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

LR6311

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

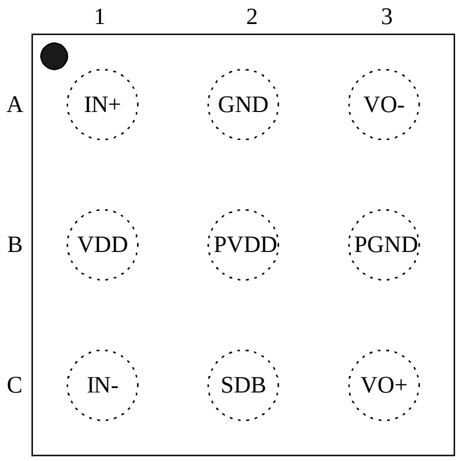
The LR6311 is a 3-W high efficiency filter-free class-D audio power amplifier in a wafer chip scale package (WCSP) that requires only three external components.

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

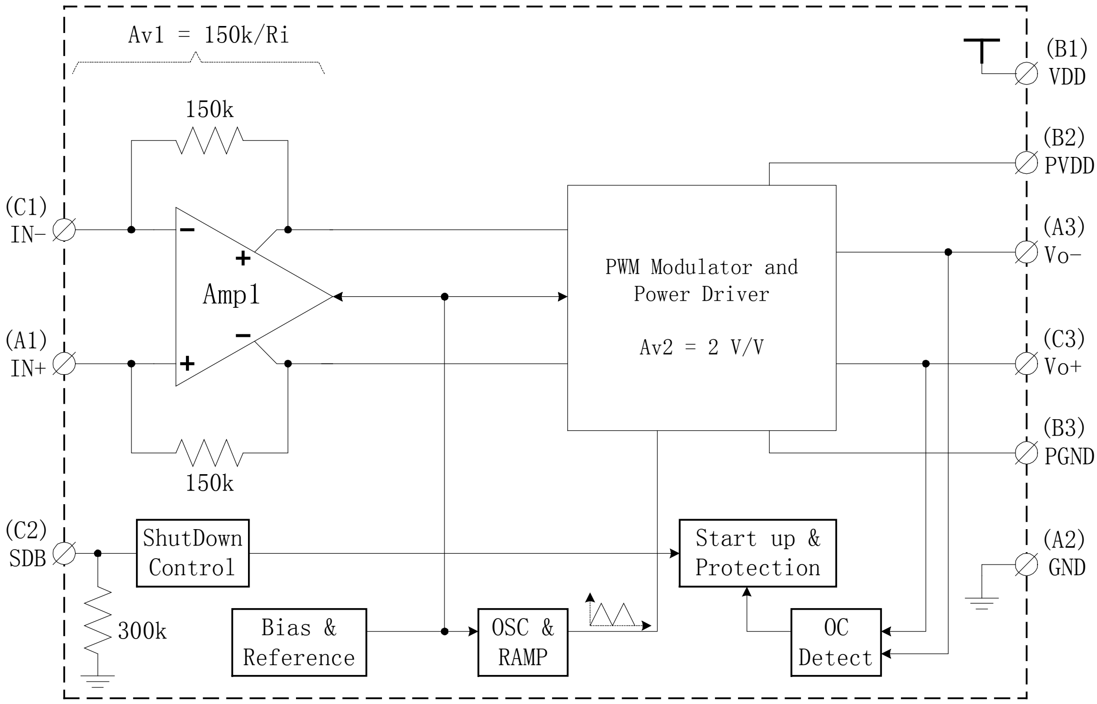


Figure 1. Function Block Diagram

Notes:

