be used when connecting a device to a switch or router.

X-Microwave System

RF Blocks are placed on the top side of the X-MWprotoplate and are connected together launch-to-launch with the ground-signal-ground (gsg) jumper solderless interconnect. Each gsg jumper is held down by two anchors, one on each side of the gsg jumper. Bias and Control X-MWblocks contain spring pins that make a connection to vias on the bottom side of the RF block.

X-MWblock RF	X-MWprobe	Anchor	X-MWblock Bias and Control	X-MWprotoplate	gsg Jumper
					

Screw Lengths

All screws are 1-72 socket head cap screws made of 18-8 stainless steel. Using the proper length screws is important so that nothing protrudes through the top or bottom of the prototyping plate. Screws that are too long can scratch or even break the board below it. (Even a single bag of standard machine screws can also vary in length due to manufacturing variability.) Screws should not be overtightened. Finger-tight is adequate for most applications if you do not have a torque wrench. The torque specification is 7 oz-in / 5 N-cm. If you overtighten the screws, you could damage the threaded holes in the prototyping plate or PCB surface.

X-MWblocks (bottom of plate)	**X-MWblocks (top)** **X-MWprobe (short)**	**X-MWanchor** **Pinbridge**	**X-MWProbe (tall)** **X-MWwall (short)**
1-72 x 1/8” **(0.125”)**	**1-72 x 5/32”** **(0.156”)**	**1-72 x 1/4”** **(0.25”)**	**1-72 x 3/8”** **(0.375”)**
			

X-MWblocks

These components are mounted to the X-MWprotoplate. Descriptions may be searched for and viewed at https://www.xmicrowave.com/.

XM-W Part Number	Description	Part MFG	MRG Part	PCB Number	Quantity
XM-A6Y2-0204D	LTCC Band Pass Filter	Mini-Circuits	BFCN-1860	29	1
XM-A2L2-0404D	Oscillator - 100 MHz	PLE	SM77D	159	1
XM-A2N1-0409D	U-Turn Transmission Line	XMW		184	1
XM-B4V6-0604D	Double-Double Balance Mixer	Marki Microwave	T3-06LCQG	191	1
XM-A2M7-0404D	Transmission Line - Straight	X-MW		306	1
XM-A5M6-0409D	PLL-VCO	ADI	ADF4355-3BCPZ	382	1
XM-A3V3-0404D	SAW Filter Centered at 168.5 MHz	Qorvo	856512	412	1
XM-B1F3-0404D	BAW Filter Centered at 1842.5 GHz	Qorvo	TQQ0303	473	1
XM-A4H9-0404D	General Purpose Amplifier	ADI	ADL5611	516	1
XM-B5A2-0404D	General Purpose Amplifier (5 V)	Mini-Circuits	Gali-51	530	1
XM-A767-0404D	Low Noise Amplifier	Qorvo	TQL9092	613	1
XM-A3K9-0604D	Digital Step Attenuator	Peregrine	PE43713	701	1
XM-B2A3-0604D	Power Amplifier	ADI	HMC453ST89	802	1
XM-B2B7-0604D	Double Balance Mixer (6 GHz)	Mini-Circuits	SIM-63LH	906	1
XM-B4V4-0420D	Microstrip and Coplanar Example	X-MW		907	1
XM-B162-0407-SP	Voltage Regulator +VIN2 – 5-Volt	X-MW		909	3
XM-B161-0407-SP	Voltage Regulator +VIN2 - 3.3-Volt	X-MW		910	1
XM-B164-0607D-SP	Bias Ctrl for PE43713 DSA +VIN2	X-MW		911	1
XM-B165-0709D-SP	Bias Ctrl for ADRF-4355-3BCPZ PLL/VCO +VIN2	X-MW		912	1
XM-B1F4-1204D	Lumped Low Pass 168.5 MHz + 45 MHz	X-MW		976	1
XM-B158-0407-SP	Voltage Regulator +VIN1 – 5-Volt	X-MW		997	1
XM-B4V5-0604D	Double Balance Mixer (500 MHz)	Mini-Circuits	ADE-1LH	1041	1

X-MWprotoplate (Top View)

The components on the X-MWprotoplate are labeled in the symbol view (left) and layout view (right) with the description below.

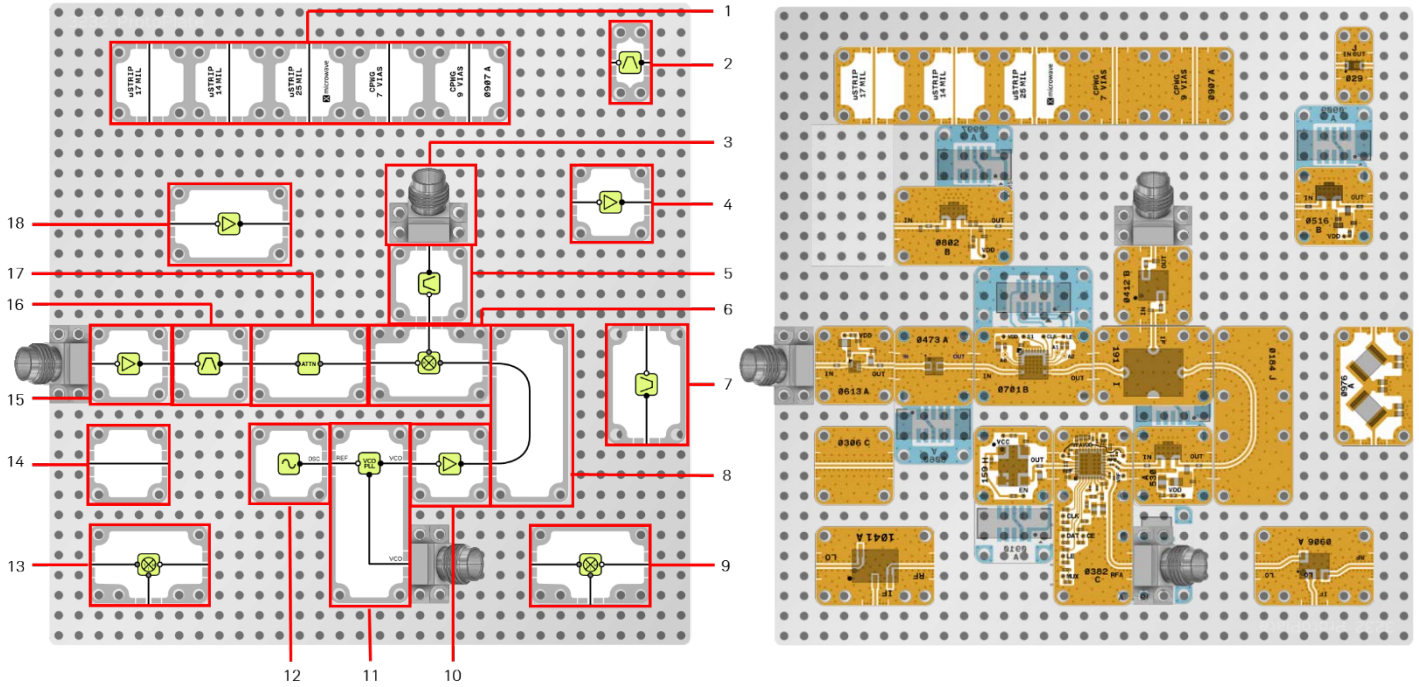


Table 1. List of items assembled on the X-MWprotoplate (top view).

	Item		Item
1	Transmission Line Samples	10	Mixer Driver Amplifier
2	LTCC Filter	11	Synthesizer / PLL
3	X-MWprobe	12	Reference Oscillator
4	Driver Amplifier	13	Mixer
5	IF Bandpass Filter (BPF)	14	Transmission Line
6	Mixer	15	Low Noise Amplifier (LNA)
7	Lumped Element LPF	16	RF Bandpass Filter (BPF)
8	Transmission Line	17	Digital Step Attenuator
9	Mixer	18	Power Amplifier

X-MWprotoplate (Bottom View)

The components on the X-MWprotoplate are labeled in layout view with the description below.

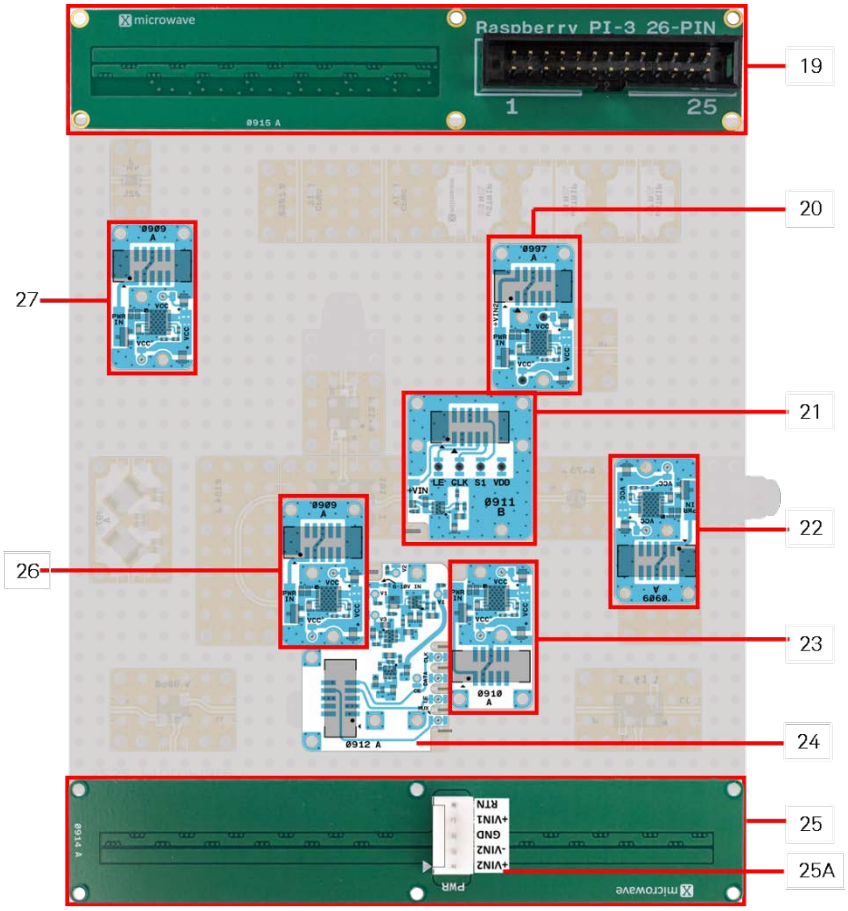


Table 2. List of items assembled on the X-MWprotoplate (bottom view).

	Item		Item
19	Programming Interface Board (PCB 915)	24	PLL 5-Volt Regulator and Control Powered by VIN2+ (PCB 912)
20	5-Volt Regulator Powered by VIN1+ (PCB 997)	25	Power Interface Board (PCB 914)
21	DSA 5-Volt Regulator and Control Powered by VIN2+ (PCB 911)	25A	Power Cable Connection
22	5-Volt Regulator Powered by VIN2+ (PCB 909)	26	5-Volt Regulator Powered by VIN2+ (PCB 909)
23	3.3-Volt Regulator Powered by VIN2+ (PCB 910)	27	5-Volt Regulator Powered by VIN2+ (PCB 909)

NOTE

- +VIN1 provides power to the Power Amplifier (PA) only.
- +VIN2 provides power to the Receiver, that is all the remaining components.
- -VIN2 is not used and reserved for future use

The X-MWcontroller and Power and Raspberry Pi Interface Boards

The X-MWcontroller

The X-MWcontroller RaspberryPi is used to program the PLL, DSA and any other programmable block. It provides a dedicated graphical user interface on an HDMI monitor or remotely on a computer.

Power Interface Board

The Power Interface board distributes power from the connected power supply to J1 through J10. +VIN1 is used for a positive supply, capable of supplying +6 V at up to 1 Amp of current. +VIN2 / -VIN2 is used for a +/- dual voltage supply providing +6 V and -6V at up to 1 amp of current. (The negative supply is not used; is reserved for future use.)

Programming Interface Board (Latch Enable (LE) and Control Ribbon Cables)

The PLL-VCO and DSA X-Microwave block each require a control board. They are programmable over SPI (Serial Peripheral Interface) bus, a 3-wire digital protocol. The DATA line is sampled on each rising edge of the CLOCK shared among all devices. Programming is enabled on each individual device through Latch Enable (LE) in an “active low” state. Data and clock lines are ignored when Latch Enable is held “high” and the device is programmed when Latch Enable is held “low”.

The X-MWcontroller RaspberryPi is connected to the Control Interface board using a 40-pin to 26-pin cable. The physical Latch Enable port is chosen by connecting the desired programmable control board to one of the six numbered LE ports (LE0 to LE5). The physical LE port on the bottom of the prototyping plate should also be selected in the X-MWcontroller software interface.

