Class-K Audio Amplifier with RF-TDD Suppression and Unique FM Mode

Features

- **K5: the 5nd Class-K Audio Amplifier, realize five kinds of operating mode**
- **Built-In RNS Function，Excellent TDD Suppression**
- **Unique FM mode, completely eliminate FM、ATV noise**
- **Unique Net audio mode**
- **NCN Function Protects the Speaker**
- **EEE Function，Greatly reduces EMI over the full bandwidth**
- **Anti-jamming one-wire pulse control technology**
- **High PSRR: -75dB (217Hz)**
- **Thermal AGC Function**
- **Class-K Audio Amplifier, uses high voltage dual-gate CMOS process**
- **Excellent Pop-Click Suppression**
- **Short-Circuit and Thermal Protection**
- **Small 3mm×3mm 20-Pin TQFN Package**

Applications

- Cellular Phones
- Portable Audio Devices
- Mini Speakers

General Description

The AW8735 is a powerful Class-K audio amplifier with AB/D output mode selection; the power stage voltage can select supplied by charge pump or straightly supplied by battery. AW8735 features unique FM mode and Net audio mode, designed for mobile phone audio application and development.

The AW8735 realizes five kinds of working mode by one-wire pulse control technology, can offer the needed working mode according to different power of the speaker. All five kinds of mode with NCN technology effectively prevent the crack noise.

The AW8735 features the RNS function which greatly reduces RF-TDD Noise.

The AW8735 features Net audio technology which can further reduces RF-TDD noise, an acceptable audible level to the customer.

The AW8735 features a built-in charge pump converter generates a 6.3V supply voltage. This provides a louder audio output than a stand-alone amplifier directly connected to the battery. The AW8735 features 2.3W output power (10% THD+N) into 8Ω load at 4.2V battery voltage.

The AW8735 features the NCN function, which adjusts the system gain automatically while detecting the “Crack” distortion of output signal, protects the speaker from damage at high power levels and brings the most comfortable listening experience to the customers.

The AW8735 is available in a small 3mm×3mm 20-Pin TQFN Package. It is specified over the extended -40℃ to +85℃ temperature range.

Pin Configuration and Top Mark

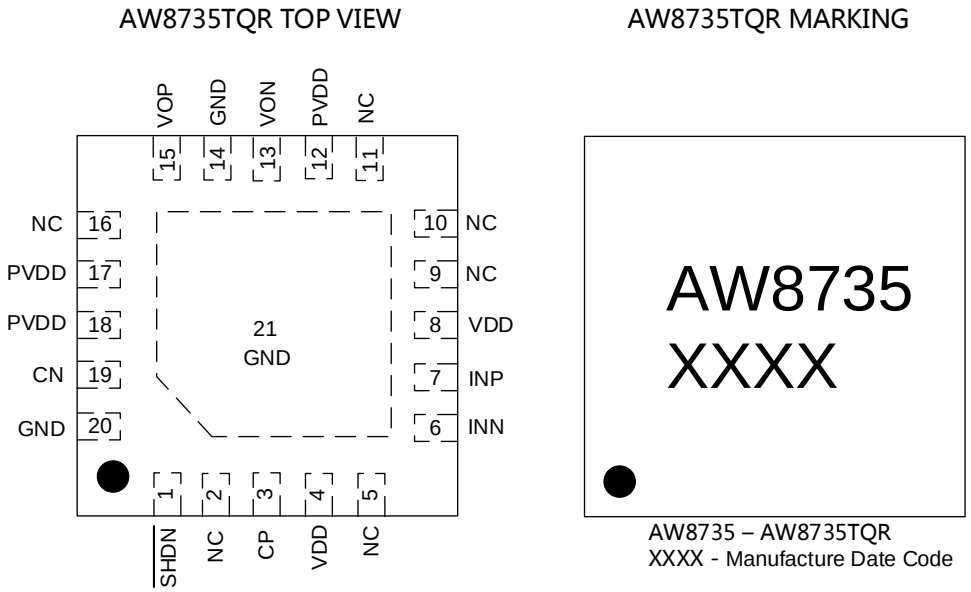


Figure 1 Pin Configuration and Top Mark of AW8735TQR

Pin Definition and Function

No.	Symbol	Description
1	$\overline{\text{SHDN}}$	Shutdown and one-wire control pin
3	CP	Positive Terminal of Flying capacitor
4，8	VDD	Supply Voltage.
6	INN	Negative Amplifier Input
7	INP	Positive Amplifier Input
12，17，18	PVDD	Charge-Pump Output.
13	VON	Negative Amplifier output
14，20	GND	Ground
15	VOP	Positive Amplifier Output
19	CN	Negative Terminal of Flying capacitor.
21	GND	Exposed Pad. Connect to GND.
2，5，9, 10，11，16	NC	No Connect

