TPA2092 PROTECTED DIGITAL AUDIO AMPLIFIER

1 Features

- Integrated analog input Class D audio amplifier driver in a small 16 pin package
- Error amplifier open loop gain > 60dB
- Programmable bidirectional over-current protection with self-reset function
- External 5V reference voltage output, low voltage side overcurrent protection threshold programmable
- Programmable timing of protected signal duration
- Programmable preset deadtime for improved THD performances
- Start and stop click noise reduction
- Integrated multi-voltage domain undervoltage protection and overvoltage clamp protection
- High noise immunity：> 50 V/ns
- ±150 V ratings deliver up to 500 W in output power
- Operates up to 800KHz
- Wide temperature range：-40 ℃ ~125 ℃
- Dynamical electrical characteristics：
  - High and low side propagation delay：350/335ns
  - OC protection delay (max)：500ns
  - Shutdown propagation delay (max)：250ns
- Output high short circuit current (Source/Sink) up to 2A
- RoHS compliant

2 RoHS compliant

- Motor Control
- Air Conditioners/ Washing Machines
- General Purpose Inverters
- Micro/Mini Inverter Drives

3 Description

The TPA2092 is a high voltage, high performance Class D audio amplifier driver with PWM modulator and protection, Design of Class D audio amplifier system for large output power.

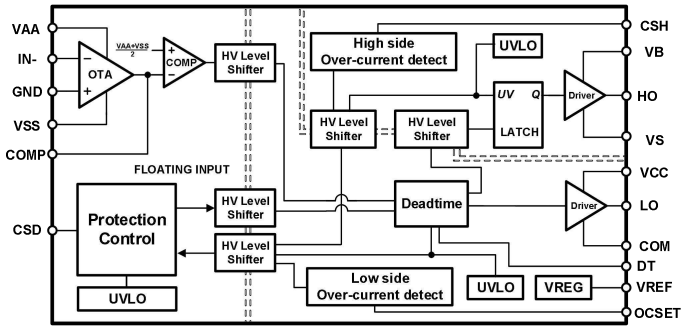
Integrated analog power amplifier, PWM wave modulation circuit, high and low voltage side overcurrent protection function (for high and low voltage side two power devices), anti-straight-through dead zone logic and three voltage domains （VAA~VSS / VCC~COM / VB~VS）, The product adopts flexible and open topology structure to realize PWM modulation function.

TPA2092 Integrated "click" sound cancellation during startup and shutdown to suppress unnecessary auditory noise during PWM signal startup and shutdown. A complete Class D audio power amplifier can be realized with a power bridge circuit and a few passive components.

Device information

Part Number	Package	Body size
TPA2092	SOIC16 (S)	9.9 mm X 3.9 mm

Functional Block Diagram



4 Ordering Guide

Part Number	LOGO	Package	Package	SPQ
TPA2092	A2092 XXXXXX	SOIC16(S)	Tape & Reel	4000

5 Revision history

Version	Content	Time
V1.0	Create	2021.11.29
V2.0	Product features and application information	2022.03.05

6 Function Pin Description

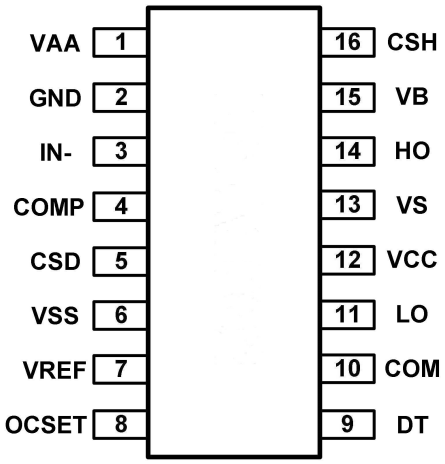


Figure6-1 16-Pin SOIC Top view

Table6-1 Lead Definitions

PIN NO.	Name	Type	Function
1	VAA	POWER	Floating input positive supply
2	GND	GROUND	Floating input supply return
3	IN-	INPUT	Analog inverting input
4	COMP	OUTPUT	Phase compensation input, comparator input
5	CSD	IN/OUTPUT	Shutdown timing capacitor
6	VSS	POWER	Floating input negative supply
7	VREF	OUTPUT	5V reference voltage to program OCSET pin
8	OCSET	INPUT	Low side over current threshold setting
9	DT	INPUT	Deadtime program input
10	COM	GROUND	Low side supply return
11	LO	OUTPUT	Low side output
12	VCC	POWER	Low side supply
13	VS	GROUND	High side floating supply return
14	HO	OUTPUT	High side output
15	VB	POWER	High side floating supply
16	CSH	INPUT	High side over current sensing input

7 Product specifications

7.1 Absolute Maximum Ratings

Absolute Maximum Ratings indicate sustained limits beyond which damage to the device may occur. All voltage parameters are absolute voltages referenced to COM; all currents are defined positive into any lead. The Thermal Resistance and Power Dissipation ratings are measured under board mounted and still air conditions.

