TEXAS INSTRUMENTS

Tone Control Evaluation Module

User's Guide

February 2001

Mixed-Signal Products

SLOU031A

IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgment, including those pertaining to warranty, patent infringement, and limitation of liability.

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

Customers are responsible for their applications using TI components.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, license, warranty or endorsement thereof.

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. Representation or reproduction of this information with alteration voids all warranties provided for an associated TI product or service, is an unfair and deceptive business practice, and TI is not responsible nor liable for any such use.

Resale of TI's 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, is an unfair and deceptive business practice, and TI is not responsible nor liable for any such use.

Also see: Standard Terms and Conditions of Sale for Semiconductor Products. www.ti.com/sc/docs/stdterms.htm

Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

Preface

How to Use This Manual

This document contains the following chapters:

- ❏ Chapter 1—Introduction
- ❏ Chapter 2—Quick Start
- ❏ Chapter 3—Details

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.

Related Documentation From Texas Instruments

- ***TI Plug-N-Play Audio Amplifier Evaluation Platform*** (literature number SLOU011) provides detailed information on the evaluation platform and its use with TI audio evaluation modules.
- ***TLC2274 Advanced LinCMOS Rail-to-Rail Operational Amplifiers*** (literature number SLOS190) This is the data sheet for the TLC2274 Quad operational amplifier integrated circuit used in the tone control EVM.
- ***TLV2231 Advanced LinCMOS Rail-to-Rail Low-Power Single Operational Amplifier*** (literature number SLOS158) This is the data sheet for the TLV2231 operational amplifier integrated circuit used in the tone control EVM.

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

Introduction

This chapter provides an overview of the Texas Instruments (TI) tone control evaluation module (SLOP109). It includes a list of EVM features, a brief description of the module illustrated with a diagram, and a list of EVM specifications.

Topic **Page**

1.1 Feature Highlights

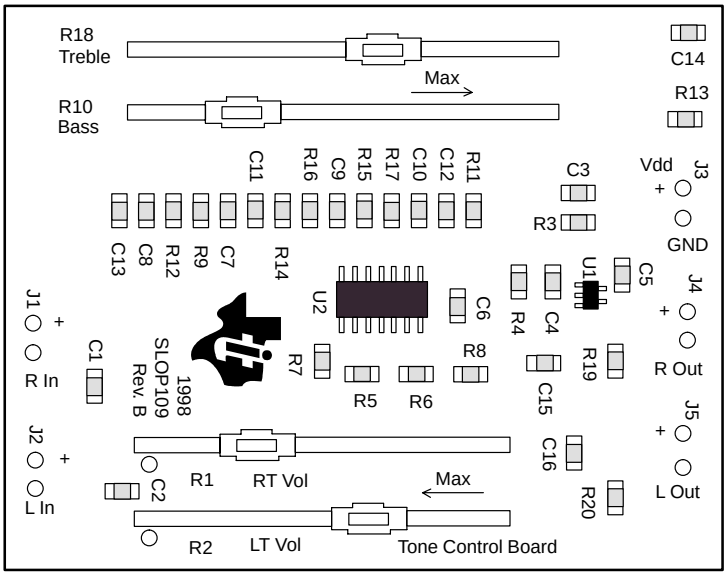
The TI tone control evaluation module and the TI plug-n-play audio amplifier evaluation platform include the following features:

- Tone Control Evaluation Module
  - Individual slide pots for left and right channel volume control
  - Individual slide pots for bass and treble—the bass control adjusts both channels simultaneously and the treble control adjusts both channels simultaneously
  - 20-dB cut and 15-dB boost for both bass and treble
  - 3.3-V and 5-V operation
- Quick and Easy Configuration with The TI Plug-N-Play Audio Amplifier Evaluation Platform
  - Evaluation module is designed to simply plug into the platform, automatically making all signal, control, and power connections
  - Platform provides flexible power options
  - Jumpers on the platform select power and module control options
  - Switches on the platform route signals
  - Platform provides quick and easy audio input and output connections
- Platform Power Options
  - External 5-V – 15-V DC V_{CC} supply inputs
  - External regulated V_{DD} supply input
  - Socket for onboard 5-V/3.3-V V_{DD} voltage regulator EVM
  - Onboard overvoltage and reverse polarity power protection
- Platform Audio Input and Output Connections
  - Left and right RCA phono jack inputs
  - Miniature stereo phone jack input
  - Left and right RCA phono jack outputs
  - Left and right compression speaker terminal outputs
  - Miniature stereo headphone jack output

1.2 Description

The tone control evaluation module is a complete audio volume level and base and treble control board that is designed primarily for use with the TI plug-n-play audio amplifier evaluation platform. It consists of separate slide potentiometers for the right- and left-channel volume control, a slide potentiometer for controlling the bass response of both channels, a slide potentiometer for adjusting the treble response of both channels, a single-channel operational amplifier IC, a quad operational amplifier IC, and a small number of passive components mounted on a circuit board that measures approximately 2 1/4 inches by 1 3/4 inches (Figure 1–1).

Figure 1–1. The Tone Control Evaluation Module



Single in-line header pins extend from the underside of the module circuit board to allow the EVM to be plugged into the TI plug-n-play audio amplifier evaluation platform, or to be wired directly into existing circuits and equipment when used stand-alone.

The platform, with room for a single tone control evaluation module, is a convenient vehicle for evaluating TI's audio power amplifier and related evaluation modules. The EVMs plug into the platform, which automatically provides power to the modules, interconnects them correctly, and connects them to a versatile array of standard audio input and output jacks and connectors. Configuration controls allow the platform and EVMs to quickly model many possible end-equipment configurations.

There is nothing to build, nothing to solder, and nothing but the speakers included with the platform to hook up.

