

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

## **User's Guide**



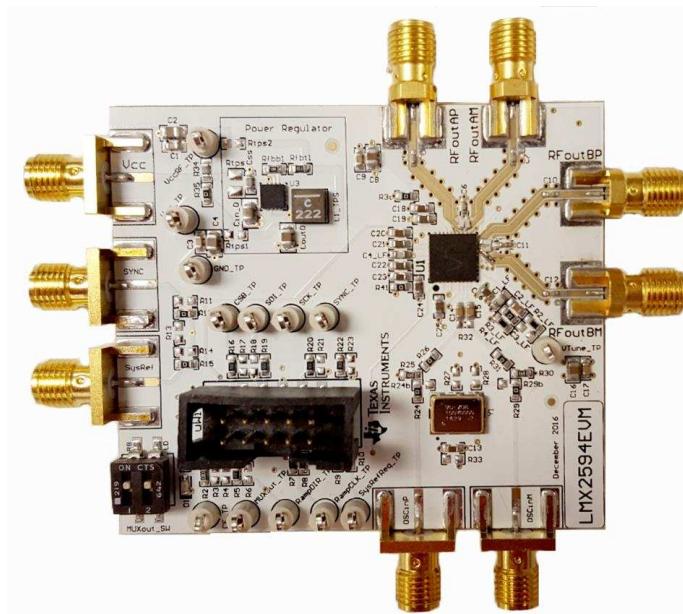
Literature Number: SNAU210

March 2017

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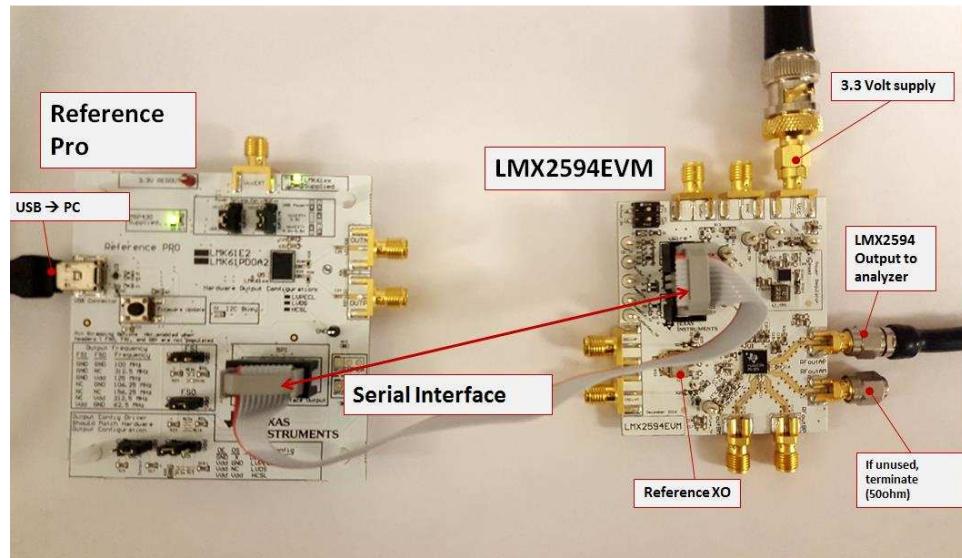
## **LMX2594 EVM Instructions – 15-GHz Wideband Low Noise PLL With Integrated VCO**



**Figure 1. LMX2594EVM**

### **1 Trademarks**

## 2 Evaluation Board Setup

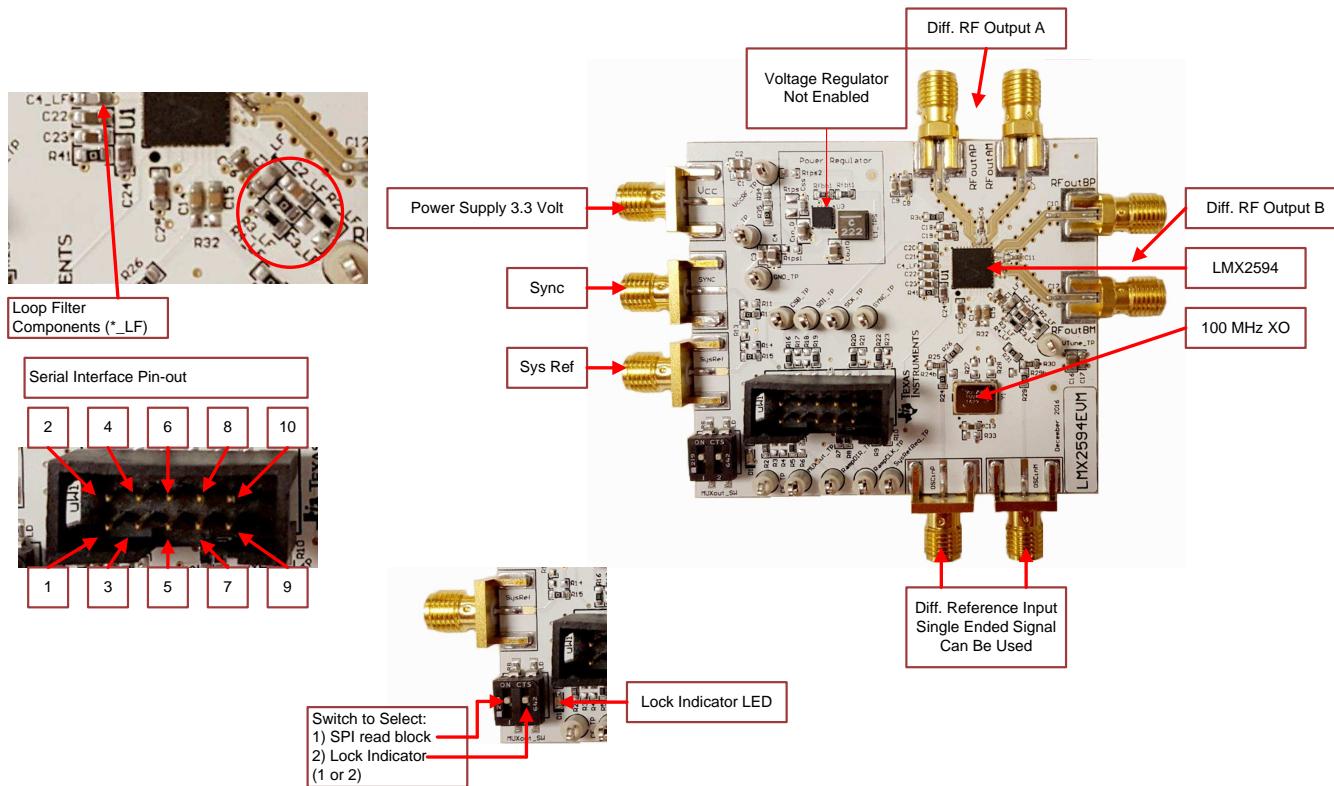


**Figure 2. LMX2594EVM Setup**

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  $50\Omega$  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:

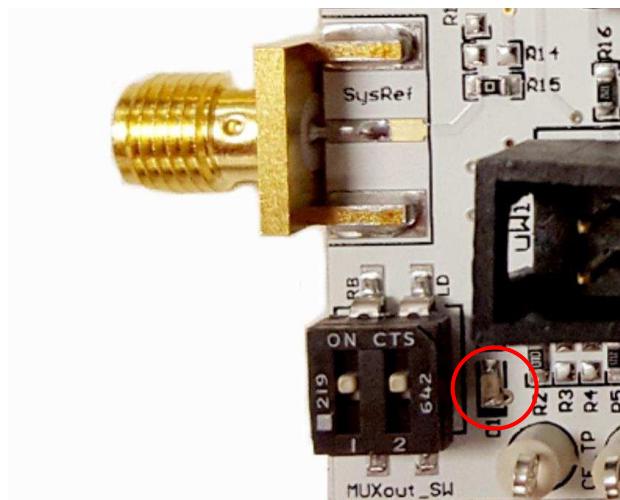
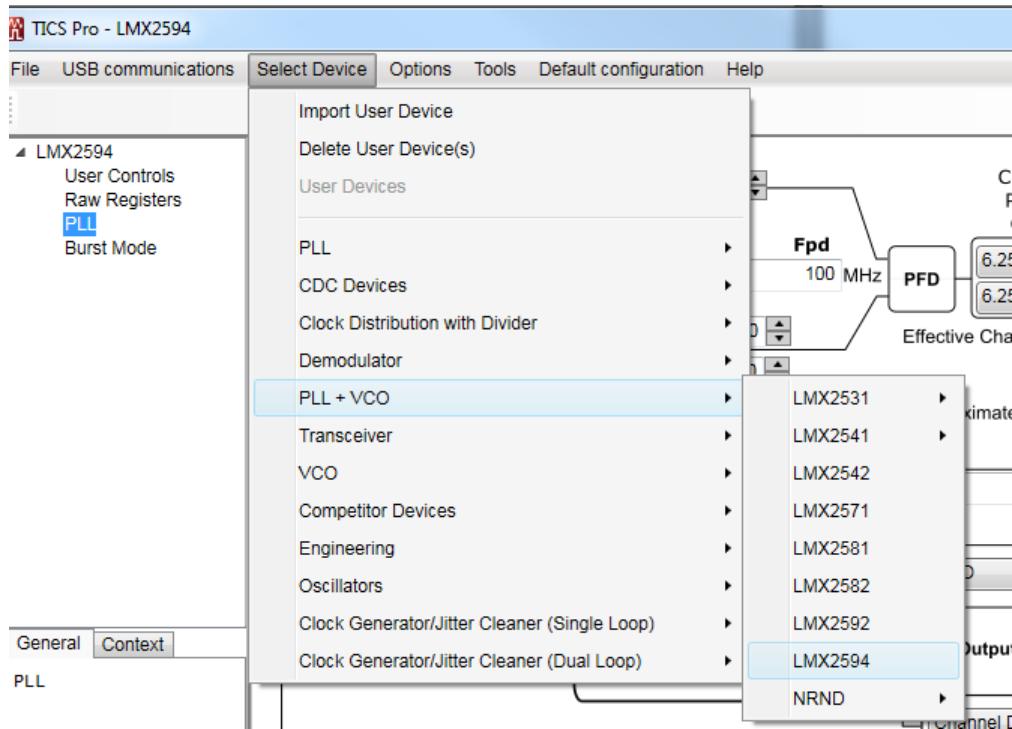


