APN 003

Tuning in amplifier input stages - CMRR

The common used amplifier input

The values of R_F and R_G set the gain. C_{FB} is used to set AC-gain to 1, C_{IN} is to AC-couple the amp, R_I is to provide bias path of IN+ and input impedance if nothing is connected at the input. R_S is to protect the amplifier from to high voltages.
R_I is normally to 10k and R_S to 4k7.

But that's the worst input stage which could be made ! The CMRR is bad (< 1dB) and THD / IMD can be increased by wrong CFB type (electrolytic) and wrong placement of GND connections. Signal-2-noise ratio is ~ 92dB (referred to 1V Vout, Ri = 10k, Rs=4k7, Rf = 33k, Rg = 2k2)

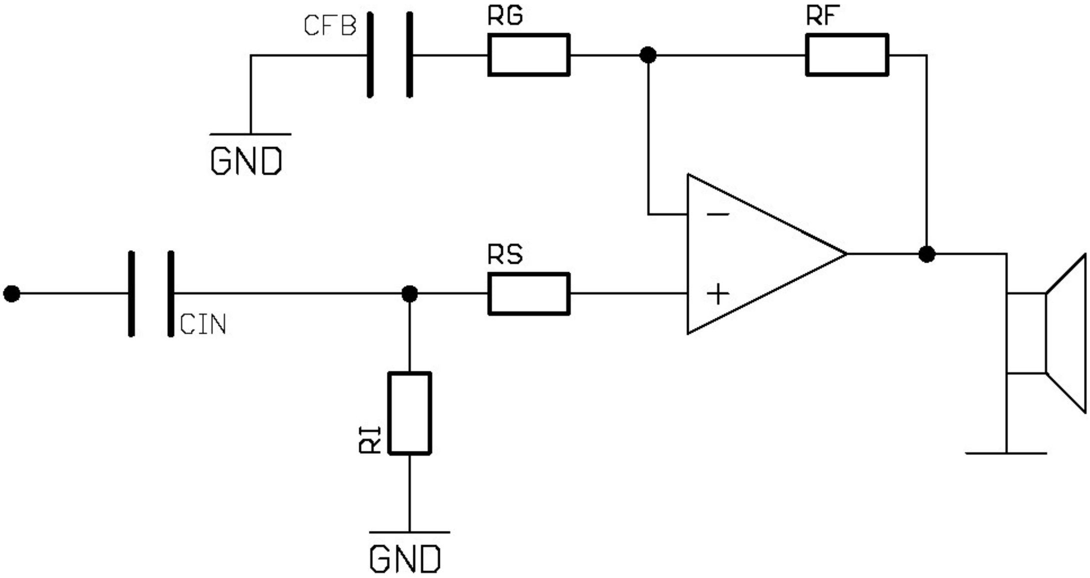

fig. 1 Common Amplifier Input stage

A better amplifier input configuration I

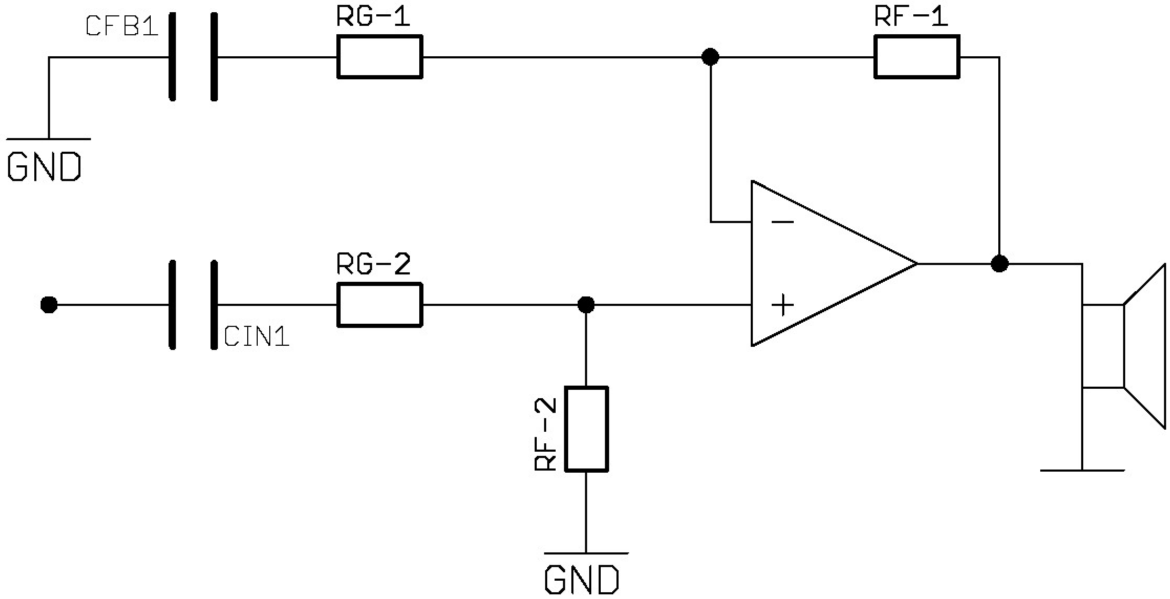

fig. 2

In fig. 2, things get better. The amp is configured as differential amplifier, if the ratio $R_{F1}/R_{G1} = R_{F2}/R_{G2}$ is given. This makes CMRR better, but only if C_{FB1} is equal in value to C_{IN1}. See fig. 3 for CMRR performance.
[fig. 2 : R_{F1}=3k3, R_{G1}=220, R_{F2}=33k, R_{G2}=2k2, C_{IN1}=8µF, C_{FB1}= 100µF]

