DOINGTER

DOS2092S

DOS2092S 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：360/335ns
    - OC protection delay (max)：500ns
    - Shutdown propagation delay (max)：250ns
- Output high short circuit current (Source/Sink) up to 1/1.2A
- RoHS compliant

2 Applications

- Home theater systems
- Mini component stereo systems
- Powered speaker systems
- General purpose audio power amplifiers

3 Description

The DOS2092S 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.
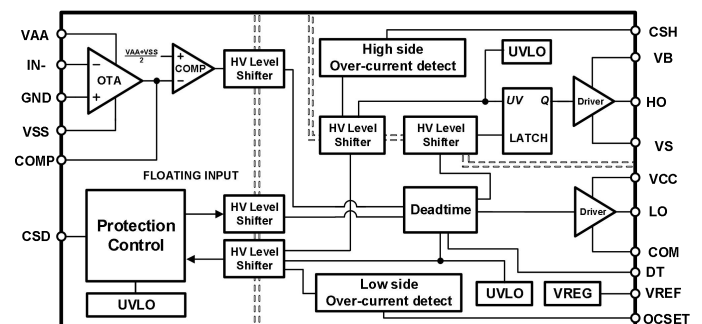
Integrated analog power amplifier, PWM wave modulation circuit, high and low voltage side overcurrent protection function (for high and low voltage side two power devices), anti-straight-through dead zone logic and three voltage domains （VAA~VSS / VCC~COM / VB~VS）, The product adopts flexible and open topology structure to realize PWM modulation function.

DOS2092S 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
DOS2092S	SOP16 (S)	9.9 mm X 3.9 mm

Functional Block Diagram

4 Function Pin Description

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            ┌─────────────┐
    VAA  1  │             │  16  CSH
    GND  2  │             │  15  VB
    IN-  3  │             │  14  HO
   COMP  4  │   DOS2092S  │  13  VS
    CSD  5  │             │  12  VCC
    VSS  6  │             │  11  LO
   VREF  7  │             │  10  COM
  OCSET  8  │             │   9  DT
            └─────────────┘
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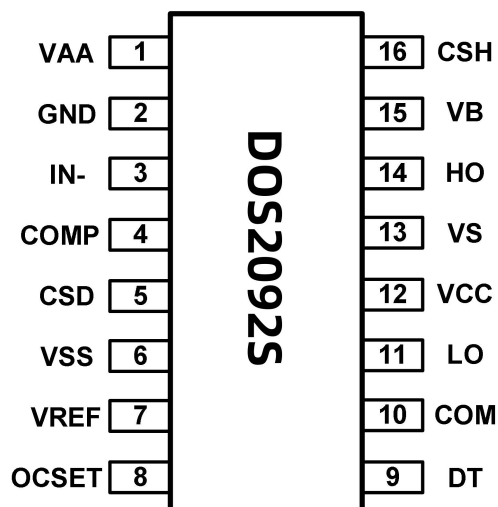
Figure4-1 16-Pin SOP Top view

Table4-1 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

5   Product specifications

5.1 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

5.2 ESD rating

Symbol	Definition	Rating	Units
ESD	HBM Model	$\pm$2000	V
	Machine Model	$\pm$1000	V

5.3 Rated power

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

5.4 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	

5.5 Recommended Operating Conditions

For proper operation, the device should be used within the recommended conditions below. The Vs and COM offset ratings are tested with supplies biased at $V_{AA}-V_{SS}=10$ V, $V_{CC}=12$ V and $V_B-V_S=12$ V. All voltage parameters are absolute voltages referenced to COM; all currents are defined positive into any lead.

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	10[V]	—	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.

