

Class-D Audio Power Amplifier with USB / I²S Interface

Features

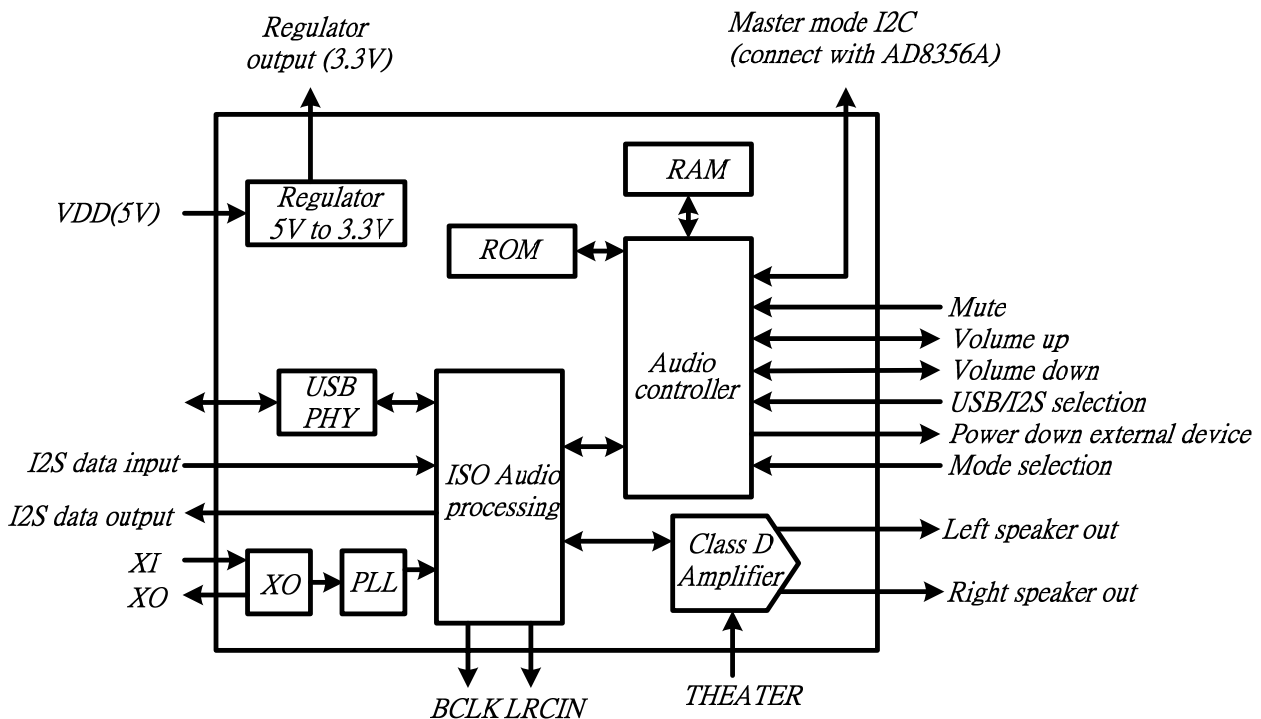
- Compliant with USB Specification v1.1, and USB 2.0 full speed
- Embedded high efficiency, high performance class D stereo amplifier
- Support I²S input and I²S output interface of master mode
Sampling frequencies(Fs) : 48kHz
- +6dB enhancement(Theater function)
- Support both bus-powered and self-powered operation
- Supports Win Me//2000/XP/Vista and MacOS
- True plug-and-play application, no driver is required for basic USB speaker application
- Support volume/mute control with external button
- Built-in 5V to 3.3V regulator for internal device operation
- Total efficiency
80% for 8Ω load @ -1dB 1kHz sine wave input
- Loudspeaker PSNR & DR (A-weighting)
80dB (PSNR), 78dB (DR) with Bead filter

- 82dB (PSNR), 78dB (DR) with Chock filter
- Anti-pop design
- Over-temperature protection
- Under-voltage shutdown
- Short-circuit detection
- 12 MHz Crystal Input
- 32-pin LQFP(Pb free)

