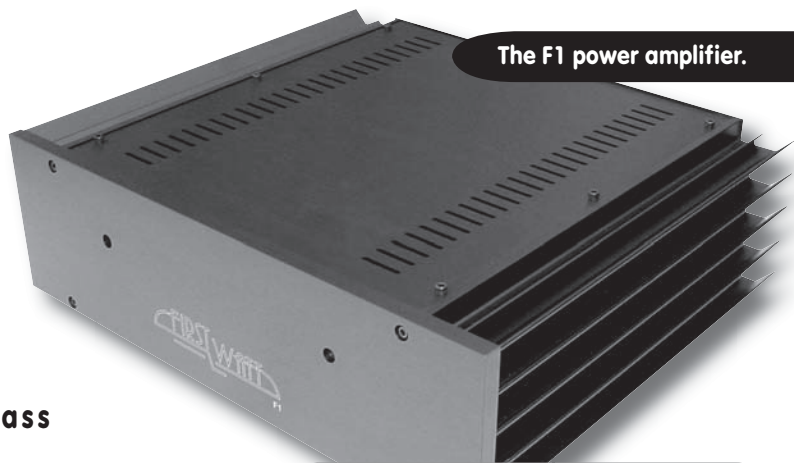


First Watt F1 Power Amplifier Service Manual

By Nelson Pass

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.



The F1 power amplifier.

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.

HOW IT WORKS

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.

more than 90dB per watt). Of greatest interest is the performance offered to high-efficiency full-range drivers, in which 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.

FEATURES

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

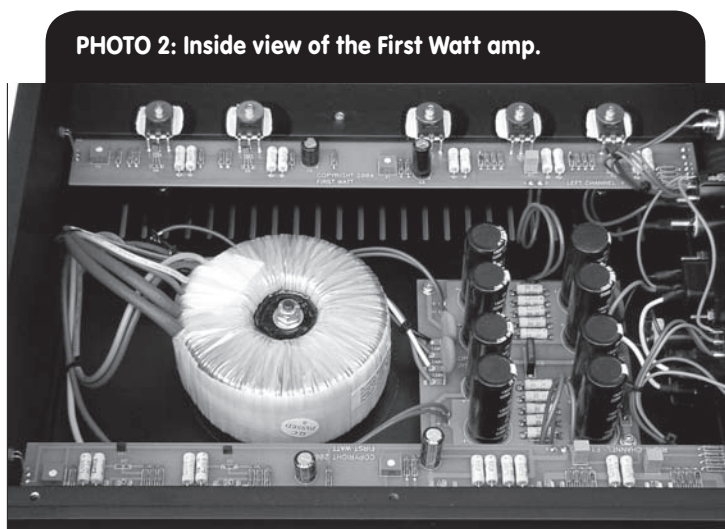


PHOTO 2: Inside view of the First Watt amp.

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

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 produce 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 two or three or four or nine. It operates in pure Class A mode, which is the very best, but at a cost of constantly drawing 100W per channel and giving only 10W 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 in **Fig. 1**, or the amp won't work properly. Some of you will lose these jumpers, but I can send a replacement. Note that pin 1 of the XLR is ground, and pin 2 is the plus input and pin 3 is the minus 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 13.8V 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.

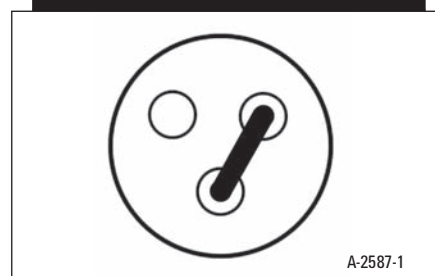
The fuse is a 3AG slow-blow type, 4A for 120V AC and 2A for 240V AC. No substitutions. Contact First Watt if you have any questions.

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.

