15W + 6W × 2 2.1 Channel CLASS-D AUDIO POWER AMPLIFIER

GENERAL DESCRIPTION

The TMPA421DS is a 2.1 Channel Class-D output audio power amplifier for driving speakers with high power efficiency. The bass output is designed as BTL (Bridge-Tied-Load) for high output power. The right& left channels are designed as SE (Single-Ended). The outputs are able to drive 4Ω, 6Ω, 8Ω or 16Ω speakers. The output power can be up to 15W for bass and 6W for either Right or Left channel. No external heat-sink is necessary.

The gain of the amplifier is defined by either gain0/gain1 gain control or by input resistance. Thermal protection and short-circuit protection are integrated for safety purpose.

The internal de-pop circuitry eliminates pop noise at power-up & shutdown operations.

APPLICATIONS

TMPA421DS is convenient for 2.1 channel applications. It can be used for LCD Monitors, TVs, DVD Players, Powered Speakers or any 2.1 channel power amplifiers.

PACKAGE

TQFP48L available

FEATURES

- **Integrated 2.1 channel power amplifier in one chip**
- **15W + 6W × 2 2.1 Channel Class-D Output**
- **Power efficiency is up to 82%**
- **Convenient gain control**
- **Time delay for de-pop control**
- **Thermal Protection**
- **Output Pin Short-Circuit Protection (Short to Other Outputs, Short to VCC, Short to Ground)**
- **Low Quiescent Current (10mA Typical at 12V)**
- **Low Current in Shutdown Mode (<1μA Typical)**
- **Separate VCC & PVCC**
- **Regulated 5-V Supply Output**

For best performance, please refer to

http://www.taimec.com.tw/English/EVM.htm

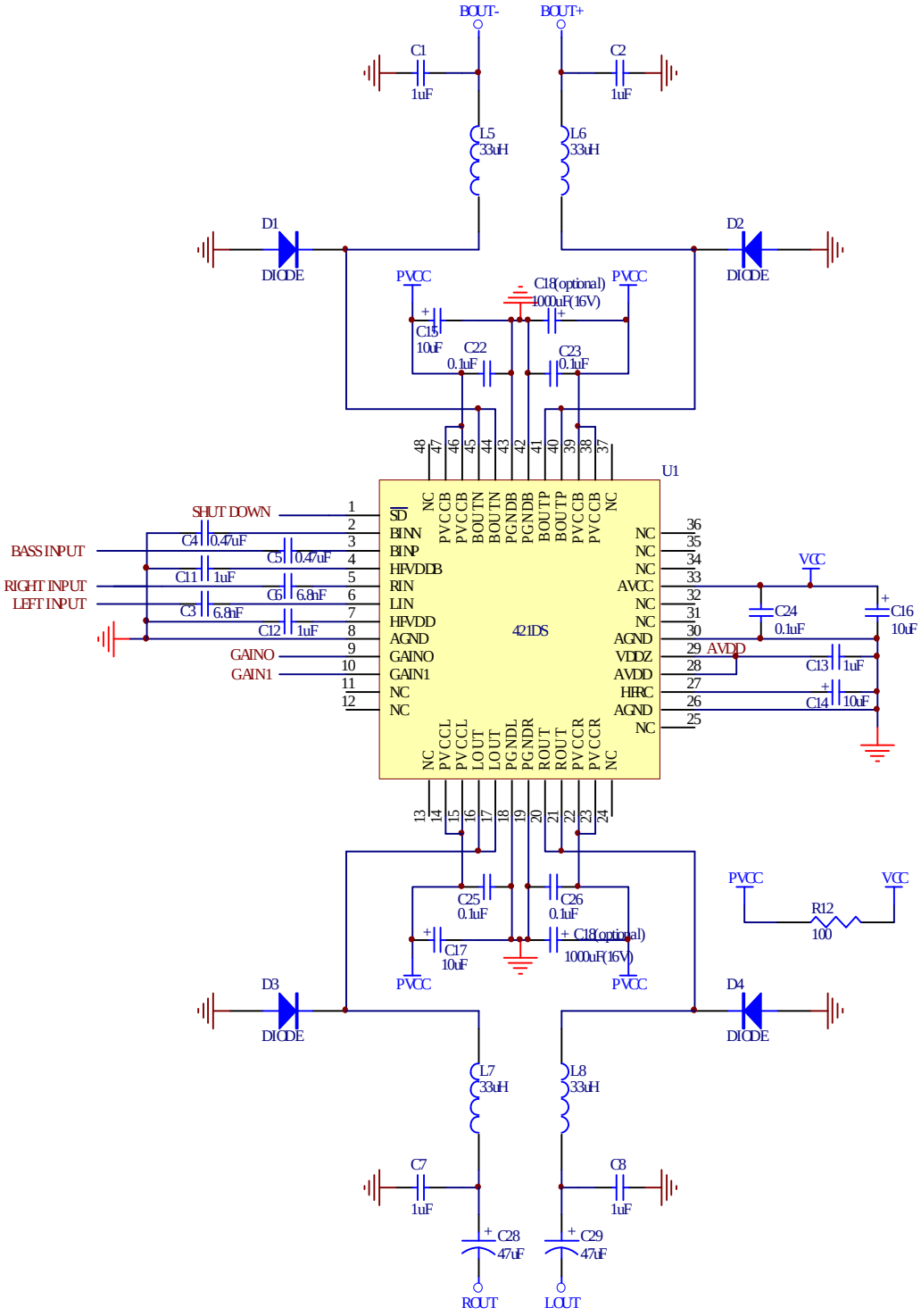
http://www.class-d.com.tw/English/EVM.htm

for PCB layout.

