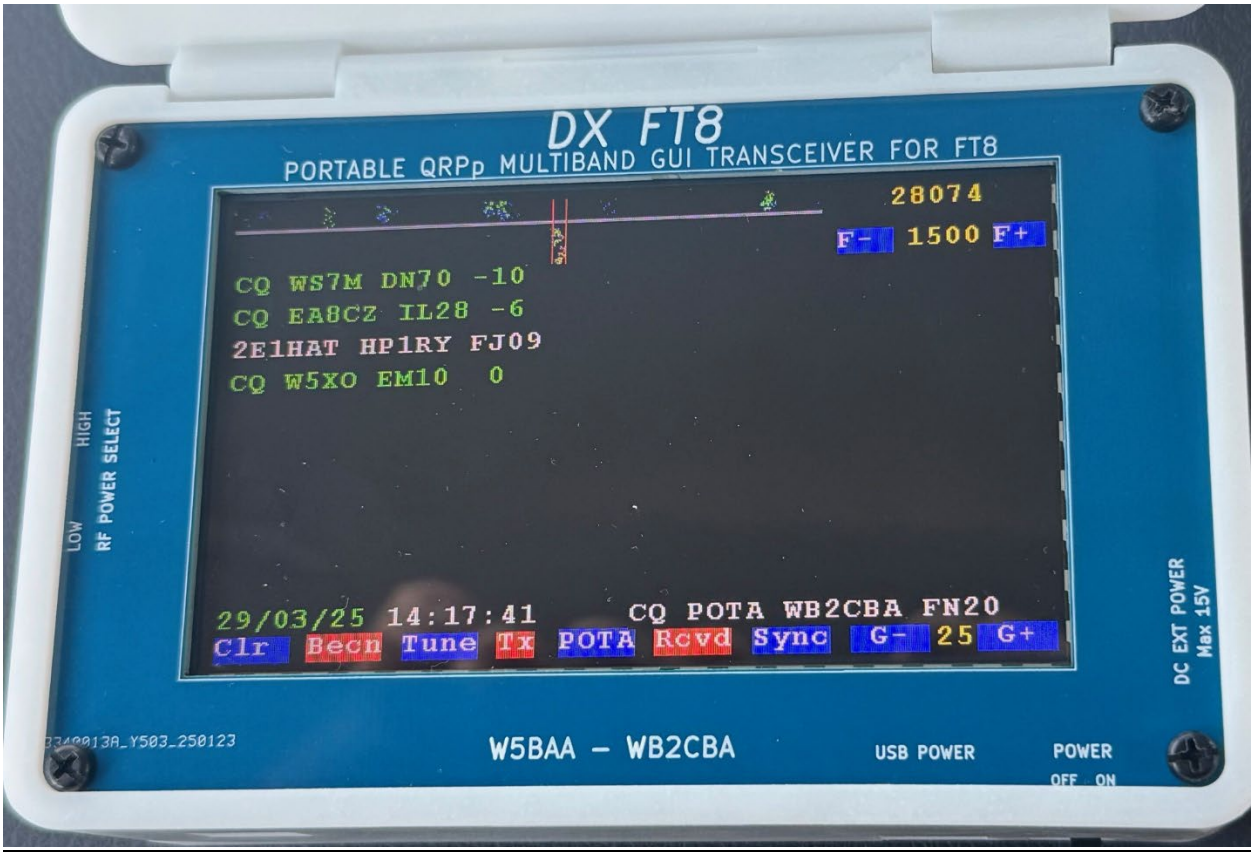
DX FT8 – FT8 DIGITAL TRANSCEIVER HARDWARE BUILD and CONTROLS, PROGRAMMING and OPERATION GUIDE for V2.1 with BMS.



DX FT8 is a FT8 Digital mode capable HF QRPp GUI (Graphical User Interface) based multiband Transceiver with internal Li-Ion battery for standalone self-powered portable operations.

Main aim of DX FT8 TRX Project is to create a highly portable self-contained FT8 GUI Transceiver. Self-contained aim is to create User interface plus Multiband transceiver in the same unit. This creates an advantage of carrying one GUI based TRX unit and no longer need to carry a PC or a laptop or tablet for GUI interface operation for FT8 with a classic transceiver.

This approach is quite appealing for smaller and lighter setups for backpacking for SOTA or POTA activations or as a travel transceiver with FT8.

Here are some highlights on DX FT8 Specifications:

- DX FT8 Transceiver GUI (Graphical User Interface) and processing power comes from ST Micro STM32F746 DISCO Evaluation board. This is a ARM CORTEX based evaluation board for STM32F746 microcontrollers with below outlined specifications:
- STM32F746NGH6 Arm® Cortex® core-based microcontroller with 1 Mbyte of Flash memory and 340 Kbytes of RAM, in BGA216 package
- 4.3" RGB 480×272 color LCD-TFT with capacitive touch screen
- 128-Mbit Quad-SPI Flash memory
- DX FT8 Transceiver RF Board plugs into STM32F746 DISCO evaluation board to form the DX FT8 transceiver.
- DX FT8 Transceiver operates on 7 HF bands. These bands are:

- 1 – 40m (7.074 MHz)
- 2- 30m (10.136 MHz)
- 3 – 20m (14.074 MHz)
- 4- 17m (18.100 MHz)
- 5- 15m (21.074 MHz)
- 6- 12m (24.915 MHz)
- 7- 10m (28.074 MHz)

- DX FT8 Transceiver has two RF Power Output Selection, LOW RF POWER and HIGH RF POWER which can be selected with the RF POWER Slide switch on the side of the transceiver.
- 40m 372mW 844mW
- 30m 373mW 843mW
- 20m 380mW 823mW
- 17m 354mW 762mW
- 15m 314mW 654mW
- 12m 259mW 520mW
- 10m 231mW 445mW

- DX FT8 Transceiver requires at least 1000mA power source to operate and Charge internal Li-Ion battery under High RF Power. DX FT8 Transceiver can operate and charge internal battery from 5V USB power bank or any 1000mA capacity USB power source or by using DC barrel Connector can be powered from 7V to 15V external power supply capable of delivering 1000 mA.

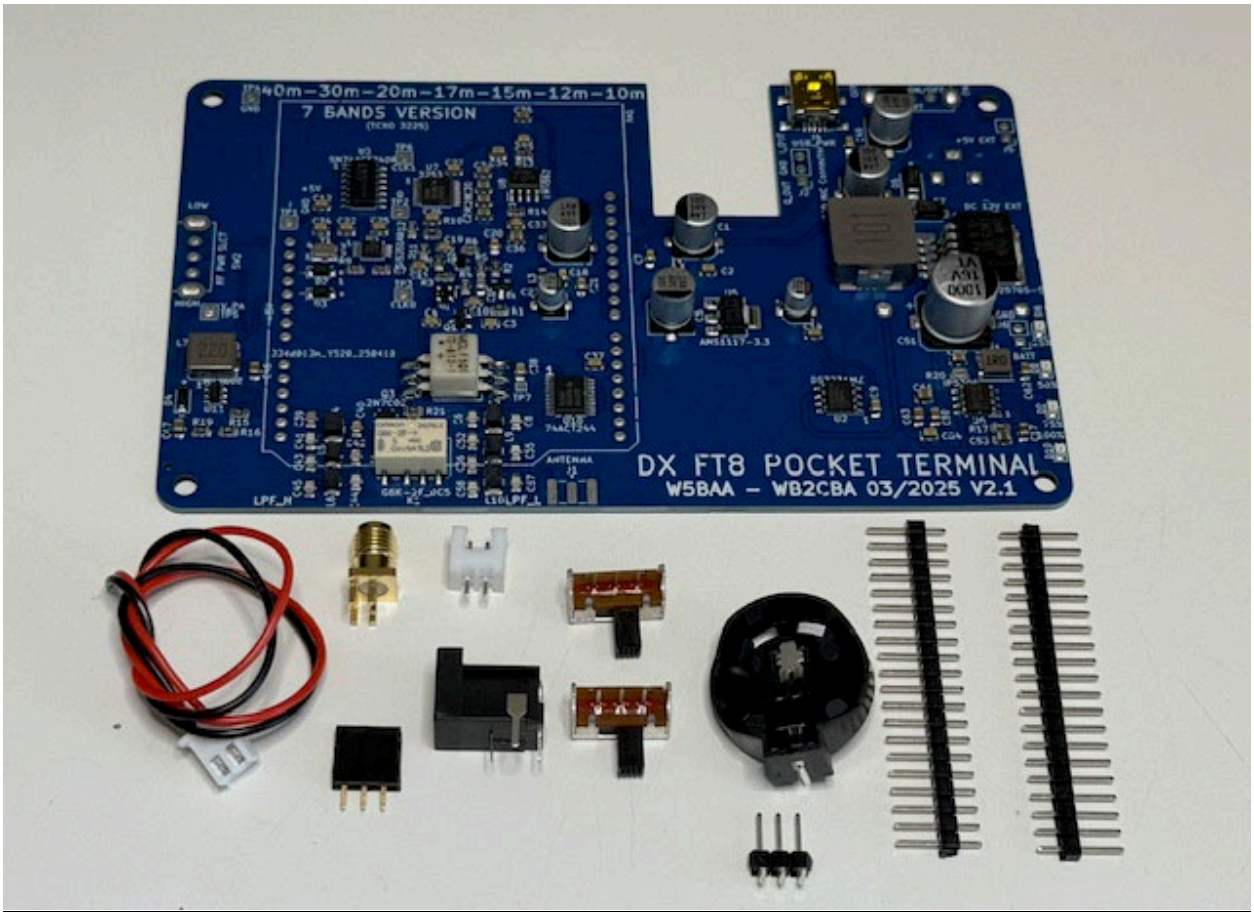
- DX FT8 TRANSCEIVER uses an unconventional RF power Amplifier consisting of a TTL octal buffer IC and step up RF Transformer. There is no MOSFET PA transistors.

This creates an extremely resilient RF PA for failure due to high SWR or no antenna accidental operations. This is an advantage for portable operations as antenna conditions can vary.

- DX FT8 TRANSCEIVER incorporates a TAYLOE detector based Quadrature Sampling detector receiver which outputs an I and Q phase output to STM32F746 DISCO board which generates through Upper Side Band SSB receive signal.

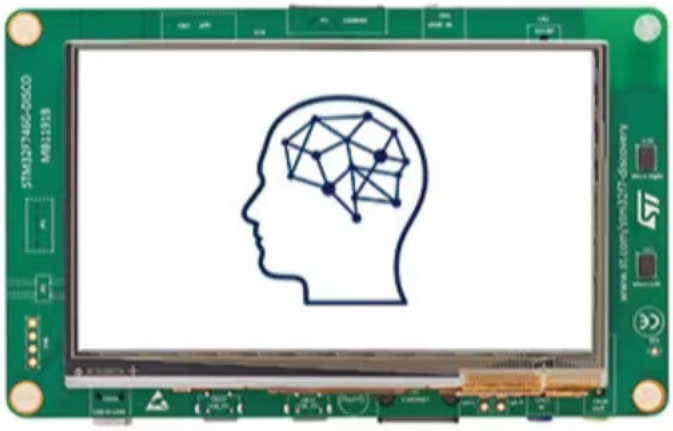
DX FT8 GUI DIGITAL MODES TRANSCEIVER PARTS

1- RF Board with parts to solder on RF board :



2- <u>Parts for installing top and bottom PCB plates:</u>

3- STM32F746 DISCOVERY DEVELOPMENT BOARD :



STM 32F746 DISCO BOARD

DX FT8 TRANSCEIVER KIT PARTS LIST:

1 x STM32F746 DISCO BOARD (**Not included in the kit**. Can be ordered from the link)
https://www.digikey.com/en/products/detail/stmicroelectronics/STM32F746G-DISCO/5267791?utm_adgroup=&utm_source=google&utm_medium=cpc&utm_campaign=PMax%20Shopping_Product_Low%20ROAS%20Categories&utm_term=&utm_content=&utm_id=go_cmp-20243063506_adg-_ad-__dev-c_ext-_prd-5267791_sig-Cj0KCQjw3bm3BhDJARIsAKnHoVUr0T9QxSX-D2SV5umDLJJGErAS_3EIW0T5bXSeHToQNmqXIEHJow4aAjdREALw_wcB&gad_source=1&gclid=Cj0KCQjw3bm3BhDJARIsAKnHoVUr0T9QxSX-D2SV5umDLJJGErAS_3EIW0T5bXSeHToQNmqXIEHJow4aAjdREALw_wcB

1 x SMD POPULATED RF BOARD

1 x TOP PLATE PCB

1 x BOTTOM PLATE PCB

1 x SMA EDGE type PCB FEMALE CONNECTOR

1 x CR2032 PCB type Battery HOLDER

1 x CR2032 Battery for RTC time keeping (**Not included in Kit**)

2 x SPDT Slide Switch

1 x PCB TYPE 2.1 mm DC BARREL CONNECTOR JACK

1 x JST-PH2.54 2 pin PCB header male

1 x JST-PH2.54 2 pin female header with cable

1 x 40 pin male header

8 x M3 HEX Male end 12mm long Nylon SPACERS

8 x M3 HEX Male end 15mm long Nylon SPACERS

4 x M3 6mm Male end HEX Nylon Spacers

8 x M3 6mm nylon screws

1 x Li-Ion Battery - 3.7V 2500mA or 3000mA – **(Not Included in kit. Can be outsourced from the links below.**)

3.7V/2500mA Battery Link:
https://a.co/d/fS2VEcK

3.7V/3000mA Battery Link:
https://a.co/d/0UoBynH

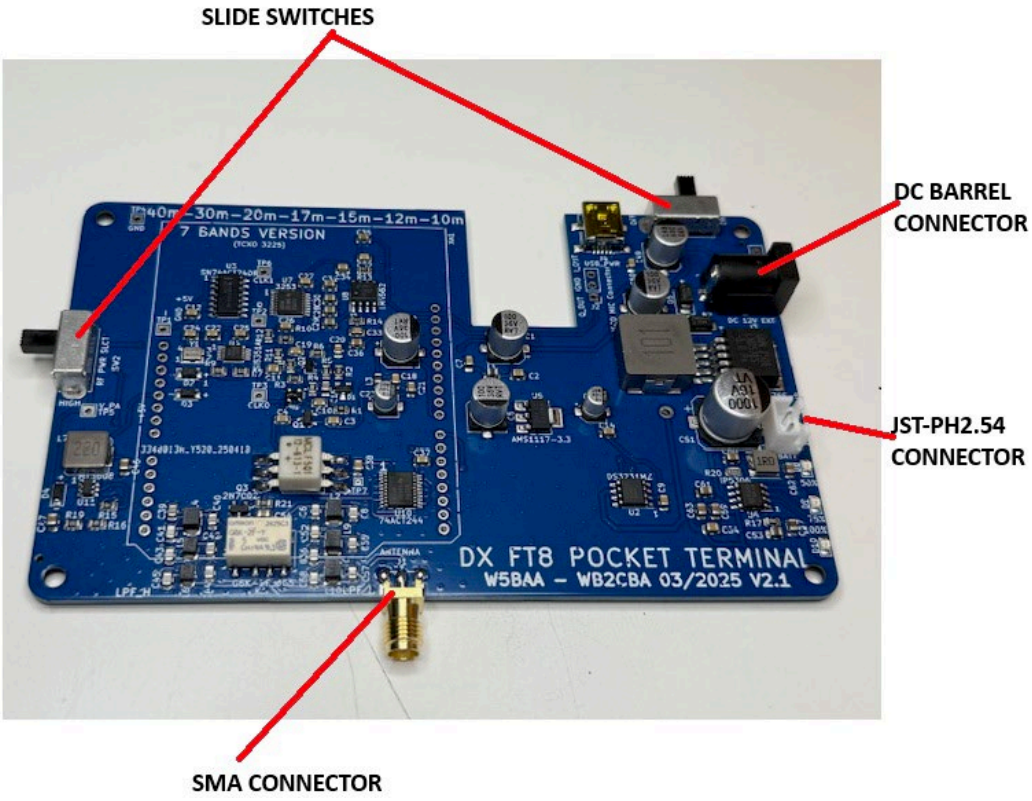
1 x Micro SD Card for logging QSOs (Not included in kit)
Micro SD Card can be a low capacity cheap sd card as in this link. Data recorded is text and minimal.

