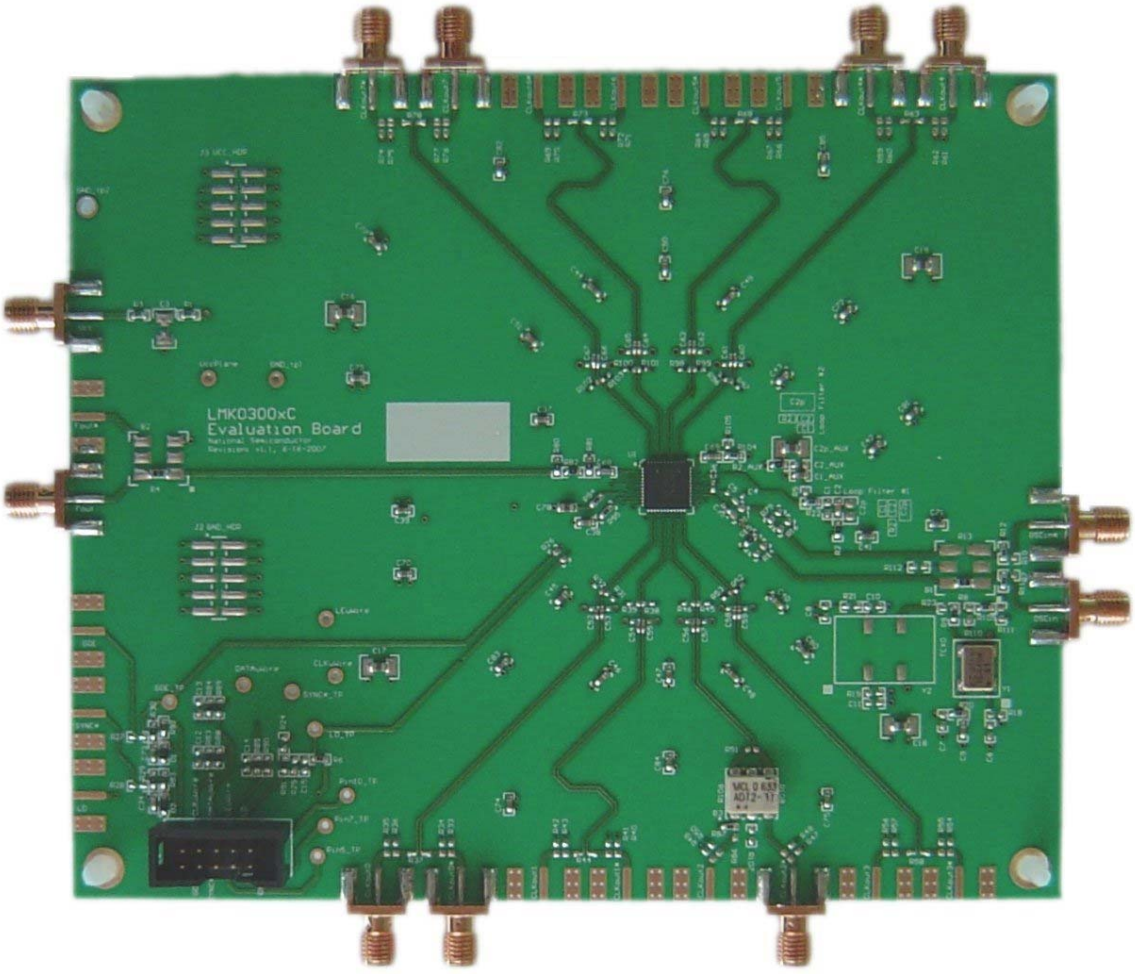
National Semiconductor

LMK03000C

Precision Clock Conditioner with Integrated VCO
Evaluation Board Operating Instructions

4-16-2009



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Interface

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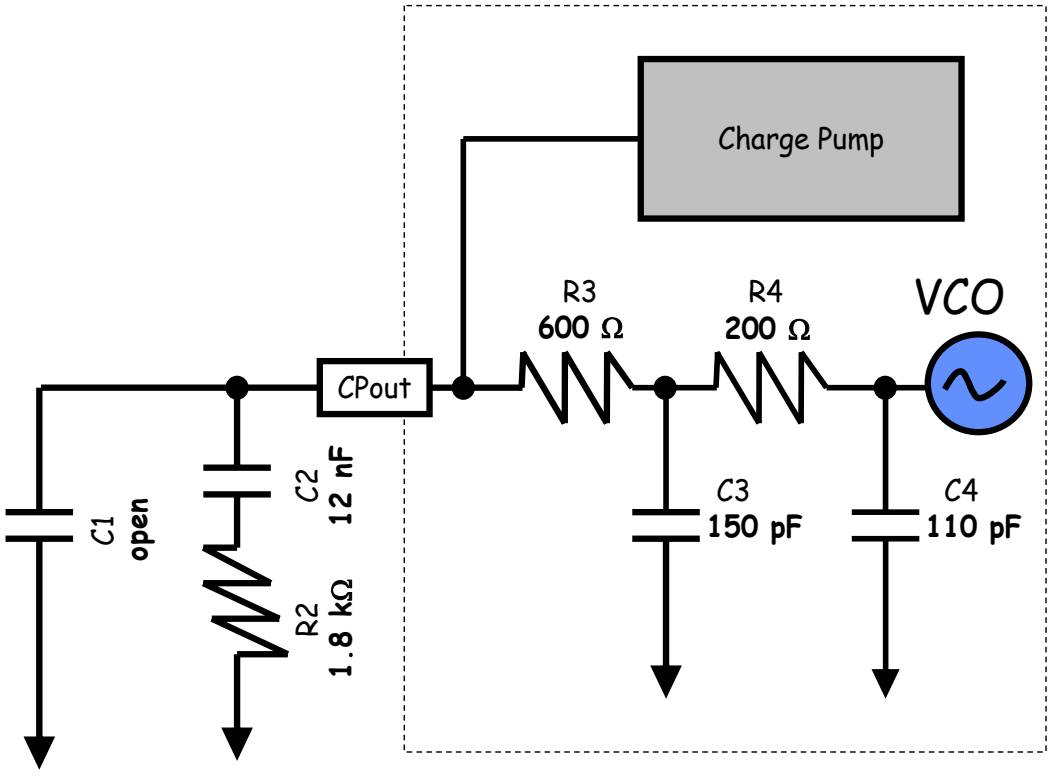
General Description

The LMK03000C Evaluation Board simplifies evaluation of the LMK03000C Precision Clock Conditioner with Integrated VCO. The package consists of an evaluation board and CodeLoader software. The *CodeLoader* software will run on a Windows 2000 or Windows XP PC. The purpose of the *CodeLoader* software is to program the internal registers of the LMK03000C device through a MICROWIRE™ interface.

Loop Filter #1			
Phase Margin	70.0º	**Kϕ**	3200 uA
Loop Bandwidth	55.3 kHz	**f_{PD}**	9.72 MHz
Crystal Frequency	19.44 MHz	**Output Frequency**	1185 to 1296 MHz
Supply Voltage	3.3 Volts	**VCO Gain**	8 MHz/Volt



Loop filter #1 is selected by placing a 0 ohm resistor on pad R22.

This loop filter has been designed for optimal RMS jitter using a low noise reference.

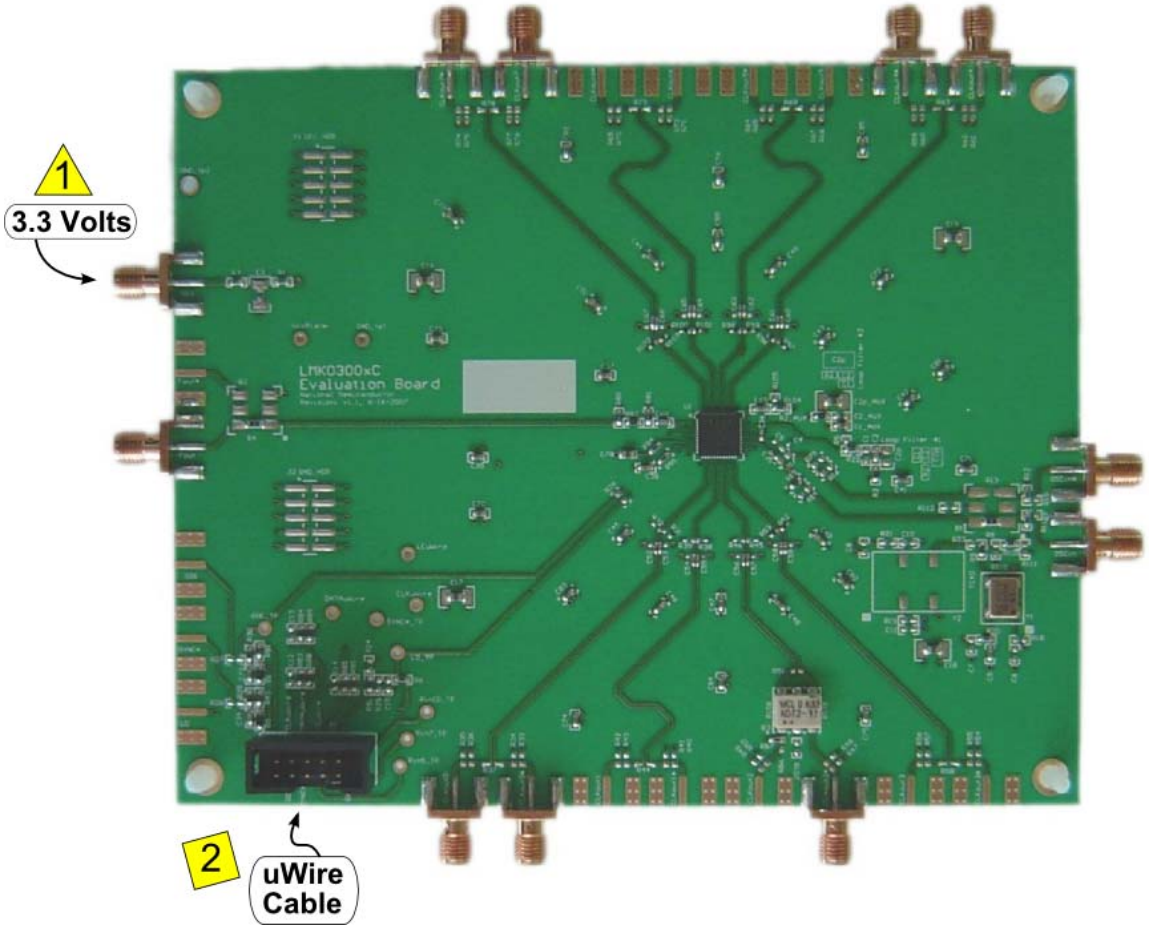
Read first, Basic Operation

Read the document, *"Installing CodeLoader 4 & USB Driver"* for instructions to prepare the computer for usage with the evaluation board before continuing with the hardware setup.

