

LMX2594 EVM Instructions – 15-GHz Wideband Low Noise PLL With Integrated VCO

User's Guide



Literature Number: SNAU210

March 2017

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LMX2594 EVM Instructions – 15-GHz Wideband Low Noise PLL With Integrated VCO

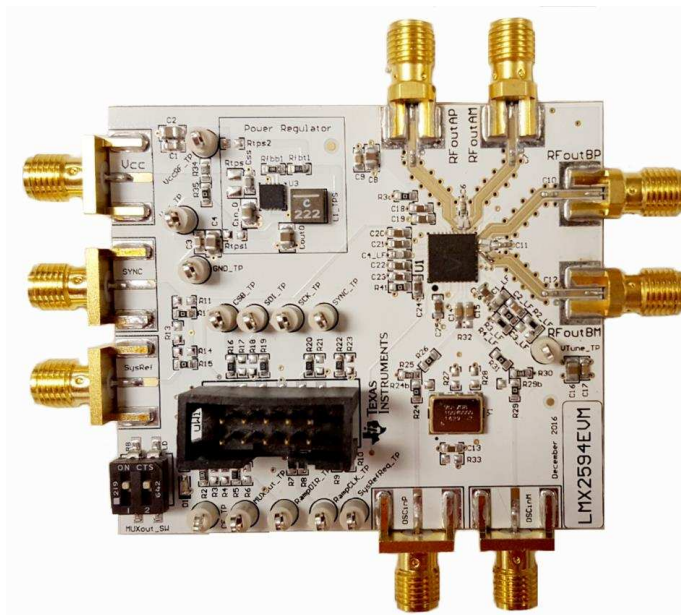


Figure 1. LMX2594EVM

1 Trademarks

2 Evaluation Board Setup

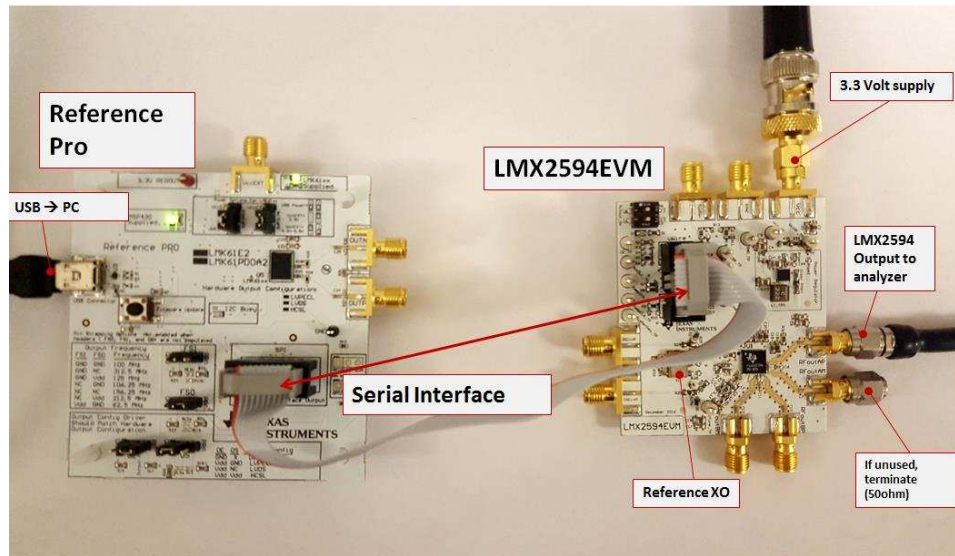


Figure 2. LMX2594EVM Setup

1. Power:
 - a. Set power supply to 3.3 V with 600-mA current limit and connect to V_{CC} SMA.
2. Input Signal:
 - a. VC-708 100-MHz on-board oscillator enabled (default). To use another reference, see [Appendix D](#).
3. Programming Interface:
 - Reference Pro will provide SPI interface to program LMX2594:
 - a. Connect USB cable from laptop or PC to USB port in Reference Pro. This provides power to Reference Pro Board and communication with TICS GUI
 - b. Connect 10 pin ribbon cable from Reference Pro to LMX2594EVM as shown above.
4. Output:
 - a. Connect RFoutAM or RFoutAP to a phase noise Analyzer. Connect a 50- Ω on the unused output if you are using only single-ended. Use a balun if you are using differential.

3 EVM Description

The LMX2594 is populated on a 4-layer PCB. This brief description should help you use the EVM:

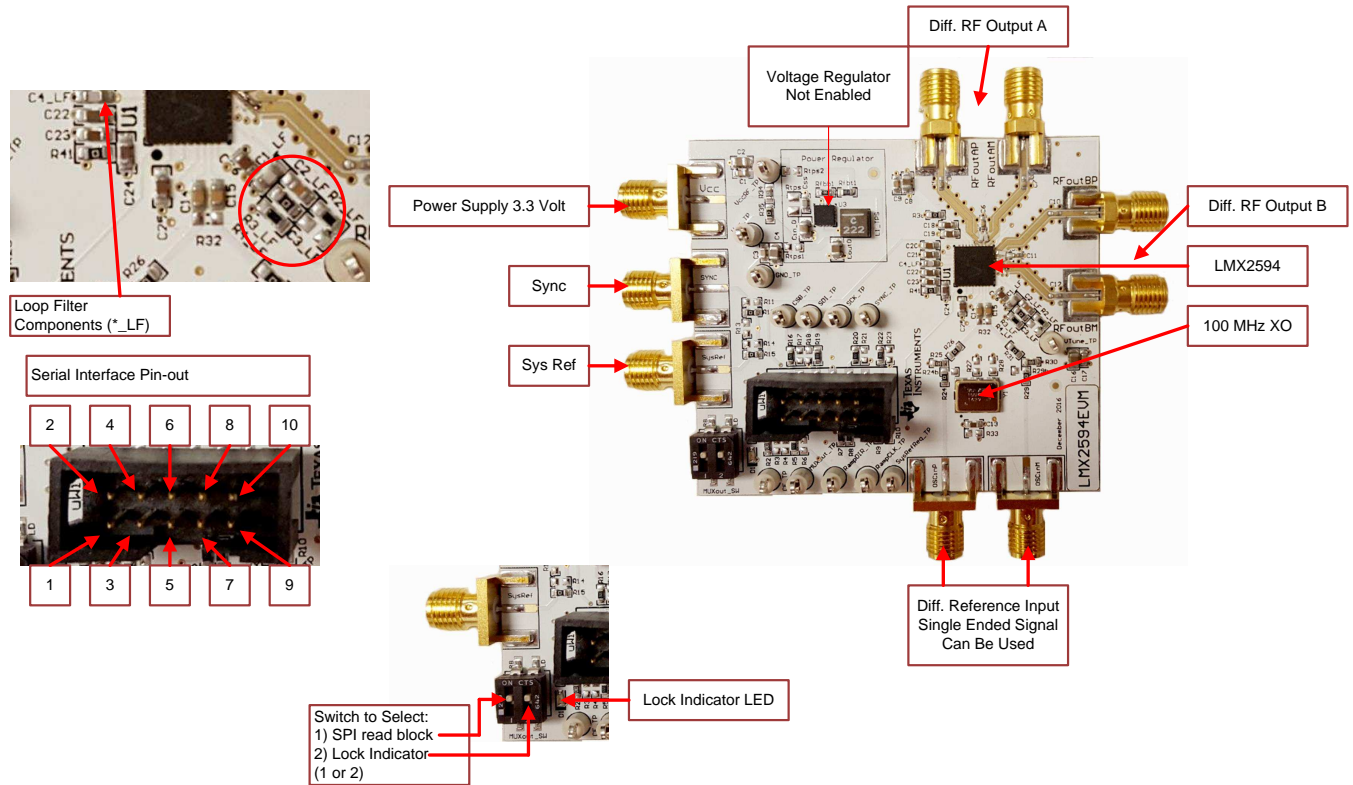


Figure 3. LMX2594EVM Description

The serial interface pin description is as follow:

Table 1. EVM and Serial Interface Connector Description

NO.	NAME
1	RAMPDIR and CE (Choose with Resistors on Board)
2	CSB
3	MUXout
4	SDI
5	Not Used
6	GND
7	RampCLK
8	SCK
9	SysRefReq
10	SYNC

The LD switch should be on to enable Lock indicator:

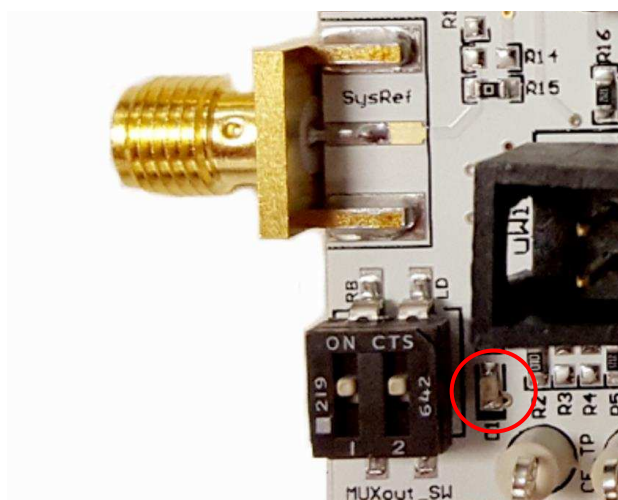


Figure 4. LD Lock Detect

3.1 Installing the Software

1. Download TICS Pro from the TI Website at www.ti.com/tool/TICSPRO-SW
2. Install it by following the wizard
3. Search for LMX2594: Click on Select Device From menu bar →PLL+VCO→LMX2594

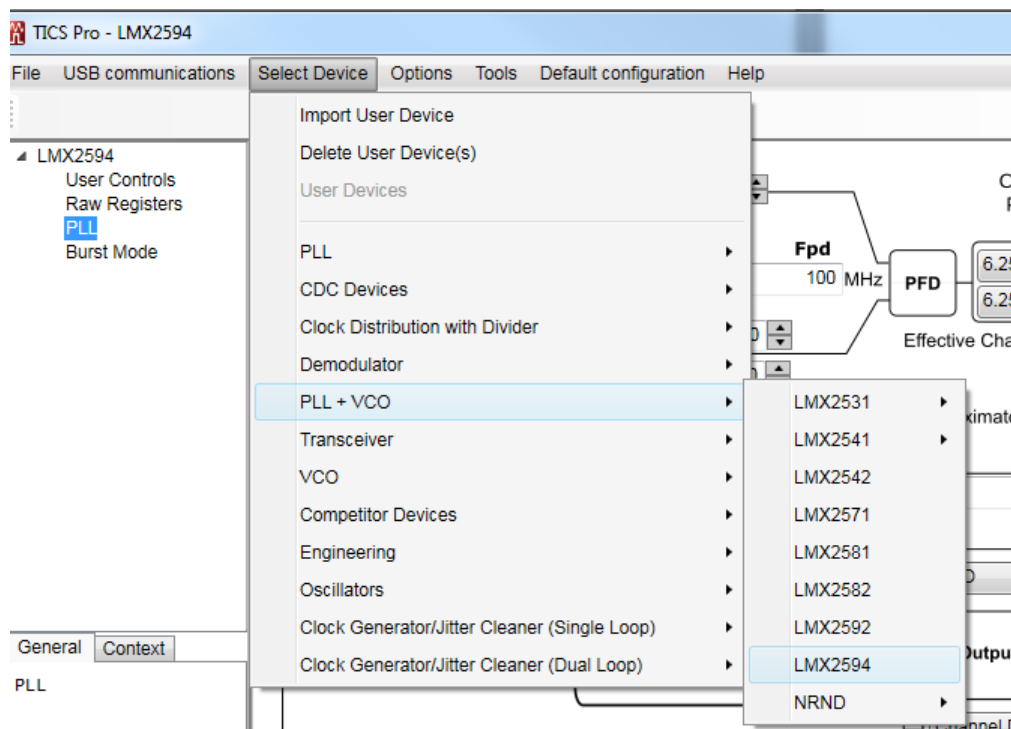


Figure 5. Search for LMX2594 on TICS Pro

4. You are now ready to use this software. Verify that you can communicate with Reference Pro. Select interface under USB communications:

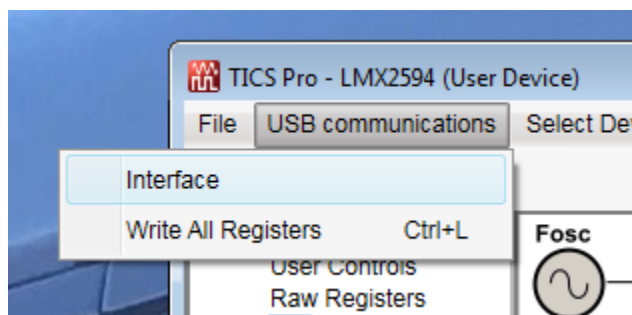


Figure 6. USB Communications on TICS Pro

- Click on identify and you should see the LED (MSP430 Supplied) Blink on Reference Pro

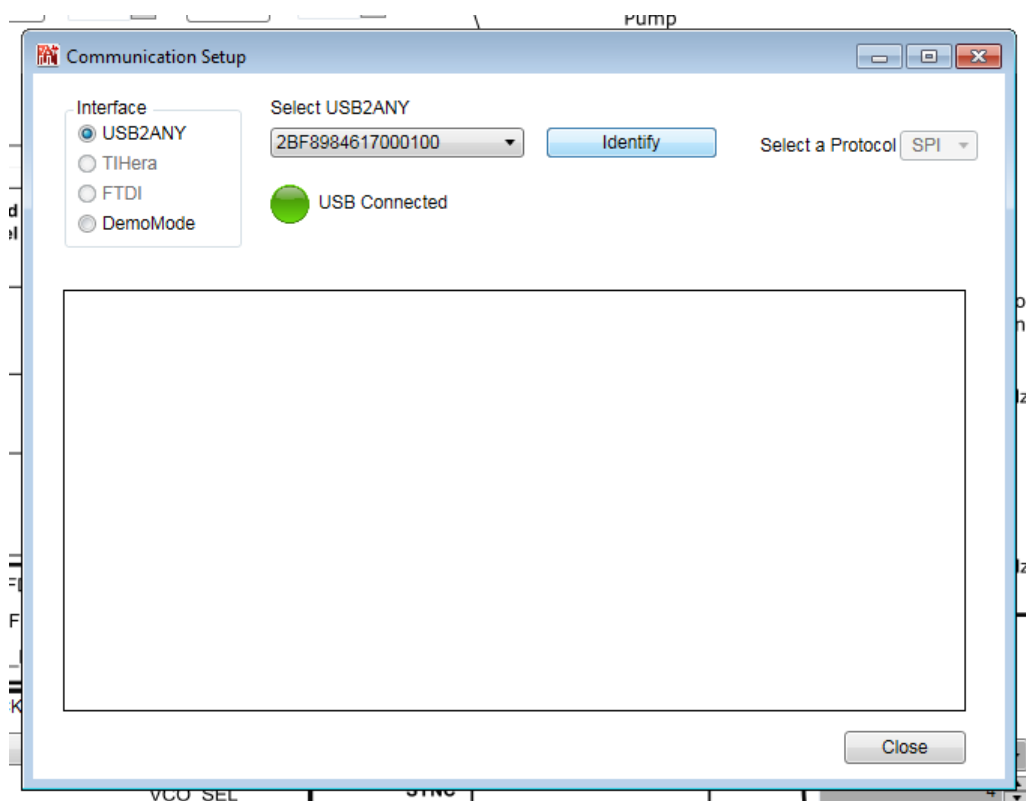


Figure 7. USB Communication Between TICS Pro and Reference Pro

4 Bringing LMX2594 to a Lock State

Load the default mode by selecting it as shown in Figure 8:

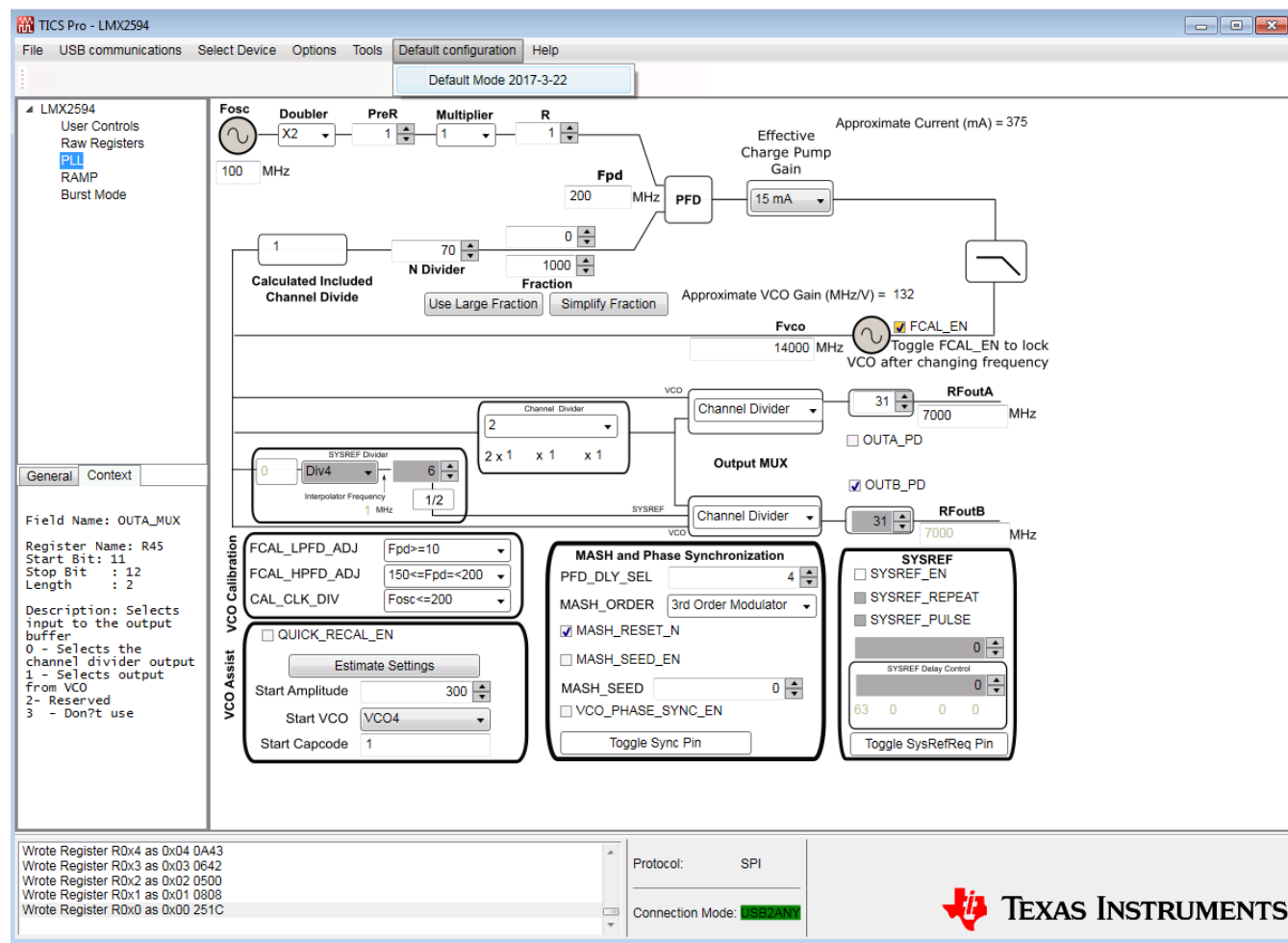


Figure 8. TICS Pro GUI LMX2594 Default Configuration

For best results, in the *User Controls* Tab in TICS Pro. Under *General Controls*, check and uncheck the Reset box. After the reset, Write all registers as shown in [Figure 9](#):

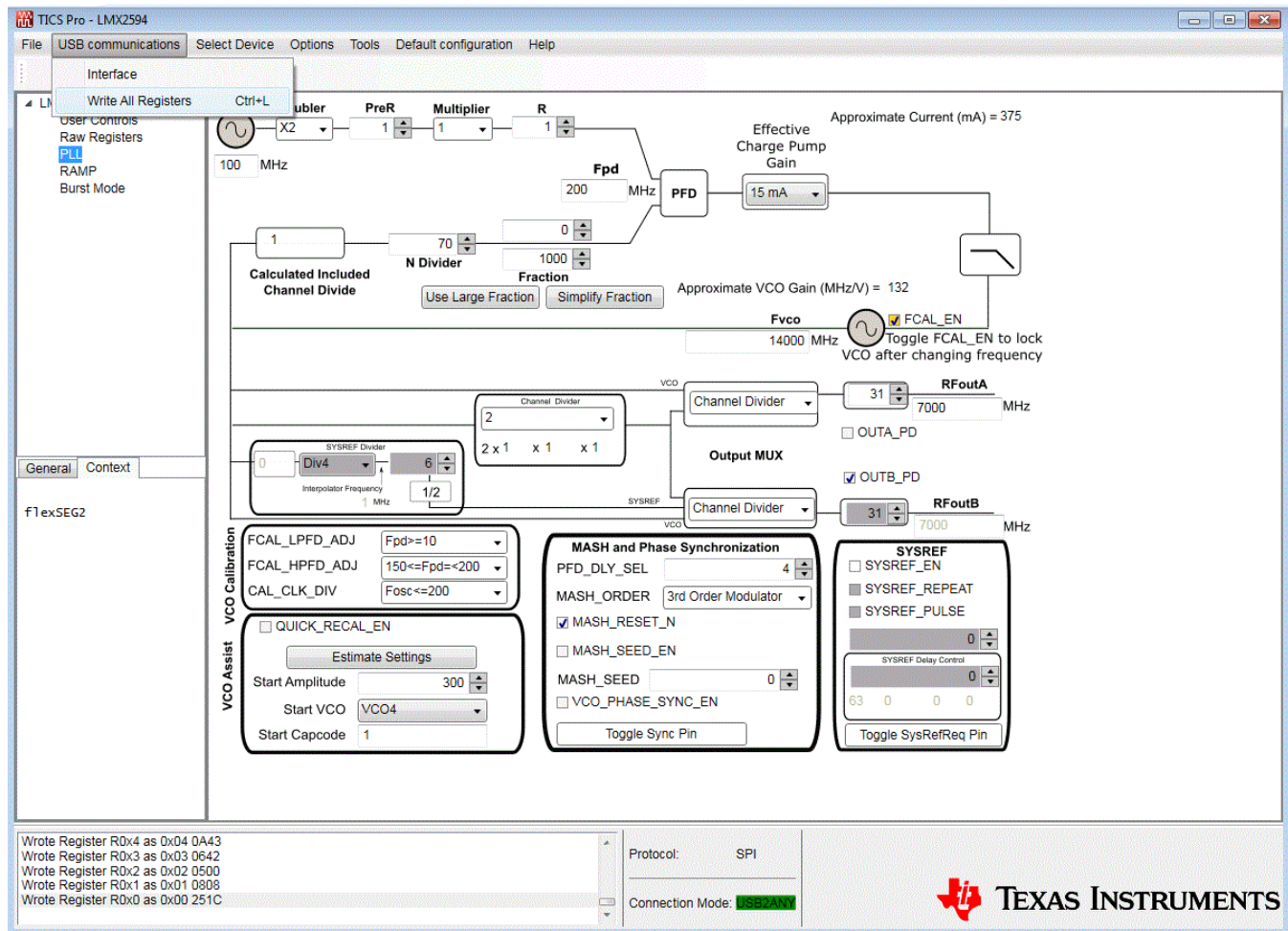


Figure 9. TICS Pro Write All Registers

5 Current Loop Filter Configuration

The parameters for the loop filters are:

Table 2. Current Loop Filter Configuration

PARAMETER	VALUE
VCO Gain	132 MHz/V
Loop Bandwidth	285 kHz
Phase Margin	65 deg
C1_LF	390 pF
C2_LF	68 nF
C3_LF	Open
C4_LF	1800 pF
R2	68 Ω
R3_LF	0 Ω
R4_LF	18 Ω
Effective Charge Pump Gain	15 mA
Phase Detector Frequency (MHz)	200 MHz
VCO Frequency	Designed for 15 GHz, but works over the whole frequency range

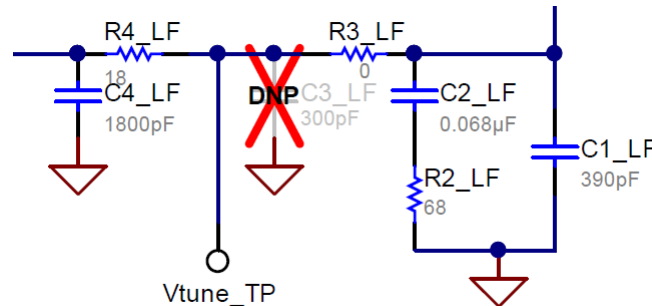


Figure 10. Current Loop Filter Configuration

For detailed design and simulation, see the [PLLatinum Sim Tool](#).

