2.5W Mono Filter-Free Class D Audio Power Amplifier

Description

The AAT5101 is a high efficiency, 2.5W mono class D audio power amplifier. The low noise, filterless PWM architecture eliminates the output filter, reduces the external component count and system cost, and simplifies system design. With high efficiency of up to 92% and the industry lowest 1.35mA quiescent current, it increases battery lifetime and dramatically lowers the junction temperature. The space saving wafer-level chip scale package (WLCSP) and minimum external component requirements make it ideal for cellular phones and PDAs.

With high PSRR, low THD+N, and 91dB SNR, the AAT5101 guarantees clean sound across the wide audio output power range and the full audio frequency domain. Short circuit and thermal protection with self-recovery prevents the device from being damaged during over current conditions.

In cellular phones, the earpiece, speaker phone and melody ringer can each be driven by the AAT5101. Also, proprietary technology successfully suppresses pop and click noise.

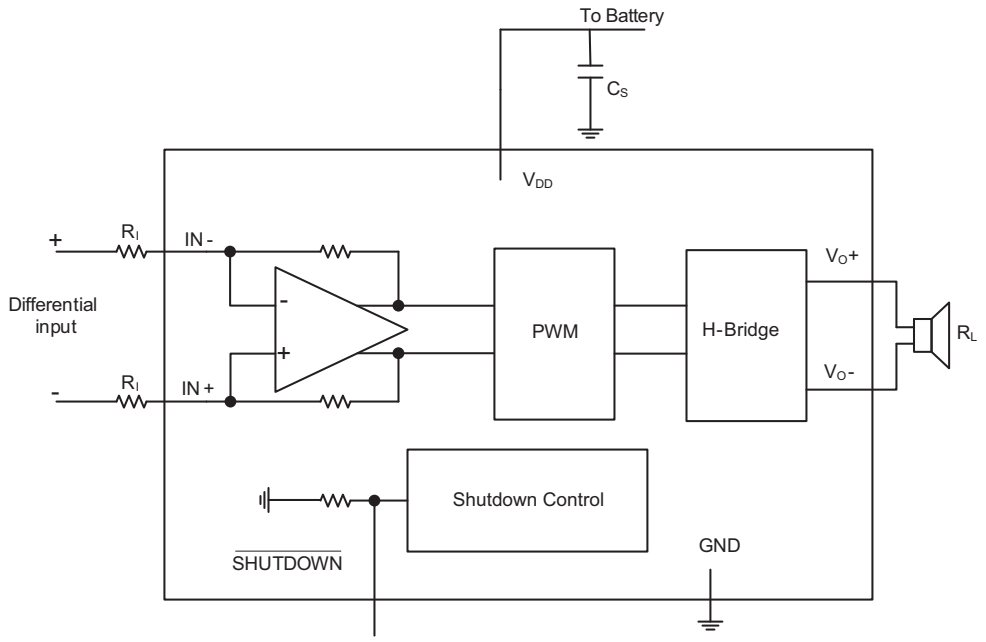
Features

- Maximum Battery Life and Minimum Heat
  - 1.35mA Quiescent Current
  - 0.06µA Shutdown Current
  - Up to 92% Efficiency
- Large Output Power Capabilities
  - 1.35W with 8Ω Load and THD+N < 1%
  - 2.5W with 4Ω Load and THD+N < 10%
- Pop and Click Noise Suppression Circuitry
- Thermal and Output Short Circuit Protection with Self-recovery
- High Performance, THD+N of 0.12% at 5V, 8Ω Load and P_{OUT} = 1.0W
- Filter-less Capability
- Internally Generated 250 kHz Switching Frequency
- Excellent PSRR and Wide Supply Voltage Range (2.1V to 5.5V)
- Fully Differential Design
- External Gain Configuration Capability
- 9-Pin Wafer-Level Chip Scale Packaging (WLCSP)

Applications

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

Typical Application

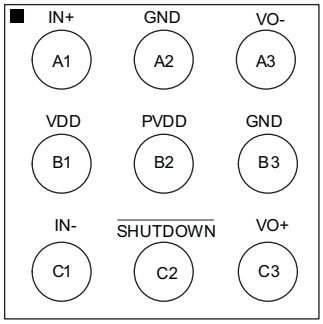


Pin Description

Pin #	Symbol	Type	Description
A1	IN+	I	Positive differential input.
A2	GND	I	Analog ground.
A3	VO-	O	Negative BTL output.
B1	VDD	I	Analog power supply.
B2	PVDD	I	Power supply for internal H-bridge stage.
B3	GND	I	Analog ground.
C1	IN-	I	Negative differential input.
C2	$\overline{\text{SHUTDOWN}}$		The device enters shutdown mode when a low level is applied on this pin. An internal 300kΩ will force the device into shutdown mode if no signal is applied to this pin. It also helps to save space and cost.
C3	VO+	O	Positive BTL output

Pin Configuration

WLCSP-9
(Top View)



Absolute Maximum Ratings

Symbol	Description		Max	Units
V_{DD}	Supply Voltage	Active Mode	5.5	V
		Shutdown Mode	6.0	
I_{OUT}	Maximum Output Current		1.5	A
T_A	Operating Ambient Temperature		-40 to +85	°C
T_J	Maximum Junction Temperature		165	°C
	Latchup Current @ T_A = 85°C		> 200	mA

Recommended Operating Conditions

Symbol	Description	Min	Max	Units
P_{VDD}, V_{DD}	Supply Voltage	2.1	5.5	V
T_A	Operating Temperature	-40	85	°C

Thermal Characteristics

Symbol	Description	Value	Units
Θ_{JA}	Maximum Thermal Resistance[1]	120	°C/W
P_D	Maximum Power Dissipation[1,2]	833	mW

1. Mounted on a FR4 board.
2. Derate 6.25mW/°C above 25°C.

Electrical Characteristics

T_A = 25°C unless otherwise noted.

