

# IS31AP2036

## HIGH EFFICIENCY, CLASS-K AUDIO POWER AMPLIFIER WITH INTEGRATED CHARGE PUMP CONVERTER

February 2016

### GENERAL DESCRIPTION

The IS31AP2036 is a Class-K audio power amplifier with high efficiency and automatic gain control. It drives up to 2.0W (10% THD+N) into an 8Ω speaker from a 4.2V  $V_{CC}$  supply.

The IS31AP2036 integrates advanced high efficiency charge pump and whole power amplifier efficiency can be up to 75%. The output power will be maintained in 0.8W, 1.0W and 1.2W.

The IS31AP2036 provides low cost, space saving solution for portable equipments which need audio output with higher power by boosting up supply voltage. Its external components just include a few capacitors and resistors (no inductor).

The IS31AP2036 use fully differential design to reduce RF noise. The IS31AP2036 integrates de-pop circuitry to reduce pop and click noise during power on/off or shutdown enable operation. The IS31AP2036 also integrates thermal and short circuit protection function.

IS31AP2036 is available in FCQFN-16 (2mm × 2mm) package. It operates from 3.0V to 5.0V over the temperature range of -40°C to +85°C.

### FEATURES

- Operates from 3.0V to 5.0V
- Ultra low output noise floor
- Low EMI
- -72dB (217Hz) high PSRR
- 0.05% low THD+N
- AGC function
- Pulse Count Control serial interface
- Output power in 0.8W, 1W and 1.2W levels
- Thermal and short-circuit protection
- Integrated Click-and-Pop suppression circuitry
- Available in FCQFN-16 (2mm × 2mm) package

### APPLICATIONS

- Smart phones
- Cellular phones
- PDAs
- GPS
- Portable electronics

### TYPICAL APPLICATION CIRCUIT

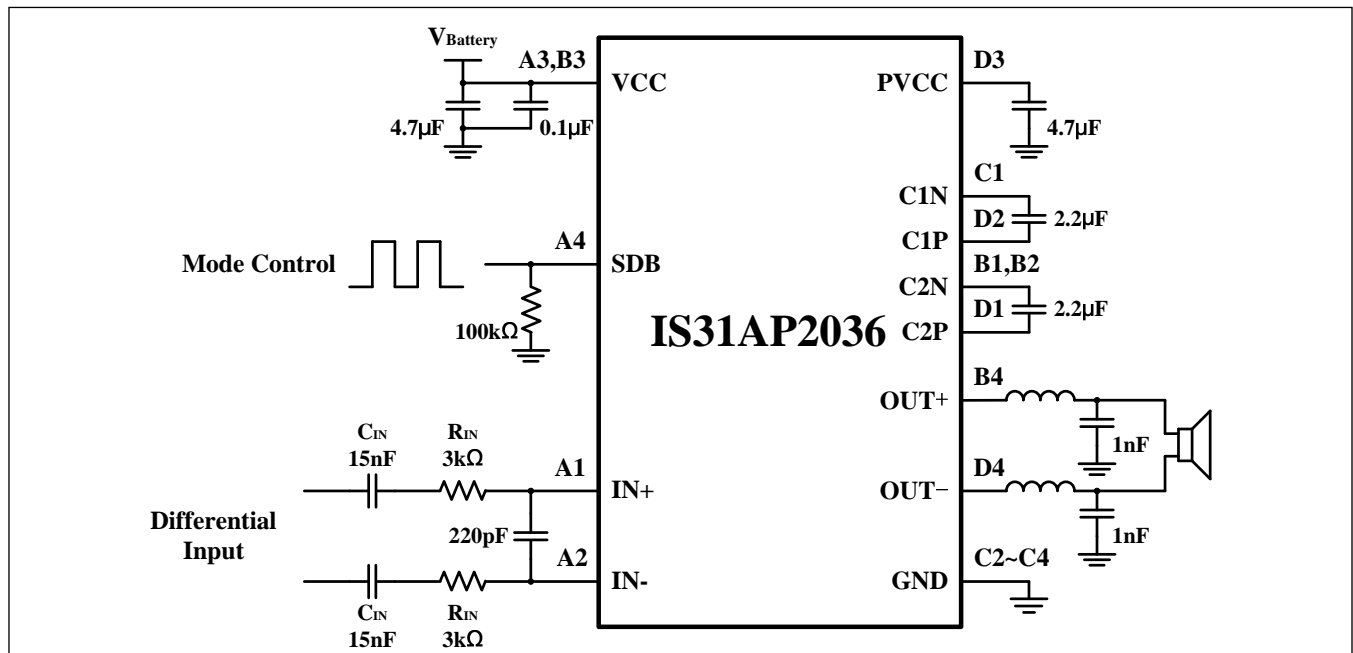


Figure 1 Typical Application Circuit (Differential Input)

# IS31AP2036

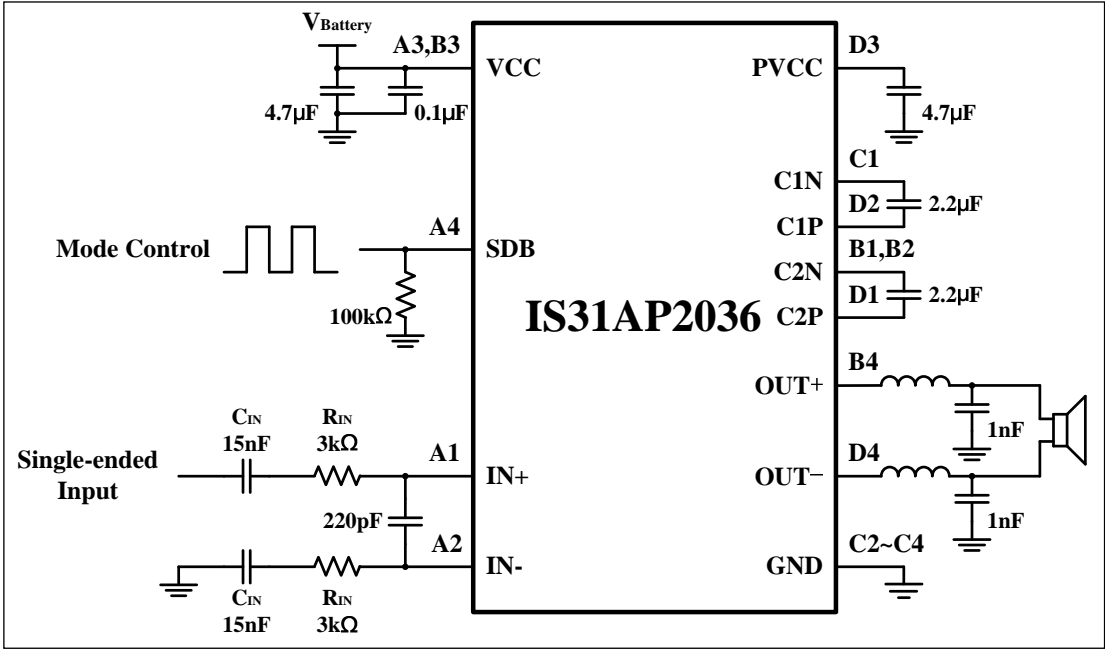
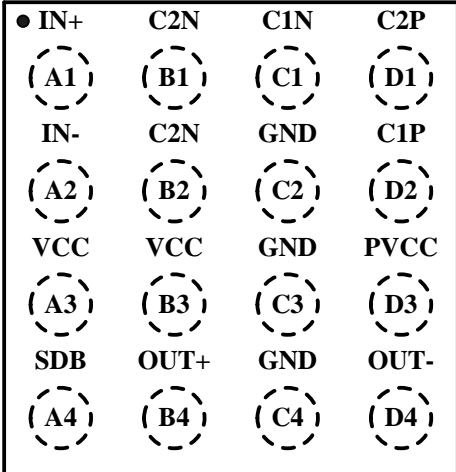


