TEXAS INSTRUMENTS

THS4502EVM

User's Guide

June 2002

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SLOU129

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EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of ±5 V and the output voltage range of +5 V and –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 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.

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Preface

Read This First

About This Manual

This manual provides information about using the THS4502 fully differential amplifier on evaluation module PCB marked with Edge # 6439396. Additionally, this document provides a good example of PCB design for high-speed applications. The user should keep in mind the following points.

- The design of the high-speed amplifier PCB is a sensitive process.
- The user must approach the PCB design with care and awareness.
- It is recommended that the user initially review the data sheet of the device under test.
- It is helpful to review the schematic and layout of the THS4502EVM to determine the design techniques used in the evaluation board.
- It is recommended that the user review the application note *Fully Differential Amplifiers* (literature number SLOA054) to learn more about differential amplifiers. This application note reviews fully differential amps and presents calculations for various filters.

How to Use This Manual

This document contains the following chapters:

- Chapter 1—Introduction and Description
- Chapter 2—Using the THS4502EVM
- Chapter 3—THS4502EVM Applications
- Chapter 4—High-Speed Amplifier PCB Layout Tips
- Chapter 5—EVM Hardware Description

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.

This is an example of a warning statement.

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

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.

Electrostatic Sensitive Components

This EVM contains components that can potentially be damaged by electrostatic discharge. Always transport and store the EVM in its supplied ESD bag when not in use. Handle using an antistatic wristband. Operate on an antistatic work surface. For more information on proper handling, refer to SSYA008.

Related Documentation From Texas Instruments

The URLs below are correct as of the date of publication of this manual. Texas Instruments applications apologizes if they change over time.

- THS4502 data sheet (literature number SLOS350)
- Application report (literature number SLOA054), *Fully Differential Amplifiers*
- Application report (literature number SLOA069), *How (Not) to Decouple High Speed Op Amp Circuits,* http://www−s.ti.com/sc/psheets/sloa069/sloa069.pdf
- Application report (literature number SLOA072), *Single Supply Differential Op Amp Techniques,* http://www−s.ti.com/sc/psheets/sloa072/sloa072.pdf

- Application report (literature number SLMA002), *Power Pad Thermally Enhanced Package*, http://www−s.ti.com/sc/psheets/slma004/slma002.pdf
- Application report (literature number SLMA004), PowerPAD Made Easy, http://www−s.ti.com/sc/psheets/slma004/slma004.pdf
- Application report (literature number SSYA008), Electrostatic Discharge (ESD), http://www−s.ti.com/sc/psheets/ssya008/ssya008.pdf

Trademarks

PowerPAD is a trademark of Texas Instruments.

Contents

Figures

Tables

Chapter 1

Introduction and Description

The Texas Instruments THS4502 evaluation module (EVM) helps designers evaluate the performance of the THS4502 fully differential operational amplifier (FDA). Also, this EVM is a good example of high-speed PCB design.

This document details the THS4502EVM. It includes a list of EVM features, a brief description of the module illustrated with a series of schematic diagrams, EVM specifications, details on connecting and using the EVM, and a discussion of high-speed amplifier design considerations.

This EVM enables the user to implement various circuits to clarify the available configurations presented by the schematic of the EVM. The user is not limited to the circuit configurations presented here. The EVM provides enough hardware hooks that the only limitation should be the creativity of the user.

Topic **Page**

1.1 Description

The THS4502EVM provides a platform for developing high-speed FDA application circuits. It contains the THS4502 high-speed FDA, a number of passive components, and various features and footprints that enable the user to experiment, test, and verify various operational amplifier circuit implementations. The PC board measures 3.08 by 2.42 inches.

1.2 Evaluation Module Features

THS4502 high-speed operational amplifier EVM features include:

- ❑ Wide operating supply voltage range: single supply 5 Vdc to dual supply ±5 Vdc operation (see the device data sheet). Single supply operation is obtained by jumpering GND (J7) to $-V_S$ (J5).
- ❑ Single-ended and fully differential input capability
- ❑ Single-ended and fully differential output capability
- ❑ Nominal 50-Ω input termination (R1||R2). Termination can be configured according to the application requirement.
- ❑ V_{OCM} direct input through TP1
- ❑ Power down (PD) direct input through TP2
- ❑ Output transformer T1
- ❑ Footprints for antialiasing filter implementation using locations R6, R7, C5, and C6
- ❑ Footprints for low pass filter implementation using locations C3, C4
- ❑ 800-Ω load provided through R8, R10, R9, and R11 reflected through T1
- ❑ Three convenient GND test points on the PCB
- ❑ Power supply ripple rejection capacitors (C8 and C11)
- ❑ Decoupling capacitors (C9, C12) populated with 0.1 μF capacitors—design final decoupling in accordance with SLOA069
- ❑ PowerPAD™ heatsinking capability
- ❑ A good example of high-speed amplifier PCB design and layout

1.3 THS4502EVM Operating Conditions

- ❑ Supply voltage range, $\pm V_S$ 5 V to ±5 V (see the device data sheet)
- ❑ Supply current, I_S (see the device data sheet)

For complete THS4502 amplifier IC specifications, parameter measurement information, and additional application information, see the THS4502 data sheet, TI literature number SLOS350.

