3.5W Ultra Low-EMI Anti-Clipping Mono Digital Class D Audio Power Amplifier with Digital Volume Control

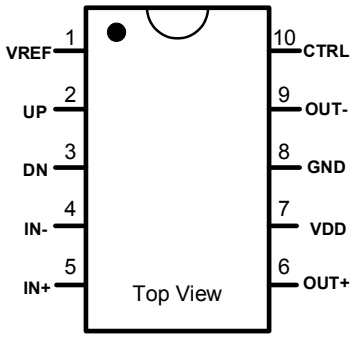
FEATURE

- Patented technology to reduce the internal Rdson and heat loss, increase the output power
  Po=3.5 W (V_{DD}=5.0V, R_L=4Ω, THD+N=10%)
  Po=5.4 W (V_{DD}=5.0V, R_L=2Ω, THD+N=10%)
- Excellent EMI Suppression Performance
  a) The radiation level is highly lower than FCC Part15 Class B standard;
  b) Without interference to FM radio, CMMB, CDMA, GSM and anyother sensitive modules with different bands;
  c) the difficulty of system design is reduced
- Anti-Clipping Function (ACF)
- low noise, High SNR
- Filter-less Modulation, Eliminating Output Filter
- Excellent Click-Pop Noise reduction function
- Low Shutdown Current, 0.01μA
- Over current protection function
- Thermal Protection function
- Low voltage malfunction prevention function
- Pb-Free Packages, MSOP10, MSOP10-PP, DFN10

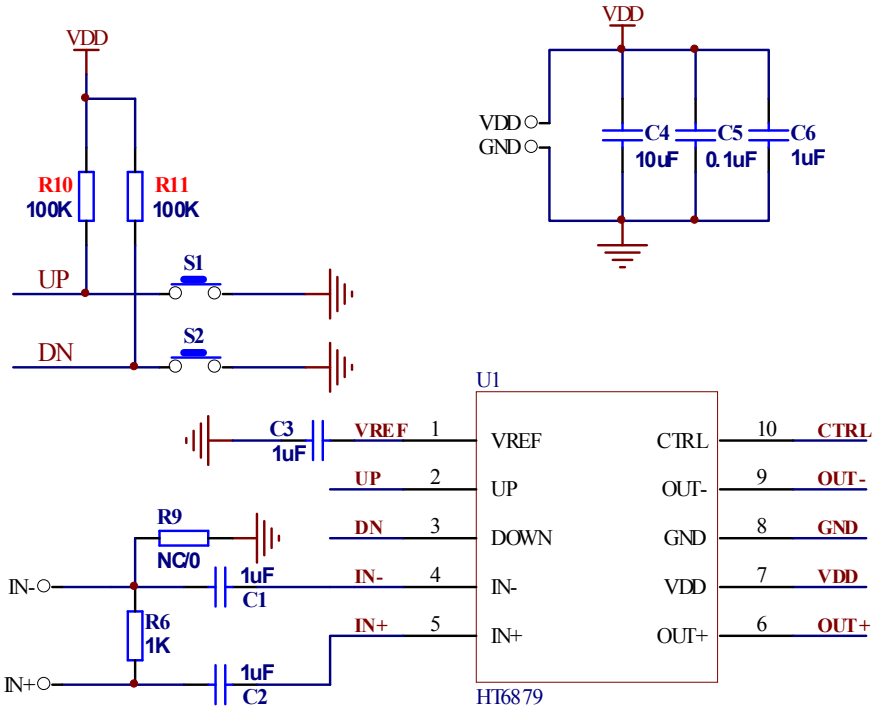
APPLICATIONS

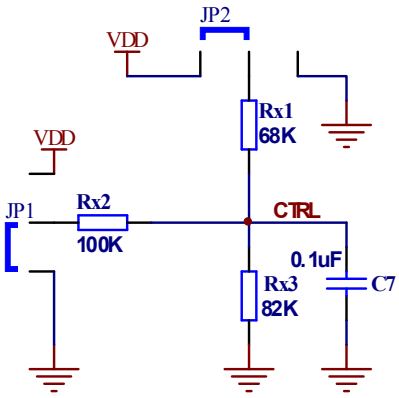
- Portable Speakers
- iphone/ipod/MP3 docking
- PMP/MP4/MP5
- Digital Photo Frame
- PDAs
- USB Speakers
- Digital Photo Frame
- GPS
- Mobile phones

