LR6311

3 Watt Mono Filter-Free Class-D Audio Power Amplifier

Features

- Efficiency With an 8-Ω Speaker:
  - 88% at 400 mW
  - 80% at 100 mW
- 2.6mA Quiescent Current
- 0.4μA Shutdown Current
- Optimized PWM Output Stage Eliminates LC Output Filter
- Internally Generated 250-kHz Switching Frequency Eliminates Capacitor and Resistor
- Improved PSRR (−75 dB) and Wide Supply Voltage (2.5 V to 5.5 V) Eliminates Need for a Voltage Regulator
- Fully Differential Design Reduces RF Rectification and Eliminates Bypass Capacitor
- Improved CMRR Eliminates Two Input Coupling Capacitors
- Available in space-saving package: 9-bump WLCSP

General Description

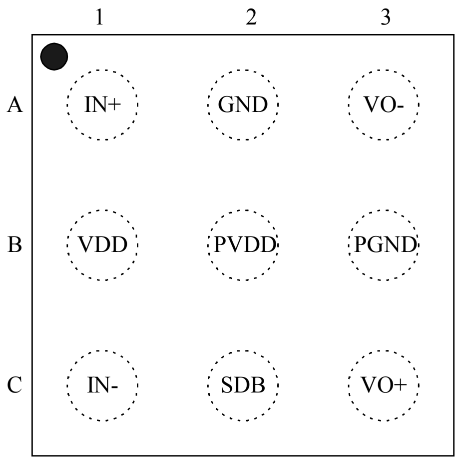
The LR6311 is a 3-W high efficiency filter-free class-D audio power amplifier in a wafer chip scale package (WCSP) that requires only three external components.

Features like 88% efficiency, −75dB PSRR, and improved RF-rectification immunity make the LR6311 ideal for cellular handsets. In cellular handsets, the earpiece, speaker phone, and melody ringer can each be driven by the LR6311.

Applications

- Mobile phone、PDA
- MP3/4、PMP
- Portable electronic devices

Pin Diagrams

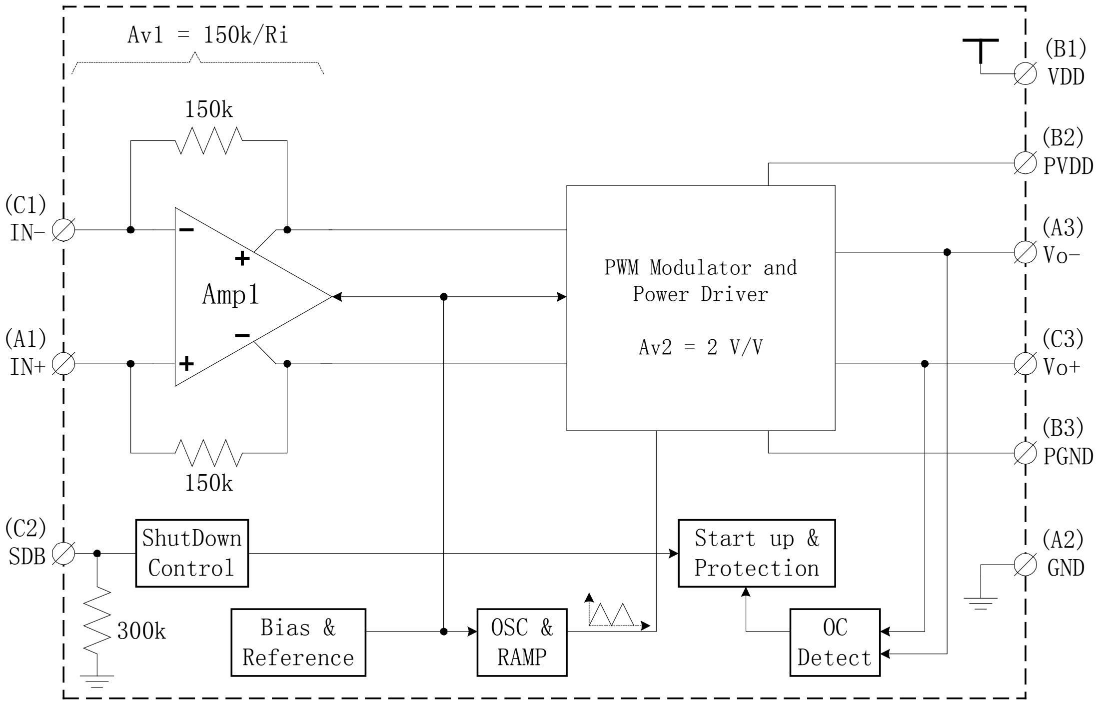


top view

Pin Description

Pin #	Name	Description
A1	IN+	Positive differential input
A2	GND	Power Ground
A3	VO-	Negative BTL output
B1	VDD	Power Supply
B2	PVDD	Power Supply
B3	PGND	Power Ground
C1	IN-	Negative differential input
C2	SDB	Shutdown terminal (low active)
C3	VO+	Positive BTL output

Function Block Diagram



$$\textbf{Notes:}\ \textit{Total Voltage Gain} = Av1 \times Av2 = 2 \times \frac{150k}{R_I}$$

