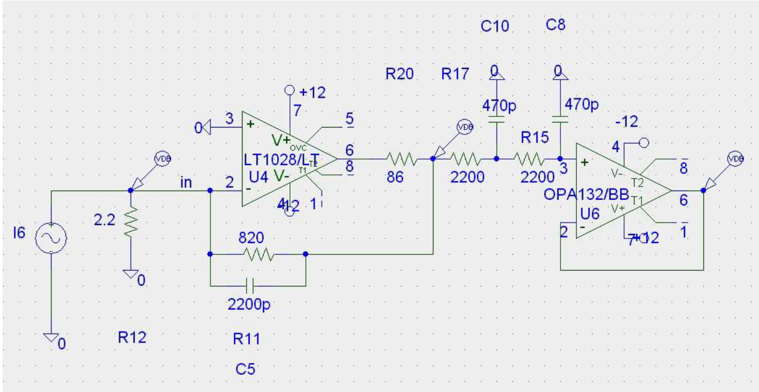
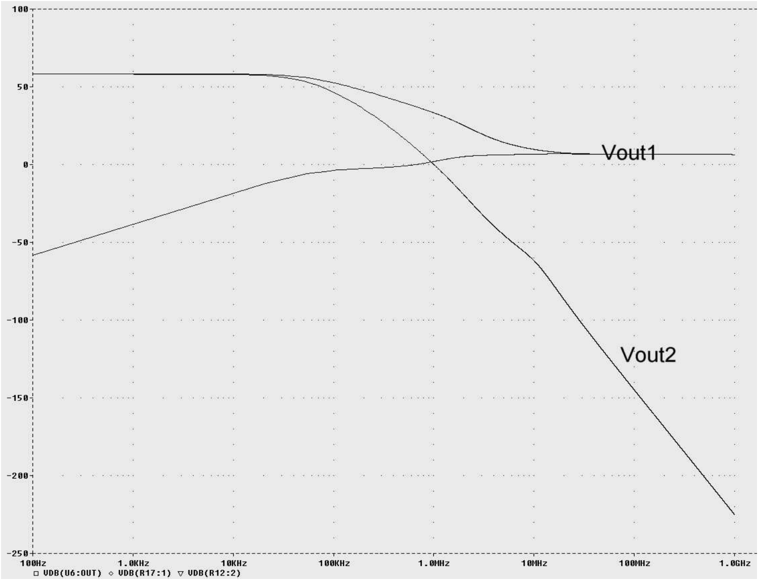
The Mature I/V-converter

By some people the output impedance of the op amps are thought to be low for a substantial roll off at high frequencies up to some hundred megahertz. With a small modification of the diagram this is not essential. With an input resistor of 2.2 Ω and some changes in the feed back loop, the attributes of the LT1028 are exploited best. (Even the 86 Ω resistor in the MicroSim diagram below, does not harm.)



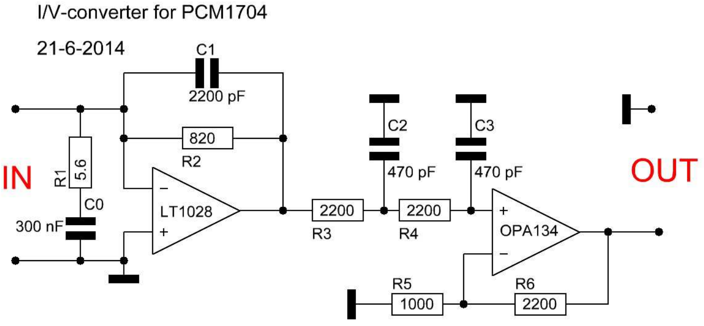


The input resistor (here R12) would start the roll off a bit to early (2 dB loss at 20 kHz) so that the feed back resistor (R11) has been changed to 820 Ω which yields: 88 kHz together with 2200 pF. This low value has also been chosen because of the larger current of DAC's like PCM1792.

The low pass filter has been established with two rather highly resistive RC-combinations of $2200^{\pm 1\%}$ Ω and $470^{\pm 1\%}$ pF (in combination with R11/C5 = 0,3727 to warrant linear phase within 1°) and an op amp follower (in the simulation an OPA132 because the old MicroSim8 does not know the OPA134). No use has been made of the circuit as shown in the article: I/V-converter (for CD-players) under paragraph 3: The lp-filter. The simple solution shown here, will sound a little bit better and is more suitable for preparing an instrumentation amplifier (for a balanced I/V-converter for eg. a PCM1792).

To the left the outcome of the simulation is shown. Vout1 is the output between R20 and R17, Vout2 is the output of the complete circuit. However, because of the 2.2 Ω resistor the feedback decreases with about 50 dB (20.log(820/2.2))! This becomes immediately clear with the larger **off set** of the op amp. This could be solved with a series capacitor, but be careful: a bare 1 μF capacitor in parallel to the virtual ground creates a peak in the input impedance at 125 kHz, which means a virtual inductance of 1.6 μH. 2.2 Ω in series with 1 μF decreases the Q of the 'resonator' far below 1.

