Si5351 SigGen/VFO

Version 1.30
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Written & Tested By:
Clint Chron – W7KEC
John Satterfield – KI5IDZ
Mark Libner – NS9N

I. OVERVIEW

A number of legacy HF transceivers produced in the 1960 to 2000 era did not have great VFOs. They were not stable, the dial readout was not accurate, and the tuning mechanism was not smooth. This article provides details on how to build an external VFO that eliminates those three problem areas. The described box can also be used as a signal generator in the frequency range of 1 MHz to 200 MHz.

There are a large number of different digital chips that can be used in a VFO. This includes the AD9834, AD9850, AD9951, Si570, and the Si5351. There are even a larger number of Web sites that sell various digital VFO kits. The following considerations were taken into account in arriving upon which particular digital chip to use:

Phase noise
Generated spurs
Generated harmonics
Available output signal drive level
Low cost

The ADxxxx chips produce excellent VFO sine wave signals, have very low phase noise, and are very stable. The one negative is that they result in a large number of receiver spurs. The Si570 chip works but I shard to find. SDR Kits offered a Si570 VFO kit, but that kit has been discontinued. The Si5351 chip works almost as good as the Si570 and is low in cost. The chip has a large number of even/odd order harmonics. This problem is resolved by using good low pass filtering in the output of the VFO.

Be sure to read the Tech Tips section in the Appendix before starting the VFO build.

A. Audience

This document is written for radio owners that want an accurate frequency display, along with a very stable VFO. A moderate set of technical skills is needed to perform the needed changes. The author is in his late 70s, has not so good close-in vision, etc. but was able to make the changes without any problems. Some SMD part soldering is needed on the main VFO circuit board. The time required for this assembly is not more than 6 - 8 hours. If one approaches the project with a systematic construction plan, then one should be successful in ending up with a fully functioning radio.

B. Objectives

This document provides details on how to build an External VFO that is very stable and provides a very accurate frequency display. The design goals were to:

Provide a detailed step-by-step process for building an external digital VFO.
Provide detailed engineering drawings that will remove confusion on how a typical radio should be modified.
Provide testing results of the installation.

C. Options

A bare bones implementation of the VFO would include the Si5351 VFO and a single low pass filter. A low pass filter is needed to remove the harmonics from the signal. Some VFOs such as the Drake TR-7 uses a single frequency range (5.05 – 5.5 MHz). For this radio, a 6 MHz low pass filter would be needed. Filters are available from QRP Labs and Mini Circuit Labs. There is enough room inside the main enclosure to attach a Mini Circuits SLP filter to the male SMA output jack on the VFO enclosure.

For an Atlas 210X/215X transceiver, the VFO frequency changes as the band is changed. A 12M low pass filter would remove most harmonics. The best option is to use a different low pass filter for each band.

A Ukraine low pass filter board is used when multiple bands are required. This filter board has seven low pass filters. The appropriate filter is selected based upon the band being used. BCD code from the VFO board is used to select the appropriate filter.

In the case of the Atlas 210X/215X radio, the following filters would be needed:

80M/20M	30M filter
40M/15M	17M filter
10M	12M filter

D. Si5351 VFO Output Signal

The output signal of the VFO board, after passing through the internal low pass filter, is about +10 dB in level. That is the right signal level for feeding most HF transceivers. An attenuator can be added if a lower signal level is needed. The output signal, after passing through the 10 db equalizer and external low pass filter is about 0 dbm.

II. SPECIFICATIONS

Here is a summary of the specs for the VFO:

Minimal cost
Code can be modified by end user
Selectable +/- IF offset by changing the code
ESP-32 chip can be programmed with a PC
About 290 ma current draw, including back-lighted TFT display

The following sections on the VFO board are connectorized:
DC power to VFO circuit board
ESP-32 microprocessor
QRP Labs Si5351 module
5.0 volt regulator
TFT Display
Front Panel Controls

Six memory channels on each band
Frequency Lock
Supports standard color TFT 170x320 display
+10.0 dbm output signal
With 1 KHz frequency step tuning – 40 KHz change per frequency control rotation
Frequency step increment selected via momentary push of toggle switch on front panel
Frequency steps of 1 Hz, 10 Hz, 100 Hz, 500 Hz, 1 KHz, 10 KHz, 100 KHz, 1 MHz, and 10 MHz
10 Hz drift after a 15 minute warmup – less than 5 Hz drift over the next 24 hours
Minimal number of spurs on all bands
Flat signal level output from 1.5 to 180 MHz

Power Supply Dissipation with 13.8 volts supply

10 ohm resistor	0.7 watts	power to 9 volt regulator
9 V regulator	0.5 watts	power to 3.3 V and 5 V voltage regulators and R5
5 V regulator	0.2 watts	power to Si5351 oscillator board
3.3 V regulator	0.6 watts	power to ESP-32, TFT display, & optical encoder
R5	0.3 watts	power to GALI-6 MMIC

III. Project Description

A. Mini-Project Tasks

The project can be divided into the following mini-projects:

Procure Parts
Machine the die cast aluminum VFO enclosure
Build QRP Labs Si5351 Oscillator
Fabricate Front Panel wiring harness
Fabricate VFO wiring harness
Program ESP-32
Build Si5351 VFO Assembly
Initial testing
Install low pass filter board in main enclosure
Install VFO enclosure in main enclosure
Final Installation and Testing

B. Parts Procurement

In order to get needed parts for the project, you will need to place several different orders. Parts can be obtained from AliExpress, Amazon, eBay, Jameco, Mouser, etc. With the current tariffs, the total cost for parts is less than $200, if you can buy in single lot quantities.

Here is a picture of the major components used in the project:
The small chip in the lower right hand corner is the MCL GALI-6 MMIC.

Bare Printed Circuit Boards
VFO board
Enclosure Front Panel
TFT Display Mounting Bracket

Populated Printed Circuit Boards
TFT Display
Ukraine Low Pass Filter Board
QRP Labs Si5351 Oscillator Board
ESP-32 microprocessor
3.3 volt regulator
5 volt regulator

5/64" four flute End Mill
The end mill is needed for the milling machine or a drill press.
https://www.amazon.com/dp/B0D52S29YW?ref=ppx_yo2ov_dt_b_fed_asin_title&th=1

ESP-32 Microprocessor board
https://www.aliexpress.us/item/2251832791060787.html?spm=a2g0o.order_list.order_list_main.10.73d71802FGFiyW&gatewayAdapt=glo2usa

TFT Color 170x320 1.90" Display
https://www.aliexpress.us/item/3256805935800579.html?spm=a2g0o.order_list.order_list_main.35.20621802lIiJvW&gatewayAdapt=glo2usa

SMA Female Chassis Bulkhead Mount
10pcs SMA Female Jack Bulkhead Nut Surface Connector Solder Panel Mount RF Coaxial Brass 50ohm Wire Terminals Straight New - AliExpress 13

Hammond 1590A Clone die cast aluminum enclosure – VFO Enclosure
https://www.aliexpress.us/item/3256802438032687.html?spm=a2g0o.order_list.order_list_main.55.3d571802V9lNu1&gatewayAdapt=glo2usa

Hammond 1455N1201BK enclosure – Main Enclosure
https://www.hawkusa.com/manufacturers/hammond-mfg/enclosures/box-metal/1455n1201bk?gad_source=1&gclid=Cj0KCQjwqcO_BhDaARIsACz62vNzv60_8X_BhhFiabZjBbFbvo_6H8enDuHVfU-tNzc5uHFsPRrZmr4aAhEYEALw_wcB

AMS-1117 5 volt voltage regulator
1/5/10PCS AMS1117 3.3V 5V DC-DC Step-Down power supply module AMS1117-5.0V Power Buck module AMS1117-3.3V LDO 800MA - AliExpress 502

AMS-1117 3.3. volt voltage regulator
Amazon.com: AMS1117-3.3 DC 4.75V-12V to 3.3V Voltage Regulator Down Power Supply Buck 800mA Module 3Pin 20pcs : Electronics

Here is a link that gives the specs for the 3.3 volt and 5 volt regulator chips:
http://www.advanced-monolithic.com/pdf/ds1117.pdf

78M09 9 volt SMD voltage regulator
10pcs/lot L78M05CDT L78M05 TO-252 78M06 78M08 78M09 78M12 78M15 79M05 - AliExpress 502

RF Choke SMD
100 uh 1210
20PCS/LOT 1210 SMD Inductance 2.2/3.3/4.7/10/22/47/100/220/470UH NLV32 3225 Inductor - AliExpress 13

Resistors – 1206 SMD
20 ohm
240 ohm 2 each
https://www.aliexpress.us/item/3256803911285437.html?spm=a2g0o.order_detail.order_detail_item.3.5c20f19cGsWJq4&gatewayAdapt=glo2usa

Resistor – through hole 1/2 watt
56 ohm
https://www.aliexpress.us/item/3256805535539702.html?spm=a2g0o.order_list.order_list_main.55.5b671802yccQDs&gatewayAdapt=glo2usa

Resistors – through hole 1/4 watt
180 ohm
2.2K ohm 3 each
100pcs 1/4W 1R~22M 1% Metal film resistor 100R 220R 1K 1.5K 2.2K 4.7K 10K 22K 47K 100K 100 220 1K5 2K2 4K7 ohm resistance - AliExpress 502

Ceramic disc capacitors – through hole
0.1 uf 50 volt 5 each
0.01 uf 50 volt 5 each
https://www.aliexpress.us/item/3256804674697278.html?spm=a2g0o.order_list.order_list_main.15.21ef18020epeZ5&gatewayAdapt=glo2usa

Ceramic disc capacitors – SMD
0.1 uf 50 volt 1 each
100PCS 1206 104 SMD Capacitor 4.7NF 10NF 22NF 47NF 100NF 220NF 50V 472 103 223 473 224 k/m/z 0.01/0.022/0.047/0.1/0.22/uf Kit - AliExpress 502

Ceramic disc capacitors – SMD
36pf 50 volt 1 each
https://www.aliexpress.us/item/3256806963299575.html?spm=a2g0o.productlist.main.21.2178d019j31JKm&algo_pvid=f1cda098-563e-4d55-90ac-900ee404919e&algo_exp_id=f1cda098-563e-4d55-90ac-900ee404919e-10&pdp_ext_f=%7B%22order%22%3A%22350%22%2C%22eval%22%3A%221%22%7D&pdp_npi=4%40dis%21USD%213.13%213.13%21%21%2122.96%2122.96%21%402103247017442207622812324ec19a%21120000039594973937%21sea%21US%213978472839%21X&curPageLogUid=2pcs3j09D6Ch&utparam-url=scene%3Asearch%7Cquery_from%3A

Tantalum capacitors – through hole
10 uf 16 volt 3 each
22 uf 16 volt 1 each
100 uf 25 volt 1 each
10PCS Tantalum Capacitor 16V 20V 25V 35V 50V 0.1UF 0.22UF 0.33UF 0.47UF 100UF 220UF 1UF 2.2UF 4.7UF 10UF 15UF 22UF 47UF DIP - AliExpress 502

Resettable Fuse – 72 volt 500 ma (Trip point = 1000 ma)
https://www.aliexpress.us/item/3256801635578473.html?spm=a2g0o.order_list.order_list_main.103.46a81802yPc6Ic&gatewayAdapt=glo2usa

1N4001 Diode
100pcs 1N4001 IN4001 Rectifier Diode 1A 50V DO-41 New Original - AliExpress

Brass Standoffs 4-40 x 5mm - 4 each
2-50pcs M2 M2.5 m3 m4 m5 m6*L hex brass standoff female to female thread brass spacer length 3mm to 50mm - AliExpress

Bourns Optical Encoder
https://www.ebay.com/itm/295327320682

Momentary Pushbutton Switch
https://www.aliexpress.us/item/2255799950576497.html?spm=a2g0o.order_list.order_list_main.49.2a9a18026Ot1Hk&gatewayAdapt=glo2usa

SPDT Toggle Switch – ON/OFF/ON – both sides momentary ON
10Pcs T8014A Standard Lever 3Pin Momentary MOM-OFF-MOM Self-Return 3-Position SPDT Mini Toggle Switch - AliExpress 13

SPDT Toggle Switch - ON/OFF/OFF – both sides latching
https://www.aliexpress.us/item/2251832729149547.html?spm=a2g0o.detail.pcDetailBottomMoreOtherSeller.18.4eeeWJU0WJU0gf&gps-id=pcDetailBottomMoreOtherSeller&scm=1007.40196.394786.0&scm_id=1007.40196.394786.0&scm-url=1007.40196.394786.0&pvid=5ede110b-6c9e-47db-a7d6-3b77d84c0001&_t=gps-id:pcDetailBottomMoreOtherSeller,scm-url:1007.40196.394786.0,pvid:5ede110b-6c9e-47db-a7d6-3b77d84c0001,tpp_buckets:668%232846%238107%231934&pdp_ext_f=%7B%22order%22%3A%2219%22%2C%22eval%22%3A%221%22%2C%22sceneId%22%3A%2230050%22%7D&pdp_npi=4%40dis%21USD%214.20%214.20%21%21%214.20%214.20%21%402103245417438983355265935e0bee%2166380523246%21rec%21US%213978472839%21XZ&utparam-url=scene%3ApcDetailBottomMoreOtherSeller%7Cquery_from%3A

SPDT Toggle Switch – ON/OFF (MTS-102)
https://www.aliexpress.us/item/3256808203625119.html?spm=a2g0o.productlist.main.47.51832827fyki52&aem_p4p_detail=202504051730039376052429001000043037 84&algo_pvid=40ad409c-6eb0-48f0-8545-6556cb808562&algo_exp_id=40ad409c-6eb0-48f0-8545-6556cb808562-23&pdp_ext_f=%7B%22order%22%3A%2249%22%2C%22eval%22%3A%221%22%7D&pdp_npi=4%40dis%21USD%213.03%212.86%21%21%2121.87%2120.64%21%402101ef5e17438994032026321e0e32%2112000044823342438%21sea%21US%213978472839%21X&curPageLogUid=WBHubKuusB6f&utparam-url=scene%3Asearch%7Cquery_from%3A&search_p4p_id=202504051730039376052429001000043037 84_6

Machine screw M2x5 Phillip's head - 4 each
Machine screw M2x4 Phillip's head - 4 each
200/ 100/ 50pcs M1 M1.2 M1.4 M1.6 M1.7 M2 M2.5 M3 M3.5 M4 M5 304 Stainless Steel Phillips Cross Recessed Pan Head Screws DIN7985 - AliExpress

Machine screw M2x4 Counter-sunk Phillip's head - 4 each
50PCS M2*3 3.5 4 5 6 8 10 12 16 18 20 25 304 Stainless Steel Cross Phillips Flat Countersunk Head Screw Bolt M2x3 M2x12 M2x25 - AliExpress 13

Machine screw M2.5x4 Phillips Truss head – 2 each
https://www.aliexpress.us/item/3256801978454684.html?spm=a2g0o.order_list.order_list_main.19.4575180200AlqQ&gatewayAdapt=glo2usa

Machine screw M2.5x4 Phillips Truss head – 2 each
https://www.aliexpress.us/item/3256801978454684.html?spm=a2g0o.order_list.order_list_main.19.600d1802yMXSMp&gatewayAdapt=glo2usa

QRP Labs Si5351 Oscillator with TCXO option
https://www.qrp-labs.com/synth.html

HF Low Pass Filter Board (eBay seller is 60dbmco from the Ukraine)
https://www.ebay.com/itm/334454204660

RG402 Cable – 4" with SMA connectors
Male right angle SMA on one end and male SMA on the other end
https://www.aliexpress.us/item/3256804552802118.html?spm=a2g0o.productlist.main.17.395cjPIsjPIsHt&algo_pvid=4113c97a-2e54-4fd1-8a56-75bb10125553&algo_exp_id=4113c97a-2e54-4fd1-8a56-75bb10125553-8&pdp_ext_f=%7B%22order%22%3A%2260%22%2C%22eval%22%3A%221%22%7D&pdp_npi=4%40dis%21USD%212.53%212.53%21%21%212.53%212.53%21%402103205217439449580971870ebc63%212120000030297775028%21sea%21US%213978472839%21X&curPageLogUid=e9IazXmnU2bx&utparam-url=scene%3Asearch%7Cquery_from%3A

Male and female pin headers
20 Pcs 10 Pairs 40 Pin 1x40 Single Row Male And Female 2.54 Breakable Pin Header PCB JST Connector Strip For Arduino DIY Kit - AliExpress 13

Mini Circuits Gali-6 MMIC
https://www.mouser.com/ProductDetail/Mini-Circuits/GALI-6%2B?qs=xZ%2FP%252Ba9zWqb5emXNudX23g%3D%3D

Ribbon cable multi-colored – 16 wire
14 inches
2Meter 6P/8P/10P/12P/16P/20P/40P 1.27mm PITCH Grey Flat Ribbon Cable 6/8/10/16/20/40 Pin 28AWG WIRE for IDC FC 2.54MM Connector - AliExpress 13

IDC ribbon female cable connector – 16 pin
Idc Connector 10 Female | Idc Female Connector 26 Pin | 34 Pin Female Connector - Connectors - Aliexpress

DC Power Jack – 5.5mm x 2.1 mm
Amazon.com: DC Power Jack Socket, 4-Pack 5.5mm x 2.1mm Barrel Mounting Female Panel Mount Solder Power Supply Jack Connector Adapter Socket : Electronics

DC Power Plug – 5.5mm x 2.1 m
Amazon.com: AiTrip 20pcs 5.5mm x 2.1mm DIY Male DC Power Plug Jack Solder Connector Adapter : Electronics

Internal DC Power Cable – JST XH 2 pin
10Sets 2/3/4/5/6/7/8/9/10 Pin Pitch Male Female Plug Socket JST XH2.54 XH 2.54mm 15cm Wire Length 24AWG Wire Cable Connector - AliExpress 13

External DC Power Cable JST SM 2 pin
https://www.aliexpress.us/item/2255801107031792.html?spm=a2g0o.order_list.order_list_main.139.6c431802cYTdvP&gatewayAdapt=glo2usa

Terminal Solder Lug M3.2 – 2 each
https://www.aliexpress.us/item/3256804355897571.html?spm=a2g0o.order_list.order_list_main.263.4a681802gWAffK&gatewayAdapt=glo2usa

#24 solid conductor tinned buss wire
https://www.amazon.com/Jameco-Valuepro-3819-100-Hook-up-Tinned-Copper/dp/B00B8866TW?source=ps-sl-shoppingads-lpcontext&ref_=fplfs&psc=1&smid=ATVPDKIKX0DER

FB43-101 Ferrite Bead
https://toroids.info/FB-43-101.php

Heat Shrink Tubing
https://www.aliexpress.us/item/3256805376954605.html?spm=a2g0o.order_detail.order_detail_item.11.2f8bf19cKsC0HL&gatewayAdapt=glo2usa
1 mm x 2” yellow – RF out and Si5351 jumper
2 mm x 6” black – TFT pin header, encoder, LPF Male Pin Headers
3 mm x 3” black – internal & external ground lug, toggle switches
3 mm x 3” green – toggle switches
4 mm x 0.5” blue - Feedthrough power lead
6 mm x 1” blue – 2 watt power resistor
12mm x 0.5” black – encoder

Tie Wraps – black 100mm long
https://www.aliexpress.us/item/3256801258424718.html?spm=a2g0o.order_list.order_list_main.43.80101802dwzxpD&gatewayAdapt=glo2usa

VFO Tuning Knob – 32 mm – black
Various models on AliExpress

IV. VFO Front Panel Control Descriptions

A. Frequency Tuning

Tuning knob is attached to a Bourns optical encoder

B. Frequency Lock

Toggle switch located below the Frequency Tuning control.
Has two positions – OFF and ON

C. Power Switch

Toggle switch that has three positions.
Center position is OFF.
Right position is ON.
Left position is ON and the low pass filter board is placed in the Bypass state.

D. Frequency Step

Push button switch with momentary ON
Each push of the switch moves to the next frequency step.
In the Atlas mode, the frequency steps are 10 Hz, 100 Hz, 500 Hz, 1 KHz, and 10 KHz.
In the Sig Gen mode, the frequency steps are 1 Hz, 10 Hz, 100 Hz, 500 Hz, 1 KHz, 10 KHz, 100 KHz, 1 MHz, and 10 MHz

E. MODE

Toggle switch with three positions with momentary ON for left and right positions
MEM position cycles through six different memory channels (A through F)
There are two band modes – Sig Gen and Atlas.

There are five different bands for Atlas (80M – 10M). Each band has five memory positions. The displayed frequency is the generated frequency +/- 5645 KHz offset. The ESP-32 code can be modified to support almost any IF offset.

In the Sig Gen mode, the displayed frequency is the actual frequency being generated.

V. Enclosure Machine Work

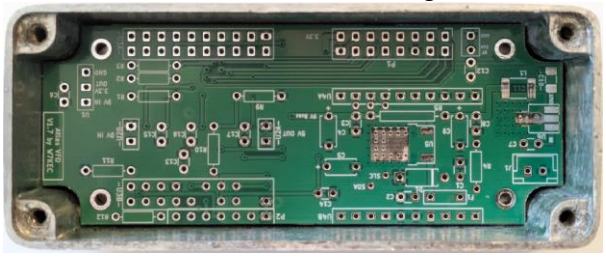
The SI5351 VFO enclosure machine work should be completed before the VFO circuit board is assembled.
The time required to complete this work is 30 - 60 minutes.
The project requires the following machine work:

Clean up any casting debris on the inside and outside of the enclosure. There may be aluminum fingers sticking up from the bottom inside of the enclosure near the four casting circles.