For basic operation…

1. Connect a low noise **3.3 V** power supply to the **Vcc** connector located at the top left of the board

2. Connect the CodeLoader cable to the **uWire** header located in the lower left.

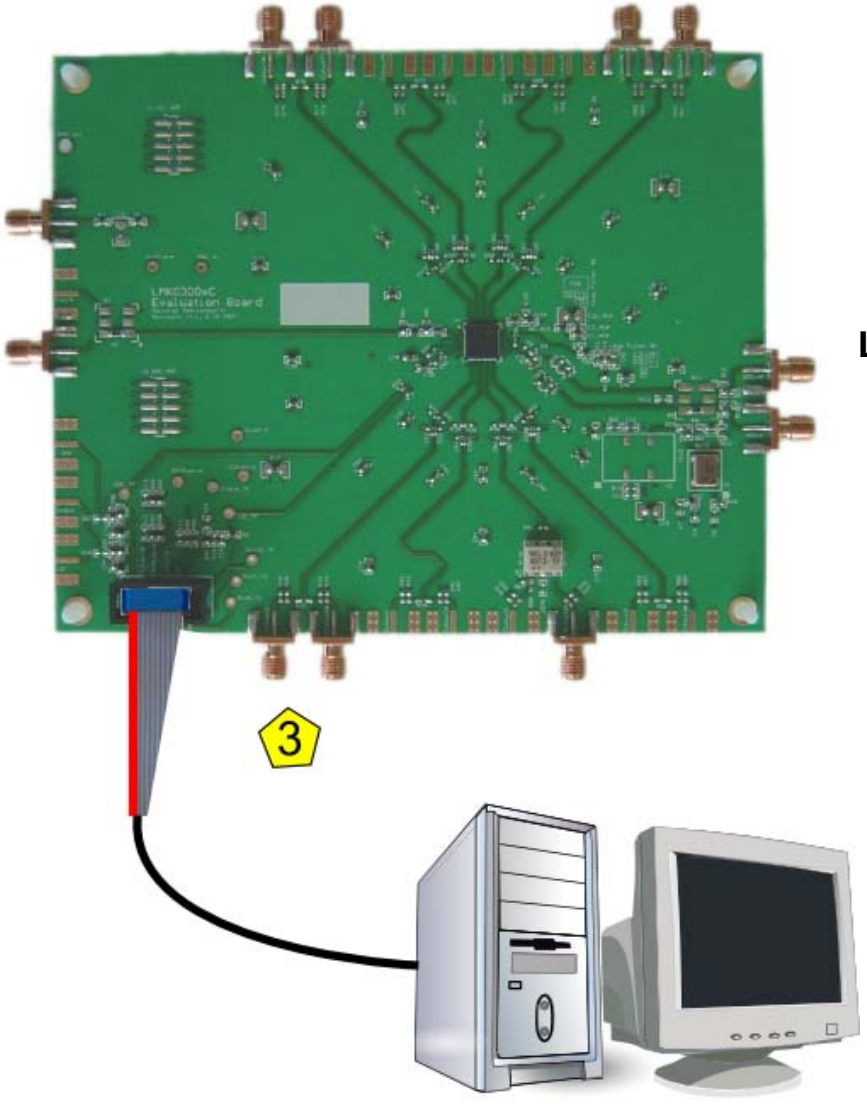


Read first, Basic Operation (Continued)

3. Connect…
   - PC directly to the evaluation board with the LPT to uWire cable, plugging the cable into an LPT port on the computer and then the 10 pin ribbon connector to the evaluation board. This setup is shown below. **The cable can be removed after programming to minimize noise and EMI.**

   or

   - Available separately, the USB <--> uWire board to the PC with the USB cable and the USB <--> uWire board to the evaluation board with the 10 pin ribbon cable.

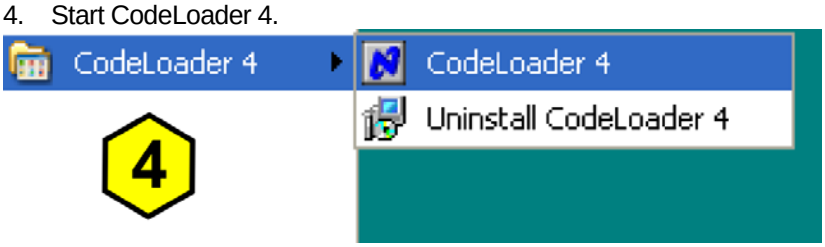


LPT Setup

LPT Cable to PC

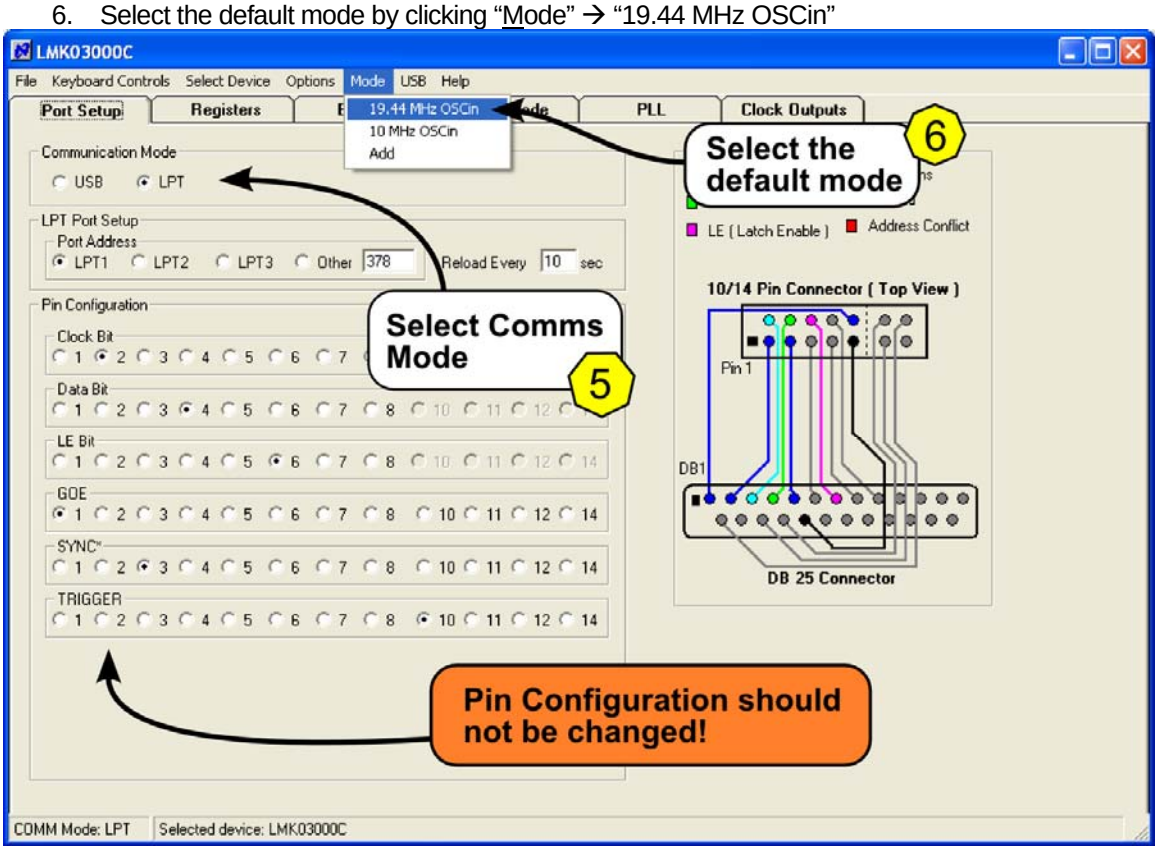
Read first, Basic Operation (Continued)

4. Start CodeLoader 4.



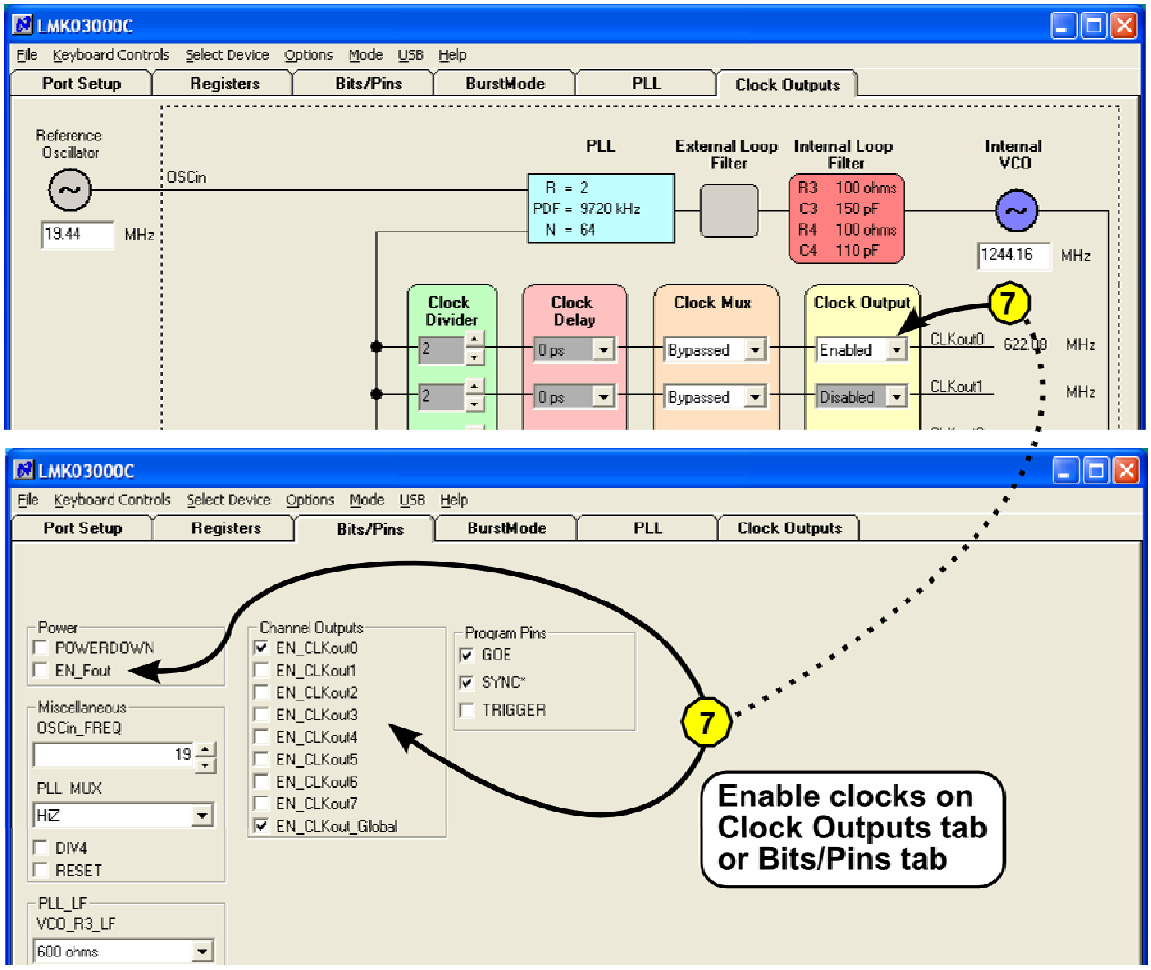
5. Select the USB or LPT Communication Mode on the Port Setup tab as appropriate.