Symbol	Definition	MIN.	MAX.	Units
V_B	High side floating supply voltage	-0.3	320	V
V_S	High side floating supply voltage II	V_B - 20	V_B + 0.3	
V_{HO}	High side floating output voltage	V_S -0.3	V_B + 0.3	
V_{CSH}	CSH pin input voltage	V_S -0.3	V_B + 0.3	
V_{CC}	Low side fixed supply voltage II	-0.3	20	
V_{LO}	Low side output voltage	-0.3	V_{CC} + 0.3	
V_{AA}	Floating input positive supply voltage II	See I_{AAZ}	310	
V_{SS}	Floating input negative supply voltage II	-1 See I_{SSZ}	GND+0.3	
V_{GND}	Floating input supply ground voltage	V_{SS}-0.3 (See I_{SSZ})	V_{AA}+0.3 (See I_{SSZ})	
I_{IN-}	Inverting input current I	—	±3	mA
V_{CSD}	CSD pin input voltage	V_{SS}-0.3	V_{AA}+0.3	V
V_{COMP}	COMP pin input voltage	V_{SS}-0.3	V_{AA}+0.3	
V_{DT}	DT pin input voltage	-0.3	V_{CC}+0.3	
V_{OCSET}	OCSET pin input voltage	-0.3	V_{CC}+0.3	
I_{AAZ}	Floating input positive supply zener clamp current II	—	20	mA
I_{SSZ}	Floating input negative supply zener clamp current II	—	20	
I_{CCZ}	Low side supply zener clamp current III	—	10	
I_{BSZ}	Floating supply zener clamp current III	—	10	
I_{OREF}	Reference output current	—	5	
dV_S/dt	Allowable Vs voltage slew rate	—	50	V/ns
dVss/dt	Allowable Vss voltage slew rate III	—	50	V/ms

I IN- contains clamping diode to GND.

II VAA-GND, GND-VSS, VCC-COM and VB-VS contain internal shunt zener diodes. Please note that the voltage ratings of these can be limited by the clamping current.

III For the rising and falling edges of step signal of 10V. VSS=15V to 300V

7.2 ESD rating

Symbol	Definition	MIN.	MAX.	Units
ESD	HBM Model	750	—	V
	Machine Model	200	—	V

7.3 Rated power

Symbol	Definition	MIN.	MAX.	Units
P_D	Package Power Dissipation @ TA ≤25°C	—	1	W

7.4 Thermal information

Symbol	Definition	MIN.	MAX.	Units
Rth_{JA}	Thermal Resistance, Junction to Ambient	—	115	°C /W
T_J	Junction Temperature	—	150	°C
T_S	Storage Temperature	-55	150	
T_L	Lead Temperature (Soldering, 10 seconds)	—	300	

7.5 Recommended Operating Conditions

For proper operation, the device should be used under the following recommended conditions. The bias ratings of VS and VSS are measured at a supply voltage of 15V, and unless otherwise specified, the ratings of all voltage parameters are referenced to VSS and the ambient temperature is 25°C.

Symbol	Definition	MIN.	MAX.	Units
V_B	High side floating supply absolute voltage	V_S +10	V_S +18	V
V_S	High side floating supply offset voltage	— I	300	
I_{AAZ}	Floating input positive supply clamp current	1	11	mA
I_{SSZ}	Floating input negative supply clamp current	1	11	
V_{SS}	Floating input supply absolute voltage	0	300	V
V_{HO}	High side floating output voltage	V_S	V_B	
V_{CC}	Low side fixed supply voltage	10	18	
V_{LO}	Low side output voltage	0	V_{CC}	
V_{GND}	GND pin input voltage	V_{SS} III	V_{AA} III	
V_{IN-}	Inverting input voltage	V_{GND}-0.5	V_{GND}+0.5	
V_{CSD}	CSD pin input voltage	V_{SS}	V_{AA}	
V_{COMP}	COMP pin input voltage	V_{SS}	V_{AA}	
C_{COMP}	COMP pin phase compensation capacitor to GND	1	—	nF
V_{DT}	DT pin input voltage	0	V_{CC}	V
I_{OREF}	Reference output current to COM II	0.3	0.8	mA
V_{OCSET}	OCSET pin input voltage	0.5	5	V
V_{CSH}	CSH pin input voltage	V_S	V_B	
dVss/dt	Allowable Vss voltage slew rate upon power-up IV	—	50	V/ms
I_{PW}	Input pulse width	10V	—	ns
f_{SW}	Switching Frequency	—	800	kHz
T_A	Ambient Temperature	-40	125	°C

I Logic operational for Vs equal to –5 V to +300 V. Logic state held for Vs equal to –5 V to $–V_{BS}$.

II Nominal voltage for V_{REF} is 5.1 V. I_{OREF} of 0.3 – 0.8 mA dictates total external resistor value on VREF to be 6.3 kΩ to 16.7 kΩ.

III GND input voltage is limited by I_{AAZ} and I_{SSZ}.

IV V_{SS} ramps up from 0 V to 300V。

V Output logic status may not respond correctly if input pulse width is smaller than the minimum pulse width.

7. 6 Electrical Characteristics

Valid for temperature range at TA= 25°C, V_{CC}=V_B= 15V, C_L=1nF, unless otherwise specified

7.6.1 Low side suply

Symbol	Definition	MIN.	TYP.	MAX.	Units	Test Condition
UV_{CC+}	Vcc supply UVLO positive threshold	8.40	8.90	9.40	V	
UV_{CC-}	Vcc supply UVLO negative threshold	8.20	8.70	9.20		
UV_{CCHYS}	UV_{CC} hysteresis	—	0.2	—		
I_{QCC}	Low side quiescent current	—	—	3	mA	V_{DT}=V_{CC}
V_{clampL}	Low side supply clamp voltage	19.6	20.4	21.6	V	I_{CC}=5mA

7.6.2 High Side Floating Supply

Symbol	Definition	MIN.	TYP.	MAX.	Units	Test Condition
UV_{BS+}	High side well UVLO positive threshold	8	8.5	9.0	V	
UV_{BS-}	High side well UVLO negative threshold	7.8	8.3	8.8		
UV_{BShys}	UV_{BS} hysteresis	—	0.2	—		
I_{QBS}	High side quiescent current	—	—	1	mA	
I_{LK}	High to Low side leakage current	—	—	50	uA	V_B=V_S=300V
V_{ClampH}	High side supply clamp voltage	19.6	20.4	21.6	V	I_{BS}=5mA

