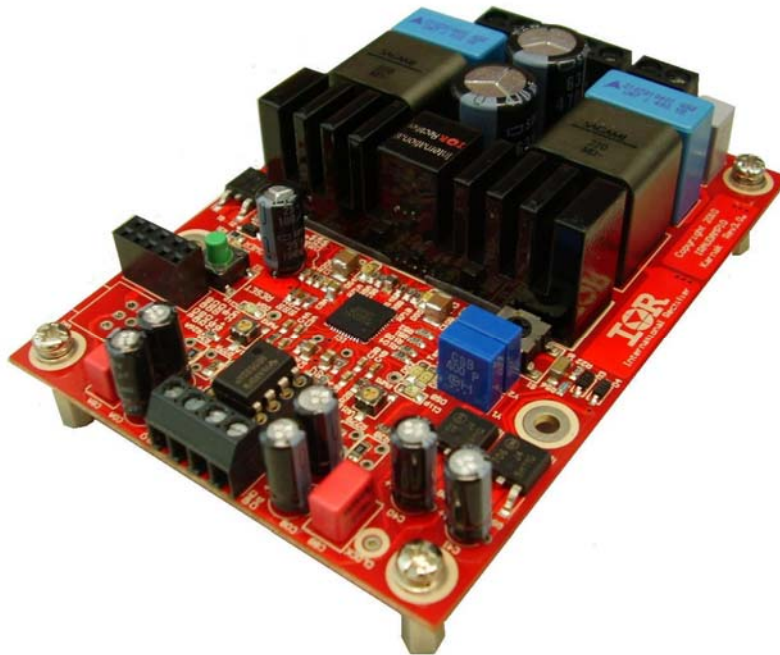


IRAUDAMP10

300W x 2 Channel Class D Audio Power Amplifier Using the IRS2052M and IRF6775

By

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CAUTION:

International Rectifier suggests the following guidelines for safe operation and handling of IRAUDAMP10 Demo board;

- Always wear safety glasses whenever operating Demo Board
- Avoid personal contact with exposed metal surfaces when operating Demo Board
- Turn off Demo Board when placing or removing measurement probes

TABLE OF CONTENTS

	PAGE
INTRODUCTION.....	3
SPECIFICATIONS	3
CONNECTION SETUP	5
CONNECTOR DESCRIPTION	5
TEST PROCEDURES.....	6
PERFORMANCE AND TEST GRAPHS	7
SOFT CLIPPING.....	10
EFFICIENCY	11
THERMAL CONSIDERATIONS	11
THERMAL INTERFACE MATERIAL'S PRESSURE CONTROL	12
POWER SUPPLY REJECTION RATIO (PSRR).....	14
SHORT CIRCUIT PROTECTION RESPONSE	15
IRAUDAMP10 OVERVIEW	16
FUNCTIONAL DESCRIPTIONS.....	18
IRS2052M GATE DRIVER IC	18
SELF-OSCILLATING FREQUENCY	19
ADJUSTMENTS OF SELF-OSCILLATING FREQUENCY	19
INTERNAL CLOCK OSCILLATOR.....	19
SELECTABLE DEAD-TIME.....	20
PROTECTION SYSTEM OVERVIEW	21
CLICK AND POP NOISE REDUCTION	23
BUS PUMPING.....	24
INPUT SIGNAL AND GAIN SETTING	24
GAIN SETTING.....	25
IRAUDAMP10 FABRICATION MATERIALS.....	27
IRAUDAMP10 PCB SPECIFICATIONS.....	31
REVISION CHANGES DESCRIPTIONS.....	34

Introduction

The IRAUDAMP10 Demo board is a reference design which uses only one IC (IRS2052M) to derive appropriate input signals, amplify the audio input, and achieve a two-channel 280 W/ch (4Ω, THD+N=1%) half-bridge Class D audio power amplifier. The reference design demonstrates how to use the IRS2052M Class D audio controller and gate driver IC, implement protection circuits, and design an optimum PCB layout using IRF6775 DirectFET MOSFETs. The reference design contains all the required housekeeping power supplies for ease of use. The two-channel design is scalable, for power and number of channels.

Applications

- AV receivers
- Home theater systems
- Mini component stereos
- Powered speakers
- Sub-woofers
- Musical Instrument amplifiers
- Automotive after market amplifiers

Features

Output Power:	300W x 2 channels (4Ω, THD+N=1%) or 370W x 2 channels (4Ω, THD+N=10%)
Residual Noise:	220μV, IHF-A weighted, AES-17 filter
Distortion:	0.008% THD+N @ 100W, 4Ω
Efficiency:	90% @ 300W, 4Ω, single-channel driven, Class D stage
Multiple Protection Features:	Over-current protection (OCP), high side and low side Over-voltage protection (OVP), Under-voltage protection (UVP), high side and low side Over-temperature protection (OTP)
PWM Modulator:	Self-oscillating half-bridge topology with optional clock synchronization

Specifications

General Test Conditions (unless otherwise noted)		Notes / Conditions
Supply Voltages	±50V	
Load Impedance	4Ω	
Self-Oscillating Frequency	500kHz	No input signal, Adjustable
Gain Setting	30.8dB	1Vrms input yields rated power

Electrical Data	Typical	Notes / Conditions
IR Devices Used	IRS2052M Audio Controller and Gate-Driver, IRF6775 DirectFET MOSFETs	
Modulator	Self-oscillating, second order sigma-delta modulation, analog input	
Power Supply Range	± 25V to ±50V	Bipolar power supply
Output Power CH1-2: (1% THD+N)	300W	1kHz, ±50V
Output Power CH1-2: (10% THD+N)	370W	1kHz, ±50V

Rated Load Impedance	8-4Ω	Resistive load
Standby Supply Current	+45/-95mA	No input signal
Total Idle Power Consumption	7W	No input signal
Channel Efficiency	90%	Single-channel driven, 300W, Class D stage

Audio Performance	Class D Output	Notes / Conditions
THD+N, 1W	0.015%	
THD+N, 20W	0.009%	1kHz, Single-channel driven
THD+N, 100W	0.008%	
THD+N, 200W	0.015%	
Dynamic Range	100dB	A-weighted, AES-17 filter, Single-channel operation
Residual Noise, 22Hz - 20kHzAES17	220μV	Self-oscillating – 500kHz
Damping Factor	51	1kHz, relative to 4Ω load
Channel Separation	74dB	100Hz
	74dB	1kHz
	70dB	10kHz
Frequency Response : 20Hz-20kHz	±1dB	1W, 4Ω - 8Ω Load
: 20Hz-35kHz	±3dB	

Physical Specifications

Dimensions	3.94"(L) x 2.83"(W) x 0.85"(H) 100 mm (L) x 72 mm (W) x 21.5 mm(H)
Weight	0.130kgm

Connection Setup

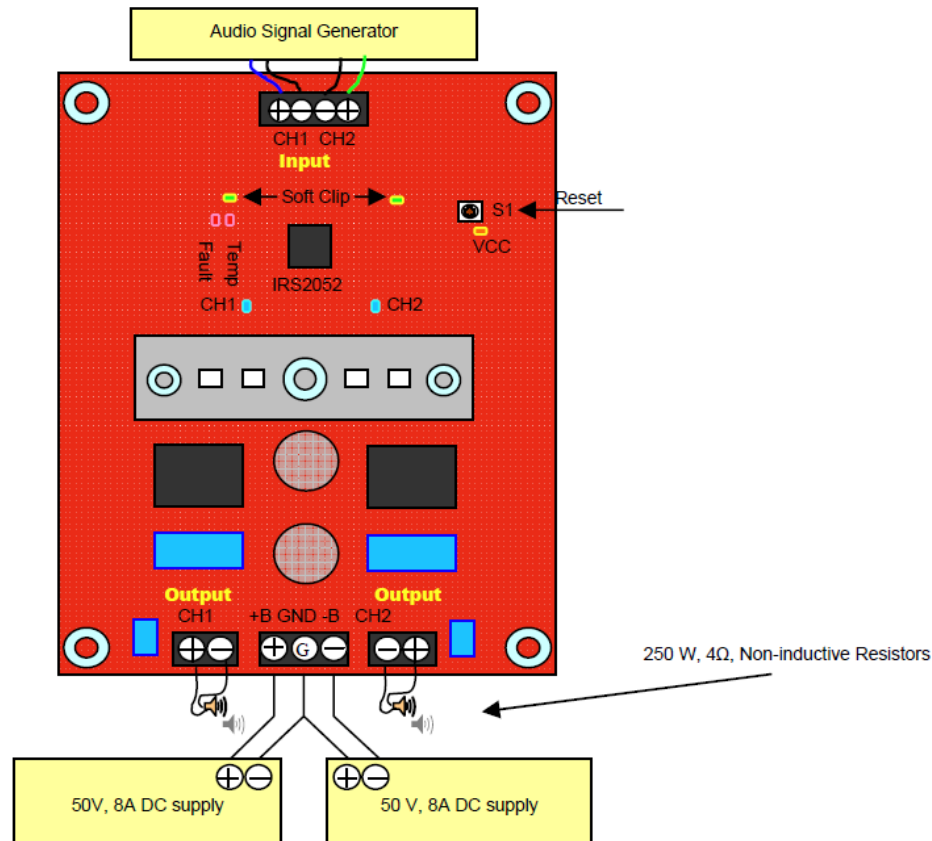


Fig 1 Typical Test Setup

Connector Description

	Pin #	Pin Name	Pin Description
CN1	1	CH1 INPUT	Analog input for CH1
	2	GND	Floating ground of Channel 1 input
	3	GND	Floating ground of Channel 2 input
	4	CH2 INPUT	Analog input for CH2
P1	1	-B	-50V supply referenced to GND.
	2	GND	Ground signal from MB.
	3	+B	+50V supply referenced to GND.
P2	1	CH2 OUTPUT	Output of Channel 2
	2	GND	Floating ground of Channel 2 output
P3	1	GND	Floating ground of Channel 1 output
	2	CH1 OUTPUT	Output of Channel 1

Test Procedures

Test Setup:

1. Connect 4 Ω -200 W dummy loads to 2 output connectors (P2 and P3 as shown on Fig 1) and an Audio Precision analyzer (AP).
2. Connect the Audio Signal Generator to CN1 for CH1~CH2 respectively (AP).
3. Set up the dual power supply with voltages of $\pm 50V$; current limit to 5A.
4. TURN OFF the dual power supply before connecting to On of the unit under test (UUT).
5. Connect the dual power supply to P1. as shown on Fig 1

Power up:

6. Turn ON the dual power supply. The $\pm B$ supplies must be applied and removed at the same time.
7. One orange and two blue LED should turn ON immediately and stay ON
8. Quiescent current for the positive supply should be 45mA \pm 10mA at +50V.
9. Quiescent current for the negative supply should be 95mA \pm 10mA at -50V.

Switching Frequency test

10. With an Oscilloscope, monitor the switching waveform at test points VS1~VS2. Adjust VR1A and VR1B to set the self oscillating frequency to 500 kHz \pm 25 kHz when DUT in free oscillating mode.