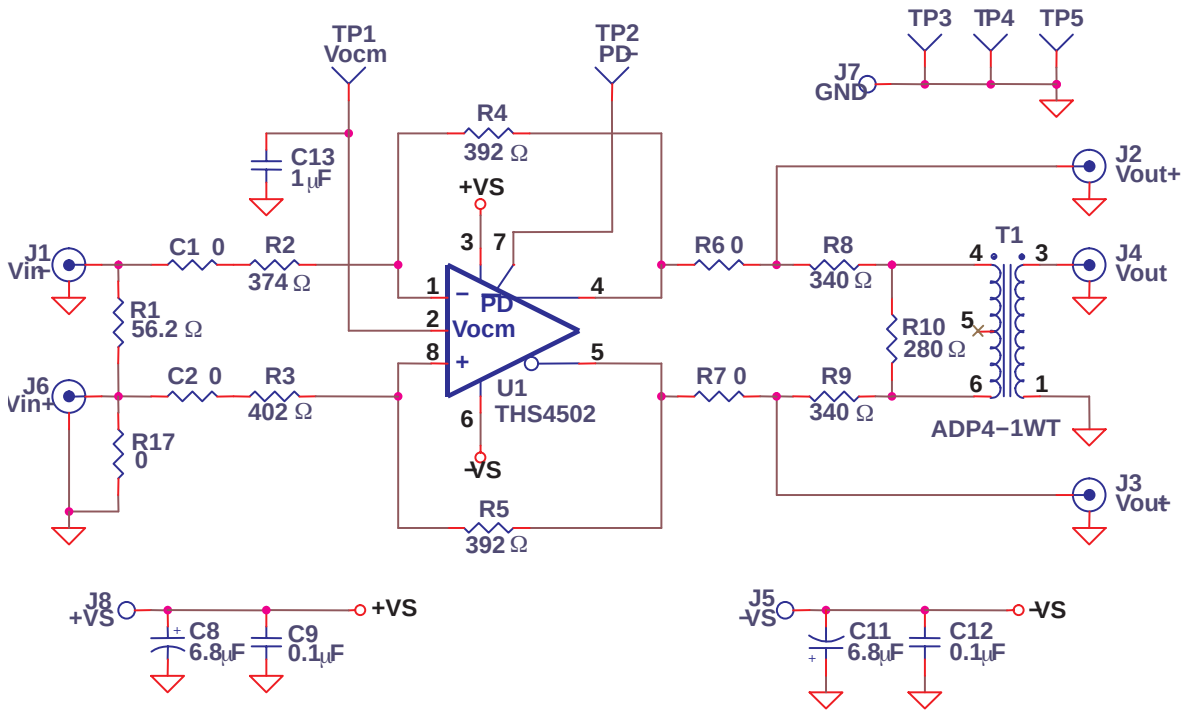
1.4 EVM Default Configuration

As delivered, the EVM has a fully functional example circuit; just add power supplies, a signal source, and monitoring instrument. See Figure 1−1 for the default schematic diagram. The user can change the gain by changing the ratios of the feedback and gain resistors (see the device data sheet for recommended resistor values). The complete EVM schematic in Chapter 5 shows component locations.

The default configuration assumes a 50-Ω signal source, and contains a termination resistor R1 for the source.

Some components such as C8, C9, C11, C12, TP1, TP2, R10, T1, and J4 are omitted on the application schematics of Chapter 3 for clarity.

Figure 1−1. Schematic of the Populated Circuit on the EVM (Default Configuration)



Chapter 2

Using the THS4502EVM

This section describes how to connect the THS4502EVM to test equipment. It is recommended that the user connect the EVM as described in this section to avoid damage to the EVM or the THS4502 installed on the board.

