

# IS31AP2111

## 2×20W STEREO/1×40W MONO DIGITAL (I2S) AUDIO AMPLIFIER WITH 20 BANDS EQ FUNCTIONS

August 2021

### GENERAL DESCRIPTION

The IS31AP2111 is a digital I2S interface audio amplifier capable of driving a pair of 8Ω speakers at 20W when operating from a 24V supply. Due to its Class-D output drive stage; it can operate without an external heat-sink or fan.

The IS31AP2111 integrates advanced audio processing capabilities, such as volume control, 20 bands speaker EQ, audio mixing, 3D surround and Dynamic Range Control (DRC). These functions are fully programmable via a simple I2C control interface.

Robust protection circuits are provided to protect the IS31AP2111 from damage due to accidental or erroneous operating conditions. Because of its digital design, the IS31AP2111 is more tolerant to noise and PVT (Process, Voltage, and Temperature) variation than the analog Class-AB or Class-D audio amplifier counterpart. It has a robust anti-pop circuit for pop free operation during power ON. It integrates protection features for short circuit and over temperature.

The IS31AP2111 is available in a thermally enhanced eTSSOP-24 package.

### APPLICATIONS

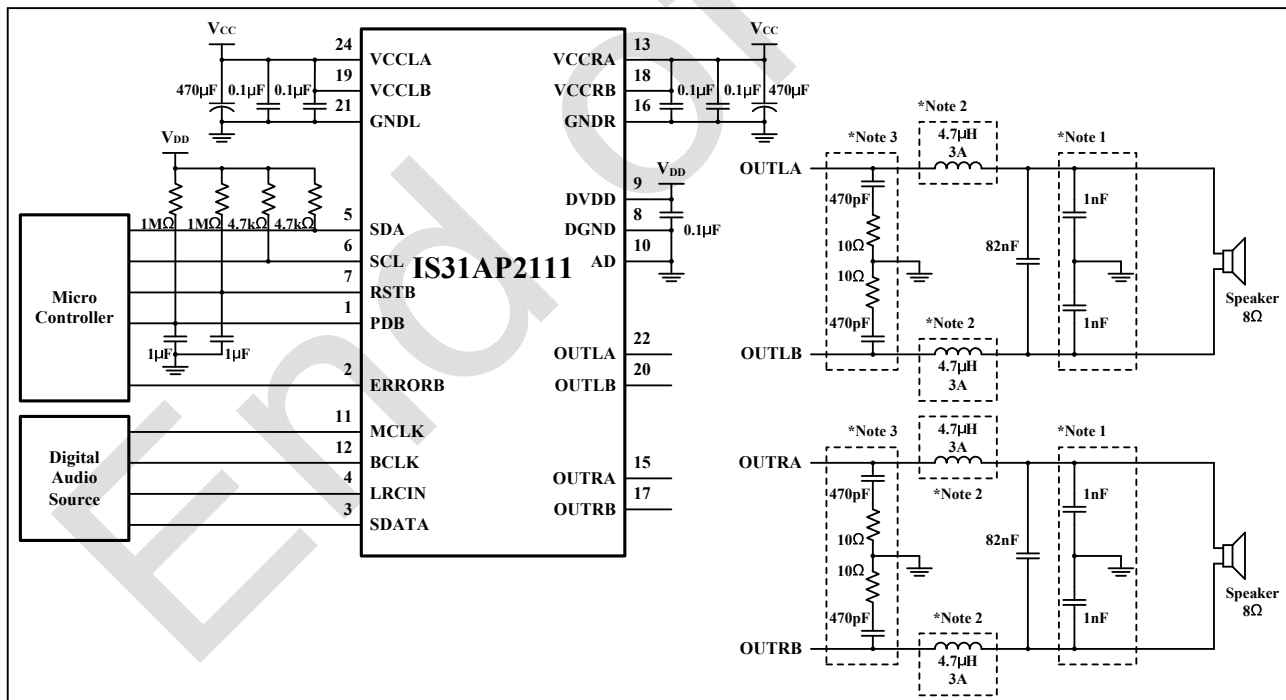
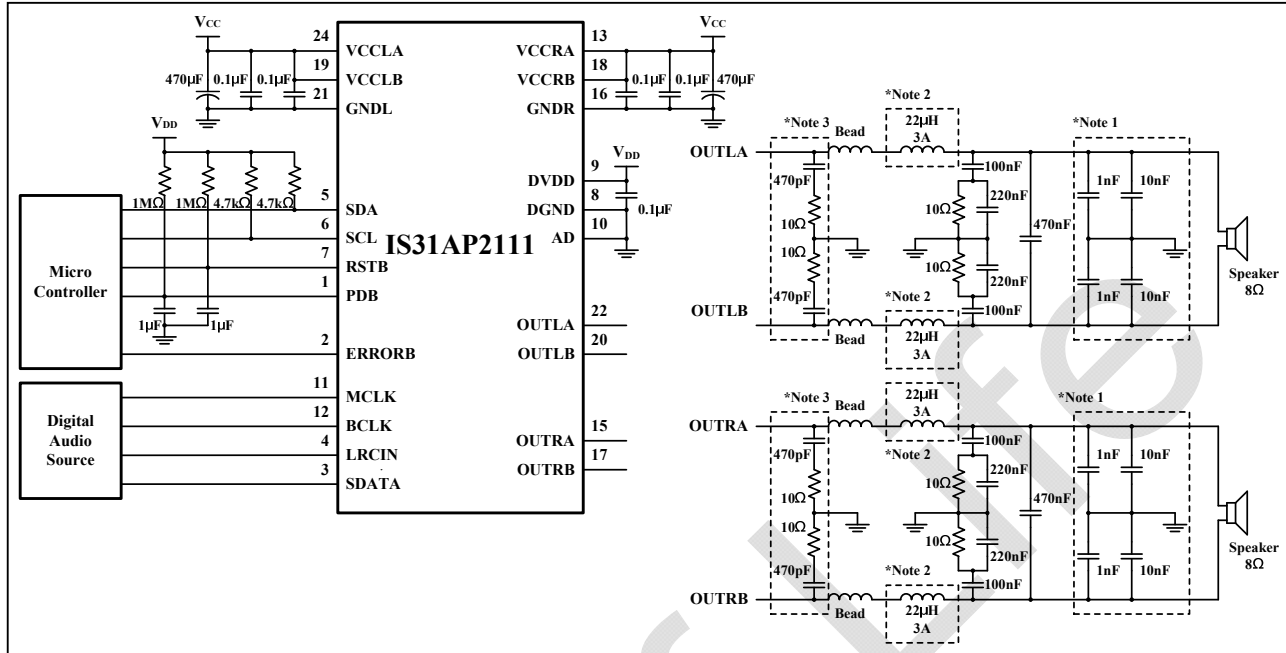
- TV audio
- Boom-box, CD and DVD receiver, docking system
- Powered speaker
- Wireless audio

### FEATURES

- 16/18/20/24-bits input with I2S, Left-alignment and Right-alignment data format
- PSNR & DR (A-weighting)  
speaker: 99dB (PSNR), 104dB (DR) @24V
- Multiple sampling frequencies ( $F_s$ )
  - 32kHz / 44.1kHz / 48kHz and
  - 64kHz / 88.2kHz / 96kHz and
  - 128kHz / 176.4kHz / 192kHz
- System clock = 64x, 128x, 192x, 256x, 384x, 512x, 576x, 768x, 1024x  $F_s$ 
  - 64x~1024x  $F_s$  for 32kHz / 44.1kHz / 48kHz
  - 64x~512x  $F_s$  for 64kHz / 88.2kHz / 96kHz
  - 64x~256x  $F_s$  for 128kHz / 176.4kHz / 192kHz
- Supply voltage
  - 3.3V for digital circuit
  - 10V~26V for speaker driver
- speaker output power at 24V
  - 10W × 2CH into 8Ω @0.24% THD+N for stereo
  - 20W × 2CH into 8Ω @0.38% THD+N for stereo
  - 40W × 1CH into 4Ω @0.12% THD+N for mono
- Sound processing including:
  - 20 bands parametric speaker EQ
  - Volume control (+24dB ~ -103dB, 0.125dB/step),
  - Dynamic range control (DRC)
  - Dual band dynamic range control
  - Power clipping
  - 3D surround sound
  - Channel mixing
  - Noise gate with hysteresis window
  - Bass/Treble tone control
  - DC-blocking high-pass filter
- Anti-pop design
- Short circuit and over-temperature protection
- I2C control interface with selectable device address
- Support hardware and software reset
- Internal PLL
- LV Under-voltage shutdown and HV Under-voltage detection
- Power saving mode

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## TYPICAL APPLICATION CIRCUIT



# IS31AP2111

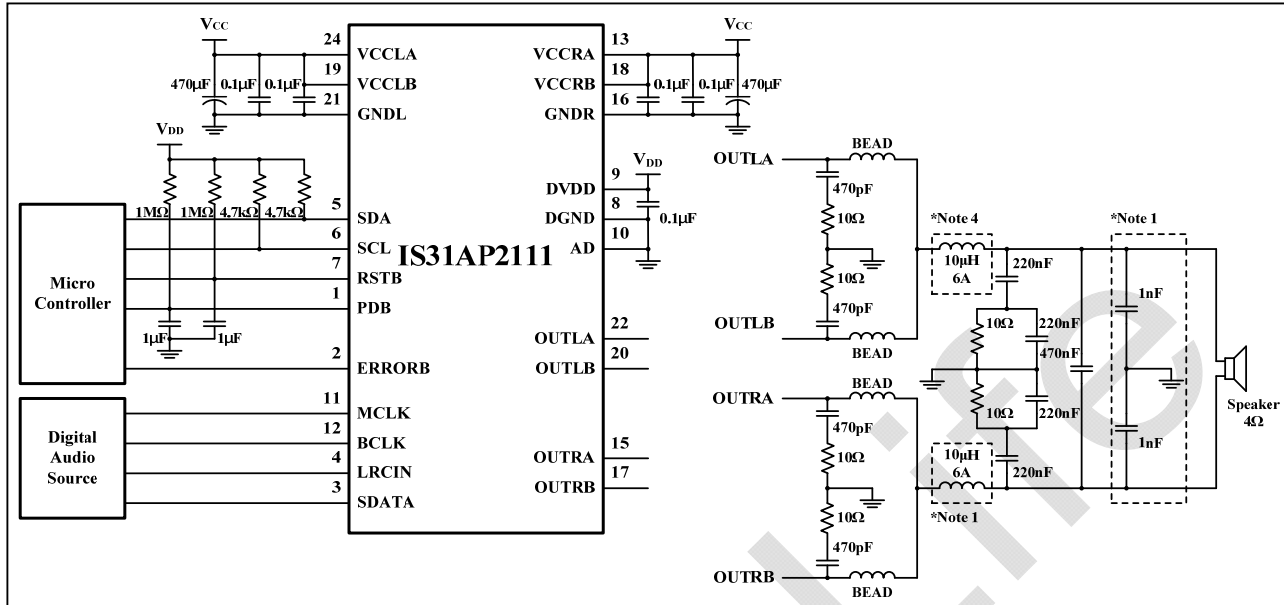


Figure 3 Typical Application Circuit (for Mono)

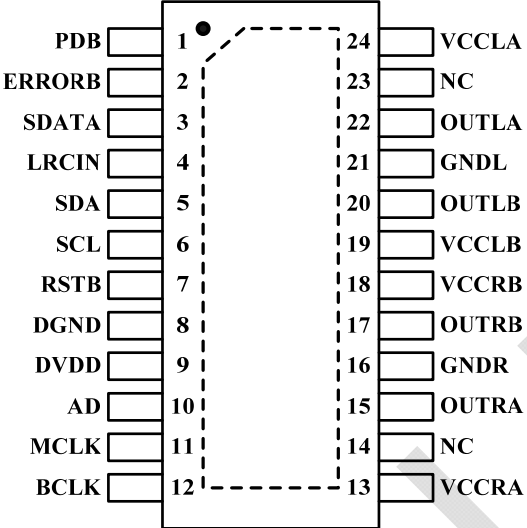
**Note 1:** These capacitors should be placed as close to speaker jack as possible, and their values should be determined according to EMI test results.

**Note 2:** When concerning about short-circuit protection, it is suggested using the choke with its  $I_{DC}$  larger than 5A.

**Note 3:** The snubber circuit can be removed while the  $V_{CC} \leq 20V$ .

**Note 4:** When concerning about short-circuit protection, it is suggested using the choke with its  $I_{DC}$  larger than 10A.

## PIN CONFIGURATION

| Package   | Pin Configuration (Top View)  |
|-----------|---|
| eTSSOP-24 |  <p>The diagram shows a top view of the eTSSOP-24 package with 24 pins. Pin 1 is the top-left corner. The pins are numbered 1 through 24. The labels for each pin are as follows:</p> <ul style="list-style-type: none"> <li>Pin 1: PDB</li> <li>Pin 2: ERRORB</li> <li>Pin 3: SDATA</li> <li>Pin 4: LRCIN</li> <li>Pin 5: SDA</li> <li>Pin 6: SCL</li> <li>Pin 7: RSTB</li> <li>Pin 8: DGND</li> <li>Pin 9: DVDD</li> <li>Pin 10: AD</li> <li>Pin 11: MCLK</li> <li>Pin 12: BCLK</li> <li>Pin 13: VCCRA</li> <li>Pin 14: NC</li> <li>Pin 15: OUTRA</li> <li>Pin 16: GNDR</li> <li>Pin 17: OUTRB</li> <li>Pin 18: VCCRB</li> <li>Pin 19: VCCLB</li> <li>Pin 20: OUTLB</li> <li>Pin 21: GN DL</li> <li>Pin 22: OUTLA</li> <li>Pin 23: NC</li> <li>Pin 24: VCCLA</li> </ul> |

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## PIN DESCRIPTION

| No.    | Pin         | Description                       | Characteristics                  |
|--------|-------------|-----------------------------------|----------------------------------|
| 1      | PDB         | Power down, low active.           | Schmitt trigger TTL input buffer |
| 2      | ERRORB      | Error status, low active.         | Open-drain output                |
| 3      | SDATA       | I2S serial audio data input.      | Schmitt trigger TTL input buffer |
| 4      | LRCIN       | Left/Right clock input ( $F_s$ ). | Schmitt trigger TTL input buffer |
| 5      | SDA         | I2C serial data.                  | Schmitt trigger TTL input buffer |
| 6      | SCL         | I2C serial clock input.           | Schmitt trigger TTL input buffer |
| 7      | RSTB        | Reset, low active.                | Schmitt trigger TTL input buffer |
| 8      | DGND        | Digital ground.                   |                                  |
| 9      | DVDD        | Digital power.                    |                                  |
| 10     | AD          | I2C select address.               | Schmitt trigger TTL input buffer |
| 11     | MCLK        | Master clock input.               | Schmitt trigger TTL input buffer |
| 12     | BCLK        | Bit clock input ( $64F_s$ ).      | Schmitt trigger TTL input buffer |
| 13     | VCCRA       | Right channel supply A.           |                                  |
| 14, 23 | NC          | No connection.                    |                                  |
| 15     | OUTRA       | Right channel output A.           |                                  |
| 16     | GNDR        | Right channel ground.             |                                  |
| 17     | OUTRB       | Right channel output B.           |                                  |
| 18     | VCCRB       | Right channel supply B.           |                                  |
| 19     | VCCLB       | Left channel supply B.            |                                  |
| 20     | OUTLB       | Left channel output B.            |                                  |
| 21     | GNDL        | Left channel ground.              |                                  |
| 22     | OUTLA       | Left channel output A.            |                                  |
| 24     | VCCLA       | Left channel supply A.            |                                  |
|        | Thermal Pad | Connect to GND.                   |                                  |

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## ORDERING INFORMATION

Industrial Range: 0°C to +70°C

| Order Part No.     | Package              | QTY       |
|--------------------|----------------------|-----------|
| IS31AP2111-ZLS1-TR | eTSSOP-24, Lead-free | 2500/Reel |
| IS31AP2111-ZLS1    |                      | 62/Tube   |

End of Life

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- a.) the risk of injury or damage has been minimized;
- b.) the user assume all such risks; and
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## ABSOLUTE MAXIMUM RATINGS

|   |                |
|---|----------------|
| Supply for driver stage (VCCR, VCCL), V <sub>CC</sub>                           | -0.3V ~ +30V   |
| Supply for digital circuit (DVDD), V <sub>DD</sub>                              | -0.3V ~ +3.6V  |
| Input voltage (SDA,SCL,RSTB,PDB,ERRORB,MCLK, BCLK,LRCIN,SDATA), V <sub>IN</sub> | -0.3V ~ +3.6V  |
| Thermal resistance, $\theta_{JA}$   | 32.8°C/W       |
| Junction temperature range, T <sub>J</sub>                                      | 0°C ~ 150°C    |
| Storage temperature range, T <sub>STG</sub>                                     | -65°C ~ +150°C |
| ESD (HBM)   | ±2kV           |
| 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.