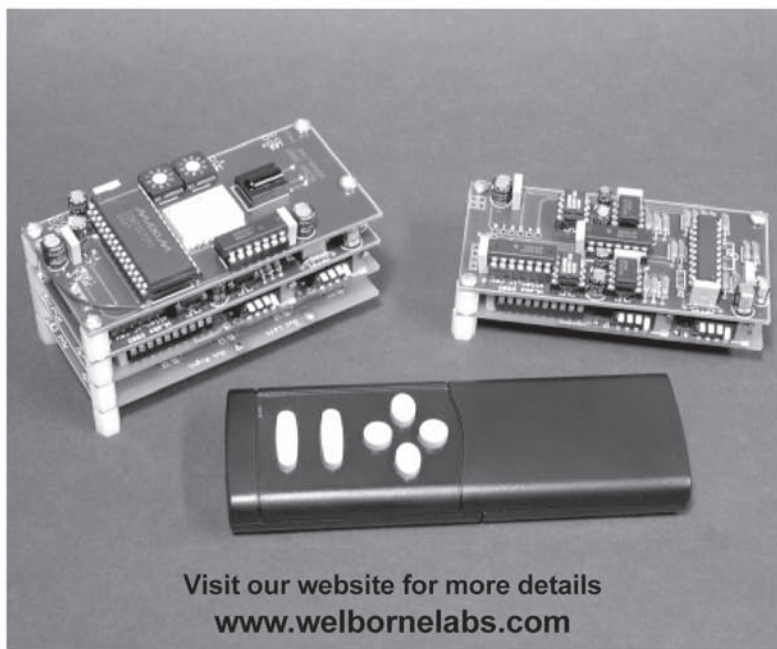
The amplifier requires about ½ hour of operation to reach normal operating temperature, and this warm-up time is appropriate for the most critical listening, but is not otherwise an issue, as the performance difference between 5 minutes and 60 minutes is very marginal. I do not personally see a reason to run the amplifier all the time.

FIGURE 1: RCA input.



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CIRCUIT OPERATION

Figure 2 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 produces 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 (**Fig. 3**).

With reference to the channel schematic, note the following typical voltages:

P1 is adjusted so that the Drains of Q1-Q4 operate at 13.8V DC relative to ground. This value is readjusted after a

1 hour warmup, with the heatsinks operating at approximately 50° 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 3V relative to ground.

The voltage across R27 - R30 is approximately 0.60V DC, which sets the bias for the gain stages, and is slightly less than 2A per side, 4A total. The bias on Q3 - Q4 is provided by bipolar PNP transistors which generate the .6V 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 7V 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 0.6A per input volt. This figure gives 14dB of gain into 8Ω.

The speakers operate across the Drains of the gain and current source MOSFETs. This is at an absolute potential of 13.8V DC, but the differential voltage seen by the loudspeaker is about 50mV, depending on the Vgs matching of Q1-2 and Q3-4. If this differential DC offset exceeds 50mV after 1 hour warmup, then it may be adjusted by placing resistance across R27 or R29 depending on the polarity of the offset. 10Ω in parallel will shift the differential DC by approximately 50mV. 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.

FIGURE 2: Simplified F1 schematic.

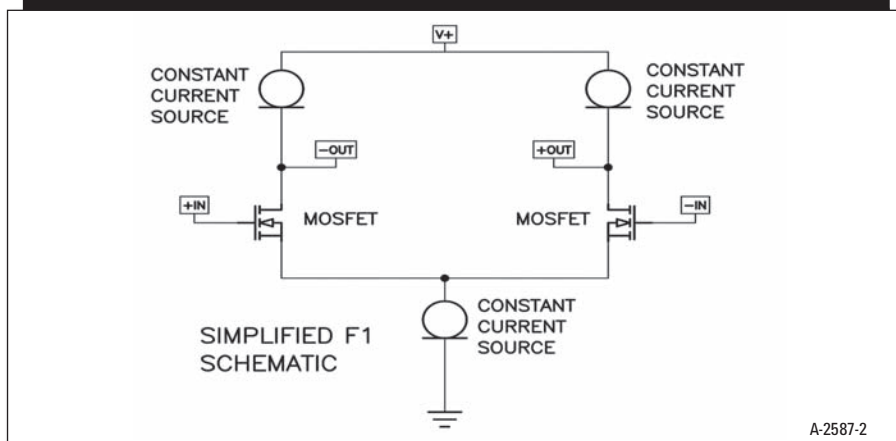


FIGURE 3: Schematic of one channel of the rear amplifier.

