The SDR 40: A simple sound card receiver for 40 metres

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Constructing a good general coverage receiver used to be a formidable undertaking. Few amateurs built them and kits had been rare for decades. Software defined radio technology has made the task easier and kits are once again available. However it's still desirable to start with something more modest such as a set for a single band.

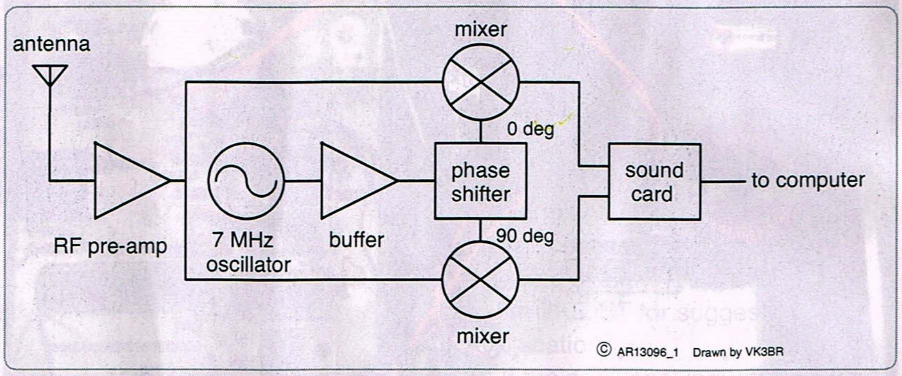


Figure 1: The block diagram.

