

# Si5351 SigGen/VFO

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## 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 well but the cost is high \$30 - \$60. 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.

For an Atlas 210X/215X transceiver, the VFO frequency changes as the band is changed. A 12M low pass filter would remove most harmonics. An enhanced option would 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 a 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.

## II. SPECIFICATIONS

Here is a summary of the specs for the VFO:

Minimal cost

Code modification to select the IF scheme for a given radio

About 240 mA current draw, including back-lighted TFT display

The following sections on the VFO board are connectorized:

DC power to circuit board

ESP-32 microprocessor

QRP Labs Si5351 module

5.0 volt regulator

TFT Display

Front Panel Controls

Five memory channels on each band

Frequency Lock

Supports standard color TFT 170x320 display

+10.0 dbm output signal

With 1 KHz frequency step tuning – 50 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

Works with standard Bourns or Oak Grigsby optical encoders

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

#### 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 die cast aluminum 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:



#### **Printed Circuit Boards**

- VFO board
- Low Pass Filter Board
- Enclosure Front Panel
- TFT Display Mounting Bracket

**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](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](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.35.20621802IliJvW&gatewayAdapt=glo2usa](https://www.aliexpress.us/item/3256805935800579.html?spm=a2g0o.order_list.order_list_main.35.20621802IliJvW&gatewayAdapt=glo2usa)

**SMA Female Chassis Bulkhead Mount**

<https://www.aliexpress.us/item/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.55.3d571802V9INu1&gatewayAdapt=glo2usa](https://www.aliexpress.us/item/3256802438032687.html?spm=a2g0o.order_list.order_list_main.55.3d571802V9INu1&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-tNzc5uHFSPRrZmr4aAhEYEAw\\_wcB](https://www.hawkusa.com/manufacturers/hammond-mfg/enclosures/box-metal/1455n1201bk?gad_source=1&gclid=Cj0KCQjwqcO_BhDaARIsACz62vNzv60_8X_BhhFiabZjBbFbvo_6H8enDuHVfU-tNzc5uHFSPRrZmr4aAhEYEAw_wcB)

**AMS-1117 5 volt voltage regulator**

<https://www.aliexpress.us/item/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**

<https://www.amazon.com/AMS1117-3.3-DC-4.75V-12V-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**

<https://www.aliexpress.us/item/10pcs-lot-L78M05CDT-L78M05-TO-252-78M06-78M08-78M09-78M12-78M15-79M05-AliExpress-502>

**RF Choke SMD**

100 uh 1210

<https://www.aliexpress.us/item/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](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](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](https://www.aliexpress.us/item/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](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](https://www.aliexpress.us/item/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**

33 pf 50 volt 1 each

[https://www.aliexpress.us/item/3256806963299575.html?spm=a2g0o.productlist.main.21.2178d019j31JKm&algo\\_pv\\_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%2112000039594973937%21sea%21US%213978472839%21X&curPageLogUid=2pcs3j09D6Ch&utparam-url=scene%3Asearch%7Cquery\\_from%3A](https://www.aliexpress.us/item/3256806963299575.html?spm=a2g0o.productlist.main.21.2178d019j31JKm&algo_pv_id=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%2112000039594973937%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

[10OPCS 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](https://www.aliexpress.us/item/10OPCS_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.103.46a81802yPc6lc&gatewayAdapt=glo2usa](https://www.aliexpress.us/item/3256801635578473.html?spm=a2g0o.order_list.order_list_main.103.46a81802yPc6lc&gatewayAdapt=glo2usa)**1N4001 Diode**[100pcs 1N4001 IN4001 Rectifier Diode 1A 50V DO-41 New Original - AliExpress](https://www.aliexpress.us/item/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](https://www.aliexpress.us/item/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/item/295327320682>

**Momentary Pushbutton Switch**

[https://www.aliexpress.us/item/2255799950576497.html?spm=a2g0o.order\\_list.order\\_list\\_main.49.2a9a180260t1Hk&gatewayAdapt=glo2usa](https://www.aliexpress.us/item/2255799950576497.html?spm=a2g0o.order_list.order_list_main.49.2a9a180260t1Hk&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](https://www.aliexpress.us/item/2255799950576497.html?spm=a2g0o.order_list.order_list_main.49.2a9a180260t1Hk&gatewayAdapt=glo2usa)

**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%22sceneld%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](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%22sceneld%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=20250405173003937605242900100004303784&algo\\_pvid=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=20250405173003937605242900100004303784\\_6](https://www.aliexpress.us/item/3256808203625119.html?spm=a2g0o.productlist.main.47.51832827fyki52&aem_p4p_detail=20250405173003937605242900100004303784&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=20250405173003937605242900100004303784_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](https://www.aliexpress.us/item/2255799950576497.html?spm=a2g0o.order_list.order_list_main.49.2a9a180260t1Hk&gatewayAdapt=glo2usa)

**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](https://www.aliexpress.us/item/2255799950576497.html?spm=a2g0o.order_list.order_list_main.49.2a9a180260t1Hk&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.19.4575180200AlqQ&gatewayAdapt=glo2usa](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.19.60\\_0d1802yMXSMp&gatewayAdapt=glo2usa](https://www.aliexpress.us/item/3256801978454684.html?spm=a2g0o.order_list.order_list_main.19.60_0d1802yMXSMp&gatewayAdapt=glo2usa)

QRP Labs Si5351 Oscillator with TCXO option

<https://www.grp-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.17.395cjPlsjPlsHt&algo\\_pv\\_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%2112000030297775028%21sea%21US%213978472839%21X&curPageLogUid=e9lazXmnU2bx&utparam-url=scene%3Asearch%7Cquery\\_from%3A](https://www.aliexpress.us/item/3256804552802118.html?spm=a2g0o.productlist.main.17.395cjPlsjPlsHt&algo_pv_id=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%2112000030297775028%21sea%21US%213978472839%21X&curPageLogUid=e9lazXmnU2bx&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**

[I2C Connector 10 Female](#) | [I2C Female Connector 26 Pin](#) | [34 Pin Female Connector - Connectors - Aliexpress](#)

## DC Power Jack

[https://www.amazon.com/dp/B01N8VV78D?ref=ppx\\_yo2ov\\_dt\\_b\\_fed\\_asin\\_title](https://www.amazon.com/dp/B01N8VV78D?ref=ppx_yo2ov_dt_b_fed_asin_title)

## **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](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](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\\_=fpfs&psc=1&smid=ATVPDKIKX0DER](https://www.amazon.com/Jameco-Valuepro-3819-100-Hook-up-Tinned-Copper/dp/B00B8866TW?source=ps-sl-shoppingads-lpcontext&ref_=fpfs&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](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](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 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 100 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.

## **V. 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.

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)

BAND Position cycles through the following bands:

8 KHz – 20 KHz

20 KHz – 200 KHz

200 KHz – 30 MHz

30 MHz – 100 MHz

100 MHz – 200 MHz

Atlas – sets up generated frequencies to work with an Atlas transceiver

The ESP-32 code can be changed to support just about any model of radio

## VI. 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.

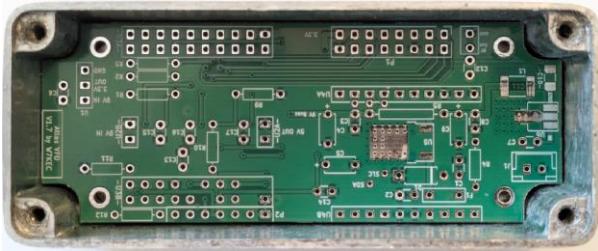
The project requires the following machine work:

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:

<b>Feedthrough</b>	Right side wall	this is the DC power feed terminal
<b>Ribbon</b>	Top center wall	the SMA jack is also on this wall
<b>USB</b>	Left side wall	optional access opening for USB plug
<b>Clearance</b>	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.

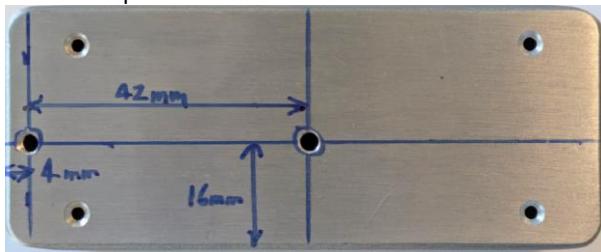


Using the four circuit board mounting holes as a guide, drill four each 5/64" holes in the bottom of the enclosure. Ensure that the drill bit is centered in each circuit board hole so that you do not remove any circuit board material while you are drilling. Also ensure that you have a sharp drill bit.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

Remove the circuit board from the enclosure.

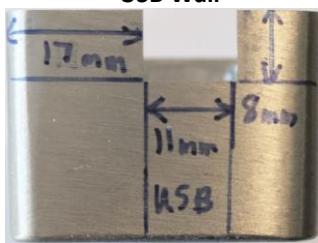
Counter sink the holes on the outside bottom of the enclosure.

Use a Phillip's countersunk screw to determine needed depth of counter sunk holes.



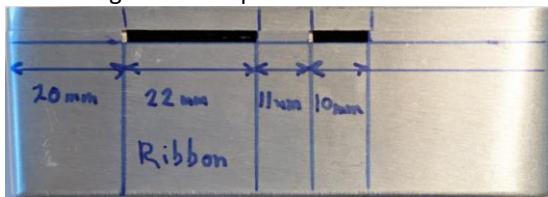
On the USB wall, cut a rectangle 11 mm wide by 8 mm high. The left edge of the rectangle should be 17 mm from the Ribbon wall. The size of the opening will depend up the size of the Micro USB connector that you use.

USB Wall

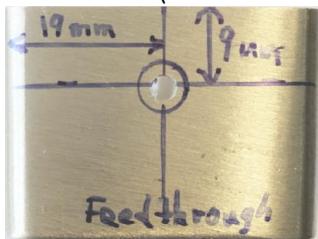


Write USB on the top cover next to the notch in the USB Wall.

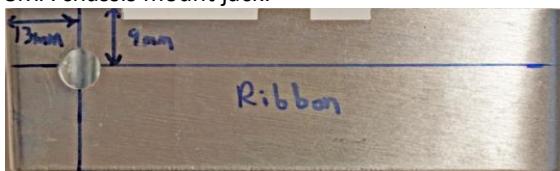
Cut two notches in the enclosure on Ribbon side. These notches are for the 16 wire and 6 wire ribbon cables. The 16 wire notch should be 20 mm from the Feedthrough end. It would be 22 mm wide and 1.5 mm deep. The 6 wire notch should be 10 mm wide and 1.5 mm deep. Cut matching notches in the enclosure 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.

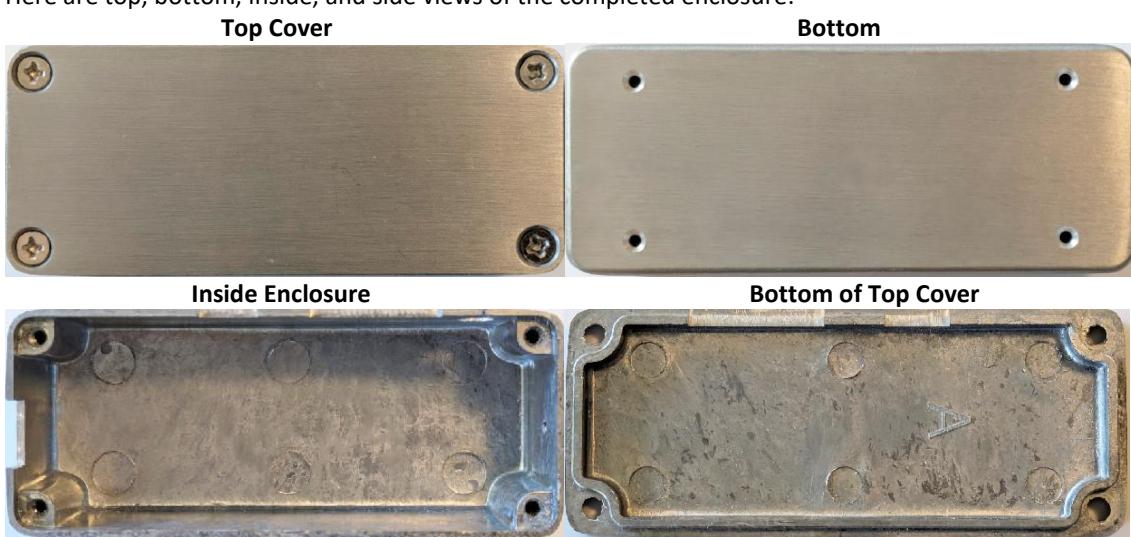


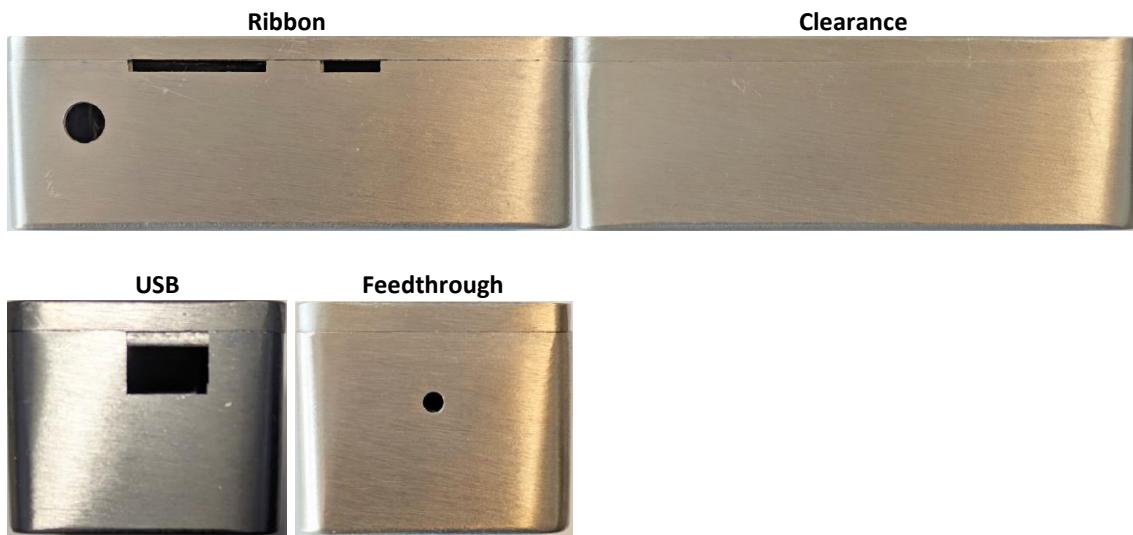
On the Ribbon wall, drill a 1/4" OD hole 13 mm from Feedthrough wall and 9 mm from the top edge for the SMA chassis mount jack.



