

## 20-W STEREO DIGITAL AUDIO POWER AMPLIFIER WITH EQ AND DRC

### FEATURES

- **Audio Input/Output**
  - 20-W Into an 8- $\Omega$  Load From an 18-V Supply
  - Wide PVDD Range, From 8 V to 24 V
  - Efficient Class-D Operation Eliminates Need for Heatsinks
  - Requires Only 3.3 V and PVDD
  - One Serial Audio Input (Two Audio Channels)
  - Supports 8-kHz to 48-kHz Sample Rate (LJ/RJ/I<sup>2</sup>S)
- **Audio/PWM Processing**
  - Independent Channel Volume Controls With 24 dB to Mute
  - Soft Mute (50% Duty Cycle)
  - Programmable 2-Band Dynamic Range Control
  - 22 Programmable Biquads for Speaker EQ and Other Audio-Processing Features
  - Programmable Coefficients for DRC Filters
  - Programmable Input and Output Mixers
  - DC Blocking Filters
  - Support for 3D Effects
  - Pseudo Bass Support
- **General Features**
  - Serial Control Interface Operational Without MCLK
  - Factory-Trimmed Internal Oscillator for Automatic Rate Detection
  - Surface Mount, 48-Pin, 7-mm  $\times$  7-mm HTQFP Package
  - Thermal and Short-Circuit Protection
- **Benefits**
  - EQ: Speaker Equalization Improves Audio Performance
  - DRC: Dynamic Range Compression. Can Be Used As Power Limiter. Enables Speaker Protection, Easy Listening, Night-Mode Listening
  - Two-Band DRC: Sets Two Different Thresholds for Low- and High-Frequency Content
  - Autobank Switching: Preload Coefficients for Different Sample Rates. No Need to Write New Coefficients to the Part When Sample Rate Changes
  - Autodetect: Automatically Detects Sample-Rate Changes. No Need for External Microprocessor Intervention

### DESCRIPTION

The TAS5709 is a 20-W, efficient, digital audio-power amplifier for driving stereo bridge-tied speakers. One serial data input allows processing of up to two discrete audio channels and seamless integration to most digital-audio processors and MPEG decoders. The device accepts a wide range of input data and data rates. A fully programmable data path routes these channels to the internal speaker drivers.

The TAS5709 is a slave-only device receiving all clocks from external sources. The TAS5709 operates with a PWM carrier between a 384-kHz switching rate and a 352-KHz switching rate, depending on the input sample rate. Oversampling combined with a fourth-order noise shaper provides a flat noise floor and excellent dynamic range from 20 Hz to 20 kHz.

The TAS5709A is identical in function to the TAS5709, but has a unique I<sup>2</sup>C device address. The address of the TAS5709 is 0x36. The address of the TAS5709A is 0x3A.

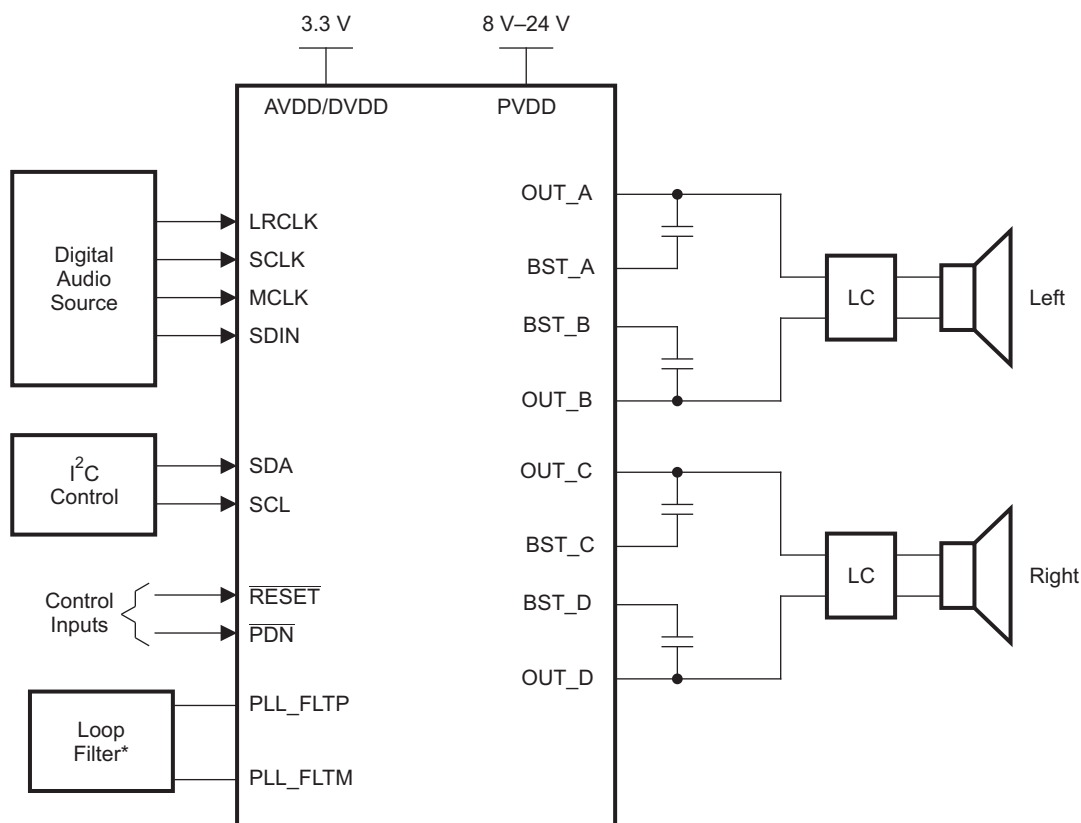


Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

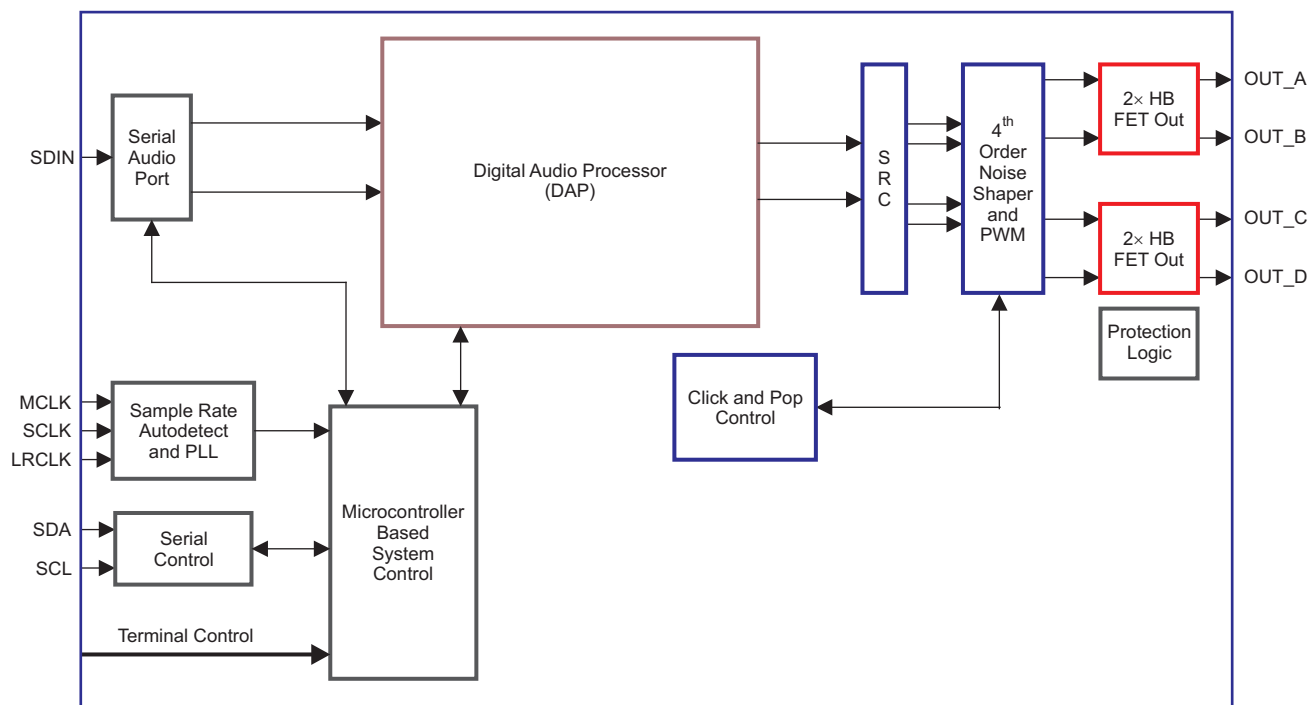
## SIMPLIFIED APPLICATION DIAGRAM



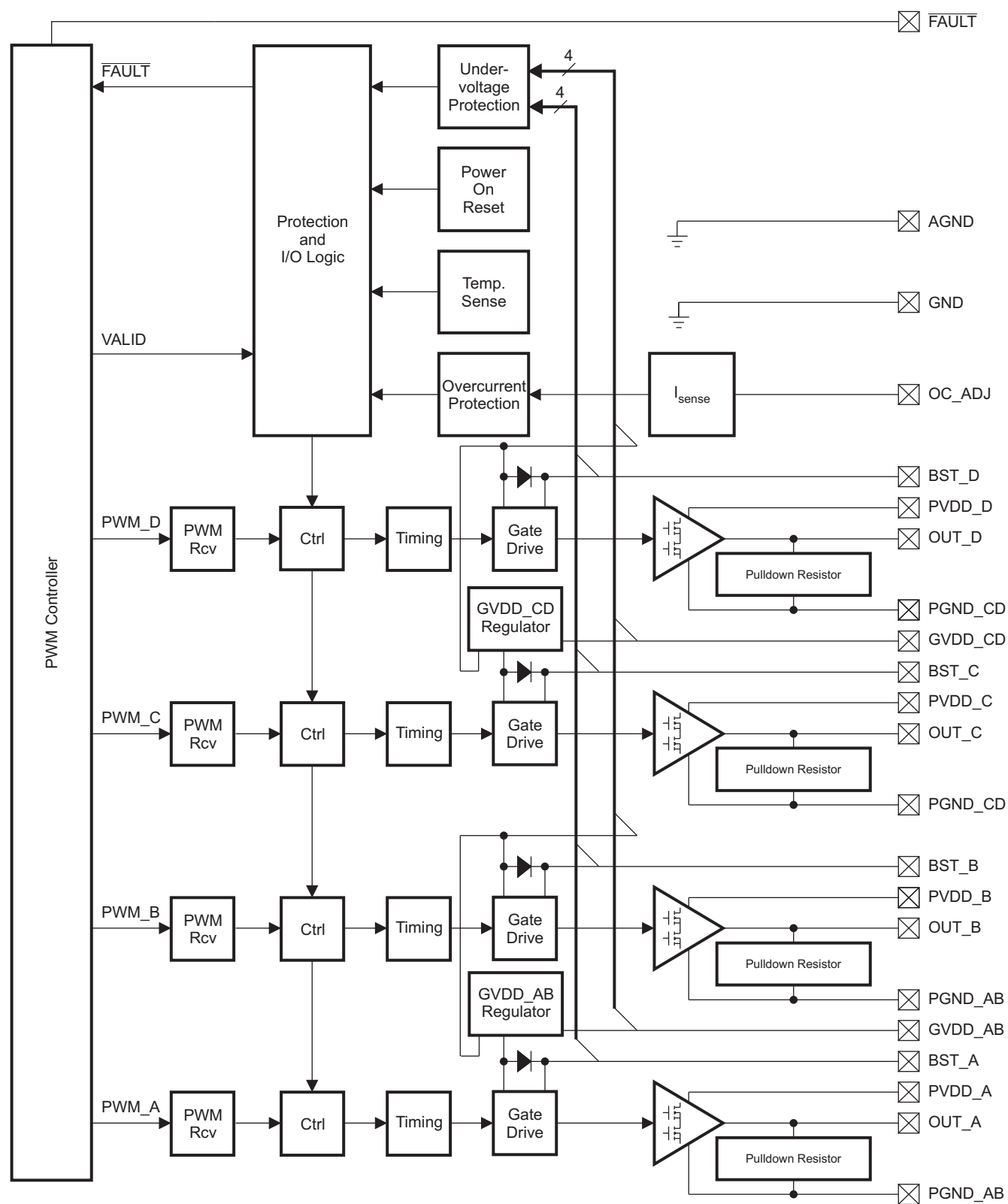
B0264-03

\*Refer to TAS5709 User's Guide for Loop Filter values

## FUNCTIONAL VIEW

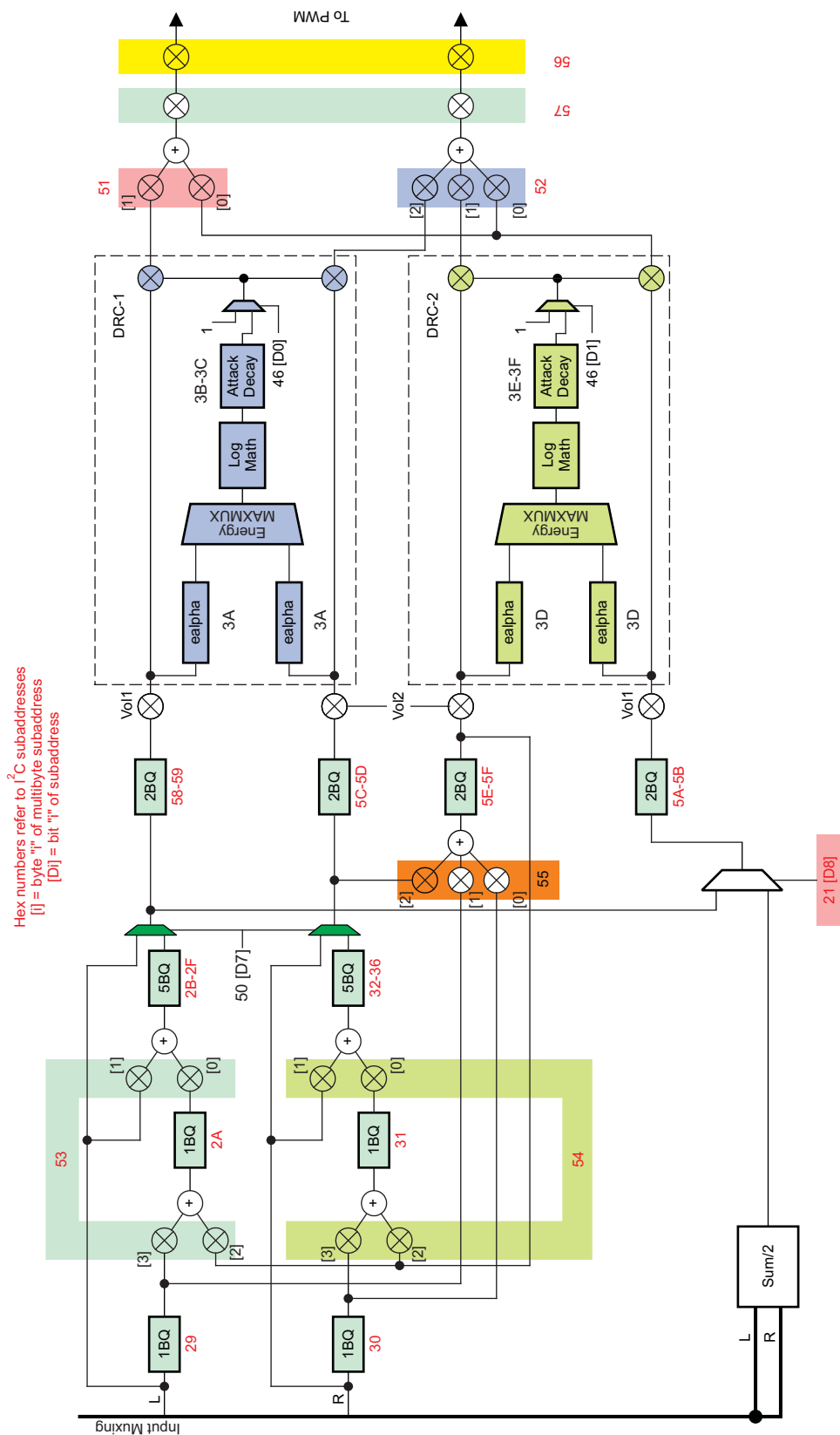


B0262-06

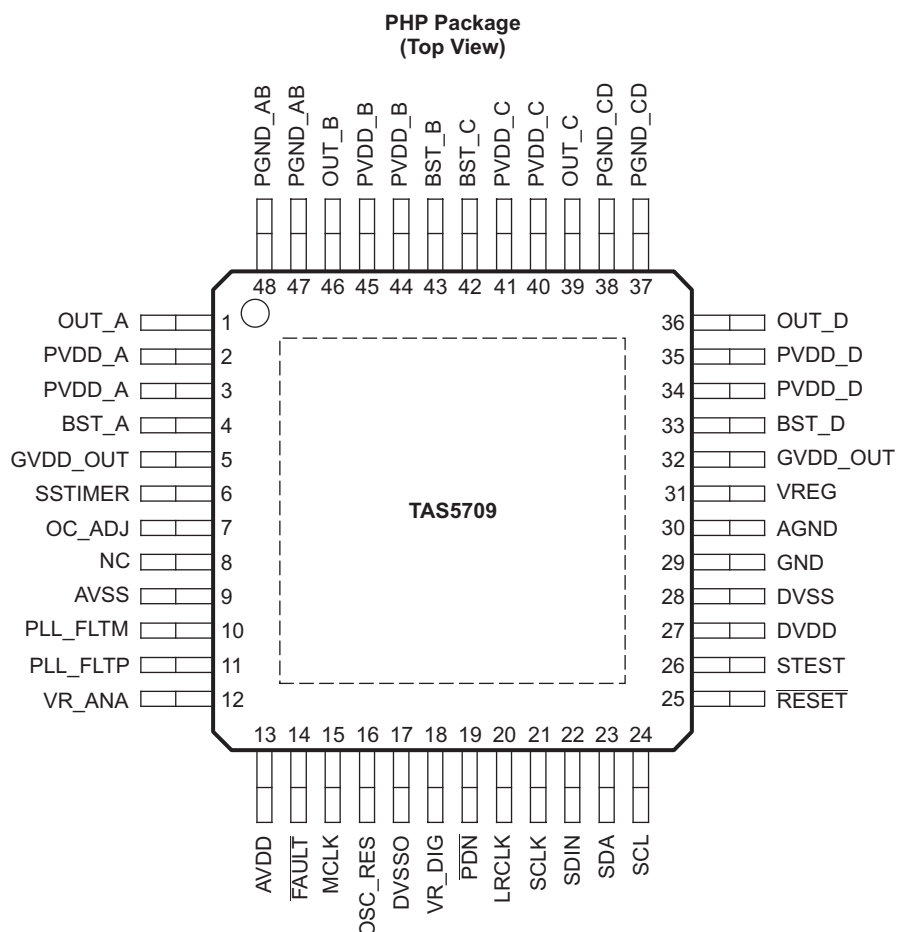


B0034-05

## DAP Process Structure



B0321-05

**48-TERMINAL, HTQFP PACKAGE (TOP VIEW)**

P0075-06

**PIN FUNCTIONS**

| PIN      |       | TYPE<br>(1) | 5-V<br>TOLERANT | TERMINATION<br>(2) | DESCRIPTION                                                  |
|----------|-------|-------------|-----------------|--------------------|--------------------------------------------------------------|
| NAME     | NO.   |             |                 |                    |                                                              |
| AGND     | 30    | P           |                 |                    | Analog ground for power stage                                |
| AVDD     | 13    | P           |                 |                    | 3.3-V analog power supply                                    |
| AVSS     | 9     | P           |                 |                    | Analog 3.3-V supply ground                                   |
| BST_A    | 4     | P           |                 |                    | High-side bootstrap supply for half-bridge A                 |
| BST_B    | 43    | P           |                 |                    | High-side bootstrap supply for half-bridge B                 |
| BST_C    | 42    | P           |                 |                    | High-side bootstrap supply for half-bridge C                 |
| BST_D    | 33    | P           |                 |                    | High-side bootstrap supply for half-bridge D                 |
| DVDD     | 27    | P           |                 |                    | 3.3-V digital power supply                                   |
| DVSSO    | 17    | P           |                 |                    | Oscillator ground                                            |
| DVSS     | 28    | P           |                 |                    | Digital ground                                               |
| GND      | 29    | P           |                 |                    | Analog ground for power stage                                |
| GVDD_OUT | 5, 32 | P           |                 |                    | Gate drive internal regulator output                         |
| LRCLK    | 20    | DI          | 5-V             | Pulldown           | Input serial audio data left/right clock (sample-rate clock) |
| MCLK     | 15    | DI          | 5-V             | Pulldown           | Master clock input                                           |

(1) TYPE: A = analog; D = 3.3-V digital; P = power/ground/decoupling; I = input; O = output

(2) All pullups are weak pullups and all pulldowns are weak pulldowns. The pullups and pulldowns are included to assure proper input logic levels if the pins are left unconnected (pullups → logic 1 input; pulldowns → logic 0 input).

**PIN FUNCTIONS (continued)**

| PIN                       |        | TYPE<br>(1) | 5-V<br>TOLERANT | TERMINATION<br>(2) | DESCRIPTION                                                                                                                                                                                                                                                 |
|---------------------------|--------|-------------|-----------------|--------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NAME                      | NO.    |             |                 |                    |                                                                                                                                                                                                                                                             |
| NC                        | 8      | –           |                 |                    | No connection                                                                                                                                                                                                                                               |
| OC_ADJ                    | 7      | AO          |                 |                    | Analog overcurrent programming. Requires resistor to ground                                                                                                                                                                                                 |
| OSC_RES                   | 16     | AO          |                 |                    | Oscillator trim resistor. Connect an 18.2-kΩ 1% resistor to DVSSO.                                                                                                                                                                                          |
| OUT_A                     | 1      | O           |                 |                    | Output, half-bridge A                                                                                                                                                                                                                                       |
| OUT_B                     | 46     | O           |                 |                    | Output, half-bridge B                                                                                                                                                                                                                                       |
| OUT_C                     | 39     | O           |                 |                    | Output, half-bridge C                                                                                                                                                                                                                                       |
| OUT_D                     | 36     | O           |                 |                    | Output, half-bridge D                                                                                                                                                                                                                                       |
| $\overline{\text{PDN}}$   | 19     | DI          | 5-V             | Pullup             | Power down, active-low. $\overline{\text{PDN}}$ prepares the device for loss of power supplies by shutting down the noise shaper and initiating PWM stop sequence.                                                                                          |
| PGND_AB                   | 47, 48 | P           |                 |                    | Power ground for half-bridges A and B                                                                                                                                                                                                                       |
| PGND_CD                   | 37, 38 | P           |                 |                    | Power ground for half-bridges C and D                                                                                                                                                                                                                       |
| PLL_FLTM                  | 10     | AO          |                 |                    | PLL negative loop-filter terminal                                                                                                                                                                                                                           |
| PLL_FLTP                  | 11     | AO          |                 |                    | PLL positive loop-filter terminal                                                                                                                                                                                                                           |
| PVDD_A                    | 2, 3   | P           |                 |                    | Power-supply input for half-bridge output A                                                                                                                                                                                                                 |
| PVDD_B                    | 44, 45 | P           |                 |                    | Power-supply input for half-bridge output B                                                                                                                                                                                                                 |
| PVDD_C                    | 40, 41 | P           |                 |                    | Power-supply input for half-bridge output C                                                                                                                                                                                                                 |
| PVDD_D                    | 34, 35 | P           |                 |                    | Power-supply input for half-bridge output D                                                                                                                                                                                                                 |
| $\overline{\text{RESET}}$ | 25     | DI          | 5-V             | Pullup             | Reset, active-low. A system reset is generated by applying a logic low to this pin. $\overline{\text{RESET}}$ is an asynchronous control signal that restores the DAP to its default conditions and places the PWM in the hard-mute (high-impedance) state. |
| SCL                       | 24     | DI          | 5-V             |                    | I <sup>2</sup> C serial control clock input                                                                                                                                                                                                                 |
| SCLK                      | 21     | DI          | 5-V             | Pulldown           | Serial audio data clock (shift clock). SCLK is the serial audio-port input-data bit clock.                                                                                                                                                                  |
| SDA                       | 23     | DIO         | 5-V             |                    | I <sup>2</sup> C serial control data interface input/output                                                                                                                                                                                                 |
| SDIN                      | 22     | DI          | 5-V             | Pulldown           | Serial audio-data input. SDIN supports three discrete (stereo) data formats.                                                                                                                                                                                |
| SSTIMER                   | 6      | AI          |                 |                    | Controls ramp time of OUT_X to minimize pop. Leave this pin floating for BD mode. Requires capacitor of 2.2 nF to GND in AD mode. The capacitor determines the ramp time.                                                                                   |
| STEST                     | 26     | DI          |                 |                    | Factory test pin. Connect directly to DVSS.                                                                                                                                                                                                                 |
| $\overline{\text{FAULT}}$ | 14     | DO          |                 |                    | Back-end error indicator. Asserted LOW for overtemperature, overcurrent, overvoltage, and undervoltage error conditions. De-asserted on recovery from an error condition                                                                                    |
| VR_ANA                    | 12     | P           |                 |                    | Internally regulated 1.8-V analog supply voltage. This pin must not be used to power external devices.                                                                                                                                                      |
| VR_DIG                    | 18     | P           |                 |                    | Internally regulated 1.8-V digital supply voltage. This pin must not be used to power external devices.                                                                                                                                                     |
| VREG                      | 31     | P           |                 |                    | Digital regulator output. Not to be used for powering external circuitry.                                                                                                                                                                                   |

## ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup>

|                                             |                                                         | VALUE                             | UNIT |
|---------------------------------------------|---------------------------------------------------------|-----------------------------------|------|
| Supply voltage                              | DVDD, AVDD                                              | –0.3 to 3.6                       | V    |
|                                             | PVDD_X                                                  | –0.3 to 30                        | V    |
| Input voltage                               | OC_ADJ                                                  | –0.3 to 4.2                       | V    |
|                                             | 3.3-V digital input                                     | –0.5 to DVDD + 0.5                | V    |
|                                             | 5-V tolerant <sup>(2)</sup> digital input (except MCLK) | –0.5 to DVDD + 2.5 <sup>(3)</sup> | V    |
|                                             | 5-V tolerant MCLK input                                 | –0.5 to AVDD + 2.5 <sup>(3)</sup> | V    |
| OUT_x to PGND_X                             |                                                         | 32 <sup>(4)</sup>                 | V    |
| BST_x to PGND_X                             |                                                         | 43 <sup>(4)</sup>                 | V    |
| Input clamp current, I <sub>IK</sub>        |                                                         | ±20                               | mA   |
| Output clamp current, I <sub>OK</sub>       |                                                         | ±20                               | mA   |
| Operating free-air temperature              |                                                         | 0 to 85                           | °C   |
| Operating junction temperature range        |                                                         | 0 to 150                          | °C   |
| Storage temperature range, T <sub>stg</sub> |                                                         | –40 to 125                        | °C   |

- (1) Stresses beyond those listed under *absolute ratings* may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under *recommended operation conditions* are not implied. Exposure to *absolute-maximum* conditions for extended periods may affect device reliability.
- (2) 5-V tolerant inputs are PDN, RESET, SCLK, LRCLK, MCLK, SDIN, SDA, and SCL.
- (3) Maximum pin voltage should not exceed 6 V
- (4) DC voltage + peak ac waveform measured at the pin should be below the allowed limit for all conditions.

## DISSIPATION RATINGS<sup>(1)</sup>

| PACKAGE           | DERATING FACTOR<br>ABOVE T <sub>A</sub> = 25°C | T <sub>A</sub> ≤ 25°C<br>POWER RATING | T <sub>A</sub> = 45°C<br>POWER RATING | T <sub>A</sub> = 70°C<br>POWER RATING |
|-------------------|------------------------------------------------|---------------------------------------|---------------------------------------|---------------------------------------|
| 7-mm × 7-mm HTQFP | 40 mW/°C                                       | 5 W                                   | 4.2 W                                 | 3.2 W                                 |

- (1) This data was taken using 1 oz trace and copper pad that is soldered directly to a JEDEC standard high-k PCB. The thermal pad must be soldered to a thermal land on the printed-circuit board. See TI Technical Briefs SLMA002 for more information about using the HTQFP thermal pad

## RECOMMENDED OPERATING CONDITIONS

|                               |                                      |                                                         | MIN | NOM | MAX | UNIT |
|-------------------------------|--------------------------------------|---------------------------------------------------------|-----|-----|-----|------|
|                               | Digital/analog supply voltage        | DVDD, AVDD                                              | 3   | 3.3 | 3.6 | V    |
|                               | Half-bridge supply voltage           | PVDD_X                                                  | 8   |     | 24  | V    |
| V <sub>IH</sub>               | High-level input voltage             | 5-V tolerant                                            | 2   |     |     | V    |
| V <sub>IL</sub>               | Low-level input voltage              | 5-V tolerant                                            |     |     | 0.8 | V    |
| T <sub>A</sub>                | Operating ambient temperature range  |                                                         | 0   |     | 85  | °C   |
| T <sub>J</sub> <sup>(1)</sup> | Operating junction temperature range |                                                         | 0   |     | 125 | °C   |
| R <sub>L</sub> (BTL)          | Load impedance                       | Output filter: L = 15 μH, C = 680 nF                    | 6   | 8   |     | Ω    |
| L <sub>O</sub> (BTL)          | Output-filter inductance             | Minimum output inductance under short-circuit condition | 10  |     |     | μH   |

- (1) Continuous operation above the recommended junction temperature may result in reduced reliability and/or lifetime of the device.