6. Select the default mode by clicking "Mode" → "19.44 MHz OSCin"

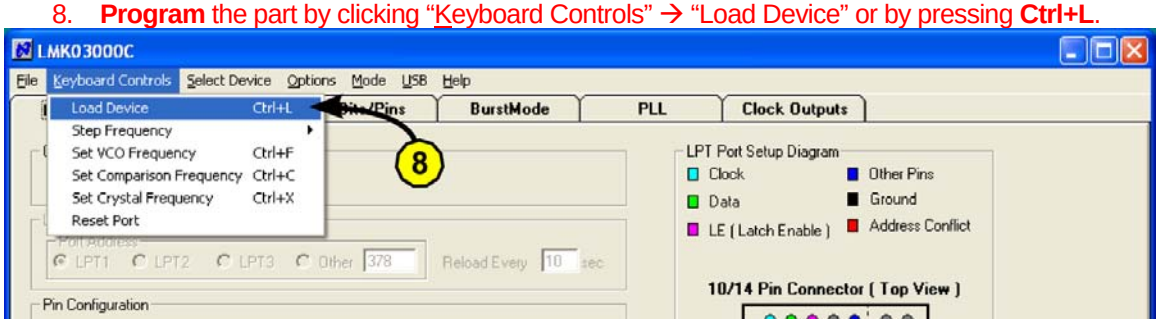


Read first, Basic Operation (Continued)

7. **Enable output to be measured**, any of CLKout(0-7) or EN_Fout from either Clock Outputs or Bits/Pins tab.



8. **Program** the part by clicking "Keyboard Controls" → "Load Device" or by pressing **Ctrl+L**.



9. Make measurements… After programming, the **uWire cable can be unplugged from the evaluation board to minimize noise and EMI.**

Board Information

OSCin

By default the board is configured to use the on-board crystal oscillator. It is also possible to use the board with a single ended or differential reference source at the OSCin port. Below are several possible configurations for driving OSCin.

OSCin using on board crystal oscillator [default]	
0 ohm	R8, R11, R20 [power to crystal oscillator], R109
39 ohm	R9 [can also be 0 ohm – depends on oscillator output power, 39 ohms to be a voltage divider]
51 ohm	R15
0.1 uF	C35, C36 (C5 is a 0.1 uF 0402 cap which may be moved to C36)
Open	C4, C5 R7, R10, R12, R13, R14, R16, R17, R79, R112

Differential OSCin setup	
0 ohm	R7, R8, R10, R13
100 ohm	R44
0.1 uF	C5, C35 (C36 is a 0.1 uF 0402 cap which may be moved to C5)
Open	C4, C36 R11, R12, R14, R15, R16, R79 R20 [remove power from crystal oscillator for noise reasons]

Single ended OSCin setup	
0 ohm	R7, R8
51 ohm	R15
0.1 uF	C35, C36 (C5 is a 0.1 uF 0402 cap which may be moved to C36)
Open	C4, C5 R10, R11, R12, R13, R14, R16, R17, R79 R20 [remove power from crystal oscillator for noise reasons]

Fout

Fout allows direct access to the internal VCO before the clock distribution section. The EN_Fout bit must be selected to enable Fout. A 3 dB pad is placed on R80, R81, and R82.

Loop Filter

R22 and R5 form a “resistor switch” which allows either one of two different loop filters to be selected.

Loop Filter	**Resistor Switch**	**Loop Filter Components**	**Default Loop Bandwidth**
Loop Filter #1 [default]	R22 Shorted	C1, C2, C2p, R2	59.1 kHz
Loop Filter #2	R5 Shorted	C1_AUX, C2_AUX, C2p_AUX, R2_AUX	77 Hz

Features of the board

- Either one of two loop filters can be selected by shorting either R22 or R5. More info about each loop filter can be found in the General Description and Appendix A.
- Test points for each of the uWire lines are scattered in the lower left corner of the board and include: GOE_TP, DATAuWire, CLKuWire, LEuWire, SYNC_TP, and LD_TP.

- **Ground** is located on the unstuffed 10 pin header on the left side of the board.
- **Ground** is located on the GND_tp2 in the upper left corner of the board and GND_tp1 located to the right of the Vcc SMA connector.
- **Ground** is located on the bottom side of the board on each pad of the unstuffed 10 pin header GND_J2.

- **Vcc** is located on the unstuffed 10 pin header on the upper left side of the board.
- **Vcc** is located on VccPlane test point located to the right of the Vcc SMA.
- **Vcc** is located on the bottom side of the board on each pad of the unstuffed 10 pin header VCC_J2

Other Important Notes

- When changing the OSCin frequency, the OSCin frequency register needs to be changed to match.
- Toggle the SYNC* pin to synchronize the clock outputs when in divided mode.
- For both loop filters, a helper silkscreen is offset from the loop filters to help identify the components according to National Semiconductor's traditional reference designators associated with loop filters.

Evaluation Board Revision v1.0 Errata

- SYNC* is labeled on the PCB as SYNC, however the logic of SYNC* is still active low!

Recommended Equipment

Power Supply
The Power Supply should be a low noise power supply. An Agilent 6623A Triple power supply with LC filters on the output to reduce noise was used in creating these evaluation board instructions.

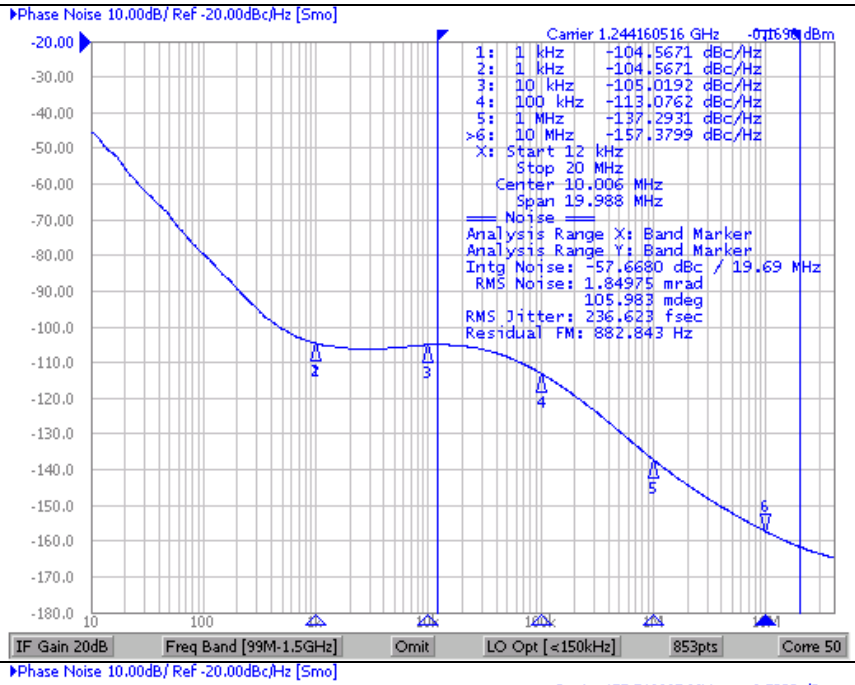
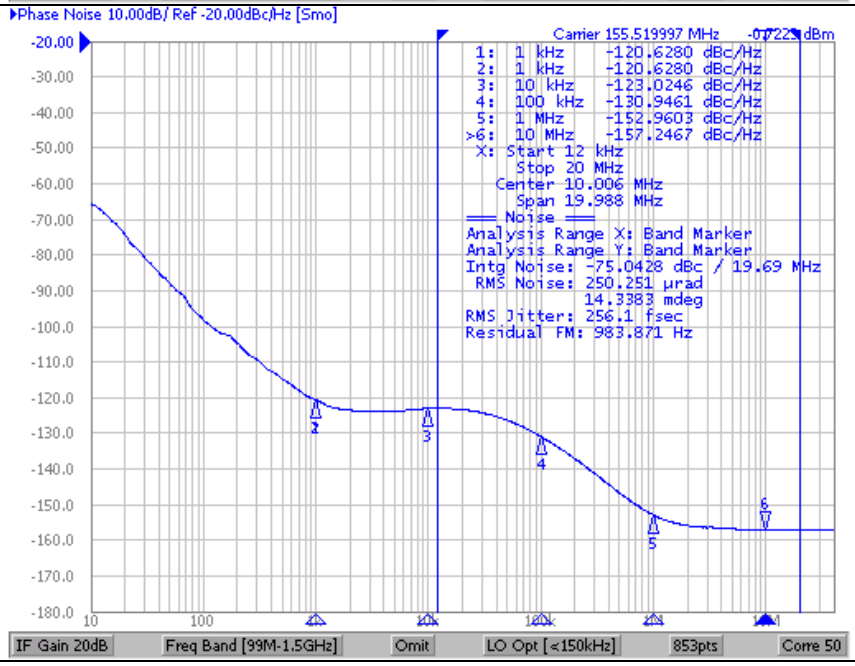
Phase Noise / Spectrum Analyzer
For measuring phase noise an Agilent E5052A is recommended. An Agilent E4445A PSA Spectrum Analyzer with the Phase Noise option is also usable although the architecture of the E5052A is superior for phase noise measurements. At frequencies less than 100 MHz the local oscillator noise of the PSA is too high and measurements will be of the local oscillator, not the device under test.

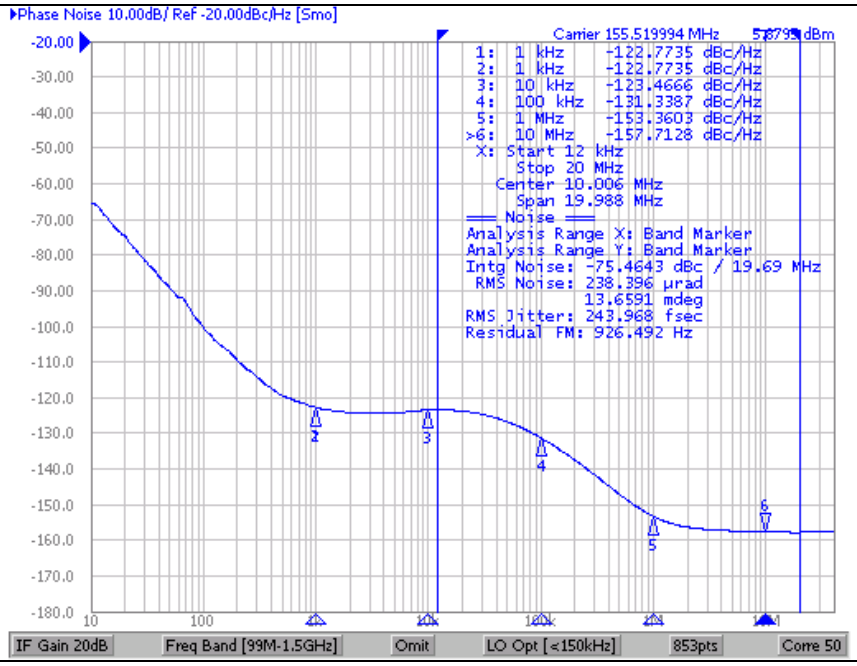
Oscilloscope
For measuring delay an Agilent Infiniium DSO81204A was used.

Reference Oscillator
The on board crystal oscillator will provide a low noise reference signal to the device at offsets greater than 1 kHz.

Note: The default loop filter has a loop bandwidth of ~60 kHz. Inside the loop bandwidth of a PLL the noise is greatly affected by any noise on the reference oscillator (OSCin). Therefore any noise on the oscillator less than 60 kHz will be passed through and seen on the outputs. For this reason the main output of a Signal Generator is not recommended for driving OSCin in this setup.

