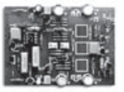

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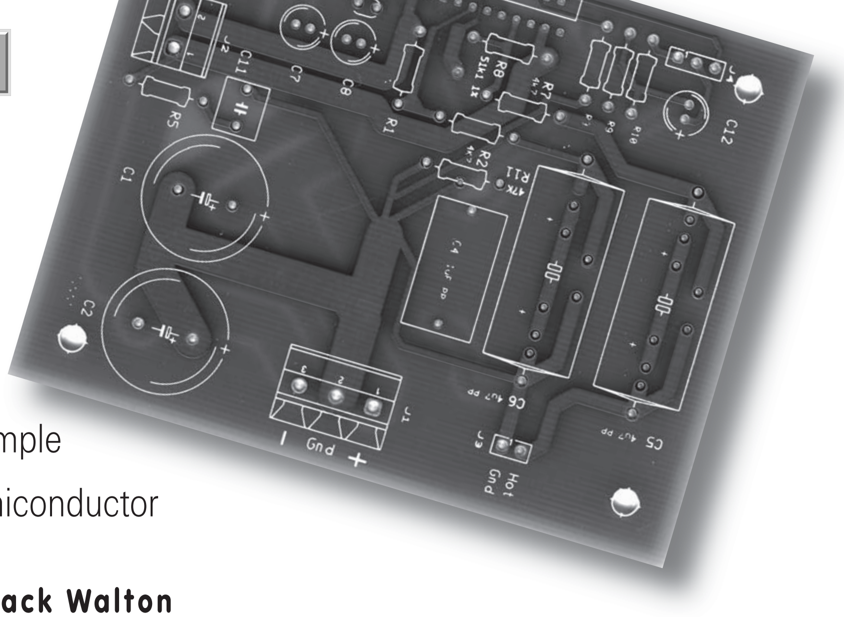


A 120W Bridged Chip Amp

This article describes a powerful yet simple amplifier based upon the National Semiconductor LM4780 audio operational amp.

By Jack Walton

While the design of this amp is straightforward, this isn't really a "beginner's project." The use of a printed circuit board is recommended, and you must exercise care in choosing an appropriate heatsink. Nevertheless, for those up to the task, this should be a rewarding project with the end result an amplifier capable of high output levels and low distortion. Gerber files for the amplifier printed circuit board are available on the audioXpress website (**www.audioXpress.com**).

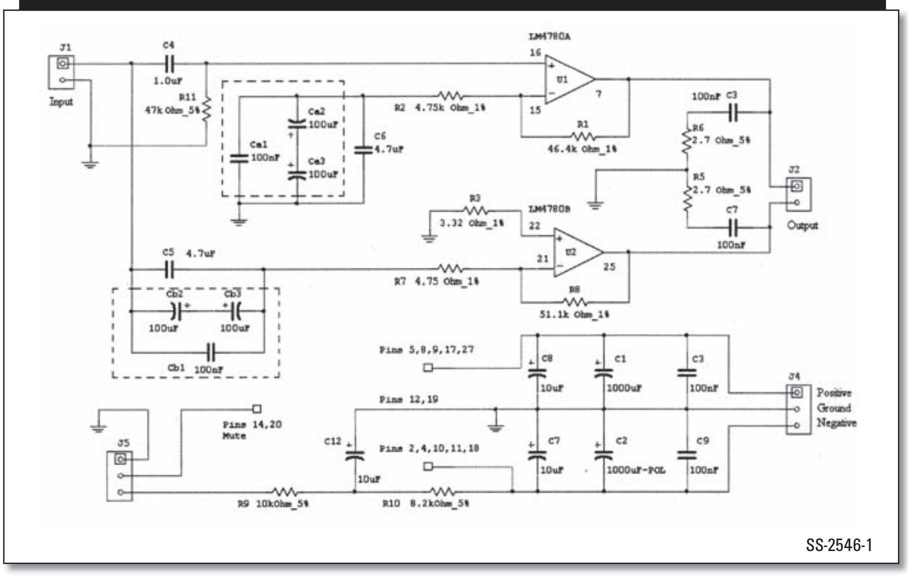
CHIP FEATURES

National Semiconductor's "**Overture Series**"™ of single-chip high power operational amplifiers has proven to be very popular with the DIY audio community. The chips are available in stereo and mono configurations, with mute capability, insulated and non-insulated packages, and power ratings up to 60W per amplifier section. National makes implementation of their chips even easier by providing the user with interactive design tools on their website, allowing you to determine the correct power supply and heatsink for each of the chips.

