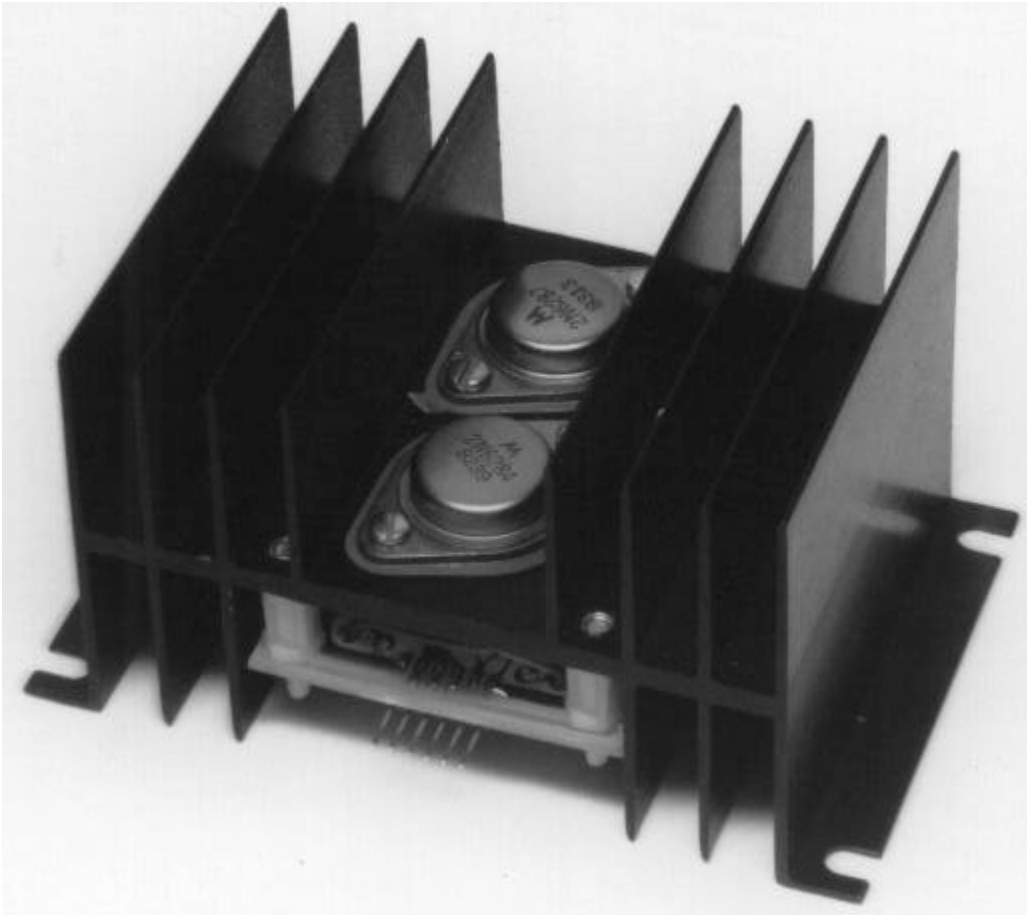# Marchand Electronics Inc.

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PM2 50Watt Amplifier
.

 This conservatively rated power amplifier module will deliver a clean, low distortion 50 Watt of power to any 8 Ohm loudpeaker. The amplifier is rated to drive reactive loads with a phase angleof up to 45 degree at full output voltage. The amplifier can take its input from any pre-amp, electronic crossover or other source. The circuit makes use of an integrated circuit driver chip and two complimentary Darlington power transistors. The compact design fits on a small 2" * 3" circuit board that is mounted directly on the heavy-duty heatsink for the output transistors.
 The available output power depends on the voltage and current rating of the power supply and the impedance of the load (8 Ohm or 4 Ohm). The power for the module can be from a dual regulated power supply of up to +/-40 VDC or from an unregulated source. A simple unregulated supply can be assembled from a 48 Volt @ 1.5 Amp center-tap transformer, a bridge rectifier and two 10.000uF filter capacitors; this supply is good for 50WRMS into a 8 Ohm load.
 The PM2 can also be operated in class A mode. In this mode the module can deliver 10 Watt RMS continuous into an 8 Ohm load, when using a +/-18 VDC power supply.
 The amplifier module is protected with an output current limiter and a temperature sensor. The output current of the amplifier will be limited to a safe value, so that the amplifier can not be damaged by short circuits at the output. In the event of overheating the amplifier will turn itself off until it cools down again.
 The PM2 power amplifier module kit is available in several versions. It is available as a bare board, as a complete kit and completely assembled and adjusted. For those who want to use their own heatsink for the output transistors, the kit is also available without heatsink.
 Assembly of the PM2 power amplifier module is made easy with the silk screened printed circuit board and the step by step assembly manual. Some experience is needed for assembly of this kit, and it is not recomended for the beginner! Simple tools, a soldering iron and a multimeter, capable of indicating a 10mV voltage (~2 Volt range) and of measuring resistance, is required for adjustment of the amplifier.

