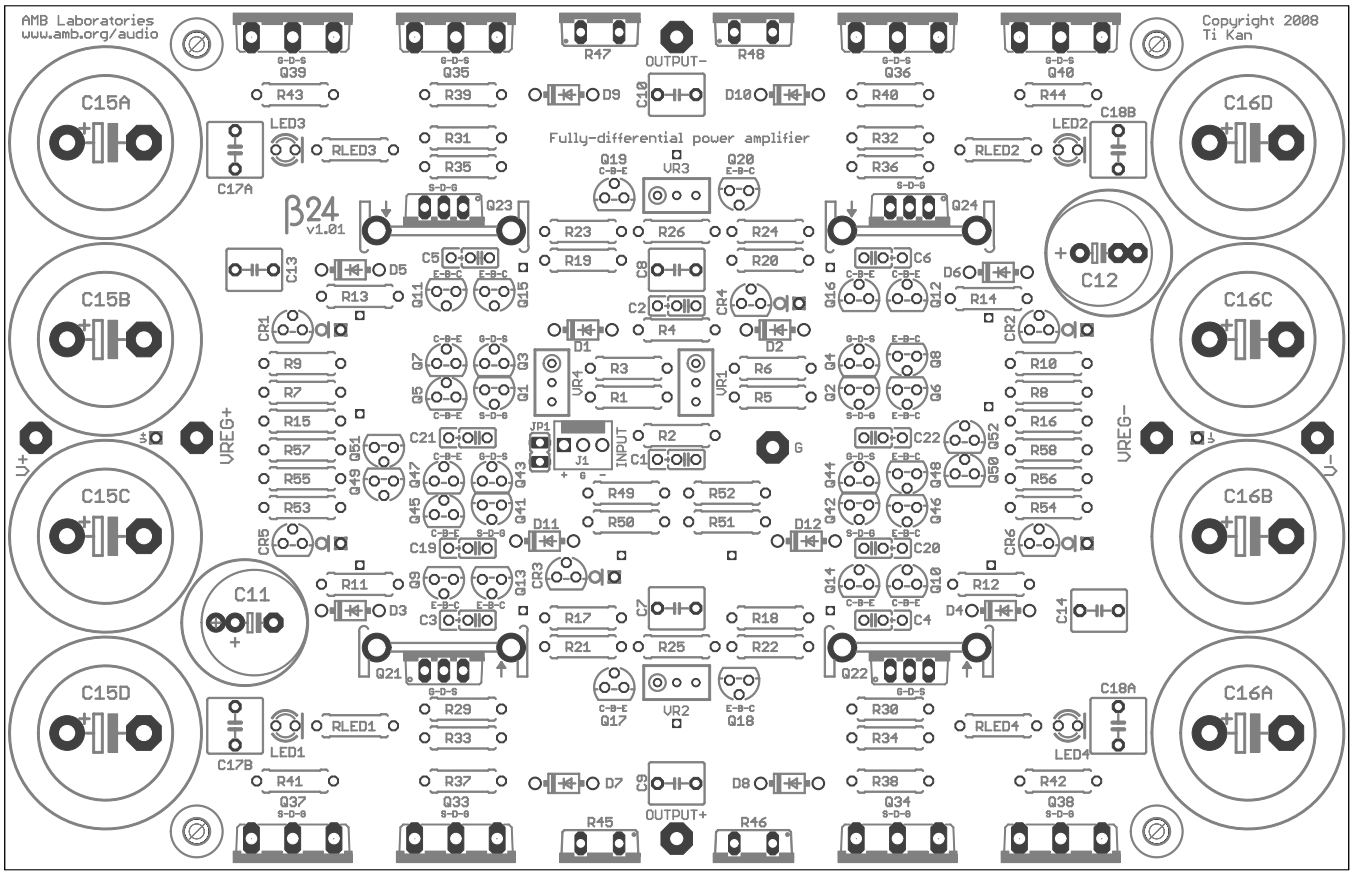
AMB

β24

Fully-differential Power Amplifier
Version 1.01 Documentation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