The image below shows the inside view of the Power Interface Board [PCB 0914] and Raspberry Pi Control Interface Board – Inside View [PCB 0915].

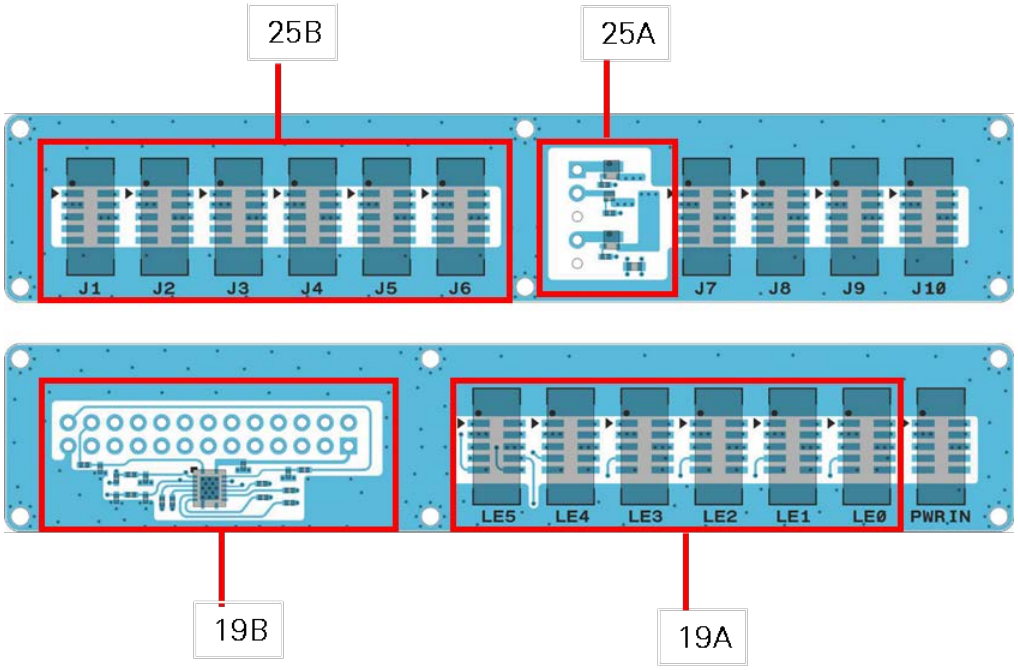


Table 3. Inside view of the Power and Raspberry Pi Interface Boards.

	Item		Item
25B	J1 to J10 distribute power to Voltage Regulators	19A	LE0 to LE5 distribute power and programming signals to Control/Voltage Regulators
25A	Power from E36312A Power Supply, +VIN1 (PA) = 6 V, +VIN2 (Receiver) = 6 V	19B	26 Pin Programming Interface to Raspberry Pi

General Purpose Voltage Regulator Boards

a. PCB 0909 = Regulates +6 V In to +5 V Out, +VIN2
b. PCB 0910 = Regulates +6 V In to +3 V Out, +VIN2
c. PCB 0997 = Regulates +6 V In to +5 V Out, +VIN1

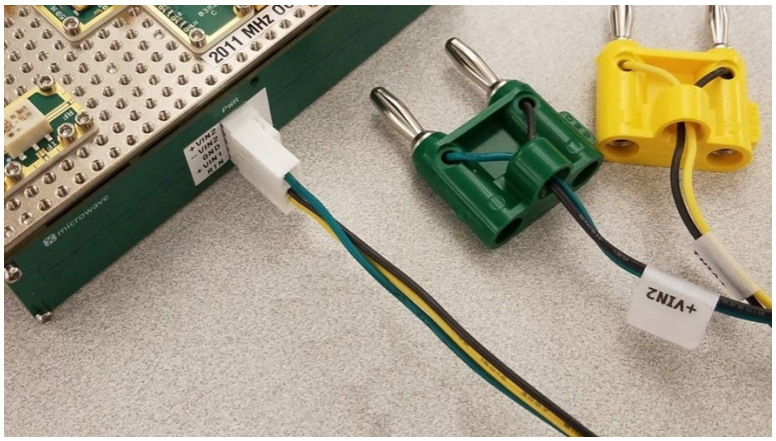
NOTE

Current Limiting is recommended at the Power Supply:

- +VIN1 powers the PA and its recommended current limit setting is 0.8 A.
- +VIN2 powers the Receiver and its recommended current limit setting is 0.5 A.
- Only energize one supply at a time, never both.

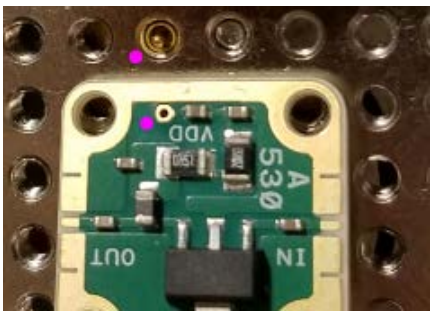
Power Cable

The diagram below shows the wiring of the power cable:



Bias and Control for X-MWblocks

Each X-MWblock (top side) that requires power will have a corresponding Voltage Regulator or Control/Regulator board on the bottom side of the X-MWprotoplate. Spring (pogo) pins pass the signal from regulator and control blocks to vias on the bottom side of RF blocks ●.



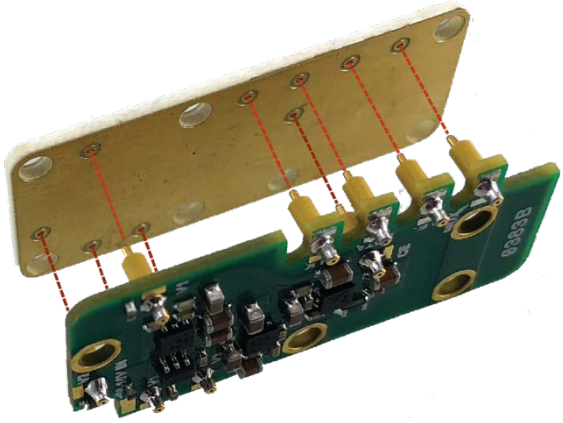
10-pin ribbon cables connect each Voltage Regulator to the Power Interface board and each control board to the Pi Control Interface board.

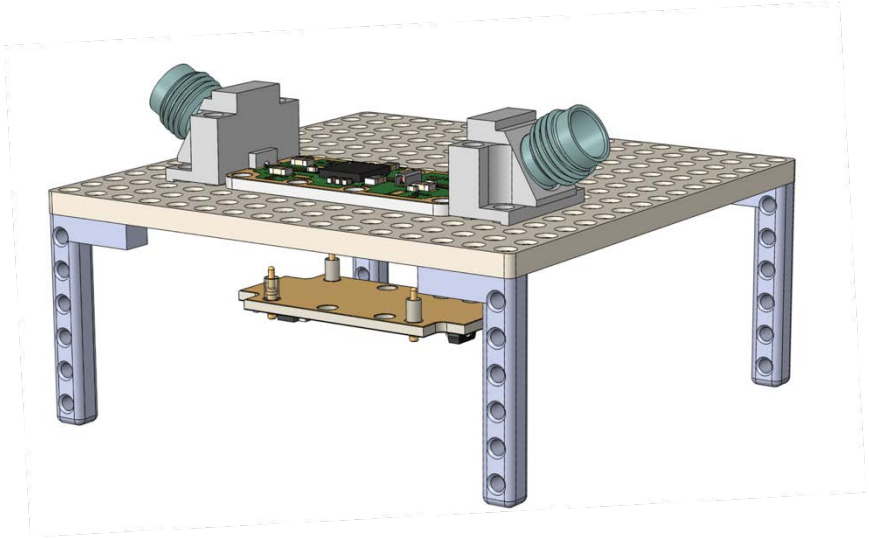
- Voltage Regulator boards may be connected to any jack (J1 – J10) on the Power Interface board.
- Control/Regulator boards must be connected as shown below to the Programming Interface board.

Bias and Control Board Placement

Matched bias voltage and control boards are placed on the bottom of the prototyping plate supplying the microwave blocks with the necessary power and control signals. Spring-pins with shielded collets are soldered to the bias and control circuit board provide a shielded electrical connection through the prototyping plate to the RF X-MWblock.

Tip: After moving an RF board, hold the prototyping plate up to the light and you can see light coming through the vias which shows you how you need to align the control board.





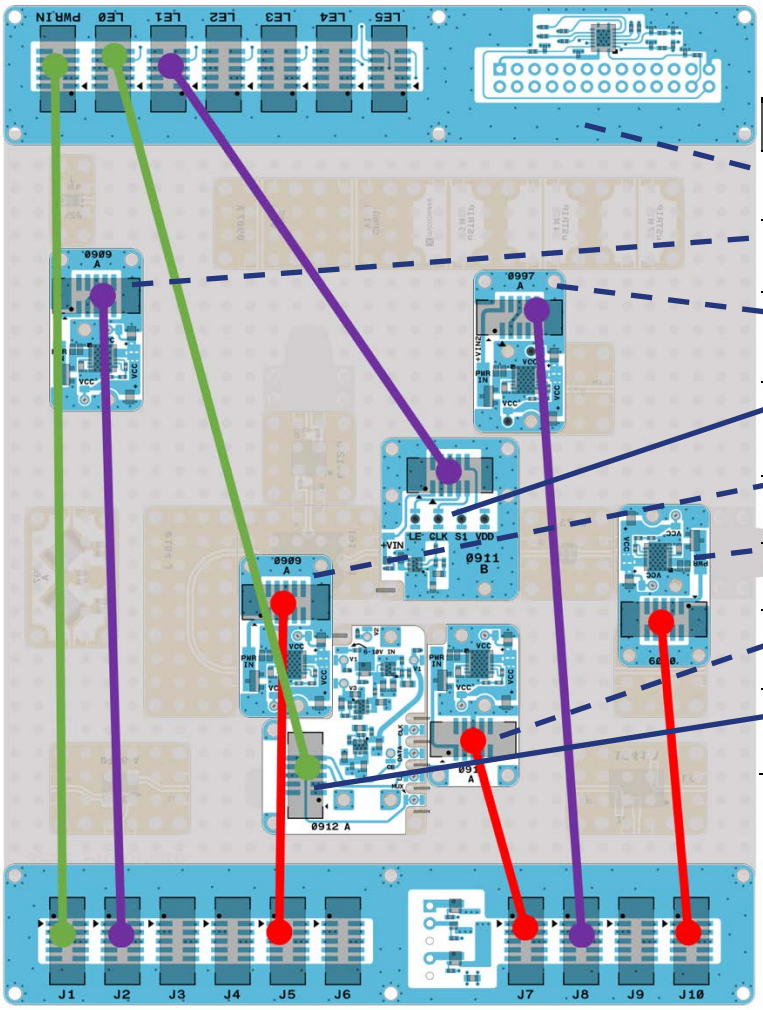
Prototyping Kit Setup

The prototyping kit should be returned to its initial configuration at the beginning of each semester. This provides a convenient way for you to verify that each block is in good working order and allows a student to easily identify each block.

Wiring between Interface Boards

Ensure that the ribbon cables on the bottom of the X-MWprotoplate are configured as follows.

NOTE The Latch Enables LE0 and LE1, annotated 5 and 9, must be configured exactly as shown.

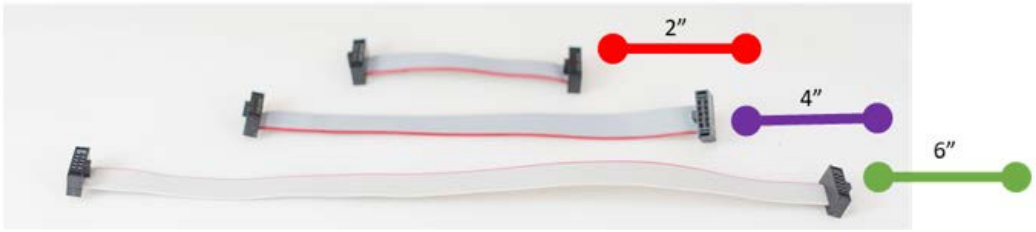


X-MWblocks assembled on X-MWprotoplate	
19	Programming Interface Board (PCB 915)
27	5-Volt Regulator Powered by VIN2+ (PCB 909)
20	5-Volt Regulator Powered by VIN1+ (PCB 997)
21	DSA 5-Volt Regulator and Control Powered by VIN2+ (PCB 911) cable to **LE1**
26	5-Volt Regulator Powered by VIN2+ (PCB 909)
22	5-Volt Regulator Powered by VIN2+ (PCB 909)
23	3.3-Volt Regulator Powered by VIN2+ (PCB 910)
24	PLL 3.3-Volt Regulator and Control Powered by VIN2+ (PCB 912) cable to **LE0**

Procedure

1. Connect the 6” cable from J1 to PWRIN on Interface Board.
2. LE0 on Interface Board, 6” Cable to PCB 912 (PLL).
3. LE1 on Interface Board, 4” Cable to PCB 911 (DSA).
4. J2 to J10, cable to PCB 909, 910, 997 can be connected to any open location.

