

# Receiver module kit

## PCB Rev 2

### 1. Introduction

This is a high performance receiver module which mixes incoming RF directly to audio (direct conversion type architecture). It may be used with other QRP Labs kits, or as the front end to a Software Defined Radio (SDR), or in your own projects.

The mixer is a double-balanced Quadrature Sampling Detector (QSD) which is also known as the “Tayloe Detector”. The circuit is similar to that used in most Software Defined Radio front-ends. The RF input is at 50-ohms and can be passed through the QRP Labs band pass filter kit. A local oscillator at 4x the receive frequency is required. The audio output is I-Q, suitable for feeding a PC stereo input sound card and SDR software. Optionally a polyphase network kit may be plugged in and used to cancel the unwanted sideband and obtain a SSB output. The audio output has 600:600-ohm audio isolation transformers to eliminate ground loops that can cause audio hum.

Construction is reasonably straightforward. The board is quite compact and so a fine-tipped soldering iron is recommended. All except one of the components are leaded through-hole type; the only Surface Mount Device (SMD) is the FST3253 IC which is not available in a through-hole package. The most tricky part of the construction is the trifilar toroidal transformer (NOT the SMD IC)

### 2. Parts List

#### Resistors

R26, R27	82-ohm
R11, R15	150-ohm
R1, R2, R3, R4, R5, R6, R7, R8, R12, R13, R17, R18	2.2K
R9, R10, R14, R15, R19, R20, R21, R22, R23, R24, R25	10K

#### Capacitors

C1, C2, C9, C10, C11, C12	1uF ceramic
C3, C4, C5, C6, C7, C8, C13, C14, C15, C16, C17	100nF capacitor

#### Semiconductors

IC1	FST3253 dual 1:4 multiplexer
IC2	74AC74 dual D-type flip flop
IC3, IC4, IC5, IC6	LM4562 dual low-noise op-amp
Q1, Q2	BS170 transistor

#### Miscellaneous

T3	FT37-43 toroid
TR1, TR2	600:600-ohm audio isolation transformer
Wire	1m 0.3mm enamelled copper wire
PCB	80 x 37mm, double sided, through-hole plated PCB
Header	20-way pin header
BPF	Two 4-way header sockets
Audio	3.5mm stereo audio socket



### **3. Circuit description**

The start of the signal chain includes a QRP Labs Band Pass Filter as the receive input filter. Although the QSD mixer has very high dynamic range (and IP3) it is still a good idea to restrict unwanted signals from the input. A transmit/receive switch is made from two BS170 transistors. This disconnects the input signal when the “TX” input to the module is high (5V). This allows the receiver module to be used together with a transmitter kit such as the Ultimate3S.

The QSD mixer requires a quadrature Local Oscillator (LO), which means two oscillator signals with a 90-degree phase difference. An analogue circuit is sometimes used to produce this phase difference but it is difficult to maintain accuracy over a wide frequency range. For this reason, in this kit the local oscillator is at four times the receive frequency. IC2 is a 74AC74 dual D-type flip-flop logic IC, configured to produce the necessary quadrature oscillator signal. The two outputs of this circuit (at pin 6 and pin 9) have the same frequency as the receive frequency (1/4 the LO frequency), but are offset from each other by a 90-degree phase difference.

IC1 is a dual 1:4 bus multiplexer which is used in this application as a 1:4 analogue switch. The IC2 quadrature LO signals cause this switch to transition through all four outputs in every complete cycle at the receive frequency. The result is four baseband (audio) signals with phase shifts of 0, 90, 180 and 270 degrees.

Improved performance is obtained by using the trifilar toroidal transformer T3 to split the incoming RF into two paths, 180-degrees out of phase.

The four phases are combined to two I-Q audio outputs using low noise LM4562 operational amplifiers connected as instrumentation amplifiers. This provides excellent common-mode rejection, and each of the four paths is presented with a consistent, high impedance load, thereby maintaining good balance between the paths. Each of the instrumentation difference amplifiers provides very low noise pre-amplification gain. The “I” output signal is derived from the difference between the 0 and 180 degree phases; the “Q” output is derived from the difference between the 90 and 270 degree phases. Additionally all four amplified outputs 0, 90, 180 and 270 are routed to sockets that connect to the optional polyphase network board kit if it is plugged in.

The two op-amps in IC6 are used to provide stable mid-rail bias voltages to the QSD circuit and the instrumentation amplifiers respectively. Separate mid-rail biases are provided in case the op-amps and the QSD are powered from different voltages. DC isolation between the two sections is provided by 1uF capacitors C9, C10, C11 and C12. The 74AC74 and FST3253 must be operated at 5V supply (actually the rated maximum is 6V). The operational amplifiers can also be powered from the same 5V supply. However a small performance improvement can be obtained by powering the op-amps from a higher supply voltage such as 12V. The power supply may be up to 35V. For this reason, separate + supply pads are provided on the board, one +5V for the 74AC74 and mixer, and one for the op-amps.

The final stage of the receiver module is a pair of 600:600-ohm audio isolation transformers. These provide DC-isolation of the audio output to the PC soundcard, and are important in many cases to reduce hum caused by ground loops.

## 4. Assembly instructions

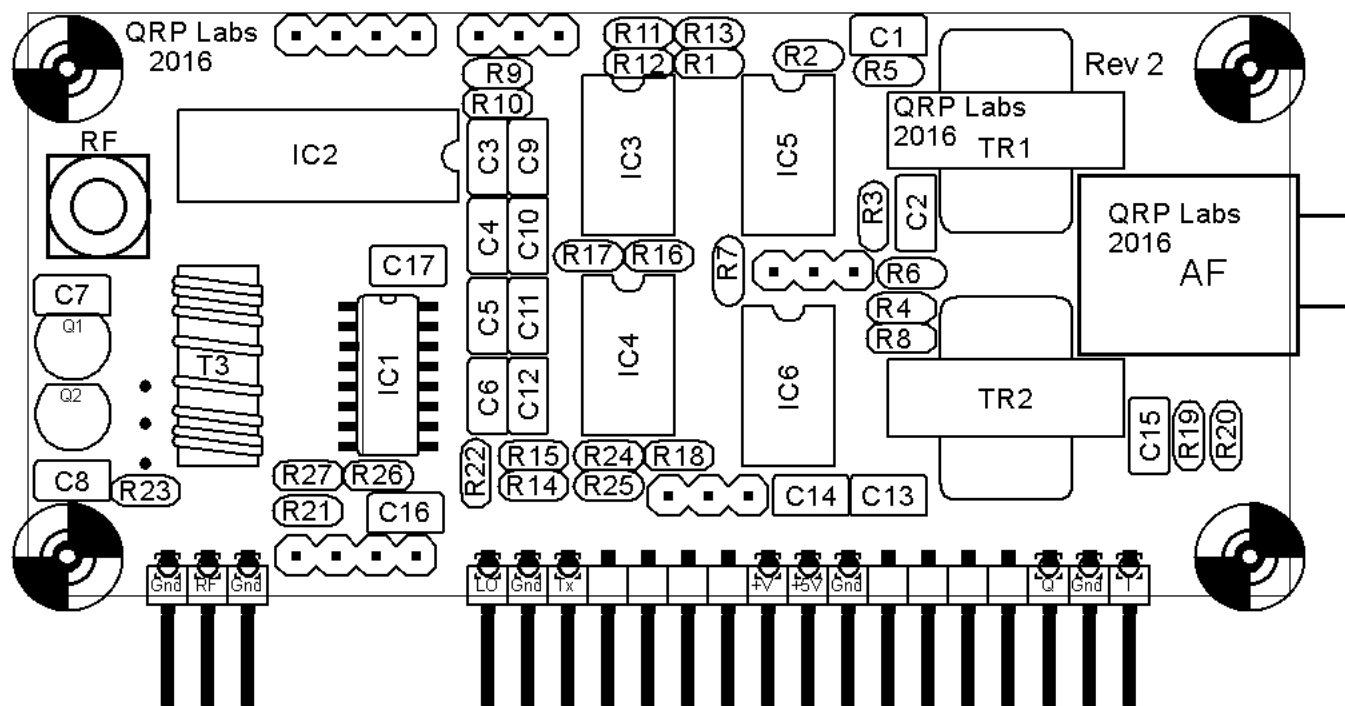
Assembly of this kit is quite straightforward. The usual kit-building recommendations apply: work in a well-lit area, with peace and quiet to concentrate. **The ICs (chips) in the kit are sensitive to static discharge. Therefore observe Electrostatic discharge (ESD) precautions. And FOLLOW THE INSTRUCTIONS!!**

If you have some “Blu Tack” then this can help keep the SMD IC in position while you solder it. A jeweller’s loupe is really useful for inspecting small components and soldered joints. You’ll need a fine-tipped soldering iron too.

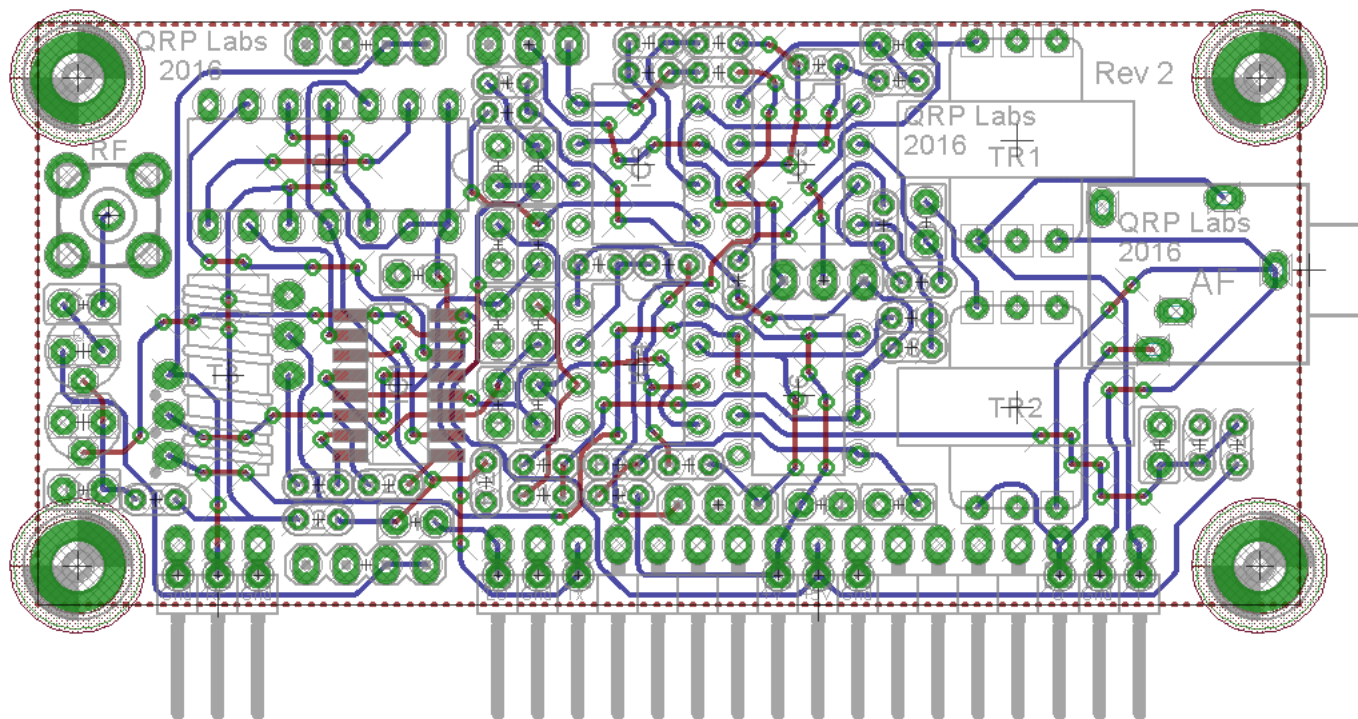
It is good to get into the habit of inspecting every joint with the magnifying glass or jeweller’s loupe, right after soldering. This way you can easily identify any dry joints or solder bridges, before they become a problem later on when you are trying to test the project.



Please refer to the layout diagram and PCB tracks diagrams below, and follow the steps carefully.