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

Application Circuit

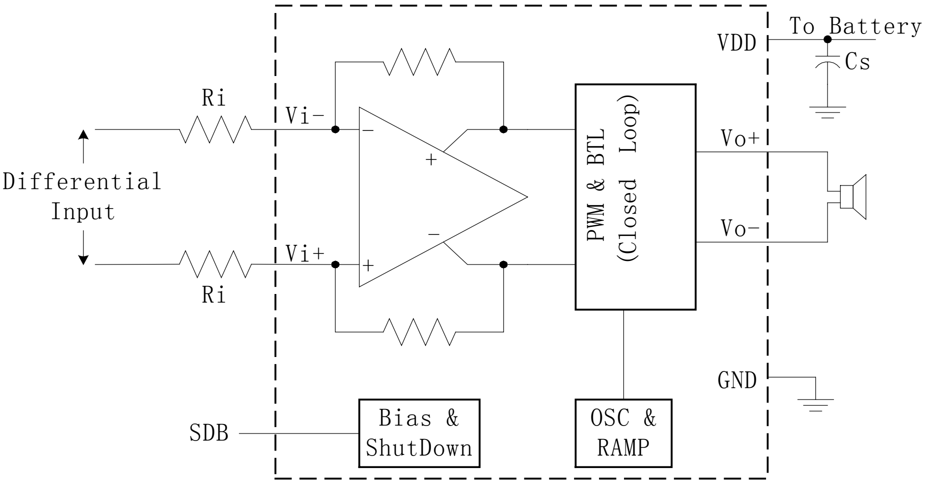


Figure 2. LR6311 Application Schematic With Differential Input

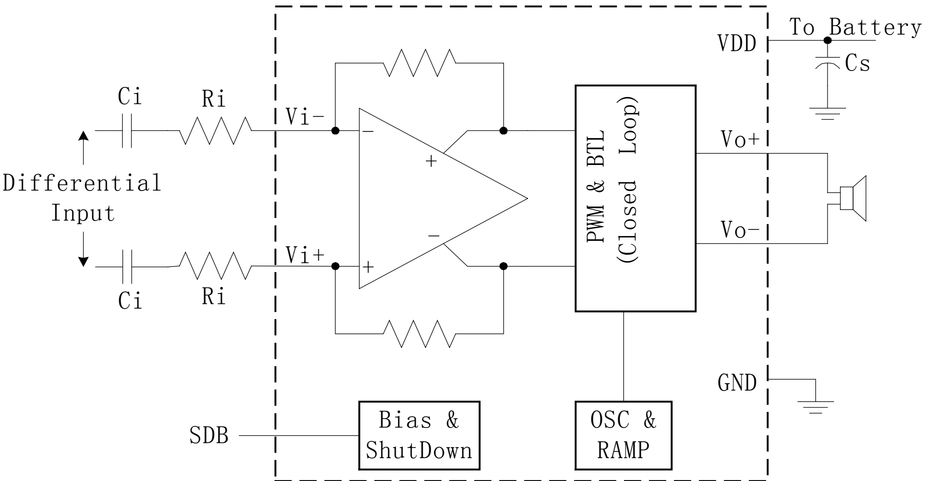


Figure 3. LR6311 Application Schematic With Differential Input and Input Capacitors

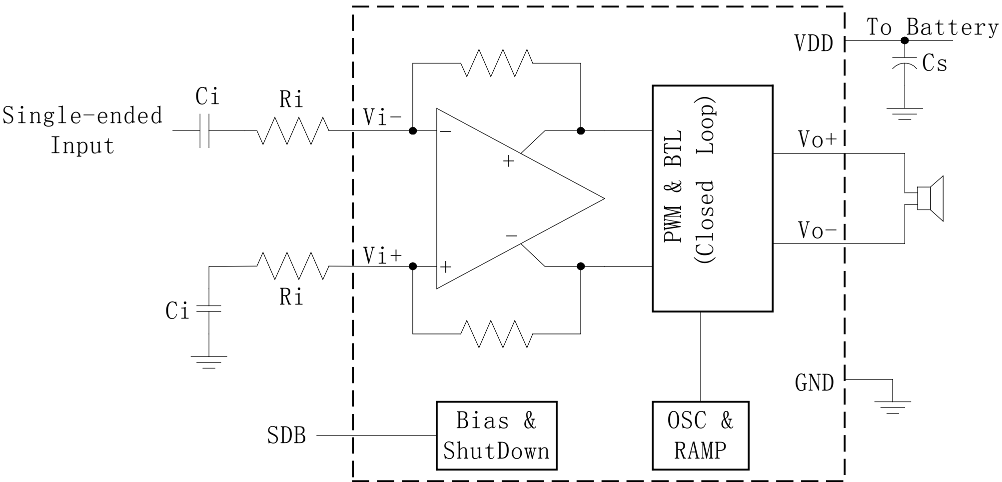


Figure 4. LR6311 Application Schematic With Single-Ended Input

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.