With the picture as a guide, use an extra fine point Sharpie to label the outside of the enclosure walls:

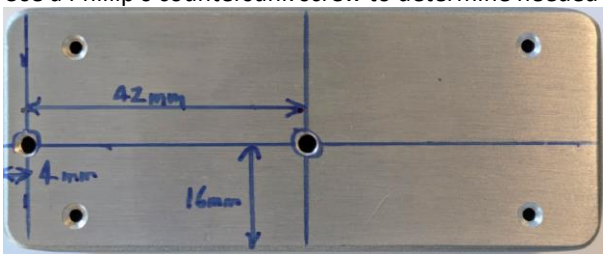
Feedthrough	Right side wall	this is the DC power feed terminal
Ribbon	Top center wall	the SMA jack is also on this wall
USB	Left side wall	optional access opening for USB plug
Clearance	Bottom side wall	no milling/drilling on this wall

Place the VFO circuit board inside the enclosure. Ensure that the circuit board is fully seated against the bottom of the enclosure – it will be a tight fit.



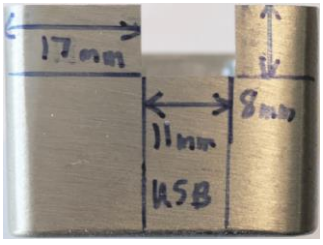
Using the four circuit board mounting holes as a guide, drill four each 5/64" holes in the bottom of the enclosure. Ensure that the drill bit is centered in each circuit board hole so that you do not remove any circuit board material while you are drilling. Also ensure that you have a sharp drill bit. Otherwise, the end of the bit will wander when you start to drill.

Remove the circuit board from the enclosure.
Counter sink the holes on the outside bottom of the enclosure.
Use a Phillip's countersunk screw to determine needed depth of counter sunk holes.



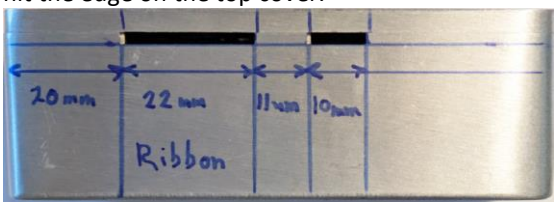
On the USB wall, cut a rectangle 11 mm wide by 8 mm high. The left edge of the rectangle should be 17 mm from the Ribbon wall. The size of the opening will depend up the size of the Micro USB connector that you use.

USB Wall

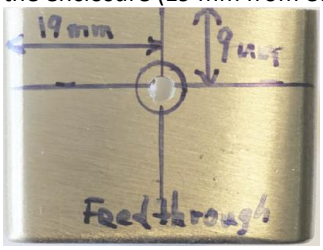


Write USB on the top cover next to the notch in the USB Wall.

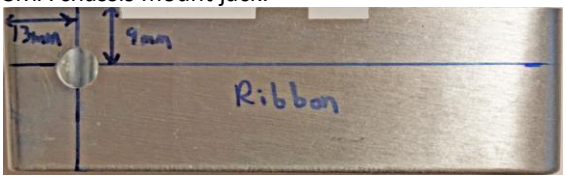
Cut two notches in the enclosure on Ribbon side. These notches are for the 16 wire and 6 wire ribbon cables. The 16 wire notch should be 20 mm from the Feedthrough end. It would be 22 mm wide and 1.5 mm deep. The 6 wire notch should be 10 mm wide and 1.5 mm deep. Cut matching notches in the enclosure cover. The wide notch should be 25 mm wide so that the IDC connector keeper bar edges will not hit the edge on the top cover.



Drill a 7/64" OD hole on the end of the enclosure labeled Feedthrough. Center the hole across the width of the enclosure (19 mm from edge) and 9 mm down from the top edge.



On the Ribbon wall, drill a ¼" OD hole 13 mm from Feedthrough wall and 9 mm from the top edge for the SMA chassis mount jack.



Remove all traces of the Sharpie pen markings from the enclosure.
All milling/drilling work is now complete on the enclosure.

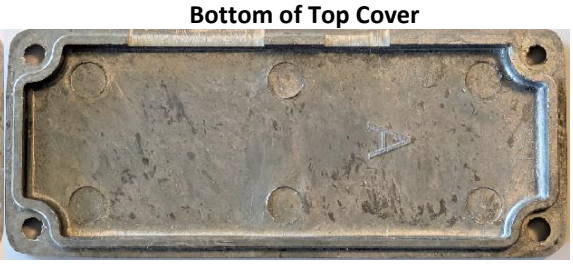
Here are top, bottom, inside, and side views of the completed enclosure:

Top Cover

Bottom

Inside Enclosure

Bottom of Top Cover



Ribbon

Clearance

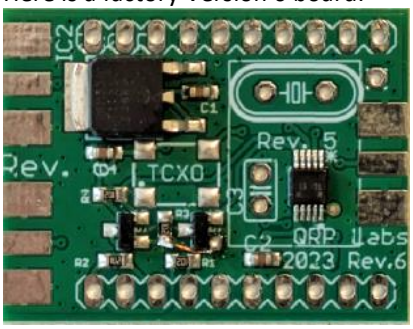
USB

Feedthrough

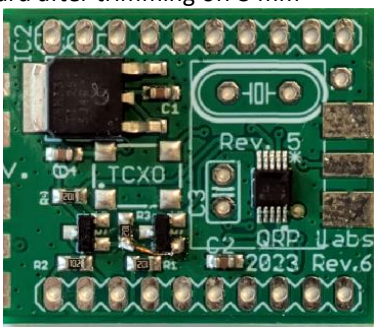
VI. Build QRP Labs Si5351 Oscillator Board

The QRP Labs Si5351 oscillator board plugs into the VFO circuit board. It needs to be shorted so that it will fit into the enclosure. Cut off a max of 4 mm and min of 3 mm of circuit board material from the end that has the Clock 1 and Clock 2 solder pads. The solder pads are 4 mm long. Clock 1 and Clock 2 are not used for the VFO. However, those two signals are still present on the board's IO header pins 19 and 20.

Here is a factory Version 6 board.



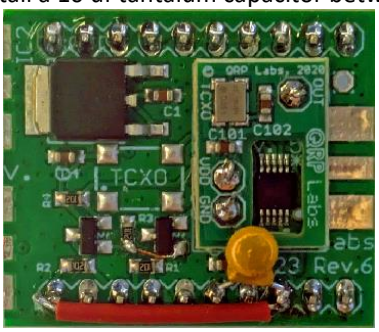
Board after trimming off 3 mm



Build the board per the info in this link:
https://qrp-labs.com/images/synth/synth_assembly6.pdf

Solder two single row male pin headers onto the oscillator board.
Cut off pins 19 and 20 on the male pin header (clock 1 and clock 2).

Do not install the crystal on the board.
Install the TCXO module on the Si5351 oscillator board per QRP Labs instructions.
On the top side of the circuit board, connect a jumper from pin 11 to pin 18.
Install a 10 uf tantalum capacitor between Pin 18 and Pin 16 (ground). Observe polarity.



Carefully inspect the solder connections on the bottom of the board. Set aside the oscillator board.
Here is some technical info about the Si5351 chip used on the board:
https://qrp-labs.com/synth/ms5351m.html

VII. VFO Enclosure Interfacing

Four cables are used to interface the VFO enclosure to main enclosure. These consist of a 16 wire ribbon cable, a 6 wire ribbon cable, a DC power cable, and a RG402 coax cable.

A. 16 Wire Ribbon Cable

The 16 wire ribbon cable performs three functions:
Interfaces to TFT display
Interfaces to front panel controls
Interfaces to optical encoder

Cut a 16 wire ribbon cable to 7".
Crimp an IDC connector on the end of the cable. Be sure to observe the cable color code. Ensure that the key on the 16 pin IDC connector will be on the inside of the enclosure – i.e. it should not be touching the wall of the enclosure.

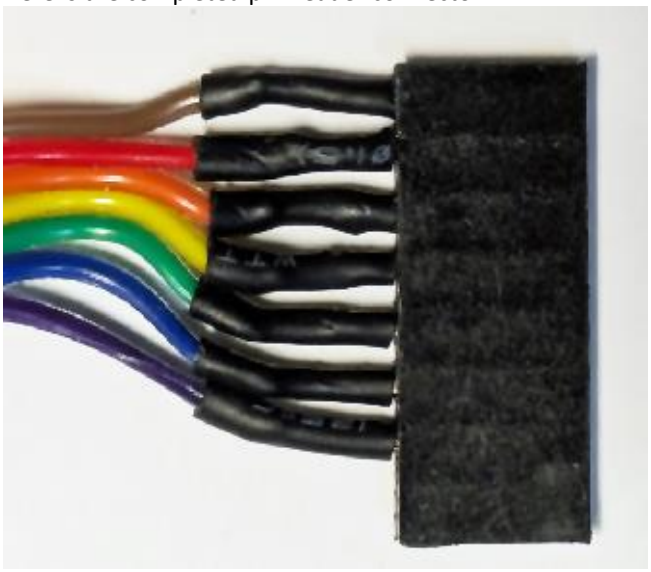
Install the protector bar on the top of the IDC connector and fold the ribbon cable over the top of the protector bar.

Separate 7 wires from the main body of the cable, starting with the outside brown color. Ensure that you do not pull a wire out of the insulation. The wire colors should be brown, red, orange, yellow, green, blue, and violet. These wires will interface with the TFT display.

Separate 4 wires from the main body of the cable. The wires colors will be gray, white, black, and brown. These wires will interface with the optical encoder.

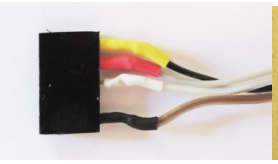
Ensure that a factory pin male header is soldered to the TFT display. Cut off pin 8.
Solder an 8 pin female pin header to 7 ribbon cable wires.

Here is the completed pin header connector:



Solder a female 5 pin header to the brown, white, gray, and black wires on the 16 wire ribbon cable. Put a large piece of black heat shrink around the ribbon cable before soldering the wire connections. Put ¼" pieces of black heat shrink around each individual pin. This header is for the optical encoder. Cut off the NC pin 4 on the encoder.

Put heat shrink tubing around the wires of the ribbon cable.



B. 6 Wire Ribbon Cable

The 6 wire ribbon cable performs provides the 5 volt power to the low pass filter board and provide 4 BCD lines to control the low pass filter relays.
Install a 4 pin female pin header on the 6 wire ribbon cable. Note color coding of wiring.
Pin 7 is not used.

Install a 3 pin female header on the 6 wire ribbon cable.

C. Ground Buss Wiring Harness

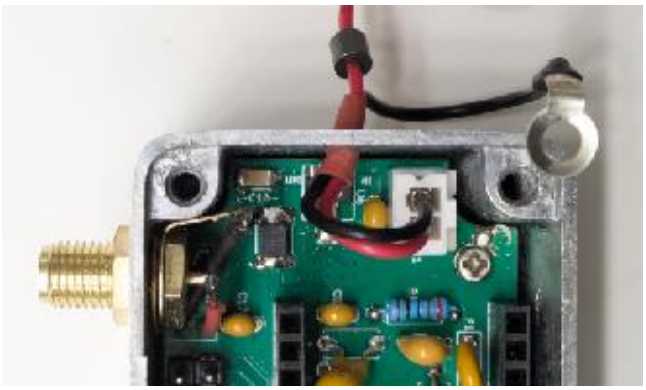
Two ground wires are soldered to a terminal lug. One wire goes to the black DC power jack on the back panel. The second ground wire goes to the female pin header attached to the front panel wiring harness.

A second ground wire is soldered to a second terminal number. This ground wire goes to the power lead that is routed through the feedthrough hole on the VFO enclosure.

D. DC Power Wiring

Route the red/black DC power cable through the Feedthrough hole (cable with white female connector on the end). Install heat shrink tube around the two wires where they go through the side of the enclosure. Put a drop of super glue on the heat shrink where is goes through the hole.

On the red wire outside the enclosure, slide on a FB43-101 ferrite bead. It will initially be a tight fit. Solder a single pin male header to the end of the red wire. Solder a terminal lug on the end of the black wire.

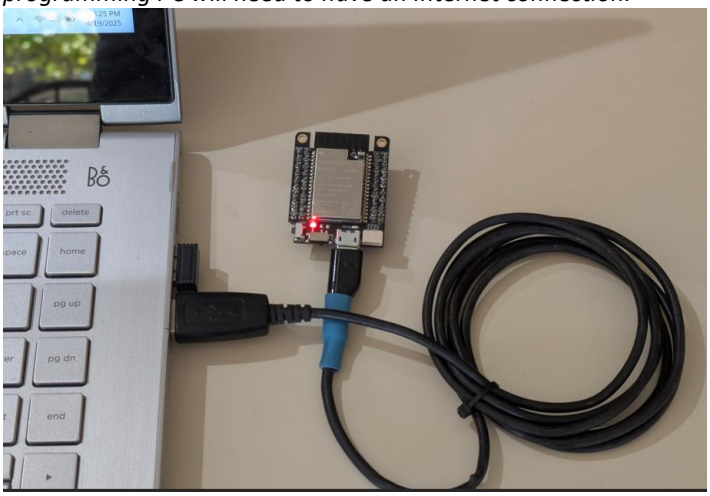


Take a piece of 10" red Teflon insulated stranded wire and solder a female pin header on one end of the wire. Install heat shrink around the male and female pin headers.

VIII. Program ESP-32 Microprocessor

Caveats:
This installation process has been tested on Windows 10 and Windows 11.

The following steps assume that the Arduino IDE app has never been installed on the PC. It is also assumed that the ESP-32 module is not installed in the VFO box and that it is connected to a USB port of a PC. The programming PC will need to have an Internet connection.



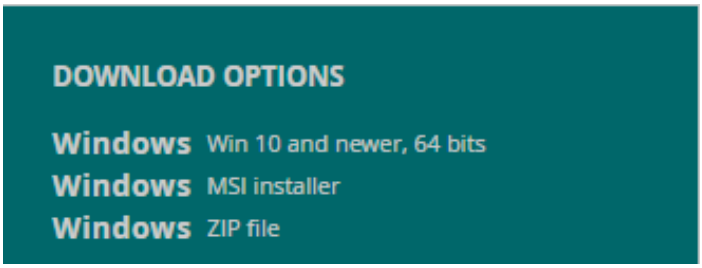
You will need to get the SigGen032.zip file in order to program an ESP-32 module. This file will be available from John Satterfield or Clint Chron. The Arduino IDE app version 2.3.6 will be used to program the ESP-32.

On your PC, create a subdirectory C:/SigGen032 and download the SigGen032.zip file. Unzip the file. Ensure that the ino file is named SigGen032.ino.

Name	Date modified	Type	Size
config.h	4/16/2025 3:41 PM	H File	32 KB
dial.cpp	4/10/2025 1:18 PM	CPP File	13 KB
dial.hpp	4/10/2025 1:18 PM	HPP File	2 KB
encodersetup.h	4/10/2025 1:18 PM	H File	1 KB
si5351mcu.cpp	4/10/2025 1:18 PM	CPP File	16 KB
si5351mcu.h	4/10/2025 1:18 PM	H File	6 KB
SigGen032.ino	4/16/2025 3:51 PM	INO File	50 KB
ST7735S_128x160.hpp	4/10/2025 1:18 PM	HPP File	9 KB
ST7789_170x320.hpp	4/10/2025 1:18 PM	HPP File	11 KB
ST7789_240x320.hpp	4/10/2025 1:18 PM	HPP File	8 KB

On your PC, open a web browser to the Arduino Web site
https://www.arduino.cc/en/software

Select the 2.3.6 download file.
Under the Download options found on the right side of the first page, click on the “Windows Win10 and newer, 64 bits” option.



You will see a couple of screens asking for a donation. Feel free to donate if you want but if not, look for the download button and click to start your download. The file download will start. When complete, the downloaded file will be about 153 MB in size.

NOTE: During the install and setup procedures for the IDE app, you may see several pop-up windows asking if it is OK to install IDE driver xxx. Hit Accept/Yes for each pop up. These pop-ups could include the following but expect many more.

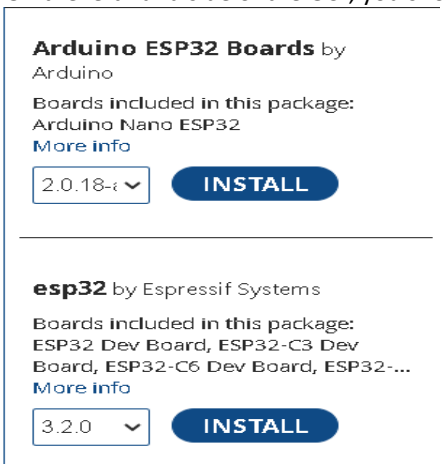
Arduino IDE	Allow
Dpinst-amd64.exe	Yes
Dpinst-amd64.exe	Yes (repeat of previous pop-up)
Arduino IDE	Allow

Double click on the downloaded file. The application installation will start.

License Agreement:	Hit I agree.
Choose Installation Options Select Anyone who uses this computer:	Hit Next
User Account Control	Hit Yes
License Agreement:	Hit I agree
Use the default installation folder	Hit Install

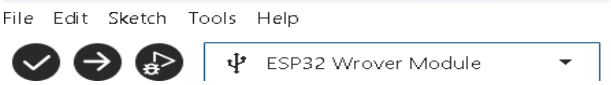
The remaining installation should take less than one minute.
Uncheck the box for “Run Arduino IDE”.
Hit Finish

Double click on the SigGen032.ino file under the SigGen032 directory. The Arduino IDE app will open.
You may see a message asking if you want to install ESP32 library 3.2.0. Hit Install later.
On the left hand side of the GUI, you should see this window:

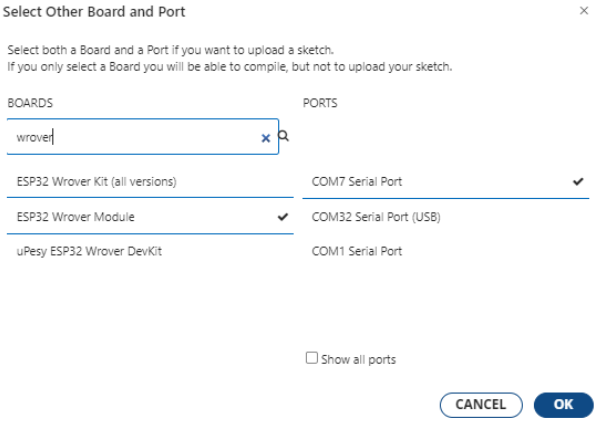


In the “esp32 by Espressif Systems” box, click on the down arrow by 3.2.0 and select 3.1.0.
Click on Install.
The library will be downloaded from the Internet and it will take about 13 minutes to install the library.

In the upper left hand side of the app GUI, you will see this box:



If you do not see “ESP32 Wrover Module”, you will need to select it.
Click on the down arrow in the box. Highlight “Select other board and port”.
In the search window, enter “Wrover”.

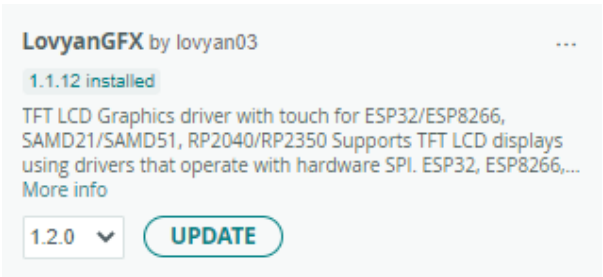


Highlight ESP32 Wrover module and kit OK.

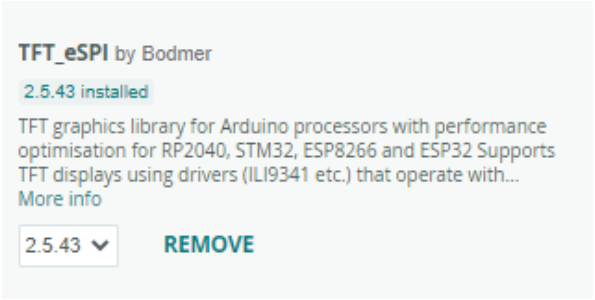
On the IDE menu, go to Files-Preferences
Under “Additional Boards Manager URLs, enter these URLs and hit OK:
The IDE app will go out to the Internet and will download the needed files.

https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package_esp32_dev_index.json
https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package_esp32_index.json

Under Tools/Manage Libraries, enter “LovyanGFX” under Filter your search.
Select version 1.2.0 and install it. Several files will be downloaded and installed.
It will take about one minute to download and install the library.



Under Tools/Manage Libraries, enter “TFT_eSPI” under Filter your search.
Select version 2.5.43 and install it. It will take less than one minute to download and install the file.

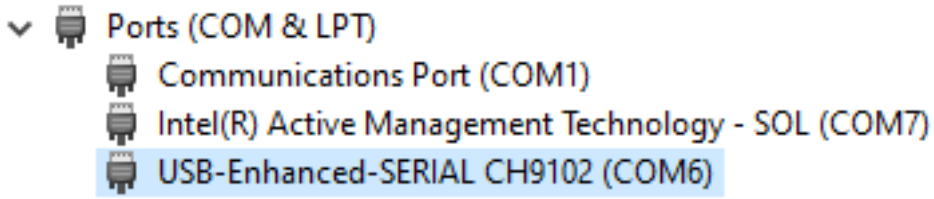


If you exit the SigGen032 program at this point or anytime going forward, when you reopen it, in the lower right corner of the app GUI, you will be prompted that updates are available for some of your boards. Do not update, instead click on “LATER”.

