Continuous Coverage V.F.O. for H.F.

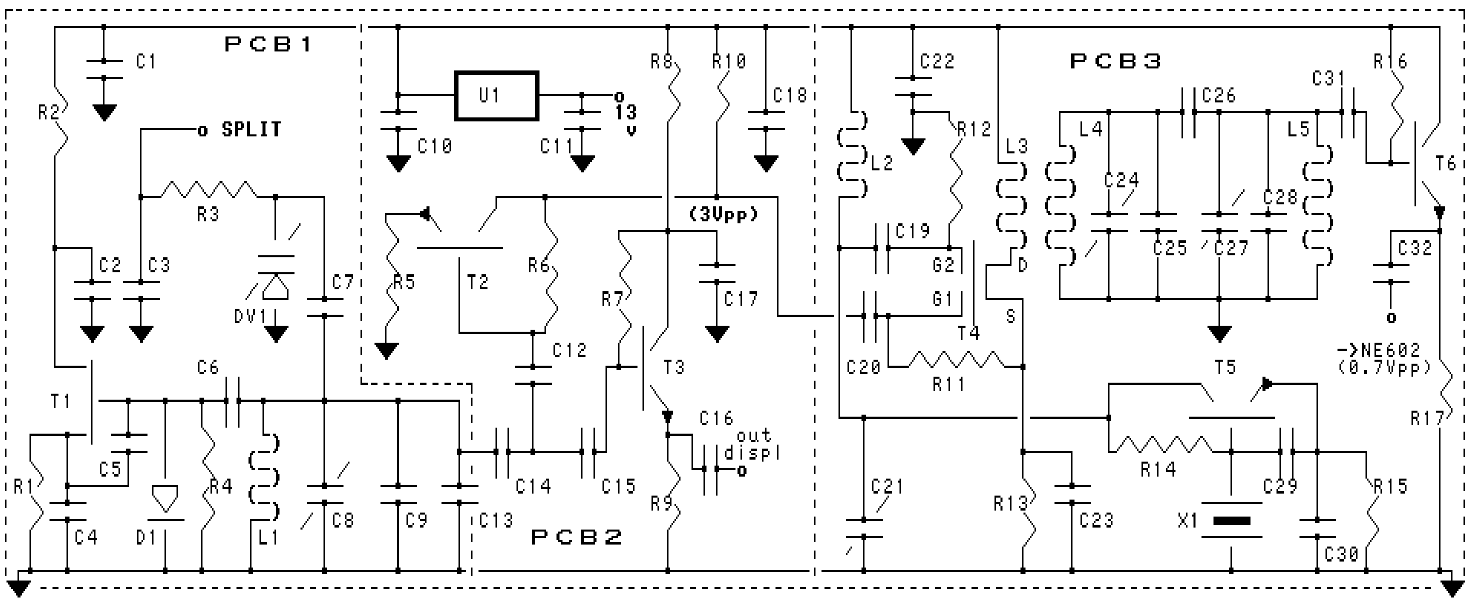
Introduction

This project arises from the need to home-build a valid tuning control for a multi band transceiver.
It consists of a *partial syntesis V.F.O.* that fits to single conversion equipments with an I.F. stage nearby 9 MHz. The circuit can cover the whole H.F. band from 3.5 to 30 Mhz (i.e. 12.5 to 39 Mhz output).
This device has been developed through several experiments based on PLL and crystal conversion circuits, and I think it may represent an acceptable compromise between the simplicity (but not enough to be regarded as an elementary job) and the performance.
Consider that some equipment is necessary for the alignment : an R.F. generator and a frequency meter are a must, but the availability of an oscilloscope makes the job easier (specially in case of troubles)

How it is made

It consists of two phisically separated units :