5.6 Electrical Characteristics

Valid for temperature range at T_A= 25°C, V_{CC}=V_B= 12V,V_{AA}=10V,V_{SS}=V_S=COM=0V, C_L=1nF, unless otherwise specified

5.6.1 Low side supply

Symbol	Definition	MIN.	TYP.	MAX.	Units	Test Condition
UV_{CC+}	Vcc supply UVLO positive threshold	8.4	8.9	9.4	V	
UV_{CC-}	Vcc supply UVLO negative threshold	8.2	8.7	9.2		
UV_{CCHYS}	UVcc 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

5.6.2 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}	UVBs 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

5.6.3 Floating Input Supply

Symbol	Definition	MIN.	TYP.	MAX.	Units	Test Condition
UV_{AA+}	VA+, VA- floating supply UVLO positive threshold from Vss	8.2	8.7	9.2	V	V_{SS}=0, GND pin floating
UV_{AA-}	VA+, VA- floating supply UVLO negative threshold from Vss	7.7	8.2	8.7		V_{SS}=0, GND pin floating
UV_{AAHYS}	UVAA 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}
$V_{CLAMPM-}$	Vss 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}

5.6.4 Audio Input

V_{GND}=0, V_{AA}=5V, V_{SS}=-5V.

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
V_{COMP}	OTA output voltage	VAA-1	—	VSS+1	V	
g_m	OTA transconductance	—	100	—	mS	V_{IN-}=5mV
G_V	OTA gain	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	—	65	—	dB	

5.6.5 PWM comparator

Symbol	Definition	MIN.	TYP.	MAX.	Units	Test Condition
Vth_{PWM}	PWM comparator threshold in COMP	—	$(V_{AA}-V_{SS})/2$	—	V	
f_{OTA}	COMP pin star-up local oscillation frequency	0.7	1.0	1.5	MHz	V_{CSD}=GND

5.6.6 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
Vth_{OCL}	Low side OC threshold in Vs	1.1	1.2	1.3		OCSET=1.2V
Vth_{OCH}	High side OC threshold in V_{CSH}	1.1+V_S	1.2+V_S	1.3+V_S		
Vth_1	CSD pin shutdown release threshold	0.62V_{AA}	0.7V_{AA}	0.78V_{AA}		
Vth_2	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} + Vth_{OCH} to Shutdown	—	—	250	ns	
t_{och}	Propagation delay time from V_{CSH} > Vth_{OCH} to Shutdown	—	—	500		
t_{ocl}	Propagation delay time from Vs> Vth_{OCL} to Shutdown	—	—	500		

5.6.7 Gate Driver

Symbol	Definition	MIN.	TYP.	MAX.	Units	Test Condition
I_{O+}	Output high short circuit current (Source)	—	1	—	A	$V_O=0V$, PW<10us
I_{O-}	Output low short circuit current (Sink)	—	1.2	—		$V_O=12V$, 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 1	0.51Vcc	0.57Vcc	0.63Vcc	V	
V_{DT2}	DT mode select threshold 2	0.32Vcc	0.36Vcc	0.40Vcc		
V_{DT3}	DT mode select threshold 3	0.21Vcc	0.23Vcc	0.25Vcc		