Connect your PC to the Micro USB port on the ESP32 module with a USB cable.
The ESP32 module will be powered up by the computer once the USB cable is connected. A red LED will light up on the ESP32 module once the connection is made.

If you see several available USB ports, then these steps will help you to select the correct port.

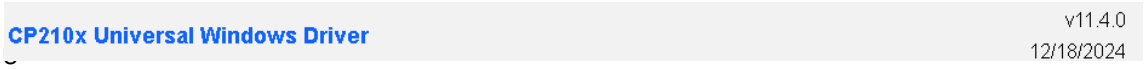
In Windows, open Device Manager
Open Ports (COM & LPT) and look at available ports
In the Arduino IDE app, select the port that shows up as “USB-Enhanced-SERIAL



If no USB Comm ports show up, it is likely that your computer does not have the driver installed for the Silicon Lab CP2104 USB to UART.

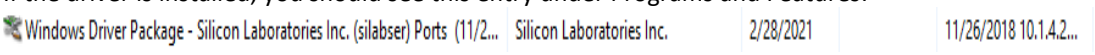
Go to this site:
https://www.silabs.com/developer-tools/usb-to-uart-bridge-vcp-drivers

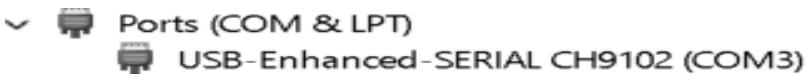
Download this driver:



nzip the file and install the driver.
Once installed, unplug your ESP32 cable from your computer and reconnect it. The driver should then install, and the module will show up under one of the Comm ports in the device manager as seen above.

If the driver is installed, you should see this entry under Programs and Features:





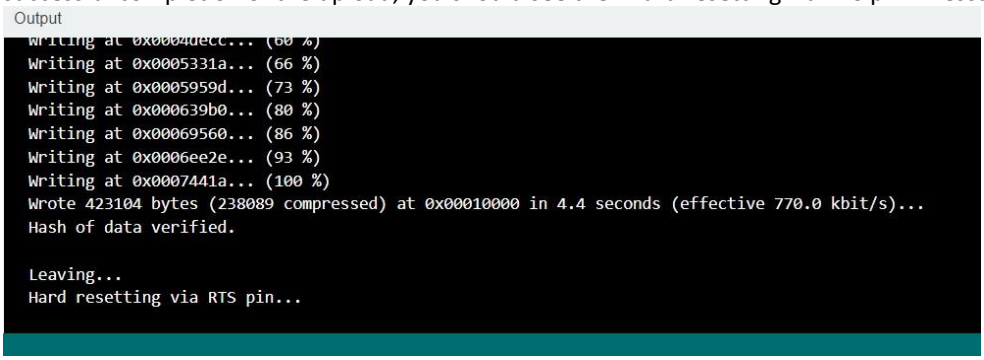
Under Device Manager, you should see this for Ports:

You may see a different value for the Com port. That is OK.

You are now ready to compile your code and see if you can program an ESP32 module.
Select Sketch-Upload (Ctrl+U). Do not use Configure and Upload or Upload Using Programmer..
Your will see a status window in the lower right-hand corner of your screen showing Compiling sketch.

If no errors are found, then the IDE will upload the code to your ESP32 module. The first phase will show Compiling sketch in the status window at the bottom right of the computer screen. This process takes some time. Just sit back and keep an eye on this window. When the sketch is fully compiled, the programming of the chip will automatically begin. If you get a comm port not found or comm port error, go back to the Select Board step above and make sure you selected the correct Comm Port.

The status of the upload functions will be shown in the black display window of the IDE app. At the successful completion of the upload, you should see the “Hard resetting via RTS pin” message.

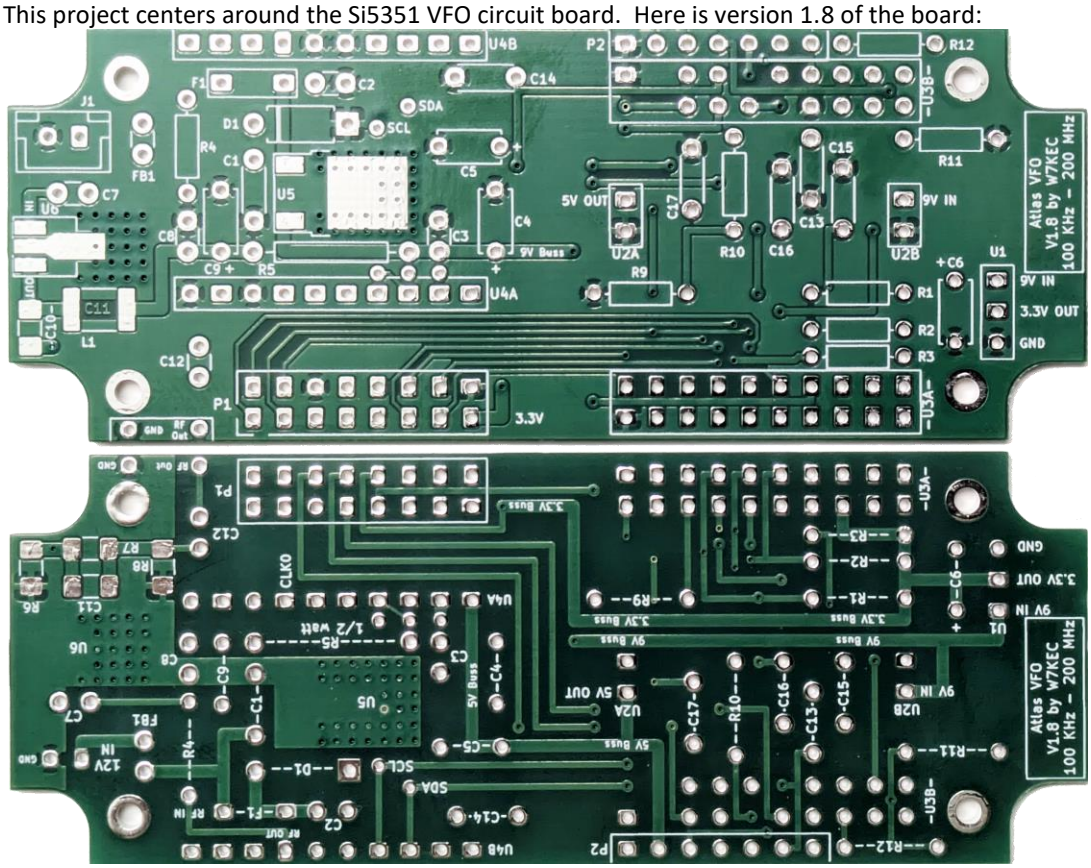


Your programmed ESP32 module can now be used on the VFO board. The green light on the ESP-32 module should be lighted. This indicates that the module has been programmed.

On subsequent Uploads, the process will be much quicker because the code has already been compiled.

IX. Build Si5351 VFO Board

This project centers around the Si5351 VFO circuit board. Here is version 1.8 of the board:

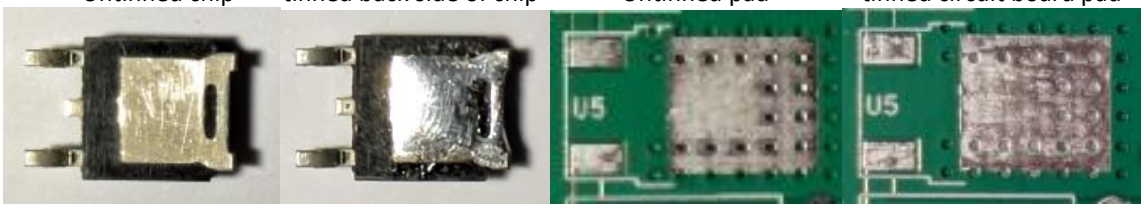


Install four brass standoffs on the bottom of the VFO circuit board with four each M2-4mm Phillip's head screws.

Sort out the resistors and capacitors by measuring their values.
Tape parts to sheet of white paper with value next to each part.

Tin the pads associated with the 78M09 voltage regulator chip and the GALI-6 chip.

Untinned chip | tinned back side of chip | Untinned pad | tinned circuit board pad

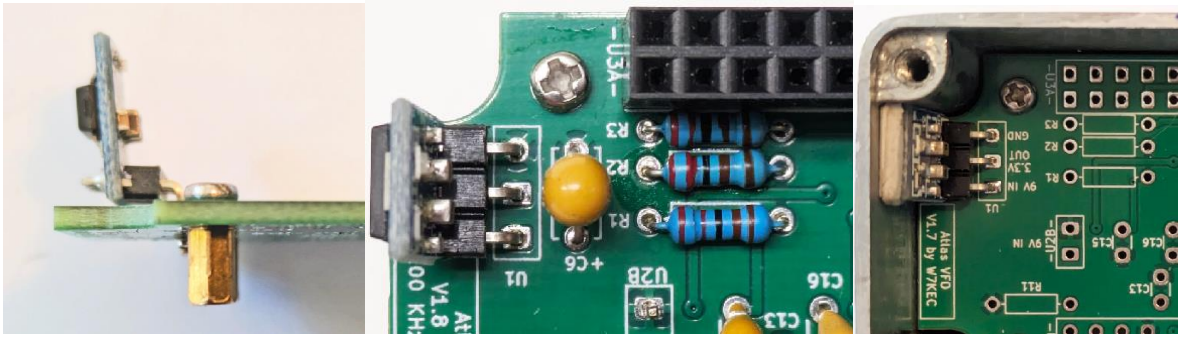


Solder the following SMD parts to the VFO circuit board:
U5 – 78M09 9 volt voltage regulator
L1 – 100 uh 1210 SMD
R6 & R8 – 240 ohms 1206 SMD – bottom of board
R7 – 20 ohms 1206 SMD – bottom of board
U6 – GALI-6 MMIC
C10 – 0.1 uf 1206 SMD
C11 – 36 pf 1206 SMD
Solder the following TH parts to the VFO circuit board:
R4 – 180 ohm

C2, C3, C7, C8 and C12 - 0.1 uf ceramic monolithic disc capacitor
[CC1]C1, C14, C15, C16, and C17 – 0.01 uf ceramic monolithic disc capacitors
C4 – 10 uf tantalum – observe polarity
C5 – 100 uf tantalum – observe polarity
C6 – 22 uf tantalum – observe polarity
C9 – 10 uf tantalum - observe polarity
D1- 1N4001 diode
F1 resettable fuse – 500 ma
R1, R2, and R3 - 2.2K ohms

Install wire jumpers across R10 and R12.

Solder the 3.3 volt regulator to the circuit board. Seat the 3.3 volt regulator on the top of the VFO circuit board with about 2mm on the three legs above the circuit board. Ensure that the board has a slight tilt toward the enclosure wall. You want the body of the AMS1117-3 chip to touch the wall of the enclosure so that the wall will provide a heat sink. Solder the three pins on the regulator board.



Insert the power jack at location J1 – matching the silk screen to the body of the plug.
Solder two pins on the jack. Connect the DC power cable to the jack and apply 11.7 VDC power.
There should be no current draw.

Solder FB1 on the board (FB43-101 ferrite bead)

Apply 11.7 VDC power to the board. The current draw should be about 7 ma. The red LED on the 3.3 volt regulator should turn on. Confirm that you have 9.0 volts out of the 9 volt regulator and 3.3 volts out of the 3.3 volt regulator.

Install R5 - 56 ohm 1/2 watt TH

All resistors, capacitors, and active devices have been installed on the circuit board.

Apply 11.7 VDC power to the board. The current draw should be about 77 ma. This current draw comes from the GALI-6 amplifier, the 9 volt regulator, and the 3.3 volt regulator. If you do not see 77 ma of current draw, then trace the voltages to the GALI-6.

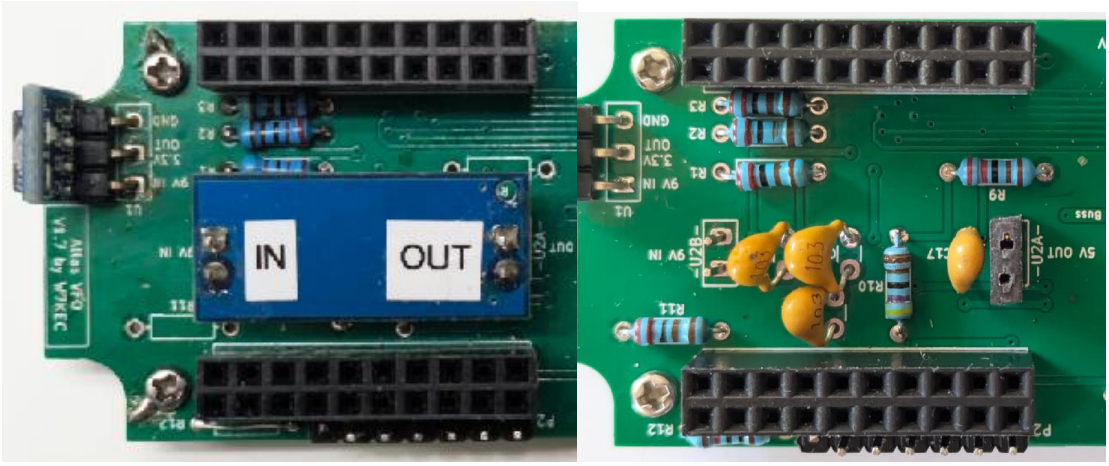
11.7 volts into 78M09
9 volts out of 78M09
9 volts into R5
5 volts out of R5
5 volts into L1
5 volts out of L1

On the circuit board, solder the following parts:
Insert four 10 pin male headers on the ESP-32 module.
Insert four 10 pin female headers onto the VFO board for the ESP-32 module.

Look at circuit board at J3A and J3B. Note pins that have no solder pads.
Remove those pins from the female pin headers.
There are five pins that will need to be removed from J3B female pin header.
Insert the female headers into the circuit board holes.
Insert the ESP-32 module into the female headers.
Solder the male header pins on the ESP-32 module.
Solder all of the pins on the female pin headers.
Remove the ESP-32 module from the circuit board
Insert two each single row 10 pin female headers into the circuit board at U4A and U4B
Insert the Si5351 oscillator board into the female pin headers
Solder all pins on the female pin headers at U4A and U4B
Remove the oscillator board from the VFO circuit board
Get two each single row 8 male pin headers
Install the pin headers at P1 on the circuit board.
The male pins may have a tight fit in the circuit board holes. Ensure that the pins do not move in the plastic body of the header.
Solder the P1 pins on the circuit board.
Get one each single row 7 male pin header.
Install the pin header at P2 on the circuit board
Solder the P2 pins on the circuit board.
Cut off the long part of pin 7. This will be a keying pin for the ribbon cable connector.

The following steps will create low profile female pin header sockets so that U2 can be mounted underneath the body of the ESP-32 module.

The body of a female pin header is 8 mm long.
Cut the top off of two mm on two each female pin headers so that the body is 6 mm long.
You should just barely see the top of the metal contact pins
Pull four pins from a male pin header.
Insert the pins into the female pins headers that you just modified.
Insert the long pins of one header into the component side of the AMS-1117 5 volt regulator on the Out pins
Insert the long pins of one header into the circuit board for U2 at the In pins
This will key the voltage regulator board so that it can only be attached one way to the VFO circuit board
Solder the four pins on the voltage regulator board
Solder the four pins on the VFO circuit board.
Cut off the excess lead length on the pins on the bottom of the VFO circuit board.
Cut off the excess lead length on the pins on the top of the voltage regulator board.
When the U2 board is installed on the VFO board, the component side of the board will be down.



You may have to fold over the capacitors in order for the regulator board to fit.
Remove the 5 volt regulator board from the VFO circuit board

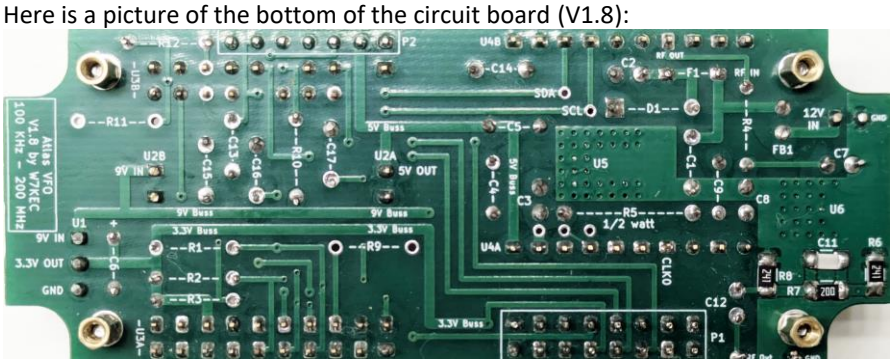
Install an insulated solid black wire (15 mm long) on the RF Out ground solder tab on the circuit board.
Install an insulated solid red or yellow wire (10 mm long) on the RF Out solder tab on the circuit board.

All pin headers, sockets, and plugs have now been installed on the VFO circuit board.
Carefully inspect all solder connections on the bottom of the board.
Check for solder splatters. Remove any flux from the bottom of the circuit board.

NOTE:
Parts will not be installed at C13, R9, R10, R11, and R12.
Wire jumpers will be installed at R10 and R12.

Here is a top view of the circuit board (V1.8):

Here is a picture of the bottom of the circuit board (V1.8):



X. Keyed Connectors

The pin headers/sockets are keyed to prevent the pin header/socket from being inserted the wrong way.
Key the following pin headers/sockets:

On the ESP-32 module male pin header, cut off the TXD pin. Fill the corresponding TXD hole on the female pin header with epoxy.

On the Si5351 board, cut off male pins 19 and 20. Fill the female socket hole 20 with epoxy.

On the low pass filter control six wire ribbon cable with the seven pin female IDC connector, pull pin 7. The male pin 7 pin was previously removed when the VFO circuit board was built. Fill the corresponding female pin header socket 7 with epoxy.

On the five pin female pin header on the sixteen wire ribbon cable, pull the unused pin 4. Fill the hole with epoxy. The corresponding pin 4 on the optical encoder was previously cut off when the wiring harness was built.

On the TFT 8 pin male pin header, cut off pin 8. On the corresponding pin 8 of the female pin header, fill the hole 8 with epoxy.

NOTES:
The AMS1117-5 volt regulator board can only be installed one way.
The 11.7 VDC JST power connector has a built-in factory key.
The 16 pin IDC ribbon cable connector has a key that should be placed so that it is closest to the female pin header for the Si5351 board.

XI. Initial VFO Testing

Ensure that the ESP-32 module, the Si5351 oscillator board, and the 5 volt regulator module have been removed from the board.

Apply 11.7 VDC to the power plug. You should see about 77 ma of current draw. This current draw comes from the 9 volt regulator feeding the Mini Circuits GALI-6 MMIC amplifier.
Remove power from the board.

Install the 5 volt regulator board.
Apply 11.7 volts to the power socket. You should see about 85 ma of current.
The red LED on 3.3 and 5 volt regulator boards should light.
Confirm that the output voltage on the 5 volt regulator board is 5.0 volts.
Remove power from the board.

Remove power from the board.
Install a programmed ESP-32 module. Apply power.
The total current draw should be around 148 ma.

Remove power from the board.
Install the QRP Labs Si5351 oscillator board. Apply power.
The total current draw should be around 183 ma.

The VFO can be tested on the bench before being installed into the main enclosure.
Connect the 16 pin ribbon cable to the VFO circuit board
Connect the TFT Display to 16 pin ribbon cable
Apply 11.7 volts to the white DC power connector on the circuit board.
The system should boot up. Total current draw will be about 236 ma.
Remove power from the board.
Connect the optical encoder to the 4 pin ribbon cable
Apply power.
The system should boot up and you should be able to change the frequency using the encoder.
Total current draw will be about 250 ma.

You should see the following lights:
Green LED – ESP-32 module
This LED will be flashing if the ESP-32 module has not been programmed. During a program upload, the light will go out. Once the ESP-32 module has been programmed, the light should be solid as opposed to flashing.

Red LED – ESP-32 module – this LED should be lighted any time power is applied to the module
Red LED – 3.3 volt regulator module
Red LED – 5 volt regulator module

With no ribbon cable wires connected to the front panel controls, you should see the following defaults on the display:

Frequency: 10.000 000 MHz
BAND: 200K-30M
STEP: 1 MHz
MEM: D
With an oscilloscope, confirm that you can see a 3.2 peak to peak voltage at the RF Output pin on the circuit board.

Apply a thin layer of heat sink compound on the body of the AMS1117-3.3 chip.
Install the circuit board into the enclosure using four each M2-3 counter-sunk Phillip's head screws
Install a thermal pad between AMS1117-3.3 volt chip and the wall of the enclosure.

Plug in the male connector on the wiring harness to the female connector on the circuit board.
Install a SMA female bulkhead connector to the ribbon side of the enclosure.
Solder the circuit board RF Out ground wire to the ground lug on the connector.
Solder the circuit board RF Out wire to the center conductor of the connector.

