

# 200W Stereo, Integrated Class D Amplifier

## Features

- 2 channel analog input Class D audio amplifier in a small 7x7mm package
- Very low  $R_{DS(ON)}$  at 24.4 m $\Omega$  typical, enabling heatsink-less operation at 2x100W at 4 $\Omega$
- 95% efficiency Class D at 2x200W at 4 $\Omega$
- Split or single power supply capable
- Differential or single-ended input
- Multiple configuration options: 2xSE, BTL, PSE (Parallel Single-Ended)
- Over-current, over-temperature and under-voltage protections with self-reset feature
- Start/stop click noise reduction
- Clip and Fault reporting outputs

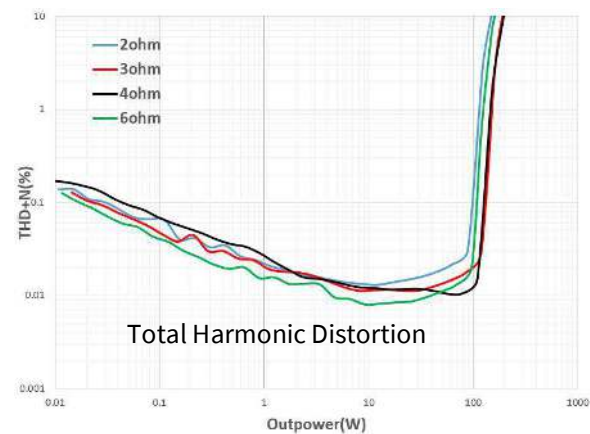


PG- IQFN-42



## Applications

- Multi-channel home theatre system
- Studio monitor
- Active speaker
- Soundbar subwoofer
- Marine amplifier
- Aftermarket car audio system
- General-purpose audio power amplifier



## Product validation

Qualified for standard applications according to the relevant tests of J-STD-020 and JESD22.

Product type	Package
MA5332MS	7x7mm PG- IQFN-42

## Description

The MA5332MS offers the same or higher output power than monolithic alternatives without heatsink and 50% less footprint. This MCM (multi-chip module) solution integrates 2 channel PWM controller, high voltage gate driver, and 4 low  $R_{DS(ON)}$  MOSFETs. Like its predecessor, IR43x2M, it includes standard Class D protection features for reliable operation over various environmental conditions. As a powerful upgrade to IR43x2M and other monolithic solutions, MA5332MS' 7x7 mm PG- IQFN-42 package showcases the benefit of small footprint, high power density, and heatsink-less operation.

Topology	Half-bridge / Full bridge
MA5332MS Output power (Half-bridge, THD+N=10%, typical)	150 W in 2 $\Omega$ / 300 W in 4 $\Omega$ 200 W in 4 $\Omega$ / 400 W in 8 $\Omega$ 160 W in 6 $\Omega$
*Residual noise (AES-17, IHF-A, typical)	250 $\mu$ Vrms
*THD+N (1kHz, 70W, 4 $\Omega$ , typical)	0.01 %

\* In a typical application

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## 1 Qualification information

<b>Qualification Level (1)</b>		<b>Standard (2)</b>
		Qualified for standard applications according to the relevant tests of J-STD-020 and JESD22
<b>Moisture Sensitivity Level (MSL) (3)</b>		MSL3 (per IPC/JEDEC J-STD-020)
<b>ESD</b>	<b>Charge Device Model</b>	Class C2a (per JEDEC standard JS-002)
	<b>Human Body Model</b>	Class 1B (per JEDEC standard JS-001)
<b>IC Latch-Up Test</b>		Class I, Level A (per JESD78)
<b>RoHS Compliant</b>		Yes

Note:

1. Qualification standards can be found at Infineon's web site <http://www.infineon.com/>
2. Higher qualification ratings may be available should the user have such requirements. Please contact your International Rectifier sales representative for further information.
3. Higher MSL ratings may be available for the specific package types listed here. Please contact your International Rectifier sales representative for further information.

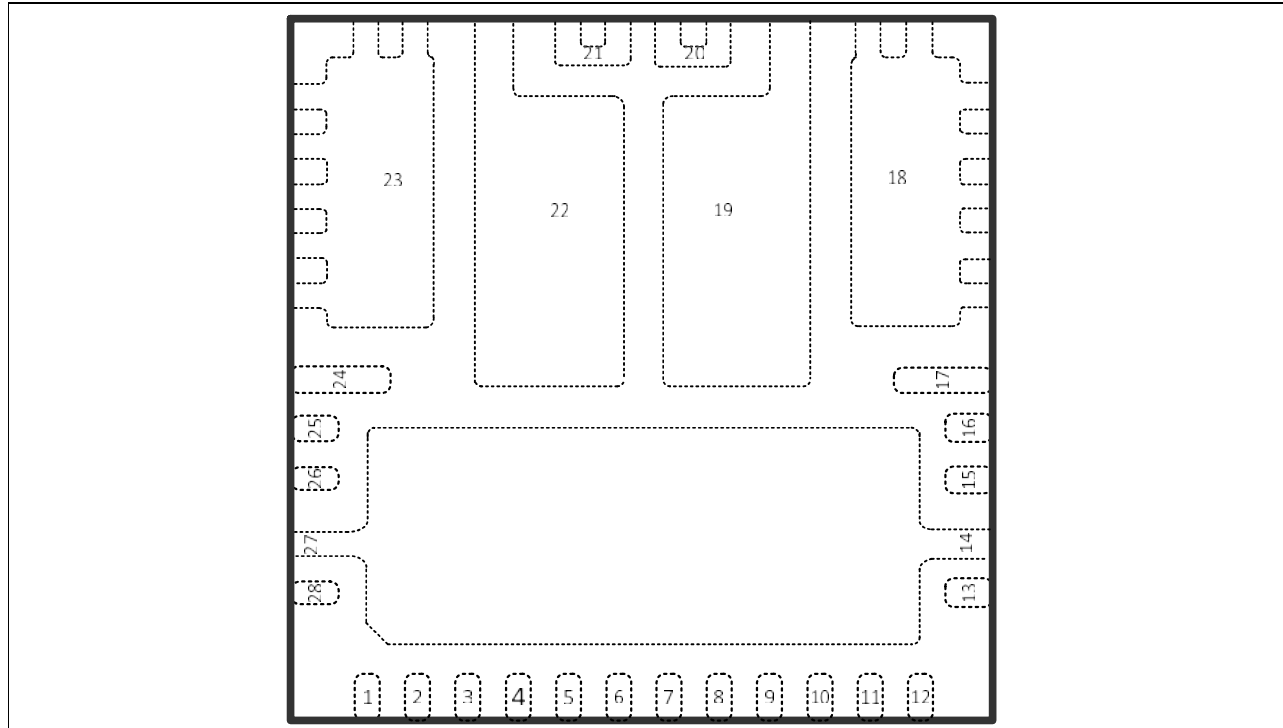
## 2 Device Comparison Table

**Table 1**

<b>Device Name</b>	<b>Description</b>
MA5332MS	200W (4 $\Omega$ )*2 channel integrated analog input Class D audio Amplifier
IR4302M	130W (4 $\Omega$ )*2 channel integrated analog input Class D audio Amplifier
IR4322M	100W (2 $\Omega$ )*2 channel integrated analog input Class D audio Amplifier
IR4312M	35W (4 $\Omega$ )*2 channel integrated analog input Class D audio Amplifier
IR4301M	160W (4 $\Omega$ ) single-channel integrated analog input Class D audio Amplifier
IR4321M	135W (2 $\Omega$ ) single-channel integrated analog input Class D audio Amplifier
IR4311M	35W (4 $\Omega$ ) single-channel integrated analog input Class D audio Amplifier

### **3 Pin Configuration**

#### **3.1 Lead assignments**



**Figure 1 Lead assignments**

**Table of contents**

**3.2 Lead definitions**

<b>Pin #</b>	<b>Symbol</b>	<b>Description</b>
1	CLIP	Clipping detection output, open drain, referenced to GND
2	COMP2	CH2 PWM comparator input
3	IN-2	CH2 Analog inverting input
4	IN+2	CH2 Analog non-inverting input
5	GND	GND for internal shunt zener diodes to VAA and VSS, a reference to FAULT and CLIP outputs.
6	VSS	Floating input negative supply
7	VAA	Floating input positive supply
8	IN+1	CH1 Analog non-inverting input
9	IN-1	CH1 Analog inverting input
10	COMP1	CH1 PWM comparator input
11	CSD	Shutdown timing capacitor / shutdown input
12	FAULT	Fault reporting output, open drain, referenced to GND
13	VCC	Low side supply
14	COM	Low side supply return, internally connected to pin 27
15	CSH1	CH1 High side over current sensing input, referenced to VS1
16	VB1	CH1 High side floating supply
17	VS1	CH1 PWM output, internally connected to pin 19
18	VP1	CH1 Positive power supply
19	VS1	CH1 PWM output
20	VN1	CH1 Negative power supply, connect to COM externally
21	VN2	CH2 Negative power supply, connect to COM externally
22	VS2	CH2 PWM output, internally connected to pin 24
23	VP2	CH2 Positive power supply
24	VS2	CH2 PWM output
25	VB2	CH2 High side floating supply
26	CSH2	CH2 High side over current sensing input, referenced to VS2
27	COM	Low side supply return, internally connected to pin 14
28	NC	

## **4 Specifications**

### **4.1 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=VN1=VN2; all currents are defined positive into any lead. The Thermal Resistance and Power Dissipation ratings are measured under board mounted and still air conditions.

<b>Symbol</b>	<b>Definition</b>	<b>Min</b>	<b>Max</b>	<b>Units</b>
V <sub>Pn</sub>	Positive power supply rail voltage, n=1-2	-	100	
V <sub>Bn</sub>	High side floating supply voltage	-0.3	115	
V <sub>Sn</sub>	High side floating supply voltage <sup>(2)</sup> , n=1-2	V <sub>Bn</sub> -15	V <sub>Bn</sub> +0.3	
V <sub>CSHn</sub>	CSH pin input voltage, n=1-2	V <sub>Sn</sub> -0.3	V <sub>Bn</sub> +0.3	
V <sub>CC</sub>	Low side supply voltage <sup>(2)</sup>	-0.3	15	
V <sub>AA</sub>	Floating input positive supply voltage <sup>(2)</sup>	-0.3	110	
V <sub>SS</sub>	Floating input negative supply voltage <sup>(2)</sup>	-1 (See I <sub>SSZ</sub> )	GND+0.3	
V <sub>IN+n</sub>	Floating input supply ground voltage, n=1-2	V <sub>SS</sub> -0.3	V <sub>AA</sub> +0.3	
I <sub>INn</sub>	Input current between IN- and IN+ pins <sup>(1)</sup> , n=1-2	-	±3	mA
V <sub>CSD</sub>	CSD pin input voltage	V <sub>SS</sub> -0.3	V <sub>AA</sub> +0.3	
V <sub>COMPn</sub>	COMP pin input voltage, n=1-2	V <sub>SS</sub> -0.3	V <sub>AA</sub> +0.3	V
V <sub>CLIP</sub>	CLIP pin input voltage	GND-0.3	V <sub>AA</sub> +0.3	
I <sub>CLIP</sub>	CLIP pin sinking current	-	5	mA
V <sub>FAULT</sub>	FAULT pin input voltage	GND-0.3	V <sub>AA</sub> +0.3	V
I <sub>FAULT</sub>	FAULT pin sinking current	-	5	
I <sub>AAZ</sub>	Floating input supply zener clamp current <sup>(2)</sup>	-	20	
I <sub>SSZ</sub>	Floating input negative supply zener clamp current <sup>(2)</sup>	-	20	mA
I <sub>CCZ</sub>	Low side supply zener clamp current <sup>(2)</sup>	-	20	
I <sub>BSZn</sub>	Floating supply zener clamp current <sup>(2)</sup> , n=1-2	-	20	
dV <sub>Sn</sub> /dt	Allowable Vs voltage slew rate, n=1-2	-	50	V/ns
dV <sub>SS</sub> /dt	Allowable Vss voltage slew rate <sup>(3)</sup>	-	50	V/ms
I <sub>d@25°C</sub>	Continuous output current, from VPn to VS <sub>n</sub> , VS <sub>n</sub> to VN <sub>n</sub> , V <sub>CC</sub> =10V, V <sub>Bn</sub> -V <sub>Sn</sub> =10V	-	16	
I <sub>d@100°C</sub>	Continuous output current, from VPn to VS <sub>n</sub> , VS <sub>n</sub> to VN <sub>n</sub> , V <sub>CC</sub> =10V, V <sub>Bn</sub> -V <sub>Sn</sub> =10V	-	10	A
I <sub>DM</sub>	Pulsed output current, from VPn to VS <sub>n</sub> , VS <sub>n</sub> to VN <sub>n</sub> , V <sub>CC</sub> =10V, V <sub>Bn</sub> -V <sub>Sn</sub> =10V <sup>(5)</sup>	-	64	
P <sub>d</sub>	Power dissipation <sup>(4)</sup> @ T <sub>c</sub> = 25°C	-	25	W
R <sub>thJC</sub>	Thermal resistance, junction to case <sup>(4)</sup>	-	5	°C/W
T <sub>JIC</sub>	Control IC junction temperature	-	150	
T <sub>JFET</sub>	FET junction temperature	-	150	°C



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$T_s$	Storage Temperature	-55	150	
$T_L$	Lead temperature (Soldering, 10 seconds)	-	300	

Note:

1.  $IN-$  and  $IN+$  contain clamping diodes between the two pins.
2.  $V_{AA}-V_{SS}$ ,  $V_{CC}-COM$  and  $V_{Bn}-V_{Sn}$  contain internal shunt zener diodes. Note that the voltage ratings of these can be limited by the clamping current.
3. For the rising and falling edges of step signal of 10V.  $V_{SS}=15V$  to 100V.
4. Per MOSFET.
5. Repetitive rating, pulse width limited by maximum junction temperature.

## 4.2 Recommended operating conditions

For proper operation, the device should be used within the recommended conditions below. The  $V_{SS}$  and  $V_{Sn}$  offset ratings are tested with supplies biased at  $COM=VN1=VN2$ ,  $V_{AA}-V_{SS}=9.6V$ ,  $V_{CC}=12V$  and  $V_{Bn}-V_{Sn}=12V$ . All voltage parameters are absolute voltages referenced to COM; all currents are defined positive into any lead.

Symbol	Definition		Min	Max	Units
$V_{Pn}$	Positive power supply voltage, n=1-2, without heatsink	MA5332MS	-	60	
	Positive power supply voltage, n=1-2, with heatsink	MA5332MS	-	80	
$V_{Bn}$	High side floating supply absolute voltage, n=1-2		$V_{Sn} + 10$	$V_{Sn} + 14$	V
$V_{Sn}$	High side floating supply offset voltage, n=1-2	MA5332MS	<sup>(6)</sup>	100	
$V_{AA}$	Floating input positive supply voltage <sup>(7)</sup>		$V_{SS} + 9.0$	$V_{SS} + 9.8$	
$V_{SS}$	Floating input negative supply voltage <sup>(7)</sup>	MA5332MS	0	100	
$I_{AAZ}$	Floating input supply zener clamp current <sup>(7)</sup>		1	15	mA
$I_{SSZ}$	Floating input negative supply zener clamp current <sup>(7)</sup>		1	15	
$V_{CC}$	Low side fixed supply voltage		10	15	
$V_{IC}$	$IN-$ and $IN+$ pins common mode input voltage		$V_{SS} + 2$	$V_{AA} - 2$	
$V_{IN-n}$	Inverting input voltage, n=1-2		$V_{IN+} - 0.5$	$V_{IN+} + 0.5$	V
$V_{CSD}$	CSD pin input voltage		$V_{SS}$	$V_{AA}$	
$V_{COMPn}$	COMP pin input voltage, n=1-2		$V_{SS}$	$V_{AA}$	
$C_{COMPn}$	COMP pin phase compensation capacitor to GND, n=1-2		1	-	nF
$V_{CSHn}$	CSH pin input voltage, n=1-2		$V_{Sn}$	$V_{Bn}$	V
$f_{SW}$	Switching frequency		-	500	kHz
$T_{J,IC}$	Junction temperature of controller IC		-40	100	°C

Note:

6. Logic operational for  $V_s$  equal to  $-5V$  to  $+100V$ . Logic state held for  $V_s$  equal to  $-5V$  to  $-V_{BS}$ .
7. GND input voltage is limited by  $I_{AAZ}$  and  $I_{SSZ}$ .

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**4.3 Electrical characteristics**

Unless otherwise specified, the following apply:

- $V_{CC}, V_{BS} = 12\text{ V}$
- $V_{SS} = V_{S1} = V_{S2} = V_{N1} = V_{N2} = \text{COM} = 0\text{ V}$
- $V_{AA} = 9.6\text{ V}$
- $T_A = 25^\circ\text{C}$

**Table 2 Electrical characteristics**

Symbol	Definition	Min	Typ	Max	Units	Test conditions
<b>Low-side supply</b>						
$UV_{CC+}$	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	V	
$UV_{CCHYS}$	$UV_{CC}$ hysteresis	-	0.2	-	V	
$I_{QCC}$	Low side quiescent current	-	-	3	mA	
$I_{CC}$	Low side supply current	-	10	-	mA	$f = 400\text{ kHz}$
$V_{CLAMPLN}$	Low side zener diode clamp voltage, $n=1-2$	14.7	15.3	16.2	V	$I_{CC} = 5\text{ mA}$
<b>High-side floating supply</b>						
$UV_{BS+n}$	High side well UVLO positive threshold, $n=1-2$	8.0	8.5	9.0	V	
$UV_{BS-n}$	High side well UVLO negative threshold, $n=1-2$	7.8	8.3	8.8	V	
$UV_{BSHYSn}$	$UV_{BS}$ hysteresis, $n=1-2$	-	0.2	-	V	
$I_{QBSn}$	High side quiescent current, $n=1-2$	-	-	2.4	mA	
$I_{QBSn\_OFF-CSH}$	High side quiescent current, with CSH pin open $n=1-2$	350	500	650	$\mu\text{A}$	
$V_{CLAMPHn}$	High side zener diode clamp voltage, $n=1-2$	14.7	15.3	16.2	V	$I_{BS} = 5\text{ mA}$
<b>Floating input supply</b>						
$UV_{AA+}$	$VA+$ , $VA-$ floating supply UVLO positive threshold from $V_{SS}$	8.2	8.7	9.2	V	$V_{SS} = 0\text{ V}$ , GND pin floating
$UV_{AA-}$	$VA+$ , $VA-$ floating supply UVLO negative threshold from $V_{SS}$	7.7	8.2	8.7	V	$V_{SS} = 0\text{ V}$ , GND pin floating
$UV_{AAHYS}$	$UV_{AA}$ hysteresis	-	0.5	-	V	$V_{SS} = 0\text{ V}$ , GND pin floating
$I_{QAA0}$	Floating Input positive quiescent supply current	-	1.5	3	mA	$V_{AA} = 9.6\text{ V}$ , $V_{SS} = 0\text{ V}$ , $V_{CSD} = V_{SS}$
$I_{QAA1}$	Floating Input positive quiescent supply current	-	4	6	mA	$V_{AA} = 9.6\text{ V}$ , $V_{SS} = 0\text{ V}$ , $V_{CSD} = V_{AA}$

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$I_{QAA2}$	Floating Input positive quiescent supply current	-	5	7.5	mA	$V_{AA}=9.6V, V_{SS}=0V,$ $V_{CSD}=GND$
$I_{LKM}$	Floating input side to Low side leakage current	-	-	50	$\mu A$	$V_{AA}=V_{SS}=V_{GND}=$ 100V
$V_{CLAMP+}$	$V_{AA}$ floating supply zener diode clamp voltage, positive, with respect to GND	4.9	5.1	5.4	V	$I_{AA}=5mA,$ $I_{SS}=5mA,$ $V_{GND}=0V,$ $V_{CSD}=V_{SS}$
$V_{CLAMP-}$	$V_{SS}$ floating supply zener diode clamp voltage, negative, with respect to GND	-5.4	-5.1	-4.9	V	$I_{AA}=5mA,$ $I_{SS}=5mA,$ $V_{GND}=0V,$ $V_{CSD}=V_{SS}$

**Audio input ( $V_{GND}=0, V_{AA}=4.8V, V_{SS}=-4.8V$ )**

$V_{OSn}$	Input offset voltage, n=1-2	-18	0	18	mV	
$I_{BINn}$	Input bias current, n=1-2	-	-	40	nA	
GBWn	Small signal bandwidth in OTA, n=1-2	-	9	-	MHz	$C_{COMP}=1nF, R_f=0$
$g_{mn}$	OTA transconductance, n=1-2	-	10	-	mS	$V_{IN+}=0V, V_{IN-}$ =10mV
$G_{Vn}$	OTA gain, n=1-2	50	-	-	dB	
$V_{Nrmsn}$	CHn OTA input noise voltage, n=1-2	-	200	330	mVrms	

**PWM**

$V_{th_{PWM}}$	PWM comparator threshold in COMP	-	$(V_{AA} - V_{SS})/2$	-	V	
$f_{OTAn}$	COMP pin star-up local oscillation frequency, n=1-2	0.7	1.0	1.5	MHz	$V_{CSD}=GND$
$T_{on\_n}$	COMP to VS rising edge propagation delay, n=1-2	-	370	-	ns	
$T_{off\_n}$	COMP to VS trailing edge propagation delay, n=1-2	-	320	-	ns	
DTn	Deadtime: Low-side turn-off to High-side turn-on ( $DT_{LO-HO}$ ) & High-side turn-off to Low-side turn-on ( $DT_{HO-LO}$ ), n=1-2	-	50	-	ns	$V_P=30V,$ $V_N=-30V,$

**Power MOSFET (FET1, FET2, FET3, FET4)**

At  $T_j=25^\circ C$ , unless otherwise specified

$V_{(BR)DSS}^{(8)}$	Drain-to-Source breakdown voltage	100	-	-	V	$V_{GS}=0V,$ $I_D=250\mu A$
$R_{DS(ON)}$	FET on resistance	-	24.4	30.5	m $\Omega$	$I_D=3.3A, V_{GS}=10V$
Qg	Total gate charge	-	12.7	19	nC	$V_{GS}=10V$
$I_{LK0}$	VP leakage current, VS=VN	-	-	20	$\mu A$	$V_P=100V^{(8)},$ $V_{CSD}=V_{SS}$