Figure 1. Function Block Diagram

Application Circuit

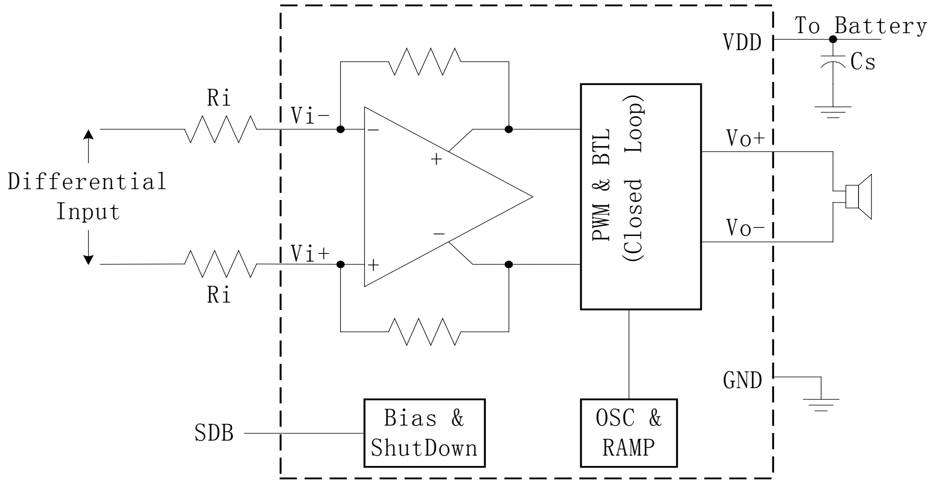


Figure 2. LR6311 Application Schematic With Differential Input

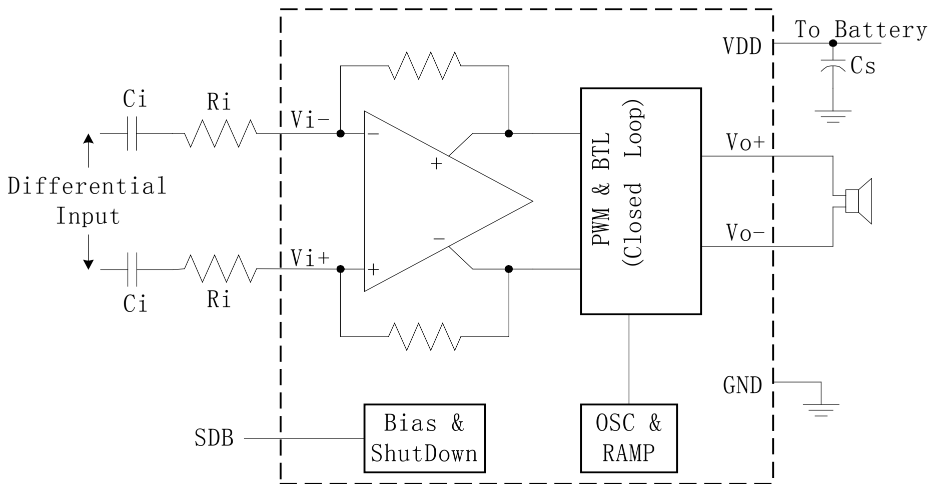


Figure 3. LR6311 Application Schematic With Differential Input and Input Capacitors

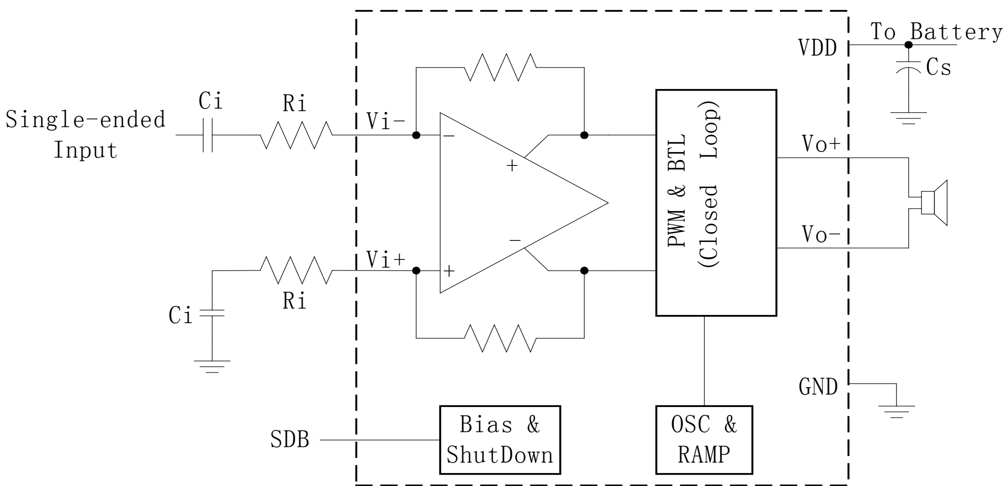


Figure 4. LR6311 Application Schematic With Single-Ended Input

Electrical Characteristics

The following specifications apply for the circuit shown in Figure 5.

T_A = 25℃, unless otherwise specified.

Symbol	Parameter	Conditions	Spec Min.	Spec Typ.	Spec Max.	Units
I_{SD}	Shutdown Current	V_{IN}=0V, V_{SDB}=0V, No Load		0.4	2	uA
I_Q	Quiescent Current	V_{DD} = 2.5V, V_{IN} = 0V, No Load		2.0		mA
		V_{DD} = 3.6V, V_{IN} = 0V, No Load		2.6		
		V_{DD} = 5.5V, V_{IN} = 0V, No Load		3.0	8	
$\|V_{OS}\|$	Output Offset Voltage	V_{IN} = 0V, A_V = 2V/V, V_{DD} = 2.5V to 5.5V		2	25	mV
PSRR	Power Supply Rejection Ratio	V_{DD} = 2.5V to 5.5V		-75		dB
CMRR	Common Mode Rejection Ratio	V_{DD} = 2.5V to 5.5V, V_{IC} = V_{DD}/2 to 0.5V, V_{IC} = V_{DD}/2 to V_{DD} - 0.8V		-68		dB
F_{SW}	Modulation frequency	V_{DD} = 2.5V to 5.5V	200	250	300	kHz
A_V	Voltage gain	V_{DD} = 2.5V to 5.5V	$\frac{285k}{R_I}$	$\frac{300k}{R_I}$	$\frac{315k}{R_I}$	V/V
R_{SDB}	Resistance from SDB to GND			300		kΩ
Z_I	Input impedance		142	150	158	kΩ
T_{WU}	Wake-up time from shutdown	V_{DD} = 3.6V		1		mS
$r_{DS(on)}$	Drain-Source resistance (on-state)	V_{DD} = 2.5V		700		mΩ
		V_{DD} = 3.6V		500		
		V_{DD} = 5.5V		400		

Operating Characteristics

❑ **V_{DD} = 5V,** R_I = 150kΩ, T_A = 25℃, unless otherwise specified.