Install Brother's labels on the top cover of the VFO enclosure:

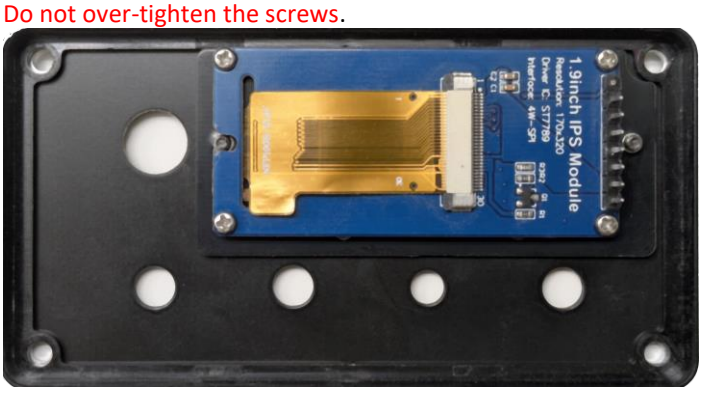
Apply 11.2 vdc power to the JST power wires.
Total current draw should be about 220 – 240 ma.
Confirm that you see a normal display and that you can change the frequency with the encoder.

Confirm that you see a 3.2 volt PP signal at the chassis mount SMA jack.

XII. TFT Display Mounting Bracket

The TFT display needs to be mounted in the window on the main enclosure front panel using a prefabricated bracket. The mounting bracket has eight drilled holes. Four of the holes secure the TFT display to the bracket. The two Standard Atlas 210X holes secure the bracket to the front panel of the enclosure.

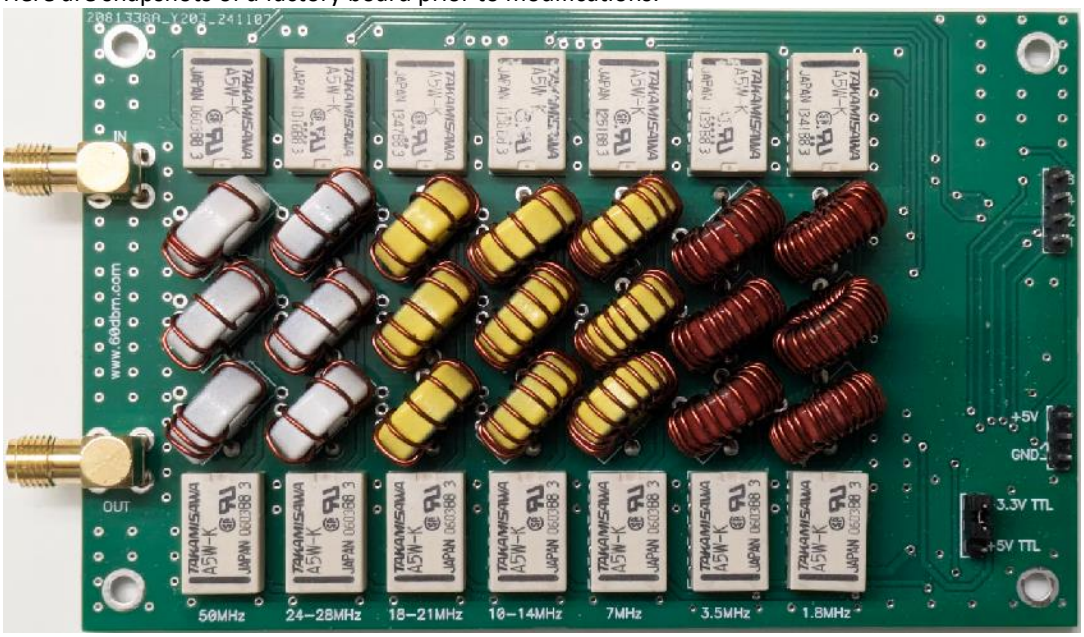
Smooth off the inside edges of the cutout with a flat file.
Using a black Fine Point Sharpie marker, mark the inside edges of the frequency window.
Secure the TFT display to the bracket with four M2 x 5mm Phillips head screws.
Do not over-tighten the screws.

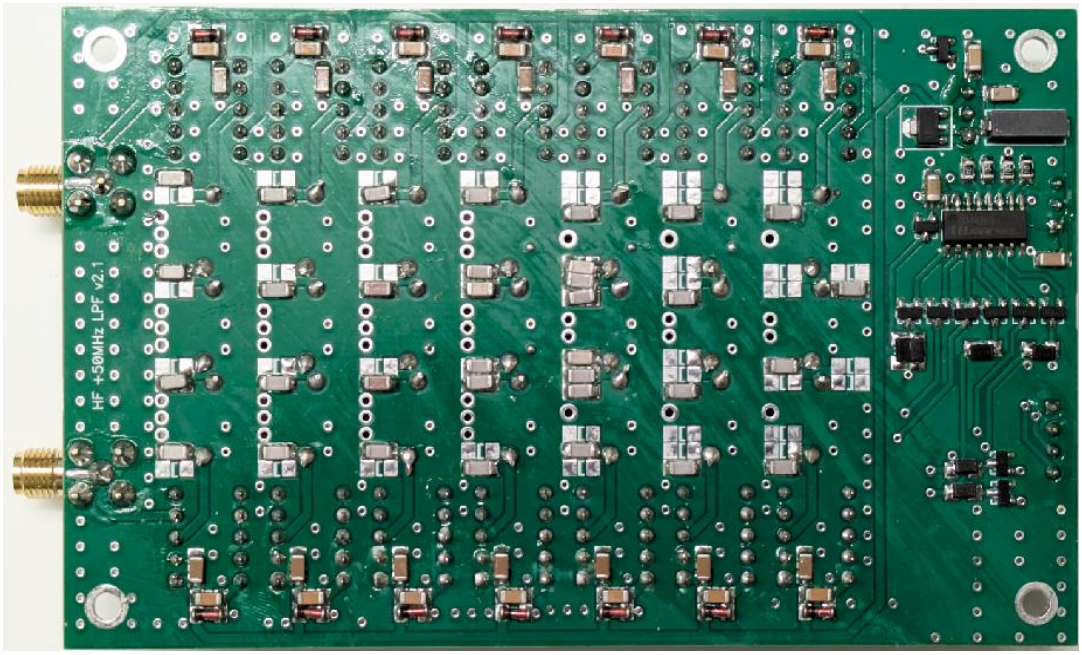


Attach the bracket to the front panel using the two M2.5 x 4mm black truss head screws.

XIII. Ukraine Low Pass Filter Board Modifications

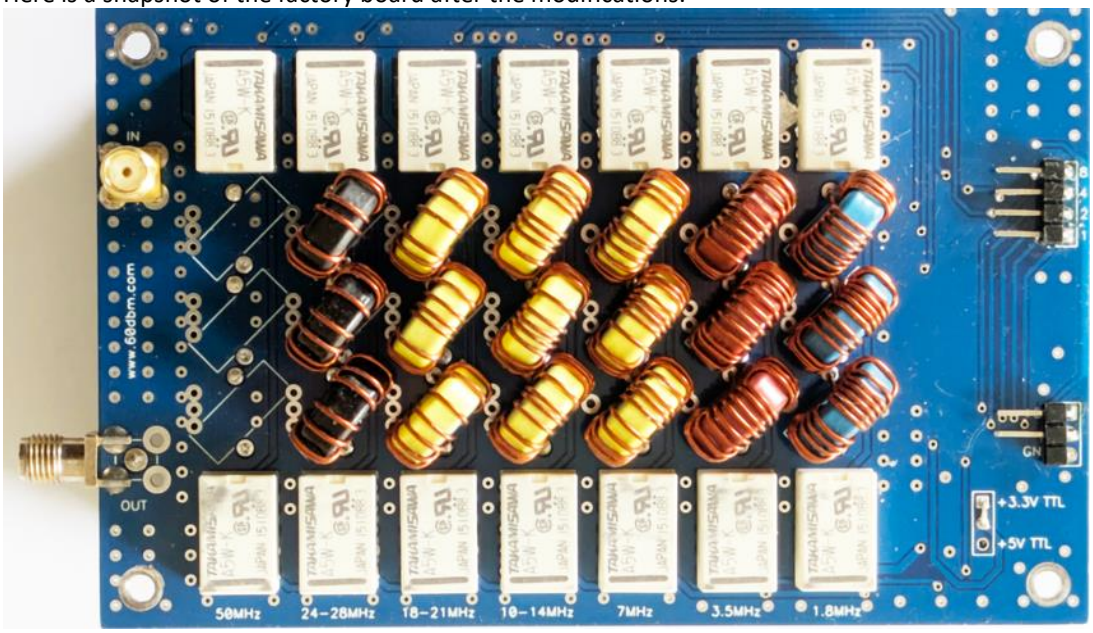
The low pass filter will need to be modified before it can be installed in the main enclosure.
Here are snapshots of a factory board prior to modifications.

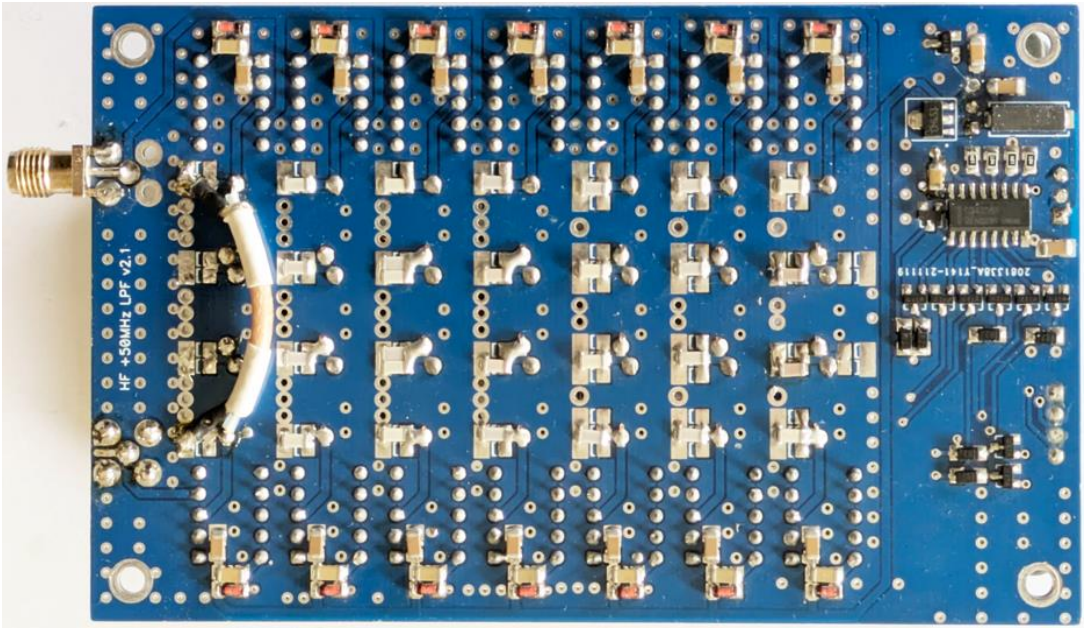




Remove the front and rear panels from the enclosure, along with the top cover.
Remove the input female SMA connector. Install a vertical mount SMA connector.
Remove capacitors and inductors for the 50 MHz filter.
Install a RG316 coax jumper between the input and output 50 MHz relay contacts.
Remove male pin headers for the TTL Logic, DC power, and BCD lines.
Install 3.3V TTL wire jumper.
Install 90 degree male pin header for 5 volts DC power.
Install 90 degree male pin header for BCD lines.

Here is a snapshot of the factory board after the modifications.





XIV. Build Out Main Enclosure

The VFO enclosure, low pass filter board, etc. are installed inside the Hammond 1455 enclosure.

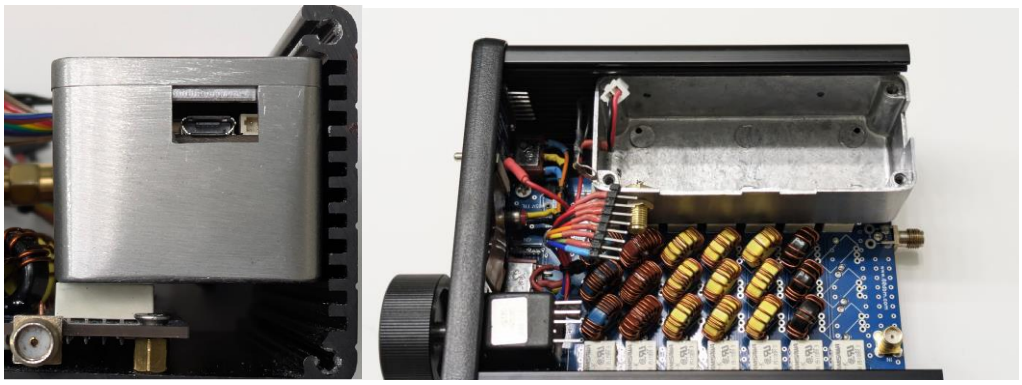
A. Mount Low Pass Filter Board

Position the low pass filter board inside the enclosure.
Mark positions of four mounting holes on the bottom of the enclosure.
Drill and countersink the four 1/8" diameter holes.
Attach the low pass filter board to 4 each 4-40 x 5mm brass standoffs.
Attach the board to the bottom of the enclosure with four 4-40 countersunk Phillips screws.
The rear set of screws are 4.5 mm from the back edge of the enclosure.
The front set of screws are 6.5 mm from the front edge of the enclosure.
Before drilling the holes, ensure that the front edge and rear edge of the board aligns with the front edge and rear edge of the enclosure.
Attach the four rubber feet to the bottom of the enclosure.

B. Mount VFO Enclosure

Drill two 3/32" holes in the left hand side of the main enclosure. The left hand screw is 22mm from the back edge of the enclosure. The right hand screw is 45 mm from the front edge of the enclosure.

Place the VFO enclosure inside the main enclosure such that it sits on top of the white relays and lines up with the back edge of the main enclosure. Drill two 5/64" holes in the VFO enclosure. The two holes in the main enclosure should line up with the two holes in the VFO enclosure. Tap the two holes with a 6-32 tap.



C. Front Panel Wiring Harness

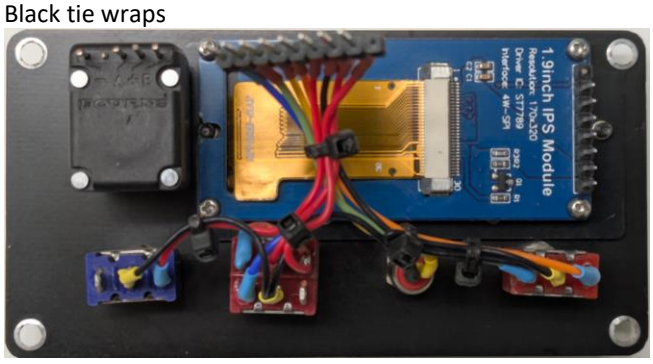
Install the following controls on the front panel:

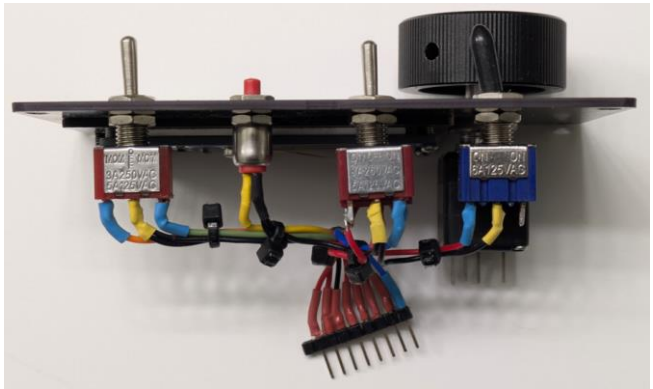
Optical Encoder

The Bourns optical encoder shaft is supported by a ball bearing and very easy to turn. Any weighed tuning knob attached to the shaft will usually turn slightly even without touching the knob (as a result of the unbalance of the knob). This can be corrected by putting tension between the back of the knob and the threaded part of the encoder. A small non-flat brass/steel washer can provide the needed tension.

Three each toggle switches
Push button switch
The TFT Display should already have been attached to the front panel.

Fabricate the wiring harness with the following parts:
9 pin male header
Heat shrink tubing
Black, red, blue, yellow, and orange Teflon wire
Black tie wraps

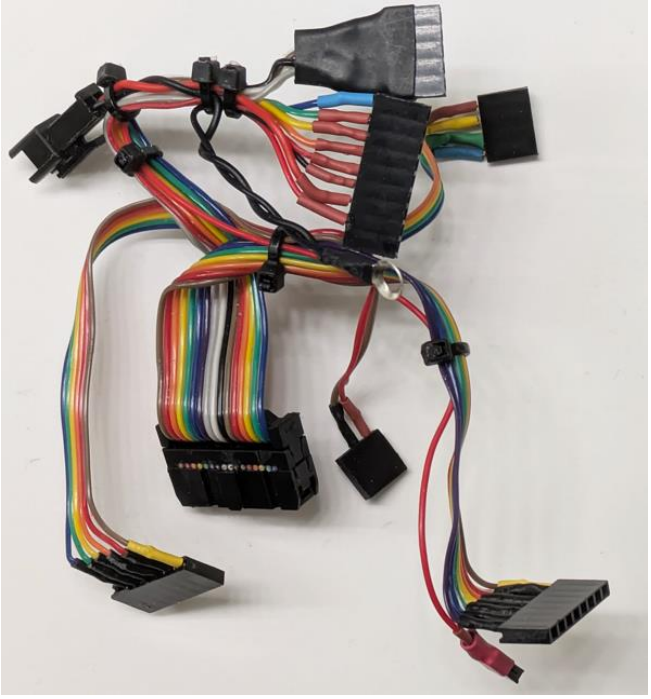




D. VFO Wiring Harness

Fabricate the VFO wiring harness with the following parts:

9 pin female header
8 pin female header
5 pin female header
4 pin female header
3 pin female header
Single pin male and female header
16 pin IDC connector
16 wire ribbon cable (7” long)
6 wire ribbon cable (7” long)
Black Teflon wire
Red Teflon wire
External DC power connector wiring pair
Terminal lug
Heat shrink tubing
Black tie wraps



E. Rear Enclosure Panel

Cut the following holes in the rear enclosure panel:

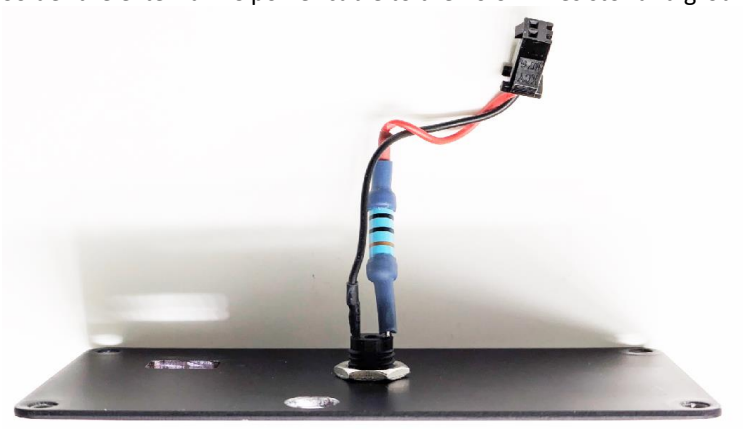
Micro USB
- rectangular hole 7 x 12mm
- 19 mm from left side of panel and 37 mm from bottom edge of panel

DC Power
- 8 mm hole
- 51 mm from left side of panel and 27 mm up from bottom edge of panel

RF Out
- 8 mm hole
- 44 mm from left side of panel and 7 mm up from bottom edge of panel

Mount the DC Power connector to the panel.
Solder a 10 ohm 2 watt resistor to the positive tab on the DC power connector.
Use heat shrink tubing as shown in the snapshot.

Solder the external DC power cable to the 10 ohm resistor and ground tab on the DC power connector.



Install Brother labels next to the holes in the panel.

F. Final Assembly

Attach the VFO enclosure to the main enclosure with two M2.5x6 mm screws.
Attach the RG402 coax cable to the output of the VFO and the input of the low pass filter.
Connect the front panel wiring harness to the VFO wiring harness.
Connect the two ground terminals to the screws on the top cover of the VFO enclosure.
Attach the front panel to front of the main enclosure.
Connect the DC power cable to the VFO wiring harness.
Slide on the top cover.
Attach the rear panel to the rear of the enclosure.

XV. VFO Testing

Power up the External VFO
Verify proper display readings on the TFT display
Allow 4 hour warmup of the VFO. Check calibration with a frequency counter.
Confirm a ~ +10 dbm VFO output for each band
Confirm proper operation of the following controls:
Frequency Lock
Mem - 6 memories per band
Step – 8 available steps
Confirm that the low pass filter board switches at the correct frequencies
- 2 to 3 MHz
- 8 to 9 MHz
- 15 to 16 MHz
- 23 to 24 MHz
- 34 to 35 MHz

Confirm that you have a clean sine wave on each of the low pass fillter bands

XVI. Appendix

A. Tech Tips

1. Parts Kit

The parts kit will come with a parts list. Be sure to confirm that you have received all of the parts that are listed on the Parts List.

