

Shirehampton A.R.C. WSPR Transmitter Mk2

Hardware- G3YHV
Software – G3YHV/G0CJG



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1. Weak Signal Propagation Reporter - WSPR

One of the things that makes communicating with amateur radio more fun than using the Internet or the phone is that you never know where your signals will be received. Short wave radio propagation is never completely predictable and can often surprise you.

WSPR (pronounced “whisper”) is a data mode that enables you to participate in a world-wide network of low power propagation beacons. WSPR enables your radio transmitter to transmit beacon signals, and your receiver to receive beacon signals from similarly equipped stations in the same amateur band. The beacon transmission consists of your callsign, Maidenhead locator square and power output in dBm using a compressed data format with forward error correction and narrow-band 4-FSK tones. Participating stations upload spots they receive in real time to a web server, you can find out within seconds of the end of each transmission exactly where and how strongly it was received, and even view the propagation paths on a map.

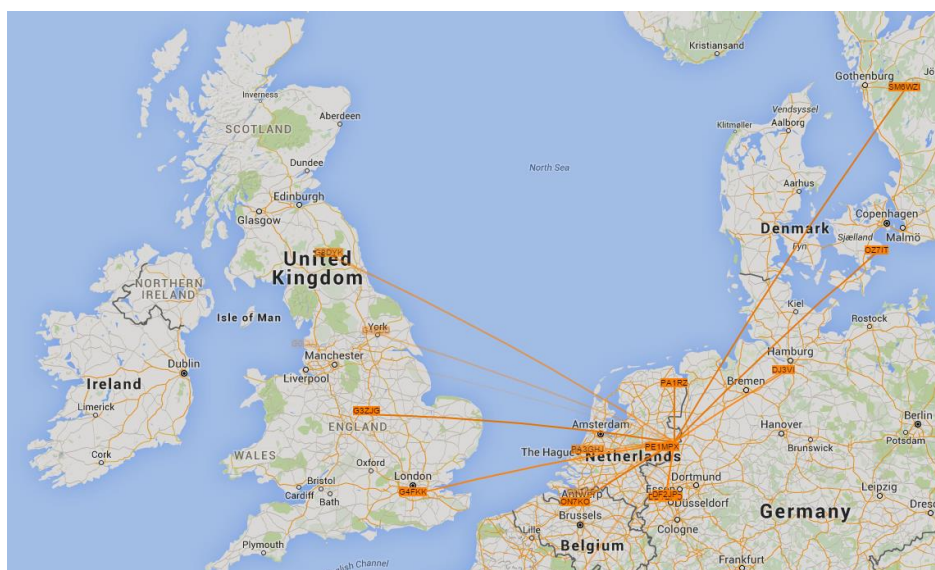


Figure 1 - WSPR Map

If you leave the WSPR TX running while you were doing something else, you can search the database (<http://wsprnet.org/drupal/wsprnet/spots>) to find out later where your signals were received during the day. You can analyse old signal reports to see the effect of daily and seasonal propagation changes or antenna improvements.

More information about WSPR and the software can be found at <http://physics.princeton.edu/pulsar/K1JT/doc/wspr/wspr-main.html#INTRO>

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2. Project Overview

This kit will enable you to construct a WSPR Transmitter capable of running 20mW to 100mW on all the HF bands (including WARC) from 1.8 to 30Mhz. The project is built on the original SARC WSPR TX which was lower power, had fewer features and was constrained by the capacity of the PIC chip.

The software complies with WSPR Type 1 and Type 2 special messages format which are explained later in this document and here (<https://physics.princeton.edu/pulsar/K1JT/doc/wspr/wspr-main.html>)

The software has been developed using Proton (Positron) Basic and the only way it can be upgraded or changed is by re-programming the PIC chip. The clock is backed up using a battery in the RTC module. All other configuration settings preserved using the NVRAM on the chip unless stated otherwise. The version/release of the software is shown when the TX is first powered up.

The initial setup requires you to enter a minimum of your callsign, locator, band, and time. There are also some steps to undertake for calibration as components have varying tolerances.

Once the initial setup is complete any other changes other than the band are down to personal preferences. As the time is managed using a real time clock module there should be no requirement to change this unless the battery goes flat, or you decide to reset all the NVRAM settings.

This unit has been well tested, and results shared around SARC members over the last few months. The antenna will be your key to success with this kit. SARC will be running several competitions during 2021 so all users of the kit can share their experiences.

As there was some spare capacity in the PIC chip there is also a CW practice feature!

The PCB board dimensions are 10cm x 7cm (4" x 2¾") for the purposes of sizing a case. All the key components are provided other than a box and a power supply which are down to you!

