A Low Power Transmitter project

by

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Introduction

The transmitter is based on a circuit in the book
Solid State Design for the radio amateur published by the ARRL.

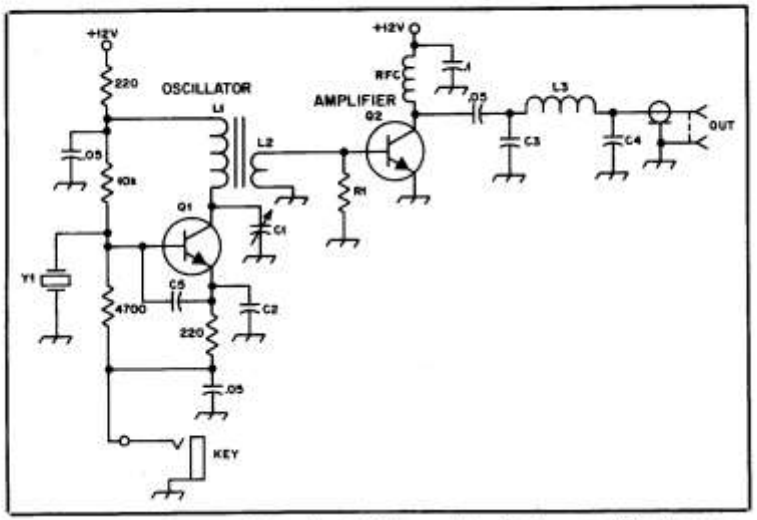


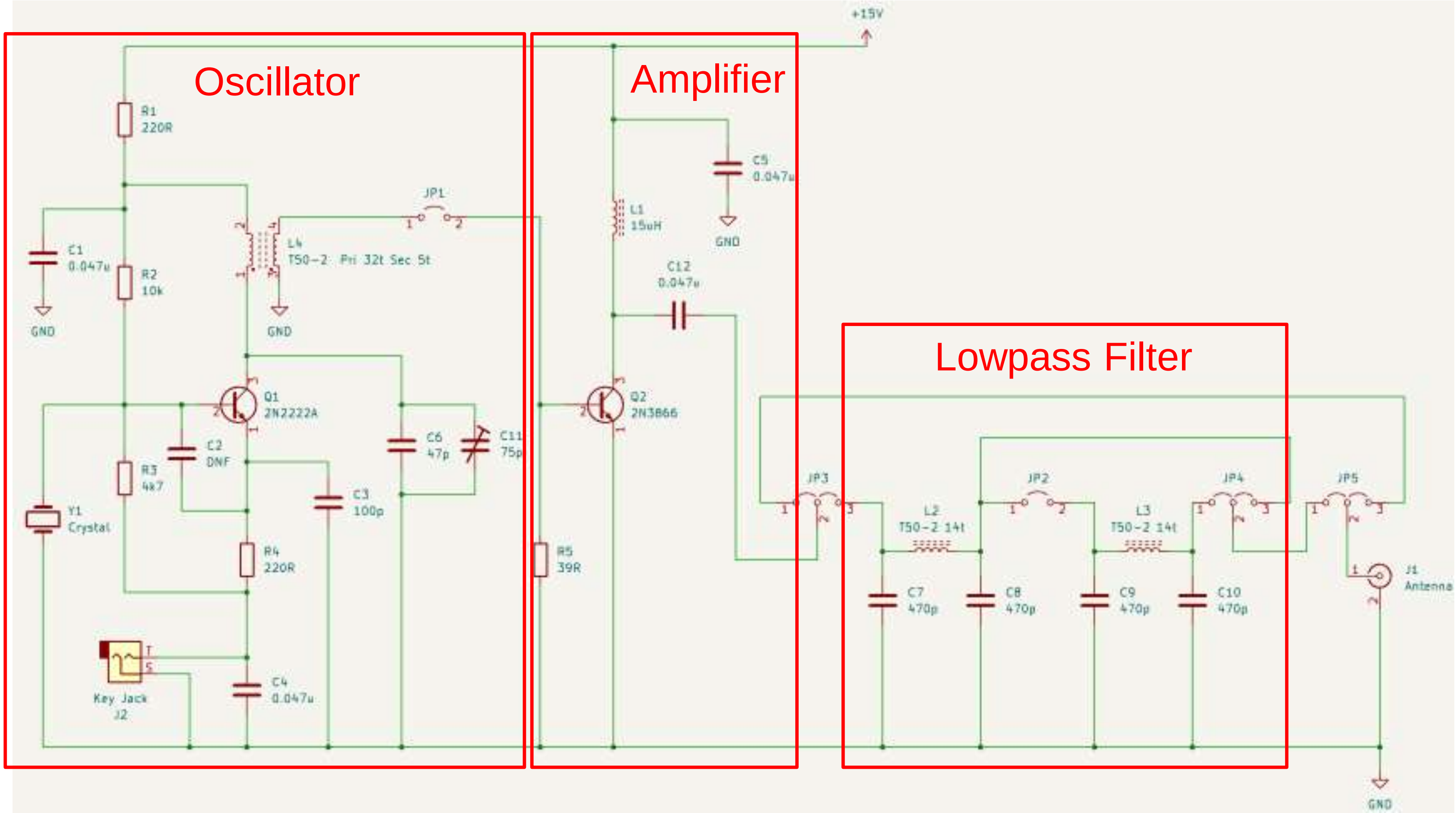
Fig. 17 – Schematic diagram of the universal QRP transmitter. Resistors are 1/2-watt composition. C1 is a trimmer capacitor. C3 and C4 are silver-mica capacitors. Remaining capacitors are disk ceramic, 50 volts or greater. See text for Q1, Q2 types. Component values not on the diagram are listed in Table 1.

