

A PIC16F628 controlled “FLL” (Frequency Locked Loop) VFO for HF

Abstract

It is described a device which joins in a single microprocessor a digital programmable frequency meter and a control logic capable to lock a manually tuned VFO to its actual frequency. The locking function is software inhibited when a manual tuning is detected, so as to provide a completely automatic working.

Why an “FLL” device ?

The challenge, while developing this project, was to find out a way to arrange a very stable VFO with a very simple design, using very cheap and common components, in fact such a device seemed to be well suited for some QRP project, direct conversion rig or other simple equipments. So I decided not to consider a PLL or DDS approach, and the choice fell on an old, not so popular design : the “frequency locked loop”.

The principle of operation is quite simple, a counter measures the VFO frequency, the new reading is compared with the previously stored value and an adequate correction is applied consequently. This process has been implemented in the past using several discrete TTL logics, now a single microprocessor can do the job much better, moreover offering a digital readout capability.

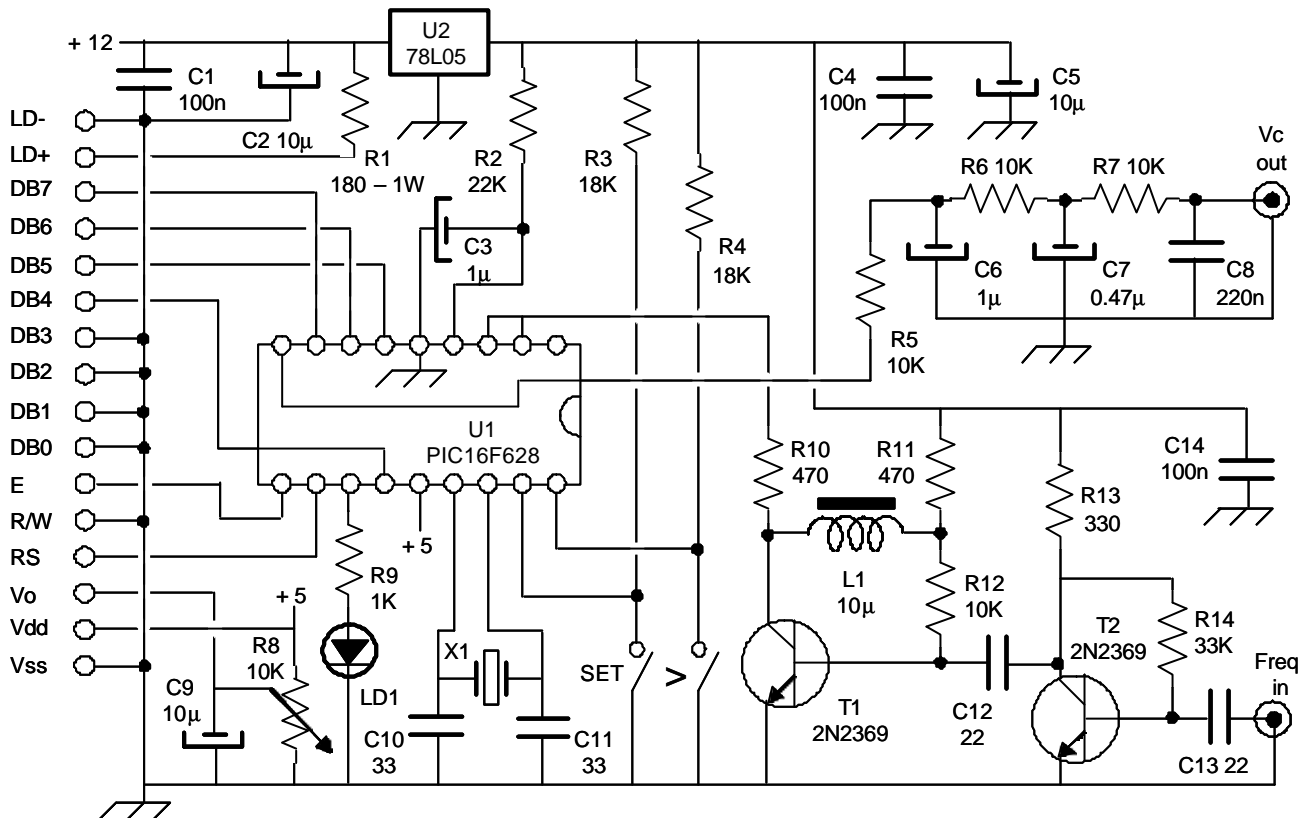
I had already the counter software designed for a PIC16F84 device ⁽¹⁾, so the remaining job was to develop an adequate code to measure the drift and control the VFO. Another problem was how to implement the control circuit. The best way seemed to be a D/A converter, driven by the PIC so as to produce a control voltage towards a varicap diode, but it would have required at least a 10 bit (better 12 bit) resolution, a component not so cheap nor so easy to find. So I considered to employ a different microprocessor, the PIC16F628. This device offers a built-in PWM module capable of delivering a 4 KHz square wave whose duty cycle may be software controlled with an accuracy of 10 bit. It was enough to add a simple RC integrator to obtain a well filtered control voltage, variable from 0 to 5V with a 1024 steps resolution.