**Protection**

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$I_{OCpN}$	Over current detection Positive threshold, $n=1-2$ <sup>(8)</sup>	-	40	-	A	
$I_{OCnN}$	Over current detection Negative threshold, $n=1-2$ <sup>(9)</sup>	-	-40	-	A	
Vth1	CSD pin shutdown release threshold	$0.62xV_{AA}$	$0.70xV_{AA}$	$0.78xV_{AA}$	V	
Vth2	CSD pin self-reset threshold	$0.26xV_{AA}$	$0.30xV_{AA}$	$0.34xV_{AA}$	V	
$I_{CSD+}$	CSD pin discharge current	70	100	130	$\mu A$	$V_{CSD} = V_{SS} + 4.8V$
$I_{CSD-}$	CSD pin charge current	70	100	130	$\mu A$	$V_{CSD} = V_{SS} + 4.8V$
$t_{SDn}$	Shutdown propagation delay from $V_S < V_{th1}$ to Shutdown, $n=1-2$	-	-	250	ns	COMP = $V_{SS}$
$t_{OCpN}$	CHn propagation delay time from $I_{On} > I_{OCpN}$ to Shutdown, $n=1-2$	-	-	500	ns	COMP = $V_{SS}$
$t_{OCnN}$	CHn propagation delay time from $I_{On} < I_{OCnN}$ to Shutdown, $n=1-2$	-	-	500	ns	COMP = $V_{SS}$
Vth+ <sub>CLIP</sub>	Clip detection positive threshold in COMP	$0.85xV_{AA}$	$0.90xV_{AA}$	$0.95xV_{AA}$	V	
Vth- <sub>CLIP</sub>	Clip detection negative threshold in COMP	$0.05xV_{AA}$	$0.10xV_{AA}$	$0.15xV_{AA}$	V	
$t_{CLIP}$	Clipping detection propagation delay	-	40	-	ns	
$t_{CLIPmin}$	Clipping detection minimum output duration	-	3	-	$\mu s$	
$T_{SD}$	Over-temperature shutdown threshold in controller IC	100	-	-	$^{\circ}C$	
$T_{SDHYS}$	Over-temperature shutdown threshold hysteresis	-	7	-	$^{\circ}C$	

#### 4.4 Audio characteristics (SE)

**Table 3**

Parameter	Test conditions	Typ	Unit
Po Power output per channel <sup>(10)</sup>	RL= 6Ω, 10%THD+N, V <sub>bus</sub> = ± 40 V	160	W
	RL= 4Ω, 10%THD+N, V <sub>bus</sub> = ± 36.5 V	200	
	RL= 3Ω, 10%THD+N, V <sub>bus</sub> = ± 31.5 V	190	
	RL= 2Ω, 10%THD+N, V <sub>bus</sub> = ± 23 V	150	
	RL= 6Ω, 1%THD+N, V <sub>bus</sub> = ± 40 V	120	
	RL= 4Ω, 1%THD+N, V <sub>bus</sub> = ± 36.5 V	150	
	RL= 3Ω, 1%THD+N, V <sub>bus</sub> = ± 31.5 V	140	
	RL= 2Ω, 1%THD+N, V <sub>bus</sub> = ± 23V	110	
Residual noise(AES-17, IHF-A, typical)	EVAL_AUDAMP25, V <sub>bus</sub> = ± 36.5 V, RL= 4Ω	250	uV
Idling supply current	EVAL_AUDAMP25, V <sub>bus</sub> = ± 36.5 V, RL= 4Ω	+55	mA
		-80	
Efficiency <sup>(11)</sup>	EVAL_AUDAMP25, V <sub>bus</sub> = ± 36.5 V, Pout=200W, RL= 4Ω	95	%

Note:

8.  $V_p$  changes over temperature at a rate of 50mV/K compared to  $T_j=25^\circ\text{C}$ .
9. Over-current protection threshold measured under  $T_j=25^\circ\text{C}$  condition.
10. Tested with heatsink (digikey part number: V8818V)
11. Class D stage only

#### 4.5 Audio characteristics (BTL)

**Table 4**

Parameter	Test conditions	Typ	Unit
Po Power output per channel <sup>(9)</sup>	RL= 8Ω, 10%THD+N, V <sub>bus</sub> = ± 36.5 V	400	W
	RL= 6Ω, 10%THD+N, V <sub>bus</sub> = ± 31.5 V	380	
	RL= 4Ω, 10%THD+N, V <sub>bus</sub> = ± 23 V	300	
	RL= 8Ω, 1%THD+N, V <sub>bus</sub> = ± 36.5 V	300	
	RL= 6Ω, 1%THD+N, V <sub>bus</sub> = ± 31.5 V	280	
	RL= 4Ω, 1%THD+N, V <sub>bus</sub> = ± 23V	220	
Residual noise(AES-17, IHF-A, typical)	EVAL_AUDAMP25, V <sub>bus</sub> = ± 36.5 V, RL= 4Ω	350	uV
Idling supply current	EVAL_AUDAMP25, V <sub>bus</sub> = ± 36.5 V, RL= 8Ω	+55	mA
		-80	
Efficiency <sup>(10)</sup>	EVAL_AUDAMP25, V <sub>bus</sub> = ± 36.5 V, RL= 8Ω	95	%

## 4.6 Audio characteristics (PSE)

**Table 5**

Parameter	Test conditions	Typ	Unit
Po Power output per channel <sup>(9)</sup>	R <sub>L</sub> = 2Ω, 10%THD+N, V <sub>bus</sub> = ± 36.5 V	400	W
	R <sub>L</sub> = 2Ω, 1%THD+N, V <sub>bus</sub> = ± 36.5V	300	
Residual noise(AES-17, IHF-A, typical)	EVAL_AUDAMP25 , V <sub>bus</sub> = ± 36.5 V ,R <sub>L</sub> = 4Ω	250	uV
Idling supply current	EVAL_AUDAMP25 , V <sub>bus</sub> = ± 36.5 V ,R <sub>L</sub> = 4Ω	+55	mA
		-80	
Efficiency <sup>(10)</sup>	EVAL_AUDAMP25 , V <sub>bus</sub> = ± 36.5 V ,R <sub>L</sub> = 4Ω	95	%

**4.7 Typical Audio characteristics (SE)**

Test conditions:

All Measurements taken at Sine wave frequency= 1 kHz, AES17+ AUX-0025 measurement filters.

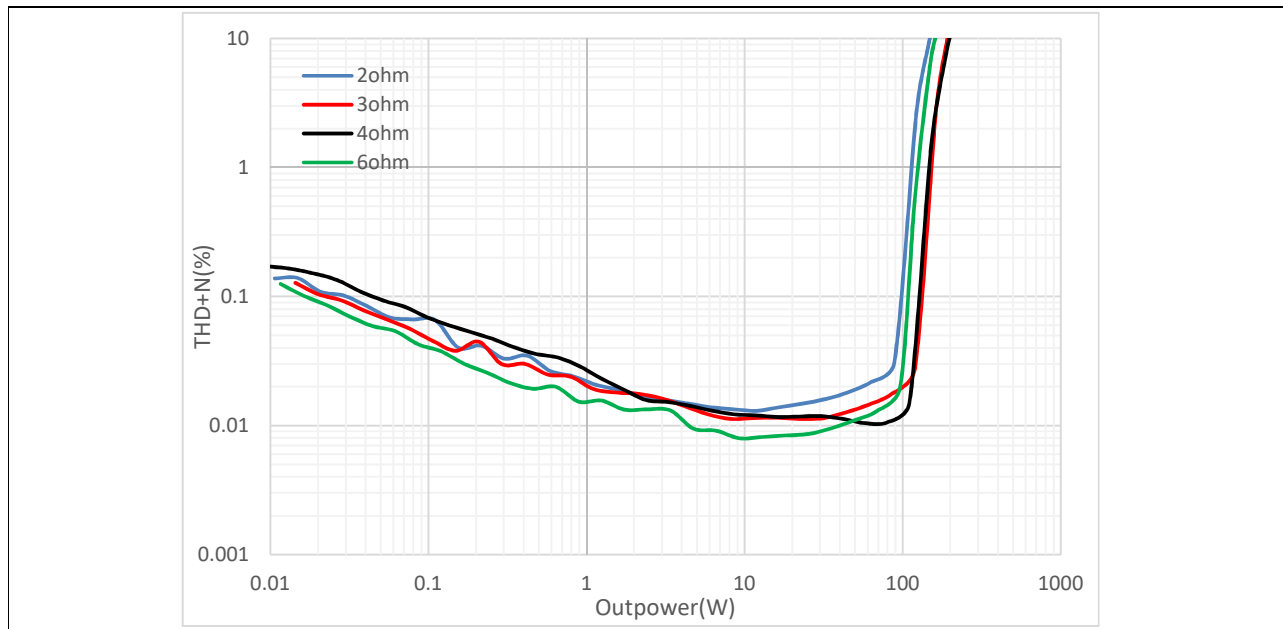
$V_{bus} = \pm 40\text{ V}$ , Load impedance = 6  $\Omega$ ,  $F_{PWM} = 400\text{ kHz}$

$V_{bus} = \pm 36.5\text{ V}$ , Load impedance = 4  $\Omega$ ,  $F_{PWM} = 400\text{ kHz}$

$V_{bus} = \pm 31.5\text{ V}$ , Load impedance = 3  $\Omega$ ,  $F_{PWM} = 400\text{ kHz}$

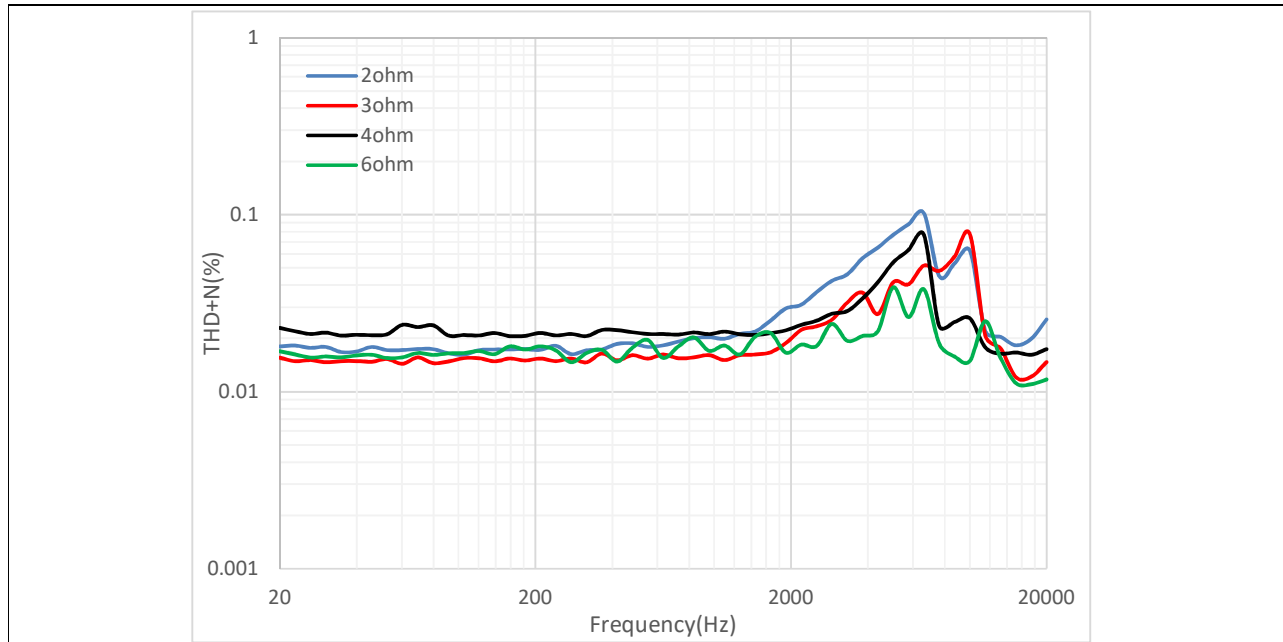
$V_{bus} = \pm 23\text{ V}$ , Load impedance = 2  $\Omega$ ,  $F_{PWM} = 400\text{ kHz}$

**4.7.1 Power vs. THD+N**



**Figure 2 Power vs. THD+N**

### 4.7.2 Frequency vs. THD+N

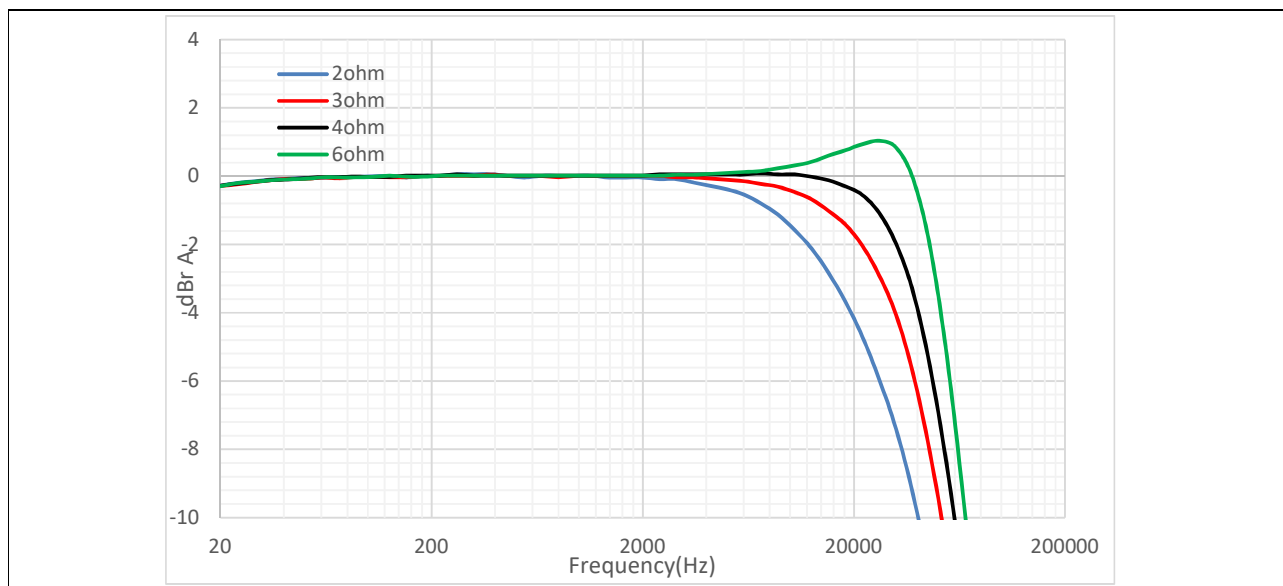


**Figure 3** Frequency vs. THD+N @1W

### 4.7.3 Frequency response

Test conditions:

Output power = 1 W, LPF = 22uH+0.47uF



**Figure 4** Frequency response



### 4.7.4 Noise floor

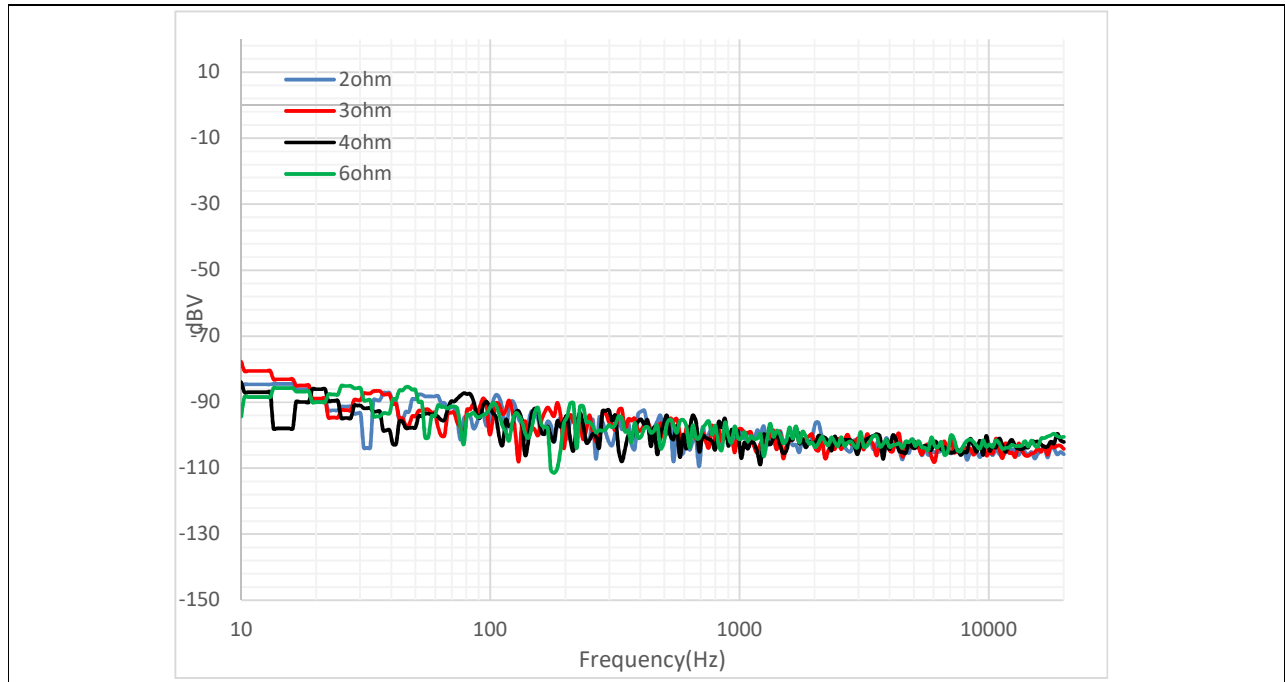


Figure 5 Noise floor

### 4.7.5 Efficiency

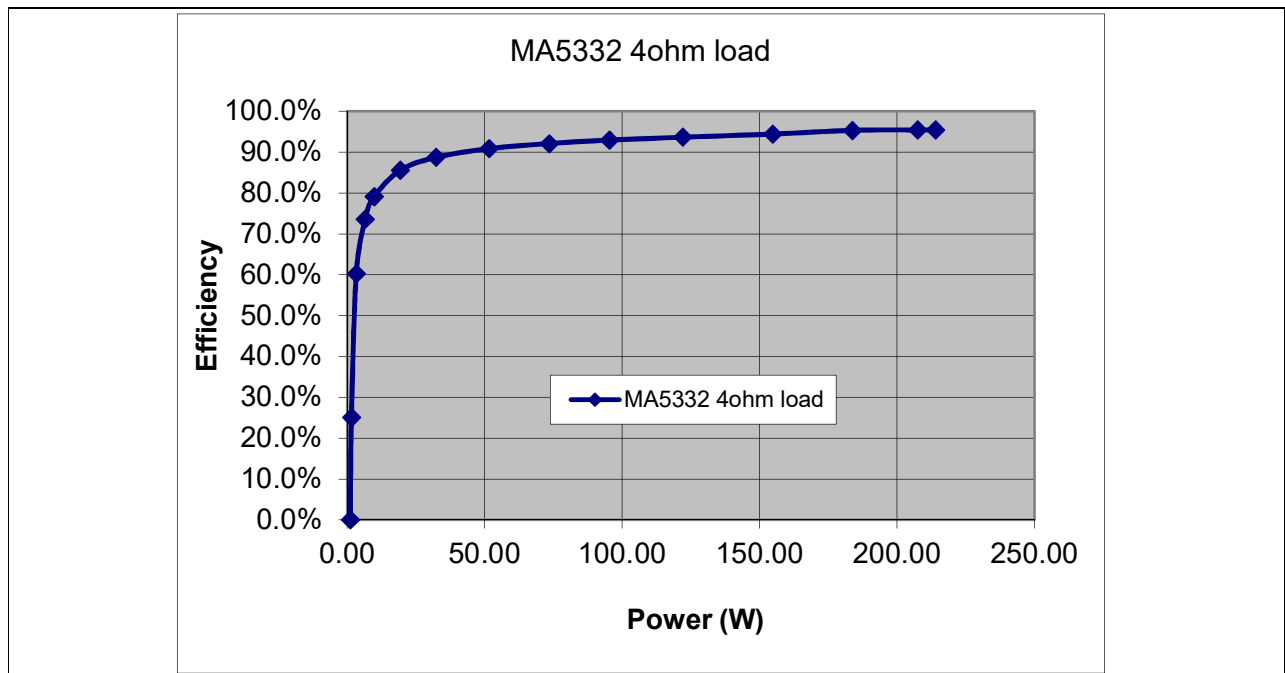


Figure 6 Efficiency 4 Ω load

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## 4.8 Typical Audio characteristics (BTL)

Test conditions:

All Measurements taken at Sine wave frequency= 1 kHz, AES17+ AUX-0025 measurement filters.