Phase Noise

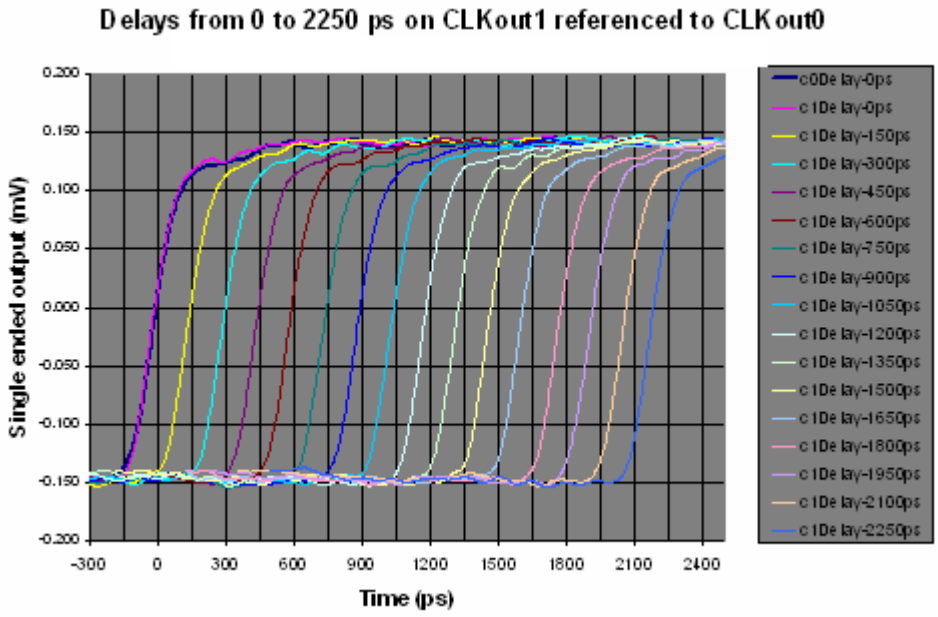
Output Frequency = 1244.16 MHz Internal VCO, Fout output		Reference source is on board 19.44 MHz crystal Below ~1 kHz phase noise is dominated by the crystal 10 Hz – 20 MHz integrated RMS jitter = 2.1 ps 100 Hz – 20 MHz integrated RMS jitter = 287 fs 12 kHz – 20 MHz integrated RMS jitter = 236 fs
LVDS output CLKout0 VCO Frequency = 1244.16 MHz, VCO_DIV=2, CLKout0_div=4 LVDS output (155.52 MHz)		Output is measured with a Minicircuits ADT2-1T balun. Reference source is on board 19.44 MHz crystal Below ~1 kHz phase noise is dominated by the crystal 10 Hz – 20 MHz integrated RMS jitter = 1.8 ps 100 Hz – 20 MHz integrated RMS jitter = 315 fs 12 kHz – 20 MHz integrated RMS jitter = 256 fs (shown)

LVPECL output CLKout4 VCO Frequency = 1244.16 MHz, VCO_DIV=2, CLKout4_div=4 LVPECL output (155.52 MHz)		Output is measured with a Minicircuits ADT2-1T balun. Reference source is on board 19.44 MHz crystal Below ~1 kHz phase noise is dominated by the crystal 10 Hz – 20 MHz integrated RMS jitter = 1.7 ps 100 Hz – 20 MHz integrated RMS jitter = 281 fs 12 kHz – 20 MHz integrated RMS jitter = 244 fs (shown)

Delays

These delay measurements illustrate how skew errors due to different length traces may be tuned out.
The delay may be adjusted in steps of 150 ps.

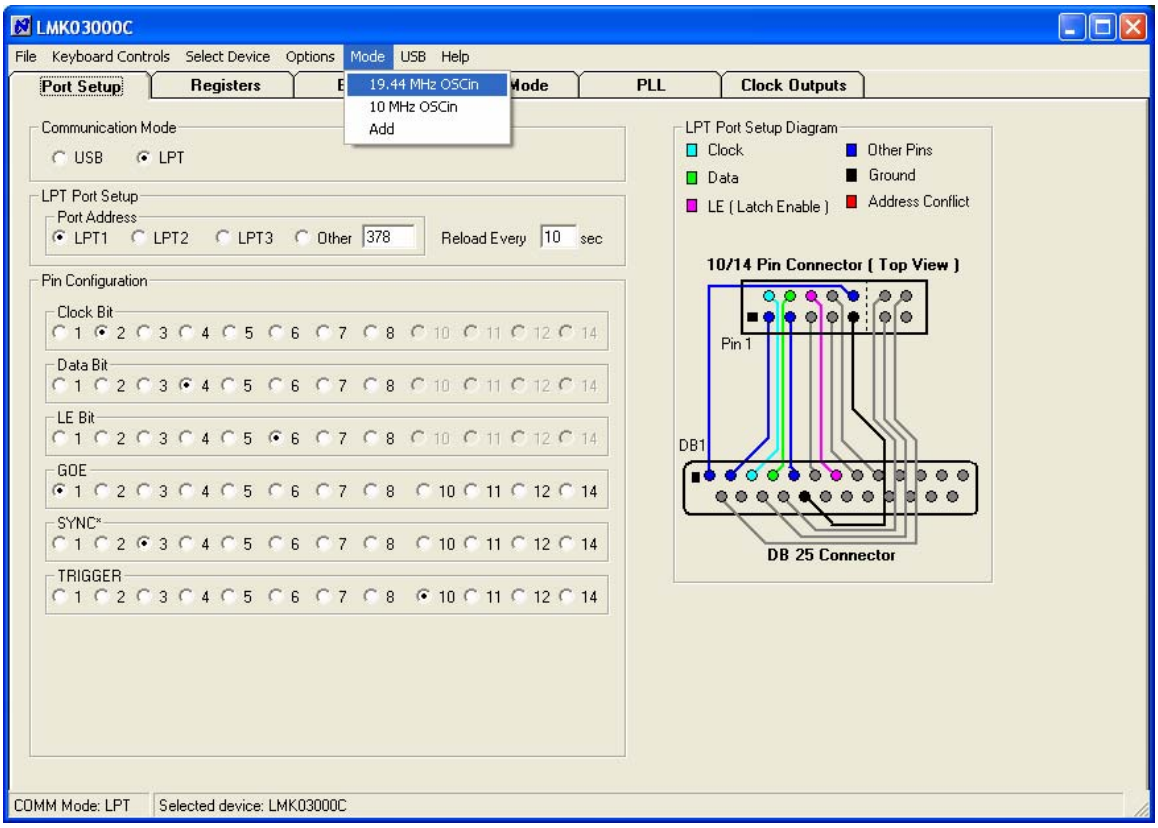
Delays 150, 300, 450, 600, 750



CLKout0_DLY = 0 ps

CLKout1_DLY = all delays programmed: 0, 150, 300, 450, 600, 750, 900, 1050, 1200, 1350, 1500, 1650, 1800, 1950, 2100, and 2250 ps

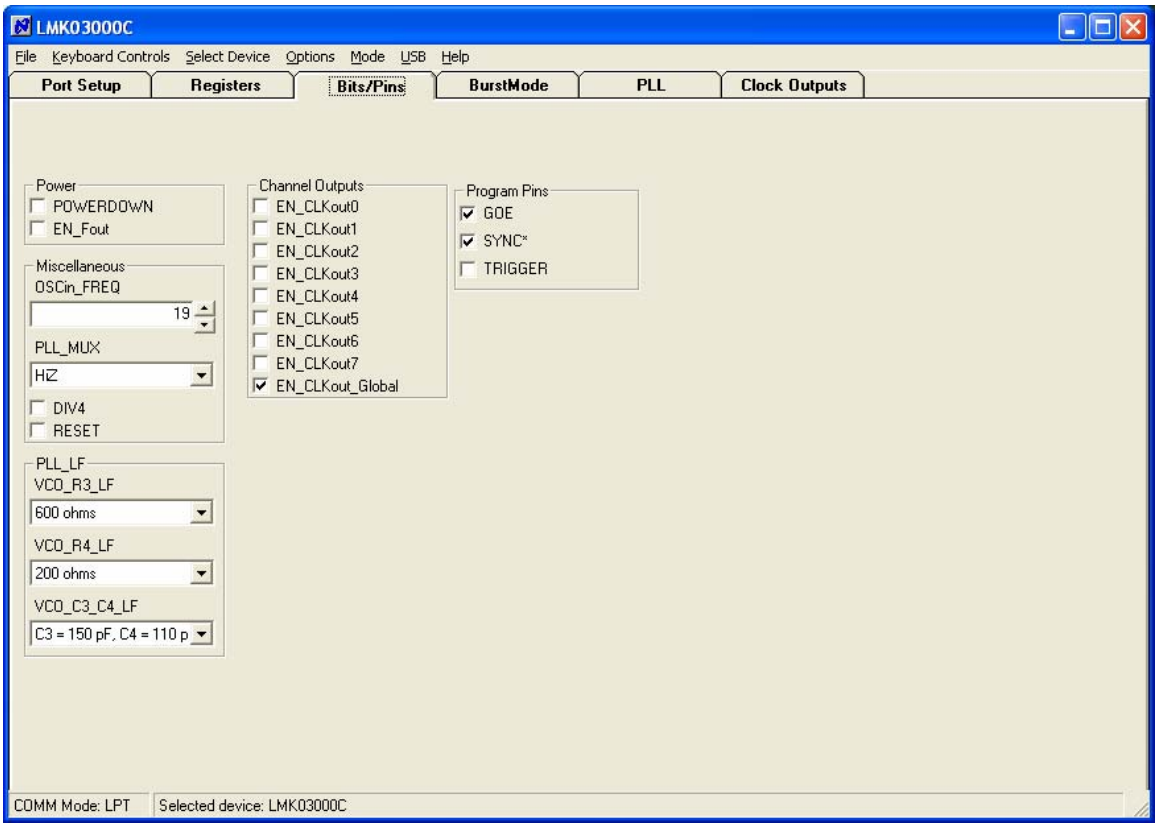
CodeLoader Settings



The Port Setup tab tells CodeLoader what signals are assigned to which pins. If this is wrong, the part will not program.

