

# TPA2014D1EVM

This user's guide describes the TPA2014D1 audio amplifier evaluation module (TPA2014D1EVM) and its operation. It includes the EVM specifications, the schematic, the printed-circuit board layout, and the parts list.

## Contents

|   |                               |   |
|---|-------------------------------|---|
| 1 | Introduction .....            | 1 |
| 2 | Operation .....               | 2 |
| 3 | TPA2014D1EVM Schematic .....  | 5 |
| 4 | TPA2014D1EVM PCB Layers ..... | 6 |
| 5 | TPA2014D1EVM Parts List.....  | 8 |

## List of Figures

|   |                                  |   |
|---|----------------------------------|---|
| 1 | TPA2014D1EVM Schematic .....     | 5 |
| 2 | TPA2014D1EVM – Top Layer .....   | 6 |
| 3 | TPA2014D1EVM – Bottom Layer..... | 7 |

## List of Tables

|   |                              |   |
|---|------------------------------|---|
| 1 | Recommended Values .....     | 5 |
| 2 | TPA2014D1EVM Parts List..... | 8 |

## 1 Introduction

This section provides an overview of the Texas Instruments (TI) TPA2014D1 audio amplifier evaluation module (TPA2014D1EVM). It includes a brief description of the module and a list of EVM specifications.

### 1.1 Description

The TPA2014D1 is a 1.5 W, Class-D amplifier with built-in boost converter. It drives up to 1.5 W (10% THD + N) into a 8-Ω speaker from low supply voltages.

The TPA2014D1 audio power amplifier evaluation module(EVM) is a complete, stand-alone audio board. It contains the TPA2014D1 QFN (RGP) Class-D audio power amplifier with an integrated boost converter. All components and the EVM are Pb-free.

### 1.2 TPA2014D1EVM Specifications

|          |  |                            |
|----------|--|----------------------------|
| $V_{DD}$ | Supply voltage range   | –0.3 V to 5.5 V            |
| $I_{DD}$ | Supply current   | 750 mA                     |
| $P_O$    | Continuous output power per channel, 8 Ω, $V_{DD} = 3.6$ V, $V_{CC} = 5$ V, THD + N =10% | 1.5 W                      |
| $V_I$    | Audio Input Voltage  | –0.3 V to $V_{DD} + 0.3$ V |
| $R_L$    | Minimum load impedance   | 8 Ω                        |

## 2 Operation

This section describes how to operate the TPA2014D1EVM.

### 2.1 Quick-Start List for Stand-Alone Operation

Use the following steps when operating the TPA2014D1EVM as a stand-alone or when connecting the EVM into existing circuits or equipment.

#### 2.1.1 Power and Ground

1. Ensure that the external power sources are set to OFF.
2. Set the power supply voltage between 2.5 V and 5.5 V. When connecting the power supply to the EVM, first attach the ground connection to the GND connector, **J1**, and then connect the positive supply to the  $V_{DD}$  connector, **J2**. Verify that the connections are made to the correct banana jacks.
3.  $V_{CC}$  can be set lower than  $V_{DD}$ . They are independent of each other.
4.  $V_{CC}$  must be greater than 3 V.
5.  $V_{CC}$  must not exceed 5.5 V.

---

**Note:** Do not connect  $V_{DD}$  to the  $V_{CC}$  header pin. This can cause damage to the device.

---

#### 2.1.2 Audio

1. Ensure that the audio source is set to the minimum level.
2. Connect the audio source to the input RCA jack VIN (**J7**). Do not connect an audio source to the pins on **J8**. The pins on **J8** are for measurement purposes only.
3. Connect speakers ( $8\ \Omega$  to  $32\ \Omega$ ) to the output RCA jacks OUT+ and OUT- (**J4** and **J5**, respectively).
4. **J6** allows the user to connect one of the outputs to an RC filter. Note that the user must provide the necessary capacitors, C7 and C8.

#### 2.1.3 Gain Control

The TPA2014D1 has three gain settings: 2 V/V, 6 V/V, and 10 V/V.

1. Use jumper **J13** to set the gain as 2 V/V, 6 V/V, or 10 V/V. To achieve 2 V/V, place the jumper between heads 1 and 2; for 10 V/V, shunt heads 2 and 3; for 6 V/V, remove the jumper and let the gain pin float.

