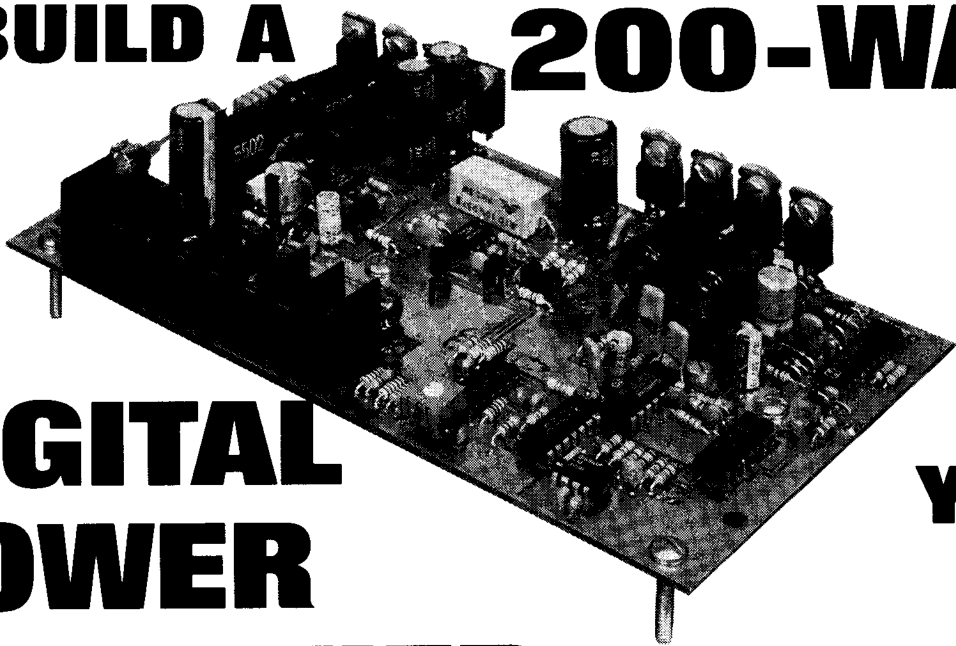
BUILD A 200-WATT DIGITAL POWER AMPLIFIER FOR YOUR CAR



ALAN BAYKO

Here's a project that will add zip to your driving experience—a low-cost, high-end amplifier that's equally at home in your car, boat, or home!

Most audio power amplifiers currently available on the market are some kind of analog design. That seems perfectly reasonable since sound is an analog signal. Unfortunately, high-powered amplifiers tend to be somewhat wasteful in power consumption, making them very hot when operating and fairly bulky due to their large heatsinks.

In the same way that switching-type power supplies are used in computer equipment for their compact size and efficiency, digital amplifiers have become a practical alternative to analog amplifiers. The 200-watt digital power amplifier presented here is designed to take advantage of that type of circuitry, especially in the areas of size, power usage, and heat dissipation.

The 200-watt digital power amplifier presented here is a class-D, single-channel, audio power amplifier that can output 200 watts rms into a 4-ohm load, or 100 watts rms into an 8-ohm load. For stereo applications, two amps will be required. The amplifier will deliver that output power at a 96% efficiency with a distortion value under 1% at 1 kHz, all in a package that measures 7 × 4 × 2 inches. The supply voltage can be between 10 and 18 volts, making it an ideal car stereo amplifier.

How It Works. In analog amplifiers, the output transistors are biased to operate somewhere in the transistor's linear-operating range. That means that some current is always flowing through the transistor, as the transistor is rarely either fully on or fully off. Current flowing through a transistor when there is a sizable voltage difference between the collector and emitter terminals causes the transistor to dissipate heat. Class D amplifiers, on the other hand, pulse-width-modulate the input signal. The analog input signal is converted to an on-off pulse of a single, steady frequency. The width of the pulses depends on the voltage of the input signal. For example, one cycle of a simple sinewave will generate a train of pulses that start with a 50% duty cycle (the ratio of on to off in a pulse train). As the sinewave rises, the duty cycle will increase as the pulses get wider, then decrease as the sinewave returns to zero volts. When the sinewave dips below zero volts, the process is reversed, with the pulses getting narrower then returning to a 50% duty cycle.

The conversion process will be easier to understand with the help of Fig. 1. A high-frequency triangle wave is used as a reference signal, and is compared digitally to the audio signal to be converted (Fig. 1A). If the voltage level of the audio signal is higher than the triangle-wave reference signal, the output is switched on. Naturally, when the audio signal is lower in voltage than the reference signal, the output turns off. That results

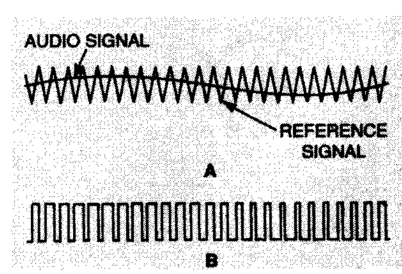


Fig. 1. Comparing an audio signal to a high-frequency, triangle-wave, reference signal (A) results in a series of high-frequency pulses whose widths track the original (B). That is how a class-D amplifier works.

in a pulse train similar to the one shown in Fig. 1B.

Pulses are easily amplified by a switching circuit. Switching circuits do not dissipate as much heat as their analog counterparts because there will be little or no voltage across the transistors when they are switched on, and no current flow when they are switched off. In either state, no power is consumed, so there will be little or no heat given off. The major cause for loss of power in switching circuits is the dumping of the stored charge in the circuit while the circuit changes state. While the transistors are switching, they are passing through their linear operating region, which is where most (if not all) of the heat generated by the amplifier comes from. Switching circuits, therefore, are very similar to CMOS logic circuits.

After the signal has been amplified, it is changed back to an analog signal by a low-pass filter. That removes the high-frequency signals introduced by pulse-width modulating the original signal. The result is an amplified version of the original input signal. If only inductive/capacitive filters are used for the output filter, losses will be very low.

Supply voltages for the 200-Watt Digital Amplifier are generated by a pair of DC-DC converters. Those converters are set up as current-mode controllers. In a current-mode controller, the amount of current flowing through a switching transistor is monitored. Knowing how much current is flowing allows the converter to

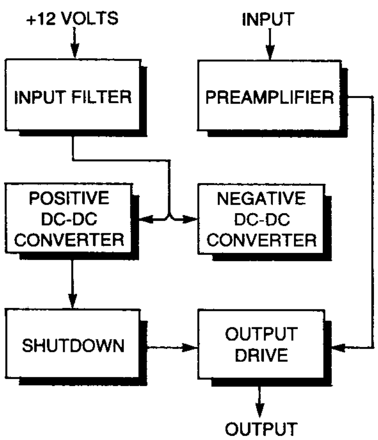


Fig. 2. The design of the 200-watt Digital Amplifier is quite straightforward. Most of the circuitry involved is connected with supply-voltage generation and fault detection.

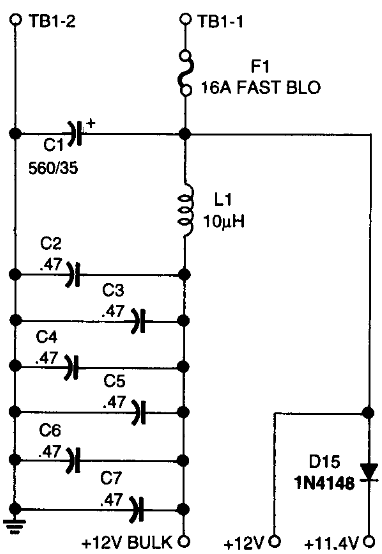


Fig. 3. The input filter for the 200-watt Digital Amplifier smoothes out any supply voltage spikes—either from the power supply or from the amplifier.

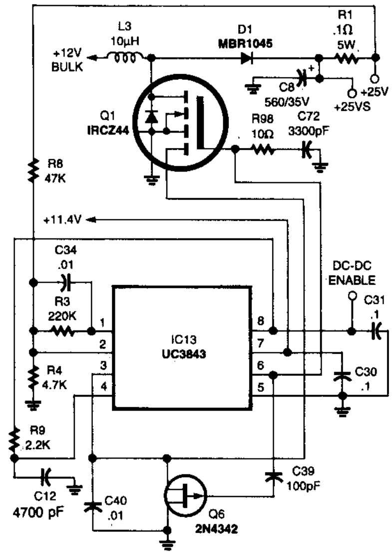


Fig. 4. The positive DC-DC converter creates a 25-volt power source from the 12-volt supply. An enable signal tells the rest of the circuit to shut down if the converter is having a problem.

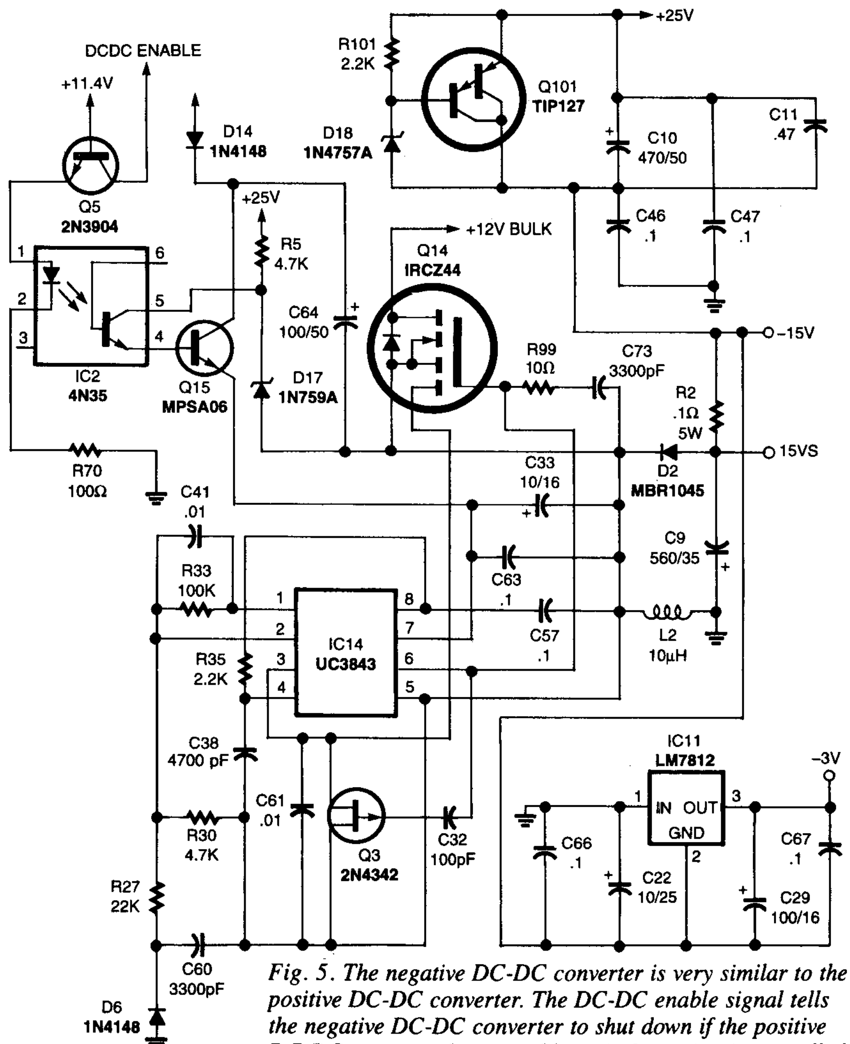


Fig. 5. The negative DC-DC converter is very similar to the positive DC-DC converter. The DC-DC enable signal tells the negative DC-DC converter to shut down if the positive DC-DC converter has a problem. A shunt circuit controlled by Q101 protects the amplifier from very inductive loads at low frequencies and high volume settings.

control how much energy is being converted by turning the transistor off at the right time. By increasing the current allowed through the transistor, the total energy converted by the circuit can be controlled. The current shut-off point is controlled by an error amplifier that monitors the output voltage. If the output voltage drops, the current through the transistor is increased until the voltage returns to the control-circuit reference.

The power amplifier circuit can be divided into the following sections: input filters, positive and negative DC-DC converters, unbalanced-load shutdown circuit, preamplifier, ramp generator, output drive, and output filter. Those sections and their interconnections are shown in Fig. 2. Each section will be described in order.

Input Filters And Converters. The input filter (Fig. 3) smoothes out any ripples that might appear in the supply voltage. The positive and negative DC-DC converters (Figs. 4 and 5) are both current-mode controllers. In both DC-DC converter circuits, the current is monitored using the voltage drop across the drain-source resistance of Q1 and Q14.

When Q1 is on, 12 volts is applied across L3, which causes current flow to build up through L3. The longer Q1 is on, the more current flows. When the error-amplifier portion of IC13 reaches the proper cutoff point, Q1 is turned off. The current in L3 continues to flow and is forced through D1 to the higher potential of the 25-volt supply. The current through L3 will decay because of the reverse potential across L3. After a preset time, Q1 is again turned on and the current through L3 will increase again. The current through L3 does not need to drop to zero before Q1 is turned on.

The negative DC-DC converter is very similar. The only difference is that Q14 and L2 are exchanged, and the polarity of D2 is reversed.

The positive DC-DC converter also generates an enable signal. In the event of a low-voltage condition, the positive DC-DC converter shuts down first. The positive DC-DC converter sends a signal to the negative DC-DC converter telling it to shut down, too.

Shutdown Control. The shutdown circuit of Fig. 6 is used to control

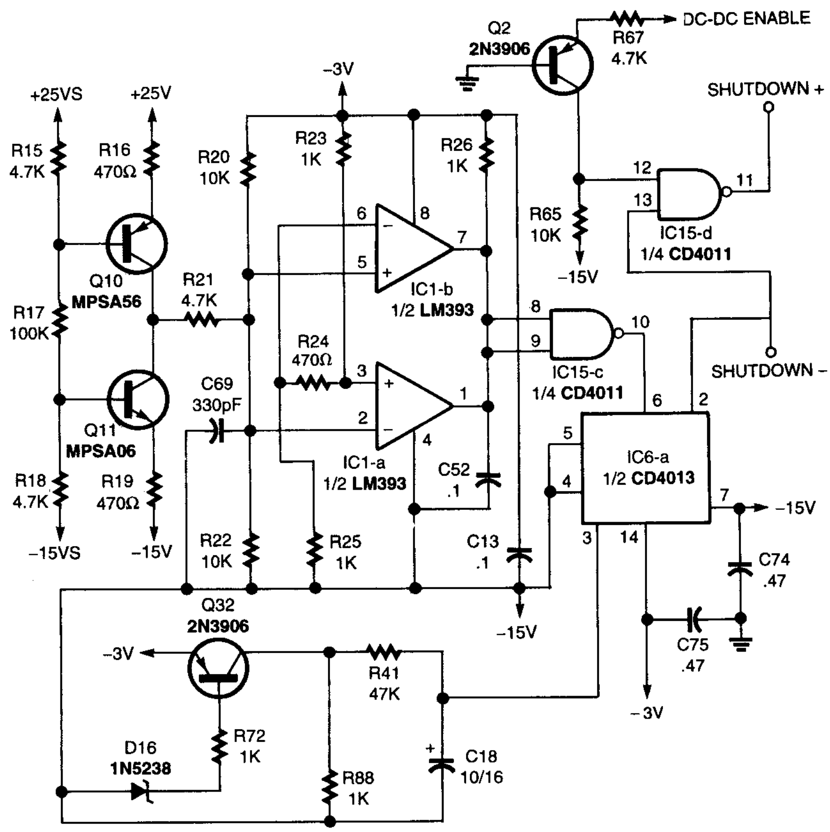


Fig. 6. The unbalanced-load shutdown circuit detects fluctuations in the supply voltages which would indicate a failure in one of the output transistors.

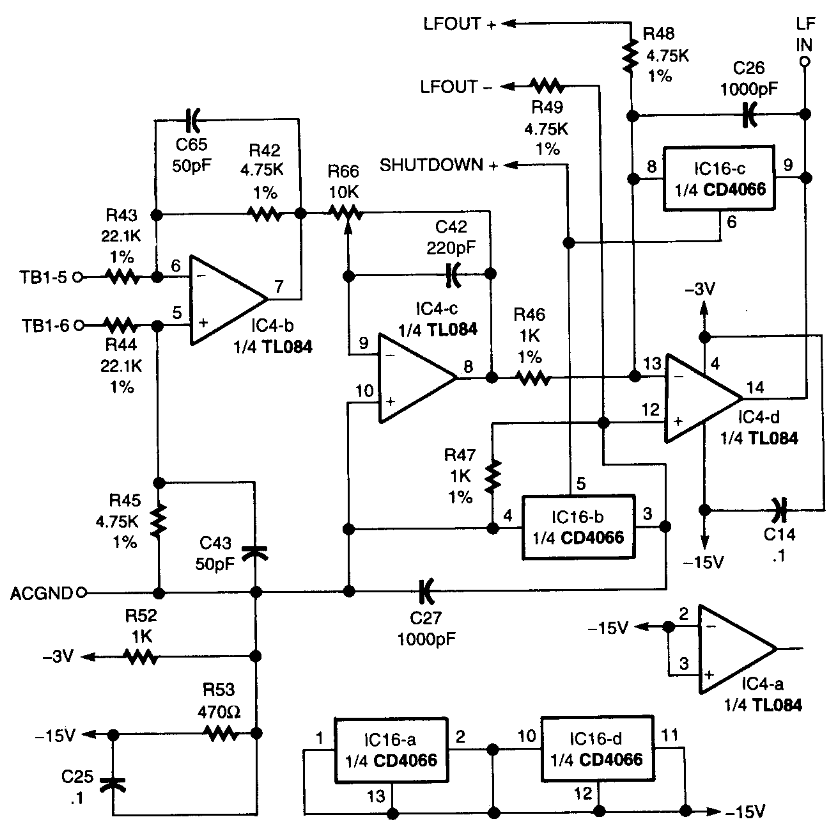


Fig. 7. The preamplifier conditions the input signal for pulse-width modulation.

whether the output transistors are active or shut down. Three conditions under which the output transistors should be shut down are when the power supply is starting up and the voltages are not stable, the input voltage is dropping and the power supply is shutting down, and when the amplifier output is shorted.