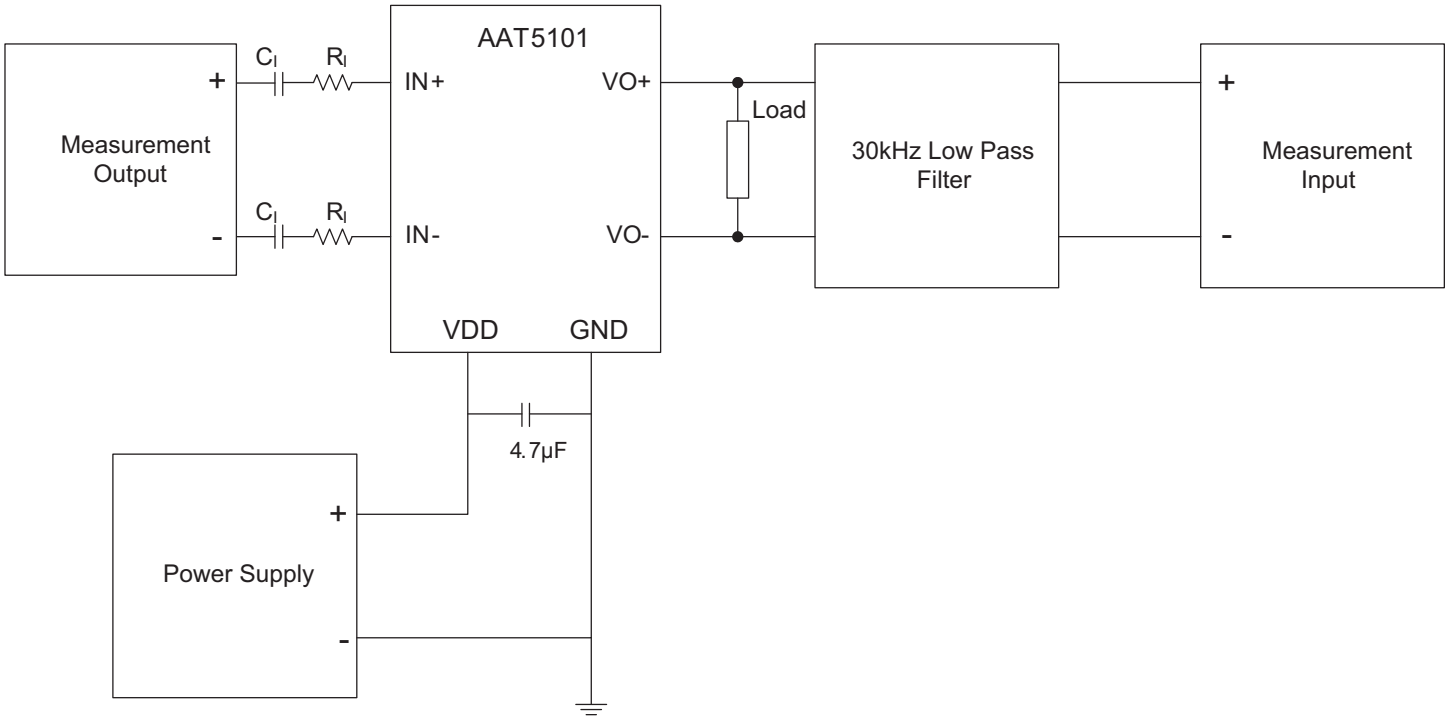
Symbol	Characteristic	Conditions	Min	Typ	Max	Units
V_{DD}	Operating Supply Voltage	T_A = -40°C to +85°C	2.1		5.5	V
I_Q	Supply Quiescent Current	V_{DD} = 5.5V, No Load		1.72	3.2	mA
		V_{DD} = 3.6V, No Load		1.35		
		V_{DD} = 2.1V, No Load		0.87	2.5	
I_{SD}	Shutdown Current	V_{DD} = 2.1V to 5.5V		0.06	1	µA
V_{SDIH}	Shutdown Voltage High	V_{DD} = 3.6V, T_A = -40°C to 85°C	1.4			V
V_{SDIL}	Shutdown Voltage Low	V_{DD} = 3.6V, T_A = -40°C to 85°C			0.6	V
F_{SW}	Switching Frequency	V_{DD} = 2.1V to 5.5V	200	250	300	kHz
G	Amplifier Gain	R_L = 4Ω	280kΩ/R_I	300kΩ/R_I	320kΩ/R_I	V/V
		R_L = 8Ω	300kΩ/R_I	320kΩ/R_I	340kΩ/R_I	
R_{DS}	Static Drain-Source On-State Resistance	V_{DD} = 5.5V		300		mΩ
		V_{DD} = 3.6V		350		
		V_{DD} = 2.1V		500		
R_S	Resistance from Shutdown to GND			300		KΩ
T_{ON}	Turn On Time	V_{DD} = 2.1V to 5.5V		8		ms
T_{OFF}	Turn Off Time	V_{DD} = 2.1V to 5.5V		8		ms

Operating Characteristics

T_A = 25°C, Gain = 2V/V, R_I = 150kΩ unless otherwise noted.

Symbol	Characteristic	Conditions		Min	Typ	Max	Units
P_{OUT}	Output Power	THD+N = 10%, f = 1kHz, R_L = 4Ω	V_{DD} = 5.0V		2.80		W
			V_{DD} = 3.6V		1.41		
			V_{DD} = 2.5V		0.62		
		THD+N = 1%, f = 1kHz, R_L = 4Ω	V_{DD} = 5.0V		2.35		
			V_{DD} = 3.6V		1.14		
			V_{DD} = 2.5V		0.46		
		THD+N = 10%, f = 1kHz, R_L = 8Ω	V_{DD} = 5.0V		1.66		
			V_{DD} = 3.6V		0.84		
			V_{DD} = 2.5V		0.37		
		THD+N = 1%, f = 1kHz, R_L = 8Ω	V_{DD} = 5.0V		1.35		
			V_{DD} = 3.6V		0.68		
			V_{DD} = 2.5V		0.29		
η	Efficiency	R_L = 8Ω, f = 1kHz	V_{DD} = 5.0V, P_{OUT} = 1.2W		92		%
			V_{DD} = 3.6V, P_{OUT} = 0.6W		91		
		R_L = 4Ω,f = 1kHz	V_{DD} = 5.0V, P_{OUT} = 2.0W		87		
			V_{DD} = 3.6V, P_{OUT} = 1.0W		85		
THD+N	Total Harmonic Distortion + Noise	R_L = 8Ω, f = 1kHz	V_{DD} = 5.0V, P_{OUT} = 1.0W		0.12		%
		R_L = 8Ω, f = 1kHz	V_{DD} = 3.6V, P_{OUT} = 0.5W		0.21		
		R_L = 8Ω, f = 1kHz	V_{DD} = 2.5V, P_{OUT} = 0.2W		0.26		
SNR	Signal-to Noise Ratio	V_{DD} = 5.0V, P_{OUT} = 1.0W, R_L = 8Ω			91		dB
CMRR	Common Mode Rejection Ratio	V_{DD} = 3.6V, V_{IC} = 1Vpp	f = 217Hz		-63		dB
PSRR	Power Supply Ripple Rejection	V_{DD} = 3.6V, Inputs AC-ground with C_I = 2.2µF	V_{RIPPLE} = 200mVpp, f = 217Hz		-60		dB
Z_I	Input Impedance	R_L = 4Ω		142	150	158	kΩ