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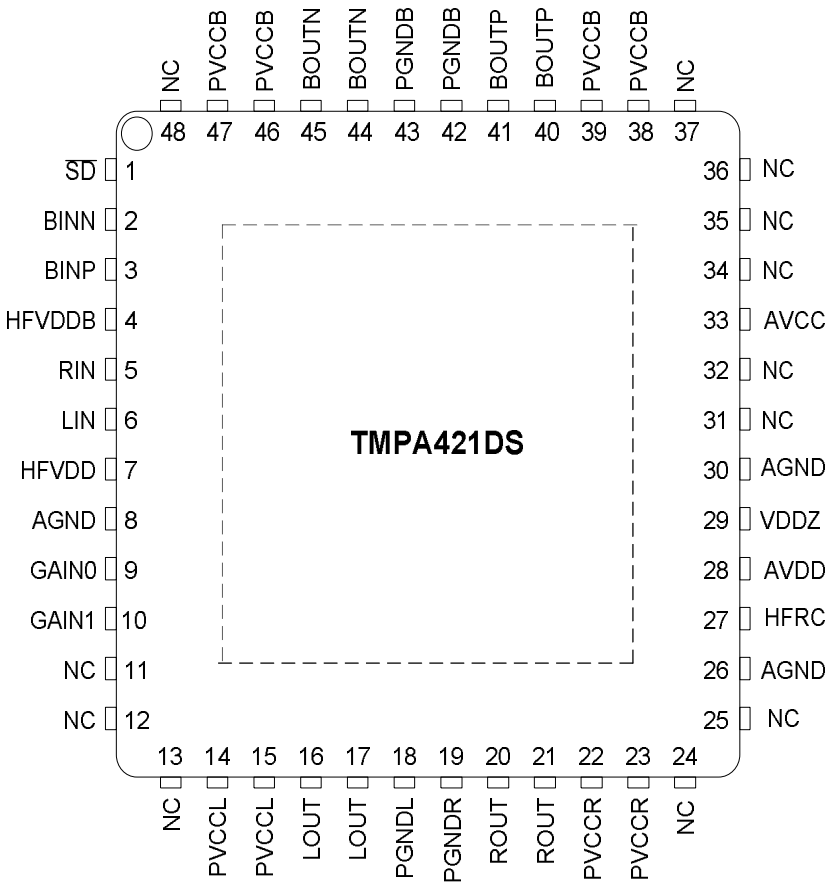
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REFERENCE CIRCUIT



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TQFP PACKAGE
(TOP VIEW)



（Please email david@taimec.com.tw for complete datasheet.）

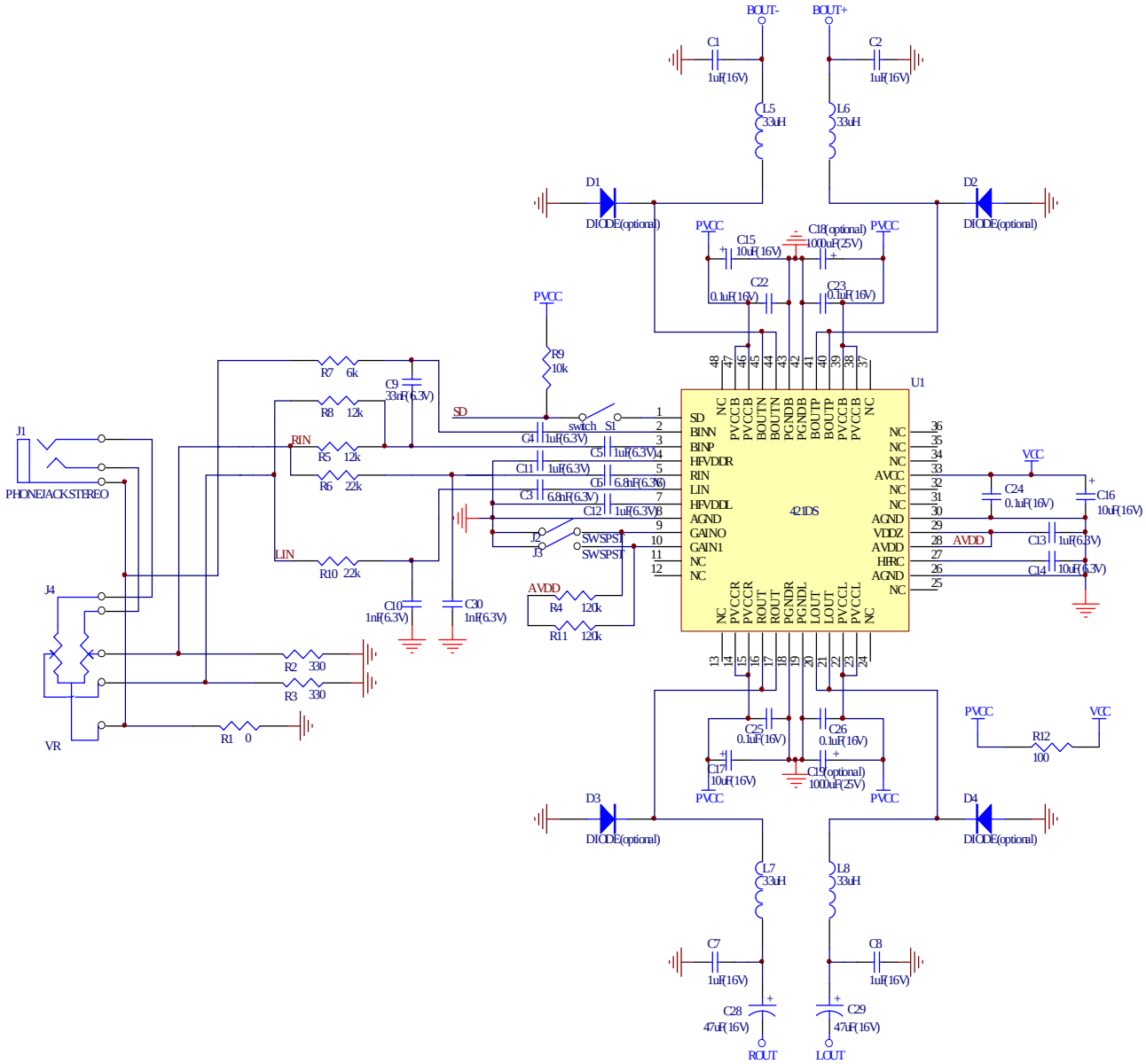
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Note that the external components or PCB layout should be designed not to generate abnormal voltages to the chip to prevent from latch up which may cause damage to the device.