Cable Type	Quantity
2”	3
4”	4
6”	2



Here are how the components for the 5G n3 Receiver will look when they have been returned to their proper positions.

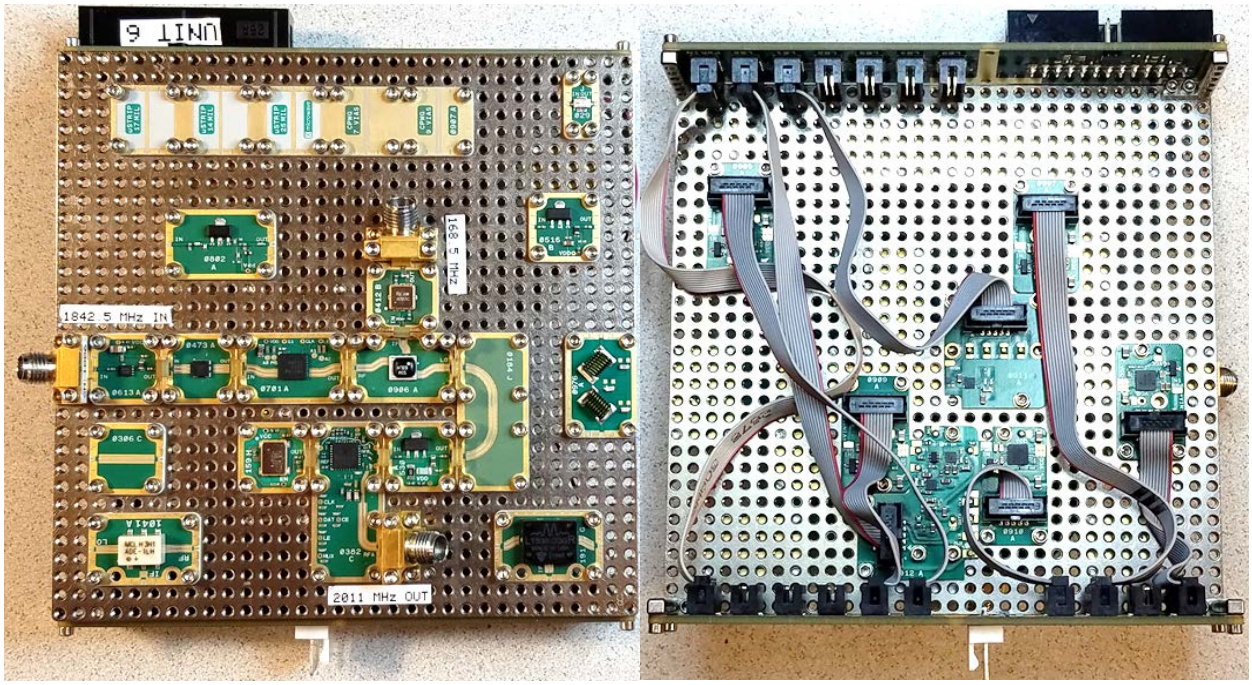


Figure 1. 5G n3 Receiver mounted on the prototyping plate on Top, Voltage Regulator and Control on Bottom.

Keysight Software Setup

System and Installation Requirements

PC operating system

- Windows 7 or 10

NOTE Software applications that may require licensing are noted in the steps below. Instrument options may also require licensing. The Lab Manager and/or Keysight Field Engineer should be consulted for assistance.

Install PathWave RF Synthesis (Genesys)

Keysight PathWave Genesys provides self-supporting RF board engineers affordable, practical design tools for RF component design to complete transceiver design including multi-element antenna arrays.

1. Download the software from https://www.keysight.com/find/eesof-genesys-latest-downloads.
2. Run the installer and use the default settings. Click **Finish** to exit the setup.
3. Consult your Lab Manager and/or Keysight Field Engineer for license purchase and activation.
4. For more information on the software, go to https://www.keysight.com/en/pc-1297125/genesys-rf-and-microwave-design-software?cc=US&lc=eng.

Install PathWave Advanced Design System (ADS)

Keysight PathWave ADS is the industry's leading Signal Integrity, RF/Microwave and Power Integrity design platform. ADS offers complete design integration for products such as cellular and portable phones, wireless networks, and radar and satellite communications systems.

1. Go to https://www.keysight.com/find/eesof-ads-latest-downloads to download the latest ADS software release.
2. Run the installer and use the default settings. Click **Finish** to exit the setup.
3. Consult your Lab Manager and/or Keysight Field Engineer for license purchase and activation.
4. For more information on the software, go to https://www.keysight.com/find/ads.

Install PathWave EM Design (EMPro)

Keysight PathWave EMPro is Keysight EEsof EDA's electromagnetic (EM) simulation software design platform for analyzing the 3D EM effects of components such as high-speed and RF IC packages, bond-wires, antennas, on-chip and off-chip embedded passives and PCB interconnects.

1. Go to https://www.keysight.com/find/eesof-empro to download the latest EMPro software release.
2. Run the installer and use the default settings. Click **Finish** to exit the setup.
3. Consult your Lab Manager and/or Keysight Field Engineer for license purchase and activation.
4. For more information on the software, go to https://www.keysight.com/find/eesof-empro.

Install PathWave System Design (SystemVue)

Keysight PathWave SystemVue is a focused electronic design automation (EDA) environment for electronic system-level (ESL) design. It enables system architects and algorithm developers to innovate the physical layer (PHY) of wireless and aerospace/defense communications systems and provides unique value to RF, DSP, and FPGA/ASIC implementers.

1. Go https://www.keysight.com/find/eesof-systemvue-latest-downloads to download the latest SystemVue software release.
2. Run the installer and use the default settings. Click **Finish** to exit the setup.
3. Consult your Lab Manager and/or Keysight Field Engineer for license purchase and activation.
4. For more information on the software, go to http://www.keysight.com/find/eesof-systemvue.

Install FieldFox Data Link

Keysight FieldFox Data Link software facilitates transferring data from the FieldFox to your PC and the creation of simple reports.

1. Download the FieldFox Data Link Software at https://www.keysight.com/main/redirector.jspx?action=ref&lc=eng&cc=MY&nfr=-11143.0.00&ckey=2085717&cname=EDITORIAL.
2. On this webpage, click the Installation Instructions for Data Link Software for FieldFox under Supporting Documentation to view the set of instructions. Otherwise, view the online Help File for FieldFox Data Link at http://na.support.keysight.com/fieldfox/help/DataLinkHelp/DataLink.htm.
3. View the troubleshooting hints for FieldFox Data Link Software at https://www.keysight.com/main/redirector.jspx?action=ref&lc=eng&cc=MY&nfr=-11143.0.00&ckey=2100766&cname=EDITORIAL.

NOTE Ensure that latest data link software supports your FieldFox and that it fulfills the minimum firmware requirement.

Install PathWave BenchVue (Optional)

Keysight PathWave BenchVue is PC software to configure a wide range of instrument controls and measurements.

1. Go to https://www.keysight.com/find/benchvue to download the latest BenchVue software release.
2. Run the installer and use the default settings. Click **Finish** to exit the setup.
3. Consult your Lab Manager and/or Keysight Field Engineer for license purchase and activation.
4. For more information on the software, go to https://www.keysight.com/find/benchvue.

X-MWcontroller Setup

Configuring the X-MWcontroller with an HDMI Display

1. Connect a HDMI Display (a DVI or VGA display may be used with an appropriate adapter cable) and USB Mouse to the X-MWcontroller.
2. Using the 40-pin to 26-pin ribbon cable, connect the populated X-MWprotoplate to the X-MWcontroller.

NOTE Proper cable orientation is critically important. Pin 1 of the ribbon cable (white stripe) should align with Pin1 of the 40-pin connector (furthest from the USB ports on the XM-MWcontroller).

---

3. Connect the AC power adapter's USB cable to the X-MWcontroller to power up.

4. The X-MW Application will appear on the screen and the mouse is used to click all buttons (keyboard is not supported)
5. Go to Using the X-MWcontroller Platform.

   When necessary, the X-MWcontroller should be shut down by selecting **Quit** from the home screen and selecting **Yes** when asked if you are sure.

Configuring the X-MWcontroller with your Computer as the Display

1 Connect the supplied LAN crossover cable (right cable in the image below) directly between the X-MWcontroller and an available LAN port on your computer.

NOTE The LAN crossover cable facilitates direct peer-to-peer LAN device connection such as the Raspberry Pi to your computer. A regular "straight through" LAN cable may be adequate for devices that have Auto MDI-X ports that automatically choose the MDI or MDI-X configuration to properly match the other end of the link. The crossover cable should not be used when connecting a device to a switch or router.

WARNING If the Raspberry Pi is to be connected to a regular LAN connection with other computers, it is **strongly recommended to change the default password**. For more information, visit https://www.raspberrypi.org/documentation/configuration/security.md.

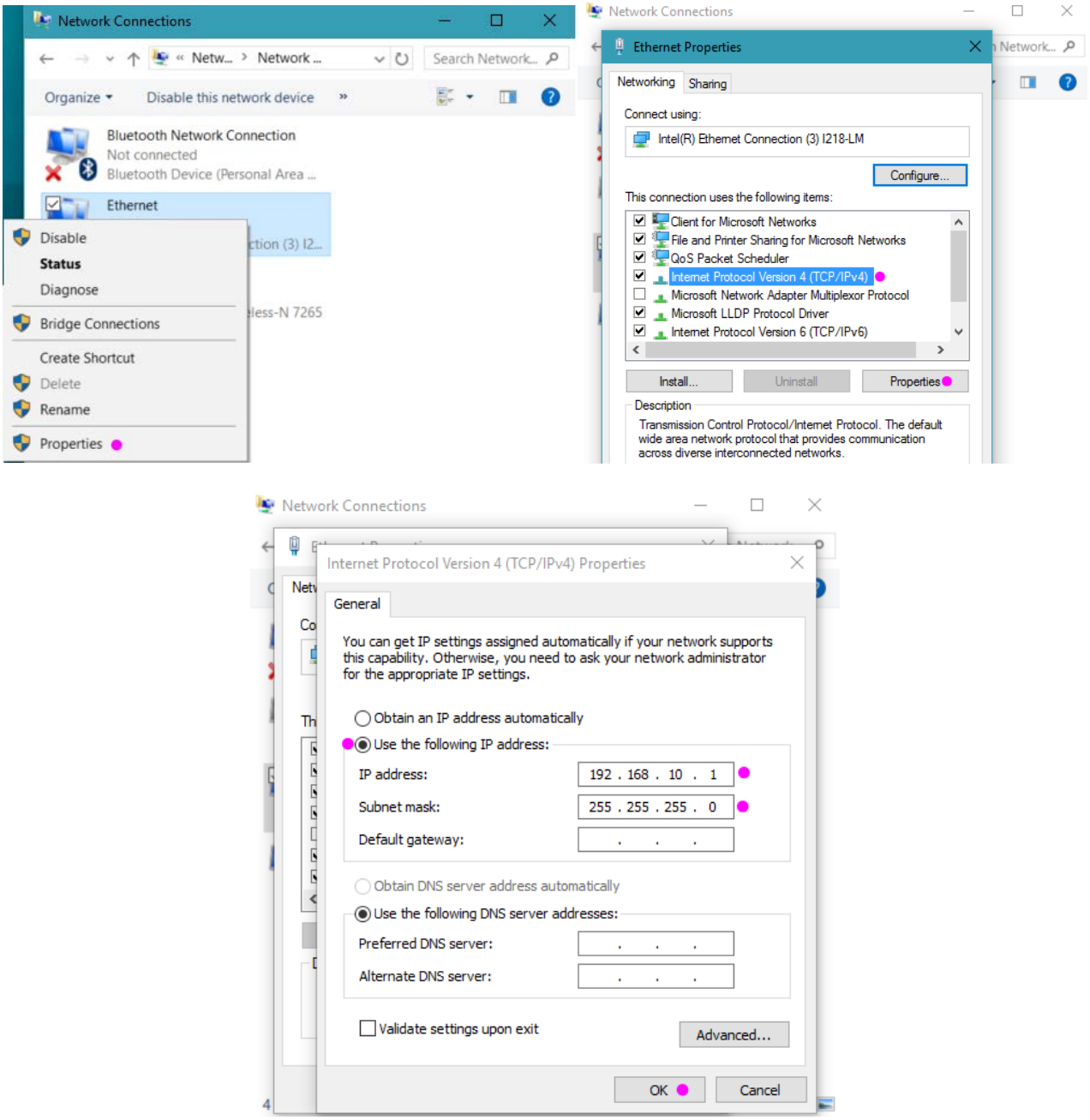
2 Using the 40-pin to 26-pin ribbon cable, connect the populated X-MWprotoplate to the X-MWcontroller, as shown above.

