eZAudio TPA2015D1 Demonstration Kit

This user's guide describes the operation of the eZAudio TPA2015D1 Demonstration Kit. This document provides setup instructions and design information including schematic, bill of materials, and printed-circuit board (PCB) layout drawings.

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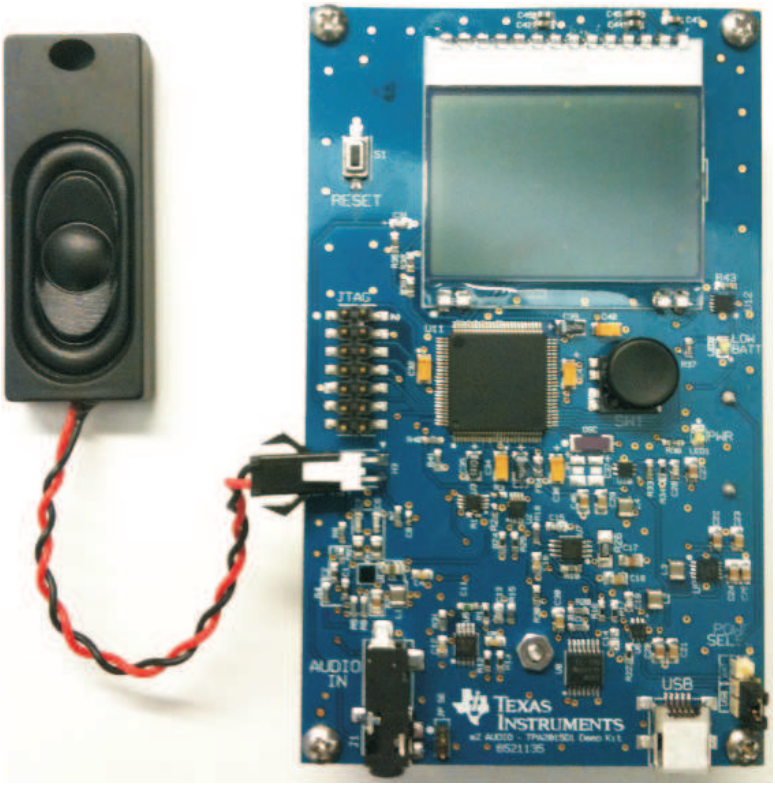
1 Overview

The ezAudio TPA2015D1 demonstration kit is a compact and versatile platform that highlights the TPA2015D1 key features of battery-tracking, SpeakerGuard™ automatic gain control (AGC) and integrated boost converter.

The demonstration kit allows the user to quickly demonstrate the advanced features of the TPA2015D1 via an intuitive LCD-based interface. The user can simulate battery depletion in order to measure the input current and power output performance related to portable applications.

The ezAudio TPA2015D1 can be powered by the included batteries or by a USB connection. Although the demonstration board is not designed for evaluation, the kit does contain a mini PCB that can be used for evaluation purposes.

NOTE: This document presents evaluation module (EVM) specifications, audio performance measurements graphs, and design documentation that includes complete circuit descriptions, schematic diagrams, a parts list, and PCB layout design. Gerber (layout) files are available from the TI Web site at http://www.ti.com.



1.1 Kit Contents

- (1) ezAudio TPA2015D1 demonstration board
- (1) TPA2015D1 WCSP (YZH) mini device
- (1) MP3 player
- (1) 3,5-mm audio cable
- (1) AAA battery
- (3) AA batteries
- (1) 8-Ω speaker
- (1) Quick-start guide cards

If any item is missing, contact the Texas Instruments Product information Center nearest you to inquire about a replacement.

1.2 Evaluation Board Specifications

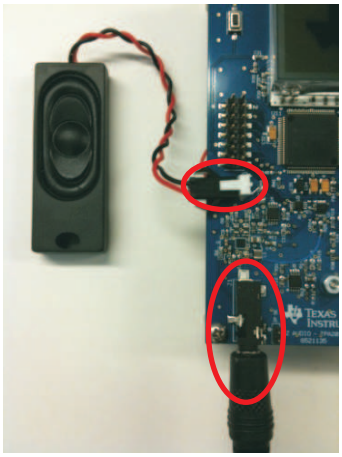
- Board supply voltage: 4.5 Vdc – 5.5 Vdc from one of the following sources:
  - Device USB cable (connected to a personal computer)
  - (3) AA batteries
- Board supply current: 30 mA, typical
- Breakout power output: 5 Vdc (500 mA, maximum)
- Speaker power: 1 W, maximum
- Dimensions: 10.5 cm × 6.5 cm × 2.2 cm (L × W × H)
- RoHS status: n/a

When the evaluation board is used in USB Host mode, the host connector is capable of supplying power to the connected USB device. The available supply current is limited to ~250 mA unless the evaluation board is powered from an external 5-V supply with a ≥ 600 mA rating.

2 Quick-Start Guide

2.1 Powering the Device

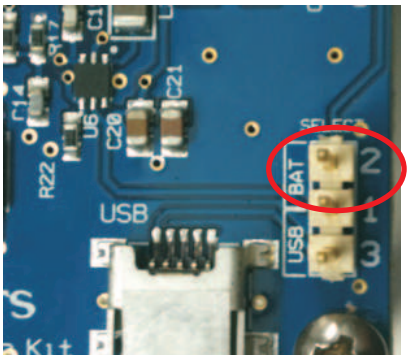
1. **Speaker.** Plug the speaker into the white jack on the left side of the board.
2. **Audio Cable.** Plug 3,5-mm audio cable into the board and MP3 player.



3. **Battery Power.** To turn on the board, move the jumper (bottom right side of board) to the BAT position.

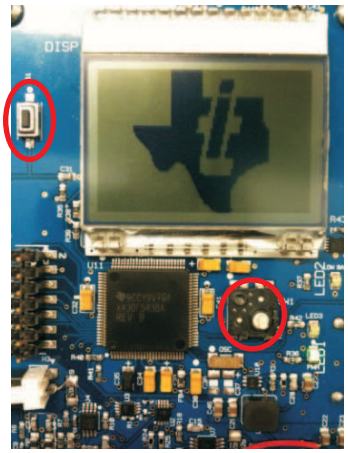
   USB Power (Optional). If batteries are discharged or unavailable, the board can be powered over a USB connection. Move the jumper (bottom right side of board) to USB position.

   Battery Indicator. A low-battery indicator is on the right side of the joystick. The LED turns on when the battery voltage drops below 3.7 V

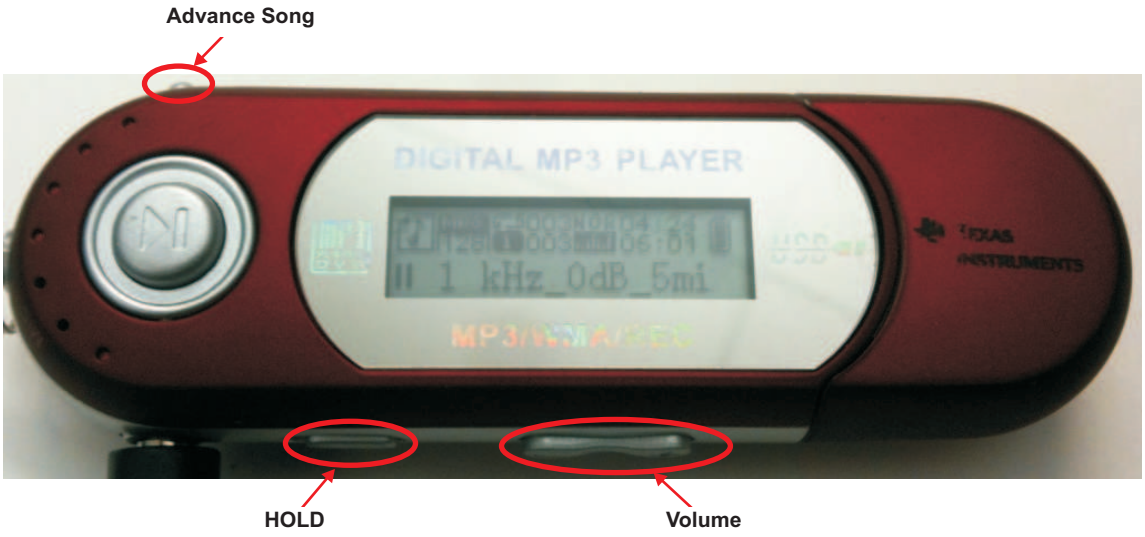


4. **Adjust Contrast.** Click (press down) the joystick button to cycle through different contrast values.

   Reset (Optional). A reset button is located to the left of the screen.