MicroSD Card Link:
https://a.co/d/0i0Kyzv

BUILDING DX FT8 TRANSCEIVER

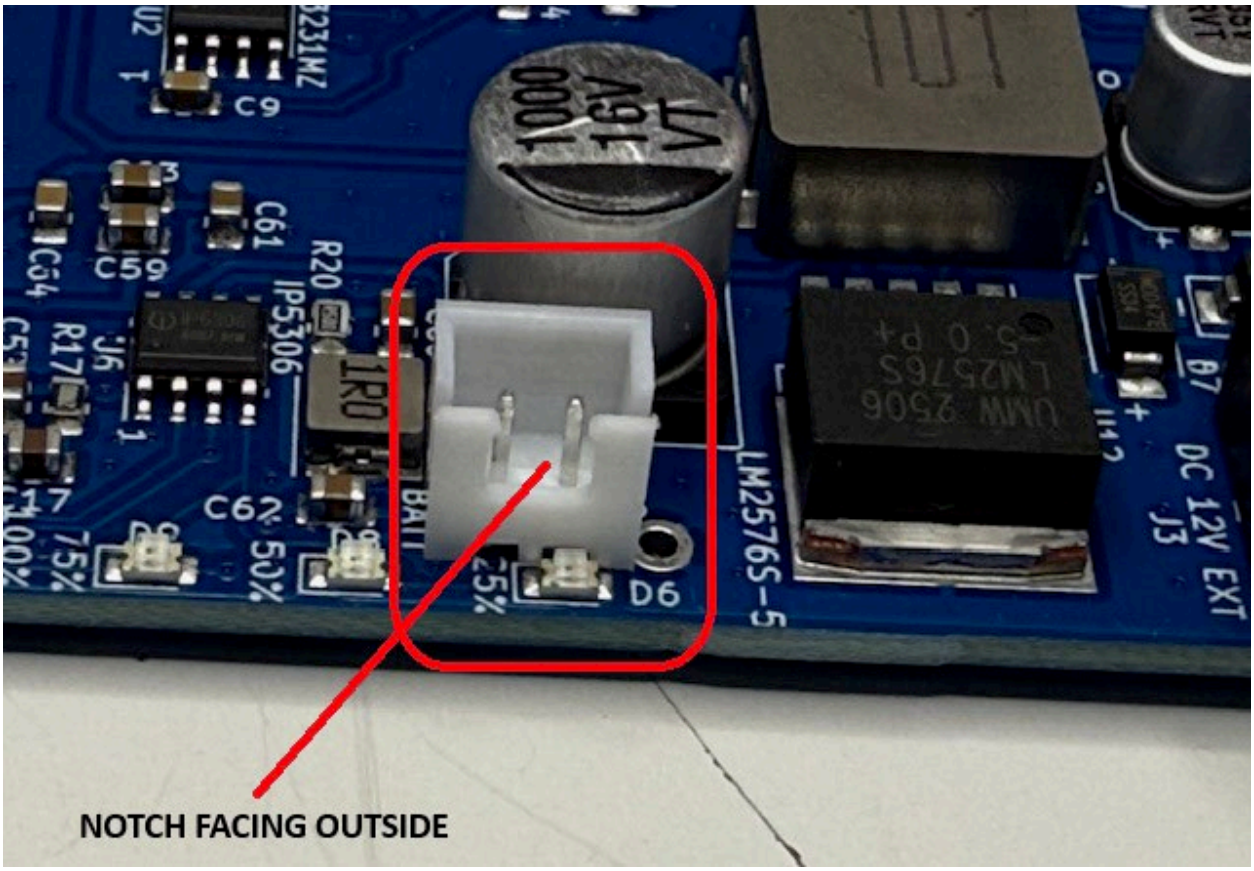
STEP 1 : RF BOARD COMPONENT SIDE COMPONENTS

1- SOLDER 2 x SLIDE SWITCHES
2- SOLDER 1 x DC BARREL CONNECTOR
3- SOLDER 1 X SMA ANTENNA CONNECTOR
4- SOLDER JST-PH2.54 CONNECTOR



When Soldering JST-PH2.54 CONNECTOR PAY ATTENTION AT ORIENTATION!

It should be soldered as in this photo:



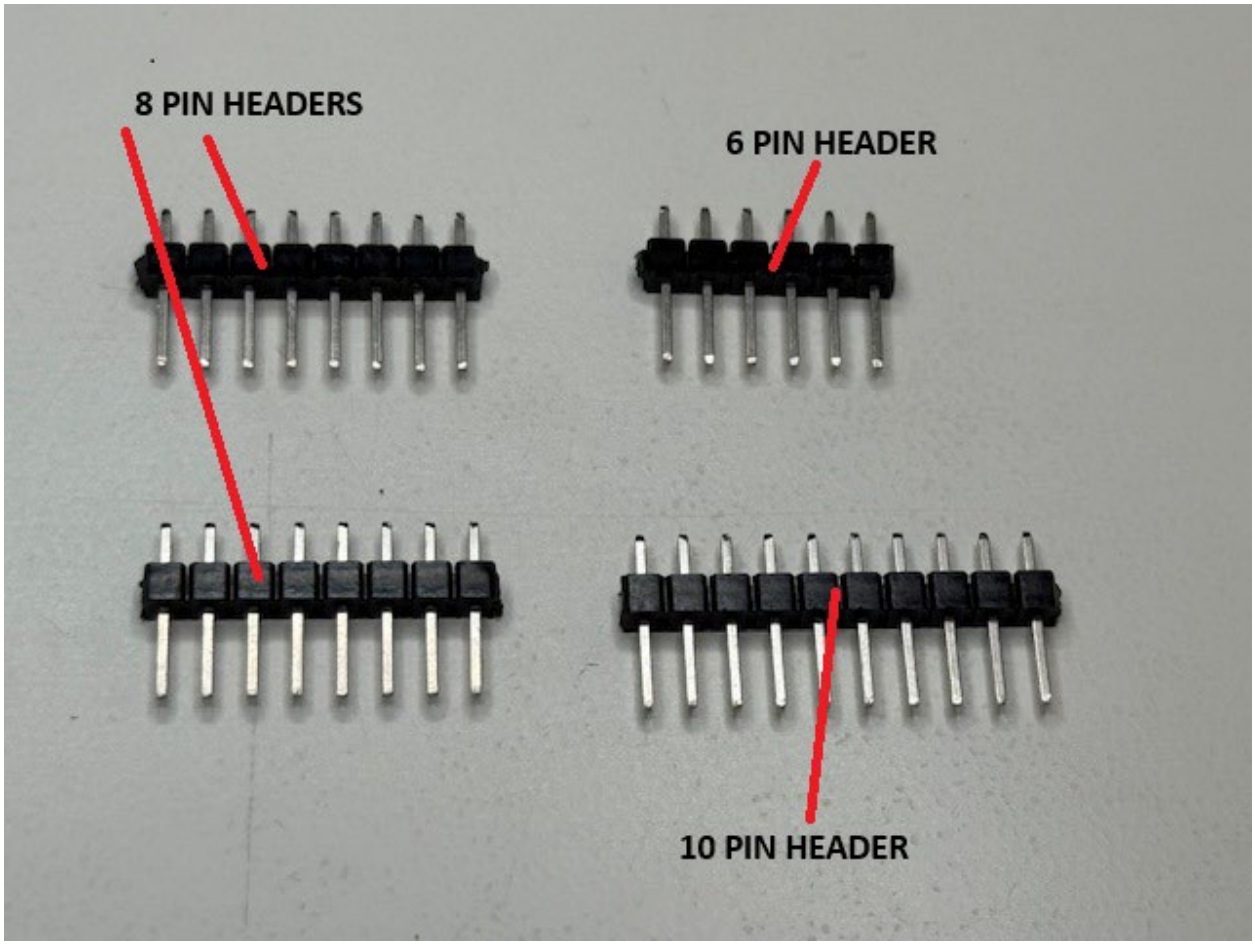
STEP 2 : RF BOARD SOLDER SIDE COMPONENTS

1- Cut 2 x 20 pin Male Headers to :

2 x 8 PIN HEADERS

1 x 10 PIN HEADER

1 x 6 PIN HEADER as shown in the photo below.

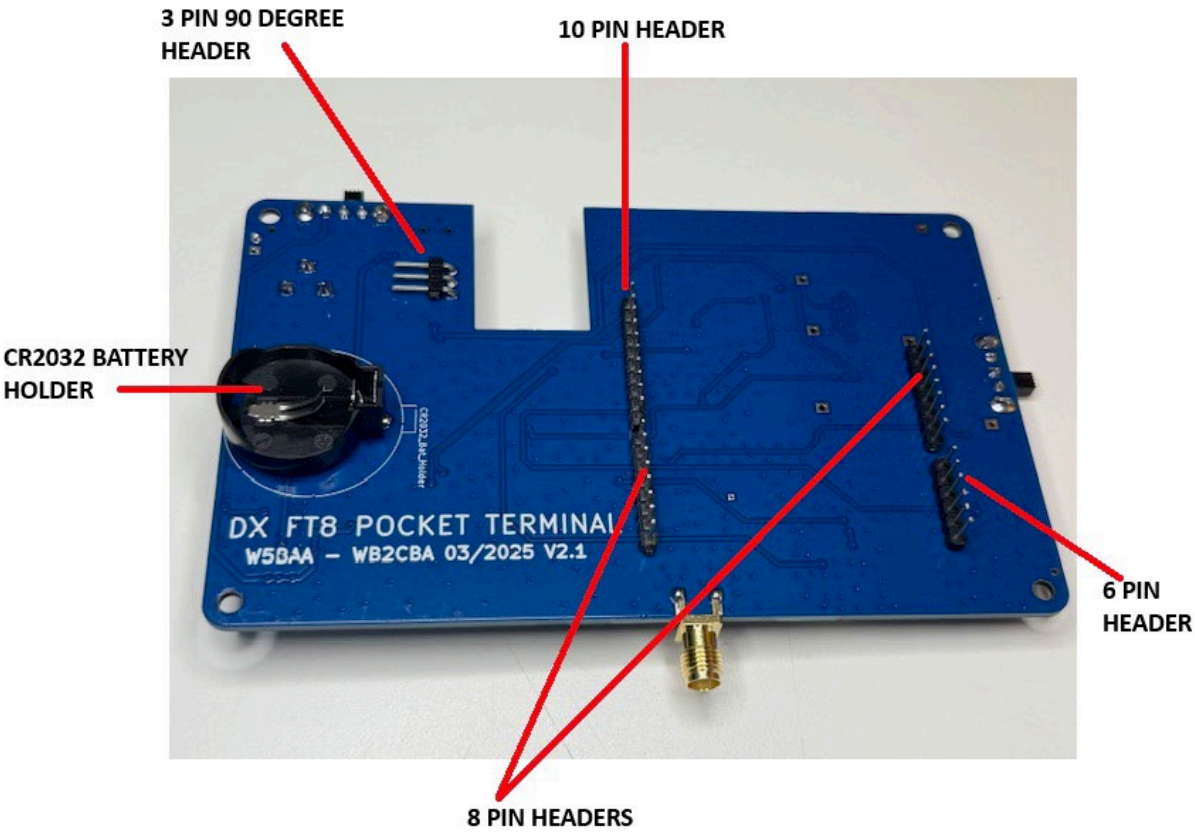


2 SOLDER 1 x 6pin, 2x8pin and 1x10pin Arduino style male headers cut from 2 x 20 pin male header.

3 SOLDER CR2032 BATTERY HOLDER

4 SOLDER 3 PIN 90 DEGREES MALE HEADER

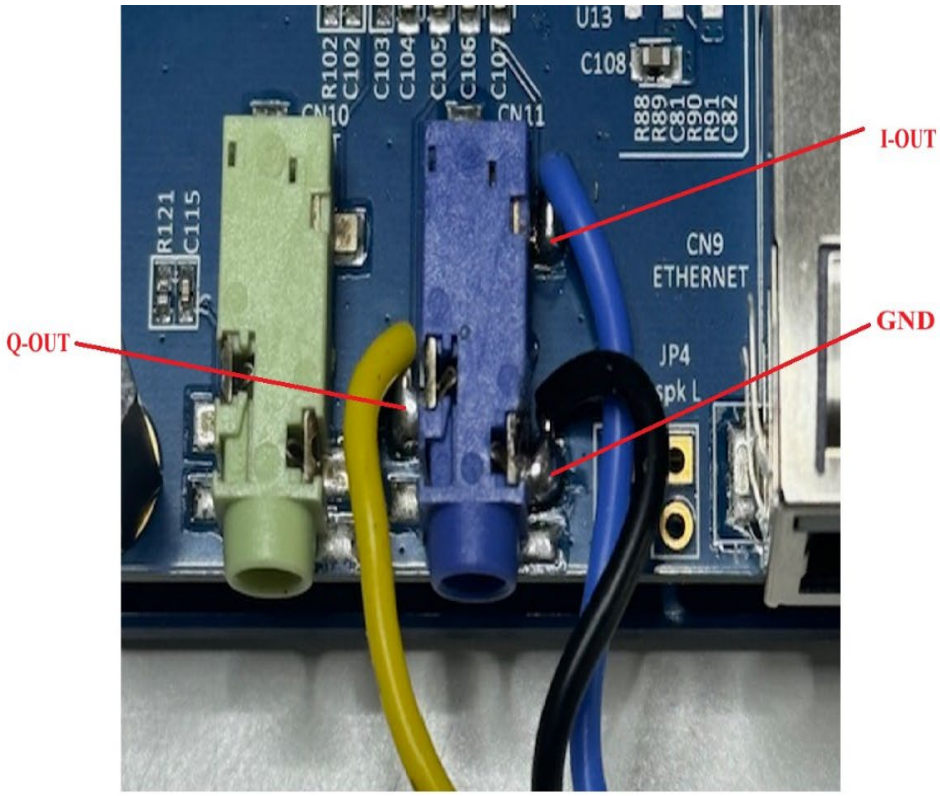
SOLDERED BOARD SHOULD LOOK LIKE IN THIS PHOTO:



This completes RF BOARD Components soldering.