#### 2.1.4 Shutdown Controls

1. The TPA2014D1EVM provides independent shutdown controls for the Class-D amplifier and the boost converter. Pins  $\overline{SDb}$  and  $\overline{SDd}$  shut down the boost converter and Class-D amplifier, respectively. They are active low. Connect jumpers between headers 2 and 3 on **J11**. Press and hold pushbutton **S1** to place the boost converter in shutdown mode. Release pushbutton **S1** to activate the boost converter.
2. Connect jumpers between headers 2 and 3 on **J12**. Press and hold pushbutton **S2** to shut down the Class-D amplifier. Release pushbutton **S2** to activate the Class-D amplifier.
3. Connect a jumper across **J9**. LED **D1** lights up. When LED **D1** is on, the boost converter is active.
4. Remove **J9** to disconnect **D1** and reduce the quiescent current of the EVM.
5. Connect a jumper across **J10**. LED **D2** lights up. When LED **D2** is on, the Class-D amplifier is active.
6. Remove **J10** to disconnect **D2** and reduce the quiescent current of the EVM.
7. The boost converter is shut down by moving jumpers **J11** between headers 1 and 2. This ties the shutdown pins directly to ground where it can be held for an indefinite period of time. Move the jumpers back between headers 2 and 3 to tie the shutdown pins to  $V_{DD}$  to enable the boost converter or Class-D amplifier. Remove **J9** and **J11** to achieve the minimum boost shutdown current.
8. The Class-D amplifier is shut down by moving jumpers **J12** between headers 1 and 2. This ties the shutdown pins directly to ground where it can be held for an indefinite period of time. Move the

jumpers back between headers 2 and 3 to tie the shutdown pins to  $V_{DD}$  to enable Class-D amplifier. Remove **J10** and **J12** to achieve the minimum Class-D shutdown current.

---

**Note:** The boost converter provides power to the Class-D amplifier. When the boost converter is shut down, no voltage is supplied to the Class-D amplifier causing the Class-D amplifier to power off.

---

## 2.2 Boost Settings

The default voltage for the boost converter is 5 V

### 2.2.1 Boost Terms

The following is a list of terms and definitions:

|                  |  |
|------------------|--|
| $C_{MIN}$        | Minimum boost capacitance required for a given ripple voltage on $V_{CC}$ .                |
| $f_{boost}$      | Switching frequency of the boost converter.  |
| $I_{CC}$         | Current pulled by the Class-D amplifier from the boost converter.                          |
| $I_L$            | Current through the boost inductor.  |
| R1 and R2        | Resistors used to set the boost voltage.   |
| $R_{ESR}$        | ESR of the boost capacitor.  |
| $V_{CC}$         | Boost voltage. Generated by the boost converter. Voltage supply for the Class-D amplifier. |
| $V_{DD}$         | Supply voltage to the integrated circuit.  |
| $\Delta I_L$     | Ripple current through the inductor.   |
| $\Delta V$       | Ripple voltage on $V_{CC}$ due to capacitance.   |
| $\Delta V_{ESR}$ | Ripple voltage on $V_{CC}$ due to the ESR of the boost capacitor.                          |

### 2.2.2 Changing the Boost Voltage

1. If a different boost voltage is desired, use [Equation 1](#) to determine the new values of R1 and R2.

$$V_{CC} = \frac{(0.5 \times (R_1 + R_2))}{R_1} \quad (1)$$

2. The recommended value of R2 is 453 k $\Omega$ .

### 2.2.3 Changing the Boost Inductor

Working inductance decreases as inductor current increases. If the drop in working inductance is severe enough, it can cause the boost converter to become unstable, or cause the TPA2014D1 to reach its current limit at a lower output power than expected. Inductor vendors specify currents at which inductor values decrease by a specific percentage. This can vary by 10% to 35%. Inductance is also affected by dc current and temperature.

The requirements of the load determine the inductor current rating. The two factors that determine inductance are the minimum value required for stability and the maximum ripple current permitted in the application.

