

TRF3703 Quadrature Modulator Evaluation Module

User's Guide



Literature Number: SLWU042B
October 2006–Revised August 2008

1	Overview	5
1.1	Purpose.....	5
1.2	EVM Circuit Overview	5
1.3	Power Requirements	5
1.4	TRF3703 EVM Operating Procedure	6
2	Physical Description	11
2.1	PCB Layout.....	11
2.2	Parts List	18
3	Circuit Description.....	18
3.1	Circuit Function	18
4	Circuit Board	19
5	Schematic	20
	Important Notices	21

List of Figures

1	Un-Optimized Sideband Suppression	7
2	Optimized Sideband Suppression	8
3	GSM EDGE EVM at 1800 MHz	9
4	1.5-V Interface Network for 19.2 mA Full Scale	10
5	3.3-V Interface Network for 19.2 mA Full Scale	10
6	Top Layer	11
7	Top Layer–NH	12
8	Ground Plane L2	13
9	Ground Plane L3	14
10	Layer 4—Bottom Layer	15
11	Layer 4—Bottom Layer–NH	16
12	Drill Pattern	17
13	Silkscreen Top Layer	19
14	TRF3703 EVM Schematic	20

List of Tables

1	Bill of Materials for TRF3703 EVM	18
2	Power Supply J1	18

TRF3703 Quadrature Modulator Evaluation Module

1 Overview

This document relates to the TRF3703-33 and TRF3703-15 (hereinafter referred to as TRF3703) direct quadrature modulator for applications in the transmit path of base stations and communications equipment. The TRF3703 operates between 400 MHz and 4 GHz. The quadrature modulator is used for upconversion of signals from the transmit chain DAC to the RF power amplifier device. Evaluating modulator complex performance involves careful bias-voltage setup, an LO signal, and two differential (I/Q) signals at the input of the modulator. This document describes the wide range of test options available and the factors that must be considered in using this EVM.

1.1 Purpose

The TRF3703 evaluation module (EVM) is intended for the evaluation of the TRF3703-33 and TRF3703-15 direct-launch quadrature modulators. Unless otherwise stated, the functionality described in this manual applies to both the TRF3703-33 and TRF3703-15 devices.

1.2 EVM Circuit Overview

The EVM comes configured for differential I/Q input signals via four SMA connectors as shown in the schematic, [Figure 14](#), and in [Table 1](#).

For the upper sideband, the I signals are connected to J4 (I+) and J3 (I–). The Q signals are connected to J5 (Q–) and J6 (Q+). The LO signal is fed to SAM connector J1, whereas J2 must be terminated with 50 Ω to ground. SMA connector J7 is used to monitor the RF output signal from the quadrature modulator (U1).

The quadrature modulator requires a supply voltage of 4.5 V–5.5V at 235 mA from a regulated power supply through headers W1 and W2. The TRF3703-33 requires a 235-mA current limit, whereas the TRF3703-15 requires 205 mA.

The TRF3703-33 and TRF3703-15 quadrature modulators require a dc common-mode bias voltage (3.3 VDC and 1.5 VDC, respectively) on all four input pins.

1.3 Power Requirements

The TRF3703 EVM requires two 5-V V_{CC} dc power-supply connectors through headers W1 and W2. Header W1 supplies 5 V to the LO circuitry, and W2 supplies 5 V to the modulator circuitry.

CAUTION

Voltage Limits

Exceeding 5.6 V may damage the TRF3703.

1.4 TRF3703 EVM Operating Procedure

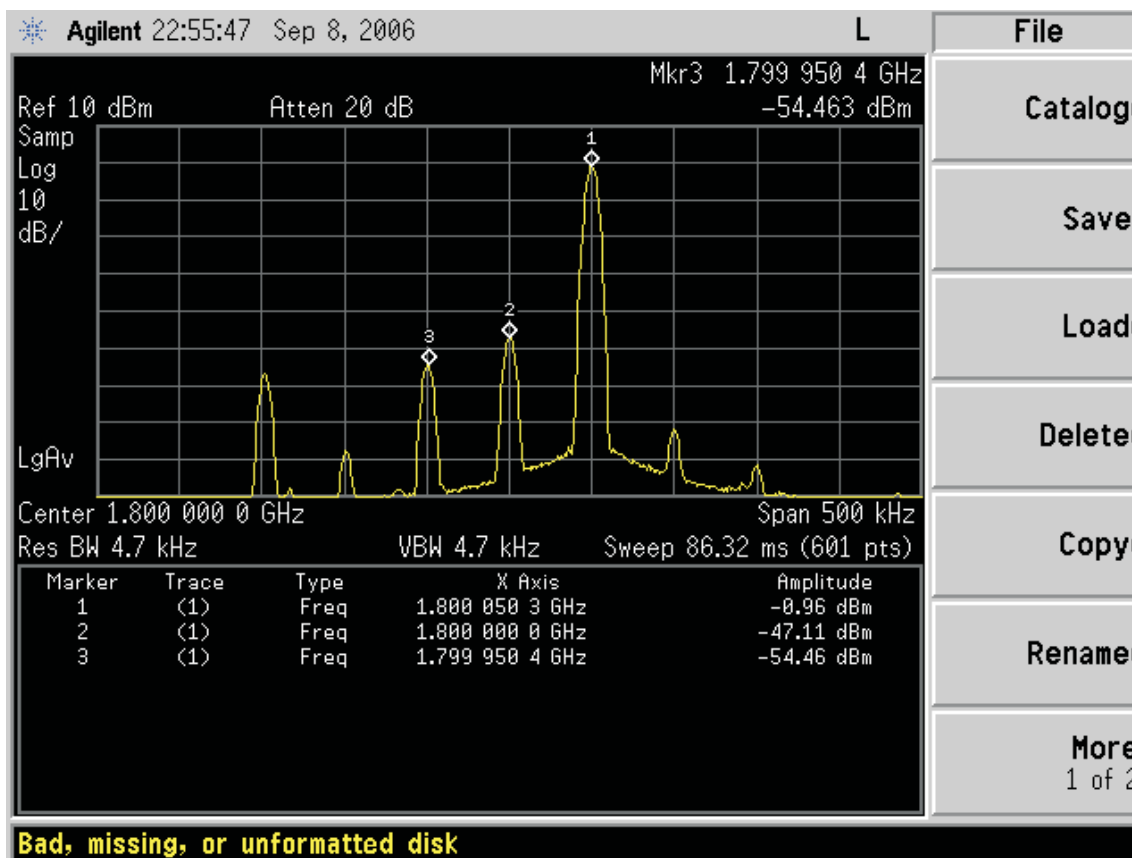
Set up the EVM as follows:

1. Power-supply connection:
 - a. Switch on the V_{CC} (5-V) supply and set the current limit set to 235 mA.
 - b. Connect the 5-V supply to headers W1 and W2.
 - c. Verify that the current drawn is approximately ≤ 205 mA for the TRF3703-15 and ≤ 235 mA for the TRF3703-33.
2. Use a suitable 50- Ω output signal generator ($LO = \pm 5$ dBm) or the TRF3761 to supply the LO signal at desired frequency to J1, and terminate J2 with 50 Ω to ground.
3. Use a DAC or an arbitrary waveform generator to provide the I/Q input signals. A typical setup is as follows: a 1-Vp-p sine wave, a frequency of 50 KHz, a dc-offset of 0 V, and an output impedance of 50 Ω (typically an ESG vector signal generator or similar).
4. Set the common mode on the ESG to either 1.65 V or 0.75 V, depending on device type (set to 1.65 V for the TRF3703-33, set to 0.75 V for the TRF3703-15).
5. Use an arbitrary waveform generator to suppress the sideband. Adjust the I/Q amplitude and phase of the CW signal coming from the arbitrary waveform generator.
6. Connect a spectrum analyzer to the SMA connector marked RFOUT (J7) and monitor the TRF3703 output.

