Little Fish Logo

LITTLE FISH BICYCLES

A HiFi Power Amp

The recent aquisition of a pair of vintage Infinity RS-5b speakers prompted a search for an amplifier According to the documentation that came with my speakers, an amplifier between 35W and 135W i recommended (not my 10W at 10% THD piece of garbage Sharp 3-in-1). Initially, I looked at comm amplifiers (Yamaha, NAD, and Rotel), but was disappointed at their fairly pedestrian distortion figur hobby project was born :)

I came up with some nominal specifications:

- Stereo. Whilst I'll use it for watching movies, my flat just doesn't have the room for a full set o sound speakers. My main motivation is listening to stereo music sources, so a stereo amplifier
- Low THD and IMD. In audio-speak, this translates either as clinical or as accurate. I'm an engi so prefer terms like THD over "warm" or "cold" which could mean anything. Given that most commercial amps offer 0.02% THD or thereabouts, I figured a good target was 0.001%. This n harmonics and intermods will be 100 dB below the fundamental, and will thus mean that the sy performance will be dictated by the source (CD) material, rather than the amplifier.
- Ample power. 100W seems a reasonable amount. I currently live in a two bedroom flat, and dc neighbours to kill me :) However seriously, I figured 100W gives me a clear 20dB headroom a listening level of 1W.
- Low noise. I usually listen to my music at reasonably low level, so it's important for the amplif have a low noise contribution.
- Moderate cost. I'm happy to blow around $1000, as long as I get plenty of enjoyable hobby hou

listening hours) as payback.
- Good looks. This thing will (along with my preamp) live in my loungeroom. That means it nee don't want something that looks like an escapee from my shed, so a significant part of the desig with building a nice case.
- Useability. This pertains more to the preamp, but I wanted the whole thing to be completely re controllable.

Design Background

When I was a kid, one of my favorite monthly reads was ETI magazine. In January 1981, they publis articles describing the ETI477 MOSFET power amplifier, designed by David Tilbrook. This monobl basis of the "series 5000" HiFi amp. I desperately wanted to build one, but being all of 9 at the time, to happen.

The neat thing about the series 5000 is that it was built around new (at the time) Hitachi lateral powe Most power MOSFETs (VMOS, trenchFETs, HexFETs etc) use a vertical structure, where the curren vertically. This has the advantage of stunningly low R_{ds} and hence high efficiency, but does nothing capacitance. Lateral MOSFETs are a much simpler structure, where the gate oxide is formed on a fla the current flows across the substrate. This results in well defined, controllable device parameters, go and relatively low gate capacitance. However, the R_{ds} of lateral MOSFETs is nothing to write home

Most amplifiers at the time (and now as well) used bipolar output drivers. Bipolar transistors are che plentiful. They have relatively high transconductance, and can operate reasonably fast. However they drawbacks when used at high power. The main one is thermal runaway. The gain of a bipolar transist it gets hotter. That means that if there's any imbalance between output transistors, the hottest one will the current, getting hotter until it ultimately expires. MOSFETs don't have this problem. Their gain d temperature, so they share the load well.

MOSFETs also have a high input impedance at low frequencies, and are capable (when driven by a s of extremely high slew-rates. Of course this very attribute makes them rather prone to HF oscillation improperly compensated, but with careful design they're capable of impressive intermod performanc

So having decided that now was the time to build a MOSFET amp, I wandered into the library at wor the old ETI series 5000 amp articles, and had a read. I subsequently found that the series 5000 wasn't final word on MOSFET amps. In 1987 he revisited the topic for a new magazine, Australian Electror This time (with the AEM6000 amplifier) he went all-out, with a matched-JFET differential input stag complementary symmetrical voltage amplifier stage. A quest for super low distortion figures, with he available gain. This looks like a good place to start.

Optimisation

There were a couple of drawbacks with the design. Firstly, it was based on obsolete TO-3 packaged l MOSFETs, and secondly the PCBs (like many kitset boards) were a pretty poor design anyway. I set redesigning the PCBs around modern flatpack equivalents (Hitachi 2SK1058 and 2SJ162). While I w swapped many of the remaining transistors for modern (faster) equivalents.

I made the following active device substitutions:

- JFET input diffamp: SST404 (SO-8). Was ECG461.
- Low power bipolars: MMBTA06/56 (SOT-23). Were BC547/557 and BC639/640.
- Medium power bipolars: MJE340/350 (TO-126). Unchanged.
- Power MOSFET drivers: 2SK1058/2SJ162 (TO-3P). Were 2SK176/2SJ56 (AEM6000) or 2SK (AEM6005 and ETI5000).

In order to dissipate 100W in an 8 Ohm speaker, one needs to put 28V RMS across the load. That's 4 the peak (assuming a resistive load) the amplifier needs supply 5A. Doing the SOA sums (more later

pairs of drivers are needed. Further, the V_{gs} for the MOSFET can be around 10V at high current. Thi
supply must be at least 10V greater than the peak output voltage. A twin 40V transformer is appropri
peak secondary voltage of +/-56V.

Now that I'd changed the transistors, I had to play with the values of most of the other components as
to get reasonable performance while maintaining stability. Firstly, I decided that rather than the usual
power input, I'd increase this a bit, to 1.8V RMS. This allows me to use more of the available dynam
preamp, and requires a gain of 16, or 24dB.

Transistors (and valves) are inherently non-linear devices. They must be linearised, or else they'll dis
There are three ways to achieve this goal:

- Use the transistor over a very small operating range.
- Use feedforward to cancel distortion (symmetry).
- Use feedback to cancel distortion.

Pretty much all amplifiers use a combination of the three. Feedback has a bad name amongst "audiop
Poorly thought out feedback (especially across multiple stages) can result in oscillation (usually at ve
frequency, which isn't audible in itself, but destroys the performance of the amplifier. Feedback need
global though. A robust scheme involves linearising each stage of an amplifier independently (for ex
emitter degeneration), then using overall feedback (with appropriate compensation) to set the gain.

I used Linear-Tech's free spice simulator to redesign the circuit around the newer parts. My main cha
increase the emitter degeneration in each stage, to improve the linearity of each stage, at the expense
overall open-loop gain. This is an approach that makes for an easily stabilised amplifier.

A somewhat simplified schematic is shown below. Yes, it's a wonderfully complex beast of an ampli
symmetry, and plenty of stages, for ample open-loop gain. The schematic doesn't show the AEM600
take on Tilbrook's design. The topology is the same, but the component values are different. For sche
AEM6000, you'll have to visit the library. Click on the schematic shown for a .pdf version of the real
including power supply decoupling and gate protection zeners etc.: