TPA3245 Evaluation Module

This user's guide describes the characteristics, operation, and use of the TPA3245 evaluation module (EVM). A complete printed-circuit board (PCB) description, schematic diagram, and bill of materials are also included.

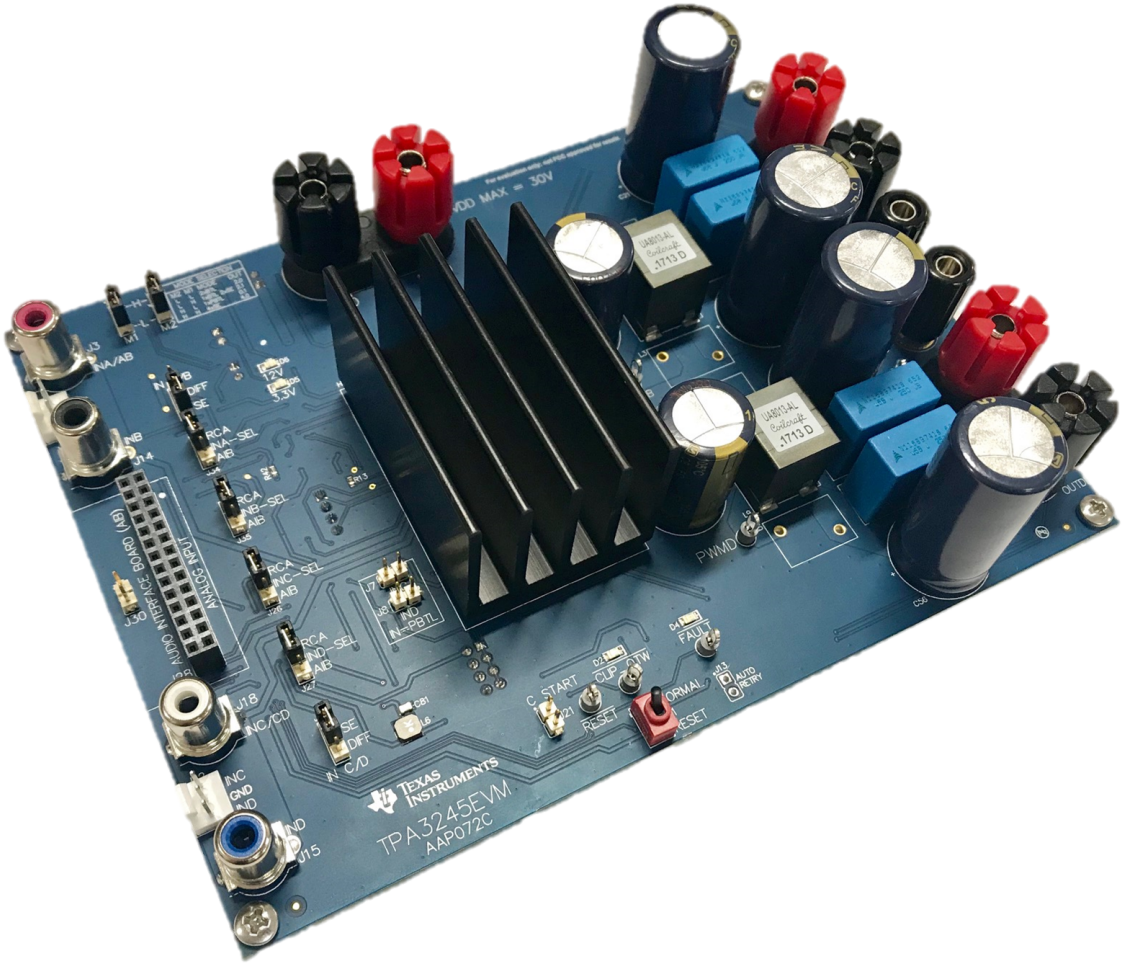

Figure 1. TPA3245 Evaluation Module

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Trademarks

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1 Quick Start (BTL Mode)

This section describes the necessary hardware, connections, configuration, and steps to quick start the EVM into bridge-tied load (BTL) mode with stereo audio playing out of two speakers.

1.1 Required Hardware

The EVM requires the following hardware:

- TPA3245EVM (AMPS030-001) power supply 18-V to 36-V DC, 15 A
- Two 2-Ω to 8-Ω, 100-W speakers or resistor loads
- Four speaker or banana cables
- RCA input cables
- Analog output audio source

1.2 Connections and Board Configuration

Figure 2 and Figure 3 show both sides of the EVM board.

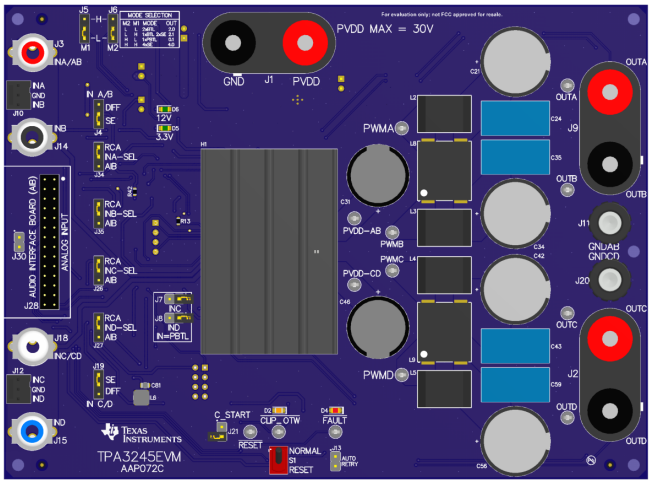


Figure 2. EVM Board (Top Side)

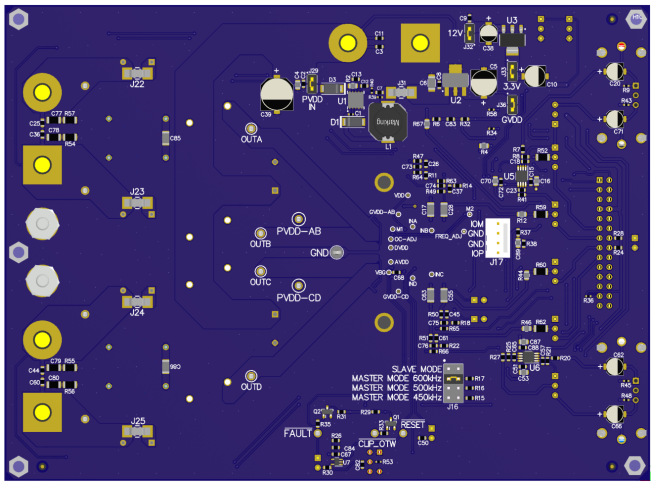


Figure 3. EVM Board (Bottom Side)

The steps for making the connections are as follows:

1. Set S1 to the *RESET* position.
2. Set the power supply to 30 V (18-V to 31.5-V range) and current to 10 A (5-A to 14-A range).
3. Connect the power supply to the TPA3245EVM positive terminal to PVDD *(J1-RED)* and negative terminal to GND *(J1-BLACK)*.
4. Connect the positive side of the *left* channel load to the TPA3245EVM *OUTA (J9-RED)* terminal.
5. Connect the negative side of the *left* channel load to the TPA3245EVM *OUTB (J9-BLACK)* terminal.
6. Connect the positive side of the *right* channel load to the TPA3245EVM *OUTC (J2-RED)* terminal.
7. Connect the negative side of the *right* channel load to the TPA3245EVM *OUTD (J2-BLACK)* terminal.
8. Be careful not to mix up PVDD, *OUTA,* and *OUTC* because the colors are the same *(RED)*.
9. Input configuration:
    a. Single-ended (SE) inputs: Set J4 and J19 to SE and set J26, J27, J34, and J35 to RCA.
        a. Connect the RCA male jack to the female RCA jack input A/AB *(J3-RED)*.
        b. Connect the RCA male jack to the female RCA jack input C/CD *(J18-WHITE)*.
    b. Differential inputs: Set J4 and J19 to DIFF and set J26, J27, J34, and J35 to RCA.
        a. Connect the positive RCA male jack to the female RCA jack input A/AB *(J3-RED)* and connect the negative RCA male jack to the female RCA jack input B *(J14-BLACK)*.

b. Connect the positive RCA male jack to the female RCA jack input C/CD *(J18-RED)* and connect the negative RCA male jack to the female RCA jack input D *(J15-BLACK)*.

c. Analog-Input Board (AIB) input: Set J26, J27, J34, and J35 to AIB.

10. Power up the power supply after correctly making all the connections. The 3.3-V and 12-V LEDs *(GREEN)* then illuminate.
11. Set S1 to the *NORMAL* position.
12. The CLIP_OTW *(ORANGE)* and FAULT *(RED)* LEDs must be off if the audio source is off.

Table 1 lists the jumper configurations in BTL mode.

Table 1. Jumper Configurations (BTL Mode)

Jumper	Setting	Comment
J29	IN	PVDD to 15-V Buck
J31	IN	12-V LDO to 12-V terminal
J32	IN	3.3-V LDO to 3.3-V terminal
J33	IN	3.3-V LDO to 3.3-V terminal
J21	OUT	CSTART SE
J16	3 to 4	Master mode
J5	2 to 3	M1 – BTL
J6	2 to 3	M2 – BTL
J22	IN	OUTA capacitor shunt
J23	IN	OUTB capacitor shunt
J24	IN	OUTC capacitor shunt
J25	IN	OUTD capacitor shunt
J26	2 to 3	INC select
J27	2 to 3	IND select
J7	OUT	PBTL select INC
J8	OUT	PBTL select IND
J10	OUT	INC/D DIFF input
J12	OUT	INC/D DIFF input
J4	1 to 2	INA/B SE input
J19	1 to 2	INC/D SE input

2 Setup By Mode

The TPA3245EVM is configurable for four different output operations. The 2.0 BTL configuration is the default set up of the TPA3245EVM as described in Section 1.2. The remaining three configurations are 2.1 BTL plus two SE outputs, 0.1 PBTL output, and 4.0 SE outputs.

Table 2. Mode Selection Pins

Mode Pins		Input Mode	Output Configuration	Description
M2	M1			
0	0	2N + 1	2 × BTL	Stereo BTL output configuration
0	1	2N/1N + 1	1 × BTL + 2 × SE	2.1 BTL + SE mode
1	0	2N + 1	1 × PBTL	Paralleled BTL configuration. Connect INPUT_C and INPUT_D to GND.
1	1	1N + 1	4 × SE	Single-ended output configuration

2.1 BTL Mode (Two-Speaker Output)

This mode is the same as described in Section 1.

2.1.1 Performance Data (BTL Mode)

All measurements are taken at an audio frequency = 1 kHz, PVDD_X = 36 V, R_L = 4 Ω, fS = 600 kHz, ROC = 22 kΩ, output filter: L = 7 µH, C = 0.68 µF, with AES17 + AUX-0025 measurement filters.