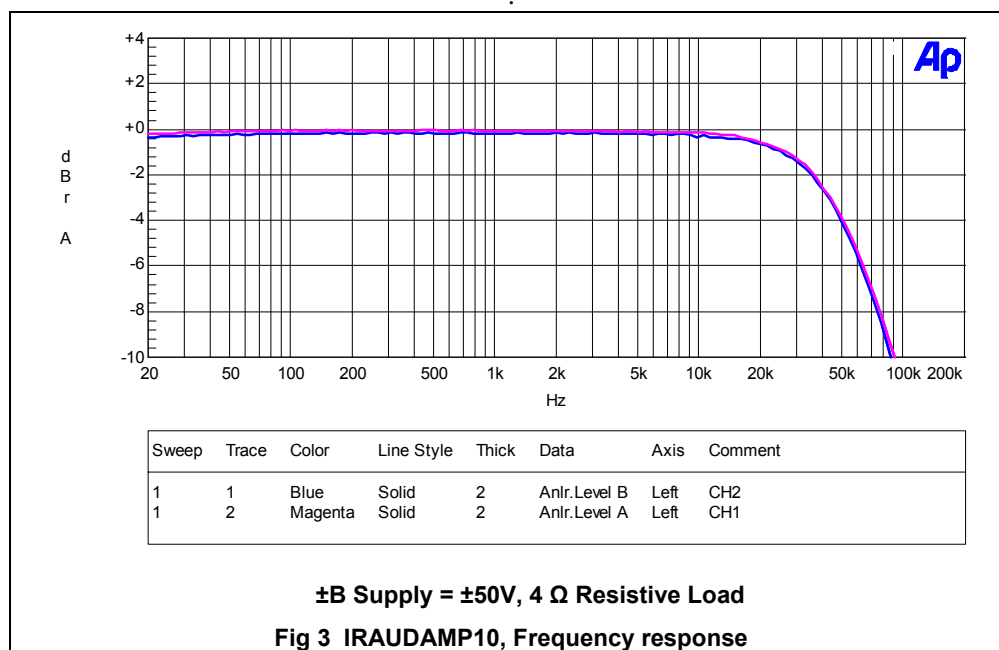
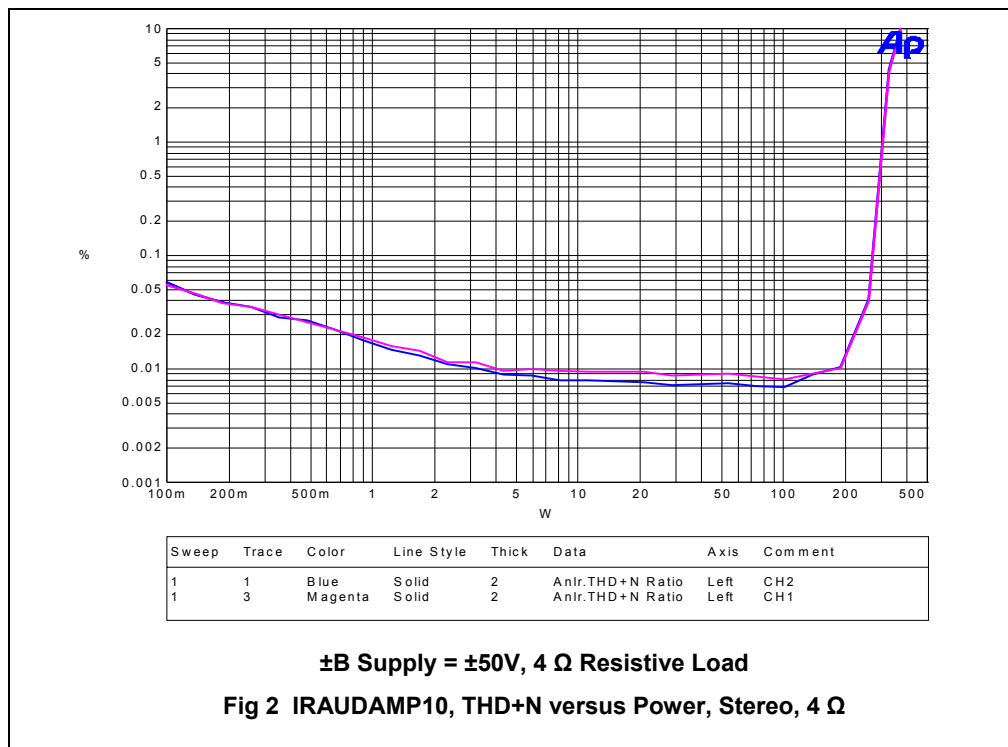
Functionality Audio Tests:

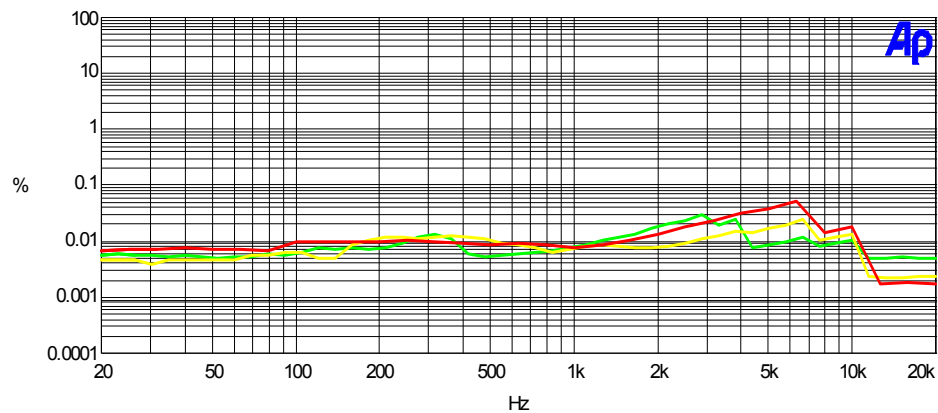
11. Set the signal generator to 1kHz, 20 mV_{RMS} output.
12. Connect the audio signal generator to CN1(Input of CH1,CH2,CH3)
13. Sweep the audio signal voltage from 15 mV_{RMS} to 1 V_{RMS}.
14. Monitor the output signals at P2/P3 with an oscilloscope. The waveform must be a non distorted sinusoidal signal.
15. Observe that a 1 V_{RMS} input generates an output voltage of 34.88 V_{RMS}(CH1/CH2). The ratio, $R4x/(R3x)$ and $R30x/(R31x)$, determines the voltage gain of IRAUDAMP10.

Test Setup using Audio Precision (Ap):

16. Use an unbalanced-floating signal from the generator outputs.
17. Use balanced inputs taken across output terminals, P2 and P3.
18. Connect Ap frame ground to GND at terminal P1.
19. Select the AES-17 filter(pull-down menu) for all the testing except frequency response.
20. Use a signal voltage sweep range from 15 mV_{RMS} to 1.5 V_{RMS}.
21. Run Ap test programs for all subsequent tests as shown in Fig 2- Fig 7below.

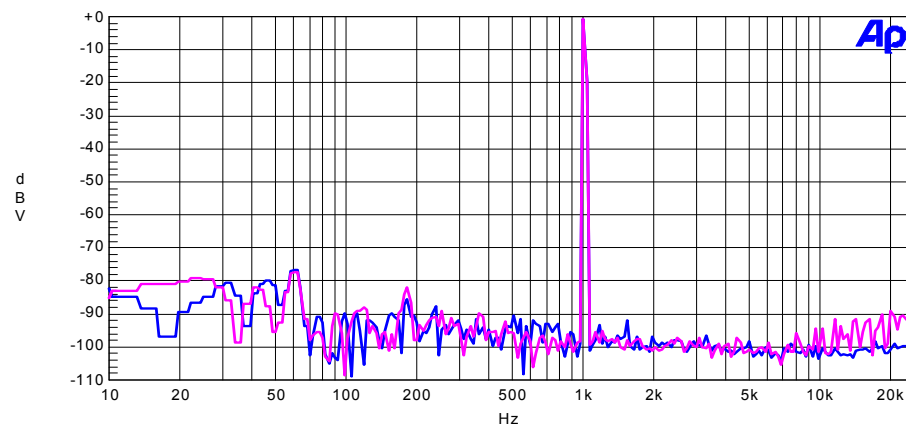
Performance and test graphs





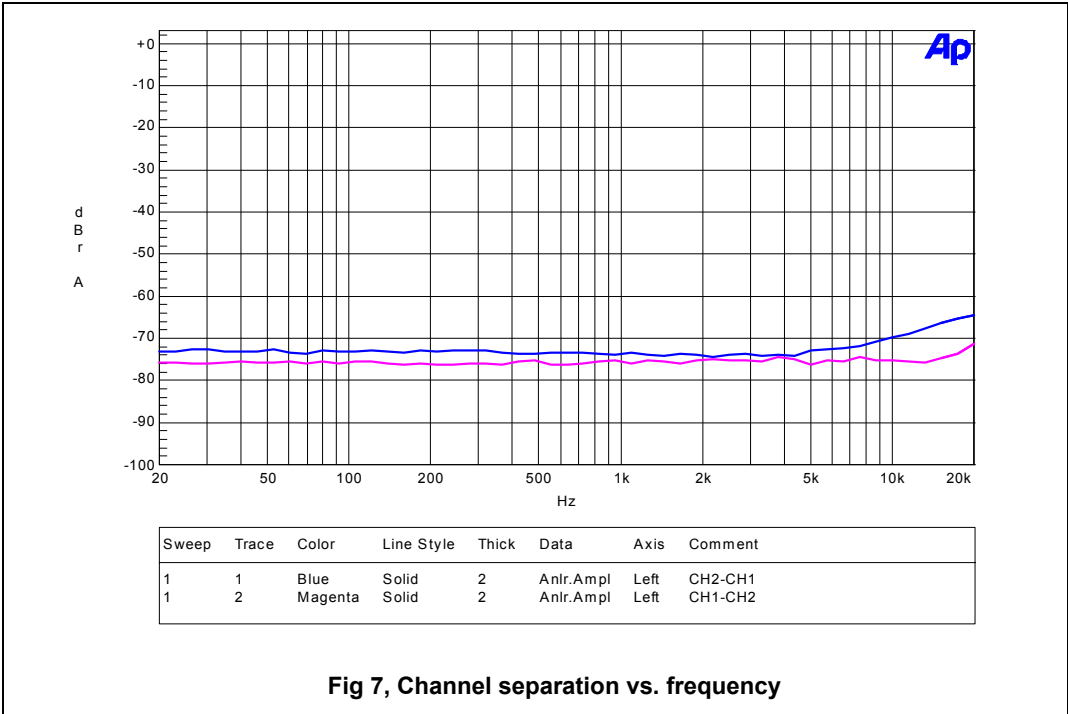
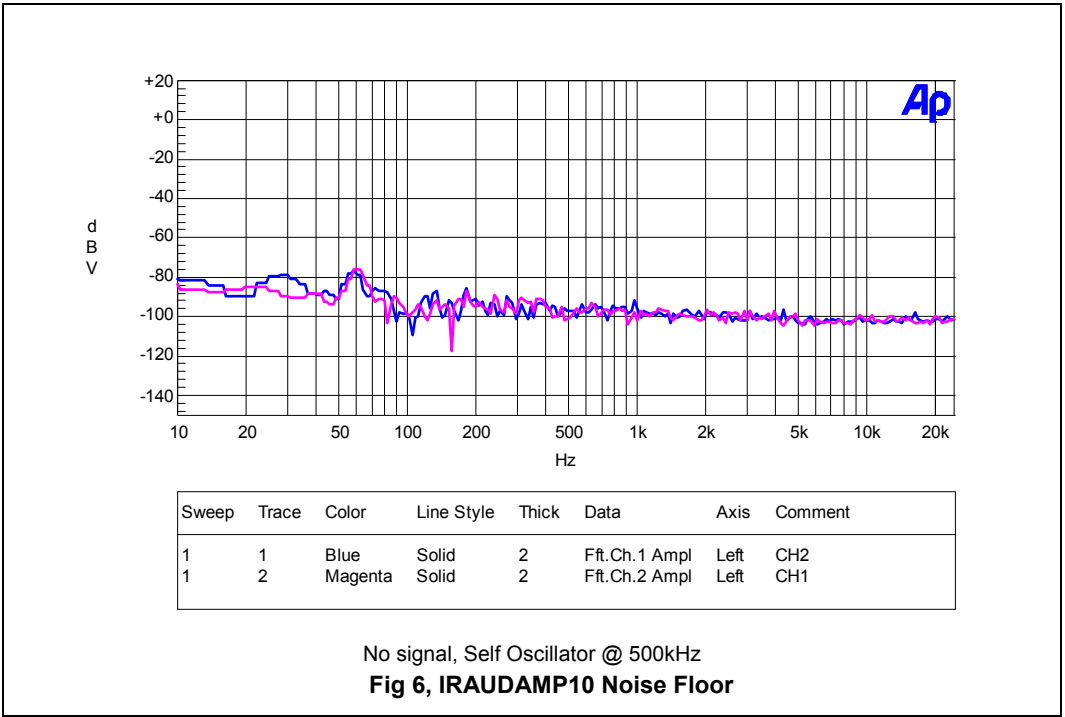
Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Green	Solid	2	Anlr. THD+N Ratio	Left	10W
2	1	Yellow	Solid	2	Anlr. THD+N Ratio	Left	50W
3	1	Red	Solid	2	Anlr. THD+N Ratio	Left	100W