NOTE Proper cable orientation is critically important. Pin 1 of the ribbon cable (white stripe) should align with Pin1 of the 40-pin connector (furthest from the USB ports on the XM-MWcontroller).

3 Connect the AC power adapter's USB cable (left cable in the image above) to the X-MWcontroller. This is to power up the X-MWcontroller.

NOTE With your instructor's or IT administrator's permission, you may also connect the Pi to a local router or department LAN. In this case you must identify the IP Address of the Raspberry Pi using the Router User Interface.

4 If you are using a separate LAN connection, configure your computer. On a PC under **Network Connections > Properties > Internet Protocol Version 4**, set a static **IP address** of **192.168.10.1** and the subnet mask of **255.255.255.0**.



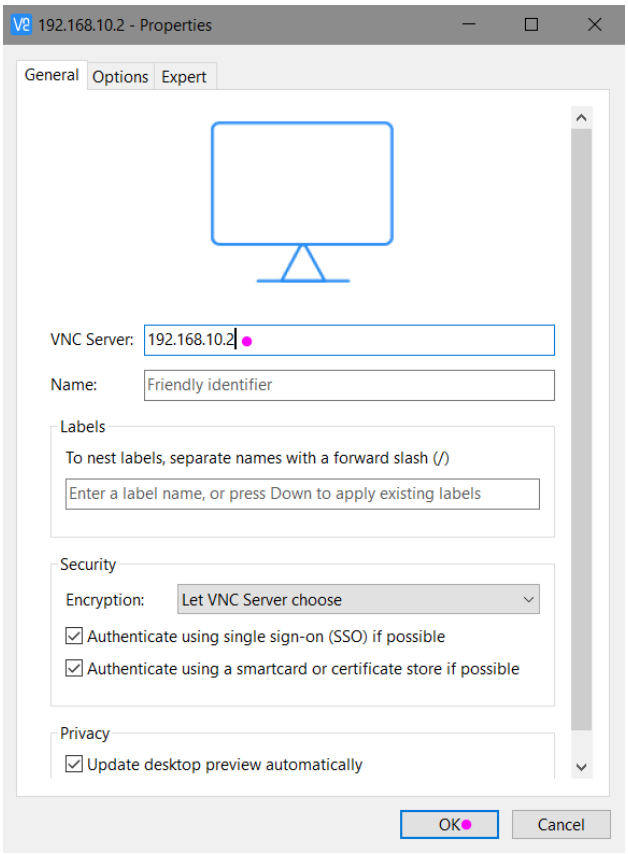
NOTE This is only for a peer-to-peer connection. If it is on a regular network router with DHCP, use the "Obtain an IP address automatically" selection.

5 Set up a RealVNC connection to your Pi following these steps:

   a Download and install the VNC Viewer at https://www.realvnc.com/en/connect/download/viewer/

   b Run the VNC viewer.

6 For a peer-to-peer connection the IP address is 192.168.10.2 for the X-MWcontroller. Enter the IP address **192.168.10.2** in the VNC Server field when prompted by VNC Viewer.



7 Login using

   a Username: pi

   b Password: raspberry

NOTE

- The official instructions for configuring VNC can be found at https://www.raspberrypi.org/documentation/remote-access/vnc/.
- Register your copy of RealVNC at https://manage.realvnc.com/en/auth. You may need a license depending on your use case.

---

8 The X-MWcontroller user interface will appear on the screen of your PC. Use the cursor on your PC to control the user interface. The USB connections for mouse and keyboard to the X-MWcontroller are not supported in VNC mode.

9 Go to Using the X-MWcontroller Platform.

Configuring the X-MWcontroller using Mac

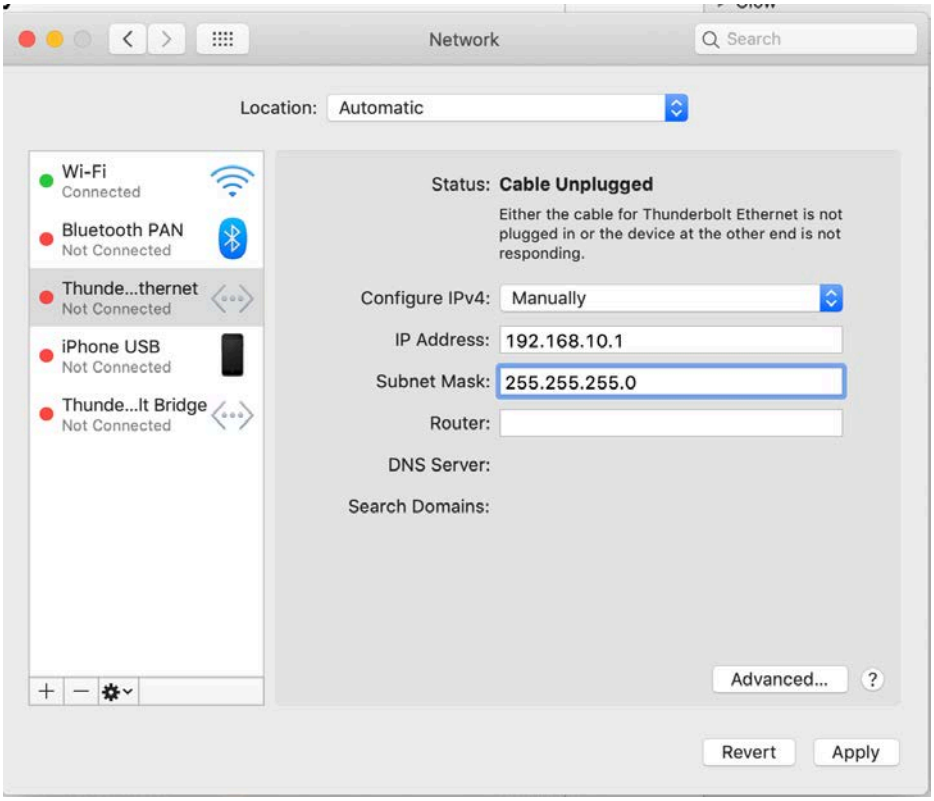
1 Under **System Preferences** > **Network** and select your Ethernet port.

   a Change Configure IPv4: **Manually**

   b IP Address: **192.168.10.1**

   c Subnet mask of **255.255.255.0**

   d Choose **Apply** and close the window.



2 Run VNC Viewer.

3 Type in the IP Address: 192.168.10.1 and Subnet Mask: 255.255.255.0.

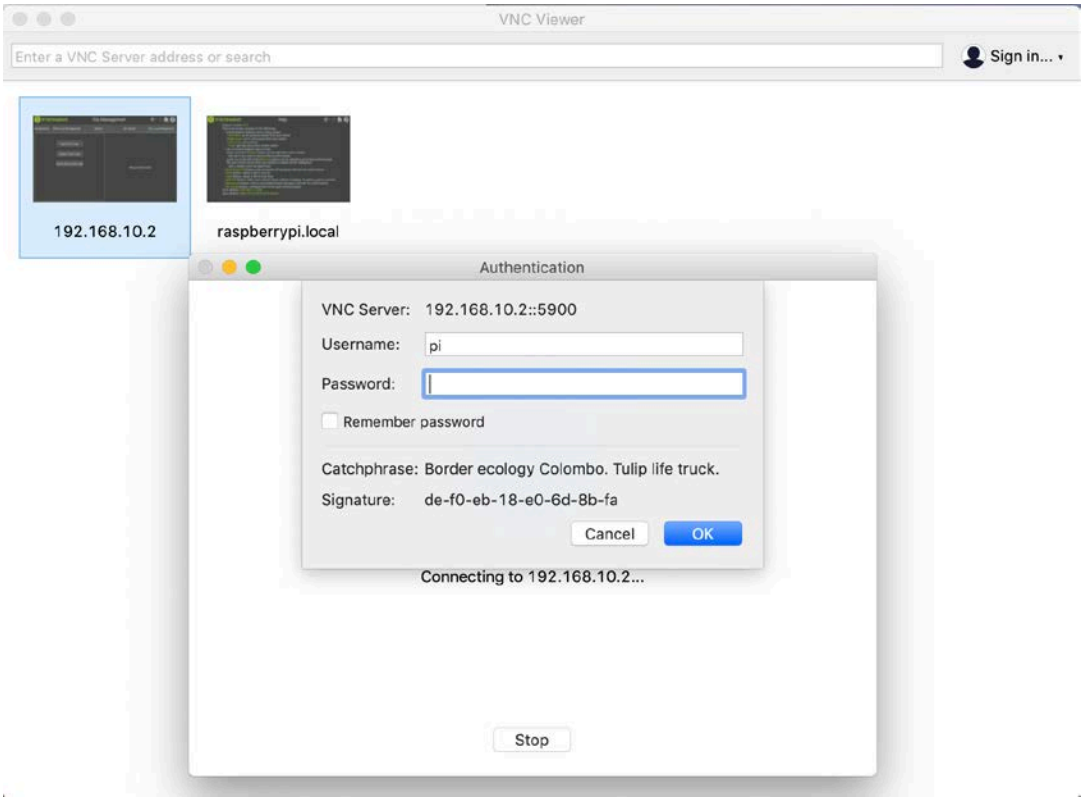
4 Login using:

   a Username: pi

   b Password: raspberry

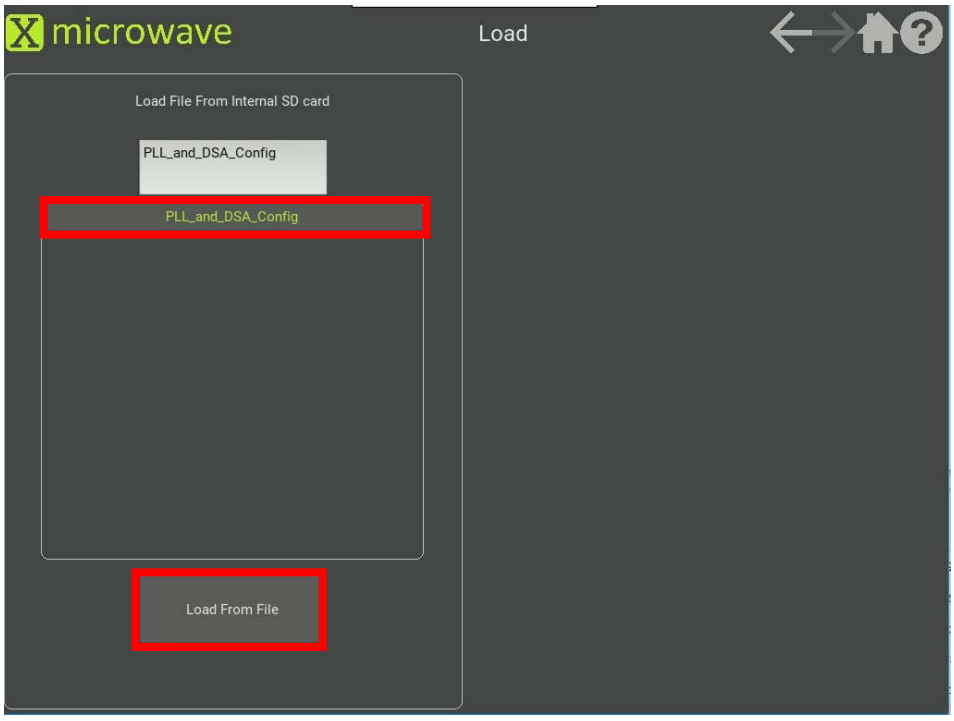
Configuring the X-MWcontroller using Linux

1 Under **Network Connections > Properties > Internet Protocol Version 4,** set a static IP address of **192.168.10.1** and the subnet mask of **255.255.255.0**. For most versions of Linux this can be found under a Network manager GUI. Refer to the network setting for your distribution of Linux.

