10W Class S Audio Amplifier with Boost Converter

Key Features

- Input voltage range: 3V to 5.5V
- Adaptive Boost regulator, Boost Output PVDD: V_{BAT} to 6.5V/7.0V/7.5V
- AGC Anti-Clipping Function
- Class D/Class AB selectable
- Class D PWM output without filter
- Output Power P_O (Class D@10% THD+N, V_{BAT} = 3.7V)
  - R_L=2Ω, 10W (BOOST PVDD= 7.5V)
  - R_L=2Ω, 8.5W (BOOST PVDD= 6.5V)
  - R_L=4Ω, 7.0W (BOOST PVDD= 7.5V)
  - R_L=4Ω, 6.0W (BOOST PVDD= 6.5V)
- Over Current Protection, Short Circuit Protection, Low voltage Protection, Thermal Protection included
- Rohs standard environmental package: ESOP8 Packages with heat sink

Applications

- Portable Speaker, Bluetooth Speaker
- Portable Game Machines
- Megaphone
- MP4/GPS
- Table PC
- Note Book

General Description

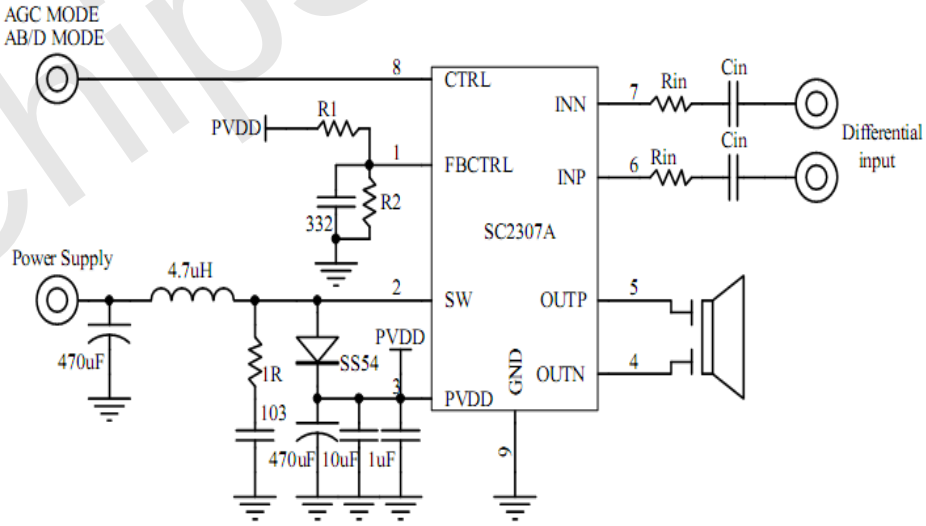
The SC2307A with built-in boost module provides ample power output to the speaker, and the maximum boost value is selectable between four voltage levels of 6.5V, 7.0 and 7.5V. When the input signal is small, the boost circuit does not work, and the Class D is directly powered by the power supply; When the input signal becomes larger, the boost module is automatically turned on to the intermediate level to supply power to the Class D; When the input signal becomes larger, the boost circuit continues to boost to the user-set maximum voltage for the Class D power supply, which can improve system efficiency and extend battery life.

SC2307A has AGC Anti-Clipping Function, which can significantly improve the sound quality, create comfortable listening enjoyment, and protect the speaker from overload damage.

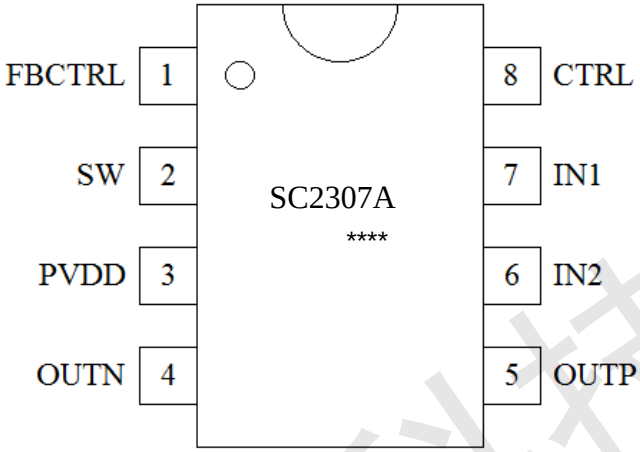
SC2307A has the Class AB/D mode switching function, and switching to the Class AB can reduce the interference of the amplifier in the system to FM.