## RECOMMENDED OPERATING CONDITIONS

| Symbol          | Parameter                         | Condition | Min. | Typ. | Max. | Unit |
|-----------------|-----------------------------------|-----------|------|------|------|------|
| V <sub>CC</sub> | Supply for driver stage to VCCR/L |           | 7    |      | 26   | V    |
| V <sub>DD</sub> | Supply for digital circuit        |           | 3.15 |      | 3.45 | V    |
| T <sub>J</sub>  | Junction operating temperature    |           | 0    |      | 125  | °C   |
| T <sub>A</sub>  | Ambient operating temperature     |           | 0    |      | 70   | °C   |

## DC ELECTRICAL CHARACTERISTICS

V<sub>CC</sub>=24V, T<sub>A</sub>=25°C, R<sub>L</sub>=8Ω (unless otherwise noted).

| Symbol              | Parameter   | Condition                                    | Min. | Typ. | Max. | Unit |
|---------------------|---|--|------|------|------|------|
| I <sub>PDH</sub>    | VCC supply current during power down              | V <sub>CC</sub> = 24V                        |      | 4    | 200  | μA   |
| I <sub>PDL</sub>    | DVDD supply current during power down             | V <sub>DD</sub> = 3.3V                       |      | 3.6  | 10   | μA   |
| V <sub>UVH_HV</sub> | Under voltage disabled (For VCC)                  |  |      | 10.2 |      | V    |
| V <sub>UVL_HV</sub> | Under voltage enabled (For VCC)                   |  |      | 9.2  |      | V    |
| V <sub>UVH_LV</sub> | Under voltage disabled (For DVDD)                 |  |      | 2.9  |      | V    |
| V <sub>UVL_LV</sub> | Under voltage enabled (For DVDD)                  |  |      | 2.8  |      | V    |
| R <sub>DS(ON)</sub> | Static drain-to-source ON-state resistor, PMOS    | V <sub>CC</sub> =24V, I <sub>D</sub> = 500mA |      | 245  |      | mΩ   |
|                     | Static drain-to-source ON-state resistor, NMOS    |  |      | 150  |      |      |
| I <sub>SC</sub>     | L/R channel over-current protection               | V <sub>CC</sub> =24V (Note 1)                |      | 5.1  |      | A    |
|                     | Mono channel over-current protection              |  |      | 10   |      |      |
| T <sub>S</sub>      | Junction temperature for driver shutdown          |  |      | 158  |      | °C   |
|                     | Temperature hysteresis for recovery from shutdown |  |      | 33   |      | °C   |

## Logic Electrical Characteristics

|                 |                           |  |     |     |     |    |
|-----------------|---------------------------|--|-----|-----|-----|----|
| V <sub>IH</sub> | High level input voltage  |  | 2.0 |     |     | V  |
| V <sub>IL</sub> | Low level input voltage   |  |     |     | 0.8 | V  |
| V <sub>OH</sub> | High level output voltage |  | 2.4 |     |     | V  |
| V <sub>OL</sub> | Low level output voltage  |  |     |     | 0.4 | V  |
| C <sub>IN</sub> | Input capacitance         |  |     | 6.4 |     | pF |

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## AC ELECTRICAL CHARACTERISTICS

$T_A=25^{\circ}\text{C}$ ,  $V_{CC}=24\text{V}$ ,  $V_{DD} = 3.3\text{V}$ ,  $f_s = 48\text{kHz}$ ,  $R_L=8\Omega$  with passive LC lowpass filter ( $L= 22\mu\text{H}$ ,  $R_{DC}= 0.12\Omega$ ,  $C=470\text{nF}$ ), input is 1kHz sinewave, volume is 0dB unless otherwise specified.

| Symbol   | Parameter                         | Condition                                  | Min. | Typ. | Max. | Unit          |
|----------|-----------------------------------|--|------|------|------|---------------|
| $P_O$    | RMS output power                  | THD+N=0.38%, +8dB volume (Note 2)          |      | 20   |      | W             |
| THD+N    | Total harmonic distortion + noise | $P_O = 10\text{W}$                         |      | 0.24 |      | %             |
| $V_{NO}$ | Output noise                      | 20Hz ~ 20kHz (Note 3)                      |      | 179  |      | $\mu\text{V}$ |
| SNR      | Signal-to-noise ratio             | +8dB volume, input level is -9dB (Note 3)  |      | 99   |      | dB            |
| DR       | Dynamic range                     | +8dB volume, input level is -68dB (Note 3) |      | 104  |      | dB            |
| PSRR     | Power supply ripple rejection     | $V_{RIPPLE} = 1V_{RMS}$ at 1kHz            |      | -68  |      | dB            |
|          | Channel separation                | 1W @1kHz                                   |      | -85  |      | dB            |

## I2C DIGITAL INPUT SWITCHING CHARACTERISTICS (Note 4)

| Symbol        | Parameter   | Standard Mode |      | Fast Mode   |      | Unit          |
|---------------|---|---------------|------|-------------|------|---------------|
|               |   | Min.          | Max. | Min.        | Max. |               |
| $f_{SCL}$     | Serial-Clock frequency  | 0             | 100  | 0           | 400  | kHz           |
| $t_{BUF}$     | Bus free time between a STOP and a START condition                              | 4.7           |      | 1.3         |      | $\mu\text{s}$ |
| $t_{HD, STA}$ | Hold time (repeated) START condition  | 4.0           |      | 0.6         |      | $\mu\text{s}$ |
| $t_{SU, STA}$ | Repeated START condition setup time   | 4.7           |      | 0.6         |      | $\mu\text{s}$ |
| $t_{SU, STO}$ | STOP condition setup time   | 4.0           |      | 0.6         |      | $\mu\text{s}$ |
| $t_{HD, DAT}$ | Data hold time  | 0             | 3.45 | 0           | 0.9  | $\mu\text{s}$ |
| $t_{SU, DAT}$ | Data setup time   | 250           |      | 100         |      | ns            |
| $t_{LOW}$     | SCL clock low period  | 4.7           |      | 1.3         |      | $\mu\text{s}$ |
| $t_{HIGH}$    | SCL clock high period   | 4.0           |      | 0.6         |      | $\mu\text{s}$ |
| $t_R$         | Rise time of both SDA and SCL signals, receiving                                |               | 1000 | $20+0.1C_b$ | 300  | ns            |
| $t_F$         | Fall time of both SDA and SCL signals, receiving                                |               | 300  | $20+0.1C_b$ | 300  | ns            |
| $C_b$         | Capacitive load for each bus line   |               | 400  |             | 400  | pF            |
| $V_{NL}$      | Noise margin at the low level for each connected device (including hysteresis)  | $0.1V_{DD}$   |      | $0.1V_{DD}$ |      | V             |
| $V_{NH}$      | Noise margin at the high level for each connected device (including hysteresis) | $0.2V_{DD}$   |      | $0.2V_{DD}$ |      | V             |



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## I2S DIGITAL INPUT SWITCHING CHARACTERISTICS (Note 4)

| Symbol    | Parameter                      | Condition | Min.   | Typ. | Max.  | Unit    |
|-----------|--------------------------------|-----------|--------|------|-------|---------|
| $t_{LR}$  | LRCIN period ( $1/F_s$ )       |           | 10.41  |      | 31.25 | $\mu s$ |
| $t_{BL}$  | BCLK rising edge to LRCIN edge |           | 50     |      |       | ns      |
| $t_{LB}$  | LRCIN edge to BCLK rising edge |           | 50     |      |       | ns      |
| $t_{BCC}$ | BCLK period ( $1/64F_s$ )      |           | 162.76 |      | 488.3 | ns      |
| $t_{BCH}$ | BCLK pulse width high          |           | 81.38  |      | 244   | ns      |
| $t_{BCL}$ | CBLK pulse width low           |           | 81.38  |      | 244   | ns      |
| $t_{bS}$  | SDATA set up time              |           | 50     |      |       | ns      |
| $t_{bH}$  | SDATA hold time                |           | 50     |      |       | ns      |

**Note 1:** Speaker over-current protection is only effective when speaker drivers are properly connected with external LC filters. Please refer to the application circuit example for recommended LC filter configuration.

**Note 2:** Thermal dissipation is limited by package type and PCB design. The external heat-sink or system cooling method should be adopted for maximum power output.

**Note 3:** Measured with A-weighting filter.

**Note 4:** Guaranteed by design.

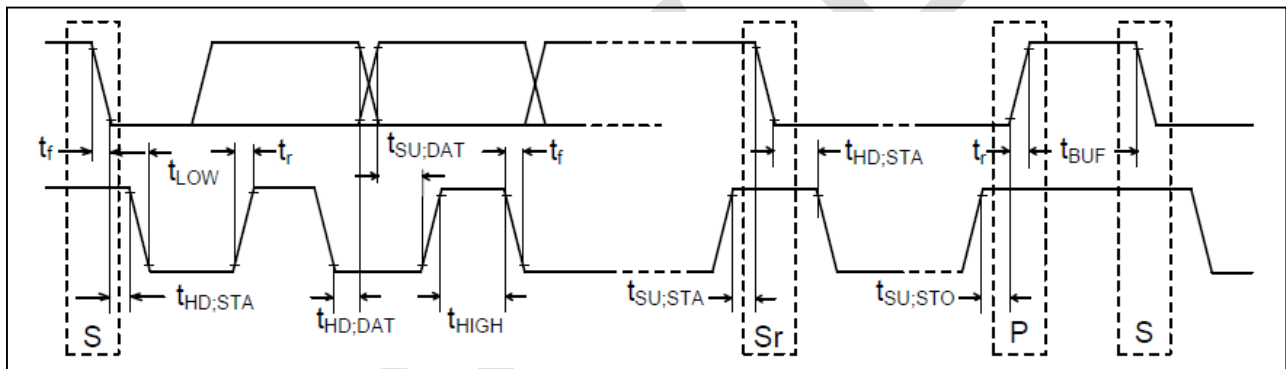


Figure 4 I2C Timing

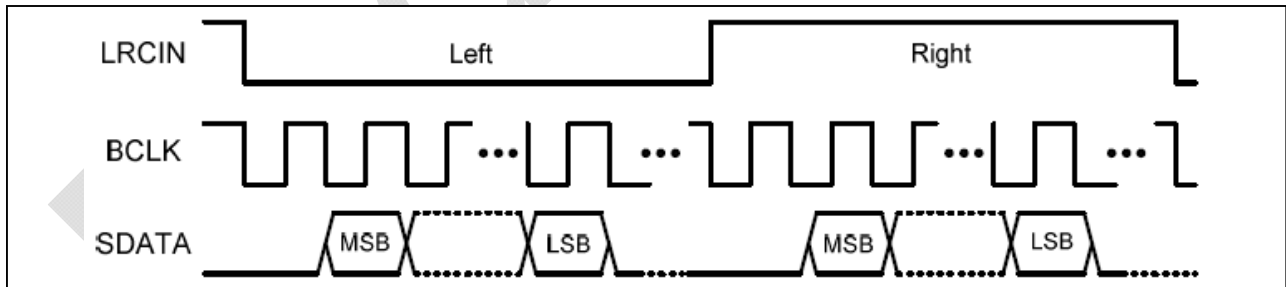


Figure 5 I2S

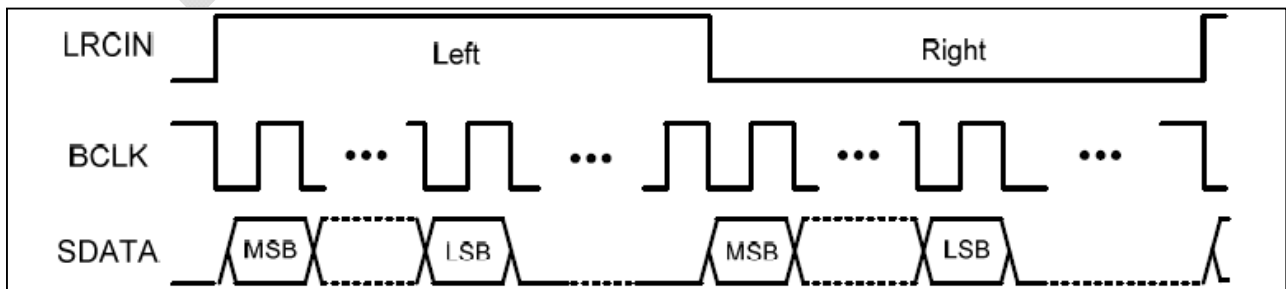


Figure 6 Left-Alignment

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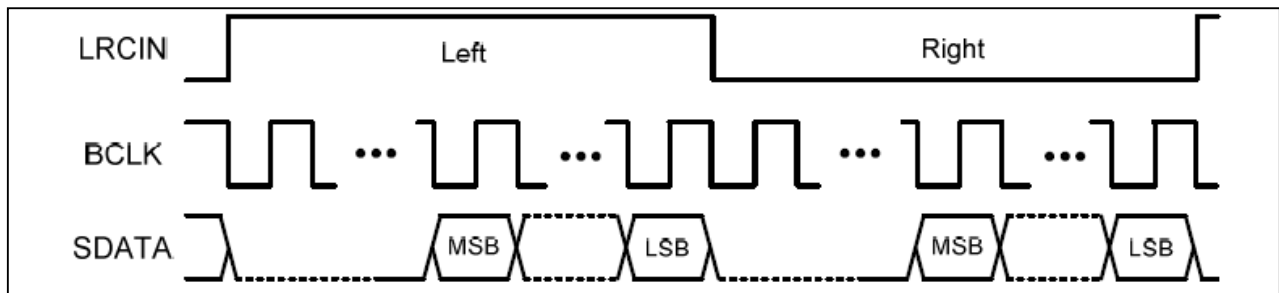


