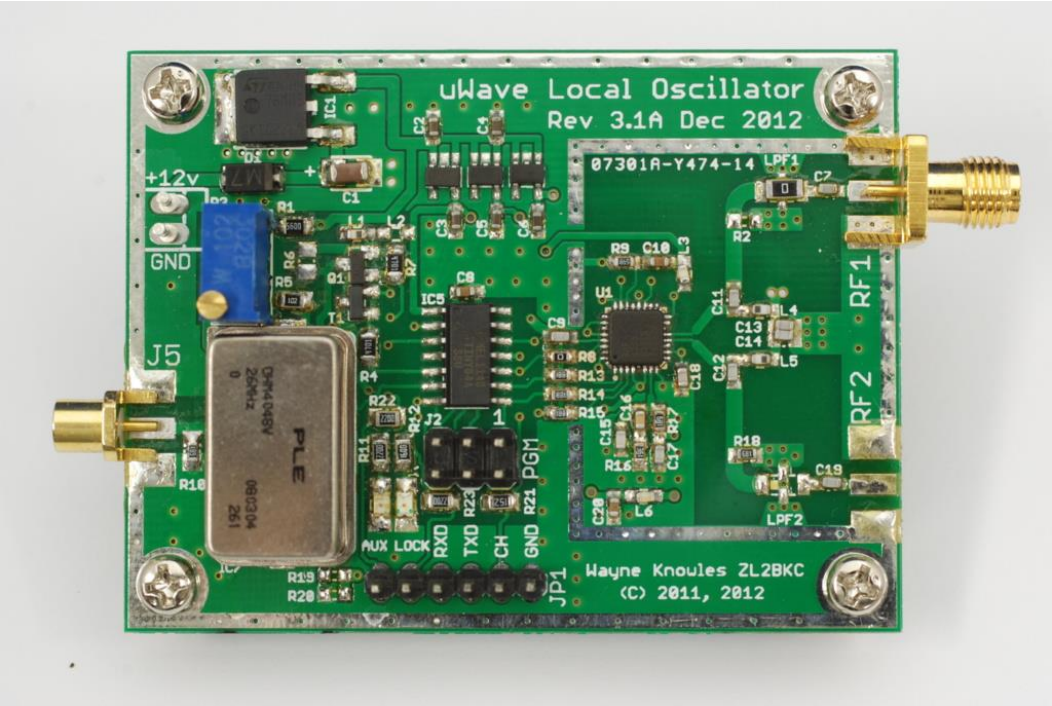
ZLPLL Local Oscillator

Wayne Knowles, ZL2BKC
w.knowles@xtra.co.nz



Contents

1 Introduction

The ZLPLL is a frequency agile synthesizer with many unique features designed for use as a local oscillator for amateur radio projects, weak signal source, or an exciter for a morse beacon (with suitable firmware)

The board is based on the Analog Devices ADF4351 PLL chip and contains a microprocessor and reference oscillator making the board fully self-contained for portable operations if required.

2 Specifications

Parameter	Specification
PLL Device	Analog Devices ADF4351
Power Supply	+8v to +15v @ 200mA (additional heatsink recommended when using >=10V)
Frequency Range	2200MHz to 4400MHz (fundamental) 31MHz to 2200MHz (using internal divider)
Frequency Resolution	1kHz
Output Level	4 levels software selectable in 2dB steps: +5dBm, +3dBm, +1dBm, -1dBm (Note: +7dBm between 500MHz and 2GHz)
Size	65mm x 50mm
Stability	After 5 minute warm-up time: < 10Hz @ 2GHz After 30 minute warm-up: 1 x 10^{-10} External Reference: As per specification for external reference
Phase Noise	-85dBc at 100Hz -98dBc at 1kHz -98dBc at 10kHz -106dBc at 100kHz -138dBc at 1MHz
Additional Features	Frequency Sweep up to 1000 points/sec with trigger output
Frequency Reference	• Internal 26MHz OCXO • External Reference of 10MHz (default) or any frequency up to 100MHz External reference is automatically selected when detected.
Connectors	RF Out: SMA RF Out 2: SMA (supplied, but customer installed) External Ref: MCX (supplied, but customer installed)

3 Performance

3.1 Phase Noise

Phase noise measured using a HP 4352B VCO analyzer and HP 8662A Reference Local Oscillator:

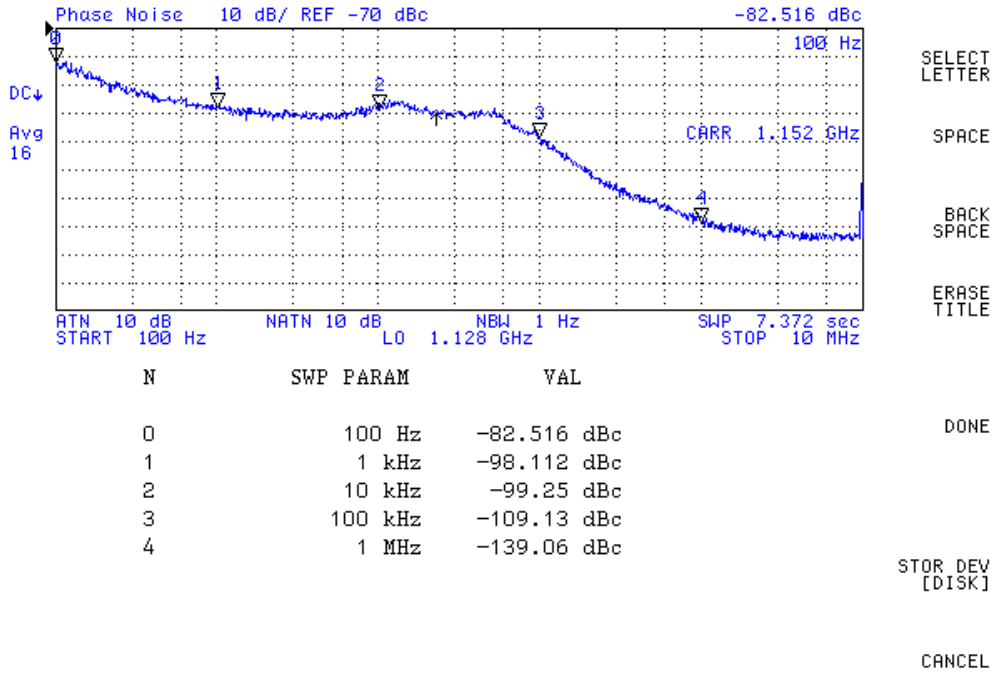
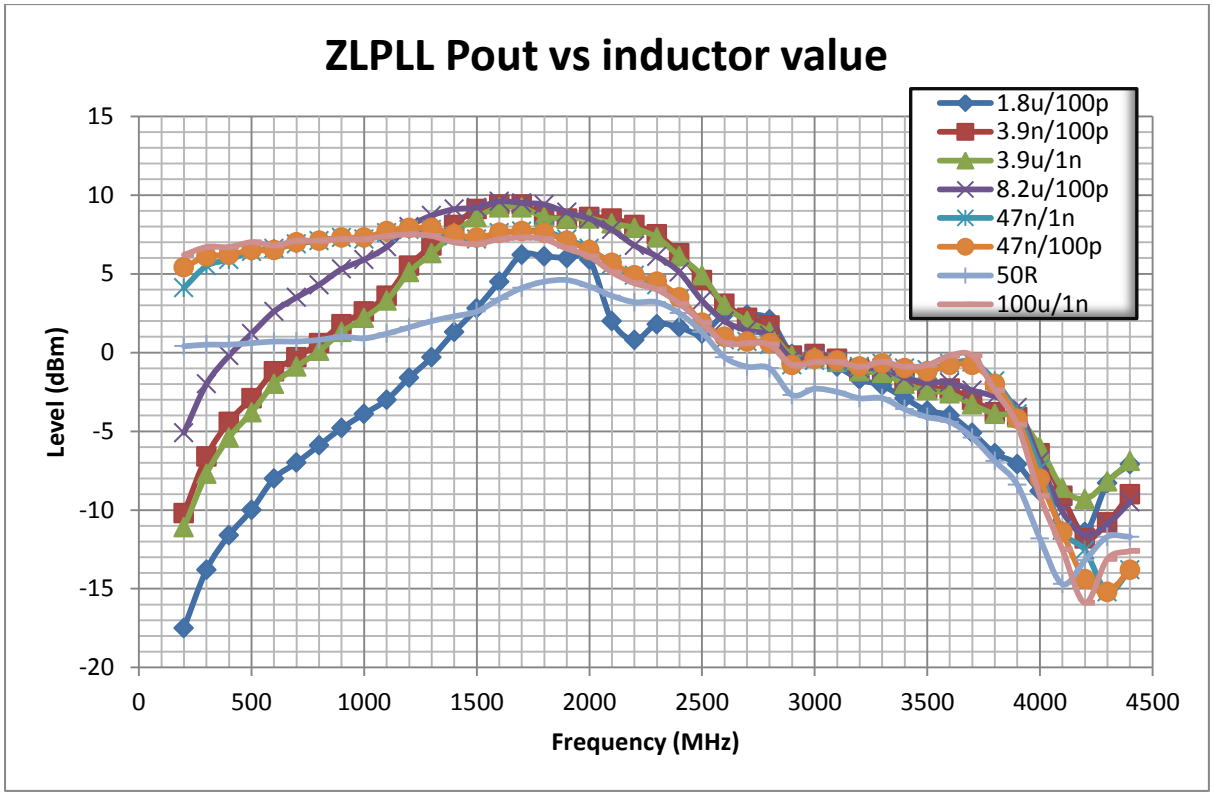


Figure 1 Performance

3.2 Output Level

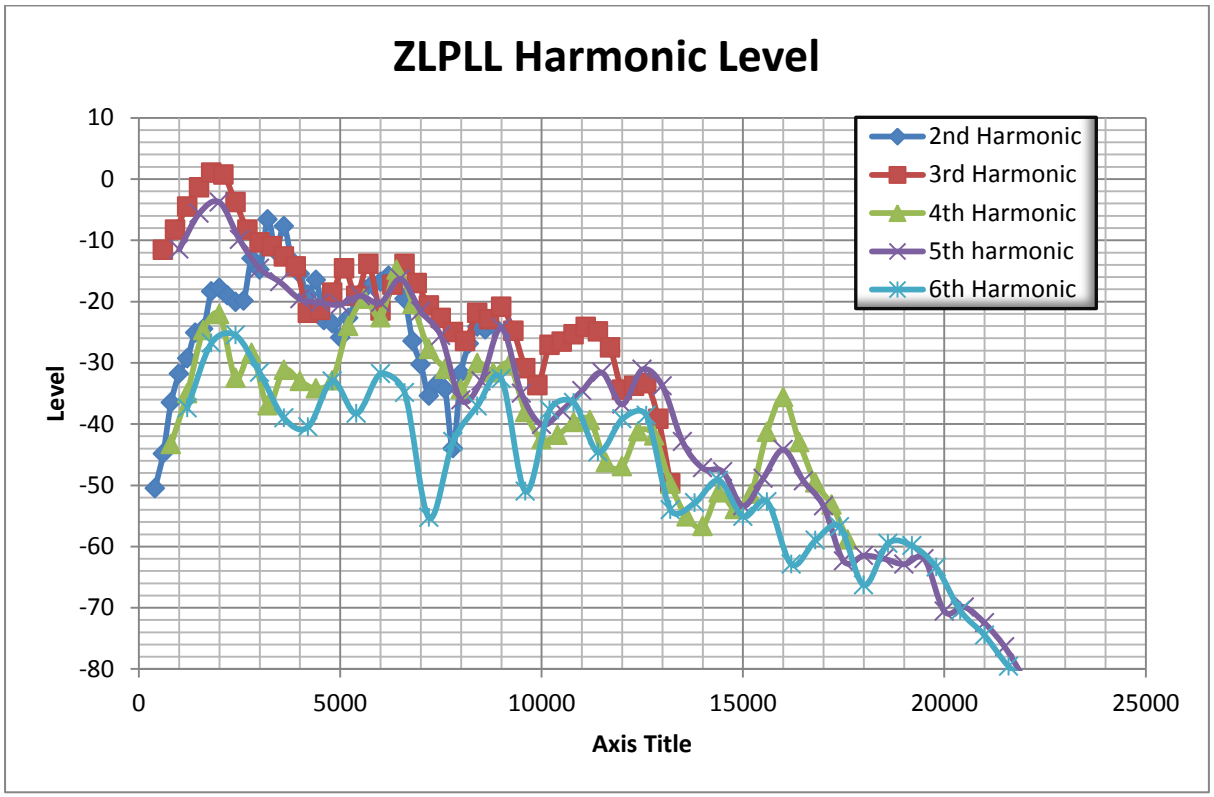
The Output level is dependent on the choice of inductor value in the output stage. The default 3.9nH inductors are suitable for frequency ranges above 1GHz and driving external multipliers.

For use below 1GHz the inductor can be changed to 47nH which improves the output level for directly driving level 7 mixers up to 2GHz. This optional inductor is supplied with the board and can be fitted on request.



3.3 Harmonic Level

The following graph can be used as a guide to determine the level of output for harmonics. As a general rule the lowest odd harmonic should be used to when wanting the highest level output on a given frequency.

