ALL-FET IV CONVERTER.
EB-109/437/VER1

The EB-109/437/VER1 is an ALL-FET IV converter with exceptional resolution, and dynamics. Its natural and transparent sound makes it equally applicable in high-end home systems as in studio monitor and recording applications. The EB-109/437/VER1 outperforms most high-end IV converters on the market in terms of sonic quality, irrespective of price.

Only FETs (JFETs and MOSFETs) are used as active elements in the amplifier. The resistors are all high quality Vishay-Dale and Caddock. All electrolytic caps are Nichicon FINE GOLD MUSE/KZ, ELNA CERAFINE/SILMIC II and the compensation caps are MICA or polystyrene.

Two amplifiers are laid out on one board (the size is 110x145mm), but they can be used independently. This facilitates testing and trouble-shooting. Two of the 437 boards are needed to provide fully balanced operation, see the application notes.

Circuit description.

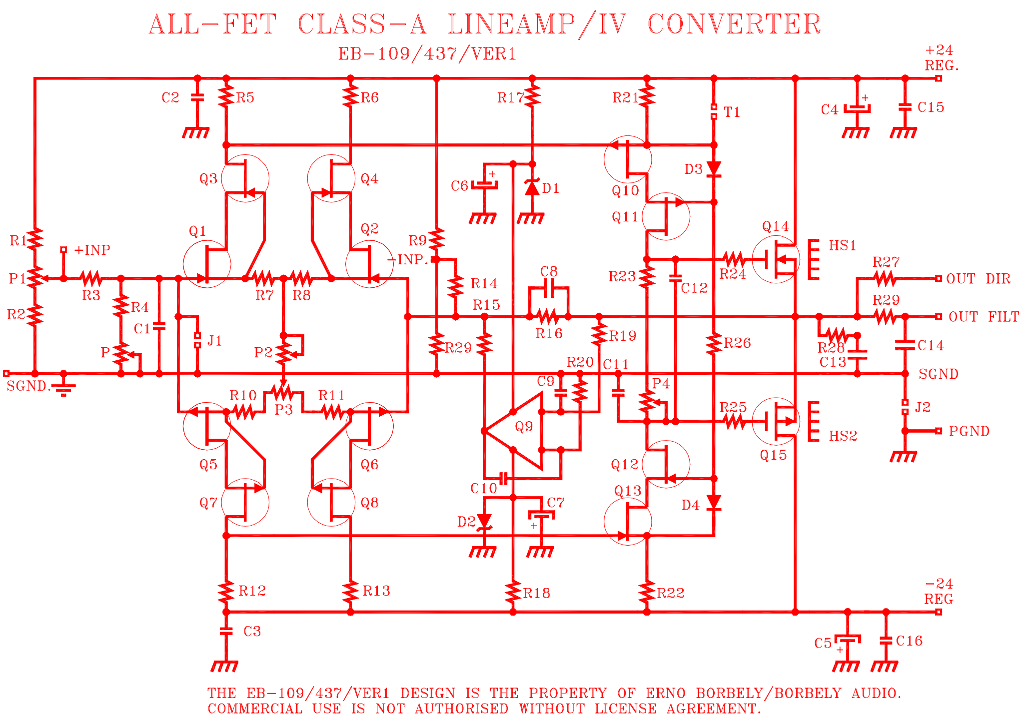


Fig. 1.

The schematic of the ALL-FET 437 is shown in fig. 1. The complementary differential input consists of very closely matched single JFETs: Q1 and Q2 are 2xK170BL and the Q5, Q6 are 2xJ74BL respectively. They are cascoded with Q3/Q4 and Q7/Q8. The second stage, consisting of JFETs Q10 and Q13, are also cascoded for good linearity. Blue LEDs D3 and D4 provide the necessary bias for the cascode JFETs Q11 and Q12. The output devices: Q14/Q15 are TO-220 MOSFETs. They are operating in Class-A at approx. 70mA; proper heat sinking is therefore mandatory.

Q9 is a JFET-input servo amplifier, providing tracking of the output offset to less than 1mV. The RC-networks of R19-C9 and R20-C10 filter out all AC signals over 1 Hz. The servo is therefore only operational at less than 1 Hz, and should not affect the sound of the amplifier. Nevertheless, if you feel that it does, don't hesitate to try different opamps for this. D1 and D2 are IC shunt regulators, supplying Q9 with ±10 Volt.

