Atlas 210X/215X Si5351 VFO

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I. OVERVIEW

Atlas Radio HF transceivers were produced from the mid to late 70s. Available models included the 180 and the 200 series of 210/215, 210X/215X, and 210X/215X LE. In a separate Atlas engineering document, a number of fixes, mods, and changes have been provided that improve the overall operation of these radios. One area of marginal performance is the factory analog VFO. Replacing this VFO with a digital unit represents a significant modification to the radio, but the change is not difficult to perform and the cost is minimal when one considers the tremendous improvement in the overall operation of the radio.

All of the Atlas radio models used the same basic VFO design, with the oscillator frequency range being changed for each band via different LC combinations. This design removed the need for a heterodyne mixing oscillator and reduced the overall cost of the radio. The downside was that the VFO was never very stable, even when new from the factory. It was also difficult to get better than 1 KHz frequency accuracy when trying a move to a specific frequency. During a 30 minute warm up, the drift was somewhere between 1 to 2 KHz. There is also a 100 to 300 Hz drift throughout the day after the radio has been warmed up. The VFO output signal also had very strong 2nd and 3rd harmonics, which degraded the performance of the receiver.

The Atlas radios have a different frequency range for each of the five ham bands. In theory, the band with the highest VFO frequency (10M) would have the most drift, but there have been some cases where a lower band had the most drift. The mechanical design of the VFO plays a major role in the resulting drift. This is due to the mechanical switching of frequency capacitors and coils in changing bands. On the Atlas assembly line, the assemblers would measure the drift on each band and install the appropriate temperature compensating ceramic disc capacitors to counter-act the drift. I am not sure of the amount of drift on a brand new radio, but as mentioned earlier, most of the 40+ year old units have quite a bit of drift.

Installation of a digital VFO greatly reduces the amount of drift. On my particular radio, with a digital VFO, I have a warm-up drift of about 10 Hz during the first 15 minutes. Over the course of 24 hours, the drift is no more than +/- 5 Hz.

Installing a digital VFO involves removing all existing parts associated with the analog VFO. This frees up a large amount of space inside the VFO compartment. Two band switch wafers are freed up inside the VFO compartment. There are two sets of switched contacts on each wafer. One set of switched contacts will be used to change the band of the digital VFO. Two sets of switched contacts are used for switching the appropriate low pass filter for the band being used.

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 on the 15M and 10M bands of the Atlas radios. The Si570 chip works well with the Atlas radio, but the cost is high $40 - $70. 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.

A. Audience

This document is written for Atlas radio owners that want an accurate frequency display, along with a very stable VFO. A moderate amount 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 SMT part soldering is needed on the main VFO circuit board. The time required for this assembly is not more than 2 – 3 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 internal 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 internal digital VFO.
Provide detailed engineering drawings that will remove confusion on how the 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 10 meter low pass filter. I have not completed any extensive testing with the bare bones setup and the Atlas receiver appears to work the same as a factory radio. One can build the bare-bones package and then update with the additional options at a later date.

1. Low Pass Filter options:

Single Mini Circuits SLP-25 low pass filter
QRP Labs low pass filters on a custom mounting board (3 filters)
Mini-Circuits PLP-xx low pass filters on a custom mounting board (3 filters)

The MCL PLP-xx filters provided the best response curves with minimal leak through around the filters. The QRP Labs filters will also work, but the response curves are degraded about 20 to 30 dB in the upper frequency ranges as a result of signal leak through around the filters.

The following MCL filters were used:

80M/20M	MCL PLP-10.7
40M/15M	MCL PLP-15
10M	MCL PLP-30

2. Si5351 VFO Output Signal

The output signal of the VFO board, after passing through a low pass filter, is about +11 dB in level. That is the right signal level for feeding the Atlas receiver mixer. That is OK if the attached load is a pure 50 ohms. In the Atlas radio, the load varies in impedance, depending upon the band being used. On the 15M and 10M bands, the output signal can be as low as +5 dB with the factory VFO.

The fix is to provide a constant 50 ohms load on all bands by using a MMIC amplifier. The VFO circuit board includes a Mini Circuits GALI-6 MMIC chip amplifier. Using the resistor values shown on the schematic, the output signal is about +11.3 dB on all bands, as measured on the SMA jack of the VFO box.

3. Si5351 Oscillator Board

The motherboard is setup to use either a QRP Labs Si5351 module or a Chinese Si5351 module. The QRP Labs module requires that two 10 socket pin headers be installed for U4. A Chinese module only has seven pins on the board. To use the Chinese board, the following changes need to be made for the build of the motherboard.

Install a single 10 socket pin header at U4A.
Install an insulated ground wire from the pin 2 solder pad to a ground point on the motherboard.

Install an insulated wire from the pin 3 solder pad to the SLC solder pad next to the U4B socket.
Install an insulated wire from the pin 4 solder pad to the SDA solder pad next to the U4B socket.
Install an insulated wire from the clock 0 pad on the oscillator board to pin 17 on the U4B socket.
The Chinese board is installed so that pin 1 goes into pin 10 of U4A.

II. SPECIFICATIONS

If one is unsure about modifying their Atlas radio, then an external VFO can be built and attached to the radio via the Accessory Socket on the rear of the radio. If one is comfortable with the operation of the VFO, then the VFO module can be removed from the external VFO box and installed inside the Atlas radio.

Here is a summary of the specs for the VFO:

Minimal cost
Code modification to select Atlas radio model – 210X or 215X
Code modification to select Atlas IF frequency – 5520 KHz or 5645 KHz
About 240 ma current draw, including back-lighted LCD display
The following modules are plug-in
 ESP-32 microprocessor
 QRP Labs Si5351 module
 5.0 volt regulator
 3.3 volt regulator
 LCD Display
 Rotary Encoder

Five memory channels on each band
Frequency Lock
Uses existing Atlas front panel frequency display window
Uses existing Atlas 210X LE front panel control openings – no need to drill any new holes
Supports standard color TFT 170x320 display
+11.3 dbm output signal
With1 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 10 Hz, 100 Hz, 500 Hz, 1 KHz, and 10 KHz
Works with standard Bourns or Oak Grigsby optical encoders
Uses freed up contacts on the Atlas band switch control to change VFO frequency band and low pass filter
LSB/USB toggle for changing display frequency when shifting sidebands of the Atlas carrier oscillator
+ IF shift for 80/40M and – IF shift for 20/15/10M
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 – especially on 15M and 10M

III. Project Overview

A. Signal Generator versus VFO

The same motherboard is used for a Si5351 signal generator or a VFO. The following changes are needed to use the motherboard as an Atlas VFO – please refer to schematic diagram in the Appendix.

Replace JP1 jumper with R8
Install R9
Do not install C11
Upload the Arduino IDE Signal Generator code.
You will now have a signal generator that puts out a 0 dbm signal.

If you want a 10 dbm output signal, then make these changes:

Replace R3 470 ohm resistor with 270 ohm resistor
Replace R5, R6, and R7 with 240, 20, and 240 ohm resistors

B. Mini-Project Tasks

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

Procure Parts
Build Si5351 VFO Assembly
Test Si5351 VFO on Atlas radio
Prepare Atlas radio
Mechanical install Si5351 VFO assembly in Atlas radio
Interface Si5351 VFO to Atlas radio
Install low pass filters
Test

C. 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. The total cost for parts is less than $200. Out of that total, $105 is for the ESP-32 processor board, the QRP Labs Si5351 oscillator board with TCXO module, and the three Mini Circuits low pass filters.

AliExpress has many of the needed parts at low prices.
https://www.aliexpress.us/

ESP-32 Microprocessor board
LILYGO® TTGO T7 Mini32 V1.5 ESP32 WROVER B Dual Core PSRAM Wireless Wi Fi Bluetooth Module Development Circuit Board CH9102|Circuits| - AliExpress

AMS-1117 5 volt voltage regulator
https://www.aliexpress.us/item/3256803546112821.html?spm=a2g0o.detail.0.0.14e9X24SX24SVx&gps-id=pcDetailTopMoreOtherSeller&scm=1007.40050.362094.0&scm_id=1007.40050.362094.0&scm-url=1007.40050.362094.0&pvid=c012cffa-7831-4384-9982-db831c3b121a&_t=gps-id:pcDetailTopMoreOtherSeller,scm-url:1007.40050.362094.0,pvid:c012cffa-7831-4384-9982-db831c3b121a,tpp_buckets:668%232846%238111%231996&pdp_npi=4%40dis%21USD%210.33%210.27%21%21%210.33%21%21%402103011516980660961726398ea56e%2112000026969548326%21rec%21US%21%21AB

AMS-1117 3.3. volt voltage regulator
https://www.aliexpress.us/item/3256804756651950.html?spm=a2g0o.productlist.main.1.402c3a8d3tv4yW&algo_pvid=2eb37010-cc48-491b-b847-504474ab3df4&algo_exp_id=2eb37010-cc48-491b-b847-504474ab3df4-0&pdp_npi=4%40dis%21USD%211.42%211.01%21%21%211.42%21%21%402101d4a716980658997023611e1d62%2112000031101603999%21sea%21US%210%21AB&curPageLogUid=9UV84keNh1lb

TFT Color 170x320 1.90” Display
https://www.aliexpress.us/item/3256805850210064.html?spm=a2g0o.order_list.order_list_main.15.6b701802u77yDw&gatewayAdapt=glo2usa

Hammond 1590A Clone die cast aluminum enclosure
https://www.aliexpress.us/item/3256802438032687.html?spm=a2g0o.order_list.order_list_main.25.21ef18020epeZ5&gatewayAdapt=glo2usa

Here are the specs for the Hammond case:
http://www.hammondmfg.com/pdf/1590A.pdf

Ceramic disc capacitors
https://www.aliexpress.us/item/3256804674697278.html?spm=a2g0o.order_list.order_list_main.15.21ef18020epeZ5&gatewayAdapt=glo2usa

Tantalum capacitors
https://www.aliexpress.us/item/3256802357267076.html?spm=a2g0o.order_list.order_list_main.20.21ef18020epeZ5&gatewayAdapt=glo2usa

Chassis Mount Feedthrough capacitor
https://www.aliexpress.us/item/3256802790468974.html?spm=a2g0o.order_list.order_list_main.30.21ef18020epeZ5&gatewayAdapt=glo2usa

Alternate source for feedthrough capacitor
(FRI) SA2A1503
https://www.surplussales.com/Feedthrus/FTholeMnt4.html

QRP Labs Si5351 Oscillator with TCXO option
https://www.qrp-labs.com/synth.html
Resistors – through hole 1/8 watt
https://www.aliexpress.us/item/2251832660697020.html?spm=a2g0o.order_list.order_list_main.50.21ef18020epeZ5&gatewayAdapt=glo2usa

Brass standoff kit
https://www.aliexpress.us/item/2251832718469363.html?spm=a2g0o.order_list.order_list_main.10.21ef18020epeZ5&gatewayAdapt=glo2usa

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

Oak-Grigsby Optical Encoder
https://www.ebay.com/itm/284621140106

M2 5mm stainless steel Phillips head screws. $7
https://www.amazon.com/gp/product/B01DKI6VD8/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1

M2 brass standoff, stainless steel screw/nut kit. $12
https://www.amazon.com/gp/product/B07ZSZW8T1/ref=ppx_yo_dt_b_asin_title_o01_s00?ie=UTF8&psc=1

40 pin male and female pin headers. $6
https://www.amazon.com/gp/product/B074HVBTZ4/ref=ppx_yo_dt_b_asin_title_o00_s00?ie=UTF8&psc=1

Mini Circuits Gali-6 MMIC
78M09 voltage regulator
Multi-color 16 wire ribbon cable, 28 gauge tinned copper, with wire pitch of 1.27 mm

Miscellaneous IDC ribbon cable connectors
Toggle and push button switches
VFO circuit board
Front panel circuit board labels
Male pin strips (Jameco)
Female pin headers (Jameco)
ON-OFF-ON toggle switch
26 gauge, stranded Teflon hook-up wire
22 gauge, stranded Teflon hook-up wire
SMA Chassis mount jack

D. Low Pass Filters

There are a number of different options for procuring the three needed low pass filters. One can design/create their own, purchase kits, or purchase units that are fully assembled. Here are possible sources:

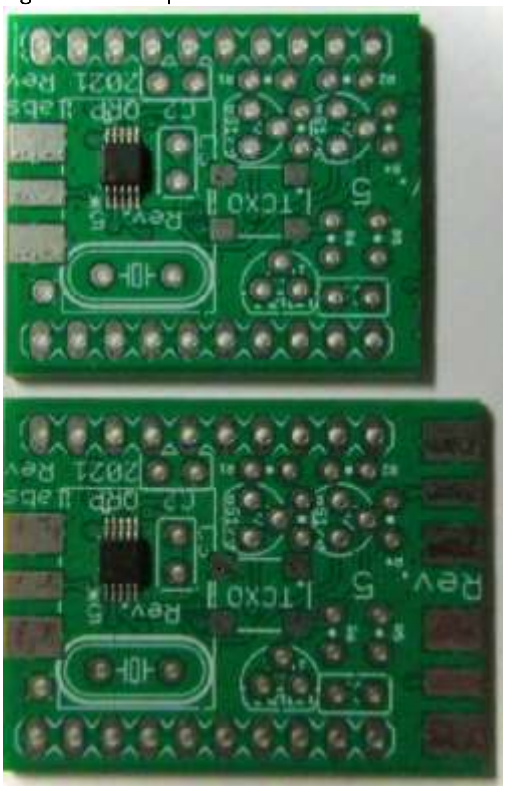
QRP Labs Low Pass Filters - http://qrp-labs.com/lpfkit.html (three kits)
Mini Circuits Low Pass Filters – http://www.minicircuits.com/products/filters_pic_low.shtml

The custom designed low pass filter board can accommodate with the Mini Circuits or the QRP Labs low pass filters.

IV. Build QRP Labs Si5351 Oscillator Board

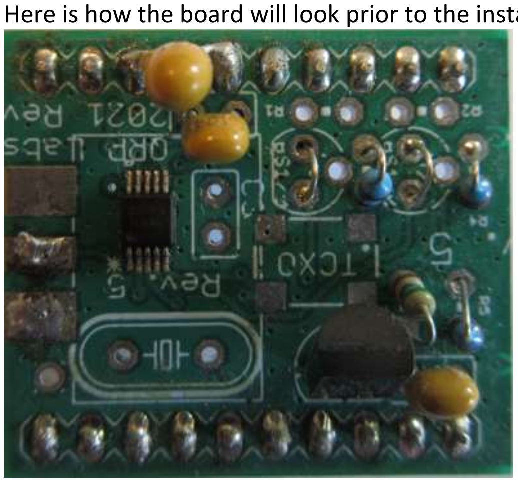
The QRP Labs Si5351 oscillator board plugs into the VFO circuit board.

On the bare QRP Labs Si5351 oscillator board, cut off 4 mm of circuit board material from the end that had the Clock 1 and Clock 2 solder pads. 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.



Build the Si5351 oscillator board per QRP Labs instructions, with the following exceptions:
Do not install Q1, Q2, R1 and R2
Install a jumper wire from the source to the drain on Q1.
Install a jumper wire from the source to the drain on Q2.
These changes provide a 3.3 volt logic level on the 12C lines as opposed to the factory 5.0 volt logic level.
Install a 10 uf tantalum capacitor between Pin 18 and Pin 16 (ground).

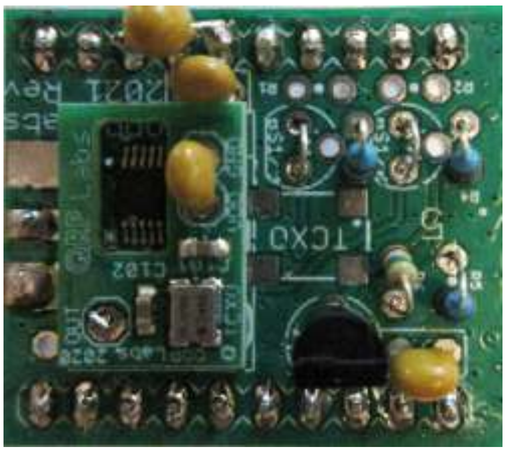
Here is how the board will look prior to the installation of the TCXO module:



Build the TCXO board and install the TCXO board onto the Si5351 board.

Install 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).

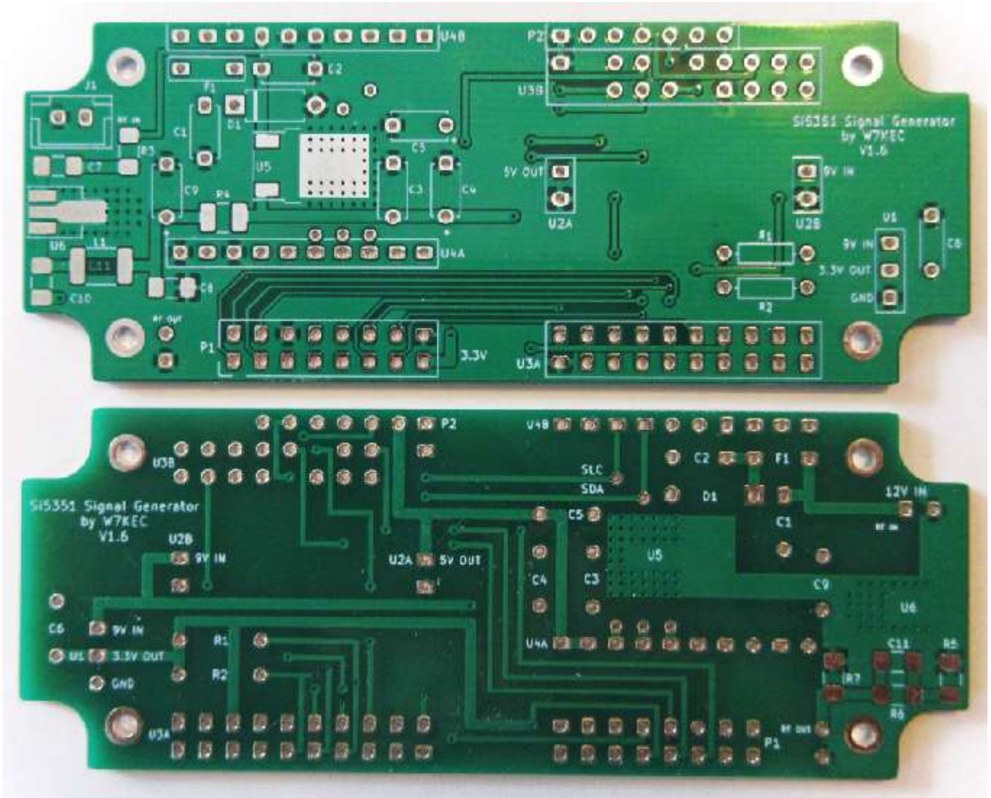
Here is the completed board with the TCXO module installed:



Carefully inspect the solder connections on the bottom of each board.
Set aside the oscillator board.

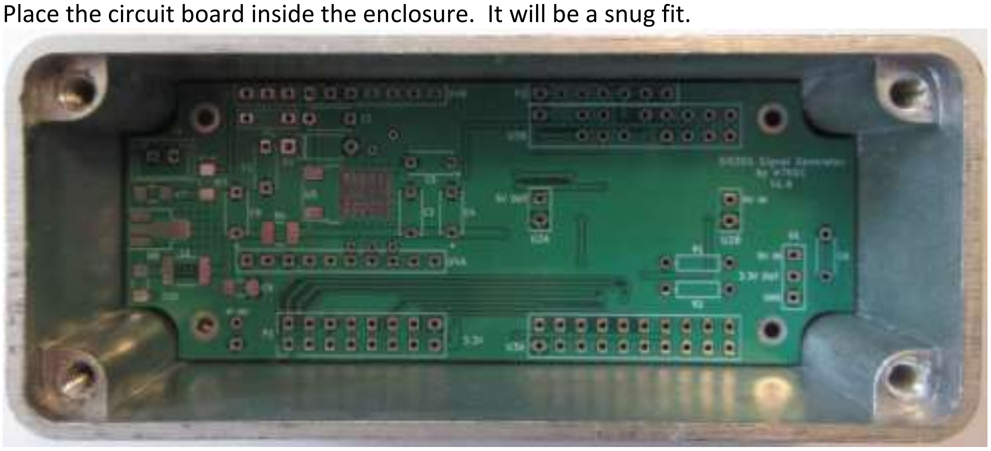
V. Build Si5351 VFO Board

This project centers around the Si5351 VFO circuit board. Here is version 1.6 of the board:



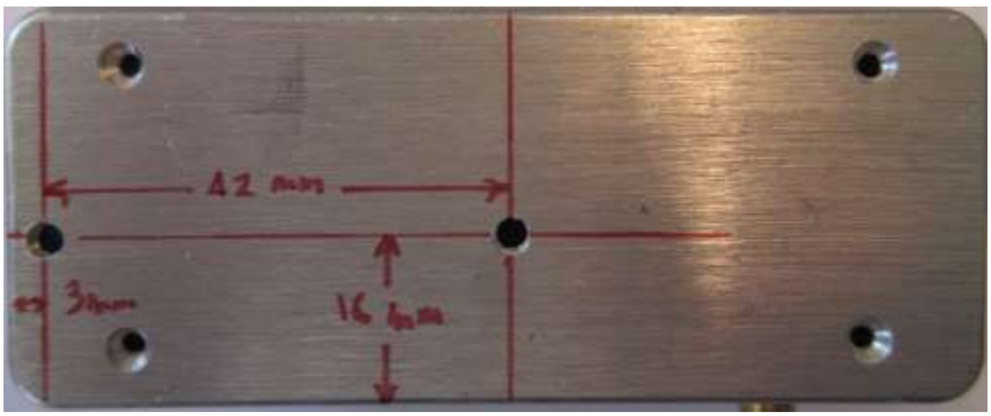
The SI5351 VFO should be assembled in the Hammond 1590A enclosure (or clone) before any modifications are made to the Atlas radio.

Place the circuit board inside the enclosure. It will be a snug fit.