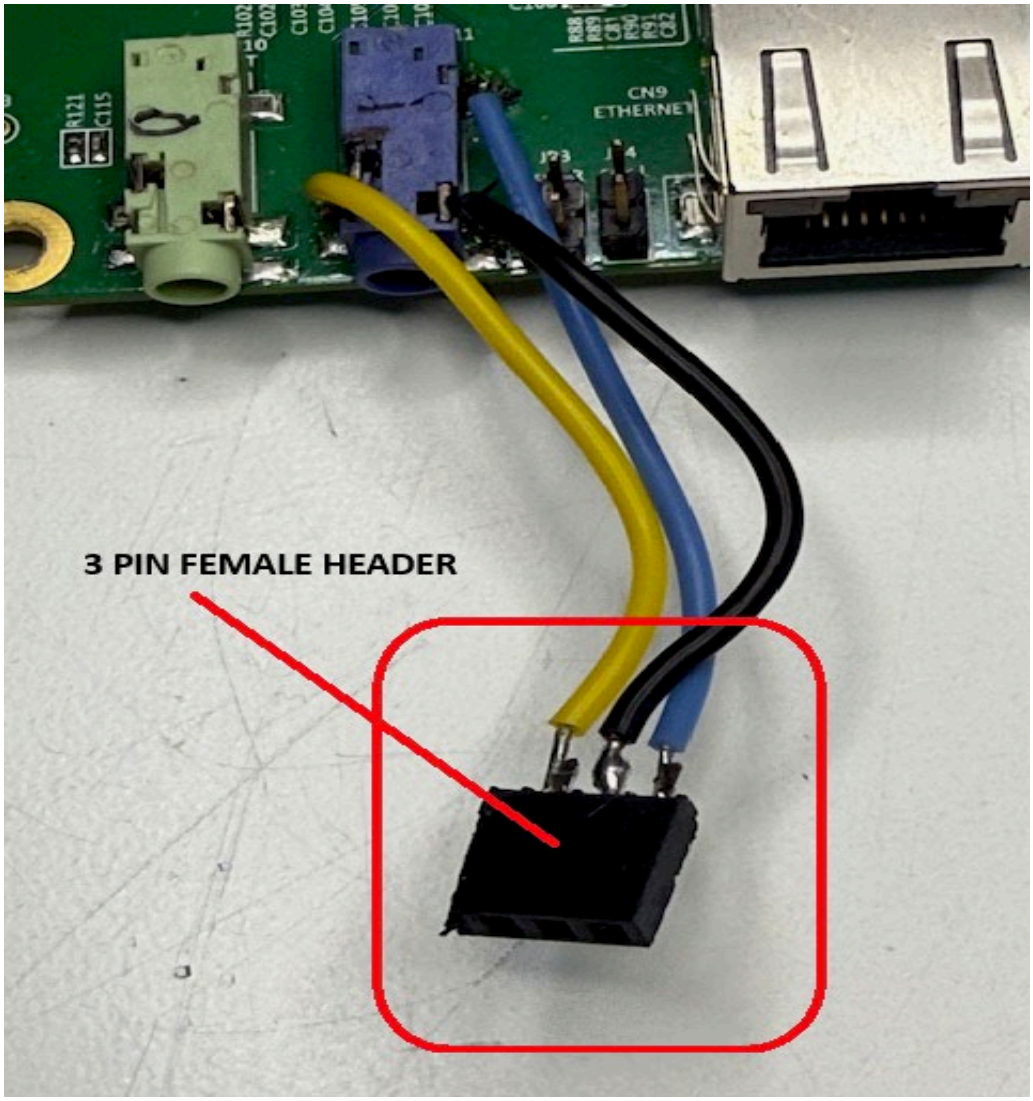
- **STEP 3: DISCO BOARD to RF BOARD AUDIO I/Q Connection:**

1 - Cut 50mm(2 inch) long 3 different colored flexible cables. Solder these cables to AUDIO out connector I,Q and GND pins on RF Board. Then Solder the other end of those cables to Disco board audio input jack as outlined in below photo. I/Q and GND is labeled on RF board component side.



DISCO BOARD AUDIO INPUT I, Q, GND CONNECTION POINTS

2- SOLDER 3 pin female header to these colored cables as shown in the photo. The middle pin is the Ground pin.

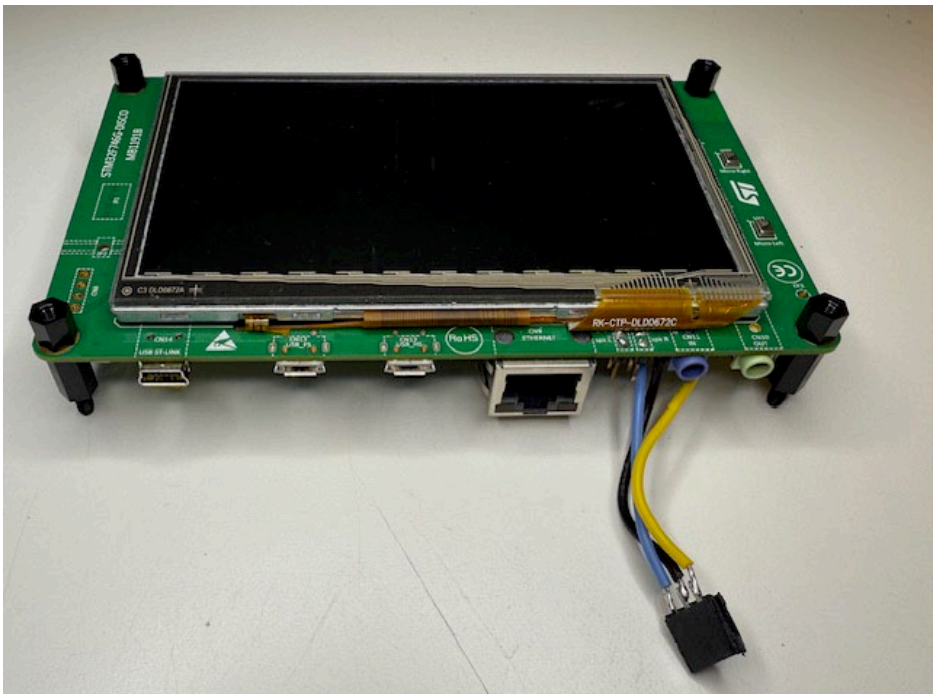


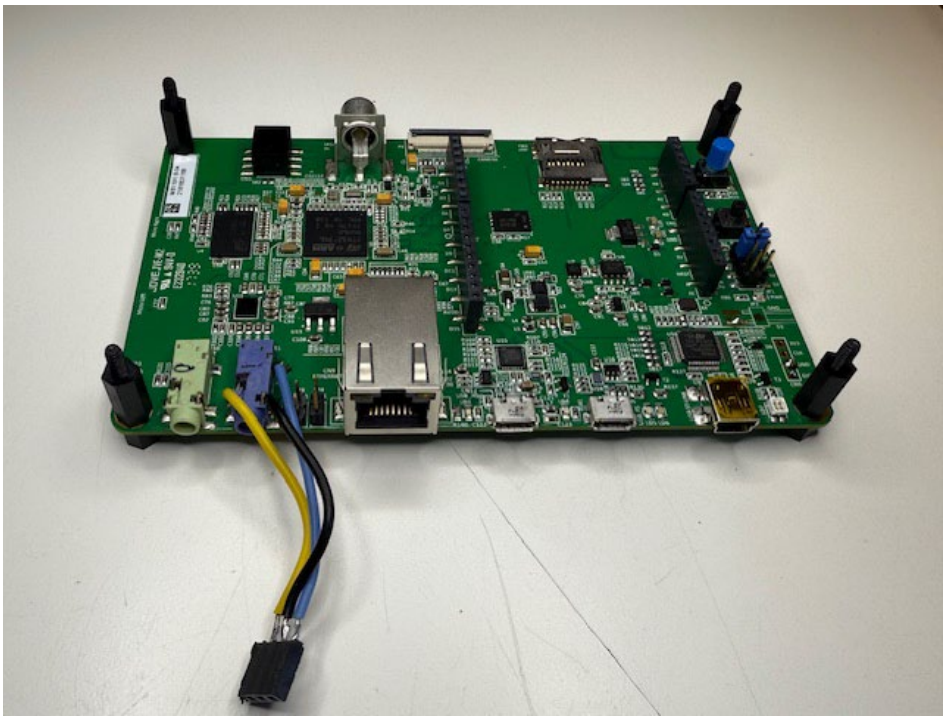
STEP 4: Assembling Disco board to RF board, installing internal Battery, Top and bottom panels

We will need these parts to assemble DX FT8 Transceiver top and bottom panels.

STEP1:

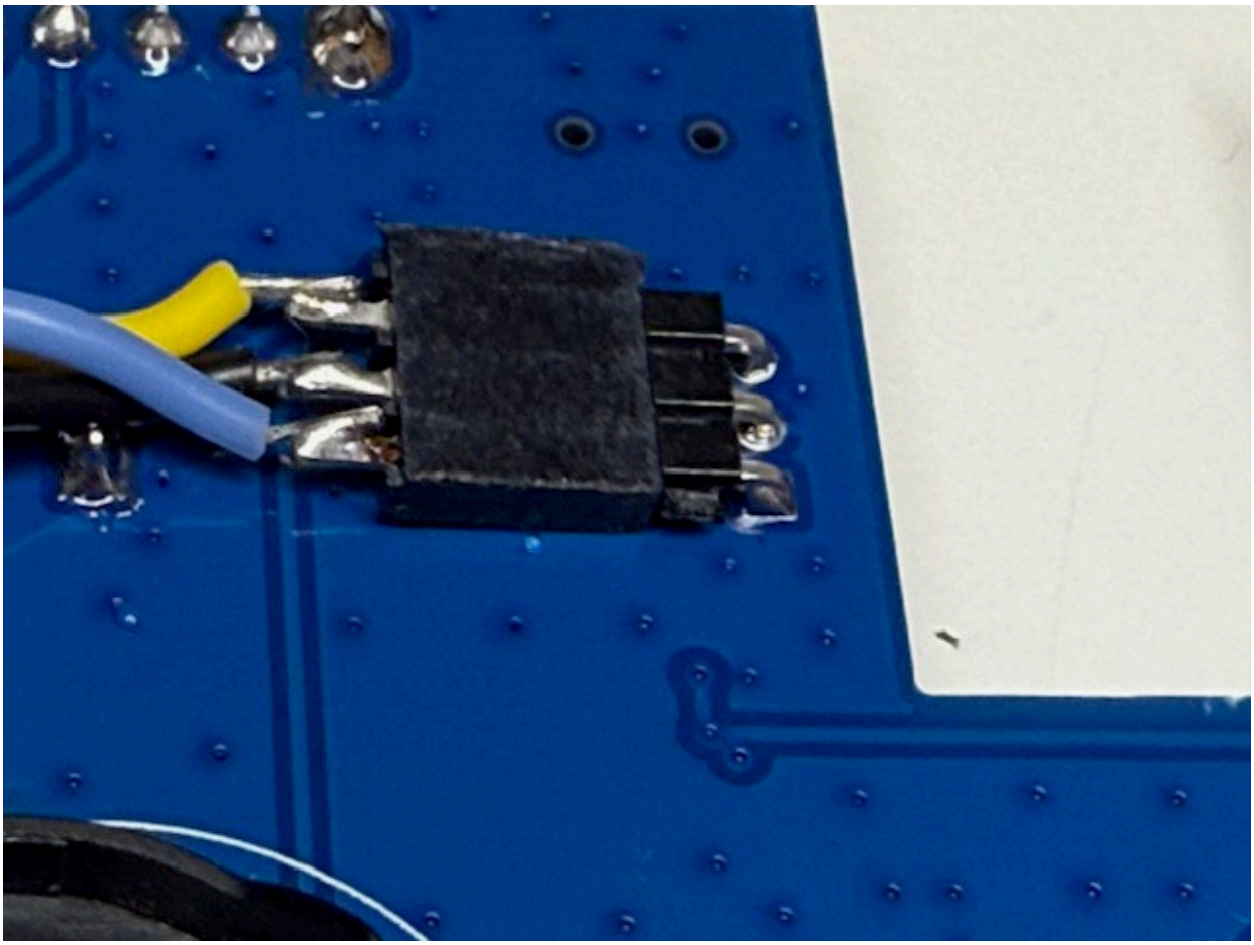
Use 4 x 6 mm spacers and 4 x 12mm spacers to start assembling 4 corners of DISCO Board with screwing 4 x 6mm spacers to 4 x 12mm spacers as shown in these photos.





STEP 2:

1 - Connect RF BOARD TO DISCOVERY BOARD audio I/Q connector as shown in the photo.



