

Stereo, Differential Input Cap-Free Line Driver

Features

- **Operating Voltage:** 2.3V~5.5V
- **Differential Input**
- **Ground Reference Output**
 - No Output Capacitor Required (for DC Blocking)
 - Save the PCB Space
 - Reduce the BOM Costs
 - Improve the Low Frequency Response
- **Low Noise and THD+N**
 - SNR > 108dB
 - Noise < 8mV_{rms}
 - THD+N < 0.02% at 20Hz~20kHz
- **Output Voltage Swing Can Reach 2.1V_{rms}/Ch into 2.5k Ω at V_{DD} =3.3V**
- **High PSRR:** 80dB at 217Hz
- **Fast Start-up Time:** 500ms
- **Integrate the De-Pop Circuitry**
- **Thermal and Short-Circuit Protection**
- **Surface-Mount Packaging**
 - SOP-14
 - TSSOP-14
- **Lead Free and Green Devices Available (RoHS Compliant)**

Applications

- Set-Top Boxes
- CD/DVD Players
- LCD TVs
- HTIBs (Home Theater in Box)

General Description

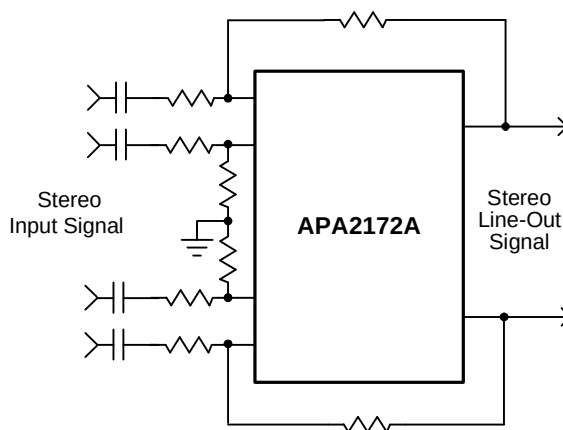
The APA2172A is a stereo, differential input, single supply, and cap-free line driver, which is available in SOP-14 and TSSOP-14 packages.

The APA2172A is ground-reference output, and doesn't need the output capacitors for DC blocking. The advantages of eliminating the output capacitor are saving the cost, eliminating component height, and improving the low frequency response.

The external gain setting is recommended using from $\pm 1\text{V/V}$ to $\pm 10\text{V/V}$. High PSRR provides increased immunity to noise and RF rectification. APA2172A has shut-down and under-voltage detector function for Depop solution.

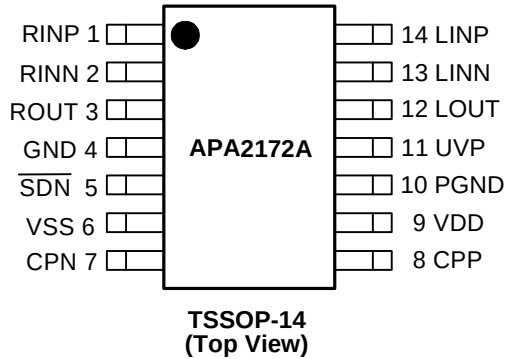
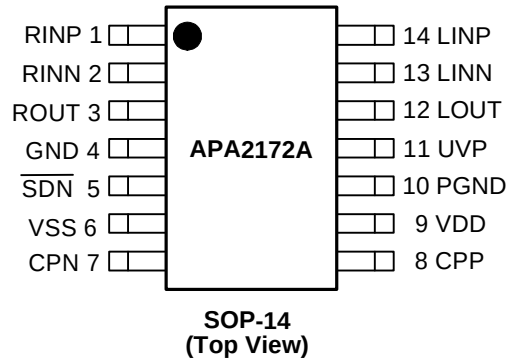
The APA2172A is capable of driving 2.1V_{rms} at 3.3V into 2.5k Ω load, and provides short-circuit and thermal protection.

Simplified Application Circuit



ANPEC reserves the right to make changes to improve reliability or manufacturability without notice, and advise customers to obtain the latest version of relevant information to verify before placing orders.

Pin Configuration



Ordering and Marking Information

<p>APA2172A □ □ - □ □ □</p> <p>└─ Assembly Material</p> <p>└─ Handling Code</p> <p>└─ Temperature Range</p> <p>└─ Package Code</p>	<p>Package Code O : TSSOP-14 K : SOP-14 Operating Ambient Temperature Range I : -40 to 85 °C Handling Code TR : Tape & Reel Assembly Material G : Halogen and Lead Free Device</p>
<p>APA2172A O : APA2172 •XXXXXA</p>	<p>XXXXX - Date Code</p>
<p>APA2172A K :  APA2172A •XXXXX</p>	<p>XXXXX - Date Code</p>

Note: ANPEC lead-free products contain molding compounds/die attach materials and 100% matte tin plate termination finish; which are fully compliant with RoHS. ANPEC lead-free products meet or exceed the lead-free requirements of IPC/JEDEC J-STD-020D for MSL classification at lead-free peak reflow temperature. ANPEC defines "Green" to mean lead-free (RoHS compliant) and halogen free (Br or Cl does not exceed 900ppm by weight in homogeneous material and total of Br and Cl does not exceed 1500ppm by weight).

Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Rating	Unit
V_{PGND_GND}	PGND to GND Voltage	-0.3 to 0.3	V
V_{DD}	Supply Voltage (VDD to GND and PGND)	-0.3 to 6.0	
V_{SDN}	Input Voltage (SDN to GND)	$V_{GND}-0.3$ to $V_{DD}+0.3$	
V_{SS}	VSS to GND and PGND Voltage	-6.0 to 0.3	
V_{OUT}	ROUT and LOUT to GND Voltage	$V_{SS}-0.3$ to $V_{DD}+0.3$	
V_{CPP}	CPP to PGND Voltage	$V_{PGND}-0.3$ to $V_{DD}+0.3$	
V_{CPN}	CPN to PGND Voltage	$V_{SS}-0.3$ to $V_{PGND}+0.3$	
T_J	Maximum Junction Temperature	150	°C
T_{STG}	Storage Temperature Range	-65 to +150	
T_{SDR}	Maximum Soldering Temperature Range, 10 Seconds	260	
P_D	Power Dissipation	Internally Limited	W

Note 1: Absolute Maximum Ratings are those values beyond which the life of a device may be impaired. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Thermal Characteristics

Symbol	Parameter	Typical Value	Unit
θ_{JA}	Thermal Resistance - Junction to Ambient ^(Note 2) TSSOP-14 SOP-14	120 120	$^{\circ}\text{C/W}$
θ_{JC}	Thermal Resistance - Junction to Case TSSOP-14 SOP-14	32 32	$^{\circ}\text{C/W}$

Note 2: Please refer to "Thermal Pad Consideration". 2 layered 5 in2 printed circuit boards with 2oz trace and copper through several thermal vias. The thermal pad is soldered on the PCB.

Recommended Operating Conditions

Symbol	Parameter	Range		Unit
		Min.	Max.	
V_{DD}	Supply Voltage	2.3	5.5	V
V_{IH}	High Level Threshold Voltage	1.0	-	
V_{IL}	Low Level Threshold Voltage	-	0.35	
T_A	Operating Ambient Temperature Range	-40	85	$^{\circ}\text{C}$
T_J	Operating Junction Temperature Range	-40	125	$^{\circ}\text{C}$
R_L	Load Resistance	16	100k	Ω

Electrical Characteristics

$V_{DD}=3.3\text{V}$, $V_{GND}=V_{PGND}=0\text{V}$, $V_{SDN}=V_{DD}$, $C_{CPF}=C_{CPO}=1\mu\text{F}$, $C_i=2.2\mu\text{F}$, $R_L=2.5\text{k}\Omega$, $T_A=25^{\circ}\text{C}$, $R_i=10\text{k}\Omega$, $R_f=20\text{k}\Omega$ (unless otherwise noted)

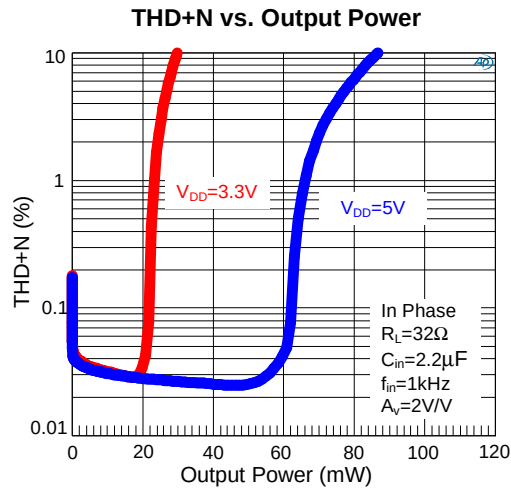
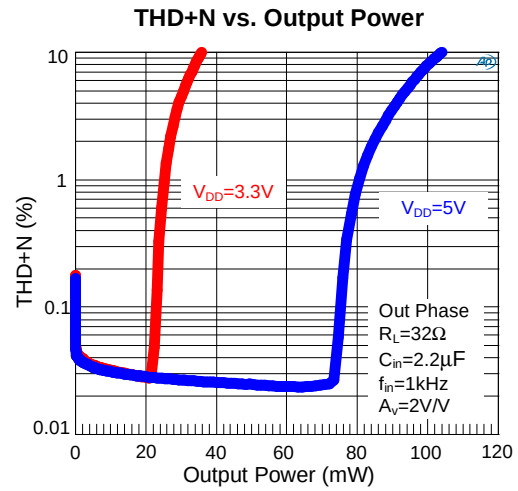
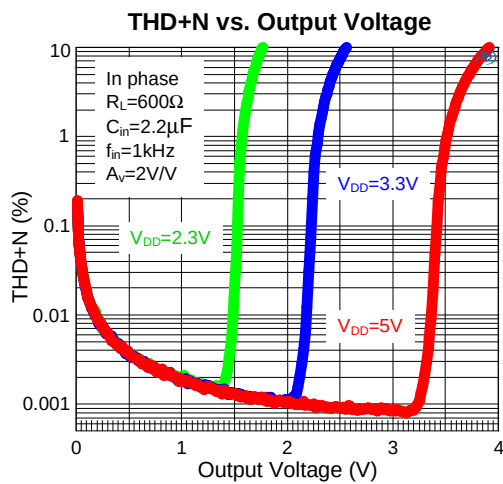
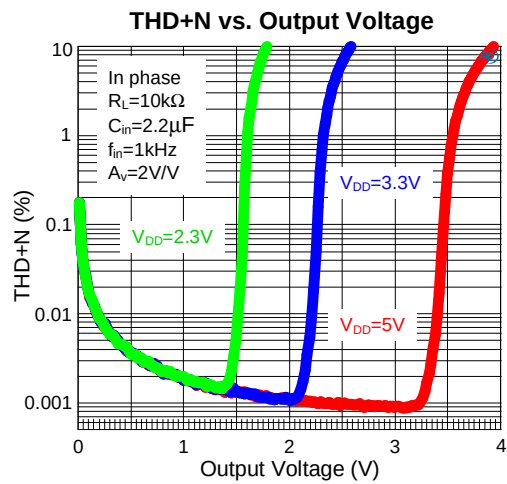
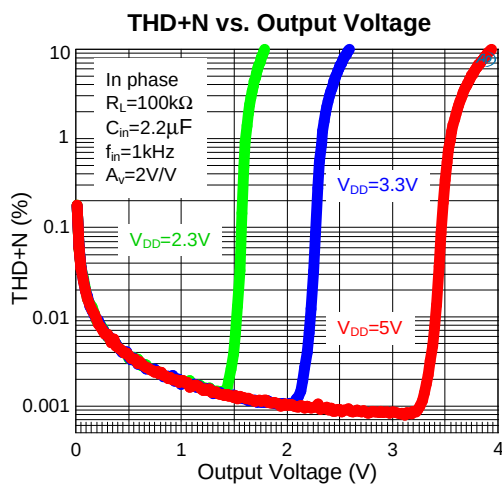
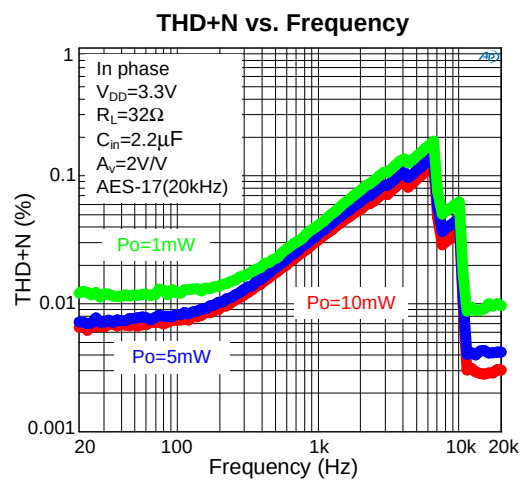
Symbol	Parameter	Test Conditions	APA2172A			Unit
			Min.	Typ.	Max.	
I_{DD}	V_{DD} Supply Current		-	10	15	mA
I_{SD}	V_{DD} Shutdown Current	$V_{SDN}=0\text{V}$	-	1	5	μA
I_I	Input Current	$\overline{\text{SDN}}$	-	0.1	-	μA
CHARGE PUMP						
f_{OSC}	Switching Frequency		400	500	600	kHz
R_{eq}	Equivalent Resistance		-	21	25	Ω
DRIVERS						
A_{VO}	Open Loop Voltage Gain		80	100	-	dB
GW	Unity Gain Bandwidth		8	10	-	MHz
V_{SR}	Slew Rate		-	4.5	-	V/ μs
V_{OS}	Output Offset Voltage	$V_{DD}=2.3\text{V}$ to 5.5V , $R_L=2.5\text{k}\Omega$	-5	-	5	mV
V_N	Output Noise	$R_i=10\text{k}\Omega$, $R_f=10\text{k}\Omega$	-	8	15	μV_{rms}
$T_{start-up}$	Start-up Time		-	500	-	μs
PSRR	Power Supply Rejection Ratio	$V_{DD}=2.3\text{V}$ to 5.5V , $V_{rr}=200\text{mV}_{rms}$ $f_{in}=217\text{Hz}$ $f_{in}=1\text{kHz}$ $f_{in}=20\text{kHz}$	-	-80 -80 -50	-60 -60 -45	dB
C_L	Maximum Capacitive Load		-	220	-	pF
V_{ESD}	ESD Protection	OUTR, OUTL	-	8	-	kV

Electrical Characteristics (Cont.)

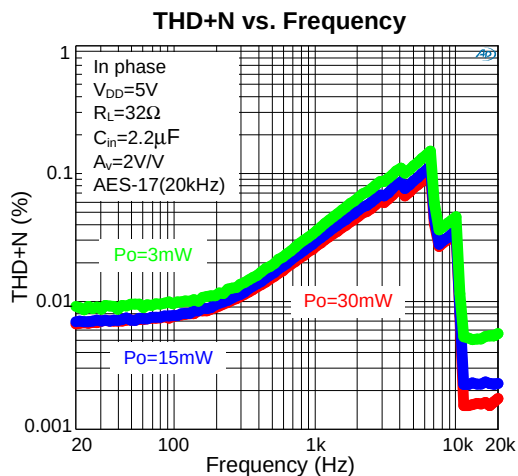
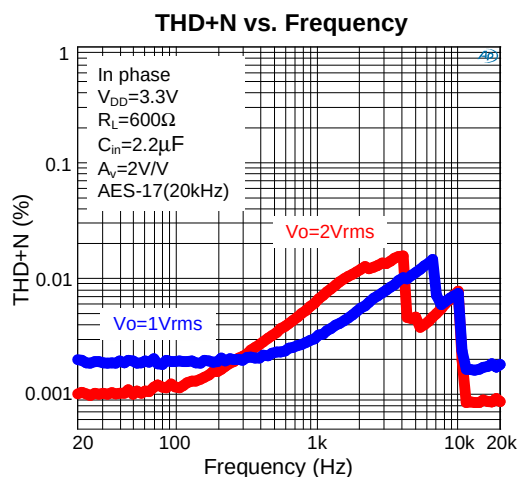
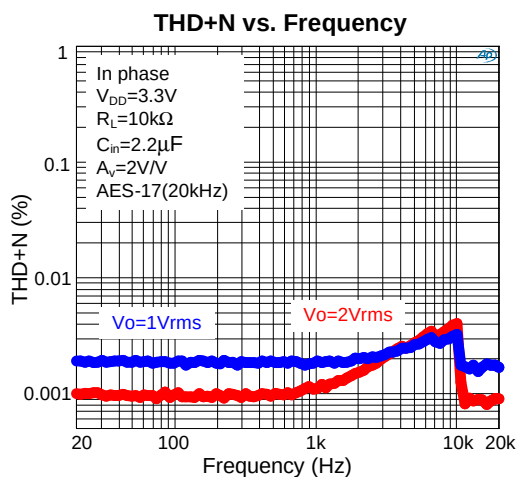
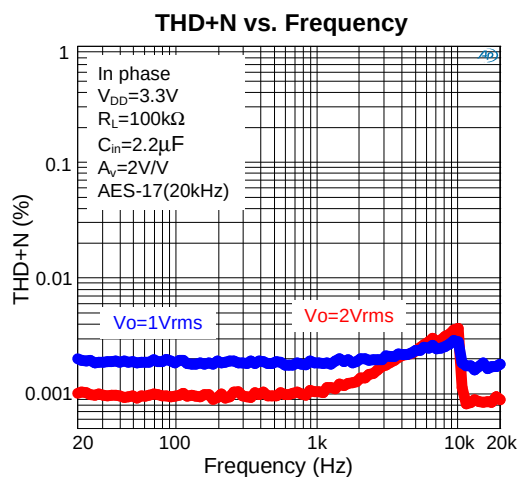
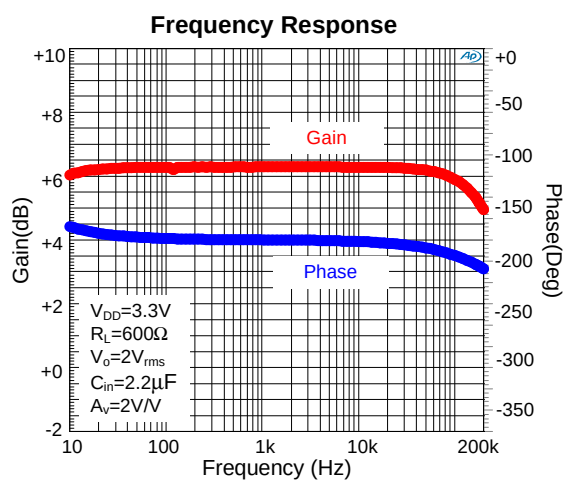
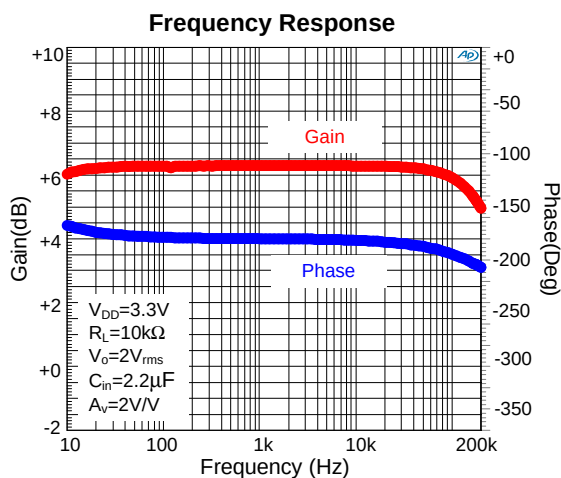
$V_{DD}=3.3V$, $V_{GND}=V_{PGND}=0V$, $V_{SDN}=V_{DD}$, $C_{CPF}=C_{CPO}=1\mu F$, $C_i=2.2\mu F$, $R_L=2.5k\Omega$, $T_A=25^\circ C$, $R_i=10k\Omega$, $R_f=20k\Omega$ (unless otherwise noted)