Part setup can be restored to the default state by clicking Mode → "19.44 MHz OSCin" The default reference oscillator used for these instructions is 19.44 MHz and the restored mode expects a 19.44 MHz OSCin signal. **For the loaded mode to take affect the device must be loaded by pressing Ctrl+L.**

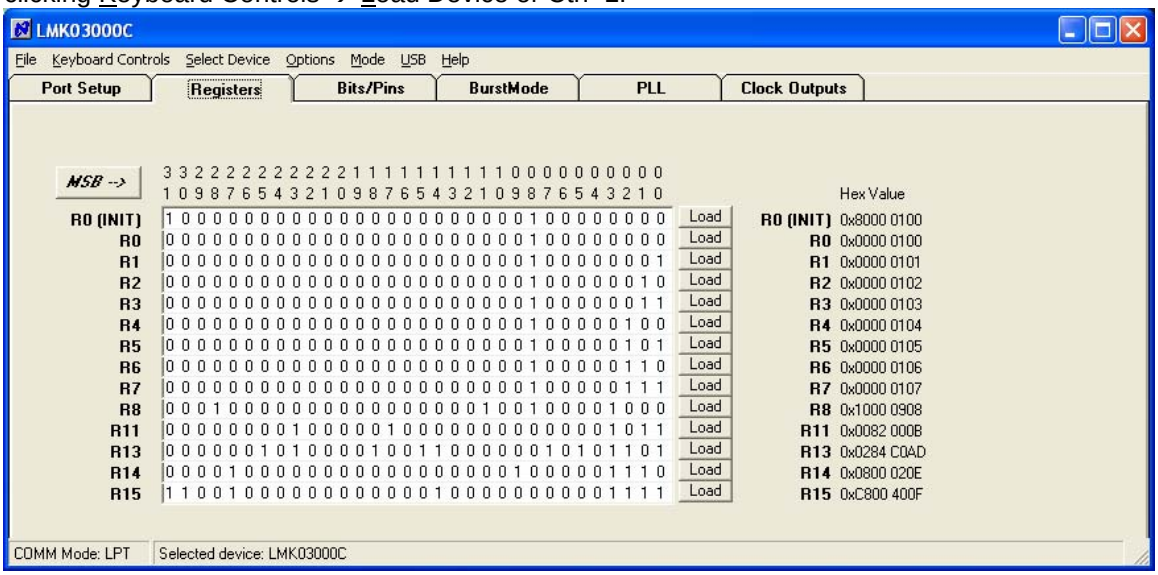
The Bits/Pins tab shows some of the internal registers which are not accessible from any of the other visual tabs like “PLL” and “Clock Outputs.” *Right click on any of the bits for description.*



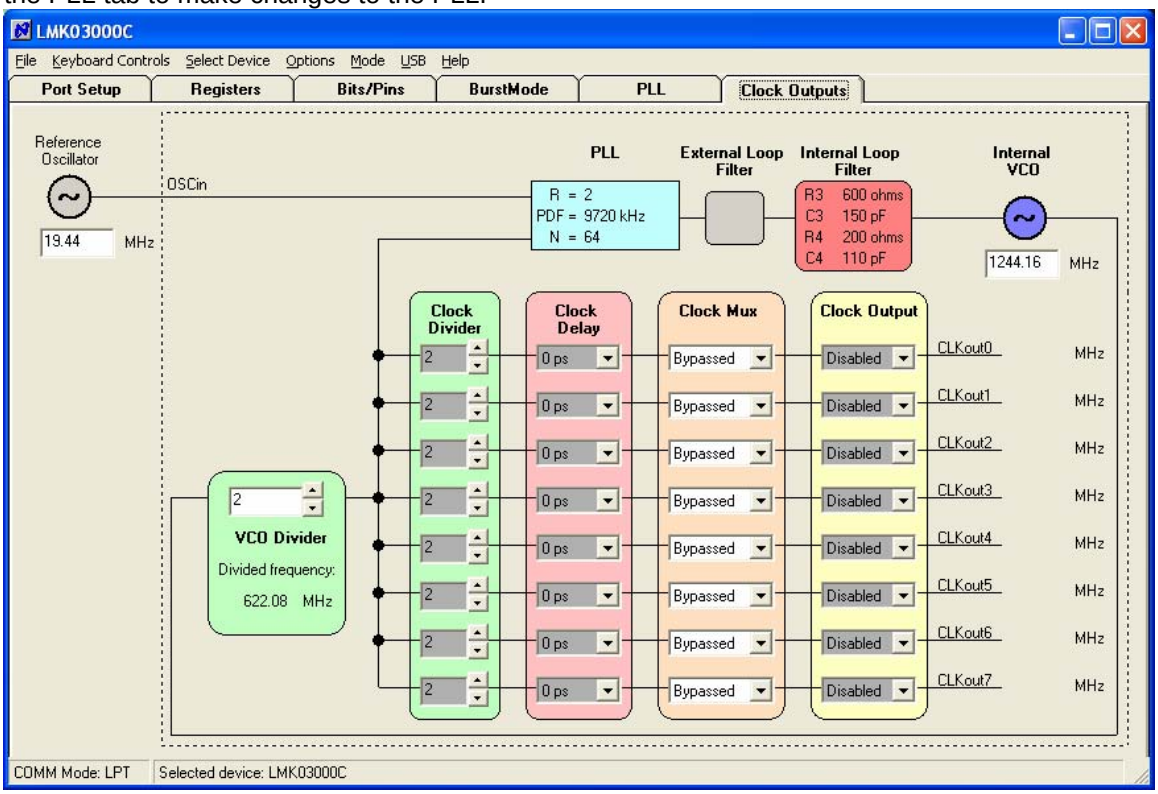
Program Bits	
POWERDOWN	Powers the part down.
EN_Fout	Turns on the Fout pin for measuring the internal VCO.
OSCin_FREQ	Must be set to the OSCin frequency in MHz.
PLL_MUX	Programmable to many different values to support Lock Detect or aid troubleshooting.
DIV4	Shall be checked for OSCin frequencies greater than 20 MHz.
RESET	The registers can be defaulted by checking and unchecking RESET. Software bits will not reflect this.
VCO_R3_LF VCO_R4_LF VCO_C3_C4_LF	Internal loop filter values, also accessible from Clock Outputs tab.
EN_CLKout0..7	Enable CLKout bits from CLKout0 to CLKout7. Also accessible from Clock Outputs tab.
EN_CLKout_Global	Enable all clock outs. If unselected then the EN_CLKouts are overridden and the outputs are all disabled.

Program Pins	
GOE	Set Global Output Enable to high or low logic level.
SYNC*	Set SYNC* pin to high or low logic level.
TRIGGER	Set auxiliary trigger pin to high or low logic level.

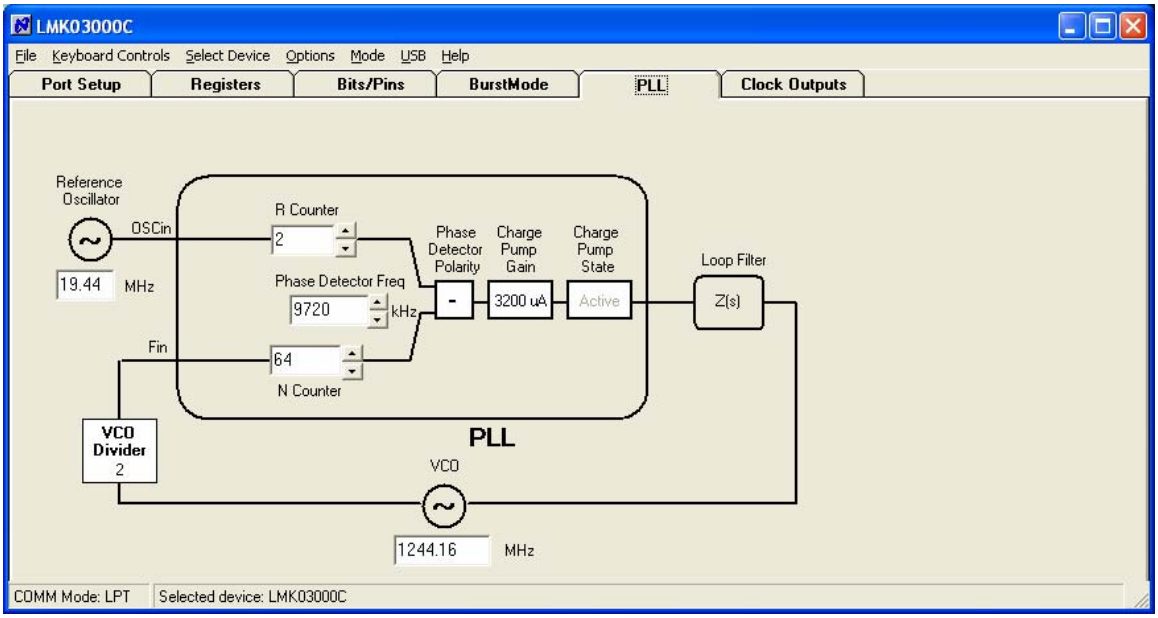
The Registers tab shows the raw bits which will be programmed when device is loaded by clicking Keyboard Controls → Load Device or Ctrl+L.



The Clock Outputs tab allows the user to visualize the clock distribution portions of the device. From this tab the device's dividers, delays, clock output muxes, and output drivers can be programmed along with internal loop filter values. The PLL block shows the R and N divider values however to change these values either click on the PLL tab or the blue PLL box to access the PLL tab to make changes to the PLL.



The PLL tab shows a conventional PLL diagram along with the VCO Divider. It is important to realize that the total effective N value is PLL N Counter * VCO Divider. This means that the **"channel spacing" is the Phase Detector Frequency * VCO Divider**. Depending on the situation, this may require the R Counter multiplied up by the value of the VCO Divider to achieve desired VCO output frequencies.



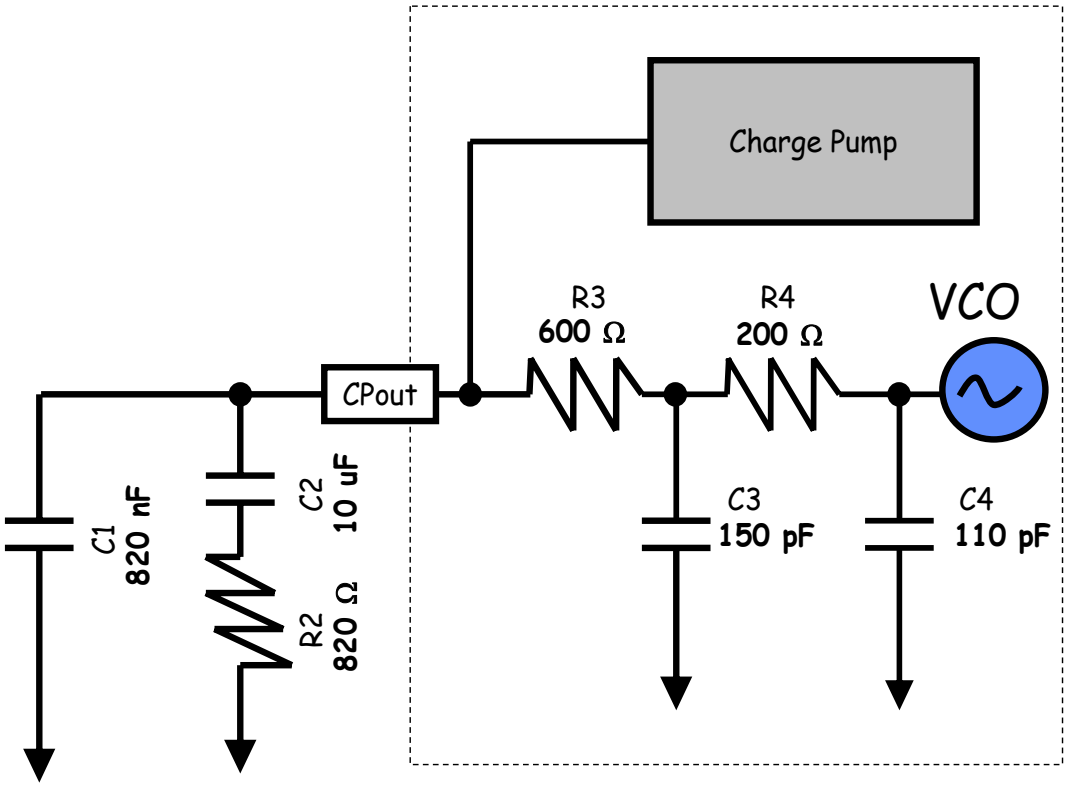
Example: If the desired VCO output frequency was 1244.16 MHz, R would need to be increased to 2 before 1253.88 MHz could be programmed because of the VCO Divider of 2 would only allow programming of 1244.16, 1263.6, 1283.04, etc. with a 9.72 MHz phase detector frequency – because changing the N counter from 64 to 65 changes to total N by two, 128 to 130!