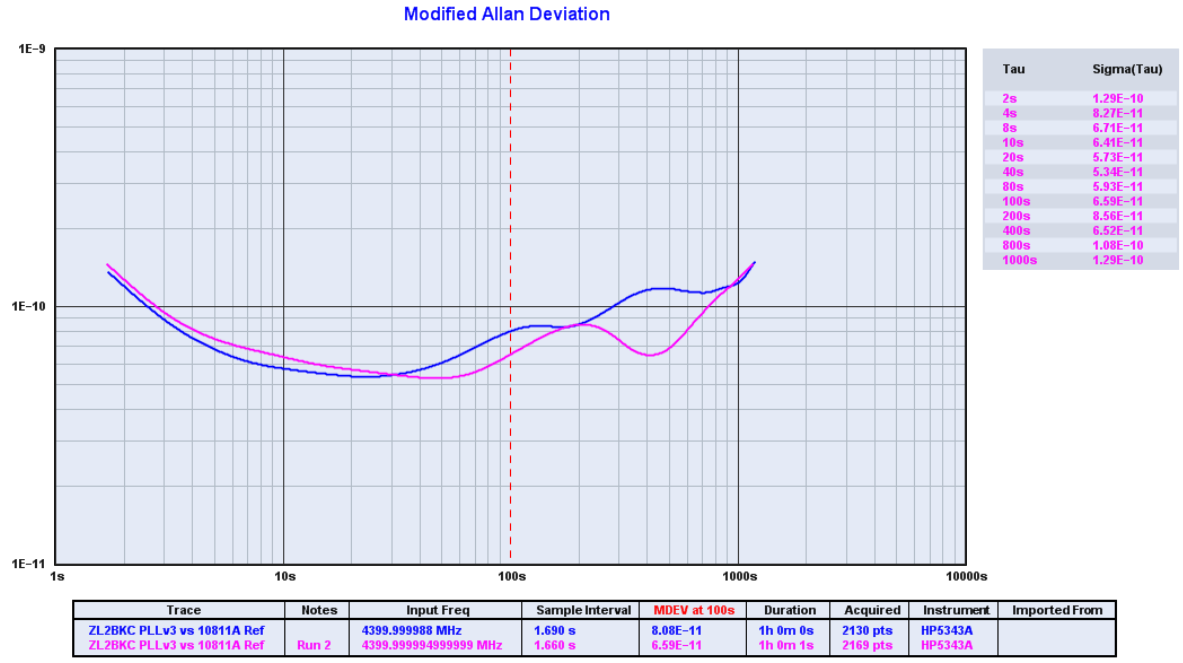


3.4 Stability

Because the ZLPLL uses an oven controlled xtal oscillator (OCXO) it has excellent frequency stability making this suitable for use on WSJT modes which require excellent stability over a 309 second to 1 minute period (depending on the mode being used).

With stability better than $1x10^{-10}$ the frequency error sufficiently allows for reliable frequency operation using all modes (including WSJT) up to 10GHz and potentially higher.

For more stringent frequency requirements an external oscillator such as Rubidium or GPSDO and the stability will be governed by the external reference.



4 Application Notes

4.1 Termination

Ensure both outputs are well matched. If the 2nd output is un-used it should be terminated otherwise oscillations will occur especially at high output levels (L2 and L3).

4.2 Power Supply

The on board voltage regulator is capable of operating up to 15V supply voltage. However for supply voltage above 9V the regulator will get very hot and it is advised to solder a small copper or brass strip to improve the heat dissipation.

4.3 Warm-up

The recommended warm-up time is 5 minutes after applying power. For applications that demand short to medium term stability such as WSJT modes a warm-up period of 30 minutes is recommended.

When using an external reference no warm-up is required as stability is governed by the external reference.

5 Features

5.1 Frequency Multiplier Correction

In cases where the LO is followed by a frequency multiplier, in particular when multiplying by an odd number, the resulting frequency may suffer from rounding errors resulting in a small frequency error in the final frequency.

In order to prevent oddball frequencies (eg with 0.3333333 MHz re-occurring) the correct procedure is to set the 'M' multiplier value to 3 and then program in desired frequency for the 3rd harmonic.

Example: Generate a Frequency of 10368.270 MHz for a beacon using the 3rd Harmonic

```
M 3
N 0.01
F 10368.280
S 0
```

Note: The frequency entered is the final frequency of the harmonic.

Without the multiplier setting the resulting frequency will be 20kHz higher.

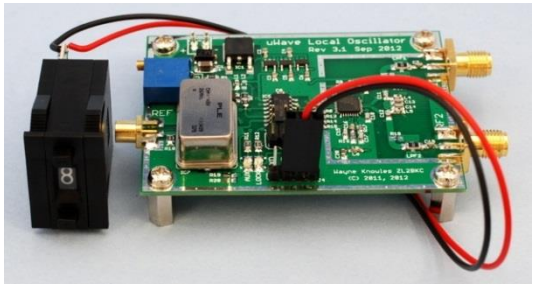
5.2 Channel Interface

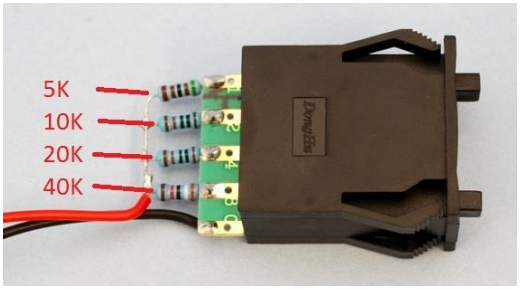
A single wire interface is provided to switch between 16 preprogrammed channels (10 with a BCD thumbwheel).

The interface consists of a resistor ladder using 5k, 10k, 20k and 40k resistors. 5k is connected to the binary 2^0 leg of the BCD thumbwheel, 10k to the binary 2^1 and so forth. See the photo below for the connection details.

The thumbwheel is connected between ground and the CHAN port on connector J4. As an extra precaution it is recommended that a single ferrite bead be placed on the CHAN signal near the PCB to avoid any RF pickup that could lead to erroneous channel changes.

For application that require only 2 channels to be selected, a simple switch or jumper can be installed between the CH and GND pins. In this case the frequencies are programmed into Channel 0 (or open) and Channel 7 (for short to ground).