Topic **Page**

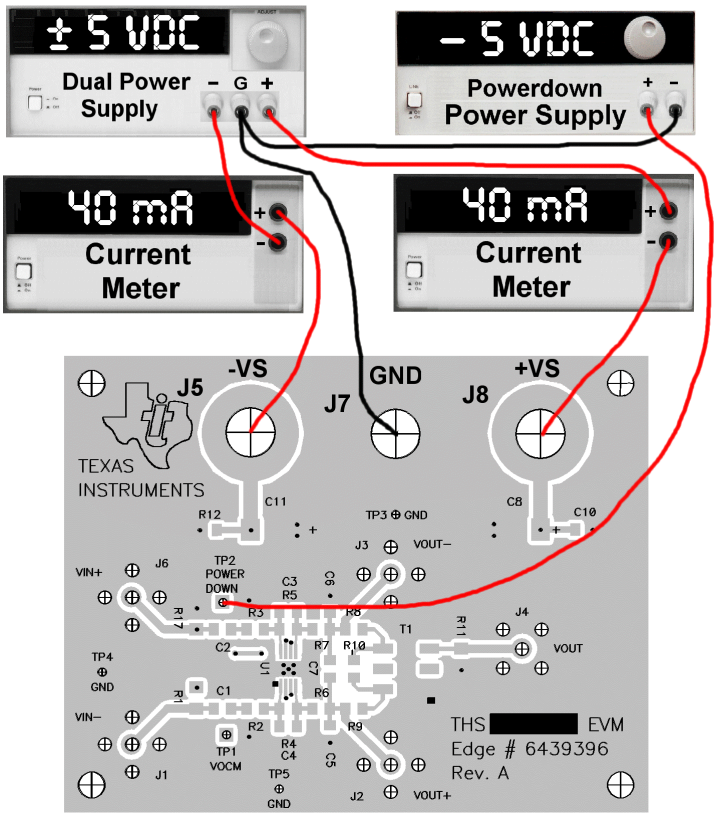
2.1 Required Equipment

- ❑ One dual-output dc power supply (±5 V, 1 A output minimum)
- ❑ One single-output dc power supply (5 V, 1 A output minimum). This power supply is used to activate the power-down function of the EVM, and will be referred to in the text of this document as the *power-down supply.*
- ❑ Two dc current meters with resolution to 1 mA and capable of the maximum current the dc power supply can supply.
- ❑ 50-Ω source impedance function generator (1 MHz, 10 V_{PP} sine wave)
- ❑ Oscilloscope (50-MHz bandwidth minimum, 50-Ω input impedance)
- ❑ Three BNC-to-SMA cables, 24 inches long
- ❑ BNC-to-BNC cable
- ❑ Seven banana-to-banana wires; 5 red, 2 black
- ❑ Banana to test clip wire

2.2 Power Supply Connection (Refer to Figure 2−1)

1) Set the dual dc power supply to ±5 V. If available, set the current limit on the dc power supply to 100 mA.
2) Make sure the dual dc power supply is turned off before proceeding to the next step.
3) Connect the positive (+) terminal of the power supply to the positive (+) terminal of the current meter number 1.
4) Connect the negative (–) terminal of the current meter number 1 to +VS (J8).
5) Connect the common ground terminal of the power supply to GND (J7).
6) Connect the negative (–) terminal of the power supply to the negative (–) terminal of the second current meter.
7) Connect the positive (+) terminal of the current meter number 2 to –VS (J5).
8) Set the power-down supply to –5 Vdc, turn it off.
9) Connect the negative (−) terminal of the power down supply to GND (J7).
10) Connect the positive (+) terminal of the power down supply to power down (TP2).

Figure 2−1. Power Supply Connection for ±5 Vdc



2.3 Function Generator Setup

Note:

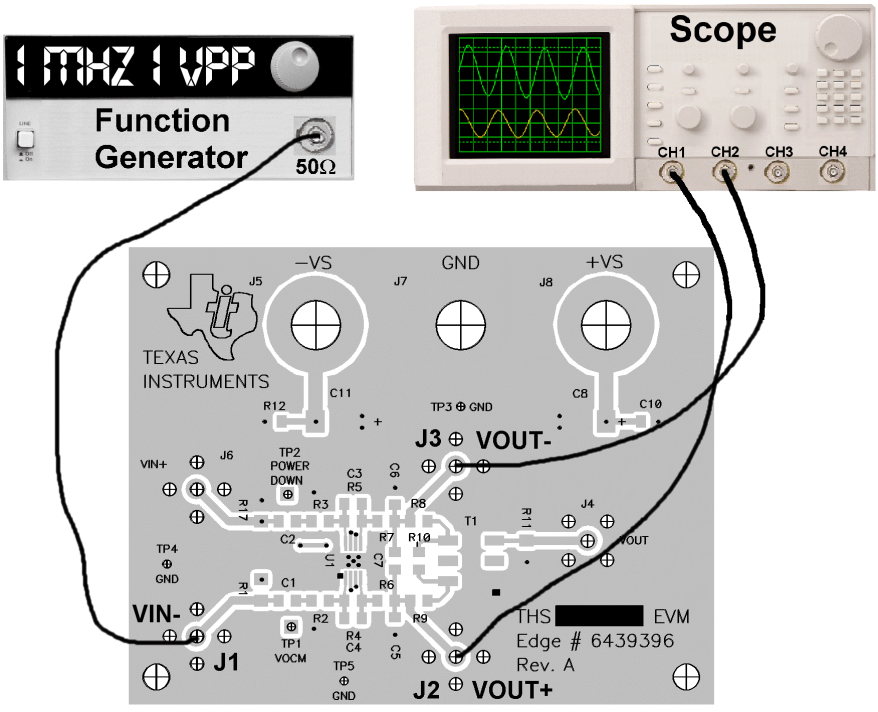
The oscilloscope channels (CH1 and CH2) must be set to 50-Ω input impedance for proper results.