I have built a score of chip amplifiers using the LM3875 and LM3886 chips, but wished to go even further with a more powerful design. While National does provide a schematic and recommendations for two "bridge-parallel" designs for these op amps (the BPA100 and BPA200), I thought that it was high time to try a relatively new chip, the LM4780, in a high power configuration. This little beast, essentially two LM3886s in one case, is capable of delivering 120W into an 8Ω load with a ±32V power supply. The chip is only slightly larger than the LM3875 and LM3886, but the pin spacing is quite a bit tighter, necessitating the use of a printed circuit board. The chip and its cousin is shown in **Photo 1**.

The amplifier discussed in this article lives up to National's specifications, providing plenty of power at relatively low levels of distortion. To maximize performance in normal operation I used a power supply that somewhat exceeds the maximum suggested in National's interactive Overture Series Design Guide (**http://www.national.com/appinfo/audio/files/Overture_Design_Guide15.xls**), with ±26V on each rail. As the rail voltage is increased, the ultimate level of distortion is lowered. There is no free lunch, however. The amount of heat dissipated by the chip, Pd_{MAX}, increases at four times the square of the absolute rail differential in the bridged configuration, and the amplifier can tend toward thermal instability if the guidelines are significantly violated.

FIGURE 1: Amp schematic.



THE AMPLIFIER SECTION

The schematic of the amplifier section is shown in **Fig. 1**. One-half of the

LM4780 is designed as an inverting amplifier, the other noninverting.

While National's parts recommendations are used in this design, there is some flexibility in the printed circuit board design for the substitution of different coupling capacitors; i.e., you may use two 4.7µF polypropylene capacitors, or a pair of "back to back" 100µF electrolytics bypassed with a 1µF or 100nF polypropylene capacitor (shown in the dashed boxes). The 4.7µF coupling capacitor seems to be more than adequate for my purposes with a –3dB point of approximately 7Hz. The alternate components will lower the –3dB point to approximately 3Hz.

Decoupling the chip from the power supply is important, because the Overture series chips, operating at high gain, are susceptible to high frequency oscillation. The 100nF ceramic capacitors tackle this problem at the high end. The 10µF/63V electrolytics, on the other hand, will reduce the likelihood of "motorboating." I view the 1000µF/63V electrolytics as a localized reservoir, limiting supply droop or I^2R losses from the power supply to the operational amplifier.

The mute function can be selectively enabled, coupling pins 14 and 20 to the negative supply through the RC network as shown on the schematic, or by grounding and thus muting the amplifier. You can bypass the mute function by omitting C12 (10µF/50V electrolytic) and connecting pins 14 and 20 to the negative supply rail at the junction of R9 and R10.

CHOICE OF HEATSINK

For a bridged amplifier using the LM4780, calculated P_{DMAX} is four times that of a single amplifier! The required heatsink is quite a bit larger than you would normally assume to be adequate. The use of a fan thus becomes necessary. The LM4780 has a relatively small surface area to make thermal contact between the chip die and heatsink. If the chip isn't cooled sufficiently, the SPIKE!™ thermal protection will kick in.

I found that without a fan the heatsink temperature rose to nearly 200F° when the amplifier ran for a few hours. With the fan, however, the temperature rose to only 110F°. The fan is a 12V computer power supply fan—I wound 15 turns of #22 insulated wire around the toroid to derive 7V AC for the fan power. (The heatsink I used measured 11″ × 4.1″ with ten 1.3″ fins.)