Typical Characteristics[1, 2]

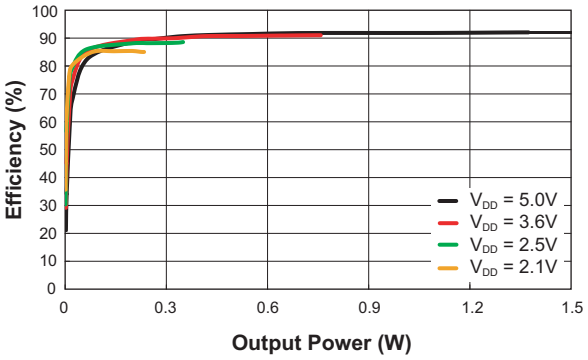


Test Set-up for Typical Characteristics Graphs.

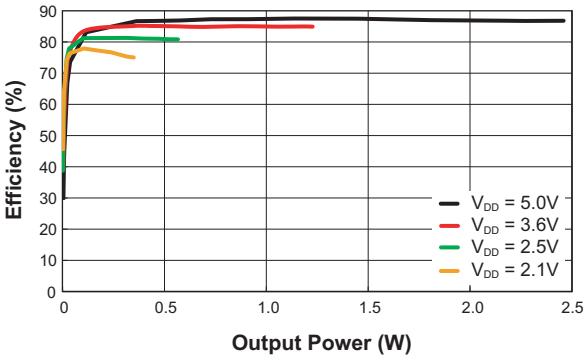
1. A 33µH inductor was placed in series with load resistor to emulate a small speaker for efficiency measurement.
2. The 30kHz low-pass filter is required even if the analyzer has an internal low-pass filter. An RC low pass filter (100Ω, 47nF) is used on each output for the data sheet graphs.

Typical Characteristics

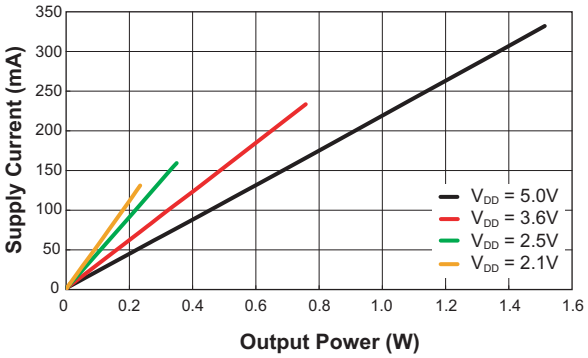
Efficiency vs. Output Power
(f = 1kHz; R_L = 8Ω + 33µH)



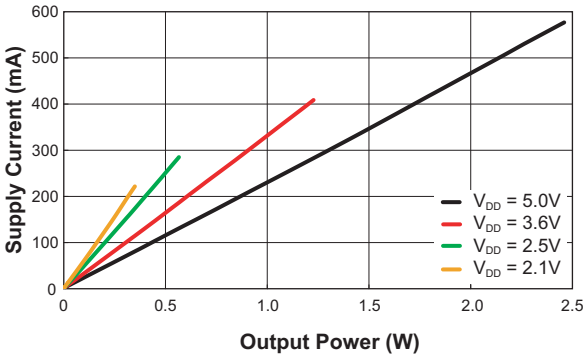
Efficiency vs. Output Power
(f = 1kHz; R_L = 4Ω + 33µH)



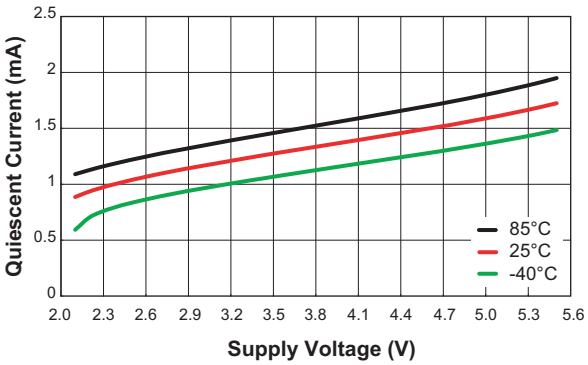
Supply Current vs. Output Power
(f = 1kHz; R_L = 8Ω + 33µH)



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

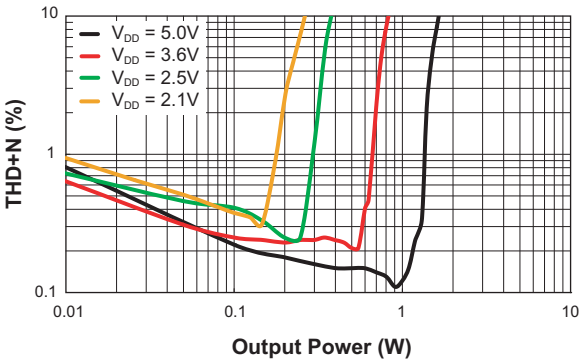


Quiescent Current vs. Supply Voltage

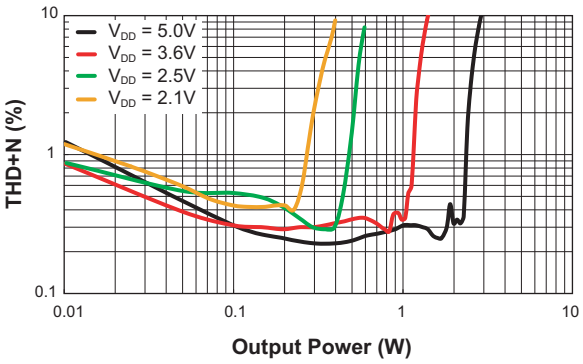


Typical Characteristics

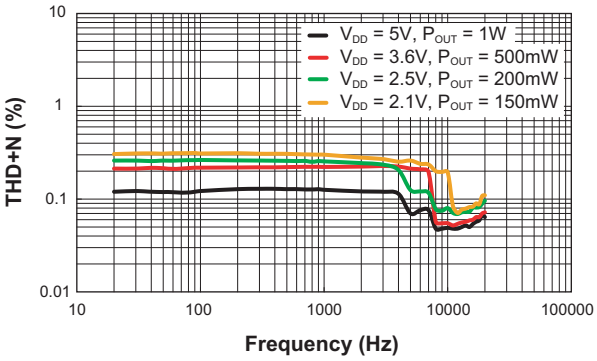
THD+N vs. Output Power
(f = 1kHz; R_L = 8Ω)