7.6.3 Floating Input Supply

Symbol	Definition	MIN.	TYP.	MAX.	Units	Test Condition
UV_{AA+}	VA+, VA- floating supply UVLO positive threshold from V_{SS}	8.2	8.7	9.2	V	V_{SS}=0, GND pin floating
UV_{AA-}	VA+, VA- floating supply UVLO negative threshold from V_{SS}	7.7	8.2	8.7		V_{SS}=0, GND pin floating
UV_{AAHYS}	UV_{AA} hysteresis	—	0.5	—		V_{SS}=0, GND pin floating
I_{QAA0}	Floating Input positive quiescent supply current	—	0.5	2	mA	V_{AA}=10V, V_{SS}=0V, V_{CSD}=VSS
I_{QAA1}	Floating Input positive quiescent supply current	—	8	11		V_{AA}=10V, V_{SS}=0V, V_{CSD}=V_{AA}
I_{QAA2}	Floating Input positive quiescent supply current	—	8	11		V_{AA}=10V, V_{SS}=0V, V_{CSD}=GND
I_{LKM}	Floating input side to Low side leakage current	—	—	50	uA	V_{AA}=V_{SS}=V_{GND}=100V
$V_{CLAMPM+}$	V_{AA} floating supply clamp voltage, positive, with respect to GND	6.0	7.0	8.0	V	I_{AA}=5mA，I_{SS}=5mA, V_{GND}=0，V_{CSD}=V_{SS}
$V_{CLAMPM-}$	V_{SS} floating supply clamp voltage, negative, with respect to GND	-8.0	-7.0	-6.0		I_{AA}=5mA，I_{SS}=5mA, V_{GND}=0，V_{CSD}=V_{SS}

7.6.4 Audio Input

Symbol	Definition	MIN.	TYP.	MAX.	Units	Test Condition
V_{OS}	Input offset voltage	-15	0	15	mV	
I_{BIN}	Input bias current	—	—	40	nA	
BW	Small signal bandwidth	—	9	—	MHz	C_{comp}=2nF， R_f=3.3k
G_m	OTA Output voltage	—	100	—	mS	V_{IN-}=5mV
G_v	OTA transconductance	60	—	—	dB	
V_{Nrms}	OTA input noise voltage	—	250	—	mVrms	BW=20 kHz, Resolution BW=22Hz
SR	Slew rate	—	±5	—	V/us	C_{comp}=1nF
CMRR	Common-mode rejection ratio	—	60	—	dB	
PSRR	Supply voltage rejection ratio	—	60	—	dB	

7.6.6 Protection

Symbol	Definition	MIN.	TYP.	MAX.	Units	Test Condition
V_{ref}	Reference output voltage	4.8	5.1	5.4	V	I_{oREF}=0.5mA
V_{thOCL}	Low side OC threshold in Vs	1.1	1.2	1.3		OCSET=1.2V
V_{thOCH}	High side OC threshold in V_{CSH}	1.1+V_S	1.2+V_S	1.3+V_S		
V_{th1}	CSD pin shutdown release threshold	0.62V_{AA}	0.7V_{AA}	0.78V_{AA}		
V_{th2}	CSD pin self reset threshold	0.26V_{AA}	0.30V_{AA}	0.34V_{AA}		
I_{CSD+}	CSD pin discharge current	70	100	130	uA	V_{CSD}=V_{SS}+5V
I_{CSD-}	CSD pin charge current	70	100	130		V_{CSD}=V_{SS}+5V
t_{sd}	Shutdown propagation delay from V_{CSD} > V_{SS} + V_{thOCH} to Shutdown	—	—	250	ns	
t_{och}	Propagation delay time from V_{CSH} > V_{thOCH} to Shutdown	—	—	500		
t_{ocl}	Propagation delay time from Vs> V_{thOCL} to Shutdown	—	—	500		

7.6.7 Gate Driver

Symbol	Definition	MIN.	TYP.	MAX.	Units	Test Condition
I_{O+}	Output high short circuit current (Source)	—	2	—	A	V_O=0V, PW<10us
I_{O-}	Output low short circuit current (Sink)	—	2	—		V_O=12V, PW<10us
V_{OL}	Low level out put voltage LO – COM, HO - VS	—	—	0.1	V	Io=0
V_{OH}	High level out put voltage VCC – LO, VB - HO	—	—	1.4		Io=0
t_{on}	High and low side turn-on propagation delay	—	360	—	ns	V_{DT}=V_{CC}
t_{off}	High and low side turn-off propagation delay	—	335	—		V_{DT}=V_{CC}
t_r	Turn-on rise time	—	20	50		
t_f	Turn-off fall time	—	15	35		
DT1	Deadtime: LO turn-off to HO turn on (DT_{LO-HO}) & HO turn-off to LO turn-on (DT_{HO-LO})	15	25	35		V_{DT}>V_{DT1}
DT2		25	40	55		V_{DT1}>V_{DT}>V_{DT2}
DT3		50	65	85		V_{DT2}>V_{DT}>V_{DT3}
DT4		85	105	135		V_{DT3}>V_{DT}

V_{DT1}	DT mode select threshold 2	0.51Vcc	0.57Vcc	0.63Vcc	V	
V_{DT2}	DT mode select threshold 3	0.32Vcc	0.36Vcc	0.40Vcc		
V_{DT3}	DT mode select threshold 4	0.21Vcc	0.23Vcc	0.25Vcc		