P_{DMAX} for an 8Ω load with a ±26V DC ($|V_{CC}|$ = 52V DC) supply can be found as:

(1) $P_{DMAX} = 4*((VCC)^2/2\pi^2R_L)$

Thus,

$P_{DMAX} = 4*((52)^2/(2\pi^2 *8)) = 68.5W$

The required thermal resistance of the heatsink is found from:

(2) $[(T_{JMAX} - T_{AMB}) - P_{DMAX} (\Theta_{JC} + \Theta_{CS})]/P_{DMAX}$

In this case, $(\Theta_{JC} + \Theta_{CS})$, the thermal resistance from "junction to sink," is approximately unity, simplifying things a bit

$\Theta_{SA} = [(150 - 25) - 68.5]/68.5$

$\Theta_{SA} = 0.82$ C°/W

The thermal impedance of this sink is impractical unless some forced air is used.

It is important to securely mount the LM4780 to the heatsink. In initial trials of the amplifier, I found that the

PHOTO 1: Relative size of L4780 (left) vs. LM3886 (right).

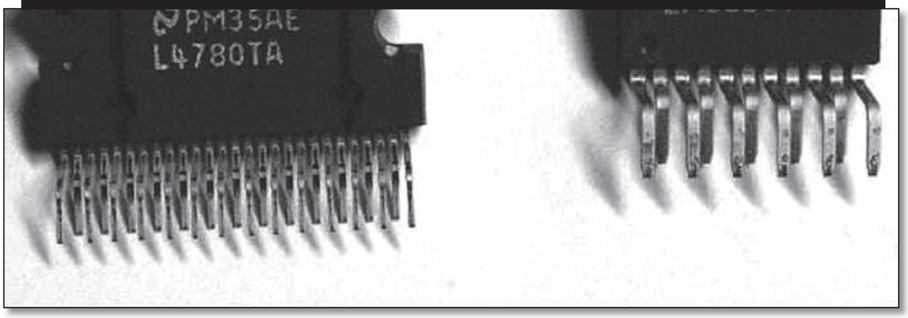
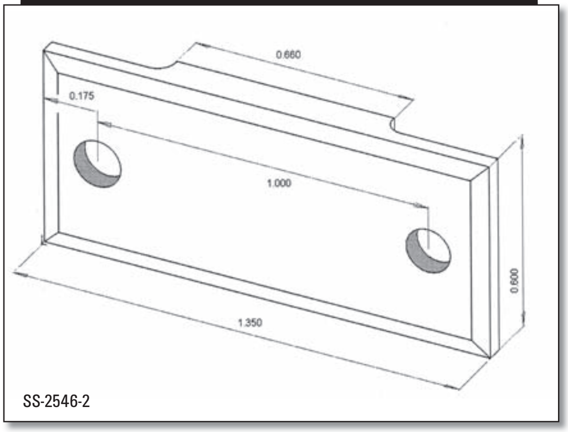


FIGURE 2: Mounting bracket.



unit would engage the SPIKE protection circuitry with only a few watts of power. To correctly secure the LM4780 to the heatsink, I fashioned a mounting bracket cut from a small piece of ⅛″ aluminum stock, drilled two 5⁄32″ holes to accommodate the mounting screws, and milled the edges down approximately 10 mils.