6 Waveform definitions
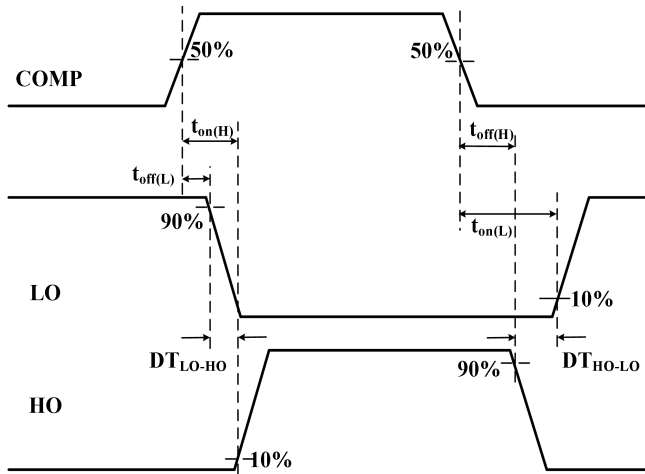
Figure 6-1. Switching Time Waveform Definitions
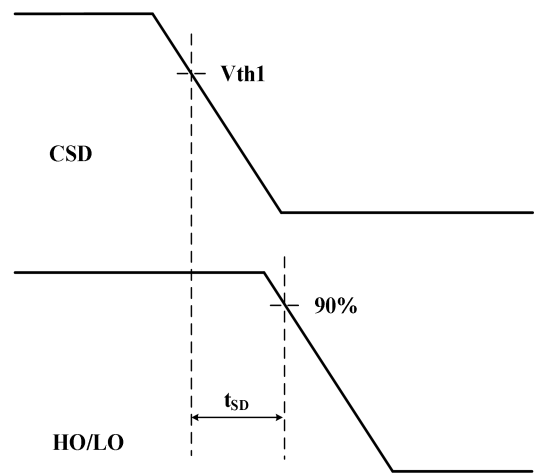
Figure 6-2. CSD to Shutdown Waveform Definitions
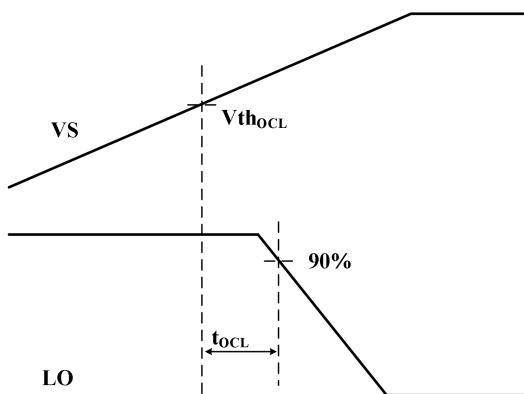