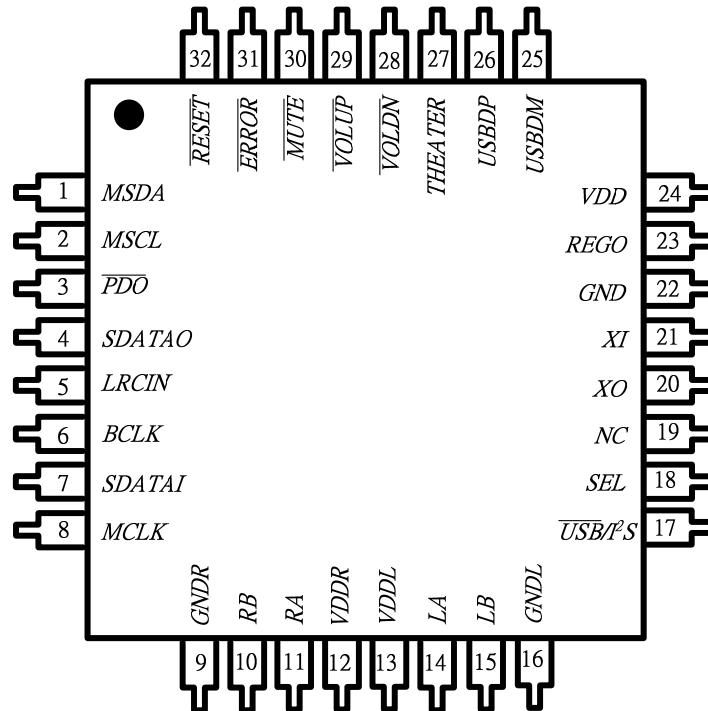
Description

AD62550A is a single chip of Class-D audio amplifier with USB/I²S interface. When using the power supplied from the USB port, AD62550A can drive a pair of up to 1W speakers due to the built-in, high efficiency and high performance class D amplifiers. The device also has an I²S input port and I²S output port. The I²S input port allows other external audio sources to use the class D amplifier to share the speakers. The I²S output port allows other high performance audio device (i.e. AD8356A/AD8256A) to be controlled by AD62550A.

Functional Block Diagram



Pin Assignment



Pin Description

Pin	Name	Type	Description	Characteristics
1	MSDA	I/O	I ² C's SDA of Master mode	Schmitt trigger TTL input buffer
2	MSCL	O	I ² C's SCL of master mode	
3	\overline{PDO}	O	Power-down output (Note1)	
4	SDATAO	O	Serial audio output (Note1)	
5	LRCIN	O	L/R clock output(Fs) (Note1)	
6	BCLK	O	BCLK output(64xFs) (Note1)	
7	SDATAI	I	Serial audio data input	Schmitt trigger TTL input buffer
8	MCLK	O	Master clock(256xFs)	
9	GNDR	P	Ground for right channel	
10	RB	O	Right channel output-	
11	RA	O	Right channel output+	
12	VDDR	P	Supply for right channel	
13	VDDL	P	Supply for left channel	
14	LA	O	Left channel output+	
15	LB	O	Left channel output-	
16	GNDL	P	Ground for left channel	

17	USB/I ² S	I	Low is USB mode, high is I ² S mode	Schmitt trigger TTL input buffer
18	SEL	I	Mode selection bit	Schmitt trigger TTL input buffer
19	NC	NC	No connection	
20	XO	O	Crystal output	
21	XI	I	Crystal input	
22	GND	P	Ground	
23	REGO	O	3.3V regulator output	
24	VDD	P	5V supply voltage	
25	USBDM	I/O	USB data D-	
26	USBDP	I/O	USB data D+	
27	THEATER	I	Theater mode, high active	Schmitt trigger TTL input buffer
28	VOLDN	I	Volume down, low active	With internal pull-up resistor
29	VOLUP	I	Volume up, low active	With internal pull-up resistor
30	MUTE	I	Power-down and mute of Class D	Schmitt trigger TTL input buffer
31	ERROR	O	Error output	Open-Drain output
32	RESET	I	Reset signal	Schmitt trigger TTL input buffer

Note1: Must be strapped resistor 1MΩ to 3.3V(REGO) or GND. BCLK, LRCIN and PDO must be strapped to GND. SDATAO is strapped to GND by 1MΩ when AD62550A's volume/mute is controlled by external button, otherwise strapped to 3.3V when AD62550A is I²C slave mode for SEL1 is logic LOW.