8 Waveform definitions

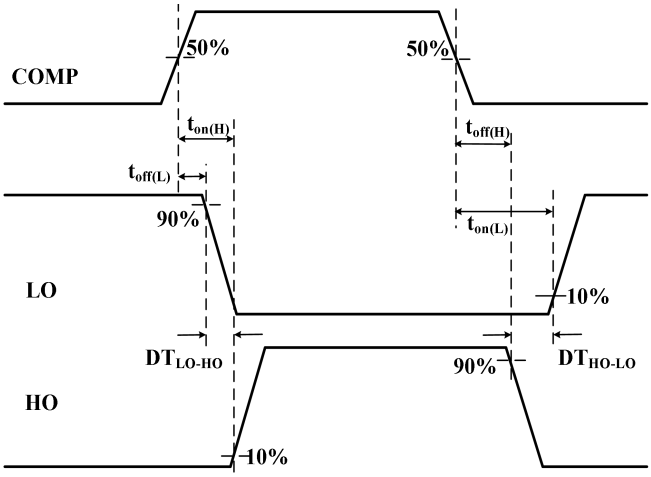


Figure 8-1. Switching Time Waveform Definitions

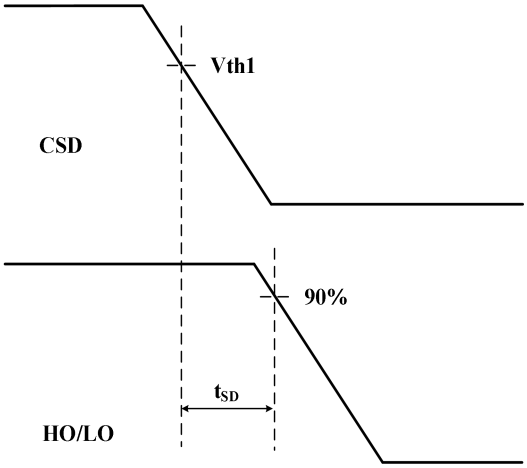


Figure 8-2. CSD to Shutdown Waveform Definitions

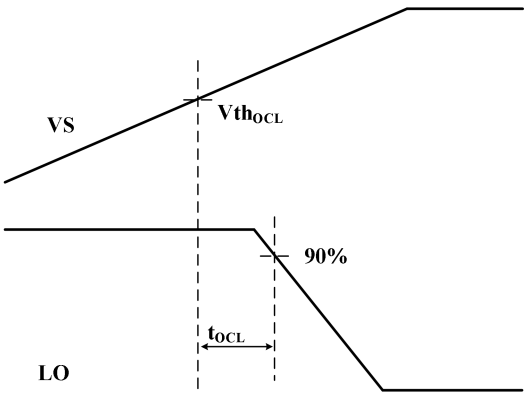


Figure 8-3. VS > VthOCL to Shutdown Waveform

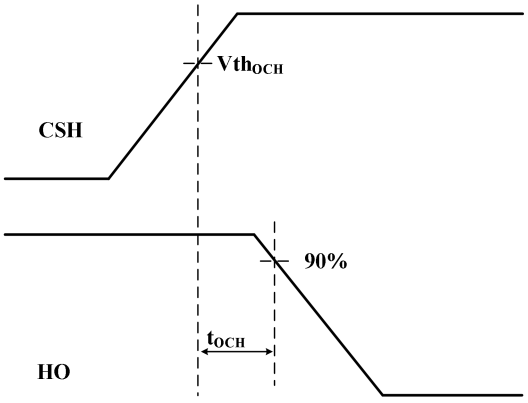


Figure 8-4. VCSH > VthOCH to Shutdown Waveform

9 Input/Output Pin Equivalent Circuit Diagrams

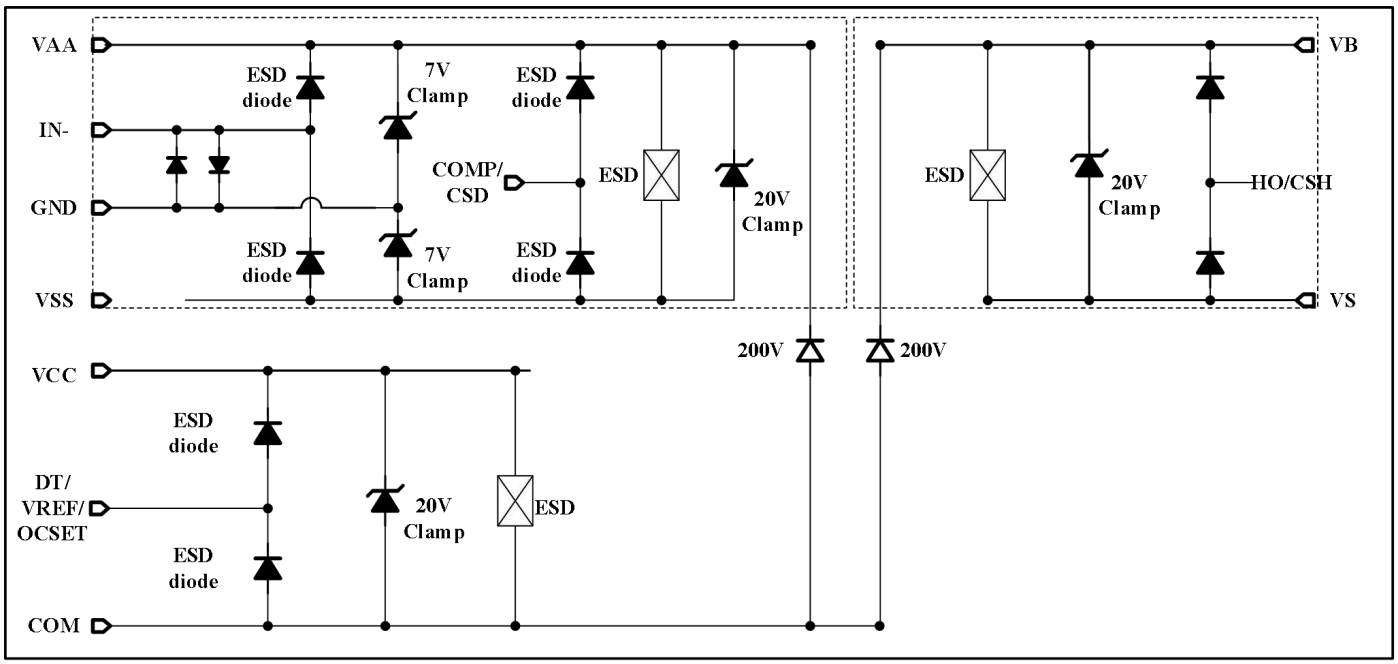


Figure 9-1 Input/Output Pin Equivalent Circuit

10 General Description

10.1 Functional Description

The TPA2092 is a Class D audio amplifier driver with integrated PWM modulator and over current protection. Combined with two external MOSFETs and a few external components, the TPA2092 forms a complete Class D amplifier with dual over current, and shoot-through protection, as well as UVLO protection for the three bias supplies. The versatile structure of the analog input section with an error amplifier and a PWM comparator has the flexibility of implementing different types of PWM modulator schemes.

Loss-less current sensing utilizes $R_{DS(on)}$ of the MOSFETs. The protection control logic monitors the status of the power supplies and load current across each MOSFET.

For the convenience of half bridge configuration, the analog PWM modulator and protection logic are constructed on a floating well.

The TPA2092 implements start-up click noise elimination to suppress unwanted audible noise during PWM start-up and shut-down.