$V_{bus} = \pm 40\text{ V}$ , Load impedance =  $8\ \Omega$ ,  $F_{PWM} = 400\text{ kHz}$

$V_{bus} = \pm 31.5\text{ V}$ , Load impedance =  $6\ \Omega$ ,  $F_{PWM} = 400\text{ kHz}$

$V_{bus} = \pm 23\text{ V}$ , Load impedance =  $4\ \Omega$ ,  $F_{PWM} = 400\text{ kHz}$

### 4.8.1 Power vs. THD+N

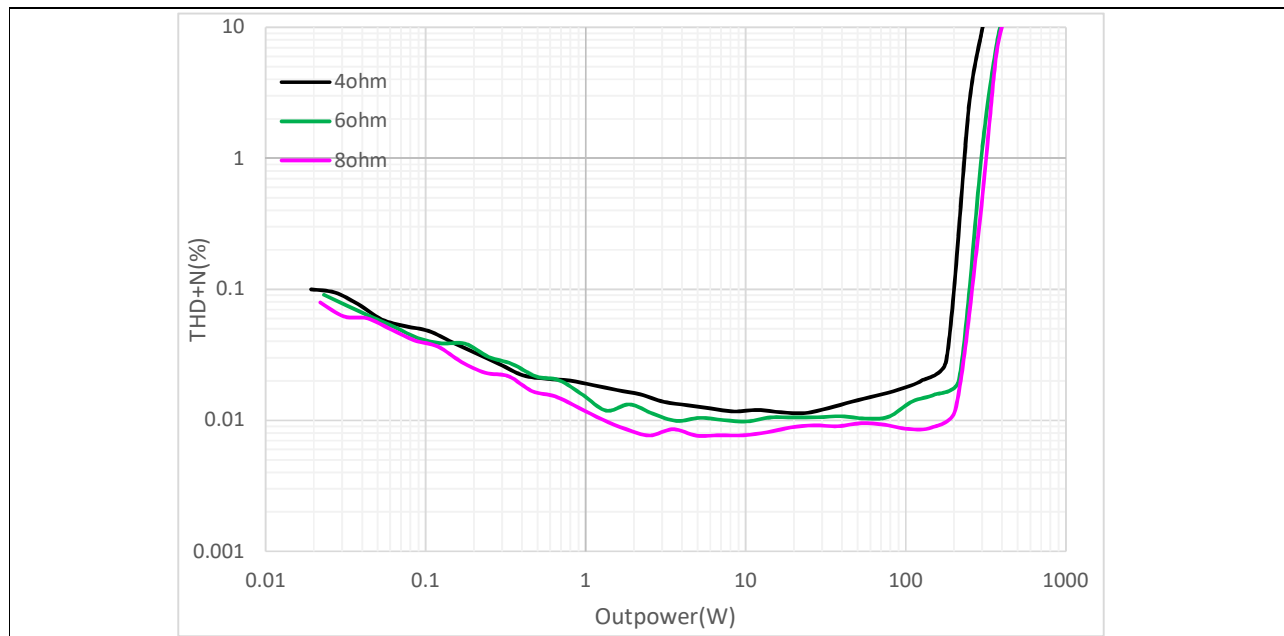


Figure 7 Power vs. THD+N

#### 4.8.2 Frequency vs. THD+N

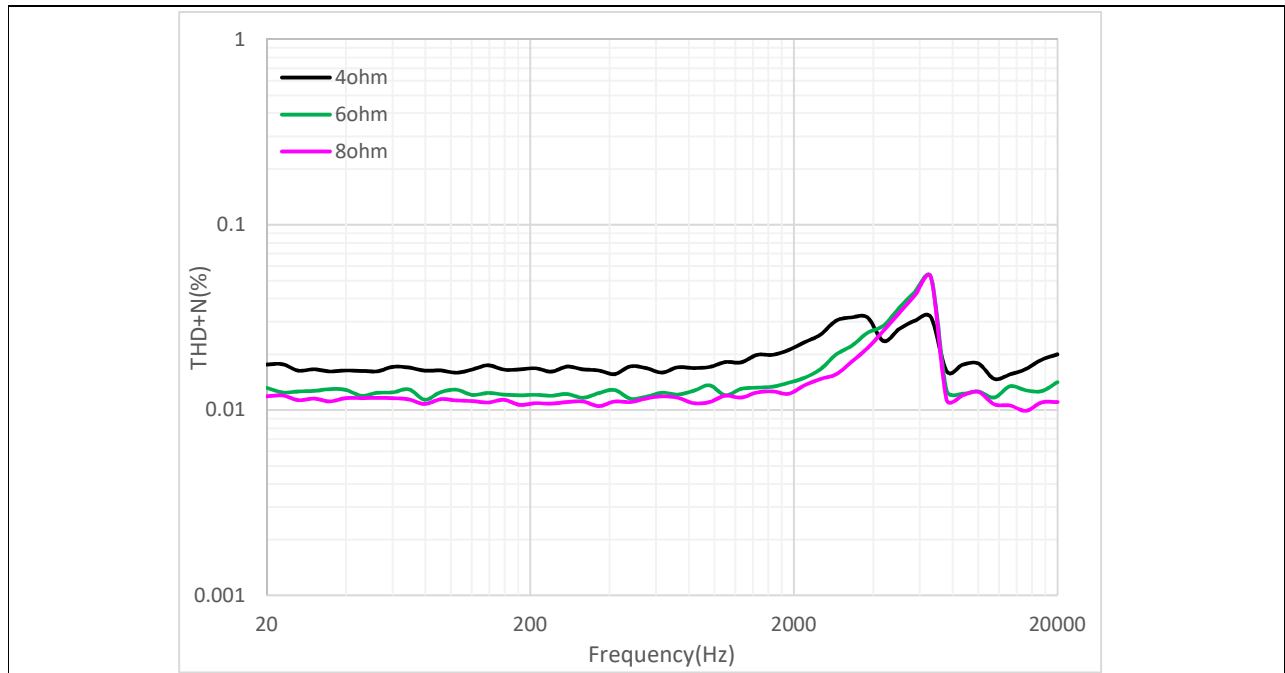


Figure 8 Frequency vs. THD+N @1W

#### 4.8.3 Frequency response

Test conditions:

Output power = 1 W, fixed LPF 22uH+0.47uF

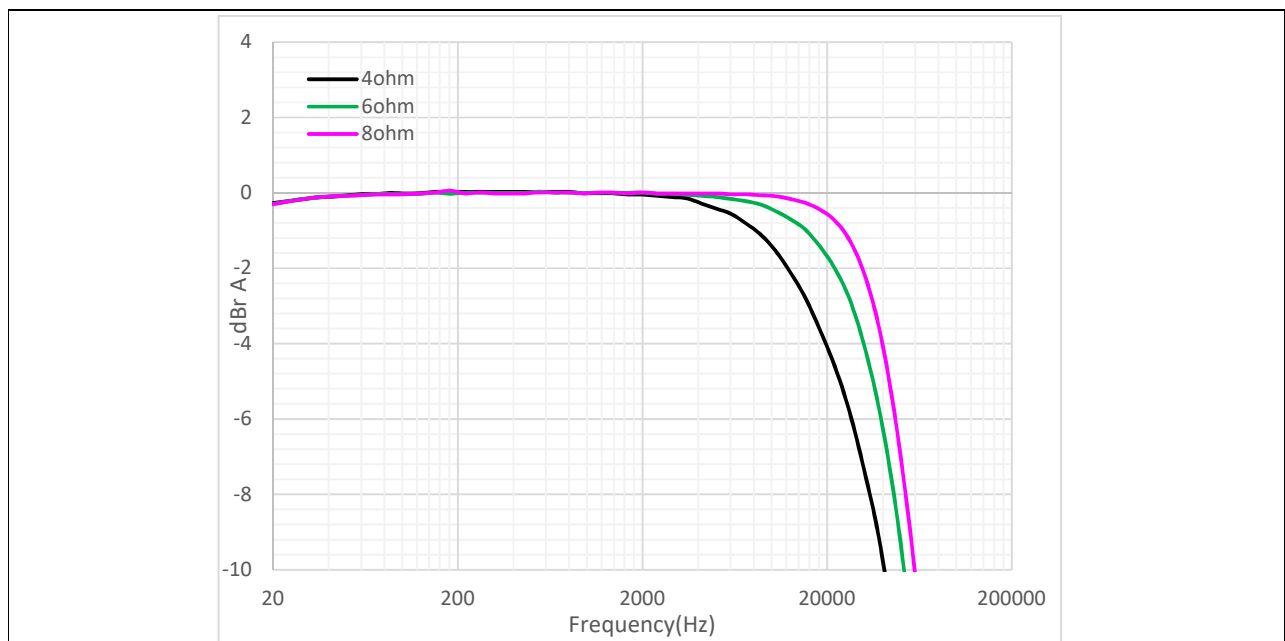


Figure 9 Frequency response

### 4.8.4 Noise floor

Test conditions:

No input signal

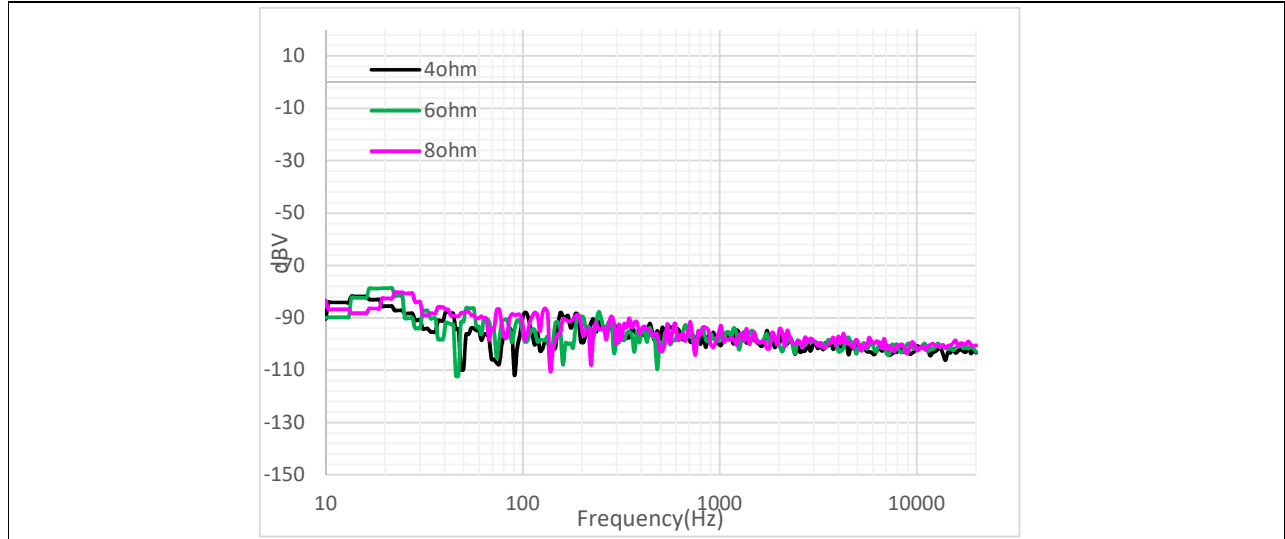


Figure 10 Noise floor

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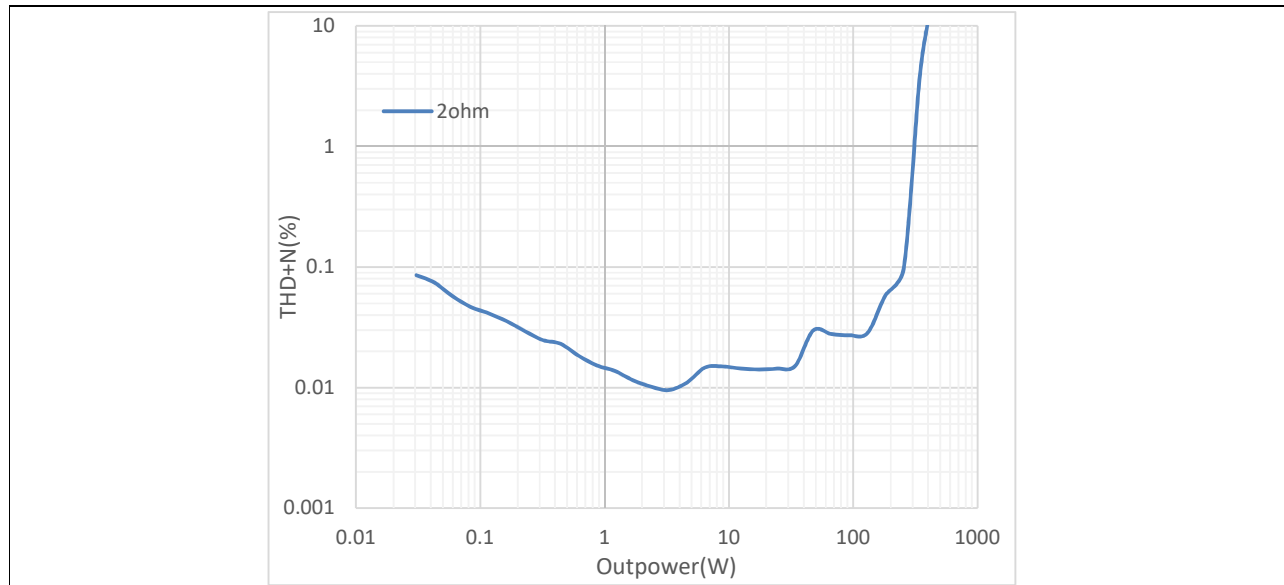
## 4.9 Typical Audio characteristics (PSE)

Test conditions:

All Measurements taken at Sine wave frequency= 1 kHz, AES17+ AUX-0025 measurement filters.

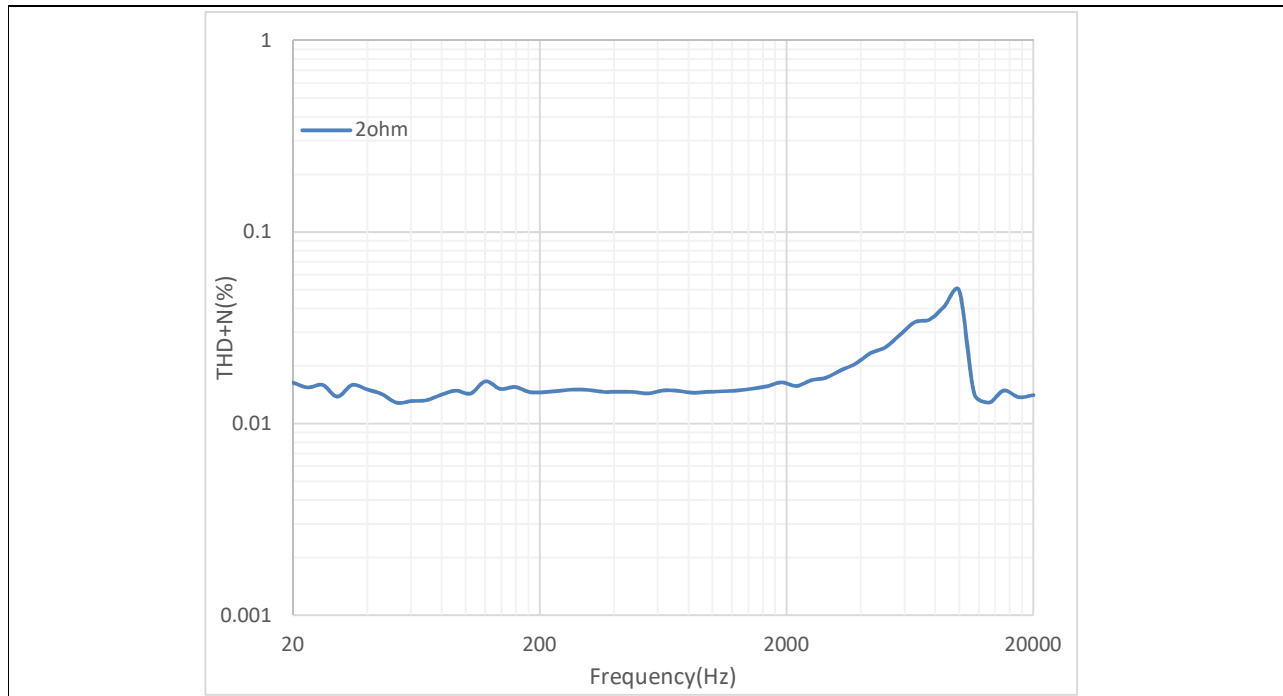
$V_{bus} = \pm 36.5\text{ V}$ , Load impedance =  $2\ \Omega$ ,  $F_{PWM} = 400\text{ kHz}$

### 4.9.1 Power vs. THD+N



**Figure 11** Power vs. THD+N

### 4.9.2 Frequency vs. THD+N

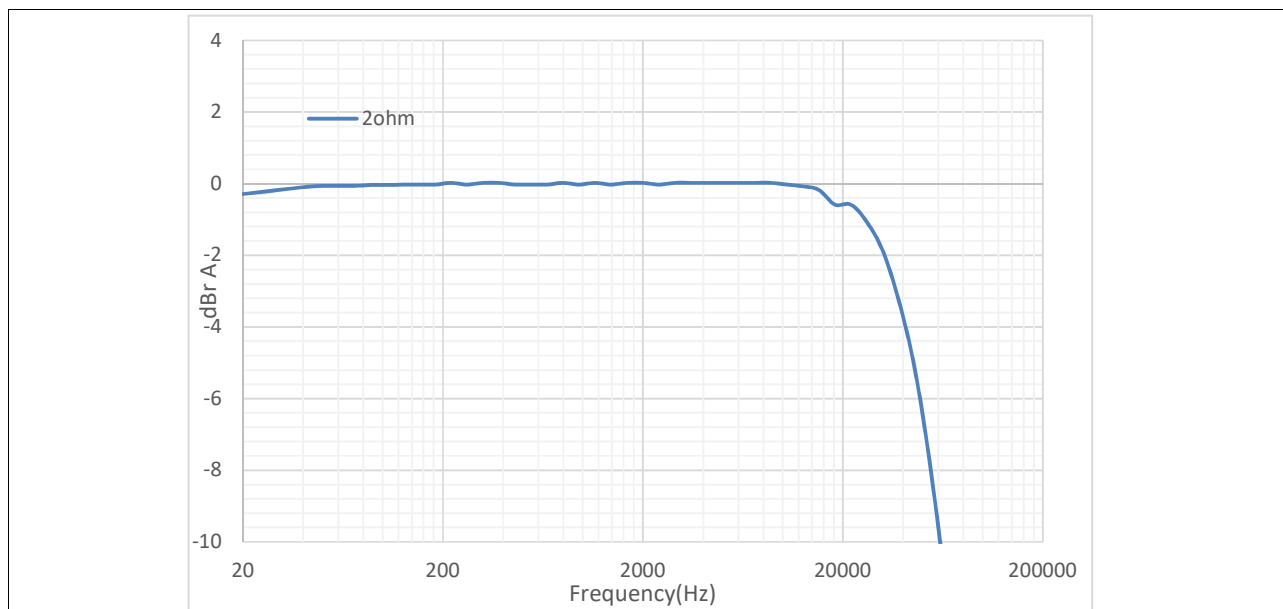


**Figure 12** Frequency vs. THD+N @1W

### 4.9.3 Frequency response

Test conditions:

Output power = 1 W, fixed LPF 22uH+0.47uF

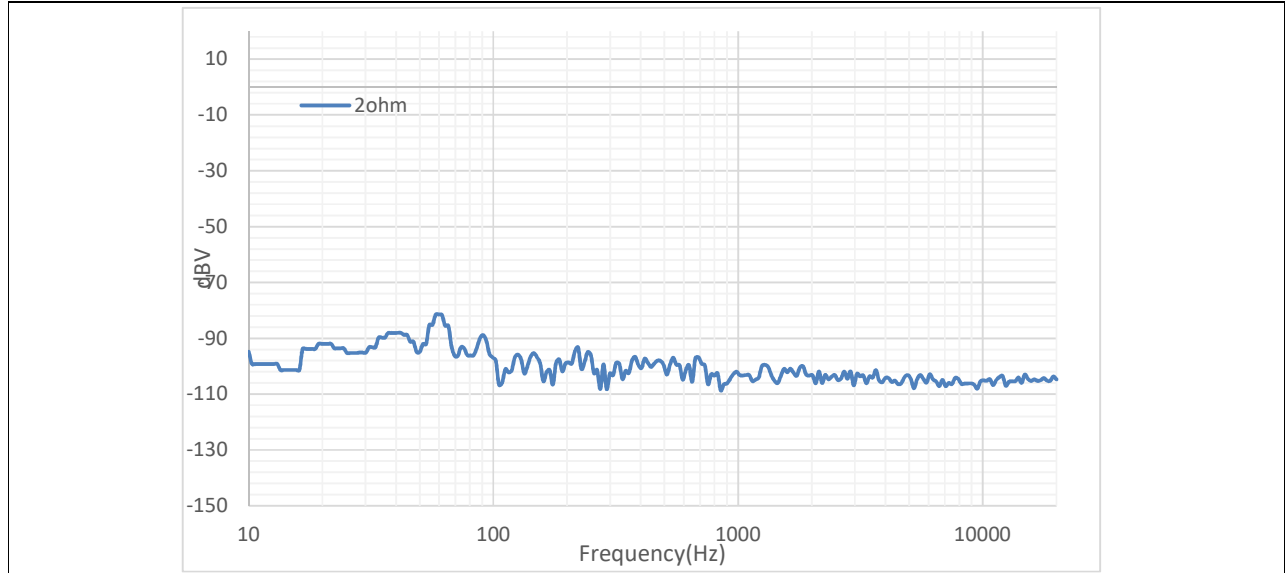


**Figure 13** Frequency response

### **4.9.4 Noise floor**

Test conditions:

No input signal



**Figure 14 Noise floor**

## 5 Thermal information

Benefits from unique co-packaging technique and superior MOSFET technology, MA5332MS has the best-in-class thermal performance, Peak power duration. It can deliver  $100W^*2/4Q$  even without a heatsink.

### 5.1 Peak power duration thermal information

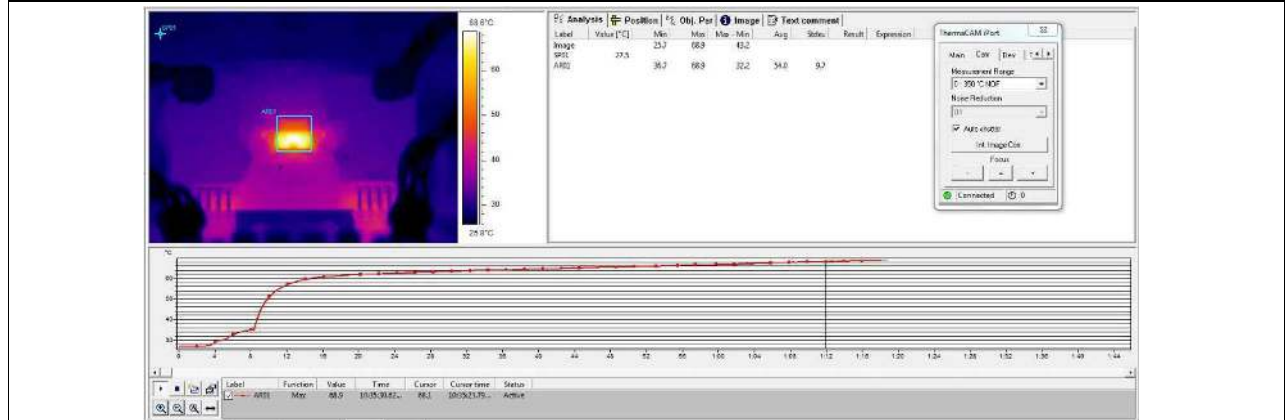
Test conditions:

All Measurements are taken at sinewave frequency= 1 kHz, AES17+ AUX-0025 measurement filters. Input signal = 1 kHz,  $F_{PWM} = 400$  kHz.