2. Hand Tools

The following equipment will be needed in order to complete the project:

Electric drill with bits	mandatory	1/16”, 5/64”, 3/32”, 1/8”, 7/64”, ¼”, 9/64”
Heat Gun	mandatory	
DC Power Supply	mandatory	
Soldering Station	mandatory	
Solder Sucker	mandatory	
Sharpie – extra fine point	mandatory	
Sharpie – fine point	mandatory	
Phillips screwdriver	mandatory	1/8”
Steel ruler in mm	mandatory	6” long
Diagonal wire cutters	mandatory	similar to Xcelite 170M
Center punch	nice to have	
Dremel tool	nice to have	with carbide cutting disk and router bit
Drill press	nice to have	with 1/8” end mill bit & 6-32 tap
Jeweler’s file	nice to have	
LCR Meter	nice to have	to check values of resistors and capacitors
PanaVise	nice to have	
Spectrum Analyzer	nice to have	
Oscilloscope	nice to have	

3. Tantalum Capacitors

There are several tantalum capacitors that will need to be installed. These capacitors have negative and positive terminals. If you install the capacitors backwards, then it will short out when DC power is applied. The long lead on the capacitor is the positive terminal.
It is recommended that you measure the capacitance of each capacitor before soldering it into the system.

4. Resistors

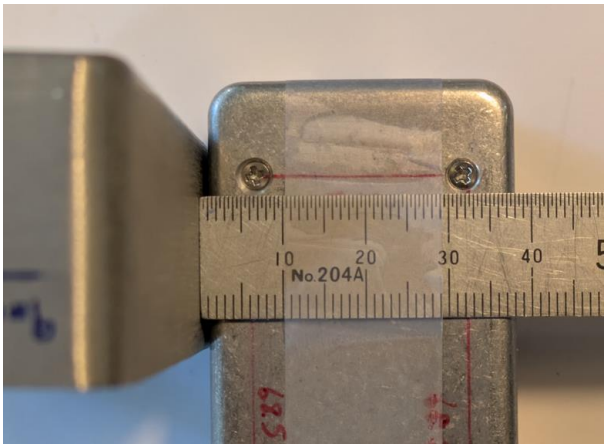
It is recommended that you measure the resistance of each resistor before soldering it into the system.

5. Heat Shrink Tubing

Most of the wiring connections require the use of heat shrink tubing. In the parts package, there are a number of different diameters and lengths of tubing. See the parts description at the beginning of this document. Be sure to slide the required tubing over the wiring before the wiring is soldered to the connection. Then use a heat gun to shrink the tubing to conform with the soldered connection.

6. Measuring distances for drilling holes

The enclosure has rounded corners on the outside of the box. When measuring hole distances, be sure to place a straight edge against the side of the enclosure to keep from using a rounded corner as a measuring reference point. Otherwise, your measurements are going to be 1 – 2 mm too short.



7. **Drilling Holes**
   Whenever you need a large hole, do not start out with a drill bit for the final hole size. Start out with a smaller bit and work your way up to the large hole. This will result in more accurate drilling and a round hole.

8. **Optical Encoder**
   The Bourns unit has a very light feel and has a short tuning shaft. With a weighted tuning knob, you may find the tuning knob turning on its own. The stop this, one needs to install a spring loaded flat washer between the back of the tuning knob and the encoder mounting shaft. Pressure is applied to the tuning knob prior to locking down the knob set screw. The amount of pressure determines the feel of the tuning knob.

9. **Magnifier (~ $20)**
   There are a lot of small parts that will need to be installed for the project. Installation will be much easier if you use some type of lighted magnifier. I use this one:

Amazon.com: Vision Aid 30x Hands-Free Magnifier with Ultra Bright 36 LED Lights and Case - 40x Loupe Magnifying Glass with Stand for Reading Jewelry Coins Watch Hobby Crafts Close Work : Health & Household

10. **Micro-Mark Mini Drill Press with Proxxon X-Y Table (~ $300)**
    The drilling of holes and the milling of the notches on the VFO enclosure is easily accomplished with a milling machine that has accurate vise control of the x and y axis. The milling can also be completed with a 5/64" end mill and a drill press with a fence.
    The quality of the milling will not be as good as that of a mill, but will be acceptable. Also keep in mind that the drill press spindle and bearings are not designed for high side forces.



These videos provides details on how to use the drill press and the x-y table.
https://www.youtube.com/watch?v=t80JeBpDMfE
https://www.youtube.com/watch?v=1CEUlFG9LFY
The x-y table can be adapted to fit most drill presses.

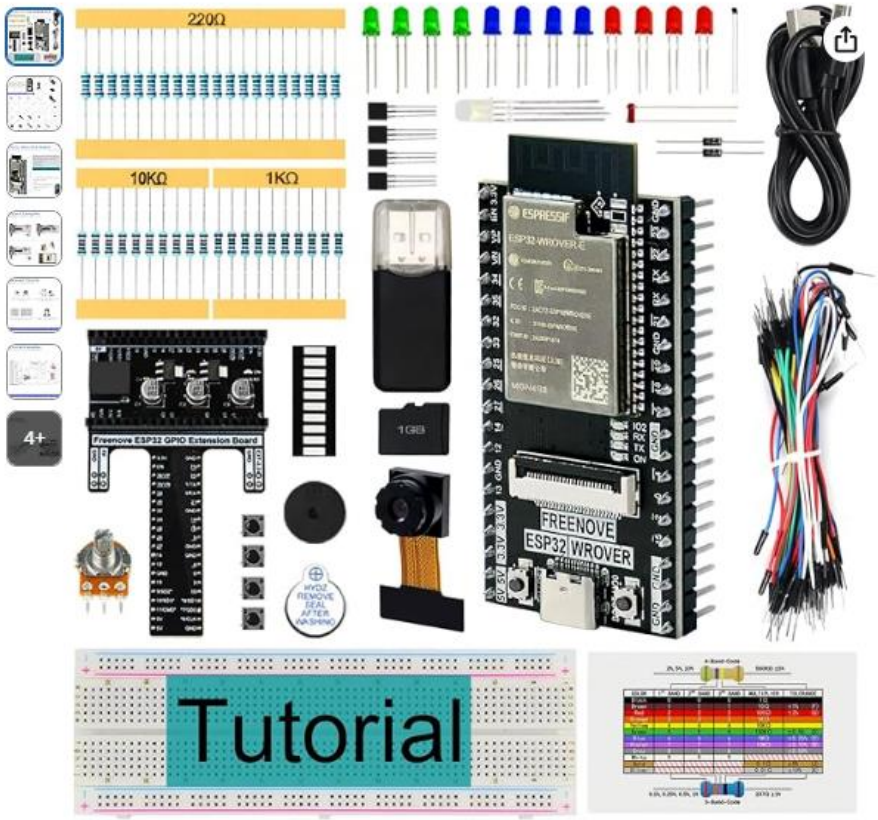
11. **Dremel Rotary Tool (~ $70)**
    A Dremel rotary tool is very handy for cutting/shaping metal, circuit boards, etc. The author uses a Model 395.

12. **Proxxon MF70 Micro Mill (~ $450)**
    Here is a milling operation using the XY table on a Proxxon MF70 micro mill.

13. **Parts Vice (~ $70)**
    A PanaVise with vacuum base and nylon jaws makes it very easy to solder parts to the circuit board, fabricate pin header wiring harnesses, etc.

14. **ESP-32 Programming Kit (~ $30)**
    If you want to learn how to program an ESP-32 chip in C/C++, then you might want to consider this expensive training kit:

    https://www.amazon.com/Freenove-ESP32-WROVER-Included-Compatible-Wireless/dp/B0CJJKSN4F/ref=sr_1_2_sspa?crid=1X8GIMO6XGK2D&dib=eyJ2IjoiMSJ9.Bb8F_GU1pt634Xoi2LYVtjEencD1RgZL6f2a6YiHxR-6RI3pf1kGfVMML9WYBEoYiI3czo5FhaCPvww4mZHYbw1-vTAMpb-dEfUjBtiLtU_rFK6LQHZcR8vDqzif1KvNh0MRHNUFFY5RQGXmOrCv2-calO1S7pYRlaXDBFWOqGKpWUi_m2PhnBqjyaciervwI2nE6-vI3BJykvwokJJ07GmDr9gk7o5YKyQcJBt_fmA.W7RUjML6A-lE1udn2J5CE_9fK3xeqF24B_VUmRhhwLc&dib_tag=se&keywords=freenove&qid=1744985767&sprefix=freenov%2Caps%2C601&sr=8-2-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&th=1



15. **LCR Meter (~ $40)**

A digital LCR meter will make it easier to determine the values of resistors, inductors, and capacitors. This unit has great performance and is low priced:

https://www.amazon.com/dp/B0DBQ4SQGK?ref=ppx_yo2ov_dt_b_fed_asin_title

B. RF Output Level Accuracy

The following signal level variations were measured with a Boonton 4220A power meter and a 51075 power sensor:

0.1 to 1.5 MHz - Internal Low Pass Filters
12.20 dbm to 10.29 dbm

1.5 to 34 MHz – Internal Low Pass Filters
10.17 dbm to 10.49 dbm

Internal Low Pass Filters with 10 db equalizer and 1 db pad on output
0.1 to 1.5 MHz
0.0 dbm to 1.91 dbm

1.5 to 34 MHz
-0.04 dbm to 0.20 dbm

External Low Pass Filters with 10 db equalizer and 1 db pad on output
34 MHz to 180 MHz
-0.38 dbm to 0.52 dbm

180 MHz to 200 MHz
-6.14 dbm to -0.24 dbm

C. Build Times

These are typical build times for various pieces of the project. As needed, one can use the External VFO as a full function signal generator. This can be accomplished by the following steps:

1. Prep ESP-32 Module
   5 minutes
   Solder four each 10 pin male headers to the module
   Program the ESP-32 module
   Test the ESP-32 module

2. Prep Si5351 Oscillator Board
   5 minutes
   Cut off end of board
   Solder two each 10 pin male headers to the module
   Solder TCXO module to the board

3. Enclosure Machine Work
   Drill holes
   Cut notches
   60 minutes

4. Build VFO Circuit Board
   2.5 hours

5. Install low pass filter board and VFO Enclosure
   30 minutes

6. Build 6 pin and 16 pin ribbon cable wiring harnesses
   30 minutes

7. Install front panel controls
   10 minutes

8. Build front panel wiring harness
   30 minutes

D. How To Remove VFO Enclosure From The Main Enclosure

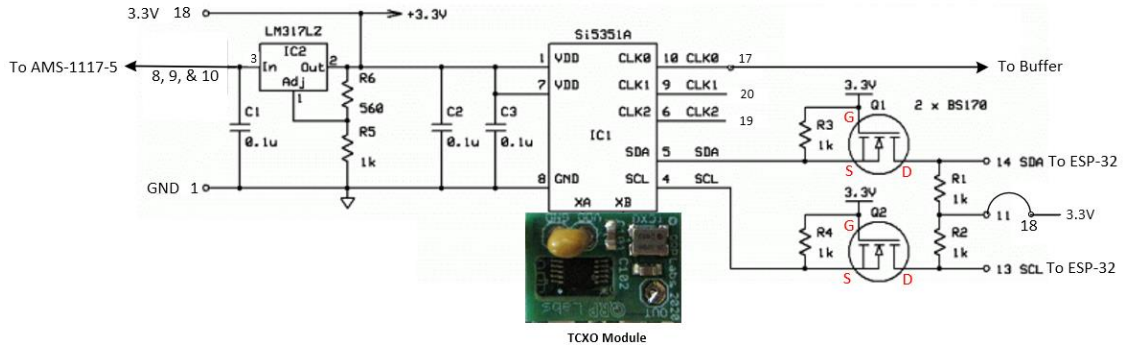
For some trouble-shooting operations, the VFO enclosure will need to be removed from the main enclosure. This can easily be done without having to unsolder any wires, by following these steps:

1. Remove the four screws holding the rear panel of the main enclosure.
2. Move the rear panel back and slide off the top cover.
3. Disconnect the DC power cable connector going to the 2 watt resistor.
4. Disconnect the red DC power wire going to the VFO enclosure.
5. Unscrew the male SMA connector from the RF Output jack on the VFO enclosure.
6. Remove the two screws holding the VFO enclosure to the main enclosure.
7. Remove the four screws holding the top cover on the VFO enclosure.
8. Remove the top cover of the VFO enclosure.
9. Remove the 16 wire and 6 wire ribbon cable plugged into the VFO circuit board.
10. Slide out the VFO enclosure out the rear of the main enclosure.
11. Unsolder the two output wires from the SMA jack.
12. Remove the four counter sunk screws from the bottom of the enclosure.
13. Unplug the white DC power plug from the circuit board.
14. Lift the circuit board out of the enclosure.

Reverse the steps for putting the VFO back together.

E. Si5351 Checks

This is the schematic for the Si5351 board. Problems in this area are usually related to bad solder joints.



Confirm that the current draw of the board is about 36 ma.

Confirm that you can see 5.0 VDC on pins 8, 9, and 10 of the Si5351 board.
Confirm that you can see 3.3 VDC on pins 11, 13, 14, and 18 of the Si5351 board.
Confirm that you can see 3.3 VDC on the VDD solder pad

Q1 is located next to R1 on the circuit board. Q2 is located next to R2. The input pin on IC2 is located next to the silkscreen text “TCXO” on the Si5351 board. The output pin on IC2 is located next to pin 7 on the Si5351 board. Confirm that you can see 5.0 VDC on the input pin and 3.3 VDC on the output pin.

Look at the OUT pin on the TCXO module with an oscilloscope. You should see a 25 MHz signal with a peak to peak voltage of about 960 mv. Find the TCXO silkscreen on the Si5351 board. On the solder pad next to the “O”, confirm that you can see a 25 MHz signal at 960 mv peak to peak.

Remove the Si5351 board from the VFO board.
Confirm continuity for the following paths on the TCXO board:
GND solder pad to pin 1 on the Si5351 board.
VDD solder pad to pin 11 n the Si5351 board.

Confirm continuity from the following paths on the Si5351 board:
pin 17 to pin 10 of the Si5351 chip.
pin 7 of the S5351 chip to the output pin of the voltage regulator.
pin 18 to the output pin of the voltage regulator
drain of Q1 to pin 14 of the Si5351 board
drain of Q2 to pin 13 of the Si5351 board
top of R1 to the drain of Q1.
bottom of R2 to the drain of Q2.
gate of Q1 to pin 18 of the Si5351 board
gate of Q2 to pin 18 of the Si5351 board.
gate of Q1 to the gate of Q2.

F. DC Voltage Checks

In the event that one finds the VFO is not working correctly, then perform the following checks:

Power down the VFO.
Perform steps 1 – 8 under "How to remove VFO enclosure from main enclosure"
Remove the ESP-32 module and Si5351 module from their sockets
Power up the External VFO from a regulated 13.7 voltage source.
You should be able to measure the following voltages:

Power Supplies	Test Point
13.7	Power Supply input to External VFO
11.7	Input to VFO Board (downstream of R13)
9.0	Input pin of the 3.3 volt regulator
3.3	Output pin of the 3.3 volt regulator
9.0	Input pin to 5 volt regulator
5.0	Output pin of the 5 volt regulator

Si5351 Osc.	Test Point
5.0	Pin 8
5.0	Pin 9
5.0	Pin 10
3.3	Pin 11
3.3	Pin 13
3.3	Pin 14
3.3	Pin 18

ESP-32 Socket	Test Point
3.10	RST
3.10	26
3.30	35
3.30	34
3.30	3.3V
3.30	22
3.30	25
3.30	21

BAND BCD Codes

BAND (MHz)	Pin #1	Pin #2	Pin #3	Pin #4	LPF Board
< 2.2	0	0	0	0	1.8 MHz
2.2 - 4.5	1	0	0	0	3.5 MHz
4.5 - 8.0	0	1	0	0	7 MHz
8.0 - 15	1	1	0	0	10 - 14 MHz
15 - 23.5	1	0	1	0	18 - 21 MHz
23.5 - 34	1	1	1	0	24 - 28 MHz
Bypass*	1	0	0	1	50 MHz

NOTES
* Any frequency greater than 34.0 MHz
* Or Power Switch in Bypass position
Sine wave generated from 1.15 MHz to 34.0 MHz

Power down the radio
Install the ESP-32 module and the Si5351 module
Remove 16 pin ribbon cable connector and 6 pin ribbon cable connectors
Power up the radio
You should see red LEDs on the 5 volt regulator, 3.3 volt regulator and the ESP-32 module
Measure the voltages on the 16 pin ribbon cable connector on the VFO board.
Measure the voltages on the 6 pin ribbon cable connector on the VFO board.

Install the 16 pin and 6 pin ribbon cables and measure the voltage on the ESP-32 pins.

The first set of ESP-32 reading are on the same side of the ESP-32 as the Reset Switch.
The second set of ESP-32 readings are on the same side of the ESP-32 as the white 12C connector.

16 Pin Ribbon Cable	Test Point
0	1
3.3	2
3.3	3
0	4
3.3	5
3.3	6
3.3	7
3.3	8
3.3	9
3.3	10
0	11
3.3	12
3.3	13
3.3	14
3.3	15
2.2	16

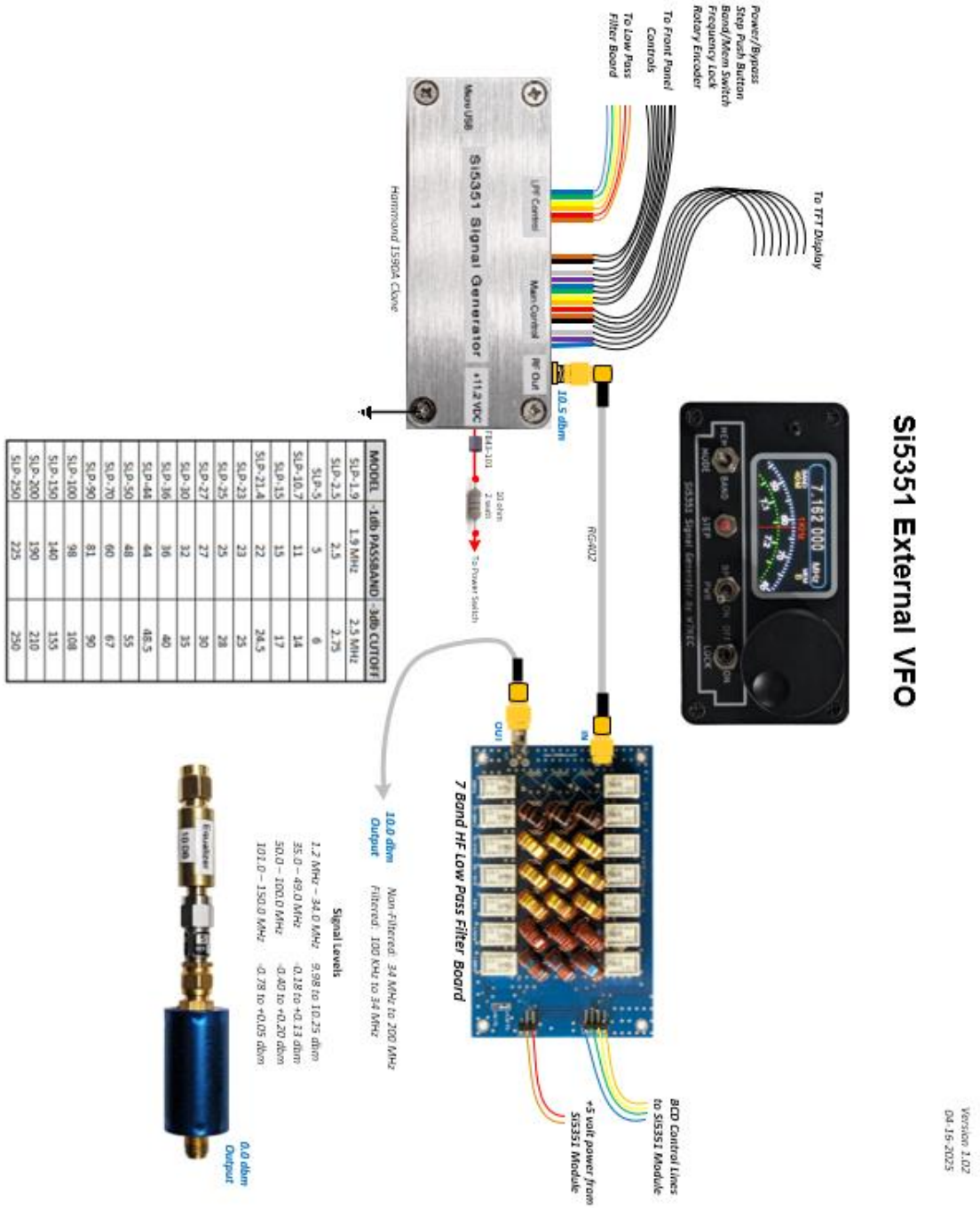
6 Pin Ribbon Cable	Test Point
0	1
5	2
3.3	3
0.3	4
0.3	5
0.3	6
NA	7

ESP-32 Pins	Test Point
0.0	GND
3.2	RST
0.0	NC
0.5	VP
0.4	VN
3.0	26
3.2	35
0.0	18
3.2	33
2.2	19
3.3	34
0.0	23
3.3	TMS
3.3	5
0.0	NC
3.3	3V3
0.0	SD2
0.0	TCK
0.0	CMD
0.0	SD3

ESP-32 Pins	Test Point
3.3	TXD
0.0	GND
2.8	RXD
1.0	27
3.3	22
0.0	25
3.3	21
3.3	32
1.0	27
0.0	TDI
3.3	25
0.0	4
0.0	GND
3.3	0
3.3	5V
0.3	2
3.3	TDO
0.0	SD1
0.0	SD0
0.0	CLK