10.2 Functional Block Diagram

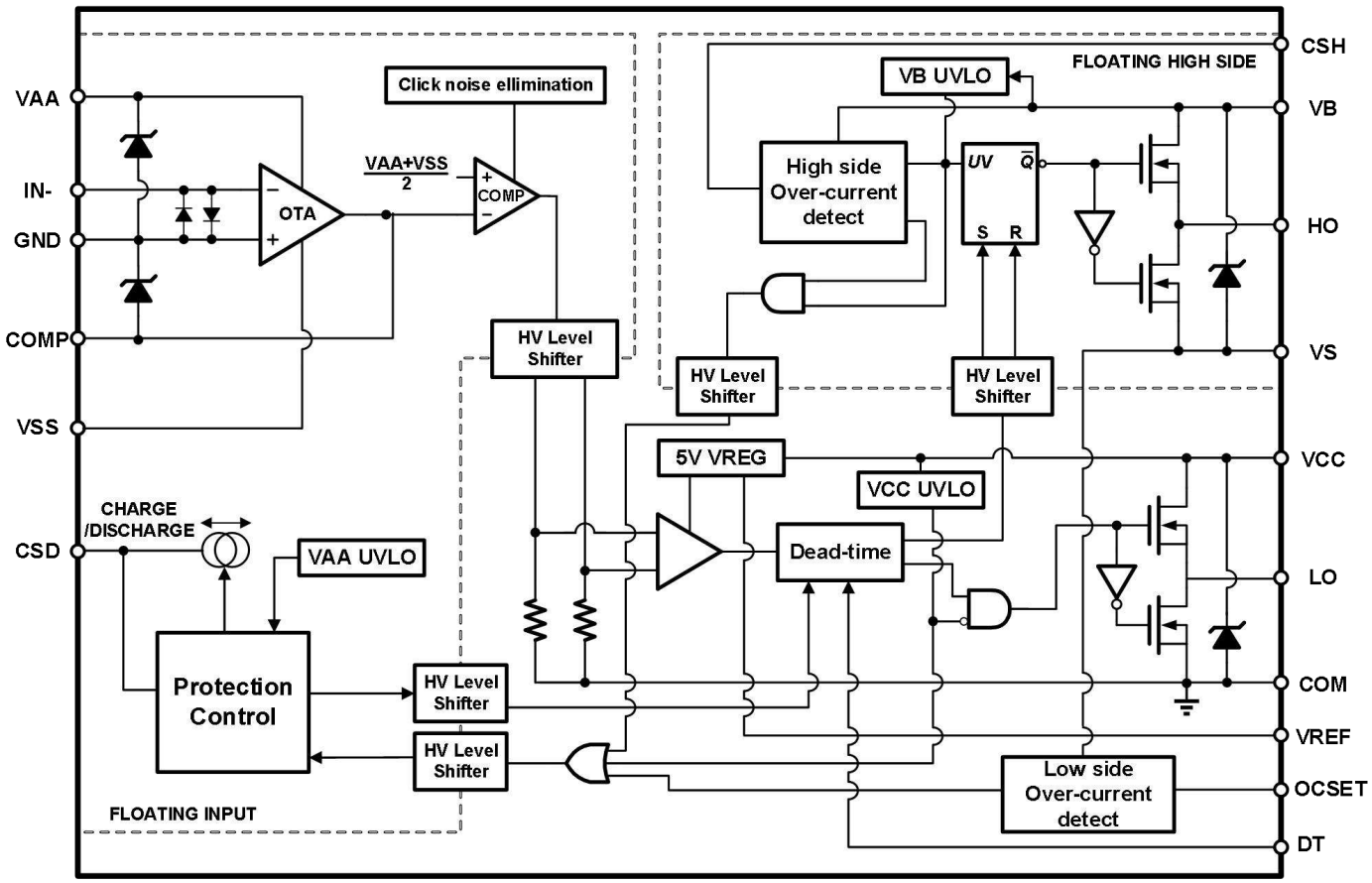


Figure10-1 Functional Block Diagram

10.3 Typical Connection Diagram

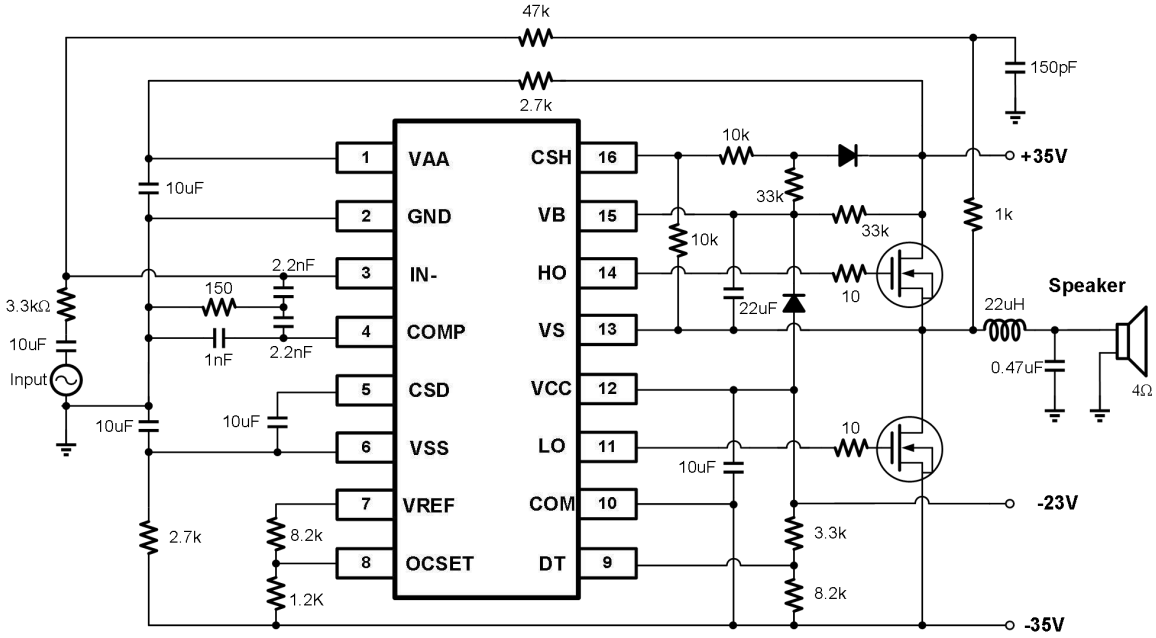


Figure10-2 Typical Connection Diagram

10.4 Typical Control Loop Design

The audio input stage of TPA2092 is configured as an inverting error amplifier. In Figure 10-3, the voltage gain of the amplifier GV is determined by input resistor RIN and feedback resistor R_{FB}.

$$Gv = \frac{R_{FB}}{R_{IN}}$$

Since the feedback resistor R_{FB} is part of an integrator time constant, which determines switching frequency, changing overall voltage gain by R_{IN} is simpler and, therefore, recommended in most cases. Note that the input impedance of the amplifier is equal to the input resistor R_{IN}.

A DC blocking capacitor C_{IN} should be connected in series with R_{IN} to minimize DC offset in the output. A ceramic capacitor is not recommended due to potential distortion. Minimizing DC offset is essential for audible noise-less Turn-ON and -OFF.

The connection of the non-inverting input IN+ is a reference for the error amplifier, and thus is crucial for audio performance. Connect IN+ to the signal reference ground in the system, which has same potential as the negative terminal of the speaker output.