1.4.1 Typical Test Results

1.4.1.1 Un-Optimized Sideband Suppression

measures the amount by which the unwanted sideband of the input signal is attenuated in the output of the modulator, relative to the wanted sideband. This assumes that the baseband inputs delivered to the modulator input pins are perfectly matched in amplitude and are exactly 90° out of phase. Un-optimized sideband suppression is measured in dBc. An iterative test is required in order to match perfectly the inputs to the modulator. This ensures that any equipment, board, or signal conditioning component imbalances are corrected before the signals are applied to the device under test. Once the baseband inputs to the modulator are balanced, the amount of suppression attained is a measure of the internal mismatches of the modulator, inherent to any modulator design. This suppression is the one specified in the TRF3703 datasheet. See [Figure 1](#).

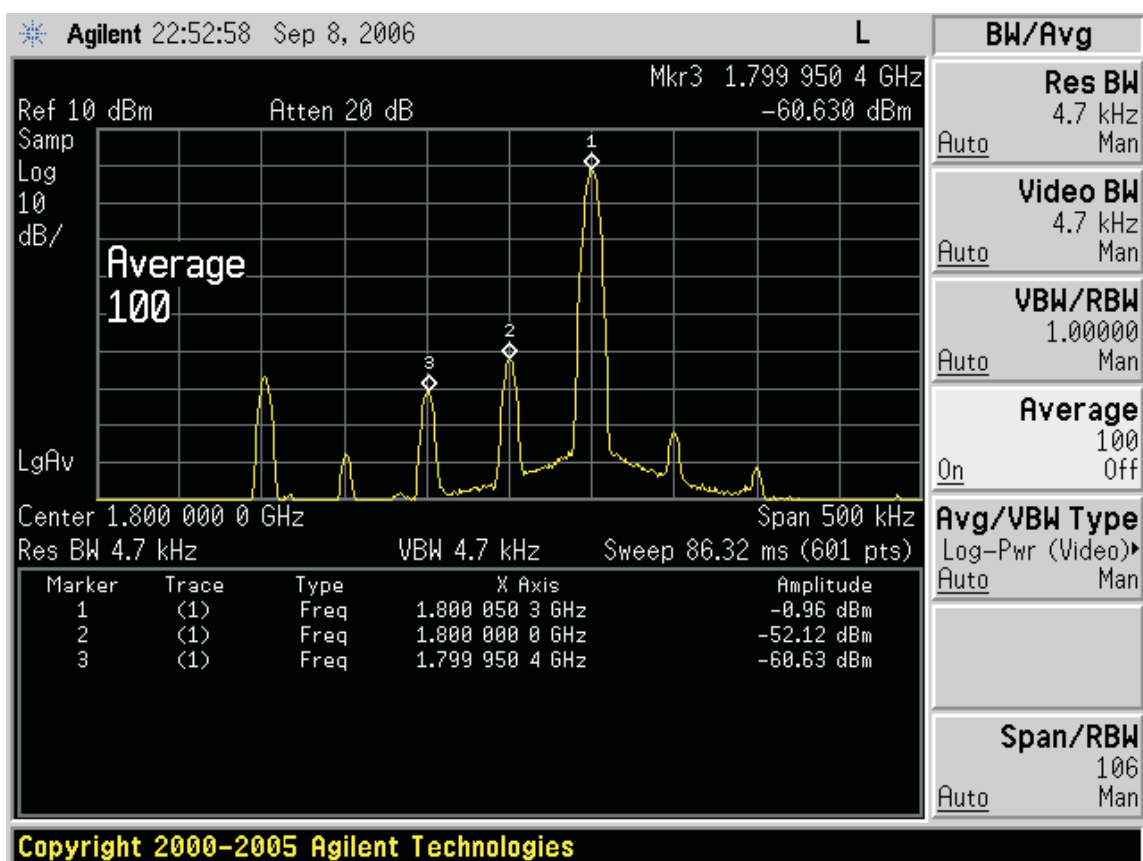


C003

Figure 1. Un-Optimized Sideband Suppression

1.4.1.2 Optimized Sideband Suppression

There are two ways to change the sideband suppression of the TRF3703. One is the amplitude between the four inputs, and the second is the phase of the four inputs. The ideal condition is when all four inputs (I , $\bar{I}$, Q , and $\bar{Q}$) have exactly the same amplitude and the phase relationship is: $I = 0^\circ$, $\bar{I} = 180^\circ$, $Q = 90^\circ$, and $\bar{Q} = 270^\circ$. Also, the optimization of the sideband is controlled by the amplitude and phase of the I and Q signals, which are controlled with the gain settings of the DAC. This is an iterative procedure that results in optimized suppression levels that exceeds 60 dBc. The level of suppression observed depends on the amount of resolution available from the DAC driving the modulator. By using TI's DAC568X, the user can take advantage of built-in features (DAC fine gain) to optimize the sideband suppression by changing the amplitude relationship of the signals. If another DAC is used, then the user must provide this level of adjustment by controlling the regular digital inputs to the DAC. See [Figure 2](#).



C002

Figure 2. Optimized Sideband Suppression

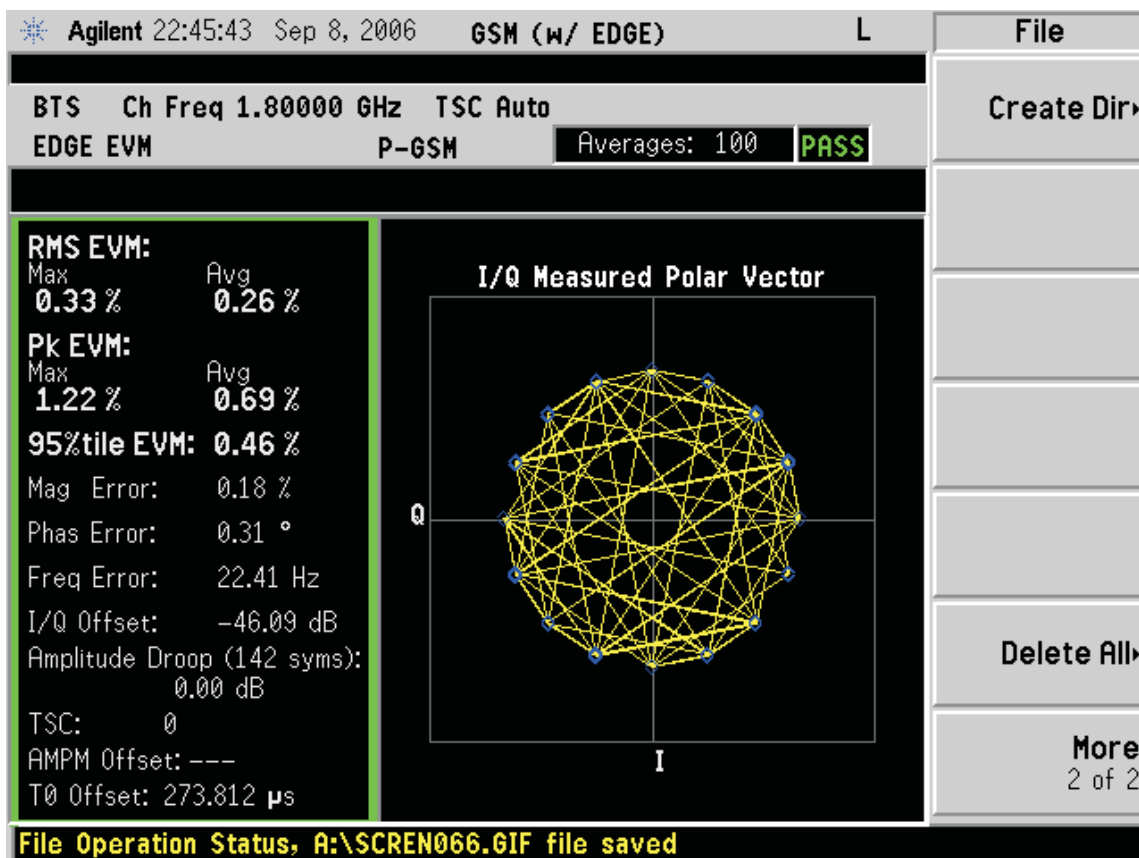
1.4.1.3 Carrier Feedthrough

Carrier feedthrough is the amount of the LO that leaks onto the output spectrum of the modulator. Ideally for the TRF3703, inputs (I, $\bar{I}$, Q, and $\bar{Q}$) must be at approximately 3.3 V for TRF3703-33 and 1.5 V for TRF3703-15. The DAC dc settings are also useful to correct the dc mismatch between I and $\bar{I}$ and between Q and $\bar{Q}$ to correct for the LO feedthrough. If using TI's DAC568X, then the internal controls for the IQ offsets provide excellent carrier suppression (very low LO leakage). Alternatively, if an ESG is being used, adjust the I and Q voltage offsets in mV steps until you obtain the minimum carrier feedthrough. A typical carrier feedthrough value exceeds 50 dBm. See [Figure 2](#).