For application notes, blogs, or videos on our products, see <http://www.ti.com/pll>.

6 Key Results to Expect

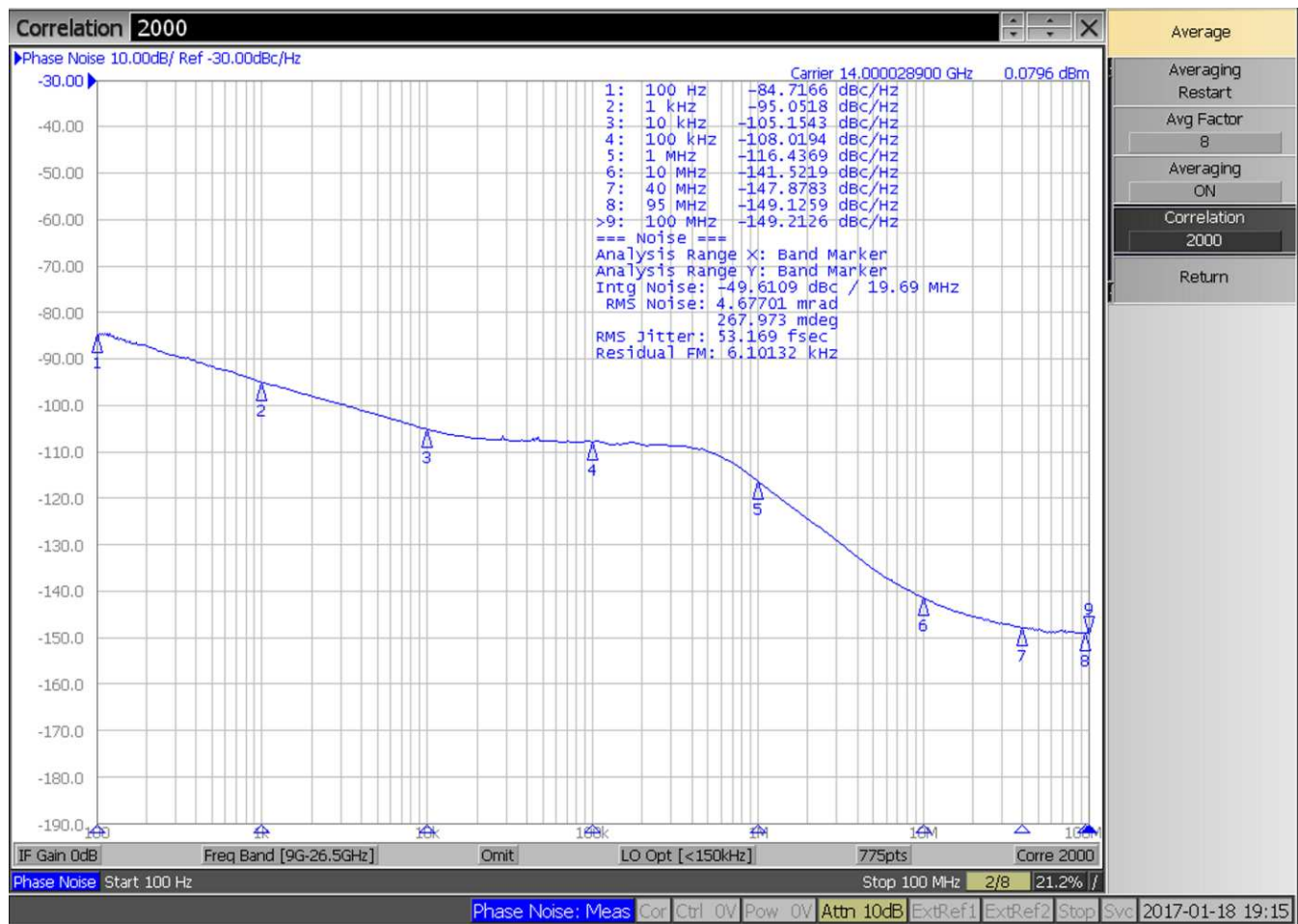


Figure 11. Phase Noise Plot at 14-GHz Output Frequency

This assumes that the input reference is very clean, such as a 100-MHz Wenzel oscillator. A signal generator is NOT sufficiently clean. The LMX2594 requires an external reference.

Schematic

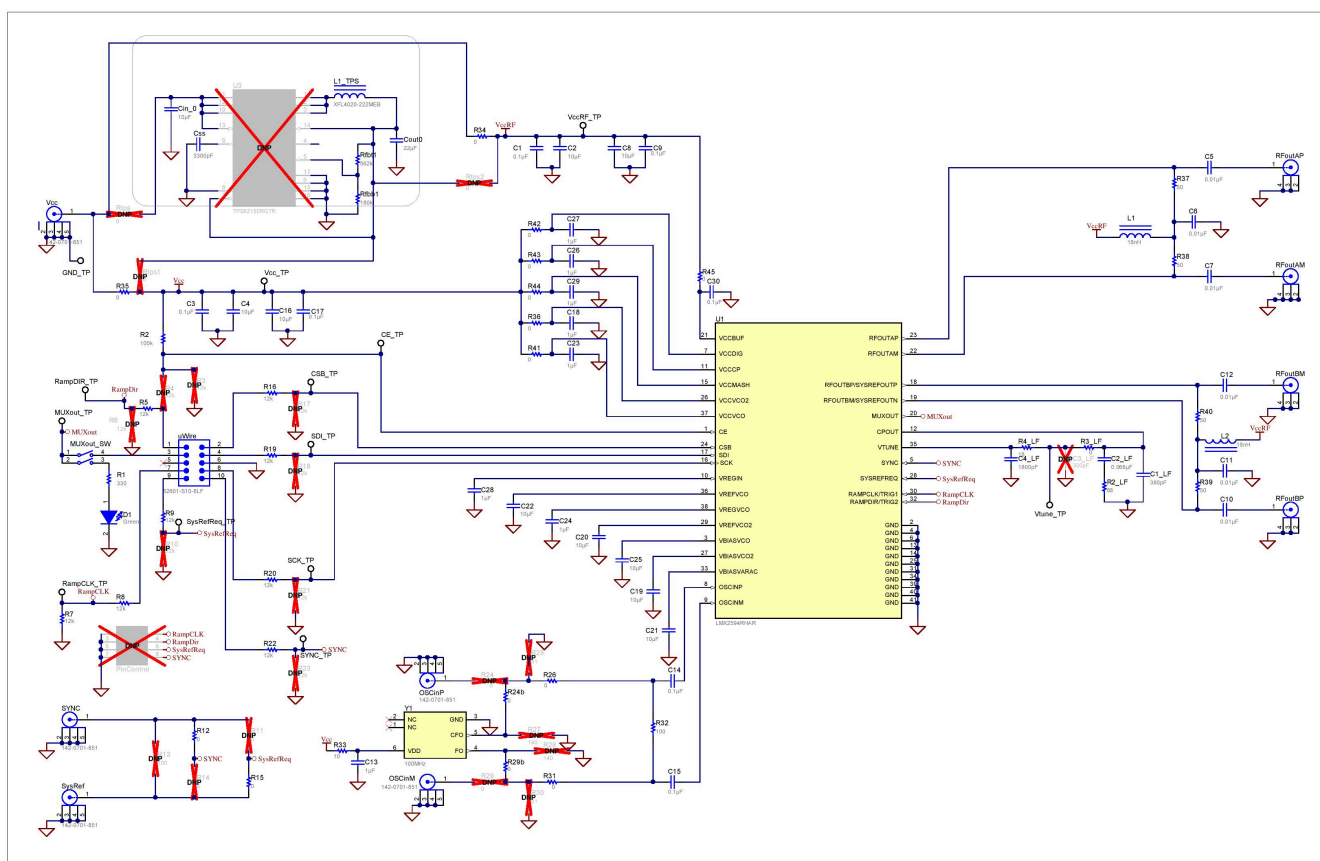


Figure 12. Schematic

Bill of Materials

Table 3. Bill of Materials

DESIGNATOR	DESCRIPTION	MANUFACTURER	PART NUMBER	QUANTITY
!PCB	Printed-Circuit Board	Any	SV601308	1
C1, C3, C9, C14, C15, C17, C30	CAP, CERM, 0.1 μ F, 16 V, \pm 5%, X7R, 0603	AVX	0603YC104JAT2A	7
C1_LF	CAP, CERM, 390 pF, 50 V, \pm 5%, C0G/NP0, 0603	Kemet	C0603C391J5GACTU	1
C2, C4, C8, C16	CAP, CERM, 10 μ F, 10 V, \pm 10%, X5R, 0805	Kemet	C0805C106K8PACTU	4
C2_LF	CAP, CERM, 0.068 μ F, 50 V, \pm 10%, X7R, 0603	MuRata	GRM188R71H683KA93D	1
C4_LF	CAP, CERM, 1800 pF, 50 V, \pm 5%, C0G/NP0, 0603	MuRata	GRM1885C1H182JA01D	1
C5, C6, C7, C10, C11, C12	CAP, CERM, 0.01 μ F, 16 V, \pm 10%, X7R, 0402	AT Ceramics	520L103KT16T	6
C13, C18, C23, C24, C26, C27, C28, C29	CAP, CERM, 1 μ F, 16 V, \pm 10%, X7R, 0603	TDK	C1608X7R1C105K080AC	8
C19, C20, C21, C22, C25	CAP, CERM, 10 μ F, 10 V, \pm 20%, X5R, 0603	TDK	C1608X5R1A106M080AC	5
CE_TP, CSB_TP, GND_TP, MUXout_TP, RampCLK_TP, RampDIR_TP, SCK_TP, SDI_TP, SYNC_TP, SysRefReq_TP, Vcc_TP, VccRF_TP, Vtune_TP	Test Point, Compact, White, TH	Keystone	5007	13
Cin_0	CAP, CERM, 10 μ F, 25 V, \pm 10%, X5R, 0805	MuRata	GRM219R61E106KA12D	1
Cout0	CAP, CERM, 22 μ F, 16 V, \pm 10%, X5R, 0805	TDK	C2012X5R1C226K125AC	1
Css	CAP, CERM, 3300 pF, 50 V, \pm 5%, C0G/NP0, 0603	MuRata	GRM1885C1H332JA01D	1
D1	LED, Green, SMD	Lite-On	LTST-C190GKT	1
L1, L2	Inductor, Multilayer, Air Core, 18 nH, 0.3 A, 0.36 Ω , SMD	MuRata	LQG15HS18NJ02D	2
L1_TPS	Inductor, Shielded, Composite, 2.2 μ H, 3.7 A, 0.02 Ω , SMD	Coilcraft	XFL4020-222MEB	1
LBL1	Thermal Transfer Printable Labels, 0.650" W x 0.200" H - 10,000 per roll	Brady	THT-14-423-10	1
MUXout_SW	Switch, SPST, Slide, Off-On, 2 Pos, 0.1 A, 20 V, SMD	CTS Electrocomponents	219-2MST	1

