6W高保真超低EMI防削顶单声道D类音频功率放大器

6W Ultra Low-EMI Anti-Clipping Mono Class D Audio Power Amplifier

■ FEATURES

・ Patented technology (EDMA) to reduce the internal Rdson and heat loss, increase the output power
Po=3.5 W (VDD=5.0V, RL=4Ω, THD+N=10%)
Po=3.0 W (VDD=3.7V, RL=2Ω, THD+N=10%)
Po=6.0 W (VDD=5.0V, RL=2Ω+33uH, THD+N=10%)

・ Excellent EMI Suppression Performance
a) Using Patented technology (AROC, Active edge Ringing and Overshoot Control circuitry)
b) The emission level is highly lower than FCC Part15 Class B standard;
c) Without interference to FM radio, CMMB, GSM, CDMA, Bluetooth and any other sensitive modules with different bands;
d) The difficulty of system design is reduced

・ THD+N=0.1% (RL=4Ω, PO=1W, f=1kHz)

・ Low noise, High SNR

・ Anti-Clipping Function (ACF)

・ Excellent Click-Pop Noise reduction function

・ Low Shutdown Current, 0.1μA

・ Filter-less Modulation, Eliminating Output Filter

・ Over Current Protection, Thermal Protection, Low voltage malfunction prevention function included

・ Pb-Free Packages, SOP8L, SOP8L-PP

・ 降低内阻和热耗的EDMA专利技术，极大提升了输出功率和产品可靠性

Po=3.5 W (V_{DD}=5.0V, R_L=4Ω, THD+N=10%)
Po=3.0 W (V_{DD}=3.7V, R_L=2Ω, THD+N=10%)
Po=6.0 W (VDD=5.0V, RL=2Ω+33uH, THD+N=10%)

・ 优异的全带宽EMI抑制性能

a) 独创的主动边沿控制专利（AROC, Active edge Ringing and Overshoot Control circuitry）
b) 辐射水平远在FCC Part15 Class B 标准之下；
c) 对系统中不同频段无线通信敏感模块无干扰，如FM、CMMB、GSM、CDMA和Bluetooth等；
d) 减小了辐射和传导干扰，降低了系统设计难度

・ 高保真，THD+N=0.1% (R_L=4Ω, P_O=1W, f=1kHz)

・ 全低噪应用，高信噪比

・ 防削顶失真功能(Anti-Clipping Function, ACF)

・ 卓越的“咔嗒-噼噗”(Click-Pop)噪声抑制性能

・ 低关断电流：0.1μA

・ 免滤波器数字调制，直接驱动扬声器

・过流、过热、欠压异常保护功能

・无铅无卤绿色封装，SOP8L，SOP8L-PP

■ APPLICATIONS

・ Bluetooth/Wi-Fi Speakers ・ Portable Speakers
・ Smart speakers ・Smart Home
・ Sound Bars, Docking stations, PC Audio

・ 蓝牙音箱/Wi-Fi音箱 ・ 便携式/USB音箱
・ 智能音箱 ・ 智能家居
・ ipad/iphone/ipod docking ・ 声霸

■ DESCRIPTION

HT6873 is a low-EMI, Anti-Clipping, filter-less, monaural Class D audio power amplifier IC with maximum output power of 3.5W. It has a high efficiency in a variety of audio terminal applications with Class AB amplifier performance.

HT6873 has excellent EMI radiation suppression characteristics. The radiation level is well below FCC Part15 Class B standards without any additive design. It keeps from interference with other EMI sensitive circuits, simplifies system design and lowers system cost.

HT6873 features Anti-Clipping Function (ACF) which detects and suppresses output signal clippings due to the over level inputs of music or voice signals. The ACF function also can adapt the output clippings caused by power supply voltage down in battery applications. It improves acoustical quality considerably, gives great listening enjoyment, and prevents speaker from overload damaging. According to different audio sources, two modes, ACF-1 and ACF-2, could be selected to achieve a best audio performance.

HT6873 has a filter-less modulation circuit which directly drives speakers while realizes low distortion and low noise characteristics. Thanks to filter-less, circuit design with fewer external parts can be made in portable applications.

HT6873 has shutdown mode, over-current protection, over-temperature protection and low supply voltage malfunction preventing function.

HT6873是一款高保真超低EMI的，具有防削顶失真功能的单声道免滤波D类音频功率放大器。在5V电源，10% THD+N，4Ω负载条件下，输出3.5W高功率，在各类音频终端应用中维持高效率并提供AB类放大器高保真、低噪声的性能。

AROC辐射和传导干扰抑制电路使HT6873具有优异的全带宽低辐射性能，在不加辅助滤波设计、输出喇叭线长20cm时的辐射水平远在FCC Part15 Class B 标准之下。

HT6873的防削顶失真功能可检测并抑制由于音乐、语音信号幅度过大或电池电压下降所引起的输出削顶失真（破音），显著提高音质，创造舒适的听音享受，并保护扬声器免受过载损坏。针对不同需求，防削顶具有ACF-1和ACF-2两种模式，分别对应约3%和10%最大THD+N，同时芯片具有ACF-Off 模式。

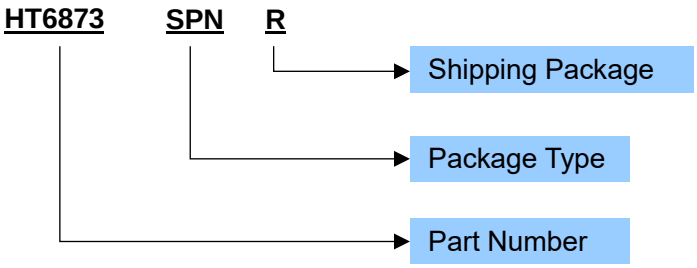
HT6873输出无需滤波网络，极少的外部元器件节省了系统空间和成本，是便携式应用的理想选择。

此外，HT6873内置的关断功能使待机电流最小化，还集成了过流保护、过温保护和欠压异常保护等功能

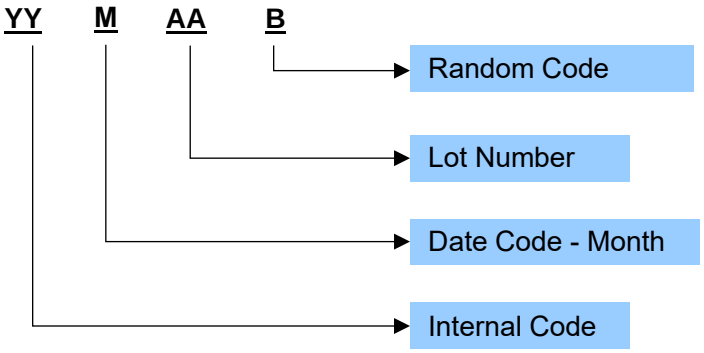
■ ORDERING INFORMATION

Ordering Number	Package Type	Marking	Operating Temperature Range	Shipping Package / MOQ
HT6873SPNT	SOP8L	HT6873 YYMAAB	-40℃～85℃	Tube 100PCS
HT6873SPNR	SOP8L		-40℃～85℃	Tape and Reel 2500PCS
HT6873SPET	SOP8L-PP		-40℃～85℃	Tube 100PCS
HT6873SPER	SOP8L-PP		-40℃～85℃	Tape and Reel 2500PCS

