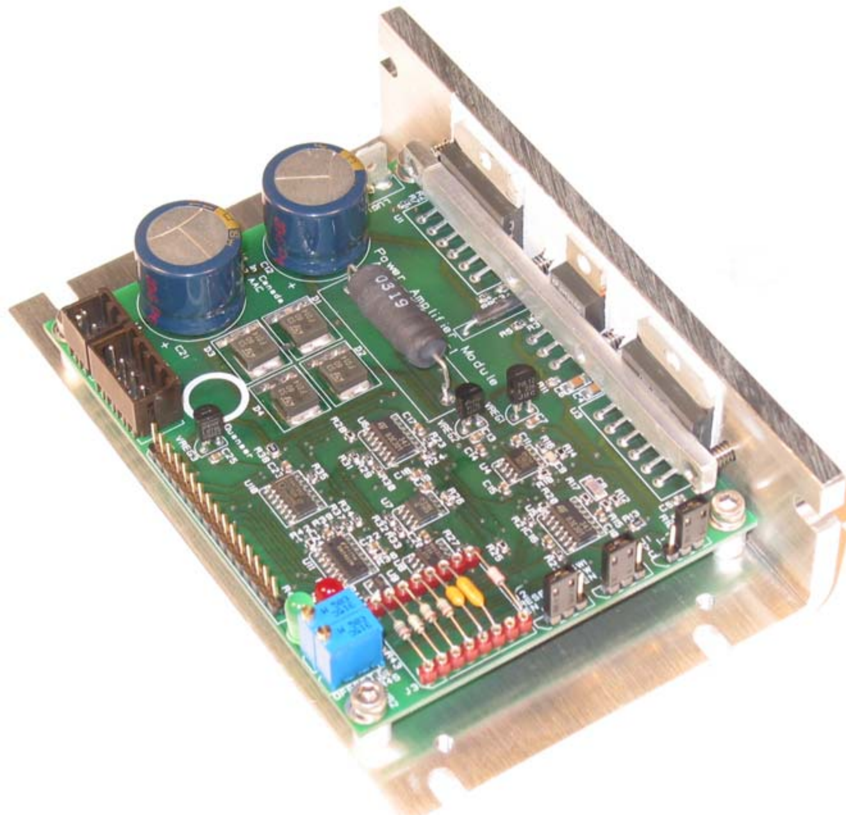
H2W Technologies, Inc.

Linear Power Amplifier Module



User's Guide

Version 2.0

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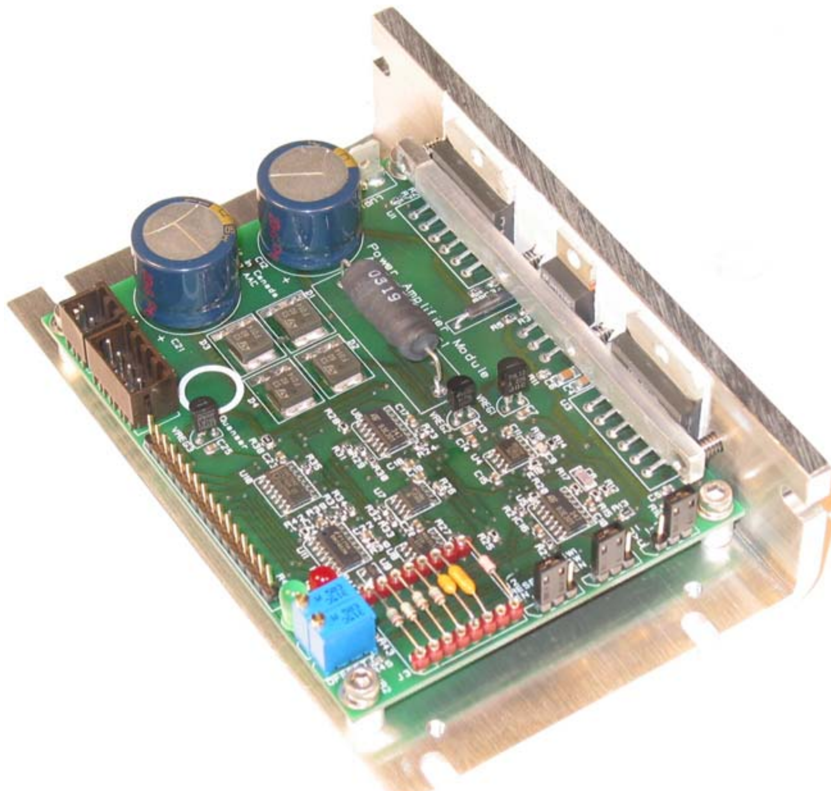
Linear Power Amplifier Module

LPAM-1



Key Features

- Linear - Designed for low noise operation
- High Output Current:
  - 7A Continuous output
  - 9A Peak output
- Wide Power Supply Range:
  - 27 Volts to 60 Volts
- Wide Bandwidth:
  - >10kHz in current mode
  - >10kHz in voltage mode
- Dual Mode Operation:
  - Voltage Mode
  - Current Mode
- Fully Protected:
  - Thermal Shutdown
  - Adjustable Current Limit
  - Power Supply Monitor
- Active High and Active Low amplifier enable inputs
- Offset Trim Adjustment
- Fault Indicator Output
- Startup / Shutdown Circuitry disables the amplifier until power supplies stabilize

Applications

- Voice Coil Actuators
- X-Y Stages
- Robotics
- Magnetic Bearings

Description

The Quanser Power Amplifier is a linear power amplifier designed to drive loads in either voltage mode or current mode.

In the current mode configuration, the amplifier is best suited for inductive loads such as dc-motors and voice coil actuators. The unit displays low noise, wide bandwidth and an offset voltage adjustable to zero.

Designed to run from a single supply, the amplifier's features include; accurate current sensing, selectable fixed gain configurations, current limiting, and thermal protection.

Technical Specifications

Absolute Maximum Ratings

Parameter	*Value*	*Units*
Supply Voltage	60	V
Output Current Continuous Peak	 7 9	 A A
Input (command) Voltage supply voltage = 27 V supply voltage = 48 V	 +/- 10 +/- 20	 V V
Operating Temperature (ambient temperature, natural convection cooling) Power de-rating occurs beyond this temperature.	50	°C

Amplifier Specifications

Parameter	*min*	*max*	*typical*	*Units*
Power Supply Range	27	60	30	V
Input Voltage (Differential, max) Supply voltage = 27 V Supply voltage = 48 V		 20 40		 V V
Input Impedance			1	MOhm
Output Impedance		<0.2		Ohms
Bandwidth Voltage Mode Current Mode		 >10 >10		 kHz kHz

Amplifier Specifications

Parameter	*min*	*max*	*typical*	*Units*
Disable input signal high TTL level, 5V low TTL level, 0V		 1 1		 mA mA
Amplifier Fault output TTL compatible, with 200 ohm resistor inline (current limited to 25 mA)	0	5		V
Current Sense output (buffered)		1		mA
Current Limit Output reference voltage 0.5 V / A			 0.5	V/A
Offset Adjust	Adjusts output to zero for zero command (input) signal.			

Amplifier Board Layout

This section of the manual describes the general layout of the board, and the location of key features. Refer to this diagram when making connections and when locating functions on the board.

