Capless 2Vrms to 3Vrms Line Driver with Adjustable Gain TD9731

General Description

The TD9731 is a 2Vrms to 3Vrms Pop&Click-less stereo line driver designed to allow the removal of the output dc-blocking capacitors for reduced component count and cost. The device is ideal for single supply electronics where size and cost are critical design parameters.

The TD9731 is capable of driving 3Vrms into a 2.5kΩ load with 5V supply voltage. The device has single input and uses external gain setting resistors, that supports a gain range of ±1V/V to ±10V/V. The use of external gain resistors also allows the implementation of a 2nd order low pass filter to compliment DAC's and SOC converters. The TD9731 has build-in shutdown control for Pop&Click-free on/off control.

Using the TD9731 in audio products can reduce component count compared to traditional methods of generating a 3Vrms output. The TD9731 doesn't require a power supply greater than 5V to generate its 8.5V_{PP} output, nor does it require a split rail power supply. The TD9731 integrates its own charge pump to generate a negative supply rail that provides a clean, pop&click-less ground biased 3Vrms output.

The TD9731 is available in Green MSOP-10 (Exposed Pad) package. It operates over an ambient temperature range of -40℃ to +85℃.

Features

- Capless Structure

---Eliminates Pop/Clicks

---Eliminates Output DC-Blocking Capacitors

---Provides Flat Frequency Response DC to 20kHz

- Low Noise and THD

---Typical SNR = 107dB

---Typical V_N = 8μVrms

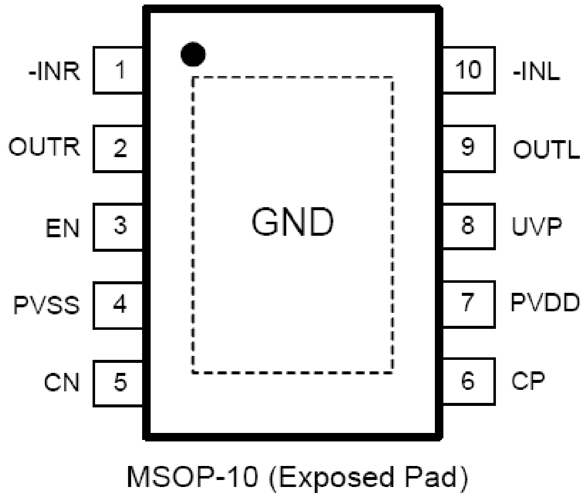
---Typical THD+N = 0.001% (f = 1kHz)

- 2Vrms Output Voltage into 2.5kΩ Load with 3.3V Supply Voltage
- 3Vrms Output Voltage into 2.5kΩ Load with 5V Supply Voltage

Applications

- Set-Top Box
- LCD TV
- Blue-Ray DVD-Players
- Home Theater in a Box

Pin Configurations



MSOP-10
(Top View)

Pin Description

NO.	NAME	FUNCTION
1	-INR	Right channel OPAMP negative input
2	OUTR	Right channel OPAMP output
3	EN	Enable input, active high
4	PVSS	Negative supply voltage output
5	CN	Charge pump flying capacitor negative terminal
6	CP	Charge pump flying capacitor positive terminal
7	PVDD	Positive supply
8	UVP	Undervoltage protection input
9	OUTL	Left channel OPAMP output
10	-INL	Left channel OPAMP negative input
--	EP	Exposed Paddle. Can only be connected to GND.