To allow the power supply to stabilize on startup, the output transistors are not enabled for ½-second after the difference between the −3-volt and −15-volt supplies reaches 12 volts. By tying C52 to the −15-volt supply, IC6-a starts up in the shut-down state. That prevents a startup pop in the speaker.

The enable signal from the DC-DC converters overrides the output of IC6-a by combining both signals using IC15-d. The enable signal goes low when the power supply is shutting down. That will temporarily shut off the output transistors until power voltages return to normal. The shutdown is temporary because it is possible for a signal spike to cause the external supply voltage to drop below 8 volts for a very short amount of time. When the amplifier is being turned off, a shutdown pop in the speaker is also prevented.

The final cause of shutdown is detected by monitoring the current in the positive and negative supply lines with Q10, Q11, and IC1. If the current in the negative supply is not the same as current in the positive supply, then there is a fault to ground. If that occurs, the output will be shut down and not restarted until power is removed and restored. There can be up to a 1-amp difference in the monitored currents before the amplifier is shut down to make up for component tolerances. A ground-fault shutdown is latched because it only occurs when there is a fault of some type in the wiring. If the shutdown is not latched in that condition, the amplifier would eventually damage itself.

Preamplifier. The preamplifier, shown in Fig. 7, is used to remove noise and condition the input signal for the drive circuit. It is also a part of the control loop for the output-drive circuit, and will be discussed later in this article.

The input signal is applied to both inputs of IC4-b. That method, called differential-input amplification, lets

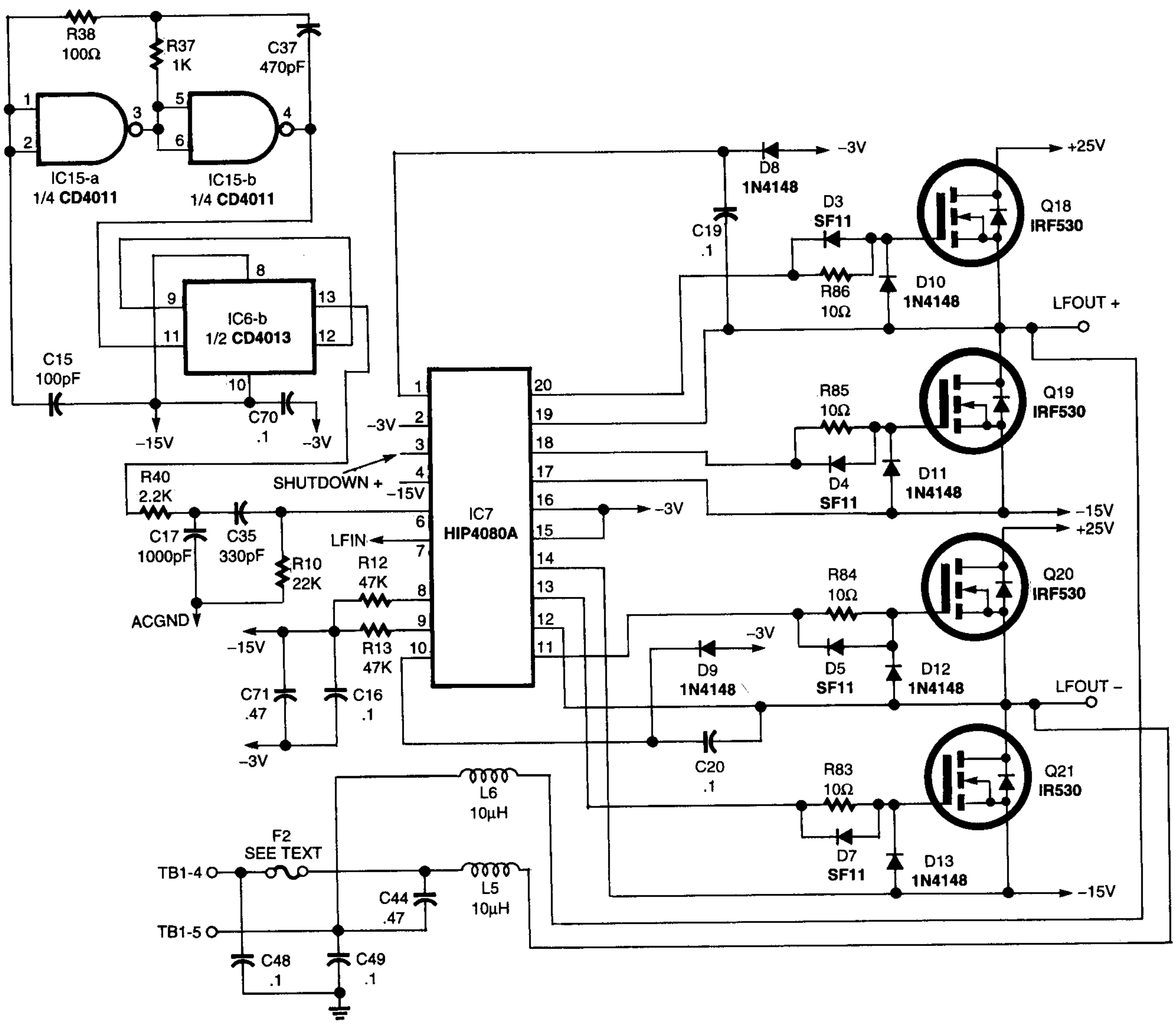


Fig. 8. The output drive circuit pulse-width-modulates and amplifies the signal. A pair of LC filters remove the high frequencies generated by pulse-width modulation.

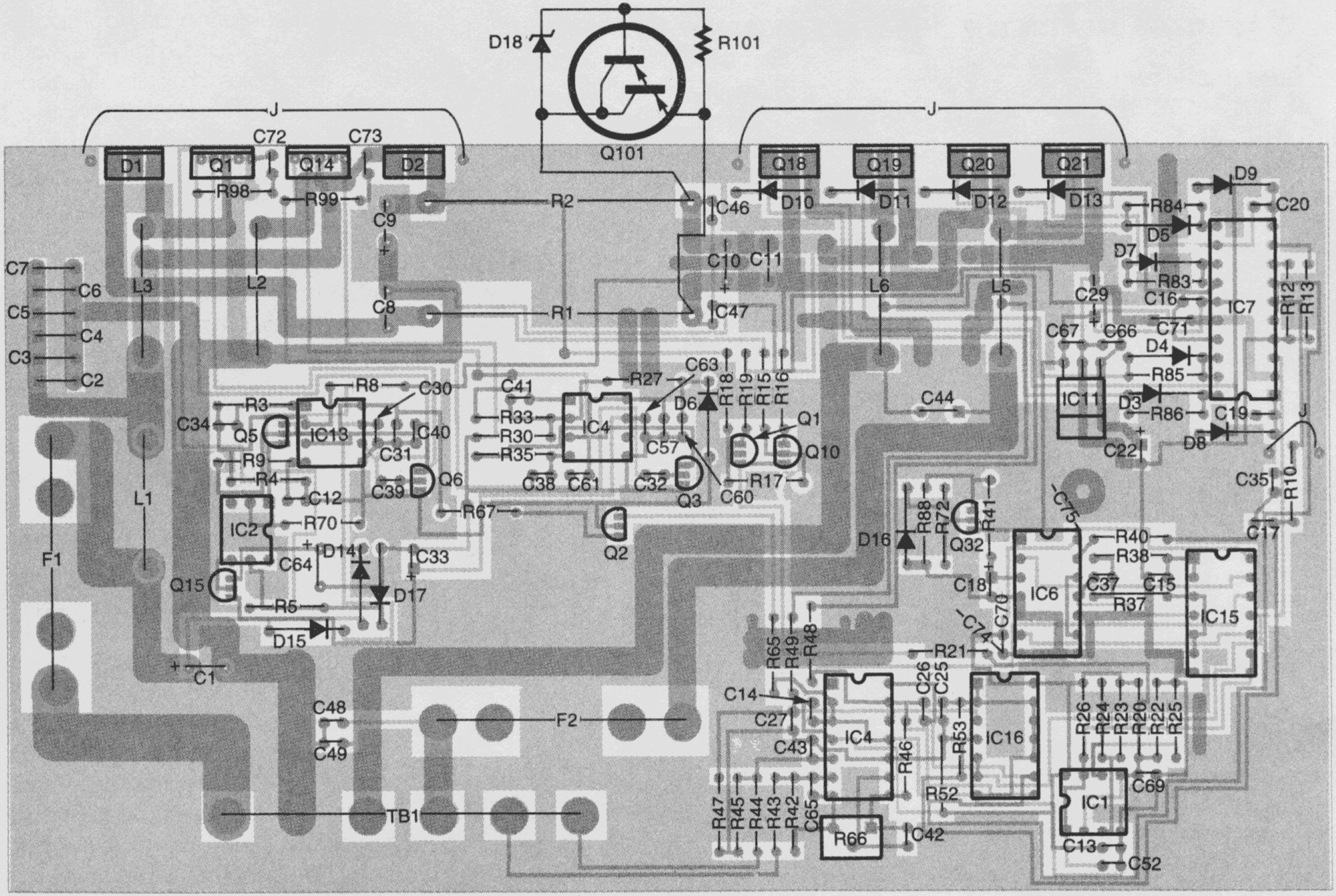
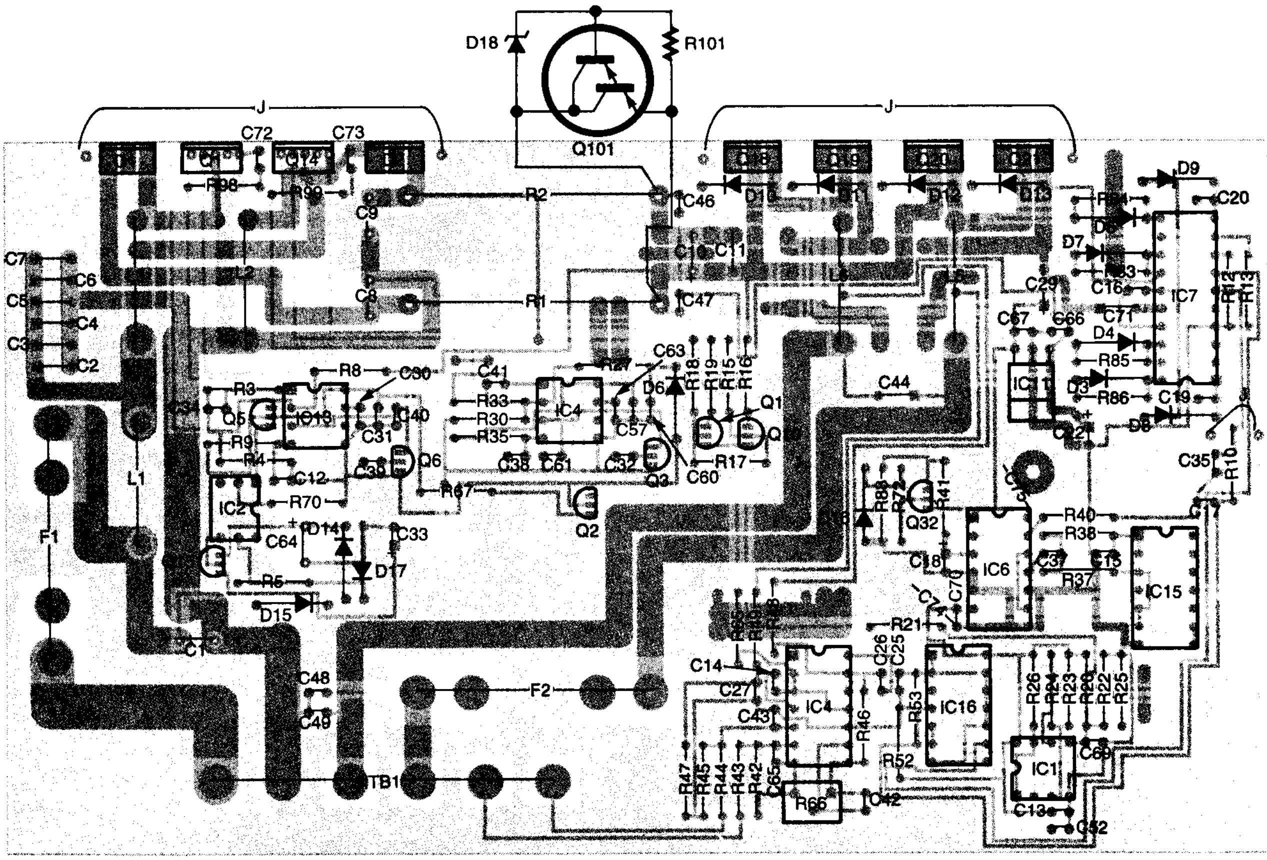


Fig. 9. Use this parts-placement diagram to locate where the various parts of the 200-watt Digital Amplifier are mounted on the PC board. Be careful when handling static-sensitive components such as IC7. Mount Q101, R101, and D18 on the case and connect them to the amplifier with insulated wire.



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IC4-b remove any common-mode noise between the local AC ground and the signal-source ground. An added advantage of using differential inputs is that the entire amplifier can be powered from an AC-isolated source, therefore preventing interference with other electronic devices. The amplifier gain can be set to any level between 0.125 and 125, with a gain of about 1.25 when R66 is set to its midpoint.

Output Drive. The actual amplification is done by the output drive and support circuitry in Fig. 8. The audio signal is pulse-width modulated and the resulting pulses amplified. The ramp generator circuit for the triangle-wave reference signal is a simple oscillator using two gates of IC15. That oscillator generates a fixed frequency of about 1 MHz. That frequency is divided in half by IC6, resulting in a perfect squarewave. Resistor R40, along with C17 and C35, forms an integrator that changes the squarewave into a triangle wave.

The triangle wave is applied to IC7, where the actual pulse-width encoding is done. The encoder is placed in a control loop with the preamplifier. That reduces any distortion and noise. The distortion is caused by a less than perfect ramp and the bridge-drive dead time (when no output transistors are on). The control-loop error amplifier is IC4-d in the preamplifier. It has a high-frequency roll off to keep the loop stable and make it immune to high-frequency switching noise.

The additional support circuitry in the output drive controls the turn-on speed of Q18–Q21 and prevents ringing. The turn-on speed of Q18–Q21 needs to be controlled in order to prevent current spikes. Those spikes originate from a freewheeling current (the speaker drive current) that turns on the body diodes of Q18–Q21. In order to prevent the stored charge in the diode from discharging too fast, the rise time of the gate voltage is limited. That discharge current is limited to about 30–50 amps.

If a short occurs across the outputs, then the fuse F2 should blow before any damage occurs. That fuse is also used to protect the speaker in the event of a transistor failure. Selecting the proper size is very important in order to properly protect the speaker. The recommended maximum size for F2 is 16 amps.

Construction. Important—The high-frequency, high-current switching used in the 200-watt Digital Amplifier might cause interference in radio equipment. The layout of the printed-circuit board is designed to limit RF radiation and prevent destructive ringing in the circuit. Component placement is important, so *do not* attempt to build the amplifier on perfboard.

Building the 200-watt Digital Amplifier is quite straightforward. Simply install the components in the board and solder them in place, following the parts placement diagram in Fig. 9. However, installing certain components before others will make construction much easier.

PARTS LIST FOR THE 200-WATT DIGITAL AMPLIFIER

SEMICONDUCTORS

D1, D2—MBR1045 silicon diode
D3–D5, D7,—SF11 silicon diode
D6, D8–D15—1N4148 silicon diode
D16—1N5238 Zener diode
D17—1N759A Zener diode
D18—1N4757A Zener diode
IC1—LM393 dual comparator, integrated circuit
IC2—4N35 optoisolator, integrated circuit
IC3, IC5, IC8–IC10, IC12—not used
IC4—TL084 quad op-amp, integrated circuit
IC6—4013 dual D-type flip-flop, integrated circuit
IC7—HIP4080AIP full-bridge driver, integrated circuit
IC11—7812 12-volt regulator, integrated circuit
IC13, IC14—UC3843 current-mode controller, integrated circuit
IC15—4011 quad NAND gate, integrated circuit
IC16—4066 quad bilateral switch, integrated circuit
Q1, Q14—IRCZ44 N-channel field-effect transistor
Q2, Q32—2N3906 PNP transistor
Q3, Q6—2N4342/J175 P-channel field-effect transistor
Q4, Q7–Q9, Q12, Q13, Q16, Q17, Q22–Q100—not used
Q5—2N3904 NPN transistor
Q10—MPSA56 PNP transistor
Q11, Q15—MPSA06 NPN transistor
Q18–Q21—IRF530 N-channel field-effect transistor
Q101—TIP127 PNP Darlington transistor

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise noted.)
R1, R2—0.1-ohm, 5-watt, 10%
R3—220,000-ohm
R4, R5, R8, R12, R13, R15, R18, R21, R30, R41, R67—4700-ohm
R6, R7, R11, R14, R28, R29, R31, R32, R34, R36, R39, R50, R51, R54–R64, R68, R69, R71, R73–R82, R87, R89–R97, R100—not used
R9, R35, R40, R101—2200-ohm
R10, R27—22,000-ohm
R16, R19, R24, R53—470-ohm
R17, R33—100,000-ohm
R20, R22, R65—10,000-ohm
R23, R25, R26, R37, R52, R72, R88—1,000-ohm
R38, R70—100-ohm
R42, R45, R48, R49—47,500-ohm, 1/4-watt, 1%, metal-film
R43, R44—22,100-ohm, 1/4-watt, 1%, metal-film
R46, R47—1,000-ohm, 1/4-watt, 1%, metal-film
R66—10,000-ohm, variable (BOURNS 3386P-1-103 or similar)
R83–R86, R98, R99—10-ohm

CAPACITORS

C1, C8, C9—560 µF, 35WVDC, electrolytic, low ESR-type
C2-C7, C11, C44, C71—0.47 µF, ceramic disc
C10—470 µF, 50WVDC, electrolytic, low ESR-type
C12, C38—4700 pF, ceramic disc
C13, C14, C16, C19, C20, C25, C30, C31, C46–C49, C52, C57, C63, C66, C67, C70—0.1 µF, ceramic disc
C15, C32, C39—100 pF, ceramic disc
C17, C26, C27—1000 pF, ceramic disc
C18, C33—10 µF, 16WVDC, electrolytic
C21, C23, C24, C28, C36, C45, C50, C51, C53–C56, C58, C59, C62, C68—not used
C22—10 µF, 25WVDC, electrolytic
C29—100 µF, 16WVDC, electrolytic
C34, C41—0.01µF, ceramic disc
C35, C69—330 pF, ceramic disc
C37—470 pF, ceramic disc
C40, C61—0.01 µF, ceramic disc
C42—220 pF, ceramic disc
C43, C65—50 pF, ceramic disc
C60, C72, C73—3300 pF, ceramic disc
C64—100 µF, 50WVDC, electrolytic
C74, C75—0.47 µF, ceramic disc

ADDITIONAL PARTS AND MATERIALS

L1–L3, L5, L6—10-amp, 10 µH coil (Miller 5502 or similar)
L4—not used
F1—16-amp fast-blow fuse
F2—see text
TB1—Terminal strip, 6-terminal, PC-mount
Printed-circuit board, case, PC-mount fuse clips, 4-40 × 1/4-inch screws, 4-40 washers, 4-40 nuts, 8-32 × 1/2-inch screws, 8-32 × 3/4-inch screws, 8-32 nuts, TO-220 mica insulators, no. 8 × 1/4-inch spacers, etc.