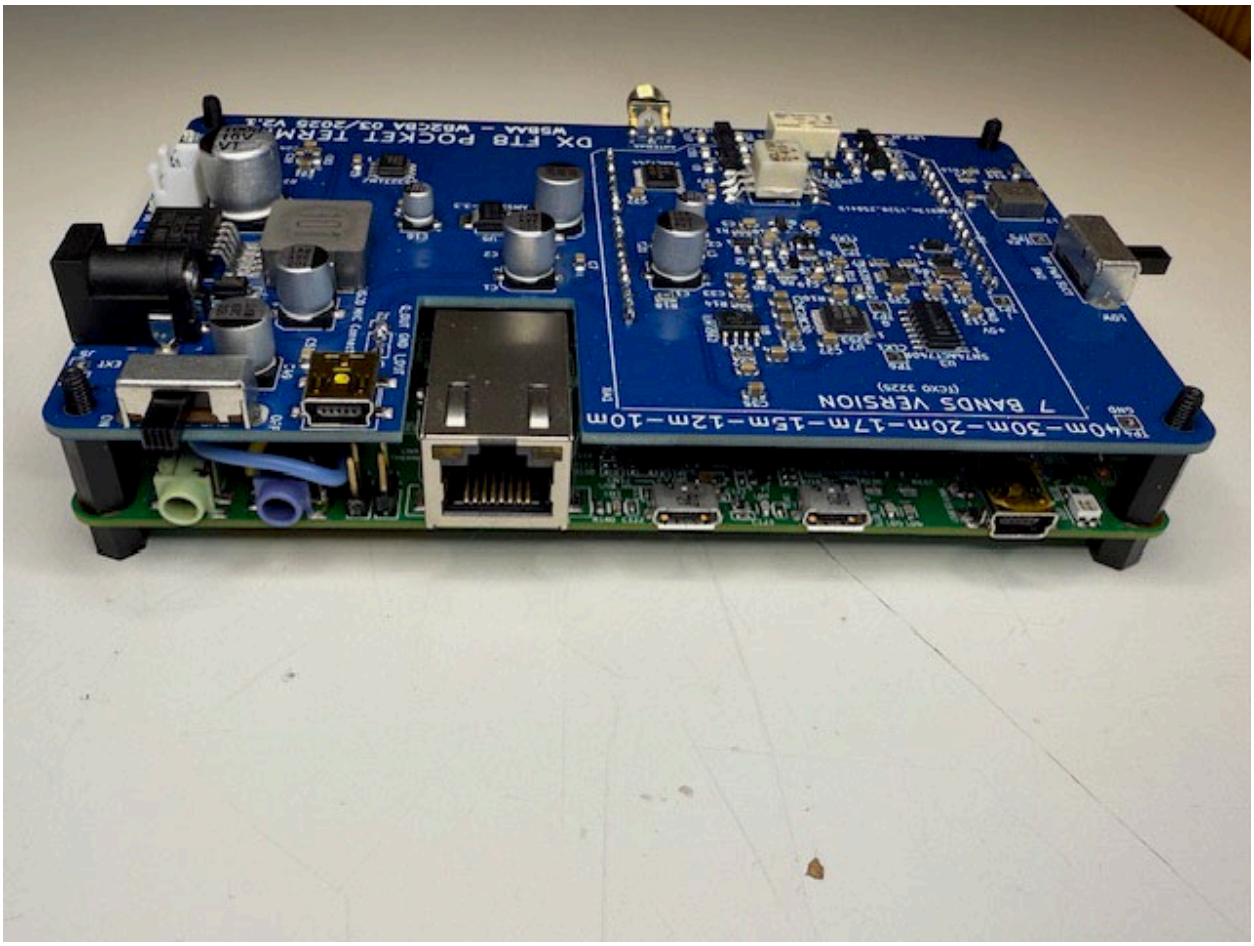
When operating the transceiver if there is no reception then swap I and Q cables . This will swap USB and LSB.

Two audio I/Q connector connected boards should look like this:

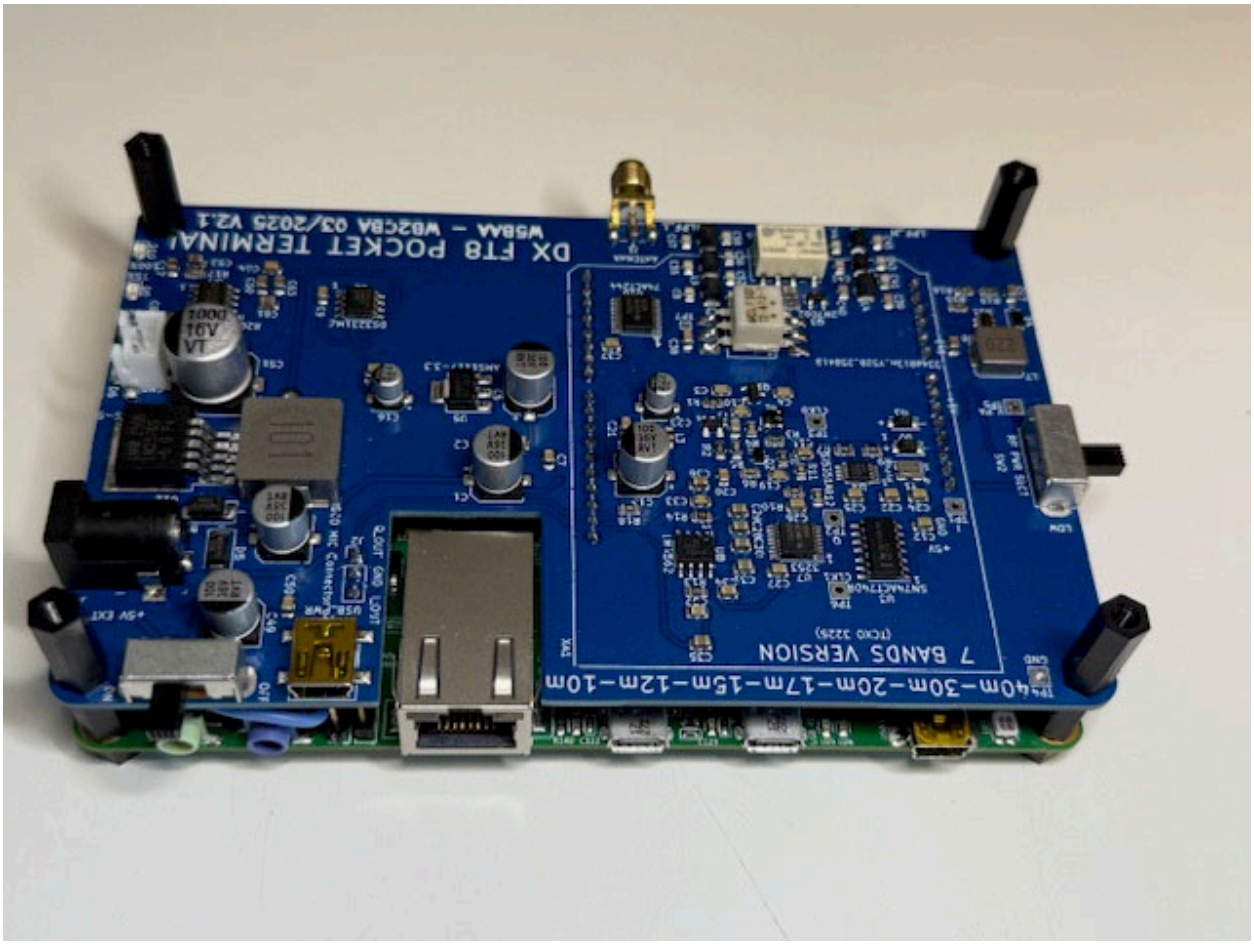
In this step insert your CR2032 lithium battery into its holder.

STEP 3:

Now carefully insert RF Board on DISCOVERY Board to match all pins of male headers on RF Board with female headers of DISCOVERY Board as in the photo:



Now Screw 4 x 15mm spacers in place as in the photo below:

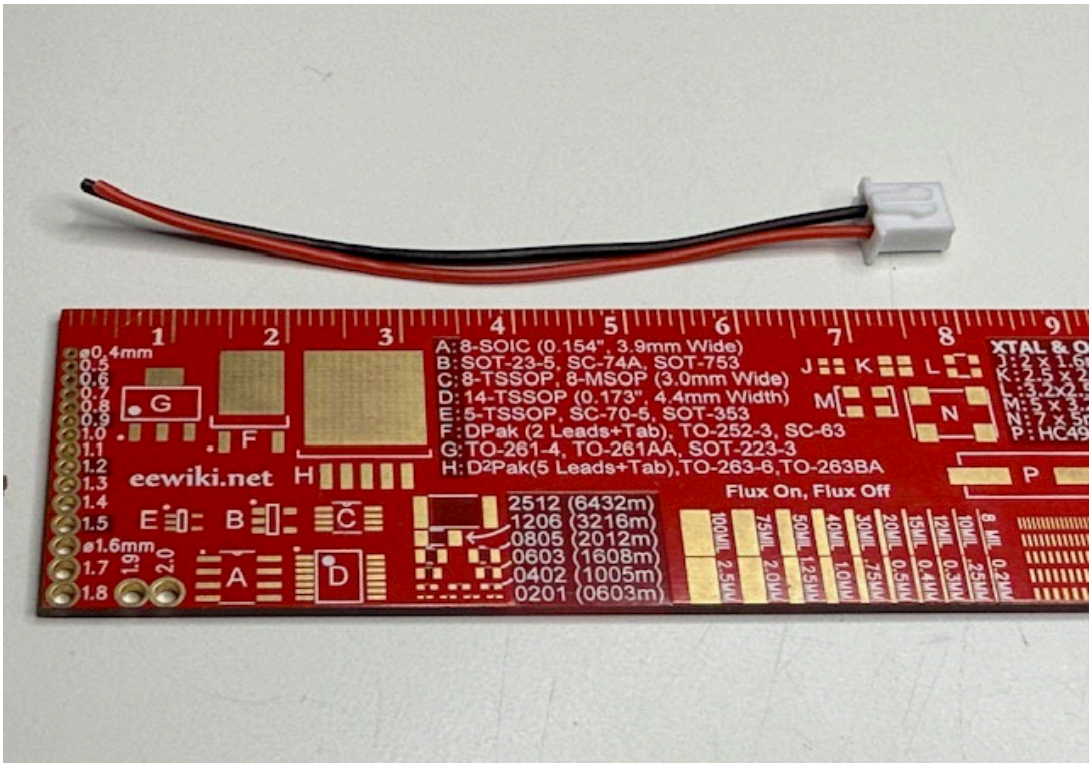


STEP 4:

Screw TOP PLATE to DX FT8 assembly using 4 x 6mm screws as shown in the photo:

STEP 5:

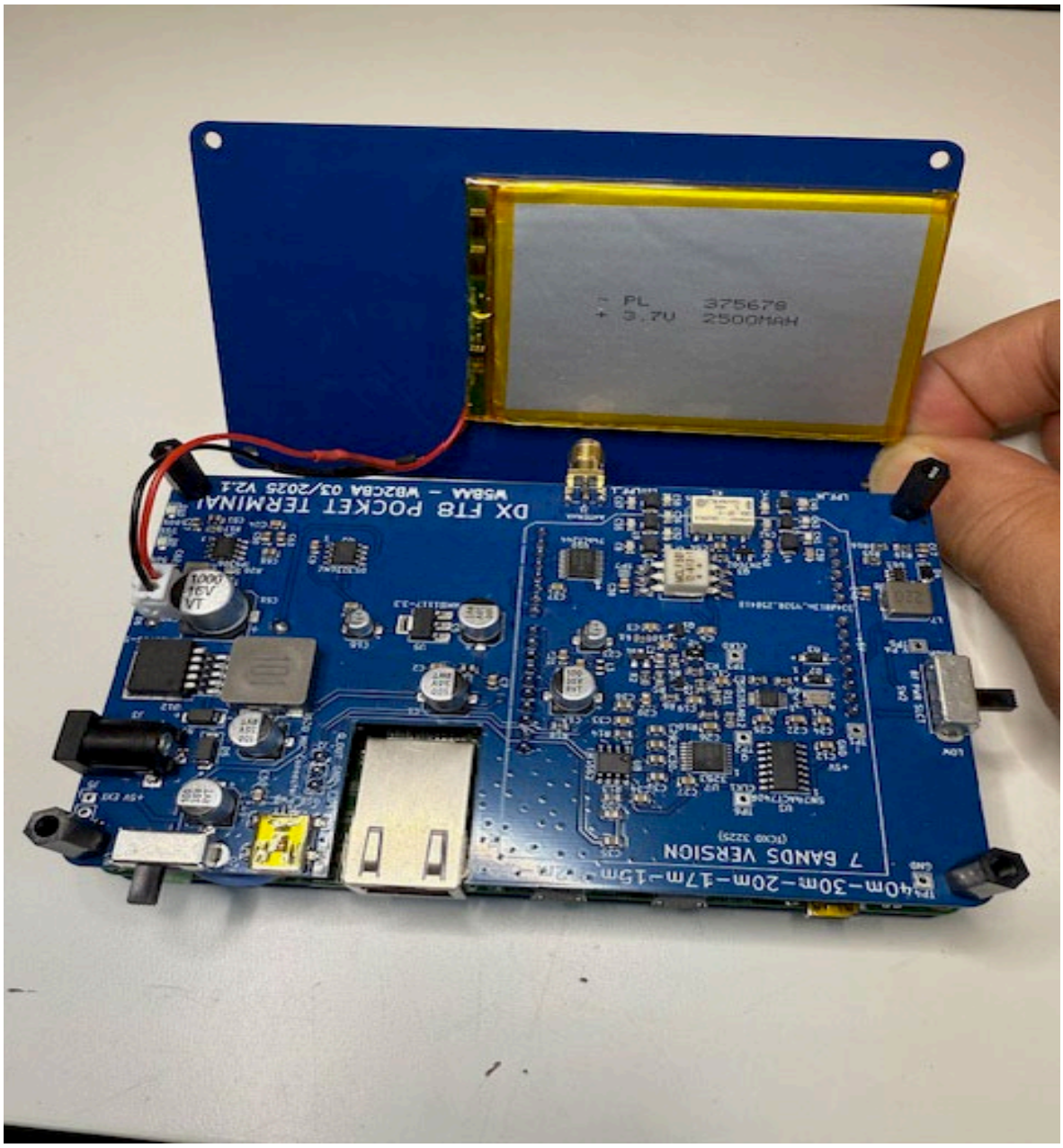
Cut 75 mm or 3 inches of JST-PH2.54 female header cable as shown in photos:



- Cut battery terminal cables coming out from battery 25 mm / 1 inch and connect JST-PH2.54 Female cable header to battery terminal cables matching red with red and black with black cable. Red is positive and black is ground.
- To isolate soldering connections use heat shrink tubing or electrical tape on them.

- Now using double sided tape fix the battery to bottom plate and plug in JST-PH2.54 female header to male header on RF Board.

