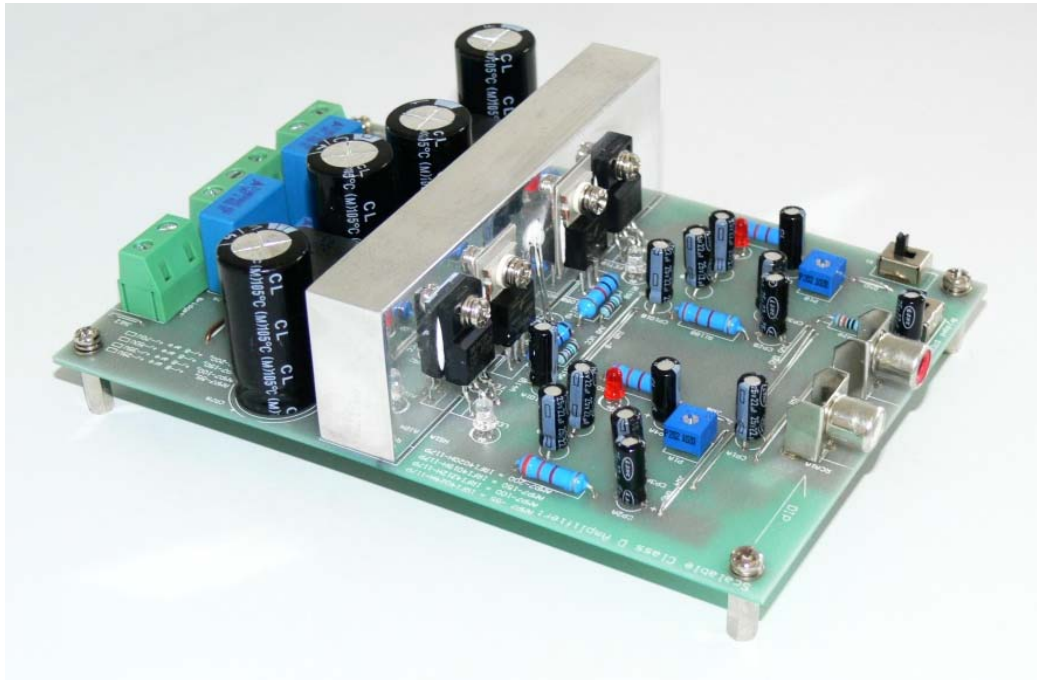


# IRAUDAMP7S

**25W-500W Scalable Output Power  
Class D Audio Power Amplifier Reference Design  
Using the IRS2092S Protected Digital Audio Driver**

*By*

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**CAUTION:**

**International Rectifier suggests the following guidelines for safe operation and handling of IRAUDAMP7S 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**

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## Introduction

The IRAUDAMP7S reference design is a two-channel Class D audio power amplifier that features output power scalability. The IRAUDAMP7S offers selectable half-bridge (stereo) and full-bridge (bridged) modes.

This reference design demonstrates how to use the IRS2092 Class D audio driver IC, along with IR's digital audio dual MOSFETs, such as IRFI4024H-117P, IRFI4019H-117P, IRFI4212H-117P and IRFI4020H-117P, on a single layer PCB. The design shows how to implement peripheral circuits on an optimum PCB layout using a single sided board.

The resulting design requires a small heatsink for normal operation (one-eighth of continuous rated power). The reference design provides all the required housekeeping power supplies and protections.

**Unless otherwise noted, this user's manual is based on 150V model, IRAUDAMP7S-150.**

Other output power versions can be configured by replacing components given in the component selection of Table 5 on page 36

## Applications

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

## Features

|                               |                                                                                                                                                                                                                              |
|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Output Power:                 | Scalable output power from 25W- 500W (see Table 1)                                                                                                                                                                           |
| Residual Noise:               | 200 $\mu$ V, IHF-A weighted, AES-17 filter                                                                                                                                                                                   |
| Distortion:                   | 0.007 % THD+N @ 60W, 4 $\Omega$                                                                                                                                                                                              |
| Efficiency:                   | 90 % @ 500W, 8 $\Omega$ , Class D stage                                                                                                                                                                                      |
| Multiple Protection Features: | Over-current protection (OCP), high side and low side MOSFET<br>Over-voltage protection (OVP),<br>Under-voltage protection (UVP), high side and low side MOSFET<br>DC-protection (DCP),<br>Over-temperature protection (OTP) |
| PWM topology:                 | Self-oscillating PWM, half-bridge or full-bridge topologies selectable                                                                                                                                                       |

**Table 1** IRAUDAMP7S Specification Table Series

| Item                   |              | Model Name                     |                                |                                |                                |
|------------------------|--------------|--------------------------------|--------------------------------|--------------------------------|--------------------------------|
|                        |              | AMP7S-55                       | AMP7S-100                      | AMP7S-150                      | AMP7S-200                      |
| IR Power MOSFET        | FET1A, FET1B | <a href="#">IRFI4024H-117P</a> | <a href="#">IRFI4212H-117P</a> | <a href="#">IRFI4019H-117P</a> | <a href="#">IRFI4020H-117P</a> |
| Half Bridge            | 8 Ω          | 25W x 2                        | 60W x 2                        | 125W x 2                       | 250W x 2                       |
|                        | 4 Ω          | 50W x 2                        | 120W x 2                       | 250W x 2                       | Not Supported                  |
| Full Bridge            | 8 Ω          | 100W x 1                       | 240W x 1                       | 500W x 1                       | Not Supported                  |
| Nominal Supply Voltage | +B, -B       | ±25V                           | ±35V                           | ±50V                           | ±70V                           |
| Min/Max Supply Voltage | +B, -B       | ±20V ~ ±28V                    | ±28V ~ ±45V                    | ±45V ~ ±60V                    | ±60V ~ ±80V                    |
| Voltage Gain           | Gv           | 20                             | 30                             | 36                             | 40                             |

**Notes:**

- All the power ratings are at clipping power (THD+N = 1 %). To estimate power ratings at THD+N=10%, multiply them by 1.33
- See Table 5 on page 36 for the complete listing of components table.

**Specifications**

**General Test Conditions for IRAUDAMP7S-150 (unless otherwise noted) Notes / Conditions**

|                            |        |
|----------------------------|--------|
| Power Supply Voltages      | ± 50V  |
| Load Impedance             | 4 Ω    |
| Self-Oscillating Frequency | 400kHz |
| Voltage Gain               | 36     |

**Electrical Data**

**Typical**

**Notes / Conditions**

|                                  |                                                                                                                                 |                             |
|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------|-----------------------------|
| IR Devices Used                  | IRS2092, Protected digital audio driver<br>IRFI4024H-117P, IRFI4019H-117P, IRFI4212H-117P, IRFI4020H-117P Digital audio MOSFETs |                             |
| PWM Modulator                    | Self-oscillating, second order sigma-delta modulation, analog input                                                             |                             |
| Power Supply Range               | ± 45V to ± 60V                                                                                                                  | Or see table 1 above        |
| Output Power CH1-2: (1 % THD+N)  | 300W                                                                                                                            | 1kHz                        |
| Output Power CH1-2: (10 % THD+N) | 400W                                                                                                                            | 1kHz                        |
| Rated Load Impedance             | 8 - 4 Ω                                                                                                                         | Resistive load              |
| Standby Supply Current           | +50 mA/-80 mA                                                                                                                   | No input signal             |
| Total Idle Power Consumption     | 7W                                                                                                                              | No input signal             |
| Channel Efficiency               | 90 %                                                                                                                            | Single-channel driven, 250W |

### Audio Performance

|                                                      | Before Demodulator                      | Class D Output                          | Notes / Conditions                                               |
|------------------------------------------------------|-----------------------------------------|-----------------------------------------|------------------------------------------------------------------|
| THD+N, 1W<br>THD+N, 10W<br>THD+N, 60W<br>THD+N, 100W | 0.01 %<br>0.005 %<br>0.005 %<br>0.007 % | 0.02 %<br>0.007 %<br>0.007 %<br>0.008 % | 1kHz, Single-channel driven                                      |
| Dynamic Range                                        | 101 dB                                  | 101 dB                                  | A-weighted, AES-17 filter, Single-channel operation              |
| Residual Noise                                       | 200 $\mu$ V                             | 200 $\mu$ V                             | 22 Hz – 20kHz, AES17 filter<br>Self-oscillating frequency 400kHz |
| Damping Factor                                       | 2000                                    | 120                                     | 1kHz, relative to 4 $\Omega$ load                                |
| Channel Separation                                   | 95 dB<br>85 dB<br>75 dB                 | 90 dB<br>80 dB<br>65 dB                 | 100Hz<br>1kHz<br>10kHz                                           |
| Frequency Response : 20 Hz-20kHz                     | 20 Hz-35kHz                             | $\pm$ 3 dB                              | 1W, 4 $\Omega$ – 8 $\Omega$ Load                                 |

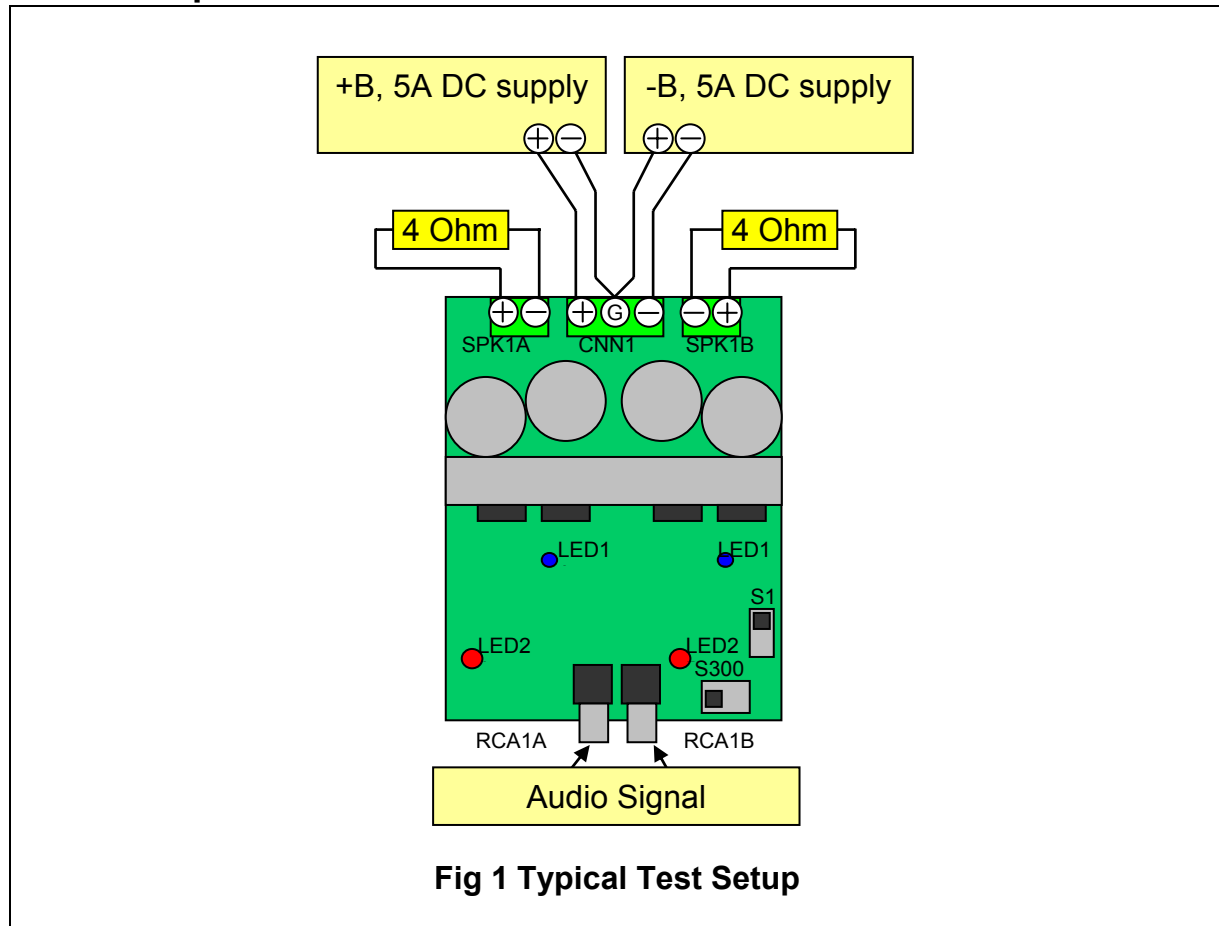
### Thermal Performance (T<sub>A</sub>=25 °C)

| Condition                    | Typical                                           | Notes / Conditions       |
|------------------------------|---------------------------------------------------|--------------------------|
| Idling                       | T <sub>C</sub> =30 °C<br>T <sub>PCB</sub> =37 °C  | No signal input          |
| 2 ch x 31W (1/8 rated power) | T <sub>C</sub> =54 °C<br>T <sub>PCB</sub> =67 °C  |                          |
| 2 ch x 250W (Rated power)    | T <sub>C</sub> =80 °C<br>T <sub>PCB</sub> =106 °C | OTP shutdown after 150 s |

### Physical Specifications

|            |                                                                  |
|------------|------------------------------------------------------------------|
| Dimensions | 5.7"(L) x 4"(W) x 1.25"(H)<br>145 mm (L) x 100 mm (W) x 35 mm(H) |
| Weight     | 0.330kgm                                                         |

## Test Setup



## Connector Description

|         |       |                                        |
|---------|-------|----------------------------------------|
| CH1 IN  | RCA1A | Analog input for CH1                   |
| CH2 IN  | RCA1B | Analog input for CH2                   |
| SUPPLY  | CNN1  | Positive and negative supply (+B / -B) |
| CH1 OUT | SPK1A | Output for CH1                         |
| CH2 OUT | SPK1B | Output for CH2                         |

## Switches Descriptions

|      |                                  |
|------|----------------------------------|
| S1   | Shutdown PWM                     |
| S300 | Half bridge / Full bridge select |

## Indicator Description

|          |                                        |
|----------|----------------------------------------|
| LED1A, B | PWM (presence of low side gate signal) |
| LED2A, B | Protection                             |

## Test Procedures

### Test Setup:

1. On the unit under test (UUT), set switch S1 to OFF and S300 to Stereo positions.
2. Connect 4  $\Omega$ -200 W dummy loads to output connectors, SPKR1A and SPKR1B, as shown on Fig 1.
3. Set up a dual power supply  $\pm 50V$  with 5A current limit
4. Turn OFF the dual power supply before connecting to UUT.
5. Connect the dual power supply to CNN1, as shown in 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. The red LEDs (Protections) turn ON immediately and stay on as long as S1 is in OFF position. Blue LEDs stay OFF.
8. Quiescent current for the positive and negative supplies must be less than 50mA, while S1 is in OFF position. Under this condition, IRS2092 is in shutdown mode.
9. Slide S1 to ON position; after one second delay, the two blue LEDs turn ON and the red LEDs turns off. The two blue LEDs indicate that PWM oscillation is present. This transition delay time is controlled by CSD pin of IRS2092, capacitor CP3
10. Under the normal operating condition with no input signal applied, quiescent current for the positive supply must be less than 50 mA; the negative supply current must be less than 100 mA.

### Switching Frequency Test:

11. With an oscilloscope, monitor switching waveform at test points VS1 & VS2 Adjust P1A & P1B to change self oscillating frequency to  $400kHz \pm 25kHz$ .  
Note: To change self-oscillating switching frequency, Adjust the potentiometer resistances of P11A and P11B for CH1 and CH2 respectively.

