LMX2571EVM User's Guide

User's Guide

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LMX2571EVM User's Guide

The Texas Instruments LMX2571EVM evaluation module (EVM) helps designers evaluate the operation and performance of the LMX2571 Wideband Frequency Synthesizer. The EVM contains one Frequency Synthesizer.

Device: U1

IC: LMX2571

Package: QFN36

Topic **Page**

1 Setup

1.1 Input and Output Connector Description

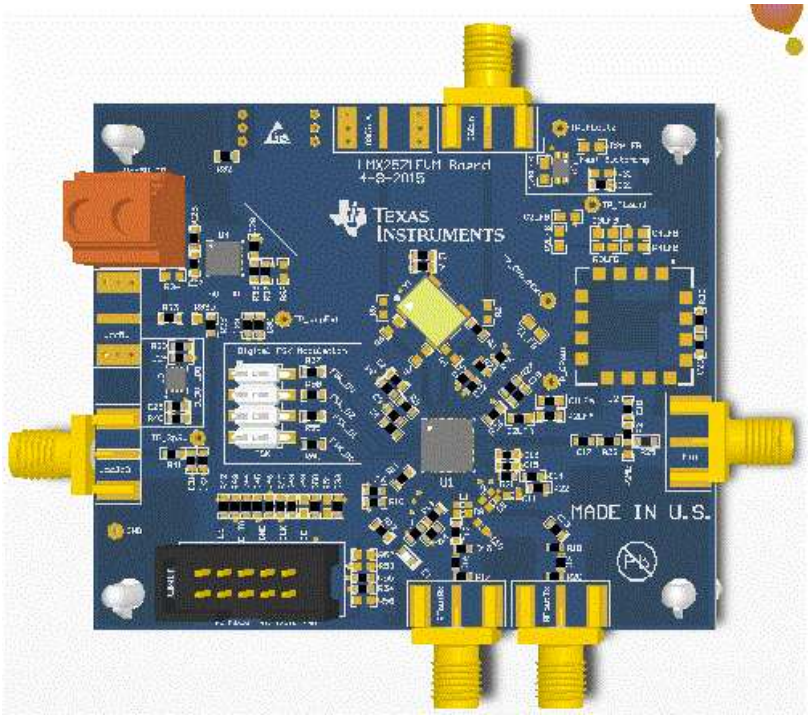

Figure 1. Evaluation Board Setup

Table 1. Inputs and Outputs

Output Name(s)	Input/Output	Required?	Function
RFoutRx RFoutTx	Output	Required	One of these outputs needs to be attached to phase noise measurement equipment, like the Agilent E5052. The unused output need not be connected.
Vcc3p3	Input	Required	Connect to a 3.3 V Power Supply. Ensure the current limit is set above 100 mA.
Vcc5V Vcc5VTV_TB	Input	Optional	Instead of using the Vcc3p3 connector, one can connect 5V to one of these outputs and it is regulated down to 3.3V on the board.
Programming Interface	Input	Required	Connect the board to a PC using the USB2ANY (HPA665-001) interface provided in kit.
OSCin	Input	Optional	The on-board 20 MHz XO has been enabled. To use this input, the XO power supply resistor (R1) should be removed and resistor R3 moved to position R2.

1.2 Installing the EVM Software

Go to http://www.ti.com/tool/codeloader and download and run the most current software.

1.3 Loop Filter Values and Configuration Information

Table 2. Loop Filter values and Configuration

Category	Parameter	Value
Configuration	OSCin Frequency (MHz)	20 MHz
	Phase Detector Frequency (MHz)	80 MHz
	VCO Frequency	4300 to 5376 MHz
	Charge Pump Gain	2500 uA = 1 x (1250 uA + 1250 uA)
VCO Gain	VCO_L	46 to 61 MHz/V
	VCO_M	50 to 65 MHz/V
	VCO_H	55 to 73 MHz/V
Loop Filter Components	C1_LF	390 pF
	C2_LF	4.7 nF
	C3_LF (Internal)	50 pF
	C4_LF (Internal)	100 pF
	R2_LF	680 Ω
	R3_LF (Internal)	800 Ω
	R4_LF (Internal)	800 Ω
Loop Filter Characteristics (Assuming Fvco=4.8 GHz, Kvco=56 MHz/V)	Loop Bandwidth	204.8 kHz
	Phase Margin	39.9°

1.4 Readback Notification

Although the LMX2571 does support readback, there are some issues with the CodeLoader software and board to do this. In order to readback, this needs to be done with external software. As a means of debugging, consider using the power down feature and monitoring the changes in the current consumption.

1.5 Lock Detect Notification

The lock detect on the LMX2571 works perfectly well. However, the LED decides to light when it feels like it. Pressing on the LED with one's fingernail can sometimes get it to work better. The key takeaway from this is the green LED is not reliable for lock detect. If it is on, it indicates lock, but if it is off, it indicates unlock or an issue with the LED diode.

1.6 Pin 8 Component Notification

Note that Pin 8 has a capacitor to ground, but it was found that this component provided no benefit, although it does no harm either.

1.7 Crystal Oscillator Noise Notification

The following plot shows the XO noise compared to a much cleaner reference. The XO is included for quick startup and evaluation, but can be bypassed or changed. The criteria for choosing the XO was availability and standard footprint, which took priority over phase noise and stability. Sometimes if the XO is burn in by letting the board run for a few hours, the phase noise and stability will improve. Optimal phase noise is obtained with a clean input signal.

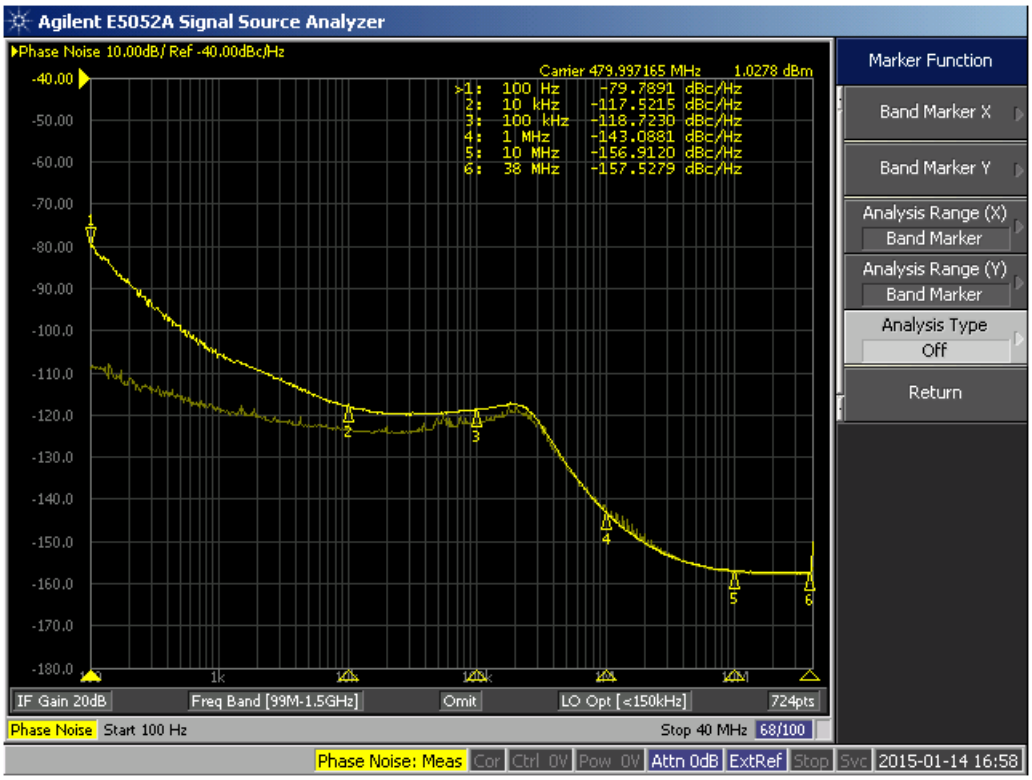

Figure 2. Impact of XO Noise

2 Using the EVM Software

2.1 Main Setup and Default Mode

Choose the default startup mode on the main tab as shown. After the default mode is loaded, don't forget to load the device with Ctrl+L or with Keyboard Controls -> Load Device.

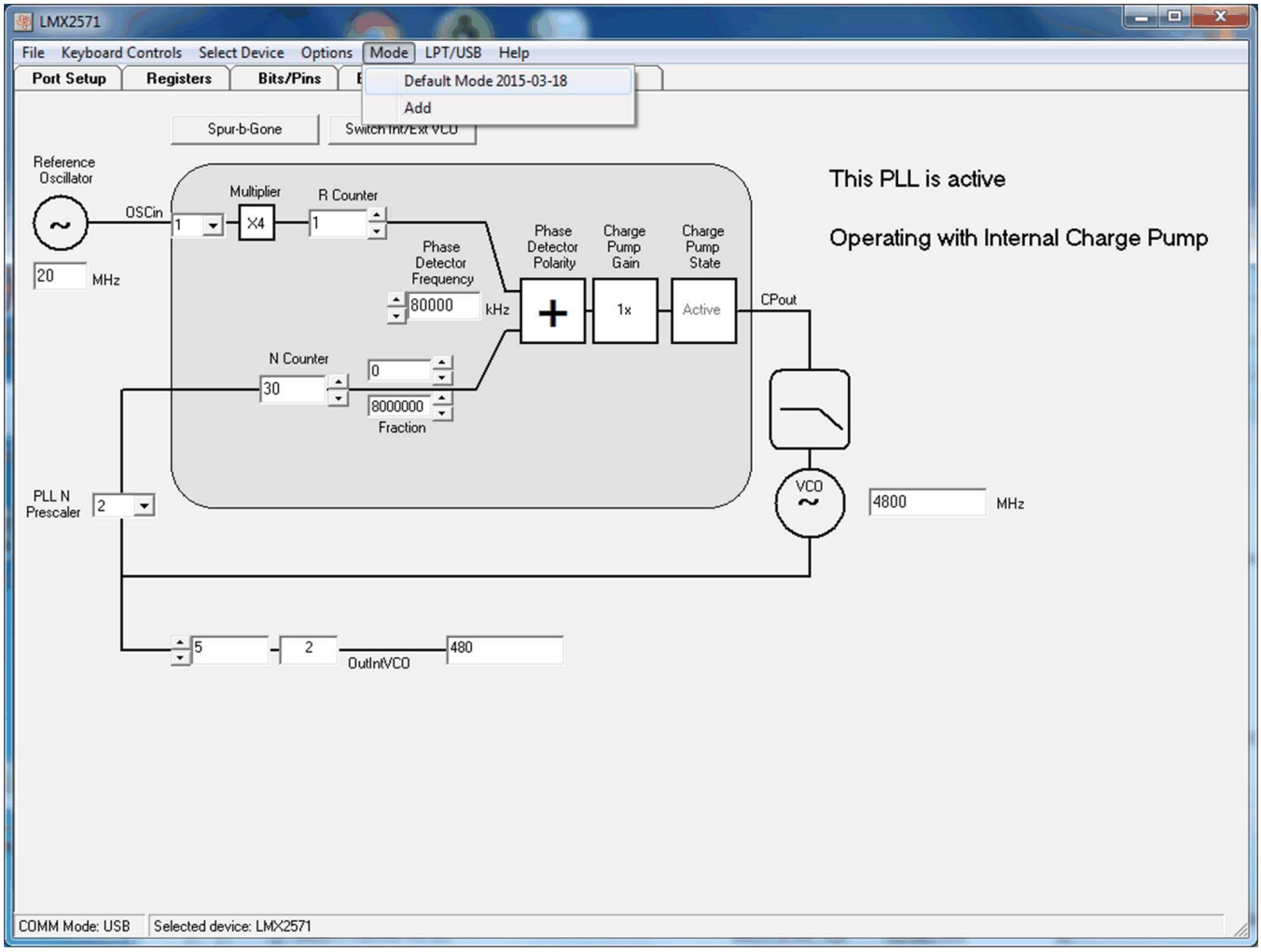

Figure 3. Loading Default Mode for the Main Configuration Screen

2.2 Port Setup

On the Port Setup tab, the user may select the type of communication port (USB or Parallel) that will be used to program the device on the evaluation board. If parallel port is selected, the user should ensure that the correct port address is entered. CodeLoader does NOT auto detect the correct settings for this. The identify function verifies that the computer is communicating wit the USB2ANY board, but does NOT verify that the USB2ANY board is communicating with the device.