The amplifier is using the best components available today. The resistors are Vishay-Dale except for the input and feedback resistors, which are Caddock. The layout it made for 0.5" (12.5mm) spacing and, most places also for 0.2” (5mm) spacing. I.e. you can use Caddock resistors almost everywhere, if you wish. Be careful when inserting the Caddocks, do not bend the leads; they fit in the 0.2” spaced layout. The frequency compensating capacitors are polystyrene or Mica caps, the electrolytics C4, and C5 are Nichicon FIND GOLD MUSE, Nichicon KZ, ELNA CERAFINE or ELNA SILMIC II.

The open loop linearity of the amplifier is exceptionally good; O.L. THD is <0.05% at 1kHz, 3VRMS. This is reduced to below the measurement limit of the HP 339A distortion analyzer when feedback is applied with resistors R16-R14. R16 is normally 10k. The rise time of the amplifier is about 200 nanoseconds for an output of +10V and the closed loop frequency response is close to 1 MHz! Output impedance is less than 1 Ohm, so resistor R27/R29 determine the actual output impedance seen by the outside world.

The closed loop gain can be reduced by changing the value of R14, however, at very low gain the compensation cap C11 has to be changed as well. These are the necessary changes for lower gain settings:

16dB:	R14=1k82 (No other change)
12dB:	R14=3k32 (No other change)
6dB:	R14=10k, C11=330pF

NOTE: the 437 in Not Unity Gain Stable (NUGS), so it should not be considered for unity gain buffer operation.

If the 437 is used as an IV converter, then it is recommended to use a 6dB/octave filter with it. This is provided by R29/C14 at the output of the 437. For a 150kHz filter R29=681R and C14=1.5nF. Note that the output impedance at the OUT FILT is then equal R29!

REGULATORS AND POWER SUPPLY.
Recommended power supply/regulator for the 437 is the dual low-noise EB-703/259 PS/regulators see fig. 2. These can supply up to 200mA current each, so theoretically each can supply two amps in balanced operation. However, for an all-out set-up we recommend to use a separate +/-regulator for each amplifier, meaning four regulators for a fully balanced lineamp.

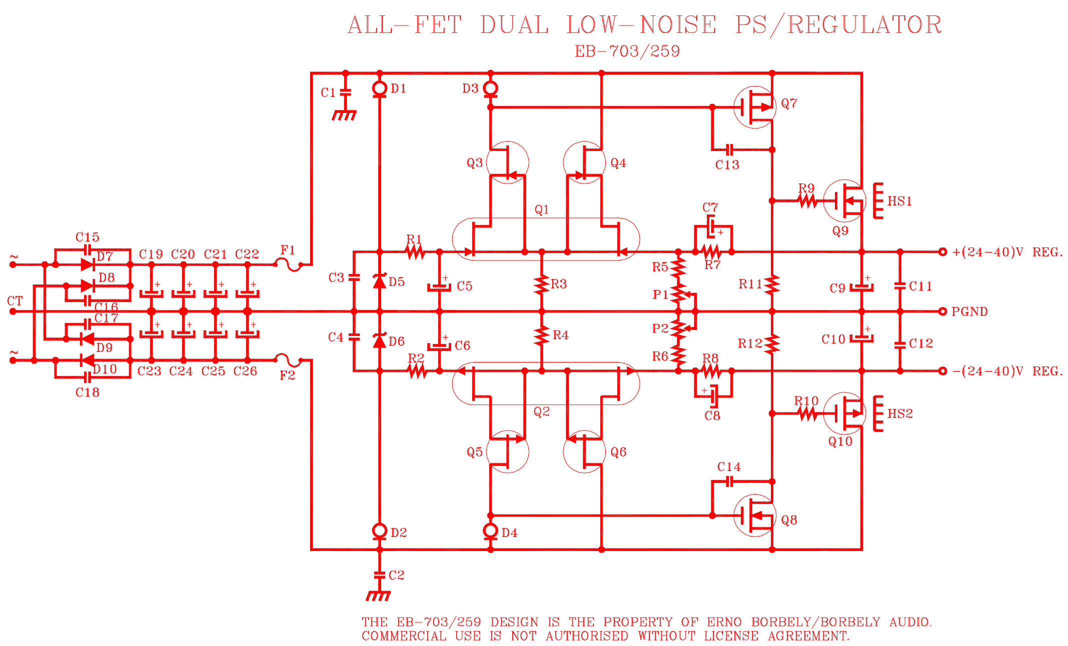


Fig. 2. The EB-703/259 ALL-FET Wide-band, Low-noise PS/regulator.