TERMINAL CONFIGURATION



TYPICAL APPLICATION





MODE CTRL(VDD=5V)			
Mode	JP1	JP2	Vctrl
ACF OFF	VDD	VDD	2.95V
ACF1	GND	VDD	1.755V
ACF2	VDD	GND	1.193V
SD	GND	GND	0

■ TERMINAL FUNCTION *1

MSOP/DFN Terminal No.	Name	I/O	ESD composition	Function
1	VREF	A	PN	Analog reference terminal
2	UP	A	PN	Volume up
3	DN	A	PN	Volume down
4	IN-	A	PN	Negative input terminal (differential -)
5	IN+	A	PN	Positive input terminal (differential +)
6	OUT+	O	-	Positive output terminal (differential +)
7	VDD	Power	-	Power supply
8	GND	GND	-	GND
9	OUT-	O	-	Negative output terminal (differential -)
10	CTRL	I	PN	Shutdown and ACF control terminal

*1: Input terminal O: Output terminal A: Analog terminal
when a voltage that is higher than the VDD potential is impressed into the terminal of PN (ESD protection circuit is composed of PMOS and NMOS), the leakage current flows through the protection circuit of PMOS.

■ ELECTRICAL CHARACTERISTI

● Absolute Maximum Ratings *2

Item	Symbol	Min.	Max.	Unit
Power supply terminal voltage range	V_{DD}	-0.3	5.8	V
Input terminal voltage range (Analog input terminal: IN+, IN-)	V_{IN}	$V_{SS}-0.6$	3	V
Input terminal voltage range (Input terminals except IN+, IN-)	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	150	℃

*2: Absolute Maximum Ratings is values which must not be exceeded to guarantee device reliability. With a system in which input voltage might exceed supply voltage of VDD/GND, external diodes are recommended to be used to assure that the voltage does not exceed the absolute maximum rating.

● Recommended Operating Condition

Item	Symbol	Conditions	Min.	Typ.	Max.	Unit
Power Supply Voltage	V_{DD}		2.5	5	5.5	V
Operating Ambient Temperature	T_a	t_{SD} (Min.)=50ms	-20	25	85	℃
		t_{SD} (Min.)=80ms	-30			
Speaker Impendance	R_L		2			Ω

* The rising time of VDD should be more than 1μs.

● 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}			1.9		V
ACF-Off mode threshold voltage for terminal CTRL	V_{MOD1}		2.00		V_{DD}	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}		V_{SS}		0.30	V
consumption current in Mute mode	I_{DD}	V_{DD}=5V, no load, no signal input		8		mA
consumption current in Shutdown mode (AVDD+PVDD)	I_{SD}	CTRL=V_{SS}, Ta=25℃		0.01		μA
Voltage of Terminal BYPASS	V_{BYPASS}			$V_{DD}/2$		V

● Analog Characteristics

V_{SS}=0V, V_{DD} =5V, Av=18dB, Ta=25ºC, C_{IN}=33nF, R_{IN}=12 kΩ, 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, V_{DD}=5V			5.4		
		R_L=4Ω, V_{DD}=3.7V			1.9		
		R_L=2Ω, V_{DD}=3.7V			3.0		
Total Harmonic Distortion plus Noise (BW：20kHz)	THD+N	R_L=4Ω, P_O=1W, f=1kHz			0.12		%
		R_L=8Ω, P_O=0.5W, f=1kHz			0.10		%
Output Noise	V_N	f=20Hz~20kHz, A-Filter, Av=18dB			45		μV_{rms}
Signal /Noise Ratio (BW：20kHz A-Filter)	SNR	A-Filter, Av=18dB			90		dB
Power supply rejection ratio	PSRR	Ripple Wave Vpp=200mV, f=1kHz			-80		dB
Efficiency	η	VDD=5V, RL=8Ω, PO=1W			89		%
Output offset voltage	V_{OS}				±5		mV
Frequency characteristics	f_{RES}	C_{IN} =0.1μF, f=100Hz~20kHz		-3	-	1	dB
Voltage Gain	Av_0	R_{IN}=12 kΩ			24		dB
ACF maximum attenuation gain	Aa			-10		0	dB

* All the values of analog characteristics were obtained by using our evaluation circumstance; Depending upon parts and pattern layout to use, characteristics may be changed.

