TPA3221 Evaluation Module

This user's guide describes the characteristics, operation, and use of the TPA3221 evaluation module. A complete printed-circuit board (PCB) description, schematic diagram, and bill of materials are also included.



Copyright © 2017, Texas Instruments Incorporated

Contents

1 Quick Start (BTL MODE) 3
1.1 Required Hardware 3
1.2 Connections and Board Configuration (BTL MODE) 4
1.3 Power-Up 5
2 Setup By Mode 6
2.1 BTL MODE (Stereo - 2 Speaker Outputs) 6
2.2 PBTL MODE (Mono – 1 Speaker Output) 6
3 Hardware Configuration 9
3.1 Indicator Overview (OTW_CLIP and FAULT) 9
3.2 PWM Frequency Adjust 9
3.3 Modulation Modes (AD Mode and HEAD Mode) 10
3.4 Output Mode Selection 10
3.5 Audio Front End 10
3.6 EVM Power Tree 11
3.7 LC Response and Overview 12
3.8 Reset Circuit and POR 13
3.9 Analog-Input-Board Connector (J28) 14
4 EVM Design Documents 16
4.1 TPA3221 Board Layouts 16
4.2 TPA3221 Board Layouts 17
4.3 TPA3221 EVM Schematics 18
4.4 TPA3221EVM Bill of Materials 21

List of Figures

1 Output Configuration BTL 3
2 EVM Board (Top Side) 4
3 EVM Board (Bottom Side) 4
4 Output Configuration PBTL - 4 Inductors 6
5 EVM Board With Connectors and Jumpers 7
6 Filter Frequency Response 13
7 RESET Circuit 13
8 AIB EVM Connector 14
9 TPA3221 EVM Top Composite Assembly 16
10 TPA3221 EVM Bottom Composite Assembly 16
11 TPA3221 EVM Board Dimensions 17
12 TPA3221 EVM Schematic 1 18
13 TPA3221 EVM Schematic 2 19
14 TPA3221 EVM Schematic 3 20

List of Tables

1 Jumper and Switch Configurations (BTL Mode) 5
2 Jumper and Switch Configurations (PBTL Mode) 8
3 Fault and Clip Overtemperature Status 9
4 Frequency Adjust Master Mode Selection (J16) 9
5 HEAD and AD Mode Selection 10
6 Output Mode and Modulation Mode Selection 10
7 Power Supply Summary 11
8 AIB Connector (J28) Pinout 14
9 AIB Power Rail Specifications 15
10 TPA3221EVM Bill of Materials 21

Copyright © 2017, Texas Instruments Incorporated

Trademarks

All trademarks are the property of their respective owners.

1 Quick Start (BTL MODE)

The following section describes the necessary hardware, connections, configuration, and steps to quick start the EVM into BTL mode with stereo audio playing out of two speakers.

Figure 1 illustrates the BTL mode output configuration.

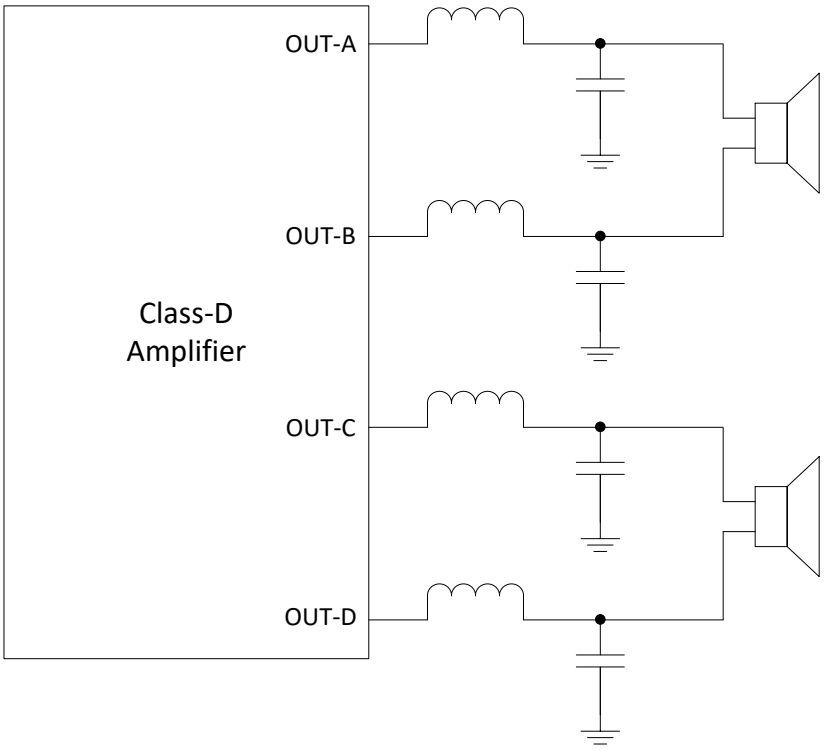


Figure 1. Output Configuration BTL

1.1 Required Hardware

The following hardware is required for this EVM:

- TPA3221EVM
- Power supply 5–14 A, 12–30 VDC
- Two 2–8 Ω speaker or resistor loads (ensure speaker/load is appropriately sized for required wattage output)
- Four speaker, banana cables
- Four XLR or two RCA input cables
- Analog output audio source

Copyright © 2017, Texas Instruments Incorporated

1.2 Connections and Board Configuration (BTL MODE)

Figure 2 shows the EVM board.

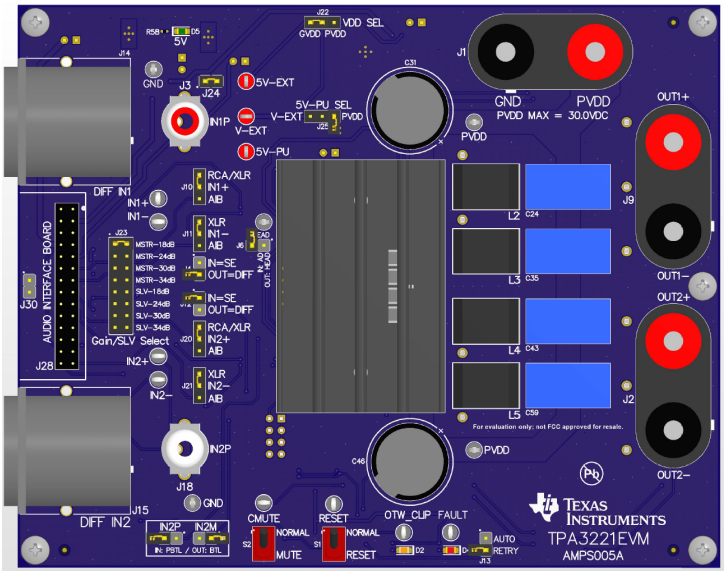


Figure 2. EVM Board (Top Side)

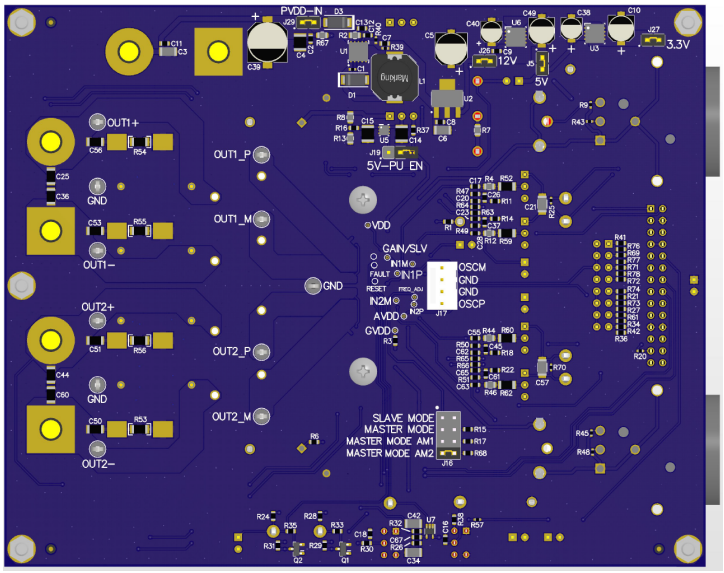


Figure 3. EVM Board (Bottom Side)

Use the following steps when connecting and configuring the board for BTL MODE:

1. Ensure the power supply is OFF. Connect the power supply positive terminal to J1 PVDD (red) and negative terminal to J1 GND (black).
2. Connect the left channel speaker, power resistor load (3–8 Ω) to the TPA3221EVM positive output terminal (J9 OUT1+ (red)) and other side of the speaker, power resistor to the TPA3221EVM negative output terminal (J9 OUT1– (black)).
3. Connect the right channel speaker, power resistor load (3–8 Ω) to the TPA3221EVM positive output terminal (J2 OUT2+ (red)) and other side of the speaker, power resistor to the TPA3221EVM negative output terminal (J2 OUT2– (black)).

