RefLocking DEMI Microwave Transverters

Steven Kerns - N3FTI

Abstract – *For many years amateurs have been utilizing PLL (Phase Lock Loop) systems to stabilize their microwave local oscillators to a highly stable frequency standard. While many of these were custom one off designs, others have gone to great lengths to document and publish their work. These systems have been based on discrete logic, commercial PLL chips, and most recently Programmable Logic Gate Arrays (PLGA). Until the advent of No-Tune Transverters, surplus commercial microwave "Brick" oscillators were the backbone of all amateur microwave transverter designs. Because of this, the majority of these systems were designed to interface with these "Brick" oscillators. The latest PLL system to enter the amateur community is the RefLock system designed by Luis Cupido, CT1DMK. The RefLock is a compact, very flexible system based on PLGA technology but is intended for use with surplus commercial "Brick" oscillators. The following article describes my work integrating the CT1DMK's RefLock PLL board with the popular line of Down East Microwave No-Tune Transverters.*

Introduction

The advent of the WSJT suite of weak signal software by Joe Taylor, K1JT, has given the VHF operator an additional tool to exploit short lived and very weak signal propagation modes. Because the software requires very high accuracy of both time and frequency, it has been best used on the VHF and lower UHF bands where frequency stability and accuracy are easily achieved. Can this software be utilized to further investigate propagation modes on the upper bands?

In order to utilize these same digital modes, we must first achieve the accuracy and frequency stability required by the software. In the case of the three digital WSJT modes, this is on the order of plus or minus 200 cycles. To achieve this kind of local oscillator stability would require more than just the classic temperature compensated crystal oscillator.

While attending Microwave Update 2002 in Enfield Connecticut I attended Tom Williams, WA1MBA's presentation [1]*"Quest for Microwave Frequency Stability or How Far Should I Tune for You?"* The basis of Tom's presentation was practical methods of improving local oscillator stability and accuracy, along with an explanation of each system. I was very interested as Tom described a PLL system designed by KD6OZH and

[1] *"Quest for Microwave Frequency Stability or How Far Should I Tune for You?"*, Tom Williams, WA1MBA, Proceedings 17th Annual Microwave Update 2002 and the 28th Eastern VHF/UHF Conference.

described in the Nov 1999 QEX [2]"Stable, Low Noise Crystal Oscillator for Microwave and Millimeter-Wave Transverter. But like many earlier PLL systems, this one was designed to provide a 90 –110 MHz reference for commercial brick oscillators.

Since I had standardized on the DEMI line of microwave transverters, I needed a simple but versatile PLL system to interface with my existing DEMI MicroLO local oscillators.

Within months of the conference I learned of a new PLL system designed by Luis Cupido, CT1DMK. Luis' design, dubbed the [3]RefLock, utilizes Programmable Logic Gate Array technology. Although designed for use with commercial brick oscillators, the RefLock is a stand-alone PLL board that can be programmed to reliably lock voltage-controlled crystal oscillators ranging in frequency from 10 to 160 MHz.

Description

The testing, modifications and implementation described here were performed on my 10GHz DEMI transverter, but will work equally well on all DEMI transverters using the MicoLO board.

Early in this project it was clear that there were some key problems that had to be solved,

1. The DEMI MicroLO oscillator (TCXO) must be converted to a variable frequency-temperature compensated crystal oscillator (VTCXO).

2. The converted DEMI VTCXO must be prescaled to fit the frequency limitations of the RefLock PLL system (160MHz)

3. Proper signal levels for *VCO* and *Ref* inputs to the RefLock board must be determined.

4. Empirically determine RefLock loop filter component values for the VCXO.

Reflock Board

It is beyond the scope of this paper to fully describe the construction and programming of the RefLock board, this is but a basic overview of the systems. I urge anyone contemplating building and programming the board to visit CT1DMK's excellent web page at http://gref.cfn.ist.utl.pt/cupido/reflock.html

The RefLock PLL board is based on the Altera EPM3064ATC44-4 or EPM3032ATC44-4 CPLD chip. These PLGA devices are in actuality 1000s of programmable logic gates

[2] " Stable, Low Noise Crystal Oscillator for Microwave and Millimeter-Wave Transverter", John Stephensen, KD6OZH, Nov 1999 QEX

[3] http://gref.cfn.ist.utl.pt/cupido/reflock.html

that can be configured as programmable dividers and phase comparators. The program is loaded into the chip via a JTAG (Joint Test Action Group) standard interface connected to the parallel port of any modern windows based computer.