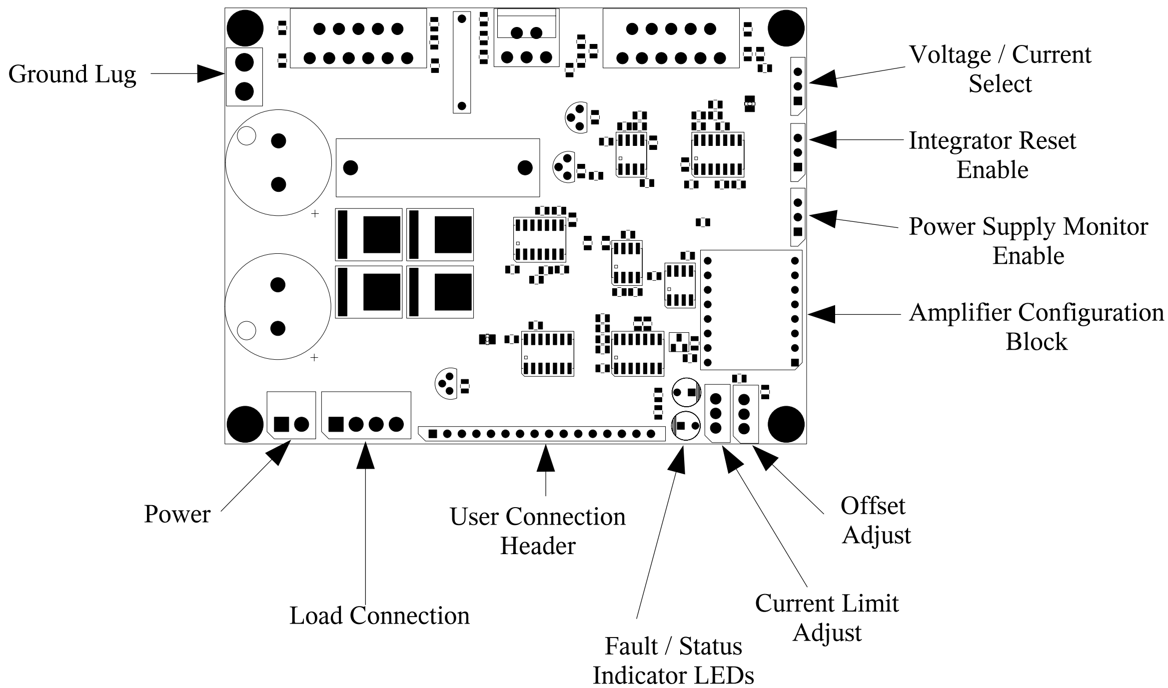


Figure 1. Layout of the amplifier board and the various features.

Pinouts

This section explains the various connections that can be made to the amplifier module. Note that all connections should be securely made with the proper connectors. Improper connections may result in poor performance, or may possibly damage the amplifier and other connected equipment.

User Connection Header

The user connection header is where the user will make the connections to the amplifier. The command signal and the feedback signal (current measurement) are present on this header

User Connection Header

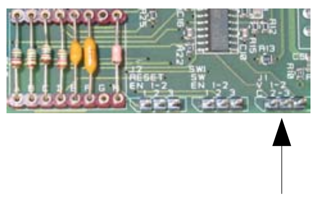
Pin Number	*Signal*	*Comments*
1	+5V	Available for signal conditioning circuitry, 10mA max.
2	GND	Ground connection.
3	-5V	Available for signal conditioning circuitry, 10mA max.
4	REF -	Command signal negative or ground reference.
5	REF +	Command signal positive or signal.
6	Current Limit Monitor	Output of current limit setting.
7	GND	Ground connection.
8	Not used	Do not make connections to this terminal.
9	Current Monitor	Current measurement output, 0.5V/A
10	GND	Ground connection.
11	/ENABLE	Amplifier Enable input. This line must be at 0V for the amplifier to operate.
12	GND	Ground connection
13	ENABLE	Amplifier Enable input. This line must be at 5V for the amplifier to operate.
14	+5V	Available for signal conditioning circuitry, 10mA max.
15	FAULT OUTPUT	Fault indication for the amplifier, external LED connection
16	GND	Ground connection

Table 1. User Connection Header signal names and pinout.

Amplifier Mode Select

Voltage / Current Selection Header

The amplifier is designed to function either as a voltage amplifier or a current amplifier. Selection of what mode the amplifier operates in is by way of a jumper. Placing jumper J1 in the 1-2 position selects voltage mode. Placing the jumper in the 2-3 position selects current mode. **The default configuration for the amplifier is current mode, with the jumper in the 2-3 position**.



Voltage / Current
Select Jumper

Figure 2. amplifier mode selection jumper.

Voltage Mode

In this configuration, the amplifier accepts a command signal and outputs a voltage proportional to the command signal. The signal can be amplified by the configurable gain setting of the amplifier. See the section titled, “Amplifier Configuration Block” for details on this procedure. Power is provided to the load at increased current driving capability, up to a maximum of 7A continuous output.

In voltage mode, the commanded signal will correspond to an output voltage related by the gain setting of the amplifier. For example, with a gain setting of 1, a 1 volt input signal will produce a 1 volt output signal at the output terminals of the amplifier. Similarly, with a gain setting of 4, a 1 volt command would provide 4 volts at the output of the amplifier. The units of the gain are therefore expressed in terms of volts per volt (V/V).

The amplifier will be able to provide an output voltage approaching the supply voltage of the amplifier. See the Technical Specifications section for details.

Current Mode

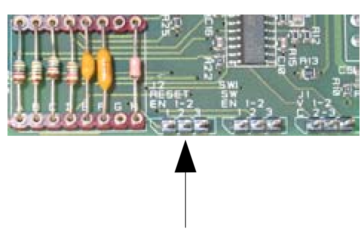
In the current mode configuration, the amplifier outputs the commanded current to the load. Despite changes in the load, the amplifier will output the commanded current. The amplifier uses a built in current feedback loop to continuously change the voltage applied to the load so the commanded current is always applied to the load. The maximum continuous current available is 7A. Consult the section titled, “Amplifier Configuration Block” for details on matching the amplifier to your load.

In current mode, the input signal corresponds to a commanded **current**. Therefore the output current of the amplifier is related to the input voltage by the current gain of the amplifier implemented using external components. For example, with a current gain setting of 1, a 1 volt input signal will produce a 1 amp output signal at the output terminals of the amplifier. Similarly, with a gain setting of 4, a 1 volt command would provide 4 amps at the output of the amplifier. The units of the gain are therefore expressed in terms of amps per volt (A/V). **The factory configuration is 2 Amps / Volt**.

It is important to consider that the voltage at the output terminals is automatically adjusted by the amplifier to provided the commanded current. For this reason, care must be taken to ensure that the amplifier is being asked to do something that it can accomplish based on the available power supply. The maximum current that the amplifier can provide is limited by the supply voltage and the impedance of the load.

Power Supply Monitor Enable

The power amplifier employs a voltage monitoring system to ensure that safe startup and shutdown conditions for the amplifier are met. This feature limits surge currents that may be sent to the load at startup or shutdown. A delay of approximately 0.5 seconds is used during turn on of the amplifier, and the amplifier will not be enabled until the power supply has reached the minimum voltages. At voltages under the specified 27 volts minimum operating voltage, the amplifier will not be enabled with this jumper in the 1-2 position. To disable this feature install the jumper in the 2-3 position. **The factory configuration is with the power supply monitor enabled, with the jumper in the 1-2 position**.



Power Supply
Monitor Jumper

Figure 3. Power supply monitor jumper location.

Integrator Reset Enable

Along with the power supply monitoring feature of this amplifier, an integrator reset feature is provided. Jumper SW EN enables / disables resetting of the integrator of the amplifier. With this jumper in the 1-2 position, the integrator used for the current feedback loop is cleared or reset to zero when the amplifier is first powered up, or when the amplifier is disabled. In the 2-3 position, this feature is disabled. **The factory default configuration is with the jumper in the 1-2 position, enabling the integrator reset feature**.

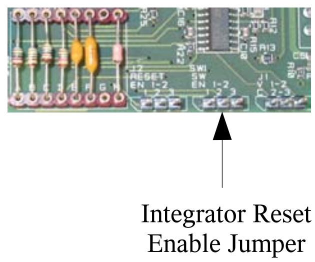


Figure 4. Integrator reset jumper detail.

