AAT5102

2.5W/Ch Stereo Class D Audio Power Amplifier

General Description

The AAT5102 is a high efficiency, high performance stereo class D audio amplifier. It is designed to operate in a wide supply voltage range from 2.5V to 5.5V and is targeted to deliver up to 2.5W output power to a 4Ω load with× 5V power supply. Efficiency of up to 90.5% makes it ideal for portable applications.

The AAT5102 has four adjustable amplifier gains with 6, 12, 18 and 24dB programmed by two external pins. Two shutdown control pins are employed to control the left and right channels independently.

The AAT5102 also integrates over-temperature protection circuitry to prevent internal junction temperature over-heating.

The AAT5102 is offered in a Pb-free, thermally enhanced, space-saving 1.645mm × 1.645mm 16-pin WLCSP package and in the 3mm × 3mm 16-pin QFN package, and is specified for operation over the -40°C to +85°C ambient temperature range.

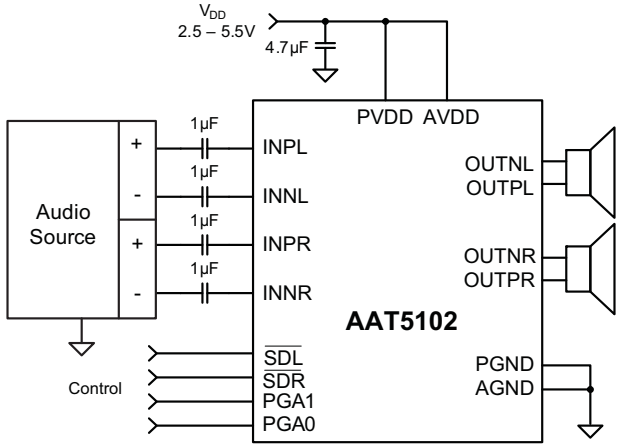
Features

- Wide Supply Voltage Range (2.5V to 5.5V)
- Maximum Battery Life and Minimum Heat
  - 5mA Quiescent Current at 3.6V V_{DD}
  - <1µA Shutdown Current
  - Up to 90.5% Efficiency
- Output Power at 10% THD+N
  - 2.5W x2 to 4Ω at 5V V_{DD}
  - 1.6W x2 to 8Ω at 5V V_{DD}
- High Performance
  - THD+N of 0.03%, at 5V V_{DD}, 8Ω Load and P_{OUT} = 1.0W
  - SNR of 102dB at 5V V_{DD}, 8Ω Load and 1% THD+N
- Shutdown Control
  - Independent Control per Channel[1]
  - Internal 300kΩ Pull-down Resistors
- Filter-less Capability
- Four Programmable Gains: 6, 12, 18 and 24dB
- Thermal Protection
- Excellent PSRR
- Built-in Pop-click Suppression Circuitry
- 1.645mm × 1.645mm 16-Pin WLCSP Package
- 3mm × 3mm 16-Pin QFN Package

Applications

- Cellular Phones
- MP4s
- Notebook Computers
- PDAs
- Portable DVD Players

Typical Application



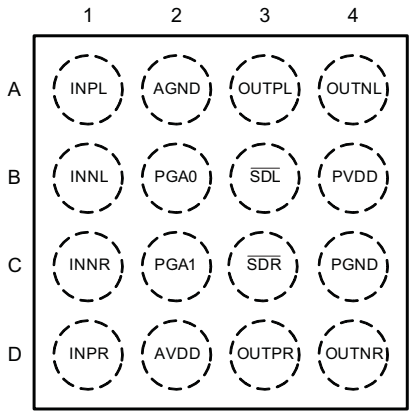
1. When independent control is used, the device ground and the audio source ground should be connected together.

Pin Descriptions

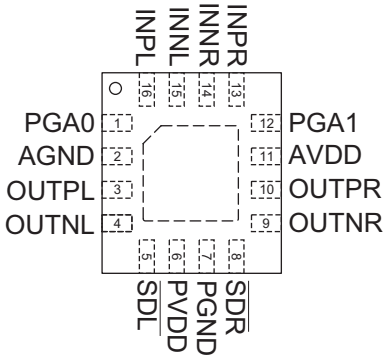
Pin Number		Symbol	Description
WLCSP-16	QFN33-16		
A1	16	INPL	Analog positive input, left channel
B1	15	INNL	Analog negative input, left channel
D1	13	INPR	Analog positive input, right channel
C1	14	INNR	Analog negative input, right channel
A3	3	OUTPL	Power stage positive output, left channel
A4	4	OUTNL	Power stage negative output, left channel
D3	10	OUTPR	Power stage positive output, right channel
D4	9	OUTNR	Power stage negative output, right channel
C2	12	PGA1	PGA gain control, TTL compatible
B2	1	PGA0	PGA gain control, TTL compatible
C3	8	$\overline{SDR}$	Right channel shutdown control (active low)
B3	5	$\overline{SDL}$	Left channel shutdown control (active low)
D2	11	AVDD	Analog power supply
B4	6	PVDD	Power supply for output drivers
A2	2	AGND	Analog power ground
C4	7	PGND	Power ground for output drivers

Pin Configuration

WLCSP-16
(Top View)



QFN33-16
(Top View)



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Absolute Maximum Ratings[1]

Symbol	Description	Value	Units
V_{DD}	Supply Voltage	-0.3 to 6.0	V
V_{IN}	Digital Input to Ground ($\overline{SDR}$, $\overline{SDL}$, PGA1 and PGA0 Pins)	-0.3 to V_{DD}+0.3	
T_J	Maximum Junction Operating Temperature Range	-40 to +150	°C
T_{LEAD}	Maximum Soldering Temperature (at leads, 10 sec)	300	
T_{STG}	Storage Temperature Range	-65 to 150	

Recommended Operating Conditions

Symbol	Description	Min	Max	Unit
V_{DD}	Supply Voltage	2.5	5.5	V
V_{IH}	High-level Input Voltage	1.5	V_{DD}	
V_{IL}	Low-level Input Voltage	0	0.5	
T_A	Operating Temperature	-40	85	°C

Thermal Information[2]

Symbol	Description		Value	Units
Θ_{JA}	Thermal Resistance	WLCSP-16	90.4	°C/W
		QFN33-16	50	
P_D	Maximum Power Dissipation	WLCSP-16	1.1	W
		QFN33-16	2	

1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device. Functional operation at conditions other than the operating conditions specified is not implied. Only one Absolute Maximum Rating should be applied at any one time.
2. Mounted on 1.6mm thick FR4 material printed circuit board.

Electrical Characteristics

V_{DD}=5.0V, C_S=4.7µF, C_I=1µF, R_L=8Ω and Gain=6dB. T_A = 25°C unless otherwise noted.

