ICOM IC-706Mk2G injection locking

Injection locking of the 30 MHz reference oscillator using a 10 MHz oven controlled oscillator.

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Prerequisite and short description

- ICOM IC-706Mk2G has not a reputation of being very frequency stable. This limits the use of it for certain modulation schemes and modes. The drift is a problem mostly at the VHF and UHF-bands of the IC-706Mk2G, especially on 432 MHz where it can be quite substantial over the Tx-Rx-cycles when the fan goes on and off.
- The ICOM IC-706Mk2G uses a 30 MHz oscillator to derive all LO-frequencies in the rig. This opens up for a quite easy way of locking all LO's in the rig.
- A few references were found on the Internet (see references below) on the possibility to injection lock this oscillator with a high accuracy external signal. I experimented with a few possibilities to do this and ended up in the below presented solution.
- I found that the square wave output of a 10 MHz oven controlled oscillator contained quite a high level of 30 MHz signal. I decided to filter out this 30 MHz signal to improve the spurious rejection and enhance the 30 MHz signal purity.
- An SMA connector mounted on the rear side of the IC-706Mk2G and a RG-316 cable routed to the 30 MHz oscillator shielded box inside the rig. A small coil couples the injection signal to the tank circuit of the internal 30 MHz oscillator. Putting a 10 dB attenuator on the external reference signal input improves isolation and ensures that the IC-706Mk2G can be used without an injection signal if needed (then with the original frequency stability).
- Voltage for powering the 30 MHz external reference unit is taken from the Acc-connector of the IC-706Mk2G.
- Warm-up time for an acceptable frequency accuracy and drift is about 2 minutes in my case.
- This frequency locking scheme has worked well for me when running 432 MHz meteor scatter skeds as well as copying digital mode signals via the Moon.

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About Injection locking

- Injection locking of oscillators is not an new idea or technique. Is has been used for many years.
- One common usage has been to lock e.g. magnetrons, Gunn and IMPATT oscillators at microwave and mm-wave frequencies. Here a circulator is commonly used to inject the control signal. I designed injection locked IMPATT oscillators at Ku-band (at QRL) in the early 80's.
- You can in most cases expect a gain of about 10 to 15 dB for a reasonable locking band width. In the case described in this presentation the requirement of the locking band width is quite small, it only has to accommodate for the temperature drift of the master oscillator of the IC-706Mk2G in the environment you are in. The phase noise of the locked oscillator is set by the control signal over the locking band width, so a good locking band width is beneficial as long as the reference signal is better than the unlocked oscillator.
- More on injection locking can be found here
  - http://www.seas.ucla.edu/brweb/papers/Journals/RSep04.pdf
  - https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19880003345.pdf
  - https://en.wikipedia.org/wiki/Injection_locking
  - http://rfic.eecs.berkeley.edu/~niknejad/ee242/pdf/eecs242_lect26_injectionlocking.pdf