The fully differential architecture of SC2307A effectively increases the chip's ability to reject RF noise. The PWM modulation structure without filter and the built-in boost module reduce the peripheral components as much as possible. In addition, SC2307A has built-in over current protection, short circuit protection and overheat protection, which effectively protects the chip from damage under abnormal working conditions.

Typical Application



Pin Configuration



Pin Function Description

Pin NO.	Pin name	I/O	Function
1	FBCTRL		Boost Maximum PVDD Select
2	SW		Boost Circuit switch
3	PVDD	POWER	Power Input
4	OUTN	OUT	Negative Output
5	OUTP	OUT	Positive Output
6	IN2	IN	Positive Input
7	IN1	IN	Negative Input
8	CTRL		AGC Function Control, Class AB/D Mode Control, Shutdown Control
Thermal PAD	GND	GND	Ground

Absolute Maximum Ratings

Parameter		Min	Max	Unit	Remarks
Supply voltage		3	5.5	V	
Storage temperature		-45	125	℃	
Input voltage		-0.3	8.8	V	
ESD resistance voltage		2000		V	
Junction temperature		-40	150	℃	
Operating temperature		-40	85	℃	
Thermal resistance	J_C(eSOP16)		23	℃/W	
	J_A(eSOP16)		110	℃/W	
Welding temperature			220	℃	

Note: the performance of chip is not guaranteed outside the limit value or under any other conditions.

Recommended Operating Conditions

Parameter	Min	Typ	Max	Unit
Supply voltage	3		5.5	V
BOOST voltage range	5.0	6.5	7.5	V
Operating temperature	-45		85	℃
Speaker resistance	2			Ω

CMOS Circuit Operation Precautions

• Static electricity is generated in many places. The following preventive measures can effectively prevent damage of MOS circuit caused by electrostatic discharge.

• The operator should be grounded through the anti-static wrist band.

• The equipment enclosure must be grounded.

• Tools used during assembly must be grounded.

• Conductor packaging or anti-static material must be used for packaging or transportation.

Electrical Specifications

TA=27°C, VBAT =3.7V, f=1KHz, RIN=10KΩ, CIN=1uF, Load=4Ω+33uH (Unless otherwise specified)

Symbol	Parameter	Condition	Min	Typ	Mac	Unit
V_{BAT}	Supply voltage range		3		5	V
I_{SD}	Shutdown Current	V_{SD}=0		<1		μA
I_{VBAT}	Quiescent Current	PVDD=6.5V, no Load, no Filter (Class D)		4		mA
		V_{BAT}=3.7V, no Load, no Filter (Class AB)		12		mA
Tstart	Start-up time			130		ms
PSRR	Power ripple rejection ratio	217Hz			-70	dB
		20KHz			-62	dB
V_{IH}	High level of logic control terminal		VBAT			V
V_{IL}	Low level of logic control terminal				0.3	V
T_{OTP}	Over temperature protection point			160		℃
T_{HYS}	Over temperature protection hysteresis			20		℃
BOOST Module						
PVDD	Boost output voltage			6.5		V
				5.7		
				7.0		
				7.5		
f_{BOOST}	Boost converter frequency			410		KHz
η_{BOOST}	Boost efficiency	FBCTRL=0，I（PVDD）=500mA		85		%
T_{BOOST}	Boost start up time	Direct mode to 5.7V		2		ms
AGC Function						
A_{MAX}	AGC maximum gain attenuation range			22		dB
A_{STEP}	AGC gain attenuation step			0.75		dB
T_{AGC}	AGC attack/release time	Attack Time		50		ms/dB
		Release Time		64		ms/dB
THD_{AGC}	AGC maximum distortion limit on output			1		%
Class D Channel						
AGCOFF						
P_O	PVDD=7.5V	THD+N	R_L=2Ω		10		W

