

## FOUR-CHANNEL AUTOMOTIVE DIGITAL AMPLIFIER

Check for Samples: [TAS5514B-Q1](#)

### FEATURES

- Single-Ended Input
- Four-Channel Digital Power Amplifier
- Four Analog Inputs, Four BTL Power Outputs
- Typical Output Power at 10% THD+N
  - 28 W/Ch Into 4  $\Omega$  at 14.4 V
  - 50 W/Ch Into 2  $\Omega$  at 14.4 V
  - 79 W/Ch Into 4  $\Omega$  at 24 V
  - 150 W/Ch Into 2  $\Omega$  at 24 V (PBTL)
- Channels Can Be Paralleled (PBTL) for High-Current Applications
- THD+N < 0.02%, 1 kHz, 1 W Into 4  $\Omega$
- Patented Pop- and Click-Reduction Technology
  - Soft Muting With Gain Ramp Control
  - Common-Mode Ramping
- Patented AM Interference Avoidance
- Patented Cycle-by-Cycle Current Limit
- 75-dB PSRR
- Master/Slave Capability to Synchronize Clocks
- Load Diagnostic Functions:
  - Output Open and Shorted Load
  - Output-to-Power and -to-Ground Shorts
- Protection and Monitoring Functions:
  - Short-Circuit Protection
  - Load-Dump Protection to 50 V
  - Fortuitous Open-Ground and -Power Tolerant
  - Patented Output DC Level Detection While Music Playing
  - Overtemperature Protection
  - Over- and Undervoltage Conditions
  - Clip Detection

- 36-Pin PSOP3 (DKD) Power SOP Package With Heat Slug
- Designed for Automotive EMC Requirements
- Qualified According to AEC-Q100
- ISO9000:2002 TS16949 Certified
- –40°C to 105°C Ambient Temperature Range

### APPLICATIONS

OEM/Retail Head Units and Amplifier Modules Where Feature Densities and System Configurations Require Reduction in Heat From the Audio Power Amplifier

### DESCRIPTION

The TAS5514B-Q1 is a four-channel digital audio amplifier designed for use in automotive head units and external amplifier modules. It provides four channels at 23 W continuously into 4  $\Omega$  at less than 1% THD+N from a 14.4-V supply. Each channel can also deliver 38 W into 2  $\Omega$  at 1% THD+N. The digital PWM topology of the device provides dramatic improvements in efficiency over traditional linear amplifier solutions. This reduces the power dissipated by the amplifier by a factor of ten under typical music playback conditions. The device incorporates all the functionality needed to perform in the demanding OEM applications area. The TAS5514B-Q1 has built-in load diagnostic functions for detecting and diagnosing misconnected outputs to help to reduce test time during the manufacturing process.

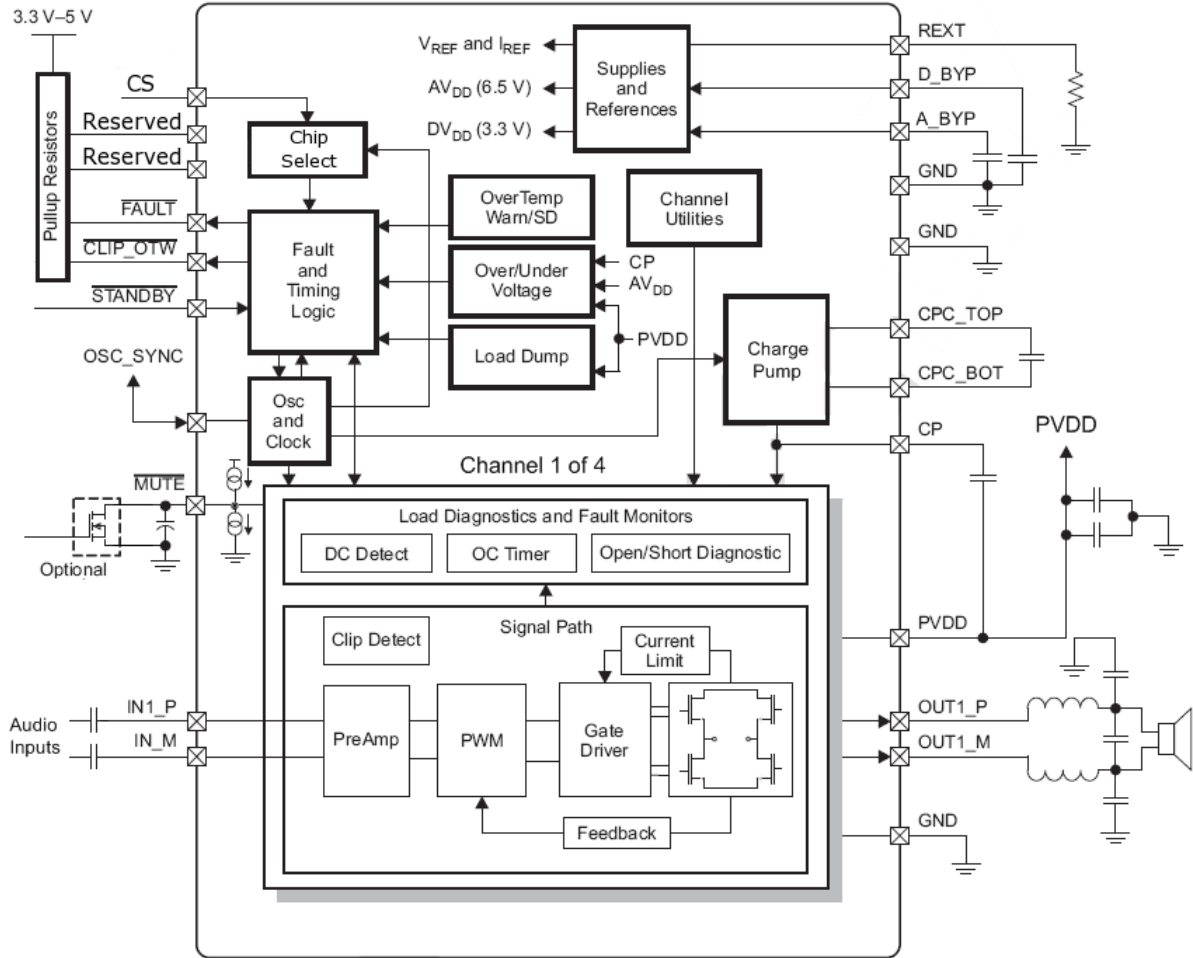


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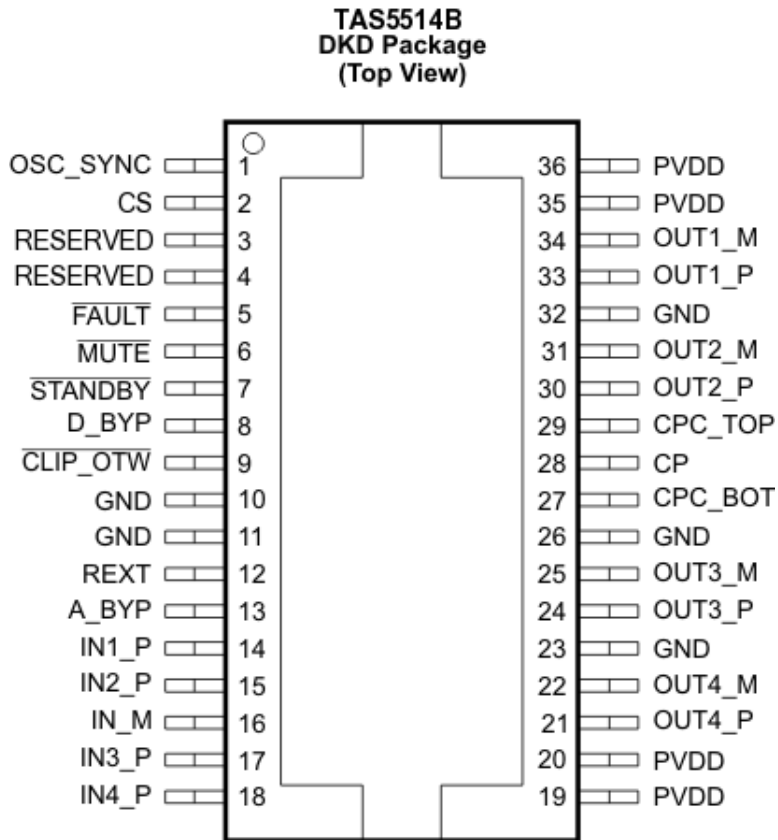
These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

**FUNCTIONAL BLOCK DIAGRAM**



## PIN ASSIGNMENTS AND FUNCTIONS

The pin assignments are shown as follows.



**Table 1. PIN FUNCTIONS**

PIN		TYPE	DESCRIPTION
NAME	DKD PACKAGE TAS5514B-Q1 NO.		
A_BYP	13	PBY	Bypass pin for the AVDD analog regulator
$\overline{\text{CLIP\_OTW}}$	9	DO	Reports CLIP, OTW, or both. It also reports tweeter detection during tweeter mode. Open-drain
CP	28	CP	Top of main storage capacitor for charge pump (bottom goes to PVDD)
CPC_BOT	27	CP	Bottom of flying capacitor for charge pump
CPC_TOP	29	CP	Top of flying capacitor for charge pump
D_BYP	8	PBY	Bypass pin for DVDD regulator output
$\overline{\text{FAULT}}$	5	DO	Global fault output (open-drain): UV, OV, OTSD, OCSD, DC
GND	10, 11, 23, 26, 32	GND	Ground
CS	2	AI	Chip select
IN1_P	14	AI	Non-inverting analog input for channel 1
IN2_P	15	AI	Non-inverting analog input for channel 2
IN3_P	17	AI	Non-inverting analog input for channel 3
IN4_P	18	AI	Non-inverting analog input for channel 4
IN_M	16	ARTN	Signal return for the four analog channel inputs
$\overline{\text{MUTE}}$	6	AI	Gain ramp control: mute (low), play (high)
OSC_SYNC	1	DI/DO	Oscillator input from master or output to slave amplifiers
OUT1_M	34	PO	– polarity output for bridge 1
OUT1_P	33	PO	+ polarity output for bridge 1
OUT2_M	31	PO	– polarity output for bridge 2
OUT2_P	30	PO	+ polarity output for bridge 2
OUT3_M	25	PO	– polarity output for bridge 3
OUT3_P	24	PO	+ polarity output for bridge 3
OUT4_M	22	PO	– polarity output for bridge 4
OUT4_P	21	PO	+ polarity output for bridge 4
PVDD	19, 20, 35, 36	PWR	PVDD supply
REXT	12	AI	Precision resistor pin to set analog reference
RESERVED	3, 4		
$\overline{\text{STANDBY}}$	7	DI	Active-low STANDBY pin. Standby (low), power up (high)