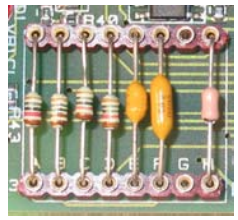
Amplifier Configuration Block

The amplifier configuration block allows customization of the amplifier to the user's needs. These customizable features include:

- gain setting
- amplifier tuning

These features allow the user to customize the amplifier to suit a specific application. Table 2 provides a description of the components used in the configuration block and the functions that they serve. Figure 6 shows the schematic details of how the components operate in the configuration of the amplifier.

Amplifier Configuration Block



A B C D E F G H

Figure 5. Amplifier configuration block details.

Voltage Mode Gain Setting

In voltage mode, the total gain of the amplifier is determined by the components A, C, and D in the configuration block. From the description in Table 2 and the schematic diagram in Figure 6, the total gain can be calculated as the product of G_1 G_2 G_F, where G_F is the final gain stage of the amplifier and is fixed to a value of 20.

$$G_T = G_1 \times G_2 \times G_F$$

It is important to note that when choosing resistor values to set the gains G1 and G2, that the values chosen do not cause the amplifier to saturate. This means that the gains used must keep the voltages below 11 volts.

Row	*Part Name*	*Function*	*Default Value*
A	R36	This resistor with D sets the first gain stage of the amplifier. The resulting gain is $G_1 = D/A$.	10k
B	R33	Current loop feedback gain resistor.	1k
C	R22	Sets the gain in voltage mode for the amplifier. The resulting gain for this stage is $G_2 = C/1k$.	10k
D	R55	With A, this resistor value sets the first gain stage for the amplifier. The resulting gain for this stage is $G_1 = D/A$.	10k
E	C10	Current loop error feedback integration capacitor	22nF
F	C9	Current loop feedback compensation capacitor – typically use factory value of 2.2nF.	2.2nF
G	-	Do not make connections in this position.	open
H	-	This enables the integrator clearing circuitry and must be installed for it to function properly.	short

Table 2. Details of the various configuration options.

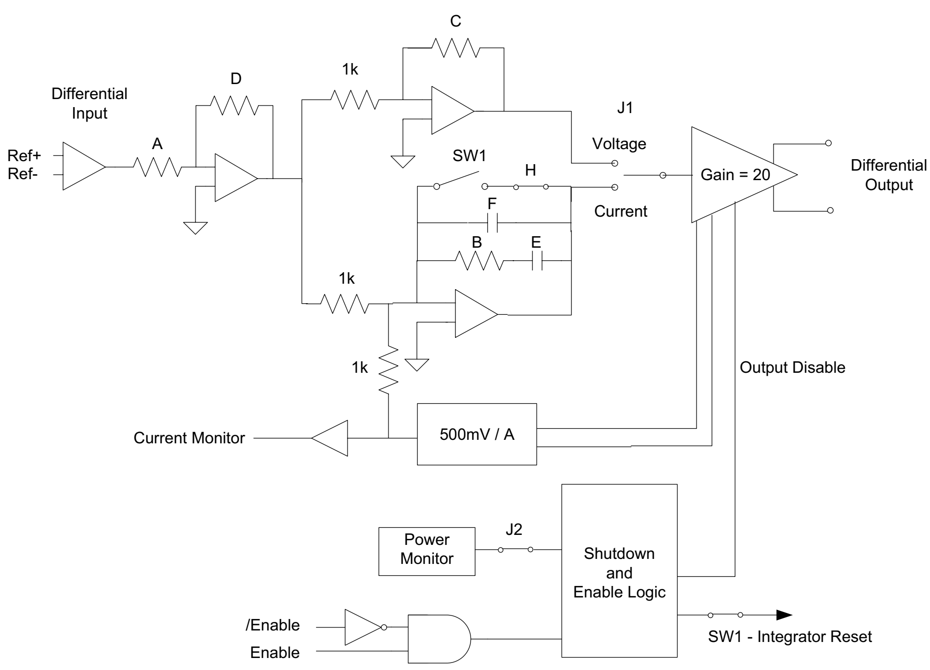


Figure 6. Schematic representation of the amplifier.

Current Mode Configuration

In order to set the gain of the amplifier, you need to select components D and A. These set the forward gain such that the amplifier delivers G Amps/V.

The equation for the forward gain of the amplifier is

$$G = 2\frac{D}{A}$$

Table 3 shows recommended values

G – Amps / V	*D – Ohms*	*A - Ohms*	*D / A*
1	5000	10000	0.5
2	**10000**	**10000**	**1**
4	20000	10000	2

Table 3. Recommend values for the forward gain in current mode.

The bolded text shows the factory configuration.

Tuning the Amplifier

In current mode the amplifier must be tuned to the load inductance and resistance. This is important to optimize its performance for the load.

The tuning components as configured at the factory are:

Component	*Purpose*	*Value*	*Units*
E	Integration gain capacitor	2.20E-008	Farads
B	Loop gain resistor	1000	Ohms

Table 4. Factory configuration of the integration components.

By changing the above components you can adjust the current loop proportional and integral gains.

Do You Want an Integrator?

First you need to determine whether you want integration or not. The capacitor E will introduce an integrator in the feedback loop in order to assure zero steady state error in current independent of load resistance and back EMF. The disadvantage of using an integrator in the current loop is the following: if you are using an actuator driving a load with very little friction, the slightest offset in the input may cause a runaway in the motor unless you are operating a stable closed loop externally. It is recommended that you first try with an integrator and adjust the offset to zero. If the motor runs away in open loop with the expected load, then you may want to completely eliminate the integrator by shorting component E.

The drawback of removing the integrator is that the forward gain will now be load dependent. The expected forward gain, with an integrator is:

$$G = 2\frac{D}{A}$$

With no integration however, the gain in the system now becomes:

$$G = 2\frac{D}{A}\frac{10Kp}{R_{load}+10Kp}$$

where Kp is determined by the equation:

$$K_p = \frac{B}{1000}$$

where B is the value of component B in ohms.

With Kp = 1 (B = 1 KOhm) , the gain will decrease as the load resistance increases as in the following table:

Kp = 1 (B = 1 K)	
R Load	**Gain**
2	0.8333
4	0.7143
6	0.6250
8	0.5556
10	0.5000

Note that the gain depends on the load resistance and will not be consistent throughout the operating temperature range of the load since the load resistance increases as the load resistance gets warm. That is another reason for using the integration in the loop.

You may chose to increase the proportional loop gain Kp instead since the gain reaches unity as Kp gets larger. For example setting Kp = 10 using a 10K resistor for B will result in the following

Kp = 10 (B = 10 K)	
R Load	**Gain**
2	0.9804
4	0.9615
6	0.9434
8	0.9259
10	0.9091

which shows that the gain is closer to unity even with load resistance changes. This gain however may result in undesired ringing if the load inductance is too low.

Implementing an Integrator

The system is shipped with the integrator in the loop active. The system is tuned for the following load:

Parameter	*Value*	*Units*
R Load	4	Ohms
L Load	0.0001	Henry

with the following components for the compensation network:

Component	*Purpose*	*Value*	*Units*
E	Integration gain capacitor	2.20E-008	Farads
B	Loop gain resistor	1000	Ohms

You can tune these values to optimize performance. A MATLAB and a Simulink model are available that will simulate the system where you can adjust these parameters online. In order to tune the amplifier for optimal performance perform the following; you will need a signal generator and an oscilloscope.

Connect the signal generator to the input of the amplifier. Connect the load to the amplifier. Connect the oscilloscope probe to the current sensor measurement. Apply a small amplitude 1KHz. square wave (about 100 mV p-p) - make sure the commanded amplitude does not saturate the amplifier or blow the load!