SPECIFICATIONS

Frequency response:	5Hz-50KHz, +/- 1dB;
Total Harmonic Distortion:	less than 0.1% @ 1KHz.;
Voltage gain:	20 dB (10x);
Input impedance:	100 KOhm, AC coupled.
Output load:	4 or 8 Ohm, DC coupled.
Max power output with	10 Watt RMS, continuous, into 8 Ohm.
+/- 18 V Power Supply	(class A)
Max power output with	50 Watt RMS, continuous, into 8 Ohm.
+/- 30 V Power Supply	(class B)
Power supply range:	+/-15V to +/-45V, dual supply.
Absolute Maximum	
Power Supply voltage:	+/- 50 Volt.

DESCRIPTION

The PM2 power amplfier module achieves high performance and low parts count by using the LM391 Audio Power Driver from National Semiconductor Corporation. This integrated circuit can directly drive the two output power darlington transistors. The circuit has output current limiting and Safe Operaring Area protection for the power transistors. The amplifier also has a turn on delay circuit that minimises the output transients when the amplifier is turned on. A temperature sensor, mounted on the heatsink of the power transistors, protects the circuit by turning the amplifier off when the temperature exceeds 65 degrees Centigrade. The PM2 is rated at 50 Watt RMS continuous operation with an 8 Ohm load.
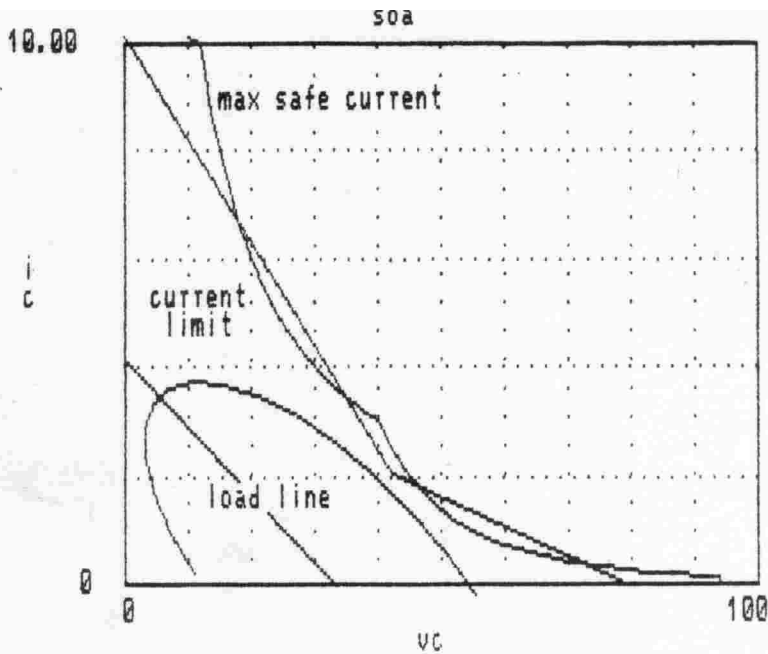
Figure 1. SOA and load curves for 2N6284.

   The circuit diagram for the amplifier is shown in figure 7. The complementary output
power darlington transistors Q1 and Q2 are driven directly by IC1, LM391 Audio Power
Driver. The output stage operates in a standard class AB configuration. The bias current
of the output stage is set with R8. The output current limit and SOA protection is set
with R6,R7, R10-R19 and D1,D2. The dual slope current limit allows the current limit
setpoint of the ouput transistor to vary with the collector voltage of the transistor.
For low collector voltage a high collector current is allowed, but as the collector
voltage increases the allowable current is reduced. At first the current is limited by
the allowed power dissipation of the device, but as the collector voltage increases over
a certain value the maximum current is reduced in order to avoid secondary breakdown of
the transistor. This secondary breakdown is a mayor factor in limiting maximum output
power of an amplifier; it is caused by hot spots that occur in bipolar transistors at the
higher power and voltage levels. The manufacturer of power transistors specify a Safe
Operating Area for the transistor that avoids all these pittfalls. Figure-1 shows the SOA
curve for the 2N6284 and 2N6287 transistors used in the PM2 amplifier. The figure shows
the DC SOA limits for the transistors and the current limits imposed by the amplfier. The
firure also shows a typical load line of output current vs. output voltage for output
loads of 8 ohm. The output load line for an inductive load with a phase angle of 40
degrees shows the capability of the amplfier to drive reactive loads. The output
transistors of the amplifier are further protected against inductive kick-back by the
free-wheeling diodes D3 and D4. Inductor L1, capacitor C10 and resistors R20 and R21
insure the stability of the amlifier. The aplifier operates as a standard operational
amplifier in a non-inverting mode. The gain is set to a value of 20dB (voltage gain of
10) with resistors R4 and R5. The input signal is coupled to the integrated circuit from
input connector P1 with C1 and R1. This capacitive coupling has a corner frequency of 1.6
Herz, and insures minimal phase distortion at the low frequencies of the audio spectrum.
R2 and C2 provide for a turn-on delay of about 1 second. The turn-off feature of the
LM391 is operated by sinking current from pin 14. When the current exceeds about 1 mA the
internal circuit will kill the drive to the output transistors. This input is also used
to activate the thermal protection of the amplfier. The temperature sensor R3 is a
temperature dependent switch. When cold it is open, but when it is heated the switch will
close at 62 degree C. This will activate the turn-off circuit of IC1. The heatsink will
now cool off because of the elimination of the power dissipation of the output
transistors. When the temperature gets down to 70 degrees R3 will switch back off, and
the amplifier will turn back on.