Figure 7 Right-Alignment

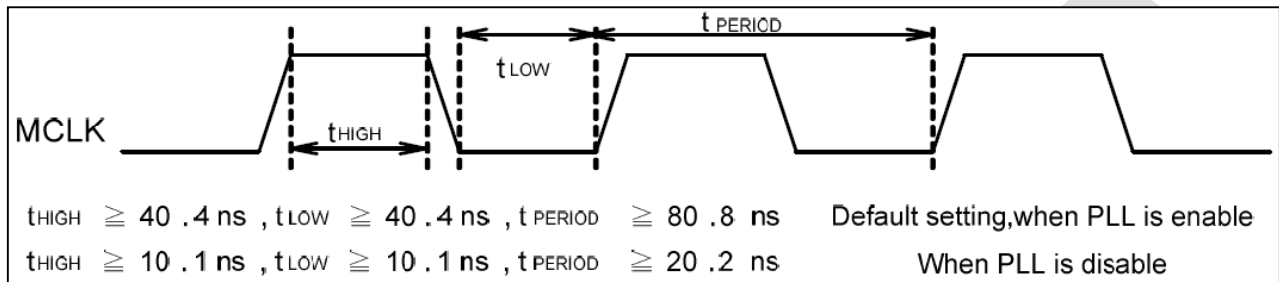


Figure 8 System Clock Timing

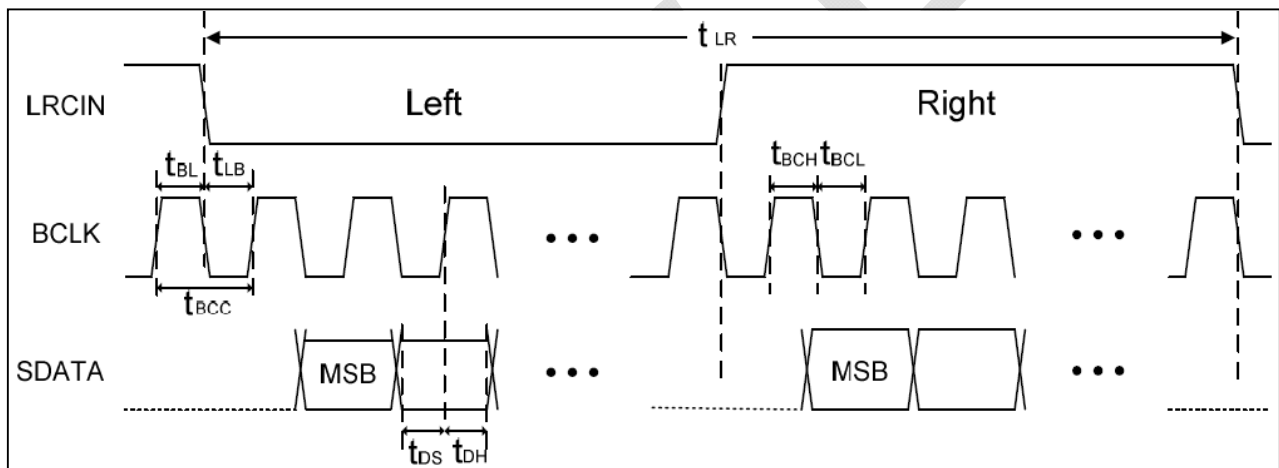


Figure 9 Timing Relationship (Using I2S format as an example)

## TYPICAL PERFORMANCE CHARACTERISTICS

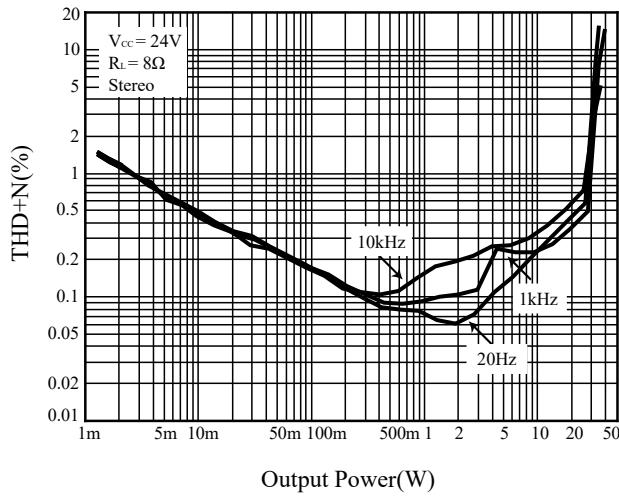


Figure 10 THD+N vs. Output Power

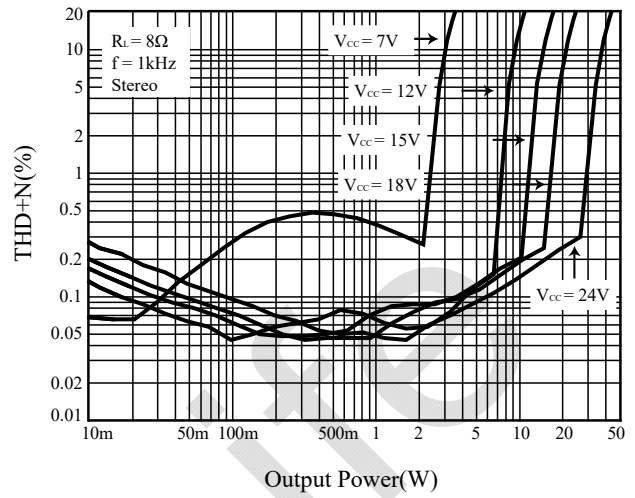


Figure 11 THD+N vs. Output Power

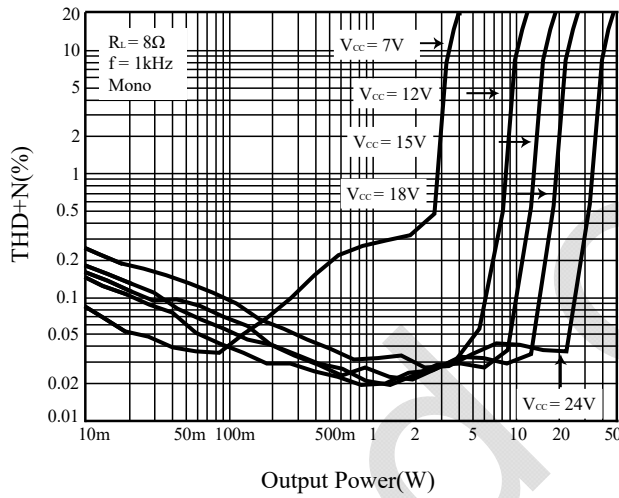


Figure 12 THD+N vs. Output Power

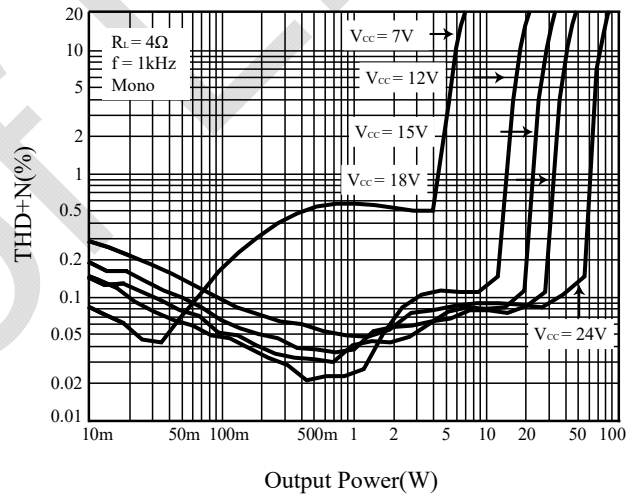


Figure 13 THD+N vs. Output Power

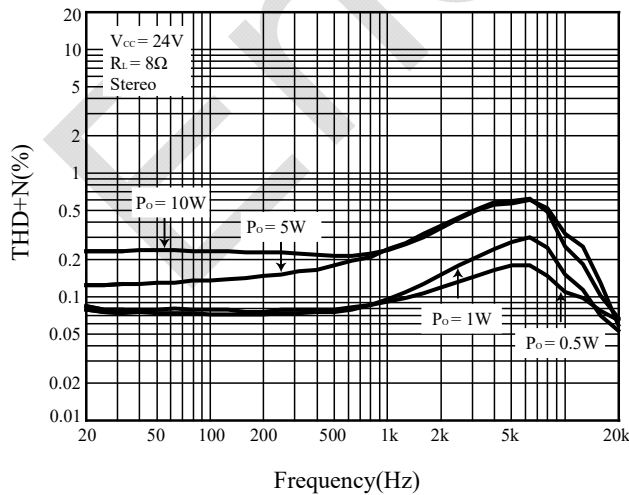


Figure 14 THD+N vs. Frequency

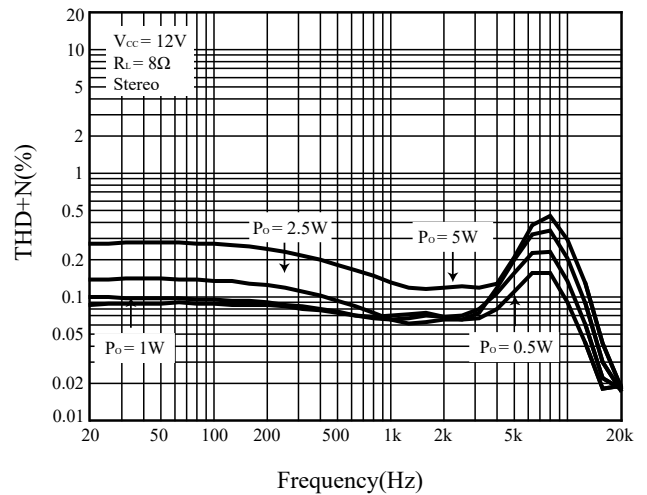
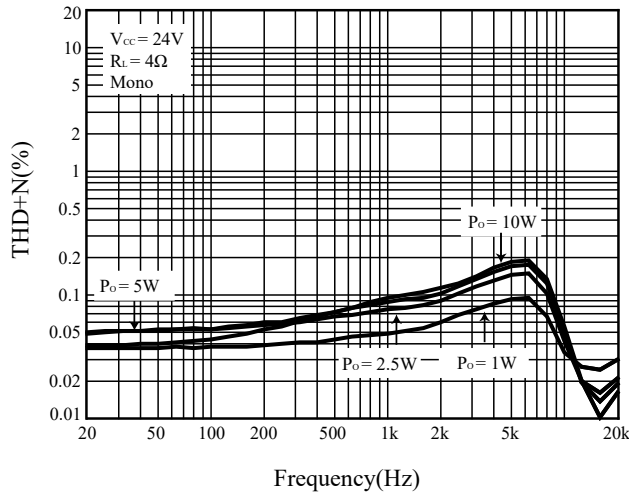
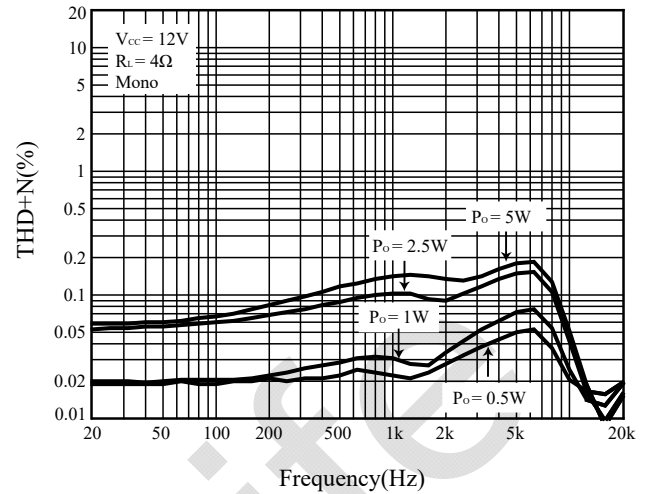