The original circuit (left) on page 26 "A Universal QRP Transmitter" has been adapted for the purposes of this tutorial demonstration.

An extra low pass filter section has been added to the output section, and several jumpers have been added to allow various sections to be easily taken in and out of circuit.

Circuit Schematic – As Built

Circuit diagram has been re-drawn. Note that the component designations are not the same as the original ARRL circuit.



Circuit Description

Oscillator

The oscillator is a colpitts type, but note that one of the feedback capacitors (C2) is not fitted on the 40 metre version of the circuit.

The frequency is determined by the crystal (Y1), 7020 kHz in this case.

The oscillator is turned on/off by the morse key inserted into the Key Jack (J2). When the key is up, no current can flow through the transistor Q1, hence no oscillation takes place.

In the collector circuit, the transformer (L4) is tuned by capacitors C6 and C11 to the oscillator frequency. A 5 turn secondary winding provides a low impedance output to drive the base of the power amplifier transistor.

Amplifier

The amplifier transistor has no fixed bias and does not conduct until driven by the oscillator.

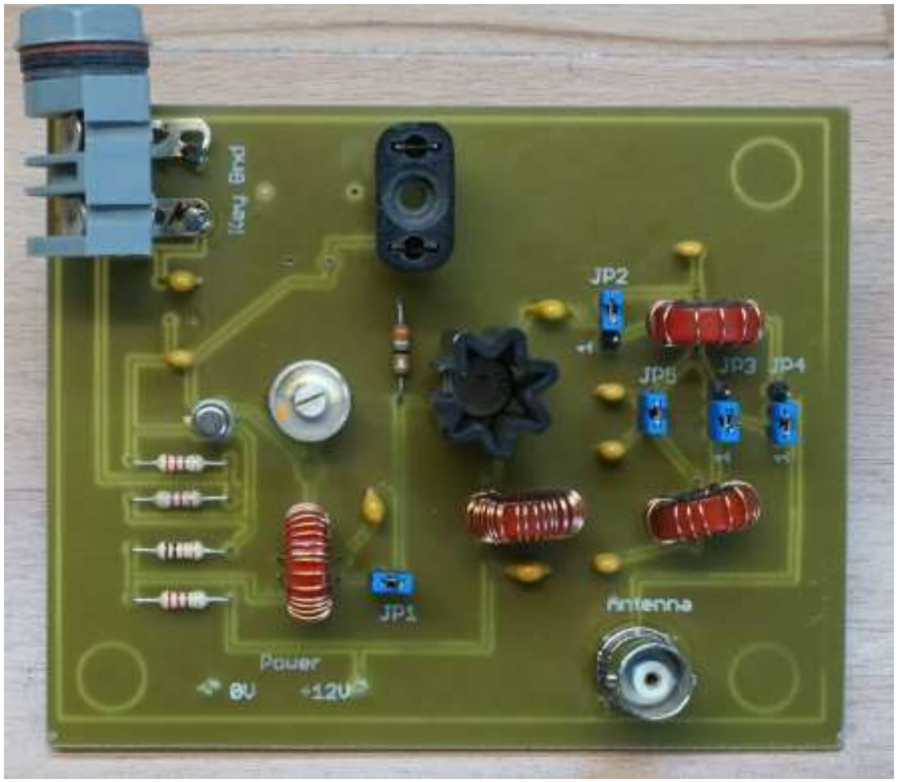
The 15uH choke (L1) in the collector circuit provides a low resistance feed for the DC supply and a 660 Ohm load to the 7Mhz signal.