Figure 2 Typical Application Circuit (Single-ended Input)

# IS31AP2036

## PIN CONFIGURATION

Package	Pin Configuration (Top View)
FCQFN-16	 <p>           • IN+    C2N    C1N    C2P            (A1)    (B1)    (C1)    (D1)            IN-    C2N    GND    C1P            (A2)    (B2)    (C2)    (D2)            VCC    VCC    GND    PVCC            (A3)    (B3)    (C3)    (D3)            SDB    OUT+    GND    OUT-            (A4)    (B4)    (C4)    (D4)         </p>

## PIN DESCRIPTION

No.	Pin	Description
A1	IN+	Positive audio input.
A2	IN-	Negative audio input.
A3, B3	VCC	Power supply.
A4	SDB	Shutdown pin. Active low.
B1, B2	C2N	Negative input for external flying cap 2.
B4	OUT+	Positive audio output.
C1	C1N	Negative input for external flying cap 1.
C2~C4	GND	Ground.
D1	C2P	Positive input for external flying cap 2.
D2	C1P	Positive input for external flying cap 1.
D3	PVCC	Charge pump output voltage.
D4	OUT-	Negative audio output.



# IS31AP2036

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## ORDERING INFORMATION

Industrial Range: -40°C to +85°C

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Order Part No.	Package	QTY/Reel
IS31AP2036-CLS2-TR	FCQFN-16, Lead-free	3000

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- b.) the user assume all such risks; and
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## ABSOLUTE MAXIMUM RATINGS

Supply voltage, $V_{CC}$	-0.3V ~ +6.0V
Voltage at IN+ and IN- pins	-0.3V ~ $V_{CC}+0.3V$
Maximum junction temperature, $T_{JMAX}$	125°C
Storage temperature range, $T_{STG}$	-65°C ~ +150°C
Operating temperature range, $T_A$	-40°C ~ +85°C
Thermal resistance, junction to ambient, $\theta_{JA}$	69°C/W
ESD (HBM)	±8kV
ESD (CDM)	±1kV

### Note:

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 condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

## DC CHARACTERISTICS

$T_A = 25^\circ\text{C}$ ,  $V_{CC} = 3.0V \sim 5.0V$ , unless otherwise noted. Typical value are  $T_A = 25^\circ\text{C}$ ,  $V_{CC} = 3.6V$ .

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
$V_{CC}$	Supply voltage		3.0		5.0	V
$I_{CC}$	Quiescent current	$V_{CC} = 3.6V$ , no load, no input		13		mA
$I_{SD}$	Shutdown current	$V_{CC} = 3.6V$ , $V_{SDB} = 0V$			1	μA
$f_{OSC}$	Clock frequency	$V_{CC} = 3.0V \sim 5.0V$		650		kHz
$A_V$	Output gain	$R_{IN} = 3k\Omega$		16.3		V/V
$t_{ON}$	Turn on time			40		ms
$ V_{OS} $	Output offset voltage	$V_{CC} = 3.0V \sim 5.0V$ , no input	-50	0	50	mV
$R_{INT}$	Internal input resistor			16.5		kΩ
$V_{IH}$	Input logic high voltage		1.3		$V_{CC}$	V
$V_{IL}$	Input logic low voltage		0		0.35	V
$T_{AGC}$	Thermal AGC threshold temperature	(Note 1)		150		°C
$T_{AGC\_HYS}$	Thermal AGC hysteresis temperature	(Note 1)		20		°C
$T_{OTP}$	Over temperature protection	(Note 1)		160		°C
$T_{TOP\_HYS}$	Hysteresis temperature	(Note 1)		30		°C

## Charge Pump

$PV_{CC}$	Charge pump output voltage	$V_{CC} = 3.0V \sim 3.8V$		$1.5V_{CC}$		V
		$V_{CC} > 3.8V$		5.8		V
$f_{CP}$	Charge pump frequency			1.05		MHz
$t_{ST}$	Soft start time	$C_{OUT} = 4.7\mu F$ , no load		0.5		ms
$I_L$	PVCC short to GND limit current	(Note 1)		350		mA

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## AC CHARACTERISTICS (NOTE 1)

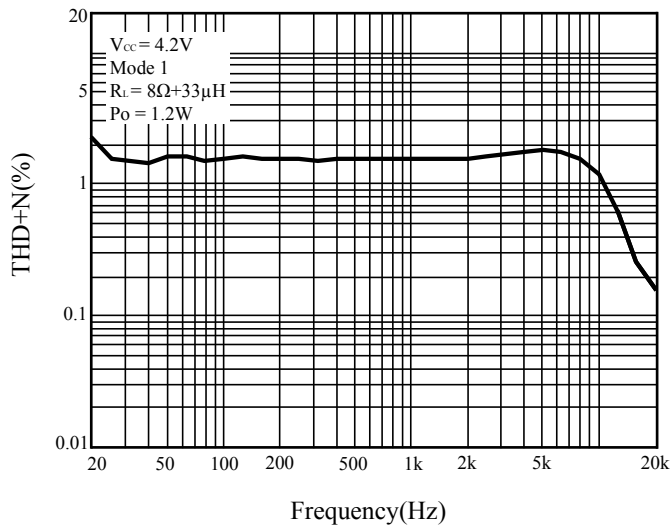
$T_A = 25^\circ\text{C}$ ,  $V_{CC} = 3.6\text{V}$ , unless otherwise noted.

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
P <sub>O</sub>	Output power, Mode 4	THD+N = 10%, f = 1kHz, R <sub>L</sub> = 8Ω+33μH	V <sub>CC</sub> = 3.6V	1.35		W
			V <sub>CC</sub> = 4.2V	2.0		
		THD+N = 1%, f = 1kHz, R <sub>L</sub> = 8Ω+33μH	V <sub>CC</sub> = 3.6V	1.1		
			V <sub>CC</sub> = 4.2V	1.55		
		THD+N = 10%, f = 1kHz, R <sub>L</sub> = 4Ω+33μH	V <sub>CC</sub> = 3.6V	1.8		
			V <sub>CC</sub> = 4.2V	2.45		
		THD+N = 1%, f = 1kHz, R <sub>L</sub> = 4Ω+33μH	V <sub>CC</sub> = 3.6V	1.55		
			V <sub>CC</sub> = 4.2V	2.1		
P <sub>NCN</sub>	NCN output power	V <sub>CC</sub> = 4.2V, R <sub>L</sub> = 8Ω+33μH	Mode 1	1.2		W
			Mode 2	1.0		
			Mode 3	0.8		
THD+N	Total harmonic distortion plus noise (Note 1)	V <sub>CC</sub> = 4.2V, P <sub>O</sub> = 1W, R <sub>L</sub> = 8Ω+33μH f = 1kHz, Mode 1		0.1		%
		V <sub>CC</sub> = 4.2V, P <sub>O</sub> = 1.2W, R <sub>L</sub> = 8Ω+33μH f = 1kHz, Mode 4		0.05		
t <sub>WU</sub>	Wake-up time from shutdown			40		ms
η	Efficiency (Note 1)	V <sub>CC</sub> = 4.2V, P <sub>O</sub> = 1.2W, R <sub>L</sub> = 8Ω		75		%
V <sub>NO</sub>	Output Noise	V <sub>CC</sub> = 3.6V, R <sub>L</sub> = 8Ω		102		μV
PSRR	Power supply rejection ratio (Note 1)	V <sub>CC</sub> = 4.2V, V <sub>P-P</sub> = 200mV, R <sub>L</sub> = 8Ω, f = 217Hz		-72		dB
		V <sub>CC</sub> = 4.2V, V <sub>P-P</sub> = 200mV, R <sub>L</sub> = 8Ω, f = 1kHz		-72		
<b>NCN</b>						
t <sub>AT</sub>	Attack time	(Note 1)		40		ms
t <sub>RL</sub>	Release time	(Note 1)		1.5		s
A <sub>max</sub>	Max attenuation gain	(Note 1)		-13.5		dB
<b>Pulse Count Control</b>						
t <sub>L</sub>	Mode control low time	V <sub>CC</sub> = 3.0V ~ 5.0V	0.75	2	10	μs
t <sub>H</sub>	Mode control high time	V <sub>CC</sub> = 3.0V ~ 5.0V	0.75	2	10	μs
t <sub>LAT</sub>	Mode latch up time	V <sub>CC</sub> = 3.0V ~ 5.0V (Note 1)	220		500	μs
t <sub>OFF</sub>	Shutdown time	V <sub>CC</sub> = 3.0V ~ 5.0V	220		500	μs