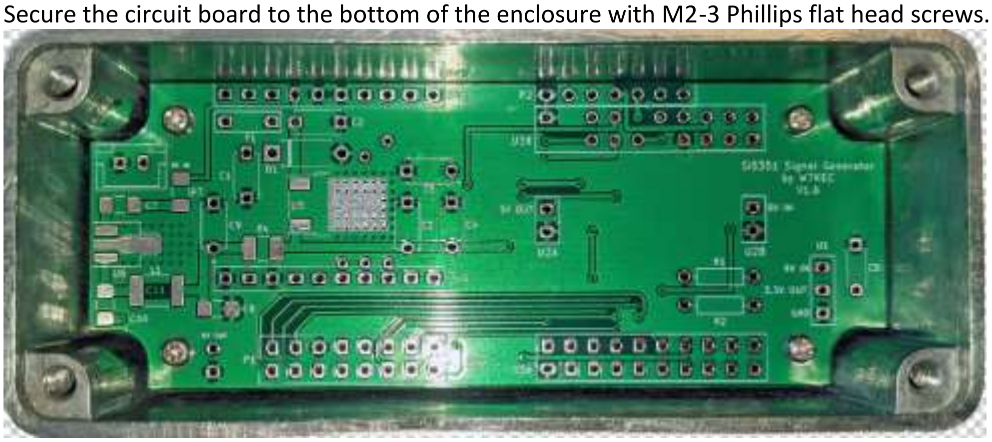


Center punch the inside bottom of the enclosure through the four mounting hole on the circuit board. Drill out each center punch with a 1/16" drill bit. Use a needle nose round file to center up the holes in each circuit board. Drill out four holes in enclosure with a 5/64" drill bit. Counter sink the holes on the outside bottom of the enclosure. Install 4 each M2-5 brass standoffs on the bottom of the circuit board using M2-5 Phillips head screws.

Mark screw hole positions on the bottom of the VFO enclosure. Mark one hole 3 mm from the left edge of the enclosure and 16 mm from the top edge of the enclosure, when looking at the enclosure from the top view. Mark a second hole 42 mm to the right of the first hole and 16 mm from the top edge of the enclosure. Center tap the positions and drill 3/32" holes. Tap the holes with a 6-32 tap.



Secure the circuit board to the bottom of the enclosure with M2-3 Phillips flat head screws.



Remove the four bottom flat head screws and remove the circuit board from the enclosure.

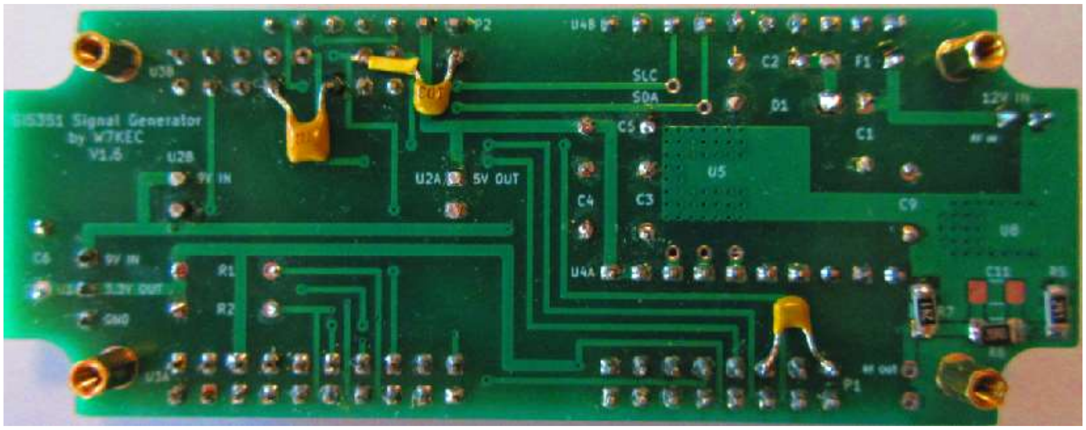
The SMT capacitors and resistors should be soldered to the VFO circuit board before any pin headers, sockets, and plugs are installed. Remove the circuit board from the enclosure. Solder the following parts to the top of the circuit board:

U5 – 9 volt voltage regulator
F1 fuse
R1 & R2 – 2.2K ohm 1/8 watt resistors
C1, C2, C3 and C6 – 0.01 uf ceramic disc capacitors
C4 – 10 uf tantalum
C5 – 100 uf tantalum
D1- 1N4001 diode
R4 56.4 ohms SMT
C7, C8 & C10 – 0.1 uf SMT
L1 – 100 uh SMT
C9 – 10 uf tantalum
R3 – 220 ohms SMT
U6 – GALI-6 MMIC
R6 – 20 ohms SMT – bottom of board
R5 & R7 – 240 ohms SMT – bottom of board

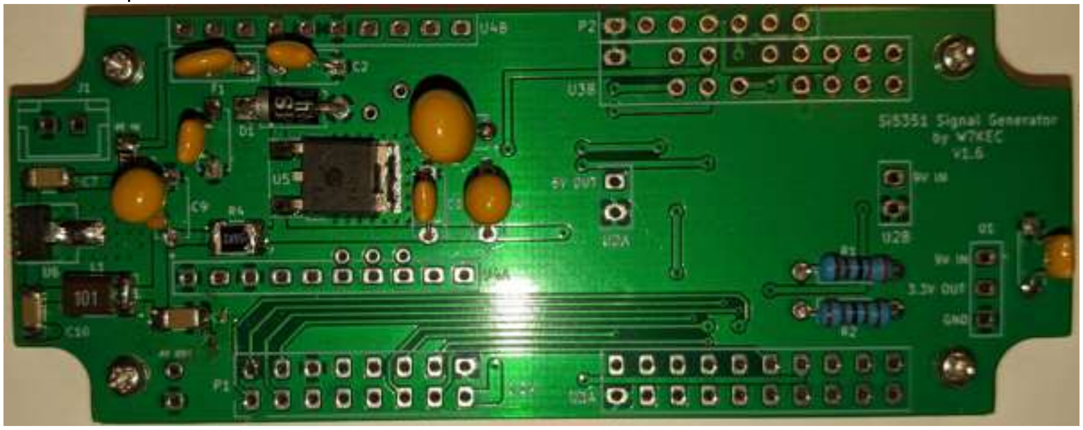
On the bottom of the VFO circuit board, solder 0.01 uf monolithic ceramic capacitors between ESP-32 pins 27 and GND, pins 32 and GND, and pins 11 and 15 on P1.

All resistors, capacitors, and active devices have been installed on the circuit board.
There will be no capacitor installed at C11.

Here is a bottom view of the board:



Here is a top view of the board:



On the circuit board, solder the following parts:
Get two double row 10 pin male headers
Insert the male headers on the ESP-32 module
Solder the pins on both pin headers

Get two double row 10 pin female headers
Look at circuit board at J3A and J3B. Note pins that have no solder pads.
Remove those pins from the pin header
There are five pins that will need to be removed from J3B female pin header.
Insert the modified female pin headers into the circuit board at J3A and J3B
Insert the ESP-32 module into the female pin headers
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
Solder the P1 pins on the circuit board.

Get one each single row 7 male pin header. If possible, use a color other than black.
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.
Insert the power jack at location J1 – matching the silk screen to the body of the plug.
Solder two pins on the jack.

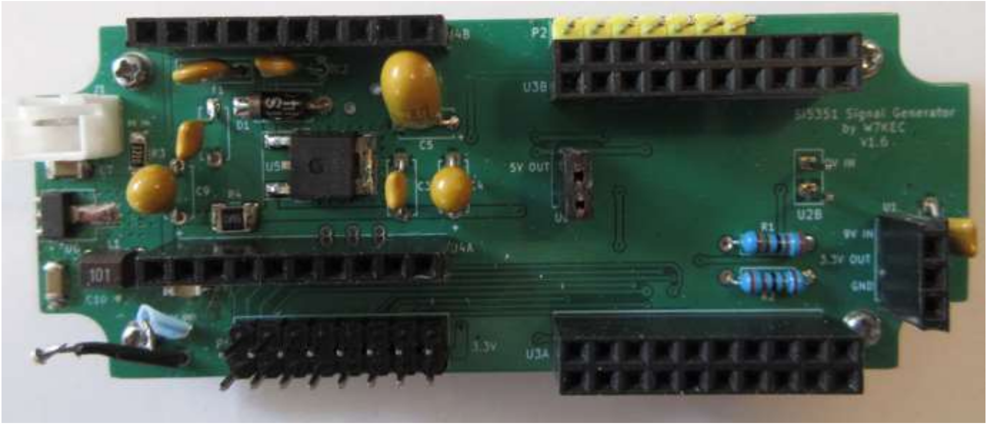
Solder a 3 pin female pin header at U1 on the circuit board. Put a small bead of super glue on either side of the header where it makes contact with the circuit board. This will keep the header from moving.

The following steps will create a low profile socket so that U2 can be mounted underneath the body of the ESP-32 module.

The body of a female pin header is 9 mm long.
Cut the top off of two each two pin female pin headers so that the body is 6 mm long.
You should just barely see the top of the metal contact pin
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
Remove the voltage regulator board from the VFO circuit board

Install an insulated solid wire on the Ground solder tab on the circuit board.
Install a 0.01 uf mono ceramic capacitor 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.
Here is a picture of the top of the completed board:



Insure that the ESP-32 module, the Si5351 oscillator board, the 5 volt regulator module, and the 3.3 volt regulator module have been removed from the board.

Apply 13.7 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 13.7 volts to the power socket. You should see about 76 ma of current.
The red LED light on the 5 volt regulator board should light.
Confirm that the output voltage on the 5 volt regulator is about 5 volts.

Remove power from the board.
Remove the 5 volt regulator board.
Install the 3.3 volt regulator board
Apply power to the board.
You should see about 76 ma of current draw and the red LED light on the 3.3 volt regulator board.
Confirm that the output voltage on the 3.3 volt regulator board is 3.3 volts.
Remove power from the board.

Install the 5 volt regulator board.
Apply power to the VFO board.
The current draw should be about 82 ma.
The red LEDs on the 3.3 volt and 5 volt regulator boards should be lighted.

Install the QRP Labs Si5351 oscillator board.
The total current draw should be around 120 ma.

Install a programmed ESP-32 module.
The total current draw should be around 160 ma.

Remove power and connect LCD display and the rotary encoder.
Power up board.
Total current draw should be about 220 ma.

Solder two wire (black-red) wires to inside connection on the feed-through capacitor and ground lug.

Carefully inspect all solder connections on the bottom of the board. Check for solder splatters and excess rosin.

VI. VFO Enclosure Modifications

The die cast aluminum enclosure will need the following modifications:

Cut rectangular 11 mm wide by 8 mm high opening on end of enclosure for USB jack.

On the cover, cut a matching notch on the edge 11 mm wide and 2 mm deep.

Cut notch in top cover inner edge for the U1 voltage regulator. The notch should be 10 mm wide and 2 mm deep. This notch will be next to the previous notch that was cut for the USB jack.

Drill a ¼" OD hole on the enclosure 15 mm from left edge and 9 mm from the top edge for the SMA chassis mount jack. Note: Please allow enough spacing between the fixed nut on the SMA jack and the 16 pin IDC pin header next to it. If there is not enough space, you will have a difficult time in plugging in the 16 pin ribbon cable.

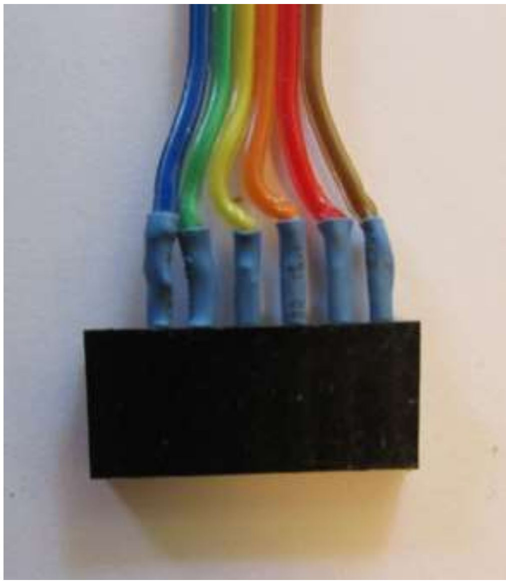
Drill a 7/64" OD hole on the end of the enclosure that has the SMA chassis mount hole. Center the hole across the width of the enclosure (19 mm from edge) and 9 mm from the top edge. This hole is for the power feed-through capacitor.

Cut a notch in enclosure on the edge of top cover and main body of enclosure for the 16 wire ribbon cable. The notch should be 20 mm wide and 1 mm deep. It should match up with the ribbon cable when the cable is folded over the top of the enclosure. The notch should be on the same side as the SMA jack.

Cut notch in enclosure on the edge of top cover and main body of enclosure for the 6 wire ribbon cable. The notch should be on the same side as the SMA jack. The notch should be 8 mm wide and 1 mm deep for top cover and main body.

Fabricate a 16 wire ribbon cable is with a female IDC connector on the end. The cable should be 9" long from the edge of the IDC connector to the end of the cable.

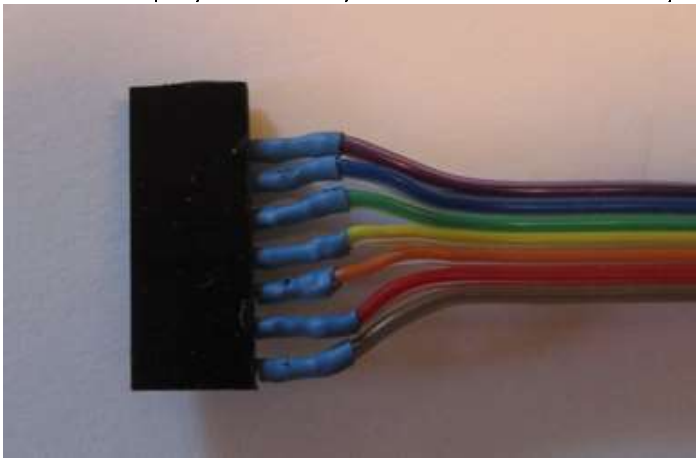
Fabricate a 6 wire ribbon cable with a female pin header socket on the end. This end will attach to the male pin header on the Si5351 circuit board. Pull pin 7 and fill the hole with epoxy.



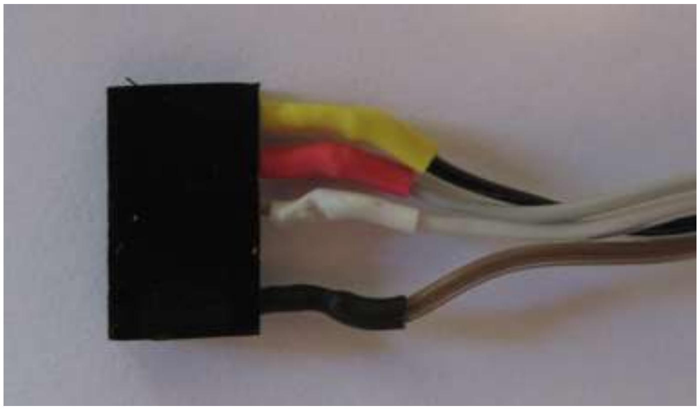
Install a SMA female chassis mount jack on the wall of the enclosure.
Install a 0.01 uf feedthrough capacitor on the wall of the enclosure, along with a ground lug on the inside of the enclosure. Solder red single pin header wire to feed through capacitor.

Connect the power cable from feed-through capacitor to J1 jack.
Connect the 6 pin ribbon cable
Connect the 16 pin ribbon cable
Install jumper wire from ground pad on circuit board to ground lug on SMA jack
Install VFO board into enclosure
Secure VFO board to bottom of enclosure with M2-3 counter sunk screws
Solder C12 to the SMA chassis jack

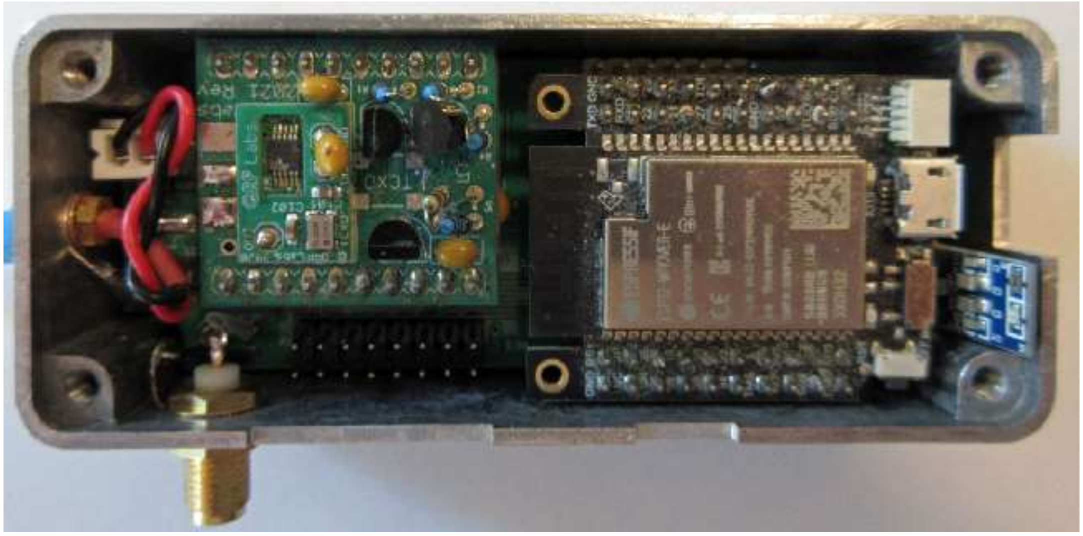
Solder an 8 pin male header to the LCD display. Cut off pin 8.
Solder a jumper wire from pin 2 to pin 8 on the LCD display.
Solder an 8 pin female pin header to appropriate wires on 16 wire ribbon cable. Fill the pin 8 hole in the header with epoxy. This will key the header so that it can only be installed one way.



Solder a female 5 pin header to the appropriate wires on the 16 wire ribbon cable. This header is for a Bourns encoder. Cut off the NC pin on the Bourns encoder. Pull the unused pin and fill the hole with epoxy. This will key the header so that it can only be installed one way.

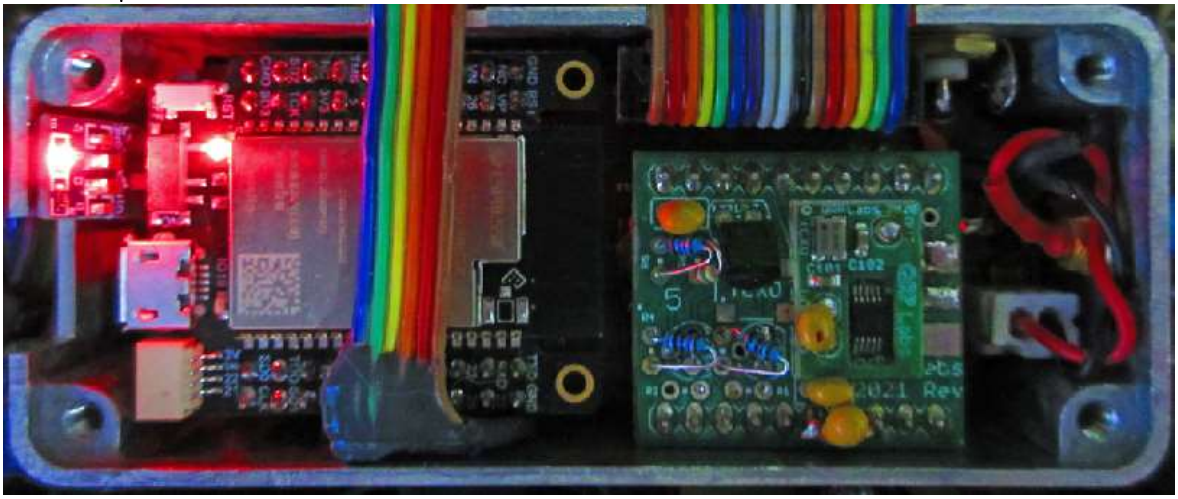


Here is a picture of the circuit board installed in the enclosure:



Label the top cover on the enclosure and install it on the enclosure.

VFO box with power applied. The green LED on the ESP-32 board is not lighted when the Nor/Opp switch is in the Nor position.



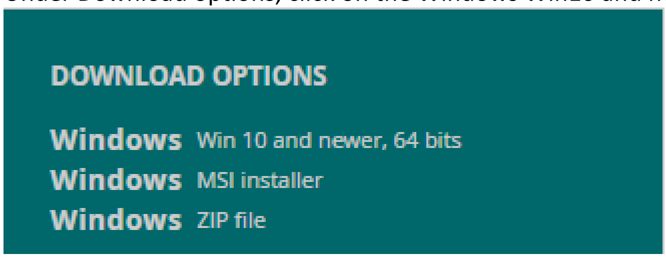
VII. Program ESP-32 Module

The following steps assume that no version of Arduino IDE has ever been installed on the PC. It is also assumed that the VFO box is installed external to the radio and it is connected to the radio's rear accessory jack for power and signal.

The app Arduino IDE 2.3.2 will be used to program the ESP-32

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

Under Download options, click on the Windows Win10 and newer, 64 bits

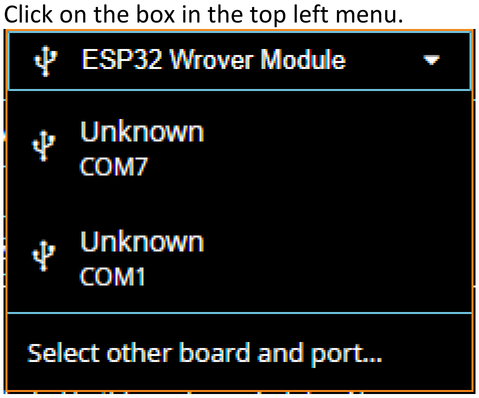


The download will start. When complete, the downloaded file will be about 146 MB in size.

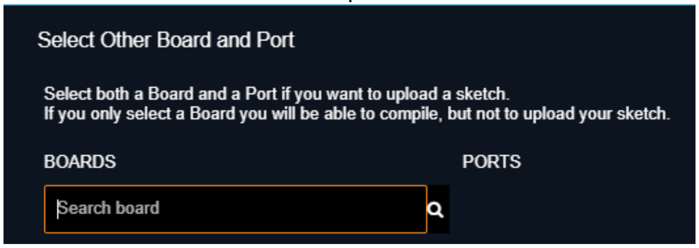
Double click on the downloaded file.
Hit I agree.
Select Anyone who uses this computer.
Hit Next
Hit Yes
Hit I agree
Use the default installation folder and hit Install
The installation will start. The install will take less than five minutes
Hit Finish
The Arduino IDE app will open.
Close the app.