Figure 6-3. VS > VthOCL to Shutdown Waveform
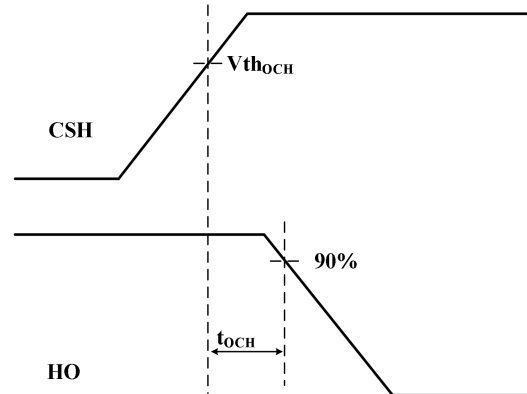
Figure 6-4. VCSH > VthOCH to Shutdown Waveform

7 Input/Output Pin Equivalent Circuit Diagrams
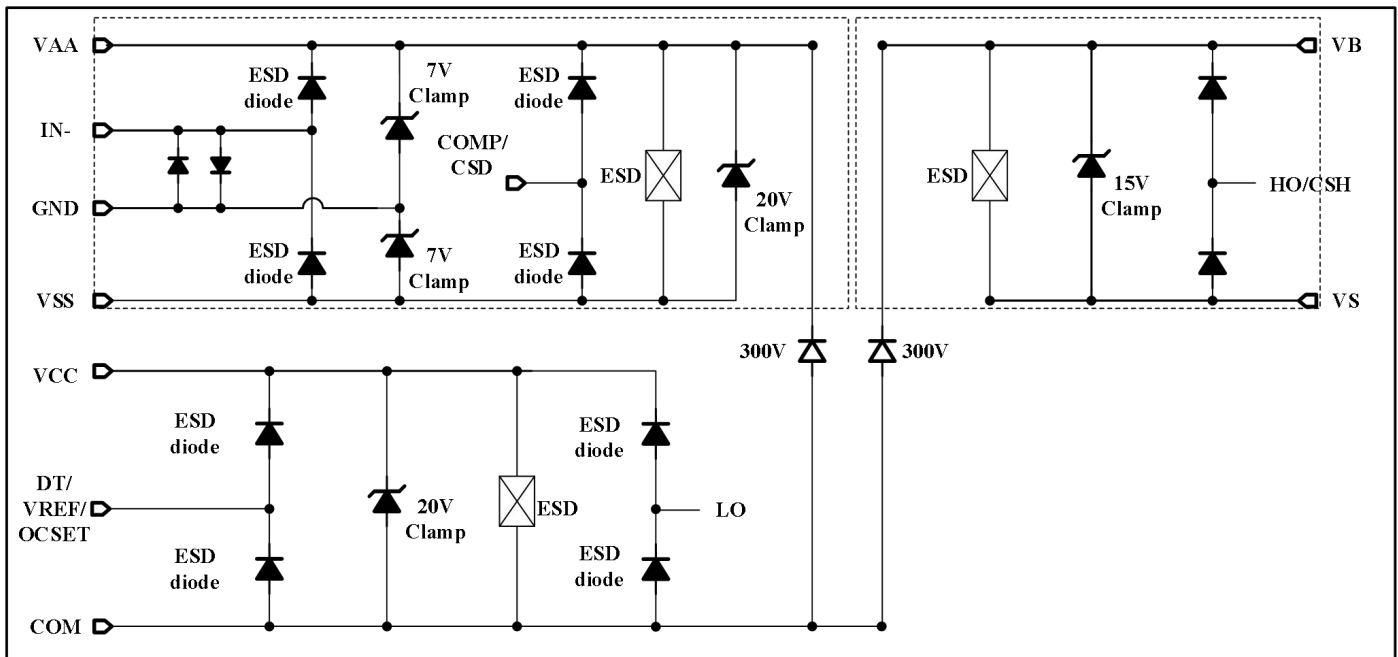
Figure 7-1 Input/Output Pin Equivalent Circuit