Note: The following items are available from: Radical Electronics, Inc., 115 Hall Cr., Saskatoon, SK S7L 7G7, Canada, Tel./Fax: 306-384-8777: Kit of all parts less case, $100. Circuit board only, $23. IC7, $12. Add $4 for shipping charges. Prices for other parts are available on request. Prices listed are in US dollars.

Before soldering any components to the PC board, drill the various mounting holes in a suitably-sized enclosure. The enclosure should be made of steel and should be large enough to hold the PC board without the board touching any sides of the enclosure. The hole sizes and locations in Fig. 10 are measured from the inside of the case. Since it is easier to mark and drill the holes from the outside of the case, measure the thickness of your case's walls and add that measurement to the information given in Fig. 10.

The case will also act as a heatsink for the transistors and diodes in the TO-220-style package. It is best to begin by installing D1, D2, Q1, Q14, Q19, and Q21. The remaining transistors, Q18 and Q20, will be installed later during testing. Put five 8-32 × ¾-inch screws into the top side of the board and secure them in place with hex nuts. Temporarily slip ¼-inch long spacers over the screws and mount the PC board in the case with additional nuts. Make sure that the board does not touch any sides of the case, although is should come close to the side where the TO-220 transistors and diodes will be mounted.

Mount the transistors and diodes onto the case with 8-32 × ¼-inch screws and nuts. Solder each lead of the components to the top side of the board. Remove the PC board from the case, turn the board over, and solder each lead on the bottom side of the board. Do not solder two leads in a row on the same component—skip from component to component. That will allow each solder joint to cool enough that it will not melt again, possibly allowing the component to shift position. If that happens, the component will not line up properly with the mounting hole in the case when the board is reinstalled in the case. Due to the size of the components and PC board layout, C46 and C47 interfere with C10, and will be very difficult to place on the top side of the board. Those components should be mounted on the solder side of the board. Be sure to solder on both sides of the board for all components if your board does not have plated-through holes. Circuit traces on both sides of the board must be connected together, including any unfilled holes.

You might want to install IC4 before

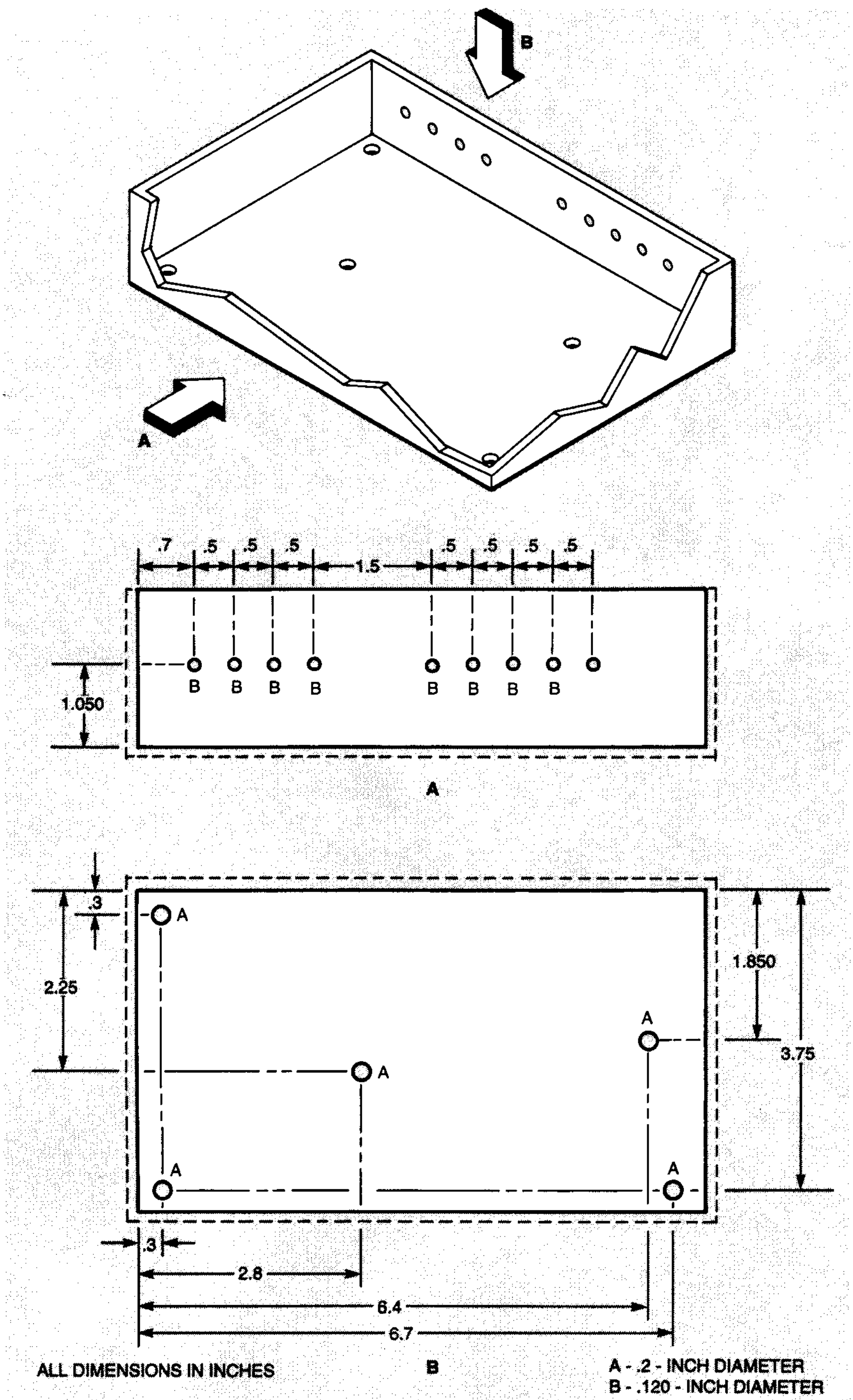


Fig. 10. The hole locations for the amplifier are shown from the outside of the case. The case should be made of steel. Not only is it used as a heatsink for the output transistors, the steel is an effective shield against radio-frequency interference.

R66, depending on the size of the trimpot's case. If needed, you can mount R66 on top of IC4, standing R66 up off the board. Capacitors C74 and C75 should be installed after IC6 is installed. Tack solder one lead of C74 to pin 7 of IC6, and the other lead to the ground plane. Install C75 the same way to pin 14 of IC6.

When installing IC11, be sure to use a mica insulator and insulated washer. The PC board's ground plane is used as a heatsink for IC11. Any contact between IC11's tab and the ground plane will short it.

There are 3 jumpers on the board that do not affect the circuit, but are required to reduce any radio-frequency interference (RFI) generated by the amplifier. They connect sections of the ground plane together. The jumper by R10 and C35 can be a scrap piece of resistor lead, but the two jumpers by the TO-220 transistors are much longer and should be insulated. Lengths of wire-wrap wire will do nicely. They should be dressed neatly along the edge of the board so they will not be pinched when the PC board is mounted in the case later.

Transistor Q101 is mounted in the unused hole in the case next to Q18. Bend the leads of Q101 so that the length of the entire component is no more than 1 inch in length from the center of the mounting hole to the bend in the leads. That will ensure that Q101, R101, and D18 will fit in between Q18 and D2.

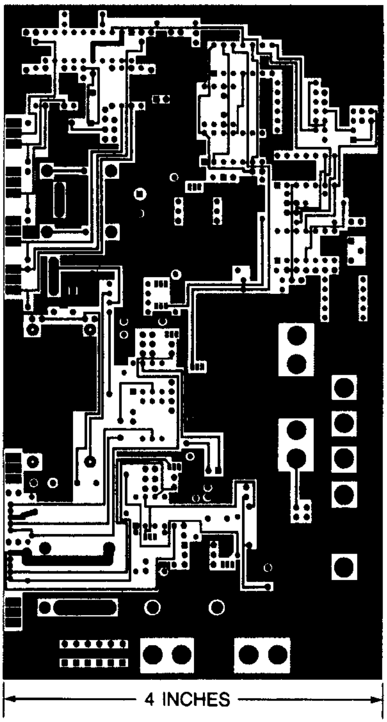
Cut two lengths of insulated wire. One wire will be about 1 inch long and the other will be about 2 inches long. Strip about ¼-inch of insulation from each end. Trim one lead of R101 and solder that lead to the emitter lead of Q101. The same is done with the anode of D18, only solder D18 to the collector lead of Q101. Carefully bend the other lead of R101 so that it crosses the cathode lead of D18, and solder it to the base lead of Q101. Wrap the cathode lead of D18 around the lead of R101 that is connected to the base lead of Q101, and solder the two leads together.

Carefully tack-solder the longer insulated wire to the emitter of Q101 and the shorter wire to the collector of Q101. The shorter wire is wrapped around the right-hand lead of R2 and the longer wire around the right-hand lead of R1. Solder those two connections.

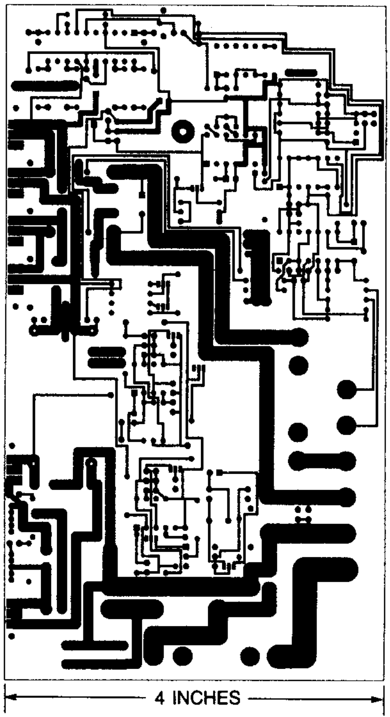
Since IC7 is *very* sensitive to static damage, it should be installed last. When installing IC7, make sure that you, your soldering-iron tip, and the circuit board are all properly grounded.

When all components except for Q18 and Q20 are installed, the amplifier is ready for testing. Be sure Q101 and its attached components are not touching any other components or the PC board.

Testing. Some of the voltages being measured during testing can only be measured when IC7 is disabled. Noise introduced into the circuit by measur-



Here is the component side of the board. It is shown half size for space reasons.



Here's the solder side of the board. It is shown half size for space reasons.

ing instruments can cause the circuit to malfunction. To measure the waveforms that do not have a return reference requires differential probes.

Connect the amplifier to a 12-volt power supply with a 4-amp capacity. If one is not available then use a supply with a 4700-µF capacitor across its outputs. Place a jumper across R24 to induces a shutdown. Apply power to the amplifier. It should not use more than 1 amp of current with an input of 12 volts.

Using ground as a reference, you should measure between 25 and 38 volts at the cathode of D1, and −15 volts ±20% at the anode of D2. The DC-DC enable signal (pin 8 of IC13) should measure somewhere between 4 and 6 volts.

Remove your voltmeter's negative probe from ground and connect it to pin 2 of IC11 (−15 volts) for the following measurements. Pin 3 of IC11 should read 12 volts with a 10% tolerance. Pin 3 of IC6 and the shutdown signal at pin 11 of IC15 should both read between 8 and 12 volts. Pins 7, 8, and 10 of IC4, along with pin 9 of IC16 should all read 4 volts ± 10%.

The triangle wave is best checked with an oscilloscope. Connect the oscilloscope's probe to pin 6 of IC7, and the ground to pin 2 of IC11. The frequency of the triangle wave should be 1 MHz with a 40% tolerance and a 3-volt peak-to-peak level sitting 4 volts above the −15-volt reference.

Now remove the jumper across R24. Place a jumper across C26 and C27 to disable the preamplifier. Again, using pin 2 of IC11 as a reference, pin 3 of IC7 should be between 0 and 4 volts. On IC1, pin 6 should read 4.8 volts, pin 3 should read 7.2 volts, and pin 5 should read 6 volts ± 10%.

Replacing the voltmeter with an oscilloscope, a 12-volt squarewave at 1 MHz should be present at pins 11, 13, 18, and 20 of IC7. Those measurements are referenced to pin 2 of IC11.

Remove power from the amplifier and install Q18 and Q20. Use the holes in the case to align the transistors in the same way as done for the other TO-220 components. Because of the other components on the board, you may use the holes from the outside of the case to align Q18 and Q20. Be sure to detach the case from the transistors before continuing the tests.

Re-apply power, and connect an oscilloscope's probe ground to TB1-2. A 1-MHz squarewave swinging between −15 and 25 volts should be present at pins 12 and 19 of IC7. The speaker outputs at TB1-4 and TB1-5 should both measure between 3 and 9 volts with a 3-volt ripple.

Now remove the jumpers across C26 and C27. With no input, the speaker outputs at TB1-4 and TB1-5 should both measure between 3 and 9 volts with a 3-volt ripple, referenced to pin 2 of IC11. Connecting the oscilloscope probes between the speaker outputs should measure between −0.25 and 0.25 volts including ripple. If all the voltages are correct, then a signal source and speaker can be attached to test out the entire amplifier. Keep the audio test at a low volume until the board is permanently mounted in the case.

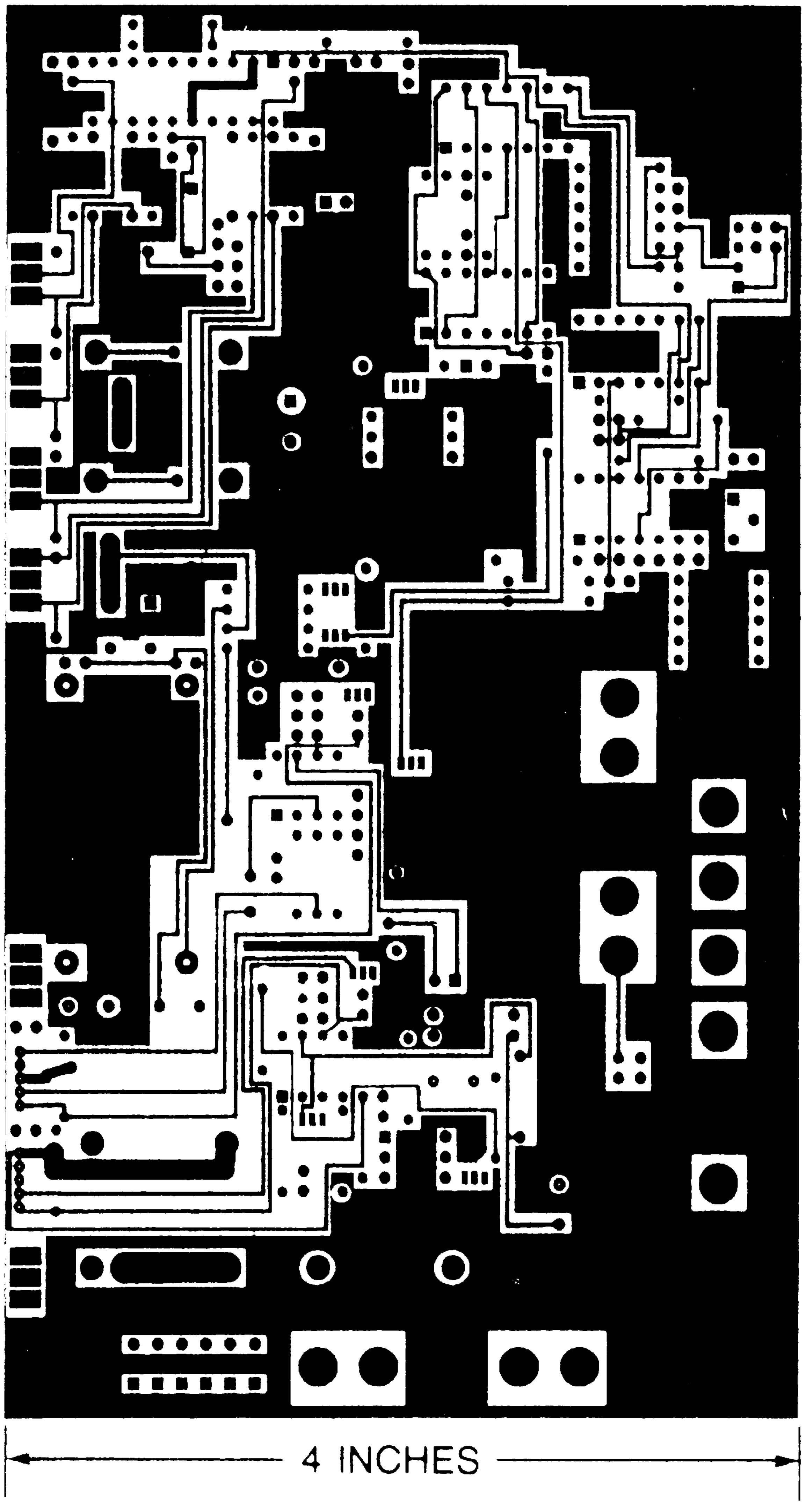
If everything checks out OK, install the PC board permanently with the ¼-inch spacers and nuts on the 8-32 screws mounted on the PC board. Use insulators, shoulder washers, and heatsink grease to attach the transistors to the case with appropriate screws and nuts.