Use [Equation 2](#) to determine the required current rating. This equation shows the approximate relationship between the average inductor current,  $I_L$ , to the load current, load voltage, and input voltage ( $I_{CC}$ ,  $V_{CC}$ , and  $V_{DD}$ , respectively.) Insert  $I_{CC}$ ,  $V_{CC}$ , and  $V_{DD}$  into [Equation 2](#) to solve for  $I_L$ . The inductor must maintain at least 90% of its initial inductance value at this current.

$$I_L = I_{CC} \times \left( \frac{V_{CC}}{V_{DD} \times 0.8} \right) \quad (2)$$

The minimum working inductance is 2.2  $\mu\text{H}$ . A lower value may cause instability.

Ripple current,  $\Delta I_L$ , is peak-to-peak variation in inductor current. Smaller ripple current reduces core losses in the inductor as well as the potential for EMI. Use [Equation 3](#) to determine the value of the inductor, L. This equation shows the relationships among inductance L,  $V_{DD}$ ,  $V_{CC}$ , the switching frequency,  $f_{\text{boost}}$ , and  $\Delta I_L$ . Insert the maximum acceptable ripple current into [Equation 3](#) to solve for L.

$$L = \frac{V_{DD} \times (V_{CC} - V_{DD})}{\Delta I_L \times f_{\text{boost}} \times V_{CC}} \quad (3)$$

$\Delta I_L$  is inversely proportional to L. Minimize  $\Delta I_L$  as much as is necessary for a specific application. Increase the inductance to reduce the ripple current. Note that making the inductance too large prevents the boost converter from responding properly to fast load changes. Typical inductor values for the TPA2014D1 are 4.7  $\mu\text{H}$  to 6.8  $\mu\text{H}$ .

Select an inductor with a small dc resistance, DCR. DCR reduces the output power due to the voltage drop across the inductor.

## 2.2.4 Changing the Boost Capacitor

The value of the boost capacitor is determined by the minimum value of working capacitance required for stability and the maximum voltage ripple allowed on  $V_{CC}$  in the application. The minimum value of working capacitance is 10  $\mu\text{F}$ . Do not use any component with a working capacitance less than 10  $\mu\text{F}$ .

For X5R or X7R ceramic capacitors, [Equation 4](#) shows the relationships among the boost capacitance, C, to load current, load voltage, ripple voltage, input voltage, and switching frequency ( $I_{CC}$ ,  $V_{CC}$ ,  $\Delta V$ ,  $V_{DD}$ ,  $f_{\text{boost}}$  respectively). Insert the maximum allowed ripple voltage into [Equation 4](#) to solve for C. A factor of about 2 is included to implement the rules and specifications listed in the "Surface Mount Capacitors" section of the TPA2014D1 data sheet ([SLOS520](#)).

$$C = 2 \times \frac{I_{CC} \times (V_{CC} - V_{DD})}{\Delta V \times f_{\text{boost}} \times V_{CC}} \quad (4)$$

For aluminum or tantalum capacitors, [Equation 5](#) shows the relationships among the boost capacitance, C, to load current, load voltage, ripple voltage, input voltage, and switching frequency ( $I_{CC}$ ,  $V_{CC}$ ,  $\Delta V$ ,  $V_{DD}$ ,  $f_{\text{boost}}$  respectively). Insert the maximum allowed ripple voltage into [Equation 5](#) to solve for C. Solve this equation assuming ESR is zero.

$$C = \frac{I_{CC} \times (V_{CC} - V_{DD})}{\Delta V \times f_{\text{boost}} \times V_{CC}} \quad (5)$$

Capacitance of aluminum and tantalum capacitors is normally insensitive to applied voltage; so, no factor of 2 is included in [Equation 5](#). However, the ESR in aluminum and tantalum capacitors can be significant. Choose an aluminum or tantalum capacitor with an ESR around 30 m $\Omega$ . For best performance with tantalum capacitors, use at least a 10-V rating. Note that tantalum capacitors must generally be used at voltages of half their ratings or less.

### 2.2.5 Recommended Inductor and Capacitor Values by Application

Use [Table 1](#) as a guide for determining the proper inductor and capacitor values.