1) V.F.O. module



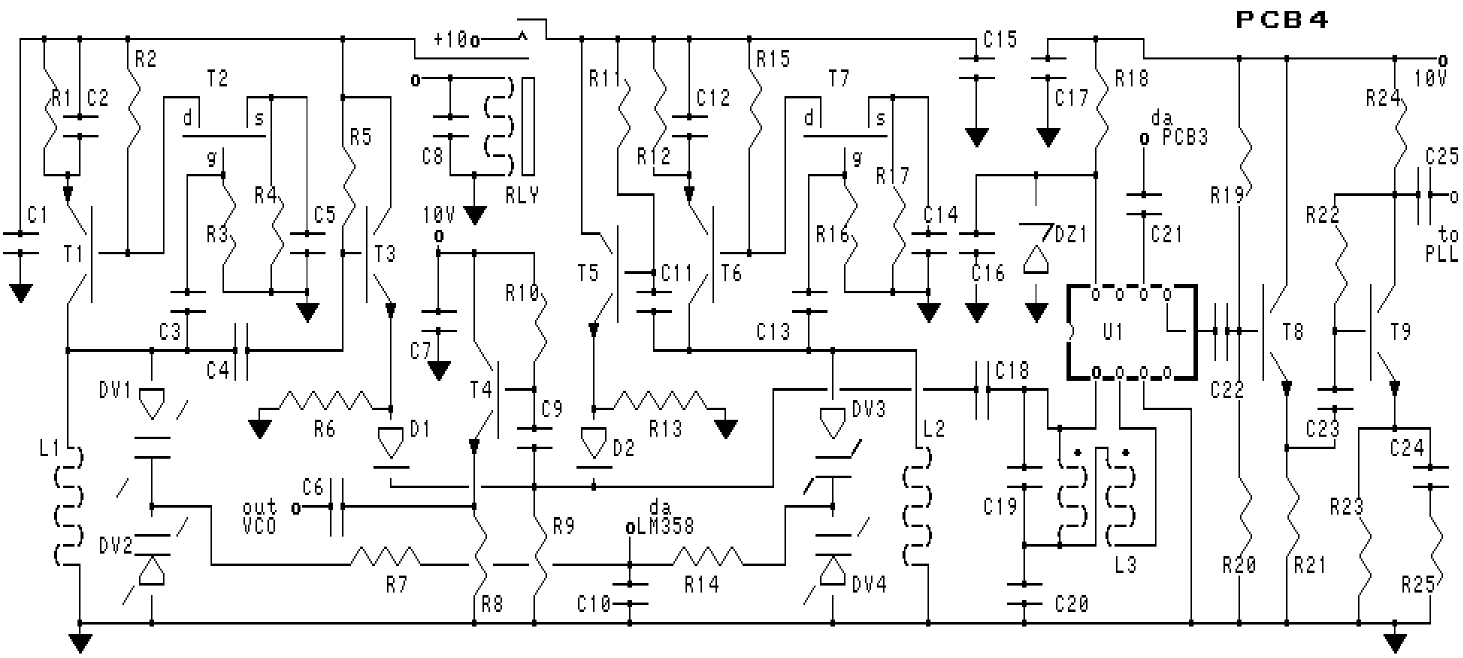
Part List of VFO unit

R1 : 1 KΩ	C4 : 100 pF	C24 : 15 pF trim	L1 : 24 turns/0.8 mm wire/13 mm diam. - 3.5 µH
R2 : 100 Ω	C5 : 47 pF	C25 : 22 pF	L2 : 9 turns/0.5 mm wire/T44-2 core – 0.42 µH
R3 : 47 KΩ	C6 : 100 pF	C26 : 1.5 pF	L3 : 2 turns/0.5 mm wire on L4
R4 : 100 KΩ	C7 : 6.8 pF	C27 : 15 pF trim	L4 : 9 turns/0.5 mm wire/T44-6 core – 0.34 µH
R5 : 220 Ω	C8 : 60 pF var	C28 : 22 pF	L5 : 9 turns/0.5 mm wire/T44-6 core – 0.34 µH
R6 : 68 KΩ	C9 : 120 pF N150	C29 : 47 pF	
R7 : 68 KΩ	C10 : 47 nF	C30 : 100 pF	
R8 : 100 Ω	C11 : 100 nF	C31 : 2.2 pF	
R9 : 1 KΩ	C12 : 220 pF	C32 : 220 pF	
R10 : 1 KΩ	C13 : 68 pF	T1 : 2N3819	
R11 : 100 KΩ	C14 : 6.8 pF	T2 : 2N2222	
R12 : 100 KΩ	C15 : 220 pF	T3 : 2N2222	
R13 : 390 Ω	C16 : 220 pF	T4 : BF960	
R14 : 220 KΩ	C17 : 47 nF	T5 : 2N2222	
R15 : 820 Ω	C18 : 47 nF	T6 : 2N2222	
R16 : 100 KΩ	C19 : 6.8 pF	U1 : 7810	
R17 : 220 Ω	C20 : 220 pF	D1 : 1N4148	
C1 : 47 nF	C21 : 40 pF trim	DV1 : BB205	
C2 : 47 nF	C22 : 47 nF	X1 : 18 MHz	
C3 : 47 nF	C23 : 470 pF		

is composed, in my arrangement, by three little PCBs (delimited by discontinous line) and the variable capacitor. The three boards are overlapped to form a wafer and the overall cabinet dimension depends essentially on the capacitor size.
This unit can be located behind the front panel of the rig