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:

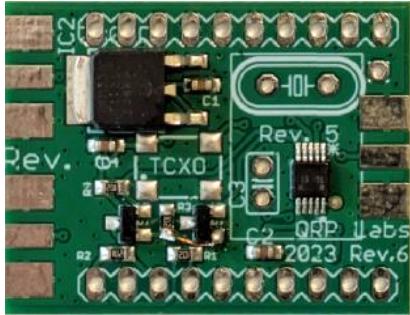




## VII. Build QRP Labs Si5351 Oscillator Board

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](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>

## **VIII. 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.



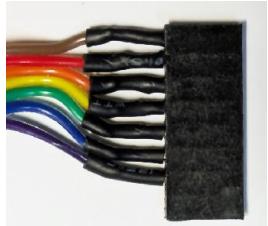
Separate 7 wires from the main body of the cable, starting with the outside brown color. Ensure that you do not pull a wire out of the insulation. The wire colors should be brown, red, orange, yellow, green, blue, and violet. These wires will interface with the TFT display.

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  $\frac{1}{4}$ " 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 it 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.



## **IX. Program ESP-32 Microprocessor**

*Caveats:*

*The following steps assume that no version of the Arduino IDE app has ever been installed on the PC. It is also assumed that the VFO box has not been built and that the ESP-32 board is on the bench with a USB cable connected to it. The other end of the USB cable is connected to the PC that will be used for the programming.*

*The programming PC will need to have an Internet connection.*

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

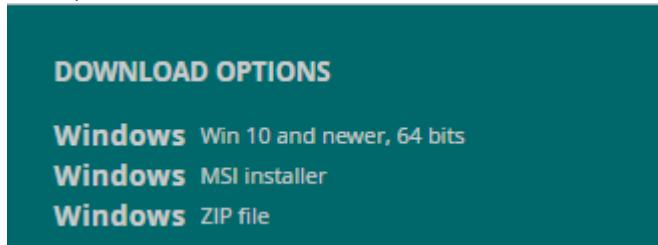
You will need to get the VFO\_4\_1.zip file in order to program an ESP-32 chip. This file will be available from John Satterfield and Clint Chron. The Arduino IDE app version 2.3.4 will be used to program the ESP-32.

Upgrading an installed version to a later version will not uninstall the current version. You will have to manually uninstall the older version.

On your PC, open a web browser to the Arduino Web site

<https://www.arduino.cc/en/software>

Under the Download options, found on the right side of the first page, click on the Windows Win10 and newer, 64 bits



Be ready for multiple 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 download will start. When complete, the downloaded file will be about 147 MB in size.

Double click on the downloaded file.

License Agreement: Hit I agree.

Select Anyone who uses this computer: Hit Next

Do you want to allow this app to make changes to your device: Hit Yes

License Agreement: Hit I agree

Use the default installation folder and hit Install

The installation will start. The install will take less than one minute on a typical Intel i5 PC.

Hit Finish

You may see several messages about allowing access to Public and Private networks. Hit yes for all.

The Arduino IDE app will open.

Close the app.

On your PC, create a subdirectory C:/VFO\_4\_1 and download the contents of the VFO4\_1.zip file.

Unzip the file. Ensure that the ino file is named VFO\_4\_1.ino.

	Name	Date modified	Type	Size
	config.h	5/29/2024 6:53 PM	H File	28 KB
	dial.cpp	5/18/2024 12:06 PM	CPP File	13 KB
	dial.hpp	5/18/2024 12:06 PM	HPP File	2 KB
	encodersetup.h	5/18/2024 12:06 PM	H File	1 KB
	PCF8574.cpp	5/18/2024 12:06 PM	CPP File	32 KB
	PCF8574.h	5/18/2024 12:06 PM	H File	8 KB
	pcf8574inputpins.h	5/18/2024 12:06 PM	H File	3 KB
	si5351.cpp	5/18/2024 12:06 PM	CPP File	42 KB
	si5351.h	5/18/2024 12:06 PM	H File	13 KB
	si5351mcu.cpp	5/18/2024 12:06 PM	CPP File	16 KB
	si5351mcu.h	5/28/2024 8:21 PM	H File	6 KB
	ST7735S_128x160.hpp	5/18/2024 12:06 PM	HPP File	9 KB
	ST7789_170x320.hpp	5/18/2024 12:06 PM	HPP File	11 KB
	VFO_4_1.ino	6/11/2024 8:22 AM	INO File	77 KB

Double click on the ino file. The Arduino IDE app will open.

**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

On the IDE menu, go to Files-Preferences

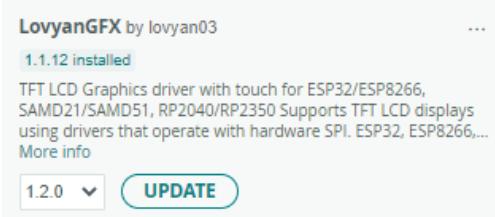
Under "Additional Boards Manager URLs, enter these URLs:

[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_dev_index.json)  
[https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package\\_esp32\\_index.json](https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package_esp32_index.json)

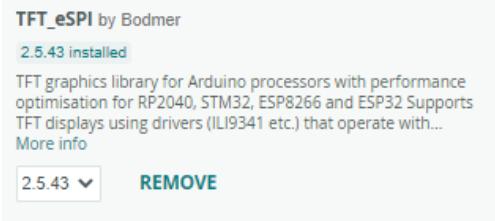
There are three ways to enter these URL's. If you are really good at typing, zero errors, type them in manually. Or you can try and copy and paste them directly from this document. The third way is to look back into your VFO\_4\_1 directly and Under the "Other Files" directory, there is a text file that has the two URLs that can be copied and pasted into the URL section.

Pick your option, input the URLs and Hit OK. Remember to make sure you load both URL files.  
The IDE app will go out to the Internet and will download the needed files.

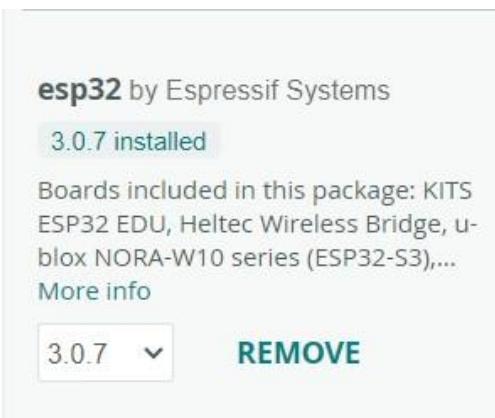
Under Tools/Manage Libraries, enter "LovyangFX" under Filter your search.  
Select version 1.2.0 and install it. Several files will be downloaded and installed.  
The file will be downloaded and installed.



Under Tools/Manage Libraries, enter “TFT\_eSPI” by Bodmer under Filter your search. Select version 2.5.43 and install it. The file will be downloaded and installed.



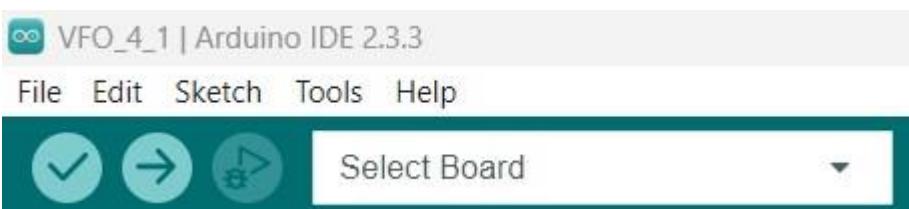
Go to Tools-Board-Boards Manager and enter “esp32” under Filter your search. Select esp32 by Espressif Systems version 3.0.7 and hit Install. **Do not install a later version.** The install will take at least five minutes to complete or longer depending on your computer and internet speed. You can watch the progress in the lower left of your screen.



If you exit the VFO\_4\_1 program at this point or anytime going forward, when you reopen it, in the lower left corner you will be prompted that updates are available for some of your boards. Do not update, instead click on “LATER”.

For the following step, you will need to connect your PC to the Micro USB port on the ESP32 module. 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.

Click on the box in the top left menu on Select Board drop down arrow and Select “other board and port”.



In the search box, type WRover.

Select ESP32 Wrover Module and the Serial port shown on the right hand side of the window.

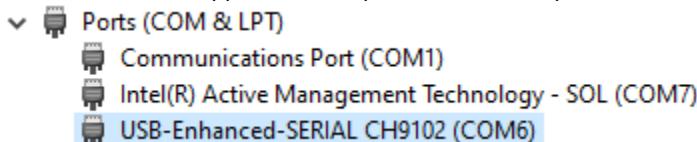
Hit OK

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 installed. You will need to Google search for this driver and install it. 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:

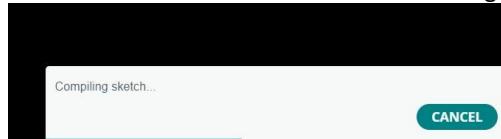
Windows Driver Package - Silicon Laboratories Inc. (silabs) Ports (11/2...) Silicon Laboratories Inc. 2/28/2021 11/26/2018 10.1.4.2...

One final step before you can program your ESP32 module. Go back into the VFO\_4\_1 folder. There you will find two sub folders – “Other Files” and “VFO\_4\_1” and 13 other files. Copy and paste the 13 other files into the VFO\_4\_1 sub folder.

You are now ready to compile your code and see if you can program an ESP32 module.

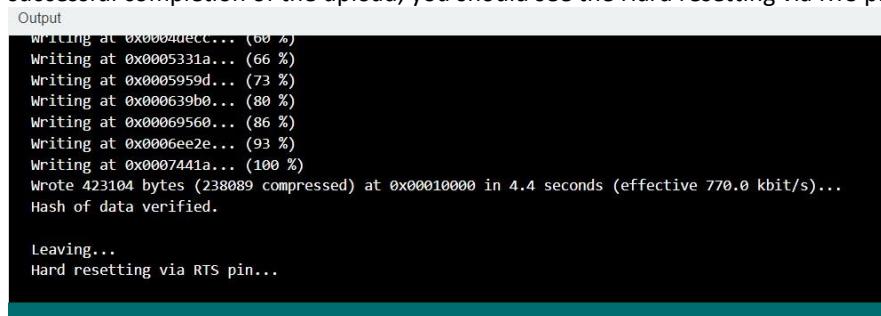
Select Sketch-Upload (Ctrl+U). Do not use Configure and Upload or Upload Using Programmer..

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.

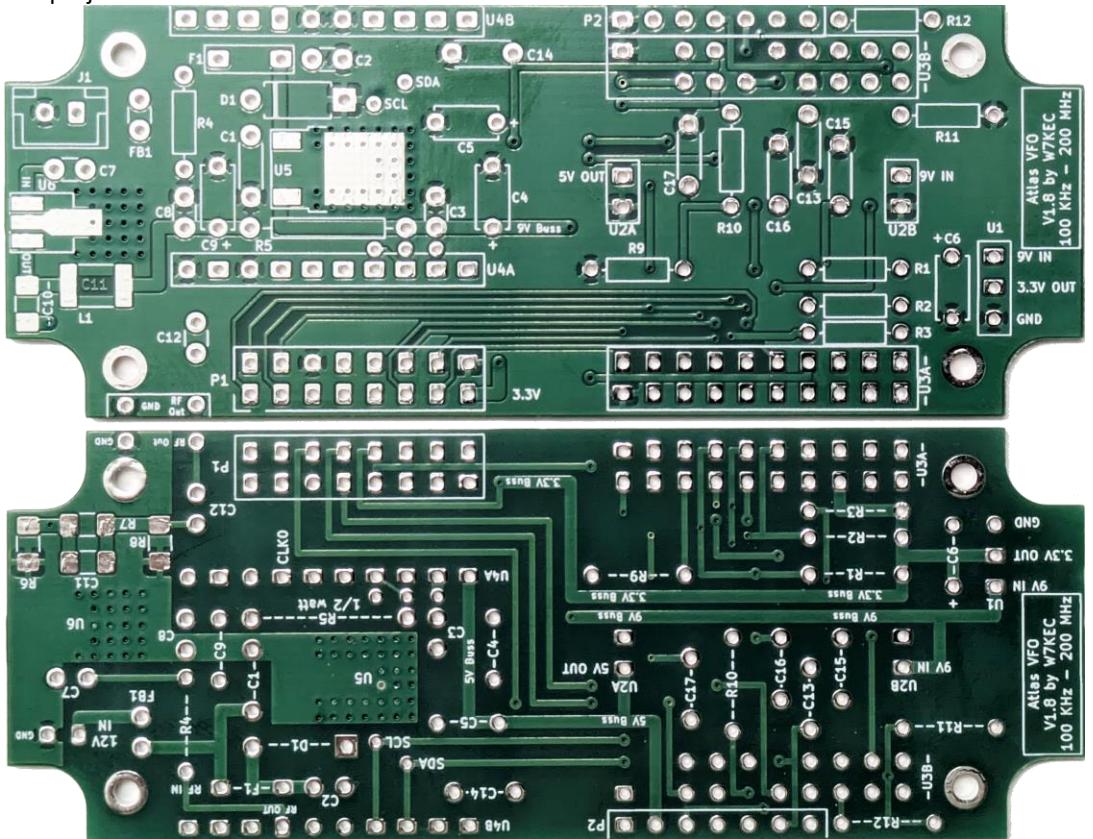
The status of the upload functions will be shown in the black display window of the IDE app. At the successful completion of the upload, you should see the Hard resetting via RTS pin.