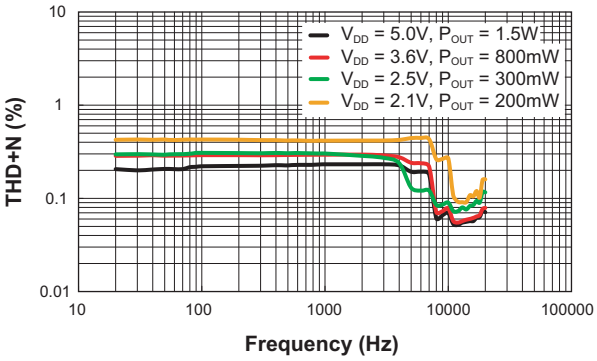
THD+N vs. Output Power
(f = 1kHz; R_L = 4Ω)



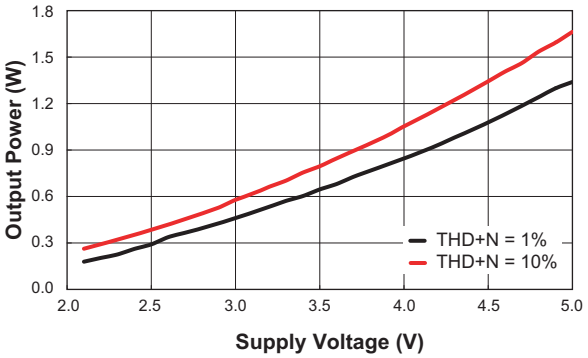
THD+N vs. Frequency
(C_I = 2.2µF; R_L = 8Ω)



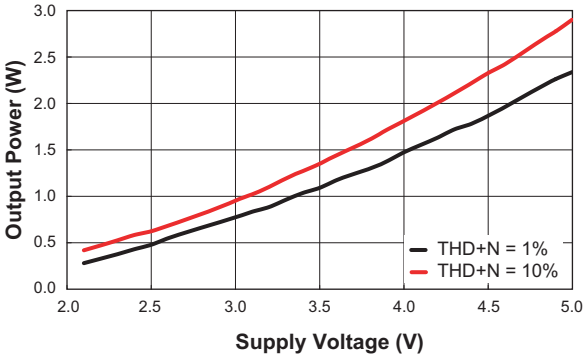
THD+N vs. Frequency
(C_I = 2.2µF; R_L = 4Ω)



Output Power vs. Supply Voltage
(f = 1kHz; R_L = 8Ω)

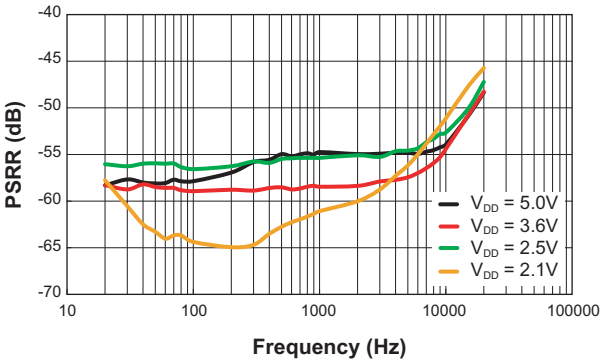


Output Power vs. Supply Voltage
(f = 1kHz; R_L = 4Ω)

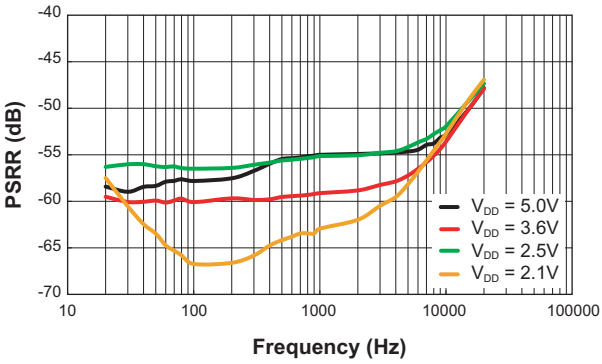


Typical Characteristics

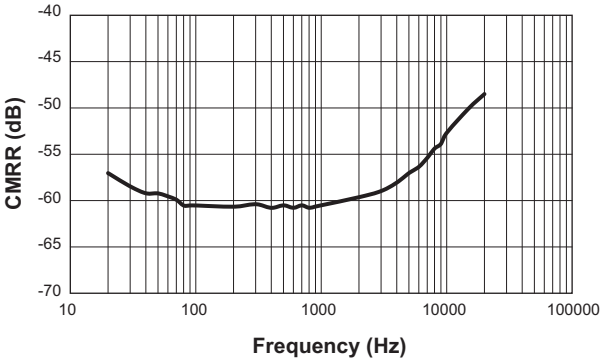
PSRR vs. Frequency
(V_{RIPPLE} = 200mVpp; C_I = 2.2µF; R_L = 8Ω; Inputs AC-grounded)



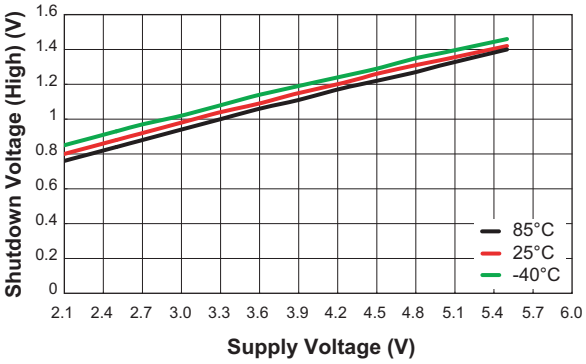
PSRR vs. Frequency
(V_{RIPPLE} = 200mVpp; C_I = 2.2µF; R_L = 4Ω; Inputs AC-grounded)



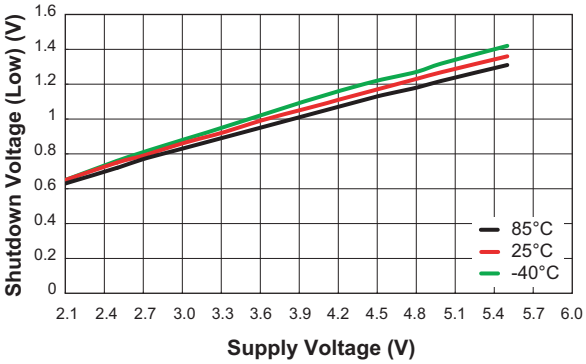
CMRR vs. Frequency
(V_{DD} = 3.6V; V_{IC} = 200mVpp; R_L = 8Ω)



Shutdown Voltage (High) vs. Supply Voltage



Shutdown Voltage (Low) vs. Supply Voltage



Application Information

Input Resistor (R_I) Selection

The input resistors (R_I) set the gain of the amplifier according to the following equation:

Gain = 300KΩ (R_L = 4Ω)
Gain = 320KΩ (R_L = 8Ω)

For input resistors (R_I), resistor matching is a very important criteria. The balance of the output around the reference voltage depends on a matched ratio of the resistors. CMRR and PSRR diminish if resistor mismatch occurs. Therefore, it is recommended to use 1% tolerance resistors or better to keep the performance optimized.

Decoupling Capacitor (C_S) Selection

The AAT5101 is a high-performance class-D audio amplifier that requires adequate power supply decoupling to ensure high efficiency and low total harmonic distortion (THD). For decoupling capacitor (C_S), a good low equivalent series resistance (ESR) 4.7µF ceramic capacitor is preferred.

Input Capacitor (C_I) Selection

The input capacitors and input resistors form a high-pass filter with the corner frequency, F_C, determined by the following equation. The value of the input capacitor is an important consideration as it directly affects the bass (low frequency) performance of the circuit. Speakers in wireless phones cannot usually respond well to low frequencies, so a high pass filter will be useful in this application.

$$F_C = \frac{1}{2 \cdot \pi \cdot R_I \cdot C_I}$$

Optional Output Filter

The AAT5101 can be designed without an output filter if the traces from the amplifier to the speaker are short. However, to lower radiated emissions as much as possible when used in filter-free mode, a ferrite bead filter can be used. If choosing a ferrite bead, choose one with high impedance at high frequencies, but very low impedance at low frequencies. The MPZ1608S221A1 from TDK is a good choice.

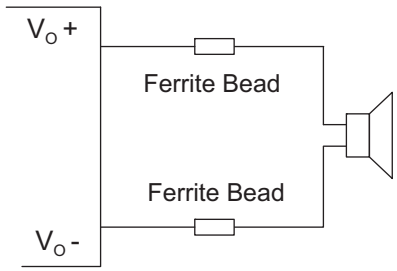


Figure 1: Optional EMI Ferrite Bead Filter.

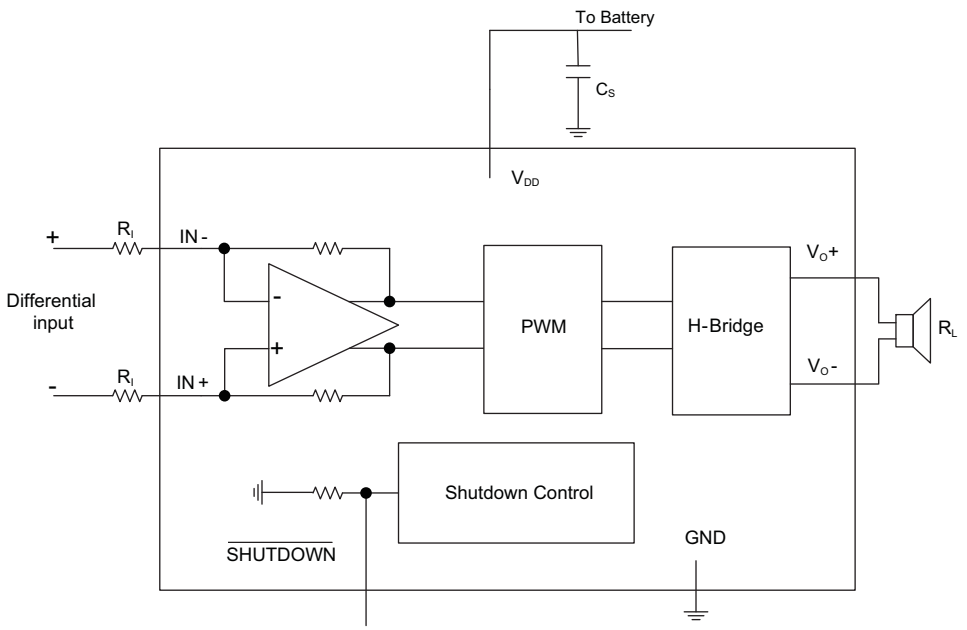


Figure 2: AAT5101 Application Schematic with DC-Coupled Fully Differential Input Configuration.

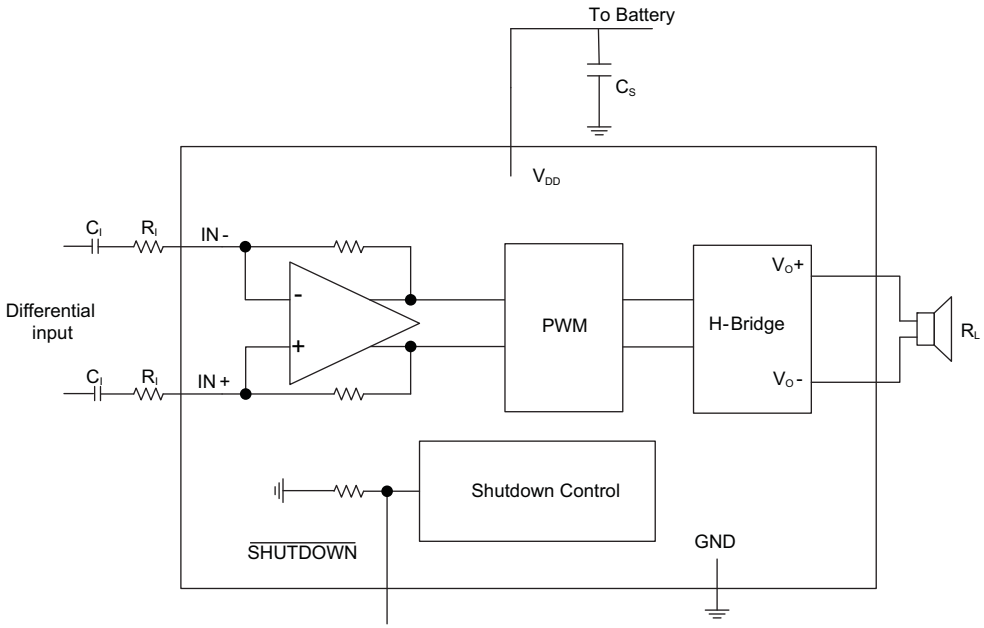


Figure 3: AAT5101 Application Schematic with AC-Coupled Fully Differential Input Configuration.