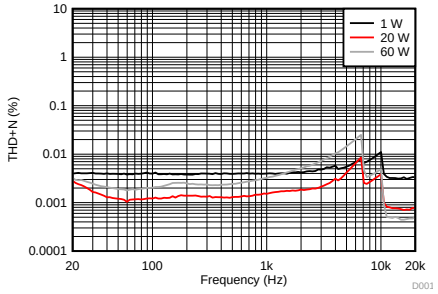


Figure 4. AIB Input: THD+N vs Frequency

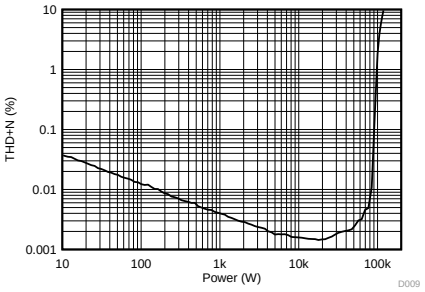


Figure 5. AIB Input: THD+N vs Power

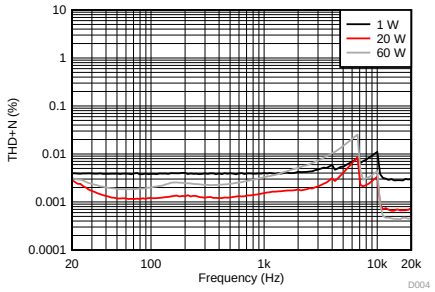


Figure 6. Molex™ Input: THD+N vs Frequency

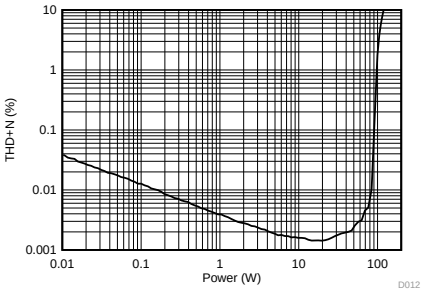


Figure 7. Molex Input: THD+N vs Power

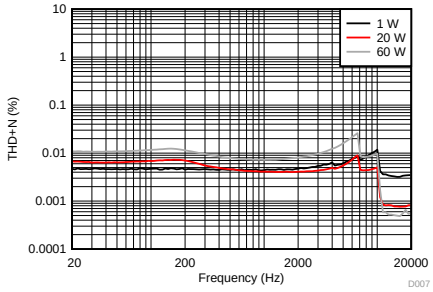


Figure 8. RCA Input: THD+N vs Frequency

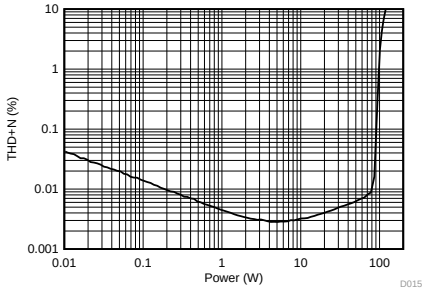


Figure 9. RCA Input: THD+N vs Power

2.2 BTL MODE (Three-Speaker Output)

OUTC and OUTD are the SE output channels and OUTA and OUTB are the BTL channels for 2.1 operations. OUTC and OUTD can only be in DIFF input mode.

1. Set J6 to L and J5 to H.
2. Remove jumpers J24 and J25.
3. Connect the positive side of the *left* channel load to *OUTC (*J2- *RED)* terminal and the negative side of the *left* channel load to the *GND* (J20) terminal.
4. Connect the positive side of the *right* channel load to *OUTD (*J2-*BLACK)* terminal and the negative side of the *right* channel load to the *GND* (J20) terminal.
5. Connect the positive terminal to *OUTA (*J9-*RED)* and the negative terminal to *OUTB (*J9-*BLACK)*.
6. Set the J19 jumper position to DIFF.
7. Input configuration:
   a. SE inputs: Connect the RCA male jack to the female RCA jack input A/AB *(*J3-*RED)* and set the *J4* jumper positions to SE. Set J26, J27, J34, and J35 to RCA.
   b. Differential inputs: Connect the positive RCA male jack to the female RCA jack input A/AB *(* J3-*RED)* and connect the negative RCA male jack to the female RCA jack input B *(*J14-*BLACK)* and set the J4 jumper positions to DIFF. Set J26, J27, J34, and J35 to RCA.
   c. AIB inputs: Set J26, J27, J34, and J35 to AIB.

Table 3. Jumper Configurations (2.1 BTL Mode)

Jumper	Setting	Comment
J29	IN	PVDD to 15-V Buck
J32	IN	12-V LDO to 12-V terminal
J33	IN	3.3-V LDO to 3.3-V terminal
J36	IN	12-V LDO to GVDD
J16	3 to 4	Master mode 600 kHz
J22	IN	OUTA capacitor shunt
J23	IN	OUTB capacitor shunt
J24	OUT	OUTC capacitor shunt
J25	OUT	OUTD capacitor shunt
J5	1 to 2	M1 – H
J6	2 to 3	M2 – L
J7	OUT	PBTL SELECT INC

2.3 PBTL Mode (One-Speaker Output)

This mode uses all four half bridges for a mono output, allowing for the maximum power output from the device across one load.

2.3.1 Connections and Board Configuration

1. Set J6 to H and J5 to L.
2. Connect the positive side of the load to *OUTA (*J9-*RED)* and *OUTC (*J2-*RED)* terminals (OUTA and OUTC shorted).
3. Connect the negative side of the load to *OUTB (*J9-*BLACK)* and *OUTD (*J2-*BLACK)* terminals (OUTB and OUTD shorted).
4. Install PBTL jumpers J7 and J8 (pulls input C and input D to GND).
5. Input configuration:
   a. SE inputs: Connect the RCA male jack to the female RCA jack input A/AB *(*J3-*RED)* and set the J4 jumper positions to SE. Set J26, J27, J34, and J35 to RCA.
   b. Differential inputs: Connect the positive RCA male jack to the female RCA jack input A/AB *(*J3-*RED)* and connect the negative RCA male jack to the female RCA jack input B *(*J14-*BLACK)*. Set the *J4* jumper position to DIFF, and set J26, J27, J34, and J35 to RCA.
   c. AIB input: Set J26, J27, J34, and J35 to AIB.

Table 4. Jumper Configuration (PBTL Mode)

Jumper	Setting	Comment
J29	IN	PVDD to 15-V Buck
J31	IN	12-V LDO to 12-V terminal
J32	IN	3.3-V LDO to 3.3-V terminal
J33	IN	3.3-V LDO to 3.3-V terminal
J21	OUT	CSTART SE
J16	3 to 4	Master mode
J5	2 to 3	M1 – PBTL
J6	1 to 2	M2 – PBTL
J22	IN	OUTA capacitor shunt
J23	IN	OUTB capacitor shunt
J24	IN	OUTC capacitor shunt
J25	IN	OUTD capacitor shunt
J26	2 to 3	INC select
J27	2 to 3	IND select
J7	2 to 3	PBTL select INC – GND
J8	2 to 3	PBTL select IND – GND
J10	OUT	INC/D DIFF input
J12	OUT	INC/D DIFF input
J4	1 to 2	INA/B SE input
J19	1 to 2	INC/D SE input

2.3.2 Performance Data (PBTL Mode)

All measurements are taken at an audio frequency = 1 kHz, PVDD_X = 36 V, R_L = 4 Ω, f_S = 600 kHz, ROC = 22 kΩ, output filter: L = 7 µH, C = 0.68 µF, with AES17 + AUX-0025 measurement filters.

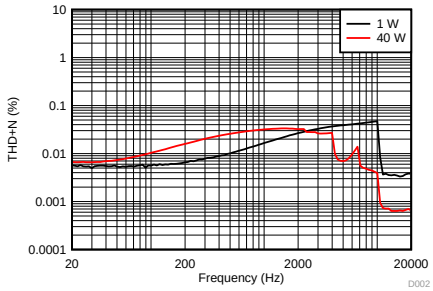


Figure 10. AIB Input: THD+N vs Frequency

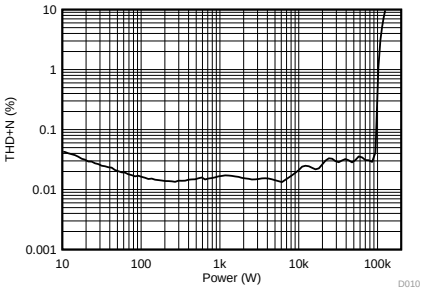


Figure 11. AIB Input: THD+N vs Power

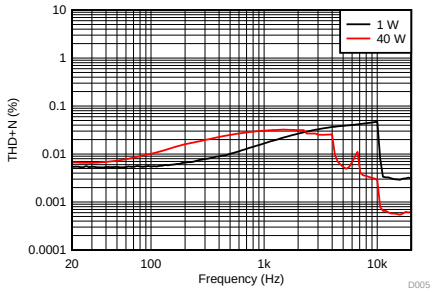


Figure 12. Molex Input: THD+N vs Frequency

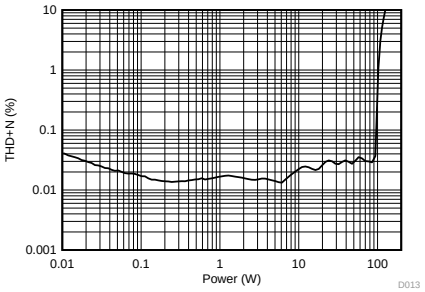


Figure 13. Molex Input: THD+N vs Power

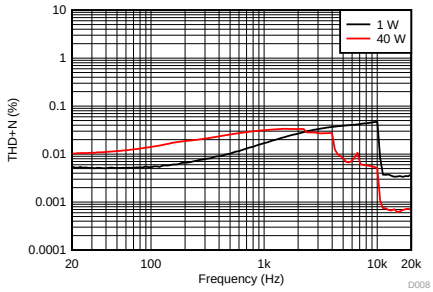


Figure 14. RCA Input: THD+N vs Frequency

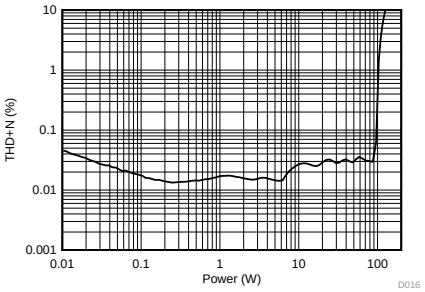


Figure 15. RCA Input: THD+N vs Power

2.4 SE Mode (Four-Speaker Output)

1. Set J6 to H and J5 to H.
2. Remove jumpers J22, J23, J24, and J25.
3. Connect the positive side of the load to the *OUTA (*J9-*RED)* terminal and the negative side of the load to the *GND* (J11) terminal.
4. Connect the positive side of the load to the *OUTB (*J9-*BLACK)* terminal and the negative side of the load to the *GND* (J11) terminal.
5. Connect the positive side of the load to the *OUTC (*J2-*RED)* terminal and the negative side of the load to the *GND* (J20) terminal.
6. Connect the positive side of the load to the *OUTD (*J2-*BLACK)* terminal and the negative side of the load to the *GND* (J20) terminal.
7. Set both J4 and J19 jumpers position to DIFF.

8. Input configuration:
   a. Differential inputs: Set J26, J27, J34, and J35 to RCA.
      i. Connect the male RCA jack to the female RCA jack input A/AB *(J3-RED)* for the *OUTA* speaker.
      ii. Connect the male RCA jack to the female RCA jack input B *(J14-BLACK)* for the *OUTB* speaker.
      iii. Connect the male RCA jack to the female RCA jack input C/CD *(J18-WHITE)* for the *OUTC* speaker.
      iv. Connect the male RCA jack to the female RCA jack input D *(J15-BLUE)* for the *OUTD* speaker.
   b. AIB input: Set J26, J27, J34, and J35 to AIB.