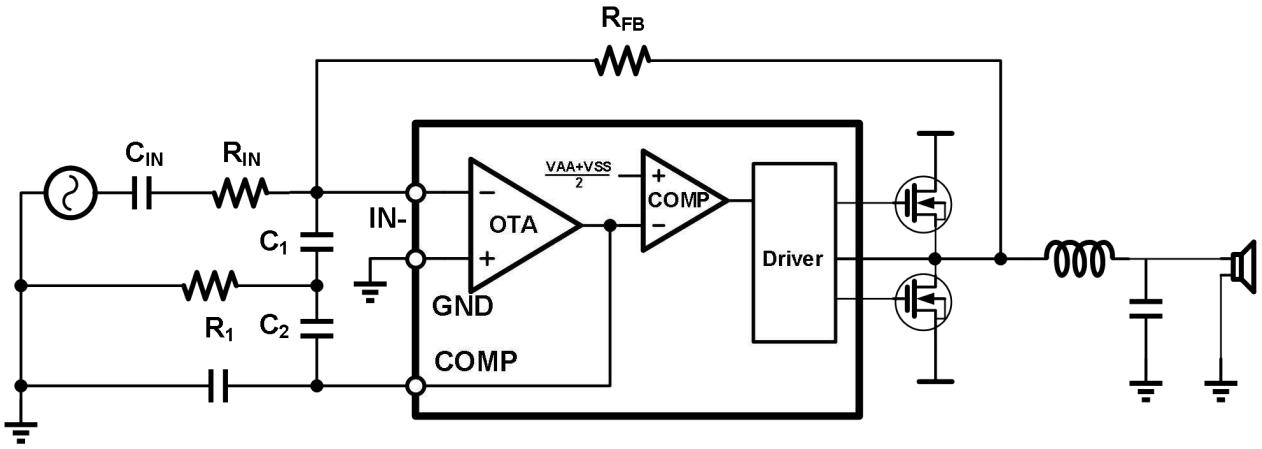


Figure10-3 Typical Control Loop Design

10.4.1 OTA

The front end error amplifier of the TPA2092 features an operational trans-conductance amplifier (OTA), which is carefully designed to obtain optimal audio performance. The OTA outputs a current output to the COMP pin, unlike a voltage output in an operational amplifier (OPA). The non-inverting input is internally tied to the GND pin.

The inverting input has clamping diodes to GND to improve recovery from clipping as well as ensuring stable start up.

The OTA output COMP is internally connected to the PWM comparator whose threshold is (VAA-VSS)/2.

For stable operation of the OTA, a compensation capacitor Cc minimum of 1nF is required.

The OTA is shut off when V_{CSD}<Vth2.

10.4.2 PWM Modulator

In this section, all the explanations are based on a typical application circuit of a self oscillating PWM. For better audio performance, 2 nd order integration in the front end is chosen. Self oscillating frequency is determined mainly by the following items in Figure 10-3.