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

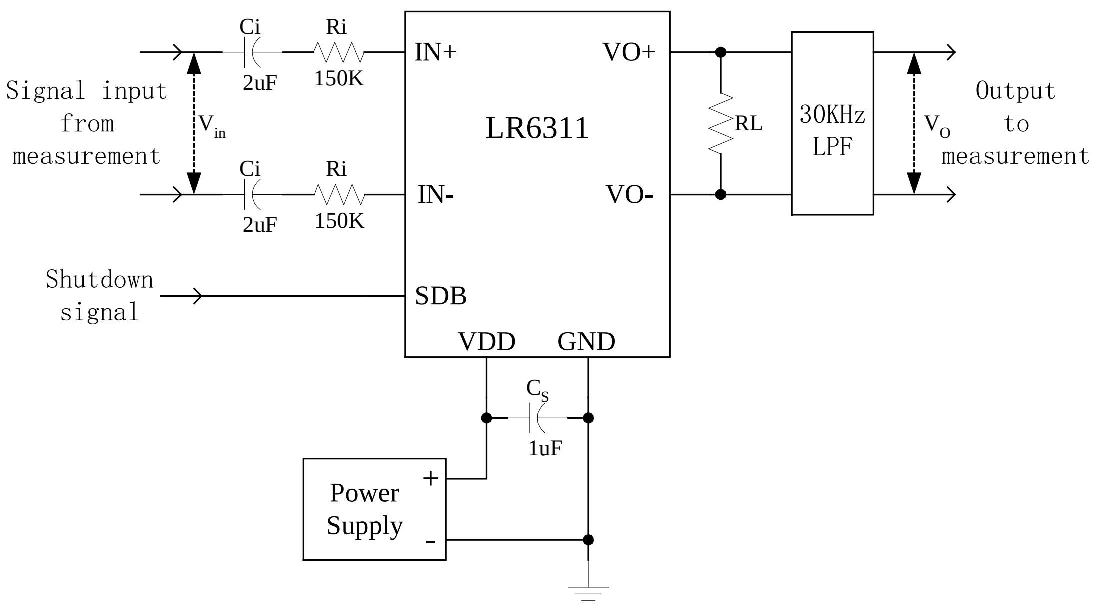


Figure 5. LR6311 test set up circuit

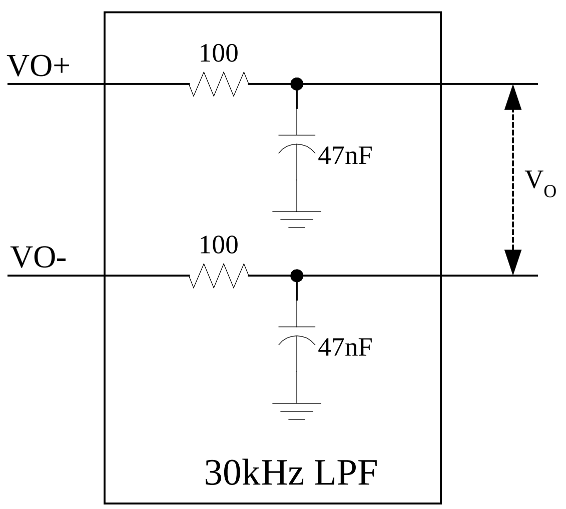


Figure 6. 30-kHz LPF for LR6311 test

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

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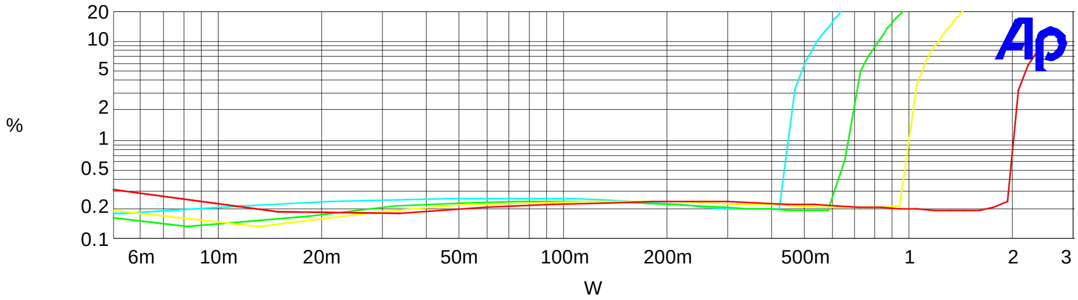

Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Cyan	Solid	1	Analyzer.THD+N Ratio B	Left	2.5v
2	1	Green	Solid	1	Analyzer.THD+N Ratio B	Left	3v
3	1	Yellow	Solid	1	Analyzer.THD+N Ratio B	Left	3.6v
4	1	Red	Solid	1	Analyzer.THD+N Ratio B	Left	5v