Symbol	Parameter	Test Conditions	APA2172A			Unit
			Min.	Typ.	Max.	
V_O	Output Voltage (Stereo, In Phase)	THD+N=1%, $f_{in}=1kHz$ $R_L=2.5k\Omega$ $R_L=100k\Omega$	2.0 -	2.1 2.3	-	V
P_O	Output Power (Stereo, In Phase)	THD+N=1%, $f_{in}=1kHz$ $R_L=32\Omega$	16	20	-	mW
		VDD=5V THD+N=1%, $f_{in}=1kHz$ $R_L=32\Omega$	48	60	-	
THD+N	Total Harmonic Distortion Plus Noise	$V_O=2V_{rms}$, $R_L=2.5k\Omega$ $f_{in}=20Hz$ $f_{in}=1kHz$ $f_{in}=20kHz$	-	0.02 0.001 0.02	- 0.002 -	%
		$P_O=10mW$, $R_L=32\Omega$, $f_{in}=1kHz$	-	0.03	-	
		VDD=5V, $P_O=30mW$, $R_L=32\Omega$, $f_{in}=1kHz$	-	0.03	-	
Crosstalk	Channel Separation	$V_O=2V_{rms}$, $R_L=2.5k\Omega$ $f_{in}=20Hz$ $f_{in}=1kHz$ $f_{in}=20kHz$	-	100 100 90	-	dB
S/N	Signal to Noise Ratio	$V_O=2V_{rms}$, $R_L=2.5k\Omega$, $R_i=10k\Omega$, $R_f=10k\Omega$, With A-weighting Filter	102	108	-	dB
T_{SD}	Thermal Shutdown Protection Temperature		-	150	-	$^\circ C$
UVP FUNCTION						
V_{UVP}	External Under Voltage Detection		1.1	1.25	1.35	V
I_{HYS}	External Under Voltage Detection Hysteresis Current		-	5.0	-	μA

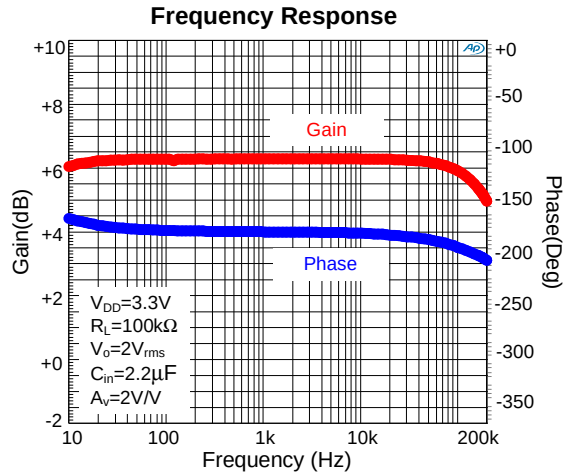
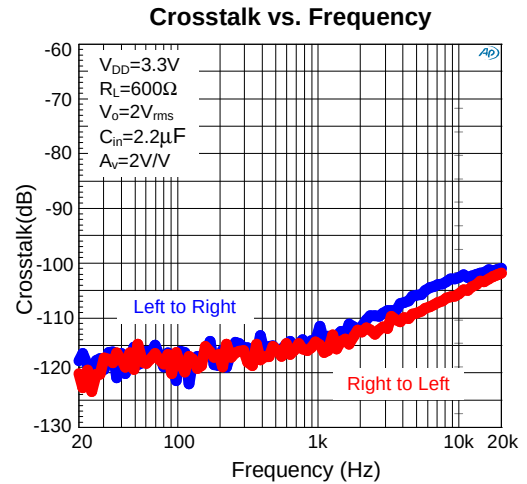
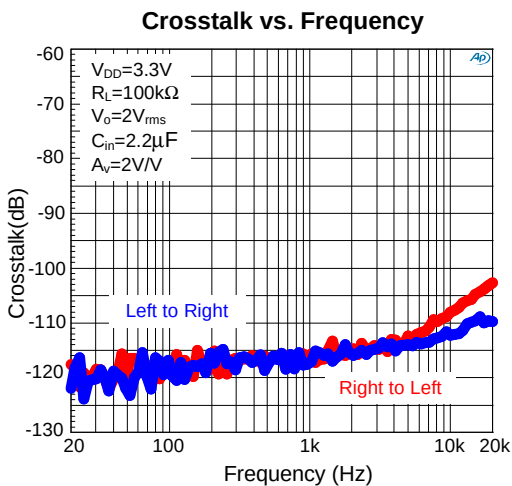
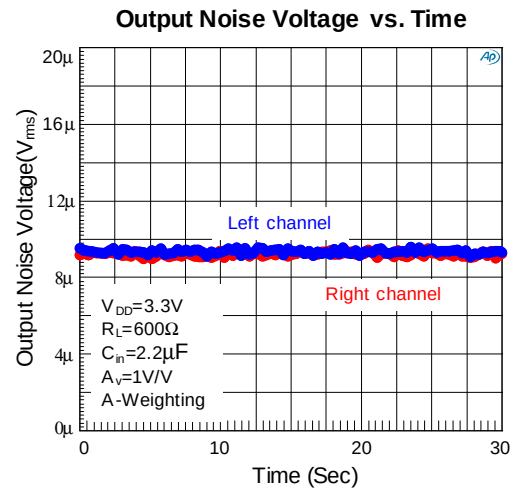
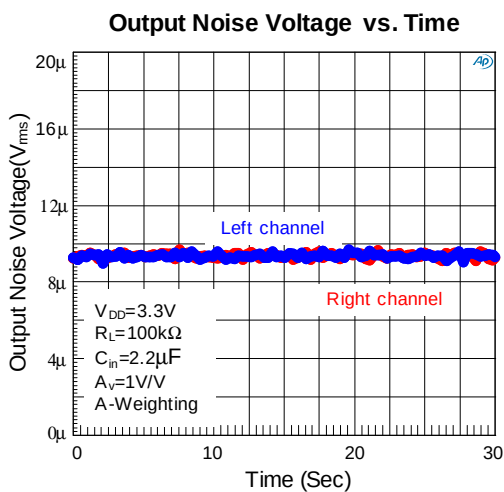
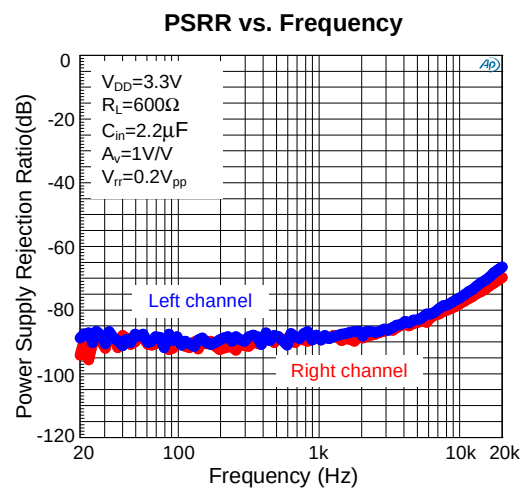
Typical Operating Characteristics



