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

July 2021

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

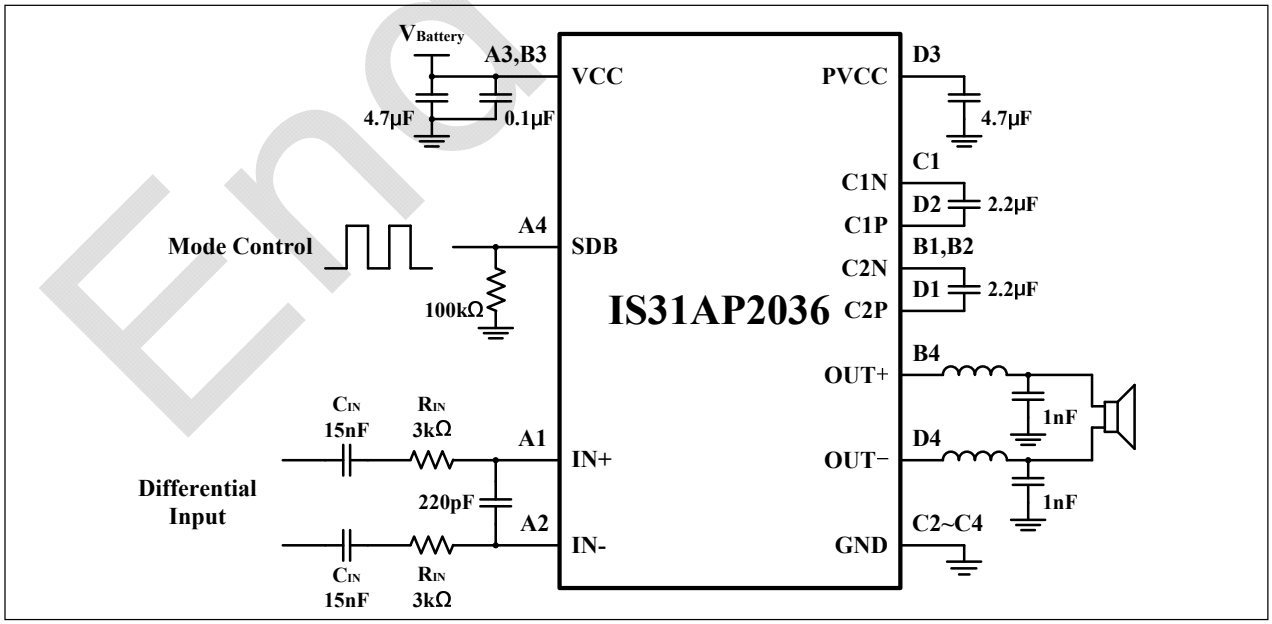


Figure 1 Typical Application Circuit (Differential Input)

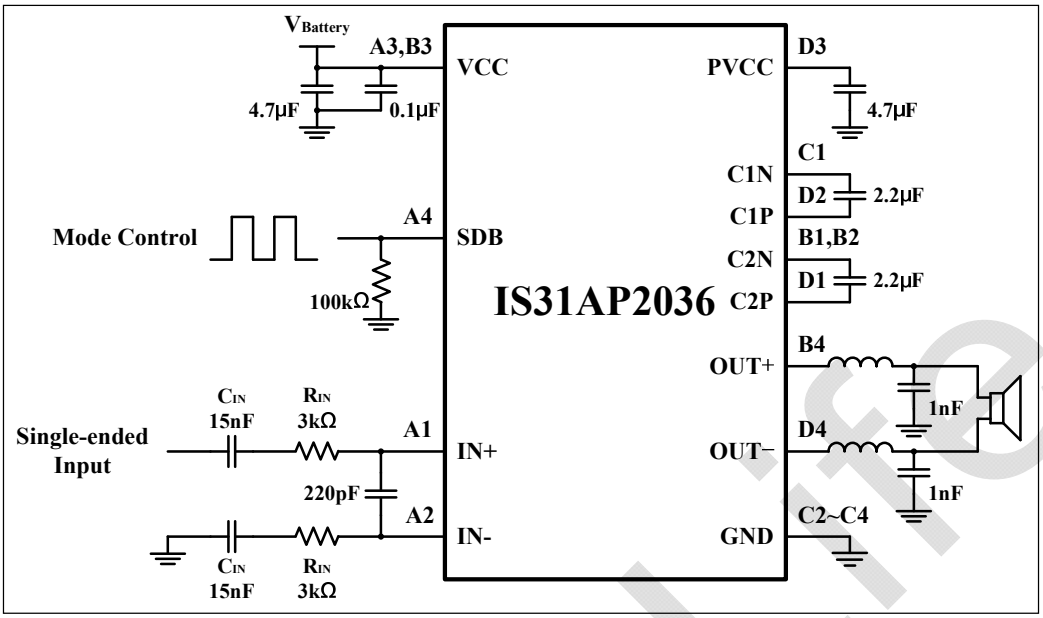
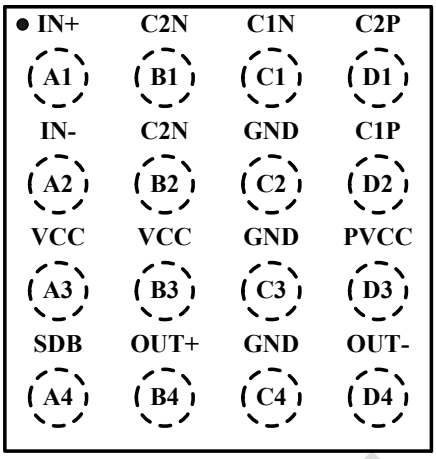


Figure 2 Typical Application Circuit (Single-ended Input)

PIN CONFIGURATION

Package	Pin Configuration (Top View)
FCQFN-16	

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.