Fig 4 THD+N Ratio vs. Frequency



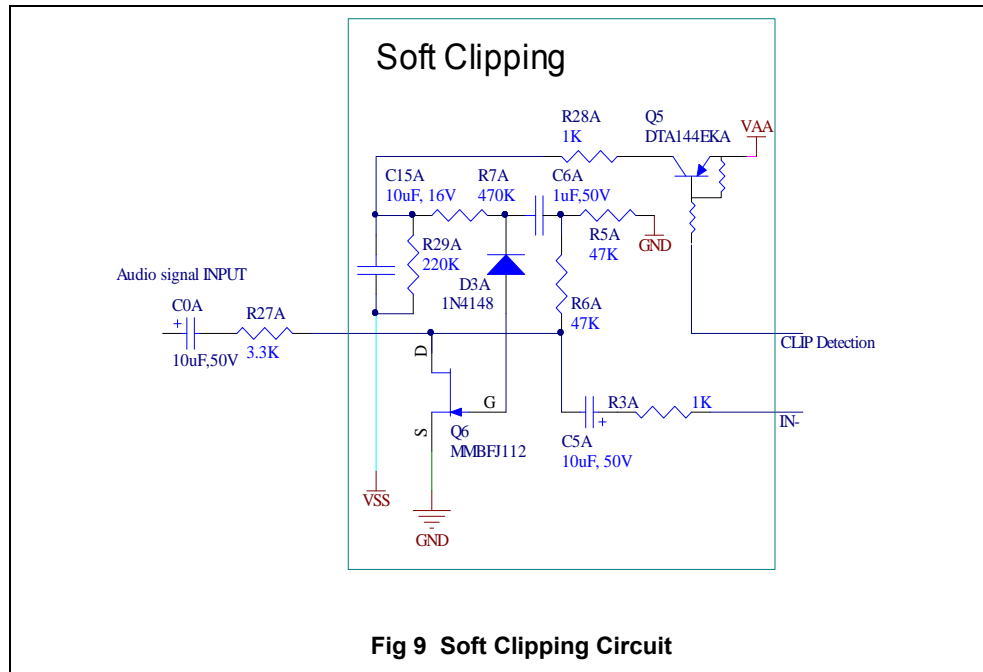
Sweep	Trace	Color	Line Style	Thick	Data	Axis	Comment
1	1	Blue	Solid	2	Fft.Ch.1 Ampl	Left	CH2
1	2	Magenta	Solid	2	Fft.Ch.2 Ampl	Left	CH1

Fig 5, 1V output Frequency Spectrum



Soft Clipping

IRS2052M has Clipping detection function, it monitors error voltage in COMP pin with a window comparator and pull an open drain nmos referenced to GND. Threshold to detect is at 10% and 90% of VAA-VSS. Each channel has independent CLIP outputs. Once IRS2052M detects Clipping, the CLIP pin can generate pulses to trigger soft clipping circuit, which can limit output's maximum power as Fig 9(soft clipping circuit is not available on AMP10 reference board).

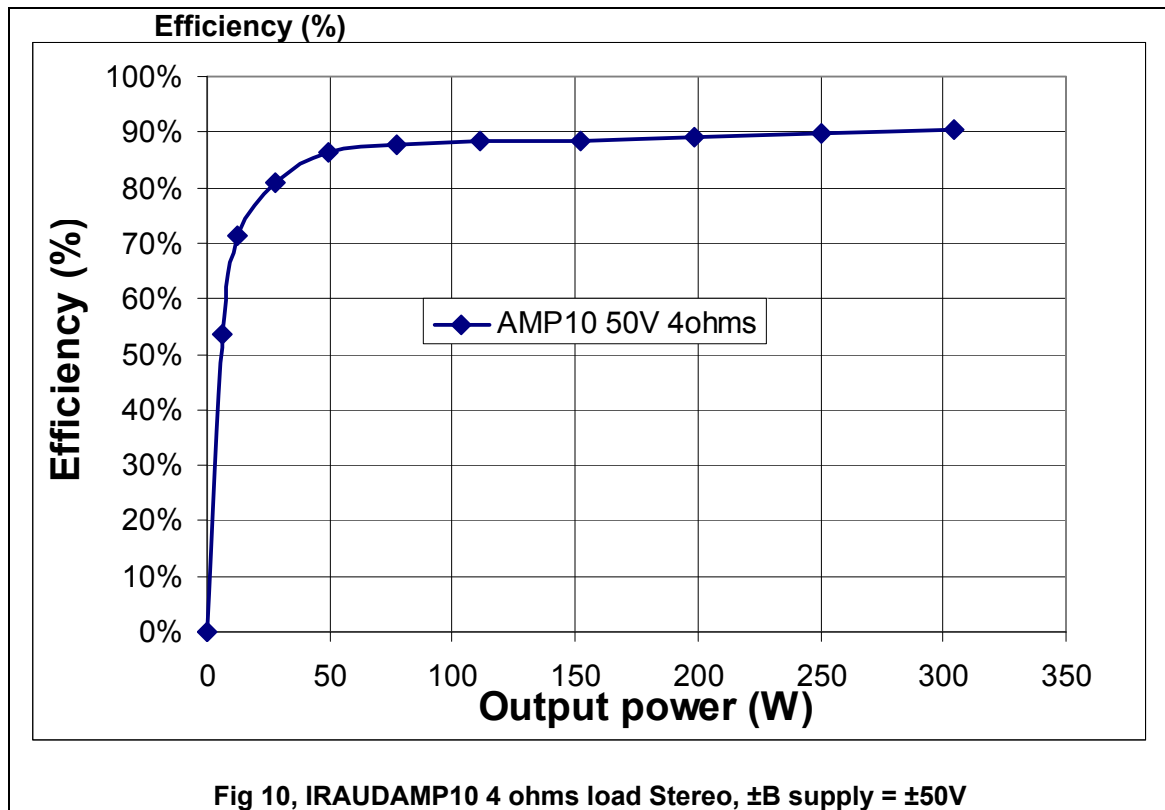


Efficiency

Fig 10 shows efficiency characteristics of the IRAUDAMP10. The high efficiency is achieved by following major factors:

- 1) Low conduction loss due to the DirectFETs offering low $R_{DS(ON)}$
- 2) Low switching loss due to the DirectFETs offering low input capacitance for fast rise and fall times

Secure dead-time provided by the IRS2052M, avoiding cross-conduction.



Thermal Considerations

With this high efficiency, the IRAUDAMP10 design can handle one-eighth of the continuous rated power, which is generally considered to be a normal operating condition for safety standards, without additional heatsinks or forced air-cooling.

Thermal Interface Material's Pressure Control

The pressure between DirectFET & TIM (Thermal Interface Material) is controlled by depth of Heat Spreader's groove. Choose TIM which is recommended by [IR](#). (Refer to AN-1035 for more details). TIM's manufacturer thickness, conductivity, & etc. determine pressure requirement. Below shows selection options recommended:

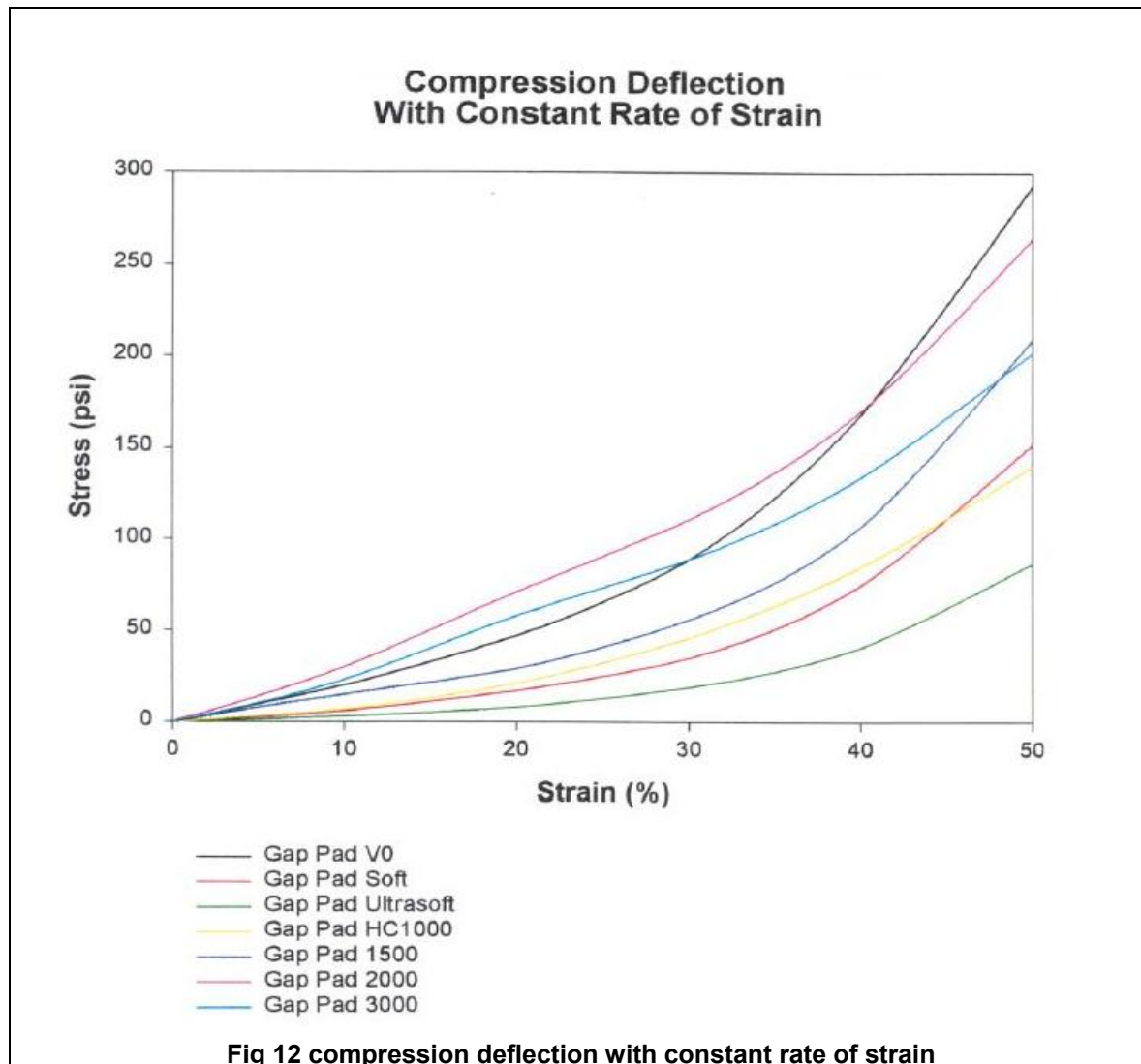
Common Thermal Interface Materials Cost Trades								
Mfr.	Material	Type	Thickness (mils)	Pressure Required	Dispense/Apply	Clips/Screws	Can be applied to heat sink?	Mechanical Placement?
Dow Corning	1-4173	1 part heat-cured adhesive	#	Yes	Dispense	Clips	N	Y
Dow Corning	SE 4451	2 part heat-cured adhesive	#	Yes	Dispense	Clips	N	Y
Dow Corning	3-6652	2 part heat-cured adhesive	#	Yes	Dispense	Clips	N	Y
Dow Corning	TP-1500 Pad	Tacky - Phase Change at 52°C	10	> 5psi, 20psi typ.	Apply	Clips	Y	Y
Bergquist	Gap Pad 3000	conformable filled polymer sheet	15	> 10psi	Apply	Clips/Screws	N	Y
Bergquist	Gap Pad 2000	conformable filled polymer sheet	10	> 10psi	Apply	Clips/Screws	N	Y
Bergquist	Hi Flow 300	Phase Change at 55°C	2.4	> 10psi	Apply	Clips	Y	*
Bergquist	Hi Flow 625	Phase Change at 65°C	5	> 10psi	Apply	Clips	Y	*
Bergquist	Hi Flow 818	Phase Change at 65°C	5.5	> 10psi	Apply	Clips	Y	*
Bergquist	Sil Pad 800	Conformable silicone elastomer	5	> 10 higher better	Apply	Clips/Screws	Y	*
Bergquist	Sil Pad 900	Conformable silicone elastomer	9	> 10 higher better	Apply	Clips/Screws	Y	*
Bergquist	Sil Pad A1500	Conformable silicone elastomer	10	10-50psi	Apply	Clips/Screws	Y	*
Bergquist	Sil Pad A2000	Conformable silicone elastomer	10	10-50psi	Apply	Clips/Screws	Y	*
Bergquist	Bond Ply 100	Pressure sensitive adhesive tape	5	> 10psi	Apply	Clips	Y	Y
Bergquist	Bond Ply 100	Pressure sensitive adhesive tape	11	> 10psi	Apply	Clips	Y	Y
Thermoset (Lord)	Gelase MG-120	Thermal grease/gel	#	5-7 lbf	Dispense	Clips	N	Y
Shin Etsu	X-23-7783D	Thermal grease	#	-	Dispense	Clips	N	Y
Shin Etsu	X-23-7762	Thermal grease	#	-	Dispense	Clips	N	Y