Typical Application

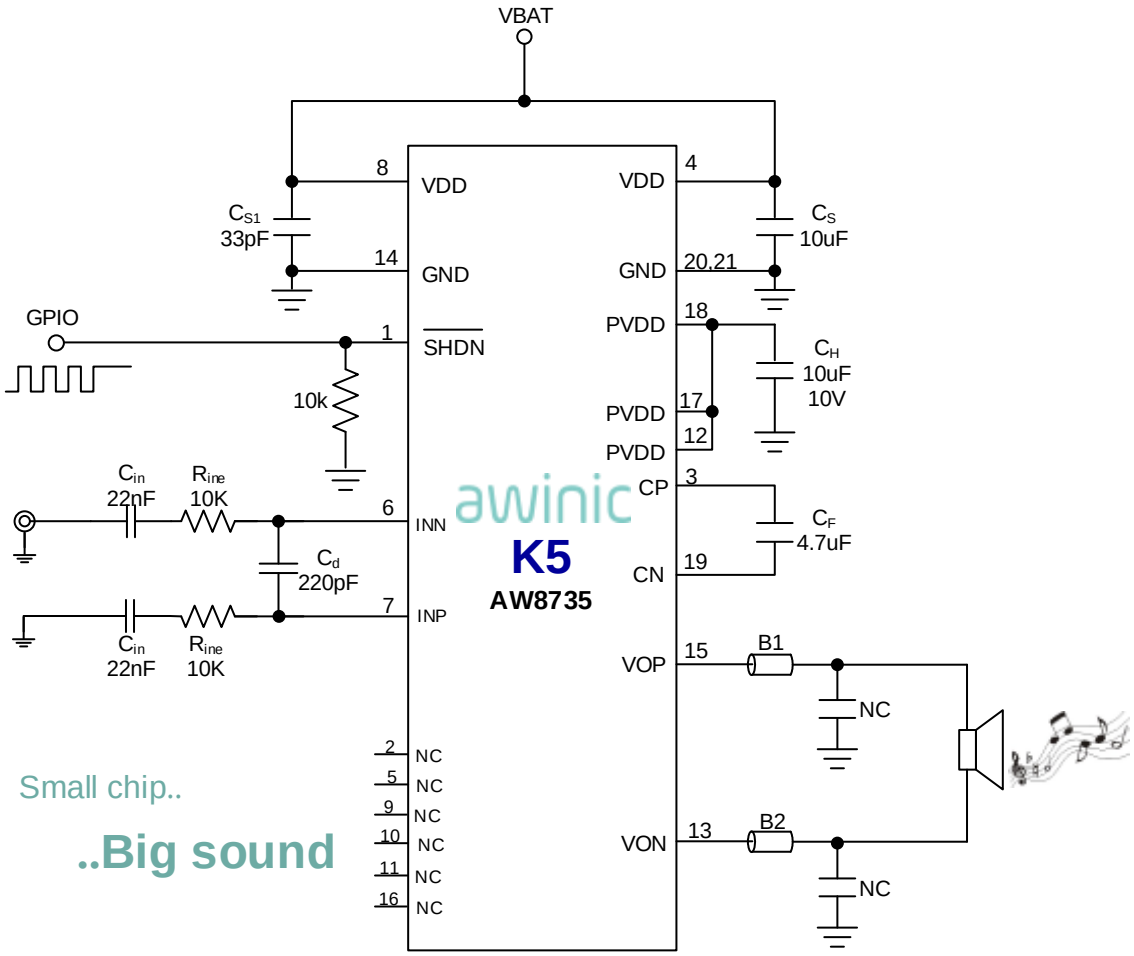


Figure 2 AW8735 Application Schematic With Single-Ended Input

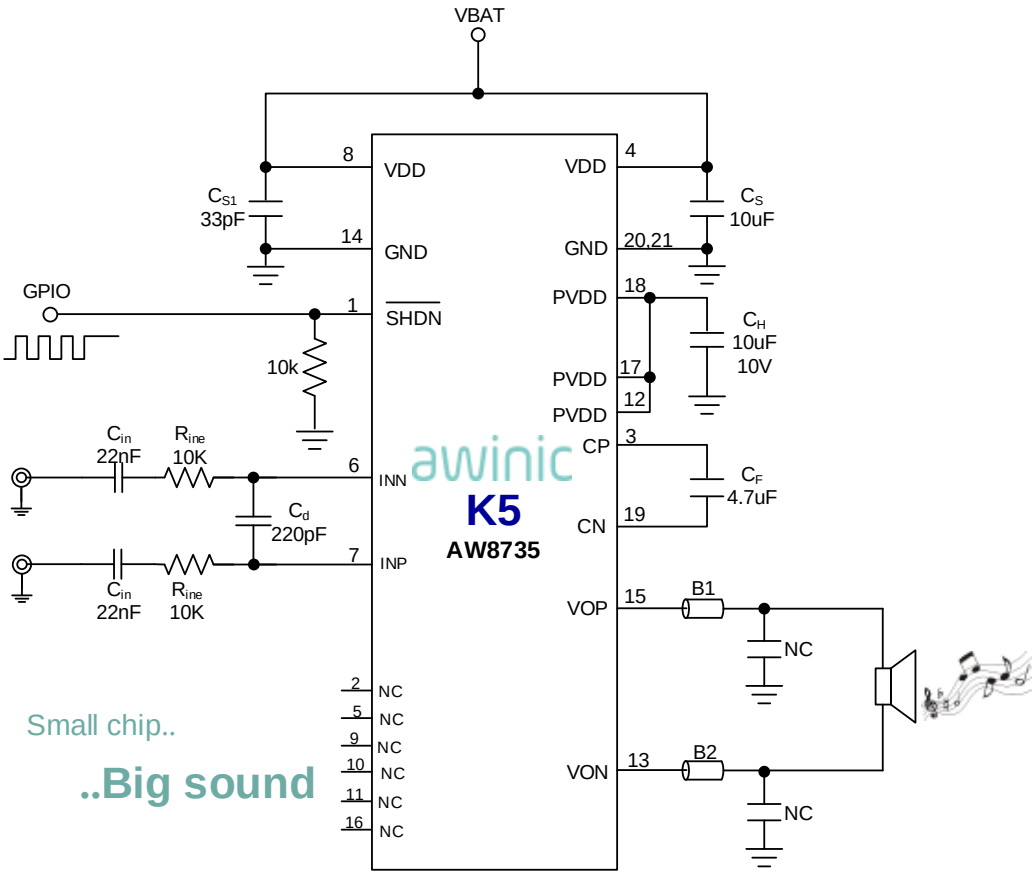
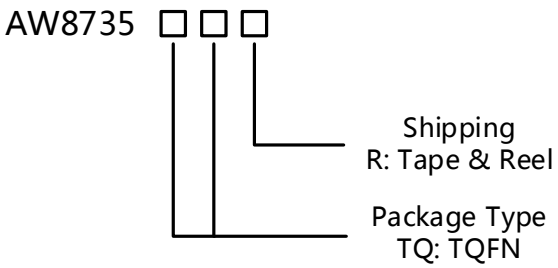


Figure 3 AW8735 Application Schematic With Differential Input

Ordering Information

Part Number	Temperature	Package	Marking	Packing Type
AW8735TQR	-40℃～85℃	3mmX3mm 20-Pin TQFN	AW8735	6000 units/Tape and Reel



Absolute Maximum Ratings(note1)

Parameter	Unit
Supply voltage V_{DD}	-0.3V to 7V
INP、INN、$\overline{SHDN}$ Pin Voltage	-0.3V to V_{DD}+0.3V
Package Thermal Resistance θ_{JA}	48℃/W
Operating free-air temperature	-40℃ to 85℃
Maximum Junction Temperature T_{JMAX}	125℃
Storage Temperature Range T_{STG}	-65℃ to 150℃
Lead Temperature (Soldering 10 Seconds)	260℃
ESD Rating(note2)	
HBM(human body model)	±8KV
Latch-up	
Test Condition：JEDEC STANDARD NO.78D NOVEMBER 2011	+IT：450mA -IT：-450mA

note1: 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.

note2: The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin. Test method: MIL-STD-883H Method 3015.8.

Operating Mode Description

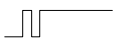
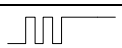
模式	$\overline{SHDN}$	Charge pump	PVDD (note3)	A_V(note 4)	NCN	RNS	描述
Class-AB mode			VBAT	12	√	√	Analog output，with prevent the cracking voice function
Class-D mode			VBAT	12	√	√	High efficiency， drives the small-power speaker
FM mode		√	6.3V	16	√	√	Analog output，charge pump on
Class-K mode		√	6.3V	24	√	√	charge pump output，drives the high-power speaker
Net audio mode		√	6.3V	24	√	√	Net audio mode， which can further reduces RF-TDD noise

Table1 Table 1 AW8735 working mode specification

note3: The power stage voltage of Class-AB and Class-D is directly supplied by VBAT, so PVDD equals VBAT. FM mode、Class-K and Net audio mode with charge pump, the voltage of PVDD equals 6.3V.

note4: The parameter Av is the gain when the external input resistance is 10KΩ.

Electrical Characteristics

Test Condition：T_A=25℃，R_L=8Ω+33uH（Unless otherwise specified）

Parameter		Conditions		Min	Typ	Max	Units
V_{DD}	Power Supply			2.5		4.5	V
I_{SD}	Shutdown current	V_{DD}=3.6V， $\overline{SHUTDOWN}$=0V			0.1		μA
V_{IH}	$\overline{SHDN}$ high-level input			1.3		V_{DD}	V
V_{IL}	$\overline{SHDN}$ low-level input			0		0.35	V
T_{TG}	Thermal AGC Protect level				155		℃
T_{TGR}	Thermal AGC Hysteresis				120		℃
T_{SD}	Thermal Protect level				160		℃
T_{SDH}	Thermal Hysteresis				40		℃
T_{ON}	Start-up time				28		ms
Charge Pump							
PVDD	Output Voltage	V_{DD} =3.3V to 4.5V，no load			6.3		V
F1	Switching Frequency	VDD=3V to 5.5V		480	600	720	kHz
T_{ST}	Soft-start time	No load，COUT=10uF			0.5		ms
I_L	PVDD short to GND current limit				300		mA
Power amplifer							
Class-AB							
I_q	Quiescent current				6.4		mA
η	efficiency	V_{DD}=3.6V，Po=0.8W，R_L=8Ω			72		%
Av	Gain	external input resistance is 10 kΩ			12		V/V
Rini	Internal impedance				10		kΩ
PSRR	Power supply rejection ratio	V_{DD}=4.2V，Vp-p_sin=200mV	217Hz		-70		dB
			1kHz		-68		dB
THD+N	Total harmonic distortion plus noise	V_{DD}=4.2V，Po=0.5W，f=1kHz			0.26		%
		V_{DD}=3.6V，Po=0.25W，f=1kHz			0.23		%
P_O	Output power	THD+N=10%，f=1kHz，V_{DD}=4.2V			1		W
		THD+N=1%，f=1kHz，V_{DD}=4.2V			0.78		W
Class-D							
I_q	Quiescent current	V_{DD}=3.6V，no input，no load			3.2		mA
η	efficiency	V_{DD}=3.6V，Po=0.9W，R_L=8Ω			80		%
Fosc	Modulation frequency	V_{DD}=2.5V to 4.5V			300		kHz
Av	magnification	external input resistance is 10 kΩ			12		V/V
Rini	Internal impedance				10		kΩ
PSRR	Power supply rejection ratio	V_{DD}=4.2V，Vp-p_sin=200mV	217Hz		-71		dB
			1kHz		-70		dB
THD+N	Total harmonic distortion plus	V_{DD}=4.2V，Po=0.5W，f=1kHz			0.18		%

	noise	V_{DD}=3.6V，Po=0.25W，f=1kHz		0.22	%
P_O	Output power	THD+N=10%，f=1kHz，V_{DD}=4.2V		1	W
		THD+N=1%，f=1kHz，V_{DD}=4.2V		0.85	W
FM mode					
I_q	Quiescent current	V_{DD}=3.6V，no input，no load		16	mA
η	efficiency	V_{DD}=3.6V，Po=1W，R_L=8Ω		43	%
Av	Gain	external input resistance is 10 kΩ		16	V/V
Rini	Internal impedance			5	kΩ
PSRR	Power supply rejection ratio	V_{DD}=4.2V，Vp-p_sin=200mV	217Hz	-80	dB
			1kHz	-75	dB
THD+N	Total harmonic distortion plus noise	V_{DD}=4.2V，Po=0.5W，f=1kHz		0.23	%
		V_{DD}=3.6V，Po=0.25W，f=1kHz		0.24	%
P_O	Output power	THD+N=10%，f=1kHz，V_{DD}=4.2V		2.1	W
		THD+N=1%，f=1kHz，V_{DD}=4.2V		1.7	W
Class-K					
I_q	Quiescent current	V_{DD}=3.6V，no input，no load		10.2	mA
η	efficiency	V_{DD}=3.6V，Po=1W，R_L=8Ω		66	%
Fosc	Modulation frequency	V_{DD}=2.5V to 4.5V		300	kHz
Av	Gain	external input resistance is 10 kΩ		24	V/V
Rini	Internal impedance			5	kΩ
PSRR	Power supply rejection ratio	V_{DD}=4.2V，Vp-p_sin=200mV	217Hz	-75	dB
			1kHz	-72	dB
THD+N	Total harmonic distortion plus noise	V_{DD}=4.2V，Po=0.5W，f=1kHz		0.2	%
		V_{DD}=3.6V，Po=0.25W，f=1kHz		0.2	%
P_O	Output power	THD+N=10%，f=1kHz，V_{DD}=4.2V		2.3	W
		THD+N=1%，f=1kHz，V_{DD}=4.2V		1.9	W
Net audio mode					
I_q	Quiescent current	V_{DD}=3.6V，no input，no load		10.2	mA
η	efficiency	V_{DD}=3.6V，Po=1W，R_L=8Ω		66	%
Fosc	Modulation frequency	V_{DD}=2.5V to 4.5V		300	kHz
Av	Gain	external input resistance is 10 kΩ		24	V/V
Rini	Internal impedance			5	kΩ
PSRR	Power supply rejection ratio	V_{DD}=4.2V，Vp-p_sin=200mV	217Hz	-85	dB
			1kHz	-80	dB
THD+N	Total harmonic distortion plus noise	V_{DD}=4.2V，Po=0.5W，f=1kHz		0.2	%
		V_{DD}=3.6V，Po=0.25W，f=1kHz		0.2	%
P_O	Output power	THD+N=10%，f=1kHz，V_{DD}=4.2V		2.3	W
		THD+N=1%，f=1kHz，V_{DD}=4.2V		1.9	W
V_{LIMIT}	Net audio Vth (Vp)	external input resistance is 10 kΩ		15	mV
A_{MAX1}	Net audio maximum attenuation			-15	dB
one-wire pulse control					