Figure 4. LD Lock Detect

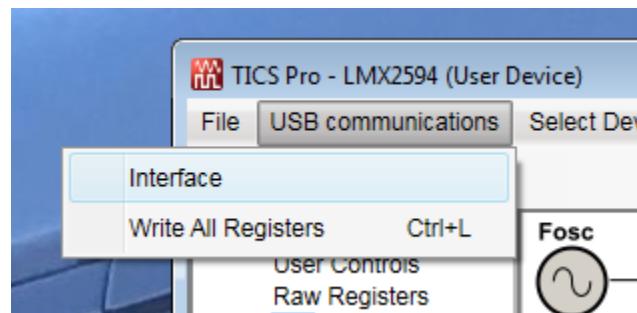
### 3.1 Installing the Software

1. Download TICS Pro from the TI Website at [www.ti.com/tool/TICSPRO-SW](http://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



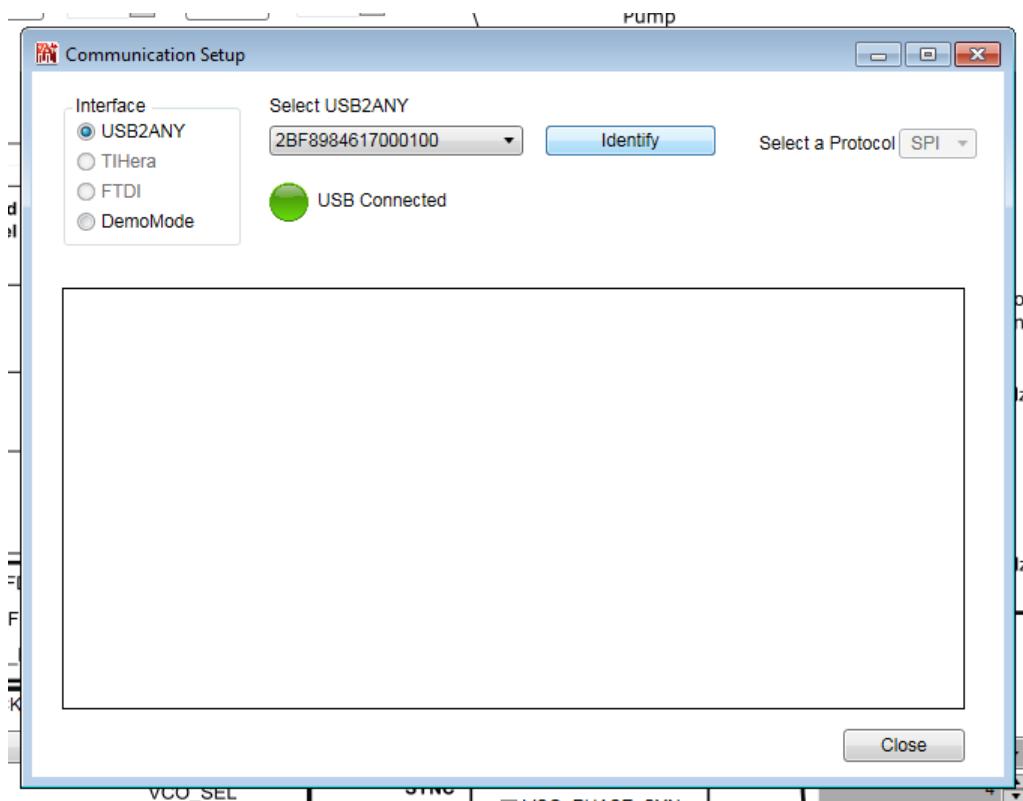
**Figure 5. Search for LMX2594 on TICS Pro**

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**

5. 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](#):

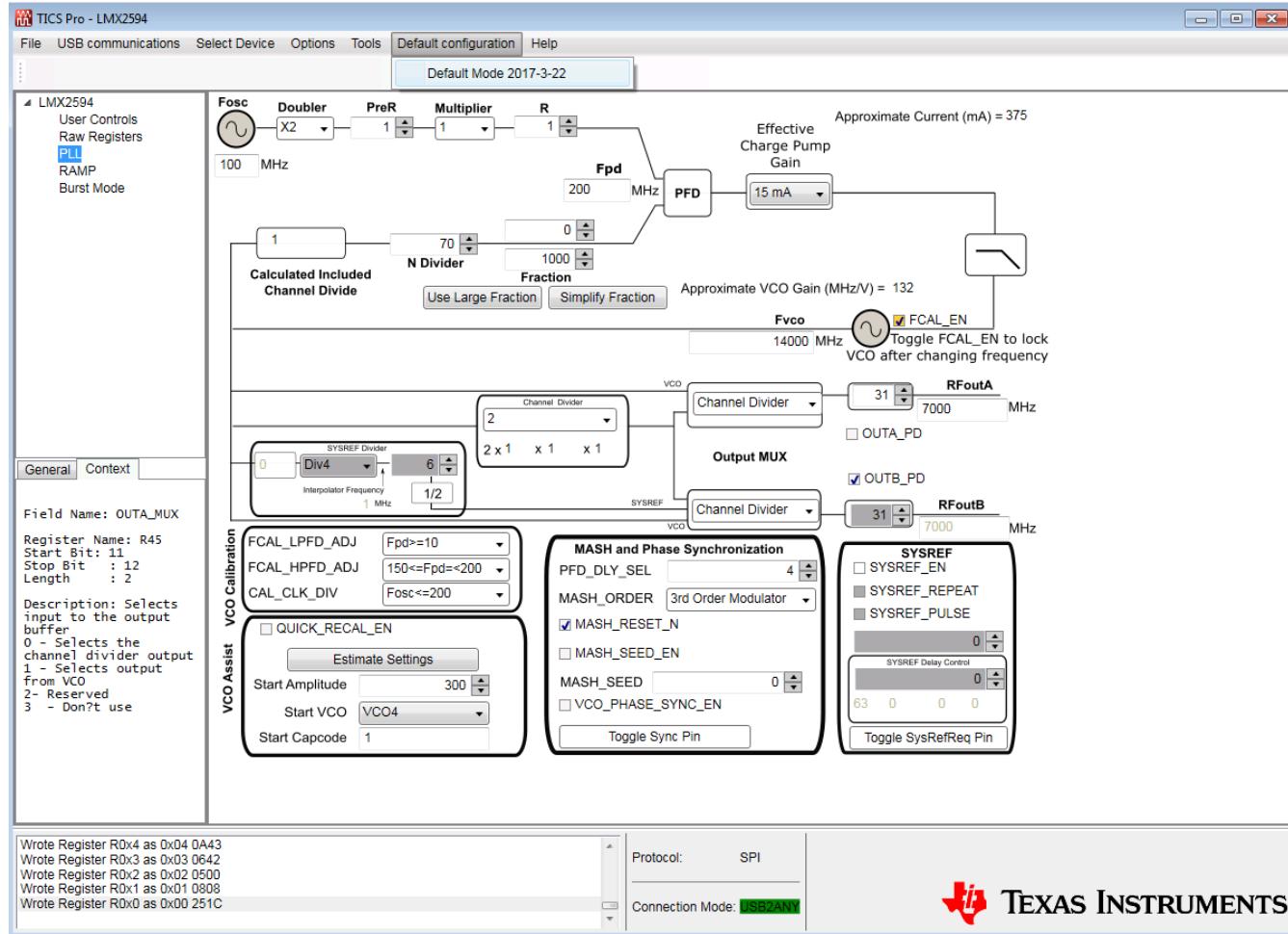
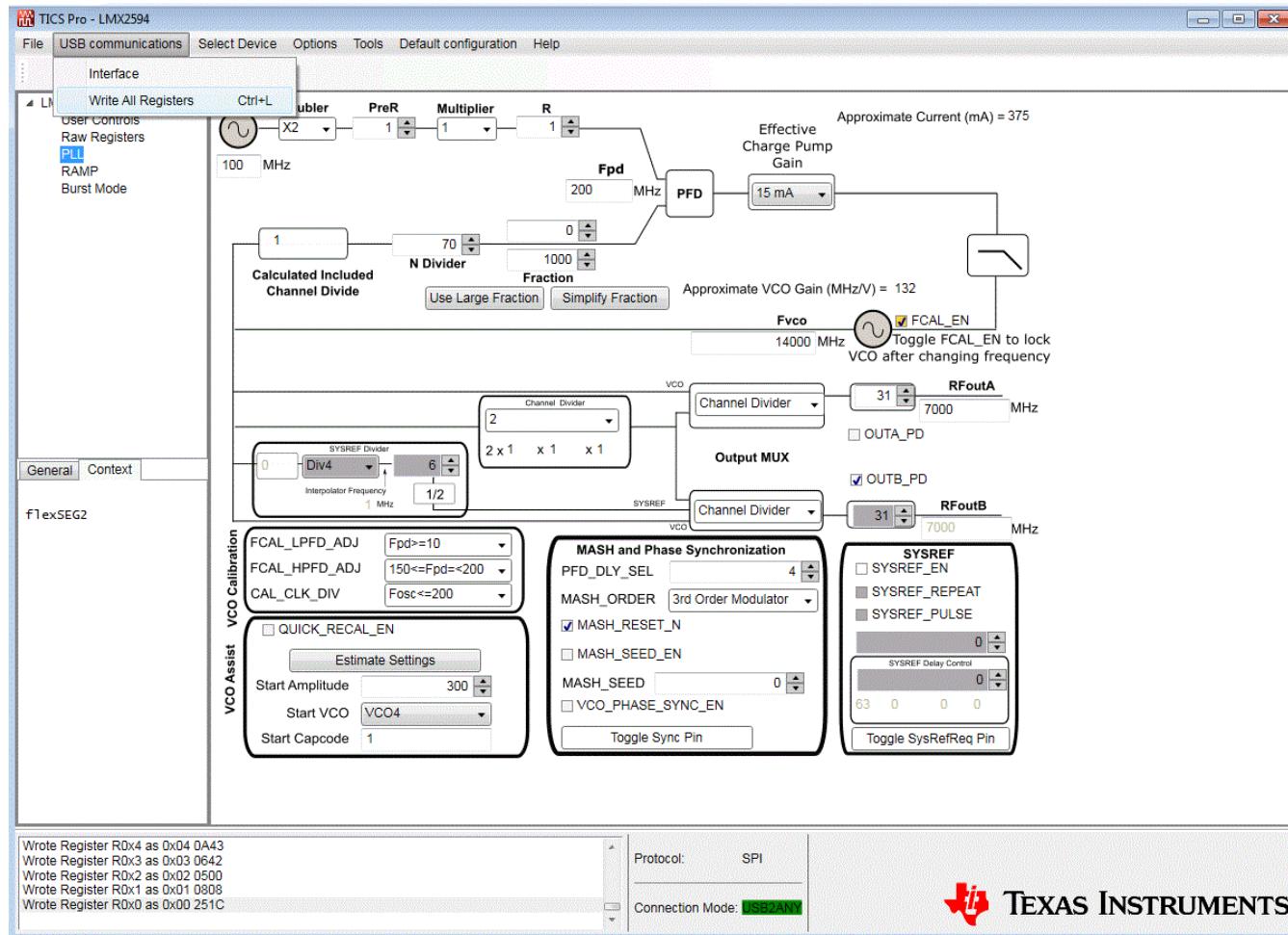