## PWM OPERATION AT RECOMMENDED OPERATING CONDITIONS

| PARAMETER          | TEST CONDITIONS                     | VALUE | UNIT |
|--------------------|-------------------------------------|-------|------|
| Output sample rate | 11.025/22.05/44.1-kHz data rate ±2% | 352.8 | kHz  |
|                    | 48/24/12/8/16/32-kHz data rate ±2%  | 384   |      |

## PLL INPUT PARAMETERS AND EXTERNAL FILTER COMPONENTS

| PARAMETER                                        | TEST CONDITIONS      | MIN    | TYP | MAX    | UNIT     |
|--------------------------------------------------|----------------------|--------|-----|--------|----------|
| $f_{\text{MCLKI}}$ MCLK frequency                |                      | 2.8224 |     | 24.576 | MHz      |
| MCLK duty cycle                                  |                      | 40%    | 50% | 60%    |          |
| $t_r / t_f(\text{MCLK})$ Rise/fall time for MCLK |                      |        |     | 5      | ns       |
| LRCLK allowable drift before LRCLK reset         |                      |        |     | 4      | MCLKs    |
| External PLL filter capacitor C1                 | SMD 0603 Y5V         |        | 47  |        | nF       |
| External PLL filter capacitor C2                 | SMD 0603 Y5V         |        | 4.7 |        | nF       |
| External PLL filter resistor R                   | SMD 0603, metal film |        | 470 |        | $\Omega$ |

## ELECTRICAL CHARACTERISTICS

### DC Characteristics

$T_A = 25^\circ$ ,  $PVCC\_X = 18\text{ V}$ ,  $DVDD = AVDD = 3.3\text{ V}$ ,  $R_L = 8\ \Omega$ , BTL AD mode,  $f_s = 48\text{ kHz}$  (unless otherwise noted)

| PARAMETER                          |                                                              |                                                                                                  | TEST CONDITIONS                                                          | MIN | TYP  | MAX | UNIT |
|------------------------------------|--------------------------------------------------------------|--------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|-----|------|-----|------|
| V <sub>OH</sub>                    | High-level output voltage                                    | $\overline{\text{FAULTZ}}$ and SDA                                                               | I <sub>OH</sub> = −4 mA<br>DVDD = 3 V                                    | 2.4 |      |     | V    |
| V <sub>OL</sub>                    | Low-level output voltage                                     | $\overline{\text{FAULTZ}}$ and SDA                                                               | I <sub>OL</sub> = 4 mA<br>DVDD = 3 V                                     |     |      | 0.5 | V    |
| I <sub>IL</sub>                    | Low-level input current                                      |                                                                                                  | V <sub>I</sub> < V <sub>IL</sub> ; DVDD = AVDD = 3.6 V                   |     |      | 75  | μA   |
| I <sub>IH</sub>                    | High-level input current                                     |                                                                                                  | V <sub>I</sub> > V <sub>IH</sub> ; DVDD = AVDD = 3.6 V                   |     |      | 75  | μA   |
| I <sub>DD</sub>                    | 3.3-V supply current                                         | 3.3 V supply voltage (DVDD, AVDD)                                                                | Normal mode                                                              |     | 48   | 83  | mA   |
|                                    |                                                              |                                                                                                  | Reset ( $\overline{\text{RESET}}$ = low, $\overline{\text{PDN}}$ = high) |     | 24   | 32  |      |
| I <sub>PVDD</sub>                  | Half-bridge supply current                                   | No load (PVDD_X)                                                                                 | Normal mode                                                              |     | 30   | 55  | mA   |
|                                    |                                                              |                                                                                                  | Reset ( $\overline{\text{RESET}}$ = low, $\overline{\text{PDN}}$ = high) |     | 5    | 13  |      |
| r <sub>DS(on)</sub> <sup>(1)</sup> | Drain-to-source resistance, LS                               | T <sub>J</sub> = 25°C, includes metallization resistance                                         |                                                                          |     | 180  |     | mΩ   |
|                                    | Drain-to-source resistance, HS                               | T <sub>J</sub> = 25°C, includes metallization resistance                                         |                                                                          |     | 180  |     |      |
| I/O Protection                     |                                                              |                                                                                                  |                                                                          |     |      |     |      |
| V <sub>Uvp</sub>                   | Undervoltage protection limit                                | PVDD falling                                                                                     |                                                                          |     | 7.2  |     | V    |
| V <sub>Uvp,hyst</sub>              | Undervoltage protection limit                                | PVDD rising                                                                                      |                                                                          |     | 7.6  |     | V    |
| OTE <sup>(2)</sup>                 | Overtemperature error                                        |                                                                                                  |                                                                          |     | 150  |     | °C   |
| OTE <sub>HYST</sub> <sup>(2)</sup> | Extra temperature drop required to recover from error        |                                                                                                  |                                                                          |     | 30   |     | °C   |
| OLPC                               | Overload protection counter                                  | f <sub>PWM</sub> = 384 kHz                                                                       |                                                                          |     | 1.25 |     | ms   |
| I <sub>OC</sub>                    | Overcurrent limit protection                                 | Resistor—programmable, max. current, R <sub>OCP</sub> = 22 kΩ                                    |                                                                          |     | 4.5  |     | A    |
| I <sub>OCT</sub>                   | Overcurrent response time                                    |                                                                                                  |                                                                          |     | 150  |     | ns   |
| R <sub>OCP</sub>                   | OC programming resistor range                                | Resistor tolerance = 5% for typical value; the minimum resistance should not be less than 20 kΩ. |                                                                          | 20  | 22   |     | kΩ   |
| R <sub>PD</sub>                    | Internal pulldown resistor at the output of each half-bridge | Connected when drivers are high-impedance to provide bootstrap capacitor charge                  |                                                                          |     | 3    |     | kΩ   |

(1) This does not include bond-wire or pin resistance.

(2) Specified by design

## AC Characteristics (BTL)

PVDD\_X = 18 V, BTL AD mode, FS = 48 KHz,  $R_L = 8\ \Omega$ ,  $R_{OCP} = 22\ k\Omega$ ,  $C_{BST} = 33\ nF$ , audio frequency = 1 kHz, AES17 filter,  $f_{PWM} = 384\ kHz$ ,  $T_A = 25^\circ C$  (unless otherwise noted). All performance is in accordance with recommended operating conditions, unless otherwise specified.

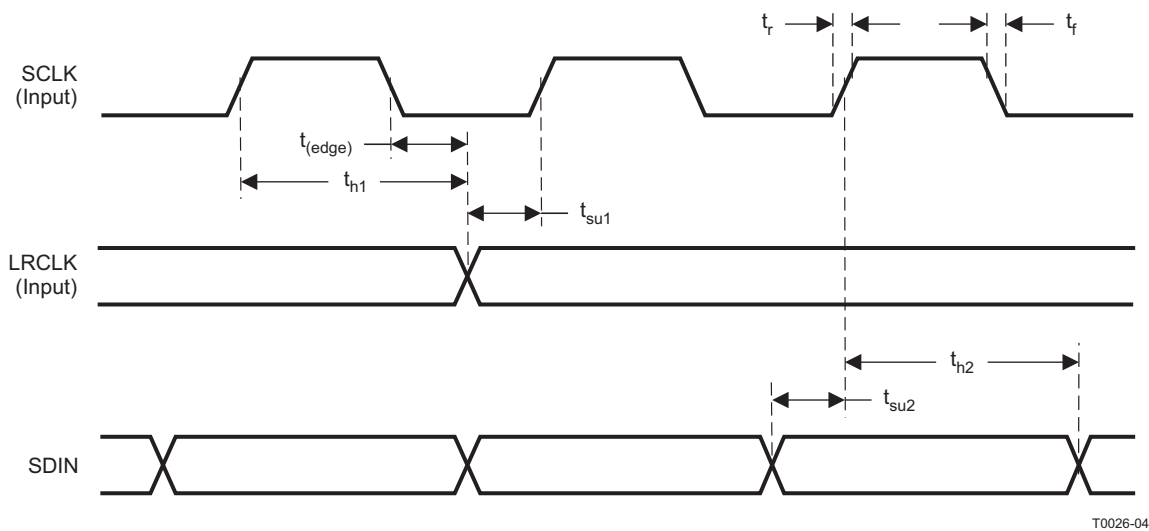
| PARAMETER      |                                      | TEST CONDITIONS                                  | MIN | TYP   | MAX | UNIT    |
|----------------|--------------------------------------|--------------------------------------------------|-----|-------|-----|---------|
| P <sub>O</sub> | Power output per channel             | PVDD = 18 V, 10% THD, 1-kHz input signal         |     | 20.6  |     | W       |
|                |                                      | PVDD = 18 V, 7% THD, 1-kHz input signal          |     | 19.5  |     |         |
|                |                                      | PVDD = 12 V, 10% THD, 1-kHz input signal         |     | 9.4   |     |         |
|                |                                      | PVDD = 12 V, 7% THD, 1-kHz input signal          |     | 8.9   |     |         |
|                |                                      | PVDD = 8 V, 10% THD, 1-kHz input signal          |     | 4.1   |     |         |
|                |                                      | PVDD = 8 V, 7% THD, 1-kHz input signal           |     | 3.8   |     |         |
| THD+N          | Total harmonic distortion + noise    | PVDD = 18 V; P <sub>O</sub> = 1 W                |     | 0.06% |     |         |
|                |                                      | PVDD = 12 V; P <sub>O</sub> = 1 W                |     | 0.13% |     |         |
|                |                                      | PVDD = 8 V; P <sub>O</sub> = 1 W                 |     | 0.2%  |     |         |
| V <sub>n</sub> | Output integrated noise (rms)        | A-weighted                                       |     | 56    |     | $\mu V$ |
|                | Crosstalk                            | P <sub>O</sub> = 0.25 W, f = 1kHz (BD Mode)      |     | –82   |     | dB      |
|                |                                      | P <sub>O</sub> = 0.25 W, f = 1kHz (AD Mode)      |     | –69   |     | dB      |
| SNR            | Signal-to-noise ratio <sup>(1)</sup> | A-weighted, f = 1 kHz, maximum power at THD < 1% |     | 106   |     | dB      |

(1) SNR is calculated relative to 0-dBFS input level.

## SERIAL AUDIO-PORT SLAVE MODE

over recommended operating conditions (unless otherwise noted)

| PARAMETER                                   |                                                                     | TEST CONDITIONS        | MIN   | TYP | MAX    | UNIT        |
|---------------------------------------------|---------------------------------------------------------------------|------------------------|-------|-----|--------|-------------|
| f <sub>SCLKIN</sub>                         | Frequency, SCLK $32 \times f_S$ , $48 \times f_S$ , $64 \times f_S$ | C <sub>L</sub> = 30 pF | 1.024 |     | 12.288 | MHz         |
| t <sub>SU1</sub>                            | Setup time, LRCLK to SCLK rising edge                               |                        | 10    |     |        | ns          |
| t <sub>H1</sub>                             | Hold time, LRCLK from SCLK rising edge                              |                        | 10    |     |        | ns          |
| t <sub>SU2</sub>                            | Setup time, SDIN to SCLK rising edge                                |                        | 10    |     |        | ns          |
| t <sub>H2</sub>                             | Hold time, SDIN from SCLK rising edge                               |                        | 10    |     |        | ns          |
|                                             | LRCLK frequency                                                     |                        | 8     | 48  | 48     | kHz         |
|                                             | SCLK duty cycle                                                     |                        | 40%   | 50% | 60%    |             |
|                                             | LRCLK duty cycle                                                    |                        | 40%   | 50% | 60%    |             |
|                                             | SCLK rising edges between LRCLK rising edges                        |                        | 32    |     | 64     | SCLK edges  |
| t <sub>(edge)</sub>                         | LRCLK clock edge with respect to the falling edge of SCLK           |                        | –1/4  |     | 1/4    | SCLK period |
| t <sub>r</sub> / t <sub>f(SCLK/LRCLK)</sub> | Rise/fall time for SCLK/LRCLK                                       |                        |       |     | 8      | ns          |

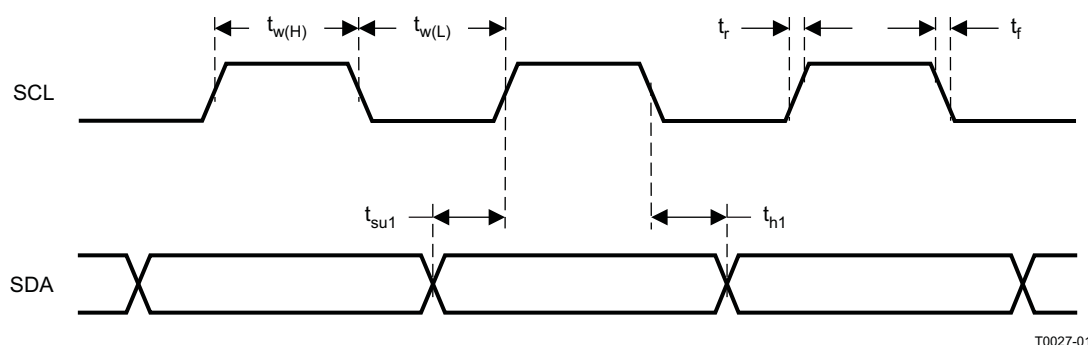


**Figure 2. Slave Mode Serial Data Interface Timing**

## I<sup>2</sup>C SERIAL CONTROL PORT OPERATION

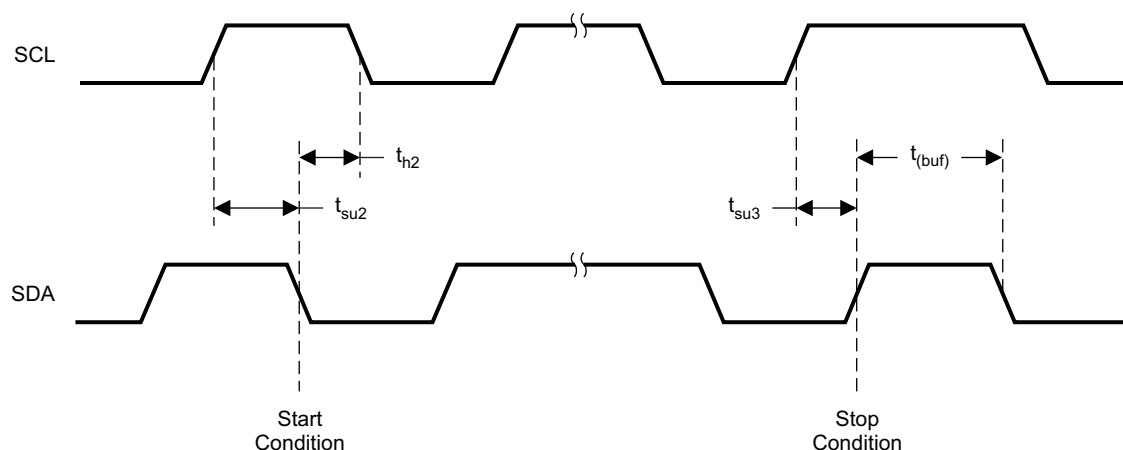
Timing characteristics for I<sup>2</sup>C Interface signals over recommended operating conditions (unless otherwise noted)

| PARAMETER   |                                                 | TEST CONDITIONS | MIN | MAX | UNIT    |
|-------------|-------------------------------------------------|-----------------|-----|-----|---------|
| $f_{SCL}$   | Frequency, SCL                                  | No wait states  |     | 400 | kHz     |
| $t_{w(H)}$  | Pulse duration, SCL high                        |                 | 0.6 |     | $\mu$ s |
| $t_{w(L)}$  | Pulse duration, SCL low                         |                 | 1.3 |     | $\mu$ s |
| $t_r$       | Rise time, SCL and SDA                          |                 |     | 300 | ns      |
| $t_f$       | Fall time, SCL and SDA                          |                 |     | 300 | ns      |
| $t_{su1}$   | Setup time, SDA to SCL                          |                 | 100 |     | ns      |
| $t_{h1}$    | Hold time, SCL to SDA                           |                 | 0   |     | ns      |
| $t_{(buf)}$ | Bus free time between stop and start conditions |                 | 1.3 |     | $\mu$ s |
| $t_{su2}$   | Setup time, SCL to start condition              |                 | 0.6 |     | $\mu$ s |
| $t_{h2}$    | Hold time, start condition to SCL               |                 | 0.6 |     | $\mu$ s |
| $t_{su3}$   | Setup time, SCL to stop condition               |                 | 0.6 |     | $\mu$ s |
| $C_L$       | Load capacitance for each bus line              |                 |     | 400 | pF      |



T0027-01

Figure 3. SCL and SDA Timing



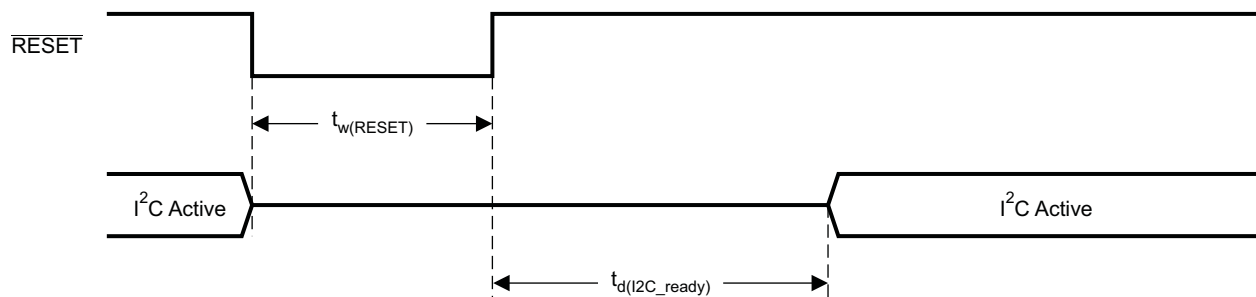
T0028-01

Figure 4. Start- and Stop-Condition Timing

## RESET TIMING ( $\overline{\text{RESET}}$ )

Control signal parameters over recommended operating conditions (unless otherwise noted). See Recommended Use Model section on usage of all terminals.

| PARAMETER                          | MIN | TYP | MAX  | UNIT          |
|------------------------------------|-----|-----|------|---------------|
| $t_{w(\text{RESET})}$              | 100 |     |      | $\mu\text{s}$ |
| $t_{d(\text{I}^2\text{C\_ready})}$ |     |     | 13.5 | ms            |



System Initialization.  
Enable via  $\text{I}^2\text{C}$ .

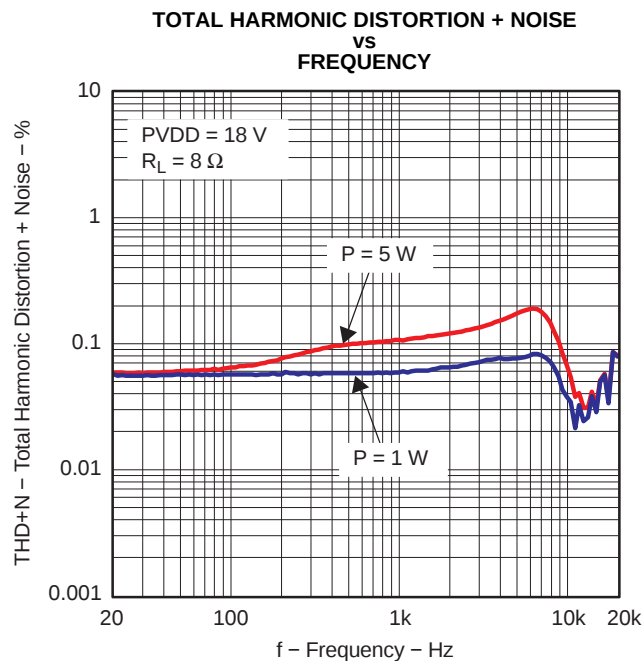
T0421-01

NOTE: On power up, it is recommended that the TAS5709  $\overline{\text{RESET}}$  be held LOW for at least 100  $\mu\text{s}$  after DVDD has reached 3 V

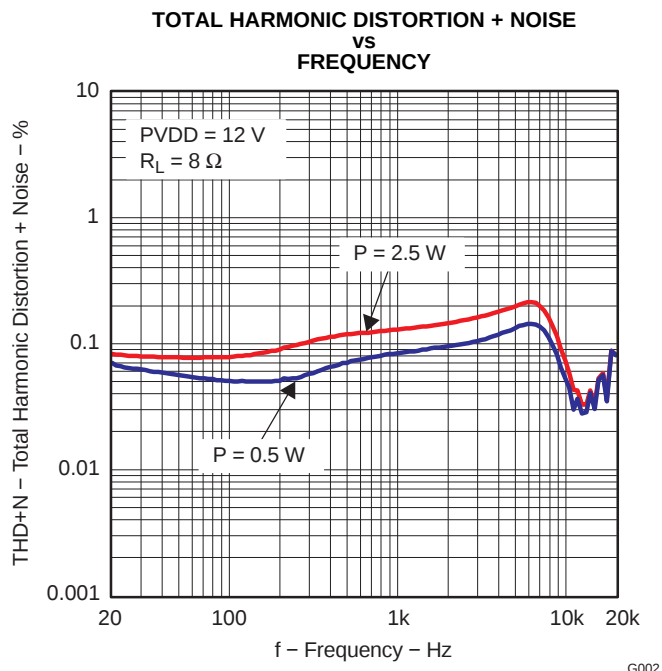
NOTE: If  $\overline{\text{RESET}}$  is asserted LOW while  $\overline{\text{PDN}}$  is LOW, then the  $\overline{\text{RESET}}$  must continue to be held LOW for at least 100  $\mu\text{s}$  after  $\overline{\text{PDN}}$  is deasserted (HIGH).

**Figure 5. Reset Timing**

## TYPICAL CHARACTERISTICS, BTL CONFIGURATION



**Figure 6.**



**Figure 7.**

## TYPICAL CHARACTERISTICS, BTL CONFIGURATION (continued)

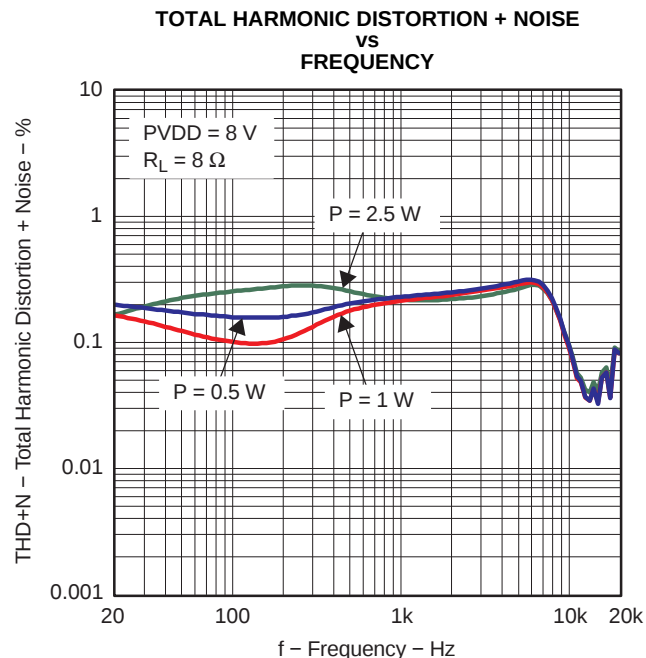


Figure 8.

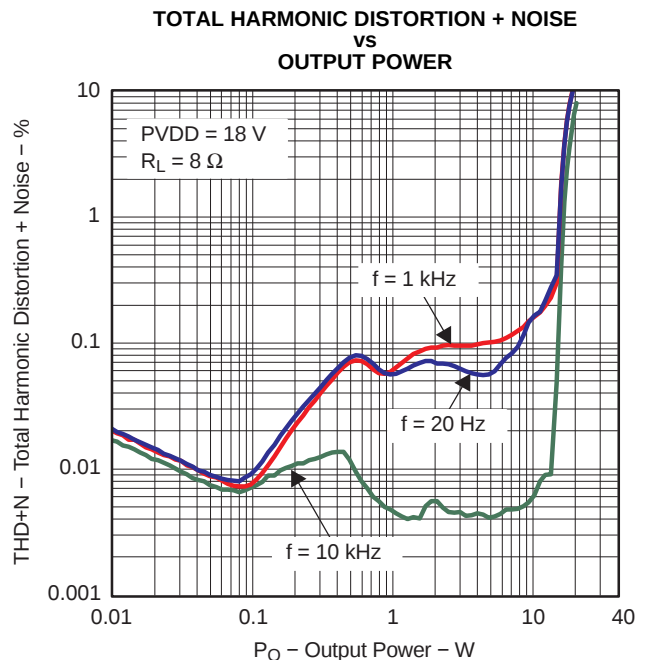


Figure 9.

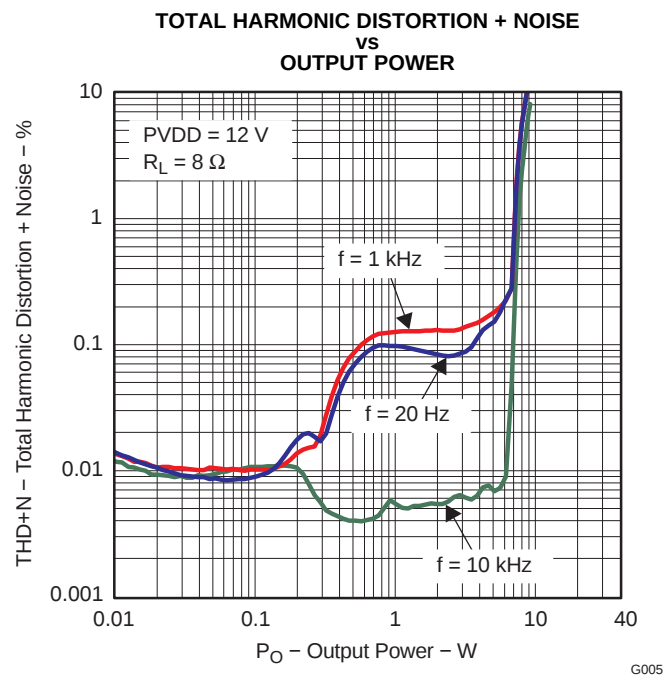


Figure 10.