		=10%	R_L=4Ω		7.0		
			R_L=8Ω		4.5		
		THD+N =1%	R_L=2Ω		7.5		
			R_L=4Ω		6.0		
			R_L=8Ω		3.8		
	PVDD=7.0V	THD+N =10%	R_L=2Ω		8.0		W
			R_L=4Ω		6.5		
			R_L=8Ω		3.7		
		THD+N =1%	R_L=2Ω		7.5		
			R_L=4Ω		5.0		
			R_L=8Ω		3.0		
	PVDD=6.5V	THD+N =10%	R_L=2Ω		8.0		
			R_L=4Ω		5.6		
			R_L=8Ω		3.0		
		THD+N =1%	R_L=2Ω		6.8		
			R_L=4Ω		4.3		
			R_L=8Ω		2.5		
	PVDD=5.7V	THD+N =10%	R_L=2Ω		7.3		
			R_L=4Ω		4.3		
			R_L=8Ω		2.3		
		THD+N =1%	R_L=2Ω		5.5		
			R_L=4Ω		3.3		
			R_L=8Ω		1.8		
AGC							
P_O	PVDD=7.5V		R_L=2Ω		7.0		W
			R_L=4Ω		5.5		
			R_L=8Ω		3.0		
	PVDD=7.0V		R_L=2Ω		7.3		
			R_L=4Ω		5.0		
			R_L=8Ω		3.0		
	PVDD=6.5V		R_L=2Ω		6.5		
			R_L=4Ω		4.0		
			R_L=8Ω		2.5		
	PVDD=5.7V		R_L=2Ω		5.3		
			R_L=4Ω		3.3		
			R_L=8Ω		1.8		
THD+N	Total distortion + noise		f=1KHz ， R_L=4Ω，P_O=0.5W		0.1		%
η	Maximum efficiency		RL=4Ω+33uH, VBAT=4.2V，Po=0.6W		85		%

	Class D + Boost	RL=4Ω+33uH, PVDD=7.5V，Po=7.0W			77		%
V_N	Output noise	A Weighting, f = 20~20KHz, Input AC ground			150		uVrms
SNR	Signal to noise ratio	A Weighting, Av=28dB, THD+N=1%			90		dB
CMRR	Common mode rejection ratio	f=1KHz			-70		dB
PSRR	Power supply rejection ratio	f=1KHz			-70		dB
V_{OS}	Output offset voltage				10	40	mV
Rdson	source-drain conduction resistance (Class D）	I_{DS}=500mA, Vgs=7V	PMOS		180		mΩ
			NMOS		140		mΩ
f_{SWD}	Class D modulation frequency				410		KHz
t_{WK_D}	Class D start setting time				130		ms
t_{MOD_D}	Class D/AB conversion setting time				130		ms
Class AB Channel							
P_O	Output Power	R_L=2Ω	V_{BAT}=5.0V, THD=10%		4.2		W
			V_{BAT}=5.0V, THD=1%		2.9		
			V_{BAT}=4.2V, THD=10%		2.7		
			V_{BAT}=4.2V, THD=1%		2.0		
			V_{BAT}=3.6V, THD=10%		2.0		
			V_{BAT}=3.6V, THD=1%		1.4		
		R_L=4Ω	V_{BAT}=5.0V, THD=10%		3.0		
			V_{BAT}=5.0V, THD=1%		2.7		
			V_{BAT}=4.2V, THD=10%		1.7		
			V_{BAT}=4.2V, THD=1%		1.3		
			V_{BAT}=3.6V, THD=10%		1.4		
			V_{BAT}=3.6V, THD=1%		1.2		
THD+N	Total distortion + noise	f=1KHz，R_L=4Ω，P_O=0.5W			0.12		%
η	Maximum efficiency	RL=4Ω+33uH, VBAT=3.7V，Po=1.2W			70		%
V_N	Output noise	A Weighting, f = 20~20KHz, Input AC ground			50		uVrms
SNR	Signal to noise ratio	R_L=4Ω, P_O=0.5W			96		dB
CMRR	Common mode rejection ratio	f=1KHz			-70		dB
PSRR	Power supply rejection ratio	f=1KHz			-70		dB
t_{WK_AB}	Class AB start setting time				130		ms
t_{MOD_AB}	Class AB/D conversion setting time				130		ms

Description :

1. Use 33uH(inductance) + 2ohm(resistor) and 33uH(inductance) + 4ohm(resistor) to simulate the characteristics of the speaker.

2. In Class AB mode, the DCDC module is automatically turned off. Due to the voltage drop VD on the external diode, power supply PVDD of Class AB actual value is VBAT-VD, and VD is different in different devices, different temperatures, and different currents.

3. Constant output power: In AGC mode, when the input signal is increased to AGC, the output power does not change with the input signal within the effective attenuation range of the AGC.

Application Information

Input Capacitor (C_{IN}) and Input resistor (R_{IN})

SC2307A accepts analog differential or single-ended audio signal inputs, outputs digital signals PWM (Class D) or analog audio signals (Class AB) to drive speakers.

Differential inputs and single-ended inputs have the same magnification.