Table 3. Bill of Materials (continued)

DESIGNATOR	DESCRIPTION	MANUFACTURER	PART NUMBER	QUANTITY
OSCinM, OSCinP, SYNC, SysRef, Vcc	Connector, SMT, End launch SMA 50 ohm	Emerson Network Power Connectivity	142-0701-851	5
R1	RES, 330 Ω , 5%, 0.1 W, 0603	Yageo America	RC0603JR-07330RL	1
R2	RES, 100 k, 5%, 0.1 W, 0603	Vishay-Dale	CRCW0603100KJNEA	1
R2_LF	RES, 68, 5%, 0.1 W, 0603	Vishay-Dale	CRCW060368R0JNEA	1
R3_LF, R12, R15, R24b, R26, R29b, R31, R34, R35, R36, R41, R42, R43, R44, R45	RES, 0, 5%, 0.1 W, 0603	Vishay-Dale	CRCW06030000Z0EA	15
R4_LF	RES, 18, 5%, 0.1 W, 0603	Vishay-Dale	CRCW060318R0JNEA	1
R5, R7, R8, R9, R16, R19, R20, R22	RES, 12 k Ω , 5%, 0.1 W, 0603	Vishay-Dale	CRCW060312K0JNEA	8
R33	RES, 10 Ω , 5%, 0.1 W, 0603	Vishay-Dale	CRCW060310R0JNEA	1
R32	RES, 100, 1%, 0.1 W, 0603	Vishay-Dale	CRCW0603100RFKEA	1
R37, R38, R39, R40	RES, 50, 0.1%, 0.05 W, 0402	Vishay-Dale	FC0402E50R0BST1	4
Rfbb1	RES, 180 k, 0.1%, 0.1 W, 0603	Yageo America	RT0603BRD07180KL	1
Rfbt1	RES, 562 k, 1%, 0.1 W, 0603	Vishay-Dale	CRCW0603562KFKEA	1
RFoutAM, RFoutAP, RFoutBM, RFoutBP	JACK, SMA, 50 Ω , Gold, Edge Mount	Johnson	142-0771-831	4
U1	High Performance, Wideband PLLatinum RF Synthesizer, RHA0040A (VQFN-40)	Texas Instruments	LMX2594RHAR	1
U3	Buck Step-Down Regulator with 3 to 17 V Input and 0.9 to 6 V Output, -40 to 85°C, 16-Pin QFN (RGT), Green (RoHS and no Sb/Br)	Texas Instruments	TPS62150RGTR	0
uWire	Header (shrouded), 100 mil, 5x2, Gold plated, SMD	FCI	52601-S10-8LF	1
Y1	Crystal Oscillator, 100 MHz, LVDS, 3.3V, SMD	Vectron	VC-708-EDE-FNXN- 100M000000	1
C3_LF	CAP, CERM, 300 pF, 100 V, \pm 5%, C0G/NP0, 0603	MuRata	GRM1885C2A301JA01D	0
FID5, FID6, FID10, FID11	Fiducial mark. There is nothing to buy or mount.	N/A	N/A	0
PinControl	Header, 100 mil, 4x2, Gold, SMT	Molex	0015910080	0
R3, R4, R6, R10, R17, R18, R21, R23	RES, 12 k Ω , 5%, 0.1 W, 0603	Vishay-Dale	CRCW060312K0JNEA	0
R11, R14, R24, R29, Rtps1, Rtps2	RES, 0, 5%, 0.1 W, 0603, RES, 0, 5%, 0.1 W, 0603, RES, 0, 5%, 0.1 W, 0603, RES, 0 Ω , 5%, 0.1W, 0603, RES, 0 Ω , 5%, 0.1 W, 0603	Vishay-Dale	CRCW06030000Z0EA	0
R13	RES, 100, 5%, 0.1 W, 0603	Vishay-Dale	CRCW0603100RJNEA	0
R25, R30	RES, 51, 5%, 0.1 W, 0603	Vishay-Dale	CRCW060351R0JNEA	0
R27, R28	RES, 140, 1%, 0.1 W, 0603	Vishay-Dale	CRCW0603140RFKEA	0
Rtps	RES, 0, 5%, 0.125 W, 0805	Vishay-Dale	CRCW08050000Z0EA	0

Board Layers Stack-Up

Total Board thickness is 62 mils.

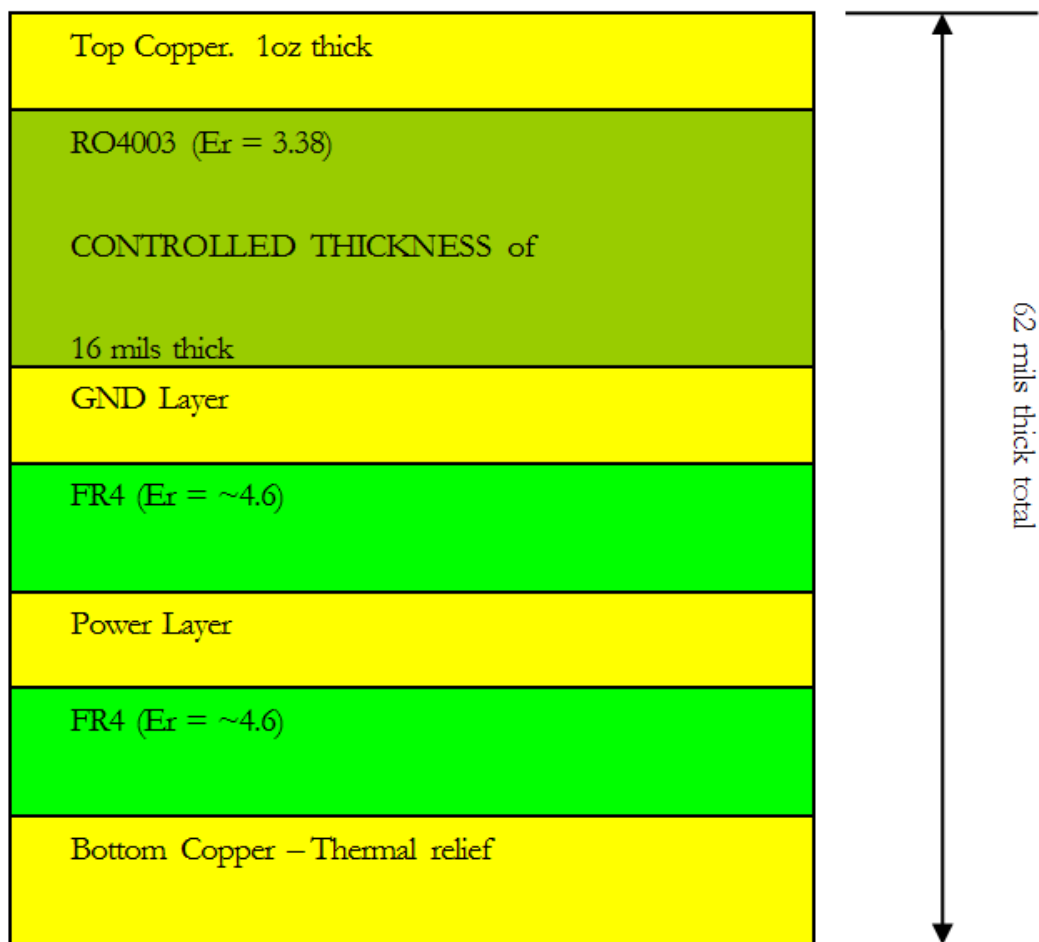


Figure 13. Board Layer Stack-Up

Changing Reference Oscillator and Setup

The reference can be single-ended or differential. To measure the performance of the PLL ONLY, the reference should have at least this level of performance. We understand that this can be a challenge at 100-Hz offset:

Table 4. Reference Oscillator Requirements

100-MHz REFERENCE MINIMUM REQUIREMENTS FOR A 0.4-dB IMPACT ON PLL INBAND PN ⁽¹⁾				
Offset [Hz]	100	1k	10k	100k
Noise level [dBc/Hz]	–139	–149	–159	–164

⁽¹⁾ A noise source 10 dB down from the PLL noise will contribute to raise the noise by 0.4 dB.

There are different options to provide a reference oscillator to LMX2594: Use on-board oscillator (default), Enable LMK61xx from Reference Pro PCB, use external oscillator.

By default the onboard oscillator is enabled. To use external reference, onboard oscillator must be disabled. Having multiple 100 MHz enabled or powered sharing V_{CC} or Gnd will degrade the phase noise performance of LMX2594.

For differential pair connection:

1. Switch R24b to R24.
2. Switch R29b to R29
3. Must remove R33 to remove power from oscillator

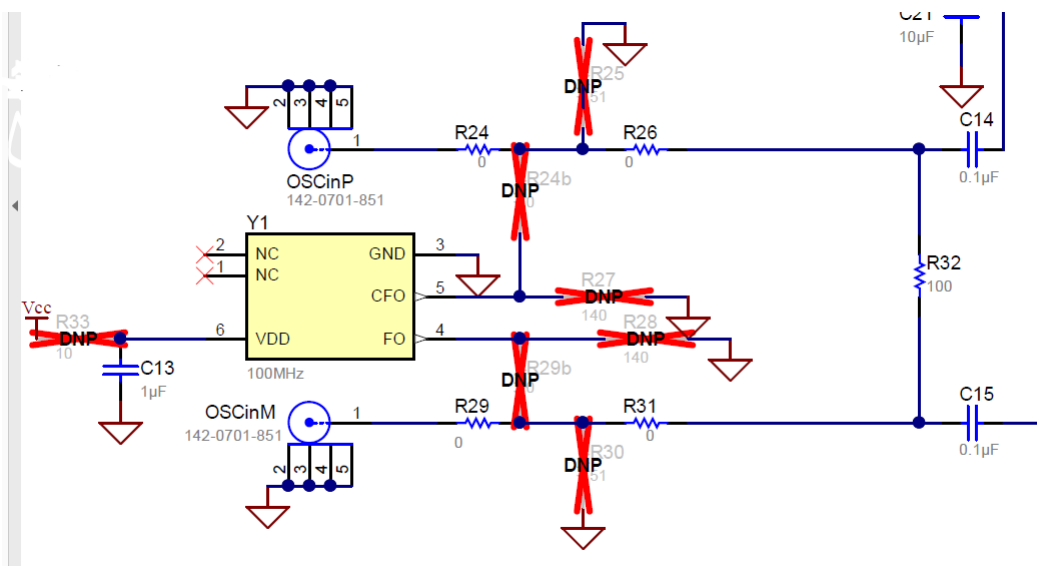


Figure 14. Single-Ended Reference Configuration

1. Switch R24b to R24.
2. Switch R29b to R29
3. Must remove R33 to remove power from oscillator
4. Populate R25 and R30.
5. Remove R32



Connecting Reference Pro

1. To use Reference Pro, change the configuration for SE or differential connection as shown on [Appendix D](#).
2. Change jumper position on Reference Pro, connect middle pin of OE header to Vdd.