Initially described in a 2002 DUBUS article, the first of three Reflock versions utilized programming files to allow the PLL to lock to one of following popular microwave brick oscillator base frequencies

90.000 MHz	90.666 MHz	96.000 MHz	100.000 MHz
106.500 MHz	117.000 MHz	122.250 MHz	125.250 MHz

The second software version used the same hardware as the first, but is programmed to function as a "Universal Version" that locks only to the last significant digit of any VCXO frequency. This is ideal for use with VCXOs, as they usually have a very narrow tuning range. The chart below lists the eight lock points programmed into this version.

2.5 KHz	3.333 KHz	5.0 KHz	10.0 KHz
33.333 KHz	25.0 KHz	50.0 KHz	100.0 KHz

The third version also utilizes the same hardware as the first two, but is programmed to utilize phase/time lag counting methods to lock a 10MHz VCXO to the 1 pps signal available from most global positioning receivers (GPS).

Because of its ease of use and the ability to be used on a wide range of frequencies, I based my work on the "Universal Version" of the RefLock.

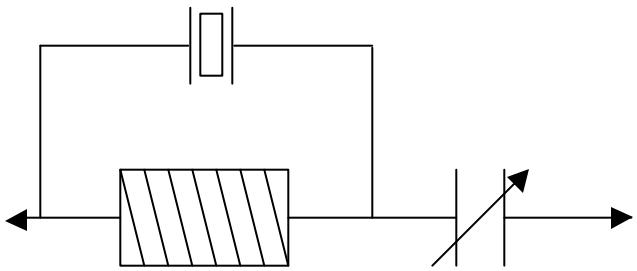
After construction and programming the RefLock frequency and mode jumpers must be configured for operation with the MicroLO oscillator. The proper setting are, PD2 Down, and the Frequency Control Jumpers set to 001. The board seems to work best when VCO and Ref levels are between 0 and +3dBm.

DEMI MicroLo Board

The MicroLO Board is utilized by DEMI for all transverters from 2304MHz to 10GHz. This temperature stabilized oscillator provides a +3dBm output in the 1100 MHz range (see Table 1) which is then further multiplied on the transverter board to the desired mixing frequency. DEMI's 903 and 1296 transverters utilize an on board version of this same base oscillator.

At the conception of this project I believed the biggest hurdle was to convert the existing DEMI MicroLO into a VTCXO. Thanks to Joe Jurecka, N5PYK this was one of the easiest tasks. Like others, Joe was working to interface his DEMI transverters to the Reflock board and we exchanged many emails concerning the project. He was also running into some of the same problems as I was. First, the unmodified MicroLO could not be tuned down to exactly 1136MHz using the frequency adjust trimmer. This was

solved by replacing the .1uH choke (L2), with a .1uH air wound inductor and placing a .7 to 10pf trimmer cap in series with the crystal and coil (Fig. 1). By adjusting the physical dimensions of the choke and adjusting the capacitor it is now possible to put the oscillator on exactly 1136.0000 MHz.



#20 AWG
10 Turns
.125" ID
.3" Long.

.7 – 10pf
Ceramic Trimmer

Figure 1

Because the upper frequency limit of the RefLock is 160MHz, the 1136MHz output of the MicroLO must be prescaled (divided) before being applied to the input. If divided by 8 the 1136MHz oscillator becomes 142MHz, well within the limits of the RefLock.

The circuit in figure 2 shows the prescaler used in this project. It consists of a MAR3 MMIC amplifier followed by a MC12093 /2/4/8 prescaler configured for /8 division. A 160MHz low pass filter follows the MC12093 to remove any harmonics that may be present in the output of the prescaler. Another MAR3 amplifier amplifies the filtered 142MHz that will be applied to the RefLock VCO Input port. C1 is located on the Microlo board, the remaining components are located in a separate shielded enclosure and connected via SMA connectors and a high quality shielded jumper. The 142MHz output of the prescaler circuit has been designed for a level of ~+3dBm, as both the *VCO* and *Ref* inputs to the RefLock board work best with a level between 0 and +3 dBm. This circuit is built dead bug style, utilizing chip components and following good microwave building techniques.

Another obstacle involved converting the temperature compensated crystal oscillator to a variable frequency temperature compensated crystal oscillator (VTCXO) and deriving the proper values for the loop filter. By adding a varactor diode and a blocking capacitor in parallel with the existing frequency control trimmer capacitor (C2) the oscillator could now be pulled in frequency by the control voltage applied by the RefLock. The initial loop filter values that were suggested for use with brick oscillators just would not work with the MicroLO. Joe suggested adding a series network composed of a 100ohm

resistor and a 10uF tantalum capacitor between the VCXO tuning voltage line and ground. This took care of all instability and the unit now locked. Figure 3 details this circuit along with proper connections to the RefLock.