In the Class D mode, the chip integrates input resistor (15K ohm) and feedback resistor(600Kohm). When R_{IN} = 10K ohm, SC2307A has a gain of 24 times (27.6dB), and the system gain can also be adjusted by the following formula:

$$A_{V\_D} = \frac{600K\Omega}{R_{IN} + 15K\Omega}$$

In the Class AB mode, the chip integrates input resistor (1.5K ohm) and feedback resistor(115Kohm). When R_{IN} = 10K ohm, SC2307A has a gain of 10 times (20dB), and the system gain can also be adjusted by the following formula:

$$A_{V\_AB} = \frac{115K\Omega}{R_{IN} + 1.5K\Omega}$$

The input capacitor and the input resistor form a high-pass filter. The cutoff frequency is:

$$f_C = \frac{1}{2p \times (R_{IN} + R_{Inside}) \times C_{IN}}$$

In the formula, R_{Inside} is the internal input resistance of the chip.

The input resistance R_{IN} is determined according to the gain of the application demand, and the input capacitance C_{IN} is determined according to the performance of the speaker. After the gain is determined, the appropriate capacitor is selected. The large input capacitor C_{IN} produces a lower cutoff frequency, which is conducive to the reproduction of low frequency sound. However, the excessive input capacitance may introduce pop sound and large low frequency noise. A large capacitor with a large device size may be detrimental to the layout of the PCB, so the input capacitor is reasonably selected according to requirements.

The mismatch in the input resistance reduces the system's PSRR, CMRR, and THD performance, so we require an input resistance of 1% accuracy.

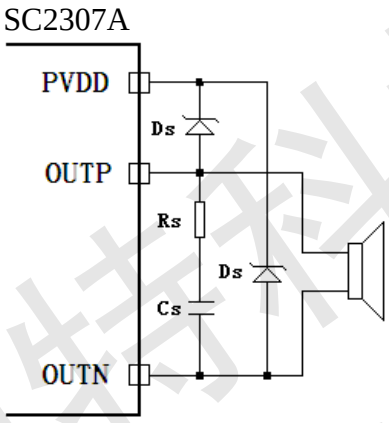
A mismatch in the input capacitance can cause a mismatch in the cutoff frequency of the input filter. A serious mismatch in the capacitance can also cause a pop sound at start up. It is recommended to use a capacitor with a tolerance of 10% or better.

It is worth noting that the output impedance of the system's pre-stage circuit should not exceed 600 ohms.

Audio amplifier output

In general, the output can be directly connected to the load horn. If the output line at the output is long or the EMI requirements are high, you can choose to add a ferrite bead or LC filter.

In addition, if the amplitude of the input signal is large, or the output voltage PVDD of the DCDC module is large, or the impedance of the load horn is small (≤4Ω), it is necessary to appropriately increase the capacitance of the power supply terminal (at least 100μF or more) and add Snubber circuit and schottky diode at the output to prevent chip abnormality.



Recommended parameter :

Rs: 1.5Ω ~ 2Ω

Cs: 330pF ~ 680pF

Ds: Positive average current(≥3A), Positive surge peak current(≥6A), Positive voltage (IF=1A)≤0.38V。

Selection of supply filter capacitor

In amplifier applications, the bypass design of the power supply is important, especially for the noise performance of application and supply voltage rejection.

The filter capacitor is required to be as close as possible to the power supply pin of the chip.

In SC2307A, pin 3 (PVDD) supplies voltage and current to the internal circuit of the chip, and is connected to the DCDC boost output through the PCB. The branch has a large current that changes rapidly. It is recommended to connect a 470μF electrolytic capacitor near the PVDD pin and place 10μF and 1μF low ESR ceramic capacitors close to the chip. The 1μF capacitor is as close as possible to the PVDD pin.

Selection of inductance in BOOST circuit

BOOST needs to use the inductance for normal operation. The value of the inductance in operation will decrease with the increase of the inductance current and temperature. If the inductance value drops

seriously during the operation, the Boost circuit may be unstable, or SC2307A triggers internal current limit and does not achieve sufficient output power.

A small inductance value introduces a large current ripple, which provides better current transient response, but also sacrifices system efficiency and increases core loss and EMI. Large inductance values reduce inductance current ripple, improve efficiency, and reduce EMI, but have a poor transient response to output current.

In order to ensure the normal operation of the chip, the inductance value recommended by SC2307A is 4.7uH (DC resistance of the inductance $DCR \leq 50m\Omega$, saturation current $I_{SAT} \geq 6A$).

