D4D: A simple QRP transceiver kit for FT8
Kit Assembly Manual

Rev. C
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CRKITS.COM

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PCB Layout by BD4RG
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>   **BD4AHS, EA3GHS and WA7DUY for beta testing and valuable feedback**
>   **EA2SN (AE2SN) for Spanish manual translation**
>   **WB9FLW and K4SWL for wide introduction**

Rev A - May 29, 2019: First release.
Rev B - June 18, 2019: Update modifications and add Raspberry Pi info.
Rev C - July 8, 2019: Update accessories, modification 5 and FAQ.

D4D stands for **D**SB transceiver **for D**igital mode. It is a Double Sided Band transceiver kit designed for digital mode, especially for FT8. If you have chance to try FT8, you will be amazed by the strong decoding capability due to the communication protocol, digital signal processing and software. I still remember clearly a YouTube video by W6LG who communicated with a bulb. I started to think how much the transceiver could be simplified if you have a moderate antenna like a full sized dipole or EFHW (End Fed Half Wave) instead of a bulb.

A DSB transceiver is compatible with but much simpler than a SSB transceiver, however it was never used for FT8 as far as I know. I did some experiments on my Choc perf board, a specially designed perf board for RF circuit experiments. I started with a direct conversion receiver for FT8 and it worked okay. Then I built a DSB transmitter and the transmitted signal can be decoded. By referring to the DSB designs of AA7EE, VK3YE and ZL2BMI, I combined them using only one NE602 and a PTT switch and it gave me success to make a few FT8 QSO's.

Personally I really enjoyed it because a manual PTT switch will save power consumption and circuit complexity, but you will need to well sync with computer, although it was not really a problem for me. Per request from a few hams, I found a VOX control circuit and modify the hold time to be compatible with FT8, and I put them together and made a few improvements on the signal purity and frequency stability, and it finally became our D4D.

Do we have to worry about the unwanted Lower Side Band (LSB) and Inter-Modulation Distortion (IMD)? Maybe, but for a transmitter of 1-watt, it is not really a big problem for occasional field, SOTA or experimental purposes. Is it just a toy for a transmitter of 1-watt and only half of the effective power? Not really, as I can easily make a few QSO's as far as 1500 miles range even for 40-meter band when the propagation opens.

Here are the brief specifications I have measured (subject to change without notice):

Summary: Crystal controlled DSB transceiver for 20m (14.074MHz for FT8), 30m (10.130MHz for JS8Call), 40m (7.074MHz for FT8) or 80m (3.573MHz for FT8), other frequencies could be added per request
Dimensions: 103mm(L) x 66mm(W) x 27mm(H), not including protruding parts
Weight: about 165 grams
Power supply: 10-14V DC regulated power supply or battery pack, 12V is recommended, center positive, reversed polarity protection supported
Current consumption in RX: about 15mA (R20* not installed) or 23mA (R20* installed) at 12V
Current consumption in TX: 200-350mA at 12V depending on audio input level
RF output: 0.5~1.5W at 12V
Antenna connector: BNC connector
Audio in connector: 3.5mm mono, at least 600mV to activate VOX, connects to headphone connector at PC sound card, no dedicated PTT connector is required
Audio out connector: 3.5mm mono, connects to microphone connector at PC sound card
Amber LED: TX status
Green LED: RX status
Frequency accuracy: -400 Hz ~ + 200 Hz
Frequency stability: Okay for FT8 mode per test. If the optional heater resistor R20* is added, after warm up, long term frequency stability in 10 min will be improved at the cost of acceptable short term frequency stability sacrifice.

Let us briefly go through the circuit.
The schematic will be available for downloading at https://groups.io/g/crkits/files/D4D%20Kit%20Documentations . The input audio will activate the VOX circuit of D2 (1N4148), Q5 (2N3906), Q6 (2N3904), Q7 (2N3904) and Relay. The relay is a DPDT type and controls both antenna and power supply. The LPF consists of L2, L3 and surrounding capacitors, and it is switched to either transmitter output or receiver input. The power supply is polarity protected by D1 (1N5817) and switched to either receiver circuit or transmitter

circuit. The receiver circuit is only for audio amplifier consists of Q1 (2N3904) and optional heater resistor R20*, while the transmitter circuit is for RX muter Q8 (2N3904), TX driver Q3 (2N3904) and TX final Q4 (BD139). X1 is a filter in the receiver front end to help eliminate strong broadcast interference, and X2 is the crystal for the built-in oscillator in U1 (NE602). U2 (78L05) is the 5V regulator for U1, and Q2 (2N3904) is a buffer amplifier in the TX chain.

Important notes for parts inventory:
A complete part list will be available for downloading at https:// groups.io/g/crkits/files/D4D%20Kit%20Documentations . Before you start soldering, please make sure you have all the parts ready. Please note C25 (10uF electro) and C26 (10uF electro NP) are very identical, but you can see NP marking on C26. Please also note that 78L05, 2N3906 and 2N3904 markings are very small and identical so **use magnifying glass if necessary**. Report missing parts to your seller.

Important notes for parts soldering and assembly:
• Follow this full manual to solder the parts in several steps. Test at the end of each step to make sure you are good to proceed. The parts are all through hole, and the clearance is big enough so you don't have to worry about the sequence of soldering.
• R20* is the heater for the crystal X2. One pin connects to the 12V receive power supply and the other pin connects to GND. You will need to put the resistor on top of the crystal X2. The pin for GND will be also soldered to the crystal case to help ground the case and better heat coupling. **Note that you must not short the pin for 12V to the crystal case!**
• T1 transformer is not difficult if you have built KN-Q7A kit before. Use 20cm red and golden enameled wires to twist 5 twists per inch. Wind 8 turns on the black toroid, scratch the coating of the wire ends, and pick red wire on one end and golden wire on another end to connect to make the middle tap by twisting them together. The middle tap will be soldered in the center bigger pad on the PCB. To verify you have winded the transformer right, you can measure any two ends of the total 3 ends and they must be conductive.
• Before you wind L1, L2 and L3 coils, please check part list to cut correct length of the wire. If you leave the wire too long, you may

run out of wire in the end. The L1 was originally designed for a fixed inductor, but later changed to a toroidal coil.

• Bend the LED pins to protrude about 2/3 length of the main body out of the board edge. The long pin is A and short pin is K.

• Put the Audio IN, Audio OUT, DC IN and ANT connectors in place and solder. If they are floating, you may have difficulty to put on the panels.

• Q4 soldering is the key. Plug in Q4 into the board and make sure it is facing the board center. Put a thermal pad (insulator) in between Q4 and the rear panel. Use the bigger screw and nut to temporarily fix them (no more insulator required for screw as TO-126 transistor has insulation in the hole). Temporarily put on nuts for ANT connector. Align the DC IN connector hole, and turn over the board to make sure the board edge is in parallel with the rear panel edge, then solder. After soldering, fix the nuts tightly.

Important notes for alignment:
You don't need to adjust any part. Use a 12V 1A or higher power supply and a 5-watt or bigger 50 ohm dummy load or a resonating antenna to perform current measurements. The overall RX current is around 23mA if R20* is connected, and TX current is 200-350mA if you inject audio above 600mV into AUDIO IN connector to trigger VOX to TX (You can use WSJT-x or JTDX Tune button and push **Pwr** bar to max and **system volume** to max as well) . Check FAQ portion of this full manual to judge if the behavior is as designed, such as IMD products.

This is the recommended steps to build your kit.

Step 1: Power supply and LED

[ ] Install DC jack.

[ ] Install polarity protection diode D1, check polarity.

[ ] Install relay.

[ ] Install power regulator U2, check marking for 78L05.

[ ] Install C18, check polarity. Short pin on the line side.

[ ] Install LED1, check polarity. Bend the LED pins to protrude about 2/3 length of the main body out of the board edge. The long pin is A and short pin is K.

[ ] Install LED2, check polarity. Bend the LED pins to protrude about 2/3 length of the main body out of the board edge. The long pin is A and short pin is K.

[ ] Install R12.

[ ] Install IC socket for U1, check orientation.

[ ] Install C1.

Test in this step:

You can use the attached DC jack to make your own power cable. Note the center pin is the positive. Apply a regulated power supply or a battery pack of 10-14V. You can test power supply voltages after diode D1 and 5V after regulator U2. LED1 will be on if the circuit works fine.

Step 2: VOX circuit

[ ] Install AUDIO IN connector. Put it in place and solder.
[ ] Install R13 [For IMD modification, you can refer to last a few pages].
[ ] Install R14.
[ ] Install R15 and R16.
[ ] Install D2, check polarity.
[ ] Install R17.
[ ] Install Q5, check marking for 2N3906.
[ ] Install Q6 and Q7.
[ ] Install C25, check polarity.
[ ] Install C26, no polarity (NP).

Test in this step:

You can test VOX operating. Power on the board and you will hear relay click and see amber LED2 on for about 1 sec and off, then green LED1 stay on. Connect an audio cable from PC sound card HEADPHONE connector to AUDIO IN connector. Use Tune function in WSJT-x or JTDX to inject audio at 1500Hz. Increase the Pwr bar to max and system volume to max as well. The relay will be triggered and the amber LED2 will be on to show it is in TX.
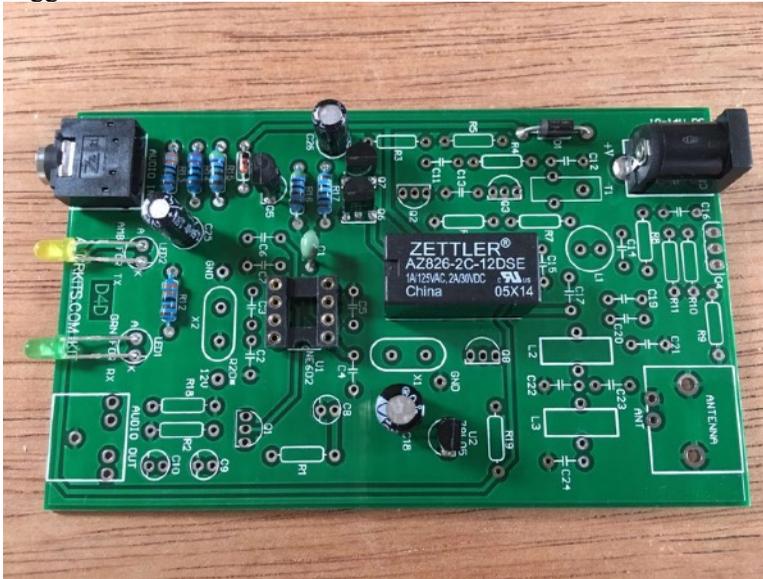
Step 3: NE602 oscillator

[   ] Install C2.
[   ] Install C3.
[   ] Install C4.
[   ] Install C5, C6 and C7 [For IMD modification, you can refer to last a few pages].
[   ] Install X1. Do not ground the case yet.
[   ] Install X2. Do not ground the case yet.
[   ] Insert U1 into socket, check orientation.

Test in this step:

You can check frequency accuracy or at least confirm it is oscillating. My way is that I use a short wire to couple to the antenna input of a receiver. Zero beat is the way to confirm frequency. It is better than a frequency counter as the probe might introduce additional capacitance so the frequency will be impacted.
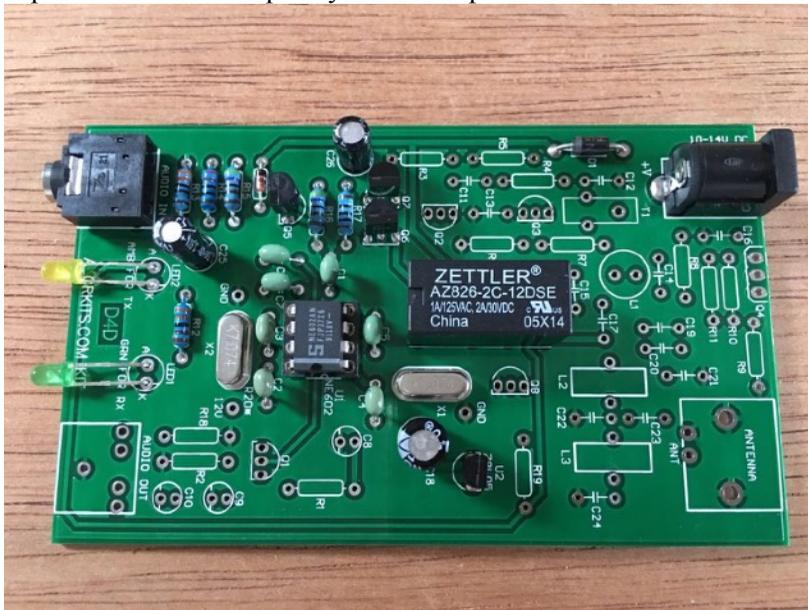
Step 4: RX audio amplifier
[   ] Install R1.
[   ] Install R2 and R18.
[   ] Install AUDIO OUT connector. Put it in place and solder.
[   ] Install C8, C9 and C10, check polarity.
[   ] Install Q1 and Q8.
[   ] Install R19.

Test in this step:
The normal low impedance headphone should be low sensitivity as the audio amplifier has high output impedance of a few hundred ohms. However, if you touch the input pin (pin 1) of NE602 with a screwdriver, you should hear some noise from headphone to show it is working.
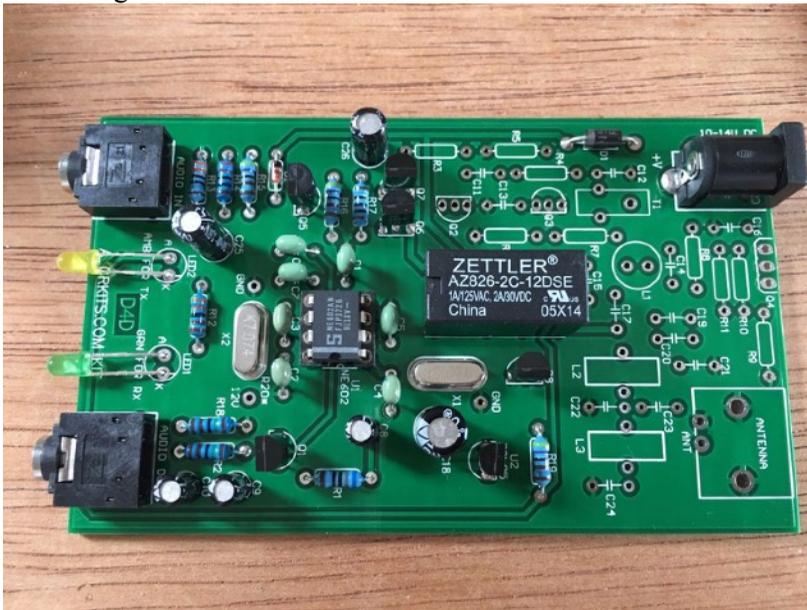
Step 5: LPF