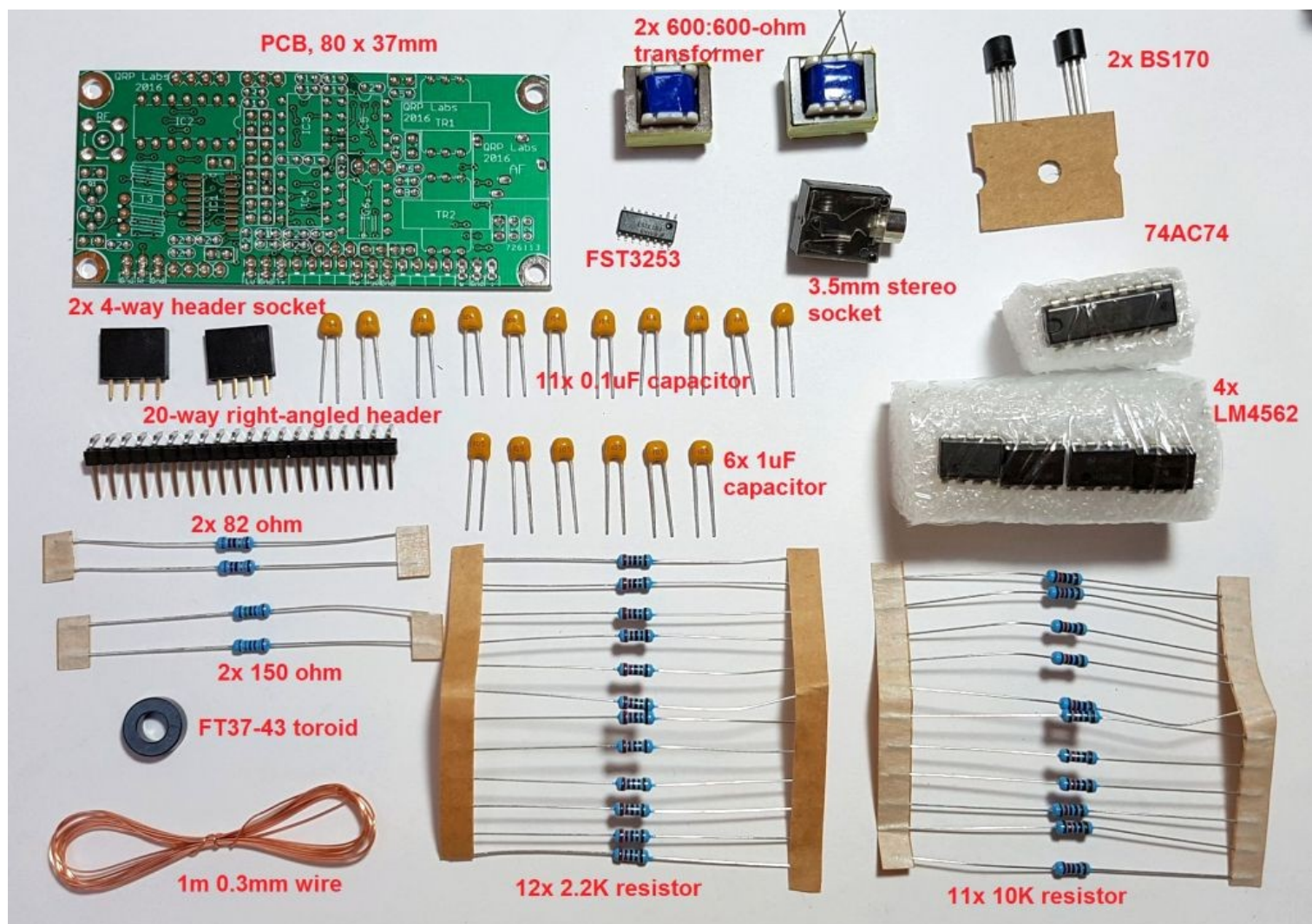


#### 4.1 Inventory parts

Refer to the parts list and this picture. Identify each component, so you are ready for the construction!

**NOTE: The FST3253 is small and loose in the bag. Be careful not to lose it when you open the bag!**

**NOTE: The kit is currently supplied with 20-way straight pin header (not right-angled).**



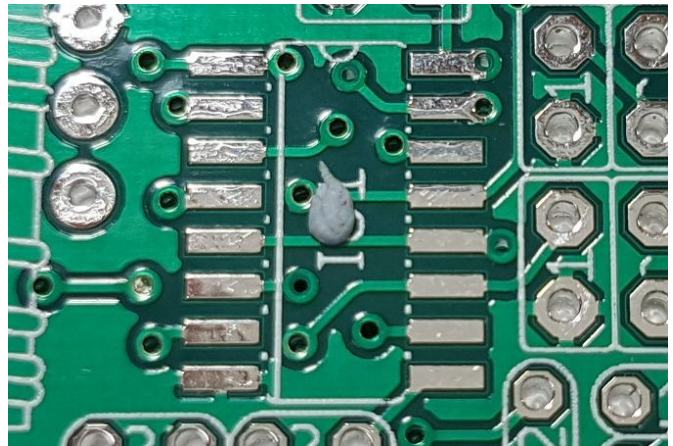


## 4.2 IC1, FST3253

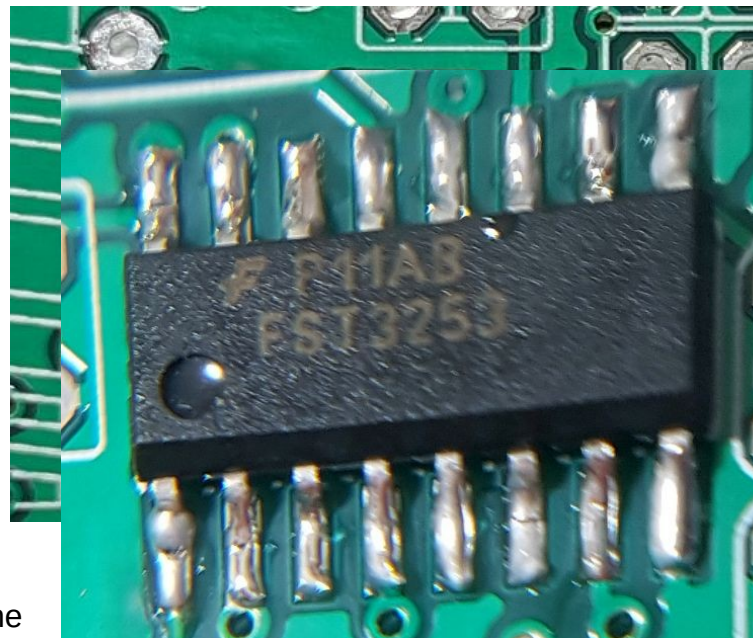
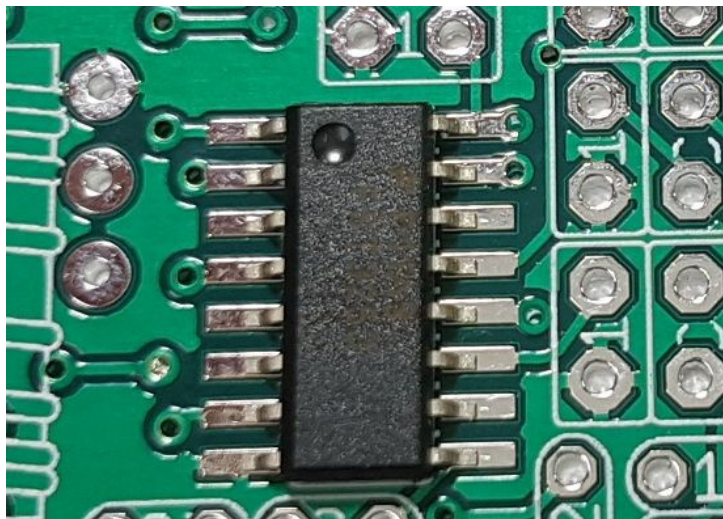
It is often best to start with any components which are small or low profile, so that it is not difficult to reach them later when other larger components have been installed. This is particularly the case with any SMD, since these are soldered to the top of the PCB.

So let's begin with IC1, the FST3253 IC. This is the only SMD in the whole kit. It is quite easy to solder, with a little care, because it is not a really tiny device. The pin spacing is 0.05-inch (1.27mm) which is half the pin spacing of a conventional DIP chip. With a fine-tipped soldering iron it will not cause any trouble.

A small piece of blu-tack helps to hold the IC in place while you solder the first few pins. Only a tiny pin-head sized piece of blu-tack is needed! Stick it in the middle of the pads on the PCB.



Check the pins of the FST3253 and if any are bent, straighten them carefully and very gently. Place the IC on the PCB with the small dimple aligned with the mark on the PCB. It is very important to orientate this IC correctly. You can check the alignment of each pin against its PCB pad using a jeweller's loupe or magnifying glass. (below left).



First solder two pins at diagonal opposites on the IC (above right). Then you can check to make sure that the chip is still nicely positioned on the PCB, and make any necessary corrections. When you are happy with the chip position, you can proceed to soldering the other pins. Pay particular attention to pin 8, which is connected to ground. Although the pad is connected to the groundplane with thin thermal traces, it will still tend to dissipate heat away from the joint, which can make it harder to get a good joint.

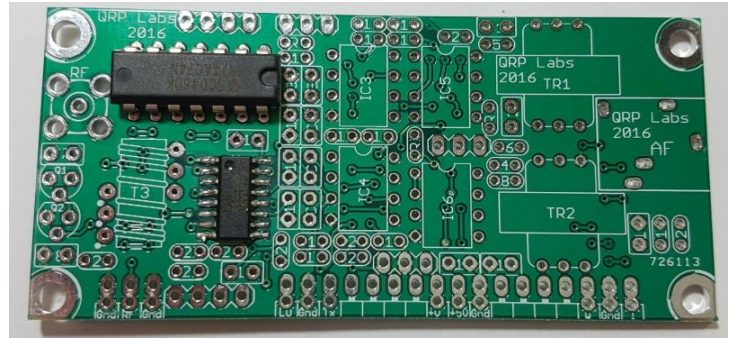
When complete, check carefully that every pin is properly soldered to its pad, and check for any solder bridges or whiskers between adjacent pins. If necessary, you can remove solder bridges with desoldering braid.

I'm maybe not the best advert for expert soldering but this magnified picture is how my FST3253 installation ended up.

### **4.3 IC2, 74AC74.**

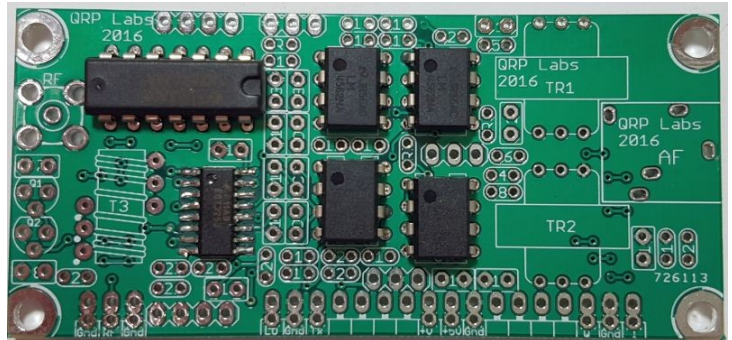
All remaining soldering will be on the bottom side of the board, because all the remaining components are through-hole leaded components.

Again, align the dimple at one end of the IC with the dimple drawn on the PCB silkscreen. The pins of ICs are always spread too wide. It is normal to have to squeeze the two rows of pins gently slightly together to fit them in the PCB. Again solder two pins at opposite diagonal ends of the chip. Then you can check that the chip is nicely seated on the board before soldering all the other pins. It is easy to make adjustments when only two pins are soldered, by re-heating the joints. But you cannot do that when you have 16 pins soldered! When you're happy with the position of the IC, solder all the other pins.



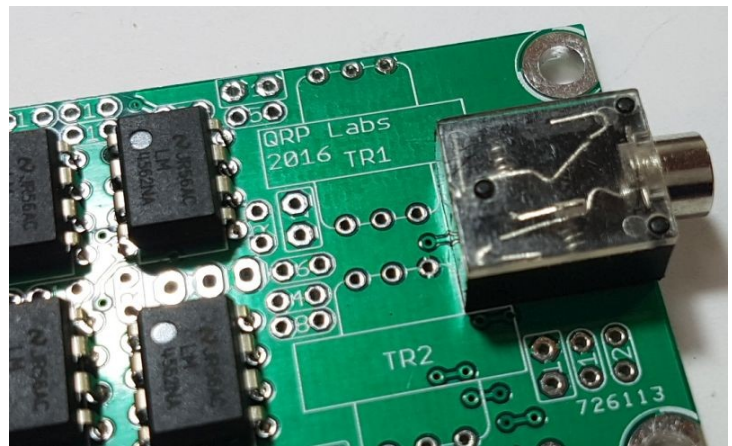
### **4.4 IC3, IC4, IC5 and IC6, four LM4562 op-amps.**

Ensure correct orientation of the IC dimples and the drawing on the PCB silkscreen! Follow the same procedure as for the 74AC74 (IC2) above.



