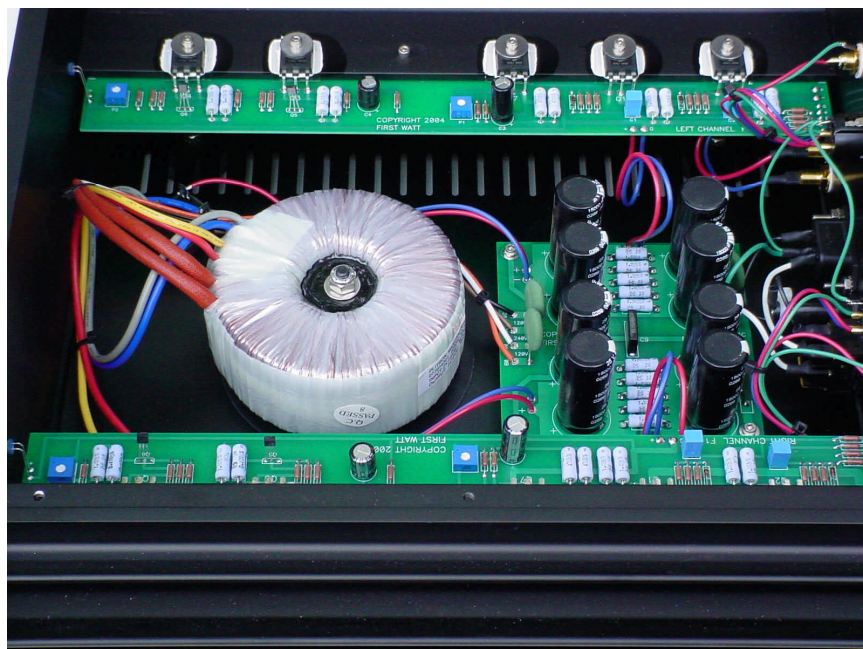


FIRST WATT

F1 POWER AMPLIFIER

SERVICE MANUAL



Introduction

This is the service manual for the First Watt F1 power amplifier. There were only 101 amplifiers built of this design and made available for sale. As none have broken in the field yet, this document is most likely to appeal immediately to the audio DIY enthusiasts, and is so structured.

Related reading would be the F1 owner's manual and the two articles about current source amplifiers posted at www.firstwatt.com and also published in AudioXpress Magazine.

The following comments are directly from the owner's manual:

The F1 is a two channel transconductance power amplifier, which is a fancy name for an active current source.

A given input voltage results in a particular output current. Ordinary amplifiers are voltage amplifiers – an input voltage translates into an output voltage. This is not that kind of amplifier, and as of this writing, the F1 is the only such amplifier available for audio use.

Being a current source, the F1 operates differently with a loudspeaker. A regular audio amplifier supplies an arbitrary output voltage, and the speaker draws current according to its complex characteristic. As such, the current through the loudspeaker is not exactly proportional to the voltage in either amplitude or time.

A current source amplifier delivers a precise current to the voice coil of the loudspeaker driver, ignoring the series impedance elements in the circuit, including the wire, the inductance of the voice coil, the resistance of the voice coil versus temperature – all that stuff.

This is potentially valuable in that the current passing through the magnetic field of the loudspeaker produces the force and acceleration on the voice coil and cone, and this translates directly into sound pressure. A current source is simply the most direct way of controlling the acceleration of the voice coil.

Since most loudspeaker systems are designed around a voltage source, only a small subset of products can take advantage of this effect. In general, these are high-efficiency drivers (ones that produce more than 90

dB per watt). Of greatest interest is the performance offered to high-efficiency full-range drivers, where not only is the loudspeaker very efficient, but also covers (or tries to cover) the full audio spectrum through a single radiating surface.

Often this translates to delicate single cone drivers such as the products from Lowther or Fostex, with big motor assemblies coupled to light fragile paper cones. These are the speakers that often don't sound good with "high quality" solid-state amplifiers, most often because the two are mismatched in impedance and wattage.

This is a very unusual amplifier that will not sound good with about 98% of the loudspeakers on the market. It requires careful attention to loudspeaker loading to get the best performance. The accompanying white paper "Current Source Amplifiers and Full-Range High-Efficiency Drivers" is required reading. This is a tinkerer's amplifier, and experimental tool. If you just want to be a consumer, then buy something else, otherwise be prepared to patiently experiment with your system to get the best performance.