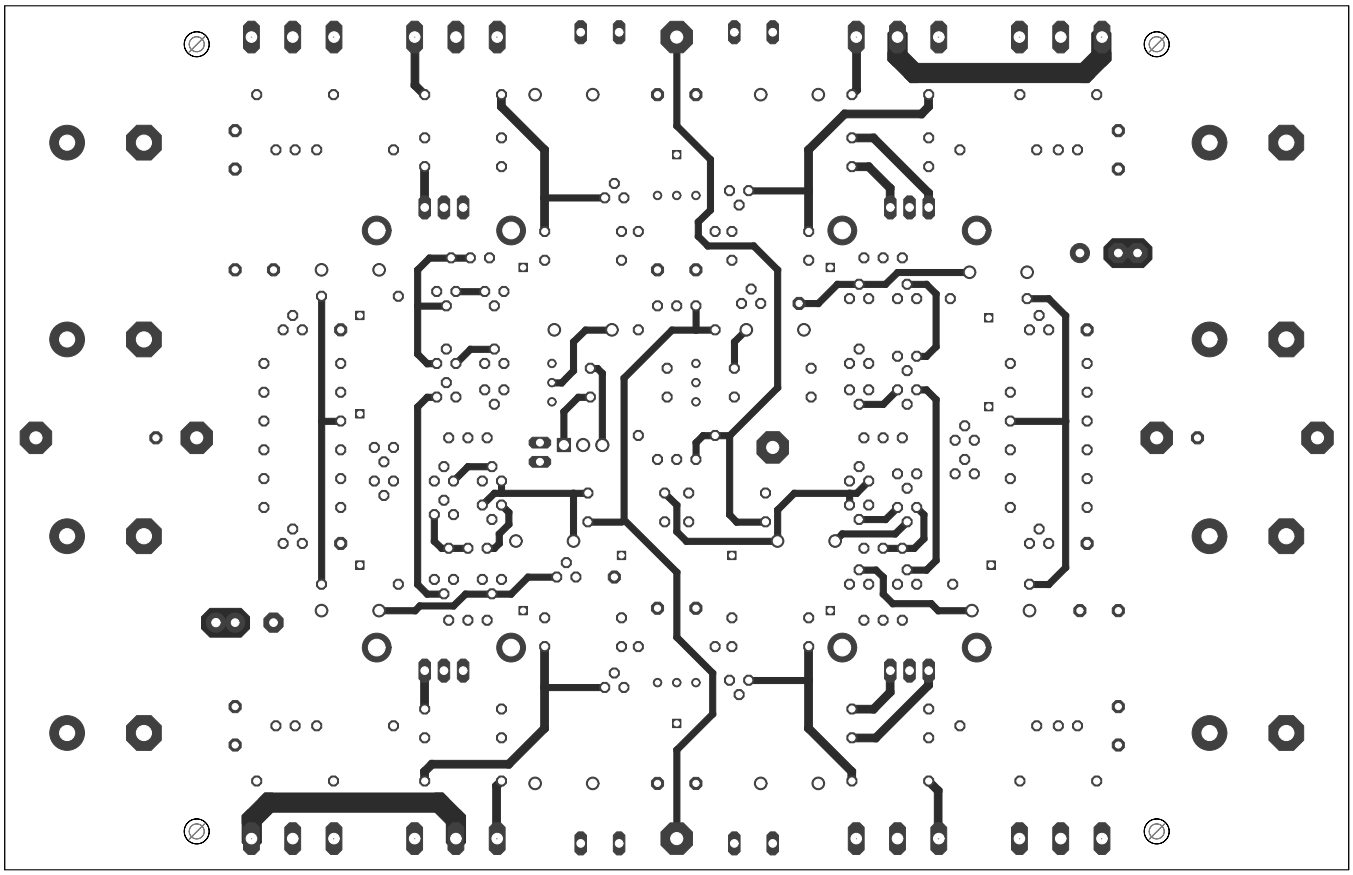
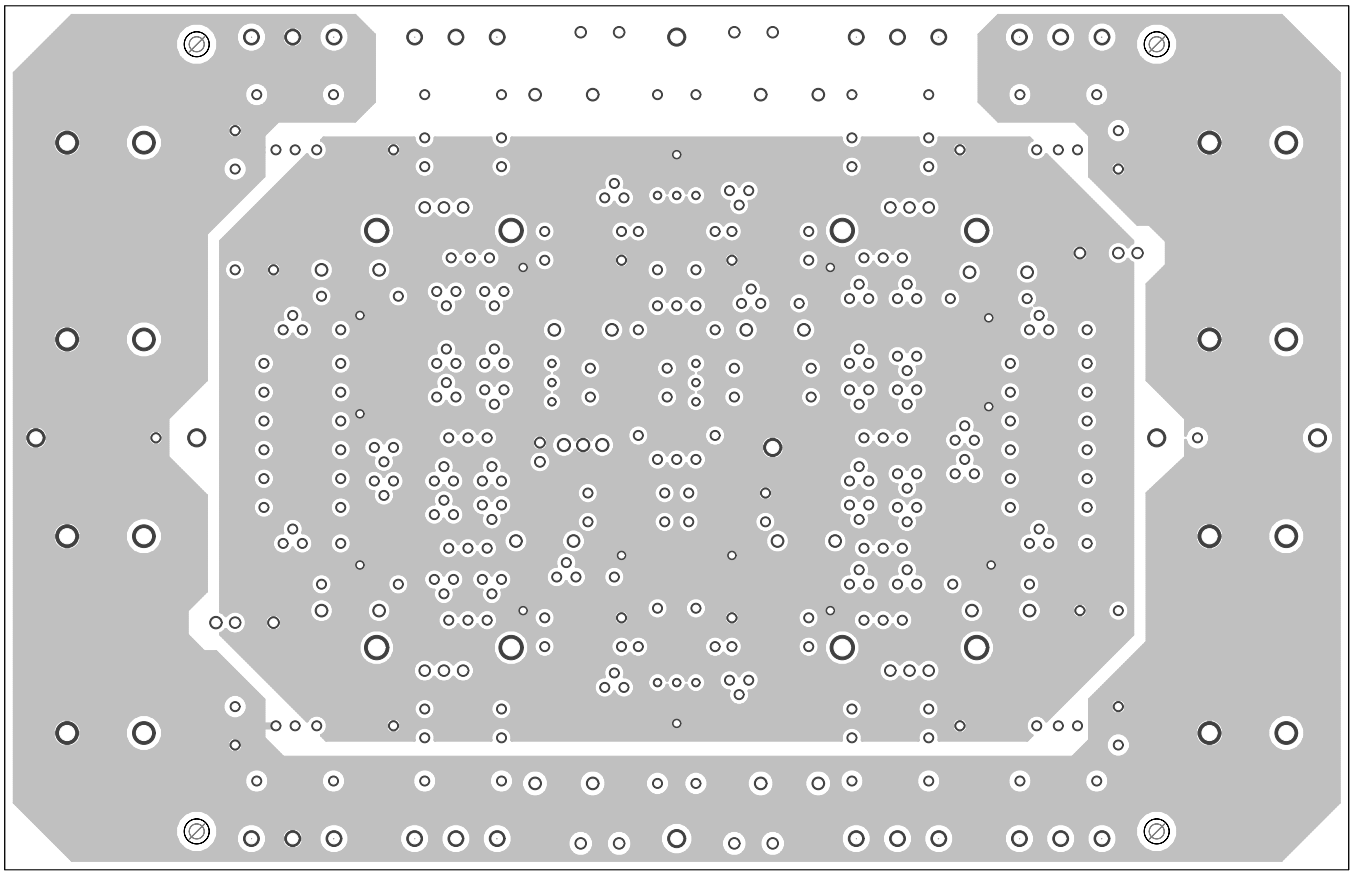
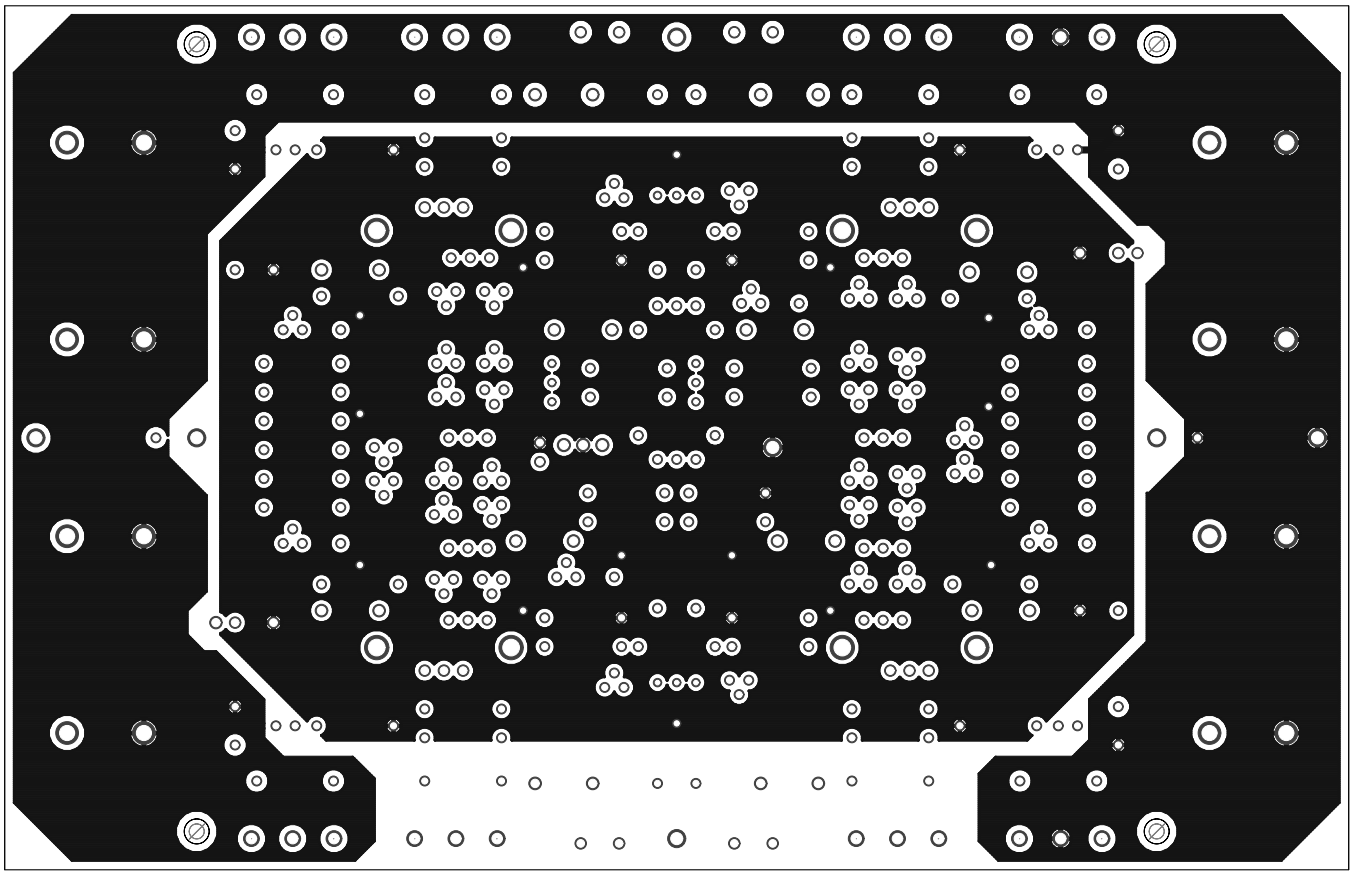
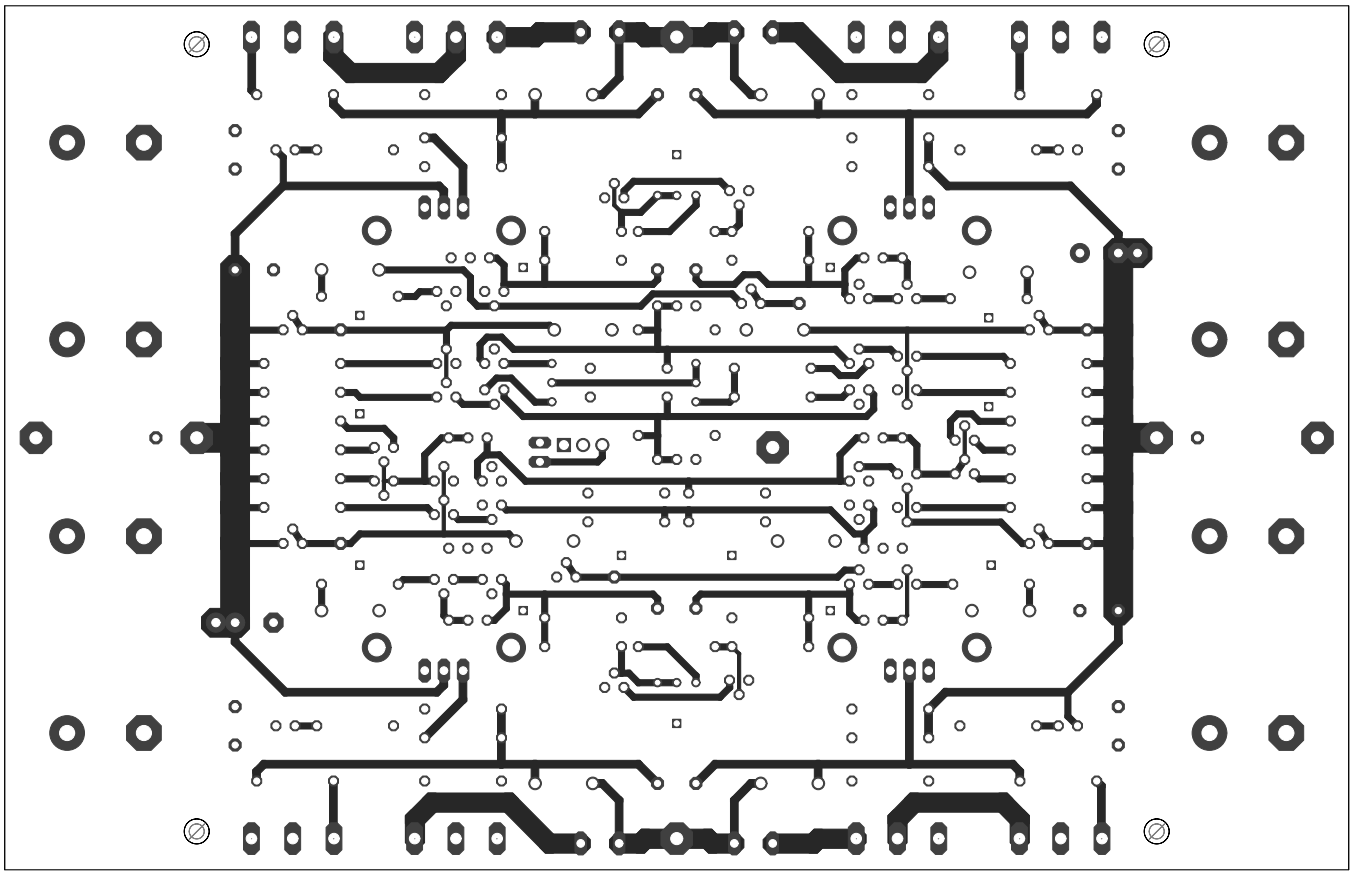
Ti Kan
Fully-differential power amplifier
β24
v1.01
OUTPUT-
OUTPUT+
INPUT
VREG+
VREG-
V+
V-
C15A
C15B
C15C
C15D
C16A
C16B
C16C
C16D
C11
C12
C17A
C17B
C18A
C18B
LED1
LED2
LED3
LED4
VR1
VR2
VR3
VR4
JP1
J1

