

可任意限幅、内置H类升压的2×8.5W立体声音频功放

■ 特点

- 可任意配置的限幅功能
 - 自由配置音频限制幅度，使输出音频信号限制在固定失真水平内
- 内置自动限温控制功能
 - 适应不同散热条件，避免出现过温关断现象
- 高效自适应升压功能
 - 自适应功放功率的H类升压轨(HT878)，和自适应G类升压(HT878T)，延长播放时间
 - 可调节最大限流值，有效防止电池拉死
 - 最大升压值可调(HT878为3档固定值；HT878T则外部任意设定)
- 支持AB类与D类切换
- THD+N: 0.04% ($R_L=4\Omega$, $f_{IN}=1\text{kHz}$, $P_o=2\times 1.0\text{W}$)
- 低静态电流：7mA, 3.7V
- 输出功率($V_{BAT}=4.2\text{V}$, $f_{IN}=1\text{kHz}$, THD+N= 1%, $R_L=4\Omega$)
 - 2×5.5W (HT878, BST=L, 连续功率)
 - 2×6W (HT878, BST=NC, 连续功率)
 - 2×6.5W (HT878, BST=H, 瞬态功率)
 - 2×7W (HT878T, $V_{POUT}=8.5\text{V}$, 连续输出)
 - 2×8.5W (HT878T, $V_{POUT}=8.5\text{V}$, THD+N = 10%, 瞬态输出)
- V_{BAT} 供电范围：2.8V至5.5V
- 三种增益选择：21dB, 25.5dB, 30dB
- 免滤波器数字调制，直接驱动扬声器
- 保护功能：过流/过热/欠压异常保护功能
- 无铅无卤封装，TSSOP24L-PP

■ 概述

HT878是一款内置自适应升压的立体声D类音频功率放大器，由锂电池供电升压至 $V_{POUT}=8\text{V}$ 时，THD+N=1%、1kHz信号条件下，能连续输出2×6W功率（4Ω负载）；HT878T升压至 $V_{POUT}=8.5\text{V}$ 时，THD+N=1%、1kHz信号条件下，能连续输出2×7W功率（4Ω负载）；另外，其还支持AB类模式。

HT878内置H类升压，可提供7.5V, 8V, 8.5V三种最大输出电压选择；HT878T内置G类升压，可任意设置最大升压值，以满足不同的输出功率需求。该升压在小音乐信号时不升压，仅当功率较大时工作，而HT878更是能提供一个适应输出功率的电压给D类功放。其可大幅提高系统效率，延长电池续航时间。

HT878具有可任意配置的限幅(Limiter)功能。限幅功能开启后，即使输入信号很大，音乐输出也能被限制在指定的功率和THD+N之内，满足不同音质体验和保护喇叭的需求。

HT878还具有自动限温控制(TFB)功能，在高功率输出、高环境温度、AB类模式低效率等情况下导致芯片片内温度较高时，芯片能自动降低系统增益，避免芯片进入过温关断保护模式，在保证音乐品质的前提下显著提升音乐峰值功率。

此外，HT878内部集成免滤波器调制技术，能够直接驱动扬声器，内置的关断功能使待机电流最小化，还集成了输出端过流保护、片内过温保护和电源欠压异常保护等功能。

芯片料号	升压方式	最大升压值
HT878MTE _x	自适应H类升压轨	固定三档
HT878TMTE _x	自适应G类升压	外部任意设定

■ APPLICATIONS

- 智能音响
- 无线音响
- 便携式音箱
- 2.1声道小音箱
- 拉杆音箱
- 便携式游戏机

2x8.5W Audio Amplifier with Class H Boost Converter and Limiter

■ FEATURES

- Flexible Limiter Function adjusted by external resistor so that the output music is limited under a preset THD+N and power
- Integrated Thermal Foldback (TFB) Function that significantly increases the peak audio power
- High Efficiency Boost Converter
 - Class H for HT878 and Class G for HT878T, extends the playing time in battery supply applications
 - Adjustable switch peak current limit to avoid over-pulling on battery current
 - Adjustable max boost voltage (fixed 3 voltages for HT878, and arbitrary voltages for HT878T)
- Both Class D and Class AB is available
- THD+N: 0.04%($R_L=4\Omega$, $f_{IN}=1\text{kHz}$, $P_O=2\times 1.0W$)
- Low Quiescent Current:7mA, 3.7V
- Output Power ($V_{BAT}=4.2V$, $f_{IN} = 1\text{kHz}$, $R_L=4\Omega$, THD+N = 1%)
 - 2x5.5W (continuous power, HT878, BST=GND)
 - 2x6W (continuous power, HT878, BST=NC)
 - 2x6.5W (instantaneous power, HT878, BST=H)
 - 2x7W (continuous power, HT878T, $V_{POUT}=8.5V$)
 - 2x8.5W (instantaneous power, HT878T, $V_{POUT}=8.5V$, THD+N = 10%)
- Power Supply V_{BAT} : 2.8V~5.5V
- Multiple Gain Available: 21dB, 25.5dB, 30dB
- Filter-less Modulation
- Thermal/Low voltage malfunction prevention function with auto recovery
- Pb-free Packages, TSSOP24L-PP

■ APPLICATIONS

- Smart Speakers
- Portable Speakers
- Megaphone
- Wireless Speakers
- 2.1Channel Speakers
- Portable Gamers

■ DESCRIPTION

The HT878 is a stereo Class D audio amplifier that drives up to continuous 2x6W (THD+N=1%, boosted to 8V) into 4ohm speaker from a Li-battery voltage; HT878T drives up to continuous 2x7W (1% THD+N, boosted to 8.5V) into 4ohm speaker. It also integrates Class AB amplifier which is to be announced.

HT878 built-in Class H boost converter generates a Class D amplifier supply rail with a max voltage of 7.5V, 8V or 8.5 V which is optional to meet different out power demands; HT878T built-in Class G boost converter supports adjustable arbitrary boost voltages. The boost converter is automatically active only when a higher audio output power is required and (for HT878) will track the signal to provide an adaptive voltage supply to the amplifier, which will significantly improve the efficiency and extends the playing time in battery supply applications.

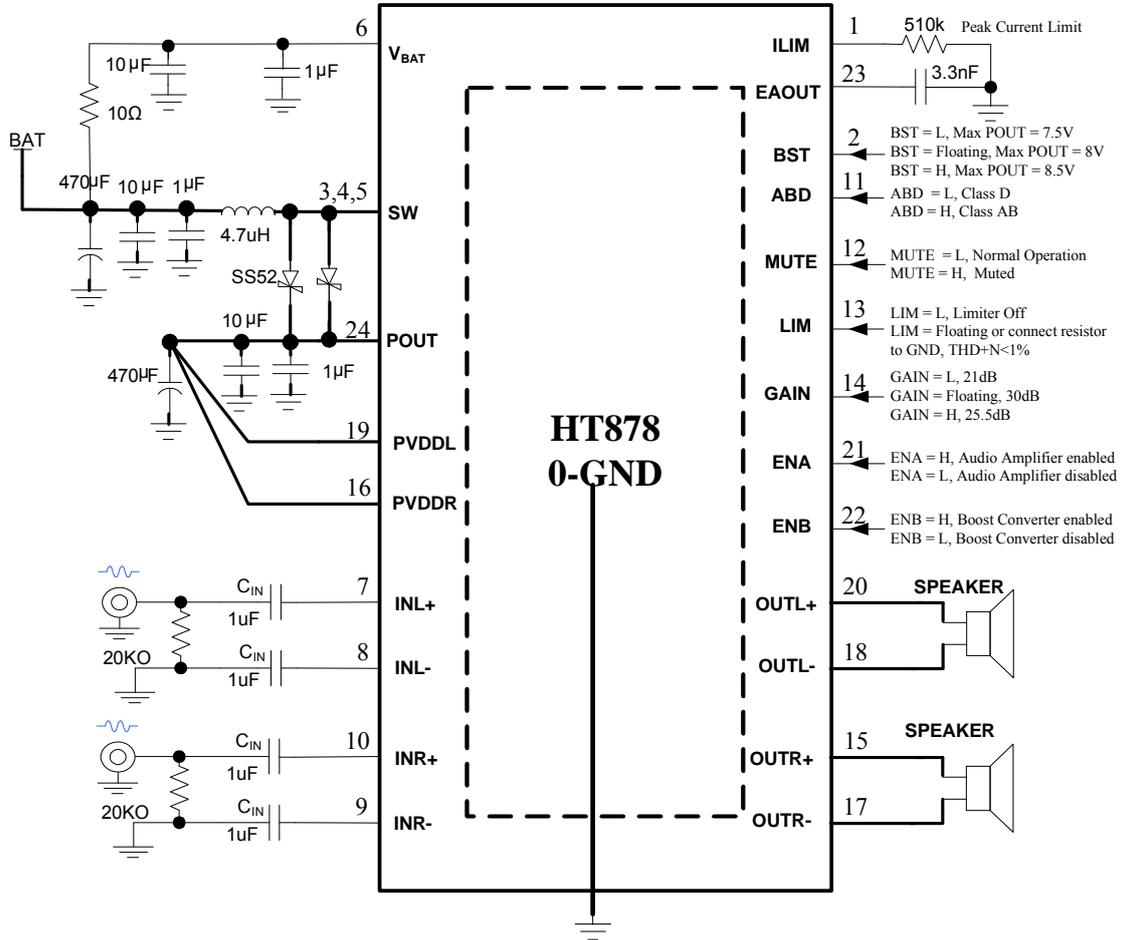
HT878 integrates Limiter function. When it is active, the output music can be limited below a certain power and THD+N. This will allow different demands in sound performance and prevent speakers from damage.