It does not often work well with ordinary passive crossover networks – the components and their locations tend to be reversed. It won't break, but probably won't sound good. If you have an electronic crossover, you're in better shape, at least until I can finish a white paper describing passive crossovers for use with a current source.

If being a current source amplifier isn't different enough, the F1 is special in other ways. It uses no feedback to reduce distortion, flatten frequency response or create a low output impedance, and it ignores the voltages that appear across the speaker terminals. It also ignores the wire and the quality of your speaker connectors and so on.

The F1 has only one gain stage, not 2 or 3 or 4 or 9. It operates in pure class A mode, which is the very best, but at a cost of constantly drawing 100 watts per channel and only giving 10 watts to the speaker.

This is a very quiet amplifier, with a typical figure of about 100 pico-watts noise. A pico-watt is a trillionth of a watt.

As Class A amplifiers go, this one is referred to as a "balanced single-ended Class A" device, in which a single "differential pair" of transistors are biased by three constant current sources.

You can use either the RCA inputs for single-ended input operation or the balanced XLR input for operation from a source with balanced outputs. If you use the RCA inputs, then be sure to use the included gold plated "U" shorting jumpers between pins 1 and 3 of the XLR connectors as shown here, or the amp won't work properly. Some of you will lose these jumpers, but I can send a replacement. Note that pin1 of the XLR is ground, and pin 2 is the + input and pin 3 is the - input. Pin 1 of the XLR is exactly the same as RCA ground, and pin 2 is exactly the same as RCA "hot".



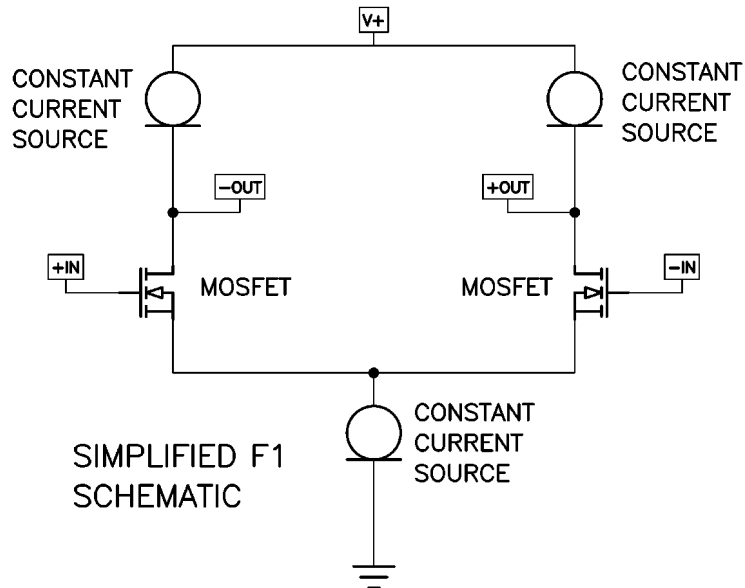
The outputs of the amplifier are balanced, and operate at a 13.8 Volt DC potential above ground, just like your car battery. Don't worry, the speaker sees only the difference between them, and not the DC, but don't expect the amplifier to operate properly if you attach either output to ground.

The fuse is a 3AG slow blow type, 4 amps for 120 VAC and 2 amps for 240 VAC. No substitutions. Contact First Watt if you have any questions.

The power supplies of each channel are isolated from each other electrically, except for a thermistor on each which connects the circuit ground to the chassis and earth ground. In this way ground loops are prevented, as the channels will typically share ground only at the source, but the thermistors stand by to conduct AC line voltage to ground until the fuse blows, in case of transformer or other such failure.

The amplifier requires about 1/2 hour of operation to reach normal operating temperature, and this warm-up time is appropriate for the most critical listening, but is not otherwise an issue, as the performance difference between 5 minutes and 60 minutes is very marginal. I do not personally see a reason to run the amplifier all the time.