T_H	$\overline{SHDN}$ high level hold time	V_{DD}=2.5V to 5.5V	0.75	2	10	us
T_L	$\overline{SHDN}$ low level hold time	V_{DD}=2.5V to 5.5V	0.75	2	10	us
T_{OFF}	$\overline{SHDN}$ delay time	V_{DD}=2.5V to 5.5V			500	us
NCN（note5）						
T_{AT}	Attack time			20		ms
T_{RL}	Release time			1.2		s
A_{MAX}	Maximum attenuation gain			-6		dB
Flying Capacitor detection（note6）						
CF_{LIMITH}	Flying capacitor high-level threshold	V_{DD}=2.5V to 4.5V	500			nF
CF_{LIMITL}	Flying capacitor low-level threshold	V_{DD}=2.5V to 4.5V			1	nF

note5: The start-up time refers to the time gain attenuation 6dB; The release time refers to the time gain recovery 6dB.

note6: The system is in charge pump mode when Flying capacitor is greater than 500nF; The system power stage voltage is straightly supplied by battery when Flying capacitor is less than 1nF

Measurement System

AW8735 features switching output signal. As shown in Figure 4. A Low-Pass RC filter can be used to remove high switching frequency in output signal.

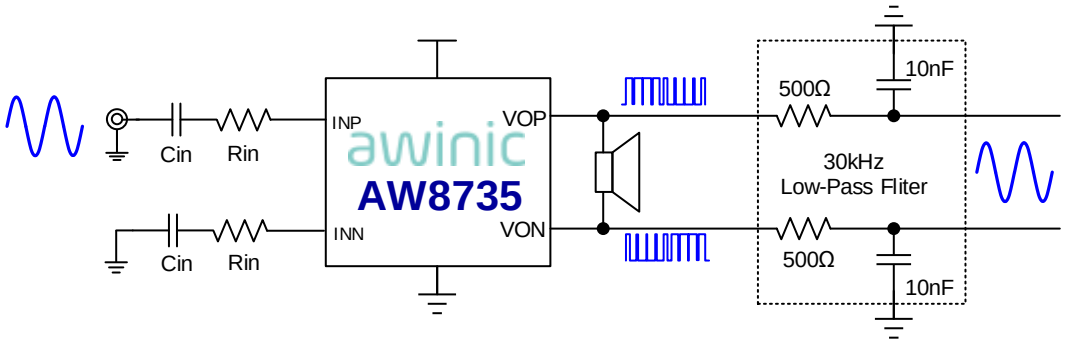


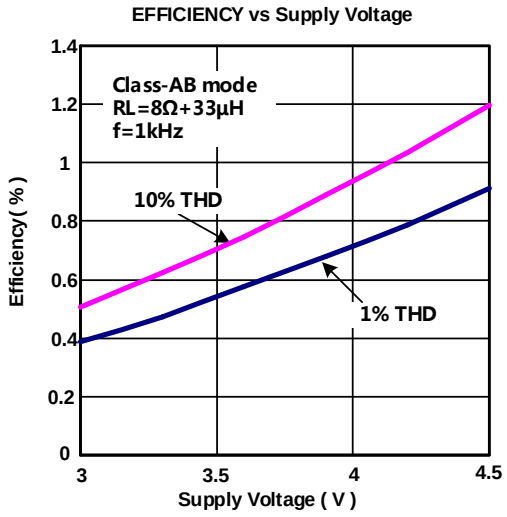
Figure 4 AW8735 measurement system

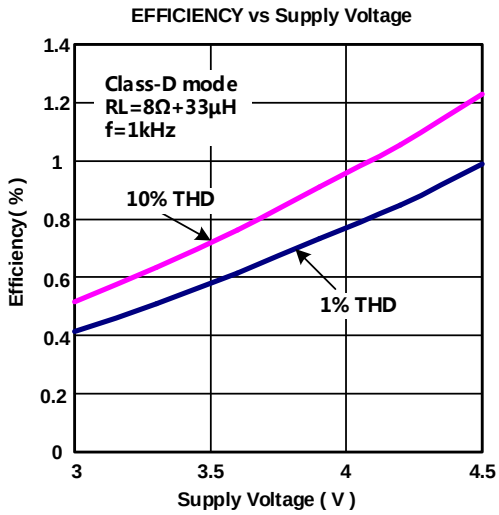
Table 2 shows recommended values of R_{filter} and C_{filter}.

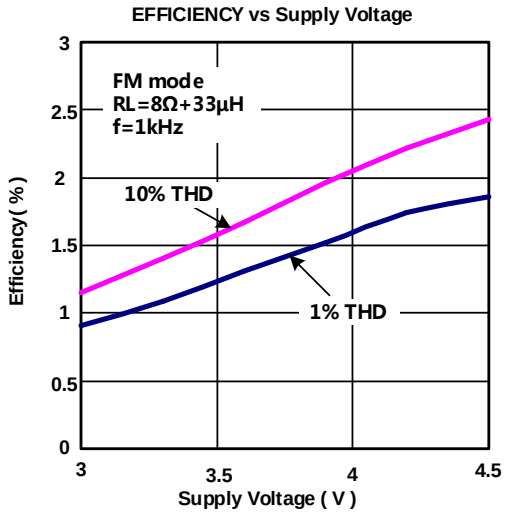
R_{filter}	C_{filter}	Low-pass cutoff frequency
500Ω	10nF	32kHz
1kΩ	4.7nF	34kHz

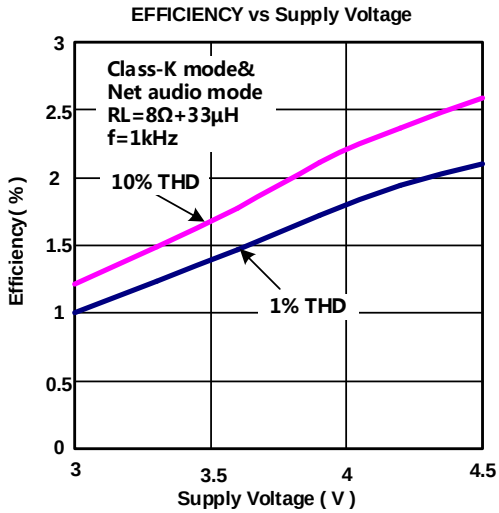
Table2 Typical RC Measurement Filter Values