Symbol	Parameter	Conditions	Spec Min.	Spec Typ.	Spec Max.	Units
P_O	Output Power	THD+N=10%, f=1KHz, R_L = 4Ω		3.0		W
		THD+N=1%, f=1KHz, R_L = 4Ω		2.4		
		THD+N=10%, f=1KHz, R_L = 8Ω		1.7		
		THD+N=1%, f=1KHz, R_L = 8Ω		1.4		
THD+N	Total Harmonic Distortion + Noise	Po=1.0Wrms, f=1kHz, R_L = 8Ω		0.19		%
SNR	Signal-to-Noise ratio	V_{DD}=5V, Po=1.0Wrms, R_L = 8Ω		97		dB

❑ **V_{DD} = 3.6V,** R_I = 150kΩ, T_A = 25℃, unless otherwise specified.

Symbol	Parameter	Conditions		Spec Min.	Spec Typ.	Spec Max.	Units
P_O	Output Power	THD+N=10%, f=1KHz, R_L = 4Ω			1.5		W
		THD+N=1%, f=1KHz, R_L = 4Ω			1.2		
		THD+N=10%, f=1KHz, R_L = 8Ω			0.9		
		THD+N=1%, f=1KHz, R_L = 8Ω			0.7		
THD+N	Total Harmonic Distortion + Noise	Po=0.5Wrms, f=1kHz, R_L = 8Ω			0.19		%
K_{SVR}	Supply ripple rejection ratio	V_{DD} = 3.6V, input ac-grounded with C_I = 2uF f=217Hz, V(Ripple)=200mV_{PP}			-68		dB
V_n	Output voltage noise	V_{DD} = 3.6V, input ac-grounded with C_I = 2uF, f=20~20kHz	No weighting		48		uV_{RMS}
			A weighting		36		
CMRR	Common Mode Rejection Ratio	V_{DD} = 3.6V, V_{IC} = 1 V_{PP}, f=217Hz			-70		dB

❑ **V_{DD} = 2.5V,** R_I = 150kΩ, T_A = 25℃, unless otherwise specified.

	Parameter	Conditions	Spec	Units

Symbol	Parameter	Conditions	Spec			Units
			Min.	Typ.	Max.	
		THD+N=10%, f=1KHz, R_L = 4Ω		0.7		
		THD+N=1%, f=1KHz, R_L = 4Ω		0.55		
		THD+N=10%, f=1KHz, R_L = 8Ω		0.4		
		THD+N=1%, f=1KHz, R_L = 8Ω		0.3		
THD+N	Total Harmonic Distortion + Noise	Po=0.2Wrms, f=1kHz, R_L = 8Ω		0.19		%