If one of the FETs should burn out, it will usually destroy the other FET in that side of the bridge. It can also destroy IC7. Replace the FETs in pairs. When installing the new FETs, IC7 can be tested by placing a jumper across C26 and C27, installing the low-side drive FET, and checking for the squarewave gate drive from IC7. If the squarewave is not present on both FETs, then IC7 should be replaced. Once both gate drives are working, the high-side drive FET can be installed and the jumpers removed.

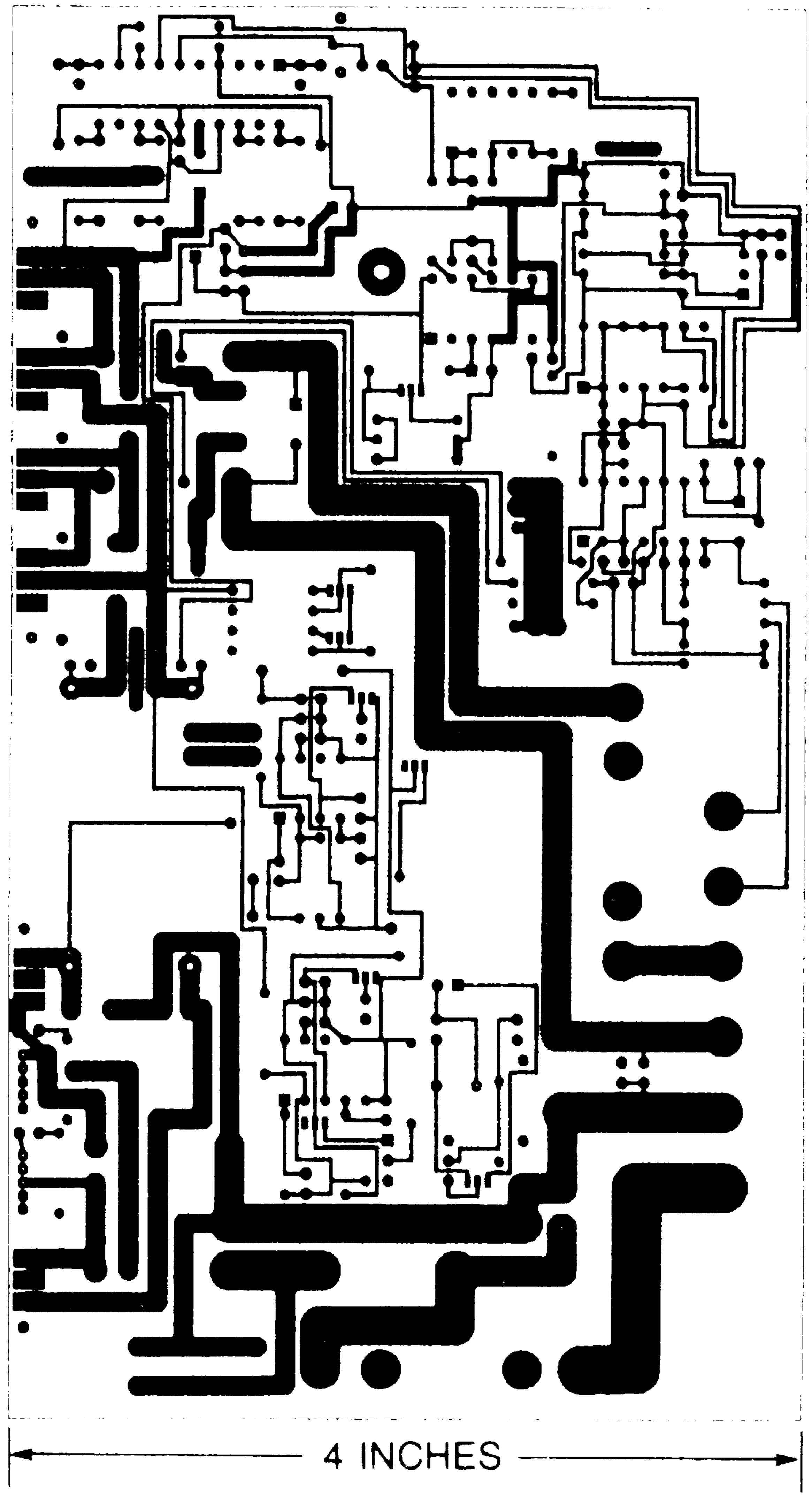
Using The Amplifier. When installing the amplifier, make sure that the input impedance of the 12-volt supply is less than 1 ohm. If the amplifier is to be installed in a home setting, or other location in which power will be drawn from a 117-volt wall socket, be sure that the 12-volt supply output has adequate isolation in order to avoid any shock hazard.

The differential inputs are very useful since the amplifier ground does not have to be at the same potential as the signal source ground. The negative input may be hooked to the source ground, using the positive input for the signal.

If you are driving the amplifier with an output that was meant to be connected directly to a speaker, you might need to add an 8-ohm resistor across the input terminals in order to reduce noise. Ω



Here is the component side of the board.



Here's the solder side of the board.

200 Watt Power Amplifier

Introduction

General Overview

Most audio power amplifiers currently available on the market are some kind of analog design. Digital amplifiers now offer a viable alternative to the standard analog amplifier design with major advantages in the areas of size and efficiency.

Specifications

The PA1X200 is a 200W per channel D class amplifier.

Frequency Range	2Hz to 20KHz +-3dB
Power Output	200W RMS into 4 ohms 400W peak
	100W RMS into 8 ohms 200W peak
Distortion	<1% at 1KHz
Size	7”x5.5”x2”
Efficiency	80% at full output into real load
	96% at full output into reactive load
Supply	10V to 18V DC up to 16A (.5A standby current)
Output Noise	60uV RMS
Input Impedance	47K
Input voltage range	-12V to +12V
CMRR	20dB

IMPORTANT

The high frequency/high current switching used in this project may cause interference in any radio equipment. Use the printed circuit layout included to limit RF radiation and prevent destructive ringing in the circuit. DO NOT attempt to construct this project on perf board. Component placement is important.

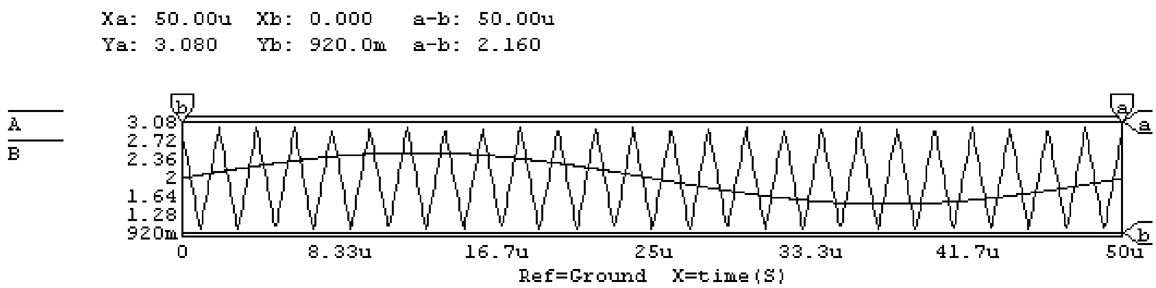
Theory of Operation (Overview)

The power amplifier consists of the 5 major blocks: DCDC converter, shutdown, output drive, preamplifier, and ramp generator. The DCDC converter generates the +25V and –15V supply. It also enables other parts of the amplifier with the DCDC ENABLE control line. In the event of a fault or low voltage condition the shutdown circuit disables the output FETs. The actual amplification is done by the output drive and support circuitry. The output drive pulse width modulates the signal and amplifies the pulses. The preamplifier is used to condition the input signal for the drive circuit. It also performs the function of error amplifier for the output drive control loop. A ramp generator is needed for the pulse width modulation. It is set for a fixed frequency of 250KHz 5Vpp.

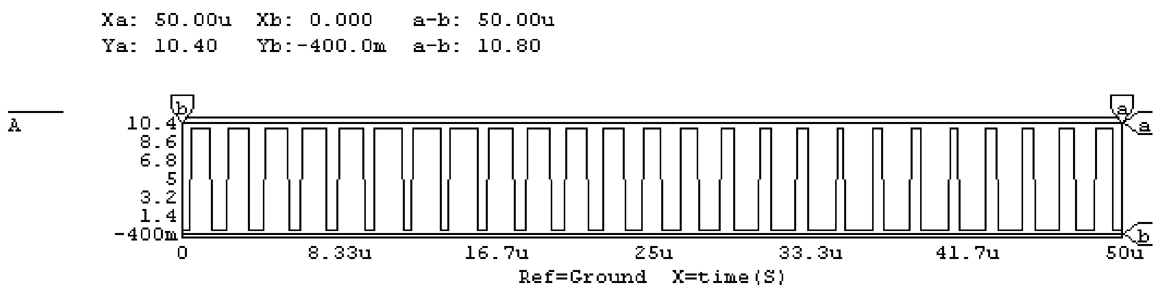
Theory of Operation - Output Stages

In an analog amplifier, the transistors are biased to operate somewhere in the linear operating range of the transistor. This means current is flowing through the transistor with a voltage across the transistor. The current and voltage causes heat to be dissipated in the transistor. Class D amplifiers use a switching circuit to amplify the signal. Switching circuits do not dissipate as much heat because when the transistors are ON there will be no voltage across them (hence no power) and when they are off there will be no current through them (and no power dissipated). The major loss of power in switching circuits is stored charge when the circuit changes state.

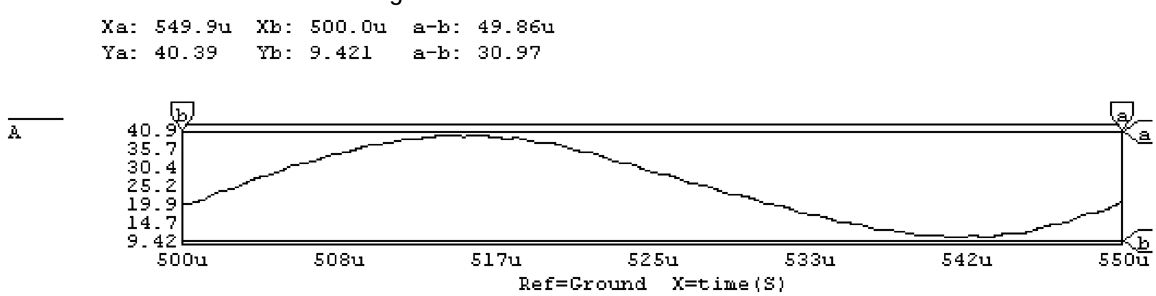
Class D amplifiers pulse width modulates the input signal. By pulse width modulating the signal, the voltage amplitude is converted to the on time duration of the pulses. Since a pulse is either a 1 or 0 a switching circuit can amplify it. After the signal has been amplified, it is returned to the analog domain by a low pass filter. This removes the high frequency components introduced by the modulation leaving an amplified version of the original input signal. If only inductive/capacitive filters are used the filter losses will be very low. See Figure 1 for waveforms.



Input and Ramp waveforms



Pulse Width Modulated Signal



Amplified, Low Pass Filtered, Pulse Width Modulated Signal

Figure 1 - Waveforms in a Class D Power Amplifier

In this application, the class D amplifier is placed in a control loop with the preamplifier. This is to reduce the distortion and noise introduced into the system. The distortion originates from an imperfect ramp and the bridge drive dead time (no FETs ON). The control loop error amplifier is IC4D in the preamplifier. It has a high frequency rolloff to keep the loop stable and make it immune to high frequency switching noise. IC4B takes the difference between IN+ and IN- to remove common mode noise between the local ac ground (ACGND) and the signal source ground. An added advantage of using differential inputs is the entire amplifier can be powered from an AC isolated source thus preventing interference with other electronics.

The additional support circuitry in the output drive controls the turn on speed of the FETs and prevents ringing. The turn on speed of the FETs needs to be controlled to prevent current spikes. These spikes originate from a freewheeling current (the speaker drive current) that turns on the body diodes of the FETs. In order to prevent the stored charge in the diode from discharging too fast, the rise of the gate voltage is limited. This discharge current is limited to about 30-50 A.

Theory of Operation - DCDC Converters

The DCDC converter used for this project is a current mode flyback converter. This means the switching transistor current is monitored to determine when the transistor is to be turned off. By increasing the current allowed through the transistor, the total energy converted by the circuit can be controlled. An error amplifier that monitors the output voltage controls the current shut off point. If the output voltage drops, the current through the transistor is increased until the voltage returns to the control circuit reference. A simplified version of the converter is shown in Figure 2. In the actual circuit, the current is monitored using the voltage drop across the drain source resistance of the FET.

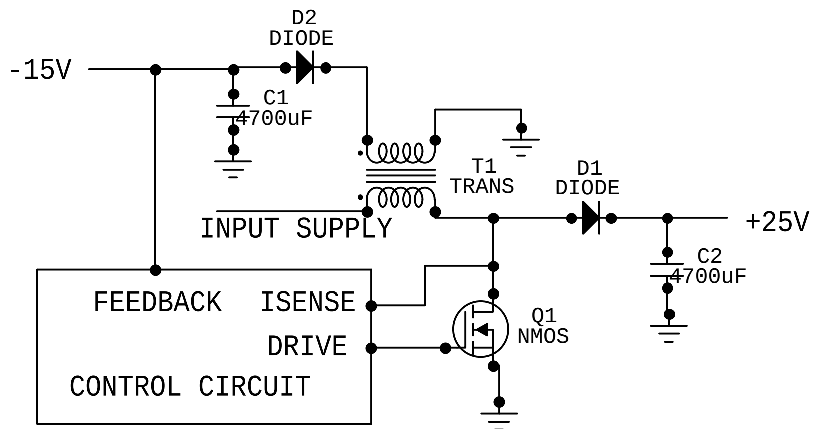


Figure 2 - Simplified Positive DCDC Converter

The positive DCDC converter a flyback converter and operates in two states:

1. When Q1 is ON, 12VDC is across the T1 primary causing a positive current to flow in T1. The longer Q1 is on, the more current flows. Q1 is turned off when the current reaches a point defined by the error amplifier.
2. When Q1 is OFF, the current through T1 continues to flow and is forced through D1 to the higher potential of the +25V supply. The current through T1 will decay because of the reverse potential across T1. Q1 is turned ON after a preset time and the current through T1 will increase again. The current through T1 does not need to be 0 before Q1 is turned ON.

The induced voltage in the second coil on the transformer generates the negative supply. The voltage on the secondary side is related to the voltage on the primary side by the turns ratio. Since the turns ratio is 1:1, the voltage generated on the secondary side will be the same as the voltage on the primary side.
During each ON cycle energy is stored in T1 from the input supply. During the OFF cycle this energy is transferred from T1 to the output of the converter. The energy stored in or removed from T1 is:

$$E = \frac{1}{2}L((I + \Delta I)^2 - I^2)$$

Where
I is the DC current in the inductor
ΔI is the change in the inductor current
L is the inductance of the primary coil.

ΔI is found using:

$$\Delta I_{ON} = \frac{V_{ON} t_{ON}}{L}$$

Where:
t_{ON} - the time Q is on
V_{ON} - the voltage across the transformer when Q1 is on (12V)

The on time, t_{ON}, is set by the time it takes for the total current I+ΔI to reach the point set by the error amplifier.

$$\Delta I_{OFF} = \frac{V_{OFF} t_{OFF}}{L}$$

Where:
t_{OFF} - The time Q1 is off
V_{OFF} - The voltage across the coil when Q1 is off. This will be 15V.

The off time, t_{OFF}, is set by a fixed oscillator.

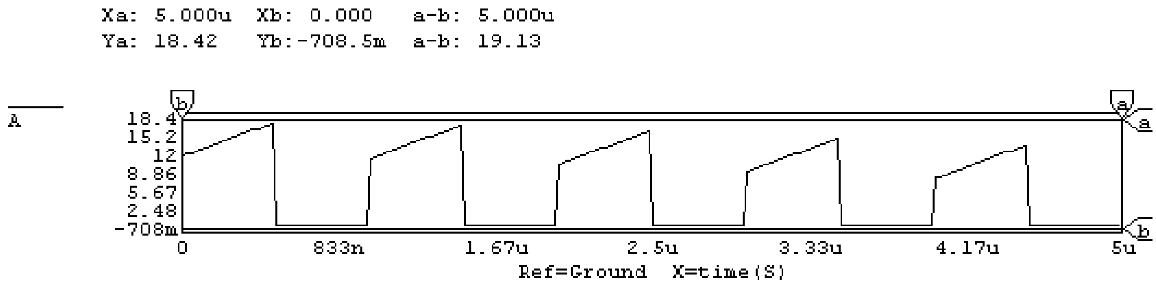
The DC primary current, I, is found using the following formula:

$$I_{tPRESENT} = I_{PREVIOUS} + \Delta I_{OFF} + \Delta I_{ON}$$

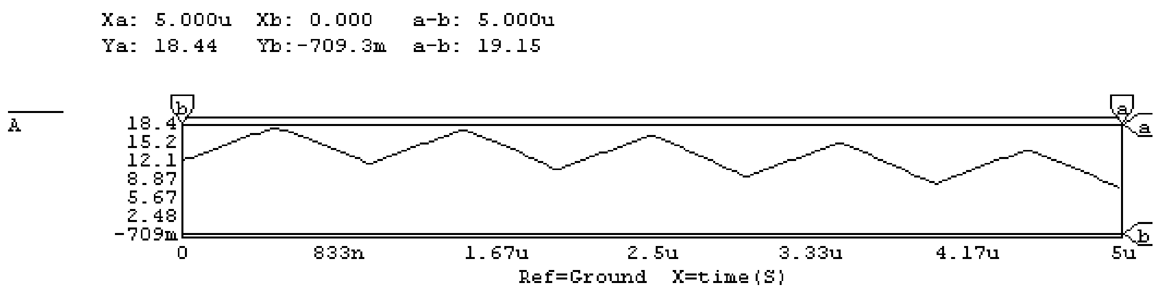
Where:
$I_{pPRESENT}$ is the DC primary current for this cycle
$I_{PREVIOUS}$ is the DC primary current from the previous cycle

If the circuit is at steady state then the change in current during the ON time must be equal to the change in current during the OFF state. If the change in currents do not cancel each other out, the DC current of the transformer will increase or decrease. This increase or decrease in current will increase or decrease the total power converted.