Symbol	Description	Conditions		Min	Typ	Max	Units
DC Characteristics							
V_{DD}	Supply Voltage			2.5		5.5	V
V_{OS}	Output Offset Voltage	Room Temperature Only		-25	5	25	mV
I_Q	Operation Quiescent Current	V_{DD} = 5.5V, $\overline{SDR}$ = $\overline{SDL}$ = high, No Load			6.5	10	mA
		V_{DD} = 3.6V, $\overline{SDR}$ = $\overline{SDL}$ = high, No Load			5	8	
		V_{DD} = 2.5V, $\overline{SDR}$ = $\overline{SDL}$ = high, No Load			4.5	7	
$I_{SD(OFF)}$	Shutdown Supply Current	$\overline{SDR}$ = $\overline{SDL}$ = low, No load		-1	0.1	1	µA
R_I	Input Impedance	PGA1 = low, PGA0 = low			28		kΩ
		PGA1 = low, PGA0 = high			14		
		PGA1 = high, PGA0 = low			28		
		PGA1 = high, PGA0 = high			14		
Gain	Amplifier Closed Loop Voltage Gain	PGA1 = low, PGA0 = low		5.3	6	6.7	dB
		PGA1 = low, PGA0 = high		11.3	12	12.7	
		PGA1 = high, PGA0 = low		17.3	18	18.7	
		PGA1 = high, PGA0 = high		23.3	24	24.7	
$R_{\overline{SD}}$	Resistance from $\overline{SDR}$/$\overline{SDL}$ to GND				300		kΩ
V_{IH}	High-level Input Voltage	$\overline{SDR}$, $\overline{SDL}$, PGA1, PGA0		1.5			V
V_{IL}	Low-level Input Voltage	$\overline{SDR}$, $\overline{SDL}$, PGA1, PGA0				0.5	
T_{SD}	Over-Temperature Shutdown Threshold				145		°C
T_{HYS}	Over-Temperature Shutdown Hysteresis				15		
AC Characteristics							
F_{SW}	Switch Frequency				350		kHz
P_{OUT}	Output Power	THD+N = 10%, f = 1kHz, R_L = 8Ω	V_{DD} = 5.0V		1.61		W
			V_{DD} = 3.6V		0.82		
		THD+N = 1%, f = 1kHz, R_L = 8Ω	V_{DD} = 5.0V		1.31		
			V_{DD} = 3.6V		0.66		
		THD+N = 10%, f = 1kHz, R_L = 4Ω	V_{DD} = 5.0V		2.66		
			V_{DD} = 3.6V		1.35		
		THD+N = 1%, f = 1kHz, R_L = 4Ω	V_{DD} = 5.0V		2.13		
			V_{DD} = 3.6V		1.08		
η	Output Power Efficiency	V_{DD} = 5.0V, f = 1kHz, P_{OUT} = 1.2W			90.5		%
THD+N	Total Harmonic Distortion + Noise	f = 1kHz, R_L = 8Ω, Gain = 6dB	V_{DD} = 5.0V, P_{OUT} = 1W		0.03		%
			V_{DD} = 3.6V, P_{OUT} = 0.5W		0.04		
V_{NO}	Noise Output Voltage	V_{DD} = 3.6V, f = 20Hz~20kHz, Inputs AC-grounded	A-weighting		26		µV
SNR	Signal to Noise Ratio	V_{DD} = 5.0V, f = 1kHz, THD+N = 1%			102		dB
PSRR	Power Supply Ripple Rejection Ratio	V_{DD} = 3.6V, V_{RIPPLE} = 200mV_{pp}, f = 217Hz, Inputs AC-grounded			-60		
CMRR	Common Mode Ripple Rejection Ratio	V_{DD} = 3.6V, V_{RIPPLE} = 1V_{pp}, f = 217Hz			-53		
T_{ON}	Turn-On Time				8		ms
T_{OFF}	Turn-Off Time				12		

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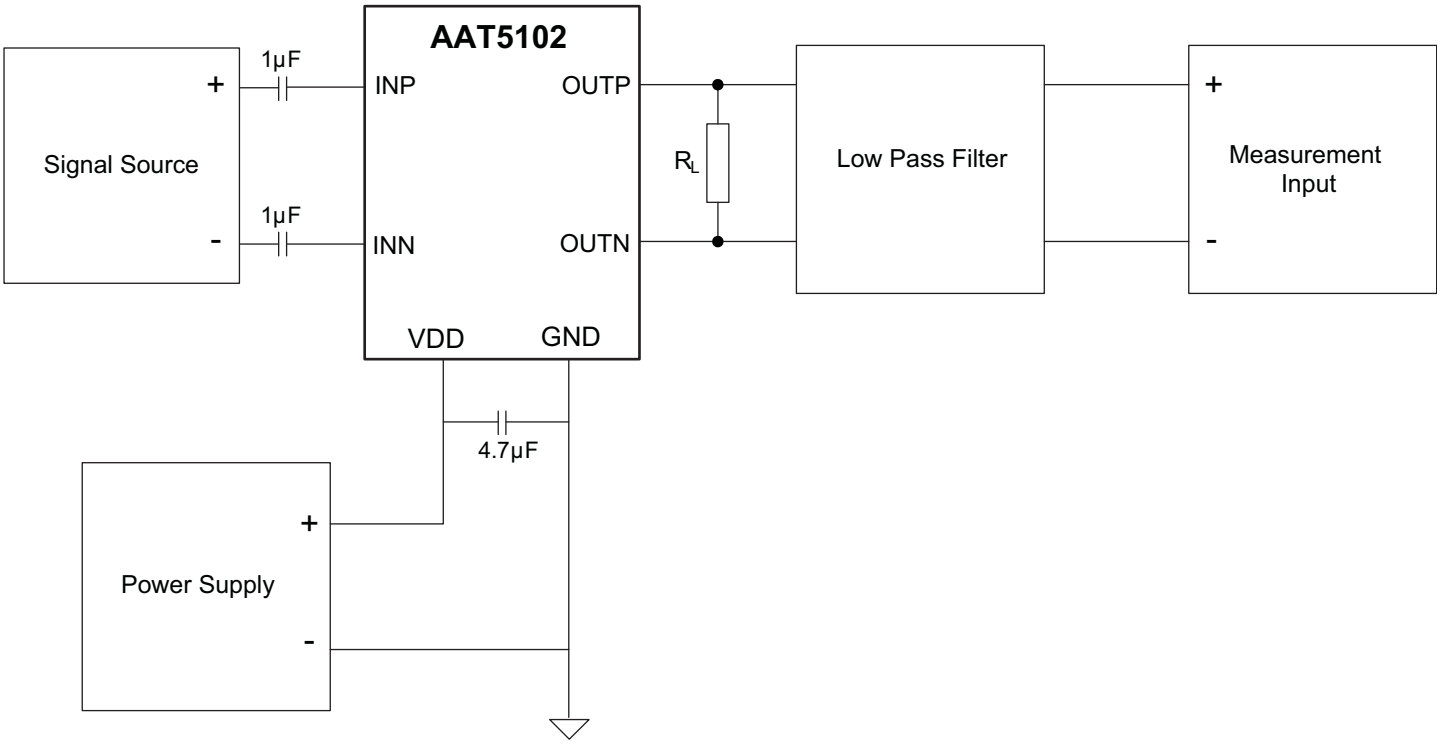
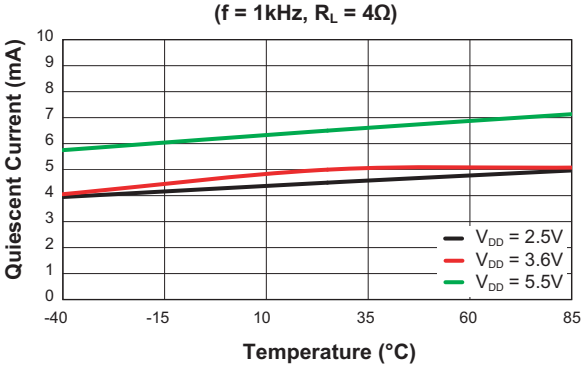
Test Set-up for Typical Characteristics Graphs (per channel)

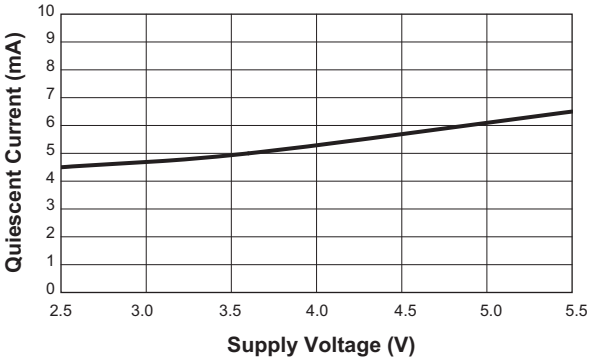


Typical Characteristics

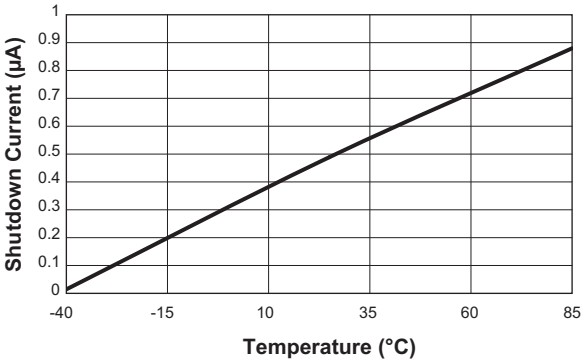
Operation Quiescent Current vs. Temperature
(f = 1kHz, R_L = 4Ω)



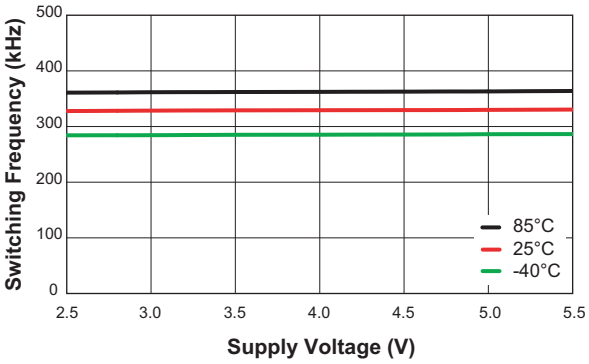
Quiescent Current vs. Supply Voltage
(No Load)