Ordering Information

Product ID	Package	Packing	Comments
AD62550A-LG	LQFP-32	250 Units/ Tray 10 Trays/ Small Box	Green

Marking Information

AD62550A

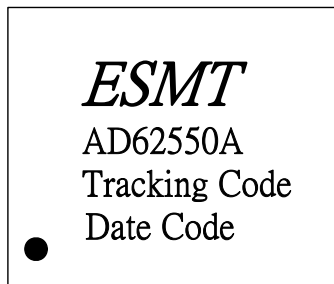
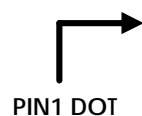
- Marking Information

Line 1 : LOGO

Line 2 : Product No

Line 3 : Tracking Code

Line 4 : Date Code



Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Units
VDD	Supply for regulator input (USB power)	0	5.5	V
VDDL(R)	Supply for Left (Right) Channel (USB power)	0	5.5	V
V _i	Input Voltage	-0.3	3.6	V
T _{stg}	Storage Temperature	-65	150	°C
T _a	Ambient Operating Temperature	0	70	°C
	Voltage Difference between V _{DDL} and V _{DDR}	-1	1	V
	V _{DDL} (V _{DDR}) Power-on Voltage Ramp		0.2	V/μs

Recommended Operating Conditions

Symbol	Parameter	Typ	Units
VDD	Supply for regulator input	4.5~5.5	V
VDDL(R)	Supply for Driver Stage	3.0~5.0	V
T _a	Ambient Operating Temperature	0~70	°C

Digital Characteristics

Symbol	Parameter	Min	Typ	Max	Units
V _{IH}	High-Level Input Voltage	2.0			V
V _{IL}	Low-Level Input Voltage			0.8	V
V _{OH}	High-Level Output Voltage	2.4			V
V _{OL}	Low-Level Output Voltage			0.4	V
C _i	Input Capacitance		6.4		pF

General Electrical Characteristics

SYMBOL	PARAMETER	CONDITION	MIN	TYP	MAX	UNITS
I _{USB}	USB Controller Operation Current	VDD=5V		44		mA
IPD	Supply Current during suspend mode			410	450	uA
	Regulator Current Limit (for REGO)	4.5V ≤ VDD ≤ 5.5V			90	mA
	Junction Temperature for Driver Shutdown			150		°C
	Temperature Hysteresis for Recovery from Shutdown			20		°C
UVH	Under Voltage Disabled (for REGO)			2.8		V
UVL	Under Voltage Enabled (for REGO)			2.7		V
Fsw	Switching Rate of Loudspeakers		8Fs	8Fs	8Fs	Hz
TPWM	Minimum PWM pulse width		$\frac{1}{256Fs}$	$\frac{1}{256Fs}$	$\frac{1}{256Fs}$	Sec
RSC	Loudspeaker Short-Circuit Detection (Note2)	VDDR(L)=5V		2.8	3.2	

Note2: Loudspeaker short-circuit protection is effective only when external LC or ferrite bead filters are properly used. Long time short-circuit will reduce device reliability. AD62550A protects itself from short-circuit damage only when the lines connected to speaker are shorted to each other or to GND. AD62550A will be burnt if the lines connected to loudspeaker are shorted to VDDL(VDDR).

Package Options

Package Type	Part Number	Thermal Information
LQFP-32	AD62550A	$\theta_{JA} = 59.9^{\circ}\text{C/W}$

Electrical Characteristics and Specifications for Loudspeaker

- Condition: VDD=VDDL=VDDR=5V, F_S=48kHz, Load=8Ω with Bead filter. Input is 1kHz sinewave.