It is strongly advised you to read all this document before starting assembly as you may wish to make some decisions around how certain parts are assembled.

If you are not purchasing this as the original kit great care must be taken to order the correct display and other modules for compatibility.

If there are any queries or issues during construction, please contact Colin colin@chidgey.co.uk



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3. Circuit Diagram

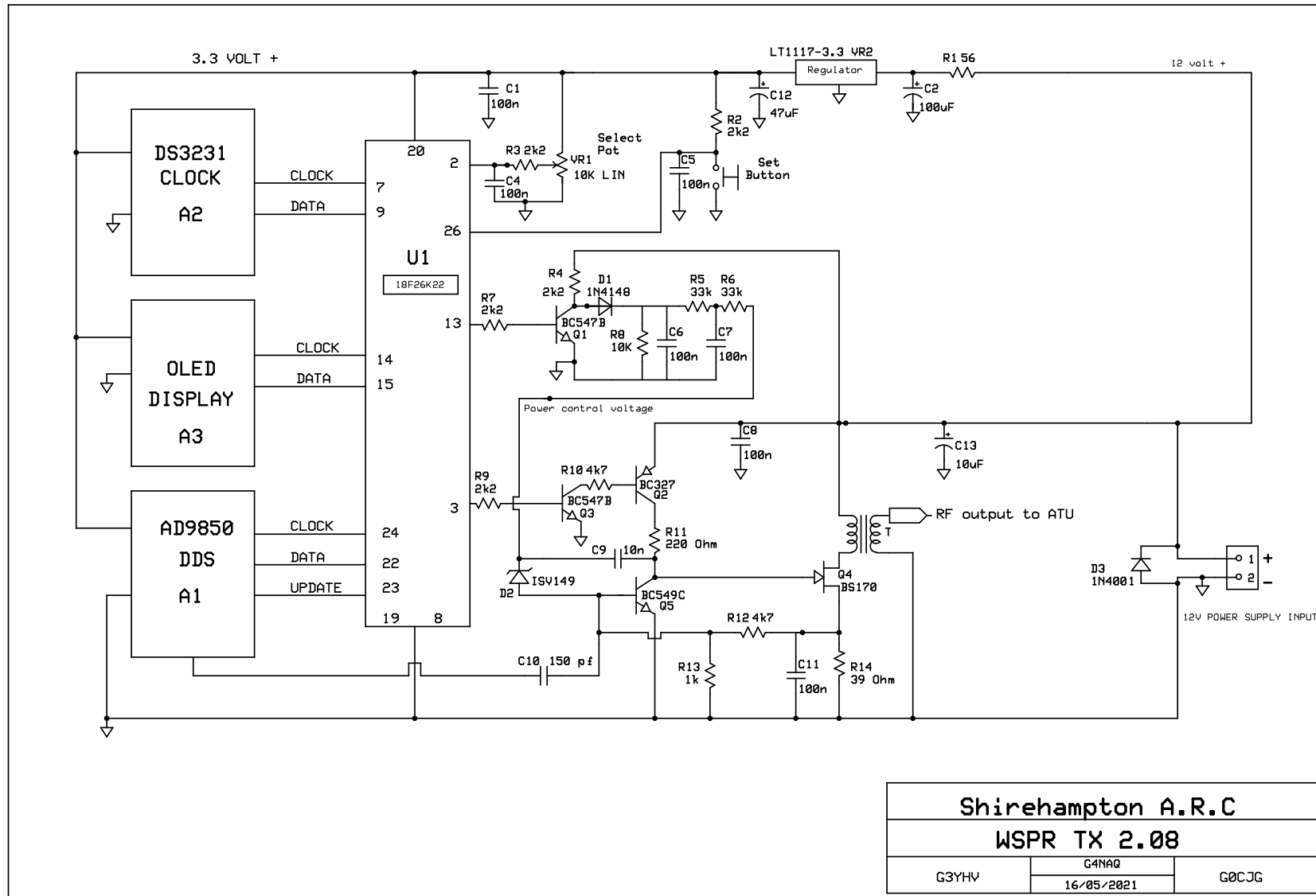


Figure 2 - Circuit Diagram

4. Components List

Supplied	Not Supplied
<p>Capacitors</p> <ul style="list-style-type: none"> 1 * 150pF (C10) - marked 151 1 * 10nF disc ceramic (C9) – marked 103 7 * 100nF disc ceramic (C1, C4, C5, C6, C7, C8, C11) -- marked 104 1 * 10uF 16v electrolytic capacitor (C13) 1 * 47uF 16v electrolytic capacitor (C12) 1 * 100uF 16v electrolytic capacitor (C2) <p>Diodes</p> <ul style="list-style-type: none"> 1 * 1N4001 diode (D3) 1 * 1N4148 diode (D1) 1 * ISV149 varicap diode (D2) <p>Resistors (all 1/8 watt unless stated)</p> <ul style="list-style-type: none"> 1 * 39Ω (R14) 1 * 56Ω 0.5w (R1) 1 * 220Ω (R11) 1 * 1k (R13) 5 * 2k2 (R2, R3, R4, R7, R9) 1 * 10k (R8) 2 * 33k (R5, R6) 2 * 4k7 (R10, R12) 1 * 10k pot (VR1) <p>Transistors</p> <ul style="list-style-type: none"> 1 * BC327 (Q2) 1 * BC549C (Q5) 2 * BC547B (Q1 & Q3) 1 * BS170 (Q4) <p>IC's</p> <ul style="list-style-type: none"> 1 * pre-programmed 18F26K22 PIC chip (U1) <p>Modules</p> <ul style="list-style-type: none"> 1 * DDS AD9850 module (A1) 1 * DS3231 clock module (A2) 1 * OLED display module SSD1306 i2c 128x64 Dot Matrix (A3) <p>Miscellaneous</p> <ul style="list-style-type: none"> 1 * Knob for VR1 (H1) 1 * FT37-43 toroid (T) pre-wound 2 * 20 pins to create 2 * 14 pin socket for PIC chip (P1) 1 * 40 pin PCB Header socket to create <ul style="list-style-type: none"> - 2 * 10 pin PCB Header socket for DDS (A1) - 1 * 6 pin PCB Header socket for RTC (A2) – see RTC 1 * 2 pin PCB Socket for power (P4) 1 * 4 pin Header pins for OLED display (P5) 1 * Push Button Switch (S1) 1 * SPST switch (S2) 1 * LT1117 3. 