8 General Description

8.1 Functional Description

The DOS2092S 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 DOS2092S 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 DOS2092S implements start-up click noise elimination to suppress unwanted audible noise during PWM start-up and shut-down.

8.2 Functional Block Diagram
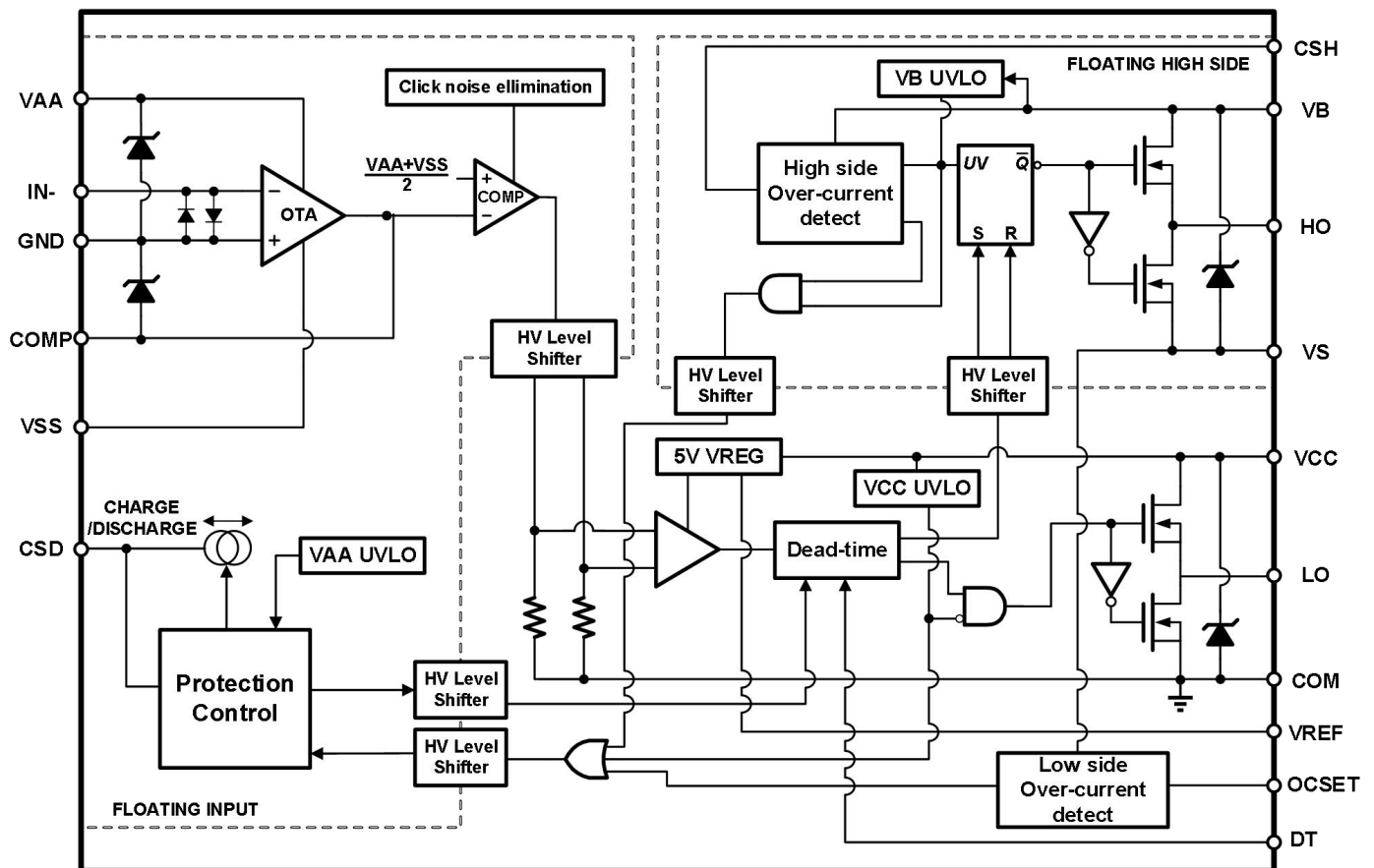
Figure8-1 Functional Block Diagram

8.3 Typical Connection Diagram
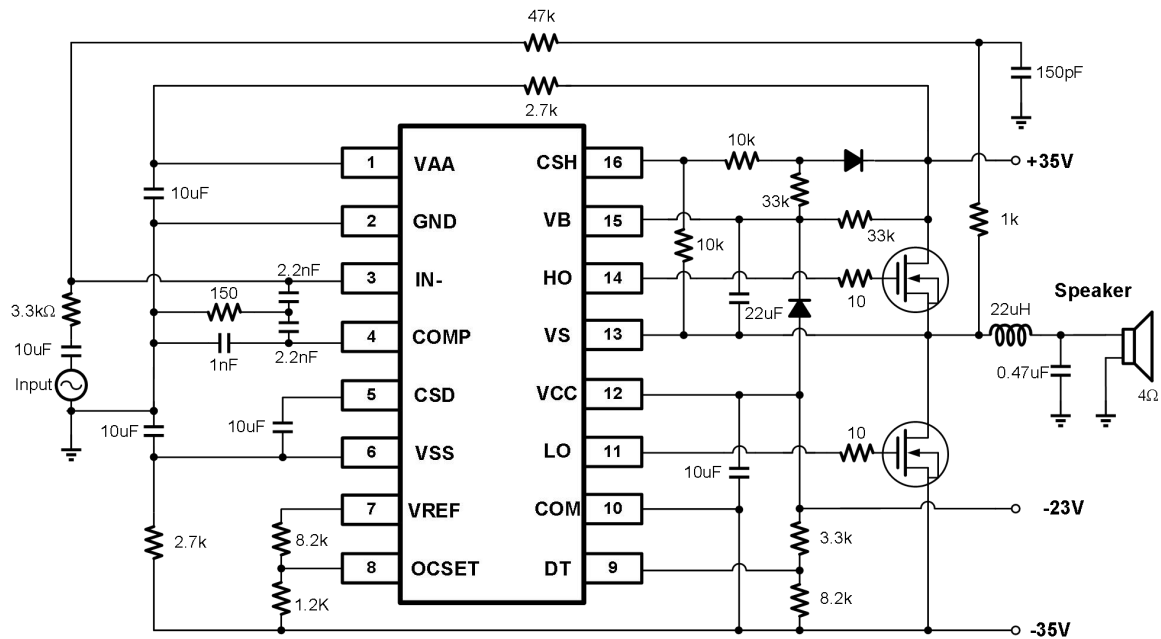
Figure8-2 Typical Connection Diagram

8.4 Typical Control Loop Design

The audio input stage of DOS2092S 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.
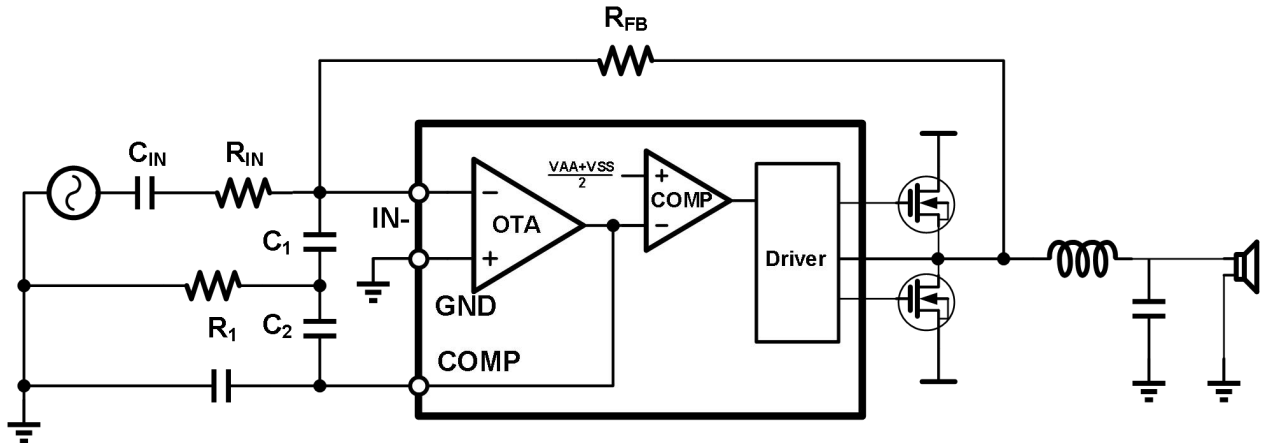