The EB-703/259 consists of fast recovery diodes, eight low ESR filter capacitors and two dual wide-band, low-noise regulators, using only FETs (JFETs and MOSFETs) as active elements. Maximum input voltage is ±45V and maximum output voltage is ±40V. Maximum output current with 5V input/output voltage difference is ±200mA.

437 Assembly.

Use 2% silver bearing solder if available. Start the assembly with the jumpers, resistors/trimpots, and then mount the capacitors. Install all small signal JFETs. Note the orientation of the capacitors and the FETs very carefully! Install the output MOSFETs on the heatsinks with the insulators provided and then install them on the PCB. Do not install Q9 yet. Test both amplifiers separately; see Setup procedure.

Setup Procedure.

Test each amplifier module separately, before you install the PCB in the chassis. This simplifies measurements, adjustments and, if necessary, component changes. If you have access to a scope, connect it to the output of the module and check whether Radio Frequency oscillations (RF) and excessive noise/hum are present. If you have complete audio instrumentation in your workshop, perform the usual gain, frequency response, noise, total harmonic distortion (THD), and intermodulation distortion (IM) measurements. Inputs should be shorted under DC measurements/adjustments.

Connect SGND to PGND at the output with jumper J2 or with a wire jumper. Connect the +INP to SGND, or install J1. Connect a mA meter in series with one of the supply lines. Turn on the supply voltage. If the current is >50mA, reduce it with P4 to 50mA. Connect a DVM across T1 and adjust the voltage drop with P2 to 3 Volt. Check the total supply current again and readjust it with P4 to 90 mA. Switch off the power supply, remove the mA meter, and connect the DVM to the output of the amplifier. Switch on the supply and adjust the output offset with P3 to less than 2 mV. Install Q9 and monitor the output offset, it should go down to less than 2 mV in a couple of minutes.

If the 437 is used for balanced passive I/V conversion, then it is recommended to do a CMRR adjustment. Connect +INP and –INP together and connect a 1kHz, 3VRMS signal to this common input. Monitor the output with an mV meter and adjust it to minimum with P. The output should be min. 60dB down referred to the 1kHz/3V input.

You can now remove the short from the +INP and –INP and if you have audio instrumentation, carry out the usual AC measurements.

Application of the 437 as an IV converter.

The 437 was developed specifically for the **HB-DAC1704** DAC board (1), but can also be used with the **HagDac** DAC (2), the **RAKK DAC** (3) and other DAC boards. The 437 can be used in a number of IV converter configurations, both in balanced passive and in balanced active mode.
Fig. 3 shows the balanced passive conversion with unbalanced audio output.

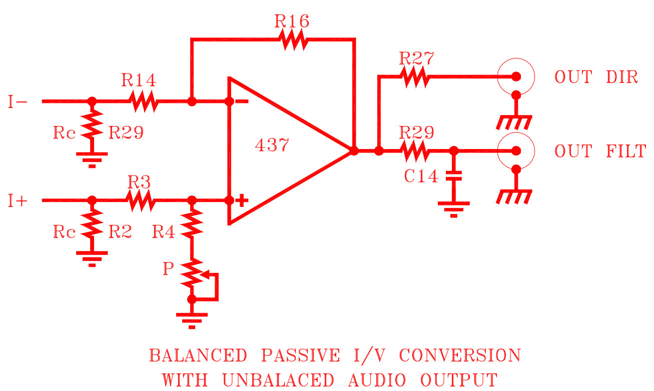


Fig. 3. Balanced passive IV conversion with unbalanced audio output.

The conversion is done with resistors R2 and R29 at the +INP and the –INP respectively. Normally these resistors cannot be chosen arbitrarily, because of the protection diodes at the current outputs, consult the appropriate DAC datasheet. Typically R2/R29 is 50-150 Ohm, which will produce a voltage of I x R2 at the +INP and I x R29 at the -INP. The 437 converter is used as a balanced-to-unbalanced converter with gain. R16 is normally 10k and the R16/R14 ratio has to be selected to provide the necessary gain. Note that the input impedances at the + and – input should be equal (remember the –input impedance is not equal R14, when both inputs are driven!!!), and a CMRR adjustment is strongly recommended.