Figure 8. TICS Pro GUI LMX2594 Default Configuration

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:



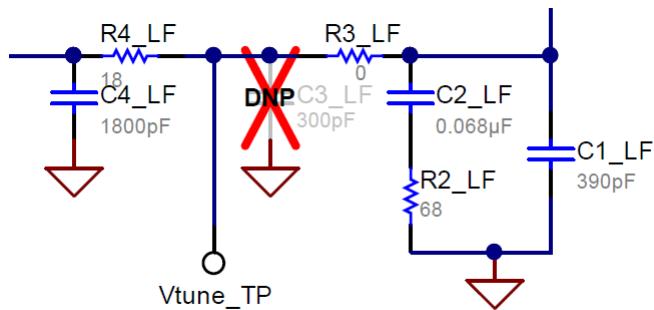
**Figure 9. TICS Pro Write All Registers**

## 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

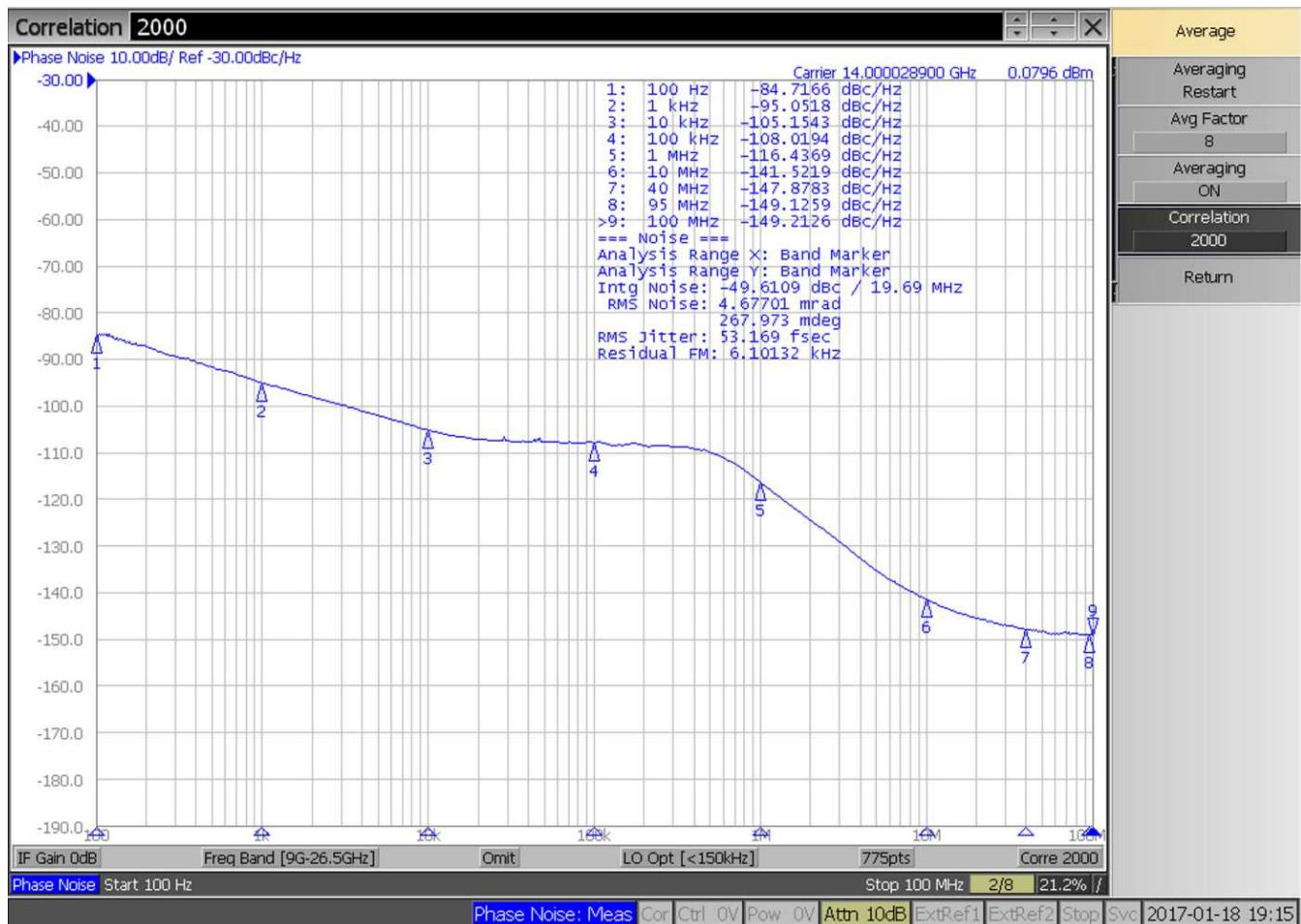


**Figure 10. Current Loop Filter Configuration**

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>.

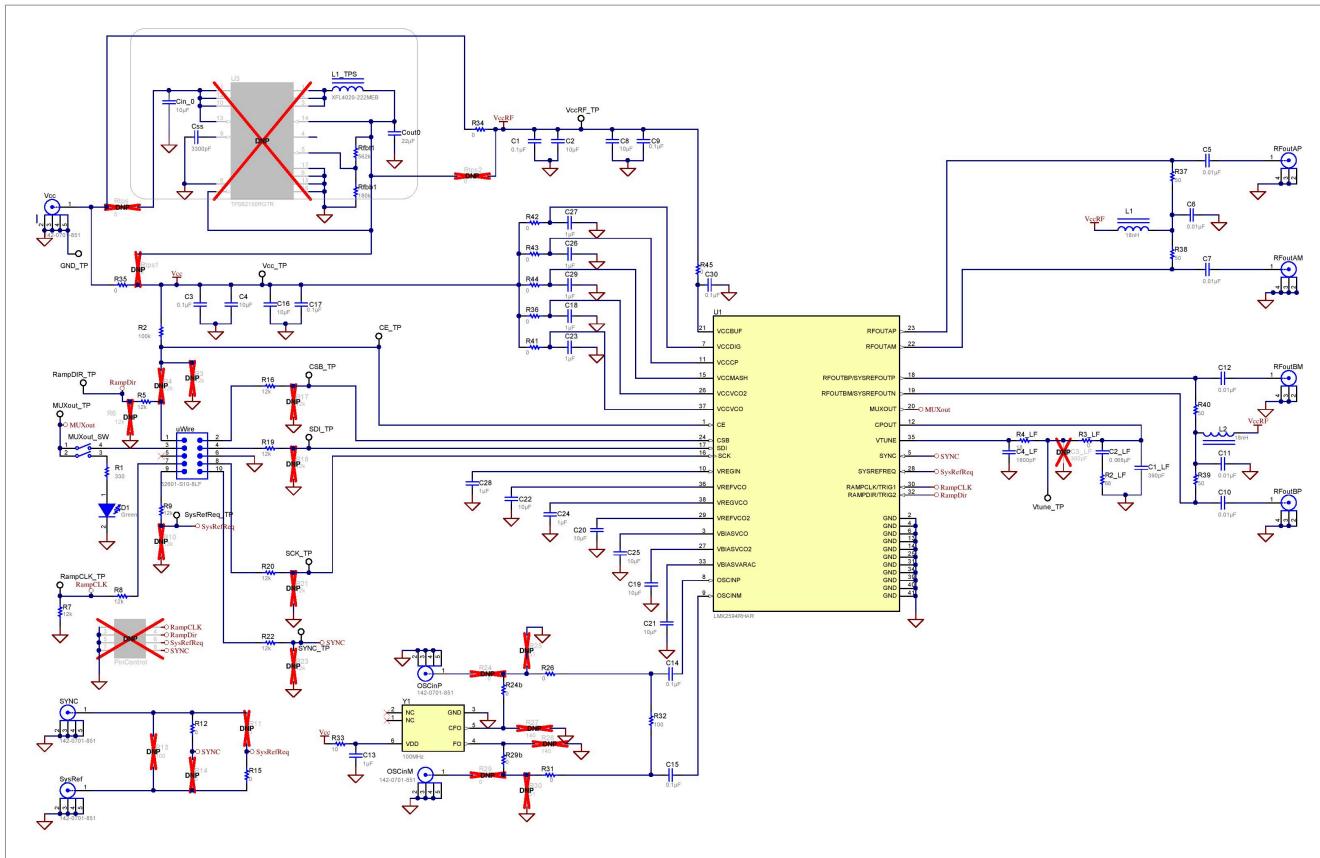
## 6 Key Results to Expect



**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 $\mu$ 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 $\mu$ F, 10 V, $\pm$ 10%, X5R, 0805	Kemet	C0805C106K8PACTU	4
C2_LF	CAP, CERM, 0.068 $\mu$ 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 $\mu$ F, 16 V, $\pm$ 10%, X7R, 0402	AT Ceramics	520L103KT16T	6
C13, C18, C23, C24, C26, C27, C28, C29	CAP, CERM, 1 $\mu$ F, 16 V, $\pm$ 10%, X7R, 0603	TDK	C1608X7R1C105K080AC	8
C19, C20, C21, C22, C25	CAP, CERM, 10 $\mu$ 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 $\mu$ F, 25 V, $\pm$ 10%, X5R, 0805	MuRata	GRM219R61E106KA12D	1
Cout0	CAP, CERM, 22 $\mu$ 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 $\Omega$ , SMD	MuRata	LQG15HS18NJ02D	2
L1_TPS	Inductor, Shielded, Composite, 2.2 $\mu$ H, 3.7 A, 0.02 $\Omega$ , 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
OSCIinM, OSCIinP, 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 kΩ, 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
Rfb1	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	Vectorn	VC-708-EDE-FNXN- 100M000000	1
C3_LF	CAP, CERM, 300 pF, 100 V, ±5%, COG/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 kΩ, 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, 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.

