TEXAS INSTRUMENTS

TRF3701/TRF3702 Quadrature Modulator Evaluation Module

User's Guide

2004

Wireless Infrastructure Products

SLWU007

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 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.

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.

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

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	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

EVM IMPORTANT NOTICE

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

This evaluation kit being sold by TI is intended for use for **ENGINEERING DEVELOPMENT OR EVALUATION PURPOSES ONLY** and is not considered by TI to be fit for commercial use. As such, the goods being provided may not be complete in terms of required design-, marketing-, and/or manufacturing-related protective considerations, including product safety measures typically found in the end product incorporating the goods. As a prototype, this product does not fall within the scope of the European Union directive on electromagnetic compatibility and therefore may not meet the technical requirements of the directive.

Should this evaluation kit not meet the specifications indicated in the EVM User's Guide, the 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. Please be aware that the products received may not be regulatory compliant or agency certified (FCC, UL, CE, etc.). 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 EVM User's Guide and, specifically, the EVM Warnings and Restrictions notice in the EVM User's Guide prior to handling the product. This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact the TI application engineer.

Persons handling the product must have electronics training and observe good laboratory practice standards.

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.

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input and output voltage ranges described in the EVM user's guide.

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 60°C. The EVM is designed to operate properly with certain components above 60°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

Preface

Read This First

About This Manual

This user's guide describes the configuration of the of the TRF3701/2 evaluation module (EVM), modes of operation, function, and the physical characteristics.

How to Use This Manual

This document contains the following chapters:

Chapter 1 - Overview

Chapter 2 - Physical Description

Chapter 3 - Circuit Description

Chapter 4 - Circuit Board Test Points

Chapter 5 - Schematic

Information About Cautions and Warnings

This book may contain cautions and warnings.

This is an example of a caution statement.

A caution statement describes a situation that could potentially damage your software or equipment.

CAUTION

This is an example of a warning statement.

A warning statement describes a situation that could potentially cause harm to you.

WARNING

The information in a caution or a warning is provided for your protection. Please read each caution and warning carefully.

FCC Warning

This equipment is intended for use in a laboratory test environment only. It generates, uses, and can radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to subpart J of 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.

Contents

Figures

Tables

Chapter 1

Overview

This document relates to the TRF3701/TRF3702 direct launch quadrature modulator for applications in the transmit path of base stations and communications equipment. The TRF3701 operates between 400 MHz and 1.5 GHz and the TRF3702 between 1.5 GHz and 2.5 GHz. A quadrature modulator is used for up conversion of signals from the transmit chain DAC to the RF power amplifier device. Evaluating a modulator complex performance involves careful bias voltage setup, an LO signal and at least two signals (I/Q) at the input to the modulator. This document describes the wide range of test options available with this EVM and the factors that must be considered in using the EVM.

Topic **Page**

1.1 Purpose

The TRF3701/TRF3702 evaluation module (EVM) is intended for the evaluation of the TRF3701 and TRF3702 direct launch quadrature modulator. Unless otherwise stated, the functionality described in this manual applies to both the TRF3701 and TRF3702 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 and Table 1-1.

The EVM has an option for differential I/Q input signals via the two THS4503 op amps as shown in the schematic and Table 1-1. The THS4503 (U2, U3) provides single-ended/differential inputs and outputs in an 8-pin package. The device has a unity gain bandwidth of 370 MHz, a slew rate of 2800 V/µs, and a IMD3 –95 dBc at 30 MHz. The outputs from U2 and U3 are applied to the TRF3701/TRF3702 quadrature modulator IC.

The I signals are connected to J4 (I+) and J8 (I-), respectively. The Q signals are connected to J5 (Q+) and J11 (Q-), respectively. The LO signal is fed to J2 and the SMA connector J3 is used to monitor the output signal from the quadrature modulator (U1).

The quadrature modulator requires a supply voltage of 5 V / 145 mA from a regulated power supply. Both the amplifiers (U2, U3) and the TRF3701/TRF3702 are powered from external power supplies connected to connector J1. The op amp supply voltage must not exceed ±7.5 V.

The TRF3701/TRF3702 quadrature modulator requires a dc common mode bias voltage (3.7 Vdc) on all four input pins. Power supply connectors J6 and J13 accepts these voltages from an external power supply.

1.3 Power Requirements

The EVM has three dc-power supply connectors: J1 accepts ±7 V for op amp supply and a V_{CC} of 5 V for the TRF3701/TRF3702. J6 accepts the VCM (3.7 V) common-mode bias voltage for the TRF3701/TRF3702. J13 accepts the VCM (3.7 V) input signal common-mode bias when using op amps U2 and U3.

Voltage Limits

Exceeding the ±7.5 V maximum may damage the THS4503 op amp.

Exceeding 5.6 V may damage the TRF3701/2

CAUTION

1.4 TRF3701/02 EVM Operating Procedure

Set up the EVM as follows:

1) Verify all settings against Table 1-1.