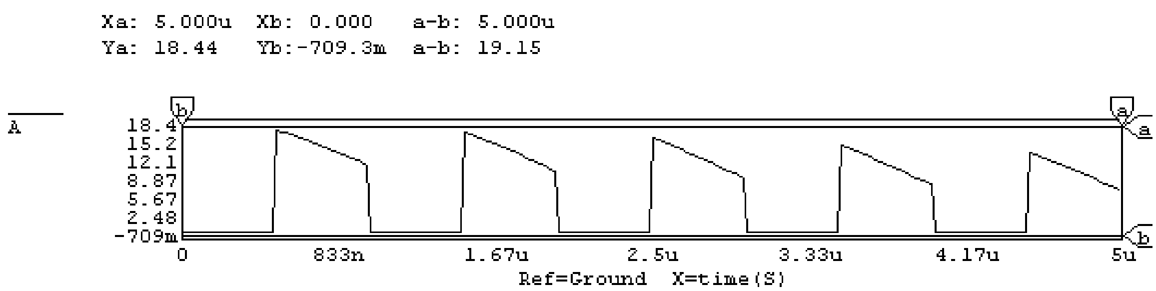
Voltage and current waveforms for the DCDC converter are shown in Figure 3. It is important to note the actual waveforms appearing in the circuit may be different depending on many factors. They are for illustration only.



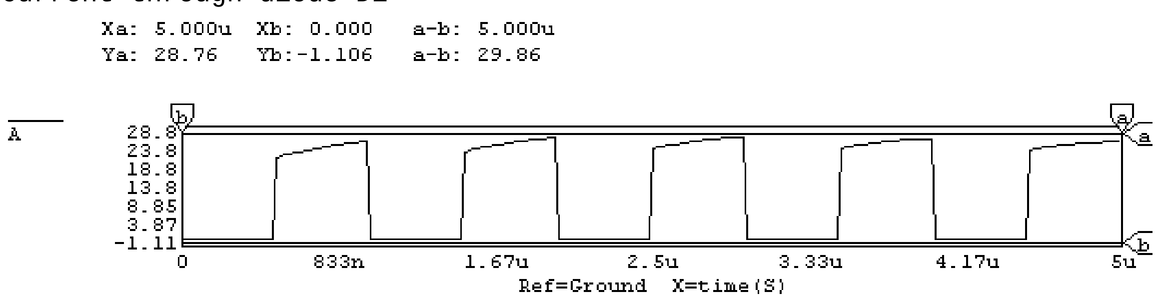
Current through Q1



Current through transformer T1



Current through diode D1



Voltage Vds for Q1

Figure 3 - Voltage and Current Waveforms for DCDC converter

The error amplifier (consisting Q203 and the op amp in IC203) monitors the output voltage of the supply. If the voltage drops below the control circuit reference voltage, the output of the error amplifier rises. The control loop is stabilized using a RC feedback loop. The current mode control structure is inherently stable for AC signals so the only delay that needs to be stabilized is the error amplifier and switching delays (time for FET switching to react to a change in control voltage).

Theory of Operation - Shutdown Control

The shutdown control circuitry is used to control whether the output FETs are active or shut down. There are three reasons to have the output FETs shut down:

1. The power supply is starting up and the voltages are not stable
2. The input voltage is dropping and the power supply is shutting down.
3. There is a short on the output of the amplifier (either terminal to ground).

To allow the power supply to stabilize on startup, the output FETs are not enabled for .5 seconds after the difference between the -3V and -15V supplies reaches 12V. By using capacitors tied to the -15V supply, the flip-flop (IC6A) starts up in the shut down state. This prevents a startup pop in the speaker.

The Supply State is monitored using the DCDC_ENABLE line from the DCDC converter. This line goes low when the supply is shutting down. It is used to temporarily shut off the output FETs until power is restored. The shutdown is temporary because it is possible for a signal spike to cause the external supply voltage to drop below 8V for a very short amount of time. This prevents a shutdown pop in the speaker.

The final cause of shutdown is detected by monitoring the current in the positive and negative supply lines. Because the output is a balanced bridge, if the current in the negative supply is not the same as current in the positive supply then there is a fault to ground. If a fault occurs the output will be shut down and not restarted until power is removed and restored. There is a window of about 1 amp to account for component tolerances and power to internal circuitry. The shutdown is latched because it only occurs when there is a fault in the wiring.

If a short occurs across the outputs then the fuse F2 should blow before any damage occurs. This fuse is also used to protect the speaker in the event of a FET failure so select a size that will protect the speaker. Use a maximum fuse size of 16A.

Construction

The amplifier is easiest to construct if the circuits are built up in the following order:
1) DCDC converter and Input Filter
2) Ramp Generator
   Unbalanced Shutdown
   Preamplifier
3) Driver
4) Output crossover

General construction notes:
-Information on component labeling is in Appendix A
-Information on soldering is in Appendix B
-After testing a section remember to discharge the large storage capacitors C201, C202, and C409. To discharge them place a 100 ohm resistor across the terminals for about 30 seconds.
-For all tests the heat dissipated by the amplifier is small and no heat sink or case is required.
-Use a supply that can supply 10A of surge current. If one is not available then use a supply with a 4700uF cap in parallel with the source.
-The first parts to install on the board are T101, L701, and L702. This is because mechanically, it is difficult to get at the leads of these parts when the other components are installed.

1)Input Filter and DCDC converter
Install all of the components in the input filter and DCDC converter as shown.
After all of the components have been installed connect the supply to the terminal strip. There should be about 12V across C102. The voltage at +25V should go to 15V plus the supply voltage. This would be about 27V for a 12V supply. The –15V supply should go to –15V.
Discharge the storage capacitors before debugging or proceeding to the next step.

Some common problems:
1)Supply doesn’t start up:
-Check for 5V on pin 8 of IC201
-Check for 12V on pin 7 of IC201
-Voltage at pin 2 is normally 2.5V. If it is higher then Q203 circuit is defective.
2)Supply doesn’t start up and input supply is held at +8 to 10V. Q201 gets hot
-Power train has a short or open in it.
-Input supply cannot provide a large enough startup surge. Before shutting down. Use a 10A supply.
3)Supply voltage is too high
-Q203 circuit is malfunctioning
4)Supply squeals or makes other obnoxious noises.
-Current feedback from Q201 is defective.

Note: If the unit is completed and has had a failure then J1 can be used to disable all of the circuits past the positive DCDC converter to allow this converter to be tested independently of the rest of the amplifier.
The schematic for the input filter is in Figure 5.
The schematic for the positive DCDC converter is in Figure 6.
Parts list in Table 1 and the parts placement diagram in Figure 11.

Table 1 - Parts List for First step.

C305-06	C101	3uF_100V_12.1A_FILM_CAP
C107-03	C102	100uF_35V_PTH
C478-03	C103	4700uF_35V_PTH
C478-03	C201	4700uF_35V_PTH
C478-03	C202	4700uF_35V_PTH
C104-01	C203	100nF 50V CERAMIC PTH 0.1"SPC
C472-01	C204	4n7F 50V CERAMIC PTH 0.1"SPC
C102-01	C205	1nF 50V CERAMIC PTH 0.1"SPC
C103-01	C206	10nF 50V CERAMIC PTH 0.1"SPC
C104-01	C207	100nF 50V CERAMIC PTH 0.1"SPC
C104-01	C208	100nF 50V CERAMIC PTH 0.1"SPC
C104-01	C209	100nF 50V CERAMIC PTH 0.1"SPC
1N4002-01	D101	1N4002 SILICONRECT 1A 100V
MBR1045-01	D201	10A_45V_SHOTKEY_RECT
MBR1045-01	D202	10A_45V_SHOTKEY_RECT
F15A3AG-01	F101	15A_3AG_FAST_BLO_FUSE
UC3843-01	IC201	UC3843_CURRENT_MODE_CONTROLLER
JMPR2P-01	J1	2 PIN 100MIL JUMP
L103-01	L101	10uH 10A ROD CHOKE
IRCZ44-01	Q201	IRCZ44_SENSEFET_0.024OHM
2N3906-01	Q203	2N3906 GEN PURPOSE PNP TRANSISTOR
R0R1-05	R201	0.1 OHM 5W 5% WIREWOUND RES.
R0R1-05	R202	0.1 OHM 5W 5% WIREWOUND RES.
R103-01	R203	10K 5% .25W PTH
R222-01	R204	2K2 5% .25W PTH
R104-01	R205	100K 5% .25W PTH
R222-01	R206	2K2 5% .25W PTH
R472-01	R207	4K7 5% .25W PTH
R472-01	R208	4K7 5% .25W PTH
R102-01	R209	1K_5%_1/4W_RESISTOR
R101-01	R210	100 OHM 5% .25W PTH
R470-01	R211	47 OHM 5% .25W PTH
R471-01	R212	470 OHM 5% .25W PTH
R101-01	R213	100 OHM 5% .25W PTH
R472-01	R214	4K7 5% .25W PTH
L153-01	T101	15uH_12A_LOW_EMI_COIL

2) Ramp generator, Unbalanced shutdown and Preamplifier.

Install all of the components shown in the schematics as shown.
Power up the amplifier and measure the voltage at ACGND.
The ramp signal should have a ramp on it (5 Vpp at 250KHz) with a DC voltage the same as ACGND. If this is not the case then there is a problem in the ramp circuit.
Shutdown+ should be at -15V.
Shut off power and jumper J2 (induce a shutdown). Don't forget to discharge the caps.
Shutdown+ should be at about -3V
Measure the voltage at the ACGND point.
Measure the voltage at pin 7, pin 8, and pin 14 of IC502. They should be at the same voltage as ACGND. If not, there is problem in the preamp.
Disconnect power but leave the jumper in place for the next test.
Discharge the caps before debugging or building up the rest of the circuit.

The parts list is in Table 2.

Table 2 – Ramp Generator, Preamp, and shutdown parts list

C103-01	C301	10nF 50V CERAMIC PTH 0.1"SPC
C104-01	C302	100nF 50V CERAMIC PTH 0.1"SPC
C106-03	C304	10uF 35V
C331-01	C401	330pF 50V CERAMIC PTH 0.1"SPC
C331-01	C402	330pF 50V CERAMIC PTH 0.1"SPC
C104-01	C403	100nF 50V CERAMIC PTH 0.1"SPC
C104-01	C404	100nF 50V CERAMIC PTH 0.1"SPC
C332-01	C405	3n3F 50V CERAMIC PTH 0.1"SPC
C102-01	C406	1nF 50V CERAMIC PTH 0.1"SPC
C109-03	C409	10000uF_50V_PTH
C104-01	C412	100nF 50V CERAMIC PTH 0.1"SPC
C107-03	C413	100uF_35V_PTH
C104-01	C414	100nF 50V CERAMIC PTH 0.1"SPC
C104-01	C415	100nF 50V CERAMIC PTH 0.1"SPC
C104-01	C416	100nF 50V CERAMIC PTH 0.1"SPC
C104-01	C417	100nF 50V CERAMIC PTH 0.1"SPC
C104-01	C418	100nF 50V CERAMIC PTH 0.1"SPC
C474-01	C501	470nF 50V CERAMIC PTH 0.2"SPC
C474-01	C502	470nF 50V CERAMIC PTH 0.2"SPC
C470-01	C503	47pF_50V_CERAMIC_PTH_0.1"SPC
C470-01	C504	47pF_50V_CERAMIC_PTH_0.1"SPC
C106-03	C506	10uF 35V
C103-01	C507	10nF 50V CERAMIC PTH 0.1"SPC
C332-01	C508	3n3F 50V CERAMIC PTH 0.1"SPC
C104-01	C509	100nF 50V CERAMIC PTH 0.1"SPC
C103-01	C510	10nF 50V CERAMIC PTH 0.1"SPC
ZD8V1-01	D301	1N5238_8V1_ZENER_DIODE
1N4148-01	D403	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D404	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D405	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D406	1N4148_SILICON_SWITCH_DIODE
LM393-01	IC301	LM393_DUAL_COMPARITOR
4011-01	IC302	4011_QUAD_NAND_GATE
4013-02	IC303	4013_DUAL_D_FLIP_FLOP
MC78M12CDT-01	IC401	7812_+12V_1.2A_VOLTA_REGULATOR_SMT
4066-02	IC501	4066_QUAD_BILATERAL_SWITCH
TL084-01	IC502	TL084_QUAD_OP_AMP
JMPR2P-01	J301	2 PIN 100MIL JUMP
20PINHDR-01	J501	20_PIN_HEADER_PTH_.1SPC
MPSA56-01	Q301	MPSA56 HI VOLT PNP TRANSISTOR
MPSA06-01	Q302	MPSA06 HI VOLT TRANSISTOR
2N3906-01	Q303	2N3906 GEN PURPOSE PNP TRANSISTOR
2N3906-01	Q304	2N3906 GEN PURPOSE PNP TRANSISTOR
2N3906-01	Q401	2N3906 GEN PURPOSE PNP TRANSISTOR
2N3904-01	Q402	2N3904 GEN PURPOSE TRANSISTOR
R472-01	R301	4K7 5% .25W PTH
R471-01	R302	470 OHM 5% .25W PTH
R104-01	R303	100K 5% .25W PTH
R472-01	R304	4K7 5% .25W PTH
R471-01	R305	470 OHM 5% .25W PTH
R102-01	R306	1K_5%_1/4W_RESISTOR
R222-01	R307	2K2 5% .25W PTH
R102-01	R308	1K_5%_1/4W_RESISTOR
R471-01	R309	470 OHM 5% .25W PTH
R222-01	R310	2K2 5% .25W PTH
R102-01	R311	1K_5%_1/4W_RESISTOR
R102-01	R312	1K_5%_1/4W_RESISTOR
R472-01	R313	4K7 5% .25W PTH
R103-01	R314	10K 5% .25W PTH

3) Driver and Output Filter

Install all of the components except for Q601 and Q603

Jumper J301 (This forces the driver to function even when a shutdown has occurred) and apply power.

Check the waveform at the gate of each FET. They should have a duty cycle of 50% and be going from -15V to -3V.

Disconnect power and install Q601 and Q603.

Apply power.

A 40Vpp 50% duty cycle square wave should be present at the LFOUT- and LFOUT+ nodes.

Disconnect power, remove all jumpers.

Apply power to the amplifier.

The voltage at the output terminals should be about 6V. If the voltages go to either -15V or +40V there is a problem in the preamplifier.

Measure the voltage across the output terminals. Use the offset control to set this voltage to 0V.

Table 3 - Parts List for Driver and Output Filter

C474-01	C601	470nF 50V CERAMIC PTH 0.2"SPC
C474-01	C602	470nF 50V CERAMIC PTH 0.2"SPC
C104-01	C603	100nF 50V CERAMIC PTH 0.1"SPC
C104-01	C604	100nF 50V CERAMIC PTH 0.1"SPC
C474-01	C605	470nF 50V CERAMIC PTH 0.2"SPC
C474-01	C606	470nF 50V CERAMIC PTH 0.2"SPC
C474-01	C607	470nF 50V CERAMIC PTH 0.2"SPC
C474-01	C608	470nF 50V CERAMIC PTH 0.2"SPC
C474-01	C701	470nF 50V CERAMIC PTH 0.2"SPC
C474-01	C702	470nF 50V CERAMIC PTH 0.2"SPC
C474-01	C703	470nF 50V CERAMIC PTH 0.2"SPC
C474-01	C704	470nF 50V CERAMIC PTH 0.2"SPC
C474-01	C705	470nF 50V CERAMIC PTH 0.2"SPC
C105-06	C706	1uF_100V_9.2A_FILM_CAP
C474-01	C709	470nF 50V CERAMIC PTH 0.2"SPC
1N4148-01	D601	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D602	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D603	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D604	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D605	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D606	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D607	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D608	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D609	1N4148_SILICON_SWITCH_DIODE
1N4148-01	D610	1N4148_SILICON_SWITCH_DIODE
F15A3AG-01	F701	15A_3AG_FAST_BLO_FUSE
HIP4080-01	IC601	HIP4080AIP_H_BRIDGE_DRIVER
JMPR2P-01	J601	2 PIN 100MIL JUMP
L103-01	L701	10uH 10A ROD CHOKE
L103-01	L702	10uH 10A ROD CHOKE
L153-01	L703	15uH_12A_LOW_EMI_COIL
L153-01	L704	15uH_12A_LOW_EMI_COIL
IRF530-01	Q601	IRF530_N_CHANNEL_FET
IRF530-01	Q602	IRF530_N_CHANNEL_FET
IRF530-01	Q603	IRF530_N_CHANNEL_FET
IRF530-01	Q604	IRF530_N_CHANNEL_FET
R473-01	R601	47K 5% .25W PTH
R473-01	R602	47K 5% .25W PTH
R102-01	R603	1K_5%_1/4W_RESISTOR
R100-01	R604	10 OHM 5% .25W PTH
R100-01	R605	10 OHM 5% .25W PTH
R100-01	R606	10 OHM 5% .25W PTH
R100-01	R607	10 OHM 5% .25W PTH

It is usually a good idea to test it out with a junk speaker at this point (although the amplifier is working) just to be sure there are no faults in the circuit. A gentle tap with a screwdriver will show up most loose connections.

If one of the FETs should burn out then usually it will destroy the other FET in that side of the bridge. It can also destroy IC601. Replace the FETs in pairs. When installing the new FETs, IC601 can be tested by installing J301 and J601, installing the low side FET, and checking for the square wave gate drive for both FETs. If the square wave is not present on both FET gate pads then IC601 should be replaced. Once both gate drives are working the high side drive FET can be installed and the jumpers removed.