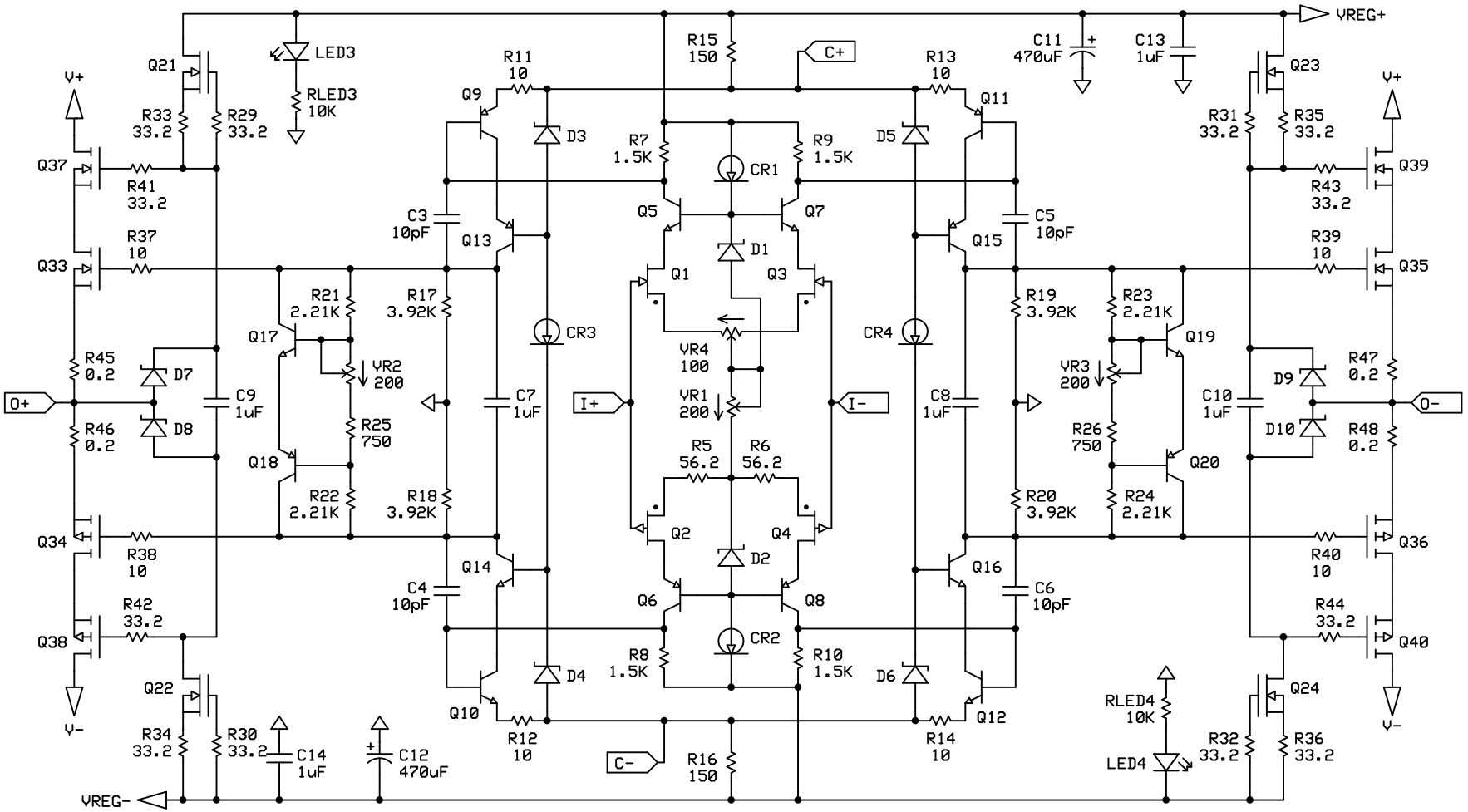




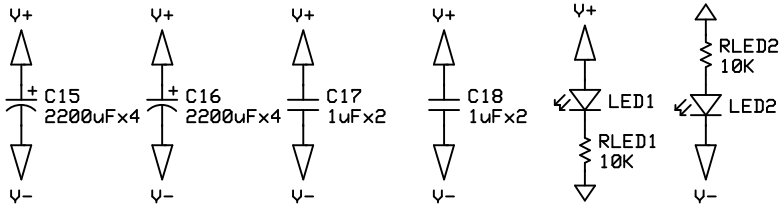




Main Amplifier Block



V+,V-: +/-30V unregulated
VREG+,VREG-: +/-36V regulated
VR1: Input/VAS bias adj
VR2: Output+ bias adj
VR3: Output- bias adj
VR4: Relative DC offset adj



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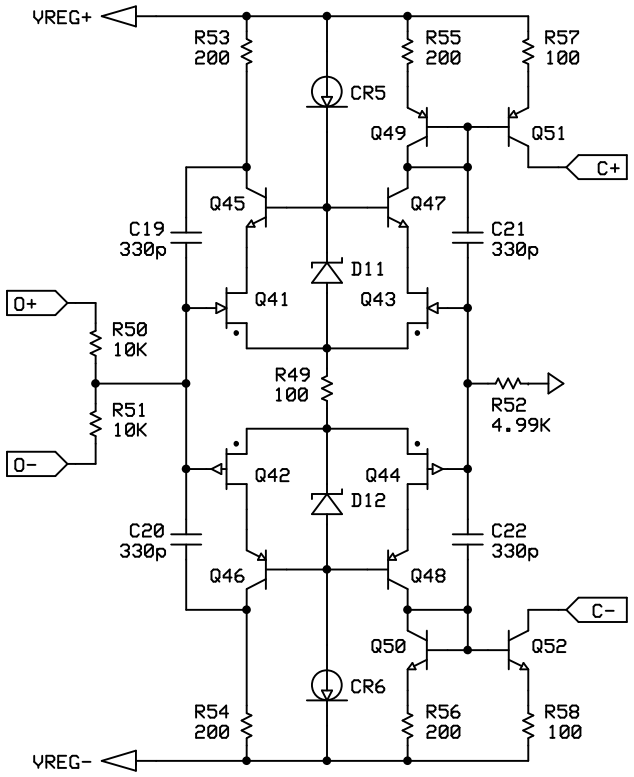
Rev 1.01
06/15/2008