Table 1-1. EVM Configuration

Configuration Table	
Op-Amp	**No Op-Amp**
Single-Ended Inputs Available – TRF370x Driven Single-Endedly	**DC-Coupled Differential Inputs Available – TRF370x Driven Differentially (Default Configuration)**
W5 pins 1-2, W1, W3, W7, W8, W9, W10, R6, R7, R13, R15, R12†, R14†, R17†, R18†, C53-C56†, W2†, W4† Apply dc offset (VCM = 3.7 Vdc) to J13. Adjust VCOM1 and VCOM2 externally to optimize.Apply I signal to J4, Q to J5.	W5 pins 1-2, W1†, W3†, W7†, W8, W9† W10, W2, W4, R12-R15†, (C53 -C56)⇒ replace with 0 Ω, (R29-R32)⇒ if 50-Ω termination required. All dc offsets adjusted externally. Apply I signal to J9, $\overline{I}$ to J7, Q to J12, $\overline{Q}$ to J10.
Differential Inputs Available – TRF370x Driven Differentially	**DC-Coupled Single-Ended Inputs Available – TRF370x Driven Single-Endedly**
W5 pins 1-2,W2, W4, W8, W10, R12-R15, R6†, R7†, R17, R18, C53-C56†, W1†, W3†, W7†, W9† Apply dc offset (VCM = 3.7 Vdc) to J13. Adjust VCOM1 and VCOM2 externally to optimize. Residual dc can be applied to op-amp inputs for adjusting the complementary inputs if desired. Apply I signal to J4, /I to J8, Q to J5 and /Q to J11.	W5 pins 1-2, W1, W3, W7†, W8, W9†, W10, W2†, W4†, R12-R15†, (C54, C56)⇒ replace with 0 Ω, C53†, C55†, (R30, R32)⇒ if 50-Ω termination required. Apply dc offset (VCM = 3.7 Vdc) to J6 and adjust R33 and R34 to optimize the dc offset level of the complementary I,Q inputs. Apply I signal to J9, Q to J12.
Single-Ended Inputs Available – TRF370x Driven Differentially	**AC-Coupled Single-Ended Inputs Available – TRF370x Driven Single-Endedly**
W5 pins 1-2, W2, W4, W8, W10, R12-R15, R6, R7, R17†, R18†, C53-C56†, W1†, W3†, W7†, W9† Apply dc offset (VCM = 3.7 Vdc) to J13. Adjust VCOM1 and VCOM2 externally to optimize. Residual dc can be applied to op-amp inputs for adjusting the complementary inputs if desired. In this case, follow the connections of the section above (differential drive). Apply I signal to J4, Q to J5.	W5 pins 1-2, W1, W3, W7, W8, W9, W10, W2†, W4†, R12-R15†, C54, C56, C53†, C55†, (R30, R32)⇒ if 50-Ω termination required. Apply dc offset (VCM = 3.7 Vdc) to J6 and adjust R33 and R34 to optimize. Apply I signal to J9, Q to J12.
	AC-Coupled Differential Inputs Available – TRF370x Driven Differentially
	W5 pins 1-2, W1, W3, W7, W8, W9, W10, W2, W4, R12-R15†, C54, C56, C53, C55, (R29-R32)⇒ if 50-Ω termination required. Apply dc offset (VCM = 3.7 Vdc) to J6 and adjust R33 and R34 to optimize. Apply I signal to J9, $\overline{I}$ to J7, Q to J12, $\overline{Q}$ to J10.

† Remove from circuit

2) Connect the regulated power supplies to the EVM as follows:

   a) Switch on the V_{CC} (5 V) supply and verify that the current drawn is approximately 130 - 140 mA.

   b) Switch on the VCM (3.7 Vdc) precision regulated bias voltage supply connected to J6 (if needed).

c) Switch on the ±7-V op amp supply, then turn on the precision regulated power supply connected to J13, set to VCM, and used to provide the VCOM1 and VCOM2 voltages (if needed).

3) Use a suitable 50-Ω output signal generator to supply the LO signal: 0 dBm.

4) Use 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 900 KHz, a dc-offset of 0 V, and an output impedance 50-Ω.

5) Connect a spectrum analyzer to the SMA connector marked RFOUT (J3) and monitor the TRF3701/TRF3702 output.

6) To optimize the carrier suppression, this modulator performs the following (if using on-board dc offset through J3):

   a) Connect a spectrum analyzer to output port J3, rotate R33 to decrease the LO feed through as required.

   b) Then rotate R34 to further decrease the LO feed through.

   c) Repeat this procedure until you obtain the minimum LO feed through. A typical optimized sideband suppression value is 60 dBc.

7) 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. A typical optimized side band suppression value is 60 dBc.

Chapter 2

Physical Description

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

Topic **Page**

2.1 PCB Layout

The EVM is constructed on a four layer, 76 mm x 76 mm x 1,575 mm thick PCB using FR-4 material. Figure 2-1 through Figure 2-4 show the individual layers.