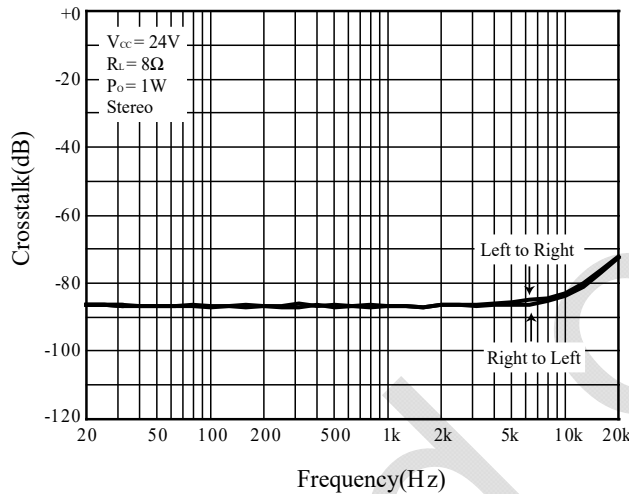
Figure 15 THD+N vs. Frequency



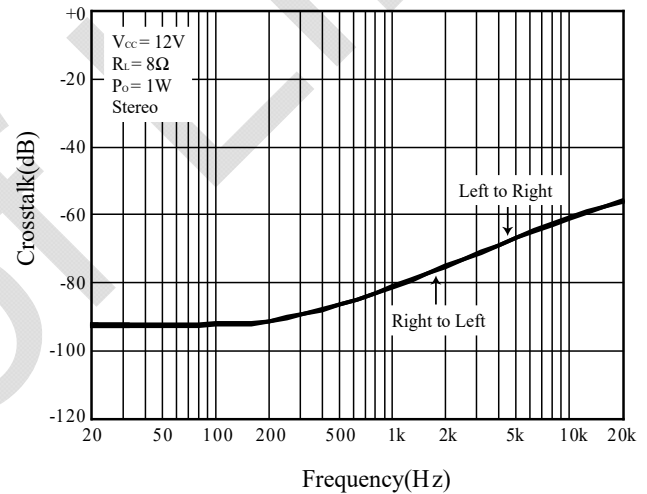
**Figure 16** THD+N vs. Frequency



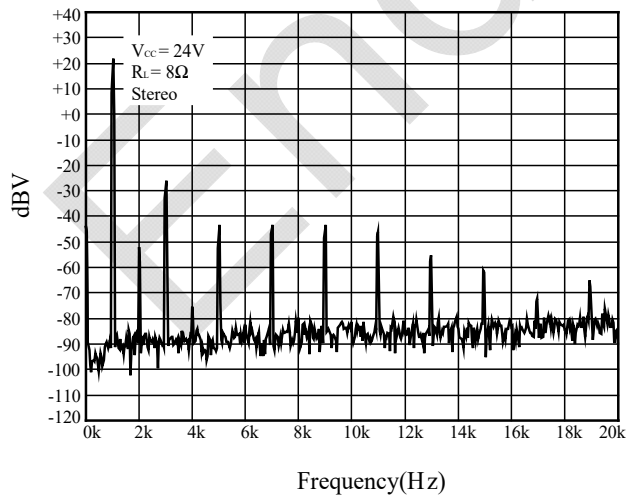
**Figure 17** THD+N vs. Frequency



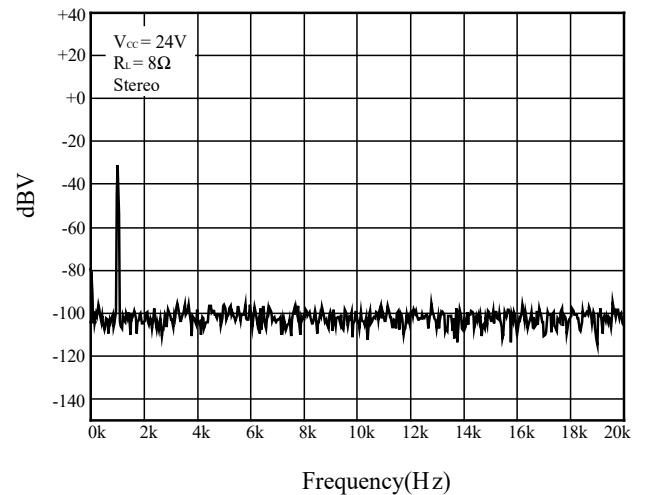
**Figure 18** Cross-Talk



**Figure 19** Cross-Talk

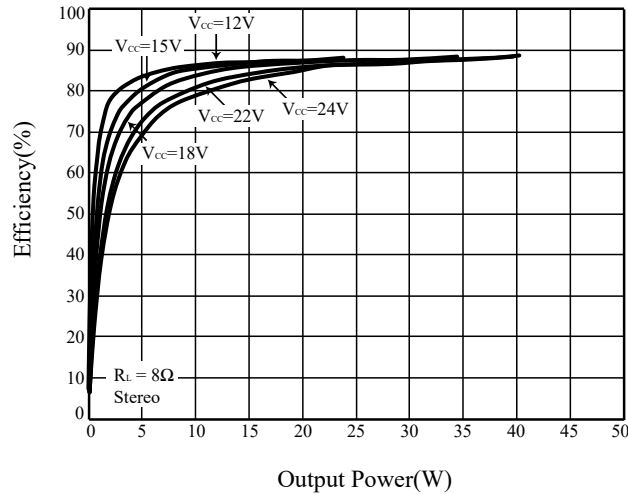


**Figure 20** Spectrum at Peak SNR at -1dB Signal Input

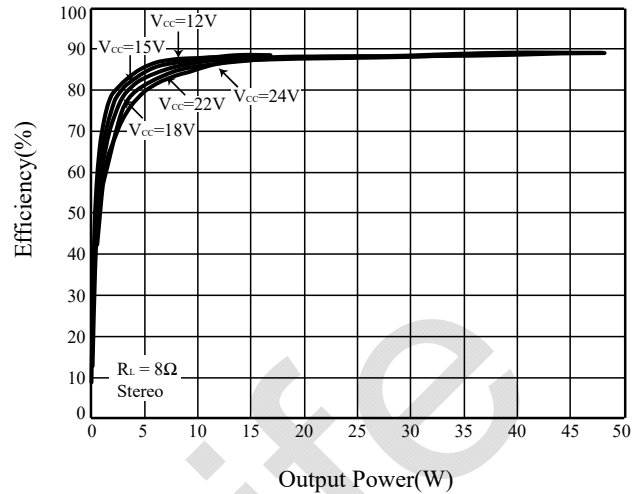


**Figure 21** Spectrum at -60dB Signal Input Level

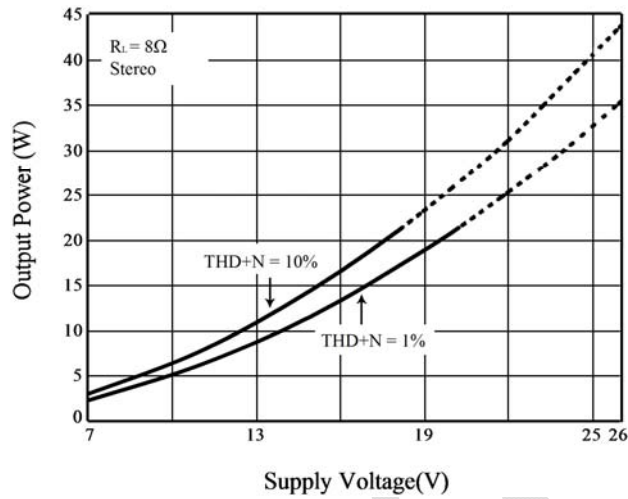
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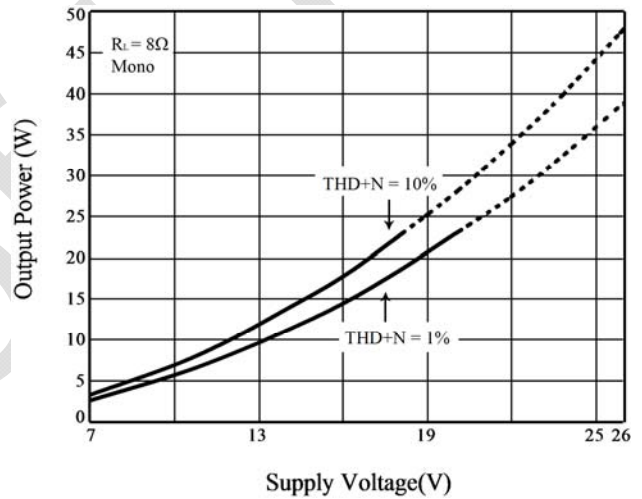
**Figure 22** Efficiency vs. Total Output Power (Without Power Saving Mode)



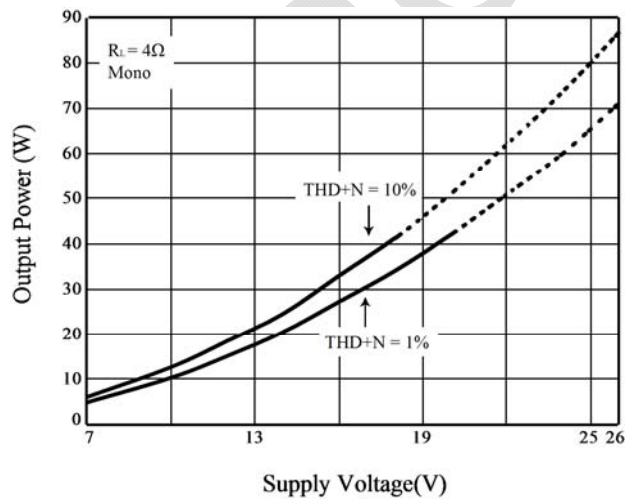
**Figure 23** Efficiency vs. Total Output Power (With Power Saving Mode)



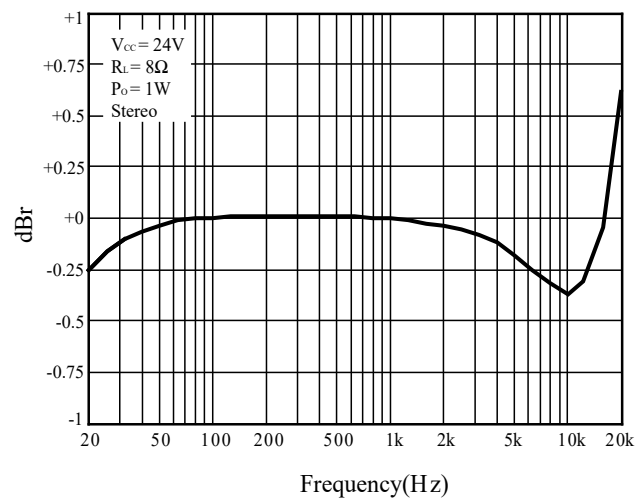
**Figure 24** Output Power vs. Supply voltage



**Figure 25** Output Power vs. Supply voltage



**Figure 26** Output Power vs. Supply voltage



**Figure 27** Frequency Response

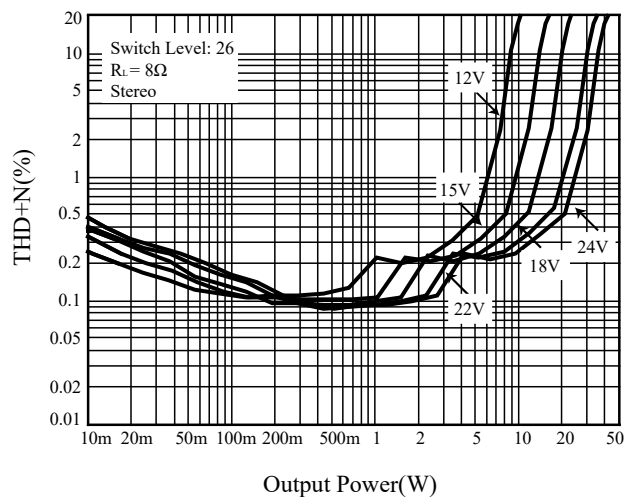
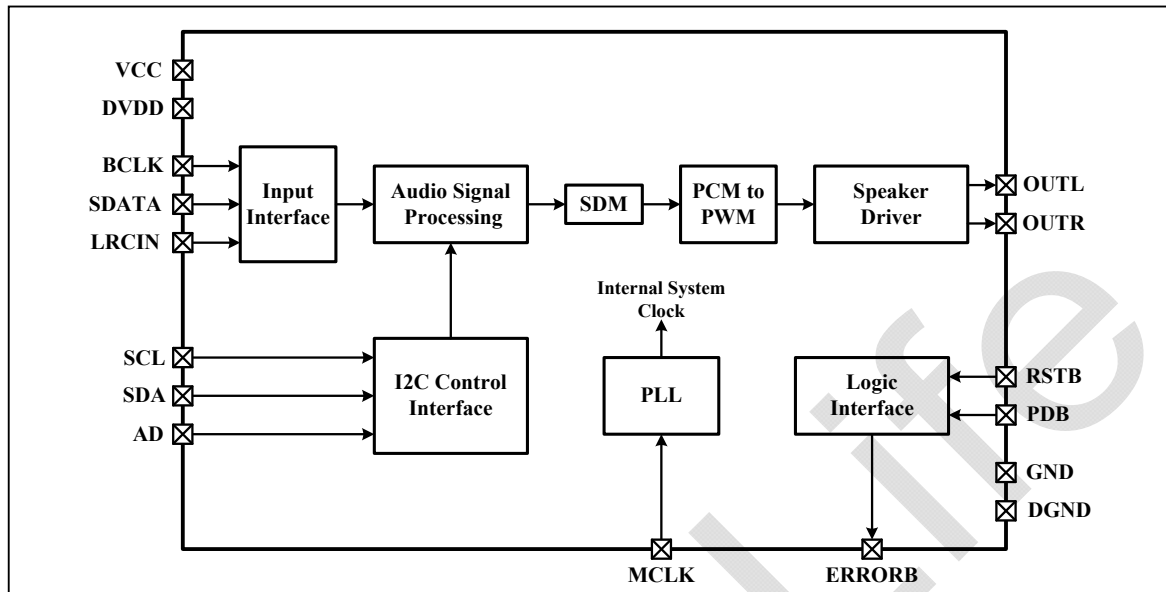


Figure 28 THD+N vs. Output Power

End of Life

## FUNCTIONAL BLOCK DIAGRAM



# IS31AP2111

## APPLICATIONS INFORMATION

### OPERATION MODES

#### Without I2C Control

The default settings, Bass, Treble, EQ, Volume, DRC are applied to register table content when using the IS31AP2111 without I2C control. For more information about default settings, please refer to the Default Column of Table 4 (Register Function).

As default state is mute, customers should send a de-mute command via I2C to enable the system.

#### With I2C Control

When using I2C control, user can program suitable parameters into the IS31AP2111 to enable or enhance specific operation features. Please refer to the register table section (Table 5 ~ Table 25) to get the more detail.

#### INTERNAL PLL

The IS31AP2111 has an integrated PLL to derive a synchronized internal clock (Fs) from the master clock (MCLK) input.

| F <sub>s</sub> | MCLK/FS Setting Ratio for PLL | MCLK Frequency | Multiple Edge Evaluation for Master Clock | PWM Career Frequency |
|----------------|-------------------------------|----------------|---|----------------------|
| 48kHz          | 256x                          | 12.288MHz      | 4x  | 384kHz               |
| 44.1kHz        | 256x                          | 11.289MHz      | 4x  | 352.8kHz             |
| 32kHz          | 256x                          | 8.192MHz       | 4x  | 256kHz               |

#### DEFAULT VOLUME

The default volume level of the IS31AP2111 is +2.0dB, and the default state is muted. Please give a de-mute command via I2C to enable the volume when the whole system is stable. For more detailed information, please refer to the register table section Table 7 (State Control 3 Register).

#### RESET

When a logic LOW is applied to the RSTB pin, the IS31AP2111 will clear the stored data and reset the register table to their default values. The IS31AP2111 will exit the reset state at the 256<sup>th</sup> MCLK cycle after the RSTB pin is raised to high.

#### POWER DOWN CONTROL

The IS31AP2111 has a built-in volume fade-in/fade-out design for power down and mute function. The relative power down timing diagrams for speakers are shown in Figure 29 and 30.

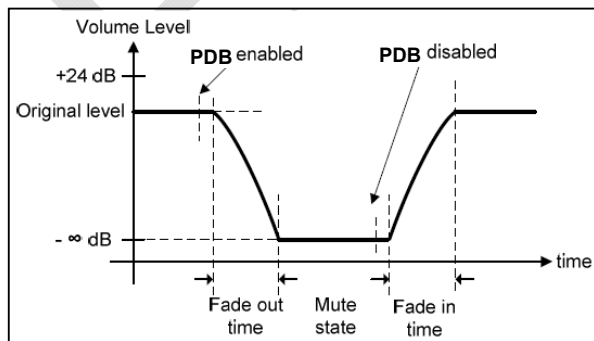


Figure 29 Power Down Timing Diagrams With Mute

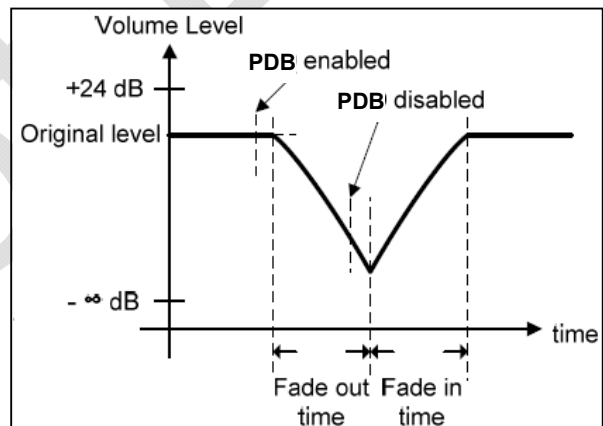


Figure 30 Power Down Timing Diagrams

$$t_{FADE} = \left| 10^{\frac{Target(dB)}{20}} - 10^{\frac{Original(dB)}{20}} \right| \times 128 \times (1/96kHz)$$

The volume level will be decreased to -∞dB in several LRCIN (Left/Right clock) cycles. Once the fade-out procedure has completed, the IS31AP2111 will turn off the power stages, stop the clock signals (MCLK, BCLK) from feeding into the digital circuit and turn off the internal analog circuit current. When PDB pin is pulled low, the IS31AP2111 requires t<sub>FADE</sub> time to finish the above procedures before entering the power down state. The IS31AP2111 will not accept programming commands while it is in the power down state. During power down, all the register table settings are kept until DVDD power is removed.

If cancel the power down function within fade-out procedure, the IC will enter into fade-in after few



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delay time (Figure 30). In addition, the IS31AP2111 will power the internal analog circuit and pass the clock signals (MCLK, BCLK) to the digital circuits. Then, the IS31AP2111 will return to its normal operation without powering down.

## SELF-PROTECTION CIRCUITS

The IS31AP2111 has built-in protection circuits including thermal, short-circuit and under-voltage detection circuits.

### Thermal Protection

When the internal junction temperature increases to greater than 158°C, the power stages will be turned off. Normal operation will begin once the device temperature cools to 125°C. The temperature values may vary by +/- 10%.