Tests are based on Eval\_AUDAMP25 board when both channels are driven.

**Table 6 Peak power with heatsink**

Load ( $\Omega$ )	$\pm V_{bus}$ (V)	10 percent THD+N power (W)	Duration
6	40	160	More than 1 minute without thermal shutdown
4	36.5	200	
3	31.5	190	
2	23	150	

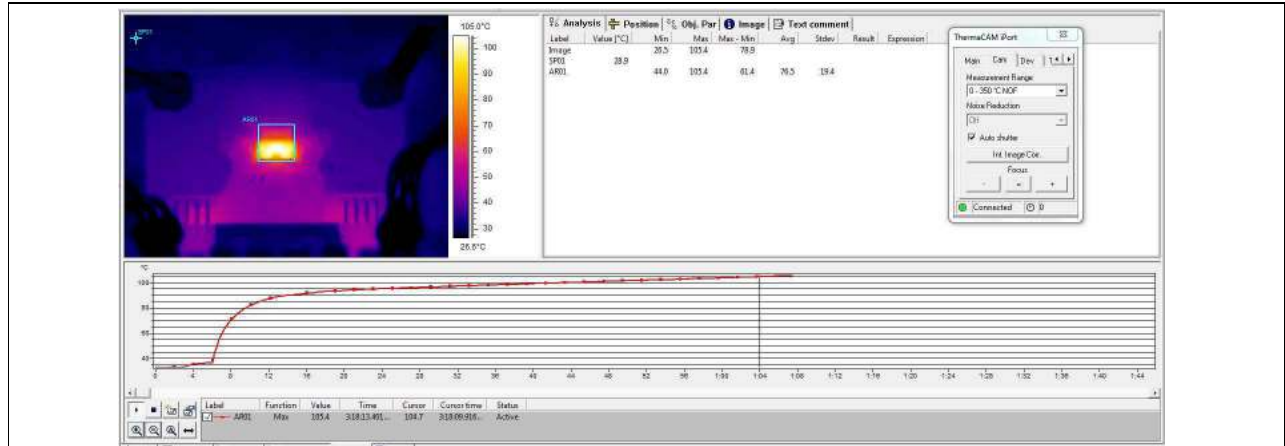


**Figure 15 Peak power  $P_{out} = 164$  W with 6  $\Omega$  load  $\pm 40$  V**

*Note: Maximum temperature 68.9°C at 1 minute.*

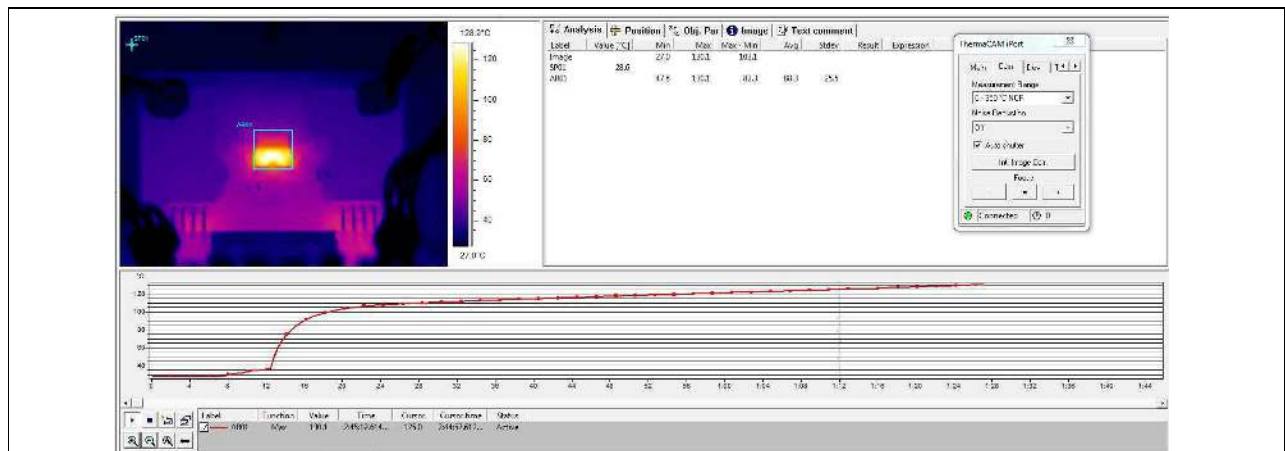


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**Figure 16** Peak power  $P_{out} = 200\text{ W}$  with  $4\ \Omega$  load  $\pm 36.5\text{ V}$

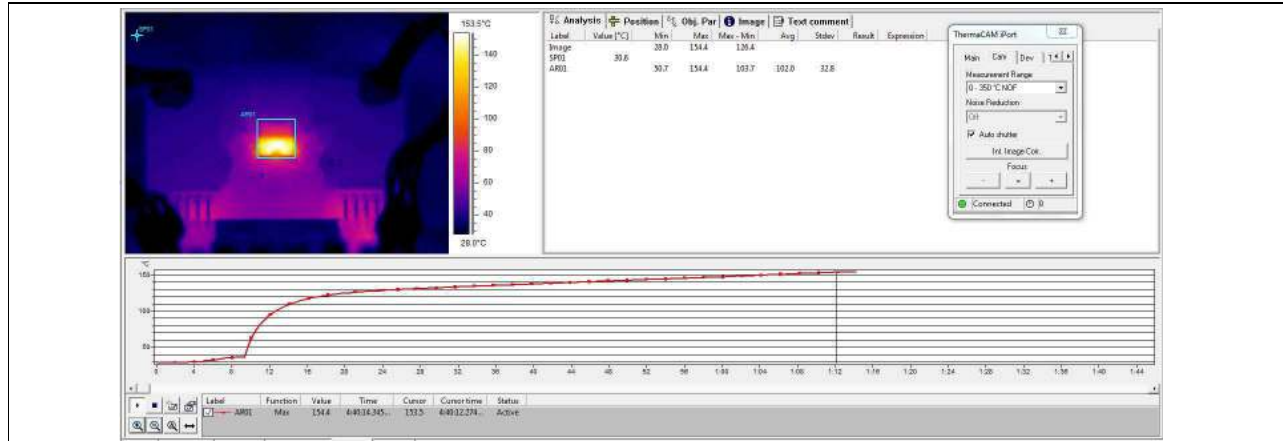
*Note:* Maximum temperature  $105^{\circ}\text{C}$  at 1 minute.



**Figure 17** Peak power  $P_{out} = 194\text{ W}$  with  $3\ \Omega$  load  $\pm 31.5\text{ V}$

*Note:* Maximum temperature  $130^{\circ}\text{C}$  at 1 minute.

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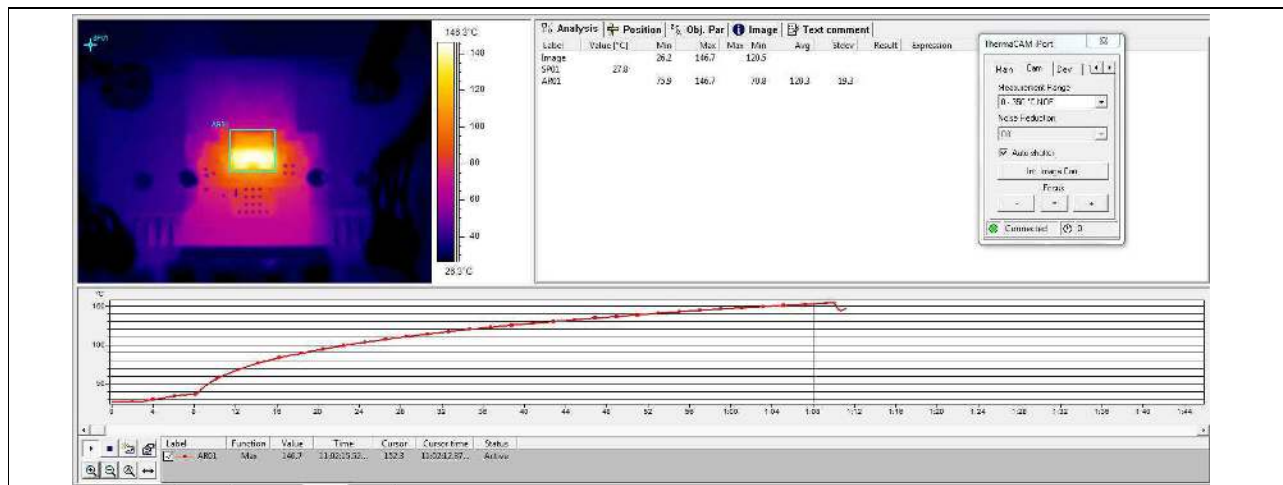


**Figure 18** Peak power  $P_{out} = 150\text{ W}$  with  $2\ \Omega$  load  $\pm 23\text{ V}$

*Note:* Maximum temperature  $154^{\circ}\text{C}$  at 1 minute.

**Table 7** Peak power without heatsink

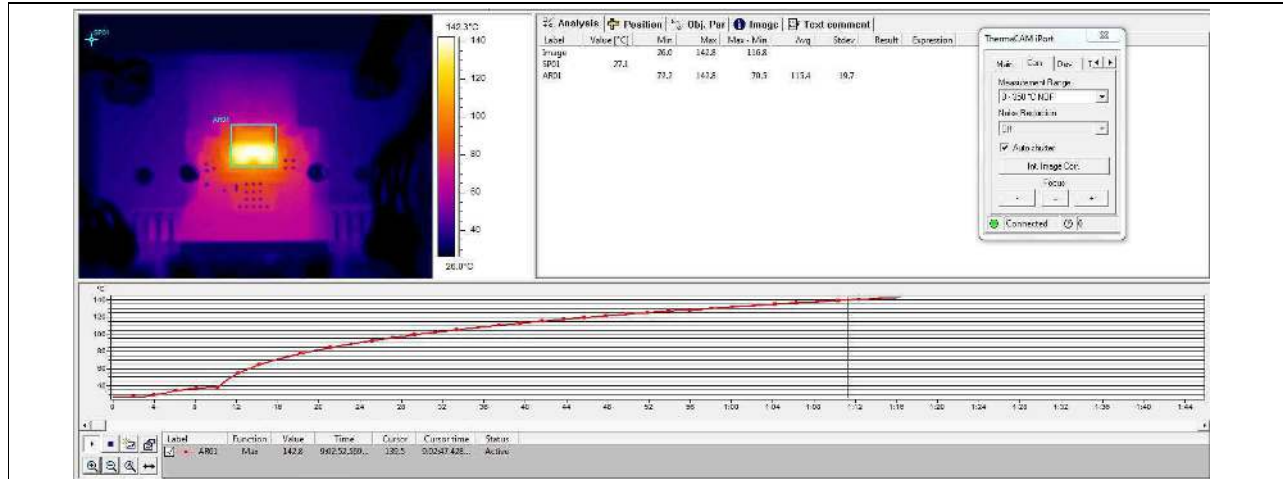
Load ( $\Omega$ )	$\pm V_{bus}$ (V)	10 percent THD+N power (W)	Duration
4	26.5	100	More than 1 minute without thermal shutdown
2	13.7	50	



**Figure 19** Peak power  $P_{out} = 102\text{ W}$  with  $4\ \Omega$  load  $\pm 26.5\text{ V}$

*Note:* Maximum temperature  $146.7^{\circ}\text{C}$  at 1 minute.

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**Figure 20** Peak power  $P_{out} = 55\text{ W}$  with  $2\ \Omega$  load  $\pm 13.7\text{ V}$

*Note:* Maximum temperature  $142.8^\circ\text{C}$  at 1 minute.

**Table 8** 1/8 power test with heatsink

Load ( $\Omega$ )	$\pm V_{bus}$ (V)	Max. T-case ( $^\circ\text{C}$ )	1/8 power (W)	Duration (minutes)
6	40	71.6	16.5	30
4	36.5	85.6	19.8	30
3	31.5	87.2	19.7	30
2	23	84.8	15	30

**Table 9** 1/8 power test without heatsink

Load ( $\Omega$ )	$\pm V_{bus}$ (V)	Max. T-case ( $^\circ\text{C}$ )	1/8 power (W)	Duration (minutes)
4	22.7	84.6	7.12	30
2	13.7	76.1	4.88	30

## 5.2 Heatsink information

Heatsink: V8818V

Thermal pad: BER161-ND



**Figure 21** Heatsink installation

## 6 Functional block diagram

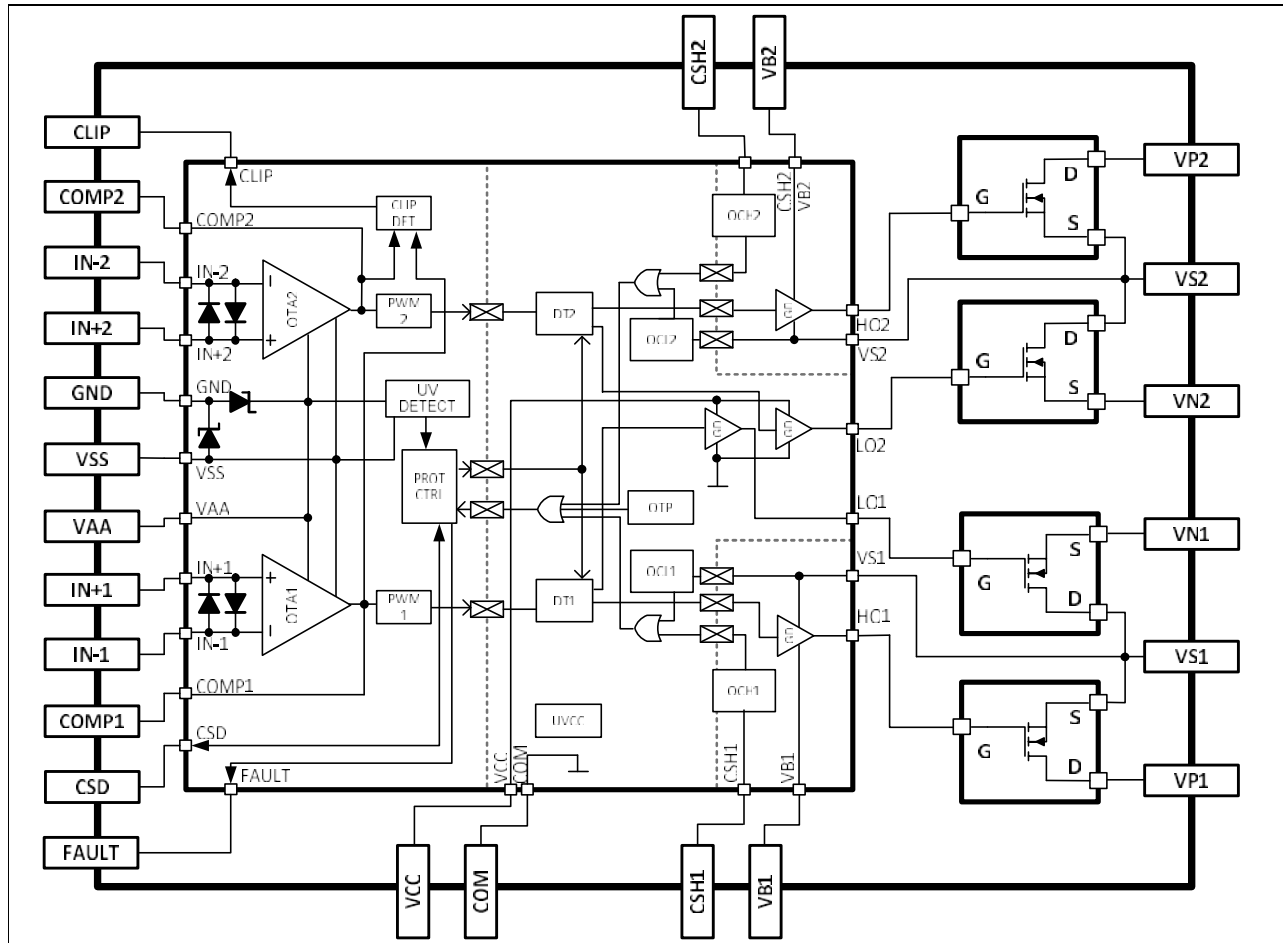
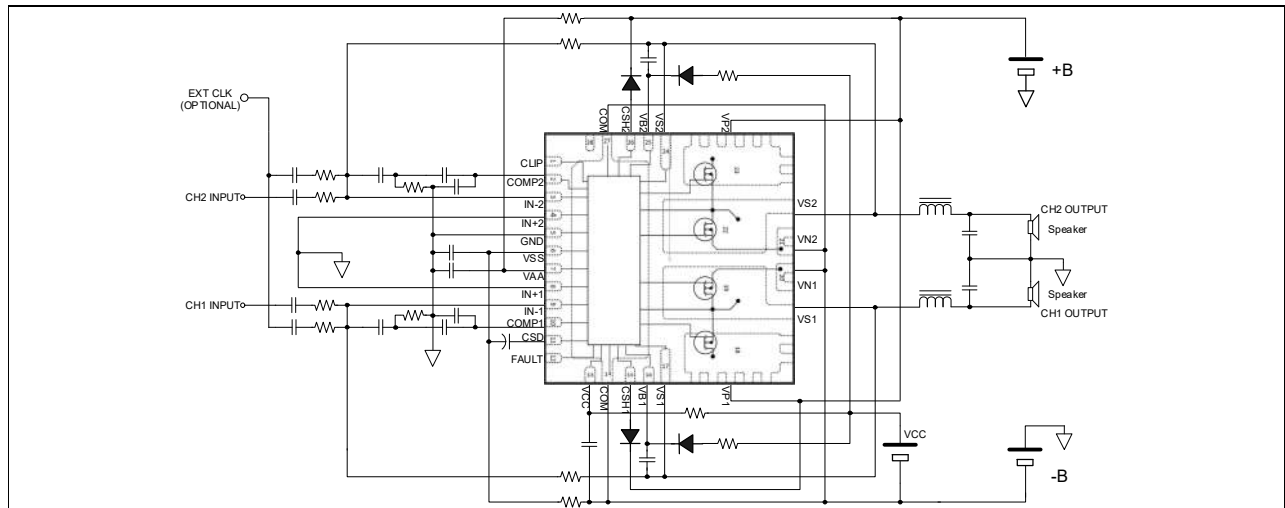


Figure 22 Block diagram

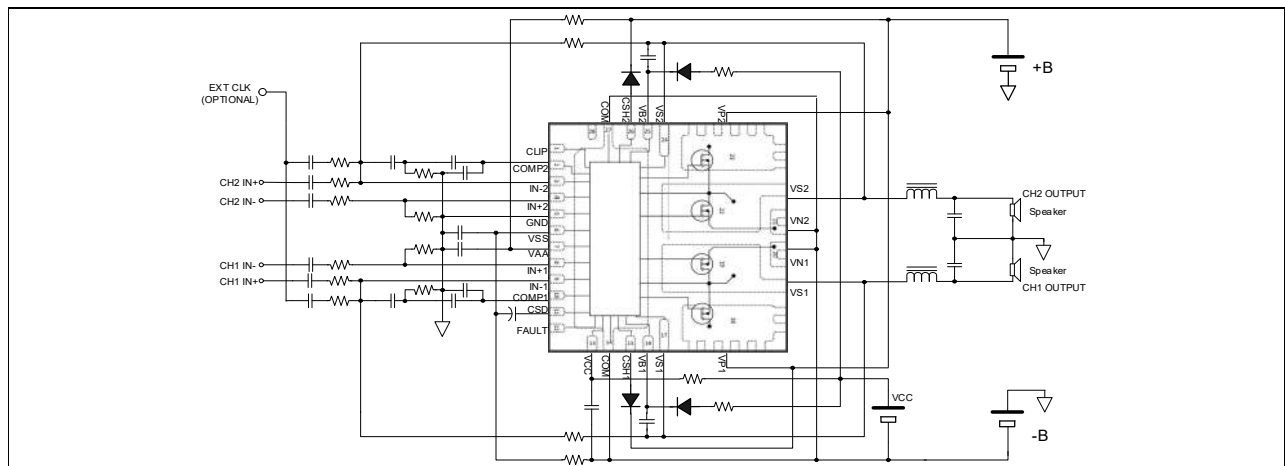
## 7 Typical Implementation

The MA5332MS can be designed as single-ended, BTL or parallel single ended (PSE) output configuration, using a single or split power supply. Here are examples of typical configurations.

A configuration for single-ended input with split power supply sets the base example. The front end section refers to GND which is common to speaker output GND.