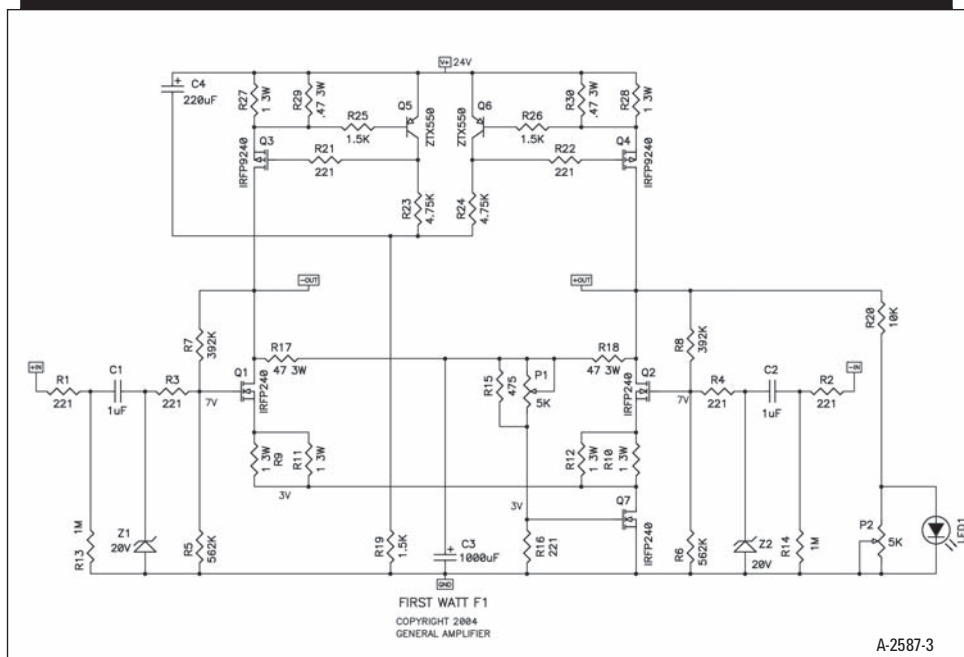


Figure 4 is the printed circuit board layout for the left and right channels. Note that they are mirror images, right and left.

POWER SUPPLY

Figure 5 is the schematic for the power supply for both channels. Note that there are separate tap arrangements for 120 and 240V AC. On the diagram of parts layout (**Fig. 6**) 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 Ω cold value and a 5A current rating. The secondary channels are completely separate, and communicate to chassis ground through thermistors.

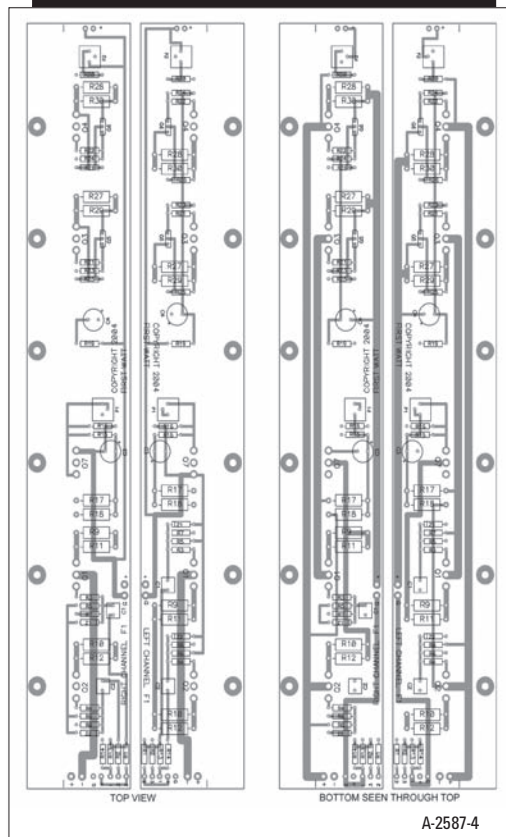
Resistors R1 - R8 and capacitors C1 - C8 form CRC-type storage banks, with a total of 120,000 μ F, with a nominal 24V DC value and ripple voltage filtered down to a few millivolts. Resistors R9 - R10 provide bleed off to remove the charge on the capacitors when the amplifier is turned off.