Table 5. Jumper Configuration (SE Mode)

Jumper	Setting	Comment
J29	IN	PVDD to 15-V Buck
J32	IN	12-V LDO to 12-V terminal
J33	IN	3.3-V LDO to 3.3-V terminal
J36	IN	12-V LDO to GVDD
J16	3 to 4	Master mode 600 kHz
J22	OUT	OUTA capacitor shunt
J23	OUT	OUTB capacitor shunt
J24	OUT	OUTC capacitor shunt
J25	OUT	OUTD capacitor shunt
J5	1 to 2	M1 – H
J6	1 to 2	M2 – H
J7	OUT	PBTL SELECT INC
J8	OUT	PBTL SELECT IND
J4	2 to 3	INA/B DIFF INPUT
J19	2 to 3	INC/D DIFF INPUT
J26	1 to 2	INC-SEL RCA
J27	1 to 2	IND-SEL RCA
J34	1 to 2	INA-SEL RCA
J35	1 to 2	INB-SEL RCA
J21	IN	C_START

NOTE: The performance of the TPA3245EVM and TPA3245D2DDV is dependent on the power supply. Design the power supply with margins that can deliver the required power. Some low-frequency applications can require additional bulk capacitance. Replacing the bulk capacitors on the TPA3245EVM with 3300 µF or more capacitance can be necessary, depending on the power supply used.

2.4.1 Performance Data (SE Mode)

All measurements are taken at audio frequency = 1 kHz, PVDD_X = 36 V, R_L = 4 Ω, f_S = 600 kHz, ROC = 22 kΩ, output filter: L = 7 µH, C = 0.68 µF, with AES17 + AUX-0025 measurement filters.

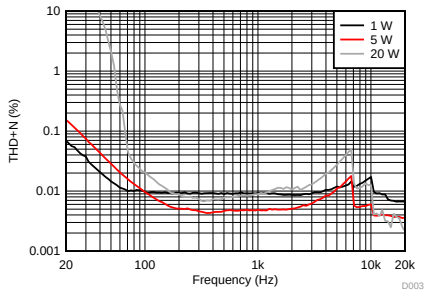


Figure 16. AIB Input: THD+N vs Frequency

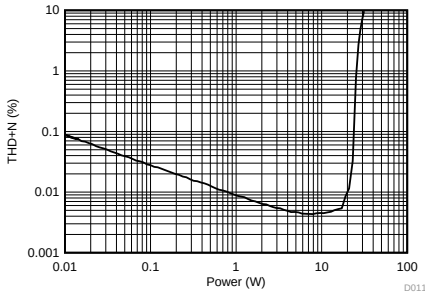


Figure 17. AIB Input: THD+N vs Power

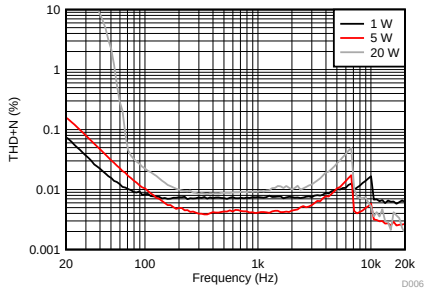


Figure 18. Molex Input: THD+N vs Frequency

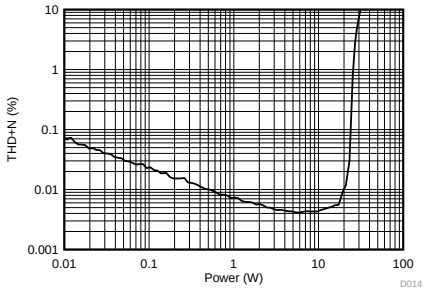


Figure 19. Molex Input: THD+N vs Power

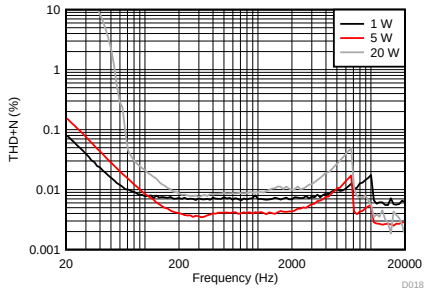


Figure 20. RCA Input: THD+N vs Frequency

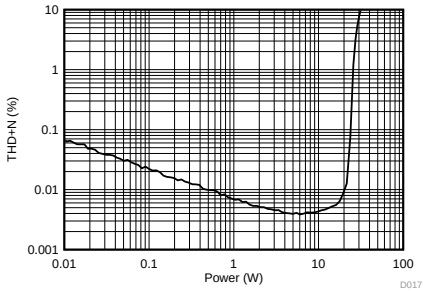


Figure 21. RCA Input THD+N vs Power

3 Hardware Configuration

3.1 Indicator Overview (OTW_CLIP and FAULT)

The TPA3245EVM is equipped with LED indicators that illuminate when the FAULT or CLIP_OTW pin (or both) goes low. See Table 6 and *TPA3245 115-W Stereo, 230-W Mono PurePath™ Ultra-HD Analog-Input Class-D Amplifier* for more details on which events trigger the pins to go low.

Table 6. Fault and Clip Overtemperature Status

$\overline{\text{FAULT}}$	$\overline{\text{CLIP\_OTW}}$	Description
0	0	Overtemperature (OTE) or overload (OLP) or undervoltage (UVP). Junction temperature higher than 125°C (overtemperature warning).
0	0	Overload (OLP) or undervoltage (UVP). Junction temperature higher than 125°C (overtemperature warning).
0	1	Overload (OLP) or undervoltage (UVP). Junction temperature lower than 125°C.
1	0	Junction temperature higher than 125°C (overtemperature warning)
1	1	Junction temperature lower than 125°C and no OLP or UVP faults (normal operation)

3.2 PWM Frequency Adjust

The TPA3245EVM offers a hardware-trimmed oscillator frequency through the external control of the FREQ_ADJ pin. Use the frequency adjust to reduce interference problems while using a radio receiver tuned within the AM band and change the switching frequency from nominal values to lower values (see Table 7). Choose these values such that the nominal- and the lower-value switching frequencies together result in the fewest cases of interference throughout the AM band. Select the oscillator frequency based on the value of the FREQ_ADJ resistor connected to GND in master mode.

Table 7. Frequency Adjust Master Mode Selection

Master Mode	Resistor to GND	PWM Frequency
Nominal	10 kΩ	600 kHz
AM1	20 kΩ	500 kHz
AM2	30 kΩ	450 kHz

For slave-mode operation, turn off the oscillator by pulling the FREQ_ADJ pin to 3.3 V. This action configures the OSC_I/O pins as inputs, which are to be slaved from an external differential clock. In a master and slave system, interchannel delay is automatically set up between the switching phases of the audio channels, which can be illustrated by no idle channels switching at the same time. This setup does not influence the audio output; rather, only the switch timing to minimize noise coupling between audio channels through the power supply. In turn, this process optimizes audio performance and results in better operating conditions for the power supply. The interchannel delay is setup for a slave device depending on the polarity of the OSC_I/O connection, such that slave mode 1 is selected by connecting OSC_I/O of the master device in phase with OSC_I/O of the slave device (+ to + and – to –), while slave mode 2 is selected by connecting the OSC_I/Os out of phase (+ to – and – to +).

3.3 TPA3245EVM Overcurrent Adjust

The TPA3245EVM offers the ability to change the current limit by changing R13 as well as having two different protection modes; *Cycle-by-Cycle Current Control* (CB3C) and *Latching Shutdown* (Latched OC). For CB3C operations, the resistance must be a value of 22 kΩ to 30 kΩ. For Latched OC operations, the resistance must be a value of 47 kΩ to 64 kΩ. By default, the resistor R13 is 22 kΩ. Table 8 shows a few resistance values and their corresponding OC threshold and OC protection mode.

Table 8. Overcurrent Protection Selection

OC_ADJ Resistor Value	Protection Mode	OC Threshold
22 kΩ	CB3C	16.3 A
24 kΩ	CB3C	15.1 A
27 kΩ	CB3C	13.5 A
30 kΩ	CB3C	12.3 A
47 kΩ	Latched OC	16.3 A
51 kΩ	Latched OC	15.1 A
56 kΩ	Latched OC	13.5 A
64 kΩ	Latched OC	12.3 A

3.4 TPA3245EVM Single-Ended and Differential Inputs

The TPA3245EVM supports both differential and SE inputs. For SE inputs, set either the J4 or J19 jumper (or both) to the SE position so that the TPA3245EVM uses the OPA1678 operational amplifier (op amp) to convert the SE input signal to differential to properly drive the differential inputs of the TPA3245 device. Use input RCA jack J3 to provide INA and INB inputs. Use RCA jack J18 to provide INC and IND inputs with SE inputs. For differential input operation, set either the J4 or J19 jumpers (or both) to the DIFF position. The TPA3245EVM uses the OPA1678 to buffer the differential input signal to the differential inputs of the TPA3245 device. Use input RCA jack J3 to provide INA, RCA jack J14 to provide INB, RCA jack J18 to provide INC, and RCA jack J15 to provide IND with differential inputs.

NOTE: The SE input settings on the TPA3245EVM must only be used for channels with output configuration BTL or PBTL, *not* SE. For SE output configuration, either jumper J4 or J19 (or both), must be set for that channel to the DIFF position so that the input signal INx is mapped directly to OUTx.

3.5 Input Connectors

The TPA3245EVM supports three different input connectors. J3, J14, J15, and J18 are RCA connectors. J10 and J12 are Molex connectors, and J28 is the AIB connector with J30 being the AIB alignment connection. Table 9 shows the AIB pinout in detail.

Table 9. AIB Connector (J28) Pinout

Pin No.	Function	Description	Audio EVM Input or Output
1	Amp Out A	Speaker-level output from audio class-D EVM (SE or one side of BTL)	O
2	Amp Out B	Speaker-level output from audio class-D EVM (SE or one side of BTL)	O
3	PVDD	PVDD voltage supply from audio class-D EVM (variable voltage depending on class-D EVM use)	O
4	GND	Ground reference between audio plug-in module and audio class-D EVM	-
5	NC	-	-
6	NC	-	-
7	3.3 V	3.3-V supply from EVM; used for powering audio plug-in module	O
8	3.3 V	3.3-V supply from EVM; used for powering audio plug-in module	O
9	12 V	12-V supply from EVM; used for powering audio plug-in module	O
10	EN and Reset	Assert enable and reset control for audio class-D EVM (active low)	I
11	Analog IN_A	Analog audio input A (analog in EVM), Master I^2S bus (digital in EVM)	I
12	NC	-	-
13	Analog IN_B	Analog audio input B (analog in EVM), bit clock I^2S bus (digital in EVM)	I
14	CLIP_OTW	Clipping detection, overtemperature warning, or both from audio class-D EVM (active low)	O
15	Analog IN_C	Analog audio input C (analog in EVM), frame clock I^2S bus (digital in EVM)	I
16	FAULT	Fault detection from audio class-D EVM (active low)	O
17	Analog IN_D	Analog audio Input D (analog in EVM), data in I^2S bus (digital in EVM)	I
18	NC	-	-
19	NC	-	-
20	NC	-	-
21	GND	Ground reference between audio plug-in module and audio class-D EVM	-
22	GND	Ground reference between audio plug-in module and audio class-D EVM	-
23	NC	-	-
24	NC	-	-
25	NC	-	-
26	NC	-	-
27	Amp Out C	Speaker-level output from audio class-D EVM (SE or one side of BTL)	O
28	Amp Out D	Speaker-level output from audio class-D EVM (SE or one side of BTL)	O

3.6 EVM Power Tree

The EVM power section is self-contained with all the necessary onboard voltages generated from the main PVDD (J1) power input. The PVDD is reduced to 15 V and then used to generate the remaining required board voltages of 12 V, 5 V, and 3.3 V. Low-dropout linear regulators (LDOs) generate supplies going to the TPA3245 device itself to reduce the chance of extra added noise. LEDs are provided on the 5-V and 3.3-V supplies for easy verification that the EVM is powered (see Figure 22).