Copyright © 2017, Texas Instruments Incorporated

4. Check to make sure that the power supply is connected to J1 only and speakers are connected to J9 or J2 only, as their colors are the same.
5. Input Configuration:
   A. **Differential Inputs:** connect one differential XLR audio input to each DIFF IN1 (J14) and DIFF IN2 (J15). Install jumpers J10, J11, J20, and J21 to position 1:2 which is labeled as **RCA** or **XLR**. Jumpers J4 and J12 must be uninstalled for DIFF input.
   B. **Single-Ended Inputs:** connect one single-ended RCA audio input to IN1P (J3) and IN2P (J18). Install jumpers J10, J11, J20, and J21 to position 1:2 which is labeled as **RCA** or **XLR**. Jumpers J4 and J12 must be installed for SE input.
   C. **Audio Interface Board Input:** Install jumpers J10, J11, J20, and J21 to position 2:3 which is labeled as **AIB**. Jumpers J4 and J12 must be installed for SE input from the AIB or uninstalled for DIFF input from the AIB.
6. Ensure that RESET S1 and MUTE S2 are in the lower positions of RESET and MUTE, respectively.
7. Check Table 1 for all jumper and switch configurations

Table 1. Jumper and Switch Configurations (BTL Mode)

Component	Component Description	Configuration for BTL
J23	Gain/SLV Select	MSTR-18dB
J24	N/A	IN
J4, J12	Input DIFF/SE Select	OUT = DIFF IN, IN = DIFF IN
J10, J11, J20, J21	AIB Input Select	Position 1:2 for XLR/RCA, Position 2:3 for AIB
J6	HEAD/AD Mode Select	IN
J7, J8	PBTL/BTL Select	OUT
J22	VDD SEL	Position 2:3 (GVDD)
J25	5V-PU SEL	OUT
S1	RESET Control	RESET
S2	MUTE Control	MUTE
J13	Auto Retry	OUT
J29	PVDD-IN	IN
J26	12V-IN	IN
J5	5V-IN	IN
J27	3.3V-IN	IN
J19	5V-PU EN	OUT
J17	OSC Output	No Connection
J16	Master/Slave Select	Position 3:4 MASTER MODE

1.3 Power-Up

Ensure that required connections and configurations have been checked. The TPA3221EVM board can now be powered on.

1. Enable the power supply at 12 V to 30 V and ensure that LED D5 illuminates. LEDs D2 and D4 should not be illuminated.
2. Bring the EVM out of RESET state by switching RESET (S1) to NORMAL. You should see the FAULT LED (D4) blink once quickly, then remain unilluminated.
3. Bring the EVM out of MUTE state by switching MUTE (S2) to NORMAL.
4. Note that the EVM does not have volume control, configure your analog input for a reasonable audio level before beginning audio playback.
5. Enable audio input playback and the EVM should begin driving audio out of the left and right speakers. If resistor loads are used for testing instead of speakers, they will now be energized.

Copyright © 2017, Texas Instruments Incorporated

2 Setup By Mode

The following sections describe the setup and configuration for each output mode. The TPA3221DDV EVM allows for two output modes: Stereo BTL and Mono PBTL.

2.1 BTL MODE (Stereo - 2 Speaker Outputs)

This mode is the same as described in *Quick Start (BTL MODE)*.

2.2 PBTL MODE (Mono – 1 Speaker Output)

This mode provides one speaker output that is more powerful than each BTL output and is useful when mono audio is to be played or when more power is needed.

Figure 4 illustrates the PBTL mode output configuration with 4 inductors.

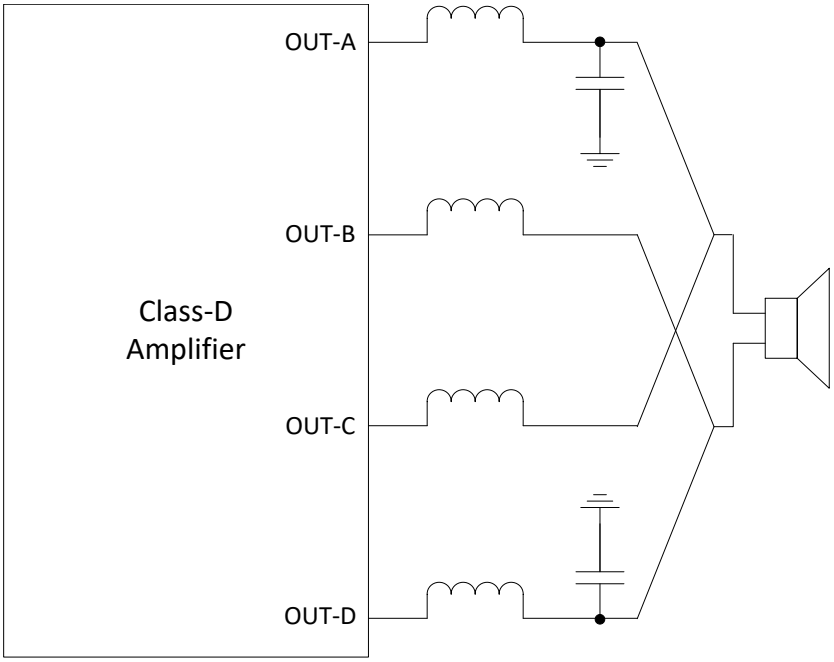


Figure 4. Output Configuration PBTL - 4 Inductors

Copyright © 2017, Texas Instruments Incorporated

2.2.1 Connections and Board Configuration

Figure 5 illustrates the connectors and jumpers on the EVM.

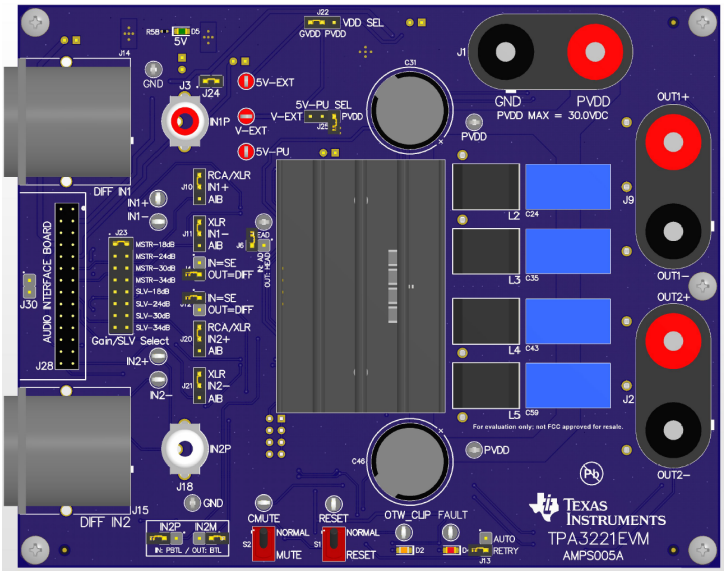


Figure 5. EVM Board With Connectors and Jumpers

Use the following steps when connecting and configuring the board:

1. Ensure the power supply is OFF. Connect power supply positive terminal to J1 PVDD (red) and negative terminal to J1 GND (black).
2. Connect one speaker, power resistor load (2–8 Ω) to TPA3221EVM positive output terminal (J9 OUT1+ (red)) and other side of speaker, power resistor to TPA3221EVM negative output terminal (J9 OUT1– (black)).
3. Use a short banana cable to connect J2 OUT2+ to J9 OUT1+ and a second banana short banana cable to connect J2 OUT2– to J9 OUT1–. This forms the parallel connection of both OUTx+ to the one side of the speaker and parallel connection of both OUTx– to the other side of the speaker.
4. Check to make sure that the power supply is connected to J1 only and the speaker is connected to J9 or J2 only, as their colors are the same.
5. Input Configuration:
    1. **Differential Inputs:** connect one differential XLR audio input to DIFF IN1 (J14). Install jumpers J10, J11, J20, and J21 to position 1:2 which is labeled as **RCA** or **XLR**. Jumpers J4 and J12 must be uninstalled for DIFF input.
    2. **Single-Ended Inputs:** connect one single-ended RCA audio input to IN1P (J3). Install jumpers J10, J11, J20, and J21 to position 1:2 which is labeled as **RCA** or **XLR**. Jumpers J4 and J12 must be installed for SE input.
    3. **Audio Interface Board Input:** Install jumpers J10, J11, J20, and J21 to position 2:3 which is labeled as **AIB**. Jumpers J4 and J12 must be installed for SE input from the AIB or uninstalled for DIFF input from the AIB.
6. Ensure that RESET S1 and MUTE S2 are in the lower positions of RESET and MUTE, respectively.

Copyright © 2017, Texas Instruments Incorporated

7. Check Table 2 for all jumper and switch configurations necessary.

Table 2. Jumper and Switch Configurations (PBTL Mode)

Component	Component Description	Configuration for PBTL
J23	Gain/SLV Select	MSTR-18dB
J24	N/A	IN
J4, J12	Input DIFF/SE Select	OUT = DIFF IN, IN = DIFF IN
J10, J11, J20, J21	AIB Input Select	Position 1:2 for XLR/RCA, Position 2:3 for AIB
J6	HEAD/AD Mode Select	IN
J7, J8	PBTL/BTL Select	IN
J22	VDD SEL	Position 2:3 (GVDD)
J25	5V-PU SEL	OUT
S1	RESET Control	RESET
S2	MUTE Control	MUTE
J13	Auto Retry	OUT
J29	PVDD-IN	IN
J26	12V-IN	IN
J5	5V-IN	IN
J27	3.3V-IN	IN
J19	5V-PU EN	OUT
J17	OSC Output	No Connection
J16	Master, Slave Select	Position 3:4 MASTER MODE

2.2.2 Power-Up

Ensure that required connections and configurations have been checked. The TPA3221EVM board can now be powered on.