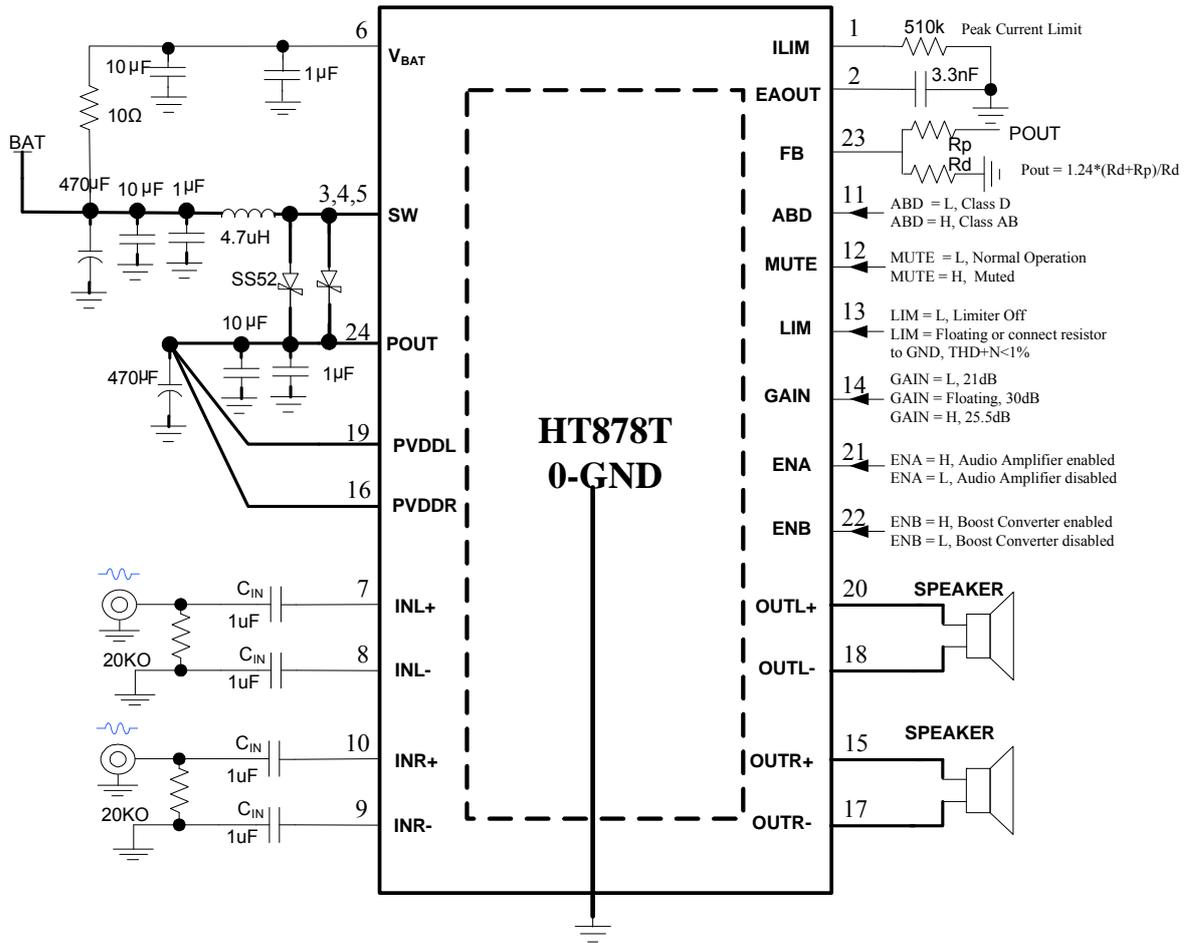
The Thermal Foldback (TFB) function is designed to protect the HT878 from excessive die temperature in case of the device being operated beyond the recommended temperature or power limit, or with a weaker thermal system than recommended. The TFB works by reducing the on-die power dissipation by reducing Gain if the temperature trig point is exceeded, so that the peak audio power is significantly increased.

HT878 has a filter-less modulation circuit which can directly drive speakers. HT878 can be shut down so that the power consumption can be minimized. As for protection function, over current protection function for speaker output terminals, over temperature protection function and low supply voltage malfunction preventing function are also prepared.

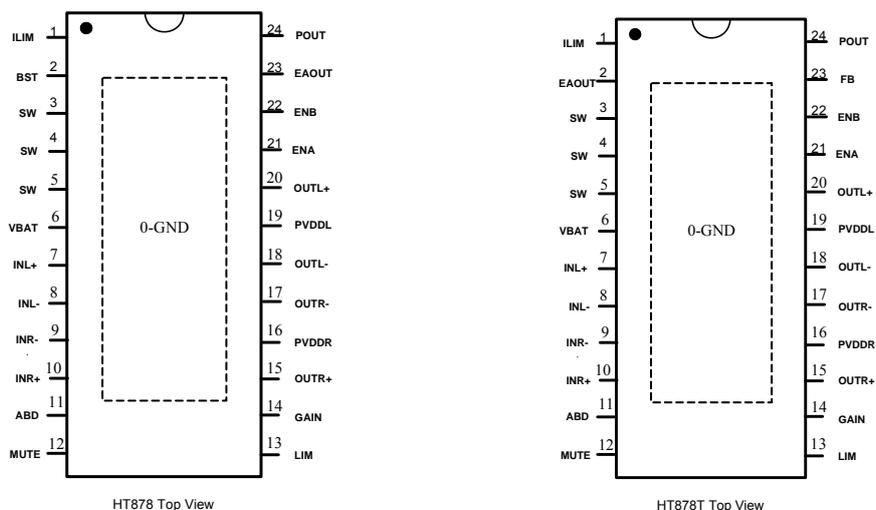
Part No.	Boost Converter	Available Max Boost Voltage
HT878MTEx	Class H	Fixed 3 levels
HT878TMTEEx	Class G	Arbitrary levels

TYPICAL APPLICATION





■ TERMINAL CONFIGURATION



■ TERMINAL FUNCTION

Terminal No.		NAME	I/O ¹	Description
HT878	HT878T			
0	0	GND	GND	Power ground.
1	1	ILIM	I	Adjustable switch peak current limit. An external resistor should be connected between this pin and GND.
2	-	BST	I	Max boost converter voltage (V_{POUT}) set. 3 V_{POUT} levels available.
-	2	EAOUT	I	Error amplifier output. Connect a 3.3nF capacity to GND typically.
3,4,5	3,4,5	SW	I	Boost and rectifying switch input.
6	6	V _{BAT}	Power	Power supply for logic.
7	7	INL+	I	Positive input (differential+) for audio amplifier of left channel
8	8	INL-	I	Negative input (differential-) for audio amplifier of left channel
9	9	INR-	I	Negative input (differential-) for audio amplifier of right channel
10	10	INR+	I	Positive input (differential+) for audio amplifier of right channel
11	11	ABD	I	Audio amplifier mode selection. Class D is selected when it is pulled low; Class AB is selected when it is pulled high.
12	12	MUTE	I	MUTE control set. The audio amplifier is muted when it is pulled high.
13	13	LIM	I	Enable the Limiter Function and select limiter level
14	14	GAIN	I	System GAIN set. Three GAIN level for select
15	15	OUTR+	O	Positive output terminal (BTL+) for right channel
16	16	PVDDR	O	Power supply terminal for right channel
17	17	OUTR-	O	Negative output terminal (BTL-) for right channel
18	18	OUTL-	O	Negative output terminal (BTL-) for left channel
19	19	PVDDL	P	Power supply terminal for left channel
20	20	OUTL+	O	Positive output terminal (BTL+) for left channel
21	21	ENA	I	Audio amplifier enabling terminal. Audio amplifier is enabled when it is pulled high.
22	22	ENB	I	Boost converter enabling terminal. Boost converter is enabled when it is pulled high
23	-	EAOUT	I	Error amplifier output. Connect a 3.3nF capacity to GND typically.
-	23	FB	I	Regulator Feedback Input
24	24	POUT	I	Boost Converter voltage detect pin.

¹ I: input O: output

ORDERING INFORMATION

Part Number	Package Type	Marking	Operating Temperature Range	MOQ/Shipping Package
HT878MTET	TSSOP24L-PP	HT878 ^{MTE} UVWXYZ ¹	-40°C~85°C	38 PCS / Tube
HT878MTER	TSSOP24L-PP	HT878 ^{MTE} UVWXYZ	-40°C~85°C	3000PCS/ Tape and Reel
HT878TMTET	TSSOP24L-PP	HT878 ^{TMTE} UVWXYZ	-40°C~85°C	Tube 38 PCS
HT878TMTER	TSSOP24L-PP	HT878 ^{TMTE} UVWXYZ	-40°C~85°C	3000PCS/ Tape and Reel

ELECTRICAL CHARACTERISTIC²
Absolute Maximum Ratings^{*3}

PARAMETER	Symbol	MIN	MAX	UNIT
Supply voltage range	V _{BAT}	-0.3	5.5	V
Input voltage range	V _{IN}	-0.3	V _{BAT}	V
Output voltage range	V _{POUT}	-0.3	9.0	V
Operating temperature range	T _A	-40	85	°C
Operating junction temperature range	T _J	-40	170	°C
Storage temperature range	T _{STG}	-50	170	°C

Recommended Operating Conditions

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
V _{BAT} supply voltage range	V _{BAT}		2.8	3.7	5.5	V
Output voltage range	V _{POUT}		V _{BAT} -0.2		8.5	V
High-level input voltage	V _{IH}		1.5		V _{BAT}	V
Low-level input voltage	V _{IL}				0.7	V
Operating temperature	T _a		-40	25	85	°C
Load impedance	R _L	BTL		4		Ω

¹ UVWXYZ is production track code

² Depending on parts and PCB layout, characteristics may be changed.

³ 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.

● Electrical Characteristics

Condition: $T_a=25^{\circ}\text{C}$, $V_{\text{BAT}} = 3.7\text{V}$, $f_{\text{IN}} = 1\text{ kHz}$, $V_{\text{POUT}} = 8\text{V}$ (BST Floating), Gain = 25.5dB (GAIN=H), $C_{\text{IN}} = 1\mu\text{F}$, Limiter Function disabled (LIM=GND), $C_{\text{EAOUT}}=3.3\text{nF}$, Load = 4ohm + 22uH, unless otherwise specified.