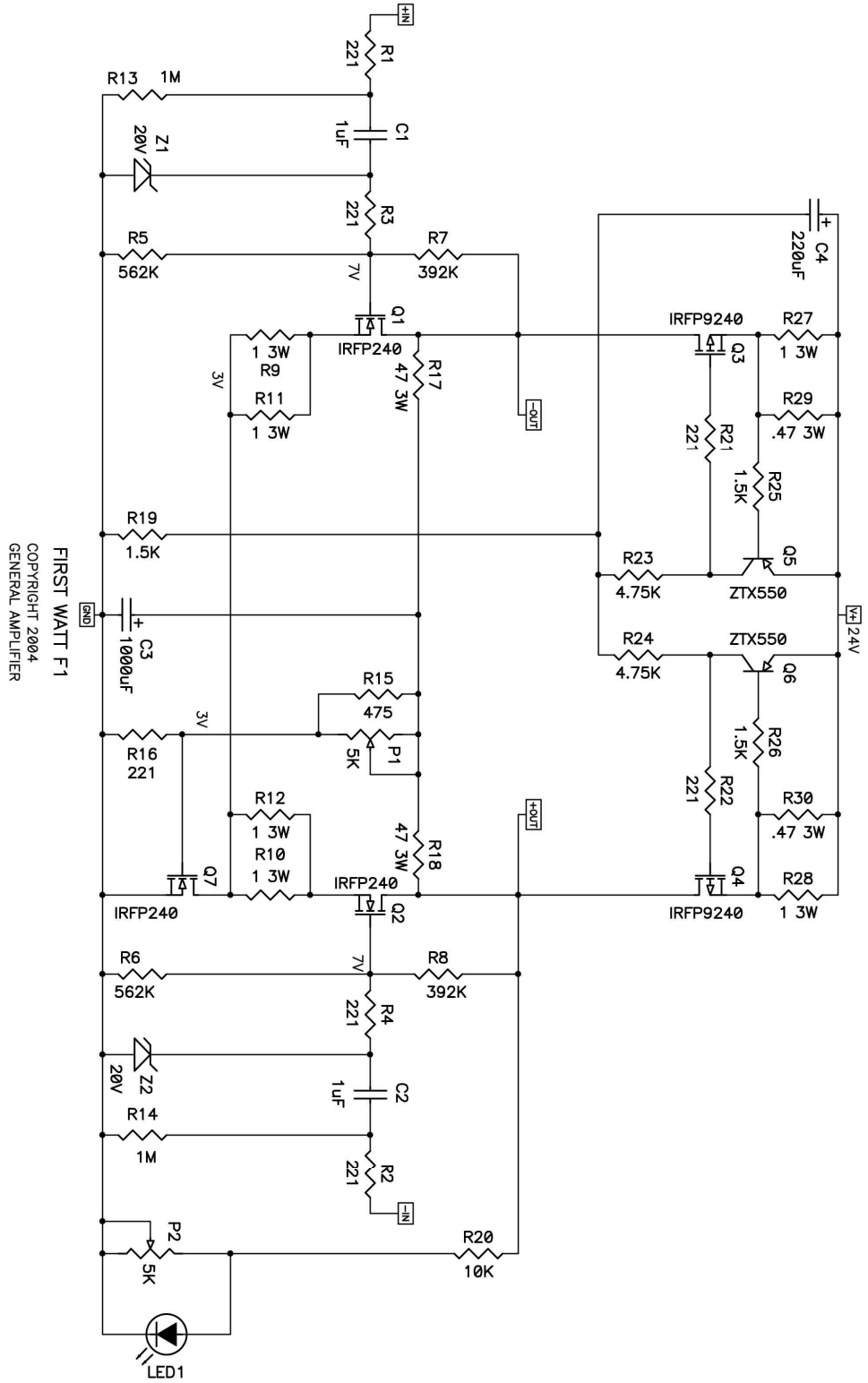
Here is a simplified schematic of the amplifier:



The principle is straightforward. The circuit is a simple differential pair of gain Mosfets commonly biased by a constant current source attached to their Source pins, with the input signal impressed upon their gates. The voltage difference between the plus and minus input signals causes current to flow in opposition between the two Mosfets, and this creates voltage and current at the Drains of the devices (the outputs), where the loudspeaker is connected. The DC bias current from the bottom constant current source is divided between the two Mosfets, and is taken up at the output by two other constant current sources, so that the loudspeaker only needs to see the AC current variation, not the DC.

If you are familiar with the Zen series of amplifiers published in AudioXpress, then you will see more than a passing similarity to the Son of Zen and some later variations, and these articles can provide more background information.

Of course this is just the simplified schematic. It would work in principle, but clearly needs more definition to make a real amplifier:



Here is the schematic of one channel of the real amplifier.

Making reference to the channel schematic, we note the following typical voltages:

P1 is adjusted so that the Drains of Q1-Q4 operate at 13.8 Volts DC relative to ground. This value is readjusted after a 1 hour warmup, with the heat sinks operating at approximately 50 deg. C. It should not need additional adjustment over the life of the amplifier, as it references the single Vgs figure (~3V) of Q7 with little gain.