1. Enable the power supply at 12 V to 30 V and ensure that LED D5 illuminates. LEDs D2 and D4 should not be illuminated.
2. Bring the EVM out of RESET state by switching RESET (S1) to NORMAL. You should see the FAULT LED (D4) blink once quickly, then remain unilluminated.
3. Bring the EVM out of MUTE state by switching MUTE (S2) to NORMAL.
4. Note that the EVM does not have volume control, configure your analog input for a reasonable audio level before beginning audio playback.
5. Enable audio input playback and the EVM should begin driving audio out of the left and right speakers. If resistor loads are used for testing instead of speakers, they will now be energized.

Copyright © 2017, Texas Instruments Incorporated

3 Hardware Configuration

3.1 Indicator Overview (OTW_CLIP and FAULT)

The TPA3221EVM is equipped with LED indicators that illuminate when the FAULT or OTW_CLIP pin goes low. See Table 3 and the TPA3221 data sheet (SLASEE9) for more details.

Table 3. Fault and Clip Overtemperature Status

$\overline{\text{FAULT}}$ LED Status	$\overline{\text{OTW_CLIP}}$ LED Status	Description
ON	ON	Overtemperature (OTE) or overload (OLP) or undervoltage (UVP). Junction temperature higher than 125°C (OTE warning)
ON	OFF	Overload (OLP) or undervoltage (UVP). Junction temperature lower than 125°C
OFF	ON	Junction temperature higher than 125°C (OTE warning)
OFF	OFF	Junction temperature lower than 125°C and no OLP or UVP faults (normal operation)

3.2 PWM Frequency Adjust

The TPA3221EVM allows for three oscillator frequency options by external configuration of the FREQ_ADJ pin. The frequency adjust can be used to reduce interference problems while using a radio receiver tuned within the AM band. These values should be chosen such that the nominal and the lower value switching frequencies together results in the fewest cases of interference throughout the AM band. The oscillator frequency can be selected by the value of the FREQ_ADJ resistor connected to GND in master mode according to Table 4.

Table 4. Frequency Adjust Master Mode Selection (J16)

FREQ_ADJ (J16) Mode	Resistor Selected to GND or Pullup	PWM Frequency
Master MODE	49.9 kΩ	600 kHz
Master MODE AM1	30 kΩ	533 kHz
Master MODE AM2	10 kΩ	480 kHz
Slave MODE	Pullup to 5 V	N/A

Selecting *Slave Mode* configures the OSC_I/O pins as inputs to be slaved from an external differential clock. In a master or 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 will not influence the audio output, but only the switch timing to minimize noise coupling between audio channels through the power supply. This will optimize audio performance and result in better operating conditions for the power supply. The inter-channel delay will be set up for a slave device depending on the polarity of the OSC_I/O connection such that slave mode 1 is selected by connecting the OSC_I/O of the master device with the OSC_I/O of the slave device with the same polarity (+ to + and – to –), while slave mode 2 is selected by connecting the OSC_I/Os with the inverse polarity (+ to – and – to +).

Copyright © 2017, Texas Instruments Incorporated

3.3 Modulation Modes (AD Mode and HEAD Mode)

The TPA3221EVM supports both AD modulation as well as HEAD modulation. In AD mode, each of the two half-bridge outputs are continuously switching. AD mode is the default mode for the TPA3221EVM. The EVM also supports HEAD mode modulation. HEAD mode also switches both half bridge outputs but also optimizes the switching for lower power loss at idle as well as increased EMI performance at cost of some performance. The device accomplishes this by reducing its duty cycle at idle and while playing small signals. At higher output levels HEAD mode will also reduce the switching on one of the half bridges. The modulation mode can be controlled through jumper J6 on the EVM as follows:

Table 5. HEAD and AD Mode Selection

J6 Jumper State	Modulation Mode
IN	AD Mode
OUT	HEAD Mode

More information on the differences between HEAD mode and AD mode as well as performance data is found in the TPA3221 data sheet (SLASEE9).

3.4 Output Mode Selection

The TPA3221 does not use discrete mode pins and therefore relies solely on the states of the IN2_M and IN2_P pins. Connecting the IN2_M and IN2_P pins to regular high output impedance audio outputs by removing J7 and J8 puts the TPA3221 into BTL mode (2 x stereo outputs). Tying the IN2_M and IN2_P pins to GND by installing J7 and J8 puts the TPA3221 into PBTL mode (1 x mono output). This is summarized in Table 6:

Table 6. Output Mode and Modulation Mode Selection

Input Jumpers J7 and J8		Input Mode	Output Configuration	Description
IN2_M	IN2_P			
OUT	OUT	1N / 2N + 1	2 × BTL	Stereo BTL output configuration
IN	IN		1 × PBTL	Mono paralleled BTL configuration. Connect OUT1+ to OUT2+ and OUT1– to OUT2–.

3.5 Audio Front End

The TPA3221EVM includes options for single-ended or differential input signals. A configurable front end is built into the TPA3221 so that both single-ended and differential inputs can achieve the full scale output of the TPA3221 device without need for external front end op-amp. Note that when EVM RCA or XLR connectors are used, jumpers J11, J10, J21, and J20 must be installed in position 1:2 named **XLR** or **RCA**.

- Single-ended input can be provided through RCA to inputs J3 and J18. Uninstall jumpers J4 and J12 using SE input so that the TPA3221 front-end will be configured for SE input.
- Differential input can be provided through XLR to inputs J14 and J15. Install jumpers J4 and J12 when using DIFF input so that the TPA3221 front-end will be configured for DIFF input.

Input can also be provided through an audio plug-in board on J28. For this input type, change jumpers J11, J10, J21, and J20 to position 2:3 named **AIB**.

See the EVM schematic section (Section 4.3) for complete details.

Copyright © 2017, Texas Instruments Incorporated

3.6 EVM Power Tree

The TPA3221EVM includes a few options for power configuration so that various input types can be evaluated.

3.6.1 TPA3221 Supplies

The TPA3221 device has a few power supplies which each have their own voltage range and rules. Details for each supply are as shown:

- **PVDD** – This is the main device supply which accepts from 7 V to 30 V. Power output of the device is derived solely from PVDD and therefore it is important to configure this supply according to the chosen output configuration and load. Complete details are included in the TPA3221 datasheet (link).
- **VDD** – This supply is used for the non-PVDD power of the device for blocks such as the front-end and control circuitry. The TPA3221 internal 5-V LDO is also powered by this pin. VDD can be powered by 5 V directly if using the TPA3221 with the internal regulator OFF. In this case, tie the GVDD and AVDD pins directly to VDD using **J22** position 2:3. When the internal regulator is used, VDD must be between 7 V and PVDD through J22 position 1:2 or providing an external voltage to V-EXT. GVDD and AVDD are only 5-V tolerant so **J22** cannot be in position 2:3. The 5 V TP or 5 V through J24 must be used to power GVDD and AVDD separate from VDD in this case.
- **GVDD** and **AVDD** – These pins are used for the gate drive and analog supply of the device. These pins accept only 5 V. When the internal regulator is used, these pins are fed internal to the device, no external connection is necessary. When the internal regulator is OFF, these pins need 5 V through the TP or 5 V through J24 as previously mentioned.

Table 7. Power Supply Summary

PVDD (V)	VDD (V)	AVDD and GVDD	Internal Regulator Status	Note
7.0 to 30.0	5.0	Externally Provided	OFF	Most Efficient
7.0 to 30.0	7.0 to PVDD	No Connection to VDD	ON	5 V internally generated
X	5.0 to 7.0	-	-	Not allowed (do not use)

3.6.2 TPA3221EVM Power Options

All options in this section assume the TPA3221 internal 5-V regulator is OFF and that 5 V is provided externally to VDD, AVDD, and GVDD. J22 must be in position 2:3 to connect VDD to the AVDD and GVDD nodes. The major input configurations are listed in the following sections by the supplies available.

3.6.2.1 PVDD Only (12 V to 30 V)

This power mode is the default setup when the board is tested and shipped. The user can connect any valid supply voltage to J1 and the onboard LDOs will generate the required non-PVDD voltages. PVDD itself always connects directly to the TPA3221 PVDD pins. Setup for this mode is the same as described in *Quick Start (BTL MODE)*.

3.6.2.2 PVDD (12 V to 30 V) and One Non-5-V Supply

This power mode is useful for certain applications where a system has one higher voltage used for PVDD and a second lower voltage that may be used for device pullups and other supplies (VDD, GVDD, and AVDD). The PVDD voltage can still be connected to J1 but jumpers J29 and J24 as well as resistor R37 must be removed.

The non-5-V supply should be connected to jumper V-EXT (7 V to 30 V only) and J25 in position 2:3 to select V-EXT as the input for U5. Install J19 to enable U5. Install R16 to connect 5VPU-VR to 5V-PU and J22 in position 2:3 to connect 5V-PU to VDD.

Copyright © 2017, Texas Instruments Incorporated

3.6.2.3 PVDD (12 V to 30 V) and 5-V Supply

This power mode is most useful for systems in which a 5-V supply is already available due to additional circuitry like an MCU or wireless module. On the EVM, this is also the preferred way to measure efficiency of the TPA3221 device. The PVDD voltage can still be connected to J1 but jumpers J29 and J24 must be removed. The 5-V supply should be connected to TP33 (5V-PU) or TP34 (5V-EXT).

If R3 is installed, these nodes will be connected and at the same voltage. The same 5-V input will be used for the TPA3221 supplies (AVDD, VDD, and GVDD), the EVM reset control (U7), all TPA3221 device pullups (Reset, HEAD, FREQ_ADJ, Fault, OTW_CLIP), and status LEDs D4 and D2.

The two 5-V supplies can be isolated by removing R3. Once R3 is removed, 5 V can be fed to only the TPA3221 supplies through TP34 (5V-EXT) and all other 5 V needs can be powered through TP33 (5V-PU).

Either approach can be used to measure efficiency, but the most accurate numbers will be with the two 5-V supplies separated so the TPA3221 supply voltage is isolated and measured independently of board LEDs, reset control, and so forth.

3.7 LC Response and Overview

Included near the output of the TPA3221 device are four output LC filters. These output filters filter the PWM output leaving only the audio content at high power which is fed to the speakers. The board uses a Sagami 10-µH inductor and 1-µF film capacitor to form this LC filter. Using the equations listed in *LC Filter Design* (SLAA701), the filter low pass cut-off is as follows:

$$F_{\text{cut-off}} = \frac{1}{2\pi\sqrt{L \times C}} = \frac{1}{2\pi\sqrt{10\,\mu H \times 1\,\mu F}} = 50.3\ \text{kHz} \quad (1)$$

Copyright © 2017, Texas Instruments Incorporated

The frequency response of the filter per output load is illustrated in Figure 6.

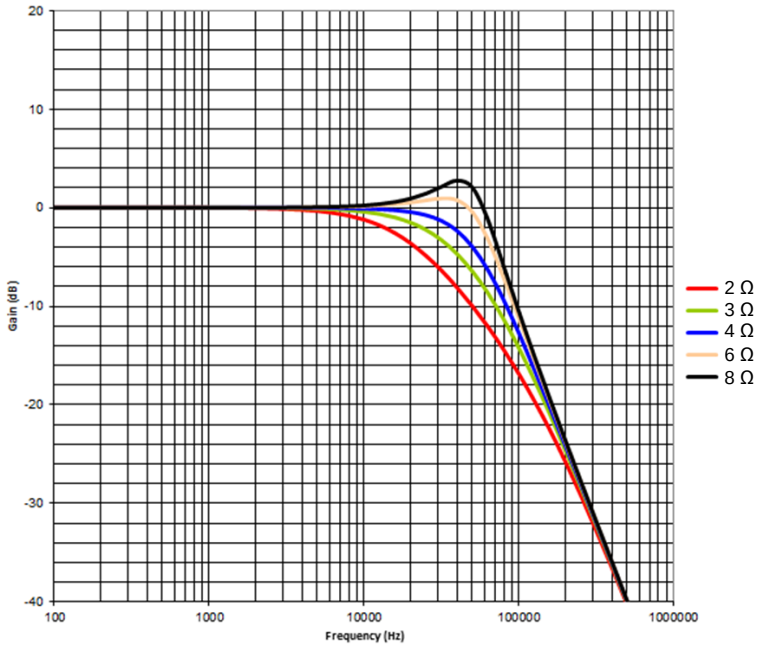


Figure 6. Filter Frequency Response

Figure 6 is taken directly from the *LC Filter Calculator* tool available on TI.com (SLAC729). The tool is configured for BTL common mode with values of 10 µH and 1 µF for the filter. This tool is also helpful when designing a different board featuring one of TI's class-D amplifiers.

The Sagami inductor used (7G14J-100M-R) has a saturation current of 18 A. This was selected for the EVM since the TPA3221 supports a maximum short-circuit output current of 10 A. The inductance versus current curve for a selected inductor is very important. It is essential for the inductor to maintain at least 5 µH of inductance at the maximum short-circuit current of the power amplifier. The Sagami inductance versus current curve is available in the 7G14J-100M-R data sheet on the Sagami web site.

Although not required, shielded inductors are used on the EVM as they reduce EMI.

3.8 Reset Circuit and POR

The TPA3221EVM includes RESET supervision so that the TPA3221 device will remain in reset until all power rails are up and stable. The RESET supervisor also ensures that the device will be put into reset if one of the power rails experiences a brown out. This circuit combined with the RESET switch (S1) help ensure that the TPA3221 can be placed in reset easily, as needed, or automatically if there is a power supply issue. Figure 7 illustrates the circuit.

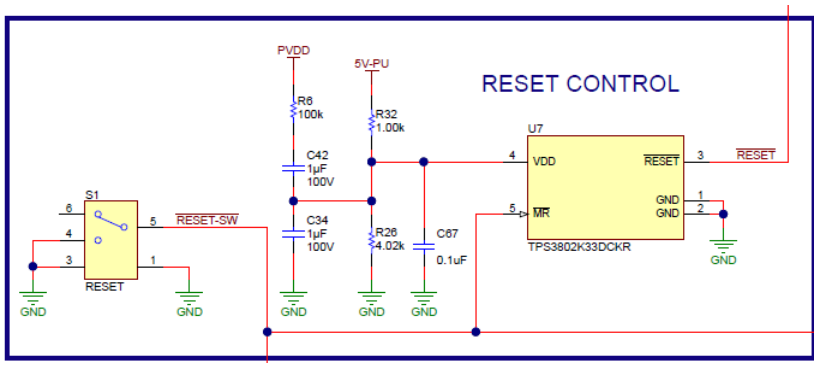


Figure 7. RESET Circuit

Copyright © 2017, Texas Instruments Incorporated

3.9 Analog-Input-Board Connector (J28)

The *Analog-Input-Board* (AIB) connector allows for cross compatibility with several *Analog Plug-in Modules* (APMs) offered by TI. This generic connector provides access to common board connections such as analog input, analog output, Fault and overtemperature warning (OTW) error reporting, common board voltages (12 V, 3.3 V, and so forth), and EVM reset. These plug-in modules allow for an application-specific front end to be plugged into the TPA3221EVM with ease. Examples of plug-in modules include front ends for guitar amplifier, karaoke, wireless sub-woofer, and front-end audio crossover.

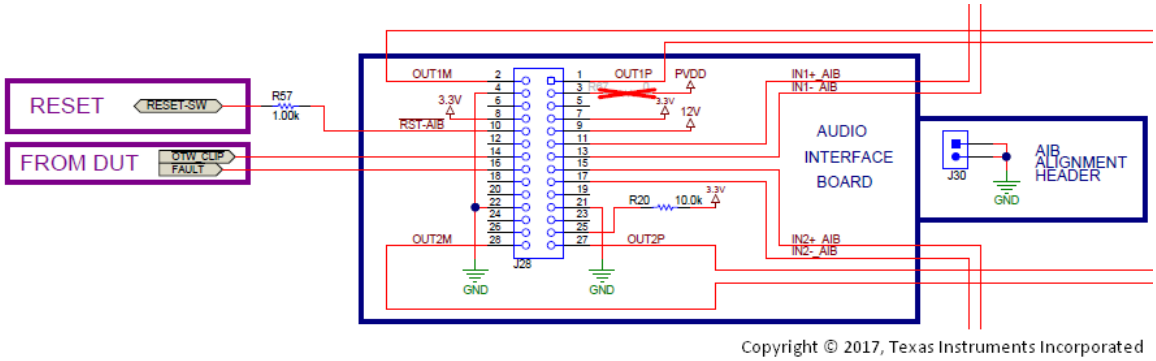


Figure 8. AIB EVM Connector

As Figure 8 shows, the AIB connector includes the following pins, associated specifications are listed in Table 9.

Table 8. AIB Connector (J28) Pinout

Pin #	Function	Description	Audio EVM Input/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 I2S Bus (digital in EVM)	I
12	NC	-	-
13	Analog IN_B	Analog audio input B (analog in EVM) , Bit Clock I2S Bus (digital in EVM)	I
14	$\overline{\text{CLIP_OTW}}$	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 I2S Bus (digital in EVM)	I
16	$\overline{\text{FAULT}}$	Fault detection from audio Class-D EVM (Active Low)	O
17	Analog IN_D	Analog audio Input D (analog in EVM) , Data In I2S 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	-	-

Copyright © 2017, Texas Instruments Incorporated

Table 8. AIB Connector (J28) Pinout (continued)

Pin #	Function	Description	Audio EVM Input/Output
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

Table 9. AIB Power Rail Specifications

EVM Power Rails	Always Available	Voltage Range	Max Current	Source
PVDD	Yes	15–80 V	500 mA	External Source
12 V	Yes	12 V	500 mA	LDO
3.3 V	Yes	3.3 V	100 mA	LDO

Copyright © 2017, Texas Instruments Incorporated

4 EVM Design Documents

This section contains the EVM board layouts, schematics, and bill of materials (BOM).

4.1 TPA3221 Board Layouts

Figure 9 and Figure 10 illustrate the EVM board layouts.

