User's Guide
SLOU211–May 2008

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.

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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 Ω to 32 Ω) 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 $\overline{\text{SDb}}$ and $\overline{\text{SDd}}$ 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.
ΔI_L	Ripple current through the inductor.
ΔV	Ripple voltage on V_{CC} due to capacitance.
ΔV_{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.

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

2. The recommended value of R2 is 453 kΩ.

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 µH. A lower value may cause instability.

Ripple current, ΔI_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_{boost}, and ΔI_L. Insert the maximum acceptable ripple current into Equation 3 to solve for L.

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

ΔI_L is inversely proportional to L. Minimize ΔI_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 µH to 6.8 µH.

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 µF. Do not use any component with a working capacitance less than 10 µF.

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}, ΔV, V_{DD}, f_{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).

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

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}, ΔV, V_{DD}, f_{boost} respectively). Insert the maximum allowed ripple voltage into Equation 5 to solve for C. Solve this equation assuming ESR is zero.

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

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 mΩ. 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)[(1)]	Class-D Load (Ω)	Minimum V_{DD} (V)	Required V_{CC} (V)	Max I_L (A)	L (μH)	Inductor Vendor Part Numbers	Max ΔV (mVpp)	C[(2)] (μF)	Capacitor Vendor Part Numbers
1	8	3	4.3	0.7	3.3	Toko DE2812C Coilcraft DO3314 Murata LQH3NPN3R3NG0	30	10	Kemet C1206C106K8PACTU Murata GRM32ER61A106KA01B Taiyo Yuden LMK316BJ106ML-T
1.2	8	3	5.0	0.90	4.7	Murata LQH43PN4R7NR0 Toko DE4514C Coilcraft LPS4018-472	30	22	Murata GRM32ER71A226KE20L 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