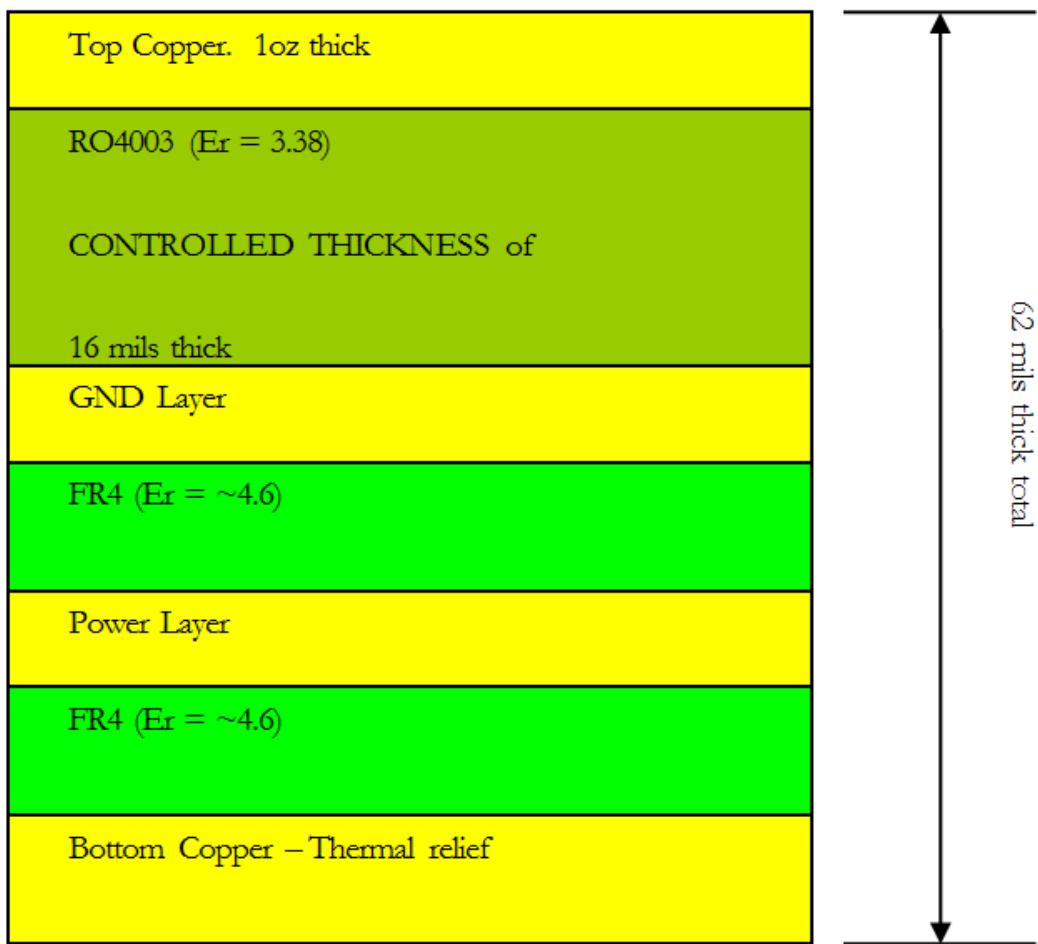


Figure 13. Board Layer Stack-Up

## ***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 <sup>(1)</sup>				
Offset [Hz]	100	1k	10k	100k
Noise level [dBc/Hz]	−139	−149	−159	−164

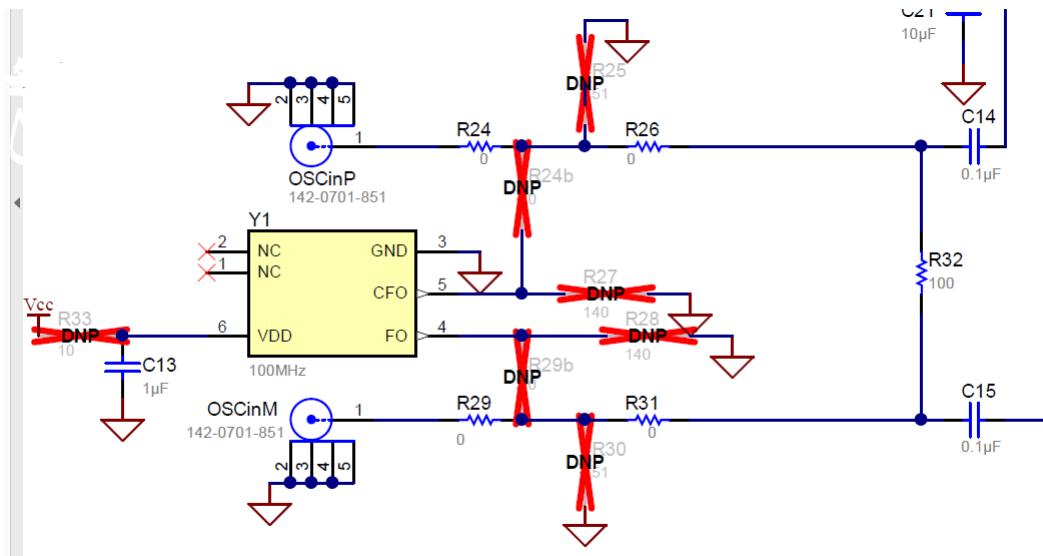
(1) A noise source 10 dB down from the PLL noise will contribute to raise the noise by 0.4 dB.

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<sub>cc</sub> or Gnd will degrade the phase noise performance of LMX2594.

For differential pair connection:

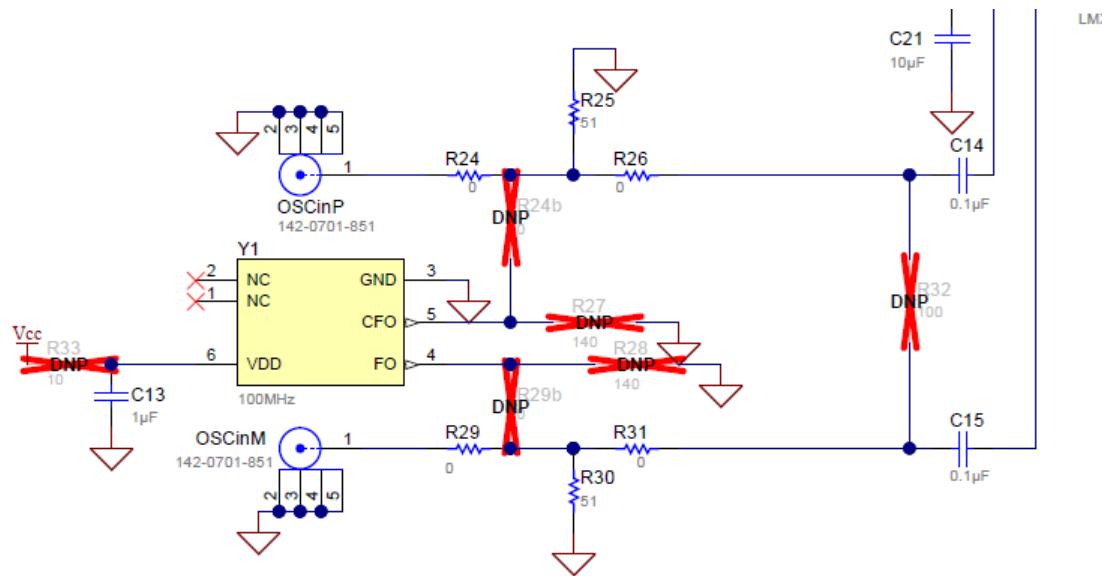
1. Switch R24b to R24.
  2. Switch R29b to R29
  3. Must remove R33 to remove power from oscillator



**Figure 14. Single-Ended Reference Configuration**

For single-ended:

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



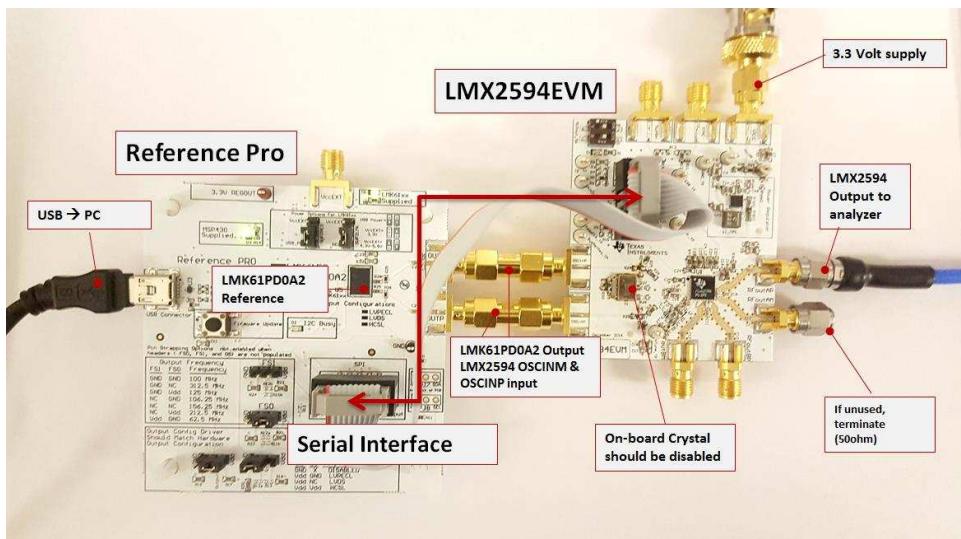
**Figure 15. Differential Reference Configuration**

## 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 LMK61PD0A2 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-k $\Omega$  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. Output Type 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](#).