Symbol	Parameter	Condition	Input Level	Min	Typ	Max	Units
P _{OMAX}	Maximum RMS Output Power / Ch		0dB		2		W
P _O	RMS Output Power for Each Channel	10% THD+N	-4.2dB		1.58		W
		1% THD+N	-6.0dB		1.2		W
I _{cc}	Required RMS Supply Current		-7dB		0.66		A
THD+N	Total Harmonic Distortion+Noise		-7dB		0.54		%
SNR	Signal to Noise Ratio (Note3)		-7dB		78		dB
DR	Dynamic Range (Note3) (Note4)		-66dB		78		dB
PSRR	Power Supply Rejection Ratio		-66dB		60		dB
	Channel Separation		-7dB		82		dB
η	Efficiency	P _O =2.0W	0dB		80		%

- Condition: VDD=VDDL=VDDR=5V, F_S=48kHz, Load=8Ω with passive LC lowpass filter (L=22μH, C=470nF); Input is 1kHz sinewave.

Symbol	Parameter	Condition	Input Level	Min	Typ	Max	Units
P _{OMAX}	Maximum RMS Output Power / Ch		0dB		2		W
P _O	RMS Output Power for Each Channel	10% THD+N	-4.4dB		1.6		W
		1% THD+N	-8.4dB		0.8		W
I _{cc}	Required RMS Supply Current		-7dB		0.55		A
THD+N	Total Harmonic Distortion+Noise		-7dB		1.45		%
SNR	Signal to Noise Ratio (Note3)		-7dB		80		dB
DR	Dynamic Range (Note3) (Note4)		-66dB		82		dB
PSRR	Power Supply Rejection Ratio		-66dB		60		dB
	Channel Separation		-7dB		82		dB
η	Efficiency	P _O =2.0W	0dB		82.7		%

Note3: Measured with A-weighting filter.

Note4: Dynamic Range (DR) is defined as Signal to Noise Ratio (SNR) at the highest volume level plus 60dB. In brief, DR= SNR of the highest volume level + 60dB.

Electrical Characteristics and Specifications for Loudspeaker

- Condition: VDD=VDDL=VDDR=5V, F_S=48kHz, Load=4Ω with Bead filter. Input is 1kHz sinewave.

Symbol	Parameter	Condition	Input Level	Min	Typ	Max	Units
P _{OMAX}	Maximum RMS Output Power / Ch		0dB		3.5		W
P _O	RMS Output Power for Each Channel	10% THD+N	-4.3dB		2.6		W
		1% THD+N	-7.9dB		1.43		W
I _{cc}	Required RMS Supply Current		-7dB		1.11		A
THD+N	Total Harmonic Distortion+Noise		-7dB		1.12		%
SNR	Signal to Noise Ratio (Note3)		-7dB		78		dB
DR	Dynamic Range (Note3) (Note4)		-66dB		75		dB
PSRR	Power Supply Rejection Ratio		-66dB		60		dB
	Channel Separation		-7dB		82		dB
η	Efficiency	P _O =3.5W	0dB		78.8		%

- Condition: VDD=VDDL=VDDR=5V, F_S=48kHz, Load=4Ω with passive LC lowpass filter (L=10μH, C=470nF); Input is 1kHz sinewave.