In the interest of low distortion and high stability metal film resistors are used for all low power resistors. No electrolytic capacitors are used in the signal path. The IC1, Q1 and Q2 are mounted in sockets, and terminal blocks for input, output and power make for ease of use.

PARTS LIST

The PM2 power amplfier kit includes the parts listed below. Please check the contents of your kit to make sure no parts are missing.

```
-----------------------------------------------------------------
|                         Parts List                            |
|                  PM2 power amplifier module                   |
|   part      ea      Description                               |
|===============================================================|
| R1,R6,R7 | 3 |   100K, 1% Metal Film                          |
| R2       | 1 |   33.2K,1% Metal Film                          |
| R3       | 1 |   Temperature sensor                          |
| R4       | 1 |   110K, 1% Metal Film                          |
| R5       | 1 |   1M,   1% Metal Film                          |
| R8       | 1 |   10K, Trimmer potentiometer                  |
| R9       | 1 |   2.00K,1% Metal Film                          |
| R10,R11  | 2 |   10K,  1% Metal Film                          |
| R12,R13  | 2 |   324K, 1% Metal Film                          |
| R14,R15  | 2 |   3.24K, 1% Metal Film                         |
| R16,R17  | 2 |   6.49K,1% Metal Film                          |
| R18,R19  | 2 |   .56 Ohm, 3 Watt                             |
| R20      | 1 |   5.6 Ohm, 3 Watt                             |
| R21      | 1 |   10 Ohm,  2 Watt, Carbon comp.               |
| L1       | 1 |   4uH, (20-25 turns #22 wire on R21)          |
| C1       | 1 |   1uF, 50 WVDC, 5% Stacked MF                 |
| C2       | 1 |   10uF, 50 WVDC, Alum. Electrolytic           |
| C3,C4    | 2 |   22pF, 600 WVDC silver mica capacitor        |
| C5,C10   | 2 |   .22uF, 100 WVDC, stacked film cap.          |
| C6,C7    | 2 |   1000pF, 100 WVDC, Ceramic disc              |
| C8,C9    | 2 |   47uF, 50 WVDC, Alum. Electrolytic           |
| IC1      | 1 |   LM391-100                                   |
| Q1       | 1 |   2N6284 NPN Power Darlington                 |
| Q2       | 1 |   2N6287 PNP Power Darlington                 |
| D1,D2    | 2 |   1N5260, 43V, 500mW Zener diode              |
| D3,D4    | 2 |   1N4937, 1Amp diode                          |
| P1       | 1 |   2 position terminal block                   |
| P2       | 1 |   6 position terminal block                   |
| M1       | 1 |   Heatsink 421 (modified)                     |
| M5       | 1 |   16 pin DIP socket                           |
| M6       | 2 |   TO3 transistor socket.                      |
| M7       | 2 |   TO3 mica insulator                          |
| M8       | 4 |   1/2" ins. standoffs, 8-32 thread            |
| M10      | 4 |   sheet metal screw,flathead,6-20*5/8"        |
| M11      | 1 |   PM2 circuit board                           |
| M12      | 1 |   hookup wire                                 |
-----------------------------------------------------------------
```

ASSEMBLY INSTRUCTIONS.

The assembly of the power amplifier is made very easy by the silk screen guide on the circuit board. The schematic diagram of the amplifier is shown in figure-7. Figure-6 shows the silkscreen and the transistor connections. All components shoud be installed on the side of the board that has the silk screen; this side is called the component side. The parts are then soldered in place on the foil side of the board. Refer also to figure-3 and the title page of this manual for pictures of PM2 after assembly.
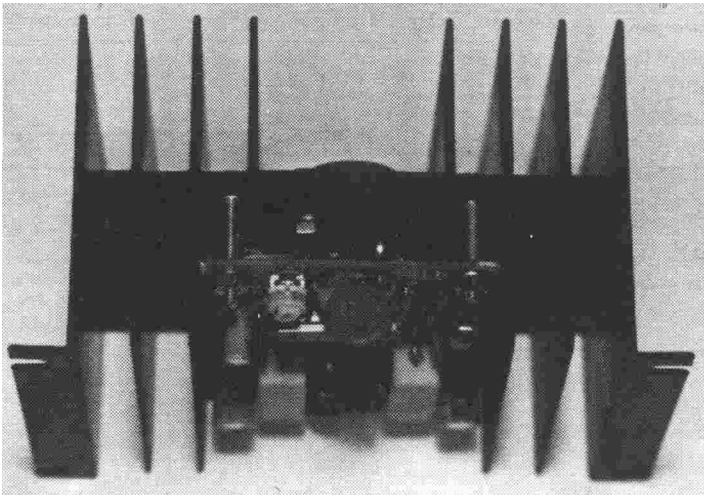
Figure 3. Assembled PM2.

Step 1 ___ Install resistor R1. Use a 1%, 100K metal film resistor. The resistor is marked with a color code to indicate the value.
The code is Brown - Black - Black - Orange -- Brown. The orientation of the resistor is not important. Solder and trim leads.

Step 2 ___ Install R2, 33.2K, 1% Metal Film resistor. Proceed as with
R1. Orange - Orange - Red - Red -- Brown.