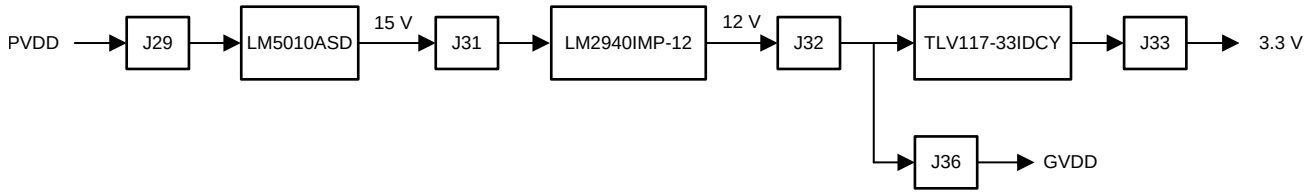


Figure 22. EVM Power Tree

3.7 LC Filter Overview

Included near the output of the TPA3245 device are four output LC filters. These output filters filter the pulse-width modulation (PWM) output, leaving only the audio content at high power, which is fed to the speakers. The board uses a CoilCraft™ 7-µH inductor and a 0.68-µF film capacitor to form this LC filter. Using the equations listed in *LC Filter Design Application Report*, the low-pass filter cutoff is calculated as follows in Equation 1:

$$F_{cut-off} = \frac{1}{2\pi\sqrt{L \times C}} = \frac{1}{2\pi\sqrt{7\ \mu H \times .68\ \mu F}} = 72.9\ kHz \quad (1)$$

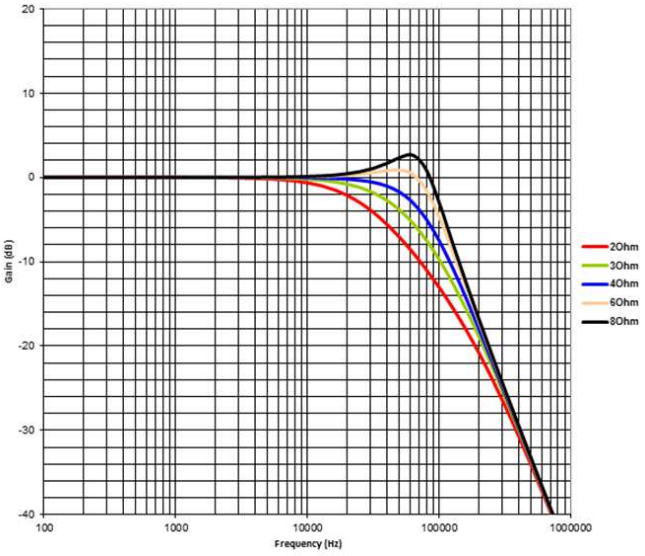


Figure 23. BTL LC Frequency Response

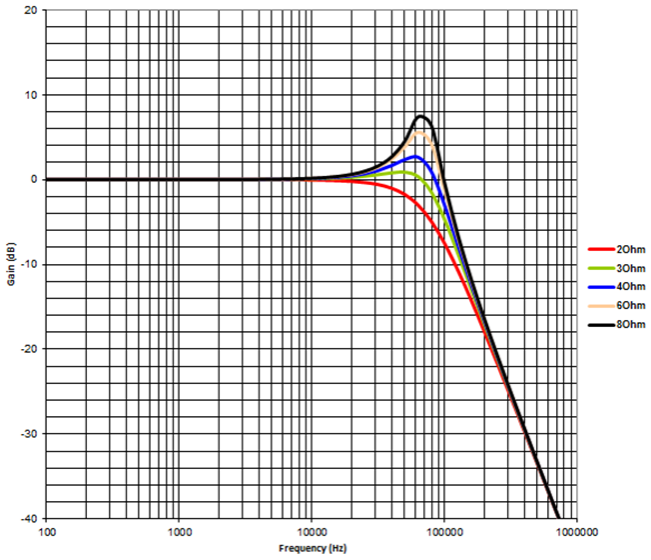


Figure 24. SE LC Frequency Response

3.8 Post-Filter Feedback (PFFB)

The TPA3245EVM has the footprints available to implement post-filter feedback to improve the audio performance of the TPA3245 amplifier. For more details on benefits and implementation, see *TPA324x and TPA325x Post-Filter Feedback*.

3.9 Reset Circuit

The TPA3245EVM includes RESET supervision so that the TPA3245 device remains in reset until all the power rails are up and stable. The RESET supervisor also ensures that the device is put into reset if one of the power rails experiences a brownout. This circuit combined with the RESET switch (S1) help ensure that the TPA3245 can be placed in reset easily as needed or automatically if there is a power supply issue.

3.10 Op Amp vs Direct Drive

The op amps are used to change a single-ended input into a differential input. By default, the gain of the op amps are set for unity gain; however, this can be modified to increase or decrease the gain through the op amps. One way to bypass the op amps for a more direct connection is using the AIB.

4 EVM Design Documents

This section contains the TPA3245EVM board layout, schematics, and bill of materials (BOM).

4.1 TPA3245EVM Board Layouts

Figure 25 and Figure 26 illustrate the EVM board layouts.

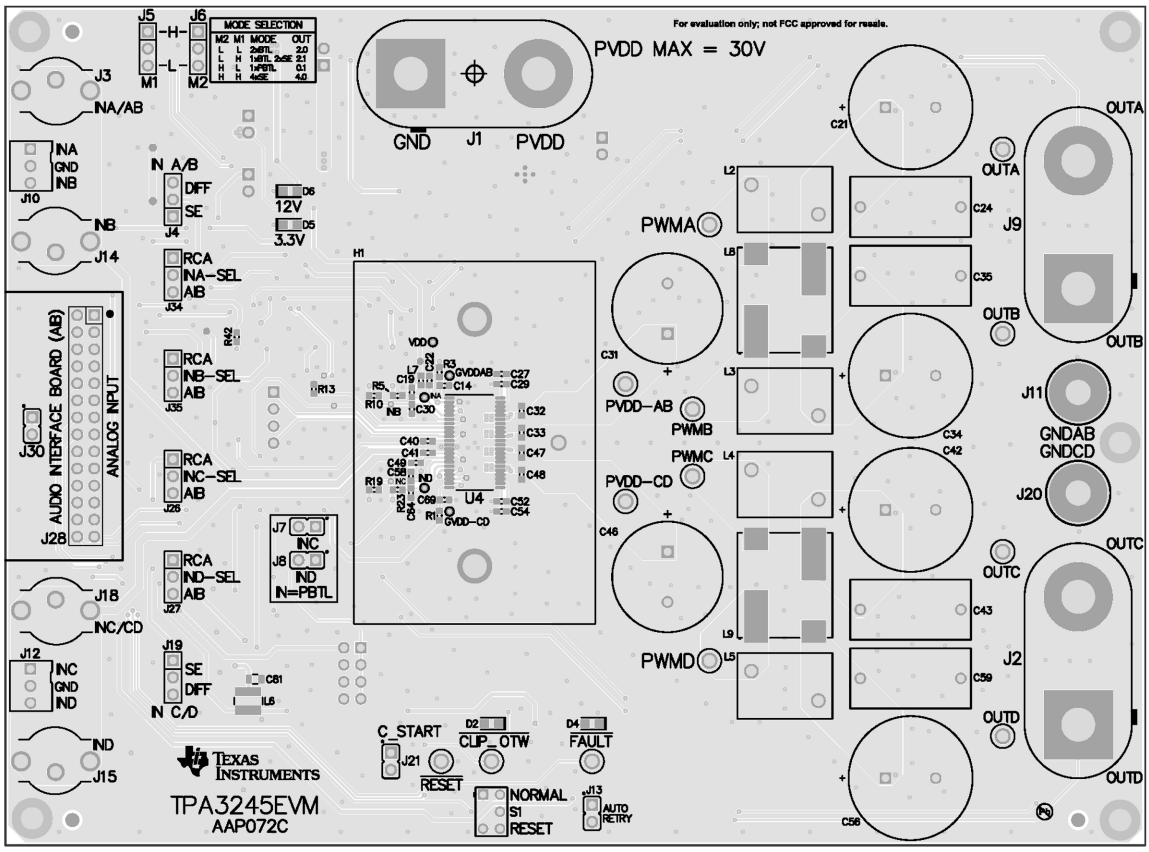


Figure 25. TPA3245 EVM Top Composite Assembly

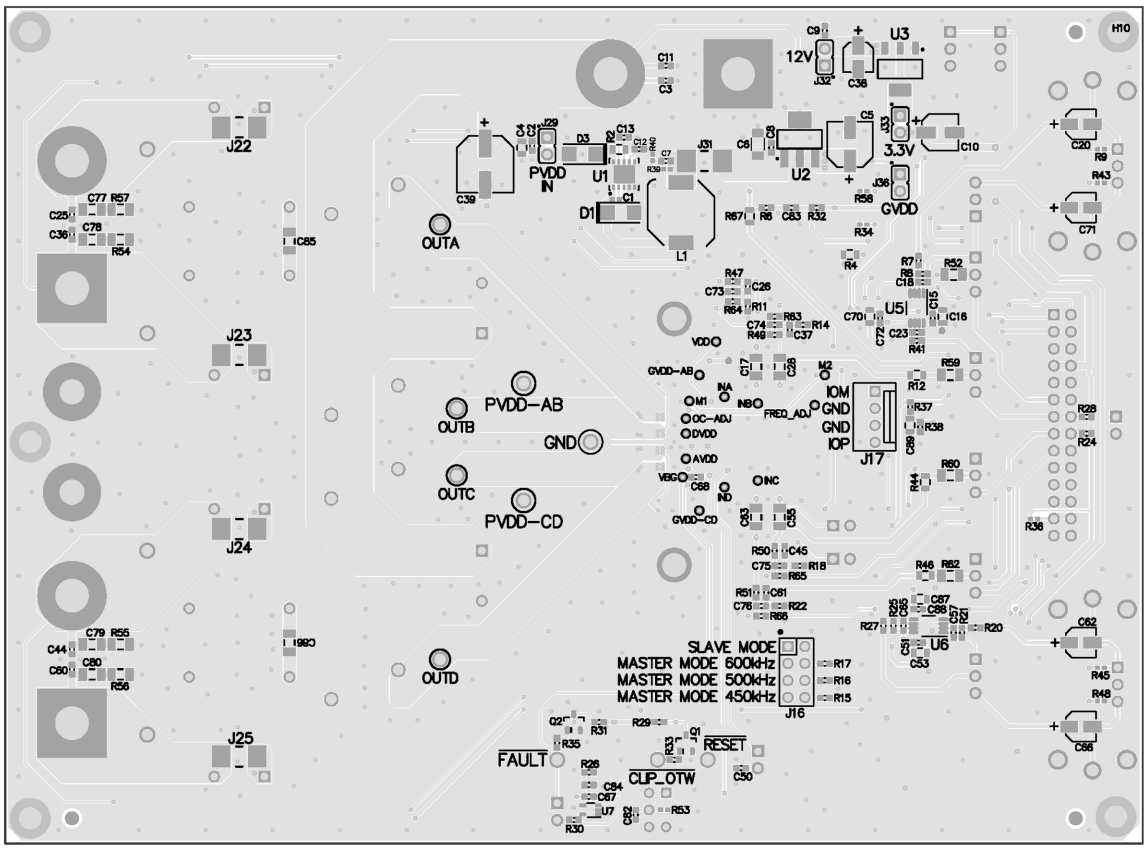


Figure 26. TPA3245 EVM Bottom Composite Assembly

4.2 TPA3245EVM Board Layouts

Figure 27 shows the EVM board dimensions.