Fig 11 TIM Information

Check the TIM's compression deflection with constant rate of strain (example as Fig.12) base on manufacturer's datasheet. According to the stress requirement, find strain range for the TIM. Then, calculate heat spreader groove depth as below:

$$\text{Groove Depth} = \text{DirectFET's Height} + \text{TIM's Thickness} * \text{strain}$$

**DirectFET's height should be measured from PCB to the top of DirectFET after reflow. The average height of IRF6775 is 0.6mm.



Power Supply Rejection Ratio (PSRR)

The IRAUDAMP10 obtains good power supply rejection ratio of -60 dB at 1kHz shown in Fig 13. With this high PSRR, IRAUDAMP10 accepts any power supply topology when the supply voltages fit between the min and max range.

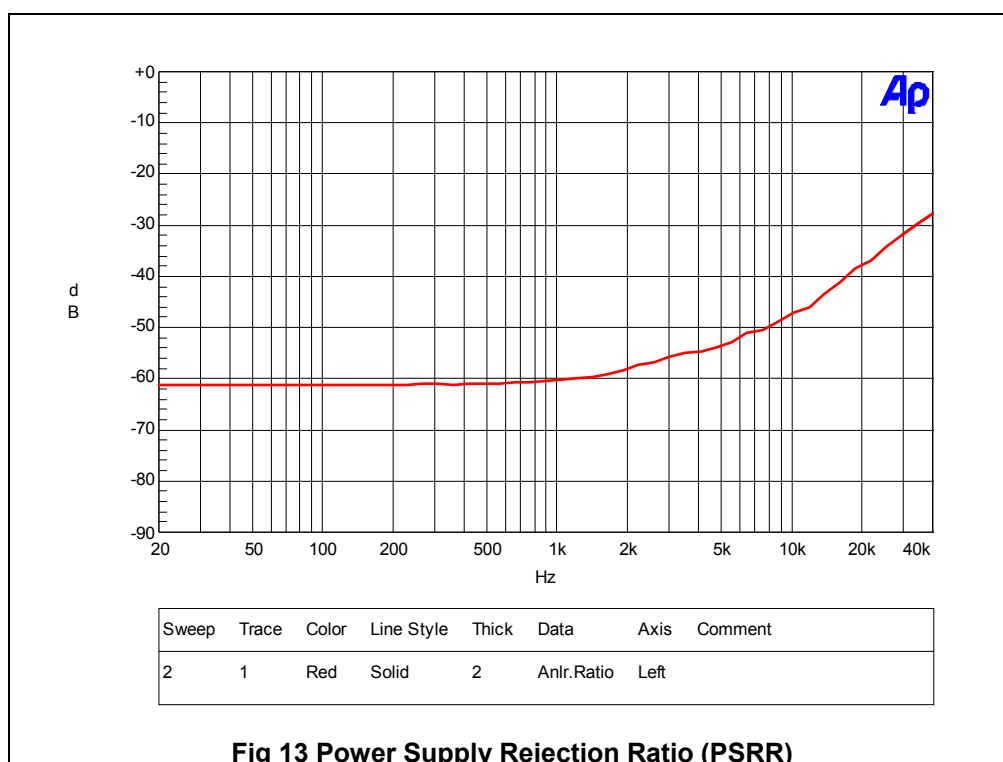
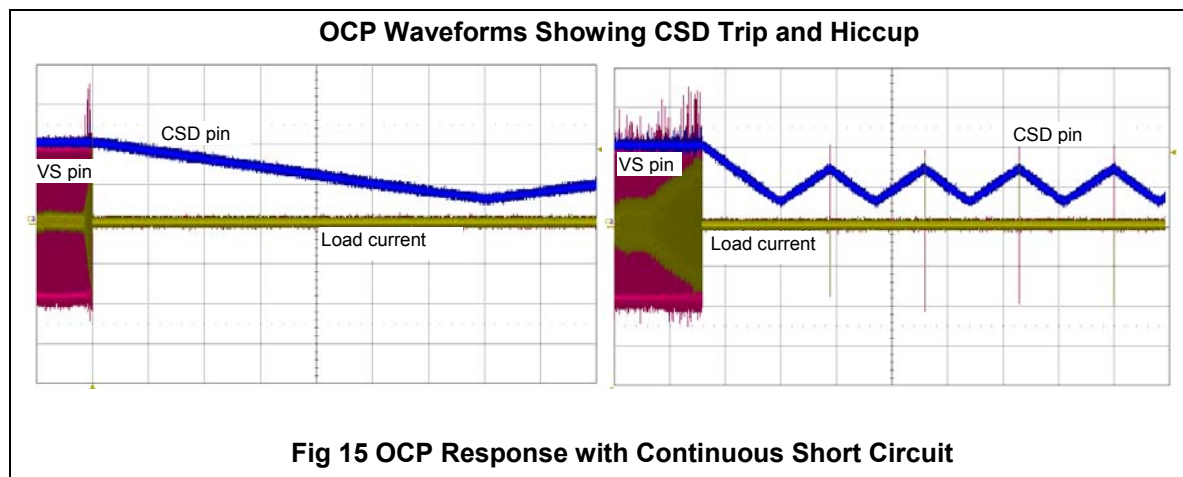
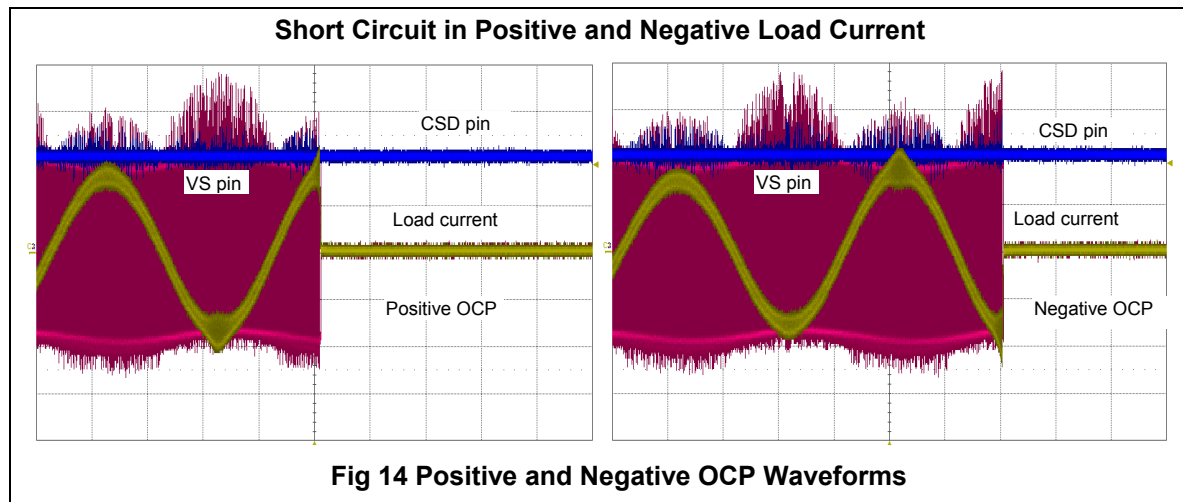


Fig 13 Power Supply Rejection Ratio (PSRR)

Short Circuit Protection Response

Figs 14-15 show over current protection reaction time of the IRAUDAMP10 in a short circuit event. As soon as the IRS2052M detects an over current condition, it shuts down PWM. After one second, the IRS2052M tries to resume the PWM. If the short circuit persists, the IRS2052M repeats try and fail sequences until the short circuit is removed.



IRAUDAMP10 Overview

The IRAUDAMP10 features a 2CH self-oscillating type PWM modulator for the smallest space, highest performance and robust design. This topology represents an analog version of a second-order sigma-delta modulation having a Class D switching stage inside the loop. The benefit of the sigma-delta modulation, in comparison to the carrier-signal based modulation, is that all the error in the audible frequency range is shifted to the inaudible upper-frequency range by nature of its operation. Also, sigma-delta modulation allows a designer to apply a sufficient amount of error correction.

The IRAUDAMP10 self-oscillating topology consists of following essential functional blocks.

- Front-end integrator
- PWM comparator
- Level shifters
- Gate drivers and MOSFETs
- Output LPF

Integrator

Referring to Fig 16 below, the input operational amplifier of the IRS2052M forms a front-end second-order integrator with R3x, C2x, C3x, and R2x. The integrator that receives a rectangular feedback signal from the PWM output via R4x and audio input signal via R3x generates a quadratic carrier signal at the COMP pin. The analog input signal shifts the average value of the quadratic waveform such that the duty cycle varies according to the instantaneous voltage of the analog input signal.

PWM Comparator

The carrier signal at the COMP pin is converted to a PWM signal by an internal comparator that has a threshold at middle point between VAA and VSS. The comparator has no hysteresis in its input threshold.

Level Shifters

The internal input level-shifter transfers the PWM signal down to the low-side gate driver section. The gate driver section has another level-shifter that level shifts up the high-side gate signal to the high-side gate driver section.