Ordering Information

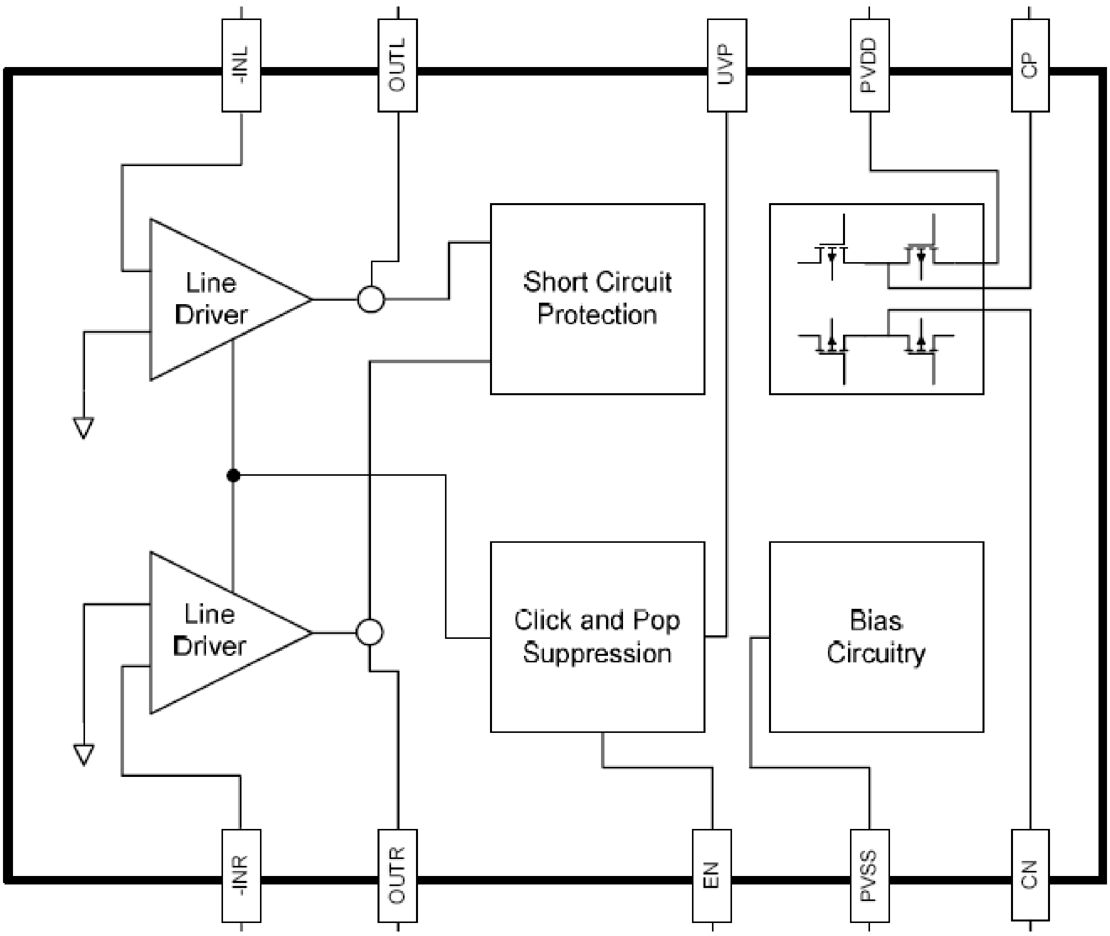
TD9731 □ □

Circuit Type

P:MSOP-10

Packing:
Blank：Tube
R:Type and Reel

Functional Block Diagram



Absolute Maximum Ratings

Symbol	Parameter	Rating	Unit
V_{PGND_GND}	PGND to GND Voltage	-0.3 to 0.3	
V_{DD}	Supply Voltage (VDD to GND and PGND)	-0.3 to 4	
$V_{\overline{SDN}}$	Input Voltage ($\overline{SDN}$ to GND)	V_{GND}-0.3 to V_{DD}+0.3	
V_{SS}	VSS to GND and PGND Voltage	-6 to 0.3	V
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	
T_{STG}	Storage Temperature Range	-65 to +150	°C
T_{SDR}	Maximum Soldering Temperature Range, 10 Seconds	260	
P_D	Power Dissipation	Internally Limited	W

N

Note1: Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Recommended Operating Conditions

Symbol	Parameter		Range		Unit
			Min.	Max.	
V_{DD}	Supply Voltage		3	3.6	
V_{IH}	High Level Threshold Voltage	$\overline{SDN}$	1.0	-	V
V_{IL}	Low Level Threshold Voltage	$\overline{SDN}$	-	0.35	
T_A	Operating Ambient Temperature Range		-40	85	°C
T_J	Operating Junction Temperature Range		-40	125	°C
R_L	Load Resistance		600	100k	Ω

Thermal Characteristics

Symbol	Parameter		Typical Value	Unit
θ_{JA}	Thermal Resistance - Junction to Ambient (Note 2)	MSOP-10	120	°C/W

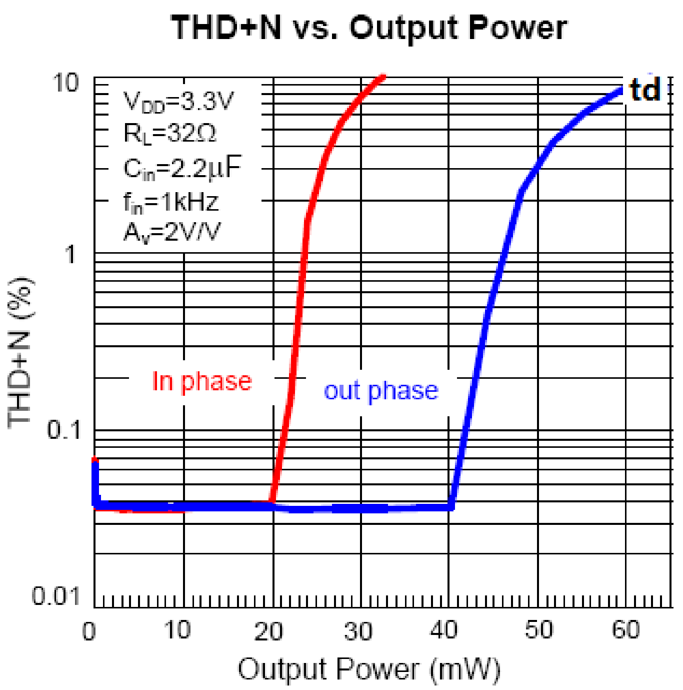
Note 2: Please refer to “Thermal Pad Consideration”. 2 layered 5 in2 printed circuit boards with 2oz trace and copper through several thermal vias. The thermal pad is soldered on the PCB.

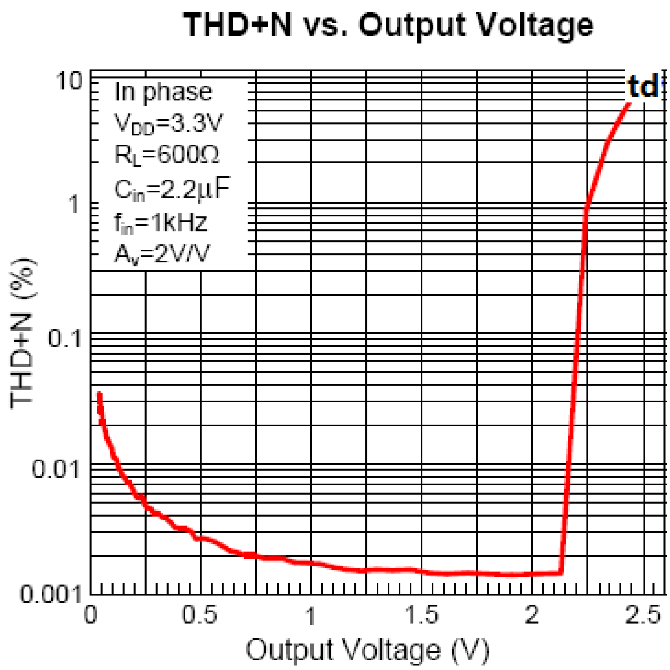
Electrical Characteristics

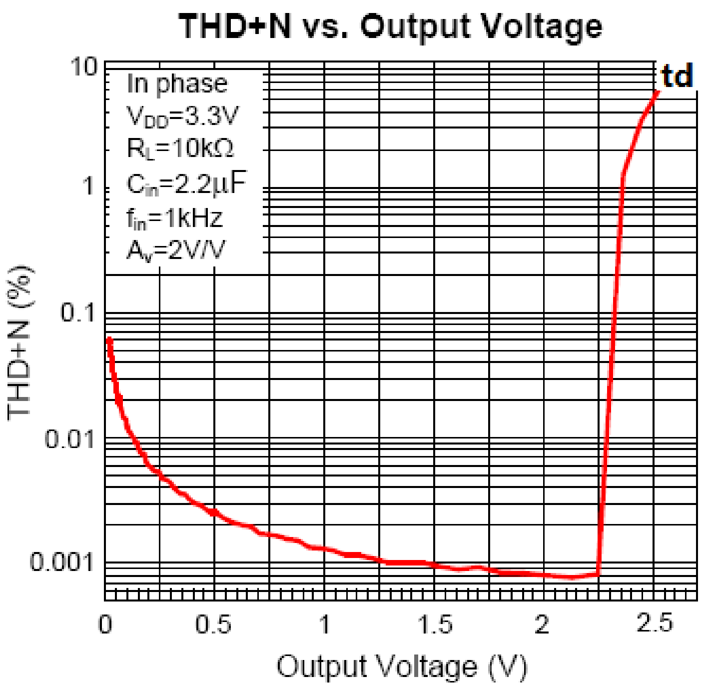
V_{DD}=3.3V, V_{GND}=V_{PGND}=0V, V_{SDN}=V_{DD}, C_{CPF}=C_{CPO}=1μF, C_i=1μF, R_L=2.5kΩ, T_A=25°C, R_i=10kΩ, R_f=20kΩ (unless otherwise noted)

