

# High Efficiency, Low Noise, Constant Large Volume, Multi-Level AGC 8<sup>th</sup>-Generation Class K Audio Amplifier

## FEATURES

- ◆ Multi-Level AGC audio algorithm, effectively eliminates noise and makes sound smooth
- ◆ Speaker and Receiver two-in-one application
  - ◆ Class D Receiver Mode: 1V/V,  $V_n=19\mu\text{V}$ , THD+N=0.025%
  - ◆ Class K Speaker Mode: 8V/V,  $V_n=43\mu\text{V}$ , THD+N=0.008%
- ◆ Power Amplifier's Overall Efficiency is up to 83%
- ◆ Selectable Speaker-Guard Power Level: 0.6W, 0.7W, 0.8W, 0.9W, 1.0W, 1.1W, 1.2W
- ◆ Within Lithium Battery Voltage Range, Outputs Constant Large Volume
- ◆ Support 6Ω Speaker
- ◆ Upgrade for AW8736, AW8737
- ◆ Super TDD-Noise Suppression
- ◆ Excellent Pop-Click Suppression
- ◆ One-Wire Pulse Control
- ◆ High PSRR: -68dB (217Hz)
- ◆ ESD Protection:  $\pm 6\text{kV}$  (HBM)
- ◆ Small Package
  - ◆ 1.60mm×1.68mm, 0.4mm Pitch CSP-14
  - ◆ 1.60mm×1.60mm, 0.4mm Pitch FCQFN-16

## APPLICATIONS

- ◆ Smart Phones

## DESCRIPTION

AW87318 is specifically designed to enhance overall sound quality. It is an upgrading 8<sup>th</sup>-generation class K audio amplifier with high efficiency, low noise, ultra-low distortion and capability of outputting constant large volume.

With integrated AWINIC proprietary Multi-Level AGC audio algorithm, AW87318 can eliminate noise in playback and improve sound quality and effect. Using a novel K-Chargepump technology, its integrated charge pump efficiency can reach 93%, and power amplifier's overall efficiency can reach 83%. With high efficiency, AW87318 can greatly prolong smart phone usage time.

AW87318 noise floor is as low as to  $43\mu\text{V}$ , with 98.8dB high signal-to-noise-ratio (SNR). The ultra-low distortion 0.008% brings high-quality musical enjoyment.

AW87318 has a setting of 7-step selectable speaker-guard output power level from 0.6W to 1.2W, suitable for different rated power speakers. Within lithium battery voltage range, it keeps output power constant, preventing voice from degrading.

AW87318 supports speaker and receiver two-in-one application. The Class D Receiver Mode has an ultra-low output noise of  $19\mu\text{V}$ . Under this mode, the power of PA is supplied by VBAT.

AW87318 has built-in over-current protection, over-temperature protection and short-circuit protection. AW87318 is available in a 1.60mm×1.68mm, 0.4mm pitch CSP-14 package, or a 1.60mm×1.60mm, 0.4mm pitch FCQFN-16 package.

## APPLICATION DIAGRAM

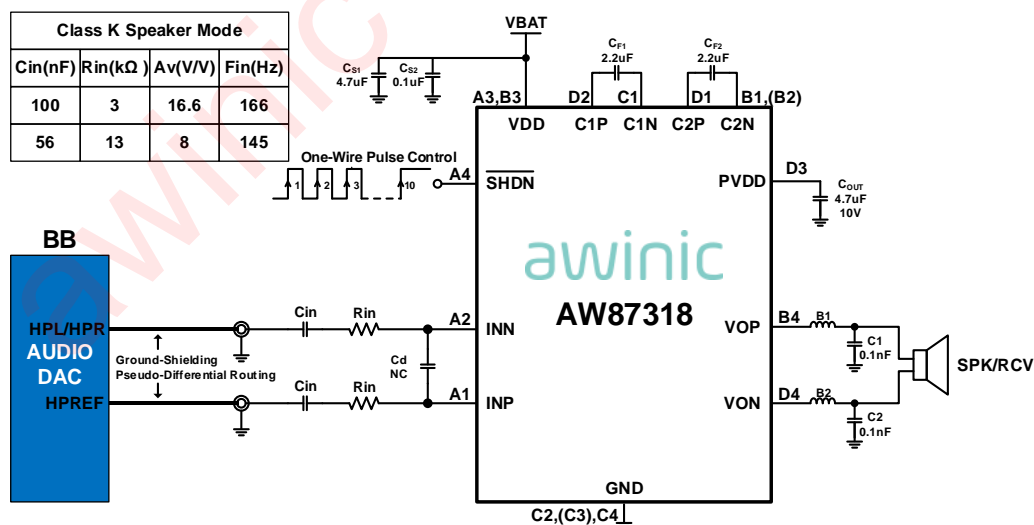


Figure 1 AW87318 Application Diagram

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## PIN DIAGRAM AND DEVICE MARKING

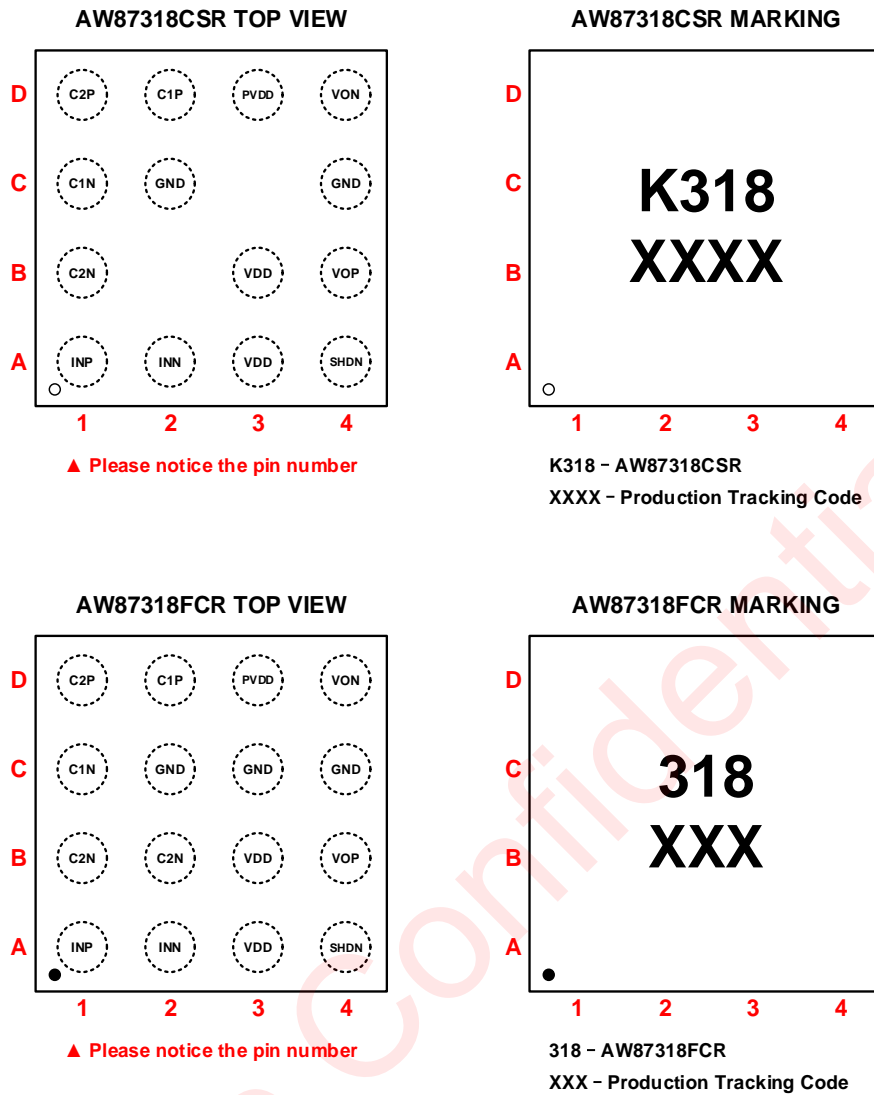


Figure 2 AW87318CSR and AW87318FCR Pin Diagram Top View and Device Marking

## PIN DESCRIPTION

AW87318CSR		
Number	Symbol	Description
A1	INP	Positive audio input
A2	INN	Negative audio input
A3, B3	VDD	Power supply
A4	SHDN	Chip power down pin, active low: one wire pulse control
B1	C2N	Negative terminal of the charge pump flying capacitor C <sub>F2</sub>
B4	VOP	Positive audio output
C1	C1N	Negative terminal of the charge pump flying capacitor C <sub>F1</sub>
C2, C4	GND	Ground
D1	C2P	Positive terminal of the charge pump flying capacitor C <sub>F2</sub>
D2	C1P	Positive terminal of the charge pump flying capacitor C <sub>F1</sub>
D3	PVDD	Charge pump output
D4	VON	Negative audio output

AW87318FCR		
Number	Symbol	Description
A1	INP	Positive audio input
A2	INN	Negative audio input
A3, B3	VDD	Power supply
A4	SHDN	Chip power down pin, active low: one wire pulse control
B1, B2	C2N	Negative terminal of the charge pump flying capacitor C <sub>F2</sub>
B4	VOP	Positive audio output
C1	C1N	Negative terminal of the charge pump flying capacitor C <sub>F1</sub>
C2, C3, C4	GND	Ground
D1	C2P	Positive terminal of the charge pump flying capacitor C <sub>F2</sub>
D2	C1P	Positive terminal of the charge pump flying capacitor C <sub>F1</sub>
D3	PVDD	Charge pump output
D4	VON	Negative audio output

## AWINIC CLASS K FAMILY

ITEM	TEST CONDITION	AW8736	AW8737	AW87317	AW8738	AW87318
PVDD (V)	VDD=4.2V	5.8	6.05	6.05	6.05	6.05
Output Noise (μV)	VDD=4.2V, f=20Hz to 20kHz Input ac grounded, 8V/V, A-weighting	125	52	53	40	43
Efficiency (%)	VDD=3.6V, P <sub>o</sub> =1.0W, R <sub>L</sub> =8Ω+33μH	75	80	80	83	83