1) Connect the function generator to oscilloscope channel 1.
2) Set vertical channels 1 and 2 of the oscilloscope to 0.2 V/division and the time base to 0.1 µs/division.
3) Set the function generator to generate a 1-MHz, ±0.5 V (1 V_{PP}) sine wave with no dc offset.
4) Verify that the output is 1 MHz, ±0.5 V (1 V_{PP}).
5) Disable the function generator output before proceeding to the next step.
6) Disconnect the cable from the oscilloscope, retaining the setting of the function generator.

2.4 Signal Connections V_{IN-}(Refer to Figure 2−2)

1) Using a BNC-to-SMA cable, connect the function generator to J1 (VIN−).
2) Using a BNC-to-SMA cable, connect the oscilloscope channel 1 to J2 (VOUT+).
3) Using a BNC-to-SMA cable, connect the oscilloscope channel 2 to J3 (VOUT−).

Figure 2−2. Signal Connections



Chapter 3

THS4502EVM Applications

Example applications are presented in this chapter. These applications are meant to demonstrate the most popular circuits to the user, but many other circuits can be constructed. The user is encouraged to experiment with different circuits, exploring new and creative design techniques. After all, that is the function of an evaluation board.

Topic **Page**

3.1 Single-Ended In/Single-Ended Out, Utilizing Transformer

The fully differential amp output can be monitored by a single-ended instrument at J4. The THS4502EVM utilizes Mini-Circuits CD542 footprint transformers to make the fully differential-to-single-ended conversion. An ADP4−1WT transformer is installed on the board.

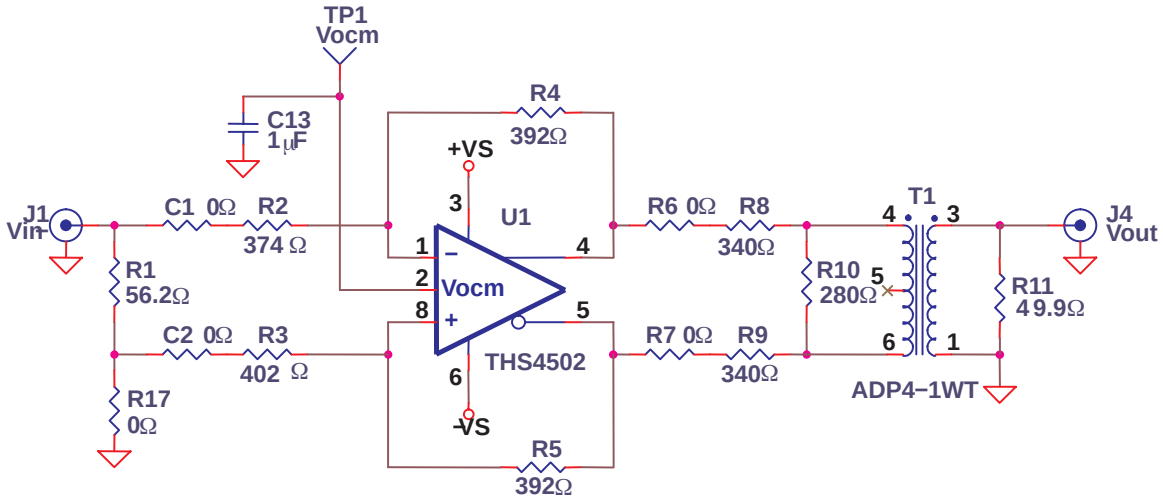
R8, R9, and R10 are chosen such that the load on the fully differential amp is 800 Ω when combined with the load impedance transformed by the turn ratio T1. This load is chosen because it is a common input impedance value for ADCs, and is the impedance at which many fully differential amp parameters were measured. The 800-Ω load occurs when one of two conditions is met:

- R11 is installed and the measuring instrument is set to 1 MΩ input impedance

or

- R11 is not installed and the measuring instrument has an input impedance of 50 Ω.

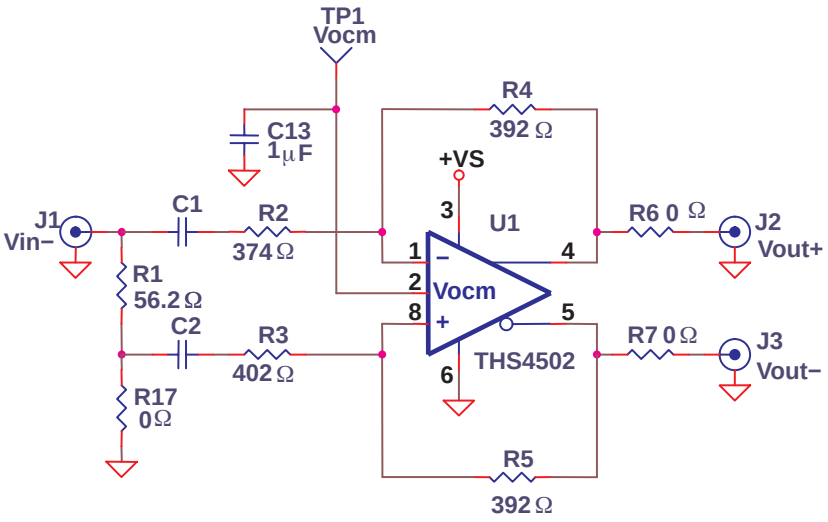
Figure 3−1. Single-Ended In/Single-Ended Out, Utilizing Transformer