3v regulator SMD (VREG1) – pre-fitted on rear 1 * SMA Antenna Socket (X1) 1 * Heatsink for BS170 (X2) – pre-fitted 1 * Polyfuse 1206 500mA SMD (F1) – pre-fitted on rear 1 * CR2032 battery for RTC 1 * 10cm SMA to chassis BNC socket for external antenna connection 	<p>Chassis</p> <p>Chassis Rear Panel</p> <ul style="list-style-type: none"> 1 * Power Socket/Lead <p>Optional: (not supplied)</p> <ul style="list-style-type: none"> 4-way Dupont Cable M-F Display to PCB (X3) or wire from display to PCB

Figure 3 - Components List

4.1. Display Module

There are a number of different variations of the SSD 1306 module available, but the software has been written to use the 0.96" 128x64 version with the I2C bus connection. You will need to provide your own connection from the board to the display.

Chassis hole for display module is 27mm/1.06" high and 29mm/1.14" wide.

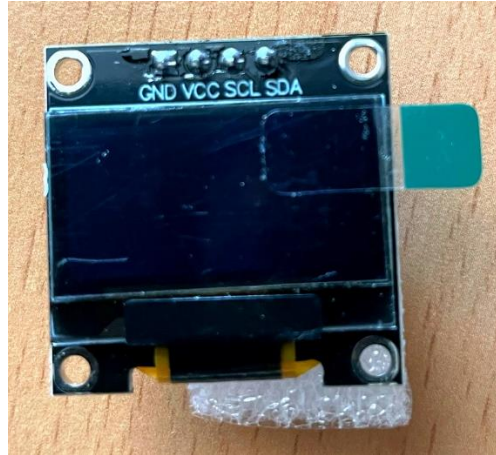


Figure 4 – SSD1306 i2c OLED Display

Wiring the display module: -

- 4 header pins provided if you wish to use a cable between the board/display. You may need to drill out these sockets a very small amount as the holes are a bit too small.
- Take care as the circuit board pin order may be different to the display panel order! (below are the pin connections for those supplied with the kit)

Display Connections	GND	VCC	SCL	SDA
Board Connections	VCC	GND	SCL	SDA

Figure 5 - OLED Connections

4.2. DDS Module

The DDS module is supplied with a set of pins which must be soldered to the bottom of the DDS board.

The kit includes a 40-pin strip of 2.54mm Female header which needs 2 x 10 sockets to be cut and fixed to the top of the main board. Fit the DDS with the LED at the bottom left of the board. It is advised to use the sockets as you may want to extract the board one day for another project.



Figure 6 – AD9850 DDS Module

4.3. PIC

The PIC chip is supplied pre-programmed and should show version 2.12 when the unit is powered on.

4.4. RTC Module

The RTC module is supplied with a set of pins which must be bent carefully through 90 degrees to fix into the board. Fit the supplied battery into holder with the +ve side facing upwards.