[   ] Install C19.
[   ] Do not install C20 for now. It leaves the possibility to change the LPF to Cauer or Elliptic filter to better suppress 2nd and 3rd harmonics.
[   ] Install C21 and C22.
[   ] Do not install C23 for now. It leaves the possibility to change the LPF to Cauer or Elliptic filter to better suppress 2nd and 3rd harmonics. Note the photo is not correct here.
[   ] Install C24.
[   ] Wind toroids for L2 and L3 as following picture, it shows 16 turns for 40m. Check part list to cut correct length of the wire.
[   ] Install L2.
[   ] Install L3.
[   ] Install BNC connector.

Test in this step:

It completes the RX portion. Connect the antenna and audio cables and test with software WSJT-x or JTDX. If the propagation opens, you should receive something. If you are a beginner, you can refer to the later chapters to know a few basic steps to start decoding.

Step 6: TX amplifiers
[   ] Install R3 and R5.
[   ] Install R6 and R7.
[   ] Install R4 and R8.
[   ] Install R9.
[   ] Install R10 and R11.
[   ] Install C11.
[   ] Install C12, C13, C14, C15, C16 and C17.
[   ] Install Q2 and Q3.
[   ] Wind toroid for L1 as following picture, it shows 8 turns. Check part list to cut correct length of the wire.
[   ] Install L1.
[   ] Wind toroid for T1 as following picture. Use 20cm red and golden enameled wires to twist 5 twists per inch. Wind 8 turns on the black toroid, scratch the coating of the wire ends, and pick red wire on one end and golden wire on another end to connect them to make the middle tap by twisting them together. The middle tap will be soldered in the center bigger pad on the PCB. To verify you have winded the transformer right, you can measure any two ends of the total 3 ends and they must be conductive.
[   ] Install T1.
[   ] Install R20* as following picture. R20* is the heater for the crystal. One pin connects to the 12V receive power supply and the other pin connects to GND. You will need to put the resistor on top of the crystal X2. The pin for GND will be also soldered to the crystal case to help ground the case and better heat coupling. **Note that you must not short the pin for 12V to the crystal case!**
[   ] Install grounding pin for X1 case.

Test in this step:
No test is required in this step.
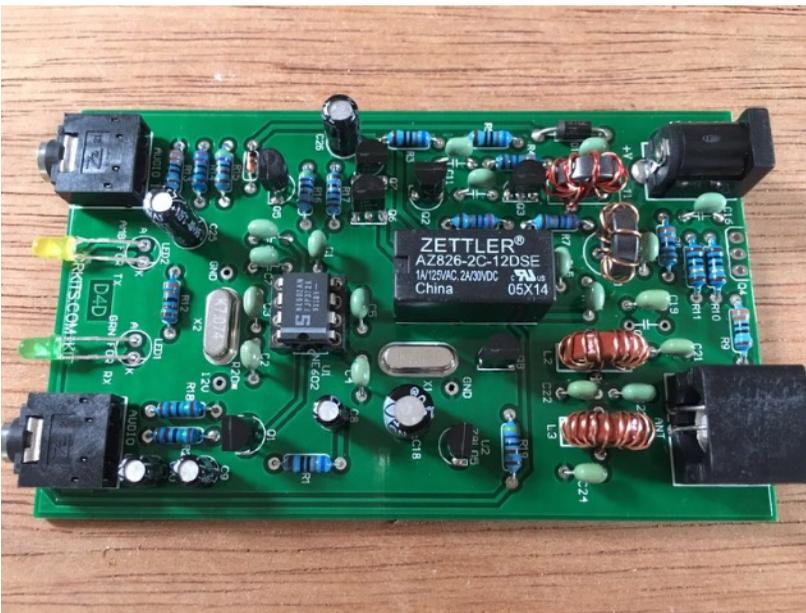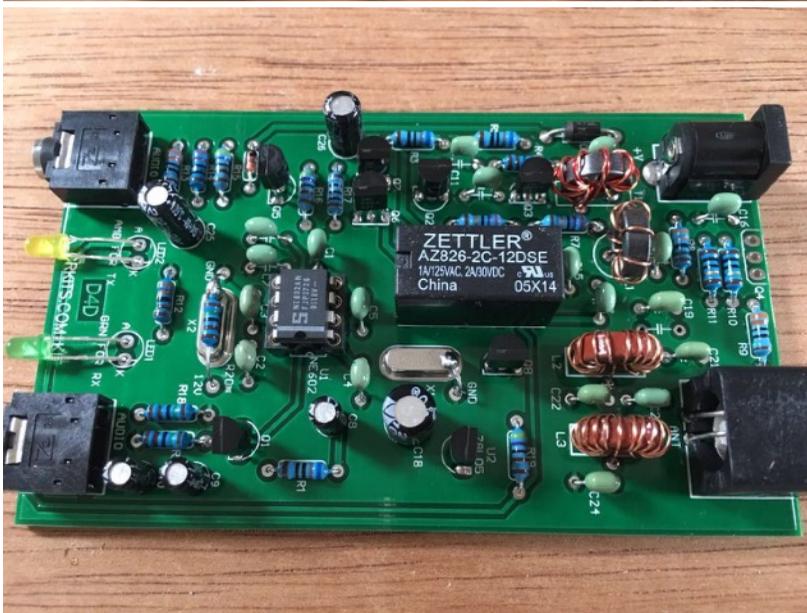
Step 7: Assembly
[ ] Split the panels and put on the thermal pad as shown.