## ABSOLUTE MAXIMUM RATINGS

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

			VALUE	UNIT
PVDD	DC supply-voltage range	Relative to GND	–0.3 to 30	V
PVDD <sub>MAX</sub>	Pulsed supply-voltage range	t ≤ 100 ms exposure	–1 to 50	V
PVDD <sub>RAMP</sub>	Supply-voltage ramp rate		15	V/ms
I <sub>PVDD</sub>	Externally imposed dc supply current per PVDD or GND pin		±12	A
I <sub>PVDD_MAX</sub>	Pulsed supply current per PVDD pin (one shot)	t < 100 ms	17	A
I <sub>O</sub>	Maximum allowed dc current per output pin		±13.5	A
I <sub>O_MAX</sub> <sup>(1)</sup>	Pulsed output current per output pin (single pulse)	t < 100 ms	±17	A
I <sub>IN_MAX</sub>	Maximum current, all digital and analog input pins <sup>(2)</sup>	DC or pulsed	±1	mA
I <sub>MUTE_MAX</sub>	Maximum current on $\overline{\text{MUTE}}$ pin	DC or pulsed	±20	mA
I <sub>IN_ODMAX</sub>	Maximum sink current for open-drain pins		7	mA
V <sub>LOGIC</sub>	Input voltage range for pin relative to GND (SCL, SDA, CS pins)	Supply voltage range: 6V < PVDD < 24 V	–0.3 to 6	V
V <sub>MUTE</sub>	Voltage range for $\overline{\text{MUTE}}$ pin relative to GND	Supply voltage range: 6 V < PVDD < 24 V	–0.3 to 7.5	V
V <sub>STANDBY</sub>	Input voltage range for $\overline{\text{STANDBY}}$ pin	Supply voltage range: 6 V < PVDD < 24 V	–0.3 to 5.5	V
V <sub>OSC_SYNC</sub>	Input voltage range for OSC_SYNC pin relative to GND	Supply voltage range: 6 V < PVDD < 24 V	–0.3 to 3.6	V
V <sub>GND</sub>	Maximum voltage between GND pins		±0.3	V
V <sub>AIN_AC_MAX_5514</sub>	Maximum ac-coupled input voltage for TAS5514B-Q1 <sup>(2)</sup> , analog input pins	Supply voltage range: 6 V < PVDD < 24 V	1.9	V <sub>rms</sub>
T <sub>J</sub>	Maximum operating junction temperature range		–55 to 150	°C
T <sub>stg</sub>	Storage temperature range		–55 to 150	°C

(1) Pulsed current ratings are maximum survivable currents externally applied to the device. High currents may be encountered during reverse battery, fortuitous open-ground, and fortuitous open-supply fault conditions.

(2) See [Application Information](#) section for information on analog input voltage and ac coupling.

## THERMAL CHARACTERISTICS

PARAMETER		VALUE (Typical)	UNIT
R <sub>θJC</sub>	Junction-to-case (heat slug) thermal resistance, DKD package	1	°C/W
R <sub>θJC</sub>	Junction-to-case (heat slug) thermal resistance, PHD package	1.2	
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	This device is not intended to be used without a heatsink. Therefore, R <sub>θJA</sub> is not specified. See the <a href="#">Thermal Information</a> section.	
	Exposed pad dimensions, DKD package	13.8 × 5.8	mm

## ELECTROSTATIC DISCHARGE (ESD)

PARAMETER	Package	Pins	VALUE (Typical)	UNIT
Human-body model (HBM) AEC-Q100-002	All	All	3000	V
Charged-device model (CDM) AEC-Q100-011	DKD/DKE	Corner pins excluding OSC_SYNC	1000	
		All other pins (including OSC_SYNC) except CP pin CP pin (non-corner Pin)	500 400	
	PHD	Corner pins excluding SCL All pins (including SCL) except CP and CP_TOP CP and CP_TOP pins	750 600 400	
Machine model (MM) AEC-Q100-003	DKD/DKE		150	
	PHD		100	

## RECOMMENDED OPERATING CONDITIONS<sup>(1)</sup>

			MIN	TYP	MAX	UNIT
PVDD <sub>OP</sub>	DC supply-voltage range relative to GND		6	14.4	24	V
V <sub>AIN_5514</sub> <sup>(2)</sup>	Analog audio input signal level (TAS5514B-Q1)	AC-coupled input voltage	0		0.25–1 <sup>(3)</sup>	Vrms
T <sub>A</sub>	Ambient temperature		–40		105	°C
T <sub>J</sub>	Junction temperature	An adequate heat sink is required to keep T <sub>J</sub> within the specified range.	–40		115	°C
R <sub>L</sub>	Nominal speaker load impedance		2	4		Ω
V <sub>PU</sub>	Pullup voltage supply (for open-drain logic outputs)		3	3.3 or 5	5.5	V
R <sub>PU_I2C</sub>	I <sup>2</sup> C pullup resistance on SDA and SCL pins		1	4.7	10	kΩ
R <sub>CS</sub>	Total resistance of voltage divider for I <sup>2</sup> C address slave 1 or slave 2, connected between D_BYP and GND pins		10		50	kΩ
R <sub>REXT</sub>	External resistance on REXT pin	1% tolerance required	19.8	20	20.2	kΩ
C <sub>D_BYP</sub> , C <sub>A_BYP</sub>	External capacitance on D_BYP and A_BYP pins		10		120	nF
C <sub>OUT</sub>	External capacitance to GND on OUT_X pins			150	680	nF
C <sub>IN</sub>	External capacitance to analog input pin in series with input signal			0.47		μF
C <sub>FLY</sub>	Flying capacitor on charge pump		0.47	1	1.5	μF
C <sub>P</sub>	Charge pump capacitor	50 V needed for load dump	0.47	1	1.5	μF
C <sub>MUTE</sub>	MUTE pin capacitor		100	220	1000	nF
C <sub>OSCSYNC_MAX</sub>	Allowed loading capacitance on OSC_SYNC pin			75		pF

(1) The *Recommended Operating Conditions* table specifies only that the device is functional in the given range. See the *Electrical Characteristics* table for specified performance limits.

(2) Signal input for full unclipped output with gains of 32 dB, 26 dB, 20 dB, and 12 dB

(3) Maximum recommended input voltage is determined by the gain setting.

## ELECTRICAL CHARACTERISTICS

Test conditions (unless otherwise noted):  $T_{Case} = 25^{\circ}C$ ,  $PVDD = 14.4 V$ ,  $R_L = 4 \Omega$ ,  $f_S = 417 kHz$ ,  $P_{out} = 1 W/ch$ ,  $R_{ext} = 20 k\Omega$ , AES17 Filter, default I<sup>2</sup>C settings, master mode operation (see application diagram)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT	
<b>OPERATING CURRENT</b>							
$I_{PVDD\_IDLE}$	PVDD idle current	All four channels in MUTE mode		170	220	mA	
$I_{PVDD\_HI-Z}$		All four channels in Hi-Z mode		93			
$I_{PVDD\_STBY}$	PVDD standby current	STANDBY mode, $T_J \leq 85^{\circ}C$		2	10	$\mu A$	
<b>OUTPUT POWER</b>							
$P_{OUT}$	Output power per channel	4 $\Omega$ , PVDD = 14.4 V, THD+N $\leq 1\%$ , 1 kHz, $T_c = 75^{\circ}C$		23		W	
		4 $\Omega$ , PVDD = 14.4 V, THD+N = 10%, 1 kHz, $T_c = 75^{\circ}C$		25	28		
		4 $\Omega$ , PVDD = 24 V, THD+N = 10%, 1 kHz, $T_c = 75^{\circ}C$		63	79		
		2 $\Omega$ , PVDD = 14.4 V, THD+N = 1%, 1 kHz, $T_c = 75^{\circ}C$			38		
		2 $\Omega$ , PVDD = 14.4 V, THD+N = 10%, 1 kHz, $T_c = 75^{\circ}C$		40	50		
		PBTL 2- $\Omega$ operation, PVDD = 24 V, THD+N = 10%, 1 kHz, $T_c = 75^{\circ}C$			150		
		PBTL 1- $\Omega$ operation, PVDD = 14.4 V, THD+N = 10%, 1 kHz, $T_c = 75^{\circ}C$			90		
$EFF_p$	Power efficiency	4 channels operating, 23-W output power/ch, $L = 10 \mu H$ , $T_J \leq 85^{\circ}C$		90%			
<b>AUDIO PERFORMANCE</b>							
$V_{NOISE}$	Noise voltage at output	Zero input, and A-weighting		60	100	$\mu V$	
Crosstalk	Channel crosstalk	$P = 1W$ , $f = 1 kHz$ , enhanced crosstalk enabled via I <sup>2</sup> C (reg 0x10)	70	85		dB	
PSRR	Power-supply rejection ratio	PVDD = 14.4 Vdc + 1 Vrms, $f = 1 kHz$	60	75		dB	
THD+N	Total harmonic distortion + noise	$P = 1W$ , $f = 1 kHz$		0.02%	0.1%		
$f_S$	Switching frequency	Switching frequency selectable for AM interference avoidance		336	357	378	kHz
				392	417	442	
				470	500	530	
$R_{AIN}$	Analog input resistance	Internal shunt resistance on each input pin	63	85	106	k $\Omega$	
$V_{IN\_CM}$	Common-mode input voltage	AC-coupled common-mode input voltage (zero differential input)		1.3		Vrms	
$V_{CM\_INT}$	Internal common-mode input bias voltage	Internal bias applied to IN_M pin		3.3		V	
G	Voltage gain ( $V_O/V_{IN}$ )	Source impedance = 0 $\Omega$ , gain measurement taken at 1 W of power per channel		11	12	13	dB
				19	20	21	
				25	26	27	
				31	32	33	
$G_{CH}$	Channel-to-channel variation	Any gain commanded	-1	0	1	dB	
<b>PWM OUTPUT STAGE</b>							
$R_{DSon}$	FET drain-to-source resistance	Not including bond wire resistance, $T_J = 25^{\circ}C$		65	90	m $\Omega$	
$V_{O\_OFFSET}$	Output offset voltage	Zero input signal, $G = 26 dB$		$\pm 10$	$\pm 50$	mV	
<b>PVDD OVERVOLTAGE (OV) PROTECTION</b>							
$V_{OV\_SET}$	PVDD overvoltage shutdown set		24.6	26.4	28.2	V	
$V_{OV\_CLEAR}$	PVDD overvoltage shutdown clear		24.4	25.9	27.4		
<b>PVDD UNDERVOLTAGE (UV) PROTECTION</b>							
$V_{UV\_SET}$	PVDD undervoltage shutdown set		4.9	5.3	5.6	V	
$V_{UV\_CLEAR}$	PVDD undervoltage shutdown clear		6.2	6.6	7.0	V	
<b>AVDD</b>							
$V_{A\_BYP}$	A_BYP pin voltage			6.5		V	
$V_{A\_BYP\_UV\_SET}$	A_BYP UV voltage			4.8		V	
$V_{A\_BYP\_UV\_CLEAR}$	Recovery voltage A_BYP UV			5.3		V	
<b>DVDD</b>							
$V_{D\_BYP}$	D_BYP pin voltage			3.3		V	