ORDERING INFORMATION

Industrial Range: -40°C to +85°C

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

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, θ_{JA}	69°C/W
ESD (HBM) ESD (CDM)	±8kV ±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°C, V_{CC} = 3.0V ~ 5.0V, unless otherwise noted. Typical value are T_A = 25°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 ~ 5.0V		650		kHz
A_V	Output gain	R_{IN} = 3kΩ		16.3		V/V
t_{ON}	Turn on time			40		ms
$\|V_{OS}\|$	Output offset voltage	V_{CC} = 3.0V ~ 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~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} = 4.7μF, no load		0.5		ms
I_L	PVCC short to GND limit current	(Note 1)		350		mA

AC CHARACTERISTICS (NOTE 1)

T_A = 25°C, V_{CC} = 3.6V, unless otherwise noted.

Symbol	Parameter	Condition		Min.	Typ.	Max.	Unit
Po	Output power, Mode 4	THD+N = 10%, f = 1kHz, R_L = 8Ω+33μH	V_{CC} = 3.6V		1.35		W
			V_{CC} = 4.2V		2.0		
		THD+N = 1%, f = 1kHz, R_L = 8Ω+33μH	V_{CC} = 3.6V		1.1		
			V_{CC} = 4.2V		1.55		
		THD+N = 10%, f = 1kHz, R_L = 4Ω+33μH	V_{CC} = 3.6V		1.8		
			V_{CC} = 4.2V		2.45		
		THD+N = 1%, f = 1kHz, R_L = 4Ω+33μH	V_{CC} = 3.6V		1.55		
			V_{CC} = 4.2V		2.1		
P_{NCN}	NCN output power	V_{CC} = 4.2V, R_L =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_{CC} = 4.2V, P_O = 1W, R_L = 8Ω+33μH f = 1kHz, Mode 1			0.1		%
		V_{CC} = 4.2V, P_O = 1.2W, R_L = 8Ω+33μH f = 1kHz, Mode 4			0.05		
t_{WU}	Wake-up time from shutdown				40		ms
η	Efficiency (Note 1)	V_{CC} = 4.2V, P_O = 1.2W, R_L = 8Ω			75		%
V_{NO}	Output Noise	V_{CC} = 3.6V, R_L = 8Ω			102		μV
PSRR	Power supply rejection ratio (Note 1)	V_{CC} = 4.2V, V_{P-P} = 200mV, R_L = 8Ω, f = 217Hz			-72		dB
		V_{CC} = 4.2V, V_{P-P} = 200mV, R_L = 8Ω, f = 1kHz			-72		
NCN							
t_{AT}	Attack time	(Note 1)			40		ms
t_{RL}	Release time	(Note 1)			1.5		s
A_{max}	Max attenuation gain	(Note 1)			-13.5		dB
Pulse Count Control							
t_L	Mode control low time	V_{CC} = 3.0V ~ 5.0V		0.75	2	10	μs
t_H	Mode control high time	V_{CC} = 3.0V ~ 5.0V		0.75	2	10	μs
t_{LAT}	Mode latch up time	V_{CC} = 3.0V ~ 5.0V (Note 1)		220		500	μs
t_{OFF}	Shutdown time	V_{CC} = 3.0V ~ 5.0V		220		500	μs

Note 1: Guaranteed by design.