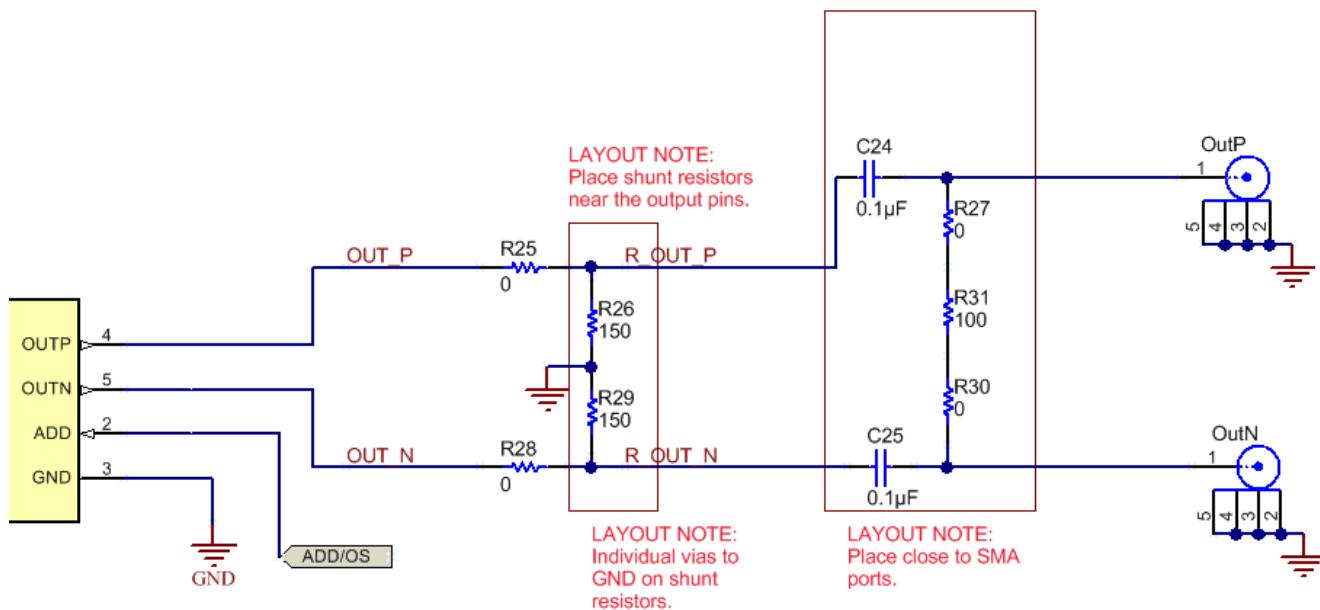
[Table 7](#) lists component values for each configuration.

**Table 7. Output Termination Schemes**

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

<sup>(1)</sup> 50 Ω to V<sub>CC</sub> – 2? V termination is required on receiver.

<sup>(2)</sup> 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 divided by 4 so that it can be seen with the HP53310A. This can be set up on the ramp GUI tab.

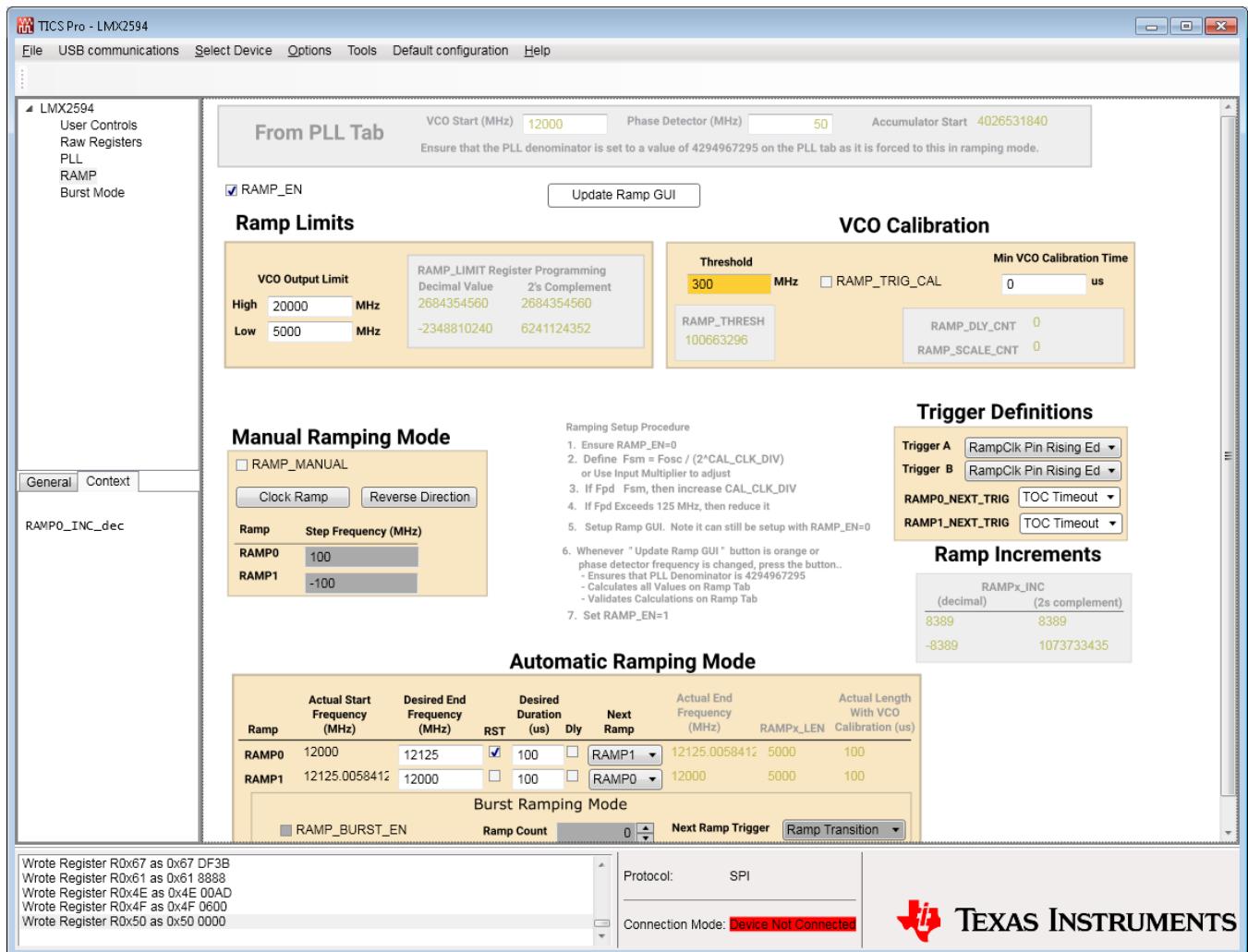
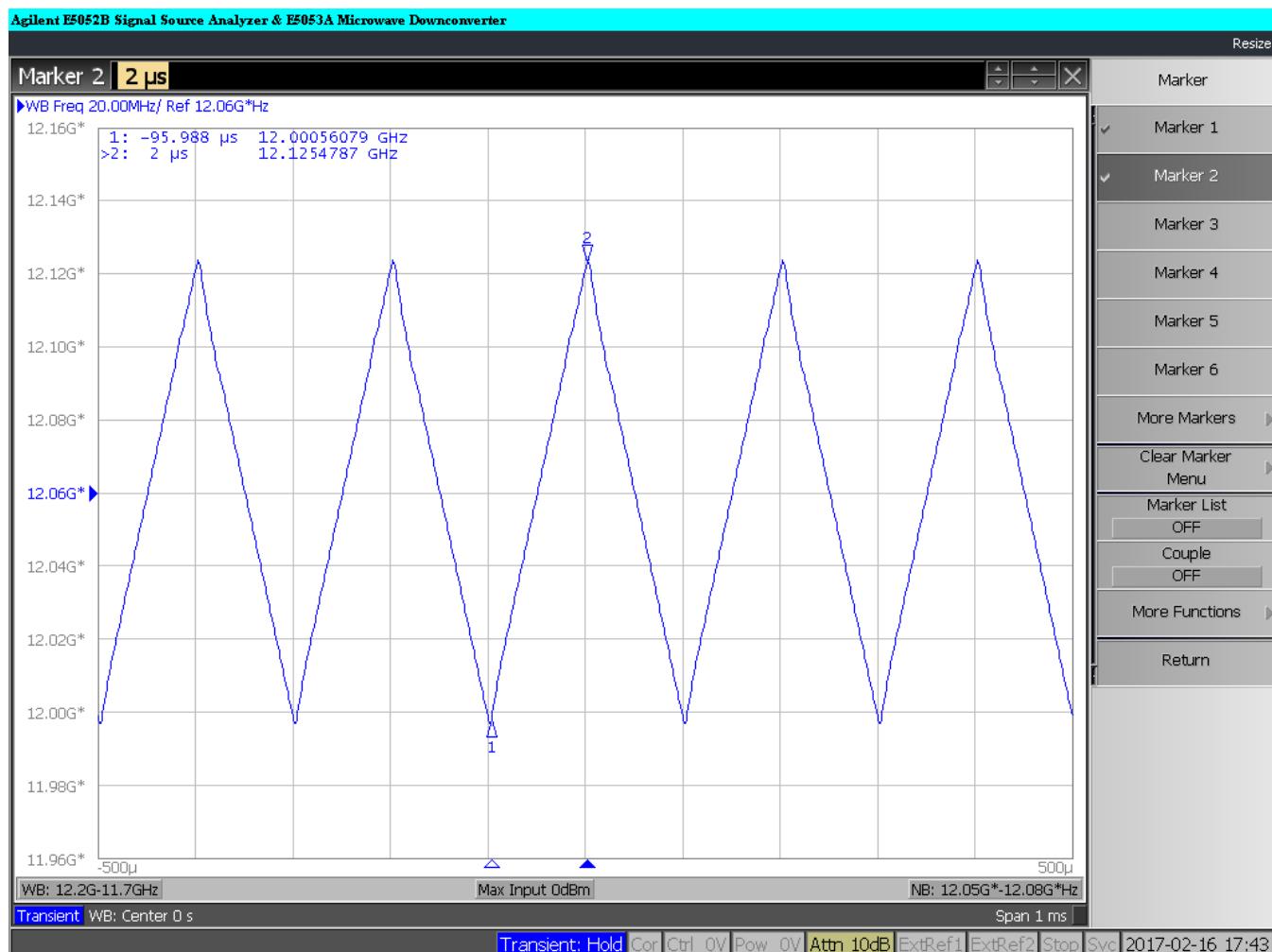