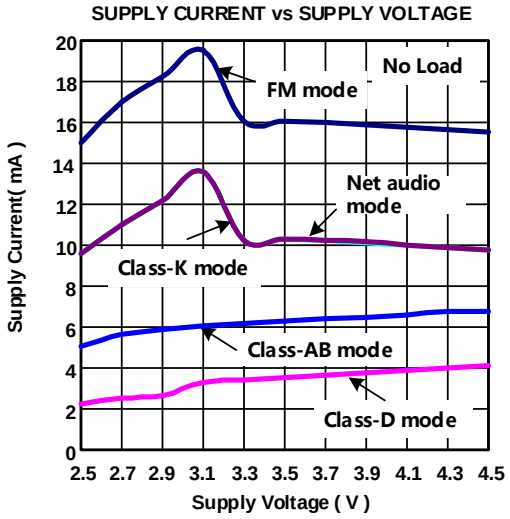
Typical Operating Characteristics

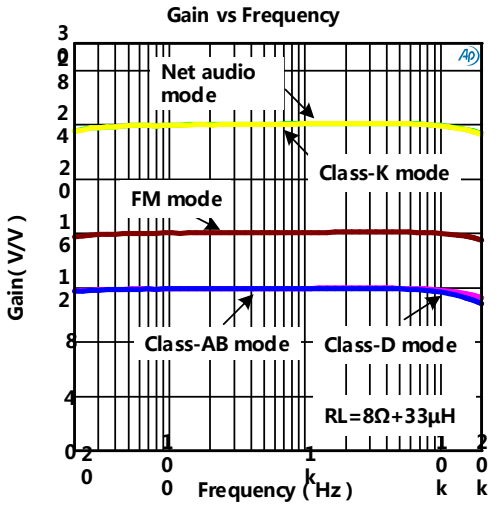


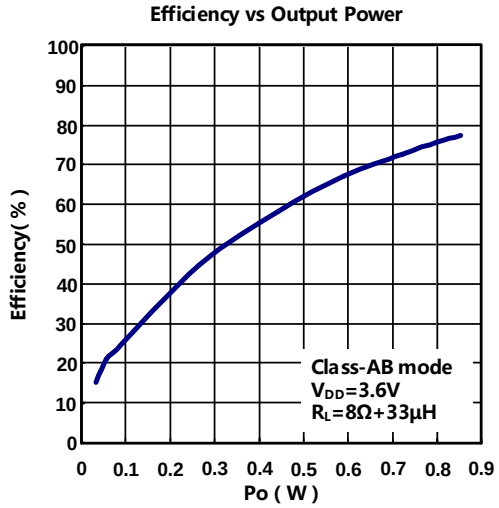


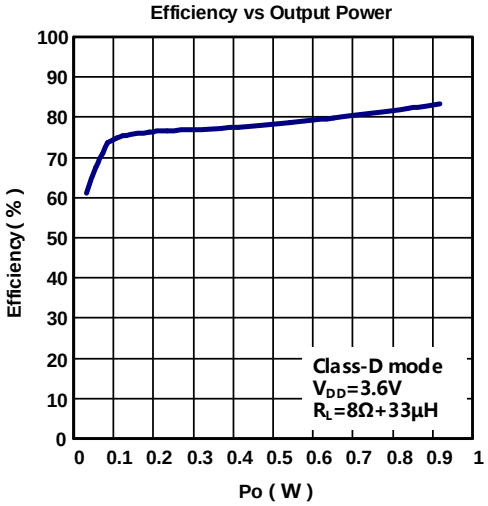


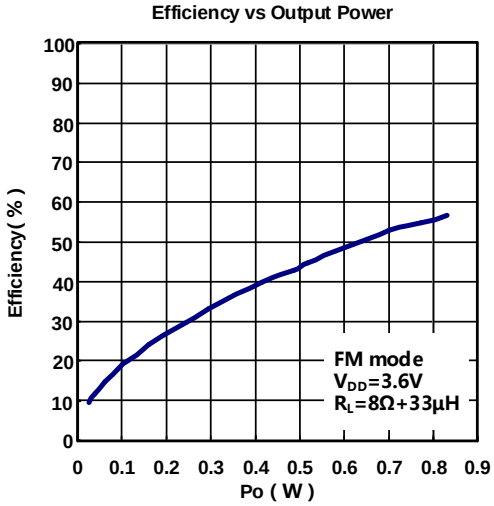


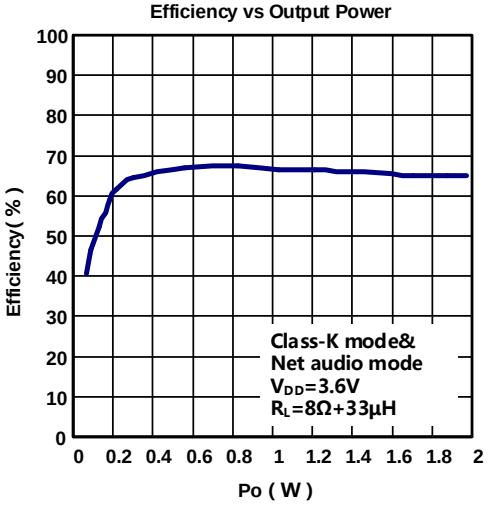


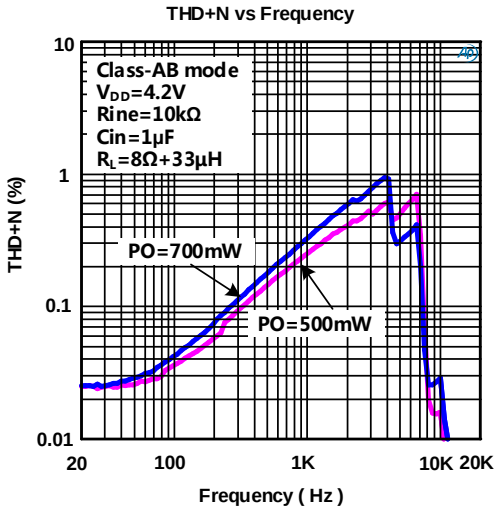


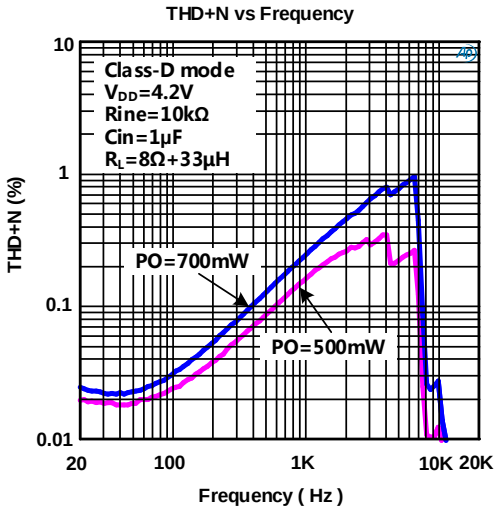




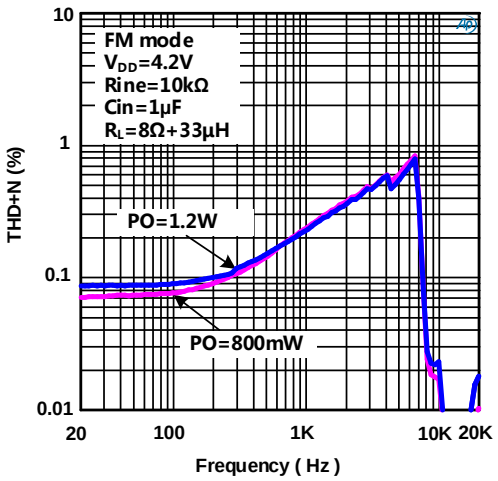




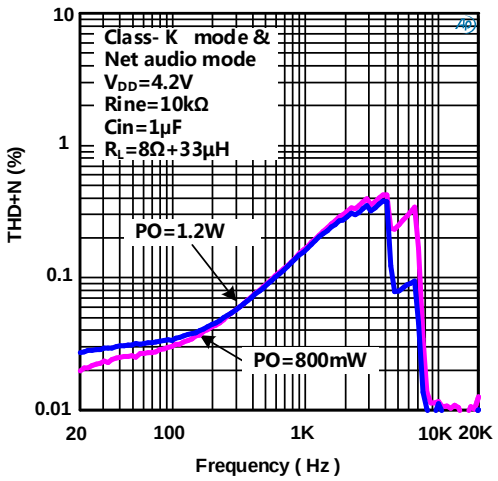




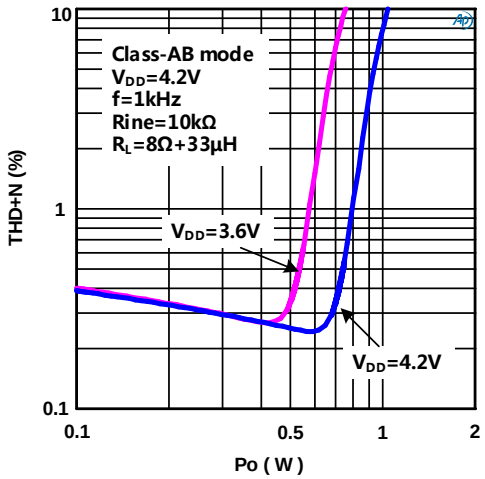
THD+N vs Frequency



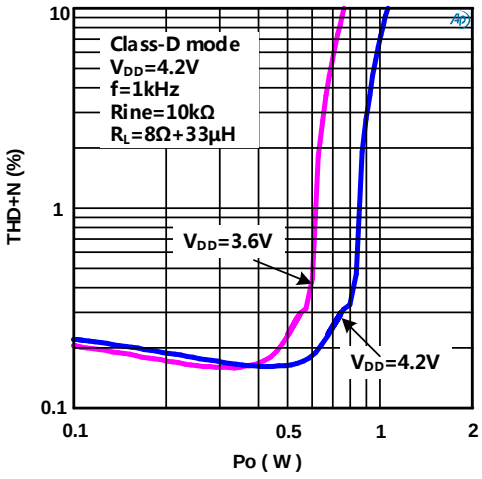
THD+N vs Frequency



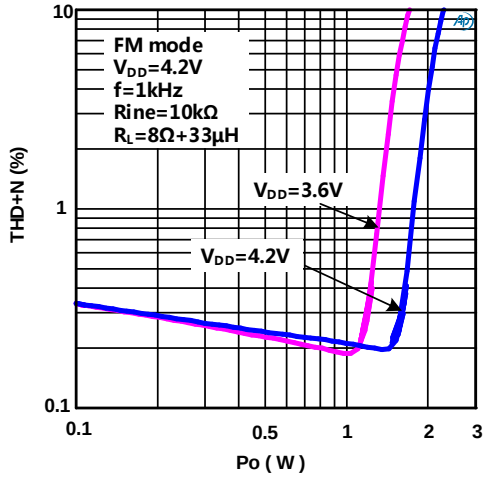
THD+N vs Output Power



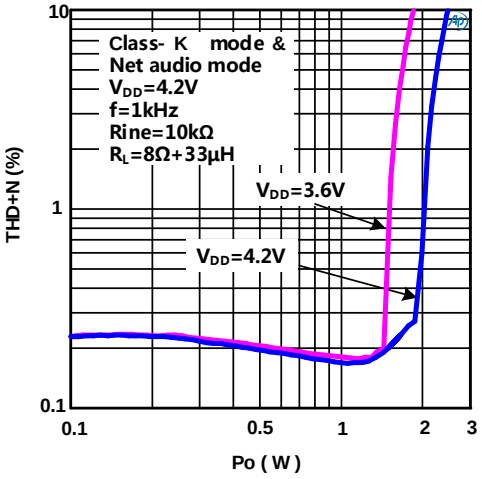
THD+N vs Output Power

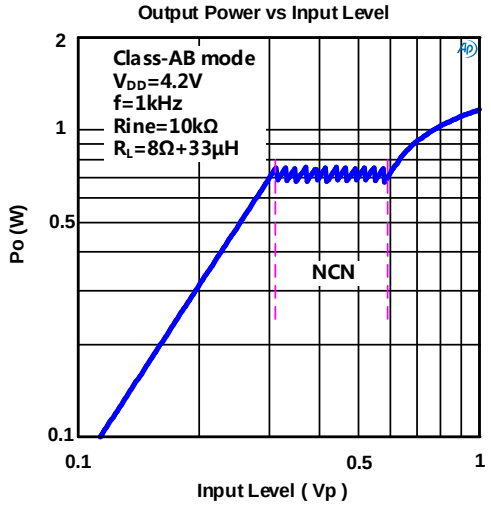


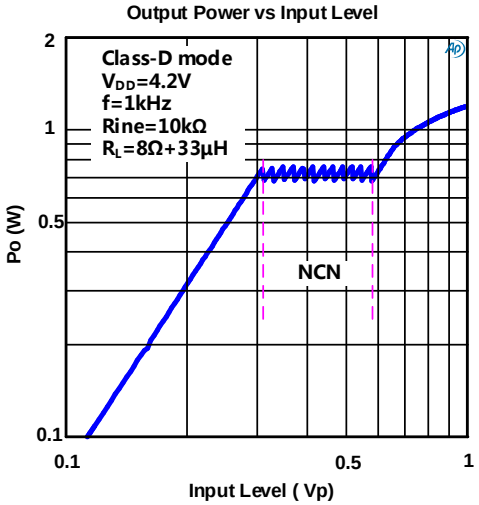
THD+N vs Output Power

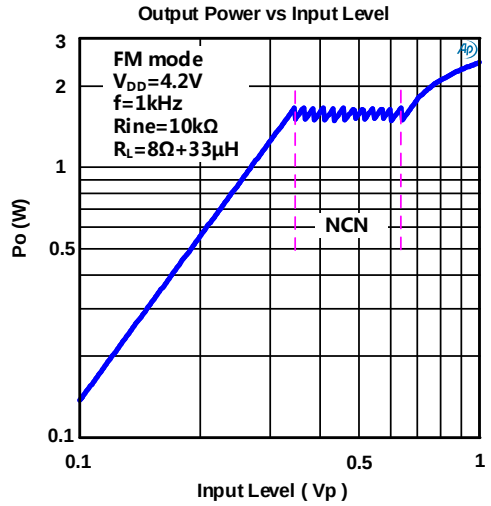


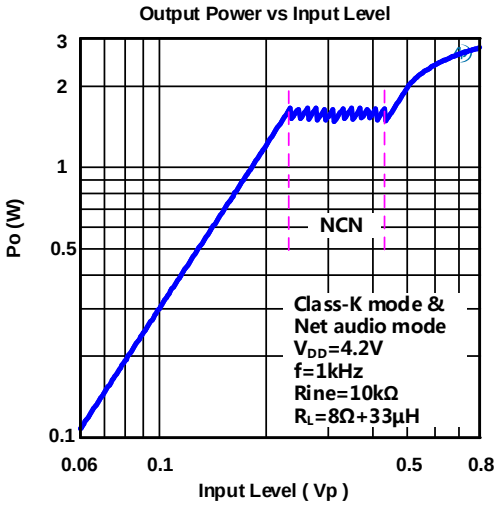
THD+N vs Output Power

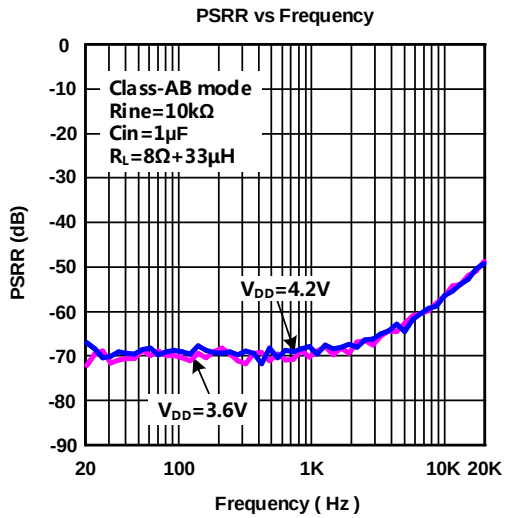


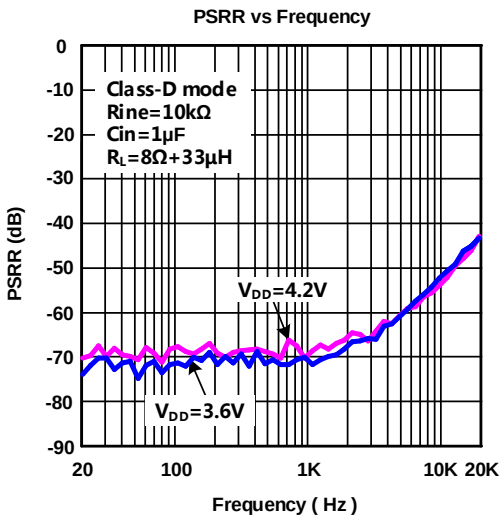




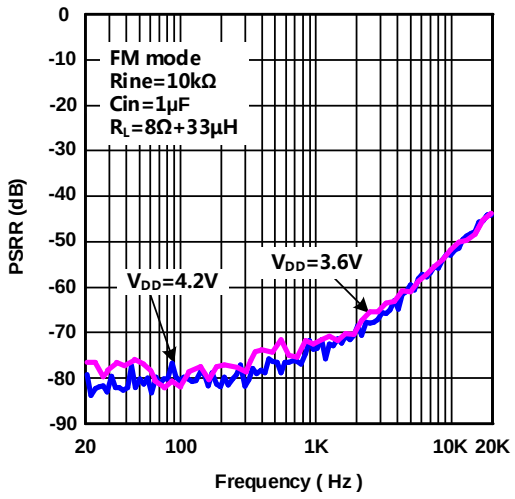




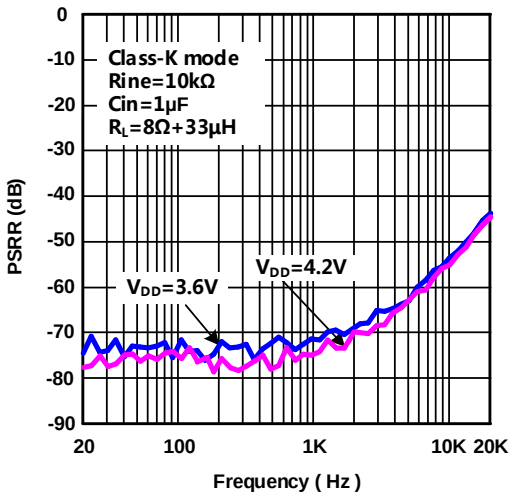




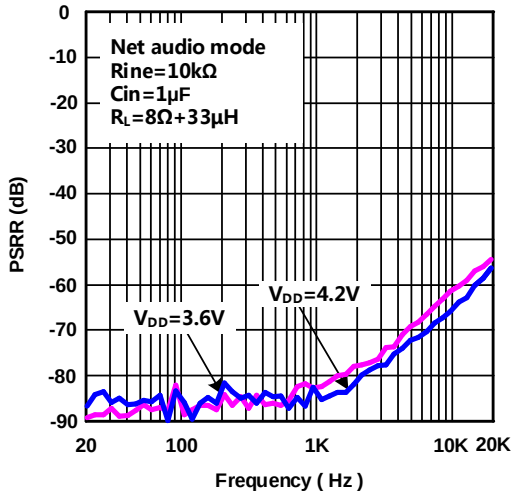
PSRR vs Frequency



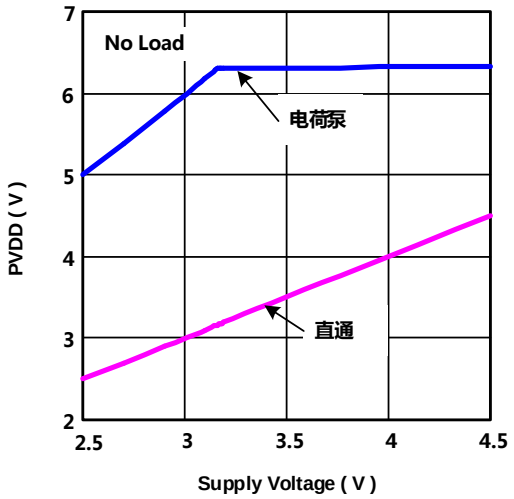
PSRR vs Frequency