G. System Diagrams

Figure 1 – Block Diagram



MODEL	-1db PASSBAND	-3db CUTOFF
SLP-1.9	1.9 MHz	2.5 MHz
SLP-2.5	2.5	2.75
SLP-5	5	6
SLP-10.7	11	14
SLP-15	15	17
SLP-21.4	22	24.5
SLP-23	23	25
SLP-25	25	28
SLP-27	27	30
SLP-30	32	35
SLP-36	36	40
SLP-44	44	48.5
SLP-50	48	55
SLP-70	60	67
SLP-90	81	90
SLP-100	98	108
SLP-150	140	155
SLP-200	190	210
SLP-250	225	250

Figure 2 – VFO Schematic

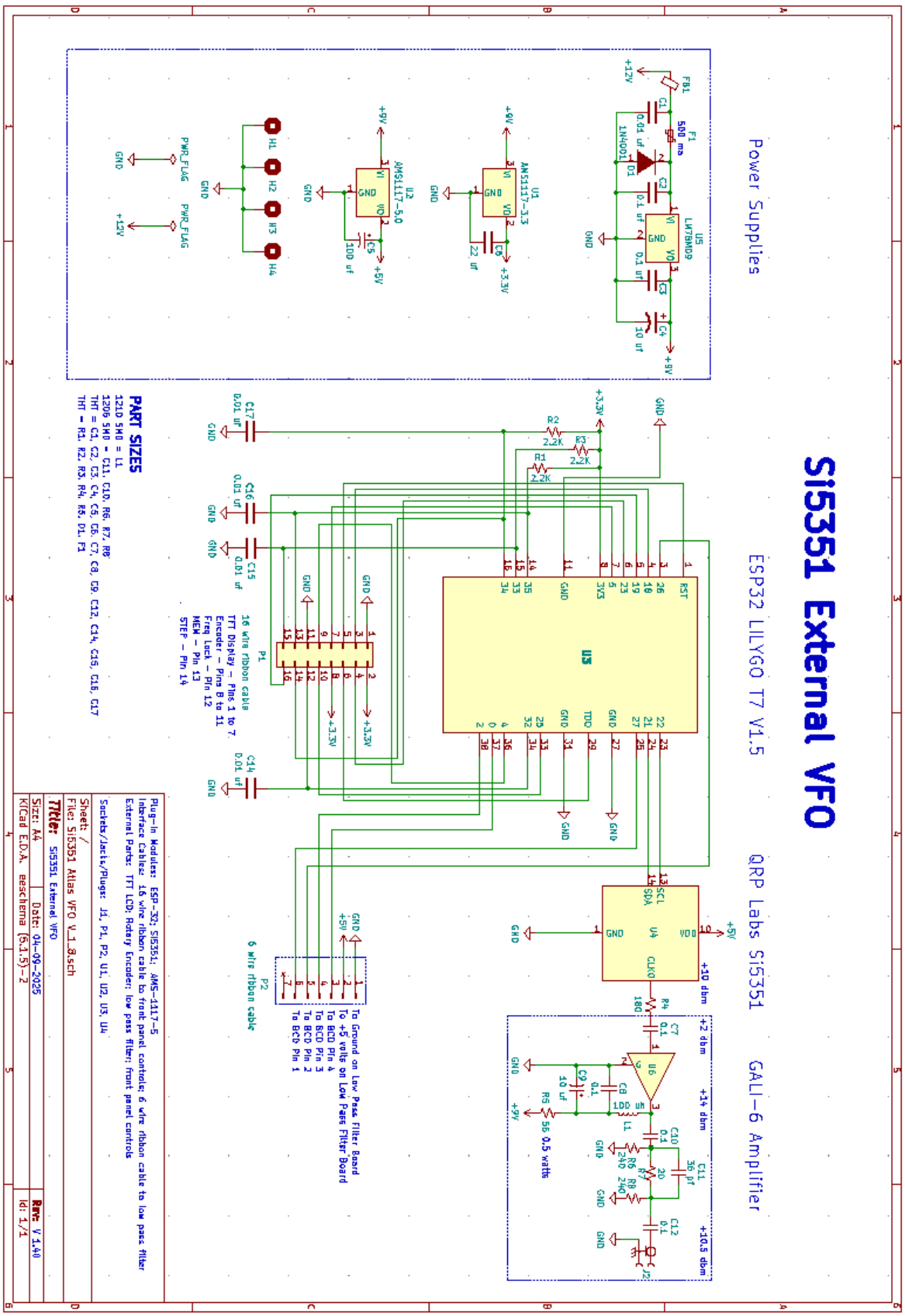
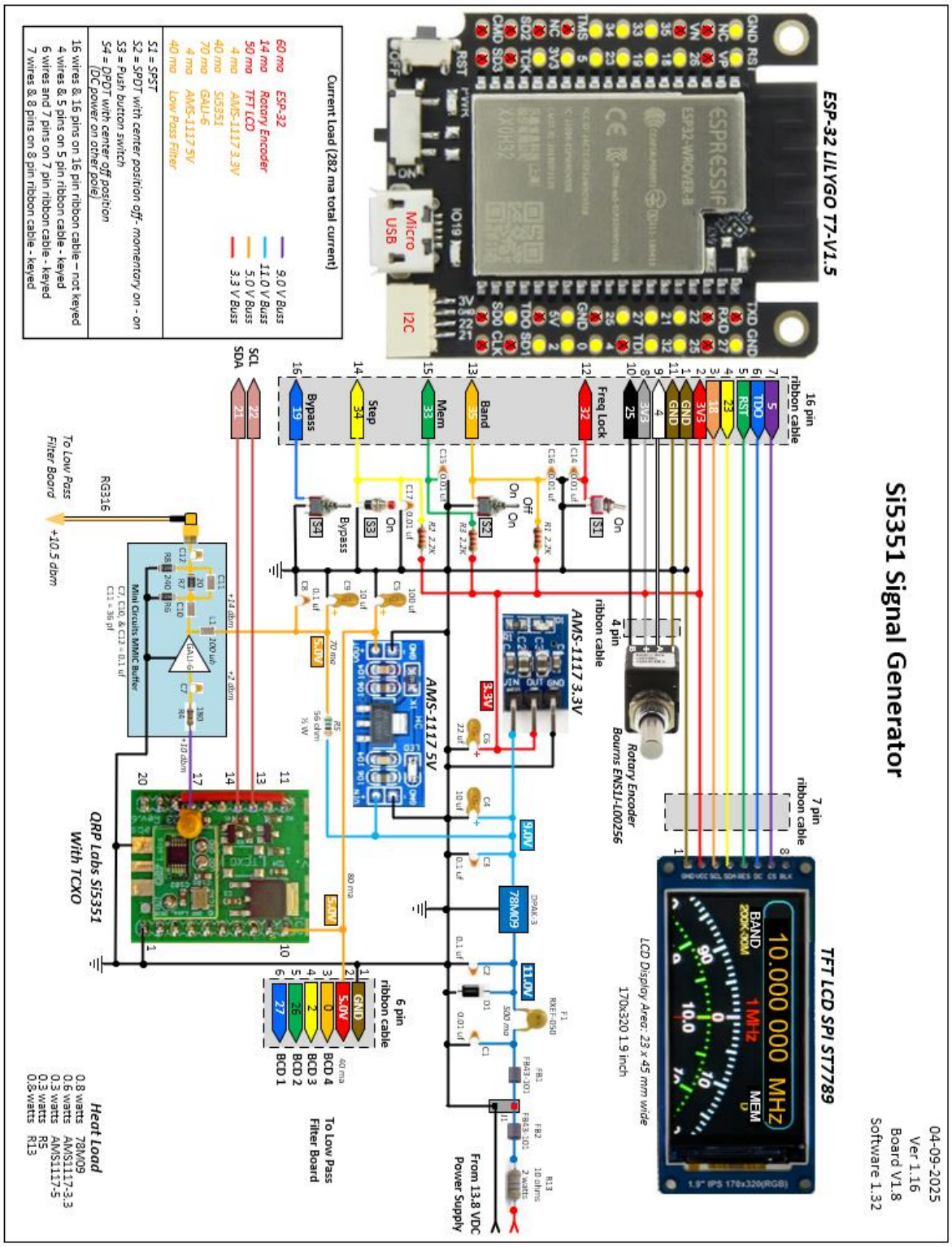


Figure 3 – Interconnection Diagram



H. VFO Harmonics

Figure 4 – 160M (10 dB pad)

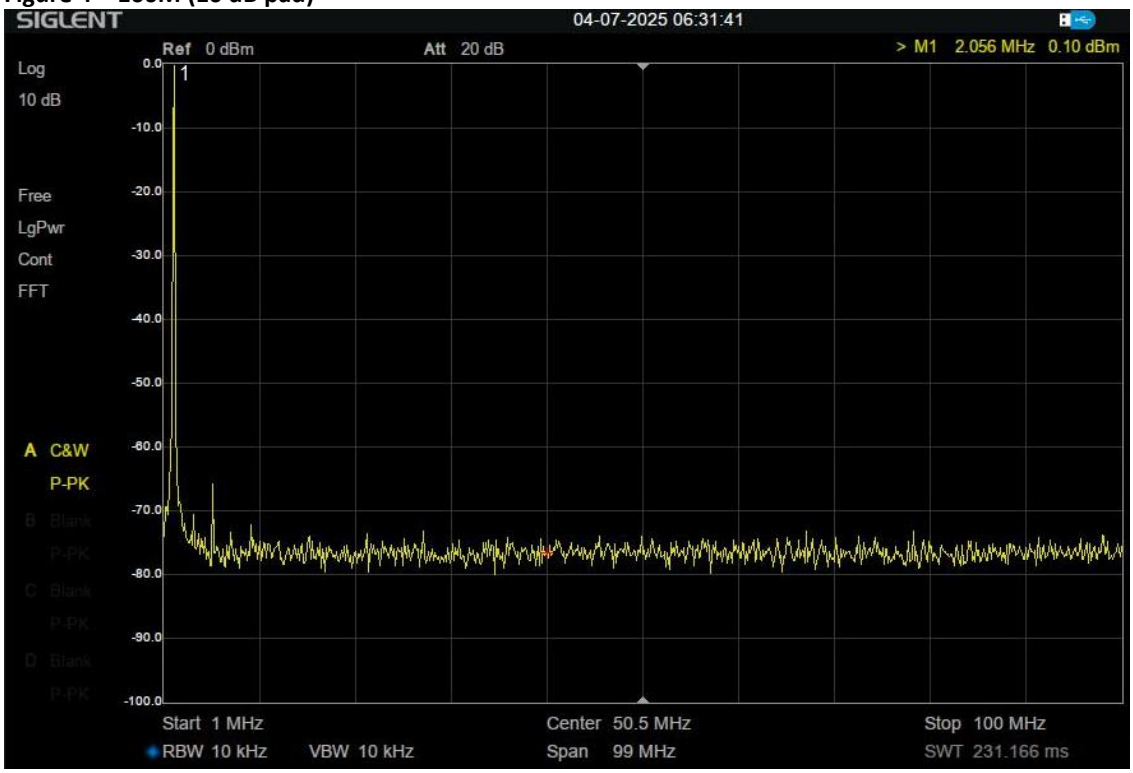


Figure 5 – 80M (10 dB pad)

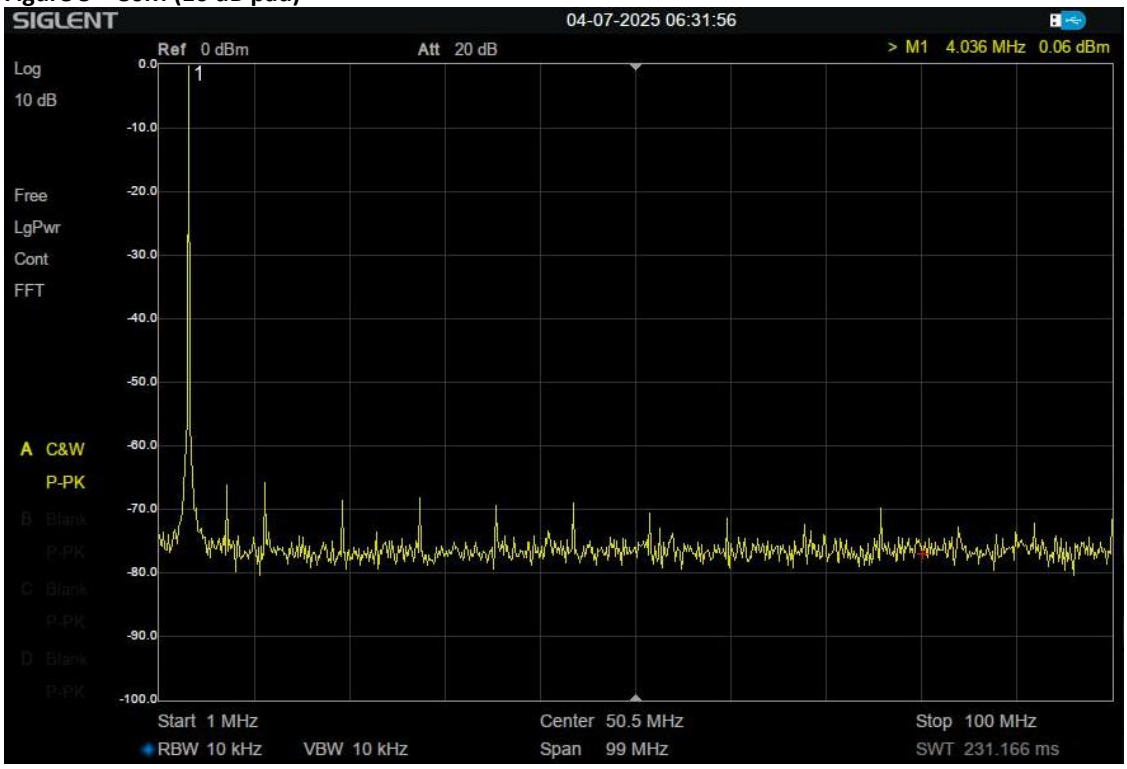


Figure 6 – 40M (10 dB pad)

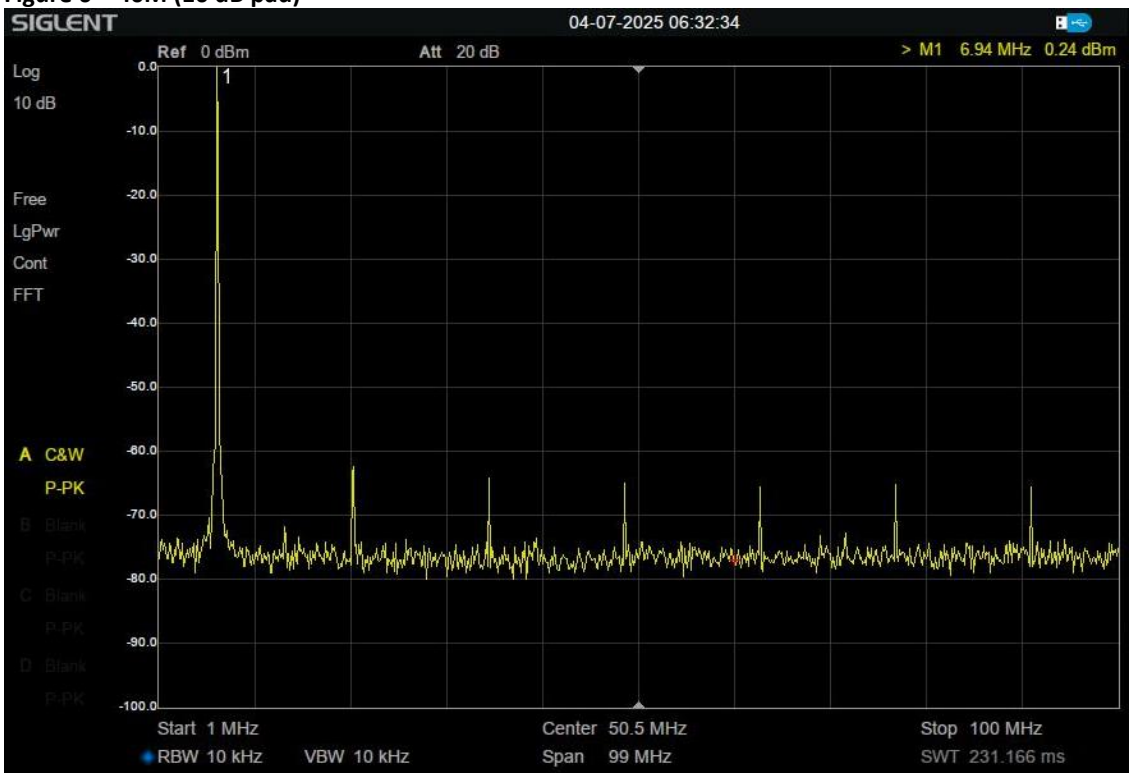


Figure 7 – 30M (10 dB pad)

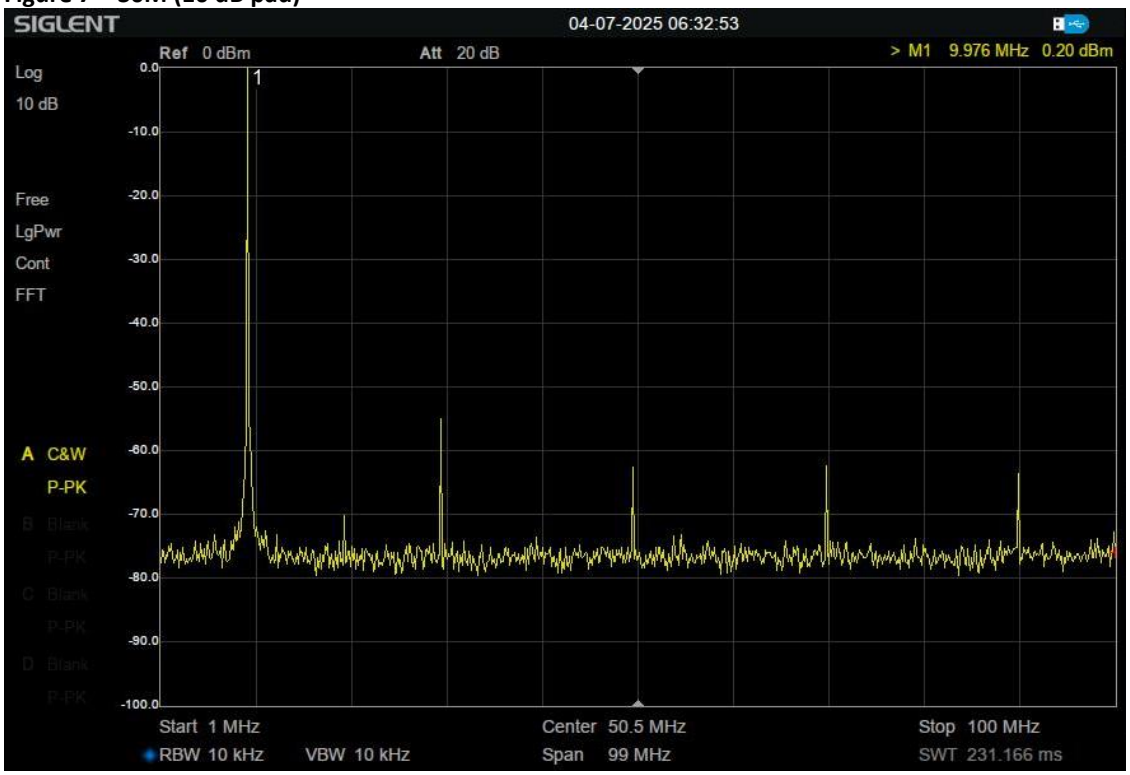


Figure 8 – 20M (10 dB pad)

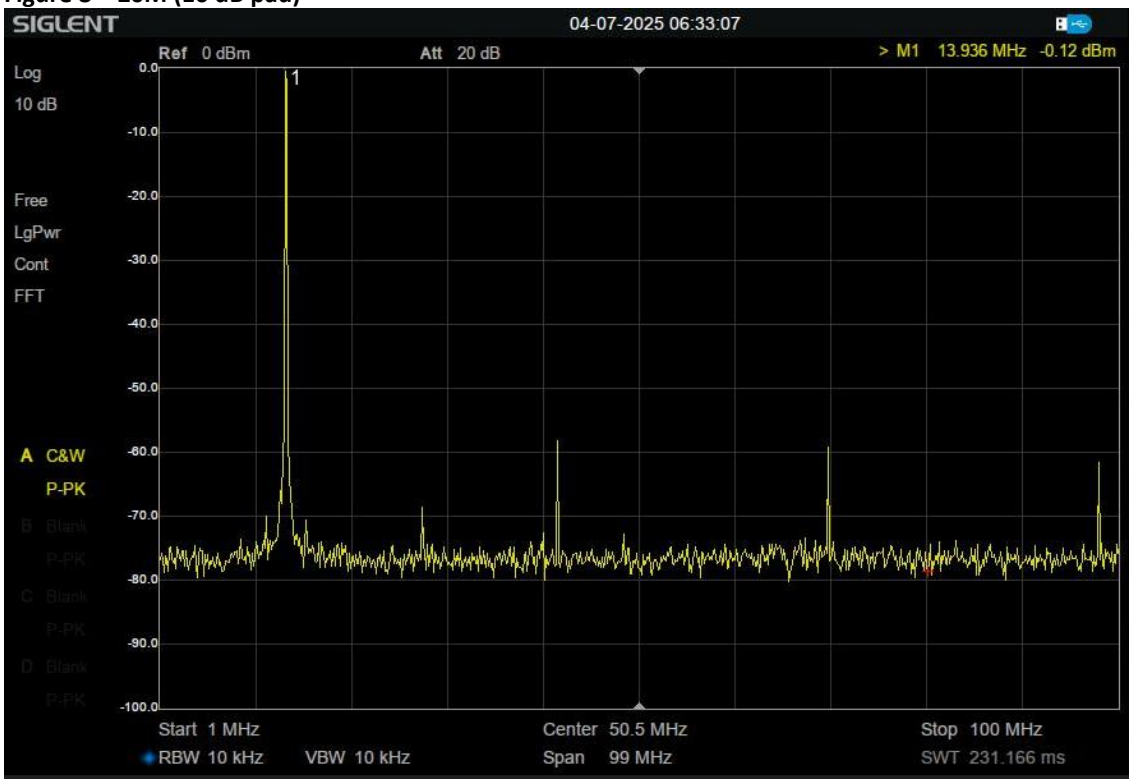


Figure 9 – 17M (10 dB pad)