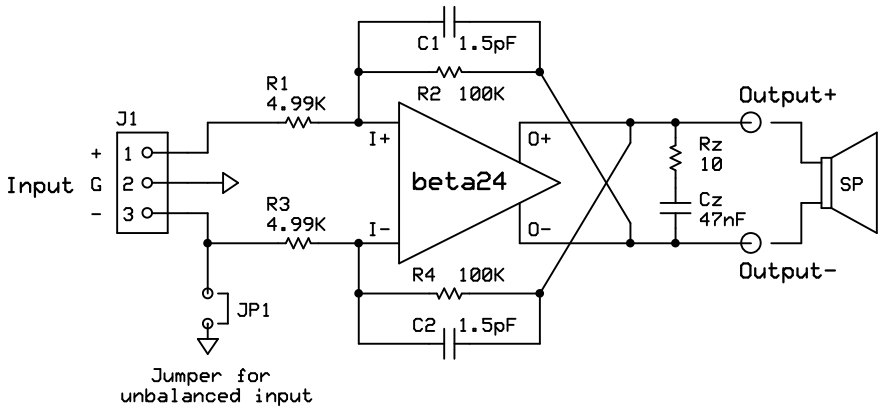
Common-Mode Feedback



Parts Notes:

Q1,Q3,Q41,Q43: 2SK170BL; Q2,Q4,Q42,Q44: 2SJ74BL
Q5,Q7,Q10,Q12,Q14,Q16,Q17,Q19,Q45,Q47,Q50,Q52: BC550C
Q6,Q8,Q9,Q11,Q13,Q15,Q18,Q20,Q46,Q48,Q49,Q51: BC560C
Q21-Q24: DN2535N5
CR1-CR6: 1N5291 or E-501
Q33,Q35,Q37,Q39: IRFP140N
Q34,Q36,Q38,Q40: IRFP9140N
D1-D6,D11,D12: BZX55C12
D7-D10: 1N5931B
R45-R48: Caddock MP915 or MP930
Rz: metal oxide 5W
All other resistors metal film 1/8W 1%
C1-C6,C19-C22: multilayer ceramic C0G/NP0 100V
C7-C10,C13,C14: MKT/MKS 63V
C11,C12: aluminum electrolytic 50V low-ESR
C15,C16: aluminum electrolytic 100V low-ESR
C17,C18,Cz: MKT/MKS 100V

Input/Output/NFB/Zobel



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AMB beta24 BOM (v1.01)

Amplifier board parts:
Not including PSU, case, output MOSFET heatsinks, input/output connectors, hardware
Quantities are for TWO boards (stereo)

Qty / Ref / Description / Recommended part(s) / Mouser, Digikey or other part #
---
2 / - / beta24 amplifier PCB / - / AMB
6 / R1,R3,R52 / 4K99 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-4.99K
4 / R2,R4 / 100K 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-100K
4 / R5,R6 / 56R2 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-56.2
8 / R7-R10 / 1K5 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-1.5K
16 / R11-R14,R37-R40 / 10R 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-10
4 / R15,R16 / 150R 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-150
8 / R17-R20 / 3K92 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-3.92K
8 / R21-R24 / 2K21 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-2.21K
4 / R25,R26 / 750R 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-750
24 / R29-36,R41-R44 / 33R2 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-33.2
8 / R45-R48 / 0R2 15W power film resistor / Caddock MP930 / Mouser 684-MP930-0.2
6 / R49,R57,R58 / 100R 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-100
12 / R50,R51,RLED1-RLED4 / 10K 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-10K
8 / R53-R56 / 200R 1/8W 1% metal-film resistor / Vishay-Dale RN55D / Mouser 71-RN55D-F-200
2 / Rz / 10R 5W non-inductive resistor / Xicon MO or Huntington Electric MRA05-10-1% / Mouser 286-10-RC, Digikey MRA05-10-ND
2 / - / 22R 10W power resistor for initial setup / cement filled wirewound or other / Xicon PW or Yageo SQP / Mouser 280-CR10-22-RC or Digikey 22W-10-ND
6 / VR1,VR2,VR3 / 200R 3/8" cermet multiturn trimpot / Vishay-Sfernice T93YA, Vishay-Spectrol 64W, Bourns 3296W / Mouser 72-T93YA-200, Digikey 3296W-201-ND
2 / VR4 / 100R 3/8" cermet multiturn trimpot / Vishay-Sfernice T93YA, Vishay-Spectrol 64W, Bourns 3296W / Mouser 72-T93YA-100, Digikey 3296W-101-ND
4 / C1,C2 / 1.2pF 100V C0G/NP0 cap 2.5mm or 5mm pitch / Murata RPE5C2A1R2C2P1B03B / Digikey 490-3618-ND
8 / C3-C6 / 10pF 100V C0G/NP0 cap 2.5mm or 5mm pitch / Kemet C315C100J1G5TA, Epcos B37979N1100J000 / Mouser 80-C315C100J1G, Digikey P4837-ND
12 / C7-C10,C13,C14 / 1uF 63V MKT/MKS 7.5mm x 5mm box cap 5mm pitch / Vishay-BC MKT370, Vishay-Roederstein MKT1817, Wima MKS2-1.0/63/5 / AMB, Mouser 505-MKS21.0/63/5, Digikey 3019PH-ND
4 / C11,C12 / 470uF 50V electrolytic cap 13mm diam 5mm pitch or 18mm diam 7.5mm pitch / Nichicon HE or PW, Panasonic FC or FM / Mouser 647-UHE1H471MHD3, Digikey P10328-ND
16 / C15A-C15D,C16A-C16D / 2200uF 100V electrolytic cap 25mm diam 10mm pitch / Panasonic TS-HA ECO-S2AA222CA / Digikey P6994-ND
8 / C17A,C17B,C18A,C18B / 1uF 100V MKT/MKS 7.5mm x 7.5mm box cap 5mm pitch / Wima MKS2-1/100/10, Epcos B32529D1105J / Mouser 505-MKS21/100/10, Digikey 495-1169-ND
8 / C19-C22 / 330pF 100V C0G/NP0 cap 2.5mm or 5mm pitch / Kemet C315C331J1G5TA / Mouser 80-C315C331J1G, Digikey 399-4173-ND