TYPICAL PERFORMANCE CHARACTERISTICS

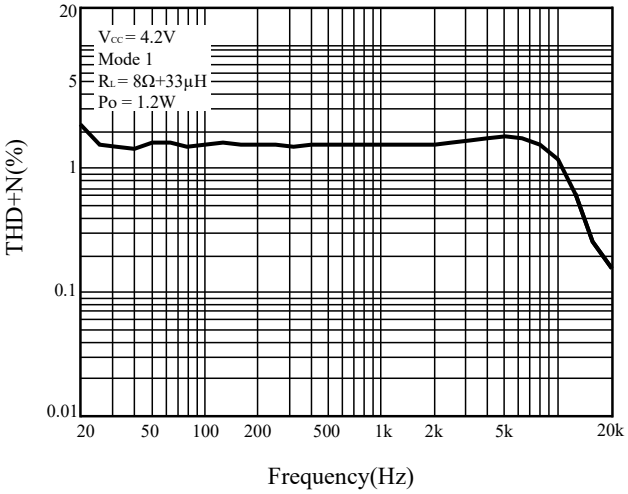


Figure 3 THD+N vs. Frequency

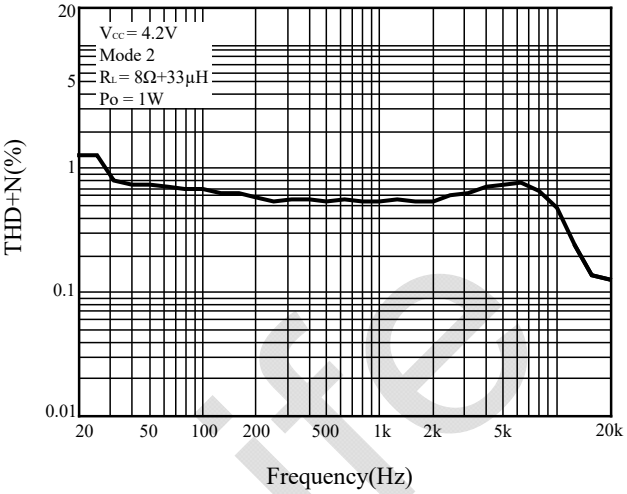


Figure 4 THD+N vs. Frequency

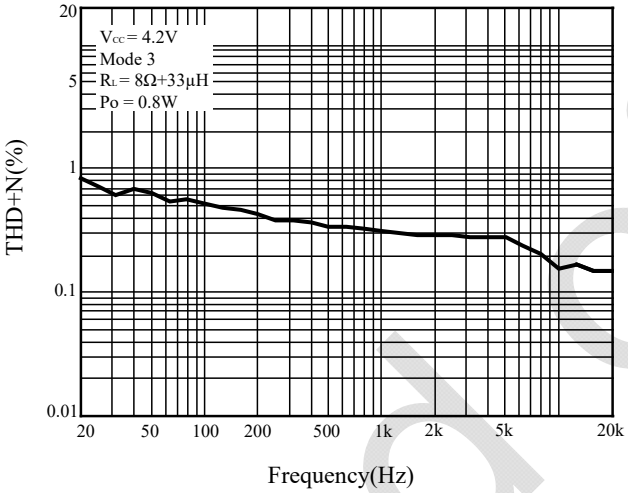


Figure 5 THD+N vs. Frequency

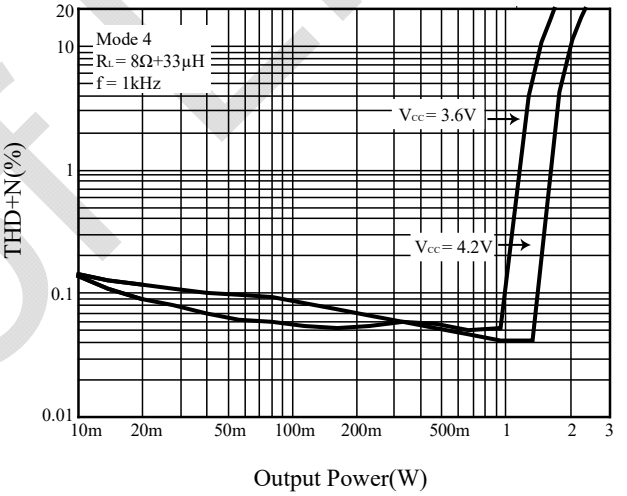


Figure 6 THD+N vs. Output Power

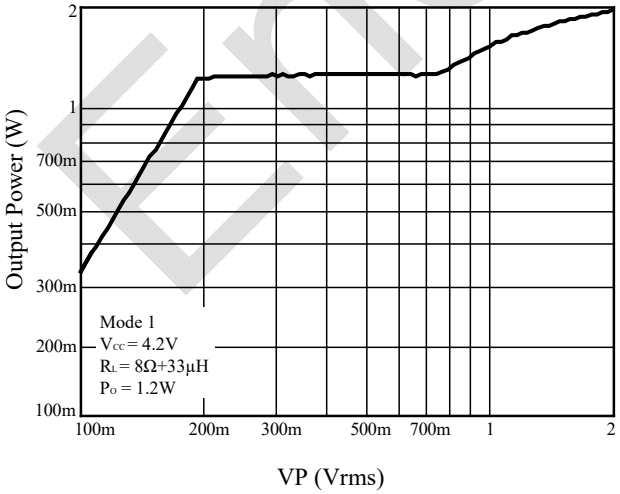


Figure 7 Output Power vs. VP

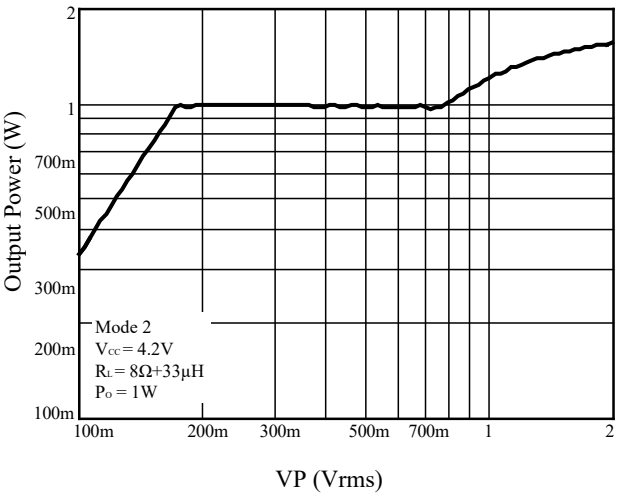