## FUNCTIONAL DIAGRAM

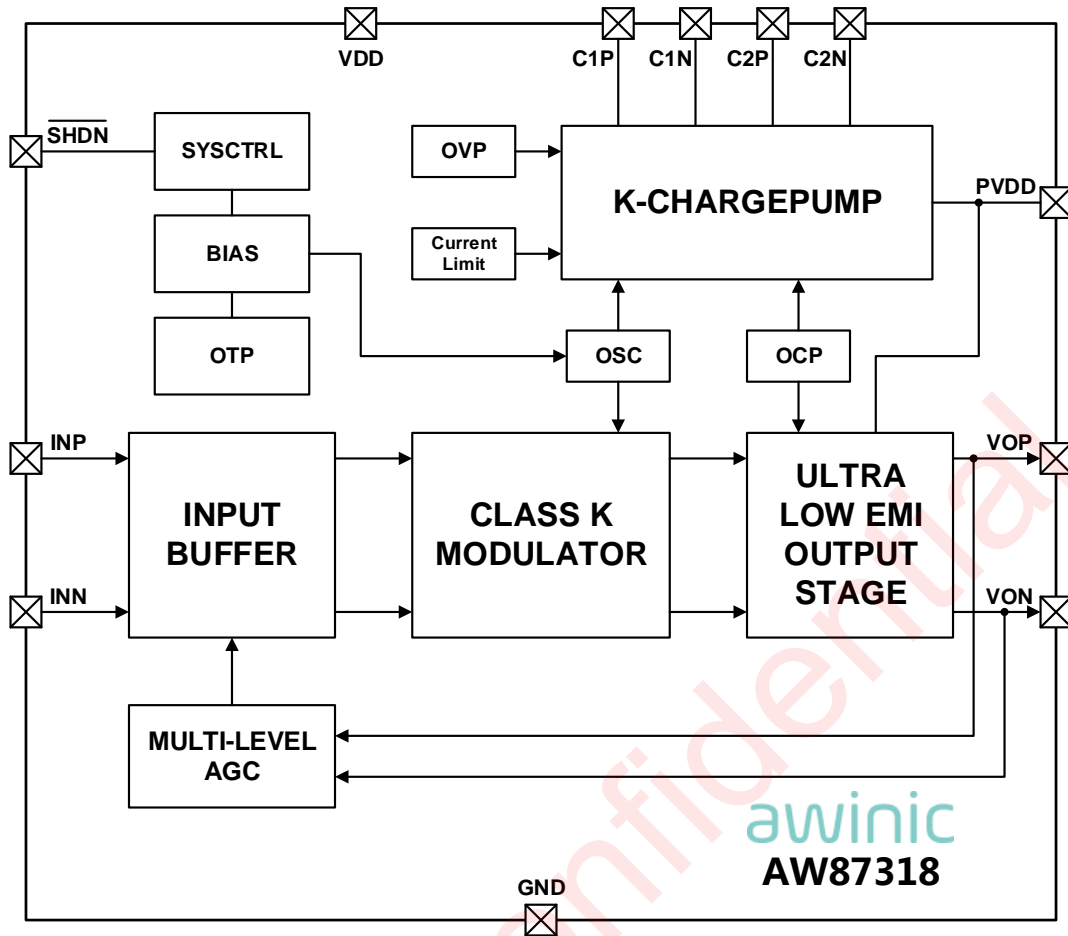


Figure 3 AW87318 Functional Diagram

APPLICATION DIAGRAM

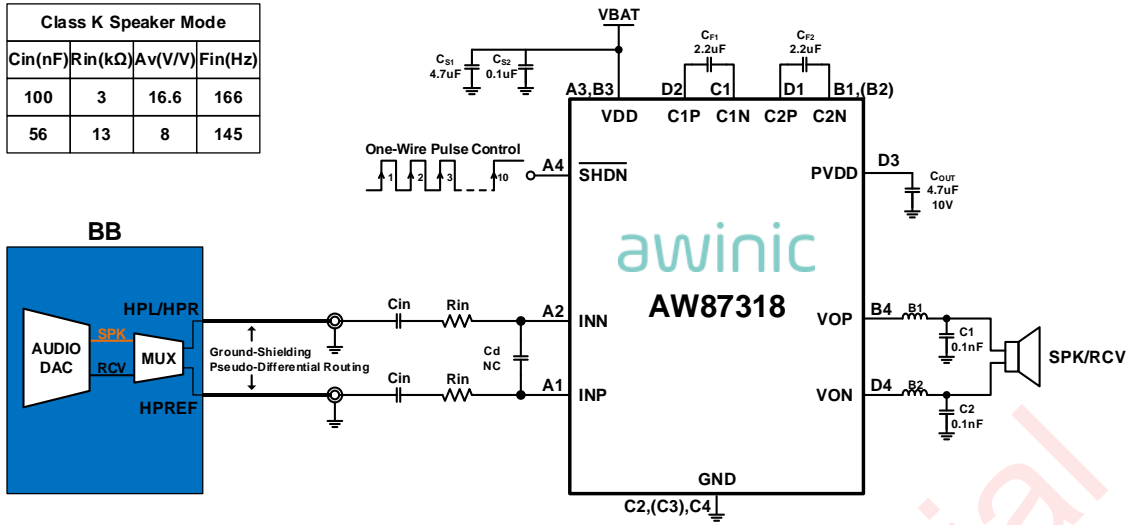


Figure 4 AW87318 Speaker Mode Application Diagram (Note 1)

**Note1:** When single-ended input, audio signal line from audio DAC (HPL or HPR) can arbitrarily connected to either of INN or INP input terminal. The other terminal must be connected to reference ground (HPREF) through input capacitor and resistor.

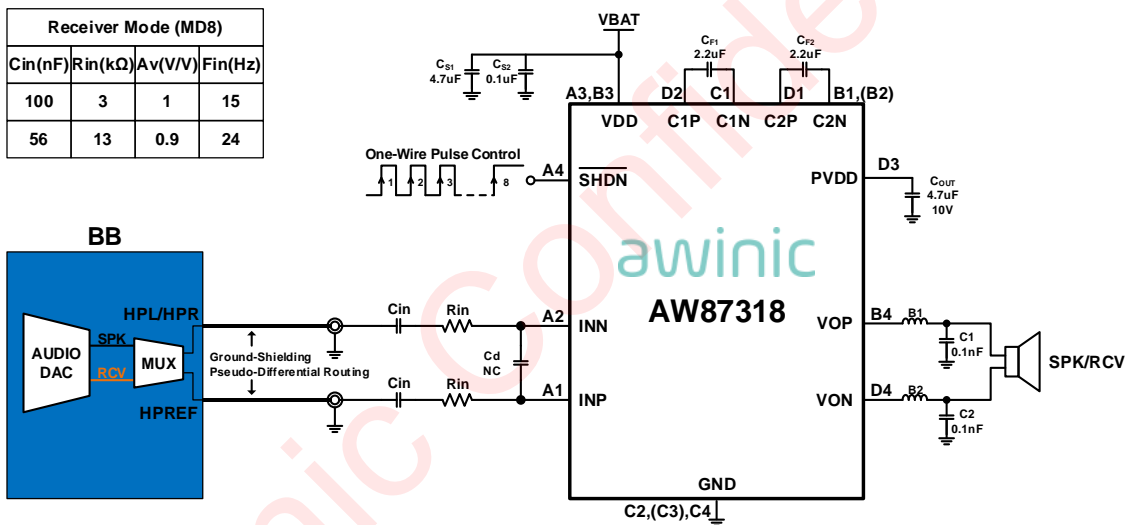
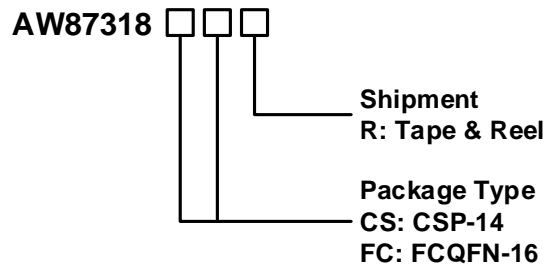


Figure 5 AW87318 Receiver Mode Application Diagram

**ORDERING INFORMATION**

Product Type	Operation Temperature Range	Package	Device Marking	Moisture Sensitivity Level (MSL)	Environmental Information	Delivery Form
AW87318CSR	-40°C to 85°C	CSP-14	K318	MSL1	ROHS+HF	Tape & Reel 3000 pcs
AW87318FCR	-40°C to 85°C	FCQFN-16	318	MSL1	ROHS+HF	Tape & Reel 3000 pcs



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**ABSOLUTE MAXIMUM RATINGS**<sup>(NOTE2)</sup>

Parameter		Range
Power Supply VDD Voltage		-0.3V to 6V
Charge Pump Output PVDD Voltage		-0.3V to 7V
VOP, VON, C1P, C2P		-0.3V to PVDD+0.3V
C1N, C2N		-0.3V to VDD+0.3V
Input Pin INP, INN Voltage		-0.3V to VDD+0.3V
Junction-to-Ambient Thermal Resistance $\theta_{JA}$	AW87318CSR	84.9°C/W
	AW87318FCR	76.5°C/W
Operating Free-Air Temperature $T_A$		-40°C to 85°C
Maximum Junction Temperature $T_{JMAX}$		165°C
Storage Temperature $T_{STG}$		-40°C to 150°C
Lead Temperature (Soldering 10 Seconds)		260°C
ESD Rating		
Human Body Model (HBM) <sup>(Note 3)</sup>		±6kV
Charged Device Model (CDM) <sup>(Note 4)</sup>		±2kV
Latch-up		
Test Condition: JEDEC STANDARD NO.78D SEPTEMBER 2010		+IT: 450mA -IT: -450mA

**Note 2:** Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

**Note 3:** The human body model is a 100pF capacitor discharged through a 1.5kΩ resistor into each pin. Test method: MIL-STD-883J Method 3015.9.

**Note 4:** Test Method: ESDA/JEDEC JS-002-2014.

**MODE DESCRIPTIONS** ( $T_A=25^{\circ}\text{C}$ ,  $V_{DD}=4.2\text{V}$ )

Under Speaker Mode (Mode 1 to Mode 7, and Mode 10) or Receiver Mode (Class D Receiver Mode, Mode 8 and Mode 9), audio signal is inserted through INP & INN pins. The AW87318 external input capacitor is  $C_{in}$  and the external input resistor is  $R_{in}$ .

- Under Speaker Mode, the internal input resistor is  $6.6\text{k}\Omega$ . The gain of AW87318 ( $A_v$ ) can be calculated by  $159.5\text{k}/(R_{in}+6.6\text{k})$  ( $R_{in}$  unit:  $\Omega$ ). Recommended operating external setting is:  $C_{in}=100\text{nF}$ ,  $R_{in}=3\text{k}\Omega$ ,  $A_v=16.6\text{V/V}$ .
- Under Class D Receiver Mode, the internal input resistor is  $106.6\text{k}\Omega$  under Mode 8 and  $36.6\text{k}\Omega$  under Mode 9. The gain of AW87318 ( $A_v$ ) can be calculated by  $110\text{k}/(R_{in}+106.6\text{k})$  ( $R_{in}$  unit:  $\Omega$ ) under Mode 8 and  $110\text{k}/(R_{in}+36.6\text{k})$  ( $R_{in}$  unit:  $\Omega$ ) under Mode 9, respectively. Recommended operating external setting is:  $C_{in}=100\text{nF}$ ,  $R_{in}=3\text{k}\Omega$ ,  $A_v=1\text{V/V}$  (Mode 8) and  $A_v=3\text{V/V}$  (Mode 9).

The operating modes of AW87318 are listed below:

MODE	Enable Signal (SHDN)	Gain (V/V)	AGC Power Level (W)				Multi-Level AGC	Class D Receiver Mode
			$R_L=8\Omega$ $+33\mu\text{H}$	$R_L=6\Omega$ $+33\mu\text{H}$	$R_L=4\Omega$ $+15\mu\text{H}$	$R_L=3\Omega$ $+15\mu\text{H}$		
1		16.6	1.2	1.6	—	—	√	
2		16.6	1.1	1.5	—	—	√	
3		16.6	1.0	1.3	2.0	—	√	
4		16.6	0.9	1.2	1.8	—	√	
5		16.6	0.8	1.0	1.6	2.0	√	
6		16.6	0.7	0.9	1.4	1.8	√	
7		16.6	0.6	0.8	1.2	1.6	√	
8		1						√
9		3						√
10		16.6	1.75W@ THD=1%	2.05W@ THD=1%	2.4W@ THD=1%	2.35W@ THD=1%		



## ELECTRICAL CHARACTERISTICS

Test condition:  $T_A=25^{\circ}\text{C}$ ,  $V_{DD}=3.6\text{V}$ ,  $R_L=8\Omega+33\mu\text{H}$ ,  $f=1\text{kHz}$  (unless otherwise noted)

Parameter		Test Conditions	Min	Typ	Max	Unit
$V_{DD}$	Power supply voltage		3.0		5.5	V
$V_{IH}$	$\overline{\text{SHDN}}$ high input voltage		1.3		$V_{DD}$	V
$V_{IL}$	$\overline{\text{SHDN}}$ low input voltage		0		0.45	V
$ V_{OS} $	Output offset voltage	$V_{IN}=0\text{V}$ , $V_{DD}=3.0\text{V to }5.5\text{V}$	-30	0	30	mV
$I_{SD}$	Shutdown current	$V_{DD}=3.6\text{V}$ , $\overline{\text{SHDN}}=0\text{V}$			2	$\mu\text{A}$
$T_{TG}$	Thermal AGC start temperature threshold			150		$^{\circ}\text{C}$
$T_{TGR}$	Thermal AGC exit temperature threshold			130		$^{\circ}\text{C}$
$T_{SD}$	Over temperature protection threshold			160		$^{\circ}\text{C}$
$T_{SDR}$	Over temperature protection recovery threshold			120		$^{\circ}\text{C}$
$T_{ON}$	Start-up time			40		ms
<b>K-Chargepump</b>						
PVDD	Output voltage	$V_{DD}=3.0\text{V to }4\text{V}$		$1.5\times V_{DD}$		V
		$V_{DD}>4\text{V}$		6.05		V
$V_{HYS}$	OVP hysteresis voltage	$V_{DD}>4\text{V}$		50		mV
$F_{CP}$	Charge pump frequency	$V_{DD}=3.0\text{V to }5.5\text{V}$	0.79	1.06	1.33	MHz
$\eta_{CP}$	Charge pump efficiency	$V_{DD}=3.6\text{V}$ , $I_{load}=200\text{mA}$		93		%
$T_{ST}$	Soft-start time	No load, $C_{OUT}=4.7\mu\text{F}$	1.0	1.2	1.4	ms
$I_L$	Current limit when PVDD short to ground		200	300	400	mA
<b>Class K power amplifier (Mode1 to Mode7, and Mode10)</b>						
$I_q$	Quiescent current	$V_{DD}=4.2\text{V}$ , $V_{in}=0$ , no load		10	15	mA
$\eta$	Efficiency	$V_{DD}=3.6\text{V}$ , $P_o=1.0\text{W}$ , $R_L=8\Omega+33\mu\text{H}$		83		%
		$V_{DD}=3.6\text{V}$ , $P_o=1.0\text{W}$ , $R_L=6\Omega+33\mu\text{H}$		83		%
Fosc	Modulation frequency	$V_{DD}=3.0\text{V to }5.5\text{V}$	600	800	1000	kHz
$A_v$	Gain	External input resistance=3k $\Omega$		16.6		V/V
$V_{in}$	Recommended max input voltage	$V_{DD}=3.0\text{V to }5.5\text{V}$			1	Vp
Rini	Internal input resistor	Mode1 to Mode7, and Mode10		6.6		k $\Omega$
Fhin	Input high pass filter corner frequency	$C_{in}=100\text{nF}$ , external input resistor=3k $\Omega$		166		Hz
Pagc	Mode1 Multi-Level AGC power	$V_{DD}=4.2\text{V}$ , $R_L=8\Omega+33\mu\text{H}$	1.08	1.2	1.32	W
		$V_{DD}=4.2\text{V}$ , $R_L=6\Omega+33\mu\text{H}$	1.44	1.6	1.76	W
		$V_{DD}=4.2\text{V}$ , $R_L=4\Omega+15\mu\text{H}$	2.16	2.4	2.64	W
		$V_{DD}=4.2\text{V}$ , $R_L=3\Omega+15\mu\text{H}$	2.16	2.4	2.64	W
	Mode2 Multi-Level AGC power	$V_{DD}=4.2\text{V}$ , $R_L=8\Omega+33\mu\text{H}$	0.99	1.1	1.21	W
		$V_{DD}=4.2\text{V}$ , $R_L=6\Omega+33\mu\text{H}$	1.35	1.5	1.65	W