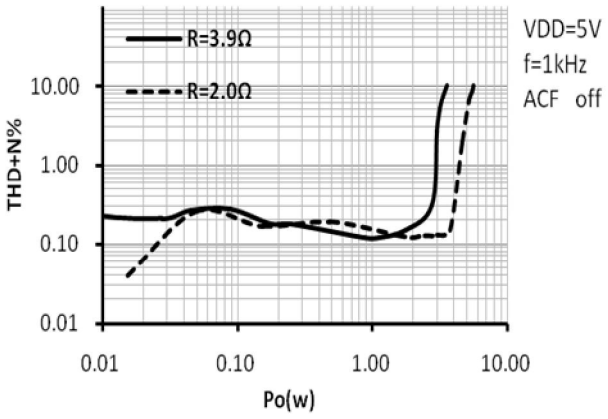
● AC Characteristics

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}			260		ms
Input cut-off frequency	f_C	C_{IN}=33nF, R_{IN}=27kΩ		179		Hz
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

Po VS THD+N%



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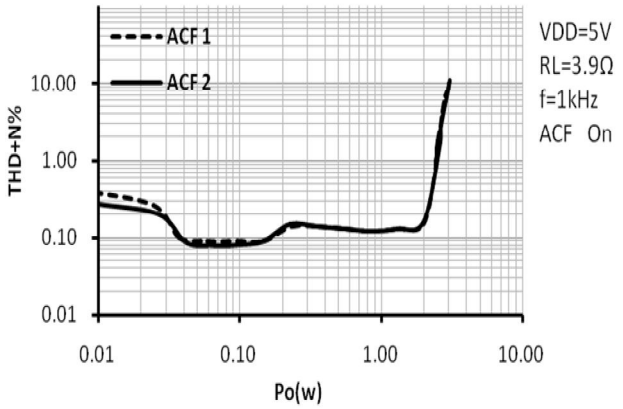
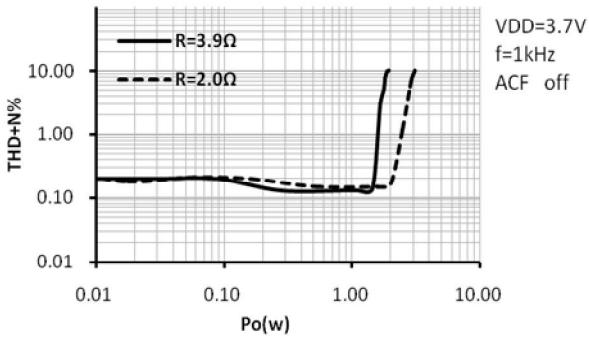
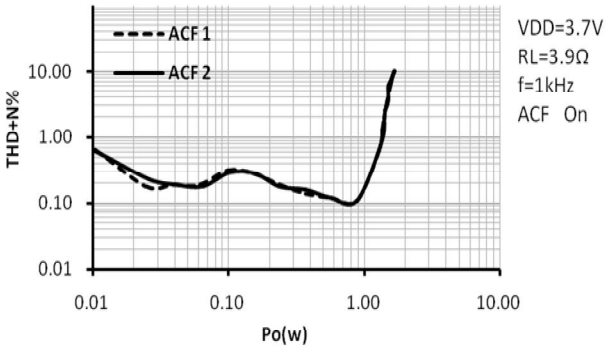