Test Circuit

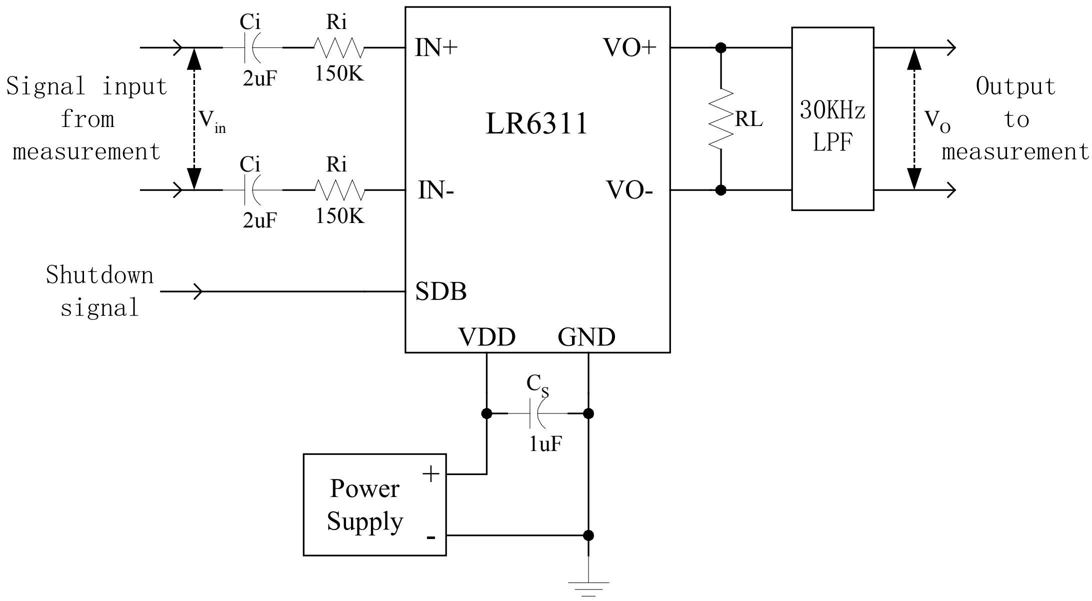


Figure 5. LR6311 test set up circuit

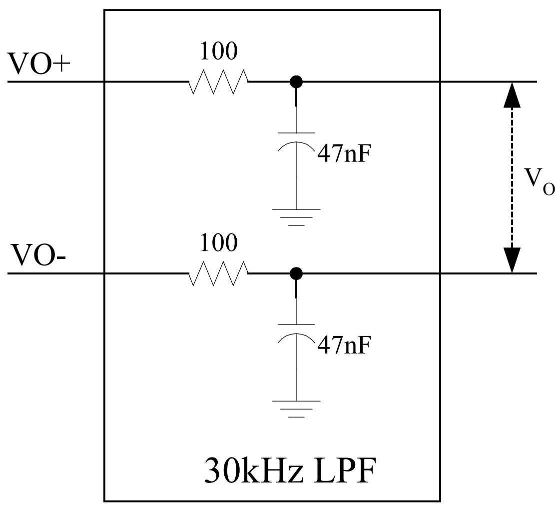


Figure 6. 30-kHz LPF for LR6311 test

Notes: 1>. C_S should be placed as close as possible to VDD/GND pad of the device

2>. Ci should be shorted for any Common-Mode input voltage measurement

3>. A 33uH inductor should be used in series with R_L for efficiency measurement

4>. The 30 kHz LPF (shown in figure 5) is required even if the analyzer has an internal LPF

Component Recommended

Due to the weak noise immunity of the single-ended input application, the differential input application should be used whenever possible. The typical component values are listed in the table:

R_I	C_I	C_S
150 k	3.3 nF	1 uF

(1) C_I should have a tolerance of ±10% or better to reduce impedance mismatch.

(2) Use 1% tolerance resistors or better to keep the performance optimized, and place the R_I close to the device to limit noise injection on the high-impedance nodes.

Input Resistors (R_I) & Capacitors (C_I)

The input resistors (R_I) set the total voltage gain of the amplifier according to *Eq1*

$$Gain = \frac{2 \times 150k\Omega}{R_I} \left(\frac{V}{V}\right) \qquad Eq1$$

The input resistor matching directly affects the CMRR, PSRR, and the second harmonic distortion cancellation.

If a differential signal source is used, and the signal is biased from 0.5V ~ V_{DD}-0.8V (shown in Figure2), the input capacitor (C_I) is not required.

If the input signal is not biased within the recommended common-mode input range in differential input application (shown in Figure3), or in a single-ended input application (shown in Figure4), the input coupling capacitors are required.

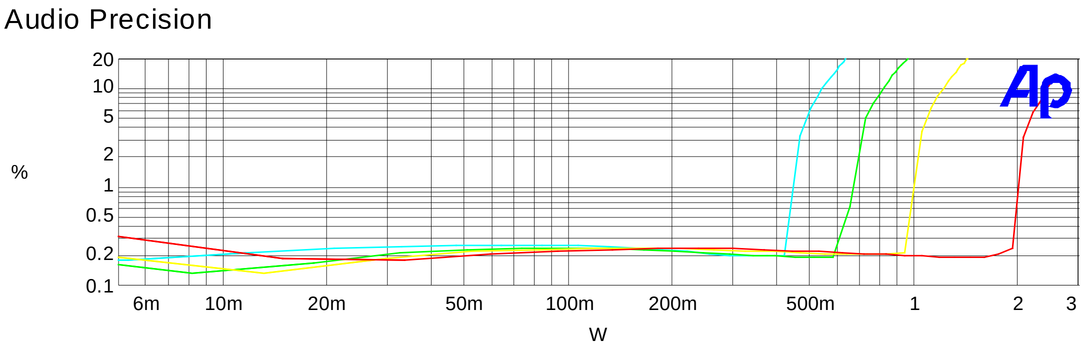
If the input coupling capacitors are used, the R_I and C_I form a high-pass filter (HPF). The corner frequency (f_C) of the HPF can be calculated by *Eq2*

$$f_C = \frac{1}{2\pi \cdot R_I \cdot C_I} \quad (Hz) \qquad Eq2$$

Decoupling Capacitor (C_S)

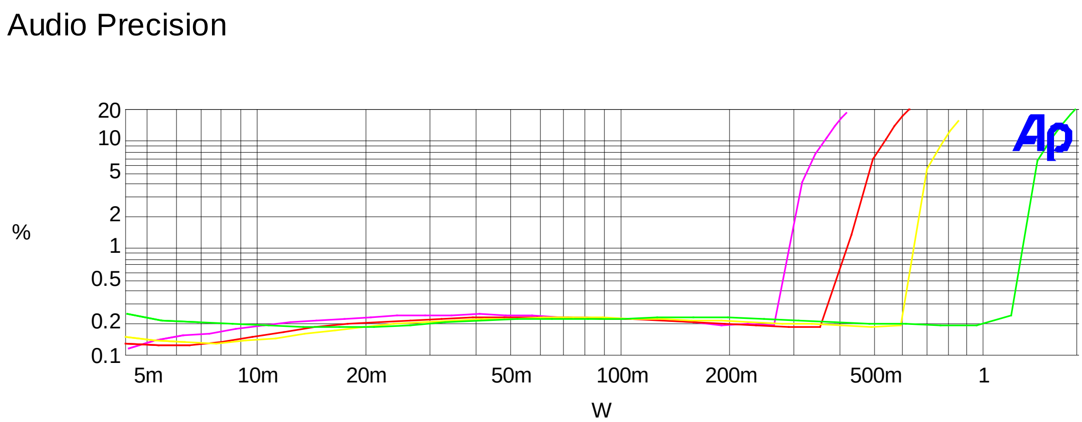
A good low equivalent-series-resistance (ESR) ceramic capacitor (C_S), used as power supply decoupling capacitor (C_S), is required for high power supply rejection (PSRR), high efficiency and low total harmonic distortion (THD). Typically C_S is 1μF, placed as close as possible to the device VDD pin.