Step 3 ___ R4, 110K, 1% MF. Brown - Brown - Black - Orange -- Brown.

Step 4 ___ R5, 1.00M, 1% MF. Brown - Black - Black - Yellow -- Brown.

Step 5 ___ R6, 100K, 1% MF. Brown - Black - Black - Orange -- Brown.

Step 6 ___ R7, 100K, 1% MF. Brown - Black - Black - Orange -- Brown.

Step 7 ___ R9, 2.00K, 1% MF. Red - Black - Black - Brown -- Brown.

Step 8 ___ R10, 10.0K, 1% MF. Brown - Black - Black - Red -- Brown.

Step 9 ___ R11, 10.0K, 1% MF. Brown - Black - Black - Red -- Brown.

Step 10 __ R12, 324K, 1% MF. Orange - Red - Yellow - Orange -- Brown.

Step 11 __ R13, 324K, 1% MF. Orange - Red - Yellow - Orange -- Brown.

Step 12 __ R14, 3.24K, 1% MF. Orange - Red - Yellow - Brown -- Brown.

Step 13 __ R15, 3.24K, 1% MF. Orange - Red - Yellow - Brown -- Brown.

Step 14 __ R16, 6.49K, 1% MF. Blue - Yellow - White - Brown -- Brown.

Step 15 __ R17, 6.49K, 1% MF. Blue - Yellow - White - Brown -- Brown.

Step 16 __ D1, 1N5260, 43V, 500 mW Zener diode. The black band at one end of the body of the diode indicates the cathode. Make sure this band is oriented as indicated on the silk screen.

Step 17 __ D2, 1N5260, 43V, 500 mW Zener diode. As step 16. Watch the band!

Step 18 __ D3, 1N4937, Amp. diode. As step 16. Watch the band!

Step 19 __ D4, 1N4937, Amp. diode. As step 16. Watch the band!

Step 20 __ Install the 16-Pin Dual In line socket for IC1. Insert the socket into the PC board and make sure all 16 pins go through the holes in the board. Also make sure that the pin-1 marker on the socket corresponds with the marking on the board; this side is identified with the half-circle at one side of the rectangle on the silk screen. Solder.

Step 21 __ Install terminal blocks P1 and P2.

Step 22 __ Install R18, .56 Ohm, 5W resistor.

Step 23 __ Install R19, .56 Ohm, 5W resistor.

Step 24 __ Install R20, 5.6 Ohm, 1W Carbon composition resistor. Green -
Blue - Black

Step 25 __ Fabricate L1. This inductor is made by winding about 20-25 turns on the body of the 10 Ohm, 2Watt carbon composition resistor. Use the 25" of #22 magnet wire. Strip and tin the ends of the wire to a length of 1/4". Solder one end of the wire to one of the leads of the resistor, close to the body. Wind the wire around the resistor very tightly, and terminate by soldering the free end to the other end of the resistor. Optionally, use some epoxy cement to glue the winding to the resistor. Insert the assembly in the PC board and solder.

Step 26 __ Install R8, 10K trimmer potentiometer.

Step 27 __ Install C1, 1uF, 50WVDC, 5% Stacked metallised film capacitor.

Step 28 __ Install C2, 10uF, 50WVDC, Aluminum electrolytic capacitor. The electrolytic capacitors are polarised, they have a positive and a negative terminal. The negative terminal is indicated on the body of the component with a minus sign. The silk screen on the PC board also has a minus sign to indicate how the capacitor should be installed. Be SURE to insert the negative lead of the capacitor as indicated on the PC board. The plus side of C2 will face towards IC1.

Step 29 __ Install C8, 47 uF, 50 WVDC, Aluminum electrolytic capacitor. As in step 28, observe the polarity. The minus side of C8 will face away from D3.

Step 30 __ Install C9, 47 uF, 50 WVDC, Aluminum electrolytic capacitor. As in step 28, observe the polarity. The minus side of C9 will face towards D4.

Step 31 __ Install C3, 22 pF, silver mica capacitor.

Step 32 __ Install C4, 22 pF, silver mica capacitor.

Step 33 __ Install C5, .22 uF, 100 WVDC stacked film capacitor.

Step 34 __ Install C10, .1 uF, 100 WVDC stacked film capacitor.

Step 35 __ Install C6, 1000 pF, 100 WVDC ceramic disc capacitor.

Step 36 __ Install C7, 1000 pF, 100 WVDC ceramic disc capacitor.

Step 37 __ Strip 1/4" of insulation from both ends of the 6" Brown insulated wire. This wire will connect the collector of Q1 to the circuit board. From the component side of the PC board, insert the wire into the smaller one of the two holes marked Q1C. Solder the wire to the board. Now pass the wire through the other hole marked Q1C, and pull through all the way. The free end of the wire will later be connected to the transistor socket for Q1.

Step 38 __ Solder the Red 6" wire to the PC board, at the location marked Q2C. Proceed as in step 37.

Step 39 __ Solder the Orange 6" wire to the PC board, at the location marked Q1E. Proceed as in step 37.

Step 40 __ Solder the Yellow 6" wire to the PC board, at the location marked Q2E. Proceed as in step 37.

Step 41 __ Solder the Green 6" wire to the PC board, at the location marked B1. Proceed as in step 37.