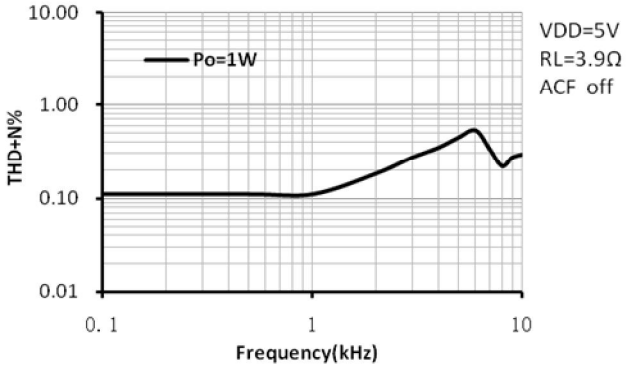
Po VS THD+N%



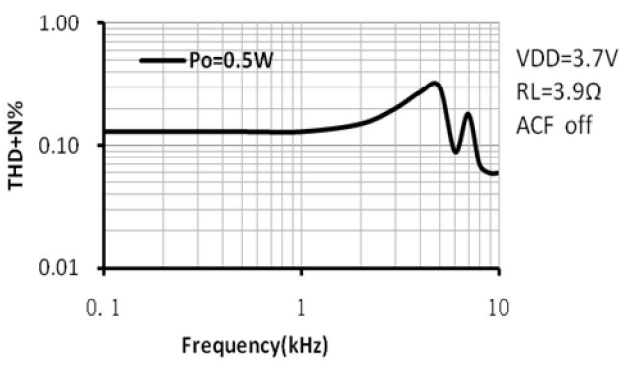
Po VS THD+N%



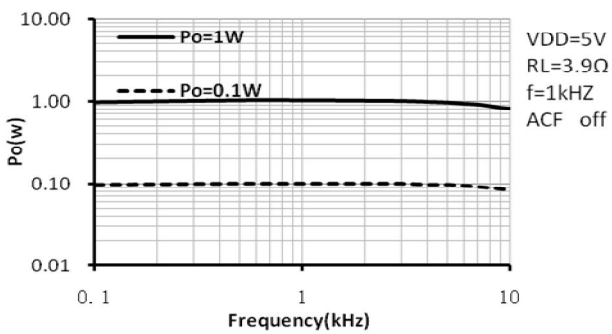
TND+N% VS Frequency



TND+N% VS Frequency



Po vs Frequency



■ APPLICATION INFORMATION

● Analog Signal Input Configuration

HT6879 is an amplifier with analog input (single-ended or differential), PWM pulse output.

For a differential input between IN+ and IN- pins, signals input via DC-cut capacitors (C_{IN}), the frequency of input signal $f_c = 1/(2\pi Z_{IN} C_{IN})$.

For a single-ended input at IN+ pin, signal input via a DC-cut capacitor (C_{IN}). IN- pin should be connected to AVSS via a DC-cut capacitor (with the same value of C_{IN}). The frequency of input signal are the same as the above case.

The output impedance (Zout) of the former source circuit, including signal paths up to INL+ terminal and IN- terminal should be designed to be 600Ω or lower.

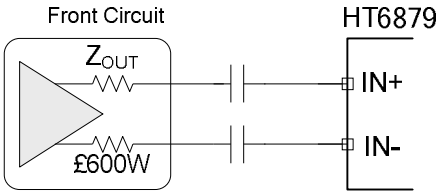


Fig.1 Differential Input

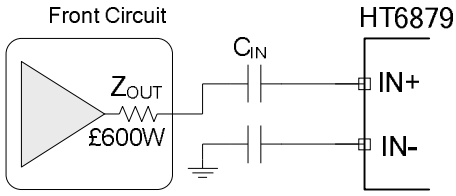


Fig.2 Single-ended Input

● Digital Volume Control

HT6879 can realize 32-step digital volume control through terminal UP/DN.The frequency of inner counter clock is shown as below:

$$f_{CLK} = f_{OSC} / 2^{13}$$

f_{OSC} is the frequency of inner oscillator, the typical value is around 216KHz. And the typical value of f_{CLK} is 26.4Hz (cycle=38ms).

Considering the effects of the internal delay and process variation, T1=24~32ms（±10%）。

Setting the UP/DN terminal to a logic low level can control the volume up or down, the control timing is shown as Fig3, in which T1 is the preventive time for chattering, and after a period of T1, the volume is up or down by one step; T2 is the switching time to automatic mode, and after a period of T2, the volume is up or down by one step continually; then, every time after a period of T3, the volume is up or down by one step to realize a quick, continuous change of the volume.