Appendix A: VCO Performance

The internal VCO performance is measured by using a narrow bandwidth loop filter. By default the narrow loop bandwidth filter is stuffed as Loop Filter #2 in positions C1_AUX, C2_AUX, C2p_AUX, and R2_AUX and has a loop bandwidth of 77 Hz.

See the Loop Filter section in Board Options for more detail about switching between the two different loop filters.

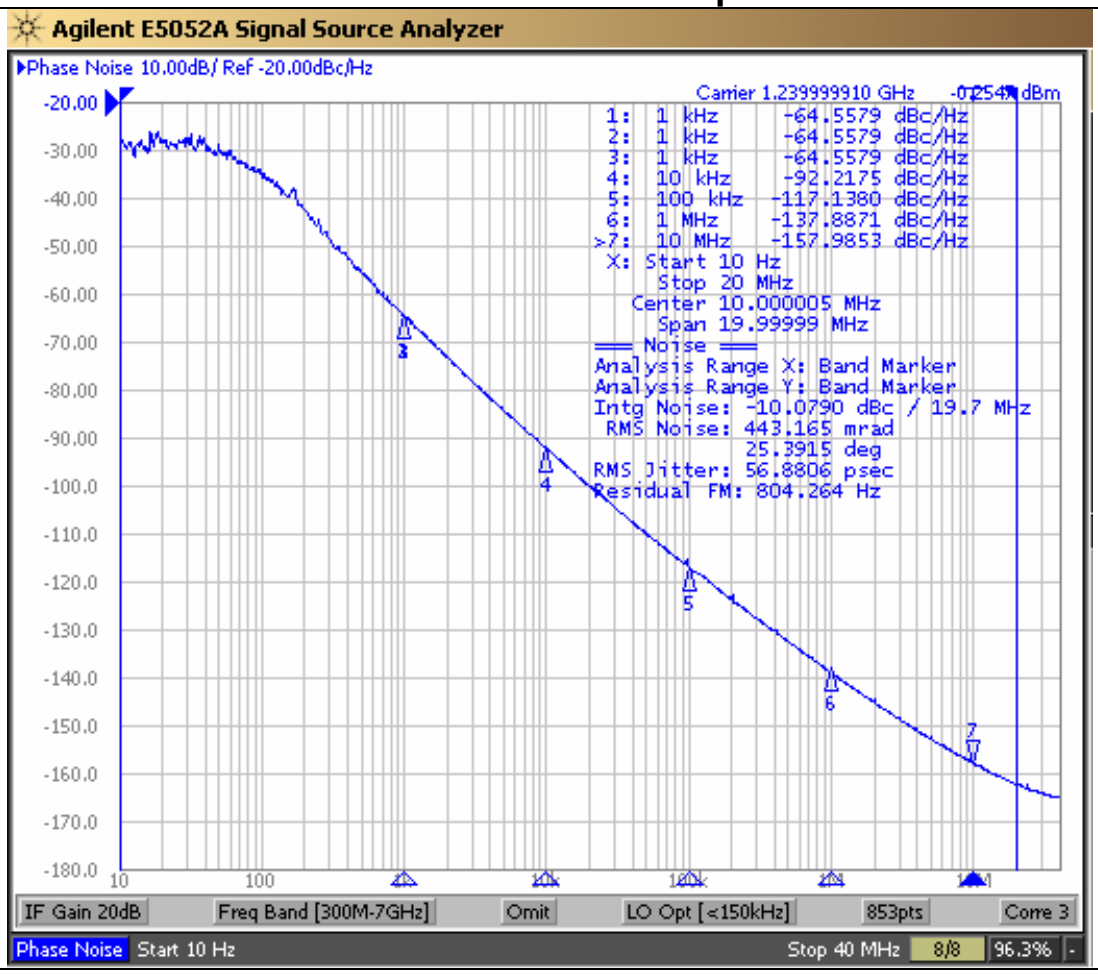
Loop Filter			
Phase Margin	58.7º	**Kϕ**	100 uA
Loop Bandwidth	77 Hz	**f_{PD}**	1.023 MHz
Crystal Frequency	19.44 MHz	**Output Frequency**	1185 to 1296 MHz
Supply Voltage	3.3 Volts	**VCO Gain**	10 MHz/Volt



This loop filter is located on the top side of the PCB and is selected by placing a 0 ohm resistor on pad R5.

This loop filter has been designed with a very small loop bandwidth to minimize the PLL from interacting with the noise of the VCO to permit a VCO phase noise measurement.

VCO Phase Noise - Narrow Loop Bandwidth



dThis plot shows the noise of the VCO at 1240 MHz using a 1 MHz Phase Detector Frequency. An external oscillator was used for this plot, since the VCO noise dominates, reference oscillator noise is not critical.

The loop bandwidth has been minimized so that the VCO is the dominant noise contributor.

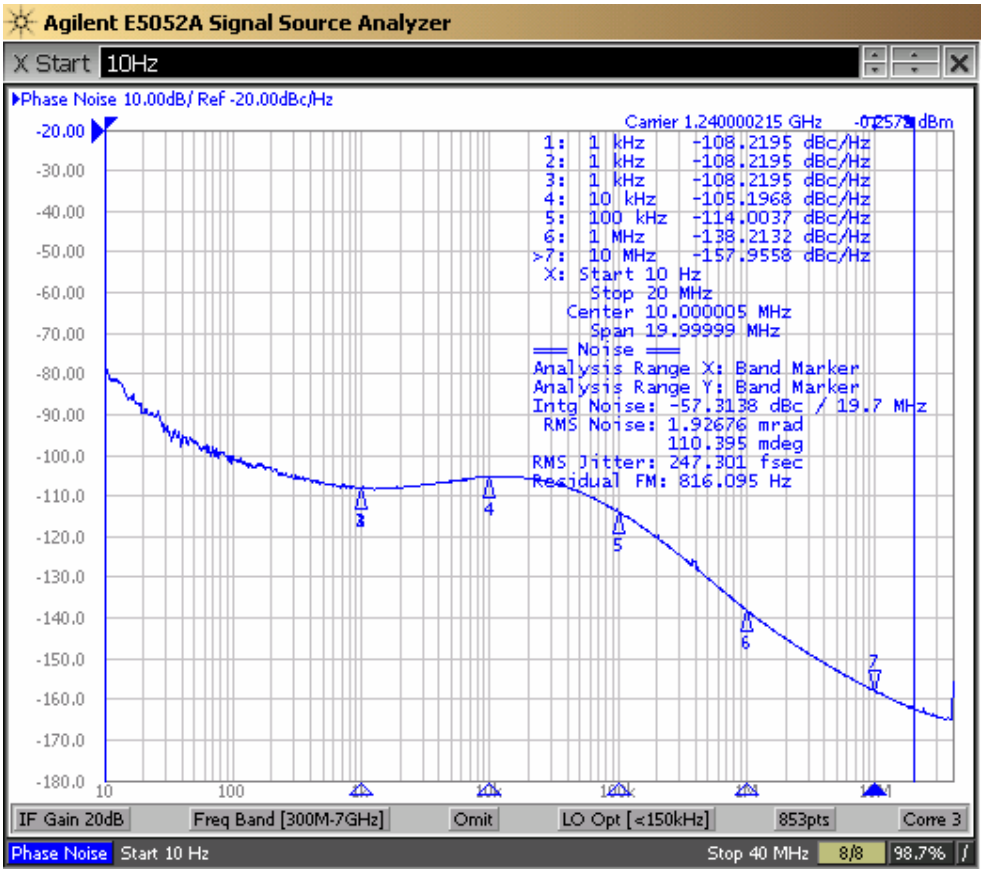
10 Hz – 20 MHz integrated RMS jitter = 56.9 ps (shown)
100 Hz – 20 MHz integrated RMS jitter = 25.0 ps
12 kHz – 20 MHz integrated RMS jitter = 0.304 ps (datasheet)

Appendix B: Impact of Reference on Phase Noise

Inside the loop bandwidth of a PLL the phase noise is set by the quality of the reference oscillator used. For this reason it is important to select a reference oscillator suitable for the application.

Test Setup

Using the same loop filter as described in the General Description and by driving the OSCin frequency with an ultra low jitter 100 MHz Wetzel Crystal (501-04517D) and setting R = 10 to achieve a phase detector frequency of 10 MHz. A very low integrated RMS jitter of 247 fs is measured vs. the 2.1 ps measured in the Phase Noise section with 19.44 MHz crystal in the bandwidth of 10 Hz to 20 MHz.