Step 42 __ Solder the Blue 6" wire to the PC board, at the location marked B2. Proceed as in step 37.

Step 43 __ Solder the two Black 6" wires to the PC board, at the locations marked R3. Proceed as in step 37.

Step 44 __ deleted

Step 45 __ The assembly of the PC board is now complete. Double check the placement of all parts. Make sure all electrolytic capacitors and diodes are installed with the proper polarity.

Step 45 __ Mount Q1, 2N6284 NPN Power Darlington transistor to the heatsink. Put some heatsink compound on both sides of one of the two blue TO3 insulators. Put the insulator on the bottom of the transistor, with the blue side towards the transistor. Hold one of the two TO3 transistor sockets on the bottom side of the heatsink. The bottom is the side where two fins have been removed, to allow the PC board to be mounted directly onto the heatsink. The two bosses of the transistor socket should be inserted in the 1/4" holes in the heatsink. Make sure the base and emitter contacts line up with the smaller holes of the heatsink. Insert the transistor and insulator into the socket from the other side. Fasten securely with two 6-20 * 5/8" sheet metal screws.

Step 46 __ Mount Q2, 2N6287 PNP Power Darlington transistor. Proceed as in step 45.

step 46a - Install the thermal switch to the heatsink. The mounting bracket of the switch is installed with a 6-32 screw on one side. The other side is fastened by slipping it under the transistor socket of one of the power transistors. The V-notch in the mounting bracket fits around one of the mounting screws.

Step 47 __ Check transistor isolation. With a multimeter, check that the transistor cases are not shorted to the heatsink.

Step 48 __ Connect the Brown wire from the PC board to the collector terminal of the socket for Q1. The collector terminal is the one that connects to the case of the transistor with the two mounting screws. Solder.

Step 49 __ Connect the Red wire to the collector terminal of Q2.

Step 50 __ Connect the Orange wire to the Emitter terminal of Q1. This terminal is identified with the letter 'E' on the bottom of the socket.

Step 51__ Connect the Yellow wire to the Emitter terminal of Q2.

Step 52 __ Connect the Green wire to the Base terminal of Q1. This terminal is identified with the letter 'B' on the bottom of the socket.

Step 53 __ Connect the Blue wire to the Base terminal of Q2.

step 53a - Solder the two black wires to the two terminals of the thermal switch.

Step 54 __ Push the solder terminals of both transistor sockets down onto the base of the socket. This way they will not short to the foil side of the PC board. Make sure nothing is shorted together.

Step 55 __ Install the PC board in the cavity of the heatsink. Screw the 4 threaded circuit board supports into the threaded holes in the heatsink. Attach the thermal sensor (see step 44) to the heatsink by screwing it down with one of the board supports. Snap the circuit board onto the 4 supports. A squeeze of the locking head permits removal of the circuit board.

Step 56 __ Carefully inspect the space between the heetsink and the PC board and make sure nothing is shorting.

The assembly of the amplifier is now complete.
Now go to next section for making the final adjustments.

Initial adjustments.

The only adjustment needed is that of the bias current of the output stage.

Step 1 ___ Hook the amplifier up to a dual power supply of +/- 30 volt. See next section for the pin connections of connector P2.

Step 2 ___ Make an initial check of the power supply hookup. Measure the voltage between ground and pin-16 on the socket of IC1. This voltage should read negative 30 volts, the same as the power supply. The voltage on pin-15 of the socket should be the same as the positive power supply. Do not proceed further if these voltages do not check out.

Step 3 ___ Turn off the power supply and insert IC1, 16-pin dual in line package LM391. Make absolutely sure that the chip is inserted properly.

Step 4 ___ Connect a voltmeter or multimeter between the emitters of Q1 and Q2. A good spot to clip the leads on to is the leads of the 3W resistors R16 and R17, next to the markings Q1E and Q2E on the silk screen.

Step 5 ___ Turn the power supply on, wait a few seconds for the turn-on delay to expire, and adjust the voltage to 40 mV. This value will give a bias current of 40 mA in the output stage.

Step 6 ___ Check the thermal protection. Short out the leads of R3, the sensor that was mounted to the heatsink. The amplifier will turn off, and the bias voltage between the emitters of Q1 and Q2 should go to zero. If not, check assembly for wiring errors. Do not operate the amplifier without a working thermal protection.

Installation and use.