1.4.1.4 GSM (EDGE EVM Measurements)

1. Provide a GSM edge signal of the desired frequency into the differential baseband inputs (example sample rate = 4.33 MHz).
2. Use a spectrum analyzer with edge personality to measure the transmit power to either 0 or -5 dBm.
3. PSA: Mode → GSM(w/ EDGE) → measure → Transmit Pwr(usually 0 or -5 dBm) → more → EDGE EVM.
4. ESG: Mode setup → select waveform → highlight EDGE → select waveform → ARB setup → type 4.33333 MHz → I/Q → I/Q output control → Common mode I/Q offset → (set to either 1.65 V for TRF3703-33 or to 0.75 V for TRF3703-15) → I/Q → I/Q output control → I/Q output atten (adjust to get desired transmit power to either 0 or -5 dBm).

See [Figure 3](#).

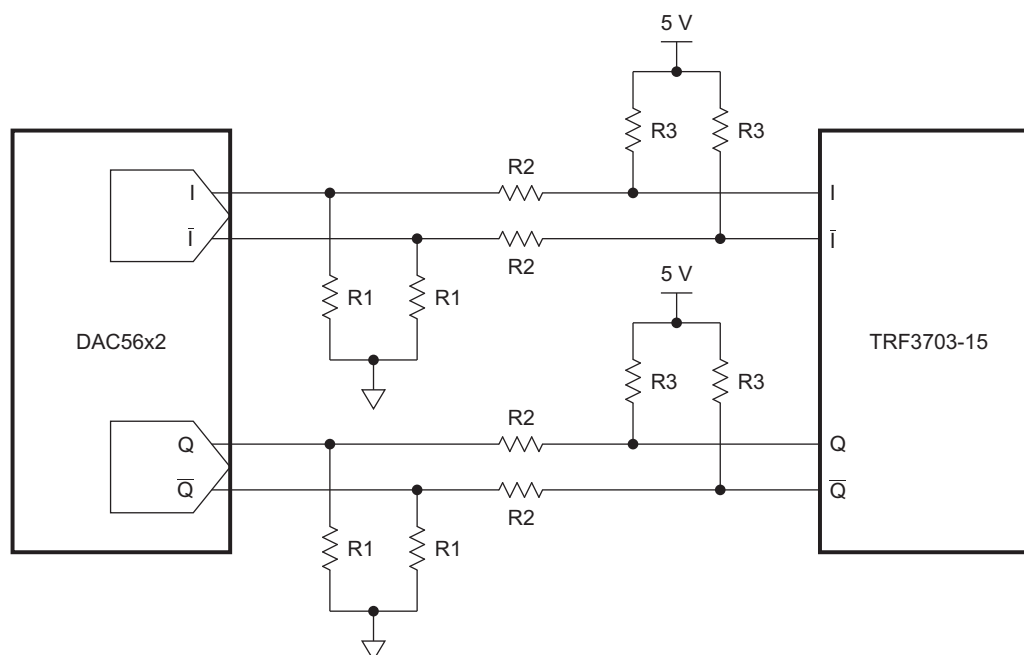


C001

Figure 3. GSM EDGE EVM at 1800 MHz

1.4.2 Interface to TI's DAC

Both the TRF3703-33 and the TRF3703-15 work well with TI's DACs. The TRF3703-33 is well suited to work with TI's DAC568X family, and the TRF3703-15 is well suited to work with TI's DAC56X2 series. Each DAC series is optimized to work at certain common-mode voltage. The DAC568X has a common-mode of 3.3 V, while the DAC56X2 has a 0.7-V common-mode voltage. Figure 1 shows an interface network to interface both DAC series to the TRF3703.

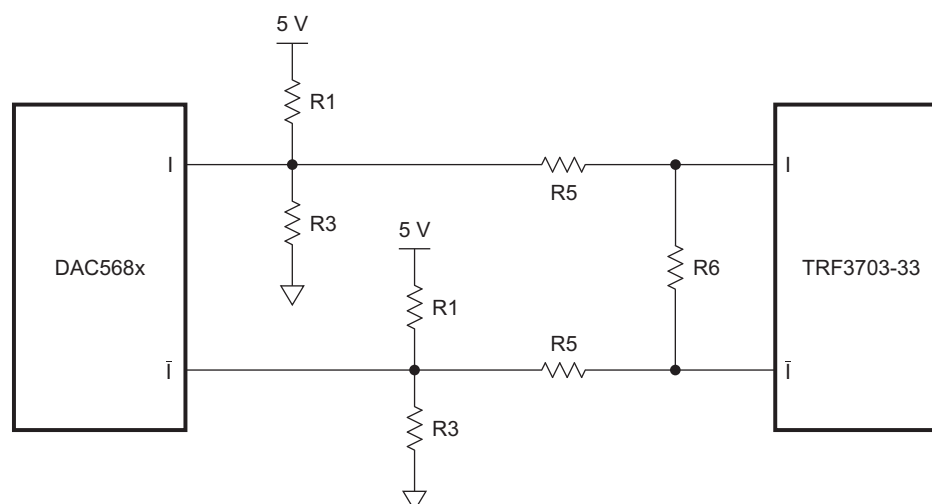


S0225-01

TYPICAL VALUES		
R1	R2	R3
53 Ω	210 Ω	931 Ω

NOTE: A DAC interface calculator is available ([SLWC083](#)).

Figure 4. 1.5-V Interface Network for 19.2 mA Full Scale



S0226-01

LOSS		1 dB	2 dB	3 dB	4 dB	5 dB
Pullup	R1	115	115	115	115	115
Pulldown	R3	634	634	634	634	634
Series	R5	11	21	30	37.4	45.3
Shunt	R6	187	165	147	130	118

