

# TAS2781 24-V Class-D Amplifier with Real Time Integrated Speaker Protection and Audio Processing

## 1 Features

### Key Features

- Integrated DSP for audio processing
- 24-V Supply for class-d output stage
- Y-Bridge multi-level supply architecture
- Hybrid-pro external boost control algorithm
- Ultrasonic output support up to 40 kHz

### Output power:

- 25 W, 1% THD+N (4 Ω, 18 V)
- 30 W Maximum output power, 10% THD+N

### Efficiency (1% THDN) and power consumption

- 82% at 1W, 4 Ω, PVDDH = 12 V, PVDDL = 3.8 V
- 83% at 1W, 8 Ω, PVDDH = 18 V, PVDDL = 5 V
- 84% at 1W, 4 Ω, PVDDH = 18 V, PVDDL = 5 V
- 90% at 15W, 4 Ω, PVDDH = 18 V, PVDDL = 5 V
- 93% at 15W, 8 Ω, PVDDH = 18 V, PVDDL = 5 V
- <0.5 μA in Hardware Shutdown Mode

### Power supplies and management:

- AVDD: 1.8 V
- IOVDD: 1.8 V/ 3.3 V
- PVDDL: 2.7 V to 5.5 V
- PVDDH: 3 V to 24 V

### Interfaces and Control:

- SDOUT for echo cancellation
- I<sup>2</sup>S/TDM: 8 channels of 32 bits up to 192 KSPS
- I<sup>2</sup>C with fast mode+ or SPI
- Inter-chip communication bus
- 16 kHz to 192 kHz sample rates

### Advanced DSP audio processing:

- Real-time IV-sense for speaker protection
- Dynamic range compressor
- Brownout protection with power limiter
- Multi-channel balancing communication

### Protection and EMI:

- Over power and low battery protection
- PVDDH/ PVDDL supply tracking limiters
- Thermal and over current protections
- Thermal foldback
- Post filter feedback and slew rate control

## 2 Applications

- [Laptop and Desktop Computers](#)
- [Smart Speakers](#)
- [Tablets and Handhelds](#)
- [Wireless Speakers](#)

## 3 Description

The TAS2781 is a mono, digital input Class-D audio amplifier optimized for efficiently driving high peak power into loudspeakers. The Class-D amplifier is capable of delivering 25 W of continuous power into a 4 Ω load with less than 1% THD+N at a supply voltage of 18 V. The broad voltage input range and the high output power makes this amplifier versatile enough to work with battery or line powered systems.

An on-chip DSP supports Texas Instruments Smart Amp speaker protection algorithm. The integrated speaker voltage and current sense provides for real-time monitoring of loudspeakers.

Y-Bridge power architecture improves amplifier efficiency by internally selecting the supplies for optimal headroom. Brownout prevention scheme with adjustable threshold allows reducing the gain in signal path when the supply drops.

The Hybrid-Pro algorithm allows user to optimize efficiency and improve battery life by controlling the external power supply.

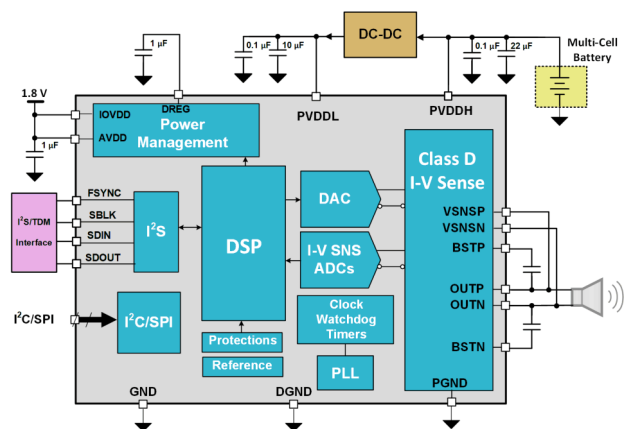
Up to eight TAS2781 devices can share a common bus via I<sup>2</sup>S/TDM and I<sup>2</sup>C/SPI interfaces.

The TAS2781 is available in a 30 pin HR-QFN package for a compact PCB footprint.

### Device Information<sup>(1)</sup>

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TAS2781	HR QFN	4 mm x 3.5 mm

- (1) For all available packages, see the orderable addendum at the end of the data sheet.



Schematic

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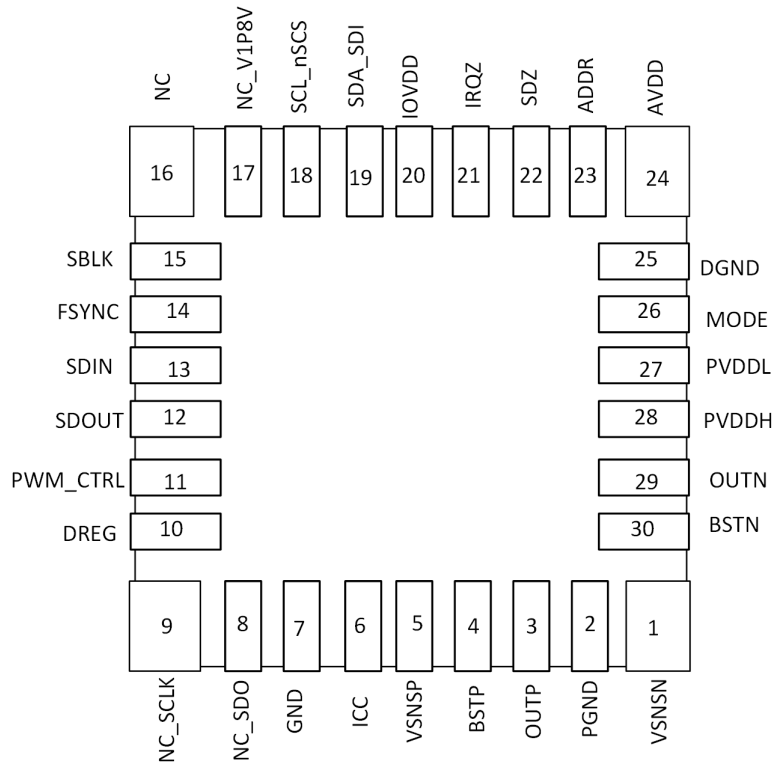
## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

<b>Changes from Revision A (November 2022) to Revision B (July 2023)</b>	<b>Page</b>
• Updated PVDD to 24 V with -20° C temp condition footnote in <i>Absolute Maximum Ratings</i> and <i>Recommended Operating Conditions</i> .....	4
• Clarifications to edge rate register description.....	34
• PFFB feature recommendation for ferrite bead filters.....	68
• Startup configuration script added to fix power-up pop issue.....	72

<b>Changes from Revision * (July 2022) to Revision A (November 2022)</b>	<b>Page</b>
• Change device status from "Advanced Information" to "Production Data.".....	1

## 5 Pin Configuration and Functions



**Figure 5-1. Package 30-Pin HR-QFN Bottom View**

**Table 5-1. Pin Functions**

PIN		I/O	DESCRIPTION
NAME	NO.		
ADDR	23	I	Address detect pin. Resistor value at this pin selects the I <sup>2</sup> C address. See <a href="#">Section 8.3.2</a> .
AVDD	24	P	Analog power input. Connect to 1.8 V supply and decouple to GND with capacitor.
BSTN	30	P	Class-D negative bootstrap. Connect a capacitor between BSTN and OUTN.
BSTP	4	P	Class-D positive bootstrap. Connect a capacitor between BSTP and OUTP.
DGND	25	P	Device substrate ground. Connect to PCB ground plane. Avoid any common routing inductance between this pin and GND pin.
DREG	10	P	Digital core voltage regulator output. Bypass to GND with a capacitor. Do not connect to external load.
FSYNC	14	I	Frame Synchronization Clock.
GND	7	P	Analog ground. Connect to PCB ground plane.
ICC	6	IO	Inter-chip communication pin used to transmit gain alignment. Connect to GND if not used.
IOVDD	20	P	Digital IO Supply. Connect to 1.8 V or 3.3 V IO supply and decouple with a capacitor to GND.
IRQZ	21	O	Open drain, active low interrupt pin. Pull up to IOVDD with resistor if optional internal pull up is not used.
MODE	26	I	External configuration defines the mode of operation.
NC	16	-	Tied to GND.
NC_SCLK	9	I	I <sup>2</sup> C Mode: NC = Tied to GND, SPI Mode: Clock pin.
NC_SDO	8	O	I <sup>2</sup> C Mode: NC = Tied to GND, SPI Mode: Serial data output pin.

**Table 5-1. Pin Functions (continued)**

PIN		I/O	DESCRIPTION
NAME	NO.		
NC_V1P8V	17	P	NC_V1P8V = Tied to GND when ICC is not used and when SPI interface is not required, NC_V1P8V = Tied to 1.8 V supply when ICC is used and when SPI interface is required,
OUTN	29	O	Class-D negative output.
OUTP	3	O	Class-D positive output.
PGND	2	P	Class-D ground. Connect to PCB ground plane.
PVDDH	28	P	Class-D power supply input. Decouple with a capacitor.
PVDDL	27	P	Single-cell battery supply input. Decouple with a capacitor.
PWM_CTRL	11	O	Control pin for external boost converter.
SBCLK	15	I	TDM Serial Bit Clock.
SCL_nSCS	18	I	I <sup>2</sup> C Mode: Clock pin; pull up to IOVDD with a resistor. SPI Mode: Active low chip select pin.
SDA_SDI	19	IO	I <sup>2</sup> C Mode: Data Pin; pull up to IOVDD with a resistor. SPI Mode: Serial data input pin.
SDIN	13	I	TDM Serial Data Input.
SDOUT	12	IO	TDM Serial Data Output.
SDZ	22	I	Active low hardware shutdown.
VSNSN	1	I	Voltage Sense negative input. Connect to Class-D negative output or after a ferrite bead filter.
VSNP	5	I	Voltage Sense positive input. Connect to Class-D positive output or after a ferrite bead filter.

## 6 Specifications

### 6.1 Absolute Maximum Ratings

		MIN	MAX	UNIT
Supply Voltage	AVDD	-0.3	2	V
	IOVDD	-0.3	5	V
	NC_V1P8V	-0.3	2	V
	PVDDH	-0.3	26	V
	PVDDL	-0.3	6	V
	PVDDH - PVDDL	-0.3	22	V
Internal Supply Voltage	DREG	-0.3	1.5	V
IO Voltage <sup>(1)</sup>	SBLK, FSYNK, SDIN, SDOUT, IRQZ, SDA_SDI, SCL_nSCS, PWM_CTRL, SDZ	-0.3	5	V
	NC_SCLK, NC_SDO, ICC, ADDR	-0.3	2	V
Operating free-air temperature, T <sub>A</sub> ; Device is functional and reliable, some performance characteristics may be degraded.	PVDD is 23 V or below	-40	85	°C
	PVDD higher than 23 V	-20	85	°C
Performance free-air temperature, T <sub>P</sub> ; All performance characteristics are met.		-20	70	°C
Operating junction temperature, T <sub>J</sub>	PVDD is 23 V or below	-40	150	°C
	PVDD higher than 23 V	-20	150	°C
Storage temperature, T <sub>stg</sub>		-65	150	°C

(1) All digital inputs and IOs are failsafe.

## 6.2 ESD Ratings

			VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±2000	V
		Charged-device model (CDM), per ANSI/ESDA/JEDEC JS-002 <sup>(2)</sup>	±500	

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.  
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

## 6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

			MIN	NOM	MAX	UNIT
AVDD	Supply voltage		1.65	1.8	1.95	V
IOVDD	Supply voltage		3	3.3	3.6	V
			1.65	1.8	1.95	
NC_V1P8V	Supply voltage for ICC Pin		1.65	1.8	1.95	V
PVDDH <sup>(2)</sup>	Supply voltage (functional) <sup>(1)</sup>	Min operating free-air and Min operating junction temperature of -20°C	3		24	V
		Min operating free-air and Min operating junction temperature of -40°C	3		23	
	Supply voltage (performance)	Min operating free-air and Min operating junction temperature of -20°C	4.5		24	
		Min operating free-air and Min operating junction temperature of -40°C	4.5		23	
PVDDL	Supply voltage (functional) <sup>(1)</sup>		2.7		5.5	V
	Supply voltage (performance with Y-bridge disabled)		3.5		5.5	
	Supply voltage (performance with Y-bridge enabled)		2.7		5.5	
R <sub>SPK</sub>	Speaker impedance		3.2			Ω
L <sub>SPK</sub>	Speaker inductance		5			μH

- (1) Device will remain functional but performance may degrade.  
(2) PVDDH supply voltage should be greater than PVDDL-0.7 V.

## 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		HR_QFN	UNIT
		30 PINS	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	44.2	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	22.4	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	12.3	°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	0.6	°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	12.1	°C/W

- (1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

## 6.5 Electrical Characteristics

T<sub>A</sub> = 25 °C, PVDDH = 18 V, PVDDL = 3.8 V, AVDD = 1.8 V, IOVDD = 1.8 V, R<sub>L</sub> = 4Ω + 15μH, f<sub>in</sub> = 1 kHz, f<sub>s</sub> = 48 kHz, Gain = 21 dBV, SDZ = 1, NG\_EN=0, EN\_LLSR=0, PWR\_MODE1, Measured filter free as in Section 7 (unless otherwise noted).

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>DIGITAL INPUT and OUTPUT</b>					
V <sub>IH</sub>	High-level digital input logic voltage threshold	SBLK, FSYNC, SDIN, SCL_nSCS, SDA_SDI		0.7xIOVDD	V
V <sub>IL</sub>	Low-level digital input logic voltage threshold	SBLK, FSYNC, SDIN, SCL_nSCS, SDA_SDI		0.3 x IOVDD	V
V <sub>IH(SDZ)</sub>	High-level digital input logic voltage threshold	SDZ		0.7xAVDD	V

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 $T_A = 25\text{ }^\circ\text{C}$ ,  $PVDDH = 18\text{ V}$ ,  $PVDDL = 3.8\text{ V}$ ,  $AVDD = 1.8\text{ V}$ ,  $IOVDD = 1.8\text{ V}$ ,  $R_L = 4\Omega + 15\mu\text{H}$ ,  $f_{in} = 1\text{ kHz}$ ,  $f_s = 48\text{ kHz}$ , Gain = 21 dBV, SDZ = 1, NG\_EN=0, EN\_LLSR=0, PWR\_MODE1, Measured filter free as in Section 7 (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$V_{IL(SDZ)}$	Low-level digital input logic voltage threshold	SDZ			0.3 x AVDD	V
$V_{IH(1P8V)}$	High-level digital input logic voltage threshold	ICC, NC_SCLK	0.7xNC_V1P8V			V
$V_{IL(1P8V)}$	Low-level digital input logic voltage threshold	ICC, NC_SCLK			0.3 x NC_V1P8V	V
$V_{OH}$	High-level digital output voltage	SDOUT; $I_{OH} = 100\text{ }\mu\text{A}$ .	IOVDD-0.2 V			V
$V_{OL}$	Low-level digital output voltage	SDOUT; $I_{OH} = 100\text{ }\mu\text{A}$ .			0.2	V
$V_{OL(I^2C)}$	Low-level digital output voltage	SDA_SDI; $I_{OL} = -1\text{ mA}$ .			0.2 x IOVDD	V
$V_{OH(1P8V)}$	High-level digital output voltage	NC_SDO	0.8xNC_V1P8V			V
$V_{OL(1P8V)}$	Low-level digital output voltage	NC_SDO			0.2xNC_V1P8V	V
$I_{IH}$	Input logic-high leakage for digital inputs	All digital pins; Input = Supply Rail.	-1		1	$\mu\text{A}$
$I_{IL}$	Input logic-low leakage for digital inputs	All digital pins; Input = GND.	-1		1	$\mu\text{A}$
$C_{IN}$	Input capacitance for digital inputs	All digital pins		5		pF
$R_{PD}$	Pull down resistance for IO pins when asserted on			18		k $\Omega$
$R_{OS}$	OUT to VSNS resistors	Load disconnected		10		k $\Omega$
IO	Output Current Strength	Measured at 0.4 V below supply and 0.4 V above GND.		8		mA
<b>AMPLIFIER PERFORMANCE</b>						
$P_{OUT}$	Peak Output Power	THD+N = 10 %, PWR_MODE0 <sup>(1)</sup> , PWR_MODE1 <sup>(2)</sup>		30		W
	Maximum Continuous Output Power	THD+N = 1 %, PVDDL = 5 V, PWR_MODE0, PWR_MODE1		25		
System Efficiency		$P_{OUT} = 1\text{ W}$ , PVDDL = 5 V, PWR_MODE1		84		%
		$P_{OUT} = 1\text{ W}$ , PVDDL = 5 V, PWR_MODE0		79		
		$P_{OUT} = 3\text{ W}$ , PVDDL = 5 V, PWR_MODE0 and PWR_MODE1		85		
		$P_{OUT} = 8\text{ W}$ , PVDDL = 5 V, PWR_MODE0 and PWR_MODE1		88		
THD+N	Total Harmonic Distortion and Noise	$P_{OUT} = 1\text{ W}$ , $f_{in} = 1\text{ kHz}$		-84		dB
		$P_{OUT} = 1\text{ W}$ , $f_{in} = 6.667\text{ kHz}$		-84		
IMD	Inter-Modulation Distortion	ITU-R, 19 kHz / 20 kHz, 1:1: 12.5 W		-83		dB
$V_N$	Idle Channel Noise	A-Weighted, 20 Hz - 20 kHz, PWR_MODE0		42		$\mu\text{V}$
		A-Weighted, 20 Hz - 20 kHz, PWR_MODE2 <sup>(3)</sup>		34		
		A-Weighted, 20 Hz - 20 kHz, PWR_MODE1		32		
	Idle Channel Noise with Ultrasonic Chirp (100 us duty cycle, 25 ms period)	A-Weighted, 20 Hz - 20 kHz, PWR_MODE3 <sup>(4)</sup> , 1 V <sub>Peak</sub> , Register 0x73 set to E0h		34		
$F_{PWM}$	Class-D PWM Switching Frequency	Average frequency in Spread Spectrum Mode, CLASSD_SYNC=0		384		kHz
		Fixed Frequency Mode, CLASSD_SYNC=0		384		
		Fixed Frequency Mode, CLASSD_SYNC=1, $f_s = 44.1\text{ kHz}$ and 88.2 kHz		352.8		
		Fixed Frequency Mode, CLASSD_SYNC=1, $f_s = 48\text{ kHz}$ and 96 kHz		384		
$V_{OS}$	Output Offset Voltage	Idle Mode	-1.3	$\pm 0.3$	1.3	mV

$T_A = 25\text{ }^\circ\text{C}$ , PVDDH = 18 V, PVDDL = 3.8 V, AVDD = 1.8 V, IOVDD = 1.8 V,  $R_L = 4\Omega + 15\mu\text{H}$ ,  $f_{in} = 1\text{ kHz}$ ,  $f_s = 48\text{ kHz}$ , Gain = 21 dBV, SDZ = 1, NG\_EN=0, EN\_LLSR=0, PWR\_MODE1, Measured filter free as in Section 7 (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
DNR	Dynamic Range	A-Weighted, -60 dBFS		110		dB
		A-Weighted, -60 dBFS, PWR_MODE2		109		
		A-Weighted, -60 dBFS, PWR_MODE0		109		
SNR	Signal to Noise Ratio	A-Weighted, Referenced to 1 % THD+N Output Level		110		dB
		A-Weighted, Referenced to 1 % THD+N Output Level, PWR_MODE2 <sup>(1)</sup>		110		
		A-Weighted, Referenced to 1 % THD+N Output Level, PWR_MODE0		109		
K <sub>CP</sub>	Click and Pop Performance	Idle mode, into and out of Shutdown mode, A-weighted		0.8		mV
	Full Scale Output Voltage	$f_s \leq 48\text{ kHz}$		21		dBV
	Minimum Programmable Gain	$f_s \leq 48\text{ kHz}$		11		dBV
	Maximum Programmable Gain	$f_s \leq 48\text{ kHz}$		21		
	Programmable Output Level Step Size			0.5		dB
	Mute attenuation	Device in Software Shutdown or Muted in normal operation		108		dB
	Chip to Chip Group Delay		-1		1	$\mu\text{s}$
	PVDDH Power Supply Rejection Ratio	PVDDH = 18 V + 200 mV <sub>pp</sub> , $f_{\text{ripple}} = 217\text{ Hz}$		118		dB
PVDDH = 18 V + 200 mV <sub>pp</sub> , $f_{\text{ripple}} = 1\text{ kHz}$			110			
PVDDH = 18 V + 200 mV <sub>pp</sub> , $f_{\text{ripple}} = 20\text{ kHz}$			98			
	PVDDL Power Supply Rejection Ratio	PVDDL = 5 V + 200 mV <sub>pp</sub> , $f_{\text{ripple}} = 217\text{ Hz}$		114		dB
PVDDL = 5 V + 200 mV <sub>pp</sub> , $f_{\text{ripple}} = 1\text{ kHz}$			109			
PVDDL = 5 V + 200 mV <sub>pp</sub> , $f_{\text{ripple}} = 20\text{ kHz}$			93			
	AVDD Power Supply Rejection Ratio	AVDD = 1.8 V + 200 mV <sub>pp</sub> , $f_{\text{ripple}} = 217\text{ Hz}$		105		dB
AVDD = 1.8 V + 200 mV <sub>pp</sub> , $f_{\text{ripple}} = 1\text{ kHz}$			103			
AVDD = 1.8 V + 200 mV <sub>pp</sub> , $f_{\text{ripple}} = 20\text{ kHz}$			88			
	Power Supply Inter-modulation	PVDDH, 217 Hz, 100-mV <sub>pp</sub> , Input f = 1 kHz @ 400 mW		-120		dB
PVDDL, 217 Hz, 100-mV <sub>pp</sub> , Input f = 1 kHz @ 400 mW			-120			
AVDD, 217 Hz, 100-mV <sub>pp</sub> , Input f = 1 kHz @ 400 mW			-80			
IOVDD 217 Hz, 100-mV <sub>pp</sub> , Input f = 1 kHz @ 400 mW			-117			
	Turn ON Time from Release of Software Shutdown	No Volume Ramping		1.13		ms
Volume Ramping			6.73			
	Turn OFF Time From Assertion of Software Shutdown to Amp Hi-Z	No Volume Ramping		0.56		ms
Volume Ramping			6			
	Out of Hardware Shutdown to first I <sup>2</sup> C command		1			ms
	SDZ timeout	Exiting HW Shutdown	2	6	23.8	ms
	Turn OFF Time when Software Shutdown	$f_s = 48\text{ ksps}$ , DVC_RMP_RT[3:2] = 3h (disabled). Multiply by $48/f_s$ for differet sampling rate.		1		ms
$f_s = 48\text{ ksps}$ , DVC_RMP_RT[3:2] = 0h (enabled). Multiply by $48/f_s$ for different sampling rate.			12.5			
<b>DIE TEMPERATURE SENSOR</b>						
	Resolution			8		bits
	Minimum Temperature Measurement Range			-40		$^\circ\text{C}$
	Maximum Temperature Measurement Range			150		$^\circ\text{C}$
	Die Temperature Resolution			1		$^\circ\text{C}$
	Die Temperature Accuracy		-5		5	$^\circ\text{C}$
<b>VOLTAGE MONITOR</b>						

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 $T_A = 25\text{ }^\circ\text{C}$ ,  $PVDDH = 18\text{ V}$ ,  $PVDDL = 3.8\text{ V}$ ,  $AVDD = 1.8\text{ V}$ ,  $IOVDD = 1.8\text{ V}$ ,  $R_L = 4\Omega + 15\mu\text{H}$ ,  $f_{in} = 1\text{ kHz}$ ,  $f_s = 48\text{ kHz}$ ,  $\text{Gain} = 21\text{ dBV}$ ,  $\text{SDZ} = 1$ ,  $\text{NG\_EN} = 0$ ,  $\text{EN\_LLSR} = 0$ ,  $\text{PWR\_MODE1}$ , Measured filter free as in Section 7 (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Resolution			12		bits
	PVDDH Measurement Range	Minimum Level		2		V
		Maximum Level		23		
	PVDDH Resolution			22.5		mV
	PVDDH Accuracy	$2\text{ V} \leq \text{PVDDHV} \leq 23\text{ V}$		$\pm 60$		mV
	PVDDL Measurement Range	Minimum Level		2.3		V
		Maximum Level		6		
	PVDDL Resolution			20		mV
	PVDDL Accuracy	$2.3\text{ V} \leq \text{PVDDL} \leq 6\text{ V}$		$\pm 20$		mV
<b>TDM SERIAL AUDIO PORT</b>						
	Minimum PCM Sample Rates and FSYNC Input Frequency			14.7		kHz
		Maximum PCM Sample Rates and FSYNC Input Frequency		192		
	Minimum SBCLK Input Frequency	I <sup>2</sup> S/TDM Operation		0.512		MHz
		Maximum SBCLK Input Frequency	I <sup>2</sup> S/TDM Operation		24.576	
	SBCLK Maximum Input Jitter	RMS Jitter below 40 kHz that can be tolerated without performance degradation			0.5	ns
		RMS Jitter above 40 kHz that can be tolerated without performance degradation			1	
	Minimum SBCLK Cycles per FSYNC in I <sup>2</sup> S and TDM Modes	Other Values: 24, 32, 48, 64, 96, 125, 128, 192, 250, 256, 384, 500		16		Cycles
		Maximum SBCLK Cycles per FSYNC in I <sup>2</sup> S and TDM Modes	Other Values: 24, 32, 48, 64, 96, 125, 128, 192, 250, 256, 384, 500		512	
<b>PCM PLAYBACK CHARACTERISTICS <math>f_s \leq 48\text{ kHz}</math></b>						
$f_s$	Minimum Sample Rate			14.7		kHz
	Maximum Sample Rate			48		
	Passband Frequency Meeting Ripple			0.454		$f_s$
	Passband Ripple	20 Hz to LPF cutoff frequency	-0.5		0.5	dB
	Stop Band Attenuation	$\geq 0.55 f_s$		60		dB
		$\geq 1 f_s$		65		
	Group Delay (Including Noise Gate)	DC to $0.454 f_s$ , DC blocker disabled, Class-H disabled		31		$1/f_s$
		DC to $0.454 f_s$ , DC blocker disabled, Class-H enabled		221		
<b>PCM PLAYBACK CHARACTERISTICS <math>f_s &gt; 48\text{ kHz}</math></b>						
$f_s$	Minimum Sample Rates			88.2		kHz
	Maximum Sample Rate			192		
	Frequency for Passband Ripple	$f_s = 96\text{ kHz}$		0.437		$f_s$
	Passband 3db Frequency	$f_s = 96\text{ kHz}$		0.459		$f_s$
	Passband Ripple	DC to LPF cutoff frequency	-0.5		0.5	dB
	Stop Band Attenuation	$\geq 0.56 f_s$		60		dB
		$\geq 1 f_s$		65		
	Group Delay (Including Noise Gate)	DC to $0.375 f_s$ , DC blocker disabled, Class-H disabled		51		$1/f_s$
		DC to $0.375 f_s$ , DC blocker disabled, Class-H enabled		242		
<b>SPEAKER CURRENT SENSE</b>						
	Resolution			16		bits



$T_A = 25\text{ }^\circ\text{C}$ ,  $PVDDH = 18\text{ V}$ ,  $PVDDL = 3.8\text{ V}$ ,  $AVDD = 1.8\text{ V}$ ,  $IOVDD = 1.8\text{ V}$ ,  $R_L = 4\Omega + 15\mu\text{H}$ ,  $f_{in} = 1\text{ kHz}$ ,  $f_s = 48\text{ kHz}$ , Gain = 21 dBV, SDZ = 1, NG\_EN=0, EN\_LLSR=0, PWR\_MODE1, Measured filter free as in Section 7 (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
DNR	Dynamic Range	Un-weighted, relative to 0 dBFS		70		dB
THD+N	Total Harmonic Distortion and Noise	Pout = 15 W		-61		dB
	Full Scale Input Current	Measured at -6 dBFS. Re-scaled at 0 dBFS.		5		A
	Differential Mode Gain	Pout = 1W, using a 40Hz - 40dBFS pilot tone	0.98		1.02	
	Frequency Response	20 Hz - 20 kHz	-0.1		0.1	dB
	Group Delay			22		1/f <sub>s</sub>
<b>SPEAKER VOLTAGE SENSE</b>						
	Resolution			16		bits
DNR	Dynamic Range	Un-weighted, relative 0 dBFS		73		dB
THD+N	Total Harmonic Distortion and Noise	Pout = 15 W		-68		dB
	Full Scale Input Voltage			16		V <sub>PK</sub>
	Differential Mode Gain	Pout = 1W, using a 40Hz - 40dBFS pilot tone	0.98		1.02	
	Frequency Response	20 Hz - 20 kHz	-0.1		0.1	dB
	Group Delay			22		1/f <sub>s</sub>
<b>SPEAKER VOLTAGE/CURRENT SENSE RATIO</b>						
	Gain Linearity	Pout ≥ 40 mW to 0.1% THD+N, using a 40 Hz -40 dBFS pilot tone, PWR_MODE0	-1		1	%
	Gain Linearity	Pout ≥ 80 mW to 0.1% THD+N, using a 40 Hz -40 dBFS pilot tone, PWR_MODE1	-1		1	%
	Gain error over temperature	-20 °C to 70 °C, Pout = 1 W		±0.6		%
	Phase Error between V and I			300		ns
<b>PROTECTION CIRCUITRY</b>						
	Brownout Prevention Latency to First Attack	BOP_SRC=1		400		µs
	Thermal Shutdown Temperature			145		°C
	Thermal Shutdown Retry	OTE_RETRY=1		1.5		s
	Output Over Current Limit on PVDDH	Output to Output, Output to GND or Output to PVDDH Short	5.5	6.7		A
	Output Over Current Limit on PVDDL	Output to Output, Output to GND or Output to PVDDL Short	2	2.6		A
	PVDDL Undervoltage Lockout Threshold	UVLO is asserted		2		V
		UVLO is de-asserted		2.16		
	AVDD Undervoltage Lockout Threshold	UVLO is asserted		1.45		V
		UVLO is de-asserted		1.51		
	IOVDD Undervoltage Lockout Threshold	UVLO is asserted		1.13		V
		UVLO is de-asserted		1.25		
	PVDDL Internal LDO Undervoltage Lockout Threshold	UVLO is asserted		4.1		V
<b>CLASS-H CONTROLLER</b>						
	Look Ahead Time	Sampling Rates 48 kHz and 96 kHz			4.8	ms
<b>BEEP PIN GENERATOR</b>						
f <sub>IN</sub>	SDZ Pin	Input PWM signal frequency	25.6		192	kHz
f <sub>IN</sub>	NC_SCLK Pin	Input PWM signal frequency	1.6		12	kHz
<b>TYPICAL CURRENT CONSUMPTION</b>						
	Hardware Shutdown	SDZ = 0, PVDDH		0.05		µA
		SDZ = 0, PVDDL		0.01		
		SDZ = 0, AVDD		0.14		
		SDZ = 0, IOVDD		0.005		

$T_A = 25\text{ }^\circ\text{C}$ , PVDDH = 18 V, PVDDL = 3.8 V, AVDD = 1.8 V, IOVDD = 1.8 V,  $R_L = 4\Omega + 15\mu\text{H}$ ,  $f_{in} = 1\text{ kHz}$ ,  $f_s = 48\text{ kHz}$ , Gain = 21 dBV, SDZ = 1, NG\_EN=0, EN\_LLSR=0, PWR\_MODE1, Measured filter free as in Section 7 (unless otherwise noted).