Figure-4 shows the input and output connections for the amplifier. The input signal is connected with connector P1, and the power is connected to P2. The loudspeaker is connected to P2 also. See also table-2 for the connector pin definitions.
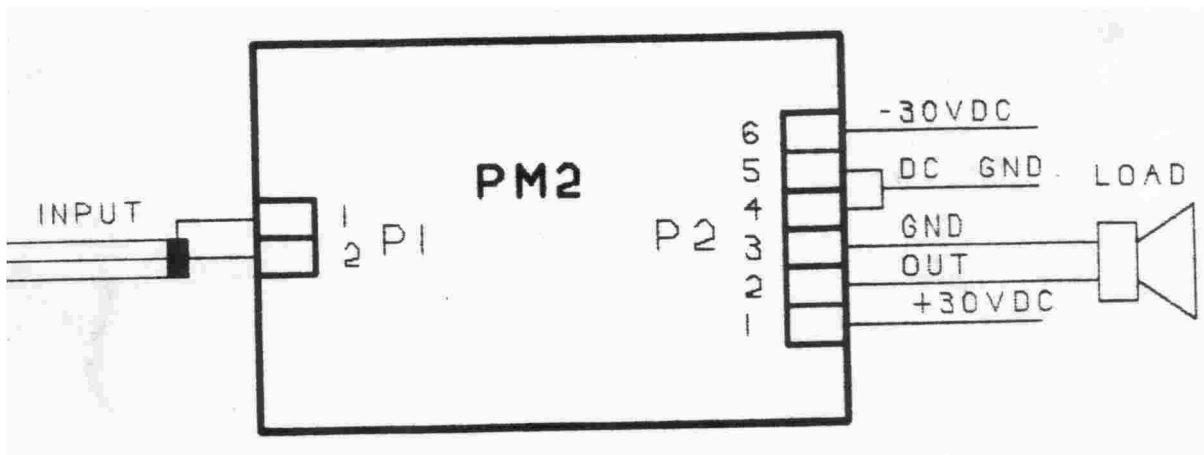
Figure 4. Amplifier hook up.

```
-------------------------------------------------------
|                     Table 2.                        |
|             Connector pin assignments.              |
| Connector   Pin #    Signal description             |
|=====================================================|
| P1          | 1 |    Input signal ground            |
| P1          | 2 |    Input signal                   |
|             |   |                                   |
| P2          | 1 |    V+, positive power supply      |
| P2          | 2 |    Output                          |
| P2          | 3 |    Output Ground                  |
| P2          | 4 |    Power Ground                   |
| P2          | 5 |    Power Ground                   |
| P2          | 6 |    V-, negative power supply       |
-------------------------------------------------------
```

Figure-5 shows the circuit for a typical unregulated supply suitable for this amplfier. A transformer with a center tapped secondary and a dual complementary rectifier circuit provide the raw DC power. The filter capacitor stores the DC energy during the peaks of the AC cycle and delivers the output current between the peaks. A large capacitance is needed for achieving a low ripple voltage. The 10K bleeder resistors allow the capacitors to discharge in a reasonable time after the supply is turned off.
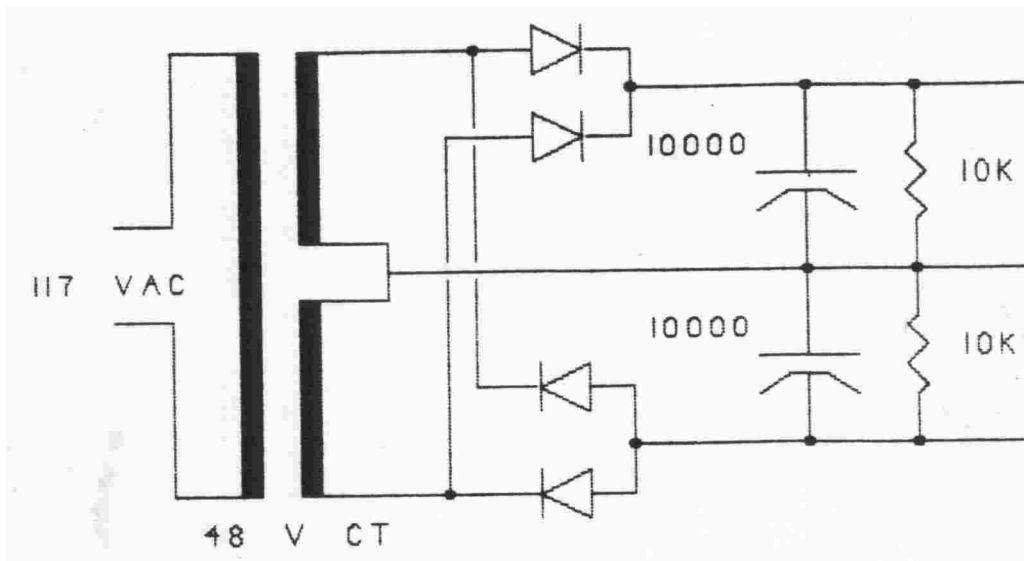

Figure 5. Typical simple unregulated power supply.

The following formula may be used for determining the transformer secondary voltage:

$$Vac = 0.7 * (Vout + Vripple + Vrect)$$

```
        Vac    = voltage of half of secondary (Volt)
        Vripple= p-p ripple voltage (Volt) (2V pp, typical)
        Vrect  = rectifier voltage drop. (Volt) (1V typical)
```

An output voltage of 30 Volt thus requires a transformer with dual secondary of Vac=23.1 Volt RMS. A transformer with a dual 24V secondary, or a 48V center tapped secondary is the proper choice and will give a Vout of 32V. The current rating of the transformer may be obtained with the following formula:

$$Idc = 0.35 * (Vdc - Vdrop) / Rload$$

$$Iac = 1.2 * Idc$$

```
        Idc   = DC power supply current (Amp)
        Iac   = transformer current (Amp)
        Vdc   = Supply voltage (Volt)
        Vdrop = amplifier dropout voltage (Volt)
        Rload = load resistance (Ohm)
```

The dropout voltage is the difference between the power supply voltage and the output at full output voltage. It is at least 3 Volt. For a 32 Volt supply and 8 Ohm load the transformer has to be rated at 1.3 amp at least. This means the transformer must have a Volt-Ampere rating of at least 65 VA.