Installation Notes

Input impedance to 12V source must be less than .1 ohms. This is usually accomplished using a large sized capacitor across input supply lines.

120VAC Input Voltage:
It is possible to run the amplifier with a transformer, rectifier and capacitor for a power supply. The important thing to remember is that the amplifier can draw 16A of current in a surge. The supply voltage ripple should not allow the input voltage to drop below 10V on one surge. The surges usually last longer than one cycle of the line voltage so the supply should be designed for a 16A load. It is important to consider the maximum ripple current ratings of the capacitors when using them for the supply.

Remote Turn On:
Many users have requested this feature. To do this, lift the anode of D101 off the board (breaking the connection to the 12V supply) and connect the anode of D101 (The side away from C102) to the remote power line. The amplifier will draw about 50mA on the remote turn on line. It is important to note that the internal supply capacitors will still be charged up. If the input power supply will see rapid rise times such as being switched on, then it would be advisable to add an inrush current limiter or a startup relay to the circuit to prevent a large inrush current.

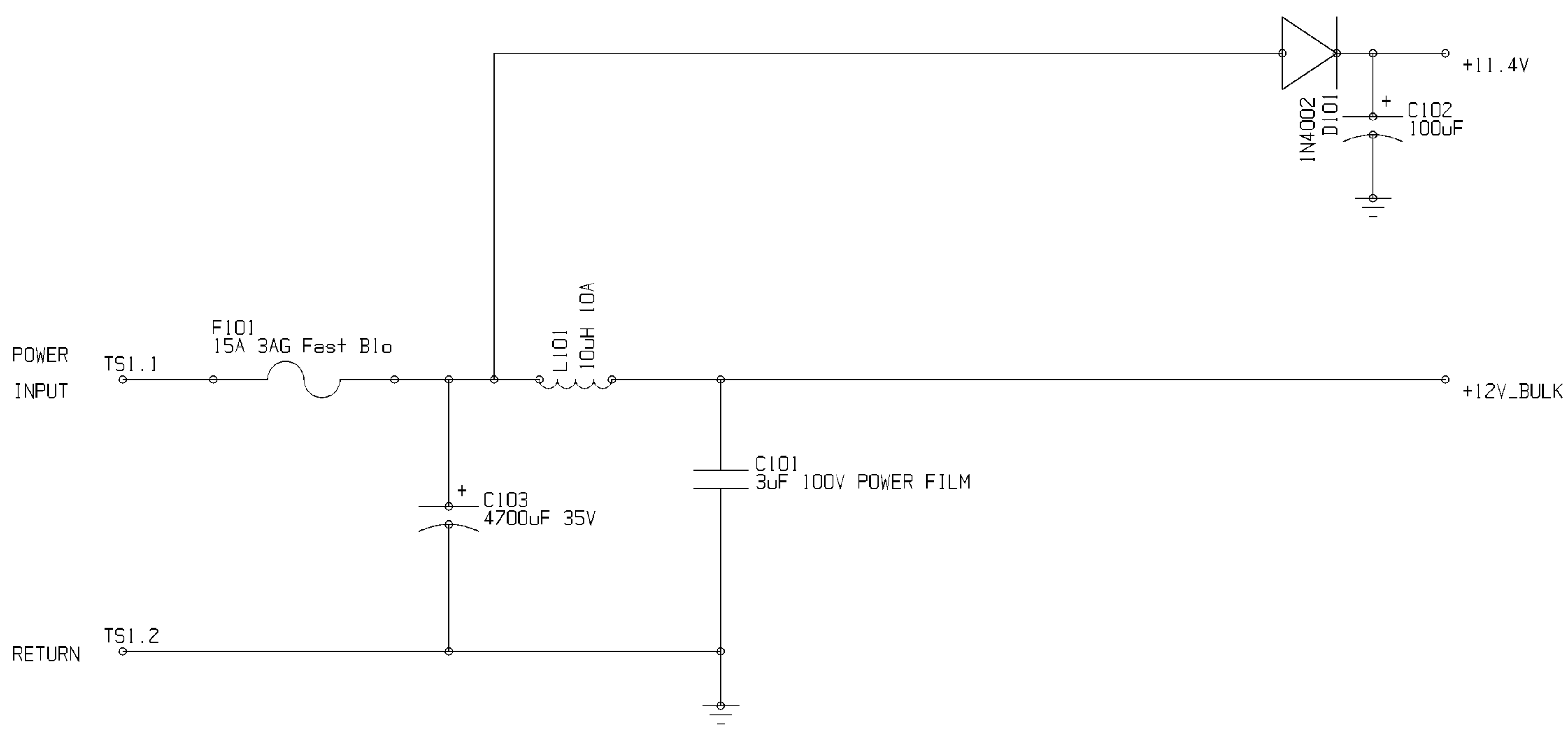
Input sources:
The amplifier can be used with either balanced or unbalanced inputs. To use an unbalanced input, connect the IN- terminal to the amplifier ground and the source ground. Connect the IN+ terminal to the signal line. For a balanced input, connect the IN+ to the positive input and the IN- to the negative input.

A note about low power head units. A resistor may be required across the input terminals (8 ohms) to load down any noise created by the head unit amplifiers.

Crossovers/Filters
When running something like a subwoofer or frequency specific speaker it is best to filter the incoming signal to the amplifier rather than amplify the entire signal and then filter the output. This has the advantage that you will not be wasting headroom amplifying useless signals.

Mechanical Installation

The mechanical installation of this kit versus previous versions has significantly changed. The board is now mounted using 4-40 screws. The board should be 1/4” above the surface of the case. The aluminum block should be drilled and optionally tapped so that it can be attached to the bottom of the board using the 4-40 mounting screws included (the mounting holes are exactly 5” apart). This block must be in contact with the surface of the case to conduct heat away from the board to the case. 1/4” spacers can be used to keep the board off the side of the chassis.

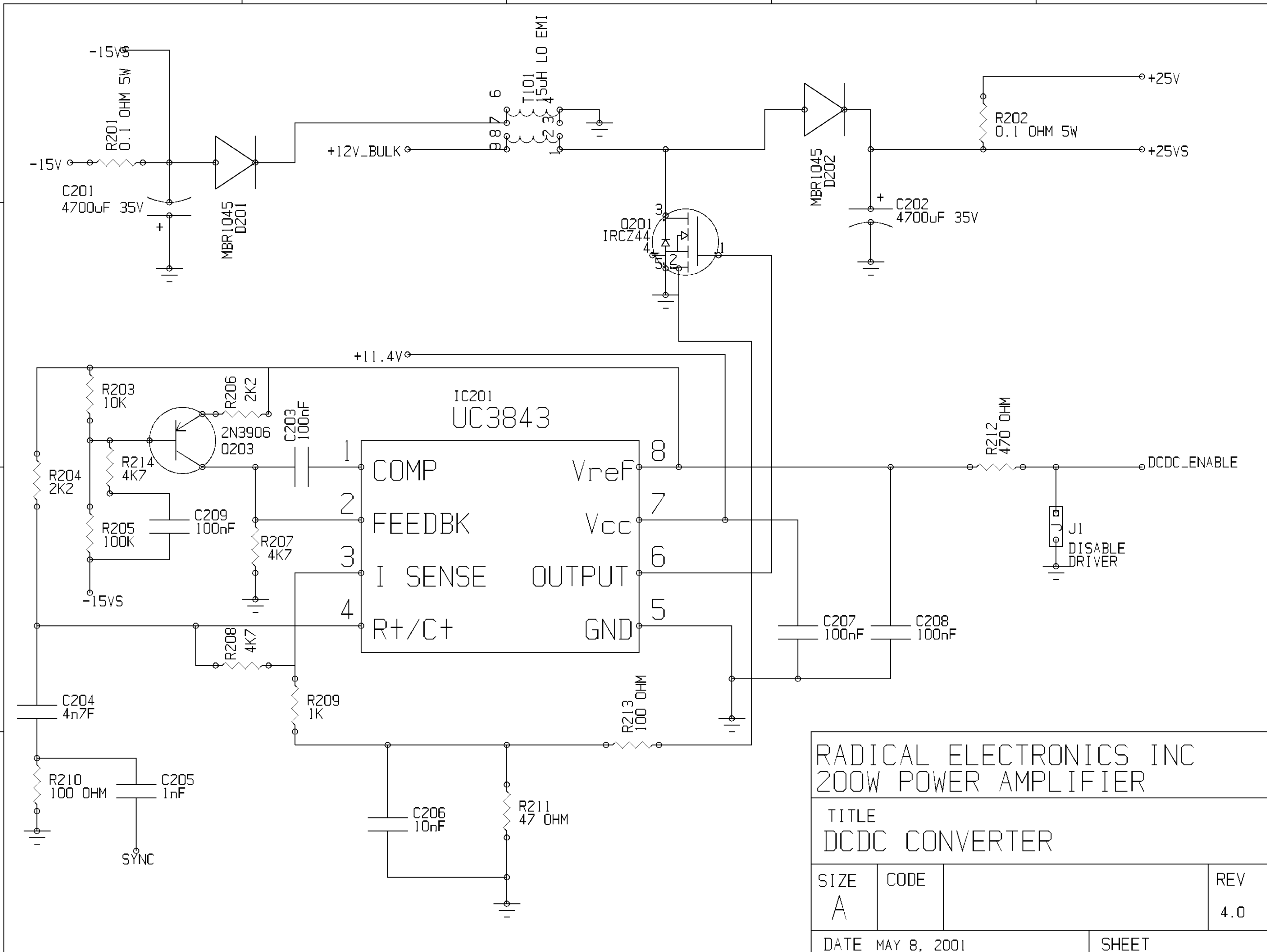


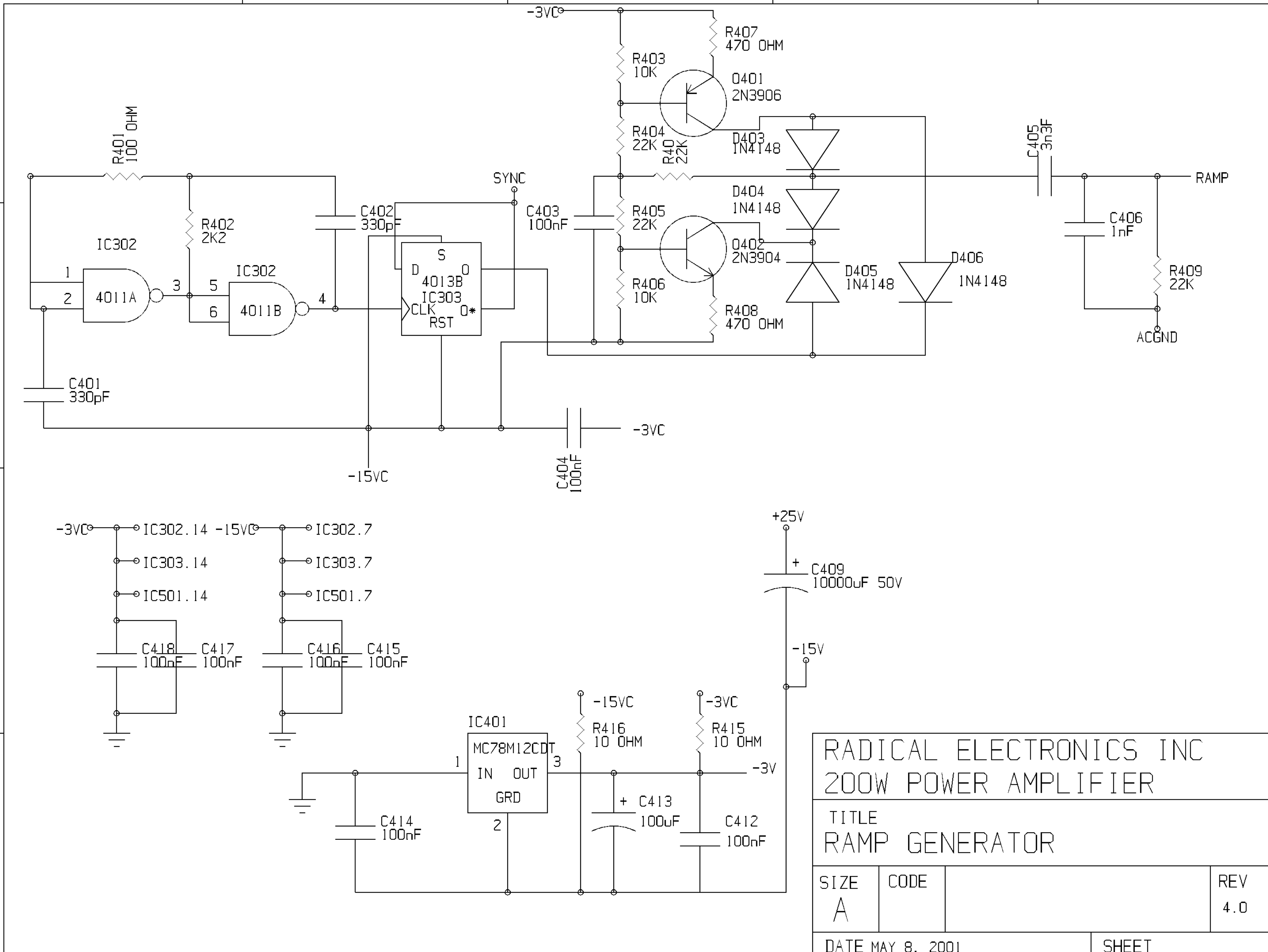
RADICAL ELECTRONICS INC.
200W POWER AMPLIFIER