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Typical Application



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TERMINAL FUNCTIONS

TERMINAL		HV/LV	I/O	DESCRIPTION
NAME	PIN NO			
AGND	8,26,30	—	—	Analog ground
AVCC	33	HV	—	High-voltage power supply (8V to 15V)
AVDD	28	LV	I	5-V voltage
HFVDDB	4	LV	O	2.5-V Reference for convenience of single-ended bass input
HFVDD	7	LV	O	2.5-V Reference for convenience of right and left channel inputs
HFRC	27	LV	O	Power up delay
LIN	6	LV	I	Left channel input
RIN	5	LV	I	Right channel input
ROUT	20,21	HV	O	Class-D right channel output
LOUT	16,17	HV	O	Class-D left channel output
PGNDR	19	—	—	Power ground for right channel
PGNDL	18	—	—	Power ground for left channel
PGNDB	42,43	—	—	Power ground for bass
PVCCR	22,23	HV	—	Power supply for right channel (8V to 15V)
PVCCL	14,15	HV	—	Power supply for left channel (8V to 15V)
PVCCB	38,39,46,47	HV	—	Power supply for bass (8V to 15V)
BINP	3	LV	I	Positive differential input for bass
BINN	2	LV	I	Negative differential input for bass
BOUTN	44,45	HV	O	Class-D negative output for bass
BOUTP	40,41	HV	O	Class-D positive output for bass
$\overline{SD}$	1	HV	I	Shutdown (Low valid)
GAIN0	9	LV	I	Gain0 control
GAIN1	10	LV	I	Gain1 control
VDDZ	29	LV	O	5-V Regulated output (25mA output max.)
NC	11,12,13,24, 25,31,32,34, 35, 36,37,48	—	—	No connection

ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature range unless otherwise noted(1)

Supply voltage, PV_{CCR}, PV_{CCL}, AV_{CC}	In normal mode	-0.3V to 18V	V
	In shutdown mode	-0.3V to 18V	V
Input voltage, $\overline{SD}$		-0.3V to AV_{CC}+0.3V	V
Input voltage, Gain0, Gain1, RIN, LIN, BINP, BINN		-0.3V to 5V	V
Continuous total power dissipation		See package dissipation ratings	
Operating free-air temperature, T_A		-20 to 85	°C
Operating junction temperature, T_J		-20 to 150	°C
Storage temperature, T_{stg}		-40 to 150	°C

(1) 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-rated conditions for extended periods may affect device reliability.

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RECOMMENDED OPERATING CONDITIONS

		MIN	MAX	UNIT
Supply voltage, V_{CC}	PV_{CCB}, PV_{CCR}, PV_{CCL}, AV_{CC}	8	15	V
High-level input voltage, V_{IH}	$\overline{SD}$, Gain0, Gain1	2.0		V
Low-level input voltage, V_{IL}	$\overline{SD}$, Gain0, Gain1		0.8	V
High-level input current, I_{IH}	V_{CC}=15V, $\overline{SD}$ =15V		100	uA
	V_{CC}=15V, Gain0=Gain1=5V		5	
Low-level input current, I_{IL}	V_{CC}=15V, $\overline{SD}$ =0V		0.5	uA
	V_{CC}=15V, Gain0=Gain1=0V		0.5	
Operating free-air temperature, T_A		-20	85	°C

PACKAGE DISSIPATION RATINGS

PACKGE	DERATING FACTOR	$T_A \leq 25$ °C POWER RATING	T_A = 70 °C POWER RATING	T_A = 85 °C POWER RATING
TQFP48L(FD)	33 mW/ °C	4.125W	2.64W	2.15W