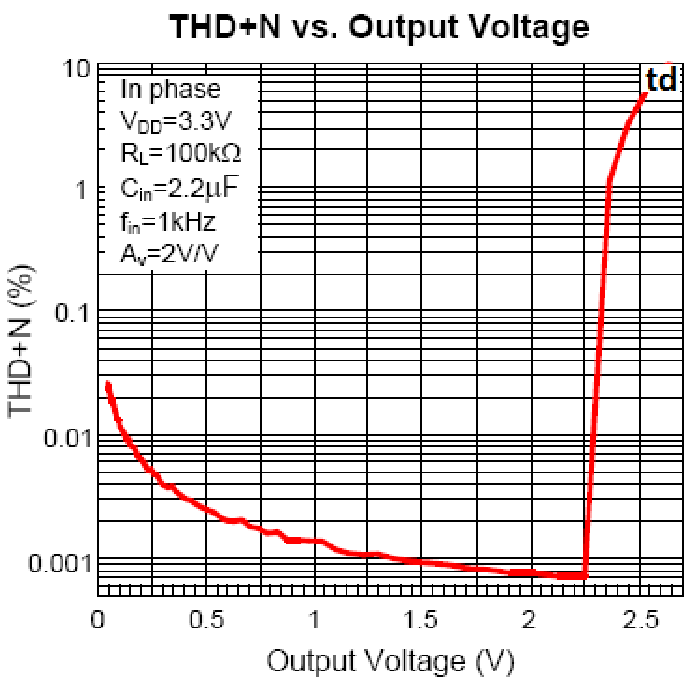
Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
I_{DD}	V_{DD} Supply Current		-	10	15	mA
I_{SD}	V_{DD} Shutdown Current	$V_{\overline{SDN}}$=0V	-	1	5	μA
I_I	Input Current	$\overline{SDN}$	-	0.1	-	μA
CHARGE PUMP						
f_{OSC}	Switching Frequency		400	500	600	kHz
R_{eq}	Equivalent Resistance		-	21	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}=3.0V to 3.6V, R_L = 2.5kΩ	-5	-	5	mV
V_N	Output Noise	R_i=10kΩ, R_f=10kΩ	-	8	15	$μV_{rms}$
$T_{start-up}$	Start-up Time		-	500	-	μs
PSRR	Power Supply Rejection Ratio	V_{DD}=3.0V to 3.6V, V_{rr}=200mV_{rms} f_{in}= 217Hz f_{in}= 1kHz f_{in}= 20kHz	-	-80 -80 -50	-60 -60 -45	dB
C_L	Maximum Capacitive Load		-	220	-	pF
V_{ESD}	ESD Protection	OUTR, OUTL	-	8	-	kV
V_O	Output Voltage (Stereo, In Phase)	THD+N=1%, f_{in}=1kHz R_L=2.5kΩ R_L=100kΩ	2.0 -	2.1 2.3	-	V
Po	Output Power (Stereo, In Phase)	THD+N=1%, f_{in}=1kHz R_L=32Ω	-	20	-	mW
THD+N	Total Harmonic Distortion Plus Noise	V_O=2V_{rms}, R_L=2.5kΩ f_{in}=20Hz f_{in}=1kHz f_{in}=20kHz	-	0.02 0.001 0.02	- 0.002 -	%
		Po=20mW, RL=32Ω f_{in}=1kHz	-	0.04	-	
Crosstalk	Channel Separation	V_O=2V_{rms}, R_L=2.5kΩ f_{in}=20Hz f_{in}=1kHz f_{in}=20kHz	-	100 100 90	-	dB
S/N	Signal to Noise Ratio	V_O=2Vrms, R_L=2.5kΩ, R_i=10kΩ, R_f=10kΩ, With A-weighting Filter	-	108	102	dB
T_{SD}	Thermal Shutdown Protection Temperature		-	150	-	°C
UVP FUNCTION						
V_{UVP}	External Under Voltage Detection		-	1.25	-	V
I_{HYS}	External Under Voltage Detection Hysteresis Current		-	5.0	-	μA