Figure 8 Output Power vs. VP

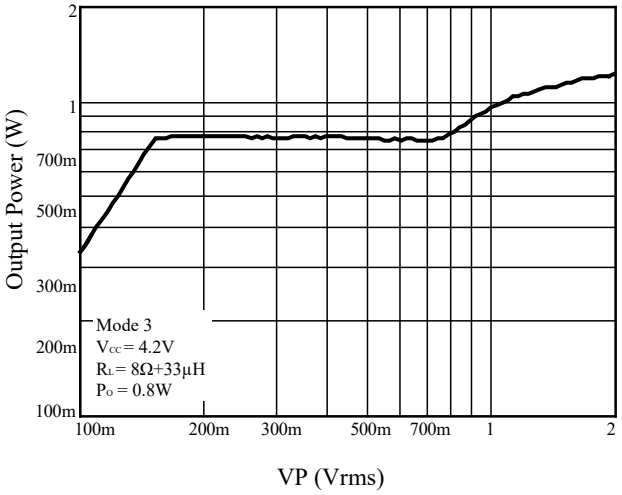


Figure 9 Output Power vs. VP

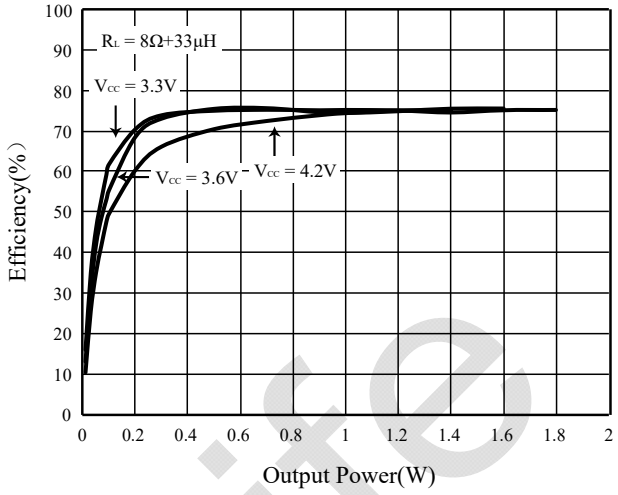


Figure 10 Efficiency vs. Output Power

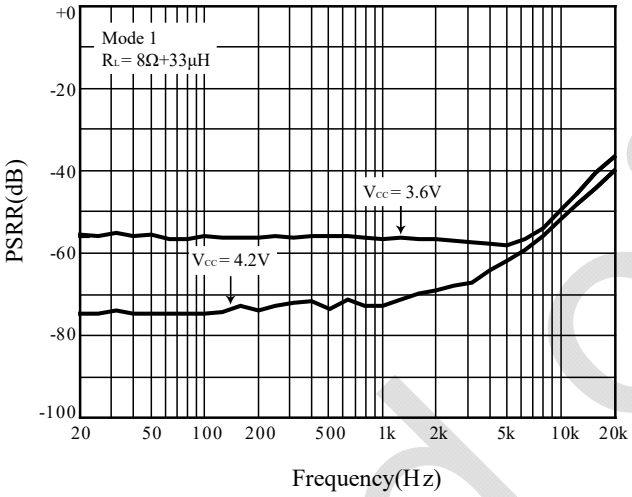


Figure 11 PSRR vs. Frequency

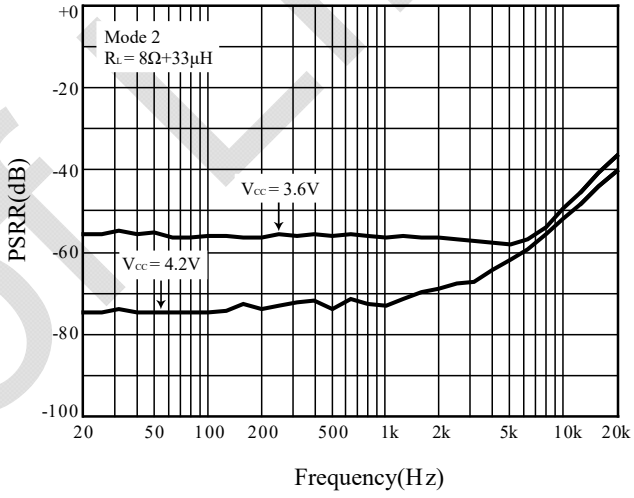


Figure 12 PSRR vs. Frequency

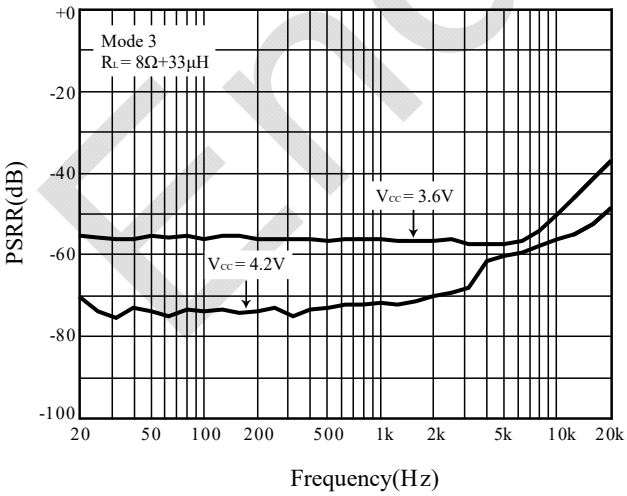


Figure 13 PSRR vs. Frequency

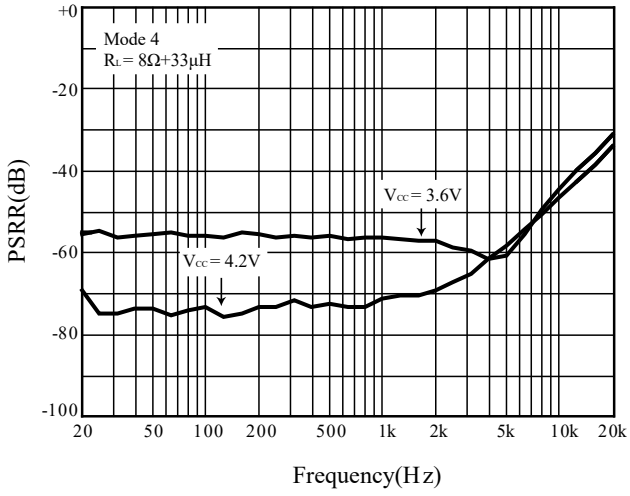