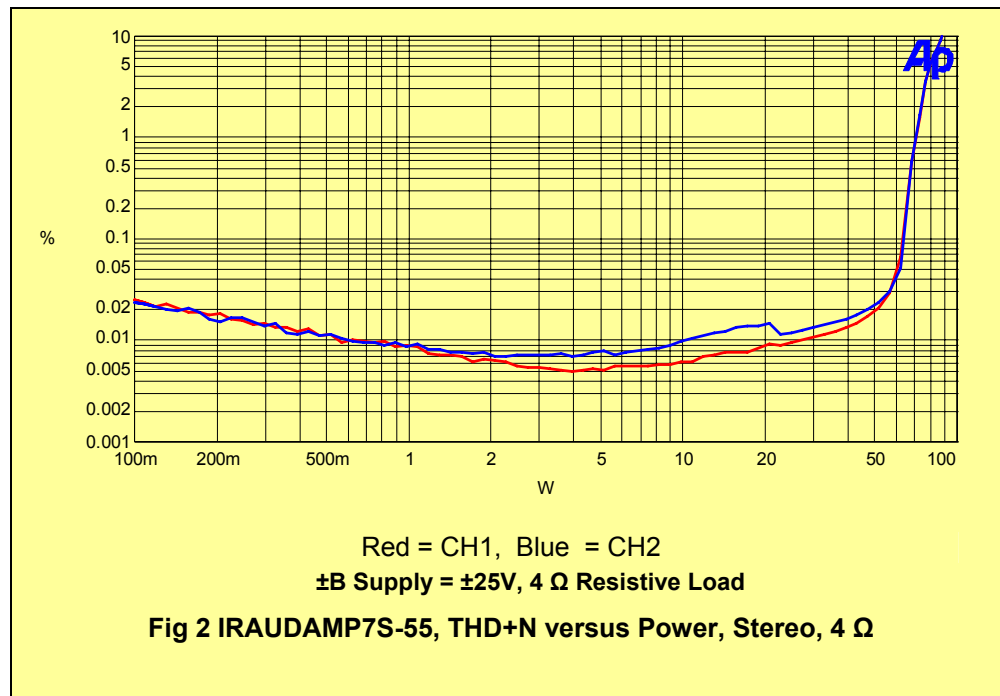
### Audio Functionality Tests:

12. Set the signal generator to 1kHz, 20 mV<sub>RMS</sub> output.
13. Connect audio signal generators to RCA1A and RCA1B.
14. Sweep the audio signal voltage from 15 mV<sub>RMS</sub> to 1 V<sub>RMS</sub>.
15. Monitor the output signals at SPK1A/B with an oscilloscope. Waveform must be a non distorted sinusoidal signal.
16. Observe 1 V<sub>RMS</sub> input generates output voltage of 36 V<sub>RMS</sub>. The ratio,  $R8/(R7+R2)$ , determines the voltage gain of IRAUDAMP7S.
17. Set switch S300 to Bridged position.
18. Observe that voltage gain doubles.

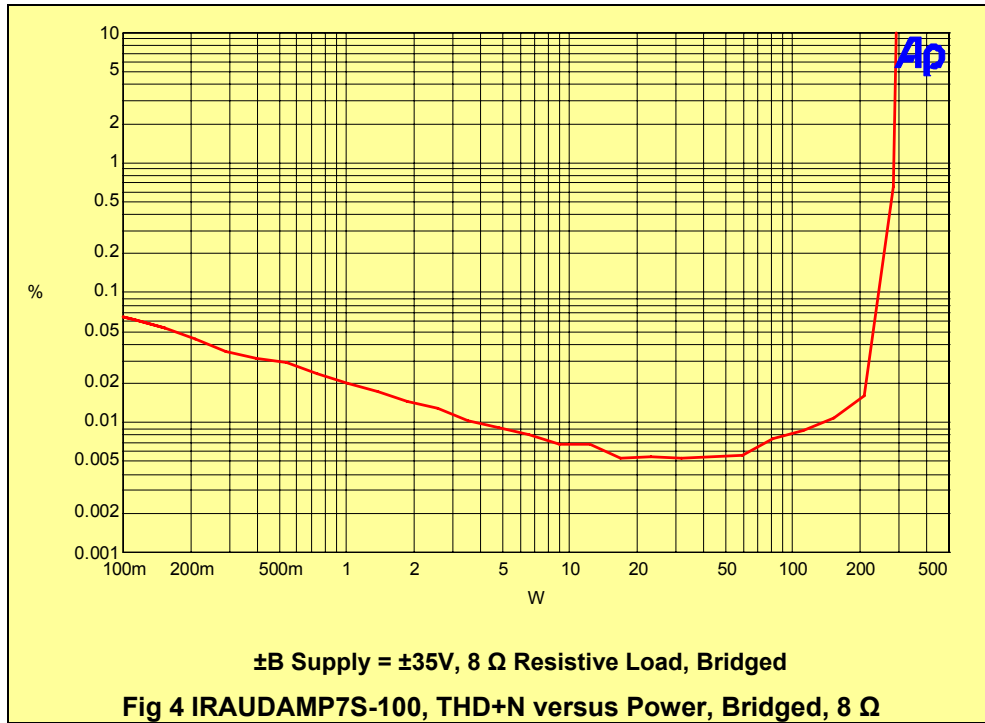
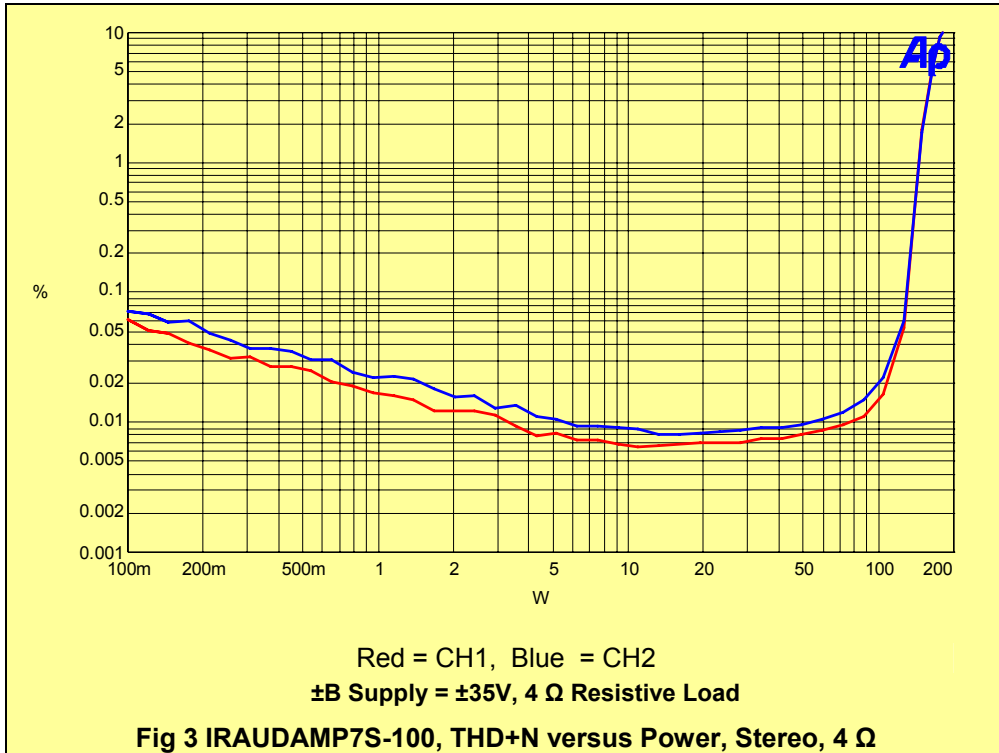
### Test Setup using Audio Precision (Ap):

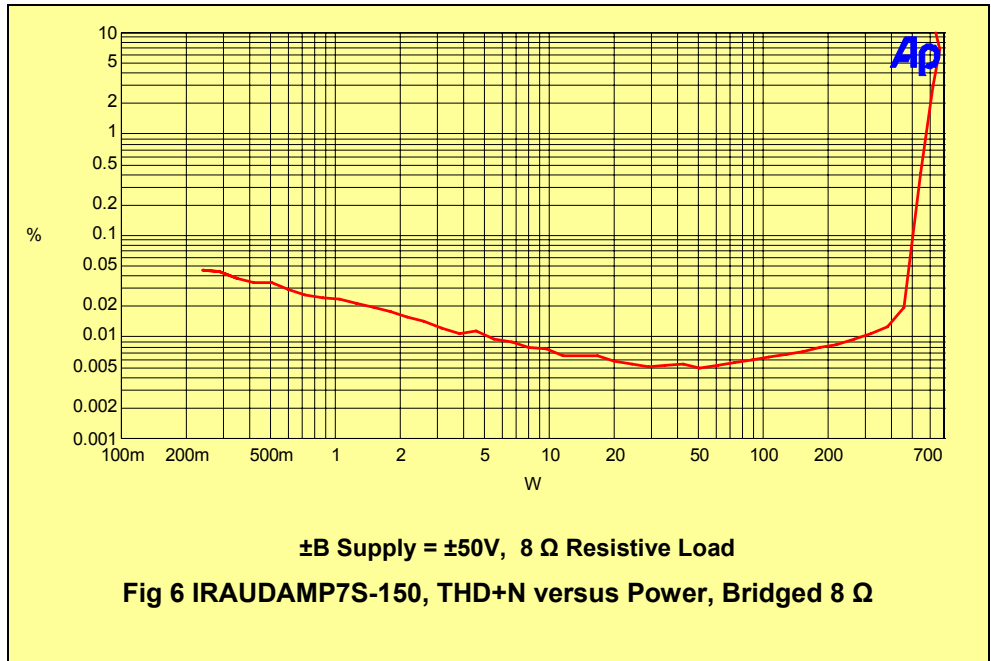
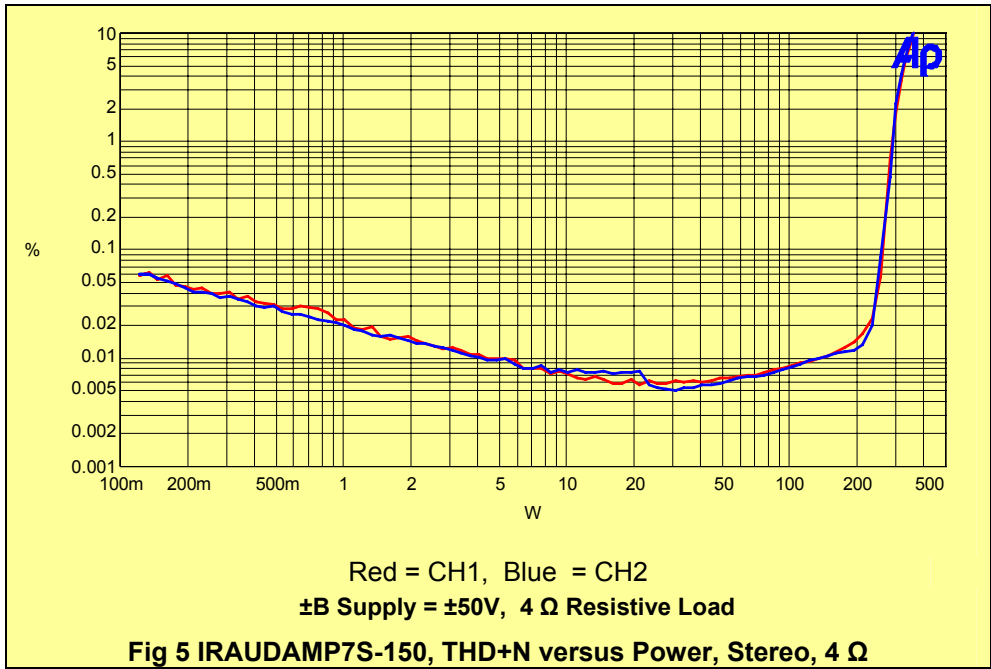
19. Use unbalance-floating signal generator outputs.
20. Use balanced inputs taken across output terminals, SPKR1A and SPKR1B.
21. Connect Ap frame ground to GND in terminal CNN1.
22. Place AES-17 filter for all the testing except frequency response.
23. Use signal voltage sweep range from 15 mV<sub>RMS</sub> to 1 V<sub>RMS</sub>.
24. Run Ap test programs for all subsequent tests as shown in Fig 2- Fig 13 below.

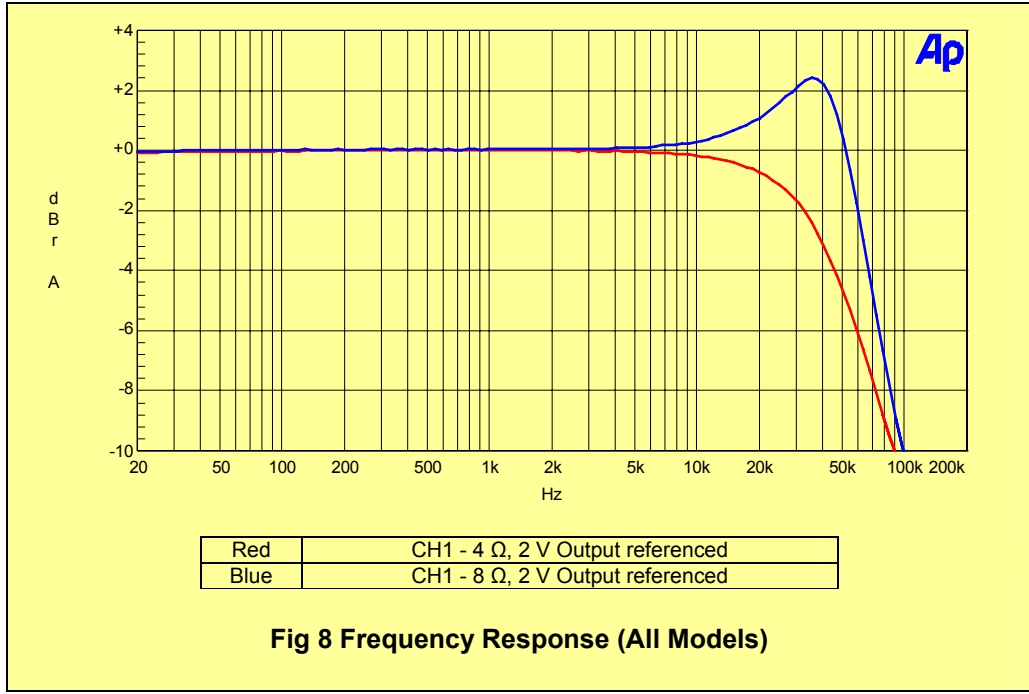
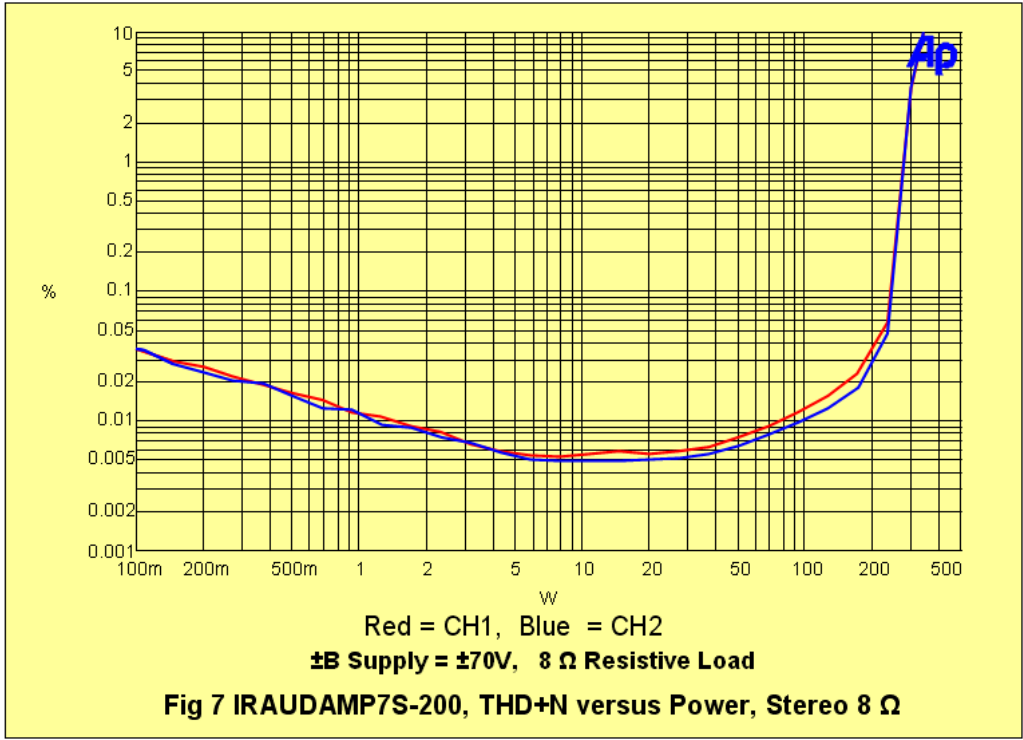
### Test Results

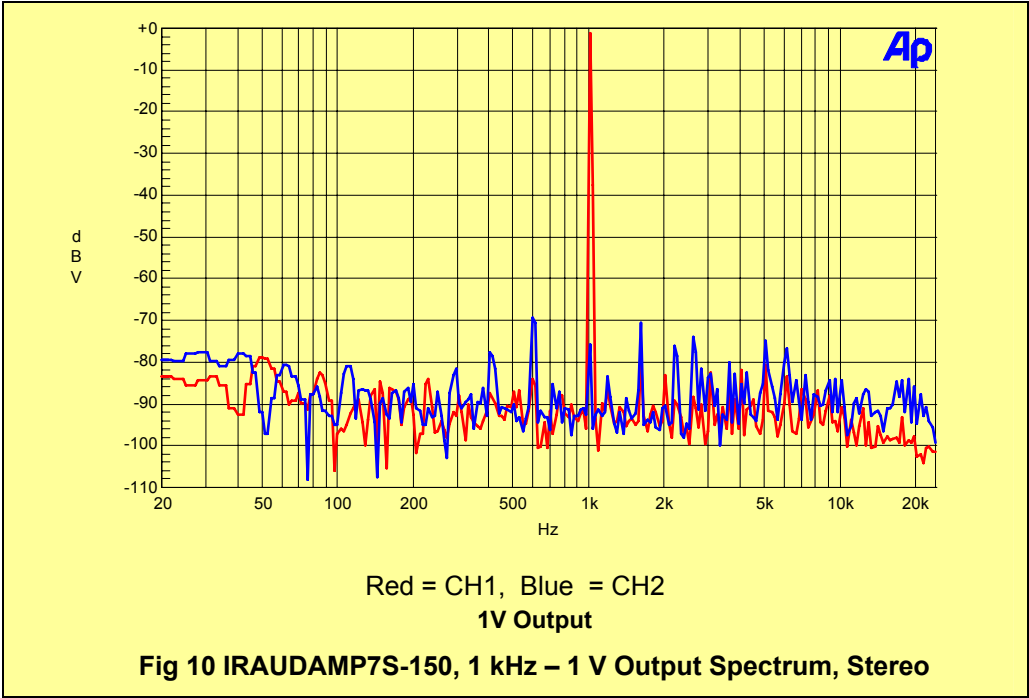
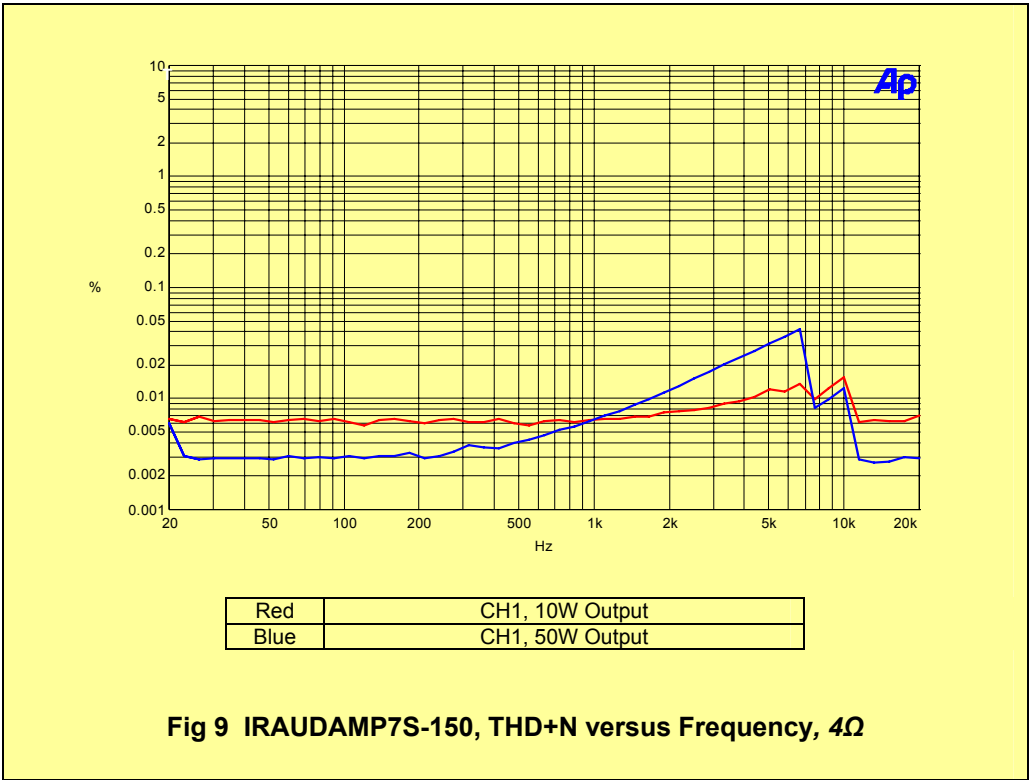


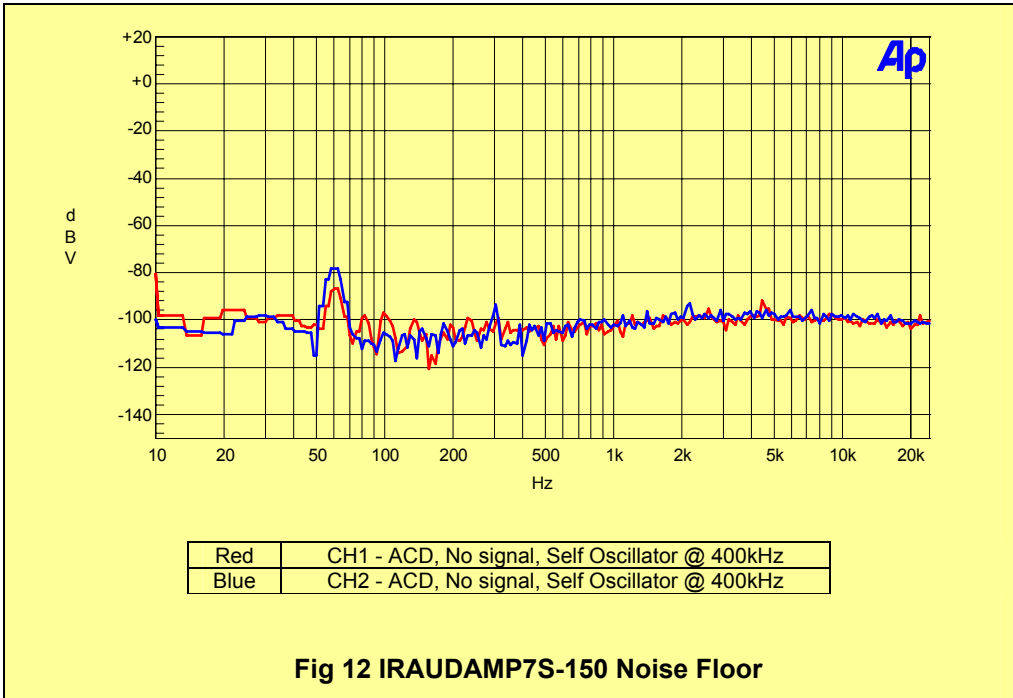
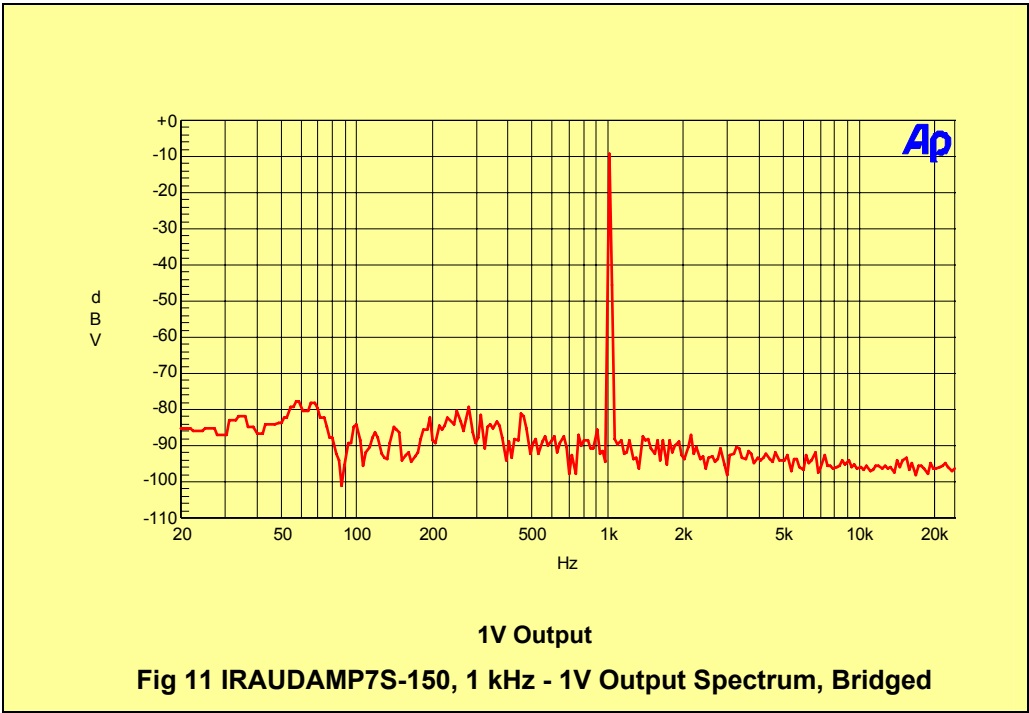




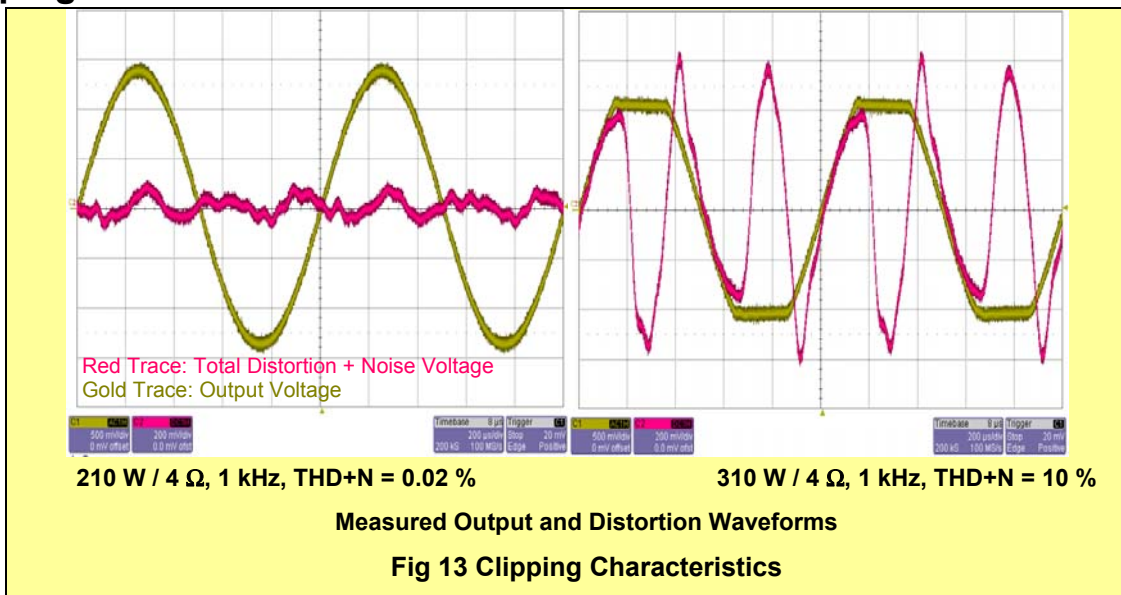








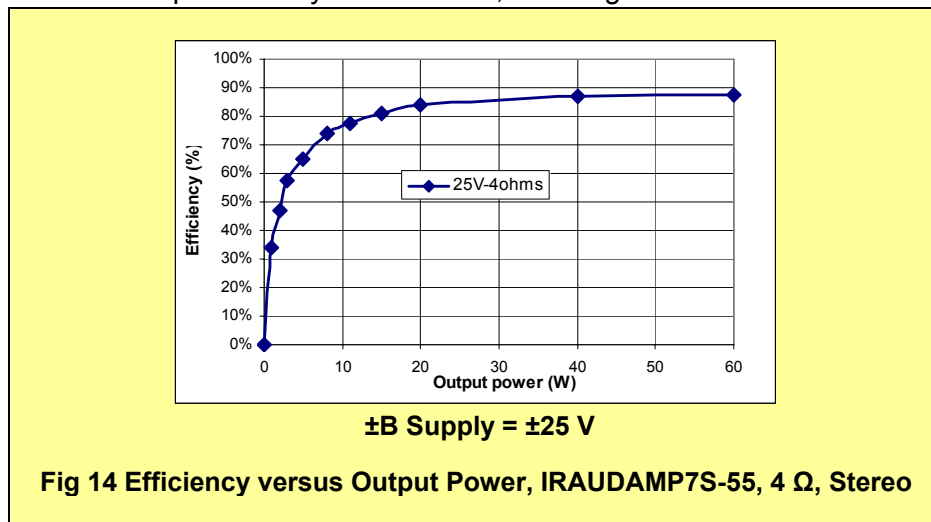
## Clipping characteristics

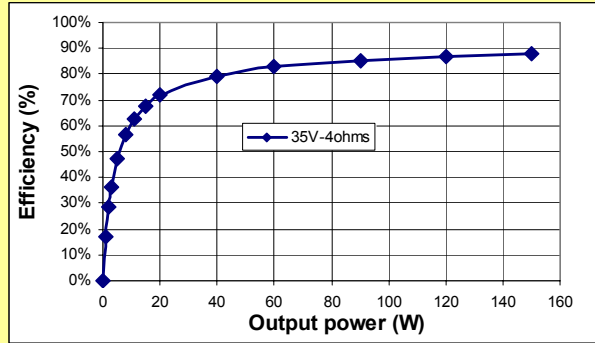


## Efficiency

Figs 14-19 show efficiency characteristics of the IRAUDAMP7S. The high efficiency is achieved by following major factors:

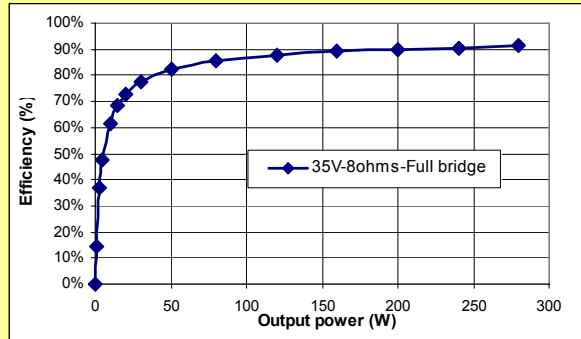
- 1) Low conduction loss due to the dual FETs offering low  $R_{DS(ON)}$
- 2) Low switching loss due to the dual FETs offering low input capacitance for fast rise and fall times
- 3) Secure dead-time provided by the IRS2092, avoiding cross-conduction





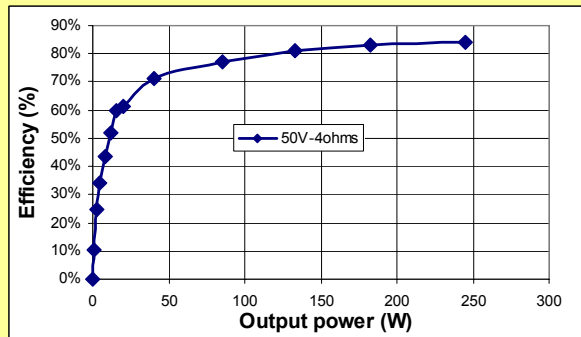
±B Supply = ±35 V

Fig 15 Efficiency versus Output Power, IRAUDAMP7S-100, 4 Ω, Stereo



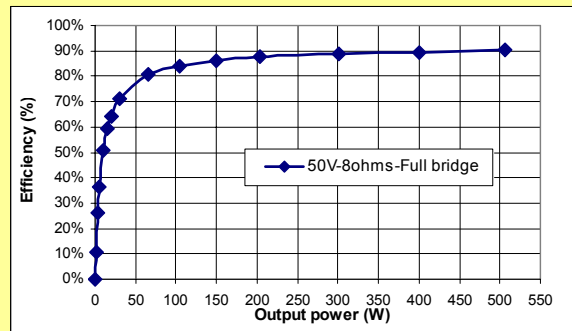
±B Supply = ±35V

Fig 16 Efficiency versus Output Power, IRAUDAMP7S-100, 8 Ω, Bridged



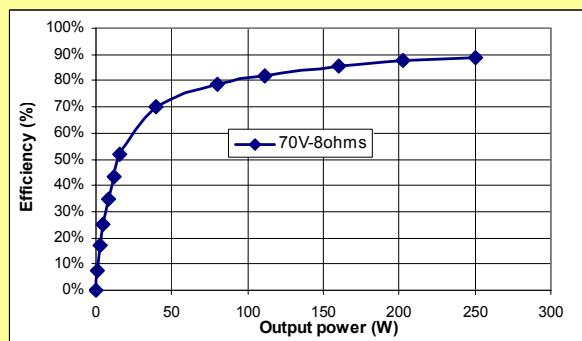
±B Supply = ±50V

Fig 17 Efficiency versus Output Power, IRAUDAMP7S-150, 4 Ω, Stereo



$\pm B$  Supply =  $\pm 50V$

Fig 18 Efficiency versus Output Power, IRAUDAMP7S-150, 8 Ω, Bridged



$\pm B$  supply =  $\pm 70V$

Fig 19 Efficiency versus Output Power, IRAUDAMP7S-200, 8 Ω, Stereo

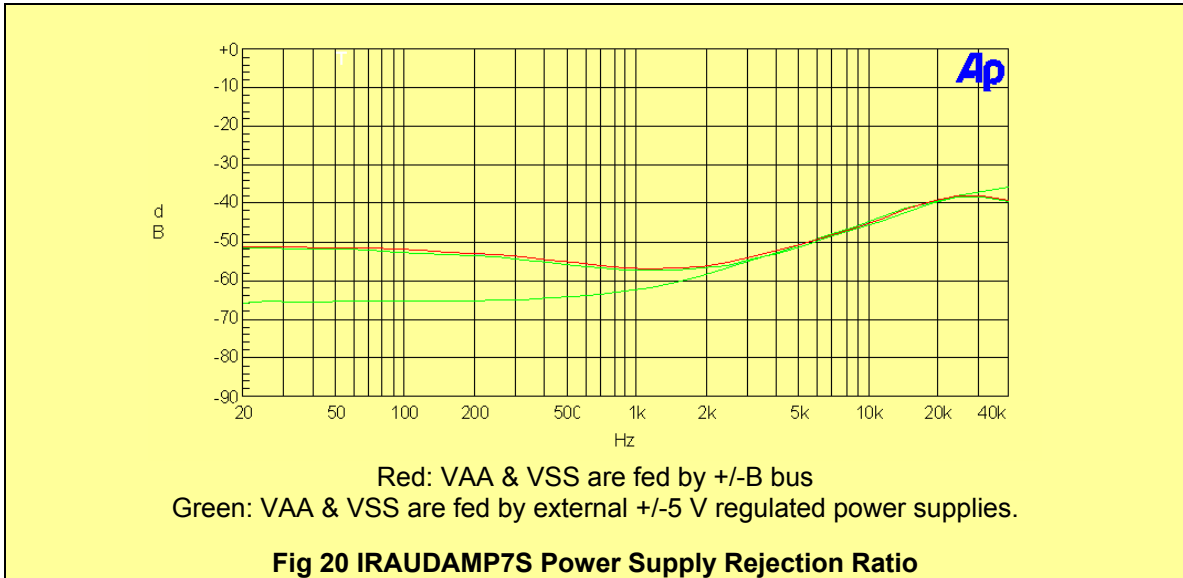
## Thermal Considerations

With this high efficiency, the IRAUDAMP7S 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 heatsink or forced air-cooling.

## Power Supply Rejection Ratio (PSRR)

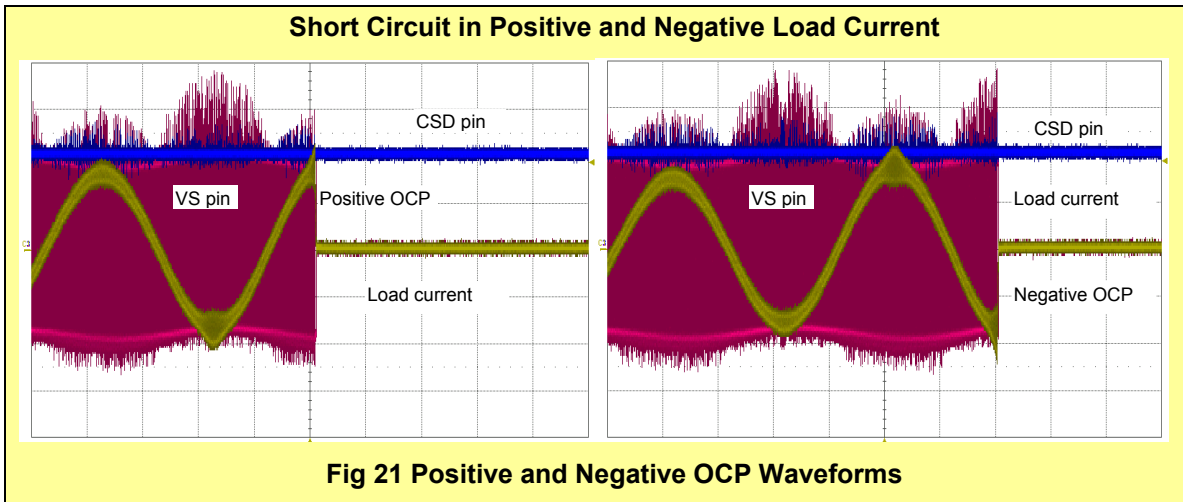
The IRAUDAMP7S obtains good power supply rejection ratio of -65 dB at 1kHz shown in Fig 20. With this high PSRR, IRAUDAMP7S accepts any power supply topology as far as the supply voltages fit in the min and max range.

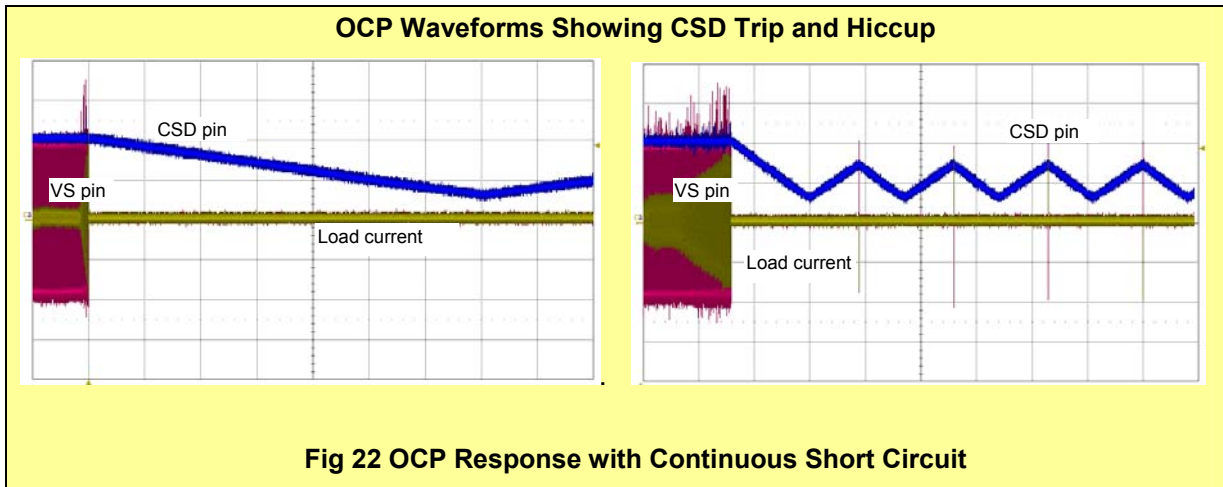




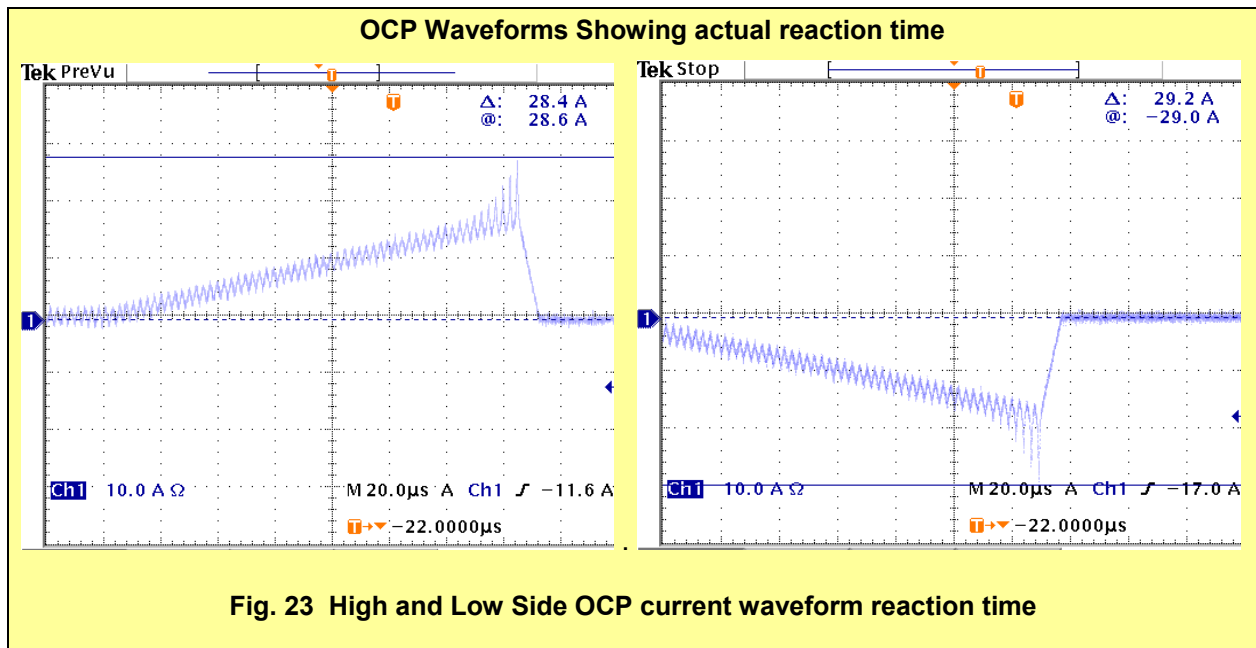
### Short Circuit Protection Response

Figs 21-23 show over current protection reaction time of the IRAUDAMP7S in a short circuit event. As soon as the IRS2092 detects over current condition, it shuts down PWM. After one second, the IRS2092 tries to resume the PWM. If the short circuit persists, the IRS2092 repeats try and fail sequences until the short circuit is removed.





### Actual Reaction Time



### IRAUDAMP7S Overview

The IRAUDAMP7S features a self-oscillating type PWM modulator for the lowest component count, 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 IRAUDAMP7S 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 24 below, the input operational amplifier of the IRS2092 forms a front-end second-order integrator with R7, C4, C6, P1, and R11. The integrator that receives a rectangular feedback signal from the PWM output via R8 and audio input signal via R7 generates quadratic carrier signal in 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 in COMP pin is converted to PWM signal by an internal comparator that has 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.

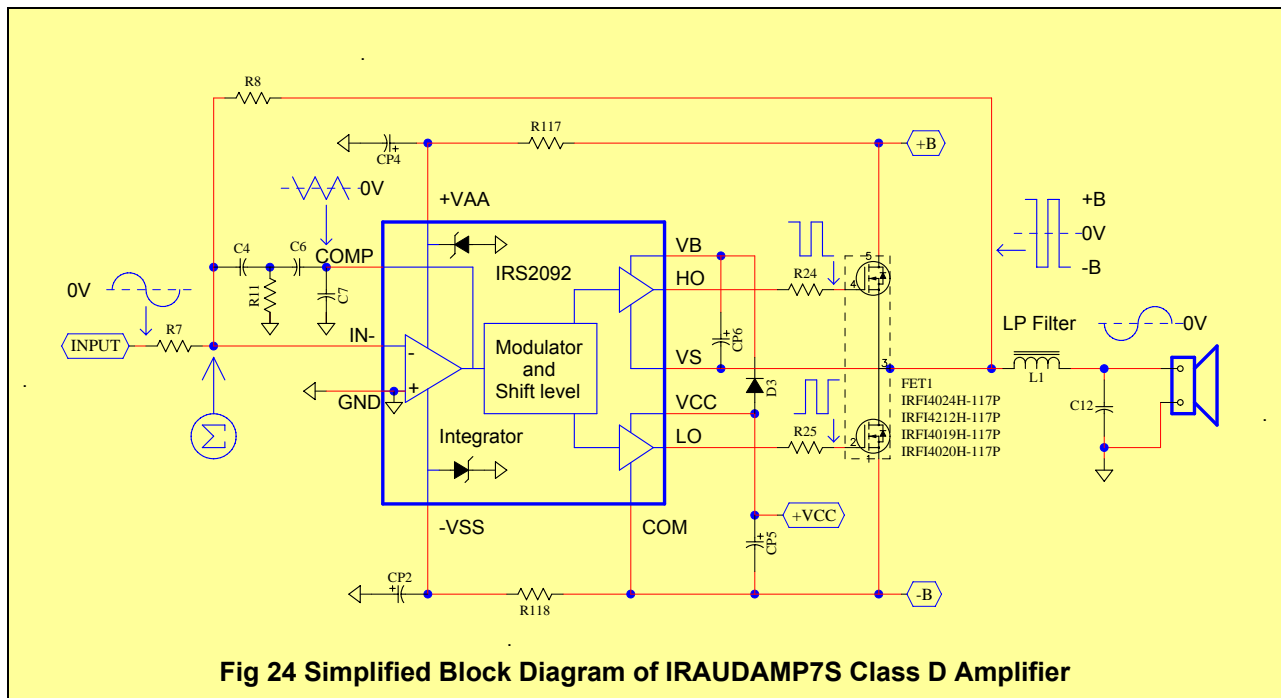
## Gate Drivers and MOSFETs

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 MOSFETs. The high-side level-shifter shifts up the high-side gate drive signal out of the dead-time block.

The IRS2092 drives two MOSFETs, high- and low-sides, in the power stage providing the amplified PWM waveform.

## Output LPF

The amplified PWM output is reconstructed back to analog signal by the output LC LPF. Demodulation LC low-pass filter (LPF) formed by L1 and C12, 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 400 kHz and greater; a design with a lower switching frequency may require an additional stage of LPF.



## Functional Descriptions

### IRS2092 Gate Driver IC

The IRAUDAMP7S uses IRS2092, a 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 IRS2092 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, R26 and R27 as shown on Fig 25 below.

The IRS2092 offers the following functions.

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

Refer to IRS2092 datasheet and AN-1138 for more details.

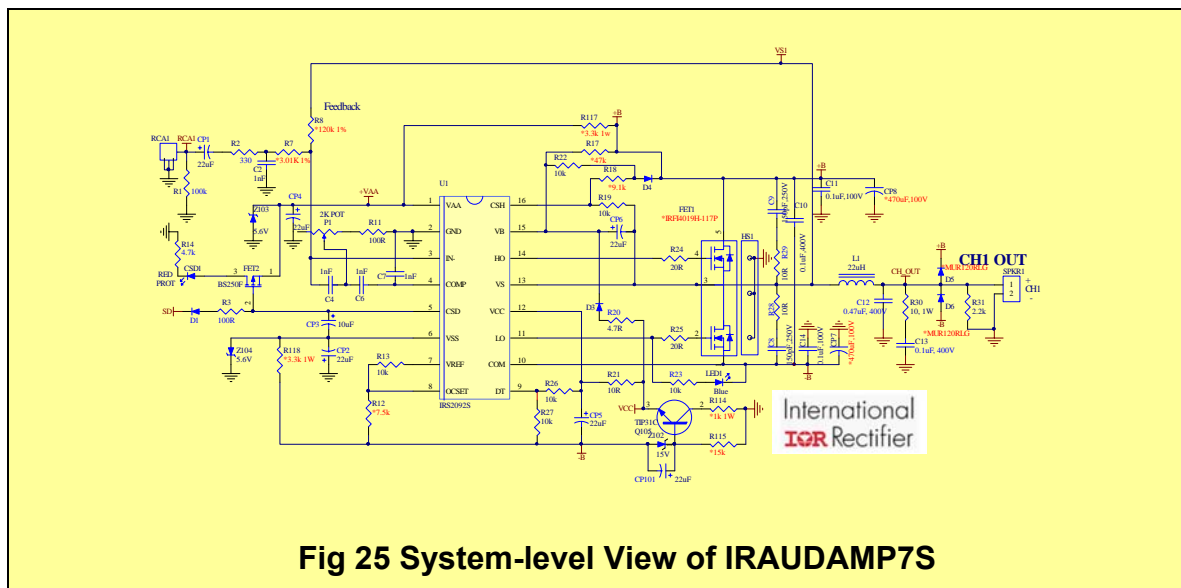


Fig 25 System-level View of IRAUDAMP7S

### 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 IRS2092, the MOSFETs switching speed, the time-constant of front-end integrator (P1, R7, R11 R8, C4, C6, C7). 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%.

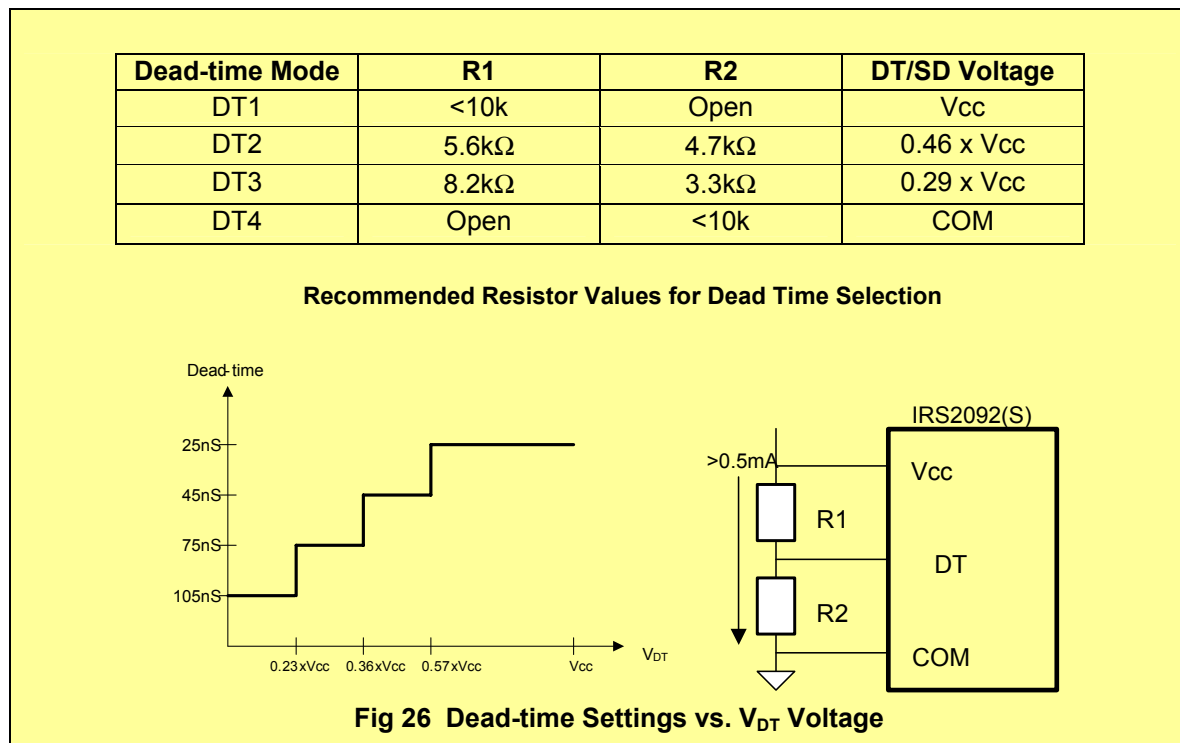
## Adjustments of Self-Oscillating Frequency

Use P1 & R11 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 the 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 400kHz in the IRAUDAMP7S.

## Selectable Dead-time

The dead-time of the IRS2092 is set based on the voltage applied to the DT pin. Fig 26 lists the suggested component value for each programmable dead-time between 25 and 105 ns. All the IRAUDAMP7S models use DT2 (45ns) dead-time.



## Protection System Overview

The IRS2092 integrates over current protection (OCP) inside the IC. The rest of the protections, such as over-voltage protection (OVP), under-voltage protection (UVP), speaker DC offset protection (DCP) and over temperature protection (OTP), are realized externally to the IRS2092 (Fig 27).

In the event that any of these external fault conditions are detected, the external shutdown circuit will disable the output by pulling down CSD pins, turning on red LEDs, and turning off blue LEDs (Fig 28). If the fault condition persists, the protection circuit stays in shutdown until the fault is removed. Once the fault is cleared, the blue LEDs turn on and red LEDs turn off.

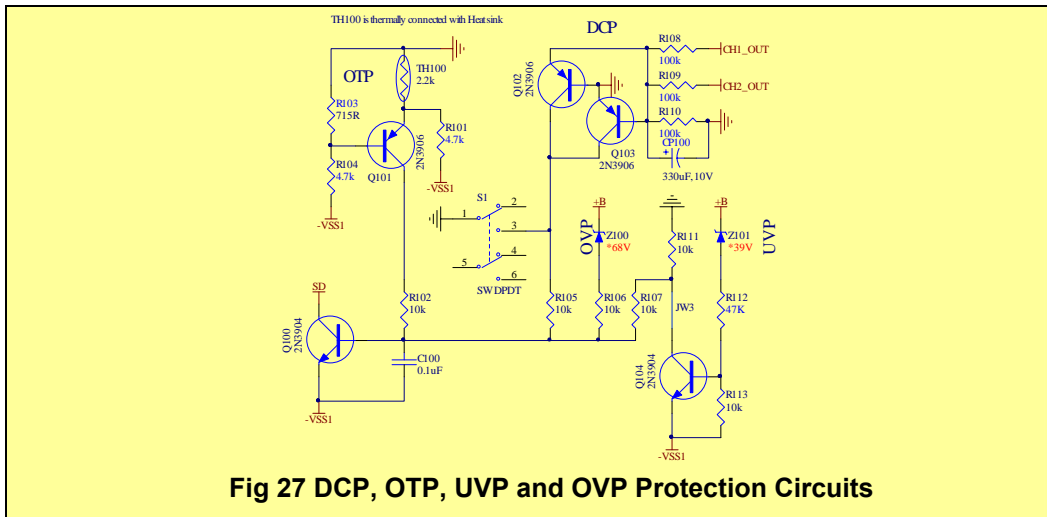


Fig 27 DCP, OTP, UVP and OVP Protection Circuits

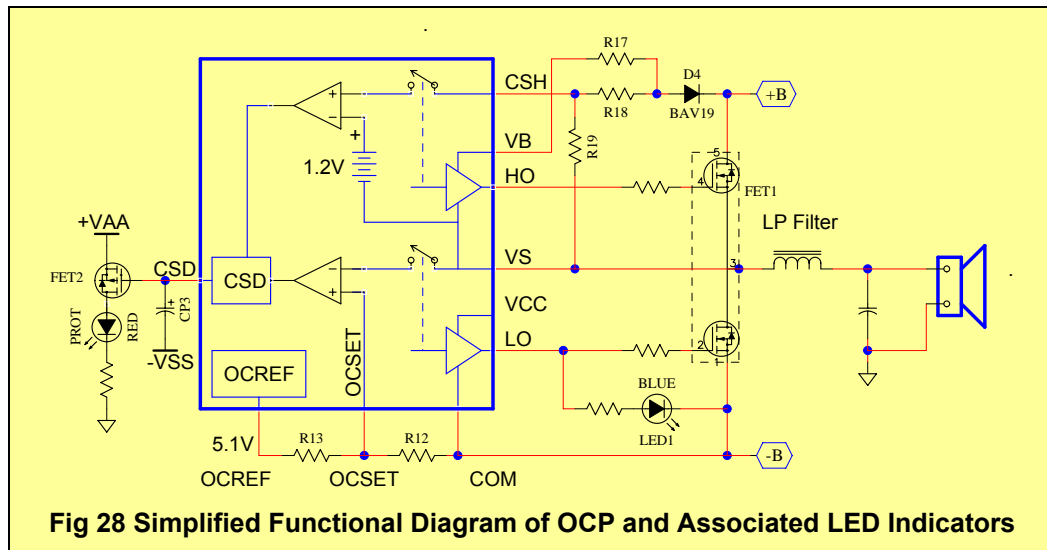


Fig 28 Simplified Functional Diagram of OCP and Associated LED Indicators

## Over-Current Protection (OCP)

### Low-Side Current Sensing

The low-side current sensing feature protects the low side MOSFET from an overload condition in 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 during low-side conduction gets higher than the OCSET voltage, the IRS2092 turns off outputs and pulls CSD down to -VSS.

### High-Side Current Sensing

The high-side current sensing protects the high side MOSFET from an overload condition in 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 MOSFET while it is in 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 MOSFET. In contrast to the low-side current sensing, the threshold of CSH pin to trigger OC protection is internally fixed at 1.2V. An external resistive divider R19, R18 and R17 are used to program a threshold as shown in Fig 26. An external reverse blocking diode D4 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 D4, the minimum threshold which can be set for the high-side is 0.6V across the drain-to-source.

**Table 2 Actual OCP table setting thresholds**

| Function                         | Device       | Amp7-55 | Amp7-100 | Amp7-150 | Amp7-200 |
|----------------------------------|--------------|---------|----------|----------|----------|
| OCSET                            | R12A<br>R12B | 1.3K    | 3.9K     | 7.5K     | 5.1K     |
| Tested OCP current 25°C          |              |         | 23A      | 30A      | 23A      |
| CSH                              | R18A<br>R18B | 0.0     | 4.7K     | 9.1K     | 8.2K     |
| Tested OCP current 25°C          |              |         | 23A      | 29A      | 23A      |
| Peak load current at rated power |              | 6.0A    | 8.7A     | 12.2A    | 8.9A     |

## Over-Voltage Protection (OVP)

OVP is provided externally to the IRS2092. OVP shuts down the amplifier if the bus voltage between GND and +B exceeds 75V. The threshold is determined by a Zener diode Z100. 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 IRS2092. 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 Z101.

### **Speaker DC-Voltage Protection (DCP)**

DCP protects speakers against DC output current feeding to its voice coil. DC offset detection detects abnormal DC offset and shuts down PWM. If this abnormal condition is caused by a MOSFET failure because one of the high-side or low-side MOSFETs short circuited and remained in the on state, the power supply needs to be cut off in order to protect the speakers. Output DC offset greater than  $\pm 4V$  triggers DCP.

### **Offset Null (DC Offset) Adjustment**

The IRAUDAMP7S requires no output-offset adjustment. DC offsets are tested to be less than  $\pm 20$  mV.

### **Over-Temperature Protection (OTP)**

A NTC resistor, TH100 in Fig 25, is placed in close proximity to two dual MOSFETs on a heatsink to monitor heatsink temperature. If the heatsink temperature rises above  $100\text{ }^{\circ}\text{C}$ , the OTP shuts down both channels by pulling down CSD pins of the IRS2092. OTP recovers once the temperature has cooled down.

### **ON-OFF Switch**

OFF position of S1 forces the IRAUDAMP7S to stay in shutdown mode by pulling down the CSD pin. During the shutdown mode the output MOSFETs are kept off.

### **Click and POP Noise Reduction**

Thanks to the click and pop elimination function built into the IRS2092, IRAUDAMP7S does not use any additional components for this function.

## Power Supply Requirements

For convenience, the IRAUDAMP7S has all the necessary housekeeping power supplies onboard and only requires a pair of symmetric power supplies. Power supply voltage depends on the model and is shown in the power selection in Table 1.

### House Keeping Power Supply

The internally-generated housekeeping power supplies include  $\pm 5.6V$  for analog signal processing, and +12V supply ( $V_{CC}$ ) referred to negative supply rail -B for MOSFET gate drive. The VAA and VSS supplying floating input section are fed from +B and -B power stage bus supplies via R117 and R118, respectively. Gate driver section of IRS2092 uses  $V_{CC}$  to drive gates of MOSFETs. The  $V_{CC}$  is referenced to -B (negative power supply). D3 and CP6 form a bootstrap floating supply for the HO gate driver.