Either solder the RTC module directly into the board or use the remaining section of a 40-pin strip of 2.54mm female header to create a 6-pin socket to be cut and fixed to the top of main board. If you use a socket, it may also benefit from some support (not provided) as it will be suspended on the board.

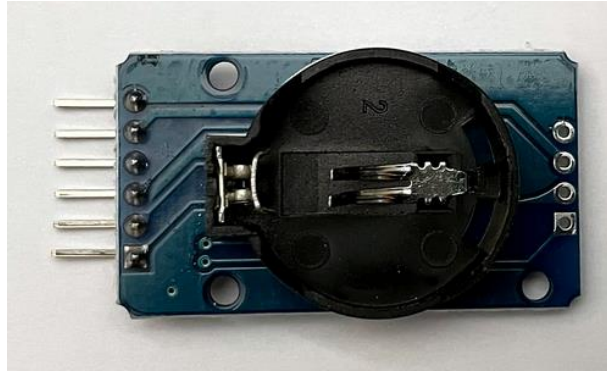


Figure 7 – DS3231 RTC Module

4.5. Power Supply

The power supply to the main board can be between 12-13.8v DC. The power consumption ~80mA in standby and ~240mA during transmissions at any power setting because the PA is in class A.

4.6. Toroid

If the toroid needs to be wound it requires 5 turns of twisted wire – one winding to the left of the PCB and the other towards the right. Install the toroid with the 2 wires of the same colour on the same side (i.e., left, or right side when the board is horizontal)

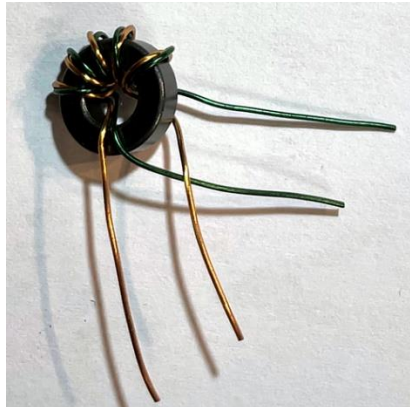


Figure 8 - Toroid

5. Construction

Construction sequence is down to you and these notes are here for guidance.

Last Minute Notes:

- **Board marking errors: -**
 - There are 2 capacitors marked 10 μ f on the board. The one near the regulator is 100 μ f.
 - Q2 – board is marked BC337 and should be BC327
- You may end up with a spare 10k resistor or be a 2k2 resistor short! The resistor below the AD9850 on the board marked 2k2 can be populated with the 10k or the 2k2 resistor and should not be a problem.
- C3 (100nf) has been removed from the circuit.
- Pre-installed / prepared components.
 - 2 SMD devices which are fitted to the bottom of the board.