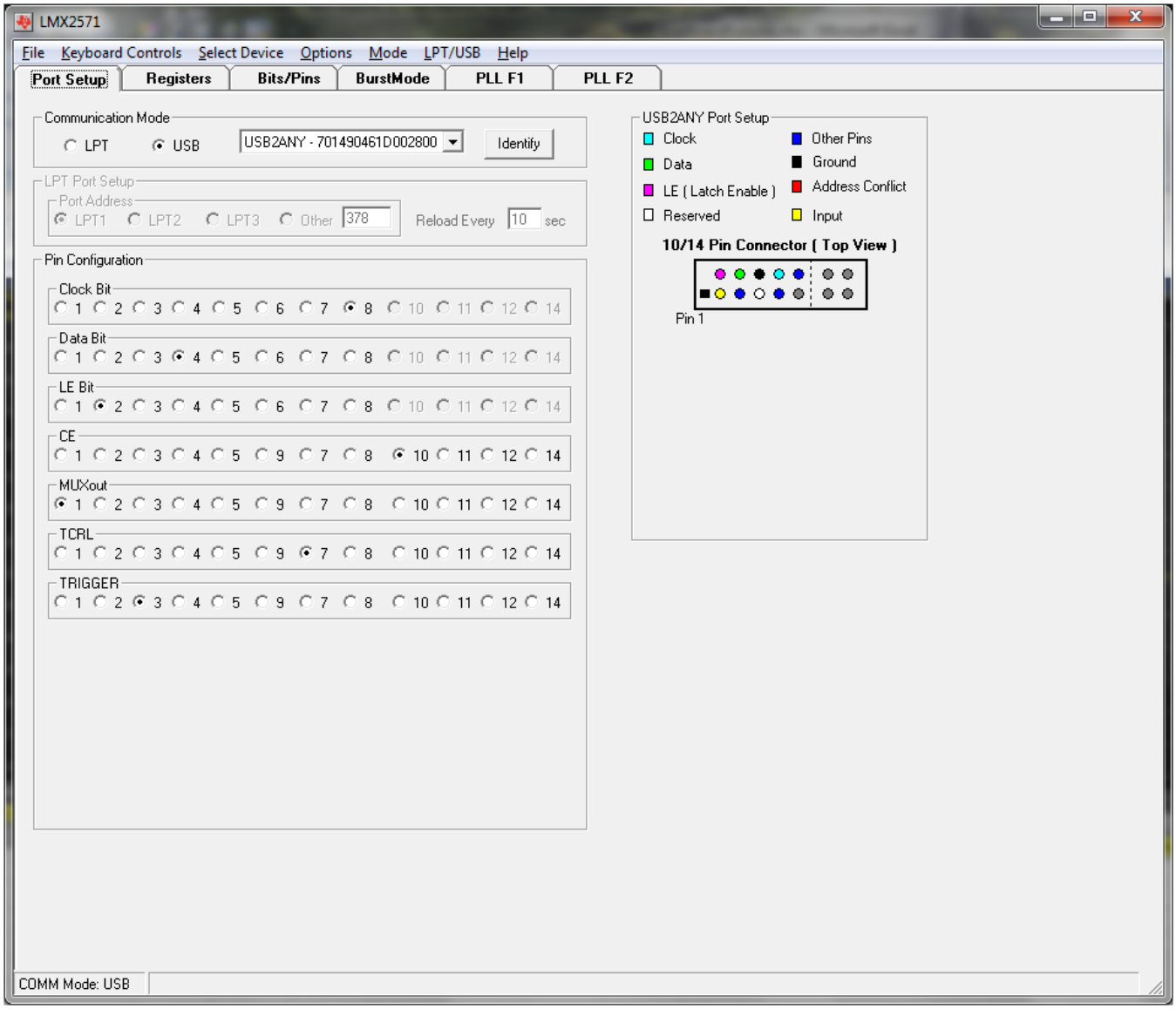

Figure 4. Port Setup Tab

2.3 Bits/Pins Settings

To view the function of any bit on the CodeLoader configuration tabs, place the cursor over the desired bit register label and click the right mouse button on it for a description.

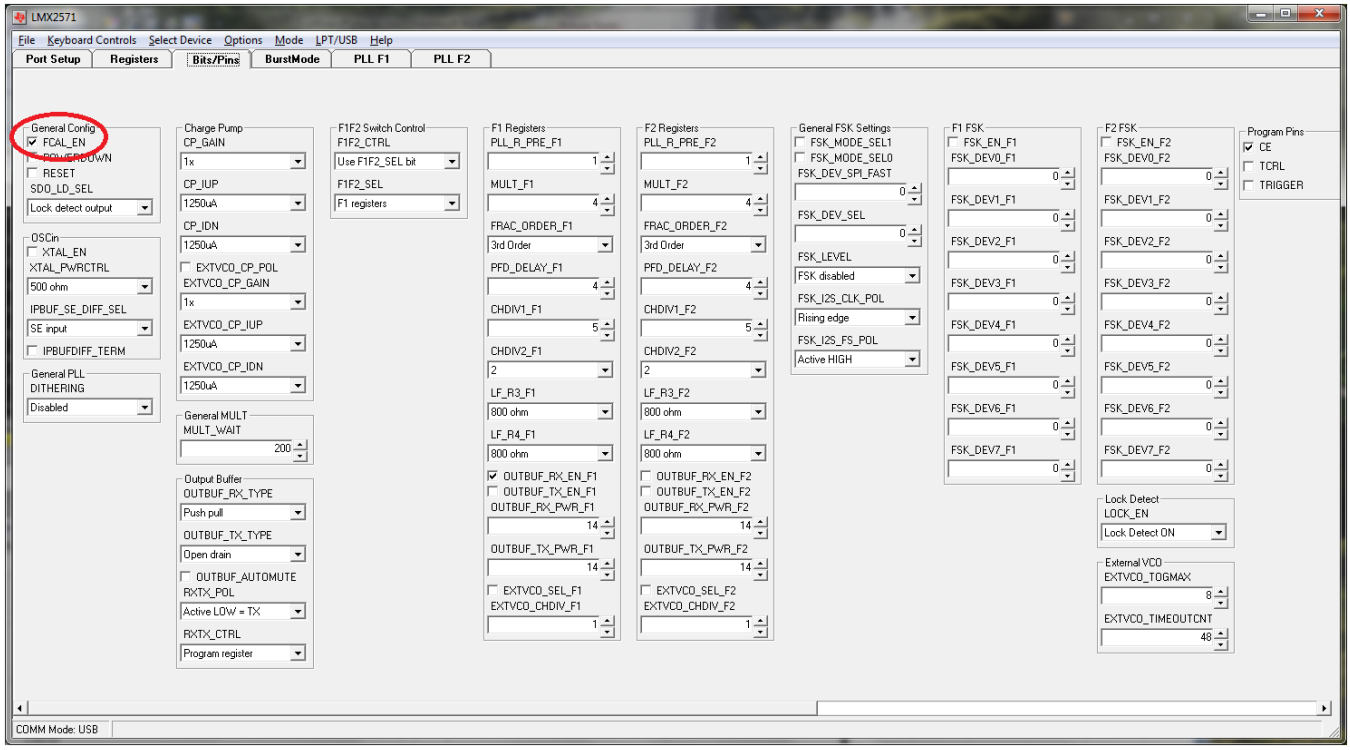

Figure 5. Bits/Pins Tab

3 Board Construction

3.1 Board Layer Stack Up

The board is made on FR4 for the Prepreg and Core Layers. The top layer is 1 oz copper.

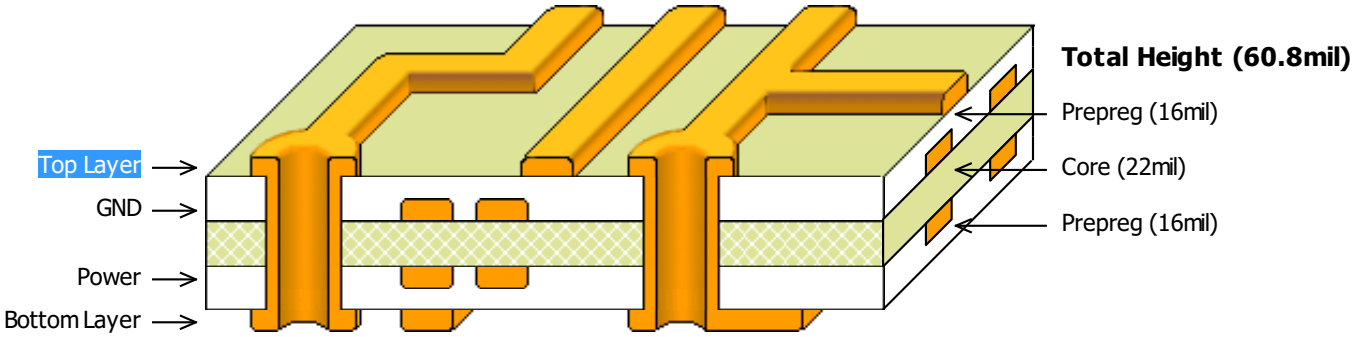

Figure 6. Board Layer Stack Up

FR4 material was chosen because of convenience, availability, and cost.