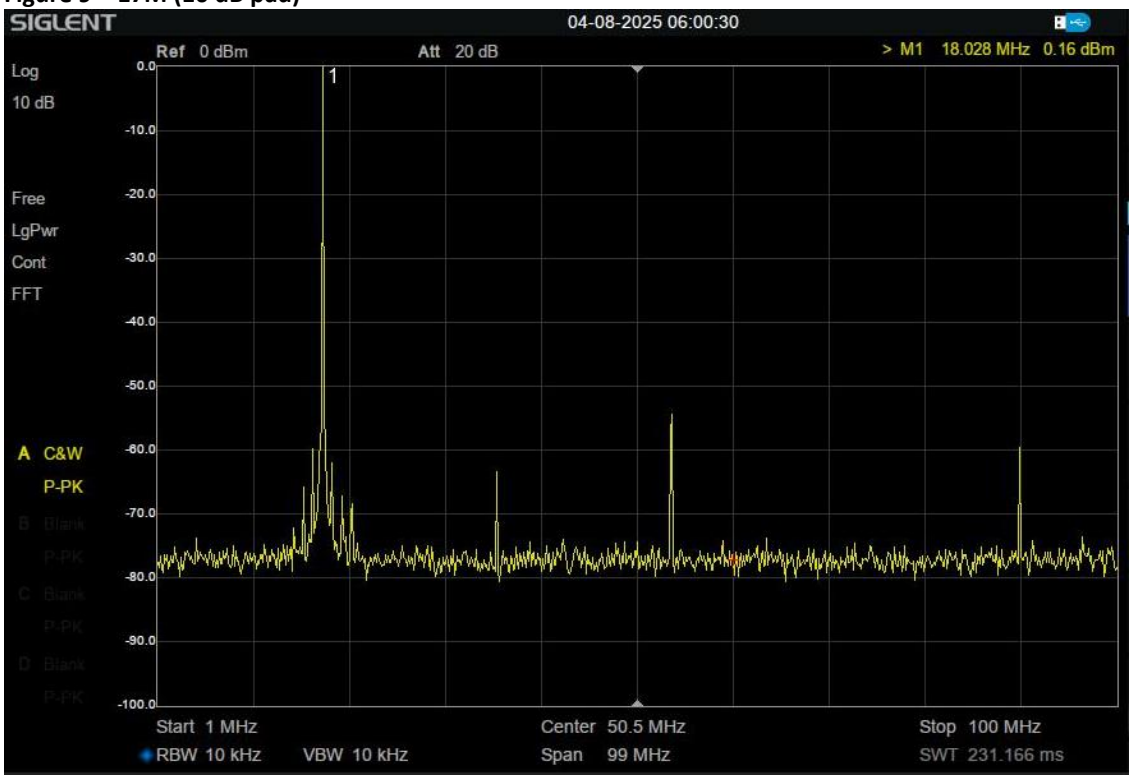


Figure 10 – 15M (10 dB pad)

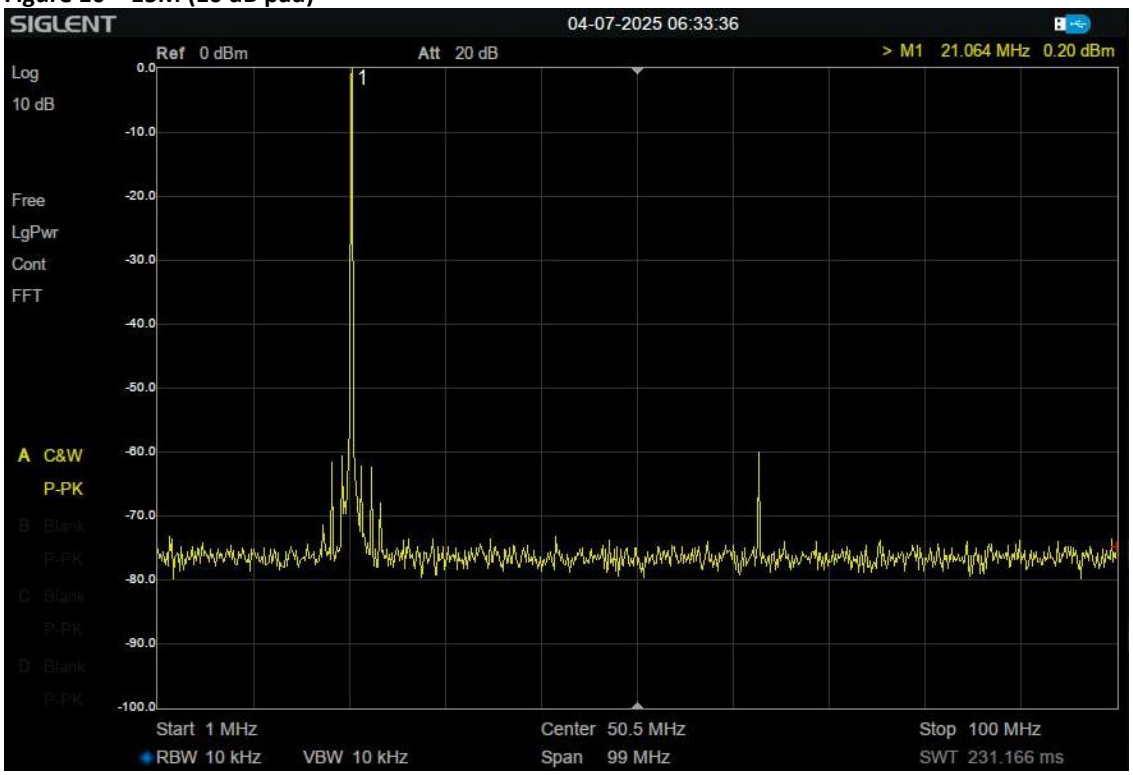


Figure 11 – 12M (10 dB pad)

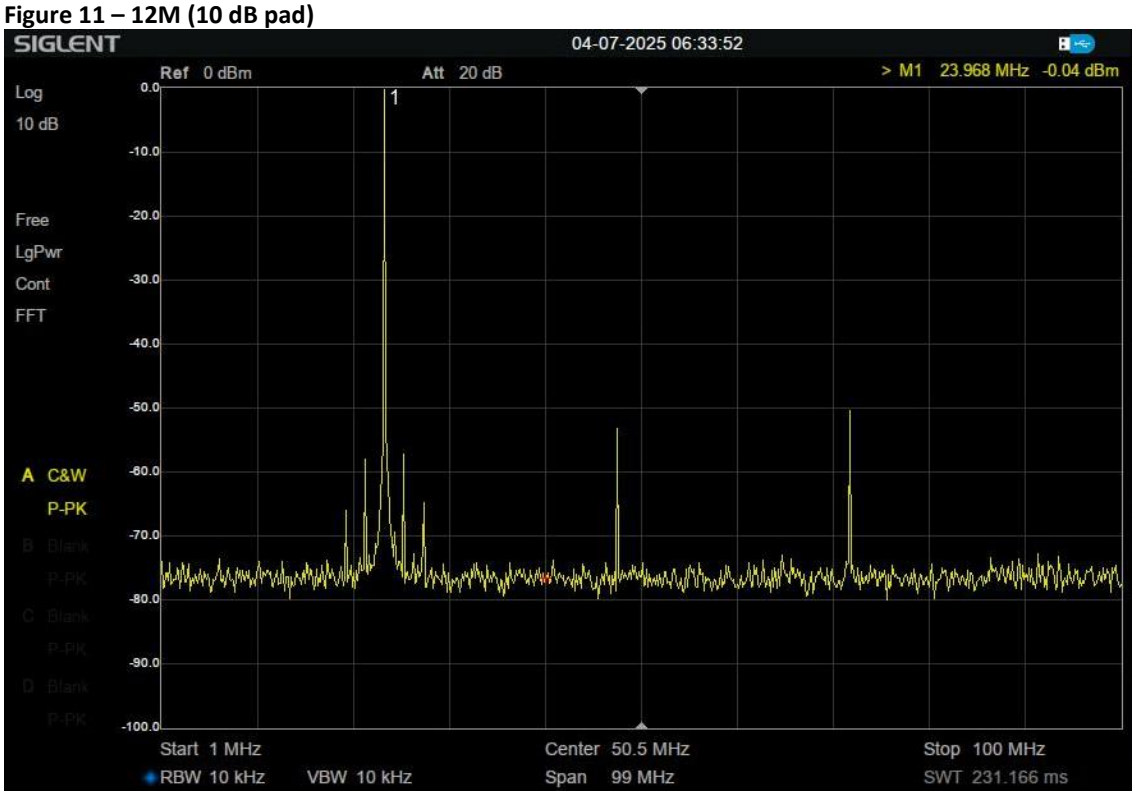
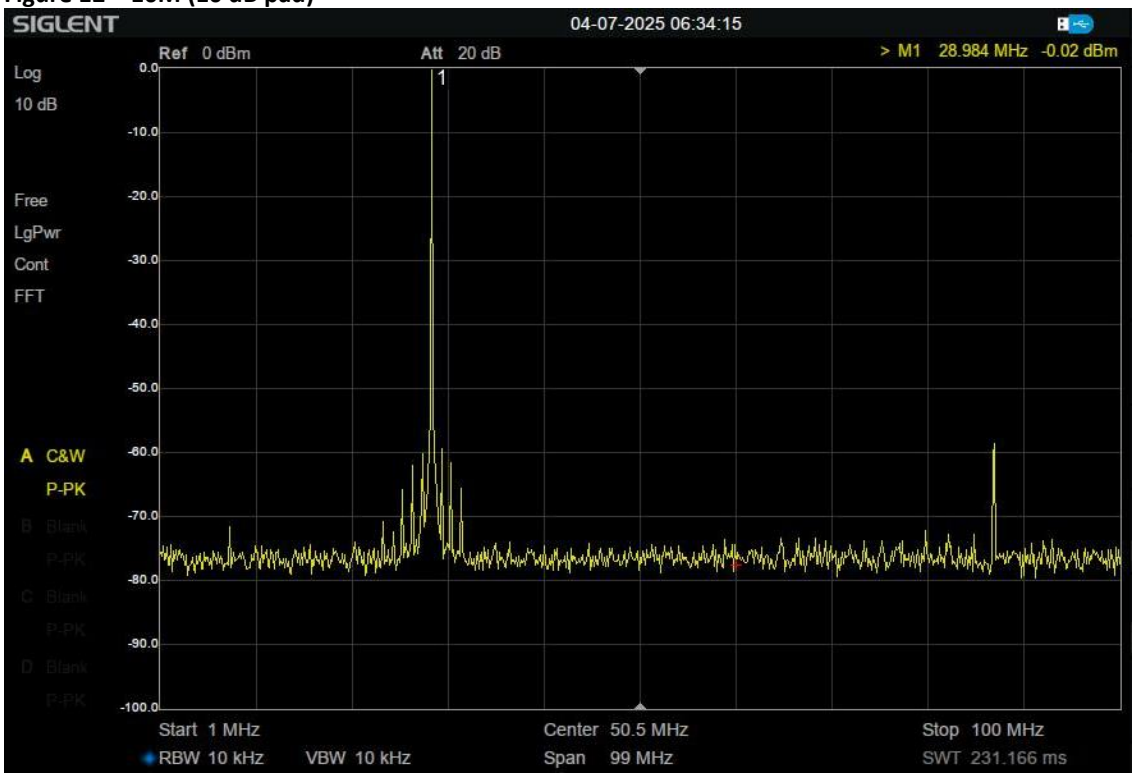


Figure 12 – 10M (10 dB pad)



I. Sine Wave Quality

Figure 13

Si5351 VFO 80M Sine Wave with Ukraine Low Pass Filter

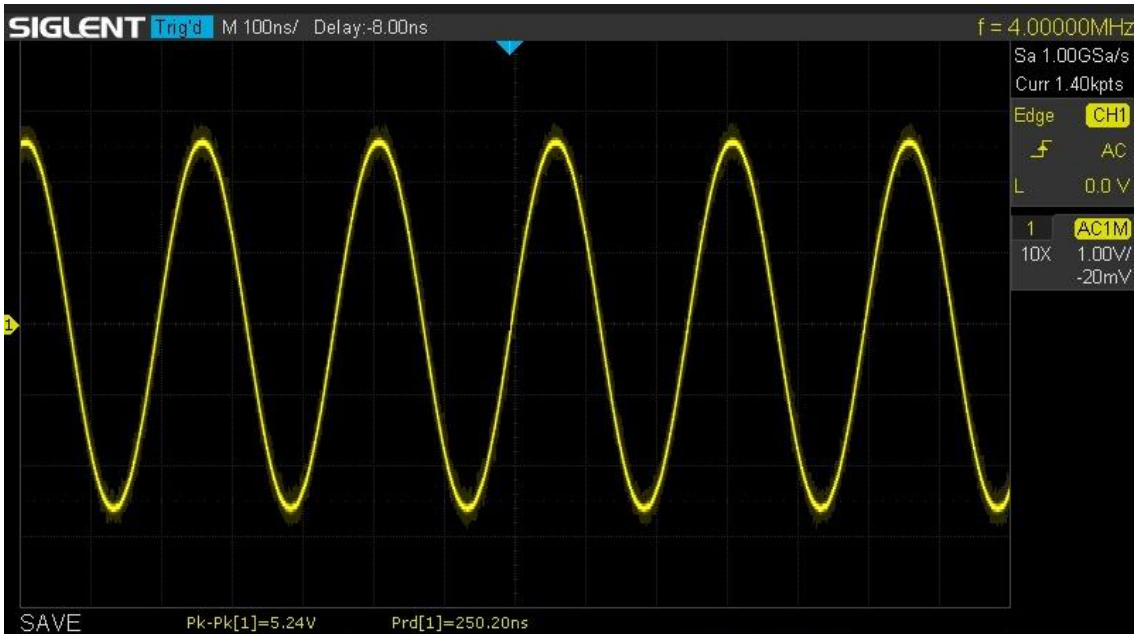


Figure 14 – Si5351 VFO 80 Signal
No low pass filter

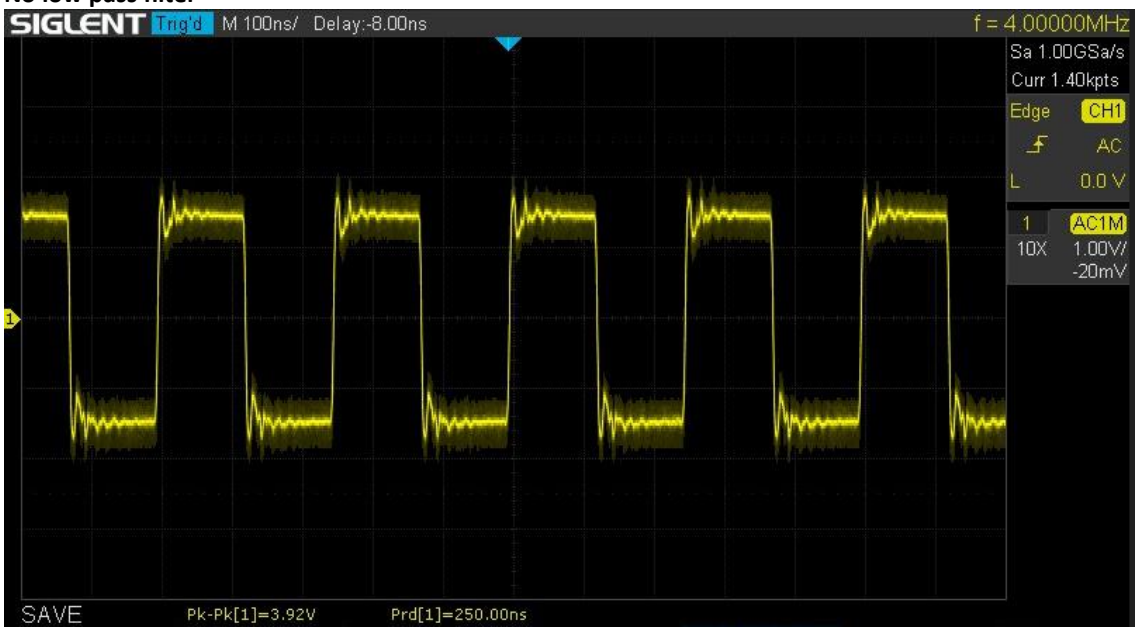
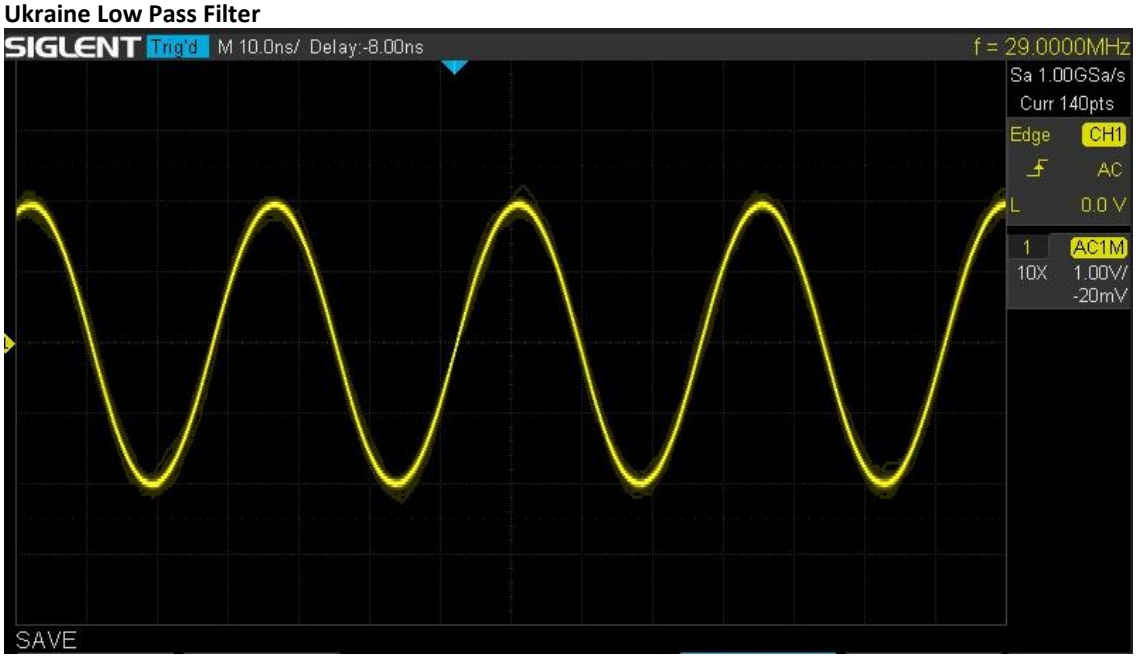


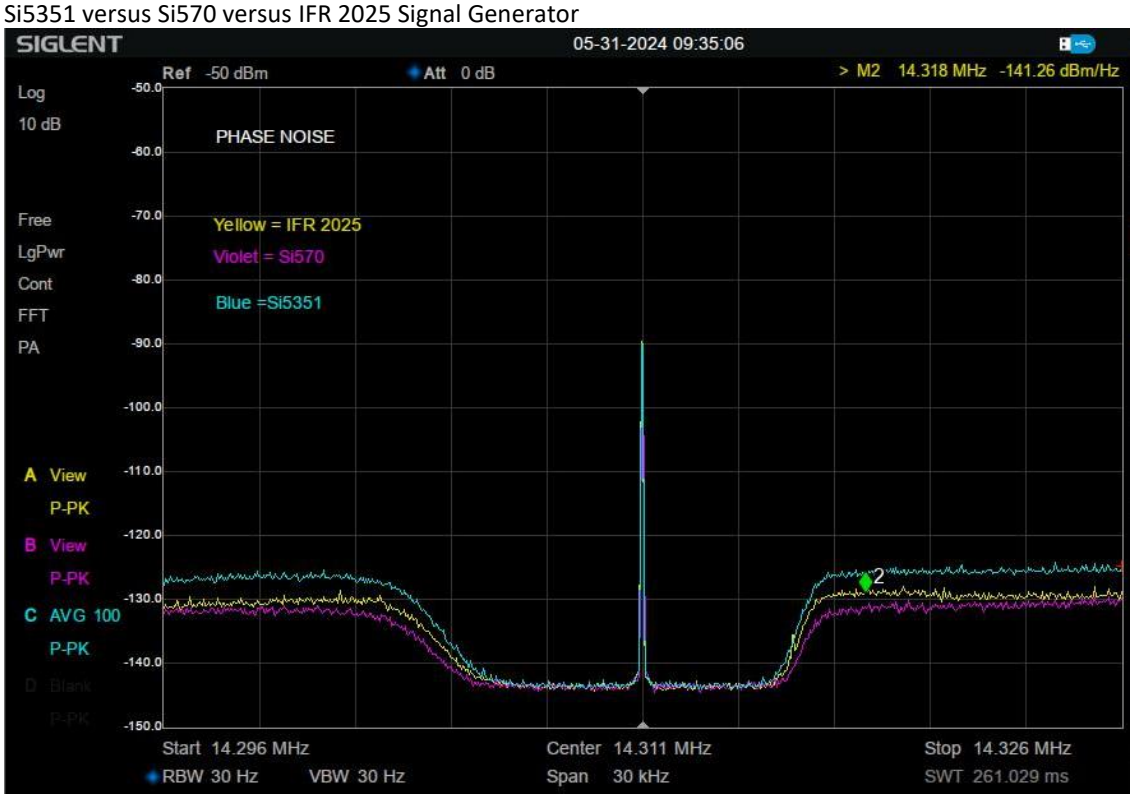
Figure 15 – Si5351 VFO 10M Sine Wave
Ukraine Low Pass Filter