Main Characteristics

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
VBAT supply voltage range	V_{BAT}	Boost + Amp work	2.8	3.6	5.5	V
Boost on threshold voltage	$V_{\text{B_TH1}}$	Amplifier Output V_{RMS}		1.6		V
	$V_{\text{B_TH2}}$	Amplifier Output V_{RMS} , HT878 only		2.7		
Start-up time	t_{ON}	$t_{\text{BOOST_ON}}$, Boost only		5		ms
		$t_{\text{AMP_ON}}$, Audio Amplifier only		60		
Closed-loop voltage gain	A_v	GAIN=L		21		dB
		GAIN=H		25.5		
		GAIN Floating		30		
Internal Input impedance (per input pin)	R_{IN}	GAIN=L		36		K Ω
		GAIN=H		24		
		GAIN Floating		15.4		

Boost Converter

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
Max Boost converter output voltage range (HT878)	V_{POUT}	BST = L		7.5		V
		BST Floating		8		
		BST = H		8.5		
Class H Mid Boost converter output voltage range	$V_{\text{POUT_H}}$	HT878		5.5		V
Reference voltage at the FB pin (HT878T)	V_{REF}			1.24		V
Boost off delay time	$t_{\text{BOOST_OFF}}$			160		ms
Boost converter input current limit	I_{L}	RILIM=510k		7.5		A
Reference voltage at I_{LIM} pin	V_{ILIM}			1.24		V
Boost converter frequency	f_{BOOST}			$f_{\text{Class-D}}$		KHz

Boost Converter + Class D (BTL)

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT	
Output power	P _O	BST=L	THD+N=1% V _{BAT} = 4.2V Load = 4ohm + 22uH		2×5.5	W	
		BST=NC			2×6.0		
		BST=H			2×6.5		
		HT878T, V _{POUT} =8.5V			2×7.0		
		BST=L		THD+N=10% V _{BAT} = 4.2V Load = 4ohm + 22uH			2×6.5
		BST=NC					2×7.4
		HT878T, V _{POUT} =8.5V					2×8.5
Total harmonic distortion plus noise	THD+N	P _O =0.25W	R _L =4Ω+22uH, f=1kHz		0.04	%	
		P _O =1.0W			0.04		
Noise output voltage	V _N	Differential input floating, f=20Hz~20kHz, A-weighted, A _v =25.5dB			60	μV _{rms}	
Signal to noise ratio	SNR	1W, f=20Hz~20kHz, A-weighted, A _v =21dB			83.5	dB	
Efficiency (Class D + Boost)	η	V _{BAT} = 3.7V, R _L = 4Ω+22uH, P _O = 2×0.5W			80	%	
		V _{BAT} = 3.7V, R _L = 4Ω+22uH, P _O = 2×1W			75		
		BST=L	V _{BAT} = 4.2V, R _L =4Ω+22uH, P _O = 2×4.0W		77.5		
		BST Floating			77		
		BST=H			76.5		
		BST=L, V _{BAT} = 4.2V, R _L =4Ω+22uH, P _O = 2×5.0W			78		
		BST Floating, V _{BAT} = 4.2V, R _L =4Ω+22uH, P _O = 2×6.0W			77.8		
HT878T, V _{POUT} =8.5V, V _{BAT} = 4.2V, R _L =4Ω+22uH, P _O = 2×7.0W			73				
Operating quiescent current	I _{BAT}	Input Grounded, With or without load			7	mA	
Shutdown quiescent current	I _{SD}	Input Grounded, With or without load			1	μA	
Class D switching frequency	f _{Class-D}				430	kHz	

Class AB Only (BTL)

PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT	
Output power	P _O	V _{BAT} = 4.2V	THD+N=1% Load = 4ohm + 22uH		2*1.59	W	
		V _{BAT} = 3.7V			2*1.17		
		V _{BAT} = 3.3V			2*0.92		
		V _{BAT} = 4.2V		THD+N=10% Load = 4ohm + 22uH			2*1.98
		V _{BAT} = 3.7V					2*1.47
		V _{BAT} = 3.3V					2*1.16
Total harmonic distortion plus noise	THD+N	P _O =1W	V _{BAT} =4.2V, f=1kHz, R _L =4Ω+22uH		0.11	%	
Noise output voltage	V _N	Differential input floating, f=20Hz~20kHz, A-weighted, A _v =25.5dB			60	μV _{rms}	
Efficiency	η	V _{BAT} = 3.7V, R _L = 4Ω+22uH, P _O = 2×1W			63	%	
Operating quiescent current	I _{BAT}	Input Grounded, With or without load			15	mA	
Shutdown quiescent current	I _{SD}	Input Grounded, With or without load			1	μA	

Other Characteristics

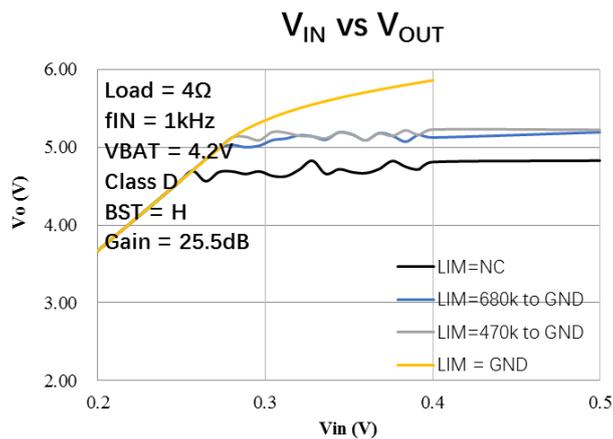
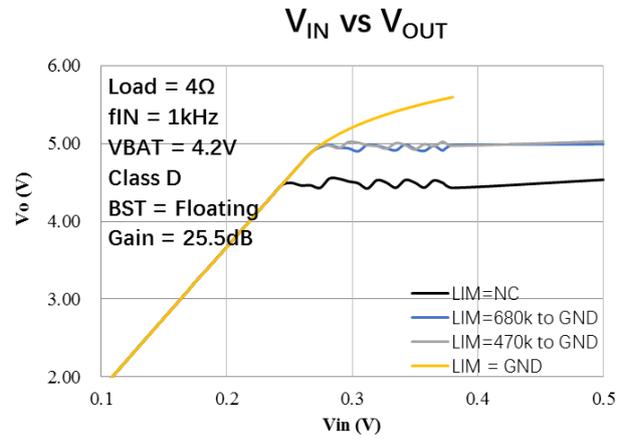
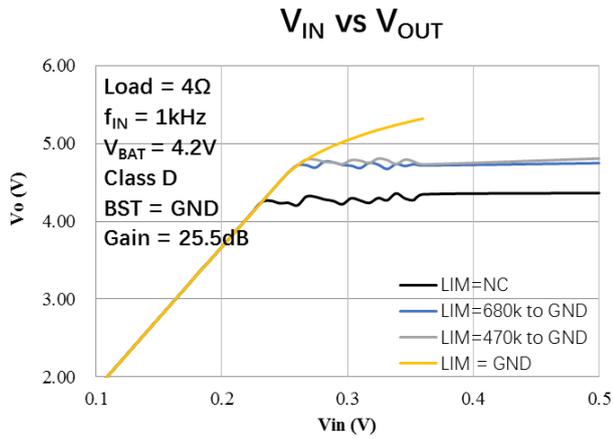
PARAMETER	Symbol	CONDITION	MIN	TYP	MAX	UNIT
Automatic Gain Control (AGC)						
AGC gain range	$A_{V_{AGC}}$			30		dB
AGC gain step	STP_{AGC}			120		/
AGC attack time	t_{A_AGC}			10		ms/dB
AGC release time	t_{R_AGC}			160		ms/dB
Limiter level (Peak)	V_{LIM_L}	LIM floating		$0.8 \times V_{POUT}$		V
Thermal Foldback (TFB)						
Over temperature protection point	OTP			150		°C
Over temperature protection hysteresis	OTP_{hys}			30		°C
Over temperature protection recovery point	OTPR			140		°C
Thermal foldback trig point	TFB			130		°C
TFB attack time	t_{A_TFB}			640		ms/dB
TFB release time	t_{R_TFB}			1280		ms/dB
Input/output						
Internal pulldown resistor of ENA, ENB, ABD, MUTE	R_{DOWN}			300		kΩ
High-level input voltage ENA, ENB, BST, ABD, MUTE, GAIN	V_{IH}		1.5			V
Low level input voltage of ENA, ENB, BST, ABD, MUTE, GAIN	V_{IL}				0.4	V

TYPICAL OPERATING CHARACTERISTICS

 Condition: $V_{BAT} = 4.2V$, $f_{IN} = 1kHz$, Gain = 25.5dB, $C_{IN} = 1\mu F$, unless otherwise specified.

Limiter

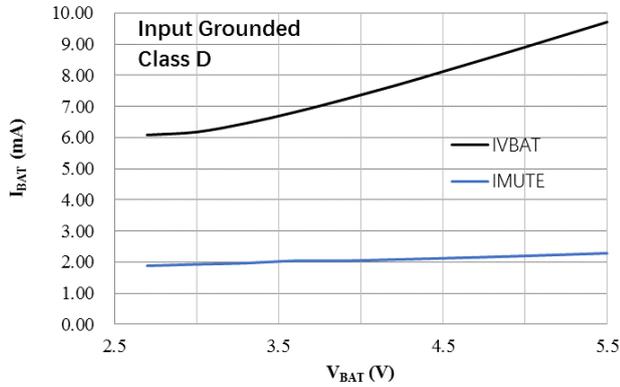
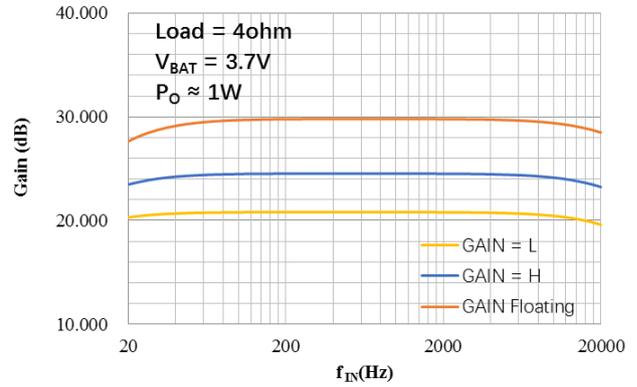
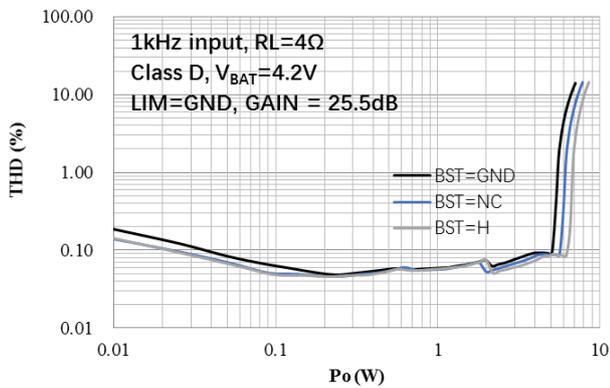
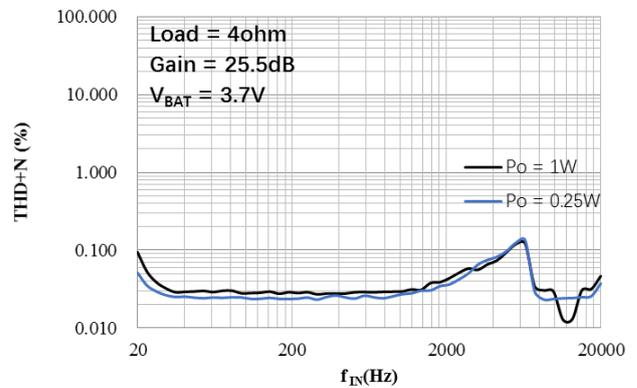
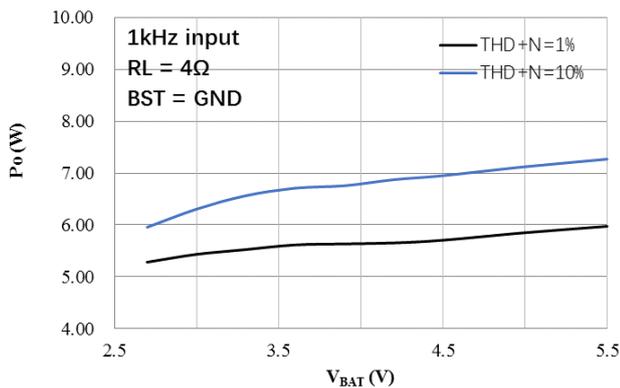
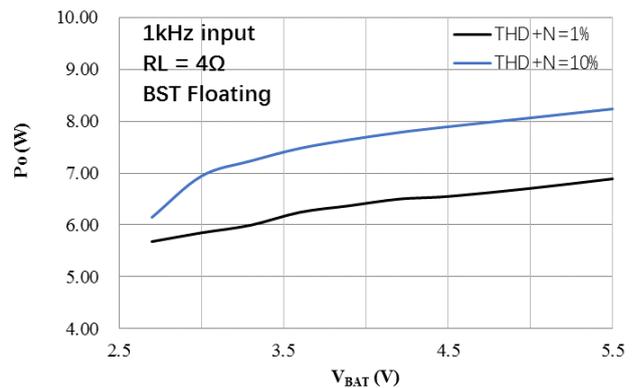
Characteristics below are measured in Class D mode.