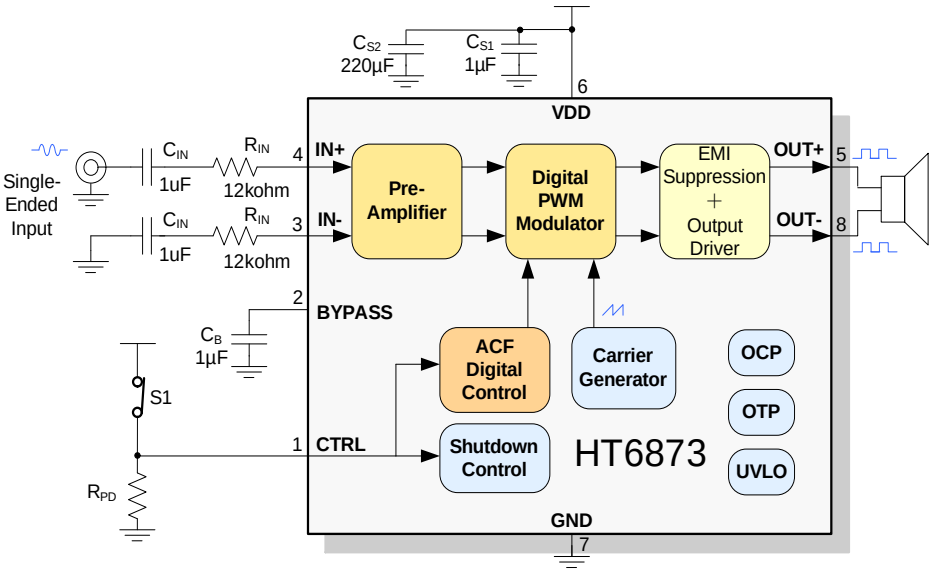
Ordering Number



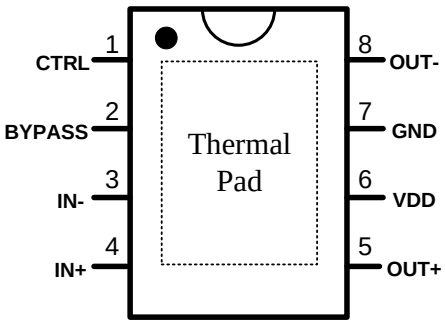
Production Tracking Code



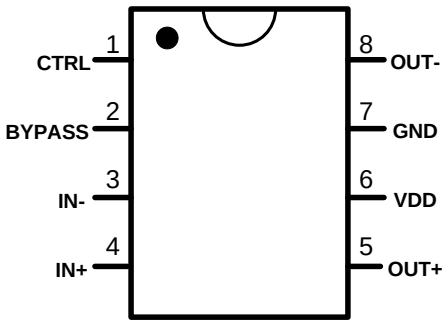
■ TYPICAL APPLICATION



■ TERMINAL CONFIGURATION



Top View
SPE (SOP8L-PP) Top View



Top View
SPN (SOP8L) Top View

■ TERMINAL FUNCTION

Terminal No.	Name	I/O[1]	Description
1	CTRL	I	Shutdown and ACF control terminal. ACF模式和关断模式控制端
2	BYPASS	O	Analog reference terminal. 模拟参考电压
3	IN-	I	Negative input terminal (differential -). 反相输入端（差分-）
4	IN+	I	Positive input terminal (differential +). 同相输入端（差分+）
5	OUT+	O	Positive output terminal (differential +). 同相输出端（BTL+）
6	VDD	P	Power supply. 电源
7	GND	G	GND. 地
8	OUT-	O	Negative output terminal (differential -). 反相输出端（BTL-）
/	Thermal Pad	/	Only available for package of SOP8L-PP. Provides thermal connection from the device to the board. A matching ground pad should be provided on the PCB and the device connected to it via solder. 仅SOP8L-PP封装可用。提供器件向板级散热的路径。PCB板上需要留有足够的铺地露铜与之良好焊接。

[1] I: Input; O: Output; G: Ground; P: Power

■ SPECIFICATIONS[1]

● Absolute Maximum Ratings[2]

Item	Symbol	Min.	Max.	Unit
Power supply terminal voltage range	V_{DD}	-0.3	6.5	V
Input terminal voltage range (IN+, IN-, BYPASS, CTRL)	V_{IN}	V_{SS}−0.3	V_{DD}+0.3	V
Operating Ambient Temperature	T_A	-40	85	℃
Junction Temperature	T_J	-40	150	℃
Storage Temperature	T_{STG}	-50	165	℃

● Power Dissipation Ratings

Package	θ_{JA}	Derating Factor[3]	T_A≤25℃	T_A=70℃	T_A=85℃
SOP8L	139 ℃/W	7.2 mW/℃	899 mW	576 mW	468 mW
SOP8L-PP	52 ℃/W	19.2 mW/℃	2404mW	1538 mW	1250 mW

● Recommended Operating Condition

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Power Supply Voltage	V_{DD}		2.5	5	6	V
Operating Ambient Temperature	T_a		-30	25	85	℃
Load Impedance	R_L		2[4]	4		Ω

● DC Characteristics

V_{SS}=0V, V_{DD}=2.5V~5.5V, Ta= -40ºC~85ºC, unless otherwise specified.

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
VDD power supply start-up threshold voltage	V_{UVLH}				2.2	V
VDD power supply shut-down threshold voltage	V_{UVLL}				2.0	V
ACF-Off mode threshold voltage for terminal CTRL	V_{MOD1}		2.00		VDD	V
ACF-1 mode threshold voltage for terminal CTRL	V_{MOD2}		1.55		1.85	V
ACF-2 mode threshold voltage for terminal CTRL	V_{MOD3}		1.10		1.40	V
SD mode threshold voltage for terminal CTRL	V_{MOD4}		VSS		0.30	V
Quiescent current	I_{DD}	V_{DD}=5V, no load, no signal input		8	20[5]	mA
Consumption current in Shutdown mode (AVDD+PVDD)	I_{SD}	CTRL=V_{SS}, Ta=25℃		0.1		μA
Voltage of Terminal BYPASS	V_{BYPASS}			VDD/2		V

[1] Depending on parts and PCB layout, characteristics may be changed.
[2] 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
[3] Derating factor measured with JEDEC Low-K board. All of the above assume no ambient airflow.
[4] SOP8L-PP package only. All characteristics under condition of 2ohm load is specified as HT6873SPE (SOP8L-PP).
[5] The quiescent current could be increased when the temperature of environment or IC getting high.

Analog Characteristics

V_{SS}=0V, V_{DD} =5V, Ta=25ºC, C_{IN}=1uF, R_{IN}=12 kΩ, R_L = 4Ω, ACF-Off mode, unless otherwise specified.