5. **MP3 Player.** To turn on the MP3 player, check that the Hold switch is to the left, and press the Play button. To advance to the next song, move the dial in the upper left corner to the right. To turn off, hold the Play button for 3 seconds.

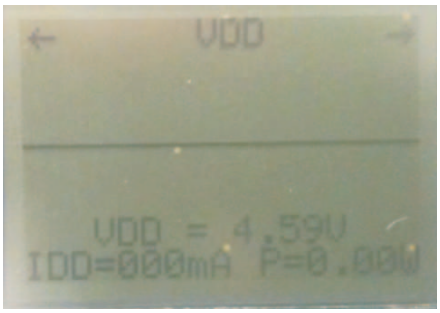


2.2 Running the Demonstration

The device defaults to the following settings when booting up: Gain: 20 dB, AGC: 3.97 V, VDD: 3.60 V, Boost: EN.

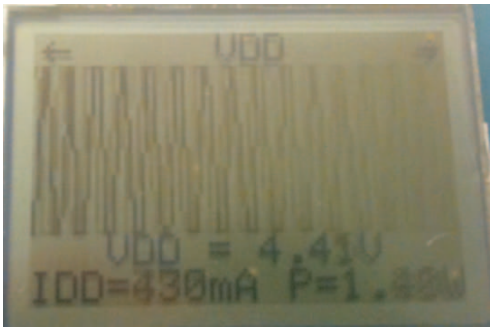
NOTE: The speaker (or similar load) must be connected to the device to ensure proper measurements. To get more steady current and power measurements, use the included sine wave MP3 file.

1. **Joystick.** Raise VDD to maximum by moving the joystick UP.



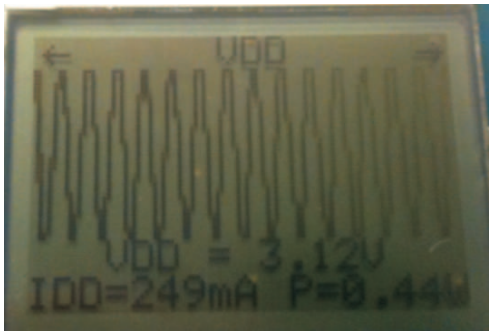
2. **MP3 Player.** Move the dial in the upper left corner to the right to select the sine wave.

3. **MP3 Player.** Increase the volume to 3/4 of maximum. At that volume, the current is approximately 400 mA (sine wave) and the power output approximately1 W.

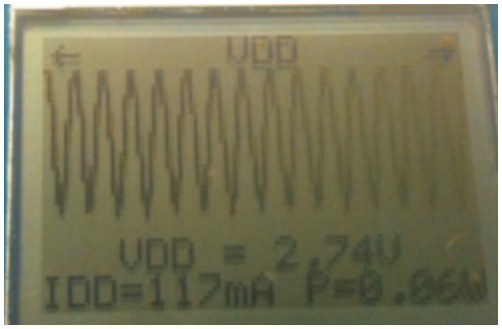


4. **Joystick.** Move the joystick down to bring VDD below the AGC inflection point (<3.97 V). Notice that the current draw (~250 mA) and power output (~0.45 W) decrease.

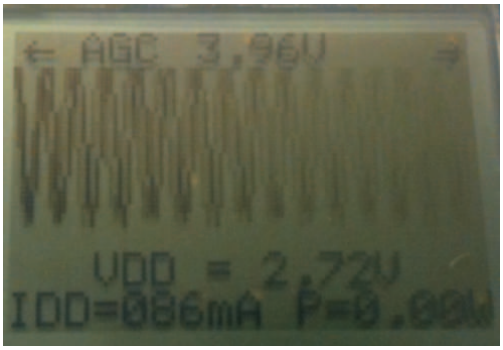
   Explanation. This demonstrates the battery tracking feature of the TPA2015D1. When the battery voltage reaches the AGC threshold, the TPA2015D1 begins to reduce automatically the gain in order to save battery life and protect the speaker.



5. **Joystick.** Move the joystick down twice to decrease the battery voltage. The current and power continue to decrease.

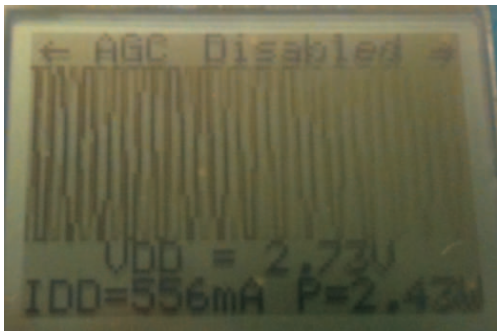


6. **Joystick.** Move the joystick to the right until you see AGC on the top menu bar.

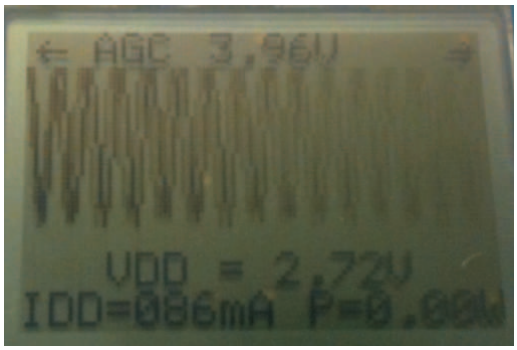


7. **Joystick.** Move the joystick down until the AGC is disabled.

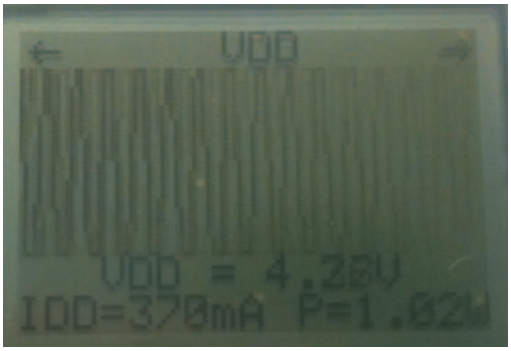
   Explanation. Notice the current draw and power output increase, indicating the device is no longer tracking the battery voltage. The current increases in order to maintain power output. The audio also sounds distorted without AGC enabled.



8. **Joystick.** Move the joystick up until AGC is enabled by choosing one of the three values.

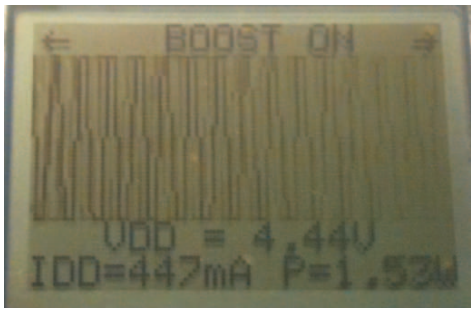


9. **Joystick.** Move the joystick to the right until VDD is displayed again.
10. **Joystick.** Move the joystick UP until VDD is at maximum.

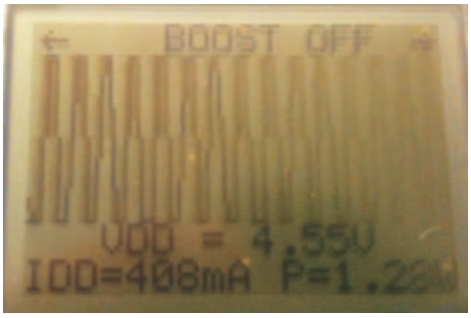


11. **MP3 Player.** Increase the volume of the MP3 player to 100%.

12. **Joystick.** Move the joystick to the right until BOOST is displayed



13. **Joystick.** Move the joystick down to disable the BOOST.



Explanation. When the boost is disabled, the sound is distorted because the signal is clipped at the battery voltage rails. When boost is enabled, the increased headroom for the output swing significantly reduces clipping.