Typical Operating Characteristics

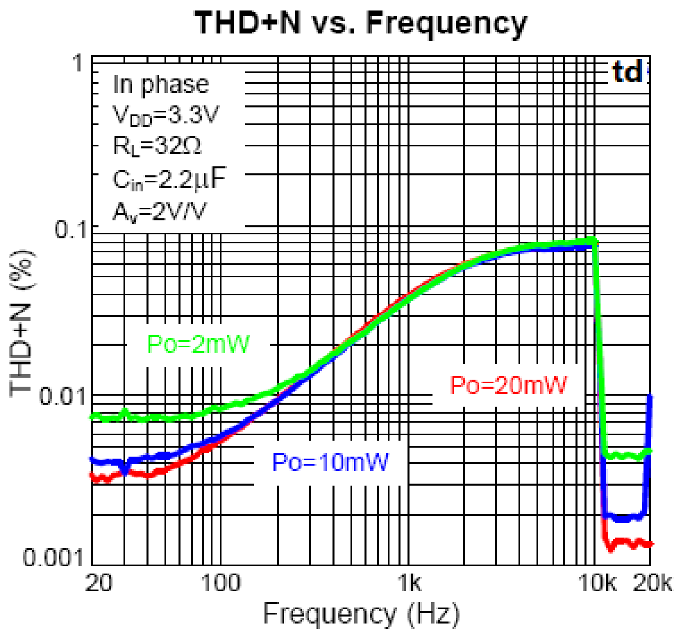


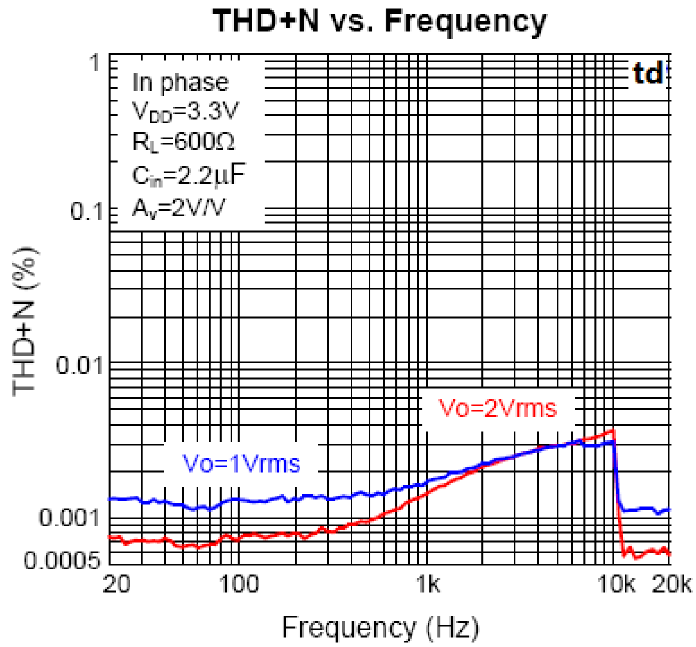


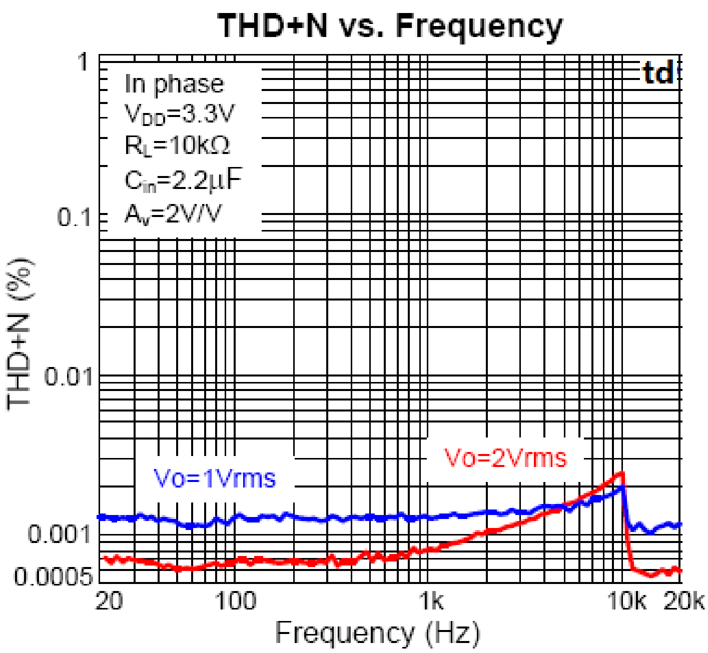


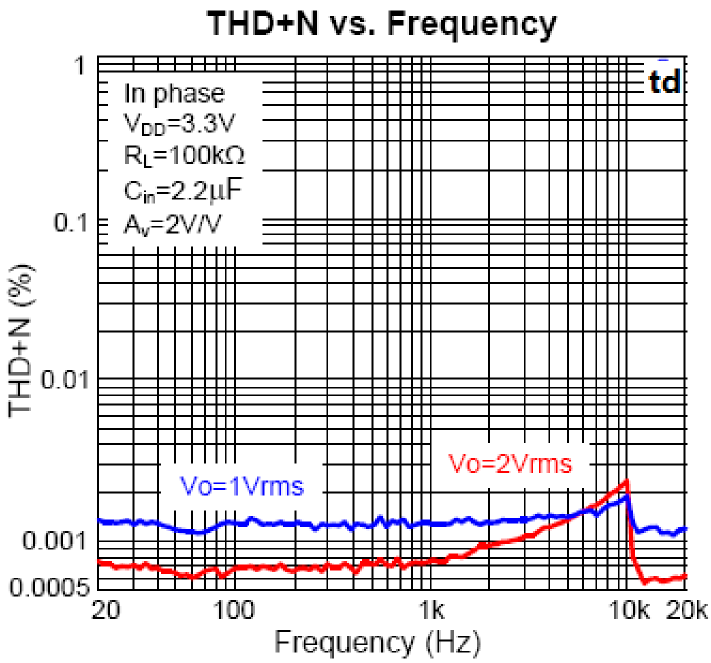


Typical Operating Characteristics(Cont.)



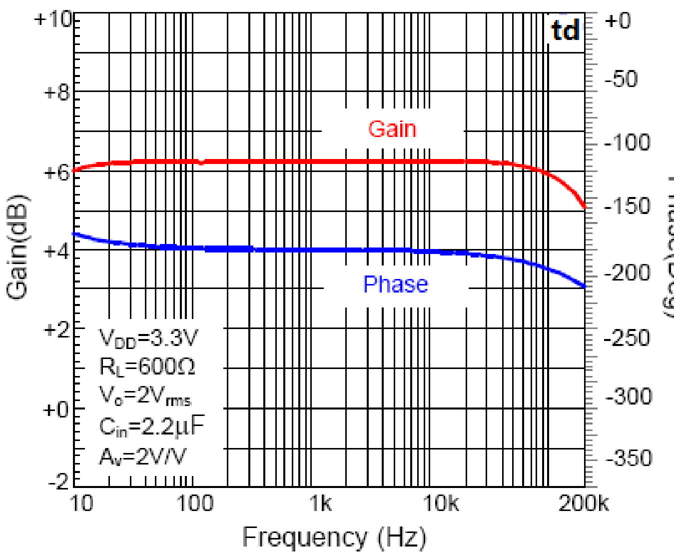




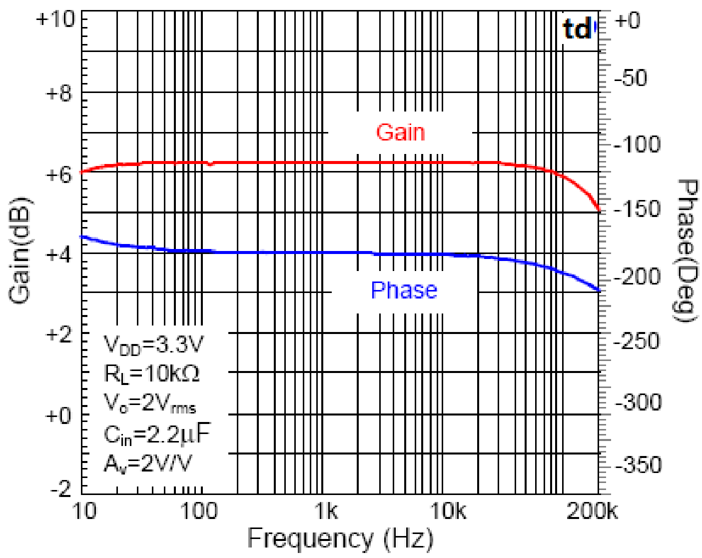


Typical Operating Characteristics(Cont.)