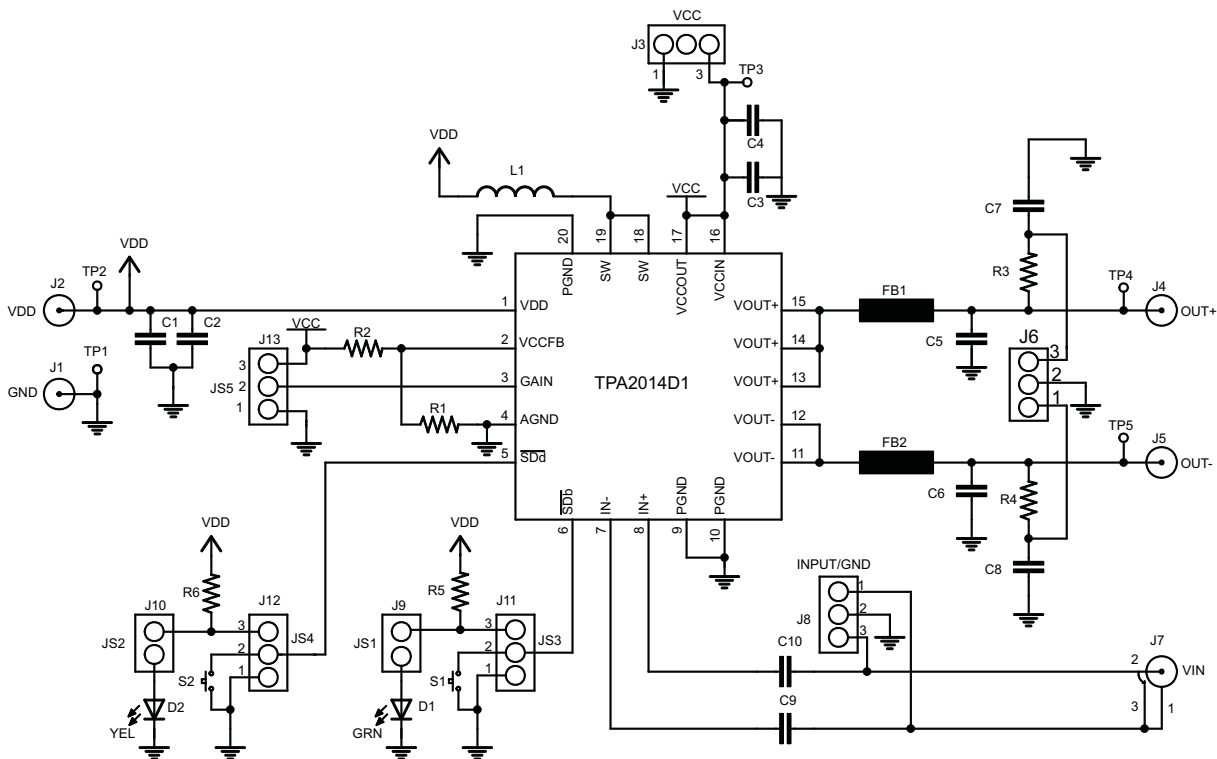
**Table 1. Recommended Values**

| Class-D Output Power (W) <sup>(1)</sup> | Class-D Load ( $\Omega$ ) | Minimum $V_{DD}$ (V) | Required $V_{CC}$ (V) | Max $I_L$ (A) | L ( $\mu$ H) | Inductor Vendor Part Numbers                                  | Max $\Delta V$ (mVpp) | C <sup>(2)</sup> ( $\mu$ F) | Capacitor Vendor Part Numbers  |
|---|---------------------------|----------------------|-----------------------|---------------|--------------|---|-----------------------|-----------------------------|--|
| 1                                       | 8                         | 3                    | 4.3                   | 0.7           | 3.3          | Toko DE2812C<br>Coilcraft DO3314<br>Murata LQH3NPN3R3NG0      | 30                    | 10                          | Kemet C1206C106K8PACTU<br>Murata GRM32ER61A106KA01B<br>Taiyo Yuden LMK316BJ106ML-T |
|   |                           |                      |                       |               | 4.7          |   |                       | 22                          |  |
| 1.2                                     | 8                         | 3                    | 5.0                   | 0.90          |              | Murata LQH43PN4R7NR0<br>Toko DE4514C<br>Coilcraft LPS4018-472 | 30                    |                             | Murata GRM32ER71A226KE20L<br>Taiyo Yuden LMK316BJ226ML-T                           |

(1) All power levels are calculated at 1% THD unless otherwise noted

(2) All values listed are for ceramic capacitors. The correction factor of 2 is included in the values.