[ ] Plug in Q4 as shown. It is facing to the board center. Please do not solder yet.
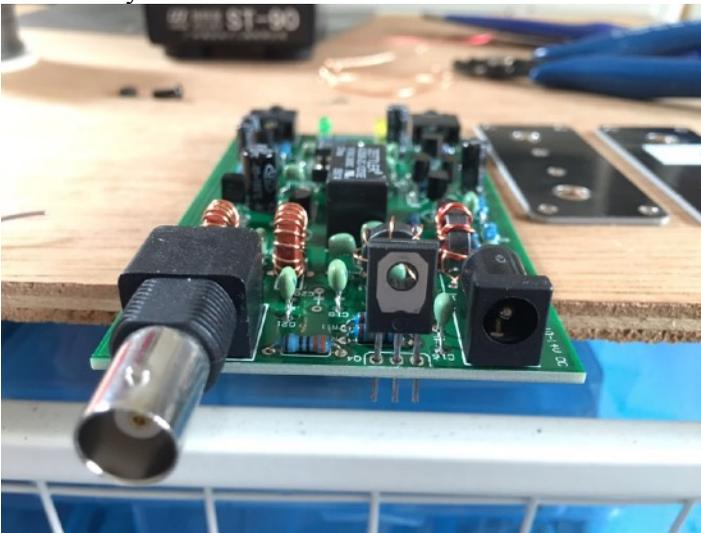
[   ] Put on the screw and nut for Q4, and put on nuts for BNC connector as well. Make sure the thermal pad is between the rear panel and Q4 metal plate.
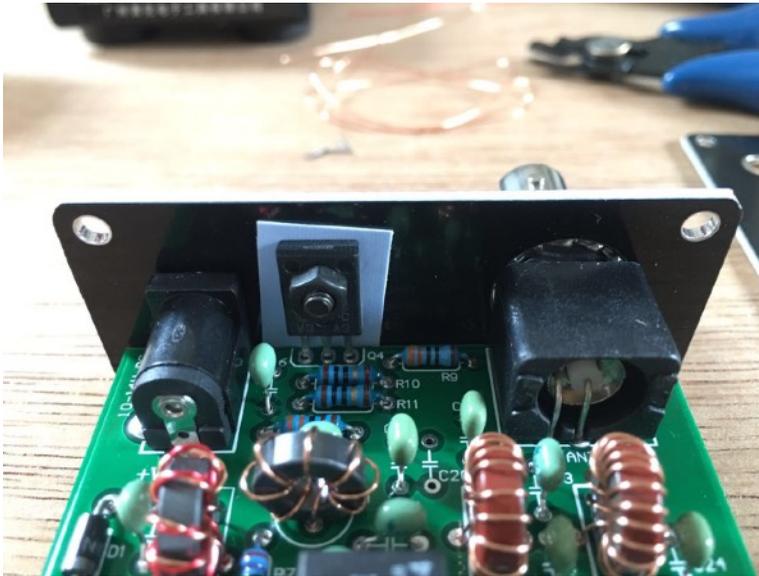
[ ] Align the DC IN connector hole, and turn over the board to make sure the board edge is in parallel with the rear panel edge, then solder. After soldering, fix the nuts tightly.
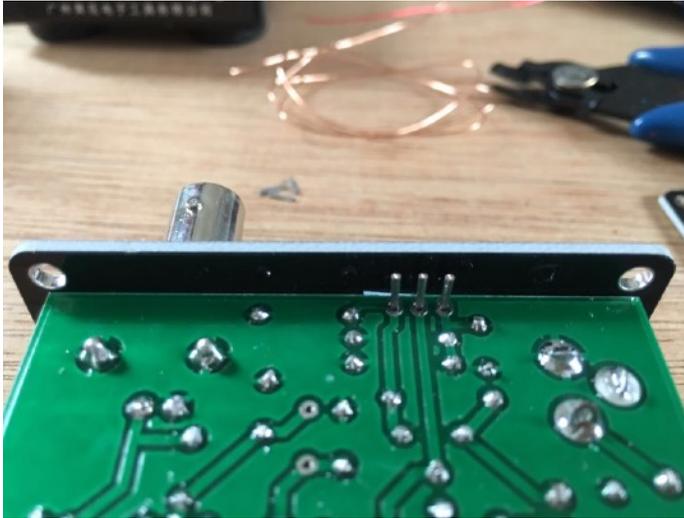
[ ] Now it is good time to perform test and measurement, before its final assembly into case.