2) PLL Module

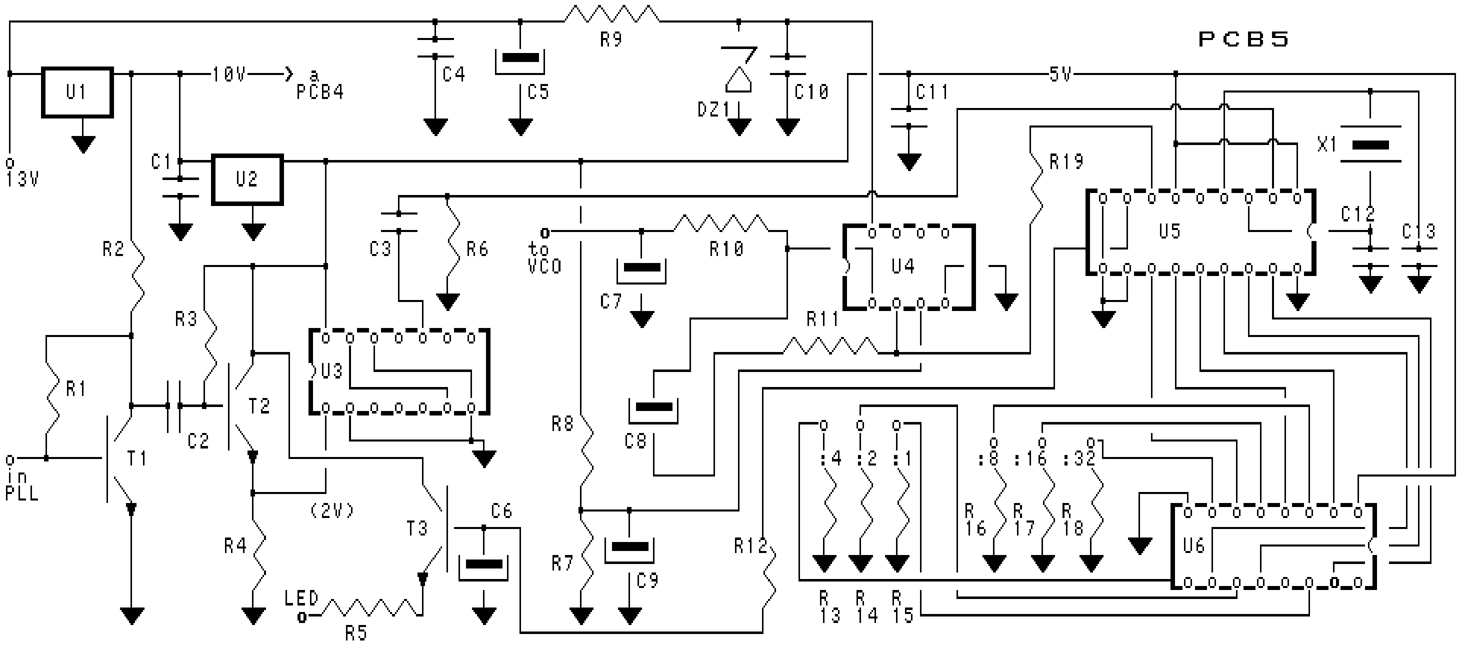
composed by the VCO PCB



Part List of VCO unit

R1 : 680 Ω	R21 : 820 Ω	C16 : 10 nF	D1 : 1N4148
R2 : 1.2 KΩ	R22 : 56 KΩ	C17 : 10 nF	D2 : 1N4148
R3 : 100 KΩ	R23 : 270 Ω	C18 : 2.2 pF	DV1 : MVAM115/BB112
R4 : 330 Ω	R24 : 270 Ω	C19 : 68 pF	DV2 : MVAM115/BB112
R5 : 56 KΩ	R25 : 27 Ω	C20 : 10 nF	DV3 : MVAM115/BB112
R6 : 1.8 KΩ	C1 : 10 nF	C21 : 150 pF	DV4 : MVAM115/BB112
R7 : 47 KΩ	C2 : 22 pF	C22 : 1 nF	DZ1 : 6.8 V – ½ W
R8 : 330 Ω	C3 : 6.8 pF	C23 : 1 nF	L1 : 7 turns/0.8 mm wire/5 mm plastic support
R9 : 1 KΩ	C4 : 6.8 pF	C24 : 120 pF	with ferrite core/ Lmin 0.18 µH – Lmax 0.48 µH
R10 : 33 KΩ	C5 : 68 pF	C25 : 1 nF	L2 : 12 turns/0.5 mm wire/5 mm plastic support
R11 : 56 KΩ	C6 : 330 pF	T1 : BF324	with ferrite core/ Lmin 0.52 µH – Lmax 1.3 µH
R12 : 680 Ω	C7 : 10 nF	T2 : BF244	L3 : 5 bifilar turns/0.5 mm wire/binocular ferrite
R13 : 1.8 KΩ	C8 : 47 nF	T3 : 2N2222	core 14x8x8 mm/type 43 material
R14 : 47 KΩ	C9 : 82 pF	T4 : 2N2222	
R15 : 1.2 KΩ	C10 : 33 nF	T5 : 2N2222	
R16 : 100 KΩ	C11 : 4.7 pF	T6 : BF324	
R17 : 330 Ω	C12 : 22 pF	T7 : BF244	
R18 : 270 Ω	C13 : 6.8 pF	T8 : 2N2222	
R19 : 3.3 KΩ	C14 : 68 pF	T9 : 2N2222	
R20 : 3.3 KΩ	C15 : 10 nF	U1 : NE602	