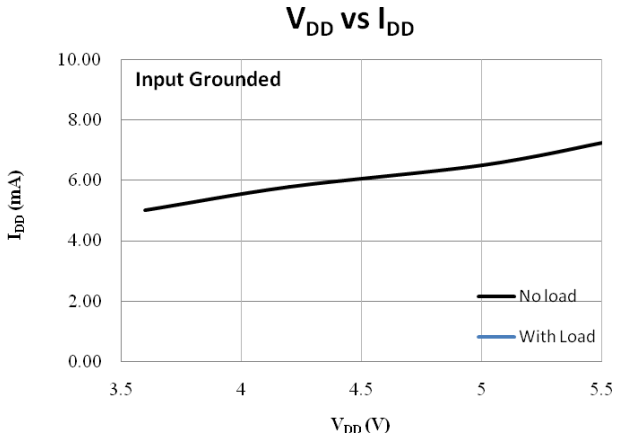
Item	Symbol	Conditions		Min.	Typ.	Max.	Unit
Output Power	P_O	R_L=4Ω, V_{DD}=5V	f=1kHz, THD+N=10%		3.5		W
		R_L=2Ω+33uH, V_{DD}=5V			6.0		
		R_L=4Ω, V_{DD}=3.7V			1.9		
		R_L=2Ω+33uH, V_{DD}=3.7V			3.0		
Total Harmonic Distortion Plus Noise (BW：20kHz)	THD+N	R_L=4Ω, P_O=1W, f=1kHz			0.1		%
Output Noise	V_N	f=20Hz~20kHz, A-Filter, Av=18dB			60		μV_{rms}
Signal /Noise Ratio (BW：20kHz A-Filter)	SNR	A-Filter, Av=18dB			95		dB
Power supply rejection ratio	PSRR	Ripple Wave Vpp=200mV, f=1kHz			-75		dB
Efficiency	η	VDD=5V, RL=8Ω, PO=1W			86		%
Output offset voltage	V_{OS}				±5	±10	mV
Frequency characteristics	f_{RES}	C_{IN} =0.1μF, f=100Hz~20kHz		-3	-	1	dB
Voltage Gain	Av_0	R_{IN}=12 kΩ			25.5		dB
ACF maximum attenuation gain	Aa			-10		0	

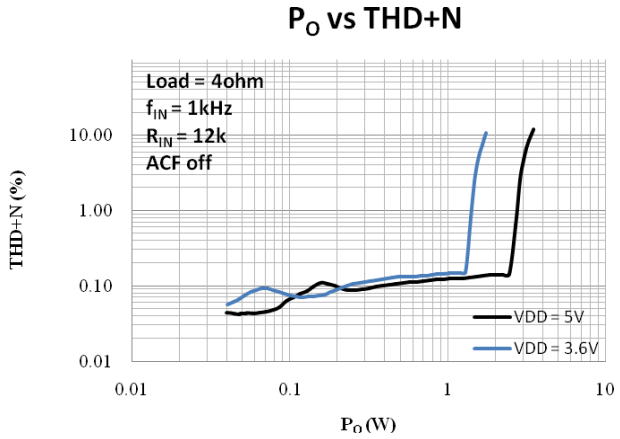
AC Characteristics

V_{SS}=0V, V_{DD} =2.5 to 5.5V, Ta=－30℃~85℃, unless otherwise specified.

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Start-up time	t_{STUP}			240		ms
ACF-1 Attack time	t_{AT1}	V_{DD}=3.6V, g=10dB		72		ms
ACF-1 Release time	t_{RL1}	V_{DD}=3.6V, g=10dB		720		ms
ACF-2 Attack time	t_{AT2}	V_{DD}=3.6V, g=10dB		20		ms
ACF-2 Release time	t_{RL2}	V_{DD}=3.6V, g=10dB		450		ms
Wake-up mode setting time	t_{WK}		35			ms
Shutdown setting time	t_{SD}	T_a(Min.)= -20℃	50			ms
		T_a(Min.)= -30℃	80			
Each mode setting time (Except shutdown)	t_{MOD}		0.1			ms
Carrier clock frequency	f_{PWM}			470		kHz

■ TYPICAL OPERATING CHARACTERISTICS





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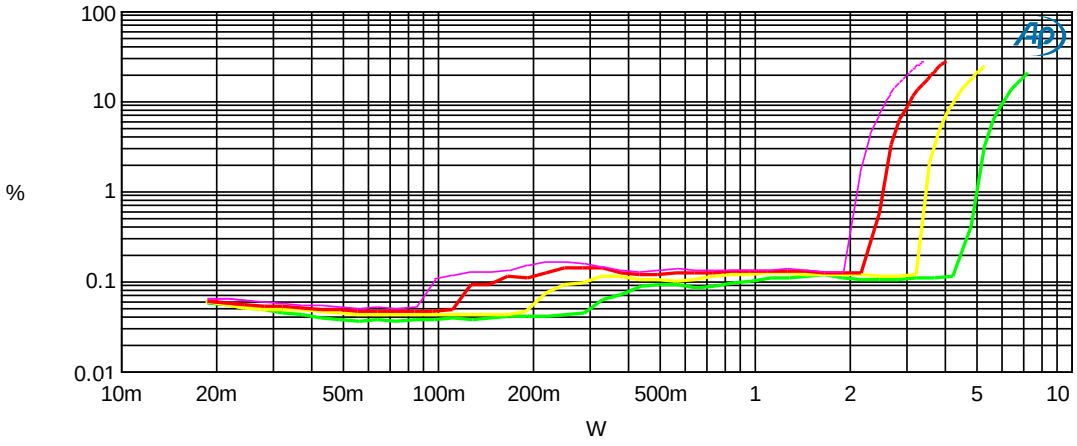

Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	1	Analyzer.THD+N Ratio A	Left	5V, 2ohm+33uH,1kHz
2	1	Yellow	Solid	1	Analyzer.THD+N Ratio A	Left	4.2V, 2ohm+33uH, 1kHz
3	1	Red	Solid	1	Analyzer.THD+N Ratio A	Left	3.6V, 2ohm+33uH, 1kHz
4	1	Magenta	Solid	1	Analyzer.THD+N Ratio A	Left	3.3V, 2ohm+33uH, 1kHz