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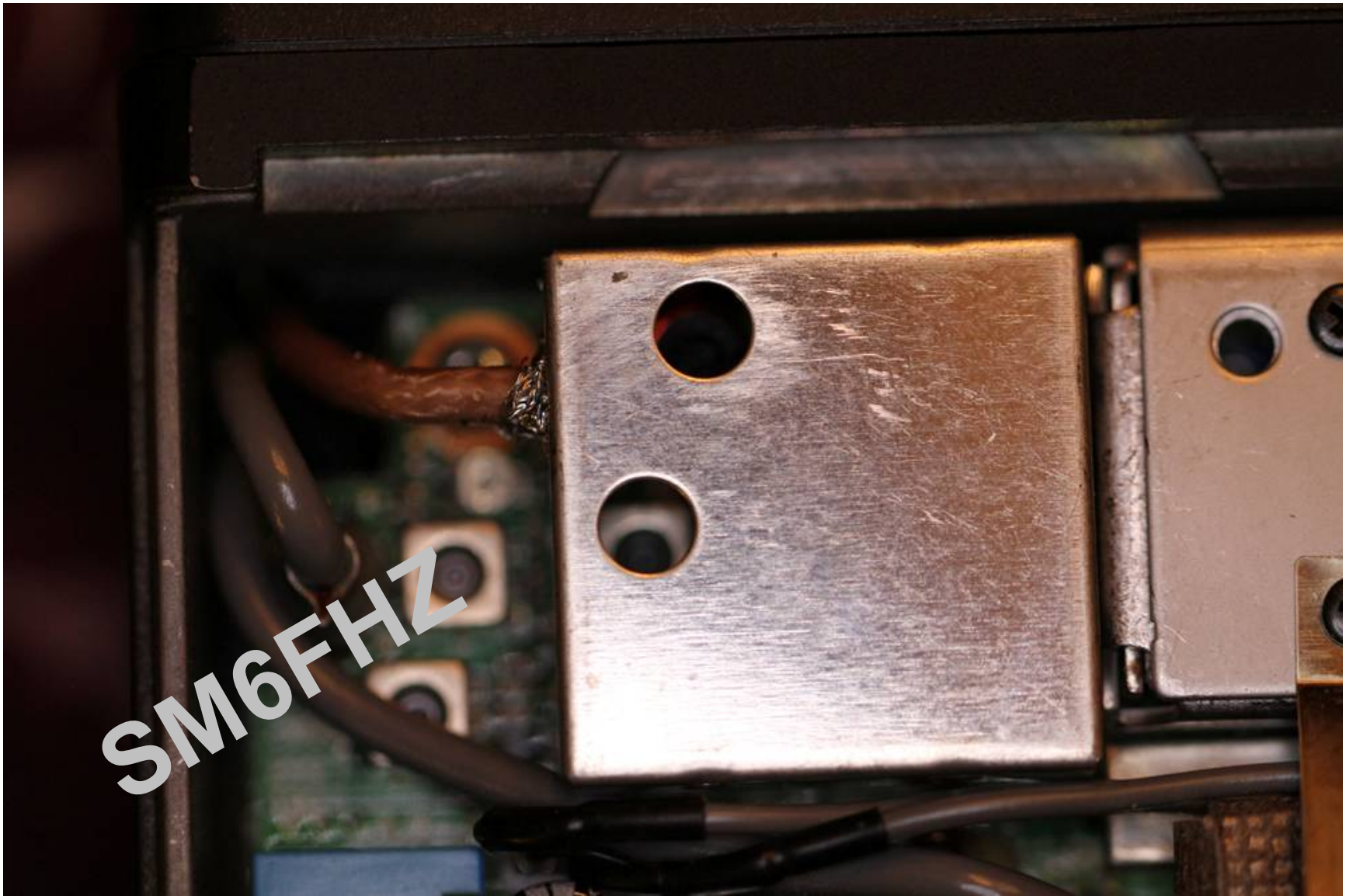
Use the ready made hole on the back side of the IC-706Mk2G, that is covered by a washer, to mount a SMA-connector

Route the double shielded Teflon coaxial cable, RG-316, to the 30 MHz oscillator box. Enter the box through the ready made hole that fits the inner dielectric of the RG-316.