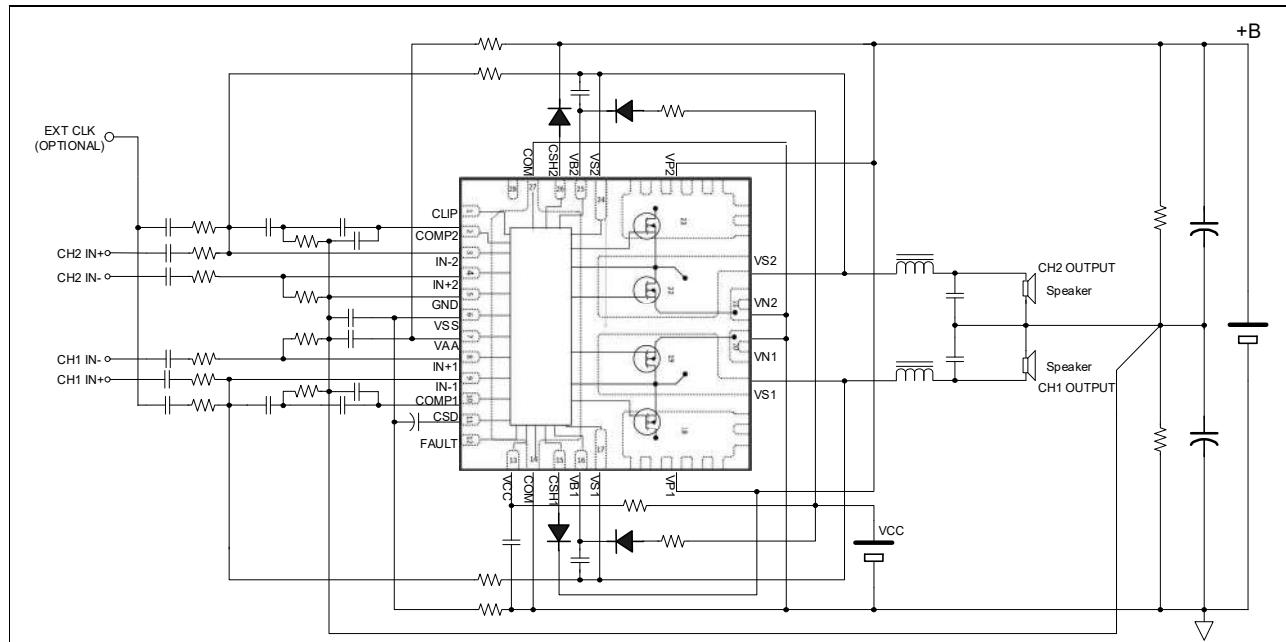
**Figure 23 Inverting amplifier with Split Power Supply**



**Figure 24 Differential amplifier with Split Power Supply**

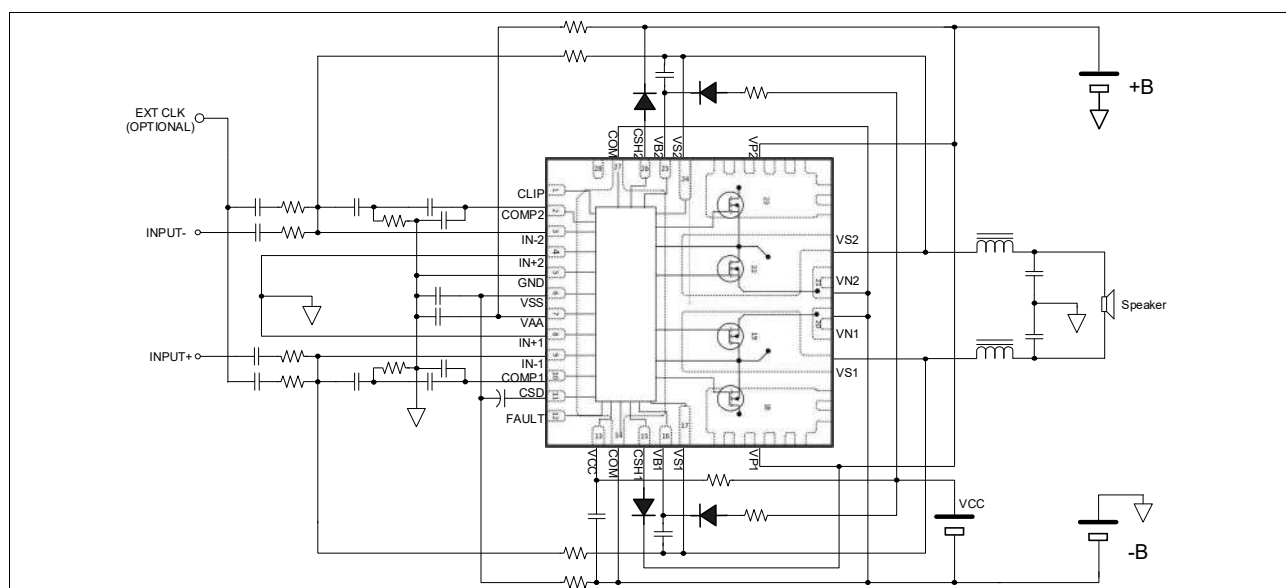
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The single-supply configuration uses a virtual GND which sits in the middle of the power supply rail. The front-end section of the amplifier refers to the virtual GND as a reference. This method uses differential input to receive an input signal from a different voltage potential. It is recommended to allow input capacitors to fully settle to steady-state values before releasing the CSD pin to start PWM oscillation. The load current and inductor ripple current flow through the bus splitting capacitor.



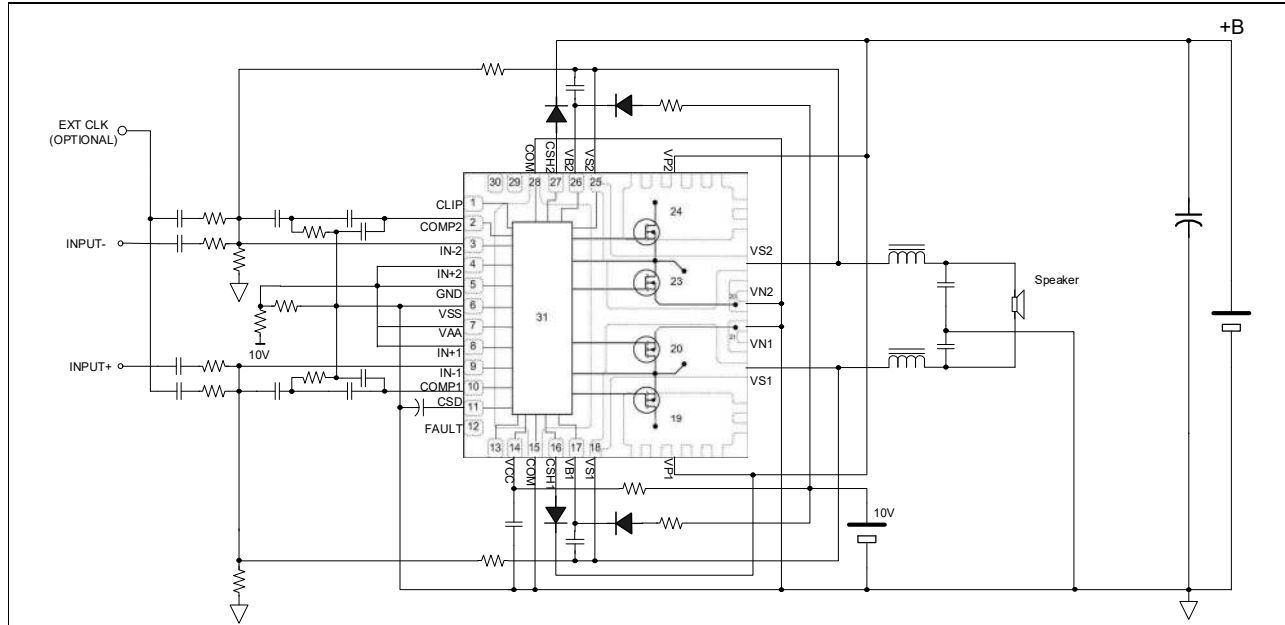
**Figure 25 Typical Application Circuit with Single Power Supply**

Balanced Tied Load (BTL) output takes two output legs for speaker output. It doubles output power with double load impedance. Any load current does not flow through supply dividing capacitor; therefore BTL configuration is free from GND fluctuations. Also, the bus splitting capacitor can be much smaller. Higher output power and absence of GND fluctuation make BTL suitable for subwoofer applications.



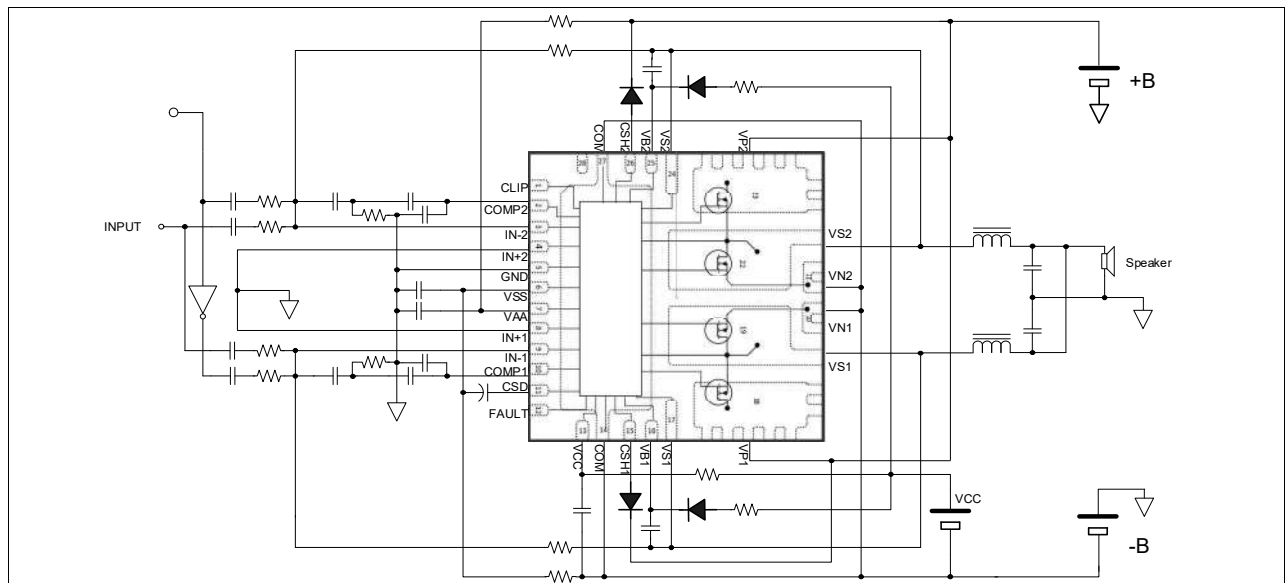
**Figure 26 Typical Bridged Tied Load (BTL) Output Application with Split Power Supply**

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**Figure 27 Typical Bridged Tied Load (BTL) Output Application with Single Power Supply**

Parallel Single Ended (PSE) output parallels two channels' output legs for one speaker output. It doubles output current and makes it easier to drive a low impedance load. Higher output current with lower bus voltage makes PSE suitable for subwoofer applications.



**Figure 28 PSE amplifier with Split Power Supply**



## 8 Input / Output pin equivalent circuit diagrams

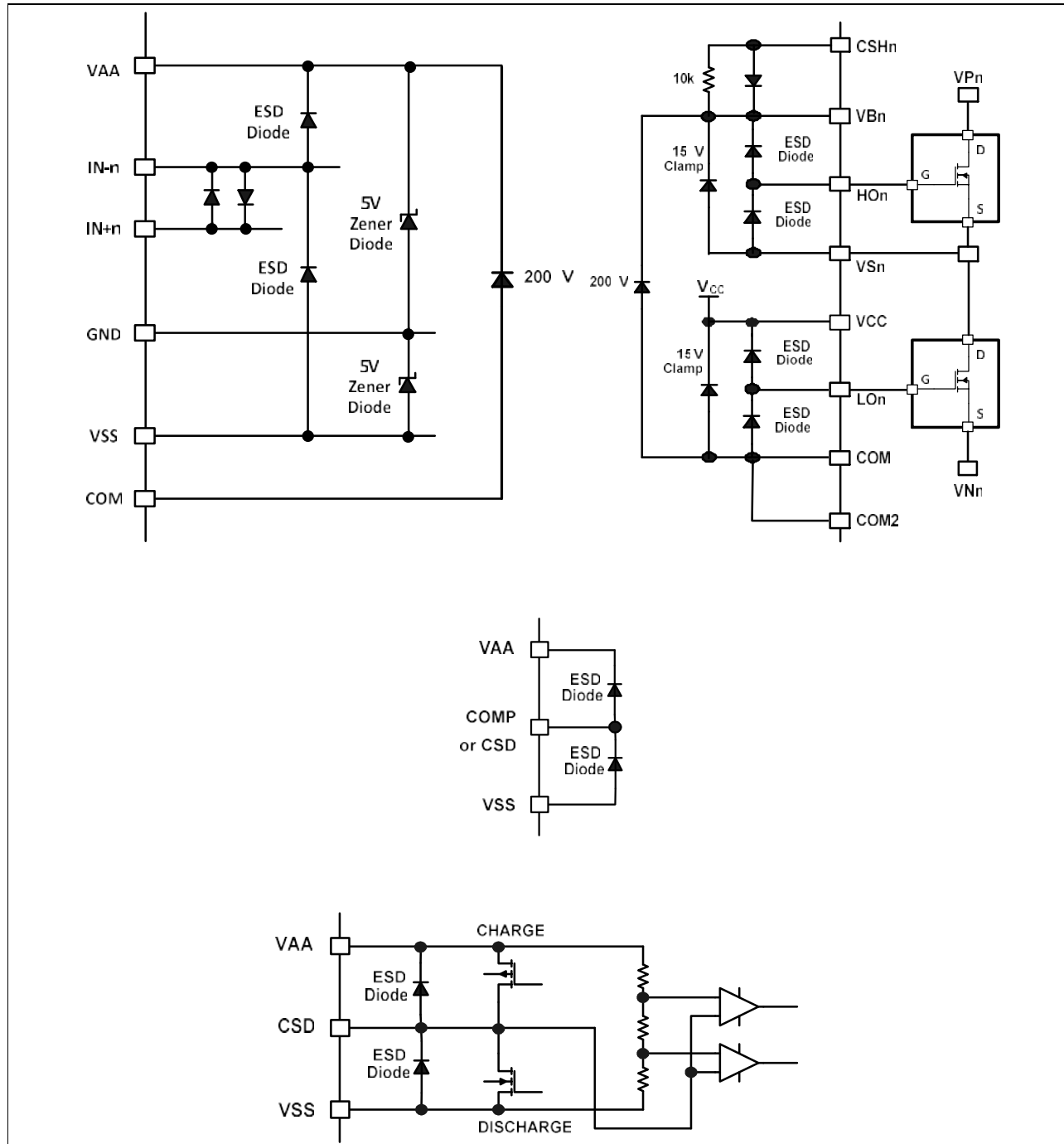
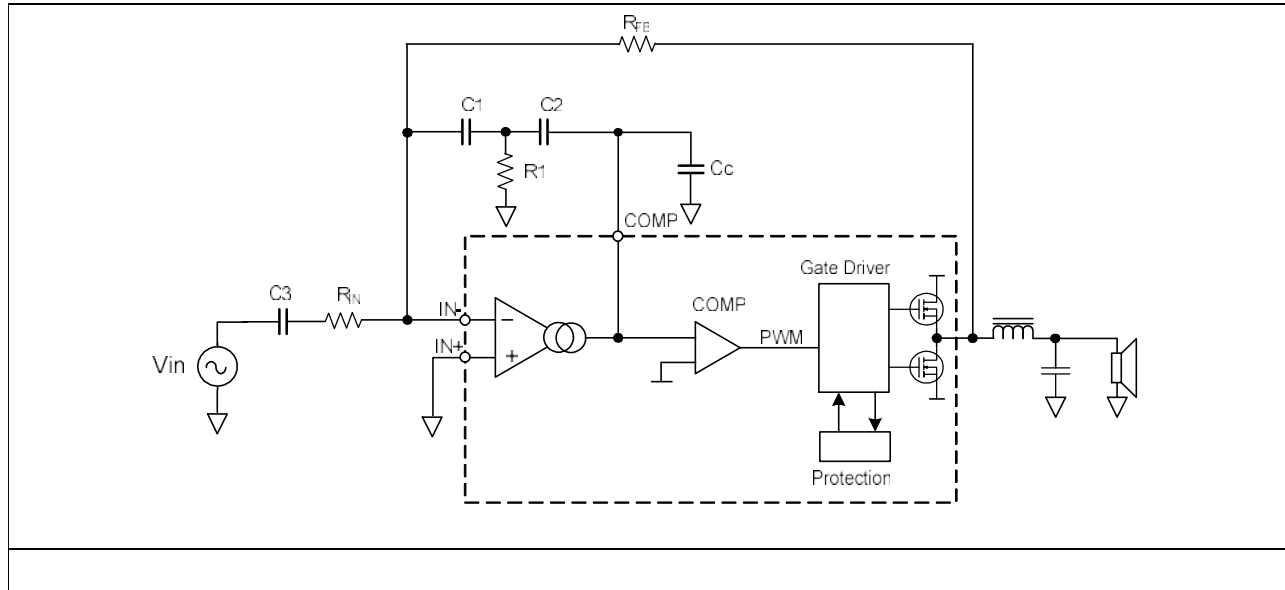


Figure 29 Input/output pin equivalent circuit diagrams

## 9 PWM Modulator Design

The open-access front-end configuration of MA5332MS enables many ways to implement a PWM modulator. This section explains how PWM modulation works based on an example of a self-oscillating PWM modulator in a typical application.



**Figure 30 MA5332MS Typical Control Loop Design**

### 9.1 Input Section

The audio input stage of MA5332MS forms an inverting error amplifier. The voltage gain of the amplifier,  $G_V$ , is determined by the ratio between input resistor  $R_{IN}$  and feedback resistor  $R_{FB}$ .

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

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

A DC blocking capacitor  $C3$  should be connected in series with  $R_{IN}$  to minimize the DC offset voltage on the output. Due to potential distortion, a ceramic capacitor is not recommended. Minimizing the DC offset is essential to minimize the audible noise during power-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 the same potential as the negative terminal of the speaker output.

## 9.2 Control Loop Design

The MA5332MS allows the user to choose from numerous methods of PWM modulator implementations. In this section, all the explanations are based on a typical application circuit of a self-oscillating

## 9.3 PWM Frequency

Choosing the switching frequency entails making a trade-off between many aspects. At lower switching frequency, conduction losses in the MOSFET stage increases due to higher inductor ripple current. The output carrier leakage in the speaker output increases. At higher switching frequency, the efficiency degrades due to higher switching losses. Higher switching frequency supports wider audio bandwidth. The inductor ripple decreases yet core loss might increase. For these reasons, 400kHz is chosen for a typical design example.

Self-oscillating frequency has little influence from the bus voltage and input resistance  $R_{IN}$ . Note that the nature of a self-oscillating PWM is for the switching frequency to decrease as PWM modulation deviates from idling.

Table 10 summarizes suggested values of components for a given target self-oscillating frequency. The front-end operational transconductance amplifier (OTA) output has limited voltage and current compliances. This set of component values ensures that OTA operates within its linear region for optimal THD+N performance. In case the target frequency is somewhere in between the frequencies listed in Table 10, simply adjust the frequency by tweaking  $R_1$ .

**Table 10 External Component Values vs. Self-Oscillation Frequency**

<b>Target Self-Oscillation Frequency (kHz)</b>	<b>C1=C2 (nF)</b>	<b>R1 (ohms)</b>
500	2.2	200
450	2.2	165
400	2.2	141
350	2.2	124
300	2.2	115
250	2.2	102
200	4.7	41.2
150	10	20.0
100	10	14.0
70	22	4.42

### 9.4 Clock Synchronization

In the PWM control loop design example, the self-oscillating frequency can be set and synchronized to an external clock. Through a set of resistors and a capacitor, the external clock injects periodic pulsating charges into the integrator, forcing oscillation to lock up to the external clock frequency. A typical setup with 5 Vp-p 50% duty clock signal uses  $R_{CK}=22\text{ k}\Omega$  and  $C_{CK}=100\text{ pF}$  in Figure 31. To maximize audio performance, the self-running frequency without clock injection should be 20 to 30% higher than the external clock frequency.

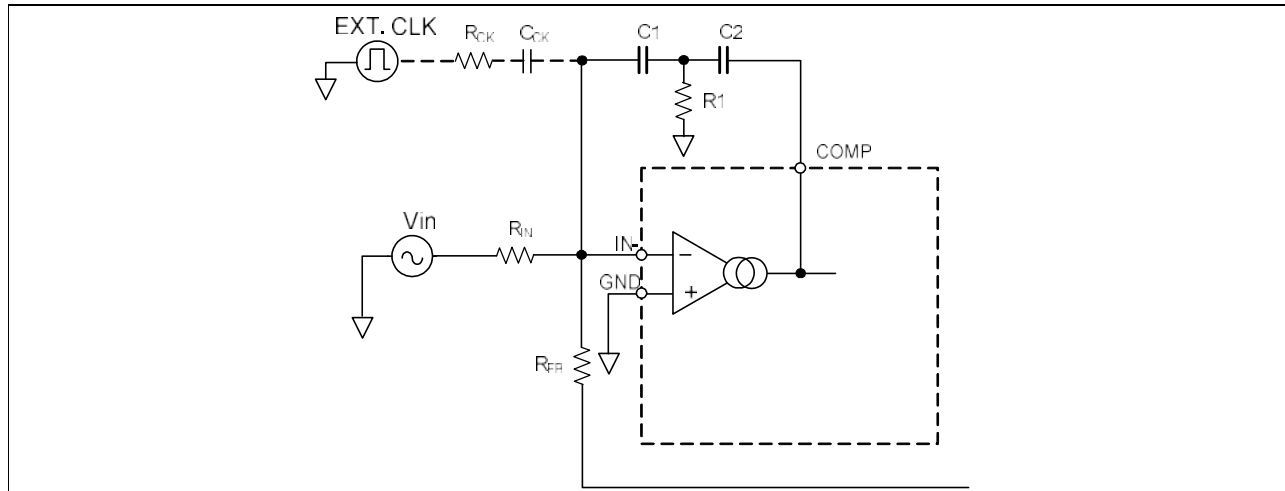


Figure 31 External Clock Synchronization

Figure 32 shows how a self-oscillating frequency locks up to an external clock frequency. A design of a 400 kHz self-oscillating frequency synchronizes to an external clock whose frequency is within the red border lines.