Start with no integration – i.e. short components E or replace it with a large capacitor e.g. 2 microfarad.

Observe the step response of the system and tune as follows:

- If the response is too slow increase the loop gain by increasing resistance B.
- If there is too much high frequency ringing, reduce the loop gain by reducing B.
- Once B gives a satisfactory response, you will note that the steady state error is not zero.
- Start introducing integral gain by reducing the value of component E.
- If the steady state error does not diminish quickly increase the integral gain by reducing the capacitance of E.

- If there is too much overshoot due to integration reduce the integral gain by increasing the capacitance of E.
- You may need to increase the loop gain using B to dampen the response after selecting E.

Also note that the higher the inductance the more proportional loop gain you will require and the less integral loop gain you will require. So for high inductance increase B & E.

Furthermore, note that the current rate of change is limited by the supply voltage and the load inductance by the equation

$$\frac{dI}{dt} = \frac{Vs}{L} \quad Ampere/second$$

and will limit the practical bandwidth of the system.

Preliminary tuning may be performed using the MATLAB script or the Simulink simulation supplied with the system as described below.

Using the MATLAB Script

You need to have MATLAB for this. Simply run the file **current_amp_design.m** from MATLAB. This will display a step response and a frequency response and print the theoretical - small signal - bandwidth of the system. The system is tuned for

Rload = 4 Ohm

Lload = 0.1mHenry

If you need to tune the system for a different load, open the file with a MATLAB Editor and change the following lines to suit your load:

```
% Power supply voltage

Vmax = 28;

% Load parameters - Minimum inductance 0.1 mHenry
```

```
Lload = .1e-3;
Rload = 4;

% tune these in the Simulink diagram or here

Comp_E = 22e-9; %integration capacitor - increase to reduce
integral gain standard 0.05 micro
Comp_B = 1e3; %feedback gain resistor - variable - increase to
increase loop gain
```

Then run the file again to see if the response as you would like it. Follow the tuning procedure described above.

Using the Simulink Model

A Simulink model is also available. Open the model **current_amp_i_c.mdl**. Run the MATLAB script **current_amp_params.m**. Run the simulation and open the two scopes to observe the current step response. Tune the Load resistance and inductance to your desired response.

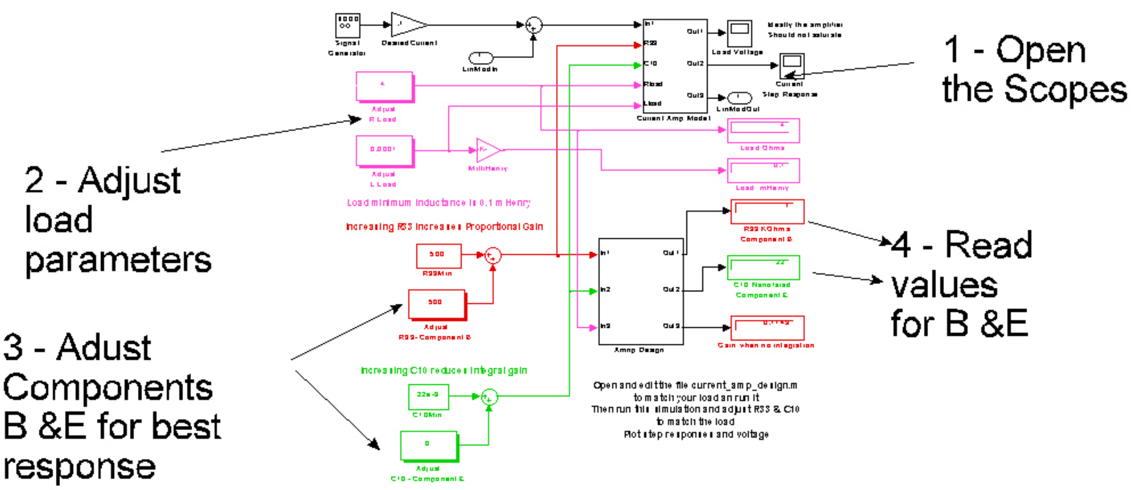


Figure 7. Simulink diagram showing the user adjustable values.

Note that the Simulink model takes into account the non-linearity introduced by amplifier voltage limits as well as other dynamic components in the amplifier that are not modeled in the small signal MATLAB model. This simulation is more realistic than the MATLAB model.

For slow systems (system with large inductance, > .01 Henry) you will need to slow the signal generator frequency in order to observe the steady state response of the system. Note that both these simulations give you a starting point for the tuning values and you may still need to adjust these on the actual system.

Power Supply

Power must be applied to these pins with the correct polarity, otherwise the amplifier may be damaged.

⚠ **Only isolated-secondary type power supplies should be used. The power supply should be a floating type supply, and not referenced to ground on the secondary.**

The amplifier employs an under-voltage lockout system to disable the amplifier in the event that the supply voltage falls below 27 volts. This feature may be disabled by removing the jumper J2 (RESET EN) from the 1-2 position and placing it in the 2-3 position. Note that this action will disable the power-up / power-down circuitry as well, and may result in surges at the output terminals of the amplifier. Power supply voltages below 27 volts may affect the performance of the amplifier.

⚠ **Reversing the power supply connection may result in permanent damage to the amplifier.**

Pin Number	*Function*
1	POWER + (27 – 60 Volts)
2	POWER -

Table 5. Power supply connection.

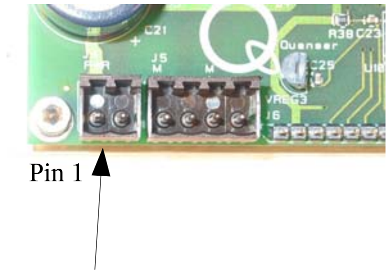


Figure 8. Power connection details.

Load Connection

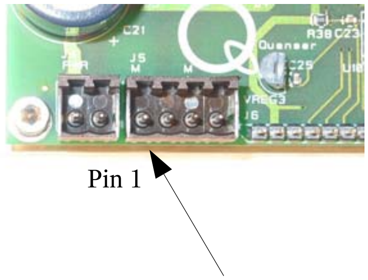
The load is connected to the amplifier at this connector. Note that the each of the pins is duplicated within this connector for additional current handling capability. User connections should make use of all the pins for optimal current handling ability.

⚠ The output of the amplifier is floating. It is not referenced to ground.

Pin Number	*Function*
1	Motor-
2	Motor-
3	Motor+
4	Motor+

Table 6. Amplifier output terminals.

Load Connection



Pin	Signal
1	Load (-)
2	Load (-)
3	Load (+)
4	Load (+)

Figure 9. Load connection details.

GND Lug

The GND lug is provided for convenience where several amplifiers are connected together (multiple channel application) and a common ground reference is needed. This is the only ground that should be treated as common between the input/output signals and the amplifier itself.

Do not use the negative (GND) power input to the amplifier as a ground reference, or damage to the amplifier and/or your equipment may result.

Pin Number	*Function*
1	Virtual Ground Reference (GND)

Table 7. Ground lug connection.

Figure 10. GND connection.

Offset Adjustment

A potentiometer is provided to allow setting the output voltage / current of the amplifier to zero for zero commanded input. Turning the potentiometer to the right (clockwise) increases the offset, making the value more positive.

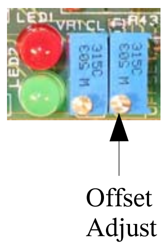


Figure 11. Offset adjustment.

Offset Adjustment Procedure

The setting of the offset to zero requires a few special tools.