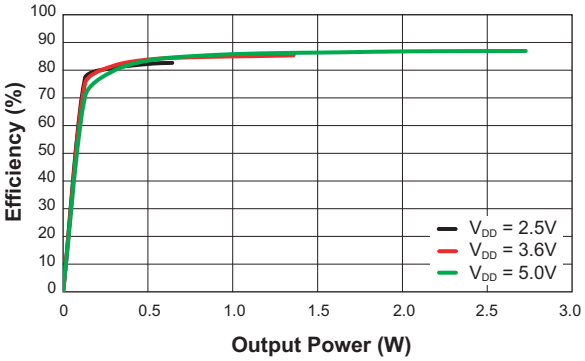
Shutdown Supply Current vs. Temperature
(f = 1kHz, R_L = 8Ω)



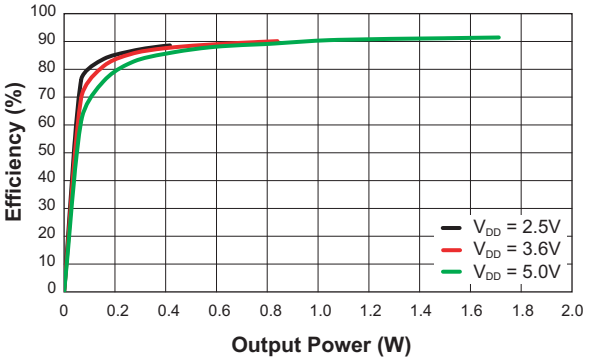
Switching Frequency vs. Input Voltage



Efficiency vs. Output Power
(f = 1kHz; R_L = 4Ω + 33µH; Gain = 6dB)

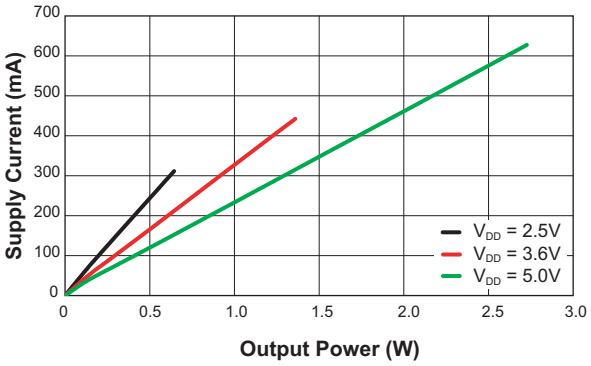


Efficiency vs. Output Power
(f = 1kHz; R_L = 8Ω + 33µH; Gain = 6dB)

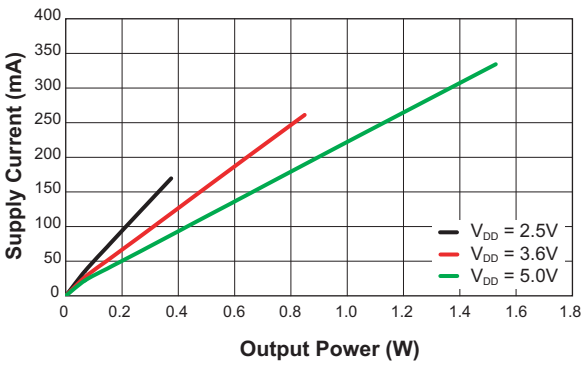


Typical Characteristics

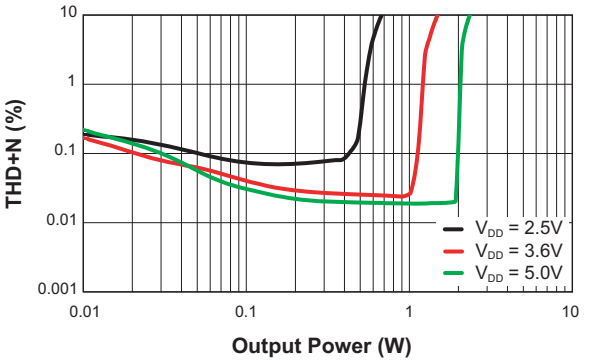
Supply Current vs. Output Power
(f = 1kHz; R_L = 4Ω + 33µH; Gain = 6dB)



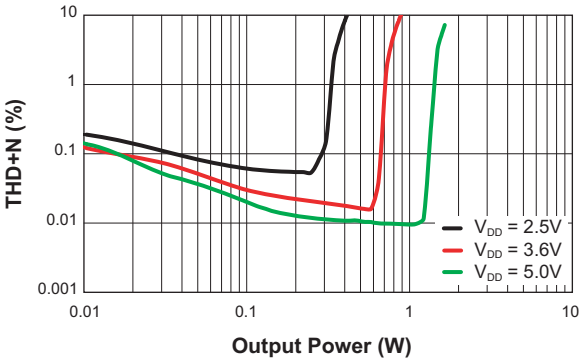
Supply Current vs. Output Power
(f = 1kHz; R_L = 8Ω + 33µH; Gain = 6dB)



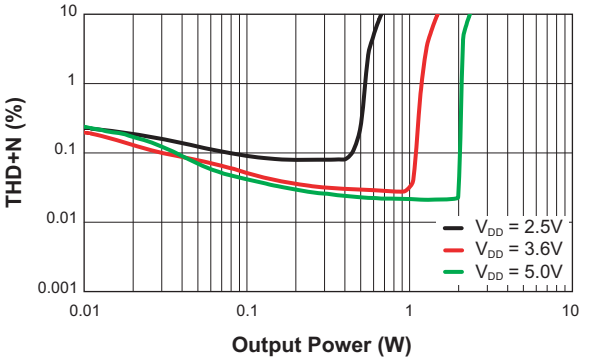
THD+N vs. Output Power
(f = 1kHz; R_L = 4Ω; Gain = 6dB)



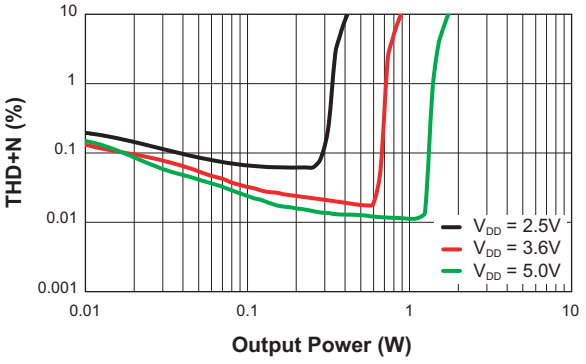
THD+N vs. Output Power
(f = 1kHz; R_L = 8Ω; Gain = 6dB)



THD+N vs. Output Power
(f = 1kHz; R_L = 4Ω; Gain = 24dB)

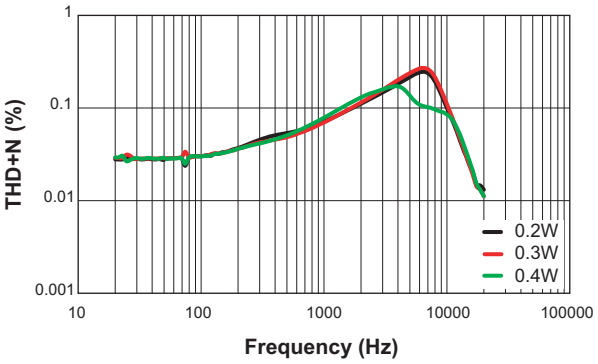


THD+N vs. Output Power
(f = 1kHz; R_L = 8Ω; Gain = 24dB)

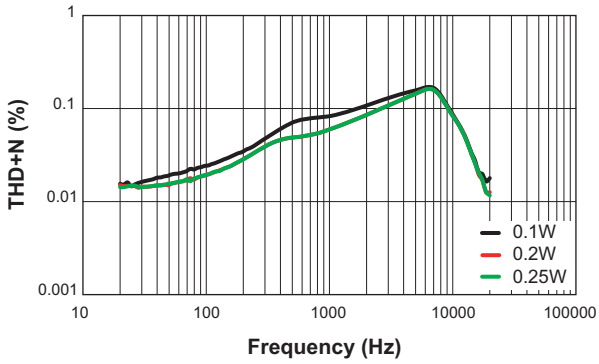


Typical Characteristics

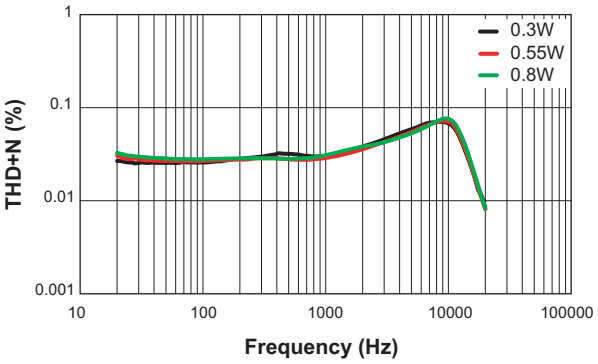
THD+N vs. Frequency
(V_{DD} = 2.5V; R_L = 4Ω; Gain = 6dB)