### Bus Pumping

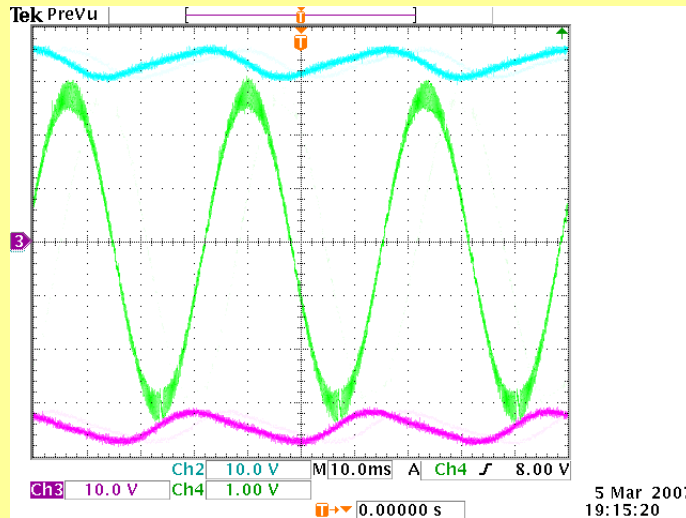
When the IRAUDAMP7S is running in the stereo mode, bus pumping effect takes place with low frequency high output. Since the energy flowing in the Class D switching stage is bi-directional, there is a period where the Class D amplifier feeds energy back to the power supply. The majority of the energy 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 IRAUDAMP7S from failure in case of excessive bus pumping. One of the easiest counter measures of bus pumping is to drive both of the channels in a stereo configuration out-of-phase so that one channel consumes the energy flow from the other and does not return it to the power supply. Bus voltage detection monitors only +B supply, assuming the bus pumping on the supplies is symmetric in +B and -B supplies.

There is no bus pumping effect in full bridge mode.



Cyan: Positive Rail voltage (+B), Green: Speaker Output, Pink: Negative Rail voltage (-B)

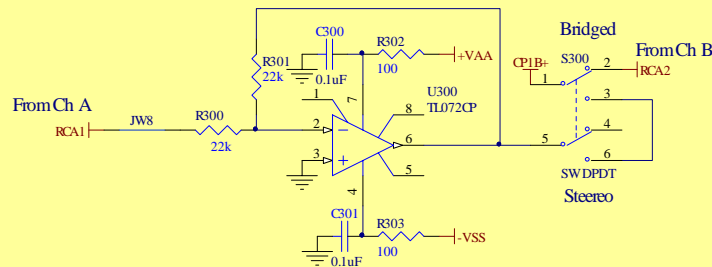
**Fig 29 Bus Pumping in Half Bridge Mode**

### Bridged Configuration

By selecting S300 to Bridged position, the IRAUDAMP7S realizes full bridge mode, also known as bridge-tied-load, or BTL configuration. Full bridge operation is achieved by feeding out-of-phase audio input signals to the two input channels as shown in the Fig 30 below.

In bridged mode, IRAUDAMP7S receives audio input signal from channel A only. The on-board inverter feed out-of-phase signal to Channel B. The speaker output must be connected between (+) of Channel A and (+) of Channel B in bridged mode.

In bridged mode, nominal load impedance is 8 Ω. (See power table in Table 1)



**Fig 30 Bridged Configuration (BTL)**

## Load Impedance

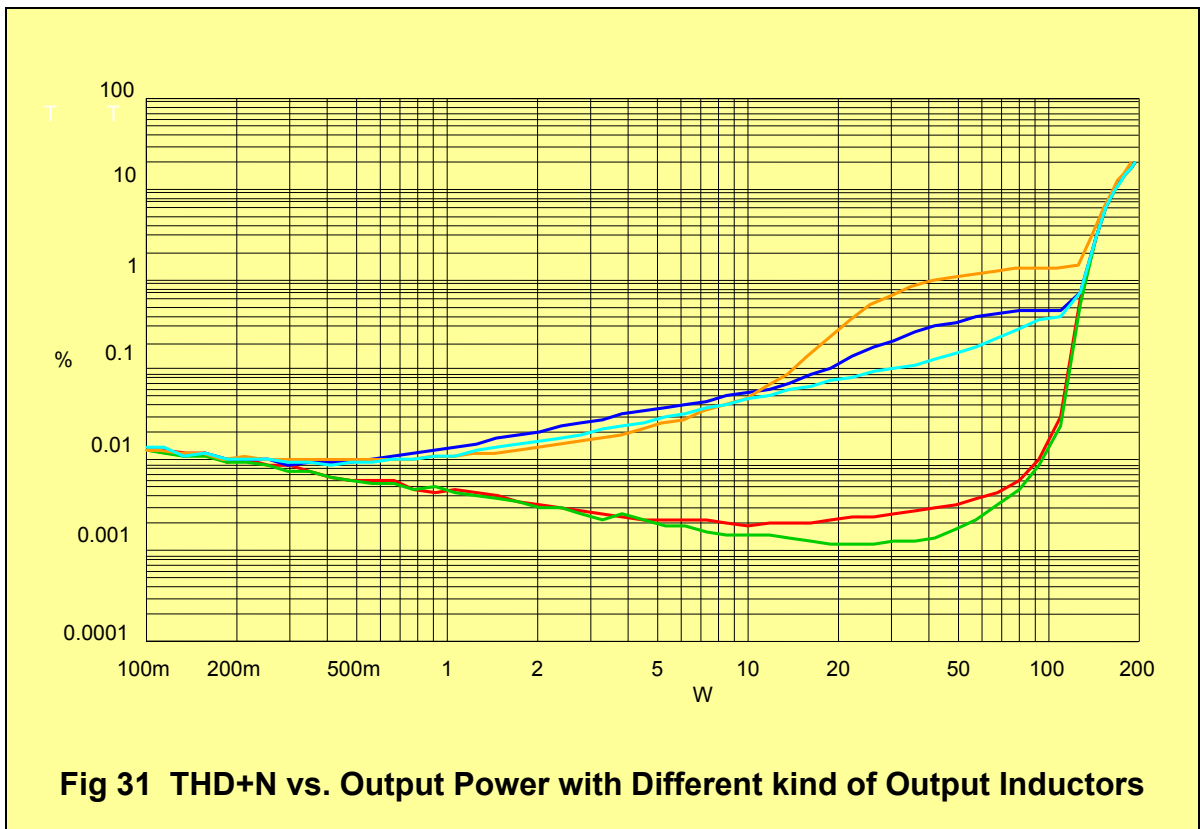
Each channel is optimized for a 4  $\Omega$  speaker load in half bridge and 8  $\Omega$  load in full bridge.

## Output Filter Selection

Since the output filter is not included in the control loop of the IRAUDAMP7S, the control loop has no ability to compensate performance deterioration caused by the output filter. Therefore, it is necessary to understand what characteristics are preferable when designing the output filter.

- 1) The DC resistance of the inductor should be minimized to 20 m $\Omega$  or less.
- 2) The linearity of the output inductor and capacitor should be high with output current and voltage.

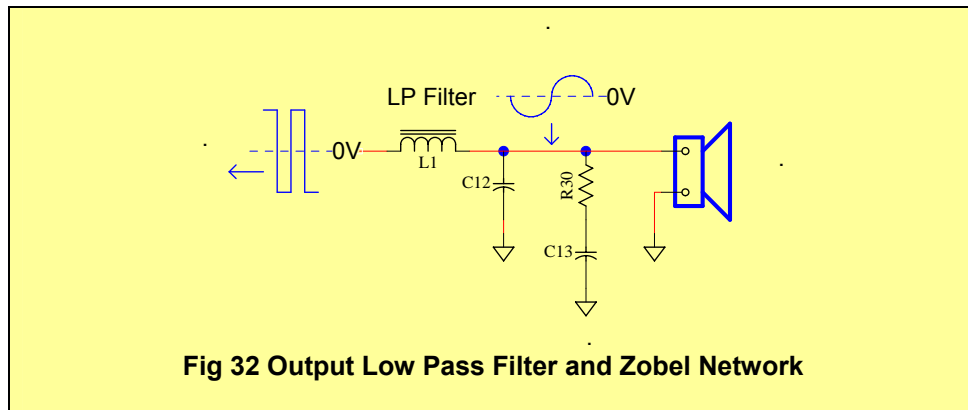
Fig 31 demonstrates THD performance difference with various inductors.



## Input Signal and Gain Setting

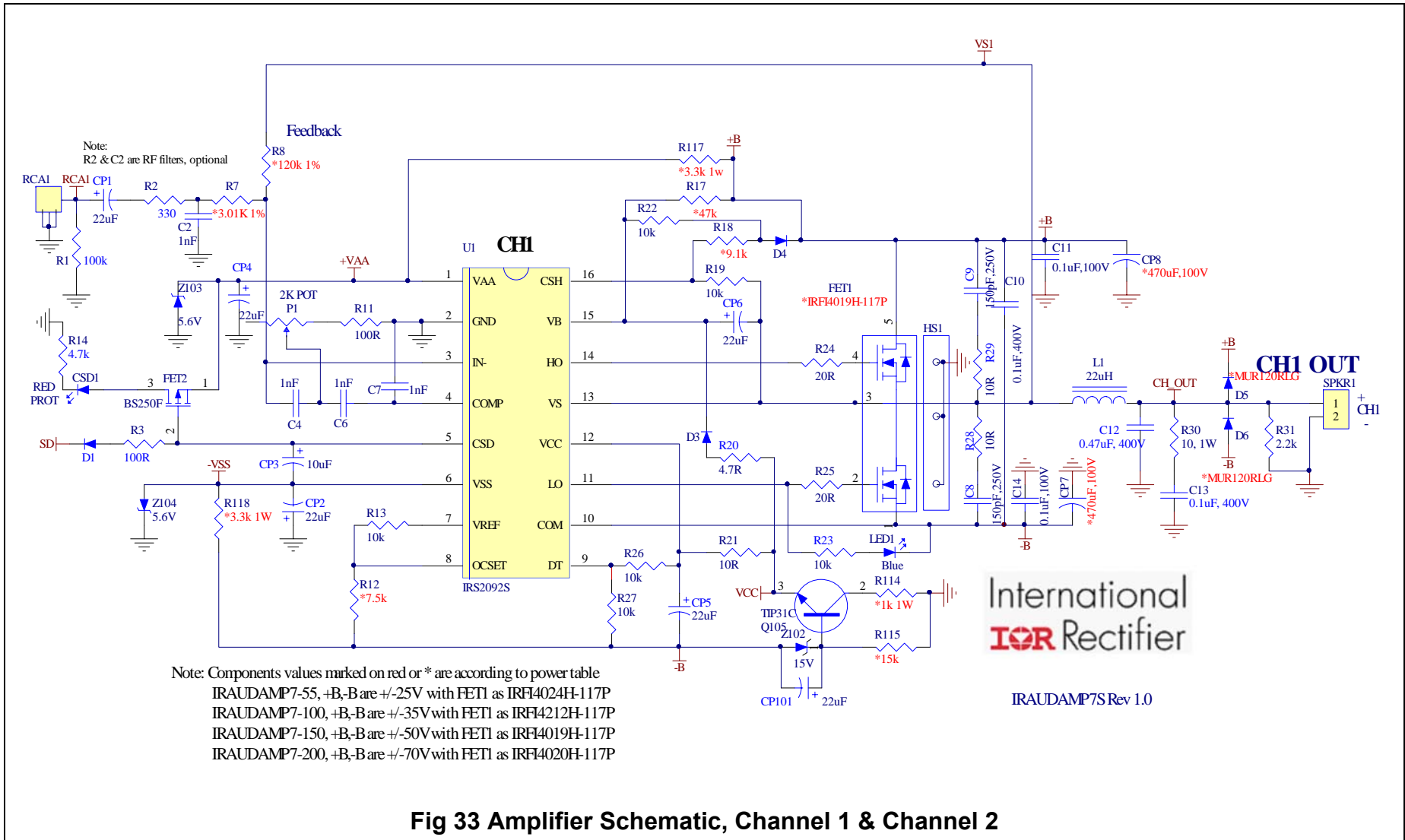
A proper input signal is an analog signal ranging from 20Hz to 20kHz with up to 3 V<sub>RMS</sub> amplitude with a source impedance of no more than 600 Ω. Input signal with frequencies from 30kHz to 60kHz may cause LC resonance in the output LPF, causing a large reactive current flowing through the switching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

The IRAUDAMP7S has an RC network called Zobel network (R30 and C13) to damp the resonance and prevent peaking frequency response with light loading impedance. (Fig 32) The Zobel network is not thermally rated to handle continuous supersonic frequencies above 20kHz. These supersonic input frequencies can be filtered out by adding R2 and C2 as shown on main schematic Fig 33 and Fig 34. This RC filter works also as an input RF filter to prevent potential radio frequency interferences.

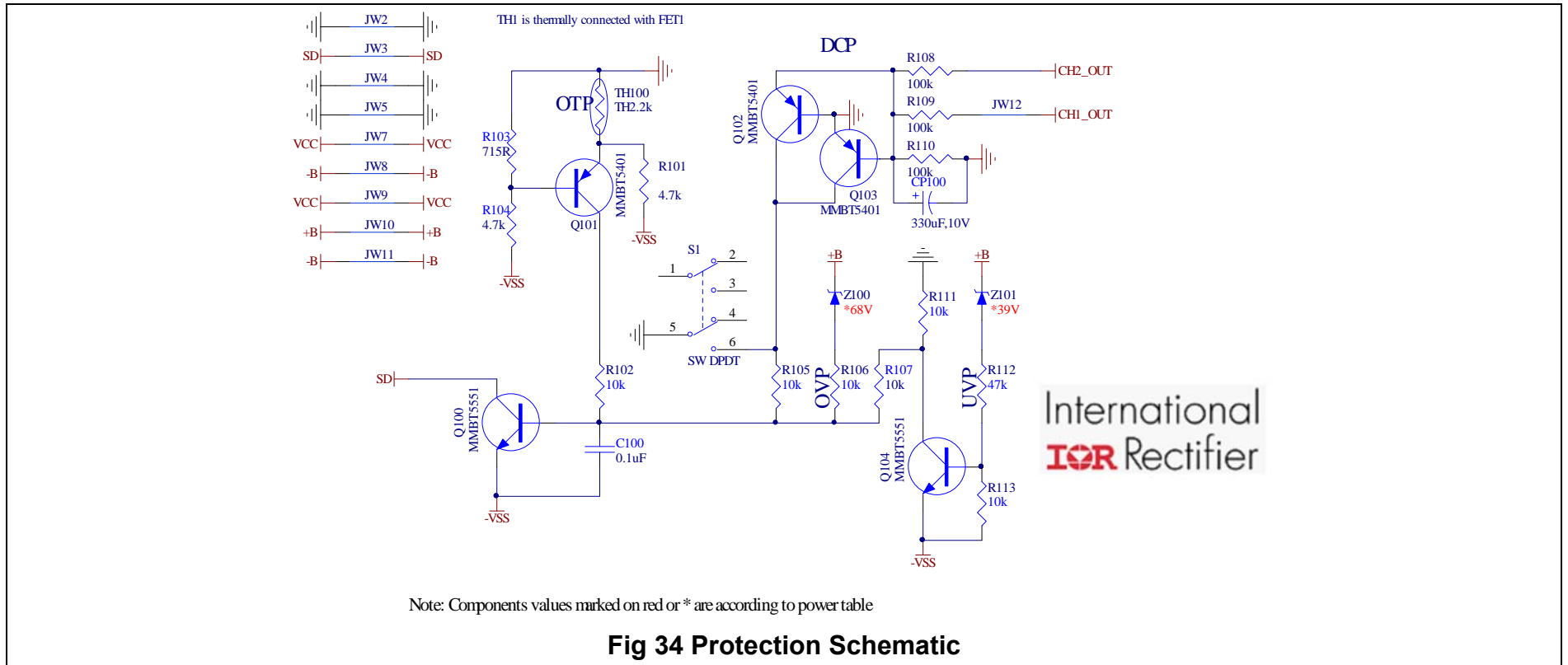


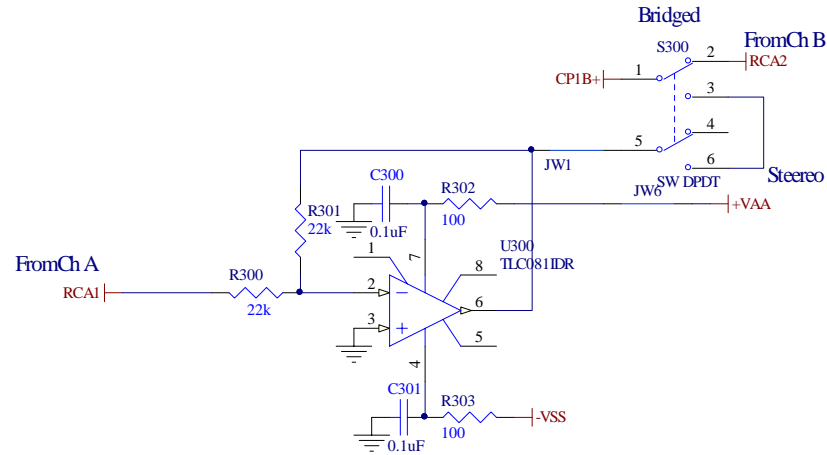
## Gain Setting

The ratio of resistors R8/R2 in Fig 33 sets voltage gain. The IRAUDAMP7S has no on board volume control. To change the voltage gain, change the input resistor term R2. Changing R8 affects PWM control loop design and may result poor audio performance.