The Drain of Q7 is operated at approximately 3 volts relative to ground.

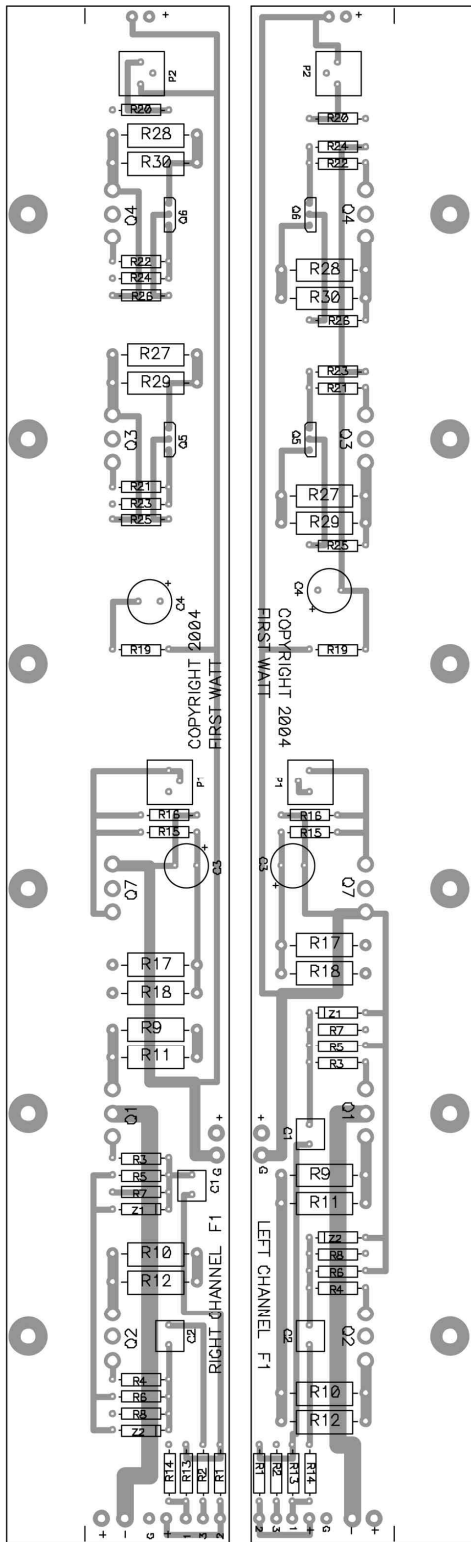
The voltage across R27 – R30 is approximately 0.60 volts DC, and this figure sets the bias for the gain stages, which is slightly less than 2 amps per side, 4 amps total. The bias on Q3 – Q4 is provided by bipolar PNP transistors which generate the .6 Volt junction reference for this value, so that these need no adjustment over the life of the amplifier.

The Gates of Q1 and Q2 are held at about 7 volts DC by the divider networks of R5 – R8, which provide DC feedback. The impedance of these resistors is very high compared to the source impedance, so they provide virtually no feedback effect at audio frequencies. The gain of the amplifier is determined by the transconductance of the Mosfets themselves plus the parallel Source resistors, for a current gain of approximately 0.6 amps per input volt. This figure gives 14 dB of gain into 8 ohms.