Your programmed ESP32 module can now be used on the VFO board.

## X. Build Si5351 VFO Board

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

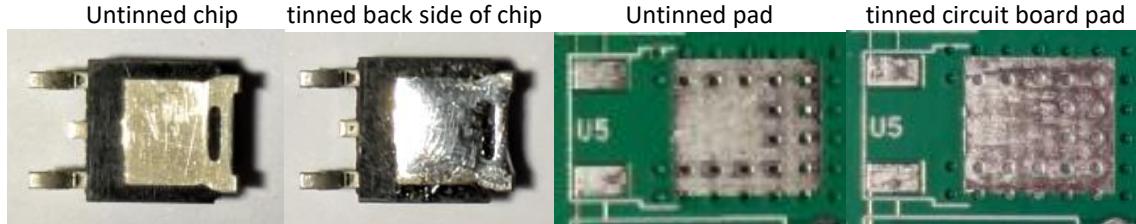


Install four brass standoffs on the bottom of the VFO circuit board with four each M2-4mm Phillip's head screws.

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.



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

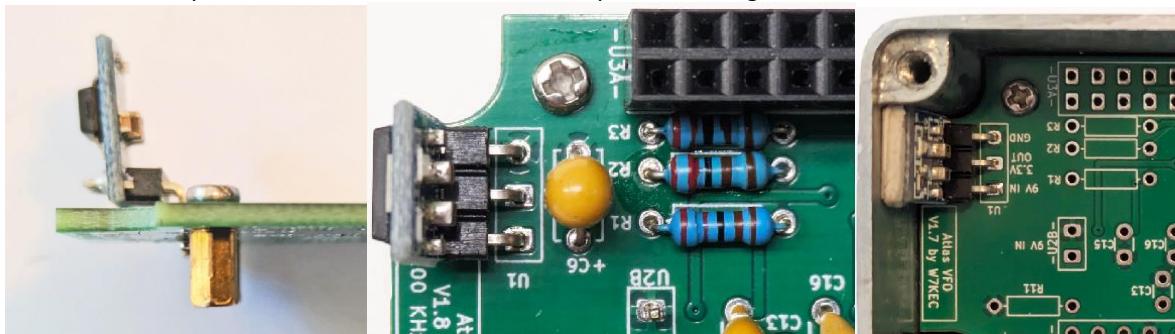
Solder the following TH parts to the VFO circuit board:

R4 – 180 ohm

C2, C3, C7, C8 and C12 - 0.1 uf ceramic monolithic disc capacitor  
 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 6 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 75 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 75 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.  
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 wire (10 mm long) on the RF Out solder tab on the circuit board.

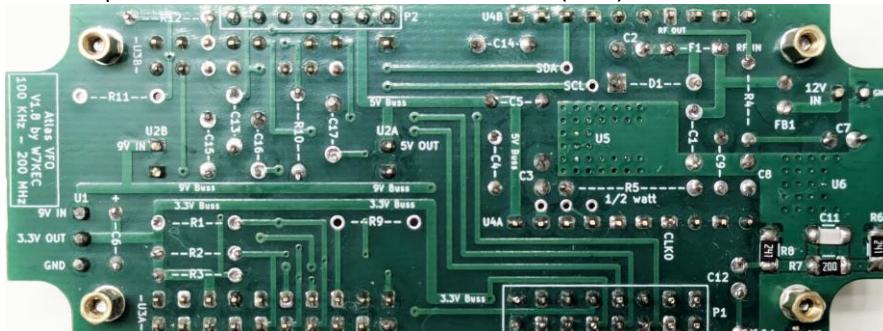
All pin headers, sockets, and plugs have now been installed on the VFO circuit board.  
Carefully inspect all solder connections on the bottom of the board.  
Check for solder splatters. Remove any flux from the bottom of the circuit board.

**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):



## XI. 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.

## **XII. 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 70 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 76 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.

Install the QRP Labs Si5351 oscillator board. Apply power.

The total current draw should be around 114 ma.

Remove power from the board.

Install a programmed ESP-32 module. Apply power.

The total current draw should be around 170 ma.

Remove power from the board.

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 213 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 230 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.

### XIII. 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.



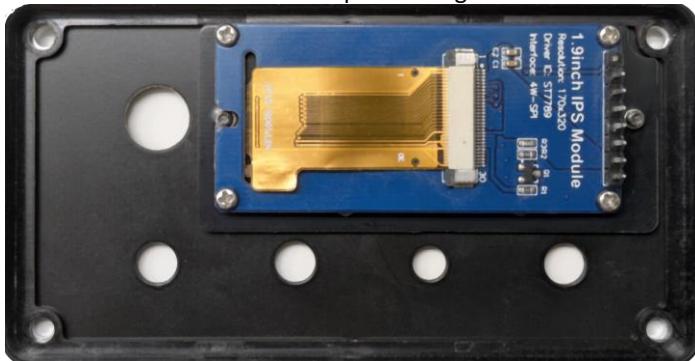
Smooth off the inside edges of the cutout with a flat file.

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.

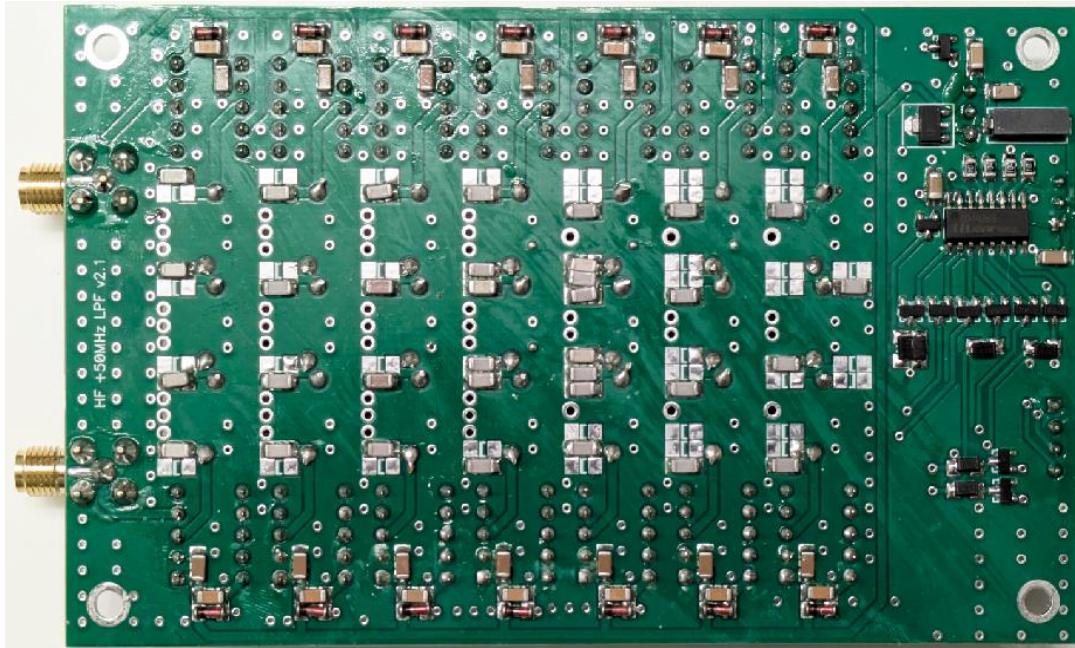
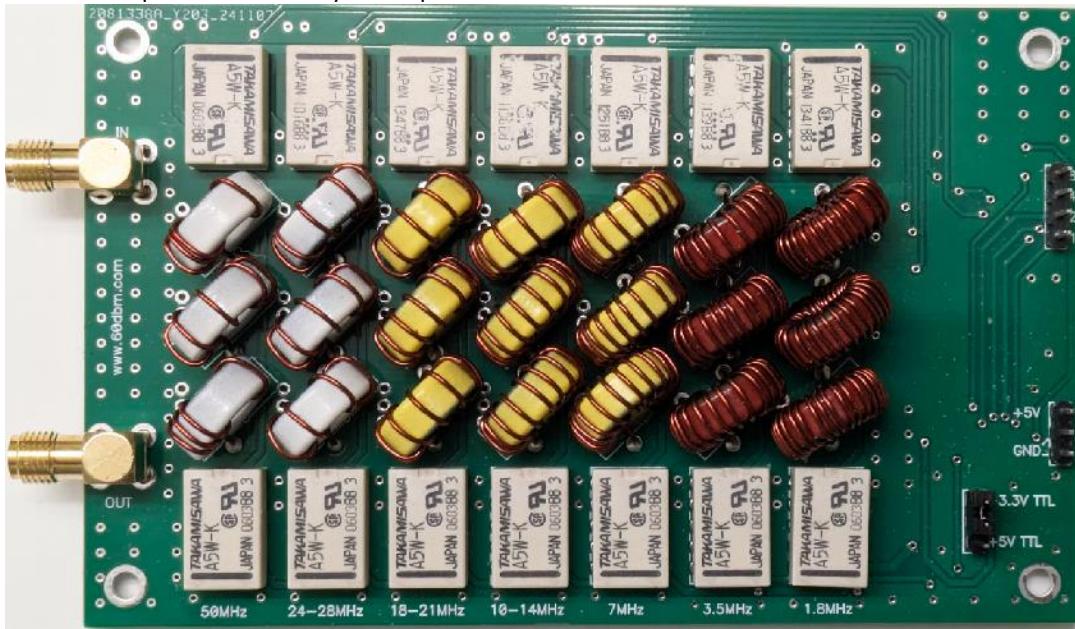
**Do not over-tighten the screws.**

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



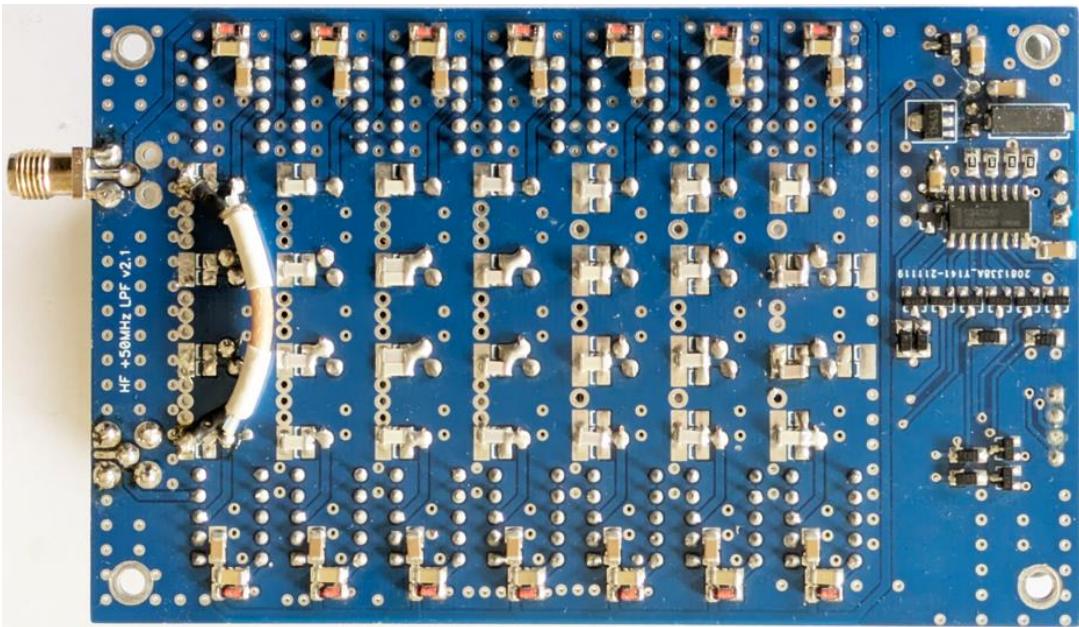
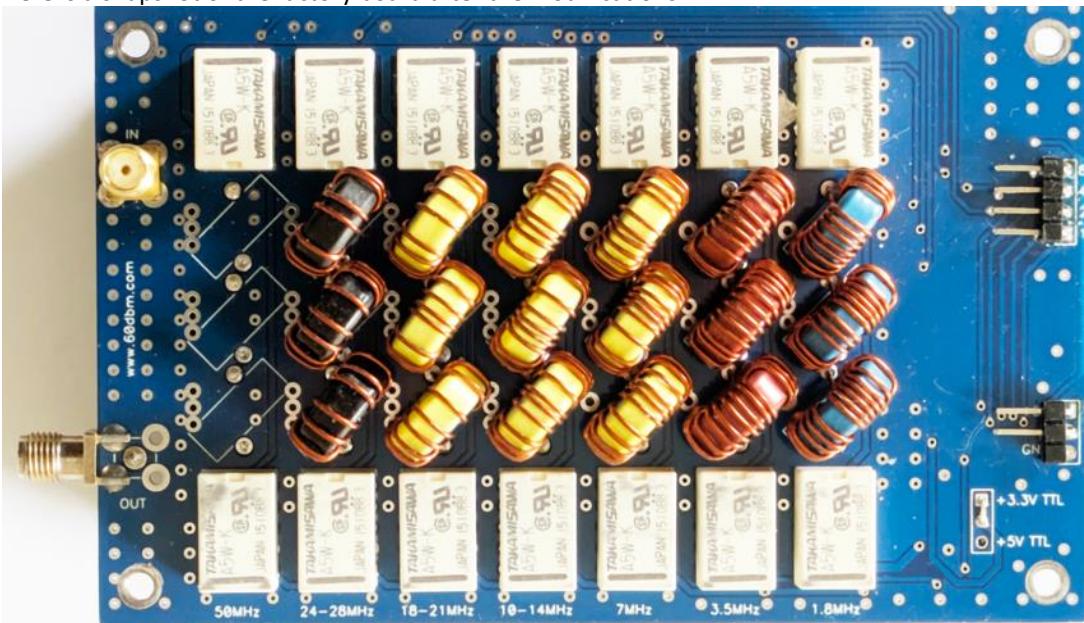
#### XIV. Ukraine Low Pass Filter Board Modifications

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.