Typical Performance Characteristics



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Cyan	Solid	1	Analyzer.THD+N Ratio B	Left	2.5v
2	1	Green	Solid	1	Analyzer.THD+N Ratio B	Left	3v
3	1	Yellow	Solid	1	Analyzer.THD+N Ratio B	Left	3.6v
4	1	Red	Solid	1	Analyzer.THD+N Ratio B	Left	5v

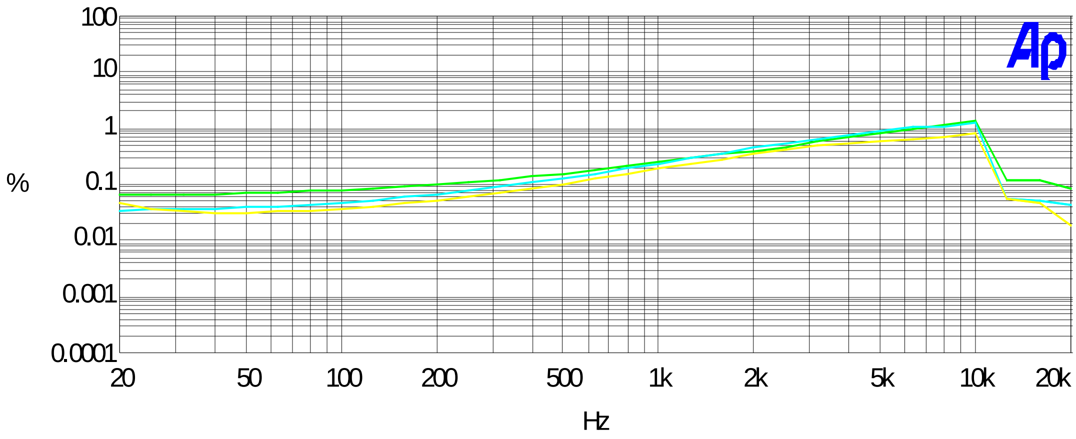
Figure7 THDN vs P_O (R_L=4ohm, f=1kHz, Gain=2)



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Magenta	Solid	1	.Analyzer.THD+N Ratio B	Left	2.5V
2	1	Red	Solid	1	.Analyzer.THD+N Ratio B	Left	3V
3	1	Yellow	Solid	1	.Analyzer.THD+N Ratio B	Left	3.6V
4	1	Green	Solid	1	.Analyzer.THD+N Ratio B	Left	5V

Figure8 THDN vs P_O (R_L=8ohm, f=1kHz, Gain=2)

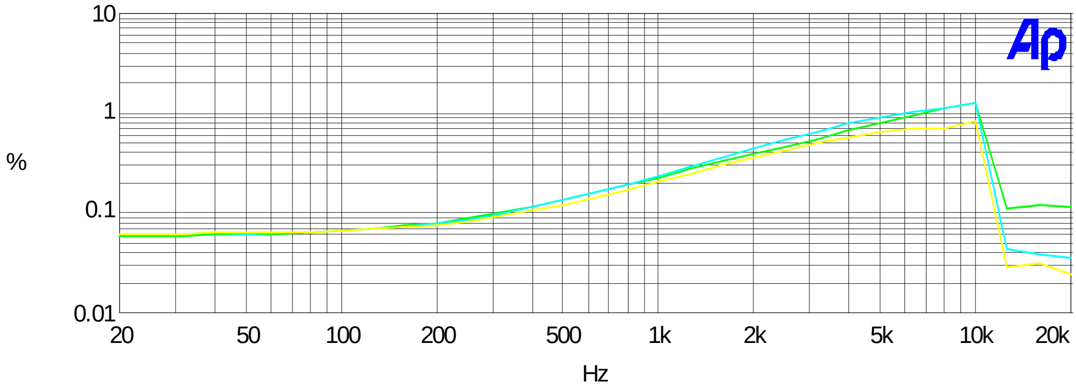
Audio Precision



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	1	Analyzer.THD+N Ratio B	Left	Po=25mW
2	1	Cyan	Solid	1	Analyzer.THD+N Ratio B	Left	Po=250mW
3	1	Yellow	Solid	1	Analyzer.THD+N Ratio B	Left	Po=1w

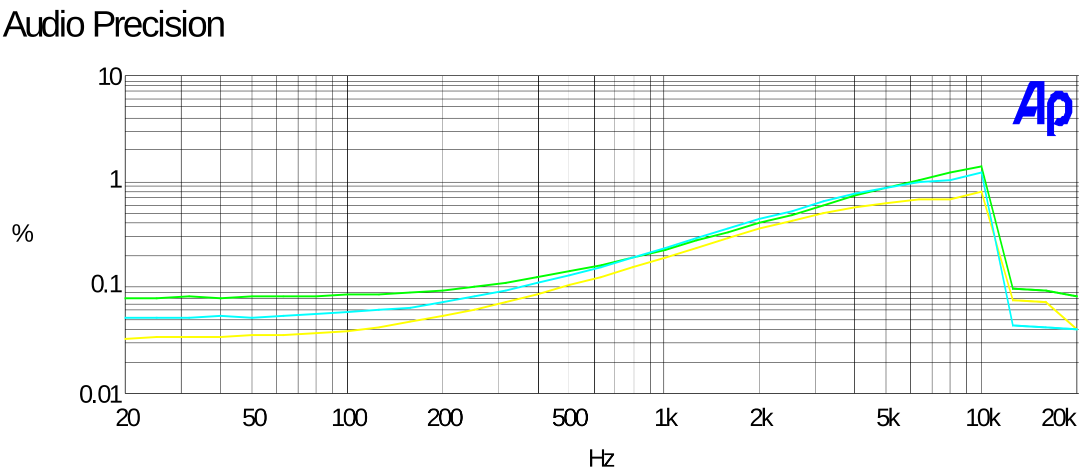
Figure9 THDN vs Frequency (V_{DD}=5V R_L=8ohm Gain=2 C_I=2uF)