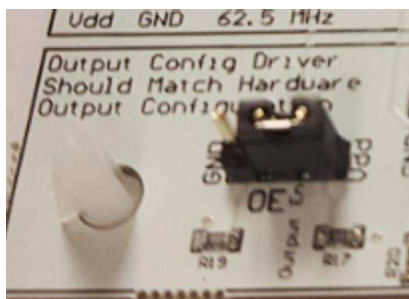


Figure 16. Reference Pro Output Enable Header

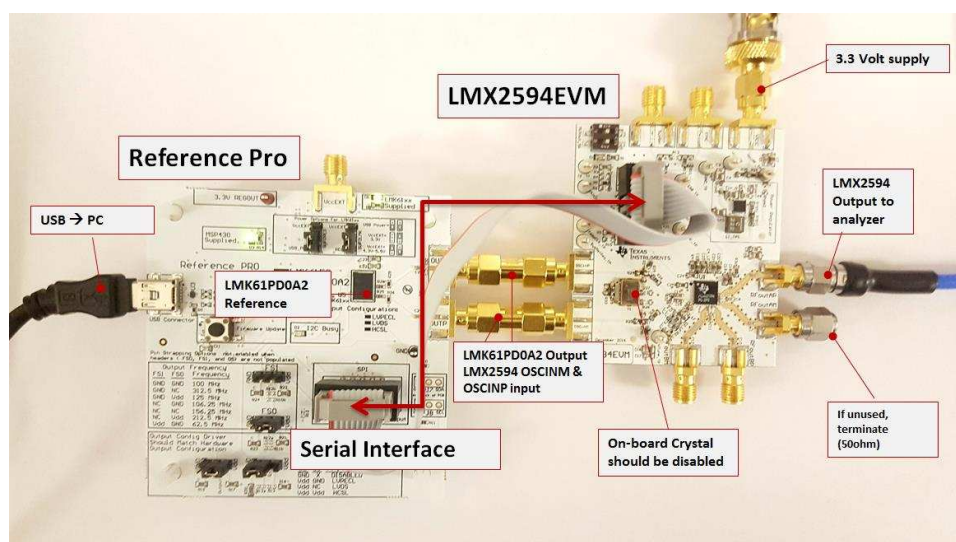


Figure 17. LMX2594EVM Setup With Reference Pro

The LMX61PD0A2 has several control pins dedicated for control of output format, output frequency, and output enable control. These control pins can be configured through the jumpers shown in [Table 5](#) and [Table 6](#).

Jumpers FS1, FS0, OS, and OE can be used to configure the corresponding control pin to either high or low state by strapping the center pin to VDD position (tie pins 2-3) or GND position (tie pins 1-2), respectively. Connections from the VDD position to the device supply or from the GND position to the ground plane are connected by 1.5-kΩ resistors.

Table 5. Output Frequency of LMK61PD0A2 (Reference Pro)

FS1	FS0	OUTPUT FREQUENCY (MHz)
0	0	100
0	NC	312.5
0	1	125
NC	0	106.25
NC	NC	156.25
NC	1	212.5
1	0	62.5

Table 6. OutputType of LMK61PD0A2 (Reference Pro)

OS	OE	OUTPUT TYPE
X	O	Disabled (PLL Functional)
0	1	LVPECL
NC	1	LVDS
1	1	HCSL

The OS pin is used to bias internal drivers and change the output type. It is imperative to match the output termination passive components as shown on [Table 7](#) with the output type from [Table 6](#).

[Table 7](#) lists component values for each configuration.

Table 7. Output Termination Schemes

OUTPUT FORMAT	COUPLING	COMPONENT	VALUE
LVPECL	AC (default EVM configuration)	R25, R28	0 Ω
		R26, R29	150 Ω
		C24, C25	0.01 μ F
		R27, R30, R31	DNP
	DC ⁽¹⁾	R25, R28, C24, C25	0 Ω
		R26, R29, R27, R30, R31	DNP
LVDS ⁽²⁾	AC	R25, R28, R27, R30	0 Ω
		R31	100 Ω
		C24, C25	0.01 μ F
		R26, R29	DNP
	DC	R25, R27, R28, R30, C24, C25	0 Ω
		R31	100 Ω
		R26, R29	DNP
HCSL	AC	R25, R28	0 Ω
		R26, R29	50 Ω
		C24, C25	0 Ω
		R27, R30, R31	DNP
	DC	R25, R28	0 Ω
		R26, R29	50 Ω
		C24, C25	0.01 μ F
		R27, R30, R31	DNP

⁽¹⁾ 50 Ω to $V_{CC} - 2$ V termination is required on receiver.

⁽²⁾ 100- Ω differential termination (R31) is provided on Reference Pro PCB. Removing the differential termination on the EVM is possible if the differential termination is available on the receiver.

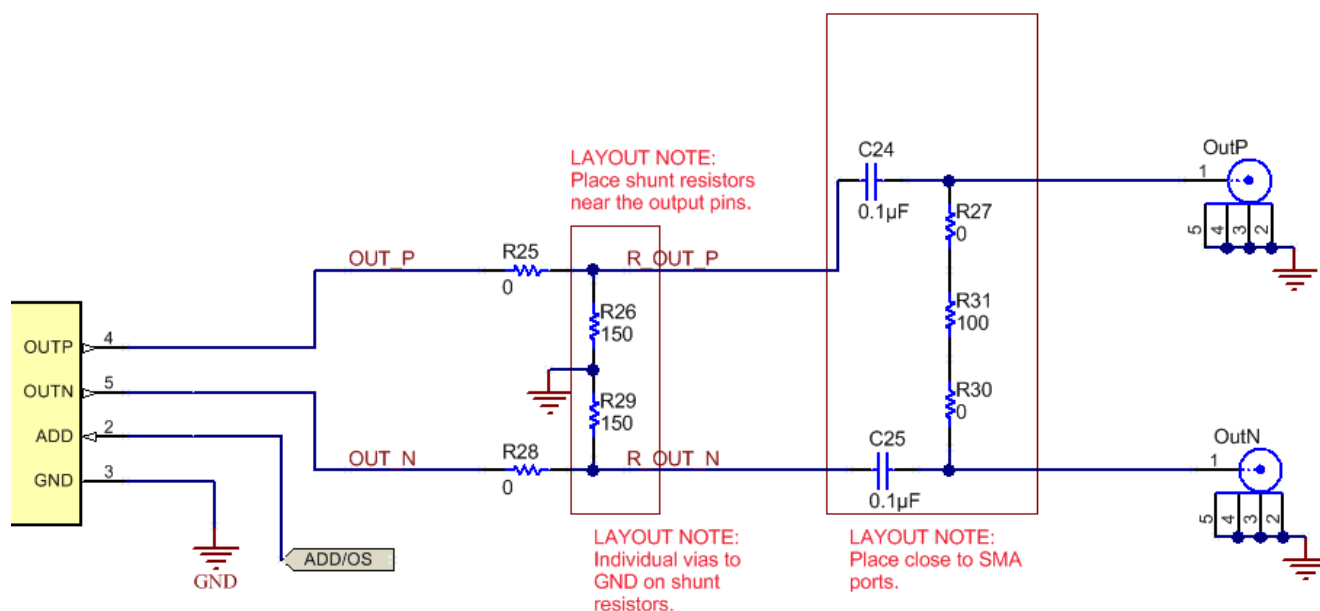
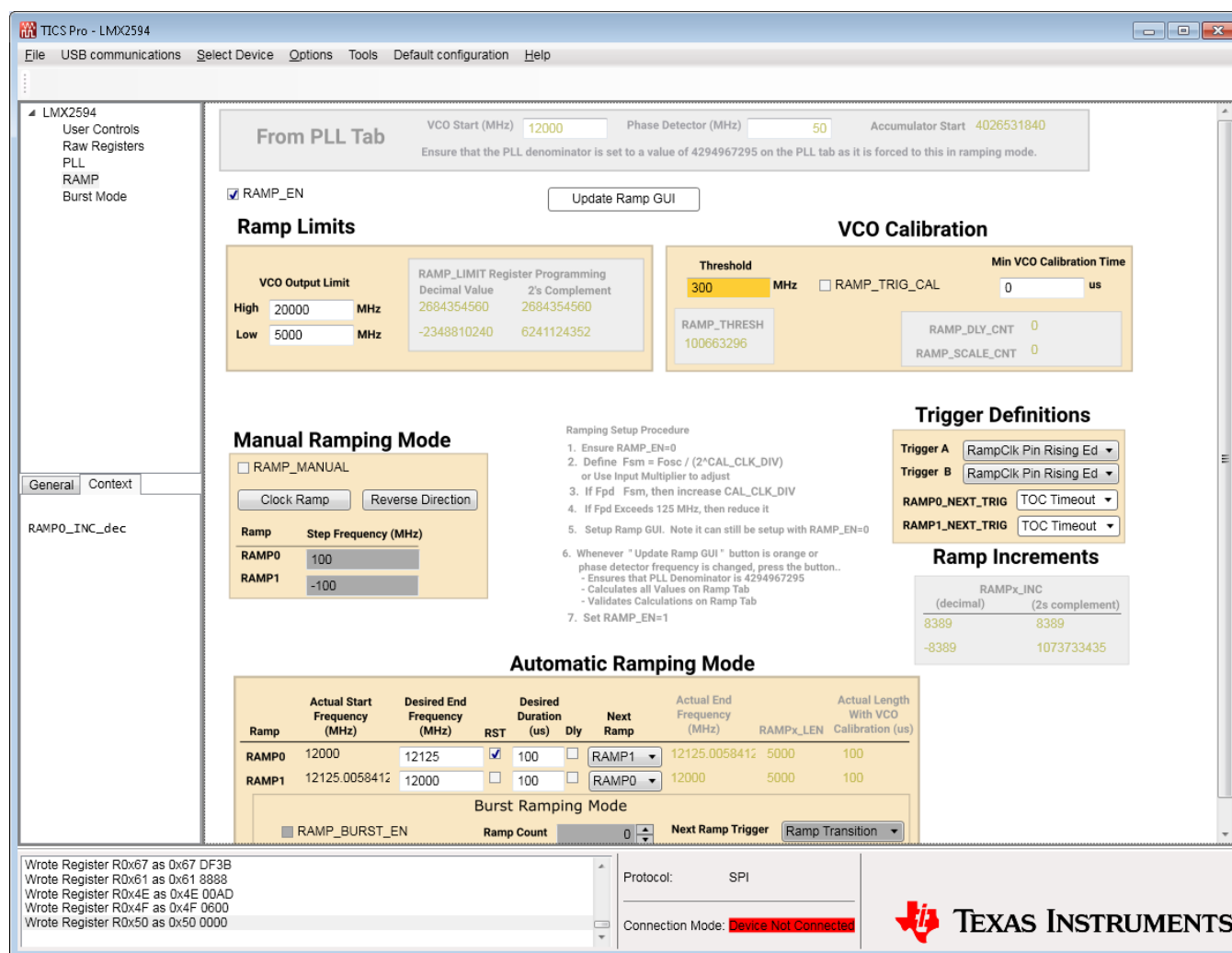


Figure 18. LMK61PD0A2 Output Termination

Ramping Feature

F.1 Ramping Example Waveform

VCO is ramping from 8 to 10 GHz and being dividing by 4 so that it can be seen with the HP53310A. This can be set up on the ramp GUI tab.



TICS Pro - LMX2594

File USB communications Select Device Options Tools Default configuration Help

LMX2594
User Controls
Raw Registers
PLL
RAMP
Burst Mode

From PLL Tab VCO Start (MHz) 12000 Phase Detector (MHz) 50 Accumulator Start 4026531840
Ensure that the PLL denominator is set to a value of 4294967295 on the PLL tab as it is forced to this in ramping mode.