Such a circuit may control the VFO frequency in a 15 KHz range with a 15 Hz unit step, notice that a single frequency adjustment is applied only when a certain drift amount is measured and, unlike a PLL system, there is no stability problem, no elongation or settling time, so it is possible to obtain a quite “clear” VFO signal, with a very low noise level. Just what I was looking for.

In short, the main performance of this device are :

- Frequency stability aligned to the reference crystal, with a maximum +/- 15 Hz drift
- Digital frequency readout, with programmable IF value and 10 Hz resolution on the LCD display
- Manual frequency tuning, through a multi-turn potentiometer
- Automatic Lock/Unlock function, unlock status is signalled by a LED diode and entered during manual tuning or in case of an excessive VFO drift
- Programmable lock range. It is the maximum allowed value for a “short term” (0.2 sec) frequency shift without exiting the locked status. This improves the capability to suit to various VFO circuits.
- The overall (long term) drift compensation capability is limited to about 15 KHz (+/- 7.5 KHz), normally enough to stabilize a well assembled VFO, however I suggest not to exceed a 20/25 MHz limit, although the counter capability may reach 35/40 MHz.

The Control Circuit schematic.



The heart of the circuit is the software running on a PIC16F628 microcontroller. The logic of the locking system is quite simple : at power-on an initial 30 seconds delay is provided to allow somewhat stabilization of the VFO. Then the actual frequency reading is stored as a reference for the locking mechanism. The counter reading period is 200 mS and corresponds to a 5 Hz accuracy, at every reading the new frequency is compared with the previously stored reference value and the following actions will be taken :

- Difference within +/- 10 Hz limits
no action will be taken, the drift is considered within lock limits
- Difference beyond +/- 10 Hz limits, but within user defined lock range limits (20 / 100 Hz)
the compensation mechanism is activated, it will vary the PWM duty cycle by one or more steps accordingly to the difference measured. Every correction step corresponds to a 15 Hz frequency compensation.
- Difference beyond the user defined lock range limits (manual tuning)
the UNLOCK condition is activated, the LED is powered and the actual frequency reading becomes the new reference value. Furthermore the PWM duty cycle is re-aligned a few steps towards the initial (central) value, so as to improve the “long term” compensation capability.

Should the PWM duty cycle limits be exceeded (0 / 1023), a “special” condition is entered, permanently deactivating the lock mechanism (till the next power-on). This condition is signalled by a continuous LED lighting.

Device programming is accomplished by means of two push buttons : “SET” and “>” in the following manner :