1.3 Tone Control EVM Specifications

Supply voltage range, V_{DD} . . . . . 3 V to 5.5 V
Supply current, I_{DD} . . . . . 6.85 mA max
Audio input voltage, V_I . . . . . 4 Vpp max
Audio output voltage, V_O . . . . . 4 Vpp max

Chapter 2

Quick Start

Follow the steps in this chapter to quickly prepare the tone control EVM for use. Using the tone control EVM with the TI plug-n-play audio amplifier evaluation platform is a quick and easy way to connect power, signal, and control inputs, and signal outputs to the EVM using standard connectors. However, the tone control EVM can be used stand-alone by making connections directly to the module pins and can be wired into existing circuits or equipment.

Topic **Page**

2.1 Precautions

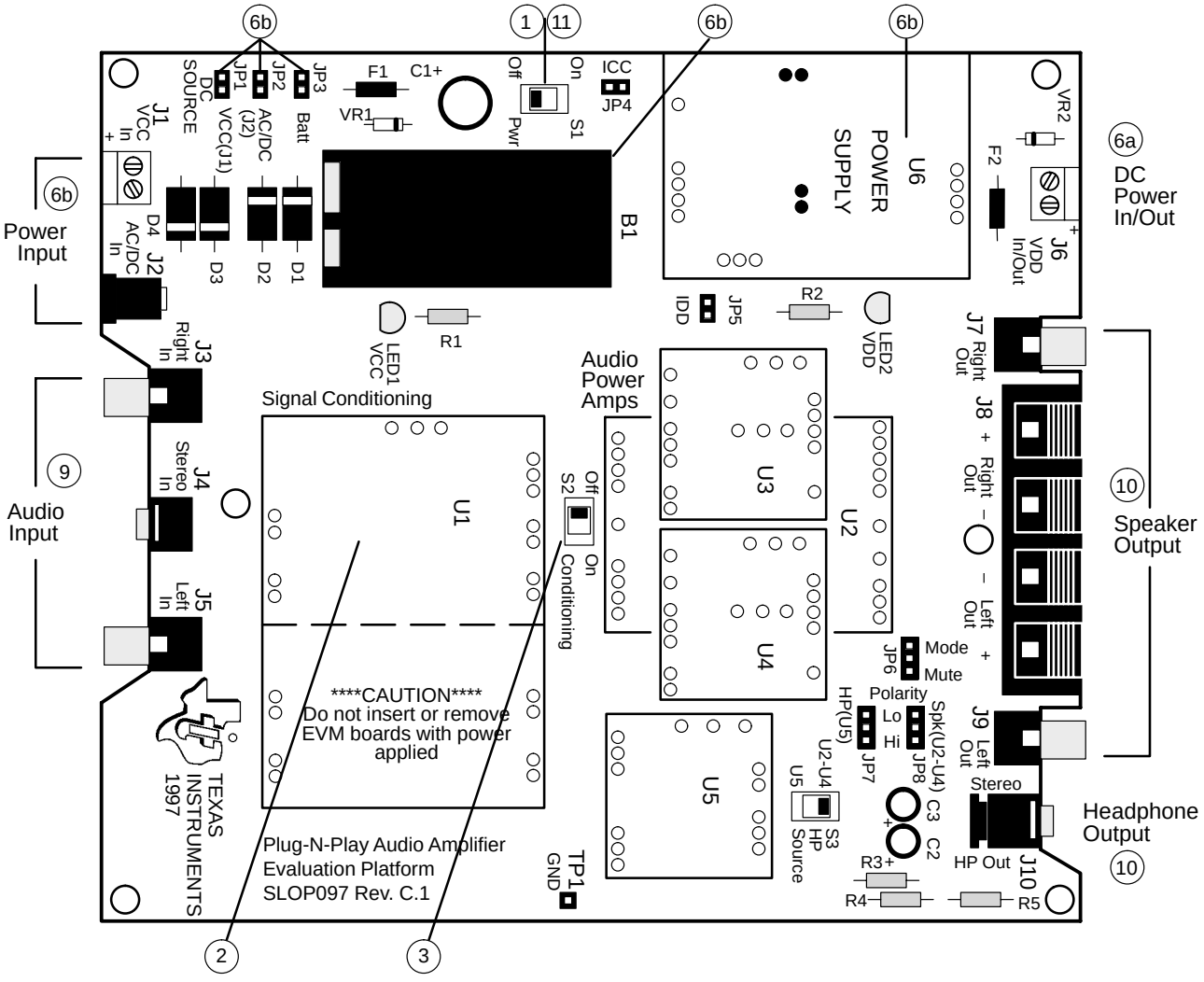
Power Supply Input Polarity and Maximum Voltage

Always ensure that the polarity and voltage of the external power connected to V_{CC} power input connector J1, J2, and/or V_{DD} power input connector J6 are correct. Overvoltage or reverse-polarity power applied to these terminals can open onboard soldered-in fuses and cause other damage to the platform, installed evaluation modules, and/or the power source.

Inserting or Removing EVM Boards

Do not insert or remove EVM boards with power applied—damage to the EVM board, the platform, or both may result.

Figure 2–1. Quick Start Platform Map



2.2 Quick Start List for Platform

Follow these steps when using the tone control EVM with the TI plug-n-play audio amplifier evaluation platform (see the platform user's guide, SLOU011, for additional details). Numbered callouts for selected steps are shown in Figure 2–1, and details appear in Chapter 3.

❑ **Platform preparations**

1) Ensure that all external power sources are set to *OFF* and that the platform power switch S1 is set to *OFF.*

2) Install the tone control module in the signal conditioning platform socket U1, taking care to align the module pins correctly.

3) Set switch S2 to *ON* to select signal conditioning by the tone control EVM.

4) Install power amplifiers and/or a headphone amplifier module in the appropriate platform sockets (see the amplifier module user's guide for details).

5) Set platform jumpers and switches in accordance with the user's guide for each amplifier module installed on the platform.

❑ **Power supply**

6) Select and connect the power supply (ensure power supply is set to *OFF*):

   a) Connect an external regulated power supply set to 5 V to platform V_{DD} power input connector J6 taking care to observe marked polarity,
      or

   b) Install a voltage regulator EVM (SLVP097 or equiv.) in platform socket U6. Connect a 7 V – 12 V power source to a platform V_{CC} power input J1 or J2 and jumper the appropriate power input (see platform user's guide).

❑ **Inputs and outputs**

7) Ensure that the audio signal source level is set to minimum.

8) Set the EVM right and left volume slide pots to minimum.

9) Connect the audio source to left and right RCA phono jacks J3 and J5 or stereo miniature phone jack J4.

10) Connect 3-Ω – 8-Ω speakers to left and right RCA jacks J7 and J9 or to stripped wire speaker connectors J8, *or* plug headphones into J10.

❑ **Power Up**

11) Verify correct voltage and input polarity and set the external power supply to *ON.* If V_{CC} and an onboard regulator EVM are used to provide V_{DD}, set platform power switch S1 to *ON.*

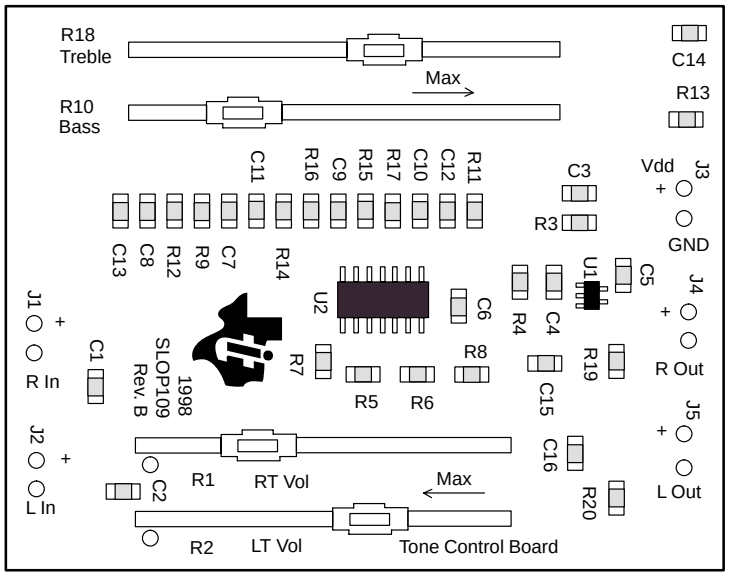
Platform LED2 should light indicating the presence of V_{DD}, and the evaluation modules installed on the platform should begin operation.

12) Adjust the signal source and tone control EVM audio levels as needed.

2.3 Quick Start List for Stand-Alone

Follow these steps to use the tone control EVM stand-alone or when connecting it into existing circuits or equipment. Connections to the tone control module header pins can be made via individual sockets, wire-wrapping, or soldering to the pins, either on the top or the bottom of the module circuit board. The tone control EVM is shown in Figure 2–2 and details appear in Chapter 3.

Figure 2–2. Quick Start Module Map—Stand-Alone



❑ **Power supply**

1) Ensure that all external power sources are set to *OFF.*

2) Connect an external regulated power supply set to 5 V to the module VDD and GND pins taking care to observe marked polarity.

❑ **Inputs and outputs**

3) Ensure that audio signal source level adjustments are set to minimum.

4) Set the tone control EVM volume slide pots to minimum.

5) Connect the audio source to the module R IN and L IN pins, taking care to observe marked polarity.

❑ **Power Up**

6) Verify correct voltage and input polarity and set the external power supply to *ON.*

The EVM should begin operation.

7) Adjust the signal source and tone control EVM audio levels as needed.

Chapter 3

Details

This chapter provides details on the tone control EVM, the steps in the Quick-Start List, additional application information, and a parts list for the tone control evaluation module.

Topic **Page**

3.1 Precautions

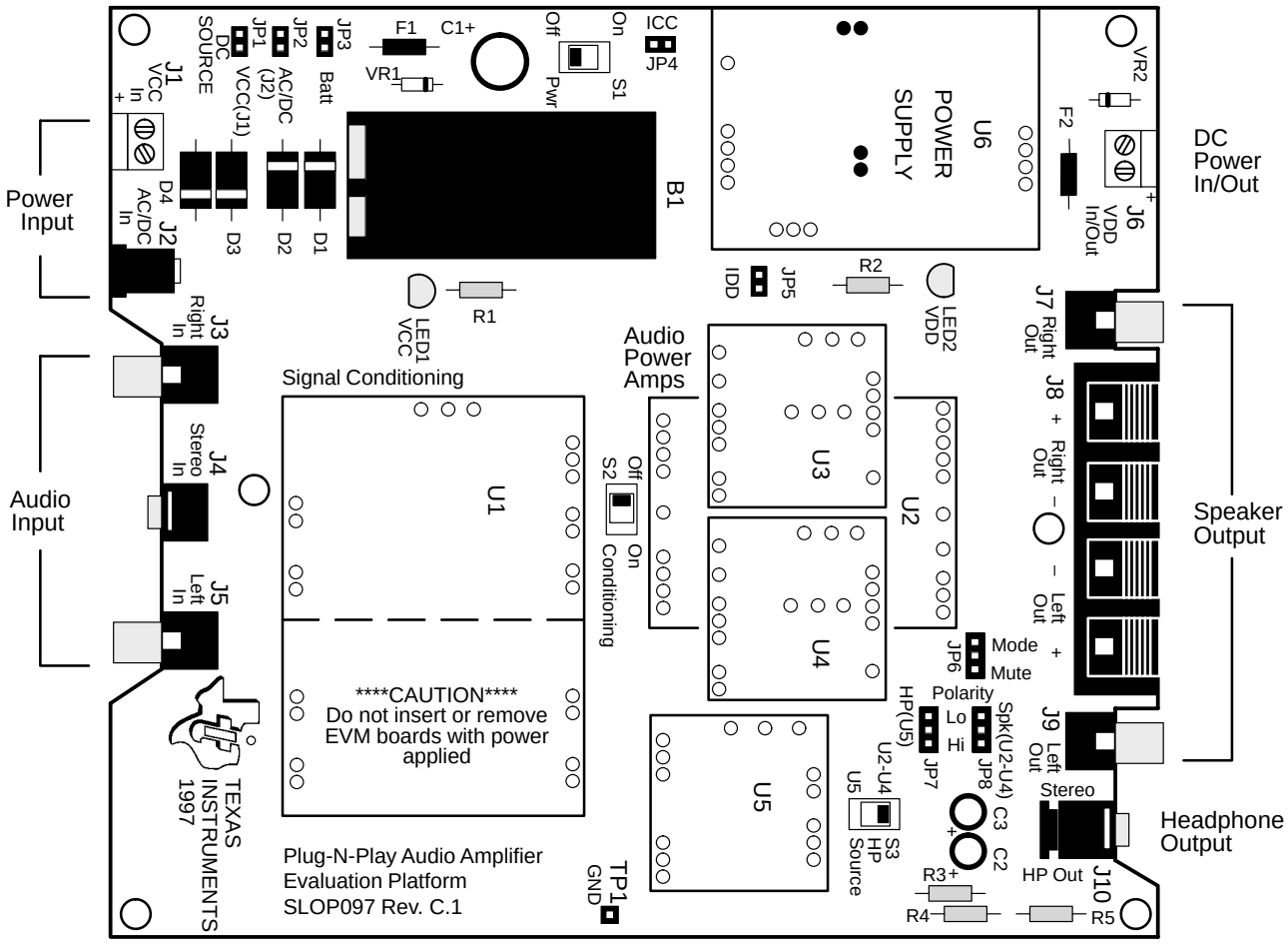
Power Supply Input Polarity and Maximum Voltage