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 four standoff mounts.

TABLE 1 Summary of the nominal specifications

Input impedance, balanced	100k Ω , 8 Ω load
Input impedance, unbalanced	50k Ω , 8 Ω load
Output impedance	80 Ω
Output power 8 Ω	10W at 5% THD 1kHz
Output power 4 Ω	6W at 5% THD 1kHz
Output power 16 Ω	9W at 5% THD 1kHz
Gain	14dB at 8 Ω
Maximum output voltage	$\pm$ 20V
Maximum output current	$\pm$ 1.75A
Frequency response	-3dB at 3Hz, 100kHz
Noise	30 μ V unweighted, 20-20kHz, 8 Ω
Power consumption	200W (100W/channel)
Fuse	3AG slow-blow type, 4A for 120V AC 2A for 240V AC

FIGURE 4: PCB layout for the left and right channels.



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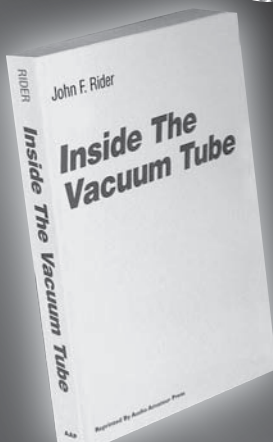
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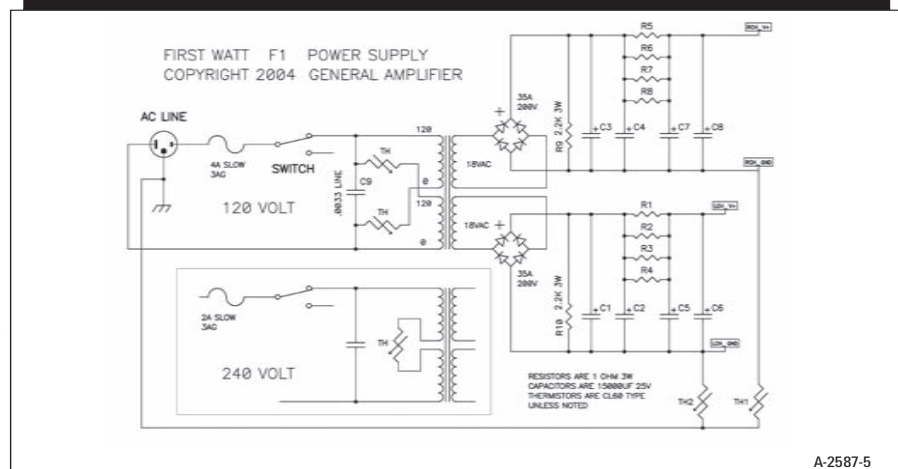
It also is connected directly to the rear of the chassis by the ground case tabs of the XLR input connectors.

Each of the two analog grounds is isolated from chassis/earth through the thermistors TH1 and TH2 which ordinarily operate at 5Ω 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.

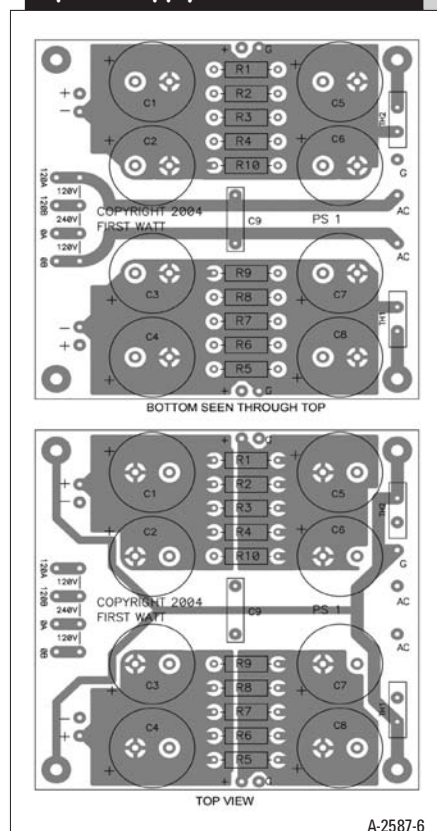
Each amplifier is tested for proper ground/chassis resistance and high-voltage-tested to withstand 2200V primary to secondary. Transformer orientation is part of the test procedure for new ampli-

FIGURE 5: Power supply for both channels.