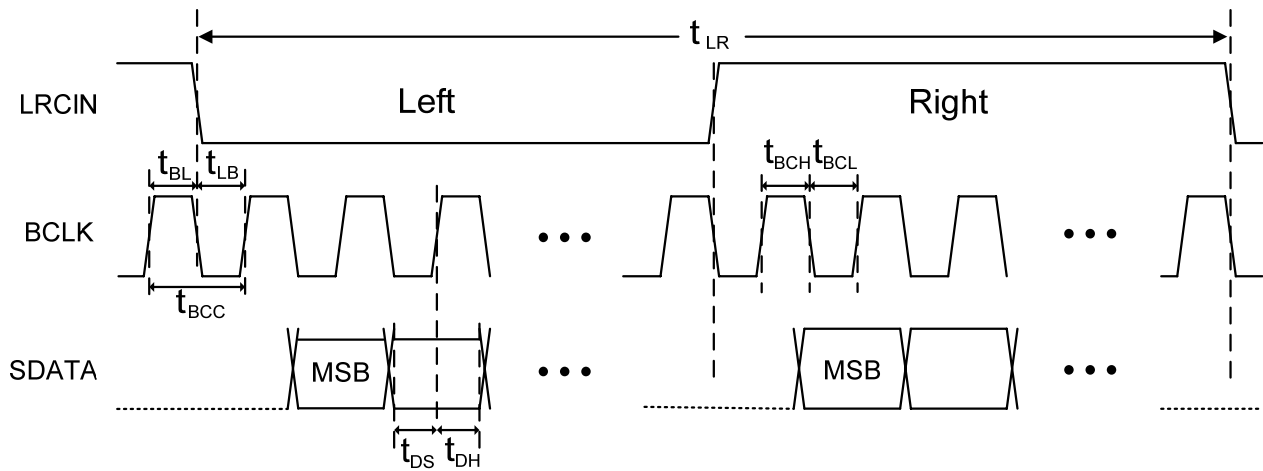
Symbol	Parameter	Condition	Input Level	Min	Typ	Max	Units
P _{OMAX}	Maximum RMS Output Power / Ch		0dB		3.5		W
P _O	RMS Output Power for Each Channel	10% THD+N	-4.6dB		2.67		W
		1% THD+N	-10.5dB		0.84		W
I _{cc}	Required RMS Supply Current		-7dB		0.9		A
THD+N	Total Harmonic Distortion+Noise		-7dB		2.7		%
SNR	Signal to Noise Ratio (Note3)		-7dB		80		dB
DR	Dynamic Range (Note3) (Note4)		-66dB		82		dB
PSRR	Power Supply Rejection Ratio		-66dB		60		dB
	Channel Separation		-7dB		82		dB
η	Efficiency	P _O =3.5W	0dB		82.6		%

Note3: Measured with A-weighting filter.

Note4: Dynamic Range (DR) is defined as Signal to Noise Ratio (SNR) at the highest volume level plus 60dB. In brief, DR= SNR of the highest volume level + 60dB.

Interface Configuration

- I²S

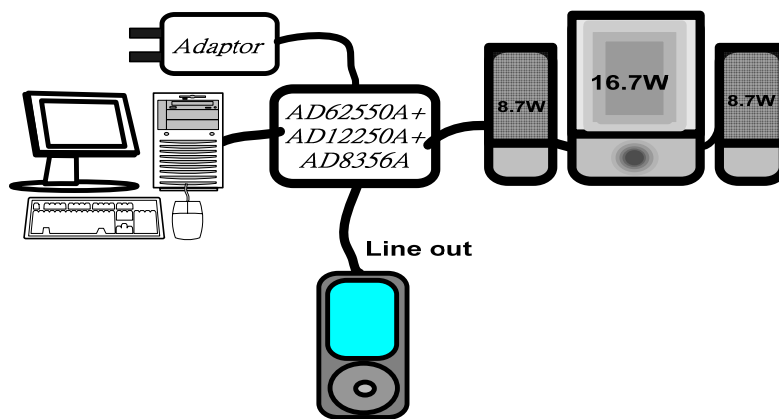
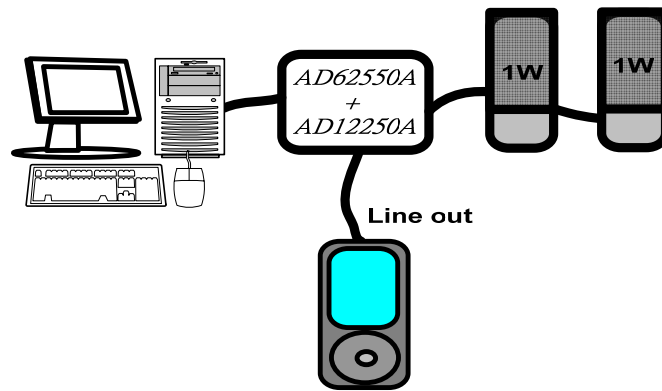


Symbol	Parameter	Min	Typ	Max	Units
t_{LR}	LRCIN Period ($1/F_s$)	10.41		125	μ s
t_{BL}	BCLK Rising Edge to LRCIN Edge	50			ns
t_{LB}	LRCIN Edge to BCLK Rising Edge	50			ns
t_{BCC}	BCLK Period ($1/64F_s$)	162.76		1953	ns
t_{BCH}	BCLK Pulse Width High	81.38		976.5	ns
t_{BCL}	BCLK Pulse Width Low	81.38		976.5	ns
t_{DS}	SDATA Set-Up Time	50			ns
t_{DH}	SDATA Hold Time	50			ns

Operation Descriptions

The following figure illustrates two more advanced applications that use AD62550A, together with an external ADC, e.g., AD12250A from ESMT that can convert stereo line-in audio to I²S output to send to AD62550A, and/or an external high-end class D amplifier such as AD8356A.