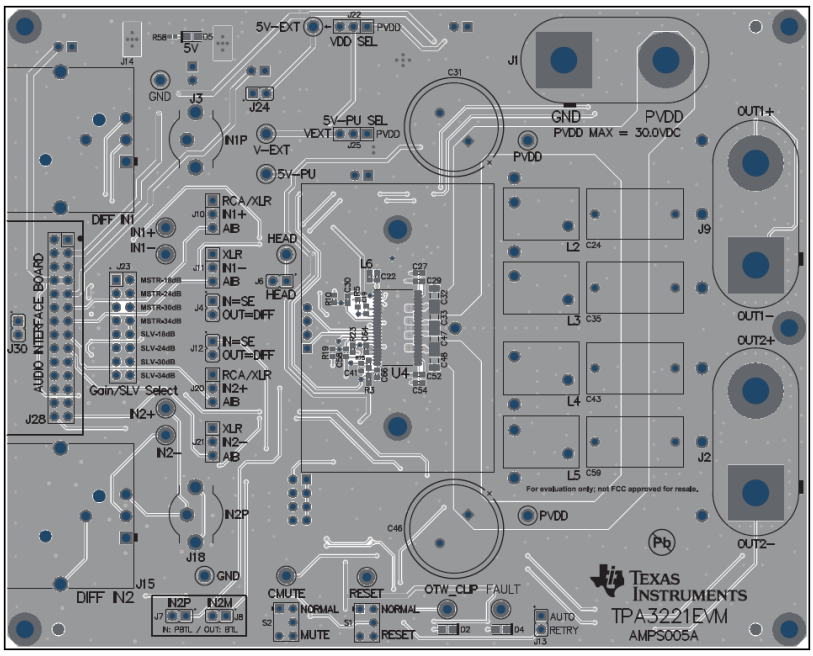


Figure 9. TPA3221 EVM Top Composite Assembly

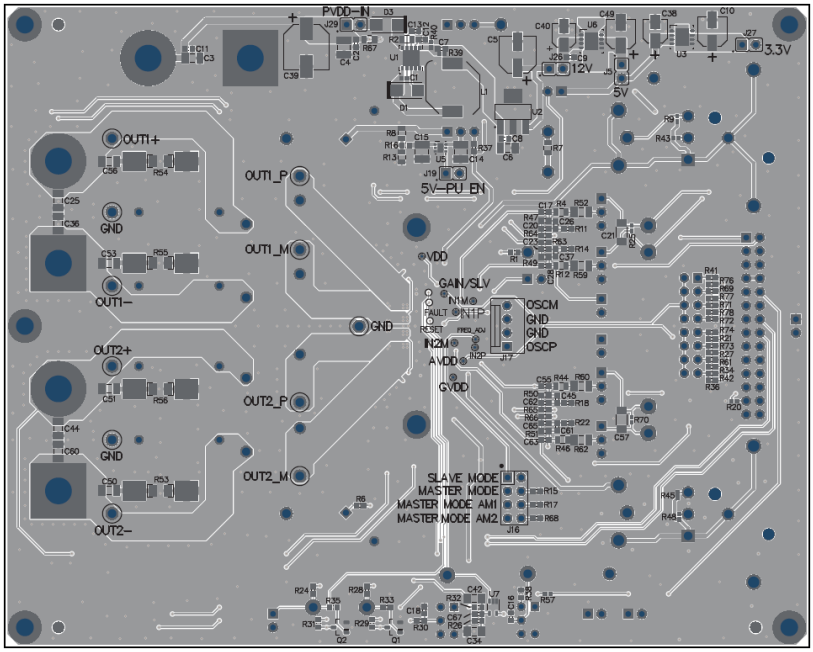


Figure 10. TPA3221 EVM Bottom Composite Assembly

Copyright © 2017, Texas Instruments Incorporated

4.2 TPA3221 Board Layouts

Figure 11 shows the EVM board dimensions.

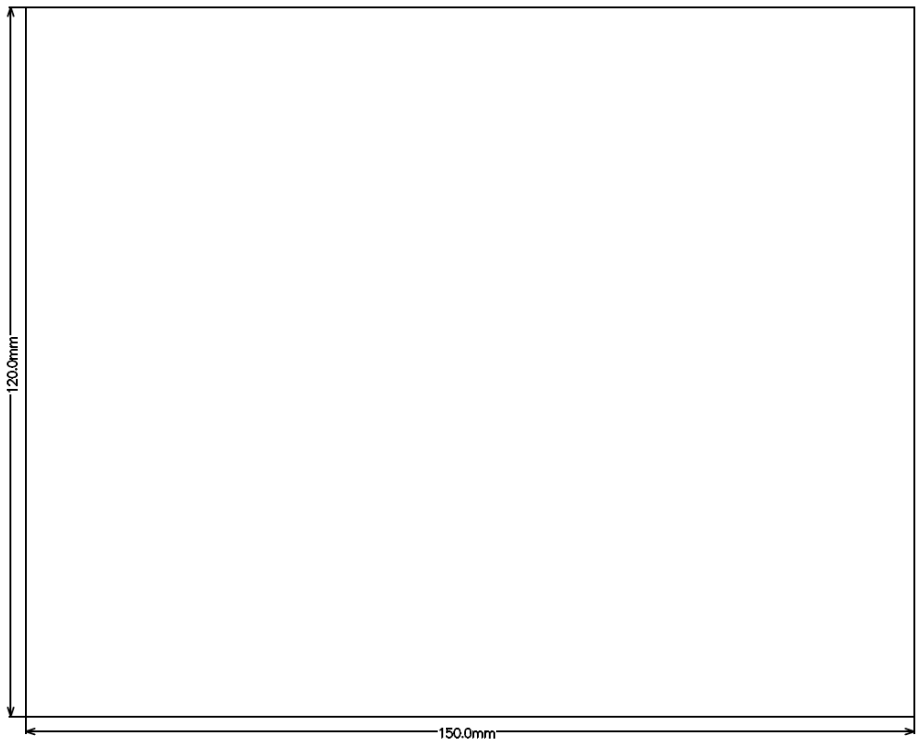


Figure 11. TPA3221 EVM Board Dimensions

Copyright © 2017, Texas Instruments Incorporated

4.3 TPA3221 EVM Schematics

Figure 12 through Figure 14 illustrate the TPA3221 EVM schematics.