2 / Cz / 0.047uF 100V MKT or X7R cap / Mouser 80-C322C473J1R5CA, Digikey 399-4370-ND
8 / Q1,Q3,Q41,Q43 / 2SK170BL N-JFET / Toshiba, TO-92, matched quad w/ 2SJ74BL / AMB
8 / Q2,Q4,Q42,Q44 / 2SJ74BL P-JFET / Toshiba, TO-92, matched quad w/ 2SK170BL / AMB
24 / Q5,Q7,Q10,Q12,Q14,Q16,Q17,Q19,Q45,Q47,Q50,Q52 / BC550C NPN BJT / TO-92 / AMB, Mouser 512-BC550CTA
24 / Q6,Q8,Q9,Q11,Q13,Q15,Q18,Q20,Q46,Q48,Q49,Q51 / BC560C NPN BJT / TO-92 / AMB, Mouser 512-BC560CTA
8 / Q21-Q24 / DN2535N5 N-DMOS / Supertex, TO-220 / Mouser 689-DN2535N5-G
8 / Q33,Q35,Q37,Q39 / IRFP140N N-MOSFET / International Rectifier, TO-247AC / Digikey IRFP140NPBF-ND
8 / Q34,Q36,Q38,Q40 / IRFP9140N P-MOSFET / International Rectifier, TO-247AC / Digikey IRFP9140NPBF-ND
12 / CR1-CR6 / 1N5291 or E-501 0.56mA CRD / Central Semiconductor or Semitec, DO-35 / AMB
16 / D1-D6,D11,D12 / BZX55C12 12V 500mW zener diode / DO-35 / AMB
8 / D7-D10 / 1N5931B 18V 3W zener diode / DO-41 / Mouser 863-1N5931BRLG
8 / LED1-LED4 / 3mm (T1) LED / various / your choice
16 / - / TO-247AC Heatsink isolation pad / Bergquist Sil-Pad K10-104 / Digikey BER120-ND
8 / - / PCB heatsink / Aavid-Thermalloy 592502B03400G, Fischer FK218 / Mouser 532-592502B34, Digikey HS372-ND
- / - / Heatsink thermal compound / for PCB heatsinks / Radio Shack 276-1372, Mouser 567-120-SA, DigiKey 345-1006-ND
2 / J1 / 3P 0.100" header / Molex KK 22-11-2032 or 22-23-2031 / Mouser 538-22-11-2032, Digikey WM2701-ND
2 / - / 3P 0.100" plug housing / Molex KK 22-01-3037 / Mouser 538-22-01-3037, Digikey WM2001-ND
6 / - / .100 crimp terminal / Molex 08-56-0110 or 08-50-0114 / Mouser 538-08-56-0110, Digikey WM1129-ND
2 / JP1 / 2P 0.100" pin strip header / (optional: for unbalanced input if not using switch) / Mouser 517-2312-6111TG, Digikey HMTSW-106-08-L-Q-318-ND
2 / JP1 / 2P 0.100" jumper shunt / (optional: for unbalanced input if not using switch) / Mouser 517-955-06, Digikey S9001-ND

Power Supply parts - AC mains and unregulated supply
(This is what AMB used in the reference build. Your choices may vary)

Qty / Ref / Description / Recommended part(s) / Mouser, Digikey or other part #
---
1 / - / Power transformer / 30V+30V 250VA+ per channel / Plitron 7391-B0-00 30Vx4 500VA shielded/encapsulated toroidal
2 / - / GBPC3504 35A 400V bridge rectifier / chassis-mount, solder tab / Mouser 512-GBPC3504, Digikey GBPC3504DI-ND
8 / - / 0.01uF 100V C0G/NP0 multilayer ceramic capacitor axial lead / Kemet AXIMAX / Mouser 80-C440C103J1G5CA or Digikey 399-4519-1-ND
4 / - / 10000uF 50V electrolytic capacitor, chassis mount / Elna or others / -
2 / - / 30R 25W aluminum chassis-mount resistor / Arcol HS25 or Stackpole KAL / Mouser 284-HS25-30F or Digikey KAL2525F-ND
1 / - / IEC AC inlet 20A, panel-mount / Schurter 6100.3300, Qualtek 703W-00/08, others / Mouser 693-6100.3300, Digikey Q336-ND, Parts-Express 090-442
1 / - / Fuse holder, panel-mount / Littelfuse 3453LF7 / Mouser 576-03453LF7H or Digikey F3122-ND
1 / - / Slo-blo AGC/3AG fuse 10A / Littelfuse 0326010.HXP / Mouser 576-0326010.HXP, Digikey F2647-ND

Sigma22 parts - regulated PSU, setup for +/-36V output
See http://www.amb.org/audio/sigma22

Quantities are per sigma22 board
Use standard sigma22 +/-36V configuration BOM. The transformer used in the AMB reference build is as follows:

Qty / Ref / Description / Recommended part(s) / Mouser, Digikey or other part #
---
1 / - / Power transformer / 35V+35V 15VA per channel / SumR custom 30VA shielded/encapsulated toroidal

Epsilon24 parts - power switch driver circuit
See http://www.amb.org/audio/epsilon24
(This is what AMB used in the reference build. Your choices may vary)
Use standard epsilon24 configuration BOM, in addition to the following.
For the transformer you can use a sigma24 board and a 12V 1.5VA EI30 transformer in lieu of the Amveco listed below.

Qty / Ref / Description / Recommended part(s) / Mouser, Digikey or other part #
---
1 / power switch / Bi-color illuminated momentary pushutton switch / Bulgin MPI002/28/D4 / Allied 566-0027
1 / power relay / 40A DC trigger solid state relay, zero crossing / Crydom D1240 / Mouser 558-D1240 or Digikey CC1003-ND
1 / bleeder relay / 20A 12VDC DPDT relay / Omron MJN2CE-DC12 / Mouser 653-MJN2CE-DC12 or Digikey Z249-ND
1 / - / inline fuse holder, 5x20mm fuse / - / -
1 / - / fuse 5x20mm 0.5A fast acting / - / -
1 / - / 12V 1.5VA transformer / Amveco TE62002 or similar/ Digikey TE62002-ND

Chassis/Misc parts (both channels in single case)
(This is what AMB used in the reference build. Your choices may vary)