 Condition: $V_{BAT} = 4.2V$, $f_{IN} = 1kHz$, Gain = 25.5dB, $C_{IN} = 1\mu F$, Limiter ON, Output = Load + Filter, Load = 4ohm, Filter = 100ohm + 47nF, unless otherwise specified.


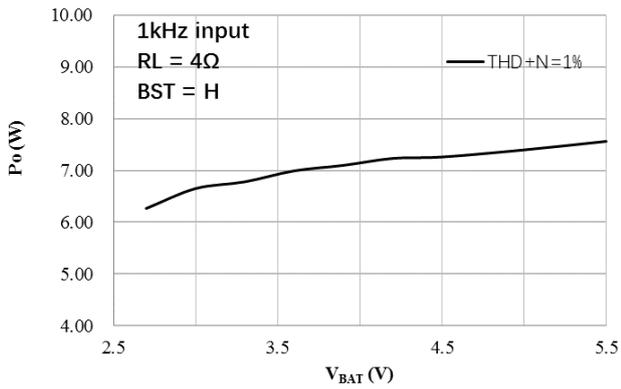
BOOST + Class D (BTL)

Condition: $V_{BAT} = 4.2V$, $f_{IN} = 1kHz$, Gain = 25.5dB, $C_{IN} = 1\mu F$, Limiter off, Output = Load + Filter, Load = 4ohm, Filter = 100ohm + 47nF, unless otherwise specified.

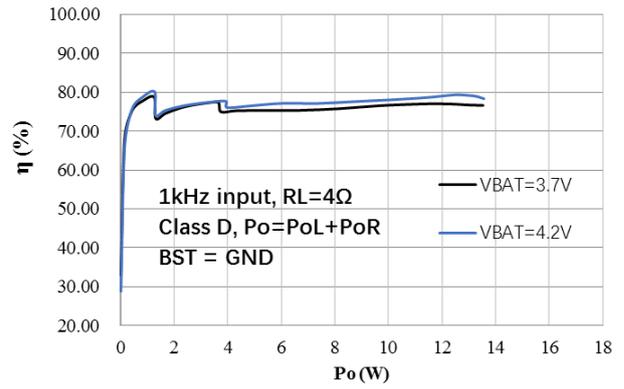
The following specifications are measured from HT878; however, they also accord with HT878T with slight variations.

 V_{BAT} vs I_{BAT}

 f_{IN} vs Gain

 P_o vs THD+N

 f_{IN} vs THD+N

 V_{BAT} vs P_o

 V_{BAT} vs P_o


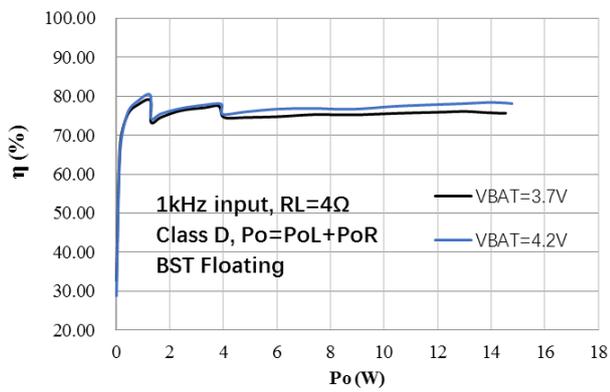
V_{BAT} vs P_o



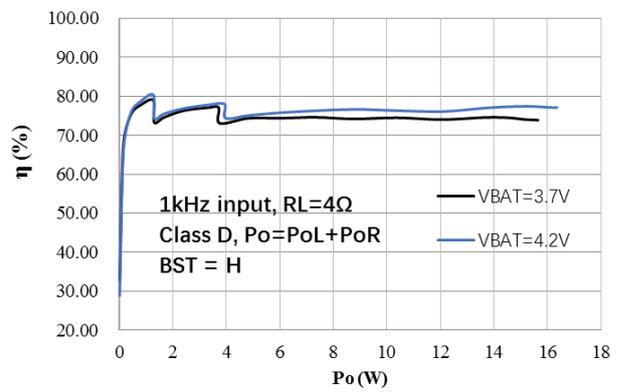
P_o vs η



P_o vs η

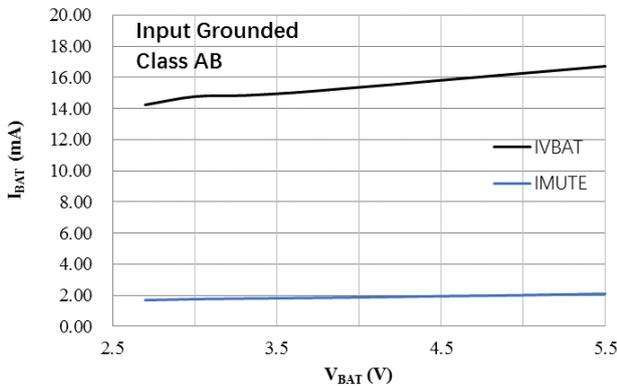
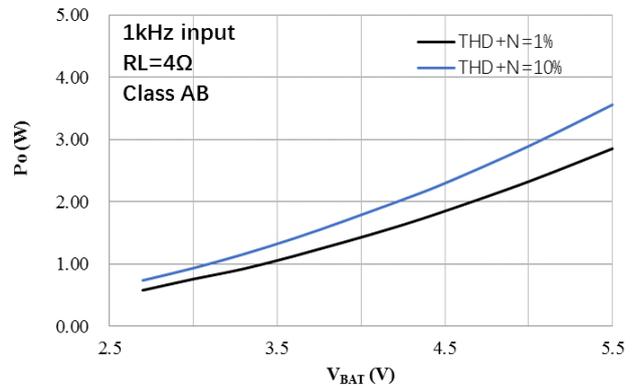
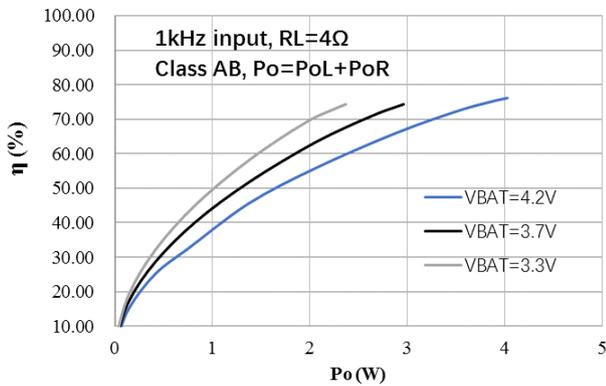
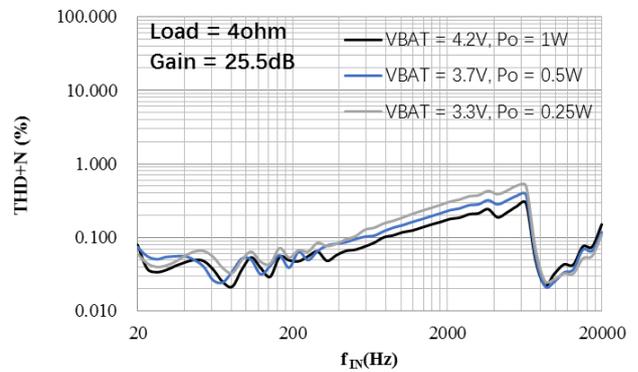
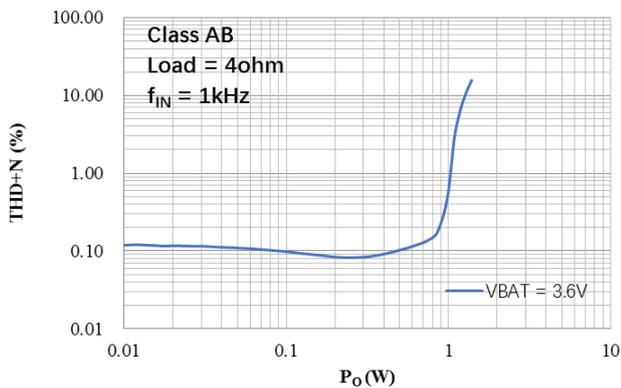
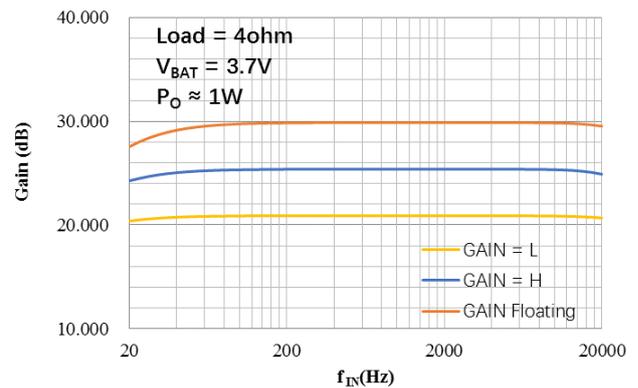


P_o vs η



Class AB Only (BTL)

Condition: $V_{BAT} = 4.2V$, $f_{IN} = 1kHz$, Gain = 25dB, $C_{IN} = 1\mu F$, Battery tracking disabled (Point off), Output = Load = 4ohm + 22uH, unless otherwise specified.

 V_{BAT} vs I_{BAT}

 V_{BAT} vs P_o

 P_o vs η

 f_{IN} vs THD+N

 P_o vs THD+N

 f_{IN} vs Gain


■ APPLICATION INFORMATION

1. Glossary

The application section may use the following terms.

AGC: Automatic gain control function, including Limiter function and Battery Tracking function.

Limiter: When Limiter function is active, the output music can be limited below the Limiter Level.