### 3 TPA2014D1EVM Schematic



**Figure 1. TPA2014D1EVM Schematic**

4 TPA2014D1EVM PCB Layers

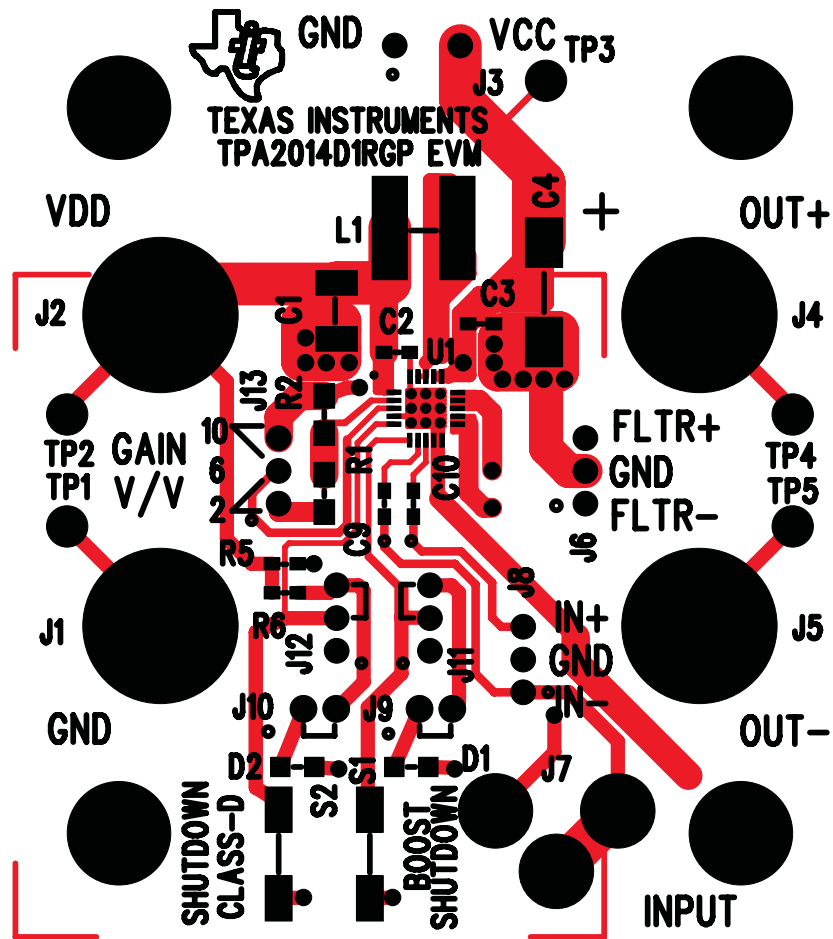


Figure 2. TPA2014D1EVM – Top Layer

**Note:** C4 has two separate pad sizes. One is for a 1210 ceramic capacitor, and the other is for a size "C" tantalum capacitor. Do not populate more than one at a time.