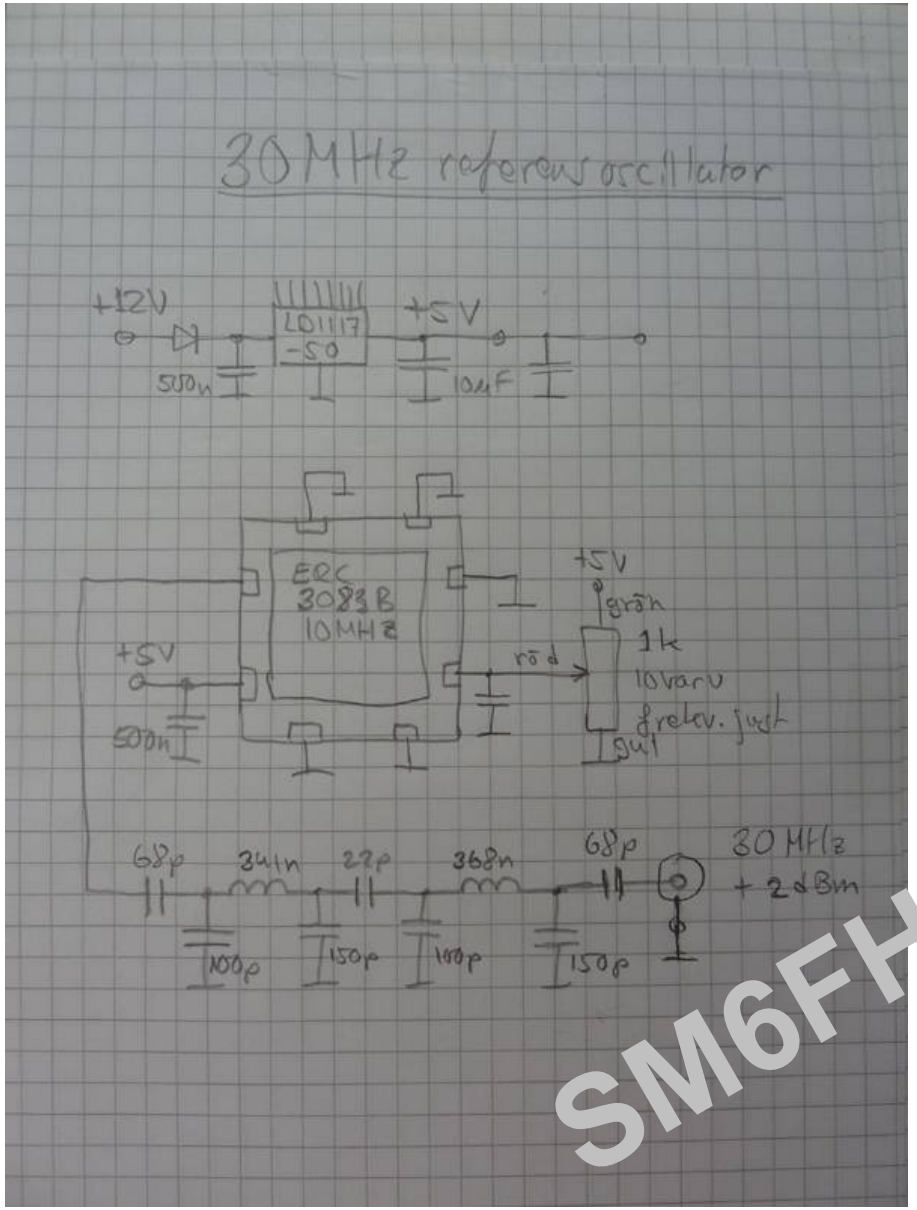


Solder the shield to the outside of the oscillator box.

Wind a 6 turn coil that fits on the L601 coil in the oscillator box.

Put a 10 dB SMA-attenuator on the input connector for isolation towards the outside world