Limiter Level: V_{LIM_L} for short. The maximum output voltage allowed before amplifier gain is automatically reduced.

Thermal Foldback: TFB for short. When this function is active, HT878(T) reduces the on-die power dissipation by reducing system gain if the on-die temperature exceeds the Thermal Foldback Trig Point in case of the device being operated beyond the recommended temperature or power limit, or with a weaker thermal system than recommended. Once the die temperature drops below the TFB trig point, the system gain is increased until the TFB trig point is reached.

Thermal Foldback Trig Point: TFB for short. The on-die temperature trig point for reducing system gain.

Attack Time: t_A for short. The rate of AGC or TFB gain decrease. The default value for AGC Attack Time is 10ms /dB, and the default value of TFB Attack Time is 640ms/dB.

Release Time: t_R for short. The rate of AGC or TFB gain increase. The default value for AGC release time is 160ms/dB, and the default value for TFB Release Time is 1280ms /dB.

Class G Adaptive Boost: Only when the output audio signal exceeds a preset voltage threshold (Boost on Threshold Voltage V_{B_TH1}), the boost converter is enabled. When the audio output voltage is lower than the threshold voltage, the boost deactivates automatically. This technology can improve the system efficiency and extend the battery life.

Class H Adaptive Boost: The boost converter is automatically active and will track the signal to provide an adaptive voltage supply to the amplifier. Basically, there are 3 levels of boost voltages to adapt the output power: V_{BAT} , Mid boost voltage (V_{POUT_H}), and Max boost voltage (V_{POUT})

Boost on Threshold Voltage: V_{B_TH} for short. The output audio signal voltage threshold for enabling boost converter. V_{B_TH1} is the threshold voltage for Class G boost and the 1st threshold voltage for Class H boost. V_{B_TH2} is the 2nd threshold voltage for Class H boost.

2. Feature Description

2.1. Limiter Function (LIM pin)

The Limiter Function can protect speakers, improve loudness, smooth the music, limit peak supply current, extend battery life, and prevent early shutdown at end-of-charge battery voltages.

When Limiter function activates, the output music can be limited below the Limiter Level (V_{LIM_L}). If the output audio signal exceeds the Limiter Level, HT87(T) decreases amplifier gain by the rate of attack time (default value 10ms/dB), 0.25dB per step. HT878(T) increases the gain by the rate release time (default value 160ms/dB), 0.25 per step, once the output audio is below the limiter level. Fig. 1 Limiter Function shows this relationship.

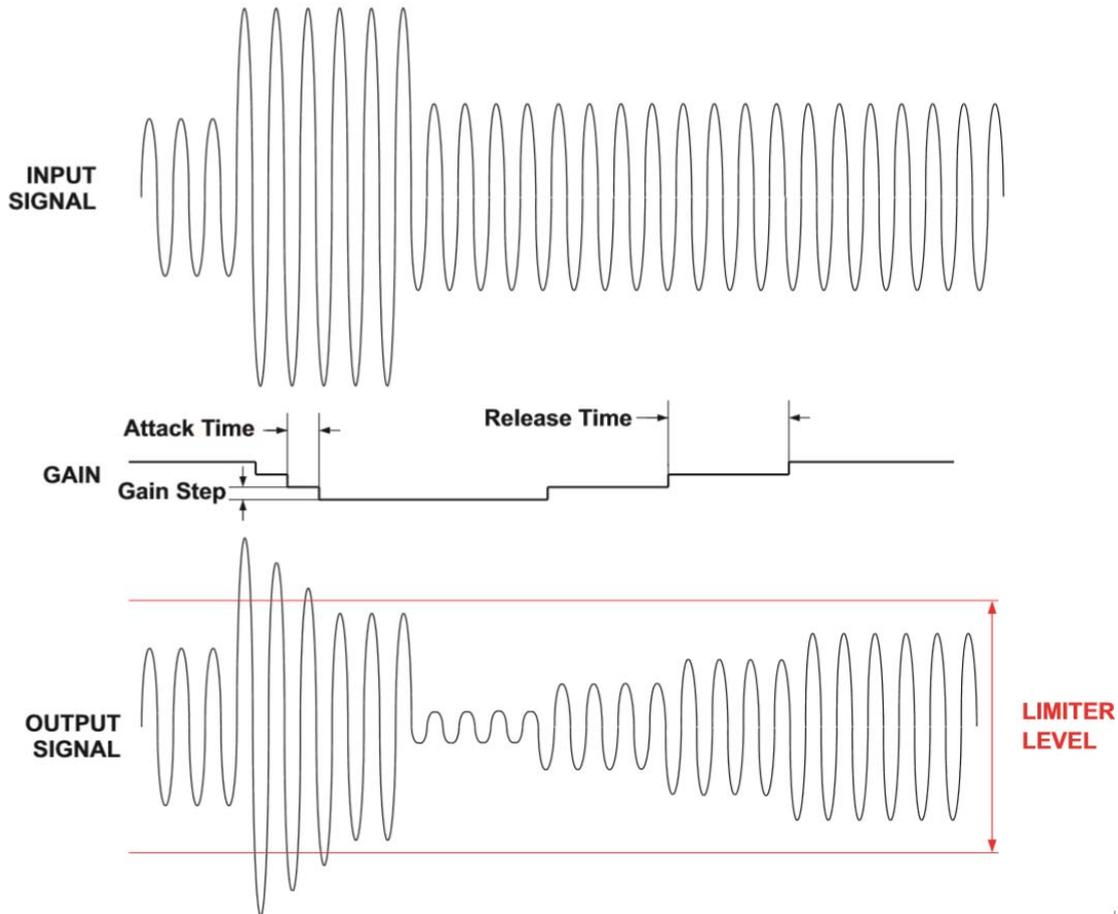


Fig. 1 Limiter Function

The Limiter Level can be modified through LIM terminal. If the LIM terminal is directly grounded, AGC function is disabled. When the LIM terminal is floating the output power can be limited under THD+N=1%. To get a larger power, connect a resistor to Ground, a resistor with smaller resistance will get a larger power. Typical configurations are shown in the following table.

Table. 1 Typical Limiter Level Configuration

LIM Terminal	Amplifier Output Voltage (V_{RMS})		
	BST = GND	BST Floating	BST = H
Floating	4.45	4.66	4.85
Grounded with 680kohm resistor	4.73	5.00	5.13
Grounded with 510kohm resistor	4.77	5.09	5.3
Grounded with 470kohm resistor	4.85	5.15	5.36
Short to GND	Limiter Disabled		

* The configurations are typically measured in applications with 4ohm load.

2.2. Adaptive Boost Converter

The HT878(T) consists of an adaptive boost converter and an audio amplifier. The boost converter takes the supply voltage, V_{BAT} , and increases it to a higher output voltage, V_{POUT} . V_{POUT} drives the supply voltage of the audio amplifier, PVDD. This improves loudness over non-boosted solutions. An external inductor and diode should be added for the boost converter.

Respectively, HT878 integrates a Class H boost converter and HT878T integrates a Class G boost converter.

2.2.1 Class G boost converter for HT878T

The boost output voltage V_{POUT} is set by a resistive voltage divider from the output voltage V_{POUT} to FB terminal, which is shown below. The output voltage can be calculated by $V_{POUT} = 1.24 \cdot (R_p + R_d) / R_d$.

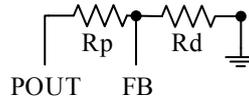


Fig. 2 FB Terminal Configuration

Some typical output voltages can be set by following settings.

Table 2. Output Voltage Setting for HT878T

V_{POUT}	$R_p(\text{ohm})$	$R_d(\text{ohm})$
$\approx 6.0\text{V}$	120k	31k
$\approx 6.8\text{V}$	120k	27k
$\approx 7.5\text{V}$	120k	24.9k
$\approx 8.0\text{V}$	120k	23.2k

The Class G boost converter is adaptive and supporting only boost on-off. It activates automatically depending on the output audio signal amplitude. When the output audio signal exceeds a preset voltage threshold (Boost on Threshold Voltage V_{B_TH1}), the boost converter is enabled, and the voltage at V_{POUT} is the preset voltage. When the audio output voltage is lower than the threshold voltage, the boost deactivates automatically. The Boost on Threshold Voltage V_{B_TH} is fixed as 1.6V.

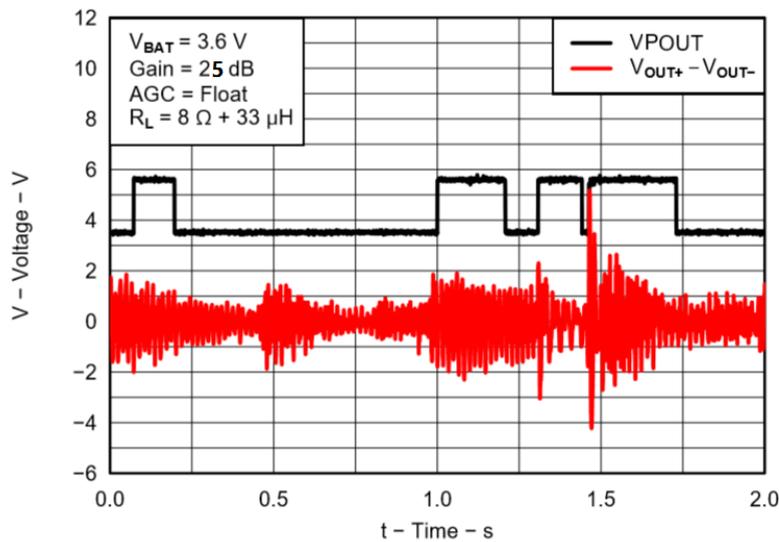


Fig. 3 Adaptive Boost Converter with Typical Music Playback

Fig. 3 shows how the adaptive boost modulates with a typical audio signal. By automatically deactivating the boost converter and passing V_{BAT} to V_{POUT} , the HT878T efficiency is improved at low output power and extend the battery life.

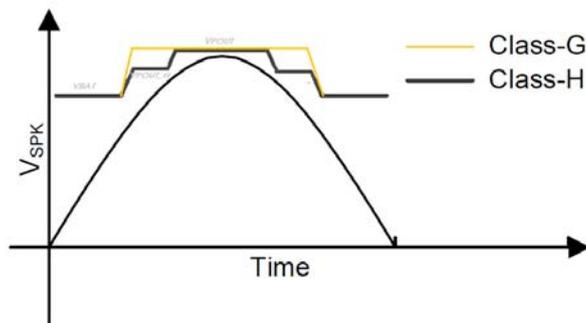
2.2.2 Class H boost converter for HT878

The Class H boost converter is adaptive and adjusted to a value just above what is needed. In short terms, a middle boost voltage (V_{POUT_H}) is added between V_{BAT} and V_{POUT} , so that a more adaptable boost voltage could be obtained to track the audio output power, and a higher efficiency could be achieved during music playing.