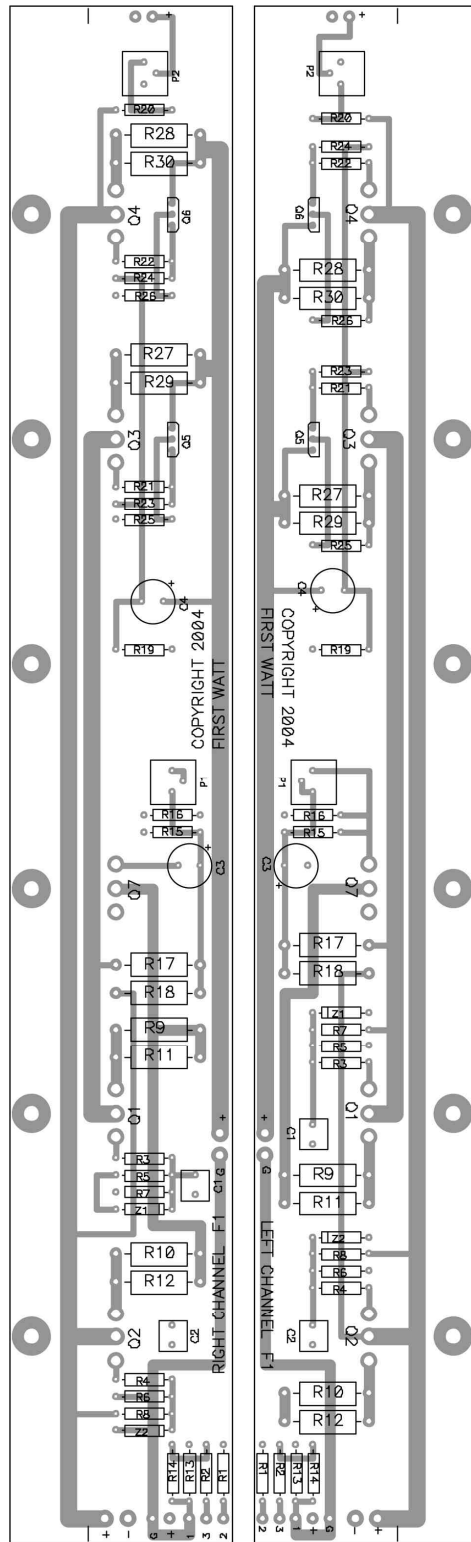
The speakers operate across the Drains of the gain and current source Mosfets. This is at an absolute potential of 13.8 V DC, but the differential voltage seen by the loudspeaker is about 50 mV, depending on the Vgs matching of Q1-2 and Q3-4. If this differential DC offset exceeds 50 mV after 1 hour warmup, then it may be adjusted by placing resistance across R27 or R28 depending on the polarity of the offset. 10 ohms in parallel will shift the differential DC by approximately 50 mV. Note that the absolute DC value should typically be blocked by a capacitor if you are using the amplifier to also drive a subwoofer amplifier.

P2 has only the effect of allowing attenuation of the brightness of the on/off leds on the front panel. It allows matching of brightness in the event that the Led output is not matched, or allows them to be completely turned off (Yes, there are customers who want them off).

Input Zener diodes Z1 and Z2 are for protection from high voltage static input, and otherwise do not perform a function.