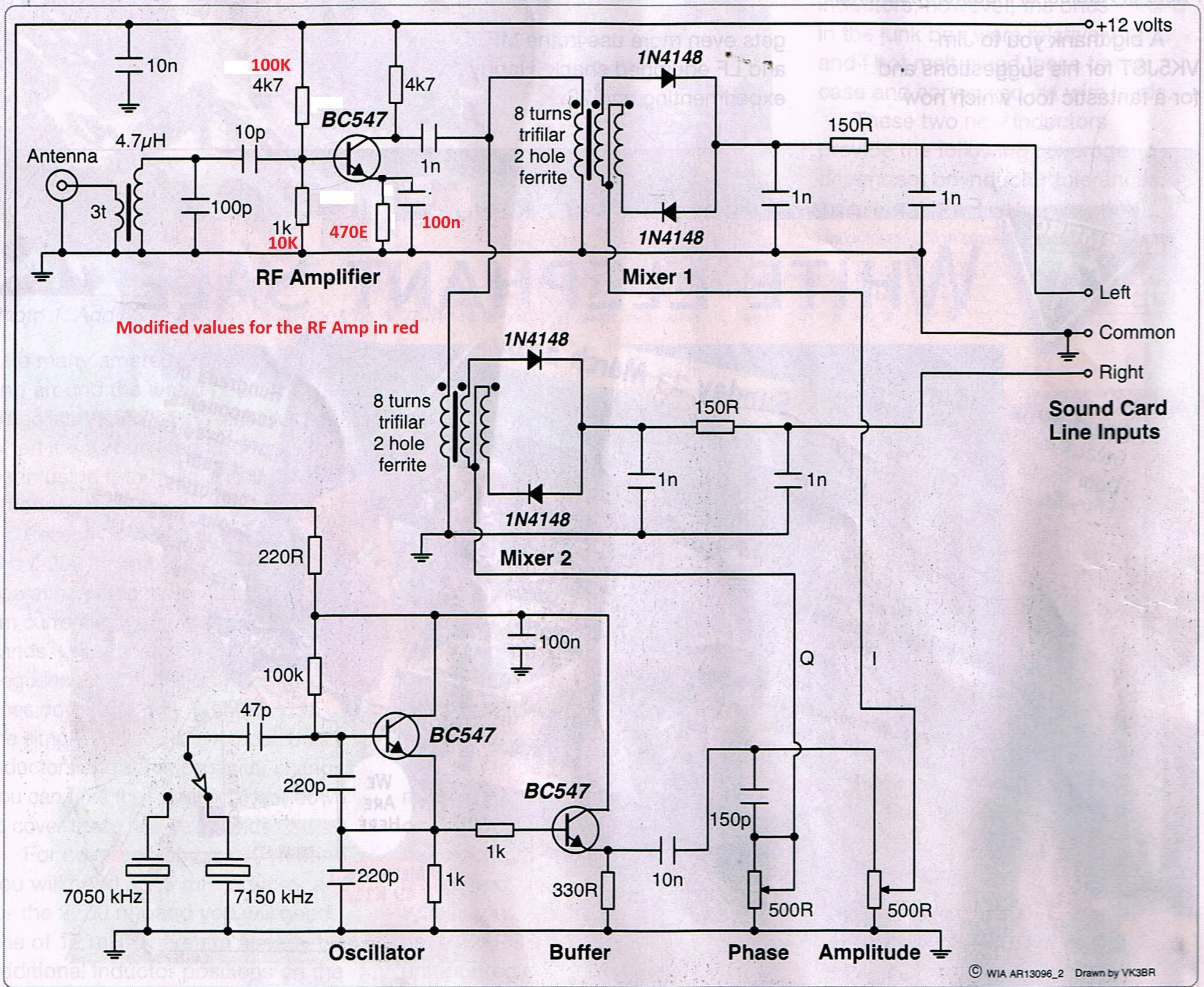


Figure 2: The schematic diagram.

Described is a simple front end with IQ outputs. In conjunction with a high quality sound card it allows reception of one or more 96 kHz segments of the 7 MHz band. It only uses readily-available discrete components and no surface mount parts are involved. Because most of the smarts are in the software, performance is out of proportion to its complexity and construction should take less than two hours.

Photo 1: The receiver with the external Sound Blaster X-Fi Surround 5.1 Pro soundcard.

How it works

Incoming signals negotiate a tuned circuit and are amplified by a NPN transistor stage. They are then fed to two identical diode mixers that are fed with different signals from the local oscillator. As a consequence the local oscillator outputs are also different and are fed to a stereo sound card for processing by the computer.

The transistor local oscillator operates in the centre of the desired tuning range (or the frequency of an available crystal). Another transistor buffers its output. This is fed to and split in a phase shift network comprising a capacitor and two trimpots.

The setting of these trimpots, labelled Phase and Amplitude, is critical and there is some interaction between them. When the phase trimpot is adjusted to match the 150 pF capacitor's reactance at 7 MHz (approximately 150 ohms) and the amplitude trimpot is set correctly the result is two local oscillator outputs of equal amplitude but 90 degrees in phase different from one another. These are often known as I and Q, or 'in-phase' and 'quadrature'.

The I output goes to one mixer while the Q output goes to the other. The output from the mixers will, like the oscillator's outputs, be similar but phase shifted by 90 degrees. The mixers' in-phase and quadrature outputs (between 0 and 48 kHz) go to a stereo sound card for processing by the radio software.

Feeding I-Q outputs to a stereo sound card is a bit like seeing with two eyes instead of one or hearing with two ears instead of one. The information arriving at each sensor is slightly different. Certain things can be discerned with two that cannot be with one.

In this case it's the relationship between incoming signals above the centre frequency and those below it. A simple mixer will generate a 10 kHz difference signal regardless of whether one of its inputs is 10 kHz above or below a fixed local oscillator frequency. Which means that if there are input signals above and below (as could be the case for a receiver mixer tuned to a busy band), the output will contain a babble of both. You wouldn't be able to tell which was which if you used a single product detector and audio amplifier as per a simple direct conversion receiver.

That is unless you move the local oscillator slightly in frequency. Signals in the direction you are tuning towards drop in pitch while those you're tuning away from rise in pitch. Hence adjusting the local oscillator up in frequency will cause signals above it to drop in pitch while signals that are lower in frequency than the local oscillator will rise in pitch as you tune away.

Knowing this doesn't help much when trying to discern a signal in a crowded band on a simple direct conversion receiver (or crude SDR). However imagine that it was possible to hear only those signals that dropped in pitch when you tuned towards them. Those signals that rose in pitch would not be audible. As a result you'd only hear signals above the local oscillator's frequency while those below would be rejected. Hence single signal reception would be achieved without an additional frequency conversion and use of a narrow crystal filter.