		$V_{DD}=4.2V, R_L=4\Omega+15\mu H$	1.98	2.2	2.42	W
Parameter		Test Conditions	Min	Typ	Max	Unit
Pagc	Mode2 Multi-Level AGC power	$V_{DD}=4.2V, R_L=3\Omega+15\mu H$	2.16	2.4	2.64	W
	Mode3 Multi-Level AGC power	$V_{DD}=4.2V, R_L=8\Omega+33\mu H$	0.9	1	1.1	W
		$V_{DD}=4.2V, R_L=6\Omega+33\mu H$	1.17	1.3	1.43	W
		$V_{DD}=4.2V, R_L=4\Omega+15\mu H$	1.8	2	2.2	W
		$V_{DD}=4.2V, R_L=3\Omega+15\mu H$	2.16	2.4	2.64	W
	Mode4 Multi-Level AGC power	$V_{DD}=4.2V, R_L=8\Omega+33\mu H$	0.81	0.9	0.99	W
		$V_{DD}=4.2V, R_L=6\Omega+33\mu H$	1.08	1.2	1.32	W
		$V_{DD}=4.2V, R_L=4\Omega+15\mu H$	1.62	1.8	1.98	W
		$V_{DD}=4.2V, R_L=3\Omega+15\mu H$	2.16	2.4	2.64	W
	Mode5 Multi-Level AGC power	$V_{DD}=4.2V, R_L=8\Omega+33\mu H$	0.72	0.8	0.88	W
		$V_{DD}=4.2V, R_L=6\Omega+33\mu H$	0.9	1	1.1	W
		$V_{DD}=4.2V, R_L=4\Omega+15\mu H$	1.44	1.6	1.76	W
		$V_{DD}=4.2V, R_L=3\Omega+15\mu H$	1.8	2.0	2.2	W
	Mode6 Multi-Level AGC power	$V_{DD}=4.2V, R_L=8\Omega+33\mu H$	0.63	0.7	0.77	W
		$V_{DD}=4.2V, R_L=6\Omega+33\mu H$	0.81	0.9	0.99	W
		$V_{DD}=4.2V, R_L=4\Omega+15\mu H$	1.26	1.4	1.54	W
		$V_{DD}=4.2V, R_L=3\Omega+15\mu H$	1.62	1.8	1.98	W
	Mode7 Multi-Level AGC power	$V_{DD}=4.2V, R_L=8\Omega+33\mu H$	0.54	0.6	0.66	W
		$V_{DD}=4.2V, R_L=6\Omega+33\mu H$	0.72	0.8	0.88	W
		$V_{DD}=4.2V, R_L=4\Omega+15\mu H$	1.08	1.2	1.32	W
$V_{DD}=4.2V, R_L=3\Omega+15\mu H$		1.44	1.6	1.76	W	
PSRR	Power supply rejection ratio	$V_{DD}=4.2V, V_{p-p\_sin}=200mV$	217Hz		-68	dB
			1kHz		-68	dB
SNR	Signal-to-noise ratio	$V_{DD}=4.2V, P_o=1.7W, THD+N=1\%, R_L=8\Omega+33\mu H, A_v=8V/V$		98.8		dB
		$V_{DD}=4.2V, P_o=2.0W, THD+N=1\%, R_L=6\Omega+33\mu H, A_v=8V/V$		98.2		dB
Vn	Output noise voltage	$V_{DD}=4.2V, f=20Hz$ to 20kHz, input ac grounded, $A_v=8V/V$	A-weighting	43		$\mu V_{rms}$
		$V_{DD}=4.2V, f=20Hz$ to 20kHz, input ac grounded, $A_v=12V/V$		48		$\mu V_{rms}$
		$V_{DD}=4.2V, f=20Hz$ to 20kHz, input ac grounded, $A_v=16V/V$		57		$\mu V_{rms}$
THD+N	Total harmonic distortion+noise	$V_{DD}=3.6V, P_o=1W, R_L=8\Omega+33\mu H, f=1kHz, Mode1$		0.008		%
		$V_{DD}=3.6V, P_o=1W, R_L=6\Omega+33\mu H, f=1kHz, Mode10$		0.009		%
P <sub>o</sub>	Mode10 output power	THD+N=10%, f=1kHz, $R_L=8\Omega+33\mu H, V_{DD}=4.2V$		2.15		W
		THD+N=1%, f=1kHz, $R_L=8\Omega+33\mu H, V_{DD}=4.2V$		1.75		W
		THD+N=10%, f=1kHz, $R_L=8\Omega+33\mu H, V_{DD}=3.6V$		1.6		W
		THD+N=1%, f=1kHz, $R_L=8\Omega+33\mu H, V_{DD}=3.6V$		1.28		W
		THD+N=10%, f=1kHz, $R_L=6\Omega+33\mu H, V_{DD}=4.2V$		2.52		W
		THD+N=1%, f=1kHz, $R_L=6\Omega+33\mu H, V_{DD}=4.2V$		2.05		W
		THD+N=10%, f=1kHz, $R_L=6\Omega+33\mu H, V_{DD}=3.6V$		1.82		W

Parameter	Test conditions	Min	Typ	Max	Units	
	THD+N=1%, f=1kHz, R <sub>L</sub> =6Ω+33μH, V <sub>DD</sub> =3.6V		1.5		W	
P <sub>O</sub>	Mode10 output power	THD+N=10%, f=1kHz, R <sub>L</sub> =4Ω+15μH, V <sub>DD</sub> =4.2V		2.8		W
		THD+N=1%, f=1kHz, R <sub>L</sub> =4Ω+15μH, V <sub>DD</sub> =4.2V		2.4		W
		THD+N=10%, f=1kHz, R <sub>L</sub> =4Ω+15μH, V <sub>DD</sub> =3.6V		2.02		W
		THD+N=1%, f=1kHz, R <sub>L</sub> =4Ω+15μH, V <sub>DD</sub> =3.6V		1.68		W
		THD+N=10%, f=1kHz, R <sub>L</sub> =3Ω+15μH, V <sub>DD</sub> =4.2V		2.63		W
		THD+N=1%, f=1kHz, R <sub>L</sub> =3Ω+15μH, V <sub>DD</sub> =4.2V		2.35		W
		THD+N=10%, f=1kHz, R <sub>L</sub> =3Ω+15μH, V <sub>DD</sub> =3.6V		1.85		W
		THD+N=1%, f=1kHz, R <sub>L</sub> =3Ω+15μH, V <sub>DD</sub> =3.6V		1.65		W
<b>Class D Receiver (Mode8 and Mode9)</b>						
I <sub>q</sub>	Quiescent current	V <sub>DD</sub> =4.2V, V <sub>IN</sub> =0, no load		5	7.5	mA
η	Efficiency	V <sub>DD</sub> =3.6V, P <sub>O</sub> =0.8W, R <sub>L</sub> =8Ω+33μH, Mode9		86		%
Fosc	Modulation frequency	V <sub>DD</sub> =3.0V to 5.5V	600	800	1000	kHz
A <sub>v</sub>	Gain	External input resistor=3kΩ, Mode8		1		V/V
		External input resistor=3kΩ, Mode9		3		V/V
R <sub>in</sub>	Internal input resistor	Mode8		106.6		kΩ
		Mode9		36.6		kΩ
P <sub>O</sub>	Mode 8 output power	THD+N=1%, f=1kHz, R <sub>L</sub> =8Ω+33μH, V <sub>DD</sub> =3.6V		250		mW
	Mode 9 output power	THD+N=1%, f=1kHz, R <sub>L</sub> =8Ω+33μH, V <sub>DD</sub> =3.6V		600		mW
F <sub>hin</sub>	Input high pass filter corner frequency	C <sub>in</sub> =100nF, external input resistor=3kΩ, Mode8		15		Hz
		C <sub>in</sub> =100nF, external input resistor=3kΩ, Mode9		40		Hz
V <sub>n</sub>	Output noise voltage	V <sub>DD</sub> =4.2V, f=20Hz to 20kHz, input ac grounded, A <sub>v</sub> =1V/V	A-weighting		19	μVrms
		V <sub>DD</sub> =4.2V, f=20Hz to 20kHz, input ac grounded, A <sub>v</sub> =3V/V			22	μVrms
THD+N	Total harmonic distortion+noise	V <sub>DD</sub> =4.2V, R <sub>L</sub> =8Ω+33μH, f=1kHz	P <sub>O</sub> =0.1W, Mode8		0.025	%
			P <sub>O</sub> =0.4W, Mode9		0.025	%
<b>One Wire Pulse Control</b>						
T <sub>H</sub>	$\overline{\text{SHDN}}$ high level duration time	V <sub>DD</sub> =3.0V to 5.5V	0.75	2	10	μs
T <sub>L</sub>	$\overline{\text{SHDN}}$ low level duration time	V <sub>DD</sub> =3.0V to 5.5V	0.75	2	10	μs
T <sub>LATCH</sub>	$\overline{\text{SHDN}}$ turn on delay time	V <sub>DD</sub> =3.0V to 5.5V	150		500	μs
T <sub>OFF</sub>	$\overline{\text{SHDN}}$ turn off delay time	V <sub>DD</sub> =3.0V to 5.5V	150		500	μs
<b>Multi-Level AGC</b> (Note 5)						
T <sub>ATF</sub>	Fast attack time	-13.5dB gain attenuation completed		1.5		ms
T <sub>ATS</sub>	Slow attack time	-13.5dB gain attenuation completed		6		ms
T <sub>ATT</sub>	Total attack time	-13.5dB gain attenuation completed		7.5		ms
T <sub>RLT</sub>	Release time	13.5dB gain release completed		280		ms
A <sub>MAX</sub>	Maximum attenuation			-13.5		dB

**Note 5:** Attack Time refers to the duration of gain attenuation by 13.5dB. Similarly, Release Time refers to the duration of gain recovery by 13.5dB.

## MEASUREMENT SETUP

AW87318 features switching digital output, as shown in Figure 6. It is crucial to connect a low pass filter after VOP/VON outputs, respectively, to filter out switch modulation frequency, then measure the differential output of filter to obtain audio analog output signal.

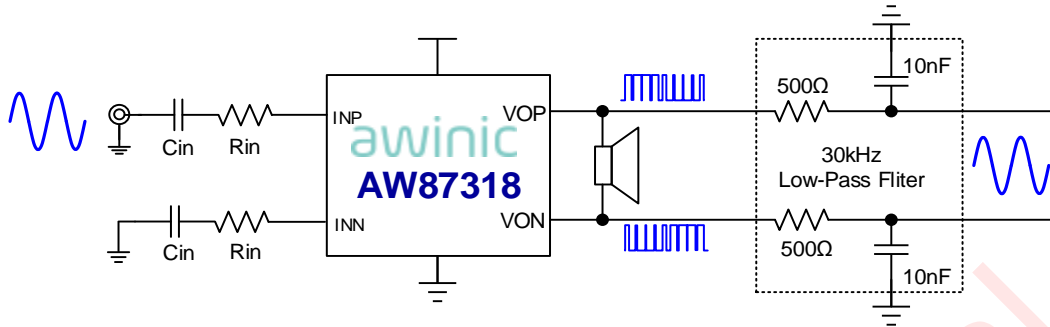


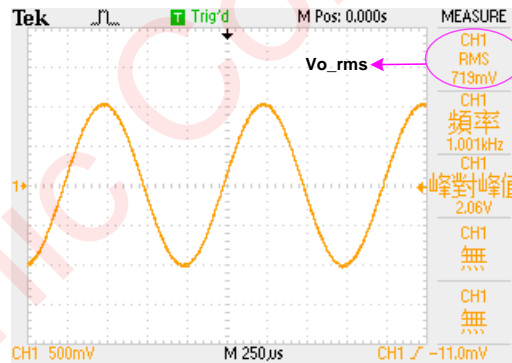
Figure 6 AW87318 Test Setup

The values of resistor and capacitor used by low pass filter are listed below:

R <sub>filter</sub>	C <sub>filter</sub>	Low-pass cutoff frequency
500Ω	10nF	32kHz
1kΩ	4.7nF	34kHz

### Output Power Calculation

According to the above test method, the differential audio analog output signal is obtained at the output of the low pass filter. The valid value Vo<sub>rms</sub> of the differential signal is as shown below:

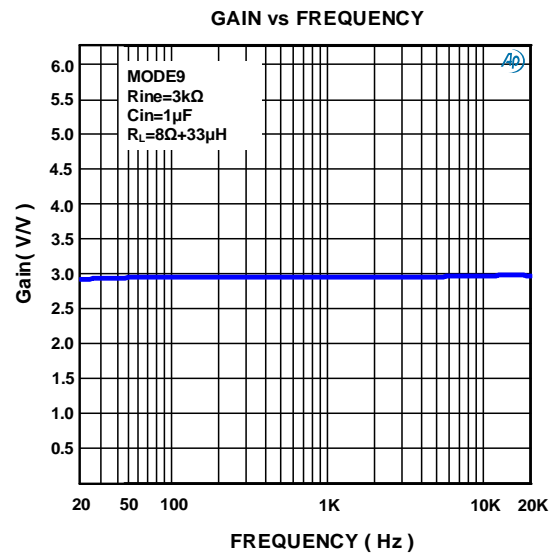
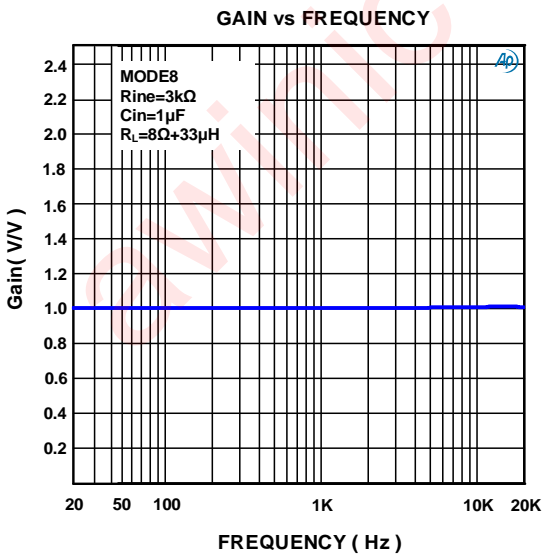
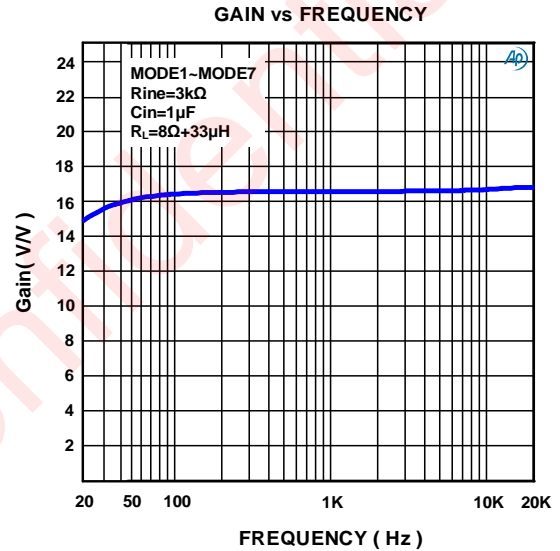
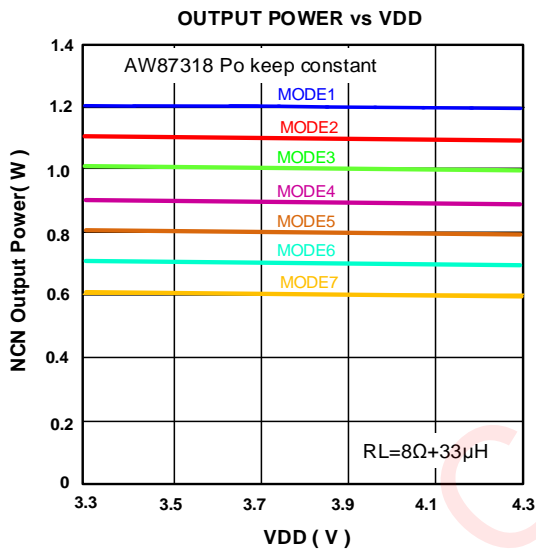
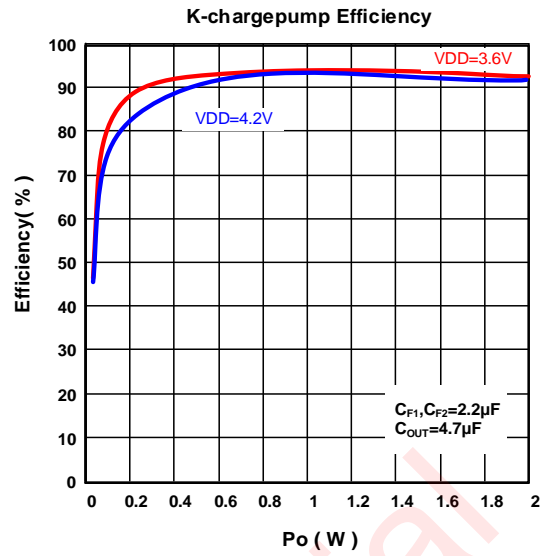
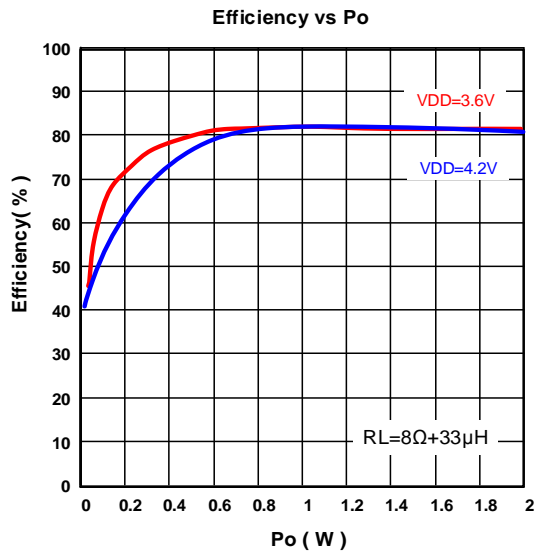


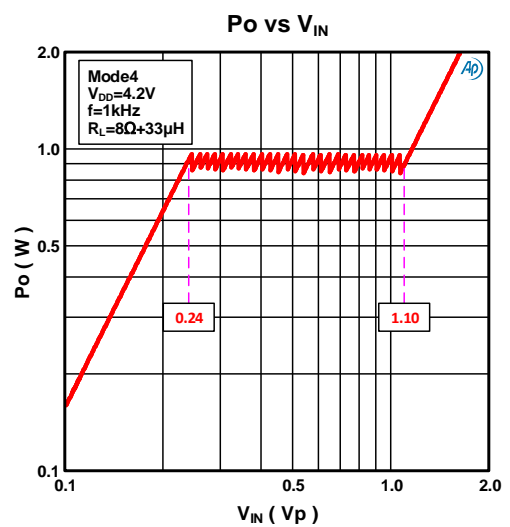
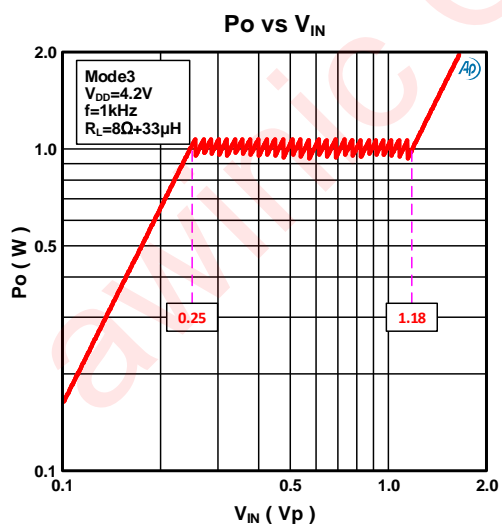
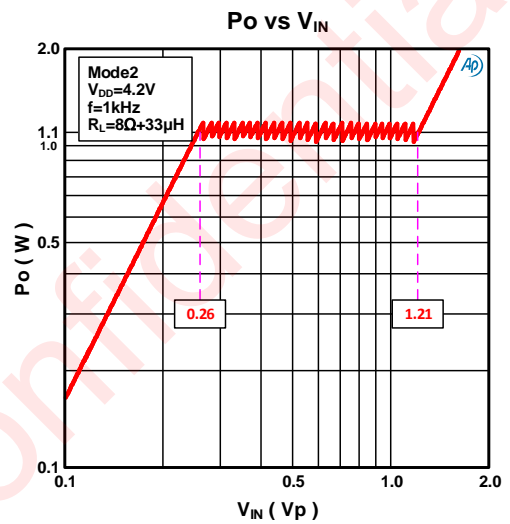
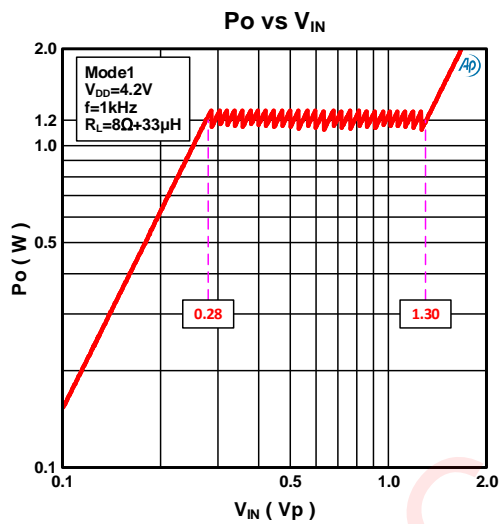
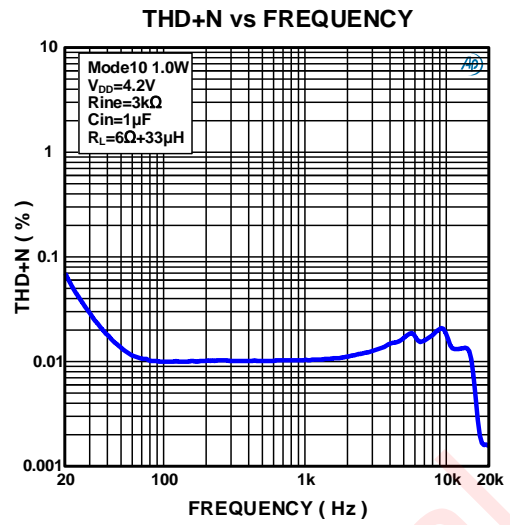
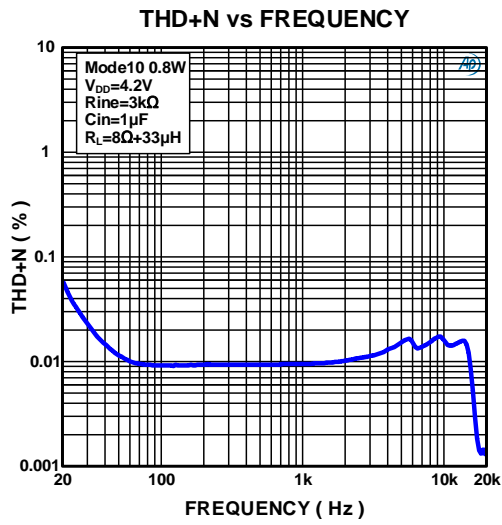
The power calculation of Speaker is as follows:

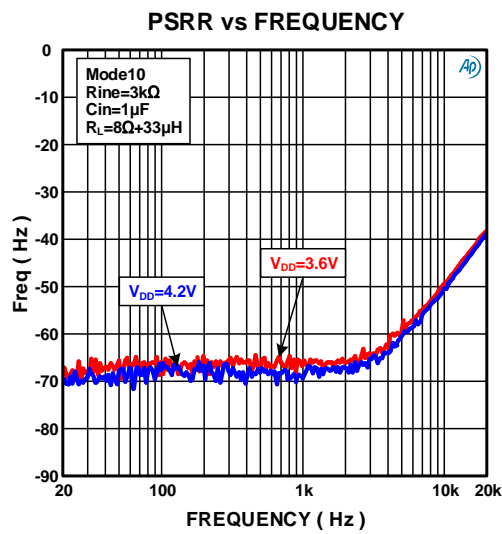
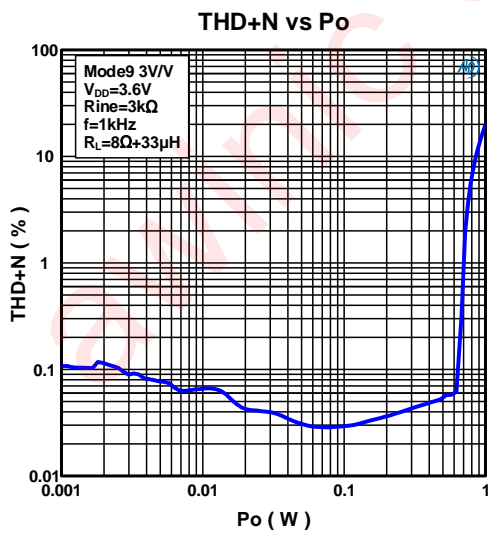
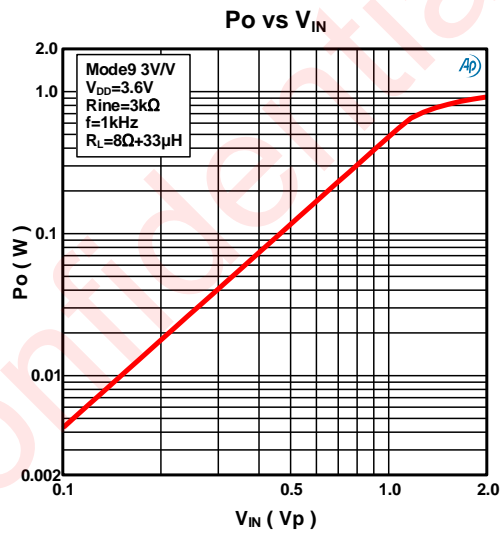
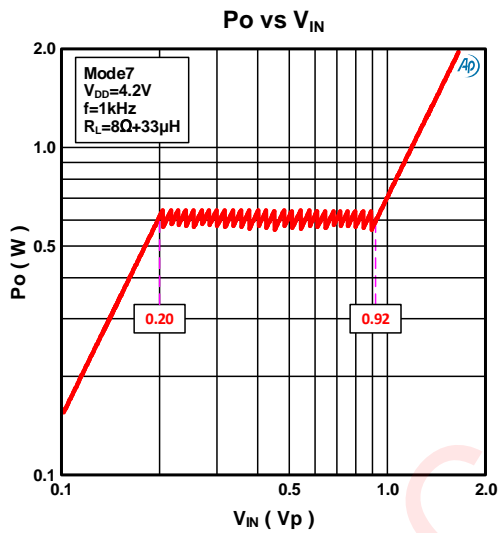
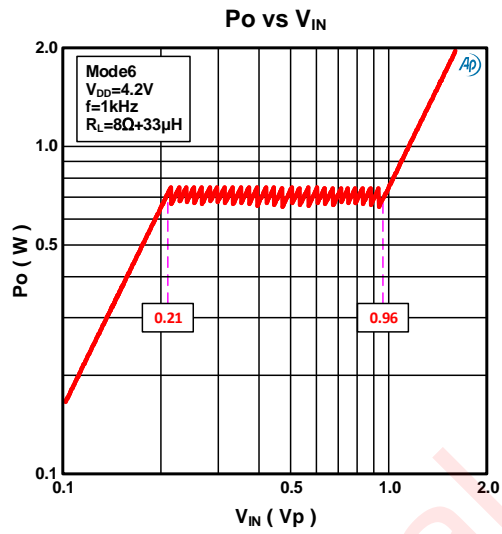
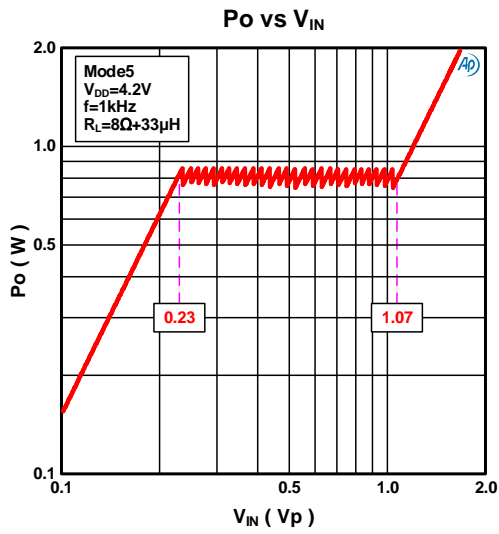
$$P_L = \frac{V_{O-RMS}^2}{R_L}$$

(R<sub>L</sub>: Load Impedance of the speaker or receiver)

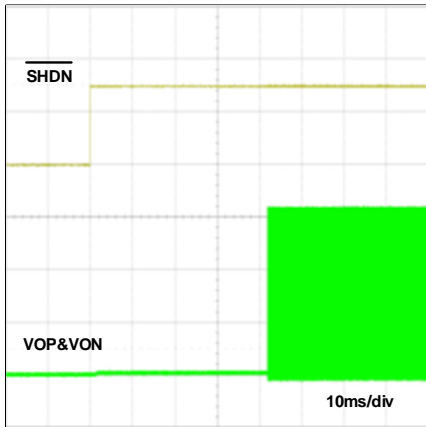
TYPICAL CHARACTERISTICS



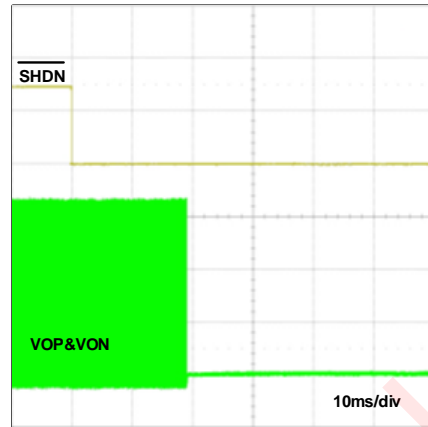




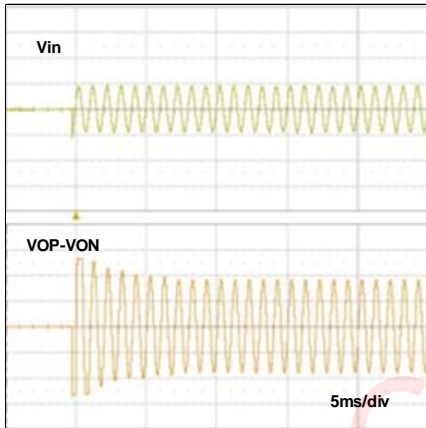
STARTUP SEQUENCE



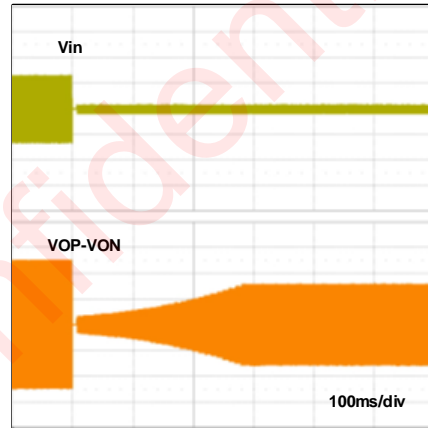
SHUTDOWN SEQUENCE



MULTI-LEVEL-AGC  
ATTACK SEQUENCE



MULTI-LEVEL-AGC  
RELEASE SEQUENCE





## DETAILED FUNCTIONAL DESCRIPTION

AW87318 is specifically designed to enhance overall sound quality. It is an upgrading 8<sup>th</sup>-generation class K audio amplifier with high efficiency, low noise, ultra-low distortion and capability of outputting constant large volume.

With integrated AWINIC proprietary Multi-Level AGC audio algorithm, AW87318 can eliminate noise in playback and improve sound quality and effect. Using a novel K-Chargepump technology, its integrated charge pump efficiency can reach 93%, and power amplifier's overall efficiency can reach 83%. With high efficiency, AW87318 can greatly prolong smart phone usage time.

AW87318 noise floor is as low as to 43 $\mu$ V, with 98.8dB high signal-to-noise-ratio (SNR). The ultra-low distortion 0.008% brings high-quality musical enjoyment.

AW87318 has a setting of 7-step selectable speaker-guard output power level from 0.6W to 1.2W, suitable for different rated power speakers. Within lithium battery voltage range, it keeps output power constant, preventing voice from degrading.

AW87318 supports speaker and receiver two-in-one application. The Class D Receiver Mode has an ultra-low output noise of 19 $\mu$ V. Under this mode, the power of PA is supplied by VBAT.

AW87318 has built-in over-current protection, over-temperature protection and short-circuit protection. AW87318 is available in a 1.60mm $\times$ 1.68mm, 0.4mm pitch CSP-14 package, or a 1.60mm $\times$ 1.60mm, 0.4mm pitch FC-16 package.

### Constant Output Power

In the smart phone audio applications, the AGC function which can promote music volume and audio quality is very attractive, but as the lithium battery voltage drops, the driver capability of ordinary audio power amplifiers will reduce gradually, leading to degrading audio effect. Therefore, it is hard to provide high-quality music within the battery voltage range.

With integrated AWINIC proprietary Multi-Level AGC audio algorithm and within lithium battery voltage range (3.3V to 4.35V), AW87318 can keep output power constant and never decreasing during lithium battery voltage dropping down. As a result, even if the battery voltage drops, AW87318 can still provide high-quality large-volume music enjoyment.

AW87318 has 10 operating modes. The first 7 modes have Multi-Level AGC function and their output AGC power levels are 1.2W, 1.1W, 1W, 0.9W, 0.8W, 0.7W, 0.6W, respectively.

### Multi-Level AGC Technology

In the current audio application, the maximum power of audio power amplifiers output tends to be larger than the rated power of speakers. For example, under the 5V power supply, for an 8-ohm speaker, the maximum undistorted power which a Class D audio power amplifier can deliver is about 1.56W, but many speakers' rated power is about 0.5W. If without output power control, the overload signal can cause damage to the speaker.

The audio power amplifier with NCN function (i.e. single-level AGC) can protect the speaker promptly, when the output power increases as the input signal increasing. When output power exceeds the setting threshold, the NCN function reduces the internal gain of amplifiers and restricts the output power below the set threshold.

However, to optimize NCN function, there is a tradeoff of attack time setting between music effect and crack noise: if the attack time is set longer, the audio volume will be larger, but crack noise will also be more evident; if the attack time is set shorter, the crack noise will be suppressed, but the audio volume will be loss.

Pop music generally has large crest factor (CF), which is in the range between 40dB to 60dB. In music playback, with larger peak exceeding the level of maximum output of the power amplifier, an audio signal will generate more crack noise. Therefore obvious noise will be heard in such music and it is necessary to use AGC with multi-level technology, so as to dynamically adjust the gain of audio power amplifiers. AGC with multi-level technology can increase the music volume and eliminate the emergence of obvious noise in large volume music at the same time, resulting in improved sound quality.

With integrated AWINIC proprietary Multi-Level AGC algorithm technology, AW87318 can eliminate noise in playback and improve sound quality and effect. The single-level AGC function and Multi-Level AGC function is shown in Figure 7, respectively.

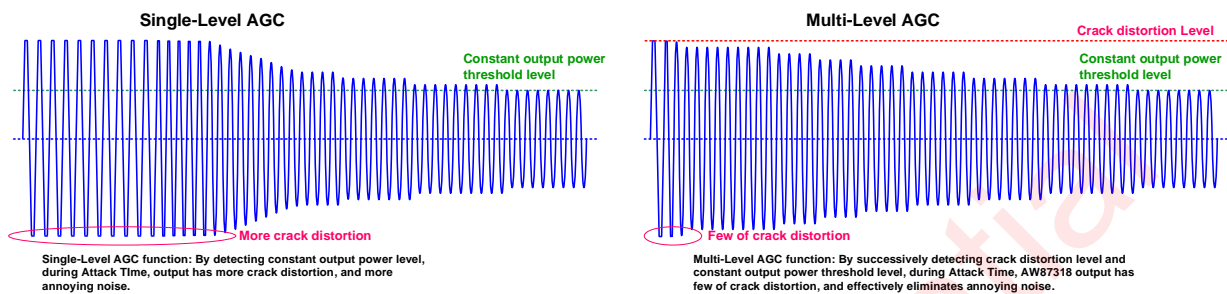


Figure 7 Single-Level AGC v.s. Multi-Level AGC

## Attack Time

Attack time is the time which Multi-Level AGC takes for the gain to be attenuated by 13.5dB when audio signal exceeds the constant output power threshold level. When crack noise occurs in output signal, the function called Fast AGC of Multi-Level AGC is firstly triggered, attenuating the gain by 10dB within 1.5ms and eliminating the crack noise. The other function called Slow AGC of Multi-Level AGC is then triggered, attenuating the gain slowly by 3.5dB within 6ms. According to features of music noise in smart phone application and demands for better music quality and volume, the AWINIC proprietary technology Multi-Level AGC integrated in AW87318, realizes smoother effect of music rhythm and protects the speaker from clipping distortion at the same time.

## Release time

Release time is the time which Multi-Level AGC takes for the gain to return to its setting value when audio signal is smaller than clipping level or constant output power threshold level. According to features of music noise in smart phone application and demands for better music quality and volume, release time of AW87318 is designed to be 280ms, which can effectively eliminate the noise, and make sound smoother.

## K-Chargepump

AW87318 adopts a new generation of charge pump technology: K-Chargepump structure. It has higher efficiency and larger driving capability. Its operating frequency is 1.06MHz. With built-in soft-start circuit, current-limit control loop and over-voltage-protection (OVP) loop, charge pump of this configuration can provide more stable and reliable power supply.

## High Efficiency

The output voltage PVDD is 1.5 times of supply voltage VDD in K-Chargepump, of which the ideal efficiency can reach 100%. Actually, the K-Chargepump efficiency can be calculated as the ratio of output power to input power, that is

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100\%$$

For example, in an ideal M-times charge pump, the input current  $I_{IN}$  is M times of the output current  $I_{OUT}$ , the efficiency formula can be written as:

$$\eta = \frac{P_{OUT}}{P_{IN}} \times 100\% = \frac{V_{OUT} \cdot I_{OUT}}{V_{IN} \cdot M \cdot I_{OUT}} \times 100\% = \frac{V_{OUT}}{M \cdot V_{IN}} \times 100\%$$

Also, M is a parameter depending on the operating mode of a charge pump;  $V_{OUT}$  is the output voltage of a charge pump;  $V_{IN}$  is the input voltage (generally is also the power supply voltage) of a charge pump;  $I_{OUT}$  is also the load current. For K-Chargepump structure, the output voltage is 1.5 times of the input voltage. Due to the switch loss and quiescent current loss inside the charge pump, the actual efficiency can still be up to 93%. As a result, the power booster technology of K-Chargepump can greatly improve the power efficiency.