- Integration capacitors, C1 and C2
- Integration resistor, R1
- Propagation delay in the gate driver
- Feedback resistor, R_{FB}
- Duty cycle

Self oscillating frequency has little influences from bus voltage and input resistance R_{IN}. Note that as is the nature of a self-oscillating PWM, the switching frequency decreases as PWM modulation deviates from idling.

Choosing switching frequency entails making a trade off between many aspects.

At lower switching frequency, the efficiency at MOSFET stage improves, but inductor ripple current increases. The output carrier leakage increases.

At higher switching frequency, the efficiency degrades due to switching loss, but wider bandwidth can be achieved. The inductor ripple decreases yet iron loss increases. The junction temperature of gate driver IC might be a stopper for going higher frequency.

10.5 Click Noise Elimination

TPA2092 has a unique feature that minimizes Turn-ON and -OFF audible click noise. When CSD is in between Vth1 and Vth2 during start up, an internal closed loop around the OTA enables an oscillation that generates voltages at COMP and IN-, bringing them to steady state values. It runs at around 1MHz, independent from the switching

oscillation.

As a result, all capacitive components connected to COMP and IN- pins, such as C1, C2, C3 and C_{IN} in Figure10-4, are pre-charged to their steady state values during the star up sequence. This allows instant settling of PWM operation.

To utilize the click noise reduction function, following conditions must be met.

（1）CSD pin has slow enough ramp up from Vth1 to Vth2 such that the voltages in the capacitors can settle to their target values.

（2）High side bootstrap power supply needs to be charged up prior to starting oscillation.

（3） Audio input has to be zero.

（4）For internal local loop to override external feedback during the startup period, DC offset at speaker output prior to shutdown release has to satisfy the following condition. DC_{offset}< 30uA * R_{FB}.

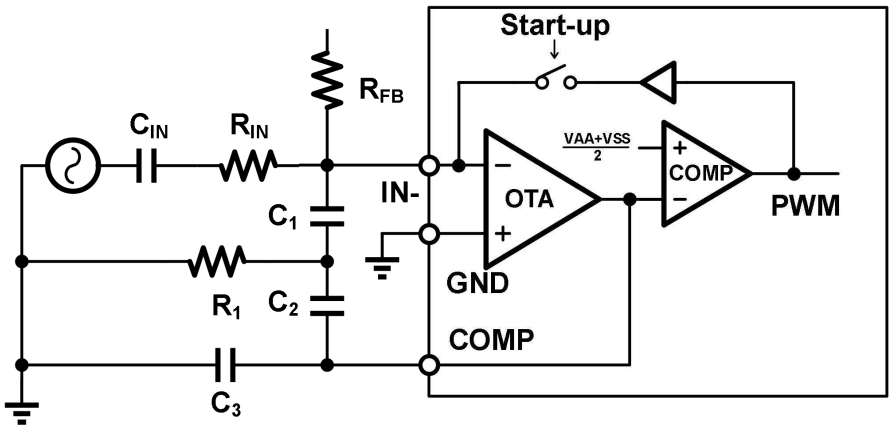


Figure10-4 Click Noise Elimination

10.6 CSD Voltage and OTA Operational Mode

The CSD pin determines the operational mode of the TPA2092. The OTA has three operational modes; cut off, local oscillation and normal operation while the gate driver section has two modes; normal and shutdown with CSD voltage.

When VCSD < Vth2, the IC is in shutdown mode and the OTA is cut off.

When Vth2< VCSD < Vth1, the HO and LO outputs are still in shutdown mode. The OTA is activated and starts local oscillation, which pre-biases all the capacitive components in the error amplifier.

When VCSD>Vth1, shutdown is released and PWM operation starts.

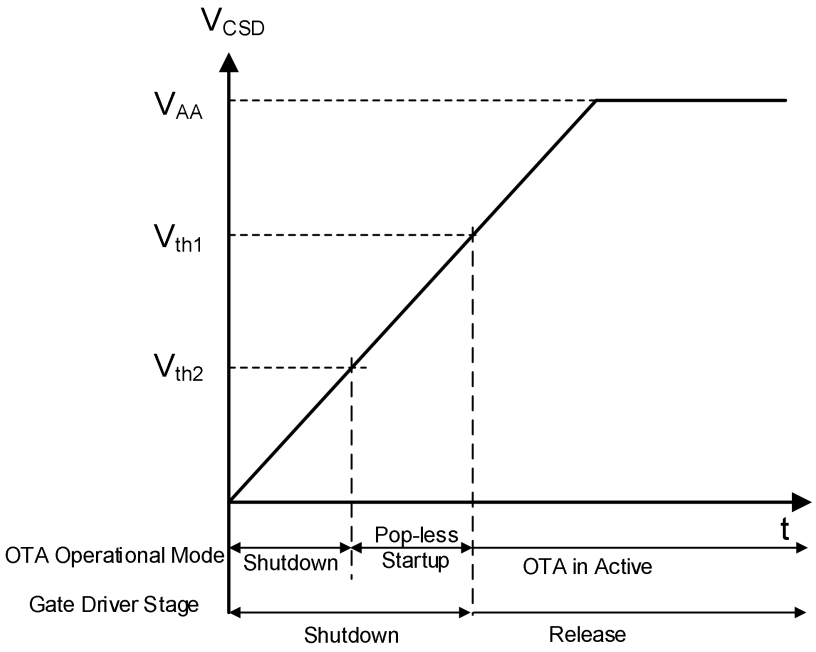


Figure10-5 V_{CSD} and OTA Mode

10.7 Over Current Protection

The TPA2092 . features over current protection to protect the power MOSFETs during abnormal load conditions. The TPA2092. starts a sequence of events when it detects an over current condition during either high side or low side turn on of a pulse.