## ELECTRICAL CHARACTERISTICS (continued)

Test conditions (unless otherwise noted):  $T_{Case} = 25^{\circ}C$ ,  $PVDD = 14.4 V$ ,  $R_L = 4 \Omega$ ,  $f_S = 417 kHz$ ,  $P_{out} = 1 W/ch$ ,  $R_{ext} = 20 k\Omega$ , AES17 Filter, default I<sup>2</sup>C settings, master mode operation (see application diagram)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>POWER-ON RESET (POR)</b>						
$V_{POR}$	PVDD voltage for POR	State machine active above this voltage			3.5	V
$V_{POR\_HY}$	PVDD recovery hysteresis voltage for POR			0.1		V
<b>REXT</b>						
$V_{REXT}$	Rext pin voltage			1.27		V
<b>CHARGE PUMP (CP)</b>						
$V_{CPUV\_SET}$	CP undervoltage			4.8		V
$V_{CPUV\_CLEAR}$	Recovery voltage for CP UV			4.9		V
<b>OVERTEMPERATURE (OT) PROTECTION</b>						
$T_{OTW\_CLEAR}$	Junction temperature for overtemperature warning		96	112	128	$^{\circ}C$
$T_{OTW\_SET}$			106	122	138	$^{\circ}C$
$T_{OTS\_CLEAR}$	Junction temperature for overtemperature shutdown		126	142	158	$^{\circ}C$
$T_{OTS}$			136	152	168	$^{\circ}C$
$T_{FB}$	Junction temperature for overtemperature foldback	Per channel	130	150	170	$^{\circ}C$
<b>CURRENT LIMITING PROTECTION</b>						
$I_{LIM}$	Current limit (load current)	Level 1	5.5	7.3	9	A
		Level 2 (default)	10.6	12.7	15	
<b>OVERCURRENT (OC) SHUTDOWN PROTECTION</b>						
$I_{MAX}$	Maximum current (peak output current)	Level 2 (default), Any short to supply, ground, or other channels	11.9	14.8	17.7	A
<b>STANDBY MODE</b>						
$V_{IH\_STBY}$	$\overline{STANDBY}$ input voltage for logic-level high		2			V
$V_{IL\_STBY}$	$\overline{STANDBY}$ input voltage for logic-level low				0.7	V
$I_{STBY\_PIN}$	$\overline{STANDBY}$ pin current			0.1	0.2	$\mu A$
<b>MUTE MODE</b>						
$G_{MUTE}$	Output attenuation	$\overline{MUTE}$ pin $\leq 0.5 V + 200mS$		100		dB
<b>DC DETECT</b>						
$V_{TH\_DC\_TOL}$	DC detect threshold tolerance			25		%
$t_{DCD}$	DC detect step response time for four channels				5.3	s
<b>CLIP_OTW REPORT</b>						
$V_{OH\_CLIPOTW}$	$\overline{CLIP\_OTW}$ pin output voltage for logic level high (open-drain logic output)	External 47-k $\Omega$ pullup resistor to 3 V–5.5 V	2.4			V
$V_{OL\_CLIPOTW}$	$\overline{CLIP\_OTW}$ pin output voltage for logic level low (open-drain logic output)				0.5	
$t_{DELAY\_CLIPDET}$	$\overline{CLIP\_OTW}$ signal delay when output clipping detected				20	$\mu s$
<b>FAULT REPORT</b>						
$V_{OH\_FAULT}$	$\overline{FAULT}$ pin output voltage for logic-level high (open-drain logic output)	External 47-k $\Omega$ pullup resistor to 3 V–5.5 V	2.4			V
$V_{OL\_FAULT}$	$\overline{FAULT}$ pin output voltage for logic-level low (open-drain logic output)				0.5	
<b>OPEN/SHORT DIAGNOSTICS</b>						
$R_{S2P}, R_{S2G}$	Maximum resistance to detect a short from OUT pin(s) to PVDD or ground				200	$\Omega$
$R_{OPEN\_LOAD}$	Minimum load resistance to detect open circuit	Including speaker wires	300	740	1300	$\Omega$
$R_{SHORTED\_LOAD}$	Maximum load resistance to detect short circuit	Including speaker wires	0.5	1	1.5	$\Omega$



**ELECTRICAL CHARACTERISTICS (continued)**

Test conditions (unless otherwise noted):  $T_{Case} = 25^{\circ}C$ ,  $PVDD = 14.4 V$ ,  $R_L = 4 \Omega$ ,  $f_S = 417 kHz$ ,  $P_{out} = 1 W/ch$ ,  $R_{ext} = 20 k\Omega$ , AES17 Filter, default I<sup>2</sup>C settings, master mode operation (see application diagram)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>Chip Select DECODER</b>						
$t_{LATCH\_CS}$	Time delay to latch CS after POR			300		$\mu s$
$V_{CS}$	Voltage on CS pin for address 0	Connect to GND	0%	0%	15%	$V_{D\_BYP}$
	Voltage on CS pin for address 1	External resistors in series between D_BYP and GND as a voltage divider	25%	35%	45%	
	Voltage on CS pin for address 2		55%	65%	75%	
	Voltage on CS pin for address 3	Connect to D_BYP	85%	100%	100%	
<b>OSCILLATOR</b>						
$V_{OH\_OSCSYNC}$	OSC_SYNC pin output voltage for logic-level high	CS pin set to MASTER mode	2.4			V
$V_{OL\_OSCSYNC}$	OSC_SYNC pin output voltage for logic-level low				0.5	V
$V_{IH\_OSCSYNC}$	OSC_SYNC pin input voltage for logic-level high	CS pin set to SLAVE mode	2			V
$V_{IL\_OSCSYNC}$	OSC_SYNC pin input voltage for logic-level low				0.8	V
$f_{OSC\_SYNC}$	OSC_SYNC pin clock frequency	CS pin set to MASTER mode, $f_S = 417 kHz$	3.13	3.33	3.63	MHz

TYPICAL CHARACTERISTICS

THD+N  
vs  
BTL OUTPUT POWER at 1kHz

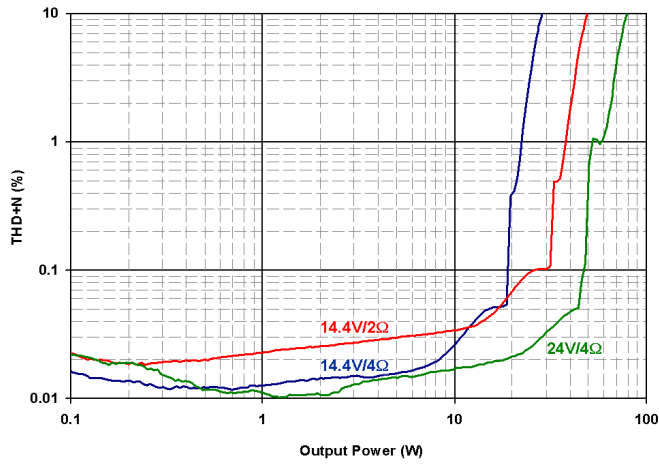


Figure 1.

THD+N  
vs  
PBTL OUTPUT POWER at 1kHz

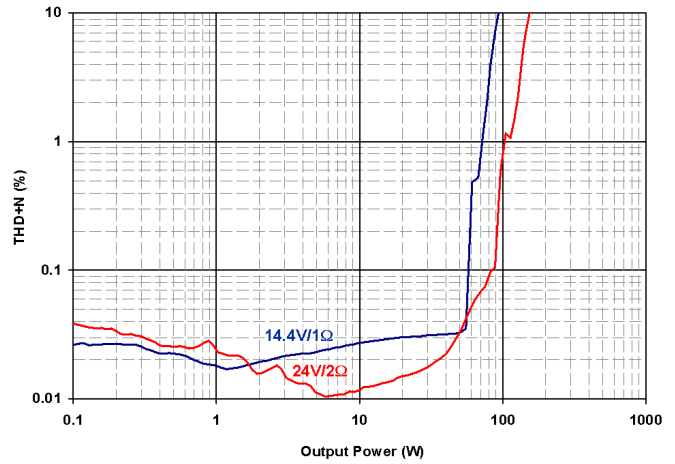


Figure 2.

THD+N  
vs  
FREQUENCY at 1 Watt

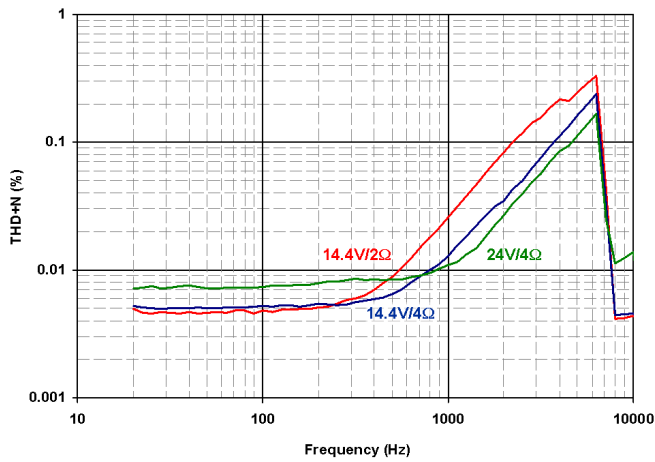


Figure 3.