Create a subdirectory /VFO4_1 and download the contents of the VFO4_1.zip file.
Insure that the ino file is named VFO4_1.ino.
Double click on the ino file. The Arduino Ide app will open.

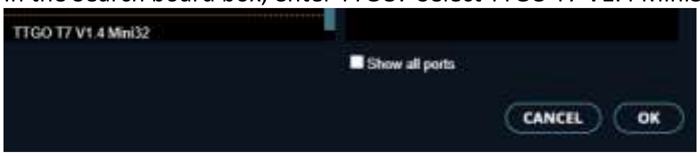
Under Tools/Manage Libraries, enter LovyanGFX under Filter your search.
Select version 1.1.12 and install it. The file will be downloaded and installed.
Click on the box in the top left menu.



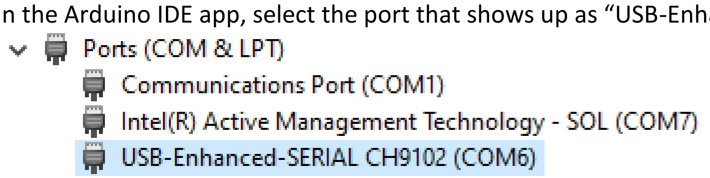
Click on Select other board and port…



In the Search board box, enter TTGO. Select TTGO T7 V1.4 Mini32 and hit OK.



On the IDE menu, go to Files-Preferences
Under “Additional Boards Manager URLs, enter this URL:
https://raw.githubusercontent.com/espressif/arduino-esp32/gh-pages/package_esp32_index.json
Hit OK
Go to Tools-Board Manager
Scroll down the libraries on the left hand side of the display.
Select esp32 by Espressif Systems version 2.0.14 and hit Install.
Power up the radio.
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



Select the Verify/Compile option. If the file compiles without any errors, then execute the Upload command. You should see this display.

The total current draw will be somewhere between 220 and 240 ma. Confirm that you can change the frequency with the encoder.
You can customize the text colors by going to this site:
https://www.computerhope.com/htmcolor.htm

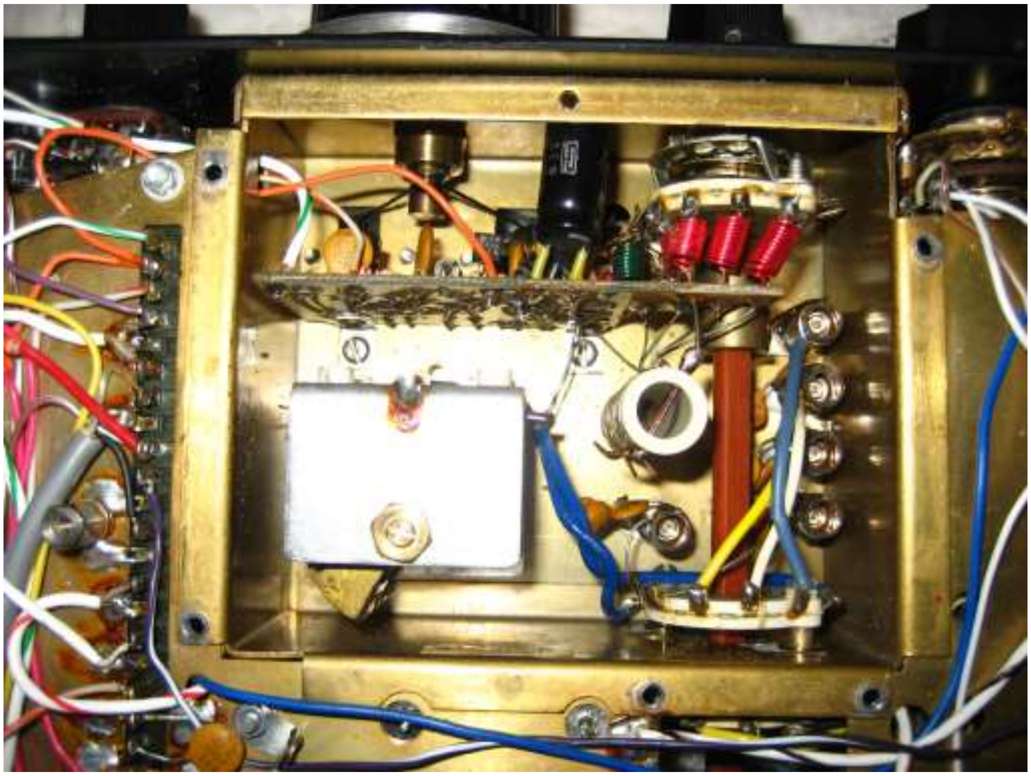
The Appendix shows the lines of code that can be customized by the end-user.
Connect a power meter to the output of the VFO. The signal level will be about +11.5 dbm from 1 MHz to 50 MHz.

VIII. Remove Factory Atlas VFO

These steps were written for an Atlas 210X/215X LE radio. Similar steps can be used for a non-LE radio.

A. 210X LE Radio Preparation

The existing 210X LE VFO parts, the RIT control, and the Dial Set control will need to be removed from the radio. It will take about 30 - 40 minutes to remove the parts. Here is a bottom view of the factory VFO before the parts were removed:



Remove the following parts:

5 minutes time
Top and bottom equipment covers to the radio
VFO bottom cover
Main VFO tuning knob (two 5/64” Allen wrench set screws)
Dial set knob (3/64” Allen wrench set screw)
RIT tuning knob (3/64” Allen wrench set screw)
Plastic frequency drum (5/64” Allen wrench set screw)
Dial cord
Dial cord pulley bracket (two screws)
VFO dial lamps (two) and power wires
Plastic frequency window (two front panel screws must be removed)
Metal pulley on the top of the VFO (it is secured to the shaft of the VFO tuning capacitor)

10 minutes time
PC-200 circuit board
Dial set pot (cut two resistor wires going to regulator terminal strip on top of chassis
There are two external wires to the RIT sub-assembly control
There are several wires that attach to the ON-XCV switch
RIT terminal strip – single screw holding ON-XCV switch
Varactor terminal strip – single screw holding strip to top of VFO enclosure
RIT wire going to VFO circuit board – cut wire at RIT terminal strip

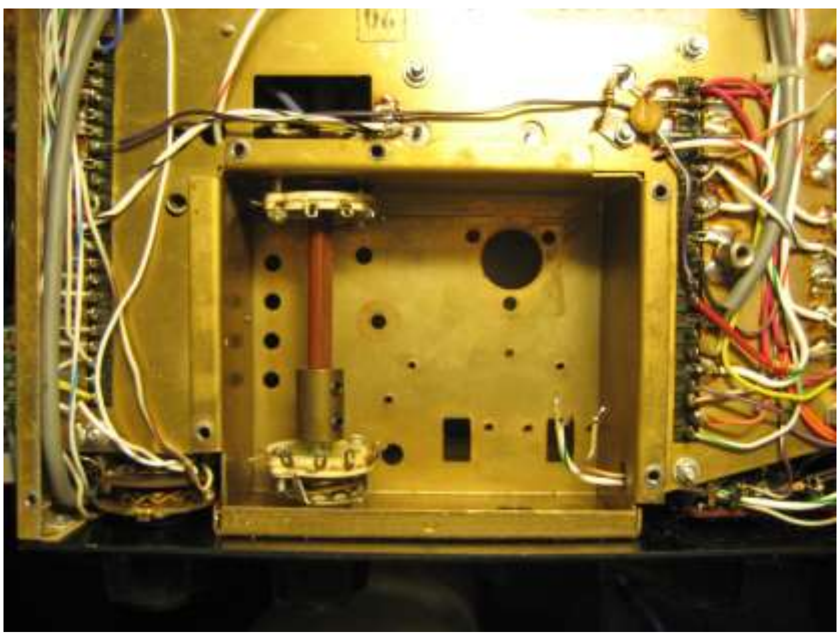
RIT pot
Main tuning capacitor (3 screws and three wires)
Three terminal strip inside VFO compartment
capacitor to band switch contact and white wire to RIT subassembly
Reattach the screw, lock washer and nut that holds the ON-XCV switch
Reinstall PC-200 circuit board
Remove the red and yellow wires going to the ON-XCVR slide switch.

Unsolder all wires between main inductor and VFO circuit board
Remove main inductor by removing single screw
Desolder all wires to the band switch wafers in the VFO compartment
Desolder the two wires to the VFO turning capacitor

17 time in minutes
Remove the following parts:

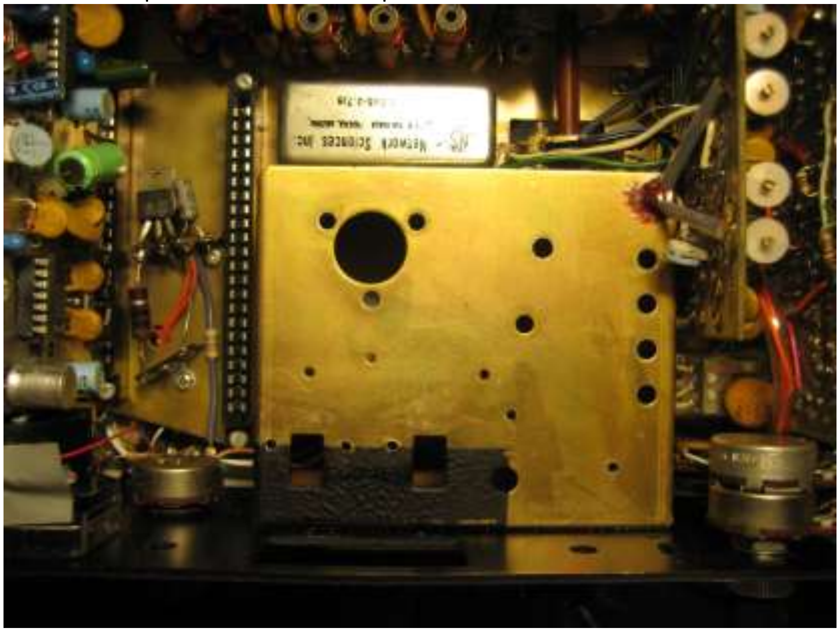
VFO circuit board orange and orange white wires – unsolder both ends of each wire
RG174 coax cable center conductor and shield on VFO circuit board – do not remove the cable
Lock nuts on 5 ceramic piston capacitors
5 wires between ceramic piston capacitors and the VFO circuit board
5 ceramic piston capacitors
All wires going to rear band-switch contacts
Inductors on front band-switch contacts that go to VFO circuit board
Two screws holding the VFO circuit board
VFO circuit board
VFO front frequency control vernier lock nut and vernier
Band labels on top of VFO compartment
Remove variable capacitor C327 on the bottom side of board PC-300

At this point, all VFO parts should have been removed. Here is how the VFO compartment will look:



Drill out the two VFO circuit board mounting holes with a 9/64” bit. These holes will be used to attach the Si5351 VFO box to the top of the VFO enclosure.

Here is the top side of the VFO compartment from a 210X LE radio:



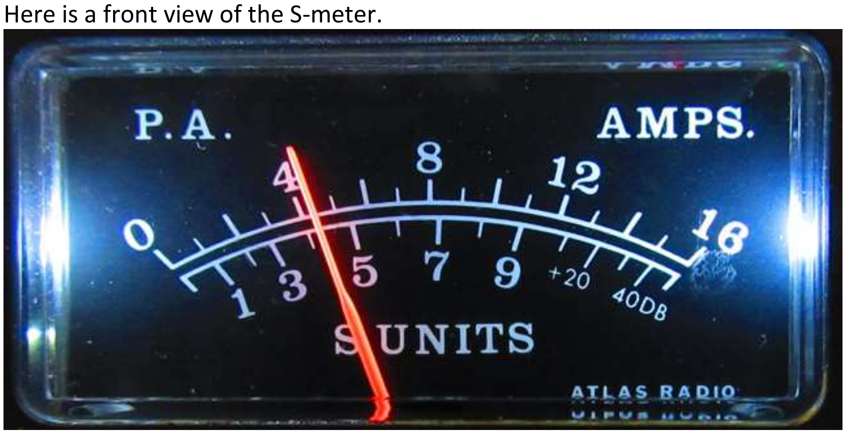
The S-Meter dial light will still be functioning, but will be drawing more current because of decreased voltage drop across R9. The two VFO dial lamps were drawing about 120 ma of current. After the factory VFO and dial lamps were removed, the total receive current draw was about 200 ma. With the Si5351 VFO connected, the total receive current was about 420 ma.

Remove the S Meter dial light. Install two white low current LEDs –one on either side of the meter. Insure that the LEDs are pointing to the S Meter as opposed to pointing to the front of radio. Connect a series 2.2K ohm resistor to the positive leads of the LEDs and connect the other end of the resistors to R9. The total current draw of both LEDs is about 7 ma.

With the LEDs installed, the total current draw in the receive mode is about 360 ma.

Here is a top view of the S-meter.

Here is a front view of the S-meter.



IX. Fabricate LCD Mounting Bracket

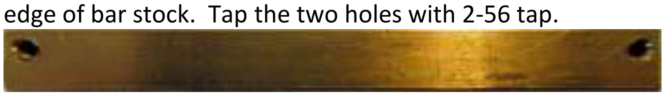
A. Procure Parts

Purchase brass bar stock
https://www.amazon.com/dp/B0C5H9RKCG?psc=1&ref=ppx_yo2ov_dt_b_product_details

Purchase 2-56 screws
https://www.amazon.com/binifiMux-Phillips-Countersunk-Assortment-Stainless/dp/B07X1CNVWD/ref=sr_1_6?crid=2FG7KATKBTP3J&keywords=2-56+screws+infinium&qid=1696891505&sprefix=2-56+screws+inifimu%2Caps%2C215&sr=8-6

B. Prepare Mounting bar

Cut brass bar stock (0.23”x0.23”) to a length of 62 mm.
Drill two 1/16” holes on one side of bar stock – centered on bar stock at 58 mm and 2.0 mm from top edge of bar stock. Tap the two holes with 2-56 tap.



Drill two 3/32” holes on top side of bar stock – look at picture – centered on bar stock at 50 mm apart and in the middle of the bar stock. Countersink the two holes.

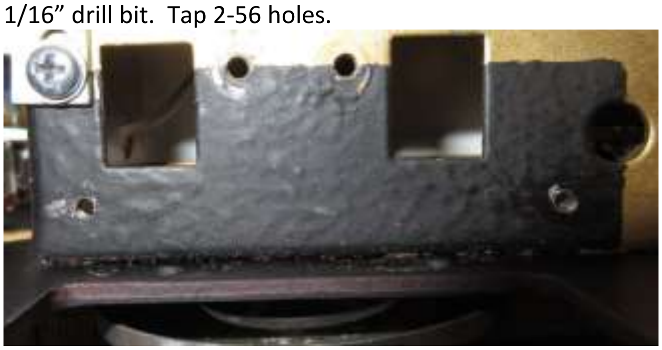
Secure LCD display to bar stock with two 2-56 5mm pan head screws.

Solder an 8 pin male pin header to the back side of the display circuit board.
Solder a jumper wire between pin 8 and pin 2 on the LCD display board. Cut off pin 8 (3.3 V).
On the ribbon cable connector from the VFO, fill the hole in pin 8 (3.3 V) with epoxy.
This will key the connector so that is cannot be connected backwards.

Apply a strip of black electrical tape to the left hand side of the display. The right edge of the tape should just cover up the narrow white trim plastic on the left hand site of the display.

Attach the display to the ribbon cable from the VFO box. Power up the VFO box. Center the TFT display in the center of the Atlas display window. Remove the clear plastic protector from the front of the display. Check for proper operation of the various front panel VFO functions.

Install the display assembly on top of the Atlas VFO box. With the TFT display centered in the Altas frequency window, mark drill holes on the top of the Atlas VFO enclosure. Drill out the two holes with a 1/16" drill bit. Tap 2-56 holes.

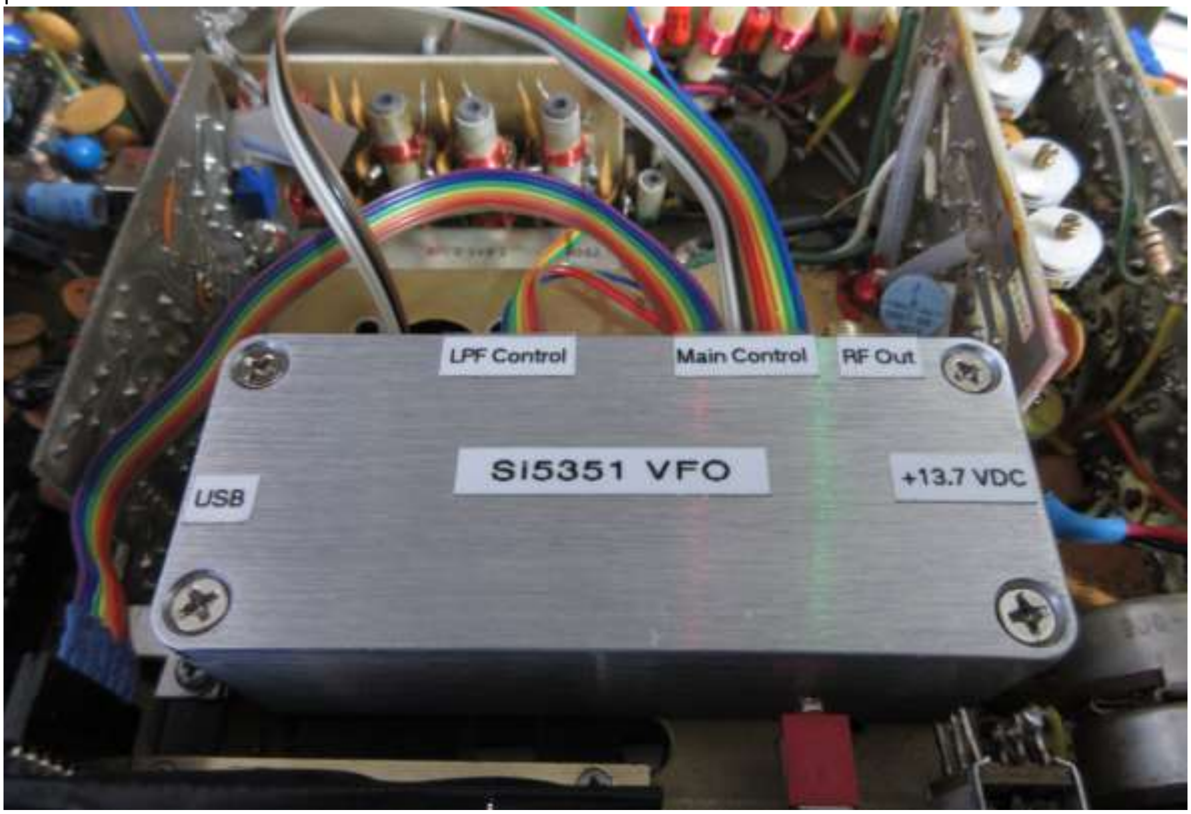


Attach the display assembly to the top of the VFO enclosure using two 2-56 10 mm counter sunk screws. As an alternative, one can drill out the holes slightly larger than 1/16" and secure the two screws with 2-56 nuts.

X. Install VFO Module and Miscellaneous Parts

Install the circuit board inside the VFO enclosure. Secure the circuit board to the bottom of the enclosure with M2-3 Phillips flat head screws. Solder the RF ground wire and the 0.1 uf coupling capacitor to the SMA jack.

Install the Si5351 VFO box on the top side of the Atlas VFO enclosure using the two screw holes that secured the VFO circuit board to the VFO Mount VFO box to top of VFO enclosure. Secure the VFO box to the top of the VFO enclosure with two 6-32 screws and lock washers. The screws inside the VFO enclosure should not protrude more than 2 mm from the bottom of the enclosure.



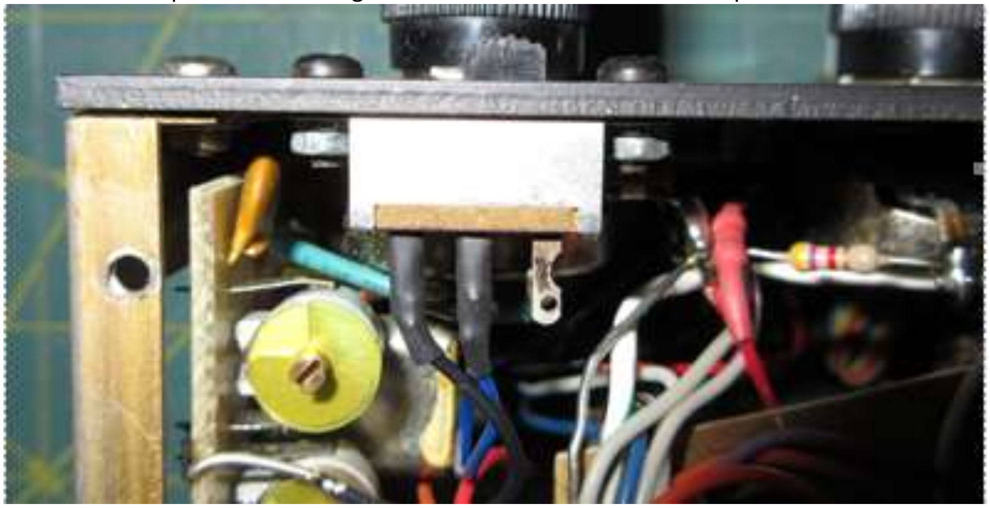
Install the rotary encoder in the front panel VFO tuning hole. Attach the VFO tuning knob to the shaft of the encoder. Use a spring loaded washer between the back side of the VFO knob and the front bushing shaft of the encoder. This will allow one to apply tension to keep the tuning know from free spinning. Attach the four control wires to a female pin header. Plug the header onto the four pins of the encoder.

Mount the front panel Scan/Mem label and the ON-OFF-ON momentary Scan/Mem toggle switch.
Mount the front panel Step label and the ON-OFF-ON momentary Step toggle switch.

Remove the PC-200 board from the radio. This will allow easy access to the voltage regulator terminal strips located on the top side of the chassis. Install a connectorized power cable between the 13V point downstream of R9 (10 ohm resistor that provided power to the original dial lamps) and the Si5351 DC power cable and the ground pin on the terminal strip. Re-install the PC-200 board.