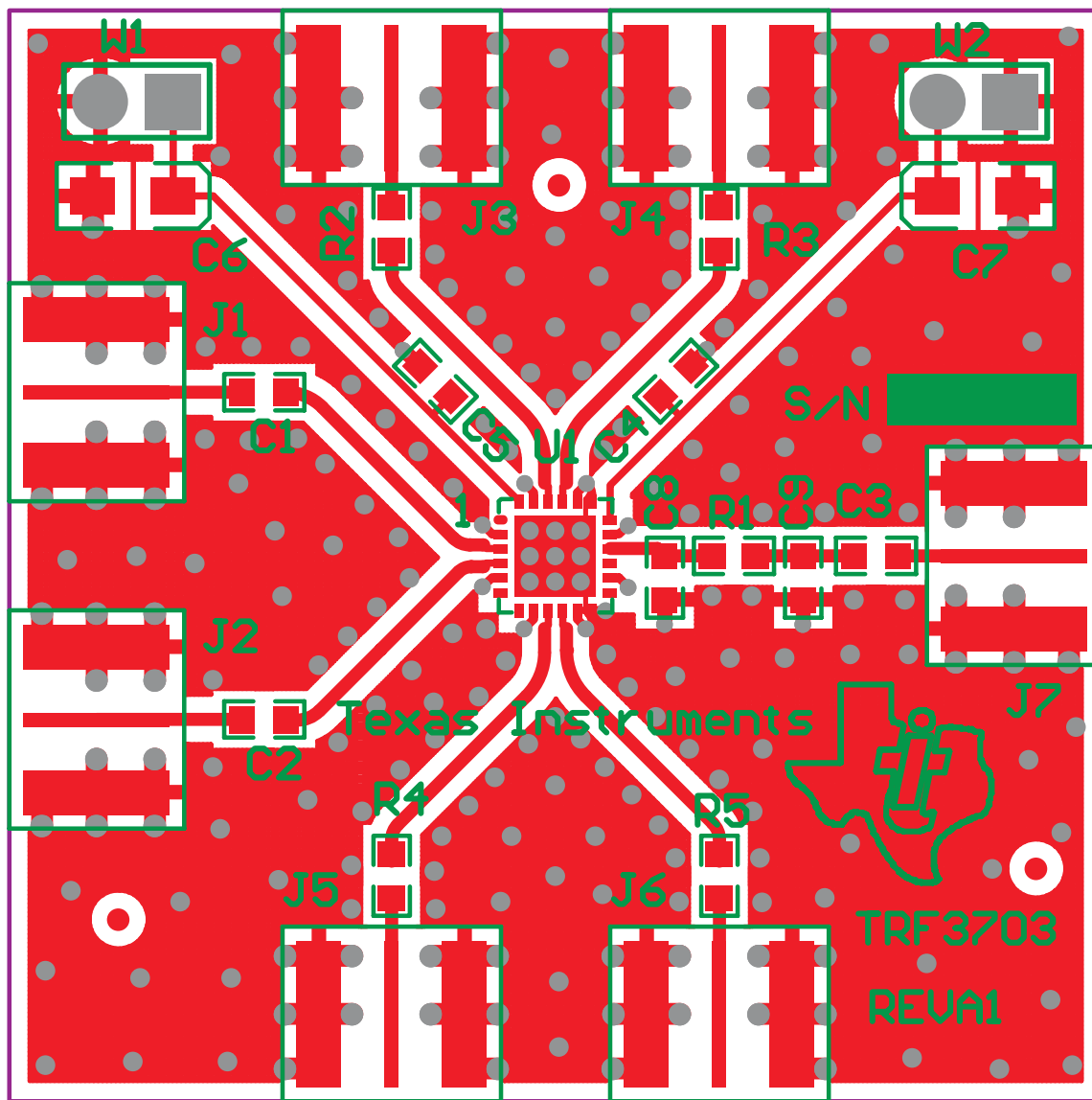
Figure 5. 3.3-V Interface Network for 19.2 mA Full Scale

2 Physical Description

This chapter discusses the four-layer PCB layout, component placement, and list of components used on the evaluation module.

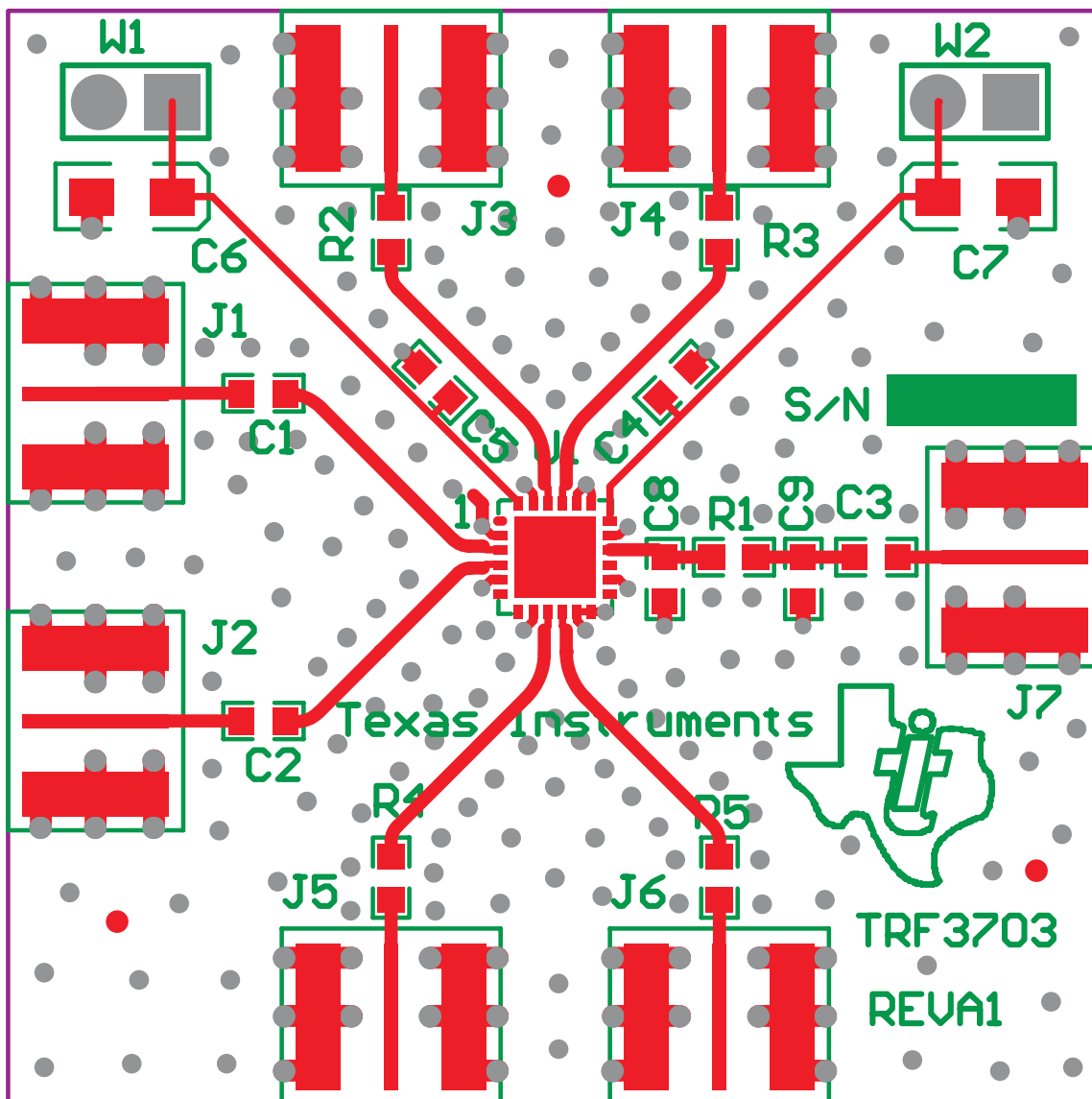
2.1 PCB Layout

The EVM is constructed on a four-layer, 38,1-mm × 38,1-mm × 1,579-mm thick PCB using FR-4 material. Figure 6 through Figure 12 show the individual layers.