J. Phase Noise

Figure 16

Si5351 versus Si570 versus IFR 2025 Signal Generator



K. Low Pass Filter Sweeps

Figure 17

Ukraine Low Pass Filter Sweeps

2 MHz, 4MHz, 7 MHz, & 14 MHz

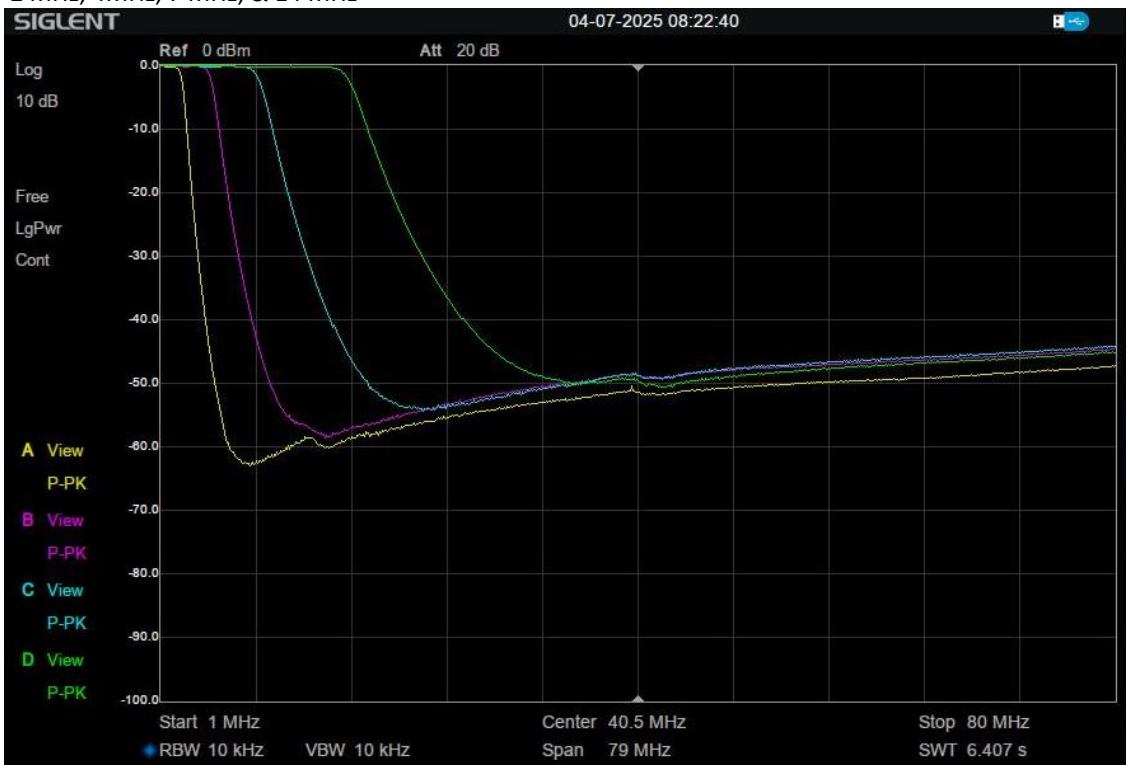
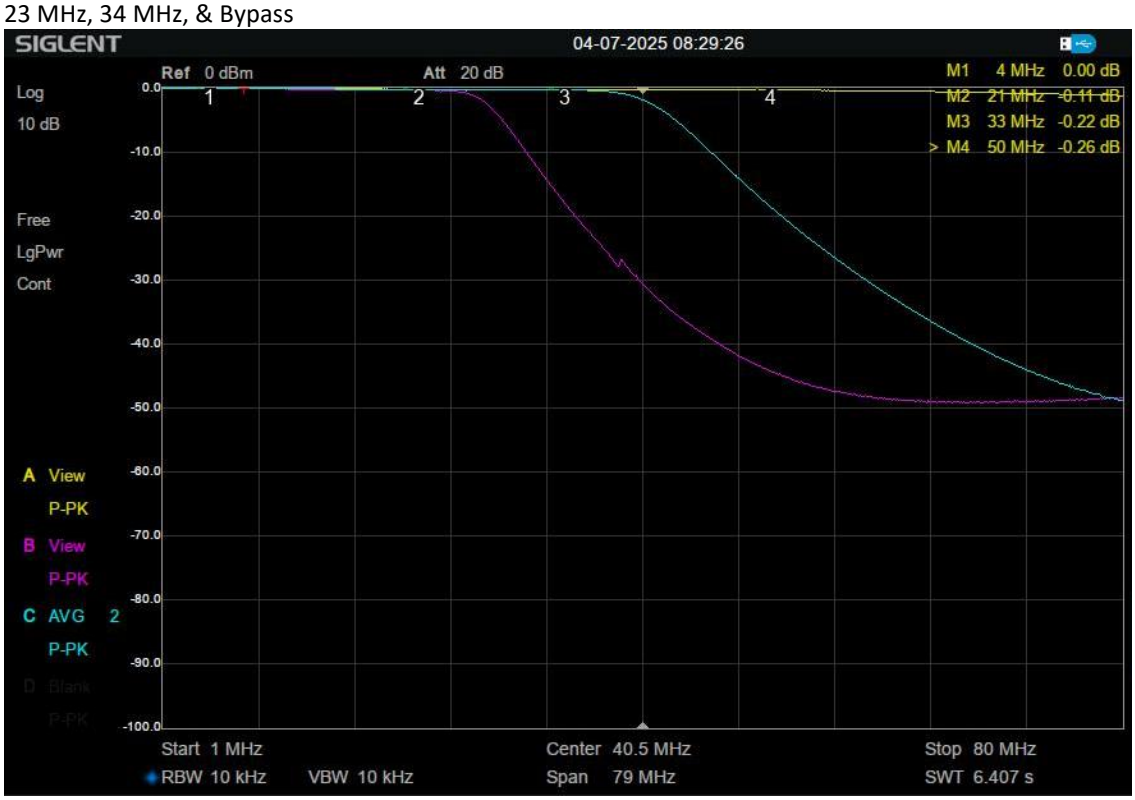


Figure 18 – Ukraine Low Pass Filter Sweeps
23 MHz, 34 MHz, & Bypass



L. VFO Spurs

Spurs were measured on each of the five ham bands. The radio was terminated with a 50 ohm load and the frequency step was set to 500 Hz. The S-meter signal level of each spur was recorded.

Using even division in the Si5351 results in fewer spurs than using fractional division. The higher the frequency step rate, the higher the probability that even division will be used. Example: A 10 KHz step rate will have fewer spurs than a 1 KHz step rate.

Spurs have very narrow bandwidths. So, if the step rate is too high, you will tune past the spur – i.e. it is there but you will not be able to hear it. If you set the step rate to 100 Hz, you will hear a lot of spurs on the 15 meter and 10 meter bands.

The Si5351 Library code has been optimized for minimal clicking/popping when changing frequency. For a given set of libraries, the amount of clicking/popping will vary depending upon what part of the band is being used, as you change frequency.

The Pavel Milanes Library uses the si5351mcu.cpp and si5351mcu.h files.
The Jason Milldrum Library uses the si5351.cpp and si5351.h files.

Overall, the Jason Milldrum library had the most spurs, especially on 10 meters. To confirm my testing process, I ran a spur test using my IFR 2025 signal generator as an external VFO. There was a total of 5 spurs across all five bands. In normal operation, a step rate of 1 KHz will be used. There is a minimal number of spurs with that step rate.

For this analysis, spurs are only shown if they generated an S Meter reading of S1 or greater. A S1 signal is a level of about -110 dbm. For these measurements, I used the Pavel Milanes Library. For a given set of libraries, the amount of clicking/popping will vary depending upon what part of the band is being used, as you change frequency.

There are several strong spurs on the 10M band with signal levels greater than S5. The strongest spur occurred at 29233.5 MHz with a S Meter reading of S9. On that band, the Internal Crystal Calibrator generates a signal of S8.

80M
Clicking/popping: Minimal

Frequency	S Meter
3536.0	S1
3629.5	S1
3702.5	S1
3763.5	S1
3946.0	S1
3978.5	S1

40M
Clicking/popping: Minimal

Frequency	S Meter
7153.0	S1
7277.0	S1

20M
Clicking/popping: None

Frequency	S Meter
14035.5	S1
14071.0	**S5**
14187.5	**S4**
14222.5	**S6**
14314.0	S3

15M
Clicking/popping: Loud clicks on some frequencies

Frequency	S Meter
21021.5	S3
21350.5	S2
21370.5	**S5**

10M

Clicking/popping: Loud clicks on some frequencies

Frequency	S Meter		
28036.0	S3		
28043.5	S2		
28162.0	S2		
28223.5	**S4**	several spurs close together	22581 – 3x5645
28226.0	**S7**		
28233.0	S2		
28253.5	S2		
28287.5	**S5**		
28398.5	**S4**		
28456.0	S1		
28478.5	S1		
28494.5	**S7**		
28515.5	S3		
28573.5	S1		
28584.0	S3		
28718.5	S2		
28763.0	**S4**		
28885.5	**S6**		
28975.5	S1		
29032.0	S3		
29098.5	S1		
29233.5	**S9**		
29252.0	S1		
29312.5	S3		
29340.5	S1		
29403.5	S2		
29506.5	S2		
29515.5	**S7**		
29550.5	S1		

M. Arduino IDE App Colors

Change color settings for code display

https://www.tydac.ch/color

https://johndecember.com/html/spec/colorhex.html#google_vignette

N. End-user Customizable Code for large display

The following lines are code is located in the config.h file:

Selects model of radio

```
41    #define RADIO  A210             // A180, A215 or A210
```

MCU selects the Pavel Milanes library to minimize birdies.
ETHERKIT selects the Jason Milldrum library.

```
47    #define SI5351_DRV MCU        // SI5351 Driver can be ETHERKIT or MCU
```

Allows use of Lilygo T7 Ver 1.4 ESP32-S2 board – actual board is Ver 1.5

```
79    #define MC_TYPE WROVER
```

Allows use of large 172 x 320 display

```
144   #define DISP_SIZE CUSTOM_DISP      // Custom display currently in use
```

Splash screen

```
160   /*-------------------------------------------------------
161   | |Splash Screen Startup intro - Version Number
162   -------------------------------------------------------*/
163
164
165   //----------Start-up Version Number---------------------------
166   #define NAME "Si5351 Sig Gen"
167   #define VERSIONID "Version 1.32"
168   #define ID " by KI5IDZ & W7KEC"
169
```

Change dial pointer

```
247   | #define DP_WIDTH       1        // Width of Dial pointer
248   | #define DP_LEN       100        // Length of Dial pointer
249   | #define DP_POS         0        // Length Dial pointer extends above dial
```

The end-user can customize the following text, font size, and location on the TFT display. It is assumed that the 172 x320 display is being used. The “CLINT” preference is used in the ino file.
The details of the Clint preferences are found in the config.h file.

```
45    #define PREFERENCE CLINT      //PREFERENCE can be defined as CLINT MARK JOHN

336   #if PREFERENCE == CLINT
337   #define   CL_BG          CL_BLACK    // Display background (Black)
338   #define   CL_POINTER     CL_RED      // Dial pointer (Red)
339   #define   CL_TICK_MAIN   CL_GREEN    // Main Ticks (Lime green)
340   #define   CL_NUM_MAIN    CL_WHITE    // Main dial numbers (White)
341   #define   CL_TICK_SUB    CL_SKYBLUE  // Sub Ticks (Light blue)
342   #define   CL_NUM_SUB     CL_WHITE    // Sub Numbers (White)
343   #define   CL_DIAL_BG     CL_BLACK    // Dial background (Black)
344   #define   CL_SPLASH      CL_LT_BLUE  // Splash screen text
345   #define   CL_FREQ_BOX    CL_CYAN     // Numerical frequency box
346   #define   CL_F_NUM       CL_ORANGE   // Numerical frequency
347   #define   CL_NUM         CL_YELLOW   // Numerical small numbers
348   #define   CL_NUM_O       CL_RED      // Step color in CUSTOM_DISP
349   #define   CL_NUM_NORM    CL_WHITE    // Normal Text inside box
350   #define   DP_POS           0         // Length Dial pointer extends above dial
351   #define   DISP_TM         30         // Top Margin moves Dial up and down
352   #define   F1_POS          15         // Vertical Position of the frequency box 14 60    32,14
353   #define   T1_POS          60         // Align the secondary text information on this line
354   #define   DIAL_SPACE      40         // Number of pixels between the main and sub arcs
355   #define   TICK_SUB1        8         // Length of Sub Tick(1)
356   #define   TICK_SUB5       14         // Length of Sub Tick(5)
357   #define   TICK_SUB10      18         // Length of Sub Tick(10)
358   #define   TICK_MAIN1       4         // Length of Main Tick(1)
359   #define   TICK_MAIN5      14         // Length of Main Tick(5)
360   #define   TICK_MAIN10     18         // Length of Main Tick(10)
361   #define   TNCL_MAIN       18         // Space between Number and Tick (Main)
362   #define   TNCL_SUB        18         // Space between Number and Tick (Sub)
363   #define TICK_PITCH_MAIN 10.5         // Main Tick Pitch (note small changes make a big difference)
364   #define TICK_PITCH_SUB   9.8         // Sub Tick Pitch  (try not to go below 4.0)
365   #define CORRECTION       0ULL        // Default correction is 0
366   #define CORRECTION_MCU   0           // Default correction is 0
367   #define EncoderStep     20           // use for 100 PIR
```

The following lines of code are located in the ino file:

Change memory frequencies

```
130   #if RADIO == A210
131   #if PREFERENCE == CLINT
132   long freqa[6] = { 3853000, 3846000, 3900000, 3916000, 3950000, 5000000};     //80M band memory presets
133   long freqb[6] = { 7155000, 7162000, 7235000, 7255000, 7275000, 5000000};     //40M band memory presets
134   long freqc[6] = {14235000,14225000, 14250000,14300000,14325000,10000000};    //20M band memory presets
135   long freqd[6] = {21285000,21300000, 21320000,21350000,21400000,15000000};    //15M band memory presets
136   long freqe[6] = {28385000,28425000,28450000, 28500000,28500000,28900000};    //10M band memory presets
137   long freqf[6] = {   10000,250000,1000000,10000000,30000000,100000000};       //Sig Generator presets
138   int recall[6] = {2,2,3,2,2,4};                                               //prefered memory recall at startup
139   const long begofBand[6] = {3803000,7178000,14225000,21275000,28300000,8000}; //General Class
140   const long endofBand[6] = {4000000,7300000,14348000,21448000,28998000,180000000}; //All bands
141   #else
```

Change Si5351 Power Out

The output power level of the VFO can be changed by modifying the setpower settings. Possible values are 2 ma, 4 ma, 6 ma, and 8 ma. The power is currently set for 4ma when in the Atlas mode. In the SigGen mode, it is set for 4ma when using the internal low pass filters.

```
235   | | si5351.setPower(0,SIOUT_4mA);       //set output power of Si5351  old=8ma
```

Here are the readings with the output of the VFO disconnected from the FET switch and terminated on a spectrum analyzer (50 ohms) via a 10 db pad.

BAND	2 ma drive	4 ma drive	6 ma drive	8 ma drive
80M	8.9 dbm	10.6 dbm	11.2 dbm	11.5 dbm
40M	8.8 dbm	10.7 dbm	11.2 dbm	11.4 dbm
20M	8.6 dbm	10.7dbm	10.9 dbm	11.2 dbm
15M	8.8 dbm	10.6 dbm	11.3 dbm	11.5 dbm
10M	8.7 dbm	10.5 dbm	11.2 dbm	11.5 dbm

Change text, font, and colors for Splash screen

```
322   | lcd.setCursor( 0.5f*(lcd.width()-lcd.textWidth(NAME) ), 0.1f*lcd.height() ); //where to write Name intro
323   | lcd.printf( NAME );                  //send name intro to display
324   | lcd.setCursor( 0.5f*(lcd.width()-lcd.textWidth(VERSIONID) ), 0.3f*lcd.height()); //where to write Version ID
325   | lcd.printf(VERSIONID);               //send version ID to display
326   | lcd.setCursor( 0.5f*(lcd.width()-lcd.textWidth(ID) ), 0.5f*lcd.height());  //where to write ID
327   | lcd.printf(ID);                     //sendi ID to display
```

Set Band names

```
671   #if RADIO == A210
672   | switch(count) {                                  //determine which position the band switch is locatec
673   | | case 1: sprintf(band_str, " 80 M"); break;    //set to 80M position USB
674   | | case 2: sprintf(band_str, " 40 M"); break;    //set to 40M position USB
675   | | case 3: sprintf(band_str, " 20 M"); break;    //set to 20M position USB
676   | | case 4: sprintf(band_str, " 15 M"); break;    //set to 15M position USB
677   | | case 5: sprintf(band_str, " 10 M"); break;    //set to 10M position USB
678   | | case 6: sprintf(band_str, "SIG GEN"); break; //Signal Generator  old=Sig. Gen
```

Set Frequency Steps

```
switch (stp) {  //used by pushbutton to change frequency step
  case 1: stp = 2; fstep = 1; break;        //step frequency of 1 Hz
  case 2: stp = 3; fstep = 10; break;       //step frequency of 10 Hz
  case 3: stp = 4; fstep = 100;break;       //step frequency of 100 Hz
  case 4: stp = 5; fstep = 500; break;      //step frequency of 500 Hz
  case 5: stp = 6; fstep = 1000; break;     //step frequency of 1 KHz
  case 6: stp = 7; fstep = 10000; break;    //step frequency of 10 KHz
  case 7: stp = 8; fstep = 100000; break;   //step frequency of 100 KHz
  case 8: stp = 9; fstep = 1000000; break;  //step frequency of 1 MHz
  case 9: stp = 1; fstep = 10000000; break; //step frequency of 10 MHz
```

Set Memory names

```
switch (memory) {
  case 1: sprintf(mem_str, " A");break;    //display memory M:A
  case 2: sprintf(mem_str, " B");break;    //display memory M:B
  case 3: sprintf(mem_str, " C");break;    //display memory M:C
  case 4: sprintf(mem_str, " D");break;    //display memory M:D
  case 5: sprintf(mem_str, " E");break;    //display memory M:E
  case 6: sprintf(mem_str, " F");break;    //display memory M:F
```

Define location of Frequency Display box

```
sprites[flip].drawRoundRect(7,F1_POS,304,40,15,CL_FREQ_BOX); // draw box (x1,y1,x2,y2,thick,color) (0,15,320,40,5,)  new=7,304
```

O. Si5351 Chinese Oscillator Board

The VFO circuit board is setup to use either a QRP Labs Si5351 module or a Chinese Si5351 module. The QRP Labs module requires that two 10 female pin headers be installed for U4. A Chinese module only has seven pins on the board and only uses the U4A socket.

To use the Chinese board, the following changes need to be made for the build of the VFO board.
Install a single 10 female pin header at U4A.
There is a solder pad connected to pin 9 of U4A.
Install an insulated ground wire from this solder pad to a ground point on the motherboard.
Near pin 14 of U4A, there is a solder pad labeled SCL.
There is a solder pad next to pin 8 of U4A and it is connected to pin 7 of U4A.
Install an insulated wire from this solder pad to the SCL solder pad next to the U4B socket.
Near pin 13 of U4A, there is a solder pad labeled SDA.
There is a solder pad next to pin 7 of U4A and it is connected to pin 8 of U4A.
Install an insulated wire from this solder pad to the SDA solder pad next to the U4B socket.
Install an insulated wire from pin 4 of U4A to pin 17 on the U4B socket.

The Chinese board is installed so that the following pins matchup:

U4A pin 4	Clk0 pin of Chinese board
U4A pin 5	Clk1 pin of Chinese board (not used)
U4A pin 6	Clk2 pin of Chinese board (not used)
U4A pin 7	SCL pin of Chinese board
U4A pin 8	SDA pin of Chinese board
U4A pin 9	GND pin of Chinese board
U4A pin 10	VIN pin of Chinese board