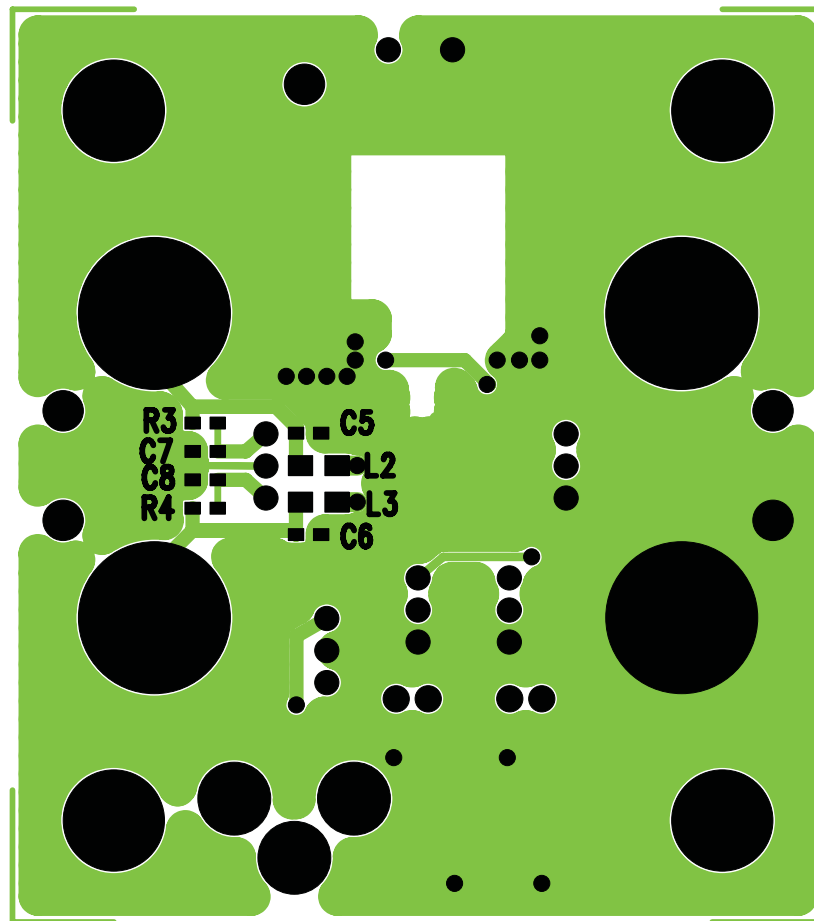


Figure 3. TPA2014D1EVM – Bottom Layer

**5 TPA2014D1EVM Parts List**
**Table 2. TPA2014D1EVM Parts List**

| Reference       | Description   | Size                | Qty | MFR/ Part No.                       | Vendor No.                   |
|-----------------|---|---------------------|-----|-------------------------------------|------------------------------|
| C1              | Capacitor, ceramic, 10 $\mu$ F, $\pm$ 10%, X7R, 10 V  | 1206                | 1   | Taiyo Yuden<br>LMK316BJ106KL-TR     | Digi-Key<br>587-1333-2-ND    |
| C2, C3, C9, C10 | Capacitor, ceramic, 1.0 $\mu$ F, $\pm$ 10%, X7R, 16 V | 0603                | 4   | TDK<br>C1608X7R1C105K               | Digi-Key<br>445-1604-2-ND    |
| C4              | Capacitor, ceramic, 47 $\mu$ F, $\pm$ 10%, X5R, 10 V  | 1210                | 1   | Murata<br>GRM32ER61A476KE20L        | Digi-Key<br>490-3887-1-ND    |
| C5, C6          | Capacitor, ceramic, 1 nF, $\pm$ 5%, C0G, 50 V         | 0603                | DNP | TDK<br>C1608COG1H102J               | Digi-Key<br>445-1293-2-ND    |
| C7, C8          | Capacitor, ceramic, 4.7 nF, $\pm$ 10%, X7R, 50V       | 0603                | DNP | Panasonic<br>ECJ-1VB1H472K          | Digi-Key<br>PCC1780TR-ND     |
| L1              | Inductor, 4.7 $\mu$ H, 1.45 A,                        | 4.5mm<br>x<br>4.7mm | 1   | Toko<br>1123AS-4R7M                 |                              |
| FB1, FB2        | Ferrite Bead, 100 $\Omega$ , 4 A                      | 0805                | 2   | TDK<br>MPZ2012S101A                 | Digi-Key<br>445-1567-1-ND    |
| R1              | Resistor, chip, 49.9 k $\Omega$ , 100 mW, 1%          | 0805                | 1   | Panasonic<br>ERJ-S06F4992V          | Digi-Key<br>ERJ-S06F4992V-ND |
| R2              | Resistor, chip, 453 k $\Omega$ , 100 mW, 1%           | 0805                | 1   | Panasonic<br>ERJ-6ENF4533V          | Digi-Key<br>ERJ-P453KCCT-ND  |
| R3, R4          | Resistor, chip, 1 k $\Omega$ , 1/10 W, 1%             | 0603                | 2   | Panasonic<br>ERJ-3EKF1001V          | Digi-Key<br>P1.00KHTR-ND     |
| R5, R6          | Resistor, chip, 270 $\Omega$ , 1/16 W, 5%             | 0603                | 2   | Panasonic<br>ERJ-3GEYJ271V          | Digi-Key<br>P270GTR-ND       |
| J1, J2, J4, J5  | Banana Jack w/knurled thumbnut, nickle plated         |                     | 4   | Johnson<br>111-2223-001             | Digi-Key<br>J587-ND          |
| J3              | Header, 3 position, 2 mm, male, center post removed   | 2 mm                | 1   | Norcomp<br>26633601RP2, 3-positions | DIBI-Key<br>2663S-36-ND      |
| J6, J8, J11-J13 | Header, 3 position, 2 mm, male                        | 2 mm                | 5   | Norcomp<br>26633601RP2, 3-positions | DIBI-Key<br>2663S-36-ND      |
| J7              | Phono Jack, PC mount, switched                        |                     | 1   | Witchcraft<br>PJ-RAN1X1U03          | Newark<br>16C1860            |
| J9, J10         | Header, 2 position, 2 mm, male                        | 2 mm                | 2   | Norcomp<br>26633601RP2, 2-positions | DIBI-Key<br>2663S-36-ND      |
| JS1 - JS6       | Shunt   | 2 mm                | 6   | Taco Electronics/Amp<br>382575-2    | DIBI-Key<br>A26244-ND        |
| S1, S2          | Switch, momentary, SDd, low profile                   |                     | 2   | Panasonic<br>E.M.-PPBA25            | DIBI-key<br>P8086S           |
| D1              | LED, Green  | 0805                | 1   | Lumen<br>S.L.-LXT0805GW             | DIBI-Key<br>67-1553-1-ND     |
| D2              | LED, Yellow   | 0805                | 1   | Lumen<br>S.L.-LXT0805YW             | DIBI-Key<br>67-1554-1-ND     |
| U1              | TPA2014D1 RGP   |                     | 1   | Texas Instruments<br>TPA2014D1RGP   |                              |
| MH1-MH4         | Standoff, 5/8" length, #4-40, Brass/Zinc plate        |                     | 4   |                                     |                              |
| MH5-MH8         | Screw, 1/2" length, #4-40, Brass/Zinc plate           |                     | 4   |                                     |                              |
| MH9-MH12        | Washer, #4, Brass/Zinc plate                          |                     | 4   |                                     |                              |