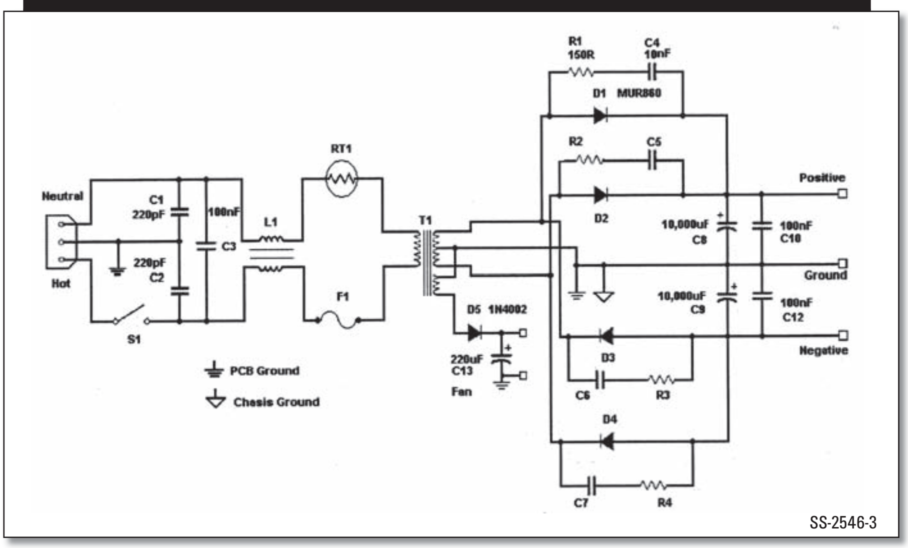
I tapped the heatsink for a 6-32 screw and mounted the device to the heatsink using the tensioning bar, 6-32 screw, and a star lock-washer. While I initially used a Berg Sil-Pad to provide insulation between the chip and heatsink, I later decided to mount the heatsinks for both channels on ¼″ birch plywood, securing them with nylon 6-32 screws. Note that the metal case of the LM4780 is connected to the negative supply rail. If you don't use an insulator on the chip itself, the heatsink must be insulated from the chassis.

THE POWER SUPPLY

The power supply is a straightforward full-wave bridge with 10,000µF filtration. To reduce RFI, use an input filter consisting of a bifilar-wound 2 × 1mH choke, two 220pF ceramic capacitors, and a 100nF "line rated" polypropylene capacitor.

Ideally, the power supply circuit should be protected with a 5A slow-blow 3AG fuse. In my amplifier, however, I used a switchable Airpax circuit breaker to provide protection since it was incorporated on the chassis that I cannibalized for the project. I used an inrush current limiter rated for 8A on the primary side of the transformer to limit the surge current, although you may find this unnecessary. I calculated the value of the RC snubbers for the MUR860 diodes using the stated diode capacitance (100pF at 30V DC), the inductance of the transformer secondary windings (15µH), and the interwinding capacitance (560pF) of the transformer. For the auxiliary fan supply I wrapped 15 turns of #22 insulated wire around the toroid. This provided approximately 7V AC, which is rectified and filtered to power the fan. The supply schematic appears in **Fig. 2**.

FIGURE 3: Power supply circuit.



PRINTED CIRCUIT BOARDS

I urge anyone building the bridged LM4780 amplifier to use a double-sided printed circuit board. The chip's pins are quite closely spaced and thin at 21 mils. The x-ray view of the PCB patterns shown pays attention to star-grounding and allows for alternate coupling capacitors. See **www.audioXpress.com** for Gerber files of the amplifier and power supply printed circuit boards. To use these files, download a Gerber file viewer such as Pentalogix "Viewmate" from **http://www.pentalogix.com/Download/download.html** and print the images onto clear, overhead transparent material to make your printed circuit board positives.

The power supply printed circuit board is single-sided. A power pole connector is shown on the AC input and output but you may directly solder to these points. I have provided for the use of Panasonic "THA" electrolytic capacitors. These have two "locating" pins—enabling those of us of a certain age to fit them in correctly, without fear of incorrect polarity!

CONSTRUCTION

For the finished amplifier I used a

PHOTO 2: Bridged amplifier.

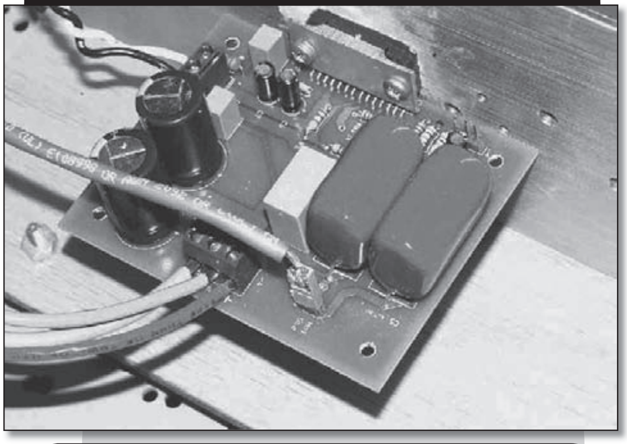


FIGURE 4: PCB Xray View 1.