Two of the circuits shown in fig. 3 can be used for balanced passive conversion with balanced audio output, see fig. 4. Again, make sure the + and – inputs have equal input impedance and a CMRR adjustment is done before connecting it to the DACs.

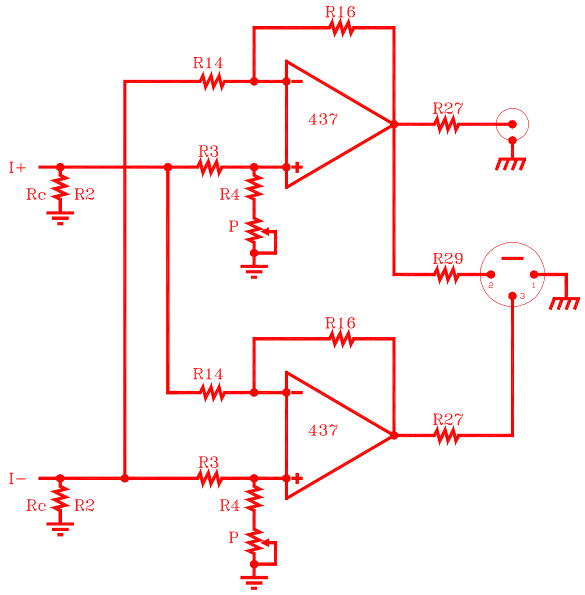


Fig. 4. Balanced passive conversion with balanced audio output

Another way to do balanced passive conversion with balanced audio output using two 437 is shown in fig 5.

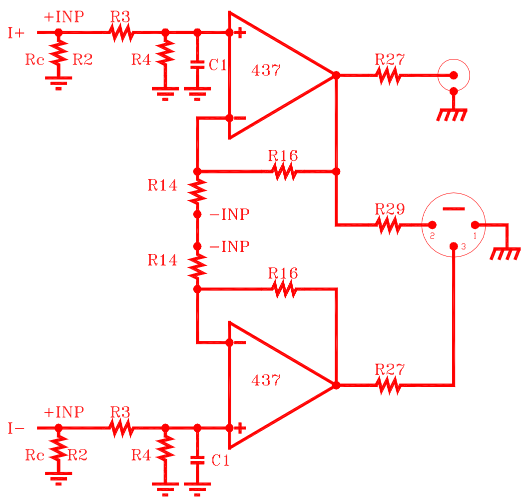


Fig 5. Using two 437 for balanced passive IV conversion with balanced audio output.

The advantage of using the 437 in this configuration is that the input impedances are high and it's easy to install a 6dB/octave low-pass filter with R3 and C1 at the inputs. The filter at the output is therefore not needed and the output impedance can be kept low.