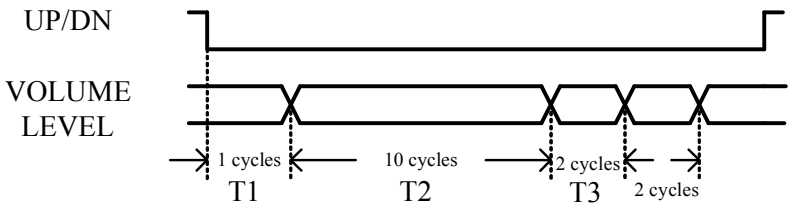


Fig.3 Volume Control Timing

Note:

- When the UP and DN terminals are set to a logic low at the same time, the volume is not changed;
- When the system is set from the Mute mode/Shut-down mode back to the normal mode, the volume is not changed;
- When the system is powered on, the initial gain is 9dB;
- The gain of 32-step volume control is shown as Table 1.

Table 1. Volume Control Gain

Step	Gain*3 (dB)	Step	Gain(dB)	Step	Gain(dB)
1	MUTE	12	-7	23	15
2	-37	13	-5	24	16
3	-34	14	-3	25	17
4	-31	15	-1	26	18
5	-28	16	1	27	19
6	-25	17	3	28	20
7	-22	18	5	29	21
8	-19	19	7	30	22
9	-16	20	9	31	23
10	-13	21	11	32	24
11	-10	22	13		

*3 The gain refers to the overall gain of the system.

● 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).

Table 2. Different Mode Setting Voltages of CTRL terminal

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

There're 2 ways to set the CTRL terminal in application as shown below, CTRL terminal set up inside the 200K Ω(± 10%) pulldown resistor:

（1）MCU Control Setting

By connecting external resistors (R_{CTRL1}, R_{CTRL2} and R_{CTRL3}, accuracy of 1%) to CTRL terminal, and setting threshold voltage of each mode to CTRL1 and CTRL2 terminal, the above four modes can be set. Connect the terminal to the ground through a capacitor C_{CTRL} (a ceramic capacitor of 0.1μF or more) to eliminate noise during mode Setting.

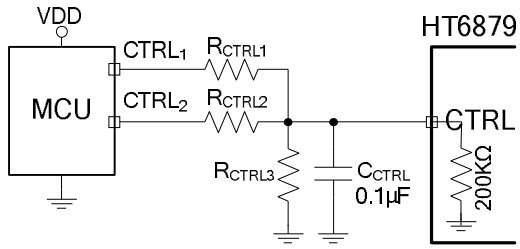


Fig. 4 CTRL terminal control circuit

Table 3. Mode Setting

CTRL1	CTRL2	Mode
H	H	ACF-Off
GND	H	ACF-1
H	GND	ACF-2
GND	GND	SD

"H" indicates High level output voltage of microcomputer's I/O port that is input to CTRL1 and CTRL2 terminals and GND indicates Ground level of the microcomputer. GND level of the microcomputer must be the same as that of HT6871. The control of CTRL terminal is based on I/O port H level output voltage of microcomputer that is connected. Set resistor values according to I/O port H levels, as shown below.

Table 4. H levels vs. Resistor Values

H levels of I/O port	5.0V
R_{CTRL1}	100kΩ
R_{CTRL2}	68kΩ
R_{CTRL3}	82kΩ

When a single control terminal of CTRL1 is used, only a switching between ACF-Off mode and SD mode is available. A setting voltage should be set according to V_{MOD1} and V_{MOD4}, and use a RC filter with time constant of 1msec or more in order to eliminate noise during transition. (As an example, R_{CTRL}=10kΩ and C_{CTRL}=0.1μF). Of course, also need to consider the built-in 200K pulldown resistor.