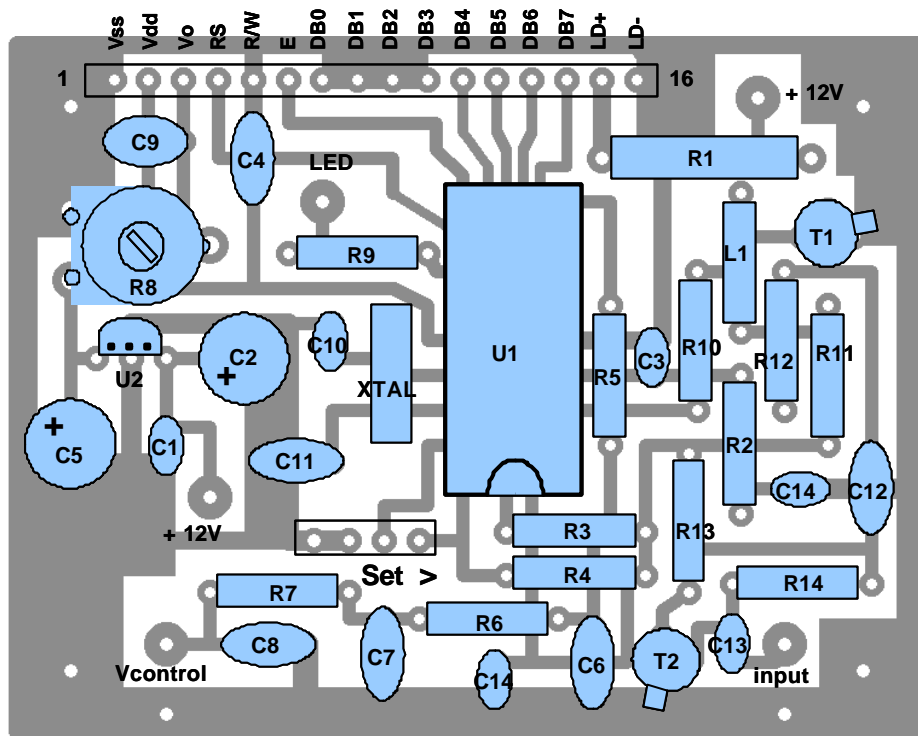
- Pressing the “SET” button a first time, the IF value will be displayed ("IFset" function) and the flashing cursor is positioned on the first digit you may modify (ten MHz), now you may modify the digit value by means of the “>” push button in the 0 - 9 range. After changing this digit you may go to the next digit by pressing again the ‘SET’ button, and so on until you reach the last digit to the right.
- Another pressing of the ‘SET’ button starts the "Mode set" function, and now you may choose, by means of “>” button, between the three operating modes : "VFO + IF", "IF - VFO", "VFO - IF".
- A further pushing of “SET” button enters the “Lock set” mode, allowing to modify the locking range limits (that is the frequency drift allowed during a single reading period) between a minimum 20 Hz value and a maximum of 100 Hz (default 25 Hz). This may be useful to allow the control circuit compensate a short time, fast frequency drift, up to 500 Hz/sec, provided that the overall long term drift remains within +/- 7.5 KHz. With the VFO circuit described below I recommend to leave unchanged the 25 Hz default.
- Finally, a last “SET” button pressure closes the menu, saves the setting parameters in the PIC EEPROM (non volatile memory), and re-activate the frequency reading function.

Keep in mind that, when operating in the "IF - VFO" or "VFO - IF" modes, the read frequency value will be displayed only if the result of the subtraction is positive.

Control circuit components list :

R1 : 180 Ω - 1W	R8 : 10 K Ω - trimmer	C1 : 100 nF	C8 : 220 nF	U1 : PIC16F628
R2 : 22 K Ω	R9 : 1 K Ω	C2 : 10 μ F	C9 : 10 μ F	U2 : 78L05
R3 : 18 K Ω	R10 : 470 Ω	C3 : 1 μ F	C10 : 33 pF	LD1 : LED diode
R4 : 18 K Ω	R11 : 470 Ω	C4 : 100 nF	C11 : 33pF (see text)	X1 : 4 MHz xtal
R5 : 10 K Ω	R12 : 10 K Ω	C5 : 10 μ F	C12 : 22 pF	L1 : 10 μ H
R6 : 10 K Ω	R13 : 330 Ω	C6 : 1 μ F tantalum	C13 : 22 pF	T1 : 2N2369
R7 : 10 K Ω	R14 : 33K Ω	C7 : 0.47 μ F tantalum	C14 : 100 nF	T2 : 2N2369
LCD : 1x16 LCD alphanumeric module (Optrex DMC-16117A, Hantronix HDM16116H-2, ...)				

The Control Circuit assembly and adjustment.