- Multimeter
- Small screwdriver

To set the offset of the amplifier to zero, follow the procedure shown below:

1. Command a zero input to the amplifier or short the command input pins together (remove the input connections to prevent damaging the signal source).
2. Connect a multimeter to the output terminals of the amplifier.
3. Adjust the potentiometer until the meter reading displays zero (0.0V)
4. The output of the amplifier should now provide zero voltage / current when the command is zero. Be sure to remove the short across the input pins of the amplifier if

one was placed there.

Current Limit Adjustment

Current limiting allows the user to set a maximum (peak) current that the amplifier will provide to the load. The amplifier will provide current up the set current limit. Continuous currents of 7 Amps are possible, while peak currents may reach 9 Amps. The current limit is adjusted by means of a multi-turn potentiometer . The current limit setting is determined by measuring the voltage present at the current limit output pin. The relationship for the current limit setting and the current limit output is shown below.

$$(Current\,Limit\,Setting) = 2 \times (Current\,Limit\,Output\,Voltage)$$

Equation 1. Current limit output voltage to current limit setting relationship.

Current limit adjustment is provided by means of a multi-turn potentiometer. Turning the potentiometer clockwise increases the current limit setting, while turning it counter-clockwise will decrease the current limit setting. The voltage at the Current Limit Output (pins 6 and 7 on the User Connection Header) should be measured for accurate determination of the maximum current setting. A meter can be connected to these two pins to measure the current limit setting. The output signal varies between 0 and 5 volts. A setting of 3.5 volts gives a current limit setting of 7 amps, the maximum rated output for the amplifier. Instantaneous currents, or peak currents may go as high as 9 A, with the output set to 5 volts. **The factory setting allows for maximum current to be delivered to the load**.

Current Limit (Amps)	*Measured Current Limit Output (Volts)*
1	0.50
2	1.00
3	1.50
4	2.00
5	2.50
6	3.00
7	3.50
MAX	5.00

Table 8. Typical current limit settings

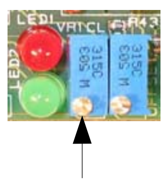


Figure 12. Current limit setting.

Pin Number	*Function*
6	Signal (0-5V)
7	GND

Table 9. Current limit output pinouts.

Current Limit Adjustment Procedure

Adjustment of the current limit requires a few special tools:

- Multimeter
- Small Screwdriver

To adjust the current limit, follow this procedure:

1. Connect the multimeter to the terminals shown in (connector J1).
2. Adjust the trimpot to the desired voltage for the required current setting shown in Table 8, or follow the relationship of Equation 1.

Status Indicator LEDs

Status indication provides a visual means of determining the operating state of the amplifier. The amplifier is provided with a thermal shutdown feature to prevent damage to the amplifier. Indication of the status is provided by means of two LEDs and a secondary output, the Fault Indicator output on pins 15 and 16 of the User Connection Header. The indicator LEDs are green and red.

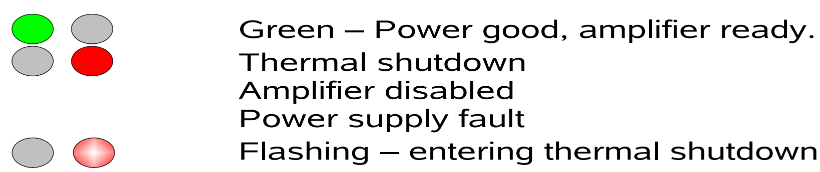


Figure 13. Amplifier status indicator LEDs.

The flashing condition of the red LED indicates that the amplifier is entering thermal shutdown. This situation typically occurs when the amplifier is driving large loads, or the amplifier is inadequately cooled. The amplifier will continue to operate, but the output will be temporarily shutdown during this interval.

External Fault Indication

The state of the red LED is duplicated on the fault output of the User Connection Header, on pins 15 (signal) and 16 (GND). The output is current limited with a 200 ohm resistor, making the signal suitable for directly driving and external LED. Alternatively, the signal may be buffered and used as a status indicator for the connection to external control circuitry.

Amplifier Enable Inputs

The amplifier is provided with two inputs which must receive the proper signals **before the amplifier will become enabled**. In the disabled state, the output of the amplifier goes into a high impedance state. The inputs, /ENABLE and ENABLE are ANDed together to determine the logical state. Table below shows the truth table for these connections.

ENABLE	*/ENABLE*	*Amplifier Status*
0V	0V	Disabled
0V	5V	Disabled
5V	5V	Disabled
5V	**0V**	**ENABLED**

Table 10. Amplifier enable truth table.

The /ENABLE input is tied to +5V through a 4.99k ohm resistor. The ENABLE input is tied to GND (0V) through a 1k ohm resistor. This default configuration leaves the amplifier in a normally disabled state.

Both the ENABLE and the /ENABLE inputs have specific thresholds that must met in order for the amplifier to be enabled for operation.

Signal	*Threshold*	*Minimum*	*Maximum*
ENABLE	> 2.4V	0V	5V
/ENABLE	< 0.8V	0V	5V

Command Signal

The input signal to the amplifier is a differential type input. This signal is called the reference signal, and is applied to the amplifier on the User Connection Header. Connections should be made at pins 4, Ref- and pin 5, Ref+. The amplifier measures the difference between the two signals present at this input and uses it as the command signal. Therefore, when only a command input is connected, **the amplifier will not be grounded**. A proper ground line should be connected to the ground lug of the amplifier if the system design mandates a grounded connection.

Pin Number	*Function*
4	Reference -
5	Reference +

Table 11. Command signal pinouts.

Current Monitoring

Outputs are provided for monitoring of the current delivered to the load by the amplifier. These outputs are available whether the amplifier is used in current mode or voltage mode.

Pin Number	*Function*
9	Current output
10	GND

Table 12. Current output pins.

The signal is calibrated to provide 0.5V / A. Therefore, for a 2 A current being delived to the load, a 1 volt signal will be present between pins 9 and 10.

Installation

Installation, mounting and information on making electrical connections to the amplifier can be found in this section.

Mechanical Mounting

The amplifier is fitted with a series of mounting holes along two surfaces. These holes make it possible to mount the amplifier to a surface in two different configurations. Appendix A shows details of the heatsink of the amplifier. The user can use this drawing as a reference when constructing enclosures or fixtures for the amplifier.

Proper mounting of the amplifier will also help cooling and prolong the service life of the amplifier. A cooler amplifier runs better, and will perform better over the long term. The surface that the amplifier is mounted to can aid in the cooling of the amplifier.

Care should be taken to ensure that the amplifier is not exposed to excessive moisture or used in areas were metal debris may come into contact with the amplifier. In these situations, a proper enclosure must be used to prevent the amplifier from being damaged, and to reduce the risk of electrical shock.

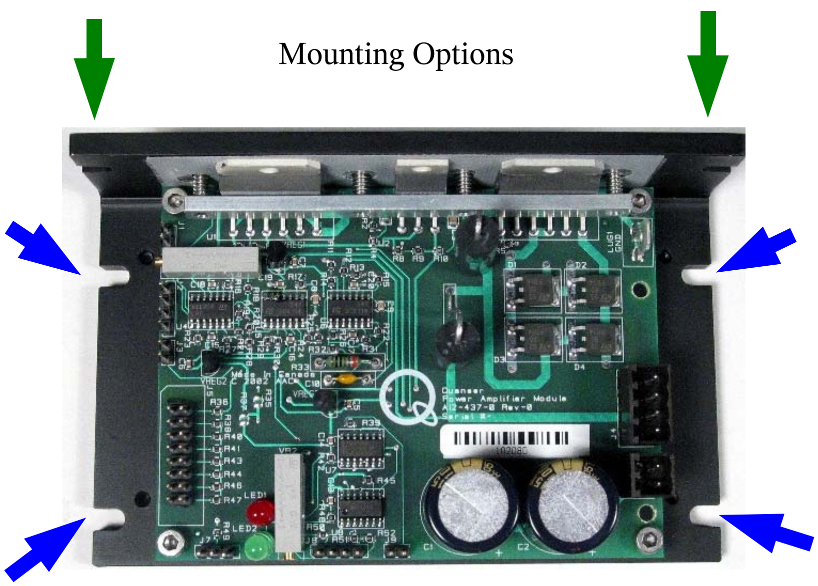


Figure 14. Mounting hole locations A (green) or B (blue).