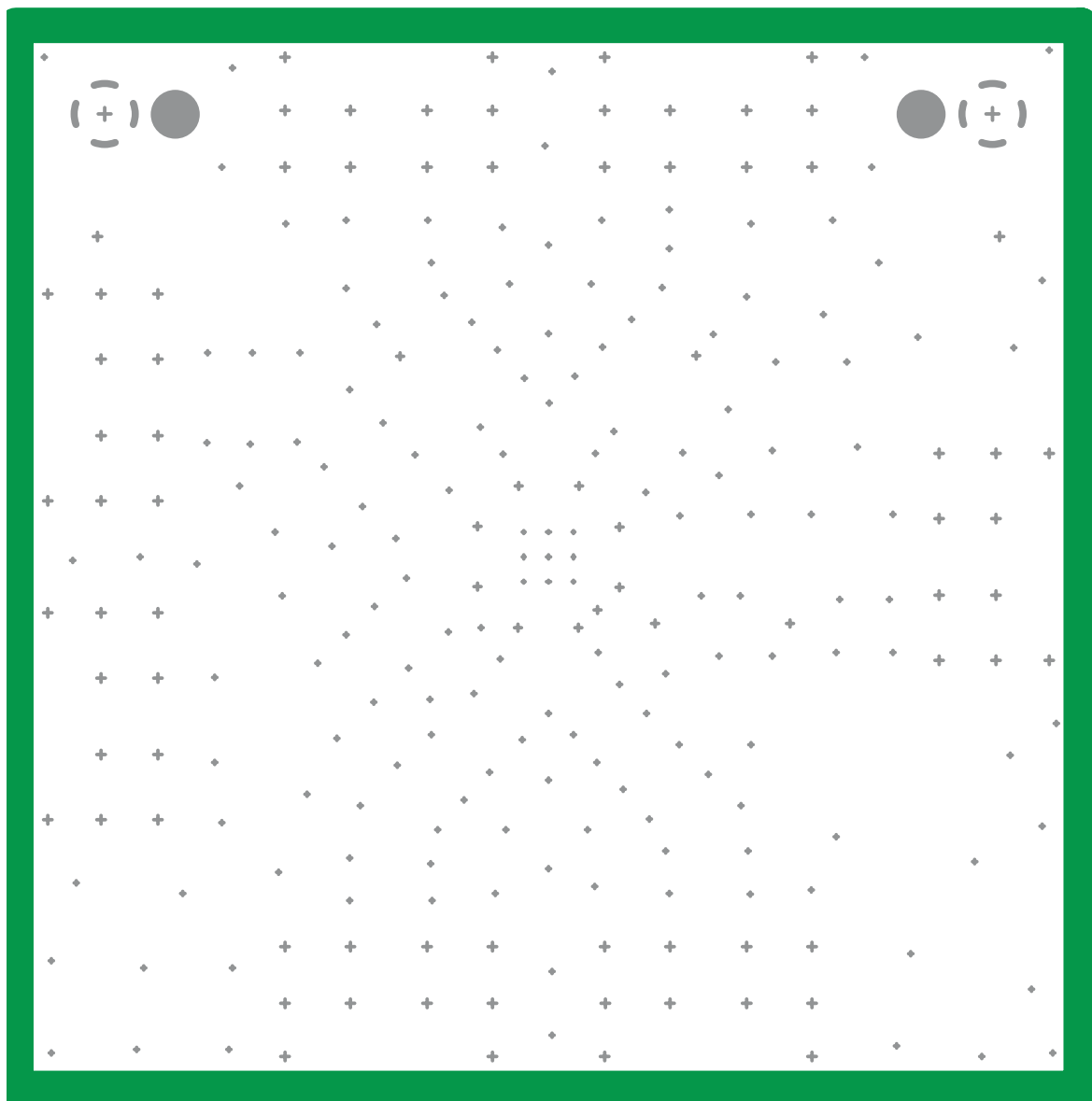
K001

Figure 6. Top Layer



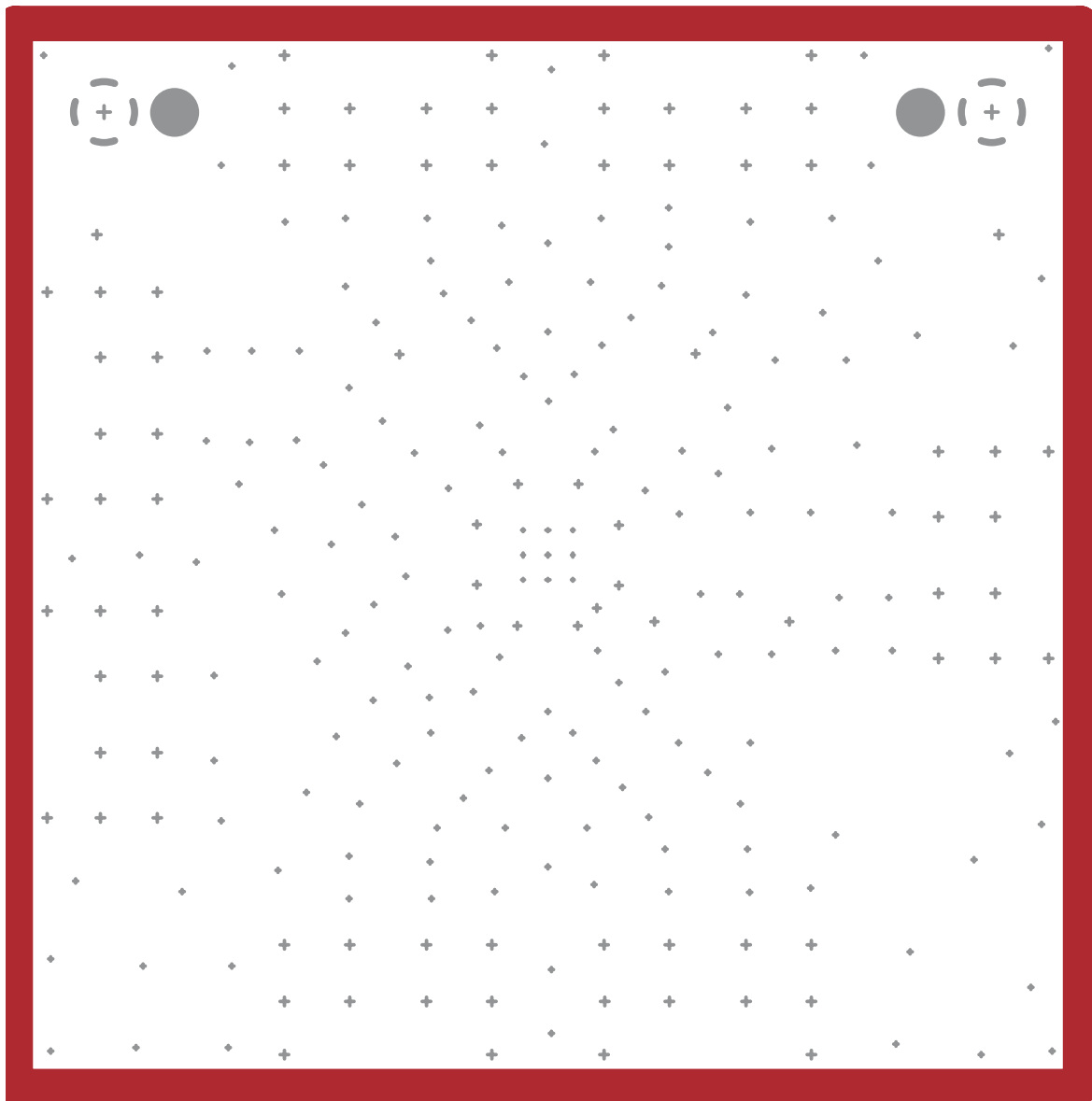
K002

Figure 7. Top Layer-NH



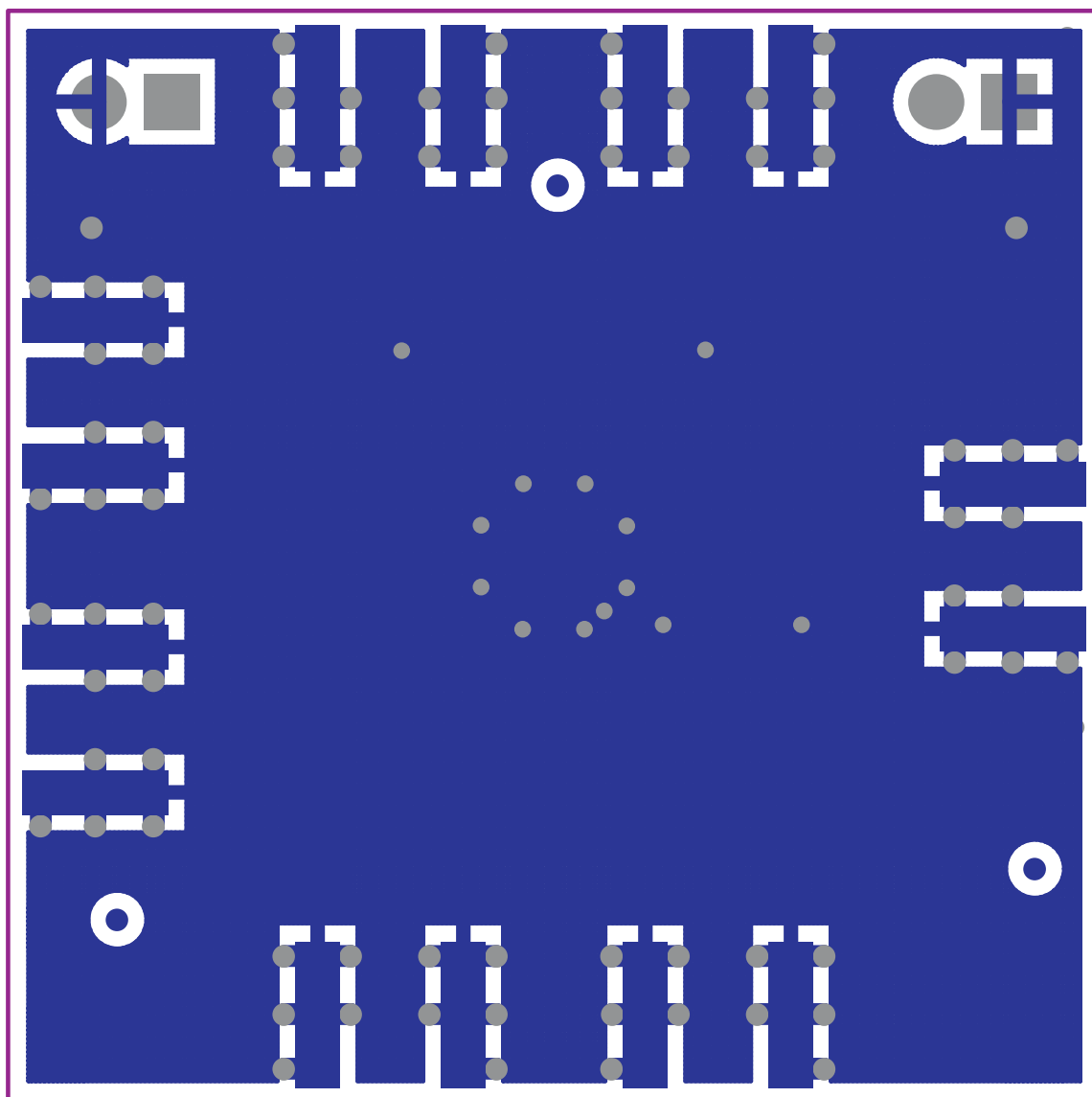
K003

Figure 8. Ground Plane L2