Audio Precision



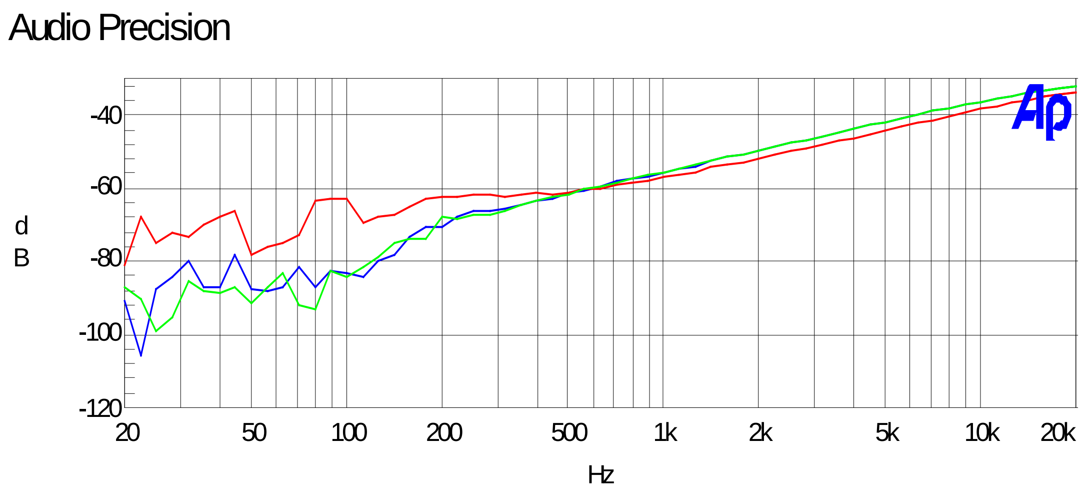
Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	1	Analyzer.THD+N Ratio B	Left	
2	1	Cyan	Solid	1	Analyzer.THD+N Ratio B	Left	
3	1	Yellow	Solid	1	Analyzer.THD+N Ratio B	Left	

Figure10 THDN vs Frequency (V_{DD}=3.6V R_L=8ohm Gain=2 C_I=2uF)



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	1	Analyzer.THD+N Ratio B	Left	Po=15mW
2	1	Cyan	Solid	1	Analyzer.THD+N Ratio B	Left	Po=75mW
3	1	Yellow	Solid	1	Analyzer.THD+N Ratio B	Left	po=200mW

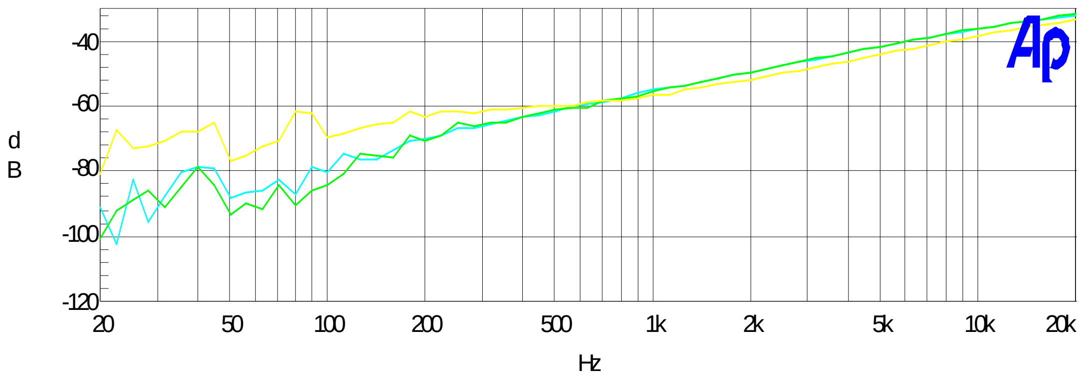
Figure11 THDN vs Frequency (V_{DD}=2.5V R_L=8ohm Gain=2 C_I=2uF)



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Blue	Solid	1	Analyzer.Crosstalk B	Left	5V
2	1	Green	Solid	1	Analyzer.Crosstalk B	Left	3.6V
3	1	Red	Solid	1	Analyzer.Crosstalk B	Left	2.5V

Figure12 PSRR vs Frequency (R_L=4ohm, Input ac-grounded)

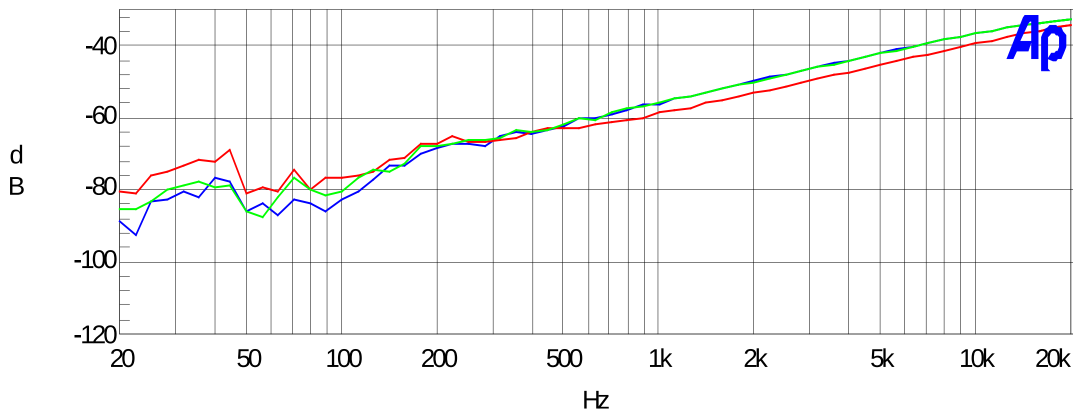
Audio Precision



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Cyan	Solid	1	Analyzer.Crosstalk B	Left	5v
2	1	Green	Solid	1	Analyzer.Crosstalk B	Left	3.6v
3	1	Yellow	Solid	1	Analyzer.Crosstalk B	Left	2.5v