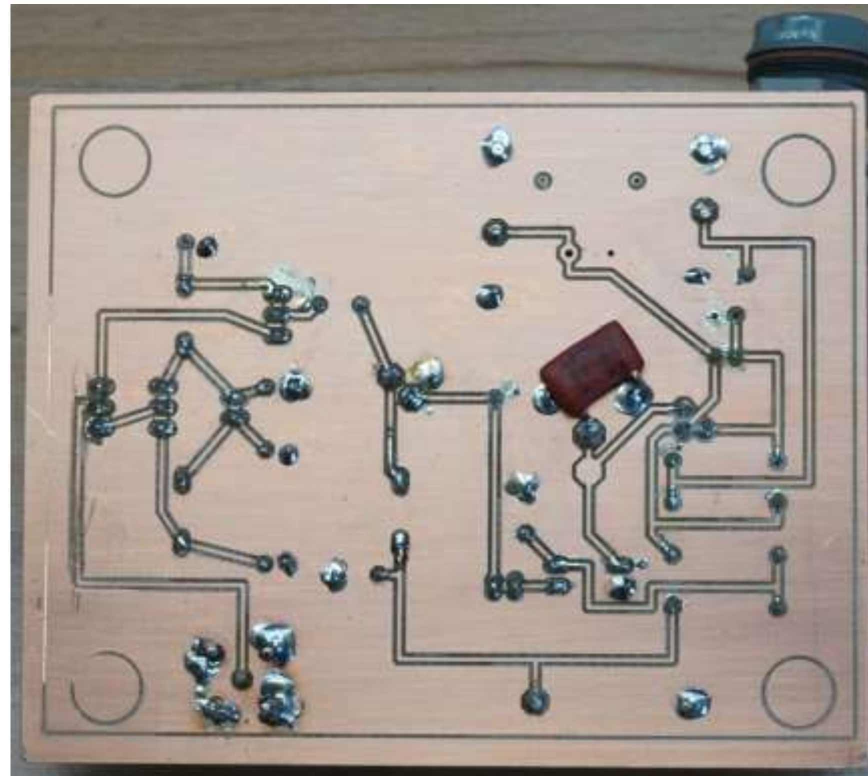
In normal operation, the load on the antenna connector is 50 Ohm, this is transferred through the lowpass filter network to the collector circuit. Thus the amplifier collector load impedance is dominated by the antenna impedance.

Lowpass Filter

The signal at the collector is very distorted and rich in harmonics. We do not want to connect this to an antenna. The LPF attenuates the harmonics while allowing the 7MHz fundamental to pass through unattenuated.