## K-Chargepump Structure

As shown in Figure 8 is a K-Chargepump fundamental functional diagram: K-Chargepump integrated in AW87318 has seven switches, of which the output voltage PVDD is boosted to 1.5 times as input voltage VDD through seven switches operating timing.

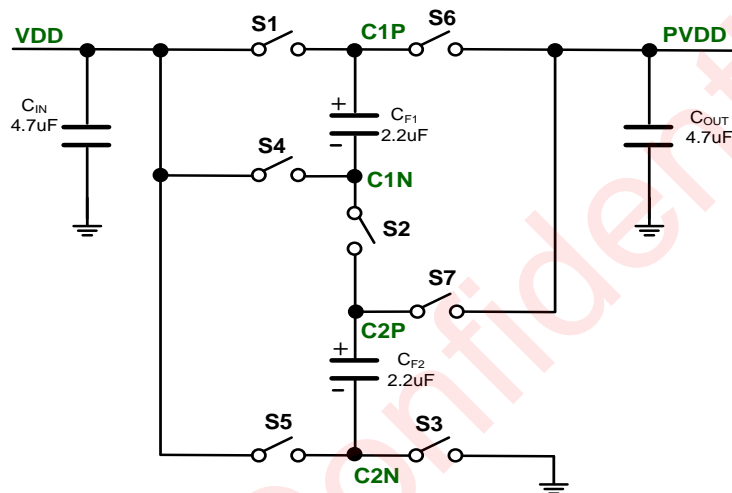


Figure 8 K-Chargepump Functional Diagram

The operation of the charge pump has two phases. In  $\Phi_1$ , as shown in Figure 9, when switches S1, S2 and S3 are closed, VDD charges to the flying capacitor  $C_{F1}$  and  $C_{F2}$ .

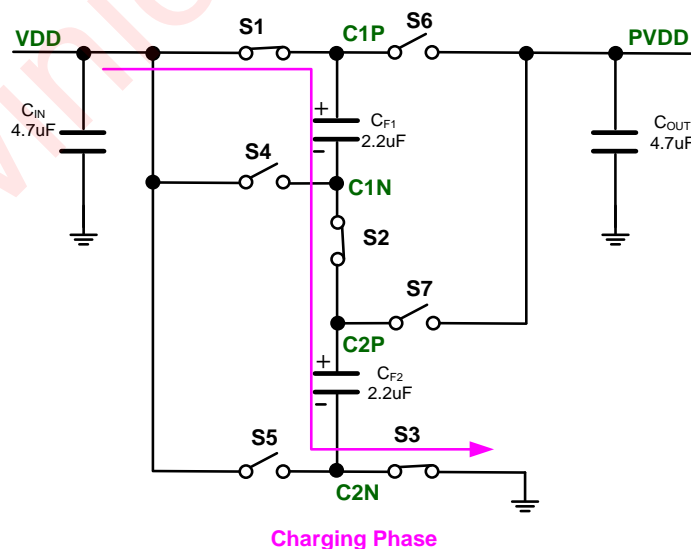


Figure 9  $\Phi_1$ : Charge Flying Capacitors  $C_{F1}$  and  $C_{F2}$

In  $\Phi_2$ , as shown in Figure 10, switches S1, S2 and S3 are opened, and switches S4, S5, S6 and S7 are closed. Because the voltage across the capacitor can't change instantaneously, so either the voltage on flying capacitors  $C_{F1}$  or  $C_{F2}$ , is added to the VDD, realizing a PVDD boosted to a higher voltage.

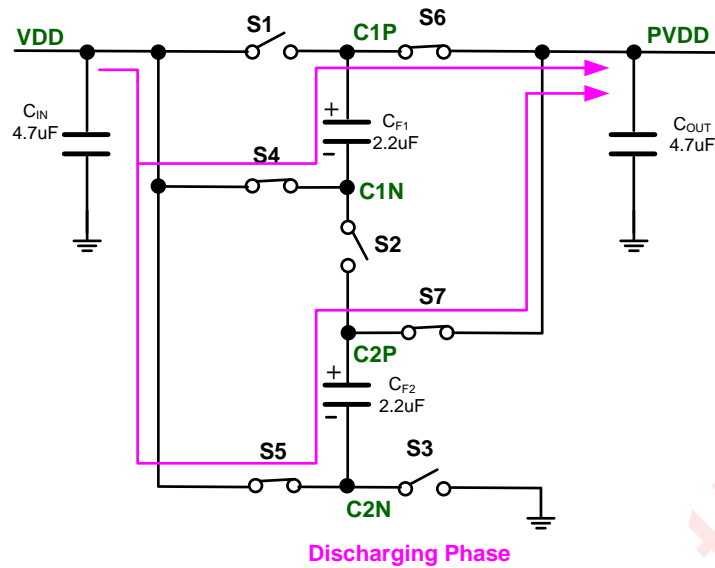


Figure 10  $\Phi_2$ : Flying Capacitor Charges Transfer to the Output Capacitor  $C_{OUT}$

## Soft Start

K-chargepump has integrated soft start function in order to limit inrush current from power supply during start-up. The current from power supply can be limited to 300mA, and the start-up time is about 1.2ms.

## Peak Current Control

K-chargepump has integrated a peak current control circuit. In normal operation, when a heavy load or a situation that makes the charge pump extracts very large current from power supply, the peak current control circuit can limit the maximum output load current, which is typically 2A.

## Over-Voltage Protection (OVP)

K-Chargepump keeps the output voltage PVDD a multiple of the input voltage VDD. It provides a high voltage power rail for internal power amplifier circuits, allowing the amplifiers provide greater output dynamic range in the lithium battery voltage range, realizing much larger volume, higher audio quality. K-Chargepump has integrated a over-voltage protection circuit. When the input voltage VDD is greater than 4V, the output voltage PVDD is no longer a multiple of VDD, but a controlled voltage by over-voltage protection (OVP) circuit and kept in 6.05V. The hysteresis voltage of OVP is about 50mV.

## Speaker & Receiver Two-in-One Application

Both Mode8 and Mode9 of AW87318 are Class D Receiver Modes. Their gain are selectable, 1V/V and 3V/V, respectively, for the application flexibility. By multiplexing the speaker's signal path, AW87318 Receiver Modes have ultra-low distortion and strong driving capability. Therefore, it is suitable for high-resolution voice calls. Another advantage is that there is no need to use additional external components, reducing system cost and saving PCB layout space.

In typical application as Figure 4 shown, with input capacitor  $C_{in}=100nF$  and input resistor  $R_{ine}=3k\Omega$ , the gain at Speaker Mode is about 16.6V/V, and the corner frequency of the input high-pass RC filter is about 166Hz. At Receiver Mode (Mode8), the gain is changed to 1V/V, with ultra-low output noise of 19 $\mu$ V, and the corner frequency of the input high-pass RC filter is about 15Hz. AW87318 can realize a speaker & receiver two-in-one application without changing any hardware.

## One-Wire Pulse Control: Principle

One-wire pulse control technology only needs a single GPIO port to turn on the chip and select a variety of functions. It is very popular in an environment lack of GPIO ports, such as portable systems.

Considering the problems of signal integrity or RF interference, there is narrow glitch in signal line when the PCB routine is too long. AWINIC one-wire pulse control technology integrated a deglitch circuit along with the internal control pin. The deglitch-module can completely eliminate the harmful glitch interference, as shown in Figure 11.

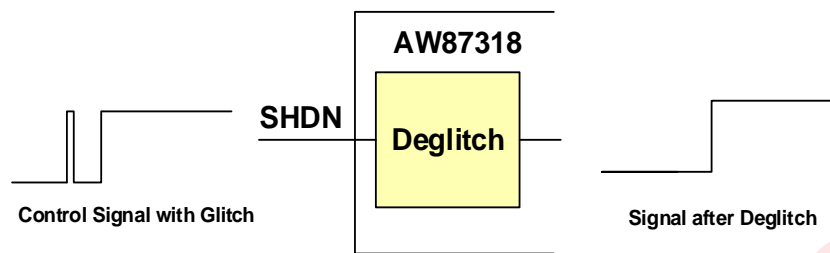


Figure 11 AWINIC Deglitch Working Principle

The traditional one-wire pulse control technology keeps working after the slave chip is powered up. Therefore, when the master chip (such as Baseband in a smart phone) sends other control signal through the same control port, the slave chip will probably enter into a wrong state. AW87318 uses one-wire pulse technology with a latch circuit, by which the right working state will be stored after the master chip sending order and AW87318 will no longer receive successive signals (except shutting down the chip firstly), as shown in Figure 12.

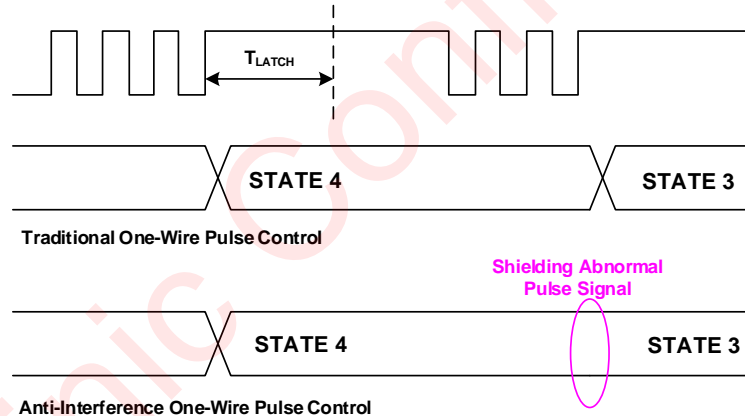


Figure 12 Anti-Interference One-Wire Pulse Control Functional Diagram

## One-Wire Pulse Control: Working Mode

Each mode of AW87318 can be set by the on-wire pulse control circuit, which can detect the number of pulses sent by master chip through SHDN pin. When SHDN pulls to high level from shutdown state (low level), i.e. only a rising edge, AW87318 will enter into Mode1, and the constant output power level of Multi-Level AGC is 1.2W (with 8Ω speaker load). When SHDN shows a high-to-low-to-high logic signal, i.e. a rising edge after a pulse, or two rising edges, AW87318 will enter into Mode2, and the level is 1.1W. Similarly, N rising edges means Mode"N", as shown in Figure 13. After all, AW87318 has ten operating modes, more than ten rising edges is forbidden.

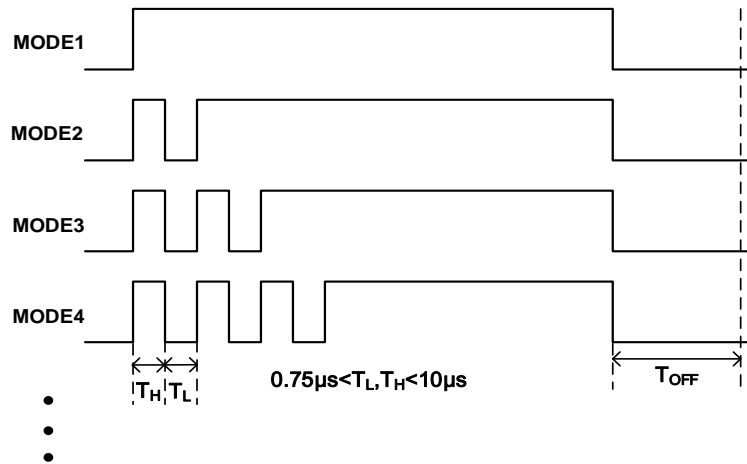


Figure 13 Working Mode Setting through One-Wire Pulse Control

To change the working mode of AW87318, one needs to keep SHDN low longer than  $T_{OFF}$  firstly (1ms is recommended), to shut down the chip. Then, send pulses to bring the chip into a right mode, as shown in Figure 14.

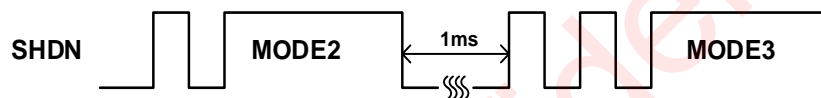


Figure 14 Mode Switch through One-Wire Pulse Control

## RNS (RF Noise Suppression)

GSM transmission adopts TDMA (Time Division Multiple Access) Technology which results in frame burst at frequency of 217Hz, also called TDD (Time Division Duplexing), leading to a strong RF interference (RF Noise) and the 217Hz energy along with its harmonics (TDD Noise) can be easily interacted with audio power amplifiers.

In applications, optimization of both layout and selection of peripheral components may decrease the AW87318's susceptibility to RF noise and prevent TDD Noise from being demodulated into audible noise. Minimization of length of routings prevents them from functioning as antennas and coupling RF noise into an AW87318. Further RF immunity can also be realized by using capacitors of which feature of frequency response is like a notch filter. Depending on manufacturers, self-resonance frequency of 10pF to 20pF capacitors typically located at RF band. Such capacitors placed in front of input pins of AW87318 can effectively suppress RF noise. Also, such capacitors must have a low-impedance, low-inductance path to the ground plane.

Even if part of RF energy is injected into AW87318 by traces connected to the chip, regardless of efforts of TDD Noise Reduction. AW87318 features a unique RNS technology, which effectively reduces RF energy and attenuates RF TDD-noise to an acceptable audible level for customers.