3.2 Schematic

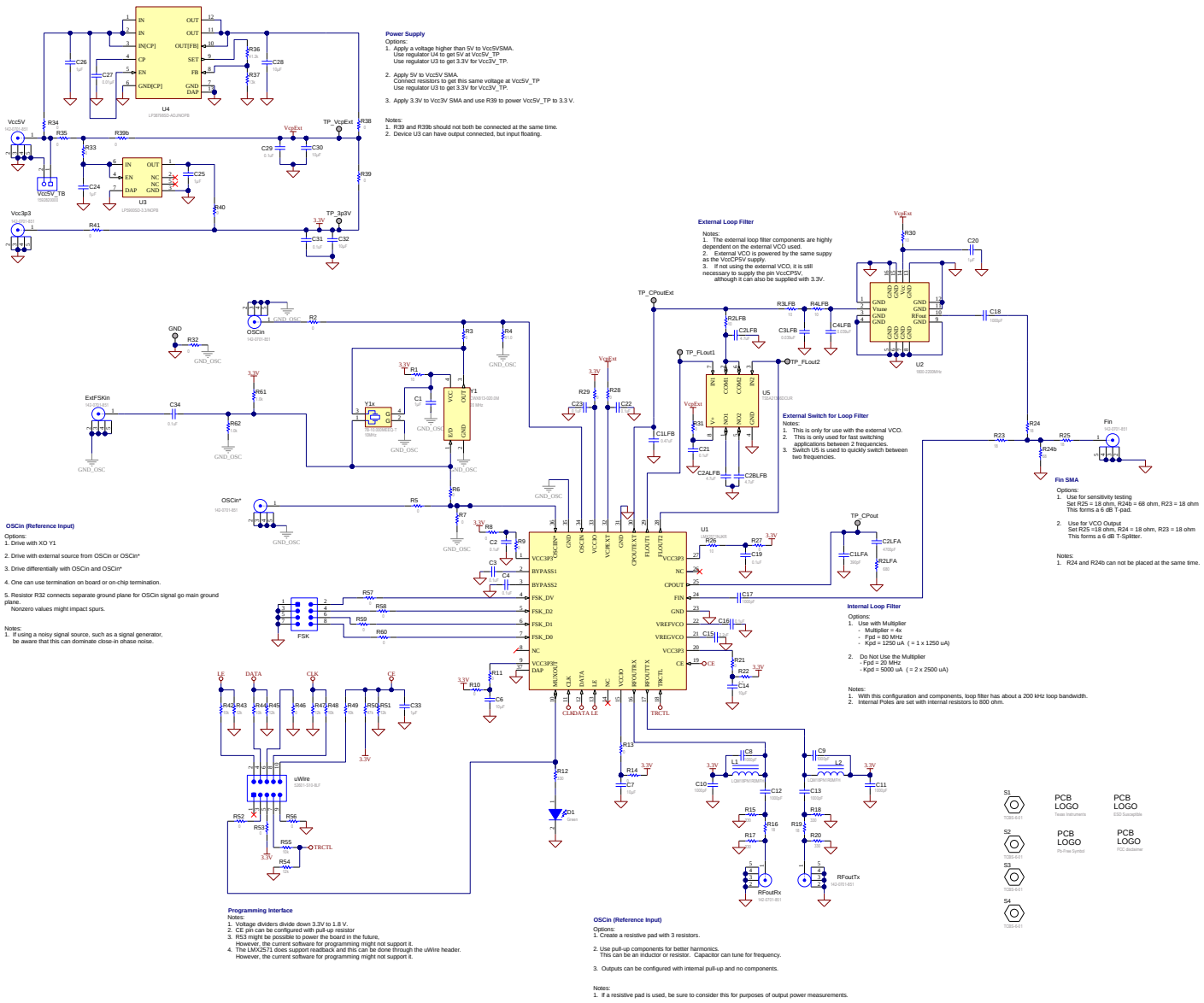

Figure 7. LMX2571 Schematic

4 PCB Layers

Figure 8 shows the assembly diagram that indicates where the components are placed.

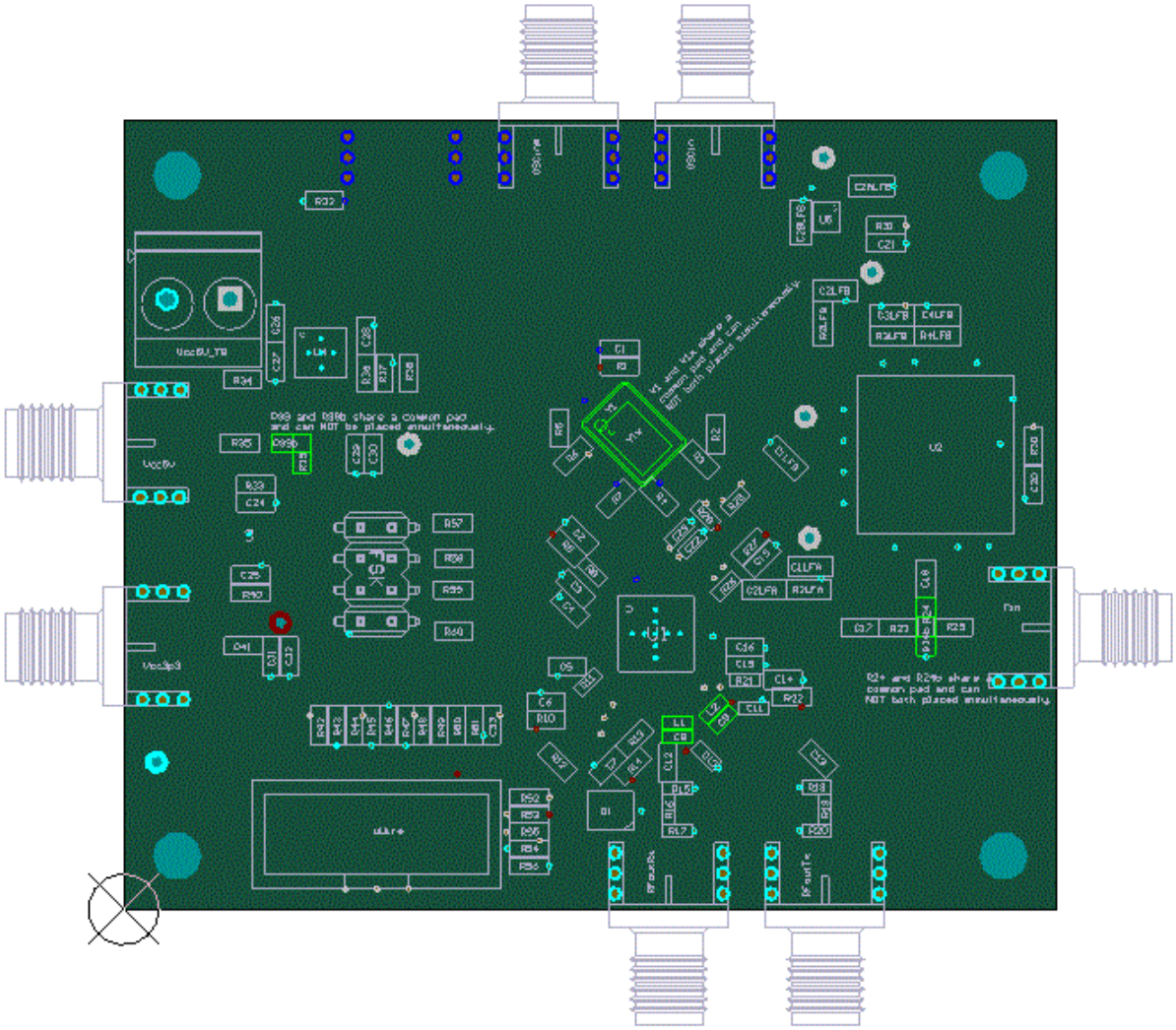

Figure 8. Top Assembly Layer

In the Top Layer, Figure 9, the ground plane is pulled far away from the signal traces to minimize the potential of spur energy coupling onto them. This board can be assembled with all components on the top layer.

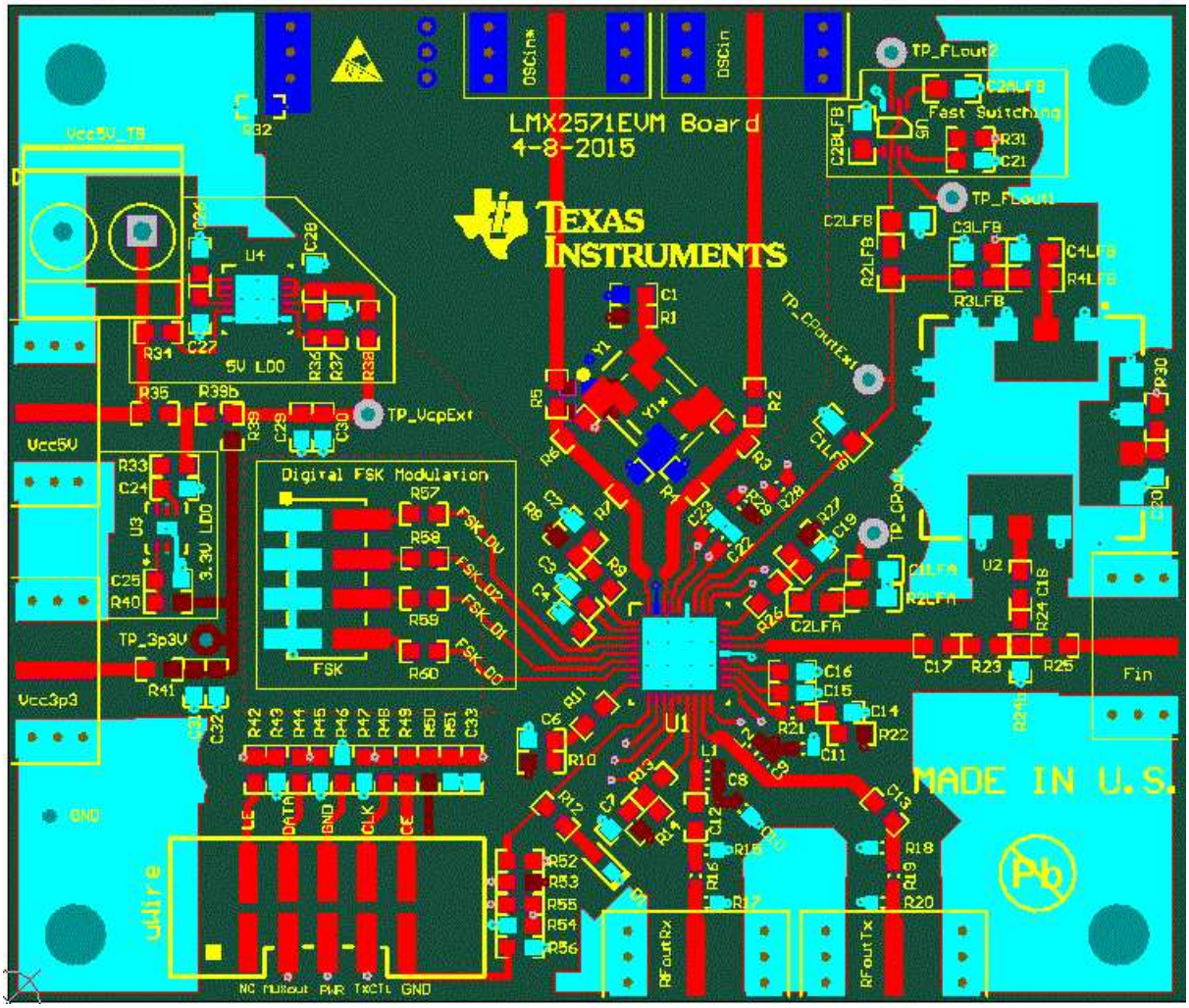

Figure 9. Top Layer

On the Ground Layer, Figure 10, notice that there is a separate ground plane below the OSCin signal. This is to prevent the OSCin signal coupling to the other ground plane. They are connected by a resistor on the top layer.