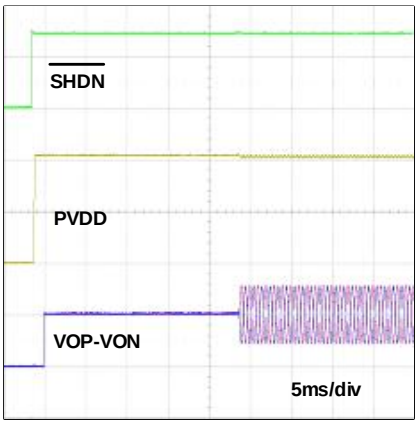
PSRR vs Frequency



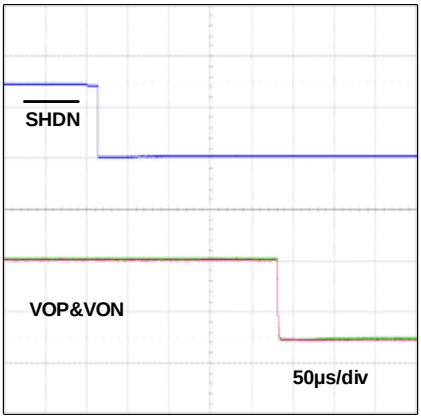
PVDD vs Supply Voltage



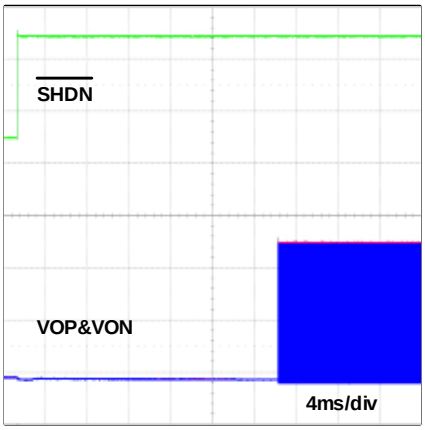
Class-AB start-up Sequence



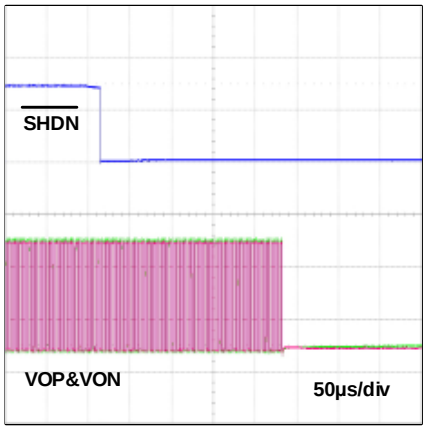
Class-AB shutdown Sequence



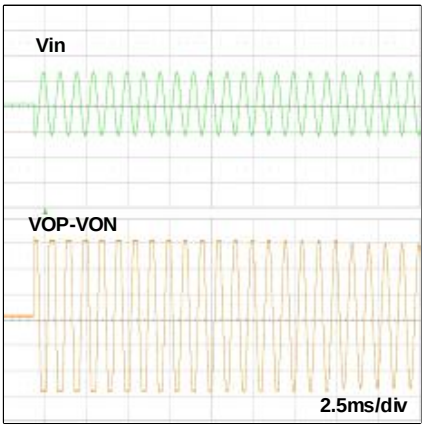
Class-D mode start-up Sequence



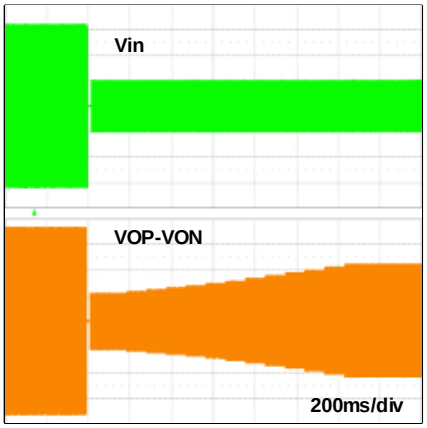
Class-D mode shutdown Sequence



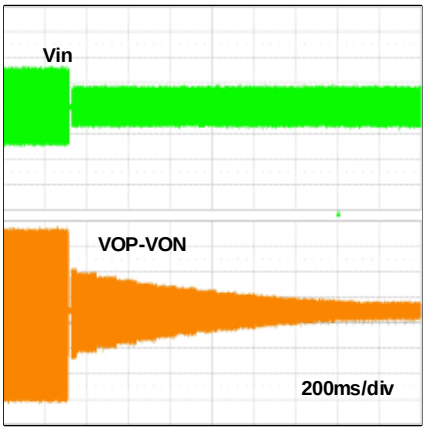
NCN Attack Timming



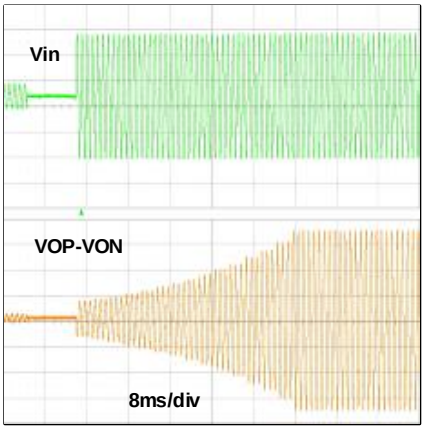
NCN Release Timming



Net audio Start-up Timming



Net audio Release Timming



Block Diagram

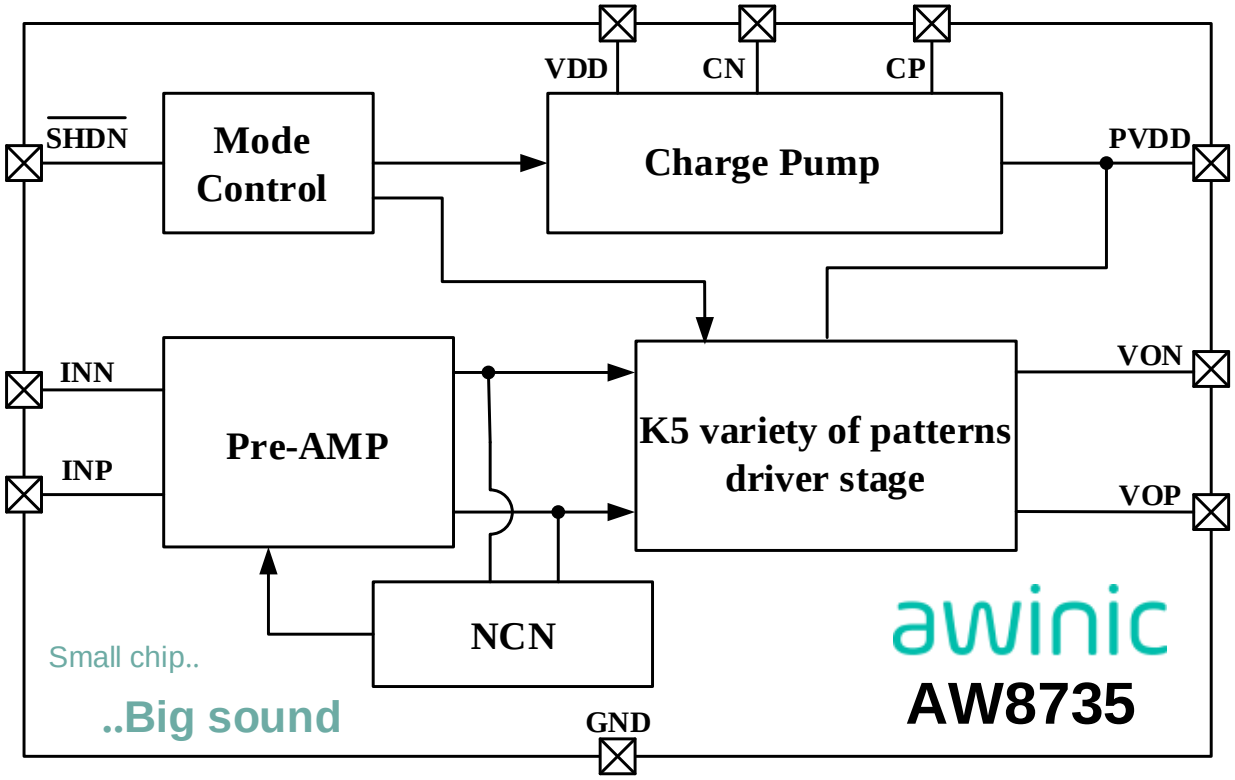


Figure 5 Functional Block Diagram of AW8735

Operation

The AW8735 is a powerful Class-K audio amplifier with AB/D output mode selection; the power stage voltage can select supplied by charge pump or straightly supplied by battery. AW8735 features unique FM mode and Net audio mode, designed for mobile phone audio application and development.

The AW8735 realizes five kinds of working mode by one-wire pulse control technology, can offer the needed working mode according to different power of the speaker. All five kinds of mode with NCN technology effectively prevent the crack noise.

The AW8735 features the RNS function which greatly reduces RF-TDD Noise.

The AW8735 features phone Net audio mode with Net audio technology which can further reduces RF-TDD noise, an acceptable audible level to the customer.

The AW8735 features the NCN function, which adjusts the system gain automatically while detecting the "Crack" distortion of output signal, protects the speaker from damage at high power levels and brings the most comfortable listening experience to the customers.

The AW8735 is available in a small 3mm×3mm 20-Pin TQFN Package. It is specified over the extended -40℃ to +85℃ temperature range.

One-wire pulse control

AW8735 select each mode by one-wire pulse control, as shown in figure 6. When $\overline{SHDN}$ pin pull high form shutdown mode, there is one rising edge, AW8735 start to work in Class-AB mode; When high-low-high signal set to $\overline{SHDN}$ pin, there are two rising edges, AW8735 start to work in Class-D mode; When there are three rising edges, AW8735 start to work in FM mode; When there are four rising edges, AW8735 start to work in Class-K mode; When there are five rising edges, AW8735 start to work in Net audio mode;

As shown in figure 6, when $\overline{SHDN}$ pull down above 500us, AW8735 will enter shutdown mode.