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Software Shutdown	All Clocks Stopped, PVDDH		0.05		$\mu\text{A}$
	All Clocks Stopped, PVDDL		0.5		
	All Clocks Stopped, AVDD		10		
	All Clocks Stopped, IOVDD		0.52		
Noise Gate Mode	$f_s = 48\text{ kHz}$ , PVDDH		0.012		mA
	$f_s = 48\text{ kHz}$ , PVDDL		0.13		
	$f_s = 48\text{ kHz}$ , AVDD		8.2		
	$f_s = 48\text{ kHz}$ , IOVDD		0.01		
Idle Mode - PWR_MODE1	$f_s = 48\text{ kHz}$ , PVDDH		0.04		mA
	$f_s = 48\text{ kHz}$ , PVDDL		2.2		
	$f_s = 48\text{ kHz}$ , AVDD, IV Sense = Enabled		15.5		
	$f_s = 48\text{ kHz}$ , AVDD, IV Sense = Disabled		11.8		
Idle Mode - PWR_MODE2	$f_s = 48\text{ kHz}$ , PVDDH		3		mA
	$f_s = 48\text{ kHz}$ , AVDD, IV Sense = Enabled		15.5		
	$f_s = 48\text{ kHz}$ , AVDD, IV Sense = Disabled		11.8		
	$f_s = 48\text{ kHz}$ , IOVDD		0.02		
Idle Mode - PWR_MODE0	$f_s = 48\text{ kHz}$ , PVDDH		2.3		mA
	$f_s = 48\text{ kHz}$ , PVDDL		2.1		
	$f_s = 48\text{ kHz}$ , AVDD, IV Sense = Enabled		15.5		
	$f_s = 48\text{ kHz}$ , AVDD, IV Sense = Disabled		11.8		
	$f_s = 48\text{ kHz}$ , IOVDD		0.02		

- (1) **PWR\_MODE0**: CDS\_MODE=10, PVDDL\_MODE=0
- (2) **PWR\_MODE1**: CDS\_MODE=00, PVDDL\_MODE=0
- (3) **PWR\_MODE2**: CDS\_MODE=11, PVDDL\_MODE=1
- (4) **PWR\_MODE3**: CDS\_MODE=01, PVDDL\_MODE=0

## 6.6 I<sup>2</sup>C Timing Requirements

T<sub>A</sub> = 25 °C, IOVDD = 1.8 V (unless otherwise noted)

		MIN	MAX	UNIT
<b>Standard-Mode</b>				
f <sub>SCL</sub>	SCL clock frequency	0	100	kHz
t <sub>HD,STA</sub>	Hold time (repeated) START condition. After this period, the first clock pulse is generated.	4		μs
t <sub>LOW</sub>	LOW period of the SCL clock	4.7		μs
t <sub>HIGH</sub>	HIGH period of the SCL clock	4		μs
t <sub>SU,STA</sub>	Setup time for a repeated START condition	4.7		μs
t <sub>HD,DAT</sub>	Data hold time: For I <sup>2</sup> C bus devices		3.45	μs
t <sub>SU,DAT</sub>	Data set-up time	250		ns
t <sub>r</sub>	SDA and SCL rise time		1000	ns
t <sub>f</sub>	SDA and SCL fall time		300	ns
t <sub>SU,STO</sub>	Set-up time for STOP condition	4		μs
t <sub>BUF</sub>	Bus free time between a STOP and START condition	4.7		μs
C <sub>b</sub>	Capacitive load for each bus line		400	pF
<b>Fast-Mode</b>				
f <sub>SCL</sub>	SCL clock frequency	0	400	kHz
t <sub>HD,STA</sub>	Hold time (repeated) START condition. After this period, the first clock pulse is generated.	0.6		μs
t <sub>LOW</sub>	LOW period of the SCL clock	1.3		μs
t <sub>HIGH</sub>	HIGH period of the SCL clock	0.6		μs
t <sub>SU,STA</sub>	Setup time for a repeated START condition	0.6		μs
t <sub>HD,DAT</sub>	Data hold time: For I <sup>2</sup> C bus devices	0	0.9	μs
t <sub>SU,DAT</sub>	Data set-up time	100		ns
t <sub>r</sub>	SDA and SCL rise time	20 + 0.1 × C <sub>b</sub> [pF]	300	ns
t <sub>f</sub>	SDA and SCL fall time	20 + 0.1 × C <sub>b</sub> [pF]	300	ns
t <sub>SU,STO</sub>	Set-up time for STOP condition	0.6		μs
t <sub>BUF</sub>	Bus free time between a STOP and START condition	1.3		μs
C <sub>b</sub>	Capacitive load for each bus line (10pF to 400pF)		400	pF
<b>Fast-Mode Plus</b>				
f <sub>SCL</sub>	SCL clock frequency		1000	kHz
t <sub>HD,STA</sub>	Hold time (repeated) START condition. After this period, the first clock pulse is generated.	0.26		μs
t <sub>LOW</sub>	LOW period of the SCL clock	0.5		μs
t <sub>HIGH</sub>	HIGH period of the SCL clock	0.26		μs
t <sub>SU,STA</sub>	Setup time for a repeated START condition	0.26		μs
t <sub>HD,DAT</sub>	Data hold time: For I <sup>2</sup> C bus devices	0		μs
t <sub>SU,DAT</sub>	Data set-up time	50		ns
t <sub>r</sub>	SDA and SCL Rise Time		120	ns
t <sub>f</sub>	SDA and SCL Fall Time		120	ns
t <sub>SU,STO</sub>	Set-up time for STOP condition	0.26		μs
t <sub>BUF</sub>	Bus free time between a STOP and START condition	0.5		μs
C <sub>b</sub>	Capacitive load for each bus line		550	pF

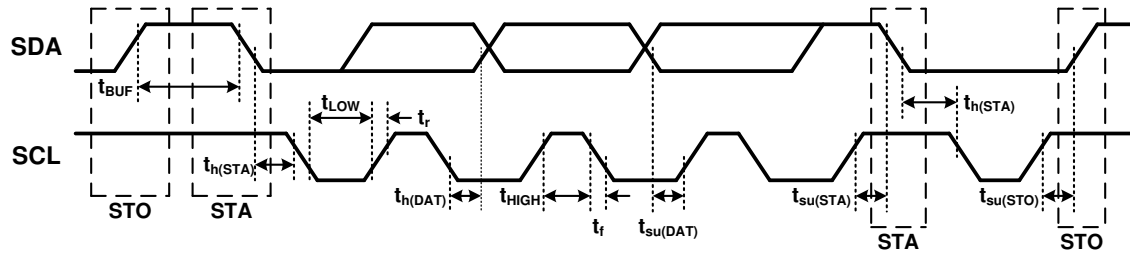


Figure 6-1. I<sup>2</sup>C Timing Diagram

### 6.7 TDM Port Timing Requirements

T<sub>A</sub> = 25 °C, IOVDD = NC\_V1P8V = 1.8 V, 20 pF load on all outputs(unless otherwise noted)

		MIN	MAX	UNIT
t <sub>H</sub> (SBCLK)	SBCLK high period	20		ns
t <sub>L</sub> (SBCLK)	SBCLK low period	20		ns
t <sub>SU</sub> (FSYNC)	FSYNC setup time	8		ns
t <sub>HLD</sub> (FSYNC)	FSYNC hold time	8		ns
t <sub>SU</sub> (SDIN/ICC)	SDIN/ICC setup time	8		ns
t <sub>HLD</sub> (SDIN/ICC)	SDIN/ICC hold time	8		ns
t <sub>d</sub> (SBCLK_SDOUT/ICC)	SBCLK to SDOUT/ICC delay	50% of SBCLK to 50% of SDOUT/ICC, IOVDD = 1.8 V		30
t <sub>r</sub> (SBCLK)	SBCLK rise time	10 % - 90 % Rise Time		8
t <sub>f</sub> (SBCLK)	SBCLK fall time	90 % - 10 % Fall Time		8

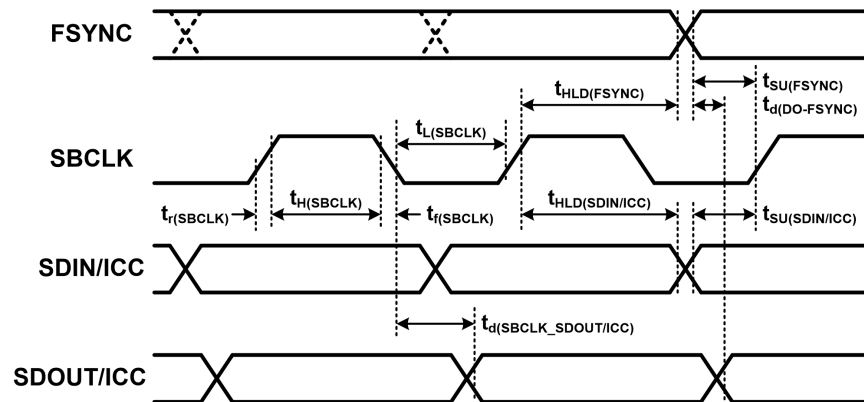
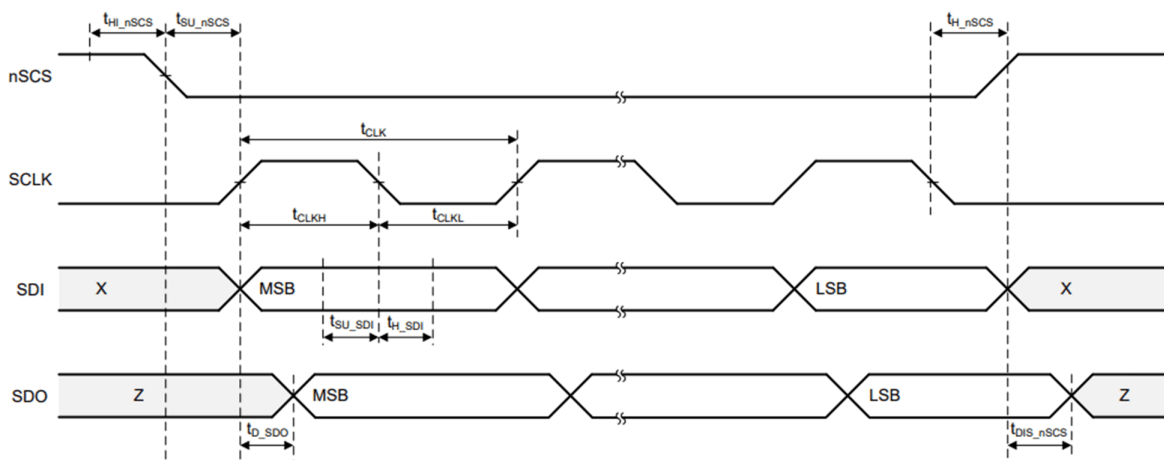


Figure 6-2. TDM and ICC Timing Diagram

## 6.8 SPI Timing Requirements

$T_A = 25\text{ }^\circ\text{C}$ ,  $NC\_V1P8V = IOVDD = 1.8\text{ V}$

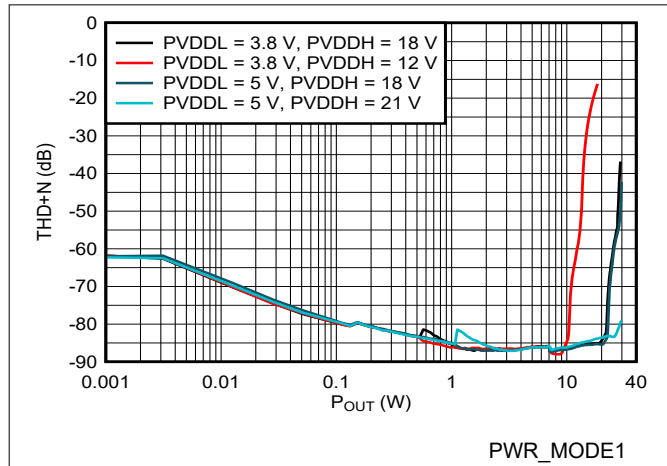
		MIN	NOM	MAX	UNIT
$t_{HI\_nSCS}$	nSCS Minimum High Time before Active Low	200			ns
$t_{SU\_nSCS}$	nSCS Input Setup Time	60			ns
$t_{H\_nSCS}$	nSCS Input Hold Time	60			ns
$t_{CLK}$	SCLK Period	60			ns
$t_{CLKH}$	SCLK Pulse Width High	30			ns
$t_{CLKL}$	SCLK Pulse Width Low	30			ns
$t_{SU\_SDI}$	SDI Input Data Setup Time	10.5			ns
$t_{H\_SDI}$	SDI Input Data Hold Time	8			ns
$t_{D\_SDO}$	SDO Data Output Delay			25	ns
$t_{DIS\_nSCS}$	nSCS Disable Delay			25	ns



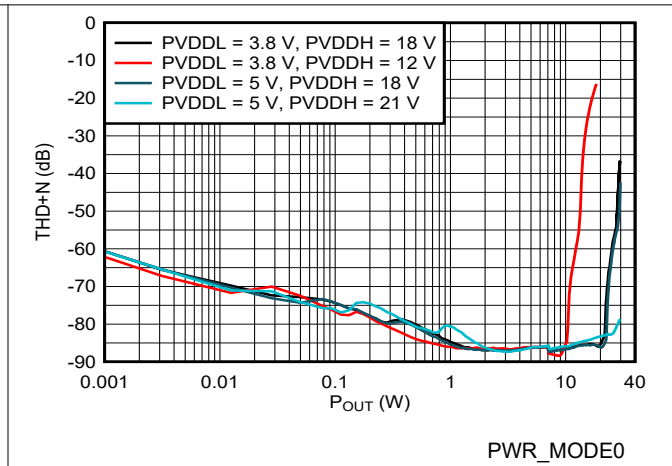
**Figure 6-3. SPI Timing Diagram**

### 6.9 Typical Characteristics

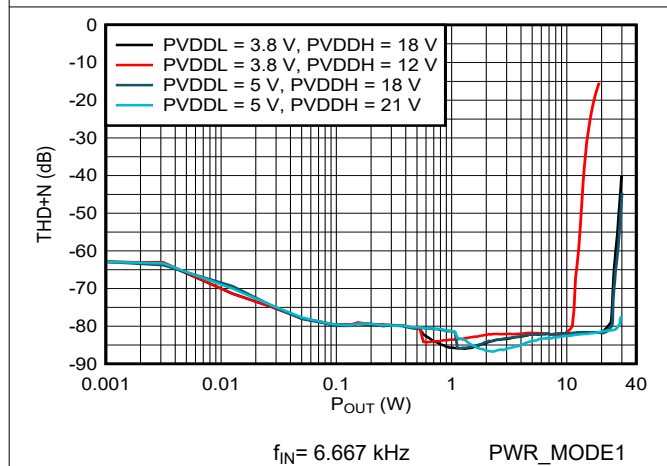
At  $T_A = 25\text{ }^\circ\text{C}$ ,  $AV_{DD} = 1.8\text{ V}$ ,  $IO_{VDD} = 1.8\text{ V}$ ,  $f_s = 48\text{ kHz}$ , Class-D Switching Frequency = 384 kHz, input signal  $f_{IN} = 1\text{ kHz}$  - Sine, Load =  $4\text{ }\Omega + 15\text{ }\mu\text{H}$ , unless otherwise noted.



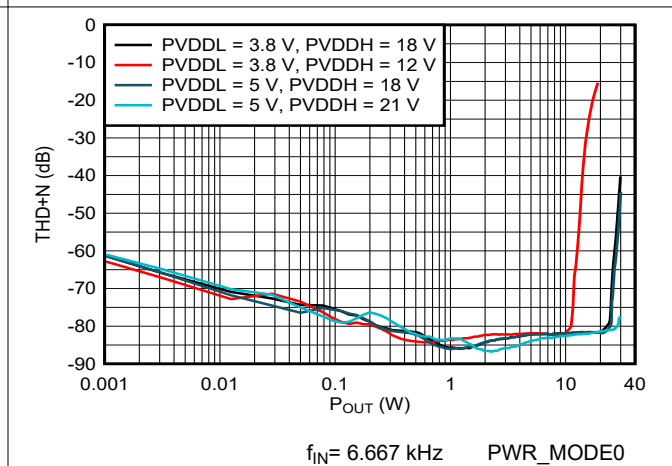
**Figure 6-4. THD+N vs Output Power**



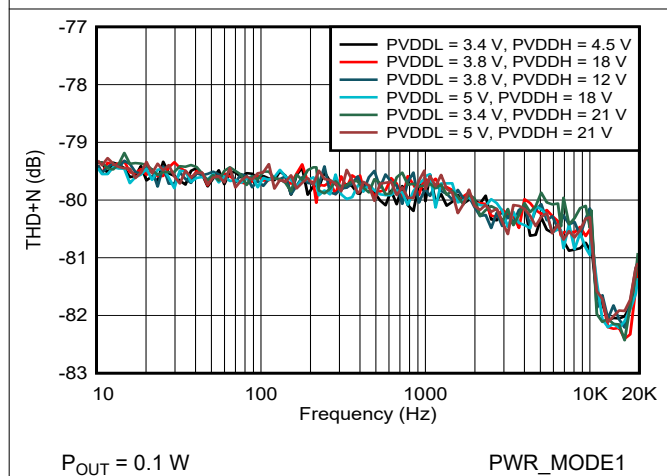
**Figure 6-5. THD+N vs Output Power**



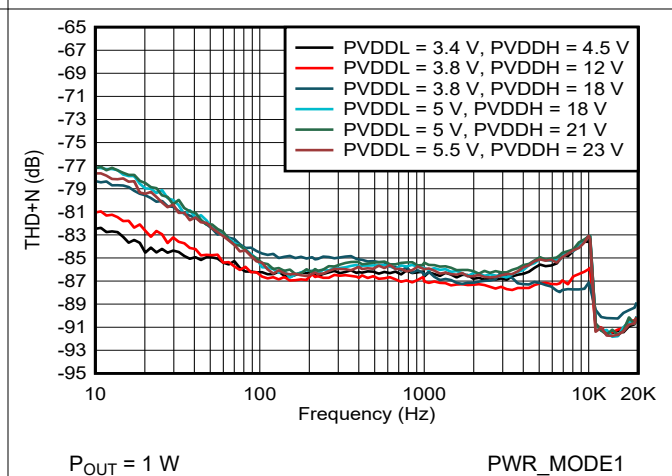
**Figure 6-6. THD+N vs Output Power**



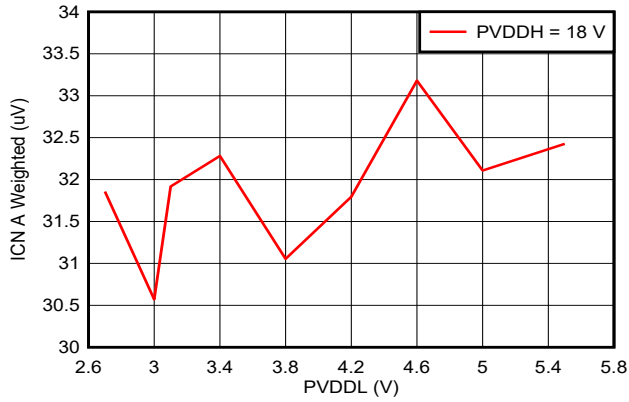
**Figure 6-7. THD+N vs Output Power**



**Figure 6-8. THD+N vs Frequency**

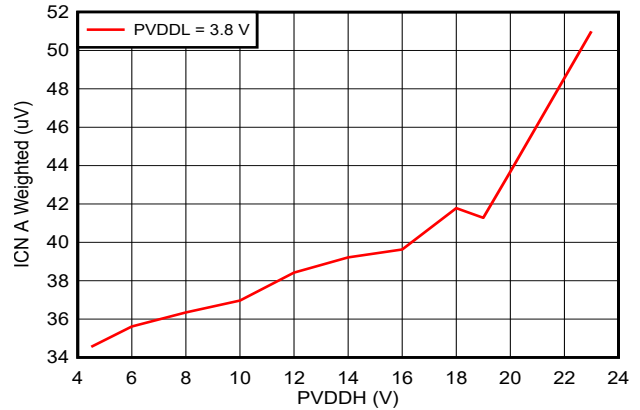


**Figure 6-9. THD+N vs Frequency**



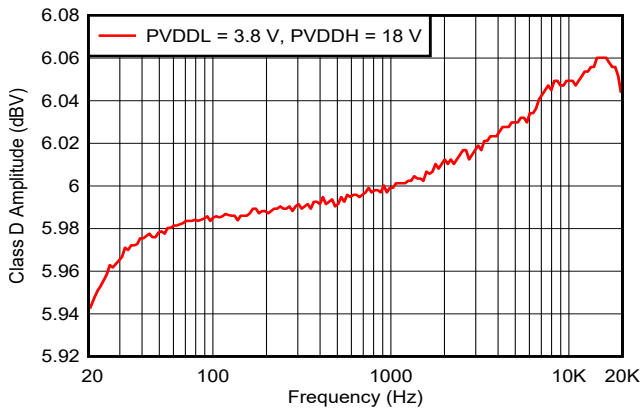
PWR\_MODE1

Figure 6-10. ICN vs PVDDL



PWR\_MODE0

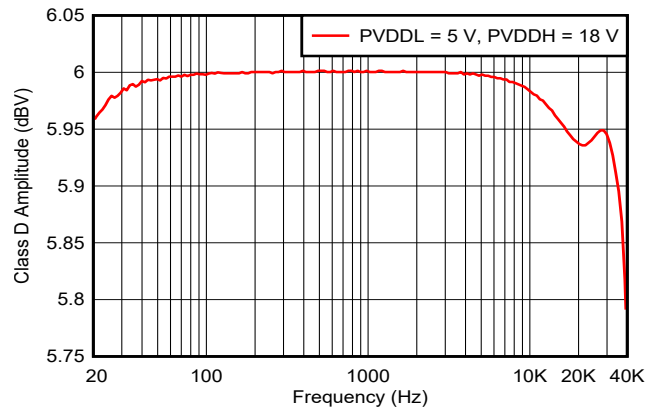
Figure 6-11. ICN vs PVDDH



P<sub>OUT</sub> = 1 W

PWR\_MODE1

Figure 6-12. Class-D Amplitude vs Frequency

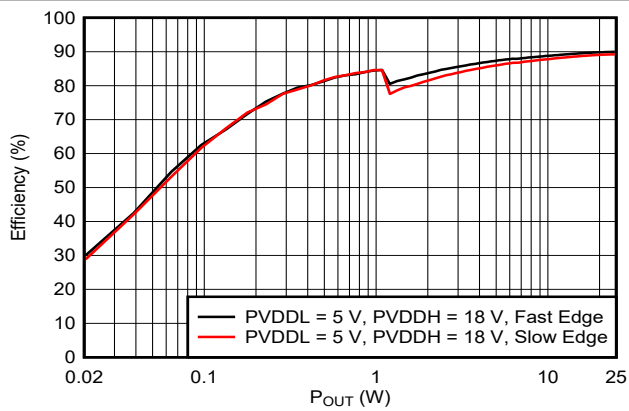


P<sub>OUT</sub> = 1 W

f<sub>s</sub> = 96 kHz

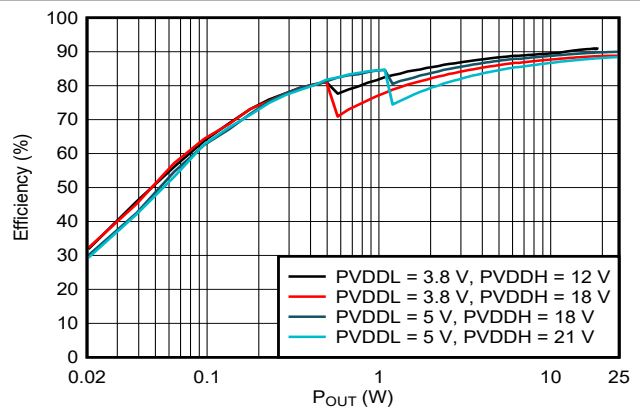
PWR\_MODE3

Figure 6-13. Class-D Amplitude vs Frequency



PWR\_MODE1

Figure 6-14. Efficiency vs Output Power



PWR\_MODE1

Figure 6-15. Efficiency vs Output Power

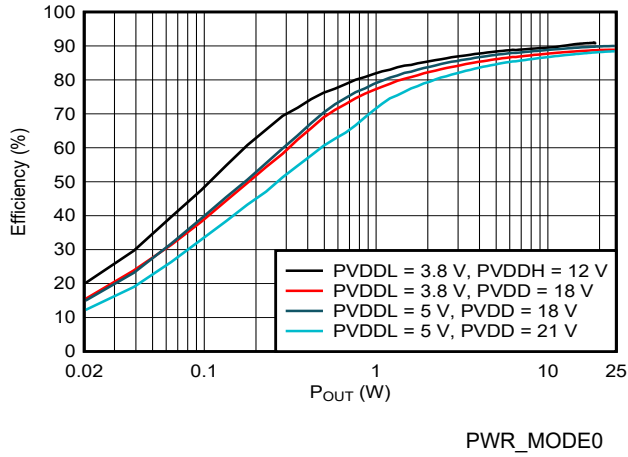


Figure 6-16. Efficiency vs Output Power

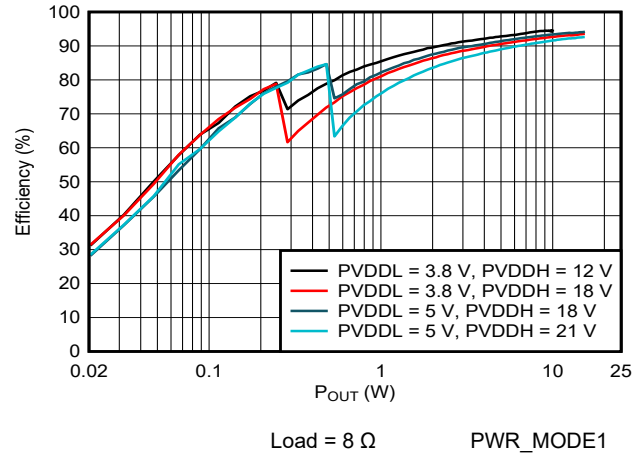


Figure 6-17. Efficiency vs Output Power

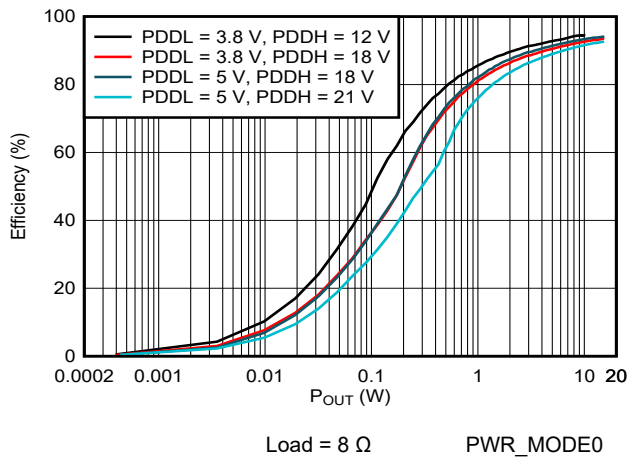


Figure 6-18. Efficiency vs Output Power

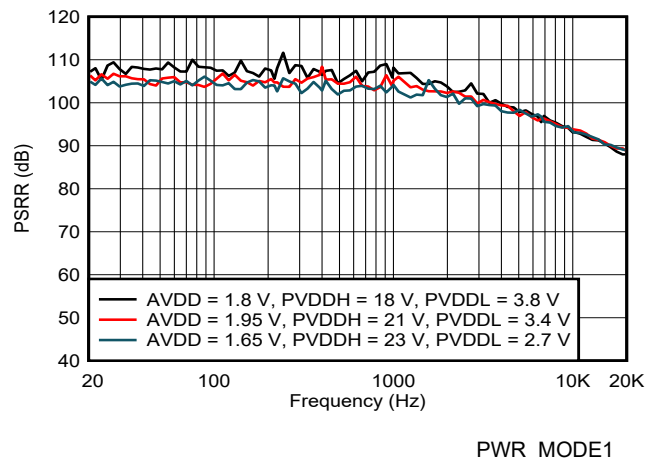


Figure 6-19. AVDD PSRR vs Frequency

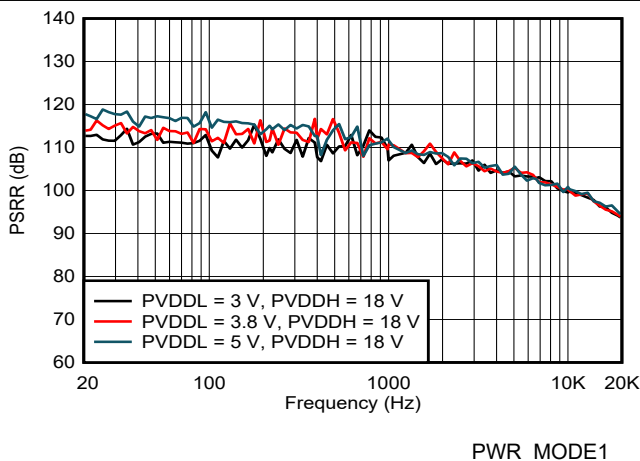


Figure 6-20. PVDDL PSRR vs Frequency

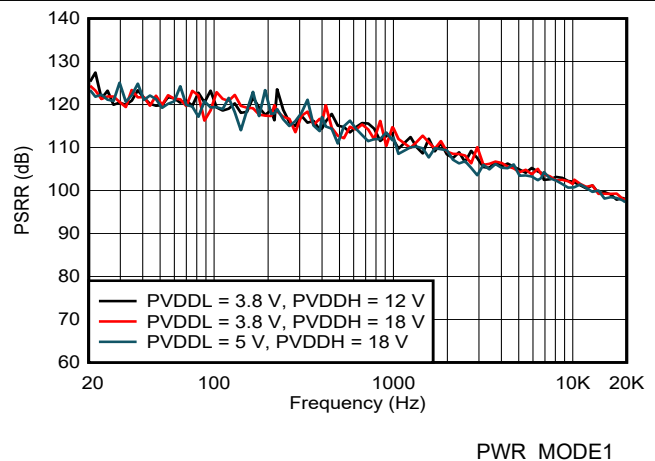


Figure 6-21. PVDDH PSRR vs Frequency



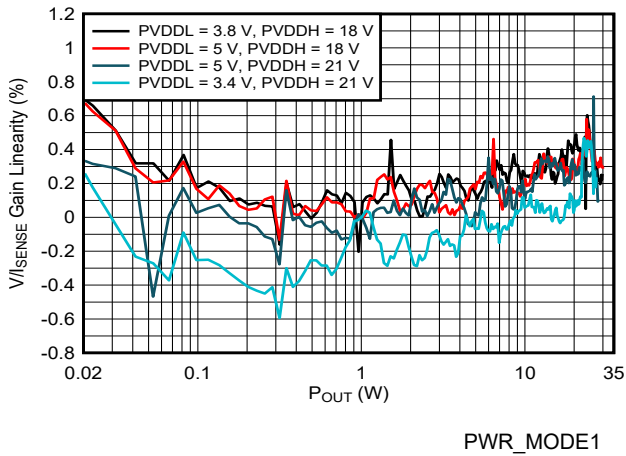


Figure 6-22. V/I Gain Linearity vs Output Power

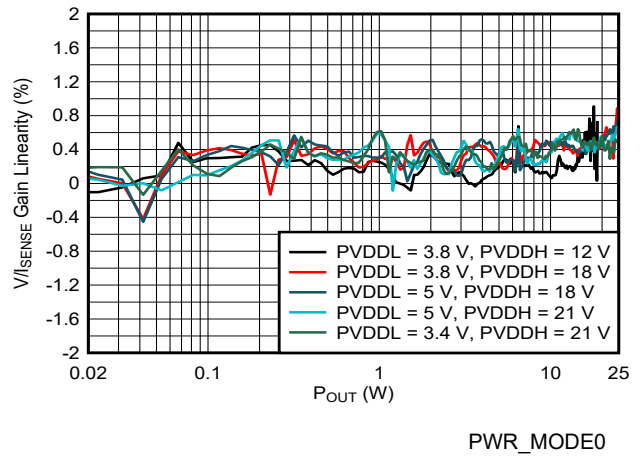


Figure 6-23. V/I Gain Linearity vs Output Power

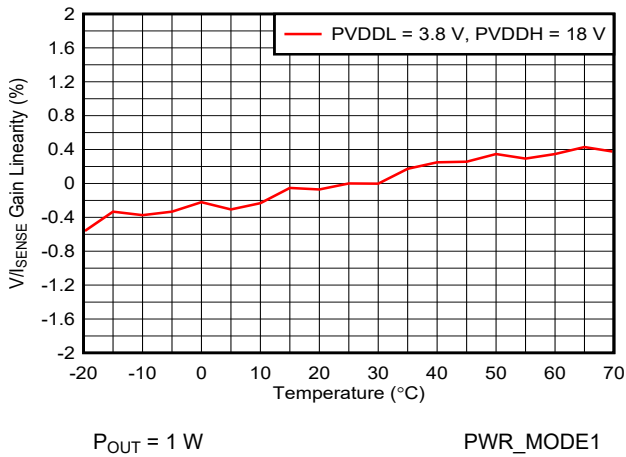


Figure 6-24. V/I Gain Linearity vs Temperature

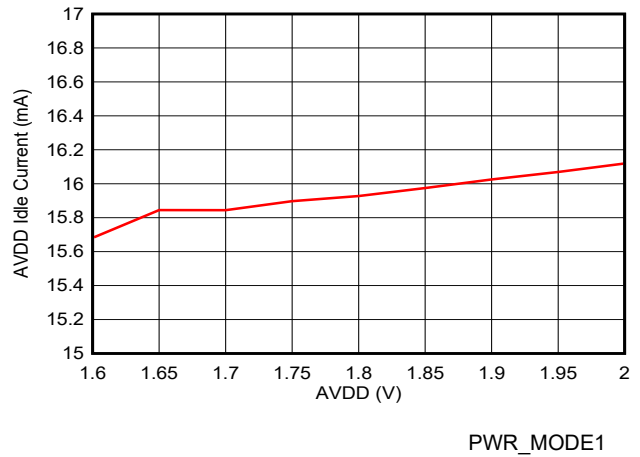


Figure 6-25. AVDD Idle Current vs AVDD

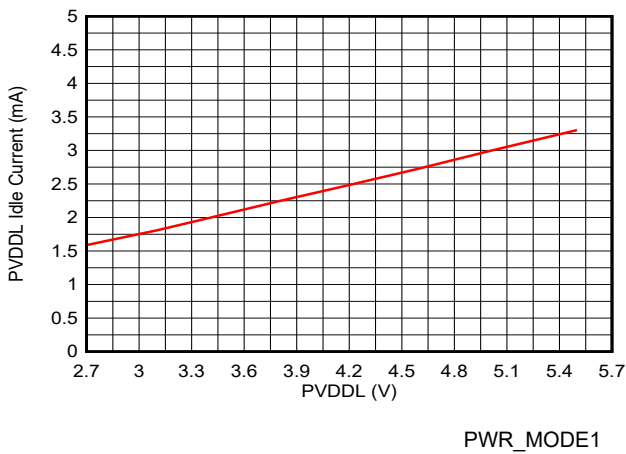


Figure 6-26. PVDDL Idle Current vs PVDDL

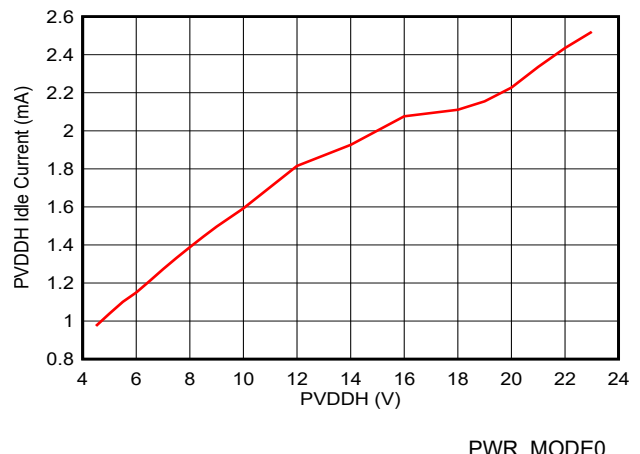


Figure 6-27. PVDDH Idle Current vs PVDDH

## 7 Parameter Measurement Information

The typical characteristics for the device are measured using the Bench Evaluation Module (EVM) and an Audio Precision Analyzer. A PSIA interface is used to allow the I<sup>2</sup>S interface to be driven directly into the Audio Precision Analyzer.