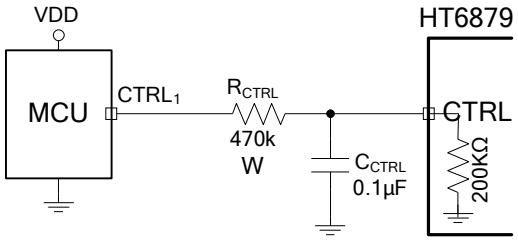


Fig. 5 CTRL terminal control circuit

Table 5. Mode Setting

CTRL1	Mode
H	ACF-Off
GND	SD

（2）Switching Control Setting

ACF-Off mode only

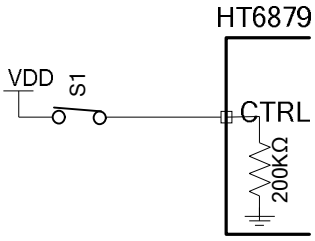


Fig. 6 ACF-Off Mode Circuit

Table 6. Mode Choice

S1	Mode
Close	ACF-Off
Open	Shutdown

If shutdown mode is not needed, S1 can be removed.

● CTRL Mode Function Detail

(一) ACF ON 模式

In ACF-1 and ACF-2 modes, HT6879 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 HT6879 also follows to the clips of the output waveform due to the decrease in the power-supply voltage.

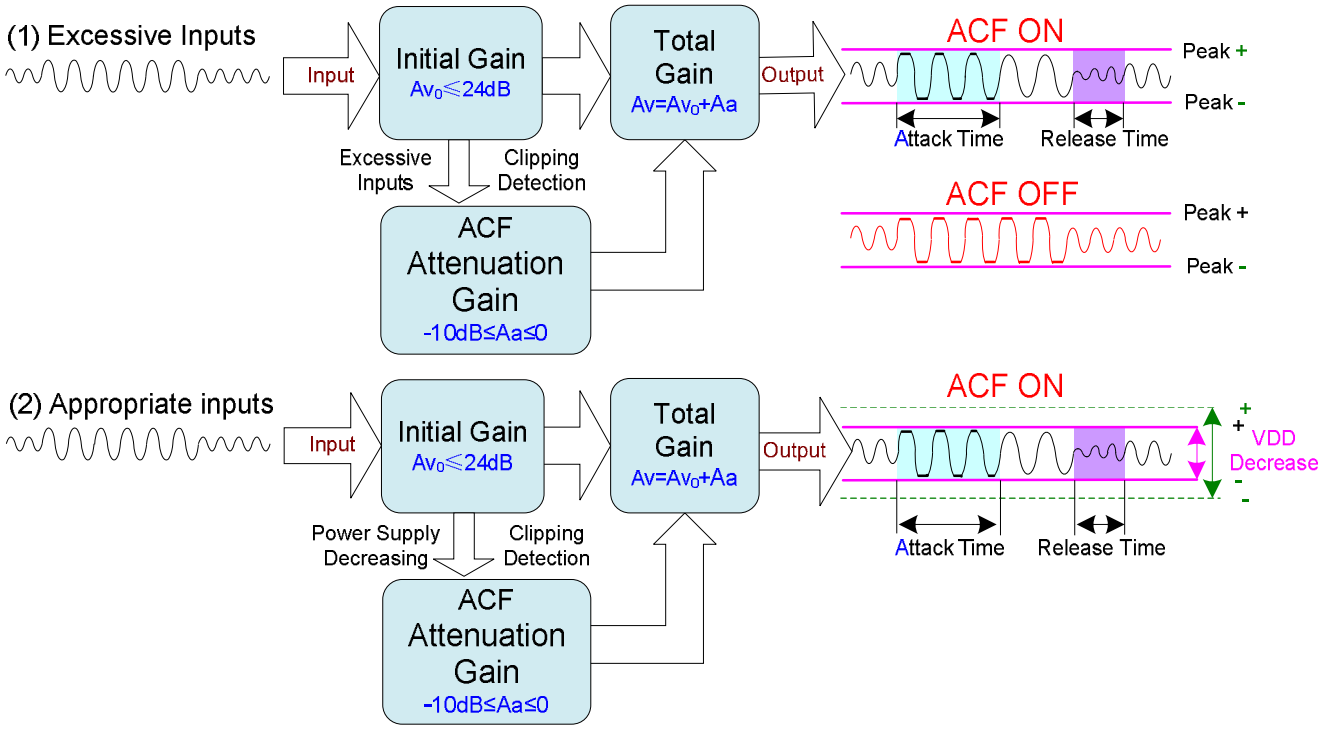


Fig.7 the ACF Function Operation Outline

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.