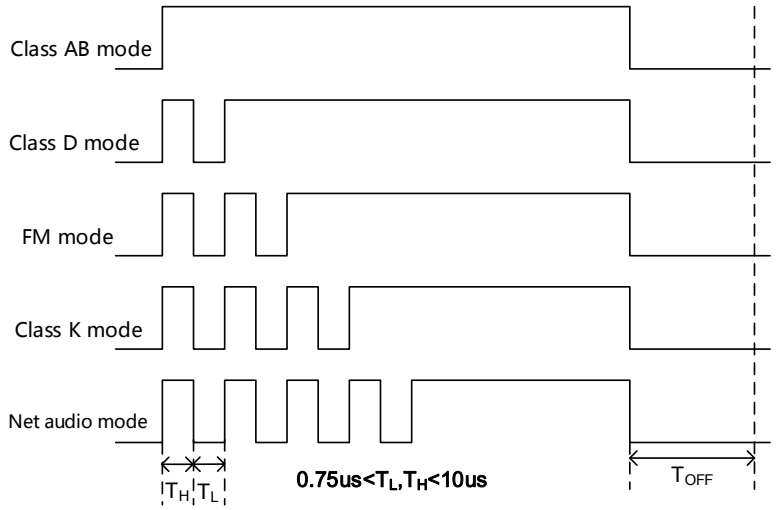


Figure 6 One-Wire pulse control

When AW8735 work in different mode,PIN CTRL should be low above 500us which make the AW735shut down, Then series pulse make the AW735 work in right mode.

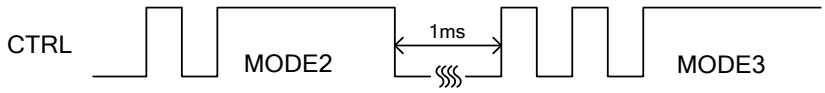


Figure 7 One-wire pulse mode switch

RNS (RF TDD Noise Suppression)

GSM radios transmit using time-division multiple access with 217Hz intervals. The result is an RF signal with strong amplitude modulation at 217Hz and its harmonics that is easily demodulated by audio amplifiers.

In RF applications, improvements to both layout and component selection decrease the AW8735's susceptibility to RF noise and prevent RF signals from being demodulated into audible noise. Minimizing the trace lengths prevents them from functioning as antennas and coupling RF signals into the AW8735. Additional RF immunity can also be obtained from relying on the self-resonant frequency of capacitors as it exhibits the frequency response similar to a notch filter. Depending on the manufacturer, 10pF to 20pF capacitors typically exhibit self resonance at RF frequencies. These capacitors, when placed at the input pins, can effectively shunt the RF noise at the inputs of the AW8735. For these capacitors to be effective, they must have a low-impedance, low-inductance path to the ground plane.

Some RF energy will couple onto audio traces regardless of the effort to prevent this phenomenon from occurring, form audible TDD Noise。The AW8735 features a unique RNS technology, which effectively reduces RF energy, attenuates the RF TDD-noise, an acceptable audible level to the customer.

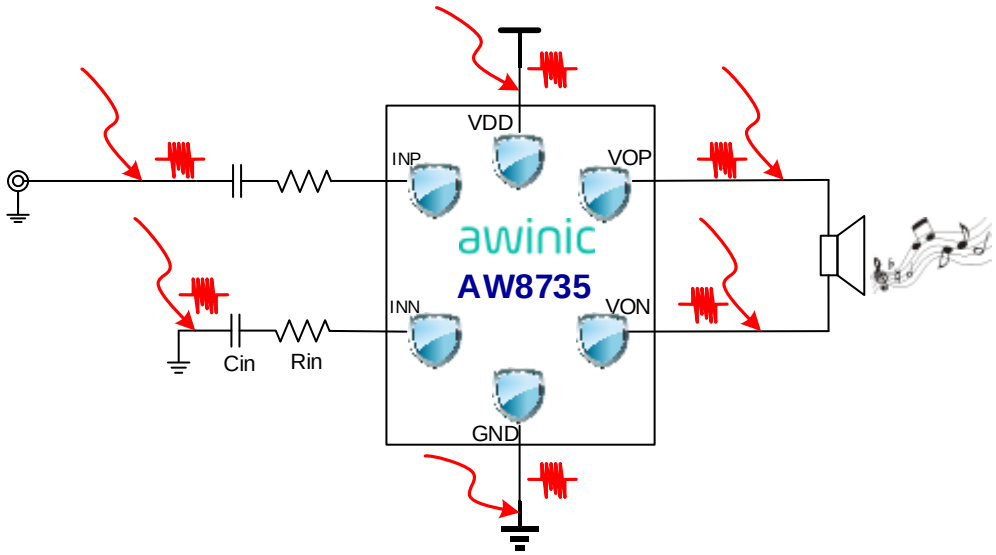


Figure 8 RF Energy Coupling Diagram

Net audio

The net audio function is the function that removes unwanted noise coming in at no-signal state. It can suppress the 217Hz TDD noise from input signal.

It can automatically attenuate the output when a signal level becomes lower than the threshold level, effectively reduce the TDD noise.

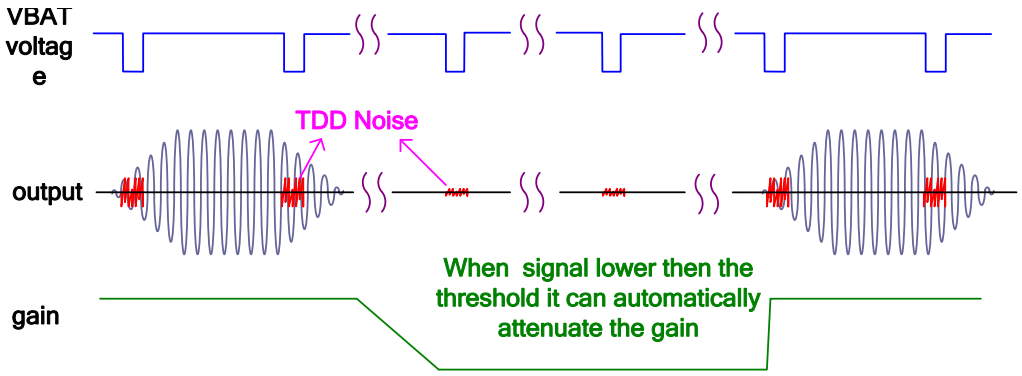


Figure 9 Net audio

NCN

In audio application, output signal will be undesirable distortion caused by too large input and power supply voltage down with battery, and clipped output signal may cause permanent damage to the speaker. The features unique non-crack-noise (NCN) Function, which adjusts system gain automatically to generate desired output by detecting the “Crack” distortion of output signal, protects the speaker from damage at high power levels and brings the most comfortable listening experience to the customers.

The five working mode of AW8735 with NCN function, effectively prevent the crack noise and protect the speaker from damage at high power.

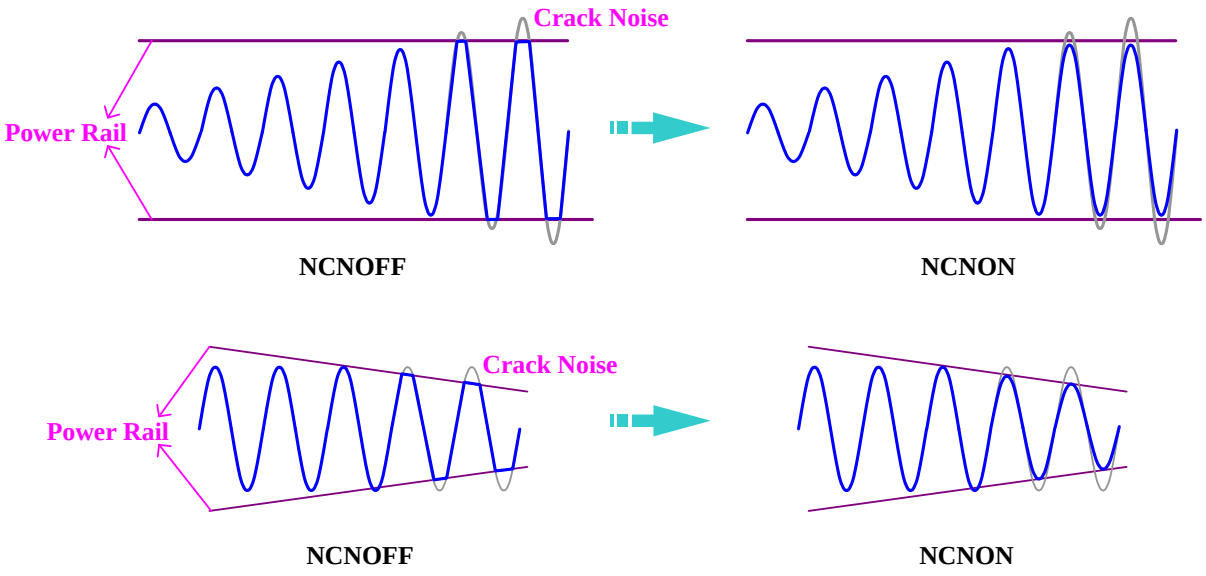


Figure 10 NCN Function Diagram

Attack time

Attack time is the time it takes for the gain to be reduced by 6dB once the audio signal exceeds the NCN threshold. Fast attack times allow the NCN to react quickly and prevent transients such as symbol crashes from being distorted. However, fast attack times can lead to volume pumping, where the gain reduction and release becomes noticeable, as the NCN cycles quickly. Slower attack times cause the NCN to ignore the fast transients, and instead act upon longer, louder passages. Selecting an attack time that is too slow can lead to increased distortion in the case of the No Clip function. Attack time is set 40ms in AW8735.