Always ensure that the polarity and voltage of the external power connected to V_{CC} power input connector J1, J2, and/or V_{DD} power input connector J6 are correct. Overvoltage or reverse-polarity power applied to these terminals can open onboard soldered-in fuses and cause other damage to the platform, installed evaluation modules, and/or the power source.

Inserting or Removing EVM Boards

Do not insert or remove EVM boards with power applied—damage to the EVM board, the platform, or both may result.

Figure 3–1. The TI Plug-N-Play Audio Amplifier Evaluation Platform



3.2 The Tone Control Evaluation Module

The tone control evaluation module provides a convenient way to control the audio volume and the tonal response of audio amplifier EVMs plugged into the TI plug-n-play audio amplifier evaluation platform. Tone controls allow the frequency response of the audio system to be adjusted to compensate for the response of speakers and their enclosures, or to simply provide a more pleasing sound. A pair of slide potentiometers adjusts the volume of each channel independently, while a single slide potentiometer adjusts the bass response of both channels simultaneously and another slide potentiometer adjusts the treble response of both channels. The module provides a gain of 2 at the maximum volume setting when both tone controls are at their midpoints (flat).

Although the tone control EVM is designed to be used with the TI plug-n-play audio amplifier evaluation platform (Figure 3–1), it can be wired directly into circuits or equipment. The module has single in-line header connector pins mounted to the underside of the board. These pins allow the module to be plugged into the TI platform, which automatically makes all the signal input and output, power, and control connections to the module.

The module connection pins are on 0.1-inch centers to allow easy use with standard perf board and plug board-based prototyping systems. Or, the EVM can be wired directly into existing circuits and equipment when used stand-alone.

The module appears in Figure 3–2 and its schematic is shown in Figure 3–3.