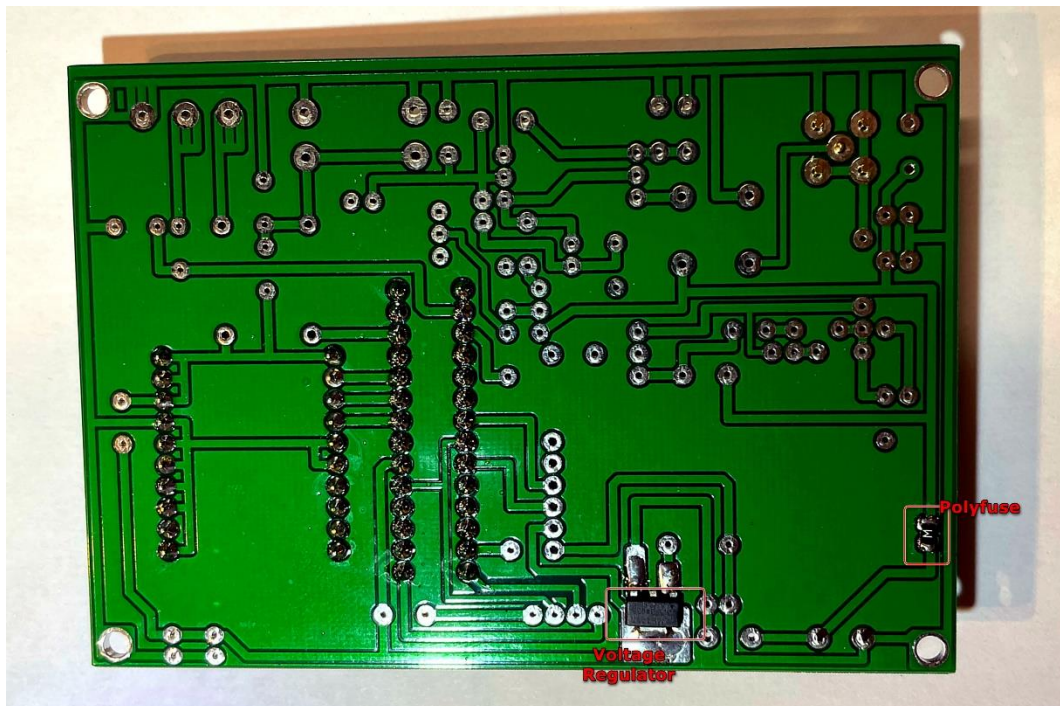


Figure 9 - Underside view with pre-installed components

- Components to be fitted.
 - Setting control VR1 can be optionally mounted on the board as pin spacing is correct. If you choose to do this it may be advisable to use some hot melt glue to provide support.
 - The BS170 transistor comes with a heat sink attached. The transistor can be mounted using the header pins used for the PIC chip or directly into the board. Whilst you could install the transistor without a heatsink it will get quite hot.
 - The toroid (if supplied pre-wound) can be soldered directly into the board without further scraping.
 - The varicap diode has no markings but looking down from the top the longer flat edge should face the antenna socket / pa.



Figure 10 - Varicap Diode Top View

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- Step 1 – Install sockets / headers / pins.



Figure 11 - Pins & Header Sockets

- When soldering in the PIC chip and DDS sockets, solder one pin first and check the alignment is vertical - if you solder them all you are unlikely to be able to correct it afterwards.
- 2 * 14 pin sets of pins required for the PIC chip socket – 2 strips of 20 supplied
- 2 * 10 pin header sockets required for the DDS
- 1 * 4 pin header socket required for the display (unless you wish to wire directly into the board)
- Power connector
- SMA Antenna socket

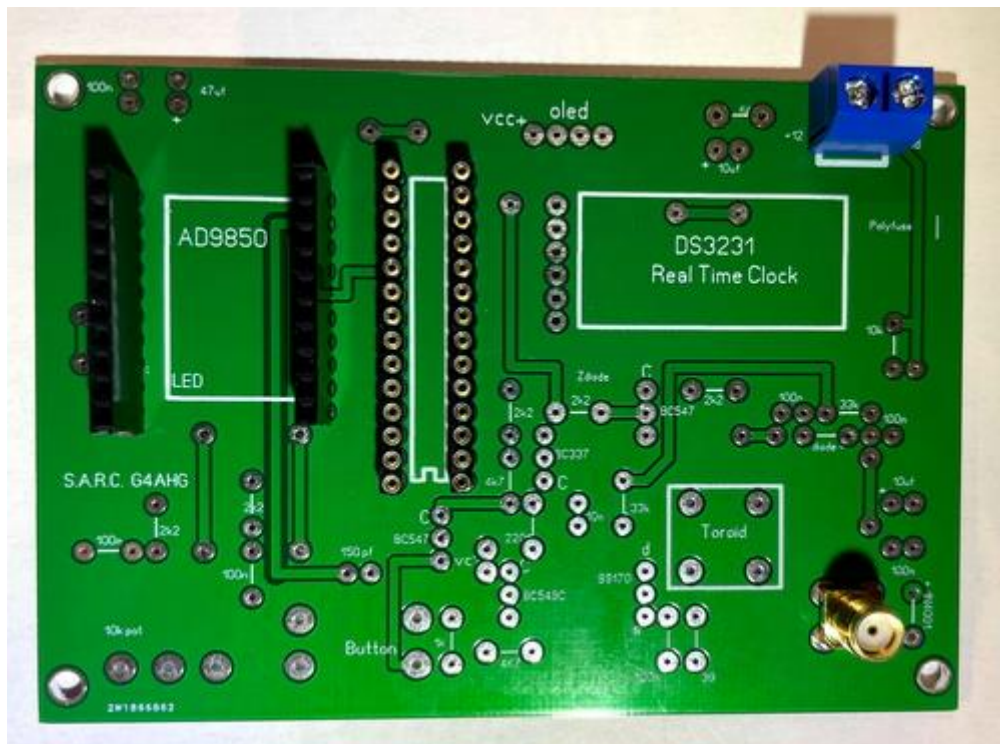


Figure 12 – End of Step 1 board

- Step 2 – Install passive components.
 - Diodes
 - Resistors
 - Capacitors
 - Inductor
- Step 3 – Install Transistors/ IC /Modules.
 - Note the orientation of one transistor next to the PIC chip.