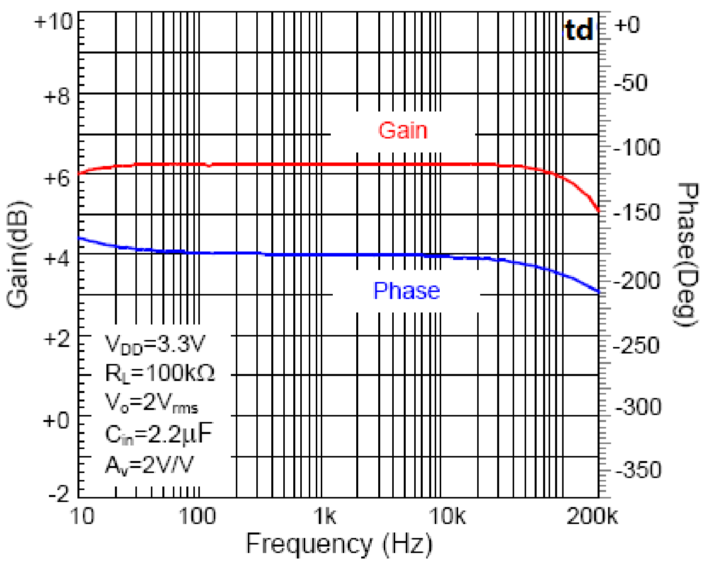
Frequency Response



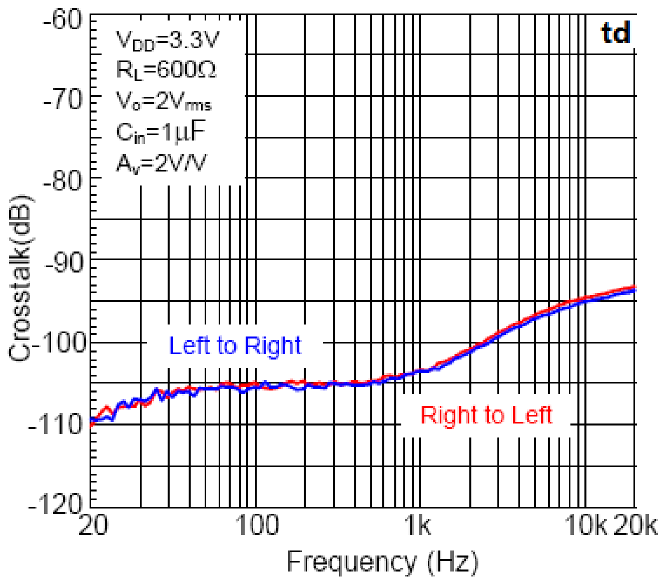
Frequency Response



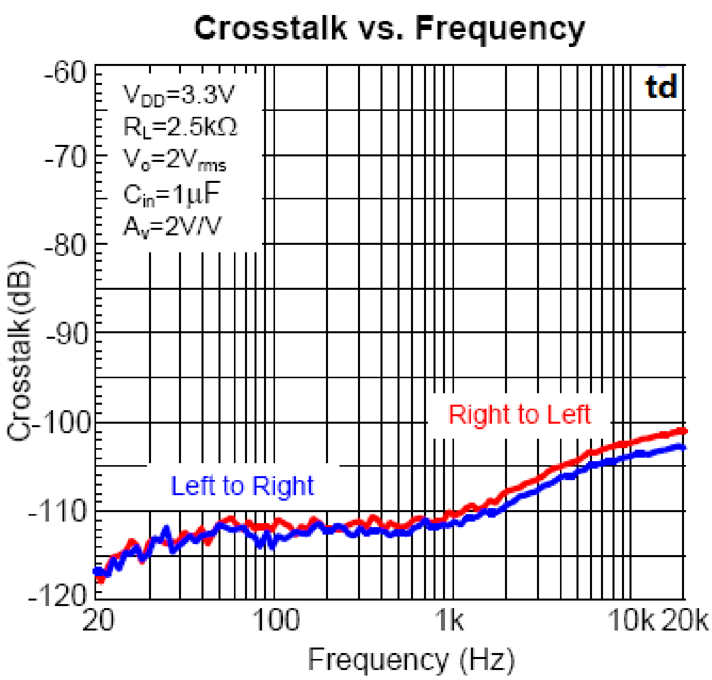
Frequency Response

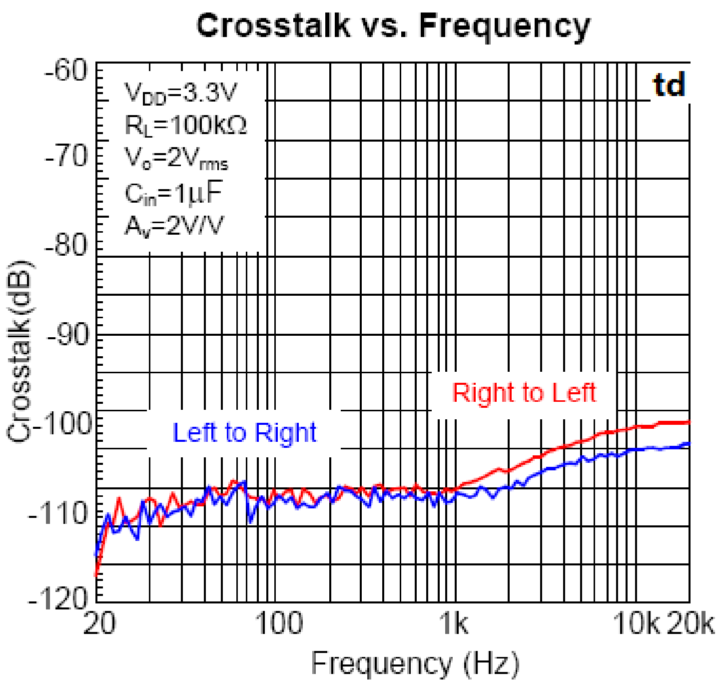


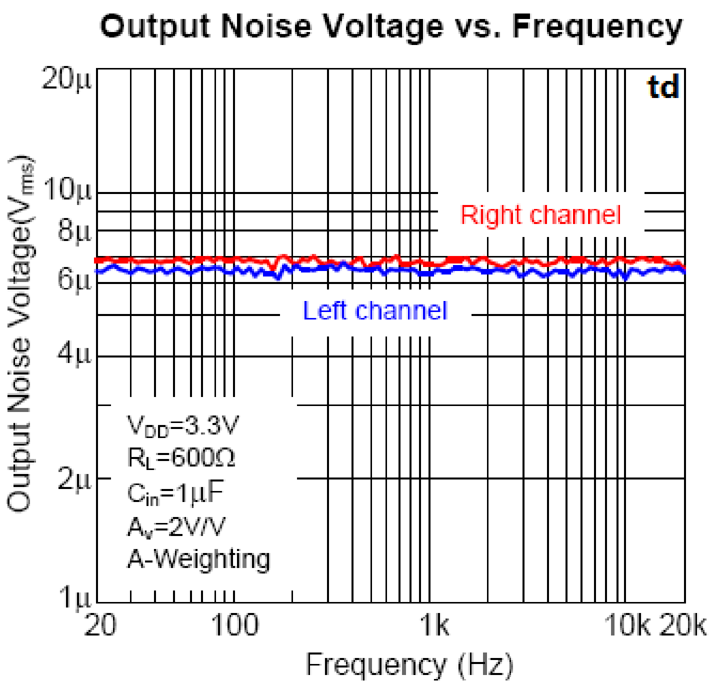
Crosstalk vs. Frequency

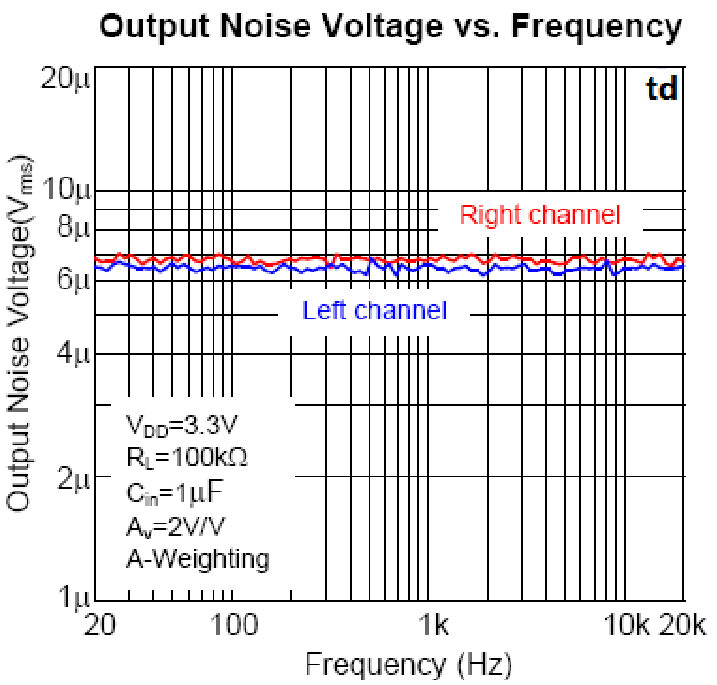


Typical Operating Characteristics(Cont.)