and the PLL PCB



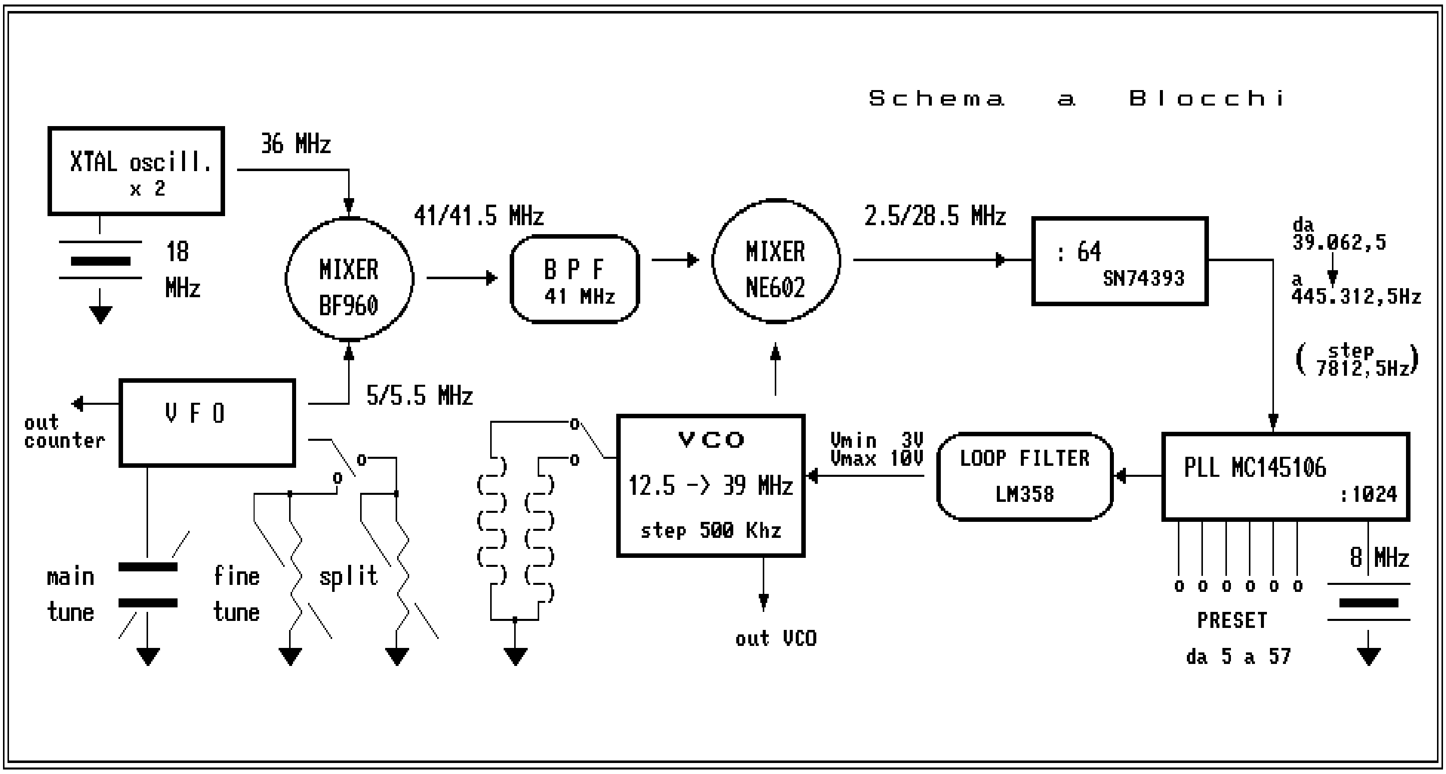
Part List of PLL unit

R1 : 33 KΩ R2 : 680 Ω R3 : 47 KΩ R4 : 330 Ω R5 : 390 Ω R6 : 3.3 KΩ R7 : 1.2 KΩ R8 : 1.8 KΩ R9 : 100 Ω R10 : 5.6 KΩ R11 : 10 KΩ R12 : 10 KΩ R13 : 10 KΩ R14 : 10 KΩ R15 : 10 KΩ R16 : 10 KΩ R17 : 10 KΩ R18 : 10 KΩ R19 : 180 KΩ C1 : 33 nF	C2 : 1 nF C3 : 4.7 nF C4 : 100 nF C5 : 100 µF C6 : 0.5 µF C7 : 0.5 µF C8 : 1.5 µF C9 : 25 µF C10 : 33 nF C11 : 33 nF C12 : 33 pF C13 : 33 pF T1 : 2N2222 T2 : 2N2222 T3 : 2N2222 U1 : 7810 U2 : 7805 U3 : 74393 U4 : LM358 U5 : MC145106	U6 : CD4050 DZ1 : 12V - ½ W X1 : 8 MHz

this unit may be located anywhere in the rig. The printed boards are double sided fiberglass and components are soldered directly on the copper drawing without drilling, so the lower side can be used to make the ground connections. The ground joints are obtained drilling the board and soldering a wire on both sides. The two PCBs are contained in an aluminium cabinet 70 x 100 x 40 mm.
The output RCA sockets and a comb connector for DC supply and band switching are located on a side of the cabinet.
Some slides show the overall arrangement.

How it works

I refer to the block diagram and schematic diagrams to describe the functions.



supposing to design the VFO in the 5/5.5 Mhz range with a 9 Mhz I.F. in the rig, other frequency values near those indicated can equally match the circuit requirements.