The value of the filter capacitor can be estimated from the formula for the ripple:

$$Ipeak = (Vdc-Vdrop) / Rload$$

$$C = Ipeak / (3 * Fac * Vripple)$$

```
        Ipeak   = peak DC current (Amp)
        C       = capacitance (Farad)
        Vdc     = Supply voltage (Volt)
        Vdrop   = amplifier dropout voltage (Volt)
        Fac     = line frequency (Herz)
        Vripple = p-p ripple voltage (Volt)
        Rload   = load resistance (Ohm)
```

With a line frequency of 60 Hz the power supply thus needs a filter capacitor of 0.01 Farad, or 10.000 uF. The rectifier diodes should be rated at at least Ipeak=3.6 Amp and twice the peak to peak AC voltage of (48 * 1.42)=68 Volt

For powering multiple amplifiers from a single supply the ratings and values should be multiplied accordingly. A supply voltage of +/- 32 volt will give an output power of 50W into 8 Ohm. A higher power supply voltage will yield a higher output power. It is very important that the power supply voltage should never exceed the absolute maximum rating of +/- 45 volt. The maximum RMS power the amplifier delivers into a resistive load is given by:

$$Vmax=Vps-Vdrop$$

$$Pmax=(Vmax)^2 / (2 * Rload)$$

```
        Pmax  = maximum deliverd power (Watt)
        Vmax  = peak output voltage (Volt)
        Rload = load resistance (Ohm)
        Vps   = power supply voltage (Volt)
        Vdrop = amp. dropout voltage (Volt)
```

        (assuming the output current limit is not exceeded).

Thus, with a supply voltage of 45 Volt, a load of 8 Ohm and a typical minimum voltage drop between power supply and output of Vdrop=5 Volt, the maximum output power is 100 Watt.

The reason that the PM2 is rated at only half this power is that the heatsinks are not big enough to allow sufficient cooling for continuous duty at this power. Also, the typical load is not a pure resistor. As can be seen in figure-1 and figure-2, the current to voltage relationship of a typical reactive load causes higher currents at lower output voltages, and this causes the output current limit to be activated sooner than expected.
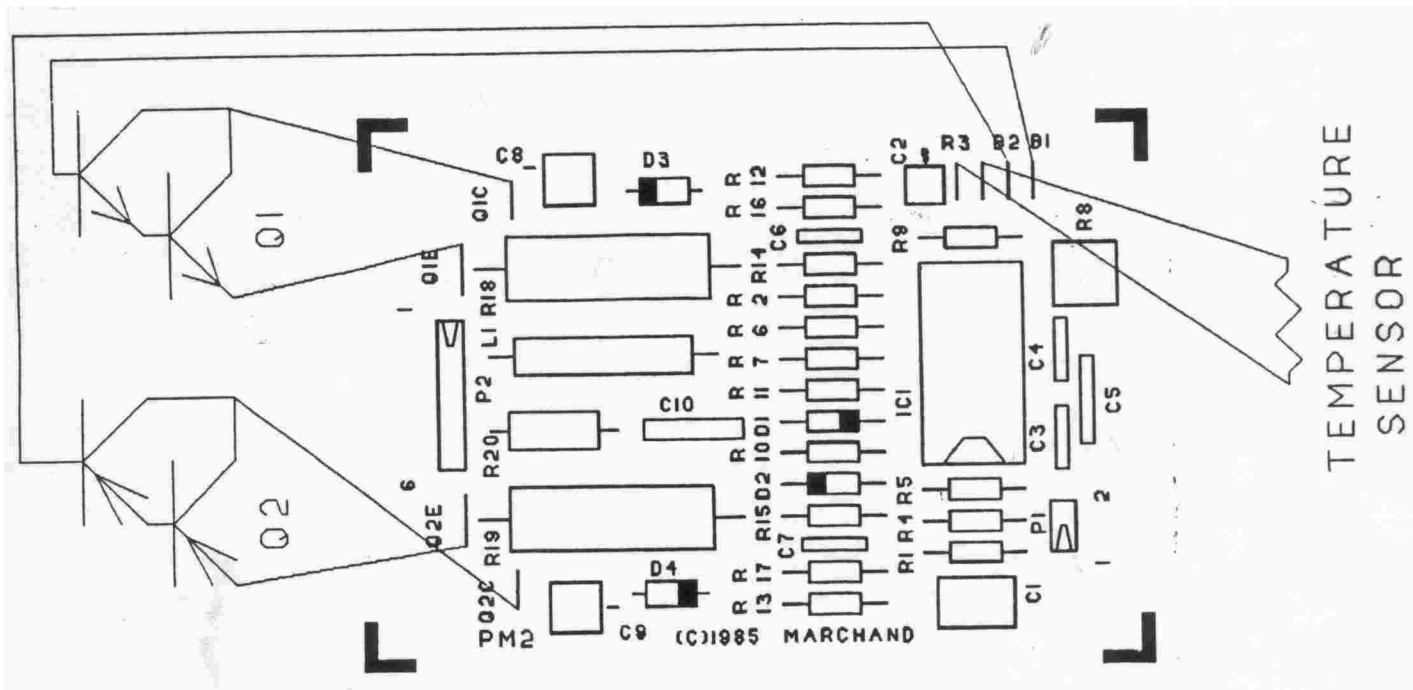

Figure 6. Silkscreen of 2.1"x3.0" board and external wiring.