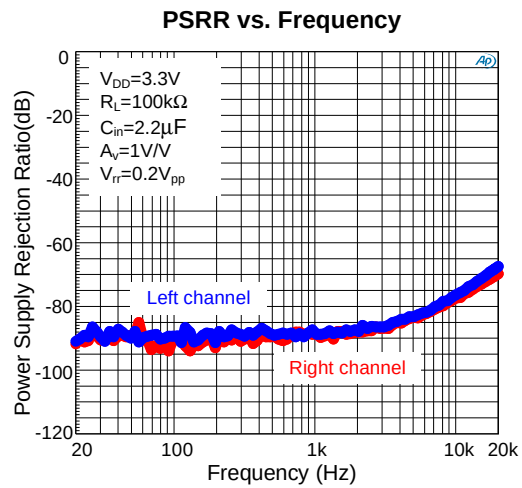
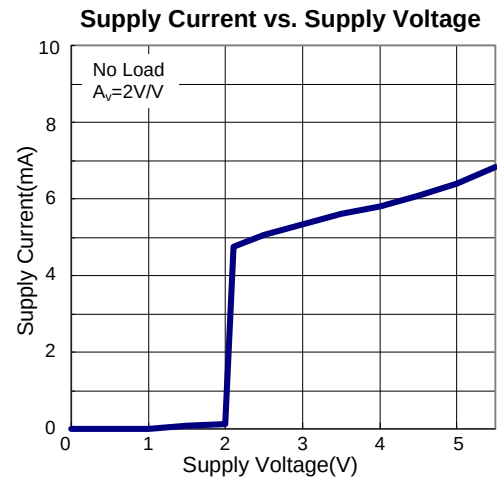
Typical Operating Characteristics



Typical Operating Characteristics (Cont.)



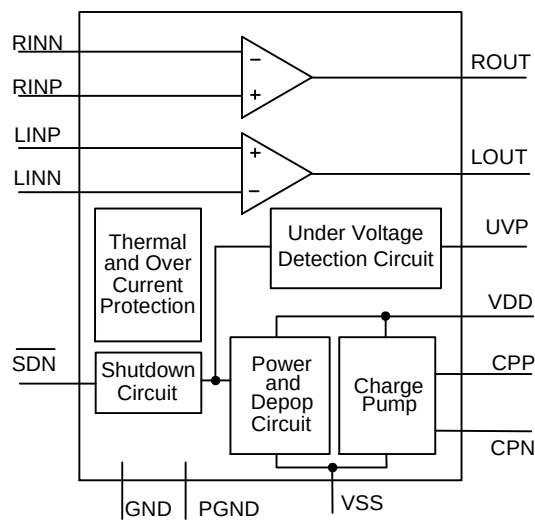
Typical Operating Characteristics (Cont.)



Pin Description

PIN		I/O/P	FUNCTION
NO.	NAME		
1	RINP	I	Right channel non-inverting input.
2	RINN	I	Right channel inverting input.
3	ROUT	O	Right channel output.
4	GND	P	Signal ground.
5	$\overline{\text{SDN}}$	I	Shutdown mod control input signal, pull low for shutdown headphone driver. This pin should be connect a 100Ω Protection Resistor.
6	VSS	P	Headphone driver negative power supply.
7	CPN	I/O	Charge pump flying capacitor negative connection.
8	CPP	I/O	Charge pump flying capacitor positive connection.
9	VDD	P	Supply voltage input.
10	PGND	P	Power ground.
11	UVP	I	Under voltage protection input. Floating or Pull "H" to disable this function.
12	LOUT	O	Left channel output.
13	LINN	I	Left channel inverting input.
14	LINP	I	Left channel non-inverting input.

Block Diagram



Line Driver Amplifier

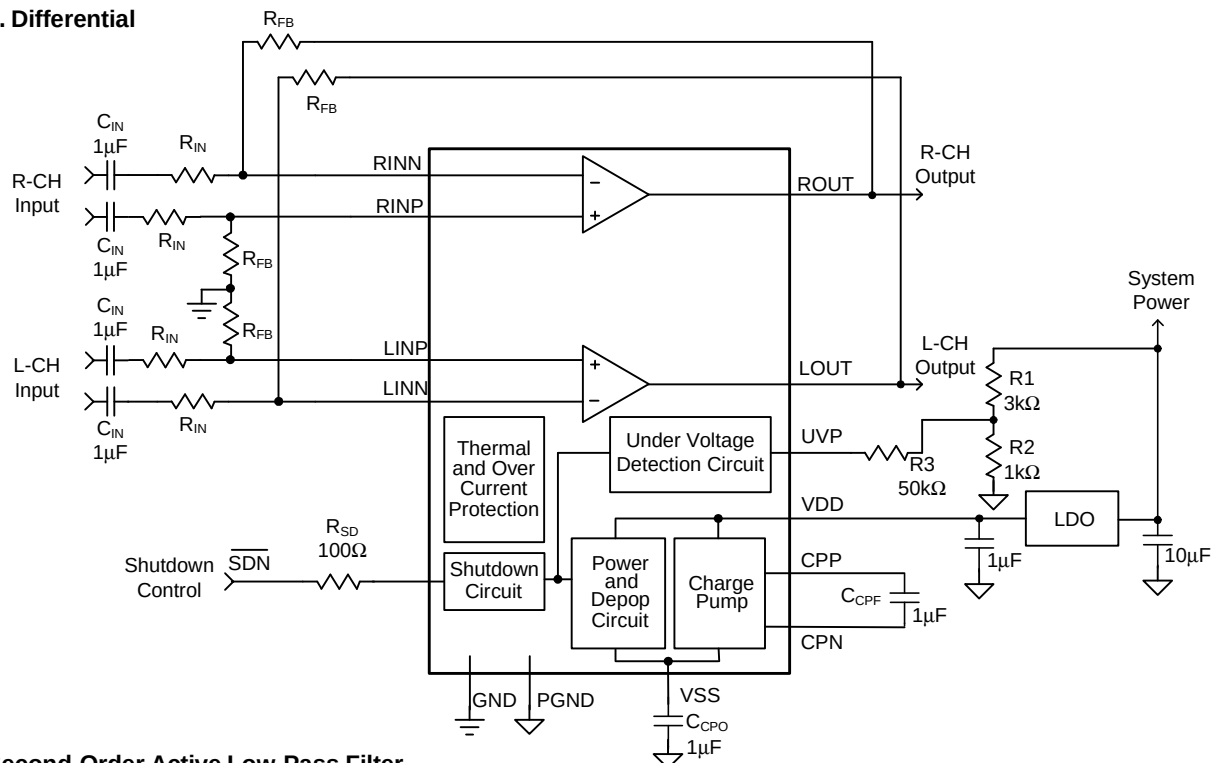
2. Non-Inverting

The schematic diagram illustrates the Non-Inverting configuration of the AD8604 op-amp. The circuit includes two input channels, R-CH and L-CH, each with a non-inverting input stage. The R-CH input is connected to the RINN pin, and the L-CH input is connected to the LINN pin. Both inputs are biased with a voltage divider consisting of R_{IN} and R_{FB} . The feedback network for the R-CH stage consists of R_{FB} and R_{FFB} . The output of the R-CH stage is ROUT, and the output of the L-CH stage is LOUT. The op-amp is powered by a VDD pin connected to a 10µF capacitor and a 100kΩ resistor to the L-CH output. The VSS pin is connected to a 10µF capacitor. The shutdown control is connected to an SDN pin through a 100Ω resistor. The op-amp includes internal blocks for Thermal and Over Current Protection, Under Voltage Detection Circuit, Shutdown Circuit, Power and Depop Circuit, and Charge Pump. The charge pump output is connected to the CPP pin, which is biased with a 1µF capacitor. The CPO pin is connected to a 1µF capacitor. The op-amp is connected to a system power supply through a 10µF capacitor and a 100kΩ resistor.

Typical Application Circuit (Cont.)