In some measurements (THD+N, ICN, DNR, and so forth), Class-D output terminals are connected to the Audio Precision Analyzer analog inputs through a Differential-to-Single Ended (D2S) filter as shown below. The D2S filter contains a second order passive pole at 120 kHz and an instrumentation amplifier. The D2S filter ensures the TAS2781 high performance Class-D amplifier has its outputs filtered and buffered before processed. This prevents measurement errors due to loading effects of AUX-00XX filter on the Class-D outputs.

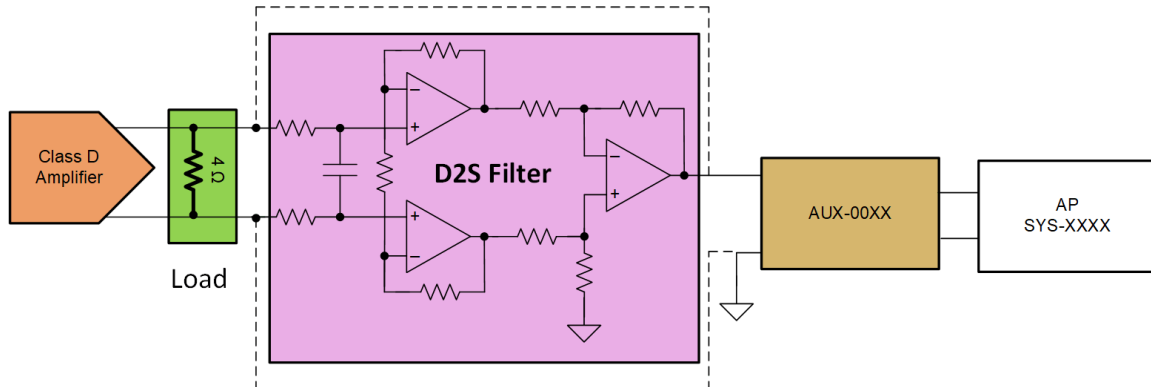


Figure 7-1. Differential to Single Ended (D2S) Filter

## 8 Detailed Description

### 8.1 Overview

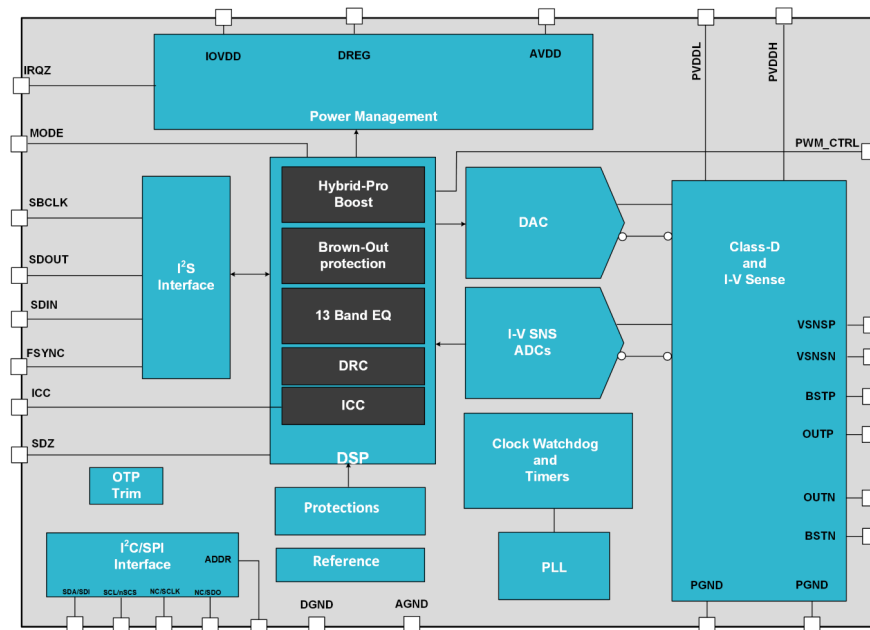
The TAS2781 is a mono digital input Class-D amplifier optimized for applications where efficient battery operation and small solution size are critical. It integrates speaker IV (current/voltage) sensing and battery tracking limiting with brown out prevention. The device operates using TDM/I<sup>2</sup>S and I<sup>2</sup>C (or SPI) interfaces.

The TAS2781 provides a Hybrid-Pro algorithm for controlling an external boost converter to extend battery life.

Table 8-1. Full Scales

Input/Output Signal	Full Scale Value
Class-D Output	21 dBV
Voltage Monitor	23 V
Current Sense	5 A
Voltage Sense	16 Vpk

## 8.2 Functional Block Diagram



## 8.3 Feature Description

### 8.3.1 MODE Selection

TAS2781 has two modes of operation selected based on the setting of the pin 26 (MODE) - see table below.

**Table 8-2. TAS2781 Control Interface**

Amplifier Mode	Control Interface	Pin 26 (MODE)
Smart Amp	I <sup>2</sup> C	Connected to GND
Smart Amp	SPI	470 Ω to GND

### 8.3.2 Device Address Selection

The TAS2781 operates using a TDM/I<sup>2</sup>S interface. Audio input and output are provided via the FSYNC, SBCLK, SDIN and SDOUT pins using formats including I<sup>2</sup>S, Left Justified and TDM. Configuration and status are provided using the I<sup>2</sup>C protocol (MODE pin tied to GND) or SPI protocol (MODE pin connected to GND through a 470 Ohms).

The table below illustrates how to configure the device for I<sup>2</sup>C address. The peripheral addresses are shown left shifted by one bit with the R/W bit set to 0 (for example, {ADDR[6:0],1b0}). Resistors with tolerance better than 5% must be used for setting the address configuration.

**Table 8-3. I<sup>2</sup>C Address Selection**

I <sup>2</sup> C Address	0x70	0x72	0x74	0x76	0x78	0x7A	0x7C	0x7E
ADDR PIN	Short to GND	470 Ω to GND	470 Ω to AVDD	2.2 kΩ to GND	2.2 kΩ to AVDD	10 kΩ to GND	10 kΩ to AVDD	Short to AVDD

The TAS2781 has a global 7-bit I<sup>2</sup>C address 0x80. When bit I2C\_GLB\_EN of register from is set high the device will respond to I<sup>2</sup>C commands at this address regardless of the ADDR pin settings. This is used to speed up device configuration when using multiple TAS2781 devices and programming similar settings across all devices. The I<sup>2</sup>C ACK / NACK cannot be used during the multi-device writes since multiple devices are responding to the I<sup>2</sup>C command. The I<sup>2</sup>C CRC function should be used to ensure each device properly received the I<sup>2</sup>C commands. At the completion of writing multiple devices using the global address, the CRC at I2C\_CKSUM register should be checked on each device using the local address for a proper value. The global I<sup>2</sup>C address can be disabled using I2C\_GBL\_EN register bit. The I<sup>2</sup>C address is detected by automatically sampling the

ADDR pin when SDZ pin is released. Additionally, the address may be re-detected by setting *I2C\_AD\_DET* register bit high after power up and the ADDR pin will be re-sampled.

### 8.3.3 SPI Interface

TAS2781 features an 1.8 V SPI interface when pin 26 (MODE) is connected to GND through a 470 Ω resistor.

Pin 17 (NC\_V1P8) of the device needs to be tied to an 1.8 V supply.

The host controller should use the mode with CPHA = 1 and CPOL = 0. The TAS2781 SPI logic block is sampling SPI input data on falling edge of SPI clock and transmitting SPI output data on rising edge of SPI clock.

### 8.3.4 Register Organization

Device configuration and coefficients are stored using a page and book scheme. Each page contains 128 bytes and each book contains 256 pages. All device configuration registers are stored in book 0 which is the default setting at power up and after a software reset. The book and page can be set by the *BOOK[7:0]* bits of register from and *PAGE[7:0]* bits of register from .

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#### Note

Programming register bits from book 0x00, pages 0x04, 0x05, 0x06, 0x08 and 0x0A needs to be done in groups of four registers (32 bit format), each byte corresponding to an 8 bit register and with less significant byte corresponding to the highest register address. For instance , when programming the limiter maximum threshold in registers from , the MSBs will be in register 0x10 and the LSBs in register 0x13.

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## 8.4 Device Functional Modes

### 8.4.1 TDM Serial Audio Port

The TAS2781 provides a flexible TDM serial audio port. The port can be configured to support a variety of formats including stereo I<sup>2</sup>S, Left Justified and TDM. Mono audio playback is available via the SDIN pin. The SDOOUT pin is used to transmit sample streams including PVDDL voltage, PVDDH voltage, die temperature, status, audio for echo cancelation.

By default, the TAS2781 will automatically detect the PCM playback sample rate (*AUTO\_RATE*= 0). This can be disabled and manually configured by setting the *AUTO\_RATE* bit of register in to high.

The TDM serial audio port valid SBCLK to FSYNC ratios are presented in register in . The device will automatically detect the number of time slots and it does not need to be programmed.

The *SAMP\_RATE[2:0]* and *SBLK\_FS\_RATIO[5:0]* register bits are used to configure the PCM audio sample rate when *AUTO\_RATE* register bit is high (auto detection of TDM sample rate is disabled). The TAS2781 employs a robust clock fault detection engine that will automatically volume ramp down the playback path if FSYNC does not match the configured sample rate (if *AUTO\_RATE* = 1) or the ratio of SBCLK to FSYNC is not supported (minimizing any audible artifacts). Once the clocks are detected to be valid in both frequency and ratio, the device will automatically volume ramp the playback path back to the configured volume and resume playback.

When using the auto rate detection the sampling rate and SBCLK to FSYNC ratio detected on the TDM bus is reported back on the read-only bits *FS\_RATIO[5:0]* and *FS\_RATE[2:0]* of registers in ] and in .

A frame begins with the transition of FSYNC from either high to low or low to high (set by the *FRAME\_START* register bit). FSYNC and SDIN are sampled by SBCLK using either the rising or falling edge (set by the *RX\_EDGE* register bit). The *RX\_OFF[4:0]* register bits define the number of SBCLK cycles from the transition of FSYNC until the beginning of time slot 0. This is typically set to a value of 0 for Left Justified format and 1 for an I<sup>2</sup>S format.

The *RX\_SLEN[1:0]* register bits set the length of the RX time slot to 16, 24 or 32 (default) bits. The length of the audio sample word within the time slot is configured by the *RX\_WLEN[1:0]* register bits. The RX port will left justify the audio sample within the time slot by default, but this can be changed to right justification via the *RX\_JSTF* register bit. The TAS2781 supports mono and stereo down mix playback ( $[L+R]/2$ ). By default the device will playback mono from the time slot equal to the I<sup>2</sup>C base address offset (set by the ADDR pin) for

playback. The `RX_SCFG[1:0]` register bits can be used to override the playback source to the left time slot, right time slot or stereo down mix set by the `RX_SLOT_R[3:0]` and `RX_SLOT_L[3:0]` register bits.

If time slot selection places reception either partially or fully beyond the frame boundary, the receiver will return a null sample equivalent to a digitally muted sample.

The TDM port can transmit a number of sample streams on the SDOUT pin: speaker voltage sense, speaker current sense, interrupts and status, PVDDH voltage and die temperature.

Either the rising or falling edge of SBCLK can be used to transmit data on the SDOUT pin. This can be configured by setting the `TX_EDGE` register bit. The `TX_OFF[2:0]` register bits define the number SBCLK cycles between the start of a frame and the beginning of time slot 0. This would typically be programmed to 0 for Left Justified format and 1 for I<sup>2</sup>S format. The TDM TX can either transmit logic 0 or Hi-Z depending on the setting of the `TX_FILL` register bit. An optional bus keeper will weakly hold the state of SDOUT pin when all devices are driving Hi-Z. Since only one bus keeper is required on SDOUT, this feature can be disabled via the `TX_KEEPEEN` register bit. The bus keeper can be configured to hold the bus for only 1 LSB or Always (permanent) using `TX_KEEPLN` register bit. Additionally, the keeper LSB can be driven for a full cycle or half of cycle using `TX_KEEPCY` register bit.

`TX_FILL` is used in mono system where there is only one amplifier on I<sup>2</sup>S bus. All the slots unused by the amplifier will be filled with zeros when `TX_FILL` is set to low. The TX bits mentioned are in the register in .

The `SDOUT_HIZ` registers from page 0x01 are useful when multiple devices are on the same I<sup>2</sup>S bus. Each device does not know configuration of slots in the other devices on the bus. It is required at the system level to program the `SDOUT_HIZ` registers appropriately, in such way that the settings are done correctly and do not create any contention both internally and externally.

The current and voltage values are transmitted at the full 16-bit measured values by default. The `IVMON_EN[1:0]` bits of register from can be used to transmit only the 8 MSB bits in one slot or 12 MSB bits values across multiple slots. The special 12-bit mode is used when only 24-bit I<sup>2</sup>S/TDM data can be processed by the host processor. The device should be configured with the voltage-sense slot and current-sense slot off by 1 slot and will consume 3 consecutive 8-bit slots. In this mode the device will transmit the first 12 MSB bits followed by the second 12 MSB bits specified by the preceding slot.

If time slot selections place transmission beyond the frame boundary, the transmitter will truncate transmission at the frame boundary.

The time slots for SAR measurements (PVDDL, PVDDH and temperature) are set using `SAR_DATA_SLOT[5:0]` register bits. To enable sample stream register bit `SAR_DATA_TX` must be set high. The slot length is selected by bit `SAR_DATA_SL` of register from .

For TDM final processed audio slot, enable and length settings use `AUDIO_SLOT[5:0]`, `AUDIO_TX` and `AUDIO_SLEN` register bits.

Information about status of slots can be find in `STATUS_SLOT[5:0]` register bits. `STATUS_TX` register bit set high enables the status transmit.

## 8.4.2 Playback Signal Path

### 8.4.2.1 Digital Signal Processor

An on-chip, low latency DSP supports Texas Instrument Smart Amp speaker protection algorithms to maximize loudness while maintaining safe speaker conditions.

The DSP also features Band EQ, stereo balancing, ultrasound and external boost controller for Class-H amplifier operation.

### 8.4.2.2 High Pass Filter

Excessive DC and low frequency content in audio playback signal can damage loudspeakers. The TAS2781 employs a high-pass filter (HPF) to prevent this from occurring for the PCM playback path. The `HPF_FREQ_PB[2:0]` register bits set the corner frequencies of HPF. The filter can be bypassed by setting the register bits to 3'b000.

### 8.4.2.3 Amplifier Inversion

The TAS2781 will output a non-inverted signal to the OUT\_P and OUT\_N pins. The output can be inverted with respect to the digital input value by setting the AMP\_INV register bit to high.

### 8.4.2.4 Digital Volume Control and Amplifier Output Level

The gain from audio input to speaker terminals is controlled by setting the amplifier output level and the digital volume control (DVC).

Amplifier output level settings are programmed using the AMP\_LVL[4:0] register bits. The amplifier levels are presented in the register from . The Digital Volume Control (DVC) is set by default to 0 dB. It should be noted that these levels may not be achievable because of analog clipping in the amplifier, so they should be used only to convey gain.

Equation (1) calculates amplifier output voltage:

$$V_{AMP} = INPUT + A_{DVC} + A_{AMP} \quad (1)$$

where

- $V_{AMP}$  is the amplifier output voltage in dBV
- $INPUT$  is the digital input amplitude as a number of dB with respect to 0 dBFS
- $A_{DVC}$  is the digital volume control setting as a number of dB
- $A_{AMP}$  is the amplifier output level setting as a number of dBV

The DVC is configurable from 0 dB to -100 dB in 0.5 dB steps by setting the DVC\_LVL[7:0] register bits. Settings greater than C8h are interpreted as mute. When a change in digital volume control occurs, the device ramps the volume to the new setting based on the DVC\_SLEW[31:0] register bits status from . The bits DVC\_RMP\_RT[1:0] of register in enable or disable the volume ramp control

The Class-D amplifier uses a closed-loop architecture. The approximate threshold for output signal clipping is given by equation (2).

$$V_{PK} = V_{SUP} * \frac{R_L}{R_{FET} + R_P + R_L} \quad (2)$$

where:

- $V_{PK}$  is the maximum peak un-clipped output voltage in V
- $V_{SUP}$  is the power supply of Class-D output stage
- $R_L$  is the speaker load in  $\Omega$
- $R_P$  is the parasitic resistance on PCB (routing, filters) in  $\Omega$
- $R_{FET}$  is the power stage total resistance (HS FET, LS FET, Sense Resistor, bonding, packaging) in  $\Omega$

When PVDDL supplies Class-D output stage typical  $R_{FET}$  value is 0.5  $\Omega$ . For PVDDH supply  $R_{FET}$  typical value is 0.25  $\Omega$ .

### 8.4.2.5 PVDDL Supply

The TAS2781 can operate with or without a PVDDL supply. When configured without a PVDDL supply, the PVDDH voltage will be used with an internal LDO to generate this supply voltage. A decoupling capacitor should still be populated as recommended in [Table 9-1](#). In this case, PVDDL\_MODE bit should be set to high before transitioning from Software Shutdown mode. More details about PVDDL supply modes of operation can be found in [Section 11.1](#).

### 8.4.2.6 Y - Bridge

The TAS2781 Class-D output uses a Y-Bridge configuration to improve efficiency during playback. The LVS () is internally used to select between the PVDDH and PVDDL supplies. This feature is enabled by setting CDS\_MODE[1:0] bits to 2'b00 when both PVDDH and PVDDL are supplied to the device. If not configured to

Y-bridge mode the device will use only the selected supply for Class-D output even if clipping would otherwise occur. The device can operate using only PVDDH to supply Class-D output. In this configuration the PVDDL can be provided from external supply (register bit *PVDDL\_MODE*=0) or generated by an internal LDO (register bit *PVDDL\_MODE*[7]=1). In this case *CDS\_MODE*[7:6] bits should be set to 2'b10. The TAS2781 Y-Bridge with low power on PVDDL can be used to switch to the PVDDL rail only at very low power when close to idle. This will reduce the Class-D output swing when near idle and limit the current requirements of the PVDDL supply. Set the *CDS\_MODE*[7:6] register to 2'b11 for this mode.

See for details on programming the power mode of operation.

The change to the Class-D supply (PVDDL to PVDDH) determined by the has a delay with respect to input signal crossing threshold and it can be programmed using *CDS\_DLY*[1:0] bits of register from .

When in Y-Bridge mode, if the PVDDH falls below (PVDDL + 2.5 V) level, the Y-Bridge will stop switching between supplies and will remain on the PVDDH supply.

#### 8.4.2.7 Low Voltage Signaling (LVS)

The TAS2781 is a mechanism used in connection with the Y Bridge configuration of the output stage of Class-D. It is based on monitoring the absolute value of the audio stream and selecting the proper supply, PVDDH or PVDDL.

When the signal is initially above the programmed LVS threshold the Class-D is supplied by PVDDH rail. If the signal level drops below this threshold for longer than the hysteresis time defined by *LVS\_HYS*[3:0] register bits, the Class-D supply will switch to PVDDL. If the signal goes back to the initial level the Class-D supply will switch back to PVDDH.

By default the LVS threshold is configured to be a value relative to the PVDDL voltage (*LVS\_DET* = 1). Use the *LVS\_RTH*[3:0] register bits for setting the threshold (default = 0.7 V).

Setting bit *LVS\_DET* bit to low forces the LVS threshold to a fixed value defined by the *LVS\_FTH*[4:0] register bits.

LVS threshold is referred to the output signal level and it is measured in dBFS.

In an use case when *CDS\_MODE*[1:0]=11 (PWR\_MODE2 from [Section 11.1](#)), the fixed LVS threshold can be set using register bits *LVS\_TH\_LOW*[1:0].

#### 8.4.2.8 Noise Gate Mode

The TAS2781 has a noise-gate feature that monitors the input signal and powers down the Class-D when the signal goes below the set threshold set by *NG\_TH*[1:0] bits for longer than the time set by *NG\_HYST\_TIMER*[2:0] bits of register from . When the signal goes above the threshold the Class-D will re-power in seven samples before the samples applied to the audio input interface reach the Class-D output.

The Noise Gate feature is enabled by setting *NG\_EN* bit to high. Once enabled it is able to power up and down the channel within the device processing delay requiring no additional external control. Volume ramping can be also used during noise gate operations by setting *NG\_DVC\_RP* bit to low.

The noise gate can be configured with finer resolution at the expense of additional I<sup>2</sup>C writes. Use *NGFR\_EN* bit to enable this mode and register bits *NGFR\_LVL*[23:0] from to set the fine resolution. The fine resolution hysteresis is set using *NGFR\_HYST*[18:3] register bits from and from .

#### 8.4.2.9 Supply Tracking Limiter

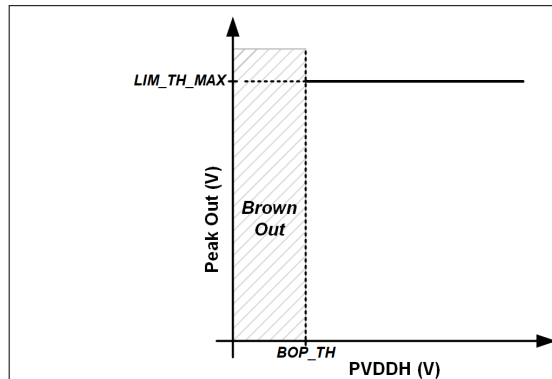
The TAS2781 monitors PVDDH supply voltage and the audio signal to automatically decrease gain when the audio signal peaks exceed a programmable threshold. This helps prevent clipping and extends playback time through end of charge battery conditions. The limiter threshold can be configured to track PVDDH below a programmable inflection point with a programmable slope. A minimum threshold sets the limit of threshold reduction from PVDDH tracking.

The limiter is enabled by setting the *LIM\_EN* bit register to high.

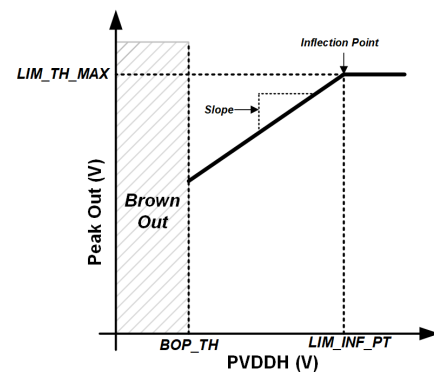
Configurable attack rate, hold time and release rate are provided to shape the dynamic response of the limiter ( $LIM\_ATK[3:0]$ ,  $LIM\_HLD[2:0]$  and  $LIM\_RLS[3:0]$  bits of registers from and .

A maximum level of attenuation applied by the limiter is configurable via the  $LIM\_MAX\_AT[3:0]$  bits of register . If the limiter is attacking and if it reaches the maximum attenuation, gain will not be reduced any further.

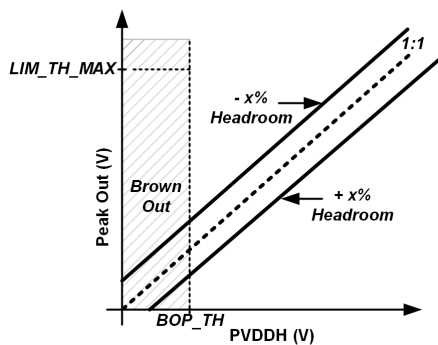
The limiter begins reducing gain when the output signal level is greater than the limiter threshold. The limiter can be configured to track PVDDH below a programmable inflection point with a minimum threshold value. shows the limiter configured to limit to a constant level regardless of PVDDH level. To achieve this behavior, set the limiter maximum threshold to the desired level via the  $LIM\_MAX\_TH[31:0]$  register bits. Set the limiter inflection point (register bits  $LIM\_INF[31:0]$ ) below the minimum allowable PVDDH setting. The limiter minimum threshold, set by register bits  $LIM\_MIN\_TH[31:0]$ , does not impact limiter behavior in this use case.



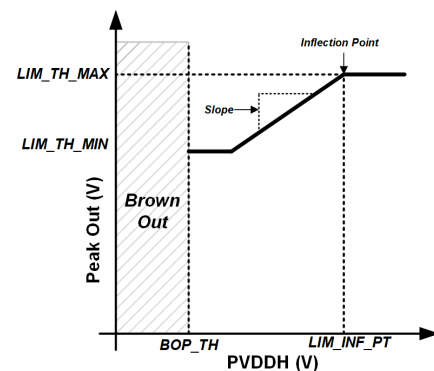
**Figure 8-1. Limiter with Fixed Threshold**



**Figure 8-2. Limiter with Inflection Point**



**Figure 8-3. Limiter with Dynamic Threshold**



**Figure 8-4. Limiter with Inflection Point and Minimum Threshold**

shows how to configure the limiter to track PVDDH below a threshold without a minimum threshold. Set the  $LIM\_MAX\_TH[31:0]$  register bits to the desired threshold and  $LIM\_INF[31:0]$  register bits to the desired inflection point where the limiter will begin reducing the threshold with PVDDH. The  $LIM\_SLP[31:0]$  register bits can be used to change the slope of the limiter tracking with PVDDH. The default value of 1 V/V will reduce the threshold 1 V for every 1 V of drop in PVDDH supply. More aggressive tracking slopes can be programmed if desired. Program the  $LIM\_MIN\_TH[31:0]$  bits below the minimum PVDDH to prevent the limiter from having a minimum threshold reduction when tracking PVDDH.

The limiter with a supply tracking slope can be configured in an alternate way. By setting  $LIM\_DYHDR$  register bit to 1'b1 in register in , a headroom can be specified as a percentage of the supply voltage using a 1V/V slope by setting  $LIM\_HDR[4:0]$  register bits. For example if a headroom of -10% is specified, the peak output voltage will be set to be 10% higher than PVDDH. In this use case presented in the limiting begins for signals above the supply voltage and will result in a fixed clipping. If a positive headroom of +10% is specified the peak output



voltage will be dynamically set 10% below the current PVDDH. In this use case the limiting will begin at signal levels lower than the supply voltage and prevent clipping from occurring.

To achieve a limiter that tracks PVDDH only up to a minimum threshold, configure the limiter *LIM\_MAX\_TH[31:0]* and *LIM\_SLP[31:0]* register bits as in the previous examples. Then additionally set the *LIM\_MIN\_TH[31:0]* register bits to the desired minimum threshold. Supply voltage below this minimum threshold will not continue to decrease the signal output voltage. This is shown in .

By setting register bit *LIM\_DYHDR* to low the limiter mechanism depends on settings for maximum and minimum thresholds, inflection point and slope. By default this bit is high and the limiter dynamic headroom is enabled.

#### **8.4.2.10 Brownout Prevention**

Brownout Prevention (BOP) feature provides a priority input to the limiter to generate a fast response to transient dips in supply voltage at end of charge conditions that can cause system level brownout. When supply voltage dips below the BOP threshold, the limiter begins reducing gain at a configurable attack rate. When supply voltage rises above the BOP threshold, the limiter will begin to release after the programmed hold time. The BOP feature can be enabled by setting the *BOP\_EN[0]* register bit high. The brownout supply source can be set using *BOP\_SRC* register bit to either PVDDH or PVDDL depending on application.