Class A operation.

The PM2 can also be operated in class A mode if so desired. In this mode the amplifier can deliver 10 Watt RMS into an 8 Ohm load. In class A mode the bias current of the output stage should be adjusted to be 0.8 Amp. The assembly and adjustment is the same as described above, but in step 5, initial adjustments, the voltage between the emitters of Q1 and Q2 is adjusted to 0.8 Volt. The amplifier should be operated with a power supply of +/- 18 to 20 Volt DC, rated at 1.5 Amp. Use a regulated supply of +/-18VDC or use the unregulated supply of figure 5, but with a transformer with a secondary of 30 to 36 VCT @ 2A.
 In class A mode the amplifier will dissipate power regardless of driving a load. This means that the amplifier will become quite warm, and special attention should be given to proper cooling of the heatsink. If the amplifier keeps turning itself on and off, and the heatsink is hot, it is obviously overheating. Best cooling is achieved with the amplifier in a vertical position (i.e. the circuit board in a vertical plane), or with the use of a cooling fan.
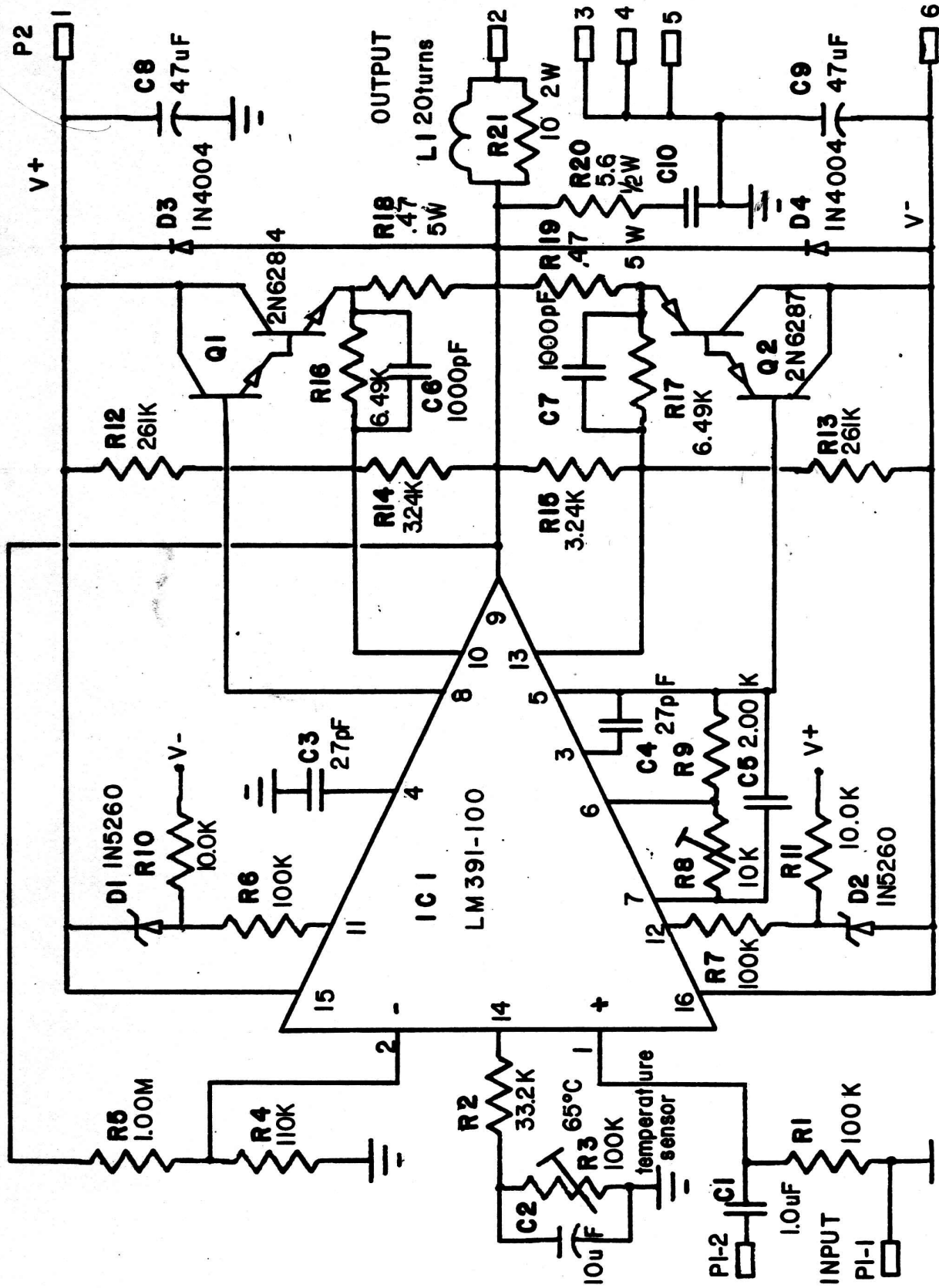
Fig.7   Model PM2   50   Watt AMPLIFIER

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