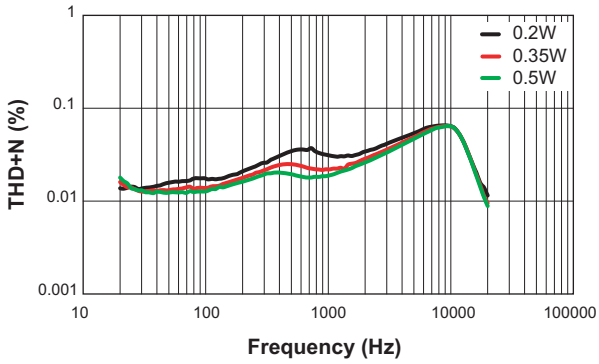
THD+N vs. Frequency
(V_{DD} = 2.5V; R_L = 8Ω; Gain = 6dB)



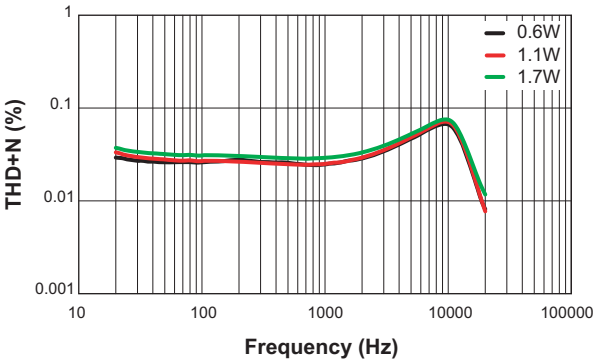
THD+N vs. Frequency
(V_{DD} = 3.6V; R_L = 4Ω; Gain = 6dB)



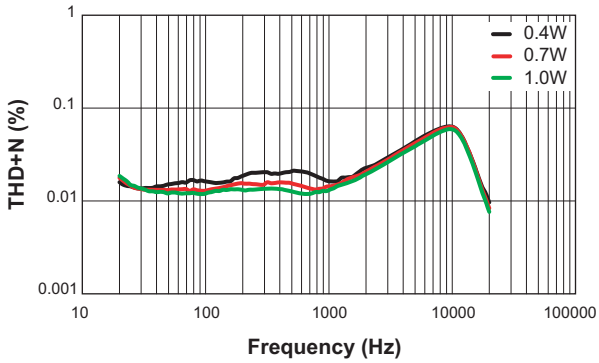
THD+N vs. Frequency
(V_{DD} = 3.6V; R_L = 8Ω; Gain = 6dB)



THD+N vs. Frequency
(V_{DD} = 5.0V; R_L = 4Ω; Gain = 6dB)

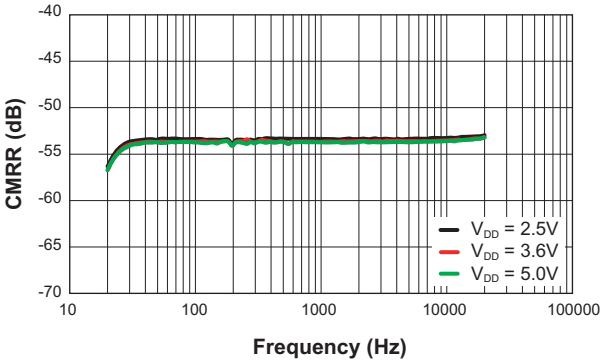


THD+N vs. Frequency
(V_{DD} = 5.0V; R_L = 8Ω; Gain = 6dB)

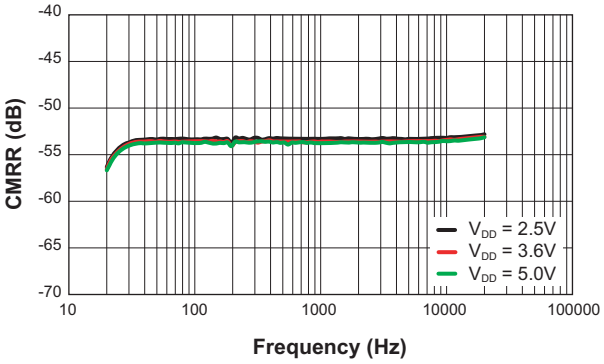


Typical Characteristics

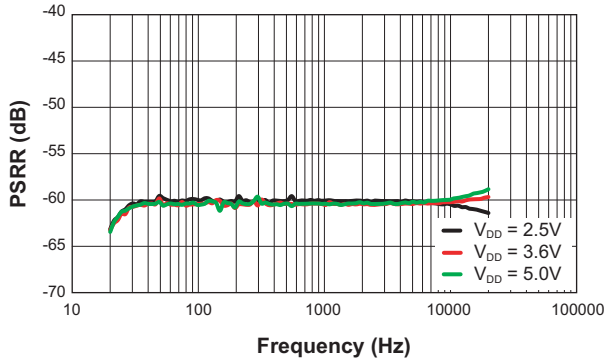
CMRR vs. Frequency
(V_{CH} = 1V_{PP}; R_L = 4Ω; Gain = 6dB)



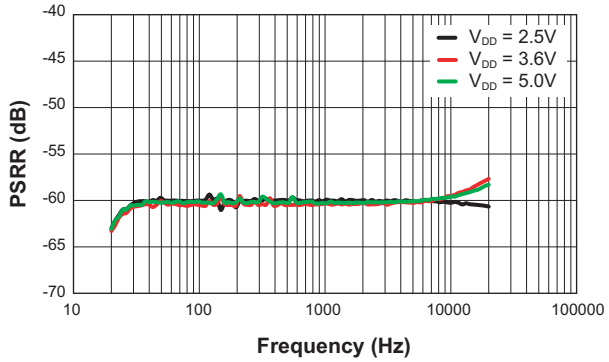
CMRR vs. Frequency
(V_{CH} = 1V_{PP}; R_L = 8Ω; Gain = 6dB)



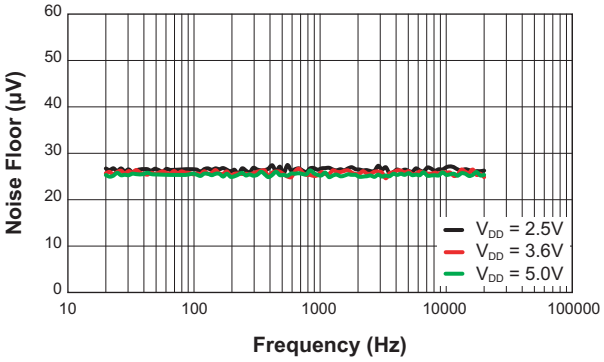
PSRR vs. Frequency
(V_{RIPPLE} = 200mVpp; R_L = 4Ω; Gain = 6dB; Inputs AC Grounded)



PSRR vs. Frequency
(V_{RIPPLE} = 200mVpp; R_L = 8Ω; Gain = 6dB; Inputs AC Grounded)

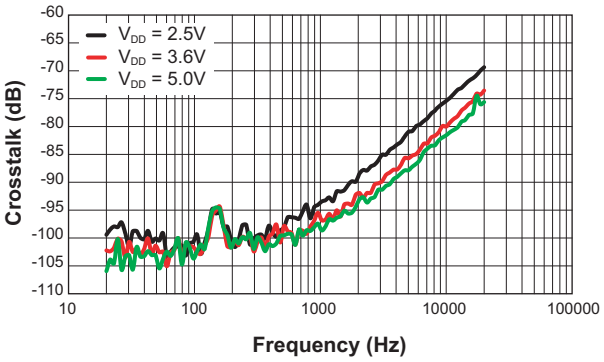


Noise Floor
(R_L = 8Ω; Gain = 6dB; Inputs AC Grounded; A weighting)

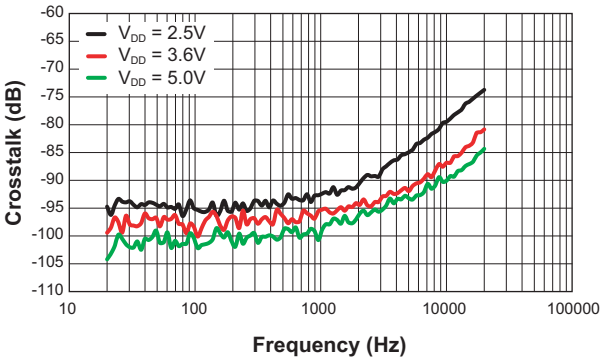


Typical Characteristics

Crosstalk vs. Frequency
(V_{IN} = 0.5V_{RMS}; R_L = 4Ω; Gain = 6dB; Left to Right)