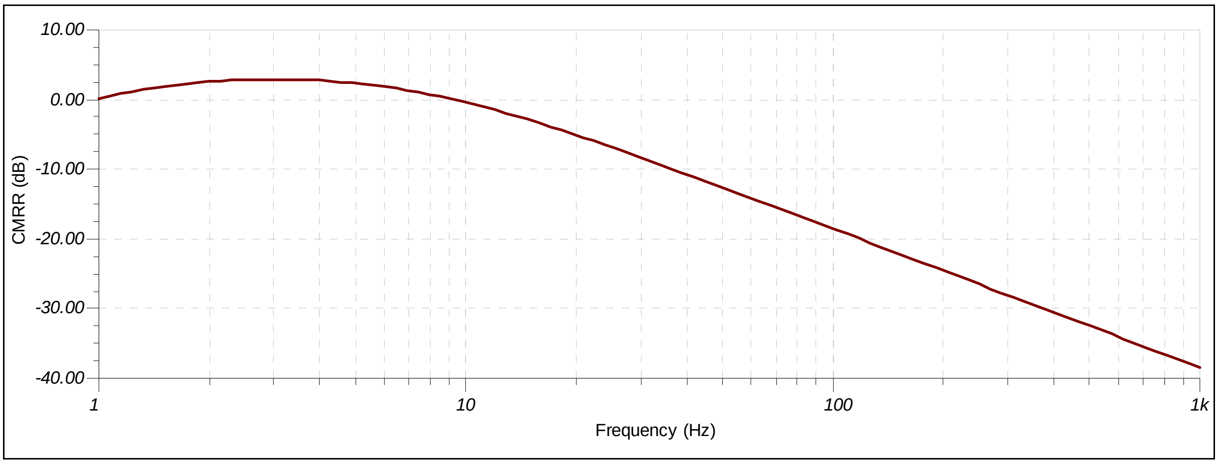

fig. 3

A better amplifier input configuration II-a

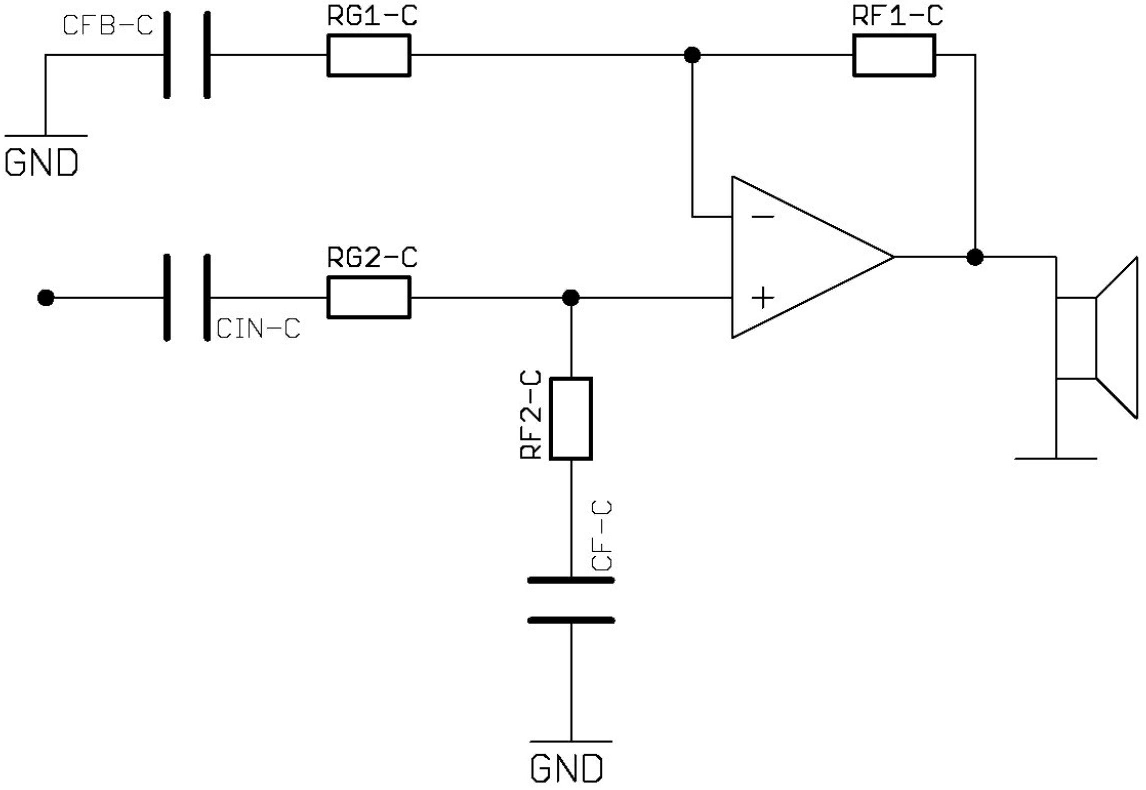

fig. 4

In the input capacitor $C_{IN\text{-}C}$ is compensated by $C_{F\text{-}C}$ which makes CMRR even better than fig. 2.
[fig. 4: R_{F1}=3k3, R_{G1}=220, R_{F2}=33k, R_{G2}=2k2, C_{IN1}=8µF, C_{FB1}= 100µF]