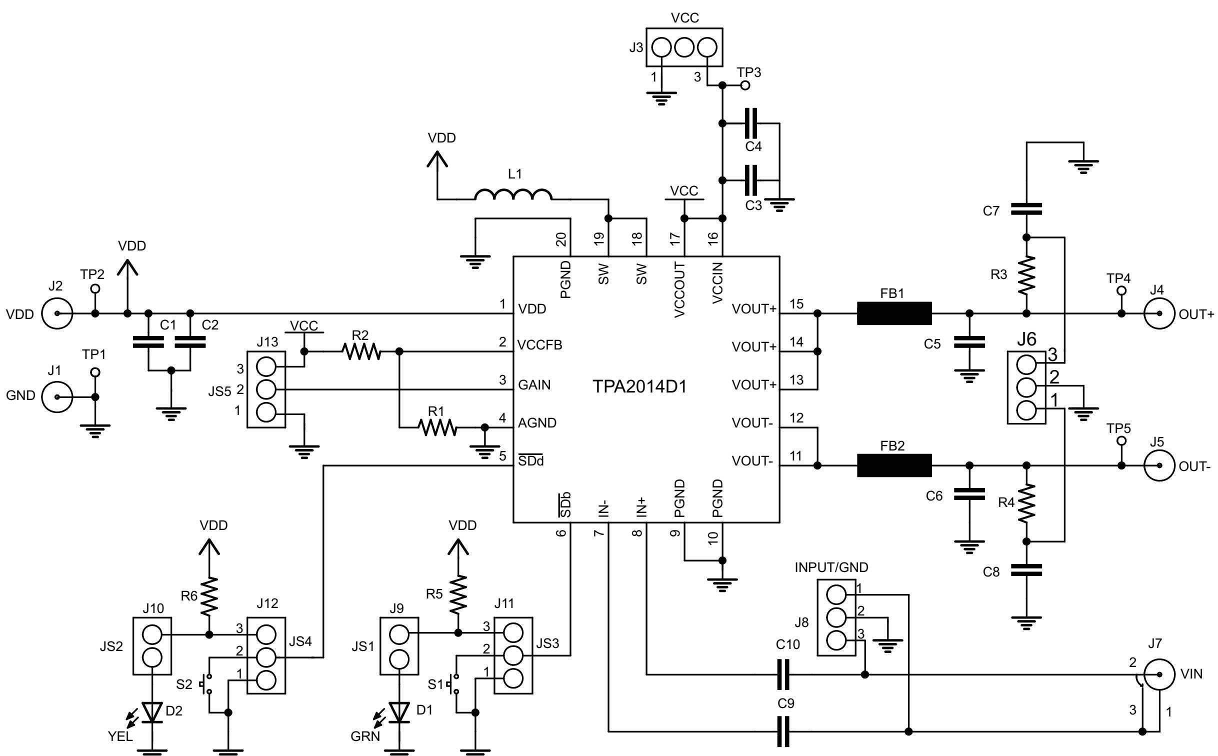

Figure 1. TPA2014D1EVM Schematic

4 TPA2014D1EVM PCB Layers

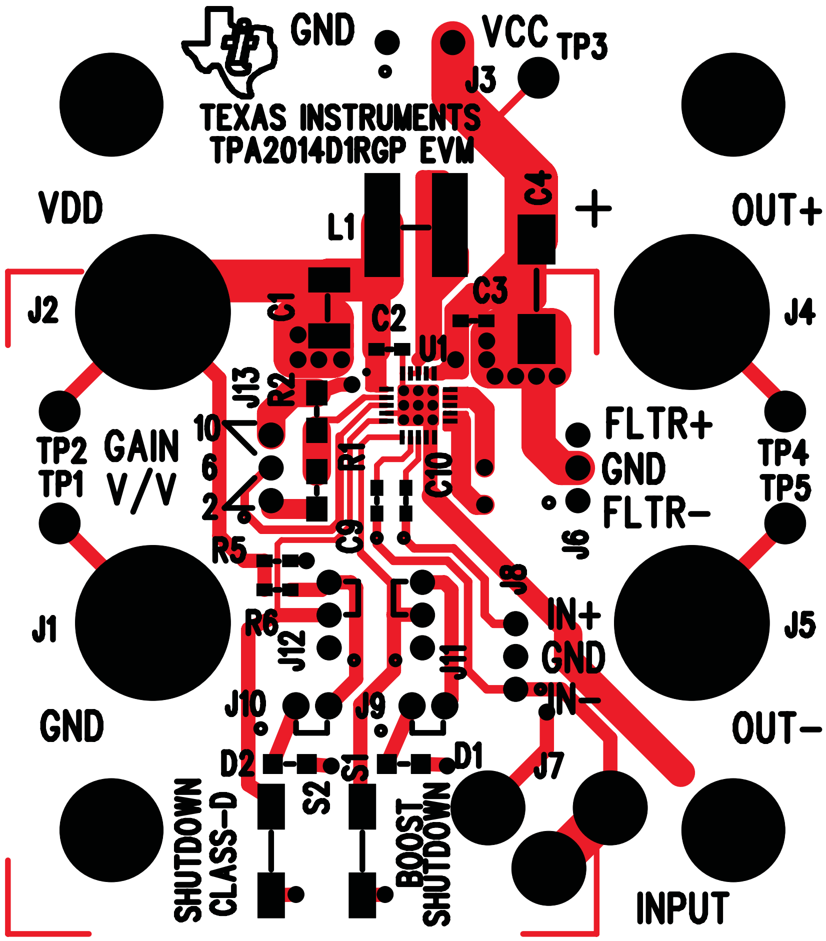

Figure 2. TPA2014D1EVM – Top Layer

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.