Po vs THD+N.ats2

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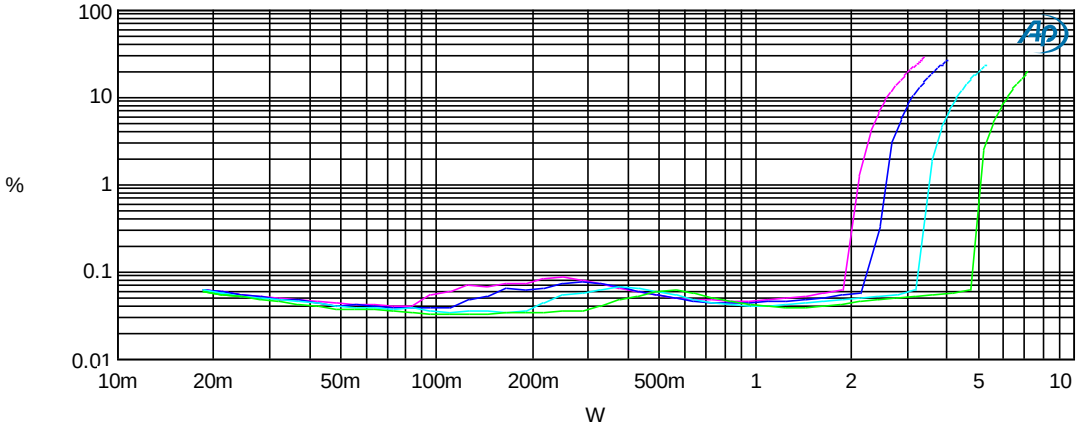
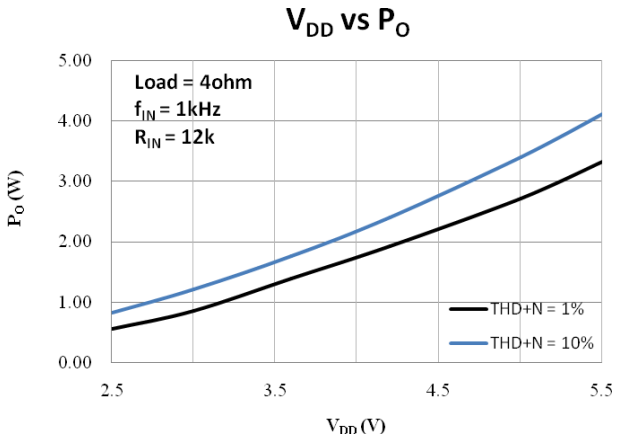
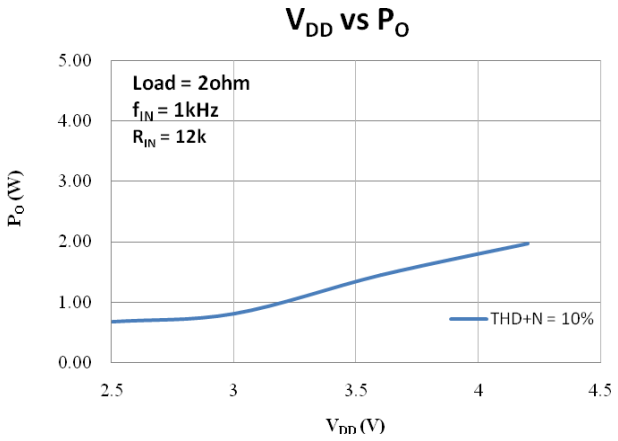
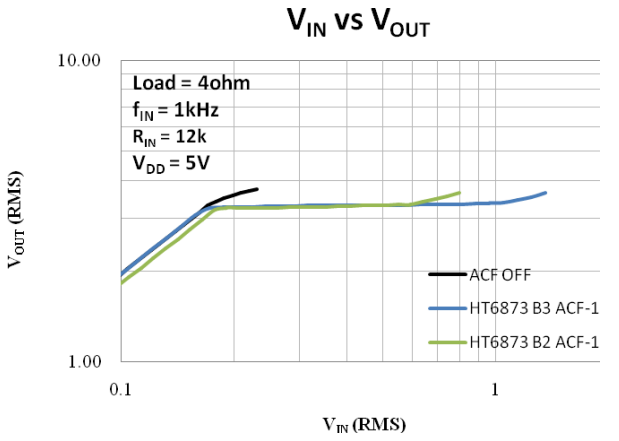


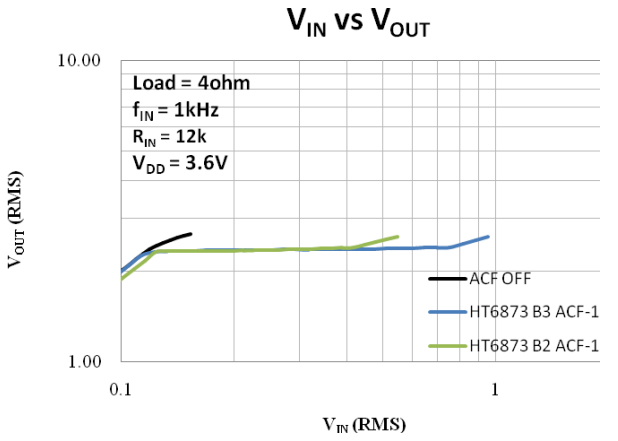
Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Magenta	Solid	1	Analyzer.THD+N Ratio A	Left	3.3V, 2ohm+33uH, 100Hz
2	1	Blue	Solid	1	Analyzer.THD+N Ratio A	Left	3.6V, 2ohm+33uH, 100Hz
3	1	Cyan	Solid	1	Analyzer.THD+N Ratio A	Left	4.2V, 2ohm+33uH, 100Hz
4	1	Green	Solid	1	Analyzer.THD+N Ratio A	Left	5V, 2ohm+33uH, 100Hz