TAS5524B-Q1  
COMMON-MODE REJECTION RATIO  
vs  
FREQUENCY

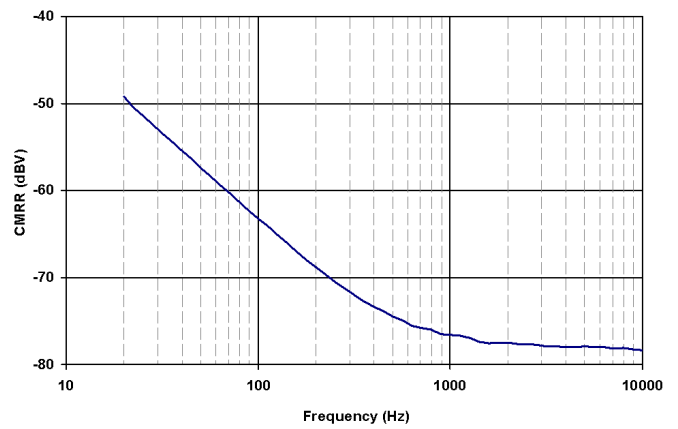


Figure 4.

TYPICAL CHARACTERISTICS (continued)

CROSSTALK  
vs  
FREQUENCY

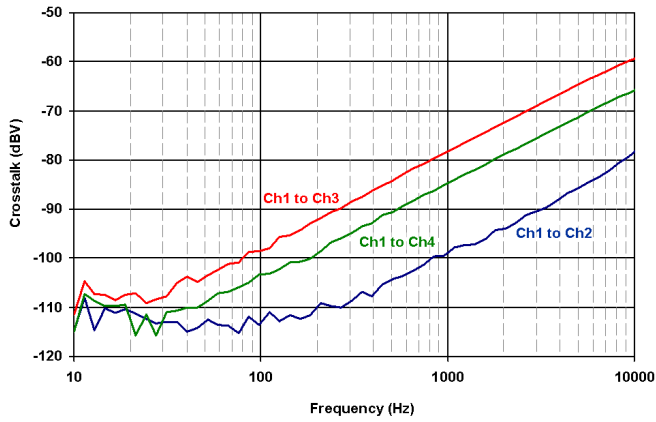


Figure 5.

NOISE FFT

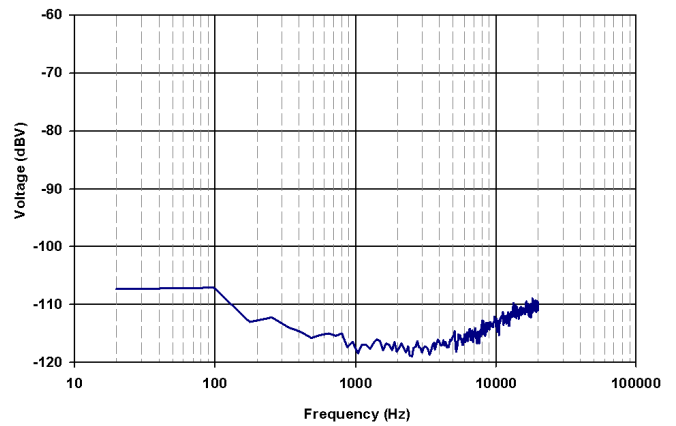


Figure 6.

EFFICIENCY,  
FOUR CHANNELS AT 4 Ω EACH

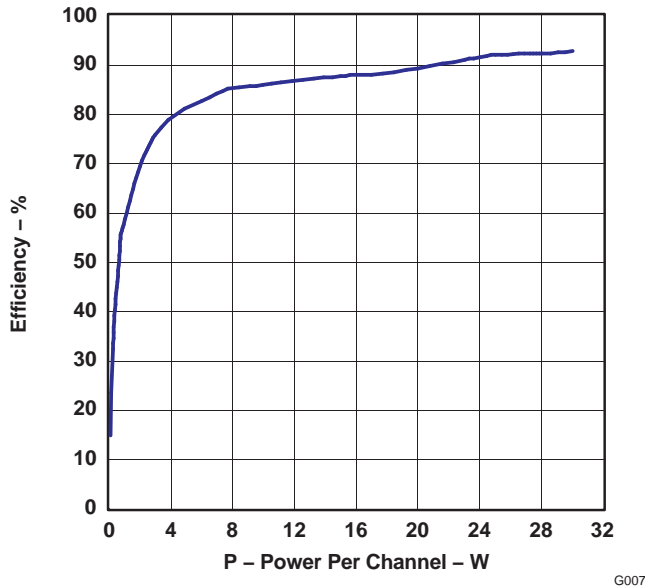


Figure 7.

DEVICE POWER DISSIPATION  
FOUR CHANNELS AT 4 Ω EACH

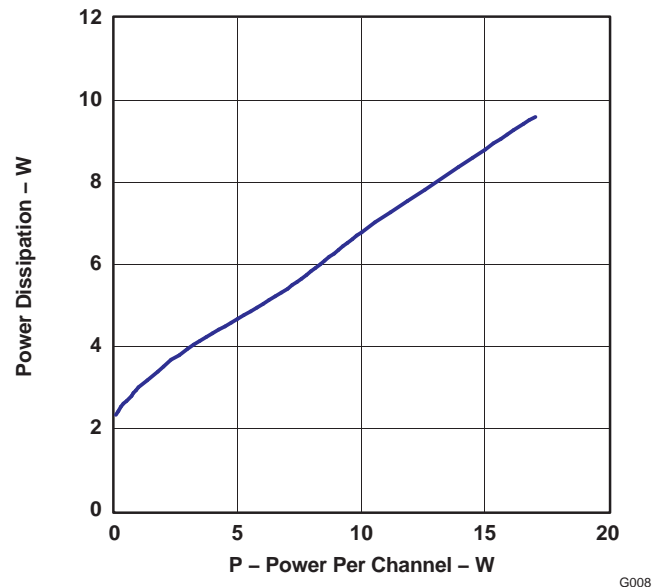


Figure 8.

## DESCRIPTION OF OPERATION

### OVERVIEW

The TAS5514B-Q1 is a single-chip, four-channel, analog-input audio amplifier for use in the automotive environment. The design uses an ultra-efficient class-D technology developed by Texas Instruments, but with changes needed by the automotive industry. This technology allows for reduced power consumption, reduced heat, and reduced peak currents in the electrical system. The device realizes an audio sound system design with smaller size and lower weight than traditional class-AB solutions.

There are eight core design blocks:

- Preamplifier
- PWM
- Gate drive
- Power FETs
- Diagnostics
- Protection
- Power supply
- State machine

### Preamplifier

The preamplifier is a high-input-impedance, low-noise, low-offset-voltage input stage with adjustable gain. The high input impedance allows the use of low-cost input capacitors while still achieving extended low-frequency response. The preamplifier is powered by a dedicated, internally regulated supply, which gives it excellent noise immunity and channel separation. Also included in the preamplifier is **Mute Pop-and-Click Control**—The device ramps the gain gradually when a mute or play command is received. Another form of click and pop can be caused by the start or stopping of switching in a class-D amplifier. The TAS5514B-Q1 incorporates a patented method to reduce the pop energy during the switching startup and shutdown sequences. Fault conditions require rapid protection response by the TAS5514B-Q1, which do not have time to ramp the gain down in a pop-free manner. The device transitions into Hi-Z mode when an OV, UV, OC, OT, or dc fault is encountered.

### Pulse-Width Modulator (PWM)

The PWM converts the analog signal from the preamplifier into a switched signal of varying duty cycle. This is the critical stage that defines the class-D architecture. In the TAS5514B-Q1, the modulator is an advanced design with high bandwidth, low noise, low distortion, excellent stability, and full 0–100% modulation capability. The patented PWM uses clipping recovery circuitry to eliminate the deep saturation characteristic of PWMs when the input signal exceeds the modulator waveform.

### Gate Drive

The gate driver accepts the low-voltage PWM signal and level-shifts it to drive a high-current, full-bridge, power FET stage. The device uses proprietary techniques to optimize EMI and audio performance.

### Power FETs

The BTL output for each channel comprises four rugged N-channel 30-V 65-m $\Omega$  FETs for high efficiency and maximum power transfer to the load. These FETs are designed to handle large voltage transients during load dump.

### Load Diagnostics

The device incorporates load diagnostic circuitry designed to help pinpoint the nature of output misconnections or faulty loads. The TAS5514B-Q1 includes functions for detecting and determining the status of output connections. The following diagnostics are performed when the device transitions from standby to play mode.

- Short to GND
- Short to PVDD
- Short across load

- Open load

The presence of any of the short or open conditions does not allow the channel with the fault to transition to play mode. Only an open load is allowed to transition to play mode.

**Output Short and Open Diagnostics**—The device contains circuitry designed to detect shorts and open conditions on the outputs. There are four phases of test during load diagnostics and two levels of test. All four phases are tested on each channel, all four channels at the same time. The diagnostics are performed as shown in Figure 9. Figure 10 shows the impedance ranges for the open-load and shorted-load diagnostics. With the default value of the MUTE capacitor the S2G and S2P phase take approximately 20 ms each, the OL phase takes approximately 100 ms, and the SL phase takes approximately 230 ms.