## XV. 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.

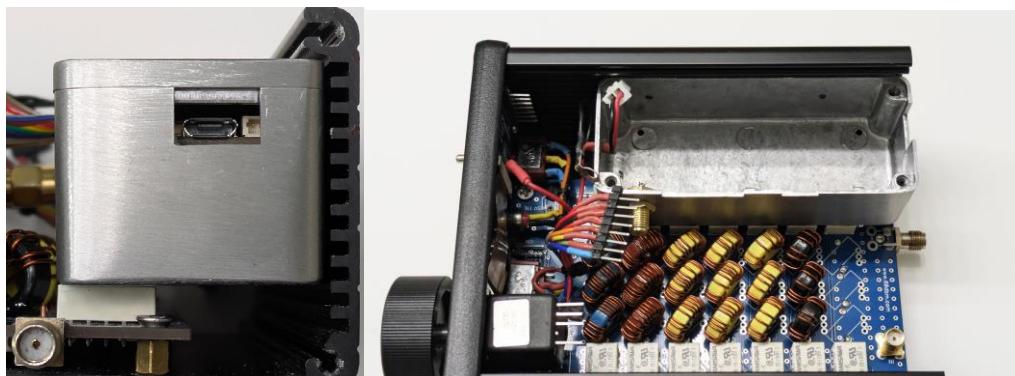


### B. Mount VFO Enclosure

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

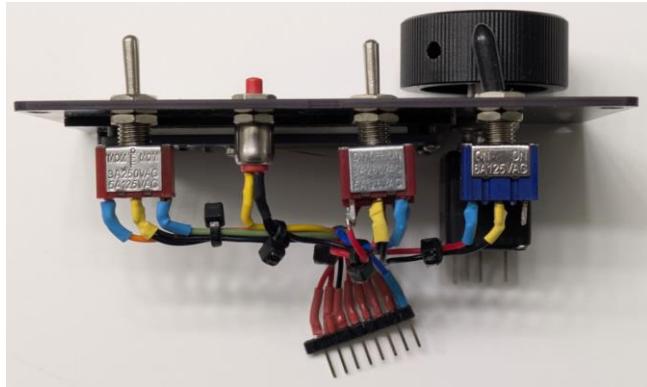
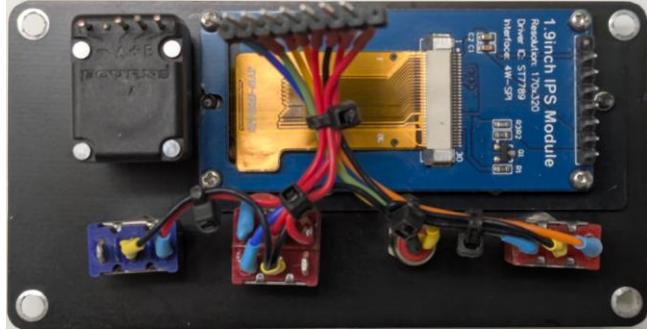
Install the following controls on the front panel:

- Optical Encoder
- 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:

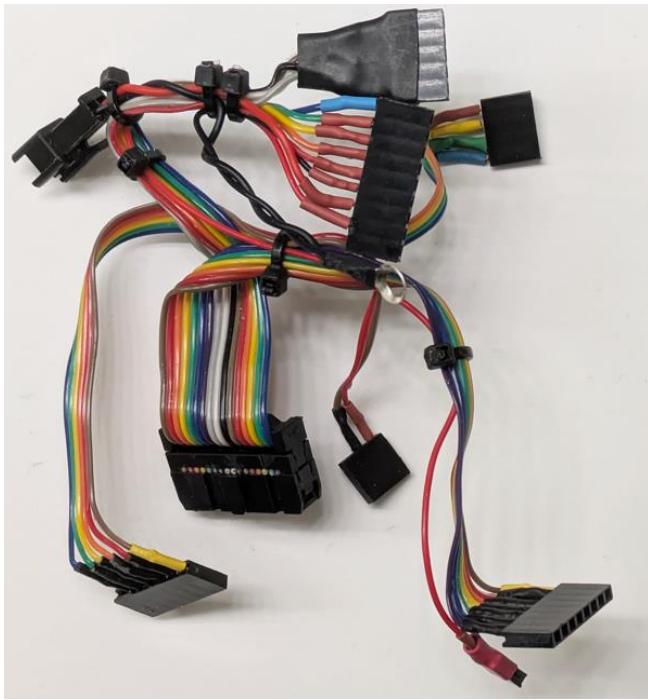
- 9 pin male header
- Heat shrink tubing
- Black, red, blue, yellow, and orange Teflon wire
- Black tie wraps



### 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

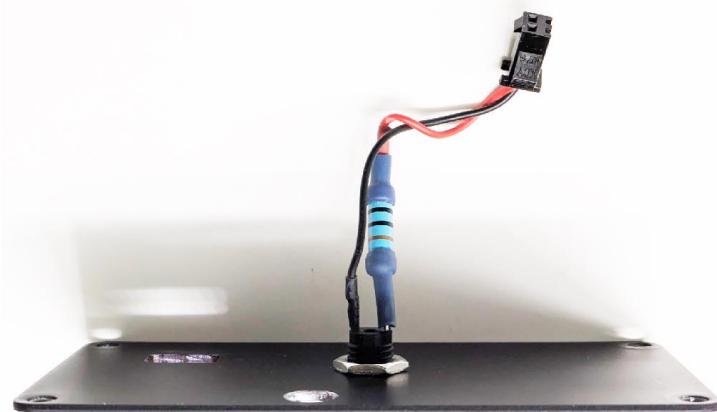
44 mm from left side of panel and 7 mm up from bottom edge of panel

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.



## **XVI. 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 filter bands

## XVII. 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", 1/4", 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. To 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](https://www.amazon.com/Vision-Aid-30x-Hands-Free-Magnifier/dp/B000FQHJLW)

#### 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=1CEUIFG9LFY>

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

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

## **B. 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  
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

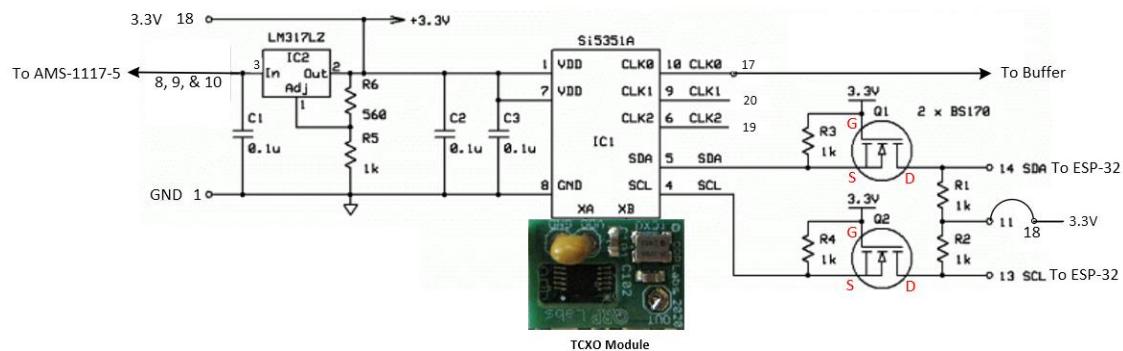
### C. How To Remove VFO Enclosure From The Main Enclosure

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.