Install a ground bus wire between the Frequency Lock slide switch, the Mem/Scan toggle switch, the LCD display, and the Step toggle switch.

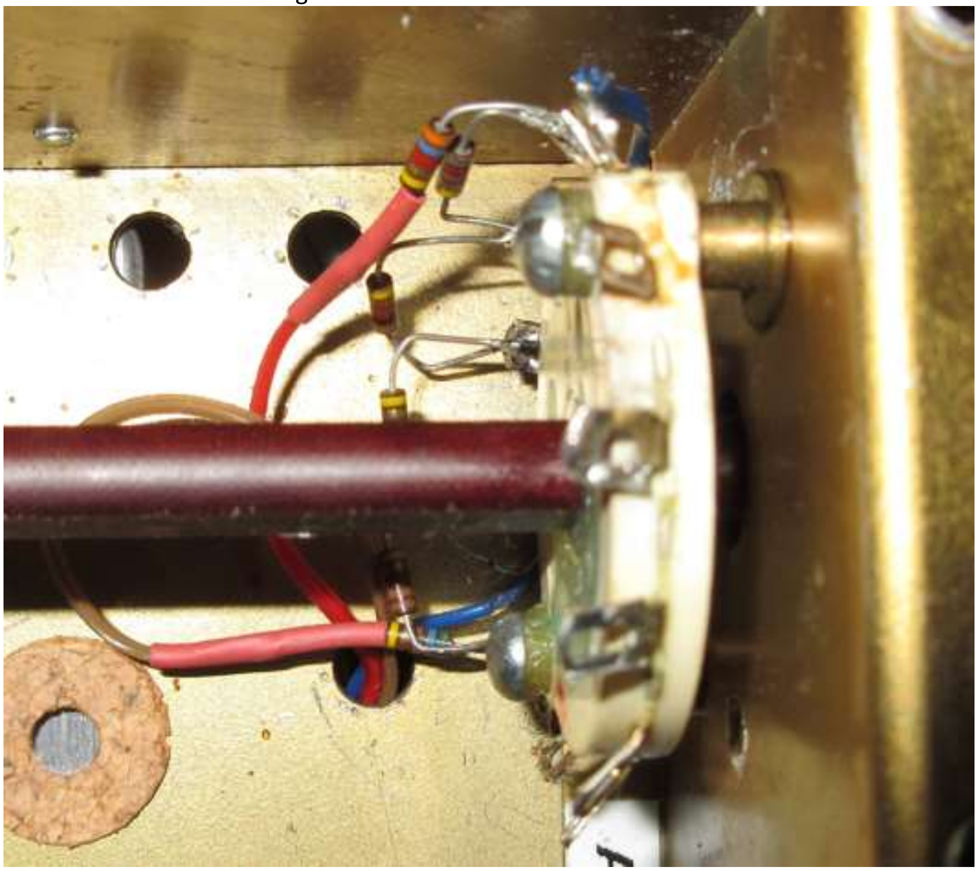
Swap positions of the original RIT slide switch and the NOR/OPP slide switch. A DPDT switch is needed at the NOR/OPP position. Reconnect the carrier oscillator switching wires on one pole. Wire in the NOR/OPP wire on the 2nd pole. Connect a ground wire to the tab on the NOR position.



Connect the appropriate ribbon cable interface wires to the Frequency Lock switch, the NOR/OPP switch, the Scan/Mem toggle switch, and the Step toggle switch.

Attach a 4.7K ohm resistor to the end of the Ext VFO lead. Attach a 2.2K ohm resistor from pin 6 on the Accessory jack to ground. Install a jumper between pins 5 and 6 on the Accessory jack.

Install the band switching resistors on the rear section 2b of the band switch wafer. Insure that the switch solder tabs are not touching the chassis.



XI. Install VFO Low Pass Filters

Three Low pass filters are needed in the output of the Si5351 in order to reduce the signal amplitude of even and odd harmonics. The filters turn the square wave signal into a nice looking sine wave. Filters are needed for the 80M/20M bands, the 40M/15M bands and the 10M band.

Install a RG316 coax cable, with a male right angle SMA connector, between the output of the Si5351 box and the RF input contact on switch 2a. Be sure to ground the shield on the end of the cable attached to the RF input contact.

Remove the factory RG174 coax cable that ran between the output of the factory VFO circuit board and Pin 3 of the Accessory jack J4 on the rear panel of the radio.

Install a RG316 coax cable between the RF output contact switch 1a and Pin 3 of the Accessory Jack J4 on the rear panel of the radio. Be sure to ground both ends of the coax cable.

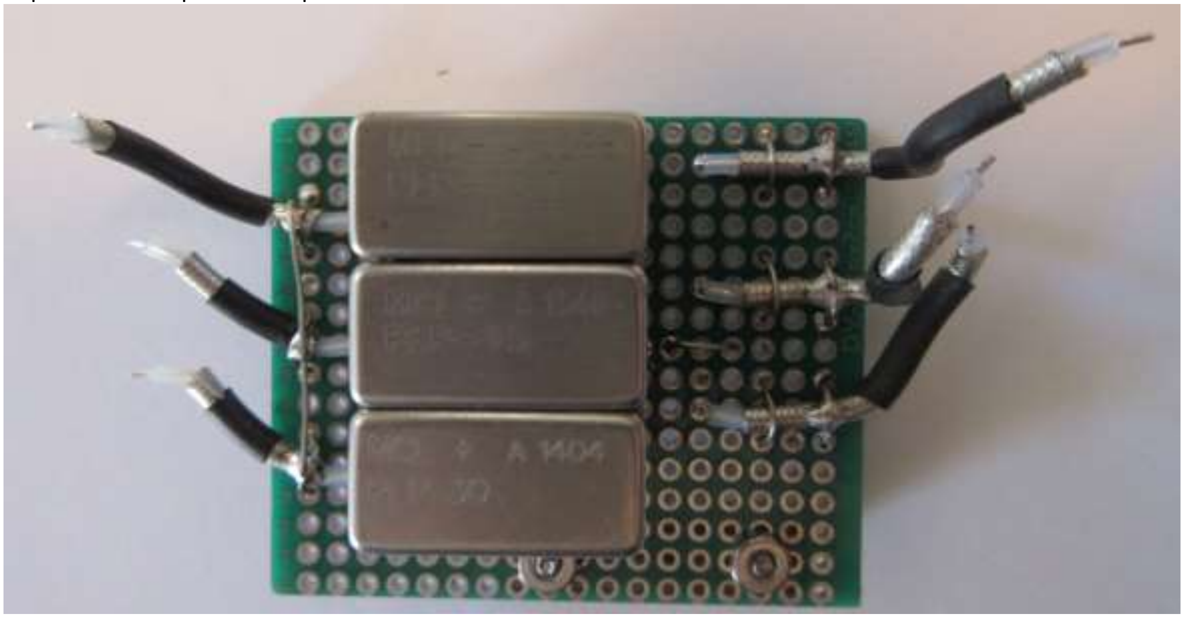
On switch 1a contacts, install insulated jumper between the 80 and 20 meter contacts.
On switch 1a contacts, install insulated jumper between the 40 and 15 meter contacts.
On switch 2a contacts, install insulated jumper between the 80 and 20 meter contacts.
On switch 2a contacts, install insulated jumper between the 40 and 15 meter contacts.

Fabricate a low pass filter board using Perfboard (50 mm long and 40 mm high). Trim the height of female pin headers to be used as sockets for the Mini Circuits PLP low pass filters. Solder the pin headers to the filter board. Solder a ground buss wire to each of the ground pins on each filter (6 pins per filter).

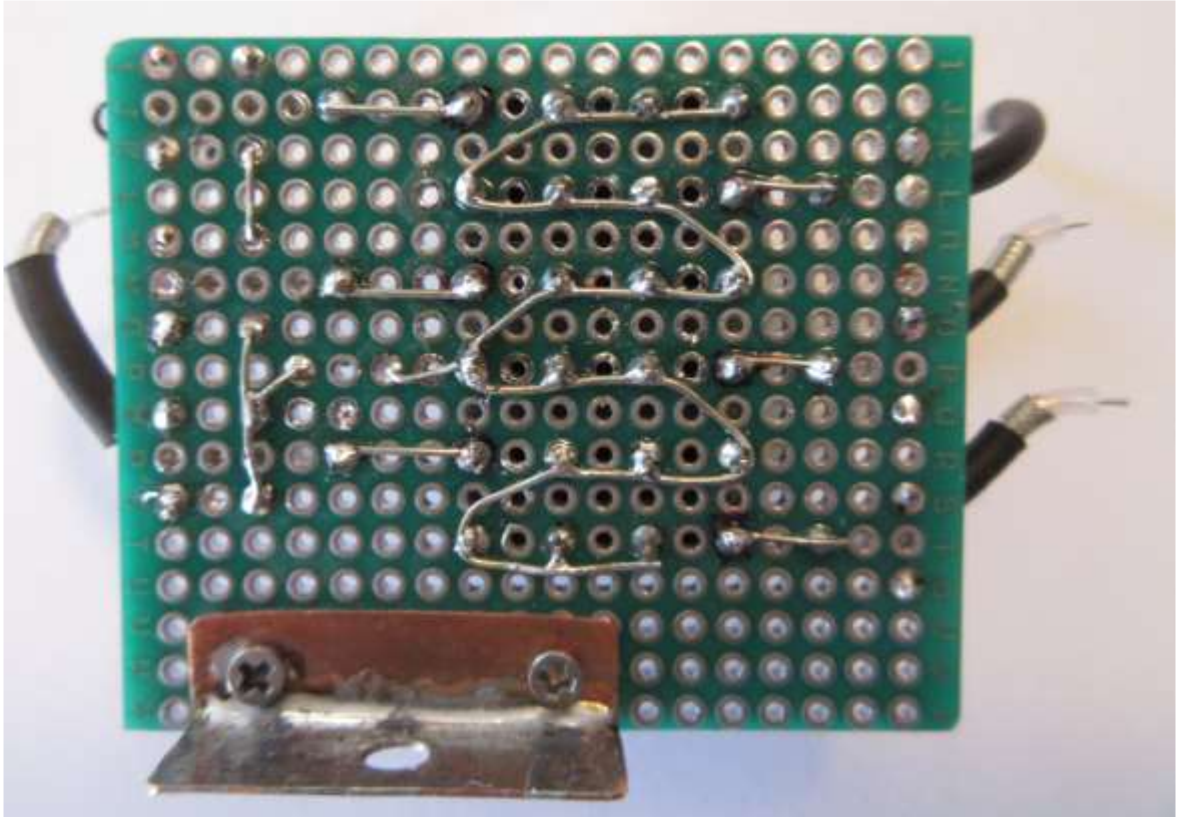
Install coax jumpers from the Band-switch contacts 2a and the inputs to the low pass filter board. There will be a jumper for 80/20M, 40/15M and 10M.

Install coax jumpers from the band-switch contacts 1a and the outputs of the low pass filter board. There will be a jumper for 80/20M, 40/15M, and 10M.

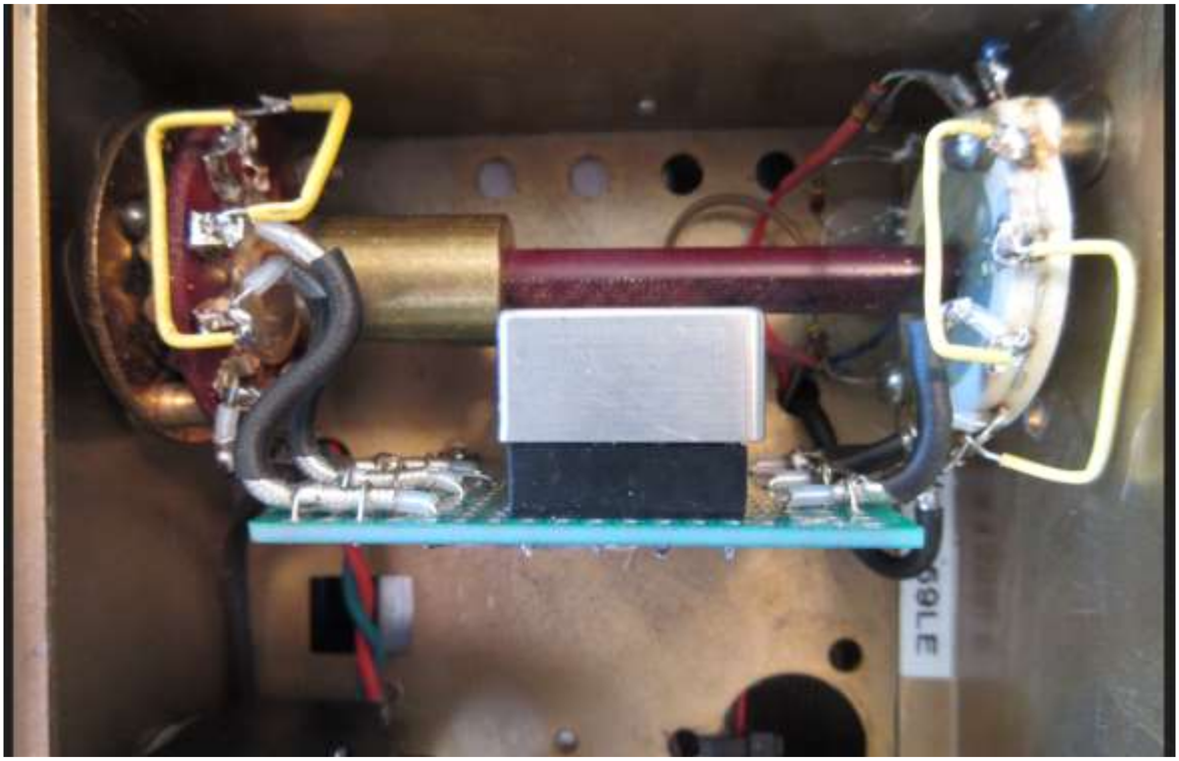
Top view of completed low pass filter board.



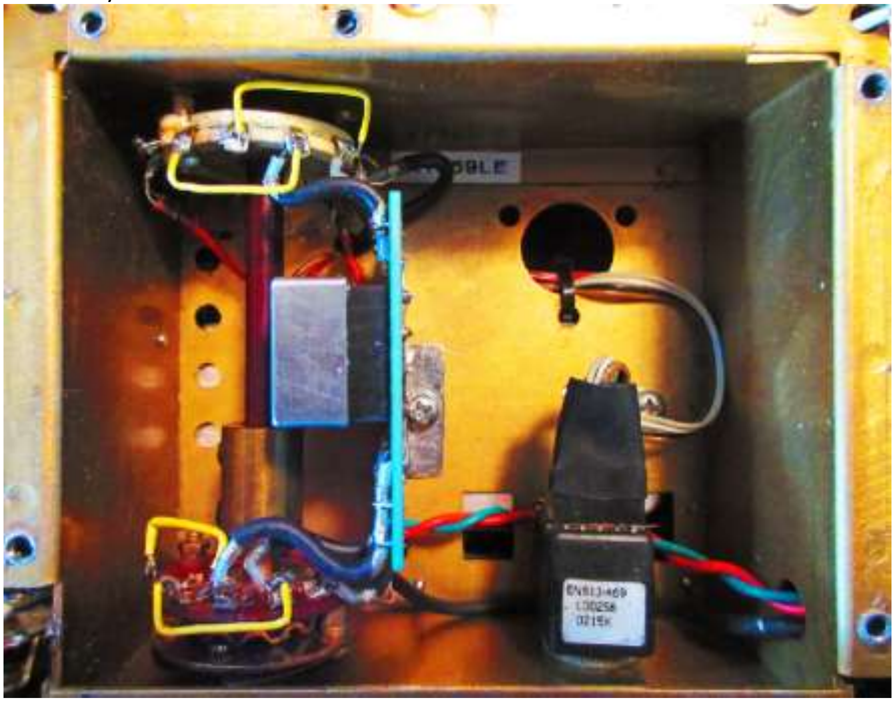
Bottom view of completed low pass filter board.



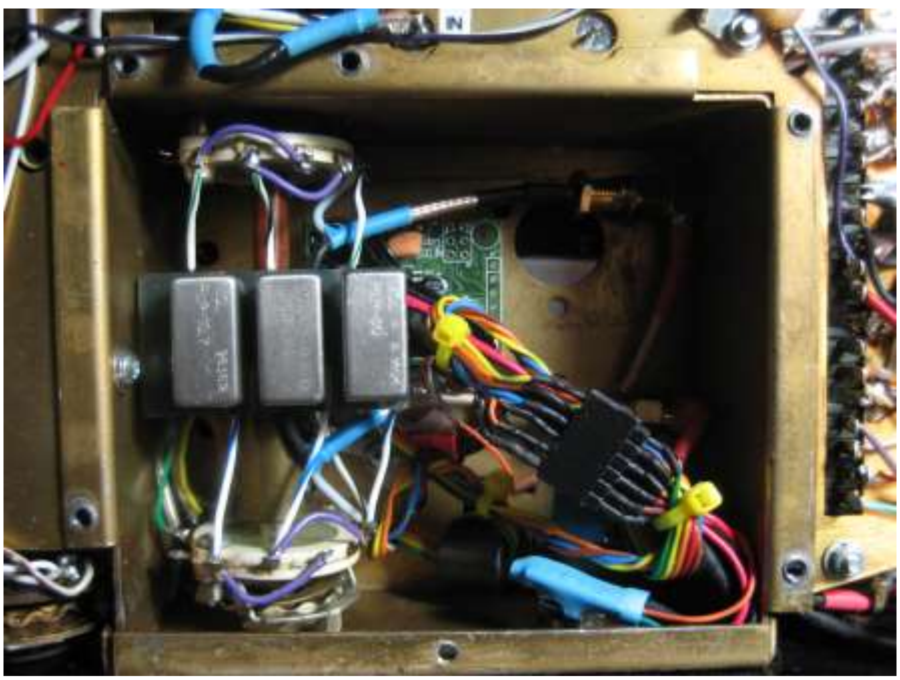
Attach the board to the bottom of the VFO enclosure with a right angle bracket. Secure the bracket underneath the screw that holds the VFO enclosure.



Here is a bottom view of the VFO compartment, showing band-switch resistor matrix, low pass filter board, and rotary encoder:

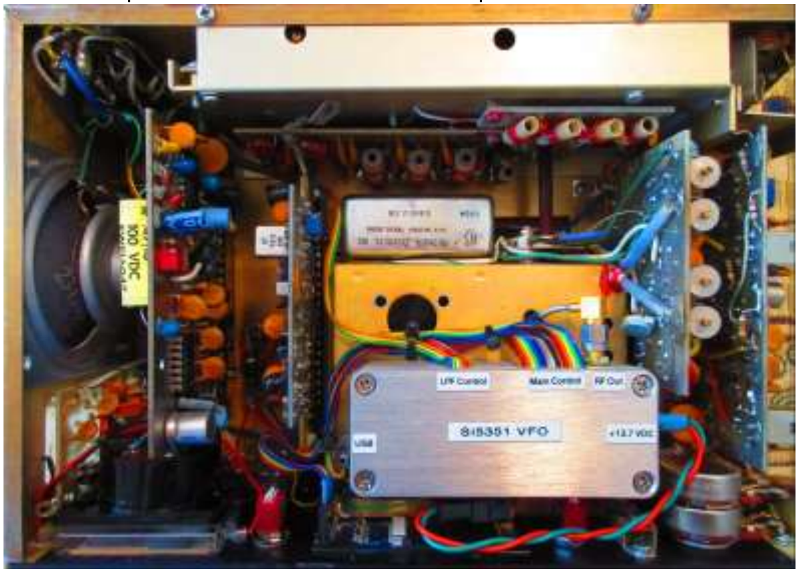


Here is alternative method for a MCL low pass filter board. This board is easier to implement.

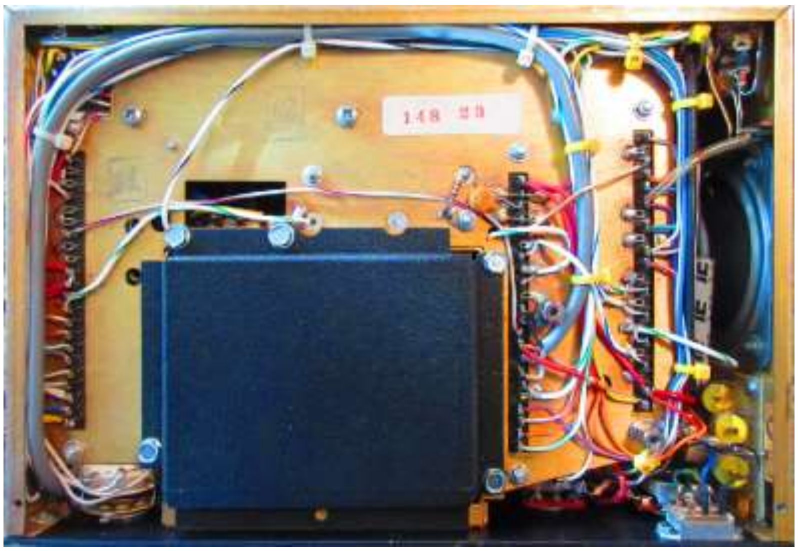


Power up the radio
Verify proper display reading on the LCD display
Allow 4 hour warmup of the VFO. Calibrate the VFO
Confirm a ~ +10 dbm VFO output for each band
Confirm proper operation of the following controls:
Lock (slide switch on LE model)
Mem (3 memories per band)
Scan – two modes

Here is a top view of the radio with the completed VFO:



Here is a bottom view of the radio:



Here is the VFO box connected to a USB cable.

XII. Si5351 VFO Front Panel Control Descriptions

There are three controls on the front panel of the 210X/215X LE radio that are needed for the operation of the Si5351 VFO.

Memory Mode

An up momentary push of the Mem/Scan switch cycles to the next memory position. A 2nd push cycles to the next memory position. Subsequent switch pushes cycles through all five memories and returns to the Memory A.

Scan Mode

A down momentary push of the Mem/Scan switch turns the Scan Mode 1 function on. In this mode, the frequency scans between the three memory frequencies. A second momentary push of the switch goes to Scan Mode 2. In this mode, the frequency scans in 1 KHz increments. Another momentary push turns the scan function off.

Lock Mode

Sliding the switch to the up position will lock the current frequency that is being displayed.