5.3 Programming

Programming can be done by connecting a **TTL** level RS232 interface onto the following pins of J4:

RXD, TXD, and GND

Baud rate: 9600 8 bits No Parity 1 stop bit

The interface levels are 3.3V but the protection circuits allow for 5V levels to also be connected without damage.

A suitable interface is a PL2303 based USB to RS232 converter, or a programming cable for a Yaesu FT8x7 transceiver.

The labeling of the pins on J4 assumes a DCE interface, thus the RXD pin is an input, and TXD is an output.

Use any terminal program, either TeraTerm, Putty or Hyperterm can be used.

```
uLO Universal Local Oscillator Rev3.1
(C)2012 W. Knowles, ZL2BKC
d
RF= 1152.000, L=3
Ref=   26.000, N=    0.025
ExtRef=   10.000
Params=23, CP=7

0 RF= 1152.000, L=3
1 RF= 1296.050, L=3
2 RF= 2400.050, L=3
3 RF= 3400.050, L=3
```

```
4 RF= 5760.050, L=3, M=3
5 RF=10368.050, L=3, M=3
6 RF=      NAN, L=3, M=63
7 RF= 1242.000, L=3
8 RF= 4400.000, L=3
9 RF=      NAN, L=3, M=63
10 RF=      NAN, L=3, M=63
11 RF=      NAN, L=3, M=63
12 RF=      NAN, L=3, M=63
13 RF=      NAN, L=3, M=63
14 RF=      NAN, L=3, M=63
15 RF=      NAN, L=3, M=63
```

The following example demonstrates the commands required to program channel 0 (the default if no channel switch installed) for 1920MHz:

M1
L3
F1920
S0

5.4 Command Reference

Command	Units	
A 0		Enable onboard oscillator and select Internal frequency reference using the value set by the 'R' command.
A 1		External frequency reference as set by the 'E' command. Note: The internal reference oscillator is powered down
A 2		Force external reference. This option is available for > 20MHz reference or for low level reference that does not auto detect.
C *n*		Load frequency settings for channel *n*
D		Display frequency and channel settings
E *n*	MHz	External reference frequency in MHz
F *n*	MHz	Set Frequency
I *n*	MHz	Step size for sweep and increment functions
L *n*		Set output level L0 = -1 dBm L1 = +1 dBm L2 = +3 dBm L3 = +5 dBm
M *n*		Frequency Multiplier
N *n*	MHz	Synthesizer frequency resolution in MHz for the fundamental band.
P *n*		Set PLL parameters (see section 5.5)
R *n*	MHz	Internal Reference frequency in MHz
S *n*		Save frequency, Multiplier and Level settings into channel n (N=0-15)
+		Add step (as set in S) to current frequency
-		Subtract step (as set in S) from current frequency

5.5 Lock and Aux LED's

The AUX and Lock LEDS can be connected to an external LED directly. The pins directly underneath the LED's are the signals with a suitable dropper resistor for driving most red/green/yellow LED's.

The Lock LED (Green) indicates the PLL is frequency locked.

The Aux LED has 2 purposes. For the standard firmware it will ight (Amber) to indicate that the external reference is selected.

For the CW Beacon version of the firmware the Aux LED is a visual indication of the CW key.

5.6 PLL Parameters

The 'P' command is used to override the PLL programming parameters.

The default value of 23 sets the correct charge pump current and ensures the LO is muted until it is fully locked. These parameters should not require changing under normal use.

Bits	Decimal	Purpose
0:3	7	Charge pump current (normally 7)
4	16	0 = Output always on 1 = Mute to Lock Detect
5	32	0 = Low Phase Noise mode 1 = Low Spur Mode
6	64	0 = Enable reference doubler for frequencies < 16MHz 1 = Disable reference doubler

5.7 Initial Programming

Several parameters have default settings, and if they are accidentally overwritten the performance of the board may be limited.

To reprogram the default settings, enter:

```
P23
E10
R26
N0.005
L3
M1
F1152
S0
```

6 Special Applications

The board is designed to cater for several end user applications. Some of the applications are outlined in this section.

6.1 Sweep Generator Mode

For experimental applications the PLL can be programmed to perform a frequency sweep with synthesizer accuracy. The ADF4350 is capable of moderately fast sweep speeds but the firmware currently forces a VCO calibration for each frequency change which currently limits the sweep speed to around 800 points per second.

Sweep operation starts when the following parameters are loaded: F (Start Frequency), G (End Frequency), I (Frequency Step) and T (Time per point in ms)

For example the following starts a sweep for tuning a 2 GHz filter:

```
F2200
G2500
I5
T1
```

At the start of each sweep the "CHAN" signal on J1 is toggled low at the start of the sweep, thus a scalar network analyzer can be realized by triggering an oscilloscope using this trigger signal and a diode detector can be connected to the A channel input.

Note: The sweep parameters cannot be saved permanently.

6.2 TX Offset

For some applications the LO frequency needs to be changed during transmit, for example generating a 20MHz repeater offset for a 1296 to 144MHz transverter.