By default BOP supply source is set to PVDDL input and the SAR converter will digitize the PVDDH and PVDDL voltages and temperature. The PVDDH undervoltage detection will be disabled.

When BOP supply source is set to PVDDH input the SAR ADC converter will digitize the PVDDH and PVDDL voltages and temperature. The PVDDH undervoltage detection will be enabled in this case. To reduce latency in the first attack of the BOP engine, PVDDL conversion can be bypassed by setting the register bit *CNV\_PVDDL* to low.

When BOP supply source is set to PVDDL input the SAR converter will digitize the PVDDH and PVDDL voltages and temperature. The PVDDH undervoltage detection will be disabled.

When the BOP is engaging the Supply Tracking Limiter is paused.

The BOP threshold is set by the *BOP\_TH[31:0]* bits from registers in . The setting of *BOP\_MUTE* bit determines if once the supply goes below the threshold the device mutes audio and shuts down or just attenuates the audio signal with no muting.

The TAS2781 can also immediately mute and then shutdown the device when a BOP event occurs by reaching the threshold set by the *BOPSD\_TH[31:0]* bits from registers in if the *BOPSD\_EN* register bit is set high. This shutdown feature is auto disabled internally when *BOP\_MUTE* is set high.

The BOP has programmable attack rate register bits *BOP\_ATK[2:0]*, attack step size register bits *BOP\_ATK\_ST[1:0]* and hold time register bits *BOP\_HLD[2:0]*.

When the system comes out of BOP the supply tracking limiter release will be engaged. If the limiter is disabled the gain will be released as per limiter release settings.

The hold time can be set to Infinite by programming the *BOP\_INF\_HLD* register bit to high. The device will need to transition through a mute or SW/HW shutdown state or the register bit *BOP\_HLD\_CLR* can be set to high (which will cause the device to exit the hold state and begin releasing).

When *BOP\_INF\_HLD* bit is set low the device will hold based on programming of *BOP\_HLD[2:0]* bits.

#### **8.4.2.11 ICC Pin and Inter-Chip Communication**

The TAS2781 supports dual gain balancing in stereo applications. One device can be paired with only one other device in the system.

The ICC pin will be connected to an ICC bus with bus keeper. Pin 17 (NC\_V1P8V) supplying ICC buffer needs to be connected to an 1.8 V supply.

The SDOOUT pin cannot be used for gain alignment.

The *ICC\_CFG[2:0]* bits of register from configure the functionality of the ICC pin.

The bits from register in enable the ICC feature and set the device pairing and gain transmitting slots.

The sampling rates of 16 kHz and 24 kHz (and 44.1 kHz equivalent) are not supported in this mode of operation.

#### 8.4.2.12 Class-D Settings

##### 8.4.2.12.1 Output Slew Rate Control

The output slew rate can be programmed using bits *EDGE\_CTRL[1:0]* from register in .

By default, if PVDDH supply is below 20 V the output slew rate will be at a fast rate, dependant on supply and load. If PVDDH goes above 20 V the slew rate will be automatically change to a slower rate.

Optionally, to improve EMI performance, user can set the slew rate to a slower rate for the entire range of PVDDH supply by setting the bits *EDGE\_CTRL[1:0]* to 2'b11.

##### 8.4.2.12.2 Synchronization

The TAS2781 Class-D amplifier supports spread spectrum PWM modulation, which can be enabled by setting the *AMP\_SS* register bit high. This can help reduce EMI in the system.

By default the Class-D amplifier switching frequency is based on the device trimmed internal oscillator. To synchronize switching to the audio sample rate, set the *CLASSD\_SYNC* register bit high. When the Class-D is synchronized to the audio sample rate, the *RAMP\_RATE* register bit must be set depending on the audio sample rate of either 44.1 kHz or 48 kHz (default) based frequency.

#### 8.4.3 SAR ADC

A SAR ADC monitors PVDDH voltage, PVDDL voltage and die temperature. The results of these conversions are available via register readback (*PVDDH\_CNV[11:0]*, *PVDDL\_CNV[11:0]* and *TMP\_CNV[7:0]* register bits). PVDDH and PVDDL voltage conversions are also used by the limiter and brown out prevention blocks.

By default, PVDDL conversion is enabled along with PVDDH and temperature in both cases, when BOP source is PVDDL (*BOP\_SRC* = 0) or BOP source is PVDDH (*BOP\_SRC* = 1).

The ADC runs at a fixed 192 kHz sample rate with a conversion time of 5.2  $\mu$ s.

Temperature is sampled once every 18<sup>th</sup> SAR conversions. Sampling rate for temperature is approximative 10K samples/sec.

PVDDH and PVDDL voltages and the die temperature can be estimated by user using equations from registers in , and .

The register bits content should always be read from MSB to LSB.

The voltage and temperature readings of SAR ADC are also available to the host through the SDOOUT pin. Use bits of register from to enable this feature and configure the slots.

#### 8.4.4 Current and Voltage (IV) Sense

The TAS2781 provides speaker voltage and current sense measurements for real time monitoring of loudspeaker behavior. The VSNSP and VSNSN pins should be connected after any ferrite bead filter (or directly to the OUTP and OUTN connections if no EMI filter is used). The V-Sense connections eliminate voltage drop error due to packaging, PCB interconnect or ferrite bead filter resistance. It should be noted that any interconnect resistance after the VSNS terminals will not be corrected for, so it is advised to connect the sense connections as close to the load as possible.

The voltage and current sense internal ADCs have a DC blocking filter. This filter cut-off frequency can be adjusted, or the filter can be bypassed using the *HPF\_FREQ\_REC[2:0]* register bits.

I-Sense and V-Sense blocks can be powered up by setting the *ISNS\_PD* and *VSNS\_PD* register bits to low.

#### 8.4.5 Post Filter Feed-Back (PFFB)

The device supports post-filter feedback by closing the amplifier feedback loop after the external filter. The feedback is applied using the VSNSN and VSNSP terminals of the device. This feature can be disabled using

the *PFFB\_EN* register bit (if an external filter that violates the amplifier loop stability is implemented). When PFFB is disabled, the feedback will be internally routed from the OUTN and OUTP pins of the device.

In the PFFB mode of operation the following conditions have to be met:  $f_0 > 10$  MHz and  $f_0/Q > 2.5$  MHz ( $f_0$  and Q are the cutoff frequency and the quality factor of the external filter).

#### 8.4.6 Thermal Foldback

The TAS2781 monitors the die temperature and can automatically limit the audio signal when the die temperature reaches a set threshold. It is recommended to use the thermal fold-back registers to configure this protection mechanism as the internal DSP will perform the necessary calculation for each register.

Thermal fold-back can be disabled using *TFB\_EN* bit . If the die temperature reaches the value set by *TF\_TMP\_TH[31:0]* bits of register from this feature will begin to attenuate the audio signal to prevent the device from shutting down due to over-temperature. It will attenuate the audio signal by a value set in *TF\_SLP[31:0]* register bits over a range of temperature set by *TF\_TMP\_TH[31:0]* register bits. The thermal fold-back attack is set using the *TF\_ATK[31:0]* register bits. A maximum attenuation can be specified using register bits *TF\_MAX\_ATN[31:0]*. However, if the device continue to heat up, eventually the device over-temperature will be triggered. The attenuation will be held for a number of samples set by register bits *TF\_HLD[31:0]*, before the attenuation will begin releasing.

#### 8.4.7 Over Power Protection

The TAS2781 monitors the temperature of the internal power FETs. If the maximum continue power is high and power FETs temperature goes above a threshold, an internal protection circuit will trigger a thermal foldback and, if temperature still increases, shutdown the device.

The protection mechanism is based on two thresholds TH1 and TH2. The TH1 threshold is set at a temperature 116 °C higher than the temperature measured by the internal bandgap but not less than 250 °C. The TH1 threshold triggers a thermal foldback.

The TH2 threshold is 40 °C above TH1 and triggers thermal shutdown.

The two detection mechanisms can be disabled by setting to low the bits *TG\_TH2* and *TG\_TH1*.

#### 8.4.8 Low Battery Protection

For PVDDL supply below 3.4 V the power FETs can go into saturation at higher load currents which could result in device damage due to the FETs connected to PVDDH going into thermal runaway.

To prevent the damage the OCP limit is adjusted based on PVDDL level measured by the internal SAR ADC. The table below presents the PVDDL thresholds where the OCP will be adjusted automatically. Lower PVDDL level will correspond to lower OC limit setting.

**Table 8-4. PVDDL Range and Thresholds**

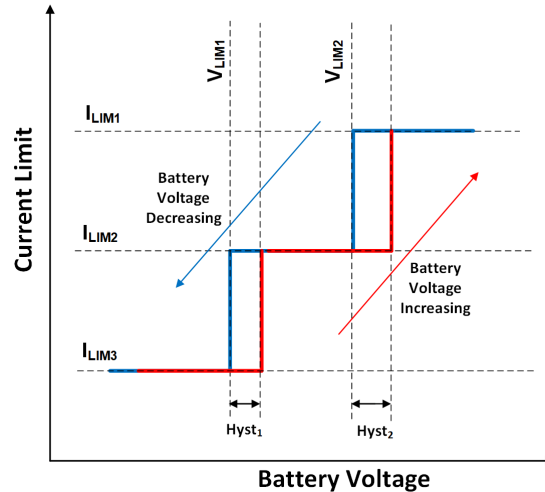
PVDDL Range
PVDDL ≥ 3.4 V
3.1 V ≤ PVDDL < 3.4 V
2.9 V ≤ PVDDL < 3.1 V
2.7 V ≤ PVDDL < 2.9 V

The control of OC limit occurs in power modes where PVDDL is supplied externaly and the output is switching on PVDDH (*PWR\_MODE0*, *PWR\_MODE1*).

#### 8.4.9 Battery Power Limiter

The TAS2781 integrates an algorithm that can control the audio power by regulating the current based on the battery voltage readout.

The algorithm provides three levels of current based on two levels of battery voltage.



**Figure 8-5. Current Limit vs Battery Voltage**

The power limiter can be applied to either PVDDL (one cell battery) or PVDDH (multi-cell battery). By default it is set on PVDDL and can be changed to PVDDH by using bit *PWR\_LIM\_SRC*.

#### 8.4.10 Clocks

The device clocking is derived from the SBCLK input clock. The tables below show the valid SBCLK clock frequencies for each sample rate and SBCLK to FSYNC ratio.

If the sample rate is properly configured via the *SAMP\_RATE[2:0]* register bits, no additional configuration is required as long as the SBCLK to FSYNC ratio is valid. The device will detect improper SBCLK frequencies and SBCLK to FSYNC ratios and volume ramp down the playback path to minimize audible artifacts. After the clock error is detected, the device will enter a low power halt mode after a time set by *CLK\_HALT\_TIMER[2:0]* register bits if *DIS\_CLK\_HALT* bit is low. Additionally, the device can automatically power up and down on valid clock signals if *CLK\_PWRUD* register bit is set to high. The device sampling rate should not be changed while this feature is enabled. In this mode the *DIS\_CLK\_HALT* bit register should be set low in order for this feature to work properly.

**Table 8-5. Supported SBCLK Frequencies [MHz] for 48 kHz Based Sample Rates**

Sample Rate (kHz)	SBCLK to FSYNC Ratio						
	16	24	32	48	64	96	125
16	NA	NA	0.512	0.768	1.024	1.526	2
24	NA	0.576	0.768	1.152	1.536	2.304	3
32	0.512	0.768	1.024	1.536	2.048	3.072	4
48	0.768	1.152	1.536	2.304	3.072	4.608	6
96	1.536	2.304	3.072	4.608	6.144	9.216	12
192	3.072	4.608	6.144	9.216	12.288	18.432	24
Sample Rate (kHz)	SBCLK to FSYNC Ratio						
	128	192	250	256	384	500	512
16	2.048	3.072	4	4.096	6.144	8	8.192
24	3.072	4.608	6	6.144	9.216	12	12.288
32	4.096	6.144	8	8.192	12.288	16	16384
48	6.144	9.216	12	12.288	18.432	24	24.576
96	12.288	18.432	24	24.576	NA	NA	NA
192	24.576	NA	NA	NA	NA	NA	NA

**Table 8-6. Supported SBCLK Frequencies [MHz] for 44.1 kHz Based Sample Rates**

Sample Rate (kHz)	SBCLK to FSYNC Ratio					
	16	24	32	48	64	96
14.7	NA	NA	NA	0.7056	0.9408	1.4112
22.05	NA	NA	0.7056	1.0584	1.4112	2.1168
29.4	NA	0.7056	0.9408	1.4112	1.8816	2.8224
44.1	0.7056	1.0584	1.4112	2.1168	2.8224	4.2336
88.2	1.4112	2.1168	2.8224	4.2336	5.6448	8.4672
176.4	2.8224	4.2336	5.6448	8.4672	11.2896	16.9344
Sample Rate (kHz)	SBCLK to FSYNC Ratio					
	128	192	256	384	512	
14.7	1.8816	2.8224	3.7632	5.6448	7.5264	
22.05	2.8224	4.2336	5.6448	8.4672	11.2896	
29.4	3.7632	5.6448	8.4672	8.192	15.0528	
44.1	5.6448	8.4672	11.2896	16.9344	22.5792	
88.2	11.2896	16.9344	22.5792	33.8688	NA	
176.4	211.5792	33.8688	NA	NA	NA	

### 8.4.11 Ultrasonic

The TAS2781 has a dedicated power mode (PWR\_MODE3) to play ultrasound in advance ultrasonic applications like presence detection, gesture recognition, etc.

When playing ultrasound it is recommended to set bits *DEM\_CTRL[1:0]* to 3h and bit *DIS\_DITH* to 1h.

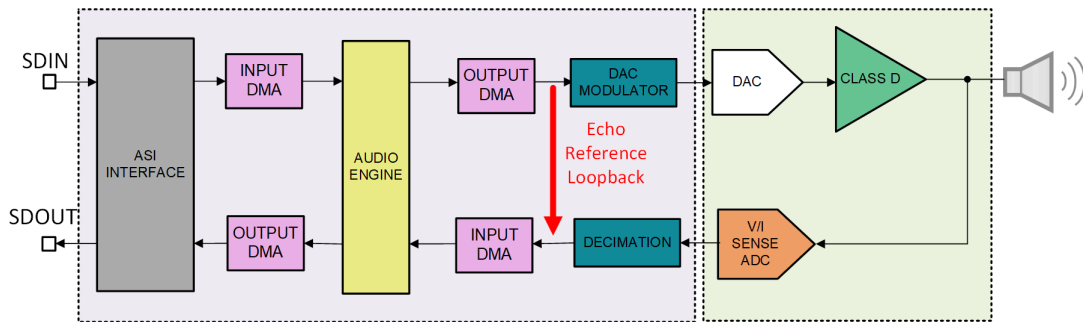
In PWR\_MODE3 mode of operation the output stage of Class-D will be supplied by external PVDDL rail.

### 8.4.12 Echo Reference

The TAS2781 can loop back the DSP output.

This feature allows user to do noise cancellation or echo correction algorithms.

A block diagram is presented in the figure below.



**Figure 8-6. Echo Reference Loopback**

The echo reference can be enabled by configuring *AUDIO\_TX* register bit. The slot length and the time slot can be selected using *AUDIO\_SLEN* and *AUDIO\_SLOT[5:0]* register bits.

### 8.4.13 Hybrid-Pro External Boost Controller

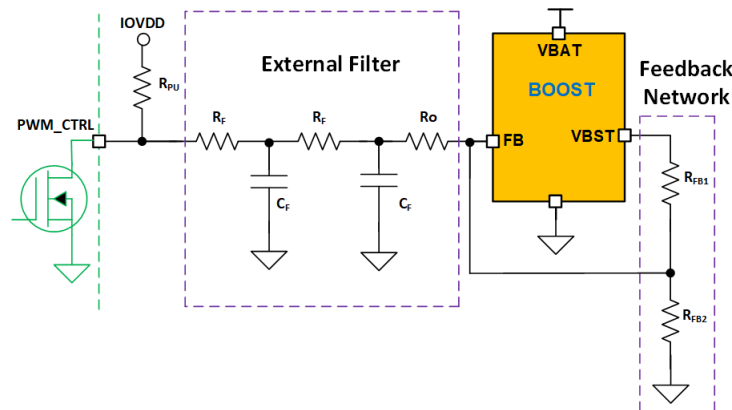
The device has implemented an internal Hybrid-Pro algorithm allowing users to optimize the efficiency in the system by controlling the external power supply and maintaining just enough margin to provide high dynamic range without clipping distortions.

Features of Hybrid-Pro control:

- Optional 8 steps 384 kHz PWM format or 16 steps 192 kHz PWM format Hybrid-Pro control waveform for external DC-DC converter.
- Configurable maximum 4 ms look-ahead audio signal delay buffer, which provides capability to fit various applications systems' DC-DC bandwidth and power supply coupling capacitance.
- Maximum 8 ms programmable audio signal peak hold to optimize power supply voltage rail transition from large audio input to small level, useful to avoid clipping distortions.
- Hybrid-Pro automatically adjusts audio signal trigger level and each step level. Fine tune available to achieve the balance between efficiency and envelope tracking speed.

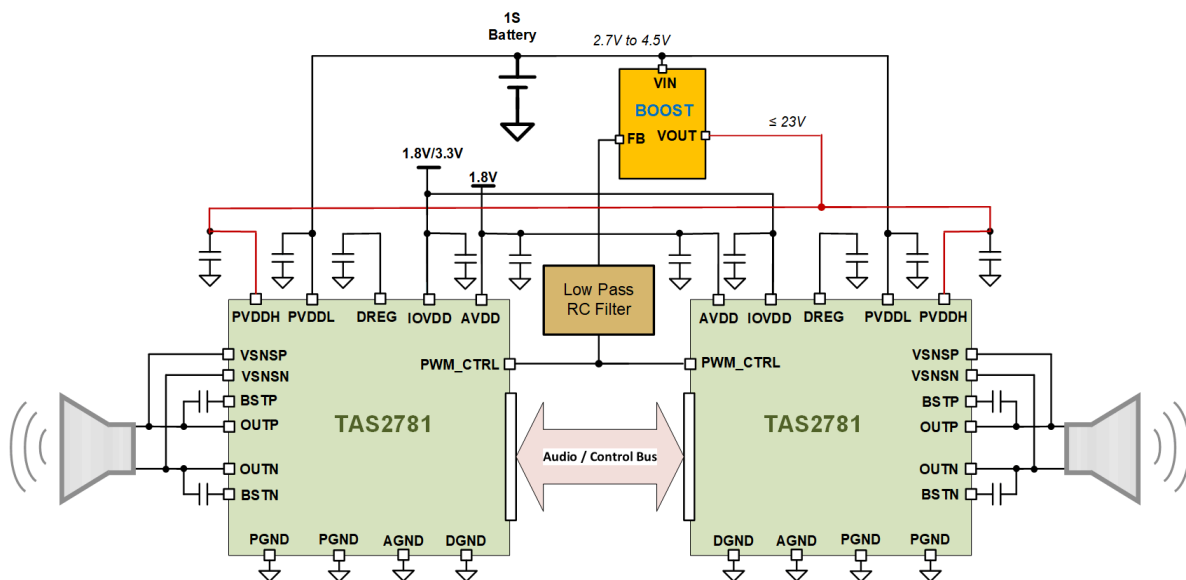
When enabled, the controller generates at PWM\_CTRL pin a signal with a duty cycle proportional to the peak voltage on the speaker. Using an external RC filter the signal is converted to an analog voltage and can be used to control boost converters with feedback input.

The figure below shows how the PWM\_CTRL pin can be connected to the external boost control RC network.



**Figure 8-7. PWM\_CTRL Pin and External Components**

By default, the PWM\_CTRL pin has an open drain configuration which allows an easy implementation of a multi-channel control loop using only one RC circuitry as shown in figure below.



**Figure 8-8. Multi - Channel Configuration using PWM\_CTRL Pin**

When only one device is controlling the boost converter it is recommended to set the *PWM\_CTRL[6]* bit to low. The PWM\_CTRL pin will change configuration to a push-pull and no pull-up resistor is required.

### Note

When using the external boost controller the supply tracking limiter should be either disabled or have the thresholds programmed to a value higher than maximum output voltage of the boost.

To program the internal Class-H controller use registers from pages 0x05 and 0x06.

See [TAS2781](#) User Manual and [SLOA326](#) Application Note for more details on programming the boost controller.

## 8.5 Operational Modes

### 8.5.1 Beep Generator

This tone generator produces a simple audio tone (beep) that is transmitted directly to the output (speaker).

The generator relies on a pulsed signal coming into either SDZ or NC\_SCLK pin.

The beep generation is executed by pulsating any of these two pins with an input frequency  $f_{IN}$  specified in .

The beep output signal will have a frequency given by:

$$f_{BEEP} = f_{IN}/64 \text{ for SDZ pin;} \quad (3)$$

$$f_{BEEP} = f_{IN}/4 \text{ for NC\_SCLK pin.} \quad (4)$$

For example, if an 800 Hz beep is needed, input a 3.2 kHz PWM signal to pin NC\_SCLK.

The beep generation can happen when the device is in Software Shutdown mode, by applying pulses on the pin. A deglitch timer will hold-off the shut-down functionality until the tone has finished and the deglitch timer has expired in which case the pin will revert to controlling the hardware shutdown of the device (SDZ) or SPI clock (NC\_SCLK).

The output power of the beep signal is controlled by the duty cycle of the input signal as discribed in the table below.

**Table 8-7. Beep Output Power**

Load ( $\Omega$ )	Duty Cycle (%)	Ouput Power ( W )
8	20 - 30	0.125
8	45 - 55	0.25
8	70 - 80	0.5

Note: When NC\_SCLK pin is used for beeping, pin 17 should be connected to an 1.8 V supply (AVDD, IOVDD).

### 8.5.2 Hardware Shutdown

The device enters Hardware Shutdown mode if the SDZ pin is asserted low. In Hardware Shutdown mode, the device consumes the minimum quiescent current from AVDD, IOVDD, PVDDH and PVDDL supplies. All registers lose state in this mode and I<sup>2</sup>C or SPI communication is disabled.

By default, when SDZ pin goes low, the device will force a hardware shutdown after a timeout set by the configurable shutdown timer (register bits SDZ\_TIMEOUT[1:0]). If SDZ is asserted low while audio is playing, the device will ramp down volume of the audio, stop the Class-D switching, power down analog and digital blocks and finally put the device into Hardware Shutdown mode. The device can also be configured for forced hardware shutdown and in this case it will not attempt to gracefully disable the audio channel. The shutdown mode can be controlled using SDZ\_MODE[1:0] register bits.

When SDZ is released, the device will sample the ADDR pin and enter the Software Shutdown mode.

### 8.5.3 Mode Control and Software Reset

The TAS2781 mode can be configured by writing the *MODE*[2:0] register bits.

A software reset can be accomplished by setting high the *SW\_RESET* register bit. This bit is self clearing. Once enabled it will restore all registers to their default values.

#### 8.5.4 Software Shutdown

Software Shutdown mode powers down all analog blocks required to playback audio, but does not cause the device to lose register state.

The registers are available through I<sup>2</sup>C or SPI interface.

Software Shutdown is enabled by asserting the *MODE[2:0]* register bits to 3'b010. If audio is playing when Software Shutdown is asserted, the Class-D will volume ramp down before shutting down. When de-asserted, the Class-D will begin switching and volume will ramp back to the programmed digital volume setting.

#### 8.5.5 Mute Mode

The TAS2781 will ramp down volume of the Class-D amplifier to a mute state by setting the *MODE[2:0]* register bits to 3'b001. During mute the Class-D still switches but transmits no audio content. If mute is de-asserted, the device will ramp volume back to the programmed digital setting.

#### 8.5.6 Active Mode

In Active Mode the Class-D switches and plays back audio. Speaker voltage and current sensing are operational if enabled. Set the *MODE[2:0]* register bits to 3'b000 to enter Active Mode.

#### 8.5.7 Noise Gate Mode

In this mode of operation described in section [Section 8.4.2.8](#) the device monitors the signal and powers down the Class-D when signal goes below a threshold.

### 8.6 Faults and Status in TAS2781

During the power-up sequence, the circuit monitoring the AVDD pin (UVLO) will hold the device in reset (including all configuration registers) until the supply is valid. The device will not exit Hardware Shutdown until AVDD is valid and the SDZ pin is released. Once SDZ is released, the digital core voltage regulator will power up, enabling detection of the operational mode. If AVDD dips below the UVLO threshold, the device will immediately be forced into a reset state.

The device also monitors the PVDDH supply and holds the analog core in power down if the supply is below the UVLO threshold (set by register bits *PVDDH\_UV\_TH[5:0]*). If the TAS2781 is in active operation and an UVLO fault occurs, the analog blocks will immediately be powered down to protect the device. These faults are latched and require a transition through HW/SW shutdown to clear the fault. The latched registers will report UVLO faults.

When exiting Software Shutdown to Active (for example: *MODE[2:0]* bits from 010b to 000b), if PVDDH undervoltage is detected, the device will go back into Software Shutdown and an interrupt (*IL\_PUVLO*) will be flagged. To exit this fault user needs to clear the interrupt and program the device in Software Shutdown using *MODE[2:0]* bits, before making another attempt to go to Active mode.

A similar situation might occur in *PWR\_MODE2*, if internal PVDDL LDO undervoltage is detected and *IL\_LDO\_UV* interrupt is flagged.

The device transitions into Software Shutdown mode if it detects any faults with the TDM clocks such as:

- Invalid SBCLK to FSYNC ratio
- Invalid FSYNC frequency
- Halting of SBCLK or FSYNC clocks

Upon detection of a TDM clock error, the device transitions into Software Shutdown mode as quickly as possible to limit the possibility of audio artifacts. Once all TDM clock errors are resolved, the device volume ramps back to its previous playback state. During a TDM clock error, the *IRQZ* pin will assert low if the clock error interrupt mask register bit *IM\_TDMCE* is set low. The clock fault is also available for read-back in the live or latched fault status registers (bits *IL\_TDMCE* and *IR\_TDMCE*).



### Note

It is mandatory to have TDM clocks available before programming I<sup>2</sup>C to enter Active mode. Entering Active mode with no clocks present will trigger a clock error, device will go into software shutdown and the interrupts associated with the clock errors will be raised.

The TAS2781 also monitors die temperature and Class-D load current and will enter software shutdown mode if either of these exceed safe values. As with the TDM clock error, the IRQZ pin will assert low for these faults if the appropriate fault interrupt mask register bit is set low for over temperature and for over current. The fault status can also be monitored in the latched fault registers as with the TDM clock error.

Die over temperature and Class-D over current errors can either be latching (i.e. the device will enter Software Shutdown until a HW/SW shutdown sequence is applied) or they can be configured to automatically retry after a prescribed time. This behavior can be configured in the *OTE\_RETRY* and *OCE\_RETRY* register bits (for over temperature and over current). Even in latched mode, the Class-D will not attempt to retry after an over temperature or over current error until the retry time period (Default = 1.5 s) has elapsed. This prevents applying repeated stress to the device in a rapid fashion that could lead to device damage. If the device has been cycled through SW/HW shutdown, the device will only begin to operate after the retry time period. By default the *RETRY* feature is disabled.

The status registers (and IRQZ pin if enabled, and for un-masked interrupts) also indicate limiter behavior including when the limiter is activated, when PVDDH is below the inflection point, when maximum attenuation has been applied, when the limiter is in infinite hold and when the limiter has muted the audio.

In the situations when the device operates in PWR\_MODE2 the PVDDL pin is supplied by an internal LDO. Protection circuits monitor this block and generate faults in case of under voltage, over voltage or if the LDO is over loaded. The device goes into shut down if one of these faults triggers.

The IRQZ pin is an open drain output that asserts low during unmasked fault conditions and therefore must be pulled up with a resistor to IOVDD. An internal 20 kΩ pull up resistor is provided. It can be accessed by setting the *IRQZ\_PU* register bit of Register 0x04 to high.

The IRQZ interrupt configuration can be set using *IRQZ\_CFG[1:0]* register bits in Register 0x5C. The *IRQZ\_POL* register bit sets the interrupt polarity and *IRQZ\_CLR* register bit allows to clear all the interrupt latch register bits.

Live flag registers are active only when the device is in Active mode of operation. If the device is in Software Shutdown by I<sup>2</sup>C command or due to any fault condition described below, the live flags will be reset. Latched flags will not be reset in this condition and available for user to read their status.

**Table 8-8. Fault Interrupt Mask**

Interrupt	Live Register	Latch Register	Mask Register	Default (1 = Mask)
Temp Over 105 °C	IL_TO105	IR_TO105	IM_TO105	1
Temp Over 115 °C	IL_TO115	IR_TO115	IM_TO115	1
Temp Over 125 °C	IL_TO125	IR_TO125	IM_TO125	1
Temp Over 135 °C	IL_TO135	IR_TO135	IM_TO135	1
Over Temp Error	Device in shutdown	IR_OT	IM_OT	0
Over Current Error	Device in shutdown	IR_OC	IM_OC	0
TDM Clock Error	Device in shutdown	IR_TDMCE	IM_TDMCE	1
TDM Clock Error: Invalid SBCLK ratio or FS rate	-	IR_TDMCEIR	-	-
TDM Clock Error: FS changed on the fly	-	IR_TDNCEFC	-	-
TDM Clock Error: SBCLK FS ratio changed on the fly	-	IR_TDMCERC	-	-
BOP Active	IL_BOPA	IR_BOPA	IM_BOPA	0
BOP Infinite Hold	IL_BOPIH	IR_BOPIH	IM_BOPIH	0
BOP Mute	IL_BOPM	IR_BOPM	IM_BOPM	-
BOP Detected	IL_BOPD	IR_BOPD	IM_BOPD	0

**Table 8-8. Fault Interrupt Mask (continued)**

Interrupt	Live Register	Latch Register	Mask Register	Default (1 = Mask)
BOP Power Down	-	IR_BOPPD	IM_BOPPD	1
PVDDH Below Limiter Inflection	IL_PBIP	IR_PBIP	IM_PBIP	1
Limiter Active	IL_LIMA	IR_LIMA	IM_LIMA	1
Limiter Max Atten	IL_LIMMA	IR_LIMMA	IM_LIMMA	1
PVDDH UVLO	Device in shutdown	IR_PUVLO	IM_PUVLO	0
PVDDL UVLO	Device in shutdown	-	-	-
OTP CRC Error	Device in shutdown	IR_OTPCRC	IM_OTPCRC	0
PVDDL Gain Limiter	IL_VBATLIM	IR_VBATLIM	IM_VBATLIM	1
Internal PLL Clock Error	Device in shutdown	IR_PLL_CLK	IM_PLL_CLK	1
Noise Gate Active	IL_NGA	-	-	-
PVDDH - PVDDL Below Threshold	IL_PVBT	IR_PVBT	IM_PVBT	0
Internal PVDDL LDO Under Voltage	Device in shutdown	IR_LDO_UV	IM_LDO_UV	0
Thermal Detector Threshold 2	Device in shutdown	IR_TDTH2	IM_TDTH2	0
Thermal Detector Threshold 1	IL_TDTH1	IR_TDTH1	IM_TDTH1	0

## 8.7 Power Sequencing Requirements

There are no power sequencing requirements for order of rate of ramping up or down as long as SDZ pin is kept low.

## 8.8 Digital Input Pull Downs

The I<sup>2</sup>S/TDM interface pins and the ICC pin have optional weak pull down resistors to prevent the pins from floating. Register bits *DIN\_PD[4:0]* from are used to enable/disable pull downs. The pull downs are not enabled during Hardware Shutdown.