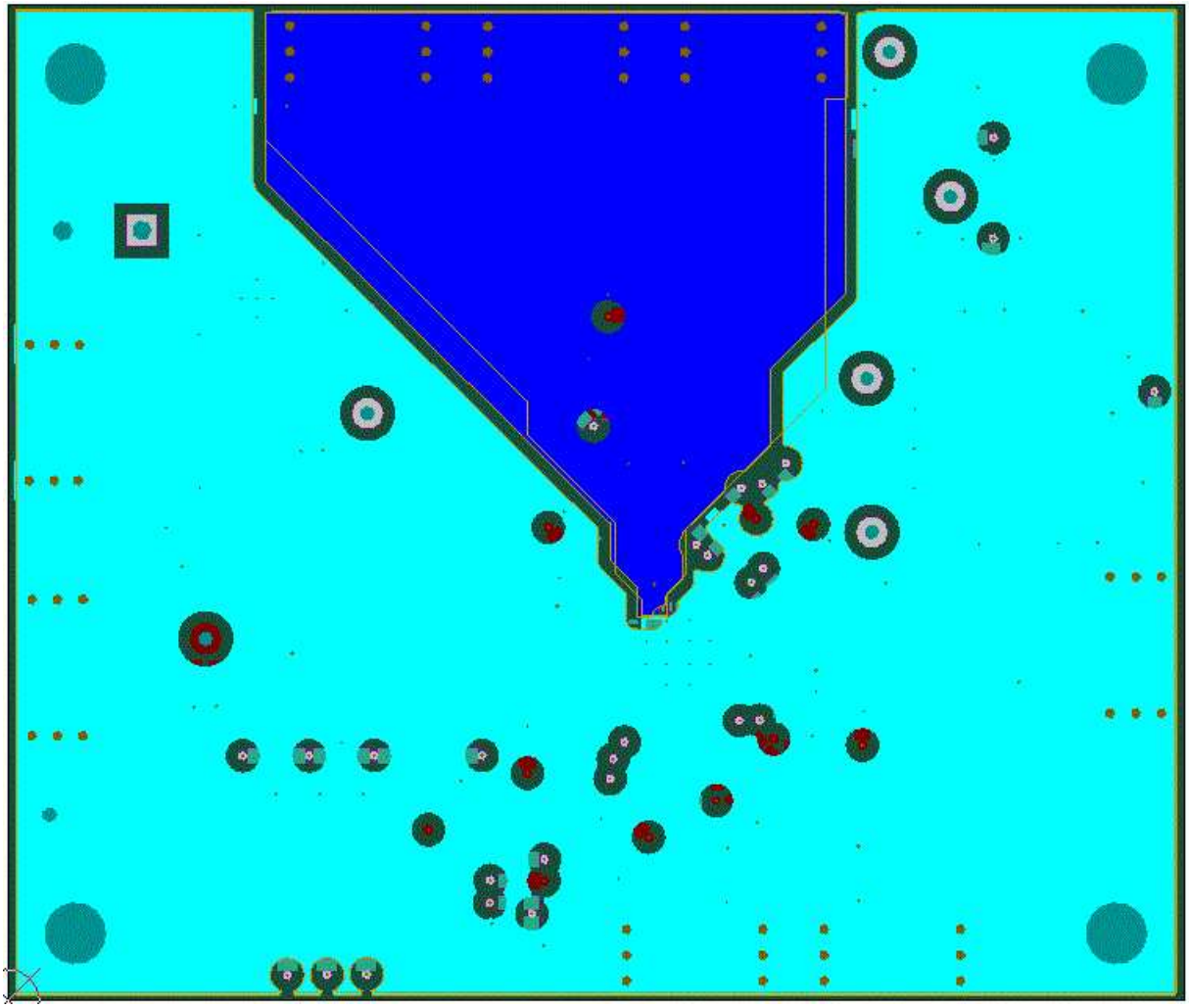

Figure 10. Ground Layer

The power layer, Figure 11, effort is made to avoid putting any plane below the OSCin signal ground, to minimize the potential of spur coupling. The upper right plane is the 5V plane and the lower left is the 3.3V plane.

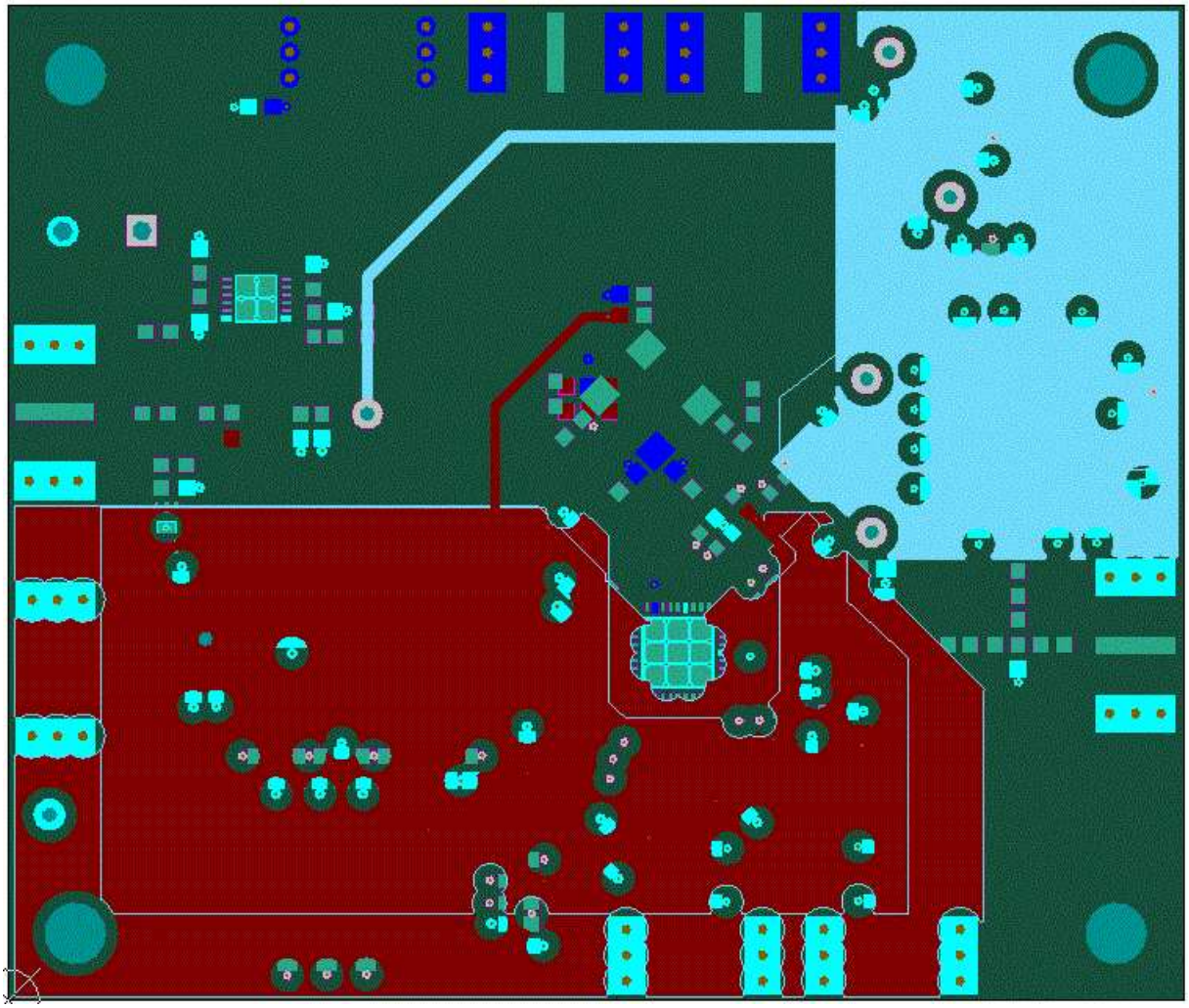

Figure 11. Power Layer

The Bottom Layer, Figure 12, is used to route less critical functions.