[   ] Stick on the rubber feet for case, and use screws to install the panels to the case, and you will complete the assembly.

Step 8: Setup your WSJT-x software

Let's take WSJT-x software as an example. If you have used WSJT-x for FT8 before, you can just focus on the special settings first:

In main window, **push the Pwr bar to max**, and check input audio in 30-60 dB range. Also you will need to **adjust the system volume to max as well**. When you click **Tune** button, you should hear loud audio. Although it can transmit, the distortion is big because of the overdriving, so you need to slowly reduce **Pwr** bar to the point to just trigger the relay stably. Since CAT is not supported, you will need to manually adjust frequency on this interface. Otherwise, you will have wrong frequency/band in the log.

In setting window Radio tab, choose Rig to None and PTT method as VOX.
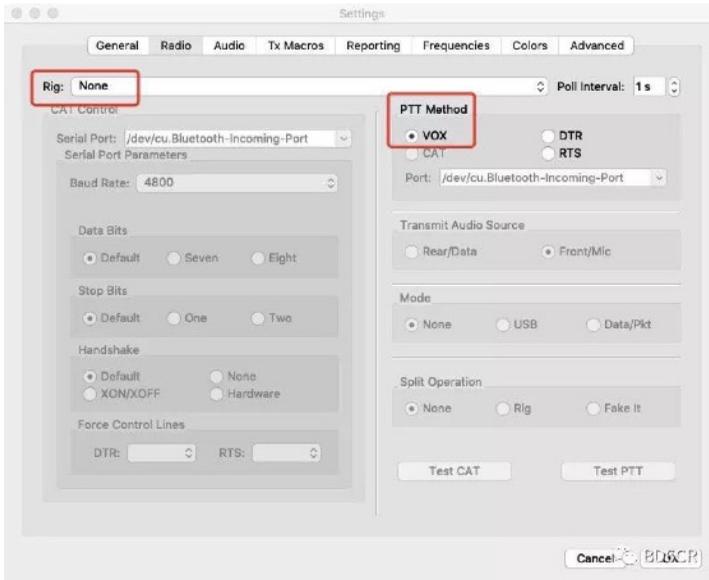
In Audio tab, choose correct audio device you connect your cables to.
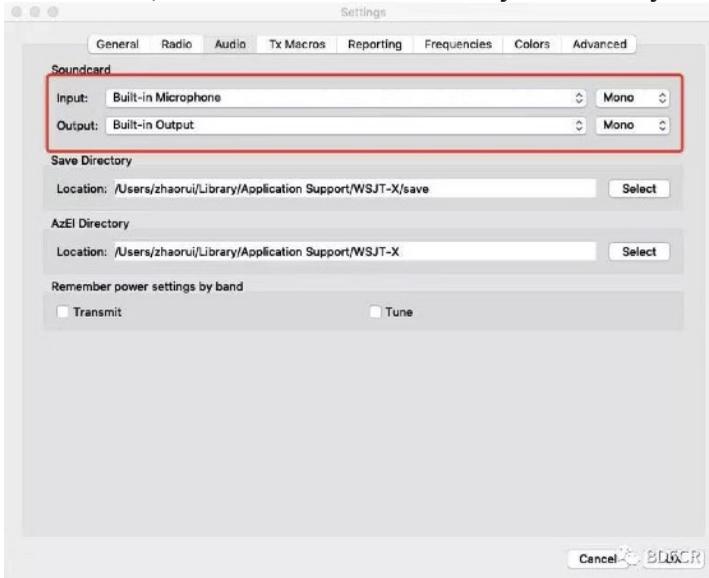
If you are a beginner, at least you will need to enter your **call sign and grid locator** in the setting window General tab. Manually adjust or **sync your system clock within 1 second accuracy**. Start with receiving and decoding. Once you can decode some signals, you can learn the whole process of a typical FT8 QSO, the signal report like -5(dB SNR) instead of 599 (RST) and other weird things of "that" digital mode (hihi). If you check **Double-click on call sets Tx enable**, the whole QSO becomes easier. That's why in China FT8 is called Senior Citizen's Toy. If you need some more help, the Internet is a great source. You can go to YouTube to search for videos for FT8 beginners, or you can read manuals for WSJT-x. Please note that you need to install WSJT-x version 2.0.0 or later, because previous versions are no longer supported. If you start with JTDX, you can find similarity from the above basic settings.
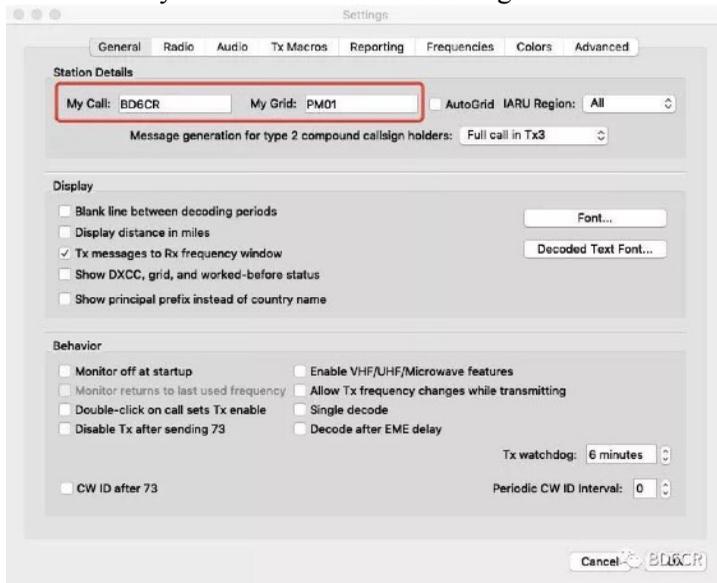
Step 9: Connect and operate your device