DC CHARACTERISTICS

T_A=25 °C, V_{CC}=15V, R_L=8Ω speaker (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
$\lvert V_{OS} \rvert$	Output offset voltage for right/left channel	LIN and RIN AC grounded			30		mV
V_{DD}/AV_{DD}	5-V Regulated output	I_O=0 to25mA, $\overline{SD}$ =High, V_{CC}=8V to 15V		4.5	5.0	5.5	V
HFV_{DD}/HFV_{DDB}	Half V_{DD} reference output	No load			0.5x AV_{DD}		
f_{OSC}	Oscillator frequency	V_{CC}=8-15V		250		350	kHz
I_{CC}	Quiescent current (no load)	$\overline{SD}$ =High, V_{CC}= 12V			10	20	mA
		$\overline{SD}$ =High, V_{CC}= 15V			16	30	
$I_{CC(SD)}$	Supply current in shutdown mode	$\overline{SD}$ =0.8V, V_{CC}= 12V			1		uA
		$\overline{SD}$ =0.8V, V_{CC}= 15V			1		
$r_{ds(on)}$	Drain-source on-state resistance for all output	V_{CC}=15V I_O=1A,	High side		600		mΩ
			Low side		500		
Gainb	Voltage Gain of bass at Vcc=15V	Gain0=High,	Gain1= High		34		dB
		Gain0=Low,	Gain1=High		28		
		Gain0=High,	Gain1= Low		22		
		Gain0=Low,	Gain1= Low		18		
	Voltage Gain of bass at Vcc=12V	Gain0=High,	Gain1= High		32		
		Gain0=Low,	Gain1=High		26		
		Gain0=High,	Gain1= Low		20		
		Gain0=Low,	Gain1= Low		16		
	Voltage Gain of bass at Vcc=9v	Gain0=High,	Gain1= High		30		dB
		Gain0=Low,	Gain1=High		25		
		Gain0=High,	Gain1= Low		19		
		Gain0=Low,	Gain1= Low		14		
Gain	Voltage Gain of right and left channel at Vcc=15V	Gain0=High,	Gain1= High		35		dB
		Gain0=Low,	Gain1=High		29		
		Gain0=High,	Gain1= Low		23		
		Gain0=Low,	Gain1= Low		19		
	Voltage Gain of right and left channel at Vcc=12V	Gain0=High,	Gain1= High		33		dB
		Gain0=Low,	Gain1=High		27		
		Gain0=High,	Gain1= Low		21		
		Gain0=Low,	Gain1= Low		17		
	Voltage Gain of right and left channel at	Gain0=High,	Gain1= High		31		

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	Vcc=9v	Gain0=Low,	Gain1=High	25	
		Gain0=High,	Gain1= Low	19	
		Gain0=Low,	Gain1= Low	15	
Zi	Input resistance ofBINN/BINP/RIN/LIN	Gain0=High,	Gain1= High	15	kΩ
		Gain0=Low,	Gain1=High	30	
		Gain0=High,	Gain1= Low	60	
		Gain0=Low,	Gain1= Low	100	

AC CHARACTERISTICS

T_A=25 °C, V_{CC}=15V, R_L=8Ω speaker (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
*$P_{O(max)}$	Maximum continuous output power of bass (r.m.s) at 1kHz	R_L=4Ω	15V		15		W
			12V		10		
			9V		6.22		
		R_L=6Ω	15V		14.5		W
			12V		9.3		
			9V		5.34		
		R_L=8Ω	15V		12.7		W
			12V		8		
			9V		4.58		
		R_L=16Ω	15V		7.65		W
			12V		4.8		
			9V		2.73		
*$P_{O(max)}$	Maximum continuous output power of right/left channel (r.m.s) at 1kHz	R_L=4Ω	15V		6		W
			12V		3.8		
			9V		2.17		
		R_L=6Ω	15V		4.6		W
			12V		3.0		
			9V		1.67		
		R_L=8Ω	15V		3.75		W
			12V		2.35		
			9V		1.34		
V_n	Output noise				-70		dBV
SNR	Signal-to-noise ratio	Maximum output at THD+N＜0.5%, f=1kHz			85		dB
Crosstalk	Crosstalk SE→BTL	Gain0=Gain1=high, V_{CC}=12V, P_O(SE)=2W, R_L=8Ω			-70		dB
	Thermal trip point				145		°C
	Thermal hysteresis				25		°C

For best performance, please refer to
http://www.taimec.com.tw/data/Tmpa421EVM/tmpa421dsEVM.pdf for PCB layout.

*Important notice：More copper area and vias are required for high output power especially when the total output power is higher than 15W.

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DETAILED DESCRIPTION

Efficiency

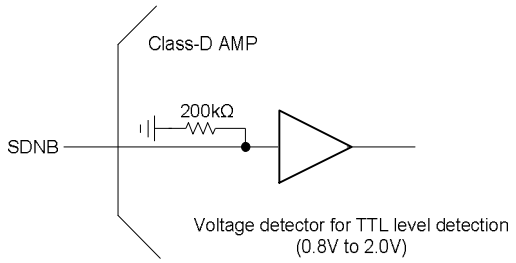
The output transistors of a class D amplifier act as switches. The power loss is mainly due to the turn on resistance of the output transistors when driving current to the load. As the turn on resistance is so small that the power loss is small and the power efficiency is high. With 8 ohm load the power efficiency can be better than 80%.

PCB layout for power dissipation

No heat sink is necessary for power dissipation. However the PCB layout should be well designed to dissipate heat for high output power. With 80% power efficiency the generated heat when driving 15 watts to the 8 ohm load is about 3.75 watts. The heat can be carried out through the thermal pad of the device to the PCB. To ensure proper dissipation of heat the PCB has to have heat path from the bottom of the device which is soldered to the PCB. The area of the metal on the PCB for heat dissipation should be big enough. It is suggested that both sides of the PCB are used for power dissipation.

Shutdown

The shutdown mode reduces power consumption. A LOW at shutdown pin forces the device in shutdown mode and a HIGH forces the device in normal operating mode. Shutdown mode is useful for power saving when not in use. Internal circuit for shutdown is shown below.

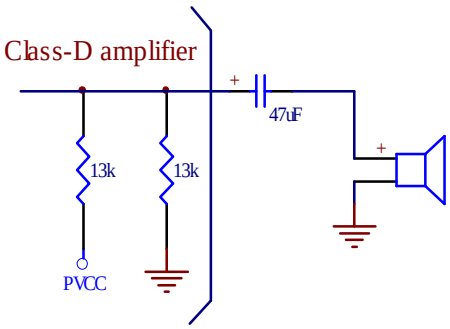


Pop-less

A soft start capacitor can be added to the HFRC pin. This capacitor introduced delay for the circuit to be stable before driving the load. The set up time for internal circuit to be stable is quite fast, typically it is less than 100ms. Thus the pop noise caused by SDNB operation can be fixed easily. But for external circuitry the setup time depends on the component values used in the application.