Figure 2-1. Top Layer

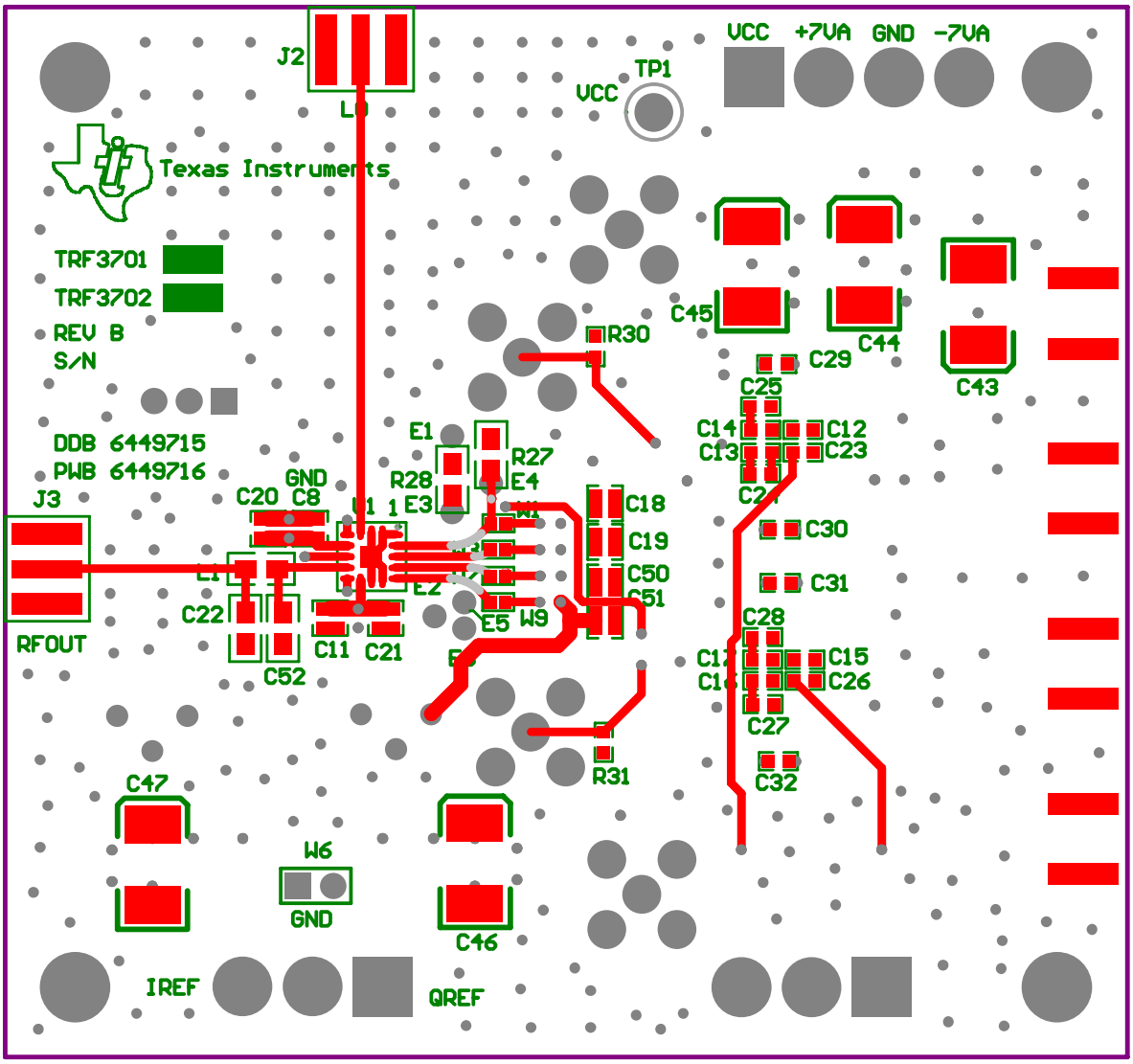


Figure 2-2. Layer 2—Ground Plane

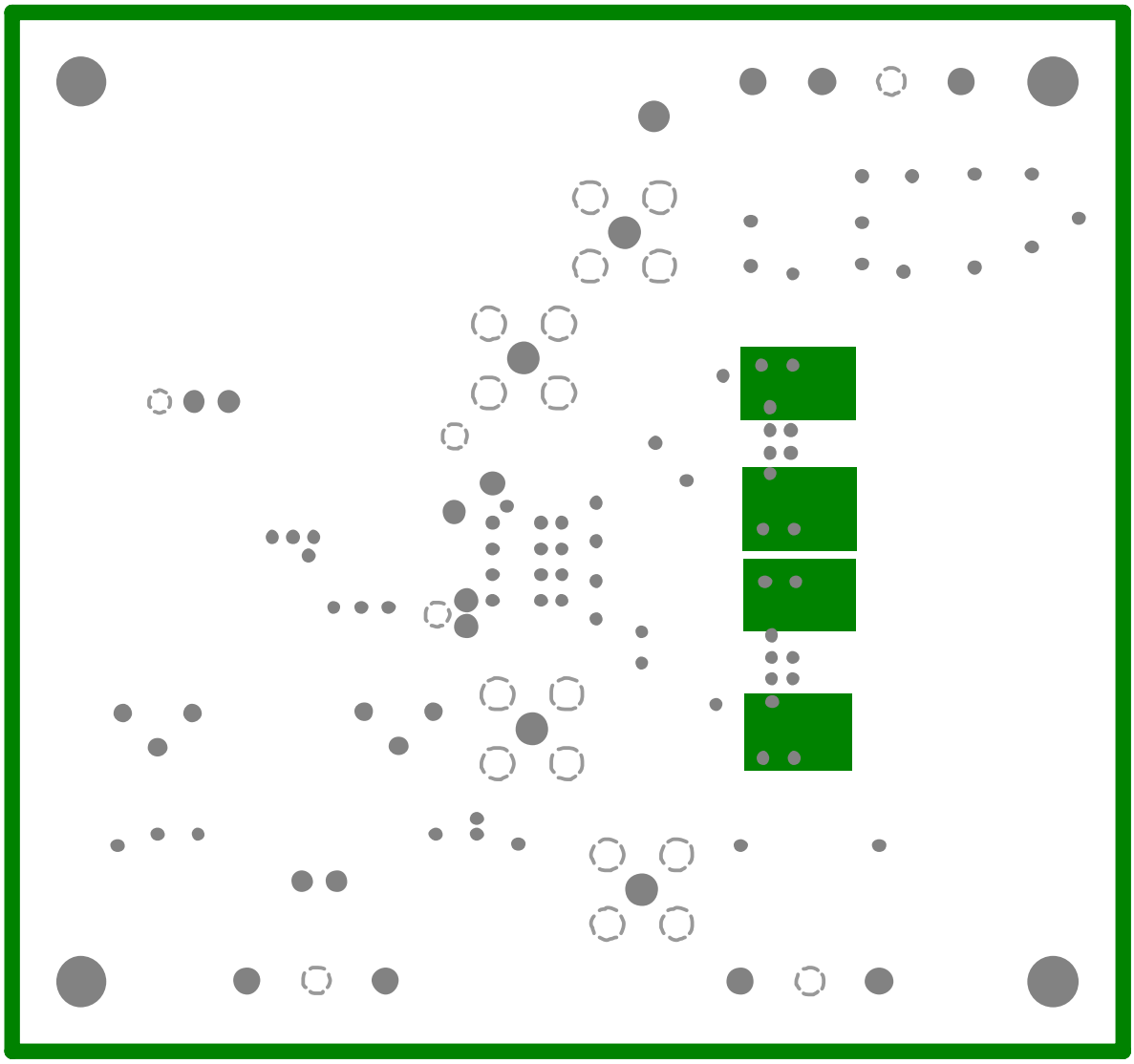