## 8.9 Register Map

### 8.9.1 Page = 0x00 Address = 0x00 [Reset = 00h]

Bit	Field	Type	Reset	Description
7-0	PAGE[7:0]	RW	0h	Sets the device page. 00h = Page 0 01h = Page 1 ... FFh = Page 255

### 8.9.2 Page = 0x00 Address = 0x01 [Reset = 00h]

Bit	Field	Type	Reset	Description
7-1	Reserved	RW	0h	Reserved
0	SW_RESET	RW	0h	Software reset 0b = De-asserted (default) 1b = Asserted

### 8.9.3 Page = 0x00 Address = 0x02 [Reset = 1Ah]

Bit	Field	Type	Reset	Description
7	BOP_SRC	RW	0h	BOP input source and PVDD UVLO 0b = PVDDL input and PVDDH UVLO disabled (default) 1b = PVDDH input and PVDDH UVLO enabled.
6-5	Reserved	RW	0h	Reserved
4	ISNS_PD	RW	1h	Current Sense 0b = Active 1b = Powered down

Bit	Field	Type	Reset	Description
3	VSNS_PD	RW	1h	Voltage Sense 0b = Active 1b = Powered down
2-0	MODE[2:0]	RW	2h	Device operational mode 000b = Active without Mute 001b = Active with Mute 010b = Software Shutdown (default) 011b -111b = Reserved

**8.9.4 Page = 0x00 Address = 0x03 [Reset = 28h]**

Bit	Field	Type	Reset	Description		
7-6	CDS_MODE[1:0]	RW	0h	Class-D switching mode 00b = Y-Bridge, high power on PVDDL (default) 01b = PVDDL Only Supply of Class D 10b = PVDDH Only Supply of Class D 11b = Y-Bridge, low power on PVDDL		
5-1	AMP_LEVEL[4:0]	RW	14h	Setting	@48ksps	@96 ksps
				00h	11 dBV	9 dBV
				01h	11.5 dBV	9.5 dBV
				02h	12.0 dBV	10 dBV
				03h	12.5 dBV	10.5 dBV
				.....	.....	.....
				13h	20.5 dBV	18.5 dBV
	14h (default)	21 dBV	19 dBV			
	Others : Reserved					
0	Reserved	RW	0h	Reserved		

**8.9.5 Page = 0x00 Address = 0x04 [Reset = 21h]**

Bit	Field	Type	Reset	Description
7	PVDDL_MODE	RW	0h	PVDDL supply is: 0h = Supplied externally 1h = Internally generated from PVDDH
6	IRQZ_PU	RW	0h	IRQZ internal pull up 0h = Disabled 1h = Enabled
5	AMP_SS	RW	1h	Spread Spectrum 0h = Disabled 1h = Enabled <i>*When Spread Spectrum and Sync Mode are both enabled, Sync Mode takes priority</i>
4-3	SAR_FLT[1:0]	RW	0h	SAR filter cut-off frequency 0h = Disabled (default) 1h = 300 kHz 2h = 150 kHz 3h = 50 kHz

Bit	Field	Type	Reset	Description
2-0	HPF_FREQ_PB[2:0]	RW	1h	Forward Path DC blocker cut-off frequency 0h = Disabled (filter bypassed) 1h = 2 Hz 2h = 50 Hz 3h = 100 Hz 4h = 200 Hz 5h = 400 Hz 6h = 800 Hz 7h = Reserved <i>* For 44.1/88.2 kHz sampling rates divide the values from above by 1.0884</i>

### 8.9.6 Page = 0x00 Address = 0x05 [Reset = 41h]

Bit	Field	Type	Reset	Description
7-4	Reserved	RW	4h	Reserved
3	TFB_EN	RW	0h	Thermal Foldback 0h = Disabled 1h = Enabled
2-0	HPF_FREQ_REC[2:0]	RW	1h	Record Path DC blocker 0h = Disabled (filter bypassed) 1h = 2 Hz 2h = 50 Hz 3h = 100 Hz 4h = 200 Hz 5h = 400 Hz 6h = 800 Hz 7h = Reserved <i>* For 44.1/88.2 kHz sampling rates divide the values from above by 1.0884</i>

### 8.9.7 Page = 0x00 Address = 0x06 [Reset = 00h]

Bit	Field	Type	Reset	Description
7-6	Reserved	RW	0h	Reserved
5	OCE_RETRY	RW	0h	Retry after over current event. 0h = Disabled 1h = Enabled, retry after timer.
4	OTE_RETRY	RW	0h	Retry after over temperature event. 0h = Disabled 1h = Enabled, retry after timer.
3	PFFB_EN	RW	0h	Post-Filter Feedback is 0h = Disabled (uses OUT_N and OUT_P pins) 1h = Enabled (uses VSNS_N and VSNS_P pins)
2	SAFE_MODE	RW	0h	Safe mode 0h = Disabled 1h = Enabled
1-0	Reserved	RW	0h	Reserved

### 8.9.8 Page = 0x00 Address = 0x07 [Reset = 20h]

Bit	Field	Type	Reset	Description
7-6	SDZ_MODE[1:0]	RW	0h	Shutdown mode configuration. 0h = Shutdown after timeout (default) 1h = Immediate forced shutdown 2h - 3h = Reserved

Bit	Field	Type	Reset	Description
5-4	SDZ_TMOUT[1:0]	RW	2h	Shutdown timeout 0h = 2 ms 1h = 4 ms 2h = 6 ms (default) 3h = 23.8 ms
3-2	DVC_RMP_RT[1:0]	RW	0h	Digital volume control ramp rate 0h = Volume ramp enabled (default) 1h - 2h = Reserved 3h = Volume ramp disabled
1	I2C_GBL_EN	RW	0h	I <sup>2</sup> C global address 0h = Disabled 1h = Enabled
0	I2C_AD_DET	RW	0h	Re-detect I <sup>2</sup> C peripheral address (self clearing bit) 0h = Normal detection 1h = Re-detect address after power up

### 8.9.9 Page = 0x00 Address = 0x08 [Reset = 09h]

Bit	Field	Type	Reset	Description
7	AMP_INV	RW	0h	Invert audio amplifier output 0h = Normal 1h = Inverted
6	CLASSD_SYNC	RW	0h	Class-D synchronization mode 0h = Not synchronized to audio clocks 1h = Synchronized to audio clocks <i>*When Spread Spectrum and Sync Mode are both enabled, Sync Mode takes priority</i>
5	RAMP_RATE	RW	0h	When CLASSD_SYNC = 1 sample rate is based 0h = 48 kHz 1h = 44.1 kHz
4	AUTO_RATE	RW	0h	Auto-detection of TDM sample rate 0h = Enabled 1h = Disabled
3-1	SAMP_RATE[2:0]	RW	4h	Sample rate of the TDM bus 0h = Reserved 1h = 14.7/16 kHz 2h = 22.05/24 kHz 3h = 29.4/32 kHz 4h = 44.1/48 kHz 5h = 88.2/96 kHz 6h = 176.4/192 kHz 7h = Reserved
0	FRAME_START	RW	1h	TDM frame start polarity 0h = Low to High on FSYNC 1h = High to Low on FSYNC

### 8.9.10 Page = 0x00 Address = 0x09 [Reset = 02h]

Bit	Field	Type	Reset	Description
7	RMP_FREQ_INCR	RW	0h	When CLASSD_SYNC = 1, ramp rate is 0h = 352 kHz 1h = 376 kHz
6	RX_JSTF	RW	0h	TDM RX sample justification within the time slot 0h = Left 1h = Right
5-1	RX_OFF[4:0]	RW	1h	TDM RX start of frame to time slot 0 offset (number of SBCLK cycles)

Bit	Field	Type	Reset	Description
0	RX_EDGE	RW	0h	TDM RX capture clock polarity 0h = Rising edge of SBCLK 1h = Falling edge of SBCLK

### 8.9.11 Page = 0x00 Address = 0x0A [Reset = 0Ah]

Bit	Field	Type	Reset	Description
7-6	IVMON_EN[1:0]	RW	0h	Sets the current and voltage data to length of 0h = 16 bits (default) 1h = 12 bits 2h = 8 bits 3h = Reserved
5-4	RX_SCFG[1:0]	RW	0h	TDM RX time slot select configuration 0h = Mono with time slot equal to I <sup>2</sup> C address offset (default) 1h = Mono left channel 2h = Mono right channel 3h = Stereo downmix (L+R)/2
3-2	RX_WLEN[1:0]	RW	2h	TDM RX word length 0h = 16 bits 1h = 20 bits 2h = 24 bits (default) 3h = 32 bits
1-0	RX_SLEN[1:0]	RW	2h	TDM RX slot length 0h = 16 bits 1h = 24 bits 2h = 32 bits 3h = Reserved

### 8.9.12 Page = 0x00 Address = 0x0C [Reset = 10h]

Bit	Field	Type	Reset	Description
7-4	RX_SLOT_R[3:0]	RW	1h	TDM RX Right Channel Time Slot (default = 1h)
3-0	RX_SLOT_L[3:0]	RW	0h	TDM RX Left Channel Time Slot (default = 0h)

### 8.9.13 Page = 0x00 Address = 0x0D [Reset = 13h]

Bit	Field	Type	Reset	Description
7	TX_KEEPCY	RW	0h	TDM TX SDOUT LSB data will be driven when TX_KEEPEN is enabled 0h = Full cycle 1h = Half cycle
6	TX_KEEPLN	RW	0h	TDM TX SDOUT will hold the bus, when TX_KEEPEN is enabled, for: 0h = 1 LSB cycle 1h = Always
5	TX_KEEPEN	RW	0h	TDM TX SDOUT bus keeper 0h = Disabled 1h = Enabled
4	TX_FILL	RW	1h	TDM TX SDOUT unused bit field fill 0h = Transmit 0 1h = Transmit Hi-Z
3-1	TX_OFFSET[2:0]	RW	1h	TDM TX start of frame to time slot 0 offset (default = 1h)
0	TX_EDGE	RW	1h	TDM TX launch clock polarity 0h = Rising edge of SBCLK 1h = Falling edge of SBCLK

**8.9.14 Page = 0x00 Address = 0x0E [Reset = C2h]**

Bit	Field	Type	Reset	Description
7	CLASSH_RES	RW	1h	Class-H resolution 0h = 8 bits 1h = 16 bits
6	VSNS_TX	RW	1h	TDM TX voltage sense transmit 0h = Disabled 1h = Enabled
5-0	VSNS_SLOT[5:0]	RW	2h	TDM TX voltage sense time slot (default = 02h)

**8.9.15 Page = 0x00 Address = 0x0F [Reset = 40h]**

Bit	Field	Type	Reset	Description
7	Reserved	R	0h	Reserved
6	ISNS_TX	RW	1h	TDM TX current sense transmit 0h = Disabled 1h = Enabled
5-0	ISNS_SLOT[5:0]	RW	0h	TDM TX current sense time slot (default = 00h)

**8.9.16 Page = 0x00 Address = 0x10 [Reset = 04h]**

Bit	Field	Type	Reset	Description
7	SAR_DATA_SL	RW	0h	TDM TX SAR data time slot length 0h = Truncate to 8 bits 1h = Left justify to 16 bits
6	SAR_DATA_TX	RW	0h	TDM TX SAR data transmit enable 0h = Disabled 1h = Enabled
5-0	SR_DATA_SLOT[5:0]	RW	4h	TDM TX SAR time slot (default = 4h)
	1. Sequence for 96 ksps: PVDDL, PVDDH, Temp, Marker. 2. Sequence for 192 ksps: PVDDL, PVDDL, PVDDH, PVDDH, Temp, Temp, Marker, Marker.			

**8.9.17 Page = 0x00 Address = 0x13 [Reset = 08h]**

Bit	Field	Type	Reset	Description
7	STAT_SLOT_TG	RW	0h	Over Power STATUS bits - TH1 and TH2 0h = Disabled 1h = <i>Bit [5]</i> from STATUS = TH2 OR-ed with OTS 1h = <i>Bit [6]</i> from STATUS = TH1
6	STATUS_TX	RW	0h	TDM TX status transmit 0h = Disabled 1h = Enabled

Bit	Field	Type	Reset	Description
5-0	STATUS_SLOT[5:0]	RW	8h	<p>TDM TX status time slot (default = 08h)</p> <p>Bit [7] - PVDDH status 0h = PVDDH UVLO not detected 1h = PVDD UVLO detected</p> <p>Bit [6] - Over current status 0h = No over current detected 1h = Over current detected</p> <p>Bit [5] - Over temperature status 0h = No over temperature detected 1h = Over temperature detected</p> <p>*Bit [4] - BOP status 0h = BOP not detected 1h = BOP detected</p> <p>*Bit [3] - Signal distortion limiter status 0h = No distortion limiter 1h = Gain attenuation done due to distortion limiter</p> <p>Bit [2] - Noise Gate status 0h = Device in normal mode 1h = Device in Noise Gate mode</p> <p>Bit [1] - Class-D power stage status 0h = Class D Power switch connected to PVDDL 1h = Class D Power switch connected to PVDDH</p> <p>Bit [0] - Power up state 0h = Device in powered down 1h = Device in active state</p>

#### 8.9.18 Page = 0x00 Address = 0x15 [Reset = 00h]

Bit	Field	Type	Reset	Description
7-5	LS_OC[2:0]	RW	0h	<p>Low side OC threshold 0h = Nominal OC threshold (default) 1h = OC threshold increased by 10% of nominal 2h = OC threshold increased by 20% of nominal 3h = OC threshold increased by 30% of nominal 4h = OC threshold reduced by 40% of nominal 5h = OC threshold reduced by 30% of nominal 6h = OC threshold reduced by 20% of nominal 7h = OC threshold reduced by 10% of nominal</p>
4-2	ICC_CFG[2:0]	RW	0h	<p>ICC pin function 0h = Gain slot transmission (default) 1h = Reserved 2h = ICC pin buffers disabled 3h = ICC pin is a general purpose input 4h = ICC pin is a general purpose output 5h - 7h = Reserved</p>
1-0	Reserved	R	0h	Reserved

#### 8.9.19 Page = 0x00 Address = 0x16 [Reset = 12h]

Bit	Field	Type	Reset	Description
7	AUDIO_SLEN	RW	0h	<p>TDM audio slot length 0h = 16 bits 1h = 24 bits</p>
6	AUDIO_TX	RW	0h	<p>TDM audio output transmit 0h = Disabled 1h = Enabled</p>
5-0	AUDIO_SLOT[5:0]	RW	12h	TDM TX status time slot (default = 12h)



**8.9.20 Page = 0x00 Address = 0x17 [Reset = 80h]**

Bit	Field	Type	Reset	Description
7-4	LIM_MAX_AT[3:0]	RW	8h	Limiter maximum attenuation (default = 8h) 0h = -1 dB 1h = -2 dB 2h = -3 dB ... 0Eh = -15 dB 0Fh = Reserved
3-0	Reserved	R	0h	Reserved

**8.9.21 Page = 0x00 Address = 0x1A [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	DVC_LVL[7:0]	RW	00h	Digital volume control 00h = 0 dB 01h = -0.5 dB 02h = -1 dB ... C8h = -100 dB Others : Mute

**8.9.22 Page = 0x00 Address = 0x1B [Reset = 62h]**

Bit	Field	Type	Reset	Description
	LIMB_SRC	RW	0h	Voltage limiter input source 0h = PVDDL input 1h = PVDDH input
7 - 6	Reserved	R	1h	Reserved
5	LIM_HR_EN	RW	1h	Limiter dynamic headroom 0h = Disabled 1h = Enabled
4-1	LIM_ATK_RT[3:0]	RW	1h	Limiter attack rate 00h = 20 μs/dB 01h = 40 μs/dB 02h = 80 μs/dB 03h = 160 μs/dB 04h = 320 μs/dB 05h = 640 μs/dB 06h = 1280 μs/dB 07h = 2560 μs/dB 08h = 5120 μs/dB 09h = 10240 μs/dB 10h = 20480 μs/dB 11h = 40960 μs/dB 12h = 81920 μs/dB 13h = 163840 μs/dB Others : Reserved
0	LIM_EN	RW	0h	Limiter is 0h = Disabled 1h = Enabled

**8.9.23 Page = 0x00 Address = 0x1C [Reset = 36h]**

Bit	Field	Type	Reset	Description
7	Reserved	R	0h	Reserved

Bit	Field	Type	Reset	Description
6-3	LIM_RLS_RT[3:0]	RW	6h	Limiter release rate 0h = 2 ms/dB 1h = 4 ms/dB 2h = 8 ms/dB 3h = 16 ms/dB 4h = 32 ms/dB 5h = 64 ms/dB 6h = 128 ms/dB 7h = 256 ms/dB 8h = 512 ms/dB 9h = 1024 ms/dB Ah = 2048 ms/dB Bh = 4096 ms/dB Ch = 8192 ms/dB Ch = 16384 ms/dB Eh - Fh = Reserved
2-0	LIM_HLD[2:0]	RW	6h	Limiter hold time 0h = Reserved 1h = 10 ms 2h = 25 ms 3h = 50 ms 4h = 100 ms 5h = 250 ms 6h = 500 ms (default) 7h = 1000 ms

#### 8.9.24 Page = 0x00 Address = 0x1D [Reset = 00h]

Bit	Field	Type	Reset	Description
7	ICC_EN	RW	0h	ICC pin 0h = Disabled 1h = Enabled
6-3	ICC_PAIR_DEV[3:0]	RW	0h	ICC device pair number (default = 0h) 0h = Device paired with Device 0 1h = Device paired with Device 1 ..... 7h = Device paired with Device 7 8h - Fh = Device not paired
2-0	ICC_DEV[2:0]	RW	0h	ICC device number (default = 0h) 0h = Device transmits gain in Slot 0 of ICC bus 1h = Device transmits gain in Slot 1 of ICC bus 2h = Device transmits gain in Slot 2 of ICC bus 3h = Device transmits gain in Slot 3 of ICC bus 4h = Device transmits gain in Slot 4 of ICC bus 5h = Device transmits gain in Slot 5 of ICC bus 6h = Device transmits gain in Slot 6 of ICC bus 7h = Device transmits gain in Slot 7 of ICC bus

**8.9.25 Page = 0x00 Address = 0x1F [Reset = 01h]**

Bit	Field	Type	Reset	Description
7-5	HS_OC[2:0]	RW	0h	High side OC threshold 0h = Nominal OC threshold (default) 1h = OC threshold increased by 10% of nominal 2h = OC threshold increased by 20% of nominal 3h = OC threshold increased by 30% of nominal 4h = OC threshold reduced by 40% of nominal 5h = OC threshold reduced by 30% of nominal 6h = OC threshold reduced by 20% of nominal 7h = OC threshold reduced by 10% of nominal
4	BOPSD_EN	RW	0h	BOP shutdown 0h = Disabled 1h = Enabled
0	BOP_HLD_CLR	RW	0h	BOP infinite hold clear (self clearing) 0h = Do not clear 1h = Clear
	BOP_INF_HLD	RW	0h	Infinite hold in BOP event 0h = Use BOP_HLD after BOP event 1h = Do not release until BOP_HLD_CLR is asserted high
	BOP_MUTE	RW	0h	Mute in BOP event 0h = Do not mute 1h = Mute followed by device shutdown
	BOP_EN	RW	1h	BOP 0h = Disabled 1h = Enabled

**8.9.26 Page = 0x00 Address = 0x20 [Reset = 2Eh]**

Bit	Field	Type	Reset	Description
7-5	BOP_ATK_RT[2:0]	RW	1h	Brown out prevention attack rate 0h = 1 step in 1 sample 1h = 1 step in 2 samples (default) 2h = 1 step in 4 samples 3h = 1 step in 8 samples 4h = 1 step in 16 samples 5h = 1 step in 32 samples 6h = 1 step in 64 samples 7h = 1 step in 128 samples
4-3	BOP_ATK_ST[1:0]	RW	1h	Brown out prevention attack step size 0h = 0.5 dB 1h = 1 dB (default) 2h = 1.5 dB 3h = 2 dB

Bit	Field	Type	Reset	Description
2-0	BOP_HLD[2:0]	RW	6h	Brown out prevention hold time 0h = 0 ms 1h = 10 ms 2h = 25 ms 3h = 50 ms 4h = 100 ms 5h = 250 ms 6h = 500 ms (default) 7h = 1000 ms

### 8.9.27 Page = 0x00 Address = 0x34 [Reset = 06h]

Bit	Field	Type	Reset	Description
7-3	Reserved	R	0h	Reserved
2-1	LVS_FTH_LOW[1:0]	RW	3h	Threshold for LVS when CDS_MODE = 3h 0h = -121.5 dBFS 1h = -101.5 dBFS (default) 2h = -81.5 dBFS 3h = -71.5 dBFS (default)
0	Reserved	R	0h	Reserved

### 8.9.28 Page = 0x00 Address = 0x35 [Reset = BDh]

Bit	Field	Type	Reset	Description
7-5	NG_HYST_TIMER[2:0]	RW	5h	Noise Gate entry hysteresis timer 0h = 400 $\mu$ s 1h = 600 $\mu$ s 2h = 800 $\mu$ s 3h = 2 ms 4h = 10 ms 5h = 50 ms (default) 6h = 100 ms 7h = 1 s
4-3	NG_TH[1:0]	RW	3h	Noise Gate audio threshold level 0h = -90 dBFS 1h = -100 dBFS 2h = -110 dBFS 3h = -120 dBFS (default)
2	NG_EN	RW	1h	Noise Gate 0h = Disabled 1h = Enabled
1-0	Reserved	R	1h	Reserved

### 8.9.29 Page = 0x00 Address = 0x36 [Reset = ADh]

Bit	Field	Type	Reset	Description
7-6	Reserved	RW	2h	Reserved
5	NG_DVC_RP	RW	1h	Volume ramping on Noise Gate 0h = Enabled 1h = Disabled
4	Reserved	R	0h	Reserved

Bit	Field	Type	Reset	Description
3-0	LVS_HYS[3:0]	RW	Dh	PVDDH to PVDDL hysteresis time 0h - 9h = Reserved Ah = 1 ms Bh = 10 ms Ch = 20 ms Dh = 50 ms (default) Eh = 75 ms Fh = 100 ms <i>*For sampling rates <math>f_s &lt; 48</math> ksp/s multiply the values by 48/<math>f_s</math></i>

**8.9.30 Page = 0x00 Address = 0x37 [Reset = A8h]**

Bit	Field	Type	Reset	Description
7	LVS_DET	RW	1h	Low Voltage Signaling threshold 0h = Fixed 1h = Relative to PVDDL voltage
6-5	Reserved	R	1h	Reserved
4-0	LVS_FTH[4:0]	RW	08h	Threshold for LVS (CDS_MODE = 0h) 00h = -18.5 dBFS 01h = -18.25 dBFS (default) 02h = -18 dBFS 03h = -17.75 dBFS 04h = -17.5 dBFS .. 08h = -16.5 dBFS (default) .. 1Eh = -11 dBFS 1Fh = -10.75 dBFS

**8.9.31 Page = 0x00 Address = 0x38 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	Reserved	R	0h	Reserved
6	DIN_PD[4]	RW	0h	Weak pull down for ICC 0h = Disabled 1h = Enabled
5	DIN_PD[3]	RW	0h	Weak pull down for SDOOUT 0h = Disabled 1h = Enabled
4	DIN_PD[2]	RW	0h	Weak pull down for SDIN 0h = Disabled 1h = Enabled
3	DIN_PD[1]	RW	0h	Weak pull down for FSYNC 0h = Disabled 1h = Enabled
2	DIN_PD[0]	RW	0h	Weak pull down for SBCLK 0h = Disabled 1h = Enabled
1-0	Reserved	R	0h	Reserved

**8.9.32 Page = 0x00 Address = 0x3B [Reset = FCh]**

Bit	Field	Type	Reset	Description
7	IM_BOPM	RW	1h	BOP mute interrupt 0h = No Mask 1h = Mask
6	IM_BOPIH	RW	1h	Bop infinite hold interrupt. 0h = No Mask 1h = Mask

Bit	Field	Type	Reset	Description
5	IM_LIMMA	RW	1h	Limiter max attenuation interrupt 0h = No Mask 1h = Mask
4	IM_PBIP	RW	1h	PVDDH below limiter inflection point interrupt 0h = No Mask 1h = Mask
3	IM_LIMA	RW	1h	Limiter active interrupt 0h = No Mask 1h = Mask
2	IM_TDMCE	RW	1h	TDM clock error interrupt 0h = No Mask 1h = Mask
1	IM_OC	RW	0h	Over current error interrupt 0h = No Mask 1h = Mask
0	IM_OT	RW	0h	Over temp error interrupt 0h = No Mask 1h = Mask

### 8.9.33 Page = 0x00 Address = 0x3C [Reset = BBh]

Bit	Field	Type	Reset	Description
7	Reserved	R	1h	Reserved
6	IM_OTPCRC	RW	0h	OTP_CRC error interrupt 0h = No Mask 1h = Mask
5-1	Reserved	R	1Dh	Reserved
0	IM_VBATLIM	RW	1h	Gain limiter active interrupt 0h = No Mask 1h = Mask

### 8.9.34 Page = 0x00 Address = 0x3D [Reset = DDh]

Bit	Field	Type	Reset	Description
7	IM_PLL_CLK	RW	1h	Internal PLL derived clock error interrupt 0h = No Mask 1h = Mask
6-0	Reserved	R	1h	Reserved

### 8.9.35 Page = 0x00 Address = 0x40 [Reset = F6h]

Bit	Field	Type	Reset	Description
7	IM_TO105	RW	1h	Temperature over 105 °C interrupt. 0h = No Mask 1h = Mask
6	IM_TO115	RW	1h	Temperature over 115 °C interrupt. 0h = No Mask 1h = Mask
5	IM_TO125	RW	1h	Temperature over 125 °C interrupt. 0h = No Mask 1h = Mask
4	IM_TO135	RW	1h	Temperature over 135 °C interrupt. 0h = No Mask 1h = Mask
3	IM_LDO_UV	RW	0h	Internal PVDDL LDO under voltage 0h = No Mask 1h = Mask

Bit	Field	Type	Reset	Description
2-1	Reserved	R	3h	Reserved
0	IM_PUVLO	RW	0h	PVDDH under voltage 0h = No Mask 1h = Mask

**8.9.36 Page = 0x00 Address = 0x41 [Reset = 14h]**

Bit	Field	Type	Reset	Description
7	IM_TDTH2	RW	0h	Thermal Detection Threshold 2 0h = No Mask 1h = Mask
6	IM_TDTH1	RW	0h	Thermal Detection Threshold 1 0h = No Mask 1h = Mask
5	IM_PVBT	RW	0h	PVDDH - PVDDL below threshold 0h = No Mask 1h = Mask
4	IM_BOPA	RW	1h	BOP active interrupt 0h = No mask 1h = Mask
3	IM_BOPD	RW	0h	BOP detected interrupt 0h = No mask 1h = Mask
2	IM_BOPPD	RW	1h	BOP device power down start 0h = No mask 1h = Mask
1-0	Reserved	R	0h	Reserved

**8.9.37 Page = 0x00 Address = 0x42 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	IL_BOPM	R	0h	Interrupt due to bop mute 0h = No interrupt 1h = Interrupt
6	IL_BOPIH	R	0h	Interrupt due to bop infinite hold 0h = No interrupt 1h = Interrupt
5	IL_LIMMA	R	0h	Interrupt due to limiter max attenuation 0h = No interrupt 1h = Interrupt
4	IL_PBIP	R	0h	Interrupt due to PVDDH below limiter inflection point 0h = No interrupt 1h = Interrupt
3	IL_LIMA	R	0h	Interrupt due to limiter active 0h = No interrupt 1h = Interrupt
2	IL_TDMCE	R	0h	Interrupt due to TDM clock error 0h = No interrupt 1h = Interrupt - <i>Device in shutdown</i>
1	IL_OC	R	0h	Interrupt due to over current error 0h = No interrupt 1h = Interrupt - <i>Device in shutdown</i>
0	IL_OT	R	0h	Interrupt due to over temp error 0h = No interrupt 1 = Interrupt - <i>Device in shutdown</i>

**8.9.38 Page = 0x00 Address = 0x43 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	Reserved	R	0h	Reserved
6	IL_OTPCRC	R	0h	Interrupt due to OTP CRC Error Flag 0h = No interrupt 1h = Interrupt - <i>Device in shutdown</i>
5-3	Reserved	R	0h	Reserved
2	IL_NGA	R	0h	Noise Gate active flag 0h = Noise Gate not detected 1h = Noise Gate detected
1	Reserved	R	0h	Reserved
0	IL_VBATLIM	R	0h	Interrupt due to gain limiter active 0h = No interrupt 1h = Interrupt

**8.9.39 Page = 0x00 Address = 0x44 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	IL_PLL_CLK	R	0h	Internal PLL Clock Error 0h = No interrupt 1h = Interrupt - <i>Device in shutdown</i>
6	Reserved	R	0h	Reserved
5	IL_PVDDL_UV	R	0h	PVDDL under voltage 0h = No interrupt 1h = Interrupt - <i>Device in shutdown</i>
4-0	Reserved	R	0h	Reserved

**8.9.40 Page = 0x00 Address = 0x47 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	IL_TO105	R	0h	Temperature over 105 °C 0b = No Interrupt 1b = Interrupt
6	IL_TO115	R	0h	Temperature over 115 °C 0b = No Interrupt 1b = Interrupt
5	IL_TO125	R	0h	Temperature over 125 °C 0b = No Interrupt 1b = Interrupt
4	IL_TO135	R	0h	Temperature over 135 °C 0b = No Interrupt 1b = Interrupt
3	IL_LDO_UV	R	0h	PVDDL internal LDO under voltage 0b = No Interrupt 1b = Interrupt - <i>Device in shutdown</i>
2-1	Reserved	R	0h	Reserved
0	IL_PUVLO	R	0h	PVDDH under voltage 0b = No Interrupt 1b = Interrupt - <i>Device in shutdown</i>

**8.9.41 Page = 0x00 Address = 0x48 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	IL_TDTH2	R	0h	Thermal detection threshold 2 0h = No interrupt 1h = Interrupt - <i>Device in shutdown</i>



Bit	Field	Type	Reset	Description
6	IL_TDTH1	R	0h	Thermal detection threshold 1 0h = No interrupt 1h = Interrupt
5	IL_PVBT	R	0h	(PVDDH - PVDDL) below threshold 0h = No interrupt 1h = Interrupt
4	IL_BOPA	R	0h	BOP active 0h = No interrupt 1h = Interrupt
3	IL_BOPD	R	0h	BOP detected 0h = No interrupt 1h = Interrupt
2-0	Reserved	R	0h	Reserved

**8.9.42 Page = 0x00 Address = 0x49 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	IR_BOPM	R	0h	Interrupt due to BOP mute 0h = No interrupt 1h = Interrupt
6	IR_BOPIH	R	0h	Interrupt due to BOP infinite hold 0h = No interrupt 1h = Interrupt
5	IR_LIMMA	R	0h	Interrupt due to limiter max attenuation 0h = No interrupt 1h = Interrupt
4	IR_PBIP	R	0h	Interrupt due to PVDDH below limiter inflection point 0h = No interrupt 1h = Interrupt
3	IR_LIMA	R	0h	Interrupt due to limiter active 0h = No interrupt 1h = Interrupt
2	IR_TDMCE	R	0h	Interrupt due to TDM clock error 0h = No interrupt 1h = Interrupt
1	IR_OC	R	0h	Interrupt due to over current 0h = No interrupt 1h = Interrupt
0	IR_OT	R	0h	Interrupt due to over temperature 0h = No interrupt 1h = Interrupt

**8.9.43 Page = 0x00 Address = 0x4A [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	Reserved	R	0h	Reserved
6	IR_OTPCRC	R	0h	Interrupt due to OTP CRC error 0h = No interrupt 1h = Interrupt
5-1	Reserved	R	00h	Reserved
0	IR_VBATLIM	R	0h	Interrupt due to gain limiter 0h = No interrupt 1h = Interrupt