**Fig 33 Amplifier Schematic, Channel 1 & Channel 2**





**Fig 35 Bridge Preamp Schematic**



## IRAUDAMP7S-150 Fabrication Materials

Table 3 IRAUDAMP7S-150 Electrical Bill of Materials

| Quantity | Value          | Description                          | Designator                                                                 | Digikey P/N                    | Vendor                                  |
|----------|----------------|--------------------------------------|----------------------------------------------------------------------------|--------------------------------|-----------------------------------------|
| 8        | 1nF,250V       | CAP CER 1000PF 250V C0G 5%           | C2A, C2B, C4A, C4B, C6A, C6B, C7A, C7B                                     | 445-2325-1-ND                  | TDK Corporation                         |
| 4        | 150pF,250V     | CAP CER 150PF 250V U2J               | C8A, C8B, C9A, C9B                                                         | 490-5025-1-ND                  | Murata Electronics                      |
| 4        | 0.1uF,400V     | CAP .10UF 400V METAL POLYPRO         | C10A, C10B, C13A, C13B                                                     | 495-1311-ND                    | EPCOS Inc                               |
| 4        | 0.1uF,100V     | CAP .10UF 100V CERAMIC X7R           | C11A, C11B, C14A, C14B                                                     | PCC2239CT-ND                   | Panasonic - ECG                         |
| 2        | 0.47uF, 400V   | CAP .47UF 400V METAL POLYPRO         | C12A, C12B                                                                 | 495-1315-ND                    | EPCOS Inc                               |
| 3        | 0.1uF, 10V     | CAP CER 0.1UF 10V SL 5%              | C100, C300, C301                                                           | 445-2686-1-ND                  | TDK Corporation                         |
| 1        | ED365/3        | TERMINAL BLOCK 7.50MM 3POS PCB       | CONN1                                                                      | ED2355-ND                      | On Shore Technology Inc                 |
| 12       | 22uF           | CAP 22UF 25V ELECT VR RADIAL         | CP1A, CP1B, CP2A, CP2B, CP4A, CP4B, CP5A, CP5B, CP6A, CP6B, CP101A, CP101B | 493-1058-ND                    | Nichicon                                |
| 2        | 10uF, 16V      | CAP ELECT 10UF 16V KS RADIAL         | CP3A, CP3B                                                                 | P966-ND                        | Panasonic - ECG                         |
| 4        | 470uF,100V     | CAP 470UF 100V ELECT PW RADIAL       | CP7A, CP7B, CP8A, CP8B                                                     | 493-1985-ND                    | Nichicon                                |
| 1        | 330uF, 10V     | CAP 330UF 10V ALUM LYTIC RADIAL      | CP100                                                                      | P5125-ND                       | Panasonic - ECG                         |
| 2        | Red LED        | LED 3MM HI-EFF RED TRANSPARENT       | CSD1A, CSD1B                                                               | 160-1140-ND                    | Lite-On Inc                             |
| 2        | 1N4148WS       | DIODE SWITCH 75V 200MW               | D1A, D1B                                                                   | 1N4148WS-FDICT-ND              | Diodes Inc                              |
| 2        | MURA120T3G     | DIODE ULTRA FAST 1A 200V             | D3A, D3B                                                                   | MURA120T3GOSCT-ND              | ON Semiconductor                        |
| 2        | BAV19WS        | DIODE SWITCH 100V 200MW              | D4A, D4B                                                                   | BAV19WS-FDICT-ND               | Diodes Inc                              |
| 4        | MURA120T3G     | DIODE ULTRA FAST 1A 200V             | D5A, D5B, D6A, D6B                                                         | MURA120T3GOSCT-ND              | ON Semiconductor                        |
| 2        | IRFI4019H-117P | IRFI4019H-117P, Dual MOSFET TO-220-5 | FET1A, FET1B                                                               | IR's Part No.                  | International Rectifier                 |
| 2        | BS250P         | MOSFET P-CH 45V 90MA                 | FET2A, FET2B                                                               | BS250FTC-ND                    | Zetex Inc                               |
| 1        | Heat Sink      | Aluminum heat spreader               | HS1A                                                                       | Drawing IRHS_Amp1              | Custom made                             |
| 1        | JW-300         | Wire Jumper #20 AWG insulated        | JW1                                                                        | Custom                         | Custom                                  |
| 3        | JW-300         | Wire Jumper #20 AWG insulated        | JW2, JW4, JW10                                                             | Custom                         | Custom                                  |
| 1        | JW-1500        | Wire Jumper #20 AWG insulated        | JW3                                                                        | Custom                         | Custom                                  |
| 1        | JW-1500        | Wire Jumper #20 AWG insulated        | JW5                                                                        | Custom                         | Custom                                  |
| 2        | JW-1800        | Wire Jumper #20 AWG insulated        | JW6, JW7                                                                   | Custom                         | Custom                                  |
| 2        | JW-2000        | Wire Jumper #20 AWG insulated        | JW8, JW9                                                                   | Custom                         | Custom                                  |
| 2        | 22uH, 13A      | Class D Inductor, 22UH               | L1A, L1B                                                                   | Sagami 7G17A-220M-R or IN09063 | Inductors, Inc. or ICE Components, Inc. |
| 2        | Blue LED       | LED 3MM DUAL FLANGE BLUE CLEAR       | LED1A, LED1B                                                               | 160-1600-ND                    | LITE-ON INC                             |
| 2        | 2K POT         | POTENTIOMETER                        | P1A, P1B                                                                   | 3362H-202LF-ND                 | Bourns Inc.                             |
| 2        | MMBT5551       | TRANSISTOR NPN 160V                  | Q100, Q104                                                                 | MMBT5551FSCT-ND                | Fairchild Semiconductor                 |

|    |             |                                              |                                                                                                            |                           |                         |
|----|-------------|----------------------------------------------|------------------------------------------------------------------------------------------------------------|---------------------------|-------------------------|
| 3  | MMBT5401    | TRANS PNP 150V 350MW SMD                     | Q101, Q102, Q103                                                                                           | MMBT5401-FDICT-ND         | Diodes Inc              |
| 2  | TIP31C      | TRANSISTOR NPN 100V 3A                       | Q105A, Q105B                                                                                               | 497-2615-5-ND             | STMicroelectronics      |
| 3  | 100k        | RES 100K OHM 1/8W 5%                         | R1A, R1B, R110                                                                                             | RHM100KARCT-ND            | Rohm                    |
| 1  | 330         | RES 330 OHM 1/8W 1%                          | R2A                                                                                                        | RHM330CRCT-ND             | Rohm                    |
| 1  | 330         | RES 330 OHM CARBON FILM                      | R2B                                                                                                        | P330BACT-ND               | Panasonic - ECG         |
| 2  | 100R        | RES 100 OHM 1/8W 5%                          | R3A, R3B                                                                                                   | P100ACT-ND                | Panasonic - ECG         |
| 2  | 3.01K       | RES 3.01K OHM 1/8W 1%                        | R7A, R7B                                                                                                   | RHM3.01KCCT-ND            | Rohm                    |
| 2  | 120k 1%     | RES METAL FILM 120K OHM 1/4W                 | R8A, R8B                                                                                                   | P120KCACT-ND              | Panasonic - ECG         |
| 2  | 100R        | RES 100 OHM 1/8W 5%                          | R11A, R11B                                                                                                 | RHM100ARCT-ND             | Rohm                    |
| 2  | 7.5k        | RES 7.5K OHM 1/8W 5%                         | R12A, R12B                                                                                                 | RHM7.5KARCT-ND            | Rohm                    |
| 18 | 10k         | RES 10K OHM 1/8W 5%                          | R13A, R13B, R19A, R19B, R22A, R22B, R23A, R23B, R26A, R26B, R27A, R27B, R102, R105, R106, R107, R111, R113 | RHM10KARCT-ND             | Rohm                    |
| 4  | 4.7k        | RES 4.7K OHM 1/8W 5%                         | R14A, R14B, R101, R104                                                                                     | RHM4.7KARCT-ND            | Rohm                    |
| 2  | 47k         | RES 47K OHM 1/8W 5%                          | R17A, R17B                                                                                                 | RHM47KARCT-ND             | Rohm                    |
| 2  | 9.1k        | RES 9.1K OHM 1/8W 5%                         | R18A, R18B                                                                                                 | RHM9.1KARCT-ND            | Rohm                    |
| 2  | 4.7R        | RES 4.7 OHM 1/4W 1%                          | R20A, R20B                                                                                                 | P4.7RCT-ND                | Panasonic - ECG         |
| 2  | 10R         | RES 10.0 OHM 1/4W 1%                         | R21A, R21B                                                                                                 | RHM10.0FRCT-ND            | Rohm                    |
| 4  | 20R         | RES 20.0 OHM 1/8W 1%                         | R24A, R24B, R25A, R25B                                                                                     | RHM20.0CRCT-ND            | Rohm                    |
| 4  | 10R         | RES 10.0 OHM 1/8W 1%                         | R28A, R28B, R29A, R29B                                                                                     | RHM10.0CRCT-ND            | Rohm                    |
| 2  | 10, 1W      | RES 10 OHM 1W 5%                             | R30A, R30B                                                                                                 | PT10XCT-ND                | Panasonic - ECG         |
| 2  | 2.2k        | RES 2.2K OHM 1/4W 5%                         | R31A, R31B                                                                                                 | RHM2.2KERCT-ND            | Rohm                    |
| 1  | 715R        | RES 715 OHM 1/8W 1%                          | R103                                                                                                       | RHM715CCT-ND              | Rohm                    |
| 1  | 100k        | RES 100K OHM 1/8W 5%                         | R108                                                                                                       | RHM100KARCT-ND            | Rohm                    |
| 1  | 100k        | RES 100K OHM CARBON FILM 1/4W 5%             | R109                                                                                                       | P100KBATB-ND              | Panasonic - ECG         |
| 1  | 47k         | RES 47K OHM 1/8W 5%                          | R112                                                                                                       | RHM47KARCT-ND             | Rohm                    |
| 2  | 1k 1W       | RES 1.0K OHM 1W 5% METAL OXIDE               | R114A, R114B                                                                                               | 1.0KW-1-ND                | Yageo                   |
| 2  | 15k         | RES 15K OHM CARBON FILM 1/4W 5%              | R115A, R115B                                                                                               | P15KBACT-ND               | Panasonic - ECG         |
| 4  | 3.3k 1w     | RES 3.3K OHM 1W 5% METAL OXIDE               | R117A, R117B, R118A, R118B                                                                                 | 3.3KW-1-ND                | Yageo                   |
| 2  | 22k         | RES 22K OHM 1/8W 5%                          | R300, R301                                                                                                 | RHM22KARCT-ND             | Rohm                    |
| 2  | 100         | RES 100 OHM 1/8W 5%                          | R302, R303                                                                                                 | RHM100ARCT-ND             | Rohm                    |
| 2  | RCJ-012     | CONN RCA JACK METAL R/A RED PCB              | RCA1A                                                                                                      | CP-1401-ND (Red)          | CUI Inc                 |
| 2  | RCJ-013     | CONN RCA JACK METAL R/A WHT PCB              | RCA1B                                                                                                      | CP-1402-ND (White)        | CUI Inc                 |
| 2  | EG2209A     | SWITCH SLIDE DPDT 12V .1A L=4                | S1, S300                                                                                                   | EG1908-ND                 | E-Switch                |
| 2  | ED365/2     | TERMINAL BLOCK 7.50MM 2POS PCB               | SPKR1A, SPKR1B                                                                                             | ED2354-ND                 | On Shore Technology     |
| 1  | 2.2k at 25C | THERMISTOR NTC 2.2K OHM LEADED               | TH100                                                                                                      | BC2304-ND                 | Vishay/BC Components    |
| 2  | IRS2092SPBF | Class D Controller, IRS2092SPbF 16-Lead SOIC | U1A, U1B                                                                                                   | IR's P/N                  | International Rectifier |
| 1  | TLC071CD    | IC SINGLE SUPPLY OPAMP 8-SOIC                | U300                                                                                                       | 296-2414-5-ND IRS2092SPBF | Texas Instruments       |
| 2  | 15V         | DIODE ZENER 500MW 15V                        | Z102A, Z102B                                                                                               | MMSZ4702T1GOSCT-ND        | ON Semiconductor        |

|                                                            |      |                        |                            |                     |                     |
|------------------------------------------------------------|------|------------------------|----------------------------|---------------------|---------------------|
| 1                                                          | 68V  | DIODE ZENER 375MW 68V  | Z100                       | 568-3782-1-ND       | NXP Semiconductors  |
| 1                                                          | 39V  | DIODE ZENER 500MW 39V  | Z101                       | BZT52C39-TPMSCT-ND  | Micro Commercial Co |
| 4                                                          | 5.6V | DIODE ZENER 500MW 5.6V | Z103A, Z103B, Z104A, Z104B | BZT52C5V6-TPMSCT-ND | Micro Commercial Co |
| Note all ½ W and 1W resistors are flame proof part numbers |      |                        |                            |                     |                     |