It would be even better if this could be done without retuning the local oscillator (which would detune the signal if receiving SSB). As it happens, this is possible thanks to the phase difference between signals above and below the local oscillator. The human ear cannot detect these but a stereo soundcard with SDR software can, provided that different I and Q signals are fed to its inputs. We ensure this difference through the use of two product detectors each fed with equal amplitude but phase shifted local oscillator signals as discussed before.

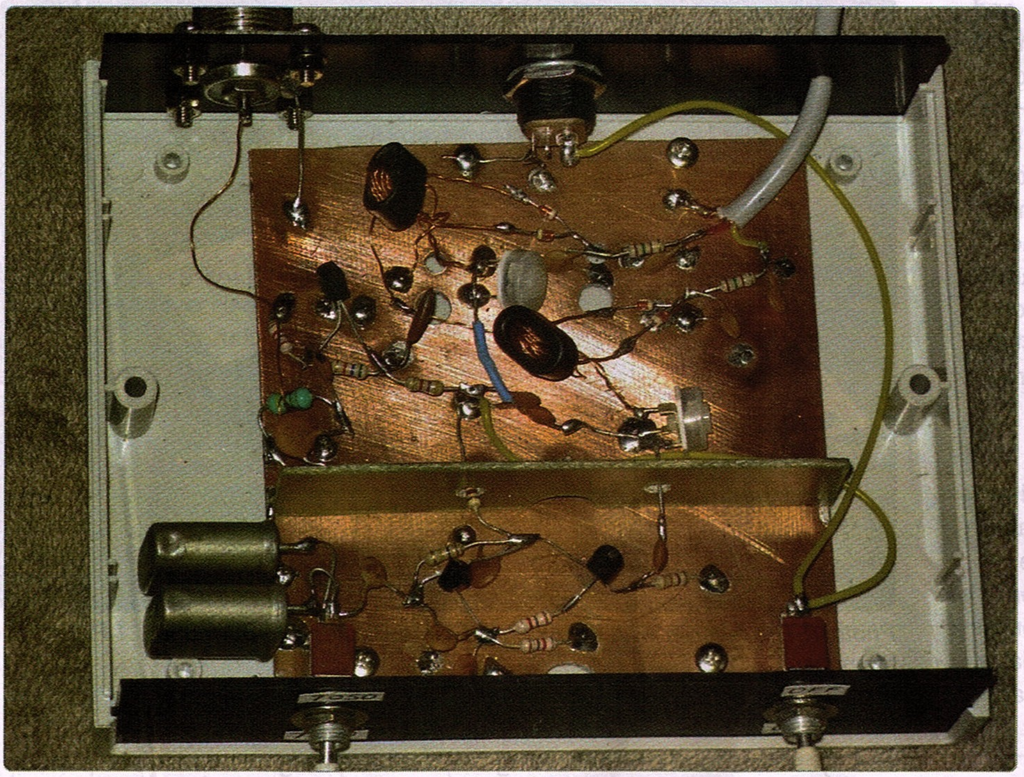


Photo 2: Inside the receiver.

a small gap around 7.1 MHz. Another approach is to use a 7.2 MHz ceramic resonator pulled down to approximately 7.1 MHz, though this will be less stable.

Build and test the oscillator and buffer stages first. Leads should be kept short. There should be shielding between it and other stages. A partition made of circuit board material was used here though a separate box would have been better.

Set the phase and amplitude trimpots to half travel for now. You should be rewarded with a carrier on or very near the crystal frequency. Its precise value is not critical unless you want a round number to enter into the software as the centre frequency.

Next build the two identical mixers. The hardest part in these to get right is the trifilar (that is, three wires twisted together) coil which is wound on a two-hole TV balun former. Available in short or long sizes these have holes approximately four mm in diameter and look like miniature binoculars.

A good way to twist the wires is to take three pieces of enamelled copper wire (approximately 0.3 to 0.4 mm diameter such as from an old power transformer) and twist them together in the chuck of a hand drill. The other end of the wires, which are about 20 or 30 cm long, can be held with pliers. Stop twisting when there are about two or three twists per centimetre.

Wind eight turns (not critical) onto the two-hole ferrite former, with each turn comprising a pass through each hole. Once done it should not be possible to easily fit very many more turns on.