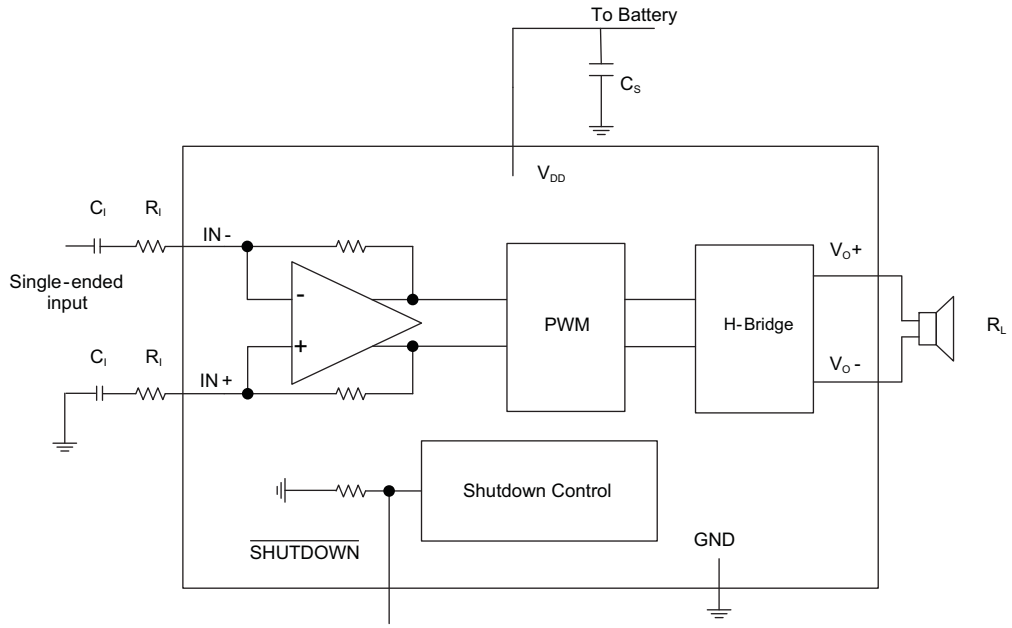


Figure 4: AAT5101 Application Schematic with Single-Ended Input Configuration.

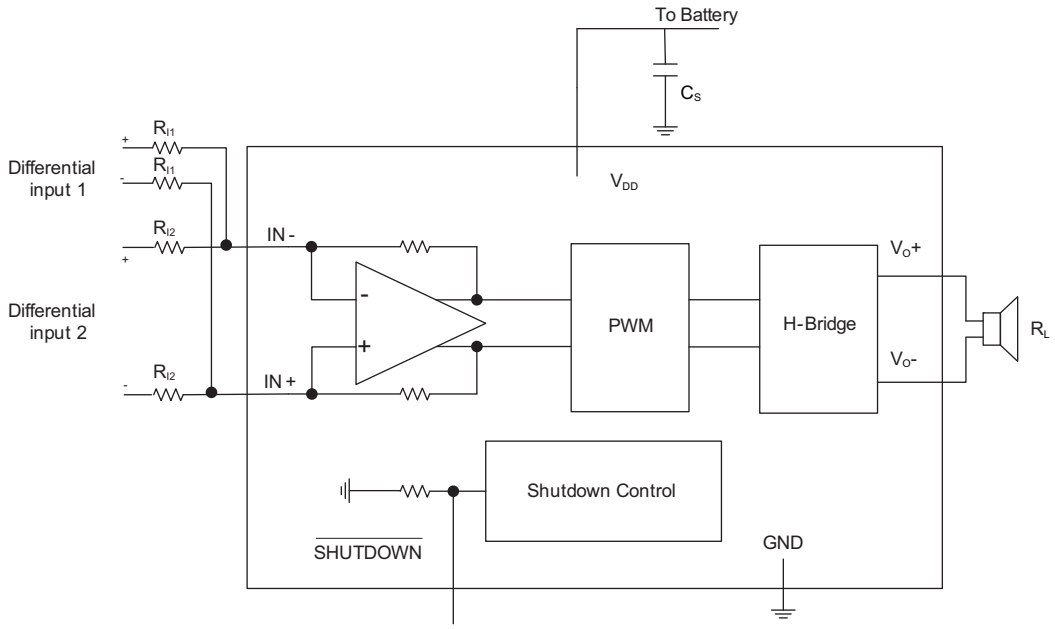


Figure 5: AAT5101 Application Schematic with AAT5101 Summing Two Differential Inputs.

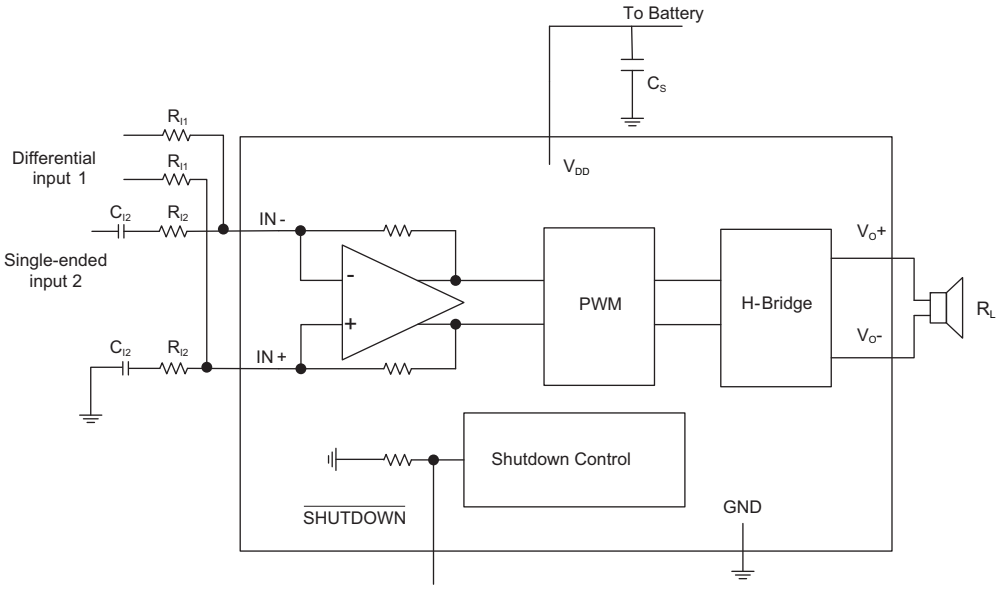


Figure 6: AAT5101 Application Schematic with AAT5101 Summing Differential Input and Single-Ended Input Signals.