### D. 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.

## E. 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

# Si5351 External VFO

F. System Diagrams  
Figure 1 – Block Diagram

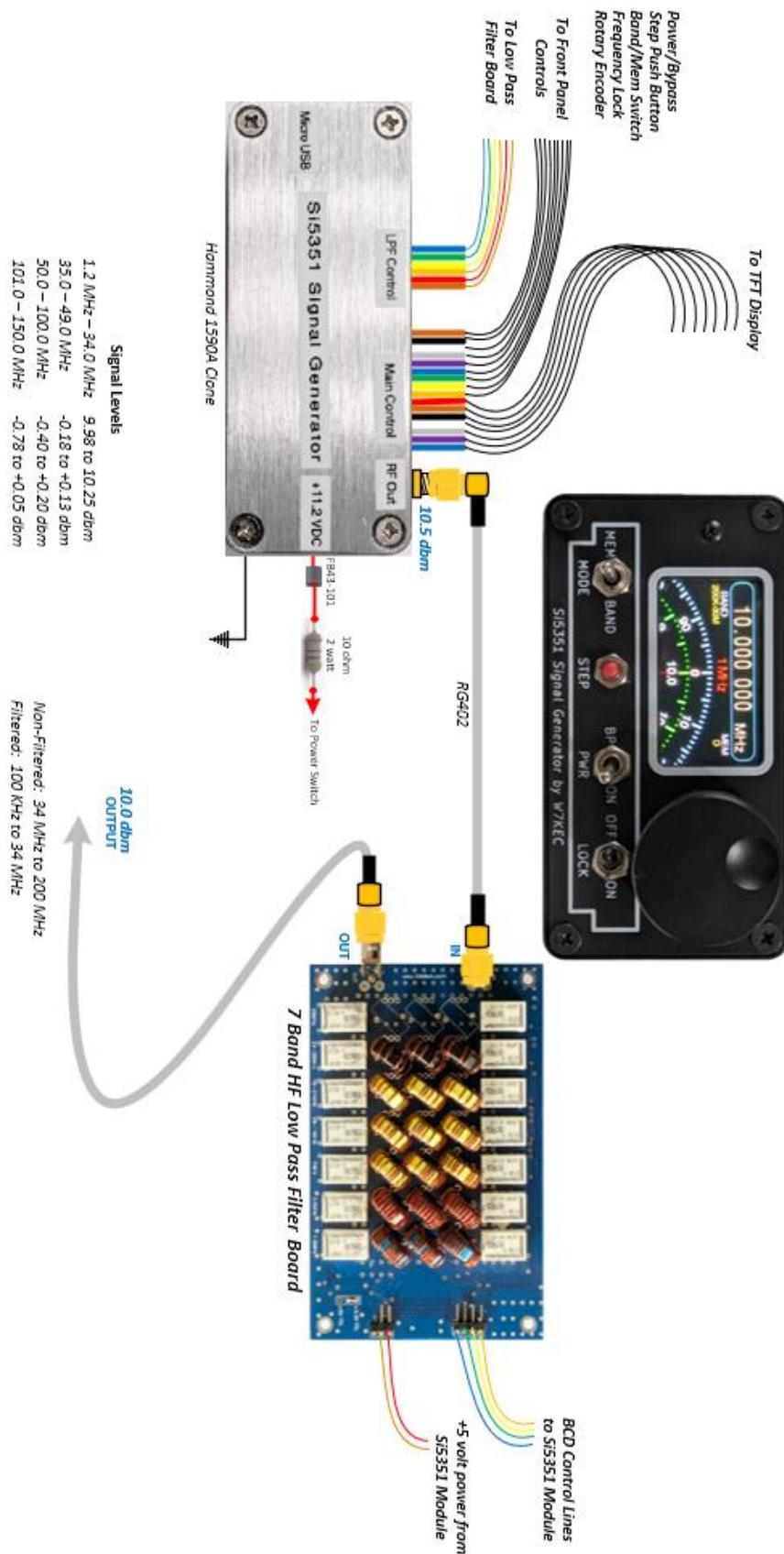


Figure 2 – Schematic

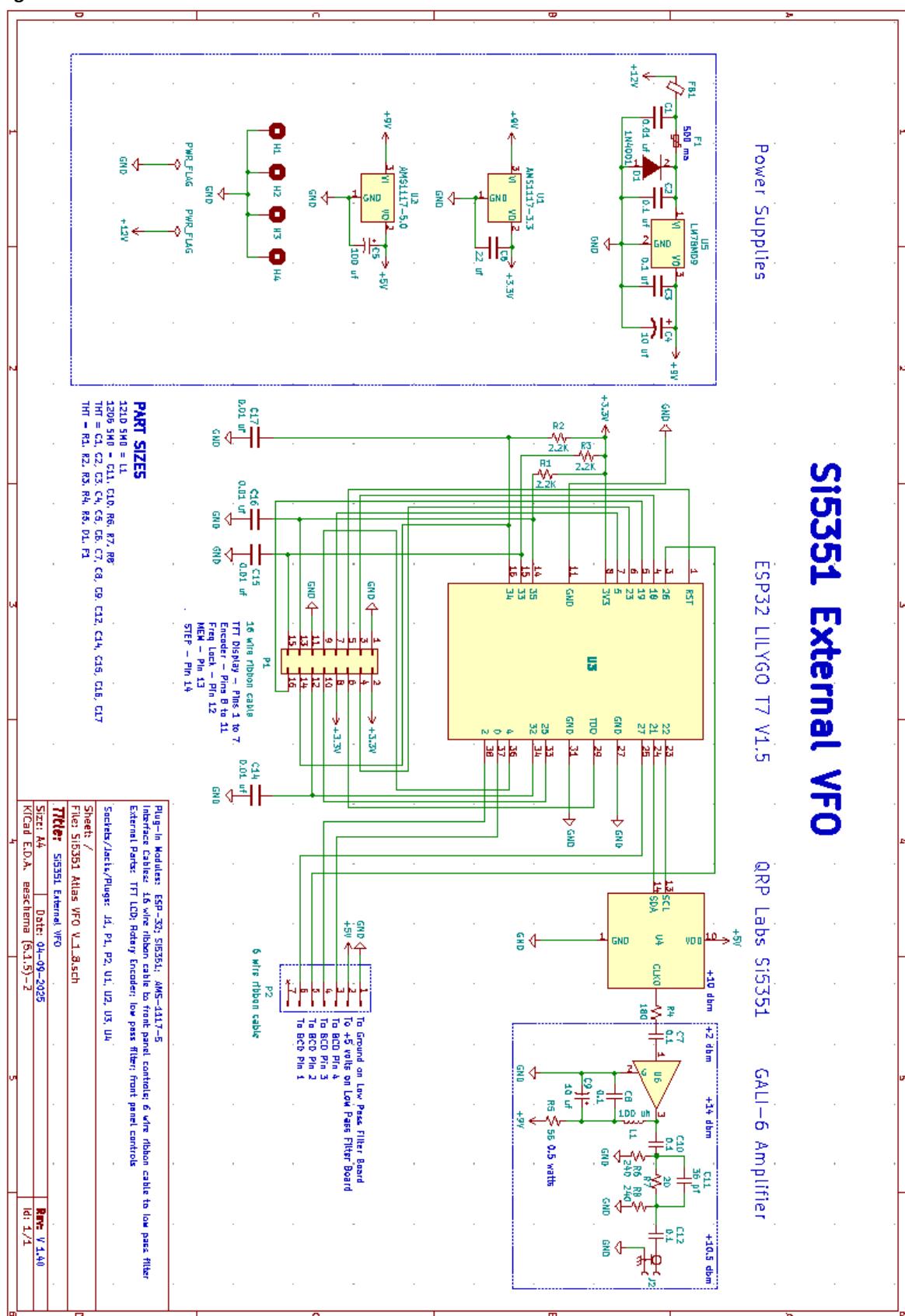
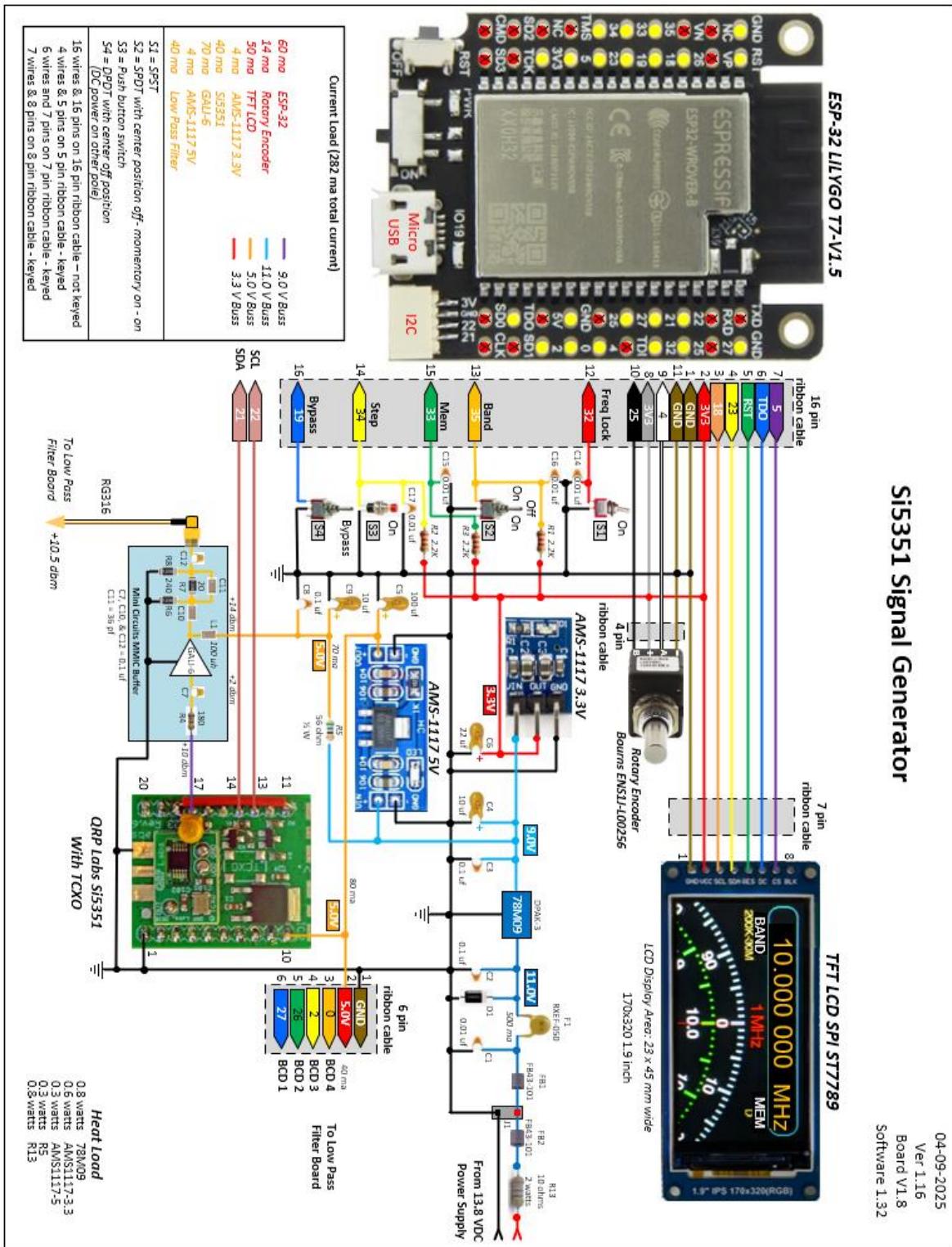


Figure 3 – Interconnection Diagram



## G. VFO Harmonics

Figure 4 – 160M (10 dB pad)

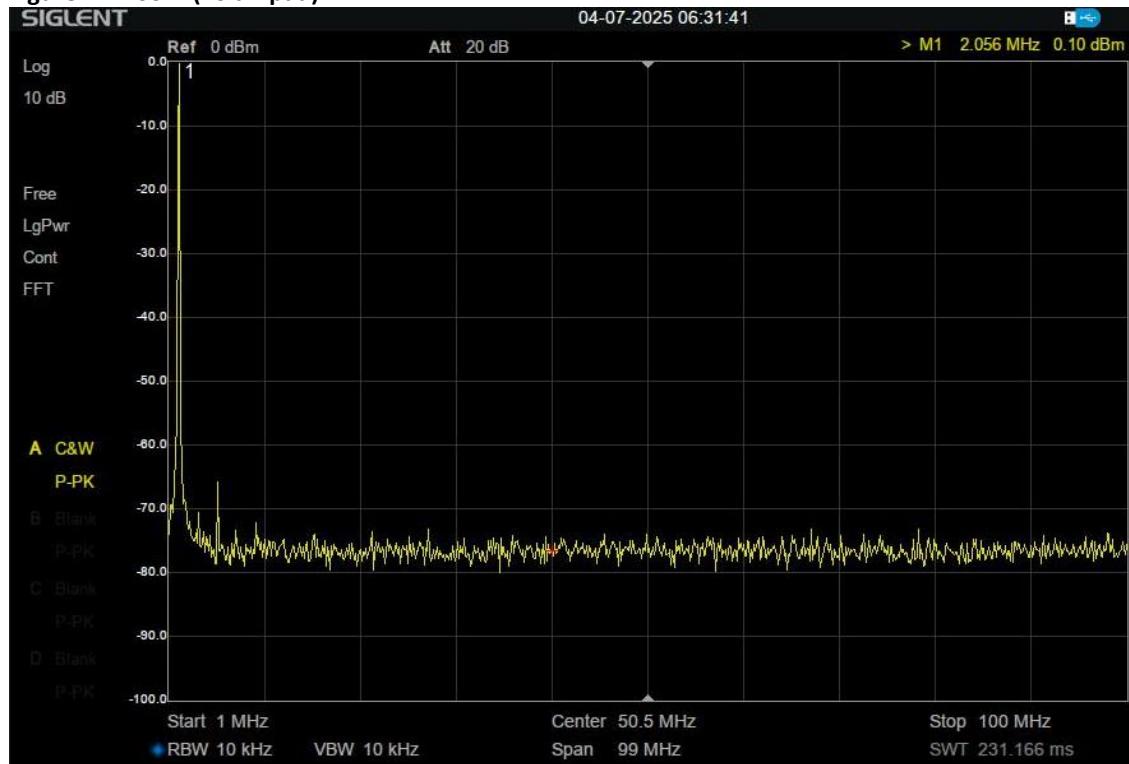
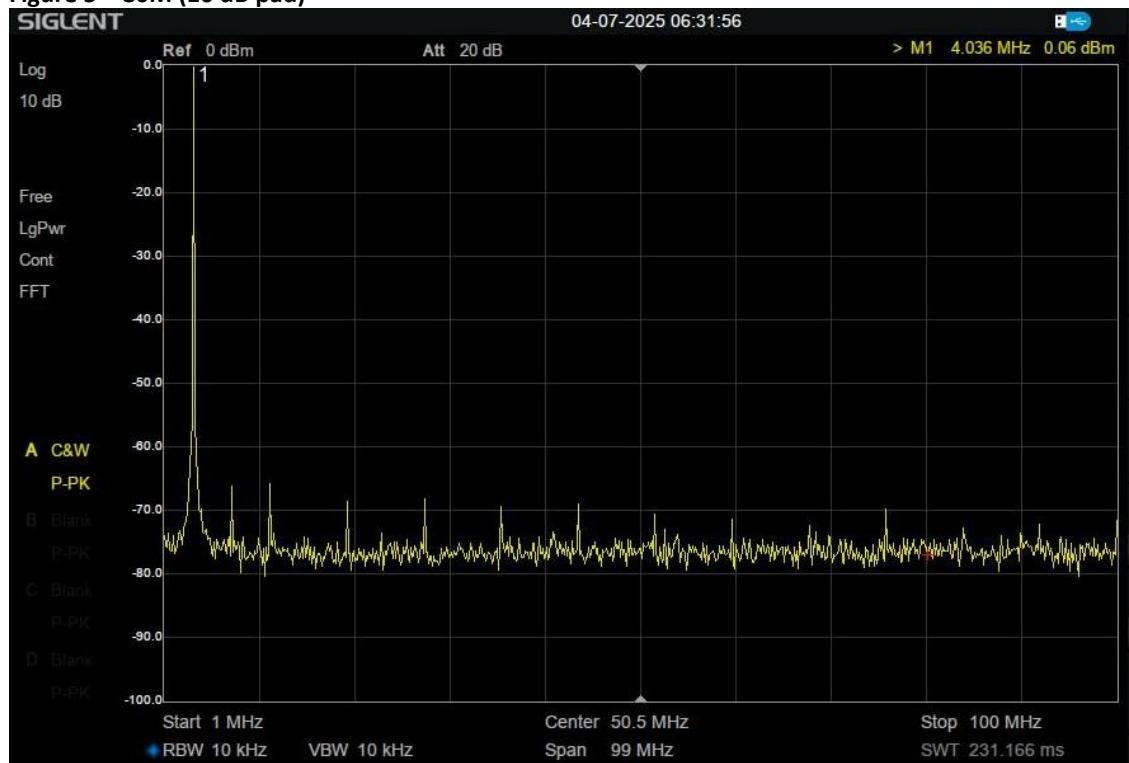
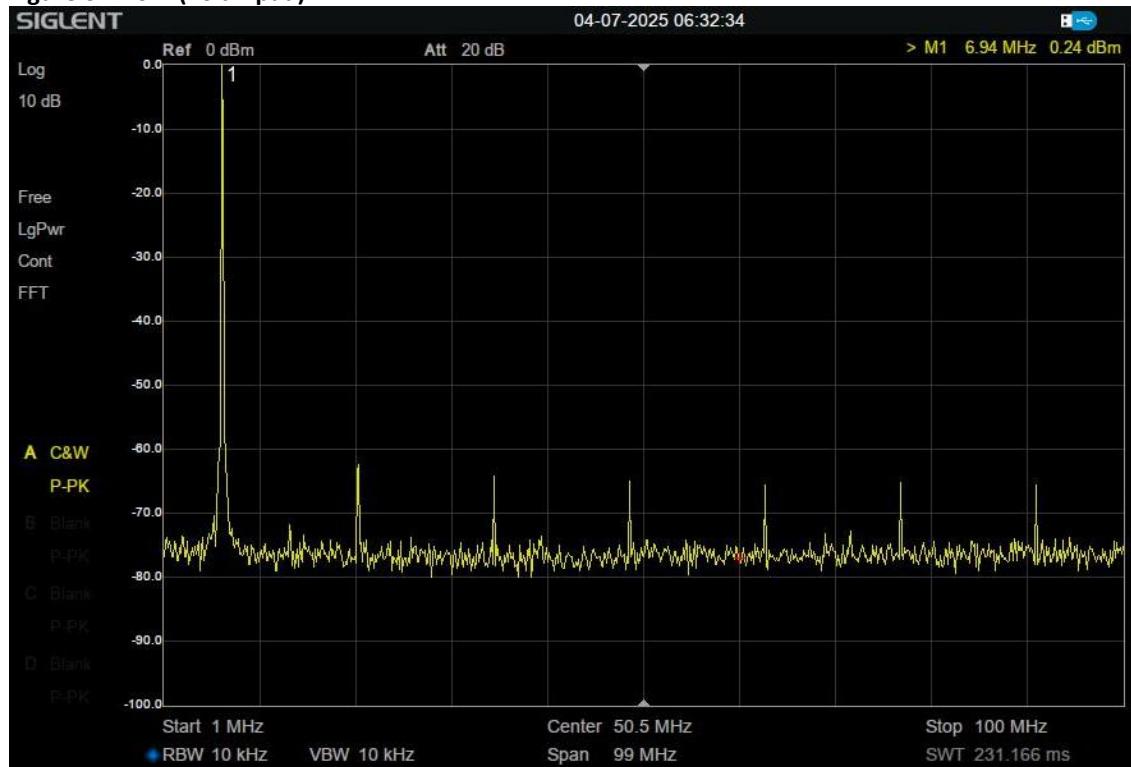