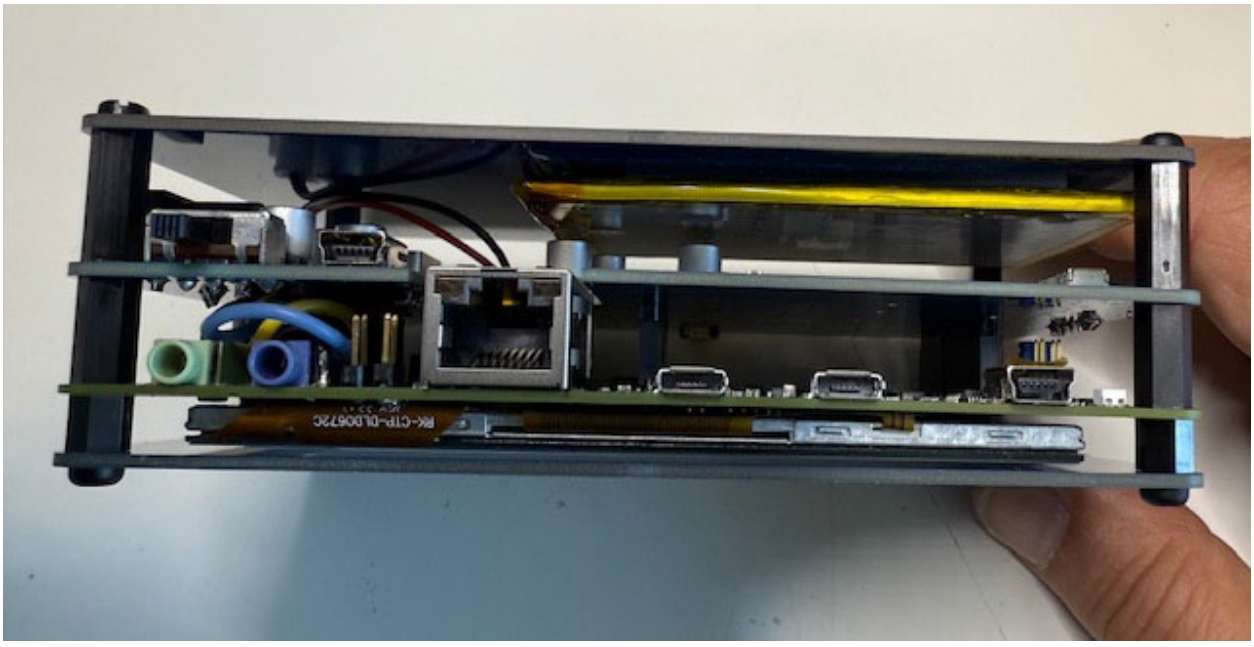
Completed Battery installation should look like in this photo:



STEP 6:

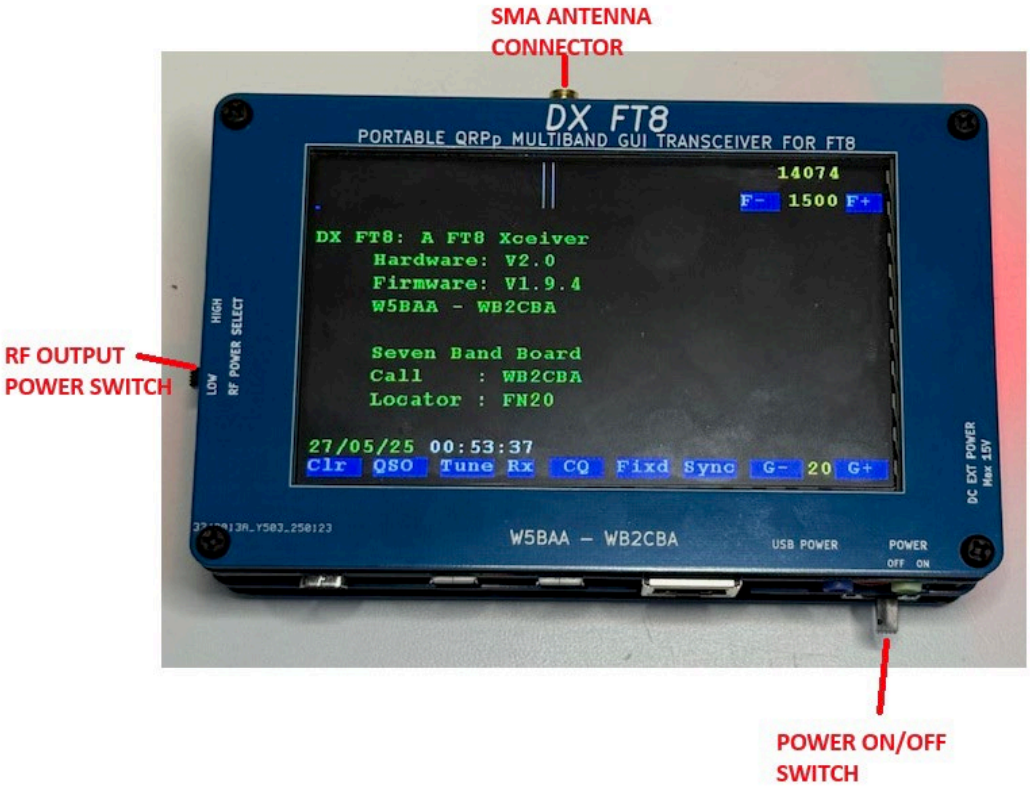
Now using 4 x 6mm screws install bottom plate in place as in this photo:

The side view of your DX FT8 Transceiver should look like this:



This completes DX FT8 Transceiver assembly.

DX FT8 CONTROLS, INPUTS and Outputs

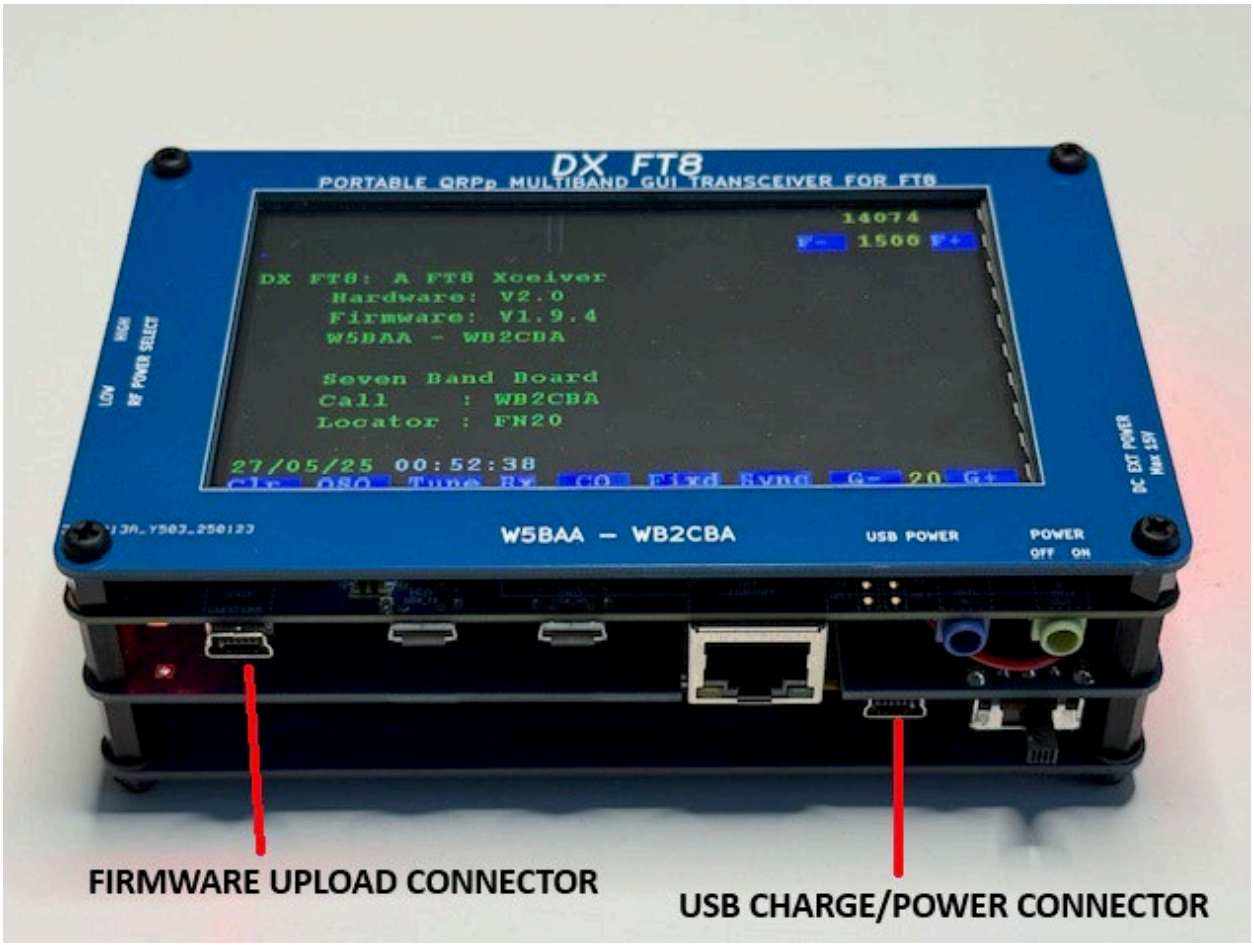


1- ANTENNA OUTPUT SMA JACK.

2- RF POWER SELECT SWITCH – Two levels of RF power output. Low power and High Power can be selected. RF power output table is at the beginning of this manual.

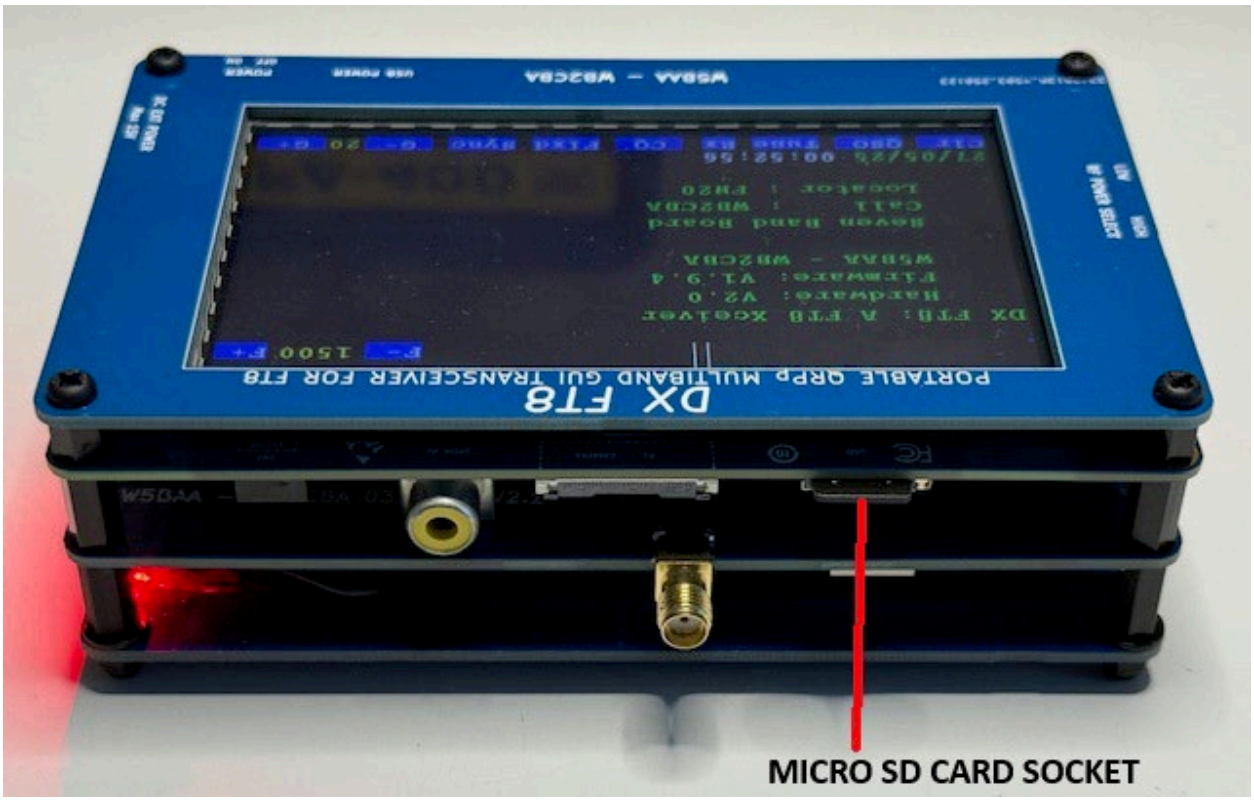
3- POWER ON/OFF SWITCH – This switch powers DX FT8 Transceiver. DX FT8 Transceiver can be charged/powered externally either from a USB cable connected to a Power bank that can deliver 5 Volts at 1000mAh or from an external DC power source connected to EXT DC POWER INPUT capable of 1000mA from 7 Volts to maximum of 15 Volts. **With this input DO NOT EXCEED 15 Volts!**

4- **DO NOT POWER/CHARGE DX FT8 USING BOTH USB and EXT DC CONNECTOR AT THE SAME TIME!**



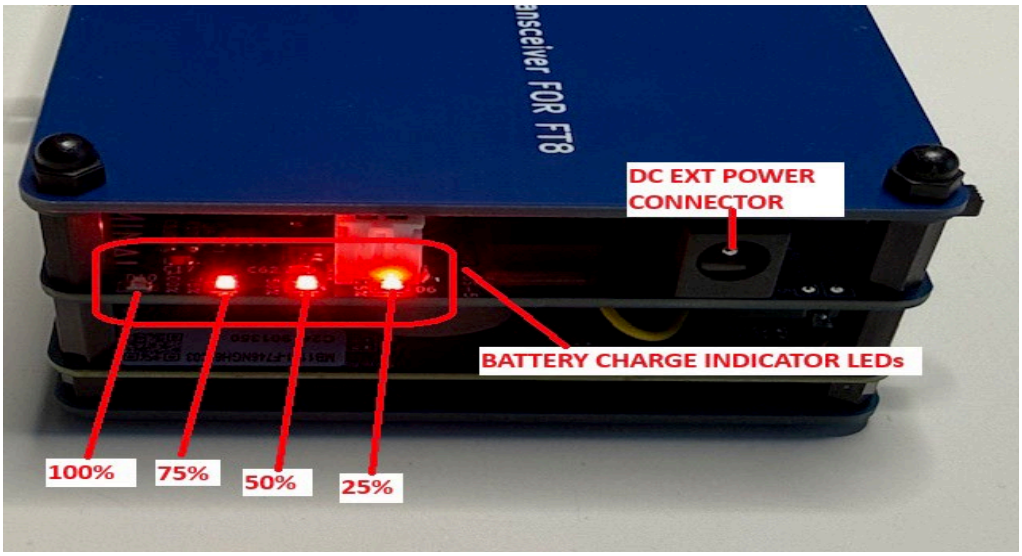
5- USB POWER INPUT – This is Mini USB type USB input for powering DX FT8 with a USB A or USB C to Mini USB cable connected to a 5 Volts 1000 mA rating Power source. **In this input DO NOT EXCEED 5 Volts!**

6- FIRMWARE UPLOAD USB CONNECTOR – Use this mini-USB connector to connect DX FT8 to your PC for uploading Firmware.