Connect audio cables as follows and enjoy some QSO. Same as normal QRP operation, it is more likely to achieve successful QSO if you answer strong signals. If you call CQ, it is recommended that you add QRP to get more attention, like CQ QRP BD6CR PM01.

Listen for a minute or two before you transmit, as it is helpful to warm up the radio and reduce thermal drift.

As this radio is tiny and portable, it is strongly recommended that you bring it to the field. You can refer to the accessories section below to get to know about the power supply, sound card and Raspberry Pi suggestions.

FOR LEGACY COMPUTERS WITH SEPARATED MIC AND HEADPHONE CONNECTORS, JUST CONNECT AUDIO IN TO HEADPHONE CONNECTOR, AND AUDIO OUT TO MIC CONNECTOR.

**FOR MODERN COMPUTERS WITH SINGLE CON-
NECTOR FOR HEADSET, USE Y-ADAPTER TO
MAKE CONNECTION. Y-ADAPTER IS AVAILABLE**

**FOR COMPUTERS LIKE MACBOOK AIR, Y-
ADAPTER WON'T WORK, SO USB SOUND CARD
WITH SEPARATED MIC AND HEADPHONE CON-
NECTS WILL BE USED.**

Modification possibilities

1. Improve IMD by reducing audio input level to NE602. Replace C5 by a 103 monolithic or ceramic capacitor. Replace R13 by a newly added 22-27 ohm and the original 330 ohm. Remove C6 and pick a 1-10uF electro capacitor, and make connections from C6 negative to the interconnection point of the two resistors, and from C6 positive to C5 and pin 2 of NE602 in the original pad. Add a 103 monolithic or ceramic capacitor at the Audio input (on the photo, it connects to both 330 ohm and 27 ohm resistors) to eliminate RF interference pickup. This modification will improve IMD but impact RF output power at the same audio input level, but you can adjust **Pwr** bar or **system volume** to adjust RF power. **This modification is highly recommended to reduce adjacent channel interference to other stations.**

2. Improve carrier leakage by cutting a trace near 78L05 and adding a 1N4148 diode to reduce power supply voltage of NE602 by about 0.7V. This is the idea from BH4DCL and my test shows very effective result without noticeable side effects.
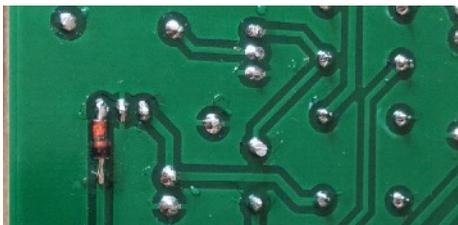
3. Change LPF to elliptical filter and it will reduce 2nd and 3rd harmonics significantly. You can follow this web page to try out https://pa3csg.nl/?page_id=40 .
4. Improve frequency stability by adding a PTC heater to stabilize the temperature. The frequency drift of a AT cut crystal is minimized when the ambient temperature is about 50 C.
5. For more modification ideas, you can refer to the post by BH4DCL in Chinese with schematics at https://github.com/cnsit/radio/blob/D4D/articles/D4D.md . For example, he suggested a simpler IMD modification to just replace C5 by a 105 monolithic capacitor.