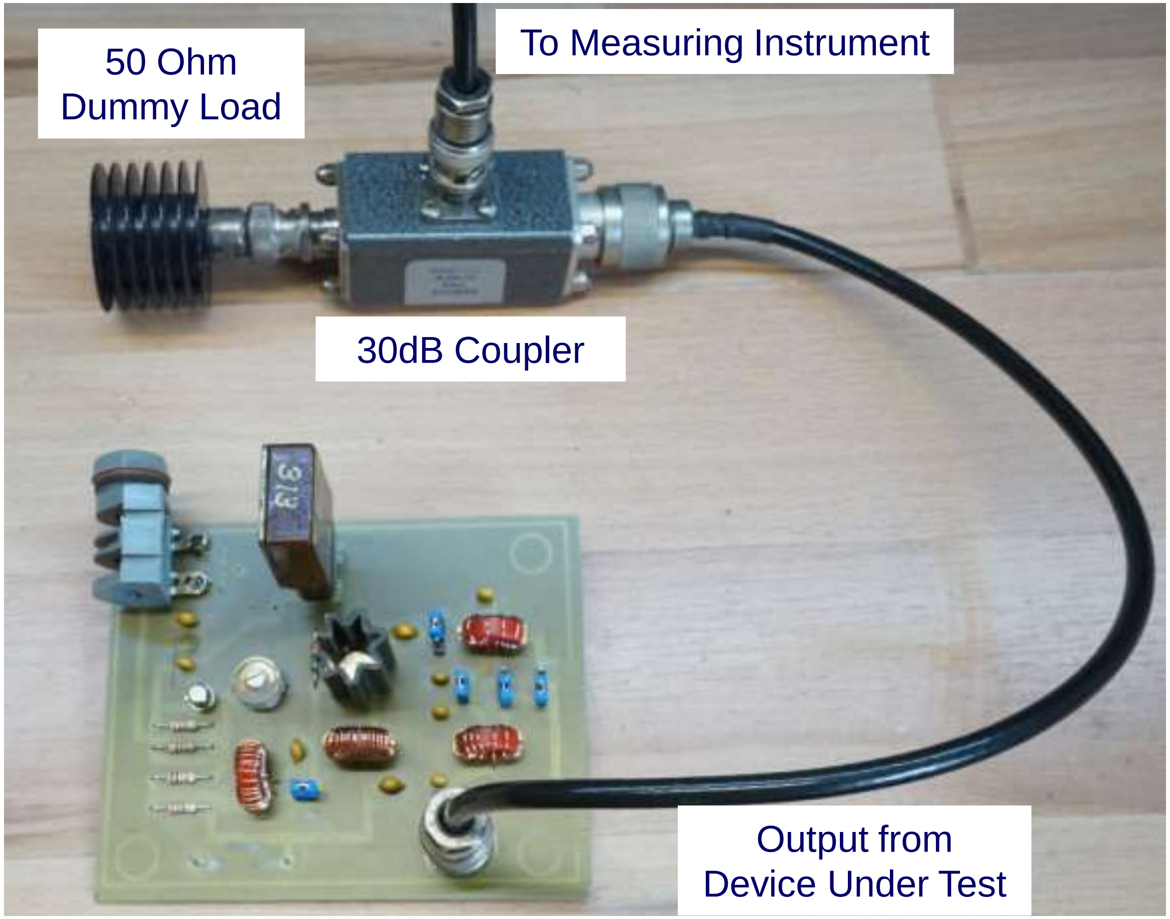
The Circuit Board (Warts and all)





Measuring the output power

If you have a simple direct reading RF Power Meter… You could just use that.



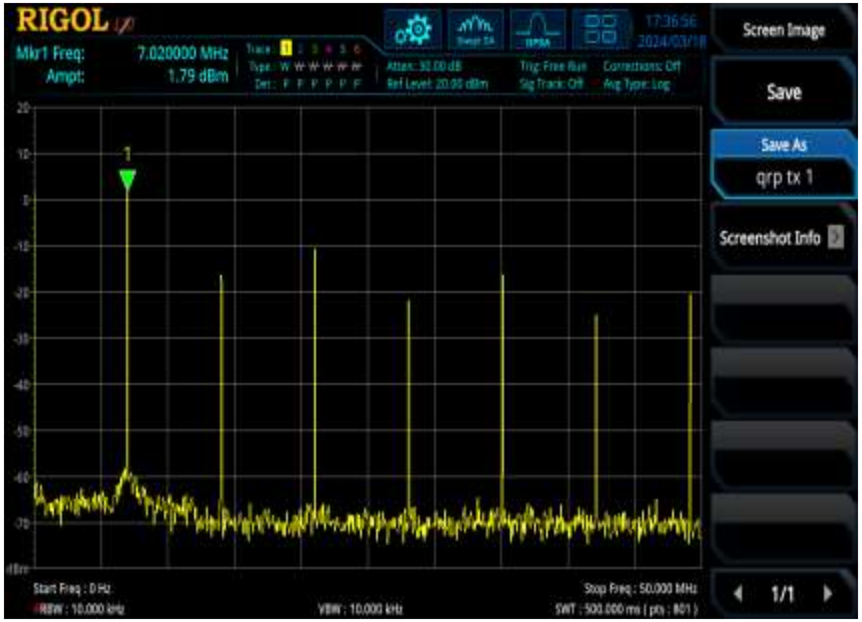
However the more elaborate setup shown here does have advantages.
The "Measuring Instrument" could be a:

- Spectrum Analyser
- Oscilloscope
- Low Level Power Meter
- Frequency Counter
- Modulation Meter

Each one being easily selected by moving the BNC cable.

Transmitter Output – No Lowpass Filter

The output has been taken directly from the collector of the amplifier transistor. The lowpass filter is bypassed.
The oscilloscope shows a very distorted waveform and the spectrum analyser shows the high level of harmonics.