Figure 14 PSRR vs. Frequency

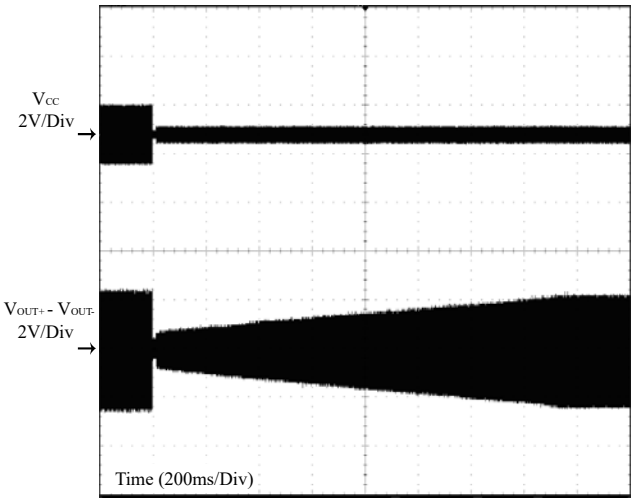


Figure 15 Release Time

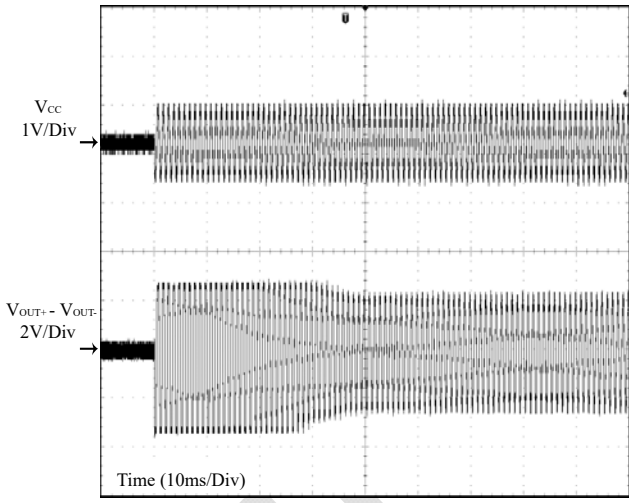


Figure 16 Attack Time

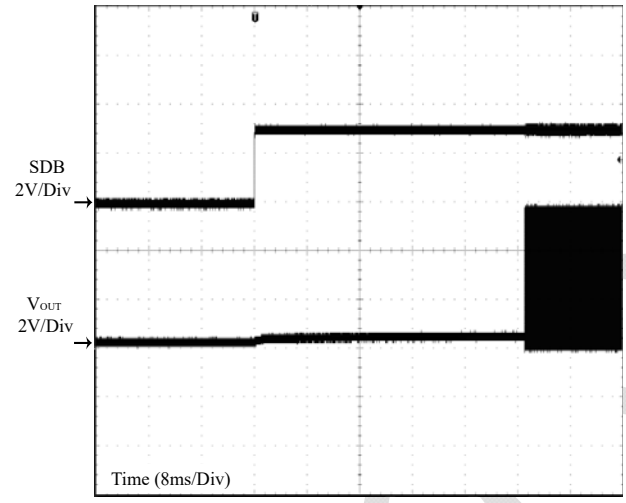


Figure 17 Turn On

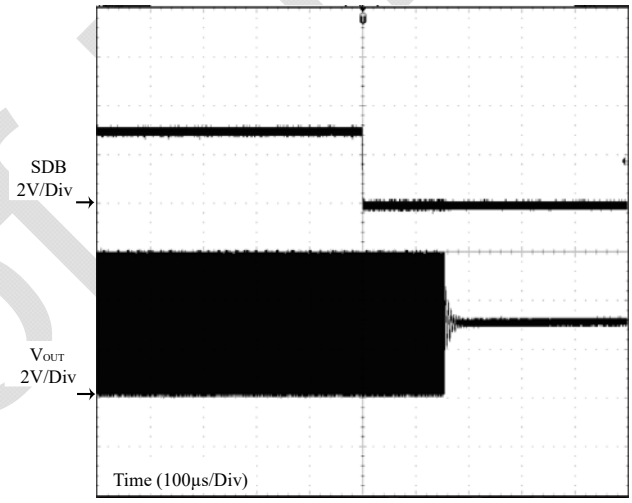


Figure 18 Turn Off

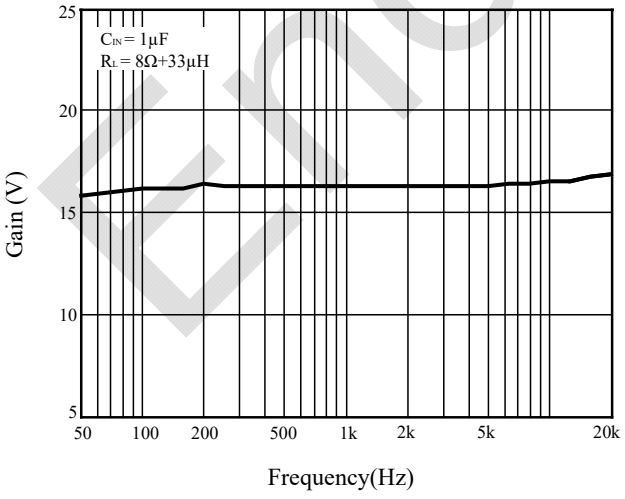


Figure 19 Gain vs. Frequency

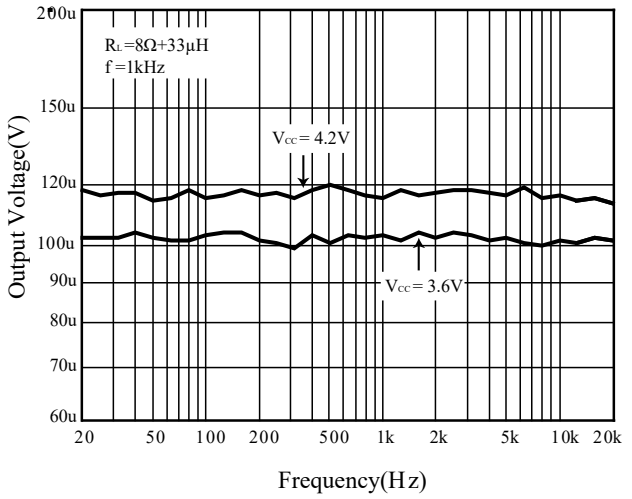
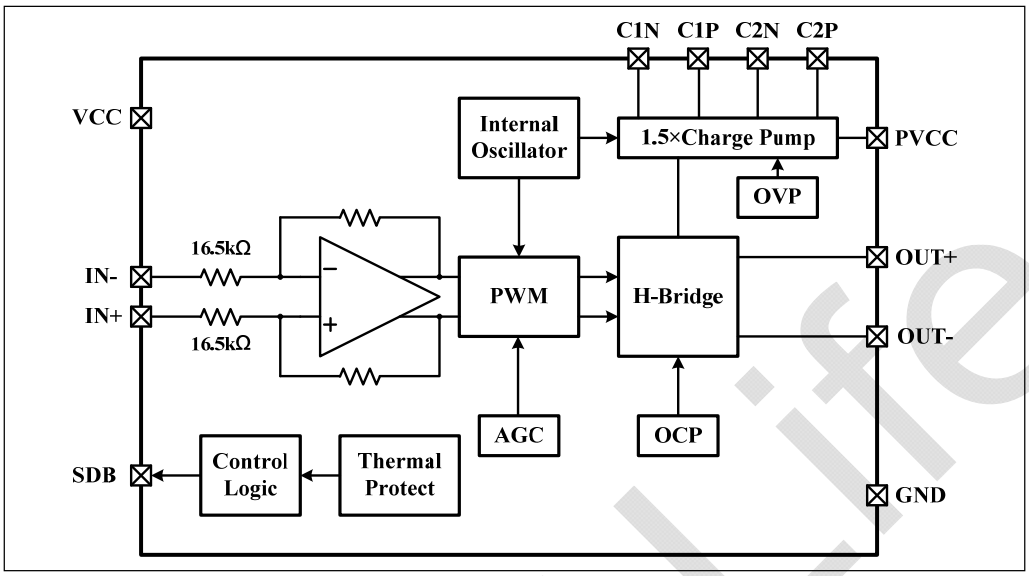