### **4.5 3.5mm stereo audio output socket**

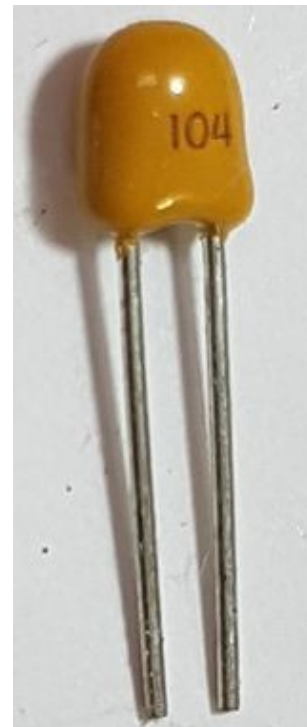
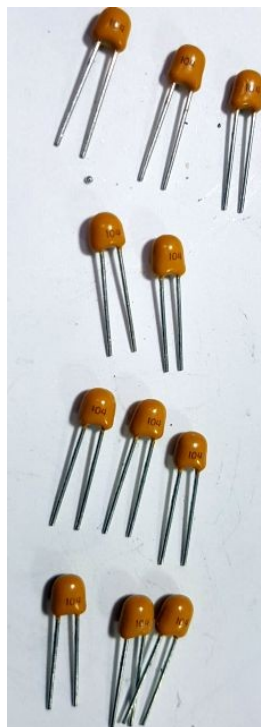
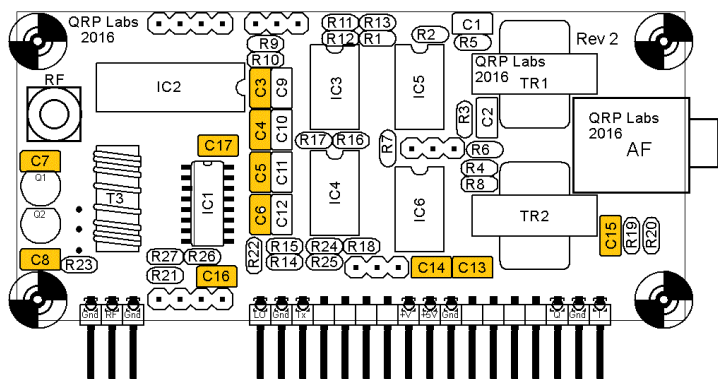
This socket has five pins. Again I recommend first soldering only two of the pins, on opposite sides. Then you can make sure that the socket is properly seated on the PCB, before continuing to solder the other pins.





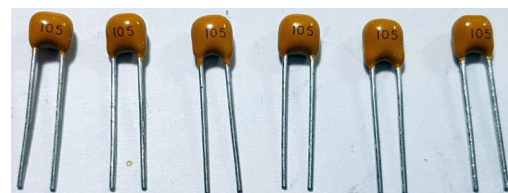
#### 4.6 100nF capacitors.

There are 11x 100nF capacitors in the kit. You need to separate them carefully from the six 1uF capacitors! The 100nF capacitors are labelled “104”. Separate them from the 1uF capacitors, which are labelled “105”. The 100nF capacitors are C3, C4, C5, C6, C7, C8, C13, C14, C15, C16 and C17. They are indicated in orange on this diagram. Be careful! Don't mix them up in the places where 1uF should be installed! When finished soldering the wires, cut off the excess wire length with wire cutters.

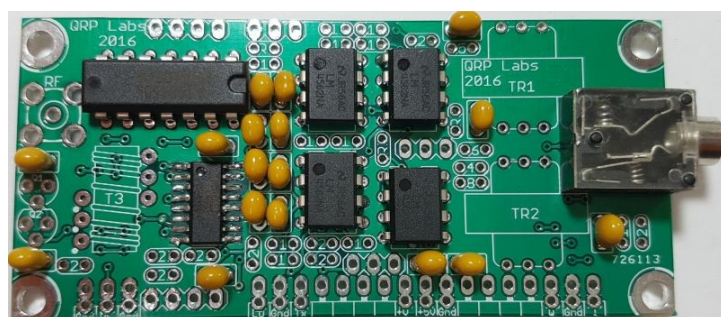
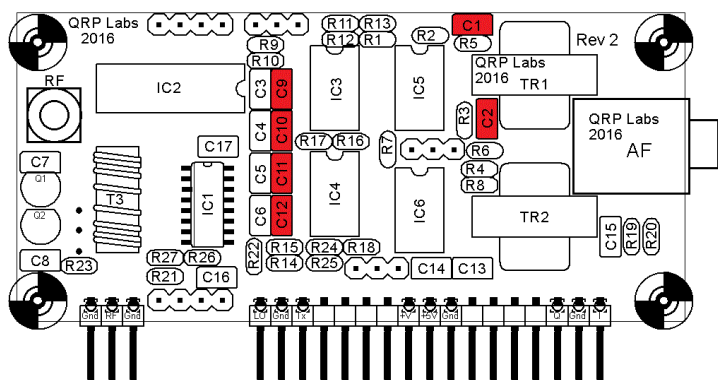


#### 4.7 1uF capacitors.

These are the remaining 6 capacitors in the kit, labelled “105”. They are C1, C2, C9, C10, C11 and C12. These are coloured RED in this diagram.



**NOTE: do NOT install C1 and C2 if you are going to use this kit with the optional plug-in polyphase board to cancel the unwanted sideband, and produce mono audio out!**



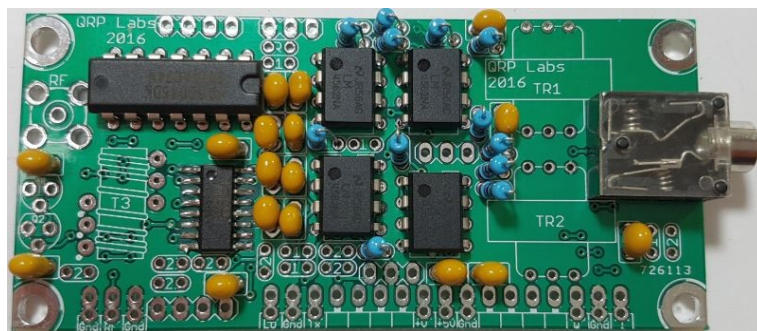
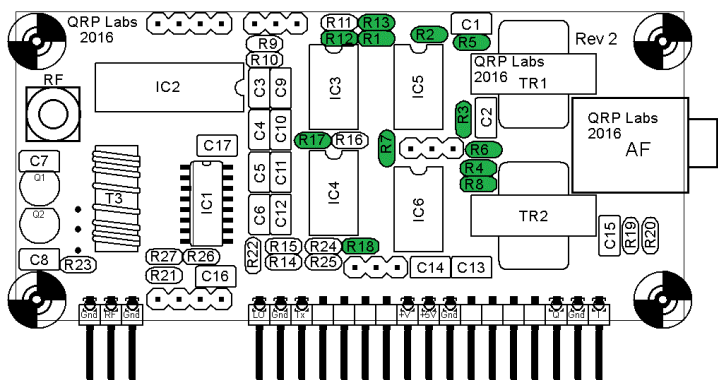
#### 4.8 2.2K resistors

These are the 12 resistors R1, R2, R3, R4, R5, R6, R7, R8, R12, R13, R17 and R18. The colour code is: red-red-black-brown-brown. All of the resistors in this kit are installed vertically. So you need to bend the wires over very resistor as in this picture (right).





The location of these resistors is shown on this diagram in green. It doesn't matter which way round the resistors are installed but I find the board looks neater if they are all the same way. For example, always solder the body on the left and the wire on the right.

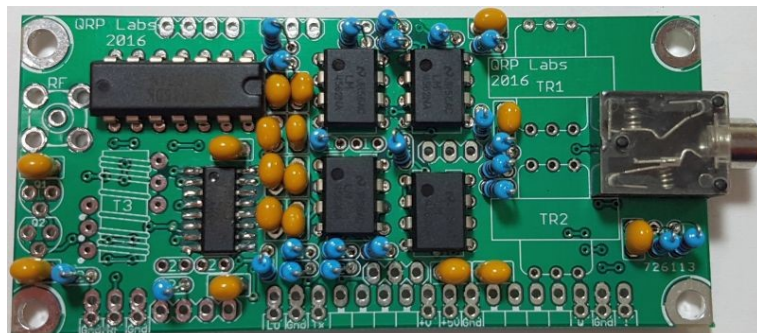
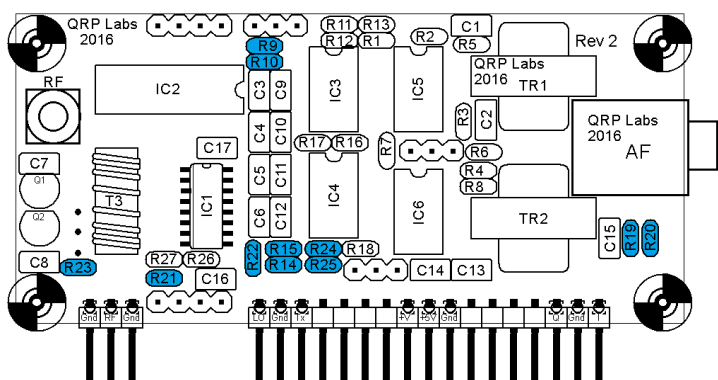


Note that only a very little solder is required. The solder will tend to fall through the hole to the other side of the PCB. So too much solder, will cause a big blob on the other side of the PCB that could cause shorts etc. Therefore only a little solder, soldered quickly with the soldering iron tip, is generally enough.

Trim the excess wire close to the PCB and inspect carefully with the magnifying lens, to check the joints. Check for any shorts to adjacent joints.

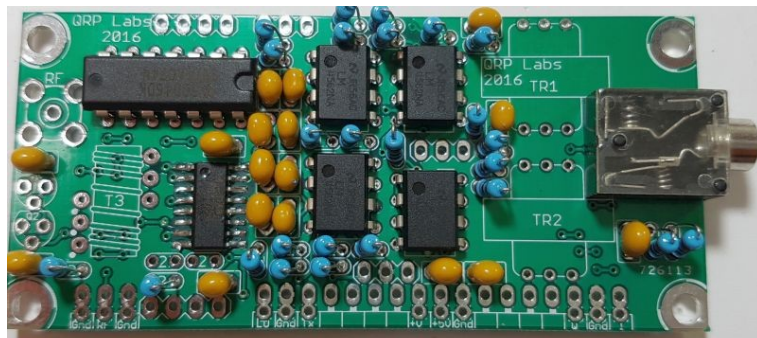
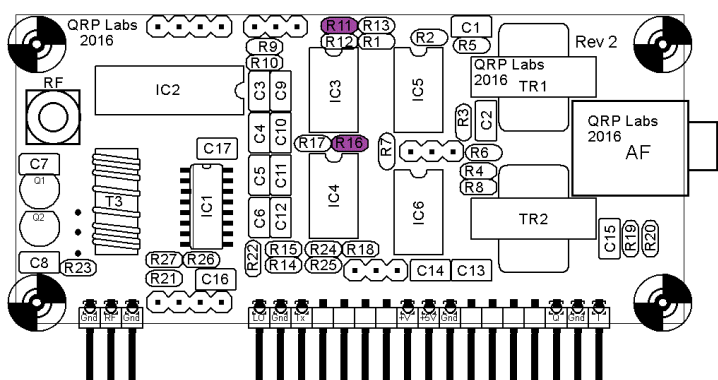
#### 4.9 10K resistors

These are the 11 resistors R9, R10, R14, R15, R19, R20, R21, R22, R23, R24 & R25. The colour code is brown-black-black-red-brown. The location of these resistors is shown in this diagram in blue.