Figure8-3 Typical Control Loop Design

8.4.1 OTA

The front end error amplifier of the DOS2092S 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.

8.4.2 PWM Modulator

In this section, all the explanations are based on a typical application circuit of a self oscillating PWM. For better audio performance, 2nd 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.

For these reasons, 400kHz is chosen for a typical design example, which can be seen in the IRAUDAMP5 reference design.

8.5 Click Noise Elimination

DOS2092S 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
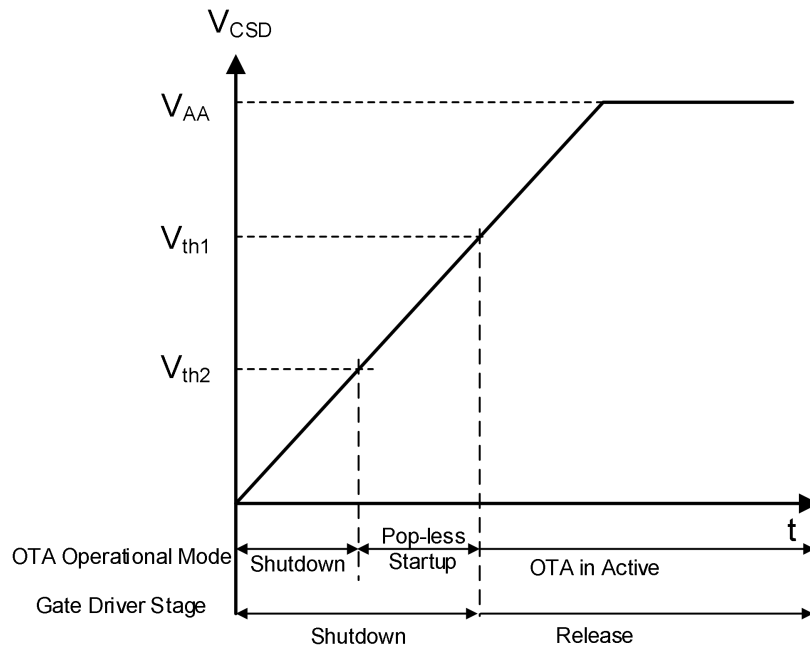
Figure8-5 V $_{CSD}$ and OTA Mode