---

**Note:** DNP = Do Not Place
 

---



## 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](http://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.

### EVM WARNINGS AND RESTRICTIONS

It is important to operate this EVM within the input voltage range of -0.3 V to 6 V and the output voltage range of -0.3 V to VDD +0.3 .

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 85°C. The EVM is designed to operate properly with certain components above 85°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                  | <a href="http://amplifier.ti.com">amplifier.ti.com</a>             |
| Data Converters             | <a href="http://dataconverter.ti.com">dataconverter.ti.com</a>     |
| DSP                         | <a href="http://dsp.ti.com">dsp.ti.com</a>                         |
| Clocks and Timers           | <a href="http://www.ti.com/clocks">www.ti.com/clocks</a>           |
| Interface                   | <a href="http://interface.ti.com">interface.ti.com</a>             |
| Logic                       | <a href="http://logic.ti.com">logic.ti.com</a>                     |
| Power Mgmt                  | <a href="http://power.ti.com">power.ti.com</a>                     |
| Microcontrollers            | <a href="http://microcontroller.ti.com">microcontroller.ti.com</a> |
| RFID                        | <a href="http://www.ti-rfid.com">www.ti-rfid.com</a>               |
| RF/IF and ZigBee® Solutions | <a href="http://www.ti.com/lprf">www.ti.com/lprf</a>               |

### Applications

|                    |  |
|--------------------|--|
| Audio              | <a href="http://www.ti.com/audio">www.ti.com/audio</a>                   |
| Automotive         | <a href="http://www.ti.com/automotive">www.ti.com/automotive</a>         |
| Broadband          | <a href="http://www.ti.com/broadband">www.ti.com/broadband</a>           |
| Digital Control    | <a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a> |
| Medical            | <a href="http://www.ti.com/medical">www.ti.com/medical</a>               |
| Military           | <a href="http://www.ti.com/military">www.ti.com/military</a>             |
| Optical Networking | <a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a> |
| Security           | <a href="http://www.ti.com/security">www.ti.com/security</a>             |
| Telephony          | <a href="http://www.ti.com/telephony">www.ti.com/telephony</a>           |
| Video & Imaging    | <a href="http://www.ti.com/video">www.ti.com/video</a>                   |
| Wireless           | <a href="http://www.ti.com/wireless">www.ti.com/wireless</a>             |

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