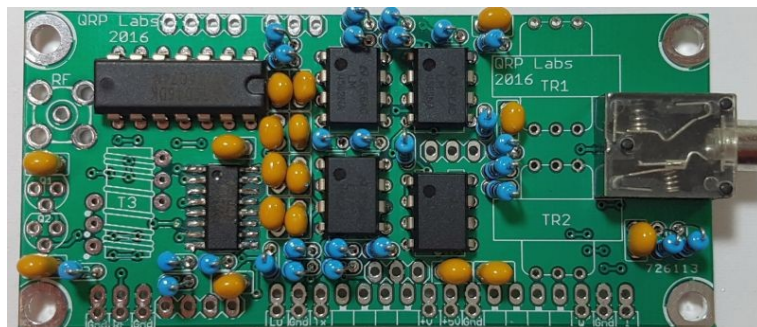
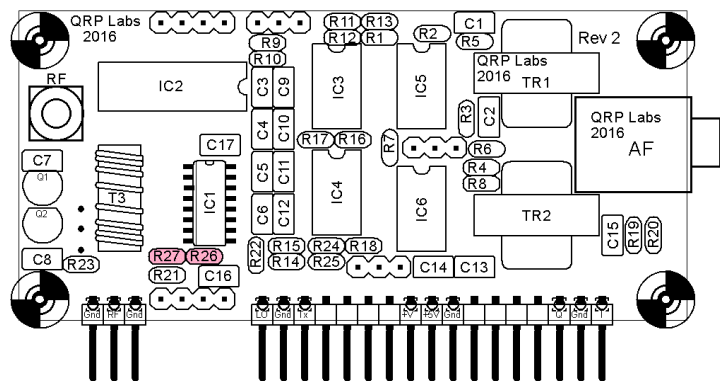
#### 4.10 150 ohm resistors

These are R11 and R16. The colour code is brown-green-black-black-brown. The location of these resistors is shown in this diagram in purple.



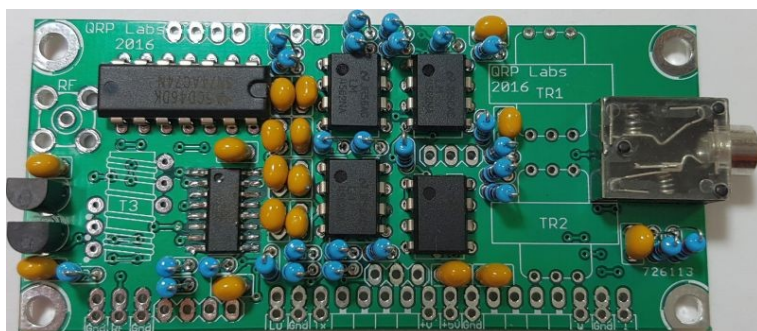
#### 4.11 82 ohm resistors

These are R26 and R27. The colour code is grey-red-black-gold-brown. The location of these resistors is shown in this diagram in pink.



#### 4.12 BS170 transistors Q1 and Q2

These are used as a transmit/receive switch if you are feeding in RF at the location of the SMA socket and wish to use Tx/Rx switching. The transistors are supplied on a short strip of plastic card. You need to bend the centre pin to match the hole layout on the PCB. Take care to ensure that the transistor is inserted into the PCB the correct way. The body shape of the transistor should match the outline on the PCB silkscreen, and in the parts layout diagram.



#### 4.13 600:600-ohm audio transformers

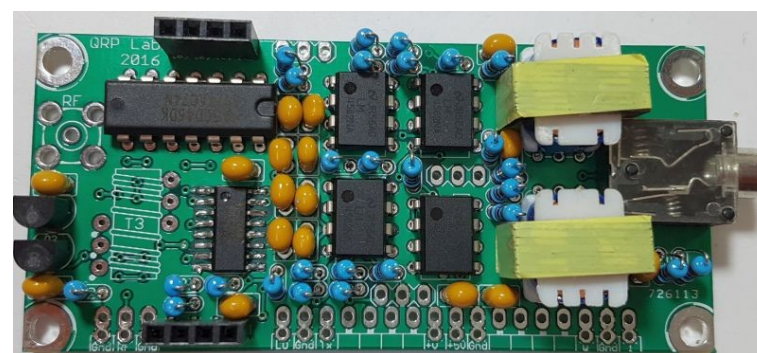
Install the two 600:600-ohm audio isolation transformers TR1 and TR2. The transformer body should match the drawing on the silkscreen (and parts layout diagram). The white former of the transformer body has 2 slots on one side and 3 slots on the other; it does not matter which way around the transformer is inserted. You may find one way fits better than the other.

**Although in this picture (below right) I have the transformers a mirror image of each other (one has the 3-slot side up, the other has the 2-slot side up), I think it would be better to be consistent and choose to have both 3-slot sides in the same direction. If there is any difference in the windings, it would be best for balance between I & Q to connect them the same way.**

#### 4.14 BPF sockets

Install the two 4-way pin header sockets that are used for the band pass filter. It is easiest to align these correctly if you plug in an actual band pass filter module, and solder in the sockets with the module in place.

#### 4.15 Trifilar toroid



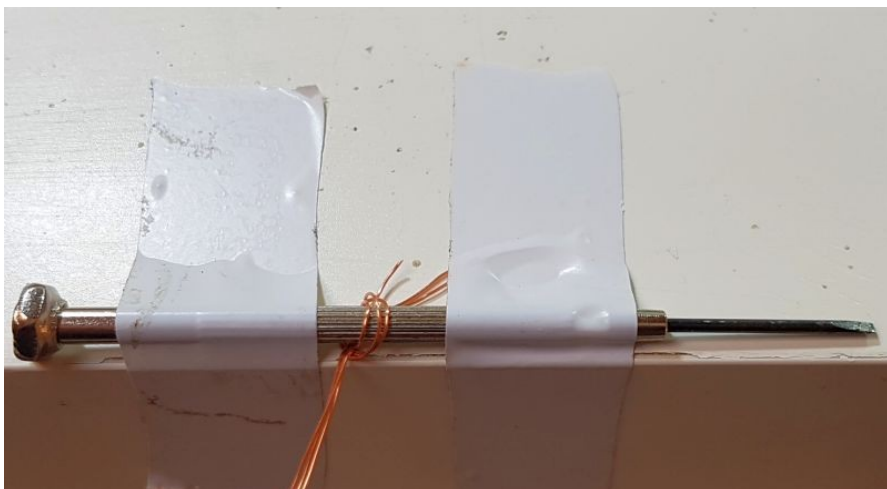
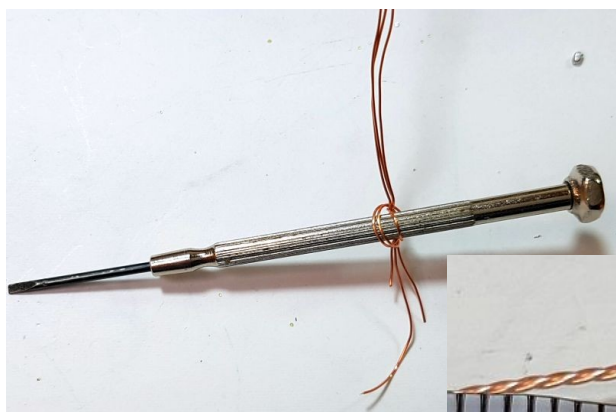
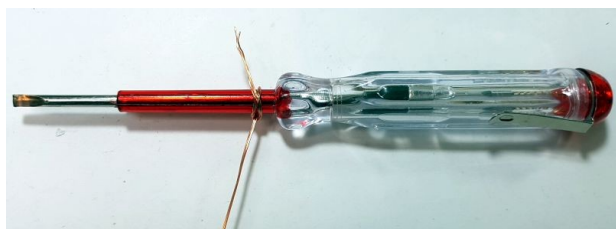


This section is probably the most difficult part of this kit assembly! It needs care so please follow these instructions very carefully. I do this last, because otherwise the toroid sticks out above the PCB while installing all the other components, and it inevitably gets squashed and moved around, putting unnecessary stress on the toroid wires and perhaps weakening or breaking them. Installing the toroid last avoids this potential headache.

Firstly, the wire. The best way to un-wind it, without tangling it up, is to think of what the kit-packing person that wound it up did. Then reverse his steps. So, first unwind the tightly wrapped part in the middle where the end of the wire has been secured. Then, open out the spool of wire so that it is a circle. Then unwind the spool, around your fingers, reversing the process of winding it in the first place.



When you have unwound the wire and straightened it, cut it into three approximately equal pieces. These three pieces now need to be tightly twisted together to make the trifilar wire. My method for this is to tie one end in a knot around a small screwdriver shaft. Similarly tie the other end around another small screwdriver. Now clamp one end somehow to something solid. You could use a vice, if you have one. If you don't, then you have to get creative and think of something. Here I taped it to the edge of the desk. Now you can twist the screwdriver at the free end, repeatedly until you twist the three wires together thoroughly. You need to keep the wire under a little tension to keep the twists evenly spaced.



I put about 70-90 twists into a 25cm length of wire. The end result is something like the photos (right).

(the measurement scale is in cm).

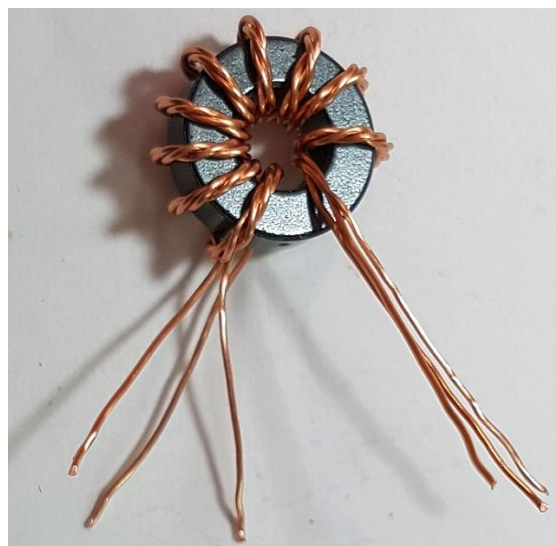
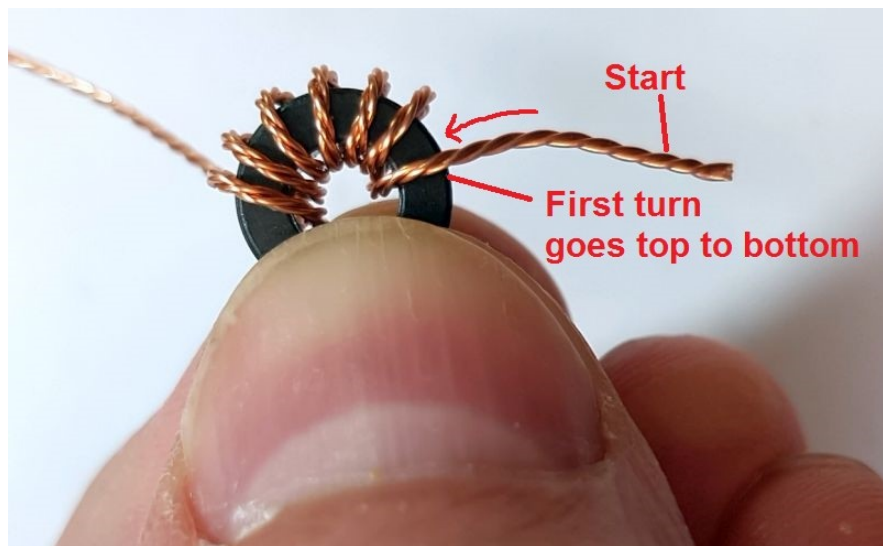






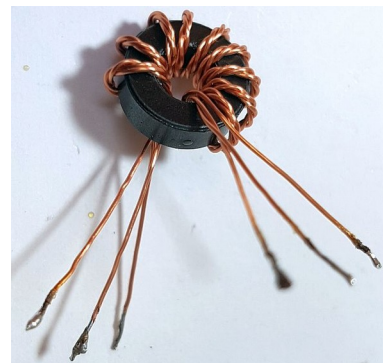
Now cut off the untidy ends, and this is the piece of wire that will be used to wind the FT37-43 toroidal core as a trifilar transformer.

Hold the core between thumb and finger. Pass the wire first from above, to below. Then take the wire from below, and bring it around to pass through the toroid again to form the second turn. After each turn, ensure the wire is fitting snugly around the toroidal core. Wind 10 turns on the core. Each time through the toroid's central hole counts as one turn. Cut off the excess wire, leaving about 2.5cm remaining.