Step Mode

The toggle switch on the left side of the frequency display window controls the Frequency Step function. Each up momentary push of the switch selects the next frequency step. On power up, the step is 1 KHz. Subsequent pushes select 10 KHz, 10 Hz, 100 Hz, 500 Hz, and 1 KHz.

Option Mode

No function has been implemented for a momentary down push of the switch. There are available I/O pins on the ESP-32 that could be programmed to support a new function that requires a momentary push switch. This spare function could also be used to enable a non-VFO function such as cycling through the noise reduction levels on a BHI DSP NEDSP1901 module.

XIII. Si5351 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 is supposed to have 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 IFT 2025 signal generator as an external VFO. There were 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.

XIV. Trouble-shooting

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

Power down the VFO, including the Atlas radio.
Remove the top cover from the radio.
Remove the top cover to the VFO box.
Remove the ESP-32 module from its socket
Select the 40 meter band

The three GND pins on the ESP-32 socket should show 0 ohms to ground.
Pin 19 should show 0 ohms to ground. Move the Nor/Opp switch to Opp. Pin 19 should not show open.
Move the slide switch to Lock. Pin 32 should show 0 ohms to ground.
Pin 26 should show 2200 ohms to ground.
Pin 2 should show 2200 ohms to ground.
All other pins should show infinite resistance

Power up the radio from a regulated 13.7 voltage source.

You should be able to measure the following voltages:

Power Supplies

13.7	Atlas Red bus (supply to R9)
11.7	input to VFO board (downstream of R9)
9.0	input pin of the 3.3 volt regulator
3.3	output pin of the 3.3 volt regulator
9.0	input pin of the 5.0 volt regulator
5.0	output pin of the 5.0 volt regulator
9.6	Pin 5 of Atlas accessory socket
9.6	Pin 6 of Atlas accessory socket

Si5351 Oscillator Board

5.0	pin 8
5.0	pin 9
5.0	pin 10
3.3	pin 13
3.3	pin 14
3.3	pin 18

ESP-32 Socket

3.1	RST	
3.1	26	
3.3	35	
3.3	34	
3.3	3.3V	
3.3	22	
3.3	25	
3.3	21	
1.0	27	band switch in 40 meter
0.35	27	band switch in 80 meter
1.65	27	band switch in 20 meter
2.23	27	band switch in 15 meter
2.74	27	band switch in 10 meter

Return band switch to 40 meter position
Power down radio
Install ESP-32 module
Remove 16 pin ribbon cable connector
Remove 6 pin ribbon cable connector
Insure Nor/Opp switch is in Nor position

Power up radio
You should see red LEDs on the 3.3 volt regulator, 5 volt regulator, and the ESP-32 module
You should a green LED on the ESP-32 module.

Measure the voltages on the 16 pin ribbon cable connector on the VFO board

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

Measure the voltages on the 6 pin ribbon cable connector on the VFO board

0	1
5.0	2
3.3	3
0.3	4
0.3	5
0.3	6
NA	7

Measure the voltages on the pins of the ESP-32 chip

These pins are on the same side of the board as the Reset switch

0	GND
0	RST
0	NC
0	VP
0.3	VN
0.5	26
3.2	35
3.2	18
3.2	33
2.2	19
3.3	34
0	23
3.3	TMS
3.3	5
0	NC
3.3	3V3
0	SD2
0	TCK
0	CMD

These pins are on the same side of the board as the 12C connector

0	SD3
3.3	TXD
0	GND
2.8	RXD
0.5	27
3.3	22
3.3	25
3.3	21
3.3	32
0.6	27
0	TDI
3.3	25
3.3	4
0	GND
3.3	0
3.3	5V
0.3	2
3.3	TDO
0	SD1
0	SDO
0	CLK

XV. Appendix

A. Diagrams

Figure 1 – Block Diagram

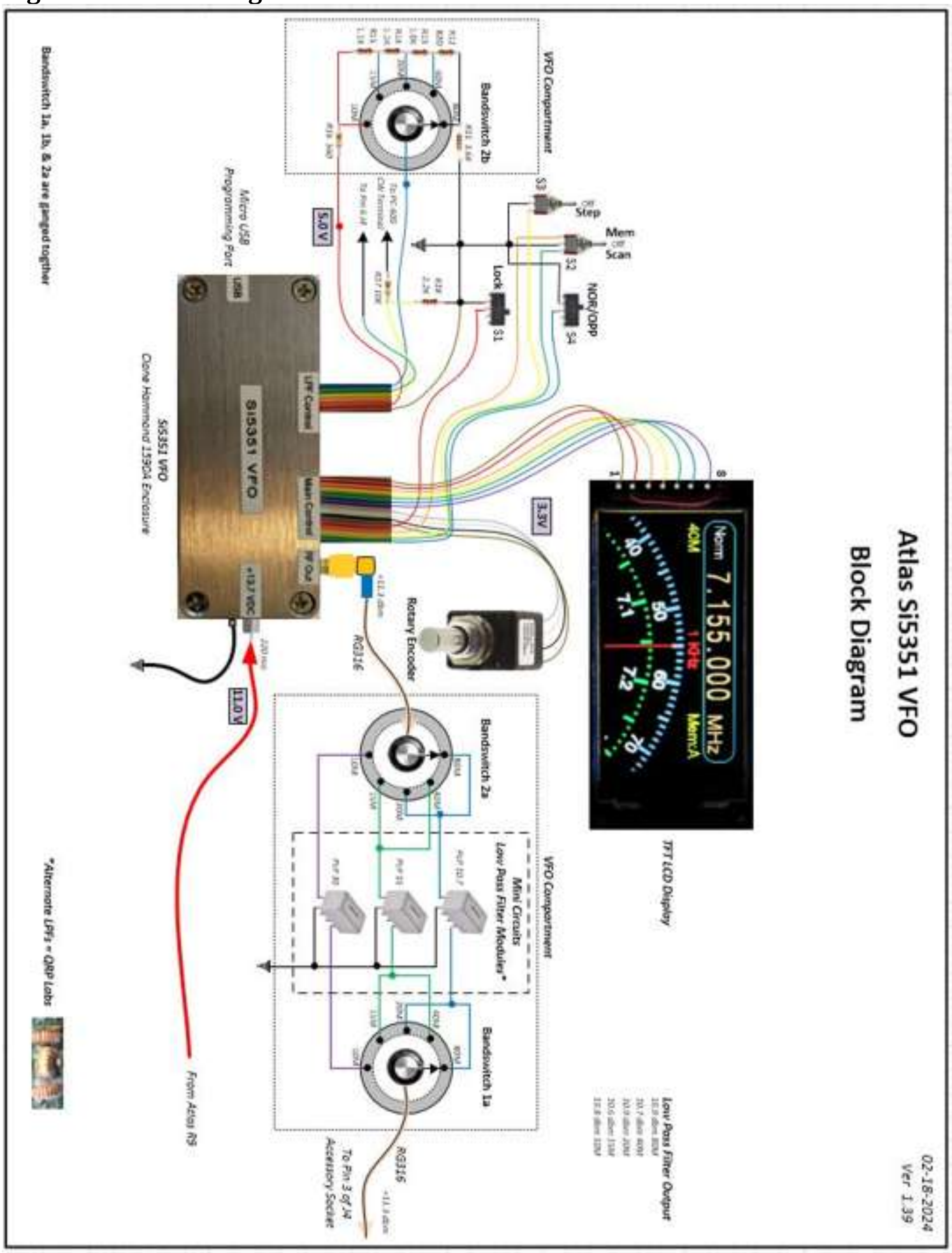


Figure 2 – Schematic

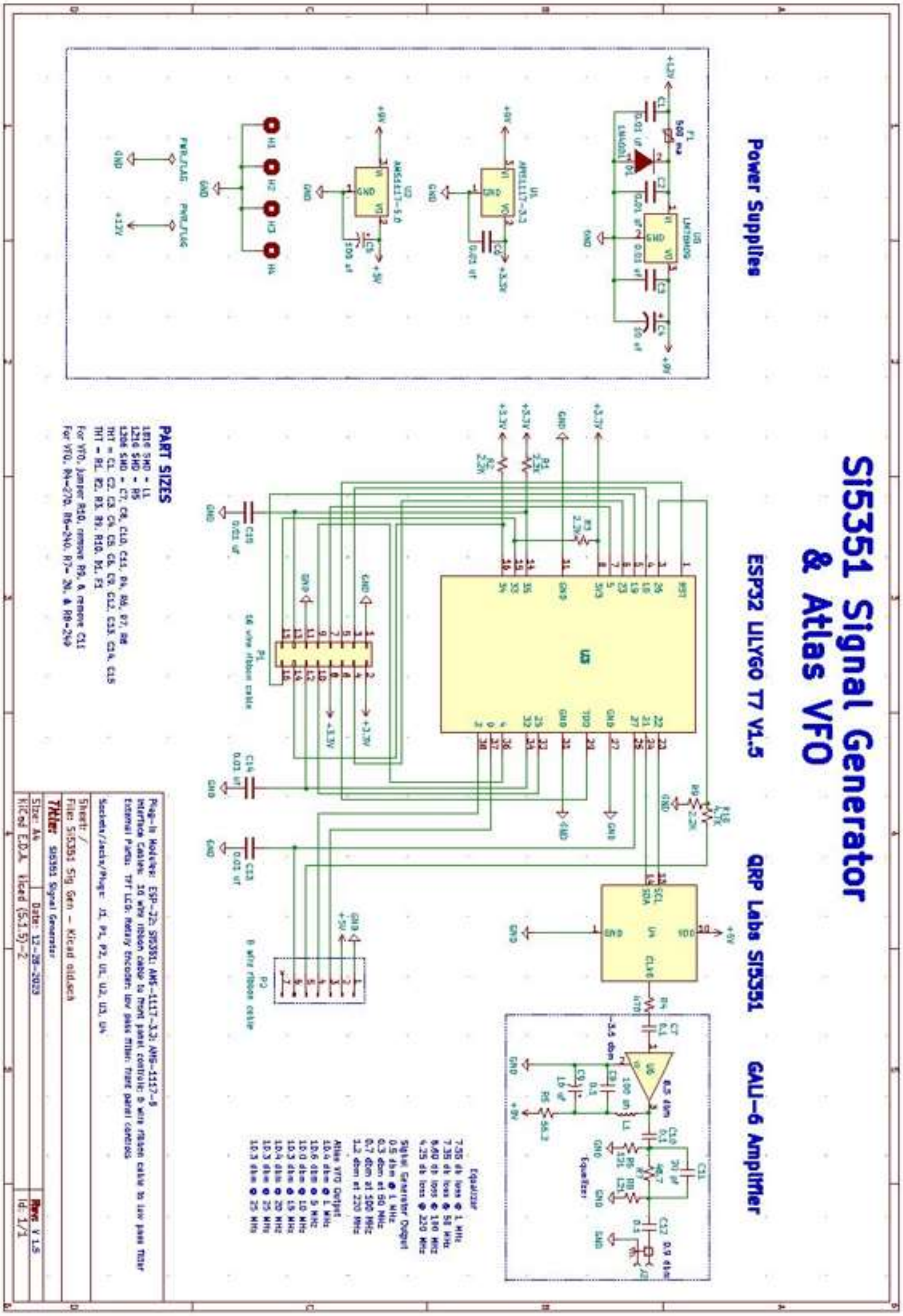
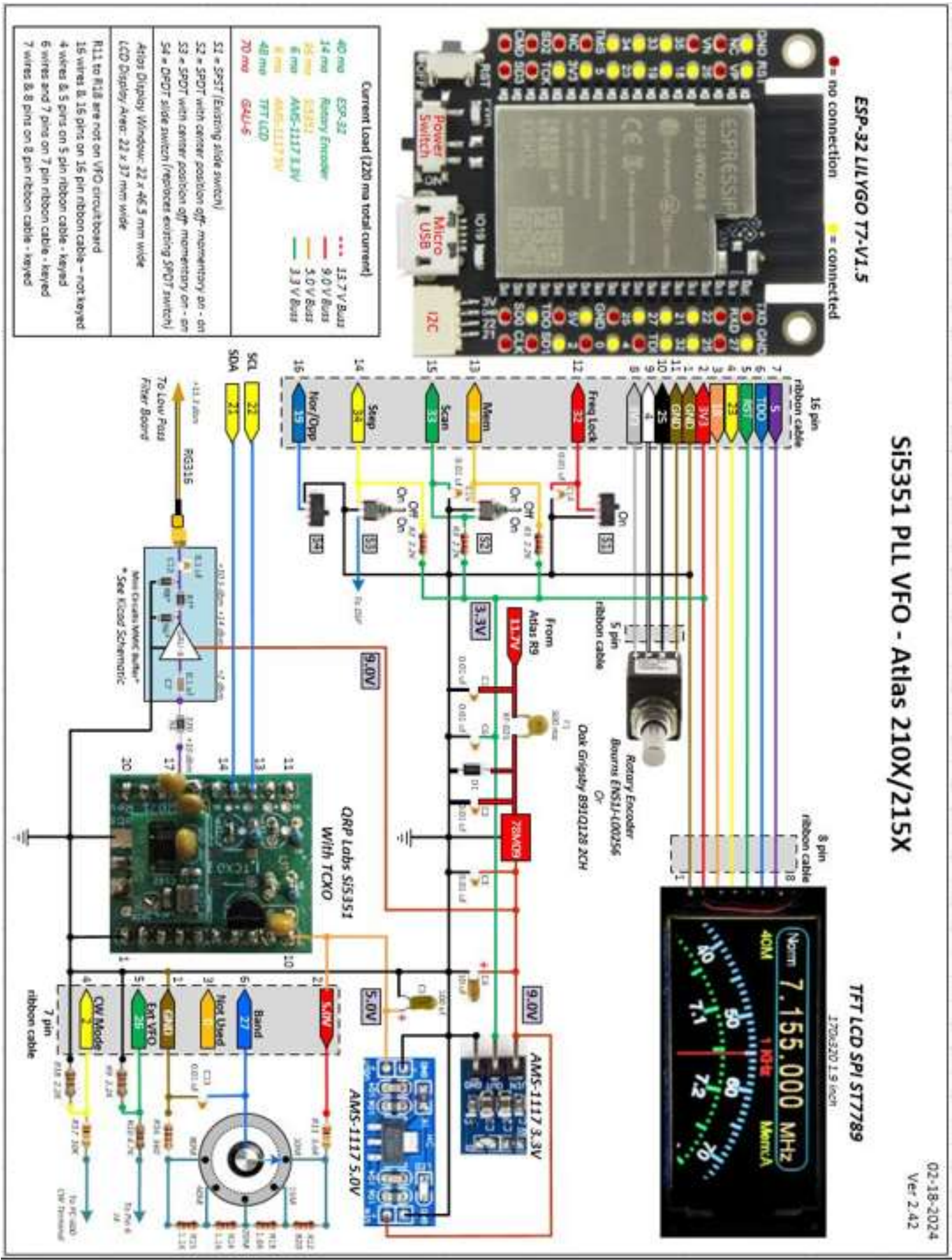


Figure 3 – Interconnection Diagram



B. Kicad Views

Figure 4 – 3D View of Circuit Board

C. VFO Harmonics

Figure 5 – Si5351 Atlas VFO with no Low Pass Filter – 80M (20 dB pad)

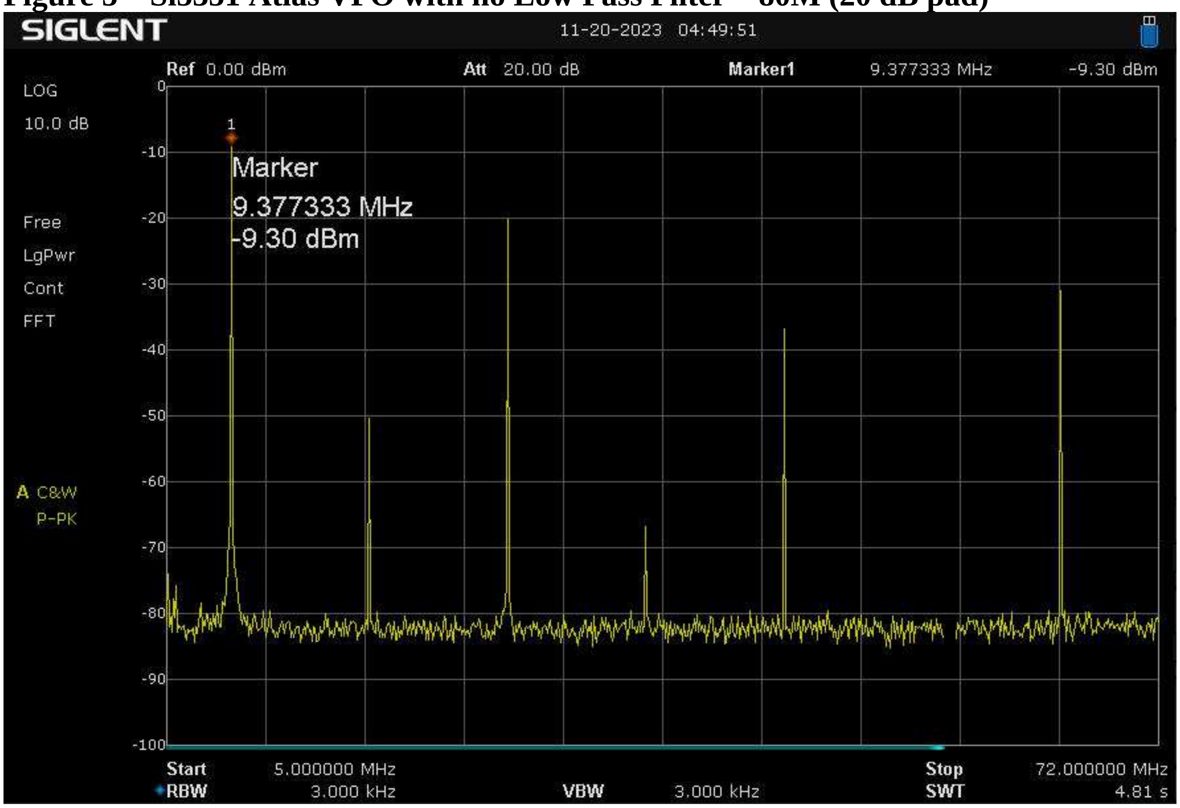


Figure 6 – Si5351 Atlas VFO with MCL PLP-10.7 Low Pass Filter – 80M (20 dB pad)

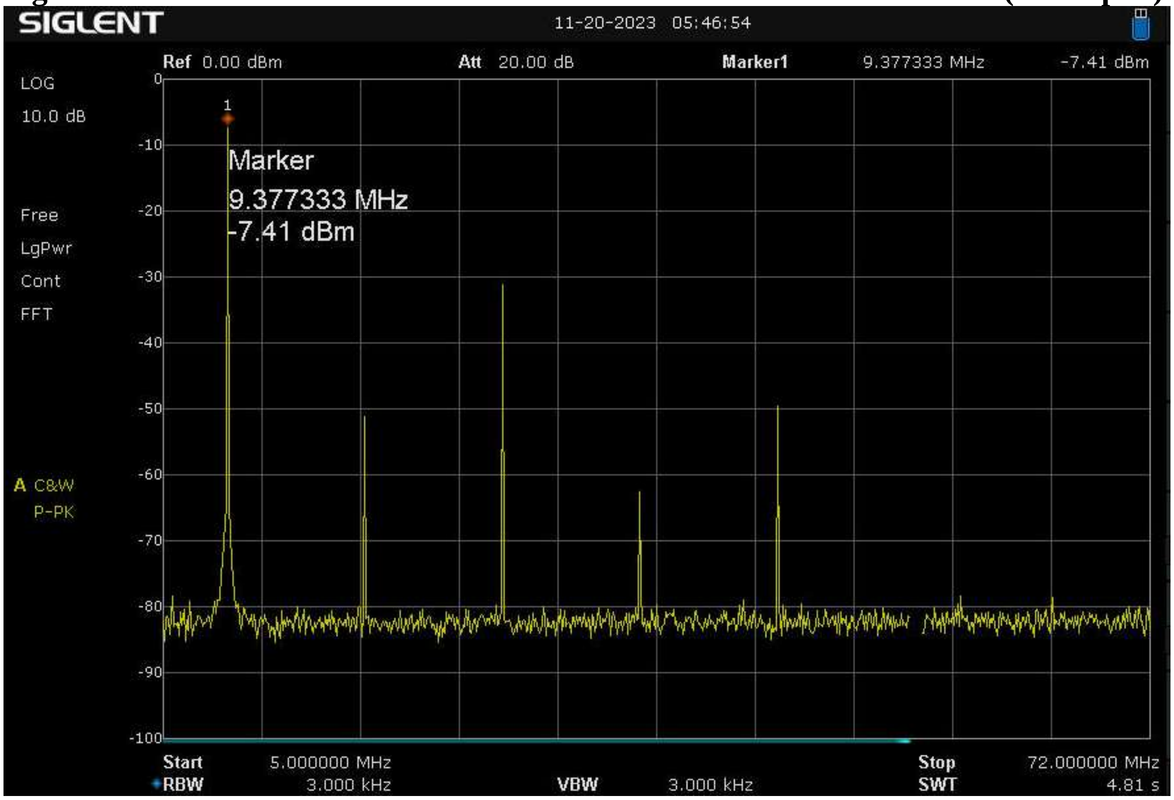


Figure 7 – Factory VFO – 80M (20 dB pad)