The black dots on the circuit diagram signify one side of each coil. You will notice that one side of one of the three wires goes to the other

Software

Various SDR programs can be freely downloaded off the web.
I use SDRadio by I2PHD. Features include a spectrum scope, frequency display, s-meter, variable gain, variable bandwidth and noise limiter.

Depending on your computer's speed it can be set to 48 kHz sampling (able to tune 24 kHz above and below the centre frequency) or 96 kHz (+/- 48 kHz range). Try a lower sampling rate if the sound output starts to break up.

Sound card

A sound card with stereo line inputs is essential. Otherwise it will not be possible to suppress unwanted signals and all transmissions will appear twice, potentially interfering with the reception of others.

The sound card also needs to be a low noise type. Otherwise receiver sensitivity will be poor and signals will not sound as clean as they should be.

Use an external USB-powered sound card if the one in your computer does not meet these requirements. I suggest a mid-priced unit such as the Sound Blaster X-Fi Surround 5.1 Pro pictured in Photo 1 below. This costs around $60 from specialist computer retailers.

Construction

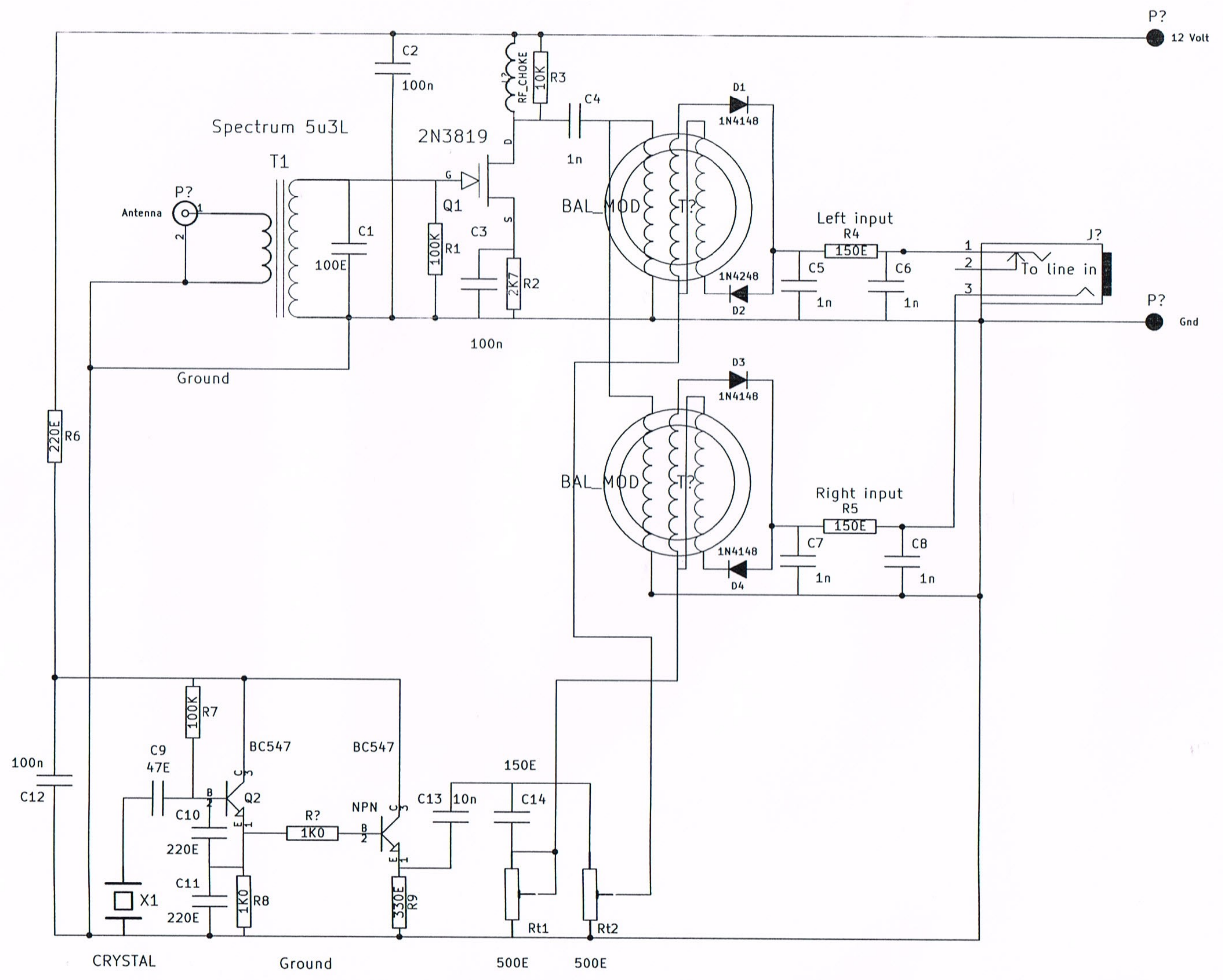
The prototype was built onto a piece of blank printed circuit board material, refer Photo 2. As with all RF circuits, avoid construction methods (for example, with Veroboard) prone to high stray capacitances.