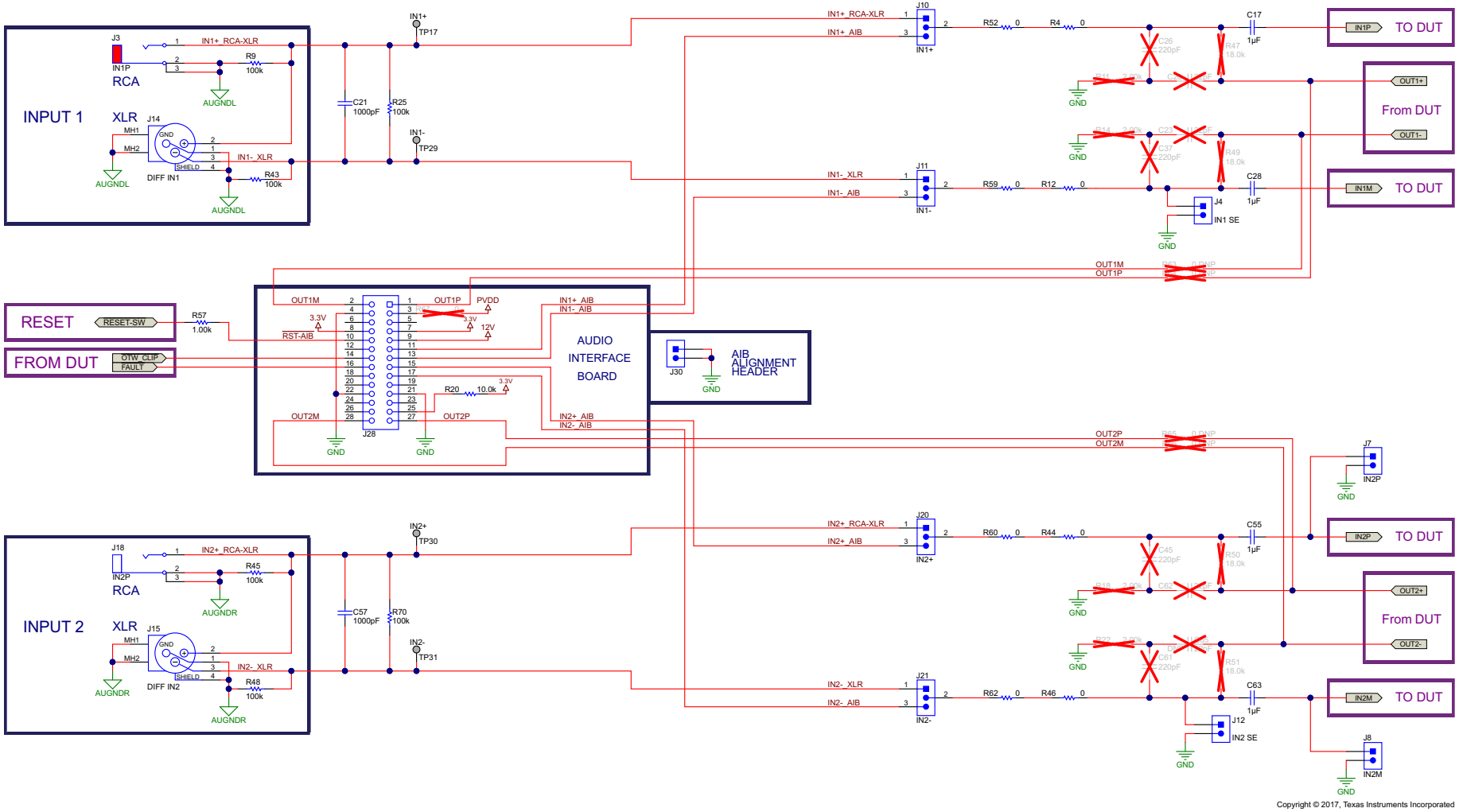


Figure 12. TPA3221 EVM Schematic 1

Copyright © 2017, Texas Instruments Incorporated

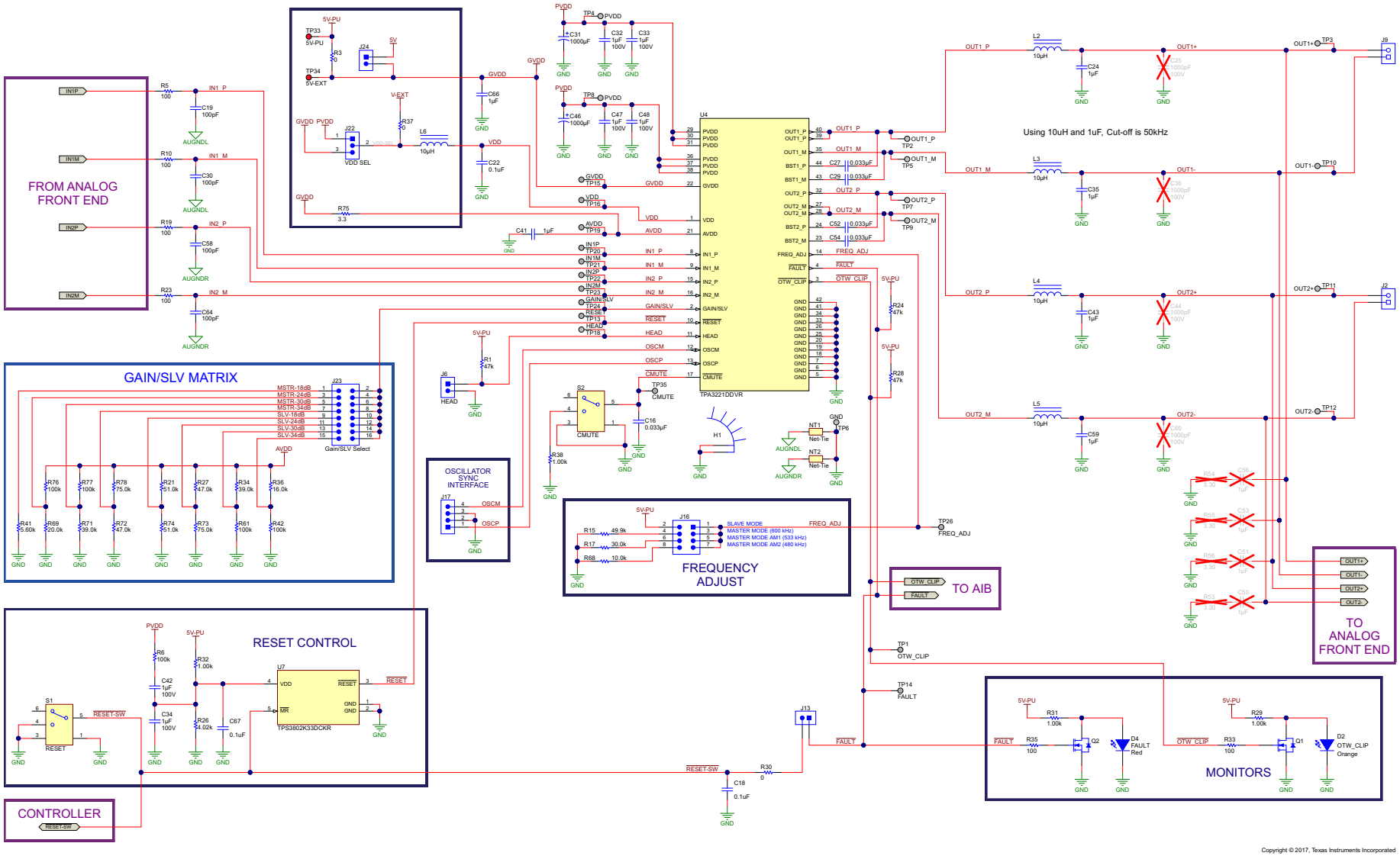
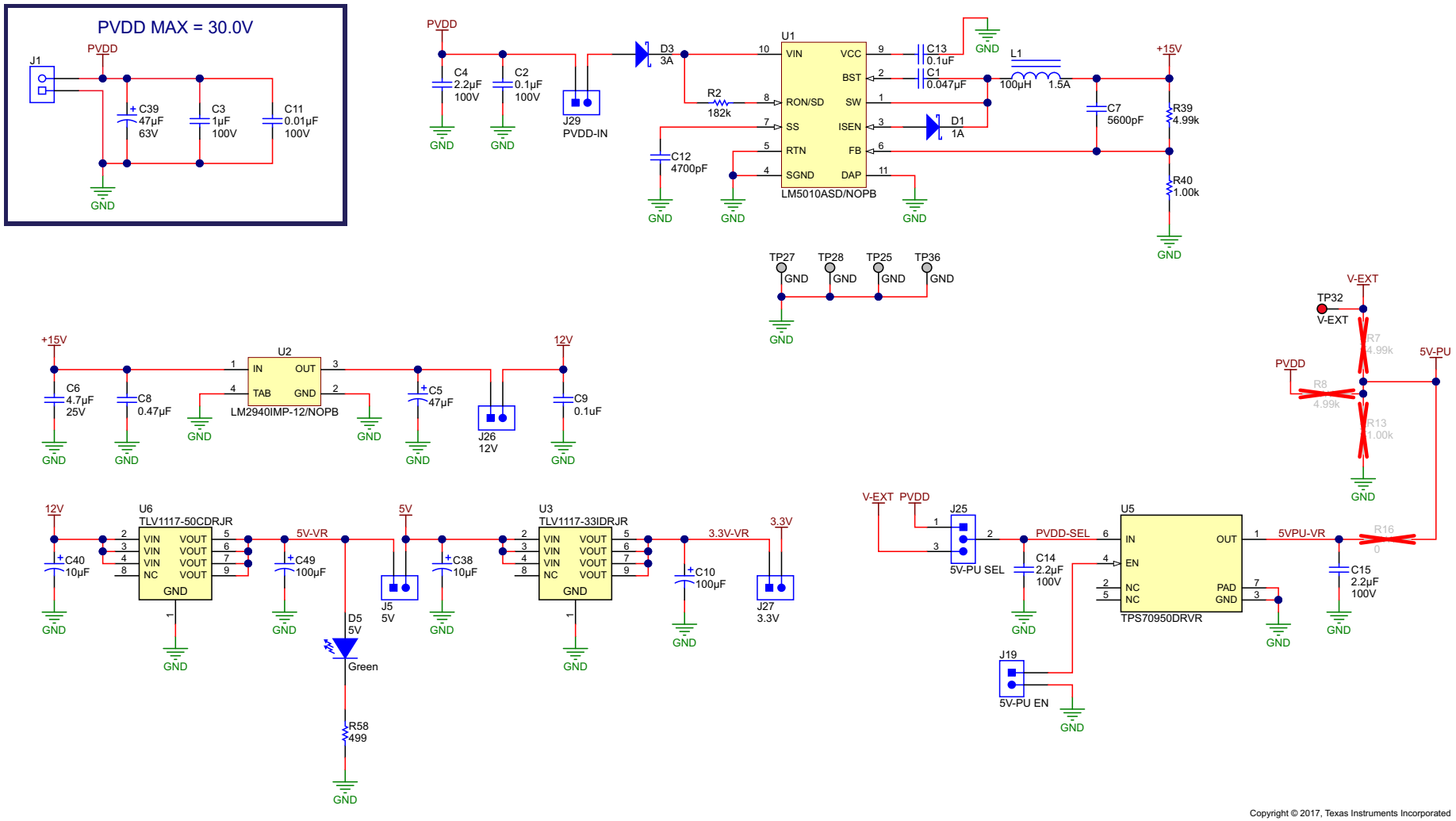


Figure 13. TPA3221 EVM Schematic 2

Copyright © 2017, Texas Instruments Incorporated



Copyright © 2017, Texas Instruments Incorporated

Figure 14. TPA3221 EVM Schematic 3

Copyright © 2017, Texas Instruments Incorporated

4.4 TPA3221EVM Bill of Materials

Table 10 lists the TPA3221 EVM BOM.