Both applications, a switch is used to select audio stream from either USB port or I²S port. When the audio stream is from I²S port, the device is operating as “docking station” mode. When the audio stream is from USB port, the device is operating as “USB speaker” mode. When AD8356A is used, since it can deliver 10Wx2 + 20W (subwoofer) power, USB bus power may be insufficient and local power supply is required. Functional description follows.



SEL

	0	1
SEL	<i>External amplifier</i>	<i>Internal amplifier</i>

Volume Control

Audio volume control is low active. Duration of low level must be longer than 3ms. The highest volume gain is 6dB for THEATER is logic HIGH and 0dB for THEATER is logic LOW, referred to the original input signal level.

RESET

When $\overline{\text{RESET}}$ is low, AD62550A will clear the data of internal storage elements and set the default volume level of class-D amplifier. The default volume level is -18dB for THEATER is logic HIGH and -24dB for THEATER logic LOW.

Mute control

$\overline{\text{MUTE}}$ is low active. Duration of low level must be longer than 3ms.

Self-protection circuit (*values used here are typical values*)

AD62550A has built-in thermal, short-circuit and under-voltage detection circuits. If the internal thermal detection junction temperature is higher than 150°C, the loudspeaker power stages will be turned off. The thermal detection circuit has a temperature hysteretic characteristic such that the AD62550A will return to normal operation when the device is cooled down to about 20°C. Due to the process variation, the triggering temperature values can have around 10% variation.

To protect loudspeaker power stages when the loudspeaker output is shorted each other or shorted to GND, the output loading detection circuits are built-in and proper protection action will take place once the short circuit condition is detected.

For normal operation, the loudspeaker output resistance larger than 3.4Ω is required. Otherwise, the short-circuit detectors will pull the $\overline{\text{ERROR}}$ pin to low. To effectively protect AD62550A from short-circuit, the $\overline{\text{ERROR}}$ pin and $\overline{\text{RESET}}/\overline{\text{MUTE}}$ pin are suggested to connected together. Once the short-circuit condition is detected, the $\overline{\text{ERROR}}$ pin will be pulled to low and whole chip is reset/mute. The output power stages will be shut off. The recommend R and C value for the RC network connected to the $\overline{\text{RESET}}/\overline{\text{MUTE}}$ pin are 2.2MΩ and 10nF, respectively. The capacitance should be as close to 10nF as possible. When VDDRL is larger than 3.6V, loudspeaker short-circuit protection is reliable only when LC or ferrite bead filters are properly used.

Once the V_{REGO} is lower than 2.7V, AD62550A will turn off its loudspeaker power stages and the digital circuit will cease operation. When V_{REGO} becomes larger than 2.8V, AD62550A will return to normal operation.

Anti-pop design

AD62550A is has an anti-pop circuit to suppress the annoying pop sounds during initial power on, power down/up, mute, power off and volume level change.

Switching between USB Speaker mode and docking station mode

When the $\overline{\text{USB/I2S}}$ pin is low, the input audio stream is from USB port. When this pin is high, the input audio stream is from I²S input port.

When operating as USB speaker mode, the volume control is from PC. When the user controls the volume from the local control pins, this volume setting is also uploaded to PC via USB protocol for the Windows operating system to take appropriate action.

Sound Theater Effect Mode

When THEATER pin is high, Sound Theater Mode is established. In this mode, the audio volume is enhanced by +6dB to simulate the theater effect.