Figure 3–2. Tone Control EVM

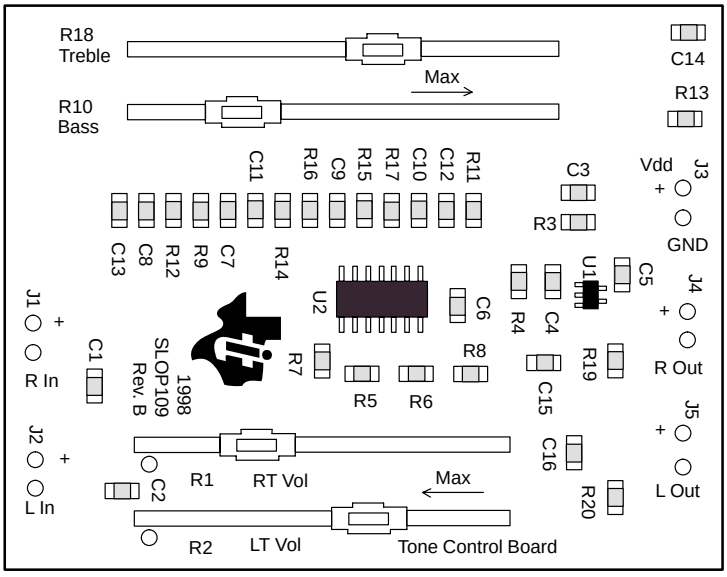
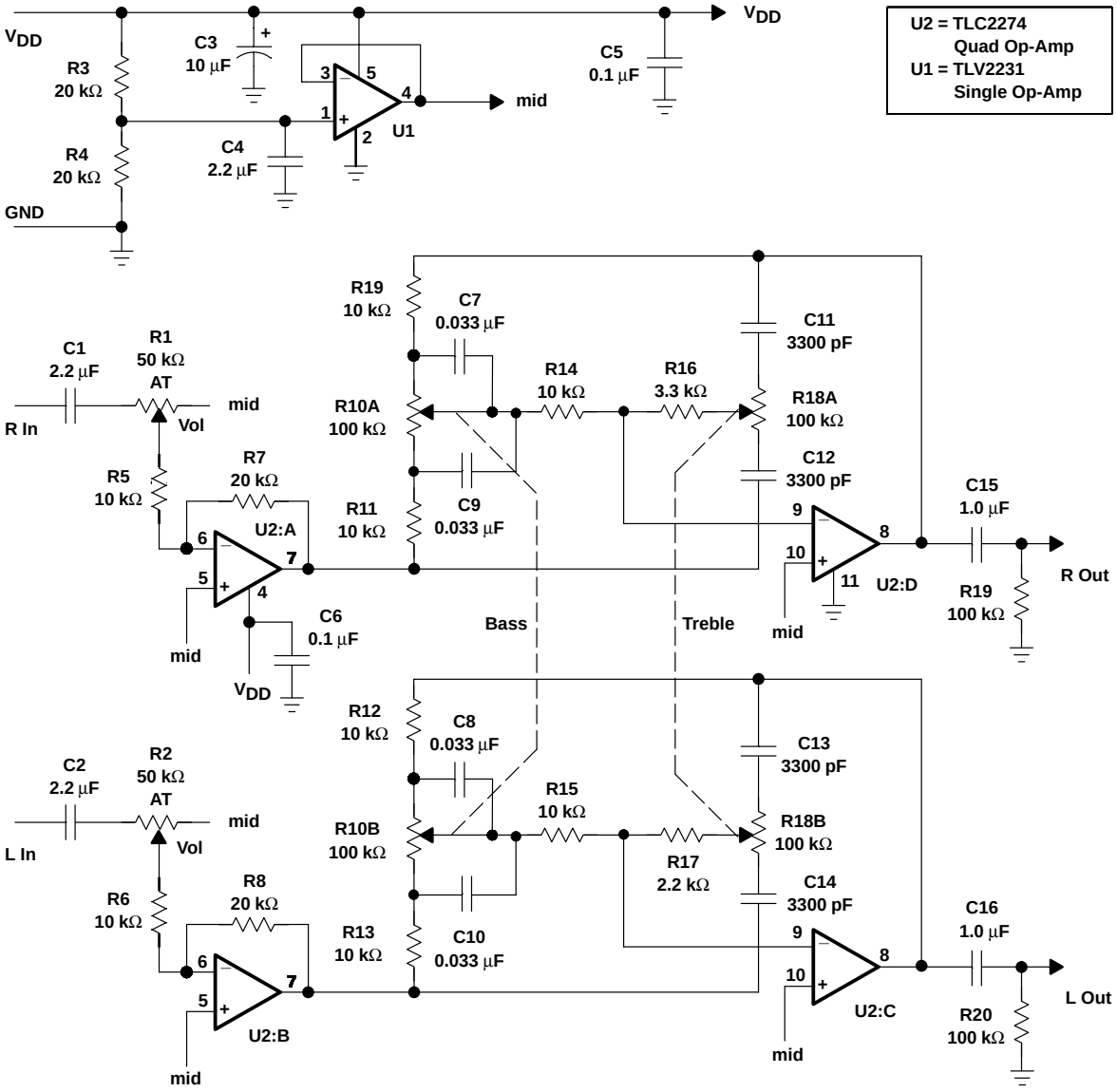


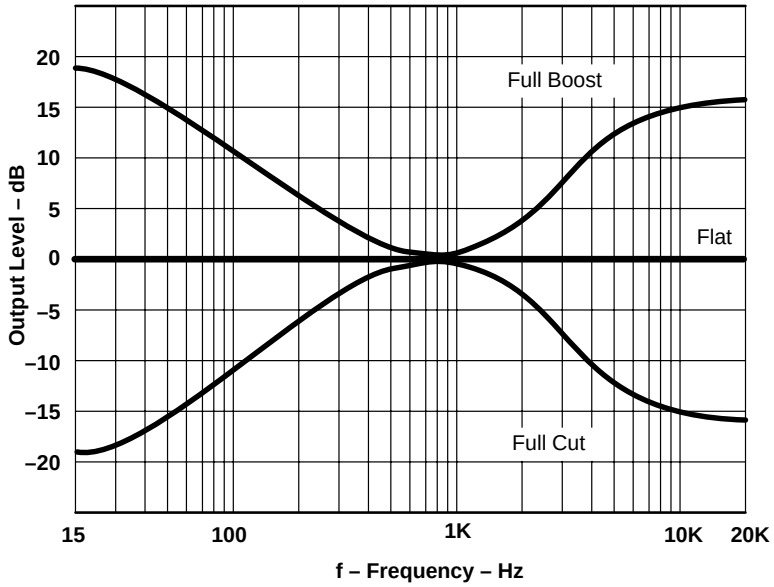
Figure 3–3. Tone Control EVM Schematic Diagram



The tone control EVM is a variation of the classic and popular Baxandall negative feedback tone control. This circuit allows a range of adjustment from cut, through flat, to boost in bass response with a single potentiometer. Another potentiometer provides the same range of adjustment for the treble response. The component values indicated in the schematic provide the response curve shown in Figure 3–4. Each of the tone adjusting potentiometers is a dual unit, allowing the simultaneous adjustment of both channels with a single control. A separate volume control for each channel allows the adjustment of balance between the channels as well as volume.

A single TLC2274 quad rail-to-rail operational amplifier IC contains all the amplifiers required for both channels. A TLV2231 operational amplifier IC is connected to provide a midpoint voltage (and signal ground) for proper operation of the TLC2274.