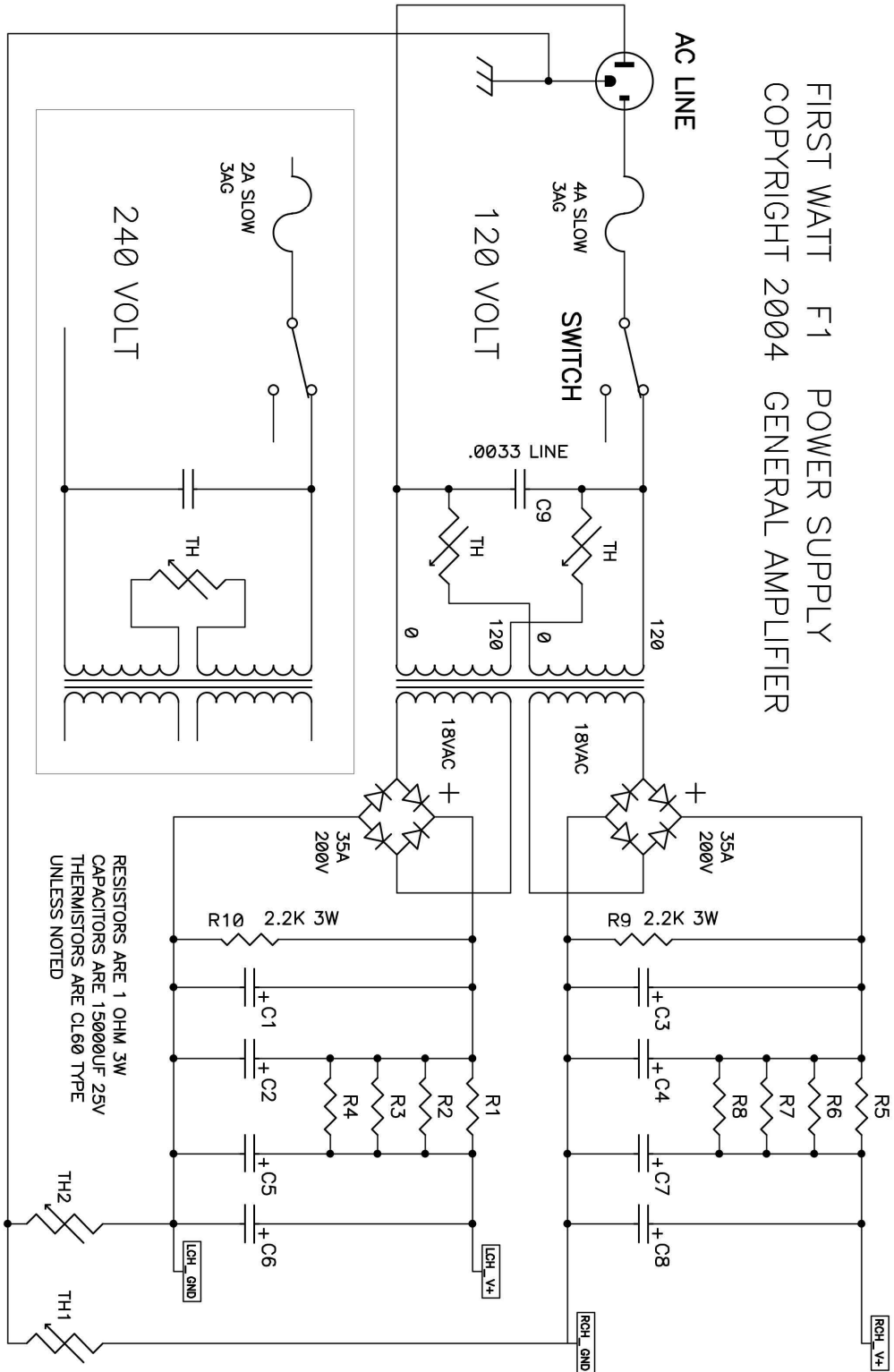
TOP VIEW



BOTTOM SEEN THROUGH TOP

This is the printed circuit board layout for the left and right channels. Note that they are mirror images, right and left.

FIRST WATT F1 POWER SUPPLY
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Here is the schematic for the power supply for both channels

Making reference to the power supply schematic:

We note that there are separate tap arrangements for 120 and 240 VAC. On the diagram of parts layout which follows, you can note the positioning of thermistors on the PC board which allow for conversion between line voltages. All thermistors in the amplifier are of the Keystone CL60 type, with a 10 ohm cold value and a 5 amp current rating.

The secondary channels are completely separate, and communicate to chassis ground through thermistors.

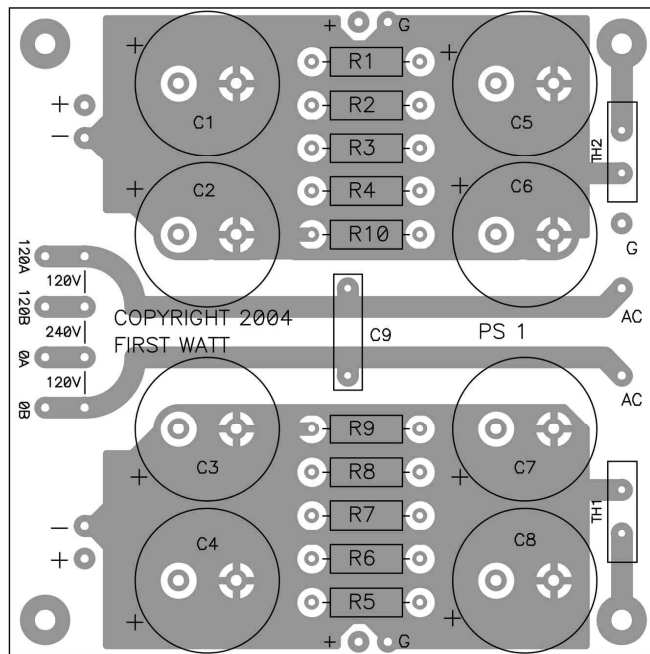
Resistors R1 – R8 and capacitors C1 – C8 form CRC-type storage banks, with a total of 120,000 uF, with a nominal 24 V DC value and ripple voltage filtered down to a few millivolts. Resistors R9 – R10 provide bleed off to remove the charge on the capacitors when the amplifier is turned off.

Safety grounding is important. You will note that the AC line Earth ground goes to the power supply board where it connects directly to the bottom of the chassis through the 4 standoff mounts. It also is connected directly to the rear of the chassis by the ground case tabs of the XLR input connectors.