TITLE
INPUT FILTER

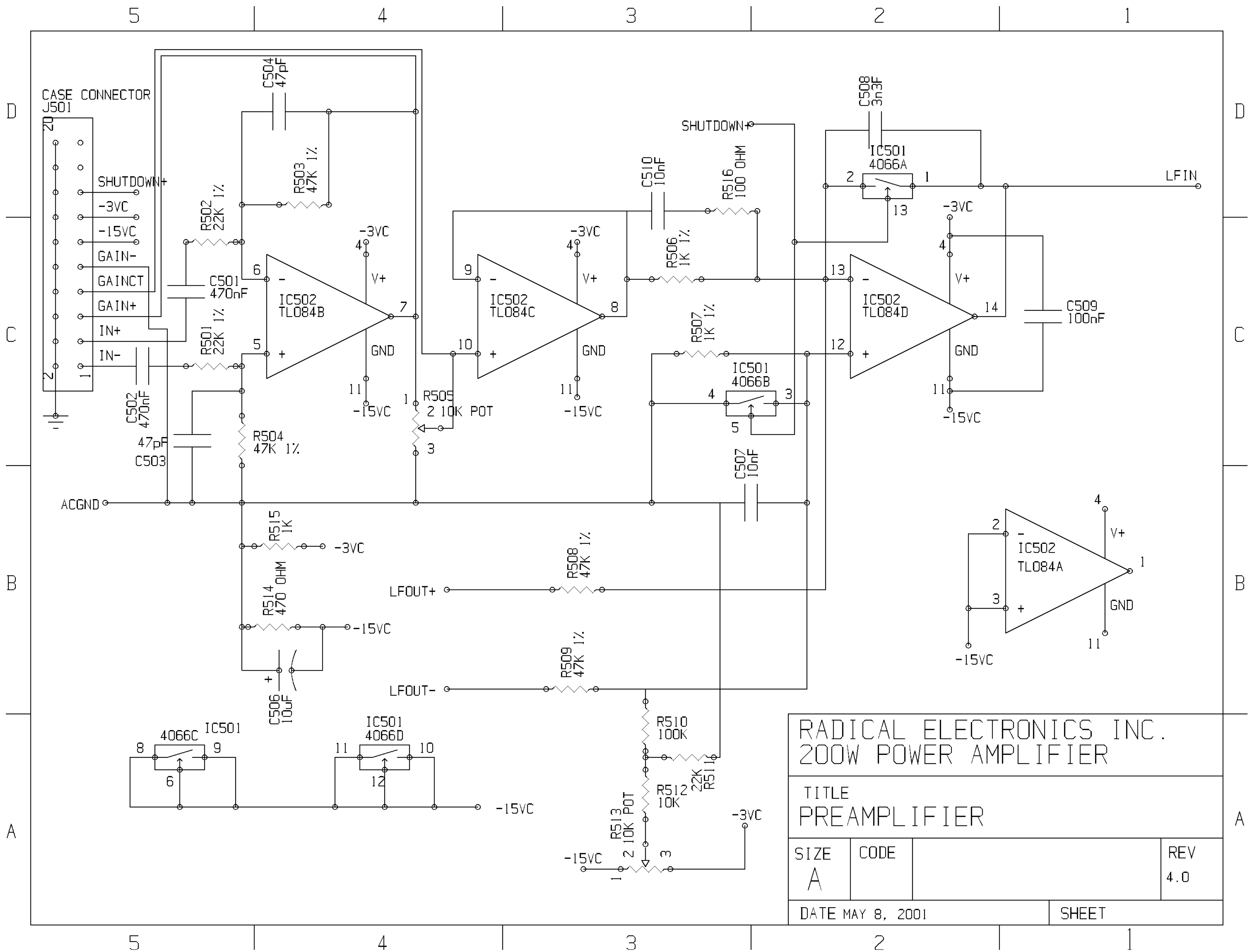
SIZE	CODE		REV
A			4.0

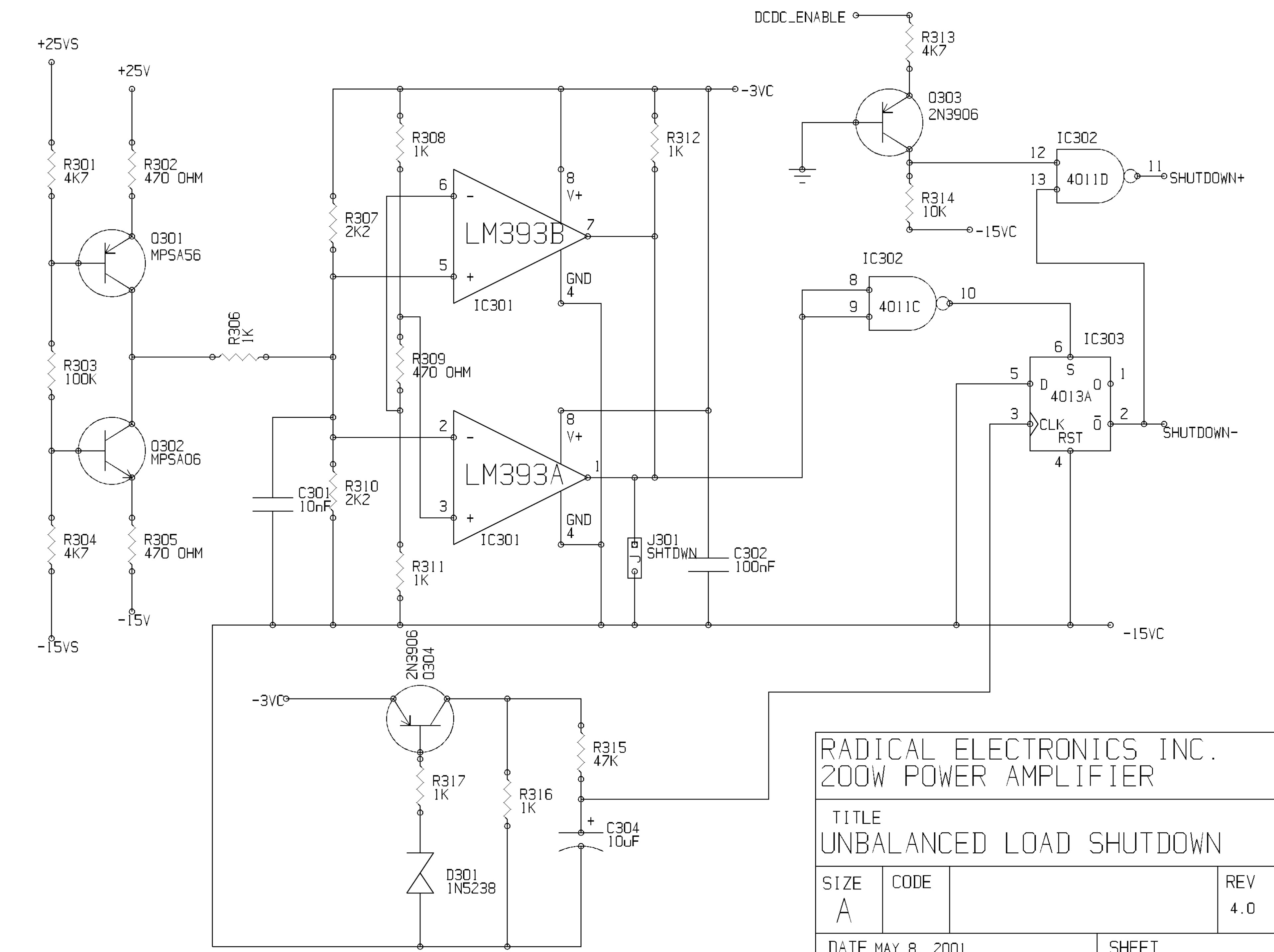
DATE MAY 8, 2001 | SHEET


-15VS
-15V
R201
0.1 OHM 5W
C201
4700uF 35V
MBR1045
D201
T101
15uH LO EMI
+12V_BULK
MBR1045
D202
R202
0.1 OHM 5W
+25V
+25VS
C202
4700uF 35V
Q201
IRCZ44
+11.4V
R203
10K
R206
2K2
2N3906
Q203
R214
4K7
R204
2K2
R205
100K
C209
100nF
-15VS
C203
100nF
R207
4K7
IC201
UC3843
COMP
FEEDBK
I SENSE
R+/C+
VreF
Vcc
OUTPUT
GND
R208
4K7
R209
1K
R213
100 OHM
C207
100nF
C208
100nF
R212
470 OHM
DCDC_ENABLE
J1
DISABLE
DRIVER
C204
4n7F
R210
100 OHM
C205
1nF
SYNC
C206
10nF
R211
47 OHM
RADICAL ELECTRONICS INC
200W POWER AMPLIFIER
TITLE
DCDC CONVERTER
SIZE
A
CODE
REV
4.0
DATE MAY 8, 2001
SHEET



RADICAL ELECTRONICS INC 200W POWER AMPLIFIER		
TITLE RAMP GENERATOR		
SIZE A	CODE	REV 4.0
DATE MAY 8, 2001		SHEET


CASE CONNECTOR
J501
SHUTDOWN+
-3VC
-15VC
GAIN-
GAINCT
GAIN+
IN+
IN-
C504 47pF
R503 47K 1%
R502 22K 1%
C501 470nF
R501 22K 1%
C502 470nF
47pF C503
R504 47K 1%
IC502 TL084B
IC502 TL084C
IC502 TL084D
IC502 TL084A
R505 2 10K POT
ACGND
R515 1K
R514 470 OHM
C506 10uF
C510 10nF
R516 100 OHM
R506 1K 1%
R507 1K 1%
IC501 4066B
IC501 4066A
C508 3n3F
C509 100nF
C507 10nF
LFIN
LFOUT+
LFOUT-
R508 47K 1%
R509 47K 1%
R510 100K
R511 22K
R512 10K
R513 2 10K POT
IC501 4066C
IC501 4066D
V+
GND
RADICAL ELECTRONICS INC.
200W POWER AMPLIFIER
TITLE
PREAMPLIFIER
SIZE A
CODE
REV 4.0
DATE MAY 8, 2001
SHEET



RADICAL ELECTRONICS INC. 200W POWER AMPLIFIER		
TITLE UNBALANCED LOAD SHUTDOWN		
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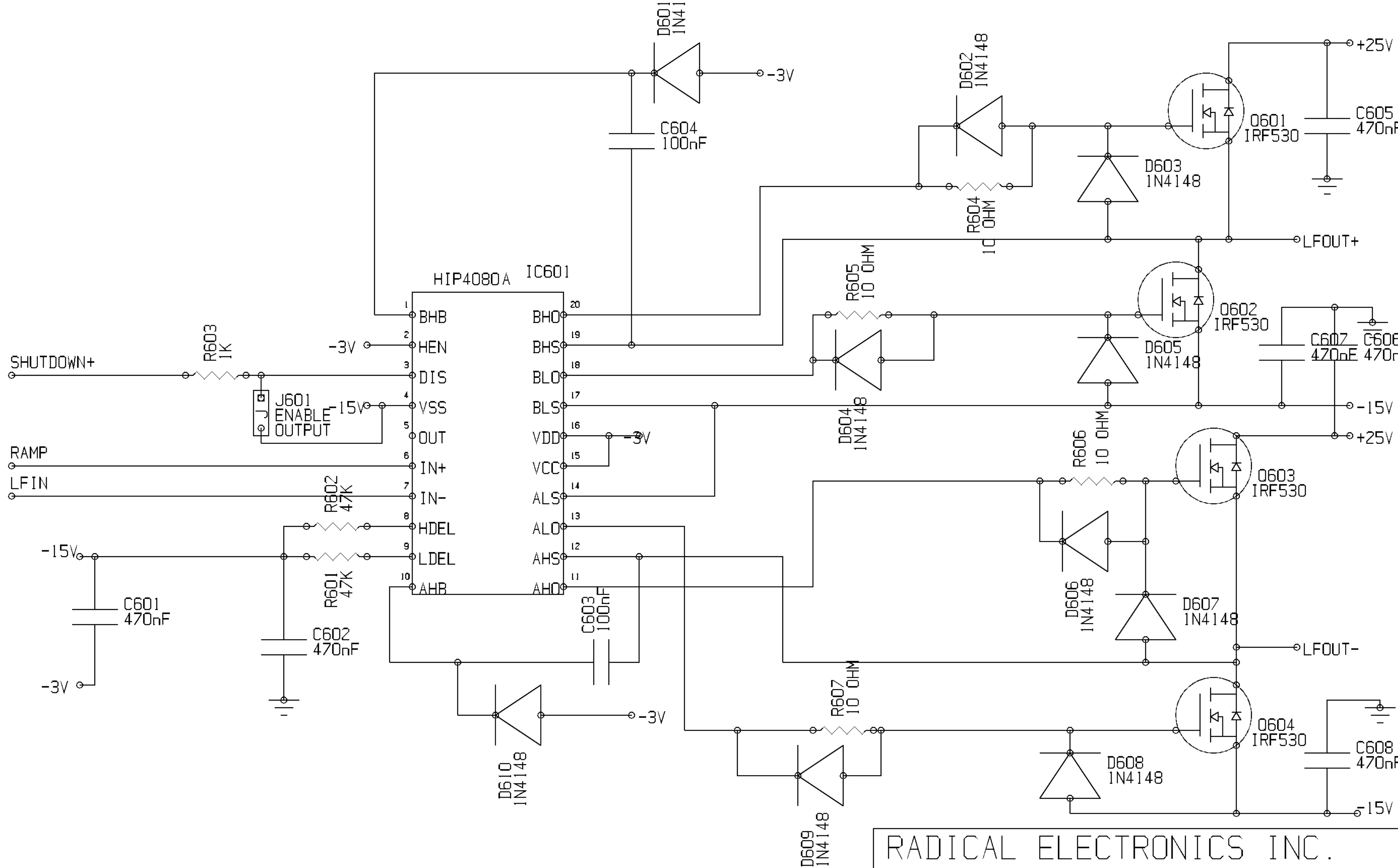
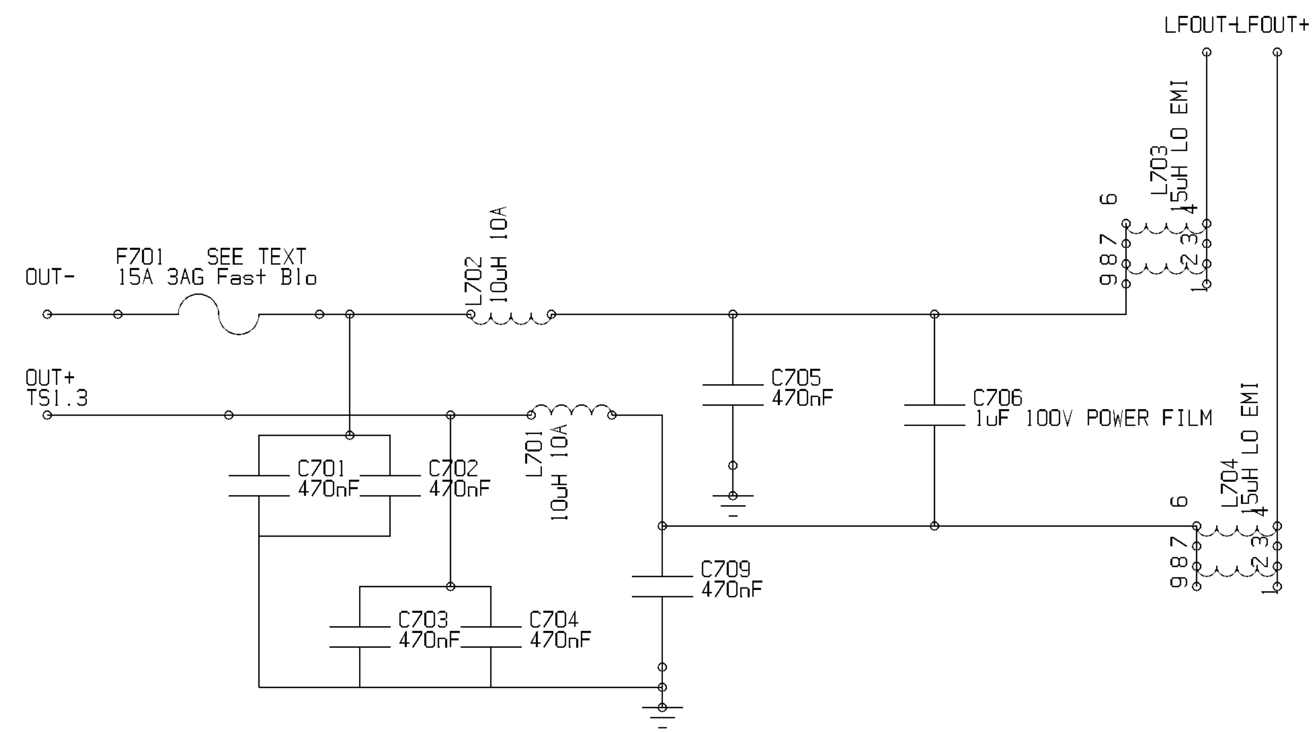
DATE MAY 8, 2001	SHEET	