Crosstalk vs. Frequency
(V_{IN} = 0.5V_{RMS}; R_L = 4Ω; Gain = 6dB; Right to Left)



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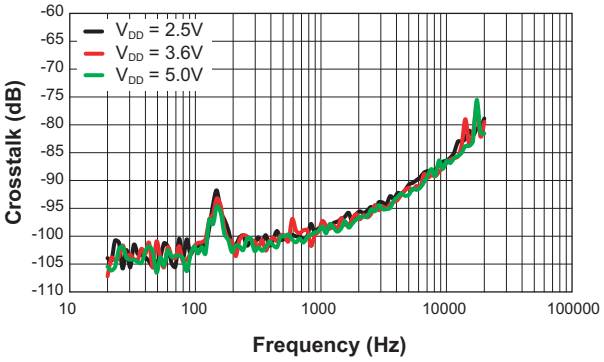
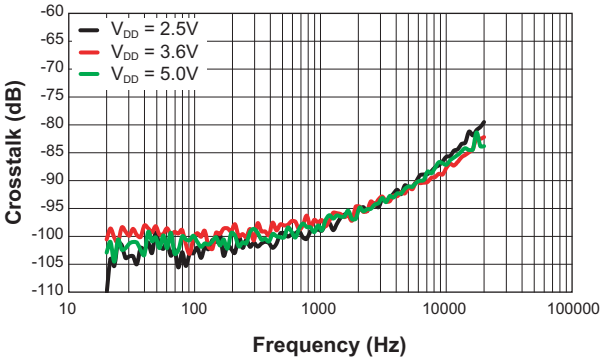
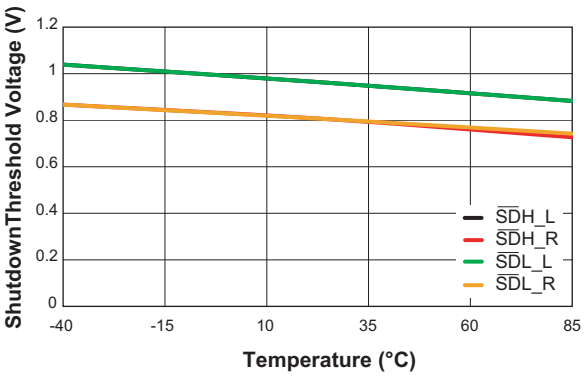


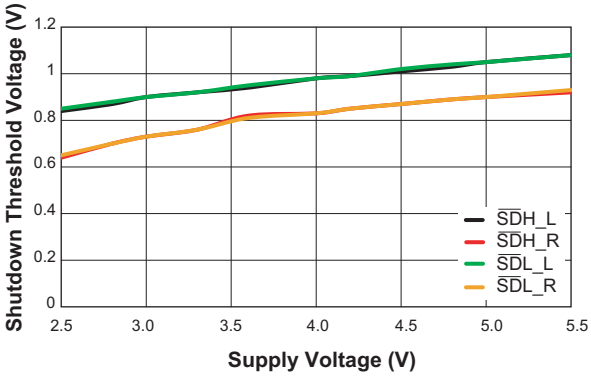
Crosstalk vs. Frequency
(V_{IN} = 0.5V_{RMS}; R_L = 8Ω; Gain = 6dB; Right to Left)



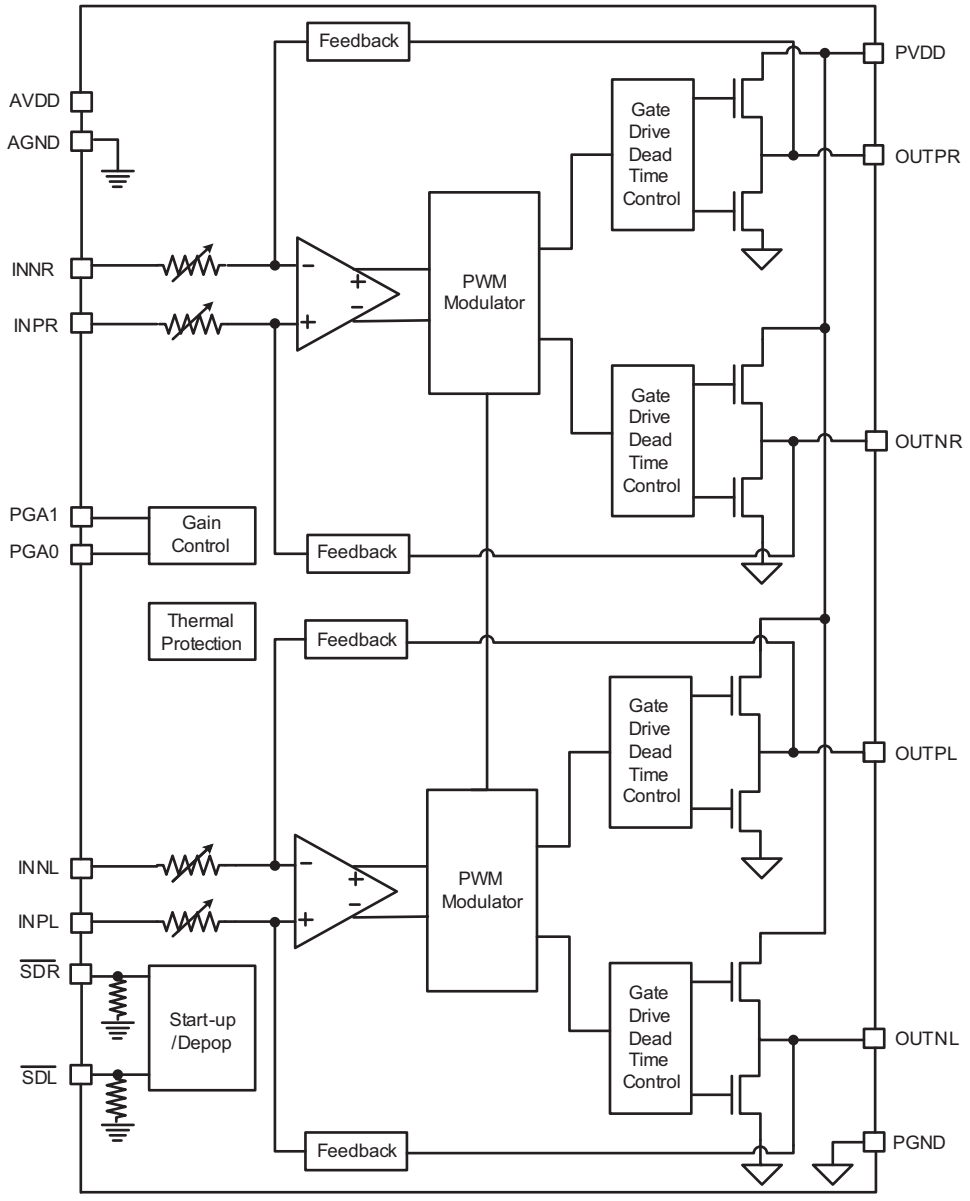
Shutdown Threshold Voltage vs. Temperature



Shutdown Threshold Voltage vs. Supply Voltage



Functional Block Diagram



Application Information

The AAT5102 is a closed loop pulse-width-modulated switch mode power amplifier for driving bridge-tied load. It features high performance with high efficiency, high SNR and low THD+N. It also offers built-in over-temperature protection.

Gain Setting

The AAT5102 voltage gain can be programmed to 6, 12, 18 and 24dB via two inputs, PGA1 and PGA0. See Table 1 for gain setting.

PGA1	PGA0	Voltage Gain (dB)	Input Impedance (kΩ)
0	0	6	28
0	1	12	14
1	0	18	28
1	1	24	14

Table 1: Gain Setting.

Input High-Pass Filter

C_{IN} is the input DC blocking capacitor which forms input high pass filter with amplifier input impedance. The corner frequency is determined from the equation:

$$f_{-3dB} = \frac{1}{2 \cdot \pi \cdot R_I \cdot C_I}$$

Where:

f_{-3dB} is -3dB corner frequency
R_I is the input resistance
C_I is the input capacitance

The value of C_I is important for the bass performance of the amplifier. The capacitors should have a tolerance of ±10% or better.

Power Supply Bypassing

The AAT5102 is a high performance Class-D amplifier, adequate supply decoupling is necessary for overall better performance. A good low equivalent series resistance (ESR) decoupling capacitor of 4.7µF or larger is recommended.