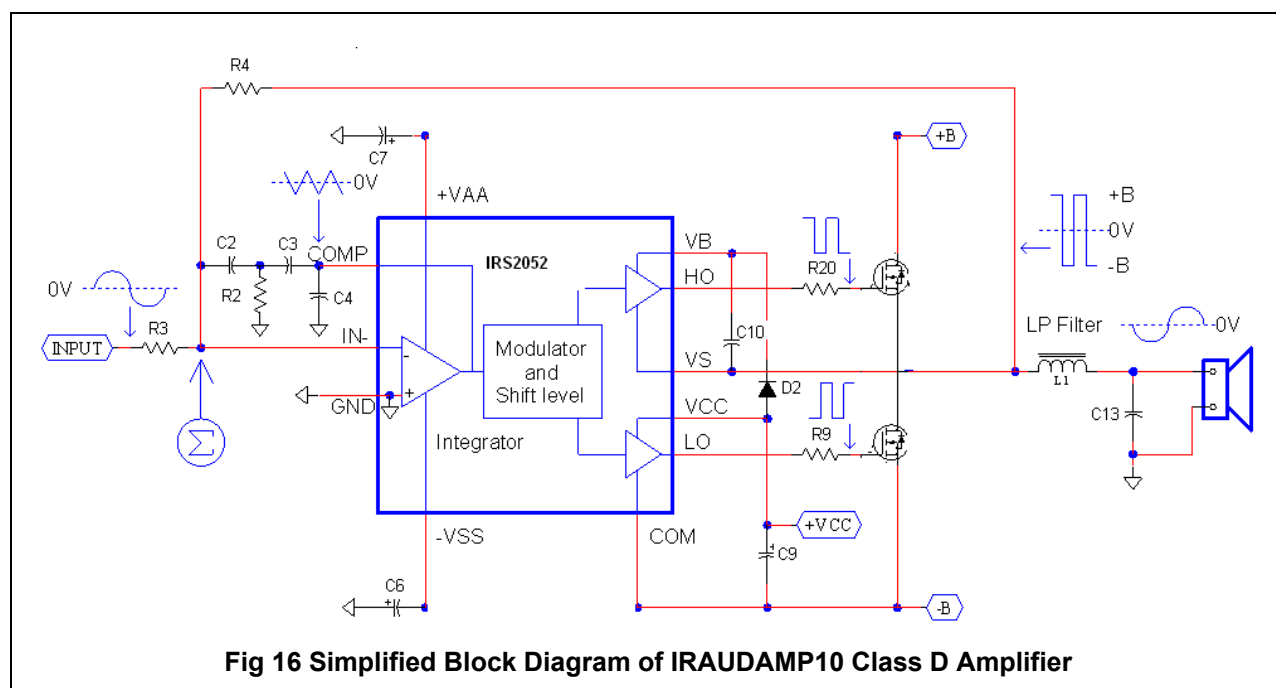
Gate Drivers and DirectFETs

The received PWM signal is sent to the dead-time generation block where a programmable amount of dead time is added into the PWM signal between the two gate output signals of LO and HO to prevent potential cross conduction across the output power DirectFETs. The high-side level-shifter shifts up the high-side gate drive signal out of the dead-time block.

Each channel of the IRS2052M's drives two DirectFETs, high- and low-sides, in the power stage providing the amplified PWM waveform.

Output LPF

The amplified PWM output is reconstructed back to an analog signal by the output LC LPF. Demodulation LC low-pass filter (LPF) formed by L1 and C13, filters out the Class D switching carrier signal leaving the audio output at the speaker load. A single stage output filter can be used with switching frequencies of 500 kHz and greater; a design with a lower switching frequency may require an additional stage of LPF.



Functional Descriptions

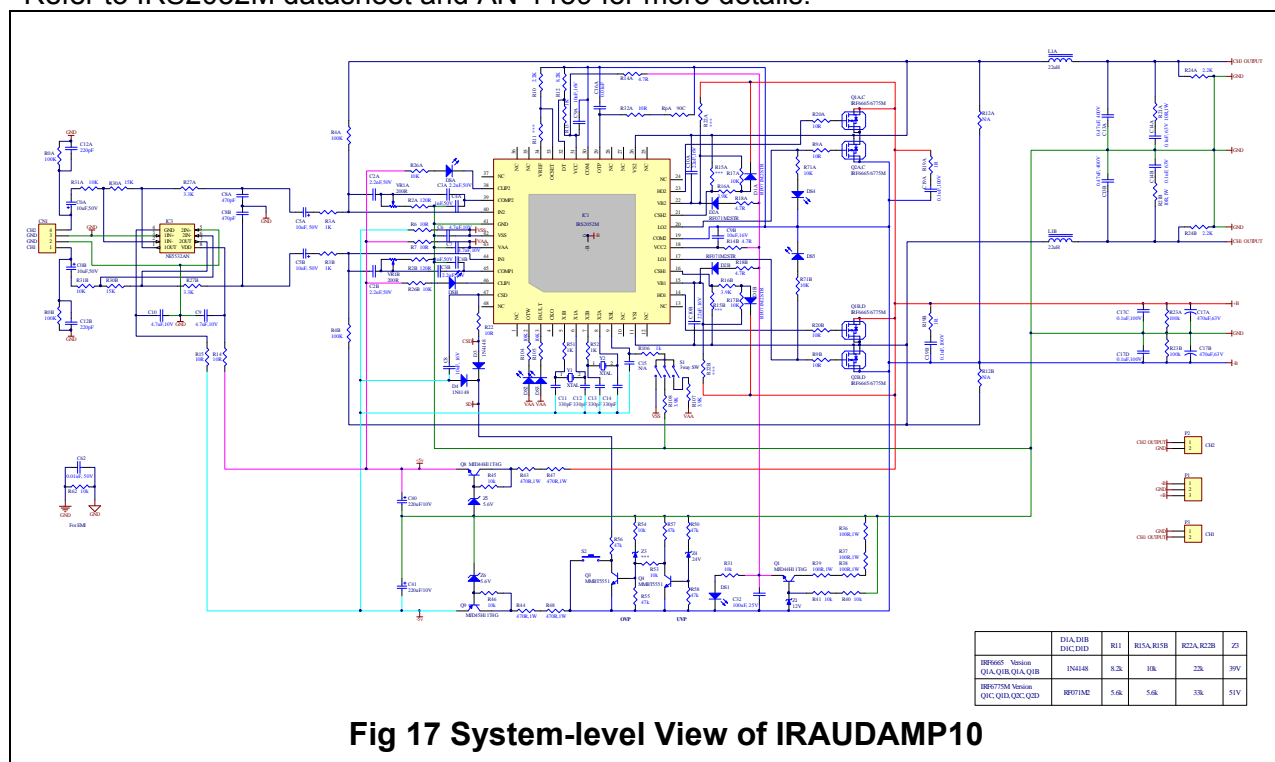
IRS2052M Gate Driver IC

The IRAUDAMP10 uses the IRS2052M, a 2 Channel high-voltage (up to 200 V), high-speed power MOSFET driver with internal dead-time and protection functions specifically designed for Class D audio amplifier applications. These functions include OCP and UVP. The IRS2052M integrates bi-directional over current protection for both high-side and low-side MOSFETs. The dead-time can be selected for optimized performance according to the size of the MOSFET, minimizing dead-time while preventing shoot-through. As a result, there is no gate-timing adjustment required externally. Selectable dead-time through the DT pin voltage is an easy and reliable function which requires only two external resistors, R12 and R13 as shown on Fig 17 or Fig 23 below.

The IRS2052M offers the following functions.

- PWM modulator
- Dead-time insertion
- Over current protection
- Under voltage protection
- Level shifters

Refer to IRS2052M datasheet and AN-1159 for more details.



Self-Oscillating Frequency

Self-oscillating frequency is determined by the total delay time along the control loop of the system; the propagation delay of the IRS2052M, the DirectFETs switching speed, the time-constant of front-end integrator (R2x, R3x, R4x, Vr1x, C2x, C3x). Variations in +B and –B supply voltages also affect the self-oscillating frequency.

The self-oscillating frequency changes with the duty ratio. The frequency is highest at idling. It drops as duty cycle varies away from 50%.

Adjustments of Self-Oscillating Frequency

Use VR1x to set different self-oscillating frequencies. The PWM switching frequency in this type of self-oscillating switching scheme greatly impacts the audio performance, both in absolute frequency and frequency relative to the other channels. In absolute terms, at higher frequencies, distortion due to switching-time becomes significant, while at lower frequencies, the bandwidth of the amplifier suffers. In relative terms, interference between channels is most significant if the relative frequency difference is within the audible range.

Normally, when adjusting the self-oscillating frequency of the different channels, it is suggested to either match the frequencies accurately, or have them separated by at least 25kHz. Under the normal operating condition with no audio input signal, the switching-frequency is set around 500kHz in the IRAUDAMP10.

Internal Clock Oscillator

The IRS2052M integrates two clock oscillators and synchronization networks for each PWM channel. To prevent AM radio reception interference, two PWM frequencies are selectable via XSL pin. As shown in Table 2, when XSL is bias to VAA, X1A and X1B are active. When XSL is GND X2A and X2B are active. When XSL is VSS, both clock oscillators are disabled.

XSL pin	X1A/B	X2A/B
VAA	Activated	Disabled
GND	Disabled	Activated
VSS	Disabled	Disabled

CKO outputs internal clock with VAA/VSS amplitude. The CKO can distribute clock signal to multiple IRS2052 devices to synchronize PWM switching timing.

Selectable Dead-time

The dead-time of the IRS2052 is set based on the voltage applied to the DT pin. Fig 18 lists the suggested component value for each programmable dead-time between 45 and 105 ns. All the IRAUDAMP10 models use DT1 (45ns) dead-time.

Dead-time Mode	R1	R2	DT/SD Voltage
DT1	<10k	Open	V _{CC}
DT2	5.6k Ω	4.7k Ω	0.46 x V _{CC}
DT3	8.2k Ω	3.3k Ω	0.29 x V _{CC}
DT4	Open	<10k	COM

Recommended Resistor Values for Dead Time Selection

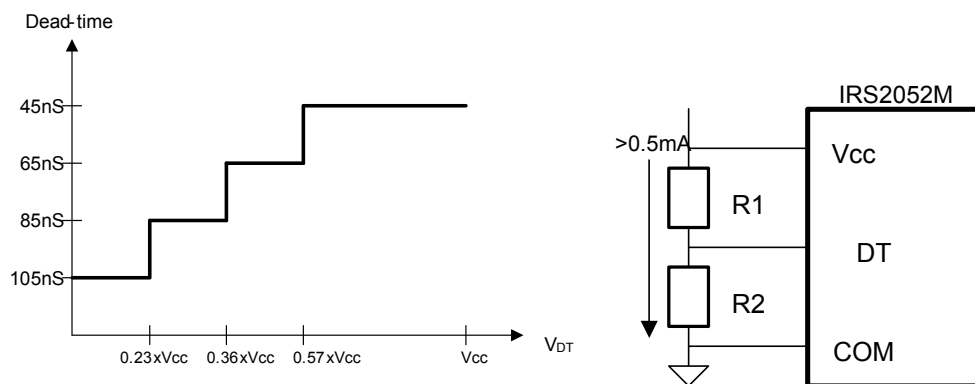
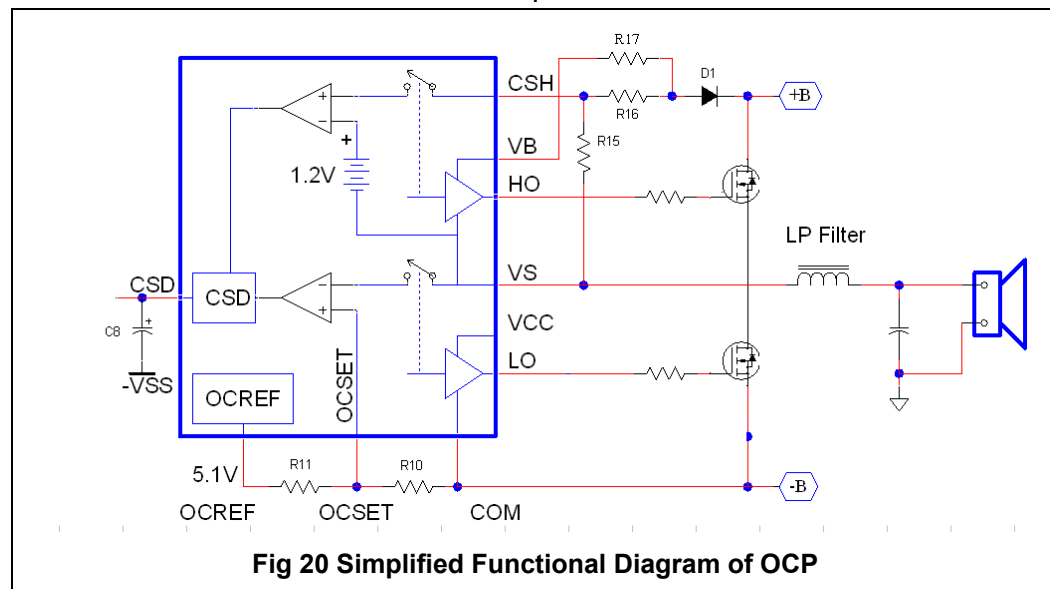
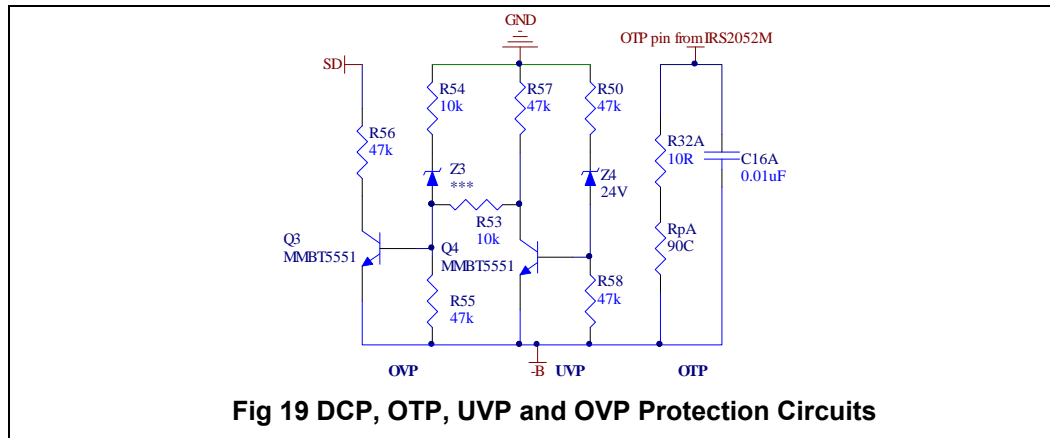