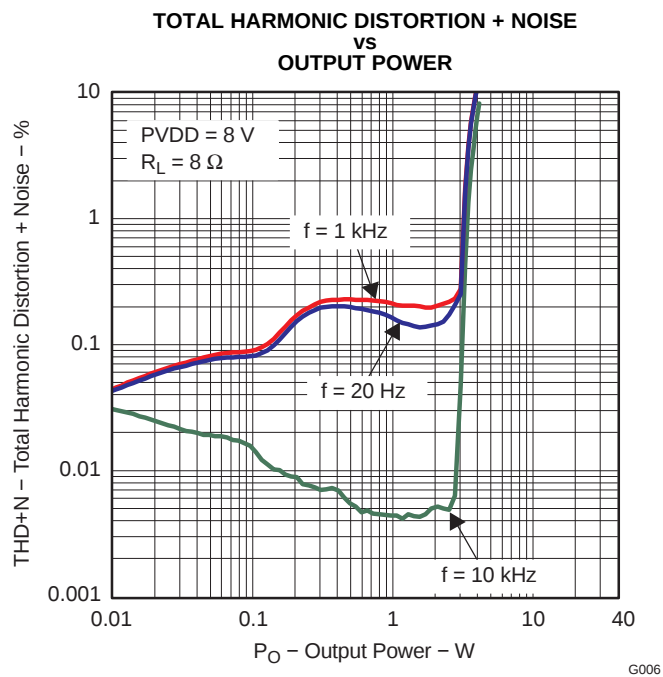
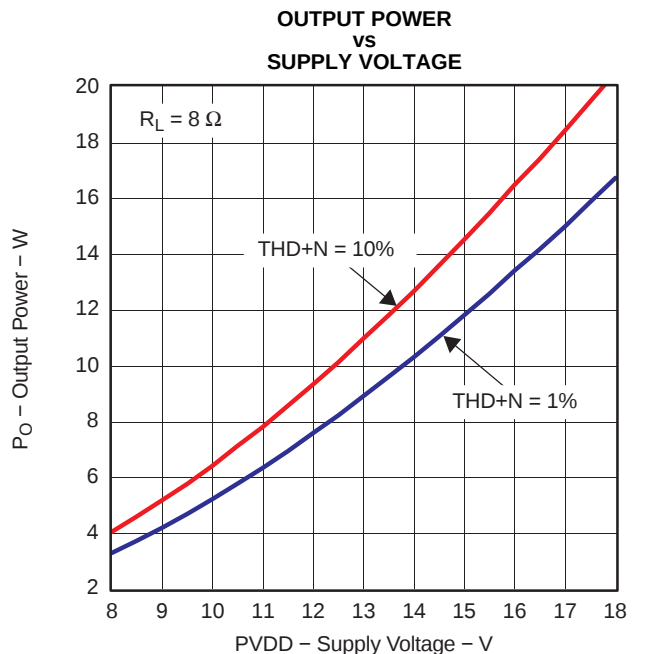
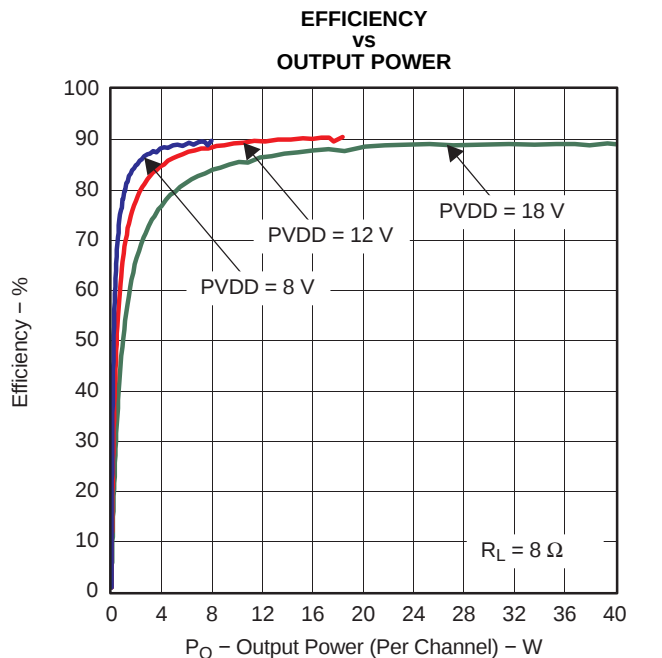


Figure 11.

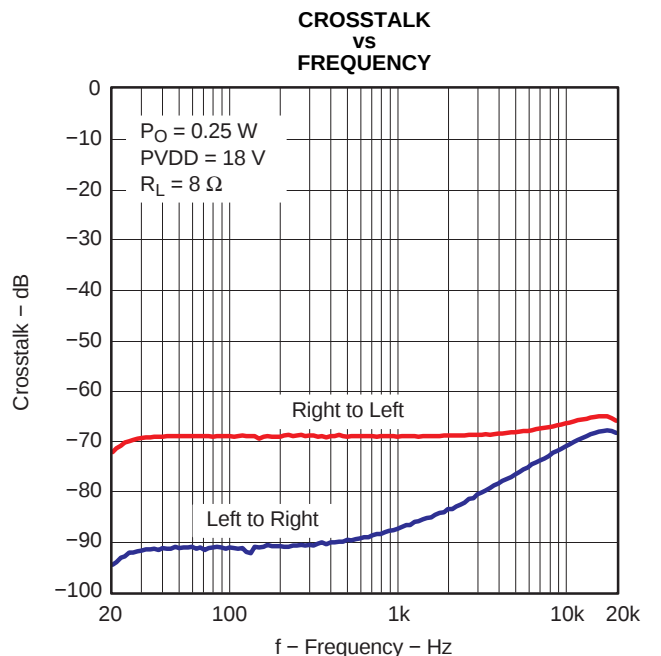
# **TYPICAL CHARACTERISTICS, BTL CONFIGURATION (continued)**



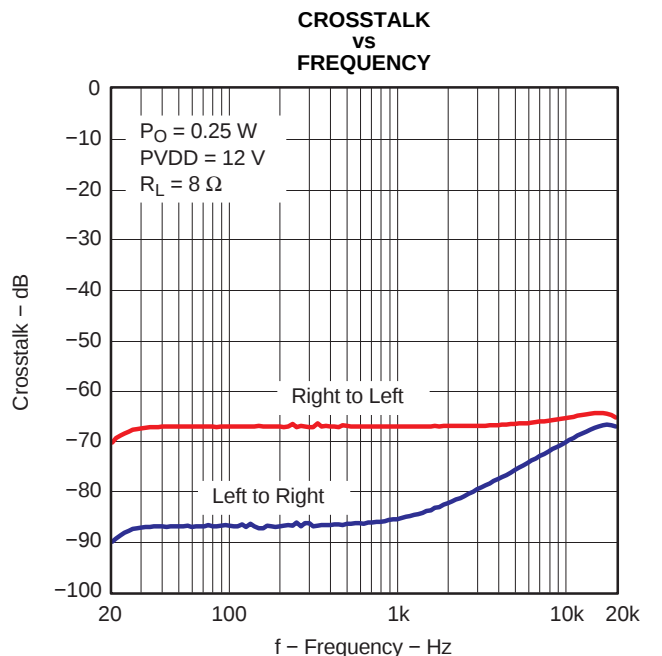
**Figure 12.**



**Figure 13.**



**Figure 14.**



**Figure 15.**

## TYPICAL CHARACTERISTICS, BTL CONFIGURATION (continued)

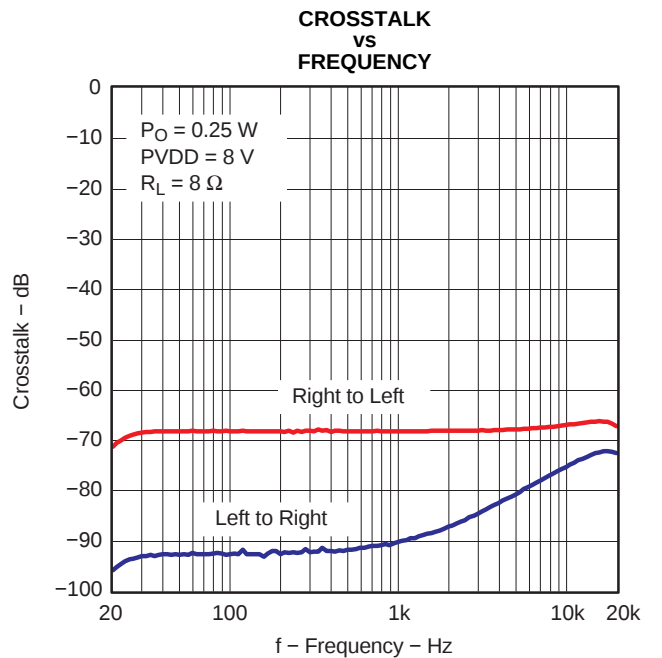


Figure 16.

## DETAILED DESCRIPTION

### POWER SUPPLY

To facilitate system design, the TAS5709 needs only a 3.3-V supply in addition to the (typical) 18-V power-stage supply. An internal voltage regulator provides suitable voltage levels for the gate-drive circuitry. Additionally, all circuitry requiring a floating voltage supply, e.g., the high-side gate drive, is accommodated by built-in bootstrap circuitry requiring only a few external capacitors.

In order to provide good electrical and acoustical characteristics, the PWM signal path for the output stage is designed as identical, independent half-bridges. For this reason, each half-bridge has separate bootstrap pins (BST\_X) and power-stage supply pins (PVDD\_X). The gate-drive voltages (GVDD\_AB and GVDD\_CD) are derived from the PVDD voltage. Special attention should be paid to placing all decoupling capacitors as close to their associated pins as possible. In general, inductance between the power-supply pins and decoupling capacitors must be avoided.

For a properly functioning bootstrap circuit, a small ceramic capacitor must be connected from each bootstrap pin (BST\_X) to the power-stage output pin (OUT\_X). When the power-stage output is low, the bootstrap capacitor is charged through an internal diode connected between the gate-drive regulator output pin (GVDD\_X) and the bootstrap pin. When the power-stage output is high, the bootstrap capacitor potential is shifted above the output potential and thus provides a suitable voltage supply for the high-side gate driver. In an application with PWM switching frequencies in the range from 352 kHz to 384 kHz, it is recommended to use 33-nF ceramic capacitors, size 0603 or 0805, for the bootstrap supply. These 33-nF capacitors ensure sufficient energy storage, even during minimal PWM duty cycles, to keep the high-side power stage FET (LDMOS) fully turned on during the remaining part of the PWM cycle.

Special attention should be paid to the power-stage power supply; this includes component selection, PCB placement, and routing. As indicated, each half-bridge has independent power-stage supply pins (PVDD\_X). For optimal electrical performance, EMI compliance, and system reliability, it is important that each PVDD\_X pin is decoupled with a 100-nF ceramic capacitor placed as close as possible to each supply pin.

The TAS5709 is fully protected against erroneous power-stage turnon due to parasitic gate charging.

### ERROR REPORTING

Any fault resulting in device shutdown is signaled by the  $\overline{\text{FAULT}}$  pin going low (see [Table 1](#)). A sticky version of this pin is available on D1 of register 0x02.

**Table 1.  $\overline{\text{FAULT}}$  Output States**

| $\overline{\text{FAULT}}$ | DESCRIPTION                                                                                      |
|---------------------------|--------------------------------------------------------------------------------------------------|
| 0                         | Overcurrent (OC) or undervoltage (UVP) error or overtemperature error (OTE) or overvoltage ERROR |
| 1                         | No faults (normal operation)                                                                     |

### DEVICE PROTECTION SYSTEM

#### Overcurrent (OC) Protection With Current Limiting

The device has independent, fast-reacting current detectors on all high-side and low-side power-stage FETs. The detector outputs are closely monitored by two protection systems. The first protection system controls the power stage in order to prevent the output current further increasing, i.e., it performs a cycle-by-cycle current-limiting function, rather than prematurely shutting down during combinations of high-level music transients and extreme speaker load-impedance drops. If the high-current condition situation persists, i.e., the power stage is being overloaded, a second protection system triggers a latching shutdown, resulting in the power stage being set in the high-impedance (Hi-Z) state. The device returns to normal operation once the fault condition (i.e., a short circuit on the output) is removed. Current limiting and overcurrent protection are not independent for half-bridges. That is, if the bridge-tied load between half-bridges A and B causes an overcurrent fault, half-bridges A, B, C, and D are shut down.

## Overtemperature Protection

The TAS5709 has an overtemperature-protection system. If the device junction temperature exceeds 150°C (nominal), the device is put into thermal shutdown, resulting in all half-bridge outputs being set in the high-impedance (Hi-Z) state and  $\overline{\text{FAULT}}$  being asserted low. The TAS5709 recovers automatically once the temperature drops approximately 30°.

## Undervoltage Protection (UVP) and Power-On Reset (POR)

The UVP and POR circuits of the TAS5709 fully protect the device in any power-up/down and brownout situation. While powering up, the POR circuit resets the overload circuit (OLP) and ensures that all circuits are fully operational when the PVDD and AVDD supply voltages reach 7.6 V and 2.7 V, respectively. Although PVDD and AVDD are independently monitored, a supply voltage drop below the UVP threshold on AVDD or either PVDD pin results in all half-bridge outputs immediately being set in the high-impedance (Hi-Z) state and  $\overline{\text{FAULT}}$  being asserted low.

## SSTIMER FUNCTIONALITY

The SSTIMER pin uses a capacitor connected between this pin and ground to control the output duty cycle when exiting all-channel shutdown. The capacitor on the SSTIMER pin is slowly charged through an internal current source, and the charge time determines the rate at which the output transitions from a near-zero duty cycle to the desired duty cycle. This allows for a smooth transition that minimizes audible pops and clicks. When the part is shut down, the drivers are high-impedance and transition slowly down through a 3-k $\Omega$  resistor, similarly minimizing pops and clicks. The shutdown transition time is independent of the SSTIMER pin capacitance. Larger capacitors increase the start-up time, whereas capacitors smaller than 2.2 nF decrease the start-up time. The SSTIMER pin should be left floating for BD modulation.

## CLOCK, AUTODETECTION, AND PLL

The TAS5709 is a slave device. It accepts MCLK, SCLK, and LRCLK. The digital audio processor (DAP) supports all the sample rates and MCLK rates that are defined in the [clock control register](#).

The TAS5709 checks to verify that SCLK is a specific value of 32 f<sub>S</sub>, 48 f<sub>S</sub>, or 64 f<sub>S</sub>. The DAP only supports a 1 × f<sub>S</sub> LRCLK. The timing relationship of these clocks to SDIN is shown in subsequent sections. The clock section uses MCLK or the internal oscillator clock (when MCLK is unstable, out of range, or absent) to produce the internal clock (DCLK) running at 512 times the PWM switching frequency.

The DAP can autodetect and set the internal clock-control logic to the appropriate settings for all supported clock rates as defined in the clock-control register.

TAS5709 has robust clock error handling that uses the built-in trimmed oscillator clock to quickly detect changes/errors. Once the system detects a clock change/error, it mutes the audio (through a single-step mute) and then forces the PLL to limp using the internal oscillator as a reference clock. Once the clocks are stable, the system autodetects the new rate and reverts to normal operation. During this process, the default volume is restored in a single step (also called hard unmute). The ramp process can be programmed to ramp back slowly (also called soft unmute) as defined in volume register (0x0E).

## SERIAL DATA INTERFACE

Serial data is input on SDIN. The PWM outputs are derived from SDIN. The TAS5709 DAP accepts serial data in 16-, 20-, or 24-bit left-justified, right-justified, and I<sup>2</sup>S serial data formats.

## PWM Section

The TAS5709 DAP device uses noise-shaping and sophisticated nonlinear correction algorithms to achieve high power efficiency and high-performance digital-audio reproduction. The DAP uses a fourth-order noise shaper to increase dynamic range and SNR in the audio band. The PWM section accepts 24-bit PCM data from the DAP and outputs two BTL PWM audio output channels.

The PWM section has individual-channel dc-blocking filters that can be enabled and disabled. The filter cutoff frequency is less than 1 Hz. Individual channel de-emphasis filters for 44.1 kHz and 48 kHz are included and can be enabled and disabled.

Finally, the PWM section has an adjustable maximum modulation limit of 93.8% to 99.2%.

For a detailed description of using audio processing features like DRC, EQ, 3D, and bass boost, see the User's Guide and TAS570X GDE software development tool documentation. Also see the GDE software development tool for the device data path.

## I<sup>2</sup>C COMPATIBLE SERIAL CONTROL INTERFACE

The TAS5709 DAP has an I<sup>2</sup>C serial control slave interface to receive commands from a system controller. The serial control interface supports both normal-speed (100-kHz) and high-speed (400-kHz) operations without wait states. As an added feature, this interface operates even if MCLK is absent.

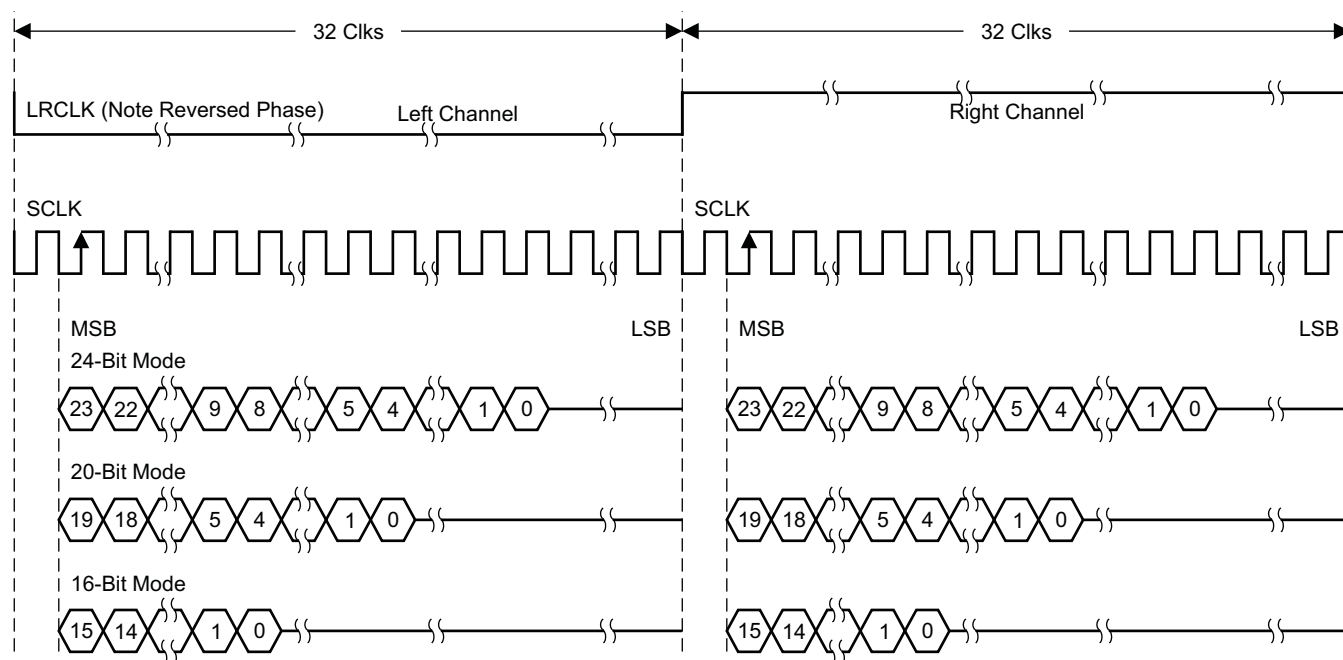
The serial control interface supports both single-byte and multiple-byte read and write operations for status registers and the general control registers associated with the PWM.

## SERIAL INTERFACE CONTROL AND TIMING

### I<sup>2</sup>S Timing

I<sup>2</sup>S timing uses LRCLK to define when the data being transmitted is for the left channel and when it is for the right channel. LRCLK is low for the left channel and high for the right channel. A bit clock running at  $32, 48, \text{ or } 64 \times f_s$  is used to clock in the data. There is a delay of one bit clock from the time the LRCLK signal changes state to the first bit of data on the data lines. The data is written MSB-first and is valid on the rising edge of the bit clock. The DAP masks unused trailing data-bit positions.

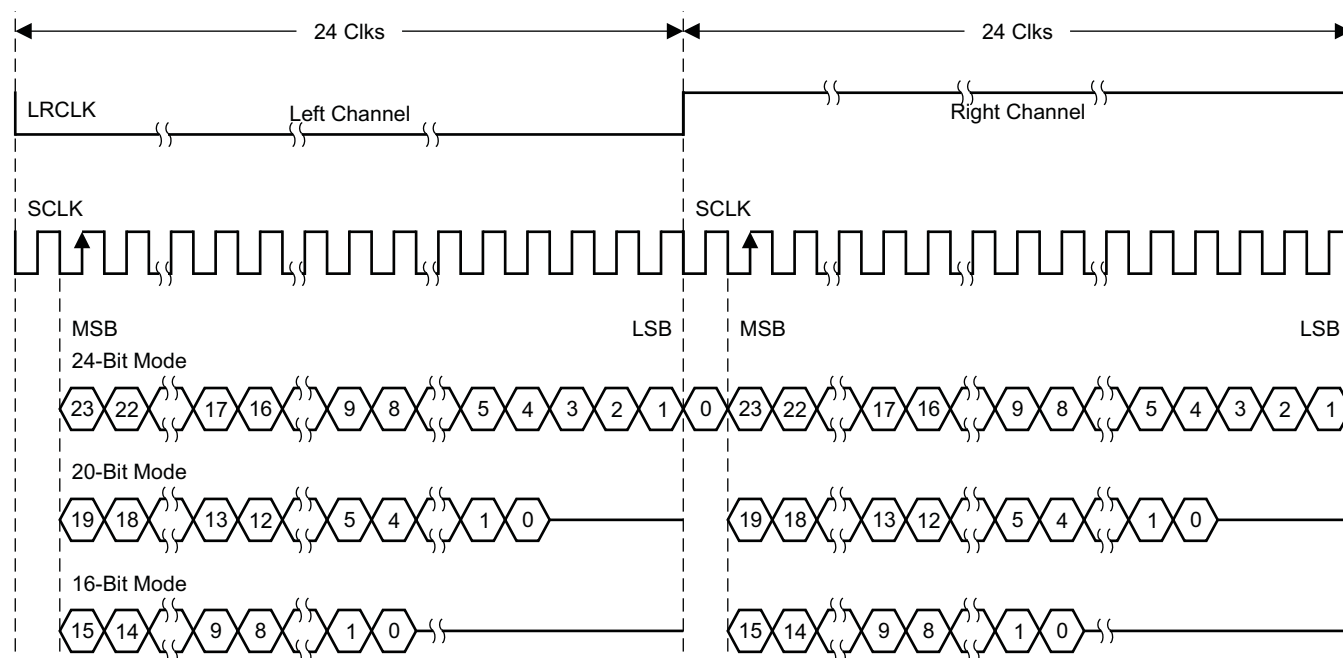
2-Channel I<sup>2</sup>S (Philips Format) Stereo Input



T0034-01

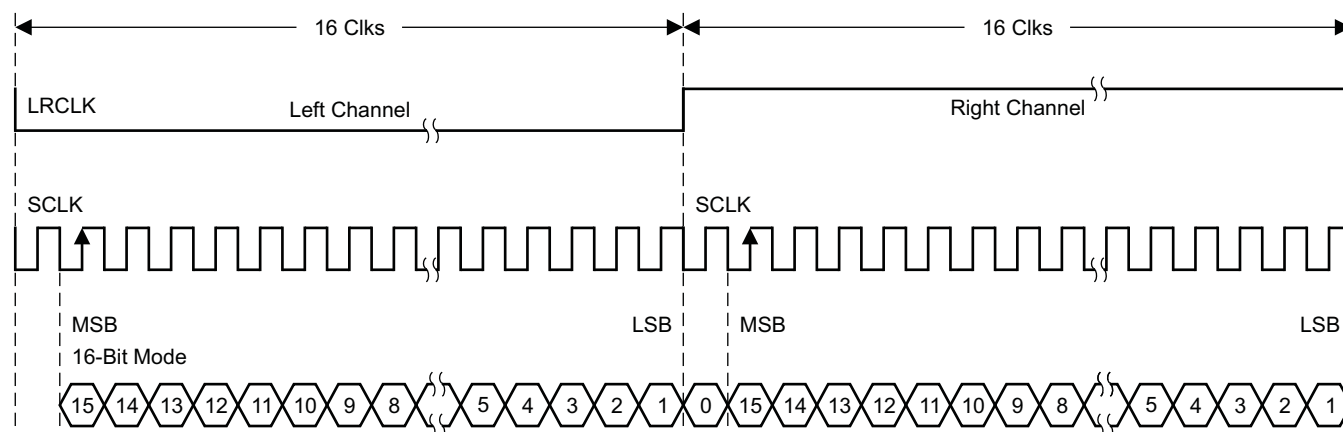
NOTE: All data presented in 2s-complement form with MSB first.

**Figure 17. I<sup>2</sup>S 64- $f_s$  Format**

2-Channel I<sup>2</sup>S (Philips Format) Stereo Input/Output (24-Bit Transfer Word Size)

T0092-01

NOTE: All data presented in 2s-complement form with MSB first.

**Figure 18. I<sup>2</sup>S 48-f<sub>s</sub> Format**2-Channel I<sup>2</sup>S (Philips Format) Stereo Input

T0266-01

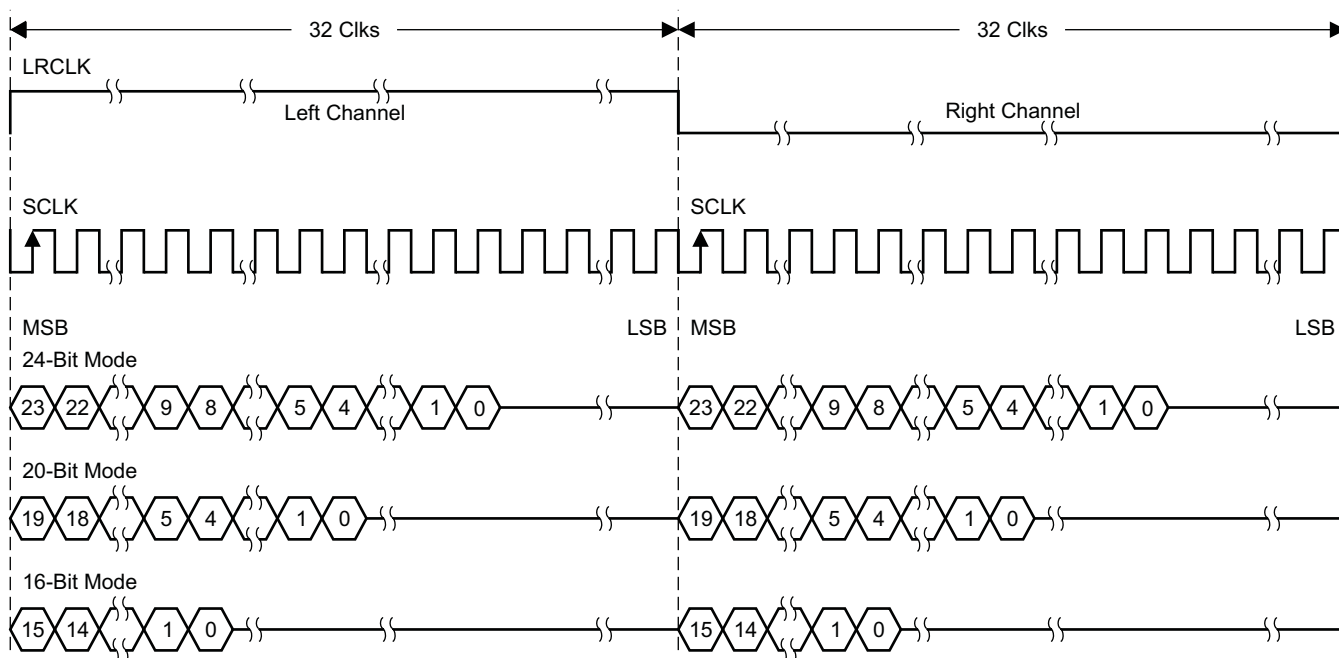
NOTE: All data presented in 2s-complement form with MSB first.

**Figure 19. I<sup>2</sup>S 32-f<sub>s</sub> Format**

## Left-Justified

Left-justified (LJ) timing uses LRCLK to define when the data being transmitted is for the left channel and when it is for the right channel. LRCLK is high for the left channel and low for the right channel. A bit clock running at  $32$ ,  $48$ , or  $64 \times f_s$  is used to clock in the data. The first bit of data appears on the data lines at the same time LRCLK toggles. The data is written MSB-first and is valid on the rising edge of the bit clock. The DAP masks unused trailing data-bit positions.

2-Channel Left-Justified Stereo Input

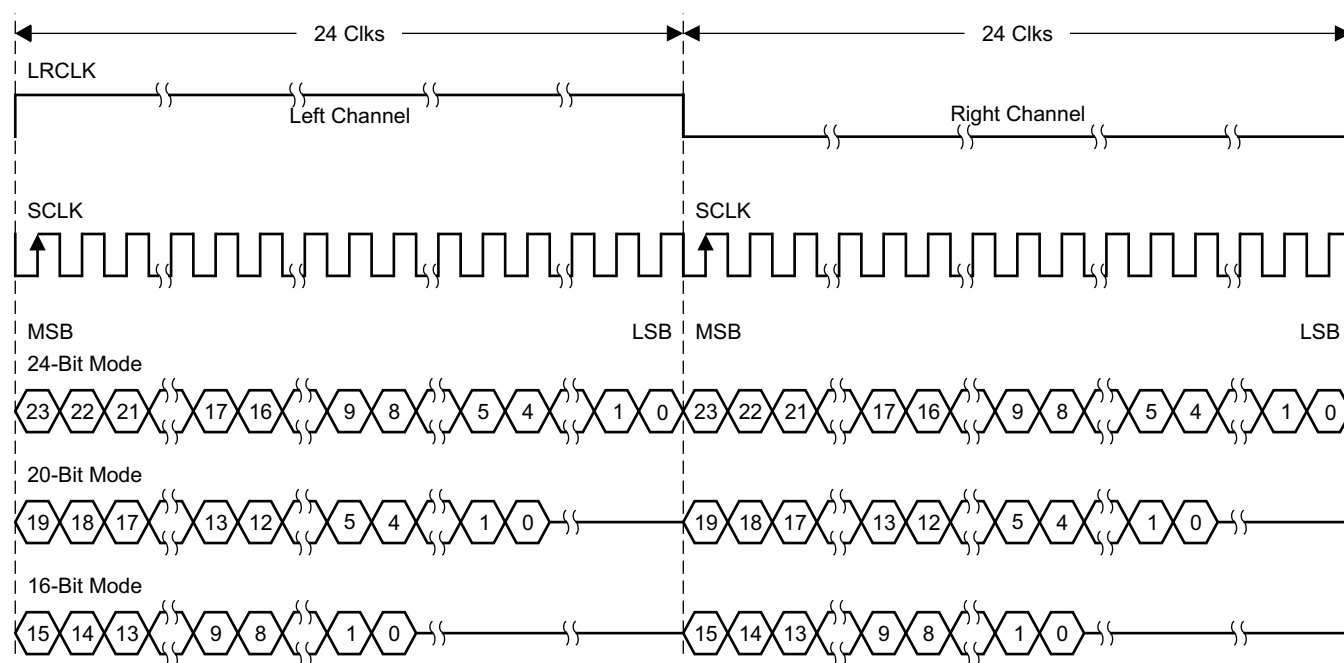


T0034-02

NOTE: All data presented in 2s-complement form with MSB first.