### Short-Circuit Protection

The short-circuit protection circuit protects the output stage when the speaker wires are shorted to each other or GND/VDD. During normal 24V stereo operation, the current flowing through the power stage should be less than 5.1A. If an over-temperature or short-circuit condition (current greater than 5.1A) occurs, the open-drain ERRORB pin will be pulled low and latched into ERROR state and the output stages are disabled.

Once the over-temperature or short-circuit condition is removed, the IS31AP2111 will exit the ERROR state when one of the following conditions are met: (1) RSTB pin is pulled low, (2) PDB pin is pulled low, or (3) Master mute is enabled through the I2C interface.

### Under-Voltage Protection

If the V<sub>DD</sub> voltage is lower than 2.8V, the IS31AP2111 will turn off its speaker power stages and disable the digital processing section. The IS31AP2111 will return to normal operation when the V<sub>DD</sub> supply increases above 2.9V.

### ANTI-POP DESIGN

The device generates control signals which suppresses pop sounds during initial power on/off, power down/up, mute, and volume level changes.

### 3D SURROUND SOUND

The IS31AP2111 includes virtual surround sound technology for stereo signals inputs.

### POWER ON SEQUENCE

At power up, the IS31AP2111's default volume setting is muted, so a de-mute command needs to be sent via the I2C interface once the device has completely powered up and stable.

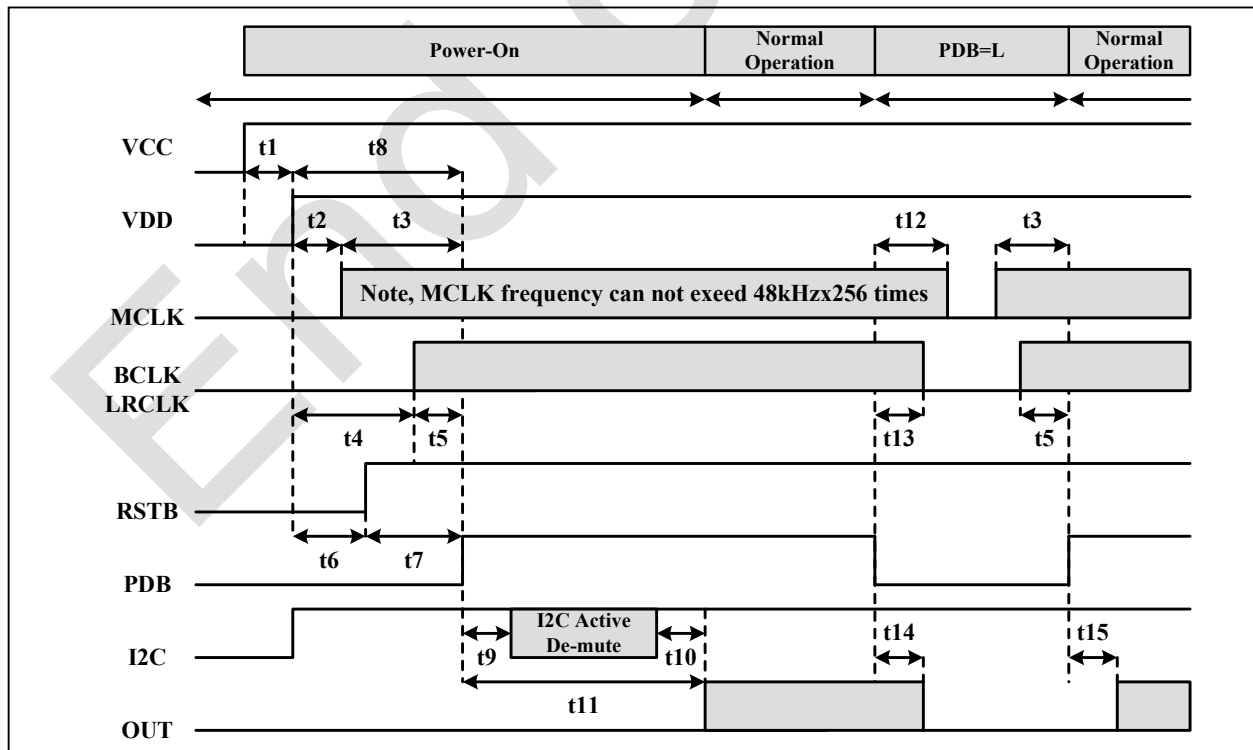


Figure 31 Power On Sequence

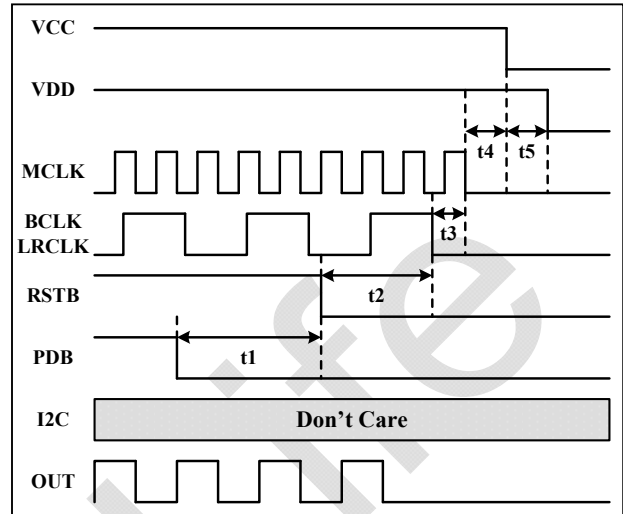
# IS31AP2111

**Table 2** Power On Sequence

| Symbol | Condition  | Min. | Max. | Unit |
|--------|------------|------|------|------|
| t1     |            | 0    | -    | ms   |
| t2     |            | 0    | -    | ms   |
| t3     |            | 10   | -    | ms   |
| t4     |            | 0    | -    | ms   |
| t5     |            | 10   | -    | ms   |
| t6     |            | 10   | -    | ms   |
| t7     |            | 0    | -    | ms   |
| t8     |            | 200  | -    | ms   |
| t9     |            | 20   | -    | ms   |
| t10    |            | -    | 0.1  | ms   |
| t11    |            | -    | 0.1  | ms   |
| t12    |            | 25   | -    | ms   |
| t13    |            | 25   | -    | ms   |
| t14    |            | -    | 22   | ms   |
| t15    | DEF=L or H | -    | 0.1  | ms   |

## POWER OFF SEQUENCE

Hereunder is IS31AP2111's power off sequence.


**Figure 32** Power Off Sequence

**Table 3** Power Off Sequence

| Symbol | Min.  |
|--------|-------|
| t1     | 35ms  |
| t2     | 0.1ms |
| t3     | 0ms   |
| t4     | 1ms   |
| t5     | 1ms   |

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## I2C-BUS TRANSFER PROTOCOL

### I2C INTERFACE

The IS31AP2111 uses a serial bus, which conforms to the I2C protocol, to control the chip's functions with two wires: SCL and SDA. The IS31AP2111 has a 7-bit slave address (A7:A1), followed by the R/W bit, A0. Set A0 to "0" for a write command and set A0 to "1" for a read command. The value of bits A3 is decided by the connection of the AD pin.

The complete slave address is:

**Table 1 Slave Address (Write only):**

| Bit   | A7:A4 | A3 | A2:A1 | A0  |
|-------|-------|----|-------|-----|
| Value | 0110  | AD | 00    | 0/1 |

AD connected to GND, AD = 0;

AD connected to VCC, AD = 1;

The SCL line is uni-directional. The SDA line is bi-directional (open-collector) with a pull-up resistor (typically 4.7kΩ). The maximum clock frequency specified by the I2C standard is 400kHz. In this discussion, the master is the microcontroller and the slave is the IS31AP2111.

The timing diagram for the I2C is shown in Figure 4. The SDA is latched in on the stable high level of the SCL. When there is no interface activity, the SDA line should be held high.

The "START" signal is generated by lowering the SDA signal while the SCL signal is high. The start signal will alert all devices attached to the I2C bus to check the incoming address against their own chip address.

The 8-bit chip address is sent next, most significant bit first. Each address bit must be stable while the

SCL level is high.

After the last bit of the chip address is sent, the master checks for the IS31AP2111's acknowledge. The master releases the SDA line high (through a pull-up resistor). Then the master sends an SCL pulse. If the IS31AP2111 has received the address correctly, then it holds the SDA line low during the SCL pulse. If the SDA line is not low, then the master should send a "STOP" signal (discussed later) and abort the transfer.

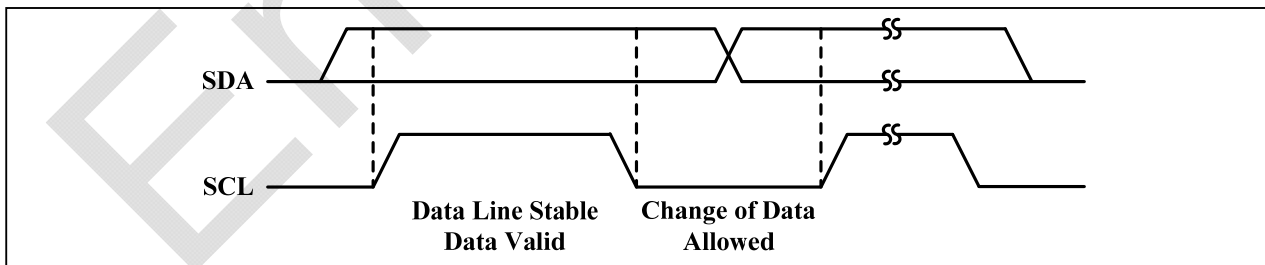
Following acknowledge of IS31AP2111, the register address byte is sent, most significant bit first. IS31AP2111 must generate another acknowledge indicating that the register address has been received.

Then 8-bit of data byte are sent next, most significant bit first. Each data bit should be valid while the SCL level is stable high. After the data byte is sent, the IS31AP2111 must generate another acknowledge to indicate that the data was received.

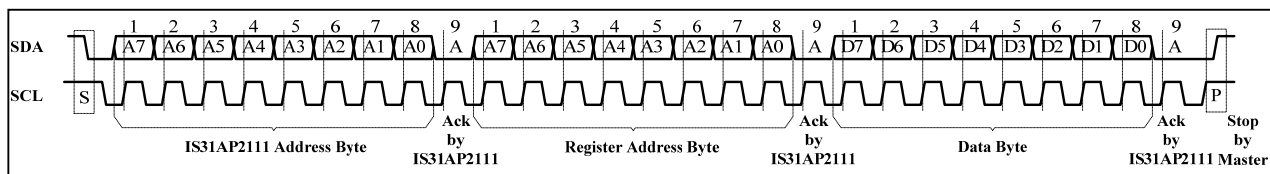
The "STOP" signal ends the transfer. To signal "STOP", the SDA signal goes high while the SCL signal is high.

### READING PORT REGISTERS

To read the device data, the bus master must first send the IS31AP2111 address with the R/W bit set to "0", followed by the command byte, which determines which register is accessed. After a restart, the bus master must then send the IS31AP2111 address with the R/W bit set to "1". Data from the register defined by the command byte is then sent from the IS31AP2111 to the master (Figure 35).



**Figure 33 Bit Transfer**



**Figure 34 Writing to IS31AP2111**



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**Table 4 Register Function**

| Address | Name                                       | Table | Default   |
|---------|--|-------|-----------|
| 00h     | State Control 1 Register                   | 5     | 000x 0000 |
| 01h     | State Control 2 Register                   | 6     | xx00 0000 |
| 02h     | State Control 3 Register                   | 7     | xxxx 111x |
| 03h     | Master Volume Control Register             | 8     | 0001 1000 |
| 04h~06h | Channel 1~3 Volume Register                | 9     | 0001 0100 |
| 07h,08h | Bass/Treble Tone Register                  | 10    | xxx1 0000 |
| 09h     | Reserved (Note)                            | -     | -         |
| 0Ah     | State Control 4 Register                   | 11    | 1001 0000 |
| 0Bh~0Ch | Channel 1~2 Configuration Register         | 12    | xxx1 0000 |
| 0Dh     | Reserved                                   | -     | -         |
| 0Eh     | DRC Limiter Attack/Release Rate Register   | 13    | 0110 1010 |
| 0Fh~10h | Reserved (Note)                            | -     | -         |
| 11h     | State Control 5 Register                   | 14    | xx11 x010 |
| 12h     | VCC Under Voltage Selection Register       | 15    | 1xxx 0001 |
| 13h     | Noise Gate Gain Register                   | 16    | xxx0 xx00 |
| 14h     | Coefficient RAM Base Address Register      | 17    | x000 0000 |
| 15h~23h | User-Defined Coefficients Register         | 18~22 | -         |
| 24h     | Coefficients Control Register              | 23    | xxxx 0000 |
| 25h~29h | Reserved (Note)                            | -     | -         |
| 2Ah     | Power Saving Mode Switching Level Register | 24    | 0000 1101 |
| 2Bh     | Volume Fine Tune Register                  | 25    | 0011 1111 |

Note: The reserved registers are not allowed to write any bits in them, or the IC will be abnormal.

**Table 5 00h State Control 1 Register**

| Bit     | D7:D5  | D4       | D3     |
|---------|--------|----------|--------|
| Name    | IF     | -        | PWML_X |
| Default | 000    | x        | 0      |
| Bit     | D2     | D1       | D0     |
| Name    | PWMR_X | LV_UVSEL | LREXC  |
| Default | 0      | 0        | 0      |

IS31AP2111 supports multiple serial data input formats including I2S, Left-alignment and Right-alignment. These formats are selected by users via D7~D5 of address 00h. The left/right channels can be exchanged to each other by programming to address 00h/D0, LREXC.

**IF** Input Format  
 000 I2S 16-24 bits  
 001 Left-alignment 16-24 bits  
 010 Right-alignment 16 bits

011 Right-alignment 18 bits  
 100 Right-alignment 20 bits  
 101 Right-alignment 24 bits  
 Others Not available

**PWML\_X** OUTLA/B exchange  
 0 No exchange  
 1 Exchange

**PWMR\_X** OUTRA/B exchange  
 0 No exchange  
 1 Exchange

**LV\_UVSEL** LV Under Voltage Selection  
 0 2.8V  
 1 3.1V

**LREXC** Left/Right Channel Exchanged  
 0 No exchange  
 1 Left/Right exchange

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**Table 6 01h State Control 2 Register**

| Bit     | D7:D6 | D5:D4 | D3:D0 |
|---------|-------|-------|-------|
| Name    | -     | FS    | PMF   |
| Default | xx    | 00    | 0000  |

IS31AP2111 has a built-in PLL and multiple MCLK/Fs ratios are supported. Detail setting is shown in the following table.

**FS** Sampling Frequency

|    |                  |
|----|------------------|
| 00 | 32/44.1/48kHz    |
| 01 | 64/88.2/96kHz    |
| 1x | 128/176.4/192kHz |

**PMF** Multiple MCLK/FS Ratio Setting

|      |  |
|------|--|
| 0000 | 1024x(FS=00)/ 512x(FS=01)/ 256x(FS=1x) |
| 0001 | 64x                                    |
| 0010 | 128x                                   |
| 0011 | 192x                                   |
| 0100 | 256x                                   |
| 0101 | 384x (Not available when FS=1x)        |
| 0110 | 512x (Not available when FS=1x)        |
| 0111 | 576x (Not available when FS=01,1x)     |
| 1000 | 768x (Not available when FS=01,1x)     |
| 1001 | 1024x (Not available when FS=01,1x)    |

Others Not available

Note: The FS × PMF should be lower than 49.152MHz, or the system will be error.