7- SD CARD SOCKET – SD Card can be a 2GB or 4GB or any less GB capacity SD Card formatted to FAT32. No need to use a large capacity SD Card as data stored is minimal. SD Card holds station data plus records QSO logs in ADIF Format in order to upload to logging sites.

8- Battery Charge indicator LEDs:



9- **BEFORE Operating DX FT8 now it's time to program STM32F746 DISCO Board with DX FT8 Firmware. Please read DX FT8 Firmware programming section to learn about How to upload Firmware to DX FT8 Transceiver.**

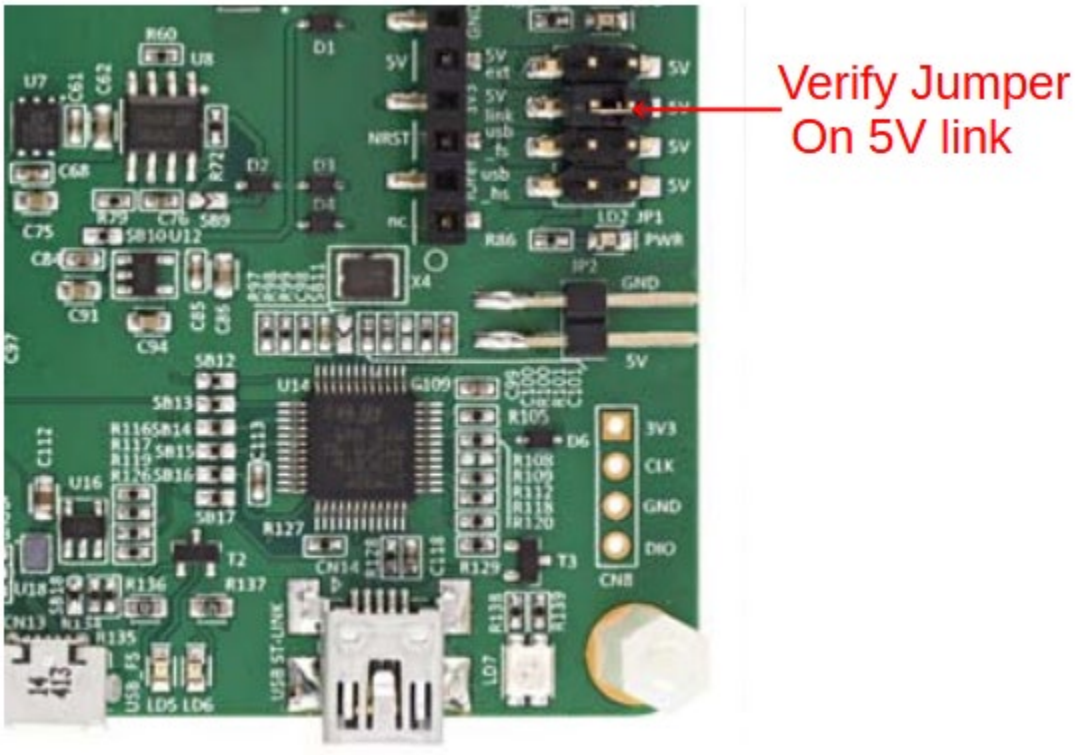
This concludes DX FT8 Transceiver Hardware build.

PROGRAMMING DX FT8 TRANSCEIVER WITH LATEST DX FT8 FIRMWARE

Step 1:
Download and review the STM32F746 User Guide found here:
https://www.st.com/resource/en/user_manual/um1907-discovery-kit-for-stm32f7-series-with-stm32f746ng-mcu-stmicroelectronics.pdf

Step 2:
Download and install "STM32 ST-Link" utility found here:
https://www.st.com/en/development-tools/stsw-link004.html

Step 3:
Make sure that a jumper is installed on JP1 on the 5V link usb pins as shown below:



Connect your computer to the Disco Board via the USB connector shown directly above.
Use the STM32 ST-Link Utility to install the firmware file entitled "DX_FT8_VX.XX.hex" found in this file folder on DX FT8 Github Link:
https://github.com/WB2CBA/DX-FT8-FT8-MULTIBAND-TABLET-TRANSCEIVER/tree/main/DX%20FT8%20FIRMWARE

Step 4:
Format an SD Card in FAT32 format properties and then create and save a file labeled “StationData.ini” which includes your Call Sign and Maidenhead Locator.

When creating **StationData.ini** file use a text editor such as **Notepad** from Windows operating system.

StationData.ini file should contain:

[Station]
<Your Call Sign>
<Your 4 DIGIT Maiden Grid Locator>

An example for valid StationData.ini file content is:

[Station]
Call=WB2CBA
Locator=FN20

This is the minimum data required to operate DX FT8 Transceiver.

In addition to Call and Maiden grid data, there can be three separate sections on StationData.ini to activate other features.

To operate DX FT8 Only the first section [Station] is required. The Call and Locator is configured in this Station section.

In the ‘FreeText’ section, up to two free text messages can be configured.

The final section ‘BandData’ introduces a new feature:
The frequency used by the transceiver for each band can be modified.
The 40M and 20M frequencies only apply to the 7-band transceiver.

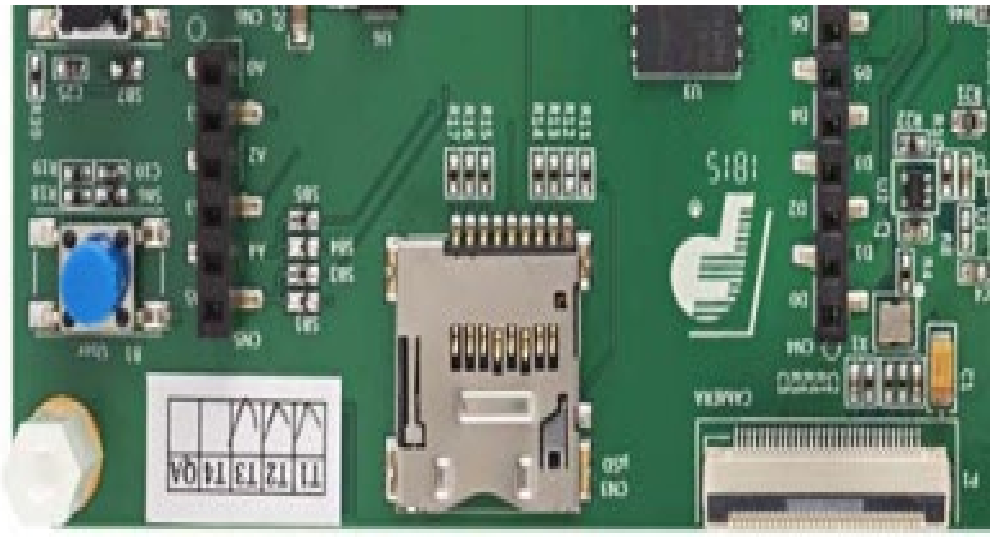
e.g. the Japan domestic FT8 frequency on 40m is 7.041Mhz, so the ‘BandData’ section to configure this would be:

[BandData]
40=7.041

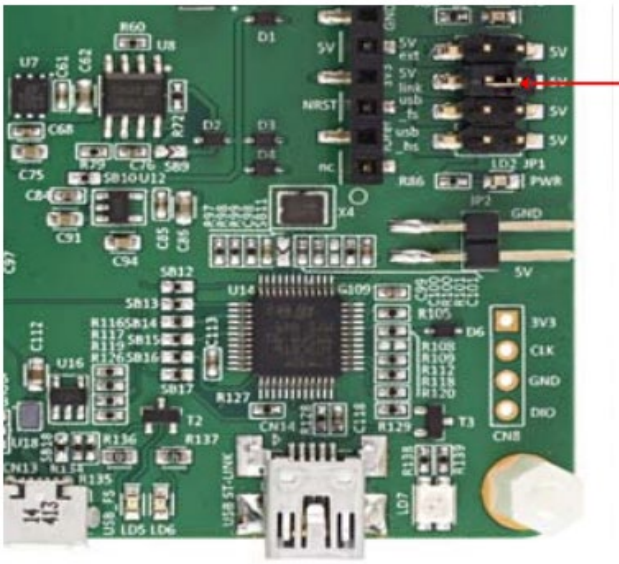
Here is an example StationData.ini file content filled out with all three sections:

[Station]
Call=WB2CBA
Locator=FN20
[FreeText]
1=CQ EU WB2CBA FN20
2=CQ DX WB2CBA FN20
[BandData]
40=7.174
30=10.136
20=14.174
17=18.201
15=21.174
12=24.925
10=28.174

After creating the file on the SD Card, insert the SD Card in the SD Card Connector as shown below:

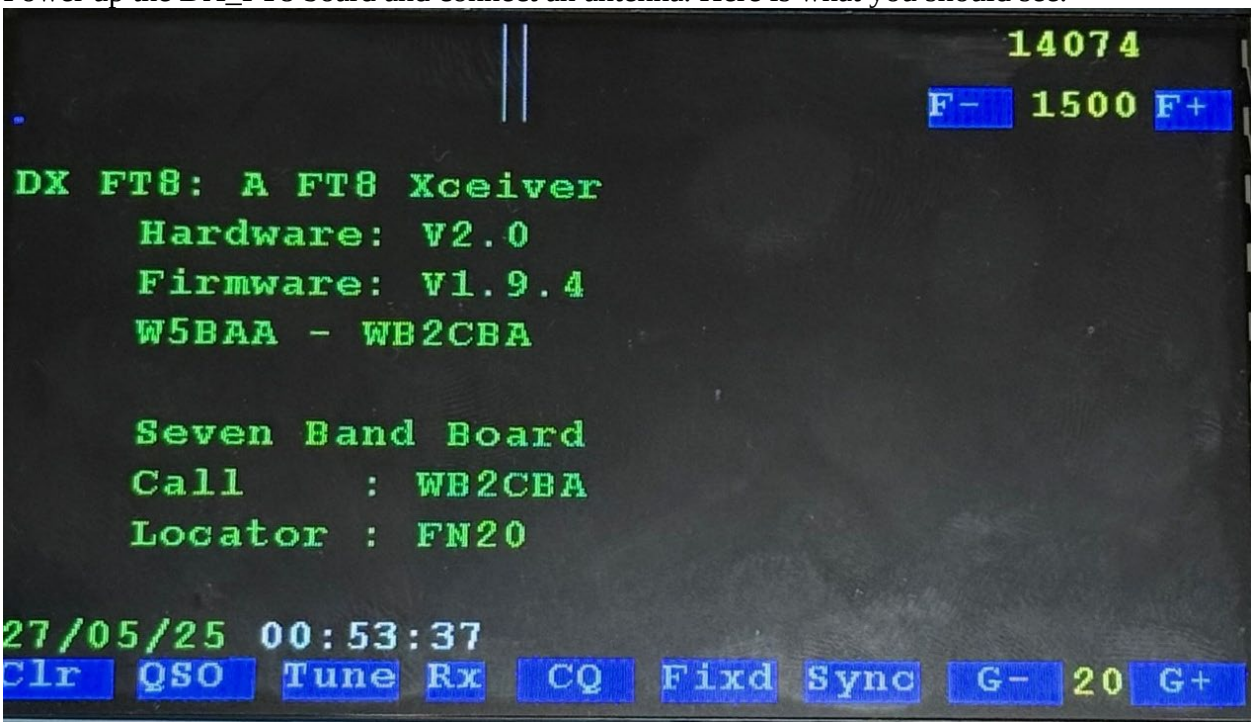


Step 5:

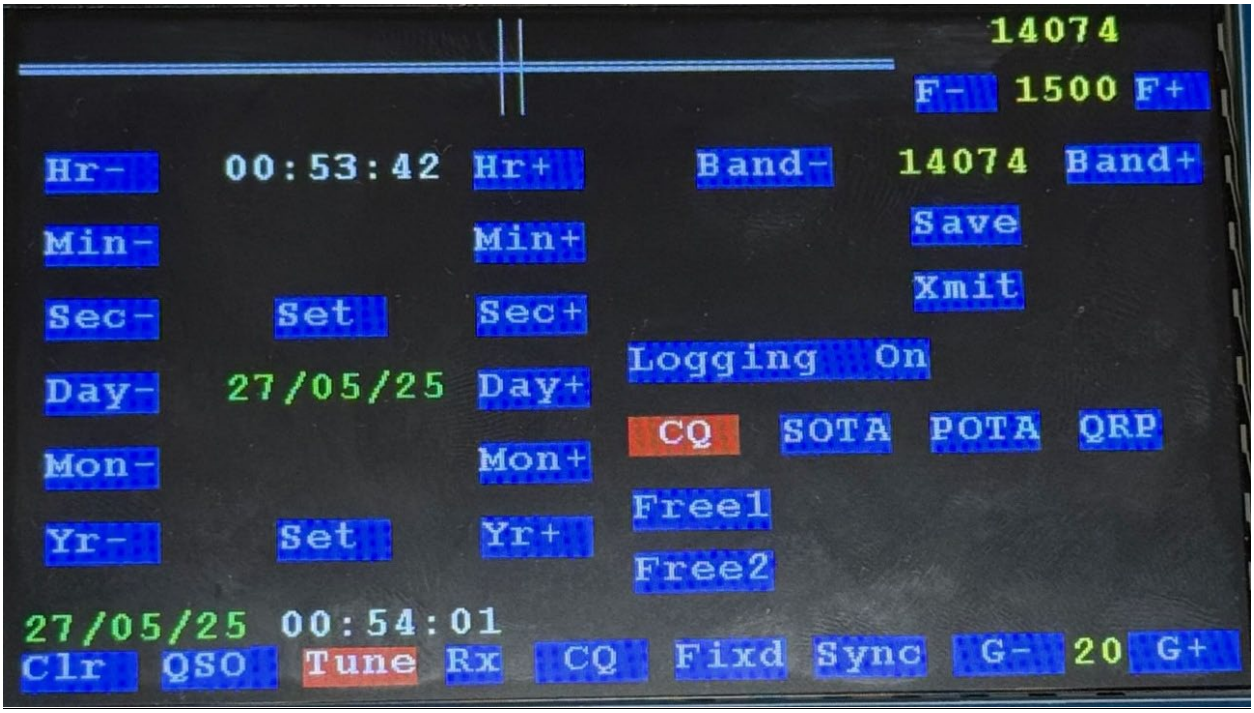


Next, move the jumper on J1 to the 5V ext pins.