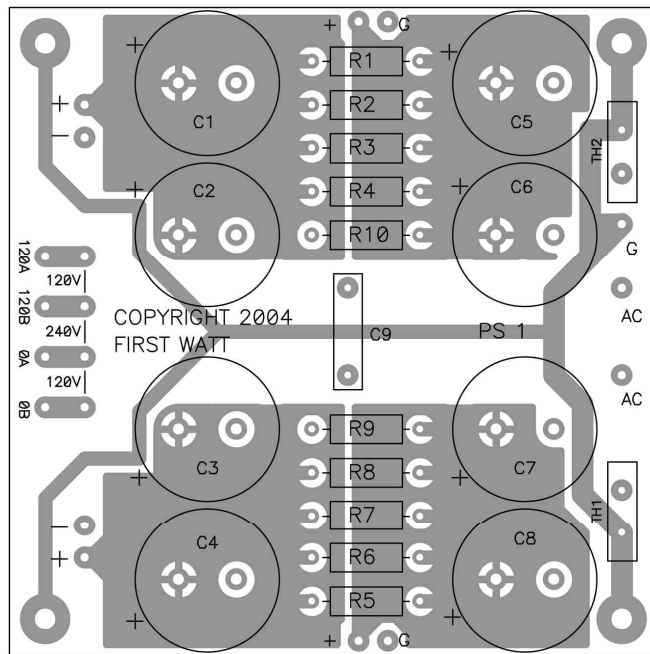
Each of the two analog grounds is isolated from chassis / Earth through the thermistors TH1 and TH2 which ordinarily operate at 5 ohms or so in the amplifier, but which rapidly reduce their resistance so that the fuse will blow before the thermistor fails in the event that the live AC line comes in contact with the secondary system. This finite resistance value is in place to allow safety conduction to ground while minimizing ground loops from an RCA input ground to the preamp and back to the other channel's RCA input, and also the F1's AC line ground back to another component's AC line ground.

Each amplifier is tested for proper ground / chassis resistance and high voltage tested to withstand 2200 volts primary to secondary.

Transformer orientation is part of the test procedure for new amplifiers – there is an optimal rotation angle which minimizes the noise pickup by the circuit. A few degrees one direction or another will take the noise down to 30 uV (unweighted audio range) output noise or less on both channels.



BOTTOM SEEN THROUGH TOP



TOP VIEW

Here is the PC Board Layout for the power supply board. Note the placement of thermistors for AC voltage on the left hand edge. (120V – 120V and 240V). All four mounting posts go to chassis ground.

Summary of the nominal specifications:

Input Impedance, balanced	100 Kohms, 8 ohm load
Input Impedance, unbalanced	50 Kohms, 8 ohm load
Output impedance	80 ohms
Output power 8 ohms	10 watts @ 5% THD 1KHz
Output power 4 ohms	6 watts @ 5% THD 1KHz
Output power 16 ohms	9 watts @ 5% THD 1KHz
Gain	14 dB @ 8 ohms
Maximum output voltage	+/- 20 volts
Maximum output current	+/- 1.75 amps
Frequency response	- 3 dB @ 3 Hz, 100 KHz
Noise	30 uV unweighted, 20-20 KHz, 8 ohms
Power consumption	200 watts (100 watts / channel)
Fuse	3AG slow blow type, 4 Amp for 120VAC 2Amp for 240 VAC

Warranty: Parts and labor for 3 years, not covering shipping or consequential damages. This amplifier is a specialty product. There is no representation that the amplifier will make you happy.

Zen amplifier is a trademark of Pass Labs, Inc.