As soon as either the high side or low side current sensing block detects over current：

（1）The OC Latch (OCL) flips logic states and shutdowns the outputs LO and HO.

（2）The CSD pin starts discharging the external capacitor Ct.

（3）When VCSD, the voltage across Ct, falls below the lower threshold Vth2, an output signal from COMP2 resets OCL.

（4）When VCSD goes above the upper threshold Vth1, the logic on COMP1 flips and the IC resumes operation.

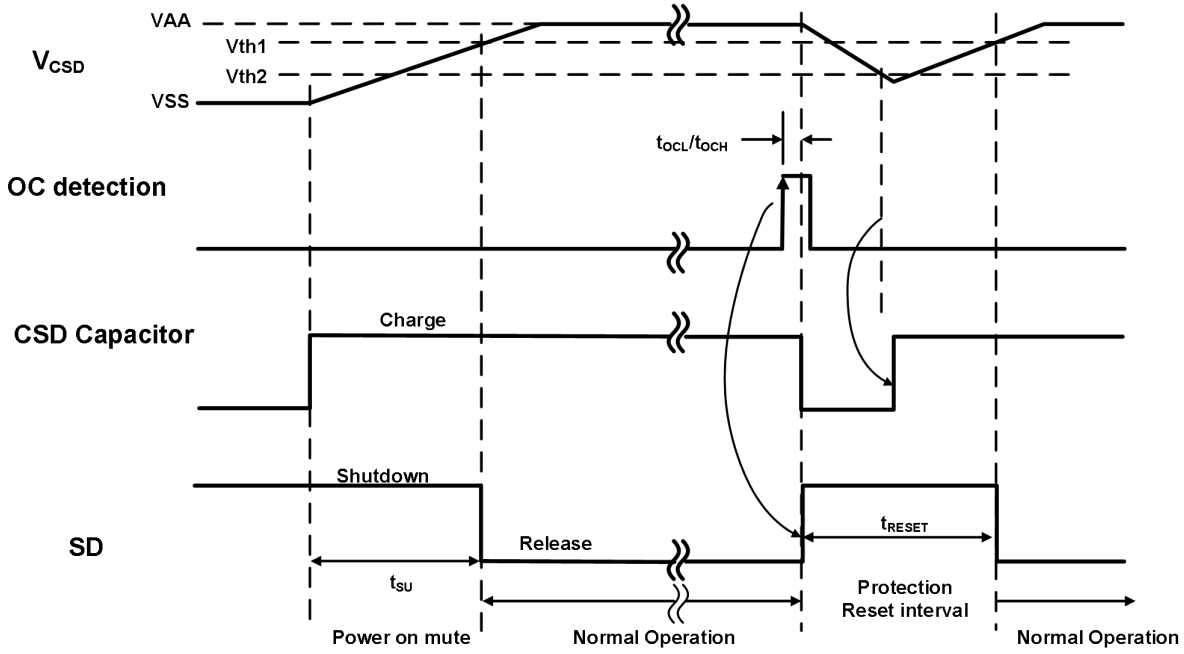


Figure10-6 Shutdown Functional Block Diagram

10.8 Programming Dead-Time

The TPA2092 selects the dead-time from a range of preset dead-time values based on the voltage applied at the DT pin.

When V_{DT} < 0.23VCC, DT = 105ns;

When 0.23VCC < V_{DT} < 0.36VCC, DT = 75ns;

When 0.36VCC < V_{DT} < 0.57VCC, DT = 45ns;

When 0.57VCC < V_{DT} < VCC, DT = 25ns.

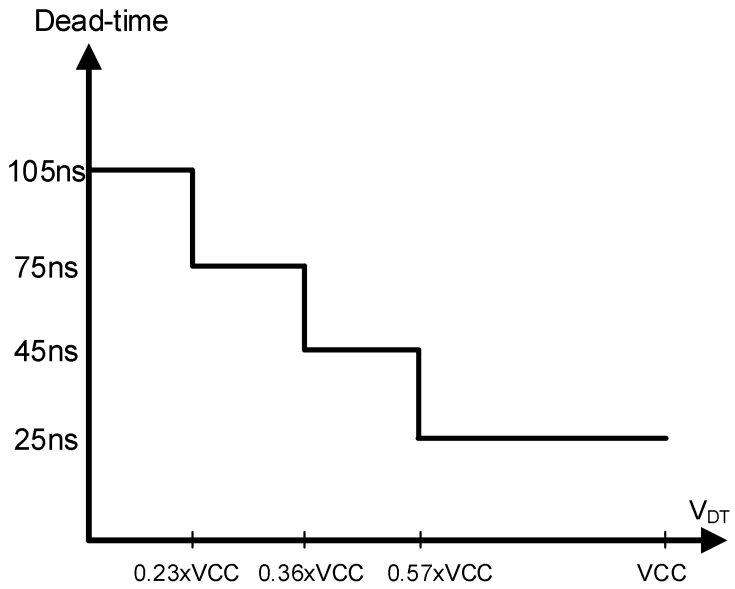


Figure10-6 Dead Time vs. V_{DT}

11 Package Information

SOIC16 Package Dimensions

Size / Symbol	MIN(mm)	TYP(mm)	MAX(mm)	Size / Symbol	MIN(mm)	TYP(mm)	MAX(mm)
A	-	-	1.75	D	9.70	9.90	10.10
A1	0.10	-	0.225	E	5.80	6.00	6.20
A2	1.30	1.40	1.50	E1	3.70	3.90	4.10
A3	0.60	0.65	0.70	e		1.27BSC	
b	0.39	-	0.48	L	0.25	-	0.50
b1	0.38	0.41	0.43	L1		1.4BSC	
c	0.21	-	0.26	θ	0	-	8°
c1	0.19	0.20	0.21				

SOIC16 Package Outlines