Power Consideration

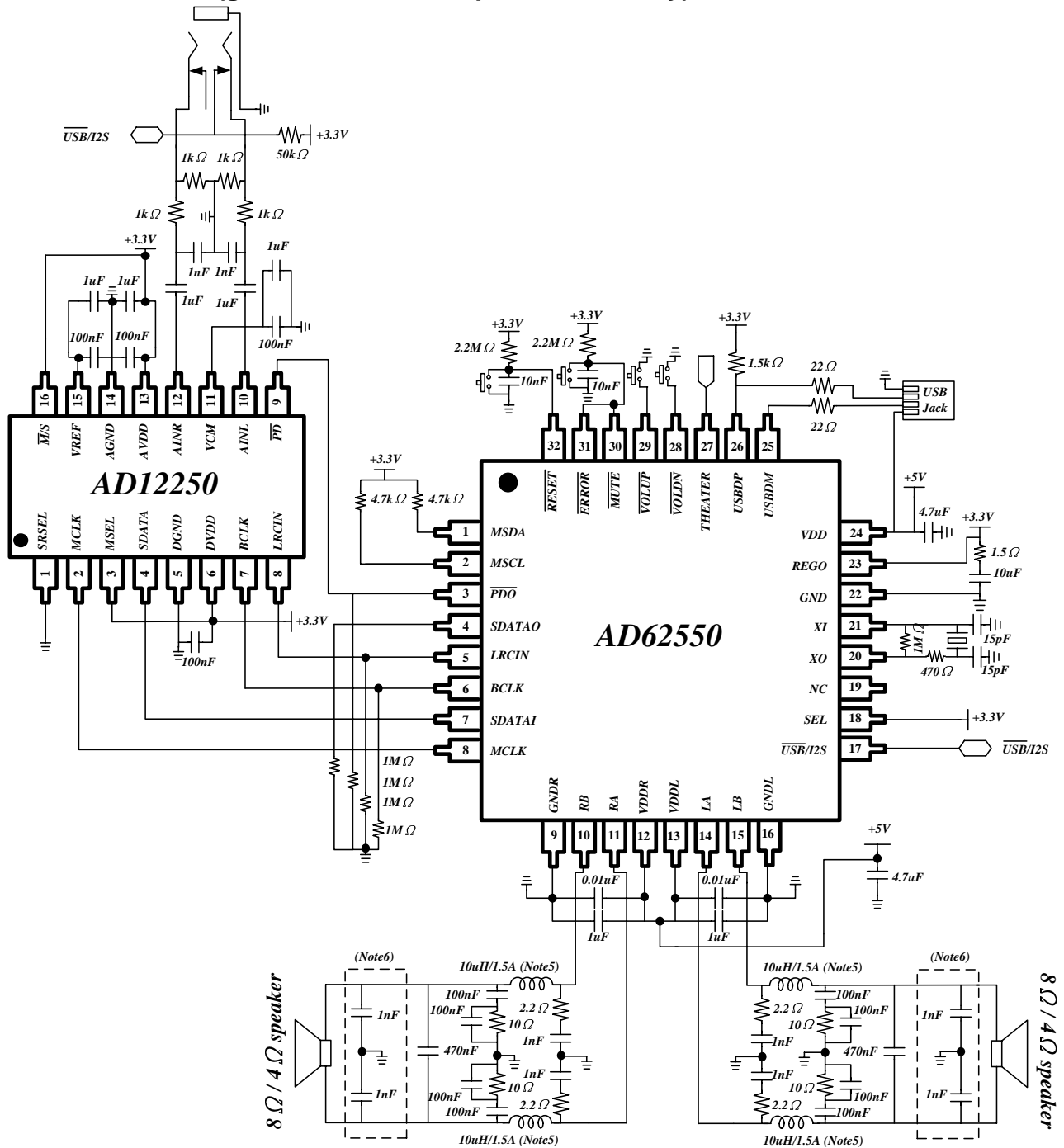
AD62550A can be powered by the USB port directly. However, the maximum current supplied by each USB port is limited 500mA. If the total power requirement of the USB audio subsystem is higher than this, local power supply, e.g., a local AC adaptor will have to be used. If the audio subsystem is attached to an USB hub, which is not locally powered, the maximum power from each USB port is only limited to 100mA, and local power must be supplied.

I²C slave mode when SEL is logic Low

AD62550A can also operate as slave in a system when SDATAO is pulled high with 1M Ω . When operating as a slave mode, AD8356A/8256A is controlled by an external uP. Functions in PC are all disable.