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

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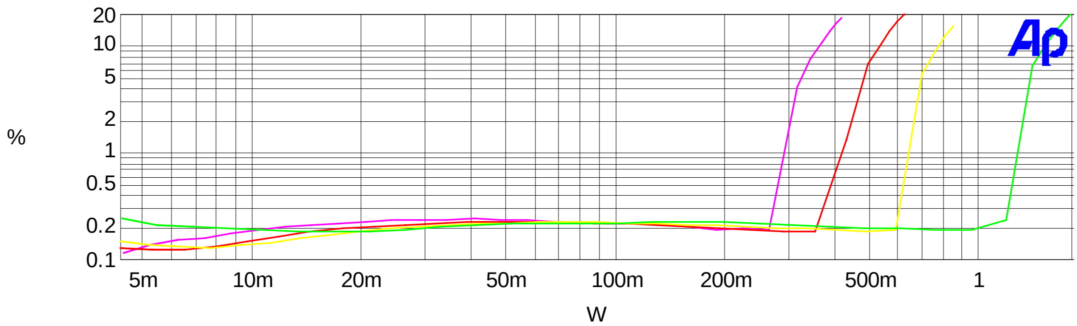

Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Magenta	Solid	1	.Analyzer.THD+N Ratio B	Left	2.5V
2	1	Red	Solid	1	.Analyzer.THD+N Ratio B	Left	3V
3	1	Yellow	Solid	1	.Analyzer.THD+N Ratio B	Left	3.6V
4	1	Green	Solid	1	.Analyzer.THD+N Ratio B	Left	5V

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

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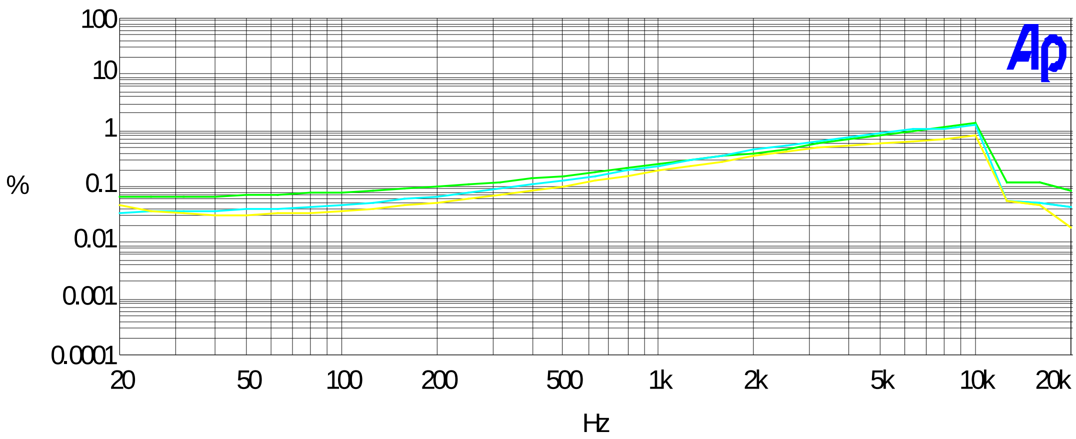

Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	1	Analyzer.THD+N Ratio B	Left	Po=25mW
2	1	Cyan	Solid	1	Analyzer.THD+N Ratio B	Left	Po=250mW
3	1	Yellow	Solid	1	Analyzer.THD+N Ratio B	Left	Po=1w