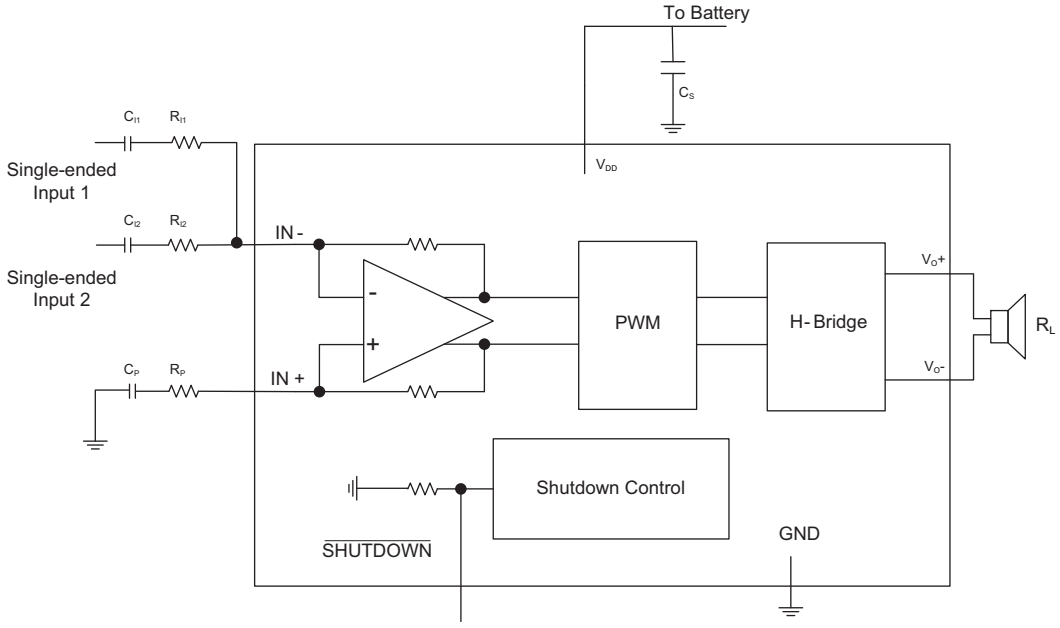


Figure 7: AAT5101 Application Schematic with AAT5101 Summing Two Single-Ended Inputs.

PCB Guidance

The suggested PCB layout for the AAT5101 is shown in Figure 9. All components are placed as close as possible to the AAT5101's leads to achieve better performance.

The following guidelines should be used to help ensure a proper layout.

1. The decoupling capacitor (C4) should connect to the VDD pin and PVDD pin as closely as possible.
2. The input resistor (R1, R2) should be placed very close to the AAT5101.
3. The input routes should be similar and the distance between the two routes should be small.
4. The output traces should be short, wide, and not pass beneath the IC in the other layers.

WLCSP Package Light Sensitivity

The electrical performance of the WLCSP package can be adversely affected by exposing the device to certain light sources, such as direct sunlight or a halogen lamp whose wavelengths are red and infra-reds. However, fluorescent lighting has very little effect on the electrical performance of the WLCSP package.

Evaluation Board Information

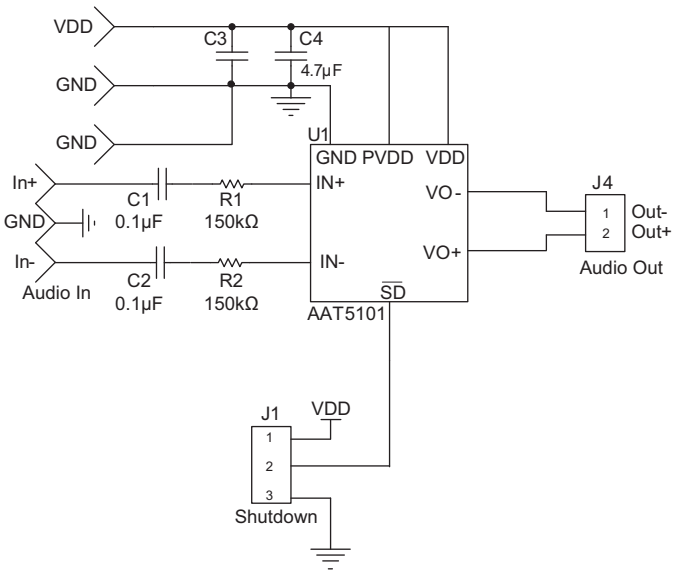
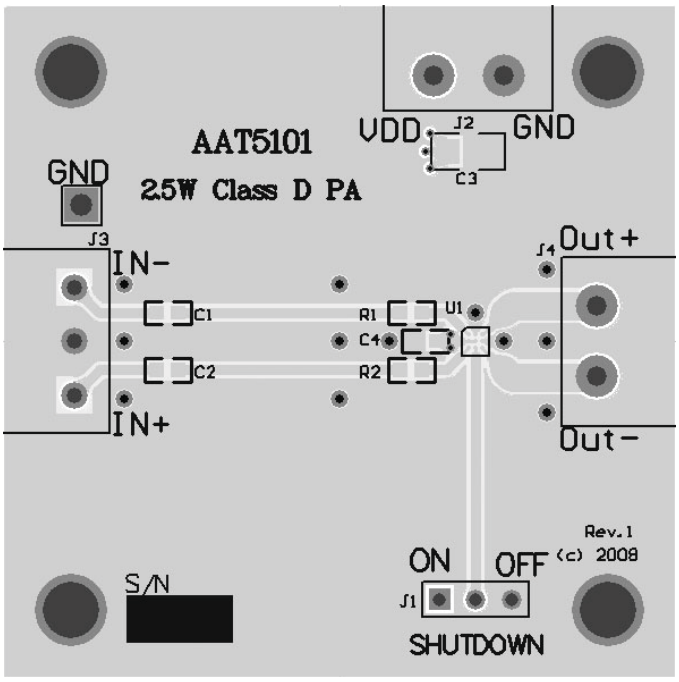