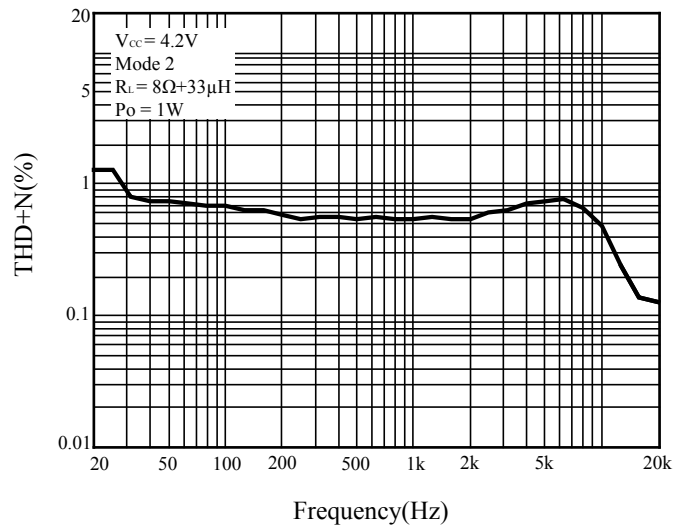
**Note 1:** Guaranteed by design.

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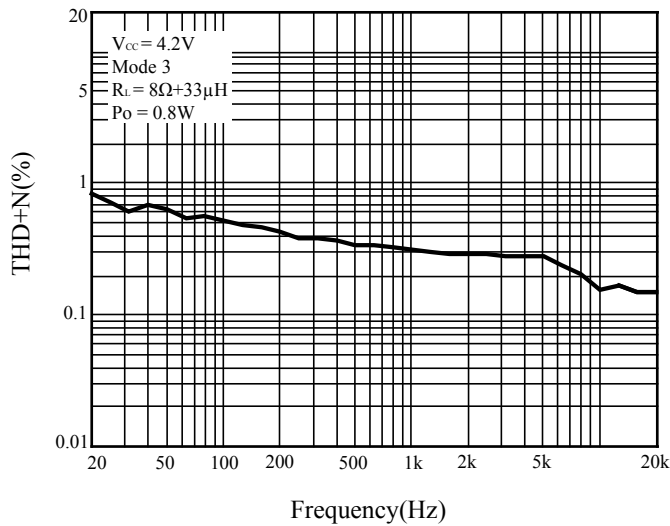
## TYPICAL PERFORMANCE CHARACTERISTICS