3 Hardware Description

3.1 TPA2015D1 Features

2-W constant output, mono Class-D audio amplifier with integrated boost converter and battery tracking SpeakerGuard™ AGC

Features

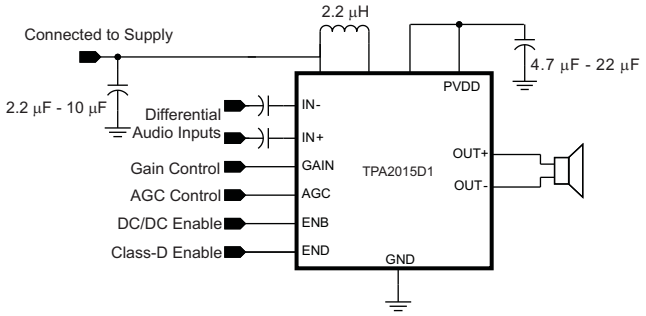
- 2 V into 8 Ω at 3.6 V (6% THD)
- Constant output power of 2 W (3.6 V – 5 V)
- 2.3-V to 5.2-V supply voltage
- Battery tracking AGC
- Battery tracking SpeakerGuard™
- High efficiency (81%) (at 1 W and 3.6 V
- Very high PSRR - 90 dB
- Ultralow quiescent current (1.7 mA)
- Integrated input low-pass filter
- 2 mm × 2 mm, 0,5-mm pitch, 16-ball WCSP

Applications

- Cell phones/smart phones
- Personal navigation devices
- Notebook PCs
- Portable clocking stations
- Portable DVD players

Benefits

- 36% Louder audio than the leading competition
- Consistent audio loudness across the Li-ion battery
- Direct connection to Li-ion/future battery technologies
- Prevents early shutdown at low-battery voltage (<3 V)
- Protects speakers by preventing clipping
- Eliminates GSM/TDMA frame rate noise
- 27% Better efficiency results in –2x longer battery life
- ~5x Lower quiescent current than the competition
- Rejects out-of-band noise from codec/DAC by 30 dB
- 20% Smaller package size than the competition