Selection of schottky diode in BOOST circuit

BOOST needs to use the schottky diode for normal operation. It is recommended to use schottky diode with a withstand voltage greater than 20V and a forward average current of not less than 5A. SC2307A recommends schottky diode of type SS54 or MBRS540.

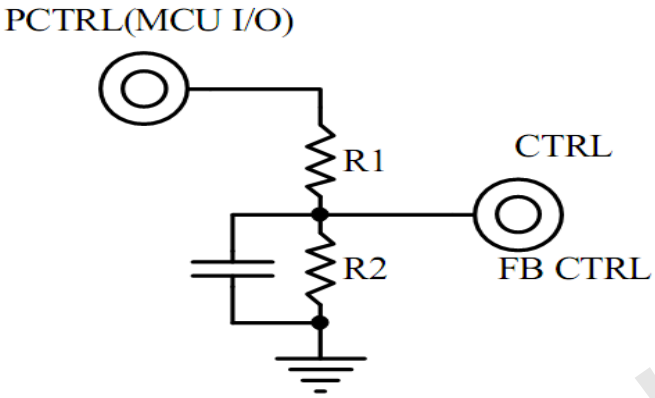
Function description of CTRL pin

Table.1 CTRL pin voltage selection for different functional modes

Voltage Range	Mode
<0.3V	SC2307A standby，low power state
0.5V-1.3V	Class AB
2.5V-VBAT	Class D, AGCOFF mode
1.7V-2.1V	Class D, AGC ON mode

In Class D mode, you can choose to enter the Anti-Clipping mode. When the circuit detects that the input signal amplitude is too large and the voltage output distortion, the chip automatically adjusts the system gain to control the output to the maximum without the clipping power. This improves the sound quality. In addition, when the supply voltage drops, the chip can also automatically adjust the output gain to achieve a maximum distortionless output voltage that matches the PVDD drop value.

The following figure shows the voltage division setting when configuring the CTRL pin and FBCTRL pin. Note: To prevent the influence of MCU I/O voltage jitter, add a filter capacitor to the MCU I/O pin as shown in the figure. It is not recommended to directly add the capacitor to the CTRL and FBCTRL pins.



Adaptive BOOST function

In order to make SC2307A output power range larger and save power, SC2307A uses an adaptive BOOST technology. The user can select the maximum boost voltage through the FBCTRL pin. See the table below:

Table.2 FBCTRL pin voltage selection for different functional modes

R1	R2	BOOST maximum voltage
120K	30K	6.5V
120K	27K	7.0V
120K	24K	7.5V

*If PCTRL is not equal to 1.8V, please adjust the resistance of R1 and R2 according to the required voltage to meet the control requirements.

SC2307A has built-in DC asynchronous switching boost circuit (DCDC BOOST) with fixed frequency and pulse width modulation (PWM), its switching frequency is 410KHz. SC2307A has an adaptive boost function, which can automatically adjust the amplitude of the boost voltage to the Class D supply according to the amplitude of the output signal. When the output signal is small, Class D is directly powered by the battery voltage (VBAT). When the output voltage is large, the boost circuit is boosted to the intermediate level of 5.7V to supply power to the Class D; when the output signal is very large, the boost circuit continues to boost to the maximum voltage value set by the user to supply power to the Class D. When the output signal becomes small, the boost circuit is stepped down to the intermediate voltage; when the output signal becomes smaller, the boost circuit is turned off, and the Class D is directly powered by the battery voltage (VBAT). This method can improve system efficiency and increase battery life.

Noise Suppression Circuit at power on and power down

SC2307A has built-in Noise Suppression Circuit at power on and power down, which effectively eliminates transient noise that may occur when the system is powered on, powered off, wake-up and shutdown.

Protection Circuit

When the temperature of the chip is too high, the chip will be turned off, and after the temperature drops, the chip will continue to work normally.

The over current protection supports a load of 2Ω. When the output of the chip is short-circuited to the power supply, ground or output, the chip will be turned off. After the short-circuit fault is removed, the chip can automatically resume normal operation.

When the power supply voltage is too low, the chip will also be turned off. After the power supply voltage is restored, the chip will start again.

PCB layout considerations

- SC2307A is a Class D power amplifier with BOOST converter. There is a large current signal in the circuit. To ensure performance, attention should be paid to the layout of large current paths.