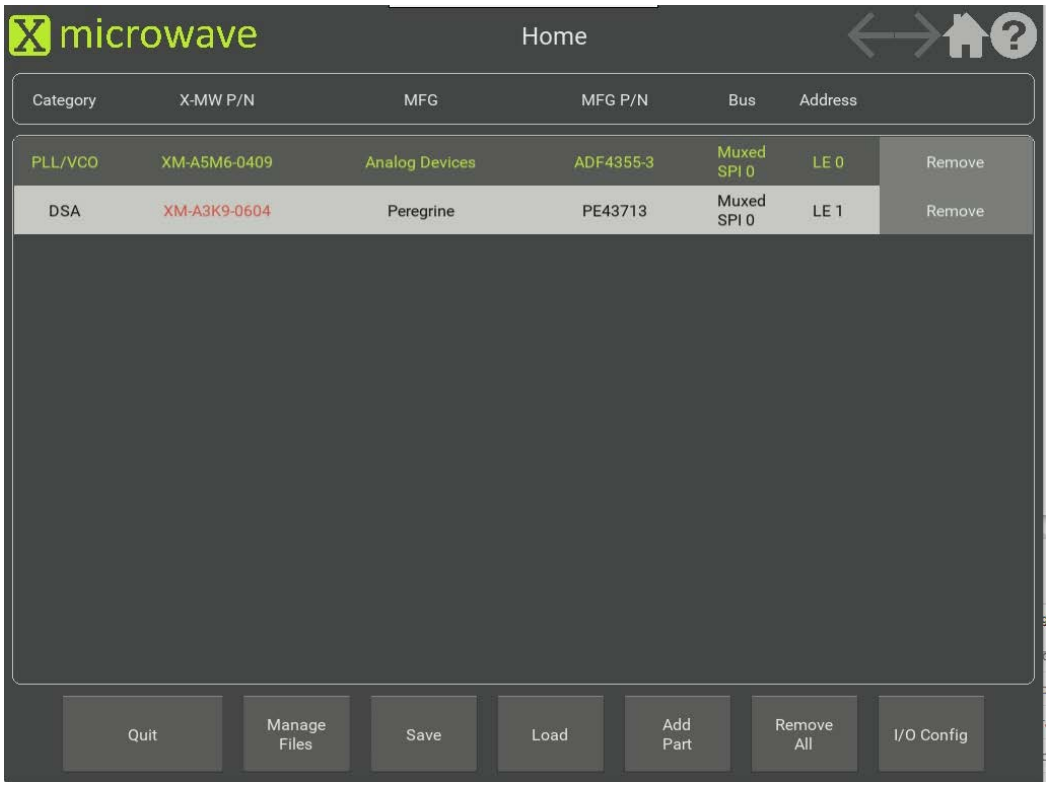


1 On the initial home page of the X-MWcontroller, select **Load** to load the XM-Wblock configuration file.

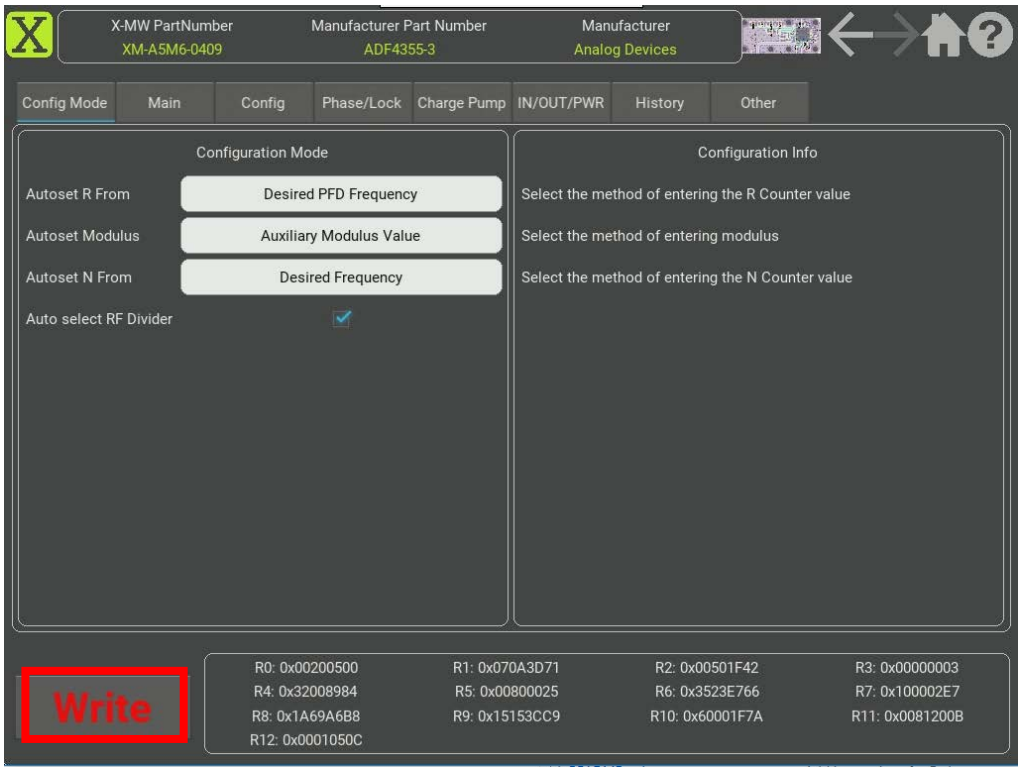
2 Select the **PLL_and_DSA_Config** in the **Load File From Internal SD card** area and select **Load From File**. If there are no configuration files available, go to this section to recreate the PLL_and_DSA_Config file.



3 After loading the configuration file, the PLL/VCO XM-A5M6-0409 and the DSA XM-A3K9-0604 should be seen on the Home screen.



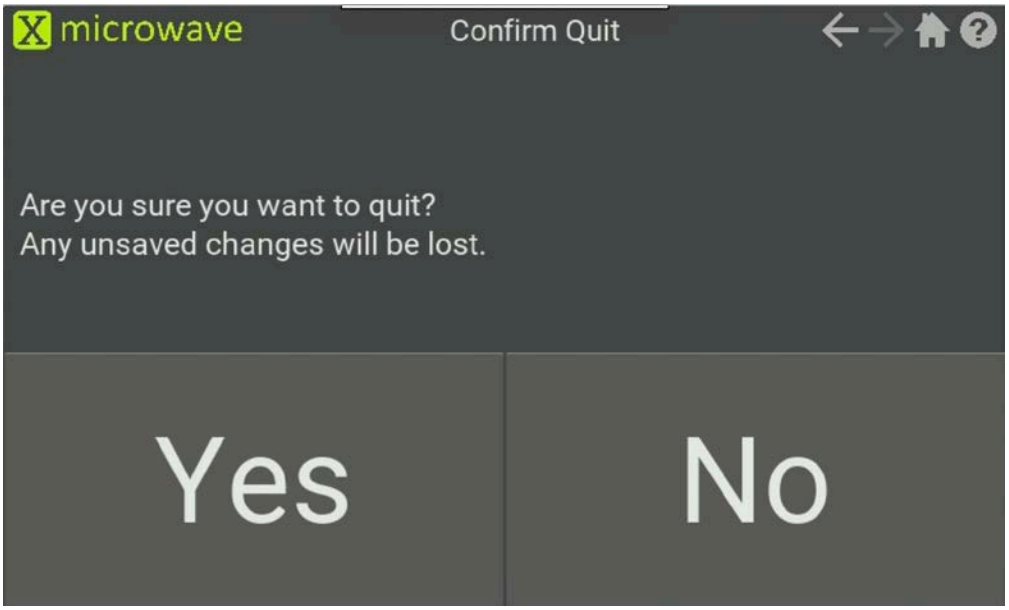
4 To write select a block (image above) and observe the configuration menu. On the lower left of the screen, select **Write** to load the configuration to the X-MWblock.



5 Once the configuration has been written to the X-MWblock, the letters in the Write button will turn green.

6 Once the XM-Wblock has been configured select the home icon to go back to the main home screen. Descend and **Write** the XM-Wblock to configure the other block.

7 Before unplugging the power from the X-MWcontroller should be shut down by selecting **Quit** from the home screen and selecting **Yes** when asked if you are sure.



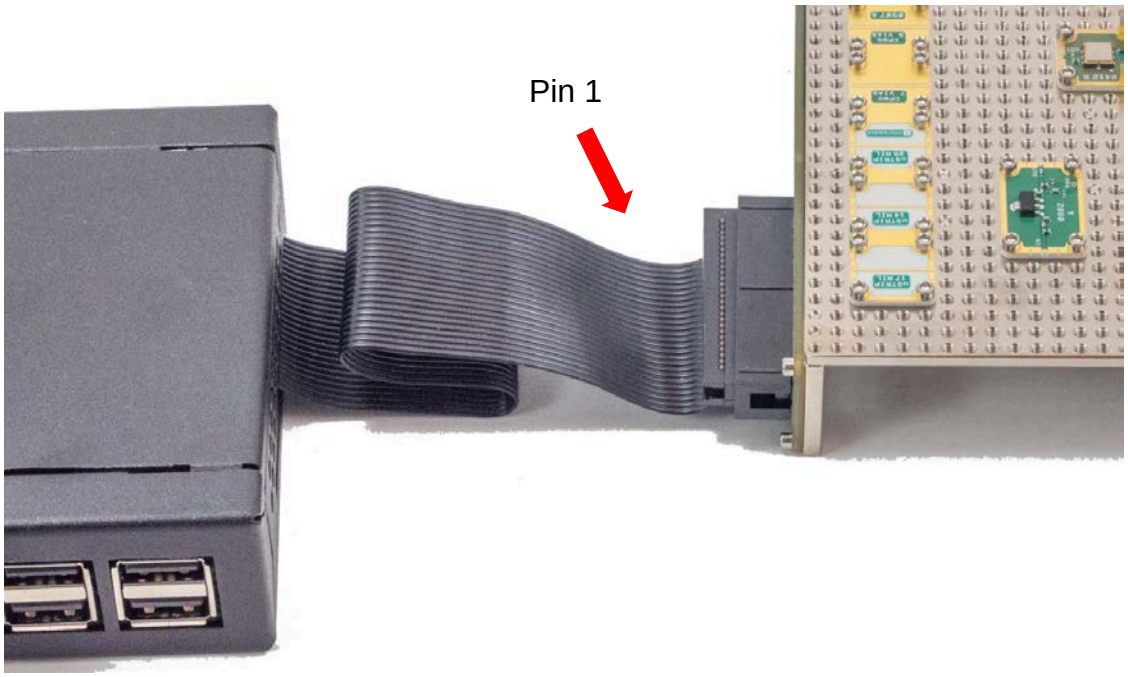
Raspberry Pi Troubleshooting

Mouse/keyboard attached to the USB port of the X-MWcontroller becomes unresponsive

Reboot the X-MWcontroller by powering off and then on with the mouse or keyboard connected.

Can't program the devices on my X-MW prototyping plate

Check ribbon cable orientation of the 40 to 26 pin cable. Pin 1 of the ribbon cable (white stripe) should align with Pin1 of the 40-pin connector (furthest from the USB ports on the XM-MWcontroller).



Can't communicate with my X-MWcontroller over VNC

1. Plug in a HDMI display and mouse directly into the X-MWcontroller
2. Choose the "?" help icon on the main screen
3. If a network cable is attached and a dynamic IP Address is assigned, the address will be shown. Example: 192.168.1.192, Subnet: 255.255.255.0
4. Ensure your computer is on the same network has a compatible IP address: 192.168.1.X (where X may be any three-digit number) could see the X-MWcontroller.
5. If you are selecting your own static IP address ensure your computer and the X-MWcontroller share the same subnet mask (255.255.255.0), but the IP addresses are different (only differing in the final three numbers).
6. For full config instructions, go to https://www.realvnc.com/en/connect/docs/raspberry-pi.html#raspberry-pi-minecraft.

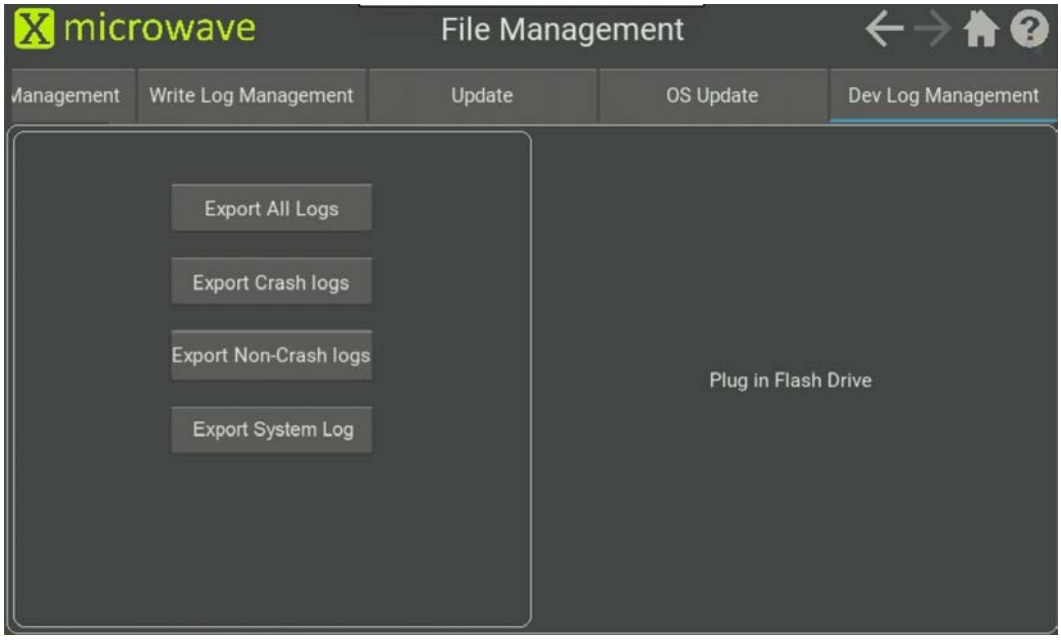
The RaspberryPi is unresponsive or not functioning properly

1. Insert a USB flash drive into one of the RaspberryPi USB ports.
2. Navigate to the screen by selecting **File Management** at the bottom of the home screen to navigate the files.
3. Navigate to the **Dev Log Management** by clicking and dragging the tabs to the left (scrolling to the right).
4. Select **Export System Log** to store a text-based log file on the USB drive.