Po vs THD+N.ats2

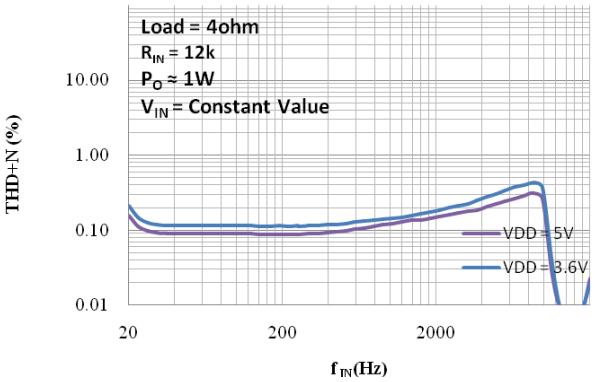




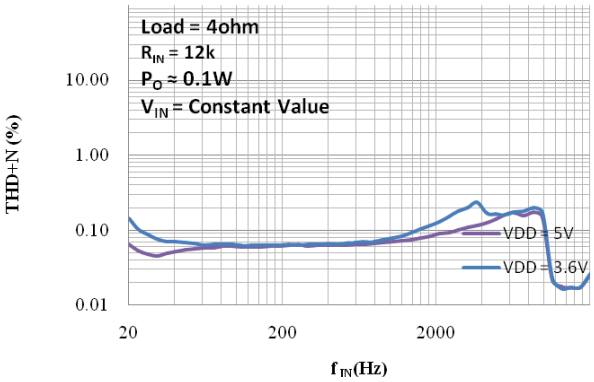




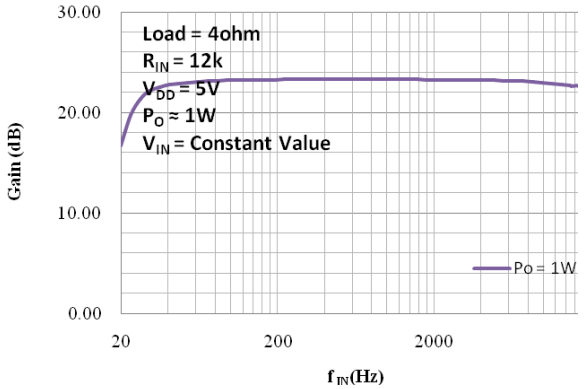
f_{IN} vs THD+N



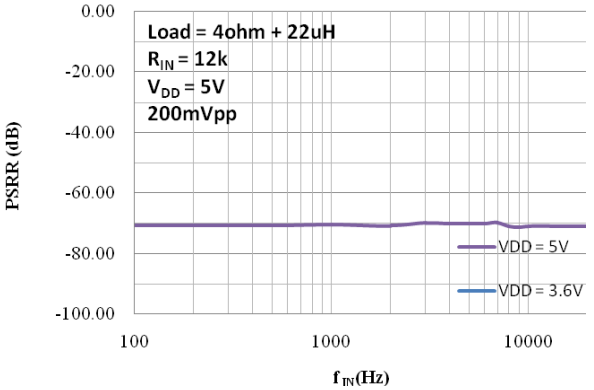
f_{IN} vs THD+N



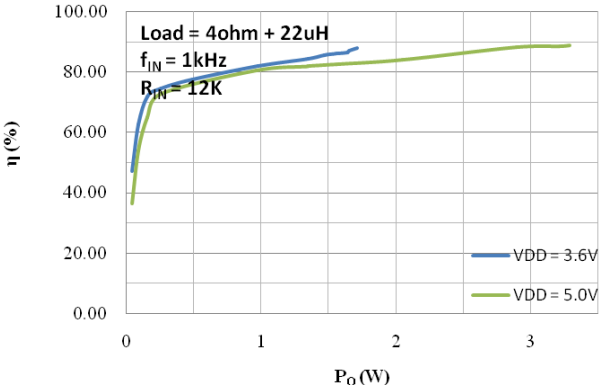
f_{IN} vs Gain



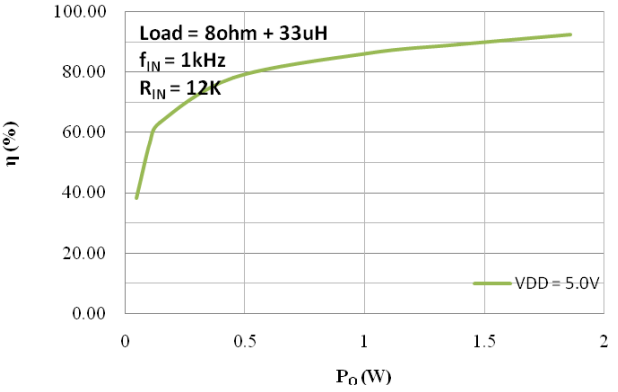
f_{IN} vs PSRR



P_O vs η



P_O vs η



■ APPLICATION INFORMATION

1. *Analog Signal Input Configuration*

HT6873 is a Class D power amplifier with analog input (single-ended or differential), PWM pulse output.

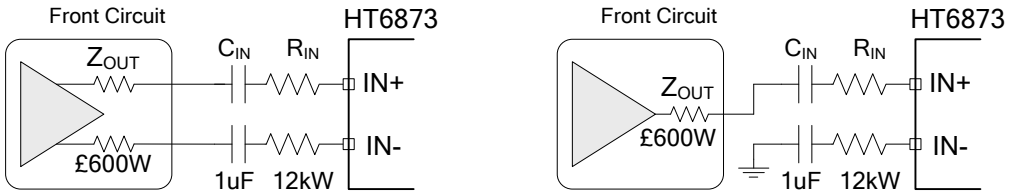
For a differential input between IN+ and IN- pins, signals input via C_{IN} and R_{IN}, the system gain is calculated by A_V=220k/R_{IN}, and the low pass cut-off frequency of input signal will be $f_c = 1/(2\pi R_{IN} C_{IN})$.

For a single-ended input at IN+ pin, signal input via C_{IN} and R_{IN}. IN- pin should be connected to GND via C_{IN} and R_{IN} with the same value. The system gain and low pass cut-off frequency are the same as the above case.

HT6873 是一款 D 类音频功率放大器，接受模拟差分或单端音频信号输入，产生 PWM 脉冲输出信号驱动扬声器。

对差分输入，通过隔直电容 C_{IN} 和输入电阻 R_{IN} 分别输入到 IN+和 IN-端。系统增益 A_V=220k/R_{IN}，输入 RC 高通滤波器的截止频率 $f_c = 1/(2\pi R_{IN} C_{IN})$。

对单端输入，则通过 C_{IN} 和输入电阻 R_{IN} 耦合到 IN+端。IN-端必须通过输入电阻和电容（与 C_{IN}、R_{IN} 值相同）接地。增益 Av 和截止频率 f_c 与差分输入时相同。



Differential Input　　Single-ended Input

Figure 1 Input Configuration

2. *EMI Suppression Performance*

HT6873 has excellent EMI suppression performance, using patented technology (AROC, Active edge Ringing and Overshoot Control circuitry). The emission level is highly lower than FCC Part15 Class B standard (margin more than 20dB) that HT6873 can hardly interference to FM radio, CMMB, GSM, CDMA, Bluetooth and any other sensitive modules with different bands. The EMI test result can be seen as follows.

HT6873 具有良好的低辐射骚扰特性，采用独创的主动边沿控制专利技术，使辐射水平远在 FCC Part15 Class B 标准之下（最小仍有 20dB 的裕量），对系统中不同频段无线通信敏感模块无干扰，如 FM、CMMB、GSM、CDMA 和 Bluetooth 等。EMI 测试结果如下图。