Table 7. Attack time and Release time

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

(二) ACF OFF Mode

In ACF-Off mode, ACF function is disenabled. HT6879 will not detect output clipping and the system gain is kept to be $Av=Av_0=24dB$. The audio quality would worsen due to clipping distortion.

(三) SD Mode

In shutdown mode, HT6879 shuts all circuit down and minimizes the power consumption. And, the output terminals become Weak Low (A high resistance grounded state).

● CTRL Mode Setting Sequence

When CTRL terminal is connected to GND potential with a holding time more than t_{SD}, the IC enters shutdown mode. In the mode, all the circuit functions stop and its current consumption becomes the lowest. On the contrary, when CTRL terminal is set to H level, the shutdown mode is canceled and the IC starts up after startup time (t_{STUP}). Please pay attention to the following startup initialization process.

(1) Please start up the former source circuit first to stabilize the DC bias (See Fig. 8-②) and then cancel the shutdown state. Signal variation in the former source circuit should be a value lower than VDD. The time required to stabilize the voltage can be found by

$$T_{DLY} \geqq C_{IN} \times 330 \times 10^{3} \times 3$$

When C_{IN}=33nF, $T_{DLY} \geqq$ 33ms.

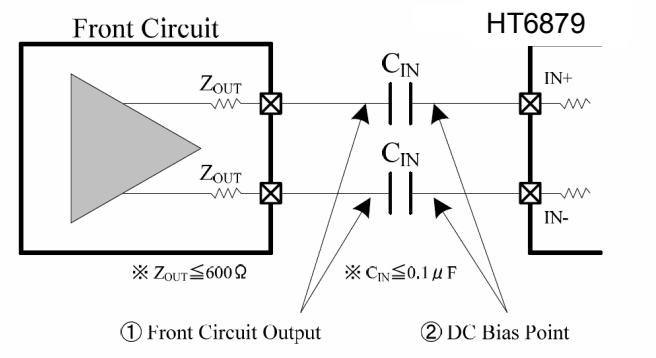


Fig. 8 the Former Circuit

● Pop-Click Noise Reduction

The Pop-Click Noise Reduction Function of HT6879 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 (CIN) 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 fist.

● Protection Function

HT6879 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 HT6879 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)。

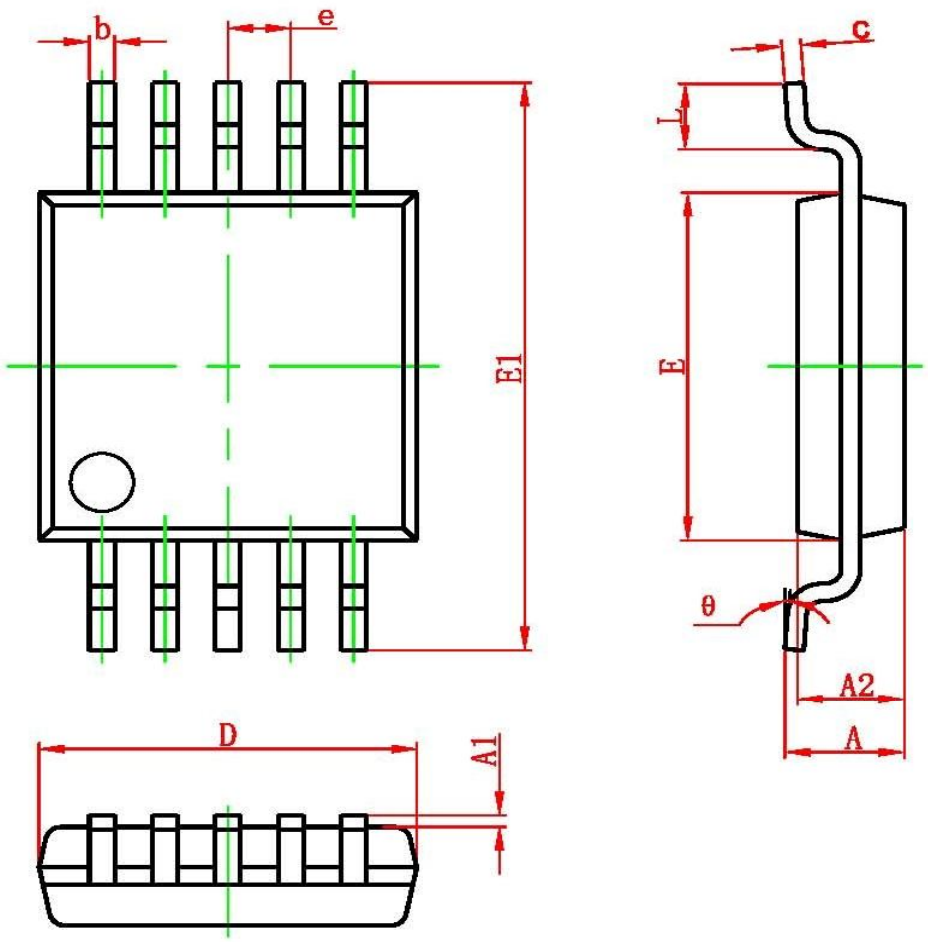
（3）Low voltage Malfunction Prevention function