Qty / Ref / Description / Recommended part(s) / Mouser, Digikey or other part #
---
1 / - / RCA jack pair, panel-mount / CMC gold front mount / -
2 / - / XLR 3P female jack, panel-mount / Neutrik / Parts-Express 092-036
2 / - / Subminiature DPDT toggle switch (for balanced/unbalanced selector) / Moutain Switch / Mouser 108-2MD1T2B3M1QE-EVX
2 / - / Binding post pair, panel-mount / CMC gold WBT-style / -
1 / - / Amplifier case / - / Hifi2000 Pesante Dissipante 1NPD04300B 4U 300mm, 10mm panel silver
1 / - / Additional panel for rear / - / Hifi2000 1FRONT1004B 4U silver
2 sets / - / Front and rear handles / - / Hifi2000 1MAL04B milled silver
4 / - / Chassis feet / - / Hifi2000 PDAMMGOMMA vibration damping
- / - / Custom milled aluminum front and rear subpanels, subchassis plates
- / - / Custom milled acrylic top cover with vent slots
- / - / Hookup wire for output, power and ground / 16 AWG stranded, various colors / -
- / - / Hookup wire for small-signal/low-current / 24 AWG stranded, various colors / -
- / - / Hardware, various / machine screws, nuts, etc. / -

AMB beta24 Power Supply

Each beta24 PCB requires two dual-rail power supplies:

VREG+/VREG-:
    Regulated supply, +/-36V (use AMB sigma22)
    This is for all stages of the circuit except the output MOSFETs.
V+/V-:
    Unregulated power supply, +/-30V to +/-40V under load
    This is for the output MOSFETs.

For lowest cost, you may use a single sigma22 PSU board and one 30VA transformer for the VREG+/VREG- of both beta24 boards, and use one unregulated PSU (consisting of a single large 500+VA transformer, one chassis-mount bridge rectifier, and one pair of filter capacitors).

A "maxed" configuration would use dual sigma22 PSU boards and dual unregulated supplies to independently power each beta24 board.

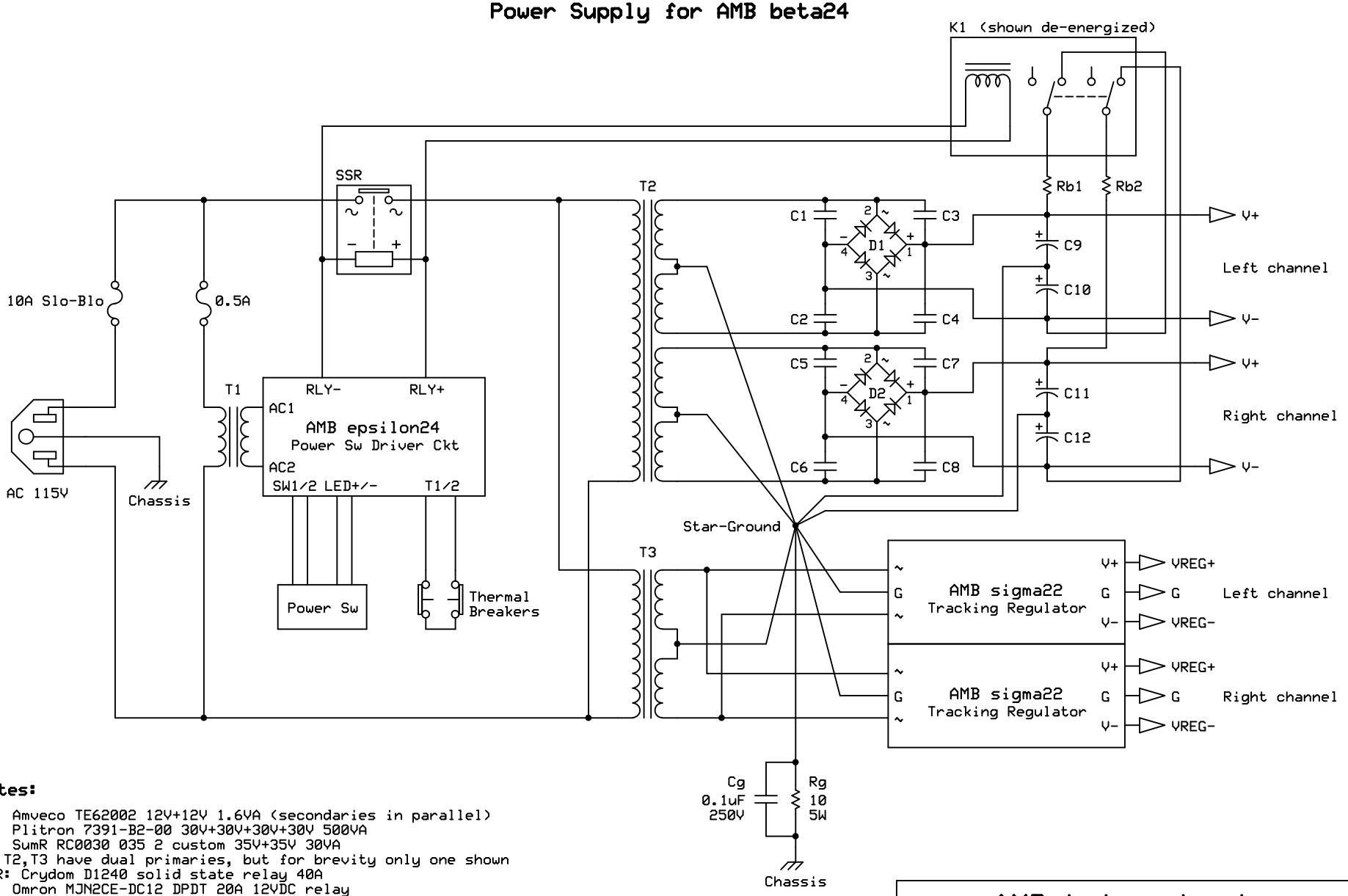
You can build your power supplies in either of these configurations, or a configuration somewhere between the two. For example, you could use two sigma22 boards for the regulated supply, but use only one transformer to supply them both.

AMB's beta24 reference build uses one SumR 30VA dual-secondary toroidal transformer to power two sigma22 boards for the regulated supply. It also employs a Plitron 500VA quad-secondary toroidal transformer, two bridge rectifiers and four filter capacitors to create independent supplies for each channel.

In addition, an AMB epsilon24 power switch driver circuit is used with a Bulgin bi-color illuminated momentary pushbutton switch, a Crydom solid state relay (to switch the amplifier on and off), and a Omron 4PDT relay (to switch-in two bleeder resistors when the amplifier is turned off), and two thermal breakers (to turn off the amplifier if it overheats).