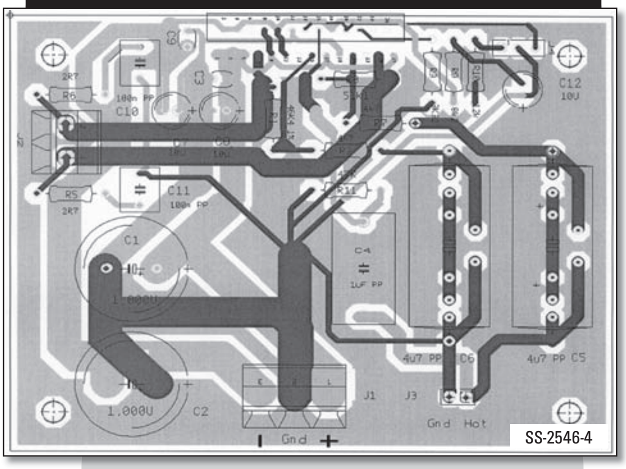


FIGURE 5: Power Supply Xray View 1.

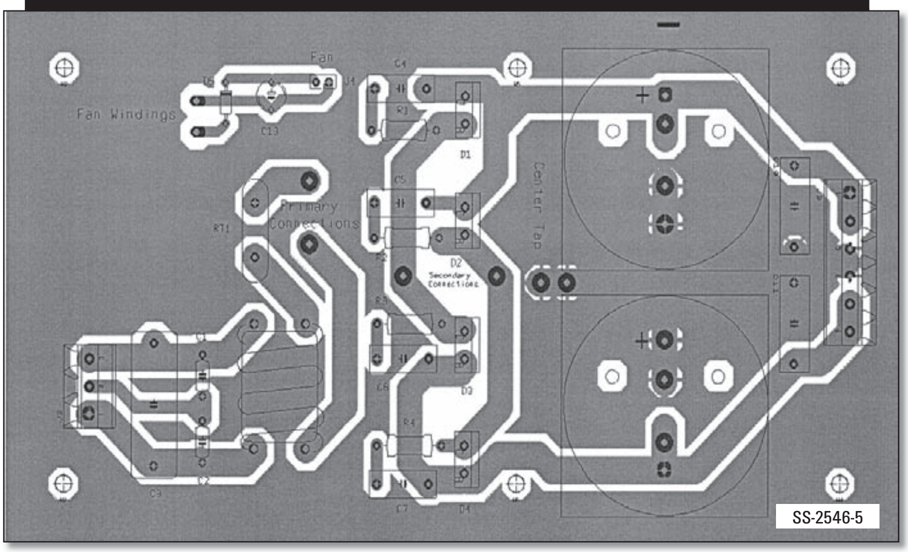


PHOTO 3: Power supply PCB mounted in chassis.