Thermal Protection

The AAT5102 features unlatched over temperature protection. During operation when the device junction temperature exceeds 145°C (typical), the device enters into shutdown state and outputs are disabled. Once device junction temperature is reduced by 15°C, the device leaves shutdown state and returns to normal operation automatically.

Shutdown Mode

When $\overline{SDR}$ and $\overline{SDL}$ are pulled down to low voltage, the device is in its maximum power saving mode. In shutdown mode, outputs are pulled in weak low state. The high logic level applied on $\overline{SDR}$ and $\overline{SDL}$ wakes up the device after turn-on time (T_{ON}). When independent shutdown control for each channel is necessary in the application, connecting the audio source ground to the device ground is highly recommended.

Output Filter

A ferrite bead should be used to reduce EMI emissions if EMI sensitive devices nearby in the system. The ferrite bead acts essentially as high impedance to a high frequency emissions but very low impedance to low frequency signal. Choose the ferrite bead with high impedance at the frequency range of interest.

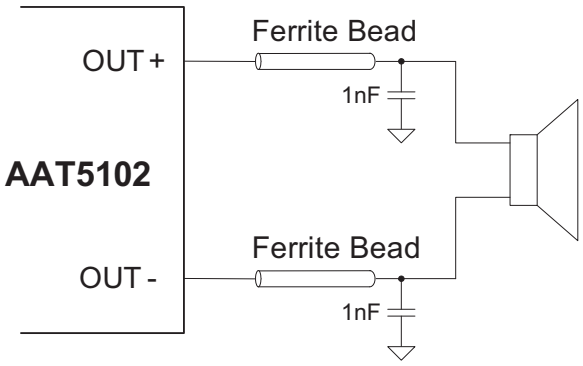


Figure 1: Typical Ferrite Bead Filter.

Manufacturer	Value (µF)	Voltage (V)	Case Size	Part Number
Murata	1	16	0603	GRM188R71C105KA12

Table 2: Recommended Input Capacitor Selection Information.

Manufacturer	Value (µF)	Voltage (V)	Case Size	Part Number
Murata	4.7	6.3	0603	GRM188R60J475KE19

Table 3: Recommended Decoupling Capacitor Selection Information

Manufacturer	Part Number	Impedance (Ω) (100MHz)	Rated Current (A) (Max)	DCR	Thickness (mm)	Case Size
TDK	MPZ1608S221A	220±25%	2	0.05	0.8	0603

Table 4: Recommended Output Ferrite Bead Selection Information.

Thermal Considerations and Maximum Output Power

The AAT5102 delivers a 5W power to 4Ω speaker. The limiting characteristic for the maximum output power is essentially package power dissipation and the device internal thermal limit.

At any given ambient temperature (T_A), the maximum package power dissipation can be determined by the following equation:

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JA}}$$

The $T_{J\ (MAX)}$, the maximum junction temperature for the device is 125°C. The package thermal resistance θ_{JA} is 90.4°C/W for the WLCSP-16 package. For example, given T_A=25°C, from above formula, the maximum power dissipation is 1.1W. With given efficiency η, the max output power can be determined by the following equation:

$$P_{O(MAX)} = \frac{P_{D(MAX)}}{1 - \eta}$$

Application Circuits

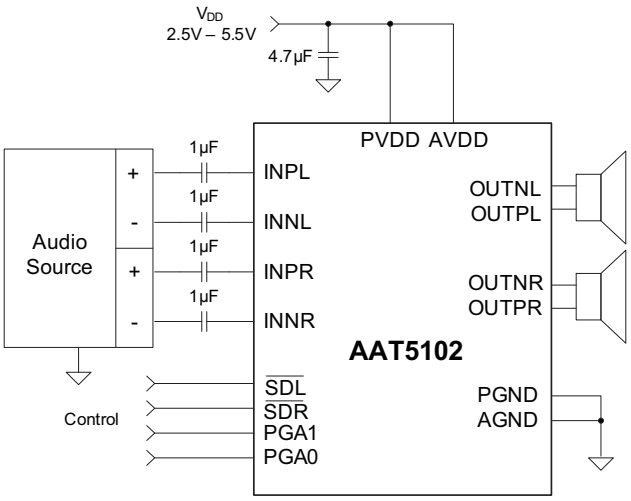


Figure 2: AAT5102 Application With Differential Input.

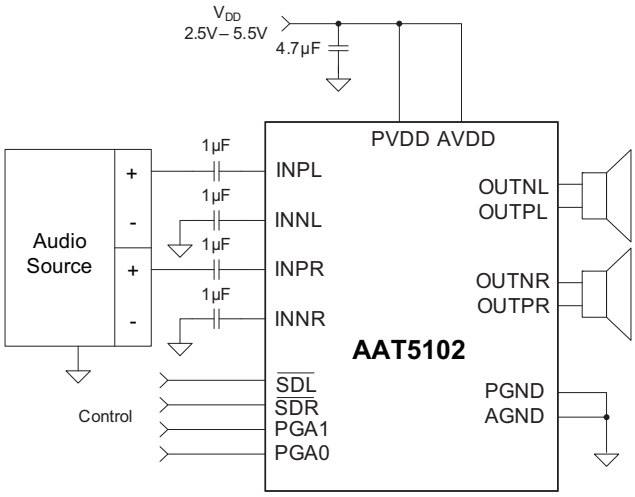


Figure 3: AAT5102 Application With Single-Ended Input.

Evaluation Board Schematic

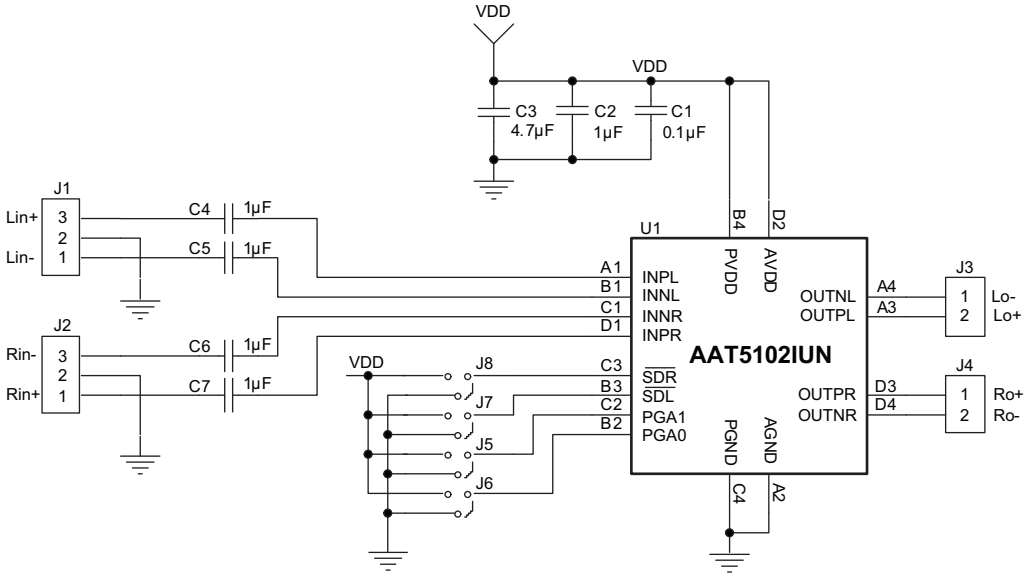


Figure 4: AAT5102IUN Evaluation Board Schematic.

Component	Part Number	Description	Manufacturer
U1	AAT5102IUN	Stereo Class D Audio Amplifier	Skyworks
C3	GRM188R60J475KE19	Cap Ceramic 4.7µF 0603 X7R 6.3V 10%	Murata
C2, C4, C5, C6, C7	GRM188R71C105KA12	Cap Ceramic 1µF 0603 X7R 16V 10%	Murata
C1	GRM188R71E104KA01	Cap Ceramic 0.1µF 0603 X7R 25V 10%	Murata

Table 5: AAT5102IUN Evaluation Board Bill of Materials.