When the TX line (shared with RS232 input) is pulled low the channel number is automatically increased by 8, or decreased by 8 for channels above 8.

6.3 Sharing LO between 2 Tranverters

In order to reduce construction costs and maximize the use of space many constructors opt to share a single LO across multiple bands. Given the PLL board contains 2 LO outputs there is a natural instinct to use these for driving multiple transverters

If the LO frequency requirement is different for each transverter the TX input can be dropped to a logic LOW which results in 8 being added to the channel number, where the different LO frequency has been setup.

Note: The interface is 3.3V logic with a pull-up to logic 1. In most cases a suitable interface circuit may need to be added externally using a NPN transistor or similar.

7 Experimental Options

7.1 2nd RF Output

The ADF4351 PLL chip provides 2 outputs with a phase difference of 180°. To enable the 2nd output remove R18 and install a 1206 0R jumper into location LPF2 and install the SMA connector.

Parts to add this option are supplied with the board.

7.2 Low Frequency operation

The ADF4350 and ADF4351 datasheets recommend different output inductors depending on frequency range. If you require a few more dB of output on the lower frequencies then the inductors L4 and L5 can be changed as follows:

Frequency Range	L4 and L5 Inductor Values
137 to 500MHz	100nH
500 to 1000MHz	47nH
1000 to 2000MHz	7.5nH
2000 to 4400MHz	3.9nH

As supplied a 3.9nH inductor is installed suitable for > 2000 operation, and replacement inductors are supplied if more output power is required on lower frequencies.

Details of the expected power levels are shown in section 3.2

7.3 10MHz Filter Option

The external reference input at the PLL is a high impedance and extremely sensitive to external noise, or aliasing used on DDS reference. An optional 10MHz Xtal can be installed in location X1 if more filtering is required.

Note that the input resistor R10, 49.9Ω may be removed to increase level by 3dB .

7.4 Low Pass Filter

When driving a frequency multiplier the LO harmonics generated are critical for producing a large signal after multiplication. However there are design applications where no multiplication is required and if there is insufficient filtering before the mixer this can result in unwanted images. For such applications a Minicircuits LFCN series Low Pass filter can be substituted with the 0Ω 1206 jumper installed in location LPF1 and LPF2.

7.5 Disable on-board oscillator power-down

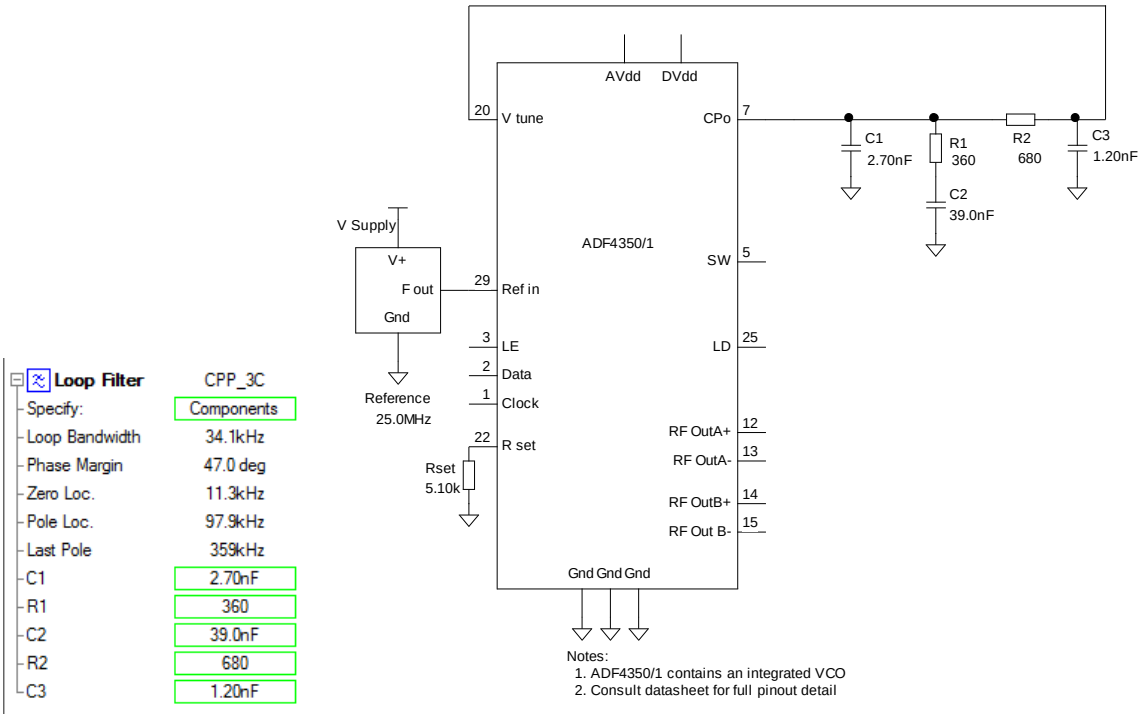
When an external reference is detected the internal oscillator is powered down for 2 reasons:

1. Power Reduction (saving approx. 50mA)
2. Reduce cross talk from internal oscillator which causes unwanted spurs

When the external oscillator is removed the internal reference starts from cold again and requires several minutes to warm-up, and 30 minutes to be become completely stable. By installing a 0Ω jumper in location R6 the internal reference is never powered off.