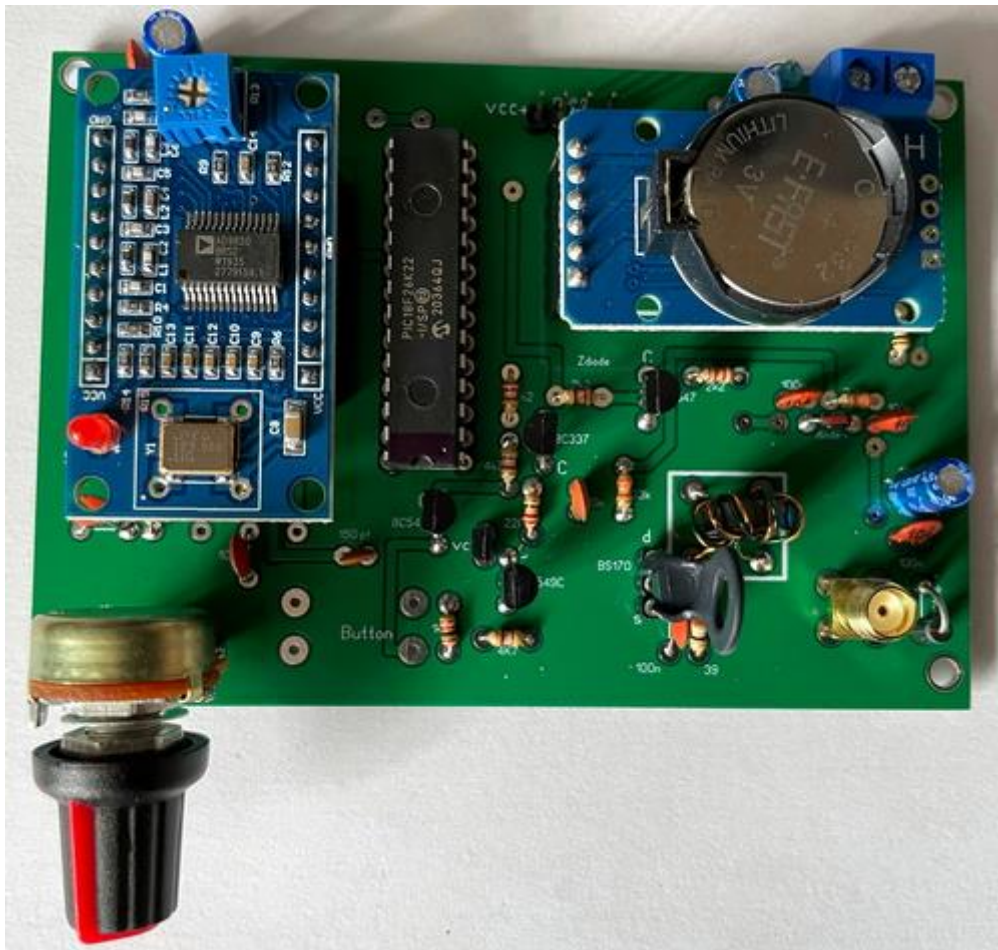


Figure 13 – Fully assembled board

- Off Board Components supplied.
 - Front Panel
 - OLED Display – no wiring supplied but suggest Dupont cable might be easiest.
 - SPST power switch
 - Push button – note this can be wired to either set of vertical aligned pins on the board
 - Rear Panel
 - An antenna lead is supplied to take the SMA board socket to your chassis which is approximately 10cm long.
 - A 2-pin header is supplied for the power connection to take out to the chassis rear.

6. Configuration

The transmitter software has been designed so the user can amend all the critical settings for WSPR operation and in addition some features requested by club members.

There are only 2 controls on the front panel.

The settings button which is used to invoke menus and to acknowledge all settings.

The setting knob is used to scroll through the available values for each setting.

There are also 2 menus.

The settings menu which you must use as part of initial configuration and is invoked by holding down the settings button whilst powering up the unit.

The user menu where additional configuration settings are available is invoked by pressing the settings button once the unit has powered and cycled through its current setting screens.

Each of the menus are described in detail in the following sections.

6.1. Initial “splash” Screen

The first screen which will always be shown at power up shows the current Software Version along with the callsigns of the developers.



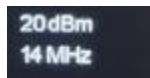
6.2. Power Up Screen Display Sequence

Once the initial configuration is complete any subsequent power up will scroll through the following sequence of screens pausing for a few seconds on each screen.

Callsign/Locator



Power/Band



Current Time / Next TX Time and Transmit Frequency



6.3.Setup Menu

Before you start the setup, you will need.

- A clock or watch showing seconds.
- WSJT-X or other WSPR software installed and able to receive on 28Mhz for calibrating the DDS.

Turn the setting knob to the far left before you start.