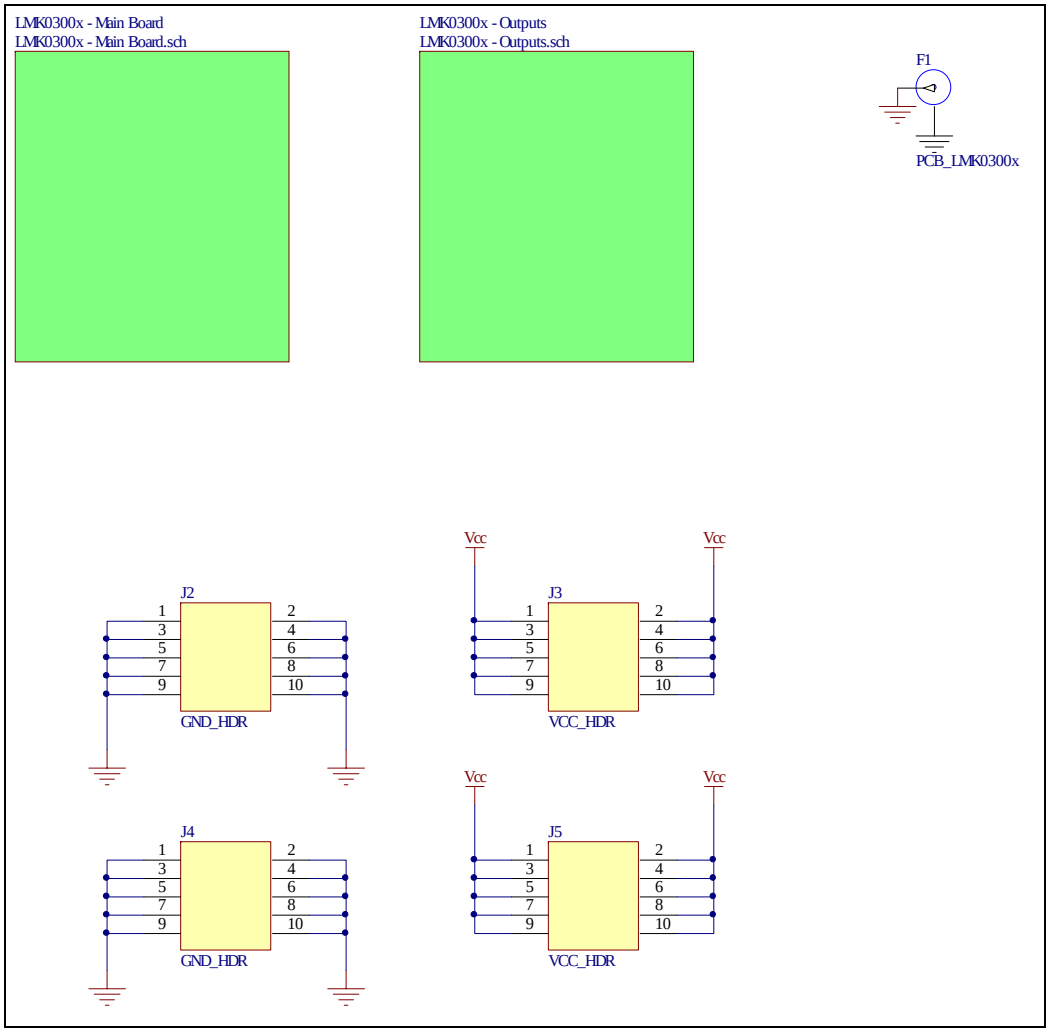


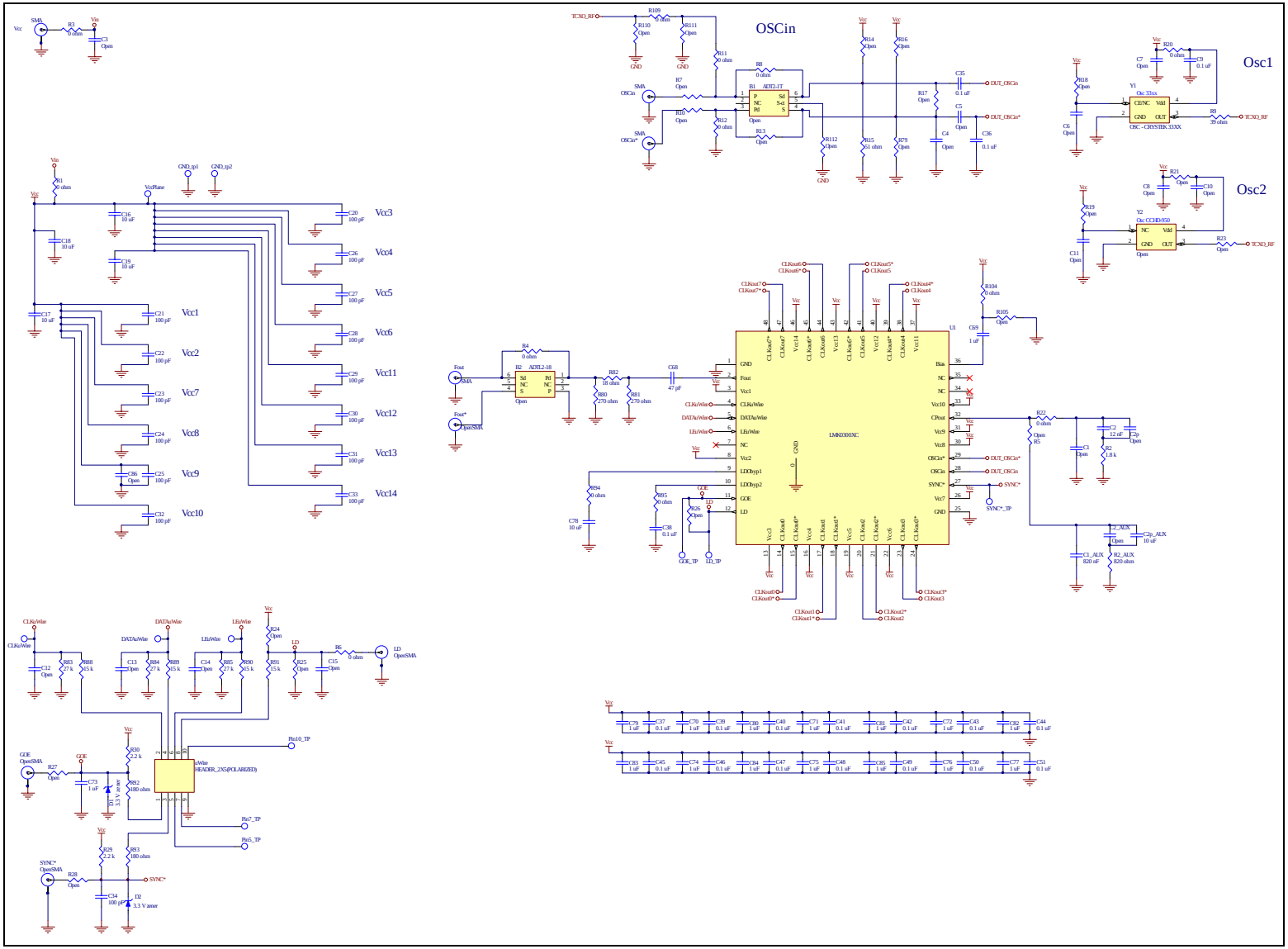
10 Hz – 20 MHz integrated RMS jitter = 247 fs (shown)
100 Hz – 20 MHz integrated RMS jitter = 243 fs
12 kHz – 20 MHz integrated RMS jitter = 222 fs

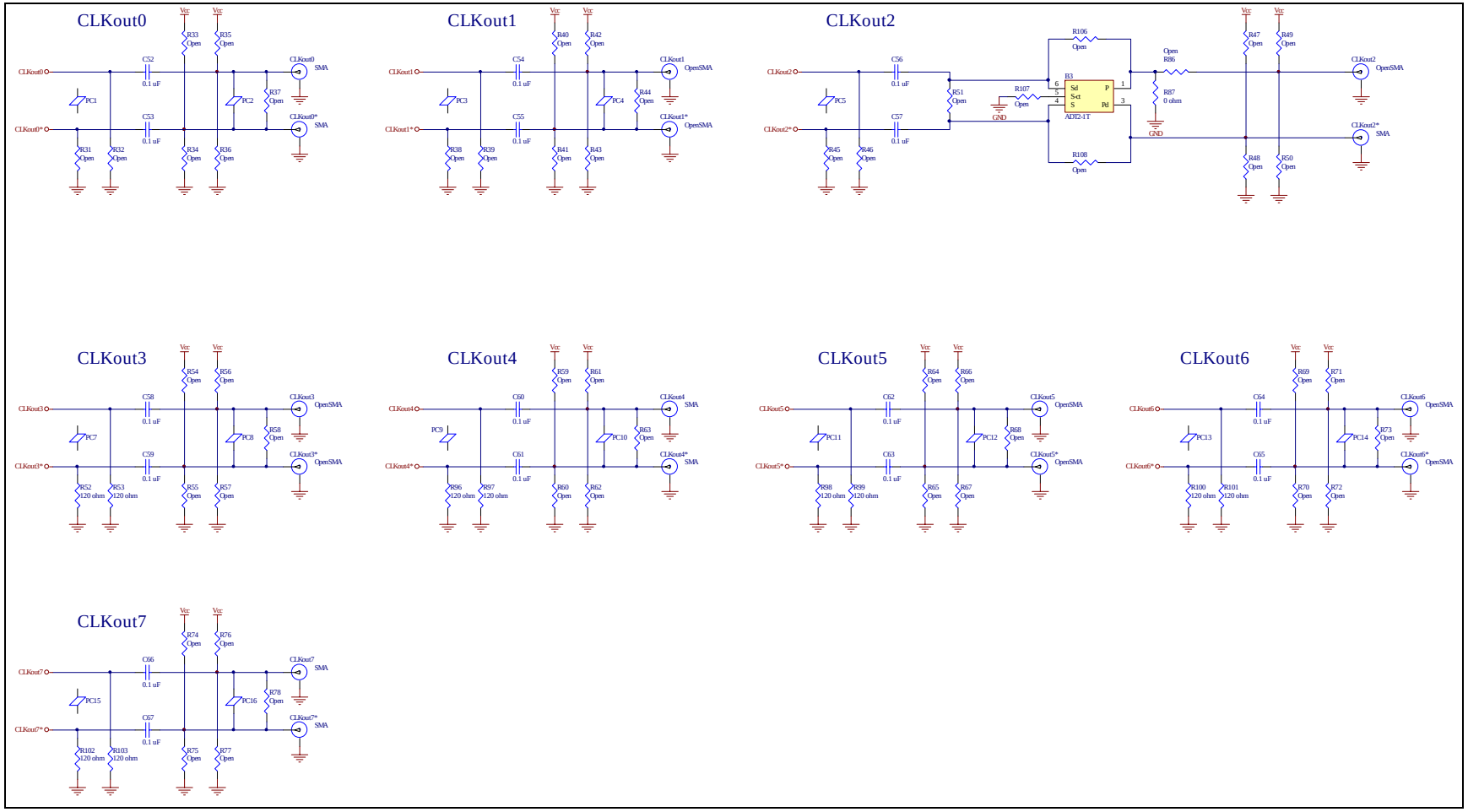
Conclusion

This diagram illustrates how the phase noise inside the loop bandwidth is set by the quality of the reference oscillator used. Phase noise outside the loop bandwidth is set by the VCO noise level.

Appendix C: Schematics




OSCin
Osc1
Osc2
Vcc1
Vcc2
Vcc3
Vcc4
Vcc5
Vcc6
Vcc7
Vcc8
Vcc9
Vcc10
Vcc11
Vcc12
Vcc13
Vcc14
LMK03000C