Figure 2-3. Layer 3—Power Plane

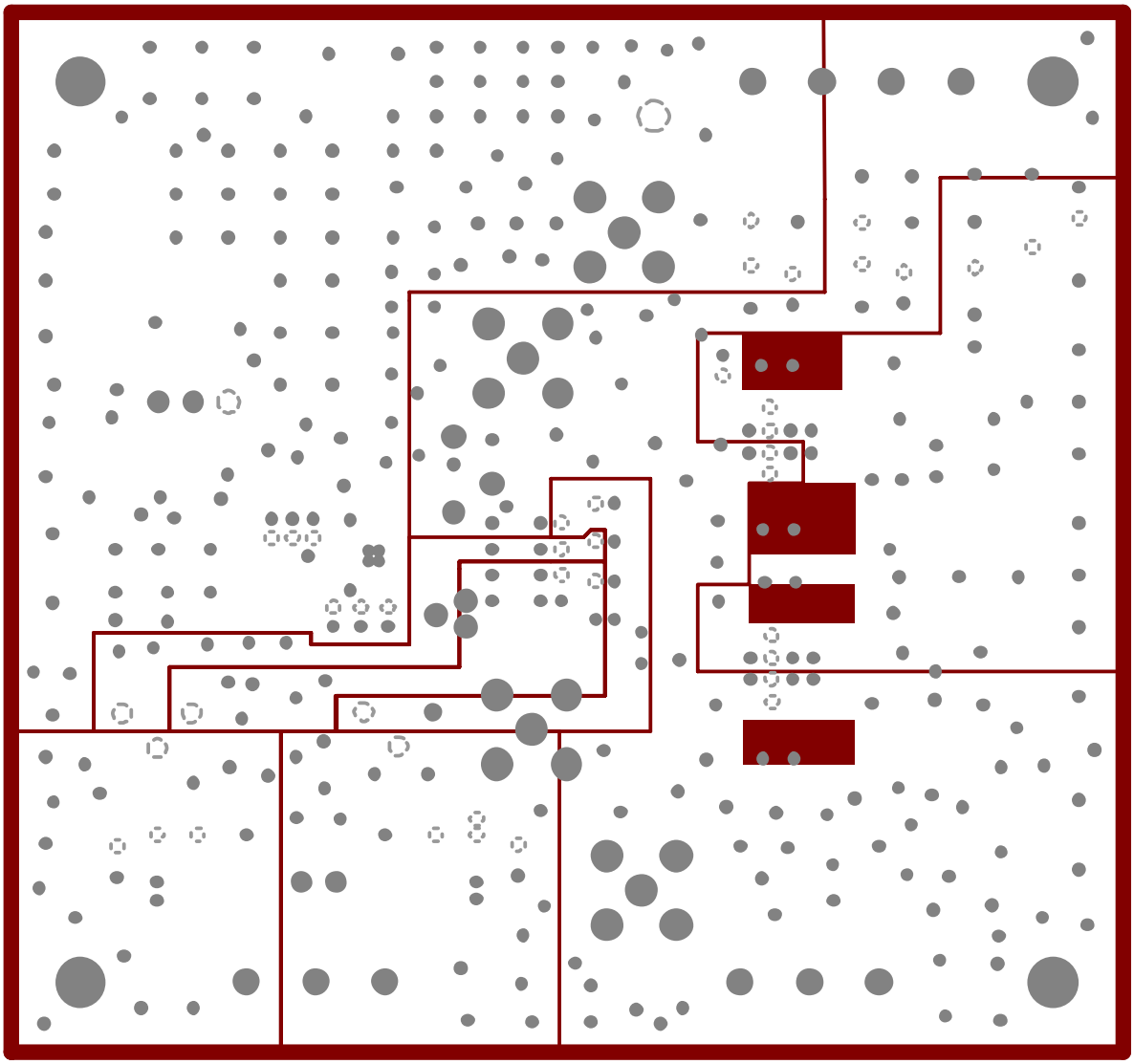
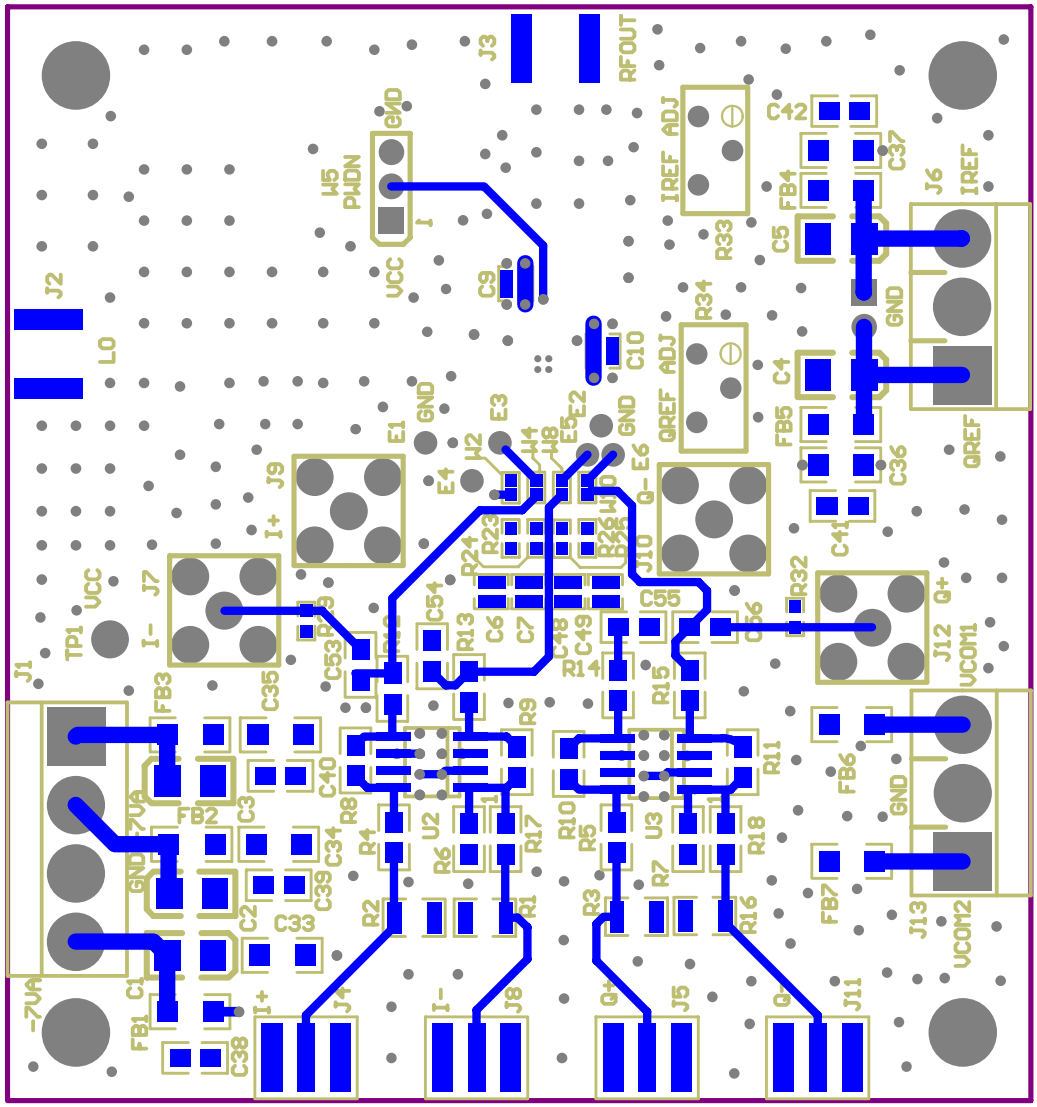