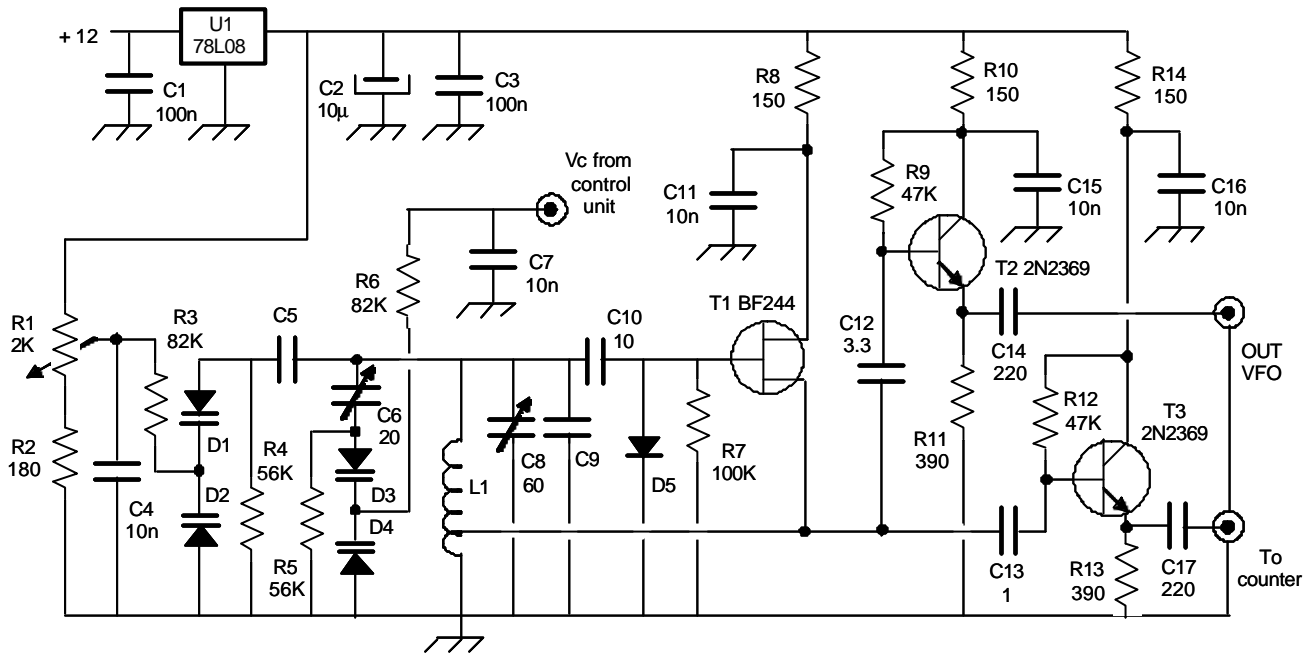
This circuit is assembled on a single side 68x52 mm PCB. To avoid possible interferences with the VFO working, I recommend to make a good shielding by housing the PCB into a little metallic enclosure. A single multi-pin connector may be employed towards LCD module, LED diode, push buttons and power supply, while two pieces of RG174 coax cable are used for the connection to VFO (RF input and V control).

The initial adjustment will be carried out in the following manner :

- Remove the PIC from its socket and verify that the T1 collector voltage is in the range 1,5 to 1,7 volts, otherwise some adjustment will be required to the R12 value.
- After inserting the PIC, turn the R8 trimmer completely toward ground side, then adjust it for the desired LCD contrast
- If a “precision” tuning of the counter is required, you may replace C11 with a little 30 pF capacitive trimmer. Employing an high impedance frequency meter or a digital receiver you’ll may adjust the XTAL frequency exactly to 4.000.000 Hz.
- If necessary, set the IF value and mode by the apposite push buttons.

Now the control circuit is ready to be connected to the VFO.

The VFO schematic.



Although any good quality VFO may be coupled to the PIC control device, I'd like to propose a basic circuit, tested on several frequencies in conjunction with the controller.

It is a common Hartley oscillator, which employs a FET whose source is inductively coupled to the gate by means of an intermediate tap on the resonant circuit. The coil is wound on a T50-6 toroidal core, and must be well fixed on the PCB. Some care must also be taken in the choice of the other components, the capacitors must be NPO type, the capacitive trimmer C8 should be ceramic and not too small.

The frequency tuning is obtained by means of a varicap diode, in conjunction with a 2 K Ω multi-turn potentiometer, so as to have a good resolution on the entire band. A second varicap is used for the frequency compensation function, this diode must provide a 15 KHz span when varying the control voltage from 0 to 5V.

Two outputs are provided, one for the locking system (about 200/300mV pp output) and the other towards the connected rig (about 600/800mV pp output).

The performances I observed are quite good; testing for stability a 14 MHz unit for 30 minute I measured about -700 Hz at room temperature and -1600 Hz when heating 10 $^{\circ}$ C the circuit. These drift values may be easily compensated by the PIC controller.