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For single-ended outputs or right/left channels a build-in voltage divider is to provide half Vcc to the output pin as shown in the above diagram. During power up this divider is to pre-charge output capacitor to half Vcc before output signal is enabled to drive the speaker. Since the equivalent resistance of the voltage divider is 6.5k ohms (13kohms//13kohms) and the capacitance of the output coupling capacitor is 47uF the RC constant is 0.3 seconds. This indicates that the power up delay has to be much longer than 0.3 seconds. Normally a capacitor of 10uF at HFRC pin would provide 2.2 seconds start up delay to save power up pop noise.

Above discussion assumes that the separation frequency is 500Hz and the speaker is 8 ohms. If the separation frequency is 200Hz and the speaker is 4 ohms instead then the output coupling capacitance would be changed to 200uF as calculated below.

f =1 / (2 π x 4 ohms x C) = 200 Hz

C = 1 / (2 π x 4 ohms x 200 Hz) = 200 uF

In this case the RC constant of the charging circuit is 6.5 k ohms x 200uF = 1.3 seconds

To save pop noise the start up delay time should be much longer than 1.3 seconds. A capacitance of 47 uF would provide 9.4 seconds delay.

For frequency separation please refer to “Band pass filter for frequency separation of bass and R/L channels”.

HFRC

HFRC provides a way of soft start up delay. A half_Vcc voltage detector is integrated to detect a RC charge up. The resistor of 320k ohms of the RC circuit is also integrated in the chip but the capacitor is externally hooked up. For C=10uF the half_Vcc delay is

$$1-e^{-t/RC}=0.5$$

or

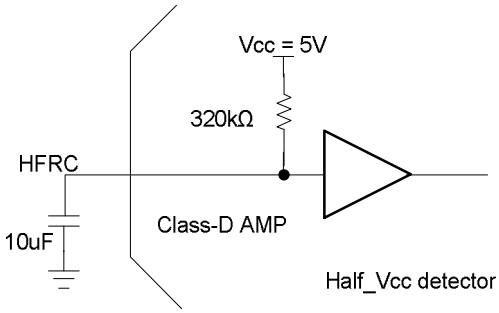
$$e^{-t/RC}=0.5$$

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that is

t = - RC In（0.5）= （320k × 10u）（0.693） = 2.2 seconds



The delay time changes linearly with capacitance at HFRC. So a 10uF capacitance will provide about 2.2 seconds delay.

Differential input VS single ended input

Differential input offers better noise immunity over single ended input. A differential input amplifier suppresses common noise and amplifies the difference voltage at the inputs. For single ended applications just tie the negative input end of the balanced input structure to ground. If external input resistors are used, the negative input has to be grounded with a series resistor of the same value as the positive input to reduce common noise.

Band pass filter for frequency separation of bass and R/L channels

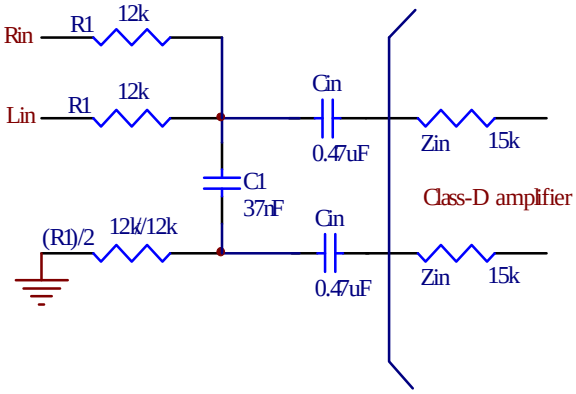
For best sound effect the frequency of bass and R/L channels has to be separated. The bass channel amplifies the lower frequencies while the R/L channels amplify the higher frequencies. The power is saved not to drive bass speaker with high frequencies and not to drive R/L channel speakers with low frequencies. The noise level can be reduced as well. Typically the frequency boundary of bass and R/L channels is set 500 Hz and the output power of bass is set around 3~5 times of the R/L channels. Note that different applications may have different requirement for these values. Please refer to EVM documentation if the separation frequency is 200 Hz instead.

Bass channel filter

If the audio source is stereo (right channel signal and left channel signal) one can generate audio source for bass amplifier by mixing right and left signals and in the mean time filter out frequencies above 500 Hz. A typical application is shown below. Note that Zin=15k ohms is the internal resistance of the class-D amplifier when gain0=gain1=High.

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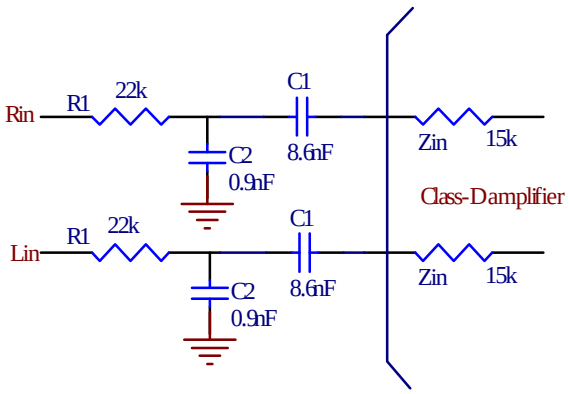


The -3db frequency at high frequency corner is f-3db = 1/ (2 π R C) where R=2(Zin // (R1)/2) and C=C1. With specified values f-3db = 500Hz.