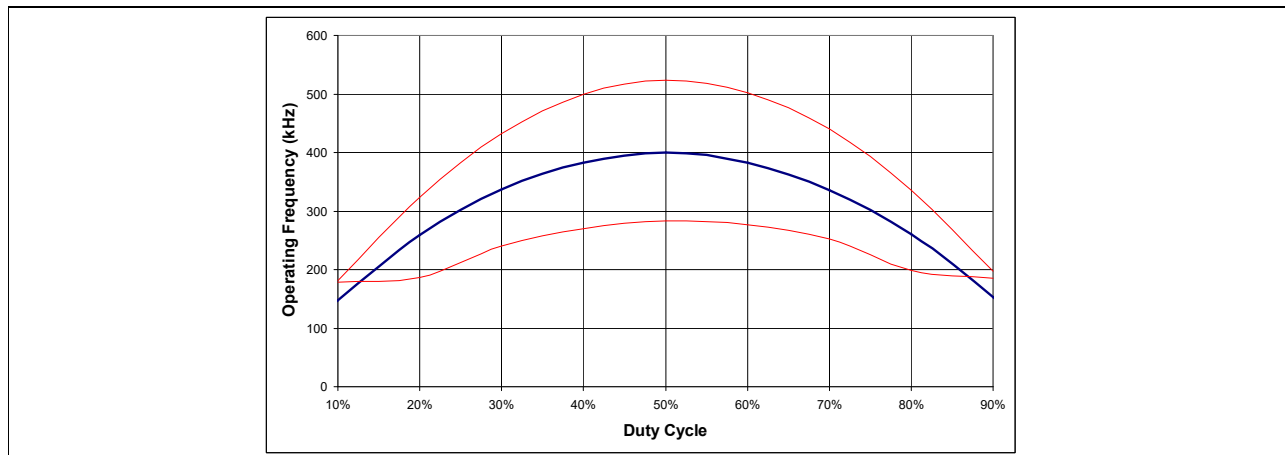
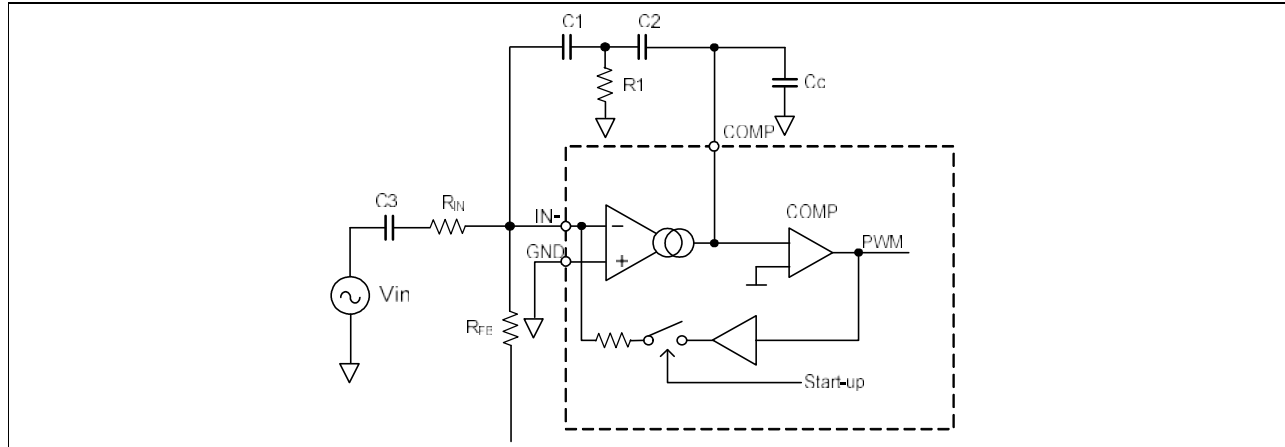


Figure 32 Typical Lock Range to External Clock ( $R_{CK}=22\text{ k}\Omega$  and  $C_{CK}=100\text{ pF}$ )

## 9.5 Click Noise Elimination

The MA5332MS has a unique feature that minimizes power-ON and -OFF audible click noise. When CSD is in between  $V_{th1}$  and  $V_{th2}$  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 1 MHz, independent from the switching oscillation.



**Figure 33 Audible Click Noise Elimination**

As a result, all capacitive components connected to COMP and IN- pins, such as C1, C2, C3 and Cc in Figure 33, are pre-charged to their steady-state values during the start-up sequence. This allows instant settling of closed-loop PWM operation.

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

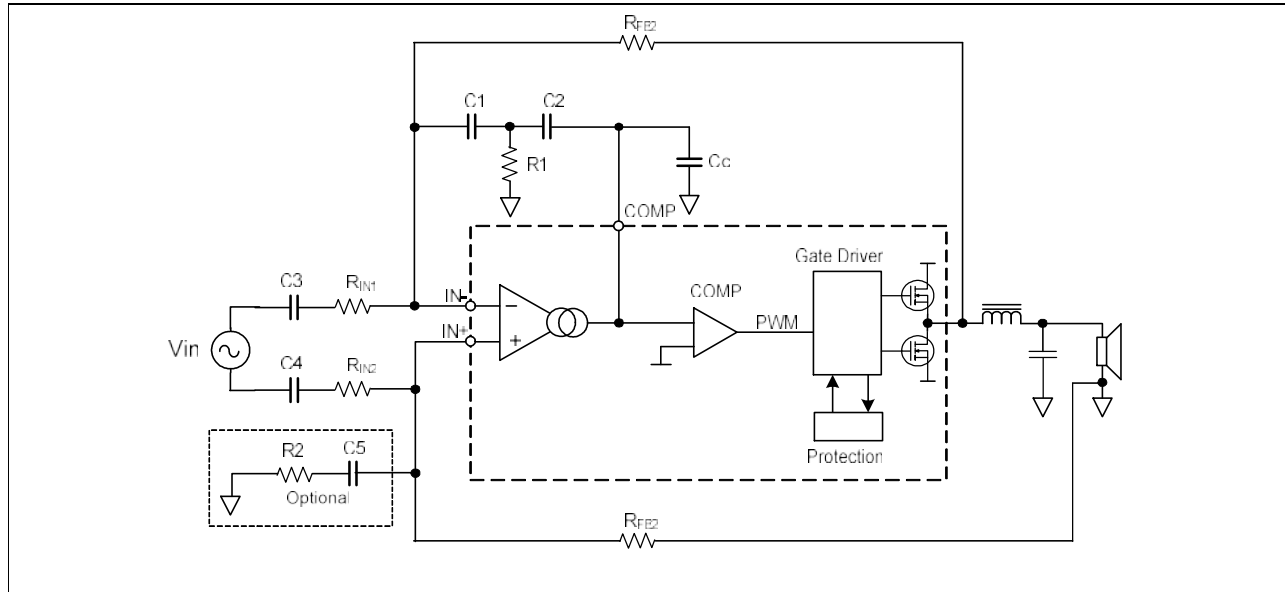
1. CSD pin has slow enough ramp up from  $V_{th1}$  to  $V_{th2}$  such that the voltages in the capacitors can settle to their target values.
2. High-side bootstrap power supply needs to be charged up prior to starting oscillation.
3. Audio input has to be zero.
4. For internal local loop to override external feedback during the startup period, DC offset at speaker output prior to shutdown release has to satisfy the following condition.

**9.6 Differential Input**

Figure 34 shows an example of a differential input configuration. This design is useful in a single supply configuration. Use  $R_{IN1}=R_{IN2}$ ,  $R_{FB1}=R_{FB2}$ ,  $C3=C4$ .

Voltage gain is given by a ratio between  $R_{IN}$  and  $R_{FB}$ .

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



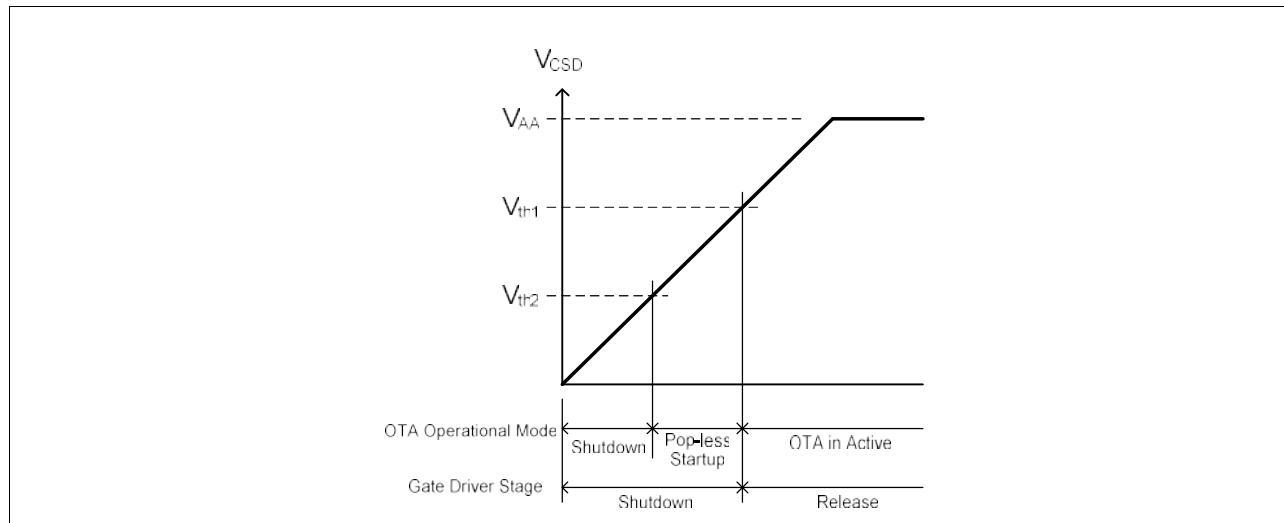
**Figure 34 Differential Input**

Although component values in the feedback network are balanced between inverting and non-inverting inputs, the integration capacitor path in the non-inverting input creates unbalance at high frequencies, causing slightly higher distortion compared to an unbalanced input configuration. To improve the THD degradations, place optional RC network  $R2=R1$  and  $C5=C1$ .

## 10 Operational Mode

The CSD pin determines the operational mode of the MA5332MS as shown in Figure 35. The OTA has three operational modes: shutdown, pop-less startup and normal operation; while the gate driver section has two modes: shutdown and normal operation.

When  $V_{CSD} < V_{th2}$ , the IC is in shutdown mode and the input OTA is cut off. When  $V_{th2} < V_{CSD} < V_{th1}$ , the output MOSFETs are still in shutdown mode. The OTA is activated and starts local oscillation for pop-less start-up which pre-biases all the capacitive components in the error amplifier. When  $V_{CSD} > V_{th1}$ , the MA5332MS enters normal operation mode and PWM operation starts.



**Figure 35**  $V_{CSD}$  and Operational Mode

### 10.1 Self-oscillation Start-up Condition

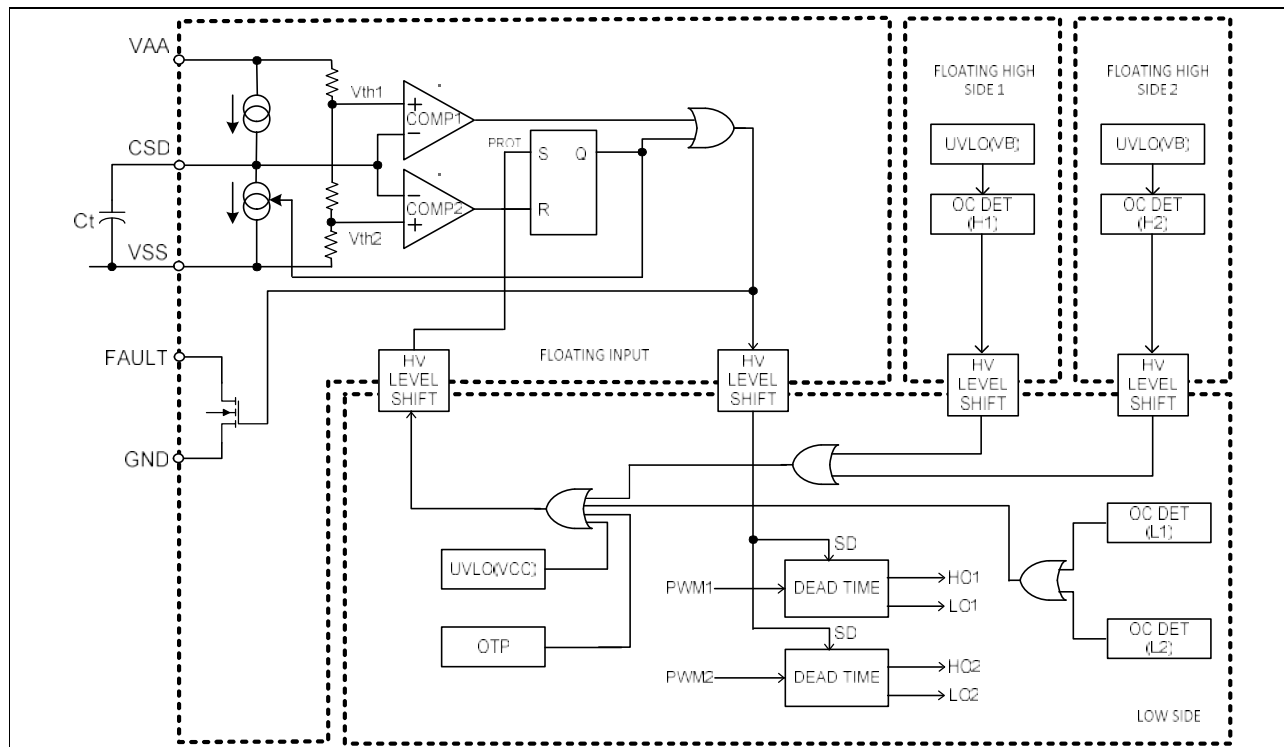
The MA5332MS requires the following conditions in order for pop-less startup to work properly.

- All the control power supplies, VAA, VSS, VCC and VBS are above the under-voltage lockout thresholds.
- CSD pin voltage is over Vth1 threshold.
- $|i_{IN}| < |i_{FB}|$

$$\text{Where } i_{IN} = \frac{V_{IN}}{R_{IN}}, i_{FB} = \frac{V_{+B}}{R_{FB}}.$$

- The duration CSD voltage transitioning from Vth2 to Vth1 is long enough to pre-charge input and integration capacitors around OTA section.

## 11 Protections



**Figure 36 Protection Functional Block Diagram**

The internal protection control block dictates the operational modes, normal or shutdown, using the input of the CSD pin. In shutdown mode, the controller IC turns off internal power MOSFETs.

The CSD pin provides five functions.

1. Power up delay timer
2. Self-reset timer
3. Shutdown input
4. Latched protection configuration
5. Shutdown status output (host I/F)

The CSD pin cannot be paralleled with another MA5332MS directly.

The operating statuses of the protection features are shown in Table 11.



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**Table 11 Events and Actions of CSD and FAULT**

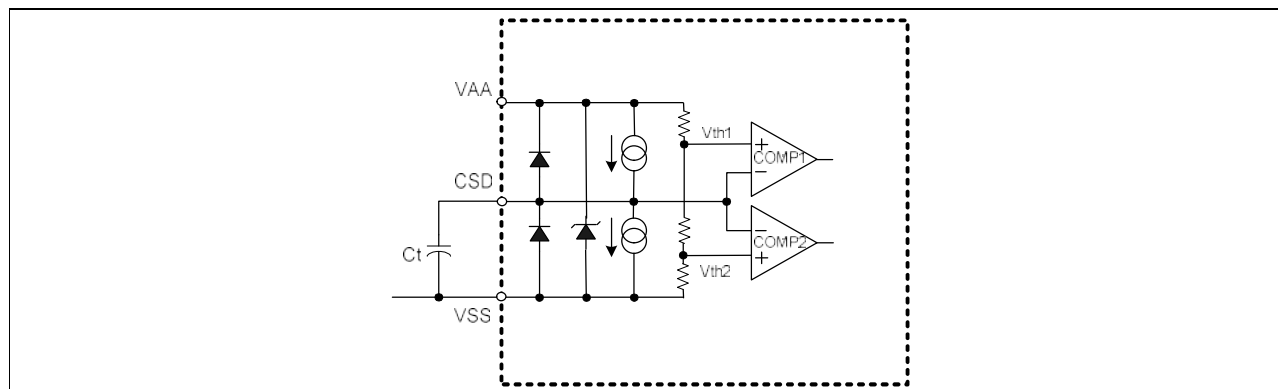
Event	CSD	FAULT
UVCC, rising edge	Recycle	L until CSD>Vth1
UVCC, falling edge	n/a	n/a
UVAA, rising edge	n/a	L at VAA<UVAA
UVAA, falling edge	n/a	L at VAA<UVAA
UVBS, rising edge	n/a	n/a
UVBS, falling edge	n/a	n/a
Over Current Protection	Keep recycling until OCP is reset	Held L until OCP is reset
Clip Detection	n/a	n/a
Over Temperature Protection	Keep recycling until OTP is reset	Held L until OTP is reset

\*CSD recycle: CSD pin voltage discharges down to Vth2 and charges back to VAA, if CSD pin is configured as self reset protection.

**11.1.1 Self-Reset Protection**

Attaching a capacitor between CSD and V<sub>SS</sub> configures the MA5332MS self-reset protection mode.

Upon an OCP event, the CSD pin discharges the external capacitor voltage V<sub>CSD</sub> down to the lower threshold V<sub>th2</sub> to reset the internal shutdown latch. Then, the CSD pin begins to charge the external capacitor, C<sub>t</sub>, in an attempt to resume operation. Once the voltage of the CSD pin rises above the upper threshold, V<sub>th1</sub>, the IC resumes normal operation.



**Figure 37 Self-Reset Protection Configuration**

**Table of contents**

**11.1.2 Designing Ct**

The external timing capacitor, Ct, programs self-reset timings: t<sub>RESET</sub> and t<sub>SU</sub>.

- t<sub>RESET</sub> is the time that elapses from when the IC enters the shutdown mode to the time when the IC resumes operation. t<sub>RESET</sub> should be long enough to avoid over heating the MOSFETs from the repetitive sequence of shutting down and resuming operation during over-current conditions. In most applications, the minimum recommended time for t<sub>RESET</sub> is 0.1 seconds.
- t<sub>SU</sub> is the time between powering up the IC in shutdown mode to the moment the IC releases shutdown to begin normal operation.

The Ct determines t<sub>RESET</sub> and t<sub>SU</sub> as following equations:

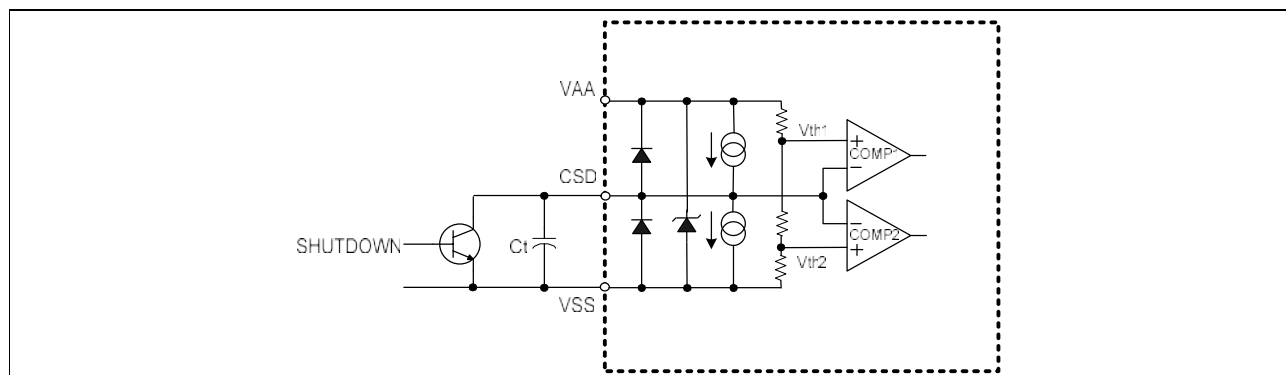
$$t_{RESET} = \frac{Ct \cdot V_{AA}}{1.1 \cdot I_{CSD}} \text{ [s]}$$

$$t_{SU} = \frac{Ct \cdot V_{AA}}{0.7 \cdot I_{CSD}} \text{ [s]}$$

where I<sub>CSD</sub>: the charge/discharge current at the CSD pin  
 V<sub>AA</sub>: the floating input supply voltage with respect to V<sub>SS</sub>.

**11.1.3 Shutdown Input**

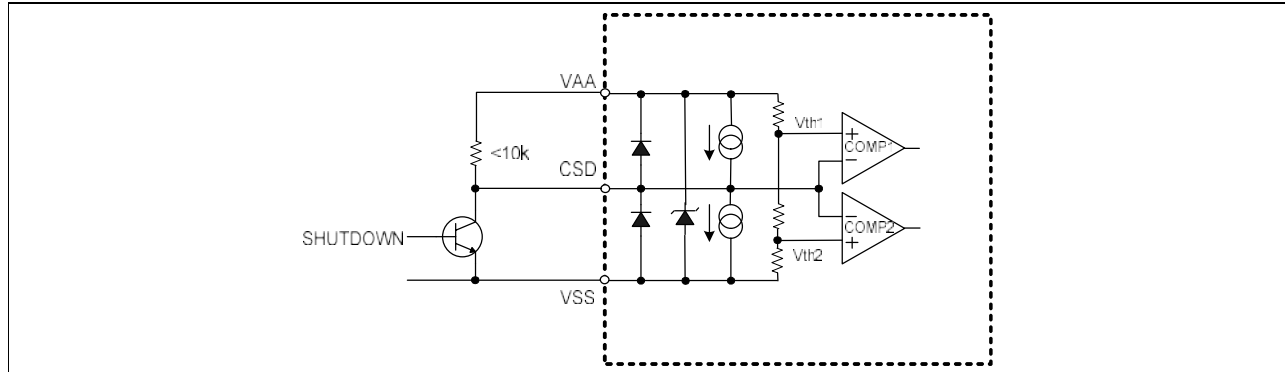
During normal operation, pulling the CSD pin below the upper threshold V<sub>th1</sub> forces the IC into shutdown mode. Figure 38 shows how to add an external discharging path to shutdown the PWM.



**Figure 38 Shutdown Input**

### 11.1.4 Latched Protection

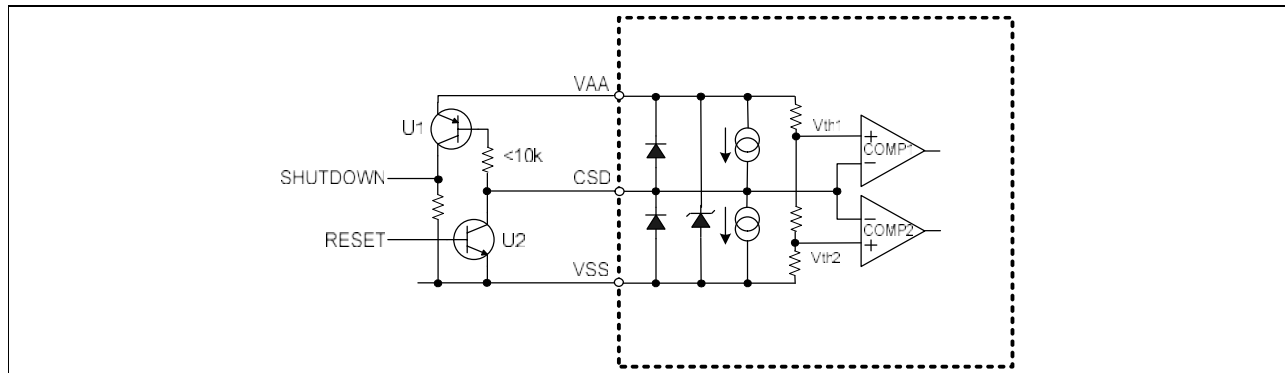
Connecting CSD to  $V_{AA}$  through a  $10\text{ k}\Omega$  or less resistor configures latched protection mode. The internal shutdown latch stays in shutdown mode after the overcurrent is detected. An external reset switch brings CSD below the lower threshold  $V_{th2}$  for a minimum of 200 ns and resets the latch. At first power-up, a reset signal to the CSD pin is required to release the IC from shutdown mode.