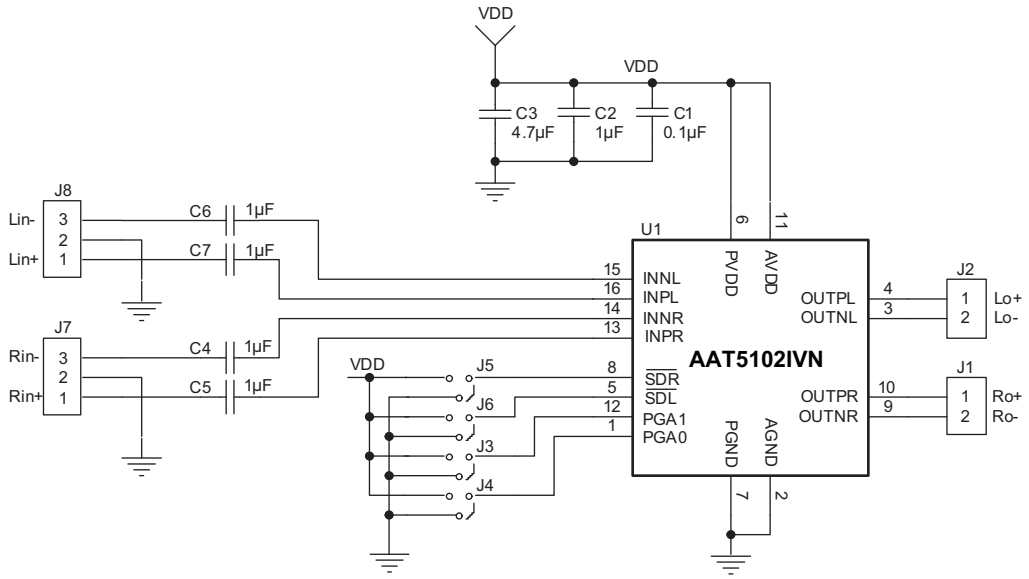
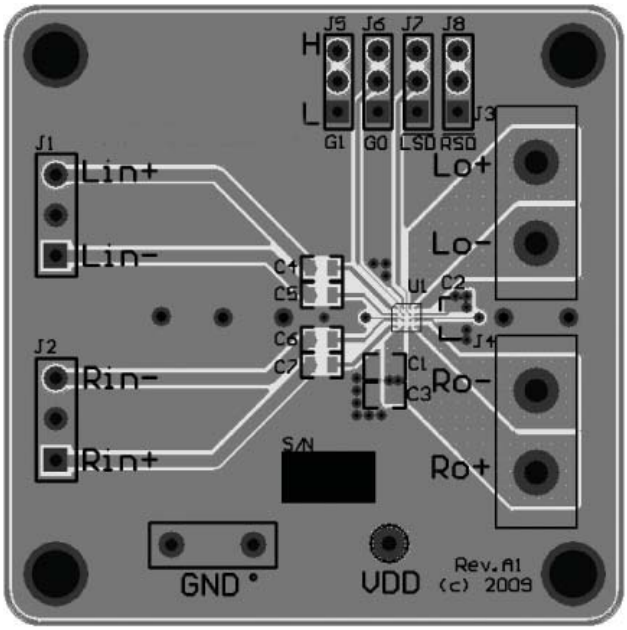


Figure 5: AAT5102IVN Evaluation Board Schematic.

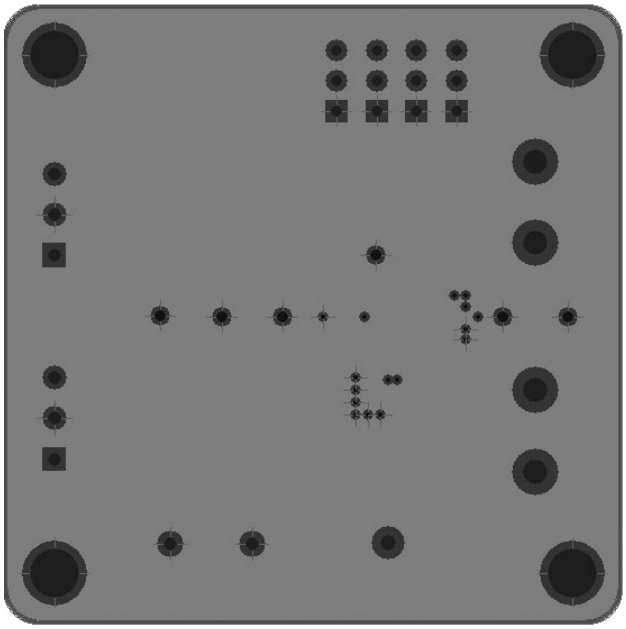
Component	Part Number	Description	Manufacturer
U1	AAT5102IVN	Stereo Class D Audio Amplifier	Skyworks
C3	GRM188R60J475KE19	Cap Ceramic 4.7µF 0603 X7R 6.3V 10%	Murata
C2, C4, C5, C6, C7	GRM188R71C105KA12	Cap Ceramic 1µF 0603 X7R 16V 10%	Murata
C1	GRM188R71E104KA01	Cap Ceramic 0.1µF 0603 X7R 25V 10%	Murata

Table 6: AAT5102IVN Evaluation Board Bill of Materials.