The -3db frequency at low frequency corner is calculated as f-3db = 1/ (2 π R C) where R=Zin + (R1)/2 and C=Cin. With specified values f-3db = 16Hz.

Right and Left channel filters

To block frequencies below 500Hz, a typical application is shown below.



The -3db frequency at low frequency corner is f-3db = 1/ (2 π R C) where R=Zin + R1 and C=C1. With specified values f-3db = 500Hz.

The -3db frequency at high frequency corner is f-3db = 1/ (2 π R C) where R=Zin // R1 and C=C2. With specified values f-3db = 20kHz.

Note that if gain0 and gain1 are set at different states the internal input resistance is changed accordingly. Please refer to DC CHARACTERISTICS for detail. As such the filters should be redesigned to meet the 500 Hz frequency boundary.

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Voltage gain

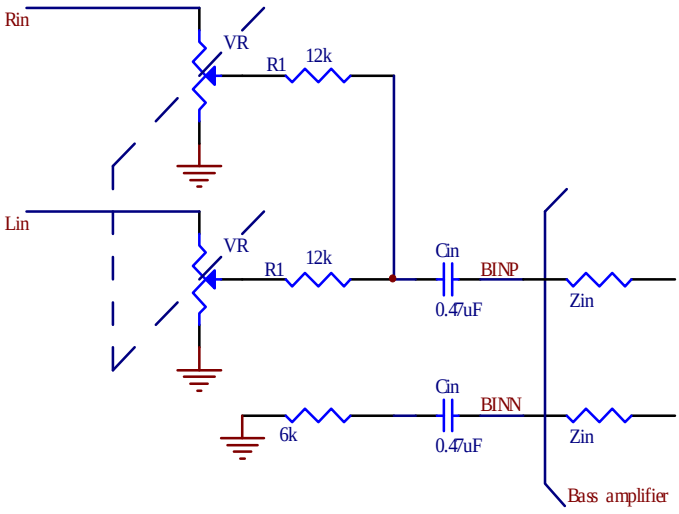
The voltage gain can be set through gain0/gain1 control or by external input resistors connecting to input pins. If external resistors are used for BINP and BINN of bass channel then these input resistors should be well matched. Well matched resistors are also required even for single ended input configuration for low noise. Suppose the external input resistors Rext are used then the voltage gain is roughly

Av=750k ohm / (Rext+15k ohm) for gain0=gain1=High

Where 15k ohm is the internal resistance of the input pins. For other gain0/gain1 states please refer to DC CHARACTERISTICS for different input resistance.

Power ratio of bass channel and right/left channels

The output power ratio of bass to R/L channels is normally set 3~5. However different music has different stress in different frequency range. It becomes difficult to define a fix voltage gain for different applications and to maintain the requirement of bass to R/L ratio. A convenient way of controlling the ratio is to make bass adjustable relative to R/L channels. An easier way is to use VR as shown below.



Another way is to use frequency synthesizer to preset voltage gain for different frequency range for particular music content.

For simply applications an example is given below to show 3X ratio between bass output power and R/L output power.

For Vcc=15v and 8ohm load the voltage gain of the bass channel is around 32. If the power ratio is 3 then the voltage ratio is $\sqrt{3}$ =1.732 and the gain of the R/L channel is 18.5. The voltage gain of the R/L channels is roughly defined as

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(750k ohms)/(Ri+15k ohms)
resulting Ri= 25.5k ohms.

To meet the -3db frequency of the R/L channels which is 500Hz, the filter capacitance should be adjusted to
C= 1/(2π x (25.5k+15k ohms) x 500Hz) = 7.86nF.

For higher output power one can consider to use 4 ohm speaker for bass and 8 ohm speakers for R/L channels. Suppose the power ratio is set 5X, then the voltage ratio is $\sqrt{5/2}$ =1.58. For Vcc=15v and 4ohm load the voltage gain of the bass channel is around 30. Thus the gain of the R/L channel is 19.
The voltage gain of the R/L channels is defined as
(750k ohms)/(Ri+15k ohms)
resulting Ri= 24.5kohms .

To meet the -3db frequency of the R/L channels which is 500Hz, the filter capacitance should be adjusted to
C= 1/(2π x (24.5+15k ohms) x 500) = 8nF.

Note that the formula for voltage gain varies with supply voltage and loading. But the procedure is to find out the value of Ri before the capacitance is determined.

Output coupling capacitor

The speaker of the bass channel is tied as BTL. There is no need to have an output capacitor at the output end. But for right and left channels coupling capacitors are required to block DC from the speakers. Since the right and left channels do not amplify frequencies below 500Hz the output coupling capacitance does not have to be big. One can choose the -3db frequency of the output coupling stage to be 200Hz, not too high to attenuate voltage at 500Hz, then the coupling capacitance is
C= 1/(2π x 8 ohm x 200Hz) =100uF for 8 ohm load.
or C= 1/(2π x 4 ohm x 200Hz) =200uF for 4 ohm load.

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Input filter

In case band pass filter for frequency separation of bass and R/L channels is not used, the AC coupling capacitors are still required to block the DC voltage from the device. They also define the –3db frequency at the low frequency side.

The –3db frequency of the low frequency side is

f-3db = 1/ (2 π R C)

where C is the AC coupling capacitance and R is the total resistance in series with C.

Note that R=Zin(internal resistance) + Rext(external resistance)

Also note that the input resistance of BINN/BINP/LIN/RIN is 15K ohms at Gain0=Gain1=high.