NOTE The System Log includes software, process, and hardware information.

---

5. Eject the USB drive or shutdown the RaspberryPi before removing the USB flash drive.
6. The log file on the USB drive can viewed on your PC as a plain text file or emailed as an attachment if requested by the technical support team.



Updating the X-MWcontroller Part Library

The X-MWcontroller can be quickly updated by USB drive following the on-screen instructions.

1. Download the latest X-MWcontroller software at https://xmicro-assets.s3.amazonaws.com/raspi-updates/latest_update.tar.gz.
2. Copy the files to a USB drive with at least 100MB of space.
3. Plug the USB drive into one of the 4 USB ports on the RaspberryPi Touch.
4. Power up the RaspberryPi Touch.
5. Navigate to **Manage Files**.
6. Select **Update** from the top menu.

NOTE Once plugged in, it may take 5 to 10 seconds for the USB drive to be recognized.

---

7. Select the desired firmware image to be installed: **Select "latest_"**. If selected it will change to green with a black background.
8. You will then be asked if you want to "...update to latest_?" Select **Yes**.
9. The system will then quickly reboot. It may take up to 20 seconds to reboot to the home screen.

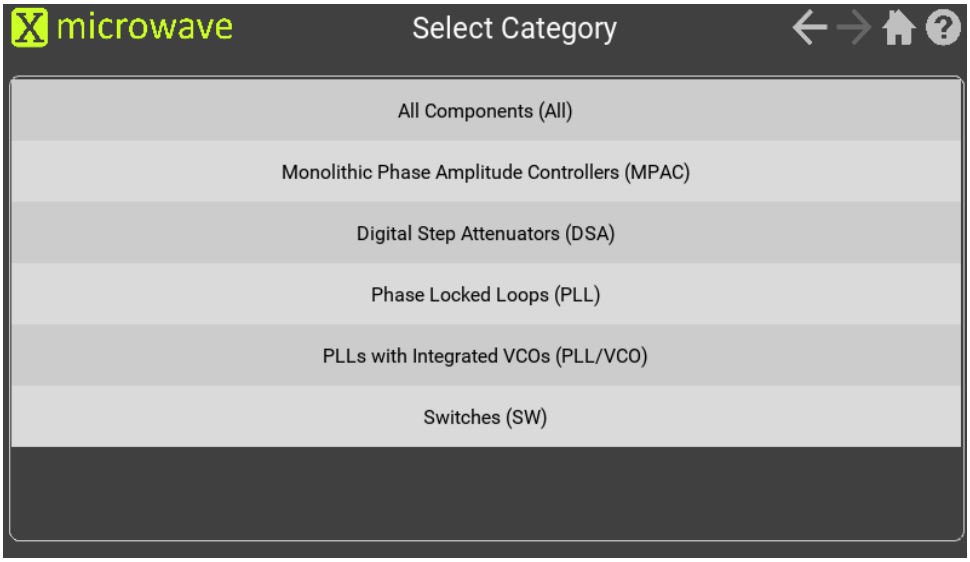
NOTE

- For any issues related to the Raspberry Pi during setup, search for the https://www.raspberrypi.org/documentation/setup/ for a solution.
- If you need assistance, contact X-Microwave at sales@xmicrowave.com.

Recreate PLL_and_DSA_Config.xmdat file

1 Connect the power cable to power up the RaspberryPi. You should see the Home screen below after boot-up. The screen will display a list of all the parts in your system once configured.

2 Select **Add Part** to add the parts to the list. Select **PLL/VCO**.



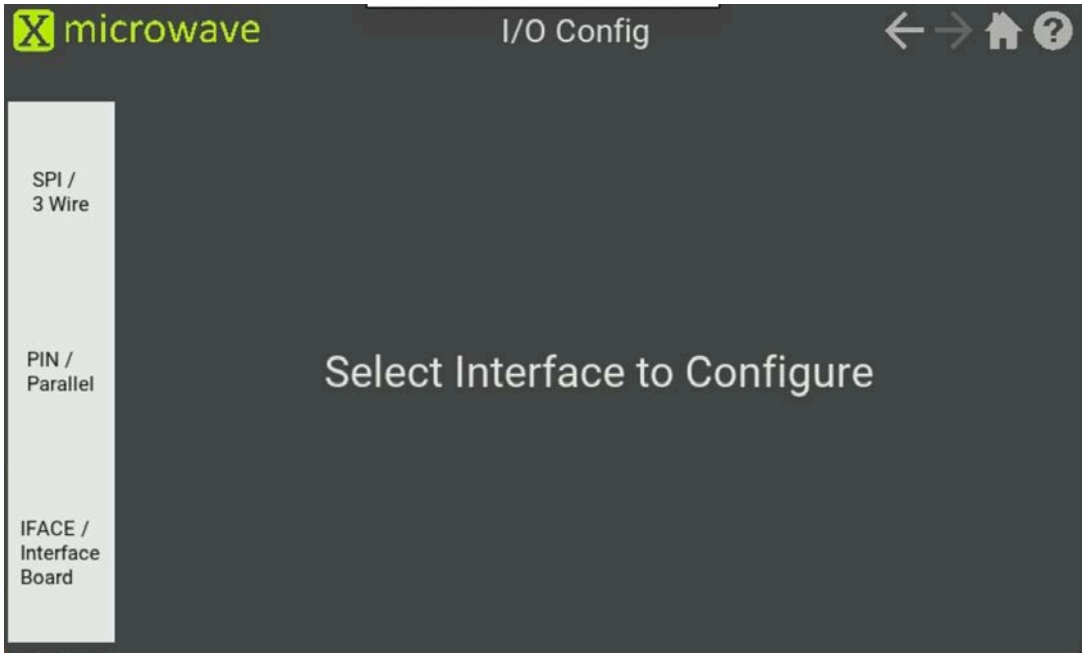
3 Select the XM-A5M6-0409D, ADF4355-3 PLL/VCO. It will be added to your list.

4 Repeat the step and add the Digital Step Attenuator: XM-A3K9-0604D, PE43713 DSA to the list.

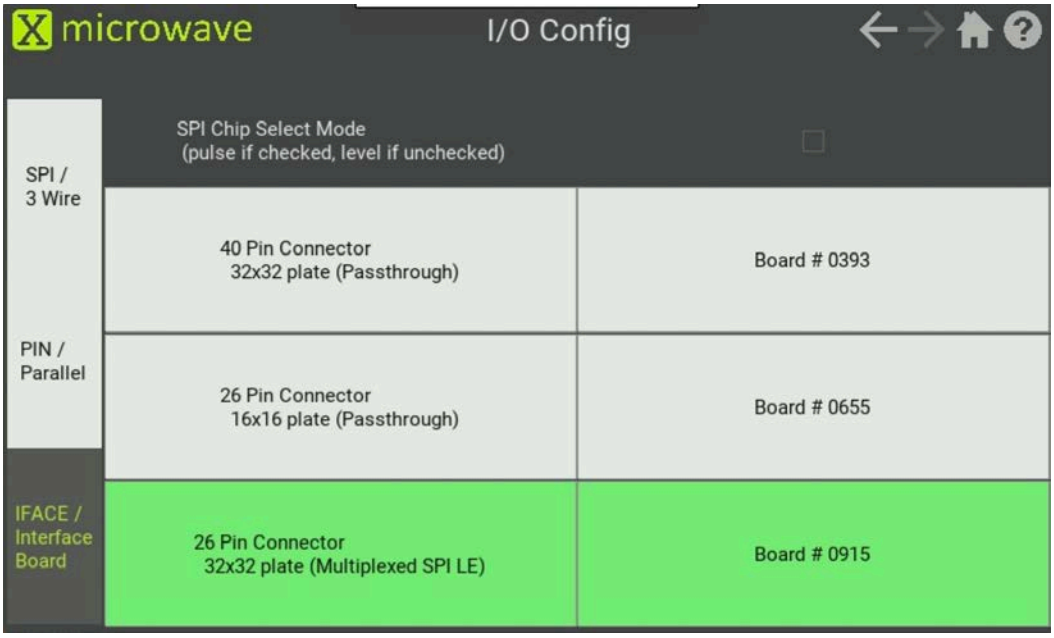
NOTE The 3-wire interface indicates serial (SPI) device while parallel indicates direct digital IO control.

5 Search for the Peregrine Digital Step Attenuator in the list. Selecting this item will add it to the Home Screen.

6 Select **I/O Config** to setup the correct Line Enable (LE) ports.

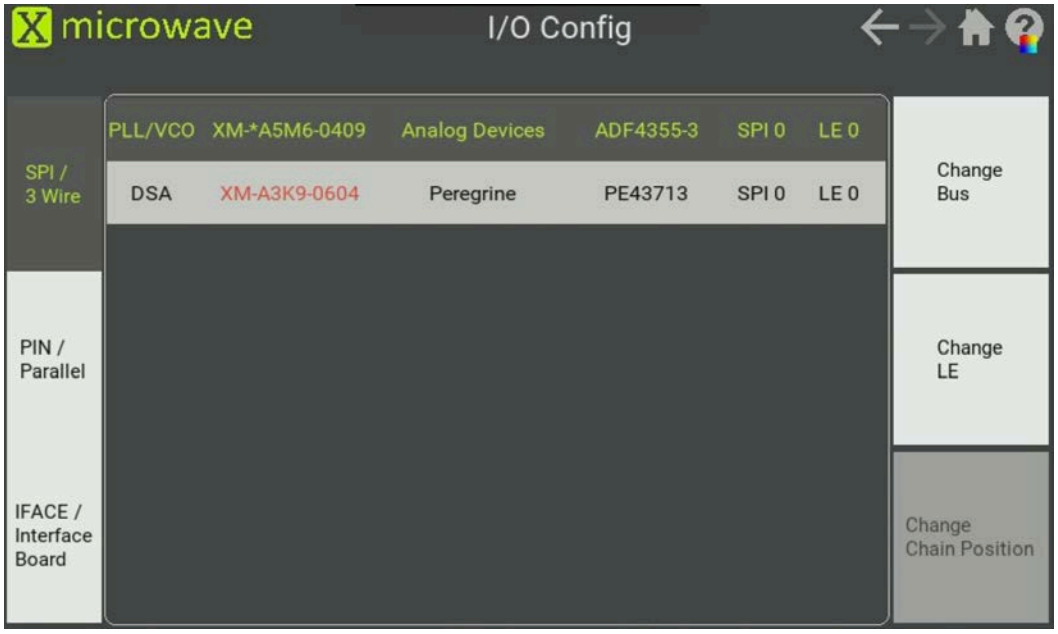


7 Select **Interface Board**.



8 Select **26 Pin Connector, Board #0915**.

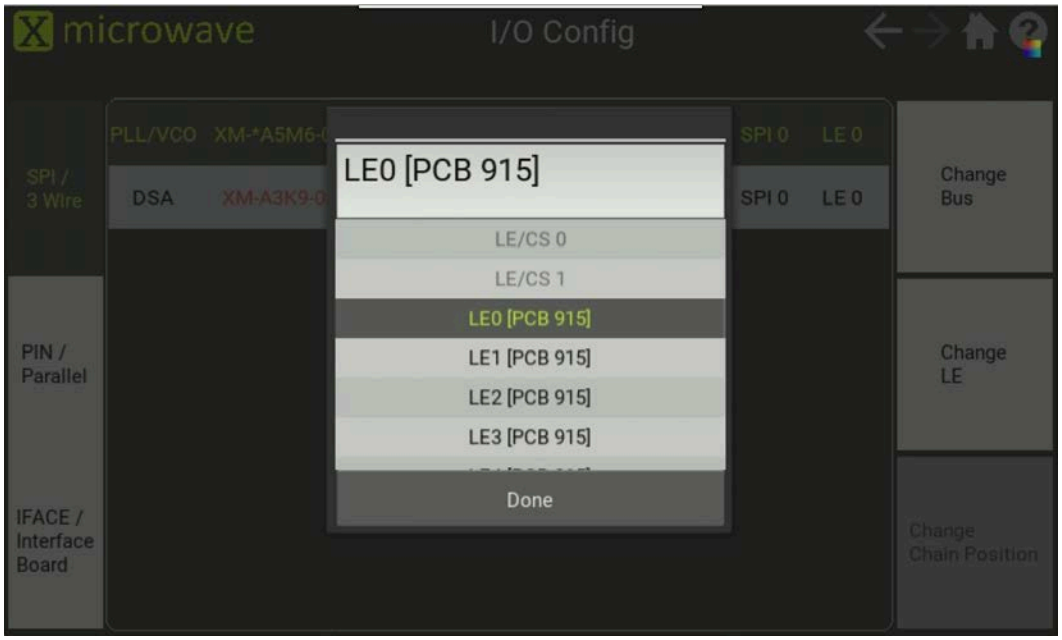
9 Select **SPI / 3 Wire** in the top right to set the Line Enable Pin for each device.