The maximum boost voltage (V_{POUT}) can be set by the BST terminal, details are as follows.

Table 3. Output Voltage Setting for HT878

BST Terminal	V _{POUT}
Logic Low	7.5V
Floating	8.0V
Logic High	8.5V



2.2.3 Component Selection

(1) BOOST Converter Input and Output Capacitor C_{IN}, C_{OUT}

For the capacitor maintaining the supply voltage, the value of the boost capacitor is determined by the minimum value of working capacitance required for stability and the maximum voltage ripple allowed on PVDD in the application. It acts as a charge reservoir, providing energy faster than the board supply, thus helping to prevent any droop in the supply voltage.

For the decoupling capacitor, a low equivalent-series-resistance (ESR) ceramic capacitor is needed. This choice of capacitor and placement helps with higher frequency transients, spikes, or digital hash on the line. Additionally, placing this decoupling capacitor close to the HT878(T) is important, as any parasitic resistance or inductance between the device and the capacitor causes efficiency loss.

Over all, 1uF//10uF//470uF (paralleled) is highly recommended to be placed in both input and output terminal as closely to the pin as possible.

(2) Inductor selection and placement

Inductor current rating is determined by the requirements of the load. The inductance is determined by two factors: the minimum value required for stability and the maximum ripple current permitted in the application. $L \geq 4.7\mu\text{H}$, $\text{DCR} < 0.5\text{ohm}$ is recommended for general application circuit. The inductor should be placed as close to the SW pin as possible with direct and wide traces. For different applications of output power, the requirement of saturation current (I_{SAT}) of the inductor is different, recommendations are as follows.

 Table 4. the Recommendations of I_{SAT} and Diode for Different Applications

Output Power (W)	I_{SAT} (A)	Diode
2×4	≥ 3.5	SS52
2×5	≥ 4.5	SS52
2×6	≥ 5.5	SS52//SS52
2×7	≥ 6.5	SS52//SS52
2×8.5	≥ 7.5	SS52//SS52

(3) Schottky Diode selection and placement

A Schottky Diode with $V_{\text{RRM}} > 12\text{V}$, $V_{\text{FM}} < 0.5\text{V}$ and high I_{F} is recommended for general application circuit. The diode should be placed as close to the SW and POUT pin as possible with direct and wide traces. For different applications of output power, the recommendations of the diode are listed in Table 4.

(4) Layout Considerations

The power traces, consisting of the GND, SW, V_{BAT} , POUT and PVDD should be kept short, direct, wide, and be placed as closely to the pin as possible. The switching mode SW should be paid more attention for EMI and reliability consideration.

Place C_{IN} and C_{OUT} near V_{BAT} and Diode as closely as possible to maintain voltage steady and filter out the pulsing current.

The GND of the HT878(T), C_{IN} and C_{OUT} should be connected close together directly to ground plane.

2.3. Thermal Foldback

The HT878(T) Thermal Foldback, TFB, is designed to protect the HT878(T) from excessive die temperature in case of the device being operated beyond the recommended temperature or power limit, or with a weaker thermal system than recommended. The TFB works by reducing the on-die power dissipation by reducing the HT878(T) system gain by the rate of attack time (640ms/dB) in steps of 0.25dB if the TFB trig point (default value 130°C) is exceeded. Once the die temperature drops below the TFB trig point, the HT878(T) gain is increased by a single or by the rate of release time (1280ms/dB) in steps of 0.25dB until the TFB trig point, or a maximum of 30dB attenuation is reached, and the system gain will be decreased again, or the system gain is at its nominal gain level. The procedure shows as follows.

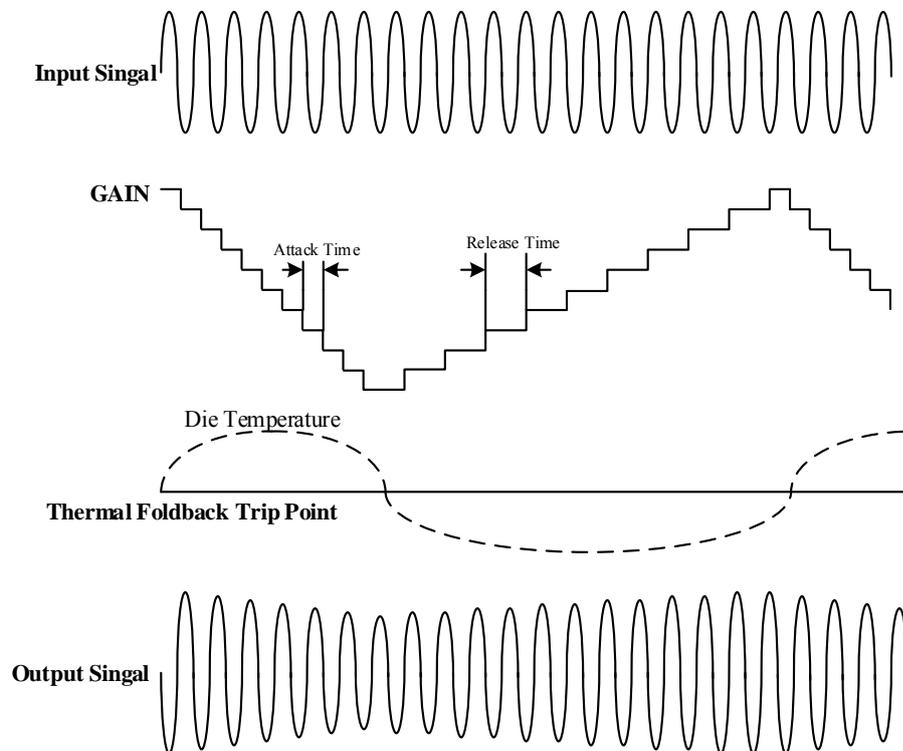


Fig. 4 Thermal Foldback Operation

2.4. Audio Amplifier Input Configuration

HT878(T) is an amplifier with analog input (single-ended or differential), that can directly drive a speaker. For a differential operation, input signals into IN+ and IN- pins via DC-cut capacitors (C_{IN}) and external input resistors R_{IN} . The input signal gain is calculated by $\text{Gain} \approx 12\text{dB} + R_F / (\text{External } R_{IN} + \text{Internal } R_{IN})$. And the

high pass cut-off frequency of input signal can be calculated by $f_c = \frac{1}{2\pi(\text{External } R_{IN} + \text{External } R_{IN}) \times C_{IN}}$.

For a single-ended operation, input signals to IN+ pin via a DC-cut capacitor (C_{IN}) and external input resistor (R_{IN}). IN- pin should be connected to ground via a DC-cut capacitor and external input resistor (R_{IN}) (with the same value of C_{IN} and R_{IN}). The Gain and high pass Cut-off frequency are the same as the above case.

The values of internal R_{IN} and R_F is shown in Table. 5.

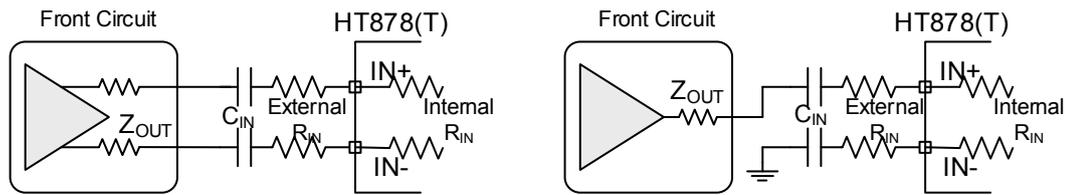


Fig. 5 (1) Differential Input;; (2) Single-ended Input

Table. 5 Internal input resistors and feedback resistors

GAIN	Internal R_{IN} (ohm)	R_F (ohm)
21dB	36k	102k
25.5dB	24k	114k
30dB	15.4k	122.8k

2.5. Amplifier Output

As mentioned before, HT878(T) can directly drive speakers without any other components. But there are exceptions. Once HT878(T) works in Class D mode, the cable lined to the speaker is very long, and EMI is concerned, ferrite beads or L-C filter is needed.

2.6. Protection Function

HT878(T) 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 Ground, Power, 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. Once the short circuit conditions are eliminated, the over current protection mode can be cancelled automatically.

(2) Thermal Protection function

When excessive high temperature of HT878(T) (OTP) 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 V_{BAT} terminal voltage becomes lower than the detection voltage (V_{UVLL}) for the low voltage malfunction prevention. And the protection mode is canceled when V_{BAT} 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). HT878 will start up within the start-up time when the low voltage protection mode is cancelled.

3. Other Terminal Configurations

3.1. ENA, ENB

By pulling ENA, ENB terminal into logic low or high, HT868(T) can enter into different modes, shown as follows.

Table. 6 ENA, ENB Terminal Configuration

ENA	ENB	Mode
H	H	Adaptive Boost +Audio Amplifier
H	L	Audio Amplifier On, Boost disabled
L	H	Boost On, Audio Amplifier disabled
L	L	Shutdown

Note that an internal 300kohm pulldown resistor is connected to ENA, ENB respectively.

3.2. Adjustable Peak Current Limit (ILIM pin)

To avoid an accidental large peak current, an internal cycle-by-cycle current limit is adopted. The low-side switch is turned off immediately as soon as the switch current touches the limit (I_{LIM}). The peak switch current limit can be set by a resistor (R_{LIM}) at the ILIM pin to ground. A resistor of 510k is recommended.

3.3. ABD Terminal Mode Control (ABD pin)

When ABD terminal is pulled logic high, HT878(T) works in Class D mode.

When ABD terminal is pulled logic low, HT878(T) works in Class AB mode.

Notice that a pull-down resistor from ABD pin to GND is placed inside the chip, the resistor value is about 300kohm.

3.4. Mute Mode Select (MUTE pin)

When MUTE terminal is pulled logic high, HT878(T) works in mute mode, in which the differential output signal becomes Weak Low state (a state grounded through high resistivity).

When MUTE terminal is pulled logic low, HT878(T) returns to the normal working state.

Notice that a pull-down resistor from MUTE pin to GND is placed inside the chip, the resistor value is about 300kohm.

3.5. Gain Select (GAIN pin)

The GAIN pin is the terminal to select system gain. There are three different choices as following.