☒ RAMP_EN Update Ramp GUI

Ramp Limits

VCO Output Limit
High 20000 MHz
Low 5000 MHz

RAMP_LIMIT Register Programming
Decimal Value 2's Complement
2684354560 2684354560
-2348810240 6241124352

VCO Calibration

Threshold 300 MHz ☐ RAMP_TRIG_CAL Min VCO Calibration Time 0 us
RAMP_THRESH 100663296 RAMP_DLY_CNT 0 RAMP_SCALE_CNT 0

Manual Ramping Mode

☐ RAMP_MANUAL
Clock Ramp Reverse Direction

Ramp Step Frequency (MHz)
RAMP0 100
RAMP1 -100

Automatic Ramping Mode

Ramp	Actual Start Frequency (MHz)	Desired End Frequency (MHz)	RST	Desired Duration (us)	Dly	Next Ramp	Actual End Frequency (MHz)	RAMPx_LEN	Actual Length With VCO Calibration (us)
RAMP0	12000	12125	<input checked="" type="checkbox"/>	100	<input type="checkbox"/>	RAMP1	12125.0058412	5000	100
RAMP1	12125.0058412	12000	<input type="checkbox"/>	100	<input type="checkbox"/>	RAMP0	12000	5000	100

Burst Ramping Mode

☐ RAMP_BURST_EN Ramp Count 0 Next Ramp Trigger Ramp Transition

Trigger Definitions

Trigger A RampClk Pin Rising Ed
Trigger B RampClk Pin Rising Ed
RAMP0_NEXT_TRIG TOC Timeout
RAMP1_NEXT_TRIG TOC Timeout

Ramp Increments

RAMPx_INC (decimal)	(2's complement)
8389	8389
-8389	1073733435

Wrote Register R0x67 as 0x67 DF3B
Wrote Register R0x61 as 0x61 8888
Wrote Register R0x4E as 0x4E 00AD
Wrote Register R0x4F as 0x4F 0600
Wrote Register R0x50 as 0x50 0000

Protocol: SPI
Connection Mode: Device Not Connected


 **TEXAS INSTRUMENTS**

Figure 19. Ramping Example Tics

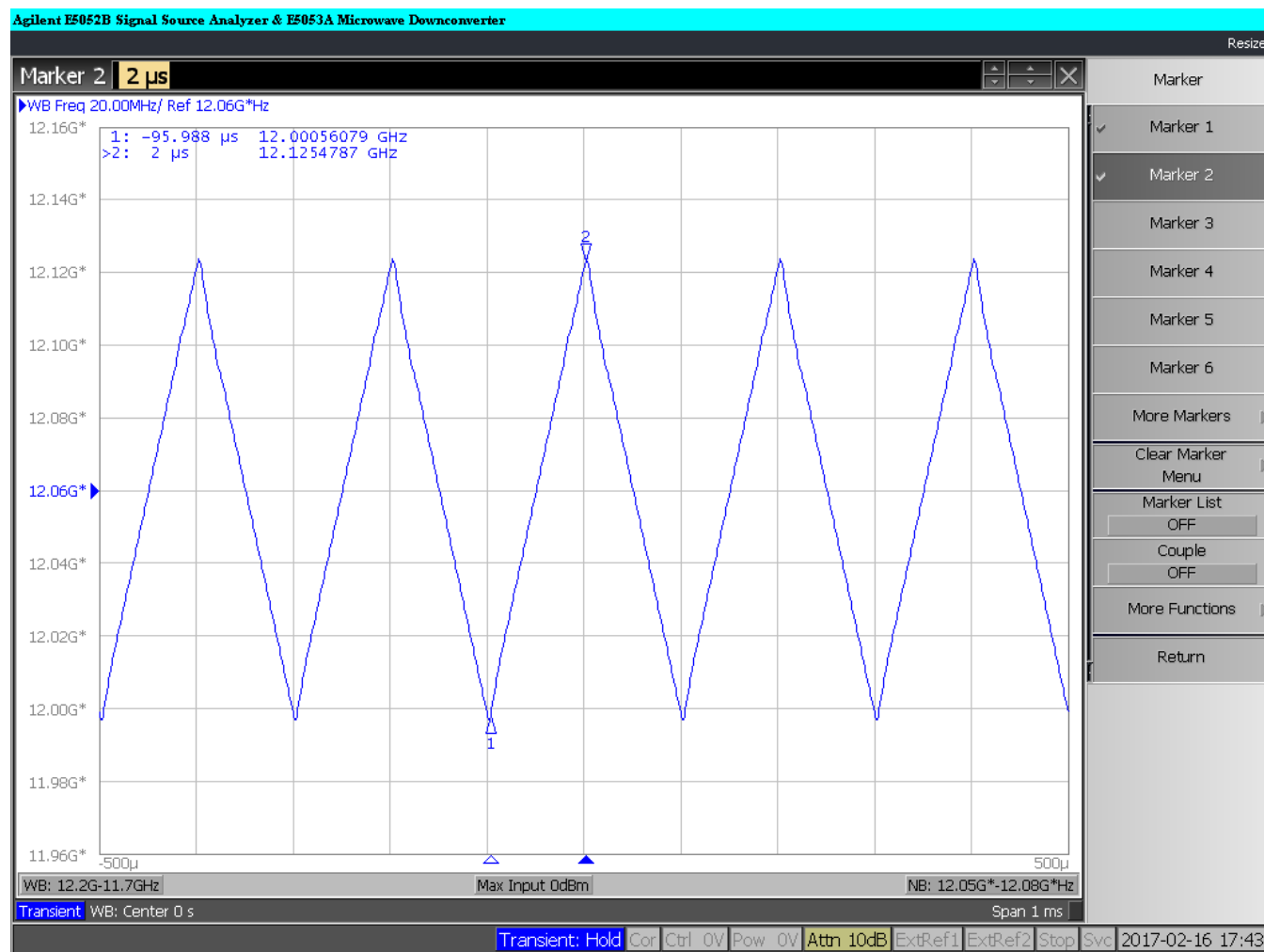


Figure 20. Ramping Example

-
- The screenshot displays the LMX2594 configuration tool interface, specifically the 'VCO Calibration' tab. The tool is configured for 'VCO Assist' mode. The main configuration area shows the VCO frequency (Fvco) at 14000 MHz, with a calculated channel divider of 4 and a fraction of 35/1000. The output mux is configured for RFoutA and RFoutB at 7000 MHz. The MASH section shows MASH_RESET_N and MASH_SYNC_EN checked. The SYSREF section shows SYSREF_EN, SYSREF_REPEAT, and SYSREF_PULSE checked. The VCO Assist section shows Start Amplitude at 250, Start VCO at VCO7, and Start Capcode at 50. The VCO Assist section also includes a 'PHASE SYNCHRONIZATION' section with VCO_PHASE_SYNC_EN checked.

Figure 21. Perform Sync For SysRef

3. Configure TICS Pro *PLL* tab for SysRef
 - Check the *SYSREF_EN* box
 - Change *OUTB_MUX* to SysRef
 - Uncheck the *OUT_PD* box

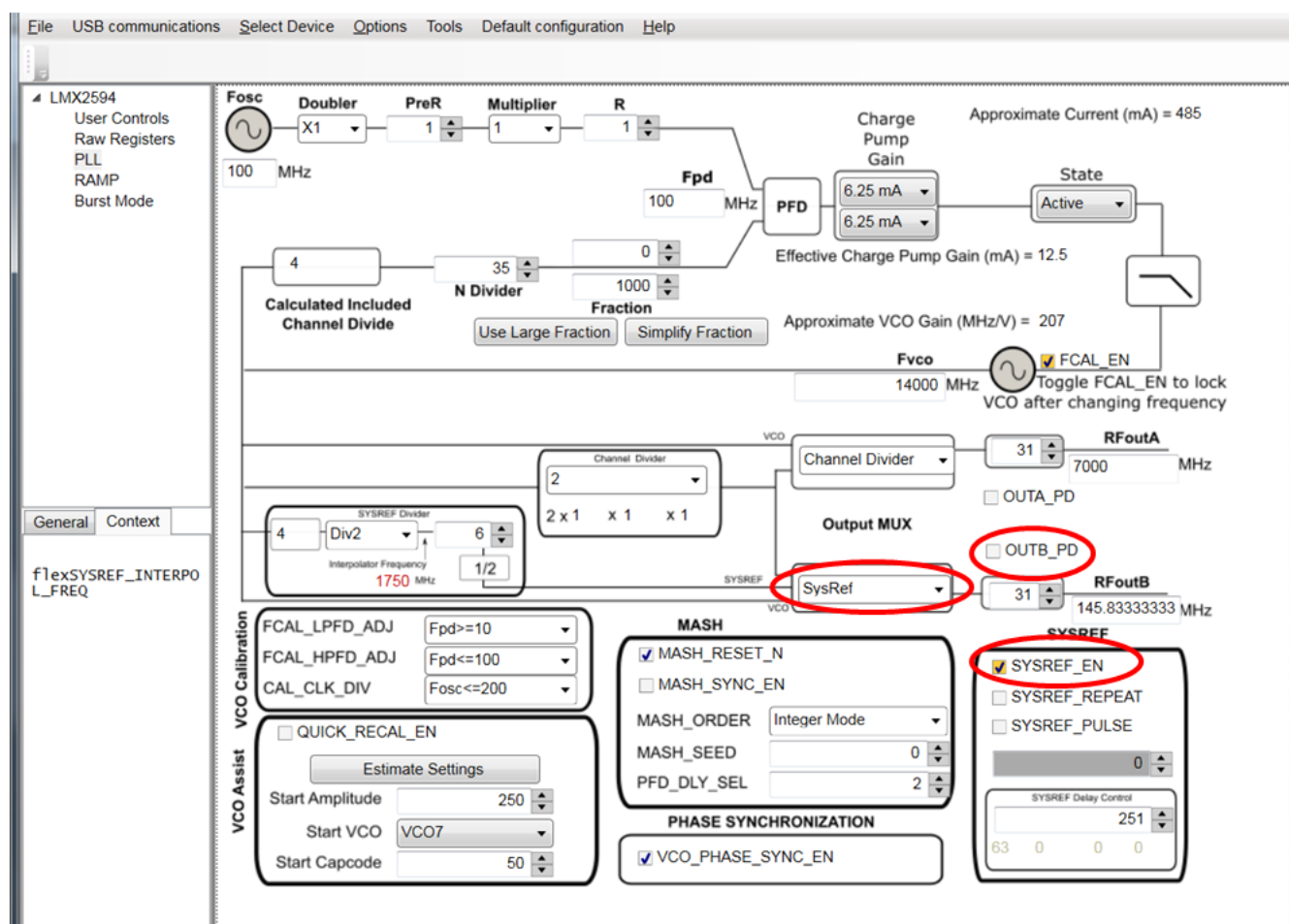


Figure 22. Configure and Enable SysRef

4. Confirm the *Interpolator Frequency* is between 800 MHz and 1500 MHz
 - If not, change the *SYSREF_DIV_PRE* drop-down to *Div2* or *Div4* to reach an appropriate *Interpolator Frequency* for the current configuration