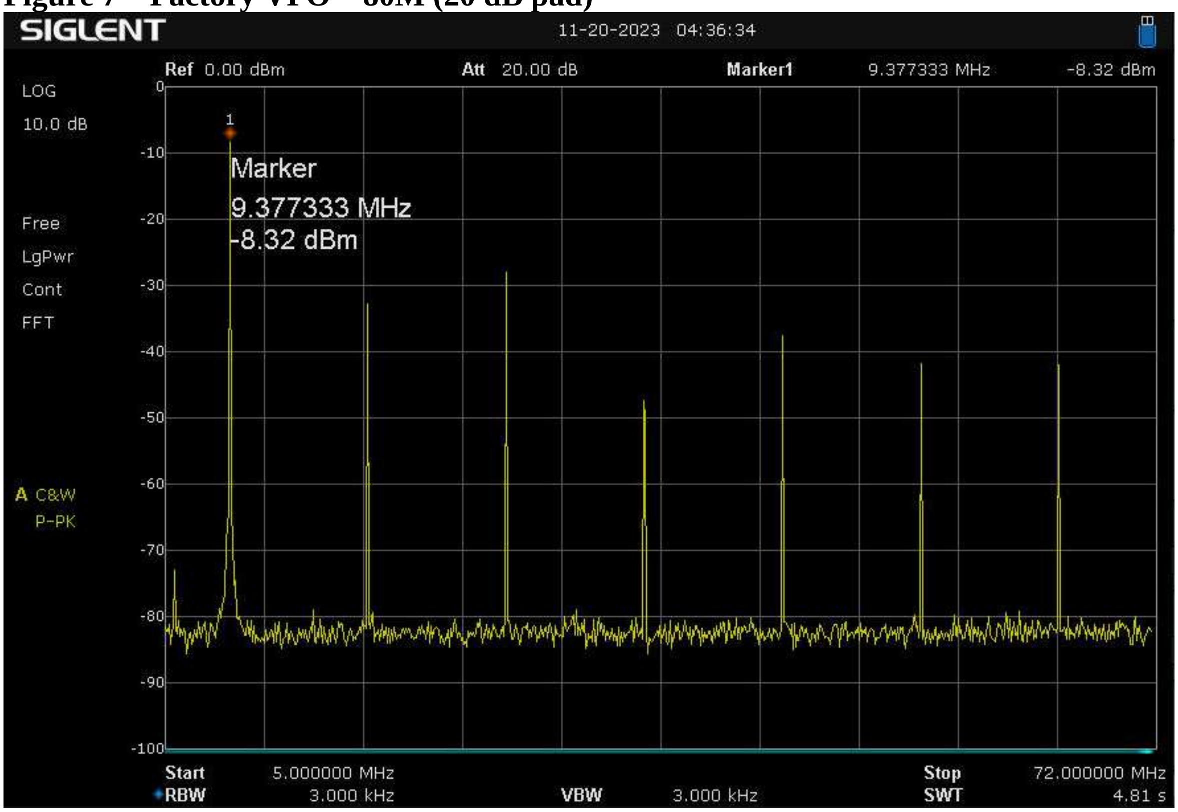


Figure 8 – Si5351 Atlas VFO with QRP Labs Low Pass Filter – 80M (20 dB pad)

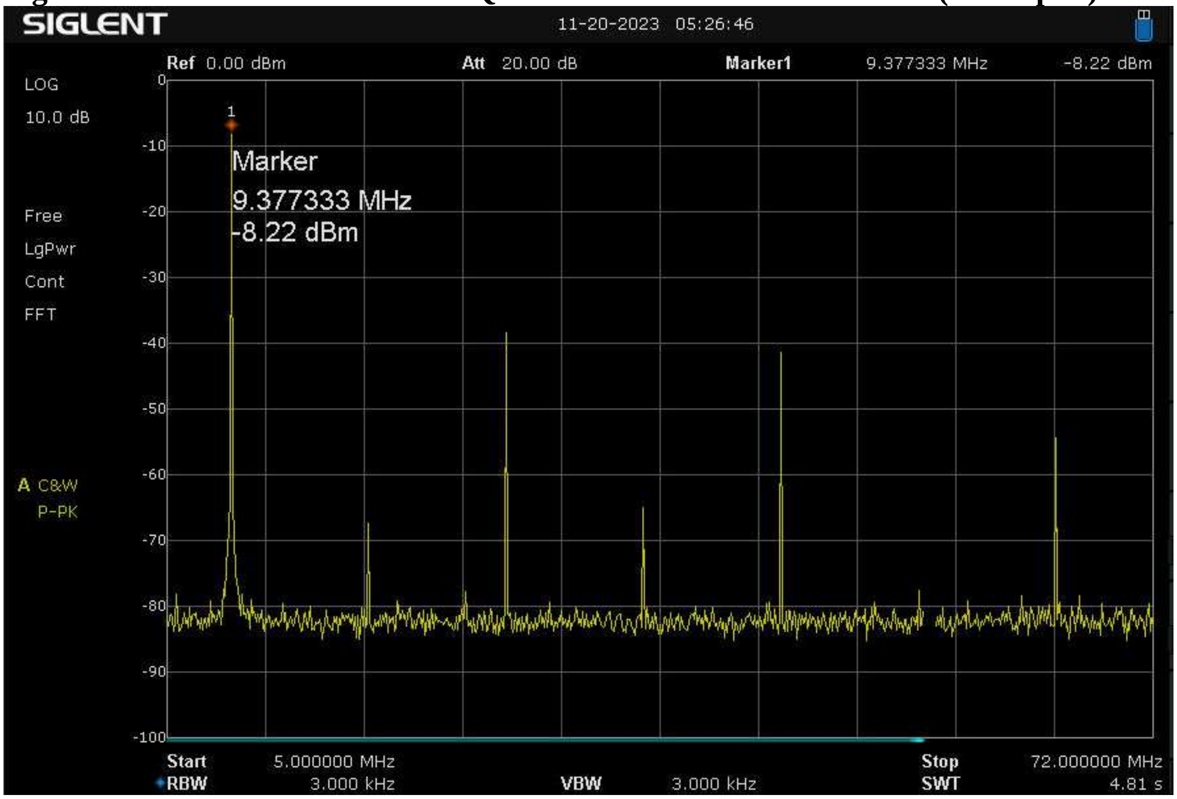


Figure 9 – Si5351 Atlas VFO with MCL Low Pass Filter – 80M (20 db pad)

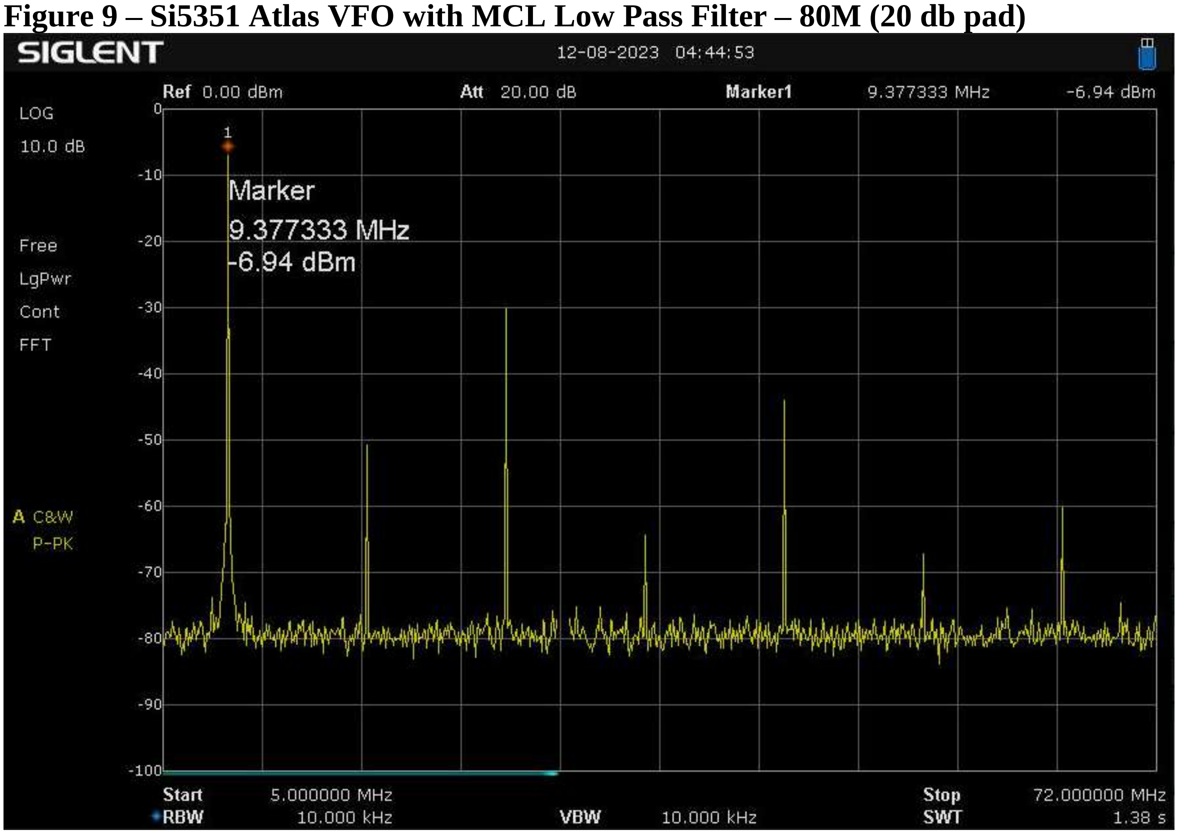


Figure 10 – Factory VFO – 40M (20 dB pad)

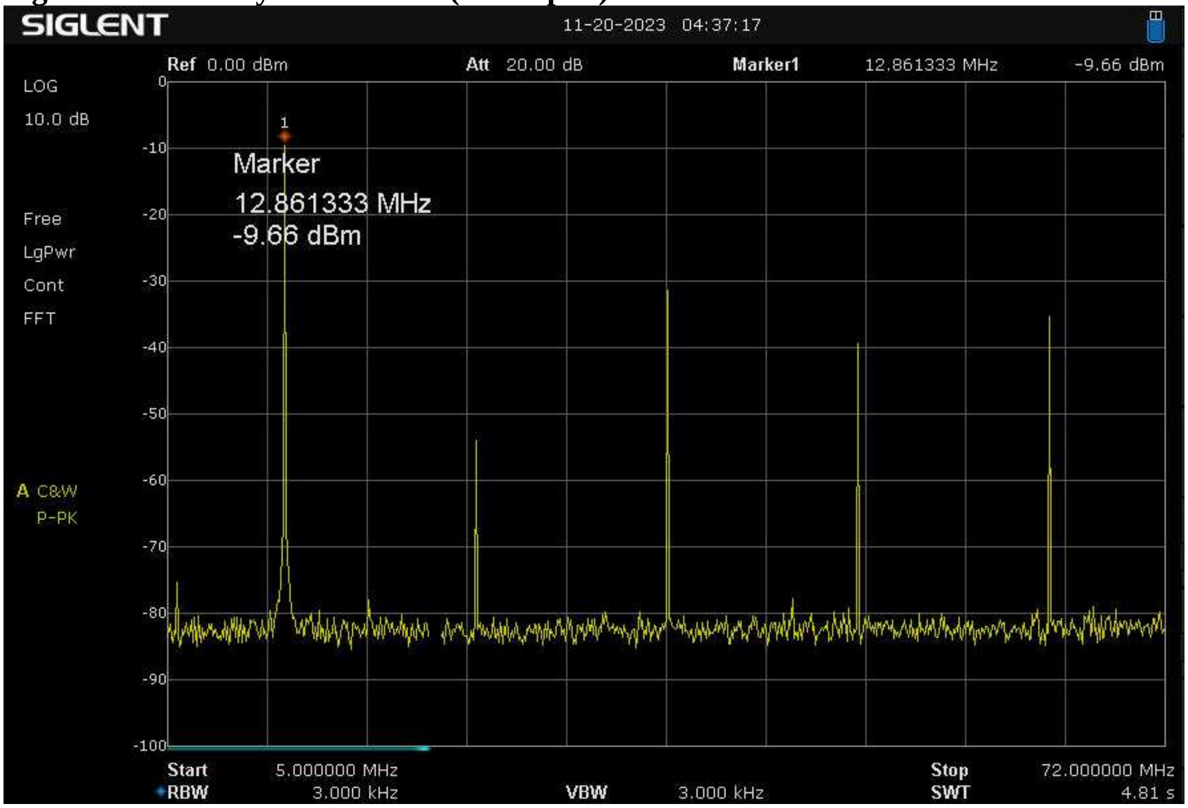


Figure 11 – Si5351 Atlas VFO with QRP Labs Low Pass Filter – 40M (20 dB pad)

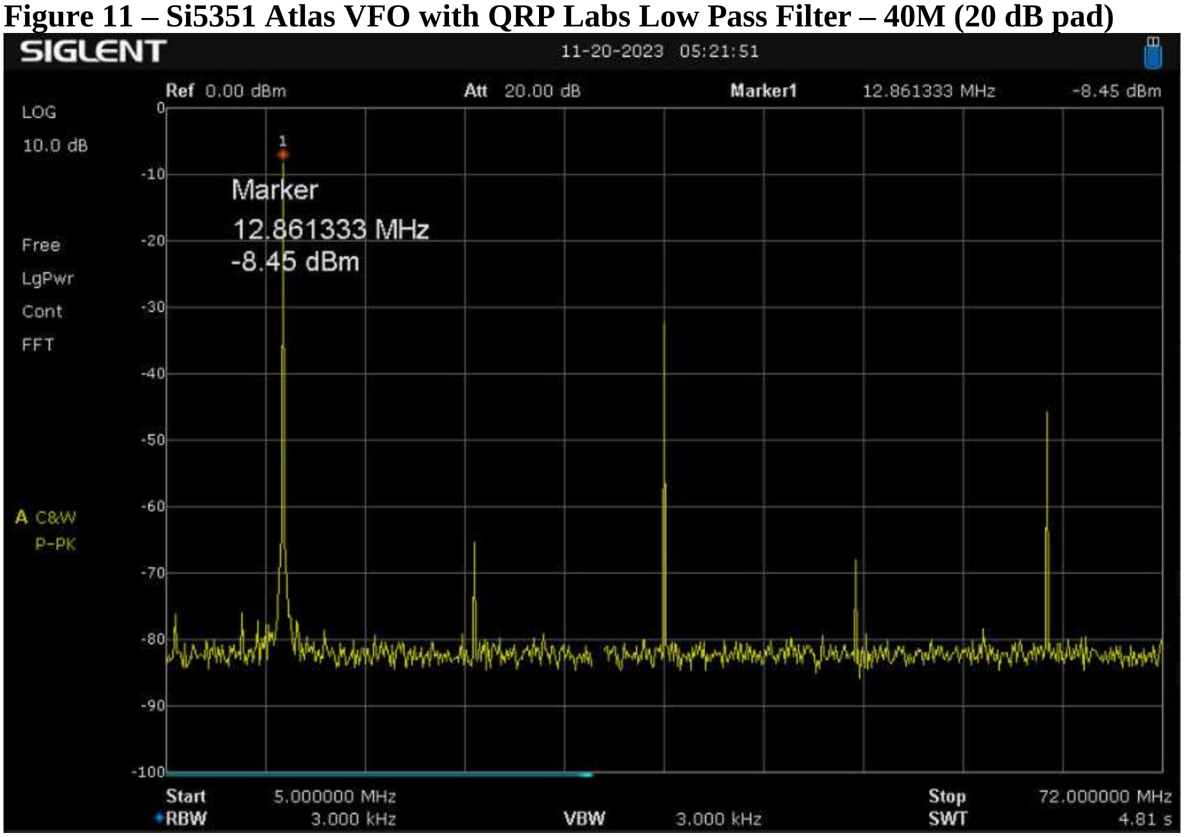


Figure 12– Si5351 Atlas VFO with MCL Low Pass Filter – 40M (20 db pad)

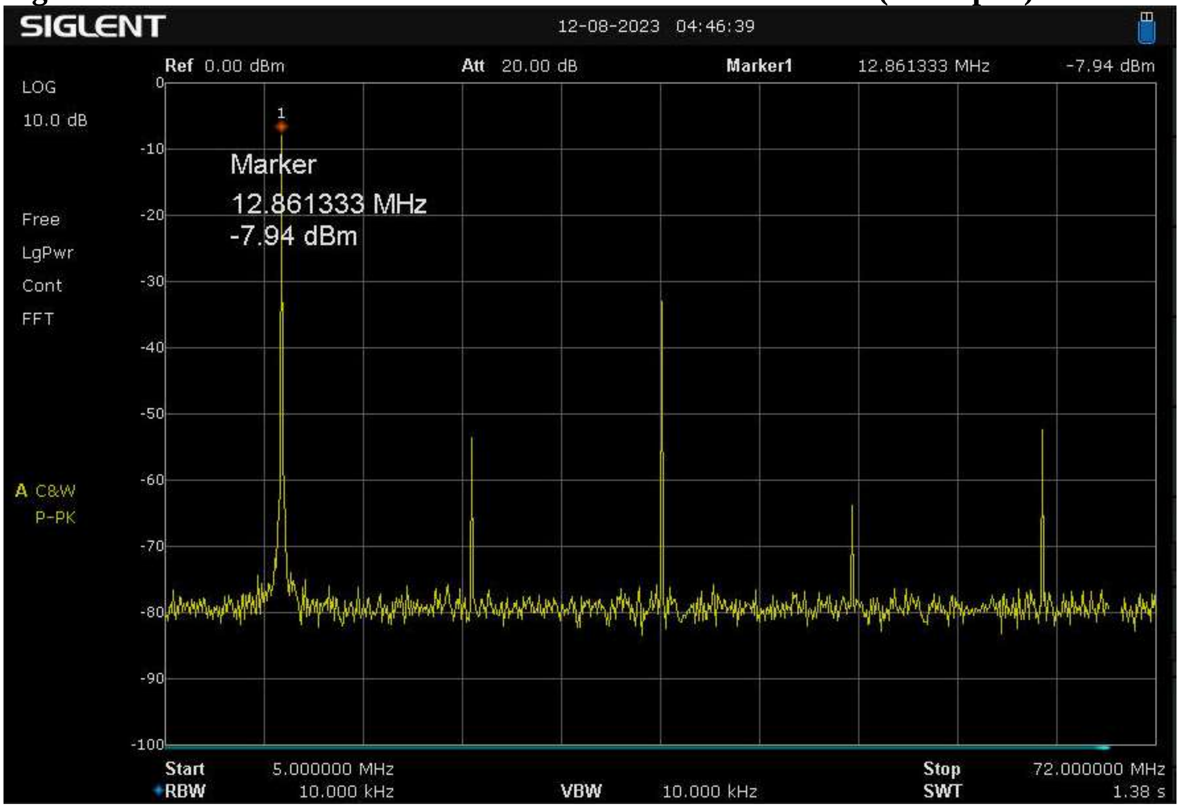


Figure 13 – Factory VFO – 20M (20 dB pad)

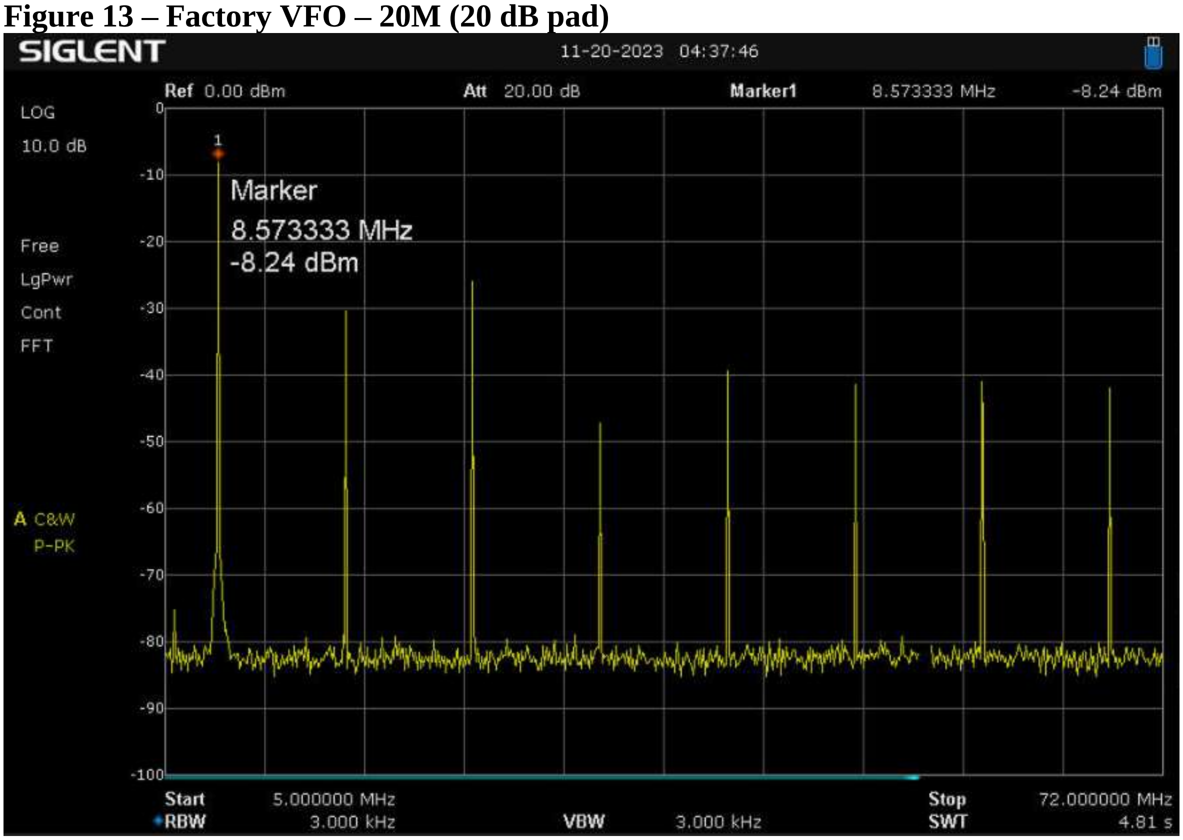


Figure 14 – Si5351 Atlas VFO with QRP Labs Low Pass Filter – 20M (20 dB pad)