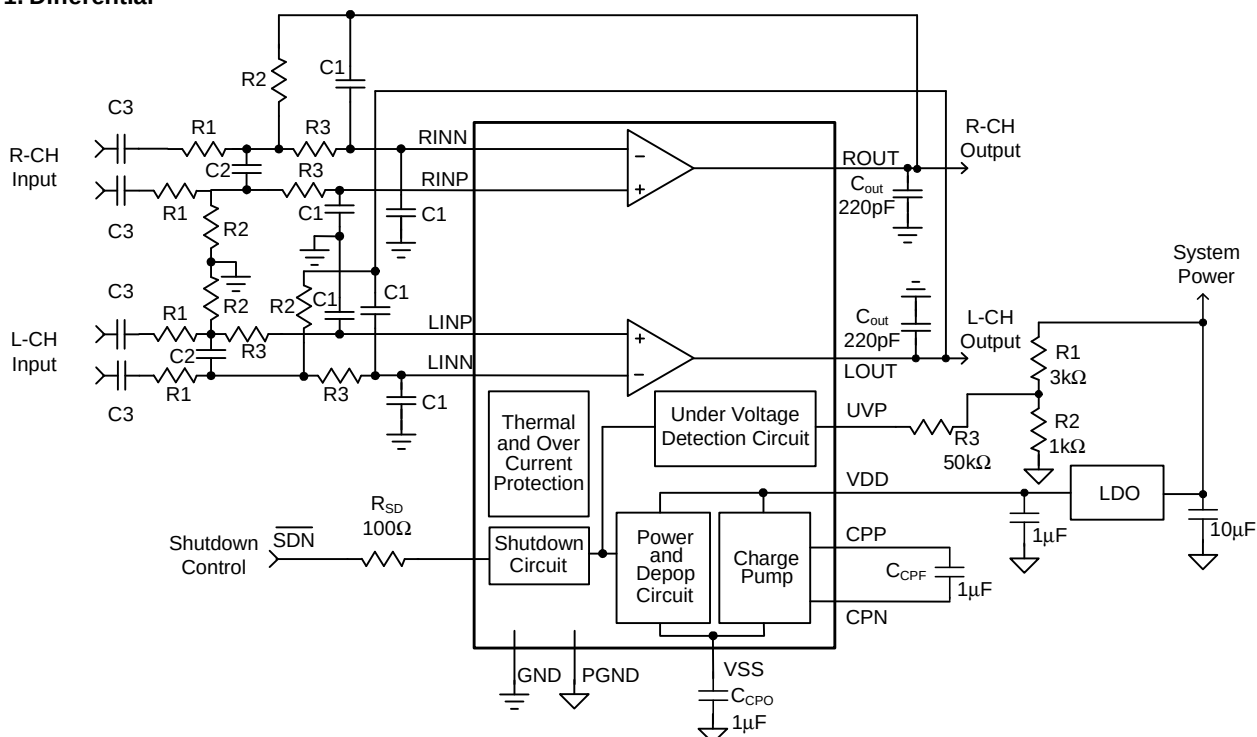
Line Driver Amplifier (Cont.)

3. Differential



Second-Order Active Low-Pass Filter

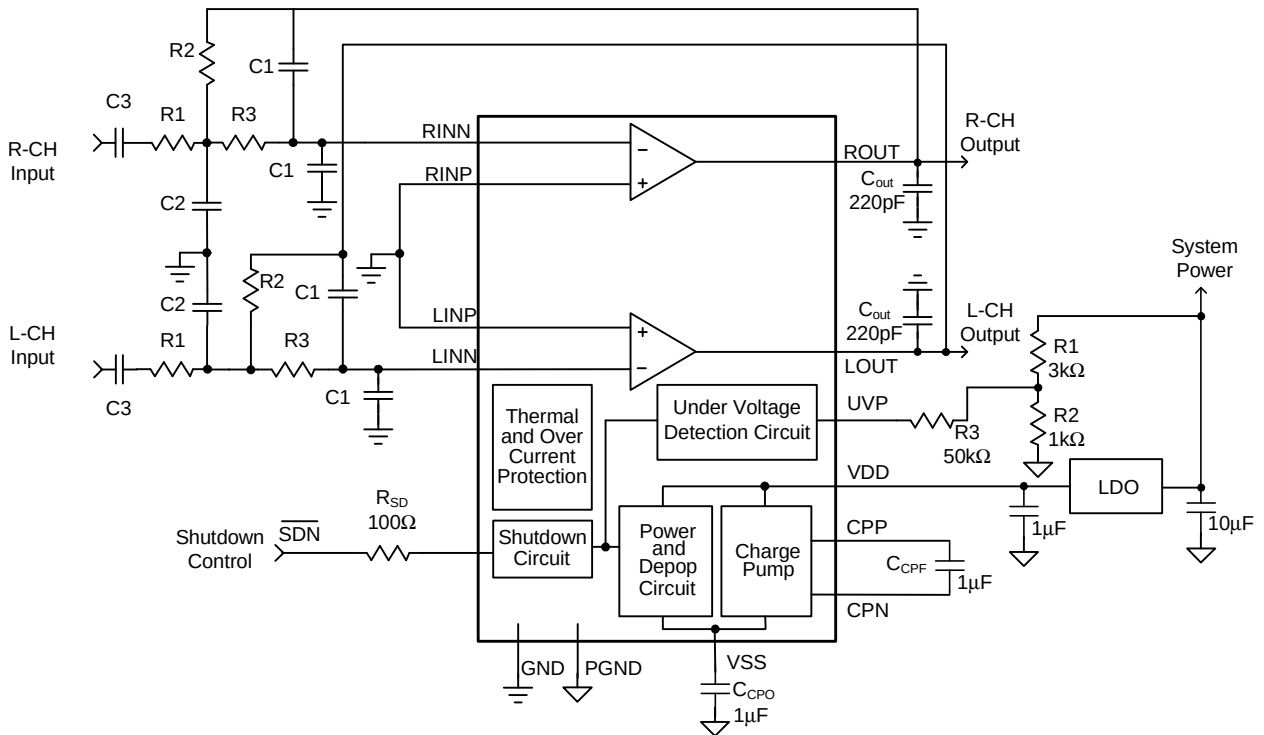
1. Differential



Typical Application Circuit (Cont.)

Second-Order Active Low-Pass Filter

2. Inverting



Function Description

Line Driver Operation

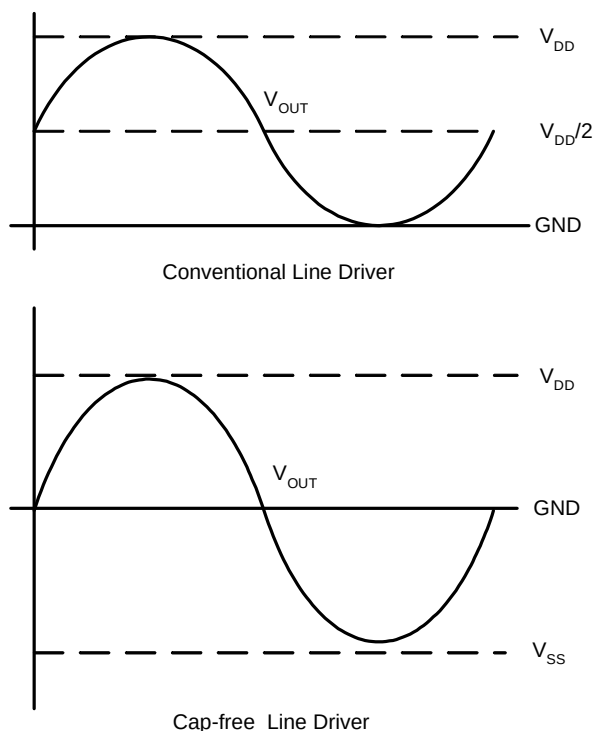


Figure 1. Cap-free Operation

The APA2172A's line drivers use a charge pump to invert the positive power supply (V_{DD}) to negative power supply (V_{SS}), see figure1. The headphone drivers operate at this bipolar power supply (V_{DD} and V_{SS}) and the outputs reference refers to the ground. This feature eliminates the output capacitor that is using in conventional single-ended headphone drive amplifier. Compare with the single power supply amplifier, the power supply range has almost doubled.

Thermal Protection

The thermal protection circuit limits the junction temperature of the APA2172A. When the junction temperature exceeds $T_j = +150^{\circ}\text{C}$, a thermal sensor turns off the driver, allowing the devices to cool. The thermal sensor allows the driver to start-up after the junction temperature down about 125°C . The thermal protection is designed with a 25°C hysteresis to lower the average T_j during continuous thermal overload conditions, increasing lifetime of the ICs.

Shutdown Function

In order to reduce power consumption while not in use, the APA2172A contains shutdown controllers to externally turn off the amplifier bias circuitry. This shutdown feature turns the amplifier off when logic low is placed on the $\overline{\text{SDN}}$ pins for the APA2172A. The trigger point between a logic high is 1.0V and logic low level is 0.35V. It is recommended to switch between ground and the supply voltage V_{DD} to provide maximum device performance. By switching the $\overline{\text{SDN}}$ pins to a low level, the amplifier enters a low-consumption current circumstance, charge pump is disabled, and I_{DD} for the APA2172A is in shutdown mode. In normal operating, the APA2172A's $\overline{\text{SDN}}$ pins should be pulled to a high level to keep the IC out of the shutdown mode. The $\overline{\text{SDN}}$ pins should be tied to a definite voltage to avoid unwanted circumstance changes.

Under-Voltage Protection

External under voltage detection can be used to shut-down the APA2172A before an input device can generate a pop. The shutdown threshold at the UVP pin is 1.25V. The user selects a resistor divider to obtain the shutdown threshold and hysteresis for the specific application. The thresholds can be determined as below:

$$V_{UVP} = (1.25 - 6\mu\text{A} \times R_3) \times (R_1 + R_2) / R_2$$

$$\text{Hysteresis} = 5\mu\text{A} \times R_3 \times (R_1 + R_2) / R_2$$

With the condition: $R_3 \gg R_1 / R_2$

For example, to obtain $V_{UVP} = 3.8\text{V}$ and 1V hysteresis, $R_1 = 3\text{k}\Omega$, $R_2 = 1\text{k}\Omega$ and $R_3 = 50\text{k}\Omega$.