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

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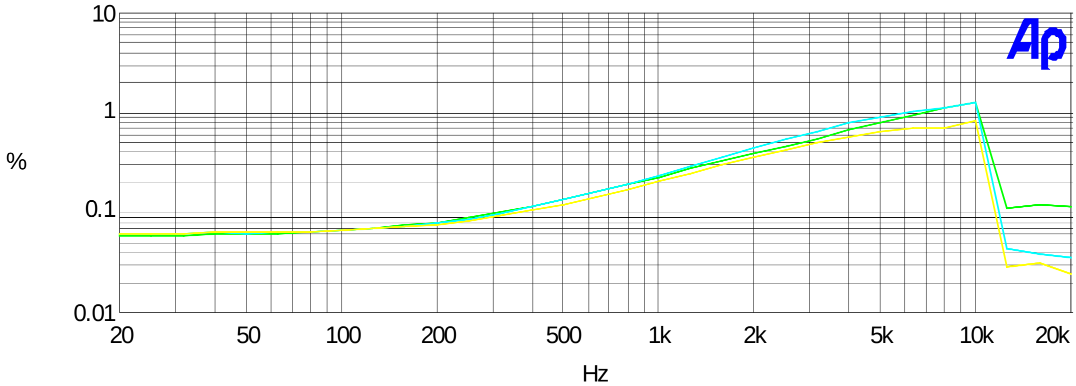
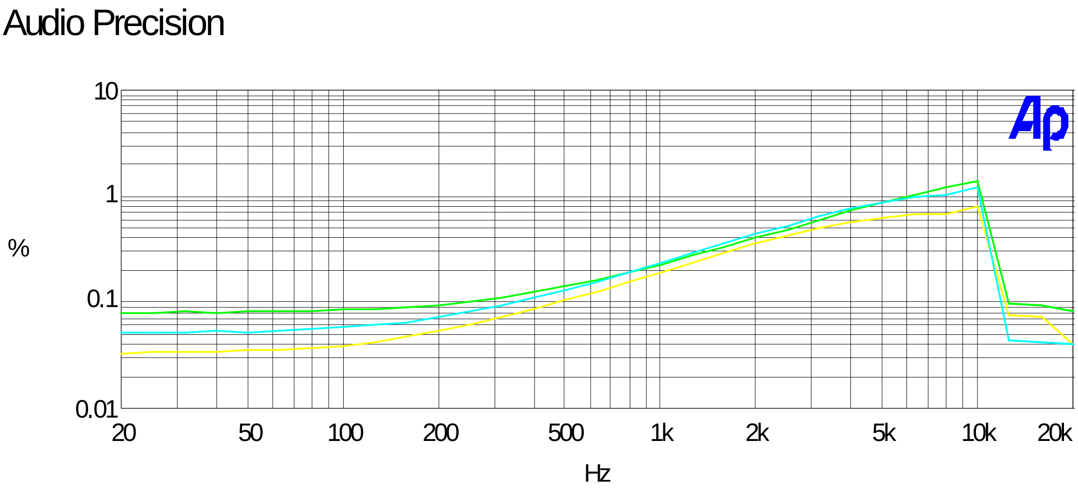


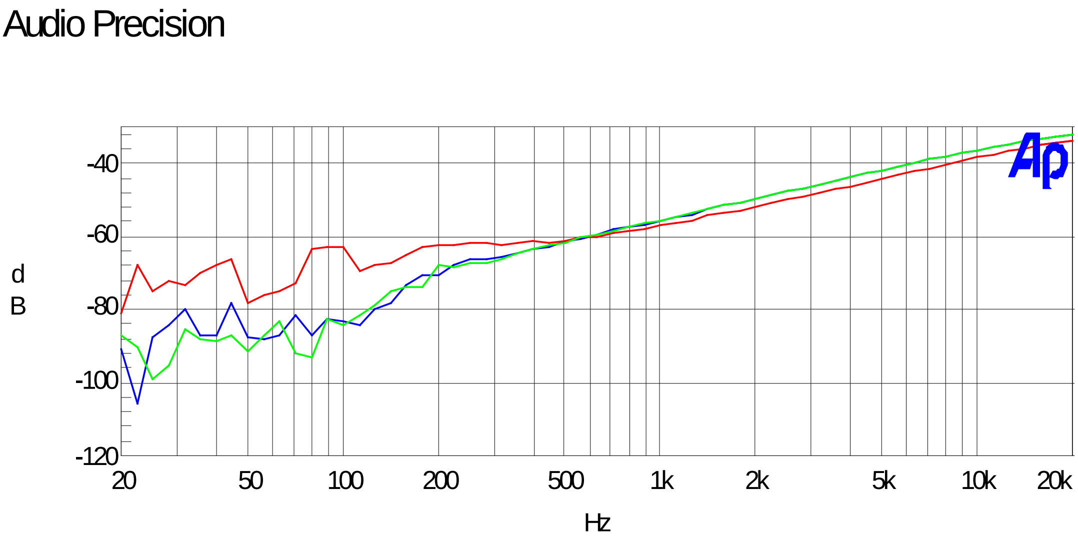
Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	1	Analyzer.THD+N Ratio B	Left	
2	1	Cyan	Solid	1	Analyzer.THD+N Ratio B	Left	
3	1	Yellow	Solid	1	Analyzer.THD+N Ratio B	Left	

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)