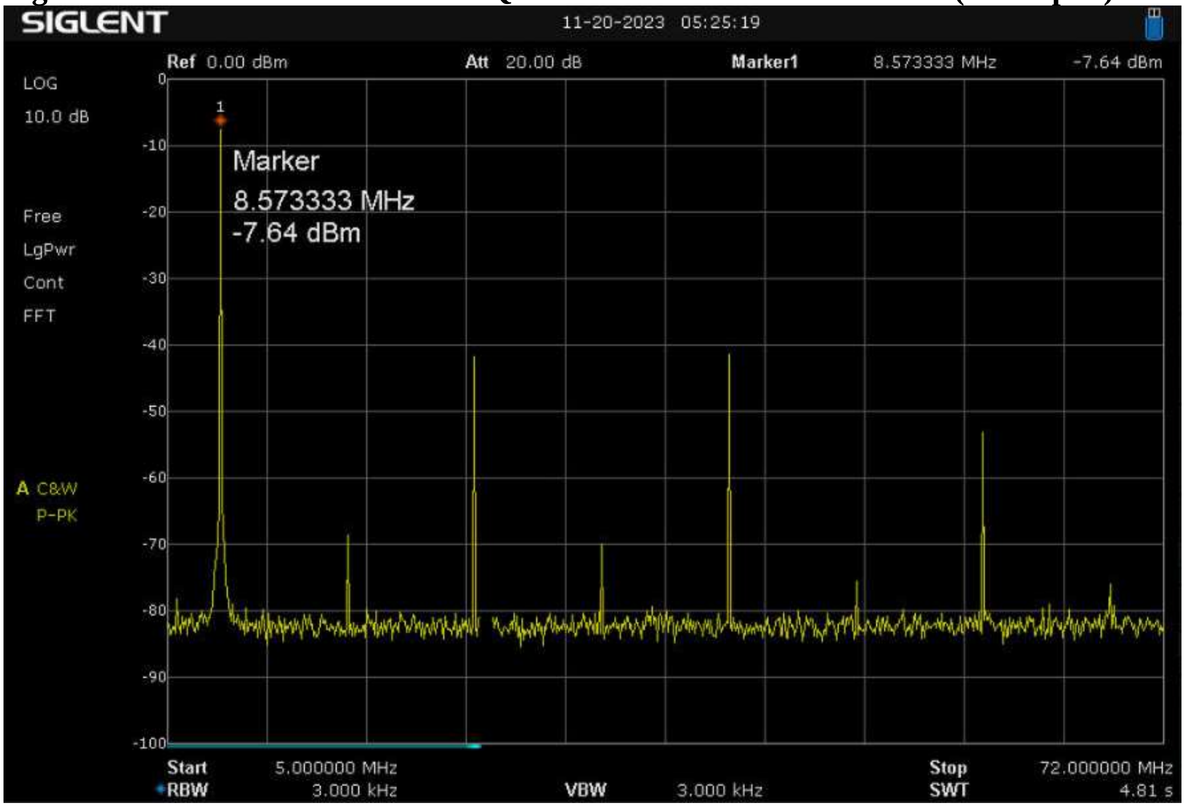


Figure 15– Si5351 Atlas VFO with MCL Low Pass Filter – 20M (20 db pad)

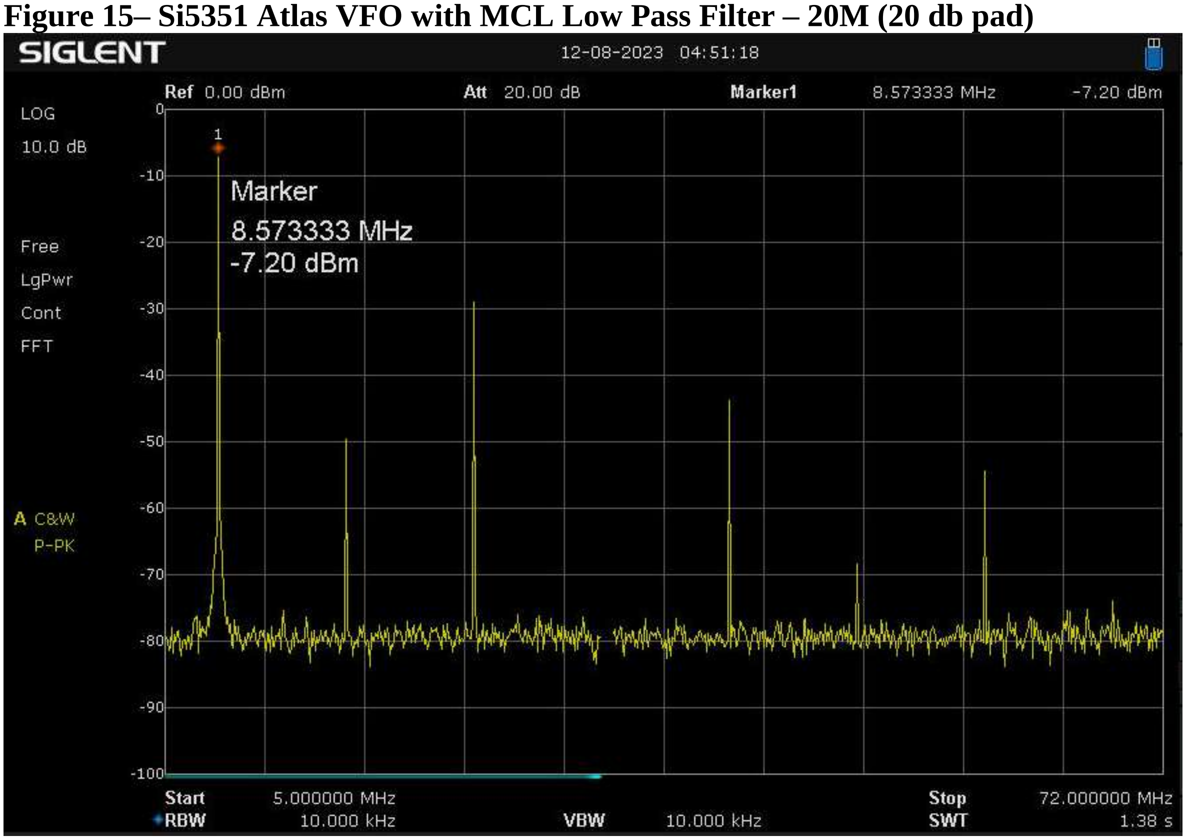


Figure 16 – Factory VFO – 15M (20 dB pad)

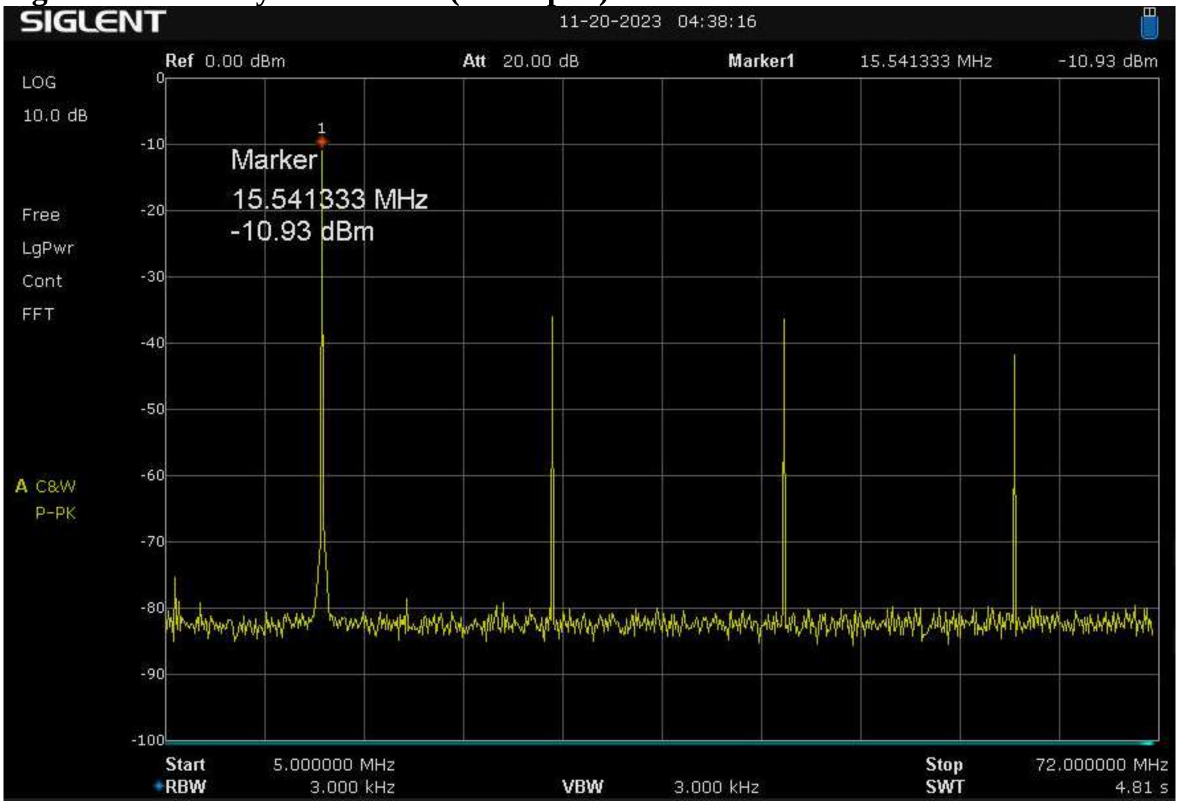


Figure 17 – Si5351 Atlas VFO with QRP Labs Low Pass Filter – 15M (20 dB pad)

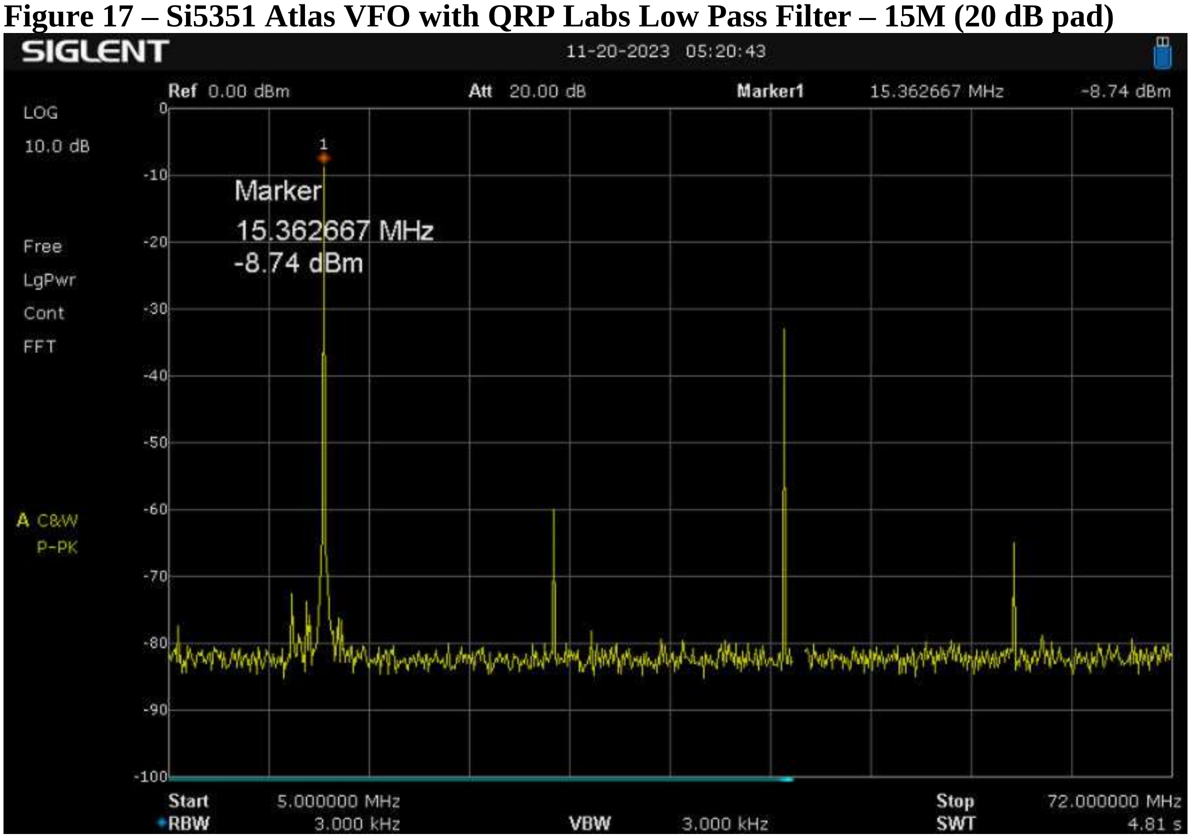


Figure 18– Si5351 Atlas VFO with MCL Low Pass Filter – 15M (20 db pad)

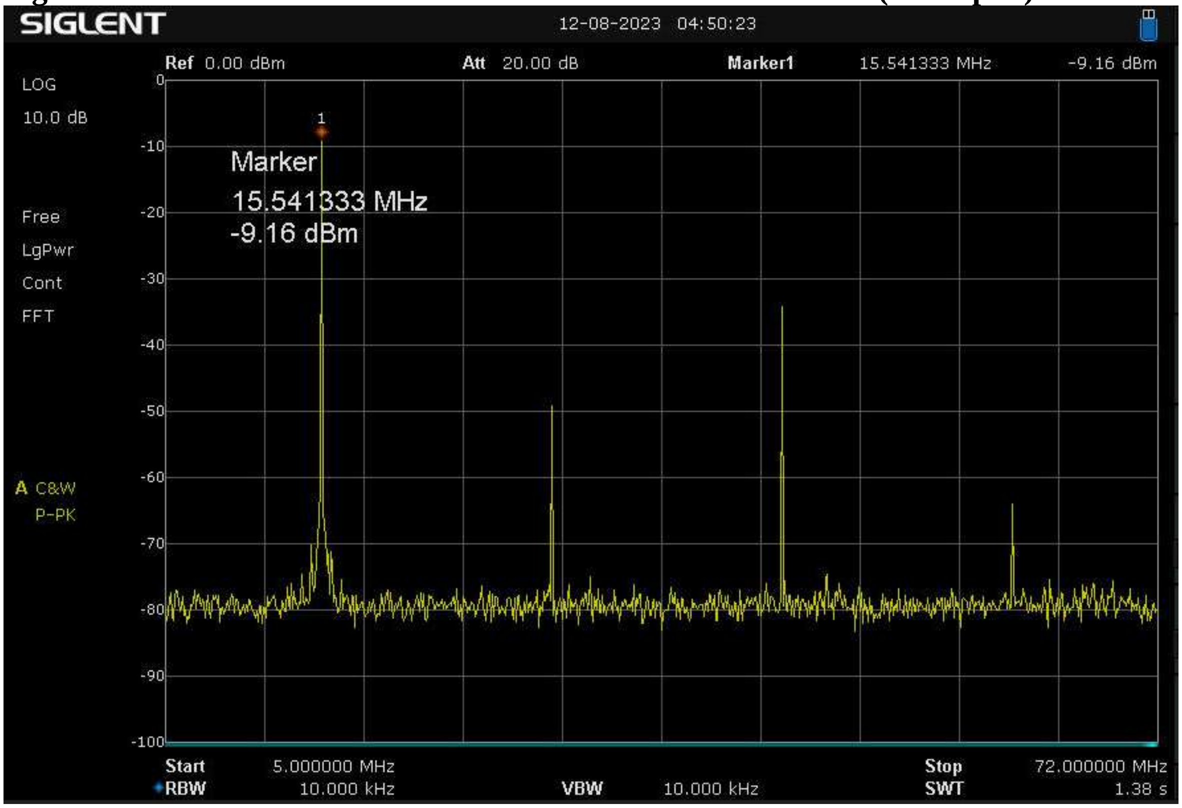


Figure 19 – Factory VFO – 10M (20 dB pad)

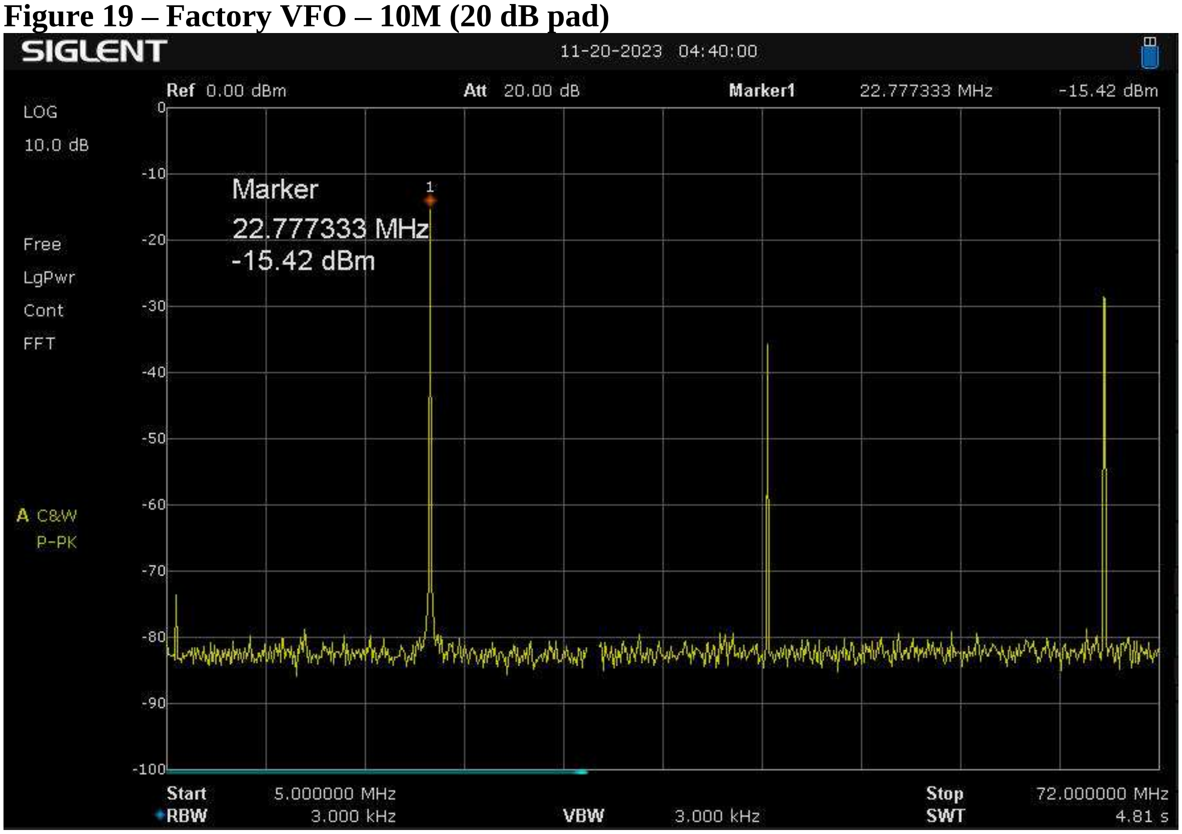


Figure 20 – Si5351 Atlas VFO with QRP Labs Low Pass Filter – 10M (20 dB pad)

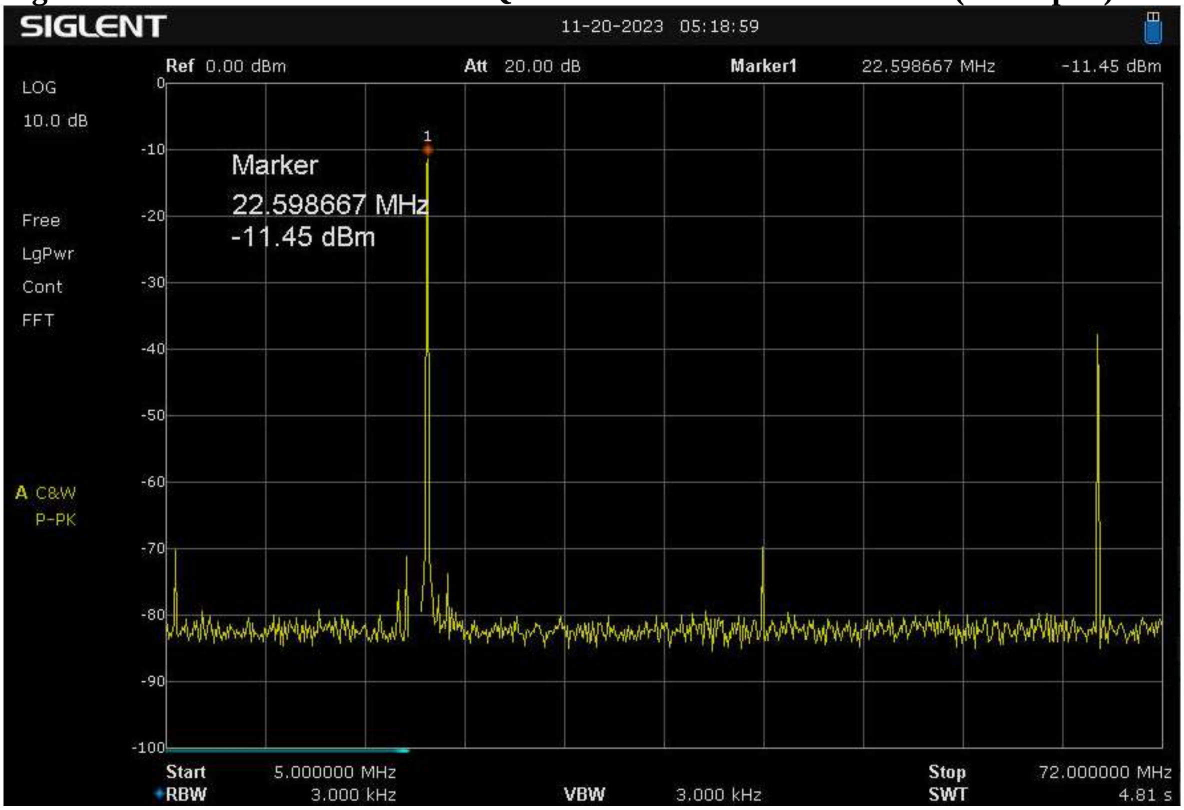
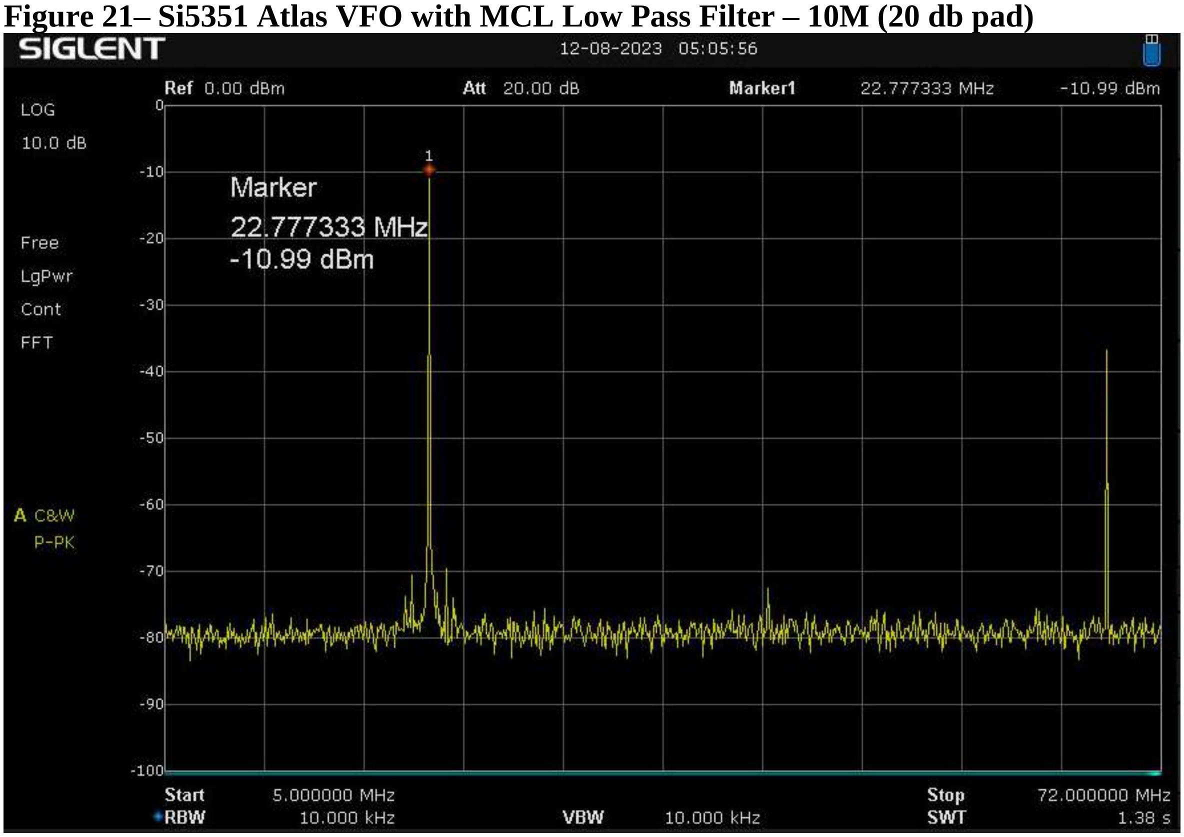