Fig 18 Dead-time Settings vs. V_{DT} Voltage

Protection System Overview

The IRS2052M integrates over current protection (OCP) inside the IC. The rest of the protections, such as over-voltage protection (OVP), under-voltage protection (UVP), and over temperature protection (OTP), are detected externally to the IRS2052M (Fig 19).

The external shutdown circuit will disable the output by pulling down CSD pins, (Fig 20). If the fault condition persists, the protection circuit stays in shutdown until the fault is removed.



Over-Current Protection (OCP)

Low-Side Current Sensing

The low-side current sensing feature protects the low side DirectFET from an overload condition from negative load current by measuring drain-to-source voltage across $R_{DS(ON)}$ during its on state. OCP shuts down the switching operation if the drain-to-source voltage exceeds a preset trip level.

The voltage setting on the OCSET pin programs the threshold for low-side over-current sensing. When the VS voltage becomes higher than the OCSET voltage during low-side conduction, the IRS2052 turns the outputs off and pulls CSD down to -VSS.

High-Side Current Sensing

The high-side current sensing protects the high side DirectFET from an overload condition from positive load current by measuring drain-to-source voltage across $R_{DS(ON)}$ during its on state. OCP shuts down the switching operation if the drain-to-source voltage exceeds a preset trip level.

High-side over-current sensing monitors drain-to-source voltage of the high-side DirectFET during the on state through the CSH and VS pins. The CSH pin detects the drain voltage with reference to the VS pin, which is the source of the high-side DirectFET. In contrast to the low-side current sensing, the threshold of the CSH pin to trigger OC protection is internally fixed at 1.2V. An external resistive divider R15, R16 and R17 are used to program a threshold as shown in Fig 20. An external reverse blocking diode D1 is required to block high voltage feeding into the CSH pin during low-side conduction. By subtracting a forward voltage drop of 0.6V at D1, the minimum threshold which can be set for the high-side is 0.6V across the drain-to-source.

Over-Voltage Protection (OVP)

OVP is provided externally to the IRS2052M. OVP shuts down the amplifier if the bus voltage between GND and -B exceeds 51V. The threshold is determined by a Zener diode Z3. OVP protects the board from harmful excessive supply voltages, such as due to bus pumping at very low frequency-continuous output in stereo mode.

Under-Voltage Protection (UVP)

UVP is provided externally to the IRS2052M. UVP prevents unwanted audible noise output from unstable PWM operation during power up and down. UVP shuts down the amplifier if the bus voltage between GND and -B falls below a voltage set by Zener diode Z4.

Offset Null (DC Offset) Adjustment

The IRAUDAMP10 requires no output-offset adjustment. DC offsets are tested to be less than ± 20 mV.

Over-Temperature Protection (OTP)

The over temperature protection input OTP is for an external PTC Thermistor to monitor temperature of MOSFET. The OTP pin equips a 0.6mA internal current source to bias the external PTC resistor. Over temperature warning activates when the voltage at any of OTP input pin goes higher than 1.4V. Over temperature protection activates when the voltage at any of OTP input pin goes higher than 2.8V. A PTC thermistors, Rpa in Fig 19, is placed on bottom side PCB; which is close to the 4 DirectFETs; and monitors DirectFETs' temperature. If the temperature rises above 90 °C on the bottom side, make OTP input pin goes high and shuts down all 2 channels by pulling down the CSD pins of the IRS2052M. OTP recovers once the temperature cools down.

On-chip Over Temperature Protection

If the junction temperature T_J of IRS2052M becomes higher than on-chip thermal warning threshold 127°C, the on-chip over temperature protection pulls OTW pin down to GND. If the junction temperature T_J keeps increasing and exceed on-chip thermal shutdown threshold 147°C, the on-chip over temperature protection shuts down PWM, pulls OTW up to VAA and pulls FAULT pin down to GND as long as the junction temperature is higher than the threshold.

Over Temperature Warning Output (OTW)

OTW output is an open drain output referenced to GND to report whether the IRS2052M is experiencing high temperature from either OTP input or on-chip OTP. OTW activates if OTP pin voltage becomes higher than warning threshold, or if junction temperature reaches warning threshold.

Fault Output

FAULT output is an open drain output referenced to GND to report whether the IRS2052M is in shutdown mode or in normal operating condition. If FAULT pin is open, the IRS2052M is in normal operation mode.

Following conditions triggers shutdown internally and pulls FAULT pin down to GND.

- Over Current Protection
- Over Temperature Protection (internal or external via OTP pin)
- Shutdown mode from CSD pin voltage

Click and POP Noise Reduction

Thanks to the click and pop elimination function built into the IRS2052M, the IRAUDAMP10 does not require any additional components for this function.

Power Supply Requirements

For convenience, the IRAUDAMP10 has all the necessary housekeeping power supplies onboard and only requires a pair of symmetric power supplies.

House Keeping Power Supply

The internally-generated housekeeping power supplies include $\pm 5V$ for analog signal processing, and +12V supply (V_{CC}) referred to the negative supply rail -B for DirectFET gate drive. The gate driver section of the IRS2052M uses V_{CC} to drive gates of the DirectFETs. V_{CC} is referenced to -B (negative power supply). D2x, R18x and C10x form a bootstrap floating supply for the HO gate driver.

Bus Pumping

When the IRAUDAMP10 is running in stereo mode, the bus pumping effect takes place with low frequency, high output. Since the energy flowing in the Class D switching stage is bi-directional, there is a period where the Class D amplifier feeds energy back to the power supply. The majority of the energy flowing back to the supply is from the energy stored in the inductor in the output LPF. Usually, the power supply has no way to absorb the energy coming back from the load. Consequently the bus voltage is pumped up, creating bus voltage fluctuations.

Following conditions make bus pumping worse:

1. Lower output frequencies (bus-pumping duration is longer per half cycle)
2. Higher power output voltage and/or lower load impedance (more energy transfers between supplies)
3. Smaller bus capacitance (the same energy will cause a larger voltage increase)

The OVP protects IRAUDAMP10 from failure in case of excessive bus pumping. Bus voltage detection monitors only +B supply, assuming the bus pumping on the supplies is symmetric in +B and -B supplies.

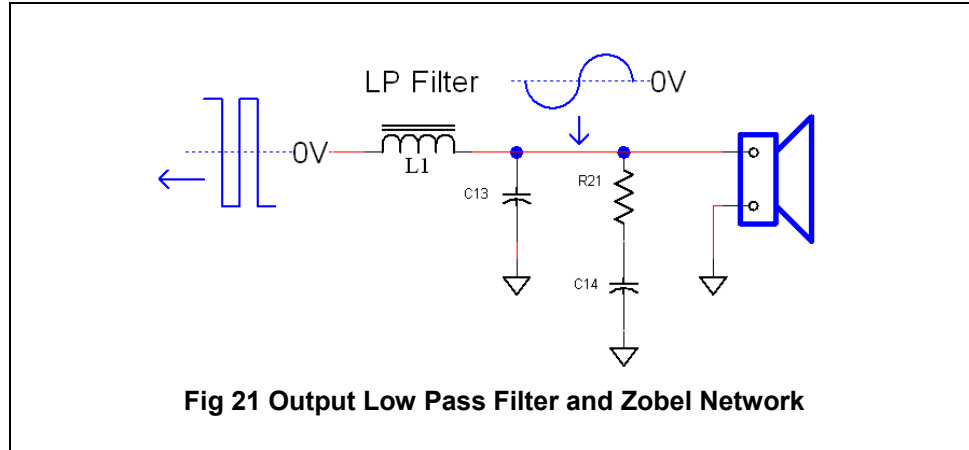
Load Impedance

Each channel is optimized for a 4 Ω speaker load in half bridge.

Input Signal and Gain Setting

A proper input signal is an analog signal ranging from 20Hz to 20kHz with up to 3 V_{RMS} amplitude with a source impedance of no more than 600 Ω . Input signal with frequencies from 30kHz to 60kHz may cause LC resonance in the output LPF, causing a large reactive current flowing through the switching stage, especially with greater than 8 Ω load impedances, and the LC resonance can activate OCP.

The IRAUDAMP10 has an RC network called a Zobel network (R21 and C14) to damp the resonance and prevent peaking frequency response with light loading impedance. (Fig 21)



Gain Setting

The ratio of resistors $\{R4x/(R3x+R27x)\} \cdot (R30x/R31x)$ in Fig 22 sets voltage gain. The IRAUDAMP10 has no on board volume control. To change the voltage gain, change the input resistor term R27x and R3x. Changing R4x affects PWM control loop design and may result poor audio performance.

Schematic

The schematic diagram illustrates a 4-channel audio amplifier system. The central component is the IC1 BQ5005DM, a 4-channel class-D audio amplifier. The circuit is powered by a 5V regulator (Q1) and a 12V regulator (Q2). The input stage uses an N5532AN op-amp (IC3) for signal processing. The output stage uses four BQ5005DM ICs (IC1, IC2, IC3, IC4) driving four 8-ohm speakers (R1, R2, R3, R4). The circuit includes various passive components like resistors (R1-R47), capacitors (C1-C47), and diodes (D1-D4). It also features a volume control potentiometer (P1) and a master volume potentiometer (P2). The schematic is color-coded: blue for power supply, red for signal, green for ground, and yellow for speaker outputs.