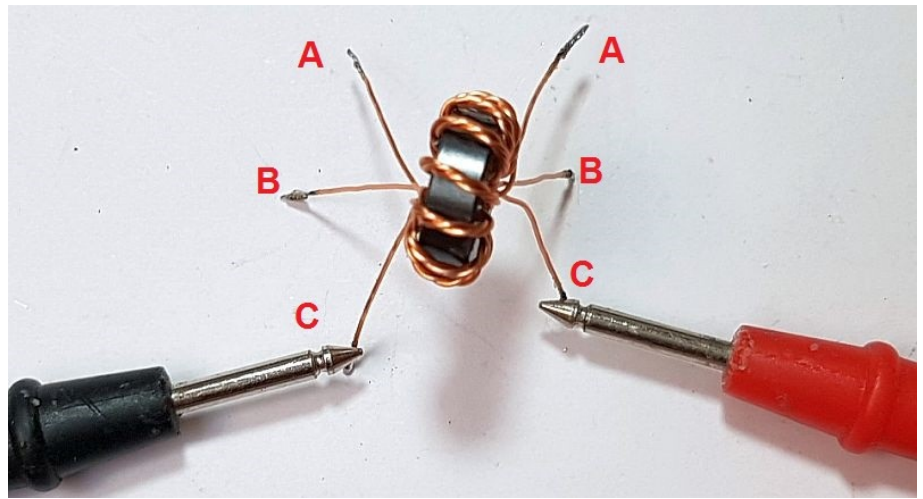
Now it's necessary to identify which wire belongs to which winding. You have three windings twisted together, they all use the same wire. The only way to do this is with a DVM as continuity tester. First, untwist and straighten the wire ends that are not wound around the toroidal core.

Now tin the last few mm at the ends of each wire. You can do this by scraping off the enamel then tinning with the soldering iron; or, if your soldering iron is powerful enough, hold the wire end in a blob of molten solder for a few (maybe 10) seconds, until the enamel burns off.

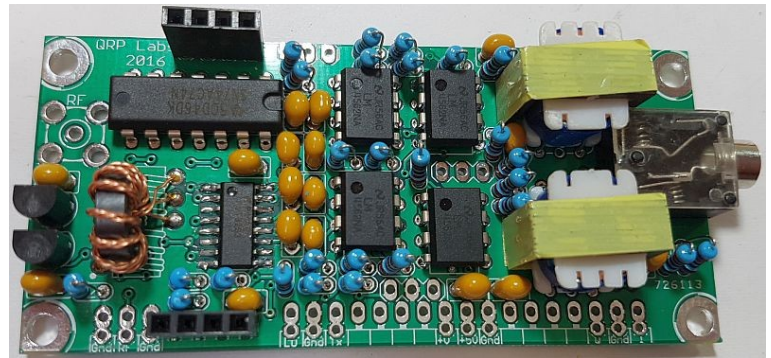


Now use a DVM to test for continuity. Re-arrange the wires so that there is continuity from A-A, B-B, and C-C in this photo.

Carefully keep this orientation of wires and insert the transformer this way into the PCB. You can carefully cut off those few mm of tinned section of wire, if it won't fit through the PCB holes. But BE CAREFUL not to lose the orientation of the wires! The right wires must be in the right holes, so that the windings are connected correctly in the circuit!



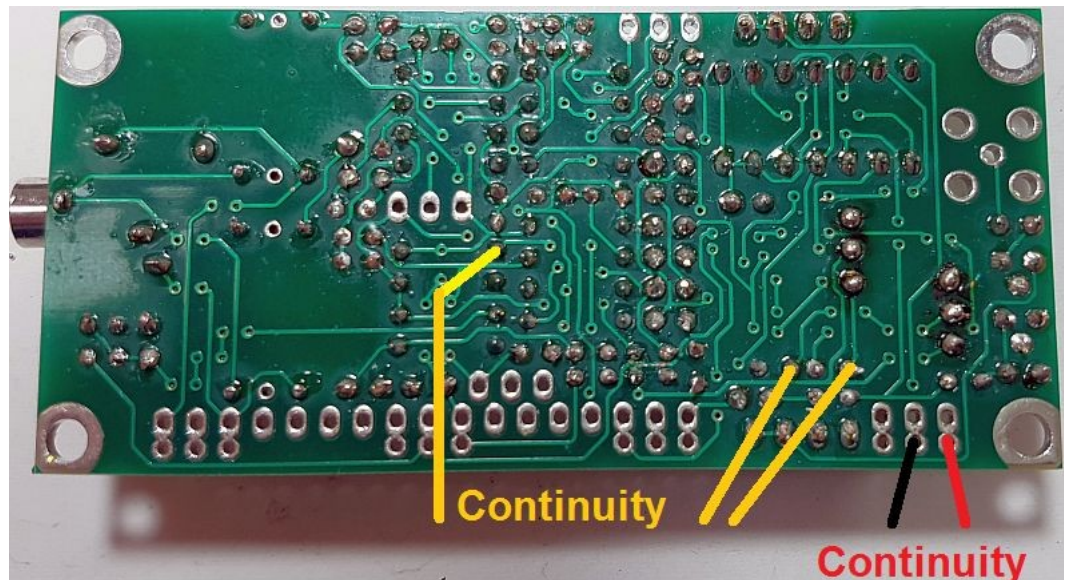
Now trim the wires underneath the board, and tin the ends again. The EASIEST way to do this is simply apply solder so that it sits in the hole and surrounds the 1mm of wire ending, and hold the soldering iron in that position for a few seconds until the enamel is burnt away.



Try to fit the toroid as far left as possible, as in this photo, so that it does not interfere with the Band Pass Filter module when plugged in.

You can test that the wires are properly soldered, as follows. First check for continuity between the RF input and ground. This tests the first winding. The easiest way to do this is just at the "RF" and adjacent "Gnd" pads at the board edge. Hold the black and red probes on the pads as indicated.

Next check for continuity between pin 1 of IC6 and the ends of the two 82-ohm resistors R26 and R27. Hold the black probe on IC6 pin 1. Hold the red probe on the resistor ends as indicated by the two nearby orange lines.



If both these checks pass, then it means that you have properly soldered the wires (removed the enamel insulation, making good electrical contact). Note that this does NOT necessarily check that you correctly orientated the windings. The only way to do that, was with the DVM continuity check before inserting the transformer; and after identifying the windings, being VERY careful not to mix the wires again while inserting the transformer in the PCB.



#### 4.16 Connector options

A 20-way pin header is supplied with the kit. It is designed to be broken into two pieces, 3-way and 17-way. It snaps into two pieces easily. See photo.

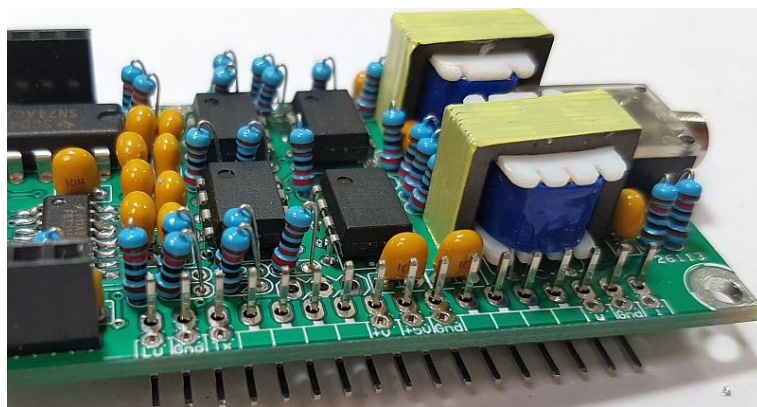
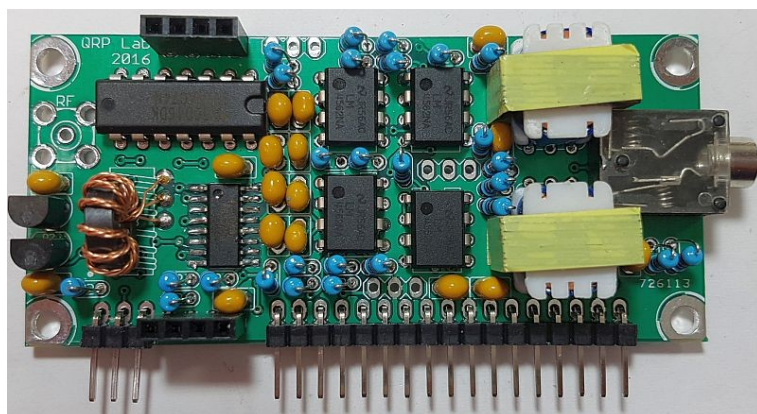
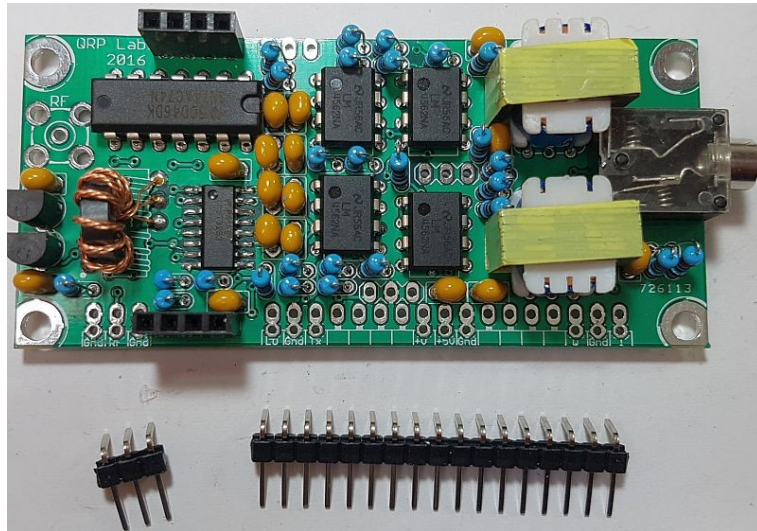
**Note, early kits used a right-angled pin header. The current kits are supplied with a straight header.**

This header can be used in various ways.

a) Don't use this pin header at all, and just solder wires to the receiver module as required. Each of the connections at the bottom edge of the PCB has both a hole for the right-angled connector strip, as well as a separate hole that can be used to solder in a wire if required.

b) Install the pin header strip in the intended way as a right-angled header. In the future, it is intended that this receiver module will be a plug-in module in future QRP Labs kits. In this configuration the receiver module will plug vertically into a horizontal mother-board.

c) If you prefer, you can install the pin header on the "wrong" side of the PCB, and solder the pins on the top side. That gives you two pins (top and bottom) at each connection, which you can solder wires to. Some people like to solder wires to pins rather than wires in holes.

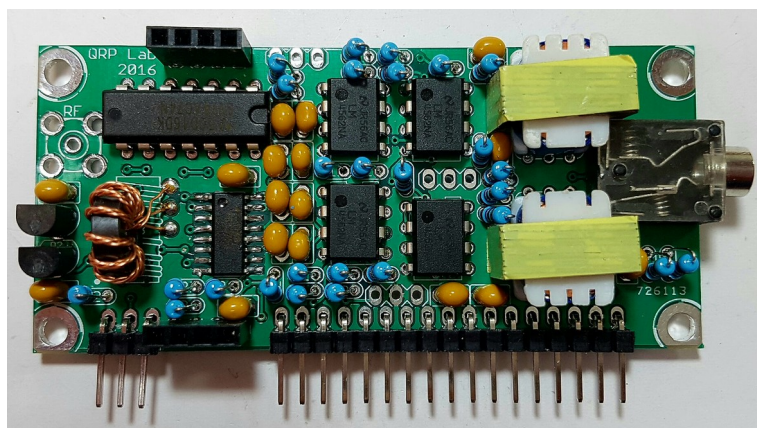


#### 4.17 SMA connector

The PCB has space for an SMA connector at the RF input. This is NOT supplied with the kit. If you wish, you may install a connector on the left side of the PCB.

#### 4.18 Completed assembly!

This completes the assembly of the receiver module! The completed board should look quite similar to this photograph!





## 5. Optional Polyphase network module

The receiver module produces an I-Q audio output, which is demodulated by digital signal processing software on a computer – for example, by the WSPR software, or by Software Defined Radio applications such as SDR# or HPSDR. This requires a stereo input soundcard, for the two output channels (I and Q).

Some PCs, particularly laptops, only have a mono microphone input. In these cases you can purchase external USB soundcards but these can be expensive. For these cases, you can plug in the optional polyphase network kit, which cancels the unwanted sideband in hardware, using a 4-column polyphase audio phase shift network and summation operational amplifiers.