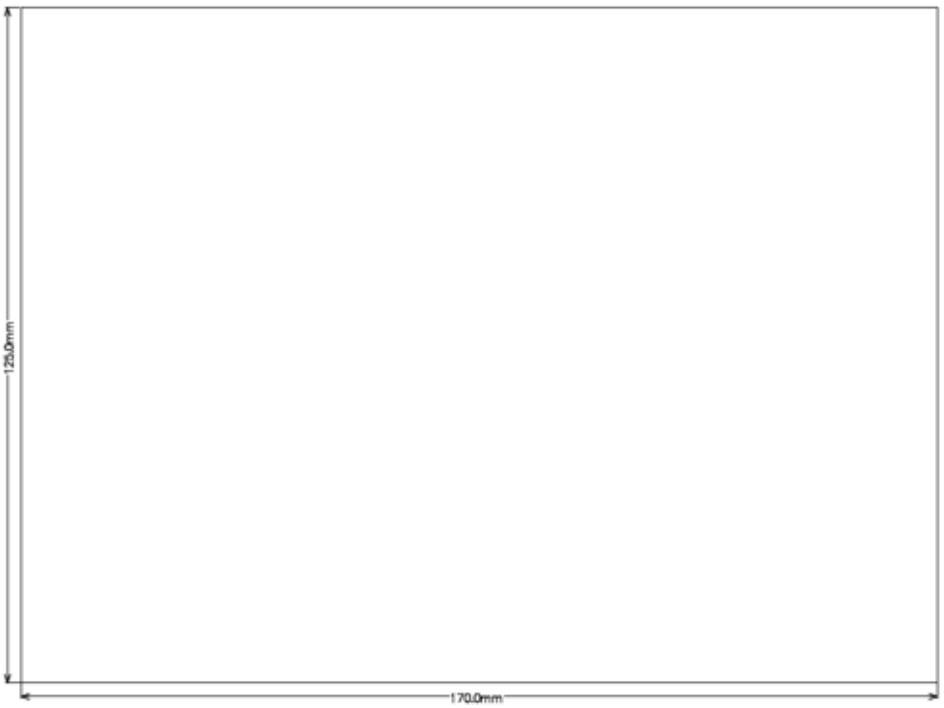


Figure 27. TPA3245EVM Board Dimensions

4.3 TPA3245 EVM Board Debug Plots

Figure 28 and Figure 29 illustrate the TPA3245EVM Debug plots

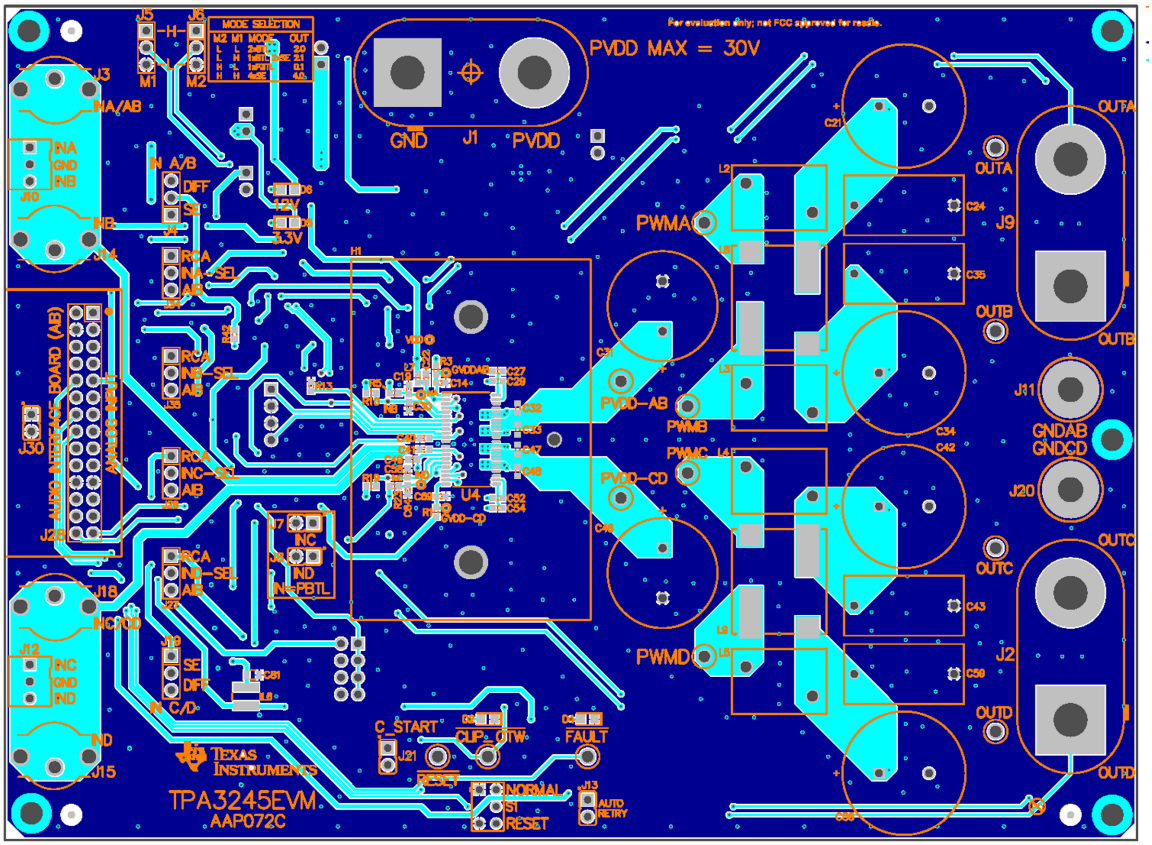


Figure 28. TPA3245 EVM Top Layer

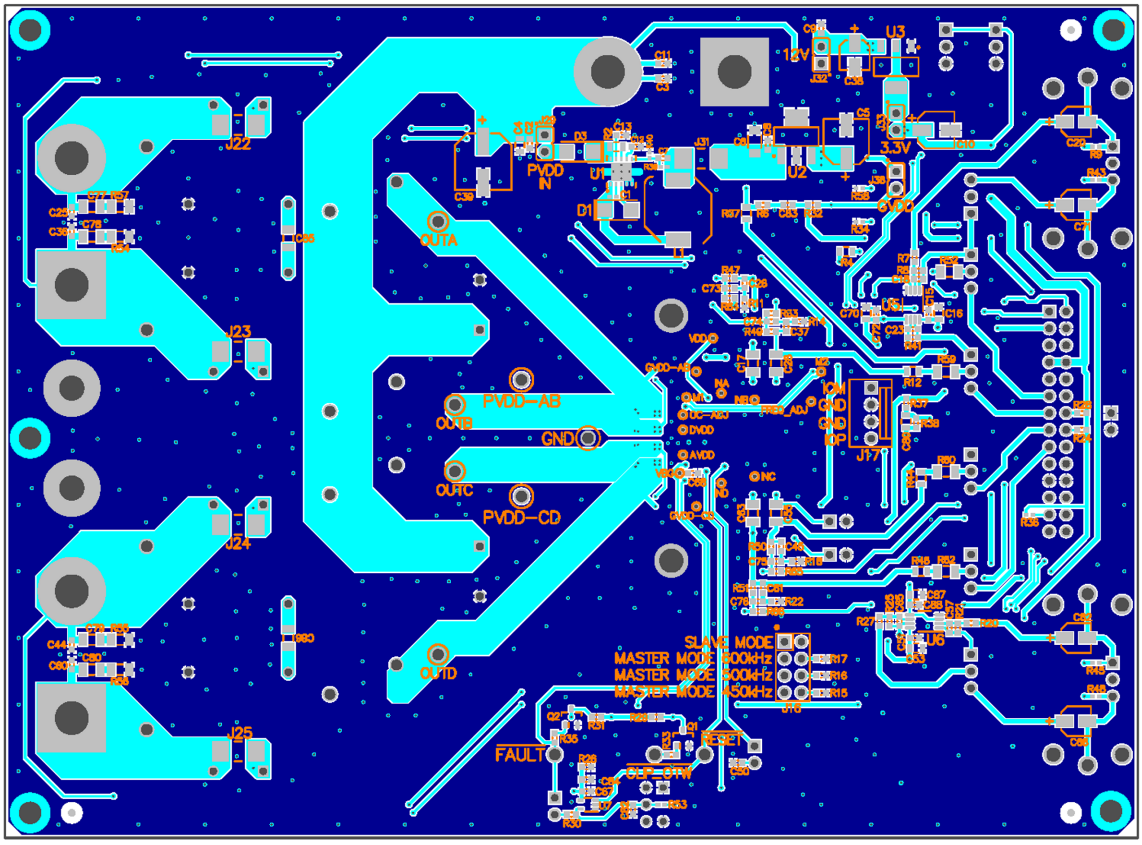


Figure 29. TPA3245 EVM Bottom Layer

4.4 TPA3245 EVM Schematics

Figure 30 through Figure 32 illustrate the TPA3245EVM schematics.