7.6 Loop Filter

The standard loop filter design has a bandwidth of 34kHz which offers a good compromise with phase noise, adjacent channel power and lock time. ADIsimPLL can be used to design alternative loop filters if one is willing to experiment using the following parameters as a starting point:



Loop Filter	CPP_3C
Specify:	Components
Loop Bandwidth	34.1kHz
Phase Margin	47.0 deg
Zero Loc.	11.3kHz
Pole Loc.	97.9kHz
Last Pole	359kHz
C1	2.70nF
R1	360
C2	39.0nF
R2	680
C3	1.20nF

8 CW Beacon Firmware

A special version of the firmware is available by request for application as a CW Beacon exciter on the 50MHz thru 3.4GHz amateur bands. It is also usable on higher bands with external multipliers and if the multiplier is set correctly in firmware there will be no frequency error experienced.

Due to memory constraints the CW beacon version of the firmware disables the following features:

- Frequency Sweep
- External Channel Switch

8.1 CW Beacon Command Set

Command	Units	Description
A 0		Enable onboard oscillator and select Internal frequency reference using the value set by the 'R' command.
A 1		External frequency reference as set by the 'E' command. Note: The internal reference oscillator is powered down
A 2		Force external reference. This option is available for > 20MHz reference or for low level reference that does not auto detect.
B 0		RF Output is continuous carrier. Use AUX LED Output to externally modulate the CW carrier
B 1		Modulate the RF output with the CW Signal
D		Display frequency and operational settings
E *n*	MHz	External reference frequency in MHz
F *n*	Mhz	Set Frequency
H		Display: Total hours on Number of power cycles
L *n*		Set output level L0 = -1 dBm L1 = +1 dBm L2 = +3 dBm L3 = +5 dBm
M *n*		Frequency Multiplier
N *n*	MHz	Synthesizer frequency resolution in MHz for the fundamental band. (Typically set to 0.001 or 0.005)
P *n*		Set PLL parameters (see section 5.5)
R *n*	MHz	Internal Reference frequency in MHz
S *n*		Save frequency, Multiplier and Level settings into channel n (N=0-15)
T		Enter CW Beacon message. *Note: Maximum message length is 300 characters*
W n		CW Speed in words per minute

8.2 Message Format

The CW message is entered using the "T" command and is ended once the return key is pressed

The following table outlines the supported more characters and special functions available. Unrecognized characters will be interpreted as a space symbol.

Sequence	Description
A-Z 0-9 . ? /	Send specified CW character
^	Send carrier for 1 second. Several characters can be combined for multiple seconds
_	Pause for 1 second. Several characters can be combined for multiple seconds
[0]	Set TX pin to Logic 1 (+3.3v)
[1]	Set TX pin to logic 0 (GND)
[^*message***]**	Send *message* if CH input is logic 1[12]
[_*message***]**	Send *message* if CH input is logic 0

8.2.1 Programmable output

The TX output pin can be used as a general purpose output pin. For example 2 antenna systems can be selected based on the output pin as selected by a PIN diode switch. For our example the antenna is selected using [0] and [1] with a custom message of NN indicating North direction and SS for South.

```
[0]^^^^^_ZL2XYZ_NTH_[1] ^^^^^_ZL2XYZ_STH_
```

8.2.2 Logic Input

The CH input pin can be used to select a custom message. To have a message included when the pin is logic 1, place the text in a block starting with [^ and ending with]

Likewise for logic 0 place the text between [_ and a closing]

For example, to send a warning when the site is on battery power the text is:

```
^^^^^_ZL2XYZ_[^BAT]_
```

8.3 Configuration example

The following is an example for programming the unit as a 2m beacon:

Command	Description
L3	Full power Output (+5dBm)
M1	No frequency multiplication on the output.
N0.001	1kHz resolution for PLL (0.001 MHz)
F144.288	Set frequency
S0	Save in channel 0 (which is the startup frequency)
B1	CW Modulate RF output
W12	CW Speed is 12 words per minute

[1] Must not exceed +3.3V. A series resistor can be used to limit the current to 1mA if applying a higher voltage
[2] Contains pullup resistor and will assume logic 1 if not connected

T **_E E E E E_ZL2XYZ_^^^^^**	Send 5 short beeps followed by the station callsign and 5 seconds of carrier

The following is a configuration example for a 10GHz beacon running on 10,368.276 MHz