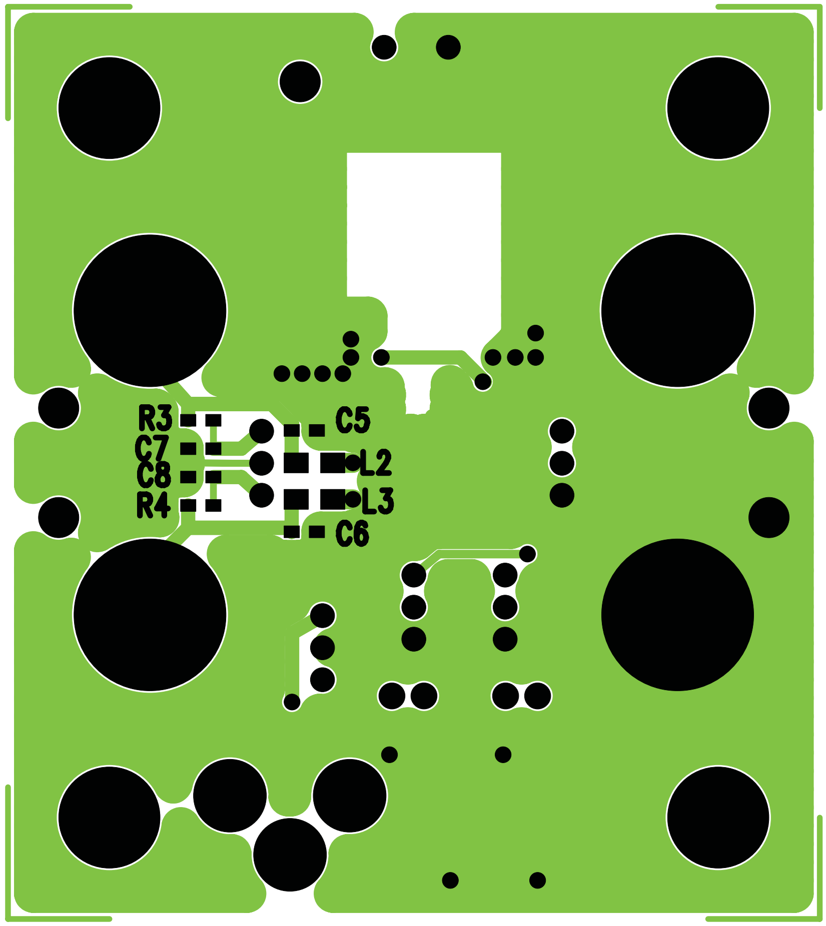

Figure 3. TPA2014D1EVM – Bottom Layer

5 TPA2014D1EVM Parts List

Table 2. TPA2014D1EVM Parts List

Reference	Description	Size	Qty	MFR/ Part No.	Vendor No.
C1	Capacitor, ceramic, 10 µF, ±10%, X7R, 10 V	1206	1	Taiyo Yuden LMK316BJ106KL-TR	Digi-Key 587-1333-2-ND
C2, C3, C9, C10	Capacitor, ceramic, 1.0 µF, ±10%, X7R, 16 V	0603	4	TDK C1608X7R1C105K	Digi-Key 445-1604-2-ND
C4	Capacitor, ceramic, 47 µF, ±10%, X5R, 10 V	1210	1	Murata GRM32ER61A476KE20L	Digi-Key 490-3887-1-ND
C5, C6	Capacitor, ceramic, 1 nF, ±5%, C0G, 50 V	0603	DNP	TDK C1608COG1H102J	Digi-Key 445-1293-2-ND
C7, C8	Capacitor, ceramic, 4.7 nF, ±10%, X7R, 50V	0603	DNP	Panasonic ECJ-1VB1H472K	Digi-Key PCC1780TR-ND
L1	Inductor, 4.7 µH, 1.45 A,	4.5mm x 4.7mm	1	Toko 1123AS-4R7M	
FB1, FB2	Ferrite Bead, 100 Ω, 4 A	0805	2	TDK MPZ2012S101A	Digi-Key 445-1567-1-ND
R1	Resistor, chip, 49.9 kΩ, 100 mW, 1%	0805	1	Panasonic ERJ-S06F4992V	Digi-Key ERJ-S06F4992V-ND
R2	Resistor, chip, 453 kΩ, 100 mW, 1%	0805	1	Panasonic ERJ-6ENF4533V	Digi-Key ERJ-P453KCCT-ND
R3, R4	Resistor, chip, 1 kΩ, 1/10 W, 1%	0603	2	Panasonic ERJ-3EKF1001V	Digi-Key P1.00KHTR-ND
R5, R6	Resistor, chip, 270 Ω, 1/16 W, 5%	0603	2	Panasonic ERJ-3GEYJ271V	Digi-Key P270GTR-ND
J1, J2, J4, J5	Banana Jack w/knurled thumbnut, nickle plated		4	Johnson 111-2223-001	Digi-Key J587-ND
J3	Header, 3 position, 2 mm, male, center post removed	2 mm	1	Norcomp 26633601RP2, 3-positions	DIBI-Key 2663S-36-ND
J6, J8, J11-J13	Header, 3 position, 2 mm, male	2 mm	5	Norcomp 26633601RP2, 3-positions	DIBI-Key 2663S-36-ND
J7	Phono Jack, PC mount, switched		1	Witchcraft PJRAN1X1U03	Newark 16C1860
J9, J10	Header, 2 position, 2 mm, male	2 mm	2	Norcomp 26633601RP2, 2-positions	DIBI-Key 2663S-36-ND
JS1 - JS6	Shunt	2 mm	6	Taco Electronics/Amp 382575-2	DIBI-Key A26244-ND
S1, S2	Switch, momentary, SDd, low profile		2	Panasonic E.M.-PPBA25	DIBI-key P8086S
D1	LED, Green	0805	1	Lumen S.L.-LXT0805GW	DIBI-Key 67-1553-1-ND
D2	LED, Yellow	0805	1	Lumen S.L.-LXT0805YW	DIBI-Key 67-1554-1-ND
U1	TPA2014D1 RGP		1	Texas Instruments 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

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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.

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