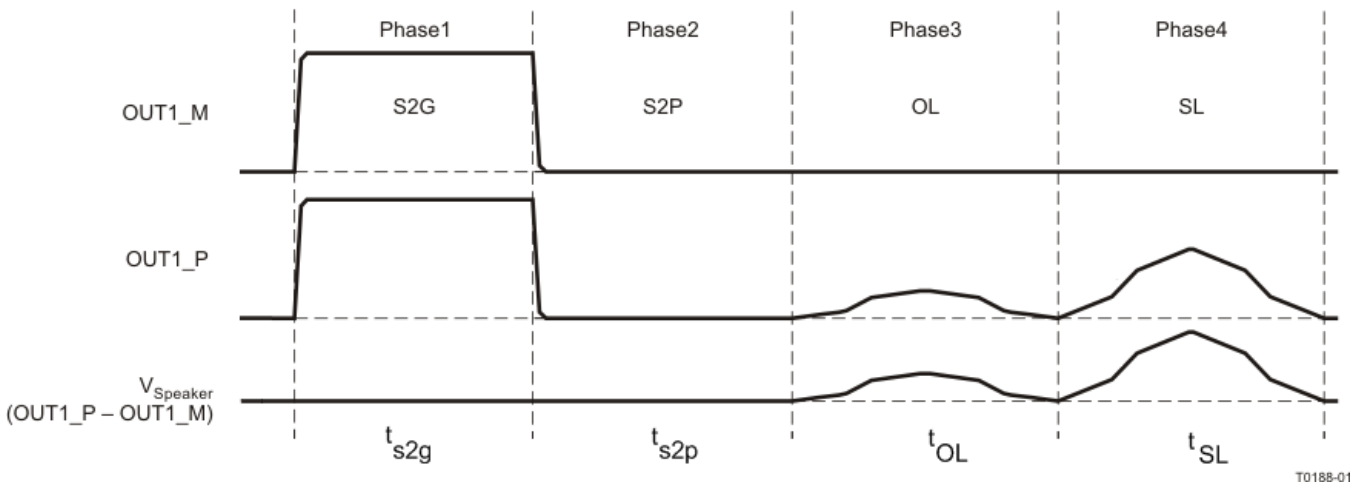


Figure 9. Load Diagnostics Sequence of Events

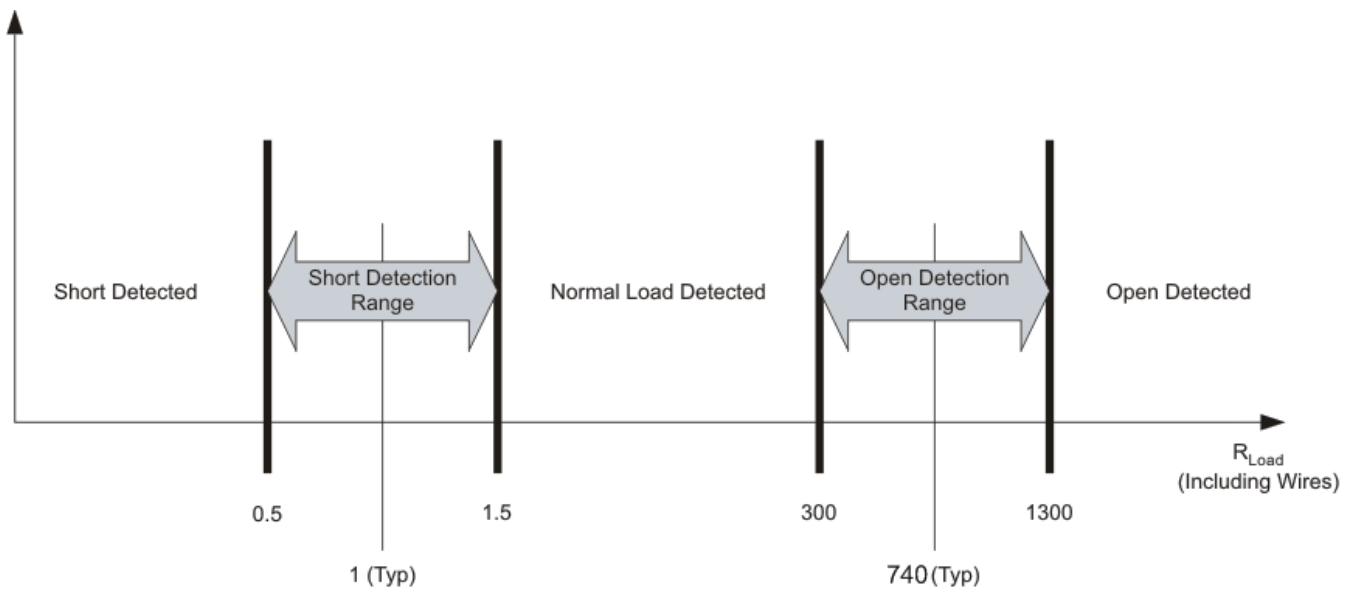


Figure 10. Open- and Shorted-Load Detection

## Protection and Monitoring

- **Cycle-By-Cycle Current Limit (CBC)**—The CBC current-limiting circuit terminates each PWM pulse to limit the output current flow when the average current limit ( $I_{LIM}$ ) threshold is exceeded. The overall effect on the audio in the case of a current overload is quite similar to a voltage-clipping event, where power is temporarily limited at the peaks of the musical signal and normal operation continues without disruption when the overload is removed. The TAS5514B-Q1 does not prematurely shut down in this condition. All four channels continue in play mode and pass signal.
- **Overcurrent Shutdown (OCSD)**—Under severe short-circuit events, such as a short to PVDD or ground, a peak-current detector is used, and the affected channel shuts down in 200  $\mu$ s to 390  $\mu$ s if the conditions are severe enough. The shutdown speed depends on a number of factors, such as the impedance of the short circuit, supply voltage, and switching frequency. Only the shorted channels are shut down in such a scenario. An OCSD event activates the fault pin, and the affected channel(s) are placed in Hi-Z mode. Normal operation is restored 1 second after the short is removed. If the supply or ground short is strong enough to exceed the peak current threshold but not severe enough to trigger the OCSD, the peak current limiter prevents excess current from damaging the output FETs, and operation returns to normal after the short is removed.
- **DC Detect**—This circuit detects a dc offset continuously during normal operation at the output of the amplifier. If the dc offset reaches the trip level for 1 second, the circuit triggers and latches off the output. The FAULT pin is asserted. The only method to recover is to cycle the device into standby mode and back to play mode. If the dc offset is still present, it latches off again after 1 second.
- **Clip Detect**—The clip detect circuit alerts the user to the presence of a 100% duty-cycle PWM due to a clipped waveform. When this occurs, a signal is passed to the CLIP\_OTW pin, and this pin is asserted until the 100% duty-cycle PWM signal is no longer present. All four channels are connected to the same CLIP\_OTW pin.
- **Overtemperature Warning (OTW), Overtemperature Shutdown (OTSD), and Thermal Foldback**—By default, the CLIP\_OTW pin is set to indicate an OTW. The CLIP\_OTW pin is asserted when the die temperature reaches the warning level as shown in the electrical characteristics. The device still functions until the temperature reaches the OTSD threshold, at which time the outputs are placed into Hi-Z mode and the FAULT pin is asserted. After the OTSD recovers at the OTSD clear value, the device automatically returns to play mode. The OTW is still indicated until the temperature drops below warning level value. The thermal foldback decreases the channel gain.
- **Undervoltage (UV) and Power-On-Reset (POR)**—The undervoltage (UV) protection detects low voltages on PVDD, AVDD, and CP. In the event of an undervoltage, the FAULT pin is asserted. Power-on-reset (POR) occurs when PVDD drops low enough. Recovery from a POR event is the same as a transition from standby to play mode.
- **Overvoltage (OV) and Load Dump**—The OV protection detects high voltages on PVDD. If PVDD reaches the overvoltage threshold, the FAULT pin is asserted. The device can withstand 50-V load-dump voltage spikes. Also depicted in this graph are the voltage thresholds for normal operation region, overvoltage operation region, and load-dump protection region. [Figure 9](#) shows the regions of operating voltage and the profile of the load dump event.

## Power Supply

The power for the device is most commonly provided by a car battery that can have a large voltage range. PVDD is a filtered battery voltage, and it is the supply for the output FETs and the low-side FET gate driver. The high-side FET gate driver is supplied by a charge pump (CP) supply. The charge pump supplies the gate-drive voltage for all four channels. The analog circuitry is powered by AVDD, which is provided by an internal linear regulator. A 0.1- $\mu$ F/10V external bypass capacitor is needed at the A\_BYP pin for this supply. It is recommended that no external components except the bypass capacitor be attached to this pin. The digital circuitry is powered by DVDD, which is provided by an internal linear regulator. A 0.1- $\mu$ F/10V external bypass capacitor is needed at the D\_BYP pin. It is recommended that no external components except the bypass capacitor and CS encoding resistors be attached to this pin.

The TAS5514B-Q1 can withstand fortuitous open-ground and power conditions. Fortuitous open ground usually occurs when a speaker wire is shorted to ground, allowing for a second ground path through the body diode in the output FETs. The diagnostic capability allows the speakers and speaker wires to be debugged, eliminating the need to remove the amplifier to diagnose the problem.

## Oscillator Master/Slave Operation

The TAS5514B includes a single pin that allows for multiple devices to work together in a system with no additional hardware required for synchronization. The CS pin sets the device in master or slave mode. Connect the CS pin to GND for master mode, but no clock is on available on the OSC\_SYNC pin. Connect the CS pin to 1.2 Vdc for a master mode with a clock on the OSC\_SYNC pin, and to D\_BYP for slave mode. In slave mode, the OSC\_SYNC pin accepts a clock signal from a master device or external clock. The outputs cease to switch if an oscillator is not present on the OSC\_SYNC pin while in slave mode.

**Table 2. Table 7. CS Pin Connection**

DESCRIPTION	CS PIN CONNECTION
TAS5514B-Q1 (master without clock)	To SGND pin
TAS5514B-Q1 (master with clock)	35% DVDD (resistive voltage divider between D_BYP pin and SGND pin) <sup>(1)</sup>
TAS5514B-Q1 (slave)	To D_BYP pin

(1)  $R_{CS}$  with 5% or better tolerance is recommended.

## Hardware Control Pins

There are four discrete hardware pins for real-time control and indication of device status.

$\overline{\text{FAULT}}$  pin: This active-low open-drain output pin indicates the presence of a fault condition that requires the device to go into the Hi-Z mode or standby mode. When this pin is asserted, the device has protected itself and the system from potential damage. However, the fault is still indicated due to the fact that the  $\overline{\text{FAULT}}$  pin is asserted. When the fault is removed, the device transitions from standby mode to play mode.

$\overline{\text{CLIP\_OTW}}$  pin: This active-low open-drain pin is configured to indicate both overtemperature warning and the detection of clipping.