**Figure 20. Left-Justified 64- $f_s$  Format**

## 2-Channel Left-Justified Stereo Input (24-Bit Transfer Word Size)

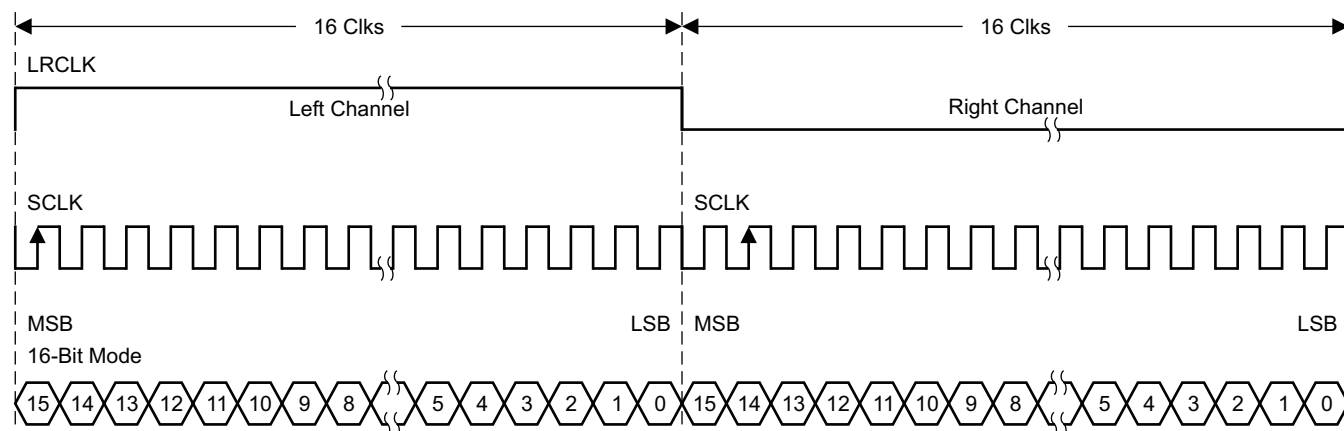


T0092-02

NOTE: All data presented in 2s-complement form with MSB first.

**Figure 21. Left-Justified 48- $f_s$  Format**

## 2-Channel Left-Justified Stereo Input



T0266-02

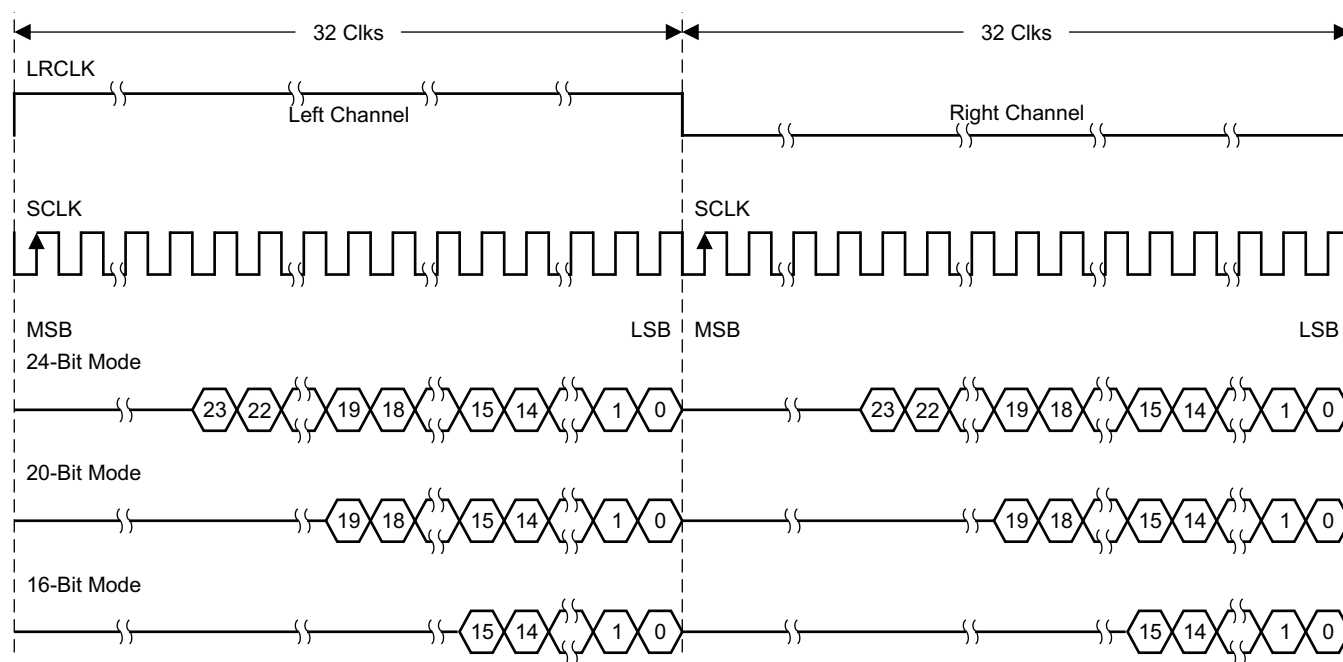
NOTE: All data presented in 2s-complement form with MSB first.

**Figure 22. Left-Justified 32- $f_s$  Format**

## Right-Justified

Right-justified (RJ) timing uses LRCLK to define when the data being transmitted is for the left channel and when it is for the right channel. LRCLK is high for the left channel and low for the right channel. A bit clock running at  $32, 48, \text{ or } 64 \times f_s$  is used to clock in the data. The first bit of data appears on the data 8 bit-clock periods (for 24-bit data) after LRCLK toggles. In RJ mode, the LSB of data is always clocked by the last bit clock before LRCLK transitions. The data is written MSB-first and is valid on the rising edge of the bit clock. The DAP masks unused leading data-bit positions.

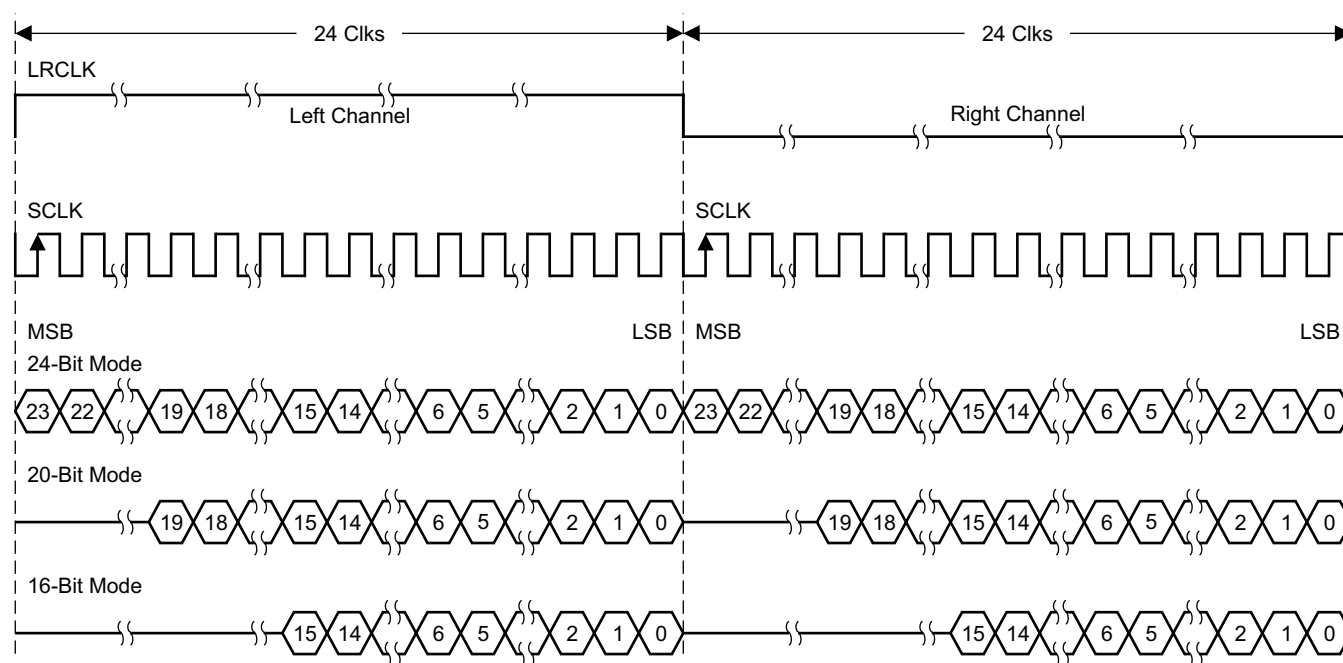
2-Channel Right-Justified (Sony Format) Stereo Input



T0034-03

**Figure 23. Right-Justified 64- $f_s$  Format**

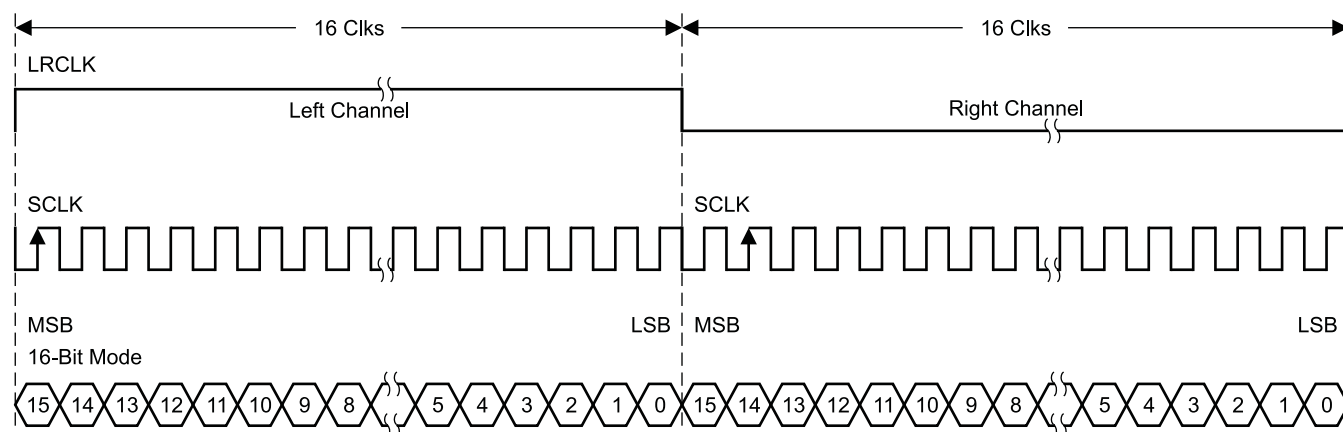
## 2-Channel Right-Justified Stereo Input (24-Bit Transfer Word Size)



T0092-03

Figure 24. Right-Justified 48- $f_s$  Format

## 2-Channel Right-Justified (Sony Format) Stereo Input



T0266-03

Figure 25. Right-Justified 32- $f_s$  Format

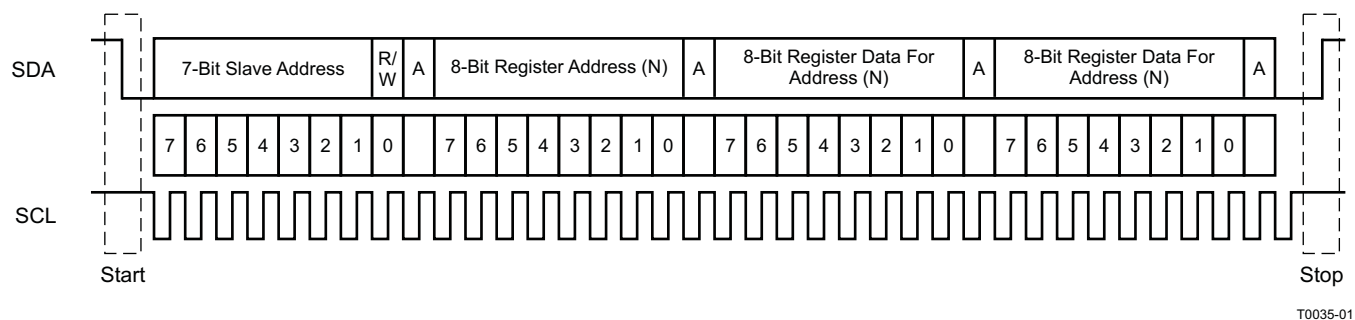
## I<sup>2</sup>C SERIAL CONTROL INTERFACE

The TAS5709 DAP has a bidirectional I<sup>2</sup>C interface that is compatible with the I<sup>2</sup>C (Inter IC) bus protocol and supports both 100-kHz and 400-kHz data transfer rates for single- and multiple-byte write and read operations. This is a slave-only device that does not support a multimaster bus environment or wait-state insertion. The control interface is used to program the registers of the device and to read device status.

The DAP supports the standard-mode I<sup>2</sup>C bus operation (100 kHz maximum) and the fast I<sup>2</sup>C bus operation (400 kHz maximum). The DAP performs all I<sup>2</sup>C operations without I<sup>2</sup>C wait cycles.

### General I<sup>2</sup>C Operation

The I<sup>2</sup>C bus employs two signals; SDA (data) and SCL (clock), to communicate between integrated circuits in a system. Data is transferred on the bus serially, one bit at a time. The address and data can be transferred in byte (8-bit) format, with the most-significant bit (MSB) transferred first. In addition, each byte transferred on the bus is acknowledged by the receiving device with an acknowledge bit. Each transfer operation begins with the master device driving a start condition on the bus and ends with the master device driving a stop condition on the bus. The bus uses transitions on the data pin (SDA) while the clock is high to indicate a start and stop conditions. A high-to-low transition on SDA indicates a start and a low-to-high transition indicates a stop. Normal data-bit transitions must occur within the low time of the clock period. These conditions are shown in Figure 26. The master generates the 7-bit slave address and the read/write (R/W) bit to open communication with another device and then waits for an acknowledge condition. The TAS5709 holds SDA low during the acknowledge clock period to indicate an acknowledgment. When this occurs, the master transmits the next byte of the sequence. Each device is addressed by a unique 7-bit slave address plus R/W bit (1 byte). All compatible devices share the same signals via a bidirectional bus using a wired-AND connection. An external pullup resistor must be used for the SDA and SCL signals to set the high level for the bus.



**Figure 26. Typical I<sup>2</sup>C Sequence**

There is no limit on the number of bytes that can be transmitted between start and stop conditions. When the last word transfers, the master generates a stop condition to release the bus. A generic data-transfer sequence is shown in Figure 26.

The 7-bit address for the TAS5709 is 0011 011 (0x36). The 7-bit address for the TAS5709A is 0011 101 (0x3A).

TAS5709 and TAS5709A addresses can be changed from 0x36 to 0x38 by writing 0x38 to device address register 0xF9.

### Single- and Multiple-Byte Transfers

The serial control interface supports both single-byte and multiple-byte read/write operations for subaddresses 0x00 to 0x1F. However, for the subaddresses 0x20 to 0xFF, the serial control interface supports only multiple-byte read/write operations (in multiples of 4 bytes).

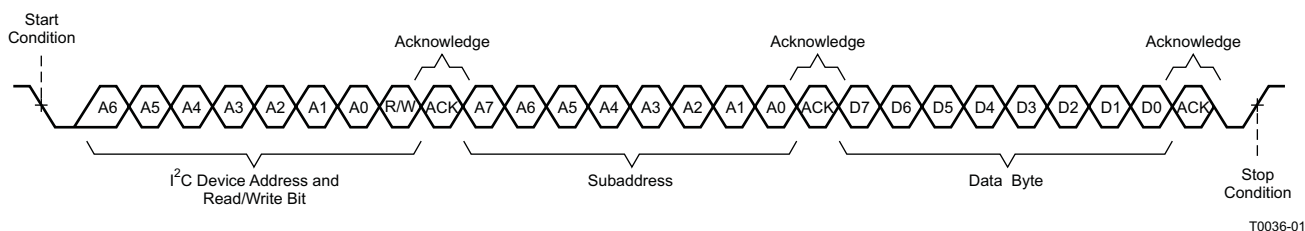
During multiple-byte read operations, the DAP responds with data, a byte at a time, starting at the subaddress assigned, as long as the master device continues to respond with acknowledges. If a particular subaddress does not contain 32 bits, the unused bits are read as logic 0.

During multiple-byte write operations, the DAP compares the number of bytes transmitted to the number of bytes that are required for each specific subaddress. For example, if a write command is received for a biquad subaddress, the DAP expects to receive five 32-bit words. If fewer than five 32-bit data words have been received when a stop command (or another start command) is received, the data received is discarded.

Supplying a subaddress for each subaddress transaction is referred to as random I<sup>2</sup>C addressing. The TAS5709 also supports sequential I<sup>2</sup>C addressing. For write transactions, if a subaddress is issued followed by data for that subaddress and the 15 subaddresses that follow, a sequential I<sup>2</sup>C write transaction has taken place, and the data for all 16 subaddresses is successfully received by the TAS5709. For I<sup>2</sup>C sequential write transactions, the subaddress then serves as the start address, and the amount of data subsequently transmitted before a stop or start is transmitted determines how many subaddresses are written. As was true for random addressing, sequential addressing requires that a complete set of data be transmitted. If only a partial set of data is written to the last subaddress, the data for the last subaddress is discarded. However, all other data written is accepted; only the incomplete data is discarded.

### Single-Byte Write

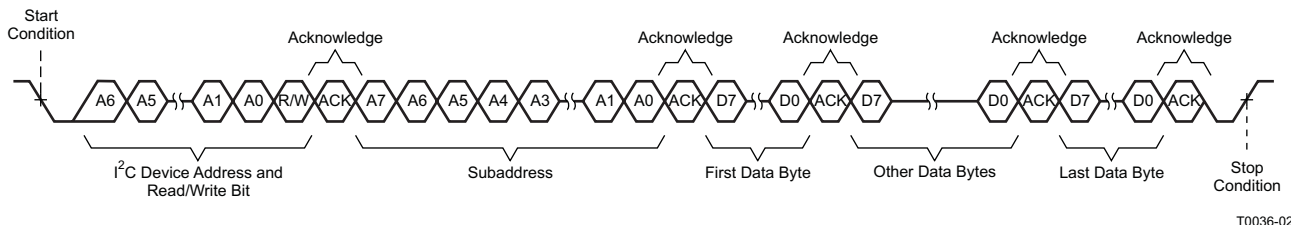
As shown in Figure 27, a single-byte data-write transfer begins with the master device transmitting a start condition followed by the I<sup>2</sup>C device address and the read/write bit. The read/write bit determines the direction of the data transfer. For a write data transfer, the read/write bit is 0. After receiving the correct I<sup>2</sup>C device address and the read/write bit, the DAP responds with an acknowledge bit. Next, the master transmits the address byte or bytes corresponding to the TAS5709 internal memory address being accessed. After receiving the address byte, the TAS5709 again responds with an acknowledge bit. Next, the master device transmits the data byte to be written to the memory address being accessed. After receiving the data byte, the TAS5709 again responds with an acknowledge bit. Finally, the master device transmits a stop condition to complete the single-byte data-write transfer.



**Figure 27. Single-Byte Write Transfer**

### Multiple-Byte Write\*\*\*

A multiple-byte data write transfer is identical to a single-byte data write transfer except that multiple data bytes are transmitted by the master device to the DAP as shown in Figure 28. After receiving each data byte, the TAS5709 responds with an acknowledge bit.



**Figure 28. Multiple-Byte Write Transfer**

## Single-Byte Read

As shown in Figure 29, a single-byte data read transfer begins with the master device transmitting a start condition followed by the I<sup>2</sup>C device address and the read/write bit. For the data read transfer, both a write followed by a read are actually done. Initially, a write is done to transfer the address byte or bytes of the internal memory address to be read. As a result, the read/write bit becomes a 0. After receiving the TAS5709 address and the read/write bit, TAS5709 responds with an acknowledge bit. In addition, after sending the internal memory address byte or bytes, the master device transmits another start condition followed by the TAS5709 address and the read/write bit again. This time the read/write bit becomes a 1, indicating a read transfer. After receiving the address and the read/write bit, the TAS5709 again responds with an acknowledge bit. Next, the TAS5709 transmits the data byte from the memory address being read. After receiving the data byte, the master device transmits a not acknowledge followed by a stop condition to complete the single byte data read transfer.

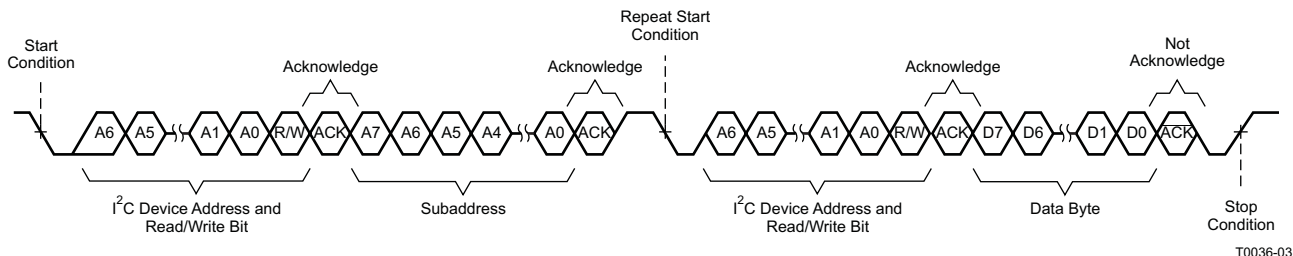


Figure 29. Single-Byte Read Transfer

## Multiple-Byte Read

A multiple-byte data read transfer is identical to a single-byte data read transfer except that multiple data bytes are transmitted by the TAS5709 to the master device as shown in Figure 30. Except for the last data byte, the master device responds with an acknowledge bit after receiving each data byte.

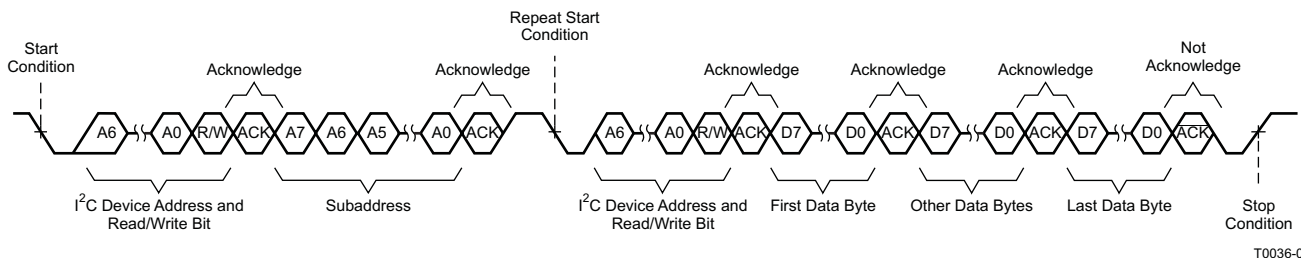


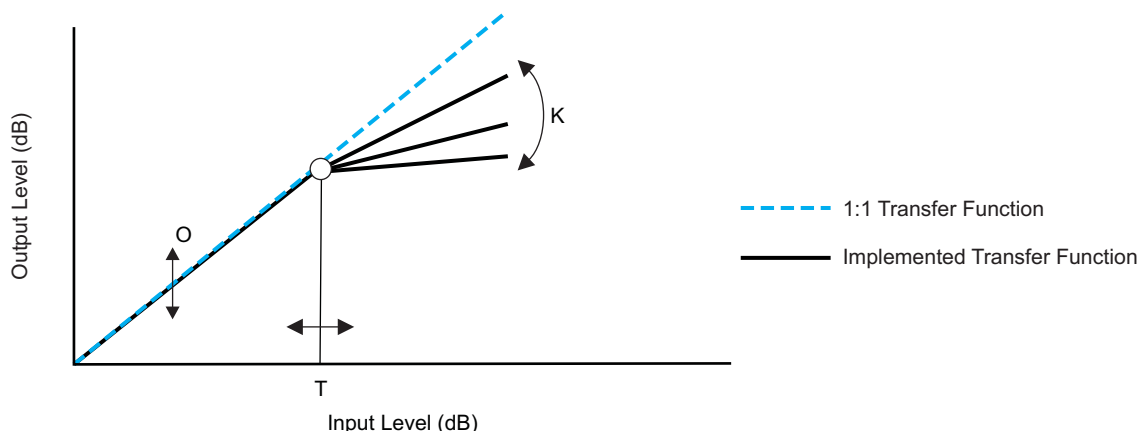
Figure 30. Multiple Byte Read Transfer

## Dynamic Range Control (DRC)

The DRC scheme has a single threshold, offset, and slope (all programmable). There is one ganged DRC for the high-band left/right channels and one DRC for the low-band left/right channels.

The DRC input/output diagram is shown in [Figure 31](#).

Refer to GDE software tool for more description on T, K, and O parameters.

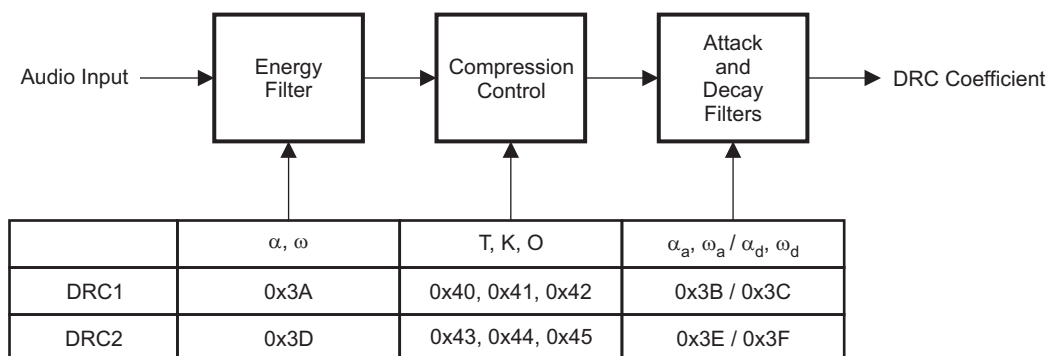


M0091-02

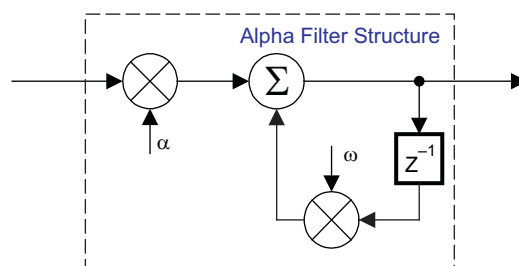
Professional-quality dynamic range compression automatically adjusts volume to flatten volume level.

- Each DRC has adjustable threshold, offset, and compression levels
- Programmable energy, attack, and decay time constants
- *Transparent compression*: compressors can attack fast enough to avoid apparent clipping before engaging, and decay times can be set slow enough to avoid pumping.

**Figure 31. Dynamic Range Control**



NOTE:  
 $\omega = 1 - \alpha$



B0265-01

T = 9.23 format, all other DRC coefficients are 3.23 format

**Figure 32. DRC Structure**

## BANK SWITCHING

The TAS5709 uses an approach called *bank switching* together with automatic sample-rate detection. All processing features that must be changed for different sample rates are stored internally in three banks. The user can program which sample rates map to each bank. By default, bank 1 is used in 32kHz mode, bank 2 is used in 44.1/48 kHz mode, and bank 3 is used for all other rates. Combined with the clock-rate autodetection feature, bank switching allows the TAS5709 to detect automatically a change in the input sample rate and switch to the appropriate bank without any MCU intervention.

An external controller configures bankable locations (0x29-0x36, 0x3A-0x3F, and 0x58-0x5F) for all three banks during the initialization sequence.

If auto bank switching is enabled (register 0x50, bits 2:0) , then the TAS5709 automatically swaps the coefficients for subsequent sample rate changes, avoiding the need for any external controller intervention for a sample rate change.