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). HT6879 will start up within the start-up time (T_{STUP}) when the low voltage protection mode is cancelled.

■ PACKAGE OUTLINE

● MSOP10

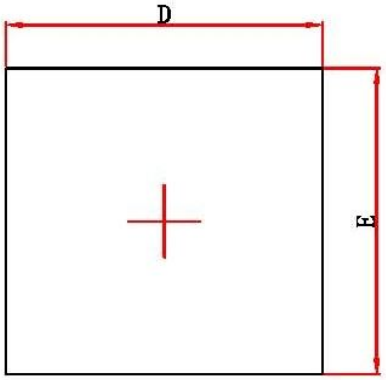
MSOP10 PACKAGE OUTLINE DIMENSIONS



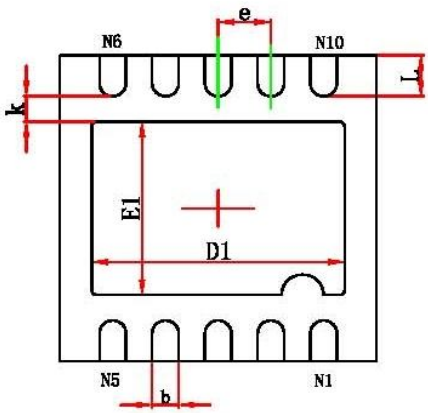
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.820	1.100	0.032	0.043
A1	0.020	0.150	0.001	0.006
A2	0.750	0.950	0.030	0.037
b	0.180	0.280	0.007	0.011
c	0.090	0.230	0.004	0.009
D	2.900	3.100	0.114	0.122
e	0.50(BSC)		0.020(BSC)	
E	2.900	3.100	0.114	0.122
E1	4.750	5.050	0.187	0.199
L	0.400	0.800	0.016	0.031
θ	0°	6°	0°	6°

- **DFN10**

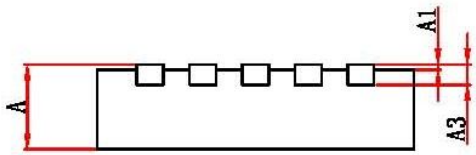
DFNWB3×3-10L(P0.50T0.75/0.85)PACKAGE OUTLINE DIMENSIONS



Top View



Bottom View



Side View

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.700/0.800	0.800/0.900	0.028/0.031	0.031/0.035
A1	0.000	0.050	0.000	0.002
A3	0.203REF.		0.008REF.	
D	2.900	3.100	0.114	0.122
E	2.900	3.100	0.114	0.122
D1	2.300	2.500	0.091	0.098
E1	1.600	1.800	0.063	0.071
k	0.200MIN.		0.008MIN.	
b	0.180	0.300	0.007	0.012
e	0.500TYP.		0.020TYP.	
L	0.300	0.500	0.012	0.020

Version Declaration

HT6809 datasheet V0.3 is not the formal version, the data is not detailed.

经销代理：深圳市宝华龙科技有限公司
联系电话：0755-83510265，83510263，83281126
联系人：白小姐：13530052189
范小姐：13922814036
梁先生：15813872244