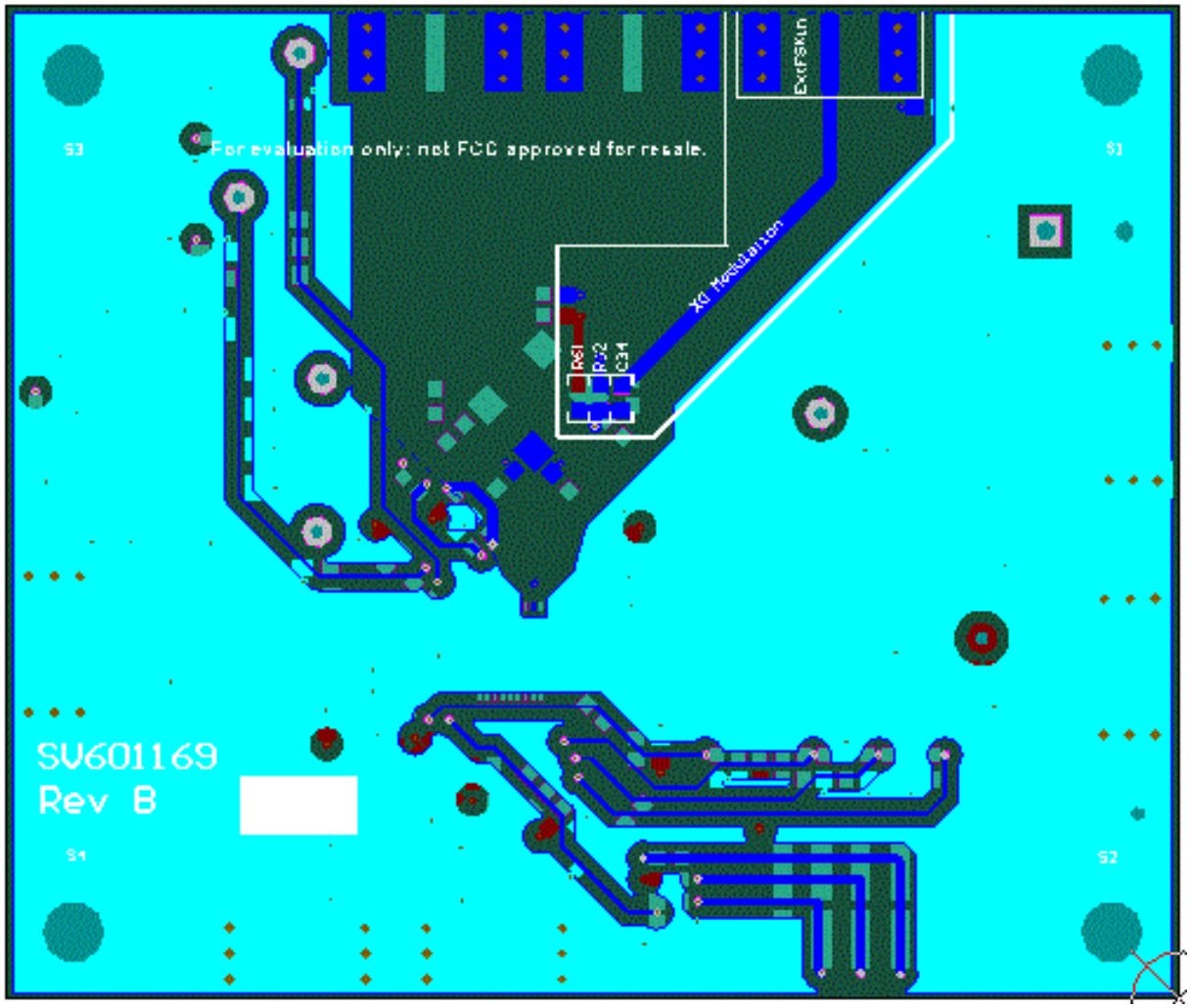

Figure 12. Bottom Layer

5 Measured Performance Data

5.1 Phase Noise in Default Mode

Figure 13 shows the phase noise in default mode.

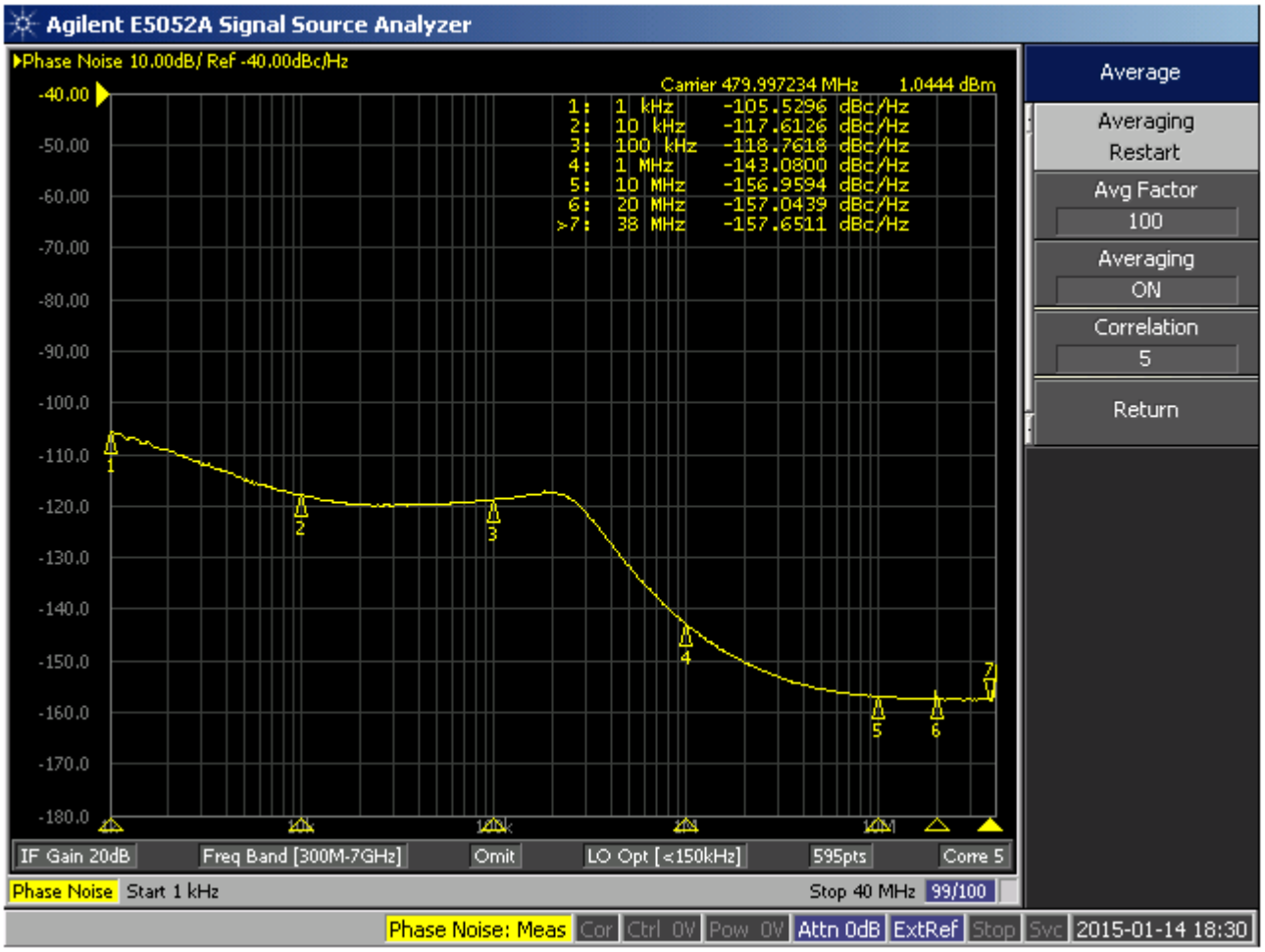

Figure 13. Phase Noise (Default Mode)

Figure 14 shows the phase noise in default mode as well. The dim trace is the default mode (Fpd=80MHz) and the bright trace has Fpd=20 MHz and 4 times the charge pump current (to keep the same bandwidth). We see that the results are similar.

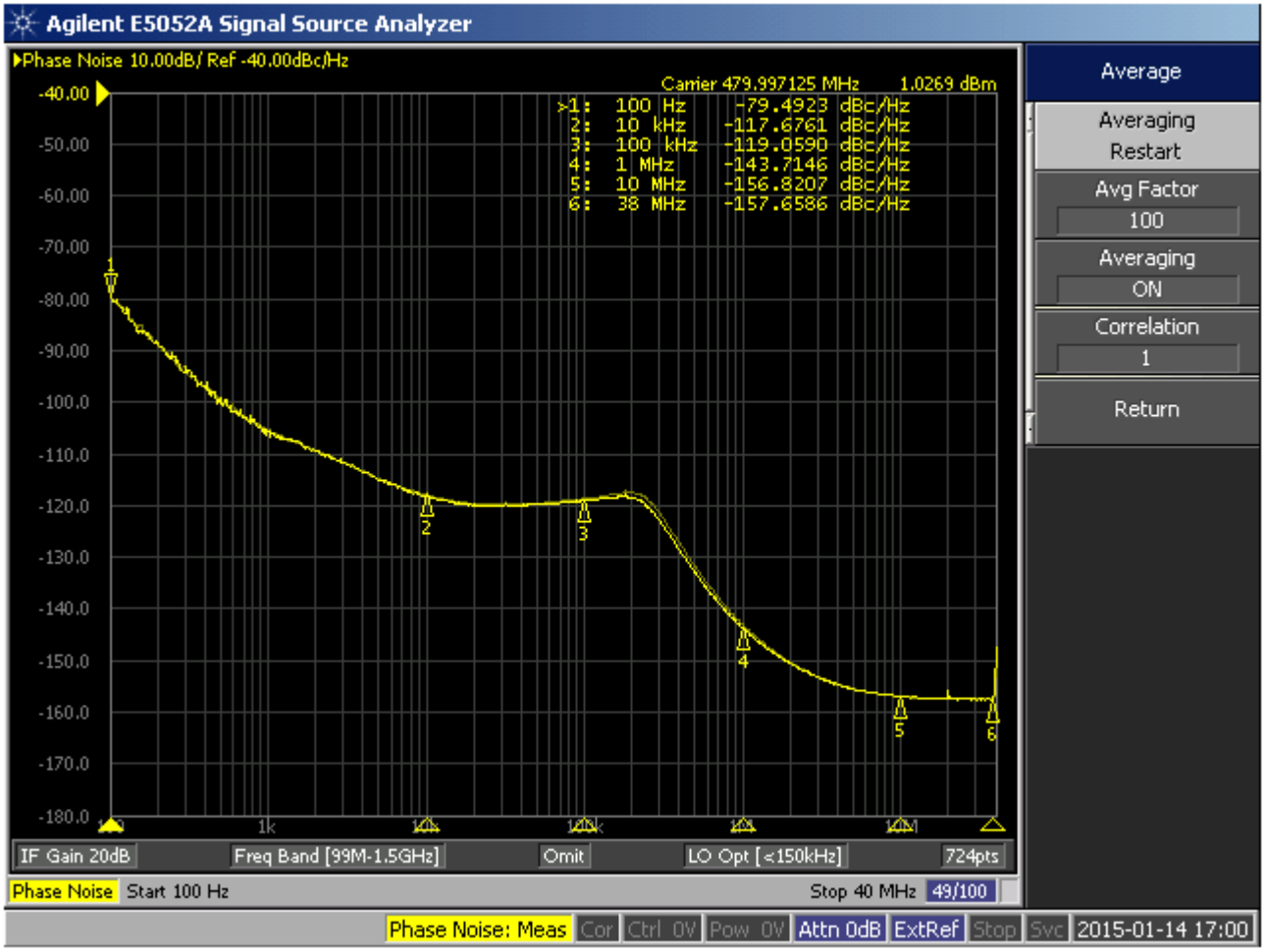

Figure 14. Default Mode vs. Fpd = 20 MHz and 4x Higher Charge Pump Gain

Figure 15 Shows the impact of taking a 4800 MHz VCO signal and dividing with the pre divider values of 4,5,6, and 7. We see a textbook 20*log relationship for phase noise. about -155 dBc/Hz. The second plot shows when the secondary channel divider is used. Close in, we see the 20*log relationship, but eventually, this hits a noise floor.