3.2 Single-Ended to Fully Differential Application

The schematic of Figure 3−2 shows the proper technique for ac-coupling. The voltage present on the V_{OCM} pin determines the dc operating point of the circuit. When no voltage is connected to TP1, the V_{OCM} voltage level is determined by a voltage divider internal to the op-amp, and is approximately equal to half of +VS. This dc voltage is present on both outputs, and also present on both inputs—being connected through R2 and R3.

Figure 3−2. Single Supply Operation



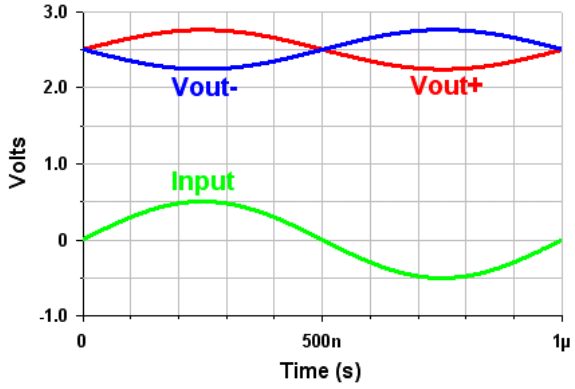
Note:

For this and some of the following circuits, it is necessary to install capacitors into locations designated for resistors, and vice versa. Because the capacitors and resistors come in the same case size, this should be easily accomplished.

The designer should note that the ground connection of the schematic at C2 through R17 is a *second input*—to avoid confusion about whether a coupling capacitor is actually needed. In fact, there is no difference between single-ended and fully differential inputs to the board, except that the single-ended circuits utilize ground as signal return, while fully differential inputs utilize the other input as signal return. Any fully differential input to the board can be converted to a single-ended input merely by connecting one of the inputs to ground.

This circuit allows the input voltage to swing below the negative power supply rail of the op-amp, as shown in Figure 3−3.

Figure 3−3. Output of an AC-Coupled, Single-Supply Application



The designer should realize that the coupling capacitors, acting with the gain resistors, produce a high pass characteristic into the circuit.

This application circuit has interaction between R_{source}, $R_{termination}$, and R_g. Texas Instruments has provided an engineer design utility to facilitate the design of these circuits. Engineer design utilities are available on the *Amplifiers and Comparators* section of the *Analog and Mixed Signal* portion of the TI web page.

The designer should be aware that each individual feedback path is an inverting path. There is no *noninverting* gain circuit for fully differential amps. The designer should also be aware that the gain is affected by the open loop characteristic of the FDA, the same assingle-ended op-amps. If there is sufficient safety margin between the closed loop response and open loop response of the FDA (40 dB or more), the error contribution from the open loop response of the FDA is negligible and can be ignored.

Chapter 4

High-Speed Amplifier PCB Layout Tips

The THS4502EVM layout has been designed for use with high-speed signals and can be used as an example when designing PCBs incorporating the THS4502. Careful attention has been given to component selection, grounding, power supply bypassing, and signal path layout. Disregarding these basic design considerations could result in less than optimum performance of the THS4502 high-speed operational amplifier. Surface-mount components were selected because of the extremely low lead inductance associated with this technology. This helps minimize both stray inductance and capacitance. Also, because surface-mount components are physically small, the layout can be very compact.

Tantalum power supply bypass capacitors at the power input pads help filter switching transients from the laboratory power supply. Power supply bypass capacitors are placed as close as possible to the IC power input pins in order to minimize the return path impedance. This improves high frequency bypassing and reduces harmonic distortion. The GND side of these capacitors should be located close to each other, minimizing the differential current loops associated with differential output currents. If poor high frequency performance is observed, replace the 0.1-μF capacitors with microwave capacitors with a self-resonance at the frequency that produces trouble. A proper ground plane on both sides of the PCB should be used with high-speed circuit design. This provides low-inductive ground connections for return current paths.

In the area of the amplifier input pins, however, the ground plane has been removed to minimize stray capacitance and reduce ground plane noise coupling into these pins. This is especially important for the inverting input pin. As low as 1 pF capacitance at the inverting input can significantly affect the response of the amplifier or even oscillation.

In general, it is best to keep signal lines as short and as straight as possible. Incorporation of microstrip or stripline techniques is also recommended when signal lines are greater than 1 inch in length. These traces must be designed with a characteristic impedance of either 50 Ω or 75 Ω, as required by the application. Such a signal line must also be properly terminated with an appropriate resistor.

Circuit pathways should be made as symmetrical as possible for both feedback pathways to minimize second and other even harmonic content.