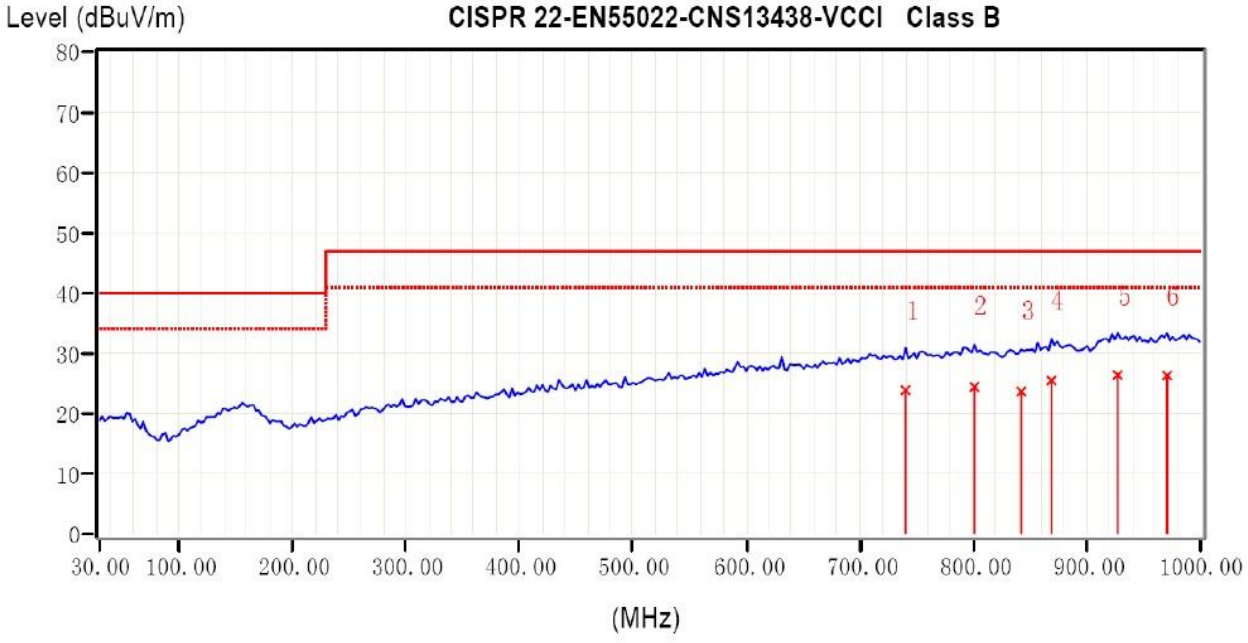


Figure 2 HT6873 RF Emission Graph in Vertical Direction

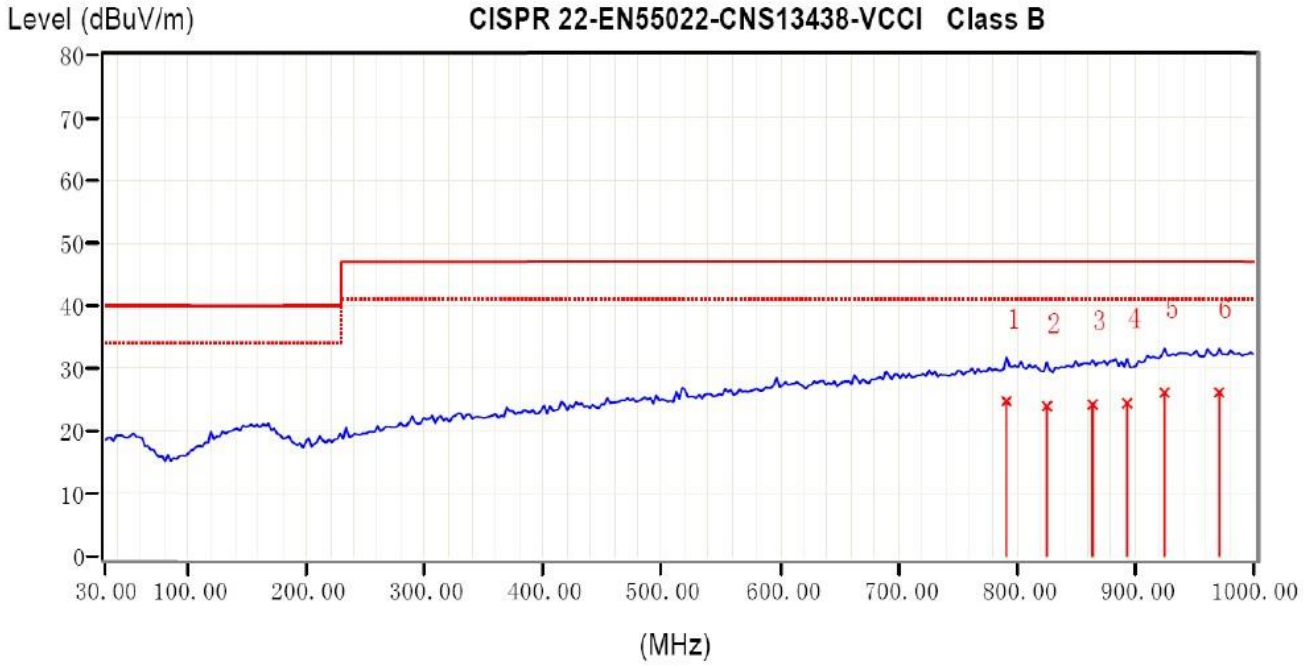


Figure 3 HT6873 RF Emission Graph in Horizontal Direction

3. *Output Terminal Configuration*

Generally, a speaker can be directly line to the output terminal of the amplifier as load. But if the EMI of the system is highly considered, a ferrite bead filter or LC filter is recommended..

一般而言，输出端可直接连接负载喇叭。如果输出端的输出线较长，或者对 EMI 的要求较高，则可选择添置铁氧体磁珠或 LC 滤波器。

4. *CTRL Terminal Mode Control*

Four operating mode, ACF-1, ACF-2, ACF-Off and SD (shutdown), could be implemented while different Setting Voltages input via CTRL terminal (see Table 1).

在 CTRL 端输入不同电压值，能实现 4 种工作模式，即防削顶模式 1（ACF-1），防削顶模式 2（ACF-2），防削顶功能关闭模式（ACF-Off）和芯片关断模式（SD），详见下表。

Table. 1 Different Mode Setting Voltages of CTRL Terminal

Item	Symbol	Min.	Typ.	Max.	Unit
ACF-Off mode setting threshold	V_{MOD1}	2.00	VDD	V_{DD}	V
ACF-1 mode setting threshold	V_{MOD2}	1.55	1.70	1.85	V
ACF-2 mode setting threshold	V_{MOD3}	1.10	1.25	1.40	V
Shutdown mode setting threshold	V_{MOD4}	V_{SS}	0	0.30	V

Notes: an internal 200kΩ(±10%) resistor is connected between CTRL and GND in HT6873.

需要注意的是，由于 CTRL 端内部设置了 200kΩ(±10%)的下拉电阻，在设置外部电阻参数时需要将此考虑进去。

5. *CTRL Mode Function Detail*

5.1. *ACF ON Mode*

In ACF-1 and ACF-2 modes, HT6873 attenuates system gain to an appropriate value when an excessive input is applied, so as not to cause the clipping at the differential signal output. In this way, the output audio signal is controlled in order to obtain a maximum output level without distortion. And HT6873 also follows to the clips of the output waveform due to the decrease in the power-supply voltage.

在 ACF-1、ACF-2 模式下，当电路检测到输入信号幅度过大而产生输出削顶时，HT6873 通过自动调整系统增益，控制输出达到一种最大限度的无削顶失真功率水平，由此大大改善了音质效果。此外，当电源电压下降时，HT6873 也能自动衰减输出增益，实现与 VDD 下降值相匹配的最大限度无削顶输出水平。