Application Circuit Examples for 8Ω/4Ω loudspeaker

- With LC filter (good SNR, DR, and power efficiency)

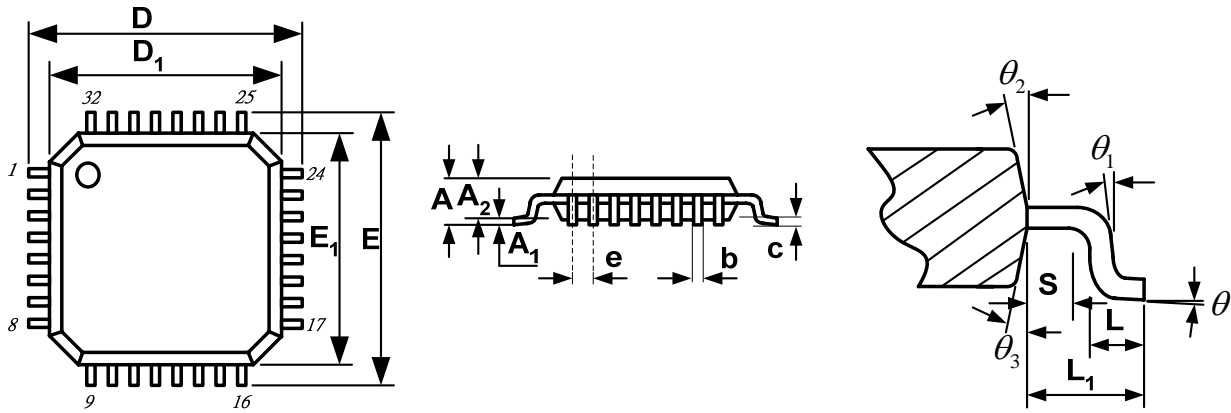


Note5: When 8Ω's loads are used, the 22uH/0.8A inductors are suggested.

Note6: These capacitors should be placed close to speaker jack as possible, and their values should be determined according to EMI test results.

Package Dimensions

- LQFP-32 Package
-



Symbol	Dimension in mm			Dimension in inch		
	Min	Nom	Max	Min	Nom	Max
A	-	-	1.6	-	-	0.063
A ₁	0.05	-	0.15	0.002	-	0.006
A ₂	1.35	1.40	1.45	0.053	0.055	0.057
b	0.30	0.37	0.45	0.012	0.015	0.018
c	0.09	-	0.20	0.004	-	0.008
θ	0°	3.5°	7°	0°	3.5°	7°
θ ₁	0°	-	-	0°	-	-
θ ₂	12° TYP			12° TYP		
θ ₃	12° TYP			12° TYP		
D	9.00 BSC			0.354 BSC		
D ₁	7.00 BSC			0.276 BSC		
E	9.00 BSC			0.354 BSC		
E ₁	7.00 BSC			0.276 BSC		
e	0.80 BSC			0.031 BSC		
L	0.45	0.60	0.75	0.018	0.024	0.030
L ₁	1.00 REF			0.039 REF		
S	0.20	-	-	0.008	-	-

Revision History

Revision	Date	Description
0.1	2006.08.21	Original
1.0	2006.11.27	Update measurement data.
1.1	2006.12.28	1. Application circuit updated 2. Modify pin23 description 3. Modify output wattage from 10W/20W to 8.7W/16.7W
1.2	2007.01.12	Added GND point at common mode filter
1.3	2007.04.27	1. P1, delete 3.3V Operation with 5V tolerate I/O ; and added: Sampling frequencies (FS) : 48kHz 2. P2-P3, modified pin1、7、17-19、27、30 and 32 characteristics become "Schmitt trigger TTL input buffer" ; delete pin21 characteristics description. 3. P3, modified symbol "Vi" maximum is to 3.6V
1.4	2008.01.07	Modified maximum rating VDD、VDDL(R) parameter
1.5	2009.09.11	1. Modified oscillator circuit 2. Added Vista OS support 3. Added order & marking information
1.6	2010.02.26	1) Put GND node for application circuit
1.7	2011.09.09	Revise packing information

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