$\overline{\text{MUTE}}$  pin: This active-low pin is used for hardware control of the mute/unmute function for all four channels. Capacitor  $C_{\text{MUTE}}$  is used to control the time constant for the gain ramp needed to produce a pop- and click-free mute function. The use of a hard mute with an external transistor does not ensure pop- and click-free operation, and is not recommended unless an *emergency hard mute* function is required. The  $C_{\text{MUTE}}$  capacitor may not be shared between multiple devices.

$\overline{\text{STANDBY}}$  pin: When this active-low pin is asserted, the device goes into a complete shutdown, and current draw is limited to 2  $\mu\text{A}$ , typical. It can be used to shut down the device rapidly. If all channels are in Hi-Z, the device enters standby in approximately 1 ms, and if not, a quick rampdown occurs that takes approximately 20 ms. The outputs are ramped down quickly if not already in Hi-Z, so externally biasing the  $\overline{\text{MUTE}}$  pin prevents the device from entering standby.

## EMI Considerations

Automotive-level EMI performance depends on both careful integrated circuit design and good system-level design. Controlling sources of electromagnetic interference (EMI) was a major consideration in all aspects of the design.

The design has minimal parasitic inductances due to the short leads on the package. This dramatically reduces the EMI that results from current passing from the die to the system PCB. Each channel also operates at a different phase to reduce EMI caused by high-current switching. The design also incorporates circuitry that optimizes output transitions that cause EMI.

## Operating Modes and Faults

The operating modes and faults are depicted in the following tables.

**Table 3. Operating Modes**

STATE NAME	OUTPUT FETS	CHARGE PUMP	OSCILLATOR	AVDD and DVDD
STANDBY	Hi-Z, floating	Stopped	Stopped	OFF
Hi-Z	Hi-Z, weak pulldown	Active	Active	ON
Mute	Switching at 50%	Active	Active	ON
Normal operation	Switching with audio	Active	Active	ON

**Table 4. Global Faults and Actions**

FAULT/ EVENT	FAULT/EVENT CATEGORY	MONITORING MODES	REPORTING METHOD	ACTION TYPE	ACTION RESULT	LATCHED/ SELF- CLEARING
POR	Voltage fault	All	$\overline{\text{FAULT}}$ pin	Hard mute (no ramp)	Standby	Self-clearing
UV		Hi-Z, mute, normal	$\overline{\text{FAULT}}$ pin		Hi-Z	
CP UV						
OV						
Load dump		All	$\overline{\text{FAULT}}$ pin		Standby	
OTW	Thermal warning	Hi-Z, mute, normal	$\overline{\text{CLIP\_OTW}}$ pin	None	None	
OTSD	Thermal fault	Hi-Z, mute, normal	$\overline{\text{FAULT}}$ pin	Hard mute (no ramp)	Standby	

**Table 5. Channel Faults and Actions**

FAULT/ EVENT	FAULT/EVENT CATEGORY	MONITORING MODES	REPORTING METHOD	ACTION TYPE	ACTION RESULT	LATCHED/ SELF- CLEARING
Open/short diagnostic	Diagnostic at turnon	Hi-Z	Channel does not play	None	None	Self-clearing
Clipping	Warning	Play	$\overline{\text{CLIP\_OTW}}$ pin	None	None	
CBC load current limit	Online protection		Current Limit	Start OC timer		
OC fault	Output channel fault		$\overline{\text{FAULT}}$ pin	Hard mute	Hi-Z	
DC detect			Hard mute	Hi-Z	Latched	
OT Foldback	Warning		$\overline{\text{CLIP\_OTW}}$ pin	Reduce Gain	None	None



### Audio Shutdown and Restart Sequence

The gain ramp of the filtered output signal corresponds to the MUTE pin voltage during the ramping process. The length of time that the MUTE pin takes to complete its ramp is dictated by the value of the external capacitor on the MUTE pin. With the default 220-nF capacitor, the turnon common-mode ramp takes approximately 26ms and the gain ramp takes approximately 76 ms.

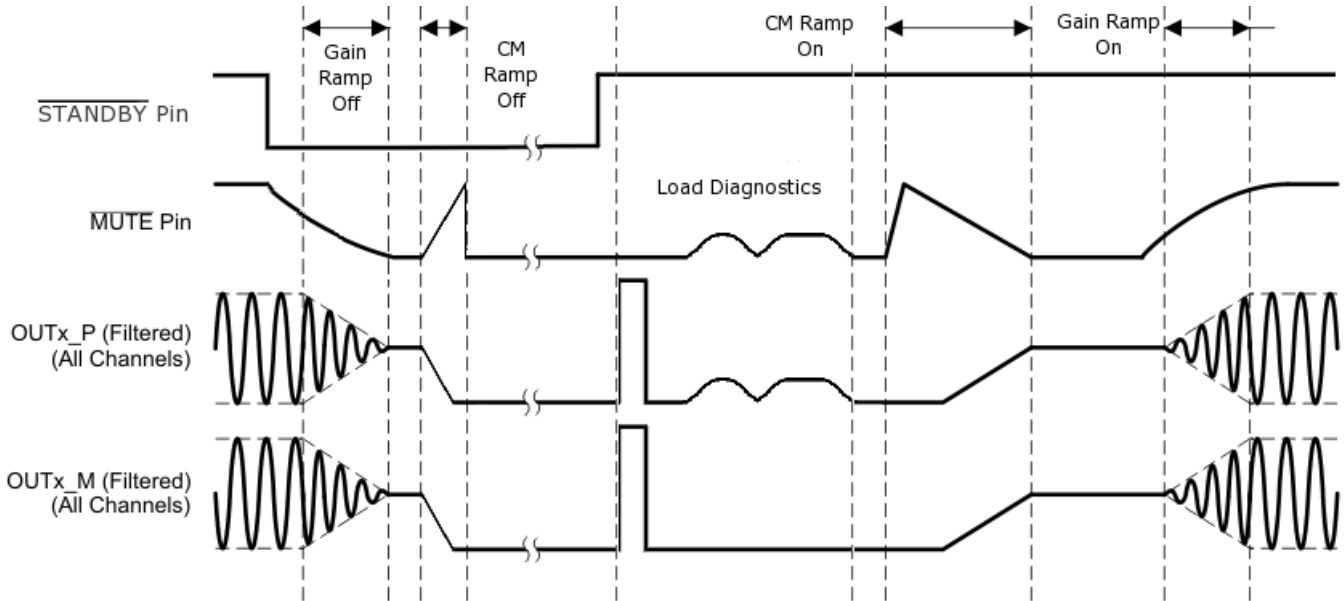


Figure 11. Click- and Pop-Free Shutdown and Restart Sequence Timing Diagram

### Fault Shutdown and Restart Sequence Control

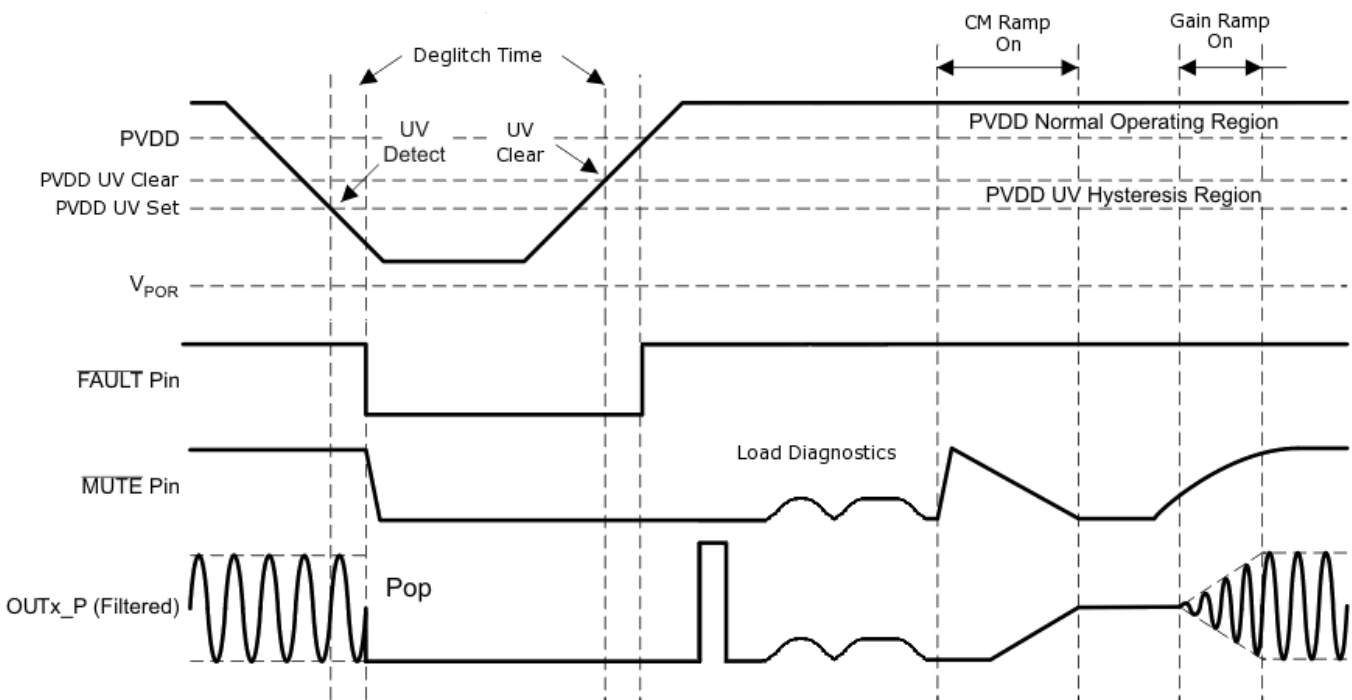
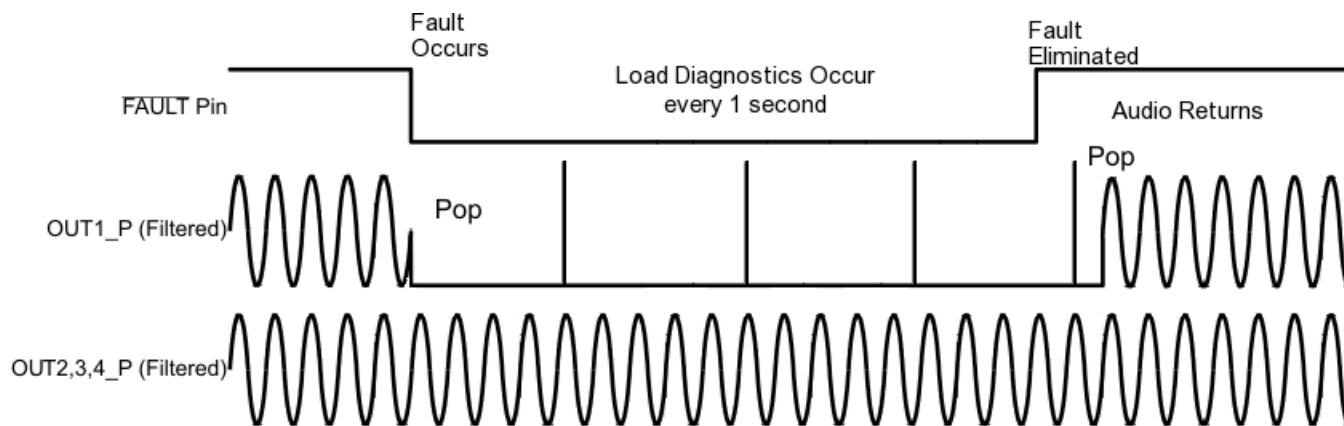