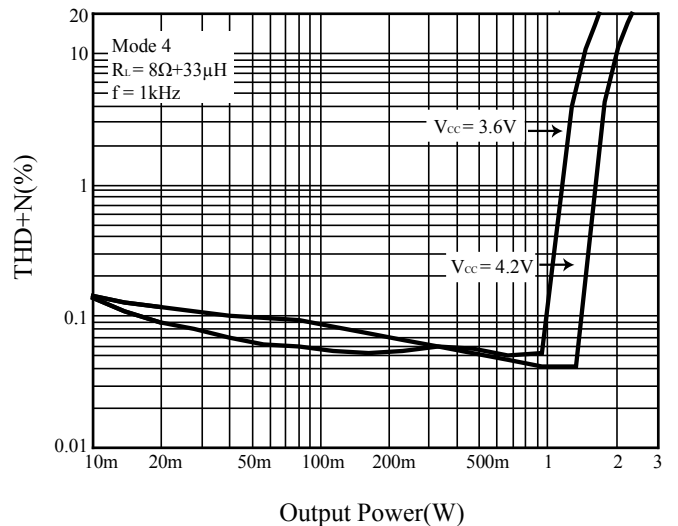
**Figure 3** THD+N vs. Frequency



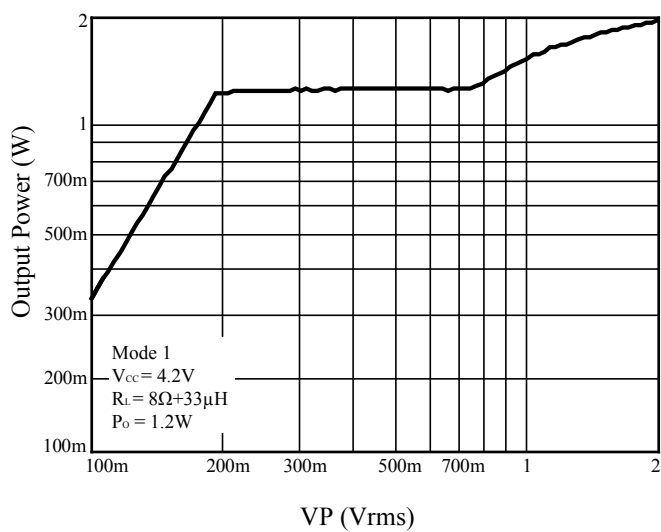
**Figure 4** THD+N vs. Frequency



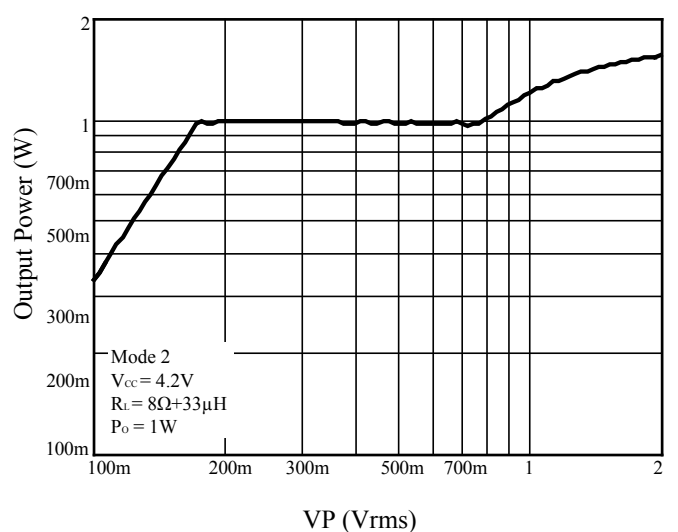
**Figure 5** THD+N vs. Frequency



**Figure 6** THD+N vs. Output Power

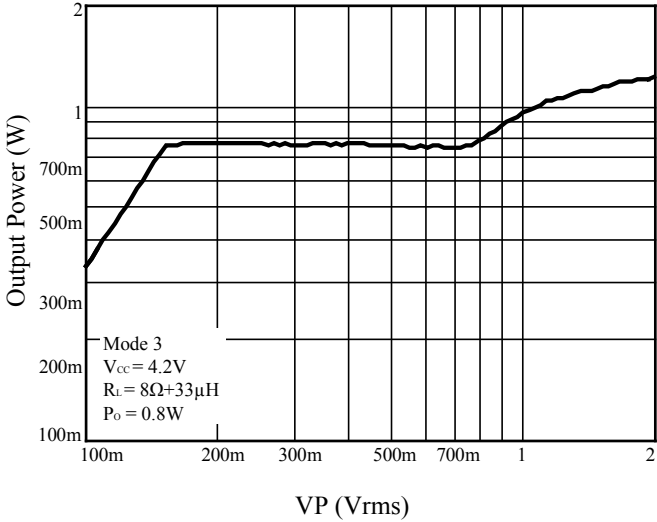


**Figure 7** Output Power vs. VP

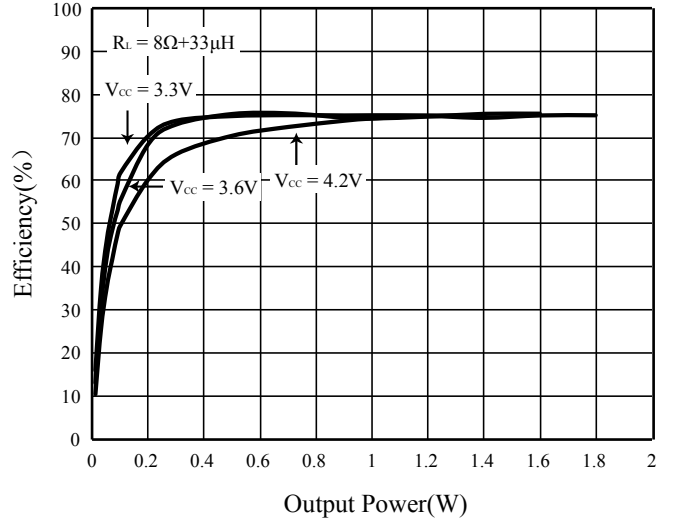


**Figure 8** Output Power vs. VP

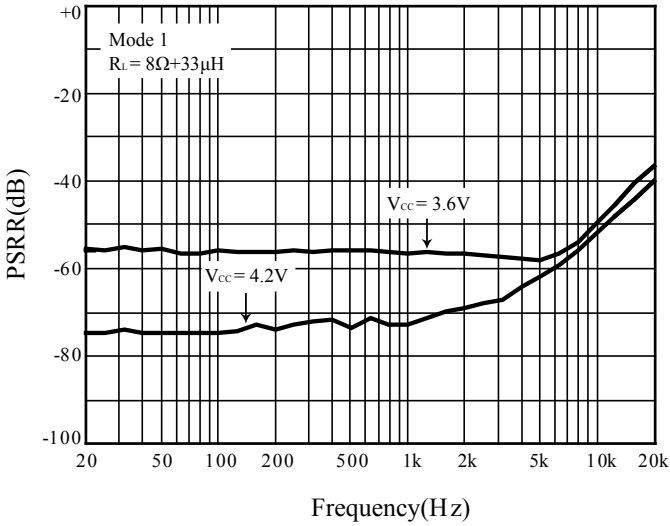
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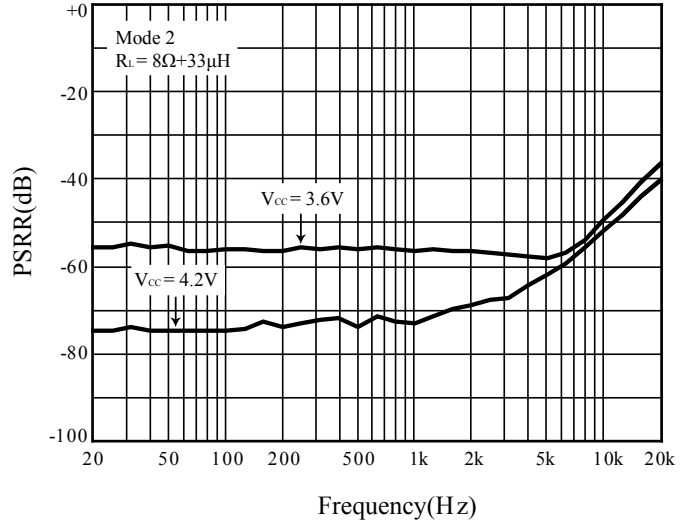
**Figure 9** Output Power vs. VP



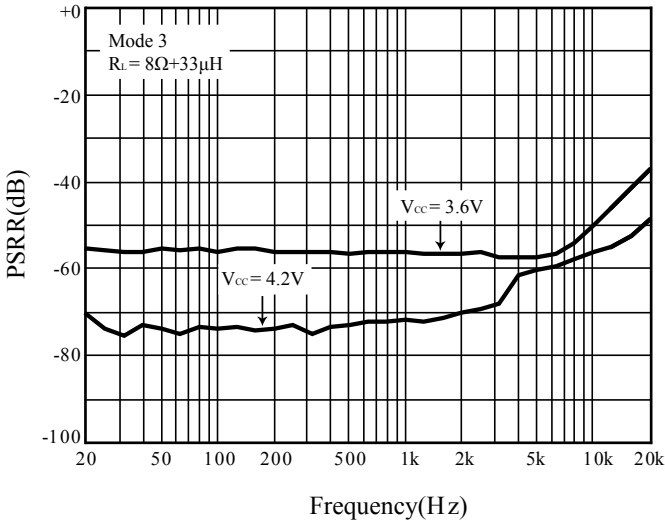
**Figure 10** Efficiency vs. Output Power