Concluding Remarks

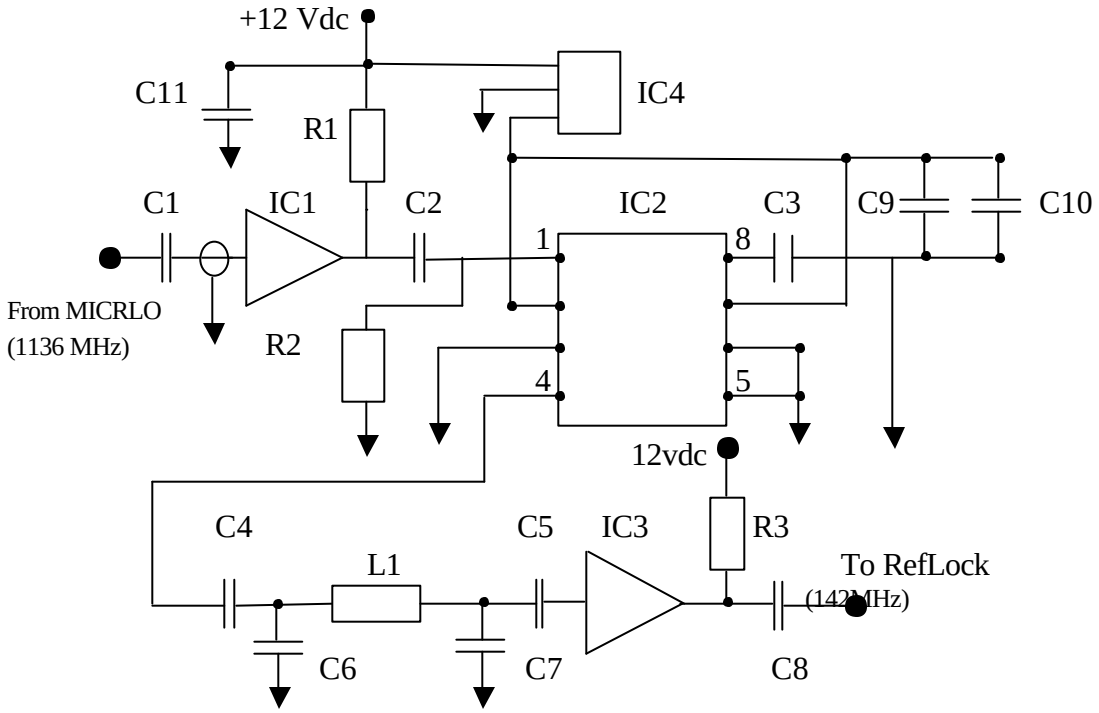
Although originally designed to phase lock surplus commercial brick oscillators, the RefLock board can also be utilized to lock the popular Down East Microwave line of microwave transverters.

Long term testing has concluded that even when using a low cost Temperature Compensated Crystal Oscillator as the reference (10MHz), local oscillator stability on the order of better than 10hz at 1136MHz (the resolution limit of my GPS referenced frequency counter) can be expected. Even greater accuracy can be expected when using a GPS, Rubidium or Cesium frequency reference. These accuracies are precise enough to utilize WSJT digital modes.

Now that the system has been proven on 10GHz, the next step will be to implement it on the lower microwave bands. Printed circuits boards for the prescaler will be engineered and made available so the system can be easily reproduced by other amateurs wishing to duplicate this work. If warranted, complete conversion kits may be made available through the Mt Airy VHF Radio Club.

Steven Kerns, N3FTI
Email - n3fti@yahoo.com

1136MHz / 8 Prescaler



Parts List

C1	10pf		
C2,C3,	1000pf	R2	50Ω
C4,C5,C8	100pf	IC1,IC3	MAR3
C6,C7	20pf	IC2	MC12093
C9	10uf /10V	IC4	LM7805
C10, C11	.1uf	R1, R3	270Ω
L1	100nH	(125” id – 10T - #22 - .3” long)	