**Figure 39 Latched Protection with Reset Input**

### 11.1.5 Interfacing with System Controller

The MA5332MS can communicate with an external system controller through a simple interfacing circuit shown in Figure 40. A generic PNP transistor, U1, detects the sink current at the CSD pin during protection event and outputs a shutdown flag signal to an external system controller. Another generic NPN transistor, U2, can then reset the internal protection logic by pulling the CSD voltage below the lower threshold  $V_{th2}$ . After the first power-up sequence, a reset signal to the CSD pin is required to release the IC from shutdown mode.



**Figure 40 Interfacing CSD with System Controller**

Protections

11.2 Over Current Protection (OCP)

The MA5332MS features over current protection to protect the internal power MOSFETs during abnormal load conditions. The control logic diagrams are in Figure 41. As soon as either the high-side or low-side current sensing block detects over current, the following sequence will occur.

1. The shutdown latch flips its logic states from normal operational mode to shutdown mode.
2. Low-side and high-side MOSFETs go into an off state condition.
3. The CSD pin starts discharging the external capacitor  $C_t$ .
4. When voltage across  $C_t$  falls below the lower threshold  $V_{th2}$ , COMP2 resets the shutdown latch to normal mode.
5. The CSD pin starts charging the external capacitor  $C_t$ .
6. When  $V_{CSD}$  goes above the upper threshold  $V_{th1}$ , the logic on COMP1 toggles and the IC resumes operation.

Figure 41 summarizes the above. As long as the over current condition exists, the IC will repeat the over current protection sequence at a repetitive rate set by the CSD capacitor.

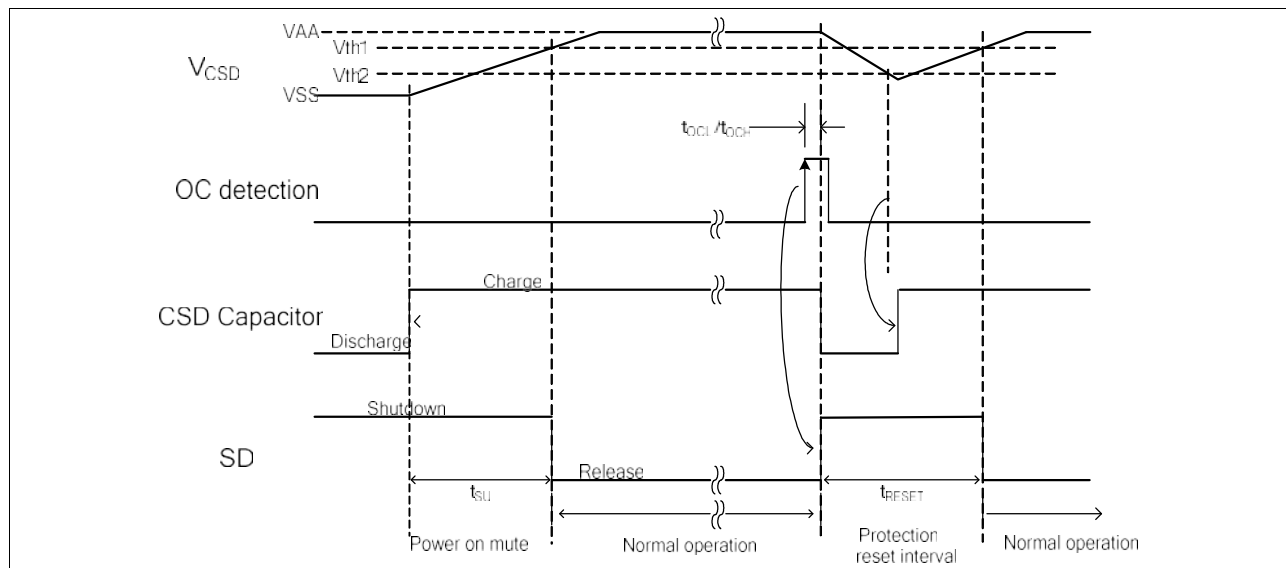


Figure 41 Overcurrent Protection Timing Chart

### Protections

#### 11.3 Over Temperature Protection (OTP)

If the junction temperature  $T_J$  of the controller IC exceeds the on-chip thermal shutdown threshold,  $T_{SD}$ , the on-chip over temperature protection shuts down the PWM.

#### 11.4 Under Voltage Protection (UVP)

In order to prevent a partial on-state of the internal MOSFET, under-voltage protection monitors the low side and high side gate bias supplies, VCC and VB. When VCC is below UVLO, both high and low side MOSFETs are turned off. When the high side supply  $V_{BS}$  is below the UVLO threshold, the high side output is disabled, while the low side works normally.

## 12 Status Output

### 12.1 Fault Output

FAULT output is an open drain output referenced to GND to report whether the MA5332MS is in shutdown mode or in normal operating mode. If the FAULT pin is open, the MA5332MS is in normal operation mode, i.e. the output MOSFETs are active. The following conditions trigger shutdown internally and pulls the FAULT pin down to GND.

- Over Current Protection
- Over Temperature Protection
- Shutdown mode from CSD pin voltage

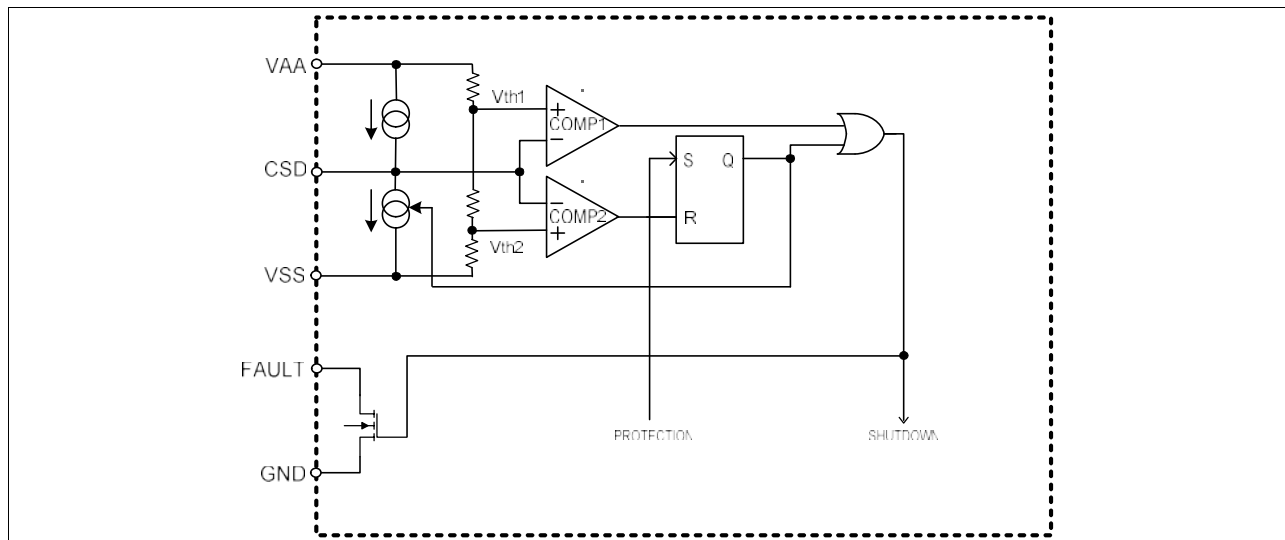
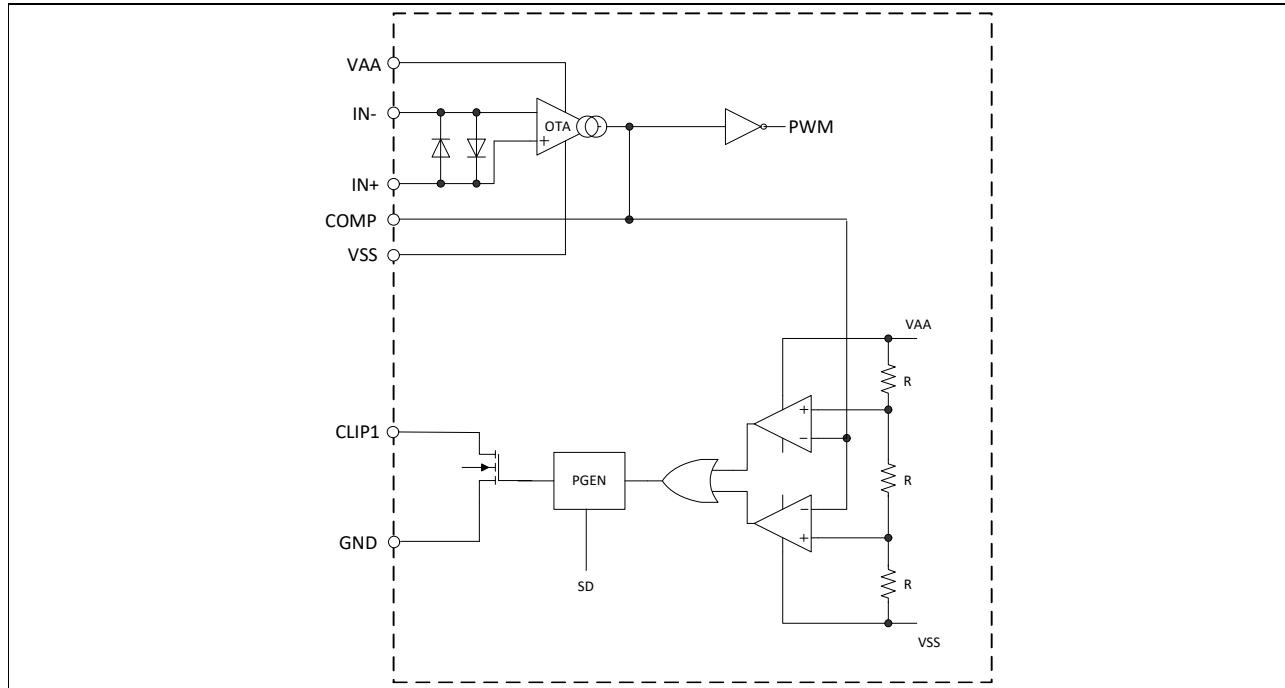


Figure 42 Fault Output

**12.2 CLIP Output**

When the output of the amplifier loses track of an expected target value, the amplifier enters into clipping condition.

The CLIP detection block monitors the COMP pin voltage with a window comparator. The CLIP pin is pulled to GND when a clipping condition is detected. The detection thresholds in the COMP pin are at 10% and 90% of VAA-VSS. The CLIP outputs are disabled in shutdown mode.



**Figure 43 CLIP Detection**

## 13 Power Supply Design

### 13.1 Supplying VAA and VSS

VAA and VSS are supply voltages to the front-end of the analog section, hence are noise sensitive. For best audio performance, use regulated power supplies for VAA and VSS.

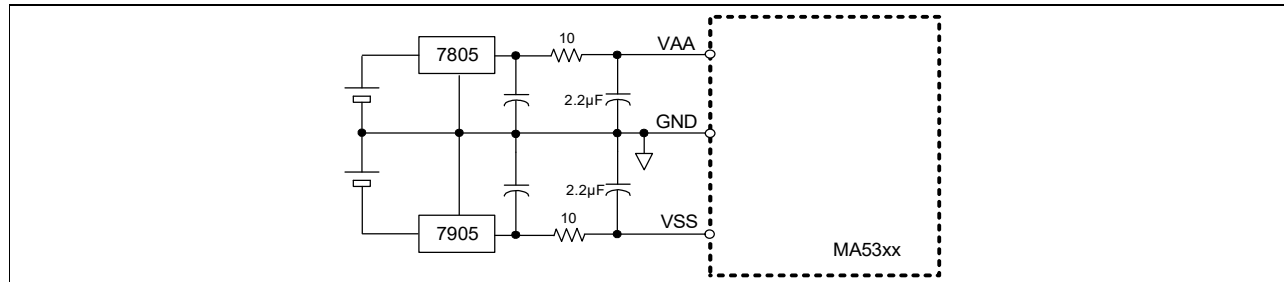


Figure 44 Supplying VAA and VSS with External Voltage Regulators

When switched-mode regulators are used as supply voltages for VAA and VSS, place a two-stage R-C noise filter in the supply lines as shown in Figure 45.

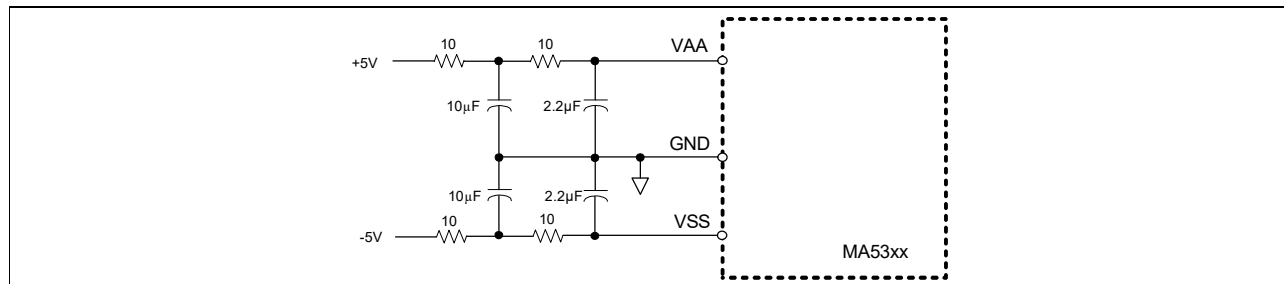


Figure 45 Supplying VAA and VSS from Switched Mode Power Supply

### 13.2 Supplying VCC and VB

Figure 46 shows the recommended power supply configuration for gate driver power supplies. The gate driver stage has three power supply inputs:

1. VCC-COM: low side gate drive supply
2. VB1-VS1: CH1 high side gate drive supply
3. VB2-VS2: CH2 high side gate drive supply

The low-side power supply, VCC, feeds the internal gate drive logic and low side gate driver. In order to protect VCC from switching noise generated by the VS node, it is recommended to insert a few ohms of  $R_{VBS}$  in the bootstrap charging path.

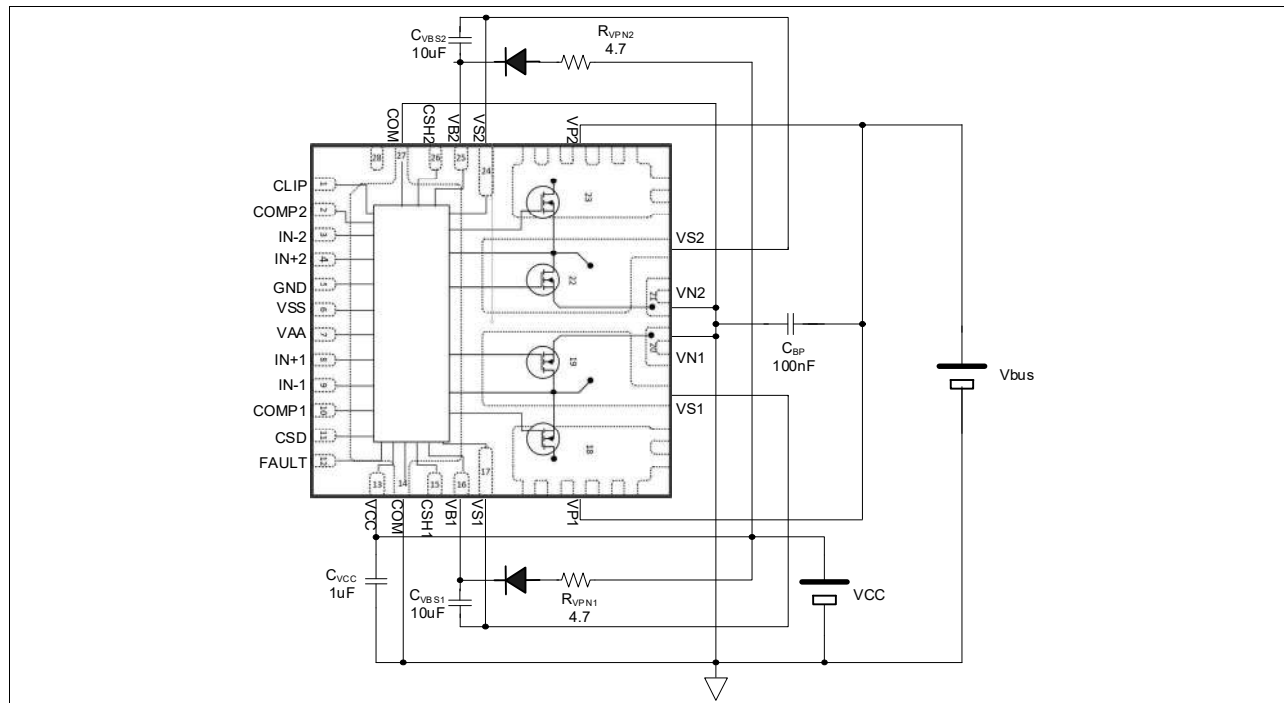
The high-side driver requires a floating supply  $V_{Bn}$  referenced to the respective switching node  $V_{Sn}$  where the source of the output MOSFET is connected. A charge pump method (floating bootstrap power supply) eliminates the need for a floating power supply and thus is used in the typical application circuit. The floating bootstrap power supply charges the bootstrap capacitor  $C_{BS}$  from the low-side power supply VCC during the low-side MOSFET ON period. When the high-side MOSFET is ON, the diode cuts off and floats the VBS supply.  $C_{BS}$  retains its VB supply voltage for the rest of the high-side ON duration.



### Power Supply Design

$$I_{VCC} \approx I_{QCC} + I_{QBS} + 2(Q_G \cdot f_{PWM}) \text{ /per channel}$$

Recommend to have minimum 20% design margin for  $I_{VCC}$ .



**Figure 46 Recommended Power Supply Configurations for Output Stage**

### 13.2.1 Choosing Bootstrap Capacitance

Often MA5332MS uses hard clipping condition. The continuous high-side ON duration could continue as long as half of the lowest audio frequency, tens of milliseconds. A typical application uses a 22 uF  $C_{BS}$  to support low audio frequency clipping. A ceramic capacitor (X7R, X5R or X5S type) or aluminum electrolytic capacitor with 25 V or higher voltage rating is recommended.

### 13.2.2 Choosing Bootstrap Diode

Use a bootstrap charging diode with voltage rating of 1.5 x the maximum bus voltage. In order to charge the bootstrap capacitor in a very short low-side ON period with a high PWM modulation ratio, a fast recovery diode type ( $t_{rr} < 50ns$ ) is recommended.

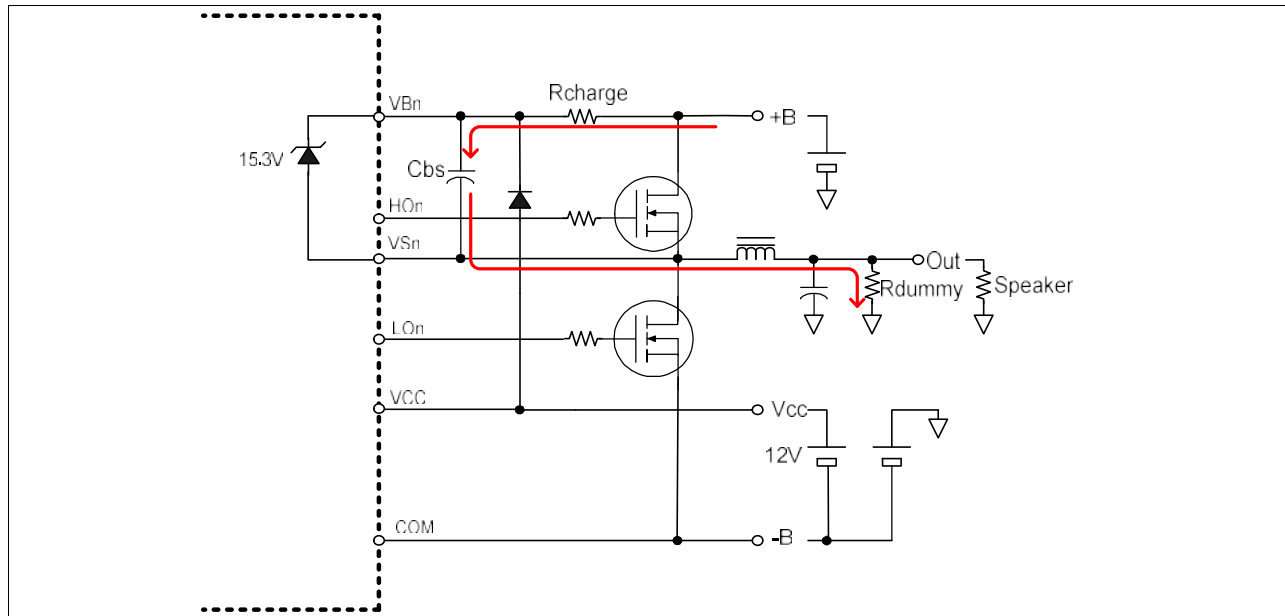
### 13.2.3 Charging $V_{BS}$ Prior to Start

For proper start-up, pre-charging the bootstrap supply  $V_{BS}$  prior to PWM start-up is necessary for self-oscillating PWM modulator topologies. A charging resistor,  $R_{CHARGE}$ , inserted between the positive supply bus and  $V_{BS}$ , charges  $C_{BS}$  prior to switching start as shown in Figure 47. The minimum resistance of  $R_{CHARGE}$  is limited by the maximum PWM modulation index of the system. When the high-side MOSFET is on,  $R_{CHARGE}$  drains the bootstrap power supply together with the quiescent current,  $I_{QBS}$ , so it reduces the holding time, resulting in maximum continuous high-side on time.

The maximum resistance of  $R_{CHARGE}$  is limited by the current charge capability of the resistor during startup.