The printed-circuit board that is used with PowerPAD packages must have features included in the design to remove the heat from the package efficiently. As a minimum, there must be an area of solder-tinned-copper underneath the PowerPAD package. This area is called the thermal land. The thermal land varies in size depending on the PowerPAD package being used, the PCB construction and the amount of heat that needs to be removed. In addition, this thermal land may or may not contain thermal vias depending on PCB construction. The requirements for thermal lands and thermal vias are detailed in http://www−s.ti.com/sc/techlit/slma002 and http://www−s.ti.com/sc/techlit/slma004.

Finally, all inputs and outputs must be properly terminated, either in the layout or in the load instrumentation. Unterminated lines, such as coaxial cable, can appear to be a reactive load to the amplifier. By terminating a transmission line with its characteristic impedance, the amplifier’s load then appears to be purely resistive, and reflections are absorbed at each end of the line. Another advantage of using an output termination resistor is that capacitive loads are isolated from the amplifier output. This isolation helps minimize the reduction in the amplifier’s phase-margin and improves the amplifier stability resulting in reduced peaking and settling times.

Chapter 5

EVM Hardware Description

This chapter describes the EVM hardware. It includes the EVM parts list, and printed circuit board layout.

Table 5−1. THS4502EVM Bill of Materials

Item	Description	SMD Size	Reference Designator	PCB Qty.	Manufacturer's Part Number	Distributor's Part Number
1	CAP, 6.8 μF, tanatalum, 35 V, 10%	D	C8, C11	2	(AVX) TAJD685K035R	(Garrett) TAJD685K035R
2	CAP, 0.1 μF, ceramic, X7R, 16 V	0508	C9, C12	2	(AVX) 0508YC104KAT2A	(Garrett) 0508YC104KAT2A
3	CAP, 1.0 μF, ceramic, X7R, 25 V	1206	C13	1	(AVX) 12063C105KAT2A	(Garrett) 12063C105KAT2A
4	Open	0805	C3, C4, C5, C6, C7, C10	6		
5	Open	1206	C14	1		
6	Open	0805	R11, R12, R13, R14, R15, R16	6		
7	Resistor, 0 Ω, 1/8 W	0805	C1, C2, R6, R7	4	(Phycomp) 9C08052A0R00JLHFT	(Garrett) 9C08052A0R00JLHFT
8	Resistor, 280 Ω, 1/8 W, 1%	0805	R10	1	(Phycomp) 9C08052A2800FKHFT	(Garrett) 9C08052A2800FKHFT
9	Resistor, 340 Ω, 1/8 W, 1%	0805	R8, R9	2	(Phycomp) 9C08052A3400FKHFT	(Garrett) 9C08052A3400FKHFT
10	Resistor, 374 Ω, 1/8 W, 1%	0805	R2	1	(Phycomp) 9C08052A3740FKHFT	(Garrett) 9C08052A3740FKHFT
11	Resistor, 392 Ω, 1/8 W, 1%	0805	R4, R5	2	(Phycomp) 9C08052A3920FKHFT	(Garrett) 9C08052A3920FKHFT
12	Resistor, 402 Ω, 1/8 W, 1%	0805	R3	1	(Phycomp) 9C08052A4020FKHFT	(Garrett) 9C08052A4020FKHFT
13	Resistor, 0 Ω, 1/4 W	1206	R17	1	(Phycomp) 9C12063A0R00JLHFT	(Garrett) 9C12063A0R00JLHFT
14	Resistor, 56.2 Ω, 1/4 W, 1%	1206	R1	1	(Phycomp) 9C12063A56R2FKRFT	(Garrett) 9C12063A56R2FKRFT
15	Transformer, 4:1	CD542	T1	1	(Mini-Circuits) ADT4−1WT	(Mini-Circuits) ADT4−1WT
16	Test points (black)		TP3, TP4, TP5	3	(Keystone) 5001	(Allied) 839−3601

Item	Description	SMD Size	Reference Designator	PCB Qty.	Manufacturer's Part Number	Distributor's Part Number
17	Test points (red)		TP1, TP2	2	(Keystone) 5000	(Allied) 839−3600
18	Jack, banana receptacle, 0.25" diameter hole		J5, J7, J8	3	(HH Smith) 101	(Newark) 35F865
19	Connector, SMA PCB Jack		J1, J2, J3, J4, J6	5	(Amphenol) 901−144−8RFX	(Newark) 01F2208
20	Standoff, 4−40 Hex, 0.625" Length			4	(Keystone) 1804	(Allied) 839−2089
21	Screw, Phillips, 4−40, 0.250"			4	SHR−0440−016−SN	
22	IC, THS4502		U1	1	(TI) THS4502DGN	
23	Board, printed circuit			1	(TI) EDGE # 6439396	

Figure 5−1. Top Layer 1 (Signals for THS4502EVM)