4 Schematics, PCB and Bill of Materials

4.1 Schematics

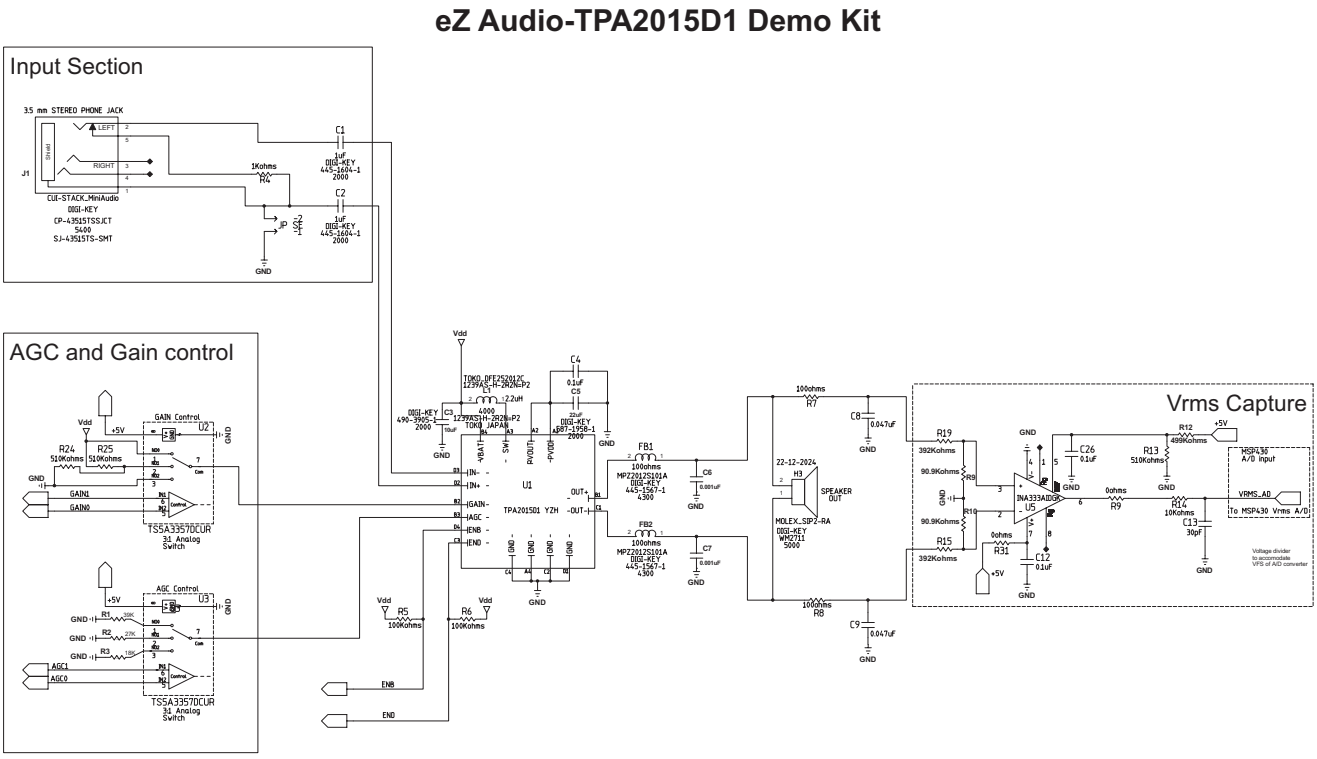


Figure 1. eZAudio TPA2015D1 Demonstration Kit Schematic

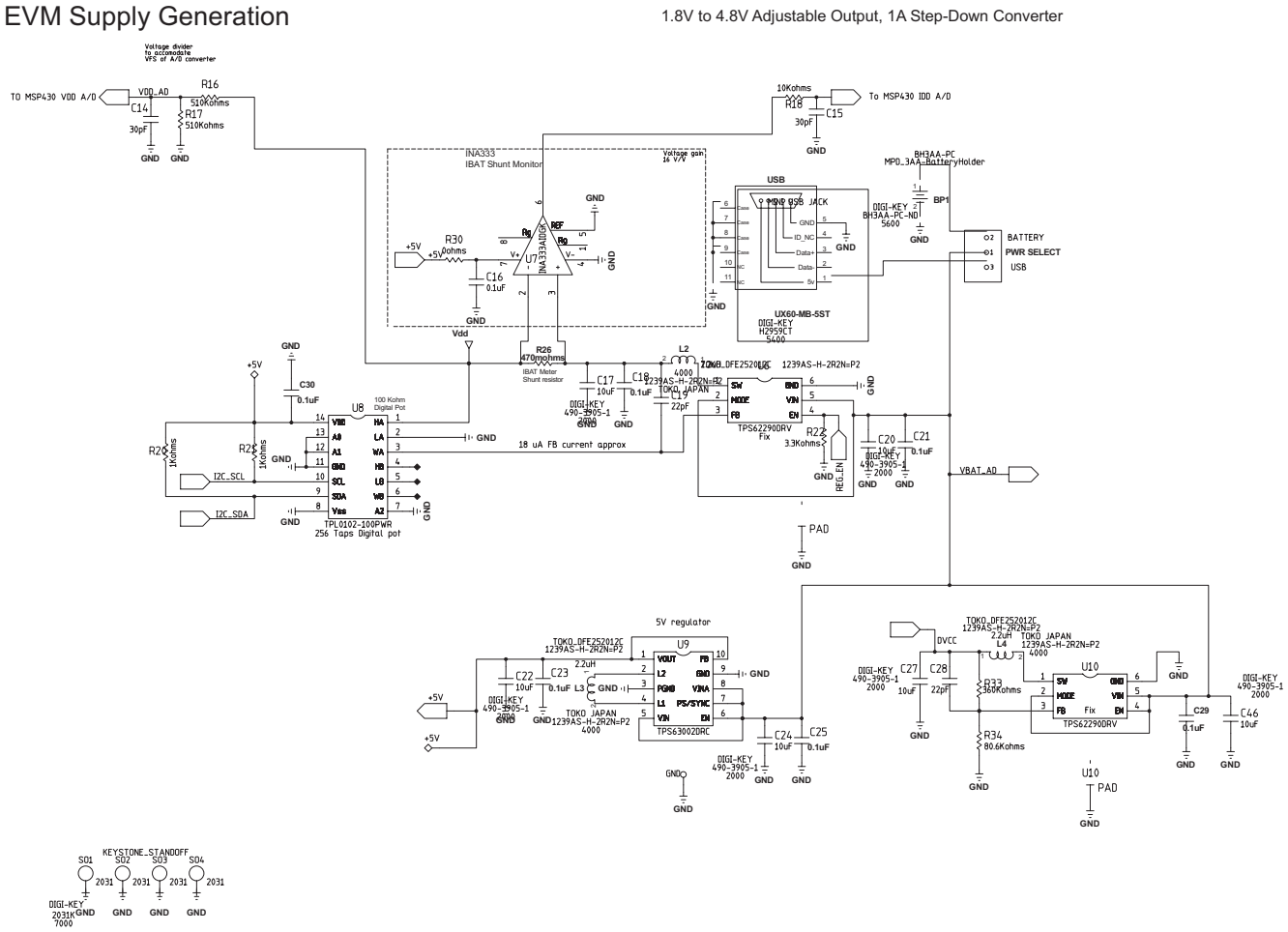


Figure 2. EVM Supply Generation Schematic

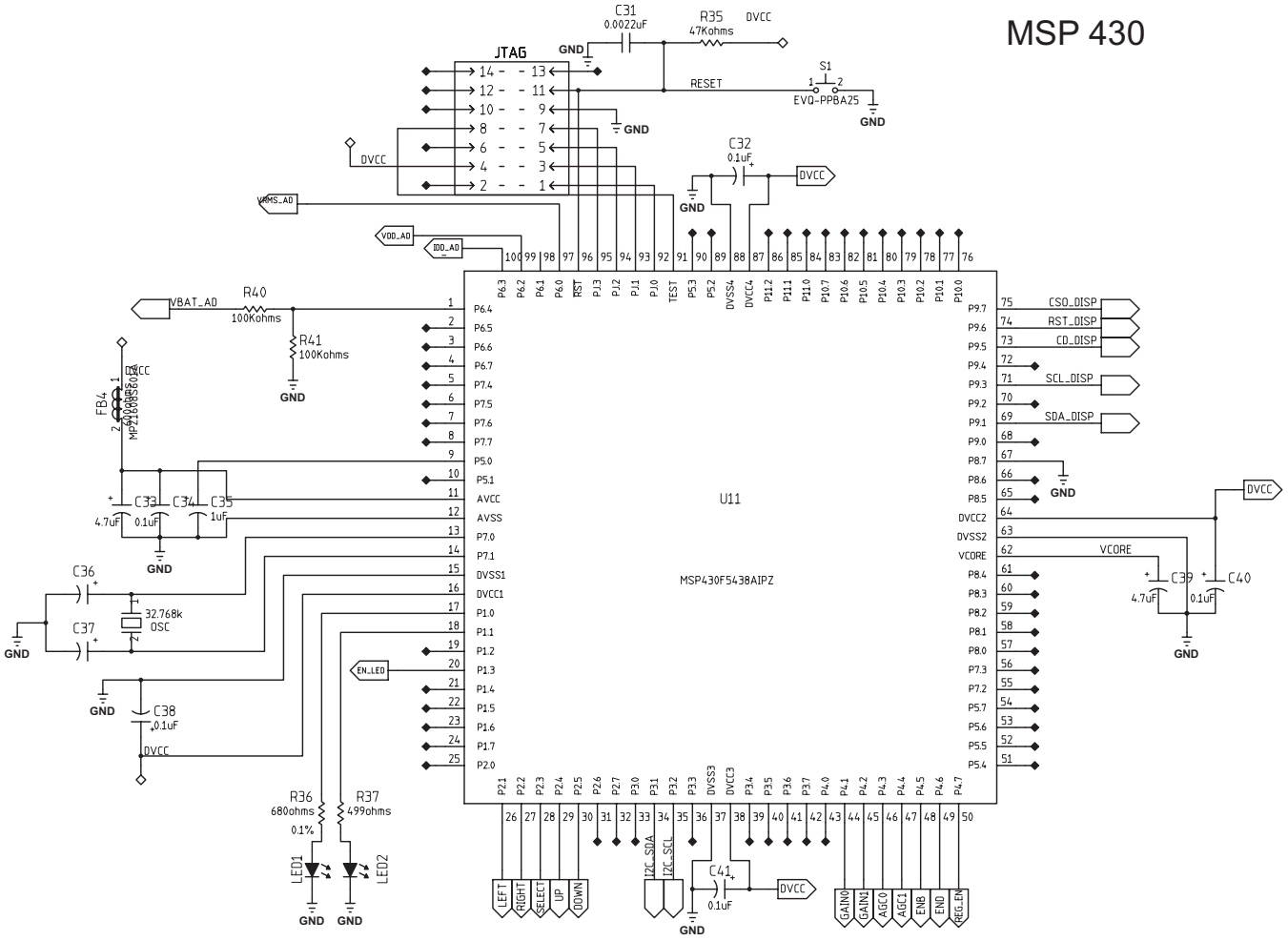


Figure 3. MSP430 Schematic

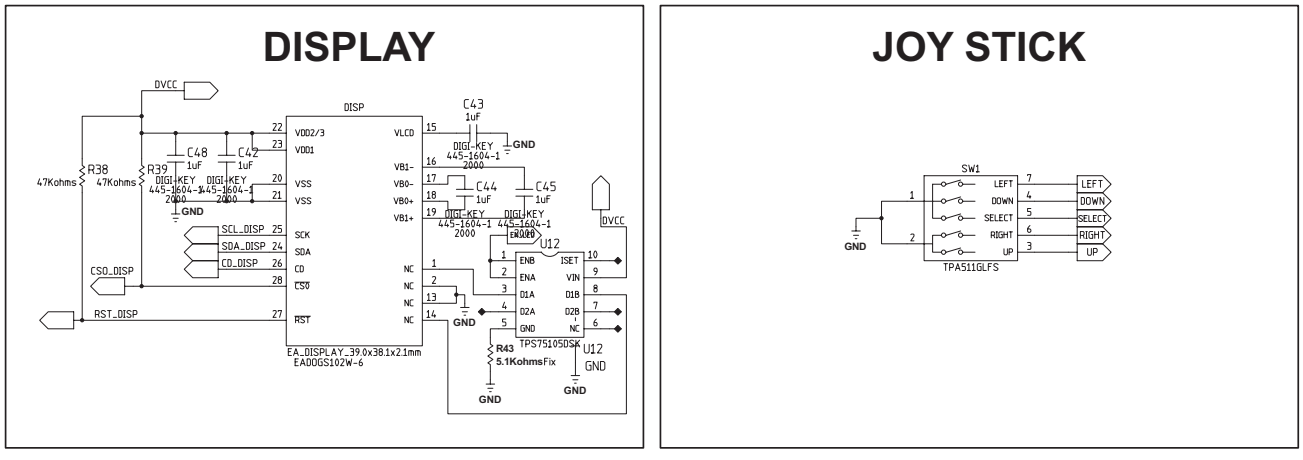


Figure 4. Display and Joystick Schematics

4.2 Printed-Circuit Board

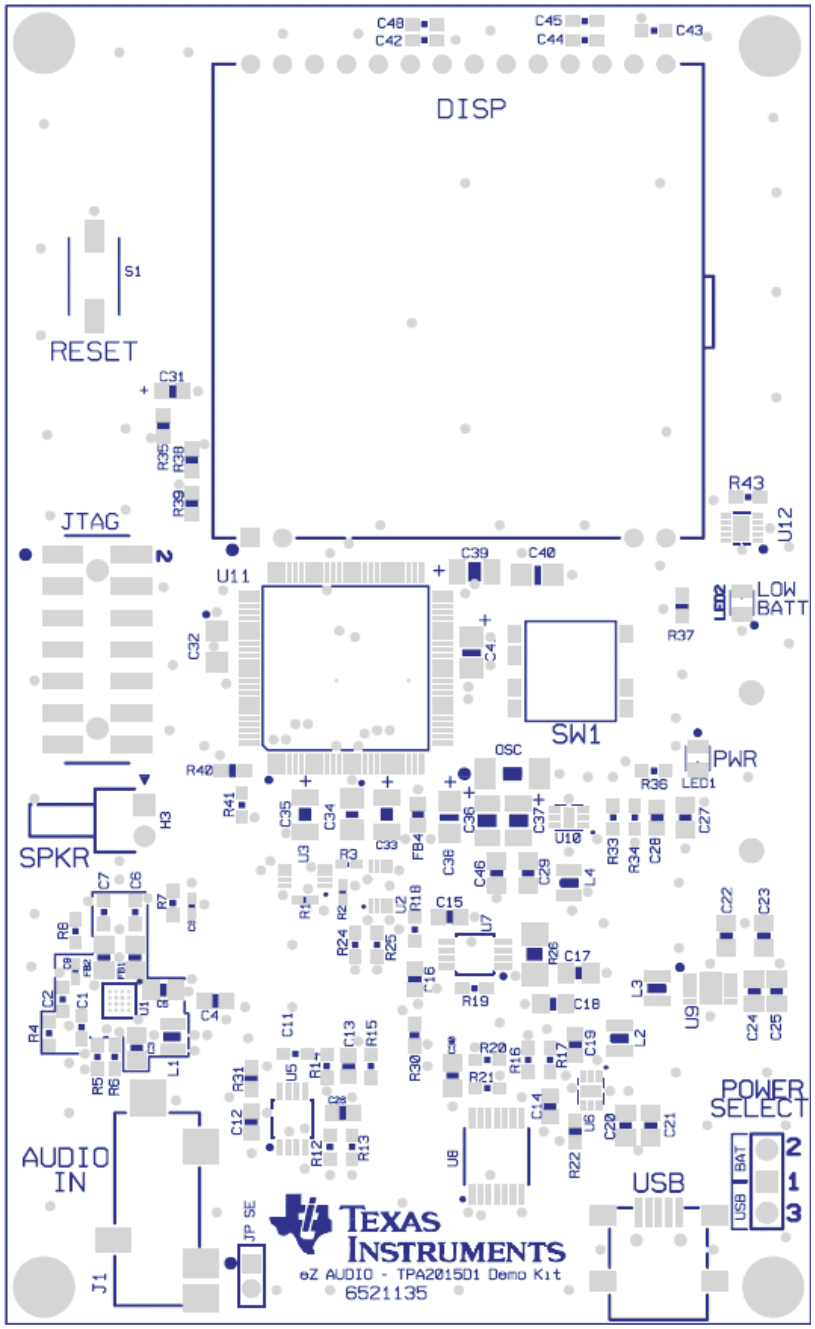


Figure 5. Top Assembly

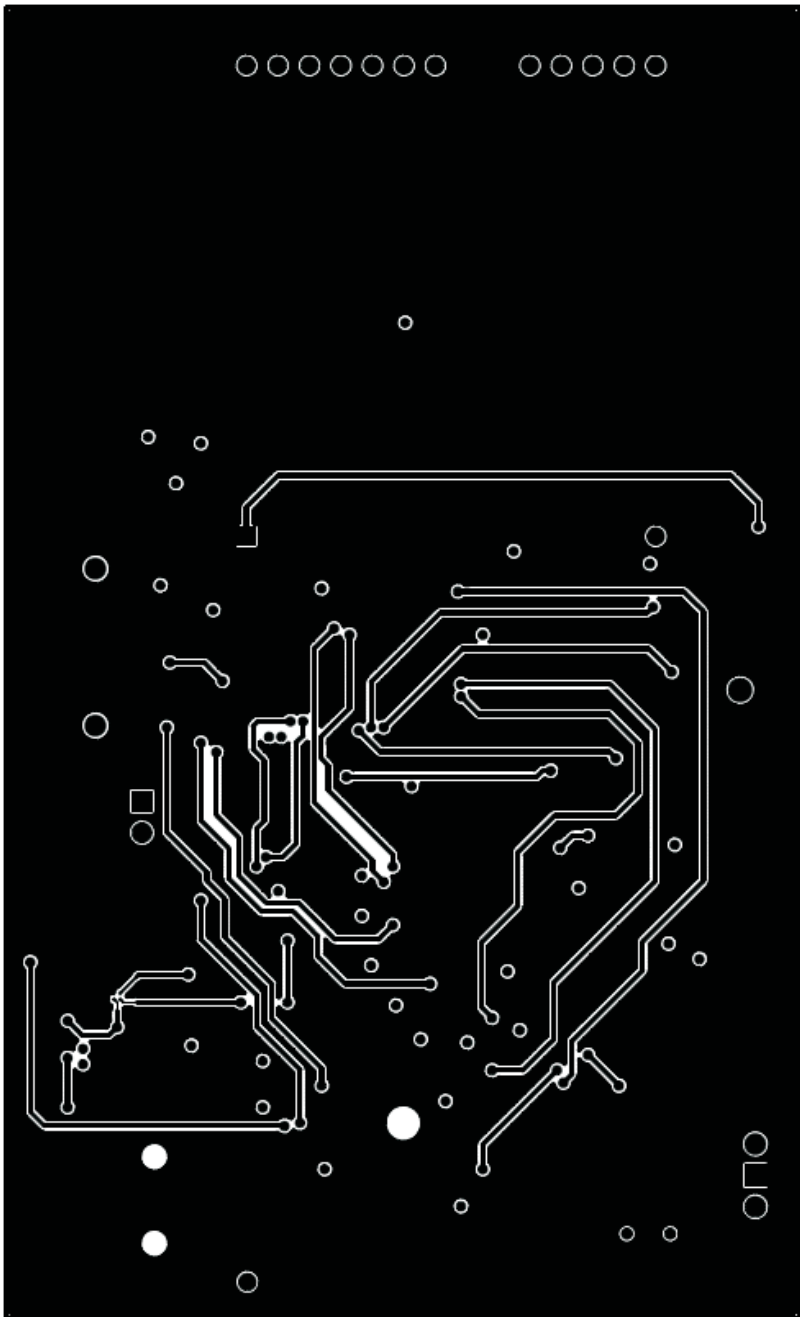


Figure 6. Bottom Copper

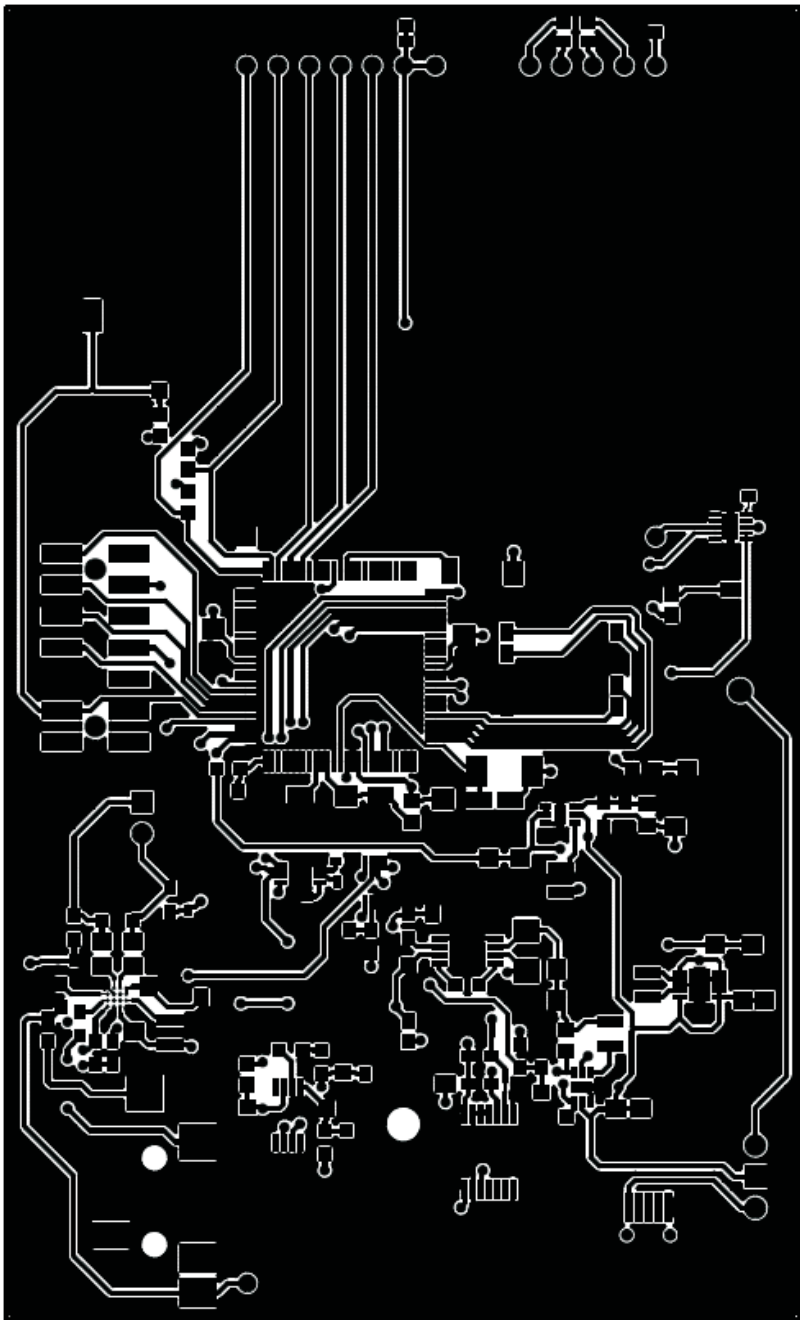


Figure 7. Top Copper

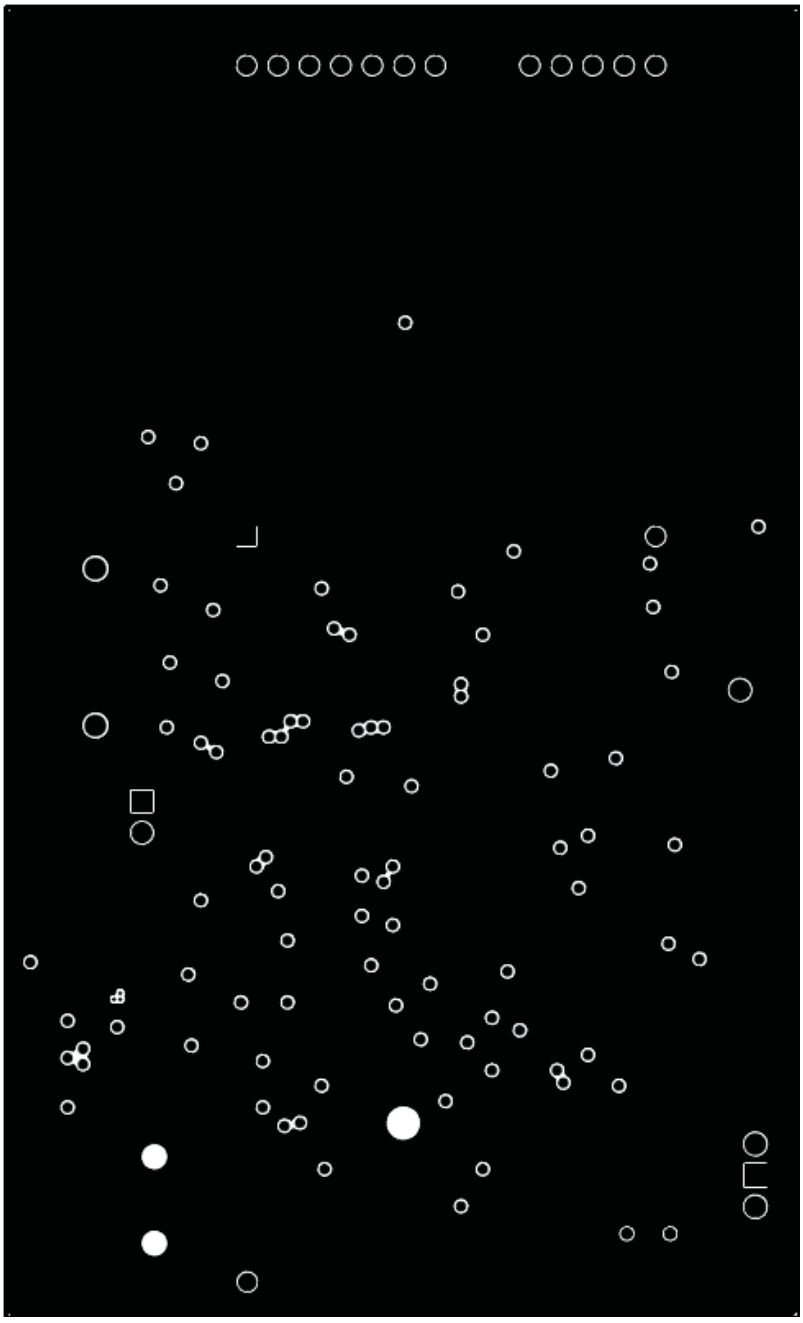


Figure 8. Copper Layer 2

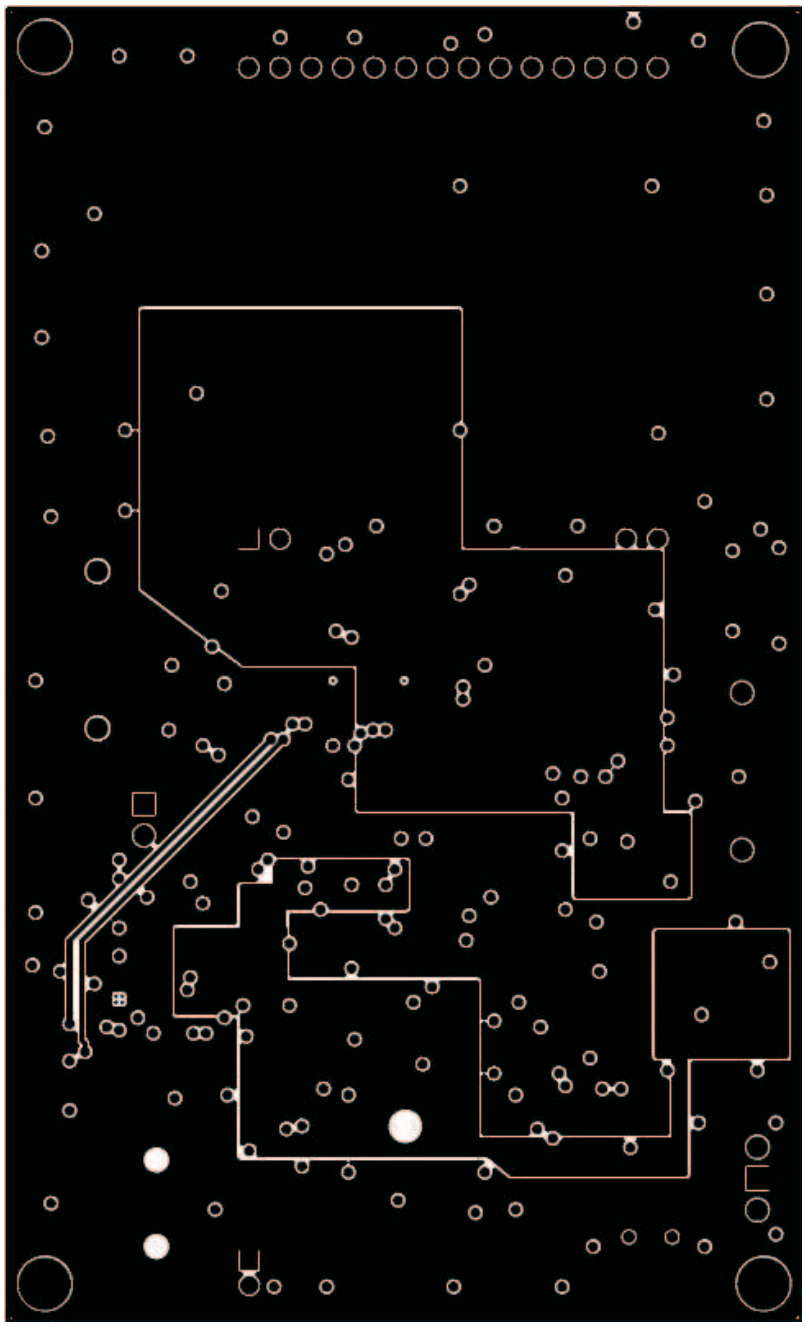


Figure 9. Copper Layer 3

4.3 Bill of Materials

Table 1. Bill of Materials for eZAudio TPA2015D1 Demonstration Kit

Mfr Part No.	Qty	Ref Des	Description	Mfr Name
CAPACITORS				
GRM21BR71A106KE51L	7	C3,C17,C20,C22, C24,C27,C46	CAP SMD0805 CERM 10UFD 10V10% X7R ROHS	MURATA
LMK212BJ226MG-T	1	C5	CAP SMD0805 CERM 22UFD 10V 20% X5R ROHS	TAIYO YUDEN
C1608X7R1C105K	8	C1,C2,C42,C43,C44, C45,C48	CAP SMD0603 CERM 1.0UFD 16V 10% X7R ROHS	TDK
INDUCTORS				
1239AS-H-2R2N=P2	4	L1,L2,L3,L4	INDUCTOR POWER SMD1008 2.2uH RDC=80mOHMS 2.3A DFE252012C ROHS	TOKO JAPAN
MPZ2012S101A	2	FB1,FB2	FERRITE BEAD, 100 Ohms 4A 100MHz SM0805 ROHS	TDK
HEADERS/JACKS				
22-12-2024	1	H3	HEADER THU 2P MALE RA 100LS ROHS	MOLEX
SJ-43515TS-SMT	1	J1	JACK AUDIO MINI(3.5MM 3-COND PCB-RA ROHS	CUI STACK