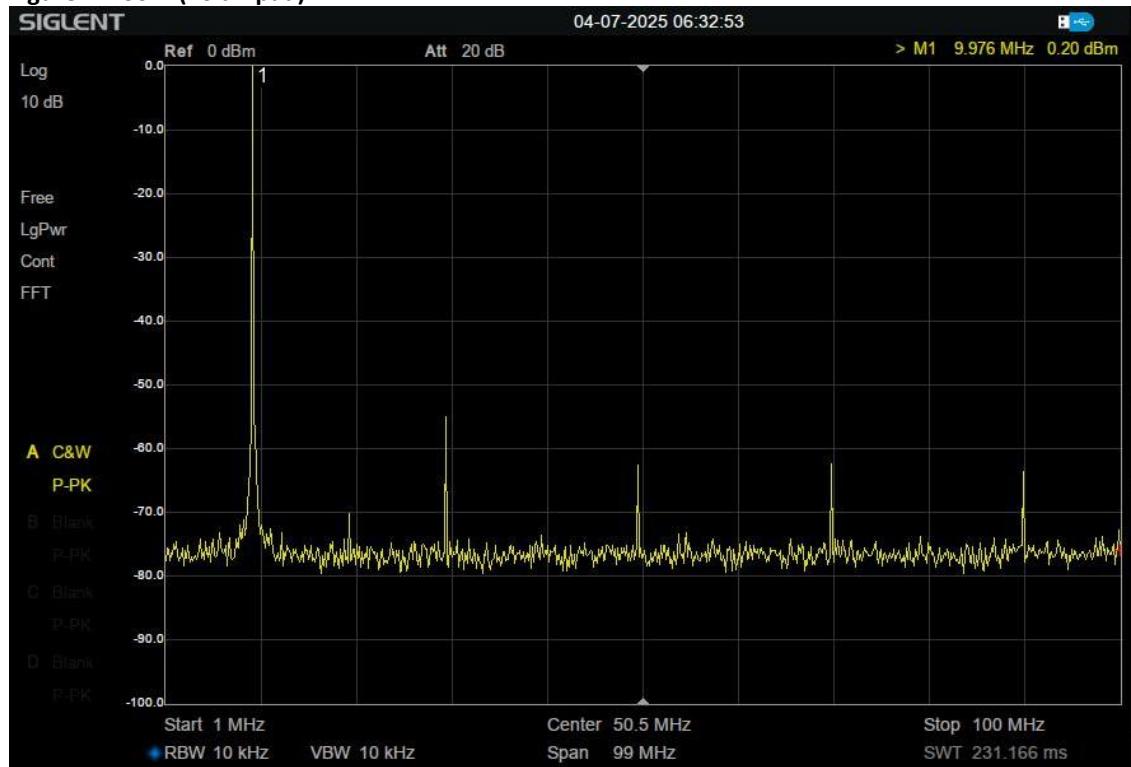
Figure 5 – 80M (10 dB pad)