**Table 7 02h State Control 3 Register**

| Bit     | D7:D4 | D3   | D2:D1   | D0 |
|---------|-------|------|---------|----|
| Name    | -     | MUTE | CM1:CM2 | -  |
| Default | xxxx  | 1    | 11      | x  |

IS31AP2111 has mute function including master mute and channel mute. When master mute is enabled, all 2 processing channels are muted. User can mute these 2 channels individually by channel mute. When the mute function is enabled or disabled, the fade-out or fade-in process will be initiated.

**MUTE** Master Mute

|   |                       |
|---|-----------------------|
| 0 | All channel not muted |
| 1 | All channel muted     |

**CMx** Channel x Mute

|   |                     |
|---|---------------------|
| 0 | Channel x not muted |
| 1 | Channel x muted     |

**Table 8 03h Master Volume Control Register**

| Bit     | D7:D0     |
|---------|-----------|
| Name    | MV        |
| Default | 0001 1000 |

IS31AP2111 supports both master-volume (03h Register) and channel-volume control (04h, 05h and 06h Registers) modes. Both volume control settings range from +12dB ~ -103dB and 0.5dB per step. Note that the master volume control is added to the individual channel volume control as the total volume control. For example, if the master volume level is set at, Level A (in dB unit) and the channel volume level is set at Level B (in dB unit), the total volume control setting is equal to Level A plus with Level B.  $-103\text{dB} \leq \text{Total volume (Level A + Level B)} \leq +24\text{dB}$ .

**MV** Master Volume

|           |           |
|-----------|-----------|
| 0000 0000 | +12.0dB   |
| 0000 0001 | +11.5dB   |
| 0000 0010 | +11.0dB   |
| ...       |           |
| 0001 1000 | 0dB       |
| ...       |           |
| 1110 0110 | -103.0dB  |
| 1110 0111 | $-\infty$ |
| Others    | $-\infty$ |

**Table 9 04h~06h Channel 1~3 Volume Registers**

| Bit     | D7:D0     |
|---------|-----------|
| Name    | CxV       |
| Default | 0001 0100 |

**CxV** Channel x Volume

|           |           |
|-----------|-----------|
| 0000 0000 | +12.0dB   |
| 0000 0001 | +11.5dB   |
| ...       |           |
| 0001 0100 | +2dB      |
| ...       |           |
| 1110 0110 | -103.0dB  |
| 1110 0111 | $-\infty$ |
| Others    | $-\infty$ |

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**Table 10 07h/08h Bass/Treble Tone Registers**

| Bit     | D7:D5 | D6:D0   |
|---------|-------|---------|
| Name    | -     | BTC/TTC |
| Default | xxx   | 10000   |

Last two sets of EQ can be programmed as bass/treble tone boost and cut. When, 0Ah Register, D6, BTE is set to high, the EQ-7 and EQ-8 will perform as bass and treble respectively. The -3dB corner frequency of bass is 360Hz, and treble is 7kHz. The gain range for both filters is +12db ~ -12dB with 1dB per step.

|                |                          |
|----------------|--------------------------|
| <b>BTC/TTC</b> | Bass/Treble Gain Setting |
| 00000          | +12dB                    |
| ...            |                          |
| 00100          | +12dB                    |
| 00101          | +11dB                    |
| ...            |                          |
| 10000          | 0dB                      |
| 10001          | -1dB                     |
| ...            |                          |
| 111xx          | -12dB                    |

**Table 11 0Ah State Control 4 Register**

| Bit     | D7   | D6  | D5     | D4  |
|---------|------|-----|--------|-----|
| Name    | SRBP | BTE | TBDRCE | NGE |
| Default | 1    | 0   | 0      | 1   |
| Bit     | D3   | D2  | D1     | D0  |
| Name    | EQL  | PSL | DSPB   | HPB |
| Default | 0    | 0   | 0      | 0   |

The IS31AP2111 provides several DSP setting as following.

**SRBP** Surround Bypass  
 0 Surround enable  
 1 Surround bypass

**BTE** Bass/Treble Selection Bypass  
 0 Bass/treble disable  
 1 Bass/treble enable

**TBDRCE** Two Band DRC Enable  
 0 Two band DRC disable  
 1 Two band DRC enable

**NGE** Noise Gate Enable  
 0 Noise gate disable  
 1 Noise gate enable

**EQL** EQ Link  
 0 Each channel uses individual EQ  
 1 Channel-2 uses channel-1 EQ

**PSL** Post-Scale Link  
 0 Each channel uses individual post-scale  
 1 Use channel-1 post-scale

**DSPB** EQ Bypass  
 0 EQ enable  
 1 EQ bypass

**HPB** DC Blocking HPF Bypass  
 0 HPF DC enable  
 1 HPF DC bypass

**Table 12 0Bh~0Ch Channel 1~2 Configuration Registers**

| Bit     | D7:D5   | D4     | D3     |
|---------|---------|--------|--------|
| Name    | -       | CxDRCM | CxPCBP |
| Default | xxx     | 1      | 0      |
| Bit     | D2      | D1     | D0     |
| Name    | CxDRCBP | -      | CxVBP  |
| Default | 0       | x      | 0      |

The IS31AP2111 can configure each channel to enable or bypass DRC and channel volume and select the limiter set. IS31AP2111 support two mode of DRC, RMS and PEAK detection which can be selected via D4.

**CxDRCM** Channel 1/2 DRC Mode  
 0 Peak detection  
 1 RMS detection

**CxPCBP** Channel 1/2 Power Clipping Bypass  
 0 Channel 1/2 PC enable  
 1 Channel 1/2 PC bypass

**CxDRCBP** Channel 1/2 DRC Bypass  
 0 Channel 1/2 DRC enable  
 1 Channel 1/2 DRC bypass

**CxVBP** Channel 1/2 Volume Bypass  
 0 Channel 1/2's master volume operation  
 1 Channel 1/2's master volume bypass



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**Table 13 0Eh DRC Limiter Attack/Release Rate Register**

| Bit     | D7:D5 | D6:D0 |
|---------|-------|-------|
| Name    | LA    | LR    |
| Default | 0110  | 1010  |

The IS31AP2111 defines a set of limiter. The attack/release rates are defines as following table.

**LA** DRC Attack Rate

|      |             |
|------|-------------|
| 0000 | 3dB/ms      |
| 0001 | 2.667dB/ms  |
| 0010 | 2.182dB/ms  |
| 0011 | 1.846dB/ms  |
| 0100 | 1.333dB/ms  |
| 0101 | 0.889dB/ms  |
| 0110 | 0.4528dB/ms |
| 0111 | 0.2264dB/ms |
| 1000 | 0.15dB/ms   |
| 1001 | 0.1121dB/ms |
| 1010 | 0.0902dB/ms |
| 1011 | 0.0752dB/ms |
| 1100 | 0.0645dB/ms |
| 1101 | 0.0563dB/ms |
| 1110 | 0.0501dB/ms |
| 1111 | 0.0451dB/ms |

**LR** DRC Release Rate

|      |             |
|------|-------------|
| 0000 | 0.5106dB/ms |
| 0001 | 0.1371dB/ms |
| 0010 | 0.0743dB/ms |
| 0011 | 0.0499dB/ms |
| 0100 | 0.0360dB/ms |
| 0101 | 0.0299dB/ms |
| 0110 | 0.0264dB/ms |
| 0111 | 0.0208dB/ms |
| 1000 | 0.0198dB/ms |
| 1001 | 0.0172dB/ms |
| 1010 | 0.0147dB/ms |
| 1011 | 0.0137dB/ms |
| 1100 | 0.0134dB/ms |
| 1101 | 0.0117dB/ms |
| 1110 | 0.0112dB/ms |
| 1111 | 0.0104dB/ms |

**Table 14 11h State Control 5 Register**

| Bit     | D7:D6 | D5      | D4        | D3 |
|---------|-------|---------|-----------|----|
| Name    | -     | SW_RSTB | LVUV_FADE | -  |
| Default | xx    | 1       | 1         | x  |

| Bit     | D2           | D1    | D0      |
|---------|--------------|-------|---------|
| Name    | DIS_MCLK_DET | QT_EN | PWM_SEL |
| Default | 0            | 1     | 0       |

The IS31AP2111 provides several DSP setting as following.

**SW\_RSTB** Software Reset  
 0 Reset  
 1 Normal operation

**LVUV\_FADE** Low Under Voltage Fade  
 0 No fade  
 1 fade

**DIS\_MCLK\_DET** Disable MCLK Detect Circuit  
 0 Enable MCLK detect circuit  
 1 Disable MCLK detect circuit

**QT\_EN** Power Saving Mode  
 0 Disable  
 1 Enable

**PWM\_SEL** PWM Modulation  
 0 Qua-ternary  
 1 Ternary

**Table 15 12h VCC Under Voltage Selection Register**

| Bit     | D7       | D6:D4 | D3:D0    |
|---------|----------|-------|----------|
| Name    | Dis_HVUV | -     | HV_UVSEL |
| Default | 1        | xxx   | 0001     |

IS31AP2111 can disable HV under voltage detection via D7. IS31AP2111 support multi-level HV under voltage detection via D3~ D0, using this function, IS31AP2111 will fade out signal to avoid pop sounds if high voltage supply disappear before low voltage supply.

**Dis\_HVUV** Disable HV Under Voltage Selection  
 0 Enable  
 1 Disable



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|                 |                    |
|-----------------|--------------------|
| <b>HV_UVSEL</b> | UV Detection Level |
| 0000            | 8.2V               |
| 0001            | 9.7V               |
| 0011            | 13.2V              |
| 0100            | 15.5V              |
| 1100            | 19.5V              |
| Others          | 9.7V               |

**Table 16 13h Noise Gate Gain Register**

| Bit     | D7:D5 | D4          |
|---------|-------|-------------|
| Name    | -     | DIS_NG_FADE |
| Default | xxx   | 0           |
| Bit     | D3:D2 | D1:D0       |
| Name    | -     | NG_GAIN     |
| Default | xx    | 00          |

IS31AP2111 provide noise gate function if receiving 2048 signal sample points smaller than noise gate attack level. User can change noise gate gain via D1~ D0. When noise gate function occurs, input signal will multiply noise gate gain (x1/8, x1/4 x1/2, x0). User can select fade out or not via D4.

**DIS\_NG\_FADE** Disable Noise Gate Fade

|   |         |
|---|---------|
| 0 | Fade    |
| 1 | No fade |

**NG\_GAIN** Noise Gate Gain

|    |      |
|----|------|
| 00 | x1/8 |
| 01 | x1/4 |
| 10 | x1/2 |
| 11 | Mute |

**Table 17 14h Coefficient RAM Base Address Register**

| Bit     | D7 | D6:D0    |
|---------|----|----------|
| Name    | -  | CFA      |
| Default | x  | 000 0000 |

An on-chip RAM in IS31AP2111 stores user-defined EQ and mixing coefficients. The content of this coefficient RAM is indirectly accessed via coefficient registers, which consist of one base address register (14h), five sets of registers (15h ~ 23h) of three consecutive 8-bit entries for each 24-bit coefficient, and one control register (24h) to control access of the coefficients in the RAM.

**CFA** Coefficient RAM Base Address

**Table 18 15h~17h User-Defined Coefficients Registers (Top/Middle/Bottom 8-bits of coefficients A1)**

| Bit     | D7:D0 |
|---------|-------|
| Name    | C1B   |
| Default | -     |

**Table 19 18h~1Ah User-Defined Coefficients Registers (Top/Middle/Bottom 8-bits of coefficients A2)**

| Bit     | D7:D0 |
|---------|-------|
| Name    | C2B   |
| Default | -     |

**Table 20 1Bh~1Dh User-Defined Coefficients Registers (Top/Middle/Bottom 8-bits of coefficients A1)**

| Bit     | D7:D0 |
|---------|-------|
| Name    | C3B   |
| Default | -     |

**Table 21 1Eh~20h User-Defined Coefficients Registers (Top/Middle/Bottom 8-bits of coefficients B2)**

| Bit     | D7:D0 |
|---------|-------|
| Name    | C4B   |
| Default | -     |

**Table 22 21h~23h User-Defined Coefficients Registers (Top/Middle/Bottom 8-bits of coefficients A0)**

| Bit     | D7:D0 |
|---------|-------|
| Name    | C5B   |
| Default | -     |

**Table 23 24h Coefficients Control Register**

| Bit     | D7:D4 | D3 | D2 | D1 | D0 |
|---------|-------|----|----|----|----|
| Name    | -     | RA | R1 | WA | W1 |
| Default | xxxx  | 0  | 0  | 0  | 0  |

**RA** Enable Of Reading A Set Of Coefficients From RAM

|   |               |
|---|---------------|
| 0 | Read complete |
| 1 | Read enable   |

**R1** Enable Of Reading A Single Coefficients From RAM

|   |               |
|---|---------------|
| 0 | Read complete |
| 1 | Read enable   |

# IS31AP2111

**WA** Enable Of Writing A Set Of Coefficients To RAM  
 0 Write complete  
 1 Write enable

**W1** Enable Of Writing A Single Coefficient To RAM  
 0 Write complete  
 1 Write enable

**Table 24 2Ah Power Saving Mode Switching Level Register**

| Bit     | D7:D5        | D4:D0       |
|---------|--------------|-------------|
| Name    | QT_SW_WINDOW | QT_SW_LEVEL |
| Default | 000          | 01101       |

If the PWM exceeds the programmed switching power level (default 26×40ns), the modulation algorithm will change from quaternary into power saving mode. It results in higher power efficiency during larger power output operations. If the PWM drops below the programmed switching power level - power saving mode hysteresis window, the modulation algorithm will change back to quaternary modulation.

**QT\_SW\_WINDOW** Power Saving Mode Hysteresis Window

|     |   |
|-----|---|
| 000 | 2 |
| 001 | 3 |
| 010 | 4 |
| 011 | 5 |
| 100 | 6 |
| 101 | 7 |
| 110 | 8 |
| 111 | 9 |

**QT\_SW\_LEVEL** Switching Level

|       |    |
|-------|----|
| 00000 | 4  |
| 00001 | 4  |
| 00010 | 6  |
| ...   |    |
| 01101 | 26 |
| ...   |    |
| 11111 | 62 |

**Table 25 2Bh Volume Fine Tune Register**

| Bit     | D7:D6 | D5:D4  | D3:D2  | D1:D0 |
|---------|-------|--------|--------|-------|
| Name    | MV_FT | C1V_FT | C2V_FT | -     |
| Default | 00    | 11     | 11     | 11    |

IS31AP2111 supports both master-volume fine tune and channel-volume control fine tune modes. Both volume control settings range from 0dB ~ -0.375dB

and 0.125dB per step. Note that the master volume fine tune is added to the individual channel volume fine tune as the total volume fine tune.