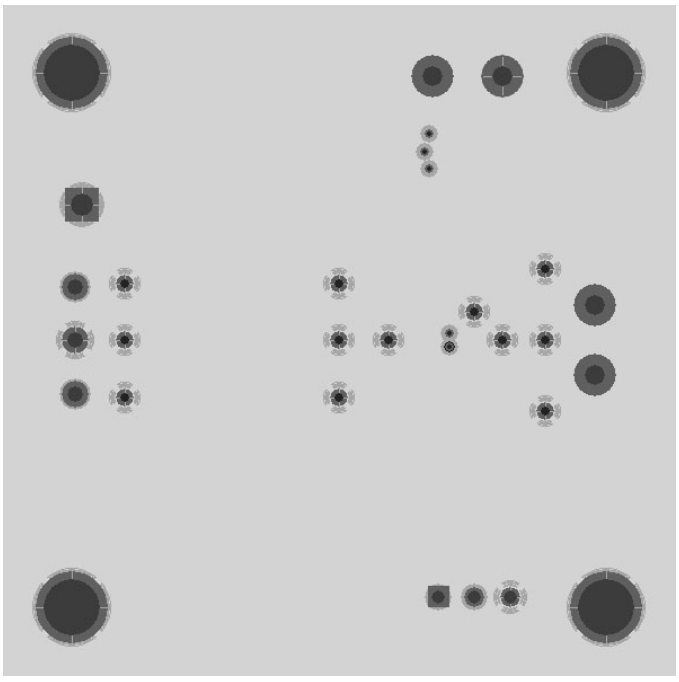
Figure 8: AAT5101 Evaluation Board Schematic.

Component Selection

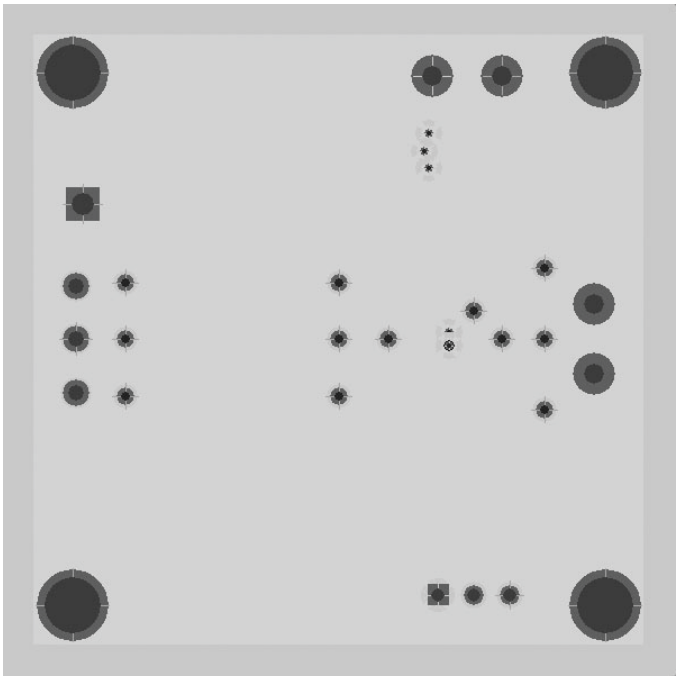
Item	Part Description	Ref	PCB Footprint	Manufacturer	Part Number
1	SMD Resistor 150KΩ	R1, R2	0603	Vishay-Draloric	CRCW0603
2	Ceramic Capacitor 0.1µF, 50V, X7R	C1, C2	0603	TDK	C1608X7R1H104KT
3	Ceramic Capacitor 4.7µF, 6.3V, X5R	C4	0603	TDK	C1608X5R0J475MT
4	Not populated	C3			



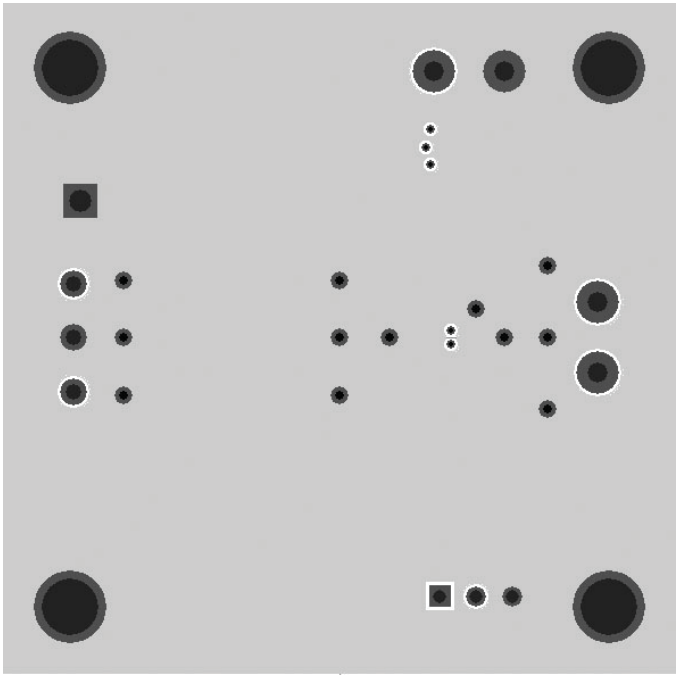
(a) Top Layer



(b) Ground Plane



(c) Power Plane



(d) Bottom Layer

Figure 9: AAT5101 Evaluation Board PCB Layout.

Ordering Information

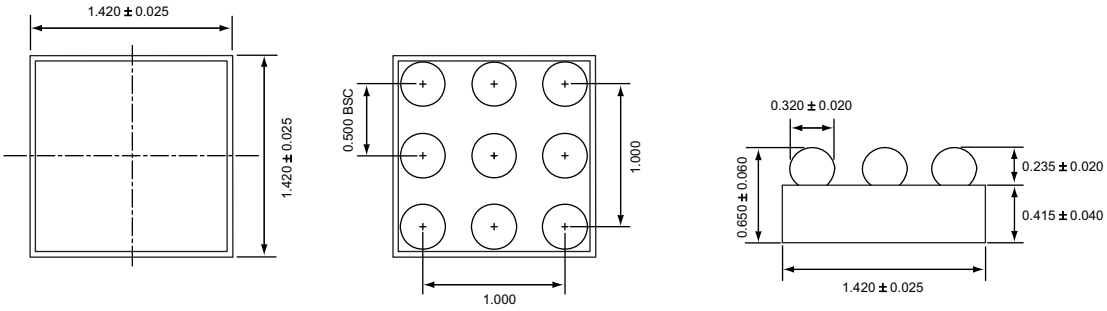
Package	Part Marking[1]	Part Number (Tape and Reel)[2]
WLCSP-9	7HYW	**AAT5101IUR-T1**

Pb-free

All AnalogicTech products are offered in Pb-free packaging. The term "Pb-free" means semiconductor products that are in compliance with current RoHS standards, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. For more information, please visit our website at http://www.analogictech.com/aboutus/quality.php.

Packaging Information

WLCSP-9



Top View Bottom View Side View

All dimensions in millimeters.

1. YW = date code.
2. Sample stock is generally held on part numbers listed in **BOLD**.

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