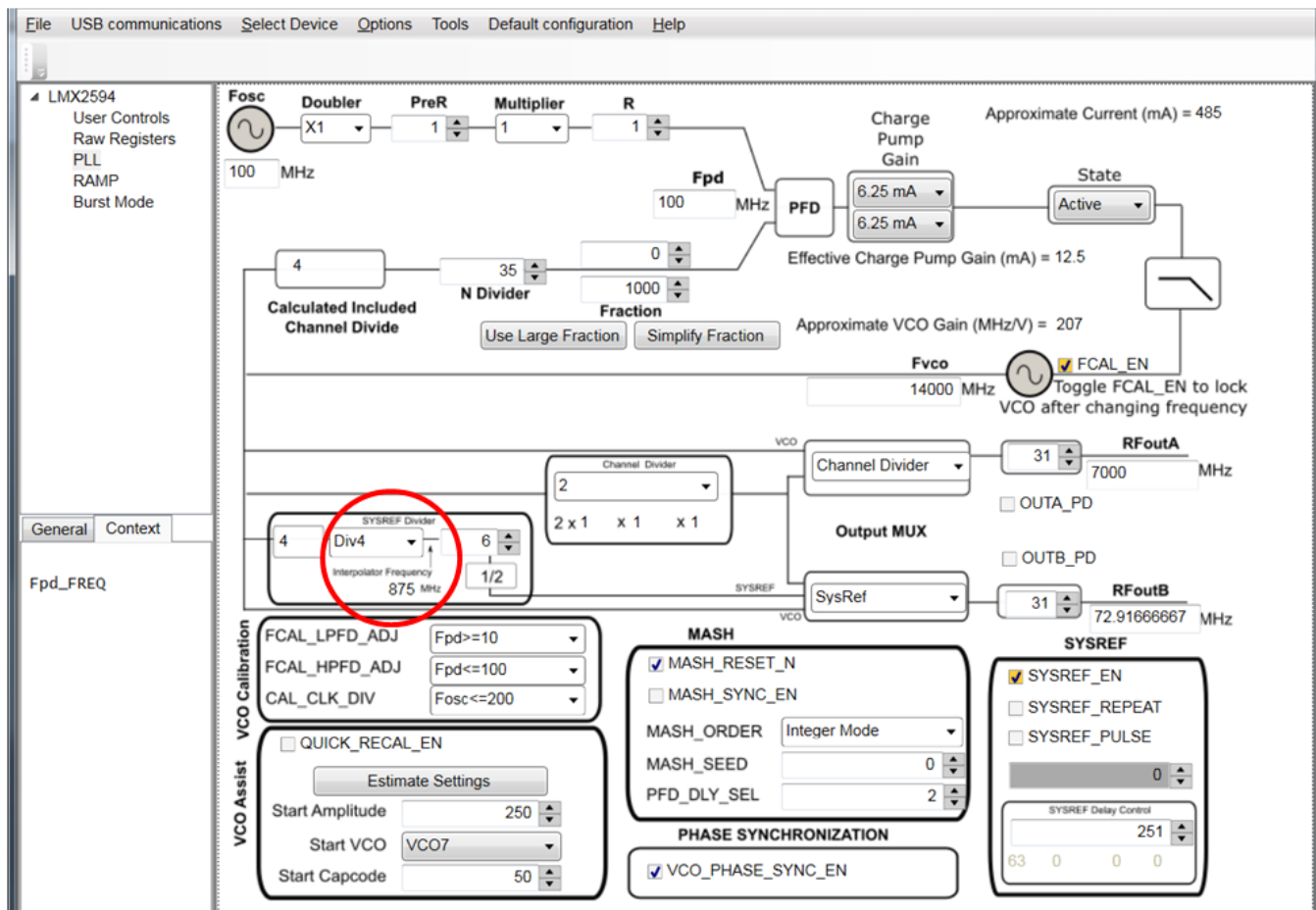


Figure 23. Interpolator Frequency For SysRef

- Go to *User Controls* in the side bar and check the *SysRefReq* box under the *Pins* section

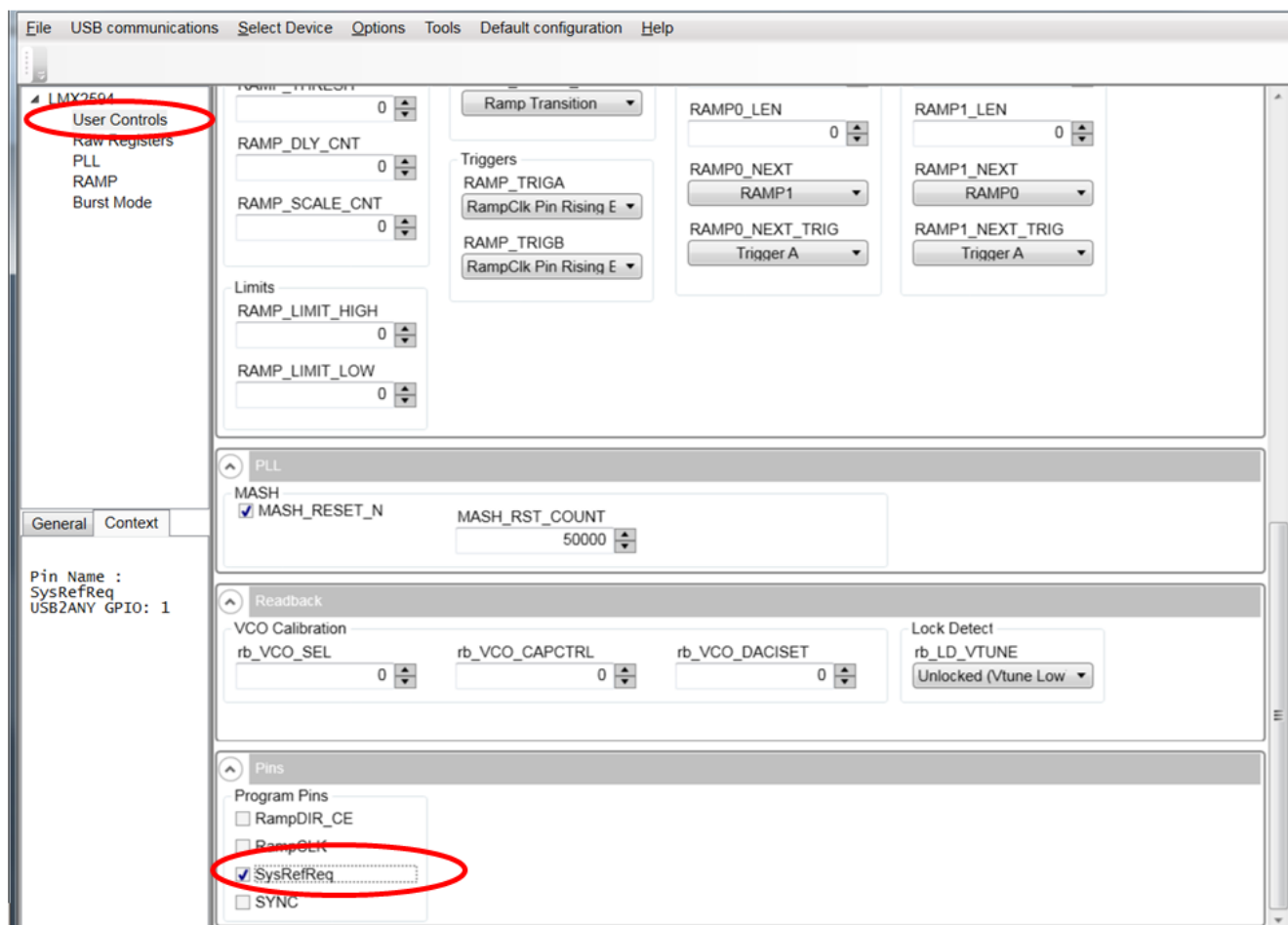


Figure 24. Check SysRefReq Box on User Controls Tab

6. To modify SysRef Frequency, change the value in the `SYSREF_DIV` box

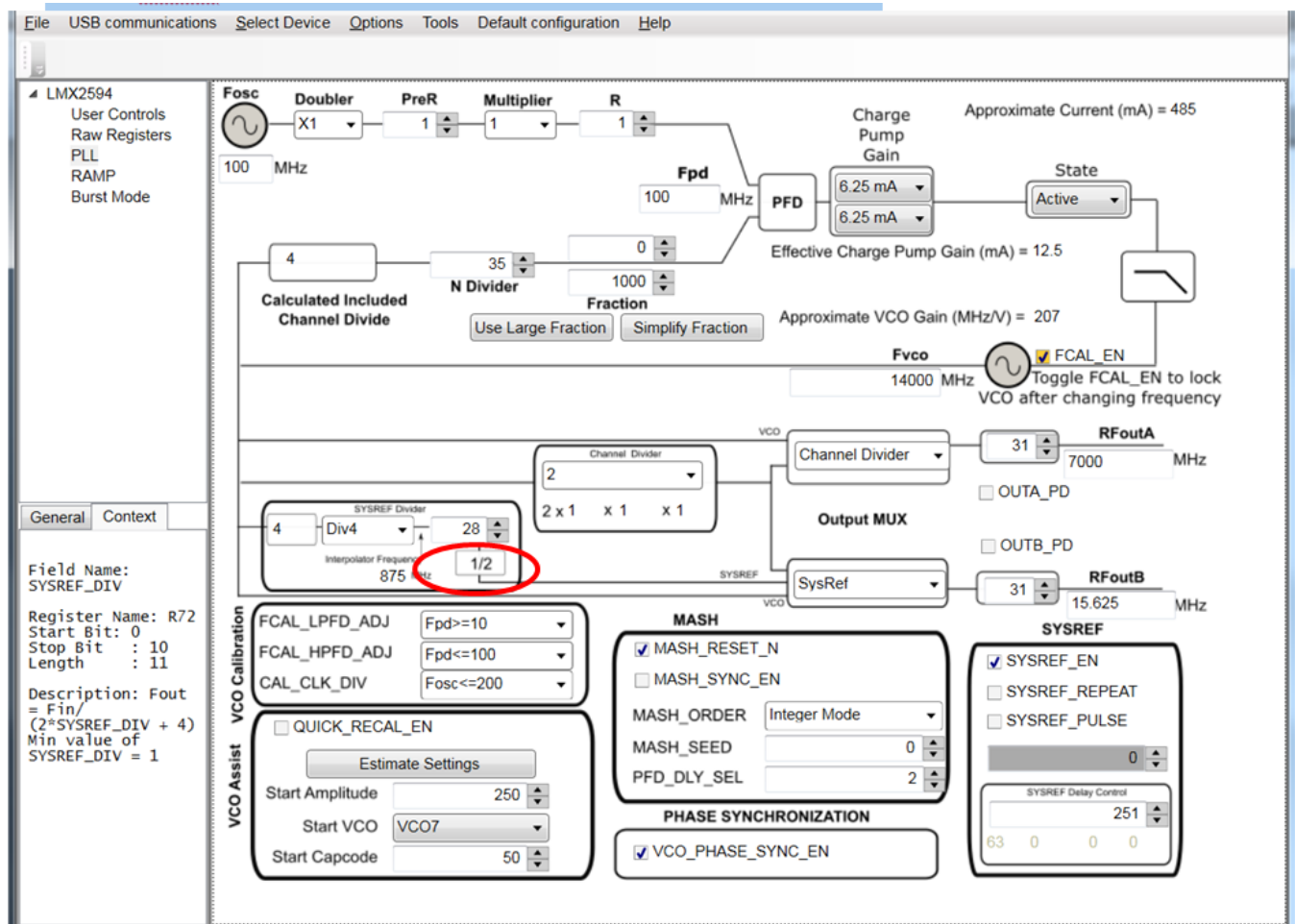


Figure 25. Modifying SysRef Frequency

Table 8. SysRef Modes

MODE NAME	DESCRIPTION	TICS PRO - SYS REF SETTINGS
Master - Continuous	LMX2594 generates SysRef pulses as long as SysRefReq pin is held high.	Default mode. See quick start instructions
Master - Pulse	LMX2594 generates a finite number of pulses as long as the SysRefReq pin is held high. Note: SysRefReq must be held high for the duration of the pulses.	<ul style="list-style-type: none"> Uncheck <i>SysRefReq</i> under <i>Pins</i> in <i>User Controls</i> tab Check <i>SYSREF_PULSE</i> Set <i>SYSREF_PULSE_CNT</i> to desired number of pulses Check <i>SysRefReq</i> under <i>Pins</i> in <i>User Controls</i> tab
Repeater	RFOUTB will repeat external input to SysRefReq pin. Output will be reclocked to LMX2594 internal Frequency	<ul style="list-style-type: none"> Uncheck <i>SysRefReq</i> Check <i>SysRef_Repeat</i>