The unit described as ***VFO module*** is a conversion VFO in the 41 Mhz range. It contains:

- a Colpitts VFO ranging from 5 to 5.5 Mhz (*the first PCB*). The mechanical assembly and the component choice must be very accurate. Use possibly a good variable capacitor (ball bearing supported) and NPO ceramic capacitors. One N150 compensation element contribute to reduce the thermal drift. L1 is wound with 24 turns, 0.8 mm wire on 13 mm plexiglass core to obtain 3.5 µH inductance value. The varactor allows a 20 Khz shift for fine tuning or SPLIT function.

N.B. The VFO circuit could be better replaced by a more sophisticated DDS unit like the *Digi VFO* and related *Digi Brain* presented in the May ‘95 and March ‘96 issues

- two buffers wich drive an external frequency counter and the first mixer stage (*the second PCB*). The output level to the mixer should be about 3 Vpp. This PCB also contains the 7810 power supply.

- the first mixer and related 41 Mhz filter (*the third PCB*). It uses a BF960 mosfet as a mixer and a 2N2222 as a christal driven oscillator to obtain the 36 Mhz output from a 18 Mhz christal. L2 is made by 9 turns, 0.5 mm wire on a T44-2 toroidal core (0.42 µH). A 41 Mhz output filter is obtained by L4 and L5 (9 turns, 0.5 mm wire on a T44-6 core, 0.34 µH) with a buffer stage (2N2222 transistor). L3 is made with 2 wires wound on L4.