Table 10. TPA3221EVM Bill of Materials(1)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
!PCB1	1		Printed Circuit Board		AMPS005	Any
C1	1	0.047uF	CAP, CERM, 0.047 µF, 25 V, +/- 10%, X7R, 0402	0402	GRM155R71E473KA88D	Murata
C2	1	0.1uF	CAP, CERM, 0.1 µF, 100 V, +/- 10%, X7R, 0603	0603	GRM188R72A104KA35J	Murata
C3, C32, C33, C34, C42, C47, C48	7	1uF	CAP, CERM, 1 µF, 100 V, +/- 10%, X7R, 1206	1206	GRM31CR72A105KA01L	Murata
C4, C14, C15	3	2.2uF	CAP, CERM, 2.2 µF, 100 V, +/- 10%, X7R, 1210	1210	C1210C225K1RACTU	Kemet
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	1	0.47uF	CAP, CERM, 0.47 µF, 25 V, +/- 10%, X7R, 0603	0603	GRM188R71E474KA12D	Murata
C9, C13, C18, C22, C67	5	0.1uF	CAP, CERM, 0.1 µF, 50 V, +/- 10%, X7R, 0603	0603	C0603C104K5RACTU	Kemet
C10, C49	2	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, 100 V, +/- 10%, X7R, 0603	0603	06031C103KAT2A	AVX
C12	1	4700pF	CAP, CERM, 4700 pF, 50 V, +/- 10%, X7R, 0603	0603	C0603X472K5RACTU	Kemet
C16, C27, C29, C52, C54	5	0.033uF	CAP, CERM, 0.033 µF, 25 V, +/- 10%, X7R, 0603	0603	GRM188R71E333KA01D	Murata
C17, C28, C41, C55, C63, C66	6	1uF	CAP, CERM, 1 µF, 16 V, +/- 10%, X7R, 0603	0603	GRM188R71C105KA12D	Murata
C19, C30, C58, C64	4	100pF	CAP, CERM, 100 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	GRM1885C1H101JA01D	Murata
C21, C57	2	1000pF	CAP, CERM, 1000 pF, 500 V, +/- 10%, X7R, 1206_190	1206_190	C1206C102KCRACTU	Kemet
C24, C35, C43, C59	4	1uF	CAP, Film, 1 µF, 250 V, +/- 5%, TH	18x9.5x17.5mm	PHE426HB7100JR06	Kemet
C31, C46	2	1000uF	CAP, AL, 1000 µF, 50 V, +/- 20%, 0.034 ohm, AEC-Q200 Grade 2, TH	D16xL25	EEU-FC1H102	Panasonic
C38, C40	2	10uF	CAP, AL, 10 µF, 16 V, +/- 20%, 1.35 ohm, SMD	SMT Radial B	EEE-FK1C100R	Panasonic
C39	1	47uF	CAP, AL, 47 µF, 63 V, +/- 20%, 0.65 ohm, SMD	SMT Radial F	EEE-FK1J470P	Panasonic
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	1	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 5mm	Screw M3 Phillips head	MPMS 003 0005 PH	B&F Fastener Supply
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
J3	1		RCA Jack, Vertical, Red, TH	RCA JACK, RED	RCJ-022	CUI Inc.
J4, J5, J6, J7, J8, J12, J13, J19, J24, J26, J27, J29, J30	13		Header, 100mil, 2x1, Gold, TH	Sullins 100mil, 1x2, 230 mil above insulator	PBC02SAAN	Sullins Connector Solutions
J10, J11, J20, J21, J22, J25	6		Header, 100mil, 3x1, Gold, TH	PBC03SAAN	PBC03SAAN	Sullins Connector Solutions

(1) Unless otherwise noted in the alternate part number or alternate manufacturer columns, all parts may be substituted with equivalents.

Copyright © 2017, Texas Instruments Incorporated

Table 10. TPA3221EVM Bill of Materials[(1)] (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
J14, J15	2		Receptacle, 160mil, 3 Position, R/A, TH	Receptacle, 160mil, 3 Position, R/A, TH	PQG3FRA112	Switchcraft
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.
J23	1		Header, 100mil, 8x2, Gold, TH	PBC08DAAN	PBC08DAAN	Sullins Connector Solutions
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, 10 µH, 4.6 A, 0.0234 ohm, TH	14x9.6mm	7G14J-100M-R	Sagami Elec Co Ltd
L6	1	10uH	Inductor, Wirewound, 10 µH, 0.08 A, 0.36 ohm, SMD	0603	GLFR1608T100M-LR	TDK
Q1, Q2	2	60V	MOSFET, N-CH, 60 V, 0.17 A, SOT-23	SOT-23	2N7002-7-F	Diodes Inc.
R1, R24, R28	3	47k	RES, 47 k, 5%, 0.1 W, 0603	0603	RC0603JR-0747KL	Yageo America
R2	1	182k	RES, 182 k, 1%, 0.125 W, 0805	0805	ERJ-6ENF1823V	Panasonic
R3, R30, R37	3	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
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, R42, R61, R76, R77	5	100k	RES, 100 k, 1%, 0.1 W, 0603	0603	CRCW0603100KFKEA	Vishay-Dale
R9, R25, R43, R45, R48, R70	6	100k	RES, 100 k, 1%, 0.063 W, 0402	0402	CRCW0402100KFKED	Vishay-Dale
R15	1	49.9k	RES, 49.9 k, 1%, 0.1 W, 0603	0603	RC0603FR-0749K9L	Yageo America
R17	1	30.0k	RES, 30.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0730KL	Yageo America
R20	1	10.0k	RES, 10.0 k, 1%, 0.1 W, 0402	0402	ERJ-2RKF1002X	Panasonic
R21, R74	2	51.0k	RES, 51.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0751KL	Yageo America
R26	1	4.02k	RES, 4.02 k, 1%, 0.1 W, 0603	0603	CRCW06034K02FKEA	Vishay-Dale
R27, R72	2	47.0k	RES, 47.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0747KL	Yageo America
R29, R31, R32, R38	4	1.00k	RES, 1.00 k, 1%, 0.1 W, 0603	0603	CRCW06031K00FKEA	Vishay-Dale
R34, R71	2	39.0k	RES, 39.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0739KL	Yageo America
R36	1	16.0k	RES, 16.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0716KL	Yageo America
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
R41	1	5.60k	RES, 5.60 k, 1%, 0.1 W, 0603	0603	RC0603FR-075K6L	Yageo America
R52, R59, R60, R62	4	0	RES, 0, 5%, 0.25 W, 1206	1206	CRCW12060000Z0EA	Vishay-Dale
R57	1	1.00k	RES, 1.00 k, 1%, 0.1 W, 0402	0402	ERJ-2RKF1001X	Panasonic
R58	1	499	RES, 499, 1%, 0.063 W, 0402	0402	CRCW0402499RFKED	Vishay-Dale
R68	1	10.0k	RES, 10.0 k, 1%, 0.1 W, 0603	0603	CRCW060310K0FKEA	Vishay-Dale
R69	1	20.0k	RES, 20.0 k, 1%, 0.1 W, 0603	0603	CRCW060320K0FKEA	Vishay-Dale
R73, R78	2	75.0k	RES, 75.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0775KL	Yageo America
R75	1	3.3	RES, 3.3, 5%, 0.1 W, 0603	0603	CRCW06033R30JNEA	Vishay-Dale
S1, S2	2		Switch, SPDT, On-On, 2 Pos, TH	Switch, 7x4.5mm	200USP1T1A1M2RE	E-Switch

Copyright © 2017, Texas Instruments Incorporated

Table 10. TPA3221EVM Bill of Materials[(1)] (continued)