- When BOOST is working, the large current path is the positive terminal of the power supply -inductor -SW -GND -flows back to the negative terminal of the power supply, and the other large current path is the positive terminal of the power supply -inductor -the diode -the capacitor(470uF) -flows back to the negative terminal of the power supply. There is also a current path from the capacitor(470uF) positive terminal -PVDD -OUTP(OUTN)-load horn -OUTN(OUTP)-GND -capacitor(470uF) negative terminal when the power amplifier is operating. The PCB layout on the above current path may cause chip performance degradation in any loop, so priority should be given to carefully consider the above path layout.

- The power supply wiring should be taken out separately from the power supply terminal (to reduce the impact on other power modules), and the wiring from the power supply to the inductance and the inductance to the SW pin should be wide(considering BOOST inductance current is large, SC2307A recommended power supply to the inductance trace width is not less than 6mm), and the path is as short as possible.

- The GND is directly connected to the solder mask in the middle of the chip, and is connected to the large area of the middle layer or the back side of the PCB through via. The ground path routing of the above-mentioned large current path should also be taken seriously. For example, the path from the negative terminal of the capacitor(470uF) to the negative terminal of the power supply and GND should be thick and short enough. Don't cut the path of the control line and cause the path to be long and thin.

- The bonded copper area in contact with the chip package heat sink determines the heat dissipation performance. The heat sink of the chip should be soldered to the heat sink solder mask. The solder masks on the front and back sides are connected by via (can be 0.3mm apart) and should be connected to a large bonded copper area. Use a solid via for the bonded copper area for heat dissipation and use a full piece of bonded copper instead of a mesh type.

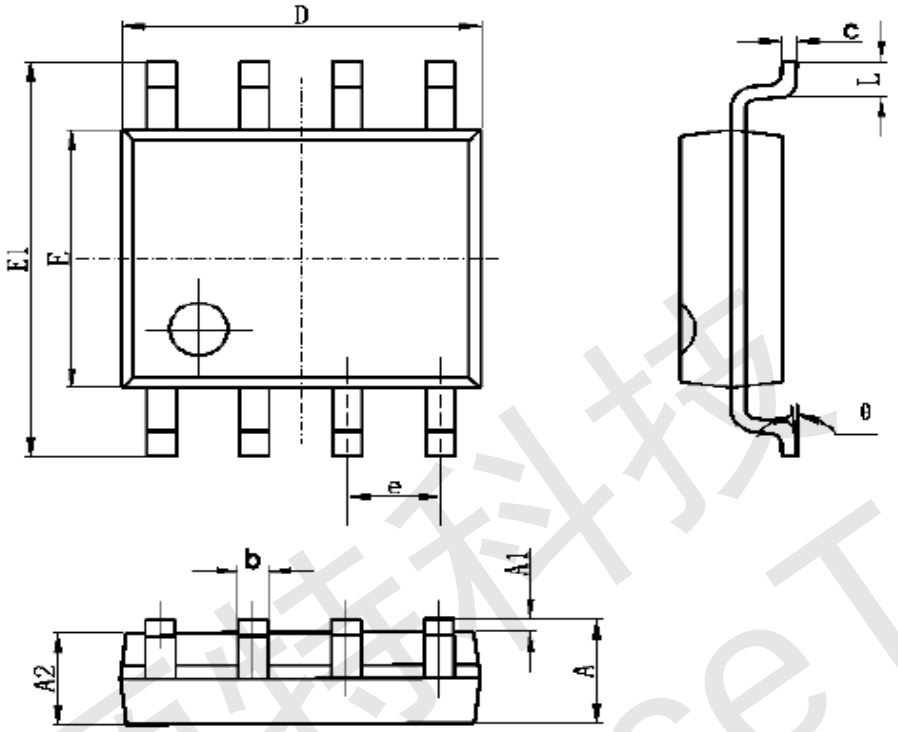
- The output line of the chip output pin to the speaker is as thick and short as possible, and the line width should not be less than 0.5mm.

- The input resistance and capacitance of SC2307A should be placed as close as possible to the IN1 and IN2 pins of the chip. The layout of the two inputs should be as consistent as possible, and should not be close to the power wiring. This can better suppress noise and interference.

- The filter capacitor of the power supply and ground should be as close as possible to the pin of the chip. Remember that the capacitor cannot be placed on the back of the board and connected through a tiny through-hole jumper.

- Sensitive signal lines should be shielded. It is best to use differential signals. Try not to have interference lines passing through sensitive signal lines.

Package Outline(ESOP8)



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.006	0.010
D	4.700	5.100	0.185	0.200
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
e	1.270(BSC)		0.050(BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°