A schematic diagram of AMB's beta24 reference power supply is shown on the next page. Please also refer to the BOM section for further details.

Power Supply for AMB beta24



Notes:

T1: Amveco TE62002 12V+12V 1.6VA (secondaries in parallel)
T2: Plitron 7391-B2-00 30V+30V+30V+30V 500VA
T3: SumR RC0030 035 2 custom 35V+35V 30VA
T1,T2,T3 have dual primaries, but for brevity only one shown
SSR: Crydom D1240 solid state relay 40A
K1: Omron MJN2CE-DC12 DPDT 20A 12VDC relay
Power Sw: Bulgin MPI002/28/D4
Thermal Breakers: Airpax 67L075
D1,D2: GBPC3504 35A 400V bridge rectifier
C1-C8: 0.01uF 100V NP0/C0G multilayer ceramic capacitor
C9-C12: 10000uF 50V aluminum electrolytic capacitor
Rb1,Rb2: Arcol HS25 30 ohm 25W aluminum power resistor

AMB Laboratories		
beta24 amplifier Power Supply		
	Rev. 0.9 6/15/2008	Preliminary

Special instructions for building AMB beta24 v1.01 PCB

1. The Q1-Q4 and Q41-Q44 JFETs (2SK170BL, 2SJ74BL) must be matched quads. They should be mounted to the PCB in the orientation as documented at the beta22 website (under "Instructions"): http://www.amb.org/audio/beta22/
   Do not install these JFETs as marked on the board silkscreen!

2. The zener diodes D7-D10 should be mounted elevated from the board surface, with at least 5mm (0.2") distance. These diodes will run hot, this prevents the diodes from charring the board and the extra lead length serve as a heatsink.

3. The default values of R25, R26, VR2 and VR3 should allow you to bias the output stage to slightly over 300mA per bank of MOSFETs. It should be sufficient for most builds (200mA is the recommended setting). However, if you want to bias the MOSFETs hotter (very large heatsink is required), you may change R25/R26 to 562R and VR2/VR3 to 500R.

4. All other parts listed in the v1.01 BOM should be installed.

Special initial setup instructions for AMB beta24 v1.01

The following is an updated initial setup procedure:

Before powering up:

1. Make sure your sigma22 power supply outputs the correct voltage (+/-36V) before connecting it to the beta24. Do not connect any speakers or preamp/source at this time. An output dummy load is not required.

2. Install a jumper at the JP1 position, next to the input Molex header J1.

3. Install a jumper across the + and G positions of the input Molex header J1.

4. Preset VR1, VR2 and VR3 to their fully-counterclockwise positions.

5. Preset VR4 to the center of its adjustment range. Measure the resistance between the VR4's center pin and each of its outer pins, and turn the screw until you have exactly the same value on both. The value should be approximately 50R (depending on the tolerance of the trimpot).

6. Measure the resistance across the following pads, you should not have a short circuit:

   * V+ and V-
   * V+ and G
   * v- and G
   * OUTPUT+ and OUTPUT-
   * OUTPUT+ and G
   * OUTPUT- and G

7. Connect the unregulated positive supply lead through a 22R 10W resistor to beta24's V+ pad. Do the same for the negative unregulated

supply lead to the V- pad. The resistors are a temporary setup to limit current, to protect the output MOSFETs against damage in case of an error or mishap.

8. Connect the VREG+, VREG- and G to the sigma22 power supply board.

9. Double check the wiring and be absolutely sure that the power supply wires are connected correctly.

Power-up initial setup:

1. Follow the steps below to set up the amplifier. If you cannot successfully complete a step, do not skip forward to the next step. When doing measurements, be VERY careful with your DMM probes. It is easy to cause an accidental short circuit with the probes due to the dense component layout on the beta24 board. Pay special attention to the Q21-Q24 heatsinks. If you did not mount these devices to the heatsinks with isolating pads, touching them with a meter probe while making a measurement elsewhere could lead to a short circuit.

2. Turn the power on. All four LEDs should light up. LED1 and LED2 are for the unregulated positive and negative rails, respectively. LED3 and LED4 are for the regulated positive and negative rails. If any LED does not light up, power off immediately and check your wiring and polarity of the LEDs.

3. Set your DMM to DC V mode (200V range on a manual-ranging meter). Measure the DC voltage across V+ and G, as well as V- and G. You should read the unregulated rail voltages (for a 30V+30V power transformer, you should read about +45V and -45V at this time).

4. Measure the DC voltage across VREG+ and G, as well as VREG- and G. You should read about +36V and -36V, respectively.

5. Input stage bias setup: Measure the voltage across the R7 resistor while turning VR1 clockwise until you read 4V. Check the voltage across R8, R9 and R10. You should also read approximately 4V.

6. VAS stage balance setup: Set your DMM to DC mV mode, measure the voltage across R11 as well as R13. Turn VR4 a small amount at a time to make the two readings as close as possible. You should get approximately 130mV across each of these resistors.

7. MOSFET bias setup: Measure the voltage across R45 while turning VR2 clockwise, until you achieve 40mV. You should also read 40mV across R46. Similarly, adjust VR3 while measuring R47, and verify the reading on R48. This corresponds to 200mA of quiescent current through each bank of MOSFETs.

8. Sanity check: Set your DMM to DC V mode (20V range on a manual-ranging meter). Measure the voltage across each of the 22R 10W resistors you installed on the unregulated supply rails. You should read about 9V. The resistors will get quite warm.

9. Null the output DC offset: Set your DMM to DC mV mode, measure the voltage across the OUTPUT+ and OUTPUT- pads. Turn the VR4 trimpot, a small amount at a time, until you get as close to 0mV as possible.

10. Let the amplifier warm up, for about 15 minutes. Repeat step 7 above to fine-tune the quiescent current.

11. Repeat step 9 to fine-tune the output DC offset.

12. Turn off the power and let all capacitors discharge. The LEDs should all extinguish. If you do not have bleeder resistors on the main filter capacitors, LED1 and LED2 will stay lit for a long time.

13. After all capacitors are discharged, remove the two 22R 10W current limit resistors and connect V+ and V- directly to the unregulated supply's positive and negative outputs, respectively.

14. Repeat all the above steps to set up the other beta24 board.

15. Remove the jumpers you installed at J1 and JP1. Before you connect any input source (preamp) to the beta24, measure it to make sure it has no DC offset at its output. Any such DC offset will be multiplied by the gain of the beta24 amplifier.

16. Connect your speakers. Enjoy.