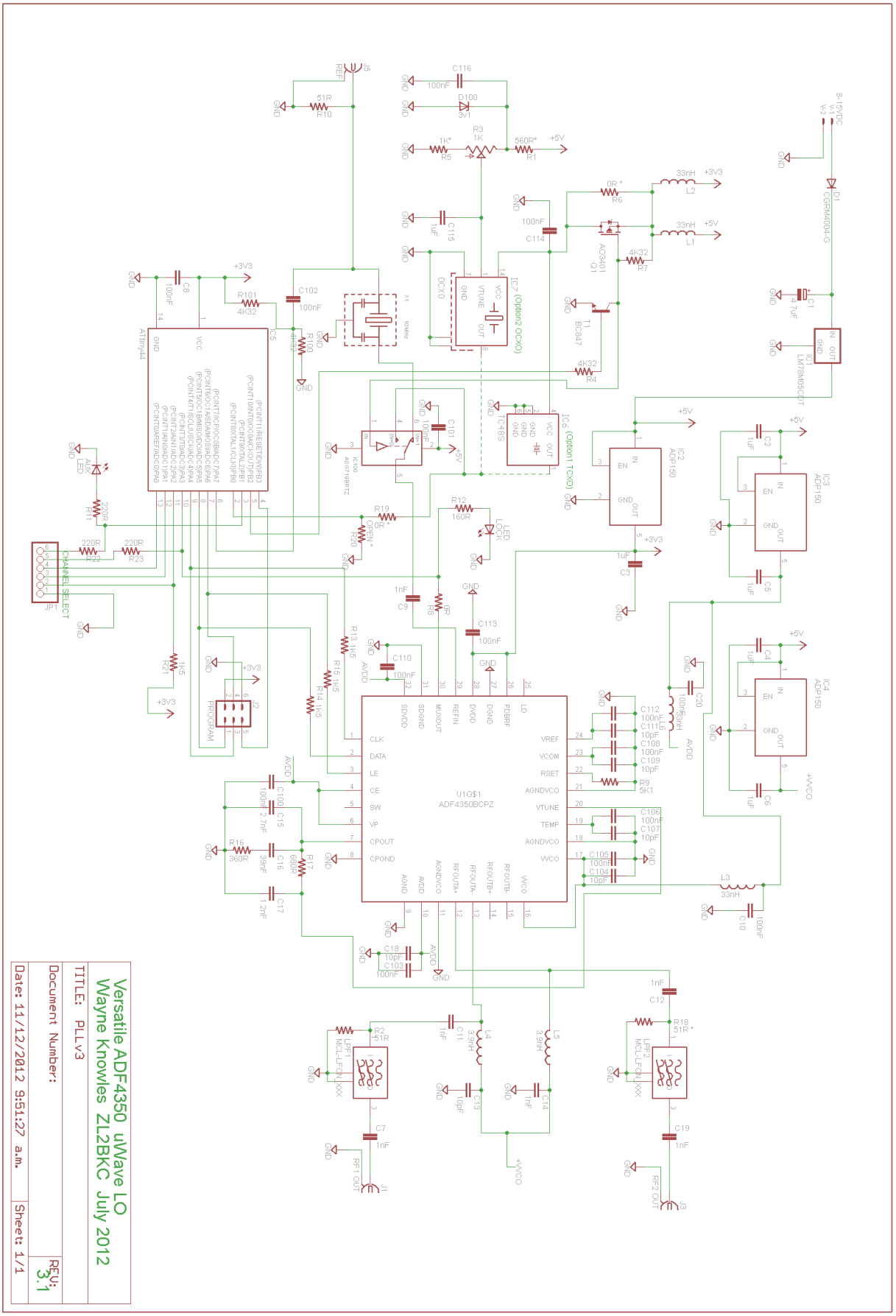
Command	Description
L3	Full power Output (+5dBm)
M3	No frequency multiplication on the output.
N0.001	1kHz resolution for PLL (0.001 MHz)
F10368.276	Set frequency
S0	Save in channel 0 (which is the startup frequency)
B1	CW Modulate RF output
W12	CW Speed is 12 words per minute
T **_E E E E E_ZL2XYZ_^^^^^**	Send 5 short beeps followed by the station callsign and 5 seconds of carrier

8.4 Application Notes

The CW carrier is modulated using the RF Mute feature of the ADF4351 PLL chip. This provides over 60dB of carrier suppression which should be sufficient for most applications.

The carrier on/off speed is between 25 and 50uS. If a slower rise time is required then a the AUX LED output can be used to externally modulate the carrier with the applicable rise time.

9 Schematic


Versatile ADF4350 uWave LO
Wayne Knowles ZL2BKC July 2012
TITLE: PLLv3
Document Number:
REV: 3.1
Date: 11/12/2012 9:51:27 a.m.
Sheet: 1/1
U1G$1
ADF4350BCPZ
ATTiny44
IC7 (Option2 OCXO)
IC6 (Option1 TCXO)
IC1 LM78M05CDT
IC2 ADP150
IC3 ADP150
IC4 ADP150
D1 CGRM4004-G
T1 BC847
Q1 AO3401
8-15VDC
+3V3
+5V
+VVCO
CHANNEL SELECT
PROGRAM