Figure 19. Ramping Example Tics

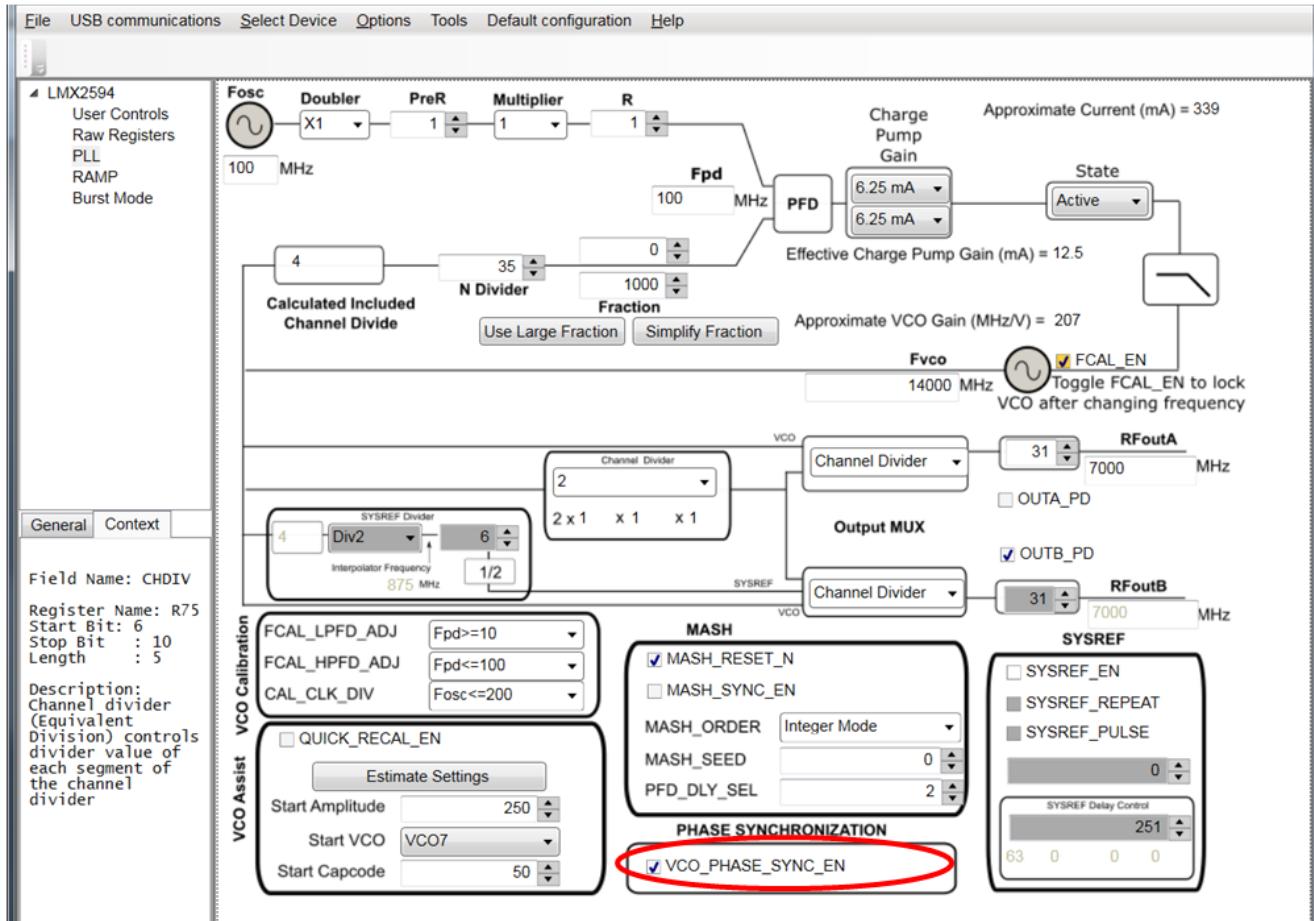


**Figure 20. Ramping Example**

## SYSREF Feature

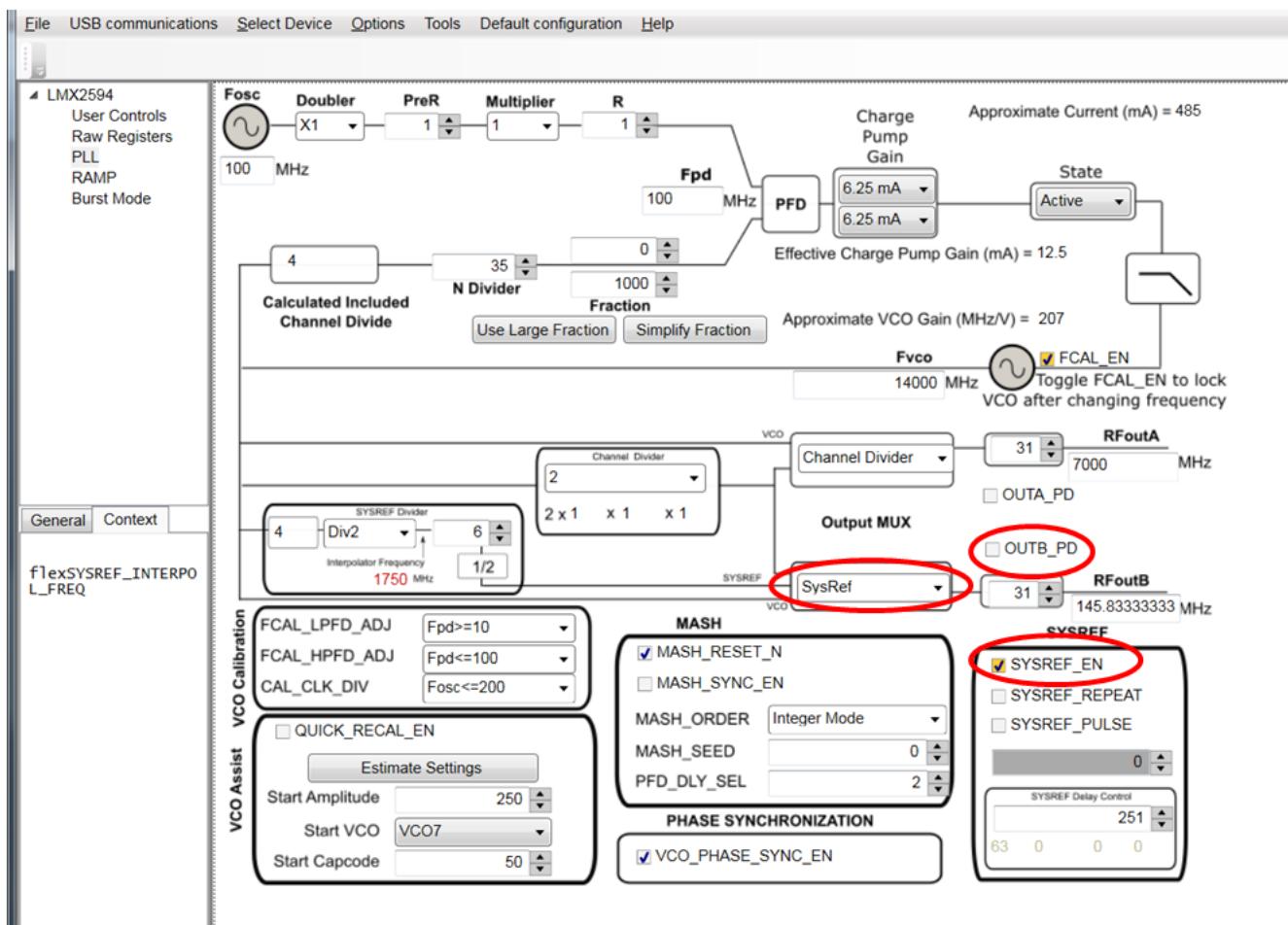
1. Bring LMX2594 to a Lock State

2. Perform Sync



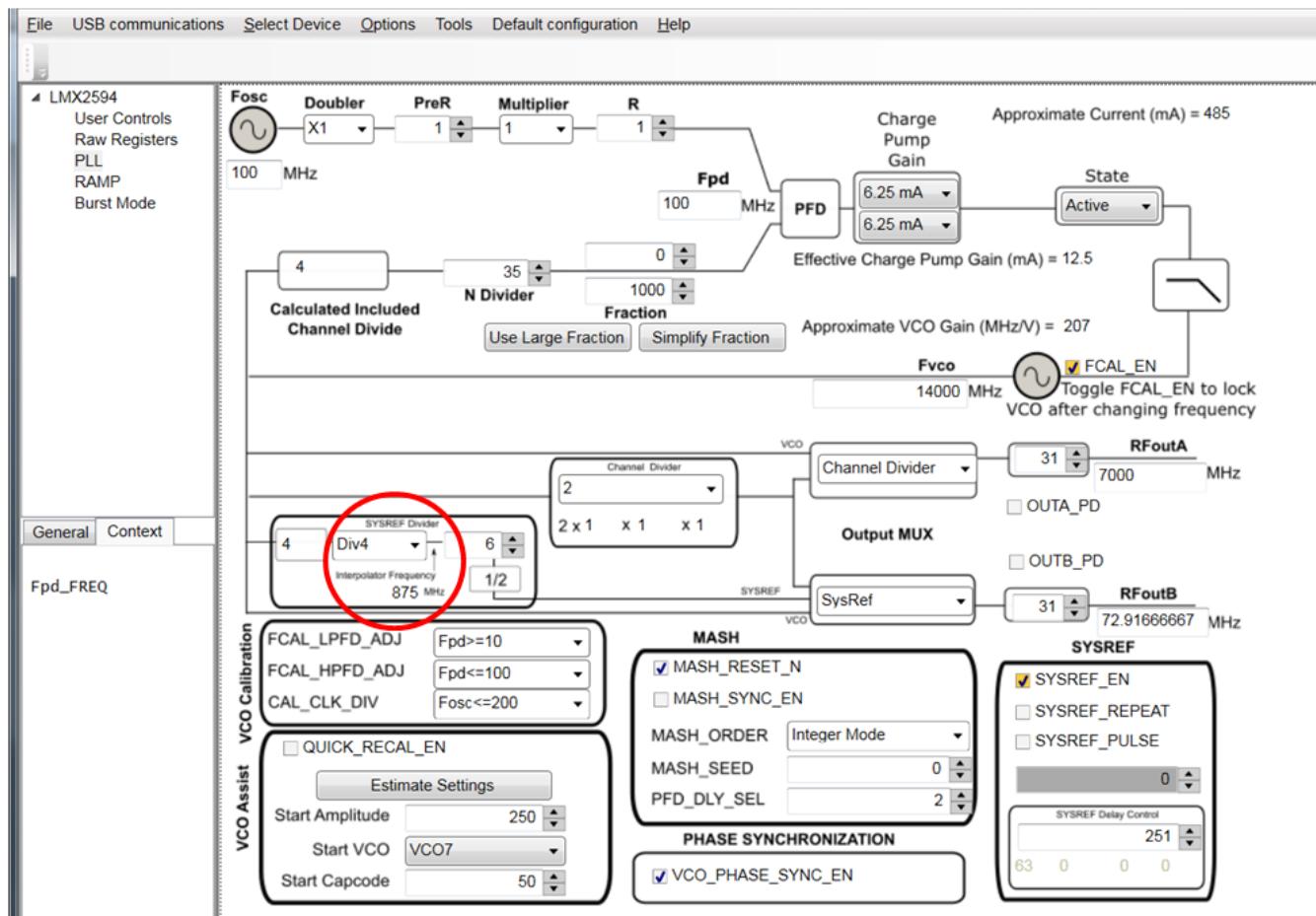
**Figure 21. Perform Sync For SysRef**

3. Configure TICS Pro *PLL* tab for SysRef
  - Check the *SYSREF\_EN* box
  - Change *OUTB\_MUX* to *SysRef*
  - Uncheck the *OUT\_PD* box