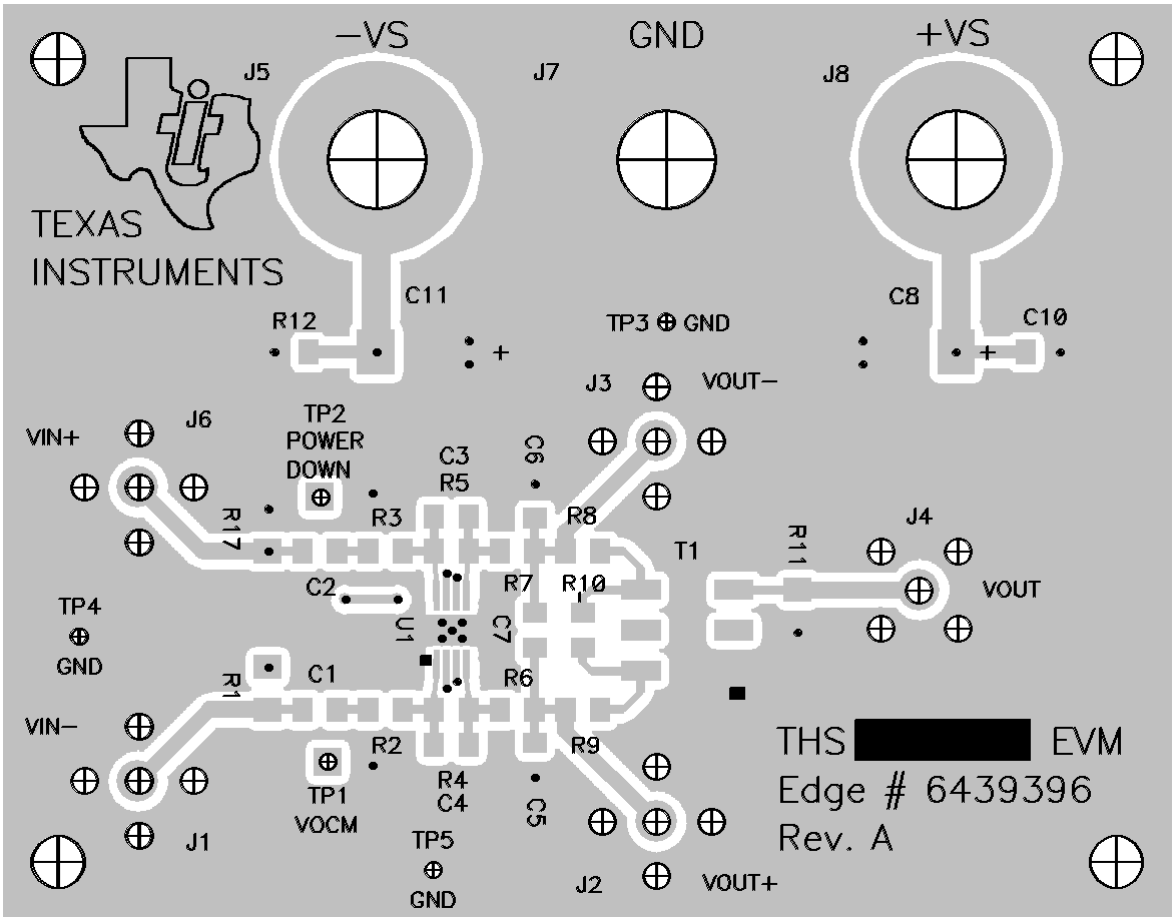


Figure 5−2. Bottom Layer 2 (Ground and Signal)