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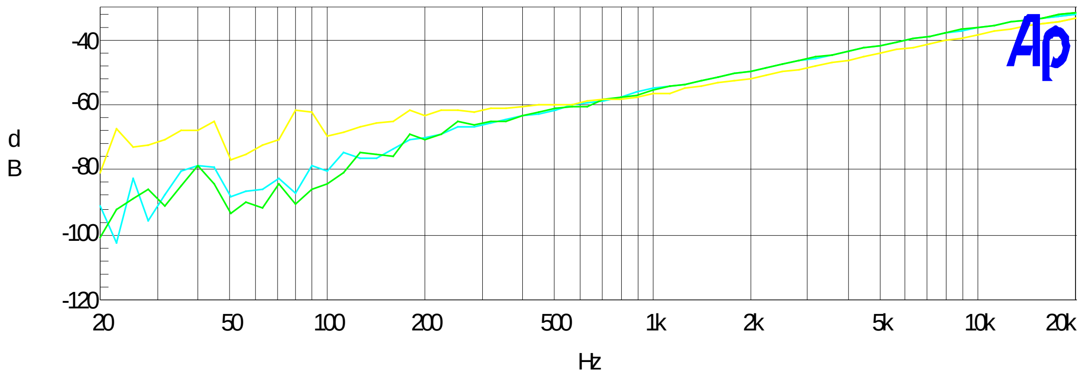
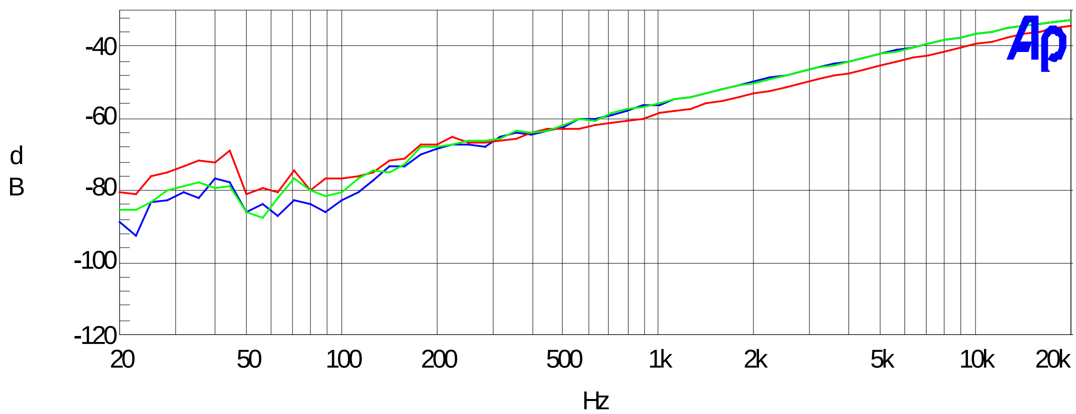


Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Cyan	Solid	1	Analyzer.Crosstalk B	Left	5v
2	1	Green	Solid	1	Analyzer.Crosstalk B	Left	3.6v
3	1	Yellow	Solid	1	Analyzer.Crosstalk B	Left	2.5v

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)