10 Select the **PLL/VCO**.

11 Select **Change LE**.

12 Set it to **LE0 [PCB 915]** and select **Done**.

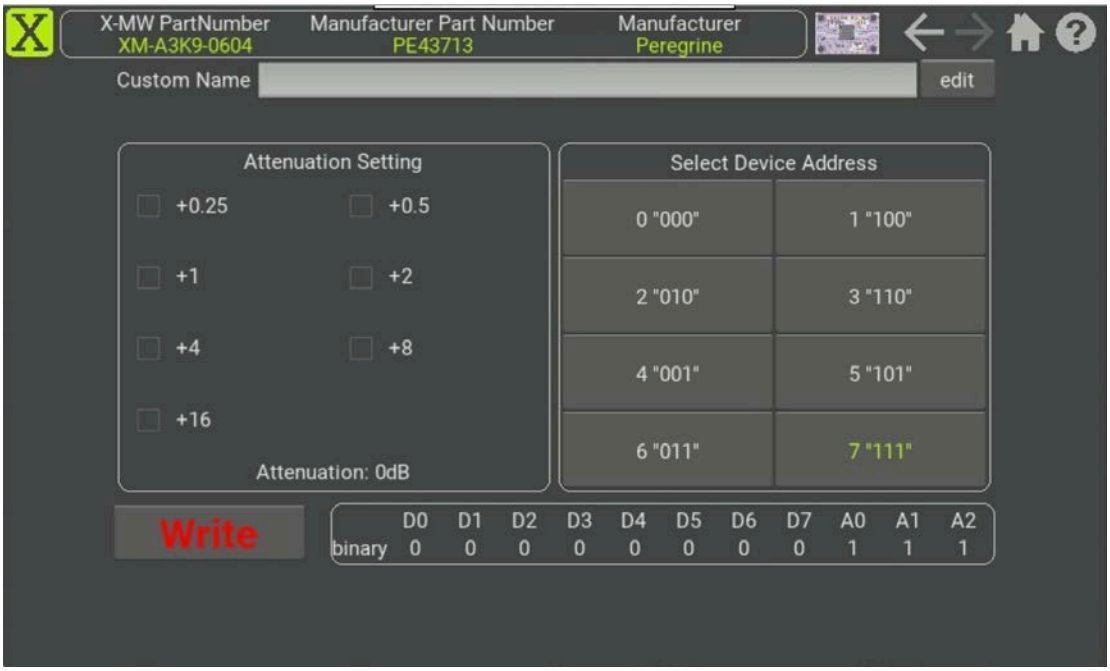


13 Repeat the procedure setting the DSA to LE1 [PCB 915].

14 Select the Home icon to go back to the main menu. It should look like the following screenshot. Pay careful attention to the MFG P/N, Bus, and Address.

15 To modify the values of the PLL/VCO or DSA, select it from the home screen.

16 For example, select DSA XM-A3K9-0604D (note the **Device Address** of the DSA is **7 “111”**).

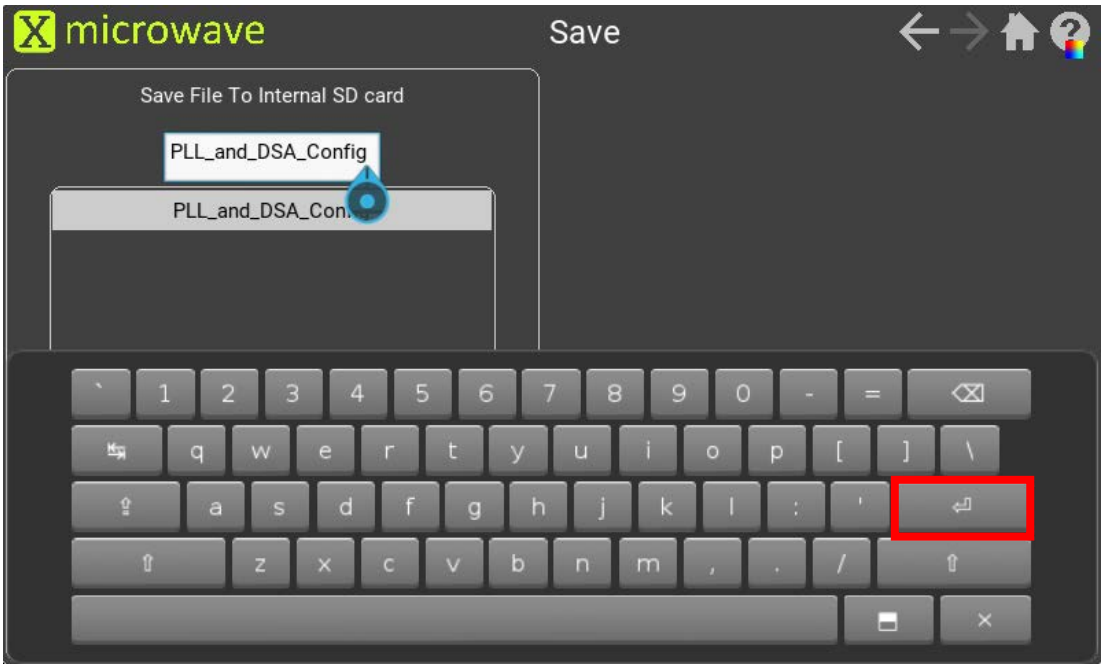


NOTE The register map is located at the bottom of the screen. It is only sent to the part when you press the **Write** button.

---

17 Select the **Home** icon and the two devices should show up on the screen with LE0 for the PLL and LE1 for the DSA. Select **Save** to save these settings.

18 Select the **Save File To** internal SD card, a keyboard should pop up. Type in a file name to save to and select the **Enter** key.



19 To recall the settings, select the **Load** and select the desired file and touch **Load From File**.

X-MWblock Default Positions and Performance Verification

The following steps should be performed at the beginning of each semester of usage of the kit to verify that the X-MWprotoplate has been returned to its original functionality.

Return Components to their Proper Positions

Ensure that all components removed from the 5G n3 Receiver have been returned to their proper positions.

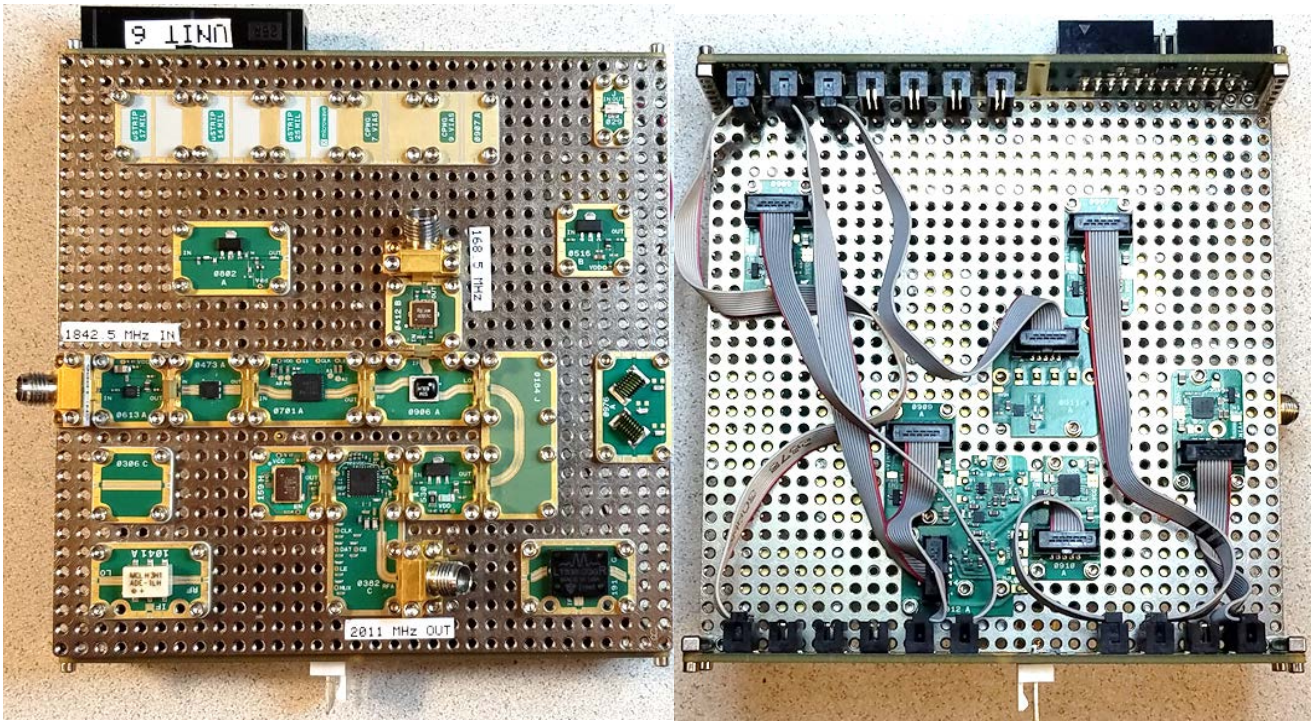


Figure 2. 5G n3 Receiver mounted on the prototyping plate on Top, Voltage Regulator and Control on Bottom

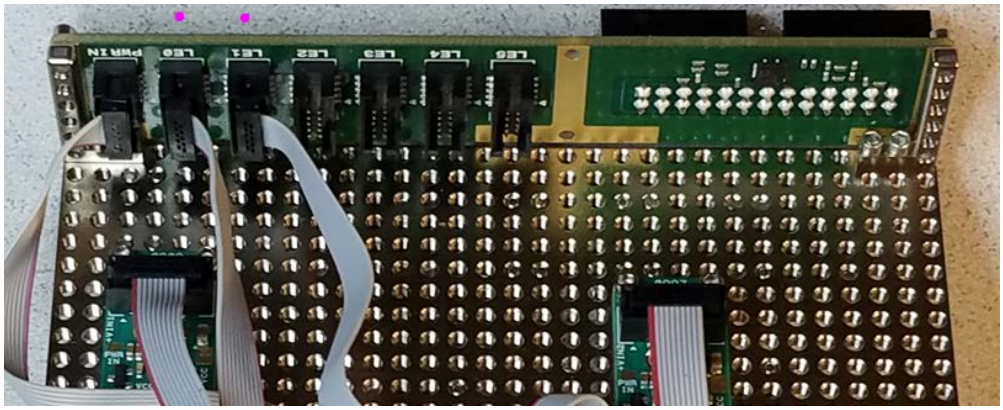


Figure 3. Latch Enables (LEs) for Control boards on Bottom with Pi Interface board

NOTE The following steps are the same as the first three measurements performed in Lab 7.

Measure the Receiver's Supply Current

This measurement can be performed directly on the Keysight E36312A Series Power Supply display.

1. Ensure **Power Source 2** (VIN2) is set to **6 V**, current limit **0.5 Amp**, and the output is turned off. The **Power Source 1** should be off.
2. Unplug one end of each of the 10-pin power and control cables from the bottom of the X-MWplate for all components that are not part of the 5G n3 Receiver. These include the HMC453ST89 Power and ADL5611 Driver Amplifier blocks.
3. Turn the output on and record the current.
4. Then, **Write** the PLL and DSA settings (loaded from the file) to the hardware using the X-MWcontroller and record the current again. Explain your results.

Table 4. Receiver Current Result

	Supply Current at 5 V
Requirement	< 500 mA (including ADL5611), otherwise < 400mA
Expected Measurement	460 mA including ADL5611, otherwise 250 mA
Actual Measurement	

Measure the Receiver's Gain

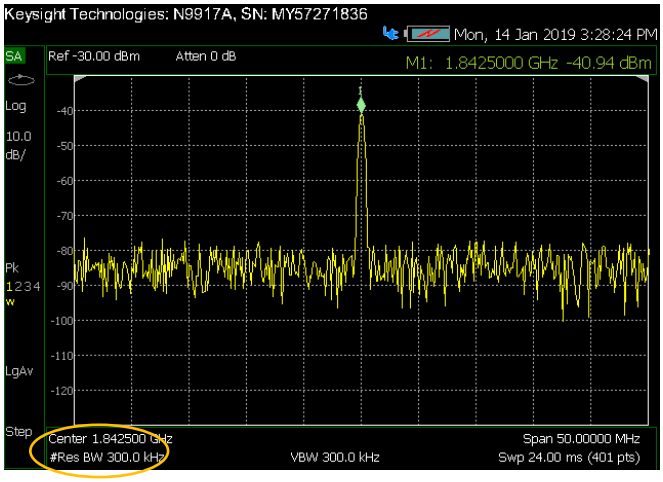
You will now measure the Gain of the receiver with a 1842.5 MHz tone using the Signal Generator (SG) and CXA Spectrum Analyzer (SA). Other sources and SA including the FieldFox internal Source and SA if so equipped may be substituted.