	D1A, D1B D1C, D1D	R11	R15A, R15B	R22A, R22B	Z
IRF6665 Version Q1A, Q1B, Q1A, Q1B	IN4148	8.2k	10k	22k	39k
IRF6775M Version Q1C, Q1D, Q2C, Q2D	RF071M2	5.6k	5.6k	33k	51k

IRAUDAMP10 Fabrication Materials

Table 1 IRAUDAMP10 Electrical Bill of Materials

Quantity	Value	Description	Designator	Part Number	Vender
4	10uF, 50V	CAP 10UF 50V ELECT SMG RAD	C0A, C0B, C5A, C5B	565-1106-ND	United Chemi-Con
4	2.2nF, 50V	CAP CER 2200PF 50V 10% X7R 0603	C2A, C2B, C3A, C3B	490-1500-1-ND	Murata Electronics North America
2	1nF, 50V	CAP 1000PF 50V CERAMIC X7R 0603	C4A, C4B	399-1082-1-ND	Kemet
4	4.7uF, 10V	CAP CERM 4.7UF 10V Y5V 0805	C6, C7, C9, C10	478-1429-1-ND	AVX Corporation
1	10uF, 16V	CAP CER 10UF 16V Y5V 1206	C8	490-3383-1-ND	Murata Electronics North America
2	470pF	Polypropylene Film Capacitors 100V 470pF 5%	C8A, C8B	505-FKP2470/100/5	WIMA
2	10uF, 16V	CAP CER 10UF 16V Y5V 0805	C9A, C9B	490-3347-1-ND	Murata Electronics North America
2	22uF, 16V	CAP CER 22UF 16V X7R 1210	C10A, C10B	445-3945-1-ND	TDK Corporation
4	330pF, 50V	CAP CER 330PF 50V X7R 0603	C11, C12, C13, C14	445-5074-1-ND	TDK Corporation
2	220pF	CAP CER 220PF 50V 10% X7R 0603	C12A, C12B	490-1483-1-ND	Murata Electronics North America
2	0.47uF, 400V	CAP .47UF 400V METAL POLYPRO	C13A, C13B	495-1315-ND	EPCOS Inc
2	0.1uF, 63V	CAP FILM MKP .1UF 63VDC 2%	C14A, C14B	BC2054-ND	Vishay/BC Components
2	0.01uF, 50V	CAP CER 10000PF 50V 10% X7R 0603	C16A, C62	490-1512-1-ND	Murata Electronics North America
2	470uF, 63V	CAP 470UF 63V ELECT SMG RAD	C17A, C17B	565-1131-ND	United Chemi-Con
4	0.1uF, 100V	CAP CER .10UF 100V X7R 10% 0805	C17C, C17D, C19A, C19B	445-1418-1-ND	TDK Corporation
1	100uF, 25V	CAP 100UF 25V ELECT SMG RAD	C32	565-1059-ND	United Chemi-Con
2	220uF, 10V	CAP 220UF 10V ELECT SMG RAD	C40, C41	565-1021-ND	United Chemi-Con
1	INPUT	TERMINAL BLOCK 3.5MM 4POS PCB	CN1	ED1516-ND	On Shore Technology Inc
4	RF071M2STR	DIODE 200V 700MA SOD123	D1A, D1B, D2A, D2B	RF071M2SCT-ND	Rohm Semiconductor
2	1N4148	DIODE SWITCH 100V 400MW SOD123	D3, D4	1N4148W-FDICT-ND	Diodes Inc
1	LED AMBER	LED AMBER CLR THIN 0805 SMD	DS1	160-1419-1-ND	Lite-On Inc
2	LED RED	LED SUPER RED CLEAR 0805 SMD	DS2, DS3	160-1415-1-ND	Lite-On Inc
2	LED BLUE	LED 468NM BLUE CLEAR 0805 SMD	DS4, DS5	160-1645-1-ND	Lite-On Inc
2	LED GREEN	LED GREEN CLEAR 0805 SMD	DSA, DSB	160-1414-1-ND	Lite-On Inc
1	IRS2052M	2ch Audio Class D Controller	IC1	IR2052MPBF	International Rectifier
1	NE5532AN	IC OPAMP DUAL LOW NOISE 8-DIP	IC3	NE5532ANGOS-ND	ON Semiconductor
2	22uH	Class D inductor, 22uH	L1A, L1B	7G17A-220M	Inductors, Inc./SAGAMI ELEC CO., LTD.
1	Header 3	CONN TERM BLOCK PCB 5.0MM 3POS	P1	281-1415-ND	Weidmuller
2	SP OUT	CONN TERM BLOCK PCB 5.0MM 2POS	P2, P3	281-1414-ND	Weidmuller
2	MJD44H11T4G	TRANS PWR NPN 8A 80V DPAK	Q1, Q8	MJD44H11T4GOSCT-ND	ON Semiconductor
4	IRF6775MPBF	MOSFET, 150V, 28A, 47 mOhm, 25 nC Qg, Med Can, optimized for Audio	Q1A, Q1B, Q2A, Q2B	IRF6775MTR1PBF	International Rectifier

0	N/A	MOSFET, 100V, 19A, 62 mOhm, 8.7 nC Qg, Small Can, optimized for Audio	Q1C, Q1D, Q2C, Q2D	IRF6665TR1PBF	International Rectifier
2	MMBT5551	TRANS NPN 160V 350MW SMD SOT23-3	Q3, Q4	MMBT5551-FDICT-ND	Diodes Inc
1	MJD45H11T4G	TRANS PWR PNP 8A 80V DPAK	Q9	MJD45H11T4GOSCT-ND	ON Semiconductor
4	100K	RES 100K OHM 1/10W 5% 0603 SMD	R0A, R0B, R23A, R23B	RHM100KGCT-ND	Rohm Semiconductor
2	120R	RES 120 OHM 1/10W 5% 0603 SMD	R2A, R2B	RHM120GCT-ND	Rohm Semiconductor
2	1K	RES 1.00K OHM 1/8W 1% 0805 SMD	R3A, R3B	RHM1.00KCRCT-ND	Rohm Semiconductor
2	100K	RES 100K OHM 1/8W 1% 0805 SMD	R4A, R4B	RHM100KCRCT-ND	Rohm Semiconductor
10	10R	RES 10 OHM 1/10W 5% 0603 SMD	R6, R7, R9A, R9B, R14, R15, R20A, R20B, R22, R32A	RHM10GCT-ND	Rohm Semiconductor
1	2.2K	RES 2.2K OHM 1/10W 5% 0603 SMD	R10	RHM2.2KGCT-ND	Rohm Semiconductor
3	5.6K	RES 5.6K OHM 1/10W 5% 0603 SMD	R11, R15A, R15B	RHM5.6KGCT-ND	Rohm Semiconductor
1	8.2K	RES 8.2K OHM 1/10W 5% 0603 SMD	R12	RHM8.2KGCT-ND	Rohm Semiconductor
0	N/A		R12A, R12B	N/A	
5	1K	RES 1.0K OHM 1/10W 5% 0603 SMD	R13, R51, R52, R106, R108	RHM1.0KGCT-ND	Rohm Semiconductor
4	4.7R	RES 4.7 OHM 1/10W 5% 0603 SMD	R14A, R14B, R18A, R18B	RHM4.7GCT-ND	Rohm Semiconductor
3	3.9K	RES 3.9K OHM 1/10W 5% 0603 SMD	R16A, R16B, R107	RHM3.9KGCT-ND	Rohm Semiconductor
13	10K	RES 10K OHM 1/10W 5% 0603 SMD	R17A, R17B, R26A, R26B, R45, R46, R53, R54, R62, R71A, R71B, R104, R105	RHM10KGCT-ND	Rohm Semiconductor
2	1R	RES 1.0 OHM 1/8W 5% 0805 SMD	R19A, R19B	RHM1.0ARCT-ND	Rohm Semiconductor
2	10R,1W	RES 10 OHM 1W 1% 2512 SMD	R21A, R21B	PT10AECT-ND	Panasonic - ECG
2	33K	RES 33.0K OHM 1/8W 1% 0805 SMD	R22A, R22B	RHM33.0KCRCT-ND	Rohm Semiconductor
2	2.2K	RES 2.2K OHM 1/8W 5% 0805 SMD	R24A, R24B	RHM2.2KARCT-ND	Rohm Semiconductor
2	3.3K	RES 3.3K OHM 1/10W 5% 0603 SMD	R27A, R27B	RHM3.3KGCT-ND	Rohm Semiconductor
2	15K	RES 15.0K OHM 1/8W 1% 0805 SMD	R30A, R30B	RHM15.0KCRCT-ND	Rohm Semiconductor
5	10K	RES 10.0K OHM 1/8W 1% 0805 SMD	R31, R31A, R31B, R40, R41	RHM10.0KCRCT-ND	Rohm Semiconductor
4	100R,1W	RES 100 OHM 1W 5% 2512 SMD	R36, R37, R38, R39	PT100XCT-ND	Panasonic - ECG
4	470R,1W	RES 470 OHM 1W 5% 2512 SMD	R43, R44, R47, R48	PT470XCT-ND	Panasonic - ECG
5	47K	RES 47K OHM 1/10W 5% 0603 SMD	R50, R55, R56, R57, R58	RHM47KGCT-ND	Rohm Semiconductor
1	90C	Thermistors - PTC PTC Temp Prot. 90C	RpA	594-2381-675-20907	Vishay/BC Components
1	3way SW	SWITCH ROTARY SP-3POS SMD	S1	401-1962-1-ND	C&K Components
1	SW-PB	6MM LIGHT TOUCH SW H=5	S2	P8010S-ND	Panasonic - ECG
2	200R VR	POT 200 OHM 3MM CERM SQ TOP SMD	VR1A, VR1B	ST32ETB201CT-ND	Copal Electronics Inc
1	XTAL	CER RESONATOR 400KHz	Y1	490-1186-ND	Murata Electronics North America
1	XTAL	CER RESONATOR 455KHz	Y2	490-1187-ND	Murata Electronics North America
1	12V	DIODE ZENER 12V 500MW SOD-123	Z1	BZT52C12-FDICT-ND	Diodes Inc

1	51V	DIODE ZENER 51V 410MW SOD-123	Z3	BZT52C51-FDICT-ND	Diodes Inc
1	24V	DIODE ZENER 24V 500MW SOD-123	Z4	BZT52C24-FDICT-ND	Diodes Inc
2	5.6V	DIODE ZENER 5.6V 500MW SOD-123	Z5, Z6	MMSZ5V6T1GOSCT-ND	ON Semiconductor

Table 2 IRAUDAMP10 Mechanical Bill of Materials

Quantity	Value	Description	Designator	Digikey P/N	Vendor
7	Washer #4 SS	WASHER LOCK INTERNAL #4 SS	Lock washer 1, Lock washer 2, Lock washer 3, Lock washer 4, Lock washer 5, Lock washer 6 Lock washer 7	H729-ND	Building Fasteners
1	PCB	Print Circuit Board IRAUDAM11 Rev 3.0 .PCB	PCB 1		Custom
7	Screw 4- 40X5/16	SCREW MACHINE PHILLIPS 4-40X5/16	Screw 1, Screw 2, Screw 3, Screw 4, Screw 5, Screw 6, Screw 7,	H343-ND	Building Fasteners
4	Stand off 0.5"	STANDOFF HEX 4- 40THR .500"L ALUM	Stand Off 1, Stand Off 2, Stand Off 3, Stand Off 4	1893K-ND	Keystone Electro- nics
1/16	AAVID 4880G	THERMAL PAD .080" 4X4" GAPPAD	thermal pad under heatsink	BER164-ND	Therm- alloy