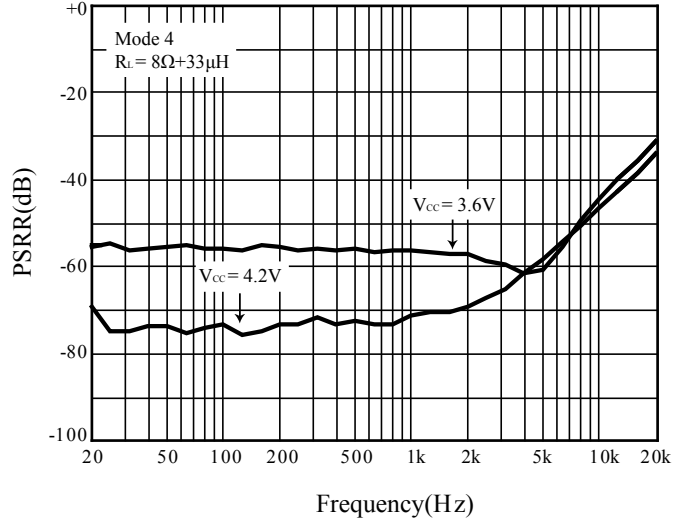
**Figure 11** PSRR vs. Frequency



**Figure 12** PSRR vs. Frequency

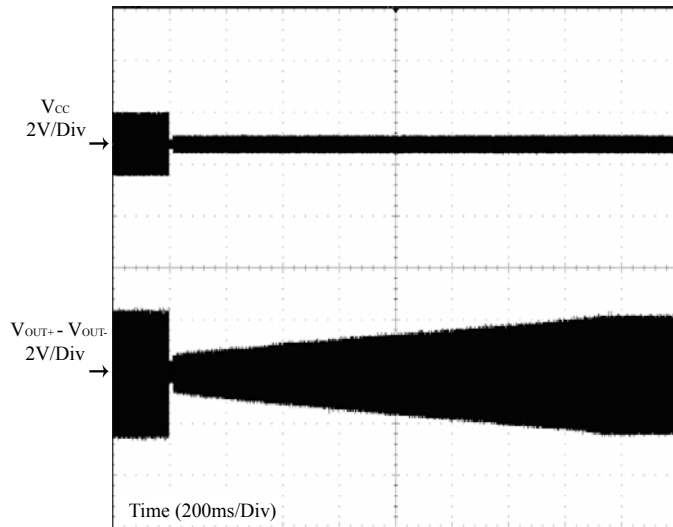


**Figure 13** PSRR vs. Frequency

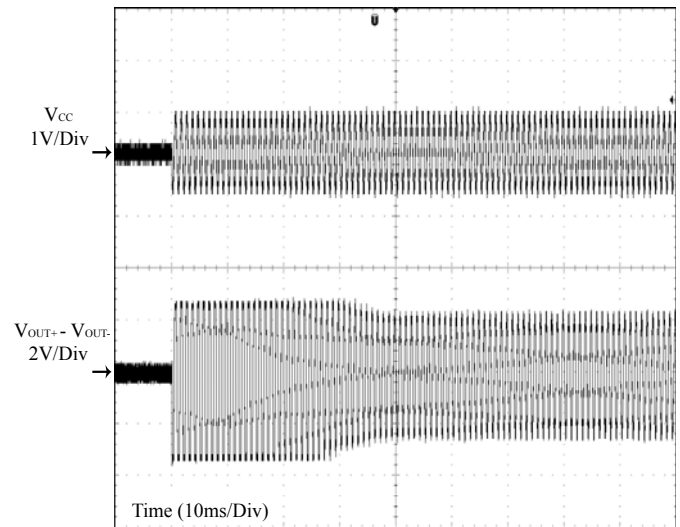


**Figure 14** PSRR vs. Frequency

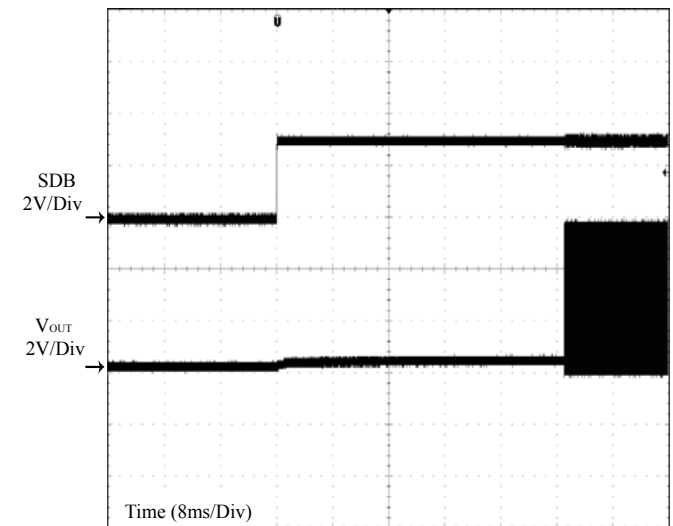




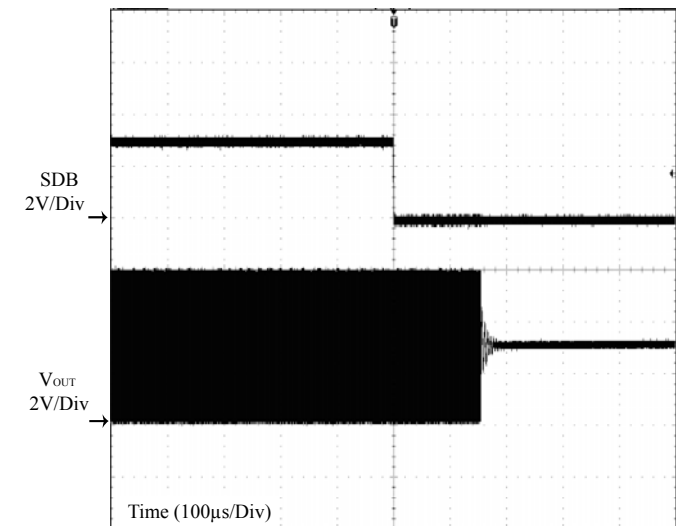
**Figure 15** Release Time



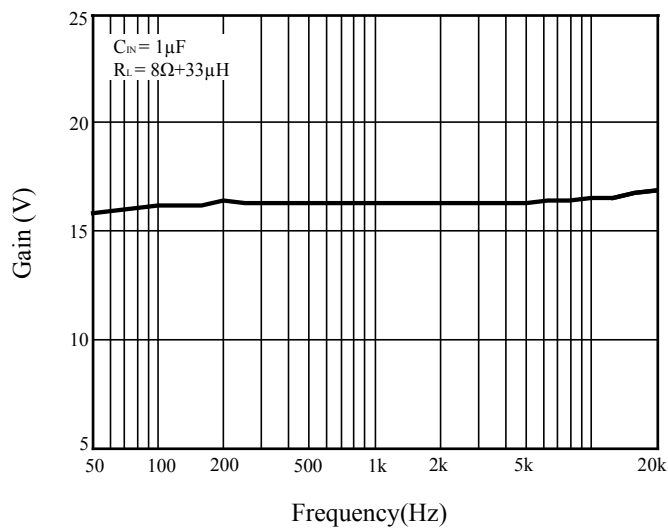
**Figure 16** Attack Time



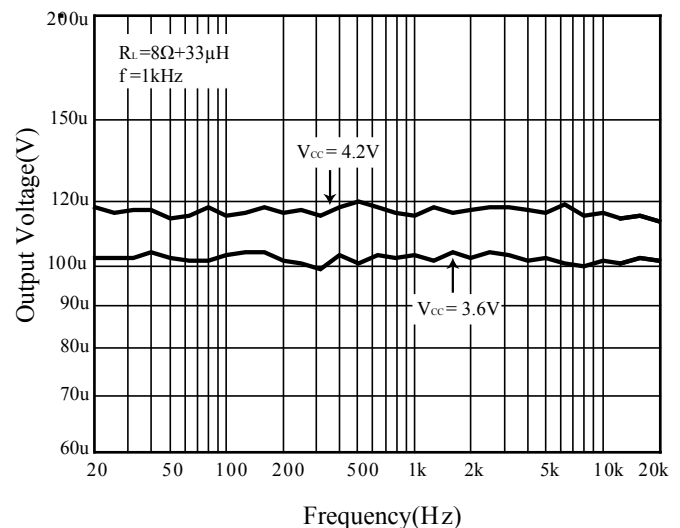
**Figure 17** Turn On



**Figure 18** Turn Off



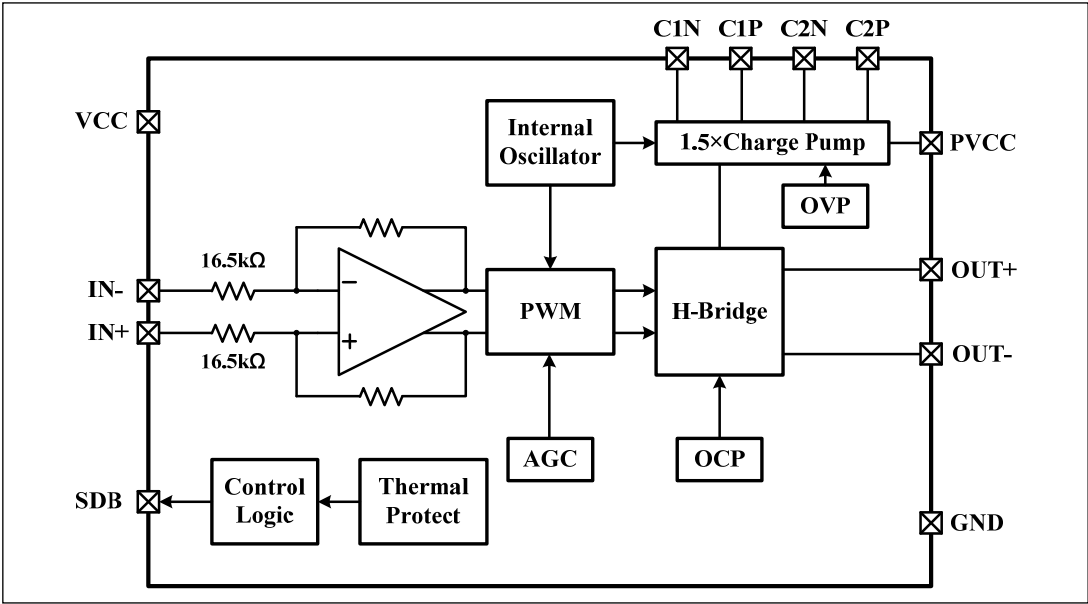
**Figure 19** Gain vs. Frequency



**Figure 20** Noise

# IS31AP2036

## FUNCTIONAL BLOCK DIAGRAM



# IS31AP2036

## APPLICATION INFORMATION

The IS31AP2036 is a Class-K audio power amplifier with high efficiency and automatic gain control. It drives up to 2.0W (10% THD+N) into an 8Ω speaker from a 4.2V  $V_{CC}$  supply.

The IS31AP2036 integrates advanced high efficiency charge pump and whole power amplifier efficiency can be up to 75%. The output power will be maintained in 0.8W, 1.0W and 1.2W.

The IS31AP2036 provides low cost, space saving solution for portable equipments which need audio output with higher power by boosting up supply voltage. Its external components just include a few capacitors and resistors (no inductor).

### CONSTANT OUTPUT POWER

The output power will fall down by the drop of supply voltage and decrease audio volume. IS31AP2036 provides advanced AGC function to maintain the output power stable within 3.3V~4.35V supply voltage. Even voltage of battery falls down in mobile application; IS31AP2036 can still provide high-quality audio. There are four operation modes for IS31AP2036 and three of these have AGC function with output power as 1.2W, 1W and 0.8W.