STEP 6:
Power up the DX_FT8 board and connect an antenna. Here is what you should see.

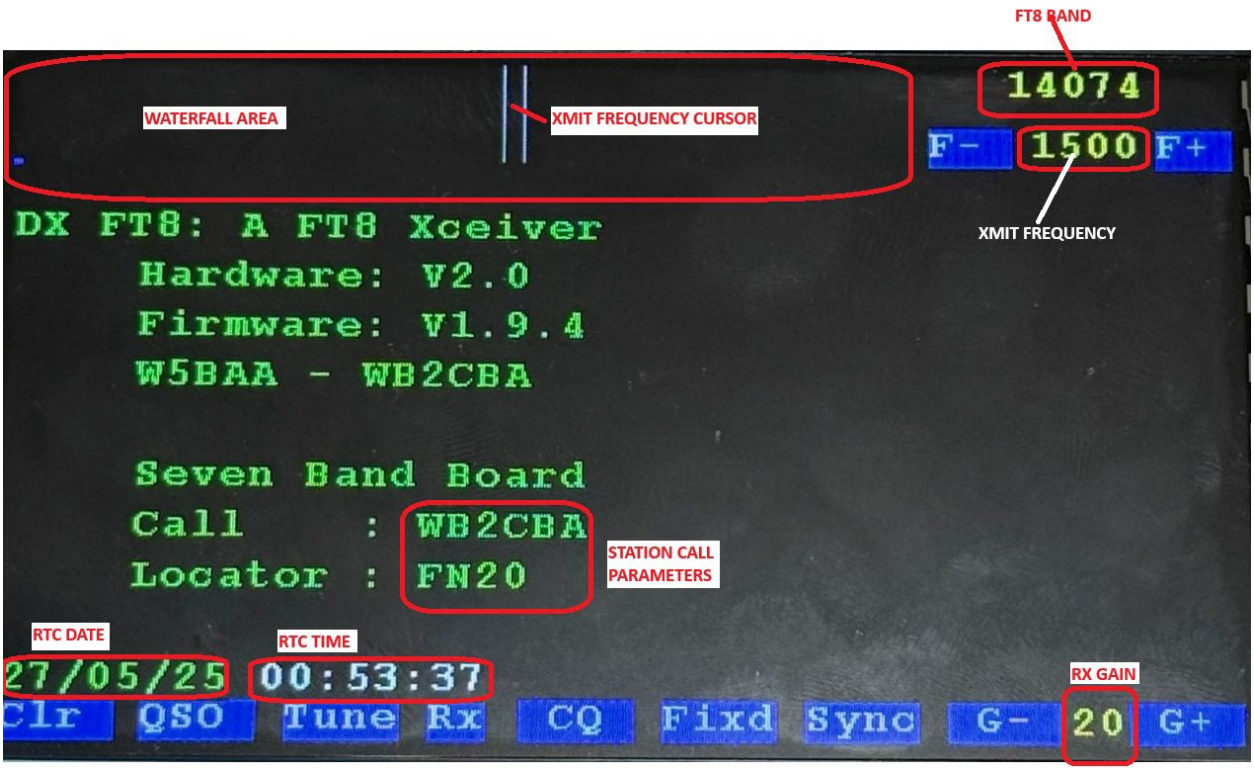


When you touch the Tune Button you will see the following display. Tune screen acts as a configuration screen and enables also to transmit on chosen band for tuning etc.



When you first set up your unit the Real Time Clock (RTC) Date and Time will probably read as 00:00:00 or be blank. You may set the RTC Date and Time by using the Tune screen.

FT8 Operations Display Legend



Clr: Touch to clear FT8 Traffic Display, momentary touch.

QSO: Touch to change FT8 Mode from QSO to Beacon, bi state touch

Tune: Touch to bring up TUNE Screen, bi state touch

Rx: No Touch, indicates either Receive or Transmit Operation

Fixd: Touch to change between Fixd and Rcv, bi state touch. In Fixd Tx is not aligned with QSO station frequency. In Rcv mode TX is aligned with QSO station frequency.

Log: Touch to turn on Logging, bi state touch

Sync: Touch to Synchronize FT8 Reception With Rest of World, turns from RED to BLUE on Sync

G-: Touch to reduce Receiver Gain by 1 dB.

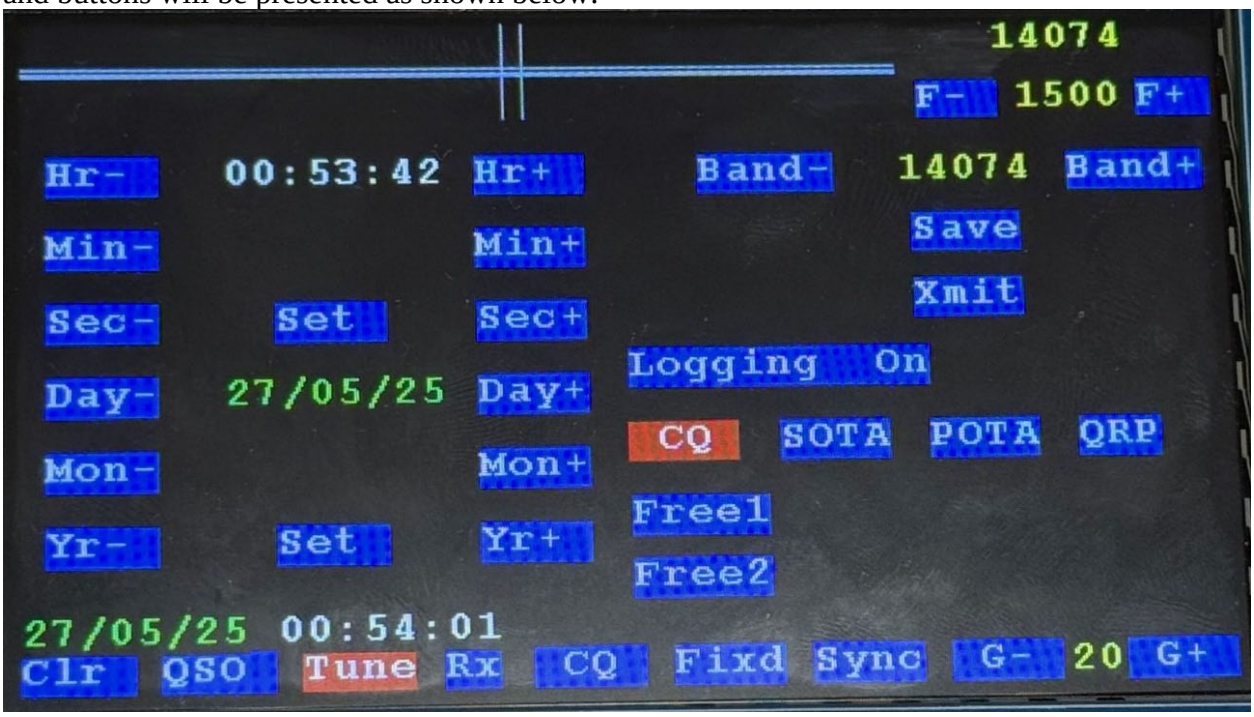
G+: Touch to increase Receiver Gain by 1 dB.

F-: Touch to reduce transmit audio frequency by 6.25 Hz

F+: Touch to reduce transmit audio frequency by 6.25

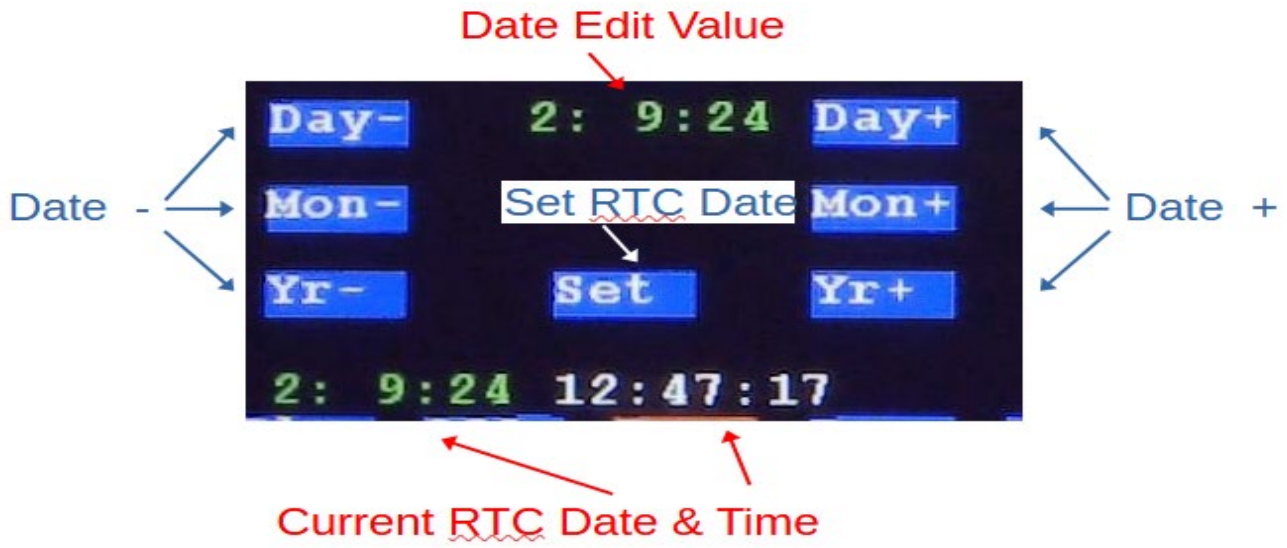
Tune Screen Data and Touch Button Legend

When you touch the **Tune Button** the unit goes into the Tune mode and additional data items and buttons will be presented as shown below:

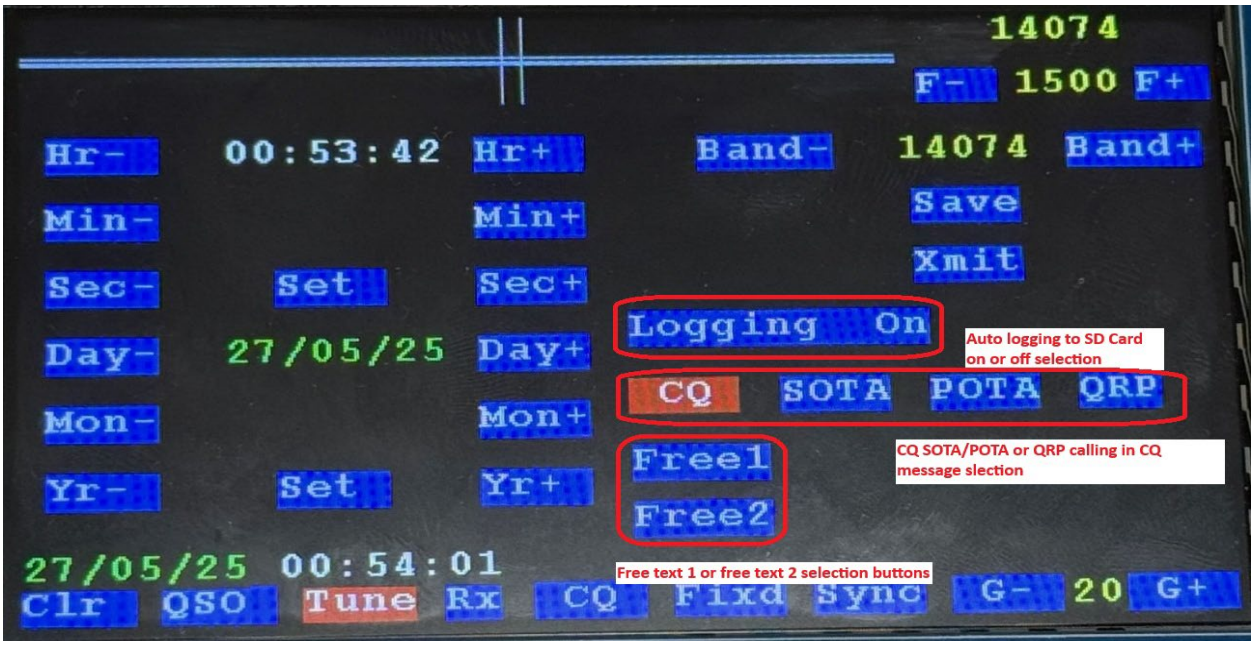


Time Edit Buttons

Date Edit Buttons



Band & Frequency Buttons



AUTO Logging on and off selection:

Auto logging QSO's to SD Card can be enabled or disabled via Logging On/Off button.

CQ/SOTA/POTA/QRP Header additions to CQ Calls:

CQ call message can be tailored as plain CQ call i.e: CQ WB2CBA FN20 or SOTA/POTA/QRP headers can be added by choosing the desired one from one of the buttons. Examples of these calls are:

CQ SOTA WB2CBA FN20

CQ POTA WB2CBA FN20

CQ QRP WB2CBA FN20

FREE TEXT 1 and FREE TEXT 2:

Free1 and Free2 buttons are for activating text that are set up in StationData.ini file for Freetext1 and Freetext2.

Time Synchronization With the FT8 World

In the world of FT8 time synchronization is vital. After various attempts such using GPS Time or pure manual synchronization, a more friendly semi-automatic method has been developed.

With this version of hardware the FT8 signals displayed on the waterfall are quite crisp and there is a very distinct band of no received signals at the end of each FT8 slot as shown below:

If you have noisy conditions and there is white snow at the end of the FT8 slot, use the G- button shown above until there is a distinct lull in signals at the end of the FT8 slot.
Then, press the Sync button and wait.

The software searches for the lull in FT8 traffic and then sets the synchronization and the Sync Button turns BLUE and FT8 messages are decoded.

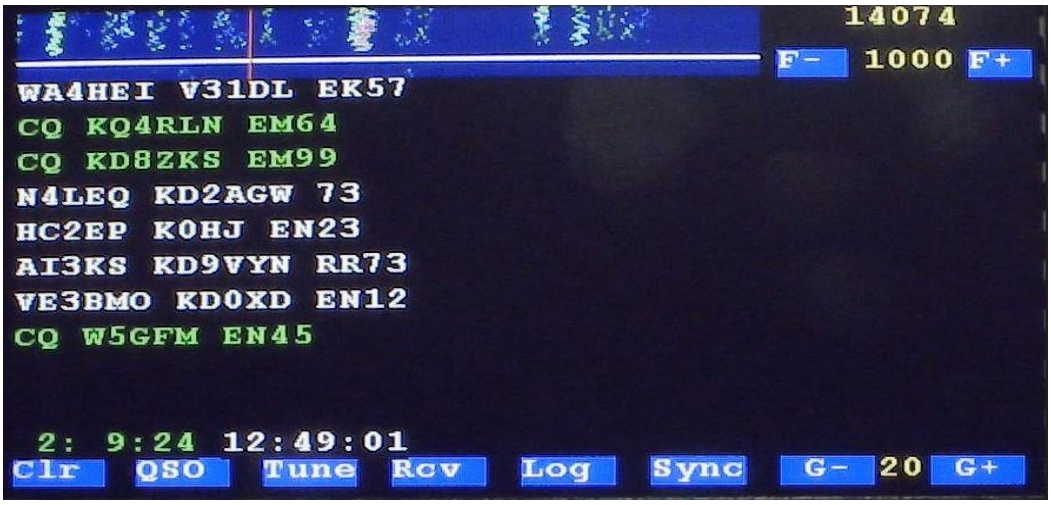
Important Information!!