Figure 2-4. Bottom Layer



2.2 Parts List

Table 2-1. Parts List

Description	Footprint	Qty	Part Number	MFR	Reference Description	Not Installed
47 µF, tantalum, 10%, 10 V	7343	5	10TPA47M	Sanyo	C43-C47	
0.1 µF, 16 V, 10% capacitor	508	8			C6-C11, C48, C49	
0.1 µF, 16 V, 10% capacitor	603	6	ECJ-1VB1C104K	Panasonic	C12-C17	
10 µF, 10 V, 10% capacitor	3528	5	GRM42X5R106K10	Murata	C1-C5	
0.01 µF, 50 V, 10% capacitor	603	6		AVX	C23-C28	
1 pF, 50 V, 10% capacitor	603	6		AVX	C18-C21, C50, C51	
1 µF, 16 V, 10% capacitor	1206	5			C33-C37	
1800 pF, 50 V, 10% capacitor	805	0				C22, C52
10 pF, 50 V, 10% capacitor	603	4	PCC120ACVCT	AVX	C29-C32	
0.01 µF, 16 V, 10% capacitor	805	5			C38-C42	
Ferrite bead	1206	7			FB1-FB7	
392-Ω resistor, 1/10 W, 1%	805	4	ERJ-6ENF392R0V	Panasonic	R8-R11	
374-Ω resistor, 1/10 W, 1%	805	4	ERJ-6ENF374R0V	Panasonic	R4, R5, R17. R18	
402-Ω resistor, 1/10 W, 1%	805	0	ERJ-6ENF402R0V	Panasonic		R6, R7
56.2-Ω resistor, 1/16 W, 1%	1210	4	ERJ-13NF56R2	Panasonic	R1-R3, R16	
1-kΩ resistor, 1/16 W, 1%	603	4	ERJ-3EKF1.00K	Panasonic	R23-R26	
49.9-Ω resistor, 1/16 W, 1%	603	0	ERJ-3EKF49R9V	Panasonic		R29-R32
22.1-Ω resistor, 1/10 W, 1%	805	0		Panasonic		R12-R15
0-Ω resistor, 1/10 W, 1%	603	0	ERJ-3EKF0R00V	Panasonic		R27, R28
0-Ω resistor, 1/10 W, 1%	805	5	ERJ-6ENF0R00V	Panasonic	L1, C53-C56	
10 kΩ Pot	BOURNS_3296Y	2	3296Y-103	Bourns	R33, R34	
SMA connectors	SMA_Jack	4	2262-0000-09	Macom	J7, J9, J10, J12	
3POS_header	3pow_jumper	1	TSW-150-07-L-S	Samtec	W5	
2POS_header	2pos_jumper	1	TSW-150-07-L-S	Samatec	W6	
2POS solder jumpers		8			W1-W4, W7 - W10	
SMA connectors	SMA_END_SMA	6	90F2624	Newark	J2-J5, J8, J11	
3-pin power connector		2	93F7124	Newark	J6, J13	
3-pin power mate		2	95F5347	Newark		P6, P13
4-pin power connector		2	93F7125	Newark	J1	
4-pin power mate		1	95F5348	Newark		P1
THS4503	8-SOP (D)	2	THS4502ID	Texas Instruments	U2, U3	
TRF3701 or TRF3702	16-RHC (QFN)	1	TRF3701 or TRF3702	Texas Instruments	U1	
Screws	4-40 screw	4				

Chapter 3

Circuit Description

This chapter discusses the various functions of the EVM.

Topic **Page**

3.1 Circuit Function

Two quad sets of SMA connectors are provided on the EVM for inputting differential I/Q signals via the op amp or directly to the input pins of TRF3701/TRF3702. Connectors J4, J8, J5, and J11 are for connecting the I/Q signals via the op amp, while connectors J7, J9, J10, and J12 are used to directly connect the signal source I/Q signals to the TRF3701/TRF3702.

3.1.1 Differential/Single-Ended Inputs via Buffer Amplifiers

Connectors J4, J8, J5, and J11 are used to dc-couple differential signal pairs I+, I- and Q+, Q- to the unity gain differential buffer amplifier U2 and U3. For a gain of two, change the value of R8, R9, R10, and R11 to 825 Ω.

For single-ended input, the I-channel input signal can be applied to either J4 or J8. However, the EVM is configured to accept the single ended I-channel signal on J4.

The Q-channel input is via J5.

3.1.2 Differential/Singled-Ended Inputs Without Buffer Amplifier

Direct I/Q inputs, without the op amp, are routed to the TRF3701/TRF3702 through another set of SMA connectors, namely: J7, J9, J10, and J12.

3.1.3 Power Down

The EVM has a 3-position jumper (W5) for controlling the operation of the device. For normal operation W5 pins 1-2 are shorted. In power-down mode, W5 pins 2-3 are shorted.

3.1.4 Input Pins Bias

The TRF3701/TRF3702 I/Q input pins common-mode bias voltage is provided either through J6 and adjusted by potentiometers R33 and R34 or via the op amp VCOM1 and VCOM2 inputs through J13.

3.1.5 Power

Power is supplied to the EVM via header J1. Header J1 is a Molex 861904 4-pin male connector, and allows easy connection to a standard bench power supply through a Molex 860504 4-pin female connector. The connector pin outs are listed in Table 3-1.

Table 3-1. Power Supply J1

J1 Pin	Description
1	5 V (V_{CC}), U1 analog supply
2	7 V, op amp supply
3	AGND
4	-7 V, op amp supply

Connectors J6 and J13 are used to supply the dc bias voltage to U1 I/Q input channels. Both connectors are a 3-position male Molex header (part number 8610903).