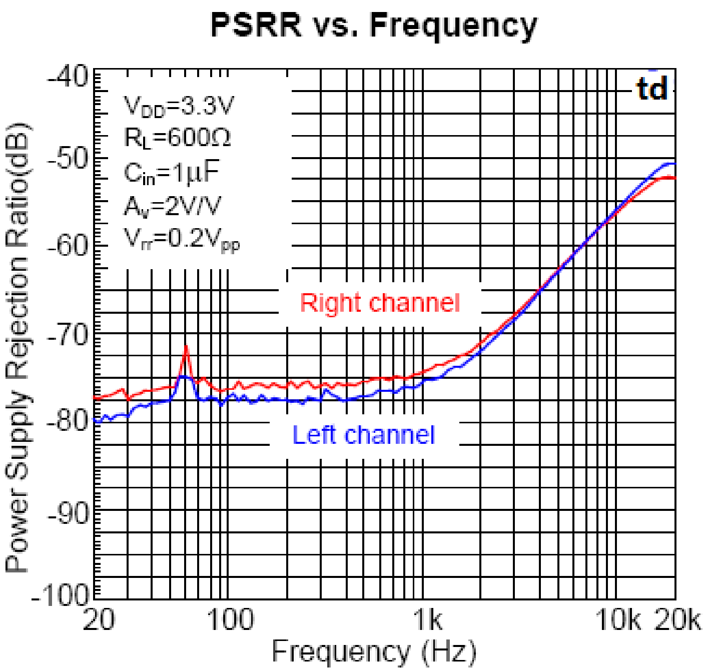


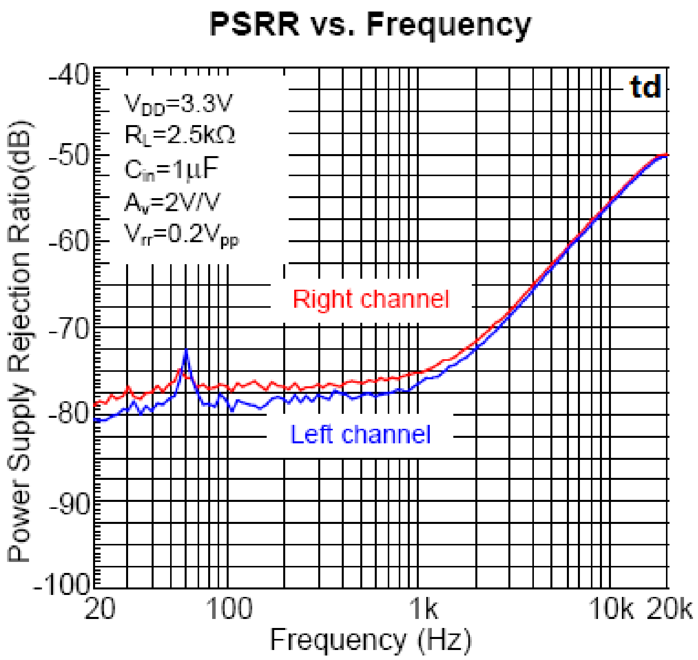


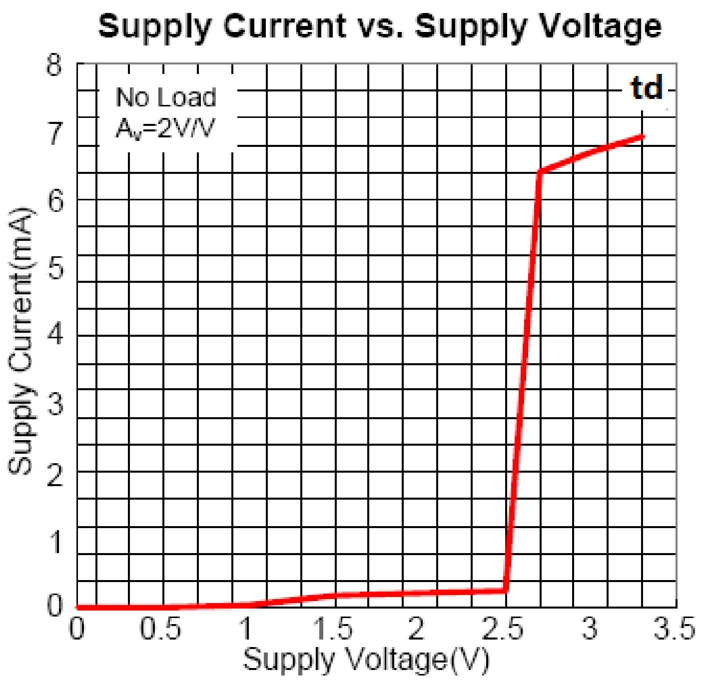




Typical Operating Characteristics(Cont.)