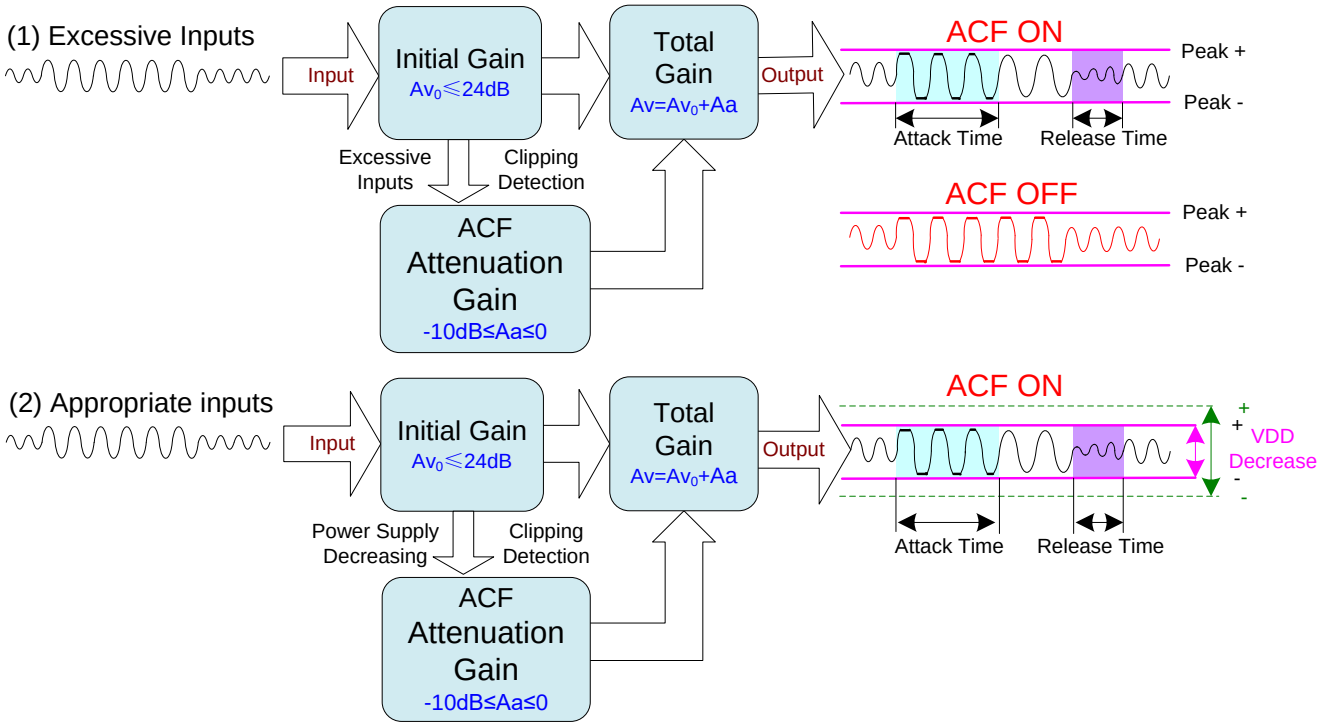


Figure 4 the ACF Function Operation Outline

The Attack time of ACF Function is a time interval until system gain falls to target attenuation gain -3dB when a big enough signal inputs. And, the Release Time is a time from target attenuation gain to not working of ACF.

For different modes of ACF ON, the attack time and release time are different, see as the following table.

ACF ON 模式下的启动时间（Attack time）指在突然输入足够大信号而产生输出削顶的条件下，从 ACF 启动对放大器的增益调整，直到增益从 Av0 衰减至距目标衰减增益 3dB 时的时间间隔；释放时间（Release time）指从产生削顶的输入条件消失，到增益退出衰减状态恢复到 Av0 的时间间隔。

ACF-1 和 ACF-2 模式具有不同的启动时间和释放时间（见下表）。

Table. 2 Attack Time and Release Time

ACF mode	Attack time	Release time
ACF-1 (Recommendation)	50ms	64ms
ACF-2	56ms	38ms

5.2. *ACF OFF Mode*

In ACF-Off mode, ACF function is disenabled. HT6873 will not detect output clipping and the system gain is kept to be Av=Av0=24dB. The audio quality would worsen due to clipping distortion.

在 ACF-Off 模式下，ACF 功能被关闭，HT6873 不对输出削顶条件作检测，也不对系统增益作自动调整操作，系统增益保持为 Av=Av0 恒定不变。HT6873 可能因输出存在破音失真而音质变坏。

5.3. *Shutdown (SD) Mode*

In shutdown mode, HT6873 shuts all circuit down and minimizes the power consumption. And, the output terminals become Weak Low (A high resistance grounded state).

在关断模式（低功耗待机）下，芯片关闭所有功能并将功耗降低到最小，输出端为弱低电平状态（内部通过高阻接地）。

6. *Pop-Click Noise Reduction*

The Pop-Click Noise Reduction Function of HT6873 works in the cases of Power-on, Power-off, Shutdown on, and Shutdown off. To achieve a more excellent noise reduction performance, it is recommended to use a DC-cut capacitor (C_{IN}) of 0.1μF or less.

Besides, POP noise can be minimal according to the following procedure of shutdown control.

・During power-on, Shutdown mode is cancelled until the power supply is stabilized enough.

・Before Power-off, set Shutdown mode first..

HT6873 内置控制电路实现了全面的杂音抑制效果，有效地抑制住了系统在上电、下电、关断及其唤醒操作过程中出现的瞬态咔嗒-噼噗（Click-Pop）噪声。

为达到更优异的咔嗒-噼噗声消除效果，一般情况下，建议采用 0.1μF 或更小的隔直电容 C_{IN}。同时 POP 噪声还可通过下列上电、下电时关断模式的时序控制措施来达到杂声微乎其微的效果：

・电源上电时，保持关断模式，等电源足够稳定后再解除关断模式。

・电源下电时，提前设为关断模式。

7. *Protection Function*

HT6873 has the protection functions such as Over-current Protection function, Thermal Protection function, and Low voltage Malfunction Prevention function.

(1) Over-current Protection function

When a short circuit occurs between one output terminal and VSS, VDD, or the other output, the over-current protection mode starts up. In the over current protection mode, the differential output terminal becomes a high impedance state. The over current protection mode can be cancelled by shutdown and startup, or turning on the power again.

(2)Thermal Protection function

When excessive high temperature of HT6873 is detected, the thermal protection mode starts up. In the thermal protection mode, the differential output terminal becomes Weak Low state (a state grounded through high impedance).。

(3)Low voltage Malfunction Prevention function

This is the function to establish the low voltage protection mode when VDD terminal voltage becomes lower than the detection voltage (V_{UVLL}) for the low voltage malfunction prevention. And the protection mode is canceled when VDD terminal voltage becomes higher than the threshold voltage (V_{UVLH}). In the low voltage protection mode, the differential output pin becomes Weak Low state (a state grounded through high impedance). HT6873 will start up within the start-up time (T_{STUP}) when the low voltage protection mode is cancelled

HT6873 具有以下几种保护功能：输出端过流保护、片内过温保护、电源欠压异常保护。

（1）过流保护

当检测到一输出端对电源、对地、或对另一输出端短路时，过流保护启动，输出端切换至高阻态，防止芯片烧毁损坏。短路情况消除后，通过关断、唤醒一次芯片，或重新上电均能使芯片退出保护模式。