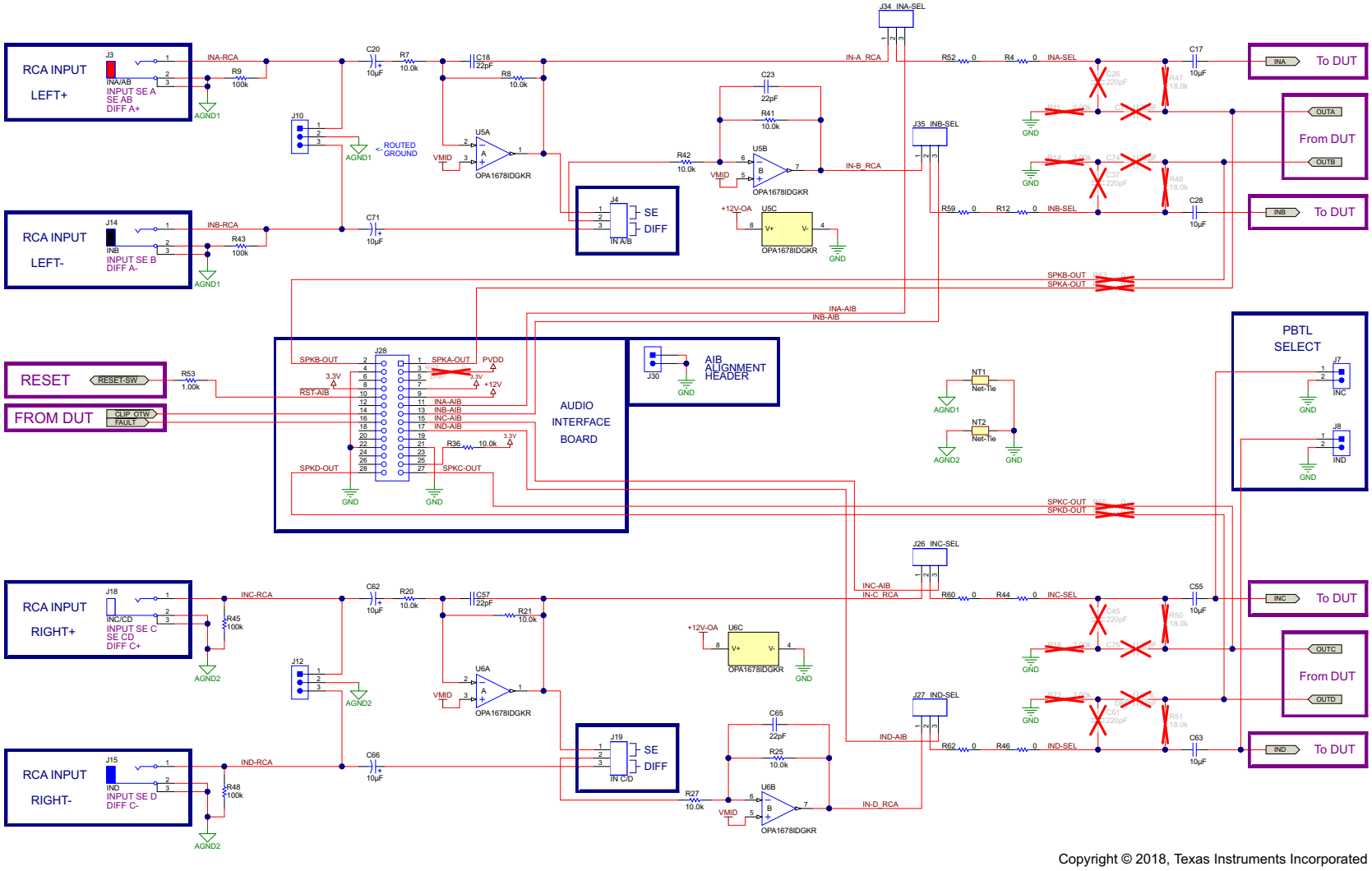
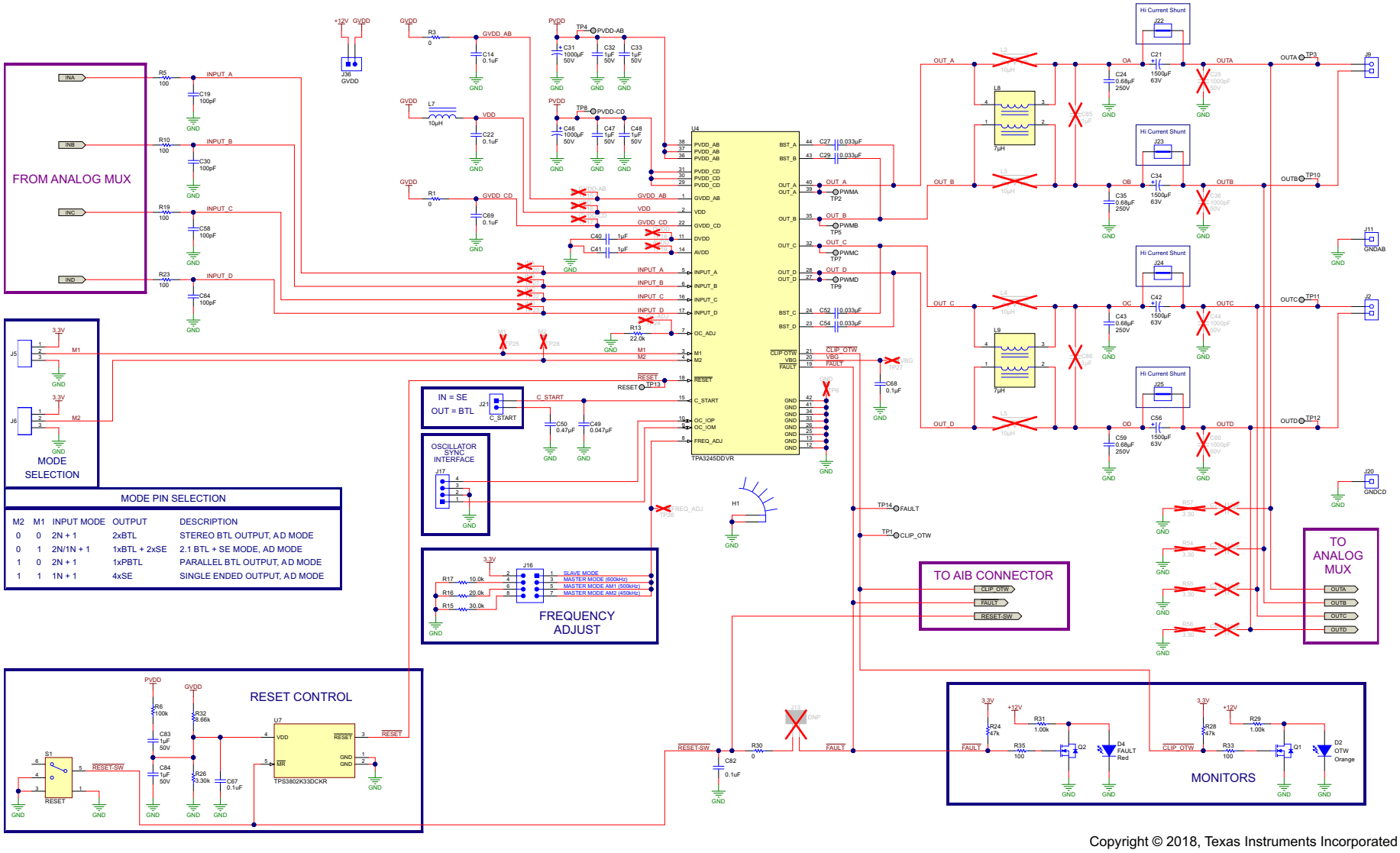


Figure 30. TPA3245EVM Schematic 1



MODE PIN SELECTION

M2	M1	INPUT MODE	OUTPUT	DESCRIPTION
0	0	2N + 1	2xBTL	STEREO BTL OUTPUT, A:D MODE
0	1	2N/1N + 1	1xBTL + 2xSE	2.1 BTL + SE MODE, A:D MODE
1	0	2N + 1	1xPBTL	PARALLEL BTL OUTPUT, A:D MODE
1	1	1N + 1	4xSE	SINGLE ENDED OUTPUT, A:D MODE

Figure 31. TPA3245EVM Schematic 2

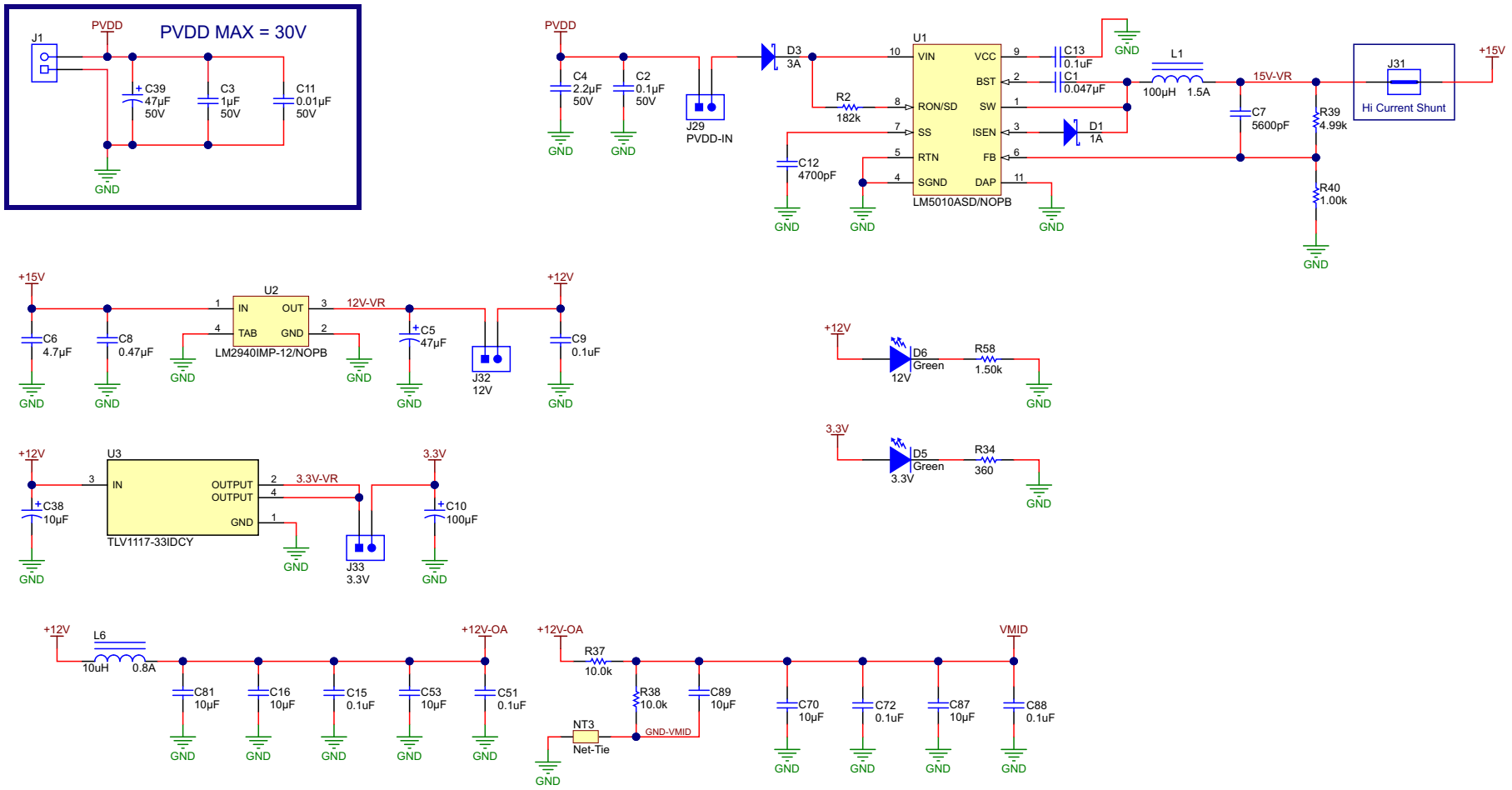


Figure 32. TPA3245EVM Schematic 3

4.5 TPA3245EVM Bill of Materials

Table 10 lists the TPA3245EVM BOM.