VCO Calibration

1. Connect an oscilloscope probe (high impedance) to MUXout of the device
2. Set trigger to about the center of the MUXout swing (approximately 1.6 V)
3. Set MUXOUT_SEL register R0[2] to a value of 1 for lock detect
4. Set your desired output frequency to lock to
5. Trigger the calibration with FCAL_EN register R0[3] to a value of 1
6. Observe the triggered pulse, there should be a pulse from MUXout digital HIGH to LOW and back to HIGH (the low indicates the instant calibration is triggered and running, then high is when done calibration). Adjust the time scale to capture the pulse (approximately 300 μ s to start)

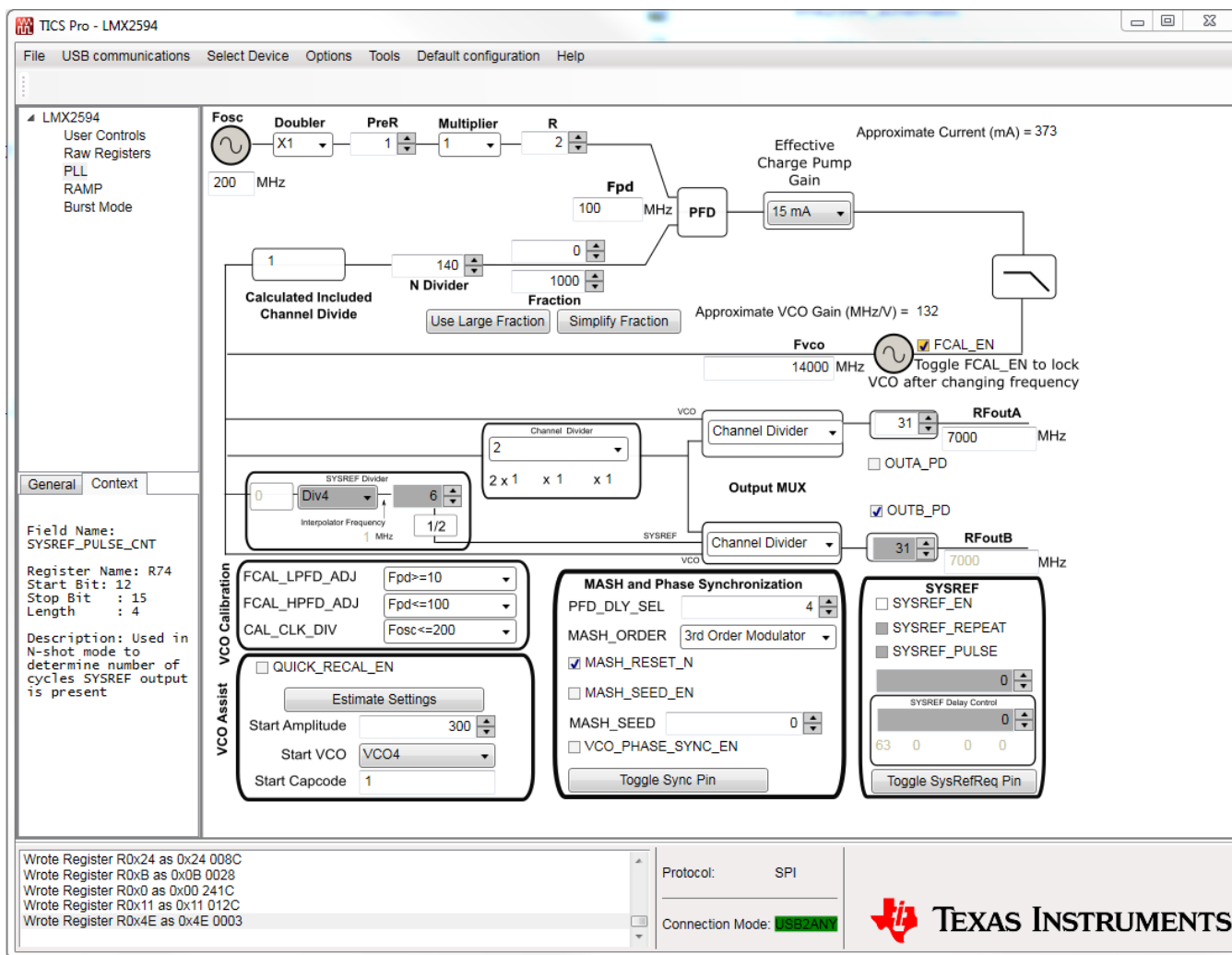


Figure 26. Unassisted Calibration TICS

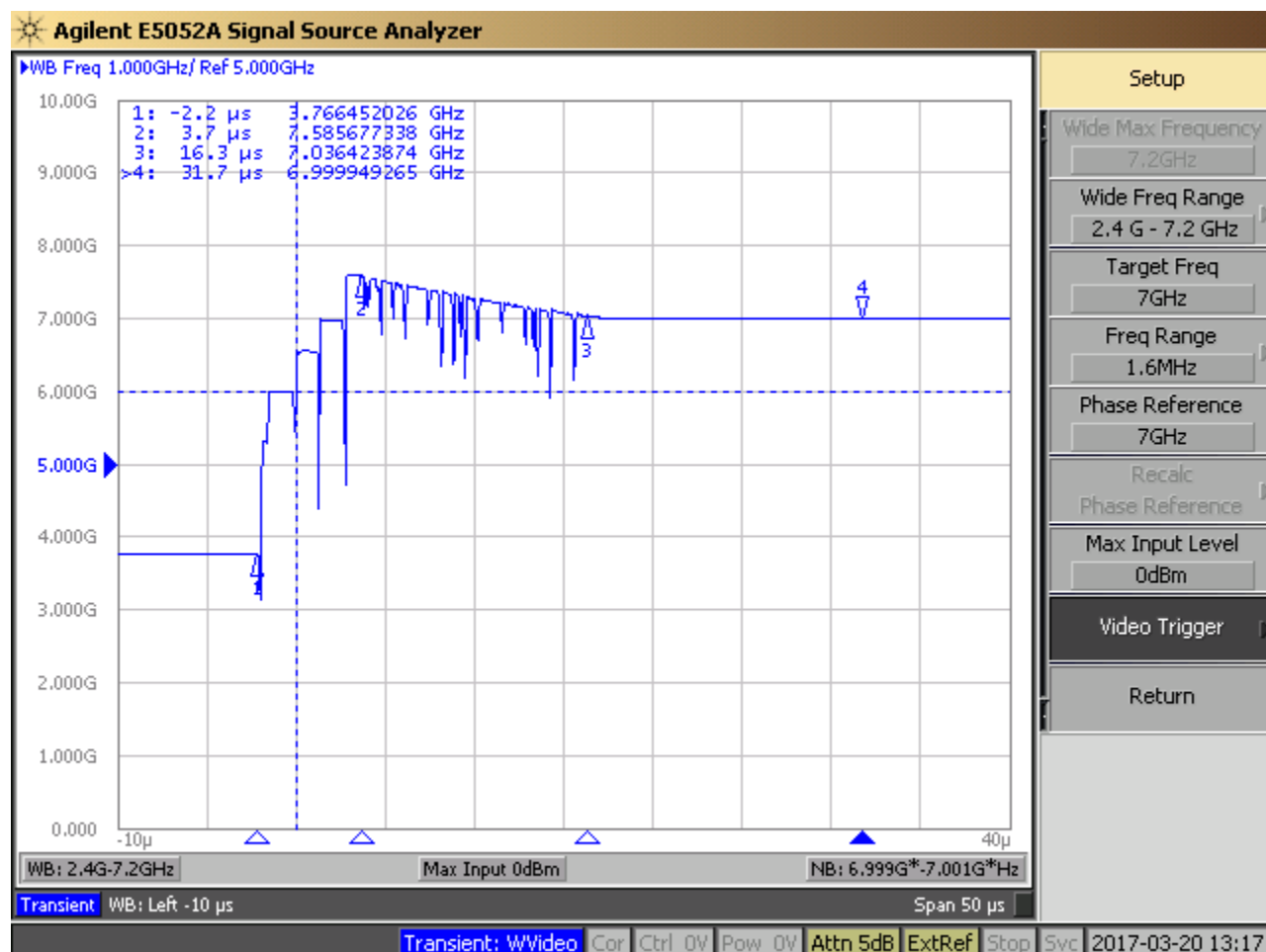


Figure 27. Unassisted Calibration Plot

Enabling Onboard DC-DC Buck Converter (TPS62150)

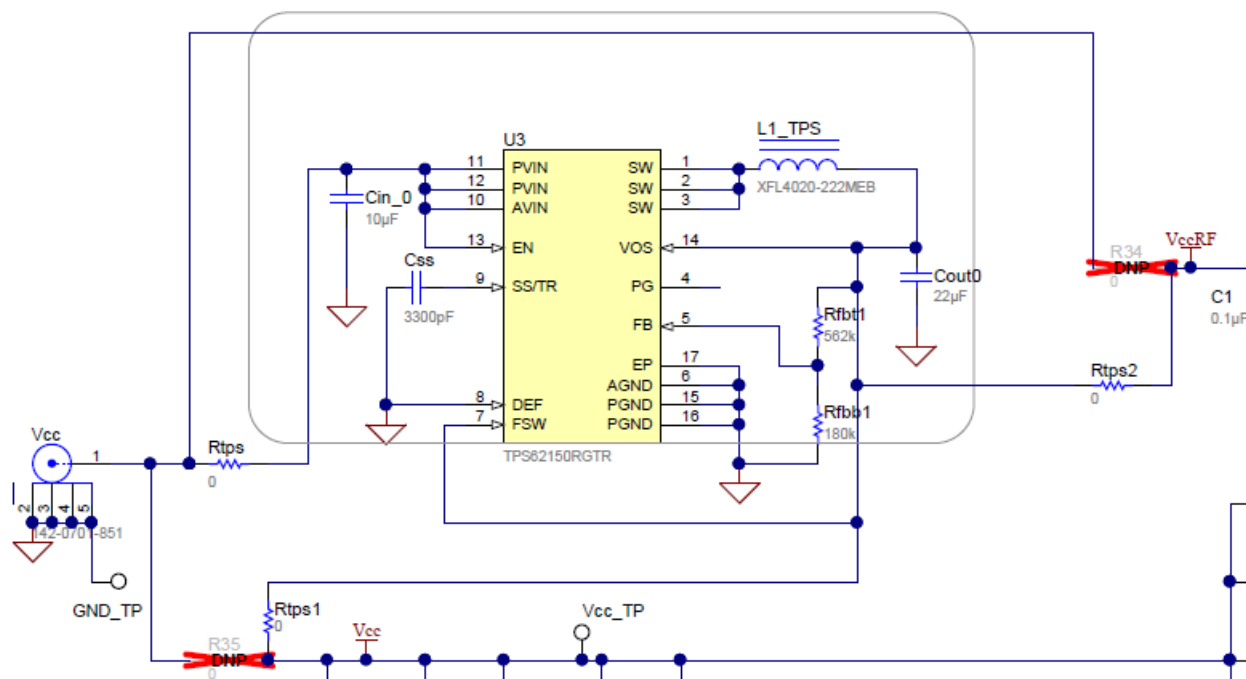


Figure 28. Resistor Configuration to Enable DC-DC

1. MUST SWITCH R35 to Rtps1
2. MUST SWITCH R34 to Rtps2
3. Populate Rtps
4. DC-DC circuitry was optimized for efficiency for 5 to 8 V, but a voltage of 3.3 V to 17 V can be applied to VCC SMA after resistor network is configured correctly from steps above.

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