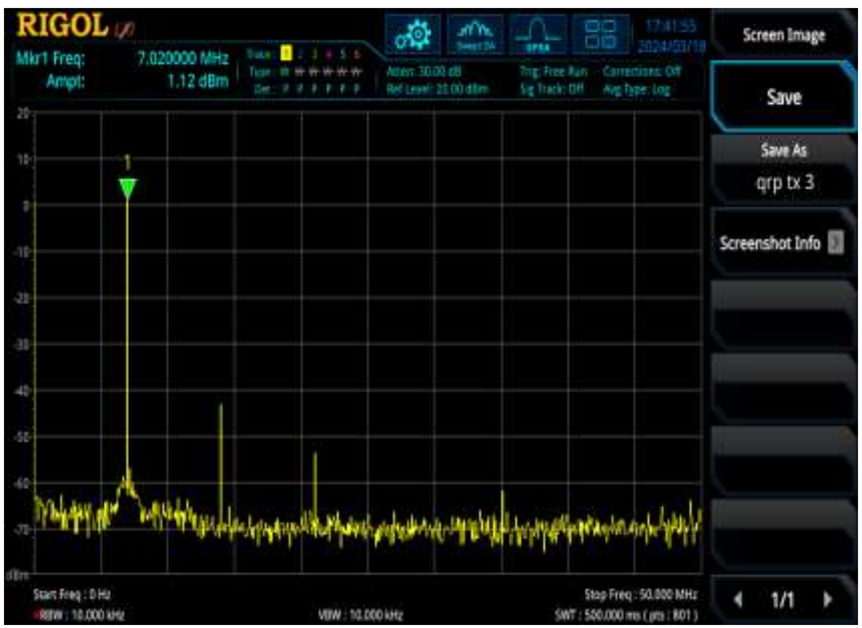


Transmitter Output – 1 section LPF

One section of lowpass filter gives reasonable attenuation to harmonics, but the 2nd and 3rd harmonics are still at a high level and exceed the ITU limits for equipment operating below 30 MHz.

Transmitter Output – 2 sections LPF

Two sections of LPF, the harmonics are below the ITU limits (-43dBc).



Due to the simple construction, single sided circuit board and no screening, it is likely that there is significant leakage past the lowpass filters. Also the links to demonstrate the effect of different filters will contribute to leakage around the filter.

Calculating the output power

In the previous slide the spectrum analyser shows the carrier to be at a level of 1.12dBm. Allowing for the attenuation in the 30dB coupler, this makes the transmitter output to be 31.12dBm.

Calculating the power in Watts

$$Power = \ 10^{\frac{dBm-30}{10}} \text{ Watts}$$

$$Power = \ 10^{\frac{31.12-30}{10}} = 10^{0.112} = 1.29\, Watts$$

On the oscilloscope the voltage is measured as 253mV RMS

$$Power = \frac{V^2}{R} = \frac{0.253^2}{50} = 1.28mW$$

Multiply by 1000 to allow for the 30dB coupler

Power = 1.28 Watts

The Lowpass Filter - 1

Examining the attenuation of the lowpass filters.

Remove the link JP2 and inject the tracking generator signal into JP2 pin3, remove link JP5, link JP3 pin2 to pin3, link JP4 pin1 to pin2.

The response of a single section of the lowpass filter is displayed.

The frequency range is from 100 kHz to 50 MHz.

The Lowpass Filter - 2

Examining the attenuation of the lowpass filters.

Remove the link JP2 and inject the tracking generator signal into JP2 pin3, insert link JP5, link JP3 pin1 to pin2, link JP4 pin1 to pin2.

The response of the two cascaded sections of the lowpass filter is displayed.

Keying – What it sounds like on the air

The QRP Transmitter

An Elecraft K2

On the oscilloscope, the blue trace represents the voltage across the key contacts, 0v = key down.

The yellow trace represents the RF output.

In both pictures, the morse letter "N" is being sent.

On the QRP Tx, there is a long >50mS delay between the key closing and the RF output starting. When the key opens, RF output stops immediately.

This sounds odd when heard on the air.

On the Elecraft K2, there is a consistent 20mS delay between the key closing and the RF output starting, and a similar 20mS delay between the key opening and the RF output stopping.

The morse character element spacing sent by the operator is thus preserved.