**MV\_FT** Master Volume Fine Tune

|    |          |
|----|----------|
| 00 | 0dB      |
| 01 | -0.125dB |
| 10 | -0.25dB  |
| 11 | -0.375dB |

**C1V\_FT** Channel 1 Volume Fine Tune

|    |          |
|----|----------|
| 00 | 0dB      |
| 01 | -0.125dB |
| 10 | -0.25dB  |
| 11 | -0.375dB |

**C2V\_FT** Channel 2 Volume Fine Tune

|    |          |
|----|----------|
| 00 | 0dB      |
| 01 | -0.125dB |
| 10 | -0.25dB  |
| 11 | -0.375dB |

## RAM ACCESS

The procedure to read/write coefficient(s) from/to RAM is as followings:

### Read A Single Coefficient From RAM:

1. Write 7-bit of address to I2C address-0X14
2. Write 1 to R1 bit in address-0X24
3. Read top 8-bits of coefficient in I2C address-0X15
4. Read middle 8-bits of coefficient in I2C address-0X16
5. Read bottom 8-bits of coefficient in I2C address-0X17

### Read A Set Of Coefficients From RAM:

1. Write 7-bits of address to I2C address-0X14
2. Write 1 to RA bit in address-0X24
3. Read top 8-bits of coefficient A1 in I2C address-0X15
4. Read middle 8-bits of coefficient A1 in I2C address-0X16
5. Read bottom 8-bits of coefficient A1 in I2C address-0X17
6. Read top 8-bits of coefficient A2 in I2C address-0X18
7. Read middle 8-bits of coefficient A2 in I2C address-0X19
8. Read bottom 8-bits of coefficient A2 in I2C address-0X1A
9. Read top 8-bits of coefficient B1 in I2C address-0X1B
10. Read middle 8-bits of coefficient B1 in I2C address-0X1C

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11. Read bottom 8-bits of coefficient B1 in I2C address-0X1D
12. Read top 8-bits of coefficient B2 in I2C address-0X1E
13. Read middle 8-bits of coefficient B2 in I2C address-0X1F
14. Read bottom 8-bits of coefficient B2 in I2C address-0X20
15. Read top 8-bits of coefficient A0 in I2C address-0X21
16. Read middle 8-bits of coefficient A0 in I2C address-0X22
17. Read bottom 8-bits of coefficient A0 in I2C address-0X23

## Write A Single Coefficient From RAM:

1. Write 7-bits of address to I2C address-0X14
2. Write top 8-bits of coefficient in I2C address-0X15
3. Write middle 8-bits of coefficient in I2C address-0X16
4. Write bottom 8-bits of coefficient in I2C address-0X17
5. Write 1 to W1 bit in address-0X24

## Write A Set Of Coefficients From RAM:

1. Write 7-bits of address to I2C address-0X14
2. Write top 8-bits of coefficient A1 in I2C address-0X15
3. Write middle 8-bits of coefficient A1 in I2C address-0X16
4. Write bottom 8-bits of coefficient A1 in I2C address-0X17
5. Write top 8-bits of coefficient A2 in I2C address-0X18
6. Write middle 8-bits of coefficient A2 in I2C address-0X19
7. Write bottom 8-bits of coefficient A2 in I2C address-0X1A
8. Write top 8-bits of coefficient B1 in I2C address-0X1B
9. Write middle 8-bits of coefficient B1 in I2C address-0X1C
10. Write bottom 8-bits of coefficient B1 in I2C address-0X1D
11. Write top 8-bits of coefficient B2 in I2C address-0X1E
12. Write middle 8-bits of coefficient B2 in I2C address-0X1F
13. Write bottom 8-bits of coefficient B2 in I2C address-0X20
14. Write top 8-bits of coefficient A0 in I2C address-0X21
15. Write middle 8-bits of coefficient A0 in I2C address-0X22
16. Write bottom 8-bits of coefficient A0 in I2C address-0X23
17. Write 1 to WA bit in address-0X24

Note: the read and write operation on RAM coefficients works only if LRCIN (Pin 15) switching on rising edge. And, before each writing operation, it is necessary to read the address-0X24 to confirm whether RAM is writable current in first. If the logic of W1 or WA is high, the coefficient writing is prohibited.

## USER-DEFINED EQUALIZER

The IS31AP2111 provides 20 parametric Equalizer (EQ). Users can program suitable coefficients via I2C control interface to program the required audio band frequency response for every EQ. The transfer function

$$H(z) = \frac{A_0 + A_1z^{-1} + A_2z^{-2}}{1 + B_1z^{-1} + B_2z^{-2}}$$

The data format of 2's complement binary code for EQ coefficient is 3.21. i.e., 3-bits for integer (MSB is the sign bit) and 21-bits for mantissa. Each coefficient range is from 0x800000 (-4) to 0x7FFFFFFF (+3.999999523). These coefficients are stored in User Defined RAM and are referenced in following manner:

CHxEQyA0=A0

CHxEQyA1=A1

CHxEQyA2=A2

CHxEQyB1=-B1

CHxEQyB2=-B2

Where x and y represents the number of channel and the band number of EQ equalizer.

All user-defined filters are path-through, where all coefficients are defaulted to 0 after being powered up, except the A0 that is set to 0x200000 which represents 1.

## MIXER

The IS31AP2111 provides mixers to generate the extra audio source from the input left and right channels. The coefficients of mixers are defined in range from 0x800000 (-1) to 0x7FFFFFFF (0.9999998808). The function block diagram is as following figure:

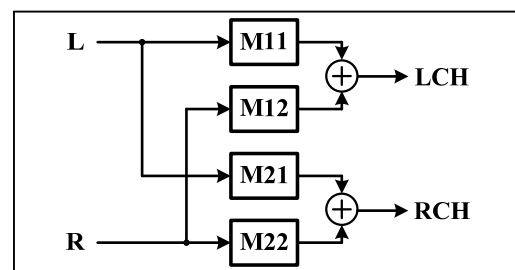


Figure 36 Mixer Function Block Diagram

# IS31AP2111

## PRE-SCALE

For each audio channel, IS31AP2111 can scale input signal level prior to EQ processing which is realized by a 24-bit signed fractional multiplier. The pre-scale factor, ranging from -1 (0x800000) to 0.9999998808 (0x7FFFFF), for this multiplier, can be loaded into RAM. The default values of the pre-scaling factors are set to 0x7FFFFF. Programming of RAM is described in RAM access.

## POST-SCALE

The IS31AP2111 provides an additional multiplication after equalizing and before interpolation stage, which is realized by a 24-bit signed fractional multiplier. The post-scaling factor, ranging from -1 (0x800000) to 0.9999998808 (0x7FFFFF), for this multiplier, can be loaded into RAM. The default values of the post-scaling factors are set to 0x7FFFFF. All channels can use the channel-1 post-scale factor by setting the post-scale link. Programming of RAM is described in RAM access.

## POWER CLIPPING

The IS31AP2111 provides power clipping function to avoid excessive signal that may destroy loud speaker. The power clipping level is defined by 24-bit representation and is stored in RAM address 0X6F. The following table shows the power clipping level's numerical representation.

**Table 26** Sample Calculation For Power Clipping

| Max. Amplitude        | dB | Linear            | Decimal                | Hex (3.21 Format)       |
|-----------------------|----|-------------------|------------------------|-------------------------|
| $V_{cc}$              | 0  | 1                 | 2097152                | 200000                  |
| $V_{cc} \times 0.707$ | -3 | 0.707             | 1484574                | 16A71E                  |
| $V_{cc} \times 0.5$   | -6 | 0.5               | 1048576                | 100000                  |
| $V_{cc} \times L$     | x  | $L = 10^{(x/20)}$ | $D = 2097152 \times L$ | $H = \text{dec2hex}(D)$ |

## ATTACK THRESHOLD FOR DYNAMIC RANGE CONTROL (DRC)

The IS31AP2111 provides dynamic range control (DRC) function. When the input exceeds the programmable attack threshold value, the output power will be limited by this threshold power level via gradual gain reduction. Attack threshold is defined by 24-bit representation and is stored in RAM address 0X71 and 0X72.

## RELEASE THRESHOLD FOR DYNAMIC RANGE CONTROL (DRC)

After IS31AP2111 has reached the attack threshold, its output power will be limited to that level. The output power level will be gradually adjusted to the programmable release threshold level. Release threshold is defined by 24-bit representation and is stored in RAM address 0X73 and 0X74. The following table shows the attack and release threshold's numerical representation.

**Table 27** Sample Calculation For Attack And Release Threshold

| Power                   | dB | Linear            | Decimal                | Hex (3.21 Format)       |
|-------------------------|----|-------------------|------------------------|-------------------------|
| $(V_{cc}^2)/R$          | 0  | 1                 | 2097152                | 200000                  |
| $(V_{cc}^2)/2R$         | -3 | 0.5               | 1048576                | 100000                  |
| $(V_{cc}^2)/4R$         | -6 | 0.25              | 524288                 | 80000                   |
| $(V_{cc}^2)/R \times L$ | x  | $L = 10^{(x/10)}$ | $D = 2097152 \times L$ | $H = \text{dec2hex}(D)$ |

To best illustrate the dynamic range control, please refer to the following figure.

# IS31AP2111

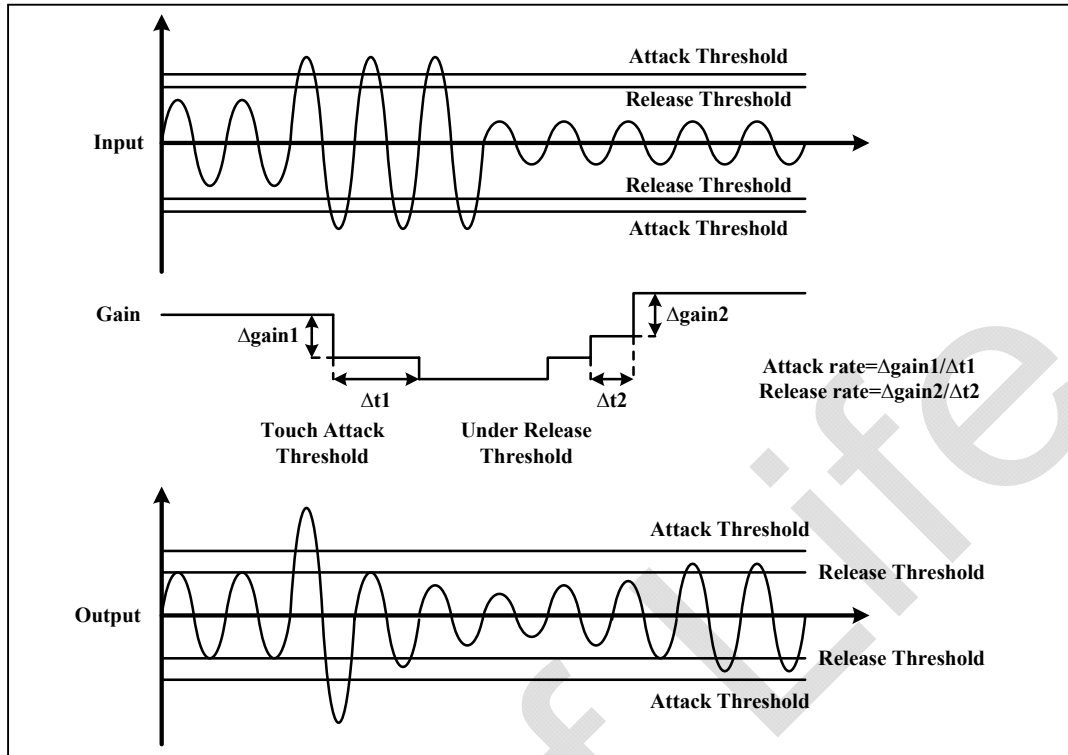


Figure 37 Attack And Release Threshold

## NOISE GATE ATTACK LEVEL

When both left and right signals have 2048 consecutive sample points less than the programmable noise gate attack level, the audio signal will multiply noise gate gain, which can be set at  $x/8$ ,  $x/4$ ,  $x/2$ , or zero if the noise gate function is enabled. Noise gate attack level is defined by 24-bit representation and is stored in RAM address 0X75.

## NOISE GATE RELEASE LEVEL

After entering the noise gating status, the noise gain will be removed whenever IS31AP2111 receives any input signal that is more than the noise gate release level. Noise gate release level is defined by 24-bit representation and is stored in RAM address 0X76. The following table shows the noise gate attack and release threshold level's numerical representation.

**Table 28** Sample Calculation For Noise Gate Attack And Release Level

| Input Amplitude | Linear            | Decimal                | Hex (1.23 Format)       |
|-----------------|-------------------|------------------------|-------------------------|
| 0dB             | 1                 | 8388607                | 7FFFFFF                 |
| -100dB          | $10^{-5}$         | 83                     | 53                      |
| -110dB          | $10^{-5.5}$       | 26                     | 1A                      |
| xdB             | $L = 10^{(x/20)}$ | $D = 2097152 \times L$ | $H = \text{dec2hex}(D)$ |

## DRC ENERGY COEFFICIENT

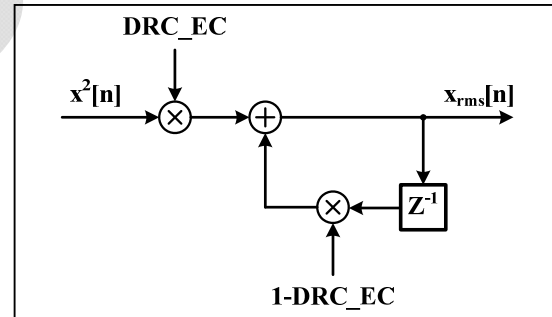


Figure 38 Digital Processing Of Calculating RMS Signal Power

The above figure illustrates the digital processing of calculating RMS signal power. In this processing, a DRC energy coefficient is required, which can be programmed for different frequency range. Energy coefficient is defined by 24-bit representation and is stored in RAM address 0X77 and 0X78. The following table shows the DRC energy coefficient numerical representation.

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**Table 29** Sample Calculation For DRC Energy Coefficient

| DRC Energy Coefficient | dB    | Linear            | Decimal                | Hex (1.23 Format)       |
|------------------------|-------|-------------------|------------------------|-------------------------|
| 1                      | 0     | 1                 | 8388607                | 7FFFFFF                 |
| 1/256                  | -48.2 | 1/256             | 524288                 | 80000                   |
| 1/1024                 | -60.2 | 1/1024            | 131072                 | 20000                   |
| L                      | x     | $L = 10^{(x/20)}$ | $D = 2097152 \times L$ | $H = \text{dec2hex}(D)$ |

End of Life

# IS31AP2111

## THE USER DEFINED RAM

The contents of user defined RAM is represented in following table.