Figure 12. Global Fault Shutdown and Restart Diagram (UV Shutdown and Auto-Recovery)



**Figure 13. Channel-Fault Shutdown and Individual Channel Restart Diagram**

APPLICATION INFORMATION

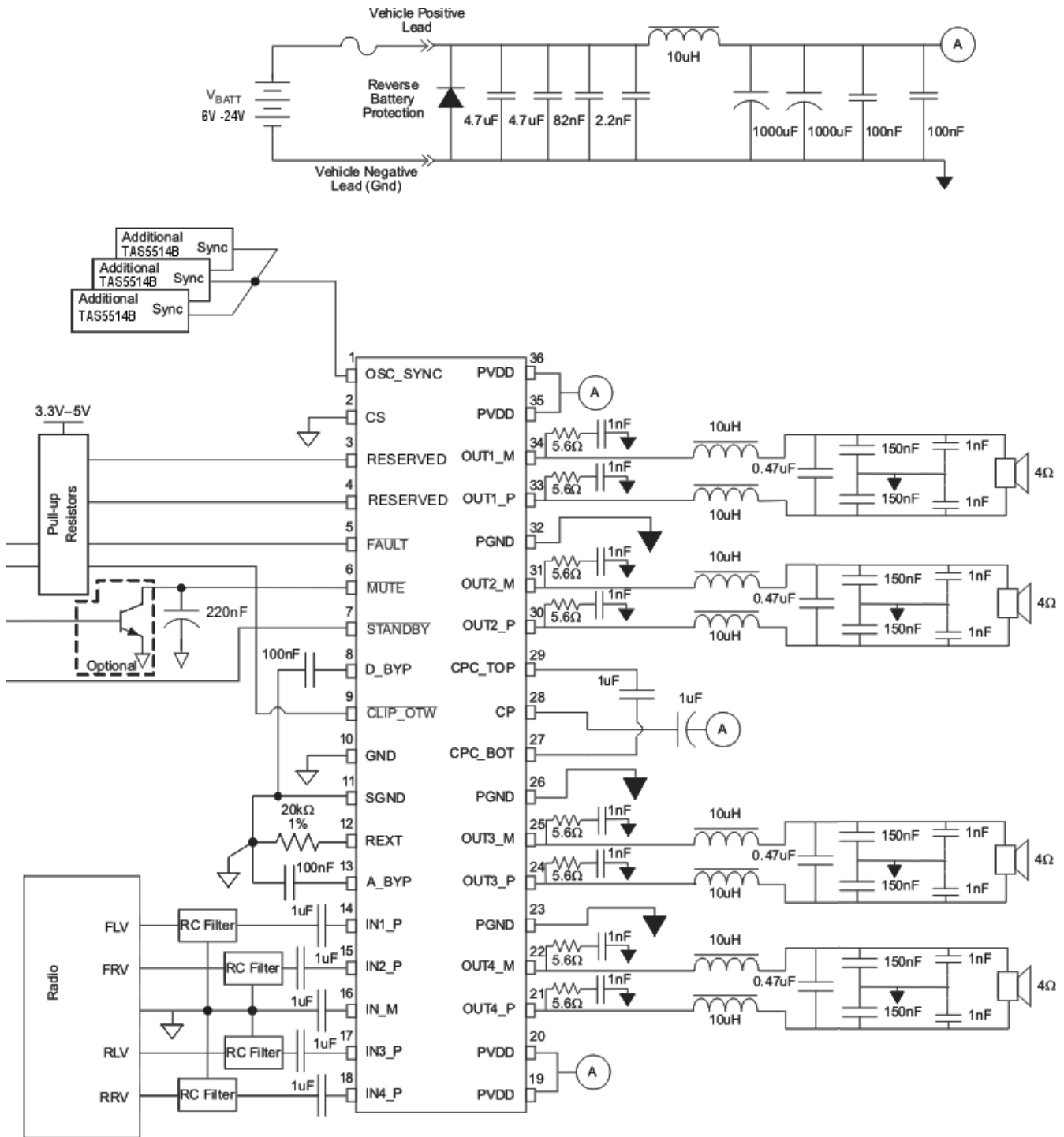


Figure 14. TAS5514B-Q1 Typical Application Schematic

## Parallel Operation (PBTL)

The device can drive more current paralleling BTL channels on the load side of the LC output filter. For parallel operation, identical I<sup>2</sup>C settings are required for any two paralleled channels in order to have reliable system performance and even power dissipation on multiple channels. For smooth power up, power down, and mute operation, the same control commands (such as mute, play, Hi-Z, etc.) should be sent to the paralleled channels at the same time. Load diagnostic is also supported for parallel connection. Paralleling on the device side of the LC output filter is not supported, and can result in device failure. When paralleling channels, it is important to monitor channels for thermal foldback and lower the system gain for paralleled channels.

## Input Filter Design

The input filter for the TAS5514B-Q1 IN\_M pin should have an impedance to GND that is equivalent to the parallel combination of the input impedances of all IN\_P channels combined, including any source impedance from the previous stage in the system design. For example, if each of the four IN\_P channels has a 1- $\mu$ F dc blocking capacitor, 1 k $\Omega$  of series resistance due to an input RC filter, and 1 k $\Omega$  of source resistance from the DAC supplying the audio signal, then the IN\_M channel should have a 4- $\mu$ F capacitor in series with a 500- $\Omega$  resistor to GND ( $4 \times 1 \mu\text{F}$  in parallel = 4  $\mu\text{F}$ ;  $4 \times 2 \text{ k}\Omega$  in parallel = 500  $\Omega$ ).

## Demodulation Filter Design

The amplifier outputs are driven by high-current LDMOS transistors in an H-bridge configuration. These transistors are either fully off or on. The result is a square-wave output signal with a duty cycle that is proportional to the amplitude of the audio signal. It is recommended that a second-order LC filter be used to recover the audio signal. The main purpose of the demodulation filter is to attenuate the high-frequency components of the output signals that are out of the audio band. Design of the demodulation filter significantly affects the audio performance of the power amplifier. Therefore, to meet the system THD+N needs, the selection of the inductors used in the output filter should be carefully considered. The rule is that the inductance should stay above 10% of the inductance value within the range of peak current seen at maximum output power in the system design.

## Line Driver Applications

In many automotive audio applications, the end user would like to use the same head unit to drive either a speaker (with several ohms of impedance) or an external amplifier (with several kilohms of impedance). The design is capable of supporting both applications; however, the output filter and system must be designed to handle the expected output load conditions.

## Thermal Information

The thermally augmented package is designed to interface directly to heat sinks using a thermal interface compound (for example, Arctic Silver or Ceramique thermal compound). The heat sink then absorbs heat from the ICs and couples it to the local air. If proper thermal management is applied, a proper operating temperature can be maintained the heat can be continually removed from the ICs. Because of the device efficiency, heat sinks can be smaller than those required for linear amplifiers of equivalent performance.

$R_{\theta JA}$  is a system thermal resistance from junction to ambient air. As such, it is a system parameter with the following components:

- $R_{\theta JC}$  (the thermal resistance from junction to case, or in this case the heat slug)
- Thermal grease thermal resistance
- Heat sink thermal resistance

The thermal grease thermal resistance can be calculated from the exposed heat slug area and the thermal grease manufacturer's area thermal resistance (expressed in  $^{\circ}\text{C}\text{-in}^2/\text{W}$  or  $^{\circ}\text{C}\text{-mm}^2/\text{W}$ ). The area thermal resistance of the example thermal grease with a 0.001-inch (0.0254-mm) thick layer is about  $0.007^{\circ}\text{C}\text{-in}^2/\text{W}$  ( $4.52^{\circ}\text{C}\text{-mm}^2/\text{W}$ ). The approximate exposed heat slug size is as follows:

36-pin PSOP3

0.124 in<sup>2</sup> (80 mm<sup>2</sup>)



**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
TAS5514BTDKDRQ1	ACTIVE	HSSOP	DKD	36	500	RoHS & Green	NIPDAU	Level-3-245C-168 HR	-40 to 105	TAS5514BQ1	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.

**OBSOLETE:** 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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## TAPE AND REEL INFORMATION



### QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TAS5514BTDKDRQ1	HSSOP	DKD	36	500	330.0	24.4	14.7	16.4	4.0	20.0	24.0	Q1

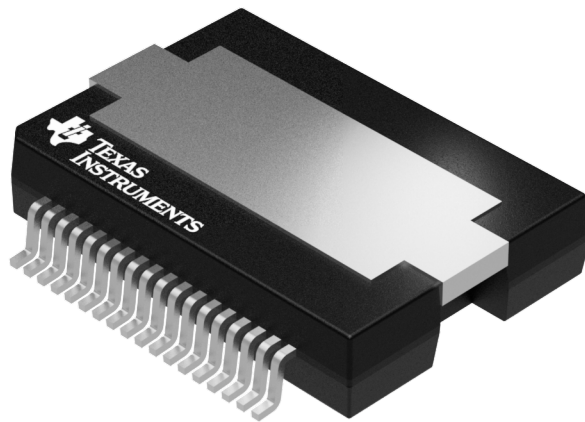
TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

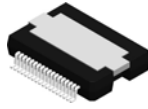
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TAS5514BTDKDRQ1	HSSOP	DKD	36	500	350.0	350.0	43.0





Images above are just a representation of the package family, actual package may vary.  
Refer to the product data sheet for package details.