Table. 7 GAIN Terminal Configuration

GAIN	Terminal GAIN	Internal R_{IN} (kohm)
21dB	Logic Low	36k
25.5dB	Logic High	24k
30dB	Floating	15.4k

3.6. EAOUT

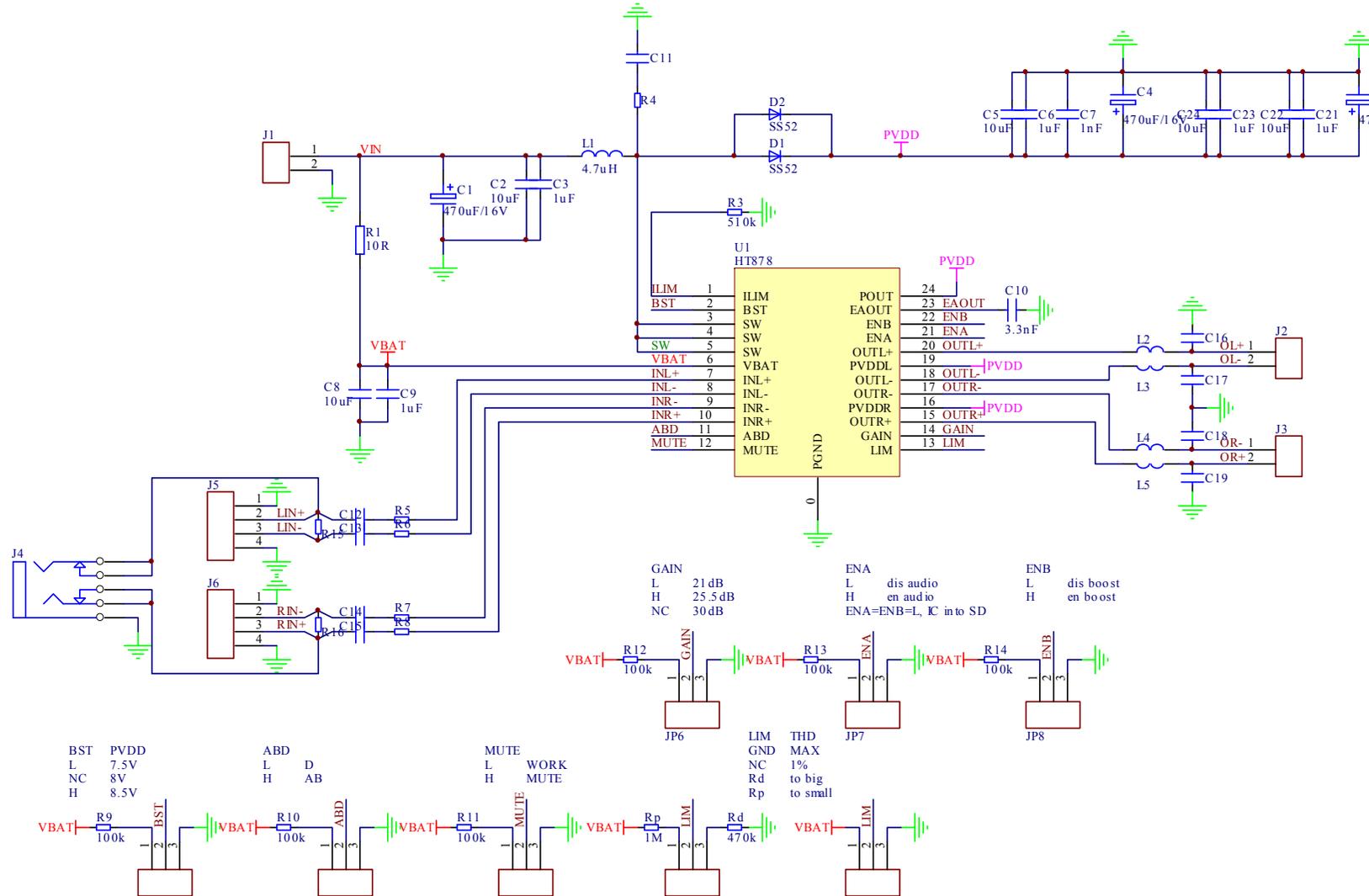
The HT878(T) requires external compensation for the stability of boost converter. The EAOUT pin is the output of the internal error amplifier. An external ceramic capacitors C_C is connected from the EAOUT pin to GND. To be simplified, C_C is 3.3nF which can be adopted in most cases.

3.7. PVDDL and PVDDR

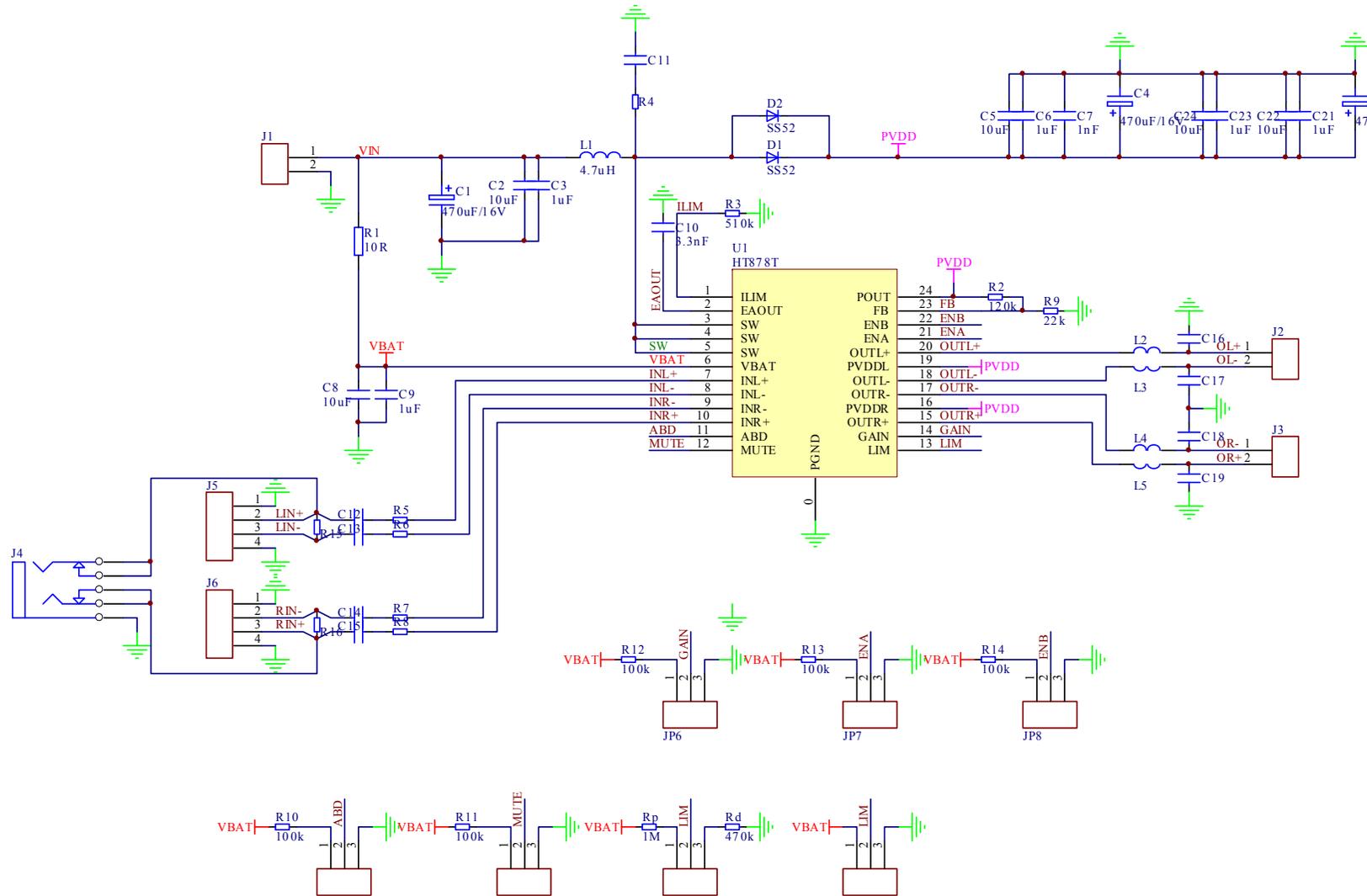
PVDDL and PVDDR are the power supply terminals for audio output driving of channel L and channel respectively. They should be connected directly to the bulk capacitor C_{OUT} of POUT closely with wide routing.

4. Typical Circuit Diagram

4.1. HT878

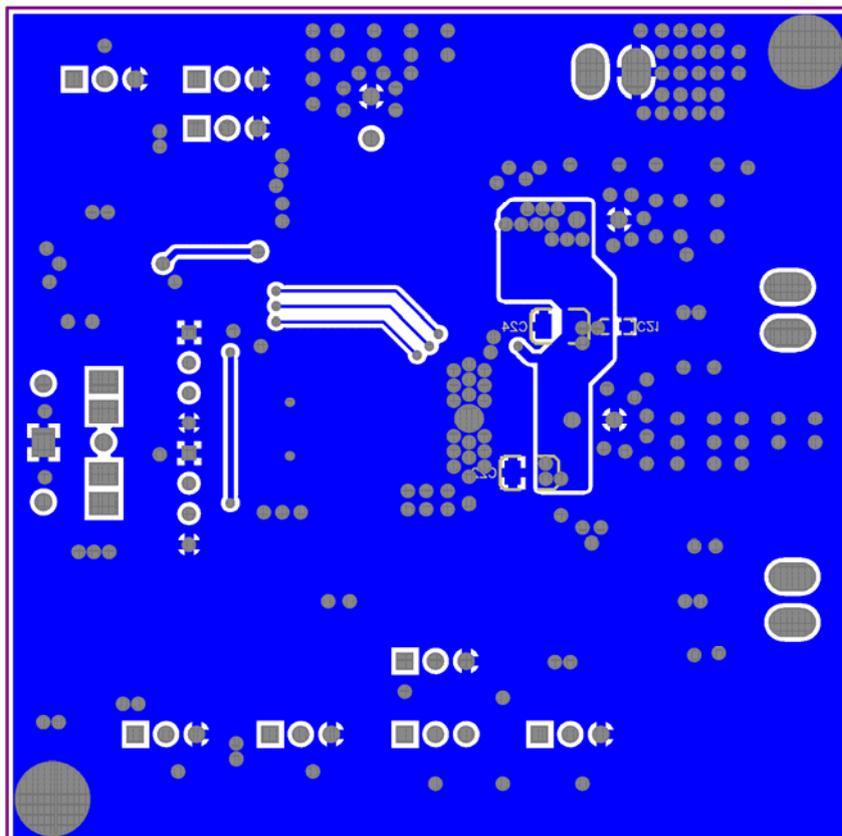
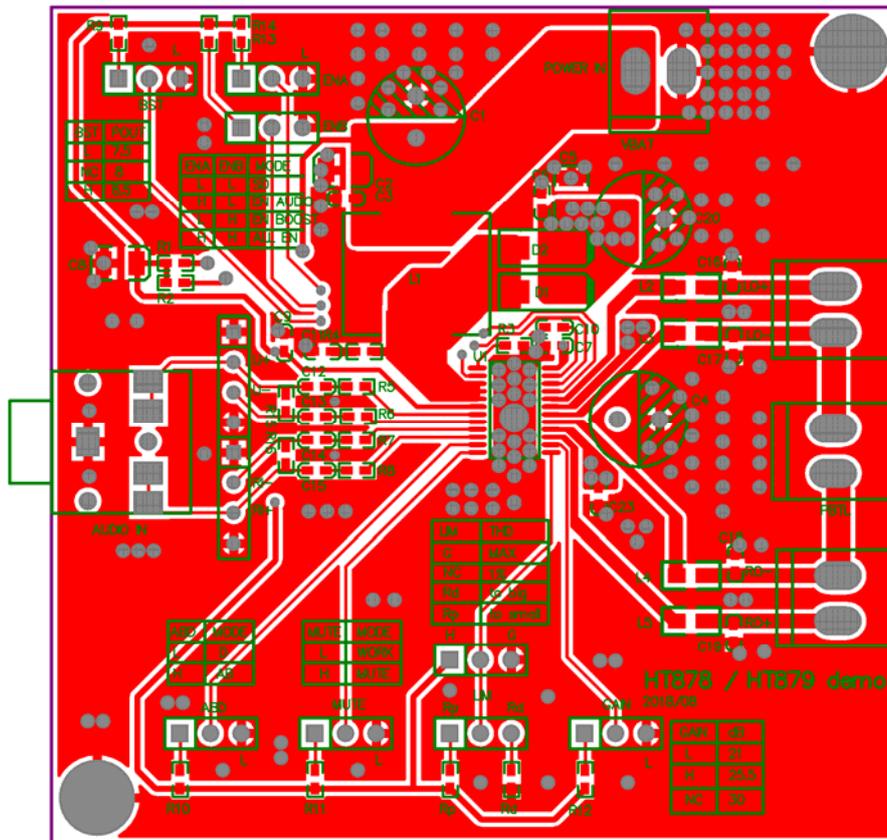