Table 10. TPA3245EVM Bill of Materials

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
!PCB	1		Printed Circuit Board		AAP072	Any
C1	1	0.047uF	CAP, CERM, 0.047 µF, 25 V, +/- 10%, X7R, 0402	0402	GRM155R71E473KA88D	Murata
C2, C9, C13, C14, C15, C22, C51, C67, C68, C69, C72, C82, C88	13	0.1uF	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, 0603	0603	C0603C104K5RACTU	Kemet
C3, C32, C33, C47, C48, C83, C84	7	1uF	CAP, CERM, 1 µF, 50 V, +/- 10%, X7R, 0603	0603	UMK107AB7105KA-T	Taiyo Yuden
C4	1	2.2uF	CAP, CERM, 2.2 µF, 50 V, +/- 10%, X7R, 0805	0805	C2012X7R1H225K125AC	TDK
C5	1	47uF	CAP, AL, 47 µF, 16 V, +/- 20%, 0.36 ohm, SMD	SMT Radial D	EEE-FK1C470P	Panasonic
C6	1	4.7uF	CAP, CERM, 4.7 µF, 25 V, +/- 10%, X7R, 1206	1206	GRM31CR71E475KA88L	Murata
C7	1	5600pF	CAP, CERM, 5600 pF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H562KA01D	Murata
C8, C50	2	0.47uF	CAP, CERM, 0.47 µF, 25 V, +/- 10%, X7R, 0603	0603	GRM188R71E474KA12D	Murata
C10	1	100uF	CAP, AL, 100 µF, 6.3 V, +/- 20%, 0.7 ohm, SMD	SMT Radial C	EEE-FK0J101UR	Panasonic
C11	1	0.01uF	CAP, CERM, 0.01 µF, 50 V, +/- 10%, X7R, 0603	0603	C0603C103K5RACTU	Kemet
C12	1	4700pF	CAP, CERM, 4700 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603X472K5RACTU	Kemet
C16, C53, C70, C81, C89, C90	6	10uF	CAP, CERM, 10 µF, 16 V, +/- 10%, X5R, 0805	0805	EMK212BJ106KG-T	Taiyo Yuden
C17, C28, C55, C63	4	10uF	CAP, CERM, 10 µF, 16 V, +/- 10%, X7R, 1206	1206	GRM31CR71C106KAC7L	Murata
C18, C23, C57, C65	4	22pF	CAP, CERM, 22 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	GRM1885C1H220JA01D	Murata
C19, C30, C58, C64	4	100pF	CAP, CERM, 100 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	GRM1885C1H101JA01D	Murata
C20, C38, C62, C66, C71	5	10uF	CAP, AL, 10 µF, 16 V, +/- 20%, 1.35 ohm, SMD	SMT Radial B	EEE-FK1C100R	Panasonic
C21, C34, C42, C56	4	1500uF	CAP, AL, 1500 µF, 63 V, +/- 20%, 0.03 ohm, AEC-Q200 Grade 2, TH	Dia 18mm	EEU-FC1J152	Panasonic
C24, C35, C43, C59	4	0.68uF	CAP, Film, 0.68 µF, 250 V,+/- 5%, TH	18x9x17.5mm	B32652A3684J	TDK
C27, C29, C52, C54	4	0.033uF	CAP, CERM, 0.033 µF, 25 V, +/- 10%, X7R, 0603	0603	GRM188R71E333KA01D	Murata
C31, C46	2	1000uF	CAP, AL, 1000 µF, 50 V, +/- 20%, 0.034 ohm, AEC-Q200 Grade 2, TH	D16xL25	EEU-FC1H102	Panasonic
C39	1	47uF	CAP, AL, 47 µF, 50 V, +/- 20%, 0.68 ohm, SMD	SMT Radial E	EEE-FK1H470P	Panasonic
C40, C41	2	1uF	CAP, CERM, 1 µF, 16 V, +/- 10%, X7R, 0603	0603	GRM188R71C105KA12D	Murata
C49	1	0.047uF	CAP, CERM, 0.047 µF, 50 V, +/- 10%, X7R, 0603	0603	GRM188R71H473KA61D	Murata
D1	1	100V	Diode, Schottky, 100 V, 1 A, SMA	SMA	B1100-13-F	Diodes Inc.
D2	1	Orange	LED, Orange, SMD	LED_0805	LTST-C170KFKT	Lite-On
D3	1	100V	Diode, Schottky, 100 V, 3 A, SMA	SMA	SK310A-TP	Micro Commercial Components
D4	1	Red	LED, Red, SMD	Red 0805 LED	LTST-C170KRKT	Lite-On
D5, D6	2	Green	LED, Green, SMD	LED_0805	LTST-C171GKT	Lite-On
H1	1		HEATSINK TI TAS5612 AND TAS5614	HEATSINK TI TAS5612 AND TAS5614	ATS-TI1OP-563-C1-R0	Advanced Thermal Solutions
H2, H3, H4, H5, H6, H12, H13	7		MACHINE SCREW PAN PHILLIPS M3	M3 Screw	RM3X8MM 2701	APM HEXSEAL
H7, H8, H9, H10, H11	5		Standoff, Hex,25mm Length, M3, Aluminum	Standoff M3	24438	Keystone
J1, J2, J9	3		Dual Binding Posts with Base, 2x1, TH	Dual Binding Posts with Base, 2x1, TH	6883	Pomona Electronics

Table 10. TPA3245EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
J3	1		RCA Jack, Vertical, Red, TH	RCA JACK, RED	RCJ-022	CUI Inc.
J4, J5, J6, J19, J26, J27, J34, J35	8		Header, 100mil, 3x1, Gold, TH	PBC03SAAN	PBC03SAAN	Sullins Connector Solutions
J7, J8, J21, J29, J30, J32, J33, J36	8		Header, 100mil, 2x1, Gold, TH	Sullins 100mil, 1x2, 230 mil above insulator	PBC02SAAN	Sullins Connector Solutions
J10, J12	2		Header, 2.54 mm, 3x1, TH	Header, 2.54mm, 3x1, TH	22-11-2032	Molex
J11, J20	2		Binding Post, BLACK, TH	11.4x27.2mm	7007	Keystone
J14	1		RCA Jack, Vertical, Black, TH	RCA Jack, Vertical, Black, TH	RCJ-021	CUI Inc.
J15	1		RCA Jack, Vertical, Blue, TH	RCA Jack, Vertical, Blue, TH	RCJ-025	CUI Inc.
J16	1		Header, 100mil, 4x2, Tin, TH	Header, 4x2, 100mil, Tin	PEC04DAAN	Sullins Connector Solutions
J17	1		Header (friction lock), 100mil, 4x1, Gold, TH	Header 4x1 keyed	0022112042	Molex
J18	1		RCA Jack, Vertical, White, TH	RCA JACK, WHITE	RCJ-023	CUI Inc.
J22, J23, J24, J25, J31	5		JUMPER TIN SMD	6.85x0.97x2.51 mm	S1911-46R	Harwin
J28	1		Receptacle, 100mil, 14x2, Gold, TH	14x2 Receptacle	SSW-114-01-G-D	Samtec
L1	1	100uH	Inductor, Shielded Drum Core, Ferrite, 100 µH, 1.5 A, 0.165 ohm, SMD	SMD	7447714101	Wurth Elektronik
L2, L3, L4, L5	4	10uH	Inductor, Toroid, Powdered Iron, 10 µH, 6.1 A, 0.026 ohm, TH	28.6x12.3mm	MA5172-AE	Coilcraft
L6	1	10uH	Inductor, Wirewound, 10 µH, 0.8 A, 0.204 ohm, SMD	2-Pin SMD, Body 4 x 4 mm, Height 1.2 mm	NRS4012T100MDGJV	Taiyo Yuden
L7	1	10uH	Inductor, Wirewound, 10 µH, 0.08 A, 0.36 ohm, SMD	0603	GLFR1608T100M-LR	TDK
L8, L9	2	7uH	Inductor, Shielded, Ferrite, 7 µH, 6.5 A, .0066 ohm, AEC-Q200 Grade 1, SMD	15.5x14mm	UA8013-ALD	Coilcraft
Q1, Q2	2	60V	MOSFET, N-CH, 60 V, 0.17 A, SOT-23	SOT-23	2N7002-7-F	Diodes Inc.
R1, R3, R30	3	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R2	1	182k	RES, 182 k, 1%, 0.125 W, 0805	0805	ERJ-6ENF1823V	Panasonic
R4, R12, R44, R46	4	0	RES, 0, 5%, 0.125 W, 0805	0805	ERJ-6GEY0R00V	Panasonic
R5, R10, R19, R23, R33, R35	6	100	RES, 100, 1%, 0.1 W, 0603	0603	CRCW0603100RFKEA	Vishay-Dale
R6	1	100k	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R7, R8, R20, R21, R25, R27, R37, R38, R41, R42	10	10.0k	RES, 10.0 k, 0.1%, 0.1 W, 0603	0603	RT0603BRD0710KL	Yageo America
R9, R43, R45, R48	4	100k	RES, 100 k, 1%, 0.063 W, 0402	0402	CRCW0402100KFKED	Vishay-Dale
R13	1	22.0k	RES, 22.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0722KL	Yageo America
R15	1	30.0k	RES, 30.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0730KL	Yageo America
R16	1	20.0k	RES, 20.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0720KL	Yageo America
R17,	1	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R24, R28	2	47k	RES, 47 k, 5%, 0.1 W, 0603	0603	RC0603JR-0747KL	Yageo America
R26	1	3.30k	RES, 3.30 k, 1%, 0.1 W, 0603	0603	RC0603FR-073K3L	Yageo America
R29, R31	2	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	CRCW06031K00FKEA	Vishay-Dale
R32	1	8.66k	RES, 8.66 k, 1%, 0.1 W, 0603	0603	RC0603FR-078K66L	Yageo America
R34	1	360	RES, 360, 5%, 0.063 W, 0402	0402	CRCW0402360RJNED	Vishay-Dale
R36	1	10.0k	RES, 10.0 k, 1%, 0.063 W, 0402	0402	CRCW040210K0FKED	Vishay-Dale
R39	1	4.99k	RES, 4.99 k, 1%, 0.063 W, 0402	0402	CRCW04024K99FKED	Vishay-Dale
R40	1	1.00k	RES, 1.00 k, 1%, 0.063 W, 0402	0402	CRCW04021K00FKED	Vishay-Dale

Table 10. TPA3245EVM Bill of Materials (continued)

Designator	Qty	Value	Description	Package Reference	Part Number	Manufacturer
R52, R59, R60, R62	4	0	RES, 0, 5%, 0.25 W, 1206	1206	CRCW12060000Z0EA	Vishay-Dale
R53	1	1.00k	RES, 1.00 k, 1%, 0.1 W, 0402	0402	ERJ-2RKF1001X	Panasonic
R58	1	1.50k	RES, 1.50 k, 1%, 0.063 W, 0402	0402	CRCW04021K50FKED	Vishay-Dale
S1	1		Switch, SPDT, On-On, 2 Pos, TH	Switch, 7x4.5mm	200USP1T1A1M2RE	E-Switch
SH1, SH2, SH3, SH4, SH5, SH6, SH7, SH8, SH9, SH10, SH11, SH12, SH13, SH14, SH15, SH16	16	1x2	Shunt, 100mil, Gold plated, Black	Shunt	969102-0000-DA	3M
TP1, TP2, TP3, TP4, TP5, TP7, TP8, TP9, TP10, TP11, TP12, TP13, TP14	13		Test Point, Multipurpose, Grey, TH	Grey Multipurpose Testpoint	5128	Keystone
U1	1		High Voltage 1A Step Down Switching Regulator, 10-pin LLP, Pb-Free	SDC10A	LM5010ASD/NOPB	Texas Instruments
U2	1		1A Low Dropout Regulator, 4-pin SOT-223, Pb-Free	MP04A	LM2940IMP-12/NOPB	Texas Instruments
U3	1		FIXED LOW-DROPOUT VOLTAGE REGULATOR, DCY0004A	DCY0004A	TLV1117-33IDCY	Texas Instruments
U4	1		150W Stereo/300W MONO PurePath HD Analog-input Power Stage, DDV0044D	DDV0044D	TPA3245DDVR	Texas Instruments
U5, U6	2		Low Distortion, Low Noise, General Purpose Audio Op Amp, DGK0008A (VSSOP-8)	DGK0008A	OPA1678IDGKR	Texas Instruments
U7	1		ULTRA-SMALL SUPPLY VOLTAGE SUPERVISORS, DCK0005A	DCK0005A	TPS3802K33DCKR	Texas Instruments
C25, C36, C44, C60	0	1000pF	CAP, CERM, 1000 pF, 50 V, +/- 1%, C0G/NP0, 0603	0603	GRM1885C1H102FA01J	MuRata
C26, C37, C45, C61	0	220pF	CAP, CERM, 220 pF, 50 V,+/- 5%, C0G/NP0, 0603	0603	GRM1885C1H221JA01D	MuRata
C73, C74, C75, C76	0	22pF	CAP, CERM, 22 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	GRM1885C1H220JA01D	Murata
C77, C78, C79, C80	0	1uF	CAP, CERM, 1 µF, 50 V, +/- 10%, X7R, 1206	1206	GRM31MR71H105KA88L	Murata
C85, C86	0	1000pF	CAP, CERM, 1000 pF, 50 V, +/- 1%, C0G/NP0, 0603	0603	GRM1885C1H102FA01J	Murata
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
J13	0		Header, 100mil, 2x1, Gold, TH	Sullins 100mil, 1x2, 230 mil above insulator	PBC02SAAN	Sullins Connector Solutions
L2, L3, L4, L5	0	10uH	Inductor, 10 µH, 4.6 A, 0.0234 ohm, TH	14x9.6mm	7G14J-100M-R	Sagami Elec Co Ltd
R11, R14, R18, R22	0	2.00k	RES, 2.00 k, 1%, 0.1 W, 0603	0603	CRCW06032K00FKEA	Vishay-Dale
R47, R49, R50, R51	0	18.0k	RES, 18.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0718KL	Yageo America
R54, R55, R56, R57	0	3.30	RES, 3.30, 1%, 0.25 W, 1206	1206	ERJ-8RQF3R3V	Panasonic
R59, R60, R61, R62	0	10.0	RES, 10.0, 1%, 0.1 W, 0603	0603	CRCW060310R0FKEA	Vishay-Dale
R63, R64, R65, R66	0	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R67	0	0	RES, 0, 5%, 0.125 W, 0805	0805	ERJ-6GEY0R00V	Panasonic
TP6	0		Test Point, Multipurpose, Grey, TH	Grey Multipurpose Testpoint	5128	Keystone
TP15, TP16, TP17, TP18, TP19, TP20, TP21, TP22, TP23, TP24, TP25, TP26, TP27, TP28	0		Testpoint	Test Point, 0.45mm hole size	TP_H0.45P0.75	Texas Instruments

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (September 2016) to A Revision	Page
• Changed entire document for board revision C.	1

STANDARD TERMS FOR EVALUATION MODULES

1. *Delivery:* TI delivers TI evaluation boards, kits, or modules, including any accompanying demonstration software, components, and/or documentation which may be provided together or separately (collectively, an “EVM” or “EVMs”) to the User (“User”) in accordance with the terms set forth herein. User's acceptance of the EVM is expressly subject to the following terms.