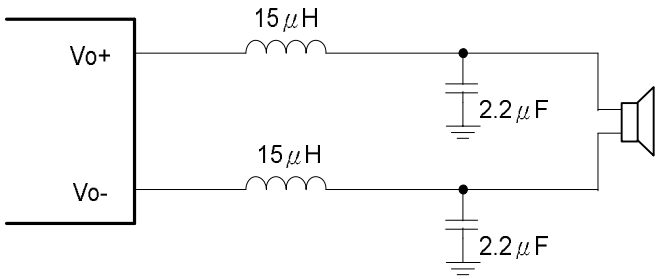
Please refer to DC CHARACTERISTICS for detail.

Output filter

Ferrite bead filter can be used for EMI purpose. The ferrite filter reduces EMI around 1 MHz and higher（FCC and CE only test radiated emissions greater than 30 MHz）. When selecting a ferrite bead, choose one with high impedance at high frequencies, but low impedance at low frequencies.

Use an LC output filter if there are low frequency（＜1 MHz）EMI sensitive circuits and/or there are long wires from the amplifier to the speaker. EMI is also affected by PCB layout and the placement of the surrounding components.

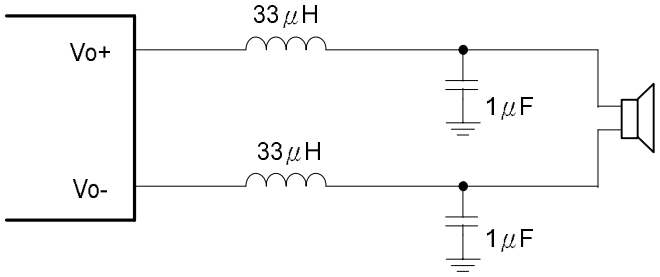
For BTL output the suggested LC values for different speaker impendence are showed in following figures.



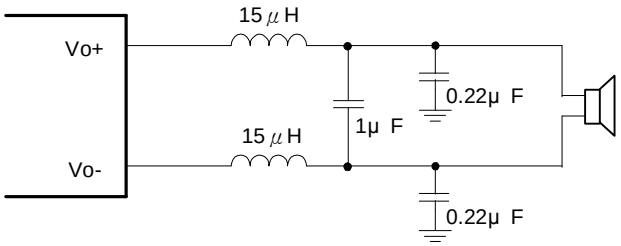
LC Output Filter, Speaker Impedance= 4Ω

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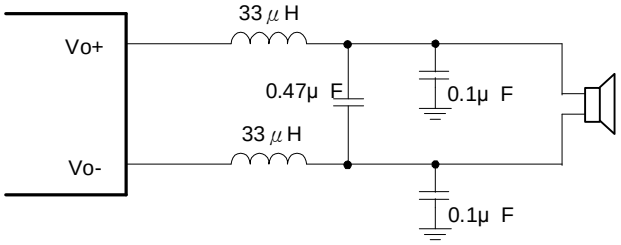
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LC Output Filter, Speaker Impedance=6Ω & 8Ω



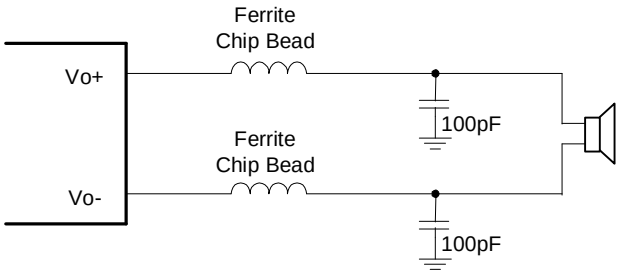
LC Output Filter, Speaker Impedance=4Ω



LC Output Filter, Speaker Impedance=6Ω & 8Ω

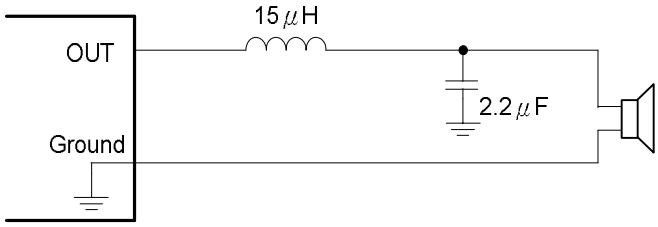
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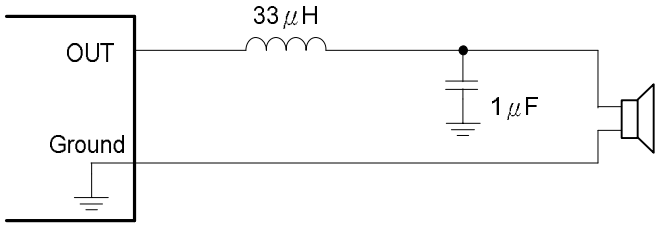


Typical Ferrite Chip Bead Filter
（Chip bead example：遠越科技 KML2012Q102N
1kohms@100MHz, DCR=0.2ohms, I=1A）

For single-ended output the suggested LC values for different speaker impendence are showed in following figures.