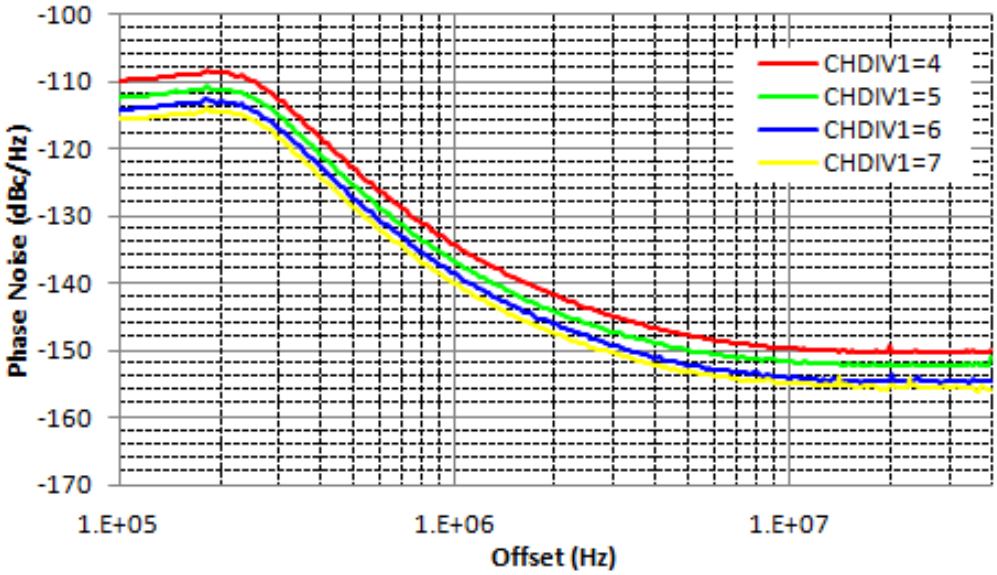

Figure 15. Phase Noise (Default Mode)

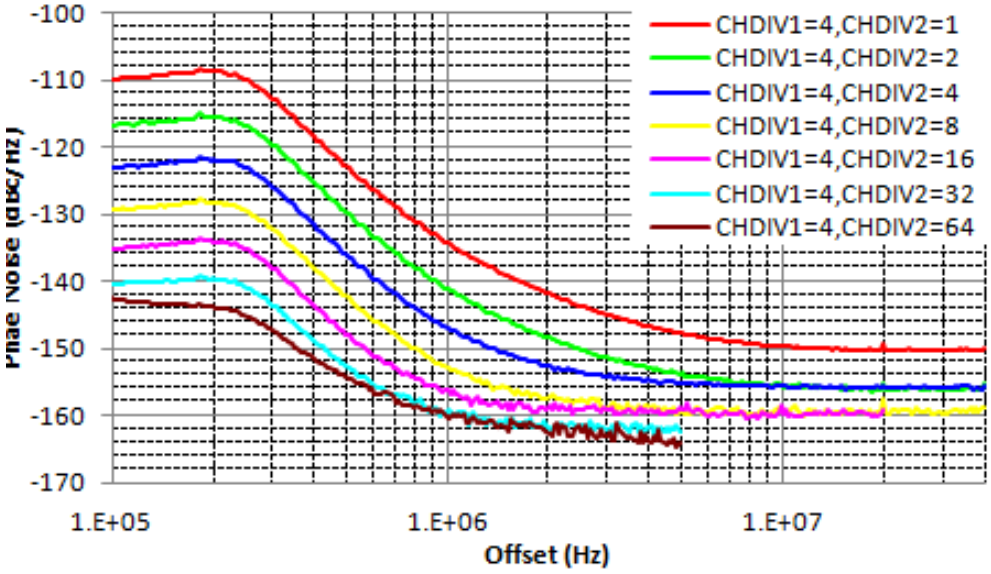

Figure 16. Noise Floor with CHDIV2

5.2 VCO Phase Noise

5.2.1 Fvco = 4400 MHz / 4

Figure 17 shows the phase noise of just the VCO at 4400 MHz and divided by 4. To take this measurement, the charge pump was set to tri-state and this is why the frequency is off.

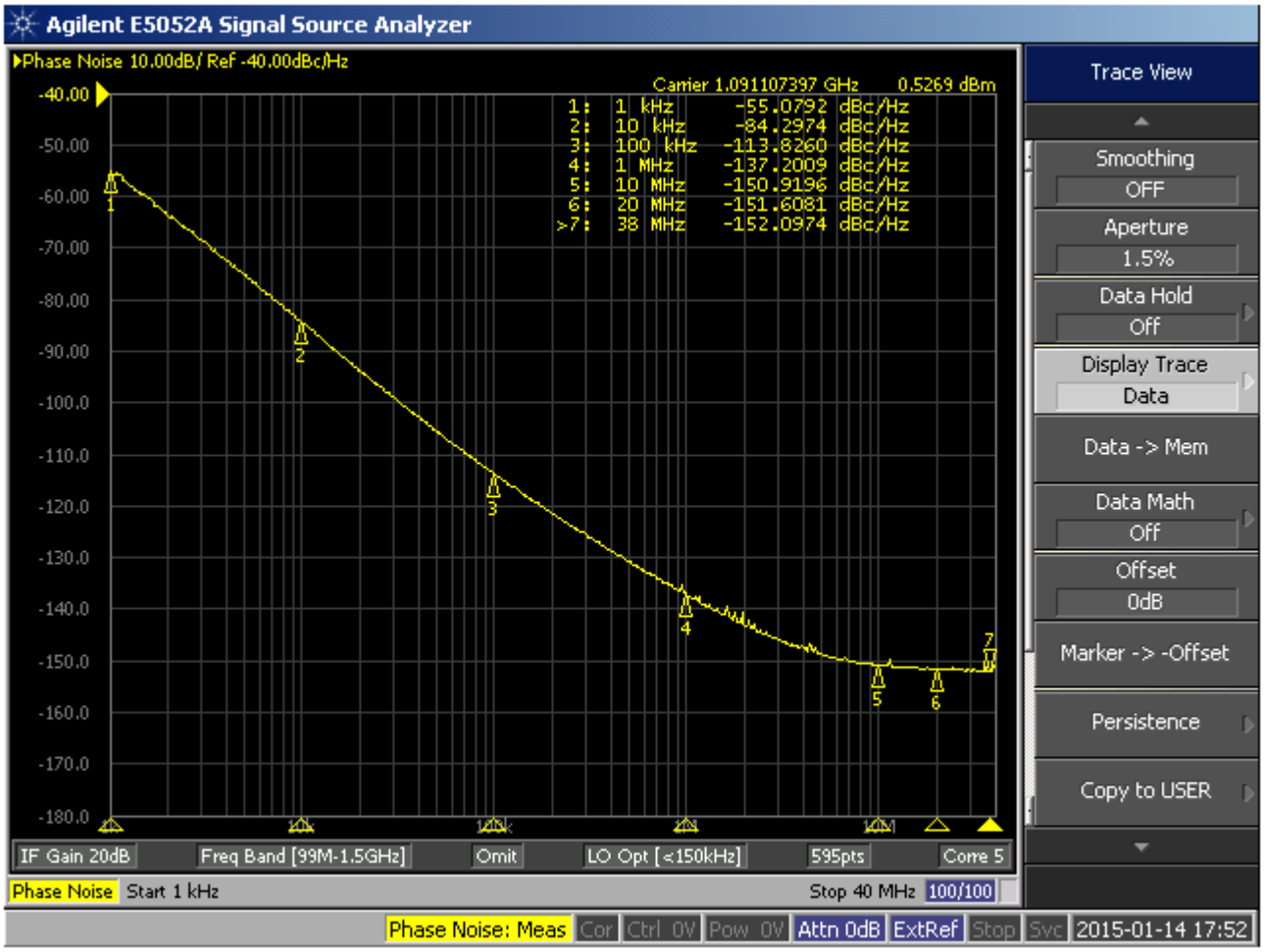

Figure 17. VCO Phase Noise
Fvco = 4800 MHz/4

5.2.2 Fvco = 4800 MHz/4

Figure 18 shows the phase noise of just the VCO at 4800 MHz and divided by 4. To take this measurement, the charge pump was set to tri-state and this is why the frequency is off.

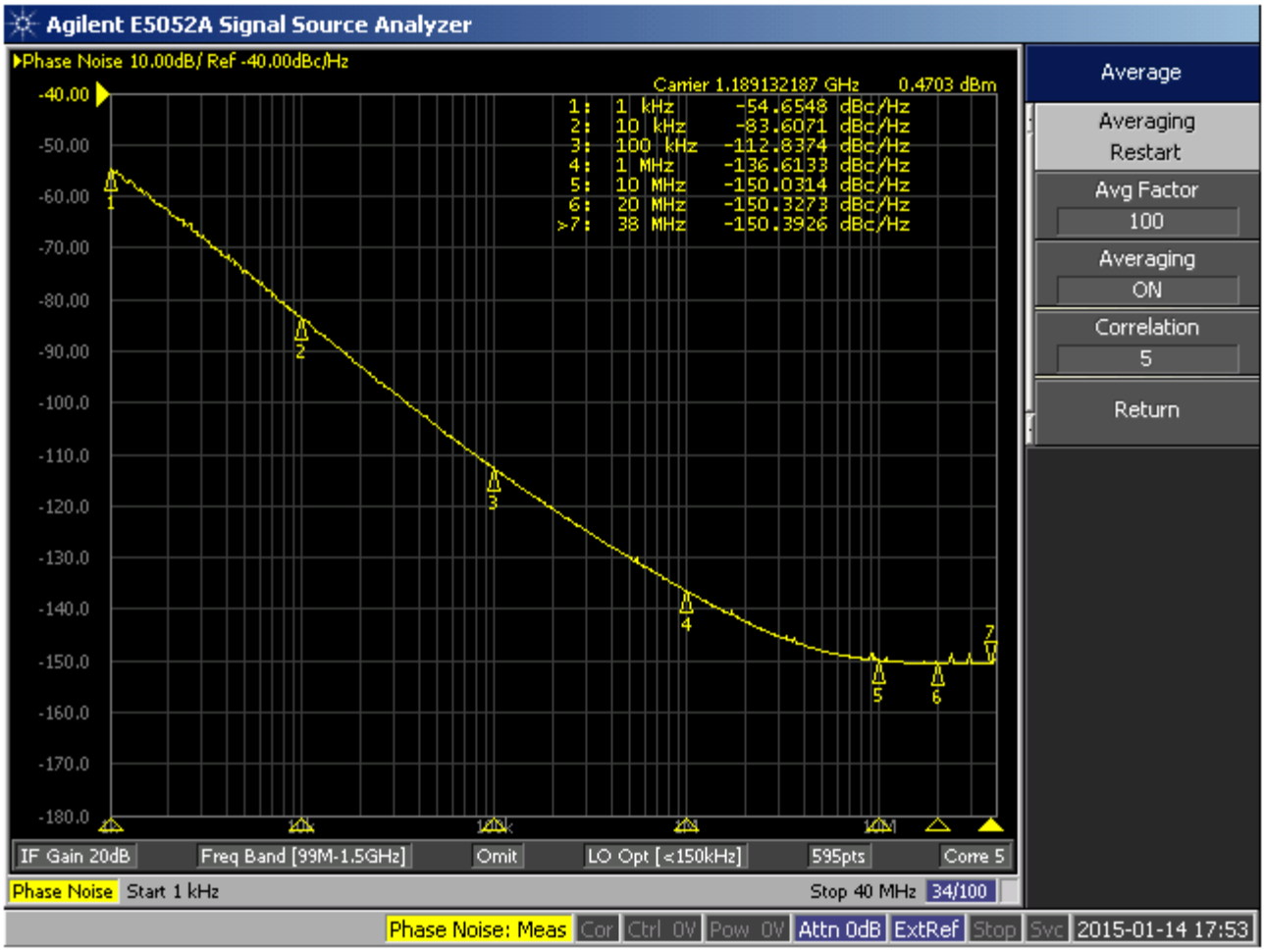

Figure 18. VCO Phase Noise Fvco = 4800 MHz/4

5.2.3 Fvco = 5200 MHz/4

Figure 19 shows the phase noise of just the VCO at 5200 MHz and divided by 4. To take this measurement, the charge pump was set to tri-state and this is why the frequency is off.