   1.1 EVMs are intended solely for product or software developers for use in a research and development setting to facilitate feasibility evaluation, experimentation, or scientific analysis of TI semiconductors products. EVMs have no direct function and are not finished products. EVMs shall not be directly or indirectly assembled as a part or subassembly in any finished product. For clarification, any software or software tools provided with the EVM (“Software”) shall not be subject to the terms and conditions set forth herein but rather shall be subject to the applicable terms that accompany such Software

   1.2 EVMs are not intended for consumer or household use. EVMs may not be sold, sublicensed, leased, rented, loaned, assigned, or otherwise distributed for commercial purposes by Users, in whole or in part, or used in any finished product or production system.

2 *Limited Warranty and Related Remedies/Disclaimers*:

   2.1 These terms do not apply to Software. The warranty, if any, for Software is covered in the applicable Software License Agreement.

   2.2 TI warrants that the TI EVM will conform to TI's published specifications for ninety (90) days after the date TI delivers such EVM to User. Notwithstanding the foregoing, TI shall not be liable for a nonconforming EVM if (a) the nonconformity was caused by neglect, misuse or mistreatment by an entity other than TI, including improper installation or testing, or for any EVMs that have been altered or modified in any way by an entity other than TI, (b) the nonconformity resulted from User's design, specifications or instructions for such EVMs or improper system design, or (c) User has not paid on time. Testing and other quality control techniques are used to the extent TI deems necessary. TI does not test all parameters of each EVM. User's claims against TI under this Section 2 are void if User fails to notify TI of any apparent defects in the EVMs within ten (10) business days after delivery, or of any hidden defects with ten (10) business days after the defect has been detected.

   2.3 TI's sole liability shall be at its option to repair or replace EVMs that fail to conform to the warranty set forth above, or credit User's account for such EVM. TI's liability under this warranty shall be limited to EVMs that are returned during the warranty period to the address designated by TI and that are determined by TI not to conform to such warranty. If TI elects to repair or replace such EVM, TI shall have a reasonable time to repair such EVM or provide replacements. Repaired EVMs shall be warranted for the remainder of the original warranty period. Replaced EVMs shall be warranted for a new full ninety (90) day warranty period.

3 *Regulatory Notices:*

   3.1 *United States*

      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      FCC NOTICE: This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

FCC Interference Statement for Class B EVM devices

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210 or RSS-247*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSSs. Operation is subject to the following two conditions:

(1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

Concernant les EVMs avec appareils radio:

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes: (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Concerning EVMs Including Detachable Antennas:

Under Industry Canada regulations, this radio transmitter may only operate using an antenna of a type and maximum (or lesser) gain approved for the transmitter by Industry Canada. To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that necessary for successful communication. This radio transmitter has been approved by Industry Canada to operate with the antenna types listed in the user guide with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

3.3 *Japan*

3.3.1 *Notice for EVMs delivered in Japan:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page 日本国内に輸入される評価用キット、ボードについては、次のところをご覧ください。
http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_01.page

3.3.2 *Notice for Users of EVMs Considered "Radio Frequency Products" in Japan:* EVMs entering Japan may not be certified by TI as conforming to Technical Regulations of Radio Law of Japan.

If User uses EVMs in Japan, not certified to Technical Regulations of Radio Law of Japan, User is required to follow the instructions set forth by Radio Law of Japan, which includes, but is not limited to, the instructions below with respect to EVMs (which for the avoidance of doubt are stated strictly for convenience and should be verified by User):

1. Use EVMs in a shielded room or any other test facility as defined in the notification #173 issued by Ministry of Internal Affairs and Communications on March 28, 2006, based on Sub-section 1.1 of Article 6 of the Ministry's Rule for Enforcement of Radio Law of Japan,
2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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3.4 *European Union*

3.4.1 *For EVMs subject to EU Directive 2014/30/EU (Electromagnetic Compatibility Directive)*:

This is a class A product intended for use in environments other than domestic environments that are connected to a low-voltage power-supply network that supplies buildings used for domestic purposes. In a domestic environment this product may cause radio interference in which case the user may be required to take adequate measures.

4 *EVM Use Restrictions and Warnings:*

4.1 EVMS ARE NOT FOR USE IN FUNCTIONAL SAFETY AND/OR SAFETY CRITICAL EVALUATIONS, INCLUDING BUT NOT LIMITED TO EVALUATIONS OF LIFE SUPPORT APPLICATIONS.

4.2 User must read and apply the user guide and other available documentation provided by TI regarding the EVM prior to handling or using the EVM, including without limitation any warning or restriction notices. The notices contain important safety information related to, for example, temperatures and voltages.

4.3 *Safety-Related Warnings and Restrictions:*

4.3.1 User shall operate the EVM within TI's recommended specifications and environmental considerations stated in the user guide, other available documentation provided by TI, and any other applicable requirements and employ reasonable and customary safeguards. Exceeding the specified performance ratings and specifications (including but not limited to input and output voltage, current, power, and environmental ranges) for the EVM may cause personal injury or death, or property damage. If there are questions concerning performance ratings and specifications, User should contact a TI field representative prior to connecting interface electronics including input power and intended loads. Any loads applied outside of the specified output range may also result in unintended and/or inaccurate operation and/or possible permanent damage to the EVM and/or interface electronics. Please consult the EVM user 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, even with the inputs and outputs kept within the specified allowable ranges, some circuit components may have elevated case temperatures. These components include but are not limited to linear regulators, switching transistors, pass transistors, current sense resistors, and heat sinks, which can be identified using the information in the associated documentation. When working with the EVM, please be aware that the EVM may become very warm.

4.3.2 EVMs are intended solely for use by technically qualified, professional electronics experts who are familiar with the dangers and application risks associated with handling electrical mechanical components, systems, and subsystems. User assumes all responsibility and liability for proper and safe handling and use of the EVM by User or its employees, affiliates, contractors or designees. User assumes all responsibility and liability to ensure that any interfaces (electronic and/or mechanical) between the EVM and any human body are designed with suitable isolation and means to safely limit accessible leakage currents to minimize the risk of electrical shock hazard. User assumes all responsibility and liability for any improper or unsafe handling or use of the EVM by User or its employees, affiliates, contractors or designees.

4.4 User assumes all responsibility and liability to determine whether the EVM is subject to any applicable international, federal, state, or local laws and regulations related to User's handling and use of the EVM and, if applicable, User assumes all responsibility and liability for compliance in all respects with such laws and regulations. User assumes all responsibility and liability for proper disposal and recycling of the EVM consistent with all applicable international, federal, state, and local requirements.

5. *Accuracy of Information:* To the extent TI provides information on the availability and function of EVMs, TI attempts to be as accurate as possible. However, TI does not warrant the accuracy of EVM descriptions, EVM availability or other information on its websites as accurate, complete, reliable, current, or error-free.

6. *Disclaimers:*

   6.1 EXCEPT AS SET FORTH ABOVE, EVMS AND ANY MATERIALS PROVIDED WITH THE EVM (INCLUDING, BUT NOT LIMITED TO, REFERENCE DESIGNS AND THE DESIGN OF THE EVM ITSELF) ARE PROVIDED "AS IS" AND "WITH ALL FAULTS." TI DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, REGARDING SUCH ITEMS, INCLUDING BUT NOT LIMITED TO ANY EPIDEMIC FAILURE WARRANTY OR IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF ANY THIRD PARTY PATENTS, COPYRIGHTS, TRADE SECRETS OR OTHER INTELLECTUAL PROPERTY RIGHTS.

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7. *USER'S INDEMNITY OBLIGATIONS AND REPRESENTATIONS.* USER WILL DEFEND, INDEMNIFY AND HOLD TI, ITS LICENSORS AND THEIR REPRESENTATIVES HARMLESS FROM AND AGAINST ANY AND ALL CLAIMS, DAMAGES, LOSSES, EXPENSES, COSTS AND LIABILITIES (COLLECTIVELY, "CLAIMS") ARISING OUT OF OR IN CONNECTION WITH ANY HANDLING OR USE OF THE EVM THAT IS NOT IN ACCORDANCE WITH THESE TERMS. THIS OBLIGATION SHALL APPLY WHETHER CLAIMS ARISE UNDER STATUTE, REGULATION, OR THE LAW OF TORT, CONTRACT OR ANY OTHER LEGAL THEORY, AND EVEN IF THE EVM FAILS TO PERFORM AS DESCRIBED OR EXPECTED.

8. *Limitations on Damages and Liability:*

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   8.2 *Specific Limitations.* IN NO EVENT SHALL TI'S AGGREGATE LIABILITY FROM ANY USE OF AN EVM PROVIDED HEREUNDER, INCLUDING FROM ANY WARRANTY, INDEMITY OR OTHER OBLIGATION ARISING OUT OF OR IN CONNECTION WITH THESE TERMS, , EXCEED THE TOTAL AMOUNT PAID TO TI BY USER FOR THE PARTICULAR EVM(S) AT ISSUE DURING THE PRIOR TWELVE (12) MONTHS WITH RESPECT TO WHICH LOSSES OR DAMAGES ARE CLAIMED. THE EXISTENCE OF MORE THAN ONE CLAIM SHALL NOT ENLARGE OR EXTEND THIS LIMIT.

9. *Return Policy.* Except as otherwise provided, TI does not offer any refunds, returns, or exchanges. Furthermore, no return of EVM(s) will be accepted if the package has been opened and no return of the EVM(s) will be accepted if they are damaged or otherwise not in a resalable condition. If User feels it has been incorrectly charged for the EVM(s) it ordered or that delivery violates the applicable order, User should contact TI. All refunds will be made in full within thirty (30) working days from the return of the components(s), excluding any postage or packaging costs.

10. *Governing Law:* These terms and conditions shall be governed by and interpreted in accordance with the laws of the State of Texas, without reference to conflict-of-laws principles. User agrees that non-exclusive jurisdiction for any dispute arising out of or relating to these terms and conditions lies within courts located in the State of Texas and consents to venue in Dallas County, Texas. Notwithstanding the foregoing, any judgment may be enforced in any United States or foreign court, and TI may seek injunctive relief in any United States or foreign court.

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