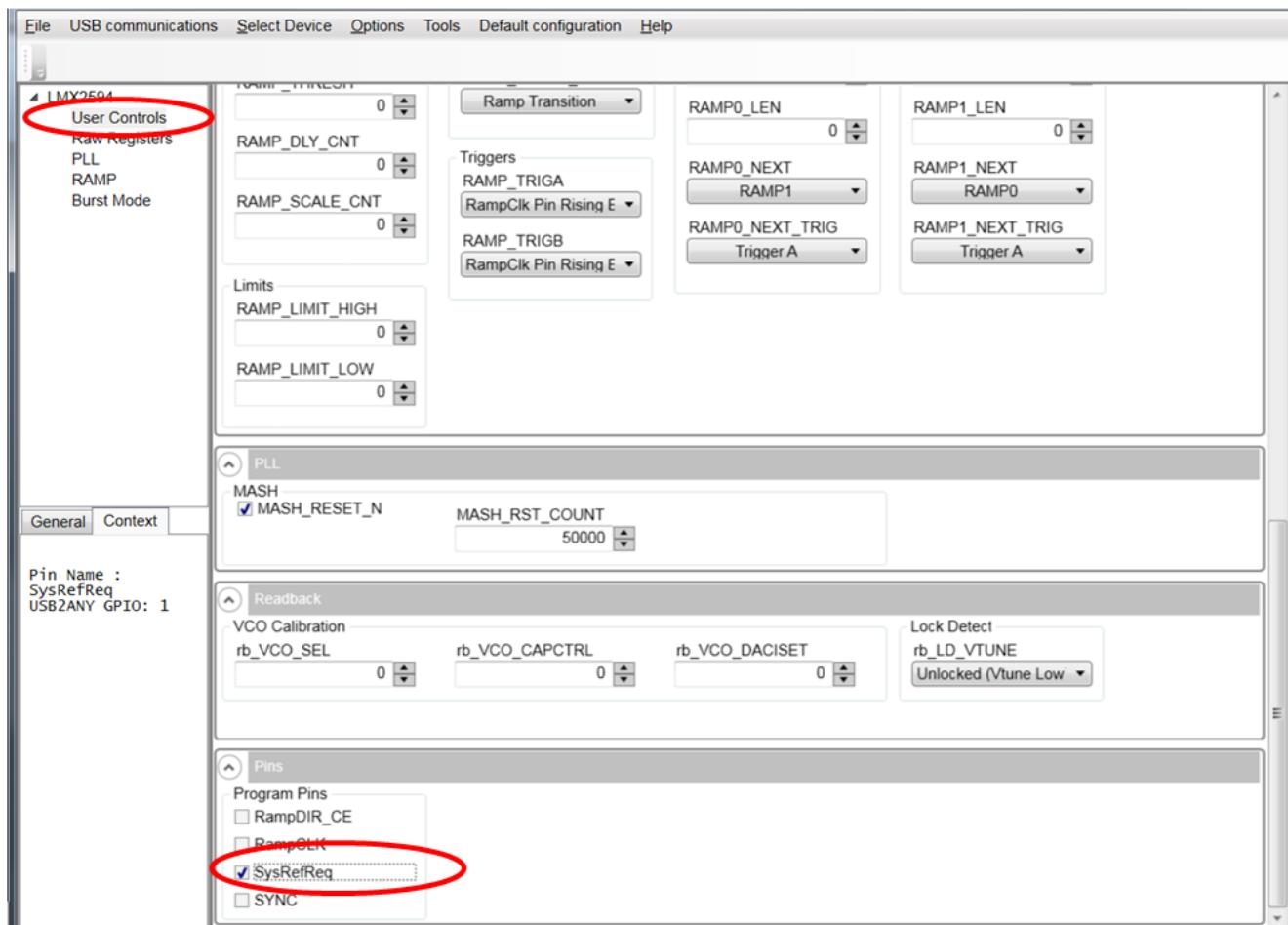
**Figure 22. Configure and Enable SysRef**

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**

5. 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

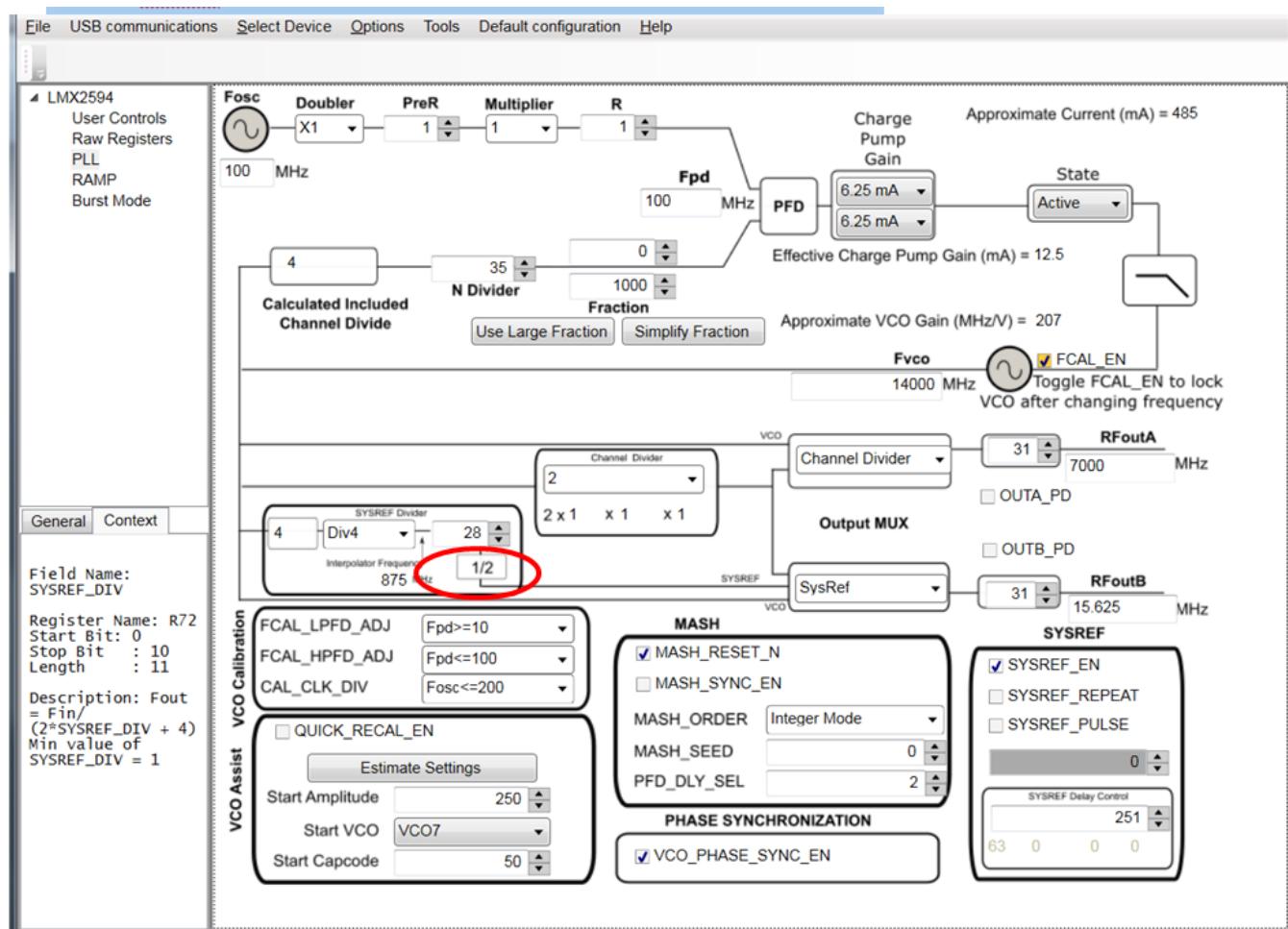


Figure 25. Modifying SysRef Frequency

Table 8. SysRef Modes

MODE NAME	DESCRIPTION	TICS PRO - SYS REF SETTINGS
Master - Continuos	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. <b>Note: SysRefReq must be held high for the duration of the pulses.</b>	<ul style="list-style-type: none"> <li>Uncheck SysRefReq under Pins in User Controls tab</li> <li>Check SYSREF_PULSE</li> <li>Set SYSREF_PULSE_CNT to desired number of pulses</li> <li>Check SysRefReq under Pins in User Controls tab</li> </ul>
Repeater	RFOUTB will repeat external input to SysRefReq pin. Output will be reclocked to LMX2594 internal Frequency	<ul style="list-style-type: none"> <li>Uncheck SysRefReq</li> <li>Check SysRef_Repeat</li> </ul>