**Table 30** User Defined RAM

| Address | Name             | Coefficient | Default  | Address | Name             | Coefficient | Default  |
|---------|------------------|-------------|----------|---------|------------------|-------------|----------|
| 0x00    | Channel 1<br>EQ1 | CH1EQ1A1    | 0x000000 | 0x32    | Channel 2<br>EQ1 | CH2EQ1A1    | 0x000000 |
| 0x01    |                  | CH1EQ1A2    | 0x000000 | 0x33    |                  | CH2EQ1A2    | 0x000000 |
| 0x02    |                  | CH1EQ1B1    | 0x000000 | 0x34    |                  | CH2EQ1B1    | 0x000000 |
| 0x03    |                  | CH1EQ1B2    | 0x000000 | 0x35    |                  | CH2EQ1B2    | 0x000000 |
| 0x04    |                  | CH1EQ1A0    | 0x200000 | 0x36    |                  | CH2EQ1A0    | 0x200000 |
| 0x05    | Channel 1<br>EQ2 | CH1EQ2A1    | 0x000000 | 0x37    | Channel 2<br>EQ2 | CH2EQ2A1    | 0x000000 |
| 0x06    |                  | CH1EQ2A2    | 0x000000 | 0x38    |                  | CH2EQ2A2    | 0x000000 |
| 0x07    |                  | CH1EQ2B1    | 0x000000 | 0x39    |                  | CH2EQ2B1    | 0x000000 |
| 0x08    |                  | CH1EQ2B2    | 0x000000 | 0x3A    |                  | CH2EQ2B2    | 0x000000 |
| 0x09    |                  | CH1EQ2A0    | 0x200000 | 0x3B    |                  | CH2EQ2A0    | 0x200000 |
| 0x0A    | Channel 1<br>EQ3 | CH1EQ3A1    | 0x000000 | 0x3C    | Channel 2<br>EQ3 | CH2EQ3A1    | 0x000000 |
| 0x0B    |                  | CH1EQ3A2    | 0x000000 | 0x3D    |                  | CH2EQ3A2    | 0x000000 |
| 0x0C    |                  | CH1EQ3B1    | 0x000000 | 0x3E    |                  | CH2EQ3B1    | 0x000000 |
| 0x0D    |                  | CH1EQ3B2    | 0x000000 | 0x3F    |                  | CH2EQ3B2    | 0x000000 |
| 0x0E    |                  | CH1EQ3A0    | 0x200000 | 0x40    |                  | CH2EQ3A0    | 0x200000 |
| 0x0F    | Channel 1<br>EQ4 | CH1EQ4A1    | 0x000000 | 0x41    | Channel 2<br>EQ4 | CH2EQ4A1    | 0x000000 |
| 0x10    |                  | CH1EQ4A2    | 0x000000 | 0x42    |                  | CH2EQ4A2    | 0x000000 |
| 0x11    |                  | CH1EQ4B1    | 0x000000 | 0x43    |                  | CH2EQ4B1    | 0x000000 |
| 0x12    |                  | CH1EQ4B2    | 0x000000 | 0x44    |                  | CH2EQ4B2    | 0x000000 |
| 0x13    |                  | CH1EQ4A0    | 0x200000 | 0x45    |                  | CH2EQ4A0    | 0x200000 |
| 0x14    | Channel 1<br>EQ5 | CH1EQ5A1    | 0x000000 | 0x46    | Channel 2<br>EQ5 | CH2EQ5A1    | 0x000000 |
| 0x15    |                  | CH1EQ5A2    | 0x000000 | 0x47    |                  | CH2EQ5A2    | 0x000000 |
| 0x16    |                  | CH1EQ5B1    | 0x000000 | 0x48    |                  | CH2EQ5B1    | 0x000000 |
| 0x17    |                  | CH1EQ5B2    | 0x000000 | 0x49    |                  | CH2EQ5B2    | 0x000000 |
| 0x18    |                  | CH1EQ5A0    | 0x200000 | 0x4A    |                  | CH2EQ5A0    | 0x200000 |
| 0x19    | Channel 1<br>EQ6 | CH1EQ6A1    | 0x000000 | 0x4B    | Channel 2<br>EQ6 | CH2EQ6A1    | 0x000000 |
| 0x1A    |                  | CH1EQ6A2    | 0x000000 | 0x4C    |                  | CH2EQ6A2    | 0x000000 |
| 0x1B    |                  | CH1EQ6B1    | 0x000000 | 0x4D    |                  | CH2EQ6B1    | 0x000000 |
| 0x1C    |                  | CH1EQ6B2    | 0x000000 | 0x4E    |                  | CH2EQ6B2    | 0x000000 |
| 0x1D    |                  | CH1EQ6A0    | 0x200000 | 0x4F    |                  | CH2EQ6A0    | 0x200000 |



# IS31AP2111

**Table 30** User Defined RAM (Continues)

| Address | Name              | Coefficient | Default  | Address | Name              | Coefficient | Default  |
|---------|-------------------|-------------|----------|---------|-------------------|-------------|----------|
| 0x1E    | Channel 1<br>EQ7  | CH1EQ7A1    | 0x000000 | 0x50    | Channel 2<br>EQ7  | CH2EQ7A1    | 0x000000 |
| 0x1F    |                   | CH1EQ7A2    | 0x000000 | 0x51    |                   | CH2EQ7A2    | 0x000000 |
| 0x20    |                   | CH1EQ7B1    | 0x000000 | 0x52    |                   | CH2EQ7B1    | 0x000000 |
| 0x21    |                   | CH1EQ7B2    | 0x000000 | 0x53    |                   | CH2EQ7B2    | 0x000000 |
| 0x22    |                   | CH1EQ7A0    | 0x200000 | 0x54    |                   | CH2EQ7A0    | 0x200000 |
| 0x23    | Channel 1<br>EQ8  | CH1EQ8A1    | 0x000000 | 0x55    | Channel 2<br>EQ8  | CH2EQ8A1    | 0x000000 |
| 0x24    |                   | CH1EQ8A2    | 0x000000 | 0x56    |                   | CH2EQ8A2    | 0x000000 |
| 0x25    |                   | CH1EQ8B1    | 0x000000 | 0x57    |                   | CH2EQ8B1    | 0x000000 |
| 0x26    |                   | CH1EQ8B2    | 0x000000 | 0x58    |                   | CH2EQ8B2    | 0x000000 |
| 0x27    |                   | CH1EQ8A0    | 0x200000 | 0x59    |                   | CH2EQ8A0    | 0x200000 |
| 0x28    | Channel 1<br>EQ9  | CH1EQ9A1    | 0x000000 | 0x5A    | Channel 2<br>EQ9  | CH2EQ9A1    | 0x000000 |
| 0x29    |                   | CH1EQ9A2    | 0x000000 | 0x5B    |                   | CH2EQ9A2    | 0x000000 |
| 0x2A    |                   | CH1EQ9B1    | 0x000000 | 0x5C    |                   | CH2EQ9B1    | 0x000000 |
| 0x2B    |                   | CH1EQ9B2    | 0x000000 | 0x5D    |                   | CH2EQ9B2    | 0x000000 |
| 0x2C    |                   | CH1EQ9A0    | 0x200000 | 0x5E    |                   | CH2EQ9A0    | 0x200000 |
| 0x2D    | Channel 1<br>EQ10 | CH3EQ1A1    | 0x000000 | 0x5F    | Channel 2<br>EQ10 | CH3EQ2A1    | 0x000000 |
| 0x2E    |                   | CH3EQ1A2    | 0x000000 | 0x60    |                   | CH3EQ2A2    | 0x000000 |
| 0x2F    |                   | CH3EQ1B1    | 0x000000 | 0x61    |                   | CH3EQ2B1    | 0x000000 |
| 0x30    |                   | CH3EQ1B2    | 0x000000 | 0x62    |                   | CH3EQ2B2    | 0x000000 |
| 0x31    |                   | CH3EQ1A0    | 0x200000 | 0x63    |                   | CH3EQ2A0    | 0x200000 |



# IS31AP2111

**Table 30** User Defined RAM (Continues)

| Address   | Name                        | Coefficient | Default   |
|-----------|-----------------------------|-------------|-----------|
| 0x64      | Channel 1 Mixer1            | M11         | 0x7FFFFFF |
| 0x65      | Channel 1 Mixer2            | M12         | 0x000000  |
| 0x66      | Channel 2 Mixer1            | M21         | 0x000000  |
| 0x67      | Channel 2 Mixer2            | M22         | 0x7FFFFFF |
| 0x68~0x69 | Reserve                     | Reserve     | -         |
| 0x6A      | Channel 1 Prescale          | C1PRS       | 0x7FFFFFF |
| 0x6B      | Channel 2 Prescale          | C2PRS       | 0x7FFFFFF |
| 0x6C      | Channel 1 Postscale         | C1POS       | 0x7FFFFFF |
| 0x6D      | Channel 2 Postscale         | C2POS       | 0x7FFFFFF |
| 0x6E      | Reserve                     | Reserve     | -         |
| 0x6F      | CH1.2 Power Clipping        | PC1         | 0x200000  |
| 0x70      | Reserve                     | Reserve     | -         |
| 0x71      | CH1.2 DRC Attack Threshold  | DRC1_ATH    | 0x200000  |
| 0x72      | CH1.2 DRC Release Threshold | DRC1_RTH    | 0x80000   |
| 0x73      | CH3 DRC Attack Threshold    | DRC2_ATH    | 0x200000  |
| 0x74      | CH3 DRC Release Threshold   | DRC2_RTH    | 0x80000   |
| 0x75      | Noise Gate Attack Level     | NGAL        | 0x0001A   |
| 0x76      | Noise Gate Release Level    | NGRL        | 0x000053  |
| 0x77      | DRC1 Energy Coefficient     | DRC1_EC     | 0x8000    |
| 0x78      | DRC2 Energy Coefficient     | DRC2_EC     | 0x2000    |

# IS31AP2111

## CLASSIFICATION REFLOW PROFILES

| Profile Feature   | Pb-Free Assembly                 |
|---|----------------------------------|
| <b>Preheat &amp; Soak</b><br>Temperature min (T <sub>smin</sub> )<br>Temperature max (T <sub>smax</sub> )<br>Time (T <sub>smin</sub> to T <sub>smax</sub> ) (t <sub>s</sub> ) | 150°C<br>200°C<br>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> )<br>Time at liquidous (t <sub>L</sub> )  | 217°C<br>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.                   |

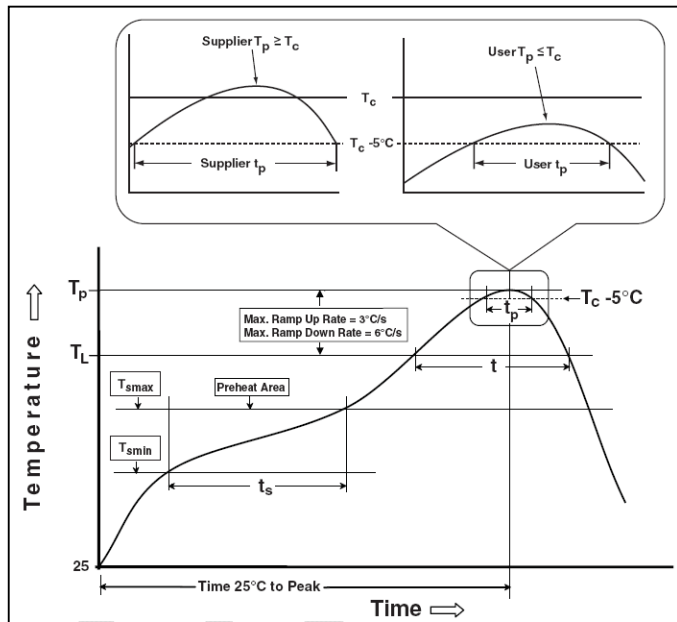
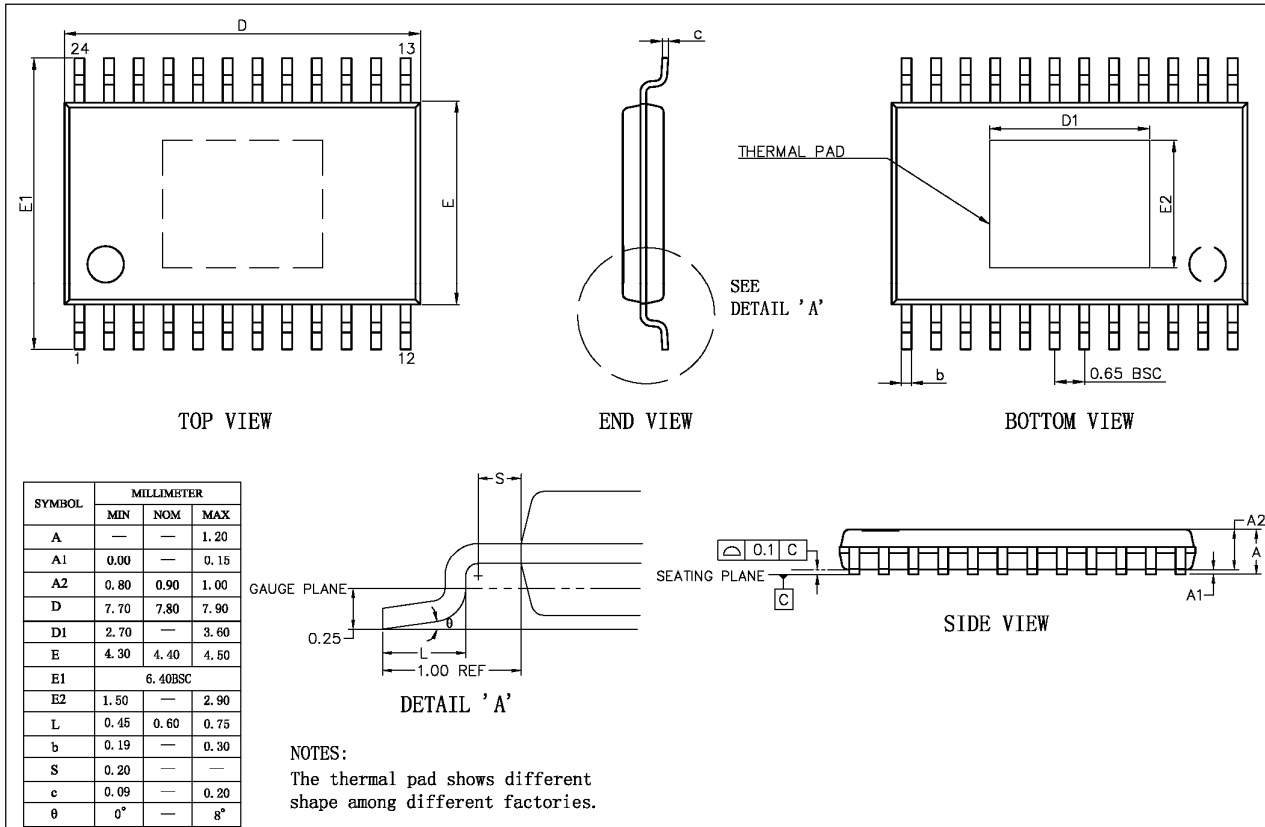


Figure 39 Classification Profile

# IS31AP2111

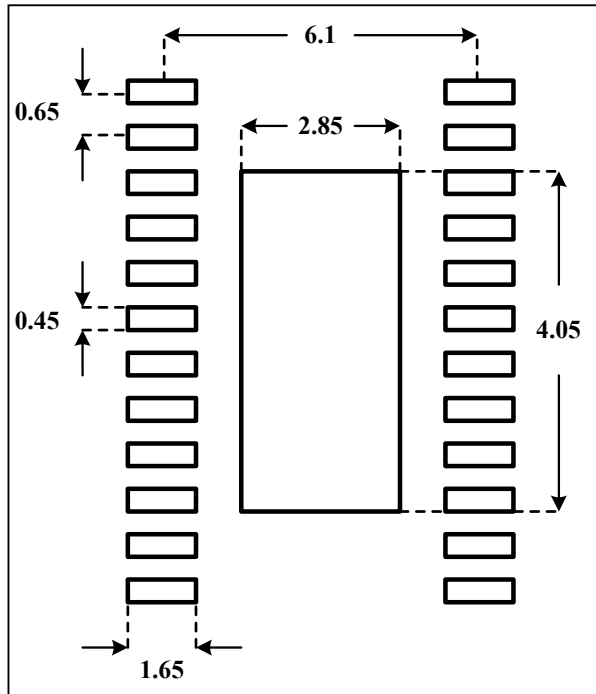
## PACKAGE INFORMATION

### eTSSOP-24



# IS31AP2111

## 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  | 2015.06.12 |
| B        | 1. Add mono mode<br>2. Update EC table<br>3. Add performance figures | 2015.10.20 |
| C        | Add "End of Life" watermark  | 2021.08.10 |

End of Life