UX60-MB-5ST	1	USB	JACK USB MINIB SMT-RA 5PIN ROHS	HIROSE
CUSTOM JACKS/CONNECTORS				
BH3AA-PC	1	BP1	BATTERY HOLDER 3 AA TH ROHS	MPD
STANDOFFS AND HARDWARE				
2031	4	SO1,SO2,SO3,SO4	STANDOFF,4-40,1.0INx3/16IN,ALUM RND F-F	KEYSTONE ELECTRONICS
BOM ITEMS WITH NO VALID SORT NUMBER				
C1608C0G1H102J	2	C6,C7	TI JAPAN ONLY CAPACITOR,SMT,0603,CERAMIC,1000pF,50V,5%	TDK
ERJ-2GEJ393	1	R1	RESISTOR,SMT,0402,THICK FILM,5%,1/16W,39K	PANASONIC
ERJ-2GEJ183	1	R3	RESISTOR,SMT,0402,THICK FILM,5%,1/16W,18K	PANASONIC
ERJ-2GEJ273	1	R2	RESISTOR,SMT,0402,THICK FILM,5%,1/16W,27K	PANASONIC
C1005X7R1C473K	2	C8,C9	CAPACITOR,SMT,0402,CER,47000pF,16V,10%,X7R	TDK
CRCW0603100F	2	R7,R8	RESISTOR,SMT,0603,1%,1/10W,100 OHM	VISHAY
CRCW06031001F	3	R4,R20,R21	RESISTOR,SMT,0603,1%,1/10W,1.00K	VISHAY
CRCW06031003F	4	R5,R6,R40,R41	RESISTOR,SMT,0603,1%,1/10W,100K	VISHAY
0603YC104JAT2A	4	C4,C12,C16,C26	CAPACITOR,SMT,0603,CERAMIC,0.1uF,16V,5%,X7R	AVX
2163-02-01-P2	1	JP SE	HEADER,THU,2P,MALE,2mmLS,SINGLE ROW,1x2,15uGOLD,118TL	NORCOMP
DUT_BGA_16YZH	1	U1	DUT,SMT,16P,BGA,0.5mmLS,2.25mmSQ (Customer Supply)	TI
CRCW06031002F	2	R14, R18	RESISTOR,SMT,0603,1%,1/10W,10.0K	VISHAY
C0603C300J5GAC	3	C13,C14,C15	CAPACITOR,SMT,0603,CERAMIC,COG(NPO),50V,5%, 30pF	KEMET
INA333AIDGK	2	U5,U7	LOW-POWER SINGLE-SUPPLY CMOS INSTRUMENT AMPLIFIERS	TI/BURR-BROWN
ERJ-3GSYJ514	5	R13,R16,R17, R24,R25	RESISTOR,SMT,0603,5%,1/10W,510K	PANASONIC
ERJ-3ENF000	2	R30,R31,R9	RESISTOR,SMT,0603,0 OHM,1%,1/10W	PANASONIC
GRM40Y5V104Z25V	6	C18,C21,C23, C25,C29,C30	25V,±20%,.1uF	MURATA