Figure 3–4. Tone Control Evaluation Module Frequency Response

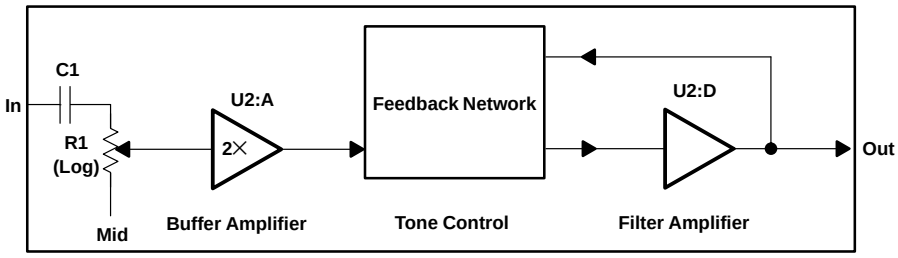


3.2.1 Tone Control EVM Circuit Description

Each of the two separate channels on the tone control EVM is basically an active filter built around an IC operational amplifier. An active filter design was chosen over a passive filter circuit because active filters have the frequency-response adjusting components located in the feedback loop of the filter amplifiers, providing much lower THD, little or no insertion loss, and a symmetrical response about the axis in both boost and cut, compared with most passive designs. Each channel also includes an input buffer amplifier to provide some gain, isolation from source impedance variations, signal inversion, and a low-impedance drive for the filter circuit.

A block diagram of the right channel of the tone control EVM is shown in Figure 3–5. The left channel is identical.

Figure 3–5. Tone Control EVM Block Diagram



The input buffer amplifier provides a gain of approximately 2 (R_F/R_{IN}) with the resistor values installed on the module. Input capacitor C1 blocks DC and sets the overall low-frequency rolloff of the EVM at approximately 16 Hz with the installed value of 2.2 μF. Volume control R1 has an audio taper to provide a perceived response in volume that is proportional to the physical position of the slider and gives an adjustment range at the output of the buffer amplifier of from 0 V to approximately 2× the audio signal input voltage.

The tone adjusting action in each channel of the tone control EVM is provided by an equalized amplifier (or active filter) created by placing a frequency-dependent negative feedback network around an operational amplifier. Almost any overall gain-versus-frequency characteristic can be defined by the design of the feedback network.

The EVM provides the familiar *Hi-Fi tone control*, in which the low audio frequencies can be boosted or cut approximately 20 dB with the bass control and the high audio frequencies can be boosted or cut approximately 20 dB with the treble control. Middle frequencies are not affected by the tone controls. An overall flat response (no boost or cut at frequency extremes) is obtained when the tone controls are at their mid-point position.

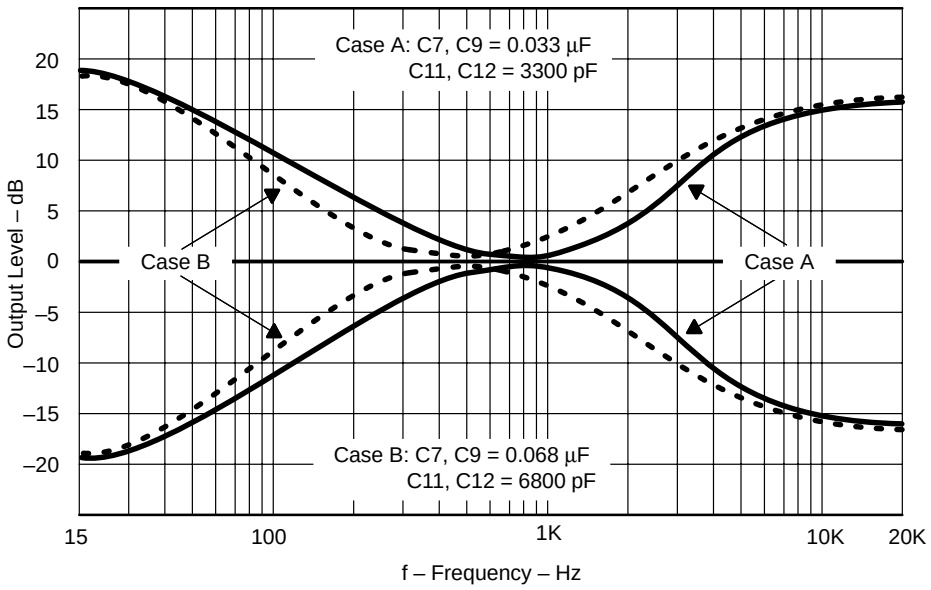
3.2.2 Tone Control EVM Frequency Response

The overall tone control EVM frequency response can be shifted up or down by changing the values of capacitors C7, C9, C11, and C12 in the tone adjusting networks on the module. Care must be taken, however, because the surface-mount solder pads on the board are somewhat fragile and will not survive a large number of soldering/desoldering operations.

To shift the EVM frequency response downward, for example, increase the values of the capacitors in the tone adjusting networks. Doubling the values of C7, C9, C11, and C12 shifts the break frequency downward a full octave (Case B, Figure 3–6). Conversly, halving the values of C7, C9, C11, and C12 shifts the break frequency upward a full octave.

Note that to keep the boost and cut break frequencies the same, the value of C7 must equal that of C9, and the value of C11 must equal that of C12. In addition, although the bass and treble break frequencies can be adjusted separately if desired, to maintain the overall shape and symmetry of the response, all four capacitors must be increased or decreased by the same factor.

Figure 3–6. Bass and Treble Tone Control Response



3.3 Using The Tone Control EVM With the Plug-N-Play Evaluation Platform

The tone control evaluation module was designed to be used with the TI plug-n-play audio amplifier evaluation platform. It simply plugs into socket U1.

The following paragraphs provide additional details for using the tone control EVM with the platform.

3.3.1 Installing and Removing EVM Boards

TI plug-n-play evaluation modules use single-in-line header pins installed on the underside of the module circuit board to plug into sockets on the platform. The EVM pins and the platform sockets are keyed such that only the correct type of EVM can be installed in a particular socket, and then only with the proper orientation.

Evaluation modules are easily removed from the platform by simply prying them up and lifting them out of their sockets. Care must be taken, however, to prevent bending the pins.