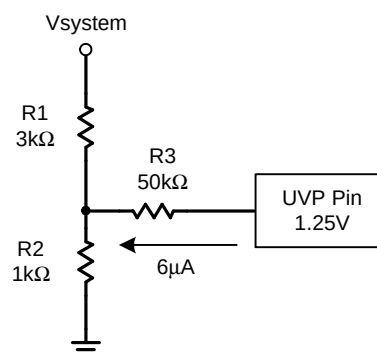


Figure 2. Under-Voltage Protection

Application Information

Using The APA2172A As A Second-Order Filter

Several audio DACs used today require an external low-pass filter to remove out-of-band noise. This is possible with the APA2172A, as it can be used like a standard Operational Amplifier. Several filter topologies can be implemented, both single-ended and differential. In Figure 3, a multi-feedback (MFB) with differential input and single-ended input is shown.

An ac-coupling capacitor to remove dc content from the source is shown; it serves to block any dc content from the source and lowers the dc-gain to 1, helping reducing the output dc-offset to minimum.

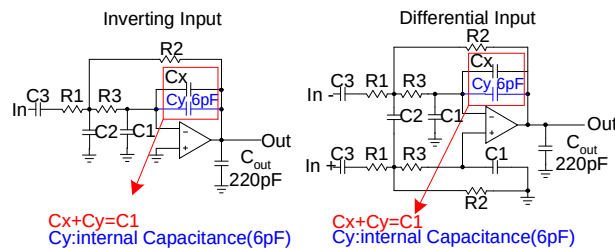


Figure 3. Second-Order Active Low-Pass Filter

Table 1: Filter Specifications.

Gain (V/V)	High Pass (Hz)	Low Pass (kHz)	C1 (pF)	C2 (pF)	C3 (mF)	R1 (kW)	R2 (kW)	R3 (kW)
-1	1.6	40	100	680	10	10	10	24
-1.5	1.3	40	68	680	15	8.2	12	30
-2	1.6	60	33	150	6.8	15	30	47
-2	1.6	30	47	470	6.8	15	30	43
-3.33	1.2	30	33	470	10	13	43	43
-10	1.5	30	22	1000	22	4.7	47	27

For Inverting Input, The overall gain is:

$$A_v = -\frac{R_2}{R_1} \quad (1)$$

The high pass filter's cutoff frequency is:

$$f_{c(\text{highpass})} = \frac{1}{2\pi R_1 C_3} \quad (2)$$

The low pass filter's cutoff frequency is:

$$f_{c(\text{lowpass})} = \frac{1}{2\pi \sqrt{R_2 R_3 C_1 C_2}} \quad (3)$$

Input Capacitor, C_i

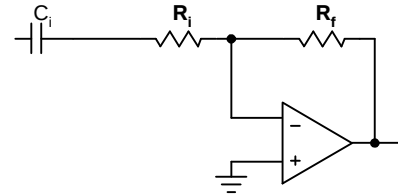


Figure 4. Typical Application Circuit

In the typical application, an input capacitor, C_i , is required to allow the amplifier to bias the input signal to the proper DC level for optimum operation. In this case, C_i and the minimum input impedance R_i from a high-pass filter with the corner frequency are determined in the following equation:

$$f_{c(\text{highpass})} = \frac{1}{2\pi R_i C_i} \quad (4)$$

The value of C_i must be considered carefully because it directly affects the low frequency performance of the circuit. R_i is the external input resistance that typical value is 10kΩ and the specification calls for a flat bass response down to 20Hz. Equation is reconfigured as below:

$$C_i = \frac{1}{2\pi R_i f_{c(\text{highpass})}} \quad (5)$$

When the input resistance variation is considered, the C_i is 0.8μF, so a value in the range of 1μF to 2.2μF would be chosen. A further consideration for this capacitor is the leakage path from the input source through the input network ($R_i + R_f, C_i$) to the load.

This leakage current creates a DC offset voltage at the input to the amplifier that reduces useful headroom, especially in high gain applications. For this reason, a low leakage tantalum or ceramic capacitor is the best choice. When polarized capacitors are used, the negative side of the capacitor should face the amplifiers' input in most applications because the DC level of the amplifiers' input is held at GND. Please note that it is important to confirm the capacitor polarity in the application.

Input Resistor, R_i

The gain of the APA2172A is be set by the external input resistor (R_i) and external feedback resistor (R_f). Please see the figure 4.

Application Information (Cont.)

Input Resistor, R_i (Cont.)

$$\text{Gain } (A_v) = \frac{R_f}{R_i} \quad (6)$$

The external gain setting is recommended using from -1V/V to -10V/V, and the R_i is in the range from 1k Ω to 47k Ω . It's recommended to use 1% tolerance resistor or better. Keep the input trace as short as possible to limit the noise injection.

The gain is recommended to set -1V/V, and R_i is 10k Ω , and R_f is 10k Ω .

Feedback Resistor, R_f

Refer the figure 4, the external gain is setting by R_i and R_f ; and the gain setting is recommended using from -1V/V to -10V/V. The R_f is in the range from 4.7k Ω to 100k Ω . It's recommended to use 1% tolerance resistor or better.

Power Supply Decoupling, C_s

The APA2172A is a high-performance CMOS audio amplifier that requires adequate power supply decoupling to ensure the output total harmonic distortion (THD+N) is as low as possible. Power supply decoupling also prevents the oscillations being caused by long lead length between the amplifier and the speaker.

The optimum decoupling is achieved by using two different types of capacitors that target on different types of noise on the power supply leads. For higher frequency transients, spikes, or digital hash on the line, a good low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1 μ F, is placed as close as possible to the device VDD and PVDD lead for the best performance. For filtering lower frequency noise signals, a large aluminum electrolytic capacitor of 10 μ F or greater placed near the audio power amplifier is recommended.

Charge Pump Flying Capacitor, C_{CPF}

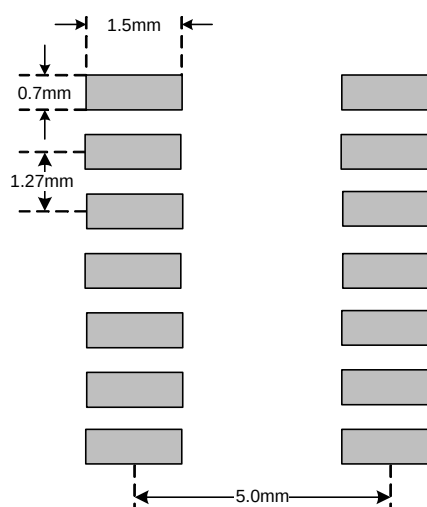
The flying capacitor affects the load transient of the charge pump. If the capacitor's value is too small, then that will degrade the charge pump's current driver capability and the performance of line drive amplifier.

Increasing the flying capacitor's value will improve the load transient of charge pump. It is recommended using the low ESR ceramic capacitors (X7R type is recommended) above 1 μ F.

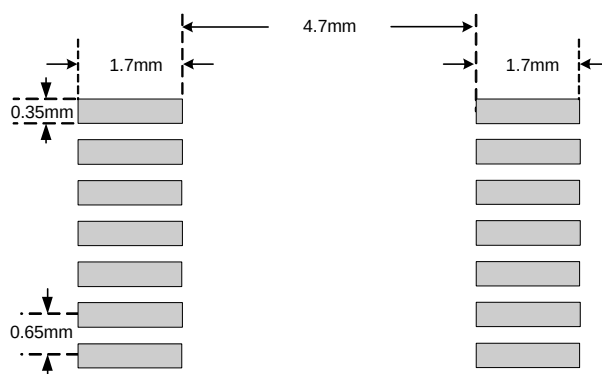
Charge Pump Output Capacitor, C_{CPO}

The output capacitor's value affects the power ripple directly at CV_{SS} (V_{SS}). Increasing the value of output capacitor reduces the power ripple. The ESR of output capacitor affects the load transient of CV_{SS} (V_{SS}). Lower ESR and greater than 1 μ F ceramic capacitor is a recommendation.