Accessories

The Y audio adapter is useful when your computer has only one audio connector for headset. Normally it is a combined 4-pin connector for microphone and headphone and it is the same as the connector on your cell phone. The Y adapter will split into two separated connectors for microphone and headphone, and can be connected to D4D using supplied audio cables. It is now ready to order from http://crkits.com, in D4D Frequency and Option drop down list. Before you order, please test the headphone output level to make sure it can drive VOX to transmit. In some laptops, the audio output is too low so you can only consider USB external sound card like below. Note that this adapter won't work on MacBook Air. We haven't tested MacBook Pro, but Apple users, you can consider the following Creative SoundBlaster Play!3.

The Creative SoundBlaster Play!3 is a great companion to D4D. Although it is the low end in Creative external USB sound card product line, it offers great SNR up to ~93dB and strong output to be able to drive 300 ohm big headphones. The big output range will offer flexibility to pursue bigger power (poor IMD) or better IMD (small power). The Creative SoundBlaster Play!3 can be ordered in many countries. It can replace Y audio adapter.

If you solder the DC plug to the 3x AA size battery holder with power switch, put in 3x 14500 sized (same as AA size) Li-Ion batteries of 1200-mAh and it will give you 8 hours of operation. The power switch is very useful as D4D does not have one. The charging can be easy if you have a charger of 12.6V 1A. What you need is just an adapter cable. **Note that play with Li-Ion battery packs with care. Protection board is required.**

If you go to field, you can consider Raspberry Pi as the replacement of your computer. I shot a YouTube video to introduce the setup of the tiny portable station. Please refer to: https://youtu.be/la6BSmRS0k0

In the above video, you can see a tiny home made EFHW antenna. Now it is made available as a PCB kit. It is called Mini Wire Antenna kit. It is recommended to order along with your D4D kit.

Also, you can find many more accessories in the drop down list when you place your order online, such as the 6-60m Coil Dipole Antenna and a low cost USB sound card.

FAQ:

1. My computer does not have separated connectors for microphone. What can I do?

Answer:

Option 1: Buy a Y-adapter along. It will split the 4-pin headset connector to two separated 3-pin connectors for microphone and headphone.

Option 2: Buy a USB sound card with separated microphone and headphone connectors.

2. VOX seems not triggered. What can I do?

Answer: Check if the audio cables are properly connected. As two audio cables are the same color and size, you might make mistakes to swap them. Sometimes, you will need adjust Audio setting to choose the proper channel Left or Right instead of the default Mono. Increase headphone volume to the max. You will need to adjust the bars in both system and WSJT-x software. We've found in some computers, the audio output level is too low to drive VOX. In this case, you can find a USB sound card like Creative SoundBlaster Play!3.

3. It seems my MacBook Air cannot detect this device as an external microphone. What can I do?

Answer: Buy a USB sound card with separated microphone and headphone connectors.

4. Is it safe to transmit a short period of time at power on?

Answer: It is safe as the power level is low.

5. Is it possible to support new FT4 mode?

Answer: Yes, and we need to customize crystals to support.

6. Is it possible to support JS8Call mode?

Answer: Yes, we already supported 10.130MHz. For other frequencies like 7.078MHz, we need to work out a way.

7. Is it normal to see audio overtones in the waterfall spectrum when I monitor the transmitted signal nearby?

Answer: It is the inter-modulation distortion products. In order to reduce it, we must reduce power as well, see modification possibilities chapter. For such a simple design, our recommendation is that we live with it, because the overtones are -10dB or lower. If you have capability to make modifications, please see the above modification instructions.

8. How to deal with the frequency offset (accuracy)?

Answer: Frequency offset of -400 ~ +200 Hz is not harmful. Just live with it. If you cannot view the whole waterfall spectrum range of 2700Hz, just change Start 0 Hz setting. For 0~200Hz range, you can keep unchanged. For -400~-100Hz, you can change 0Hz to 400~100Hz.

9. How to deal with the frequency drift?

Answer: Frequency drift of a few hertz won't impact decoding. If you really care, you can manually adjust your TX audio frequency following the station you are communicating with.

10. What should I do if the VOX is mis-triggered?

Answer: Check if it is due to RF interference, especially for end-fed antennas, although the power output is small. Use coaxial cable to connect the radio to keep distance from antenna. Add EMI suppressor toroids at the ends of power cable and audio cables. If it is due to hum, check your power supply quality or ground the case.

11. Is it legal to operate FT8 mode with a DSB transceiver?

Answer: Check with your local regulatory agency. This is something new so it will take quite a discussion. It is recommended that you strictly follow the instructions to operate when it is clarified.