The polyphase kit will also be useful for people who wish to construct a standalone receiver project, without using a PC for removing the unwanted sideband.

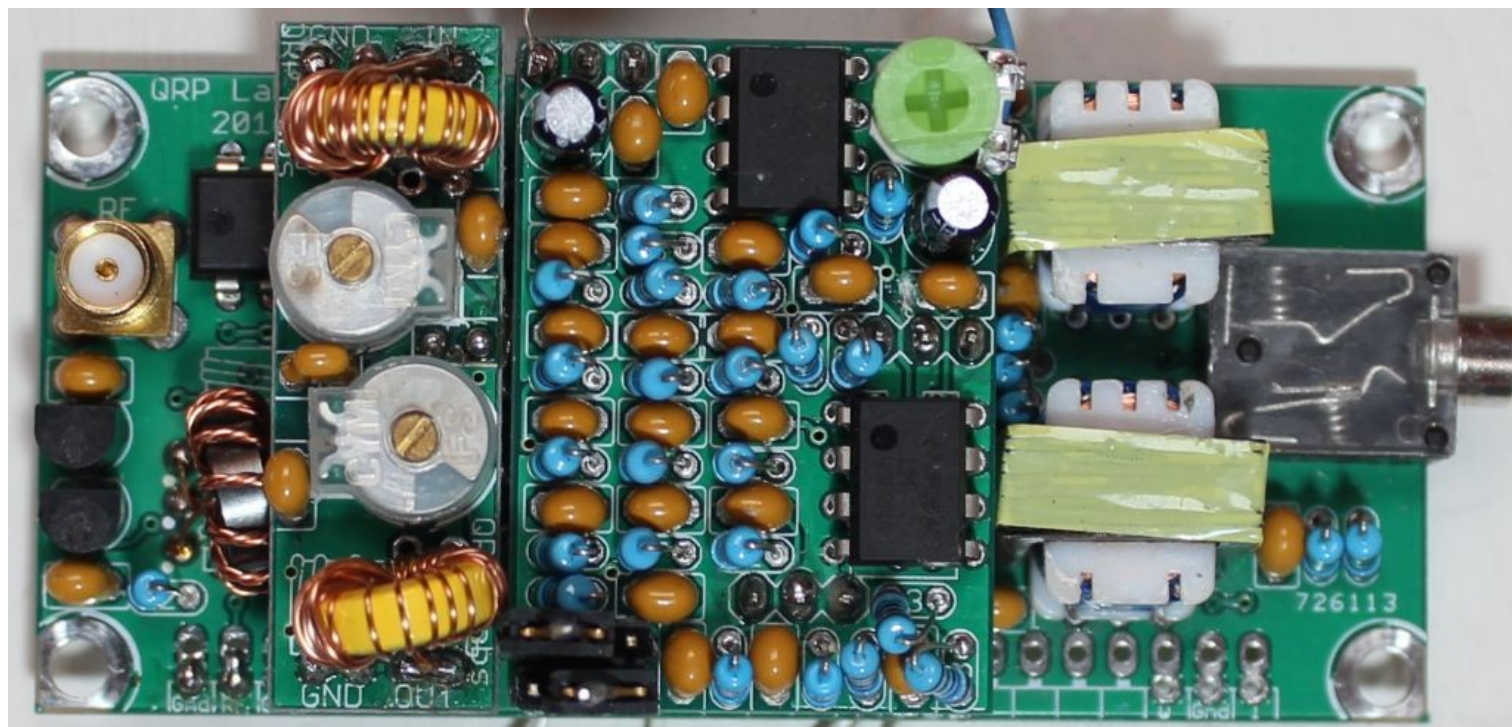
The polyphase network kit has separate assembly instructions.

This photograph shows the receiver module with Band Pass Filter module and polyphase module plugged in on top.

**When using the polyphase network, capacitors C1 and C2 must not be installed!** See the QRP Labs receiver kit page <http://qrp-labs.com/receiver> for photos of a modification by Mike G8NXD, using a pair of 2-pin turned pin sockets, so that C1 and C2 can be easily removed for fitting the polyphase board.

This is because the audio transformer TR1 is fed by the output of the polyphase network module, NOT by IC5. In fact, since IC5 is not used, you do not actually need to install IC5, TR2, or the associated resistors R1-R8 in the final difference amplifiers (IC5a, IC5b). There is no harm to having these components fitted, as long as C1 and C2 are NOT installed, so that the IC5 outputs are not routed to the audio outputs.

The three 3-way header sockets that the polyphase board plugs into are supplied in the polyphase kit, not the receiver kit.



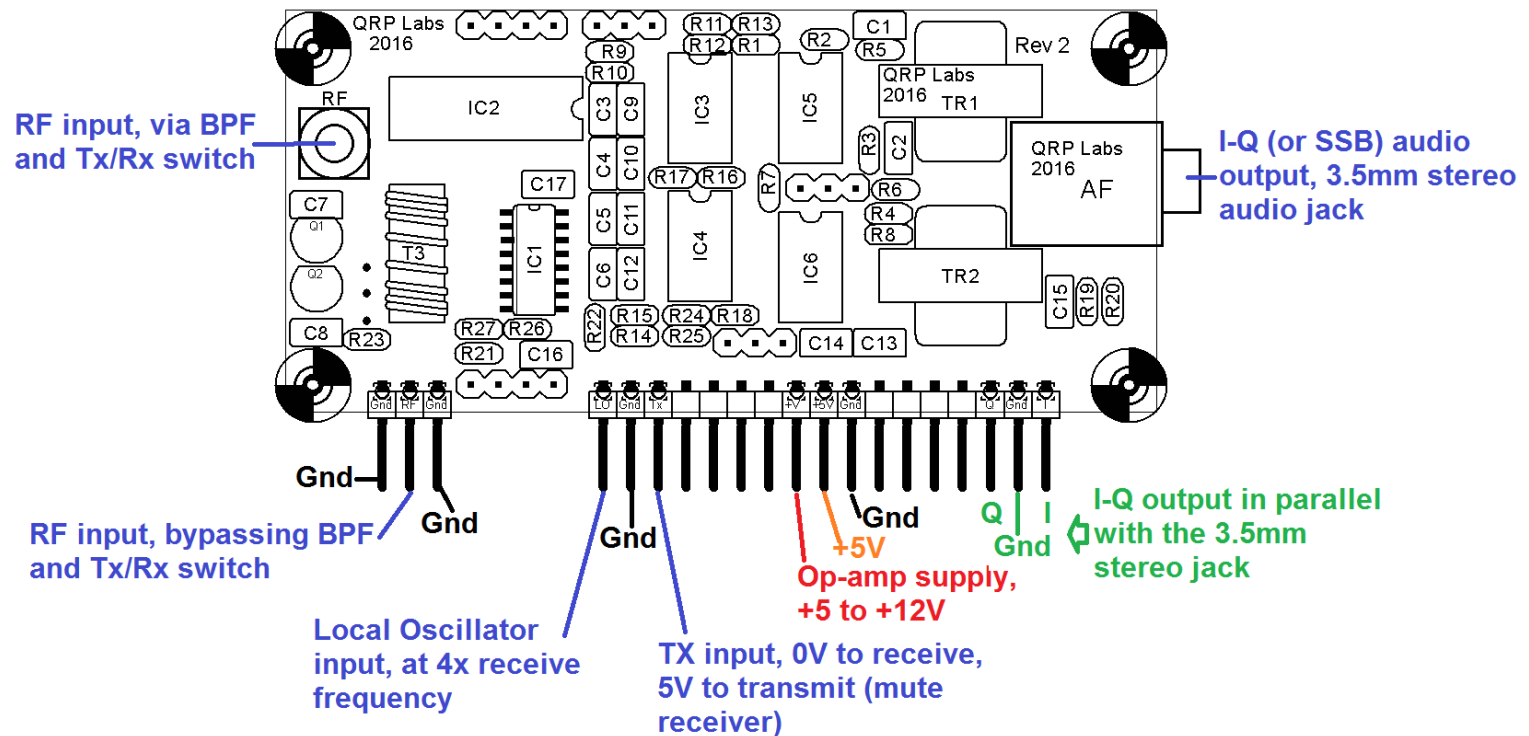
## 6. Connecting the Receiver

This receiver kit may be used in many different ways. The local oscillator (LO) signal can be generated by various QRP Labs kits (e.g. Ultimate3S QRSS/WSPR transmitter, VFO/Signal Generator and ProgRock kits).

This section will describe the pinout of the receiver module and provide examples of how to connect it.

### 6.1 Connections to the PCB

The following diagram shows the connections to the PCB.



#### Power supply

A single +5V supply may be connected to Gnd and +5V, and also to the op-amp supply pin. Alternatively, the op-amp supplies may be powered separately by a higher supply voltage such as 12V. This will provide some slight performance improvement (higher dynamic range). Of course the supply voltages should be well-regulated and low noise!

#### RF input

There are two options for RF input. Firstly, the RF may be fed in at the “RF” SMA connector. A SMA connector (not supplied) may be installed here, or simply wire coax directly to the PCB. The RF is routed through the Tx/Rx switch, and through the plug-in Band Pass Filter, before reaching the trifilar transformer TR3.

Secondly, where the receiver is used as a module in a larger project, such as a multi-band transceiver, and you have provisions for band pass receiver input filtering and transmit/receive switching elsewhere – you can feed RF directly into the header pin labelled RF. This is connected directly to the trifilar transformer TR3, bypassing the Tx/Rx switch and the BPF.

## LO input

A local oscillator signal is required, at 4x the receive frequency. This signal may typically be supplied by the 3.3V peak-peak squarewave output of a Si5351A Synthesiser, but other oscillators are also suitable. The input is AC-coupled and biased to 2.5V by C16, R21 and R22 (see circuit diagram). A sinewave oscillator with 2-5V amplitude is also acceptable. A squarewave input is preferable to sinewave. If you have sinewave, use sinewave. If you have squarewave, use squarewave – but do NOT use a LPF to make it into a sinewave – because the receiver input anyway converts to squarewave, and prefers squarewave.

## Transmit/Receive switch

(where the SMA connector RF input is used). This pin is labelled “TX”. A high on this pin (5V) disconnects the RF input from the receiver using the transistors Q1 and Q2. If the direct connection RF input on the pin headers is used, this Tx/Rx switch has no effect. However you must still always connect the TX signal (e.g. to ground, to enable), in order to switch on the FST3253 in the Quadrature Sampling Detector. If the receiver module is being used in a receive-only application, then you wire the “TX” transmit/receive switch input to ground permanently. **Never leave the TX connection floating!**

## Audio output

The I-Q audio output (or Single Sideband if polyphase board is fitted) is a 3.5mm stereo jack socket. This is connected directly to your PC soundcard input, if you are using the PC to demodulate SSB (e.g. with SDR software, or WSPR software). I is Right, Q is left.

The same audio outputs I, Q and Ground are also available at the pin header.

Note that this “ground” is not the same as the power supply ground, or the groundplane of the PCB! This “ground” is the isolated ground from the 600:600-ohm audio isolation transformers! Do not connect this ground to the power supply ground or the PCB groundplane – doing so just removes the benefits of the audio isolation transformers. These transformers reduce hum caused by ground loops.

## Band Pass Filter socket

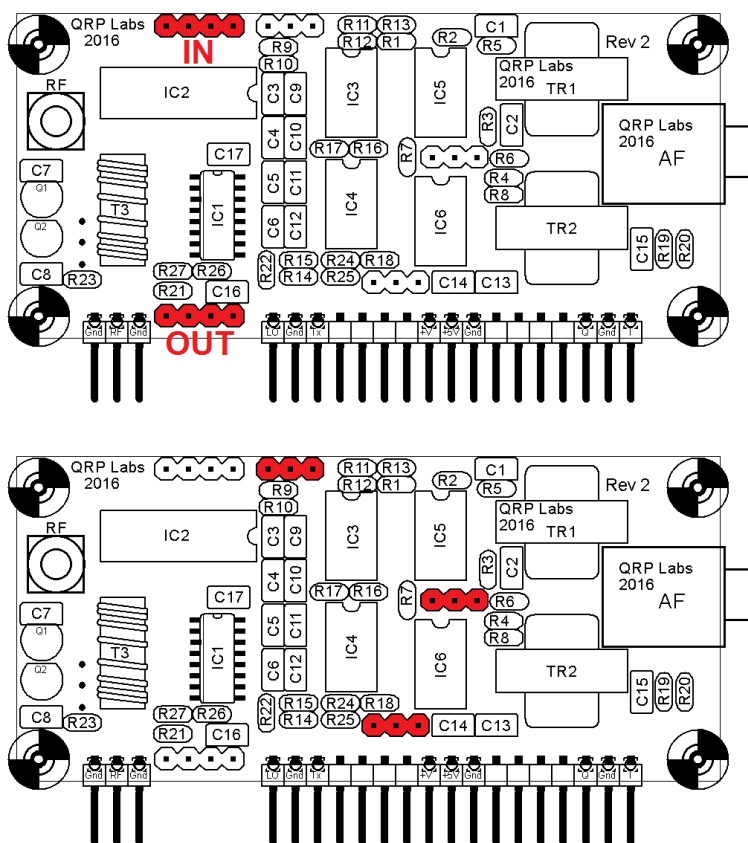
A QRP Labs BPF module should be plugged in to the receiver to protect the mixer against strong out of band signals, thereby reducing the possibility of intermodulation.