### AGC Function

This is the function to control the output in order to obtain a maximum output level without distortion when an excessive input is applied which would otherwise cause clipping at the differential signal output. That is, with the traditional AGC function, lowers the gain of the digital amplifier to an appropriate value so as not to cause clipping at the differential signal output (Figure 21).

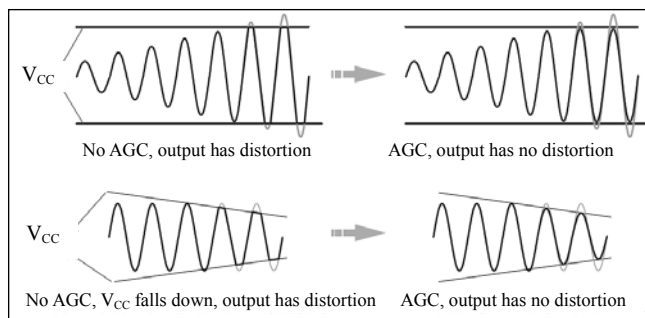


Figure 21 AGC Function

IS31AP2036 adopts advanced AGC function which maintains constant output power without signal distortion when the supply voltage falling down (Figure 22, 23).

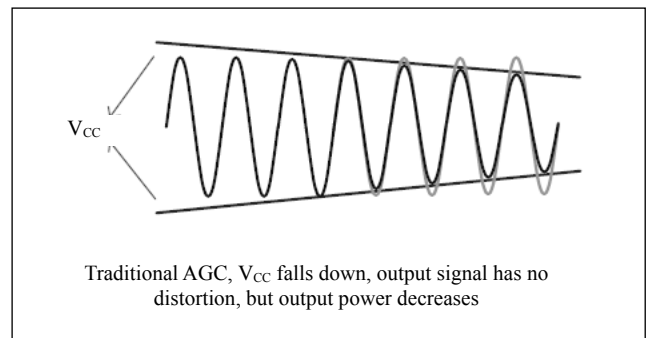


Figure 22 Traditional AGC Function

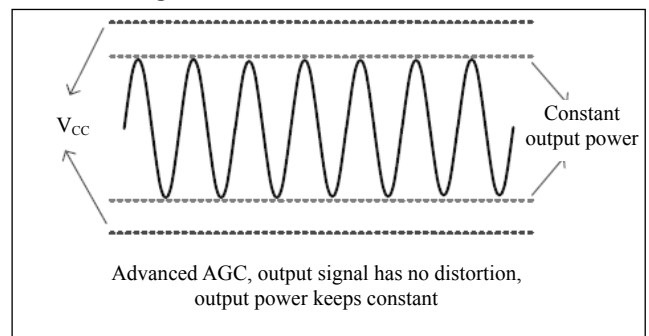


Figure 23 IS31AP2036 Advanced AGC Function

### Attack and Release Time

The attack time is a time interval that gains falls down with a big signal input enough. And the release time is a time from target attenuation to no AGC attenuation.

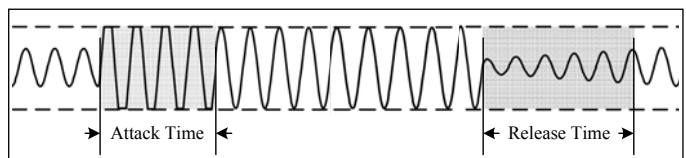


Figure 24 Attack and Release Time

### K-CHARGE PUMP

IS31AP2036 adopts advanced K-CHARGE PUMP techniques, which increases high efficiency and drive power with 750kHz operation frequency and integrates soft-start, over current and over voltage control circuit to guarantee stable operation.

### Soft-Start

To limit inrush current in charge pump start procedure, the K-CHARGE PUMP adopts soft-start function. The soft-start time is 0.7ms and limits the supply current within 350mA.

### Over Voltage Protection

K-CHARGE PUMP output voltage,  $PV_{CC}$  is  $V_{CC}$  of 1.5 times to provide high voltage for internal power amplifier. K-CHARGE PUMP integrates over voltage protection function.  $PV_{CC}$  is not times  $V_{CC}$  when supply voltage is over 3.8V. The OVP circuit will keep  $PV_{CC}$  in 5.8V (Typ.).