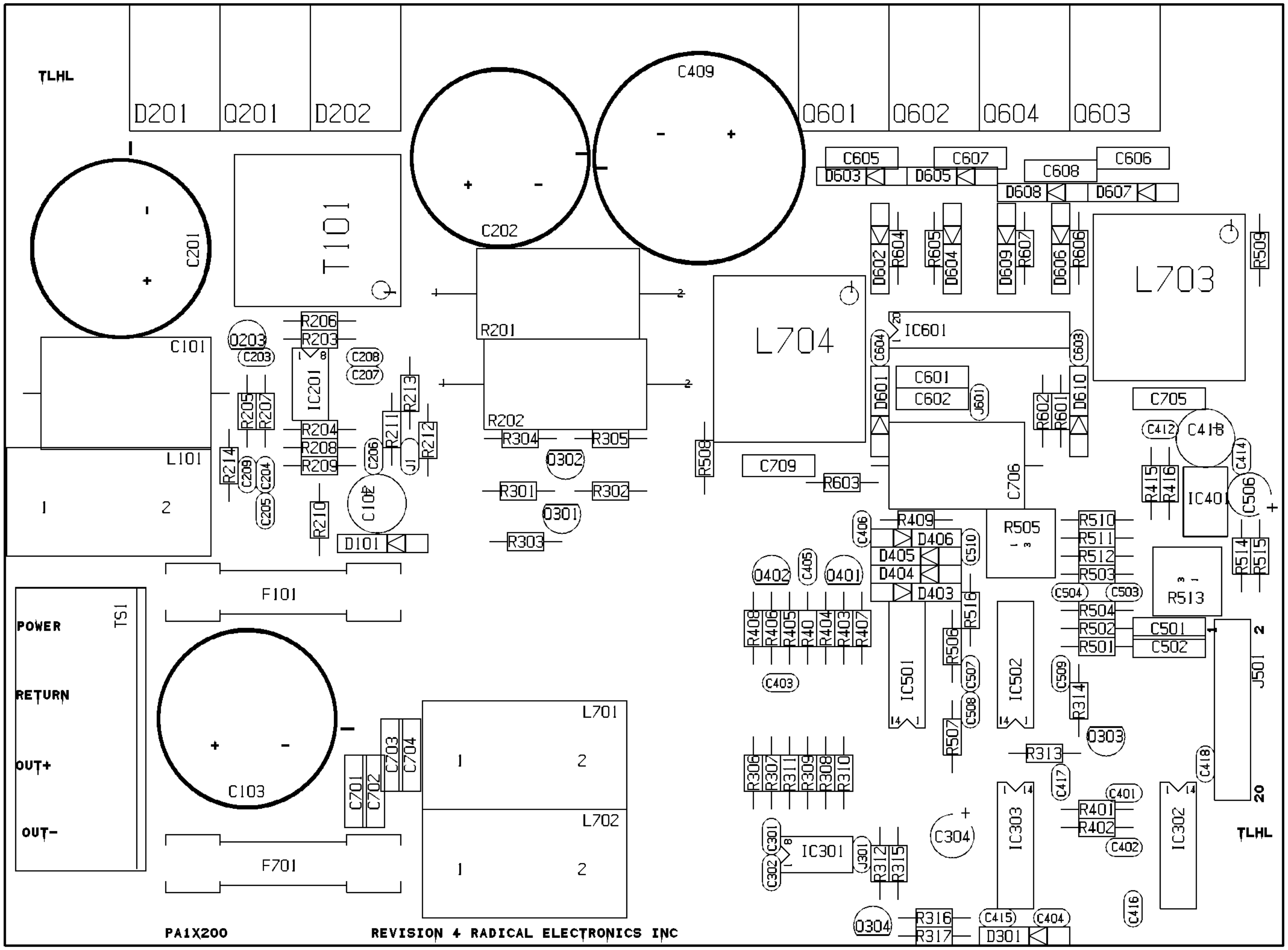


RADICAL ELECTRONICS INC.
200W POWER AMPLIFIER

TITLE OUTPUT DRIVE CIRCUIT		
SIZE A	CODE	REV 4.0
DATE MAY 8, 2001	SHEET	



RADICAL ELECTRONICS INC. 200W POWER AMPLIFIER		
TITLE OUTPUT FILTER		
SIZE A	CODE	REV 4.0
DATE MAY 8, 2001		SHEET



TOP

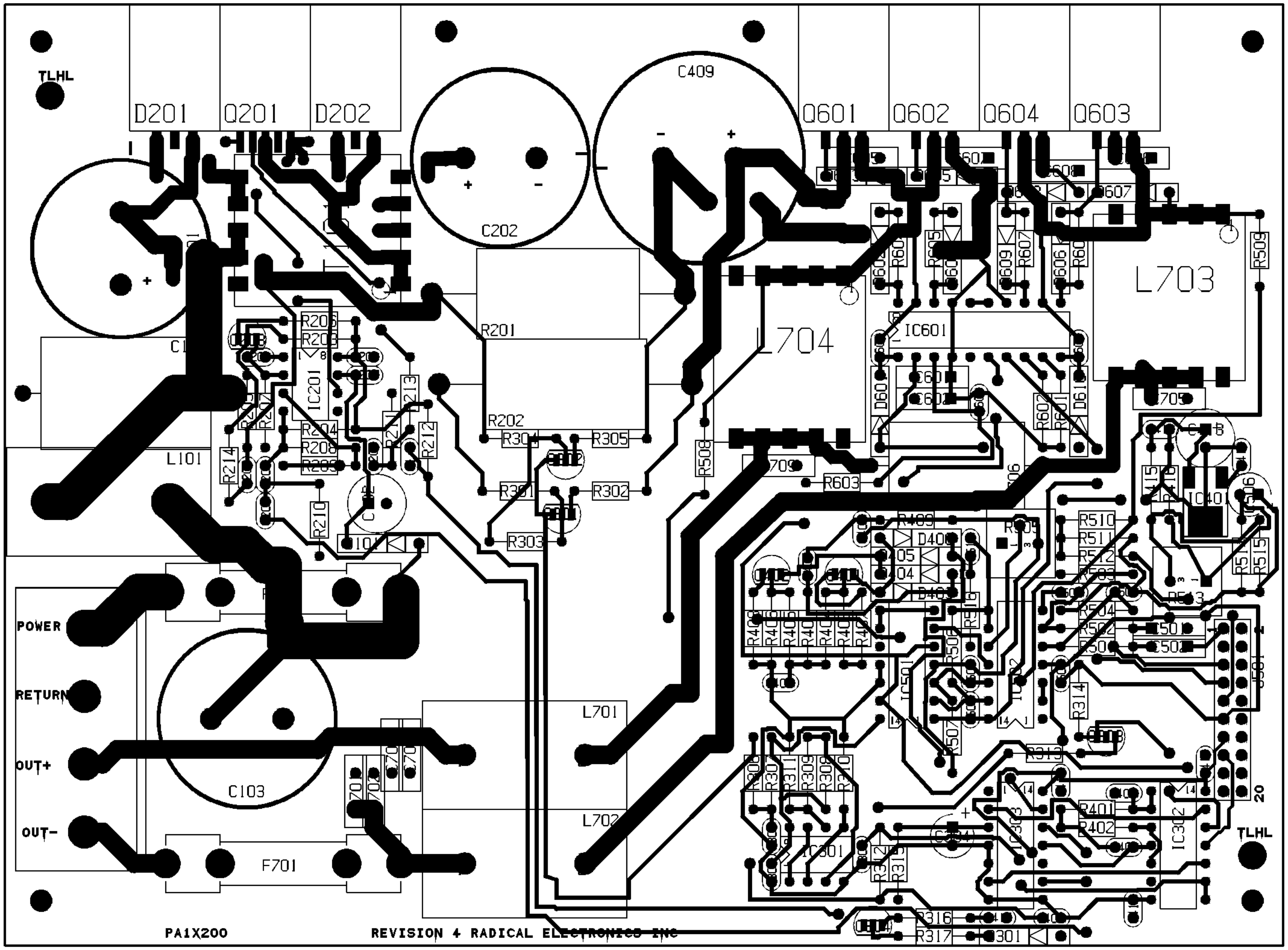
TITLE
PA1X200

TOP SILKSCREEN

REV **3.0**

DATE **MARCH**

SHEET



TOP

TITLE PA1X200		
TOP LAYER TOP SILKSCREEN		REV 3.0
DATE MARCH	SHEET	

Appendix A – Component Marking

Resistors:
Resistors are marked with a standard banding system. Each band represents a number. The colors and the numbers they represent are:
Black 0
Brown 1 or 1% tolerance
Red 2 or 2% tolerance
Orange 3
Yellow 4
Green 5
Blue 6
Purple 7
Grey 8
White 9
Gold 0.1 multiplier or 5% tolerance
Silver 0.01 multiplier or 10% tolerance

The bands will be in the following order:
Significant figures (2 for standard, 3 for 1% resistors)
Multiplier (the number of zeroes following the significant figures)
Tolerance

The first band is usually closer to the end of the resistor than the final band.

Power resistors usually have the value written on the side of them.

Surface mount resistors and POTs have the value screen printed on the top. A 1% resistor will have 4 digits consisting of 3 significant figures and the multiplier. The 5% resistors only have 2 significant digits followed by the multiplier. A part marked 102 would be a 1K resistor. Be careful, the number 102 upside down can be read as 501 which would be 500 ohms. For small values you may see the resistors marked with an R. The R is the decimal place holder. A component marked 1R3 is a 1.3 ohm resistor.

Capacitors:
Small value capacitors will have a number written on the side. It will be 3 digits with possibly a letter following it. This number is the value of the capacitor in picofarads. The first 2 digits are the significant figures of the value and the last digit is the number of zeroes following the number.

Example:
The number 472 on the side of the capacitor would mean that the first 2 significant digits are 47 followed by 2 zeroes. The value of the part is 4700 pF.

Surface mount capacitors may not be marked. Whenever dealing with surface mount parts, keep them on the tape until you are ready to install them. If they are mixed up, there is no way to tell (except the circuit doesn't work).

Large value capacitors are big enoug that the ratings are still written on them.

Transistors:
The part number should be marked on the flat side of the transistor for through hole components.

Surface mount parts may not be marked so keep them in the tape until you are about to install the part.

Integrated Circuits:

For generic chips, the usual format is some letters to indicate the manufacturer, the part number followed by the package info. There will be a date code and other info. Components that do not follow this are noted on the parts list.

Diodes
The general purpose switching diodes are not marked. They only have the band on them (1N4148).

Other diodes have the number written on the side of them.

Coils and Inductors

The parts will either be marked with the part number or only fit in one location.

Metric System and Scientific notation

The prefixes that are applied to units such as farads (F), meters(m), and any other units of measure act as multipliers to those units. For example Kohm means 1000 ohms. mm means 1/1000 meter. Multipliers that are less than 1 are not capitalized, Multipliers greater than 1 are.

Femto(f) = 1e-15 or 0.000 000 000 000 001
Pico (p) = 1e-12 or 0.000 000 000 001
Nano (n) = 1e-9 or 0.000 000 001
Micro (u) = 1e-6 or 0.000 001
Milli (m) = 1e-3 or 0.001
None =1
Kilo (K) = 1e3 or 1000
Mega (M) = 1e6 or 1 000 000
Giga (G) = 1e9 or 1 000 000 000
Tera (T) = 1e12 or 1 000 000 000 000

Sometimes numbers are expressed in the format of N.NNN e MMM. This basically takes the number N.NNN and multiplies it by 10 to the power of MMM.

Reading Schematics

The rules that are used to determine connectivity on the schematics is as follows:
1)Wires that cross without pins (the connection dot) are not connected.
2)Wires that end on another wire are connected to that wire. No pin is required for connection.
3)Named wires are connected to wires with the same name. This applies to all schematics in a project. If a wire is named “LFIN” it will be connected to all other wires named “LFIN” on all of the schematics. The name usually appears beside or at the end of a wire. The one exception is when the wire is connected to a bus.
4)When a wire ends on a bus (the fat lines), it will have a name. All the wires with the same name connected to that bus will be connected. The busses may span schematics the same way a named wire can span schematics. A bus with the same name on different schematics in the project are connected.

PA1X200 Case Assembly Instructions

Printed circuit board assembly

The components are installed as shown on the parts placement diagram with the following exceptions:
1)RLY1 mounts on the back side of the board
2)The 20 pin header mounts on the back side of the board
3)C5 and C4 need to be mounted with enough slack in their leads that they can be bent over and not run into the front of the enclosure.
4)The 10K pots need to have the leads bent away from the board and wires are needed to connect them to the board. Trimmed part leads are good for this.
5)Since there is a fuse on the amplifier board, F1 is replaced with a wire.

There is one wiring error on the board. Pin 8 of IC1 should be connected to the lead of R1 that is closest to pin 1 of IC1. The lead of R1 should still be connected to the board.

Set the gain control pot on the power amplifier board to half way.

The pads marked POWER, RETURN, OUT+, and OUT- should be connected to the pads(or terminals if a terminal strip is used) on the power amplifier marked POWER, RETURN, OUT+ and OUT- using 18 gauge wire. Use 6 inch pieces for enough slack to put the case together. Slide the 20 pin ribbon cable on the 20 pin headers. The red stripe should go towards pin 1 on both the front panel and the amplifier.

If you are using the case with the revision 4 power amplifier, the following components are not needed: RLY1, D5, D4, R5, Q2, D3, R19, SW1. This is because the revision 4 amplifiers are AC coupled and the remote turn on is not done using a relay.
To implement the remote turn on with a revision 4 PCB, Lift the end of D101 connected to the power input. Connect TS1 pin 1 to the open end of D101. Insulate the connection with tubing or electrical tape.

Testing the Amplifier with the Front Panel

All of these tests should be done without an input or speaker connected to the amplifier.

Set the gain pot (R20) to the midpoint.
Connect the return and power leads to the power supply. The relay should not turn on.
Connect the REM terminal to the POWER terminal. The following things should happen:
- -The relay should click.
- -Both the red and green LEDs should turn on
- -The red LED should go out.

Using a voltmeter, measure the voltage from the RETURN terminal to both of the OUT terminals. The voltage should be the same at approximately 6V. If there is a big difference between the two:
- -Disconnect power
- -remove the 20 pin cable
- -apply power

Test the output terminals again. If the difference still exists then the fault is in the power amplifier. If it disappears then the fault is in the preamplifier or filter circuits on the front panel board.
If the problem is in the front panel:

Reconnect the front panel and check the voltages in the preamplifier. Using the voltage at the junction between R18 and R21 as a reference, the voltages at the inputs and outputs of the op amps should be +/-.5V. The voltage at the junction of R18 and R20 should be around -6 to -10V with respect to the RETURN terminal.

Disconnect the REM lead and connect the input(signal source) to the power amplifier. Reconnect the REM lead. Check the output terminals again. If there is a big voltage difference on the output terminals then try putting SW1 in the up position. This will put the DC block in to prevent DC biasing of the input.

Connect the voltmeter across the OUT+ and OUT- terminals. Adjust the offset pot(R19) to get 0V. It is now time to install the amplifier into the metalwork.

Due to electrical changes in the design of the revision 4 amplifier, the following things need to be done:

Installing the Front Panel and the Power Amplifier into the Case

To mount the power amplifier in the case it requires five 1/4" 4-40 screws. These hold the amplifier into the top of the case. If you are using a Revision 2 or Revision 3 power amplifier kit, then there are 2 mounting standoffs that do not line up properly. The holes need to be extended by .1 inch towards the edge of the board. This can be done by a couple of different ways:
1)Use a fine tooth hacksaw (or just the blade) to cut from the edge of the board to the hole. This will change the hole to a slit that the bolt can sit in.
2)File the hole using a small file to allow the bolt to fit
3)Use a dremmel or drill to extend the hole by drilling a second one next to it. Use a 1/8" drill bit. Center punching may help the bit stay on target.

If you are using a revision 4 power amplifier, you will need to add an insulator over the center mounting post to prevent it from shorting to the top of the PCB.

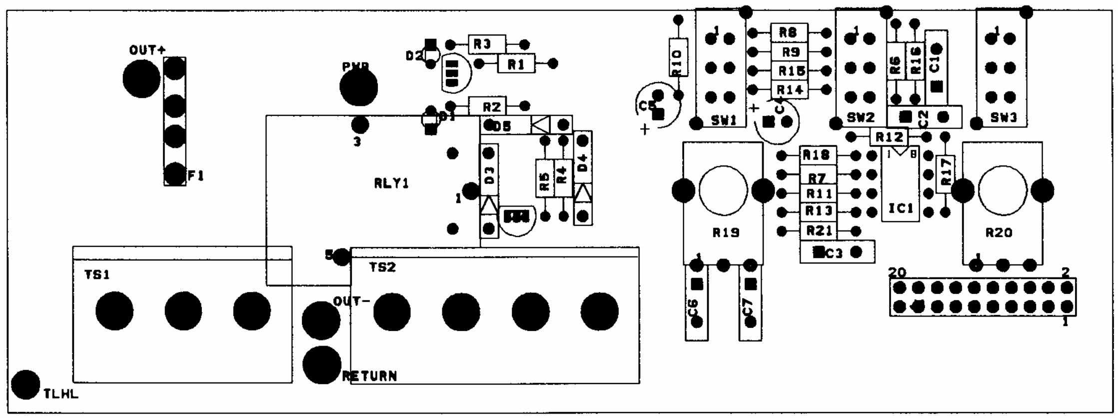
To install the front panel you will be using four of the standoffs on the bottom half of the case. The mounting posts line up with four corners of the board.
On 3 of the mounting posts, you need to use the aluminum standoffs to space the board an extra 1/8" away from the front of the case. These posts are located in the corners near F1, TS1, and J1. For the last corner the 3/8" nylon standoff is slipped over the installed standoff. The last mounting post is in the corner near the switches. To mount the front panel board use the 3/8" 4-40 screws.

Once the 2 boards are installed then connect the wiring up as it was during the tests. Connect the POWER, RETURN, OUT+, and OUT- to their respective pads (or terminals) on the power amplifier. Install the 20 pin ribbon cable from the front panel to the power amplifier.

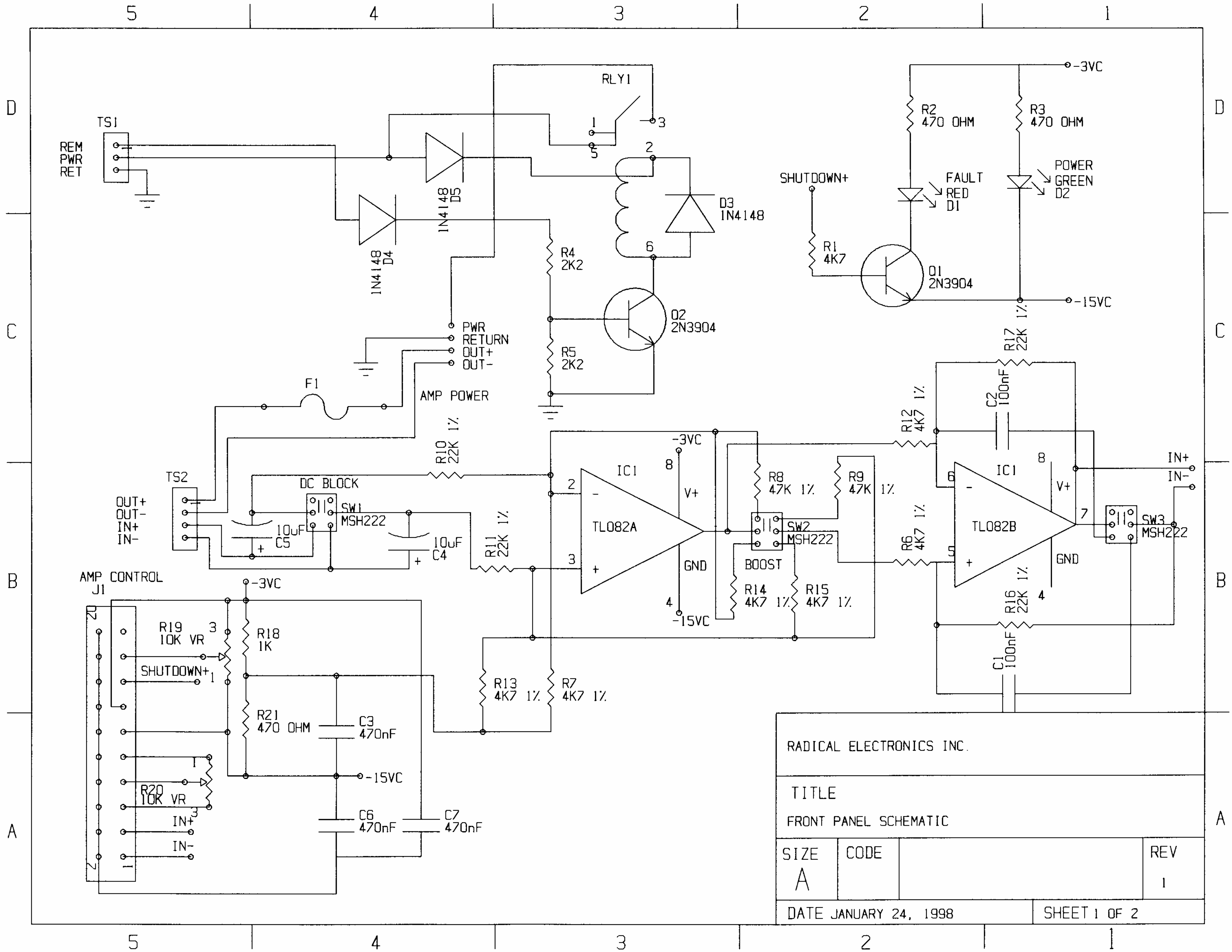
At this point in time it is probably worth testing out the amplifier to make sure nothing was damaged during the installation (see the previous tests)

If everything is functioning, the case can be put together. Use the 6 #2-56 flat head hex screws to hold the chassis together. Use 2 on the front, 2 on the bottom and 2 on the back. There are more mounting holes than that in the chassis but some do not line up due to mechanical tolerances. 6 screws are plenty to hold the case together.

Retest the amplifier and front panel and install the amplifier according to the directions in the manual. The only changes to the installation procedure in the manual is that the control adjustments are done on the front panel.



TITLE PA1X200 FRONT PANEL PRINTED CIRCUIT BOARD		
TOP SILKSCREEN		REV
DATE JULY 10, 1998	SHEET	



TS1
REM
PWR
RET
RLY1
D5 1N4148
D4 1N4148
D3 1N4148
R4 2K2
R5 2K2
Q2 2N3904
PWR
RETURN
OUT+
OUT-
AMP POWER
F1
SHUTDOWN+
R1 4K7
Q1 2N3904
R2 470 OHM
R3 470 OHM
FAULT RED D1
POWER GREEN D2
-3VC
-15VC
TS2
OUT+
OUT-
IN+
IN-
DC BLOCK
SW1 MSH222
C5 10uF
C4 10uF
R10 22K 1%
R11 22K 1%
IC1
TL082A
V+
GND
R8 47K 1%
R9 47K 1%
SW2 MSH222
BOOST
R14 4K7 1%
R15 4K7 1%
R12 4K7 1%
R6 4K7 1%
R17 22K 1%
C2 100nF
TL082B
R16 22K 1%
C1 100nF
SW3 MSH222
IN+
IN-
AMP CONTROL J1
R19 10K VR
R18 1K
R21 470 OHM
C3 470nF
C6 470nF
C7 470nF
R20 10K VR
R13 4K7 1%
R7 4K7 1%
RADICAL ELECTRONICS INC.
TITLE
FRONT PANEL SCHEMATIC
SIZE A
CODE
REV 1
DATE JANUARY 24, 1998
SHEET 1 OF 2