TPL0102-100PWR	1	U8	256 TAPS DUAL CHAN POT W/NVM	TI
VJ0603A220FXAAT	1	C19	CAPACITOR,SMT,0603,CERAMIC,22pF,50V,1%,COG(NPO),30ppm	VISHAY
RL1632R-R470-F	1	R26	RESISTOR,SMT,1206,THIN FILM, 0.47OHM,1%,1/2W	SISUMO
TPS62290DRV	2	U6,U10	1A STEP DOWN CONV ADJ	TI
TPS63002DRC	1	U9	HIGH EFFIC SING INDUC BUCK BOOST CONV W/ 1.8A SW	TI
ERJ-3GSYJ332	1	R22	RESISTOR,SMT,0603,5%,1/10W,3.3K	PANASONIC
MSP430F5438AIPZ	1	U11	MIXED SIGNAL MICROCONTROLLER	TI
GRM39COG220J50V	1	C28	CAPACITOR,SMT,0603,CERAMIC,50V,5%,22pF	MURATA
ERJ-3GSYJ364	1	R33	RESISTOR,SMT,0603,5%,1/10W,360K	PANASONIC
CRCW06038062F	1	R34	RESISTOR,SMT,0603,1%,1/10W,80.6K	VISHAY
ERJ-3GSYJ473	3	R35,R38,R39	RESISTOR,SMT,0603,5%,1/10W,47K	PANASONIC
T491A104K035AS	5	C32,C34,C38, C40,C41	TAN CAP,SMT,EIA-A,0.10uF,35V,10%	KEMET

Table 1. Bill of Materials for eZAudio TPA2015D1 Demonstration Kit (continued)

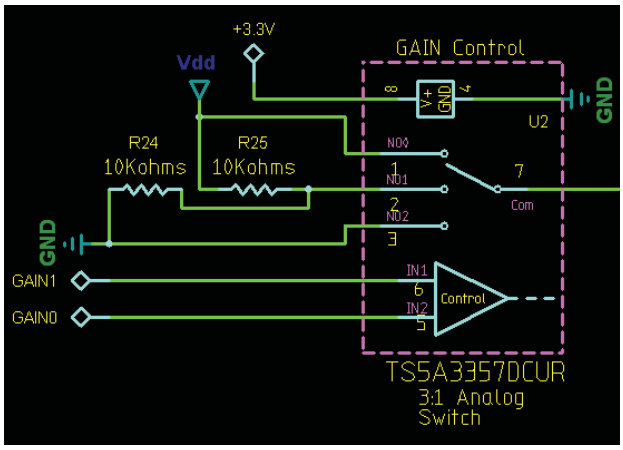
Mfr Part No.	Qty	Ref Des	Description	Mfr Name
293D475X5016A2T	2	C33,C39	CAP,TAN,SMT, 4.7uF,16V,±5%,–55~85C	VISHAY SPRAGE
MPZ1608S601A	1	FB4	FERRITE,SMT,0603,600 OHM,1A	TDK
CC4V-T1	1	OSC	*HAND SOLDER*CRYSTAL,SMT,32.768kHz, 9pF±100ppm	MICRO CRYSTAL
ECS-T1AY225R_UN	2	C36,C37	(Uninstalled Part)	UNINSTALLED
ERA-3YEB681V	1	R36	RESISTOR,SMT,0603,680 OHM,0.1%,1/16W	PANASONIC
ERJ-3GSYJ499	1	R37	RESISTOR,SMT,0603,1%,1/10W,499	PANASONIC
EADOGS102W-6	1	DISP	DISPLAY,THU,102X64 DOTS	EA
TPA511GLFS	1	SW1	SWITCH,MULTIDIR,SMD	C&K
TS5A3357DCUR	2	U2,U3	5 OHM SP3T ANALOG SWITCH SINGLE-CHANNEL 3:1 MULTI/DEMULTIPLEXER	TI