Cooling Fans

Most applications of the power amplifier module will require the use of cooling fans, to maintain the amplifier at a safe operating temperature.

The heatsink of the amplifier has holes tapped to accept #8 mounting hardware. Either two 1.25” fans may be used, or one 2” fan can be used.

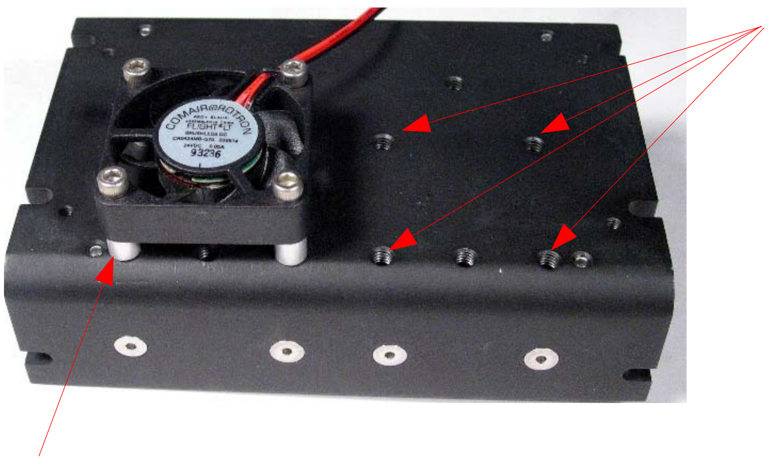
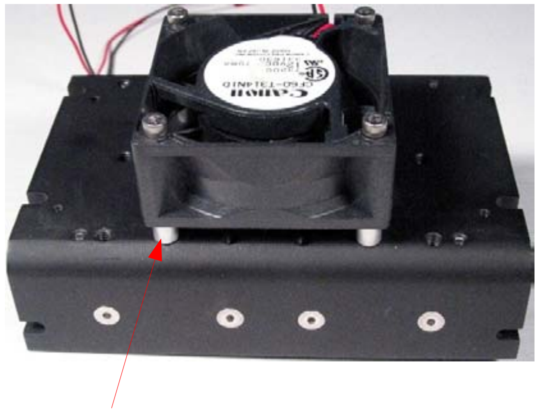


Figure 15. Mounting locations for the small (twin) fans.

Mounting of two smaller fans may be useful in situations where space is limited or where the noise from a larger fan may be an issue. As well, dual fans does provide a degree of redundancy in demanding applications.

Note that spacers are used to separate the fan from the surface of the heatsink to provide a proper path for cooling. As well, attention should be paid to the direction of airflow. Airflow should be flowing **towards** the surface of the heatsink. Determination of the proper CFM rating for the selected fan depends highly on the application and the enclosure of the amplifier. Note that the mounting surface of the amplifier may contribute to the total effective cooling area. This may greatly reduce the airflow requirements of a fan. The maximum power capacity of the amplifier is under 500W, so the maximum power that would need to be dissipated cannot reach this value. As a result, a fan with a maximum CFM rating of 30 CFM is required for applications where a 30°C temperature rise can be tolerated. Keep in mind that the maximum operating temperature (ambient temperature) is 50°C.



Spacer

Figure 16. Mounting location of the large fan.

Two fans rated for 4.5 CFM or 1 rated 9 CFM or greater should suffice for most applications.

Determining the Dissipated Power

Calculation of the power dissipated by the amplifier is critical to determining the amount of cooling required of the amplifier. Assuming the worst-case scenario of a DC output, the power dissipated is given by any of the following:

$$P_D = 2 \times I_{load} \times (V_{supply} - V_{output})$$

$$P_D = 2 \times \frac{V_{output}}{R_{load}} \times (V_{supply} - V_{output})$$

$$P_D = 2 \times I_{load} \times (V_{supply} - I_{load} \times R_{load})$$

The second and third equations are obtained by substituting Ohm's law for the required parameter. Power dissipated P_D is given in Watts. This power will be given off as excess heat in the amplifier, and must be removed by natural convection or through forced air cooling.

Determining the Required Airflow for Cooling

The power dissipated must be removed from the amplifier. This is best accomplished with the use of a fan. Calculations for the required airflow for the fan are as follows.

$$Q_{CFM} = \frac{3.16 \times P}{\Delta T_F} = \frac{1.76 \times P}{\Delta T_C}$$

$$Q_{m^3/min.} = \frac{0.09 \times P}{\Delta T_F} = \frac{0.05 \times P}{\Delta T_C}$$

The equations shown give the required flow rate in CFM (cubic feet per minute) or m^3 per minute). P is the amount of heat, in Watts, that must be dissipated. The constant in the equations is obtained from the density of air (1.29 kg/m^3) and the specific heat of air (930 J/kg/°C). The constant is then adjusted to provide results in the units desired.

Example:

R_{load} = 1 ohm

V_{supply} = 27 volts

$I_{load\ (max)}$ = 5 amps

$$P_D = 2 \times I_{load} \times (V_{supply} - I_{load} \times R_{load})$$

P_D = 220 Watts. If we allow the temperature of the amplifier to increase 20 °C, then we have:

$$Q_{CFM} = \frac{1.76 \times P}{\Delta T_C}$$

Q_{CFM} = 19.4 CFM, or 0.55 m^3/min. Fans should be selected to achieve at least this airflow rate. Most manufactures of fans have additional information that will help determine the optimal fan based on required flow rate and enclosure selection. The user should be careful to understand that the fan will need to be mounted within the manufacturer's guidelines to ensure that the specified airflow rate is achieved.

Note that the above example assumes a continuous DC signal. This assumes the worst case possible. Typical applications will not require the output of a continuous DC current, and the power dissipation of the amplifier can be adjusted accordingly.

Electrical Connections

The power amplifier module uses two different types of connector. The high power connections required for the power supply and for the load connections are made using terminal block connectors. Suitable types of connectors are shown below.

Description	*Manufacturer*	*Supplier*
Connector plug terminal block, 2 position, 3.50mm	Weidmuller 1638780000	Digi-Key 281-1018-ND
Connector plug terminal block, 4 position, 3.500mm	Weidmuller 1638800000	Digi-Key 281-1020-ND
Connector housing, 16 positions, 0.100 single row	AMP / Tyco Electronics 2-87499-9	Digi-Key A3025-ND
Connector socket pins, 22-26AWG, crimp type. (16 pins required, maximum)	AMP / Tyco Electronics 1-87756-8	Digi-Key A25966-ND

The other type of connector required are the pin header connectors. These connectors may be assembled from components, or may be purchased pre-assembled. The spacing of the pins is 2.54mm or 0.1”. Manufacturers of these components include AMP, Tyco and HRS. Digi-key is one supplier of these components.

Configuration of the amplifier is done by way of shunts. The power amplifier module is shipped with jumpers installed. However, in case additional jumpers are required, they may be purchased from various manufacturers.

Description	*Manufacturer*	*Supplier*
Shorting Jumpers	3M/ISD 929950-00	Digi-Key 929950-ND

Selecting a Power Supply

A power supply is required to provide electrical power to the amplifier. The size, type and capacity of the power supply are highly dependent on the application.

Operating Voltage

The operating voltage of the power supply should be chosen to match the power requirements of the intended load. This will allow the amplifier to provide the maximum power to the load while minimizing the power that is dissipated by the amplifier itself. Proper selection of the operating voltage will allow the amplifier to remain cool, and minimize the cooling requirements.