3.3.1.1 EVM Insertion

1) Remove all power from the evaluation platform.
2) Locate the appropriate socket on the platform.
3) Orient the module correctly.
4) Carefully align the pins of the module with the socket pin receptacles.
5) Gently press the module into place.
6) Check to be sure that all pins are seated properly and that none are bent over.

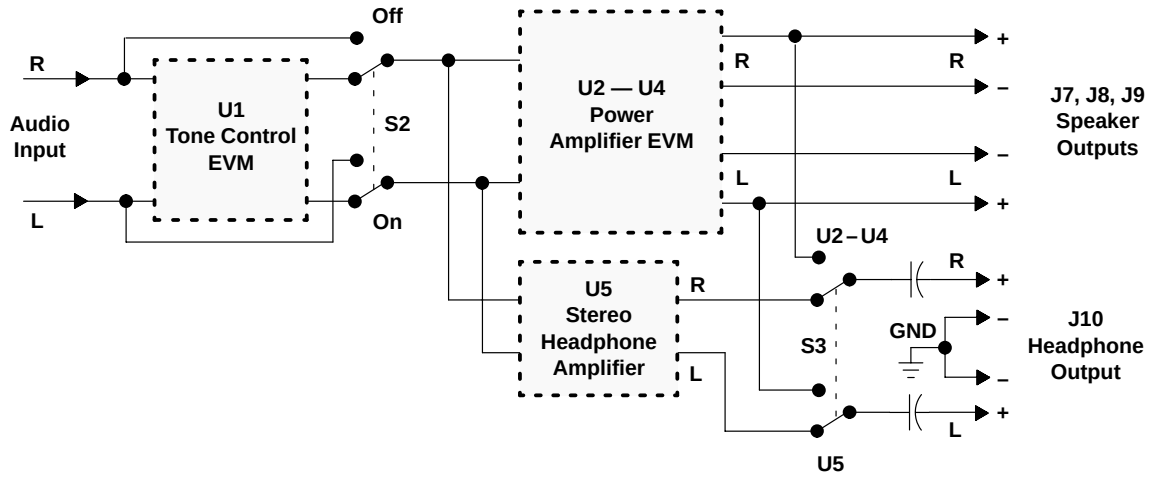
3.3.1.2 EVM Removal

1) Remove all power from the evaluation platform.
2) Gently pry up one side of the module a small amount.
3) Change to the opposite side of the module and pry that side up a small amount.
4) Alternate between sides, prying the module up a little more each time to avoid bending the pins, until it comes loose from the socket.
5) Lift the EVM off the platform.

3.3.2 Signal Routing

Signal flow on the platform is controlled by two signal routing switches, as shown in Figure 3–7.

Figure 3–7. Platform Signal Routing and Outputs



3.3.2.1 Signal Conditioning

The tone control EVM plugs into the signal conditioning socket (U1) on the platform. The audio signal from the platform input jacks can be applied to the signal conditioning socket (U1) or can bypass socket U1 as determined by conditioning switch S2.

- ❑ Switch S2 selects the tone control signal conditioning or bypasses it.

3.3.2.2 Headphone Output Jack

Switch S3 is the source select for the stereo headphone output jack, J10. The headphone jack is capacitively coupled (via 470 μF electrolytics). The jack can output either the signal from the headphone amplifier in socket U5, or the signal from the power amplifier installed in sockets U2 – U4, as determined by the setting of switch S3.

When S3 is set to the power amplifier position (U2 – U4), the headphone jack is connected to the power amplifier OUT+ output lines. When a plug is inserted into the jack, signals output through J10 are returned to platform ground, requiring single-ended power amplifier operation. A switch inside the headphone jack produces a control signal that can be routed to the power amplifier socket to shut down the power amplifier EVM or switch it to single-ended output mode when a plug is inserted.

See the user's guide for the power amplifier and/or the headphone amplifier installed on the platform for information on the correct setting of switch S3.

3.3.3 Mute/Mode

Some power amplifier EVMs have a mute or mode control input pin. This allows the power amplifier to enter the mute state for decreased power consumption or to switch output modes in response to a control signal applied to this pin.

In typical applications, as often found in notebook computers, portable audio products, and such, the internal speakers mute when headphones are plugged into the headphone jack, or internal speakers mute when external speakers are connected. In applications using separate speaker and headphone amplifiers, the power amplifier can be shut down (muted) to conserve power when the headphone amplifier is in use.

Output mode switching allows some power amplifier EVMs to operate in the bridge-tied load (BTL) output mode for increased power to internal speakers and then switch to single-ended mode to drive headphones when a plug is inserted into the headphone jack, eliminating the need for a separate headphone amplifier.

The platform is equipped with mute/mode control signal select and polarity jumpers and a headphone source switch to provide the maximum flexibility in configuring the operation of the various power amplifier and headphone amplifier EVMs that might be installed on the platform. See the user’s guide for the power amplifier and/or the headphone amplifier installed on the platform for information on the correct settings of platform mute, mode, polarity jumpers, and the platform headphone source switch.

3.3.4 Power Requirements

The tone control evaluation module can operate from any voltage between approximately 3 V and 5.5 V. For best performance (highest output power with lowest distortion), the module should be operated at approximately 5 V unless there is a specific reason for operating it from a lower voltage.

The TI plug-n-play audio amplifier evaluation platform with a voltage regulator EVM installed on it can provide a regulated V_{DD} supply from a wide variety of unregulated V_{CC} voltage inputs between approximately 5.5 V and 12 V, including an onboard 9-V battery. Or, an external regulated power source can be used to supply V_{DD} voltage to the platform and the tone control evaluation module installed on it.

Although the tone control EVM draws a very small amount of current from the supply, power amplifiers installed on the platform can draw as much as approximately 2 A from the power supply during continuous full power output. Any power supply connected to the platform should be capable of providing adequate current to the power amplifier installed on the platform to avoid clipping of the output signal during peaks. Current consumption driving speakers at normal listening levels is typically 0.5 A or less.