A commonly available 7.159 MHz crystal is suggested for testing. This has the bonus of making the oscillator useful for an SDR covering a useful segment of 40 metres, 7.111 to 7.207 MHz if using 96 kHz sampling. Crystals for other frequencies such as 7.030, 7.040 or 7.122 MHz are cheaply available from overseas suppliers and will cover the lower part of the band.

If you only had to have one crystal, I would suggest 7.122 MHz for SSB or 7.040 MHz for CW as best able to cover most band activity. The prototype's use of switched 7.050 and 7.150 MHz crystals is also good except for

This project is based on "The SDR 40" A simple sound card receiver for 40 Metres by Peter Parker (VK3YE) published in the March 2014 edition or Amateur Radio, a WIA publication

Modifications by Phil Storr (Vk5SRP) include a FET RF Amplifier and a more efficient Antenna coil. This is a Spectrum Communications 5u3L coil.



The mixer transformers are "Trifilar" windings on two hole cores.
The old ones used in TV Baluns will work or use the smaller ones available from electronics stors.

Use 0.3 or 0.4 mm enamelled copper wire twisted in the chuck of and electric drill.

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Size: A4 Date: 20 may 2014 Rev:
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The values in red on the first circuit diagram are my modifications to the RF Amplifier The FET RF Amplifier inj the above circuit gives more gain and better selectivity.

The transistor in RF Amplifier in the original circuit is saturated, I suspect Peter put the circuit from a 5 Volt rail version of one of his projects in the AR article, not what he had actually built.

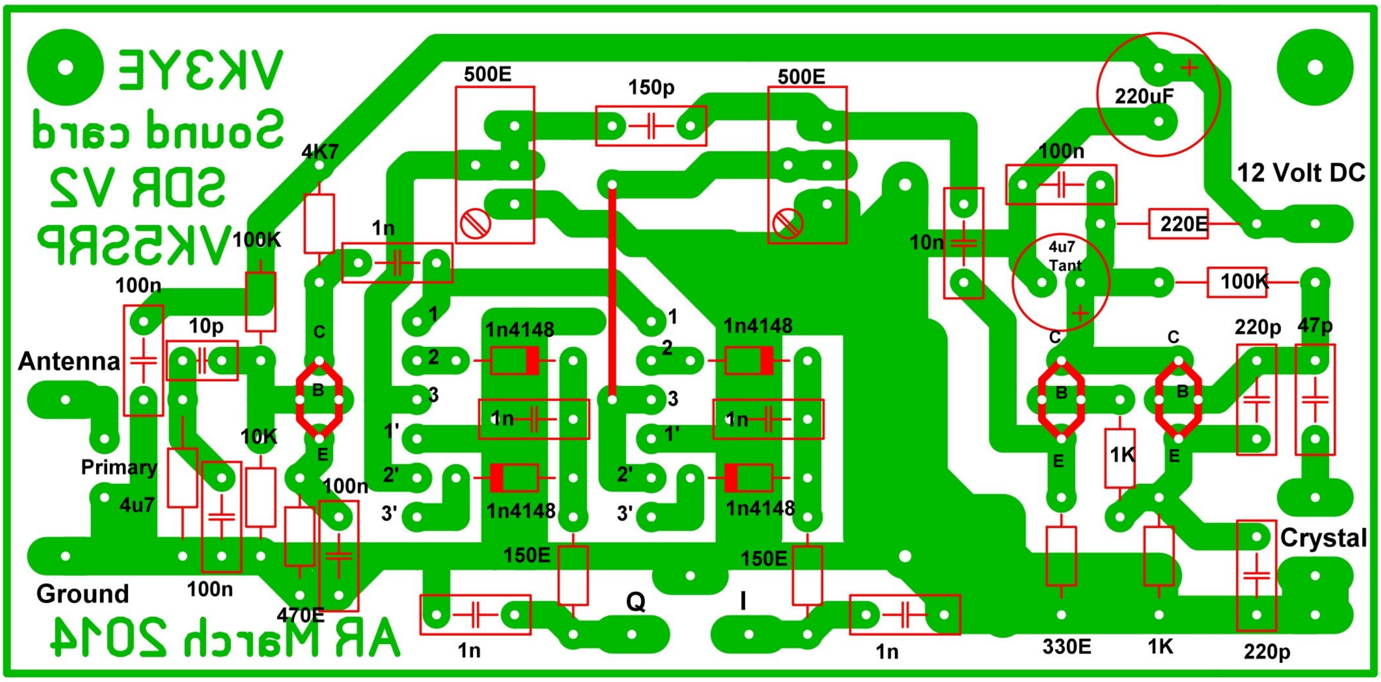
I always taught (and was taught a very long time ago) it was bad practice to have no Emitter resistor and also bad practice to use just a single Base resistor from the supply rail. The simple configuration used in the original SDR-40 circuit does not take into account the wide variation of current gain in typical transistors.