For a load resistance of 2 ohms, requiring a maximum current of 4A, Ohm's Law shows that the required voltage is 8 Volts. Since the minimum operating voltage is 27 volts, this voltage should be used.

$$v = iR$$

Similarly, the maximum current that the power amplifier can supply may be limited by the supply voltage to the amplifier, even if the power supply can supply the current. For example, if the load is 8 ohms, and the supply voltage is 27 volts, the maximum current is given by:

$$i = \frac{v}{R}$$

which in this case results in a maximum current of 3A.

This shows the theoretical minimum voltage required, and in practice should be raised by at least 3 volts, to account for the overhead required by the amplifier. In addition, if the power supply is located a significant distance from the amplifier, drops in the supply voltage may become critical. In this case the voltage of the power supply will need to be even higher.

Current Handling Capability

The power supply chosen must be able to deliver the expected power to the load, plus some additional power used by the amplifier itself. Typically, to use the amplifier at its fully rated current ability, the power supply must be capable of delivering 10A continuous, minimum. Additional capacity of the power supply will promote longer service life of the supply. In most cases, a current handling capacity of 8A is sufficient.

In multiple amplifier configurations, the supply must be able to handle the requirements of all amplifiers. This typically means that the required supply current is 8A times the number of amplifiers present in the system. For example, with 4 amplifiers, the current capacity of the power supply would need to be 32A, assuming that all 4 amplifiers would be required to provide full power at any given moment.

Power Supply Type

The type of power supply selected – switching or linear, is up to the user. Either type of power supply can be used with the power amplifier module. As long as the power requirements are met, almost any type of supply can be used.

One important note is that isolated power supplies only should be used. Off-line type switching supplies that have the secondary common with the primary may damage the amplifier, and prove dangerous.

⚠ **Only isolated-secondary type power supplies should be used with the power amplifier module.**

Connecting A Single Unit

A single amplifier can be connected as shown in figure 17. The figure shows the required connection to make the amplifier work in a given system. Not the location of the system ground in the figure. The amplifier uses a virtual ground point as a reference, and this reference must be used as the system ground reference. Isolated secondary power supplies are used, meaning the secondary or output of the power supply is isolated from the mains supply.

Note that only the command input is a required input to the amplifier. The amplifier will function without connection to the shutdown inputs. Current monitoring, current limiting, and fault indication are all options available to the user, but do not necessarily need to be connected. In addition, the gain selection jumper and the current / voltage mode jumper must be installed for the amplifier to function.

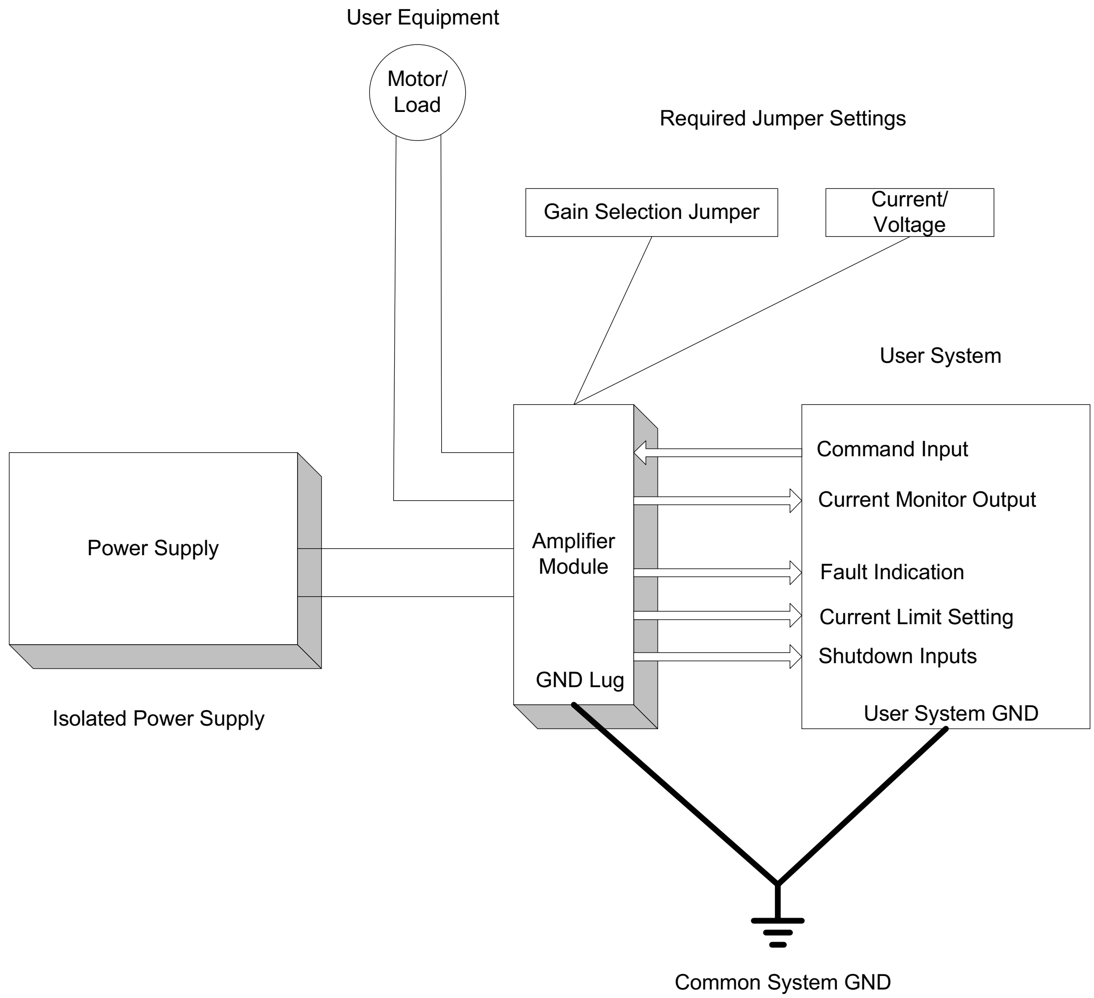


Figure 17. Single amplifier connections.

Connecting Multiple Units

Several amplifier units can be connected together to allow for multi-channel configurations. In this setup, a common ground point is often required. The ground lug should be used for this purpose. Figures 18 and 19 show two types of possible connections. Note that the ground lug is used as the ground point for the common system ground reference.

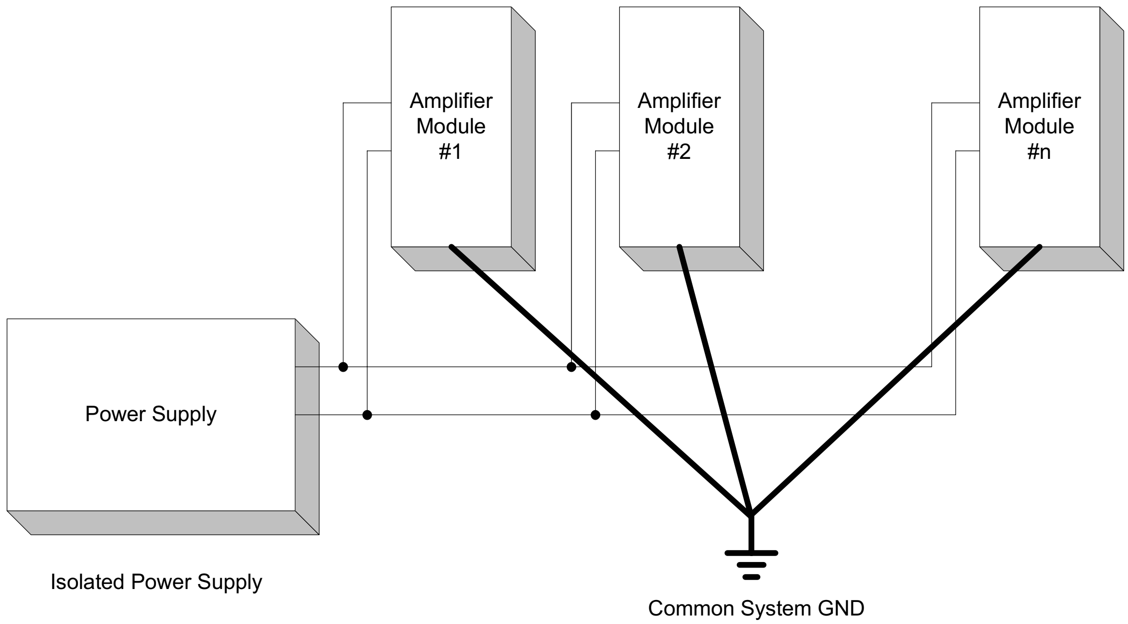


Figure 18. Multiple amplifiers connected with a single power supply.