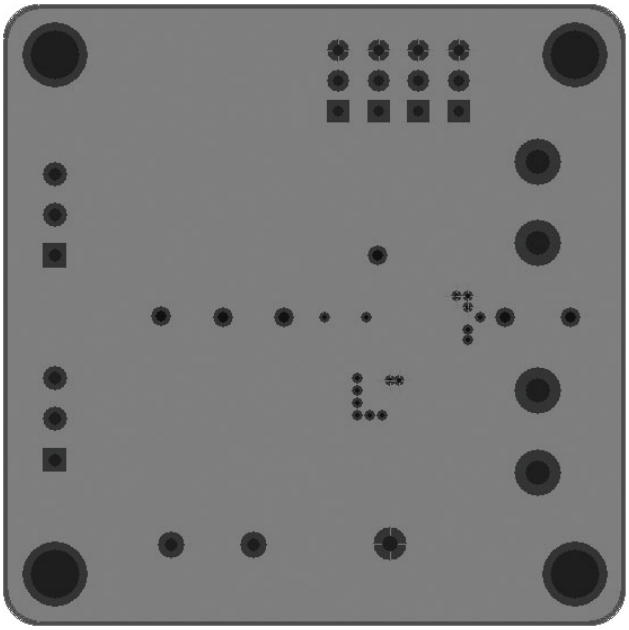
Evaluation Board PCB Layout



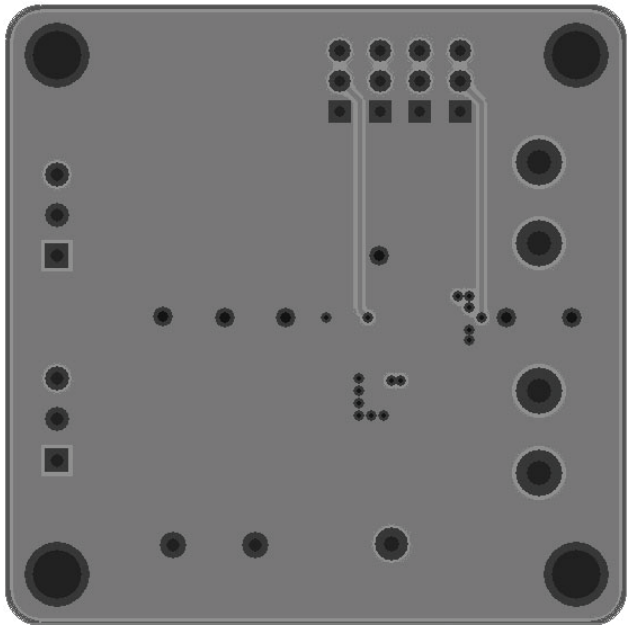
a: Top Layer



b: Ground Plane

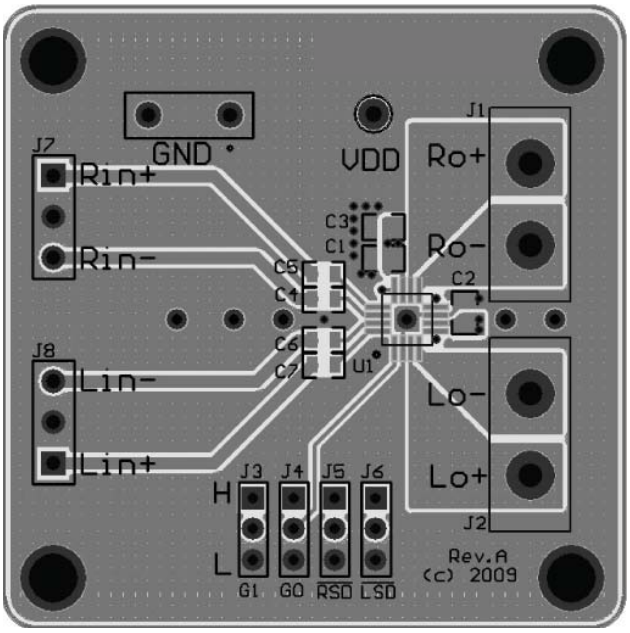


c: Power Plane

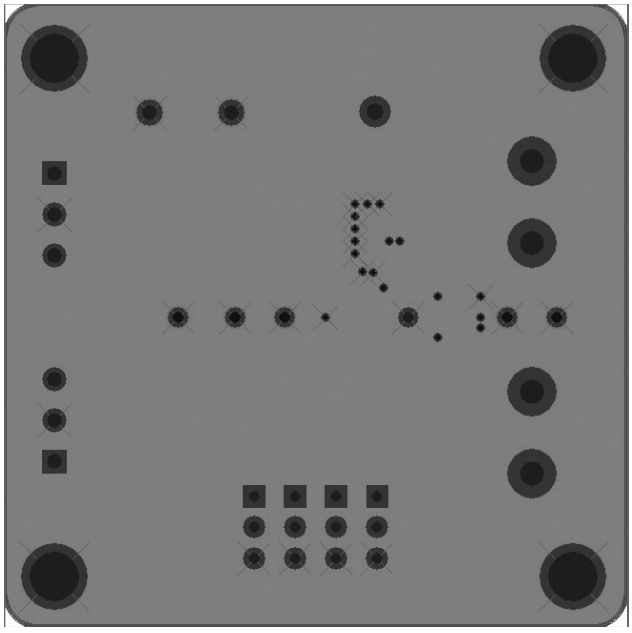


d: Bottom Layer

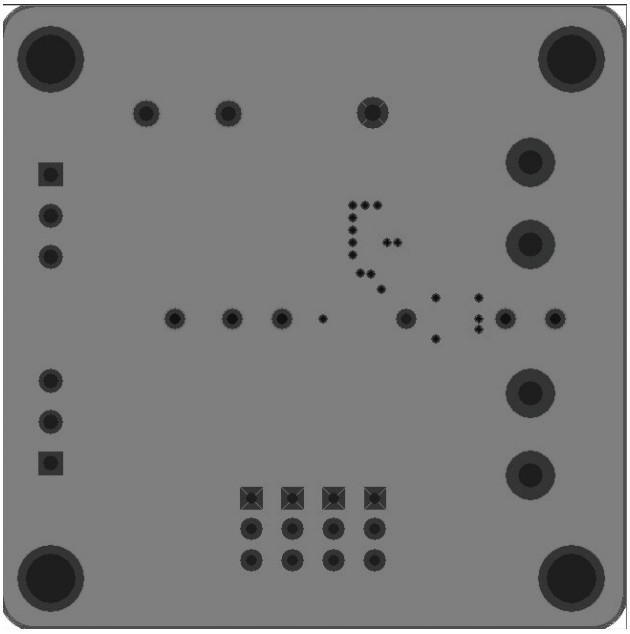
Figure 6: AAT5102IUN Evaluation Board PCB Layout.



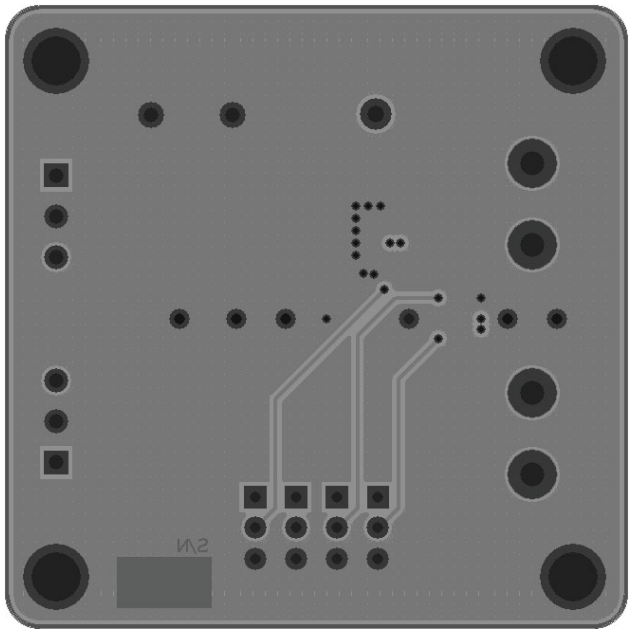
a: Top Layer



b: Ground Plane



c: Power Plane



d: Bottom Layer

Figure 7: AAT5102IVN Evaluation Board PCB Layout

Ordering Information

Package	Marking[1]	Part Number (Tape and Reel)[2]
WLCSP-16	9PYY	**AAT5102IUN-T1**
QFN33-16	C3XYY	**AAT5102IVN-T1**

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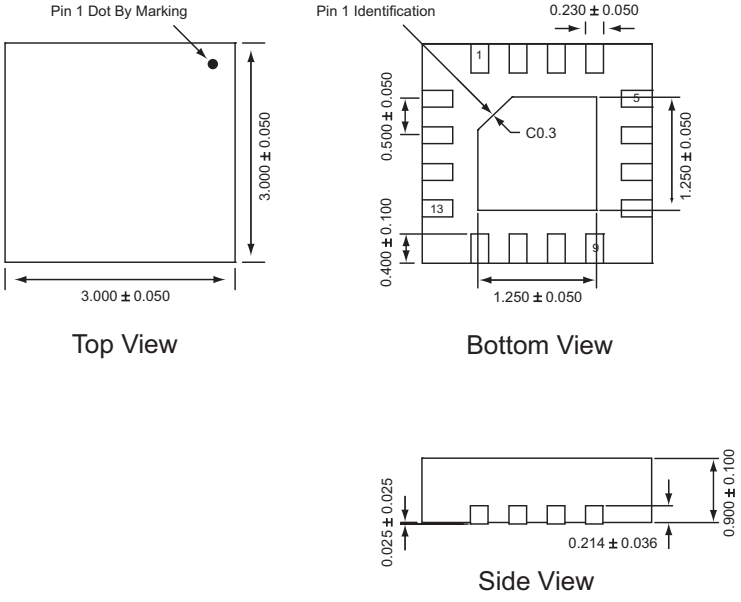
Package Information

QFN33-16[3]



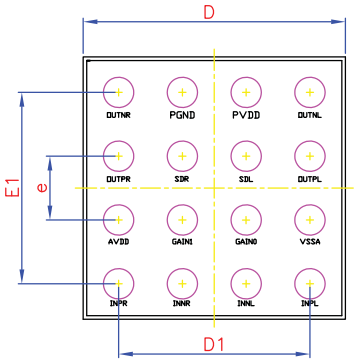
All dimensions in millimeters.

1. YY, XYY = assembly and date code.
2. Sample stock is generally held on part numbers listed in **BOLD**.
3. The leadless package family, which includes QFN, TQFN, DFN, TDFN and STDFN, has exposed copper (unplated) at the end of the lead terminals due to the manufacturing process. A solder fillet at the exposed copper edge cannot be guaranteed and is not required to ensure a proper bottom solder connection.

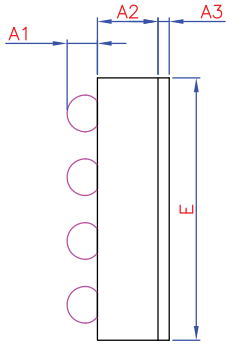
WLCSP-16

Dimension Table (Unit: mm)

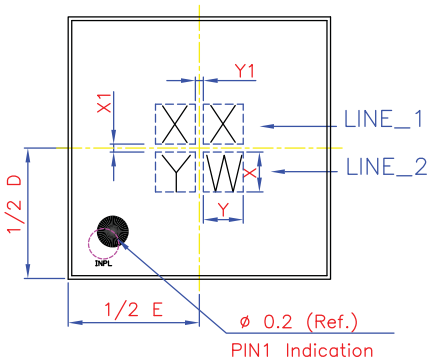
Symbol	Min	Nominal	Max
A	0.510	0.595	0.680
A1	0.120	0.145	0.170
A2	0.355	0.380	0.405
A3	0.035	0.070	0.105
D	1.610	1.645	1.680
E	1.610	1.645	1.680
D1	–	1.200	–
E1	–	1.200	–
SD	–	0.200	–
SE	–	0.200	–
e	0.400 BSC		
b	0.195	0.220	0.245
X	0.30	–	–
Y	0.30	–	–
X1	–	0.1	–
Y1	–	0.1	–
N	16 (Balls)		



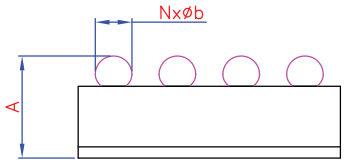
(BTW View)



(Side View)



(TOP View)



(Side View)