Table 3-2. CM Bias Voltage

J6 Pin	Description
1	QREF1, QREF2 (VCM = 3.7 Vdc)
2	AGND
3	IREF1, IREF2 (VCM = 3.7 Vdc)

Table 3-3. CM Bias Voltages via Op Amp

J13 Pin	Description
1	VCOM2 (VCM = 3.7 Vdc)
2	AGND
3	VCOM1 (VCM = 3.7 Vdc)

Chapter 4

Circuit Board Test Points

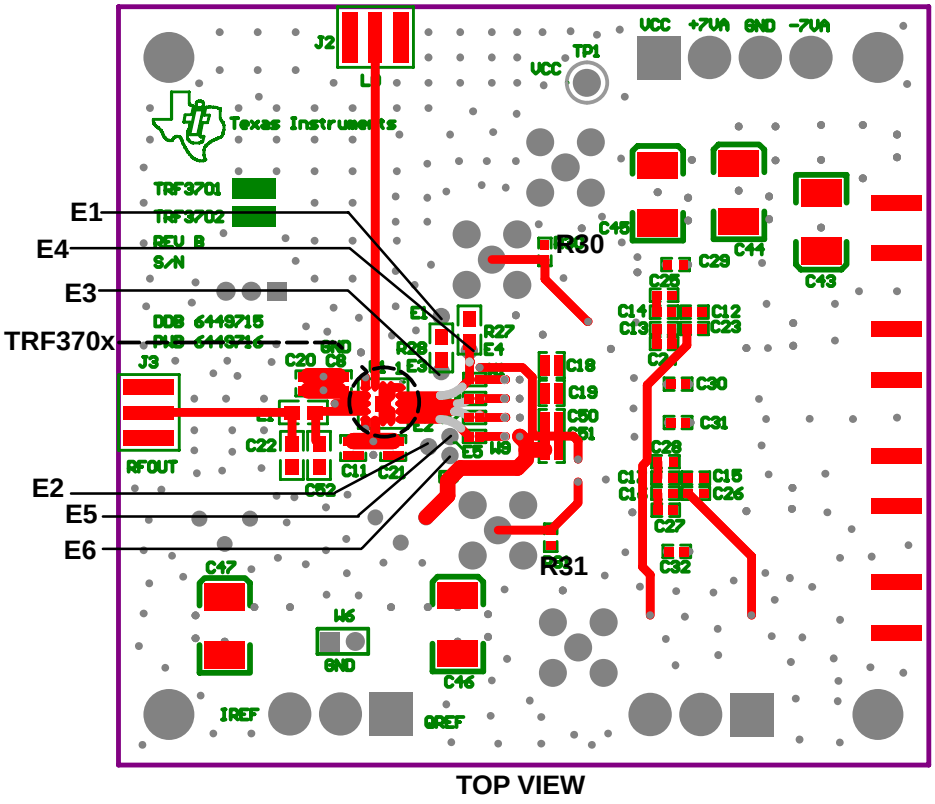
This chapter shows the circuit board test points.

Topic **Page**

4.1 Circuit Board Test Point Locations

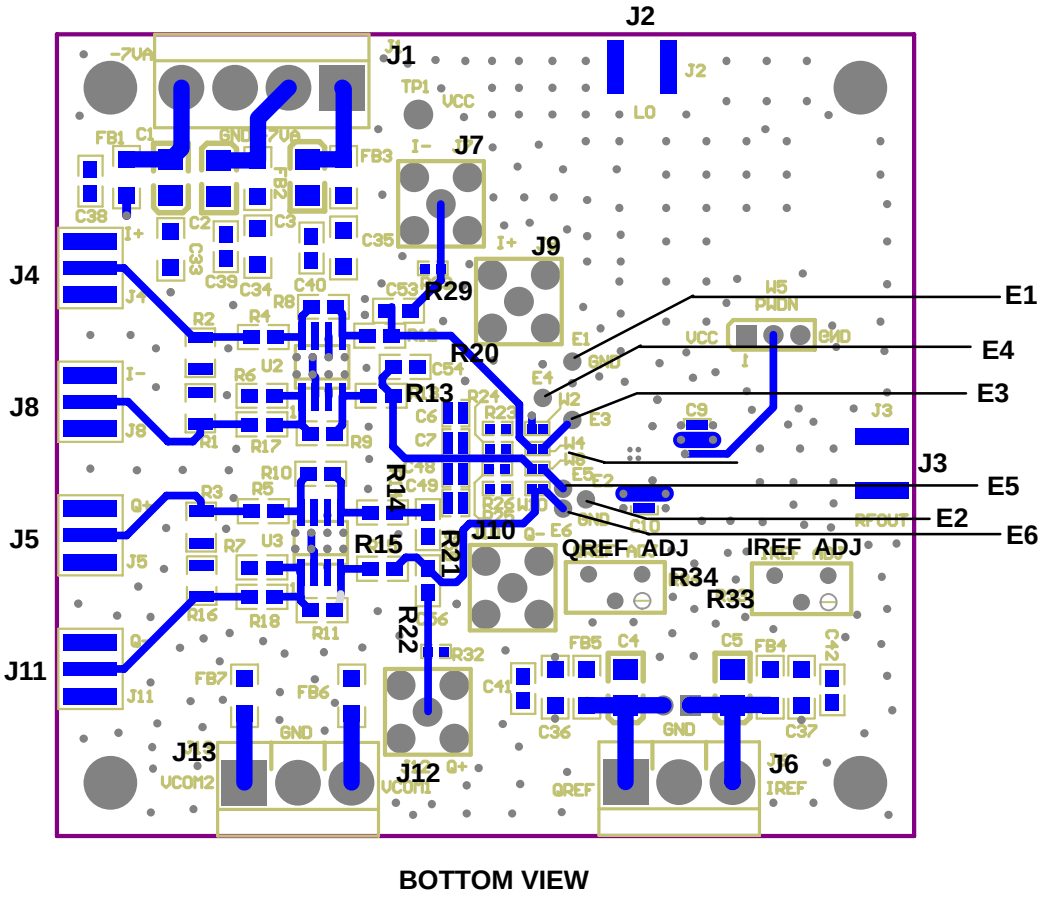
When a quick indication of the dc-bias level and ac-signal level on the I/Q inputs is required, simply probe the appropriate test points in Figure 4-1 and Figure 4-2.