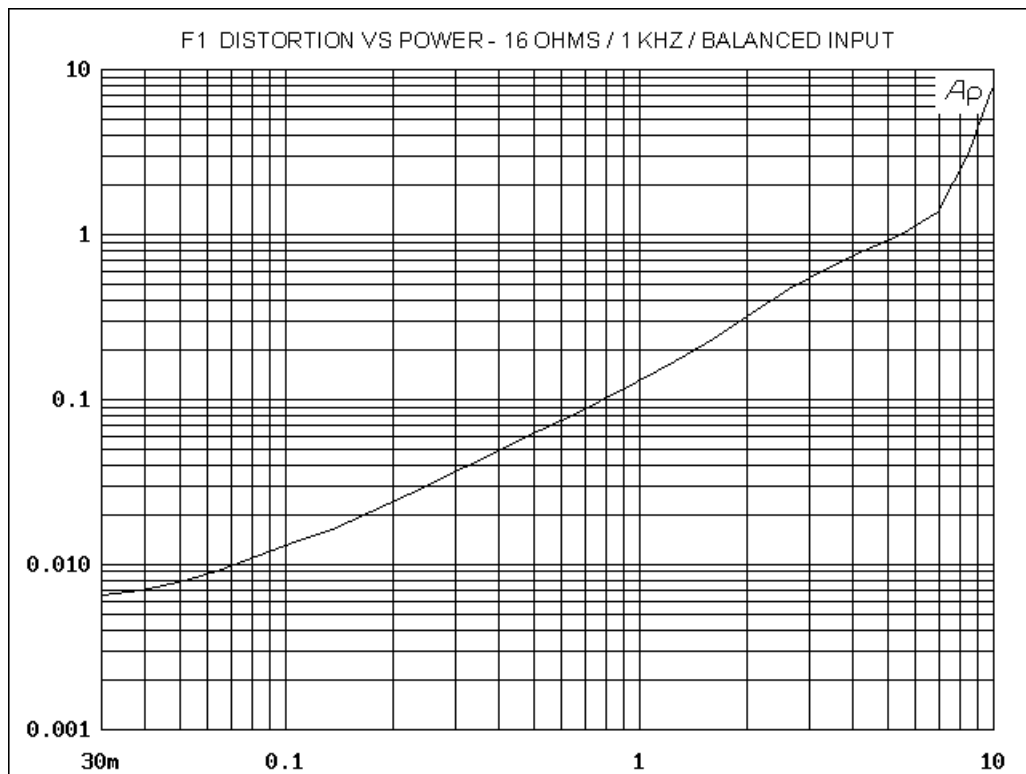
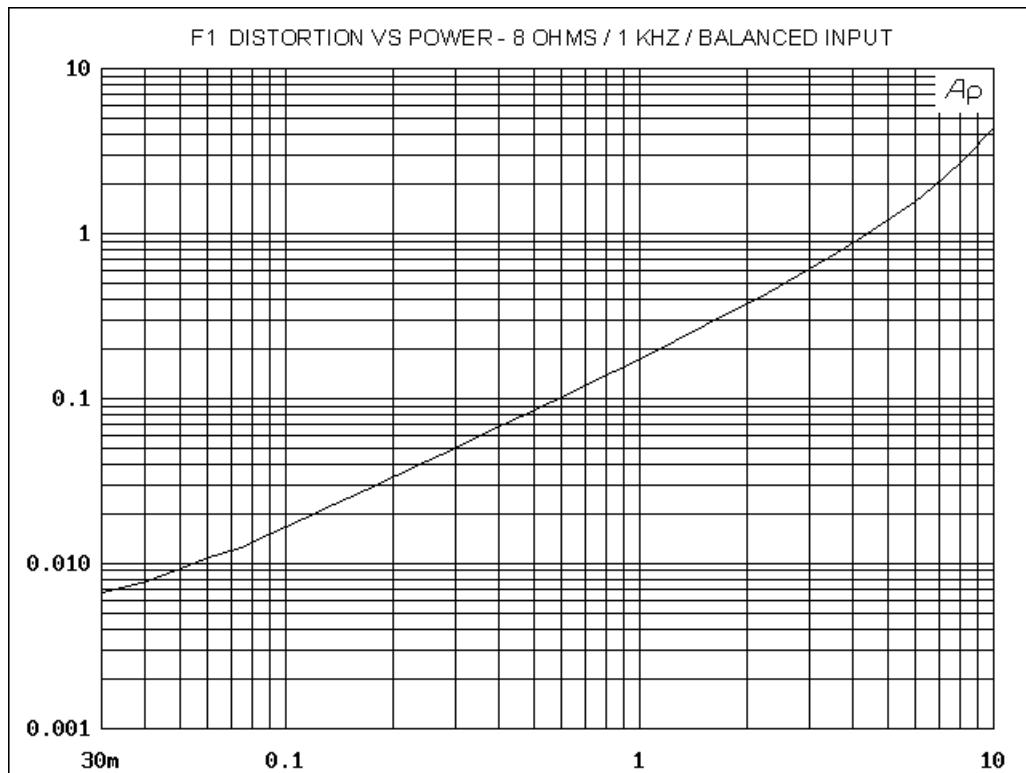
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Typical performance curves:



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