Release time

Release time is the time it takes for the gain to return from 6dB to its normal level once the audio signal returns below the NCN threshold. A fast release time allows the NCN to react quickly to transients, preserving the original dynamics of the audio source. However, similar to a fast attack time, a fast release time contributes to volume pumping. A slow release time reduces the effect of volume pumping. Release time is set 1.2s in AW8735.

Flying capacitor detection

K5 integrates Awinic's proprietary Flying capacitor detection technology, K5 power stage voltage is straightly supplied by battery when there is no Flying capacitor. At this time, $\overline{SHDN}$ can only control K5 work in the top two mode(Class-AB or Class-D mode), as shown in figure 11.

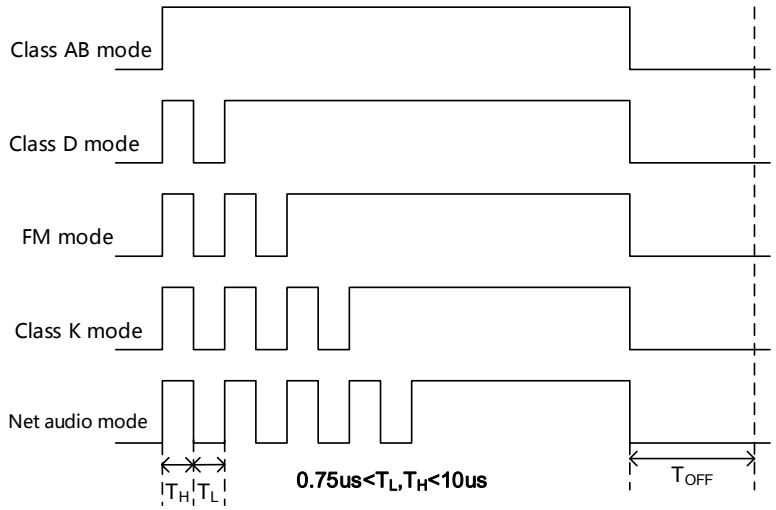


Figure 11 K5 working mode control by one-wire pulse without Flying capacitor

Filter-Free Modulation Scheme

The AW8735 features a filter-free PWM architecture that reduces the LC filter of the traditional Class-D amplifier, increasing efficiency, reducing board area consumption and system cost.

EEE

The AW8735 features a unique Enhanced Emission Elimination (EEE) technology, that controls fast transition on the output, greatly reduces EMI over the full bandwidth.

Pop-Click Suppression

The AW8735 features unique timing control circuit, that comprehensively suppresses pop-click noise, eliminates audible transients on shutdown, wakeup, and power-up/down.

Protection Function

When a short-circuit occurs between VOP/VON pin and VDD/GND or VOP and VON, the over-current circuit shutdown the device, preventing the device from being damaged. When the condition is removed, the AW8735 reactivate itself. When the junction temperature is high, the over-temperature circuit shutdown the device. The circuit switches back to normal operation when the temperature decreases to safe levels.

Applications Information

External Input Resistor-R_{ine}（Gain setting）

The AW8735 is a differential audio amplifier. The IC integrates two internal input resistors, which 10kΩ in Class-AB and Class-D mode, 5kΩ in FM mode、Class-K mode and Net audio mode. Take external input resistor R_{ine}=10kΩ for an example, gain setting as follows：

Class-AB mode： $$A_V = \frac{240k\Omega}{R_{ine}+R_{ini}} = \frac{240k\Omega}{10k\Omega+10k\Omega} = 12V/V$$

Class-D mode： $$A_V = \frac{240k\Omega}{R_{ine}+R_{ini}} = \frac{240k\Omega}{10k\Omega+10k\Omega} = 12V/V$$

FM mode： $$A_V = \frac{240k\Omega}{R_{ine}+R_{ini}} = \frac{240k\Omega}{10k\Omega+5k\Omega} = 16V/V$$

Class-K mode： $$A_V = \frac{360k\Omega}{R_{ine}+R_{ini}} = \frac{360k\Omega}{10k\Omega+5k\Omega} = 24V/V$$

Net audio mode： $$A_V = \frac{360k\Omega}{R_{ine}+R_{ini}} = \frac{360k\Omega}{10k\Omega+5k\Omega} = 24V/V$$

Input Capacitor-C_{in}（input high-pass cutoff frequency）

The input coupling capacitor blocks the DC voltage at the amplifier input terminal. The input capacitors and input resistors form a high-pass filter with the corner frequency:

$$f_H(-3dB) = \frac{1}{2*\pi*R_{intotal}*C_{in}}(Hz)$$

Setting the high-pass filter point high can block the 217Hz GSM noise coupled to inputs. Better matching of the input capacitors improves performance of the circuit and also helps to suppress pop-click noise.

Take typical application in Figure 2 as an example:

Class-AB mode，Class-D mode：

$$f_H(-3dB) = \frac{1}{2*\pi*R_{intotal}*C_{in}}(Hz) = \frac{1}{2*\pi*20k\Omega*22nF}(Hz) = 364Hz$$

FM mode，Class-K mode，Net audio mode：

$$f_H(-3dB) = \frac{1}{2*\pi*R_{intotal}*C_{in}}(Hz) = \frac{1}{2*\pi*15k\Omega*22nF}(Hz) = 485Hz$$

Supply Decoupling Capacitor（C_S）

The AW8735 is a high-performance audio amplifier that requires adequate power supply decoupling. Place a low equivalent-series-resistance (ESR) ceramic capacitor, typically 0.1μF. 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 AW8735 is important, as any parasitic resistance or inductance between the device and the capacitor causes efficiency loss. In addition to the 0.1μF ceramic capacitor, place a 10μF capacitor on the VBAT supply trace. This larger capacitor acts as a charge reservoir, providing energy faster than the board supply, thus helping to prevent any droop in the supply voltage.

Flying Capacitor（C_F）

The value of the flying capacitor (C_F) affects the load regulation and output resistance of the charge pump. A C_F value that is too small degrades the device's ability to provide sufficient current drive. Increasing the value of C_F improves load regulation and reduces the charge pump output resistance to an extent. A 4.7μF capacitor is recommended.

Hold Capacitor（C_H）

The output capacitor value and ESR directly affect the ripple at PVDD. Increasing C_H reduces output ripple. Likewise, decreasing the ESR of C_H reduces both ripple and output resistance. A 10μF@10V capacitor is recommended.

Optional Ferrite Bead Filter

The AW8735 passed FCC and CE radiated emissions with no ferrite chip beads and capacitors. Use ferrite chip beads and capacitors if device near the EMI sensitive circuits and/or there are long leads from amplifier to speaker, placed as close as possible to the output pin.

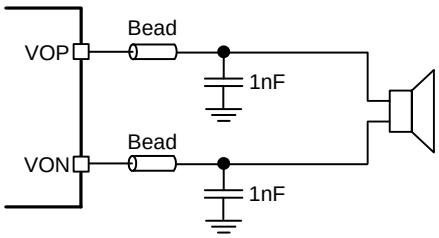
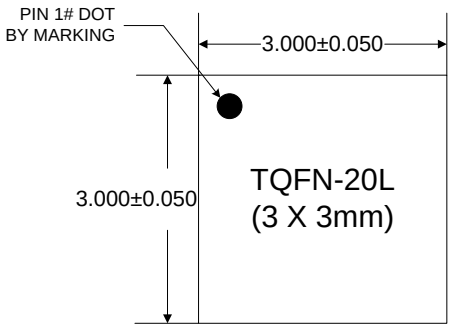
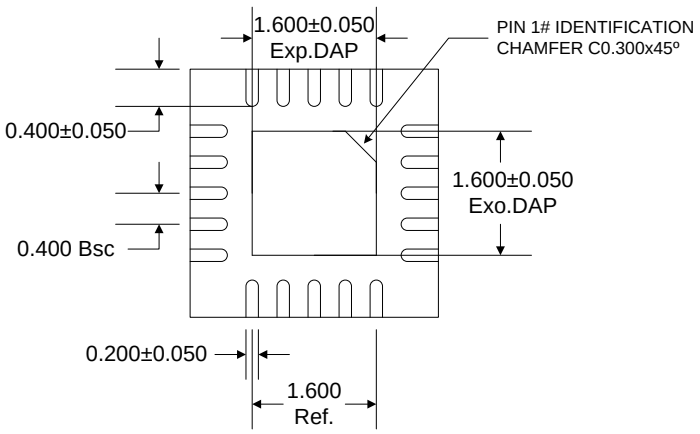


Figure 12 Ferrite Chip Bead and capacitor

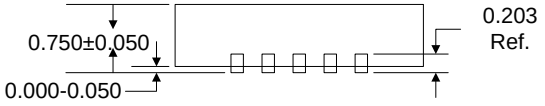
Package Description



TOP VIEW



BOTTOM VIEW



SIDE VIEW

VERSION INFORMATION

Version	Date	Description
V1.0	2015-6-10	AW8735 datasheet V1.0