（2）过温保护

当检测到芯片内温度超过 150℃时，过温保护启动，正负输出端切换至弱低电平状态（内部通过高阻接地），防止芯片被热击穿损坏。

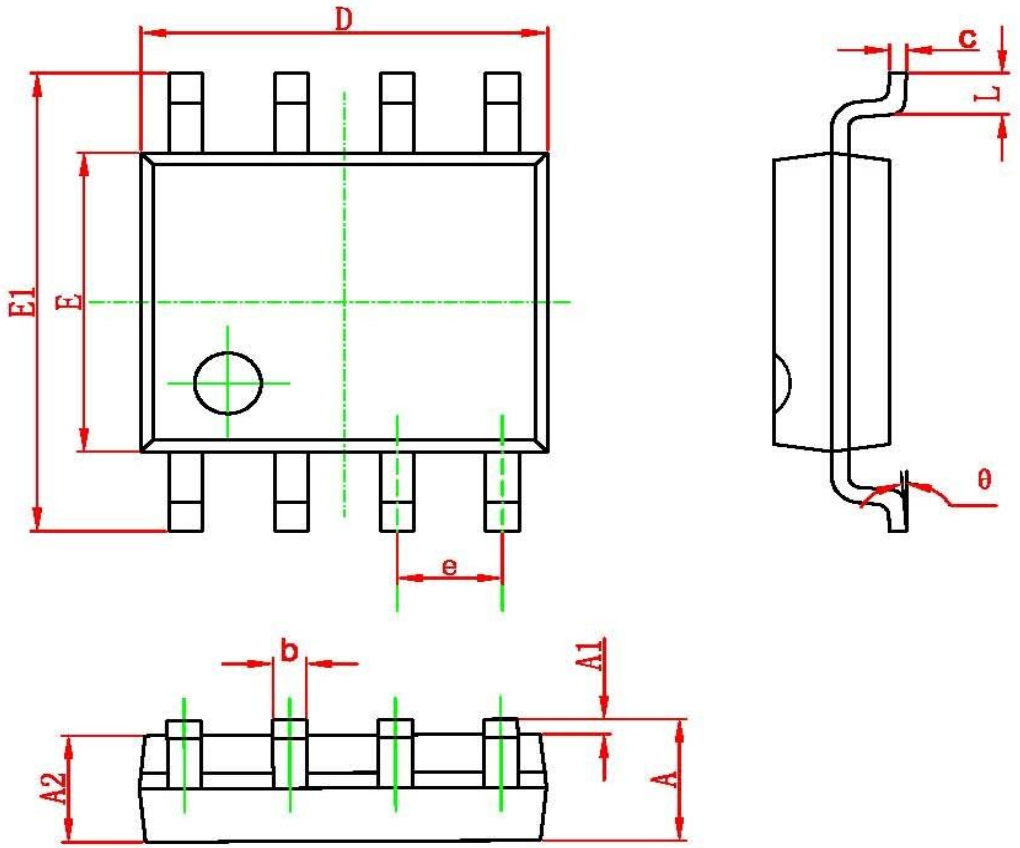
（3）欠压保护

当检测到电源端 VDD 低于 V_{UVLL}（2V），启动欠压保护，输出端为弱低电平状态（内部通过高阻接地）；当检测到 VDD 高于 V_{UVLH}（2.2V），保护模式自动解除，经启动时间 T_{STUP} 后进入正常工作状态。

■ PACKAGE OUTLINE

SPN (SOP8L)

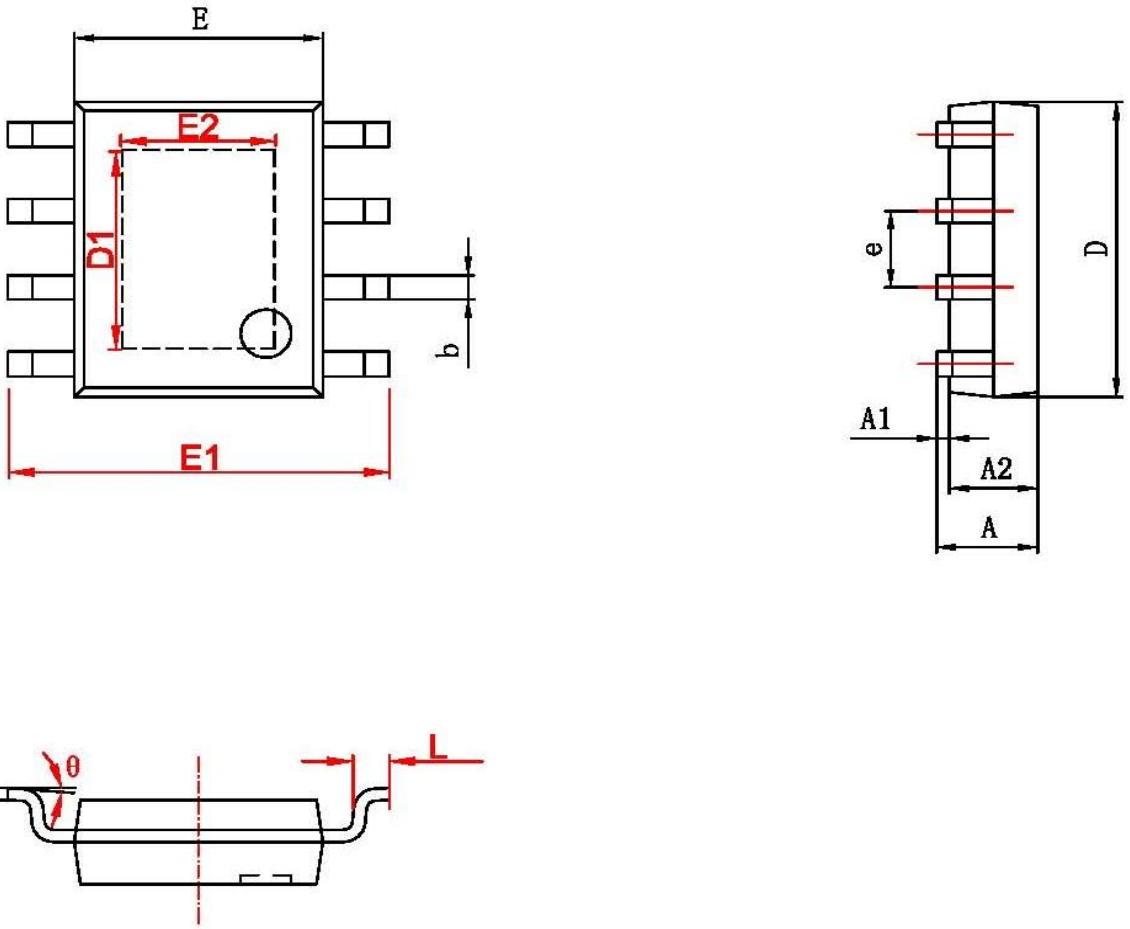
SOP8 PACKAGE OUTLINE DIMENSIONS



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°

SPE (SOP8L-PP)

SOP8-PP(EXP PAD) PACKAGE OUTLINE DIMENSIONS



字符	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.050	0.150	0.002	0.006
A2	1.350	1.550	0.053	0.061
b	0.330	0.510	0.013	0.020
c	0.170	0.250	0.007	0.010
D	4.700	5.100	0.185	0.200
D1	3.202	3.402	0.126	0.134
E	3.800	4.000	0.150	0.157
E1	5.800	6.200	0.228	0.244
E2	2.313	2.513	0.091	0.099
e	1.270 (BSC)		0.050 (BSC)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

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