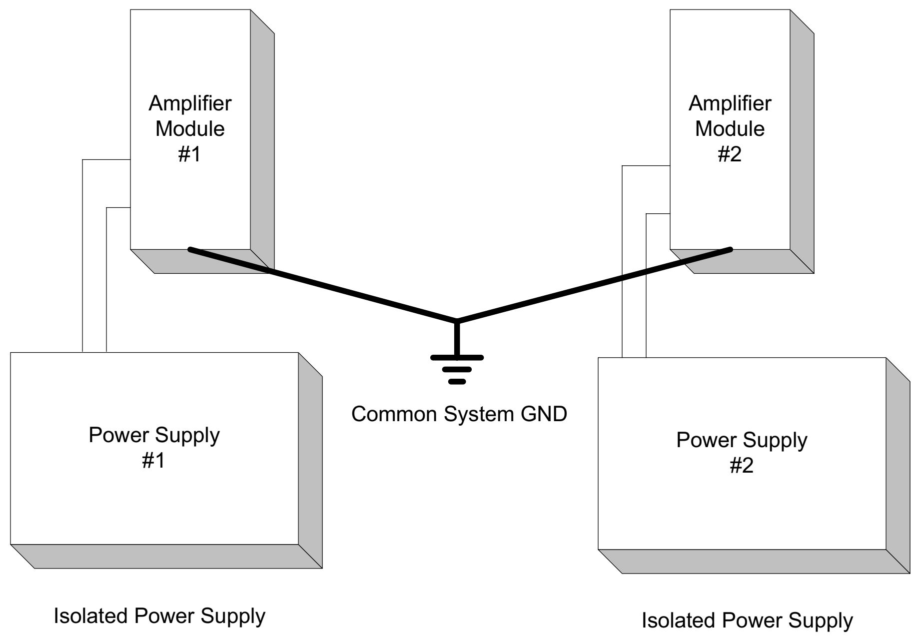
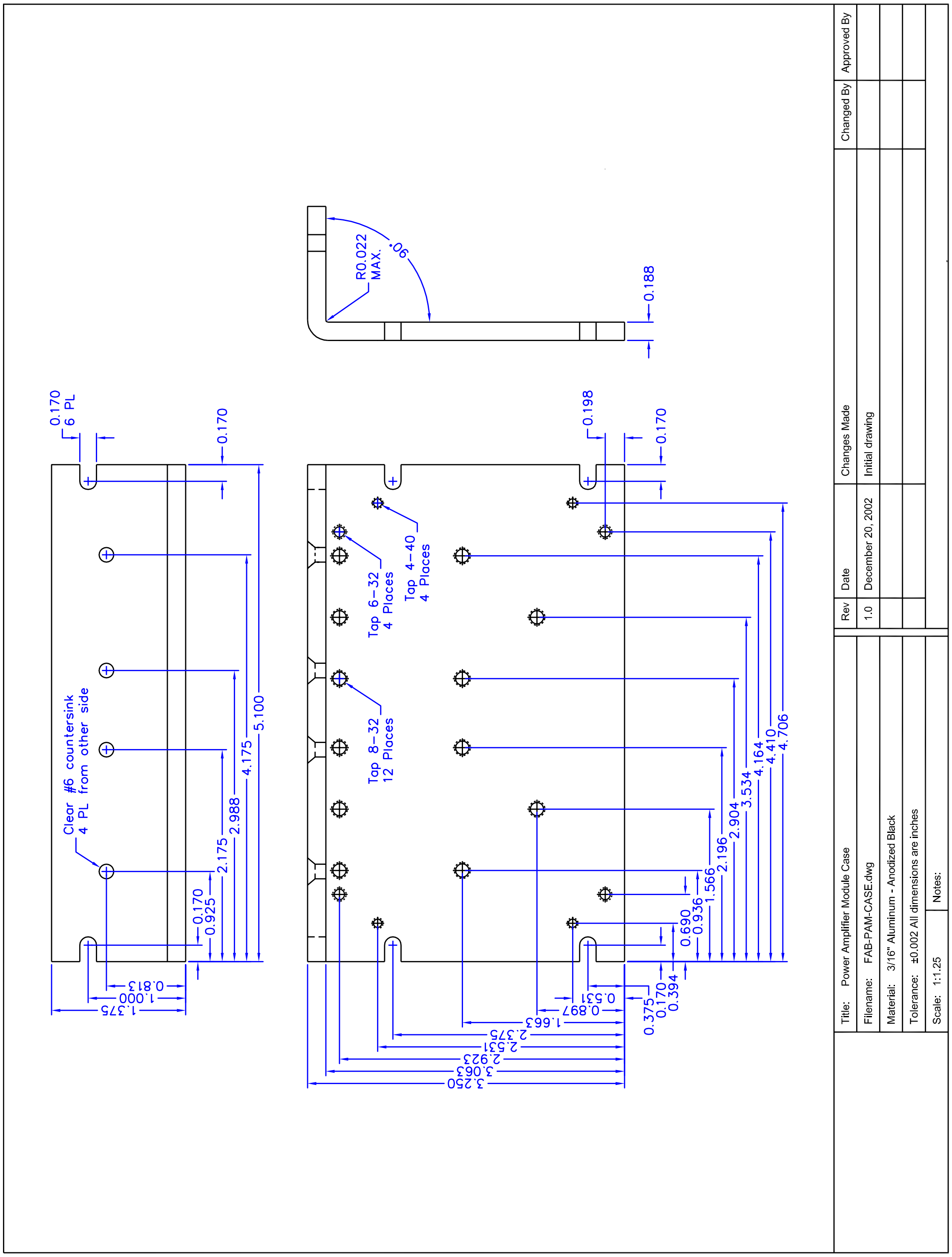


Figure 19. Multiple power supplies to drive multiple power amplifiers.

Appendix A

Dimensions

The following pages show the mechanical drawings for the heatsink of the power amplifier module. These drawings can be used in the fabrication of the enclosure of a mounting fixture.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Filename: FAB-PAM-CASE.dwg
Material: 3/16" Aluminum - Anodized Black
Tolerance: ±0.002 All dimensions are inches
Scale: 1:1.25
Notes:
Rev
Date
Changes Made
Changed By
Approved By
1.0
December 20, 2002
Initial drawing
Clear #6 countersink
4 PL from other side
Top 6-32
4 Places
Top 4-40
4 Places
Top 8-32
12 Places
R0.022
MAX.
90°
0.170
6 PL
0.188
0.198
0.170
0.925
2.175
2.988
4.175
5.100
0.813
1.000
1.375
0.690
0.936
1.566
2.196
2.904
3.534
4.164
4.410
4.706
0.375
0.394
0.531
0.897
1.663
2.375
2.531
2.923
3.063
3.250