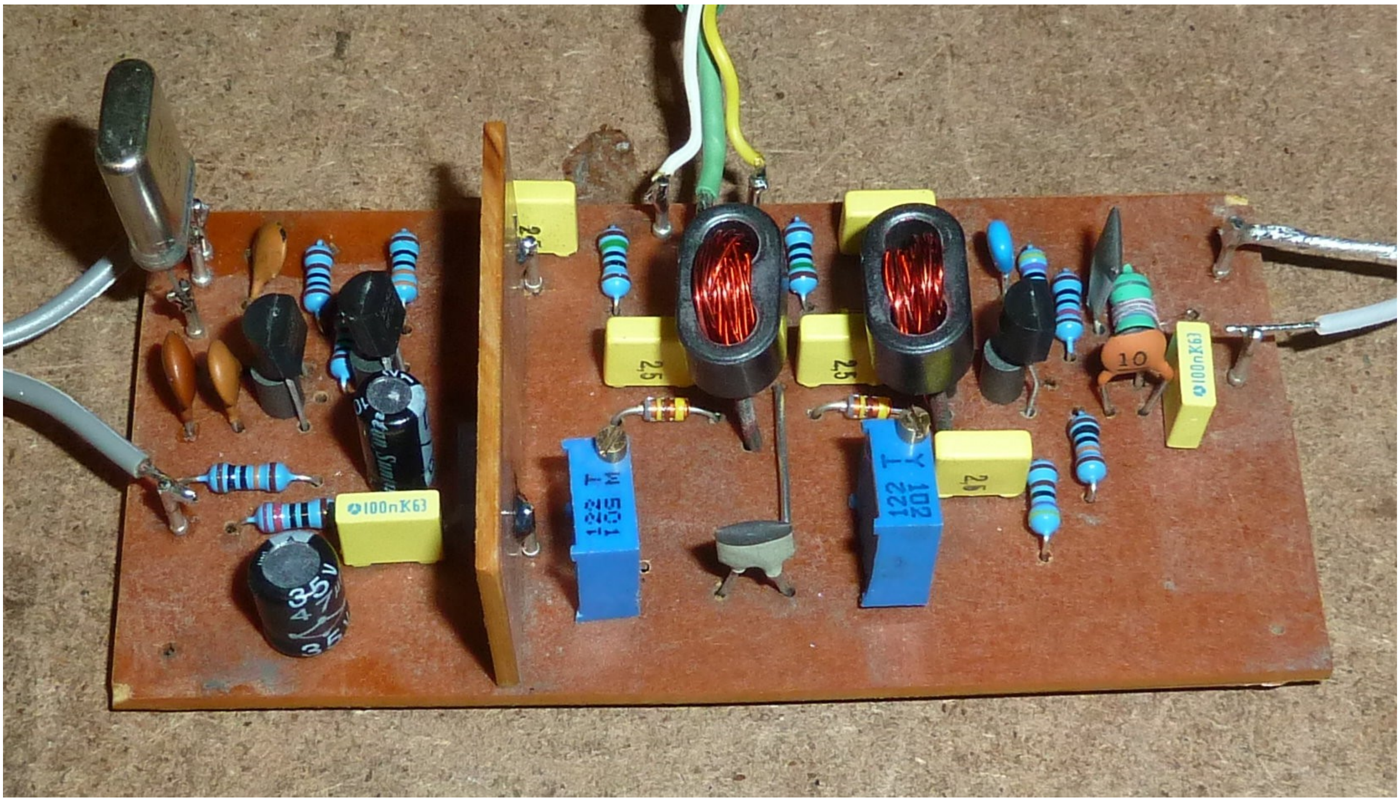
My final version of the SDR-40 uses a FET RF Amp and a Spectrum Communications coil for the Antenna input because the simple tuned circuit using the 4u7 choke was not selective enough to keep ou a local AM broadcast station. These coils are 60P from Spectrum Communications in the UK or from the GQRP club if you are a member of this worth while group.