The mixer alignement can be made in the following manner :
- remove the christal so as the oscillator goes off
- input a 41.2 MHz signal to gate 1 and tune the capacitors to obtain maximum output
- insert the christal and drive a 5 Mhz signal into gate 1 tuning the 60 pF capacitor for the maximum output (0.7 to 1 Vpp)

The ***VCO unit*** (*forth PCB*) contains :

- VCO wich covers the range from 12.5 to 39 Mhz using two distinct oscillators switched by a relay driven from an appropriate band switch section.
The varactors are high capacity devices for AM use (MVAM115, BB112, etc..). The circuit configuration of the oscillators and use of compensation networks allowed to obtain a good quality and constant level output over the entire frequency range.
L1 is wound with 7 turns, 0.8 mm wire on a 5mm plastic support with type 43 ferrite variable core, the inductance range is 0.18 µH (core out) – 0.48 µH (core in)
L2 is made by 12 turns, 0.5 mm wire on a similar support, the inductance range is 0.52 µH (core out) – 1.3 µH (core in).
The alignement can be made in the following manner :
- supply a 3.5 to 9.5 variable voltage to the varactors (do not excede these limits)
- tune the ferrite cores of L6 and L7 to obtain the frequency ranges :
22 to 39 Mhz with L6
12.5 to 22 Mhz with L7
the output level (on a 200 Ohm load) should be about 3 Vpp

- second MIXER wich uses an NE602 IC. This device allowed to obtain the best results concerning linearity and balancement over the entire frequency range. The input VCO signal is lowered by a capacitive divider and the two balanced inputs (pins 1 and 2) are driven in opposite phase using a broadband transformer so as to limit the sporious outputs.
L3 is made by 5 bifilar 0.5 mm wires into a binocular ferrite core, type 43 material 13x8x8 mm.
Some tuning may be required on the value of 2.2 pF capacitor so as to obtain a level of 100-200 mV pp into pins 1 and 2 of the IC.
A buffer stage equipped with two 2N2222 transistors and a compensation network on the second stage emitter allow to obtain a substantially constant output level over the entire frequency range covered by the mixer. This is very important to ensure a good working by the TTL 74393 divider.

The ***PLL unit*** (*fifth PCB*) contains :

- frequency DIVIDER using a TTL 74LS393 wich divides by 64 the frequency coming from mixer. So the output frequency is comparable to the internal reference of the PLL and we can obtain 500 Khz steps (7812,5 Hz x 64 = 500 Khz, see also block diagram).
If you have an oscilloscope, you can verify the correct working of the divider stage:
- suppressing the connection from the VFO to pin 6 of the NE602 on PCB4 and supplying to the varactors a voltage ranging from 3 to 10 V you should notice no output signal from divider (otherwise try to eliminate the hitch reducing the signal level at pins 1 and 2 of NE602)

- driving the two varactors in the same manner and reconnecting the VFO you should see a clear TTL signal on both ranges covered (otherwise you can try some change to the compensation network in the buffer stage described above)

- PLL circuit using a dedicated Motorola MC145106. This IC features :
    - a 1024 divider, used to obtain the reference frequency from an 8 Mhz christal
    - a programmable 9 stages divider, programmed to obtain division ratios from 5 to 57, corresponding to a frequency range from 2.5 to 28.5 Mhz outcoming from the mixer (see also the block diagram).

The programming can be done by diode matrix or binary switches according to the following formula (see also the block diagram) :

Division Ratio = (32 - desired Mhz band) x 2

where 32 is the difference between the VFO frequency and the IF value (41 - 9 MHz).
To obtain the coverage of the 28,5 Mhz band, for example, you have to set :

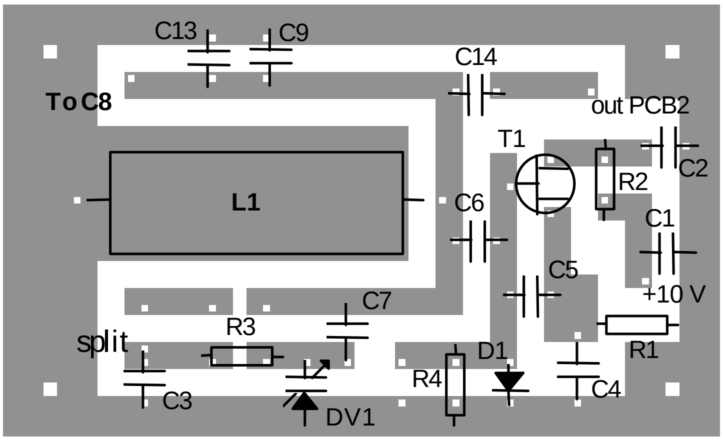
Division Ratio = (32 - 28,5) x 2 = 7

a 4050 CMOS Hex Buffer allows to use any programming voltage between 5 and 15 volts, and a Led signals the PLL lock condition