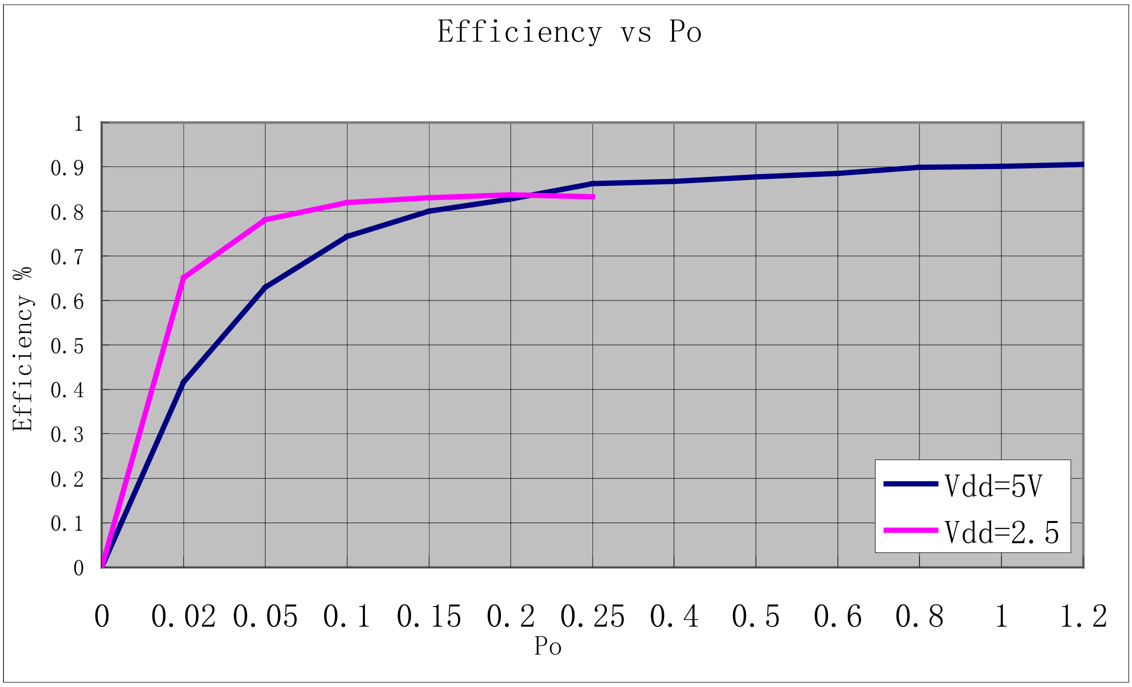


Figure15 GSM Power Supply Rejection vs Time (RL=8Ω+33uH)

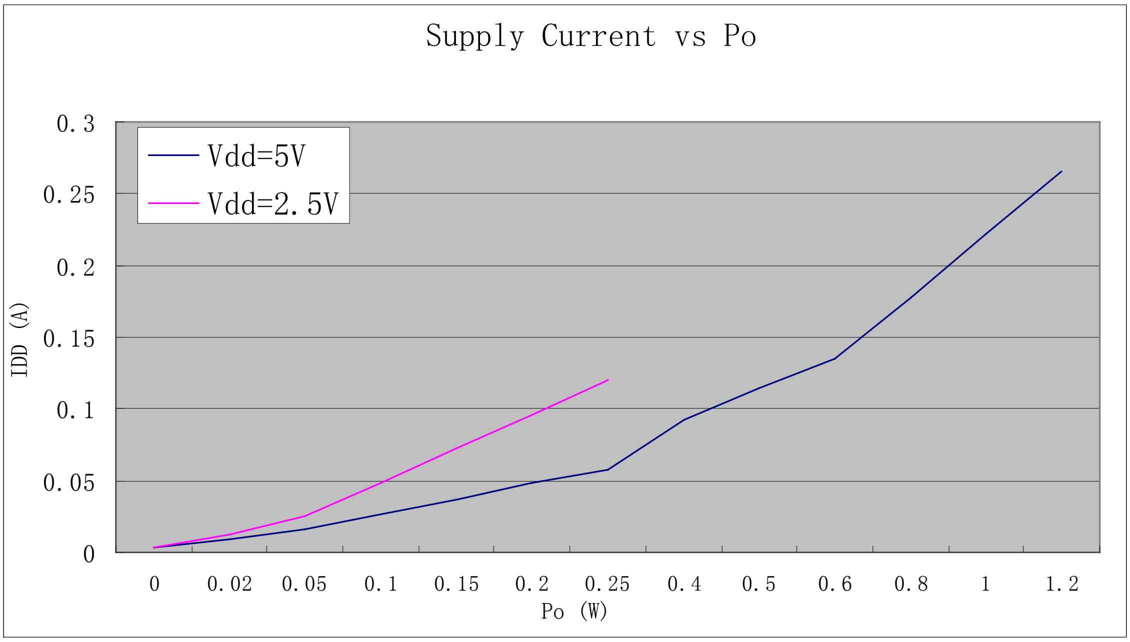


Figure16 Supply Current vs Output Power (RL=8Ω+33uH)