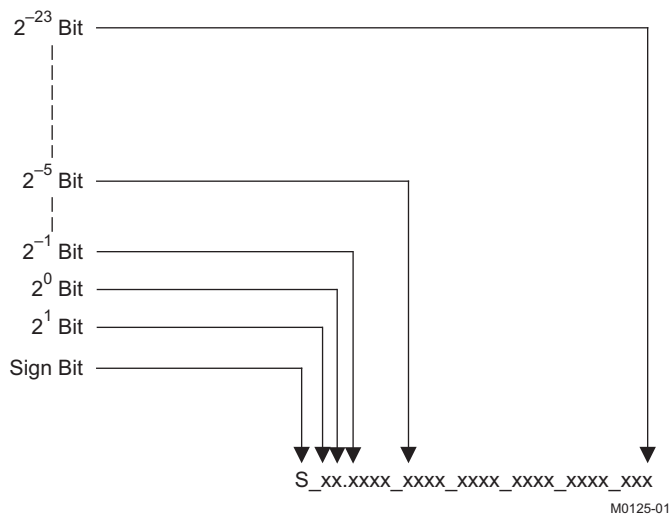
By default, bits 2:0 have the value 000; indicating that bank switching is disabled. In that state, updates to bankable locations take immediate effect. A write to register 0x50 with bits 2:0 being 001, 010, or 011 brings the system into the coefficient-bank-update state *update bank1*, *update bank2*, or *update bank3*, respectively. Any subsequent write to bankable locations updates the coefficient banks stored outside the DAP. After updating all the three banks, the system controller should issue a write to register 0x50 with bits 2:0 being 100; this changes the system state to automatic bank switching mode. In automatic bank switching mode, the TAS5709 automatically swaps banks based on the sample rate.

**Command sequences for updating DAP coefficients can be summarized as follows:**

1. **Bank switching disabled (default):** DAP coefficient writes take immediate effect and are not influenced by subsequent sample rate changes.  
OR  
**Bank switching enabled:**
  - a. Update bank-1 mode: Write "001" to bits 2:0 of reg 0x50. Load the 32 kHz coefficients.
  - b. Update bank-2 mode: Write "010" to bits 2:0 of reg 0x50. Load the 48 kHz coefficients.
  - c. Update bank-3 mode: Write "011" to bits 2:0 of reg 0x50. Load the other coefficients.
  - d. Enable automatic bank switching by writing "100" to bits 2:0 of reg 0x50.

## 26-Bit 3.23 Number Format

All mixer gain coefficients are 26-bit coefficients using a 3.23 number format. Numbers formatted as 3.23 numbers means that there are 3 bits to the left of the decimal point and 23 bits to the right of the decimal point. This is shown in [Figure 33](#) .



**Figure 33. 3.23 Format**

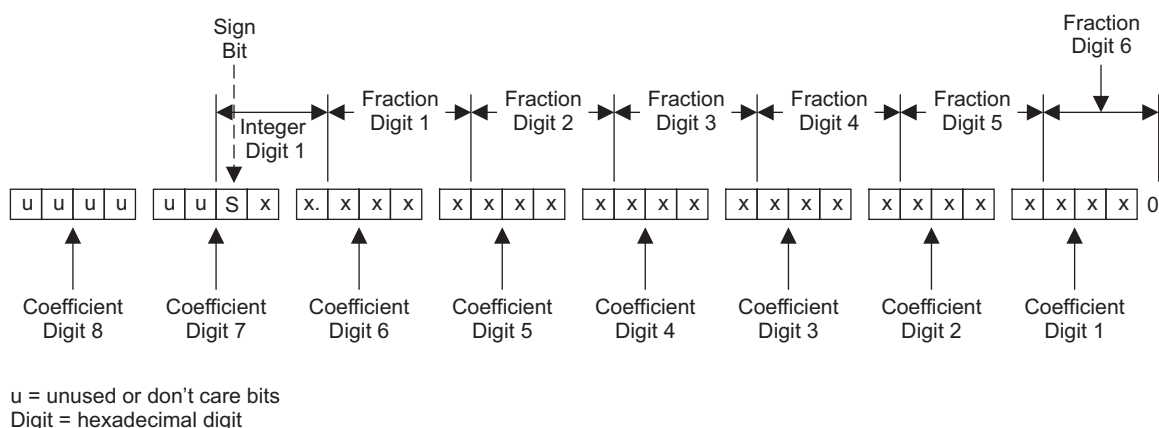
The decimal value of a 3.23 format number can be found by following the weighting shown in Figure 33. If the most significant bit is logic 0, the number is a positive number, and the weighting shown yields the correct number. If the most significant bit is a logic 1, then the number is a negative number. In this case every bit must be inverted, a 1 added to the result, and then the weighting shown in Figure 34 applied to obtain the magnitude of the negative number.

$$\begin{array}{c}
 2^1 \text{ Bit} \quad 2^0 \text{ Bit} \quad 2^{-1} \text{ Bit} \quad 2^{-4} \text{ Bit} \quad 2^{-23} \text{ Bit} \\
 \downarrow \quad \downarrow \quad \downarrow \quad \downarrow \quad \downarrow \\
 (1 \text{ or } 0) \times 2^1 + (1 \text{ or } 0) \times 2^0 + (1 \text{ or } 0) \times 2^{-1} + \dots (1 \text{ or } 0) \times 2^{-4} + \dots (1 \text{ or } 0) \times 2^{-23}
 \end{array}$$

M0126-01

**Figure 34. Conversion Weighting Factors—3.23 Format to Floating Point**

Gain coefficients, entered via the I2C bus, must be entered as 32-bit binary numbers. The format of the 32-bit number (4-byte or 8-digit hexadecimal number) is shown in Figure 35



**Figure 35. Alignment of 3.23 Coefficient in 32-Bit I2C Word**

#### Sample calculation for 3.23 format

| db | Linear            | Decimal                | Hex (3.23 Format)          |
|----|-------------------|------------------------|----------------------------|
| 0  | 1                 | 8388608                | 800000                     |
| 5  | 1.77              | 14917288               | 00E39EA8                   |
| -5 | 0.56              | 4717260                | 0047FACC                   |
| X  | $L = 10^{(X/20)}$ | $D = 8388608 \times L$ | $H = \text{dec2hex}(D, 8)$ |

#### Sample calculation for 9.17 format

| db | Linear            | Decimal               | Hex (9.17 Format)          |
|----|-------------------|-----------------------|----------------------------|
| 0  | 1                 | 131072                | 20000                      |
| 5  | 1.77              | 231997                | 38A3D                      |
| -5 | 0.56              | 73400                 | 11EB8                      |
| X  | $L = 10^{(X/20)}$ | $D = 131072 \times L$ | $H = \text{dec2hex}(D, 8)$ |

## Recommended Use Model

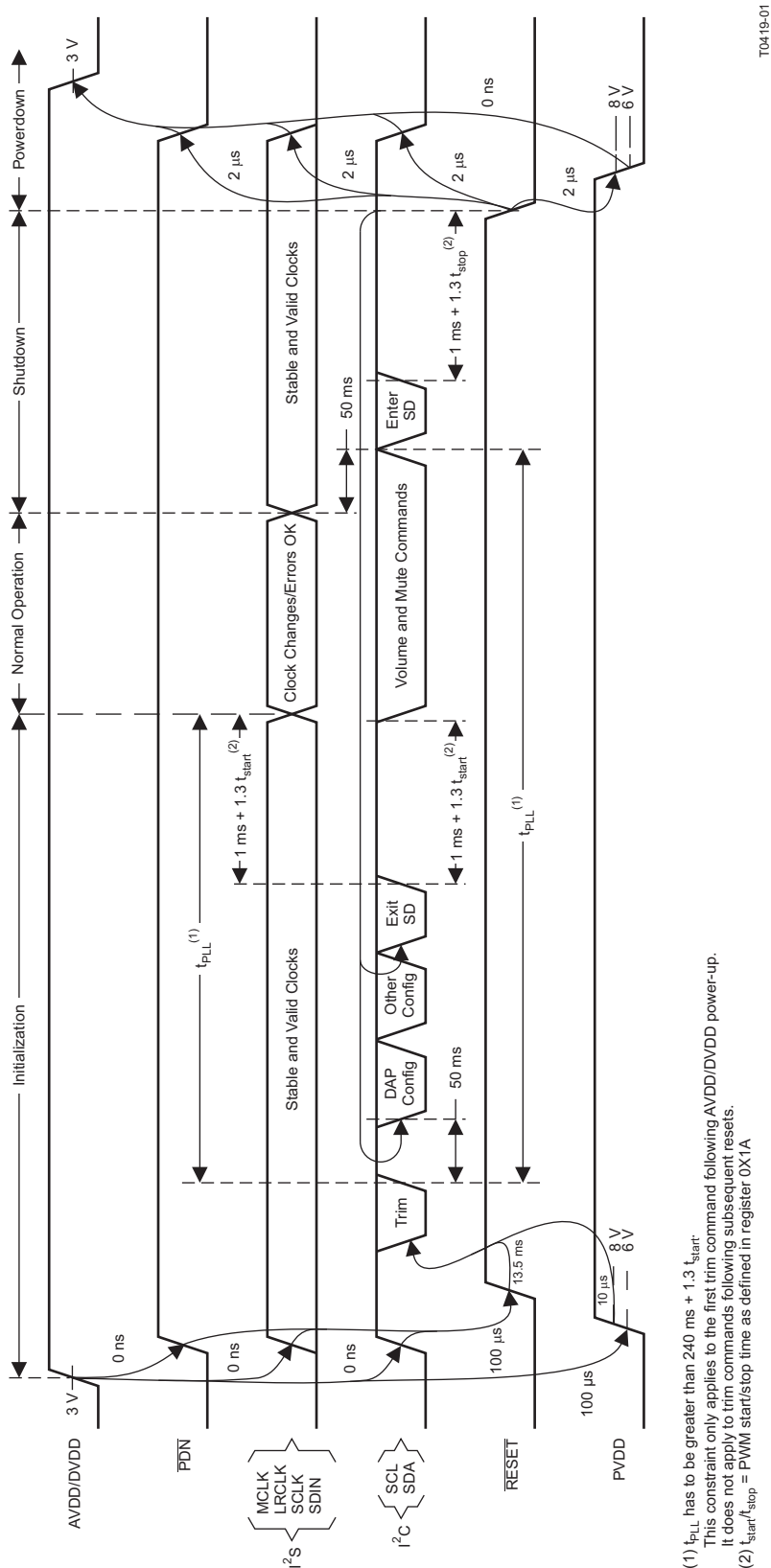


Figure 36. Recommended Command Sequence

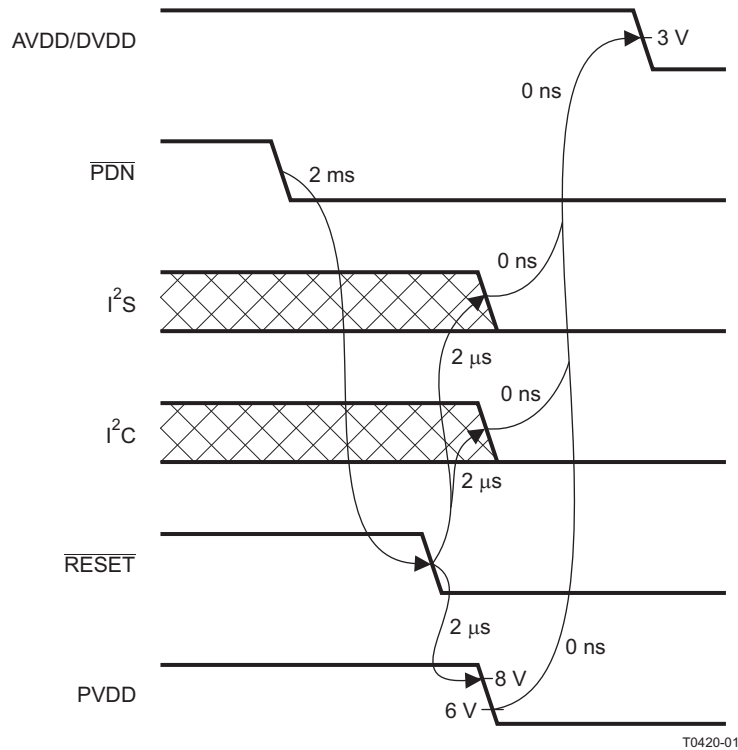


Figure 37. Power Loss Sequence

### Recommended Command Sequences

The DAP has two groups of commands. One set is for configuration and is intended for use only during initialization. The other set has built-in click and pop protection and may be used during normal operation while audio is streaming. The following supported command sequences illustrate how to initialize, operate, and shutdown the device.

#### Initialization Sequence

Use the following sequence to power-up and initialize the device:

1. Hold all digital inputs low and ramp up AVDD/DVDD to at least 3V.
2. Initialize digital inputs and PVDD supply as follows:
  - Drive RESETZ=0, PDNZ=1, and other digital inputs to their desired state while ensuring that all are never more than 2.5V above AVDD/DVDD. Provide stable and valid I2S clocks (MCLK, LRCLK, and SCLK). Wait at least 100μs, drive RESETZ=1, and wait at least another 13.5ms.
  - Ramp up PVDD to at least 8V while ensuring that it remains below 6V for at least 100μs after AVDD/DVDD reaches 3V. Then wait at least another 10μs.
3. Trim oscillator (write 0x00 to register 0x1B) and wait at least 50ms.
4. Configure the DAP via I2C (see Users's Guide for typical values):
  - Ch4 source select (0x21)
  - Biquads (0x29-36 and 0x58-5F)
  - DRC parameters (0x3A-46)
  - Bank select (0x50)
  - Mixers and gains (0x51-57)

5. Configure remaining registers
6. Exit shutdown (sequence defined below).

### Normal Operation

The following are the only events supported during normal operation:

- (a) Writes to master/channel volume registers
- (b) Writes to soft mute register
- (c) Enter and exit shutdown (sequence defined below)
- (d) Clock errors and rate changes

**Note:** Events (c) and (d) are not supported for  $240\text{ms} + 1.3 \cdot T_{\text{start}}$  after trim following AVDD/DVDD powerup ramp (where  $T_{\text{start}}$  is specified by register 0x1A).

### Shutdown Sequence

Enter:

1. Ensure I2S clocks have been stable and valid for at least 50ms.
2. Write 0x40 to register 0x05.
3. Wait at least  $1\text{ms} + 1.3 \cdot T_{\text{stop}}$  (where  $T_{\text{stop}}$  is specified by register 0x1A).
4. Once in shutdown, stable clocks are not required while device remains idle.
5. If desired, reconfigure by ensuring that clocks have been stable and valid for at least 50ms before returning to step 4 of initialization sequence.

Exit:

1. Ensure I2S clocks have been stable and valid for at least 50ms.
2. Write 0x00 to register 0x05 (exit shutdown command may not be serviced for as much as 240ms after trim following AVDD/DVDD powerup ramp).
3. Wait at least  $1\text{ms} + 1.3 \cdot T_{\text{start}}$  (where  $T_{\text{start}}$  is specified by register 0x1A).
4. Proceed with normal operation.

### Powerdown Sequence

Use the following sequence to powerdown the device and its supplies:

1. If time permits, enter shutdown (sequence defined above); else, in case of sudden power loss, assert  $\text{PDNZ}=0$  and wait at least 2ms.
2. Assert  $\text{RESETZ}=0$ .
3. Drive digital inputs low and ramp down PVDD supply as follows:
  - Drive all digital inputs low after  $\text{RESETZ}$  has been low for at least 2 $\mu\text{s}$ .
  - Ramp down PVDD while ensuring that it remains above 8V until  $\text{RESETZ}$  has been low for at least 2 $\mu\text{s}$ .
4. Ramp down AVDD/DVDD while ensuring that it remains above 3V until PVDD is below 6V and that it is never more than 2.5V below the digital inputs.

**Table 2. Serial Control Interface Register Summary**

| SUBADDRESS  | REGISTER NAME                  | NO. OF BYTES | CONTENTS                                | INITIALIZATION VALUE |
|-------------|--------------------------------|--------------|-----------------------------------------|----------------------|
|             |                                |              | A u indicates unused bits.              |                      |
| 0x00        | Clock control register         | 1            | Description shown in subsequent section | 0x6C                 |
| 0x01        | Device ID register             | 1            | Description shown in subsequent section | 0x70                 |
| 0x02        | Error status register          | 1            | Description shown in subsequent section | 0x00                 |
| 0x03        | System control register 1      | 1            | Description shown in subsequent section | 0xA0                 |
| 0x04        | Serial data interface register | 1            | Description shown in subsequent section | 0x05                 |
| 0x05        | System control register 2      | 1            | Description shown in subsequent section | 0x40                 |
| 0x06        | Soft mute register             | 1            | Description shown in subsequent section | 0x00                 |
| 0x07        | Master volume                  | 1            | Description shown in subsequent section | 0xFF (mute)          |
| 0x08        | Channel 1 vol                  | 1            | Description shown in subsequent section | 0x30 (0 dB)          |
| 0x09        | Channel 2 vol                  | 1            | Description shown in subsequent section | 0x30 (0 dB)          |
| 0x0A        | Fine master volume             | 1            | Description shown in subsequent section | 0x00 (0 dB)          |
| 0x0B - 0x0D |                                | 1            | Reserved <sup>(1)</sup>                 |                      |
| 0x0E        | Volume configuration register  | 1            | Description shown in subsequent section | 0x91                 |
| 0x0F        |                                | 1            | Reserved <sup>(1)</sup>                 |                      |
| 0x10        | Modulation limit register      | 1            | Description shown in subsequent section | 0x02                 |
| 0x11        | IC delay channel 1             | 1            | Description shown in subsequent section | 0xAC                 |
| 0x12        | IC delay channel 2             | 1            | Description shown in subsequent section | 0x54                 |
| 0x13        | IC delay channel 3             | 1            | Description shown in subsequent section | 0xAC                 |
| 0x14        | IC delay channel 4             | 1            | Description shown in subsequent section | 0x54                 |
| 0x15-0x19   |                                | 1            | Reserved <sup>(1)</sup>                 |                      |
| 0x1A        | Start/stop period register     | 1            |                                         | 0x0F                 |
| 0x1B        | Oscillator trim register       | 1            |                                         | 0x82                 |
| 0x1C        | BKND_ERR register              | 1            |                                         | 0x02                 |
| 0x1D–0x1F   |                                | 1            | Reserved <sup>(1)</sup>                 |                      |
| 0x20        | Input MUX register             | 4            | Description shown in subsequent section | 0x0001 7772          |
| 0x21        | Ch 4 source select register    | 4            | Description shown in subsequent section | 0x0000 4303          |
| 0x22 -0x24  |                                | 4            | Reserved <sup>(1)</sup>                 |                      |
| 0x25        | PWM MUX register               | 4            | Description shown in subsequent section | 0x0102 1345          |
| 0x26-0x28   |                                | 4            | Reserved <sup>(1)</sup>                 |                      |
| 0x29        | ch1_bq[0]                      | 20           | u[31:26], b0[25:0]                      | 0x0080 0000          |
|             |                                |              | u[31:26], b1[25:0]                      | 0x0000 0000          |
|             |                                |              | u[31:26], b2[25:0]                      | 0x0000 0000          |
|             |                                |              | u[31:26], a1[25:0]                      | 0x0000 0000          |
|             |                                |              | u[31:26], a2[25:0]                      | 0x0000 0000          |
| 0x2A        | ch1_bq[1]                      | 20           | u[31:26], b0[25:0]                      | 0x0080 0000          |
|             |                                |              | u[31:26], b1[25:0]                      | 0x0000 0000          |
|             |                                |              | u[31:26], b2[25:0]                      | 0x0000 0000          |
|             |                                |              | u[31:26], a1[25:0]                      | 0x0000 0000          |
|             |                                |              | u[31:26], a2[25:0]                      | 0x0000 0000          |

(1) Reserved registers should not be accessed.

**Table 2. Serial Control Interface Register Summary (continued)**

| SUBADDRESS | REGISTER NAME | NO. OF BYTES | CONTENTS           | INITIALIZATION VALUE |
|------------|---------------|--------------|--------------------|----------------------|
| 0x2B       | ch1_bq[2]     | 20           | u[31:26], b0[25:0] | 0x0080 0000          |
|            |               |              | u[31:26], b1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], b2[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a2[25:0] | 0x0000 0000          |
| 0x2C       | ch1_bq[3]     | 20           | u[31:26], b0[25:0] | 0x0080 0000          |
|            |               |              | u[31:26], b1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], b2[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a2[25:0] | 0x0000 0000          |
| 0x2D       | ch1_bq[4]     | 20           | u[31:26], b0[25:0] | 0x0080 0000          |
|            |               |              | u[31:26], b1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], b2[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a2[25:0] | 0x0000 0000          |
| 0x2E       | ch1_bq[5]     | 20           | u[31:26], b0[25:0] | 0x0080 0000          |
|            |               |              | u[31:26], b1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], b2[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a2[25:0] | 0x0000 0000          |
| 0x2F       | ch1_bq[6]     | 20           | u[31:26], b0[25:0] | 0x0080 0000          |
|            |               |              | u[31:26], b1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], b2[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a2[25:0] | 0x0000 0000          |
| 0x30       | ch2_bq[0]     | 20           | u[31:26], b0[25:0] | 0x0080 0000          |
|            |               |              | u[31:26], b1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], b2[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a2[25:0] | 0x0000 0000          |
| 0x31       | ch2_bq[1]     | 20           | u[31:26], b0[25:0] | 0x0080 0000          |
|            |               |              | u[31:26], b1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], b2[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a2[25:0] | 0x0000 0000          |
| 0x32       | ch2_bq[2]     | 20           | u[31:26], b0[25:0] | 0x0080 0000          |
|            |               |              | u[31:26], b1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], b2[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a2[25:0] | 0x0000 0000          |
| 0x33       | ch2_bq[3]     | 20           | u[31:26], b0[25:0] | 0x0080 0000          |
|            |               |              | u[31:26], b1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], b2[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a1[25:0] | 0x0000 0000          |
|            |               |              | u[31:26], a2[25:0] | 0x0000 0000          |

**Table 2. Serial Control Interface Register Summary (continued)**

| SUBADDRESS  | REGISTER NAME          | NO. OF BYTES | CONTENTS                               | INITIALIZATION VALUE |
|-------------|------------------------|--------------|----------------------------------------|----------------------|
| 0x34        | ch2_bq[4]              | 20           | u[31:26], b0[25:0]                     | 0x0080 0000          |
|             |                        |              | u[31:26], b1[25:0]                     | 0x0000 0000          |
|             |                        |              | u[31:26], b2[25:0]                     | 0x0000 0000          |
|             |                        |              | u[31:26], a1[25:0]                     | 0x0000 0000          |
|             |                        |              | u[31:26], a2[25:0]                     | 0x0000 0000          |
| 0x35        | ch2_bq[5]              | 20           | u[31:26], b0[25:0]                     | 0x0080 0000          |
|             |                        |              | u[31:26], b1[25:0]                     | 0x0000 0000          |
|             |                        |              | u[31:26], b2[25:0]                     | 0x0000 0000          |
|             |                        |              | u[31:26], a1[25:0]                     | 0x0000 0000          |
|             |                        |              | u[31:26], a2[25:0]                     | 0x0000 0000          |
| 0x36        | ch2_bq[6]              | 20           | u[31:26], b0[25:0]                     | 0x0080 0000          |
|             |                        |              | u[31:26], b1[25:0]                     | 0x0000 0000          |
|             |                        |              | u[31:26], b2[25:0]                     | 0x0000 0000          |
|             |                        |              | u[31:26], a1[25:0]                     | 0x0000 0000          |
|             |                        |              | u[31:26], a2[25:0]                     | 0x0000 0000          |
| 0x37 - 0x39 |                        | 4            | Reserved <sup>(2)</sup>                |                      |
| 0x3A        | DRC1 ae <sup>(3)</sup> | 8            | u[31:26], ae[25:0]                     | 0x0080 0000          |
|             | DRC1 (1 – ae)          |              | u[31:26], (1 – ae)[25:0]               | 0x0000 0000          |
| 0x3B        | DRC1 aa                | 8            | u[31:26], aa[25:0]                     | 0x0080 0000          |
|             | DRC1 (1 – aa)          |              | u[31:26], (1 – aa)[25:0]               | 0x0000 0000          |
| 0x3C        | DRC1 ad                | 8            | u[31:26], ad[25:0]                     | 0x0080 0000          |
|             | DRC1 (1 – ad)          |              | u[31:26], (1 – ad)[25:0]               | 0x0000 0000          |
| 0x3D        | DRC2 ae                | 8            | u[31:26], ae[25:0]                     | 0x0080 0000          |
|             | DRC 2 (1 – ae)         |              | u[31:26], (1 – ae)[25:0]               | 0x0000 0000          |
| 0x3E        | DRC2 aa                | 8            | u[31:26], aa[25:0]                     | 0x0080 0000          |
|             | DRC2 (1 – aa)          |              | u[31:26], (1 – aa)[25:0]               | 0x0000 0000          |
| 0x3F        | DRC2 ad                | 8            | u[31:26], ad[25:0]                     | 0x0080 0000          |
|             | DRC2 (1 – ad)          |              | u[31:26], (1 – ad)[25:0]               | 0x0000 0000          |
| 0x40        | DRC1-T                 | 4            | T1[31:0] (9.23 format)                 | 0xFDA2 1490          |
| 0x41        | DRC1-K                 | 4            | u[31:26], K1[25:0]                     | 0x0384 2109          |
| 0x42        | DRC1-O                 | 4            | u[31:26], O1[25:0]                     | 0x0008 4210          |
| 0x43        | DRC2-T                 | 4            | T2[31:0] (9.23 format)                 | 0xFDA2 1490          |
| 0x44        | DRC2-K                 | 4            | u[31:26], K2[25:0]                     | 0x0384 2109          |
| 0x45        | DRC2-O                 | 4            | u[31:26], O2[25:0]                     | 0x0008 4210          |
| 0x46        | DRC control            | 4            | Description show in subsequent section | 0x0000 0000          |
| 0x47–0x4F   |                        | 4            | Reserved <sup>(2)</sup>                |                      |
| 0x50        | Bank switch control    | 4            | Description show in subsequent section | 0x0F70 8000          |
| 0x51        | Ch 1 output mixer      | 8            | Ch 1 output mix1[1]                    | 0x0080 0000          |
|             |                        |              | Ch 1 output mix1[0]                    | 0x0000 0000          |
| 0x52        | Ch 2 output mixer      | 12           | Ch 2 output mix2[2]                    | 0x0080 0000          |
|             |                        |              | Ch 2 output mix2[1]                    | 0x0000 0000          |
|             |                        |              | Ch 2 output mix2[0]                    | 0x0000 0000          |

(2) Reserved registers should not be accessed.

(3) "ae" stands for  $\infty$  of energy filter, "aa" stands for  $\infty$  of attack filter and "ad" stands for  $\infty$  of decay filter and  $1 - \infty = \omega$ .

**Table 2. Serial Control Interface Register Summary (continued)**

| SUBADDRESS | REGISTER NAME         | NO. OF BYTES | CONTENTS                          | INITIALIZATION VALUE |
|------------|-----------------------|--------------|-----------------------------------|----------------------|
| 0x53       | Ch 1 input mixer      | 16           | Ch 1 input mixer[3]               | 0x0080 0000          |
|            |                       |              | Ch 1 input mixer[2]               | 0x0000 0000          |
|            |                       |              | Ch 1 input mixer[1]               | 0x0000 0000          |
|            |                       |              | Ch 1 input mixer[0]               | 0x0080 0000          |
| 0x54       | Ch 2 input mixer      | 16           | Ch 2 input mixer[3]               | 0x0080 0000          |
|            |                       |              | Ch 2 input mixer[2]               | 0x0000 0000          |
|            |                       |              | Ch 2 input mixer[1]               | 0x0000 0000          |
|            |                       |              | Ch 2 input mixer[0]               | 0x0080 0000          |
| 0x55       | Channel 3 input mixer | 12           | Channel 3 input mixer [2]         | 0x0080 0000          |
|            |                       |              | Channel 3 input mixer [1]         | 0x0000 0000          |
|            |                       |              | Channel 3 input mixer [0]         | 0x0000 0000          |
| 0x56       | Output post-scale     | 4            | u[31:26], post[25:0]              | 0x0080 0000          |
| 0x57       | Output pre-scale      | 4            | u[31:26], pre[25:0] (9.17 format) | 0x0002 0000          |
| 0x58       | ch1 BQ[7]             | 20           | u[31:26], b0[25:0]                | 0x0080 0000          |
|            |                       |              | u[31:26], b1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], b2[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a2[25:0]                | 0x0000 0000          |
| 0x59       | ch1 BQ[8]             | 20           | u[31:26], b0[25:0]                | 0x0080 0000          |
|            |                       |              | u[31:26], b1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], b2[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a2[25:0]                | 0x0000 0000          |
| 0x5A       | ch4 BQ[0]             | 20           | u[31:26], b0[25:0]                | 0x0080 0000          |
|            |                       |              | u[31:26], b1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], b2[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a2[25:0]                | 0x0000 0000          |
| 0x5B       | ch4 BQ[1]             | 20           | u[31:26], b0[25:0]                | 0x0080 0000          |
|            |                       |              | u[31:26], b1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], b2[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a2[25:0]                | 0x0000 0000          |
| 0x5C       | ch2 BQ[7]             | 20           | u[31:26], b0[25:0]                | 0x0080 0000          |
|            |                       |              | u[31:26], b1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], b2[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a2[25:0]                | 0x0000 0000          |
| 0x5D       | ch2 BQ[8]             | 20           | u[31:26], b0[25:0]                | 0x0080 0000          |
|            |                       |              | u[31:26], b1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], b2[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a1[25:0]                | 0x0000 0000          |
|            |                       |              | u[31:26], a2[25:0]                | 0x0000 0000          |

**Table 2. Serial Control Interface Register Summary (continued)**

| SUBADDRESS | REGISTER NAME          | NO. OF BYTES | CONTENTS                                                 | INITIALIZATION VALUE |
|------------|------------------------|--------------|----------------------------------------------------------|----------------------|
| 0x5E       | ch3 BQ[0]              | 20           | u[31:26], b0[25:0]                                       | 0x0080 0000          |
|            |                        |              | u[31:26], b1[25:0]                                       | 0x0000 0000          |
|            |                        |              | u[31:26], b2[25:0]                                       | 0x0000 0000          |
|            |                        |              | u[31:26], a1[25:0]                                       | 0x0000 0000          |
|            |                        |              | u[31:26], a2[25:0]                                       | 0x0000 0000          |
| 0x5F       | ch3 BQ[1]              | 20           | u[31:26], b0[25:0]                                       | 0x0080 0000          |
|            |                        |              | u[31:26], b1[25:0]                                       | 0x0000 0000          |
|            |                        |              | u[31:26], b2[25:0]                                       | 0x0000 0000          |
|            |                        |              | u[31:26], a1[25:0]                                       | 0x0000 0000          |
|            |                        |              | u[31:26], a2[25:0]                                       | 0x0000 0000          |
| 0x60–0xF8  |                        | 4            | Reserved <sup>(4)</sup>                                  | 0x0000 0000          |
| 0XF9       | Update Dev Address Reg | 4            | u[31:8], New Dev Id[7:0] (New Dev Id = 0X38 for TAS5709) | 0x0000 0036          |
| 0xFA–0xFF  |                        | 4            | Reserved <sup>(4)</sup>                                  | 0x0000 0000          |

(4) Reserved registers should not be accessed.