**8.9.44 Page = 0x00 Address = 0x4B [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	IR_PLL_CLK	R	0h	Internal PLL Clock Error 0h = No interrupt 1h = Interrupt
6-0	Reserved	R	00h	Reserved

**8.9.45 Page = 0x00 Address = 0x4F [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	IR_TO105	R	0h	Temperature over 105 °C 0h = No Interrupt 1h = Interrupt
6	IR_TO115	R	0h	Temperature over 115 °C 0h = No Interrupt 1h = Interrupt
5	IR_TO125	R	0h	Temperature over 125 °C 0h = No Interrupt 1h = Interrupt
4	IR_TO135	R	0h	Temperature over 135 °C 0h = No Interrupt 1h = Interrupt
3	IR_LDO_UV	R	0h	Internal PVDDL LDO under voltage 0h = No Interrupt 1h = Interrupt
2-1	Reserved	R	0h	Reserved
0	IR_PUVLO	R	0h	PVDDH under voltage 0h = No Interrupt 1h = Interrupt

**8.9.46 Page = 0x00 Address = 0x50 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	IR_TDTH2	R	0h	Thermal detection threshold 2 0h = No interrupt 1h = Interrupt
6	IR_TDTH1	R	0h	Thermal detection threshold 1 0h = No interrupt 1h = Interrupt
5	IR_PVBT	R	0h	Interrupt due to (PVDDH - PVDDL) below threshold 0h = No interrupt 1h = Interrupt
4	IR_BOPA	R	0h	BOP active flag 0h = No interrupt 1h = Interrupt
3	IR_BOPD	R	0h	BOP detected 0h = No interrupt 1h = Interrupt
2	IR_BOPPD	R	0h	Interrupt due to BOP triggered shutdown 0h = No interrupt 1h = Interrupt
1-0	Reserved	R	0h	Reserved

**8.9.47 Page = 0x00 Address = 0x51 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-3	Reserved	R	00h	Reserved

Bit	Field	Type	Reset	Description
2	IR_TDMCEIR	R	0h	TDM clock error: invalid SBCLK ratio or sampling rate 0h = No Interrupt 1h = Interrupt
1	IR_TDMCEFC	R	0h	TDM clock error: sampling rate changed on the fly 0h = No Interrupt 1h = Interrupt
0	IR_TDMCERC	R	0h	TDM clock error: SBCLK to FSYNC ratio changed on the fly 0h = No Interrupt 1h = Interrupt

**8.9.48 Page = 0x00 Address = 0x52 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	PVDDL_CNV[11:4]	R	00h	Returns SAR ADC PVDDL conversion MSB $8 \times \{\text{hex2dec}(\text{PVDDL\_CNV}[11:0])\} / 4096$

**8.9.49 Page = 0x00 Address = 0x53 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-4	PVDDL_CNV[11:4]	R	0h	Returns SAR ADC PVDDL conversion LSB $8 \times \{\text{hex2dec}(\text{PVDDL\_CNV}[11:0])\} / 4096$
3-0	Reserved	R	0h	Reserved

**8.9.50 Page = 0x00 Address = 0x54 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	PVDDH_CNV[11:4]	R	00h	Returns SAR PVDDH conversion MSB $23 \times \{\text{hex2dec}(\text{PVDDH\_CNV}[11:0])\} / 4096$

**8.9.51 Page = 0x00 Address = 0x55 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-4	PVDDH_CNV[3:0]	R	0h	Returns SAR PVDDH conversion LSBs $23 \times \{\text{hex2dec}(\text{PVDDH\_CNV}[11:0])\} / 4096$
3-0	Reserved	R	0h	Reserved

**8.9.52 Page = 0x00 Address = 0x56 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	TEMP_CNV[7:0]	R	00h	Returns SAR temperature sensor conversion $\{\text{hex2dec}(\text{TEMP\_CNV}[7:0])\} - 93$

**8.9.53 Page = 0x00 Address = 0x5C [Reset = 19h]**

Bit	Field	Type	Reset	Description
7	CLK_PWRUD	RW	0h	Clock based device power up/power down feature 0h = Disabled 1h = Enabled
6	DIS_CLK_HALT	RW	0h	Clock halt timer 0h = Enable clock halt detection after clock error 1h = Disable clock halt detection after clock error

Bit	Field	Type	Reset	Description
5-3	CLK_HALT_TIMER[2:0]	RW	3h	Clock halt timer values 0h = 820 $\mu$ s 1h = 3.27 ms 2h = 26.21 ms 3h = 52.42 ms (default) 4h = 104.85 ms 5h = 209.71 ms 6h = 419.43 ms 7h = 838.86 ms
2	IRQZ_CLR	RW	0h	Clear interrupt latch registers 0h = Do not clear 1h = Clear (self clearing bit)
1-0	IRQZ_CFG[1:0]	RW	1h	IRQZ interrupt configuration. IRQZ will assert 0h = On any unmasked live interrupt 1h = On any unmasked latched interrupt (default) 2h = For 2 - 4 ms one time on any unmasked live interrupt event 3h = For 2 - 4 ms every 4 ms on any unmasked latched interrupt

**8.9.54 Page = 0x00 Address = 0x5D [Reset = 80h]**

Bit	Field	Type	Reset	Description
7	IRQZ_POL	RW	1h	IRQZ pin polarity 0h = Active high 1h = Active low
6-0	Reserved	R	00h	Reserved

**8.9.55 Page = 0x00 Address = 0x60 [Reset = 0Dh]**

Bit	Field	Type	Reset	Description
7-2	SBLK_FS_RATIO[5:0]	RW	3h	SBLCLK to FS ratio when AUTO_RATE=1 (disabled). See <a href="#">Table 8-9</a> .
1-0	Reserved	R	1h	Reserved

**Table 8-9. SBCLK to FSYNC Ratio (AUTO\_RATE=1)**

00h = 16	01h = 24	02h = 32	03h = 48 (default)	04h = 64
05h = 96	06h = 128	07h = 192	08h = 256	09h = 384
0Ah = 512	0Bh = 125	0Ch = 250	0Dh = 500	0Eh - 3Fh = Reserved

**8.9.56 Page = 0x00 Address = 0x63 [Reset = 48]**

Bit	Field	Type	Reset	Description
7	IDLE_IND	RW	0h	Idle channel optimization 0h = Used for inductors , 15 $\mu$ H and higher 1h = Used for 5 $\mu$ H inductors
6-0	Reserved	R	48h	Reserved

**8.9.57 Page = 0x00 Address = 0x65 [Reset = 08]**

Bit	Field	Type	Reset	Description
7	PWR_LIM_SRC	RW	0h	Limiter power source 0h = PVDDL 1h = PVDDH
6-0	Reserved	R	08h	Reserved

### 8.9.58 Page = 0x00 Address = 0x67 [Reset = 00h]

Bit	Field	Type	Reset	Description
7-2	Reserved	R	00h	Reserved
1-0	IDCH_HYST[1:0]	RW	0h	Idle channel hysteresis timer 0h = 50 ms (default) 1h = 100 ms 2h = 200 ms 3h = 1000 ms *For sampling rates $f_s < 48$ ksp/s multiply the values by $48/f_s$

### 8.9.59 Page = 0x00 Address = 0x68 [Reset = 30h]

Bit	Field	Type	Reset	Description
7-6	Reserved	R	0h	Reserved
5-0	FS_RATIO[5:0]	RW	30h	Detected SBCLK to FSYNK ratio. See <a href="#">Table 8-10</a> .

**Table 8-10. Detected SBCLK to FSYNK Ratio**

00h = 16	01h = 24	02h = 32	03h = 48	04h = 64
05h = 96	06h = 128	07h = 192	08h = 256	09h = 384
0Ah = 512	0Bh = 125	0Ch = 250	0Dh = 500	0Eh - 3Fh = Reserved

### 8.9.60 Page = 0x00 Address = 0x6A [Reset = 12h]

Bit	Field	Type	Reset	Description
7-6	CDS_DLY[1:0]	RW	0h	Delay ( $1/f_s$ ) of the Y-bridge switching with respect to the input signal. See <a href="#">Table 8-11</a> .
5-4	LVS_DLY[1:0]	RW	1h	Delay ( $1/f_s$ ) of the PWM_CTRL pin signaling with respect to the input signal, when Class H is disabled. See <a href="#">Table 8-12</a> .
3-0	LVS_RTH[3:0]	RW	2h	Relative threshold for Low Voltage Signaling (headroom from PVDDL voltage). 0h = 0.5 V 1h = 0.6 V 2h = 0.7 V ... Eh = 1.9 V Fh = 2 V

**Table 8-11. CDS Delay ( $1/f_s$ )**

	48 ksp/s		96 ksp/s	
	NG Enabled	NG Disabled	NG Enabled	NG Disabled
0h (default)	8.1	6.1	12.6	9.6
1h	7.1	5.1	10.6	7.6
2h	6.1	4.1	8.5	5.6
3h	5.6	3.6	7.6	4.6

**Table 8-12. LVS\_Delay ( $1/f_s$ )**

	48 ksp/s		96 ksp/s	
	NG Enabled	NG Disabled	NG Enabled	NG Disabled
0h	7.8	5.8	12.1	9.1
1h (default)	6.8	4.8	10.1	7.1
2h	5.8	3.8	8.1	5.1
3h	5.1	3.1	6.6	3.6

**8.9.61 Page = 0x00 Address = 0x6B [Reset = 7Bh]**

Bit	Field	Type	Reset	Description
7	Reserved	R	0h	Reserved
6	CNV_PVDDL	RW	1h	Convert the PVDDL when BOP source is PVDDH 0h = No PVDDL conversion 1h = PVDDL conversion
5-3	FS_RATE[2:0]	RW	7h	Detected sample rate of TDM bus 0h - 3h = Reserved 4h = 44.1/48 kHz 5h = 88.2/96 kHz 6h = Reserved 7h = Error condition (default)
2	NGFR_EN	RW	0h	Noise Gate fine resolution register mode 0h = Disabled 1h = Enabled
1-0	Reserved	R	3h	Reserved

**8.9.62 Page = 0x00 Address = 0x6C - 0x6E [Reset = 00001Ah]**

Bit	Field	Type	Reset	Description
23-0	NGFR_LVL[23:0]	RW	00001Ah	Sets Noise Gate threshold to a level NGLV(dBFS) dec2hex[round(10^(NGLV/20)*2^31)]

**8.9.63 Page = 0x00 Address = 0x6F [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	NGFR_HYST[18:11]	RW	0h	Sets Noise Gate hysteresis to a value NGHYS(ms) dec2bin[(NGHYS*f <sub>s</sub> ), 19] f <sub>s</sub> = sampling rate in kHz Recommended to be set above 1ms.

**8.9.64 Page = 0x00 Address = 0x70 [Reset = 96h]**

Bit	Field	Type	Reset	Description
7-0	NGFR_HYST[10:3]	RW	96h	Sets Noise Gate hysteresis to a value NGHYS(ms) dec2bin[(NGHYS*f <sub>s</sub> ), 19] f <sub>s</sub> = sampling rate in kHz

**8.9.65 Page = 0x00 Address = 0x71 [Reset = 02h]**

Bit	Field	Type	Reset	Description
7	CLASSH_EN	RW	0h	Class-H controller 0h = Disabled (default) 1h = Enabled
6	PWM_POL	RW	0h	Select PWM polarity 0h = Normal 1h = Inverted
5-0	PVDDH_UV_TH[5:0]	RW	02h	PVDDH under voltage threshold 00h = 1.753 V 01h = 2.09 V 02h = 2.428 V (default) ..... 3Fh = 23 V

**8.9.66 Page = 0x00 Address = 0x73 [Reset = 08h]**

Bit	Field	Type	Reset	Description
7-6	DEM_CTRL[1:0]	RW	0h	DAC MSB and LSB DEM enable/disable control 0h = MSB Enabled, LSB = Enabled (default) 1h = MSB Enabled, LSB = Disabled 2h = MSB Disabled, LSB = Enabled 3h = MSB Disabled, LSB = Disabled - Recommended setting for ultrasonic use case
5	DIS_DITH	RW	0h	DAC MSB modulator dither control 0b = Enabled 1b = Disabled - Recommended for ultrasonic use case
4-0	LIM_HDR[4:0]	RW	08h	Limiter headroom 00h = -20% 01h = -17.5% 02h = -15% ..... 0Fh = 17.5% 10h = 20% 11h - 1F = Reserved

**8.9.67 Page = 0x00 Address = 0x77 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	SPC_PD	RW	0h	Weak pul down on SPI clock pin (NC_SCLK) 0h = Disabled 1h = Enabled
6	SPM_PD	RW	0h	Weak pul down on SPI data output pin (NC_SDO) 0h = Disabled 1h = Enabled
5-0	Reserved	R	00h	Reserved

**8.9.68 Page = 0x00 Address = 0x7A [Reset = 60h]**

Bit	Field	Type	Reset	Description
7	Reserved	RW	0h	Reserved
6	PWM_CTRL	RW	1h	PWM_CTRL pin configuration 0h = Push-pull 1h = Open drain
5-0	Reserved	RW	20h	Reserved

**8.9.69 Page = 0x00 Address = 0x7E [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	I2C_CKSUM[7:0]	RW	00h	Returns I <sup>2</sup> C checksum. Writing to this register will reset the checksum to the written value. This register is updated on writes to other registers on all books and pages.

**8.9.70 Page = 0x00 Address = 0x7F [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	BOOK[7:0]	RW	0h	Sets the device book. 00h = Book 0 01h = Book 1 ... FFh = Book 255

**8.9.71 Page = 0x01 Address = 0x17 [Reset = D0h]**

Bit	Field	Type	Reset	Description
7-5	Reserved	R	6h	Reserved
4	CMP_HYST_LP	RW	1h	Class D comparator dependency of low power 0h = Disabled 1h = Enabled
3	SAR_IDLE	RW	0h	Idle channel interaction to SAR 0h = Enabled 1h = Disabled
2-0	Reserved	R	0h	Reserved

**8.9.72 Page = 0x01 Address = 0x19 [Reset = 60h]**

Bit	Field	Type	Reset	Description
7	Reserved	R	0h	Reserved
6	EN_LLSR	RW	1h	Modulation 0b = LSR 1b = Linear LSR
5-0	Reserved	R	20h	Reserved

**8.9.73 Page = 0x01 Address = 0x28 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-6	Reserved	R	0h	Reserved
5-4	EDGE_CTRL[1:0]	RW	0h	Output slew rate 0h = Auto adjust slew rate based on PVDD range (default) 1h = Reserved 2h = Reserved 3h = Slow slew rate for full range of PVDDH
3-0	Reserved	R	0h	Reserved

**8.9.74 Page = 0x01 Address = 0x35 [Reset = 75h]**

Bit	Field	Type	Reset	Description
7-2	Reserved	R	1Dh	Reserved
1-0	BIAS_NOISE[1:0]	RW	1h	Settings for noise improvement

**8.9.75 Page = 0x01 Address = 0x36 [Reset = 08h]**

Bit	Field	Type	Reset	Description
7-6	INT_LDO[1:0]	RW	0h	Internal LDO Setting 0h = User can program device with bit PVDDL_MODE, register 0x04, page 0x00 (default) 1h = Use external PVDDL 2h = Use internal LDO for PVDDL supply 3h = Reserved
5-0	Reserved	R	08h	Reserved

**8.9.76 Page = 0x01 Address = 0x3D [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	SDOUT_HIZ1[7:0]	RW	00h	Force '0' output control for slots 7 down to 0. This register to be programmed to zero in case the slot is not valid as per SBLK to FSYNC ratio.



**8.9.77 Page = 0x01 Address = 0x3E [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	SDOUT_HIZ2[7:0]	RW	00h	Force '0' output control for slots 15 down to 8. This register to be programmed to zero in case the slot is not valid as per SBLK to FSYNC ratio.

**8.9.78 Page = 0x01 Address = 0x3F [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	SDOUT_HIZ3[7:0]	RW	00h	Force '0' output control for slots 23 down to 16. This register to be programmed to zero in case the slot is not valid as per SBLK to FSYNC ratio.

**8.9.79 Page = 0x01 Address = 0x40 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	SDOUT_HIZ4[7:0]	RW	00h	Force '0' output control for slots 31 down to 24. This register to be programmed to zero in case the slot is not valid as per SBLK to FSYNC ratio.

**8.9.80 Page = 0x01 Address = 0x41 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	SDOUT_HIZ5[7:0]	RW	00h	Force '0' output control for slots 39 down to 32. This register to be programmed to zero in case the slot is not valid as per SBLK to FSYNC ratio.

**8.9.81 Page = 0x01 Address = 0x42 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	SDOUT_HIZ6[7:0]	RW	00h	Force '0' output control for slots 47 down to 40. This register to be programmed to zero in case the slot is not valid as per SBLK to FSYNC ratio.

**8.9.82 Page = 0x01 Address = 0x43 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	SDOUT_HIZ7[7:0]	RW	00h	Force '0' output control for slots 55 down to 48. This register to be programmed to zero in case the slot is not valid as per SBLK to FSYNC ratio.

**8.9.83 Page = 0x01 Address = 0x44 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-0	SDOUT_HIZ8[7:0]	RW	00h	Force '0' output control for slots 63 down to 56. This register to be programmed to zero in case the slot is not valid as per SBLK to FSYNC ratio.

**8.9.84 Page = 0x01 Address = 0x45 [Reset = 00h]**

Bit	Field	Type	Reset	Description
7	SDOUT_FCNT	RW	0h	Control over sending "0" to un-used slots 0h = All un-used slots will have 'Hi-Z' transmitted 1h = Un-used slots transmit '0' as per registers 0x3D - 0x44 settings
6-0	Reserved	R	00h	Reserved

**8.9.85 Page = 0x01 Address = 0x47 [Reset = AB]**

Bit	Field	Type	Reset	Description
7-2	Reserved	R	2Ah	Reserved
1	TG_TH2	RW	1h	Thermal threshold 2 0h = Disabled 1h = Enabled
0	TG_TH1	RW	1h	Thermal threshold 1 0h = Disabled 1h = Enabled

**8.9.86 Page = 0x01 Address = 0x4C [Reset = 00h]**

Bit	Field	Type	Reset	Description
7-2	Reserved	R	0h	Reserved
1-0	ADC_FLT[1:0]	RW	0h	PVDDL/PVDDH SAR filter frequency 0h = Disabled (default) 1h = 300 kHz 2h = 150 kHz 3h = 50 kHz

**8.9.87 Page = 0x04 Address = 0x08 - 0x0B [Reset = 034A516Ch]**

Bit	Field	Type	Reset	Description
31-0	DVC_SLEW[31:0]	RW	034A516Ch	Sets slew rate for volume control to a SR(s) value: $\text{dec2hex}(\text{round} \{ (1 - \exp[-1 / (0.2 * \text{fs} * \text{SR})]) * 2^{31} \})$ Default SR = 28 $\mu\text{s}$ .

**8.9.88 Page = 0x04 Address = 0x10 - 0x13 [Reset = 34000000h]**

Bit	Field	Type	Reset	Description
31-0	LIM_MAX_TH[31:0]	RW	34000000h	Sets limiter maximum threshold to a MAX_TH(V) value: $\text{dec2hex}[\text{round}(\text{MAX\_TH} * 2^{26})]$ Default MAX_TH = 13 V.

**8.9.89 Page = 0x04 Address = 0x14 - 0x17 [Reset = 14000000h]**

Bit	Field	Type	Reset	Description
31-0	LIM_MIN_TH[31:0]	RW	14000000h	Sets limiter minimum threshold to a MIN_TH(V) value: $\text{dec2hex}[\text{round}(\text{MIN\_TH} * 2^{26})]$ Default MIN_TH = 5 V.

**8.9.90 Page = 0x04 Address = 0x18 - 0x1B [Reset = 0D333333h]**

Bit	Field	Type	Reset	Description
31-0	LIM_INF[31:0]	RW	0D333333h	Sets limiter inflection point to a INF(V) value: $\text{dec2hex}[\text{round}(\text{INF} * 2^{26})]$ Default INF = 3.3 V.

**8.9.91 Page = 0x04 Address = 0x1C - 0x1F [Reset = 10000000h]**

Bit	Field	Type	Reset	Description
31-0	LIM_SLP[31:0]	RW	10000000h	Sets limiter slope to a SLP(V/V) value: $\text{dec2hex}[\text{round}(\text{SLP} * 2^{28})]$ Default SLP = 1 V/V.

**8.9.92 Page = 0x04 Address = 0x20 - 0x23 [Reset = 0B999999h]**

Bit	Field	Type	Reset	Description
31-0	BOP_TH[31:0]	RW	0B999999h	Sets BOP threshold to a BOP_TH(V) value: dec2hex[round(BOP_TH*2 <sup>26</sup> )] Default BOP_TH= 2.9 V.

**8.9.93 Page = 0x04 Address = 0x24 - 0x27 [Reset = 0ACCCCDh]**

Bit	Field	Type	Reset	Description
31-0	BOP_TH[31:0]	RW	0ACCCCDh	Sets BOP shutdown threshold to a BOPSD_TH(V) value: dec2hex[round(BOPSD_TH*2 <sup>26</sup> )] Default BOPSD_TH = 2.7 V.

**8.9.94 Page = 0x04 Address = 0x40 - 0x43 [Reset = 721482C0h]**

Bit	Field	Type	Reset	Description
31-0	TF_SLP[31:0]	RW	721482C0h	Sets thermal foldback limiter slope to a TF_SLP(dB/°C) value: dec2hex[round((10 <sup>TF_SLP</sup> /20)*2 <sup>31</sup> )] Default TF_SLP = -1 dB/°C.

**8.9.95 Page = 0x04 Address = 0x44 - 0x47 [Reset = 00000258h]**

Bit	Field	Type	Reset	Description
31-0	TF_HLD[31:0]	RW	00000258h	Sets thermal foldback limiter hold count to a TF_HLD(s) value: dec2hex[round(TF_HLD*f <sub>s</sub> /8)], f <sub>s</sub> ≤ 48 kHz dec2hex[round(TF_HLD*6000)], f <sub>s</sub> > 48 kHz

**8.9.96 Page = 0x04 Address = 0x48 - 0x4B [Reset = 40BDB7C0h]**

Bit	Field	Type	Reset	Description
31-0	TF_RLS[31:0]	RW	40BDB7C0h	Sets thermal foldback limiter release rate to a TF_RLS(dB/sample) value: dec2hex[round(10 <sup>(8*TF_RLS)</sup> /20)*2 <sup>30</sup> ], f <sub>s</sub> ≤ 48 kHz dec2hex[round(10 <sup>(16*TF_RLS)</sup> /20)*2 <sup>30</sup> ], f <sub>s</sub> > 48 kHz

**8.9.97 Page = 0x04 Address = 0x4C - 0x4F [Reset = 3982607Fh]**

Bit	Field	Type	Reset	Description
31-0	TF_TMP_TH[31:0]	RW	3982607Fh	Sets thermal foldback limiter temperature threshold to a TF_TH(°C) value: dec2hex[round(TF_TH*2 <sup>23</sup> )] Default TF_TH = 115 °C.

**8.9.98 Page = 0x04 Address = 0x50 - 0x53 [Reset = 2D6A866Fh]**

Bit	Field	Type	Reset	Description
31-0	TF_MAX_ATN[31:0]	RW	2D6A866Fh	Sets thermal foldback limiter maximum gain reduction to a TF_MAXA(dB) value: dec2hex[round(10 <sup>(TF_MAXA)</sup> /20)*2 <sup>31</sup> )] Default TF_MAXA= -9 dB.

**8.9.99 Page = 0x04 Address = 0x54 - 0x57 [Reset = 7C5E4E02h]**

Bit	Field	Type	Reset	Description
31-0	TF_ATK[31:0]	RW	7C5E4E02 h	Sets thermal foldback limiter attack rate to a TF_ATK(dB/sample) value: dec2hex[round( $10^{(8*TF\_ATK/20)*2^{31}}$ )], $f_s \leq 48$ kHz dec2hex[round( $10^{(16*TF\_ATK/20)*2^{31}}$ )], $f_s > 48$ kHz

**8.9.100 Page = 0x05 Address = 0x14 - 0x17 [Reset = 6CCCCCCh]**

Bit	Field	Type	Reset	Description
31-0	CLASSD_EFF[31:0]	RW	6CCCCC Ch	Class-D Efficiency set to an EFF(%) value: dec2hex[round (EFF*2 <sup>31</sup> )]

**8.9.101 Page = 0x05 Address = 0x1C - 0x1F [Reset = 4CCCCCCh]**

Bit	Field	Type	Reset	Description
31-0	INF_FCT[31:0]	RW	4CCCCC h	Inflation factor for Low Voltage Signaling set to IF: dec2hex[round(IF*2 <sup>30</sup> )]

**8.9.102 Page = 0x05 Address = 0x20 - 0x23 [Reset = 00000180h]**

Bit	Field	Type	Reset	Description
31-0	MAX_HLD_CLH[31:0]	RW	00000180h	Sets hold time of Class-H to HT (s): dec2hex[round(HT*f <sub>s</sub> )], f <sub>s</sub> ≤ 48ksp dec2hex[round(HT*48kHz)], f <sub>s</sub> > 48ksp

**8.9.103 Page = 0x05 Address = 0x24 - 0x27 [Reset = 00000000h]**

Bit	Field	Type	Reset	Description
31-0	RLS_WD[31:0]	RW	00000000h	Sets release window time of Class-H to RWT (s), when back door is enabled (Section 8.9.125): dec2hex[round(RWT*f <sub>s</sub> )], f <sub>s</sub> ≤ 48ksp dec2hex[round(RWT*48kHz)], f <sub>s</sub> > 48ksp

**8.9.104 Page = 0x05 Address = 0x28 - 0x2B [Reset = 79999999h]**

Bit	Field	Type	Reset	Description
31-0	PHVD[31:0]	RW	79999999h	Sets Class-H peak hold value decay to PHV (decay rate/sample): dec2hex[round(PHV*2 <sup>31</sup> )]

**8.9.105 Page = 0x05 Address = 0x2C - 0x2F [Reset = 0538EF34h]**

Bit	Field	Type	Reset	Description
31-0	AL_SMTH[31:0]	RW	0538EF34h	Class-H configuration time constant AS (s): dec2hex[round( $[1-\exp(-1/AS*f_s)]*2^{31}$ )], f <sub>s</sub> ≤ 48ksp dec2hex[round( $[1-\exp(-1/AS*48\text{ kHz})]*2^{31}$ )], f <sub>s</sub> > 48ksp

**8.9.106 Page = 0x05 Address = 0x30 - 0x33 [Reset = 40000000h]**

Bit	Field	Type	Reset	Description
31-0	NF_FCT_H[31:0]	RW	40000000h	Inflation factor Class-H set to IF: dec2hex[round(IF*2 <sup>30</sup> )]

**8.9.107 Page = 0x05 Address = 0x34 - 0x37 [Reset = 65AC8C2Fh]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST1[31:0]	RW	65AC8C2F h	Class-H step level 1 set to ST1: dec2hex[round(ST1*2^31)] ST1 = margin*(Vm + (15/16)*(VM-Vm))/15.8489 where: VM = maximum boost output Vm = minimum boost output margin = Class-D efficiency

**8.9.108 Page = 0x05 Address = 0x38 - 0x3B [Reset = 50C335D3h]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST2[31:0]	RW	50C335D3 h	Class-H step level 2 set to ST2: dec2hex[round(ST2*2^31)] ST2 = margin*(Vm + (14/16)*(VM-Vm))/15.8489

**8.9.109 Page = 0x05 Address = 0x3C - 0x3F [Reset = 4026E73Ch]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST3[31:0]	RW	4026E73Ch	Class-H step level 3 set to ST3: dec2hex[round(ST3*2^31)] ST3 = margin*(Vm + (13/16)*(VM-Vm))/15.8489

**8.9.110 Page = 0x05 Address = 0x40 - 0x43 [Reset = 32F52CFEh]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST4[31:0]	RW	32F52CFE h	Class-H step level 4 set to ST4: dec2hex[round(ST4*2^31)] ST4 = margin*(Vm + (12/16)*(VM-Vm))/15.8489

**8.9.111 Page = 0x05 Address = 0x44 - 0x47 [Reset = 287A26C4h]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST5[31:0]	RW	287A26C4h	Class-H step level 5 set to ST5: dec2hex[round(ST5*2^31)] ST5 = margin*(Vm + (11/16)*(VM-Vm))/15.8489

**8.9.112 Page = 0x05 Address = 0x48 - 0x4B [Reset = 2026F30Fh]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST6[31:0]	RW	2026F30Fh	Class-H step level 6 set to ST6: dec2hex[round(ST6*2^31)] ST6 = margin*(Vm + (10/16)*(VM-Vm))/15.8489

**8.9.113 Page = 0x05 Address = 0x4C - 0x4F [Reset = 198A1357h]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST7[31:0]	RW	198A1357h	Class-H step level 7 set to ST7: dec2hex[round(ST7*2^31)] ST7 = margin*(Vm + (9/16)*(VM-Vm))/15.8489

**8.9.114 Page = 0x05 Address = 0x50 - 0x53 [Reset = 144960C5h]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST8[31:0]	RW	144960C5h	Class-H step level 8 set to ST8: dec2hex[round(ST8*2 <sup>31</sup> )] ST8 = margin*(Vm + (8/16)*(VM-Vm))/15.8489

**8.9.115 Page = 0x05 Address = 0x54 - 0x57 [Reset = 101D3F2Dh]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST9[31:0]	RW	101D3F2Dh	Class-H step level 9 set to ST9: dec2hex[round(ST9*2 <sup>31</sup> )] ST9 = margin*(Vm + (7/16)*(VM-Vm))/15.8489

**8.9.116 Page = 0x05 Address = 0x58 - 0x5B [Reset = 0CCCCCCh]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST10[31:0]	RW	0CCCCCCh	Class-H step level 10 set to ST10: dec2hex[round(ST10*2 <sup>31</sup> )] ST10 = margin*(Vm + (6/16)*(VM-Vm))/15.8489

**8.9.117 Page = 0x05 Address = 0x5C - 0x5F [Reset = 0A2AADD1h]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST11[31:0]	RW	0A2AADD1h	Class-H step level 11 set to ST11: dec2hex[round(ST11*2 <sup>31</sup> )] ST11 = margin*(Vm + (5/16)*(VM-Vm))/15.8489

**8.9.118 Page = 0x05 Address = 0x60 - 0x63 [Reset = 08138561h]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST12[31:0]	RW	08138561h	Class-H step level 12 set to ST12: dec2hex[round(ST12*2 <sup>31</sup> )] ST12 = margin*(Vm + (4/16)*(VM-Vm))/15.8489

**8.9.119 Page = 0x05 Address = 0x64 - 0x67 [Reset = 081385615h]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST13[31:0]	RW	081385615h	Class-H step level 13 set to ST13: dec2hex[round(ST13*2 <sup>31</sup> )] ST13 = margin*(Vm + (3/16)*(VM-Vm))/15.8489

**8.9.120 Page = 0x05 Address = 0x68 - 0x6B [Reset = 08138561h]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST14[31:0]	RW	08138561h	Class-H step level 14 set to ST14: dec2hex[round(ST14*2 <sup>31</sup> )] ST14 = margin*(Vm + (2/16)*(VM-Vm))/15.8489

**8.9.121 Page = 0x05 Address = 0x6C - 0x6F [Reset = 08138561h]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST15[31:0]	RW	08138561h	Class-H step level 15 set to ST15: dec2hex[round(ST15*2^31)] ST15 = margin*(Vm + (1/16)*(VM-Vm))/15.8489

**8.9.122 Page = 0x05 Address = 0x70 - 0x73 [Reset = 08138561h]**

Bit	Field	Type	Reset	Description
31-0	CLH_ST16[31:0]	RW	08138561h	Class-H step level 16 set to ST16: dec2hex[round(ST16*2^31)] ST16 = margin*Vm/15.8489