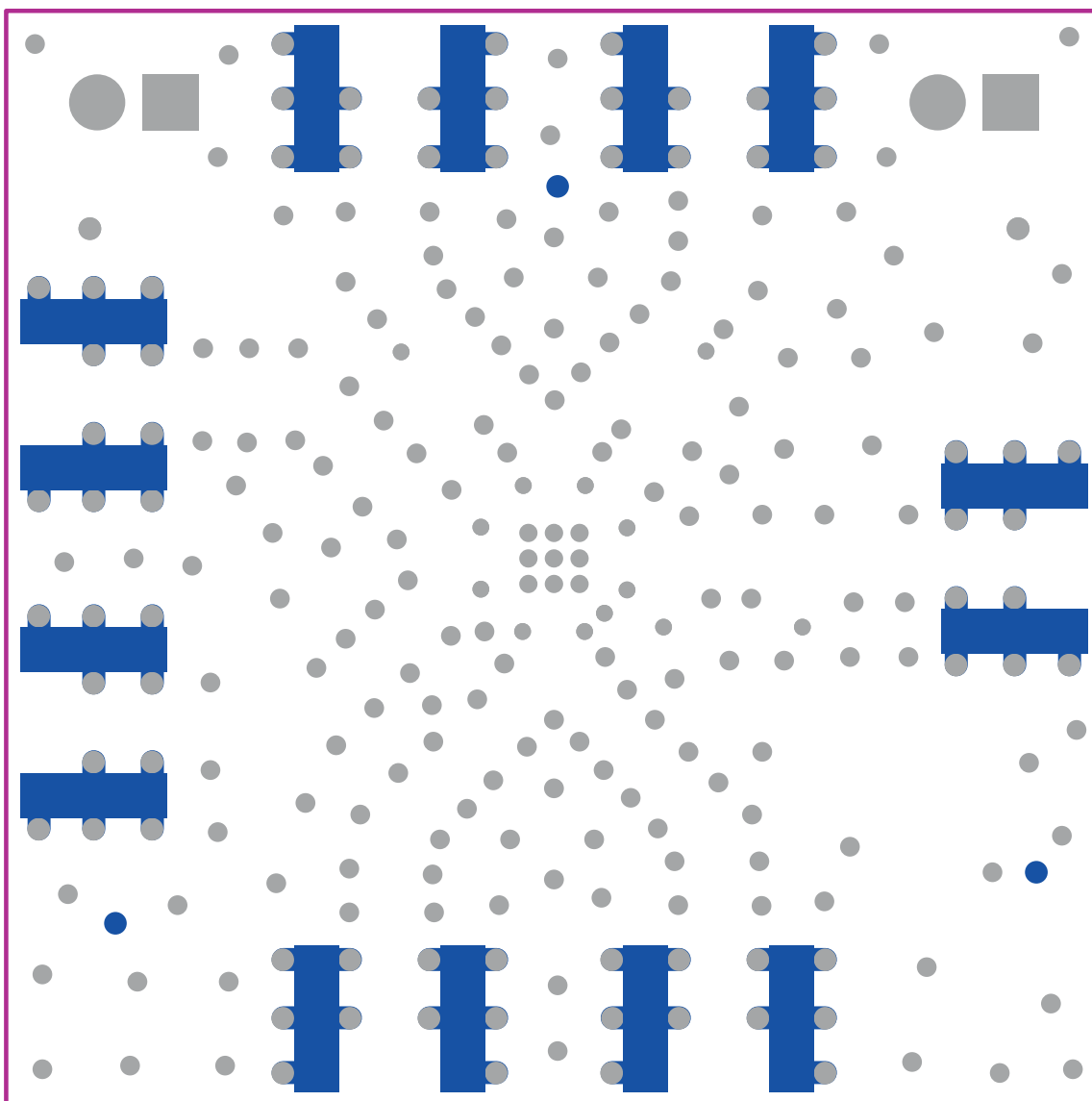
K004

Figure 9. Ground Plane L3



K005

Figure 10. Layer 4—Bottom Layer

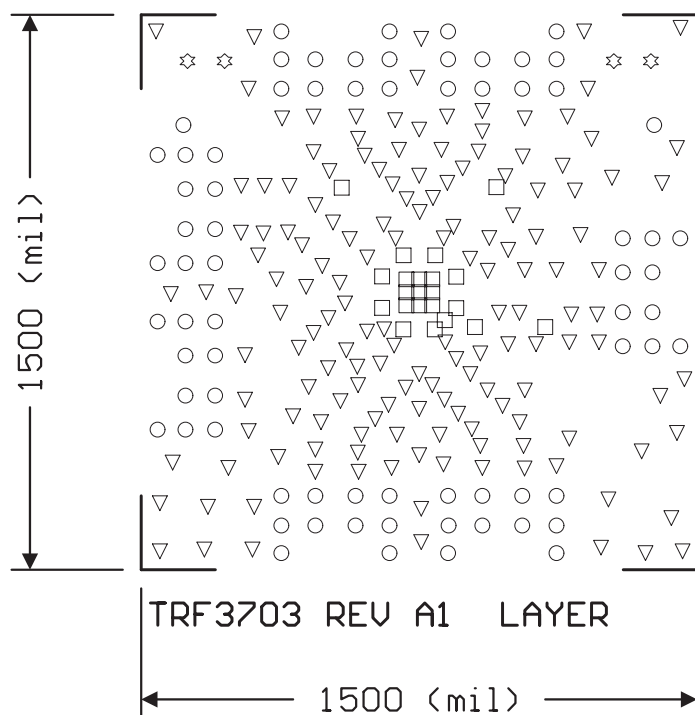


K006

Figure 11. Layer 4—Bottom Layer—NH

Notes:

1. PWB TO BE FABRICATED TO MEET OR EXCEED IPC-6012, CLASS 3 STANDARDS AND WORKMANSHIP SHALL CONFORM TO IPC-A-600, CLASS 3 - CURRENT REVISIONS
2. BOARD MATERIAL AND CONSTRUCTION TO BE UL APPROVED AND MARKED ON THE FINISHED BOARD.
3. LAMINATE MATERIAL: POLYCAD 370 TURBO/HR
4. COPPER WEIGHT: 1oz FINISHED
5. FINISHED THICKNESS: .062 +/- .010. TOP METAL TO GND PLANE DIELECTRIC THICKNESS TO BE 10 MIL +/- .5 MIL
6. MIN PLATING THICKNESS IN THROUGH HOLES: .001"
7. GOLD FINISH, 50-100 MICRO OF NICKEL
8. LPI SOLDERMASK BOTH SIDES USING APPROPRIATE LAYER ARTWORK: COLOR = GREEN
9. LPI SILKSCREEN AS REQUIRED: COLOR - WHITE
10. VENDER INFORMATION TO BE INCORPORATED ON BACK SIDE WHENEVER POSSIBLE
11. MINIMUM COPPER CONDUCTOR WIDTH IS: 10 MILS
MINIMUM CONDUCTOR SPACING IS: 5 MILS
13. TOP LAYER 18 MIL TRACES ARE CONTROLLED IMPEDANCE, 50 OHM LINES.



TRF3703 BOARD STACKUP	
TOP LAYER	1.2
370 TURBO	10.0
GND PLANE 1	1.2
TBD	37.2
GND PLANE 2	1.2
370 TURBO	10.0
BOTTOM LAYER	1.2

□	22	10 mil	0.254 mm	PTH
○	72	12 mil	0.3048 mm	PTH
▽	156	13 mil	0.3302 mm	PTH
☆	4	37 mil	0.9398 mm	PTH
	254	Total		

Figure 12. Drill Pattern

D001

2.2 Parts List

Table 1. Bill of Materials for TRF3703 EVM

Value	Footprint	QTY	Part Number	Vendor	Digi-Key Number	REF DES	Not Installed
Tantalum 4.7- μ F, 10-V, 10% capacitor	3216	2	T491A475K010AS	KEMET	399-1561-1-ND	C6, C7	
1000-pF, 50-V, 5% capacitor	603	2	ECJ-1VC1H102J	Panasonic	PCC2151CT-ND	C4, C5	
100-pF, 50-V, 5% capacitor	603	3	ECJ-1VC1H101J	Panasonic	PCC101ACVCT-ND	C1, C2, C3	
Capacitor	603	0					C8, C9
0- Ω resistor, 1/10-W, 5%	603	5	ERJ-3GEY0R00V	Panasonic	P0.0GCT-ND	R1, R2, R3, R4, R5	
TRF3703	24-QFN-PP-4X4MM	1		TI		U1	
SMA connectors	SMA_END_SMALL	6	16F3627	Newark	142-0711-821	J1, J2, J3, J4, J5, J6, J7	
2POS_HEADER	2POS_JUMP	2	HTSW-150-07-L-S	SAMTEC	N/A	W1, W2	

3 Circuit Description

This chapter discusses the various functions of the EVM.

3.1 Circuit Function

- Headers W1 and W2 supply 5-V V_{CC} dc power to the modulator. Header W1 supplies 5 V to the LO circuitry, and W2 supplies 5 V to the modulator circuitry.
- Four SMA connectors are provided on the EVM for inputting differential I/Q signals directly to the input pins of the TRF3703. Connectors J3, J4, J5, and J6 are used to connect the signal source I/Q signals directly to the TRF3703.
- Two SMA connectors are provided for LO input: J1 = LOP and J2 = LON. Terminate whichever LO port is not being used through 50 Ω to ground.
- One SMA connector is for RF_OUT: J7.

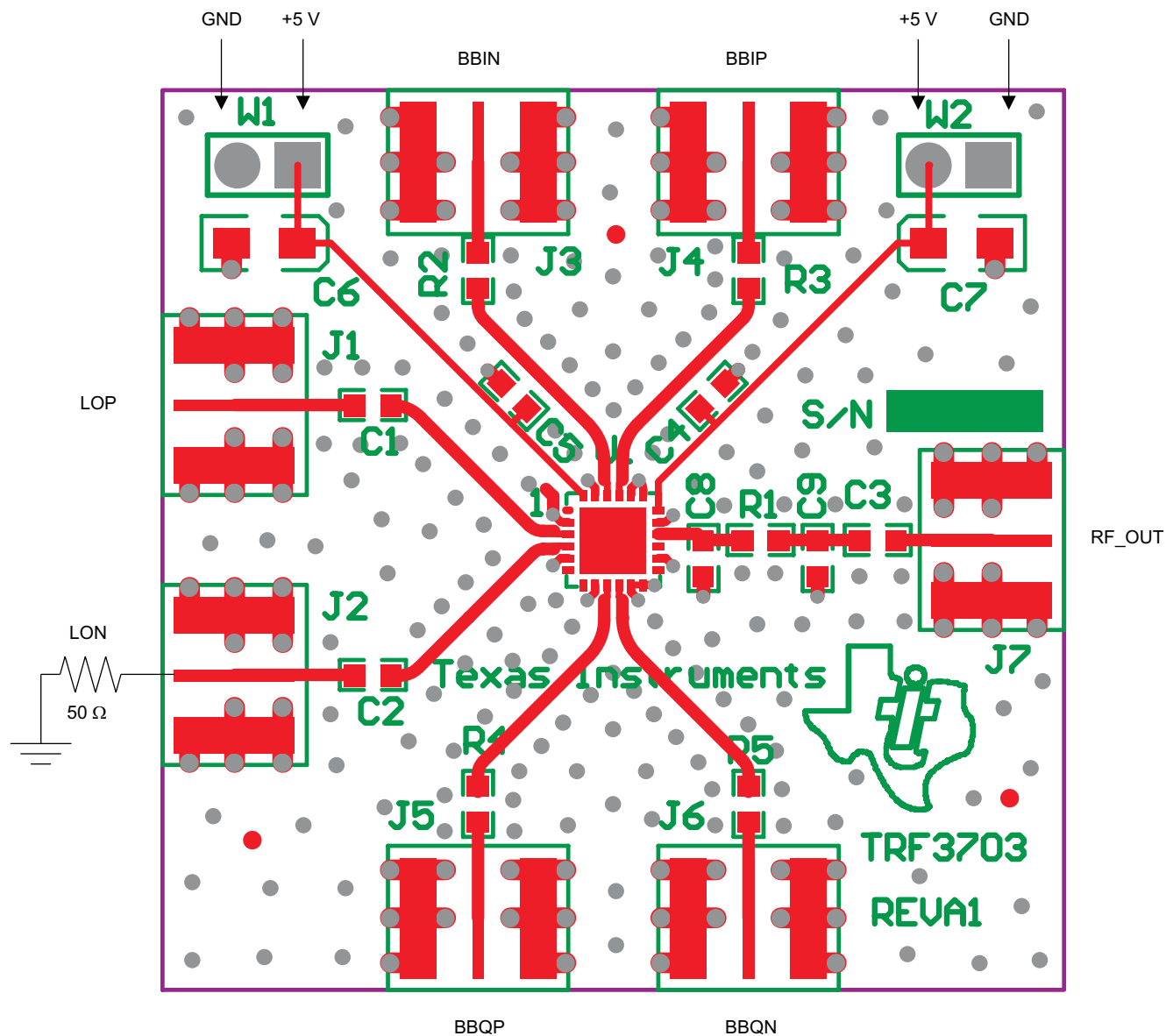
3.1.1 Power

Table 2. Power Supply J1

J1 Pin	Description
W1	5-V (V_{CC}), U1 analog supply
W2	5-V (V_{CC}), U1 analog supply

4 Circuit Board

This chapter shows the circuit board test points.