Figure 20 Noise

FUNCTIONAL BLOCK DIAGRAM



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).

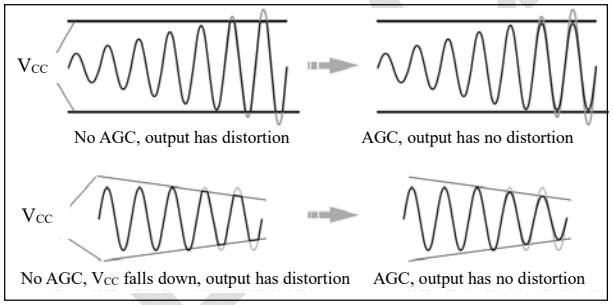


Figure 21 AGC Function

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

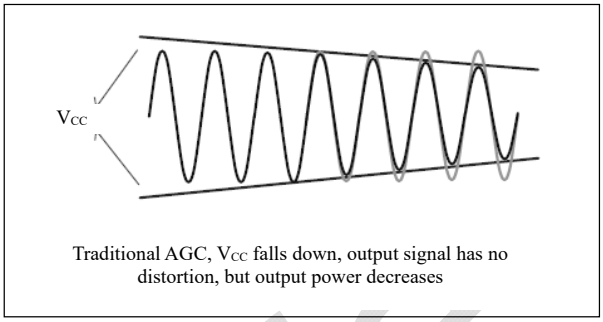


Figure 22 Traditional AGC Function

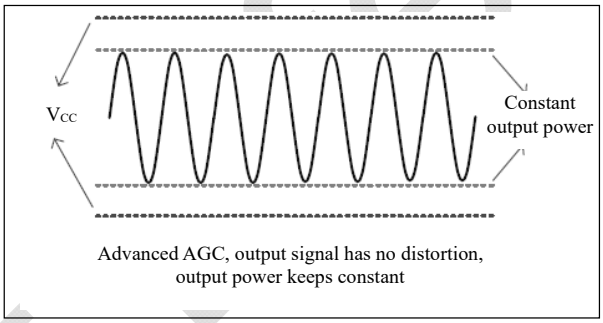


Figure 23 IS31AP2036 Advanced AGC Function

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.