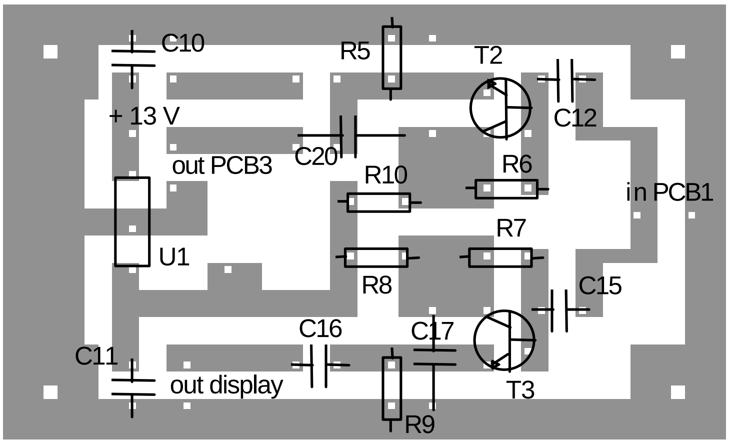
- LOOP FILTER using an LM358 operational IC as an integrator, followed by a low pass filter. This circuit showed the best performance concerning to :
- locking speed of PLL, so as to follow the VFO frequency changes, also when you are turning quickly the tuning knob
- PLL stability
- output error voltage clearness, i.e. good spectral purity of the VCO supplied frequency

The PCBs and main Components layout

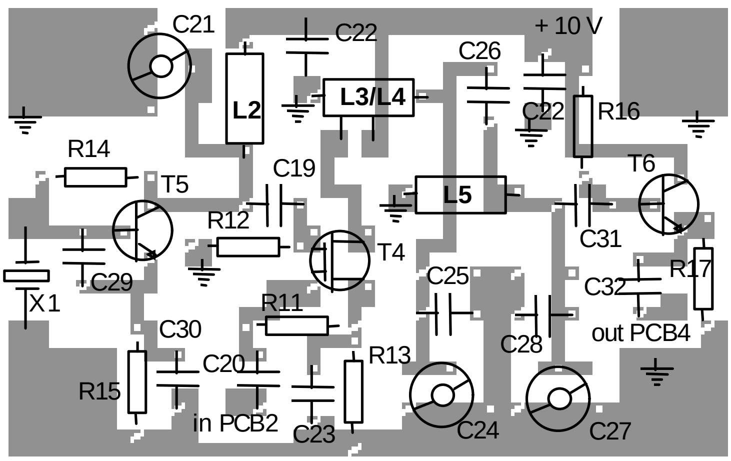
PCB1 (real dimensions 42 x 68 mm)



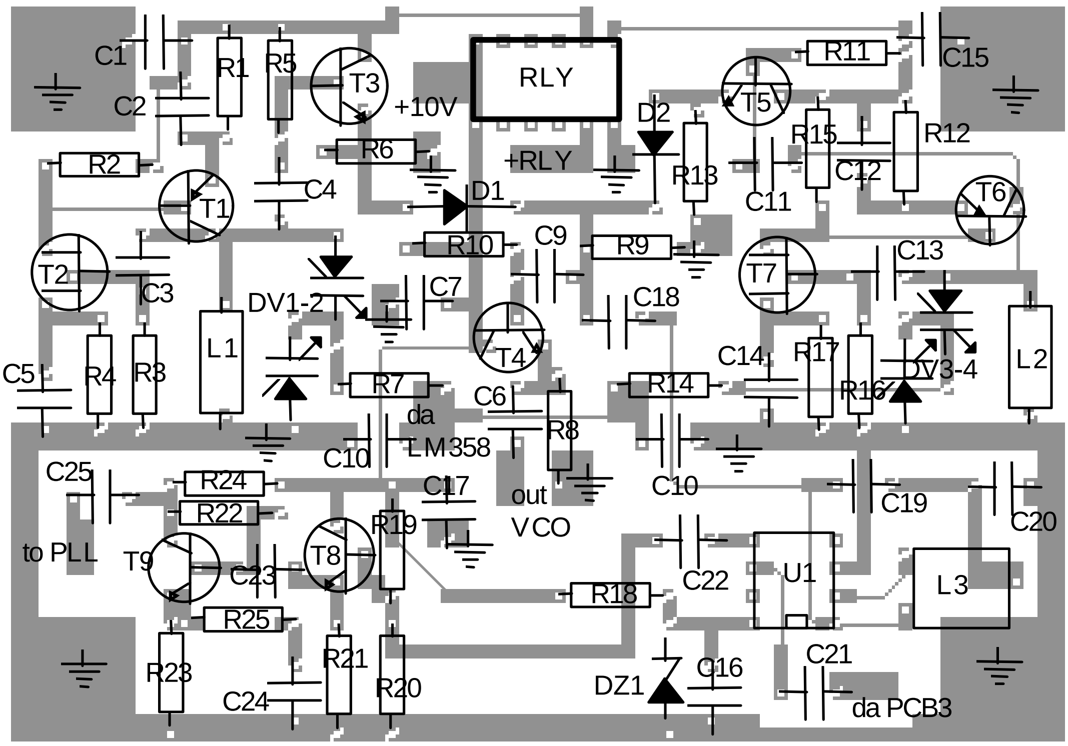
PCB2 (real dimensions 42 x 68 mm)