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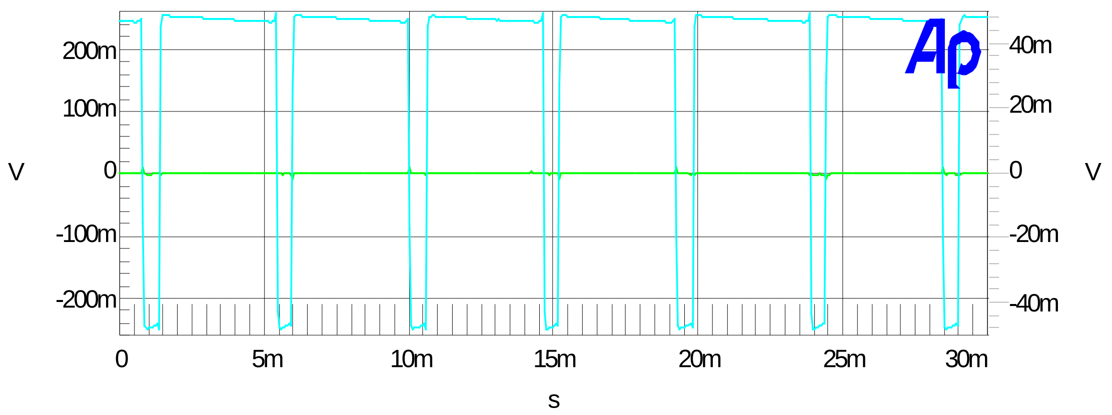

Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Cyan	Solid	1	FFT.ChA Amplitude	Left	
1	2	Green	Solid	1	FFT.ChB Amplitude	Right	

Figure17 GSM Power Supply Rejection vs Time

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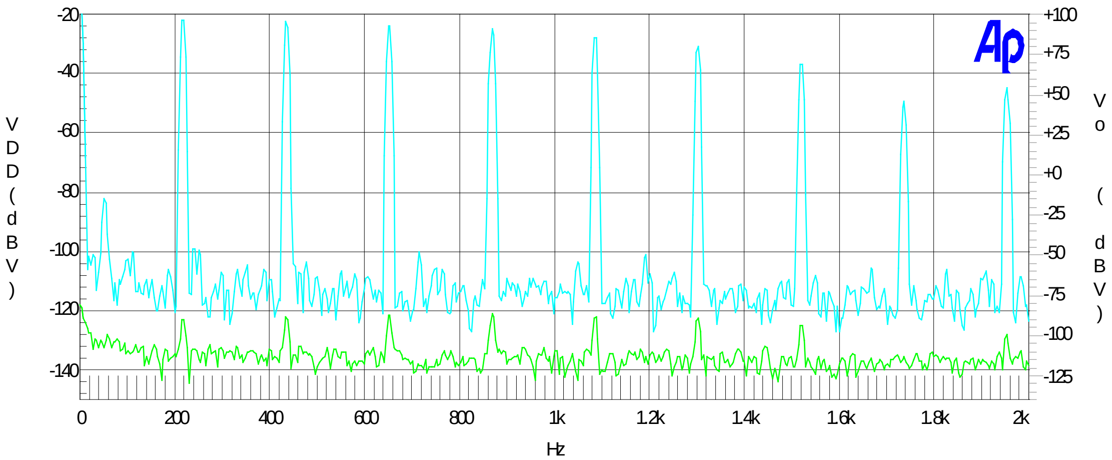
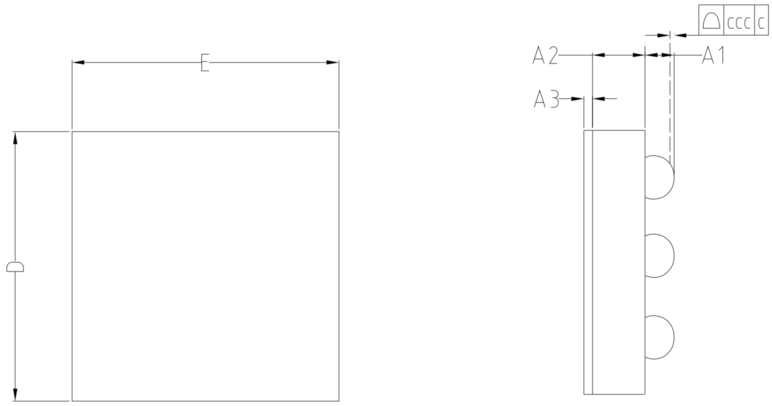


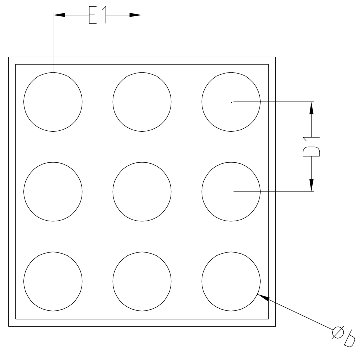
Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Cyan	Solid	1	FFT.ChA Amplitude	Left	
1	2	Green	Solid	1	FFT.ChB Amplitude	Right	

Figure18 GSM Power Supply Rejection vs Frequency

Package Dimensions



TOP VIEW



BOTTOM 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