All DAP coefficients are 3.23 format unless specified otherwise.

## CLOCK CONTROL REGISTER (0x00)

The clocks and data rates are automatically determined by the TAS5709. The clock control register contains the auto-detected clock status. Bits D7–D5 reflect the sample rate. Bits D4–D2 reflect the MCLK frequency.

**Table 3. Clock Control Register (0x00)**

| D7       | D6       | D5       | D4       | D3       | D2       | D1       | D0       | FUNCTION                                                                |
|----------|----------|----------|----------|----------|----------|----------|----------|-------------------------------------------------------------------------|
| 0        | 0        | 0        | –        | –        | –        | –        | –        | $f_s = 32\text{-kHz}$ sample rate                                       |
| 0        | 0        | 1        | –        | –        | –        | –        | –        | Reserved <sup>(1)</sup>                                                 |
| 0        | 1        | 0        | –        | –        | –        | –        | –        | Reserved <sup>(1)</sup>                                                 |
| <b>0</b> | <b>1</b> | <b>1</b> | –        | –        | –        | –        | –        | <b><math>f_s = 44.1/48\text{-kHz}</math> sample rate</b> <sup>(2)</sup> |
| 1        | 0        | 0        | –        | –        | –        | –        | –        | $f_s = 16\text{-kHz}$ sample rate                                       |
| 1        | 0        | 1        | –        | –        | –        | –        | –        | $f_s = 22.05/24\text{-kHz}$ sample rate                                 |
| 1        | 1        | 0        | –        | –        | –        | –        | –        | $f_s = 8\text{-kHz}$ sample rate                                        |
| 1        | 1        | 1        | –        | –        | –        | –        | –        | $f_s = 11.025/12\text{-kHz}$ sample rate                                |
| –        | –        | –        | 0        | 0        | 0        | –        | –        | MCLK frequency = $64 \times f_s$ <sup>(3)</sup>                         |
| –        | –        | –        | 0        | 0        | 1        | –        | –        | MCLK frequency = $128 \times f_s$ <sup>(3)</sup>                        |
| –        | –        | –        | 0        | 1        | 0        | –        | –        | MCLK frequency = $192 \times f_s$ <sup>(4)</sup>                        |
| –        | –        | –        | <b>0</b> | <b>1</b> | <b>1</b> | –        | –        | <b>MCLK frequency = <math>256 \times f_s</math></b> <sup>(2)(5)</sup>   |
| –        | –        | –        | 1        | 0        | 0        | –        | –        | MCLK frequency = $384 \times f_s$                                       |
| –        | –        | –        | 1        | 0        | 1        | –        | –        | MCLK frequency = $512 \times f_s$                                       |
| –        | –        | –        | 1        | 1        | 0        | –        | –        | Reserved <sup>(1)</sup>                                                 |
| –        | –        | –        | 1        | 1        | 1        | –        | –        | Reserved <sup>(1)</sup>                                                 |
| –        | –        | –        | –        | –        | –        | <b>0</b> | –        | <b>Reserved<sup>(1)</sup></b>                                           |
| –        | –        | –        | –        | –        | –        | –        | <b>0</b> | Reserved <sup>(1)</sup>                                                 |

(1) Reserved registers should not be accessed.

(2) Default values are in **bold**.

(3) Only available for 44.1 kHz and 48 kHz rates.

(4) Rate only available for 32/44.1/48 KHz sample rates

(5) Not available at 8 kHz

## DEVICE ID REGISTER (0x01)

The device ID register contains the ID code for the firmware revision.

**Table 4. General Status Register (0x01)**

| D7 | D6       | D5       | D4       | D3       | D2       | D1       | D0       | FUNCTION                   |
|----|----------|----------|----------|----------|----------|----------|----------|----------------------------|
| X  | –        | –        | –        | –        | –        | –        | –        | Reserved                   |
| –  | <b>1</b> | <b>1</b> | <b>1</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>Identification code</b> |

## ERROR STATUS REGISTER (0x02)

The error bits are sticky and are not cleared by the hardware. This means that the software must clear the register (write zeroes) and then read them to determine if they are persistent errors.

Error Definitions:

- MCLK Error : MCLK frequency is changing. The number of MCLKs per LRCLK is changing.
- SCLK Error: The number of SCLKs per LRCLK is changing.
- LRCLK Error: LRCLK frequency is changing.
- Frame Slip: LRCLK phase is drifting with respect to internal Frame Sync.

**Table 5. Error Status Register (0x02)**

| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | FUNCTION                                                              |
|----|----|----|----|----|----|----|----|-----------------------------------------------------------------------|
| 1  | -  | -  | -  | -  | -  | -  | -  | MCLK error                                                            |
| -  | 1  | -  | -  | -  | -  | -  | -  | PLL autolock error                                                    |
| -  | -  | 1  | -  | -  | -  | -  | -  | SCLK error                                                            |
| -  | -  | -  | 1  | -  | -  | -  | -  | LRCLK error                                                           |
| -  | -  | -  | -  | 1  | -  | -  | -  | Frame slip                                                            |
| -  | -  | -  | -  | -  | -  | 1  | -  | Over current, Over Temperature, Over voltage or Under voltage errors. |
| -  | -  | -  | -  | -  | -  | -  | 1  | Overtemperature warning (sets around 145°)                            |
| 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0  | <b>No errors</b> <sup>(1)</sup>                                       |

(1) Default values are in **bold**.

## SYSTEM CONTROL REGISTER 1 (0x03)

The system control register 1 has several functions:

- Bit D7: If 0, the dc-blocking filter for each channel is disabled.  
If 1, the dc-blocking filter (-3 dB cutoff <1 Hz) for each channel is enabled (default).
- Bit D5: If 0, use soft unmute on recovery from clock error. This is a slow recovery. Unmute takes same time as volume ramp defined in reg 0x0E.  
If 1, use hard unmute on recovery from clock error (default). This is a fast recovery, a single step volume ramp
- Bits D1–D0: Select de-emphasis

**Table 6. System Control Register 1 (0x03)**

| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | FUNCTION                                                       |
|----|----|----|----|----|----|----|----|----------------------------------------------------------------|
| 0  | -  | -  | -  | -  | -  | -  | -  | PWM high-pass (dc blocking) disabled                           |
| 1  | -  | -  | -  | -  | -  | -  | -  | <b>PWM high-pass (dc blocking) enabled</b> <sup>(1)</sup>      |
| -  | 0  | -  | -  | -  | -  | -  | -  | <b>Reserved</b> <sup>(1)</sup>                                 |
| -  | -  | 0  | -  | -  | -  | -  | -  | Soft unmute on recovery from clock error                       |
| -  | -  | 1  | -  | -  | -  | -  | -  | <b>Hard unmute on recovery from clock error</b> <sup>(1)</sup> |
| -  | -  | -  | 0  | -  | -  | -  | -  | <b>Reserved</b> <sup>(1)</sup>                                 |
| -  | -  | -  | -  | 0  | -  | -  | -  | <b>Reserved</b> <sup>(1)</sup>                                 |
| -  | -  | -  | -  | -  | 0  | -  | -  | <b>Reserved</b> <sup>(1)</sup>                                 |
| -  | -  | -  | -  | -  | -  | 0  | 0  | <b>No de-emphasis</b> <sup>(1)</sup>                           |
| -  | -  | -  | -  | -  | -  | 0  | 1  | Reserved                                                       |
| -  | -  | -  | -  | -  | -  | 1  | 0  | De-emphasis for $f_s = 44.1$ kHz                               |
| -  | -  | -  | -  | -  | -  | 1  | 1  | De-emphasis for $f_s = 48$ kHz                                 |

(1) Default values are in **bold**.

## SERIAL DATA INTERFACE REGISTER (0x04)

As shown in [Table 7](#), the TAS5709 supports 9 serial data modes. The default is 24-bit, I<sup>2</sup>S mode,

**Table 7. Serial Data Interface Control Register (0x04) Format**

| RECEIVE SERIAL DATA<br>INTERFACE FORMAT | WORD<br>LENGTH | D7–D4       | D3       | D2       | D1       | D0       |
|-----------------------------------------|----------------|-------------|----------|----------|----------|----------|
| Right-justified                         | 16             | 0000        | 0        | 0        | 0        | 0        |
| Right-justified                         | 20             | 0000        | 0        | 0        | 0        | 1        |
| Right-justified                         | 24             | 0000        | 0        | 0        | 1        | 0        |
| I <sup>2</sup> S                        | 16             | 000         | 0        | 0        | 1        | 1        |
| I <sup>2</sup> S                        | 20             | 0000        | 0        | 1        | 0        | 0        |
| <b>I<sup>2</sup>S</b> <sup>(1)</sup>    | <b>24</b>      | <b>0000</b> | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> |
| Left-justified                          | 16             | 0000        | 0        | 1        | 1        | 0        |
| Left-justified                          | 20             | 0000        | 0        | 1        | 1        | 1        |
| Left-justified                          | 24             | 0000        | 1        | 0        | 0        | 0        |
| Reserved                                |                | 0000        | 1        | 0        | 0        | 1        |
| Reserved                                |                | 0000        | 1        | 0        | 1        | 0        |
| Reserved                                |                | 0000        | 1        | 0        | 1        | 1        |
| Reserved                                |                | 0000        | 1        | 1        | 0        | 0        |
| Reserved                                |                | 0000        | 1        | 1        | 0        | 1        |
| Reserved                                |                | 0000        | 1        | 1        | 1        | 0        |
| Reserved                                |                | 0000        | 1        | 1        | 1        | 1        |

(1) Default values are in **bold**.

## SYSTEM CONTROL REGISTER 2 (0x05)

When bit D6 is set low, the system exits all channel shutdown and starts playing audio; otherwise, the outputs are shut down(hard mute).

**Table 8. System Control Register 2 (0x05)**

| D7       | D6       | D5       | D4       | D3       | D2       | D1       | D0       | FUNCTION                                                |
|----------|----------|----------|----------|----------|----------|----------|----------|---------------------------------------------------------|
| <b>0</b> | –        | –        | –        | –        | –        | –        | –        | Reserved <sup>(1)</sup>                                 |
| –        | <b>1</b> | –        | –        | –        | –        | –        | –        | Enter all channel shut down (hard mute). <sup>(1)</sup> |
| –        | 0        | –        | –        | –        | –        | –        | –        | Exit all channel shutdown (normal operation)            |
| –        | –        | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | Reserved <sup>(1)</sup>                                 |

(1) Default values are in **bold**.

## SOFT MUTE REGISTER (0x06)

Writing a 1 to any of the following bits sets the output of the respective channel to 50% duty cycle (soft mute).

**Table 9. Soft Mute Register (0x06)**

| D7       | D6       | D5       | D4       | D3       | D2       | D1       | D0       | FUNCTION              |
|----------|----------|----------|----------|----------|----------|----------|----------|-----------------------|
| –        | –        | –        | –        | –        | –        | –        | <b>1</b> | Soft mute channel 1   |
| –        | –        | –        | –        | –        | –        | –        | <b>0</b> | Soft unmute channel 1 |
| –        | –        | –        | –        | –        | –        | <b>1</b> | –        | Soft mute channel 2   |
| –        | –        | –        | –        | –        | –        | <b>0</b> | –        | Soft unmute channel 2 |
| <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | –        | –        | Reserved              |

## VOLUME REGISTERS (0x07, 0x08, 0x09)

Step size is 0.5 dB.

|                  |                          |
|------------------|--------------------------|
| Master volume    | – 0x07 (default is mute) |
| Channel-1 volume | – 0x08 (default is 0 dB) |
| Channel-2 volume | – 0x09 (default is 0 dB) |

**Table 10. Volume Registers (0x07, 0x08, 0x09)**

| D<br>7   | D<br>6   | D<br>5   | D<br>4   | D<br>3   | D<br>2   | D<br>1   | D<br>0   | FUNCTION                                                           |
|----------|----------|----------|----------|----------|----------|----------|----------|--------------------------------------------------------------------|
| 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | 24 dB                                                              |
| <b>0</b> | <b>0</b> | <b>1</b> | <b>1</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0 dB (default for individual channel volume)</b> <sup>(1)</sup> |
| 1        | 1        | 0        | 0        | 1        | 1        | 0        | 1        | –78.5 dB                                                           |
| 1        | 1        | 0        | 0        | 1        | 1        | 1        | 0        | –79.0 dB                                                           |
| 1        | 1        | 0        | 0        | 1        | 1        | 1        | 1        | Values between 0xCF and 0xFE are Reserved                          |
| 1        | 1        | 1        | 1        | 1        | 1        | 1        | 1        | MUTE                                                               |

(1) Default values are in **bold**.

## MASTER FINE VOLUME REGISTER (0x0A)

This register can be used to provide precision tuning of master volume. If fine master volume is used, output mixers (0x51 and 0x52) should not be used. Similarly, this feature cannot be used if features like 2-band DRC or Bass Boost are being used. Write a "1" to bit D7 to enable changes to this register.

**Table 11. Master Fine Volume Register (0x0A)**

| D7       | D6 | D5 | D4 | D3 | D2 | D1       | D0       | FUNCTION                             |
|----------|----|----|----|----|----|----------|----------|--------------------------------------|
| –        | –  | –  | –  | –  | –  | <b>0</b> | <b>0</b> | <b>0 dB</b> <sup>(1)</sup>           |
| –        | –  | –  | –  | –  | –  | 0        | 1        | 0.125 dB                             |
| –        | –  | –  | –  | –  | –  | 1        | 0        | 0.25 dB                              |
| –        | –  | –  | –  | –  | –  | 1        | 1        | 0.375 dB                             |
| 1        | –  | –  | –  | –  | –  | –        | –        | Write enable bit                     |
| <b>0</b> | –  | –  | –  | –  | –  | –        | –        | <b>Ignore Write to register 0x0A</b> |

(1) Default values are in **bold**.

## VOLUME CONFIGURATION REGISTER (0x0E)

Bits D2–D0: Volume slew rate (Used to control volume change and MUTE ramp rates). These bits control the number of steps in a volume ramp. Volume steps occur at a rate that depends on the sample rate of the I2S data as follows

| Sample Rate (KHz) | Approximate Ramp Rate |
|-------------------|-----------------------|
| 8/16/32           | 125 us/step           |
| 11.025/22.05/44.1 | 90.7 us/step          |
| 12/24/48          | 83.3 us/step          |

**Table 12. Volume Control Register (0x0E)**

| D7       | D6       | D5       | D4       | D3       | D2       | D1       | D0       | FUNCTION                                                                       |
|----------|----------|----------|----------|----------|----------|----------|----------|--------------------------------------------------------------------------------|
| <b>1</b> | <b>0</b> | <b>0</b> | <b>1</b> | <b>0</b> | –        | –        | –        | <b>Reserved</b> <sup>(1)</sup>                                                 |
| –        | –        | –        | –        | –        | 0        | 0        | 0        | Volume slew 512 steps (43 ms volume ramp time at 48kHz)                        |
| –        | –        | –        | –        | –        | <b>0</b> | <b>0</b> | <b>1</b> | <b>Volume slew 1024 steps (85 ms volume ramp time at 48kHz)</b> <sup>(1)</sup> |
| –        | –        | –        | –        | –        | 0        | 1        | 0        | Volume slew 2048 steps (171 ms volume ramp time at 48kHz)                      |
| –        | –        | –        | –        | –        | 0        | 1        | 1        | Volume slew 256 steps (21ms volume ramp time at 48kHz)                         |
| –        | –        | –        | –        | –        | 1        | X        | X        | Reserved                                                                       |

(1) Default values are in **bold**.

## MODULATION LIMIT REGISTER (0x10)

**Table 13. Modulation Limit Register (0x10)**

| D7 | D6 | D5 | D4 | D3 | D2       | D1       | D0       | MODULATION LIMIT |
|----|----|----|----|----|----------|----------|----------|------------------|
| –  | –  | –  | –  | –  | 0        | 0        | 0        | 99.2%            |
| –  | –  | –  | –  | –  | 0        | 0        | 1        | 98.4%            |
| –  | –  | –  | –  | –  | <b>0</b> | <b>1</b> | <b>0</b> | <b>97.7%</b>     |
| –  | –  | –  | –  | –  | 0        | 1        | 1        | 96.9%            |
| –  | –  | –  | –  | –  | 1        | 0        | 0        | 96.1%            |
| –  | –  | –  | –  | –  | 1        | 0        | 1        | 95.3%            |
| –  | –  | –  | –  | –  | 1        | 1        | 0        | 94.5%            |
| –  | –  | –  | –  | –  | 1        | 1        | 1        | 93.8%            |
| 0  | 0  | 0  | 0  | 0  | –        | –        | –        | RESERVED         |

## INTERCHANNEL DELAY REGISTERS (0x11, 0x12, 0x13, and 0x14)

Internal PWM Channels 1, 2,  $\bar{1}$ , and  $\bar{2}$  are mapped into registers 0x11, 0x12, 0x13, and 0x14.

**Table 14. Channel Interchannel Delay Register Format**

| BITS DEFINITION | D7       | D6       | D5       | D4       | D3       | D2       | D1 | D0 | FUNCTION                                           |
|-----------------|----------|----------|----------|----------|----------|----------|----|----|----------------------------------------------------|
|                 | 0        | 0        | 0        | 0        | 0        | 0        | –  | –  | Minimum absolute delay, 0 DCLK cycles              |
|                 | 0        | 1        | 1        | 1        | 1        | 1        | –  | –  | Maximum positive delay, $31 \times 4$ DCLK cycles  |
|                 | 1        | 0        | 0        | 0        | 0        | 0        | –  | –  | Maximum negative delay, $-32 \times 4$ DCLK cycles |
|                 |          |          |          |          |          |          | 0  | 0  | RESERVED                                           |
| SUBADDRESS      | D7       | D6       | D5       | D4       | D3       | D2       | D1 | D0 | Delay = (value) $\times 4$ DCLKs                   |
| <b>0x11</b>     | <b>1</b> | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> | <b>1</b> | –  | –  | <b>Default value for channel 1</b> <sup>(1)</sup>  |
| <b>0x12</b>     | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> | –  | –  | <b>Default value for channel 2</b> <sup>(1)</sup>  |
| <b>0x13</b>     | <b>1</b> | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> | <b>1</b> | –  | –  | <b>Default value for channel 1</b> <sup>(1)</sup>  |
| <b>0x14</b>     | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> | –  | –  | <b>Default value for channel 2</b> <sup>(1)</sup>  |

(1) Default values are in **bold**.

ICD settings have high impact on audio performance (eg: Dynamic Range, THD, Cross talk etc.) Therefore, appropriate ICD settings must be used. By default device has ICD settings for AD mode. If used in BD mode, then update these registers before coming out of all channel shutdown.

| MODE | AD MODE | BD MODE |
|------|---------|---------|
| 0x11 | AC      | B8      |
| 0x12 | 54      | 60      |
| 0x13 | AC      | A0      |
| 0x14 | 54      | 48      |

**START/STOP PERIOD REGISTER (0x1A)**

This register is used to control the soft-start and soft-stop period following an enter/exit all channel shut down command or change in the  $\overline{\text{PDN}}$  state. This helps reduce pops and clicks at start-up and shutdown. The times are only approximate and vary depending on device activity level and I2S clock stability.

**Table 15. Start/Stop Period Register (0x1A)**

| D7       | D6       | D5       | D4       | D3       | D2       | D1       | D0       | FUNCTION                                                       |
|----------|----------|----------|----------|----------|----------|----------|----------|----------------------------------------------------------------|
| <b>0</b> | <b>0</b> | <b>0</b> | –        | –        | –        | –        | –        | <b>Reserved</b>                                                |
| –        | –        | –        | 0        | 0        | –        | –        | –        | No 50% duty cycle start/stop period                            |
| –        | –        | –        | 0        | 1        | 0        | 0        | 0        | 16.5-ms 50% duty cycle start/stop period                       |
| –        | –        | –        | 0        | 1        | 0        | 0        | 1        | 23.9-ms 50% duty cycle start/stop period                       |
| –        | –        | –        | 0        | 1        | 0        | 1        | 0        | 31.4-ms 50% duty cycle start/stop period                       |
| –        | –        | –        | 0        | 1        | 0        | 1        | 1        | 40.4-ms 50% duty cycle start/stop period                       |
| –        | –        | –        | 0        | 1        | 1        | 0        | 0        | 53.9-ms 50% duty cycle start/stop period                       |
| –        | –        | –        | 0        | 1        | 1        | 0        | 1        | 70.3-ms 50% duty cycle start/stop period                       |
| –        | –        | –        | 0        | 1        | 1        | 1        | 0        | 94.2-ms 50% duty cycle start/stop period                       |
| –        | –        | –        | <b>0</b> | <b>1</b> | <b>1</b> | <b>1</b> | <b>1</b> | <b>125.7-ms 50% duty cycle start/stop period<sup>(1)</sup></b> |
| –        | –        | –        | 1        | 0        | 0        | 0        | 0        | 164.6-ms 50% duty cycle start/stop period                      |
| –        | –        | –        | 1        | 0        | 0        | 0        | 1        | 239.4-ms 50% duty cycle start/stop period                      |
| –        | –        | –        | 1        | 0        | 0        | 1        | 0        | 314.2-ms 50% duty cycle start/stop period                      |
| –        | –        | –        | 1        | 0        | 0        | 1        | 1        | 403.9-ms 50% duty cycle start/stop period                      |
| –        | –        | –        | 1        | 0        | 1        | 0        | 0        | 538.6-ms 50% duty cycle start/stop period                      |
| –        | –        | –        | 1        | 0        | 1        | 0        | 1        | 703.1-ms 50% duty cycle start/stop period                      |
| –        | –        | –        | 1        | 0        | 1        | 1        | 0        | 942.5-ms 50% duty cycle start/stop period                      |
| –        | –        | –        | 1        | 0        | 1        | 1        | 1        | 1256.6-ms 50% duty cycle start/stop period                     |
| –        | –        | –        | 1        | 1        | 0        | 0        | 0        | 1728.1-ms 50% duty cycle start/stop period                     |
| –        | –        | –        | 1        | 1        | 0        | 0        | 1        | 2513.6-ms 50% duty cycle start/stop period                     |
| –        | –        | –        | 1        | 1        | 0        | 1        | 0        | 3299.1-ms 50% duty cycle start/stop period                     |
| –        | –        | –        | 1        | 1        | 0        | 1        | 1        | 4241.7-ms 50% duty cycle start/stop period                     |
| –        | –        | –        | 1        | 1        | 1        | 0        | 0        | 5655.6-ms 50% duty cycle start/stop period                     |
| –        | –        | –        | 1        | 1        | 1        | 0        | 1        | 7383.7-ms 50% duty cycle start/stop period                     |
| –        | –        | –        | 1        | 1        | 1        | 1        | 0        | 9897.3-ms 50% duty cycle start/stop period                     |
| –        | –        | –        | 1        | 1        | 1        | 1        | 1        | 13,196.4-ms 50% duty cycle start/stop period                   |

(1) Default values are in **bold**.

## OSCILLATOR TRIM REGISTER (0x1B)

The TAS5709 PWM processor contains an internal oscillator to support autodetect of I2S clock rates. This reduces system cost because an external reference is not required. Currently, TI recommends a reference resistor value of 18.2 kΩ (1%). This should be connected between OSC\_RES and DVSSO.

Writing 0x00 to reg 0x1B enables the trim that was programmed at the factory.

Note that trim must always be run following reset of the device.

**Table 16. Oscillator Trim Register (0x1B)**

| D7       | D6       | D5       | D4       | D3       | D2       | D1       | D0       | FUNCTION                                                              |
|----------|----------|----------|----------|----------|----------|----------|----------|-----------------------------------------------------------------------|
| <b>1</b> | –        | –        | –        | –        | –        | –        | –        | <b>Reserved</b> <sup>(1)</sup>                                        |
| –        | <b>0</b> | –        | –        | –        | –        | –        | –        | <b>Oscillator trim not done (read-only)</b> <sup>(1)</sup>            |
| –        | <b>1</b> | –        | –        | –        | –        | –        | –        | Oscillator trim done (read only)                                      |
| –        | –        | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | –        | –        | <b>Reserved</b> <sup>(1)</sup>                                        |
| –        | –        | –        | –        | –        | –        | <b>0</b> | –        | Select factory trim (Write a 0 to select factory trim; default is 1.) |
| –        | –        | –        | –        | –        | –        | <b>1</b> | –        | <b>Factory trim disabled</b> <sup>(1)</sup>                           |
| –        | –        | –        | –        | –        | –        | –        | <b>0</b> | <b>Reserved</b> <sup>(1)</sup>                                        |

(1) Default values are in **bold**.

## BKND\_ERR REGISTER (0x1C)

When a back-end error signal is received from the internal power stage, the power stage is reset stopping all PWM activity. Subsequently, the modulator waits approximately for the time listed in [Table 17](#) before attempting to re-start the power stage.

**Table 17. BKND\_ERR Register (0x1C)** <sup>(1)</sup>

| D7       | D6       | D5       | D4       | D3       | D2       | D1       | D0       | FUNCTION                                                  |
|----------|----------|----------|----------|----------|----------|----------|----------|-----------------------------------------------------------|
| <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>X</b> | Reserved                                                  |
| –        | –        | –        | –        | <b>0</b> | <b>0</b> | <b>1</b> | <b>0</b> | <b>Set back-end reset period to 299 ms</b> <sup>(2)</sup> |
| –        | –        | –        | –        | <b>0</b> | <b>0</b> | <b>1</b> | <b>1</b> | Set back-end reset period to 449 ms                       |
| –        | –        | –        | –        | <b>0</b> | <b>1</b> | <b>0</b> | <b>0</b> | Set back-end reset period to 598 ms                       |
| –        | –        | –        | –        | <b>0</b> | <b>1</b> | <b>0</b> | <b>1</b> | Set back-end reset period to 748 ms                       |
| –        | –        | –        | –        | <b>0</b> | <b>1</b> | <b>1</b> | <b>0</b> | Set back-end reset period to 898 ms                       |
| –        | –        | –        | –        | <b>0</b> | <b>1</b> | <b>1</b> | <b>1</b> | Set back-end reset period to 1047 ms                      |
| –        | –        | –        | –        | <b>1</b> | <b>0</b> | <b>0</b> | <b>0</b> | Set back-end reset period to 1197 ms                      |
| –        | –        | –        | –        | <b>1</b> | <b>0</b> | <b>0</b> | <b>1</b> | Set back-end reset period to 1346 ms                      |
| –        | –        | –        | –        | <b>1</b> | <b>0</b> | <b>1</b> | <b>X</b> | Set back-end reset period to 1496 ms                      |
| –        | –        | –        | –        | <b>1</b> | <b>1</b> | <b>X</b> | <b>X</b> | Set back-end reset period to 1496 ms                      |

(1) This register can be written only with a "non-Reserved" value. Also this register can be written once after the reset.

(2) Default values are in **bold**.

**INPUT MULTIPLEXER REGISTER (0x20)**

This register controls the modulation scheme (AD or BD mode) as well as the routing of I2S audio to the internal channels.