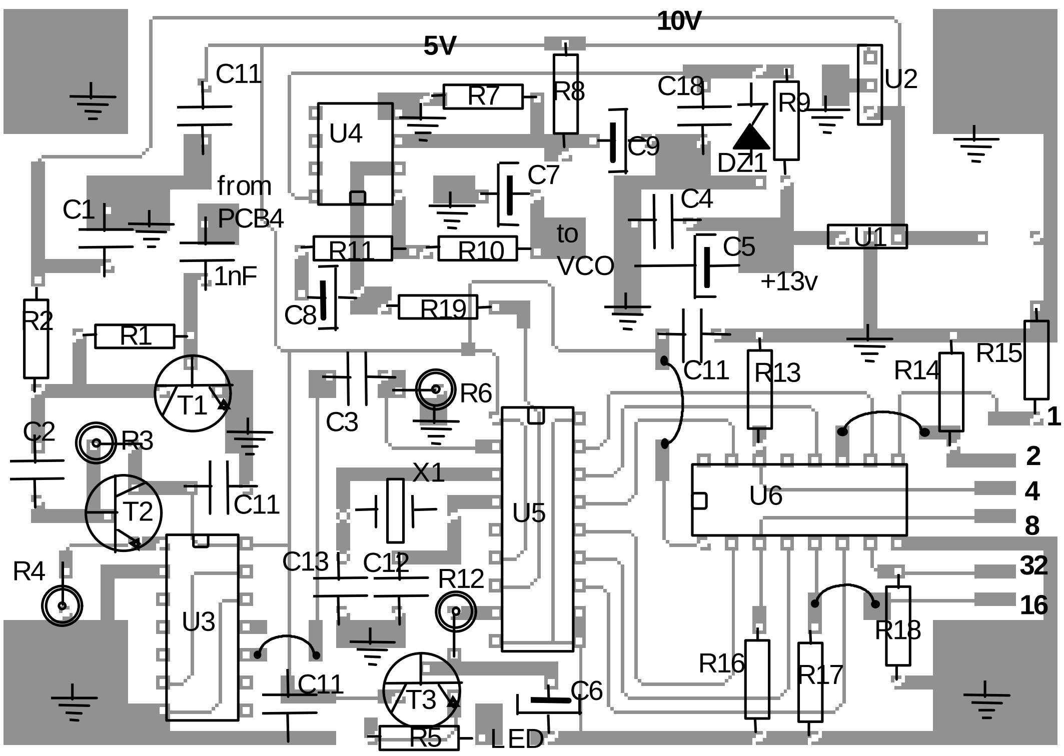
PCB3 (real dimensions 42 x 68 mm)



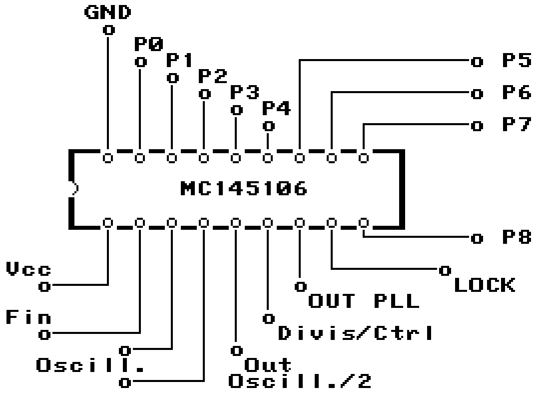
PCB4 (real dimensions 67 x 96 mm)



PCB5 (real dimensions 67 x 96 mm)



MC145106 pins layout



Final Considerations

Making a correct assembly, and following the few suggested rules, the device should work properly without bringing particular troubles. Consider, however, that an adeguate test equipment can make the good result easier.

The only hard to find component may be the Motorola MC145106, wich can be ordered to : RF PARTS - 435 South Pacific Street - San Marcos - CA 92069