Layout Recommendation



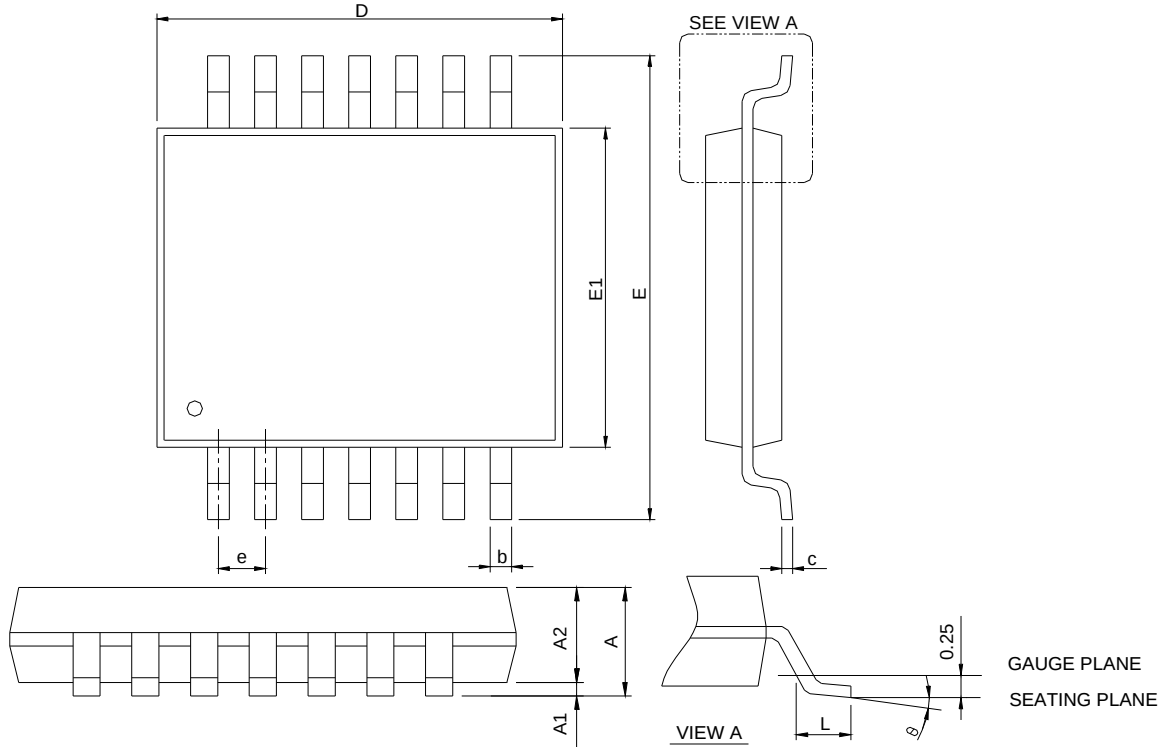
SOP-14 Land Pattern Recommendation



TSSOP-14 Land Pattern Recommendation

Package Information

TSSOP-14

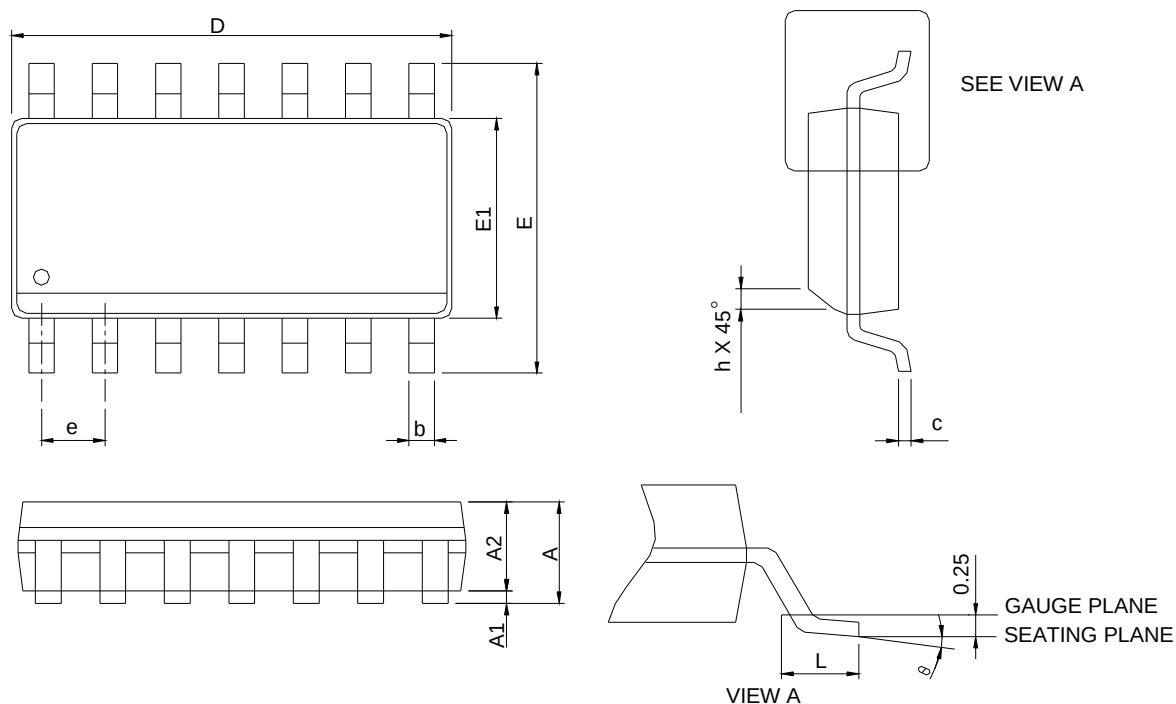


SYMBOL	TSSOP-14			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A		1.20		0.047
A1	0.05	0.15	0.002	0.006
A2	0.80	1.05	0.031	0.041
b	0.19	0.30	0.007	0.012
c	0.09	0.20	0.004	0.008
D	4.90	5.10	0.193	0.201
E	6.20	6.60	0.244	0.260
E1	4.30	4.50	0.169	0.177
e	0.65 BSC		0.026 BSC	
L	0.45	0.75	0.018	0.030
θ	0°	8°	0°	8°

- Note : 1. Follow from JEDEC MO-153 AB-1.
 2. Dimension "D" does not include mold flash, protrusions or gate burrs. Mold flash, protrusion or gate burrs shall not exceed 6 mil per side.
 3. Dimension "E1" does not include inter-lead flash or protrusions. Inter-lead flash and protrusions shall not exceed 10 mil per side.

Package Information

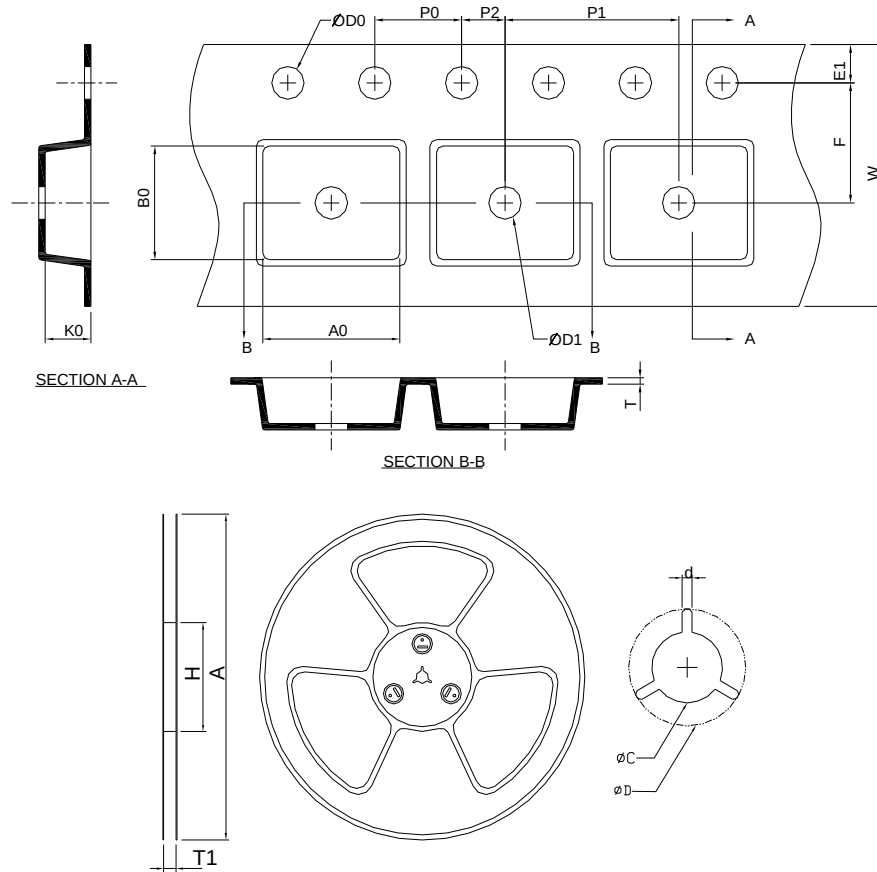
SOP-14



SYMBOL	SOP-14			
	MILLIMETERS		INCHES	
	MIN.	MAX.	MIN.	MAX.
A		1.75		0.069
A1	0.10	0.25	0.004	0.010
A2	1.25		0.049	
b	0.31	0.51	0.012	0.020
c	0.17	0.25	0.007	0.010
D	8.55	8.75	0.337	0.344
E	5.80	6.20	0.228	0.244
E1	3.80	4.00	0.150	0.157
e	1.27 BSC		0.050 BSC	
h	0.25	0.50	0.010	0.020
L	0.40	1.27	0.016	0.050
θ	0°	8°	0°	8°

- Note: 1. Follow JEDEC MS-012 AB.
 2. Dimension "D" does not include mold flash, protrusions or gate burrs.
 Mold flash, protrusion or gate burrs shall not exceed 6 mil per side.
 3. Dimension "E" does not include inter-lead flash or protrusions.
 Inter-lead flash and protrusions shall not exceed 10 mil per side.