I used a 7.159 MHz crystal and with a good external sound interface I can view at least 50KHz of the 40M band.

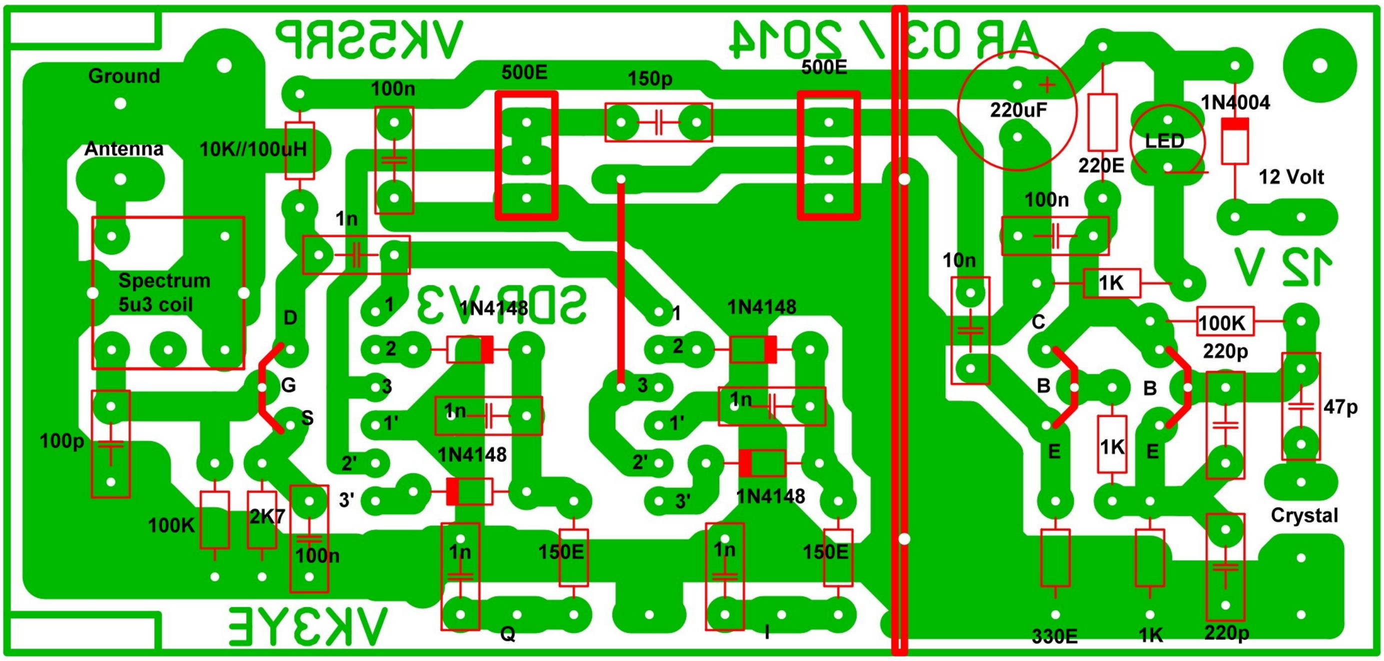
I am now working on a simple DDS circuit that is based on a VK5TM (Terry) project. On his web site you will find details of two DDS projects, one is a one band DDS which can be configured for any band and any range of frequencies. The other is intended to replace four crystals in a crystal locked radio. I talked to Terry about extending this to eight single frequencies and he has now done this. My guess is details of the new version will be on his web site soon.