The BPF module **MUST** be plugged in with the correct orientation. The BPF PCB has “In” and “Out” printed on its silkscreen. These must match the red text in this diagram.

## Polyphase module

If the optional polyphase network kit is used to cancel the unwanted sideband, rather than using digital signal processing (e.g. SDR or WSPR software), then it plugs into these sockets as indicated in red. **C1 and C2 must be omitted!**

The SSB audio is output on the Q channel, which is the LEFT channel of the stereo connector.





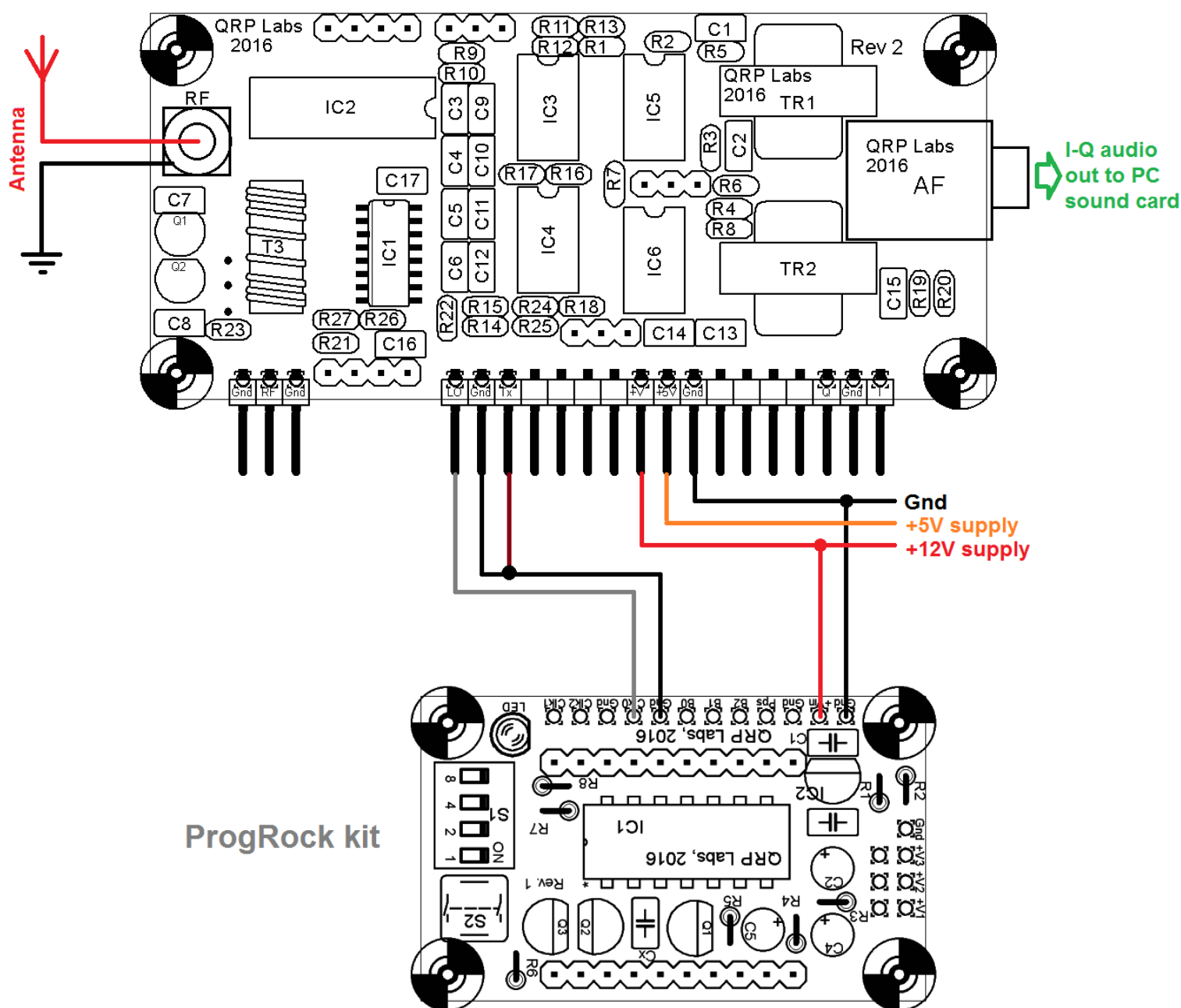
This example shows the ProgRock kit used to provide a configurable fixed frequency LO for the receiver module. Remember to set the LO frequency to 4x the required reception frequency.

The ProgRock Clk0 output is connected to the receiver LO input. Read the ProgRock instructions about the GPS connection, if you are using GPS to calibrate/discipline the ProgRock frequency. If not, connect the 1pps input to ground.

In this receive-only application, the transmit/receive switch is always switched on; so connect the “TX” input of the receiver module to ground.

The example shows a 12V supply used to power ProgRock and the op-amps, and a separate 5V supply for the 74AC74 and FST3253 QSD mixer IC. You could also experiment with using the LM317LZ 5V regulator on the ProgRock board, as the supply the 5V on the receiver module board.

Read the ProgRock manuals too.



### 6.3 Example: Using the receiver with a QRP Labs VFO/SigGen kit

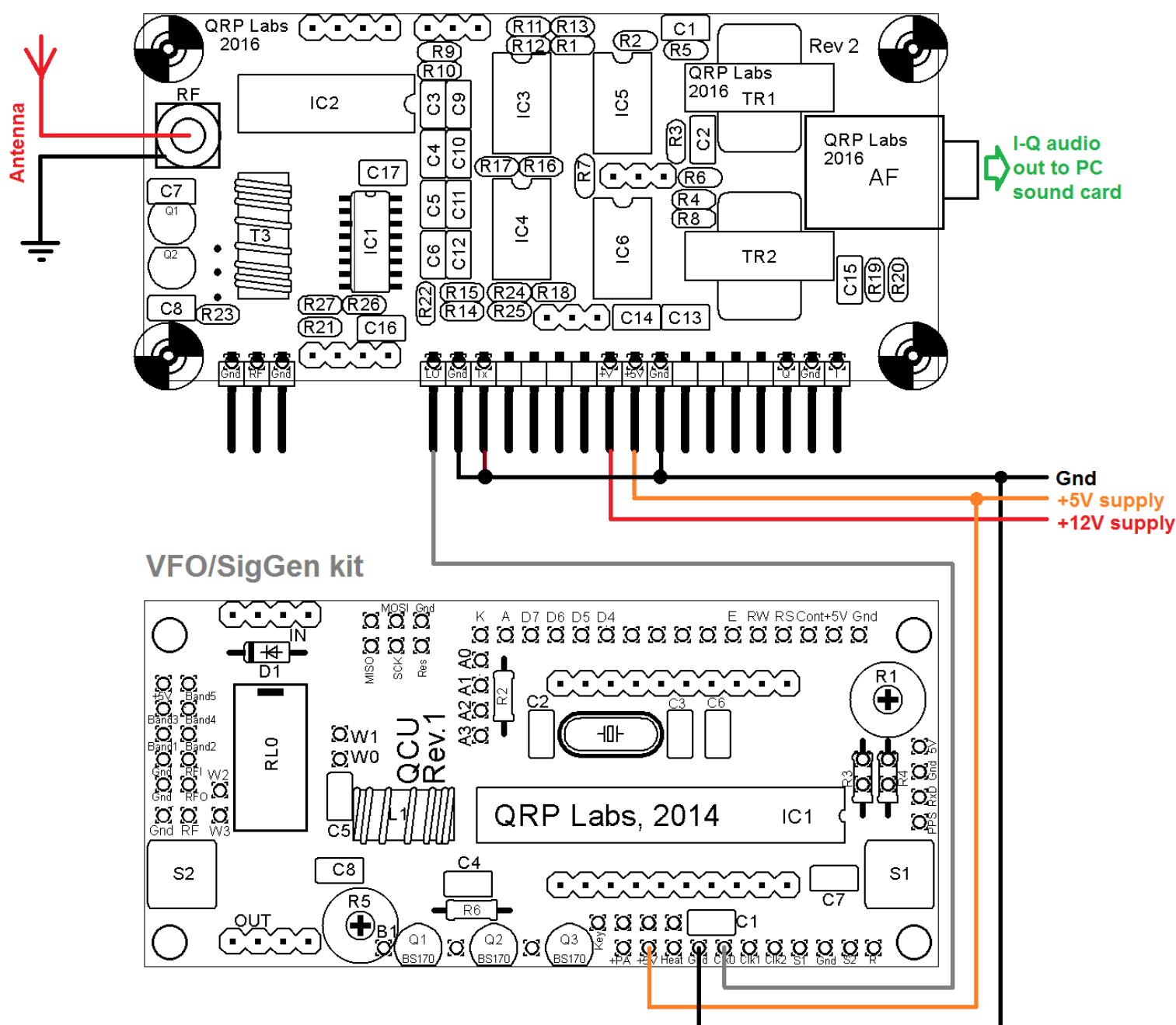
This example shows the VFO/SigGen kit used to provide a rotary-encoder tuned variable frequency LO for the receiver. The VFO/SigGen kit has a “Multiplier” setting which should be set to 4, so that the output frequency is 4x the displayed (reception) frequency.

The VFO/SigGen Clk0 output is connected to the receiver LO input. The VFO/SigGen may also be GPS disciplined by connecting a GPS module such as the QRP Labs QLG1.

In this receive-only application, the transmit/receive switch is always switched on; so connect the “TX” input of the receiver module to ground.

The example shows a 12V supply used to power the op-amps, with a separate 5V supply for the VFO/SigGen kit and the receiver’s 74AC74 and FST3253 QSD mixer IC. If preferred, you can power the receiver op-amps from 5V (see discussion above).

Read the VFO/SigGen instructions carefully too.