Figure 21– Si5351 Atlas VFO with MCL Low Pass Filter – 10M (20 db pad)



D. Signal Quality

Figure 22 – Si5351 Atlas VFO 80M Sine Wave with MCL Low Pass Filter (14.9 dbm)

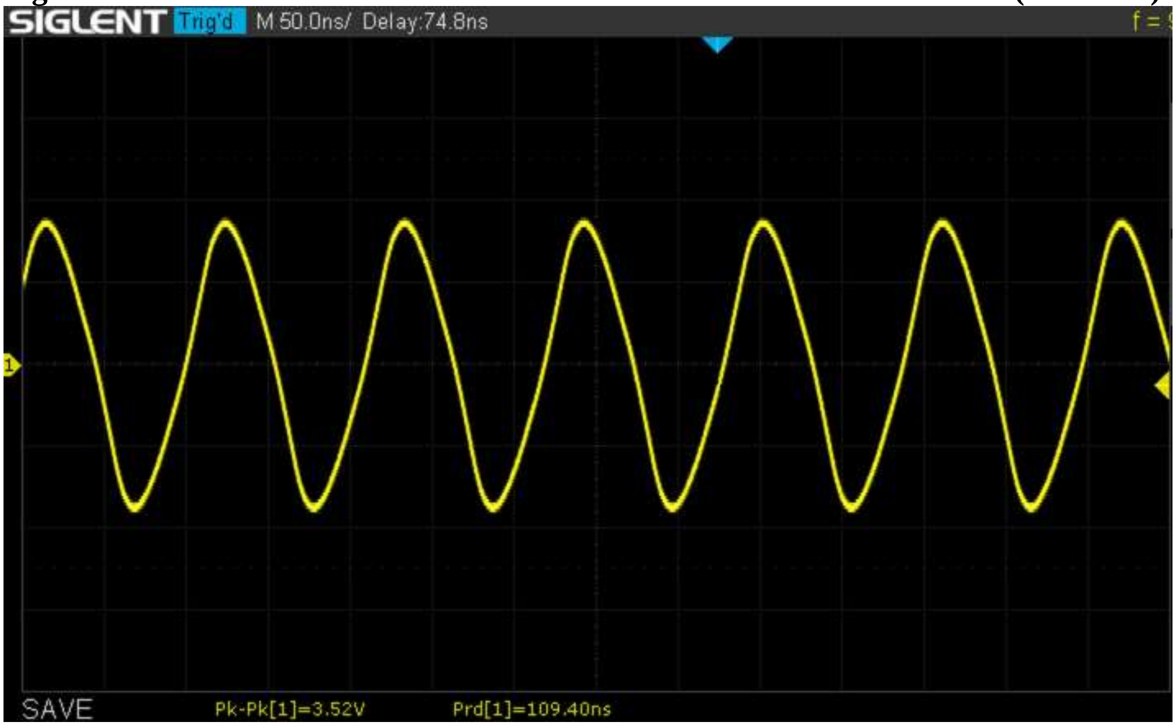


Figure 23 – Si5351 Atlas VFO 40M Sine Wave with MCL Low Pass Filter (14.3 dbm)

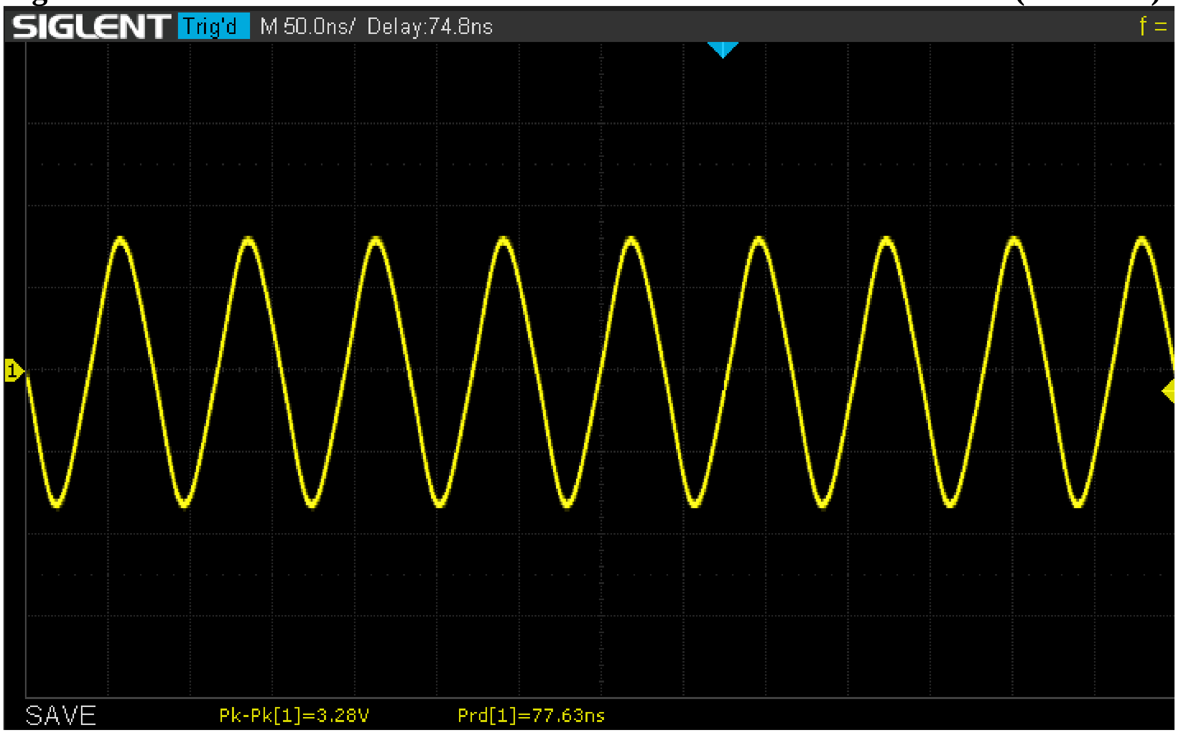


Figure 24 – Si5351 Atlas VFO 20M Sine Wave with MCL Low Pass Filter (14.8 dbm)

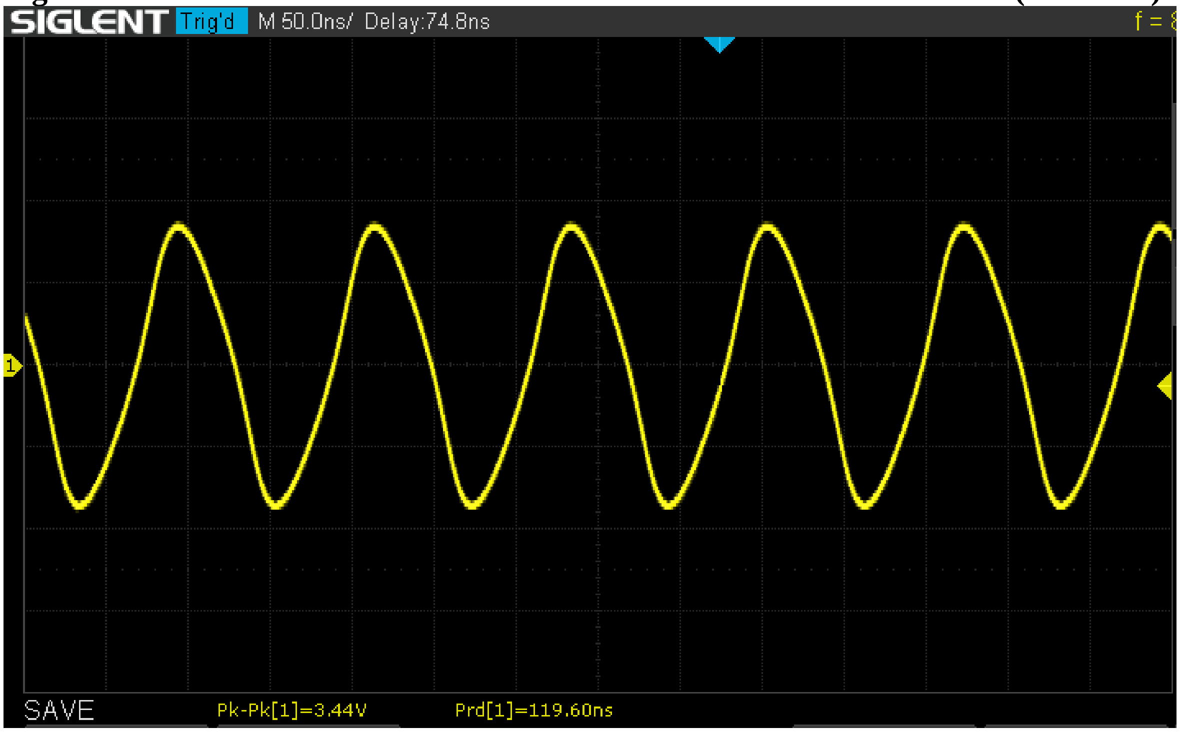


Figure 25 – Si5351 Atlas VFO 15M Sine Wave with MCL Low Pass Filter (12 dbm)

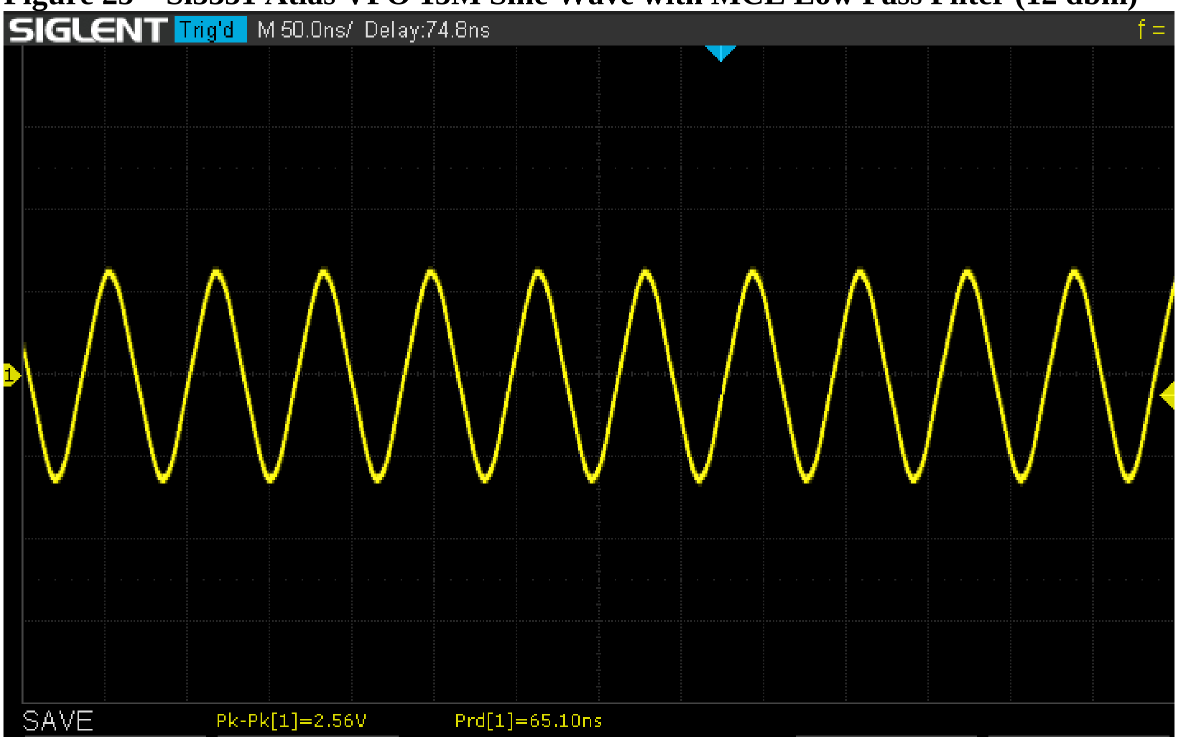
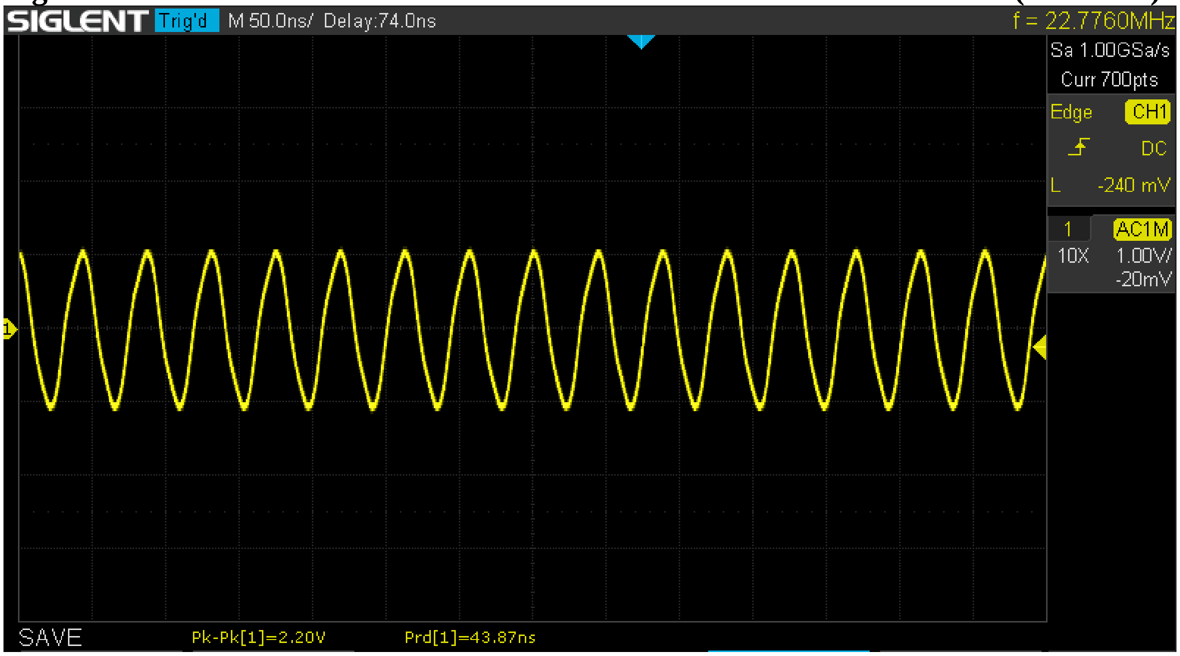


Figure 26 – Si5351 Atlas VFO 10M Sine Wave with MCL Low Pass Filter (10.8 dbm)



E. Signal Generator

For some types of testing and/or special functions, it may be advantageous to convert the Atlas VFO to a full function signal generator. This can be accomplished by the following steps:

1. Arduino IDE app
   Run the Arduino IDE application on our PC

2. Board
   In the IDE application, go to Tools-Board-Board Manager
   Select "Select other board and port"
   In the search window, enter "TTGO T1.7"
   Select TTGO T7 V1.4 Mini32
   Hit OK
   Under Board Manager on the left side of the app, search on "ESP"
   You should see esp32 by Espressif Systems version 2.0.14
   From the version drop down box, select version 1.0.6
   Hit Install
   The older version will be installed. The install takes less than 30 seconds.
   Select Tools-Board-Board Manager. This will close the Board Manager GUI

3. Hardware config
   Make sure your Si5351 VFO is powered down
   Replace the large LCD display with the small LCD display
   Connect USB cable between the VFO USB port and the USB port on your PC
   The VFO board will power up and the LCD screen will be white

4. Program upload
   Select File-Open
   Find your Si5351 Signal Generator directory
   Select the ino file in the directory and hit Open
   The ino file and associated files will load into a new Arduino IDE GUI
   Insure that you have the correct Com port selected by using the Windows Device Manager.
   Select Sketch-Upload

The ino file will compile and will then load
The LCD display should have the Signal Generator screen layout
Disconnect the USB cable to the VFO box
Power up your Atlas radio
The signal generator will power up at 10 MHz
You can now use the Signal Generator

Insure that you are using the right Com port, per the earlier setup instructions

F. Arduino IDE App

Change color settings for code display
https://johndecember.com/html/spec/colorhex.html#google_vignette

G. End-user Customizable Code in small display ino file

The end-user can customize the following text, font size, and location on the LCD display. It is assumed that the 172 x320 display is being used. The "CLINT" preference is used in the code.

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

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

Config.h
Allows use of Lilygo T7 Ver 1.4 ESP32-S2 board

```
#define MC_TYPE WROVER
```

Config.h
Allows use of large 172 x 320 display

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

Config.h
Splash screen

```
/*-----------------------------------------------------------
  | Splash Screen Startup intro - Version Number
-------------------------------------------------------------*/
#define NAME "VFO System"      //Start-up Intro with version number
#define VERSIONID "VFO4.1 - Ver. 9.62" //version ID number
#define ID "by KI5IDZ"         //ID writer of program code
```

Config.h
Change dial pointer

```
#define DP_WIDTH        1         // Width of Dial pointer
#define DP_LEN        100         // Length of Dial pointer
#define DP_POS         10         // Length Dial pointer extends above dial
```

Config.h
Si5351 Calibration factor. With the QRP Labs Si5351 board, with the TCXO module, the calibration factor is very close to zero.

```
#define CORRECTION_MCU  0
```

Config.h

Change encoder step for frequency change (config.h)

```
#define EncoderStep  12
```

VFO4_1.ino

Change memory frequencies

```
//The following are the default memory frequencies for each band
#if PREFERENCE == CLINT
long freqa[5] = { 3853000, 3900000, 3916000, 3950000, 5000000};  //80M band memory presets
long freqb[5] = { 7155000, 7162000, 7235000, 7255000, 5000000};  //40M band memory presets
long freqc[5] = {14235000,14250000,14300000,14325000,10000000};  //20M band memory presets
long freqd[5] = {21285000,21300000,21320000,21350000,15000000};  //15M band memory presets
long freqe[5] = {28385000,28425000,28450000,28500000,28900000};  //10M band memory presets
int recall[5] = {2,1,3,2,2};                                     //prefered memory recall at startup
#else
```

VFO4_1.ino

Enable Clock 0

```
    si5351.set_int(SI5351_CLK0,1);                        //initialize CLK0
```

VFO4_1.ino

Change Si5351 Power Out

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

The Si5351 has an output impedance of about 200 ohms. Here are the power out reading for various values of mA:

Current	**J4 Pin 2**	**Si5351 Clk0 pad**
8 ma	+11.9 dbm	+14.0 dbm
6 ma	+11.6 dbm	+13.6 dbm
4 ma	+11.2 dbm	+13.0 dbm
2 ma	+10.0 dbm	+11.0 dbm

VFO4_1.ino

Change text, font, and colors for Splash screen

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

VFO4_1.ino

Change scanning times

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

VFO4_1.ino

Set Band names

```
//---------------------------code to handle band display 2--------------------

void display_Band() {                        //code to display the current selected band
  switch(count) {                            //determine which position the band switch is located
    case 1: sprintf(band_str, " 80 M"); break; //set to 80M position USB
    case 2: sprintf(band_str, " 40 M"); break; //set to 40M position USB
    case 3: sprintf(band_str, " 20 M"); break; //set to 20M position USB
    case 4: sprintf(band_str, " 15 M"); break; //set to 15M position USB
    case 5: sprintf(band_str, " 10 M"); break; //set to 10M position USB
```

VFO4_1.ino

Change Digital display Band font and text and color

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

VFO4_1.ino

Change Digital display Band location

```
      sprites[flip].setCursor(8, 60 );   // place cursor here
```

VFO4-1.ino

Set Frequency Steps

```
//---------------------------code to handle step display 2--------------------
void display_Step() {                        //code to handle large & custom display
  #if  DISP_SIZE == LARGE_DISP || DISP_SIZE == CUSTOM_DISP
  switch (fstep) {                                   //determine step position
    case 10: sprintf(step_str,  "10 Hz");break;    //step frequency is 10Hz
    case 100: sprintf(step_str, "100 Hz");break;  //step frequency is 100Hz
    case 500: sprintf(step_str, "500 Hz");break;  //step frequency is 500Hz
    case 1000: sprintf(step_str,"1 KHz");break;   //step frequency is 1KHz
    case 10000: sprintf(step_str,"10 KHz");break; //step frequency is 1KHz
```

VFO4-1.ino

Change Digital display Step font and text and color

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

VFO4-1.ino

Set Memory names

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

VFO4-1.ino

Change Digital display Memory font and text and color

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

VFO4-1.ino

Define location of Frequency Display box

```
        sprites[flip].drawRoundRect(5,15,305,40,15,CL_FREQ_BOX); // draw box (x1,y1,x2,y2,thick,color) (15,40)
```