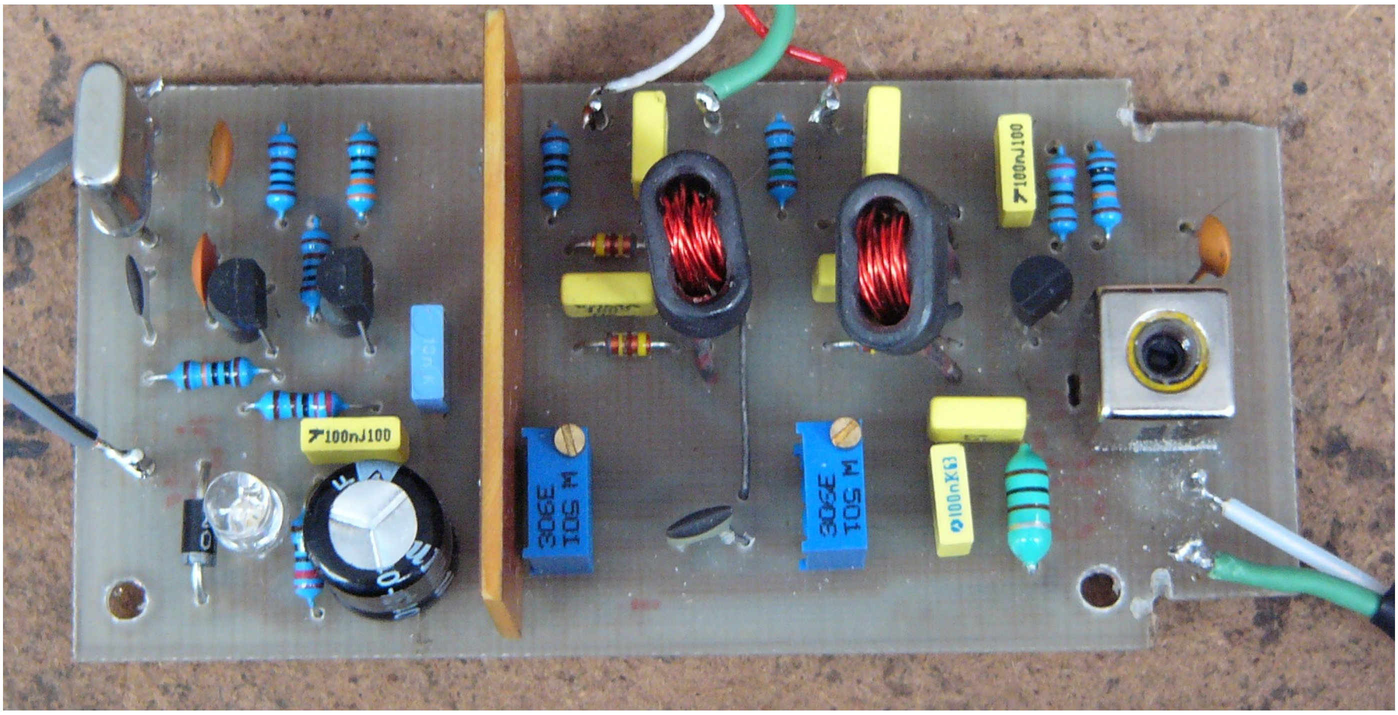
The first two photographs below is of my Mk2 version with the modified BiPolar RF Amp.





Here is the Mk3 board with the JFET RF Amp and the Spectrum Communications coil. The 10K resistor across the RF choke in the drain lead of the RF Amp is under the circuit board. The RF choke is 100uH.

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