06035C222JAT2A	1	C31	CAPACITOR,SMT,0603,CERAMIC,0.0022uF,50V,5%,X7R	AVX
ECS-T1CY105R	1	C35	CAP,TAN,SMT, 1.0uF,16V,20%,DF=0.04	PANASONIC
EVQ-PPBA25	1	S1	SWITCH,SMT,2P,SPST-NO,2.5mm HEIGHT,DUST PROOF	PANASONIC
LTST-C170KGKT	2	LED1,LED2	LED,SMT,0805,ULTRA-BRIGHT GREEN,2.0V	LITEON
TPS75105DSK	1	U12	LOW DROPOUT LED DRIVER	TI
TSM-107-01-T-DV	1	JTAG	HEADER,SMT,14P,2x7,MALE,2 ROWS,100LS	SAMTEC
TSW-103-07-G-S W/SHUNT	1	PWR	SELECT HEADER,THU,3P,1X3,MALE,SINGLE,100LS,100TL WITH SHUNT JUMPER	SAMTEC
CRCW06034993F	1	R12	RESISTOR,SMT,0603,1%,1/10W,499K	VISHAY
ERA-3YEB512V	1	R43	RESISTOR,SMT,0603,5.1K,0.1%,1/16W	No Manufacturer Data
CRCW06033923F	2	R19,R15	RESISTOR,SMT,0603,1%,1/10W,392K	VISHAY
CRCW06039092F	2	R9,R10	RESISTOR,SMT,0603,1%,1/10W,90.9K	VISHAY
Component Count: 115				

Appendix A Technical Specifications

A.1 Control Signals from MSP430 to TPA2015D1

- Nine signals are used to control functions of the TPA2015D1. These signals come from the onboard MSP430.
- Gain0, Gain1 (Control TPA2015D1 gain)
- AGC0, AGC1 (Control TPA2015D1 inflection point)
- ENB (TPA2015D1 Enable for the boost)
- END (TPA2015D1 Enable for the Class-D)
- REG_EN (Enable for VDD regulator)
- I2C_SCL, I2C_SDA(for Digital POT, VDD control)

Gain0, Gain1

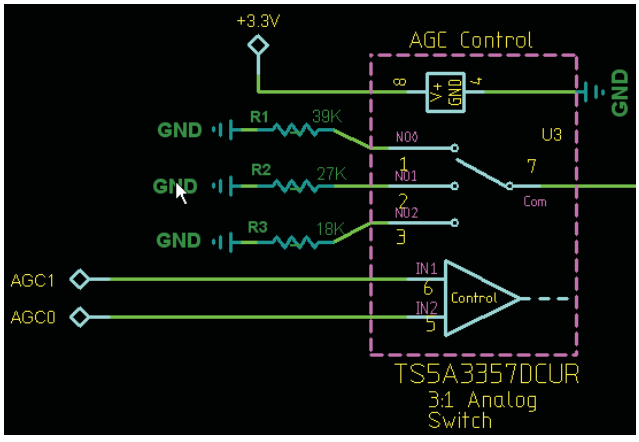


Gain0	Gain1	TPA2015D1 Gain Pin	Gain
L	L	Float	15.5 dB
H	L	Vdd/2	15.5 dB
L	H	Vdd	20 dB
H	H	GND	6 dB

L = 0 V and H = 3.3 V

Gain0 and Gain1 change the gain settings for the TPA2015D1. They control the 3:1 analog switch to set proper gain voltage.