When FT8 messages and decoded it is important to understand and remember how messages are displayed. There are two panes displayed, one on the left and one on the right. The Left Pane displays
Live FT8 Traffic. The Right Pane shows messages you generate or are sent to your Call Sign.

Using The QSO Mode of Operation
When in the QSO Mode all outgoing FT8 Messages are generated by the user using software tools.

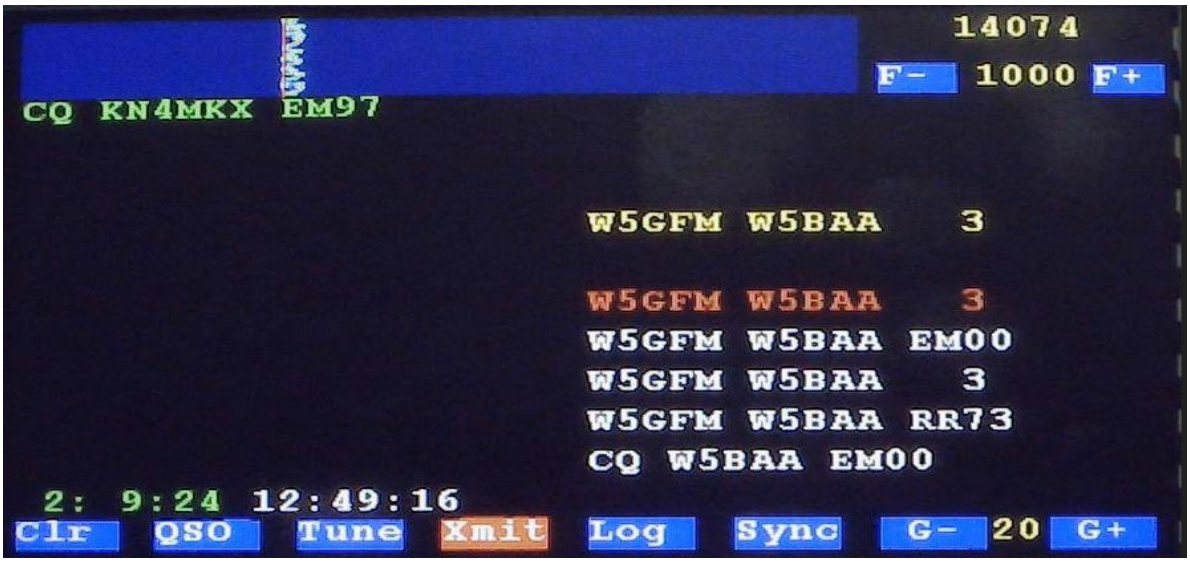
To generate an FT8 message select a station that you wish to contact by touching their message in the Right Pane. In the figure below the user sees that W5GFM is calling CQ and wishes to contact this station by touching the message “CQ W5GFM EN45” message.

The user is then presented with the messages shown below:



In this example, the user decides to send the “W5GFM W5BAA 3” message by touching the software generated message displayed in the Right Pane.
The selected message is “Qued Up” for transmission and is shown in RED and logged in the short term traffic log shown in YELLOW.

The Qued UP message is then automatically transmitted in the next FT8 Slot. Please see the figure below which shows the “Off The Air” receipt of the message transmitted in the Left Pane and the Qued Up message in RED is erased.



Beacon Mode of Operation

To enter the Beacon Mode of Operation touch the QSO button. You will see that the button turns RED and the button legend says “Becn”. The unit will stay in the Beacon Mode until you touch the QSO / Beacon button again.

Beacon mode is an automated mode which calls CQ, completes QSO with replying parties and logs automatically without any operator input.

The software requires that FT8 messages be decoded before transmitting a CQ message. The software will transmit a CQ then listen for a reply. If no one calls, another CQ message is transmitted.

When a station replies to your CQ, a message giving the calling station a signal report is transmitted.

If the calling station replies again, a RR73 message is transmitted.

When the software no longer sees stations calling your station call, it will then start calling CQ again.

Please see an example of the display of FT8 traffic while in the Beacon Mode. The display is a temporary log of the FT8 messages sent and received. Up to 10 messages are displayed with the oldest
message at the top of the list and most recent at the bottom of the list.

Logging Function

To turn on the logging function from Tune screen to automatically start logging QSO.

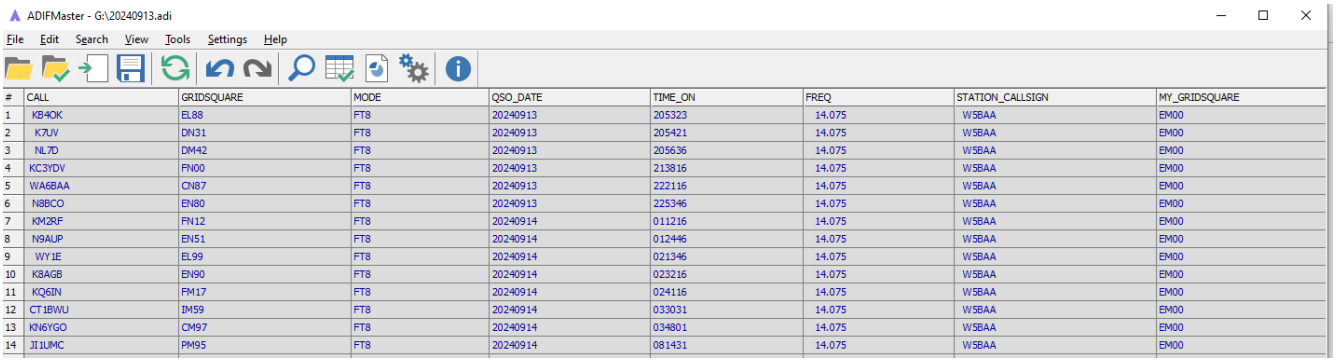
Logging works while operating in the QSO Mode or Beacon mode. When an FT8 contact is made, the contact is not logged until either a 73 or RR73 message is received from the target station.

The name of the log file will be the current RTC date. The log data is stored in an ADIF format and given the extension ".adi". An example filename is "20200902.adi.

The filename is made using the current Date.

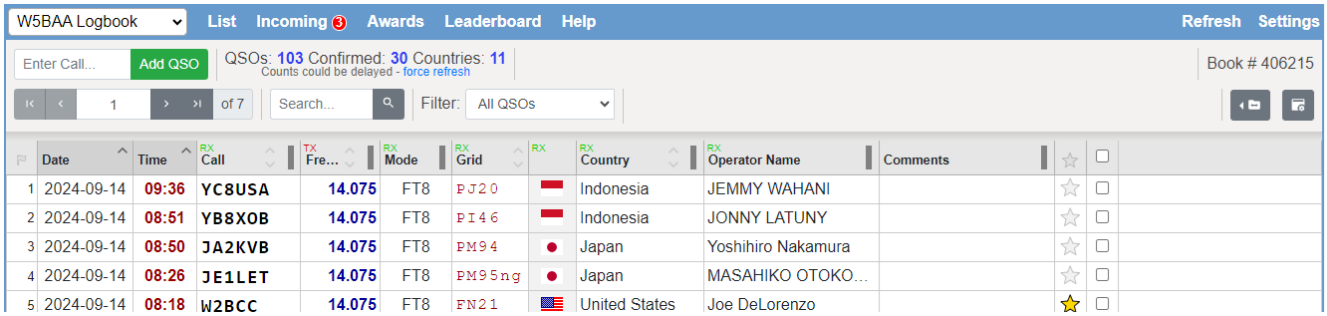
On a given day, the same filename will used for all log entries until the date is changed by the RTC.
An ADIF file may be displayed and edited by the ADIF viewer ADIFMaster which may found at this location: https://www.dxshell.com/

Please see an example of a log file's contents below:



#	CALL	GRIDSQUARE	MODE	QSO_DATE	TIME_ON	FREQ	STATION_CALLSIGN	MY_GRIDSQUARE
1	KB4OK	EL88	FT8	20240913	205323	14.075	W5BAA	EM00
2	K7UV	DN31	FT8	20240913	205421	14.075	W5BAA	EM00
3	NL7D	DM42	FT8	20240913	205636	14.075	W5BAA	EM00
4	KC3YDV	FN00	FT8	20240913	213816	14.075	W5BAA	EM00
5	WA6BAA	CN87	FT8	20240913	222116	14.075	W5BAA	EM00
6	N8BCO	EN80	FT8	20240913	225346	14.075	W5BAA	EM00
7	KM2RF	FN12	FT8	20240914	011216	14.075	W5BAA	EM00
8	N9AUP	EN51	FT8	20240914	012446	14.075	W5BAA	EM00
9	WY1E	EL99	FT8	20240914	021346	14.075	W5BAA	EM00
10	K8AGB	EN90	FT8	20240914	023216	14.075	W5BAA	EM00
11	KQ6IN	FM17	FT8	20240914	024116	14.075	W5BAA	EM00
12	CT1BWU	IM59	FT8	20240914	033031	14.075	W5BAA	EM00
13	KN6YGO	CM97	FT8	20240914	034801	14.075	W5BAA	EM00
14	JI1UMC	PM95	FT8	20240914	081431	14.075	W5BAA	EM00

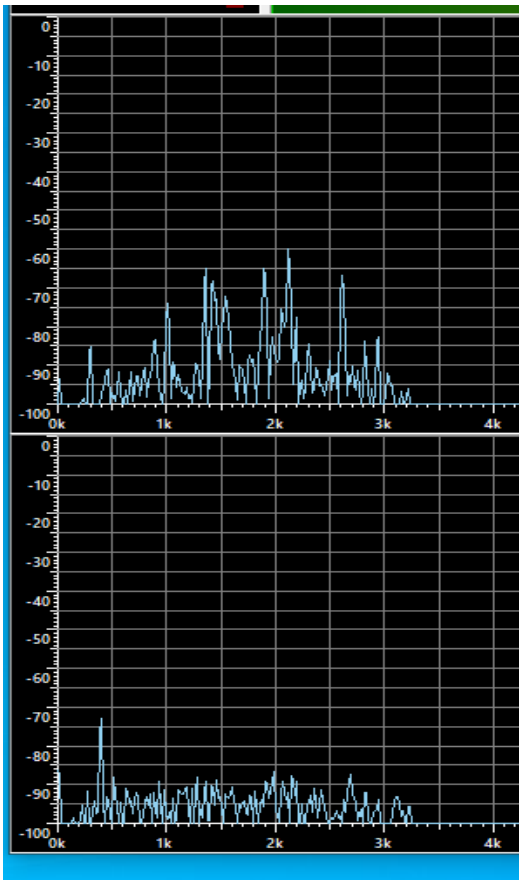
Further, the log file may be uploaded to your QRZ Logbook found here: https://logbook.qrz.com/logbook.
For example:



	Date	Time	RX Call	TX Fre...	RX Mode	RX Grid	RX	RX Country	RX Operator Name	Comments
1	2024-09-14	09:36	YC8USA	14.075	FT8	PJ20		Indonesia	JEMMY WAHANI	
2	2024-09-14	08:51	YB8XOB	14.075	FT8	PI46		Indonesia	JONNY LATUNY	
3	2024-09-14	08:50	JA2KVB	14.075	FT8	PM94		Japan	Yoshihiro Nakamura	
4	2024-09-14	08:26	JE1LET	14.075	FT8	PM95ng		Japan	MASAHIKO OTOKO...	
5	2024-09-14	08:18	W2BCC	14.075	FT8	FN21		United States	Joe DeLorenzo	

Monitoring Receiver Audio Output

The demodulated signal audio output may be observed via the Green 3.5 mm stereo audio jack, CN10. The top audio spectrum is the received Upper Sideband audio and the bottom spectrum is the Lower Sideband audio. Please note the excellent unwanted sideband suppression from DX FT8 board.



A nice tool for observing the audio output is an application called “Goldwave” which may be found
here: https://goldwave.com/

Extra Benefits

One of the key benefits of the STM32F746 board that has significantly contributed to the success of the DX FT8 project are the ARDUINO connectors shown below. All signals except for the IQ Audio signals required for this project are made thru these connectors. Also the required power connections are made thru these connectors.

Table 5. ARDUINO® connectors (CN4, CN5, CN6 and CN7)

Left connectors						Right connectors				
CN No.	Pin No.	Pin name	STM32 pin	Function		Function	STM32 pin	Pin name	Pin No.	CN No.
						I2C1_SCL	PB8	D15	10	CN7 digital
						I2C1_SDA	PB9	D14	9	
						AVDD	-	AREF	8	
						Ground	-	GND	7	
CN6 power	1	NC	-	-		SPI2_SCK	PI1	D13	6	
	2	IOREF	-	3.3V Ref		SPI2_MISO	PB14	D12	5	
	3	RESET	NRST	RESET		TIM12_CH2, SPI2_MOSI	PB15	D11	4	
	4	+3V3	-	3.3V input/output		TIM1_CH1	PA8	D10	3	
	5	+5V	-	5V output		TIM2_CH1	PA15	D9	2	
	6	GND	-	Ground		-	PI2	D8	1	
	7	GND	-	Ground		-				
	8	VIN	-	Power input		-	PI3	D7	8	CN4 digital
-						TIM12_CH1	PH6	D6	7	
CN5 analog	1	A0	PA0	ADC3_IN0		TIM5_CH4,SPI2_NSS	PI0	D5	6	
	2	A1	PF10	ADC3_IN8		-	PG7	D4	5	
	3	A2	PF9	ADC3_IN7		TIM3_CH1	PB4	D3	4	
	4	A3	PF8	ADC3_IN6		-	PG6	D2	3	
	5	A4	PF7 or PB(1)	ADC3_IN5 (PF7) or I2C1_SDA (PB9)		USART6_TX	PC6	D1	2	
	6	A5	PF6 or PB8(1)	ADC3_IN4 (PC0) or I2C1_SCL (PB8)		USART6_RX	PC7	D0	1	

1. Refer to *Table 12* for details.