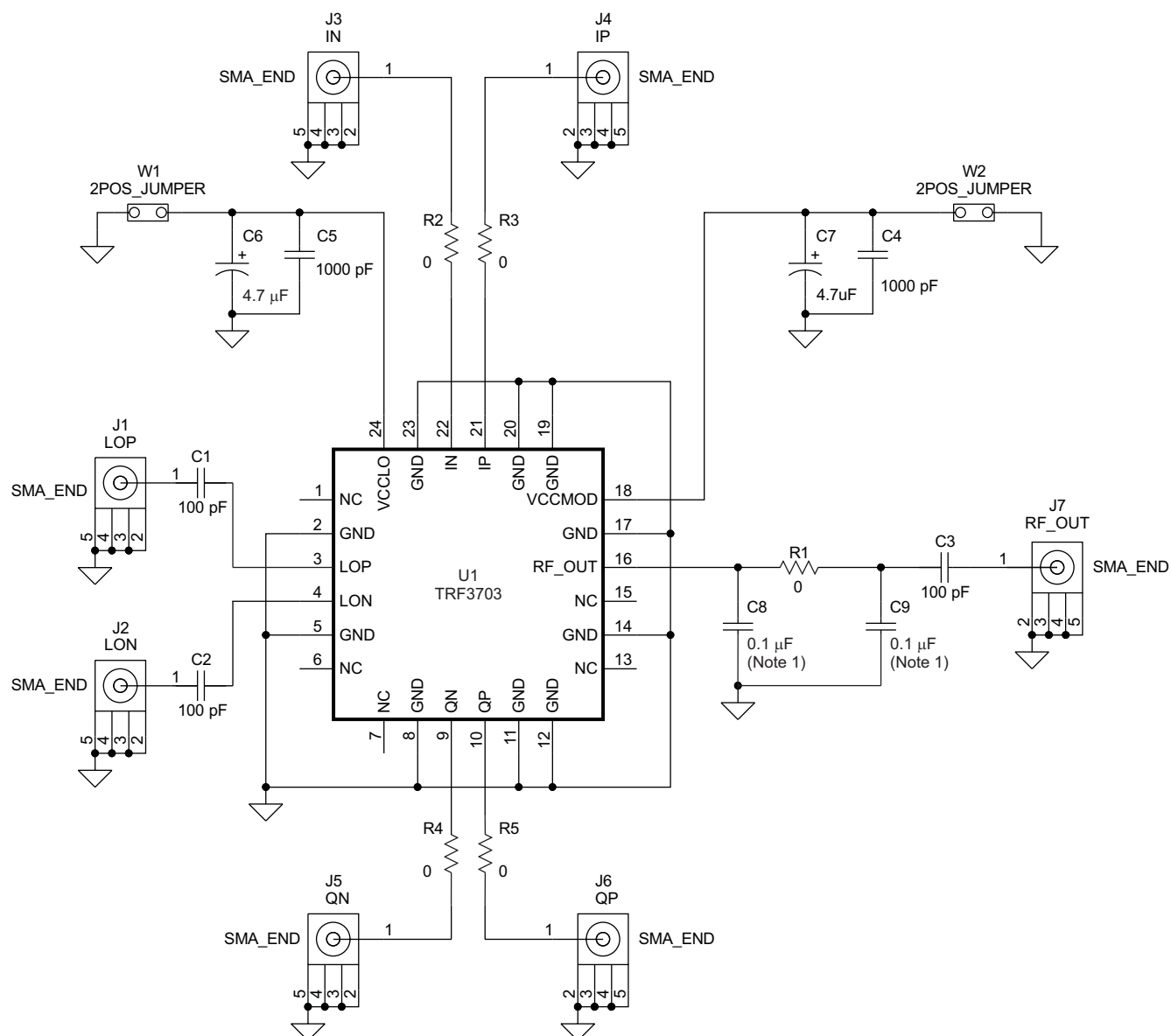


K001

Figure 13. Silkscreen Top Layer

5 Schematic

This chapter shows the EVM schematic.



(1) Do not install.

S0214-01

Figure 14. TRF3703 EVM Schematic

EVALUATION BOARD/KIT IMPORTANT NOTICE

Texas Instruments (TI) provides the enclosed product(s) under the following conditions:

This evaluation board/kit is intended for use for **ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. Persons handling the product(s) must have electronics training and observe good engineering practice standards. As such, the goods being provided are not intended to be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety and environmental measures typically found in end products that incorporate such semiconductor components or circuit boards. This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and therefore may not meet the technical requirements of these directives or other related directives.

Should this evaluation board/kit not meet the specifications indicated in the User's Guide, the board/kit may be returned within 30 days from the date of delivery for a full refund. **THE FOREGOING WARRANTY IS THE EXCLUSIVE WARRANTY MADE BY SELLER TO BUYER AND IS IN LIEU OF ALL OTHER WARRANTIES, EXPRESSED, IMPLIED, OR STATUTORY, INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE.**

The user assumes all responsibility and liability for proper and safe handling of the goods. Further, the user indemnifies TI from all claims arising from the handling or use of the goods. Due to the open construction of the product, it is the user's responsibility to take any and all appropriate precautions with regard to electrostatic discharge.

EXCEPT TO THE EXTENT OF THE INDEMNITY SET FORTH ABOVE, NEITHER PARTY SHALL BE LIABLE TO THE OTHER FOR ANY INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

TI currently deals with a variety of customers for products, and therefore our arrangement with the user **is not exclusive**.

TI assumes **no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein.**

Please read the User's Guide and, specifically, the Warnings and Restrictions notice in the User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For additional information on TI's environmental and/or safety programs, please contact the TI application engineer or visit www.ti.com/esh.

No license is granted under any patent right or other intellectual property right of TI covering or relating to any machine, process, or combination in which such TI products or services might be or are used.

FCC Warning

This evaluation board/kit is intended for use for **ENGINEERING DEVELOPMENT, DEMONSTRATION, OR EVALUATION PURPOSES ONLY** and is not considered by TI to be a finished end-product fit for general consumer use. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC rules, which are designed to provide reasonable protection against radio frequency interference. Operation of this equipment in other environments may cause interference with radio communications, in which case the user at his own expense will be required to take whatever measures may be required to correct this interference.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2008, Texas Instruments Incorporated

EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of 4.5 V to 5.5 V and the output voltage range of 4.5 V to 5.5 V.

Exceeding the specified input range may cause unexpected operation and/or irreversible damage to the EVM. If there are questions concerning the input range, please contact a TI field representative prior to connecting the input power.

Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's 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, some circuit components may have case temperatures greater than 59°C. The EVM is designed to operate properly with certain components above -40°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2008, Texas Instruments Incorporated

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
RF/IF and ZigBee® Solutions	www.ti.com/lprf

Applications

Audio	www.ti.com/audio
Automotive	www.ti.com/automotive
Broadband	www.ti.com/broadband
Digital Control	www.ti.com/digitalcontrol
Medical	www.ti.com/medical
Military	www.ti.com/military
Optical Networking	www.ti.com/opticalnetwork
Security	www.ti.com/security
Telephony	www.ti.com/telephony
Video & Imaging	www.ti.com/video
Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2008, Texas Instruments Incorporated