The platform is equipped with overvoltage and reverse-polarity supply voltage input protection in the form of fused crowbar circuits.

- V_{DD} voltage applied to platform screw terminals J6 *must not* exceed the absolute maximum rating for *any* EVM installed on the platform, or damage may result. In no case should V_{DD} voltage of the incorrect polarity or in excess of 6.1 V be applied to screw terminals J6 of the platform, or the power protection circuit on the V_{DD} line will trip.
- V_{CC} voltage applied to the platform *must not* exceed the maximum voltage input specified for the voltage regulator module installed in socket U6 (12 V for the SLVP097), or damage to the voltage regulator module may result. In no case should V_{CC} voltage applied to the platform exceed 15 V, or the overvoltage protection circuit on the V_{CC} bus will trip.

3.3.5 Inputs and Outputs

The TI plug-n-play audio amplifier evaluation platform is equipped with several standard conectors for audio inputs and outputs.

3.3.5.1 Inputs

Audio signals enter the platform through either a pair of RCA phono jacks (J3 and J5) or a miniature (1/8″) stereo phone jack (J4). The platform audio signal input jacks (J3, J4, and J5) are of the closed-circuit type, grounding the signal input lines when no plugs are inserted.

3.3.5.2 Outputs

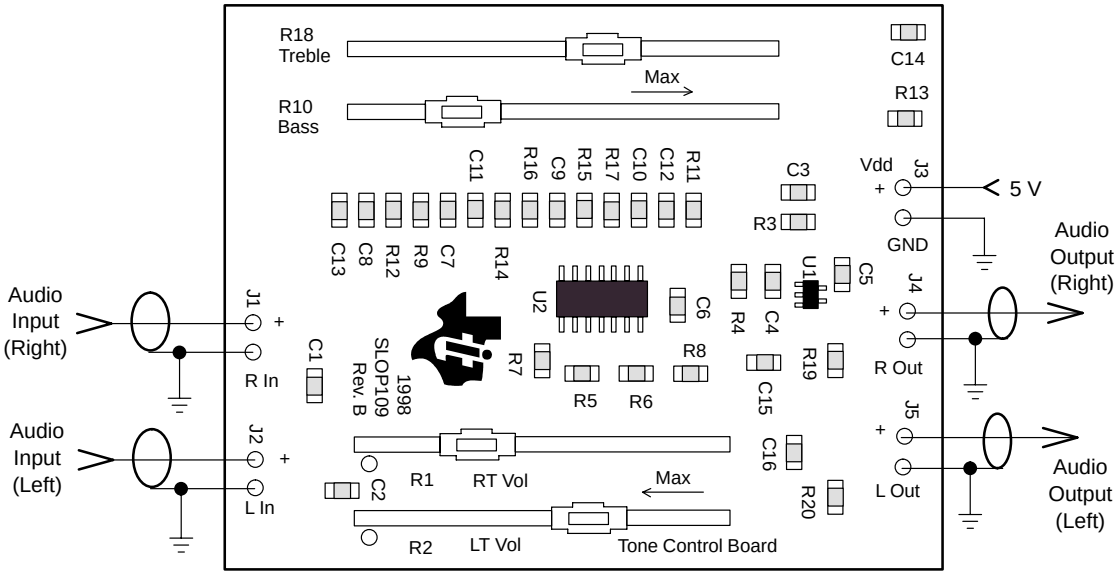
Amplified audio output signals leave the platform through left and right RCA phono jacks (J7 and J9), left and right pairs of compression connectors for stripped speaker wires (J8), and optionally, through a miniature (1/8″) stereo phone jack (J10), for headphones.

3.4 Using The Tone Control EVM Stand-Alone

Using the tone control evaluation module stand-alone is much the same as using it with the platform. The same 5-V power supply requirement exists.

3.4.1 Tone Control EVM Connected for Stand-Alone Operation

Figure 3–8. Tone Control EVM Stand-Alone Operation



3.5 Tone Control Evaluation Module Parts List

Table 3–1. Tone Control EVM Parts List

Reference	Description	Size	EVM Qty.	Source/ Part Number
C1, C2, C4	Capacitor, ceramic, 2.2 μF, 16 V, YV5	1206	3	TDK C3216Y5V1C225Z
C3	Capacitor, ceramic, 10 μF, 16 V, YV5	1210	1	TDK C3216Y5V1C106Z
C15, C16	Capacitor, ceramic, 1 μF, 16 V, YV5	1206	2	TDK C3216Y5V1C105Z
C7, C8, C9, C10	Capacitor, ceramic 0.033 μF, 50 V, NPO	1206	2	Digi-Key
C5, C6	Capacitor, ceramic, 0.1 μF, 50 V, X7R	1206	2	Digi-Key PCC104BCT–ND
C11, C12, C13, C14	Capacitor, ceramic 3300 pF, 50 V, NPO	1206	4	Digi-Key
R10, R18	Dual potentiometer, 100 kΩ, linear taper, slide control		2	CTS 448XC351109
R1, R2	Potentiometer, 50 kΩ, audio taper, slide control		2	CTS 448XC3503BAN
R5, R6, R9, R11, R12, R13, R14, R15	Resistor, CF, 10 kΩ, 1/8 W, 5%	1206	8	
R3, R4, R7, R8	Resistor, CF, 20 kΩ, 1/8 W, 5%	1206	4	
R16, R17	Resistor, CF, 3.3 kΩ, 1/8 W, 5%	1206	2	
R19, R20	Resistor, CF, 10 kΩ, 1/8 W, 5%	1206	2	
J1–J5	Header, 2 position, 100-mil centers		5	Digi-Key S1022–36ND
U1	TLV2231IDBV IC operational amplifier	SOT-23	1	TI
U2	TLC2274CD quad IC operational amplifier	SOIC	1	TI
PCB	PCB, tone control EVM		1	TI SLOP109