QRP Tx

RIGOL
WAIT
H
50.00ms/
A
20kSa/s
Peak
10kpts
50μs/pt
D
200.00ms
T
2
248.00mV
N
Default
Measure
Flex Knob
HDO4404 2024-03-26 02:20:42
Waveform View
1.5V
1V
500mV
0V
-1V
0s
50ms
100ms
150ms
200ms
250ms
300ms
350ms
400ms
CH1
1.00V/
-2.08V
20MHz
CH2
500.00mV/
0.00V
20MHz
CH3
50.00mV/
0.00V
CH4
50.00mV/
0.00V
Math1
Math2
Math3
Math4
02:20:41
2024/03/26

Elecraft K2

RIGOL
WAIT
H
50.00ms/
A
20kSa/s
Peak
10kpts
50µs/pt
D
200.00ms
T
2
248.00mV
N
Default
Measure
Flex Knob
HDO4404 2024-03-26 02:15:52
Waveform View
2.54V
2.04V
1.54V
1.04V
540mV
40mV
-460mV
0s
50ms
100ms
150ms
200ms
250ms
300ms
350ms
400ms
CH1
500.00mV/
-1.04V
20MHz
CH2
200.00mV/
0.00V
20MHz
CH3
50.00mV/
0.00V
CH4
50.00mV/
0.00V
Math1
Math2
Math3
Math4
02:15:52
2024/03/26

Chirp

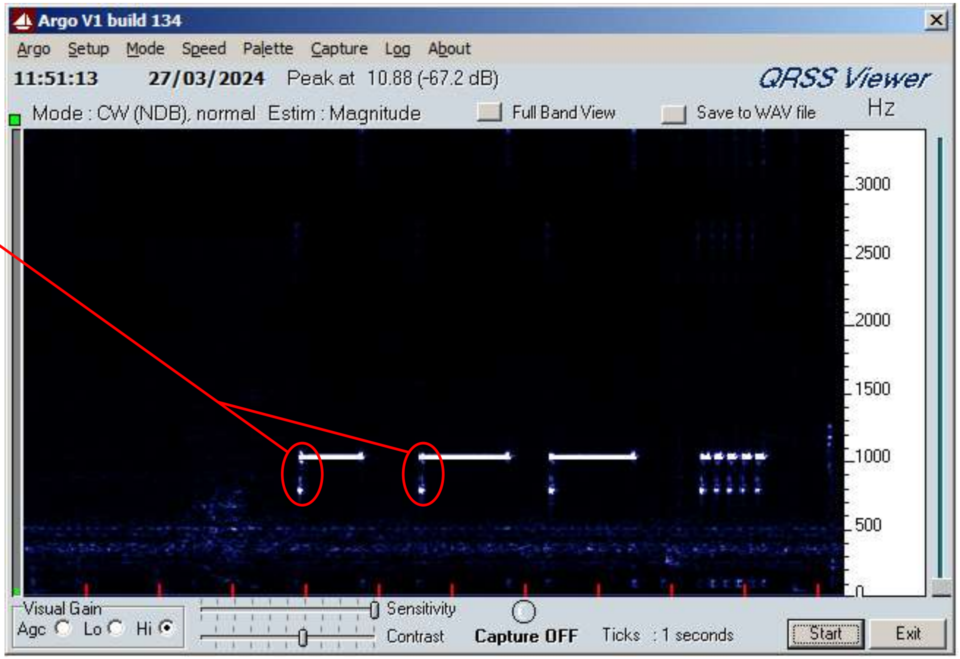
Chirp is a condition where the frequency of a transmitter changes as it is keyed on/off.

This can be very noticeable as a CW transmitter is keyed, and depending on magnitude of the change in frequency can be quite objectionable.

Our QRP Tx does exhibit chirp under some conditions.

We can observe chirp using a waterfall type display.
Here we see the characteristics of our transmitter by connecting the audio output of a receiver to the external mic connector of a PC which is running ARGO software:

Note that as the transmission starts, the frequency is about 200Hz lower for a few milli-seconds before settling during the key-down period.



How to improve this transmitter?

Mount it in a proper box
Add an antenna changeover switch
Add supply switching to enable “netting” without enabling transmit
All part of a correctly engineered unit, rather than a first prototype, which is what this unit is.

Improve the lowpass filtering
Adding a third “Pi” section to the LPF should practically eliminate all the harmonics.
Re-lay the circuit board, a final design does not need all those jumper links.
And, don’t forget to move the amplifier transistor away from the crystal. (Doh!)

Improve the keying characteristics
Remove the chirp
Leave the oscillator running and key the amplifier stage would eliminate the long start-up delay on the oscillator and go a long way to removing the chirp.

Make provision for a VFO
Crystal control, while simple can be a bit limiting in on the air operation.

The End