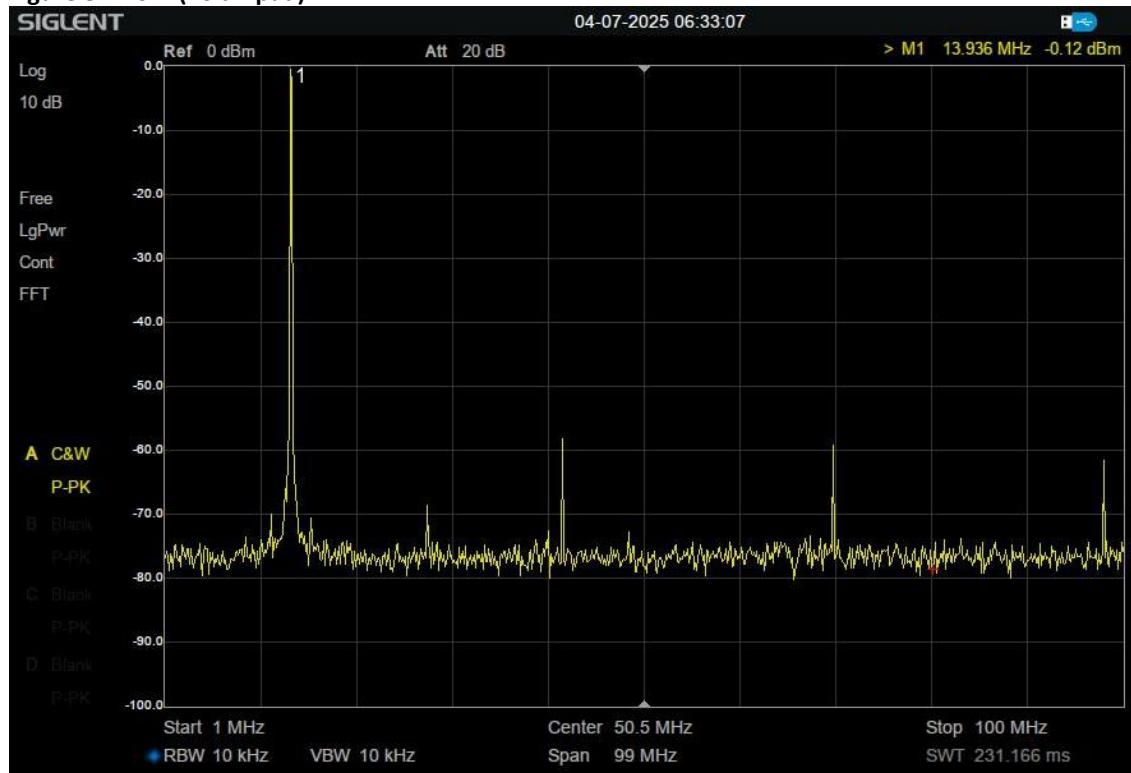
**Figure 6 – 40M (10 dB pad)**



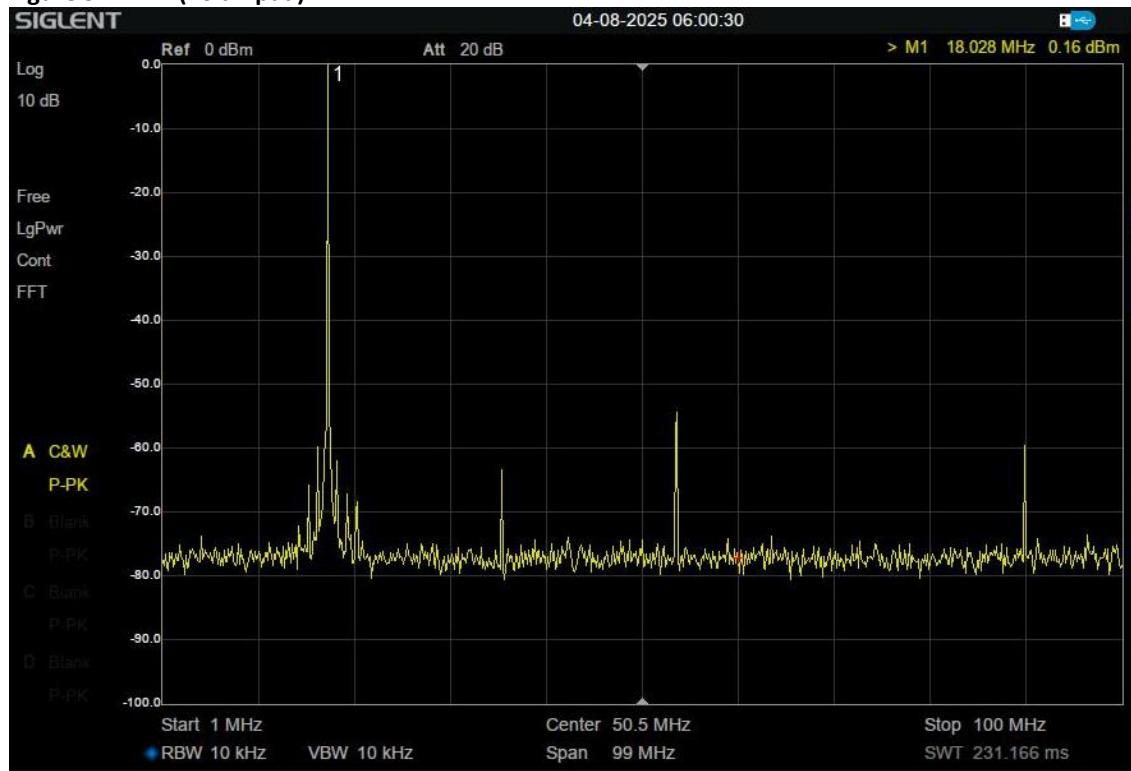
**Figure 7 – 30M (10 dB pad)**



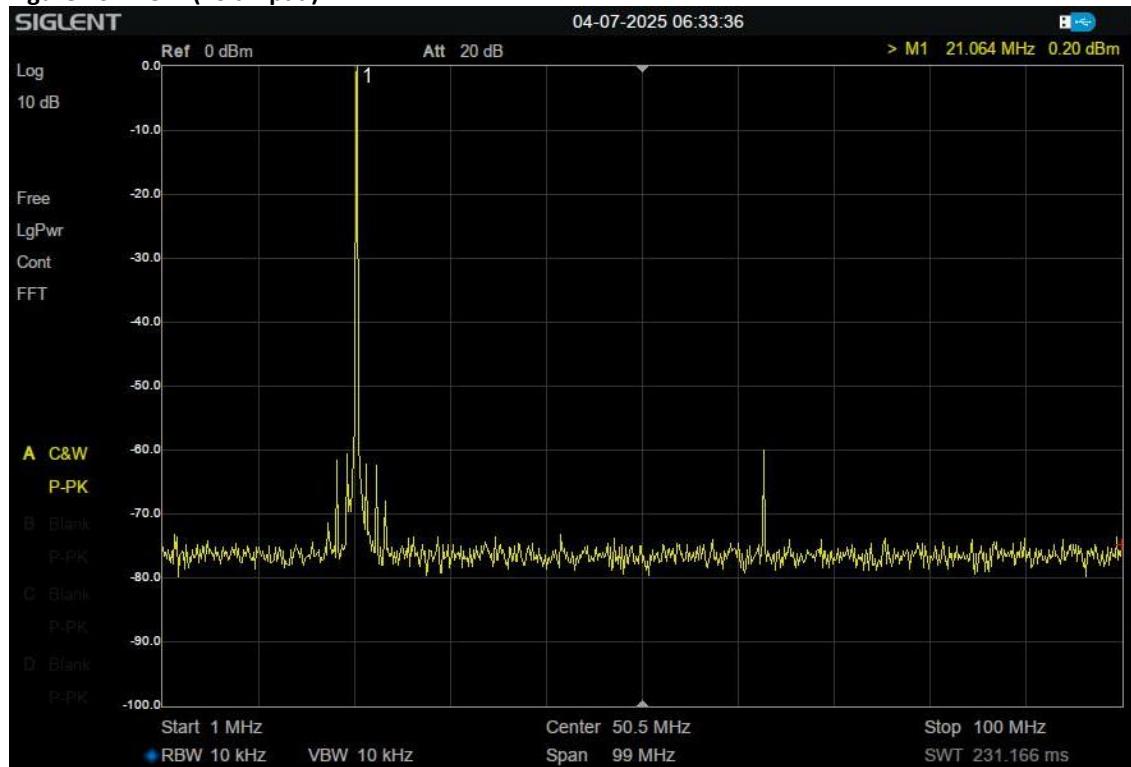
**Figure 8 – 20M (10 dB pad)**



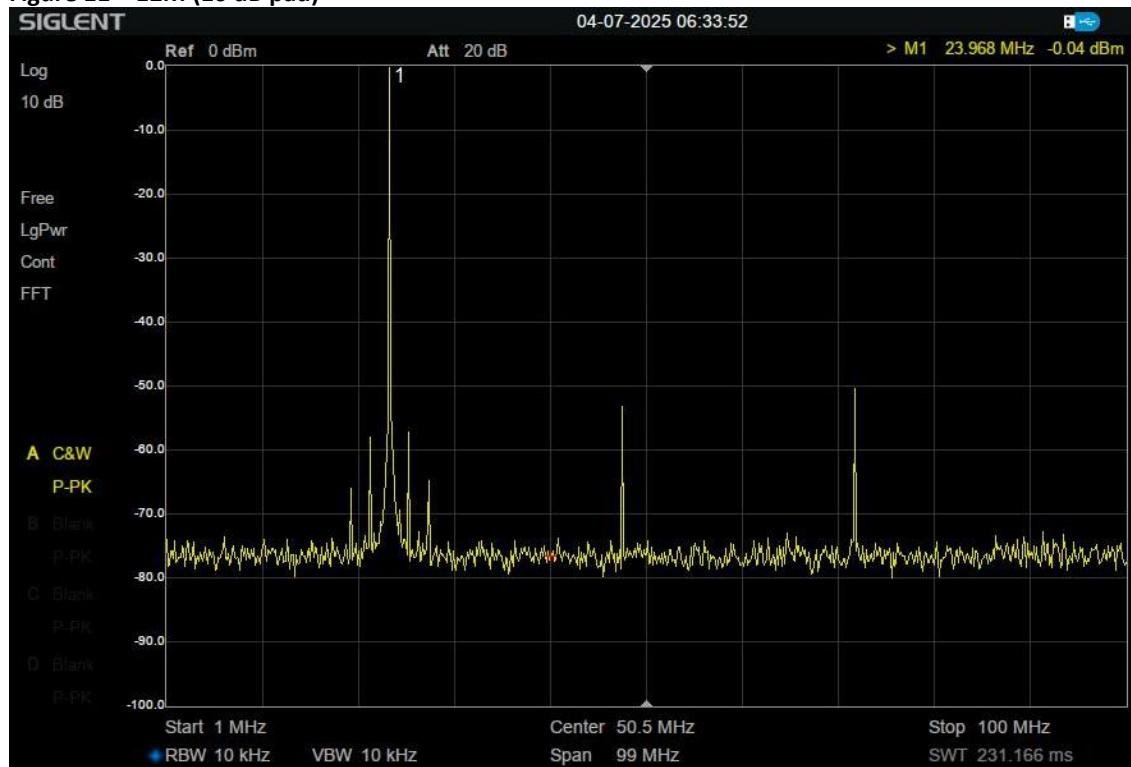
**Figure 9 – 17M (10 dB pad)**



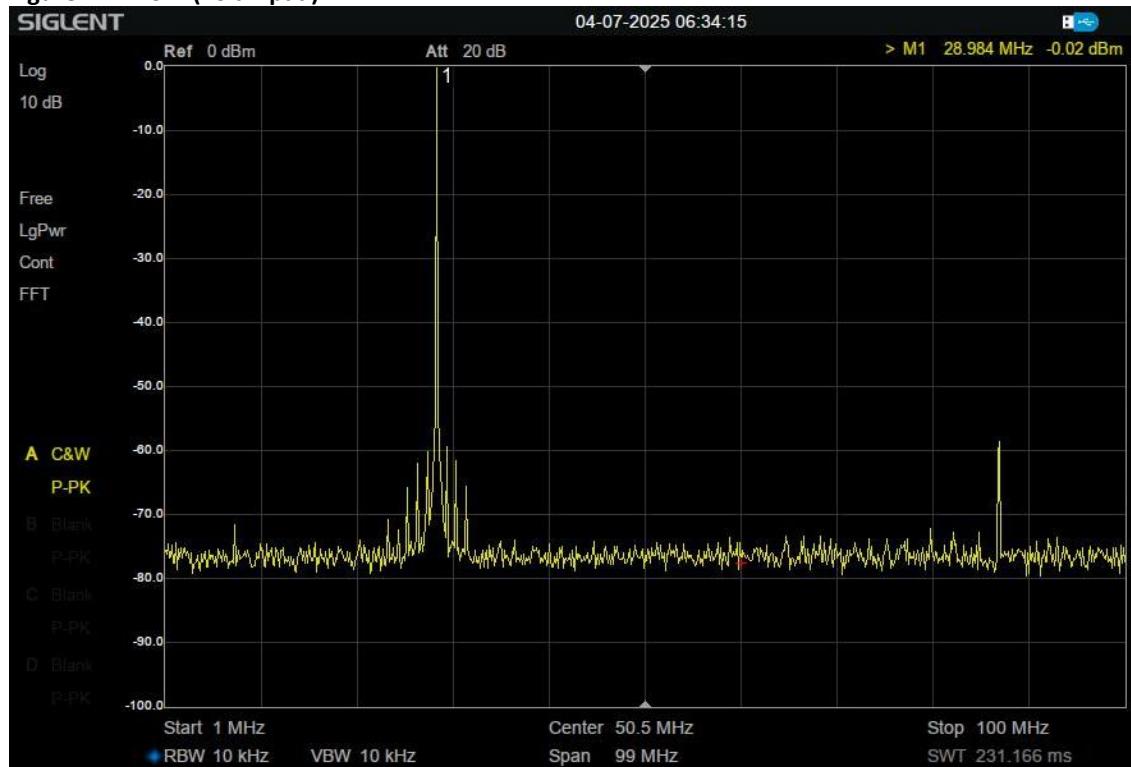
**Figure 10 – 15M (10 dB pad)**



**Figure 11 – 12M (10 dB pad)**



**Figure 12 – 10M (10 dB pad)**



#### H. Sine Wave Quality

**Figure 13 – Si5351 VFO 80M Sine Wave with Ukraine Low Pass Filter**

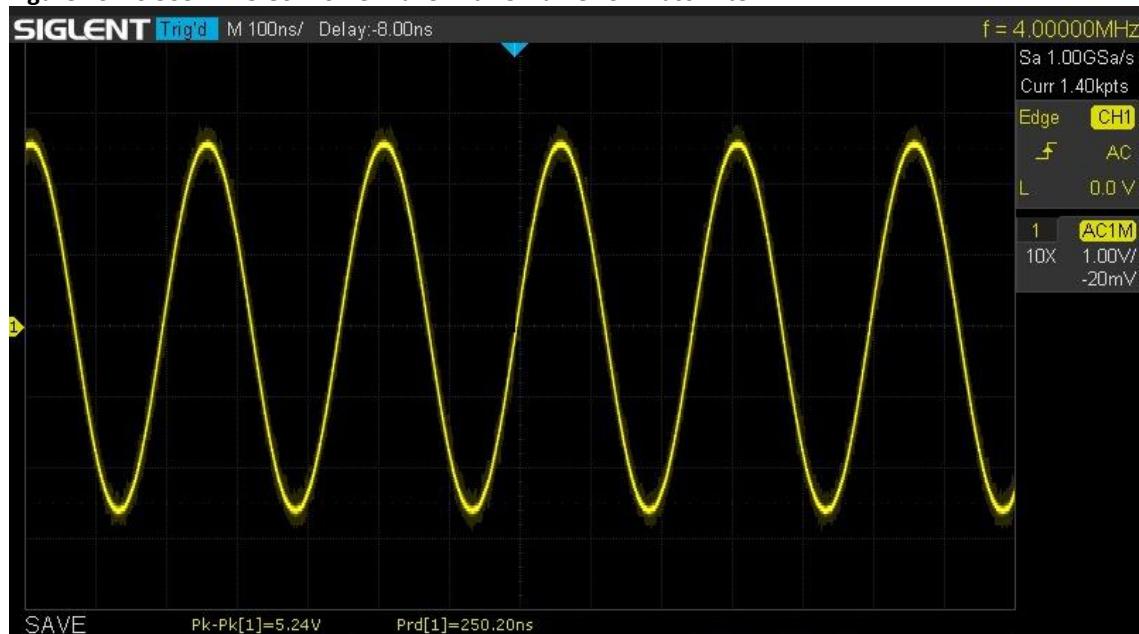


Figure 14 – Si5351 VFO 80 Signal with no low pass filter

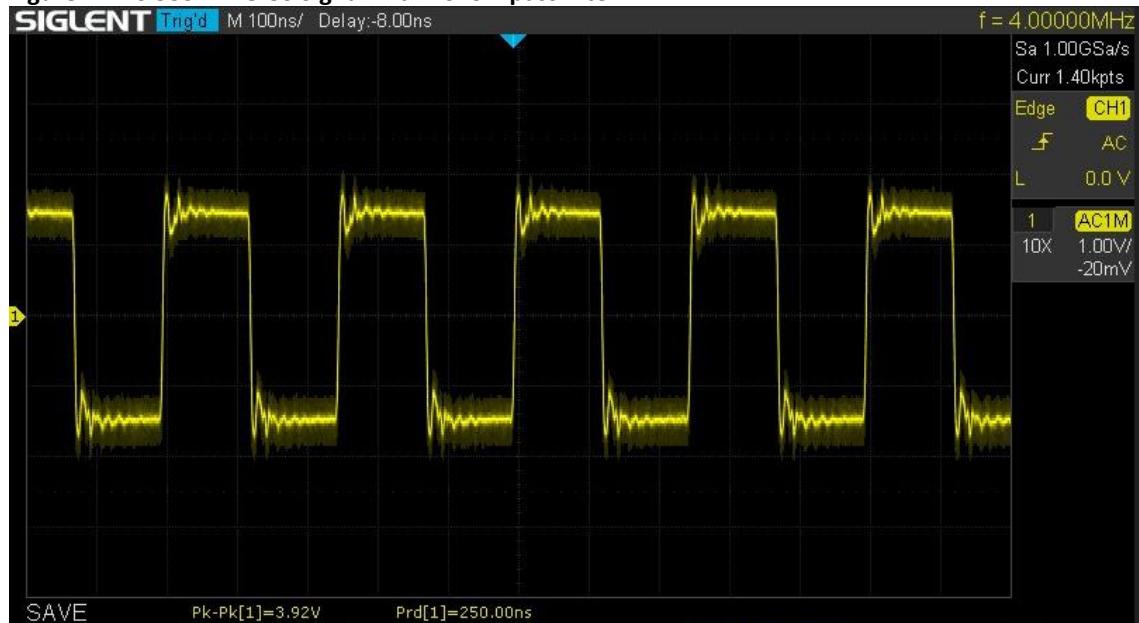
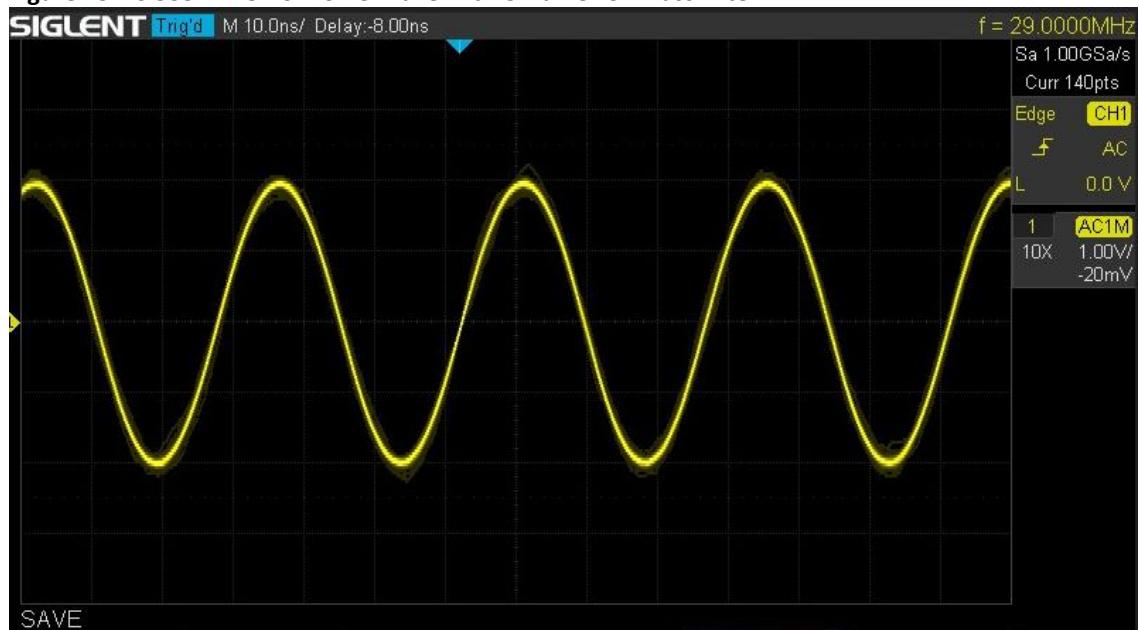


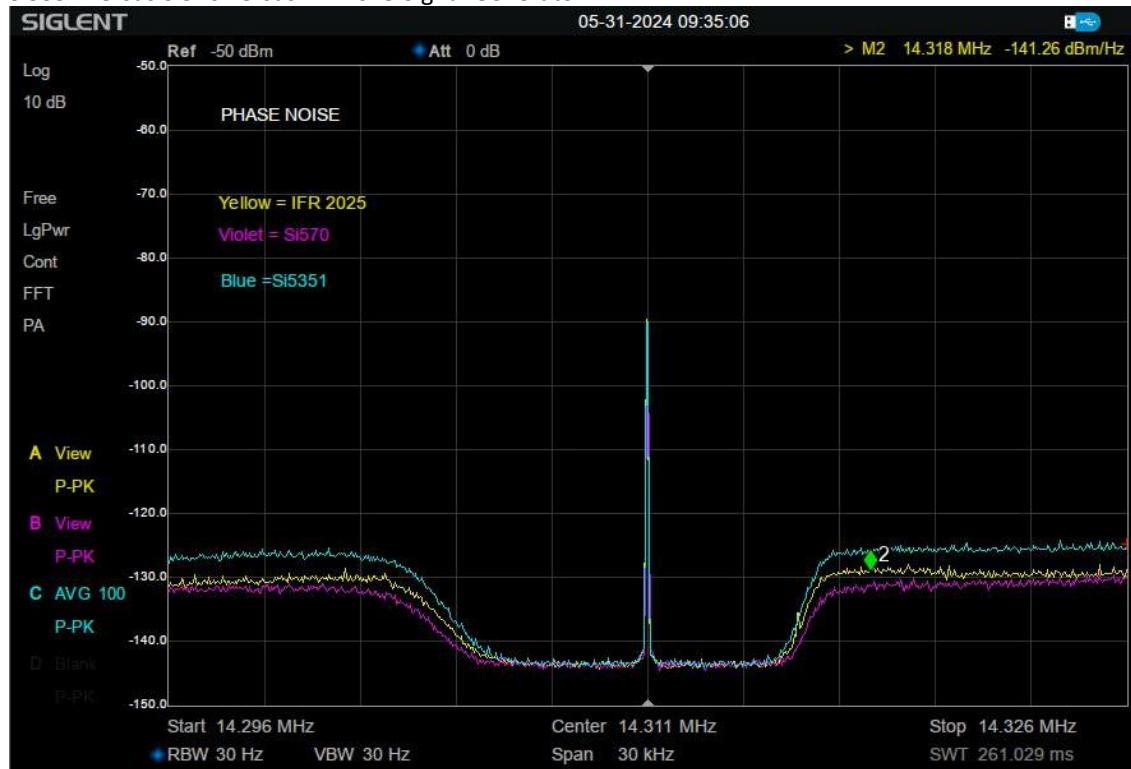
Figure 15 – Si5351 VFO 10M Sine Wave with Ukraine Low Pass Filter