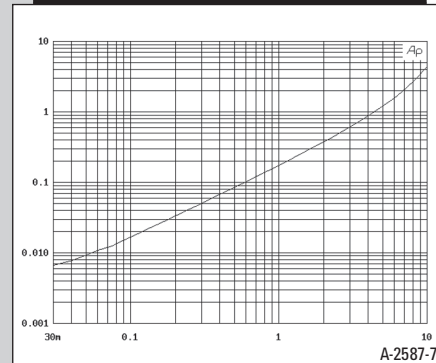
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FIGURE 6: PCB layout for the power supply board.



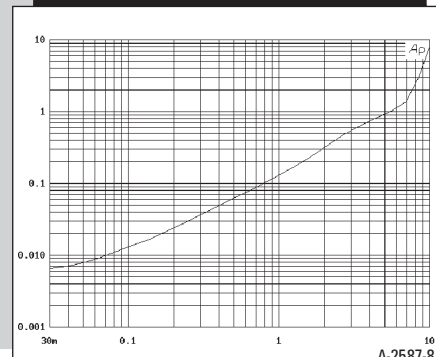
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FIGURE 7: F1 distortion vs. power-8Ω/1kHz/balanced input.



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FIGURE 8: F1 distortion vs. power-16Ω/1kHz/balanced input.



A-2587-8

fiers—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 $30\mu\text{V}$ (unweighted audio range) output noise or less on both channels.

Note in **Fig. 6** the placement of thermistors for AC voltage on the left-hand edge (120V - 120V and 240V). All four mounting posts go to chassis ground. Typical performance curves are in **Figs. 7-10**. *ax*

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Typical performance curves are in **Figs. 7 and 8**. More curves are in **Figs. 9 and 10**.

FIGURE 9: F1 distortion vs. power-4 Ω /1kHz/balanced input.

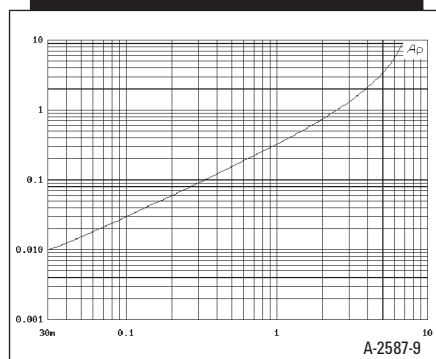
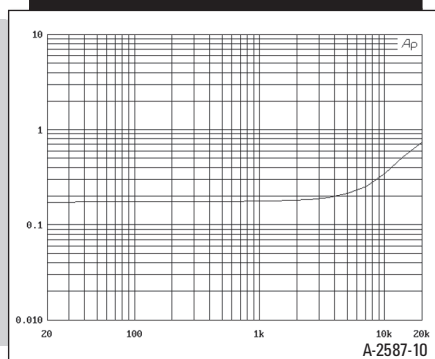
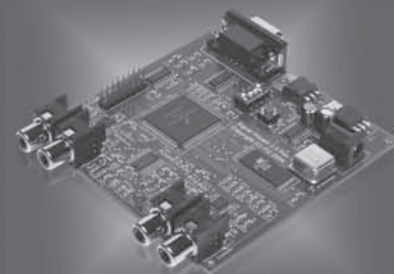


FIGURE 10: F1 distortion vs. frequency-8 Ω /1W/balanced input.



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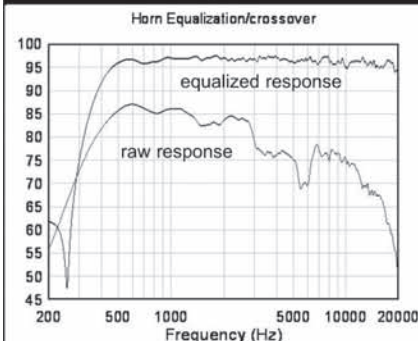
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