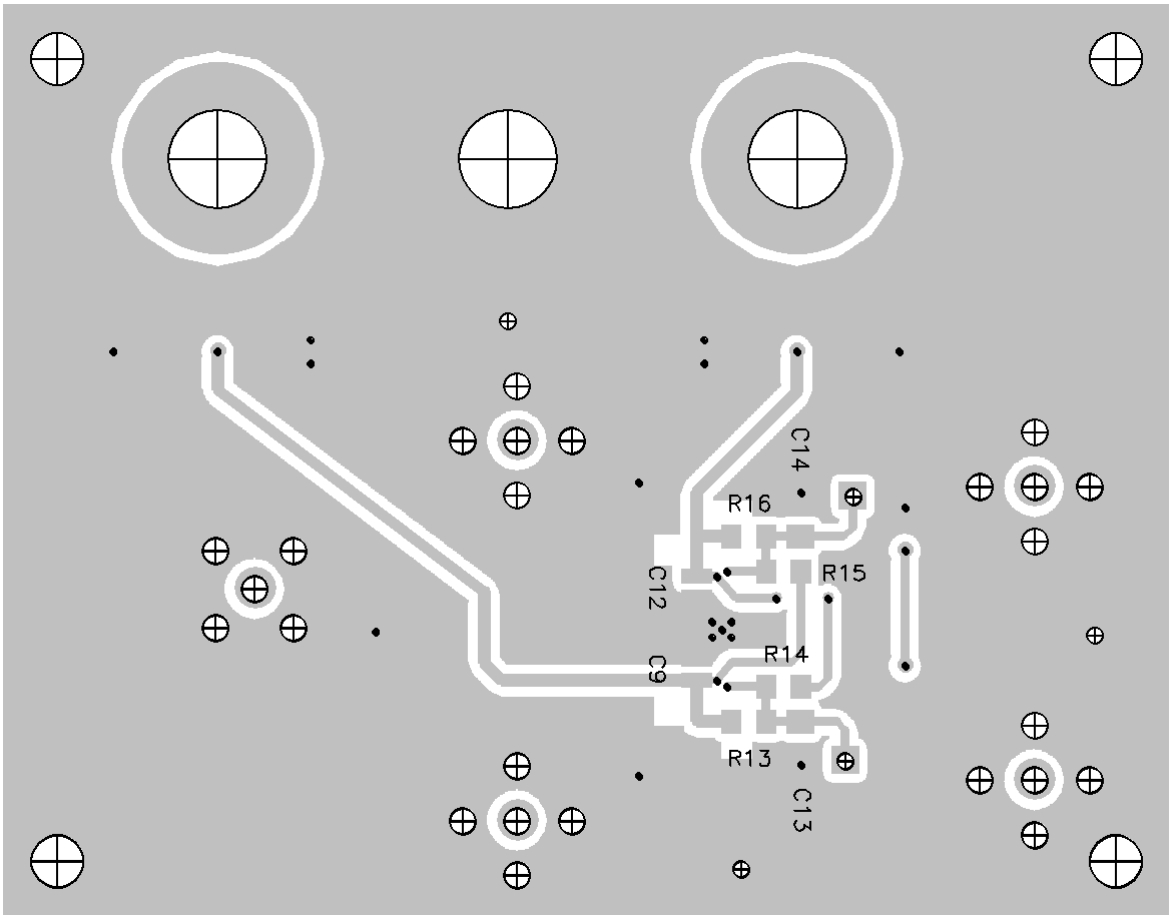
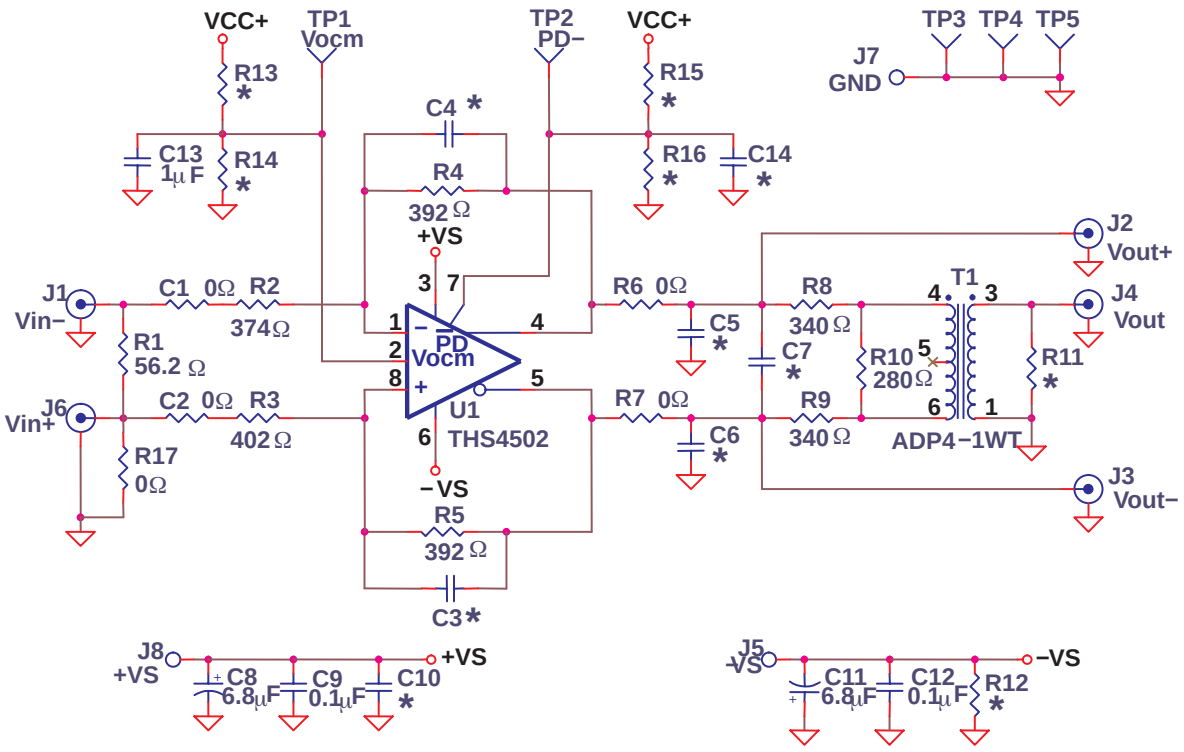


Figure 5−3. Schematic Diagram



Note: Devices designated with an * are not installed on the EVM. The user must supply these components.