Figure13 PSRR vs Frequency (R_L=8ohm, Input ac-grounded)

Audio Precision



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Blue	Solid	1	Analyzer.Crosstalk B	Left	5V
2	1	Green	Solid	1	Analyzer.Crosstalk B	Left	3.6V
3	1	Red	Solid	1	Analyzer.Crosstalk B	Left	2.5V

Figure14 PSRR vs Frequency (R_L=8ohm, Input floating)

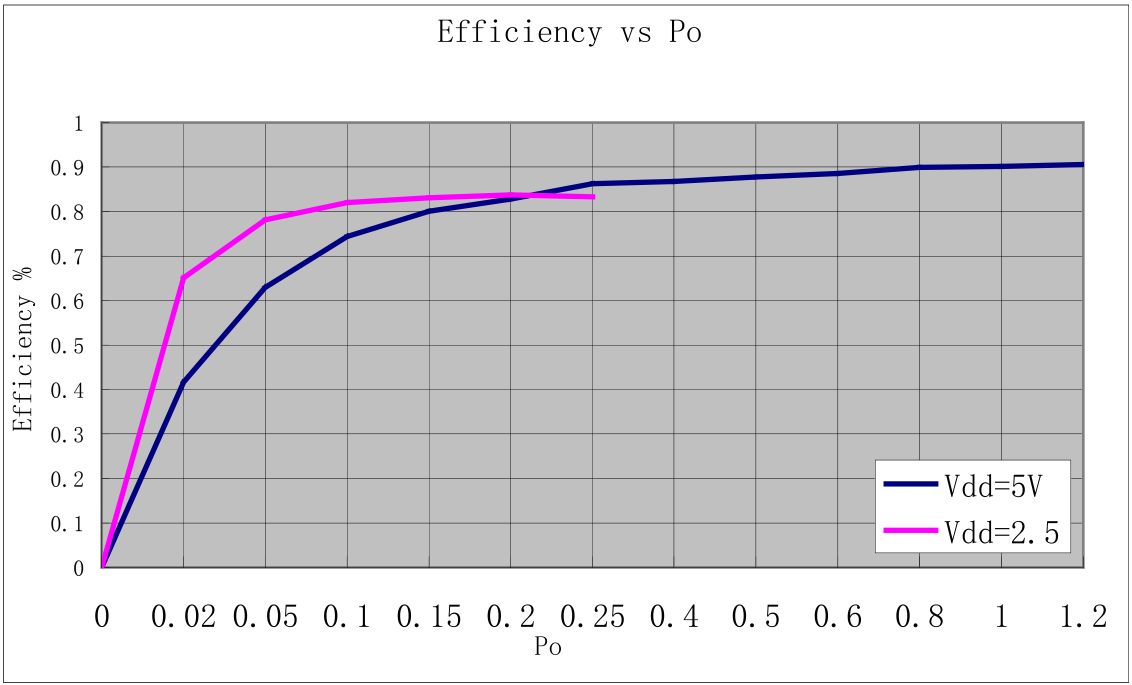


Figure15 GSM Power Supply Rejection vs Time (RL=8 Ω +33uH)

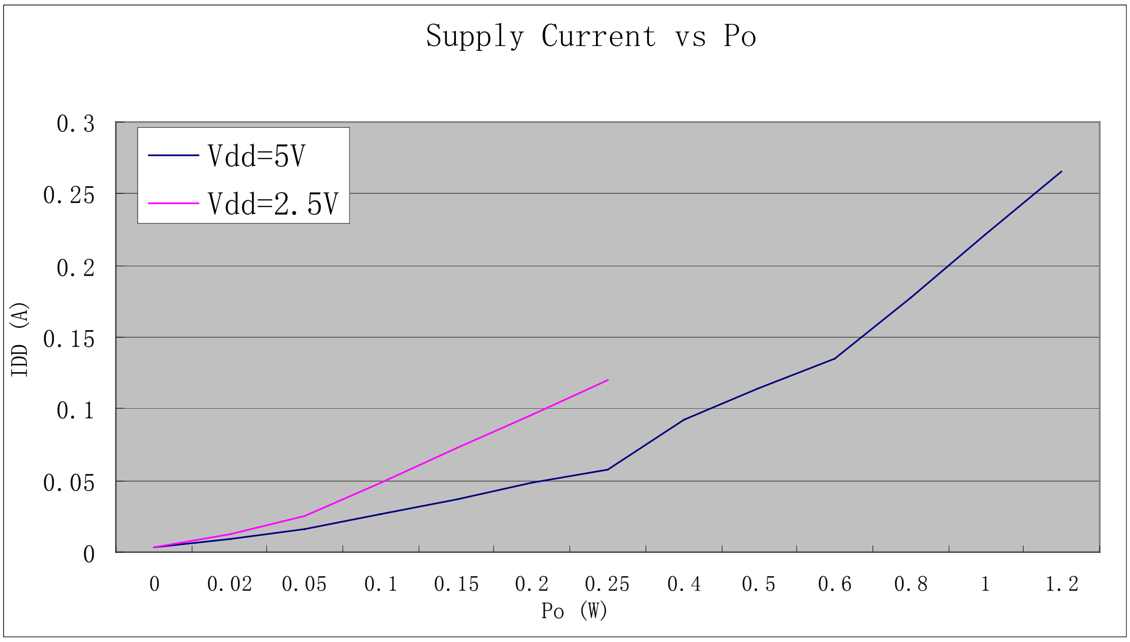
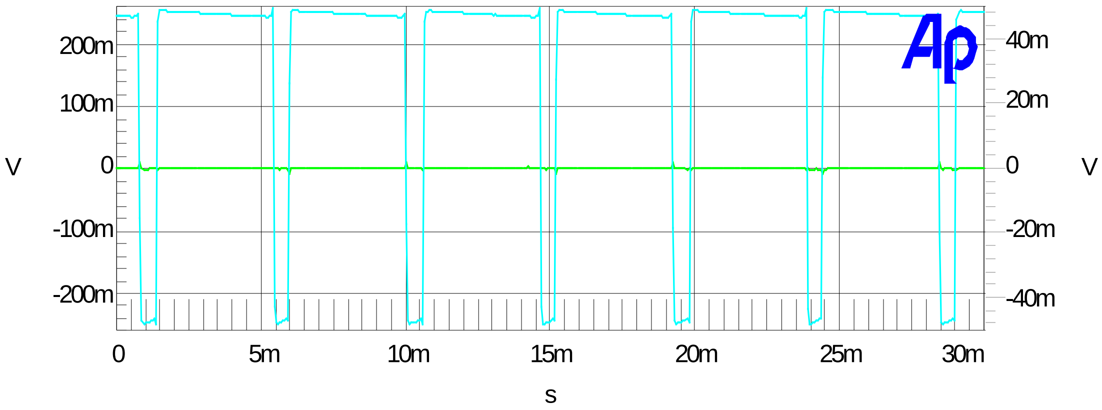