**8.9.123 Page = 0x05 Address = 0x74 - 0x77 [Reset = 000000BFh]**

Bit	Field	Type	Reset	Description
31-0	CLH_DLY[31:0]	RW	000000BFh	Class-H delay HDLY (s) dec2hex[round(HDLY*fs) - 1] *Should be less than 4 ms

**8.9.124 Page = 0x05 Address = 0x78 - 0x7B [Reset = 000000Eh]**

Bit	Field	Type	Reset	Description
31-0	LVSPR_DLY[31:0]	RW	000000Eh	Sets LVS Delay to LVDL(s) dec2hex[round(LVDL*96k)-1], range: 0 -15, for fs = 48 kHz/96 kHz round( LVDL* 2*fs) -1, range: 0 -15, for fs < 48k

**8.9.125 Page = 0x05 Address = 0x7C - 0x7F [Reset = 66676869h]**

Bit	Field	Type	Reset	Description
31-0	BKD_EN[31:0]	RW	66676869h	Back door is enabled for any non-zero value

**8.9.126 Page = 0x06 Address = 0x08 - 0x0B [Reset = 00000000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_08_01[31:0]	RW	00000000h	8 step Class-H duty cycle is 0 %

**8.9.127 Page = 0x06 Address = 0x0C - 0x0F [Reset = 80800000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_08_02[31:0]	RW	80800000h	8 step Class-H duty cycle is 12.5 %

**8.9.128 Page = 0x06 Address = 0x10 - 0x13 [Reset = C0C00000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_08_03[31:0]	RW	C0C00000h	8 step Class-H duty cycle is 25 %

**8.9.129 Page = 0x06 Address = 0x14 - 0x17 [Reset = E0E00000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_08_04[31:0]	RW	E0E00000h	8 step Class-H duty cycle is 37.5 %

**8.9.130 Page = 0x06 Address = 0x18 - 0x1B [Reset = F0F00000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_08_05[31:0]	RW	F0F00000h	8 step Class-H duty cycle is 50 %

**8.9.131 Page = 0x06 Address = 0x1C - 0x1F [Reset = F8F80000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_08_06[31:0]	RW	F8F80000h	8 step Class-H duty cycle is 62.5 %

**8.9.132 Page = 0x06 Address = 0x20 - 0x23 [Reset = FCFC0000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_08_07[31:0]	RW	FCFC0000h	8 step Class-H duty cycle is 75 %

**8.9.133 Page = 0x06 Address = 0x24 - 0x27 [Reset = FCFC0000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_08_08[31:0]	RW	FCFC0000h	8 step Class-H duty cycle is 75 % For 87.5 % set registers to FEFE0000h

**8.9.134 Page = 0x06 Address = 0x28 - 0x2B [Reset = FCFC0000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_08_09[31:0]	RW	FCFC0000h	8 step Class-H duty cycle is 75 % For 100 % set registers to FFFF0000h

**8.9.135 Page = 0x06 Address = 0x2C - 0x2F [Reset = 00000000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_01[31:0]	RW	00000000h	16 step Class-H duty cycle is 0 %

**8.9.136 Page = 0x06 Address = 0x30 - 0x33 [Reset = 80000000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_02[31:0]	RW	80000000h	16 step Class-H duty cycle is 6.25 %

**8.9.137 Page = 0x06 Address = 0x34 - 0x37 [Reset = C0000000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_03[31:0]	RW	C0000000h	16 step Class-H duty cycle is 12.5 %

**8.9.138 Page = 0x06 Address = 0x38 - 0x3B [Reset = E0000000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_08_04[31:0]	RW	E0000000h	16 step Class-H duty cycle is 18.75 %

**8.9.139 Page = 0x06 Address = 0x3C - 0x3F [Reset = F0000000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_05[31:0]	RW	F0000000h	16 step Class-H duty cycle is 25 %



**8.9.140 Page = 0x06 Address = 0x40 - 0x43 [Reset = F800000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_06[31:0]	RW	F800000h	16 step Class-H duty cycle is 31.25 %

**8.9.141 Page = 0x06 Address = 0x44 - 0x47 [Reset = FC00000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_07[31:0]	RW	FC00000h	16 step Class-H duty cycle is 37.5 %

**8.9.142 Page = 0x06 Address = 0x48 - 0x4B [Reset = FE00000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_08[31:0]	RW	FE00000h	16 step Class-H duty cycle is 43.75 %

**8.9.143 Page = 0x06 Address = 0x4C - 0x4F [Reset = FF00000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_09[31:0]	RW	FF00000h	16 step Class-H duty cycle is 50 %

**8.9.144 Page = 0x06 Address = 0x50 - 0x53 [Reset = FF80000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_10[31:0]	RW	FF80000h	16 step Class-H duty cycle is 56.25 %

**8.9.145 Page = 0x06 Address = 0x54 - 0x57 [Reset = FFC0000h]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_11[31:0]	RW	FFC0000h	16 step Class-H duty cycle is 62.5 %

**8.9.146 Page = 0x06 Address = 0x58 - 0x5B [Reset = FFE0000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_12[31:0]	RW	FFE0000h	16 step Class-H duty cycle is 68.75 %

**8.9.147 Page = 0x06 Address = 0x5C - 0x5F [Reset = FFF0000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_13[31:0]	RW	FFF0000h	16 step Class-H duty cycle is 75 %

**8.9.148 Page = 0x06 Address = 0x60 - 0x63 [Reset = FFF0000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_14[31:0]	RW	FFF0000h	16 step Class-H duty cycle is 75 % For 81.25 % set registers to FF80000h

**8.9.149 Page = 0x06 Address = 0x64 - 0x67 [Reset = FFF0000h ]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_15[31:0]	RW	FFF0000h	16 step Class-H duty cycle is 75 % For 87.5 % set registers to FFFC000h

**8.9.150 Page = 0x06 Address = 0x68 - 0x6B [Reset = FFF00000h]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_16[31:0]	RW	FFF00000h	16 step Class-H duty cycle is 75 % For 93.75 % set registers to FFFE0000h

**8.9.151 Page = 0x06 Address = 0x6C - 0x6F [Reset = FFF00000h]**

Bit	Field	Type	Reset	Description
31-0	WVSH_16_17[31:0]	RW	FFF00000h	16 step Class-H duty cycle is 75 % For 100 % set registers to FFFF0000h

**8.9.152 Page = 0x08 Address = 0x18 - 0x1B [Reset = 9C000000h]**

Bit	Field	Type	Reset	Description
31-0	VOL_CVR[31:0]	RW	9C000000h	Unmute audio channel Write 00 00 00 00 to unmute

**8.9.153 Page = 0x08 Address = 0x28 - 0x2B [Reset = 00000000h]**

Bit	Field	Type	Reset	Description
31-0	UNMUTE_CVR[31:0]	RW	00000000h	Unmute audio channel Write 40 00 00 00 to unmute

**8.9.154 Page = 0x0A Address = 0x48 - 0x4B [Reset = 9C000000h]**

Bit	Field	Type	Reset	Description
31-0	VOL_NVR[31:0]	RW	9C000000h	Unmute audio channel Write 00 00 00 00 to unmute

**8.9.155 Page = 0x0A Address = 0x58 - 0x5B [Reset = 00000000h]**

Bit	Field	Type	Reset	Description
31-0	UNMUTE_NVR[31:0]	RW	00000000h	Unmute audio channel Write 40 00 00 00 to unmute

**8.9.156 Page = 0xFD Address = 0x3E [Reset = 4Dh]**

Bit	Field	Type	Reset	Description
7-4	Reserved	R	4h	Reserved
3-0	OPT_DMIN[3:0]	RW	Dh	DMIN optimization settings

## 8.10 SDOOUT Equations

The following equations will allow to convert data read on SDOOUT.

$$PVDDH (V) = 23 * [\text{Hex2Dec}(\text{SDOOUTdata})] / 2^{\text{PVDDH\_SlotLength}} \quad (5)$$

By default, PVDDH\_SlotLength = 8.

$$PVDDL (V) = 8 * [\text{Hex2Dec}(\text{SDOOUTdata})] / 2^{\text{PVDDL\_SlotLength}} \quad (6)$$

By default, PVDDL\_SlotLength = 8.

$$\text{TEMP } (^{\circ}\text{C}) = 256 * [\text{Hex2Dec}(\text{SDOOUTdata})] / 2^{\text{TEMP\_SlotLength}} - 93 \quad (7)$$

TEMP\_SlotLength = 8.

## 9 Application and Implementation

### Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

### 9.1 Application Information

The TAS2781 is a digital input Class-D audio power amplifier with integrated DSP supporting Texas Instruments Smart Amp algorithm for speaker protection. I<sup>2</sup>S audio data is supplied by host processor. I<sup>2</sup>C or SPI bus is used for configuration and control. The Hybrid-Pro controller for an external boost converter allows efficiency improvement.

### 9.2 Typical Application

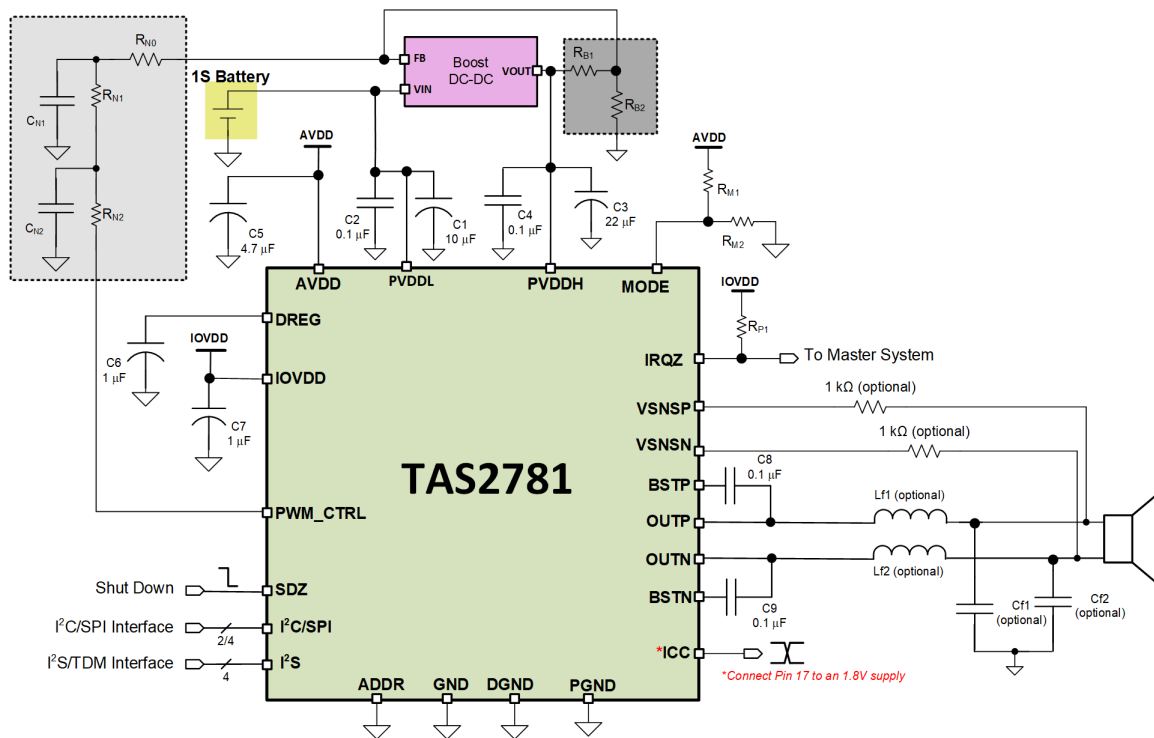


Figure 9-1. Typical Application - 1S Battery Supply and External Boost Control

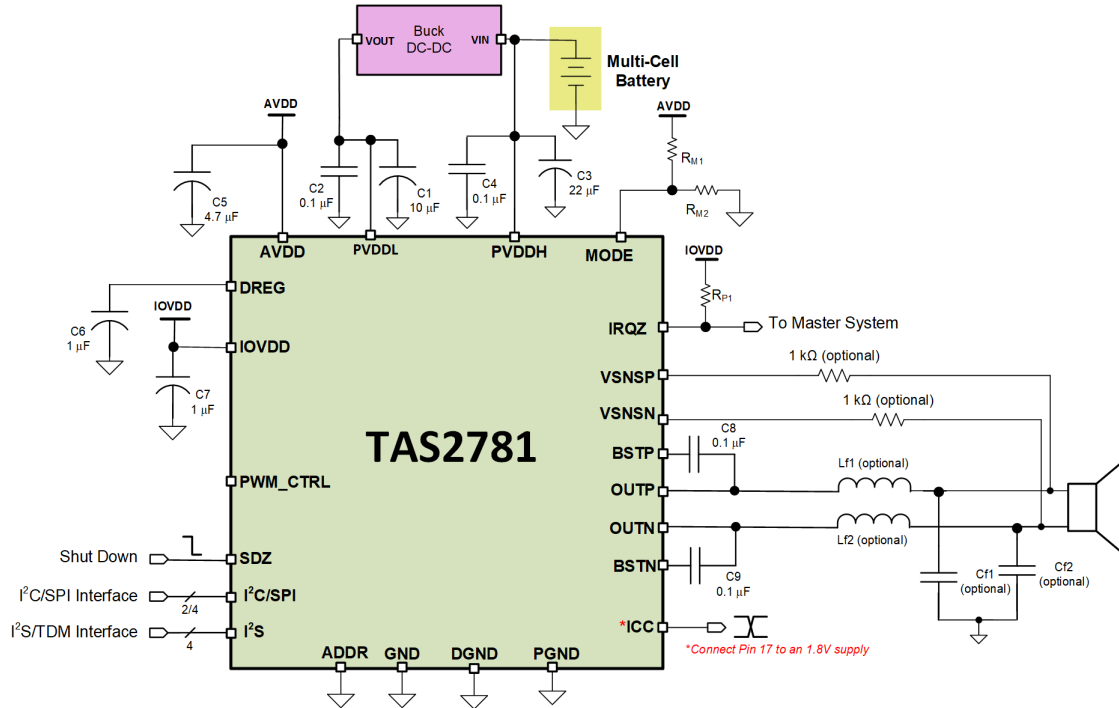


Figure 9-2. Typical Application - Multi-Cell Battery Supply

Table 9-1. Recommended External Components

COMPONENT	DESCRIPTION	SPECIFICATION	MIN	TYP	MAX	UNIT
C1	PVDDL Decoupling Capacitor - PVDDL External Supply (PWR_MODE0/1/3)	Type	X7R			
		Capacitance, 20% Tolerance		10		μF
		Rated Voltage		10		V
	PVDDL Decoupling Capacitor - PVDDL Internally Generated (PWR_MODE2)	Type	X7R			
		Capacitance, 20% Tolerance	0.68	1		μF
		Rated Voltage		10		V
C2	PVDDL Decoupling Capacitor	Type	X7R			
		Capacitance, 20% Tolerance		100		nF
		Rated Voltage		10		V
C3	PVDDH Decoupling Capacitor	Type	X7R			
		Capacitance, 20% Tolerance	22			μF
		Rated Voltage	30			V
C4	PVDDH Decoupling Capacitor	Type	X7R			
		Capacitance, 20% Tolerance		100		nF
		Rated Voltage	30			V
C5	AVDD Decoupling Capacitor	Type	X7R			
		Capacitance, 20% Tolerance <i>AVDD=1.8V, IOVDD=3.3V</i>	4.7			μF
		Capacitance, 20% Tolerance <i>AVDD=1.8V and tied to IOVDD</i>	6.8			
		Rated Voltage	6			V
C6	DREG Decoupling Capacitor	Type	X7R			
		Capacitance, 20% Tolerance		1		μF
		Rated Voltage	6			V
C7	IOVDD Decoupling Capacitor <i>IOVDD=3.3V and not connected to AVDD</i>	Type	X7R			
		Capacitance, 20% Tolerance		1		μF
		Rated Voltage	6			V

**Table 9-1. Recommended External Components (continued)**

COMPONENT	DESCRIPTION	SPECIFICATION	MIN	TYP	MAX	UNIT
C8, C9	Bootstrap Capacitors	Type	X7R			
		Capacitance, 20% Tolerance		100		nF
		Rated Voltage	6			V
Lf1, Lf2 (optional)	EMI filter inductors are optional. TAS2781 device support filter less Class-D operation. PFFB feature is recommended if ferrite bead EMI filters are used	Impedance at 100MHz		120		$\Omega$
		DC Resistance			0.095	$\Omega$
		DC Current	7			A
Cf1, Cf2 (optional)	EMI filter capacitors are optional. Design must use Lf2, Lf3 if Cf1, Cf2 are used	Capacitance		1		nF

### 9.3 Design Requirements

For this design example, use the parameters shown in [Section 9.2](#).

**Table 9-2. Design Parameters**

DESIGN PARAMETER	EXAMPLE VALUE
Audio Input	Digital Audio, I <sup>2</sup> S
Current and Voltage Data Stream	Digital Audio, I <sup>2</sup> S
Mono or Stereo Configuration	Mono
Max Output Power at 1% THD+N, R <sub>L</sub> = 4 $\Omega$	25 W

### 9.4 Detailed Design Procedure

#### 9.4.1 Mono/Stereo Configuration

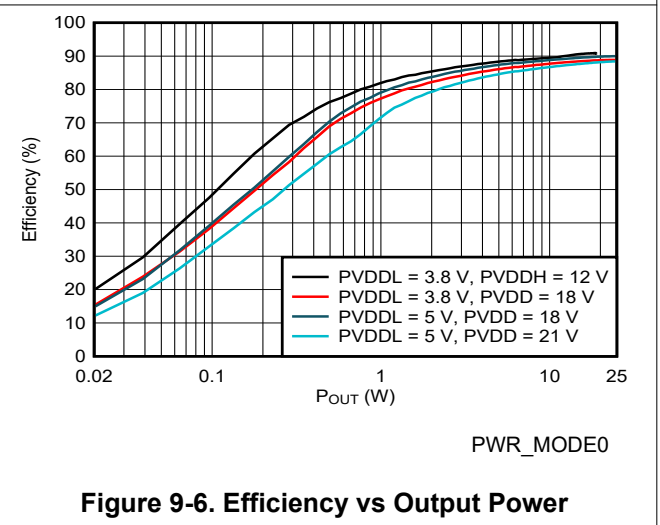
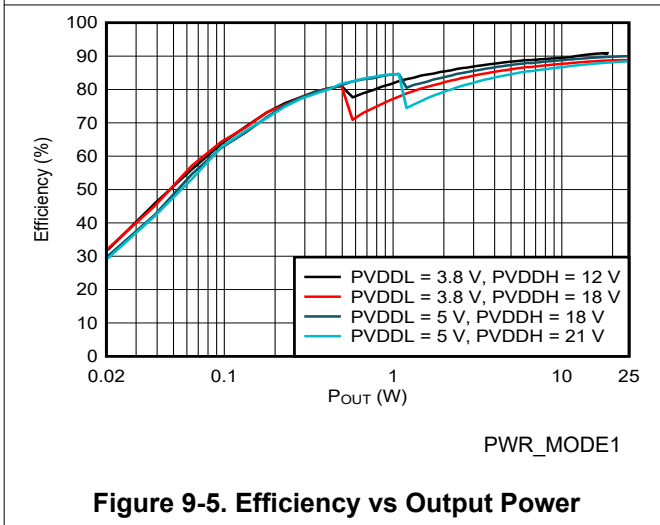
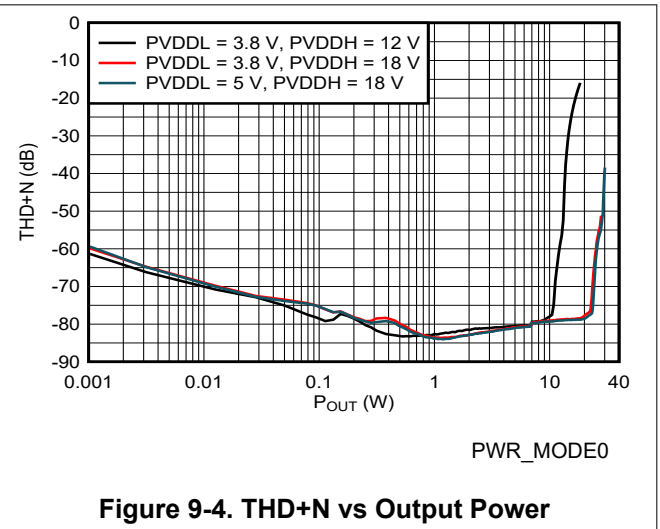
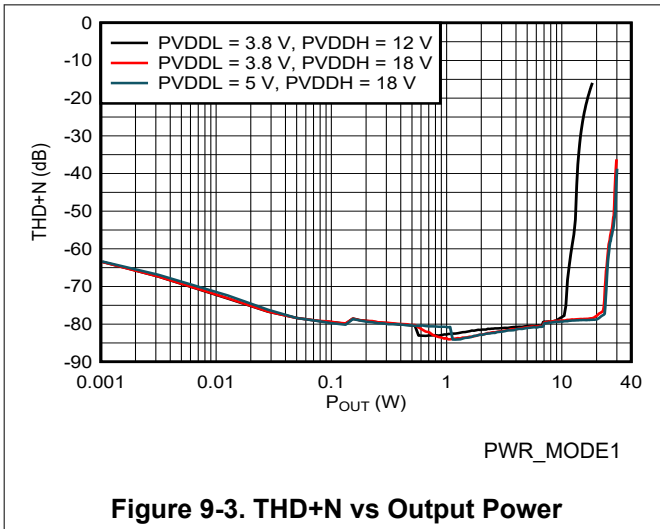
In applications the device is assumed to be operating in mono mode. See [Section 8.3.2](#) for information on changing the I<sup>2</sup>C address of the TAS2781 to support stereo operation. Mono or stereo configuration does not impact the device performance.

#### 9.4.2 EMI Passive Devices

The TAS2781 supports spread spectrum to minimize EMI. It is allowed to include passive devices on the Class-D outputs. The passive devices (LC filter) have to be properly selected to maintain the stability of the output stage. See [Section 8.4.5](#) for details.

## 9.5 Application Curves

At  $T_A = 25\text{ }^\circ\text{C}$ ,  $f_{\text{SPK\_AMP}} = 384\text{ kHz}$ , input signal  $f_{\text{IN}} = 1\text{ kHz}$  - Sine, Load =  $4\text{ }\Omega + 15\text{ }\mu\text{H}$ , unless otherwise noted.



## 10 Initialization Set Up

### 10.1 Initial Device Configuration - Power Up and Software Reset

The following I<sup>2</sup>C sequence needs to be used:

- At power up, when SDZ = 1 (out of Hardware Shutdown into Software Shutdown);
- when device is in Software Shutdown or Active mode and user runs a Software Reset command: bit[0] of register 0x01 = 1.

```
##### Pre-Reset Configuration
w 70 00 01 #Page 0x01
w 70 37 3A #Bypass

w 70 00 FD #Page 0xFD
w 70 0D 0D #Access page
w 70 06 C1 #Set Dmin

w 70 00 01 #Page 0x01
w 70 19 E0 #Force modulation
w 70 00 FD #Page 0xFD
w 70 0D 0D #Access page
w 70 06 D5 #Set Dmin

##### Software Reset
w 70 00 00 #Page 0x00
w 70 7F 00 #Book 0x00
w 70 01 01 #Software Reset
d 01 #1 ms Delay

##### Post-Reset Configuration
w 70 00 01 #Page 0x01
w 70 37 3A #Bypass

w 70 00 FD #Page 0xFD
w 70 0D 0D #Access page
w 70 06 C1 #Set Dmin
w 70 06 D5 #Set Dmin
```

### 10.2 Initial Device Configuration - PWR\_MODE0

The following I<sup>2</sup>C sequence is an example of initializing the device in PWR\_MODE0.

```
w 70 00 00 #Page 0x00
w 70 0E C4 #TDM TX vsns transmit enable with slot 4
w 70 0F 40 #TDM TX isns transmit enable with slot 0

w 70 00 01 #Page 0x01
w 70 17 C8 #SARBurstMask=0
w 70 19 20 #LSR Mode
w 70 35 74 #DC noise minimized

w 70 00 FD #Page 0xFD
w 70 0D 0D #Access Page
w 70 3E 4A #Optimal Dmin
w 70 0D 00 #Remove access

w 70 00 04 #Page 0x04
w 70 30 00 00 00 01 #Merge Limiter and Thermal Foldback gains

w 70 00 08 #Page 0x08
w 70 18 00 00 00 00 #0dB volume
w 70 28 40 00 00 00 #Unmute

w 70 00 0A #Page 0x0A
w 70 48 00 00 00 00 #0dB volume
w 70 58 40 00 00 00 #Unmute

w 70 00 00 #Page 0x00
w 70 03 A8 #PWR_MODE0 selected
w 70 71 03 #PVDDH UVLO set to 2.76V
w 70 02 80 #Play audio, power up with playback, IV enabled
```



### 10.3 Initial Device Configuration - PWR\_MODE1

The following I<sup>2</sup>C sequence is an example of initializing the device in PWR\_MODE1.

```
w 70 00 00 #Page 0x00
w 70 0E C4 #TDM TX vsns transmit enable with slot 4
w 70 0F 40 #TDM TX isns transmit enable with slot 0

w 70 00 01 #Page 0x01
w 70 17 C8 #SARBurstMask=0
w 70 35 74 #DC noise minimized
w 70 19 20 #LSR Mode

w 70 00 FD #Page 0xFD
w 70 0D 0D #Access Page 0xFD
w 70 3E 4A #Optimal Dmin
w 70 0D 00 #Remove access Page 0xFD

w 70 00 04 #Page 0x04
w 70 30 00 00 00 01 #Merge Limiter and Thermal Foldback gains

w 70 00 08 #Page 0x08
w 70 18 00 00 00 00 #0dB volume
w 70 28 40 00 00 00 #Unmute

w 70 00 0A #Page 0x0A
w 70 48 00 00 00 00 #0dB volume
w 70 58 40 00 00 00 #Unmute

w 70 00 00 #Page 0x00
w 70 02 00 #Play audio, power up with playback, IV enabled
```

### 10.4 Initial Device Configuration - PWR\_MODE2

The following I<sup>2</sup>C sequence is an example of initializing the device in PWR\_MODE2.

```
w 70 00 00 #Page 0x00
w 70 0E C4 #TDM TX vsns transmit enable with slot 4
w 70 0F 40 #TDM TX isns transmit enable with slot 0

w 70 00 01 #Page 0x01
w 70 17 C0 #SARBurstMask=0
w 70 19 20 #LSR Mode
w 70 35 74 #DC noise minimized

w 70 00 FD #Page 0xFD
w 70 0D 0D #Access Page 0xFD
w 70 3E 4A #Optimal Dmin
w 70 0D 00 #Remove access Page 0xFD

w 70 00 04 #Page 0x04
w 70 30 00 00 00 01 #Merge Limiter and Thermal Foldback gains

w 70 00 08 #Page 0x08
w 70 18 00 00 00 00 #0dB volume
w 70 28 40 00 00 00 #Unmute

w 70 00 0A #Page 0x0A
w 70 48 00 00 00 00 #0dB volume
w 70 58 40 00 00 00 #Unmute

w 70 00 00 #Page 0x00
w 70 03 E8 #PWR_MODE2
w 70 04 A1 #Int LDO mode for internal PVDDL
w 70 71 0E #PVDDH UVLO 6.5V
w 70 02 80 #Power up audio playback with I,V enabled
```

## 10.5 Initial Device Configuration - PWR\_MODE3

The following I<sup>2</sup>C sequence is an example of initializing the device in PWR\_MODE3, for ultrasonic applications.

```
w 70 00 00 #Page 0x00
w 70 0E C4 #TDM TX vsns transmit enable with slot 4
w 70 0F 40 #TDM TX isns transmit enable with slot 0

w 70 00 01 #Page 0x01
w 70 17 C8 #SARBurstMask=0
w 70 19 20 #LSR

w 70 00 04 #Page 0x04
w 70 30 00 00 00 01 #Merge Limiter and Thermal Foldback gains

w 70 00 08 #Page 0x08
w 70 18 00 00 00 00 #0dB volume
w 70 28 40 00 00 00 #Unmute

w 70 00 0A #Page 0x0A
w 70 48 00 00 00 00 #0dB volume
w 70 58 40 00 00 00 #Unmute

w 70 00 00 #Page 0x00
w 70 03 68 #PVDDL only mode
w 70 73 E0 #DEM dither disabled
w 70 02 00 #play audio, power up with playback, IV enabled
```

## 11 Power Supply Recommendations

The power sequence between the supply rails can be applied in any order as long as SDZ pin is held low. Once all supplies are stable the SDZ pin can be set high to initialize the part. After a hardware or software reset additional commands to the device should be delayed for at least 1 ms to allow the OTP memory to load (see section [Section 10](#)).

When PVDDL is internally generated (see [Section 11.1](#)) it is recommended that the device enters Software Shutdown mode before entering Hardware Shutdown mode. This ensures that PVDDL pin is discharged using the internal 5 kOhms pull down resistor (not present in Hardware Shutdown mode).

### 11.1 Power Supply Modes

The TAS2781 can operate with both PVDDL and PVDDH as supplies or with only PVDDH or PVDDL as supply. The table below shows different power supply modes of operation depending on the user need.

**Table 11-1. Device Configuration and Power Supply Modes**

Supply Power Mode	Output Switching Mode	Supply Condition	PVDDL Mode	Device Configurations	Use Case and Device Functionality
<b>PWR_MODE0</b>	High Power on PVDDH	PVDDH>PVDDL	External	PVDDL_MODE=0 CDS_MODE[1:0]=10	PVDDH is the only supply used to deliver output power.
<b>PWR_MODE1</b>	Y Bridge - High Power on PVDDL	PVDDH	External	PVDDL_MODE=0 CDS_MODE[1:0]=00	PVDDL is used to deliver output power based on level and headroom configured. When audio signal crosses a programmed threshold Class-D output is switched over PVDDH.
<b>PWR_MODE2</b>	Y Bridge - Low Power on PVDDL	PVDDH	Internal	PVDDL_MODE=1 CDS_MODE[1:0]=11	PVDDH is the only supply. PVDDL is delivered by an internal LDO and used to supply at signals close to idle channel levels. When audio signal levels crosses -100dBFS (default), Class-D output switches to PVDDH.
<b>PWR_MODE3</b>	PVDDL	PVDDL	External	PVDDL_MODE=0 CDS_MODE[1:0]=01	The device can be forced to work out of a low power rail mode of operation. For example this can be used for a low power ultrasonic chirp when audio is not played.

When PVDDL is external (PWR\_MODE0, PWR\_MODE1), if PVDDH falls below (PVDDL + 2.5 V) level, the Y-bridge will stop switching between supplies and will remain on the PVDDH supply.

In PWR\_MODE2 user needs to ensure that PVDDH supply level is at least 2.5 V above the PVDDL voltage generated internally in order to take advantage of Y bridge mode of operation. To enable voltage protection the under voltage threshold of PVDDH supply should be set above 7.3 V by using register bits *PVDD\_UVLO[5:0]*. This will ensure that, with an internally generated PVDDL of 4.8 V, PVDDH supply is at least 2.5 V higher than PVDDL.

## 12 Layout

### 12.1 Layout Guidelines

All supply rails should be bypassed by low-ESR ceramic capacitors as shown and described in [Section 9.2](#).