4.2. HT878T

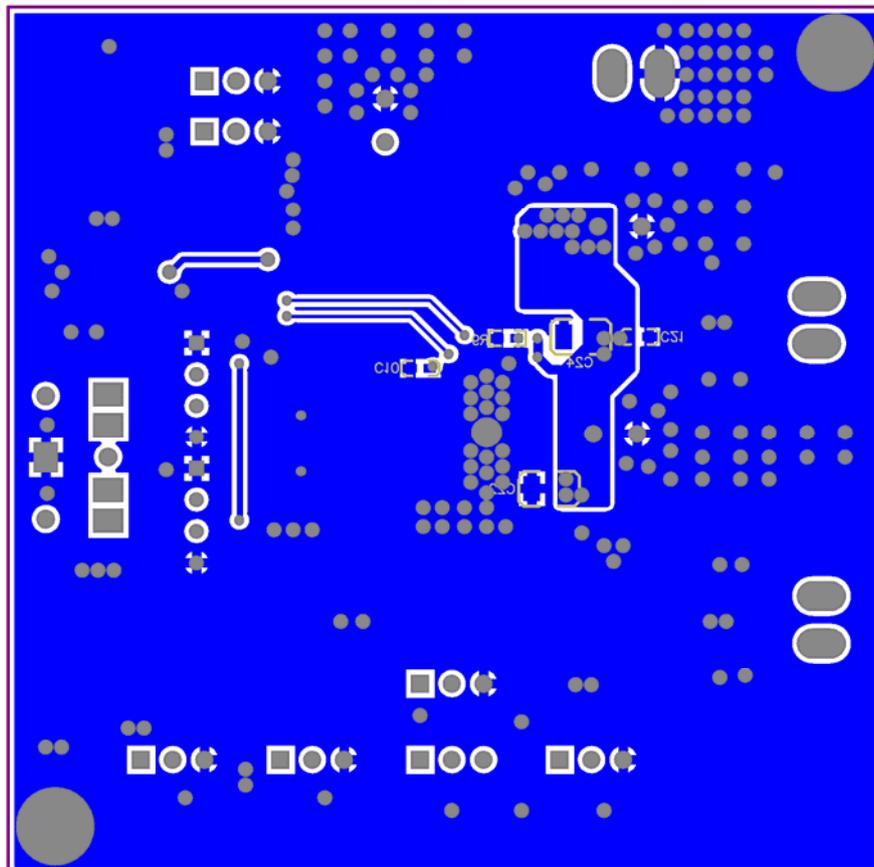
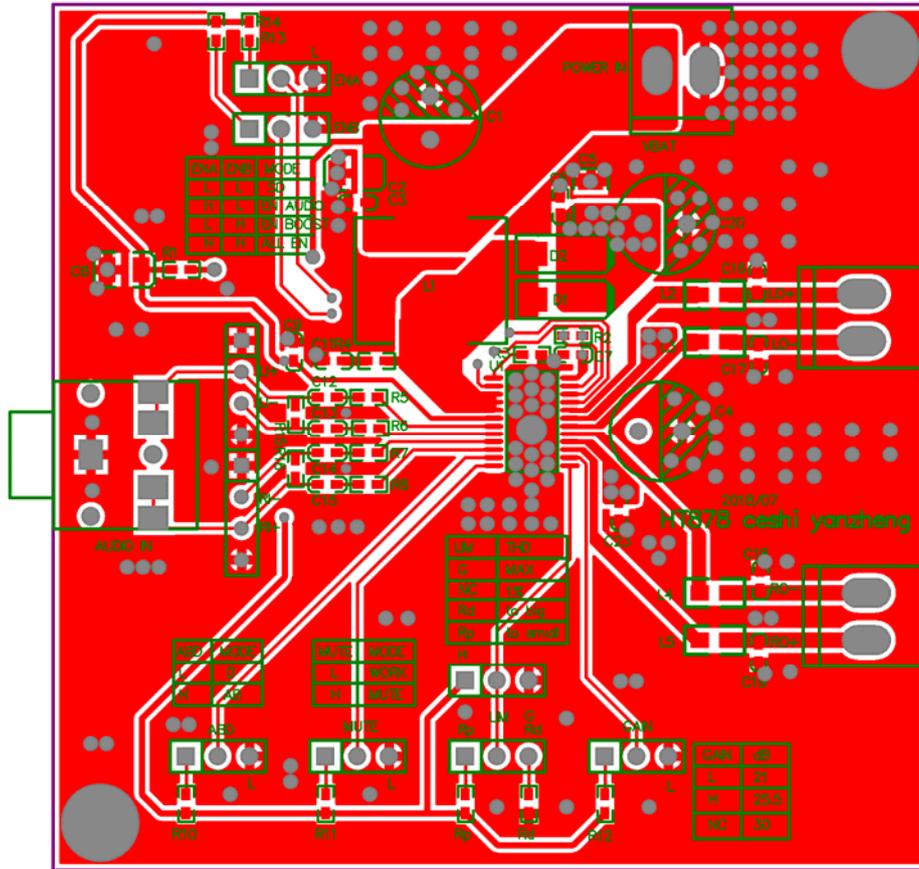


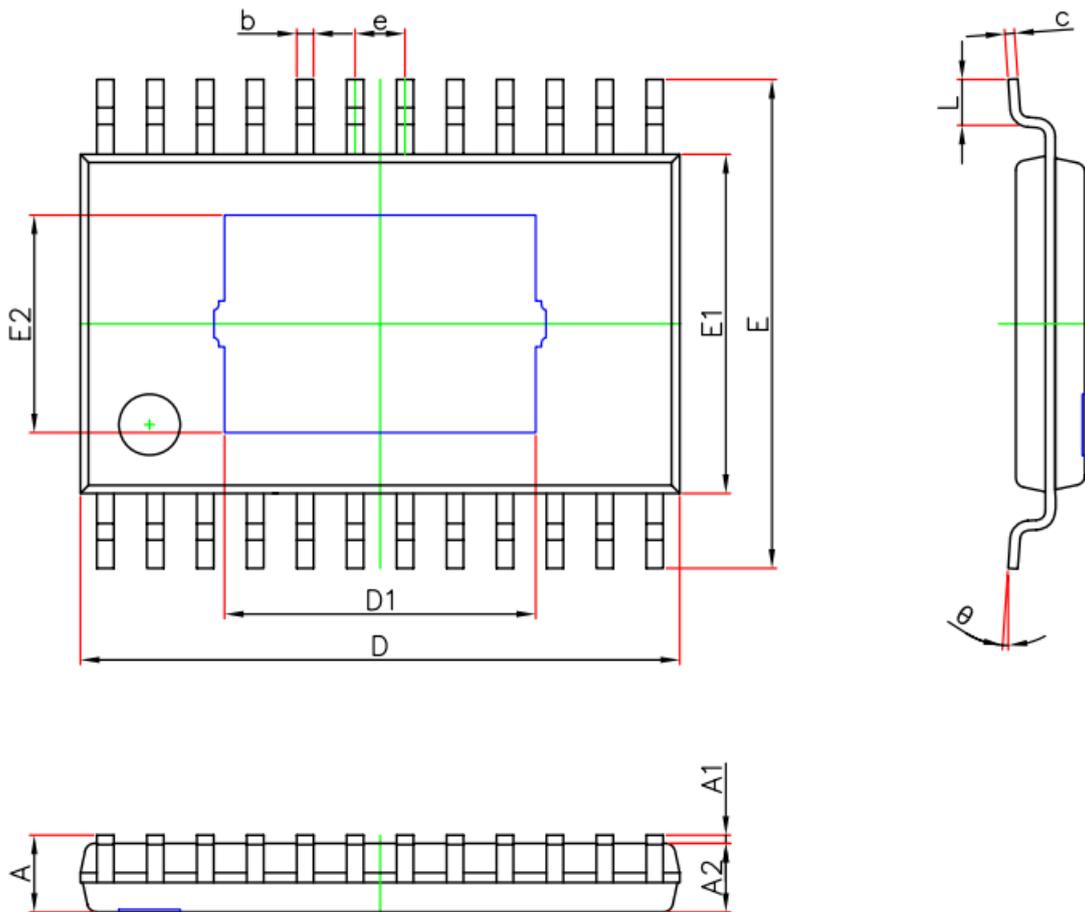
5. PCB Layout

5.1. HT878



5.2. HT878T



PACKAGE OUTLINE


Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	—	1.200	—	0.047
A1	0.050	0.150	0.002	0.006
A2	0.800	1.050	0.031	0.041
b	0.190	0.300	0.007	0.012
c	0.090	0.200	0.004	0.008
D	7.700	7.900	0.303	0.311
D1	3.950	4.150	0.156	0.163
E	6.250	6.550	0.246	0.258
E1	4.300	4.500	0.169	0.177
E2	2.750	2.950	0.108	0.116
e	0.650(BSC)		0.026(BSC)	
L	0.450	0.750	0.018	0.030
θ	0°	8°	0°	8°

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