If the setting button is pressed at the time of power on the Setup Menu is displayed.

These parameters are updated in conjunction with the setting knob and depending on where the knob is positioned will determine which setting is initially shown.

From left to right the settings are: -

- Set Clock
- Set Callsign
- Set Locator
- Set Power
- Calibrate DDS
- Erase NVM !
- Calibrate TX drive levels
- Setup Finished

6.3.1. Set Clock

The 24-hour clock is set in several stages. Before you start you will need access to a clock or watch with seconds available.

First you will be prompted to set the hour.

Then set the next minute e.g., if your watch shows 17:10 set the minute to 11.

You will then be prompted to press the set button again when the minute reaches “00” i.e., the next minute.

6.3.2. Set Callsign

The callsign field can be up to 6 characters. Each individual character must be set i.e., select the character using the tuning knob then press the setting button. When finished rotating the setting knob to the right and the screen will show “return to the settings menu”, now press the setting button again. If the callsign is NOT set it will show as “CALL?” on the power up sequence.

See “Set Suffix” in the User Menu section for adding a suffix character to your callsign.

6.3.3. Set Locator

Enter a 6-character locator e.g., IO81QL. Each individual character must be set i.e., select the character using the tuning knob then press the setting button. When finished rotating the setting knob to the right and the screen will show “return to the settings menu”, now press the setting button again. If the locator is NOT set it will show as “QRA?” on the power up sequence.

Basic (Type1) WSPR only sends the first 4 characters of the Locator. This unit also supports Type 2 messages which encode the 6-character Locator. See “Set Send Long QRA” in the User Menu section for further information.

6.3.4. Set Power

The unit transmits at three power levels 0, 10 and 20 dBm, selectable in this menu. The power level selected is also coded in the WSPR message.

6.3.5. Calibrate DDS

This compensates for variations in the output RF frequency due to the DDS crystal. Adjust the pot to get the RF output into the centre of the 10mWSPR band.

6.3.6. Erase NVM!

Use with caution as you will have to input all the above configuration settings once again. You will be prompted with an "are you sure message" on the display and you must respond within a few seconds by pressing the set button to confirm the action. This erases all the settings **except** the calibration. If you do not respond promptly the software will reboot, it will also reboot once you confirm the action.

6.3.7. Calibrate TX drive

The design includes a varactor attenuator allowing accurate settings of the output power from 1.8MHz through 28MHz. Initial calibration of each unit is required to compensate for variations in components and construction. Three power levels 0, 10 and 20 dBm are calibrated for each of 10 bands.

The procedure assumes you can connect the unit to a 50Ω load and measure the peak-to-peak voltage of the output waveform. A 30 MHz scope would be more than adequate for this.

In outline, the procedure requests an output level, the user adjusts the pot to reach that level, the user then presses the button to store the setting in NVram and move on to the next setting. There are 30 settings to be made.

UNUSUALLY, the requested output levels are expressed in TENTHS of a volt (dV). The program will request 6dV for 0.6V ptp, 20dV for 2V ptp and 63dV for 6.3V ptp. (In some circumstances you may be asked to enter a level, and this should also be in units of dV)

If you are unable to set the required level (do not press yet!) adjust to the closest you can do (still do not press!) note the dV peak to peak and now press and HOLD until the screen blanks, then release and adjust the pot to show the number of dV you noted, now press to store this information, and move onto the next setting.

(If your PA was only producing 5V (50dV) instead of 6.3V (63dV) clearly you will not be producing the target 100mW (20dBm). We will not modify the "Set Power" menu and you will choose 20dBm (100mW) as before but only get 18dBm. We do however WSPR encode the actual power that you have told us, in this case it would be 17dBm (WSPR only encodes levels of 0, 3, 7, 10, 13, 17, 20 dBm etc). Of course, the actual amount of power coming out of the box depends on the output impedance it is working into.

Finally, if you want to modify a setting (keeping others unchanged) select "Calibrate TX drive levels" as before. At each setting, monitor the scope and if it is OK just press to keep it, otherwise adjust the settings knob, and press the setting button to store the new setting. (Once you adjust the settings knob the old setting is lost). You need to keep going through the complete 30 settings (just a minute or less if you are not changing anything).

6.3.8. Setup Finished

Exit the menu and return to normal operation.

6.4. User Menu

Turn the setting knob to the far left before you start. If the setting button is pressed following the initial display sequence is complete, you can make further adjustments to the configuration. Settings are updated in conjunction with the setting knob and depending on where the setting knob is positioned will determine which setting is initially shown.