8.7 Over Current Protection

The DOS2092S features over current protection to protect the power MOSFETs during abnormal load conditions. The DOS2092S 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.
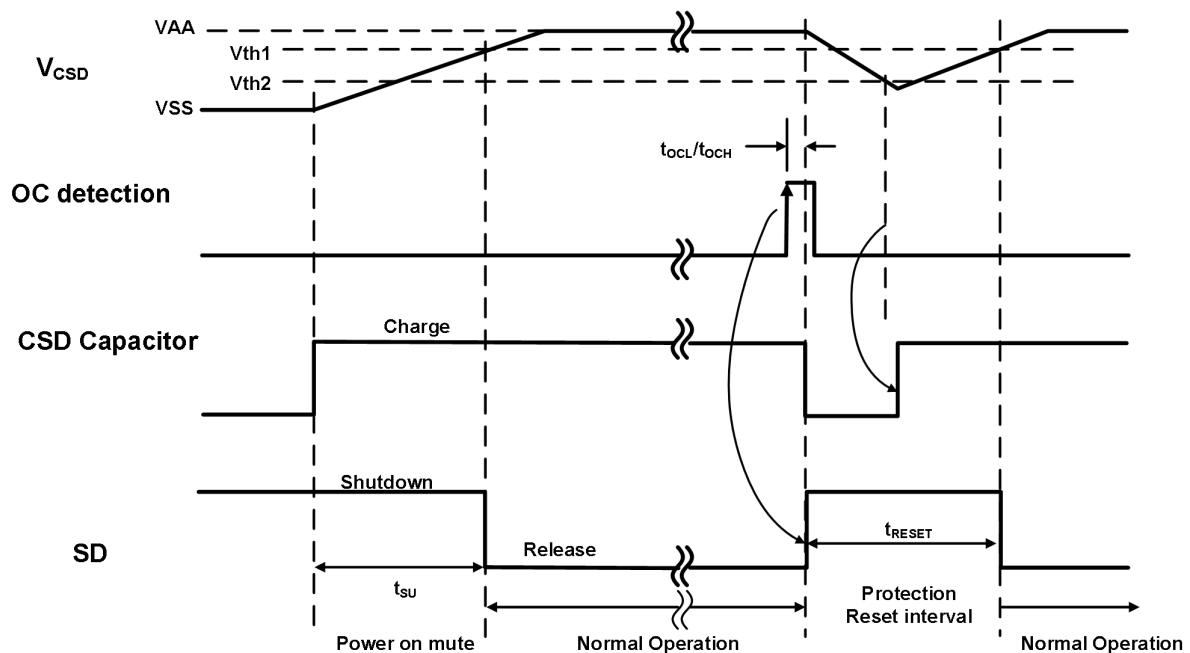

Figure8-6 Shutdown Functional Block Diagram

8.8 **Programming Dead-Time**

The DOS2092S 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 = 65ns;

When $0.36VCC < V_{DT} < 0.57VCC$, DT = 40ns;

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

Figure8-6 Dead Time vs. V_{DT}
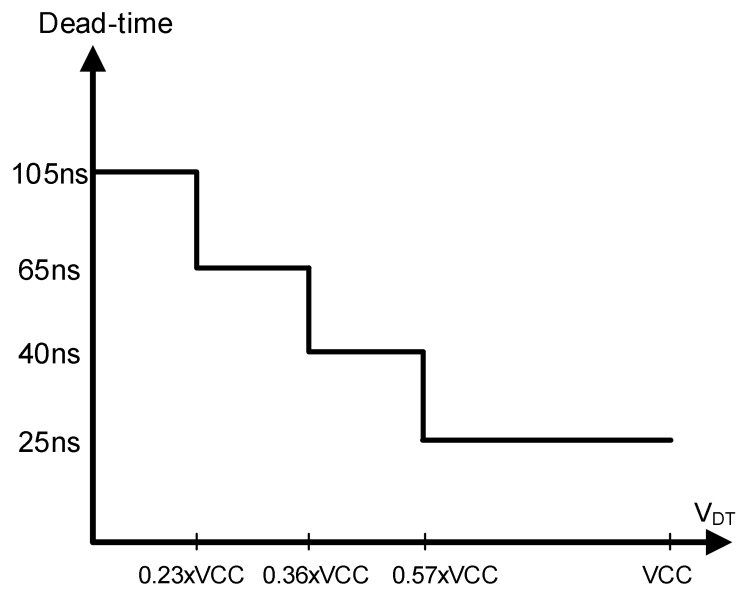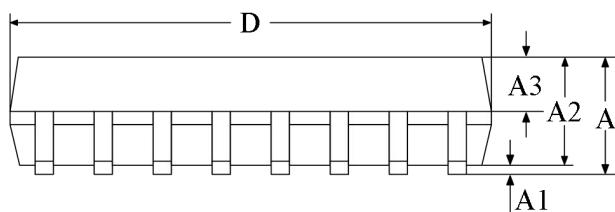
DOS2092S

9 Package Information

SOP16 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				

SOP16 Package Outlines