## I. Phase Noise

Figure 16

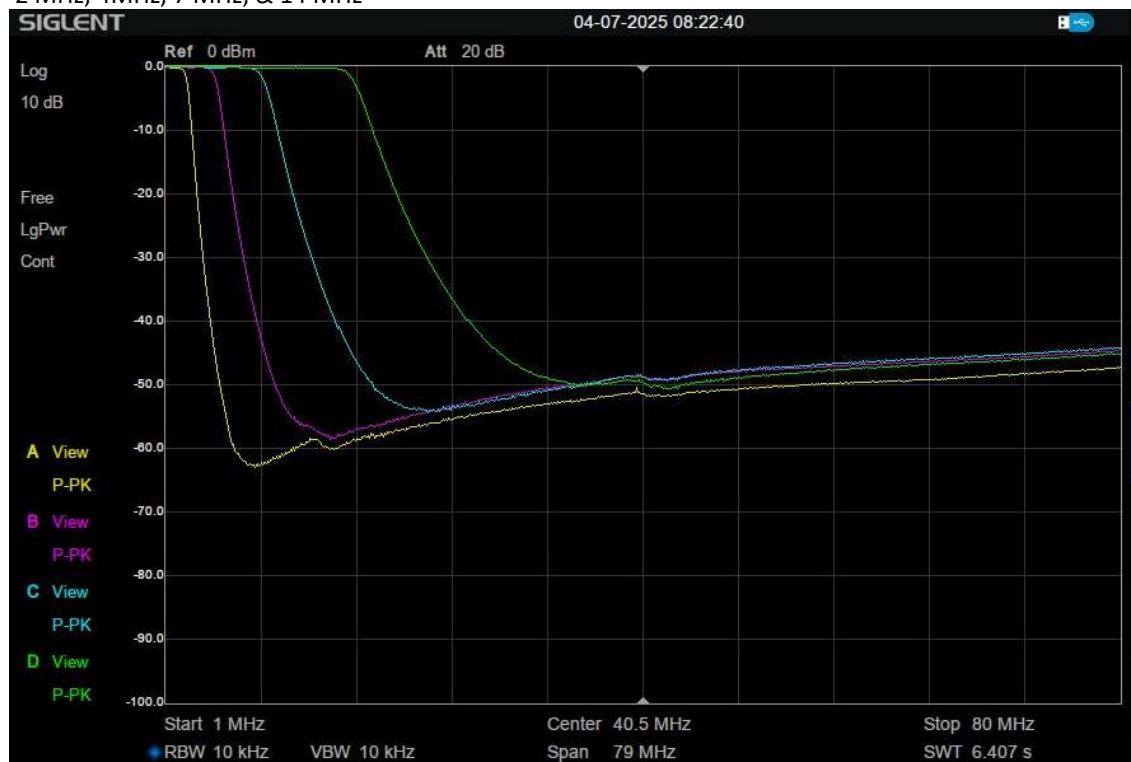
Si5351 versus Si570 versus IFR 2025 Signal Generator



## J. Low Pass Filter Sweeps

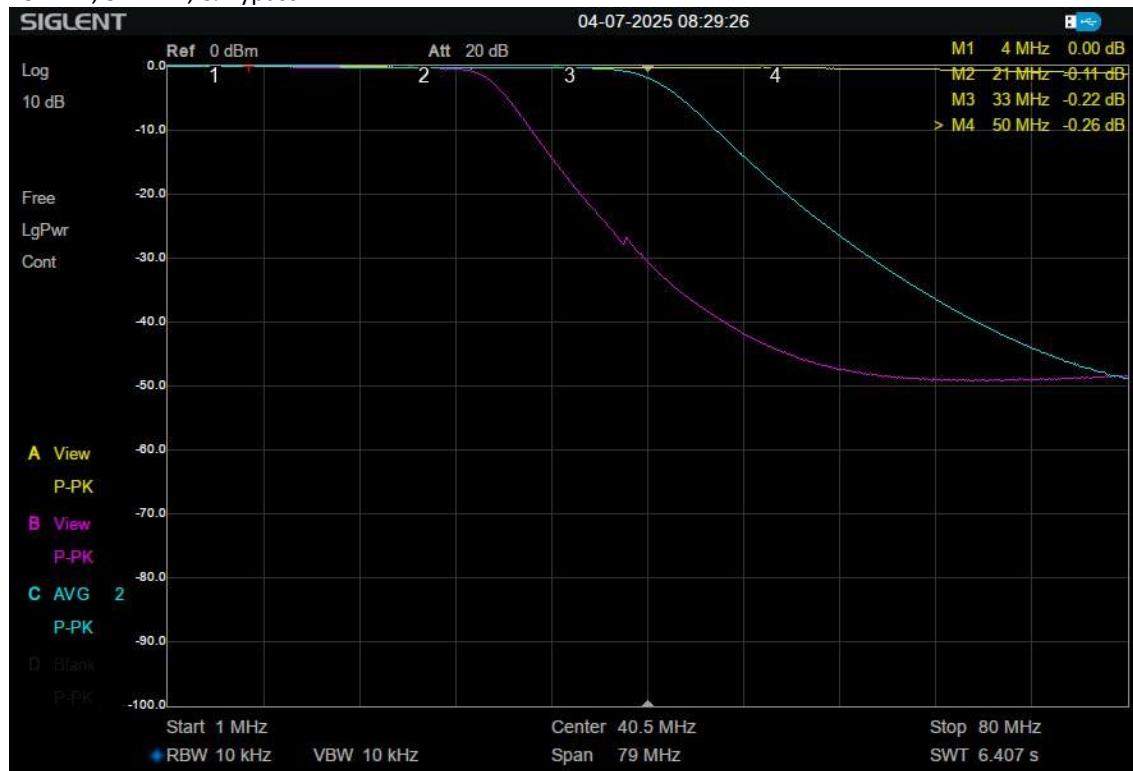
Figure 17 – Ukraine Low Pass Filter Sweeps

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



**Figure 18 – Ukraine Low Pass Filter Sweeps**

23 MHz, 34 MHz, & Bypass





```

350 #if PREFERENCE == CLINT
351 #define CL_BG CL_BLACK // Display background (Black)
352 #define CL_POINTER CL_RED // Dial pointer (Red)
353 #define CL_TICK_MAIN CL_GREEN // Main Ticks (Lime green)
354 #define CL_NUM_MAIN CL_WHITE // Main dial numbers (White)
355 #define CL_TICK_SUB CL_SKYBLUE // Sub Ticks (Light blue)
356 #define CL_NUM_SUB CL_WHITE // Sub Numbers (White)
357 #define CL_DIAL_BG CL_BLACK // Dial background (Black)
358 #define CL_SPLASH CL_LT_BLUE // Splash screen text
359 #define CL_FREQ_BOX CL_CYAN // Numerical frequency box
360 #define CL_F_NUM CL_ORANGE // Numerical frequency
361 #define CL_NUM CL_YELLOW // Numerical small numbers
362 #define CL_NUM_0 CL_RED // Step color in CUSTOM_DISP
363 #define CL_NUM_NORM CL_WHITE // Normal Text inside box
364 #define DP_POS 0 // Length Dial pointer extends above dial
365 #define DISP_TM 30 // Top Margin moves Dial up and down
366 #define F1_POS 15 // Vertical Position of the frequency box 14 60 32,14
367 #define T1_POS 60 // Align the secondary text information on this line
368 #define DIAL_SPACE 40 // Number of pixels between the main and sub arcs
369 #define TICK_SUB1 8 // Length of Sub Tick(1)
370 #define TICK_SUB5 14 // Length of Sub Tick(5)
371 #define TICK_SUB10 18 // Length of Sub Tick(10)
372 #define TICK_MAIN1 4 // Length of Main Tick(1)
373 #define TICK_MAIN5 14 // Length of Main Tick(5)
374 #define TICK_MAIN10 18 // Length of Main Tick(10)
375 #define TNCL_MAIN 18 // Space between Number and Tick (Main)
376 #define TNCL_SUB 18 // Space between Number and Tick (Sub)
377 #define TICK_PITCH_MAIN 10.5 // Main Tick Pitch (note small changes make a big difference)
378 #define TICK_PITCH_SUB 9.8 // Sub Tick Pitch (try not to go below 4.0)
379 #define CORRECTION 0ULL
380 #define CORRECTION MCU 0
381 #define EncoderStep 12
382 #define CO ATLAS_CO
383 #define LOCK_OK
384 #undef CLOCK_OK
385 #undef SHORT16_OK
386 #endif
387

```

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

#### Change memory frequencies

```

136 #if PREFERENCE == CLINT
137 long freqa[5] = { 3853000, 3900000, 3916000, 3950000, 5000000}; //80M band memory presets
138 long freqb[5] = { 7155000, 7162000, 7235000, 7255000, 5000000}; //40M band memory presets
139 long freqc[5] = {14235000,14250000,14300000,14325000,10000000}; //20M band memory presets
140 long freqd[5] = {21285000,21300000,21320000,21350000,15000000}; //15M band memory presets
141 long freqe[5] = {28385000,28425000,28450000,28500000,28900000}; //10M band memory presets
142 int recall[5] = {2,1,3,2,2}; //preferred memory recall at startup
143 const long begofBand[5] = {3803000,7178000,14225000,21275000,28300000}; //General Class
144 const long endofBand[5] = {4000000,7300000,14348000,21448000,28998000}; //All bands
145 #else

```

#### Change scanning times

```

199 int delaytime1 = 2000; //Delay time in ms for frequency scanning
200 int delaytime2 = 5000; //Delay time in ms for memory scanning

```

#### 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 8ma.

```

295 | | si5351.setPower(0,SIOUT_8mA); // Set output power of CLI0 Si5351

```

Here are the readings with the output of the VFO disconnected from the FET switch and terminated on a spectrum analyzer via a 10 db pad:

<b>BAND</b>	<b>50 ohm Load</b>	<b>50 ohm load</b>
	<b>2 ma drive</b>	<b>8 ma drive</b>
80M	+8.0 dbm	+10.0 dbm
40M	+7.8 dbm	+ 9.9 dbm
20M	+7.8 dbm	+ 9.9 dbm
15M	+8.0 dbm	+10.1 dbm
10M	+7.1 dbm	+ 9.3 dbm

#### Change text, font, and colors for Splash screen

```

439  lcd.setCursor( 0.5f*(lcd.width()-lcd.textWidth(NAME) ), 0.1f*lcd.height() ); //where to write Name intro
440  lcd.printf( NAME );
441  lcd.setCursor( 0.5f*(lcd.width()-lcd.textWidth(VERSIONID) ), 0.3f*lcd.height()); //where to write Version ID
442  lcd.printf(VERSIONID);
443  lcd.setCursor( 0.5f*(lcd.width()-lcd.textWidth(ID) ), 0.5f*lcd.height()); //where to write ID
444  lcd.printf(ID); //sendi ID to display

```

#### Set Band names

```

1056 #if RADIO == A210
1057   switch(count) { //determine which position the band switch is located
1058     case 1: sprintf(band_str, " 80 M"); break; //set to 80M position USB
1059     case 2: sprintf(band_str, " 40 M"); break; //set to 40M position USB
1060     case 3: sprintf(band_str, " 20 M"); break; //set to 20M position USB
1061     case 4: sprintf(band_str, " 15 M"); break; //set to 15M position USB
1062     case 5: sprintf(band_str, " 10 M"); break; //set to 10M position USB

```

#### Change Digital display Band font and text and color

```

1065  sprites[flip].setFont(&fonts::Font4); // Set font
1066  sprites[flip].setTextSize(0.75f); // Scale font size
1067  sprites[flip].setTextColor(CL_NUM); // Set font color

```

#### Set Frequency Steps

```

1089 void display_Step() { //code to handle large & custom display
1090   #if DISP_SIZE == LARGE_DISP || DISP_SIZE == CUSTOM_DISP
1091     switch (fstep) { //determine step position
1092       case 10: sprintf(step_str, "10 Hz");break; //step frequency is 10Hz
1093       case 100: sprintf(step_str, "100 Hz");break; //step frequency is 100Hz
1094       case 500: sprintf(step_str, "500 Hz");break; //step frequency is 500Hz
1095       case 1000: sprintf(step_str,"1 KHz");break; //step frequency is 1KHz
1096       case 10000: sprintf(step_str,"10 KHz");break; //step frequency is 1KHz

```

#### Change Digital display Step font and text and color

```

1108  sprites[flip].setFont(&fonts::Font4); // Set font
1109  sprites[flip].setTextSize(0.75f); // Scale font size
1110  sprites[flip].setTextColor(CL_NUM); // Set font color

```

#### Set Memory names

```

1230 //-----code to handle memory Display 2 -----
1231 void display_Mem() { //code to display the current memory A, B, or C
1232   #if DISP_SIZE == LARGE_DISP || DISP_SIZE == CUSTOM_DISP
1233     switch (memory) { //determine memory position
1234       case 1: sprintf(mem_str, "Mem:A");break; //memory A
1235       case 2: sprintf(mem_str, "Mem:B");break; //memory B
1236       case 3: sprintf(mem_str, "Mem:C");break; //memory C
1237       case 4: sprintf(mem_str, "Mem:D");break; //memory D
1238       case 5: sprintf(mem_str, "Mem:E");break; //memory E

```

### Change Digital display Memory font and text and color

```
1250 |     sprites[flip].setFont(&fonts::Font4); // Set font size  
1251 |     sprites[flip].setTextSize(0.75f);    // Set font scale  
1252 |     sprites[flip].setTextColor(CL_NUM); // Set font color
```

### Define location of Frequency Display box

```
1295 |     sprites[flip].drawRoundRect(1,F1_POS+1,318,38,5,CL_FREQ_BOX); // draw box (x1,y1,x2,y2,thick,color) (15,40)
```

## M. 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