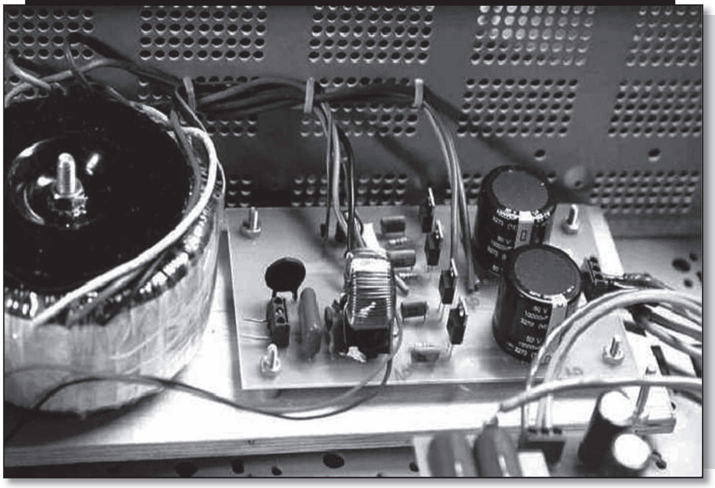
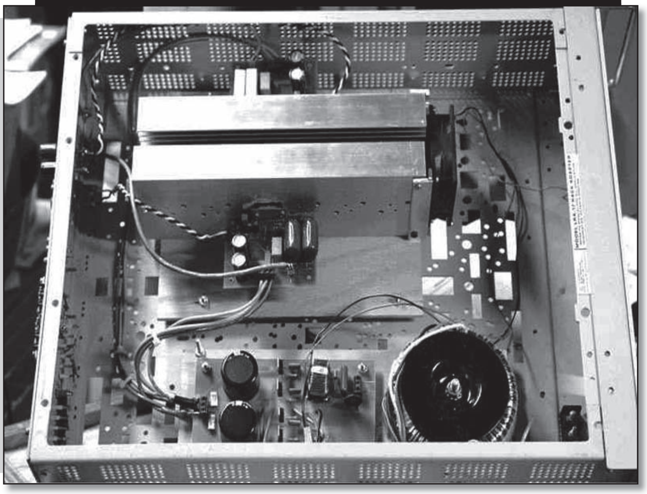


PHOTO 4: Completed amplifier.



spare chassis from a Lambda rack-mount power supply. The steel chassis allows an enormous amount of room to mount two amplifier boards, the heatsinks, and power supply, and it offers the distinct advantage that it was free. Those of you who are—from time to time—troubled by "domestic considerations" may choose a more elegant format for your design.

The completed amplifier is shown in **Photo 3**.

PERFORMANCE CHARACTERISTICS

The amplifier matches or exceeds the specifications published by National. As illustrated in **Fig. 4**, power is essentially flat through the audio band. Similarly, total harmonic distortion averages approximately 0.0033% from 10 to 120W across the audio spectrum, but climbs above 56kHz.

The test setup includes a Tektronix SG505 Signal Generator, Tektronix DA4084 and Boonton 1120 Distortion Analyzers, Tektronix TDS3014B Oscilloscope, and a Hewlett-Packard 3575A Phase-Gain Meter. The resistive load consisted of five 40Ω, 40W precision Dale resistors in parallel.

PARTS LIST

I have included a parts list (**Table 1**) with manufacturer and Digi-key part numbers. Not included are the part numbers for components that you probably have on your workbench. The transformer is available from several advertisers in *audioXpress* or on the web. You can wind the bifilar-wound input choke on a surplus computer power supply toroid. *aX*

FIGURE 6: Power performance.

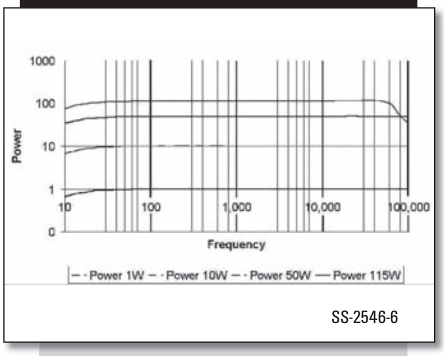


FIGURE 7: Bridged LM4780 THD + N%.

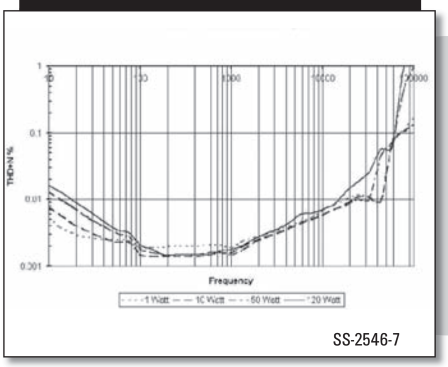


FIGURE 8: Frequency performance.