Designator	QTY	Value	Description	Package Reference	Part Number	Manufacturer
SH1, SH2, SH3, SH4, SH5, SH6, SH7, SH8, SH9, SH10, SH11, SH12, SH13, SH14, SH15, SH16, SH17, SH18, SH19, SH20	20	1x2	Shunt, 100mil, Gold plated, Black	Shunt	969102-0000-DA	3M
TP1, TP13, TP14, TP17, TP29, TP30, TP31, TP35	8		Test Point, Compact, Grey, TH	TestPoint, Grey, 220mil, TH	5123	Keystone
TP2, TP3, TP4, TP5, TP6, TP7, TP8, TP9, TP10, TP11, TP12, TP18, TP25, TP27, TP28, TP36	16		Test Point, Multipurpose, Grey, TH	Grey Multipurpose Testpoint	5128	Keystone
TP32	1		Test Point, Compact, Red, TH	Red Compact Testpoint	5005	Keystone
TP33, TP34	2		Test Point, Multipurpose, Red, TH	Red Multipurpose Testpoint	5010	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		LDO with 4.7 to 15 V Input and 3.3 V Output, -40 to 125 degC, 8-Pin SON (DRJ), Green (RoHS & no Sb/Br)	DRJ0008A	TLV1117-33IDRJR	Texas Instruments
U4	1		100-W Stereo, 200-W Mono HD-Audio, Analog-Input, Class-D Amplifier, DDV0044D (TSSOP-44)	DDV0044D	TPA3221DDVR	Texas Instruments
U5	1		150-mA, 30-V, Ultra-Low IQ, Wide Input Low-Dropout Regulator with Reverse Current Protection, DRV0006A (WSON-6)	DRV0006A	TPS70950DRVR	Texas Instruments
U6	1		LDO with 6.4 to 15 V Input and 5 V Output, 0 to 125 degC, 8-Pin SON (DRJ), Green (RoHS & no Sb/Br)	DRJ0008A	TLV1117-50CDRJR	Texas Instruments
U7	1		ULTRA-SMALL SUPPLY VOLTAGE SUPERVISORS, DCK0005A	DCK0005A	TPS3802K33DCKR	Texas Instruments
C20, C23, C62, C65	0	22pF	CAP, CERM, 22 pF, 50 V, +/- 5%, C0G/NP0, 0603	0603	GRM1885C1H220JA01D	Murata
C25, C36, C44, C60	0	1000pF	CAP, CERM, 1000 pF, 100 V, +/- 5%, C0G/NP0, 1206	1206	12061A102JAT2A	AVX
C26, C37, C45, C61	0	220pF	CAP, CERM, 220 pF, 50 V,+/- 5%, C0G/NP0, 0603	0603	GRM1885C1H221JA01D	Murata
C50, C51, C53, C56	0	1uF	CAP, CERM, 1 µF, 50 V, +/- 10%, X7R, 1206	1206	GRM31MR71H105KA88L	Murata
FID1, FID2, FID3, FID4, FID5, FID6	0		Fiducial mark. There is nothing to buy or mount.	N/A	N/A	N/A
R7, R8	0	4.99k	RES, 4.99 k, 1%, 0.125 W, 0805	0805	CRCW08054K99FKEA	Vishay-Dale
R11, R14, R18, R22	0	2.00k	RES, 2.00 k, 1%, 0.1 W, 0603	0603	CRCW06032K00FKEA	Vishay-Dale
R13	0	1.00k	RES, 1.00 k, 1%, 0.125 W, 0805	0805	CRCW08051K00FKEA	Vishay-Dale
R16, R63, R64, R65, R66	0	0	RES, 0, 5%, 0.1 W, 0603	0603	CRCW06030000Z0EA	Vishay-Dale
R47, R49, R50, R51	0	18.0k	RES, 18.0 k, 1%, 0.1 W, 0603	0603	RC0603FR-0718KL	Yageo America
R53, R54, R55, R56	0	3.30	RES, 3.30, 1%, 0.25 W, 1206	1206	ERJ-8RQF3R3V	Panasonic
R67	0	0	RES, 0, 5%, 0.125 W, 0805	0805	ERJ-6GEY0R00V	Panasonic

Copyright © 2017, Texas Instruments Incorporated

Revision History

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

Changes from A Revision (October 2017) to B Revision	Page
• Device status has changed from ADVANCE INFORMATION to production data.	1

Copyright © 2017, Texas Instruments Incorporated

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.

【無線電波を送信する製品の開発キットをお使いになる際の注意事項】 開発キットの中には技術基準適合証明を受けていないものがあります。 技術適合証明を受けていないもののご使用に際しては、電波法遵守のため、以下のいずれかの措置を取っていただく必要がありますのでご注意ください。

1. 電波法施行規則第6条第1項第1号に基づく平成18年3月28日総務省告示第173号で定められた電波暗室等の試験設備でご使用いただく。
2. 実験局の免許を取得後ご使用いただく。
3. 技術基準適合証明を取得後ご使用いただく。

なお、本製品は、上記の「ご使用にあたっての注意」を譲渡先、移転先に通知しない限り、譲渡、移転できないものとします。

上記を遵守頂けない場合は、電波法の罰則が適用される可能性があることをご留意ください。 日本テキサス・インスツルメンツ株式会社

東京都新宿区西新宿６丁目２４番１号

西新宿三井ビル

3.3.3 *Notice for EVMs for Power Line Communication:* Please see http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

電力線搬送波通信についての開発キットをお使いになる際の注意事項については、次のところをご覧ください。http://www.tij.co.jp/lsds/ti_ja/general/eStore/notice_02.page

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.

   6.2 EXCEPT FOR THE LIMITED RIGHT TO USE THE EVM SET FORTH HEREIN, NOTHING IN THESE TERMS SHALL BE CONSTRUED AS GRANTING OR CONFERRING ANY RIGHTS BY LICENSE, PATENT, OR ANY OTHER INDUSTRIAL OR INTELLECTUAL PROPERTY RIGHT OF TI, ITS SUPPLIERS/LICENSORS OR ANY OTHER THIRD PARTY, TO USE THE EVM IN ANY FINISHED END-USER OR READY-TO-USE FINAL PRODUCT, OR FOR ANY INVENTION, DISCOVERY OR IMPROVEMENT, REGARDLESS OF WHEN MADE, CONCEIVED OR ACQUIRED.

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:*

   8.1 *General Limitations*. IN NO EVENT SHALL TI BE LIABLE FOR ANY SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL, OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF THESE TERMS OR THE USE OF THE EVMS , REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. EXCLUDED DAMAGES INCLUDE, BUT ARE NOT LIMITED TO, COST OF REMOVAL OR REINSTALLATION, ANCILLARY COSTS TO THE PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES, RETESTING, OUTSIDE COMPUTER TIME, LABOR COSTS, LOSS OF GOODWILL, LOSS OF PROFITS, LOSS OF SAVINGS, LOSS OF USE, LOSS OF DATA, OR BUSINESS INTERRUPTION. NO CLAIM, SUIT OR ACTION SHALL BE BROUGHT AGAINST TI MORE THAN TWELVE (12) MONTHS AFTER THE EVENT THAT GAVE RISE TO THE CAUSE OF ACTION HAS OCCURRED.

   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.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2017, Texas Instruments Incorporated

IMPORTANT NOTICE FOR TI DESIGN INFORMATION AND RESOURCES

Texas Instruments Incorporated ('TI") technical, application or other design advice, services or information, including, but not limited to, reference designs and materials relating to evaluation modules, (collectively, "TI Resources") are intended to assist designers who are developing applications that incorporate TI products; by downloading, accessing or using any particular TI Resource in any way, you (individually or, if you are acting on behalf of a company, your company) agree to use it solely for this purpose and subject to the terms of this Notice.

TI's provision of TI Resources does not expand or otherwise alter TI's applicable published warranties or warranty disclaimers for TI products, and no additional obligations or liabilities arise from TI providing such TI Resources. TI reserves the right to make corrections, enhancements, improvements and other changes to its TI Resources.

You understand and agree that you remain responsible for using your independent analysis, evaluation and judgment in designing your applications and that you have full and exclusive responsibility to assure the safety of your applications and compliance of your applications (and of all TI products used in or for your applications) with all applicable regulations, laws and other applicable requirements. You represent that, with respect to your applications, you have all the necessary expertise to create and implement safeguards that (1) anticipate dangerous consequences of failures, (2) monitor failures and their consequences, and (3) lessen the likelihood of failures that might cause harm and take appropriate actions. You agree that prior to using or distributing any applications that include TI products, you will thoroughly test such applications and the functionality of such TI products as used in such applications. TI has not conducted any testing other than that specifically described in the published documentation for a particular TI Resource.

You are authorized to use, copy and modify any individual TI Resource only in connection with the development of applications that include the TI product(s) identified in such TI Resource. NO OTHER LICENSE, EXPRESS OR IMPLIED, BY ESTOPPEL OR OTHERWISE TO ANY OTHER TI INTELLECTUAL PROPERTY RIGHT, AND NO LICENSE TO ANY TECHNOLOGY OR INTELLECTUAL PROPERTY RIGHT OF TI OR ANY THIRD PARTY IS GRANTED HEREIN, including but not limited to any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information regarding or referencing third-party products or services does not constitute a license to use such products or services, or a warranty or endorsement thereof. Use of TI Resources 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.

TI RESOURCES ARE PROVIDED "AS IS" AND WITH ALL FAULTS. TI DISCLAIMS ALL OTHER WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, REGARDING TI RESOURCES OR USE THEREOF, INCLUDING BUT NOT LIMITED TO ACCURACY OR COMPLETENESS, TITLE, ANY EPIDEMIC FAILURE WARRANTY AND ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF ANY THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

TI SHALL NOT BE LIABLE FOR AND SHALL NOT DEFEND OR INDEMNIFY YOU AGAINST ANY CLAIM, INCLUDING BUT NOT LIMITED TO ANY INFRINGEMENT CLAIM THAT RELATES TO OR IS BASED ON ANY COMBINATION OF PRODUCTS EVEN IF DESCRIBED IN TI RESOURCES OR OTHERWISE. IN NO EVENT SHALL TI BE LIABLE FOR ANY ACTUAL, DIRECT, SPECIAL, COLLATERAL, INDIRECT, PUNITIVE, INCIDENTAL, CONSEQUENTIAL OR EXEMPLARY DAMAGES IN CONNECTION WITH OR ARISING OUT OF TI RESOURCES OR USE THEREOF, AND REGARDLESS OF WHETHER TI HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES.

You agree to fully indemnify TI and its representatives against any damages, costs, losses, and/or liabilities arising out of your non-compliance with the terms and provisions of this Notice.

This Notice applies to TI Resources. Additional terms apply to the use and purchase of certain types of materials, TI products and services. These include; without limitation, TI's standard terms for semiconductor products http://www.ti.com/sc/docs/stdterms.htm), evaluation modules, and samples (http://www.ti.com/sc/docs/sampterms.htm).

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2017, Texas Instruments Incorporated