## 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  $\mu$ s to start)

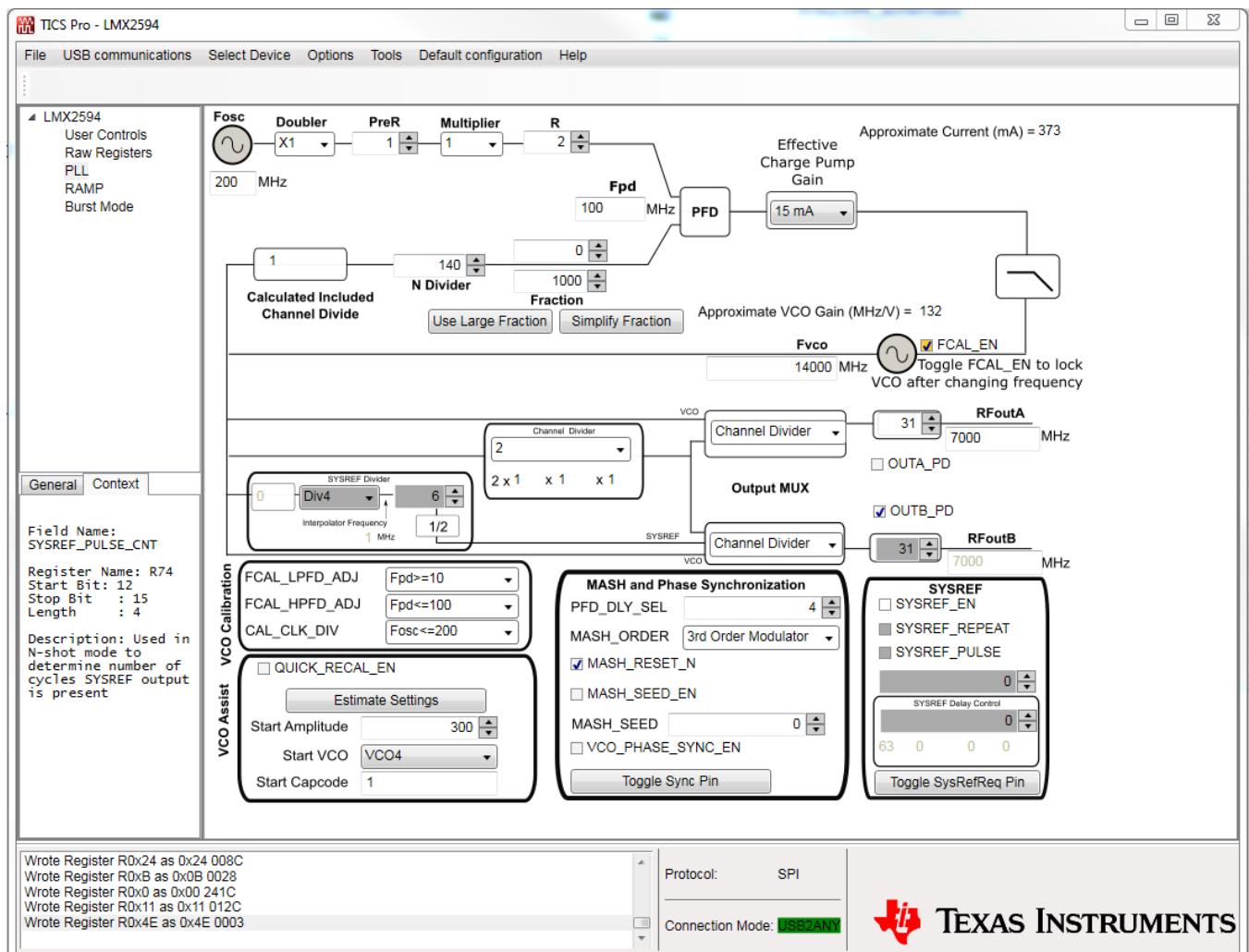


Figure 26. Unassisted Calibration TICS

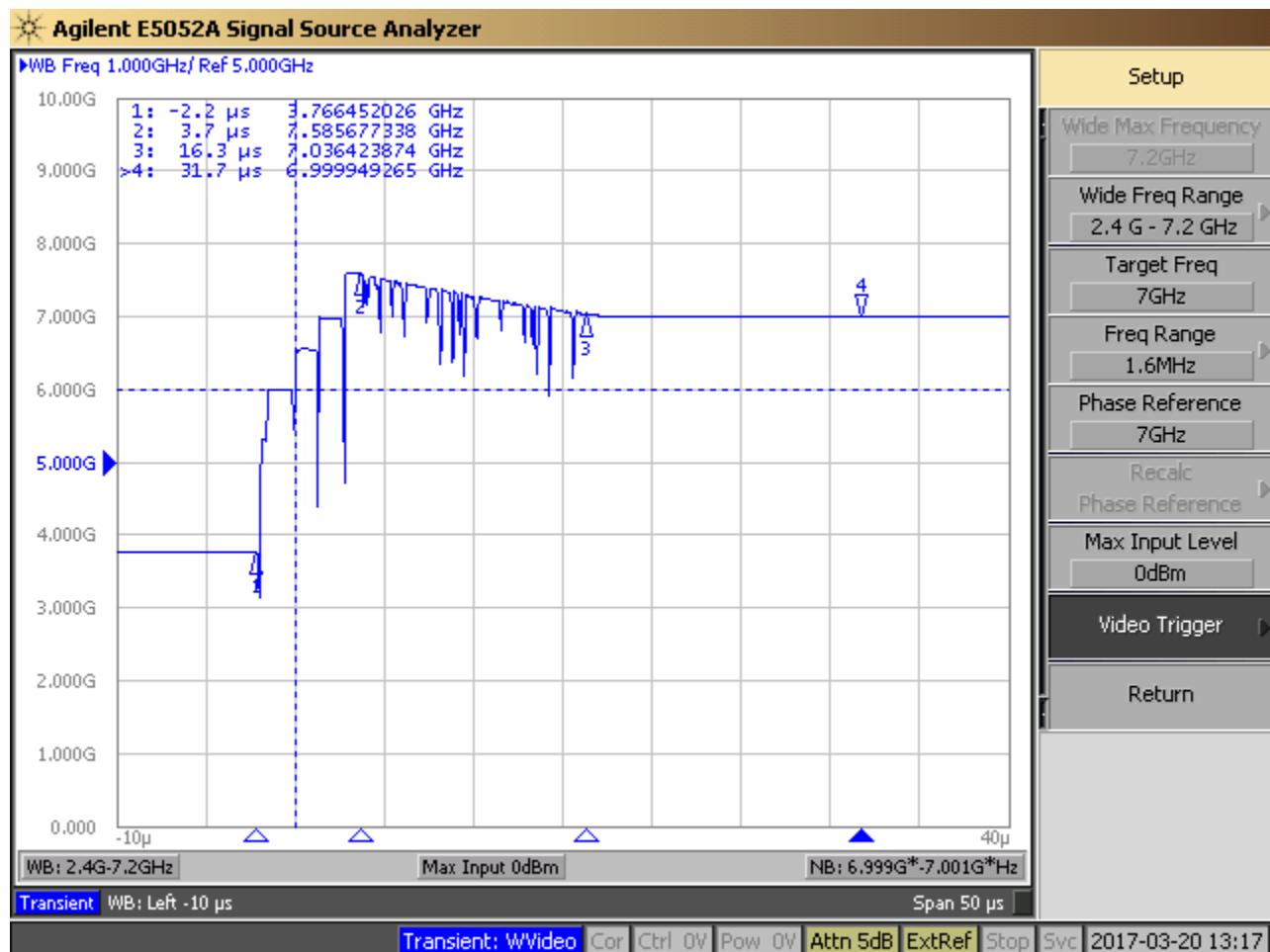
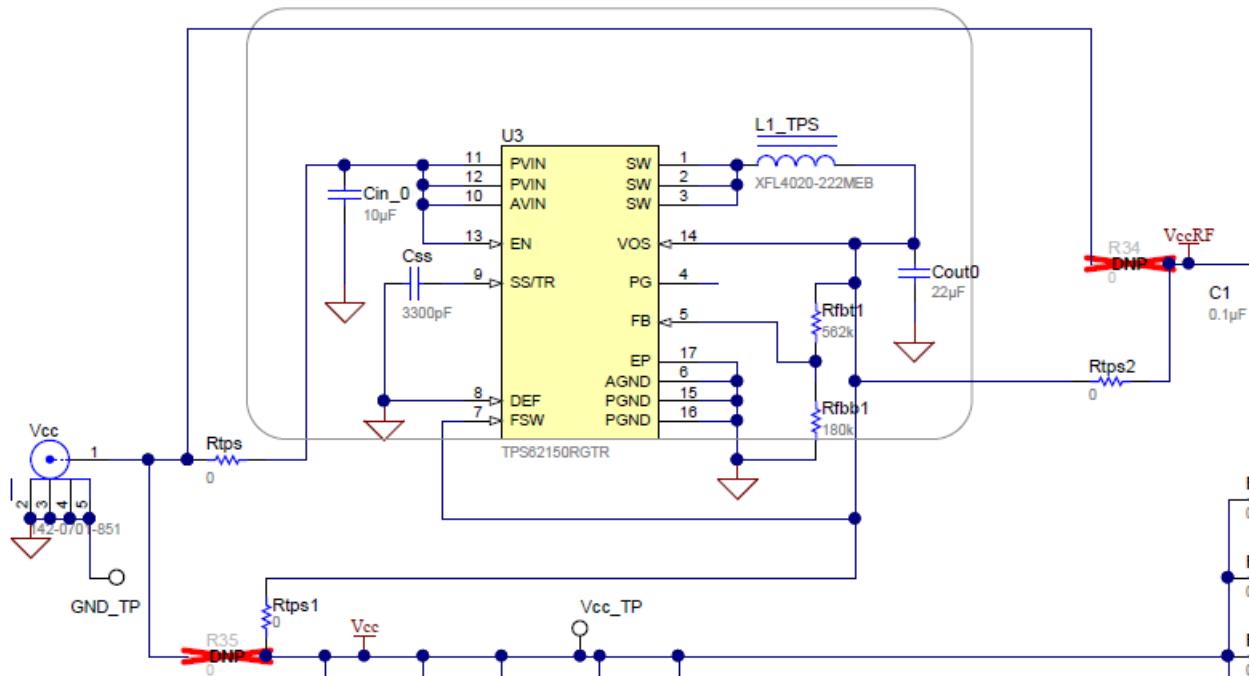


Figure 27. Unassisted Calibration Plot

## ***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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