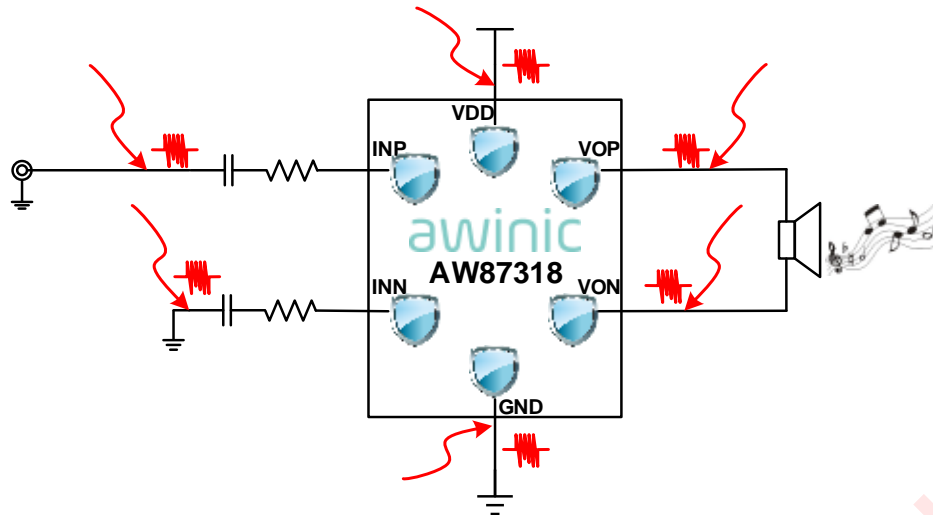


Figure 15 AW87318 Rejection of RF Noise

### Filter-Free Pulse Width Modulation (Filter-Free PWM)

AW87318 features a filter-free PWM architecture which removes a LC filter behind the output stage of a traditional Class D power amplifier, resulting in improvement of overall efficiency, decrease of PCB area and reduction of system cost.

### Enhanced Emission Elimination (EEE)

AW87318 features a unique Enhanced Emission Elimination (EEE) technology, which adjusts the speed of waveform transition of PWM output signal, and effectively reduces EMI over FM/AM bandwidth.

### Pop-Click Suppression

AW87318 integrates a unique timing-control circuit, which fundamentally suppresses pop-click noise, and eliminates audible crack at shut-down, wake-up, and power-up/down.

### Protection

When a short-circuit occurs among output pins (VOP, VON) and power pins (VDD, GND, PVDD) of AW87318, an over-current protection (OCP) circuit will be triggered and shut down the chip immediately, preventing the device from being damaged. When abnormal condition is removed, AW87318 can restart automatically without wake-up.

When junction temperature in AW87318 is too high, an over-temperature protection (OTP) circuit will be triggered and shut down the chip immediately. The circuit will turn the device on once the temperature decrease into a safe scope.

## APPLICATION INFORMATION

### Gain Setting -- Selection of External Input Resistor ( $R_{ine}$ )

AW87318 is a differential-input audio power amplifier. It integrates two internal input resistors ( $R_{ini}$ ), which are both 6.6k $\Omega$ . Take external input resistors  $R_{ine}=3k\Omega$  for instance, overall gain ( $A_V$ ) can be set as below:

AW87318 Mode	Calculation of Overall Gain (V/V)
Class K Speaker Mode (Mode1~7, and Mode10)	$A_V = \frac{159.5k\Omega}{R_{ine} + R_{ini}} = \frac{159.5k\Omega}{3k\Omega + 6.6k\Omega} = 16.6V/V$
Class D Receiver Mode with 1V/V gain (Mode8)	$A_V = \frac{110k\Omega}{R_{ine} + R_{ini}} = \frac{110k\Omega}{3k\Omega + 106.6k\Omega} = 1V/V$
Class D Receiver Mode with 3V/V gain (Mode9)	$A_V = \frac{110k\Omega}{R_{ine} + R_{ini}} = \frac{110k\Omega}{3k\Omega + 36.6k\Omega} = 3V/V$

### Input High-Pass Cutoff Frequency Setting -- Selection of Input Capacitor ( $C_{in}$ )

Input capacitors in front of external input resistors can block DC component of input audio signals. An input capacitor ( $C_{in}$ ) along with input resistors ( $R_{ine}+R_{ini}$ ) forms an input high-pass filter with a corner frequency ( $f_H$ ) calculated as below:

$$f_H(-3dB) = \frac{1}{2\pi(R_{ine} + R_{ini})C_{in}}$$

A higher  $f_H$  results in a better suppression of 217Hz GSM input noise. A better matching of input capacitors improves capability of blocking of common-mode interference of input stage in AW87318 and also helps to reduce pop-click noise.

Take typical application in Figure 1 for instance:

$$f_H(-3dB) = \frac{1}{2\pi(R_{ine} + R_{ini})C_{in}} = \frac{1}{2\pi \cdot 9.6k\Omega \cdot 100nF} = 166Hz$$

Besides, take Class D Receiver Mode with 1V/V gain (Mode8) for instance:

$$f_H(-3dB) = \frac{1}{2\pi(R_{ine} + R_{ini})C_{in}} = \frac{1}{2\pi \cdot 110k\Omega \cdot 100nF} = 15Hz$$

### Input Low-Pass Cutoff Frequency Setting -- Selection of Differential Input Capacitor ( $C_d$ )

A differential input capacitor behind external input resistors can block high-frequency component of input audio signals, such as screechy part in a song. A differential input capacitor ( $C_d$ ) along with input resistors ( $R_{ine}+R_{ini}$ ) forms an input low-pass filter with a corner frequency ( $f_L$ ) calculated as below:



$$f_L(-3dB) = \frac{1}{4\pi(R_{ine} // R_{ini})C_d}$$

Take typical application in Figure 1 with  $C_d=220\text{pF}$  and  $R_{ine}=3\text{k}\Omega$  for instance:

$$f_L(-3dB) = \frac{1}{4\pi \cdot (3\text{k}\Omega // 6.6\text{k}\Omega) \cdot 220\text{pF}} = 176\text{kHz}$$

### Selection of Power Supply Decoupling Capacitor (Cs)

AW87318 is a high-performance audio power amplifier. It is essential to place a ceramic capacitor ( $C_s$ ) with low equivalent-series-resistance (ESR) (typical  $0.1\mu\text{F}$ ) for power supply decoupling. Optimized selection and placement of decoupling capacitors protect AW87318 from interference injection from power supply, such as high-frequency transients, spikes, or digital noise. Specifically, a layout of decoupling capacitor closer to AW87318 is preferred, since fewer parasitic resistance or inductance between power pin and the capacitor, less decoupling efficiency loss. In addition to a  $0.1\mu\text{F}$  ceramic capacitor, another  $10\mu\text{F}$  capacitor as a charge reservoir is required, providing transient power energy for AW87318 and preventing remarkable drop of the power supply voltage.

### Selection of Charge Pump Flying Capacitor (Cf)

Value of charge pump flying capacitors ( $C_f$ ) affects load regulation and output impedance of the charge pump. Small capacitance may degrade driving capability of AW87318. A  $2.2\mu\text{F}/6.3\text{V}$  ceramic capacitor is usually recommended.

### Selection of Charge Pump Output Capacitor (Cout)

Capacitance and ESR of charge pump output capacitors ( $C_{OUT}$ ) directly affect ripple magnitude of charge pump output voltage (PVDD). Increasing  $C_{OUT}$  Capacitance reduces variations of PVDD and decreasing  $C_{OUT}$  ESR also reduces both ripple and output resistance. A  $4.7\mu\text{F}/10\text{V}$  ceramic capacitor is usually recommended.

### Usage of Ferrite Bead and Filter Capacitor

Without ferrite beads and filter capacitors, AW87318 can still pass the specifications of FCC and CE. If there is any EMI sensitive device near AW87318 and/or there are long traces routing from the amplifier to a speaker, use ferrite beads and filter capacitors and place beads and capacitors as close as possible to output pins (VOP&VON), as Figure 16 below.

In Class K Speaker Mode, outputs of AW87318 are square-wave PWM signals, which charge and discharge filter capacitors in each period, and result in additional static power consumption. Bigger filter capacitance, larger current consumption. Therefore,  $0.1\text{nF}$  ceramic capacitor is usually recommended for low power application.

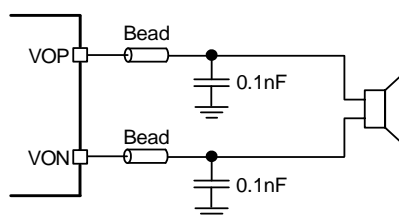


Figure 16 Ferrite Beads and Filter Capacitors

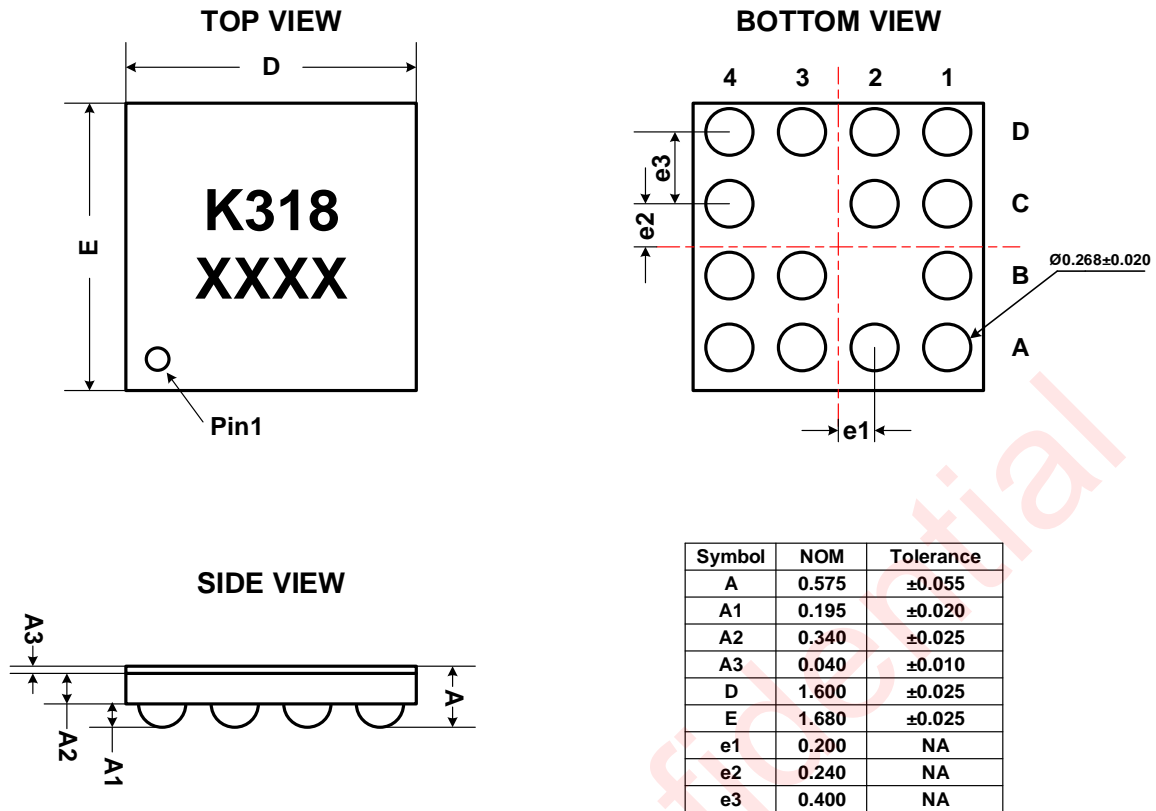
## PCB AND DEVICE LAYOUT CONSIDERATION

In order to exploit best performance of AW87318, PCB layout must be carefully considered. Design consideration should be followed as below:

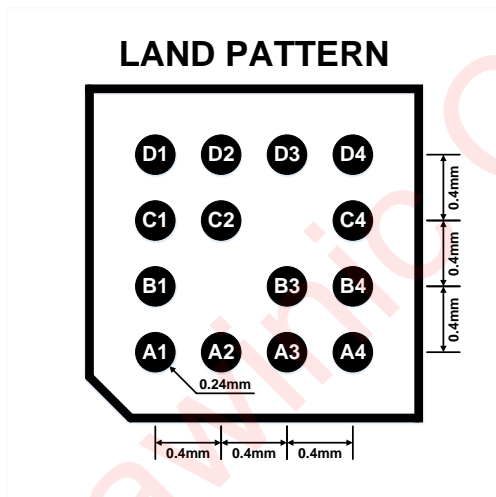
1. Isolated, short and wide power lines for both VDD pin and GND pin are required for better driving-capability of AW87318. The copper width is recommended to be larger than 0.75mm (30mil). Power supply decoupling capacitors should be placed as close as possible to power supply pins.
2. Flying capacitors  $C_{F1}$ ,  $C_{F2}$  should be placed as close as possible to C1N, C1P pins and C2N, C2P pins. Likewise, capacitor  $C_{OUT}$  should be close to PVDD pin. The trace from  $C_{OUT}$  to both PVDD pin and GND pin should be short and wide.
3. Input capacitors and resistors should be close to INN and INP pins. Differential and ground-shielding input routing is required to suppress noise coupling.
4. Ferrite beads and filter capacitors should be close to VON and VOP pins. The trace from output pins to speaker should be short and wide. The copper width is recommended to be larger than 0.5mm (20mil).