**Table 18. Input Multiplexer Register (0x20)**

| D31 | D30 | D29 | D28 | D27 | D26 | D25 | D24 | FUNCTION                                  |
|-----|-----|-----|-----|-----|-----|-----|-----|-------------------------------------------|
| 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | Reserved <sup>(1)</sup>                   |
| D23 | D22 | D21 | D20 | D19 | D18 | D17 | D16 | FUNCTION                                  |
| 0   | –   | –   | –   | –   | –   | –   | –   | <b>Channel-1 AD mode</b>                  |
| 1   | –   | –   | –   | –   | –   | –   | –   | Channel-1 BD mode                         |
| –   | 0   | 0   | 0   | –   | –   | –   | –   | <b>SDIN-L to channel 1 <sup>(1)</sup></b> |
| –   | 0   | 0   | 1   | –   | –   | –   | –   | SDIN-R to channel 1                       |
| –   | 0   | 1   | 0   | –   | –   | –   | –   | Reserved                                  |
| –   | 0   | 1   | 1   | –   | –   | –   | –   | Reserved                                  |
| –   | 1   | 0   | 0   | –   | –   | –   | –   | Reserved                                  |
| –   | 1   | 0   | 1   | –   | –   | –   | –   | Reserved                                  |
| –   | 1   | 1   | 0   | –   | –   | –   | –   | Ground (0) to channel 1                   |
| –   | 1   | 1   | 1   | –   | –   | –   | –   | Reserved                                  |
| –   | –   | –   | –   | 0   | –   | –   | –   | <b>Channel 2 AD mode</b>                  |
| –   | –   | –   | –   | 1   | –   | –   | –   | Channel 2 BD mode                         |
| –   | –   | –   | –   | –   | 0   | 0   | 0   | SDIN-L to channel 2                       |
| –   | –   | –   | –   | –   | 0   | 0   | 1   | <b>SDIN-R to channel 2 <sup>(1)</sup></b> |
| –   | –   | –   | –   | –   | 0   | 1   | 0   | Reserved                                  |
| –   | –   | –   | –   | –   | 0   | 1   | 1   | Reserved                                  |
| –   | –   | –   | –   | –   | 1   | 0   | 0   | Reserved                                  |
| –   | –   | –   | –   | –   | 1   | 0   | 1   | Reserved                                  |
| –   | –   | –   | –   | –   | 1   | 1   | 0   | Ground (0) to channel 2                   |
| –   | –   | –   | –   | –   | 1   | 1   | 1   | Reserved                                  |
| D15 | D14 | D13 | D12 | D11 | D10 | D9  | D8  | FUNCTION                                  |
| 0   | 1   | 1   | 1   | 0   | 1   | 1   | 1   | Reserved <sup>(1)</sup>                   |
| D7  | D6  | D5  | D4  | D3  | D2  | D1  | D0  | FUNCTION                                  |
| 0   | 1   | 1   | 1   | 0   | 0   | 1   | 0   | Reserved <sup>(1)</sup>                   |

(1) Default values are in **bold**.

## CHANNEL 4 SOURCE SELECT REGISTER (0x21)

This register selects the channel 4 source.

**Table 19. Subchannel Control Register (0x21)**

| D31 | D30 | D29 | D28 | D27 | D26 | D25 | D24 | FUNCTION                |
|-----|-----|-----|-----|-----|-----|-----|-----|-------------------------|
| 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | Reserved <sup>(1)</sup> |
| D23 | D22 | D21 | D20 | D19 | D18 | D17 | D16 | FUNCTION                |
| 0   | 0   | 0   | 0   | 0   | 0   | 0   | 0   | Reserved <sup>(1)</sup> |
| D15 | D14 | D13 | D12 | D11 | D10 | D9  | D8  | FUNCTION                |
| 0   | 1   | 0   | 0   | 0   | 0   | 1   |     | Reserved <sup>(1)</sup> |
| –   | –   | –   | –   | –   | –   | –   | 0   | (L + R)/2               |
| –   | –   | –   | –   | –   | –   | –   | 1   | Left-channel post-BQ    |
| D7  | D6  | D5  | D4  | D3  | D2  | D1  | D0  | FUNCTION                |
| 0   | 0   | 0   | 0   | 0   | 0   | 1   | 1   | Reserved <sup>(1)</sup> |

(1) Default values are in **bold**.

## PWM OUTPUT MUX REGISTER (0x25)

This DAP output mux selects which internal PWM channel is output to the external pins. Any channel can be output to any external output pin.

Bits D21–D20: Selects which PWM channel is output to OUT\_A

Bits D17–D16: Selects which PWM channel is output to OUT\_B

Bits D13–D12: Selects which PWM channel is output to OUT\_C

Bits D09–D08: Selects which PWM channel is output to OUT\_D

Note that channels are encoded so that channel 1 = 0x00, channel 2 = 0x01, ..., channel 4 = 0x03.

**Table 20. PWM Output Mux Register (0x25)**

| D31 | D30 | D29 | D28 | D27 | D26 | D25 | D24 | FUNCTION                                    |
|-----|-----|-----|-----|-----|-----|-----|-----|---------------------------------------------|
| 0   | 0   | 0   | 0   | 0   | 0   | 0   | 1   | Reserved <sup>(1)</sup>                     |
| D23 | D22 | D21 | D20 | D19 | D18 | D17 | D16 | FUNCTION                                    |
| 0   | 0   | –   | –   | –   | –   | –   | –   | Reserved <sup>(1)</sup>                     |
| –   | –   | 0   | 0   | –   | –   | –   | –   | Multiplex channel 1 to OUT_A <sup>(1)</sup> |
| –   | –   | 0   | 1   | –   | –   | –   | –   | Multiplex channel 2 to OUT_A                |
| –   | –   | 1   | 0   | –   | –   | –   | –   | Multiplex channel 1 to OUT_A                |
| –   | –   | 1   | 1   | –   | –   | –   | –   | Multiplex channel 2 to OUT_A                |
| –   | –   | –   | –   | 0   | 0   | –   | –   | Reserved <sup>(1)</sup>                     |
| –   | –   | –   | –   | –   | –   | 0   | 0   | Multiplex channel 1 to OUT_B                |
| –   | –   | –   | –   | –   | –   | 0   | 1   | Multiplex channel 2 to OUT_B                |
| –   | –   | –   | –   | –   | –   | 1   | 0   | Multiplex channel 1 to OUT_B <sup>(1)</sup> |
| –   | –   | –   | –   | –   | –   | 1   | 1   | Multiplex channel 2 to OUT_B                |
| D15 | D14 | D13 | D12 | D11 | D10 | D9  | D8  | FUNCTION                                    |
| 0   | 0   | –   | –   | –   | –   | –   | –   | Reserved <sup>(1)</sup>                     |
| –   | –   | 0   | 0   | –   | –   | –   | –   | Multiplex channel 1 to OUT_C                |
| –   | –   | 0   | 1   | –   | –   | –   | –   | Multiplex channel 2 to OUT_C <sup>(1)</sup> |
| –   | –   | 1   | 0   | –   | –   | –   | –   | Multiplex channel 1 to OUT_C                |

(1) Default values are in **bold**.

**Table 20. PWM Output Mux Register (0x25) (continued)**

| –  | –  | 1  | 1  | –        | –        | –        | –        | Multiplex channel 2 to OUT_C                       |
|----|----|----|----|----------|----------|----------|----------|----------------------------------------------------|
| –  | –  | –  | –  | <b>0</b> | <b>0</b> | –        | –        | <b>Reserved</b> <sup>(1)</sup>                     |
| –  | –  | –  | –  | –        | –        | 0        | 0        | Multiplex channel 1 to OUT_D                       |
| –  | –  | –  | –  | –        | –        | 0        | 1        | Multiplex channel 2 to OUT_D                       |
| –  | –  | –  | –  | –        | –        | 1        | 0        | Multiplex channel 1 to OUT_D                       |
| –  | –  | –  | –  | –        | –        | <b>1</b> | <b>1</b> | <b>Multiplex channel 2 to OUT_D</b> <sup>(1)</sup> |
| D7 | D6 | D5 | D4 | D3       | D2       | D1       | D0       | FUNCTION                                           |
| 0  | 1  | 0  | 0  | 0        | 1        | 0        | 1        | RESERVED                                           |

**DRC CONTROL (0x46)**

| D31      | D30      | D29      | D28      | D27      | D26      | D25      | D24      | FUNCTION                              |
|----------|----------|----------|----------|----------|----------|----------|----------|---------------------------------------|
| 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | <b>Reserved</b> <sup>(1)</sup>        |
| D23      | D22      | D21      | D20      | D19      | D18      | D17      | D16      | FUNCTION                              |
| 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | <b>Reserved</b> <sup>(1)</sup>        |
| D15      | D14      | D13      | D12      | D11      | D10      | D9       | D8       | FUNCTION                              |
| 0        | 0        | 0        | 0        | 0        | 0        | 0        | 0        | <b>Reserved</b> <sup>(1)</sup>        |
| D7       | D6       | D5       | D4       | D3       | D2       | D1       | D0       | FUNCTION                              |
| –        | –        | –        | –        | –        | –        | –        | <b>0</b> | <b>DRC1 turned OFF</b> <sup>(1)</sup> |
| –        | –        | –        | –        | –        | –        | –        | 1        | DRC1 turned ON                        |
| –        | –        | –        | –        | –        | –        | <b>0</b> | –        | <b>DRC2 turned OFF</b> <sup>(1)</sup> |
| –        | –        | –        | –        | –        | –        | 1        | –        | DRC2 turned ON                        |
| <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | <b>0</b> | –        | –        | <b>Reserved</b> <sup>(1)</sup>        |

(1) Default values are in **bold**.

## BANK SWITCH AND EQ CONTROL (0x50)

**Table 21. Bank Switching Command**

| D31 | D30 | D29 | D28 | D27 | D26 | D25 | D24 | FUNCTION                                                 |
|-----|-----|-----|-----|-----|-----|-----|-----|----------------------------------------------------------|
| 0   | –   | –   | –   | –   | –   | –   | –   | <b>32 kHz, does not use bank 3</b> <sup>(1)</sup>        |
| 1   | –   | –   | –   | –   | –   | –   | –   | 32 kHz, uses bank 3                                      |
| –   | 0   | –   | –   | –   | –   | –   | –   | Reserved                                                 |
| –   | –   | 0   | –   | –   | –   | –   | –   | Reserved                                                 |
| –   | –   | –   | 0   | –   | –   | –   | –   | <b>44.1/48 kHz, does not use bank 3</b> <sup>(1)</sup>   |
| –   | –   | –   | 1   | –   | –   | –   | –   | 44.1/48 kHz, uses bank 3                                 |
| –   | –   | –   | –   | 0   | –   | –   | –   | 16 kHz, does not use bank 3                              |
| –   | –   | –   | –   | 1   | –   | –   | –   | <b>16 kHz, uses bank 3</b> <sup>(1)</sup>                |
| –   | –   | –   | –   | –   | 0   | –   | –   | 22.025/24 kHz, does not use bank 3                       |
| –   | –   | –   | –   | –   | 1   | –   | –   | <b>22.025/24 kHz, uses bank 3</b> <sup>(1)</sup>         |
| –   | –   | –   | –   | –   | –   | 0   | –   | 8 kHz, does not use bank 3                               |
| –   | –   | –   | –   | –   | –   | 1   | –   | <b>8 kHz, uses bank 3</b> <sup>(1)</sup>                 |
| –   | –   | –   | –   | –   | –   | –   | 0   | 11.025 kHz/12, does not use bank 3                       |
| –   | –   | –   | –   | –   | –   | –   | 1   | <b>11.025/12 kHz, uses bank 3</b> <sup>(1)</sup>         |
| D23 | D22 | D21 | D20 | D19 | D18 | D17 | D16 | FUNCTION                                                 |
| 0   | –   | –   | –   | –   | –   | –   | –   | <b>32 kHz, does not use bank 2</b> <sup>(1)</sup>        |
| 1   | –   | –   | –   | –   | –   | –   | –   | 32 kHz, uses bank 2                                      |
| –   | 1   | –   | –   | –   | –   | –   | –   | <b>Reserved</b> <sup>(1)</sup>                           |
| –   | –   | 1   | –   | –   | –   | –   | –   | <b>Reserved</b> <sup>(1)</sup>                           |
| –   | –   | –   | 0   | –   | –   | –   | –   | 44.1/48 kHz, does not use bank 2                         |
| –   | –   | –   | 1   | –   | –   | –   | –   | <b>44.1/48 kHz, uses bank 2</b> <sup>(1)</sup>           |
| –   | –   | –   | –   | 0   | –   | –   | –   | <b>16 kHz, does not use bank 2</b> <sup>(1)</sup>        |
| –   | –   | –   | –   | 1   | –   | –   | –   | 16 kHz, uses bank 2                                      |
| –   | –   | –   | –   | –   | 0   | –   | –   | <b>22.025/24 kHz, does not use bank 2</b> <sup>(1)</sup> |
| –   | –   | –   | –   | –   | 1   | –   | –   | 22.025/24 kHz, uses bank 2                               |
| –   | –   | –   | –   | –   | –   | 0   | –   | <b>8 kHz, does not use bank 2</b> <sup>(1)</sup>         |
| –   | –   | –   | –   | –   | –   | 1   | –   | 8 kHz, uses bank 2                                       |
| –   | –   | –   | –   | –   | –   | –   | 0   | <b>11.025/12 kHz, does not use bank 2</b> <sup>(1)</sup> |
| –   | –   | –   | –   | –   | –   | –   | 1   | 11.025/12 kHz, uses bank 2                               |
| D15 | D14 | D13 | D12 | D11 | D10 | D9  | D8  | FUNCTION                                                 |
| 0   | –   | –   | –   | –   | –   | –   | –   | 32 kHz, does not use bank 1                              |
| 1   | –   | –   | –   | –   | –   | –   | –   | <b>32 kHz, uses bank 1</b> <sup>(1)</sup>                |
| –   | 0   | –   | –   | –   | –   | –   | –   | Reserved                                                 |
| –   | –   | 0   | –   | –   | –   | –   | –   | Reserved                                                 |
| –   | –   | –   | 0   | –   | –   | –   | –   | <b>44.1/48 kHz, does not use bank 1</b> <sup>(1)</sup>   |
| –   | –   | –   | 1   | –   | –   | –   | –   | 44.1/48 kHz, uses bank 1                                 |
| –   | –   | –   | –   | 0   | –   | –   | –   | <b>16 kHz, does not use bank 1</b> <sup>(1)</sup>        |
| –   | –   | –   | –   | 1   | –   | –   | –   | 16 kHz, uses bank 1                                      |
| –   | –   | –   | –   | –   | 0   | –   | –   | <b>22.025/24 kHz, does not use bank 1</b> <sup>(1)</sup> |
| –   | –   | –   | –   | –   | 1   | –   | –   | 22.025/24 kHz, uses bank 1                               |
| –   | –   | –   | –   | –   | –   | 0   | –   | <b>8 kHz, does not use bank 1</b> <sup>(1)</sup>         |
| –   | –   | –   | –   | –   | –   | 1   | –   | 8 kHz, uses bank 1                                       |
| –   | –   | –   | –   | –   | –   | –   | 0   | <b>11.025/12 kHz, does not use bank 1</b> <sup>(1)</sup> |
| –   | –   | –   | –   | –   | –   | –   | 1   | 11.025/12 kHz, uses bank 1                               |

(1) Default values are in **bold**.

**Table 21. Bank Switching Command (continued)**

| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 | FUNCTION                                                                                                                                                                   |
|----|----|----|----|----|----|----|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 0  |    |    |    |    |    |    |    | <b>EQ ON</b>                                                                                                                                                               |
| 1  | –  | –  | –  | –  | –  | –  | –  | EQ OFF (bypass BQ 0-6 of channels 1 and 2)                                                                                                                                 |
| –  | 0  | –  | –  | –  | –  | –  | –  | <b>Reserved</b> <sup>(2)</sup>                                                                                                                                             |
| –  | –  | 0  | –  | –  | –  | –  | –  | <b>Ignore bank-mapping in bits D31–D8. Use default mapping.</b> <sup>(2)</sup>                                                                                             |
|    |    | 1  |    |    |    |    |    | Use bank-mapping in bits D31–D8.                                                                                                                                           |
| –  | –  | –  | 0  | –  | –  | –  | –  | <b>L and R can be written independently.</b> <sup>(2)</sup>                                                                                                                |
| –  | –  | –  | 1  | –  | –  | –  | –  | L and R are ganged for EQ biquads; a write to Left channel BQ is also written to Right channel BQ. (0X29-2F is ganged to 0X30-0X36. Also 0X58-0X5B is ganged to 0X5C-0x5F) |
| –  | –  | –  | –  | 0  | –  | –  | –  | <b>Reserved</b> <sup>(2)</sup>                                                                                                                                             |
| –  | –  | –  | –  | –  | 0  | 0  | 0  | <b>No bank switching. All updates to DAP</b> <sup>(2)</sup>                                                                                                                |
| –  | –  | –  | –  | –  | 0  | 0  | 1  | Configure bank 1 (32 kHz by default)                                                                                                                                       |
| –  | –  | –  | –  | –  | 0  | 1  | 0  | Configure bank 2 (44.1/48 kHz by default)                                                                                                                                  |
| –  | –  | –  | –  | –  | 0  | 1  | 1  | Configure bank 3 (other sample rates by default)                                                                                                                           |
| –  | –  | –  | –  | –  | 1  | 0  | 0  | Automatic bank selection                                                                                                                                                   |
| –  | –  | –  | –  | –  | 1  | 0  | 1  | Reserved                                                                                                                                                                   |
| –  | –  | –  | –  | –  | 1  | 1  | X  | Reserved                                                                                                                                                                   |

(2) Default values are in **bold**.

## PACKAGING INFORMATION

| Orderable part number        | Status<br>(1) | Material type<br>(2) | Package   Pins   | Package qty   Carrier  | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|------------------------------|---------------|----------------------|------------------|------------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">TAS5709APHP</a>  | Active        | Production           | HTQFP (PHP)   48 | 250   JEDEC TRAY (5+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | 0 to 85      | (TAS5709, TAS5709A) |
| TAS5709APHP.A                | Active        | Production           | HTQFP (PHP)   48 | 250   JEDEC TRAY (5+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | 0 to 85      | (TAS5709, TAS5709A) |
| TAS5709APHP.B                | Active        | Production           | HTQFP (PHP)   48 | 250   JEDEC TRAY (5+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | 0 to 85      | (TAS5709, TAS5709A) |
| <a href="#">TAS5709APHPR</a> | Active        | Production           | HTQFP (PHP)   48 | 1000   LARGE T&R       | Yes         | NIPDAU                               | Level-3-260C-168 HR               | 0 to 85      | (TAS5709, TAS5709A) |
| TAS5709APHPR.A               | Active        | Production           | HTQFP (PHP)   48 | 1000   LARGE T&R       | Yes         | NIPDAU                               | Level-3-260C-168 HR               | 0 to 85      | (TAS5709, TAS5709A) |
| <a href="#">TAS5709PHP</a>   | Active        | Production           | HTQFP (PHP)   48 | 250   JEDEC TRAY (5+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | 0 to 85      | TAS5709             |
| TAS5709PHP.A                 | Active        | Production           | HTQFP (PHP)   48 | 250   JEDEC TRAY (5+1) | Yes         | NIPDAU                               | Level-3-260C-168 HR               | 0 to 85      | TAS5709             |
| <a href="#">TAS5709PHPR</a>  | Active        | Production           | HTQFP (PHP)   48 | 1000   LARGE T&R       | Yes         | NIPDAU                               | Level-3-260C-168 HR               | 0 to 85      | TAS5709             |
| TAS5709PHPR.A                | Active        | Production           | HTQFP (PHP)   48 | 1000   LARGE T&R       | Yes         | NIPDAU                               | Level-3-260C-168 HR               | 0 to 85      | TAS5709             |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

<sup>(5)</sup> **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

<sup>(6)</sup> **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "-" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

**Important Information and Disclaimer:** The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

## TAPE AND REEL INFORMATION



\*All dimensions are nominal

| Device       | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|--------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TAS5709APHPR | HTQFP        | PHP             | 48   | 1000 | 330.0              | 16.4               | 9.6     | 9.6     | 1.5     | 12.0    | 16.0   | Q2            |
| TAS5709PHPR  | HTQFP        | PHP             | 48   | 1000 | 330.0              | 16.4               | 9.6     | 9.6     | 1.5     | 12.0    | 16.0   | Q2            |

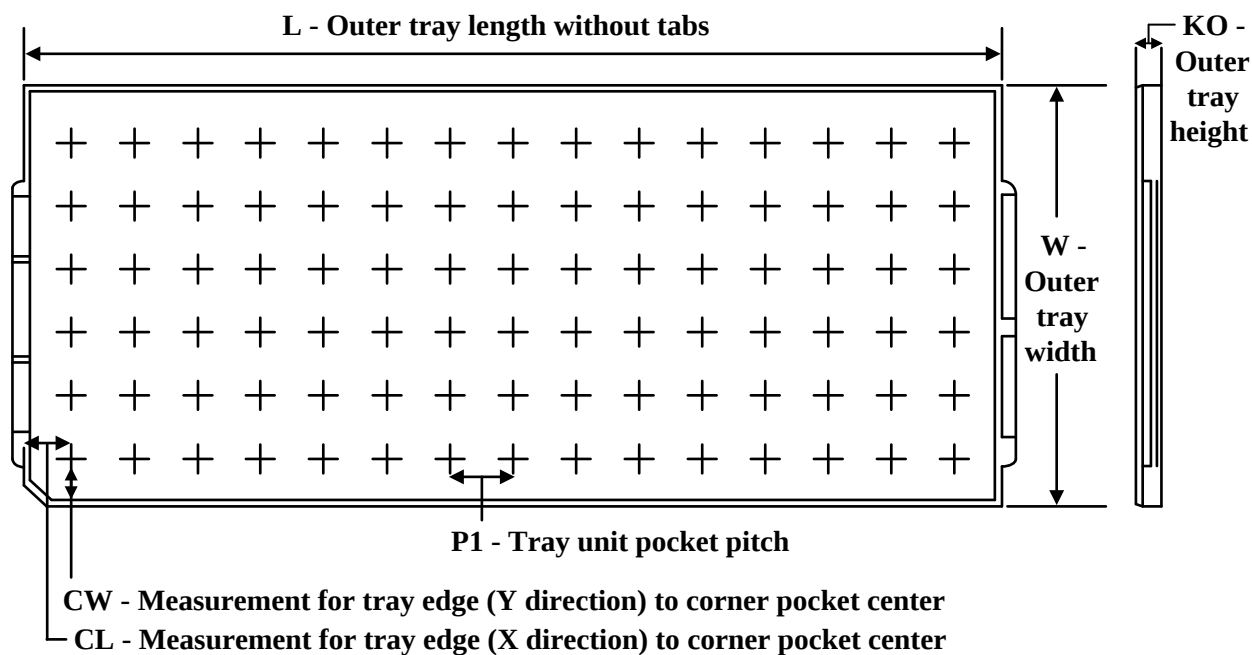
## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

| Device      | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TAS5709APHR | HTQFP        | PHP             | 48   | 1000 | 336.6       | 336.6      | 31.8        |
| TAS5709PHPR | HTQFP        | PHP             | 48   | 1000 | 336.6       | 336.6      | 31.8        |

## TRAY



Chamfer on Tray corner indicates Pin 1 orientation of packed units.

\*All dimensions are nominal

| Device        | Package Name | Package Type | Pins | SPQ | Unit array matrix | Max temperature (°C) | L (mm) | W (mm) | K0 (μm) | P1 (mm) | CL (mm) | CW (mm) |
|---------------|--------------|--------------|------|-----|-------------------|----------------------|--------|--------|---------|---------|---------|---------|
| TAS5709APHP   | PHP          | HTQFP        | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| TAS5709APHP   | PHP          | HTQFP        | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| TAS5709APHP.A | PHP          | HTQFP        | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| TAS5709APHP.A | PHP          | HTQFP        | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| TAS5709APHP.B | PHP          | HTQFP        | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| TAS5709APHP.B | PHP          | HTQFP        | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| TAS5709PHP    | PHP          | HTQFP        | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| TAS5709PHP    | PHP          | HTQFP        | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| TAS5709PHP.A  | PHP          | HTQFP        | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |
| TAS5709PHP.A  | PHP          | HTQFP        | 48   | 250 | 10 x 25           | 150                  | 315    | 135.9  | 7620    | 12.2    | 11.1    | 11.25   |

## GENERIC PACKAGE VIEW

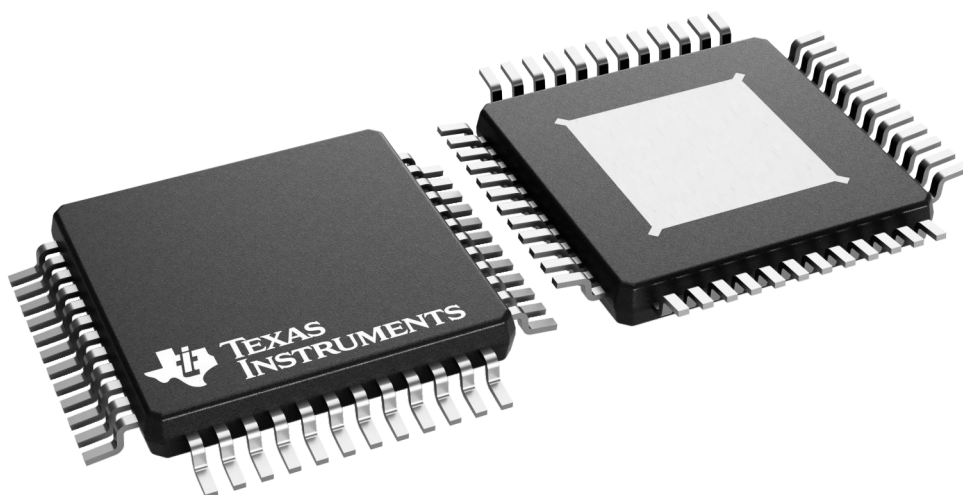
**PHP 48**

**TQFP - 1.2 mm max height**

7 x 7, 0.5 mm pitch

QUAD FLATPACK

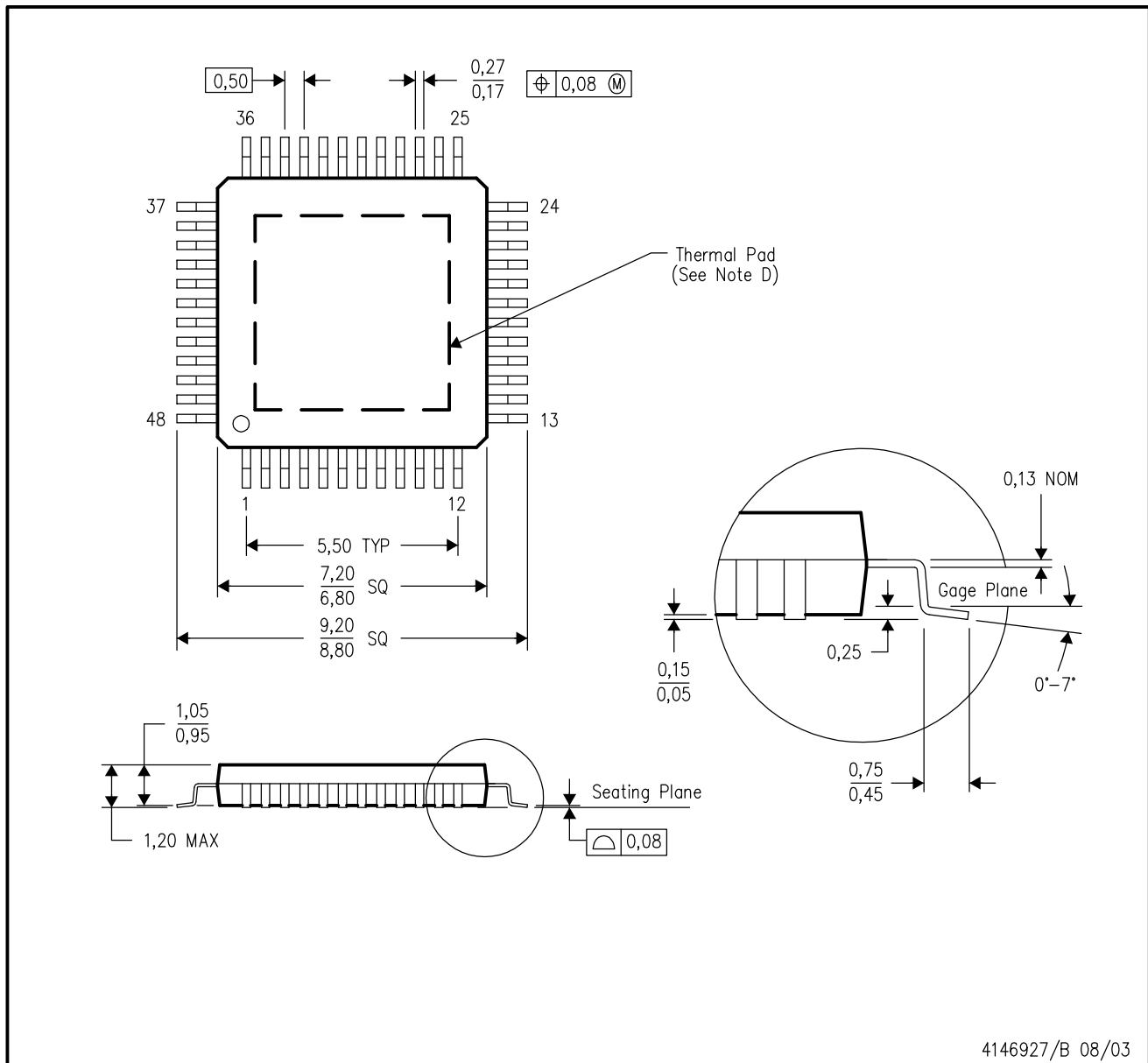
This image is a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.