IRAUDAMP10 Hardware

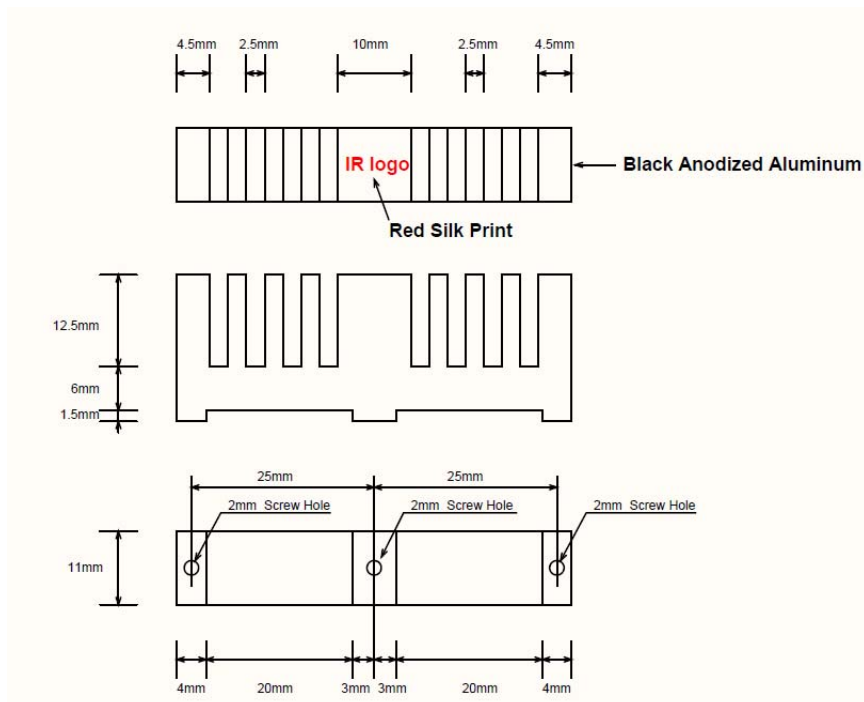


Fig 23 Heat Spreader

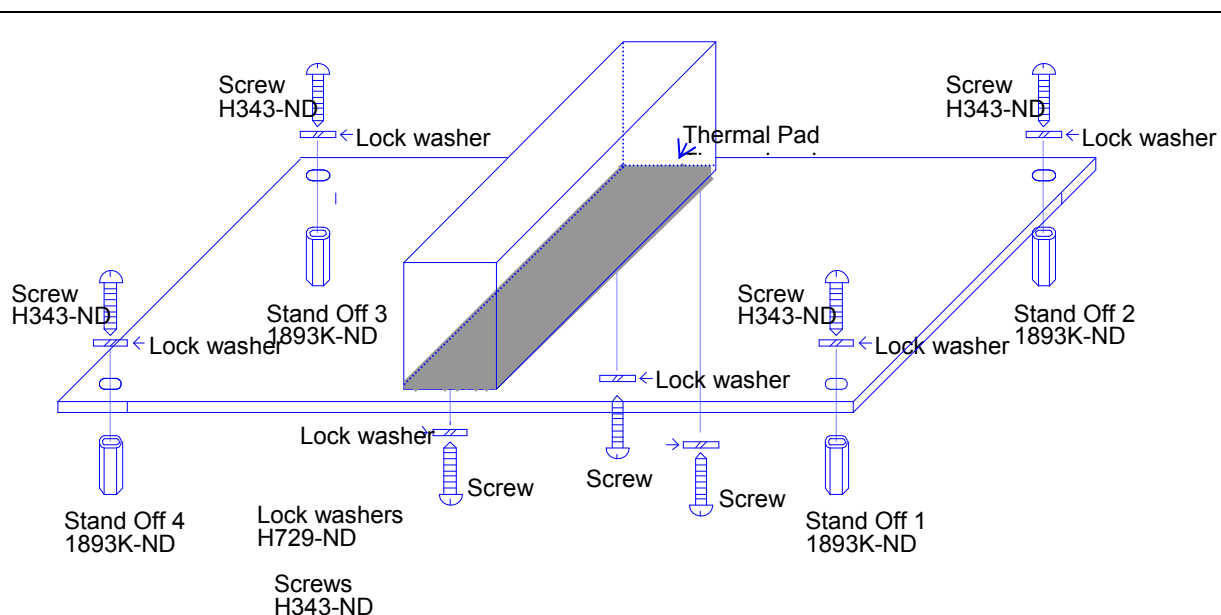


Fig 26 Hardware Assemblies

IRAUDAMP10 PCB Specifications

PCB:

1. Two Layers SMT PCB with through holes
2. 1/16 thickness
3. 2/0 OZ Cu
4. FR4 material
5. 10 mil lines and spaces
6. Solder Mask to be Green enamel EMP110 DBG (CARAPACE) or Enthone Endplate DSR-3241 or equivalent.
7. Silk Screen to be white epoxy non conductive per IPC–RB 276 Standard.
8. All exposed copper must finished with TIN-LEAD Sn 60 or 63 for 100u inches thick.
9. Tolerance of PCB size shall be 0.010 –0.000 inches
10. Tolerance of all Holes is $-.000 + 0.003$ "
11. PCB acceptance criteria as defined for class II PCB'S standards.

Gerber Files Apertures Description:

All Gerber files stored in the attached CD-ROM were generated from Protel Altium Designer Altium Designer 6. Each file name extension means the following:

1. .gtl Top copper, top side
2. .gbl Bottom copper, bottom side
3. .gto Top silk screen
4. .gbo Bottom silk screen
5. .gts Top Solder Mask
6. .gbs Bottom Solder Mask
7. .gko Keep Out,
8. .gm1 Mechanical1
9. .gd1 Drill Drawing
10. .gg1 Drill locations
11. .txt CNC data
12. .apr Apertures data

Additional files for assembly that may not be related with Gerber files:

13. .pcb PCB file
14. .bom Bill of materials
15. .cpl Components locations
16. .sch Schematic
17. .csv Pick and Place Components
18. .net Net List
19. .bak Back up files
20. .lib PCB libraries

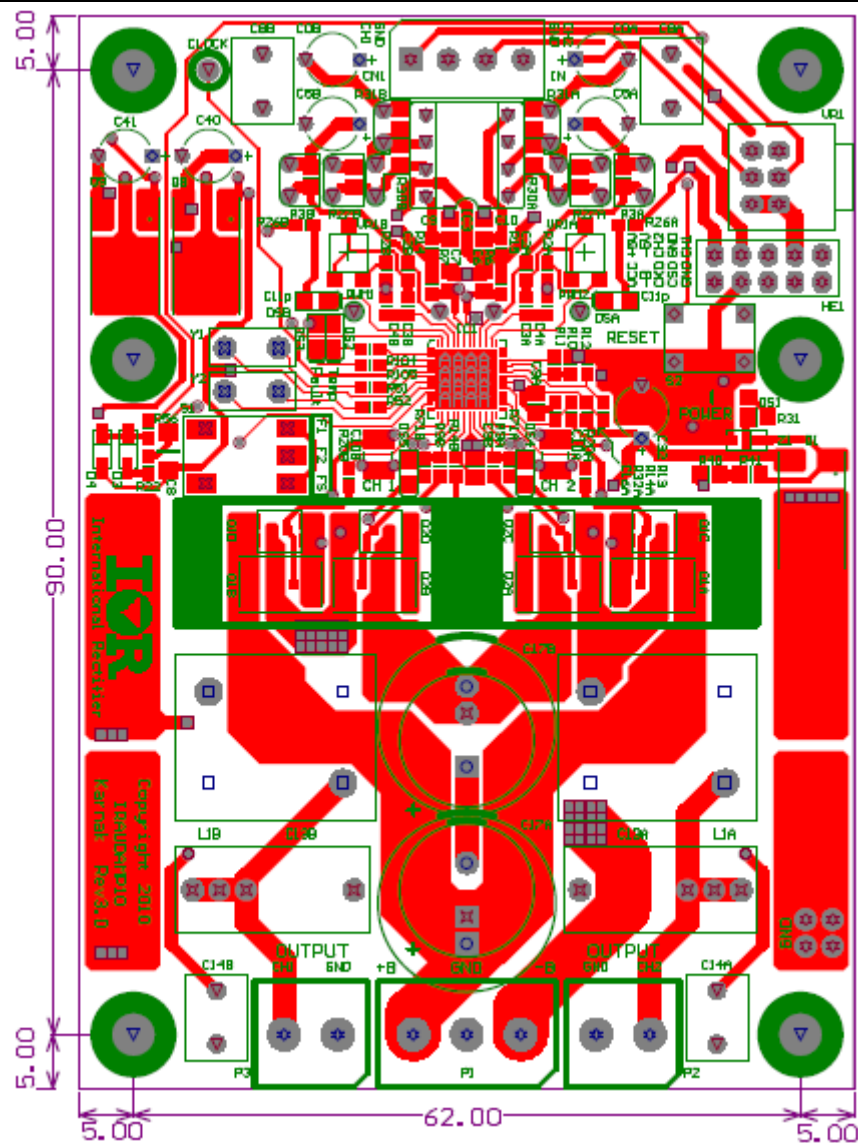


Fig 27 IRAUDAMP10 PCB Top Overlay (Top View)

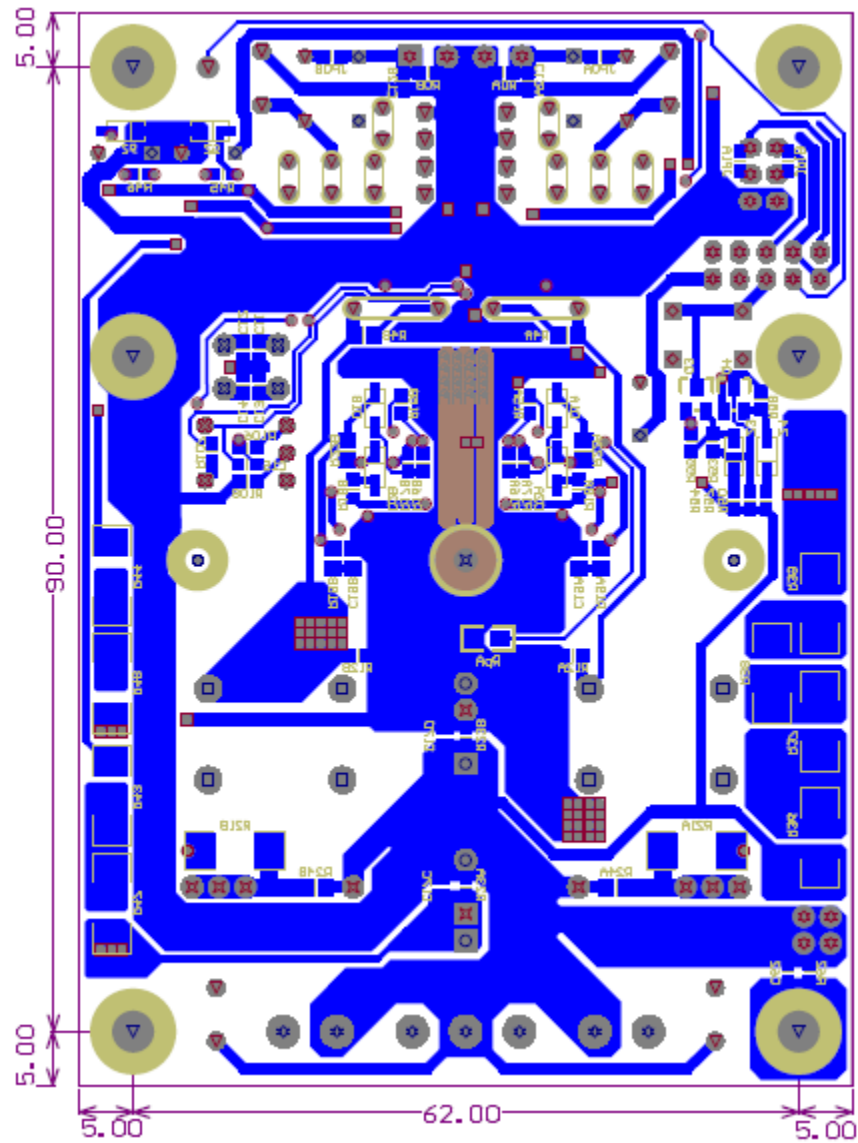


Fig 28 IRAUDAMP10 PCB Bottom Layer (Top View)

Revision changes descriptions

Revision	Changes description	Date
Rev 1.0	Released	March, 29 2011
Rev 1.1	Correct polarity of XSL pin function in Internal Clock Oscillator	Jan, 25 2012

Mouser Electronics

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