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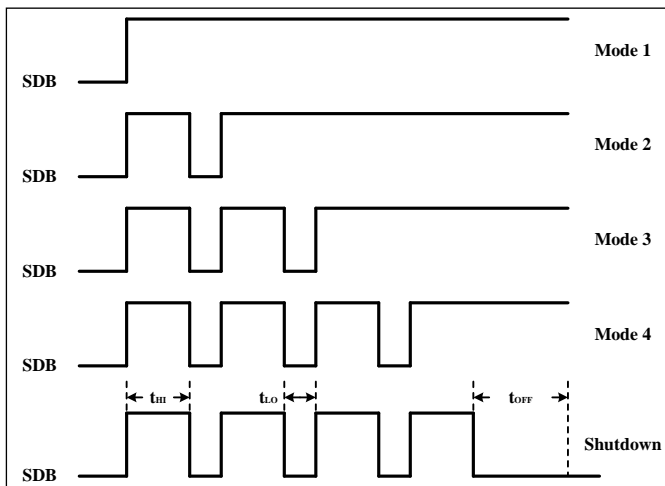
## PULSE COUNT CONTROL

The operating mode and gain are controlled by Pulse Count Control (PCC wire) serial interface. The interface records rising edges of the SDB pin and decodes them into 4 operating modes as below figure.

If the SDB pin is pulled to high, receiving one rising edge, the IC starts up and operates in Mode 1. If the SDB pin receives two rising edges, the IC operates in Mode 2. If the SDB pin receives three rising edges, the IC operates in Mode 3. If the SDB pin receives four rising edges, the IC operates in Mode 4. IS31AP2036 only has 4 operation modes, the number of rising edge is not allowed over 4.

**Table 1** Mode Control ( $V_{CC}=4.2V$ ,  $R_L = 8\Omega$ )

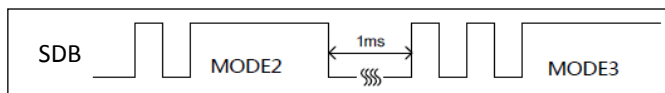
Mode	Gain	Power	AGC
Mode 1	16.4	1.2W	Yes
Mode 2	16.4	1.0W	Yes
Mode 3	16.4	0.8W	Yes
Mode 4	16.4	1.55W@THD=1%	No



**Figure 25** Operating Mode Control

$t_{HI}$  and  $t_{LO}$  are from  $0.75\mu s$  to  $10\mu s$  and  $2\mu s$  is recommended.

It should pull down the SDB pin low over  $t_{OFF}$  (recommended 1ms) to shut down the IC and send pulse again to switch modes.



**Figure 26** Mode Switch

## INPUT RESISTORS ( $R_{IN}$ )

The total input resistors ( $R_{IN\_T}$ ) set the gain of the amplifier according to Equation (1).  $R_{IN\_T} = R_{IN} + 16.5k\Omega$ .

$$Gain = \frac{320k\Omega}{R_{IN\_T}} \left( \frac{V}{V} \right) \quad (1)$$

For example, in Figure 1,

$$R_{IN\_T} = 3k\Omega + 16.5k\Omega = 19.5k\Omega,$$

$$\text{So, } Gain = \frac{320k\Omega}{19.5k\Omega} \approx 16.4 \left( \frac{V}{V} \right)$$

Resistor matching is very important in fully differential amplifiers. The balance of the output on the reference voltage depends on matched ratios of the resistors. CMRR, PSRR, and cancellation of the second harmonic distortion diminish if resistor mismatch occurs. Therefore, it is recommended to use 1% accuracy resistors or better to keep the performance optimized. Matching is more important than overall accuracy.

Place the input resistors close to the IS31AP2036 to reduce noise injection on the high-impedance nodes.

## INPUT CAPACITORS ( $C_{IN}$ )

The input capacitors ( $C_{IN}$ ) and total input resistor ( $R_{IN\_T}$ ) form a high-pass filter with the corner frequency,  $f_c$ , determined in Equation (2).  $R_{IN\_T} = R_{IN} + 16.5k\Omega$ .

$$f_c = \frac{1}{2\pi R_{IN\_T} C_{IN}} \quad (2)$$

For example, in Figure 1,

$$C_{IN} = 15nF, R_{IN\_T} = 3k\Omega + 16.5k\Omega = 19.5k\Omega,$$

$$\text{So, } f_c = \frac{1}{2\pi \times 19.5k\Omega \times 15nF} \approx 544 Hz$$

The capacitors should have a tolerance of  $\pm 10\%$  or better, because any mismatch in capacitance causes an impedance mismatch at the corner frequency and below.

## CLASS-D AMPLIFIER WITHOUT FILTER

Traditional Class-D amplifier output antiphase square waves in idle state. The antiphase waves in speaker load will generate switch current dissipation. To resume analog audio signal, add LC filter on output is necessary. But it will increase cost, PCB area and power dissipation and decrease THD+N capability.

IS31AP2036 adopts no filter Class-D frame without output LC filter. Two outputs (OUT+, OUT-) are inphase square waves in idle state. It won't generate switch current on speaker load. When load input signal, output duty cycle will change which OUT+ is bigger

## IS31AP2036

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and OUT- is smaller. Then differential signal will be on speaker.

### **POP-AND-CLICK SUPPRESSION**

Pop-and-Click is the noise which happens with amplifier start and shutdown. IS31AP2036 integrates Pop-and-Click suppression circuitry to decrease noise effectively.

### **THERMAL AGC**

IS31AP2036 adopts Thermal AGC techniques which adjust output gain automatically by IC junction temperature to decrease power dissipation. When the junction temperature is over threshold value (150°C), the IC will start up automatic control circuit to decrease

output gain. Thus, power dissipation will be decreased and junction temperature stops rising. When the junction temperature falls down to the operating temperature (130°C), automatic control circuit will resume output gain. If the junction temperature continues rising to the OVP threshold (160°C), IC will shut down until junction temperature comes back to 130°C.

### **OVER CURRENT PROTECTION**

IS31AP2036 integrates over current protection function. IC will shut down when over current is detected to prevent IC damage. As clean up short-circuit, IC will resume operation without restart.

# IS31AP2036

## CLASSIFICATION REFLOW PROFILES

Profile Feature	Pb-Free Assembly
<b>Preheat &amp; Soak</b> Temperature min (T <sub>smn</sub> ) Temperature max (T <sub>smax</sub> ) Time (T <sub>smn</sub> to T <sub>smax</sub> ) (t <sub>s</sub> )	150°C 200°C 60-120 seconds
Average ramp-up rate (T <sub>smax</sub> to T <sub>p</sub> )	3°C/second max.
Liquidous temperature (T <sub>L</sub> ) Time at liquidous (t <sub>L</sub> )	217°C 60-150 seconds
Peak package body temperature (T <sub>p</sub> )*	Max 260°C
Time (t <sub>p</sub> )** within 5°C of the specified classification temperature (T <sub>c</sub> )	Max 30 seconds
Average ramp-down rate (T <sub>p</sub> to T <sub>smax</sub> )	6°C/second max.
Time 25°C to peak temperature	8 minutes max.