**Table 4 IRAUDAMP7S Mechanical Bill of Materials**

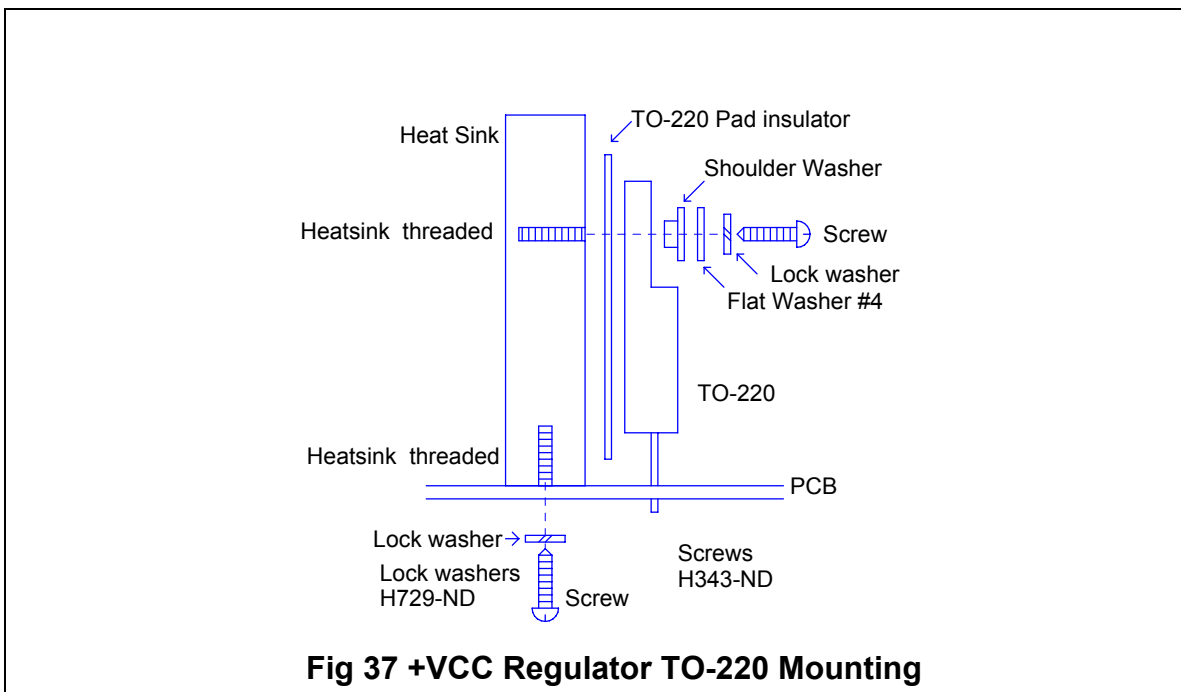
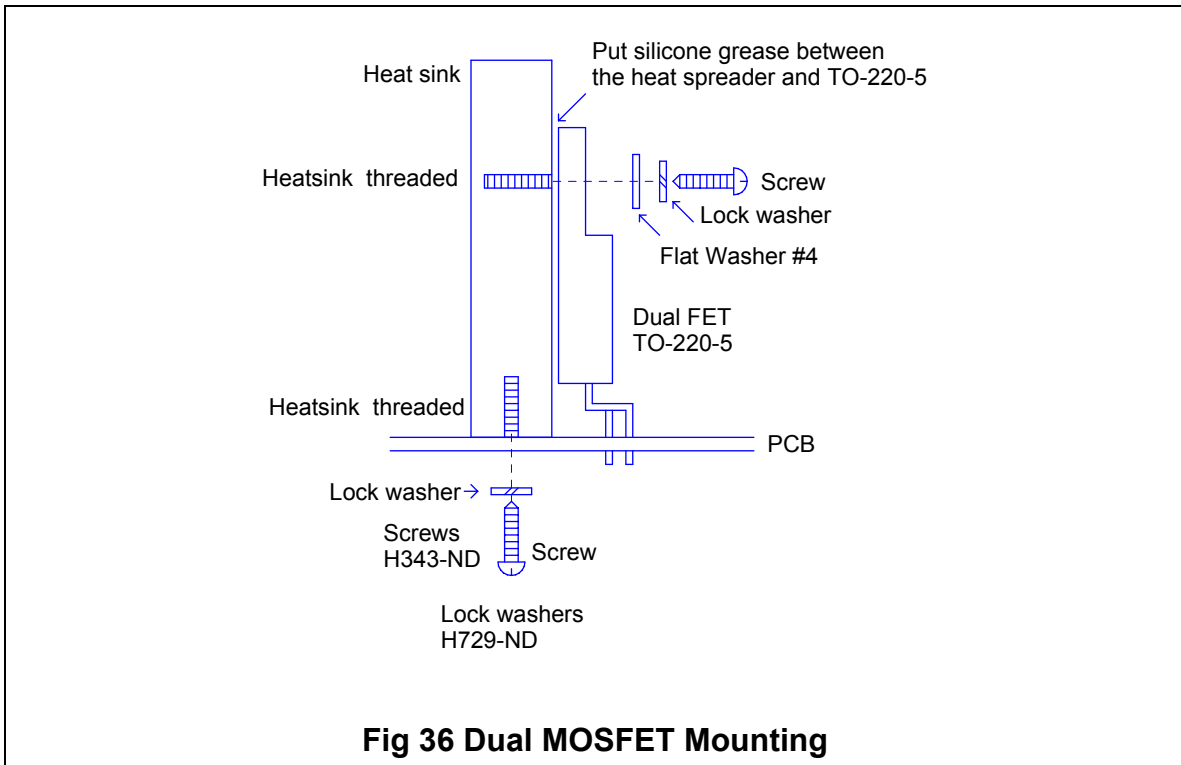
| Quantity | Value           | Description                                   | Designator                                                                                                    | Digikey P/N     | Vendor               |
|----------|-----------------|-----------------------------------------------|---------------------------------------------------------------------------------------------------------------|-----------------|----------------------|
| 5        | Washer #4 SS    | WASHER LOCK INTERNAL #4 SS                    | Lock washer 1, Lock washer 2, Lock washer 3, Lock washer 4, Lock washer 5                                     | H729-ND         | Building Fasteners   |
| 1        | PCB             | Print Circuit Board IRAUDAMP7S_Rev 2.2 .PCB   | PCB 1                                                                                                         |                 | Custom               |
| 12       | Screw 4-40X5/16 | SCREW MACHINE PHILLIPS 4-40X5/16              | Screw 1, Screw 2, Screw 3, Screw 4, Screw 5, Screw 6, Screw 7, Screw 8, Screw 9, Screw 10, Screw 11, Screw 12 | 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 Electronics |
| 1        | Stand off 0.5"  | STANDOFF HEX M/F 4-40 .500" ALUM, Chassis GND | Stand Off 5                                                                                                   | 8401K-ND        | Keystone Electronics |
| 1        | AAVID 4880G     | Thermalloy TO-220 mounting kit with screw     | TO-220 mounting kit 1                                                                                         | Newuark 82K6096 | Thermalloy           |

**Table 5 IRAUDAMP7S Models Differential Table**

| Item               |                          | Model Name                      |                                 |                            |                                 | Notes             |
|--------------------|--------------------------|---------------------------------|---------------------------------|----------------------------|---------------------------------|-------------------|
|                    |                          | AMP7S-55                        | AMP7S-100                       | AMP7S-150                  | AMP7S-200                       |                   |
| IR Power MOSFETS   | FET1                     | IRFI4024H-117P                  | IRFI4212H-117P                  | IRFI4019H-117P             | IRFI4020H-117P                  |                   |
| Half Bridge Output | 8 Ω                      | 25 W x 2                        | 60 W x 2                        | 125 W x 2                  | 250 W x 2                       | Stereo            |
|                    | 4 Ω                      | 50 W x 2                        | 120 W x 2                       | 250 W x 2                  | N/A                             | Stereo            |
| Full Bridge Output | 8 Ω                      | 100 W x 1                       | 240 W x 1                       | 500 W x 1                  | N/A                             | Bridged           |
| Power Supply       | +B, -B                   | ±25 V                           | ±35 V                           | ±50 V                      | ±70 V                           |                   |
|                    | ±B Voltage Range         | ±3 V                            | ±5 V                            | ±8 V                       | ±10 V                           |                   |
| Audio Gain         | Gain                     | 20                              | 30                              | 36                         | 40                              |                   |
| Feedback           | R8A,R8B                  | 68k                             | 100k                            | 120k                       | 130 k                           |                   |
| +VAA               | R117A*<br>R117B*         | 1 k, 1 W                        | 2.2 k, 1 W                      | 3.3 k, 1 W                 | 5.1 k, 1 W                      |                   |
| -VSS               | R118A*<br>R118B*         | 1 k, 1 W                        | 2.2 k, 1 W                      | 3.3 k, 1 W                 | 5.1 k, 1 W                      |                   |
| VCC                | R114A*<br>R114B*         | 100,1 W                         | 220, 1 W                        | 1 k, 1 W                   | 2.2 k 1 W                       |                   |
|                    | R115A<br>R115B           | 4.7 k                           | 10 k                            | 15 k                       | 20 k                            |                   |
| OCSET              | R12A<br>R12B             | 1.3 k<br>(20 A)                 | 3.9 k<br>(23 A)                 | 7.5 k<br>(30 A)            | 5.1 k<br>(23 A)                 | (Trip level)      |
| CSH                | R18A<br>R18B             | 0.0<br>(20A)                    | 4.7 k<br>(23A)                  | 9.1 k<br>(29A)             | 8.2 k<br>(23 A)                 | (Trip level)      |
| VB                 | R17A<br>R17B             | 20 k                            | 33 k                            | 47 k                       | 75 k                            |                   |
| OVP                | Z100                     | 24 V<br>BZT52C24-TPMSCT-ND      | 47 V<br>MMSZ5261BT1GO<br>SCT-ND | 68 V<br>568-3782-1-ND      | 91 V<br>MMSZ5270BT1G<br>OSCT-ND | Zener Digikey P/N |
| UVP                | Z101                     | 12 V<br>MMSZ5242BT1GO<br>SCT-ND | 30 V<br>MMSZ5256BT1GO<br>SCT-ND | 39 V<br>BZT52C39-TPMSCT-ND | 51 V<br>MMSZ5262BT1G<br>OSCT-ND | Zener Digikey P/N |
| Clamping Diode     | D5A<br>D5B<br>D6A<br>D6B | MURA120T3OSCT-ND                | MURA120T3OSCT-ND                | IMURA120T3OSCT-ND          | N/A                             |                   |

**\* Marked components are axial, ±5 %, ¼ w, and flame proof type.**

**IRAUDAMP7S Hardware**



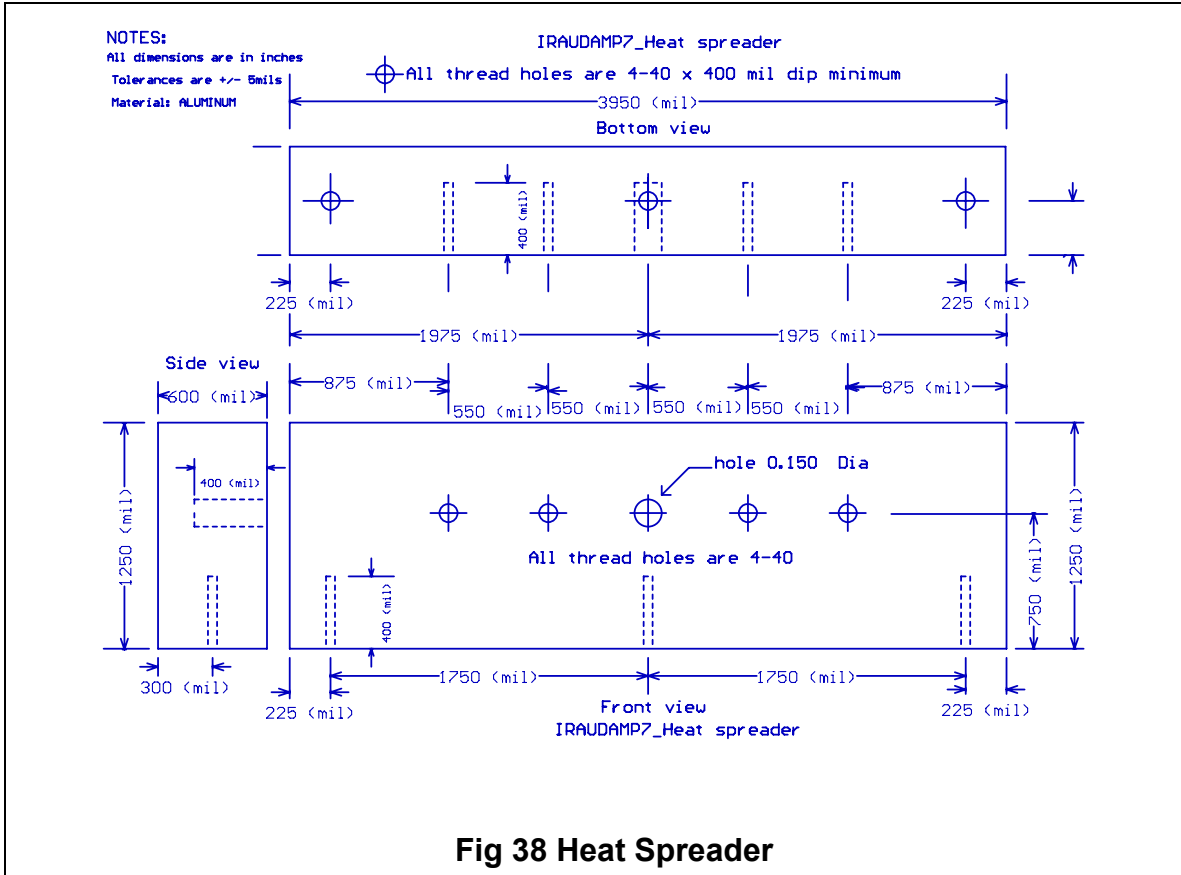


Fig 38 Heat Spreader

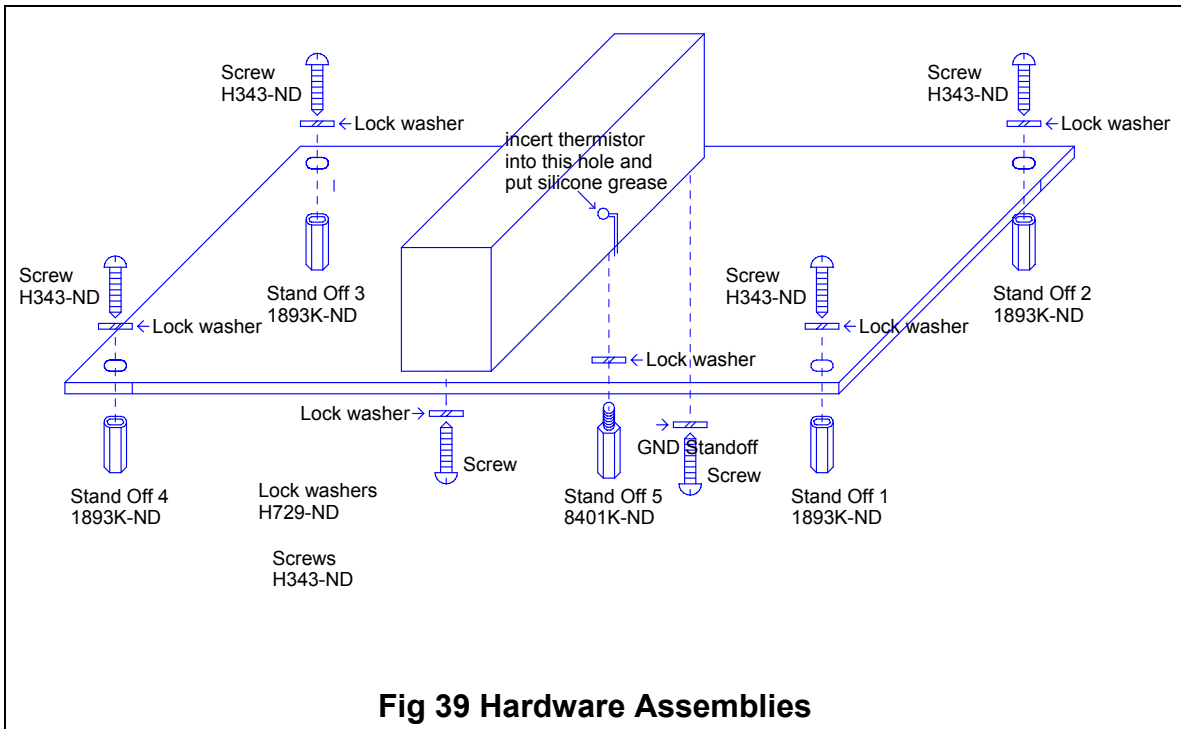


Fig 39 Hardware Assemblies

## IRAUDAMP7S PCB Specifications

PCB:

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

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

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





## Revision changes descriptions

| Revision | Changes description                                            | Date             |
|----------|----------------------------------------------------------------|------------------|
| Rev 1.1  | Released                                                       | Sep, 03 2008     |
| Rev 1.2  | ROHS Compliant(BOM updated)                                    | May, 29 2009     |
| Rev 1.3  | BOM updated :Ice Components as a second vender of the inductor | October 28, 2009 |