Figure 2

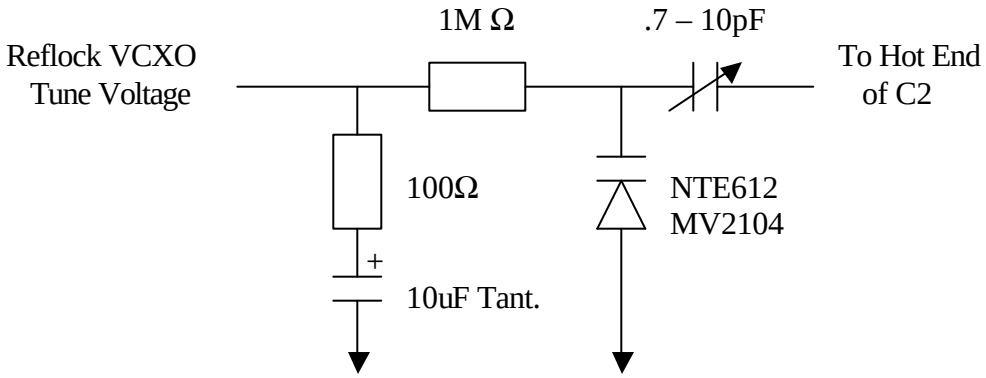


Figure 3

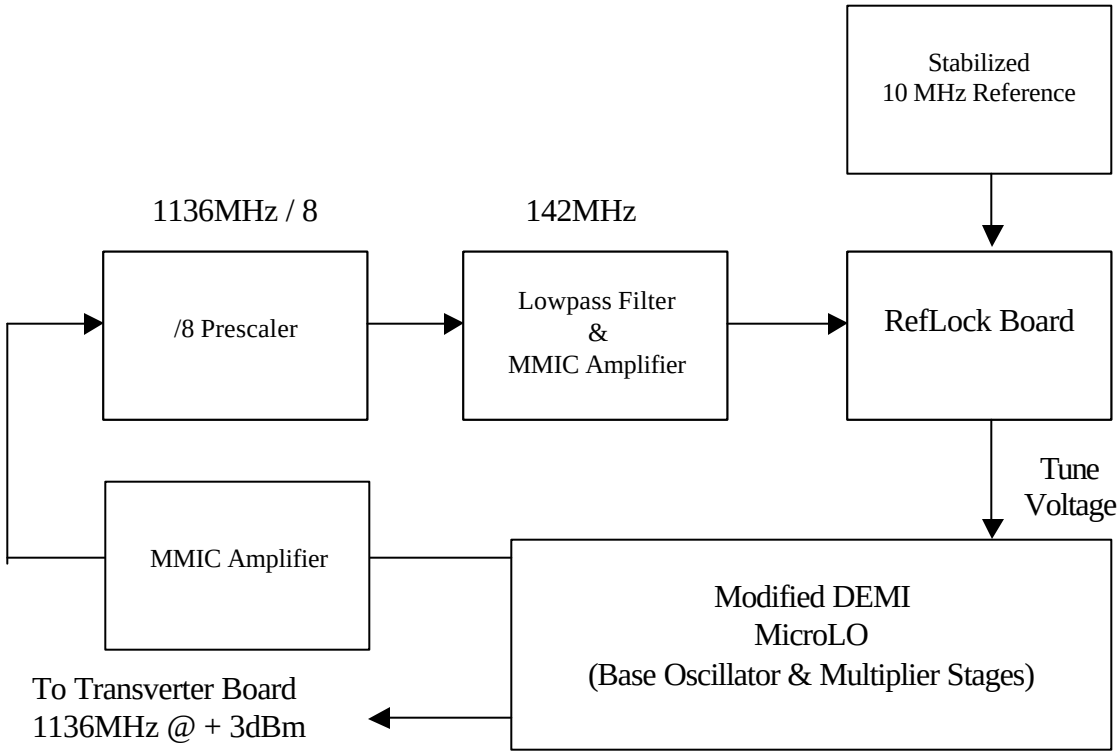


Figure 4

Band	Crystal Frequency	Microlo Output Frequency and Power	Transverter Multiplication	Xverter LO Frequency
903	189.750 MHz	759.000 MHz	NA	759.000 MHz
1296	192.000 MHz	1152.000 MHz	NA	1152.000 MHz
2304	180.000 MHz	1080.000 MHz +3dBm	X2	2160.000 MHz
2400	188.000 MHz.	1128.000 MHz. +3dBm	X2	2256.000 MHz.
3456	184.000 MHz.	1104.000 MHz. +3dBm	X3	3312.000 MHz.
5760	187.200 MHz.	1123.200 MHz. +3dBm	X5	5616.000 MHz.
10368	189.333 MHz.	1136.000 MHz. +3dBm	X9	10224.000MHz.

Table 1

Band	LO Frequency	LO / 8
903 MHz	759.000 MHz	94.875 MHz
1296 MHz	1152.000 MHz	144.000 MHz
2304 MHz	1080.000 MHz	135.000 MHz
2400 MHz	1128.000 MHz	141.000 MHz
3456 MHz	1104.000 MHz	138.000 MHz
5760 MHz	1123.200 MHz	140.375 MHz
10.3 GHz	1136.000 MHz	142.000 MHz

Table 2

RefLock Printed Circuit Boards are available from Kent Britain, WA5VJB
Email - wa5vjb@flash.net

All other parts are available from Newark Electronics
Web Site – http://www.newark.com