Figure 4-1. Silkscreen Top Layer—Test Points Location



TOP VIEW

Figure 4-2. Bottom Layer—Test Points Location

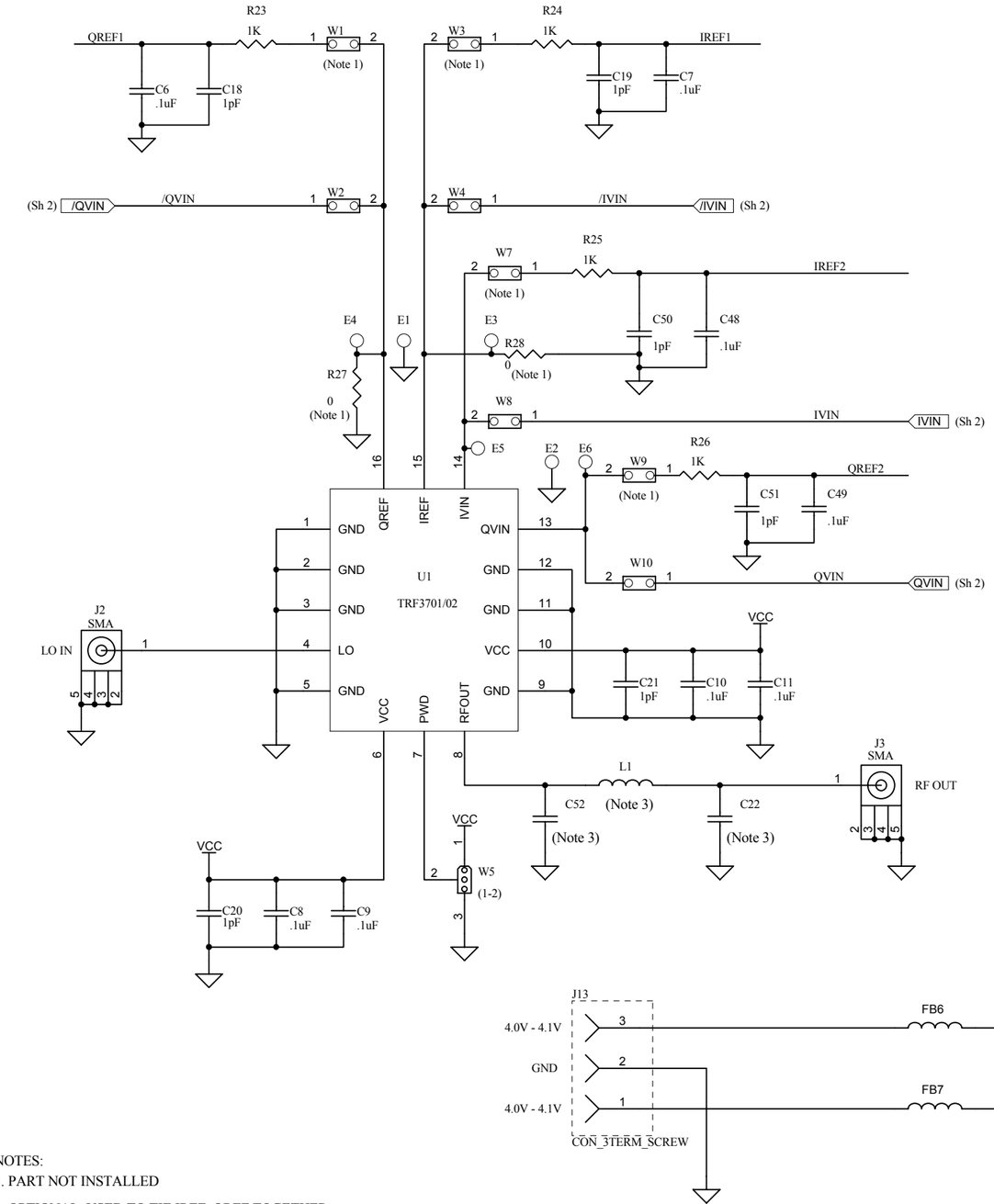


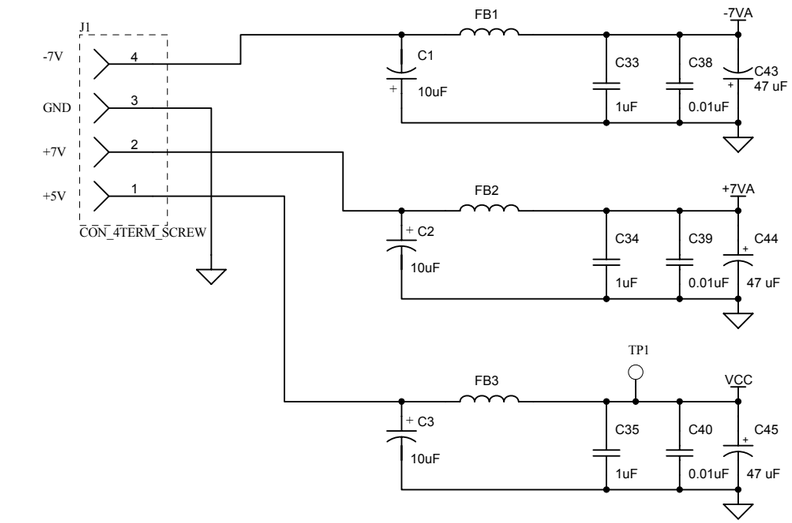
Chapter 5

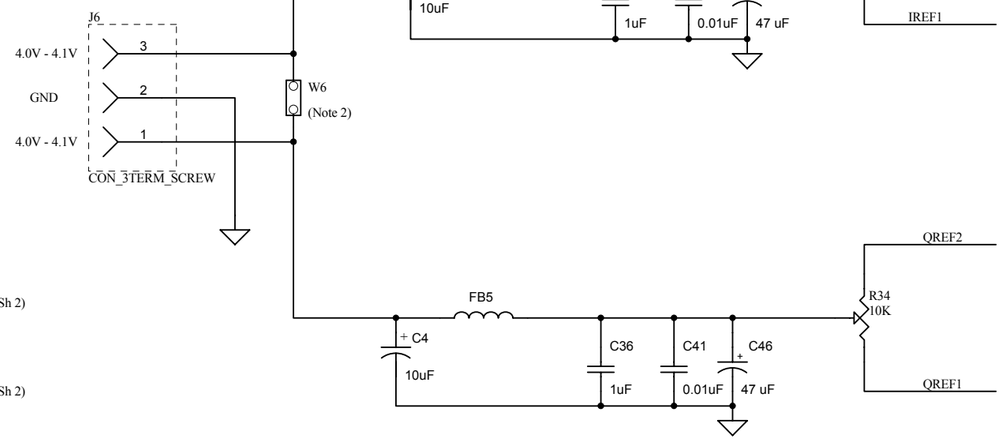
Schematics

This chapter shows the EVM schematic.

Revision History		
REV	ECN Number	Approved







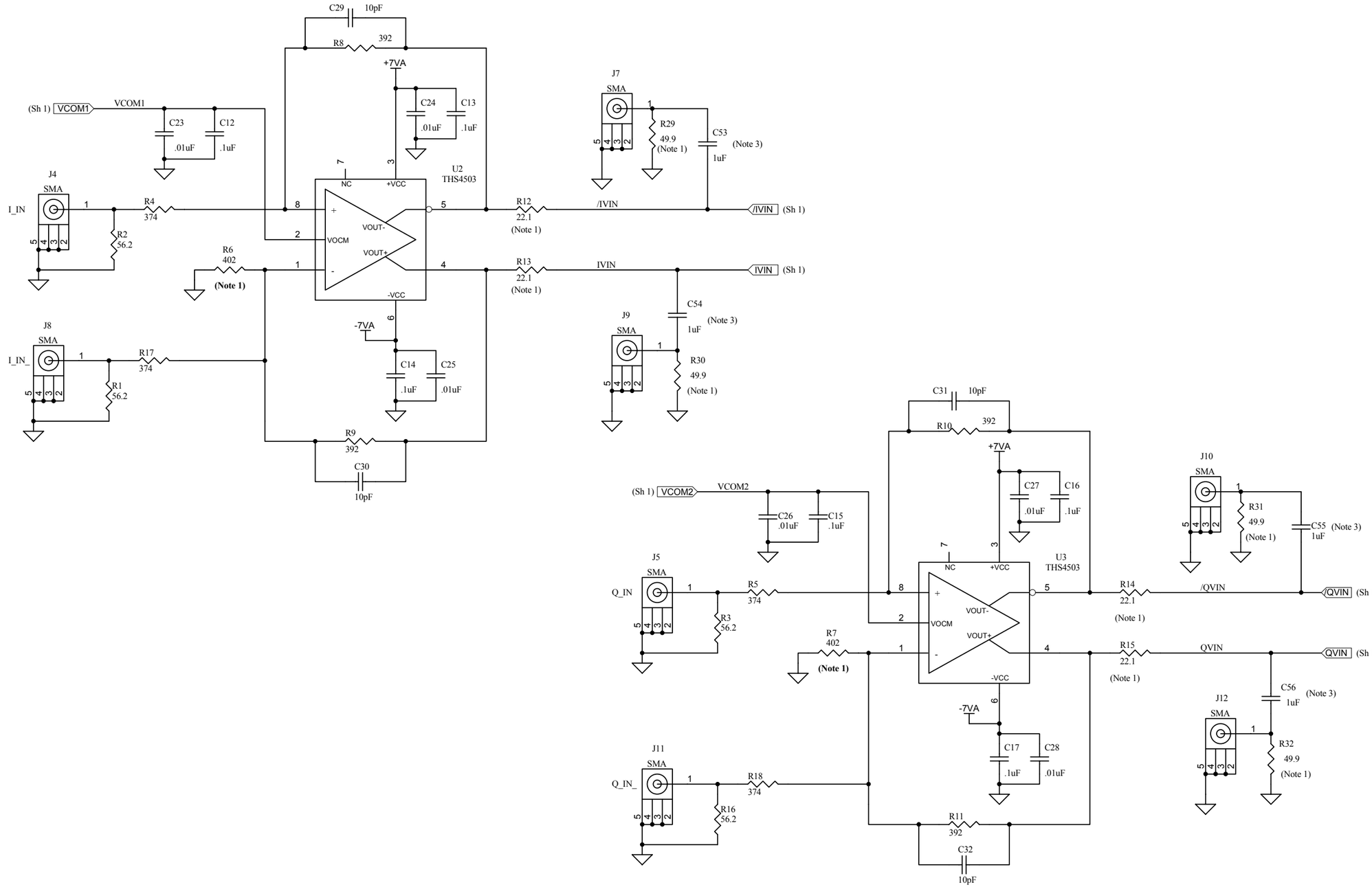
NOTES:

1. PART NOT INSTALLED
2. OPTIONAL, USED TO TIE IREF, QREF TOGETHER
3. VALUE UNKNOW, TO BE DETERMINED BY MATCHING. IF NOT USING MATCHING, MAKE L1 A 0 OHM RESISTOR, LEAVE C22 AND C52 UNPOPULATED.

TEXAS INSTRUMENTS

12500 TI Boulevard. Dallas, Texas 75243

Title: TRF3701/02			
Engineer: P. MILLER	DOCUMENTCONTROL #		REV: A
Drawn By: Y.DEWONCK			
FILE: Sheet1.Sch	DATE: 3-Jun-2004	SIZE:	SHEET: 1 OF: 2



NOTES:

1. PART NOT INSTALLED
2. REMOVE R6 AND R7 WHEN R17 AND R18 ARE INSTALLED
3. DEFAULT CONFIGURATION REPLACES CAPACITOR WITH A 0 OHM RESISTOR

TEXAS INSTRUMENTS

12500 TI Boulevard. Dallas, Texas 75243

Engineer: P. MILLER	Title: TRF3701/02		
Drawn By: Y.DEWONCK	DOCUMENTCONTROL #		REV: A
FILE:	DATE: 3-Jun-2004	SIZE:	SHEET: 2 OF: 2