#### 6.4 Example: Using the receiver with a QRP Labs Ultimate3S QRSS/WSPR transmitter kit

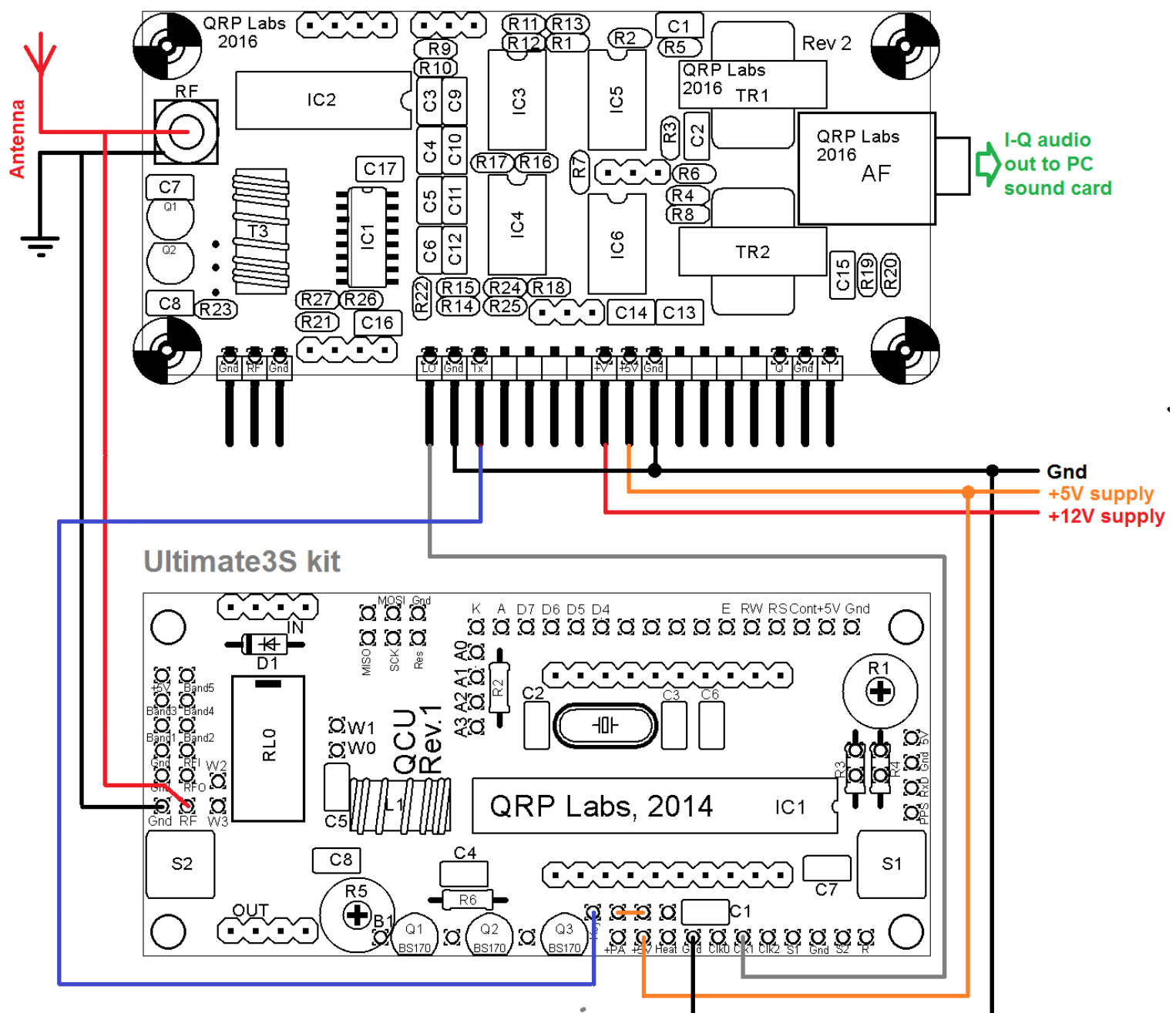
This example shows the QRP Labs Ultimate3S kit used to provide a fixed configurable LO frequency for the receiver. The Ultimate3S kit's Clk1 output is connected to the receiver LO input. Set the U3S' Park Mode setting to 4, and the Park Frequency to 4x desired reception frequency. Remember that the LO frequency must be 4x the reception frequency!

The Clk1 output will be set to the configured frequency, and operate receiver module. In Park Mode 4 the Clk1 output is available continuously, even during the GPS calibration (if used).

In this application we have a transmitter and receiver connected to the antenna. Therefore we must use the transmit/receive switch! So connect the receiver module's "TX" input to the "Key" output of the U3S. This output is high during transmit (5V) and will switch off the receiver's transmit/receive switch.

The example shows a 12V supply used to power the op-amps, with a separate 5V supply for the Ultimate3S kit and the receiver's 74AC74 and FST3253 QSD mixer IC. If preferred, you can power the receiver op-amps from 5V (see discussion above).

Read the Ultimate3S manuals carefully too!





## 6 Using the receiver module for WSPR decoding

In all examples described below, it is important to remember to calibrate the reference frequency of your oscillator; this applies whether using the ProgRock, Ultimate3S, or VFO/SigGen kits – or indeed, any frequency source of your own. The most common cause for failure to transmit/receive WSPR is poor frequency calibration! If you are using a QRP Labs kit with GPS connected, then you can calibrate/discipline the frequency automatically. Please refer to the relevant kit documentation.

### 6.1 Receiver module kit with polyphase kit and mono-input soundcard

This is the simplest case. Just connect the receiver audio output to the mono input (often labelled “microphone” of your PC. The WSPR software can be used to decode WSPR without further configuration. Read the WSPR software documentation for further information on how to use it.

In this case, set the Local Oscillator frequency to 4x the desired reception frequency. The standard WSPR frequencies are listed in a panel on the left side of the WSPRnet home page (see right). These frequencies are the centre frequencies of a 200Hz sub-band used for WSPR, and are the USB dial frequencies. What this means, is that when a receiver is used in “USB mode”, this is the frequency that will be displayed on the dial, in order to receive audio at 1500Hz centre frequency (1400Hz to 1600Hz WSPR band). This frequency is also applicable to the QRP Labs receiver module.

For example, if you want to receive 30m WSPR, and you are using a ProgRock to generate the frequency, then set the ProgRock frequency to  $10.1387 \times 4 = 40.554800\text{MHz}$ .

#### Frequencies

USB dial (MHz): 0.136, 0.4742, 1.8366, 3.5926, 5.2872, 7.0386, 10.1387, 14.0956, 18.1046, 21.0946, 24.9246, 28.1246, 50.293, 70.091, 144.489, 432.300, 1296.500

### 6.2 Using WSPR software in I-Q mode to demodulate the SSB

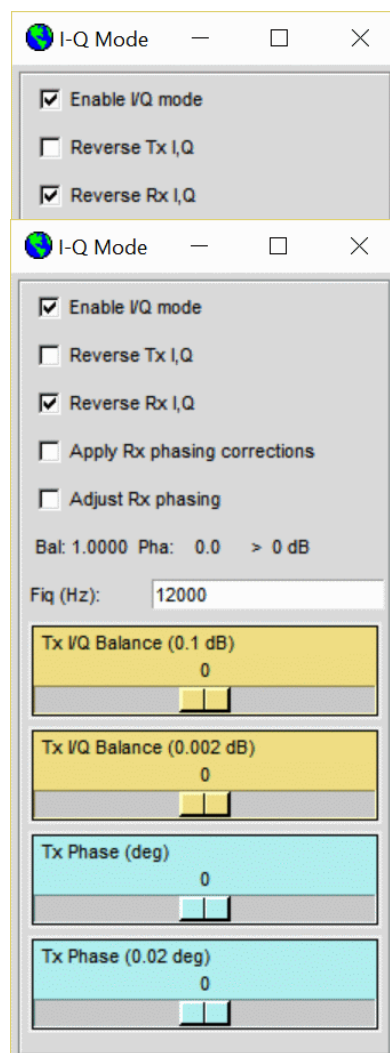
The WSPR software has an I-Q mode, which uses Digital Signal Processing similar to a Software Defined Radio, to cancel out the unwanted sideband resulting in single sideband reception.

Connect the receiver audio output to the input of a stereo input soundcard. Start the WSPR software and press keyboard key F8. This opens the “I-Q Mode” window.

- Tick the checkbox “Enable I/Q mode”
- Tick the checkbox “Reverse Rx I,Q”
- Set “F<sub>iq</sub> (Hz):” to zero (more on this in the next section)

Now configure the receiver LO as in the section 6.1, and WPSR will demodulate the Upper Sideband from the I & Q outputs supplied by the receiver output.

### 6.3 Using “F<sub>iq</sub> (Hz):” for improved performance



The WSPR software has a very useful feature, which allows you to offset the decoded slice of spectrum from the baseband 0Hz frequency by a defined amount.

The reason that this is so useful is that it is often very difficult to completely get rid of 50Hz (or 60Hz in US and some areas) mains line frequency hum, and other low frequency noise. You can easily see this if you observe the usual 0 to 3000Hz audio frequency in SDR software or the Argo software. You can often see lots of noise, horizontal lines spaced every 100 (120) Hz, etc. These will all be capable of interfering with your WSPR decoding. Often if you can get a little further away from 0Hz, you can substantially reduce the noise, and therefore improve WSPR reception!

This is all controlled by the “Fq (Hz):” parameter. The default is 12000Hz, meaning a 12kHz offset.

You must also remember to offset the receiver LO frequency by the same amount. As an example, let us suppose that you want to receive 20m WSPR. You check the WSPRnet homepage and observe that the centre frequency for 20m WSPR operations is shown as 14.0956 USB dial frequency. Now if you are using a 12kHz “Fq (Hz):” offset, then you must set the receive frequency to  $14.0956\text{MHz} - 12\text{kHz} = 14.083600\text{MHz}$ . “Minus” is because we are receiving Upper Sideband. Now remember that the LO must operate on 4x the receive frequency – so set the LO frequency to  $14.0836 \times 4 = 56.334400\text{MHz}$ .

Note that if you are using the VFO/SigGen for your LO, and have the “Multiplier” set to 4, then the firmware does this multiplication by 4 for you.

#### **6.4 Transmitting WSPR using the Ultimate3S QRSS/WSPR transmitter**

A point of confusion often arises surrounding transmitter frequency. In the Ultimate3S kit the configured frequency on a transmit screen is the ACTUAL transmitted frequency. The frequencies listed in the WSPRnet homepage centre frequency panel are DIAL frequencies, assuming USB and the usual 1500Hz offset – meaning that WSPR is received at audio frequencies from 1400Hz to 1600Hz. To convert from the listed USB dial frequency to the actual transmit frequency, we must add 1500Hz.

So for 20m, for example – the dial frequency is listed as 14.0956MHz. The actual transmit frequency is therefore  $14.0956\text{MHz} + 1500\text{Hz} = 14.097100\text{MHz}$ . This is only the CENTRE of the 200Hz wide WSPR sub-band. Correct WSPR transmissions are therefore in the range 14,097,000 to 14,097,200 Hz.

So for example, suppose you wanted to transmit and receive on 20m WSPR (receiving in the gaps between transmissions). You want to use the “Fq (Hz):” offset feature of WSPR in I-Q mode for maximum performance.

You would configure your Ultimate3S transmit screen to transmit on 14,097,050 (say); and configure Park Mode 2, Park Frequency 56,334,400. This sets the Clk1 output to 56.3344MHz on receive, which is the required LO frequency for the receiver when operating with the WSPR offset feature (see section 6.2).

## **7. Resources**

- Please see the kit page <http://grp-labs.com/receiver> for information and latest updates.
- “A software Defined Radio for the Masses, Part 4”, by Gerald Youngblood, AC5OG in QEX March/April 2003 describes the Quadrature Sampling Detector, including the double-balanced version see <http://www.arrl.org/files/file/Technology/tis/info/pdf/030304qex020.pdf>
- Dan Tayloe’s description of the QSD, which is also known as “Tayloe detector”.  
[http://www.wparc.us/presentations/SDR-2-19-2013/Tayloe\\_mixer\\_x3a.pdf](http://www.wparc.us/presentations/SDR-2-19-2013/Tayloe_mixer_x3a.pdf)
- WSPRnet home page: <http://wsprnet.org/drupal/>
- WSPR may be downloaded from the WSJT home page <http://physics.princeton.edu/pulsar/K1JT/>

## **8. Document version history**

### **1 24-Aug-2016**

- Initial document version

### **2 24-Aug-2016**

- Fixed typo in section 6.4, which said the U3S was variable rotary encoder tuned (that belongs in the VFO section)

### **3 25-Aug-2016**

- Fixed typos – “BNC” should be “SMA”

### **4 26-Aug-2016**

- Fixed circuit description which incorrectly mentioned  $\frac{1}{2}$  LO as the frequencies to the FST3253 – it should be  $\frac{1}{4}$  LO

### **5 26-Aug-2016**

- Added note in section 6.1 – the TX connection should never be floating, even if the Tx/Rx switch is not used, because it enables the FST3253

### **6 29-Aug-2016**

- Added clarification in section 6.1 about sinewave vs squarewave – the latter is preferable
- Amended section 6.4 to suggest the use of Park Mode 4 when using the U3S kit (not park mode 2), which operates the Si5351A Clk1 output continuously, even during calibration

### **7 13-Sep-2016**

- Added emphasis about Electrostatic Discharge precautions
- Added note about fitting turned pin sockets (modification by G8NXD) for capacitors C1 and C2

### **8 15-Sep-2016**



- Corrected reversed orientation of BPF module in section 6.1 and photo in section 5.

**9      20-Sep-2016**

- Corrected typo in receiver URL in section 5

**9      20-Sep-2016**

- Moved warning about not installing C1 and C2 when using the polyphase kit, to BEFORE the figure, in section 4.7

**10     25-Nov-2017**

- Corrected section 5, it said IC4 does not need to be installed; correction is that IC5 does not need to be installed (when you use the polyphase board)