4226443/A

PHP (S-PQFP-G48)

PowerPAD™ PLASTIC QUAD FLATPACK



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. Falls within JEDEC MS-026

PowerPAD is a trademark of Texas Instruments.

PHP (S-PQFP-G48)

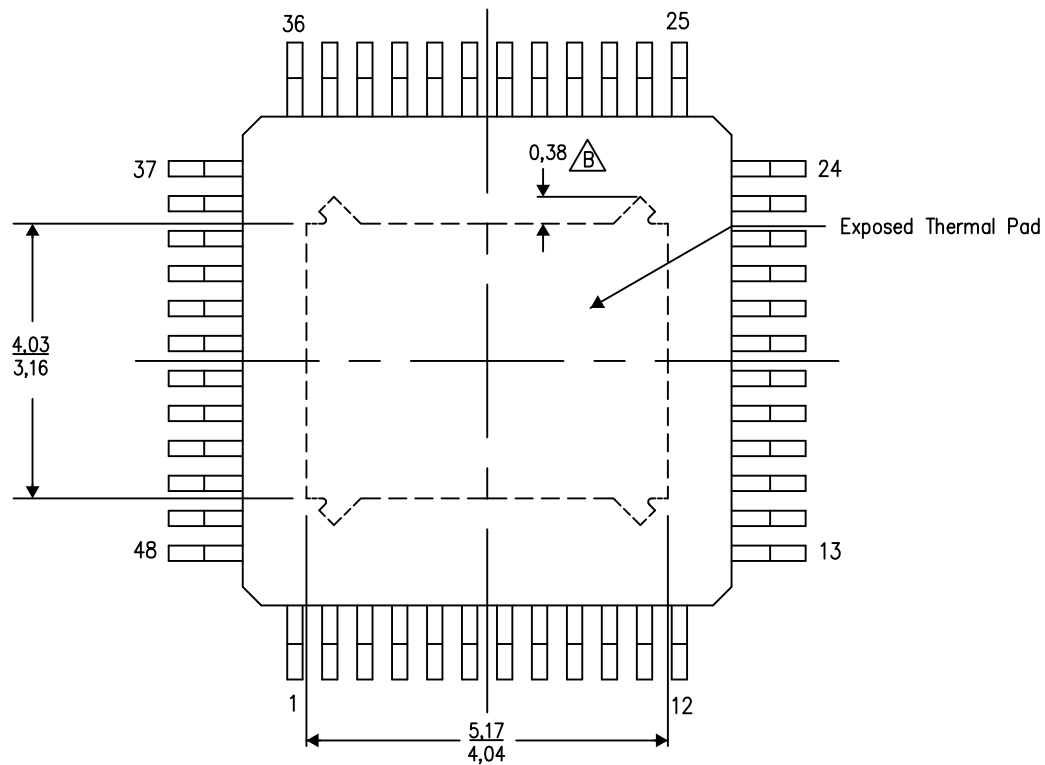
PowerPAD™ PLASTIC QUAD FLATPACK

## THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.

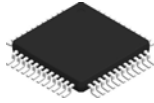


4206329-18/P 03/15

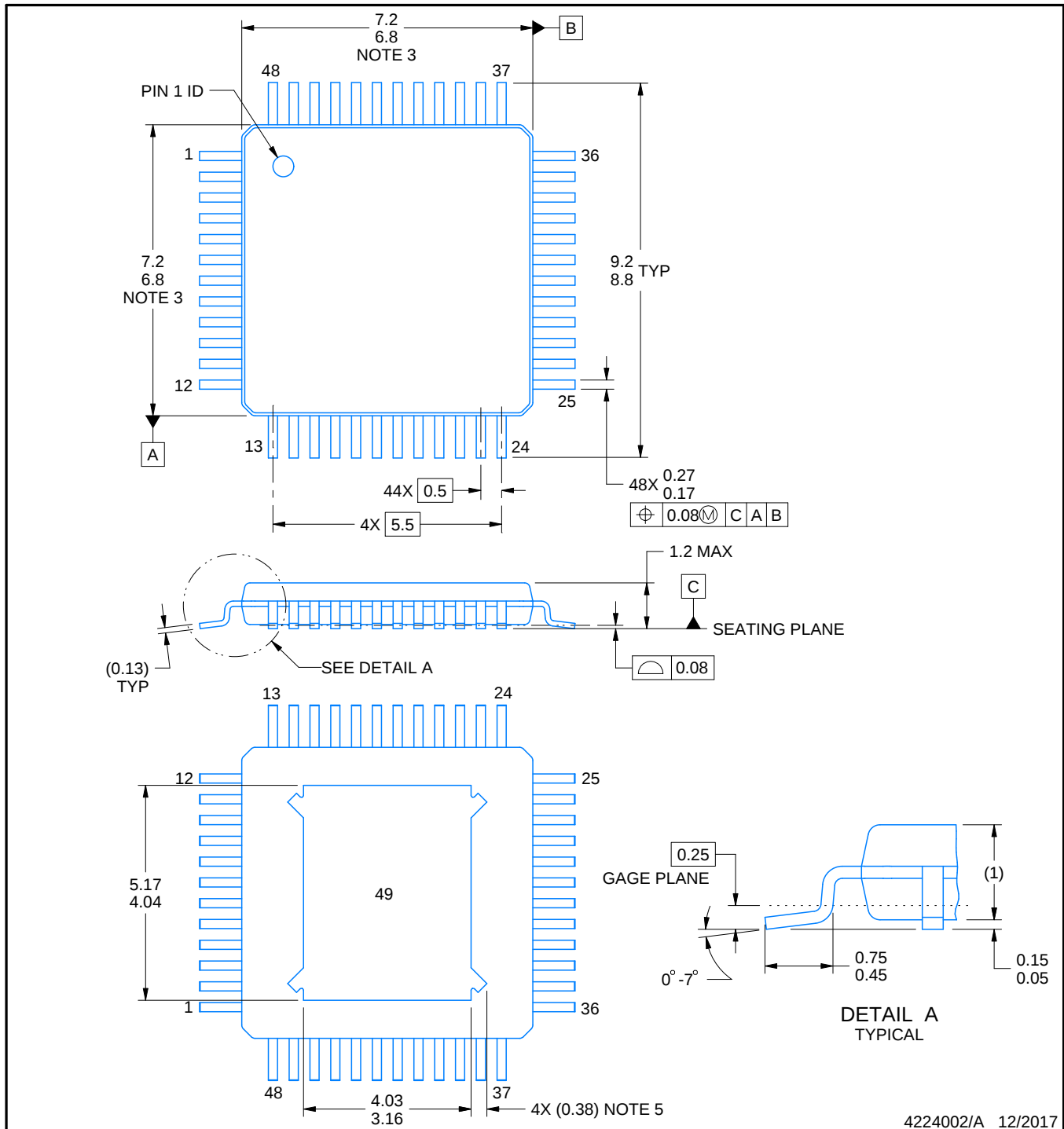
NOTE: A. All linear dimensions are in millimeters

 Tie strap features may not be present.

PowerPAD is a trademark of Texas Instruments

**PHP0048K****PowerPAD™ HTQFP - 1.2 mm max height**

PLASTIC QUAD FLATPACK



4224002/A 12/2017

**NOTES:**

PowerPAD is a trademark of Texas Instruments.

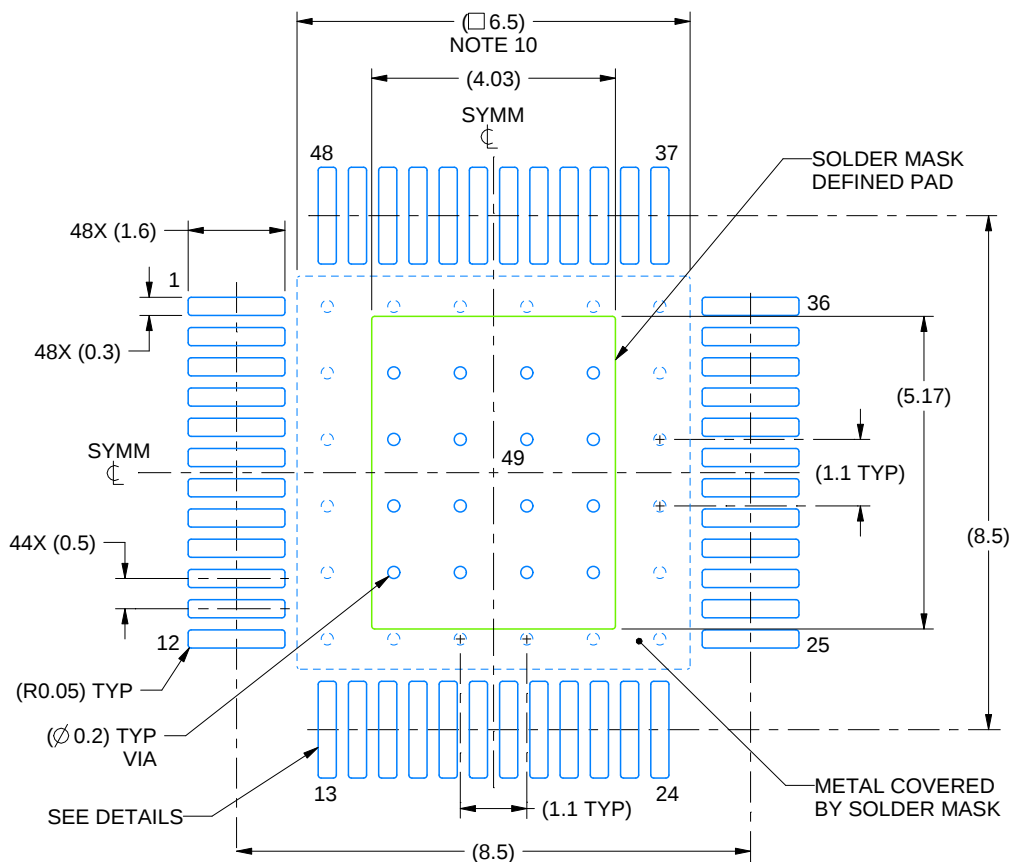
- All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
- This drawing is subject to change without notice.
- This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
- Reference JEDEC registration MS-026.
- Feature may not be present.

# EXAMPLE BOARD LAYOUT

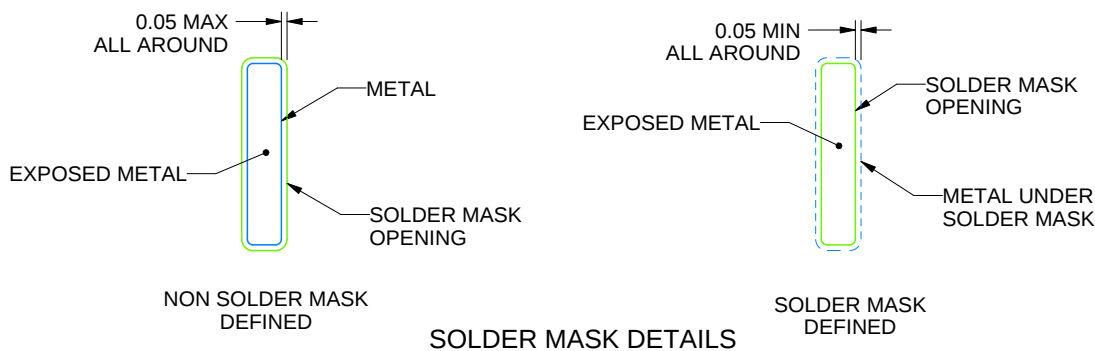
PHP0048K

PowerPAD™ HTQFP - 1.2 mm max height

PLASTIC QUAD FLATPACK



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



SOLDER MASK DETAILS

4224002/A 12/2017

NOTES: (continued)

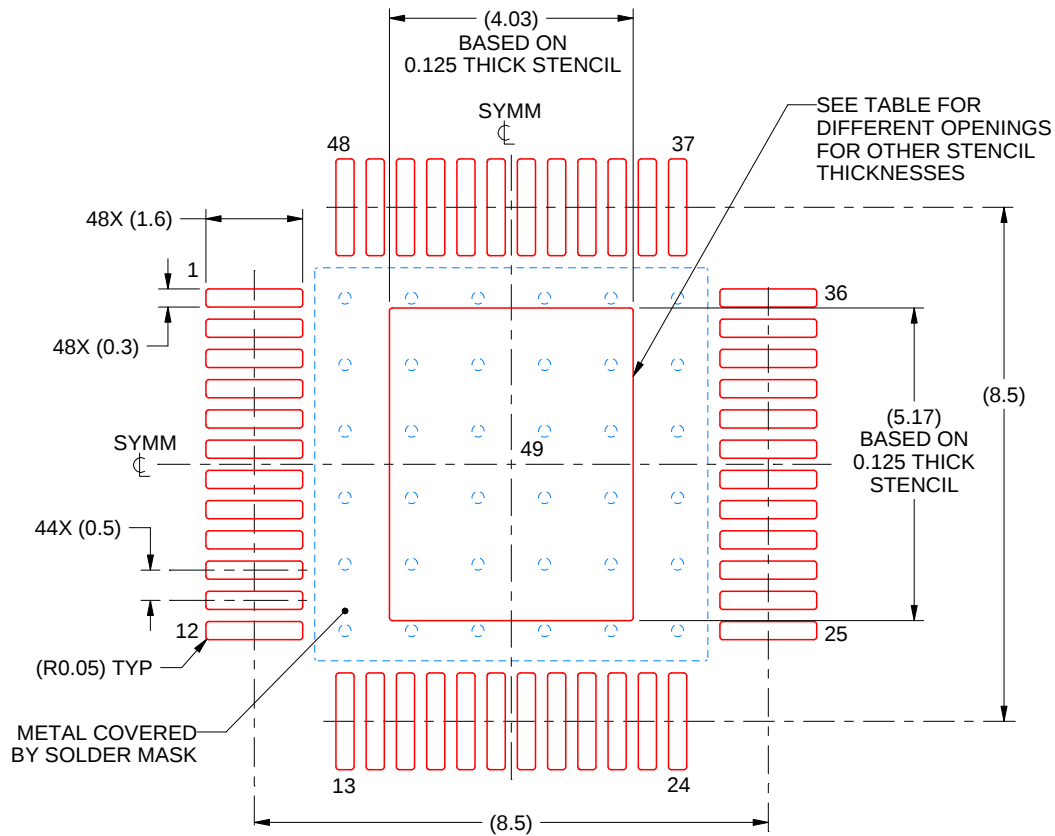
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. This package is designed to be soldered to a thermal pad on the board. See technical brief, Powerpad thermally enhanced package, Texas Instruments Literature No. SLMA002 ([www.ti.com/lit/slma002](http://www.ti.com/lit/slma002)) and SLMA004 ([www.ti.com/lit/slma004](http://www.ti.com/lit/slma004)).
9. Vias are optional depending on application, refer to device data sheet. It is recommended that vias under paste be filled, plugged or tented.
10. Size of metal pad may vary due to creepage requirement.

# EXAMPLE STENCIL DESIGN

PHP0048K

PowerPAD™ HTQFP - 1.2 mm max height

PLASTIC QUAD FLATPACK



**SOLDER PASTE EXAMPLE**  
EXPOSED PAD  
100% PRINTED SOLDER COVERAGE BY AREA  
SCALE:8X

| STENCIL THICKNESS | SOLDER STENCIL OPENING |
|-------------------|------------------------|
| 0.1               | 4.51 X 5.78            |
| 0.125             | 4.03 X 5.17 (SHOWN)    |
| 0.150             | 3.68 X 4.72            |
| 0.175             | 3.41 X 4.37            |

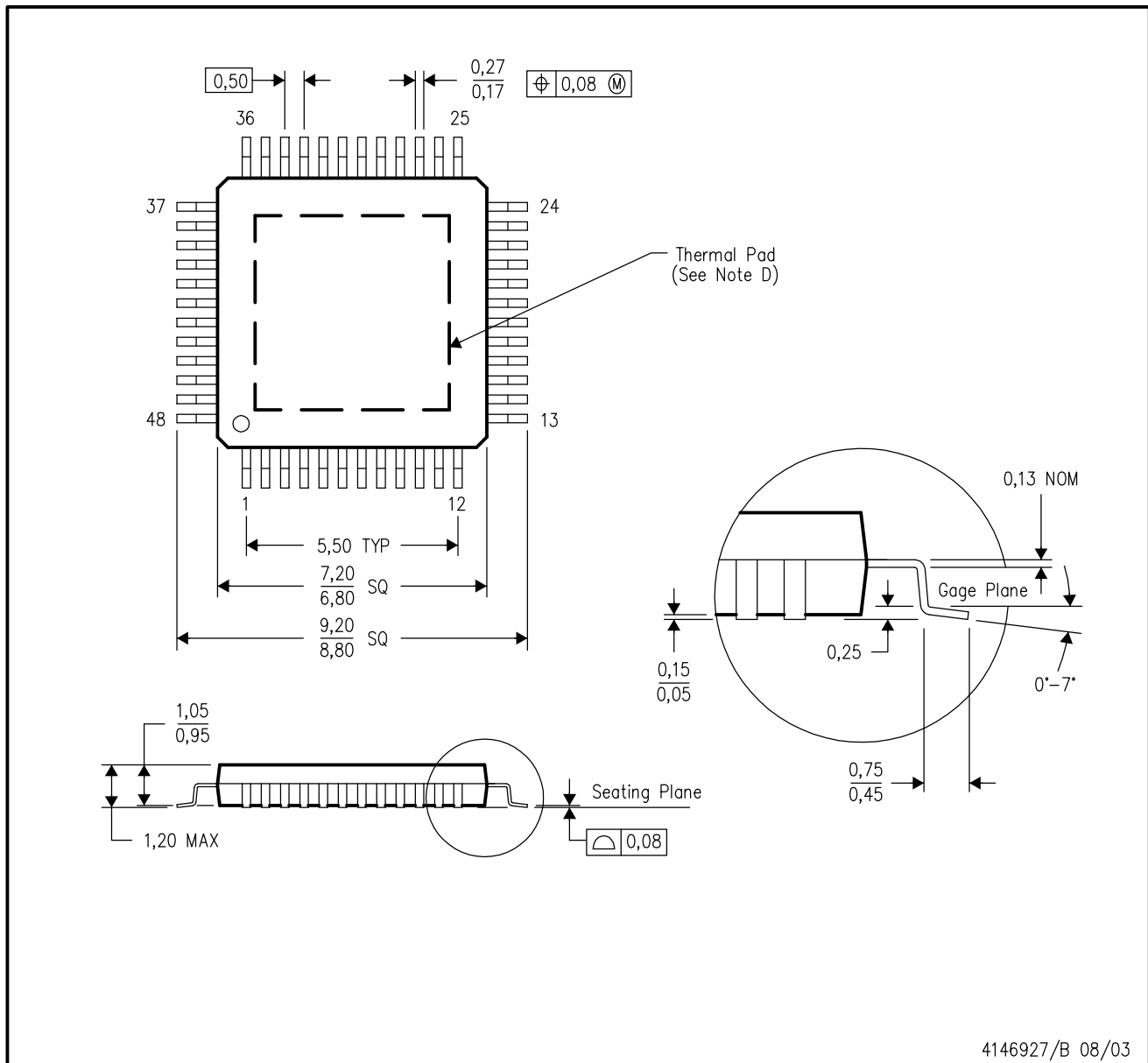
4224002/A 12/2017

NOTES: (continued)

11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
12. Board assembly site may have different recommendations for stencil design.

PHP (S-PQFP-G48)

PowerPAD™ PLASTIC QUAD FLATPACK



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body dimensions do not include mold flash or protrusion
  - D. This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 for information regarding recommended board layout. This document is available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - E. Falls within JEDEC MS-026

PHP (S-PQFP-G48)

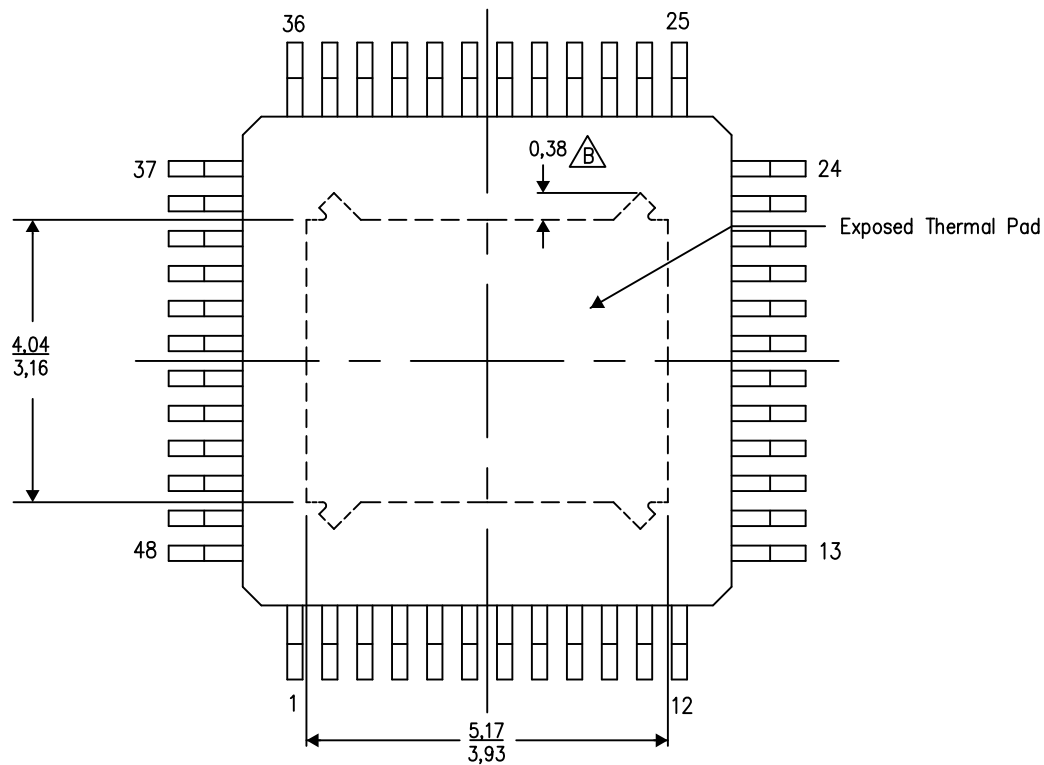
PowerPAD™ PLASTIC QUAD FLATPACK

## THERMAL INFORMATION

This PowerPAD™ package incorporates an exposed thermal pad that is designed to be attached to a printed circuit board (PCB). The thermal pad must be soldered directly to the PCB. After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For additional information on the PowerPAD package and how to take advantage of its heat dissipating abilities, refer to Technical Brief, PowerPAD Thermally Enhanced Package, Texas Instruments Literature No. SLMA002 and Application Brief, PowerPAD Made Easy, Texas Instruments Literature No. SLMA004. Both documents are available at [www.ti.com](http://www.ti.com).

The exposed thermal pad dimensions for this package are shown in the following illustration.



4206329-9/P 03/15

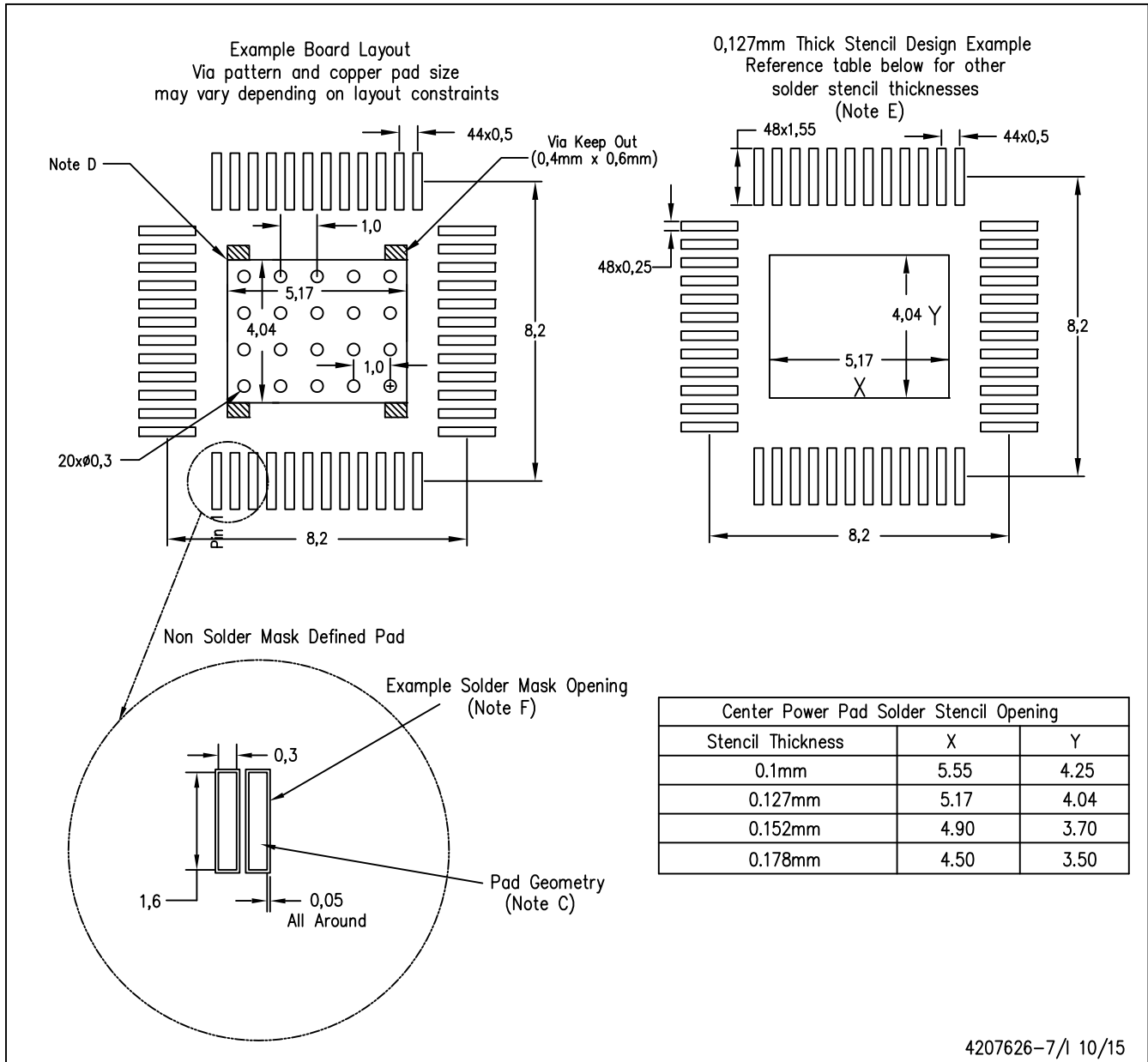
NOTE: A. All linear dimensions are in millimeters

$\triangle B$  Tie strap features may not be present.

PowerPAD is a trademark of Texas Instruments

PHP (S-PQFP-G48)

PowerPAD™ PLASTIC QUAD FLATPACK



- NOTES:
- All linear dimensions are in millimeters.
  - This drawing is subject to change without notice.
  - Publication IPC-7351 is recommended for alternate designs.
  - This package is designed to be soldered to a thermal pad on the board. Refer to Technical Brief, PowerPad Thermally Enhanced Package, Texas Instruments Literature No. SLMA002, SLMA004, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at [www.ti.com](http://www.ti.com) <<http://www.ti.com>>.
  - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
  - Customers should contact their board fabrication site for recommended solder mask tolerances and via tenting options for vias placed in the thermal pad.

PowerPAD is a trademark of Texas Instruments

## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, regulatory or other requirements.

These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you fully indemnify TI and its representatives against any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to [TI's Terms of Sale](#), [TI's General Quality Guidelines](#), or other applicable terms available either on [ti.com](#) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products. Unless TI explicitly designates a product as custom or customer-specified, TI products are standard, catalog, general purpose devices.

TI objects to and rejects any additional or different terms you may propose.

Copyright © 2026, Texas Instruments Incorporated

Last updated 10/2025