From left to right the settings are: -

- Set Tuneupmode
- Set Three Band Hopping
- Set No Hopping
- Set Send Long QRA
- Set Power
- Set Send Suffix
- Set Transmitter % on time
- Set the band
- Set Screenmode
- Morse Practice
- Exit the menu

Turn the settings knob to locate the parameter you wish to update and then press the settings button. The settings knob will now allow you to scroll through the available options. Press the settings button to confirm any changes. Once you exit the menu the transmitter will resume normal operation and transmit on the next interval.

6.4.1. Tune Up Mode

Enabling this feature will put the WSPR TX into transmit for 45 seconds or until you press the button. The display shows a countdown from 255-0.

6.4.2. Three Band Hopping

This option will enable 3 band hopping which will use the current band and the next 2 bands increasing in frequency e.g., if the band is currently set to 7Mhz then at the next TX interval it will step to 10Mhz and then 14Mhz before returning to 7Mhz. This setting is also shown on the screen as part of the power up sequence if enabled.

Note: This feature only works up to 21Mhz i.e., if the band is set to 24Mhz it will “hop” between 24Mhz and 28Mhz but not “hop” to 1.8Mhz and if the band is set to 28Mhz it will not “hop” to another band.

6.4.3. No Hopping

By selecting this option this will disable 3 band hopping mode.

6.4.4. Send Long QRA

This sends a type 2 message including the full 6-character Locator (QRA).

It also contains a hash of your callsign (special index) which allows the receiving station to match up the locator with your callsign. You can see both messages in WSJT-X. WSPRnet will then have the information to report your full QRA.

Only one message is sent, and this setting is not stored.

6.4.5. Power

The unit transmits at three power levels 0, 10 and 20 dBm, selectable in this menu. The power level selected is also coded in the WSPR message.

6.4.6. Suffix

A single character suffix can be chosen e.g., G0CJG/3. Select the character using the settings knob and press the settings button to store it. Selecting a space will turn the suffix feature off. Since a suffix requires two messages to be decoded by a WSPR receiver it is more susceptible to low SNR. (message one contains 6 char QRA, callsign hash and power, message two contains a 6-character callsign, suffix and power).

6.4.7. Transmitter on time %

This feature allows you to change the 20% default transmit interval to either 1, 5, 20 or 50% transmissions per hour. Transmissions will occur at the following times depending on the % selected.

Min	1%	5%	20%	50%
2		X	X	X
4				X
6			X	X
10				X
12		X	X	X
16			X	X
20				X
24		X	X	X
26				X
30			X	X
36				X
40	X	X	X	X
46				X
50			X	X
56				X

Figure 14 - Transmitter TX Time

6.4.8. Band

This feature allows you to select the TX band and covers all HF bands including WARC from 1.8 – 30Mhz.

6.4.9. Screen mode

This feature enables you to vary the display brightness, in addition the screen background/foreground can be inverted by turning the setting knob quickly.

Note: This setting is not stored!

6.4.10. Morse Practice

This feature will send groups of 5 letters or numbers at approximately 18wpm on the band the transmitter is set to with the PA disabled, you must listen on a local receiver. Firstly, you must choose letters or numbers by adjusting the setting knob and press the setting button. Finally, the inter letter gap can be adjusted using the settings knob. Press the settings button to commence sending. The character sent will be shown on the screen.

Pressing the settings button once the morse has commenced will stop sending and reboot the TX. If set to very long delays you need to hold the button (for the delay length).

6.4.11. Exit the menu.

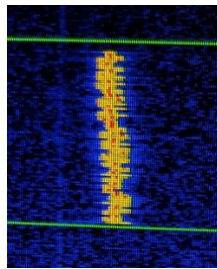
Exit the menu and return to normal operation.

6.5. Normal Operation

Once the transmitter has been setup as required then transmissions will automatically start on the next interval which is shown on the main display.



The 125 MHz oscillator in the DDS module has a warm-up drift. They are stable after the first couple of transmissions from a cold start. This can be seen on the WSJT-X software display as a curved shape transmission.



During transmissions, the display changes to the above layout. The Frequency at the top and a series of indicators.

In the middle of the screen are 4 vertical bars which represent which of the 4-FSK tones is being transmitted, only 1 bar is shown at any time.

At the bottom of the screen is a progress bar which shows at what point in the 162 tone sequence the transmission has reached.

Once operational for a few transmissions check the WSPR website to establish how well you are being heard. <http://wsprnet.org/drupal/wsprnet/spotquery>

Change History

Version	Date	Details of Changes
1.0	12 May 2021	Updated for the v2 hardware/software
1.1	14 May 2021	Updated board markings vs component issues
1.2	16 May 2021	Updates following feedback
1.3		Cosmetic changes to images\text