Figure16 Supply Current vs Output Power (RL=8 Ω +33uH)

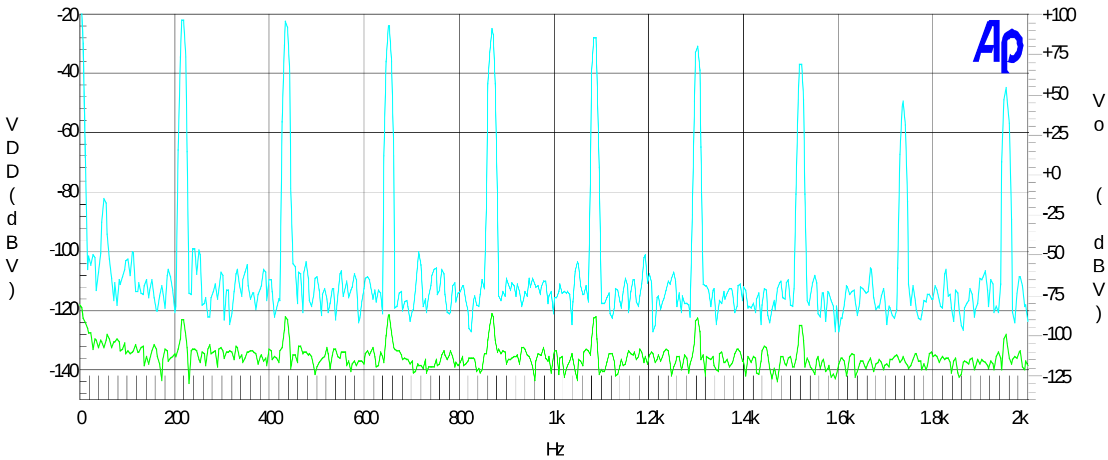
Audio Precision



Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Cyan	Solid	1	FFT.ChA Amplitude	Left	
1	2	Green	Solid	1	FFT.ChB Amplitude	Right	

Figure17 GSM Power Supply Rejection vs Time

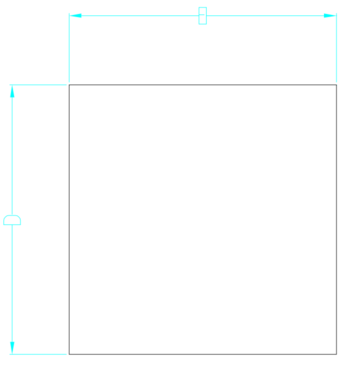
Audio Precision



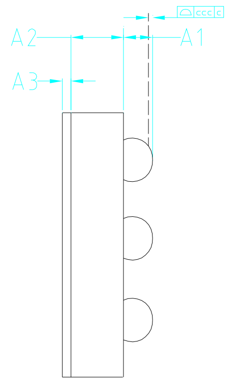
Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Cyan	Solid	1	FFT.ChA Amplitude	Left	
1	2	Green	Solid	1	FFT.ChB Amplitude	Right	

Figure18 GSM Power Supply Rejection vs Frequency

Package Dimensions

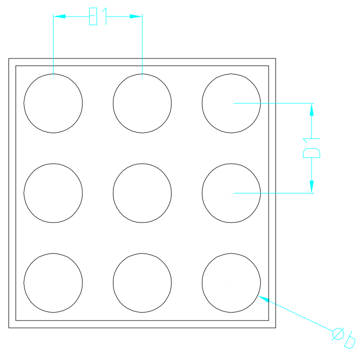


TOP VIEW



9 Bump WLCSP Dimensions (mm)

REF	MIN	TYP	MAX
A1	0.215	0.235	0.255
A2	0.355	0.380	0.405
A3	0.020	0.035	0.050
D	1.485	1.500	1.515
D1		0.500	
E	1.485	1.500	1.515
E1		0.500	
b	0.300	0.320	0.340



BOTTOM VIEW