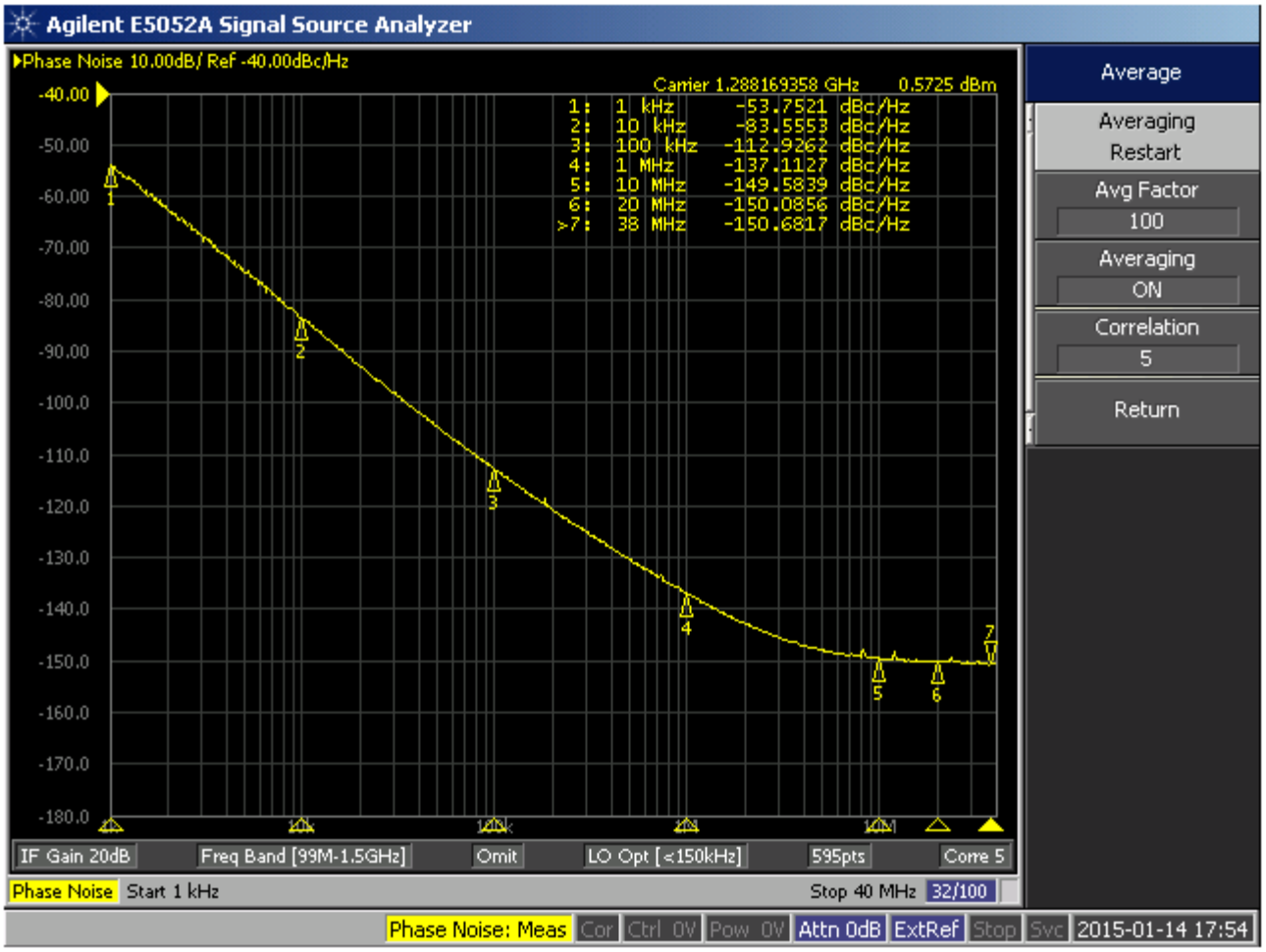

Figure 19. VCO Phase Noise
Fvco = 5200 MHz/4

5.3 Fractional Spurs and Spur-b-Gone

This plot is for a VCO frequency of 4881 MHz, which is very close to the integer boundary of 4880 MHz. Note the 1 MHz spur and also we see 1 MHz/4 = 250 kHz from the output divider

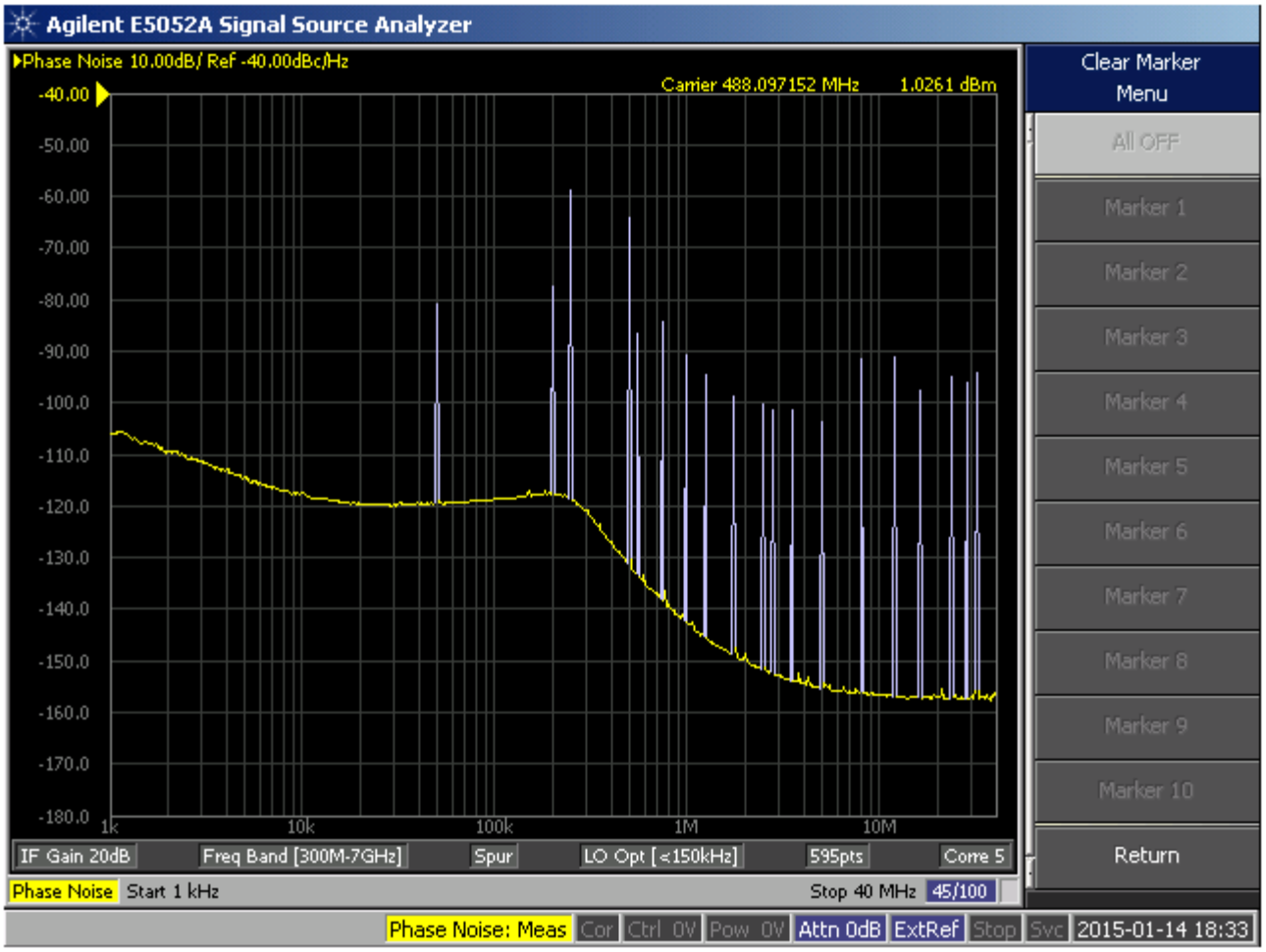

Figure 20. No Spur-b-Gone
Fvco = 4881 MHz/10,
Fpd = 80 MHz

After using Spur-B-Gone, the phase detector changes from 80 to 110 MHz and we see that the spurs are substantially reduced.