### Power Supply Design

Pre-charging current flows into the speaker load. In order to startup without the load connected, a dummy load  $R_{dummy}$  in parallel with the speaker output provides a pre-charging current path.



**Figure 47** Bootstrap Supply Pre-Charging

### 13.3 Power Supply Sequence

The protection control block in the MA5332MS monitors the status of  $V_{AA}$  and  $V_{CC}$  to ensure that both voltage supplies are above their respective UVLO (under voltage lockout) thresholds before starting normal operation. If either  $V_{AA}$  or  $V_{CC}$  is below the under voltage threshold, the output MOSFETs are disabled in shutdown mode until both  $V_{AA}$  and  $V_{CC}$  rise above their voltage thresholds. As soon as  $V_{AA}$  or  $V_{CC}$  falls below its UVLO threshold, protection logic in the MA5332MS turns off high-side and low-side.

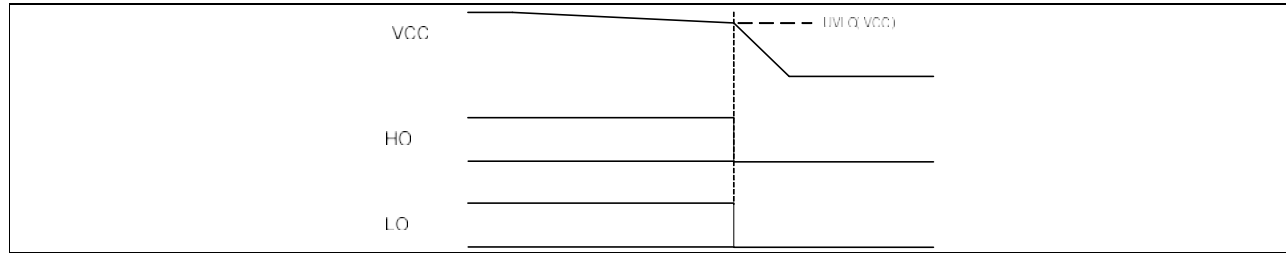


Figure 48 MA5332MS UVLO Timing Chart

## 14 Package details

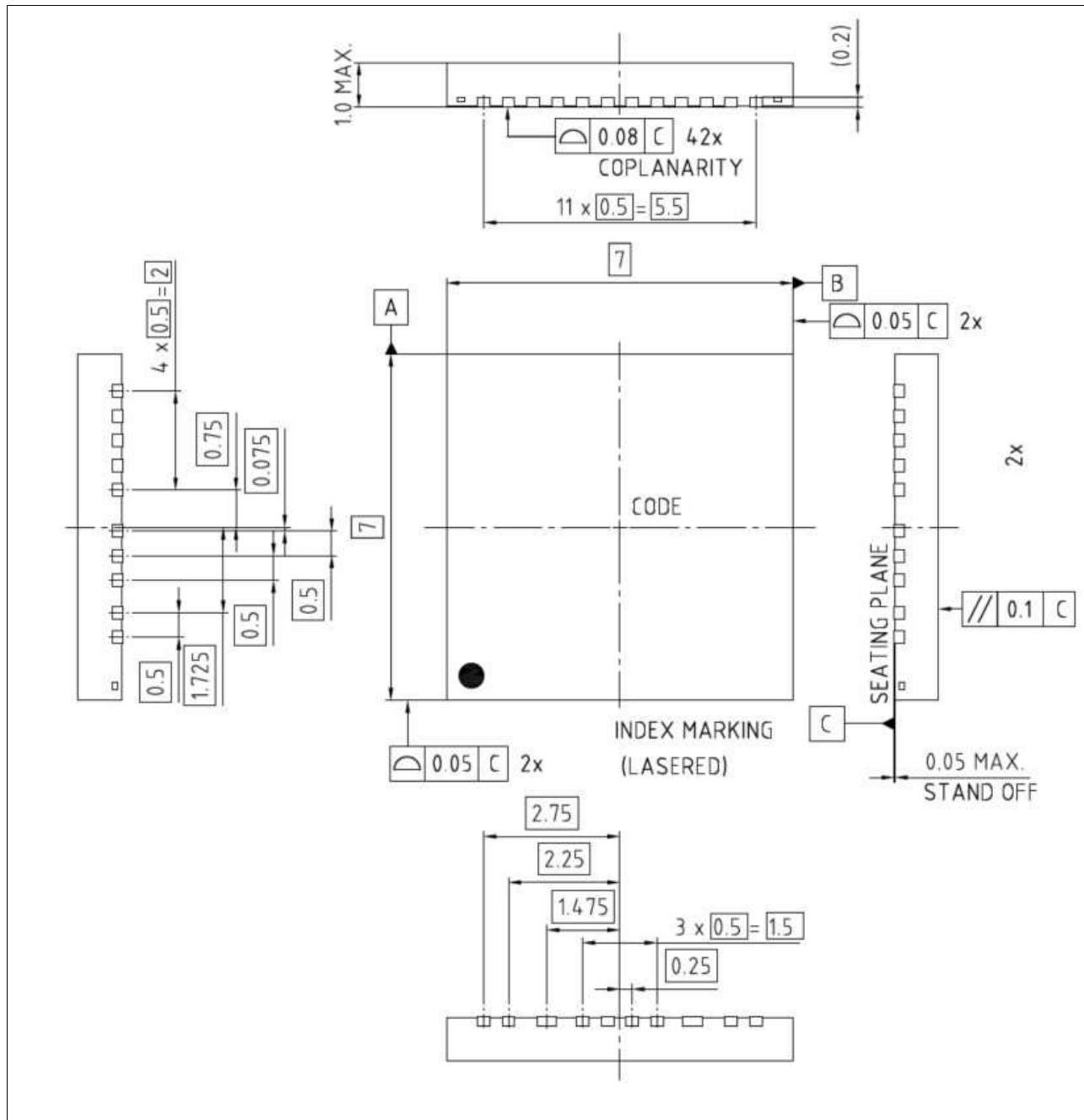


Figure 49 Package details



Package details

Dimension Table				
Thickness Symbol	V			Note
	Minimum	Normal	Maximum	
A	0.80	0.90	1.00	
A1	0.00	0.02	0.05	
A3	---	0.20 Ref	---	
b1	0.20	0.25	0.30	5
b2	0.35	0.40	0.45	5
D	7.00 BSC			
E	7.00 BSC			
D1	2.013	2.163	2.263	
E1	4.832	4.892	5.082	
D2	2.55	2.700	2.800	
E2	0.925	1.075	1.175	
D3	2.684	2.834	2.934	
E3	1.325	1.475	1.575	
L1	0.30	0.40	0.50	
L2	0.90	1.00	1.10	
L3	0.35	0.45	0.55	
aaa	0.05			
bbb	0.10			
ccc	0.10			
ddd	0.05			
eee	0.08			
N	42			3
Notes	1,2			

Figure 51 Dimension table

## 15 Board mounting, part marking, and ordering information

Reliability of products in the PQFN package is subject to the board mounting process. The Soldering process is critical. Refer to Application Note AN-1170 Audio IC Board Mounting Application Note for specific footprint design and soldering methods.

### Device outline

Figure 52 shows the outline for these devices. The relative pad positions are controlled to an accuracy of  $\pm 0.050\text{mm}$ . For full dimensions and tolerances of each device, and to find out its size and outline, refer to the relevant product data sheet and package outline drawing.

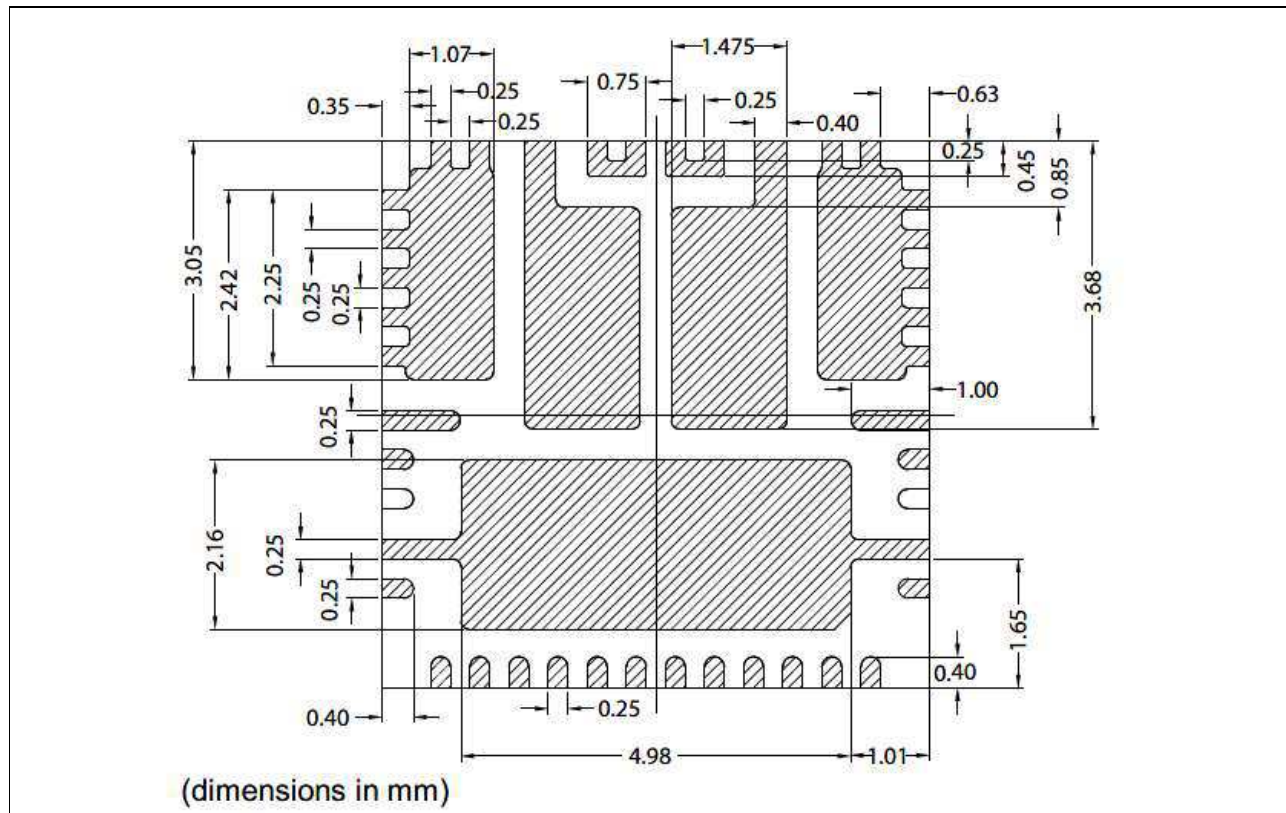


Figure 52 42-lead 7x7 device outline





#### Stencil Design

Evaluations have shown that the best overall performance is achieved using the stencil design shown in Figure 55-58.

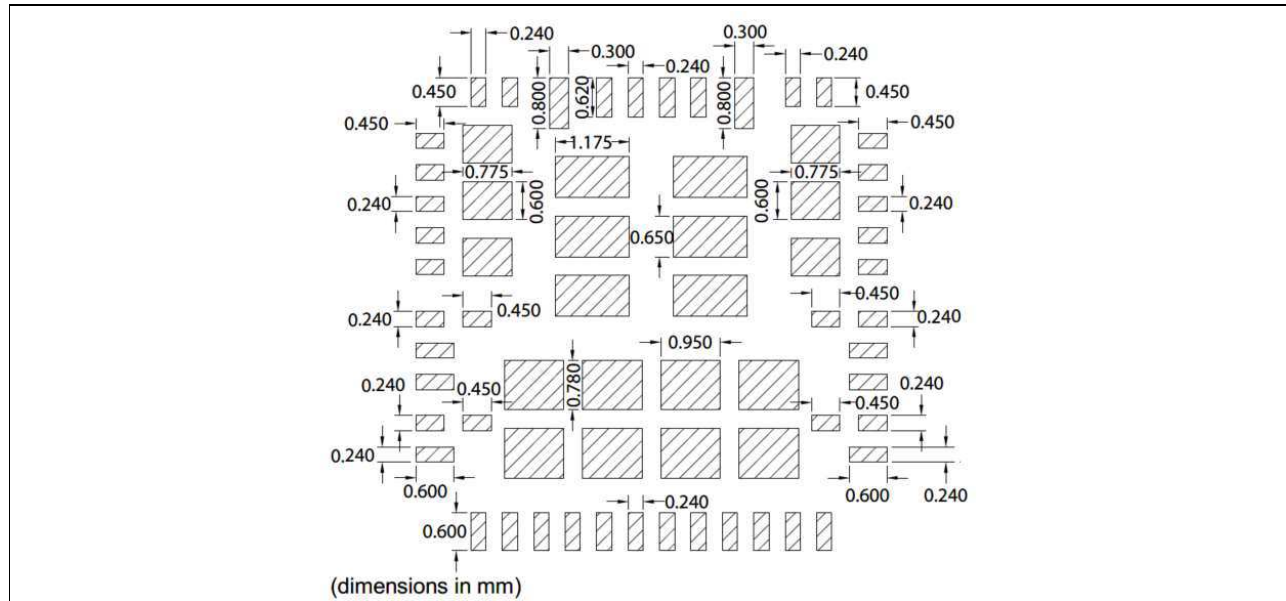


Figure 55 42-lead 7x7 stencil design\_1

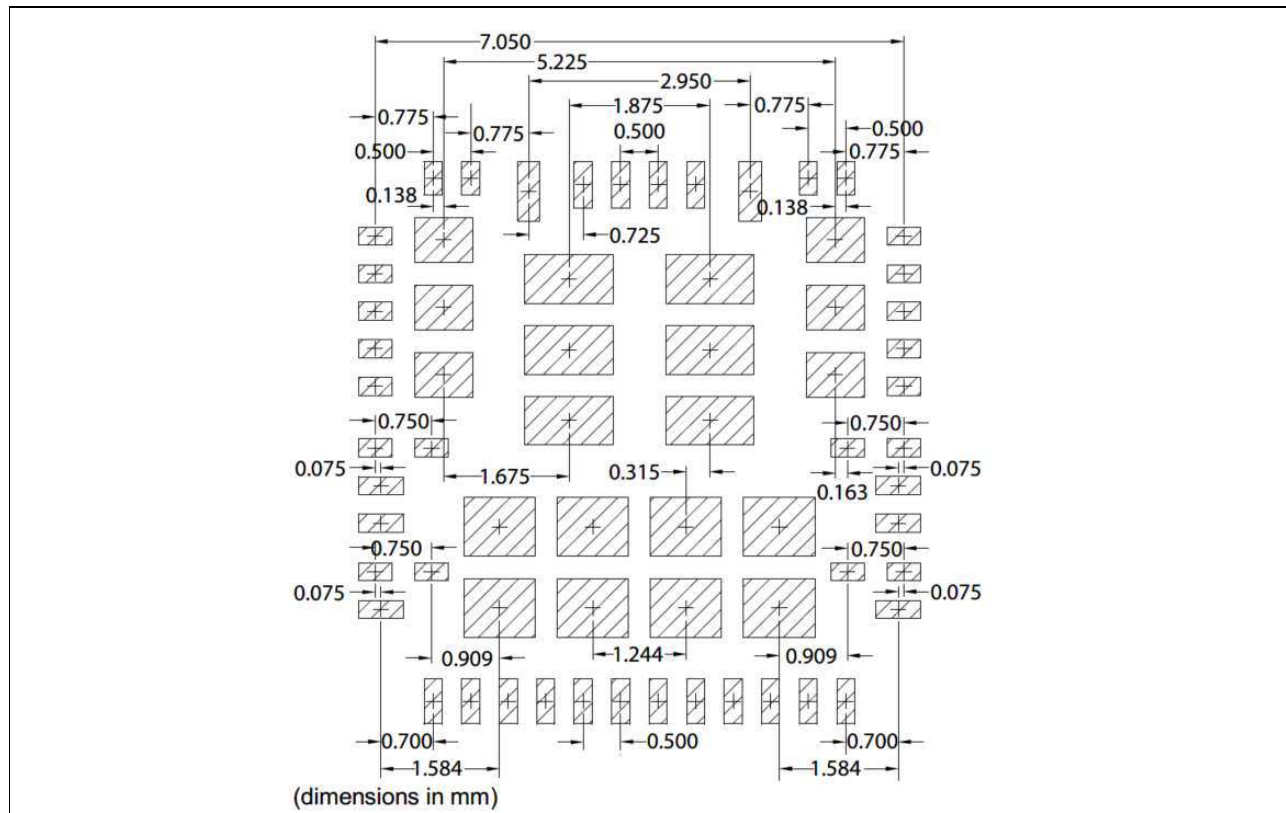


Figure 56 42-lead 7x7 stencil design\_2

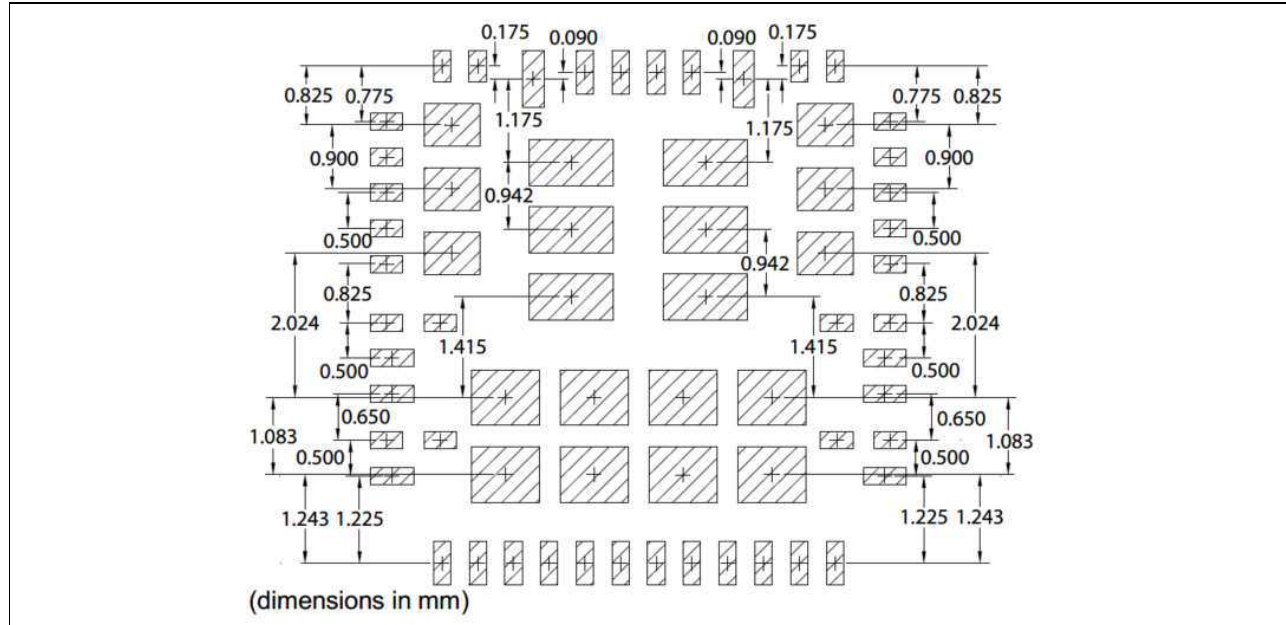


Figure 57 42-lead 7x7 stencil design\_3

Note: This design is for a stencil thickness of 0.127mm (0.005"). The reduction should be adjusted for stencils of other thicknesses. All soldering conditions are necessary to ensure reliability. More details please refer to Application Note AN-1170 Audio Power Quad Flat No-Lead (PQFN) Board Mounting Application

Part marking

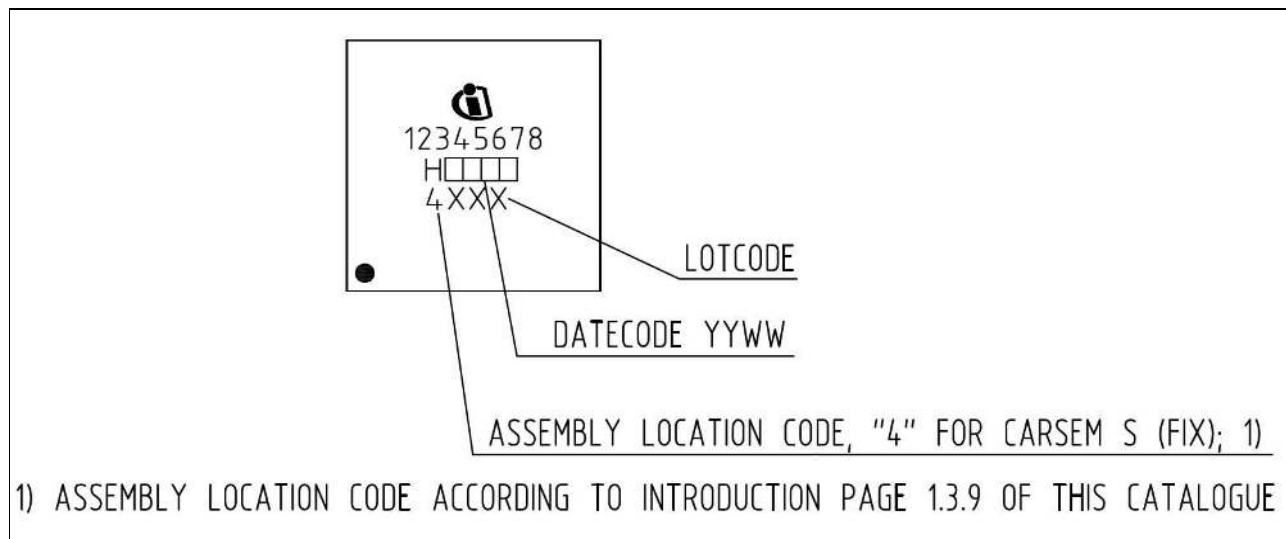


Figure 58 Part marking

#### Ordering information

Base part number	Package type	Standard pack		Complete part number
		Form	Quantity	
MA5332MS	7x7mm PG- IQFN-42	Tape and Reel	3000	MA5332MS

### Revision History

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MA5332MS

**Revision: 2021-09-25, Rev. 2.0**

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Previous Revision

Revision	Date	Subjects (major changes since last revision)
2.0	2021-09-25	Release of final version

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