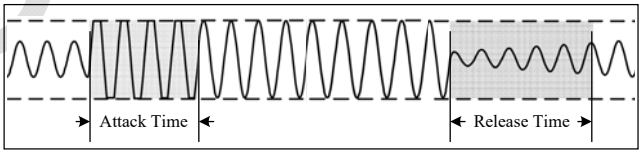


Figure 24 Attack and Release Time

K-CHARGEPUMP

IS31AP2036 adopts advanced K-CHARGEPUMP 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-CHARGEPUMP adopts soft-start function. The soft-start time is 0.7ms and limits the supply current within 350mA.

Over Voltage Protection

K-CHARGEPUMP output voltage, PV_{CC} is V_{CC} of 1.5 times to provide high voltage for internal power amplifier. K-CHARGEPUMP 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.).

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 = 8Ω)

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

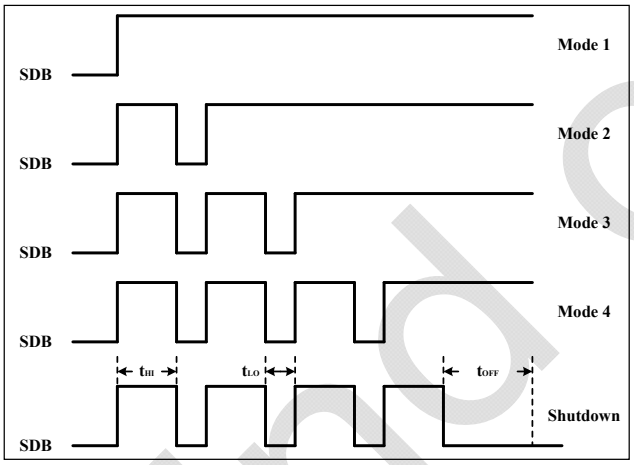


Figure 25 Operating Mode Control

t_{HI} and t_{LO} are from 0.75μs to 10μs and 2μs 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.

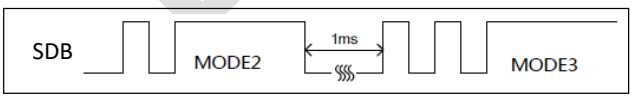


Figure 26 Mode Switch

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}+16.5kΩ.

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

For example, in Figure 1,

R_{IN_T} = 3kΩ+16.5kΩ=19.5kΩ,

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}+16.5kΩ.

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

For example, in Figure 1,

C_{IN} = 15nF, R_{IN_T} = 3kΩ+16.5kΩ=19.5kΩ,

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

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

CLASS-D AMPLIFIER WITHOUT FLITER

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

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 untill 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.

CLASSIFICATION REFLOW PROFILES

Profile Feature	Pb-Free Assembly
Preheat & Soak Temperature min (Tsmin) Temperature max (Tsmax) Time (Tsmin to Tsmax) (ts)	150°C 200°C 60-120 seconds
Average ramp-up rate (Tsmax to Tp)	3°C/second max.
Liquidous temperature (TL) Time at liquidous (tL)	217°C 60-150 seconds
Peak package body temperature (Tp)*	Max 260°C
Time (tp)** within 5°C of the specified classification temperature (Tc)	Max 30 seconds
Average ramp-down rate (Tp to Tsmax)	6°C/second max.
Time 25°C to peak temperature	8 minutes max.