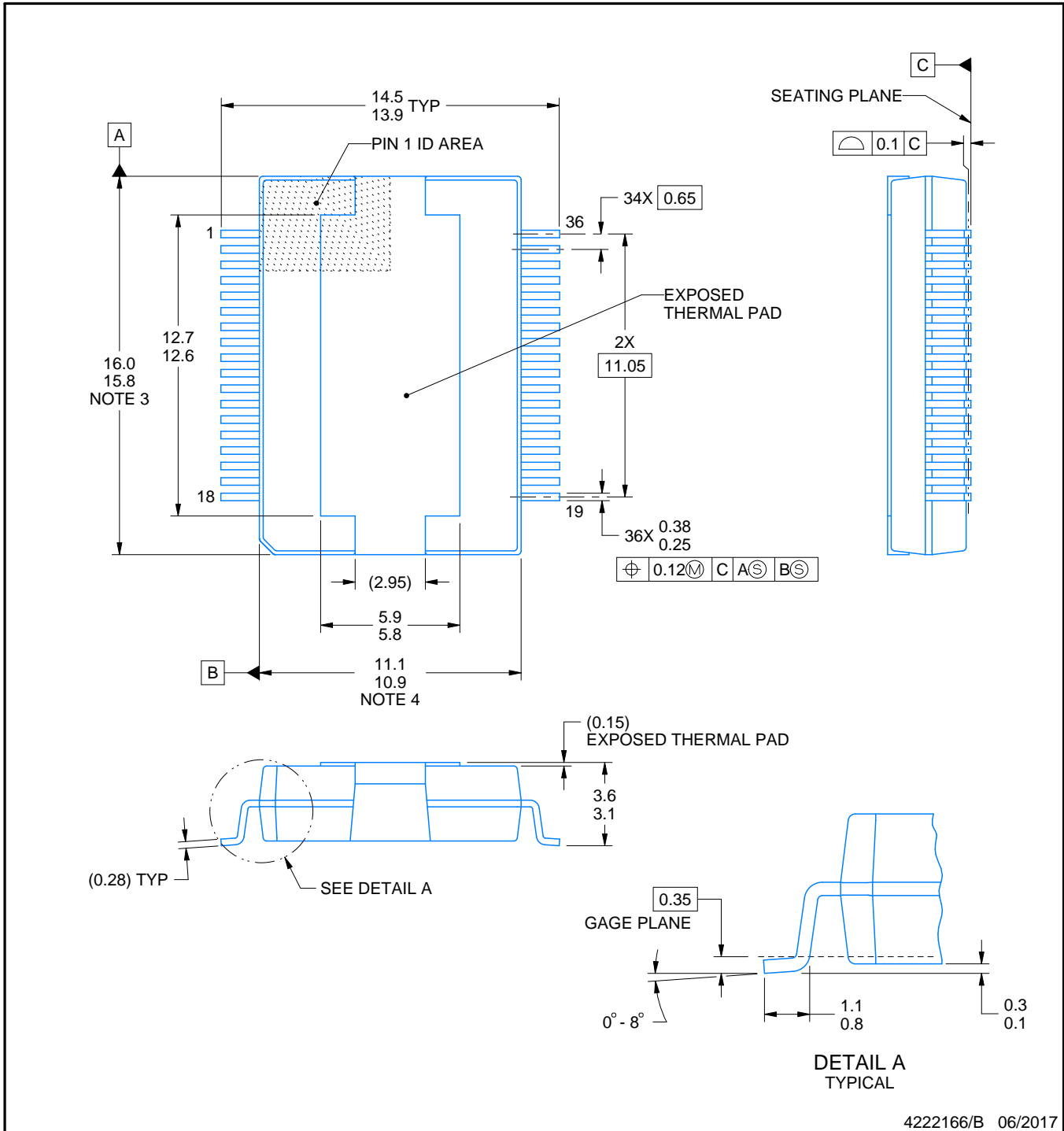
DKD0036A



PACKAGE OUTLINE

PowerPAD™ SSOP - 3.6 mm max height

PLASTIC SMALL OUTLINE



4222166/B 06/2017

NOTES:

PowerPAD is a trademark of Texas Instruments.

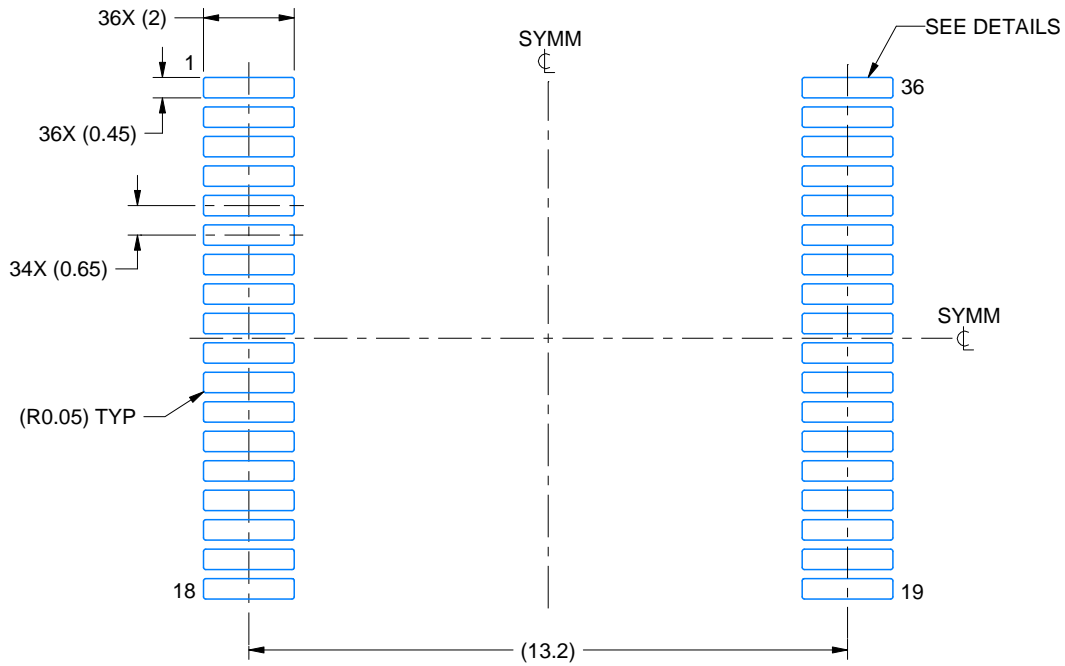
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. The exposed thermal pad is designed to be attached to an external heatsink.

# EXAMPLE BOARD LAYOUT

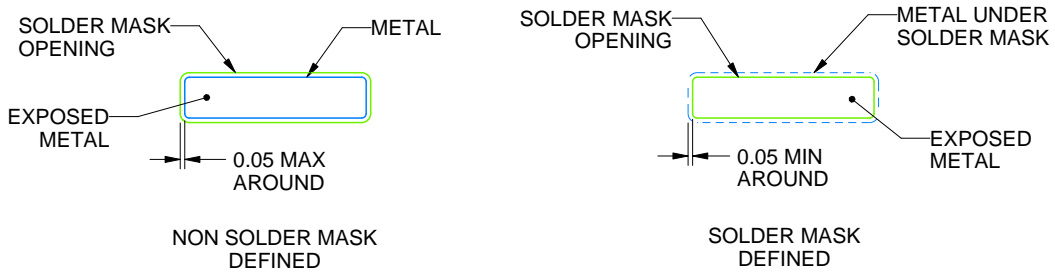
DKD0036A

PowerPAD™ SSOP - 3.6 mm max height

PLASTIC SMALL OUTLINE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:6X



SOLDER MASK DETAILS  
NOT TO SCALE

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NOTES: (continued)

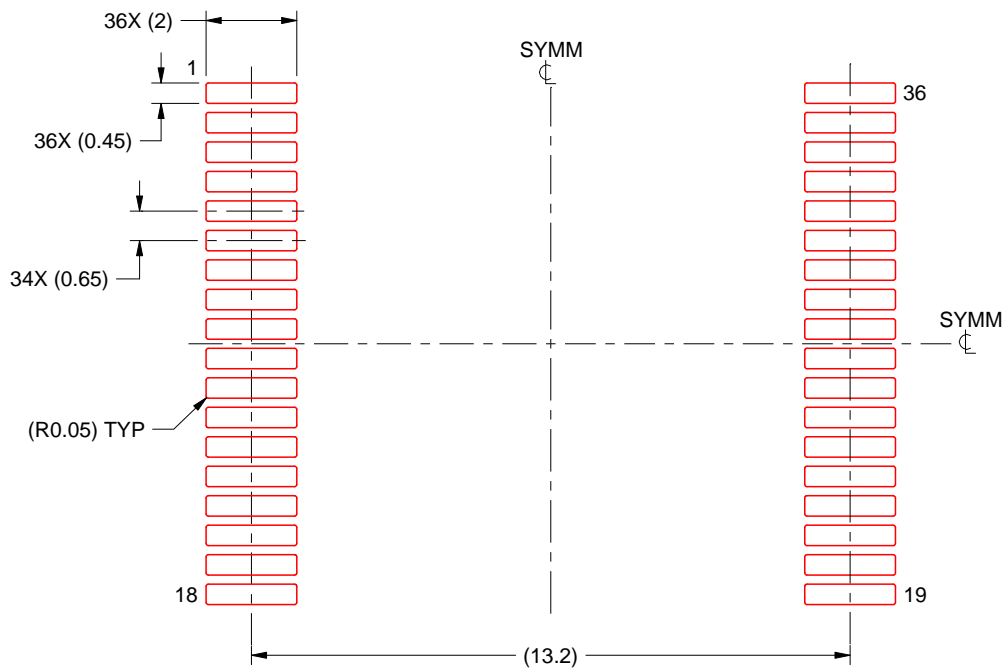
- 5. Publication IPC-7351 may have alternate designs.
- 6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

DKD0036A

PowerPAD™ SSOP - 3.6 mm max height

PLASTIC SMALL OUTLINE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 MM THICK STENCIL  
SCALE:6X

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NOTES: (continued)

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

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