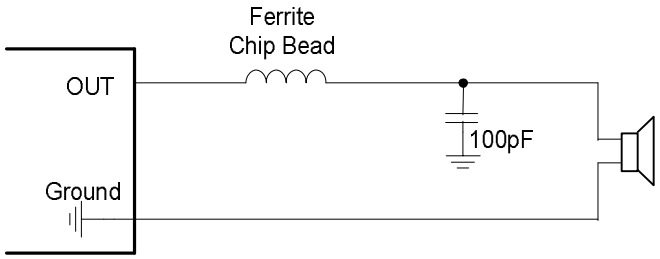
LC Output Filter, Speaker Impedance= 4Ω



LC Output Filter, Speaker Impedance= 6Ω & 8Ω

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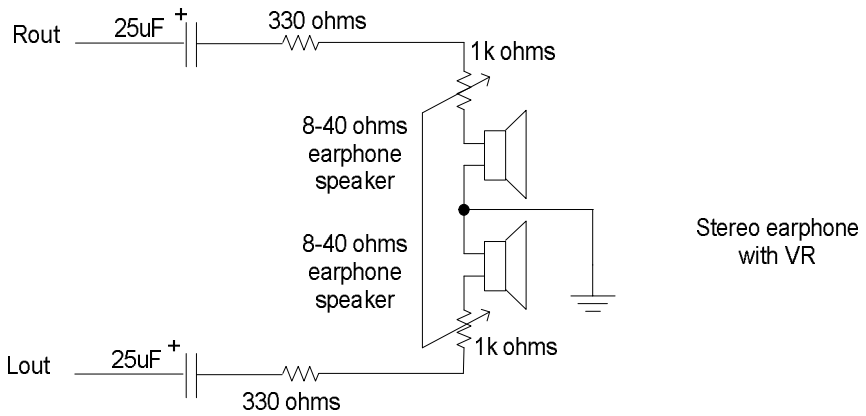
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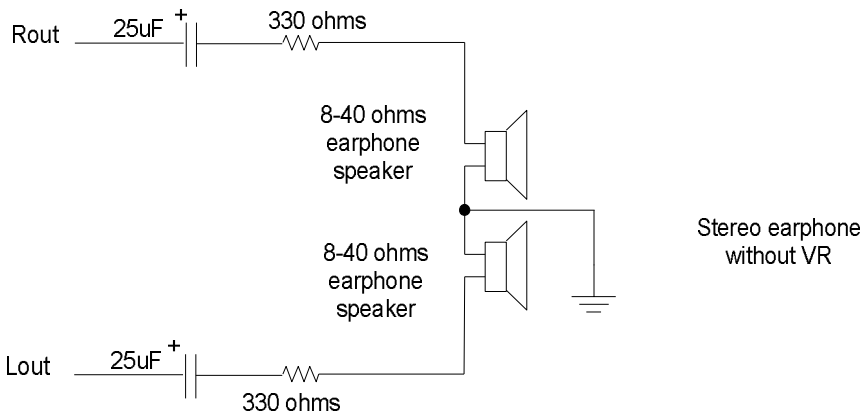
EARPHONE USE

Class-D output can be used to drive earphone. However to avoid high power to overdrive earphone and to prevent human ear to accidentally be hurt by loud noise, a resistor has to be put in series with the earphone speaker. Typically a resistor of 330 ohms is adequate for this purpose.



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Over temperature protection

A temperature sensor is built in the device to detect the temperature inside the device. When a high temperature around 145oC and above is detected the switching output signals are disabled to protect the device from over temperature. Automatic recovery circuit enables the device to come back to normal operation when the internal temperature of the device is below around 120oC.

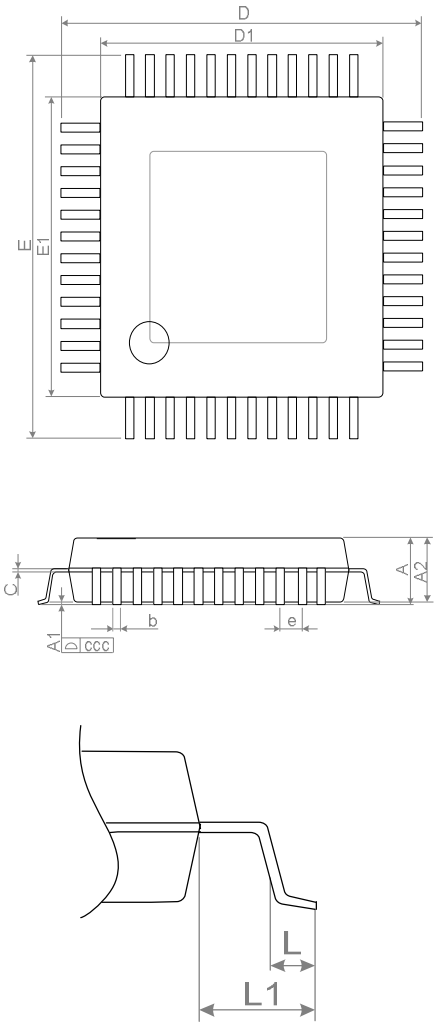
Over current protection

A current detection circuit is built in the device to detect the switching current of the output stages of the device. It disables the device when a pulse current beyond 8 amps is detected. It protects the device when there is an accident short between outputs or between output and power/gnd pins. It also protects the device when an abnormal low impedance is tied to the output. High current beyond the specification may potentially causes electron migration and permanently damage the device. Shutdown or power down is necessary to resolve the protection situation. There is no automatic recovery from over current protection.

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Physical Dimensions (IN MILLIMETERS)



SYMBOLS	MIN.	NDM.	MAX.
A	-	-	1.15
A1	0.00	-	0.10
A2	0.95	1.00	1.05
b	0.17	0.22	0.27
C	0.09	-	0.20
D1	6.90	7.00	7.10
D	8.80	9.00	9.20
E1	6.90	7.00	7.10
E	8.80	9.00	9.20
e	-	0.50(TYP)	-
L	0.45	0.60	0.75
L1	-	1.00(REF)	-
ccc	-	-	0.08

TQFP48

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