Carrier Tape & Reel Dimensions



Application	A	H	T1	C	d	D	W	E1	F
TSSOP-14	330.0±2.00	50 MIN.	16.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	12.0±0.30	1.75±0.10	5.50±0.10
	P0	P1	P2	D0	D1	T	A0	B0	K0
	4.00±0.10	8.00±0.10	2.00±0.10	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	6.40±0.20	5.20±0.20	1.60±0.20
Application	A	H	T1	C	d	D	W	E1	F
SOP-14	330.0±2.00	50 MIN.	16.4+2.00 -0.00	13.0+0.50 -0.20	1.5 MIN.	20.2 MIN.	16.0±0.30	1.75±0.10	7.50±0.10
	P0	P1	P2	D0	D1	T	A0	B0	K0
	4.0±0.10	8.0±0.10	2.0±0.10	1.5+0.10 -0.00	1.5 MIN.	0.6+0.00 -0.40	6.40±0.20	9.00±0.20	2.10±0.20

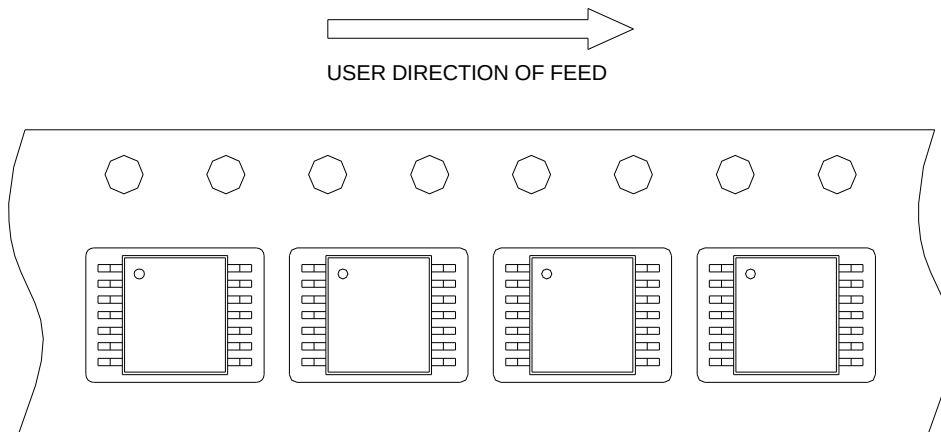
(mm)

Devices Per Unit

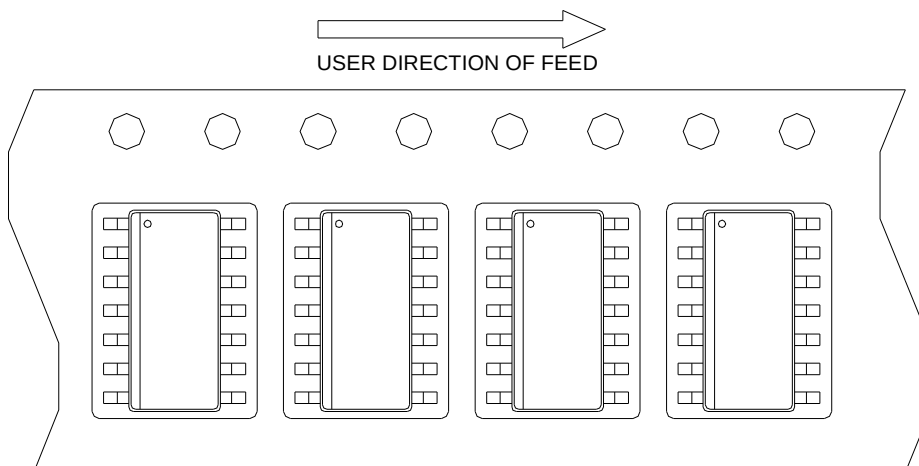
Package Type	Unit	Quantity
TSSOP-14	Tape & Reel	2500
SOP-14	Tape & Reel	2500

Taping Direction Information

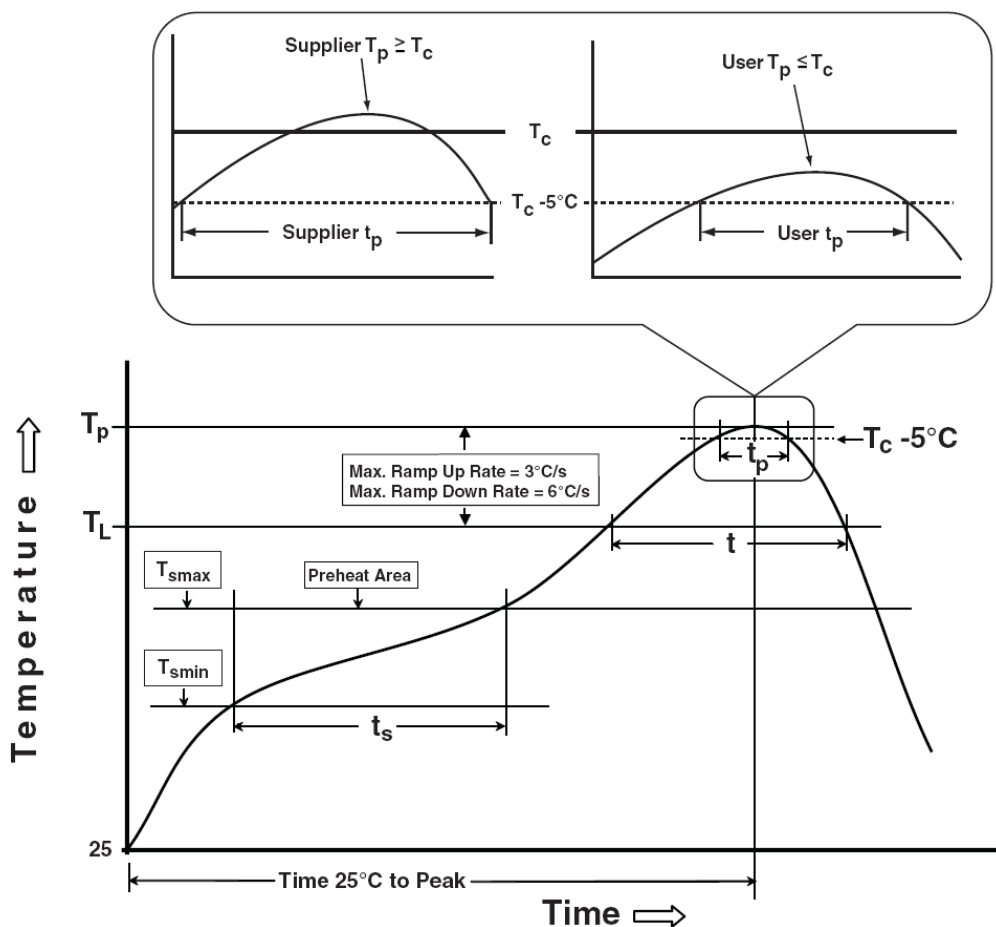
TSSOP-14



SOP-14



Classification Profile



Classification Reflow Profiles

Profile Feature	Sn-Pb Eutectic Assembly	Pb-Free Assembly
Preheat & Soak		
Temperature min (T_{smin})	100 °C	150 °C
Temperature max (T_{smax})	150 °C	200 °C
Time (T_{smin} to T_{smax}) (t_s)	60-120 seconds	60-120 seconds
Average ramp-up rate (T_{smax} to T_p)	3 °C/second max.	3 °C/second max.
Liquidous temperature (T_L)	183 °C	217 °C
Time at liquidous (t_L)	60-150 seconds	60-150 seconds
Peak package body Temperature (T_p)*	See Classification Temp in table 1	See Classification Temp in table 2
Time (t_p)** within $5^\circ C$ of the specified classification temperature (T_c)	20** seconds	30** seconds
Average ramp-down rate (T_p to T_{smax})	6 °C/second max.	6 °C/second max.
Time 25°C to peak temperature	6 minutes max.	8 minutes max.
* Tolerance for peak profile Temperature (T_p) is defined as a supplier minimum and a user maximum.		
** Tolerance for time at peak profile temperature (t_p) is defined as a supplier minimum and a user maximum.		

Classification Reflow Profiles (Cont.)

Table 1. SnPb Eutectic Process – Classification Temperatures (Tc)

Package Thickness	Volume mm ³ <350	Volume mm ³ ≥ 350
<2.5 mm	235 °C	220 °C
≥2.5 mm	220 °C	220 °C

Table 2. Pb-free Process – Classification Temperatures (Tc)

Package Thickness	Volume mm ³ <350	Volume mm ³ 350-2000	Volume mm ³ >2000
<1.6 mm	260 °C	260 °C	260 °C
1.6 mm – 2.5 mm	260 °C	250 °C	245 °C
≥2.5 mm	250 °C	245 °C	245 °C

Reliability Test Program

Test item	Method	Description
SOLDERABILITY	JESD-22, B102	5 Sec, 245°C
HOLT	JESD-22, A108	1000 Hrs, Bias @ T _j =125°C
PCT	JESD-22, A102	168 Hrs, 100%RH, 2atm, 121°C
TCT	JESD-22, A104	500 Cycles, -65°C~150°C
HBM	MIL-STD-883-3015.7	VHBM ≥ 2KV
MM	JESD-22, A115	VMM ≥ 200V
Latch-Up	JESD 78	10ms, I _{tr} ≥ 100mA

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