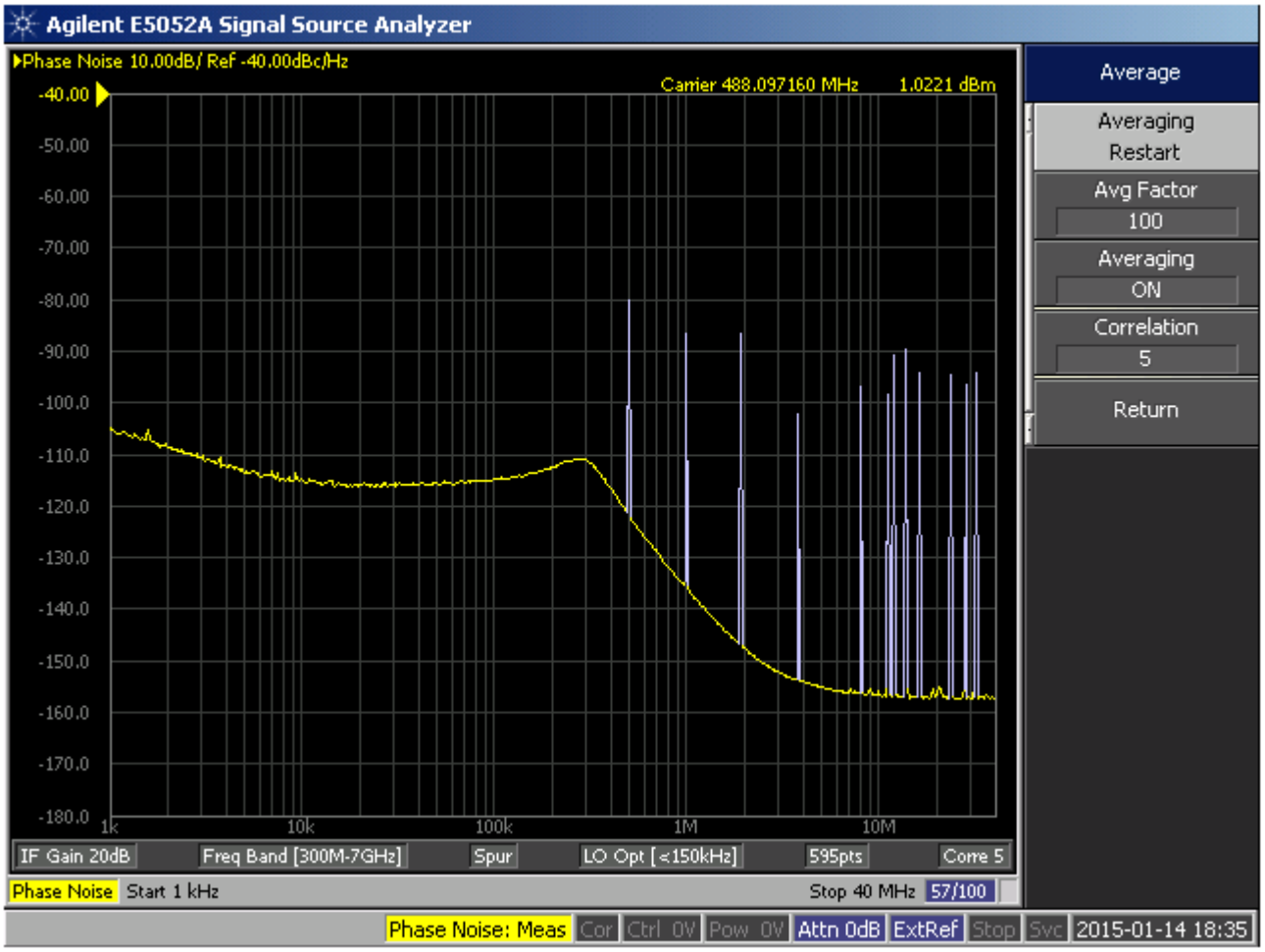

Figure 21. With Spur-b-Gone:
Fvco = 4881 MHz/10,
Fpd = 110 MHz

6 Bill of Materials

Table 3. LMX2571 Bill of Materials

Designator	Qty	Value	Description	PartNumber
C1, C20, C24, C25, C26, C33	6	1uF	CAP, CERM, 1 µF, 16 V, +/- 10%, X7R, 0603	GRM188R71C105KA12D
C1LFA	1	390pF	CAP, CERM, 390pF, 50V, +/-5%, C0G/NP0, 0603	06035A391JAT2A
C2, C3, C4, C16, C19, C21, C22, C23, C29, C31	10	0.1uF	CAP, CERM, 0.1uF, 16V, +/-5%, X7R, 0603	0603YC104JAT2A
C2LFA	1	4700pF	CAP, CERM, 4700pF, 100V, +/-5%, X7R, 0603	06031C472JAT2A
C6, C7, C14, C28, C30, C32	6	10uF	CAP, CERM, 10 µF, 25 V, +/- 20%, X5R, 0603	GRM188R61E106MA73
C12, C13	2	1000pF	CAP, CERM, 1000 pF, 100 V, +/- 5%, X7R, 0603	06031C102JAT2A
C15	1	2.2uF	CAP, CERM, 2.2uF, 10V, +/-10%, X5R, 0603	C0603C225K8PACTU
C17, C18	2	1000pF	CAP, CERM, 1000pF, 100V, +/-5%, X7R, 0603	06031C102JAT2A
C27	1	0.01uF	CAP, CERM, 0.01 µF, 50 V, +/- 10%, X7R, 0603	GRM188R71H103KA01D
D1	1	Green	LED, Green, SMD	LTST-C190GKT
Fin, OSCin, RFoutRx, RFoutTx, Vcc3p3	5		Connector, End launch SMA, 50 ohm, SMT	142-0701-851
FSK	1		Header, 100mil, 4x2, Gold, SMT	0015910080
R1, R30	2	10	RES, 10 ohm, 5%, 0.1W, 0603	CRCW060310R0JNEA
R2LFA	1	680	RES, 680 ohm, 5%, 0.1W, 0603	CRCW0603680RJNEA
R3, R8, R9, R10, R11, R13, R14, R21, R27, R28, R29, R32, R33, R35, R39, R40, R41, R46, R57, R58, R59, R60	22	0	RES, 0 ohm, 5%, 0.1W, 0603	CRCW06030000Z0EA
R12	1	330	RES, 330 ohm, 5%, 0.1W, 0603	RC0603JR-07330RL
R15, R17, R18, R20	4	330	RES, 330 ohm, 1%, 0.1W, 0603	RC0603FR-07330RL
R16, R19, R23, R24, R25	5	18	RES, 18 ohm, 5%, 0.1W, 0603	CRCW060318R0JNEA
R22	1	4.7	RES, 4.7, 5%, 0.1 W, 0603	CRCW06034R70JNEA
R26	1	10	RES, 10, 5%, 0.1 W, 0603	CRCW060310R0JNEA
R36	1	41.2k	RES, 41.2 k, 1%, 0.1 W, 0603	CRCW060341K2FKEA
R37	1	13k	RES, 13k ohm, 5%, 0.1W, 0603	CRCW060313K0JNEA
R42, R44, R48, R55	4	10k	RES, 10k ohm, 5%, 0.1W, 0603	CRCW060310K0JNEA
R43, R45, R47, R54	4	12k	RES, 12k ohm, 5%, 0.1W, 0603	CRCW060312K0JNEA
R50	1	47k	RES, 47 k, 5%, 0.1 W, 0603	CRCW060347K0JNEA
S1, S2, S3, S4	4		HEX STANDOFF SPACER, 9.53 mm	TCBS-6-01
U1	1		Low Power Synthesizer with FSK Modulation, NJK0036A	LMX2571NJKR
U3	1		Ultra Low Noise, 150mA Linear Regulator for RF/Analog Circuits Requires No Bypass Capacitor, 6-pin LLP, Pb-Free	LP5900SD-3.3/NOPB
U4	1		Ultra Low Noise, 800 mA Linear Voltage Regulator for RF/Analog Circuits, DNT0012B	LP38798SD-ADJ/NOPB
U5	1		0.75-O DUAL SPST ANALOG SWITCH WITH 1.8-V COMPATIBLE INPUT LOGIC, DCU0008A	TS5A21366DCUR

Table 3. LMX2571 Bill of Materials (continued)

Designator	Qty	Value	Description	PartNumber
uWire	1		Header (shrouded), 100mil, 5x2, Gold plated, SMD	52601-S10-8LF
Vcc5V_TB	1		Terminal Block, 10.76x17x11 mm, 2POS, 26-12AWG, TH	1592820000
Y1	1		Oscillator, 20MHz, 3.3 V, SMD	CWX813-020.0M
Items below this ine are Do not Place as Indicated by Quantity of Zero				
C1LFB	0	0.47uF	CAP, CERM, 0.47uF, 16V, +/-10%, X7R, 0603	C0603C474K4RACTU
C2ALFB, C2BLFB, C2LFB	0	4.7uF	CAP, CERM, 4.7uF, 16V, +/-10%, X5R, 0603	GRM188R61C475KAAJ
C3LFB, C4LFB	0	0.039uF	CAP, CERM, 0.039uF, 100V, +/-10%, X7R, 0603	C0603C393K1RACTU
C8, C9	0	1000pF	CAP, CERM, 1000 pF, 100 V, +/- 5%, X7R, 0603	06031C102JAT2A
C10, C11	0	1000pF	CAP, CERM, 1000pF, 100V, +/-5%, X7R, 0603	06031C102JAT2A
C34	0	0.1uF	CAP, CERM, 0.1uF, 16V, +/-5%, X7R, 0603	0603YC104JAT2A
ExtFSKin, OSCin*, Vcc5V	0		Connector, End launch SMA, 50 ohm, SMT	142-0701-851
L1, L2	0	1uH	Inductor, Ferrite, 1uH, 0.7A, 0.15 ohm, SMD	LQM18PN1R0MFH
R2, R5, R6, R7, R31, R34, R38, R39b, R52, R53, R56	0	0	RES, 0 ohm, 5%, 0.1W, 0603	CRCW06030000Z0EA
R2LFB, R3LFB, R4LFB	0	10	RES, 10 ohm, 5%, 0.1W, 0603	CRCW060310R0JNEA
R4	0	51.0	RES, 51.0 ohm, 1%, 0.1W, 0603	RC0603FR-0751RL
R24b	0	68	RES, 68 ohm, 5%, 0.1W, 0603	CRCW060368R0JNEA
R49	0	10k	RES, 10k ohm, 5%, 0.1W, 0603	CRCW060310K0JNEA
R51	0	12k	RES, 12k ohm, 5%, 0.1W, 0603	CRCW060312K0JNEA
R61, R62	0	1.0k	RES, 1.0k ohm, 5%, 0.1W, 0603	CRCW06031K00JNEA
U2	0		VCO, 1800-2200MHz, SMD	CVCO55BE-1800-2200
Y1x	0		Crystal, 10.000MHz, 10pF, SMD	7B-10.000MEEQ-T

Revision History

Changes from Original (January 2015) to A Revision **Page**

- Changed test after changed 3
- Changed Updated some errors in the Loop Filter Values and Configurations table 4
- Changed Pin 8 is now No Connect. Updated Schematic and BOM to Reflect New Board 10

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

STANDARD TERMS AND CONDITIONS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, or documentation (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms and conditions set forth herein. Acceptance of the EVM is expressly subject to the following terms and conditions.

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   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms and conditions do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for any defects that are caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI. Moreover, TI shall not be liable for any defects that result from User's design, specifications or instructions for such EVMs. Testing and other quality control techniques are used to the extent TI deems necessary or as mandated by government requirements. TI does not test all parameters of each EVM.

   2.3 If any EVM fails to conform to the warranty set forth above, TI's sole liability shall be at its option to repair or replace such EVM, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required by Radio Law of Japan to follow the instructions below with respect to EVMs:

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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2. 実験局の免許を取得後ご使用いただく。
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3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative. During normal operation, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

   6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY WRITTEN DESIGN MATERIALS PROVIDED WITH THE EVM (AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

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7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS AND CONDITIONS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS ANDCONDITIONS OR THE USE OF THE EVMS PROVIDED HEREUNDER, REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN ONE YEAR AFTER THE RELATED CAUSE OF ACTION HAS OCCURRED.

   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY WARRANTY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS AND CONDITIONS, OR ANY USE OF ANY TI EVM PROVIDED HEREUNDER, EXCEED THE TOTAL AMOUNT PAID TO TI FOR THE PARTICULAR UNITS SOLD UNDER THESE TERMS AND CONDITIONS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM AGAINST THE PARTICULAR UNITS SOLD TO USER UNDER THESE TERMS AND CONDITIONS SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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