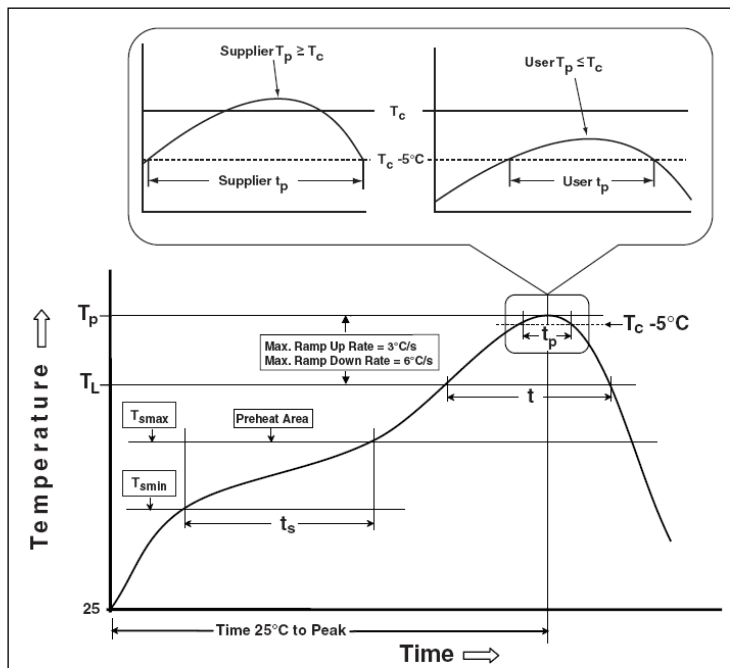
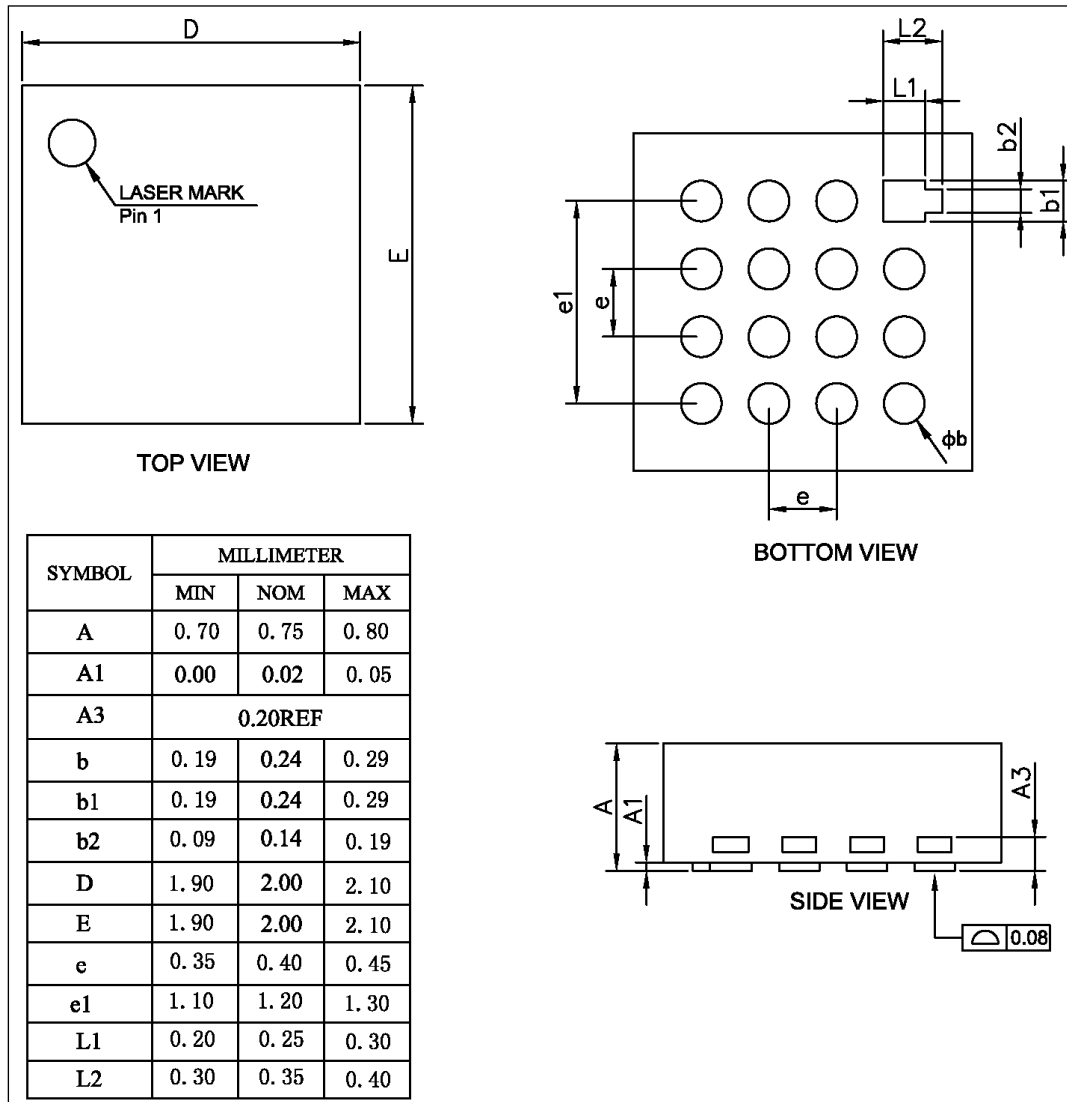


Figure 27 Classification Profile

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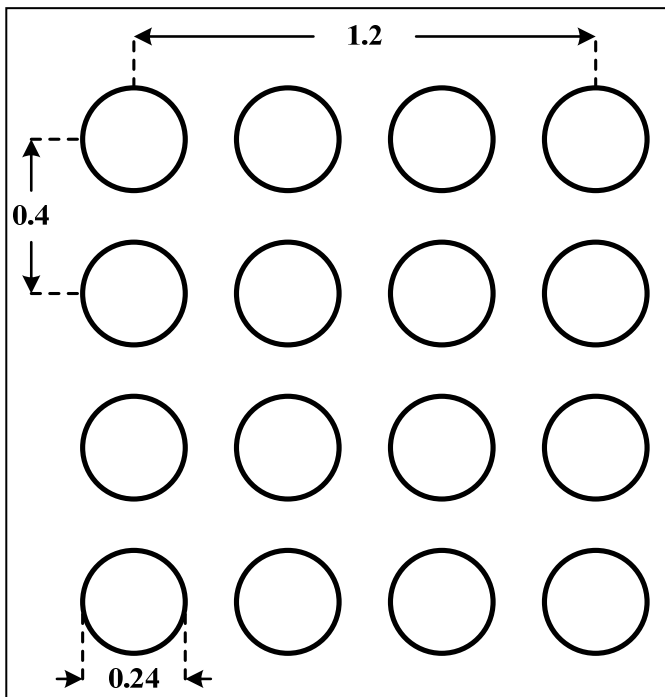
## PACKAGE INFORMATION

### FCQFN-16



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## RECOMMENDED LAND PATTERN



**Note:**

1. Land pattern complies to IPC-7351.
2. All dimensions in MM.
3. This document (including dimensions, notes & specs) is a recommendation based on typical circuit board manufacturing parameters. Since land pattern design depends on many factors unknown (eg. user's board manufacturing specs), user must determine suitability for use.



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## REVISION HISTORY

Revision	Detail Information	Date
A	Initial release	2015.04.23
B	1. Revise $t_{OFF}$ and $t_{LAT}$ value in EC table 2. Add land pattern 3. Add revision history	2015.06.10
C	Update POD	2015.08.13
D	Update EC parameters	2016.02.03