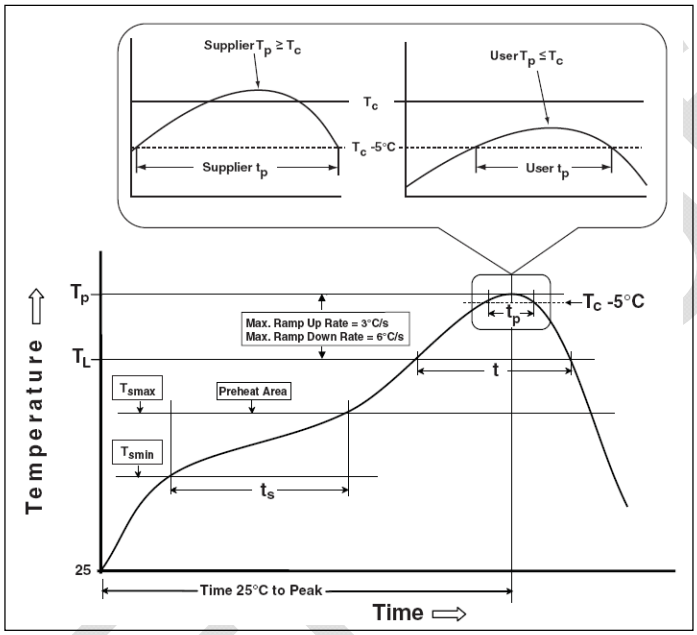
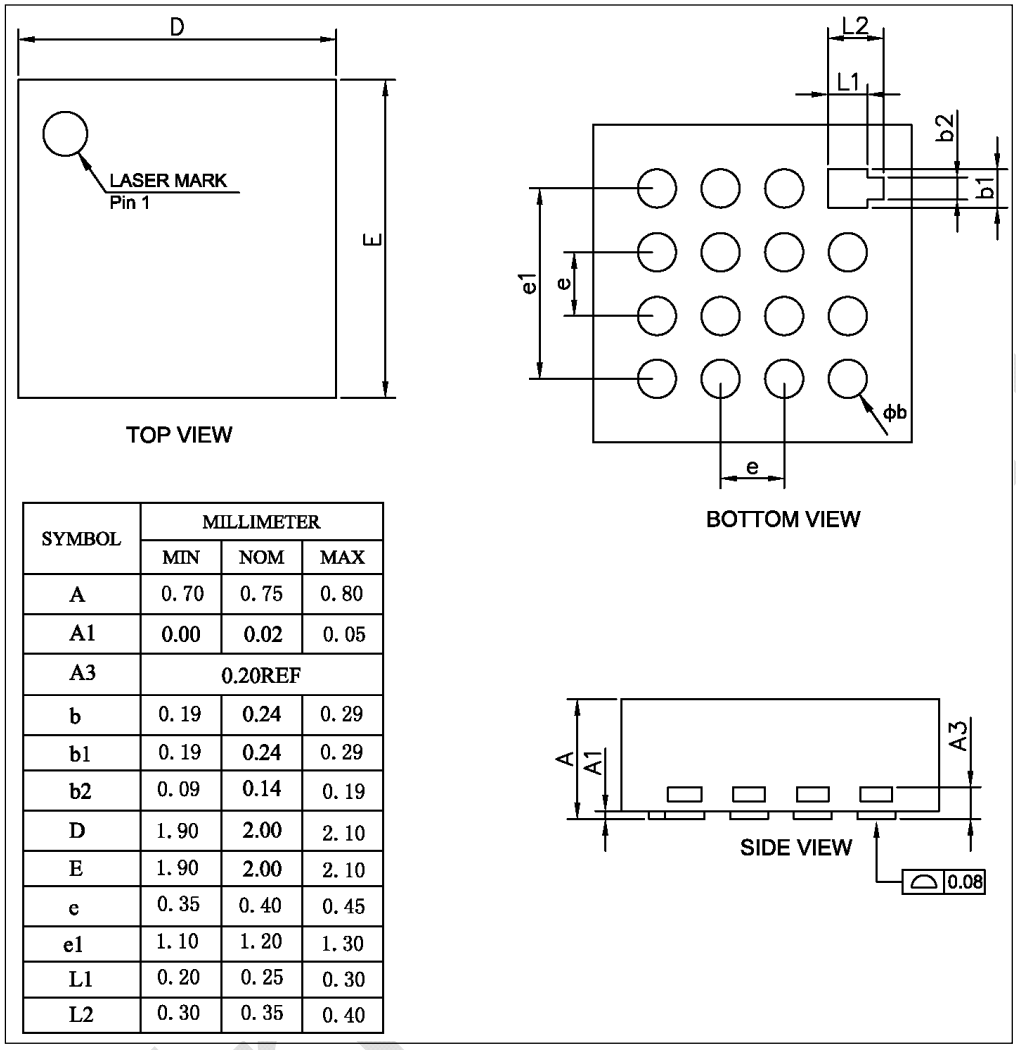


Figure 27 Classification Profile

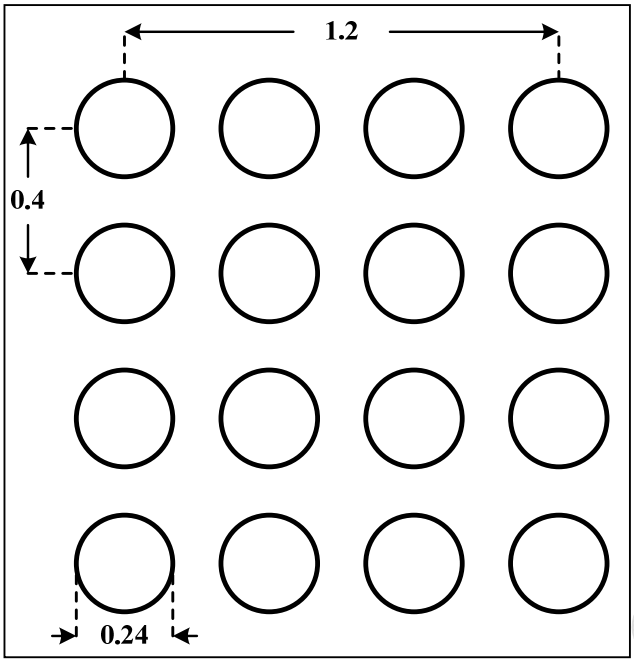
PACKAGE INFORMATION

FCQFN-16



SYMBOL	MILLIMETER		
	MIN	NOM	MAX
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A3	0.20REF		
b	0.19	0.24	0.29
b1	0.19	0.24	0.29
b2	0.09	0.14	0.19
D	1.90	2.00	2.10
E	1.90	2.00	2.10
e	0.35	0.40	0.45
e1	1.10	1.20	1.30
L1	0.20	0.25	0.30
L2	0.30	0.35	0.40

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.

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
E	Add “End of Life” watermark	2021.07.13