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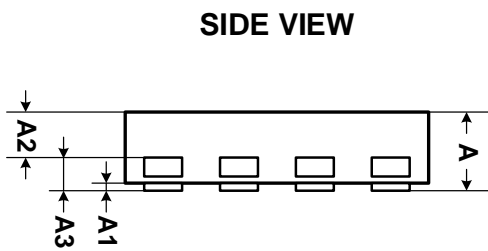
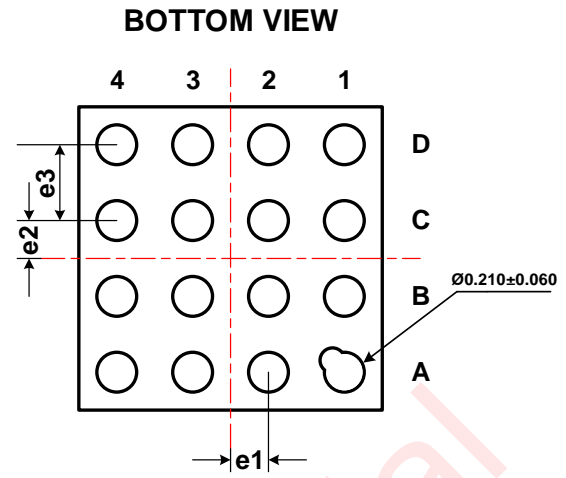
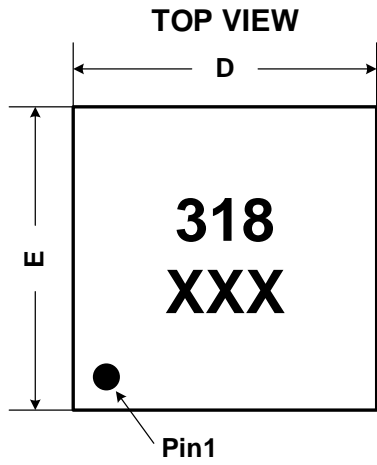
PACKAGE INFORMATION FOR AW87318CSR



Unit: mm

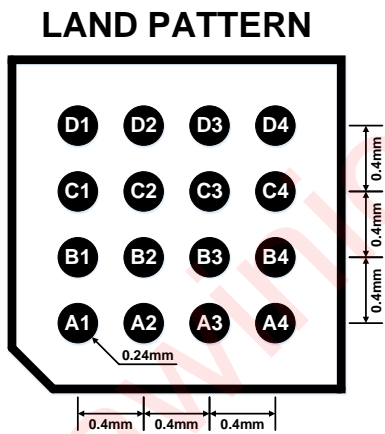


PACKAGE INFORMATION FOR AW87318FCR

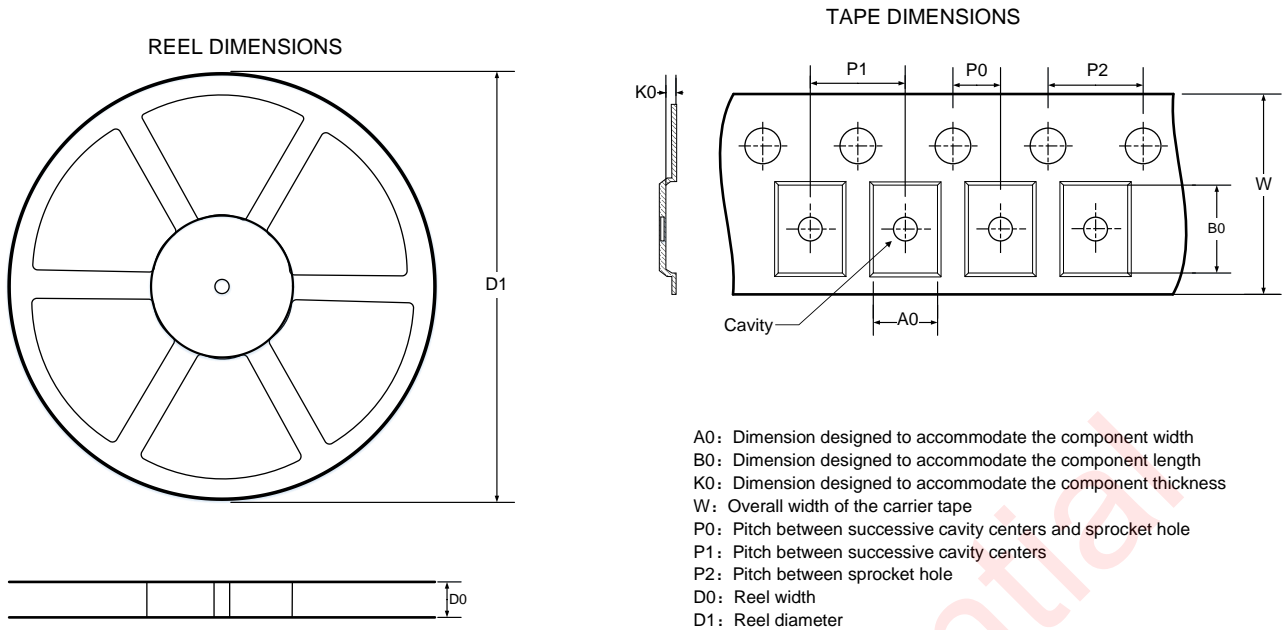


Symbol	NOM	Tolerance
A	0.55	±0.05
A1	0.02	-0.02/+0.03
A2	0.4	NA
A3	0.152	NA
D	1.6	±0.1
E	1.6	±0.1
e1	0.200	NA
e2	0.200	NA
e3	0.400	NA

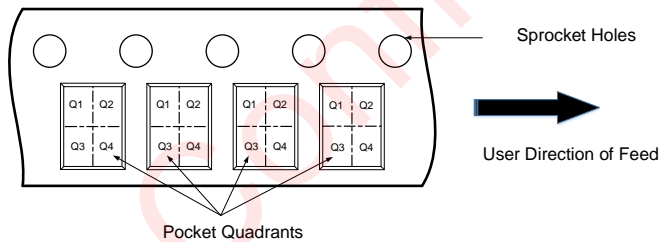
Unit: mm



### TAPE AND REEL INFORMATION FOR AW87318CSR



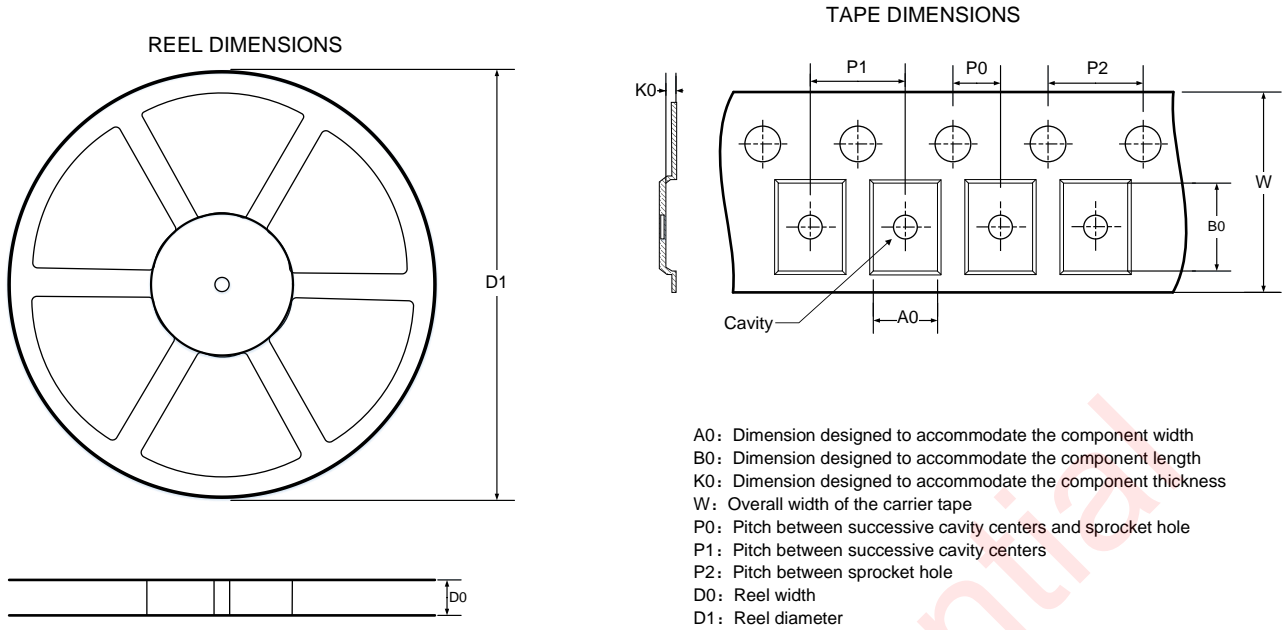
#### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



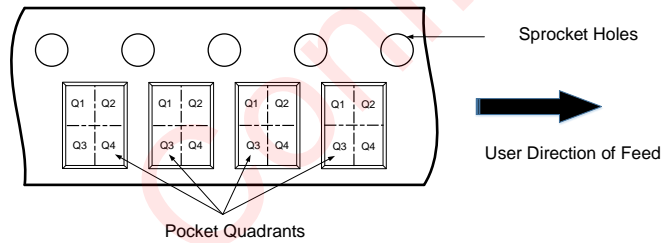
All dimensions are nominal

D1 (mm)	D0 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
179	9	1.76	1.81	0.75	2	4	4	8	Q2

TAPE AND REEL INFORMATION FOR AW87318FCR



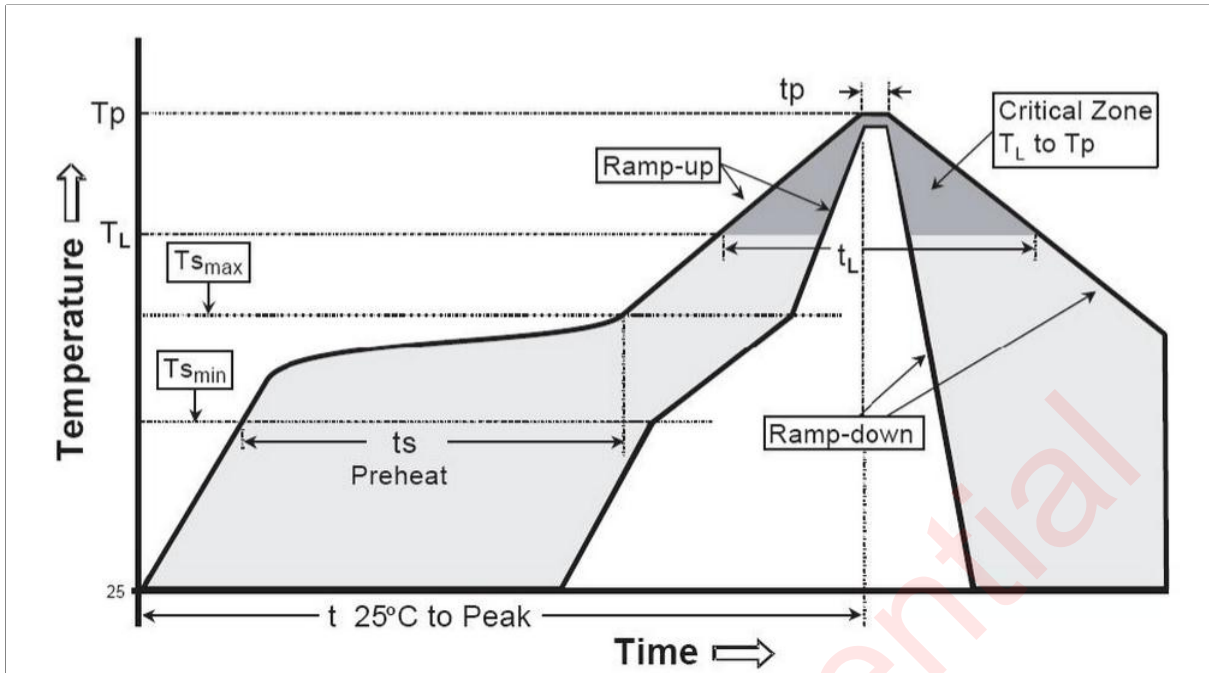
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



All dimensions are nominal

D1 (mm)	D0 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
180	9.5	1.73	1.73	0.72	2	4	4	8	Q1

## REFLOW SOLDERING CURVE



Reflow Note	Spec
Average Ramp-up Rate (217°C to Peak)	Max. 3°C/sec
Time of Preheat temp. (from 150°C to 200°C)	60sec-120sec
Time to be Maintained above 217°C	60sec-150sec
Peak Temperature	250°C~260°C
Time within 5°C of Actual Peak Temp	20sec-40sec
Ramp-down Rate	Max. 6°C/sec
Time from 25°C to Peak Temp	Max. 8min

**VERSION INFORMATION**

Version	Date	Description
V1.0	2015-10-16	AW87318CSR datasheet V1.0 released
V1.1	2017-05-16	Add LAND PATTERN description, Carrié tap description, PIN1 location, tap description and reflow soldering curve, modify Flying capacitor rated voltage
V1.2	2018-02-05	Add New Package Info Add Output Power of Receiver Mode Add Curve of Po vs Vin and THD+N vs Po of Mode 9

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