Schematic of the 30 MHz reference oscillator



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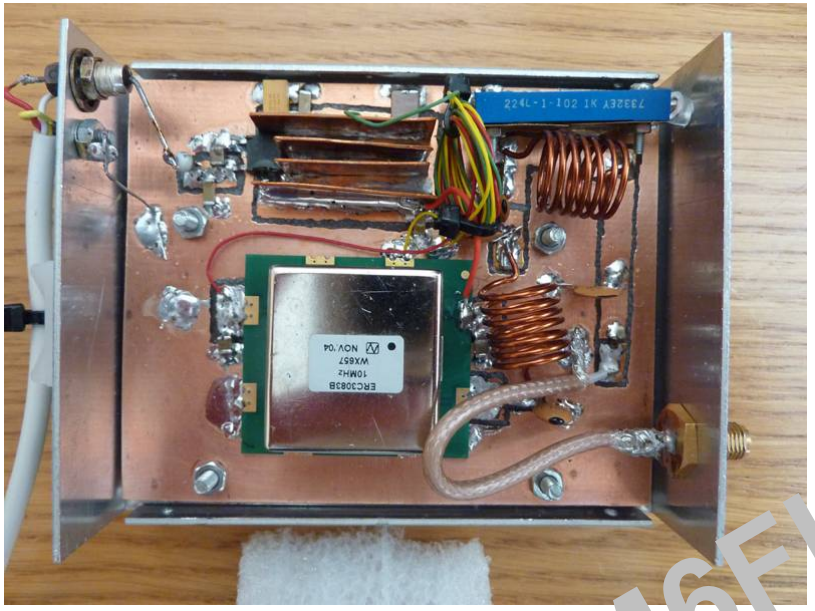
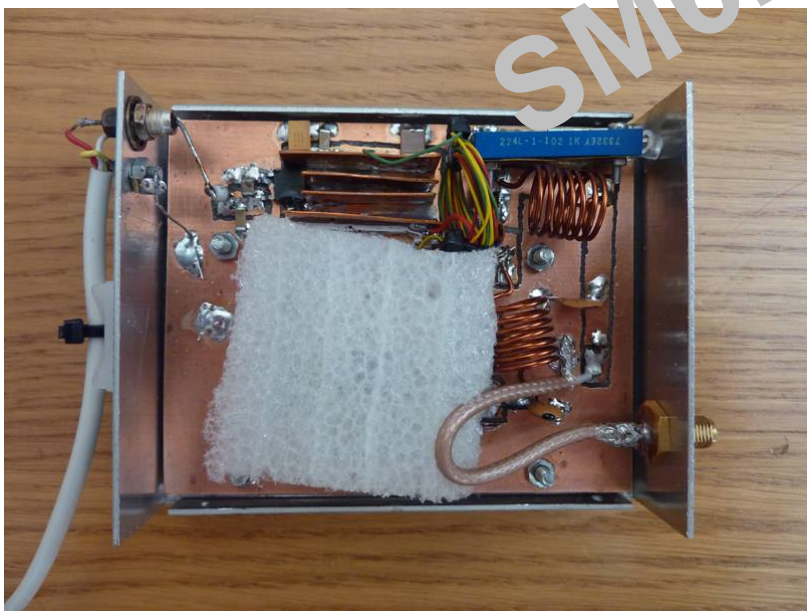
- 10 MHz oven controlled X-tal oscillator ERC 3083B (that I used). Can be found on Ebay. Other oscillators may work as well.
- +12V supplied from ICOM IC-706Mk2G and stabilized to +5V.
- Frequency adjustment is facilitated by the use of a 1 kohm 10-turn potentiometer.
- A band pass filter at 30 MHz filters out the 30 MHz frequency component from the oscillators square wave output. Measured level at 30 MHz on my oscillator is +2 dBm.
- Specified warm-up time for the ERC 3083B is <6 minutes at room temperature to reach +/-0.1 ppm from final frequency. My oscillator needs ~2 minutes to reach a acceptable frequency accuracy and stability on 432 MHz.

Interior of reference oscillator





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- The oscillator is housed in a small metal box with filtered +12V voltage input to the upper left. SMA 30 MHz output connector in the lower right corner and frequency adjustment potentiometer in the upper right corner.
- The +5V regulator is cooled using four small copper sheet metal pieces soldered to the large pad on the PCB where the regulator output is connected.
- The 30 MHz BPF can be seen to the right of the oscillator.
- The oscillator has a small foamed plastic thermal insulator hat to enhance frequency stability and slightly reduce oven supply current (lower picture).
- The PCB pattern is made from a double copper sided FR4 board by using a Dremel with a 1.6mm engraving bit. Surprisingly simple and fast process. Not a very beautiful art object, but fully functional.

Performance

- The 30 MHz oscillator in my ICOM IC-706Mk2G locks to the injected signal from a level of -20 to -15 dBm. That means -10 to -5 dBm is needed from the external reference oscillator when the 10 dB attenuator is used. A small margin in input signal is good to have to ensure good locking at all times.
- Using a 10 MHz TTL compatible square wave without anything else I get a good lock using the 10 dB attenuator. Checking it using a spectrum analyzer showed that the 30 MHz component was about -12 dBm (on my 10 MHz working reference used for my frequency counter and signal generator). This may vary a lot from oscillator to oscillator.
- It would be nice to use a 10 MHz to 30 MHz filtered tripler as show in the references. However, experiments showed that the conversion loss of the tripler (10 MHz to 30 MHz) was so high that the 30 MHz component of the square wave directly from the oscillator gave a better signal at 30 MHz than using the tripler. The tripler contains filters and does not benefit from the oscillators signal level at 30 MHz for it's output. I did end up not using the tripler after all. If you use a 10 MHz reference oscillator with a sine wave output the tripler solution might be the way to go.
- The frequency locking scheme used proved to be a very simple yet efficient way of locking the ICOM IC-706Mk2G to a external 10 MHz reference.

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References

- http://www.vk3hz.net/XRef/XRef_Icom_IC-706MKIIG.pdf
- http://www.wenzel.com/documents/2diomult.html

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