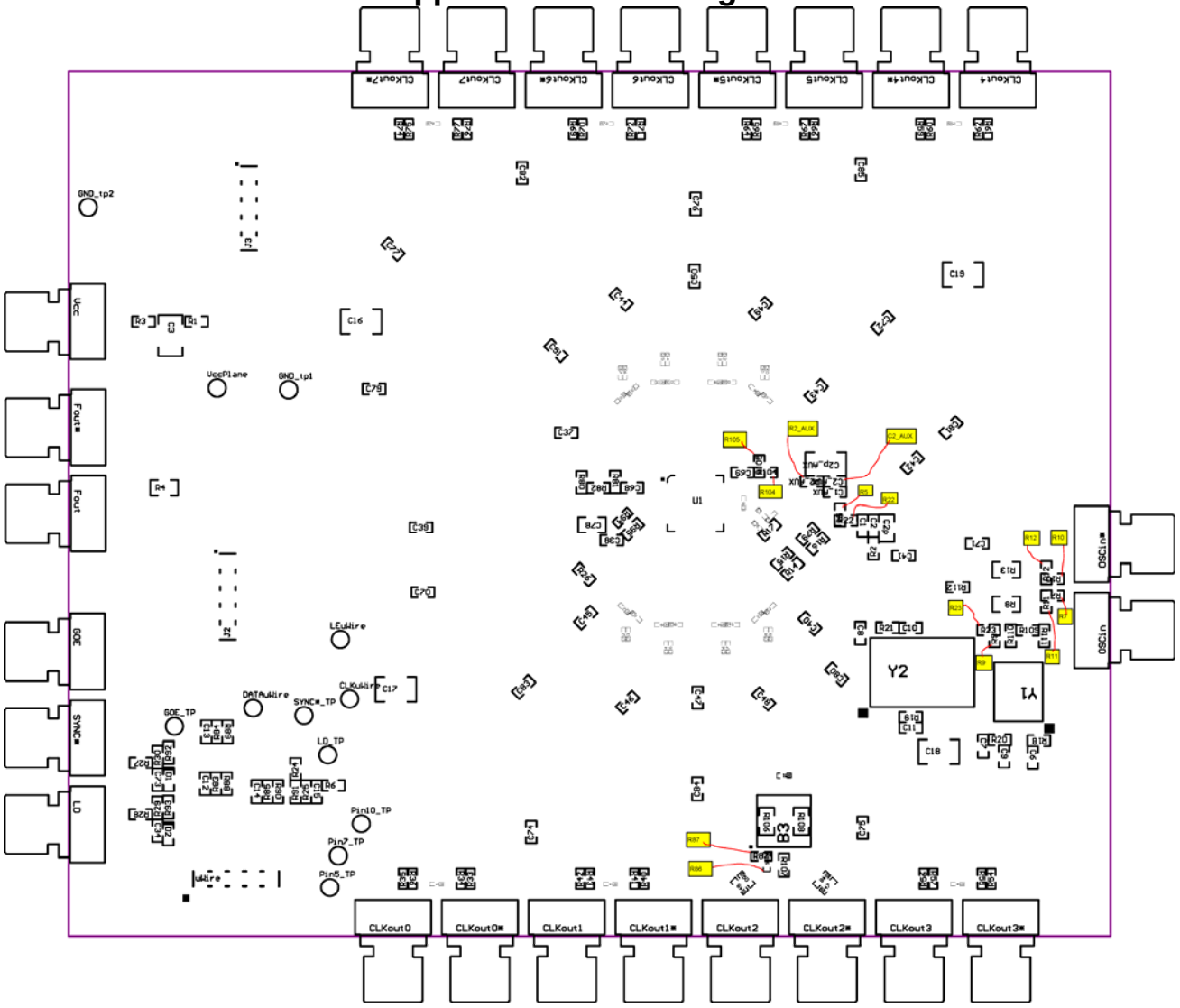

CLKout0
CLKout0
CLKout0*
C52
C53
0.1 uF
PC1
PC2
R31
R32
R33
R34
R35
R36
R37
Open
CLKout0
SMA
CLKout0*
SMA
CLKout1
CLKout1
CLKout1*
C54
C55
PC3
PC4
R38
R39
R40
R41
R42
R43
R44
CLKout1
OpenSMA
CLKout1*
OpenSMA
CLKout2
CLKout2
CLKout2*
C56
C57
PC5
R45
R46
RS1
R106
R107
R108
GND
B3
ADT2-1T
R86
R87
0 ohm
R47
R48
R49
R50
CLKout2
OpenSMA
CLKout2*
SMA
CLKout3
CLKout3
CLKout3*
C58
C59
PC7
PC8
RS2
RS3
RS4
RS5
RS6
RS7
RS8
120 ohm
CLKout3
OpenSMA
CLKout3*
OpenSMA
CLKout4
CLKout4
CLKout4*
C60
C61
PC9
PC10
R96
R97
R59
R60
R61
R62
R63
CLKout4
SMA
CLKout4*
SMA
CLKout5
CLKout5
CLKout5*
C62
C63
PC11
PC12
R98
R99
R64
R65
R66
R67
R68
CLKout5
OpenSMA
CLKout5*
OpenSMA
CLKout6
CLKout6
CLKout6*
C64
C65
PC13
PC14
R100
R101
R69
R70
R71
R72
R73
CLKout6
OpenSMA
CLKout6*
OpenSMA
CLKout7
CLKout7
CLKout7*
C66
C67
PC15
PC16
R102
R103
R74
R75
R76
R77
R78
CLKout7
SMA
CLKout7*
SMA
Vcc
0.1 uF
120 ohm
Open

Appendix D: Bill of Materials

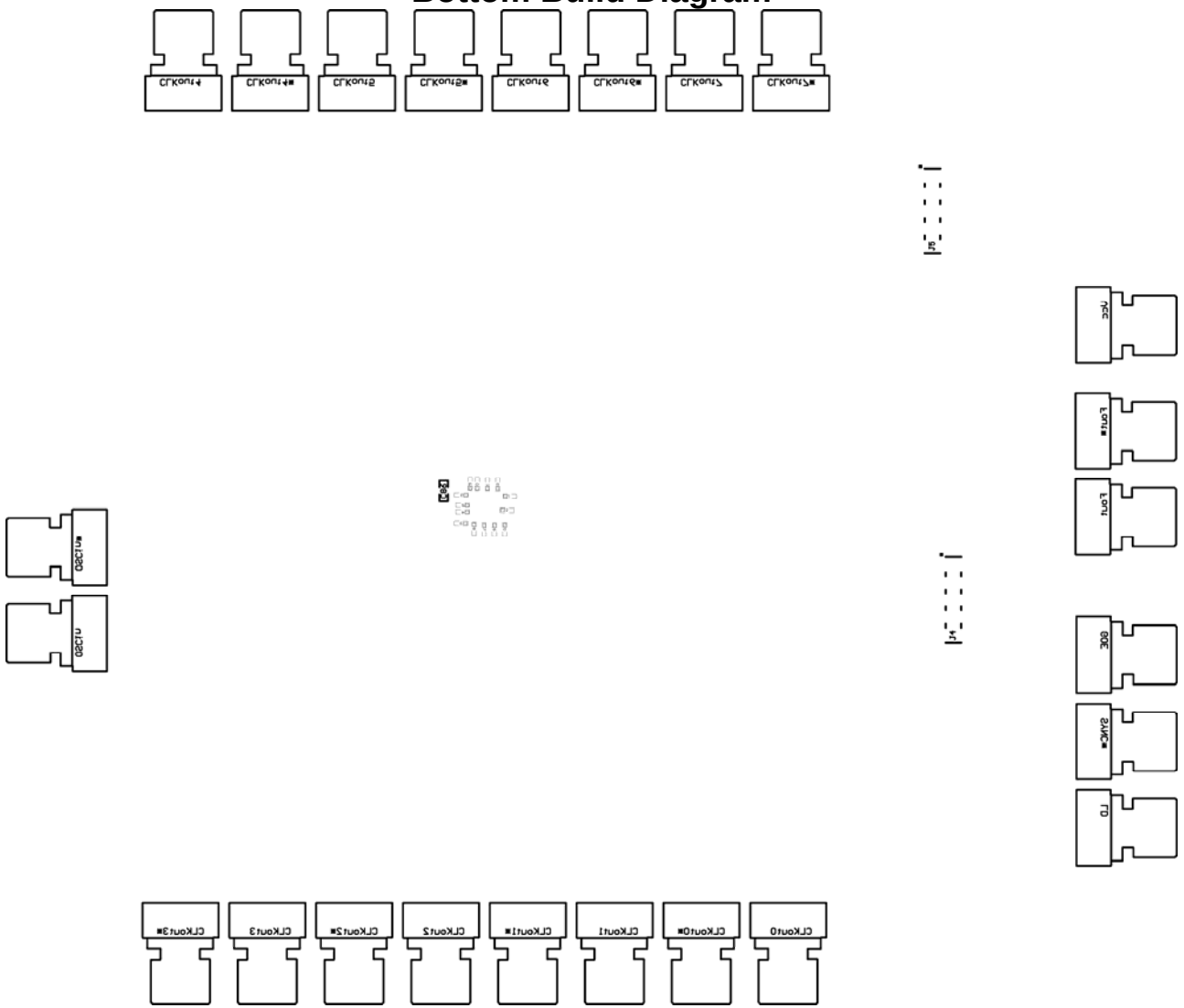
Part	Manufacturer	Part Number	Qnt	Identifier
Capacitors				
47 pF	Kemet	C0603C470J5GAC	1	C68
100 pF	Kemet	C0402C101J5GAC	14	C20, C21, C22, C23, C24, C25, C26, C27, C28, C29, C30, C31, C32, C33
100 pF	Kemet	C0603C101J5GAC	1	C34
12 nF	Kemet	C0603C123K1RACTU	1	C2
0.1 uF	Kemet	C0603C104J3RAC	16	C9, C37, C38, C39, C40, C41, C42, C43, C44, C45, C46, C47, C48, C49, C50, C51
0.1 uF	Kemet	C0402C104J4RAC	18	C35, C36, C52, C53, C54, C55, C56, C57, C58, C59, C60, C61, C62, C63, C64, C65, C66, C67
820 nF	Kemet	C0603C824K8PAC	1	C1_AUX
1 uF	Kemet	C0603C105K8VAC	16	C69, C70, C71, C72, C73, C74, C75, C76, C77, C79, C80, C81, C82, C83, C84, C85
10 uF	Kemet	C0805C106K9PAC	5	C2p_AUX, C16, C17, C18, C19
10 uF	Kemet	C0805C106K9PAC	1	C78
Resistors				
0 ohm	Vishay	CRCW0603000ZRT1	10	R1, R3, R6, R11, R12, R20, R22, R95, R104, R109
0 ohm	Yageo	RC0805JR-070RL	2	R4, R8
0 ohm	Vishay	CRCW0603000ZRT1	2	R87, R94
18 ohm	Vishay	CRCW0603180JRT1	1	R82
39 ohm	Vishay	CRCW0603390JRT1	1	R9
51 ohm	Vishay/Dale	CRCW060351R0JNEA	1	R15
120 ohm	Vishay	CRCW0402120RJNED	10	R52, R53, R96, R97, R98, R99, R100, R101, R102, R103
180 ohm	Vishay	CRCW0603181JRT1	2	R92, R93
270 ohm	Vishay	CRCW0603271JRT1	2	R80, R81
820 ohm	Vishay	CRCW0603821JRT1	1	R2_AUX
1.8 k	Vishay/Dale	CRCW06031K80JNEA	1	R2
2.2 k	Vishay/Dale	CRCW06032K20JNEA	2	R29, R30

15 k	Vishay	CRCW0603153JRT1	4	R88, R89, R90, R91
27 k	Vishay	CRCW0603273JRT1	3	R83, R84, R85
Other				
LMK0300xC	National Semiconductor	LMK03000CI	1	U1
OSC - CRYSTEK 33xx	Crystek	C3391-19.440	1	Y1
ADT2-1T	Minicircuits	ADT2-1T	1	B3
SMA	Johnson Components	142-0701-851	11	CLKout0, CLKout0*, CLKout2*, CLKout4, CLKout4*, CLKout7, CLKout7*, Fout, OSCin, OSCin*, Vcc
3.3 V zener	Comchip	CZRU52C3V3	2	D1, D2
PCB_LMK0300x	Printed Circuits Corp	PCB_LMK0300x rev 1.1, 6-16-2007	1	F1
HEADER_2X5(POLARIZED)	FCI Electronics	52601-S10-8	1	uWire
SPCS-8	SPC Technology	SPCS-8	4	Standoffs in the four corners (insert from bottom)
Open				
Open	-	Open	2	B1, B2
Open	-	603	32	C1, C2_AUX, C6, C7, C8, C10, C11, C12, C13, C14, C15, R5, R7, R10, R14, R16, R17, R18, R19, R21, R23, R24, R25, R26, R27, R28, R79, R105, R107, R110, R111, R112
Open	-	805	1	C2p
Open	-	Open	1	C3
Open	-	402	16	C4, C5, R31, R32, R37, R38, R39, R44, R45, R46, R51, R58, R63, R68, R73, R78
Open	-	603	34	C86, R33, R34, R35, R36, R40, R41, R42, R43, R47, R48, R49, R50, R54, R55, R56, R57, R59, R60, R61, R62, R64, R65, R66, R67, R69, R70, R71, R72, R74, R75, R76, R77, R86
OpenSMA	-	Open	13	CLKout1, CLKout1*, CLKout2, CLKout3, CLKout3*, CLKout5, CLKout5*, CLKout6, CLKout6*, Fout*, GOE, LD, SYNC*
Open	-	HEADER_2X5	2	J2, J4
Open	-	HEADER_2X5	2	J3, J5
Open	-	805	3	R13, R106, R108
Open	-	Open	1	Y2

Appendix E: Build Diagram



Bottom Build Diagram



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