AGC0, AGC1

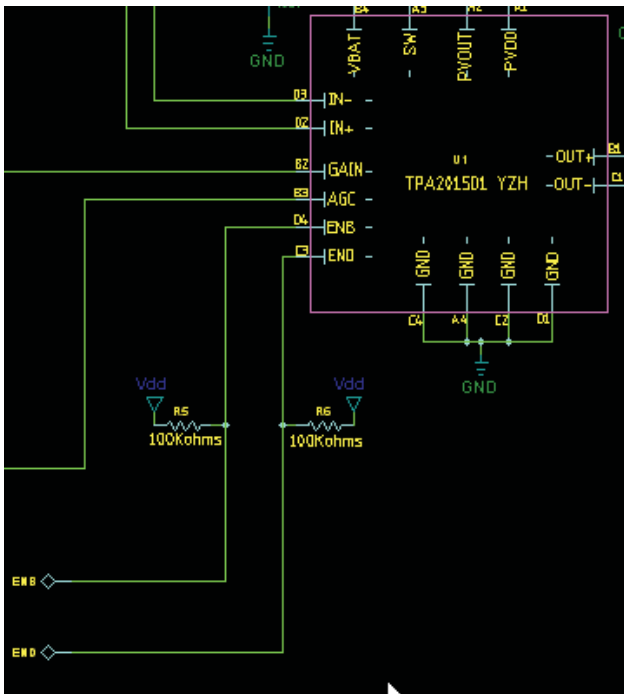


AGC0	AGC1	TPA2015D1 Inflection Point (V)	RAGC
L	L	Disabled	Open
L	H	3.35 V	
H	L	3.78 V	
H	H	3.96 V	

L = 0 V and H = 3.3 V

AGC0 and AGC1 change the inflection point for the TPA2015D1. They control the 3:1 analog switch to set the external AGC resistor.

ENB, END

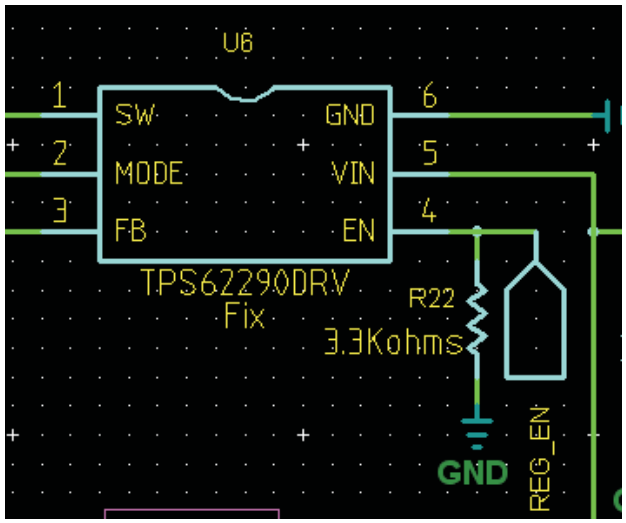


END: Enable for the Class-D. Set to *Logic High* to enable

ENB: Enable for the Boost converter. Set to *Logic High* to enable

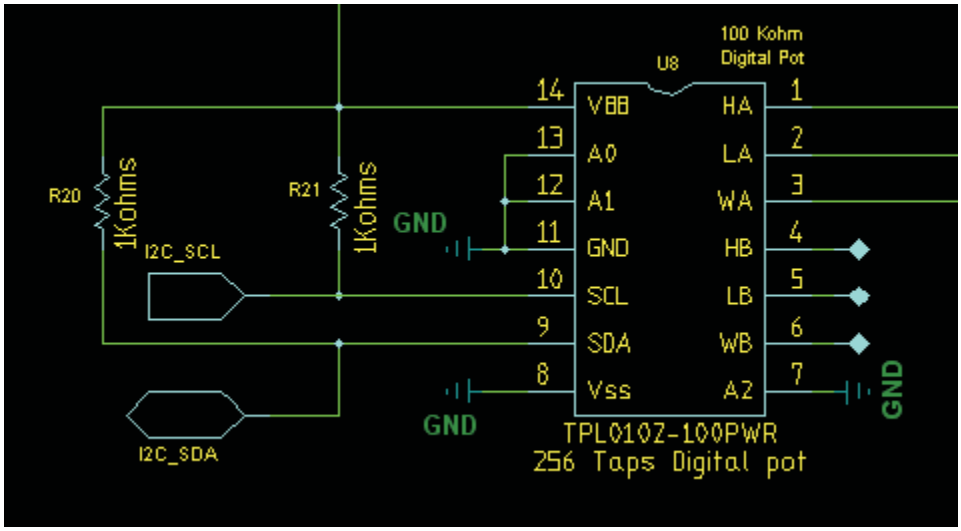
These control signals must be asserted HIGH after all switches and digital potentiometers have been set to default conditions, and Default VDD voltage has been measured by Stellaris MCU (VDD default is 3.6 V) .

REG_EN



This control signal enables U6, the adjustable VDD regulator. This signal needs to be asserted HIGH after the analog switches and digital potentiometers have been set to default conditions.

I2C_SDA, I2C_SCL: Digital POT control



These are the I2C control signals for the 100-kΩ digital potentiometer. The digital potentiometer must be set to position #41 (VDD=3.6 V) before U6 is enabled. The digital potentiometer sets the feedback voltage for VDD regulator.

I2C Slave Address: 0x50 (for MSP430 hardware I2C)
Register Address: 0x00 (write/read)
Hexadecimal Code for wiper position #41 (VDD=3.7 V): 0x29

Wiper position can be read back from this register at power up (Nonvolatile).

Allowed wiper range for this application is from #85 (0x55) to #32 (0x20), which corresponds to supply voltage range 1.8 V to 4.8 V

For the full voltage range use USB power option (batteries give only up to 4.5 V).

For more information on the digital potentiometer, see the TPL0102 data sheet (SLIS134).

Table 2. Control From MSP430 to TPA2015D1(1)

TPA2015D1	MSP430 MCU
Gain0	P4.1 (pin 44)
Gain1	P4.2 (pin 45)
AGC0	P4.3 (pin 46)
AGC1	P4.4 (pin47)
ENB	P4.5 (pin 48)
END	P4.6 (pin 49)
REG_EN	P4.7 (pin 50)
I2C_SDA	P3.1 (pin 34)
I2C_SCL	P3.2 (pin 35)

(1) MSP430 Control signals are +3.3V compatible

A.2 Measurements and Calculations on eZAudio TPA2015D1EVM

- Supply voltage (VDD_AD)
  - Measured voltage must be multiplied by 2. VDD = 2 × Vmeas
- Supply current (IDD_AD)
  - Is measured as a voltage out of INA333. Idd = Vmeas/4
- Output power
  - Is calculated as P = $(Voutrms)^2$ / Rload

- Display inflection point

Note: Output power and efficiency are calculated by MSP430 MCU.

Table 3. MSP430 MCU A/D Signal Equivalents(1)

TPA2015D1	MSP430 MCU
VRMS_AD	P6.1 (pin 98)
VDD_AD	P6.2 (pin 99)
IDD_AD	P6.3 (pin 100)

(1) A/D VFS range is 3V (internal reference is set to 3V)

A.3 eZAudio TPA2015D1EVM Power-up Sequence

1. ENB = Low
2. END = Low
3. REG_EN = Low
4. Gain0 = Low
5. Gain1 = Low
6. AGC0 = Low
7. AGC1 = Low
8. Set Digital pot wiper resistance to position #41 (write 0x29 to register 0x00) and wait 50 ms.
9. REG_EN = High
10. Measure supply voltage to make sure it's around 3.6V
11. END = High
12. ENB = High

Note: After the preceding sequence, the user can change gain and inflection point settings and activate/deactivate boost converter.

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