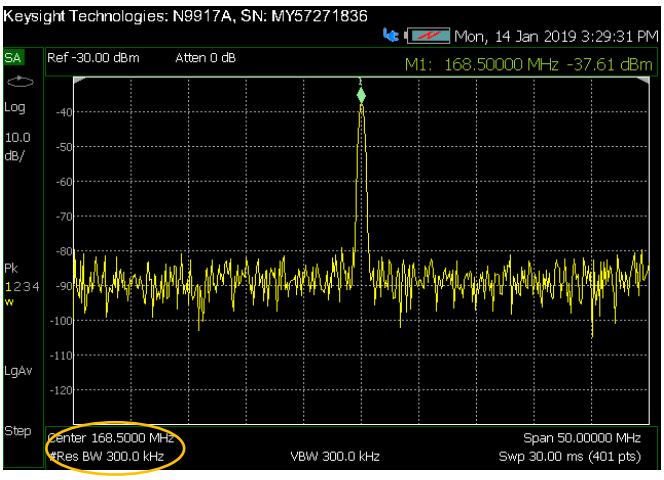
1. Continue with the Power Supply turned on.
2. Configure the SG output to 1842.5 MHz and -40 dBm.
3. Connect the cables from the SG output and the SA input together using the "through" and measure and record the power.

4. Ensure the Receiver's Local Oscillator is configured to 2011 MHz and the Digital Step Attenuator (DSA) for minimum attenuation, the 0 dB setting.
5. Disconnect the cable at the SA and reconnect it to the Receiver's RF input.
6. Connect Receiver's IF output to the SA with a different cable.
7. Measure the IF output at 168.5 MHz and record the Gain, that is the difference between the two levels.

Table 5. Receiver Gain Result

Gain	SG output	IF output	Gain
Requirement	N/A	N/A	1 dB
Expected Measurement	-41 dB	-38 dB	-38 – (-41) = 3 dB
Actual Measurement			





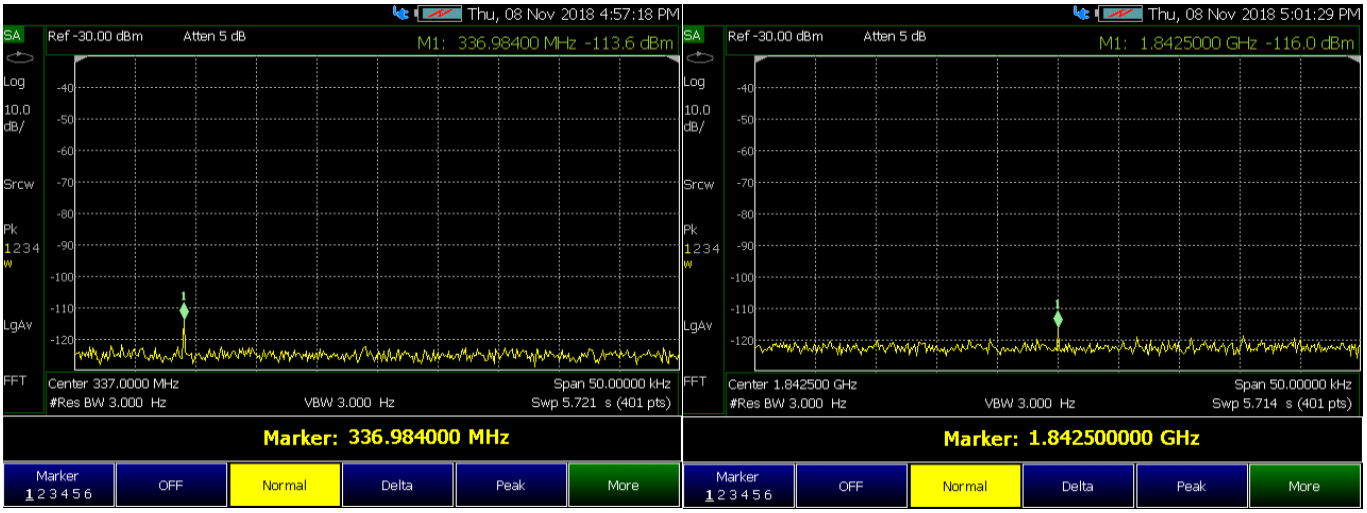
Measure the Receiver's Spurious Responses

You will now measure the spurious responses of the receiver with the same 1842.5 MHz tone at -40 dBm used above.

1. Continue with the power supply turned on, minimum attenuation and the LO at 2011 MHz.
2. Measure the spurious response at 2 × 168.5 MHz = 337 MHz.
3. Measure the spurious response at 1842.5 MHz (input feedthrough).
4. Measure the spurious response at 2011 MHz (LO feedthrough).

Table 6. Receiver Spurious Results

Spurious Responses	337 MHz	1842.5 MHz Input Feedthrough	2011 MHz LO Feedthrough
Requirement	<-100 dBm	<-100 dBm	<-80 dBm
Expected Measurement of Spurious	-113.6 dBm	-116 dBm	-73.1 dBm
Expected Spurious (re-stated) re to Input or LO	N/A	-116 - (-40) = 76 dB	-73.1 - (-1) = 72.1 dB
Actual Measurement of Spurious			
Actual Spurious (re-stated) re to Input or LO			



Troubleshooting the Signal Path

The following steps may help you find problems in the signal path that could result in low or high current draw, or poor or no signal transmission from the RF Input to the IF Output of the receiver.

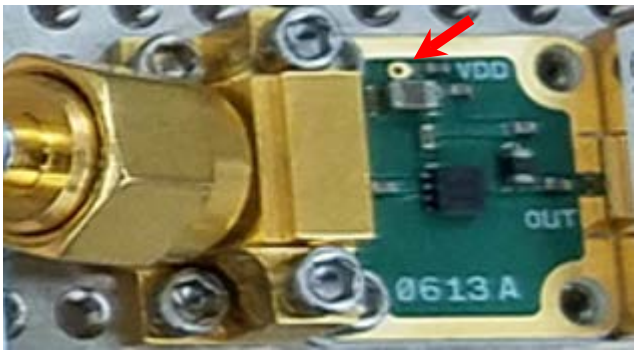
1 Verify the power input connection on the Power Interface Board.

   a Connect +VIN1 to + 6 V and verify that it is supplying approximately 750 mA to the Power Amplifier. Then disconnect or turn this supply off.

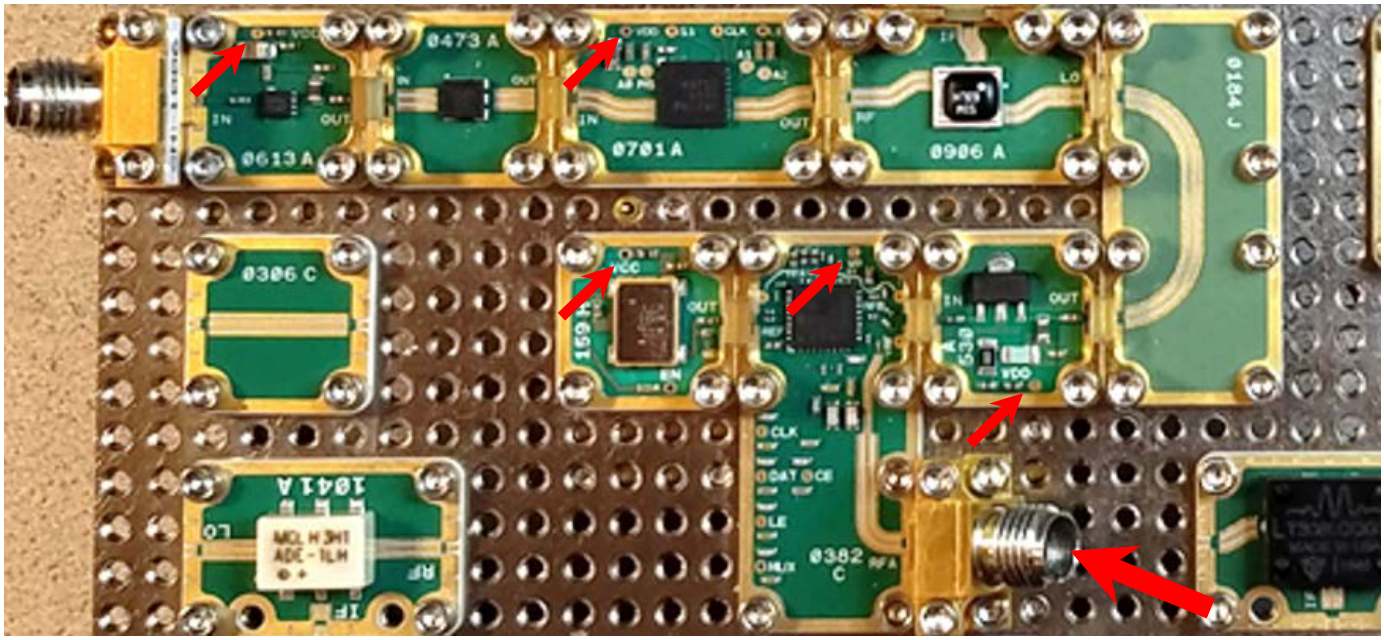
   b Connect +VIN2 to + 6 V and verify that it is supplying approximately 250 to 360 mA to the Receiver components.

   c -VIN2 should not be connected.

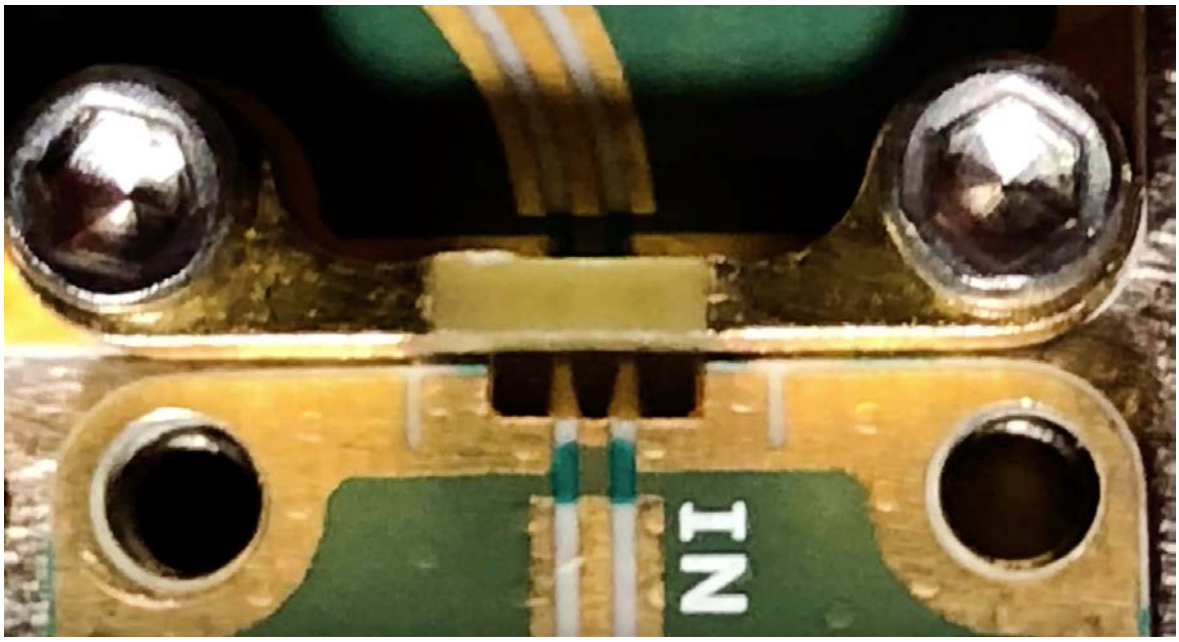
2 Verify Vdd on each X-MWblock. This can be done using a voltmeter with its COMMON input connected to the X-MWprotoplate. Use its Voltage Input to probe the Vdd or Vcc power “via” on each X-MWblock.
All Vdd = 5 V and Vcc = 3.3 V (with < 5% tolerance).



3 Verify 100 MHz is present at Output A of the PLL (large arrow, < 0.01% tolerance).



4 Lift one of each pair of X-MWanchors to verify the proper location of the GSG Jumper to ensure it is connecting the signal and not shorted to ground.



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