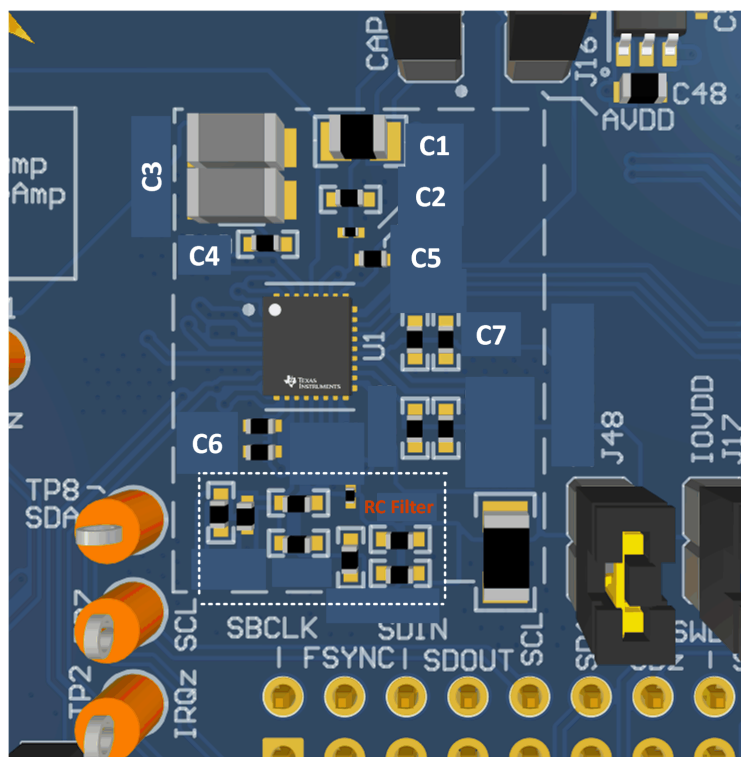
To create a low impedance connection to PGND, DGND and GND and minimize the ground noise, ground planes with multiple conductive epoxy filled vias should be used in layout.

Specific layout design recommendations should be followed for this device:

- Use wide traces for signals that carry high current: PVDDH, PVDDL, PGND, DGND, GND and the speaker OUTP, OUTN.
- PGND pin should be directly connected and shorted to the ground plane.
- DGND pin should be directly connected to the ground plane.
- Connect VSNSP and VSNSN as close as possible to the speaker.
- VSNSP and VSNSN should be connected between the EMI ferrite filter and the speaker if EMI ferrites are used at the outputs.
- VSNSP and VSNSN routing should be separated and shielded from switching signals (interface signals, speaker outputs, bootstrap pins).
- Place bootstrap capacitors as close as possible to the BST pins.
- Place decoupling capacitors of PVDDH and PVDDL as close as possible to the pins (see [Section 12.2](#)).

### 12.2 Layout Example

[Figure 12-1](#) below describes the placement of critical components as assigned in [Figure 9-1](#).



**Figure 12-1. Component Placement**

An example of layout design is presented in the next two images.

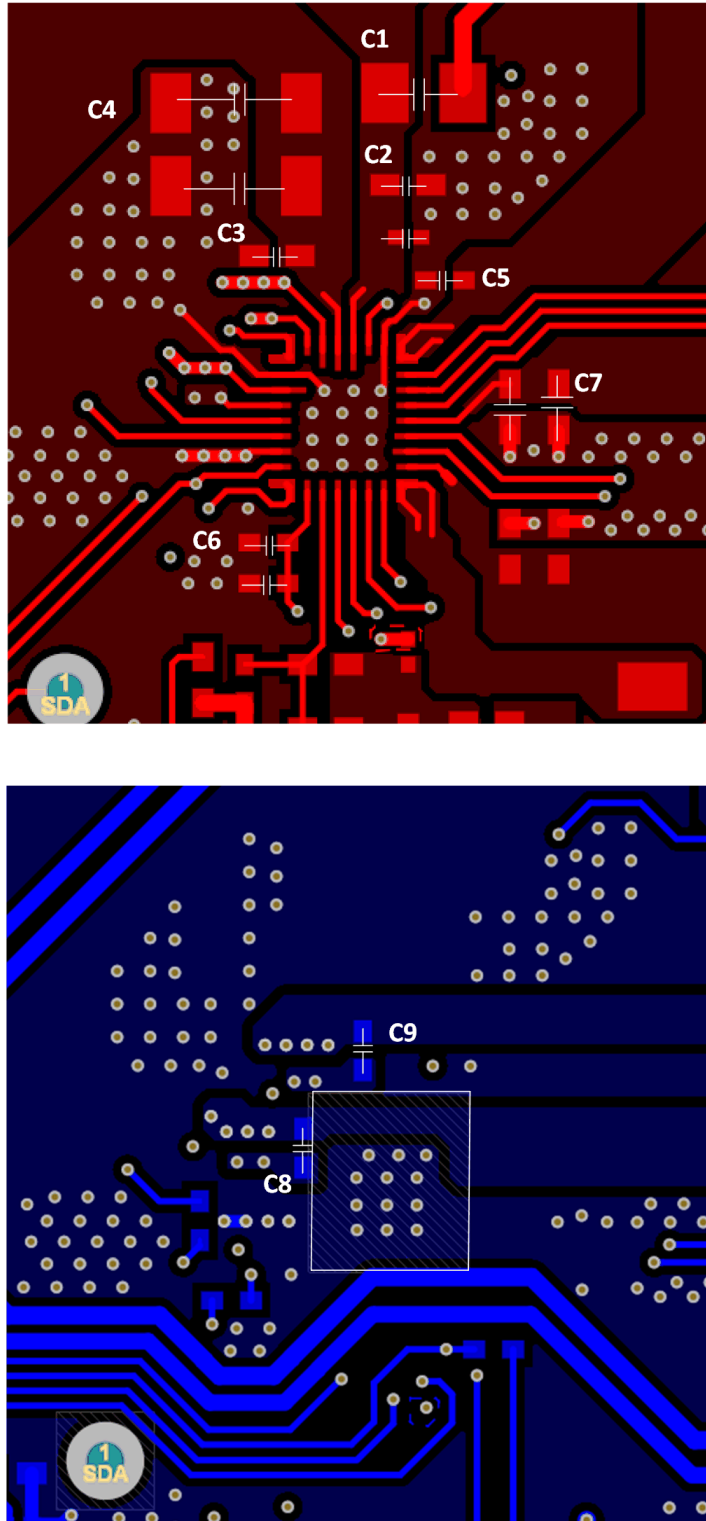


Figure 12-2. Layout Example - Top and Bottom Layers

## **13 Device and Documentation Support**

### **13.1 Receiving Notification of Documentation Updates**

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### **13.2 Community Resources**

### **13.3 Trademarks**

All trademarks are the property of their respective owners.

## **14 Mechanical, Packaging, and Orderable Information**

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

## 14.1 Package Option Addendum

### Packaging Information

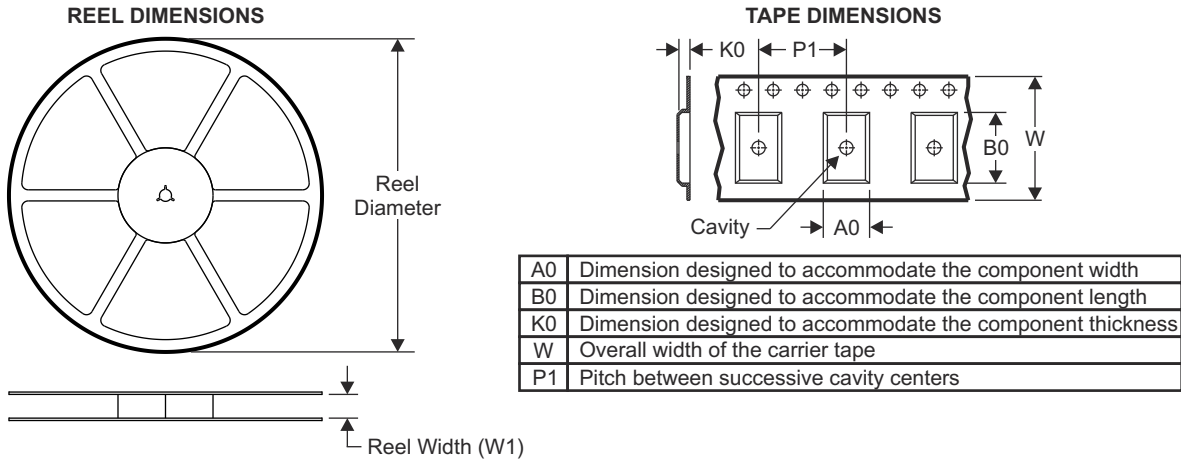
Orderable Device	Status(1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan(2)	Lead/Ball Finish(6)	MSL Peak Temp(3)	Op Temp (°C)	Device Marking(4/5)
PTAS2781RYYR	ACTIVE	VQFN-HR	RYY	30	3000	RoHS & Green	NiPdAu	Level-1-260C -UNLIM	-40 to 85	P278-SA
TAS2781RYYR	ACTIVE	VQFN-HR	RYY	30	3000	RoHS & Green	NiPdAu	Level-1-260C -UNLIM	-40 to 85	TAS2781

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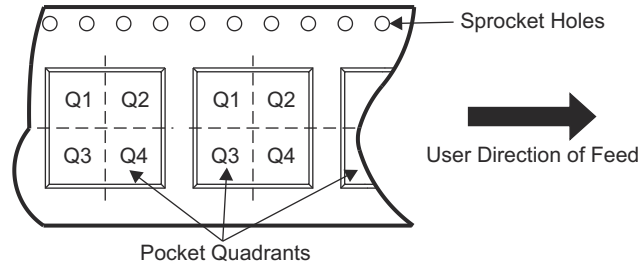
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.



## 14.2 Tape and Reel Information

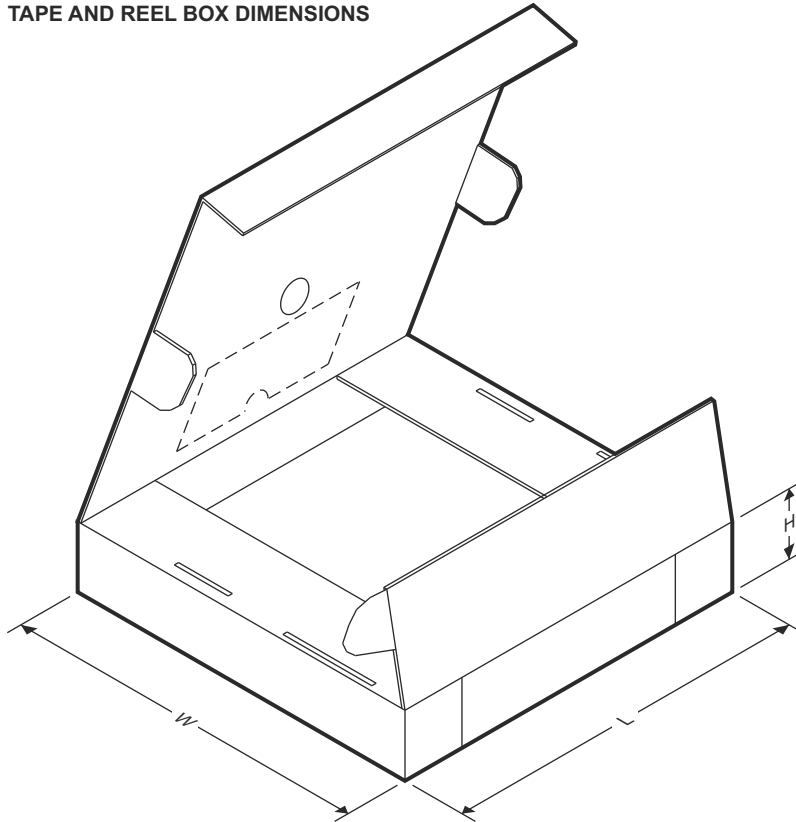


### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



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
PTAS2781RYYR	VQFN-HR	RYY	30	3000	330	12.4	3.8	4.3	1.5	8	12	Q1
TAS2781RYYR	VQFN-HR	RYY	30	3000	330	12.4	3.8	4.3	1.5	8	12	Q1

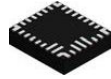
**TAPE AND REEL BOX DIMENSIONS**



Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
PTAS2781RYYR	VQFN-HR	RYY	30	3000	367	367	35
TAS2781RYYR	VQFN-HR	RYY	30	3000	367	367	35

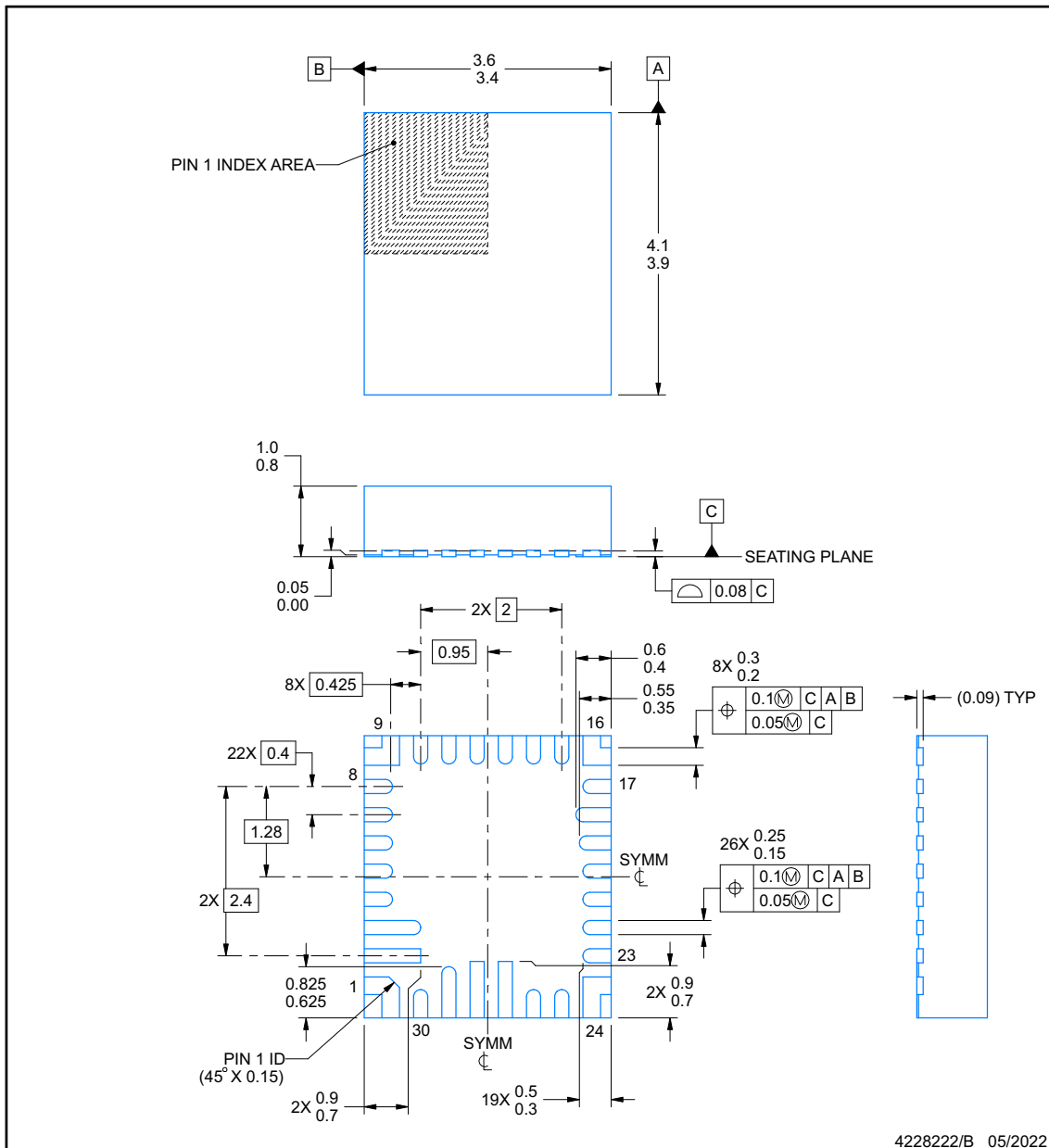
**PACKAGE OUTLINE**

**RYY0030A**



**VQFN-HR - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



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**NOTES:**

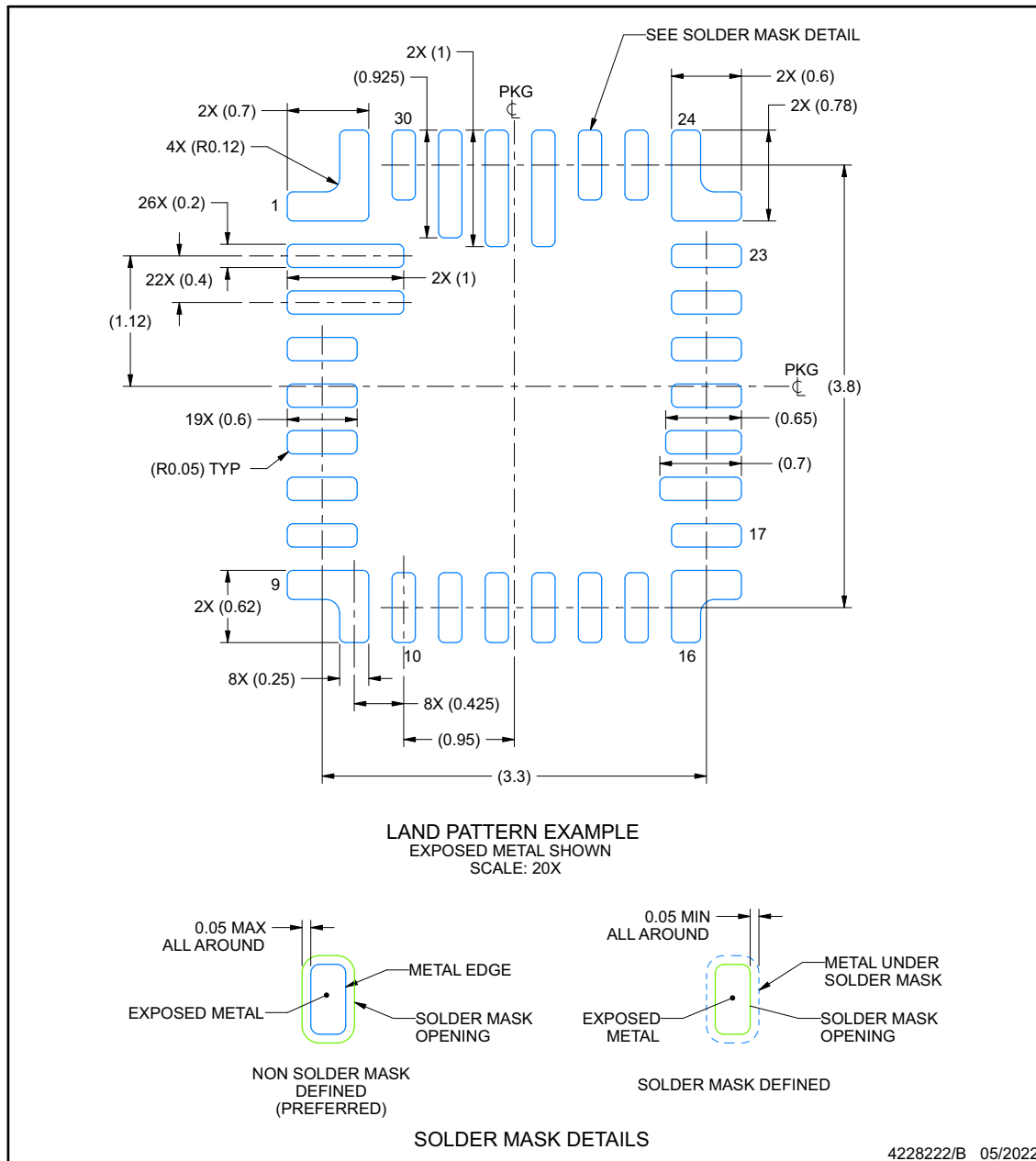
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

## EXAMPLE BOARD LAYOUT

**RYY0030A**

**VQFN-HR - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



NOTES: (continued)

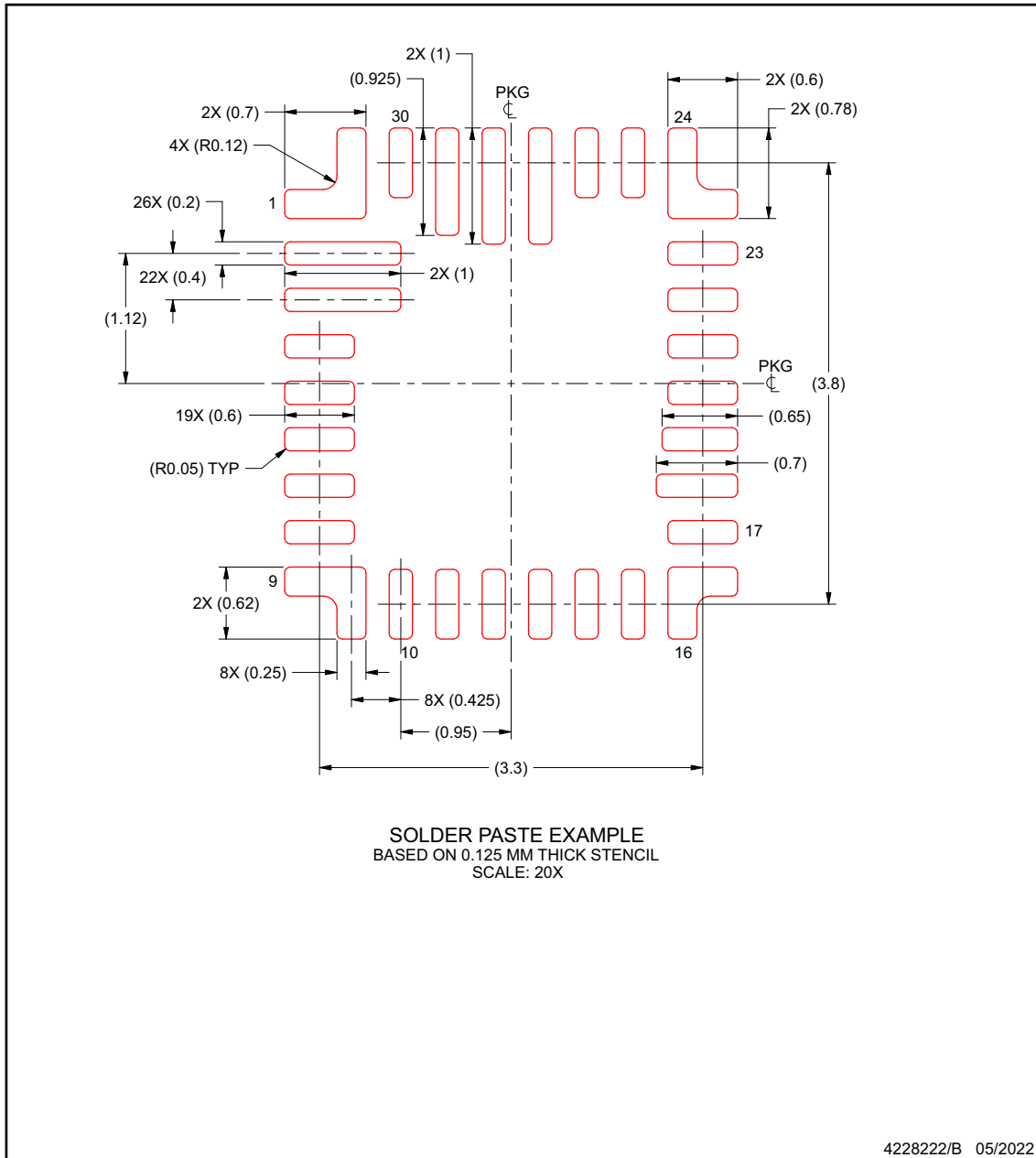
- This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
- Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

## EXAMPLE STENCIL DESIGN

**RYY0030A**

**VQFN-HR - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



NOTES: (continued)

- 6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TAS2781RYYR	ACTIVE	VQFN-HR	RYY	30	3000	RoHS & Green	SN	Level-1-260C-UNLIM	-40 to 85	TAS2781	Samples

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSELETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

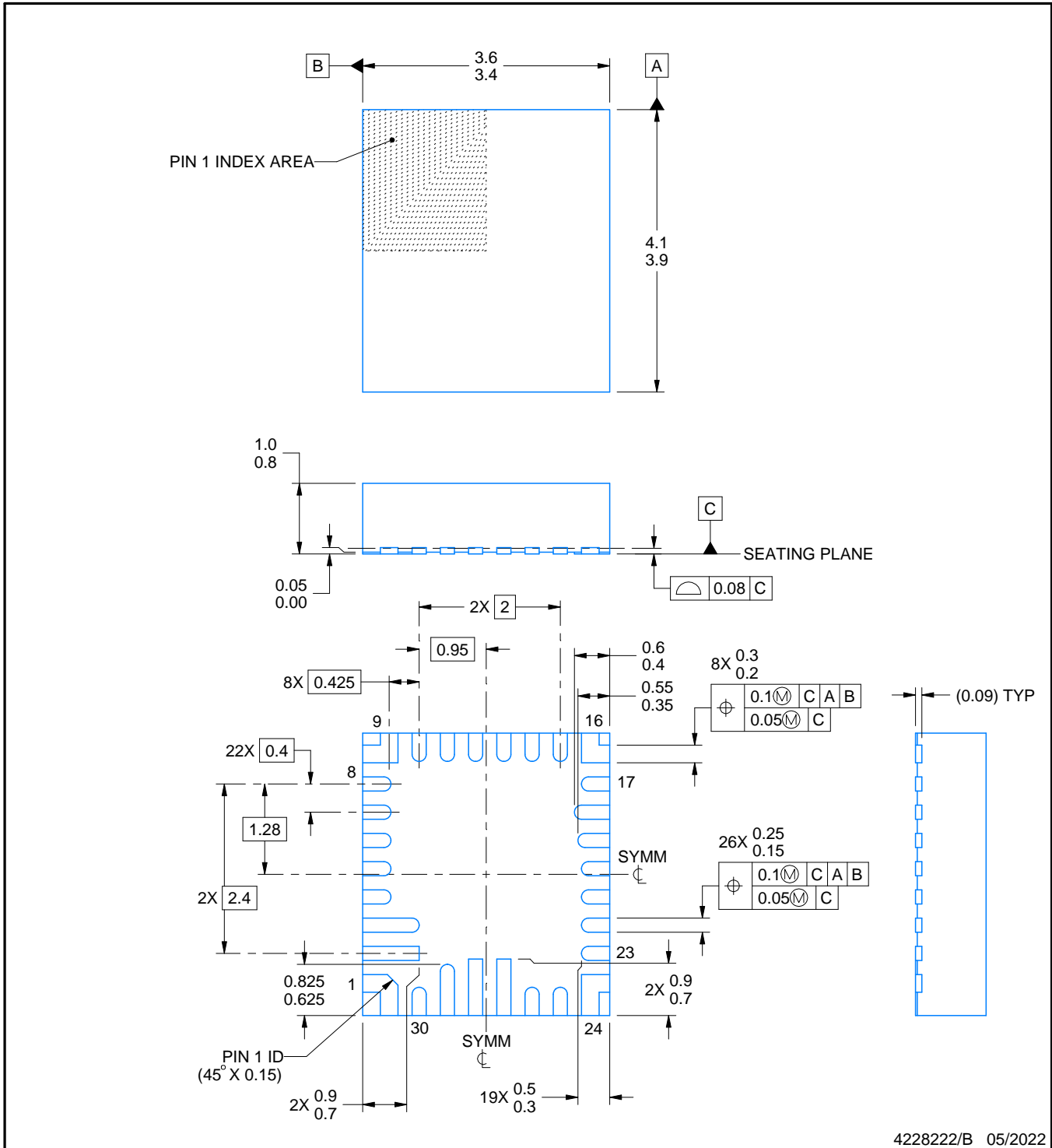
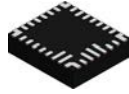
(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices 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.

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NOTES:

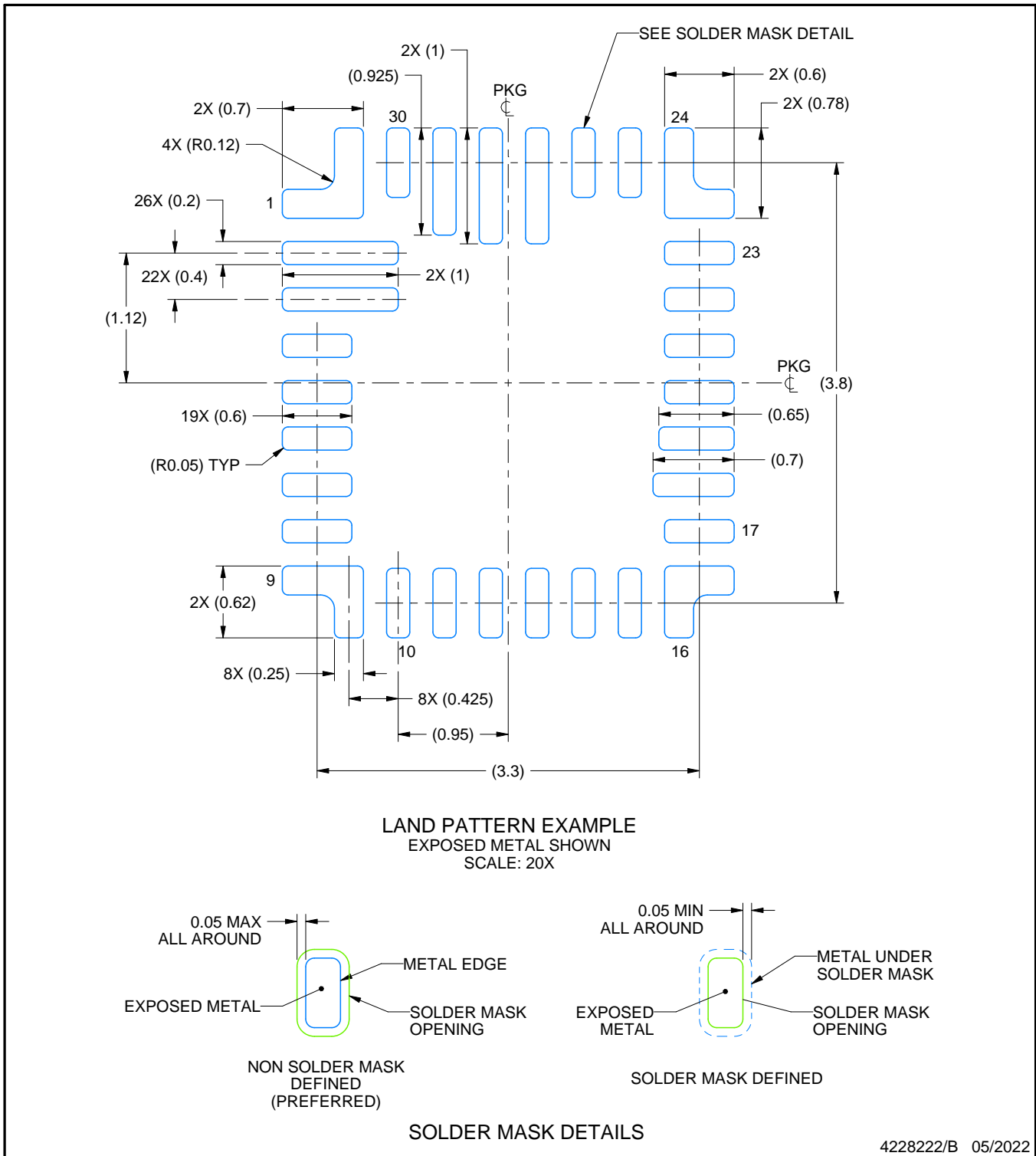
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

# EXAMPLE BOARD LAYOUT

**RYY0030A**

**VQFN-HR - 1 mm max height**

PLASTIC QUAD FLATPACK - NO LEAD



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NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 ([www.ti.com/lit/sluea271](http://www.ti.com/lit/sluea271)).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.





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