Mature I/V-converter for the PCM1704



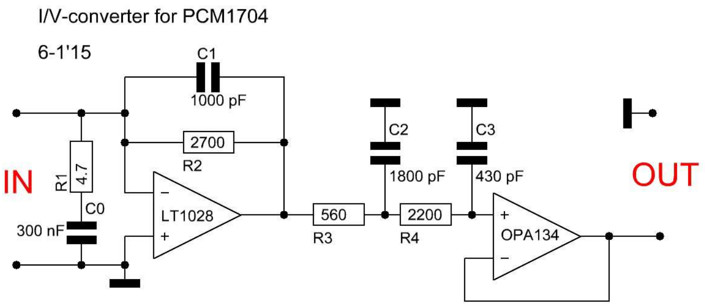
The current of a PCM1704 is only ±1.2 mA so that the gain will be less than with a PCM1792. One could change R2 for more output from the I2V but mind the phase linearity! (See "I2V-details on subelements" on this site.) It is more simple to change the gain of the OPA134 adding R5 and R6. The (high) output of 8.8 V_{tt} at 0 dB, as with the PCM1792, will be obtained again.

Be aware of the virtual ground which derives at the negative input connection. Near DC the gain is reduced with 50 dB by R1 (without C0) as we saw before. This means that the offset of the op amp will be rather high. Also the distortion will be 50 dB worse. To avoid this for audio, C0 should be put in series with R1. The cross over frequency of 300 nF and 5,6 Ω is 95 kHz.

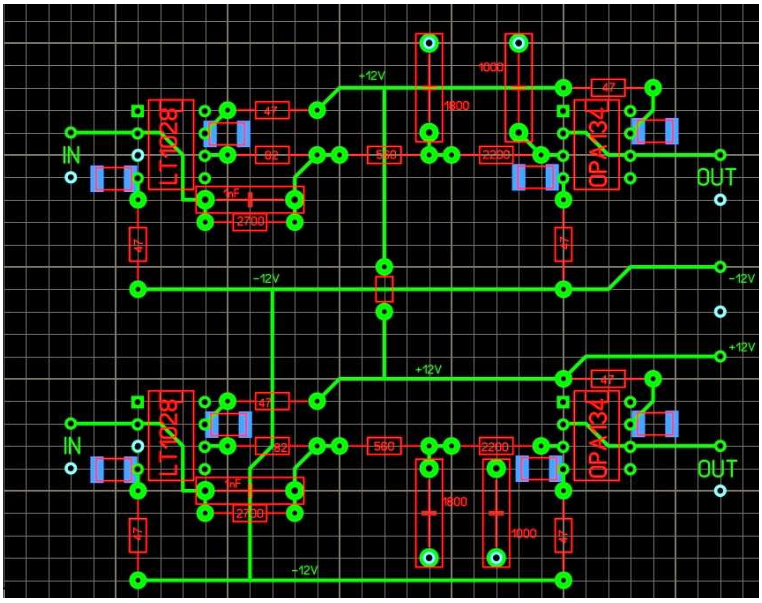
I do not like an overcompensation capacitor between pin 5 and 6 which could be used with heavy capacitive loads of the LT1028.

C0 must have a very low ESR so that it should be a 'solid polymer aluminum SMT capacitor' or a (ceramic) MLCC which capacitance is voltage dependent. This does not harm because the voltage at pin 2 (virtual ground) of the LT1028 is zero!

A different, very nice solution is the diagram below. I offer it without any explanation. The phase characteristics are even better!

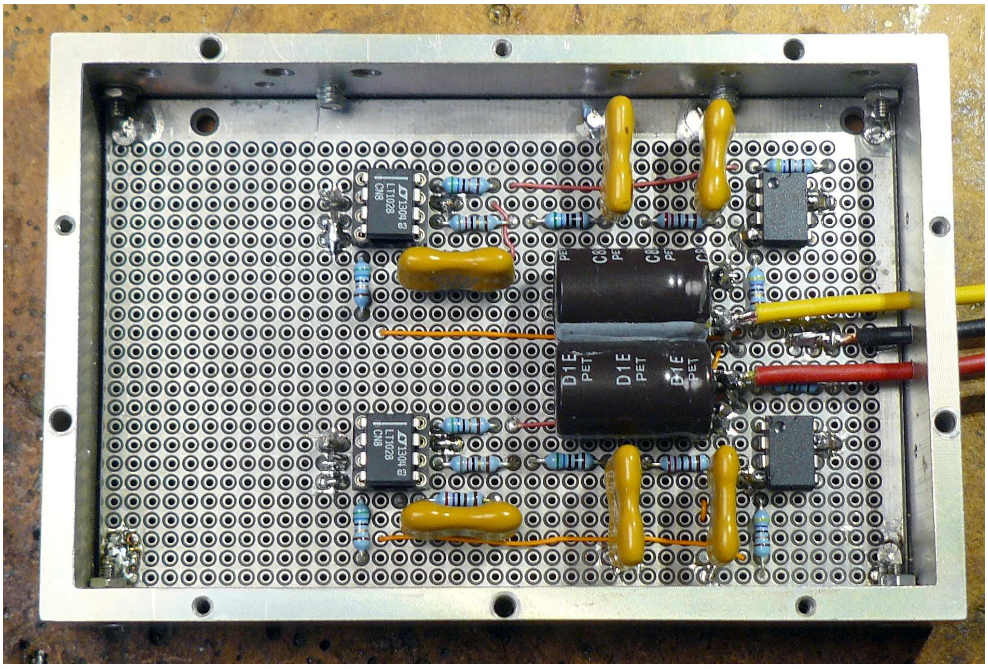


The circuit could be fixed in a small box for both channels like below:



The decoupling to ground of the power connections of the op amp's has been made with 1 uF SMD chip-C's.
The 4.7 Ω SMD resistor (R1) and C0 are not shown in the print layout.
Mind that the value of C3 is not correct: it is marked as '1000'.
The component values should be within 1% to guarantee the zero phase distortion response within 0.5º.

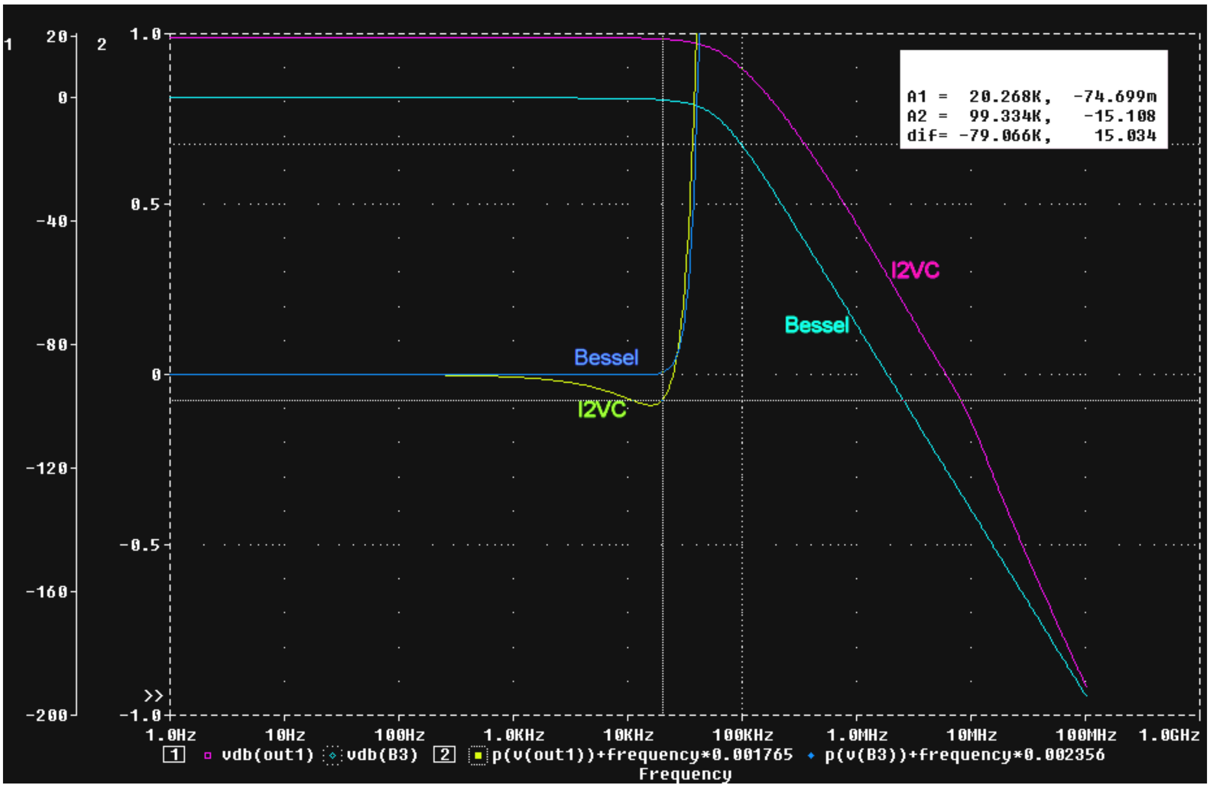
The implementation could look like the picture below if a 0.1" board is used:



Mind the mica capacitors!

The output off set of the total circuit is smaller than 0.1 mV!

For an impression of the amplitude and phase distortion characteristic as function of frequency, see next page:



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A1 =  20.268K,  -74.699m
A2 =  99.334K,   -15.108
dif= -79.066K,    15.034
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The blueish curves belong to the theoretical third order Bessel function for fl = 60 kHz. Such a function is phase linear until fl/3 = 20 kHz as is shown by the blue curve. The light-blue curve shows its amplitude.

The ‘red’ and light-green curves show the results of the last I2VC-circuit above. Mind that the scale for the phase linearity distortion runs from -1º to +1º !!! The largest deviation is -80 milli degrees at 18 kHz. At 20 kHz the deviation is about -75 milli degrees as could be seen in the probe cursor window. The ‘red’ amplitude curve is over 10 MHz even steeper than the Bessel function.

Phase linearity errors smaller than ±1º within the audio range are supposed to be inaudible, if at all.

6-1’15