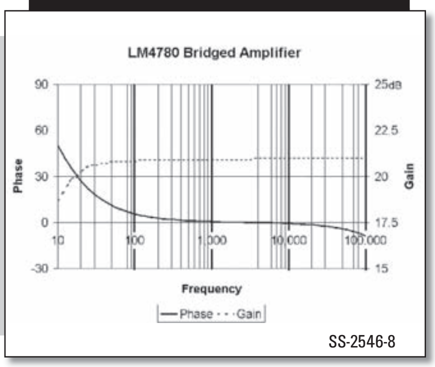


TABLE 1

PARTS LIST

Amplifier

Quantity	Reference	Description	Manufacturer, Part Number	Digi-key Part
2	C1,C2	1,000µF, 63V Radial Electrolytic Capacitor	Panasonic ECA-1JHM102	P5197-ND
2	C3,C9	100nF, 50V Ceramic Capacitor	Kemet C320C104K5R5CA	399-2054-ND
1	C4	1.0µF 63V MKP Polypropylene Capacitor	BC Components 2222 416 71005	BC2076-ND
2	C5,C6	4.7µF 250V MKT Polypropylene Capacitor	BC Components 2222 373 41475	BC1787-ND
3	C7,C8,C12	10 µF, 63V Radial Electrolytic Capacitor	Panasonic ECA-1JHG100	P5578-ND
2	C10,C11	100nF, 63V Polypropylene Capacitor	BC Components 2222 416 41004	BC2054-ND
1	R1	46K4 1% 0.25W Metal Film Resistor	Yaego MFR-25FBF-46K4	46.4KXBK-ND
2	R2, R7	4K75 1% 0.25W Metal Film Resistor	Yaego MFR-25FBF-4K75	4.75KXBK-ND
1	R3	3K32 1% 0.25W Metal Film Resistor	Yaego MFR-25FBF-3K32	3.32KXBK-ND
2	R5, R6	2R7 2W Metal Film Resistor	BC Components BC2.7W-2CT	BC2.7W-2CT-ND
1	R8	51K1 1% 0.25W Metal Film Resistor	Yaego MFR-25FBF-51K1	51.1KXBK-ND
1	R9	8K2 5% 0.25W Resistor	Yaego MFR-25FBF8K2	8.2KXBK-ND
1	R10	10K 1% 0.25W Metal Film Resistor	Yaego MFR-25FBF-10K0	10.0KXBK-ND
1	J1	1X3 Chassis Power Connector	OnShore ED1624	ED1624-ND
1	J2	1X2 Chassis Power Connector	OnShore ED1623	ED1623-NS
1	J3	0.100″ 1X2 Pin Molex Male Pin Header		NA
1	J4	0.100″ 1X3 Pin Molex Male Pin Header		NA
1	U1	LM4780 Amplifier Chip	LM4780T	LM4780TA-ND
Power Supply				
5	,C4,C5,C6,C7	1.0nF 400V Polypropylene Capacitor	BC Components 2222 419 41002	BC2177-ND
2	C2,C3	100pF 1kV Disc Ceramic Capacitor		P10804-ND
2	C8,C9	39,000 50V Snap In Electrolytic	Panasonic ECE-T1HA393FA	P10635-ND
2	C10,C11	100nF/63V Radial Polyester	Epcos B32529C104J	495-1103ND
4	D1,D2,D3,D4	MUR860 Diode 8A 600VDC TO-220	OnSemi MUR860	MUR860S-ND
4	R2,R3,R4,R5	150R 5% 1W Resistor		
2	RT1,RT2	2R5/0R06R Current Limiter, 8A	Thermometrics CL-30	KC003L-ND
1	T1	20-0-20, 400VA Transformer		NA
1	F1	3AG Type Fuseholder		NA
1	J1	AC Input Connector	OnShore ED1624	ED1624-ND
1	L1	Dual 1mH, bifilar wound input choke	Self made	NA
1	S1	SPST Switch		NA