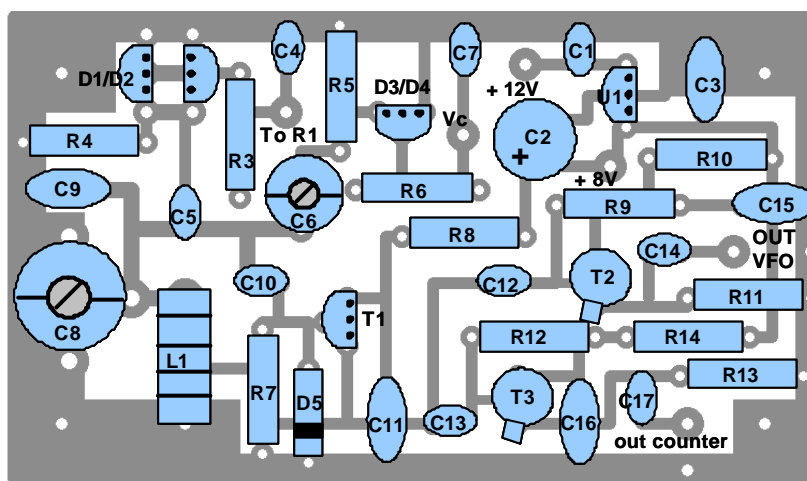
VFO components list :

R1 : 2 K Ω 10 turns pot	R9 : 47 K Ω	C3 : 100 nF	C13 : 1 pF	U1 : 78L08
R2 : 180 Ω	R10 : 150 Ω	C4 : 10 nF	C14 : 220 pF	T1 : BF244
R3 : 82 K Ω	R11 : 390 Ω	C6 : 20 pF trimmer	C15 : 10 nF	T2 : 2N2369
R4 : 56 K Ω	R12 : 47 K Ω	C7 : 10 nF	C16 : 10 nF	T3 : 2N2369
R5 : 56 K Ω	R13 : 390 Ω	C8 : 60 pF trimmer	C17 : 220 pF	
R6 : 82 K Ω	R14 : 150 Ω	C10 : 10 pF	D1/D2 : BB204 double varicap	
R7 : 100 K Ω	C1 : 100 nF	C11 : 10 nF	D3/D4 : BB204 double varicap	
R8 : 150 Ω	C2 : 10 μ F	C12 : 3.3 pF	D5 : 1N4148	

Band specific components :

Band	D1 / D2	C5	C9	L1	use
5 – 5.5 MHz	2 x BB204 parallel connected	1 nF	82 pF	36 t. ϕ 0.4 mm, tap at 10 t. from ground on T50-6 toroid	single conversion, 9 MHz IF rig
7 – 7.3 MHz	2 x BB204 parallel connected	150 pF	180 pF	21 t. ϕ 0.5 mm, tap at 6 t. from ground on T50-6 toroid core	direct conversion rig
14 – 14.35 MHz	single BB204	82 pF	120 pF	12 t. ϕ 0.5 mm, tap at 4 t. from ground on T50-6 toroid core	direct conversion rig
21 – 21.45 MHz	single BB204	33 pF	82 pF	9 t. ϕ 0.5 mm, tap at 3 t. from ground on T50-6 toroid core	direct conversion rig

The VFO assembly and adjustment.



The VFO circuit is assembled on a little single side PCB measuring 68x39 mm. Consider that it is important to make a good shielding by housing the PCB into a metallic enclosure, using coax cables (RG174) to bring the output signals and the control voltage. R2 is soldered directly on the R1 potentiometer and is not shown on the PCB.

The tuning of VFO will be accomplished in the following manner :

- Wait some minutes after power-on to allow stabilization of the circuit.
- Apply a 2.5 voltage to the Vc pin by means of a 10 K Ω trimmer temporarily connected to +8V.
- Adjust the C8 capacitive trimmer so as to measure the desired frequency range when completely rotating the R1 potentiometer. To obtain this result some little adjustment could be required to C9 and R2 values.
- Turn R1 all clockwise (upper frequency) and then adjust the capacitive trimmer C6 so as to measure about 15 KHz frequency range when varying the control voltage from 0 to 5V (use the temporary trimmer for this purpose). I recommend not to exceed this limit.

Now the VFO circuit is ready to be connected to the PIC controller.

References.

- (1) see the PIC16F84 μ -counter project at my WEB site : www.qsl.net/ik3oil ,
see also : AN592 - Frequency Counter Using PIC16C5X, application note from Microchip:
www.microchip.com/1010/suppdoc/appnote/all/an592/index.htm ,
and :
- *A PIC based Digital Frequency Display*, by Neil Heckt, QST, May 1997
- *The Unicounter, a multipurpose frequency counter/electronic dial*, by Ron Stone KA3J,
QST, Dec 2000