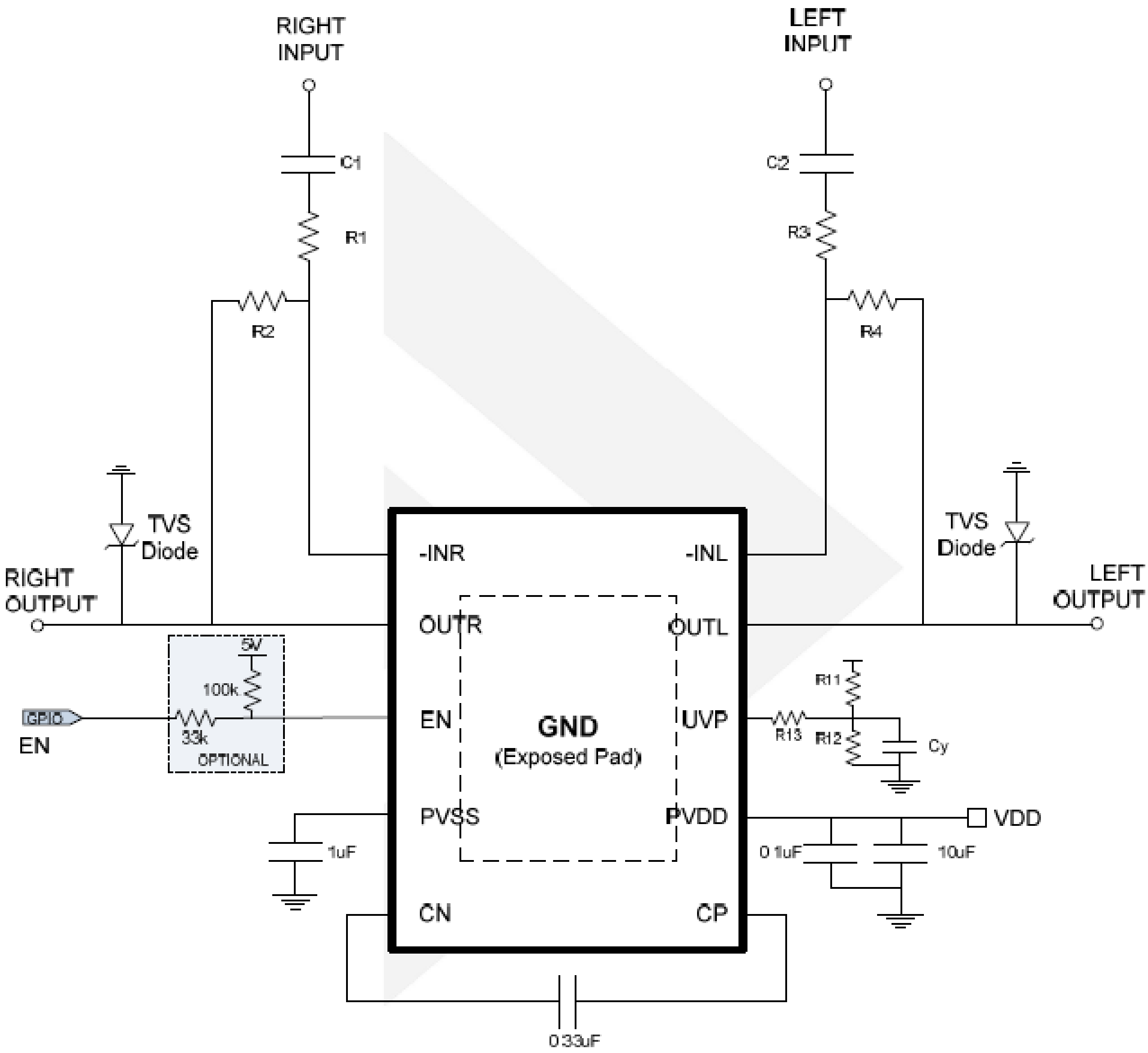






Type Application Circuit

Line Driver Amplifier



Function Description

Line Driver Operation

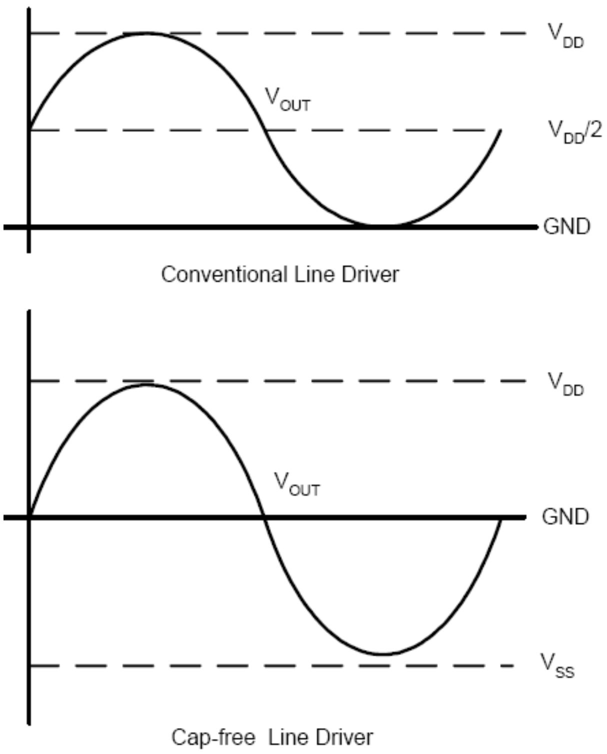


Figure 1. Cap-free Operation

The TD9731'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 TD9731. When the junction temperature exceeds T_J=+150oC, 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 125oC. The thermal protection is designed with a 25oC 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 TD9731 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 SDN pins for the TD9731. 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 SDN pins to a low level, the amplifier enters a low-consumption current circumstance, charge pump is disabled, and I_{DD} for the TD9731 is in shutdown mode. In normal operating, the TD9731's SDN pins should be pulled to a high level to keep the IC out of the shutdown mode. The 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 shutdown the TD9731 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:

VUVP = (1.25-6μAxR3) x (R1+R2)/R2

Hysteresis = 5μA x R3 x (R1+R2)/R2

With the condition: R3>>R1//R2

For example, to obtain V_{UVP}=3.8V and 1V hysteresis, R1=3kΩ, R2=1kΩ and R3=50kΩ.

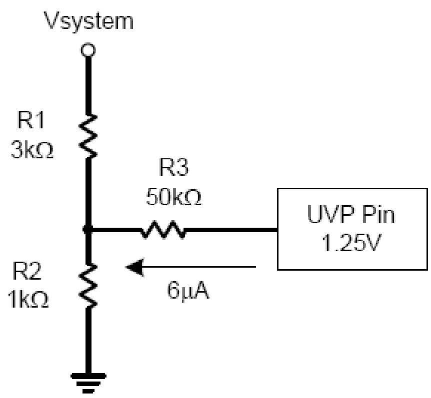


Figure 2. Under-Voltage Protection

Application Information

Using The TD9731 As A Second-Order Filter

Several audio DACs used today require an external lowpass filter to remove out-of-band noise. This is possible with the TD9731, as it can be used like a standard Operational Amplifier. Several filter topologies can be implemented, single-ended and differential. In Figure3, 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.

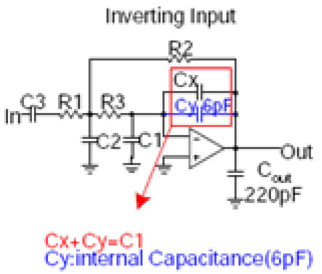


Figure 3. Second-Order Active Low-Pass Filter

Gain (V/V)	High Pass (Hz)	Low Pass (kHz)	C1 (pF)	C2 (pF)	C3 (μF)	R1 (kΩ)	R2 (kΩ)	R3 (kΩ)
-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:

$$A_V = -\frac{R2}{R1}$$

The high pass filter's cutoff frequency is:

$$f_{c(highpass)} = \frac{1}{2\pi R1C3}$$

The low pass filter's cutoff frequency is:

$$f_{c(lowpass)} = \frac{1}{2\pi\sqrt{R2R3C1C2}}$$

Input Capacitor, C_i

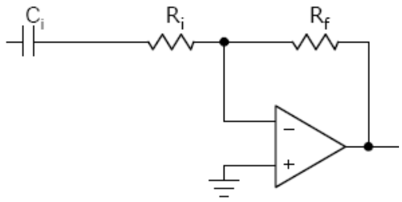


Figure 4. Typical Application Circuit

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:

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

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:

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

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 TD9731 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.)

$$\text{Gain}(A_V) = \frac{R_f}{R_i}$$

The external gain setting is recommended using from -1V/V to -10V/V, and the R_i is in the range from 1kΩ to 47kΩ. 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 10kΩ, and R_f is 10kΩ.

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 4.7kΩ to 100kΩ. It's recommended to use 1% tolerance resistor or better.

Power Supply Decoupling, C_S

The TD9731 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 0.1μF, 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 10μF 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.

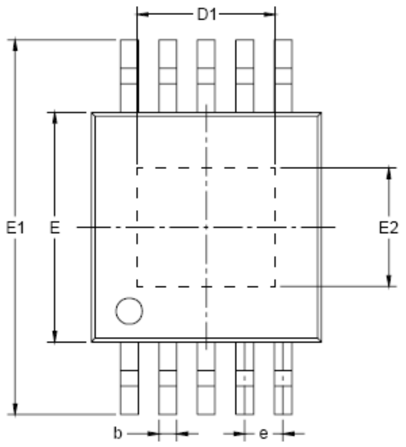
Increasing the flying capacitor's value will improve the load transient of charge pump. It is recommended using the low ESR ceramic capacitors (X7R type is recommended) above 1μF.

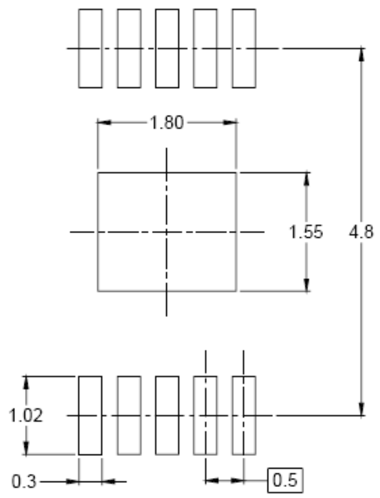
Charge Pump Output Capacitor, C_{CPO}

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 1μF ceramic capacitor is a recommendation.

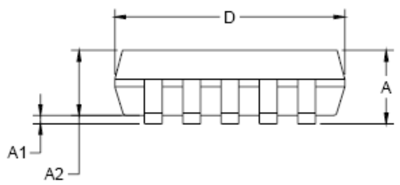
Package Information

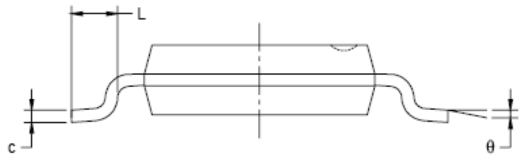
MSOP-10





RECOMMENDED LAND PATTERN (Unit: mm)





Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.180	0.280	0.007	0.011
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
D1	1.700	1.900	0.067	0.075
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
E2	1.450	1.650	0.057	0.065
e	0.500 BSC		0.020 BSC	
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

Design Notes