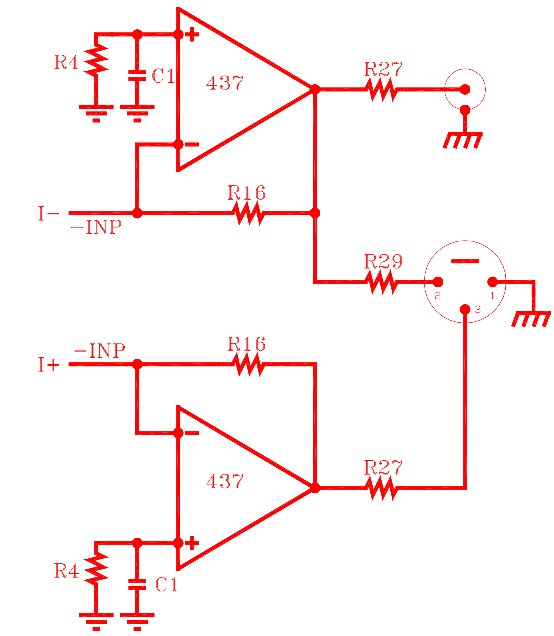


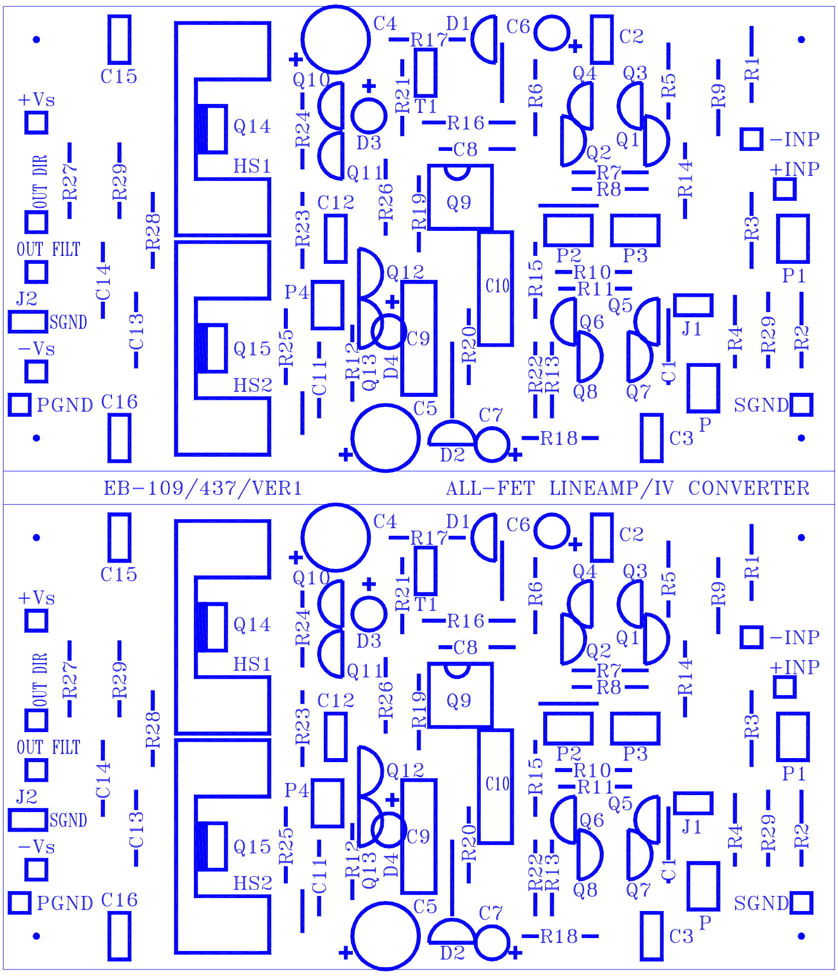
Fig. 6. Balanced active conversion with balanced audio output.

Balanced active conversion is shown in fig. 6. For current output DACs the output from the DAC is connected to the –INP of the converter, with R14 shorted. The feedback resistor R16 determines the conversion factor, i.e. the V_{out}/I_{in} ratio. If the DAC current is ±1.2mA like with the PCM1704, and you select R16=2k4, then the maximum output voltage will be $V_{out}=I_{in}$ x R16=5.7V peak-to-peak or 2V RMS at the unbalanced output and twice that at the XLR output. For balanced PCM1704 with 4 DAC chips or paralleled PCM1704 R16 should be 1k2.

Note that the unbalanced output is generated from the I- only. Should a high CMRR unbalanced output be needed then it has to be made from both outputs using a balanced-to-unbalanced converter.

For DACs operating with symmetrical ± supply (PCM1704, etc.) the + input of the IV converter is grounded (actually terminated with R4 in parallel with C1 for proper DC and AC operation). When DACs with single supply are used the + input has to be biased at approx. ½ of the supply voltage. Typical example is the AD1955, which requires 2.8V, see the AD1955 datasheet. This voltage is generated from the supply voltage of the IV converter with the voltage divider R1-R2 and P1.
The –INP has to be pulled up by the resistor R9, see instructions in the datasheet.

Fig. 7 shows the stuffing guide, which is printed on the PCB.



EB-109/437/VER1
ALL-FET LINEAMP/IV CONVERTER

Fig. 7. Stuffing guide for EB-109/437.

References.

1. BORBELY AUDIO: HB-DAC1704 Ver. 3.01 DAC board using 4 or 8 PCM-1704 DAC chips for balanced or parallel operation.
2. **Hagerman Technology**, http://www.hagtech.com/hagdac.html
HagDac DAC card custom modified for Borbely Audio
3. **K&K Audio**. http://www.kandkaudio.com/digitalaudio.html
RAKK DAC Mark II Digital-to-Analog Converter.