Gain = g = $R_{F1C}/R_{G1C} = R_{F2C}/R_{G2C}$
$C_{FC} = C_{INC}/g$

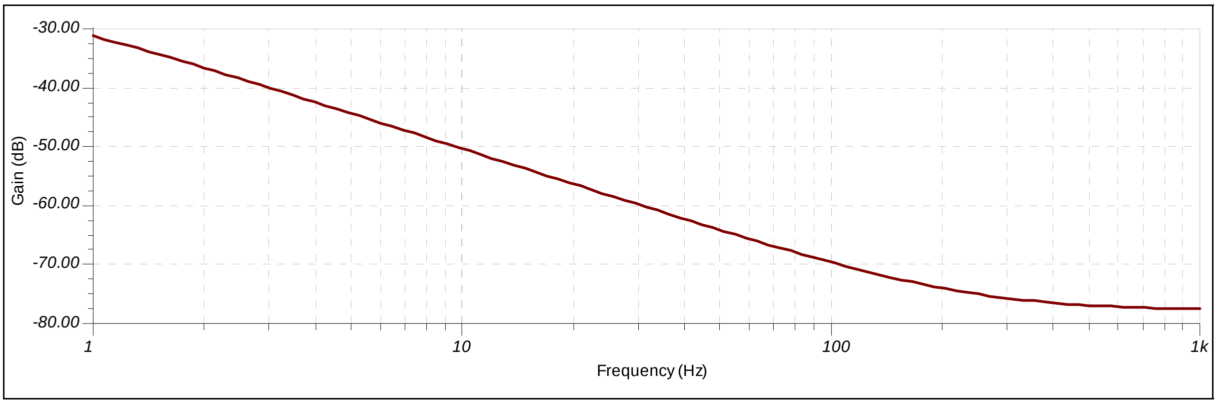

fig. 5

A better amplifier input configuration II-b

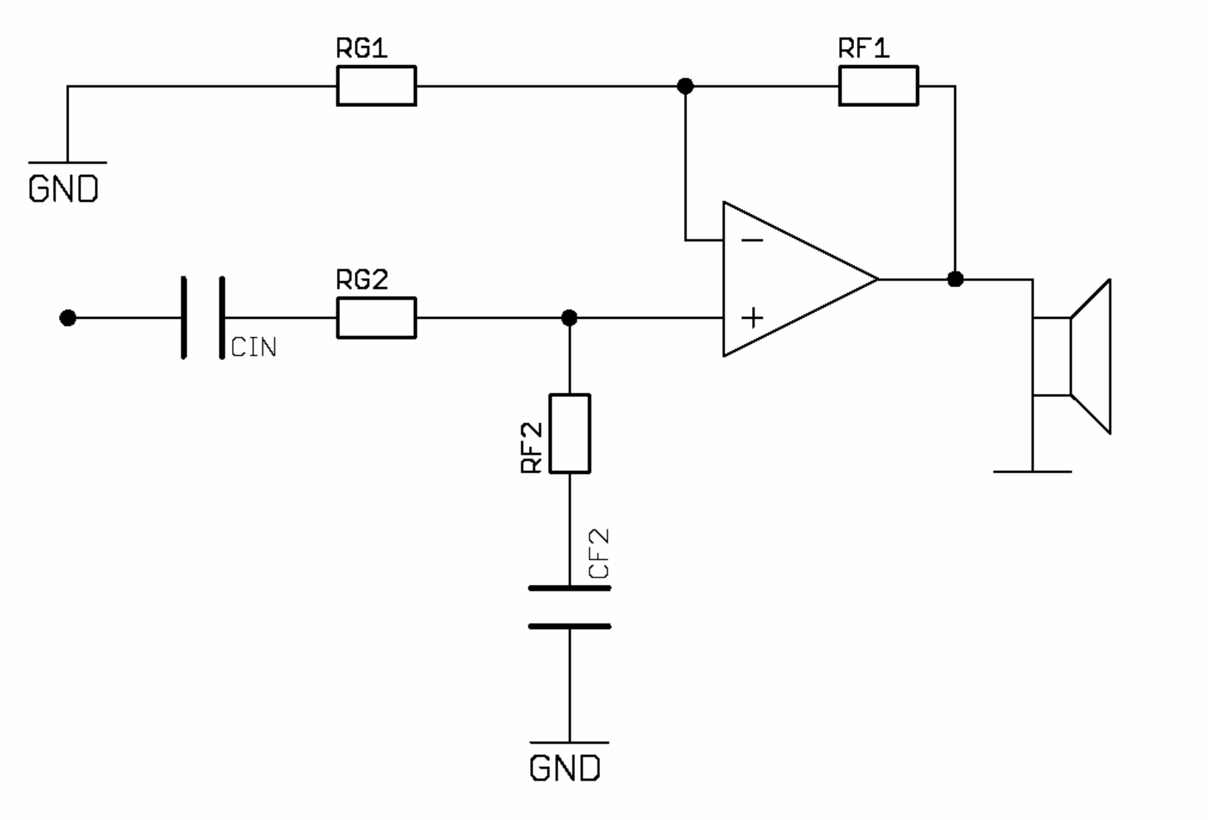

fig. 6

Now, C_{FB} is removed, so CMRR is almost ideal. C_{F2}'s value is approximated from 533,333 nF to 533 nF which limits CMRR to ~ -80dB.
But now, AC-gain = DC-gain and therefore the amps internal DC is found at the output multiplied by the gain.
[fig. 6: R_{F1}=3k3, R_{G1}=220, R_{F2}=33k, R_{G2}=2k2, C_{IN1}=8µF]

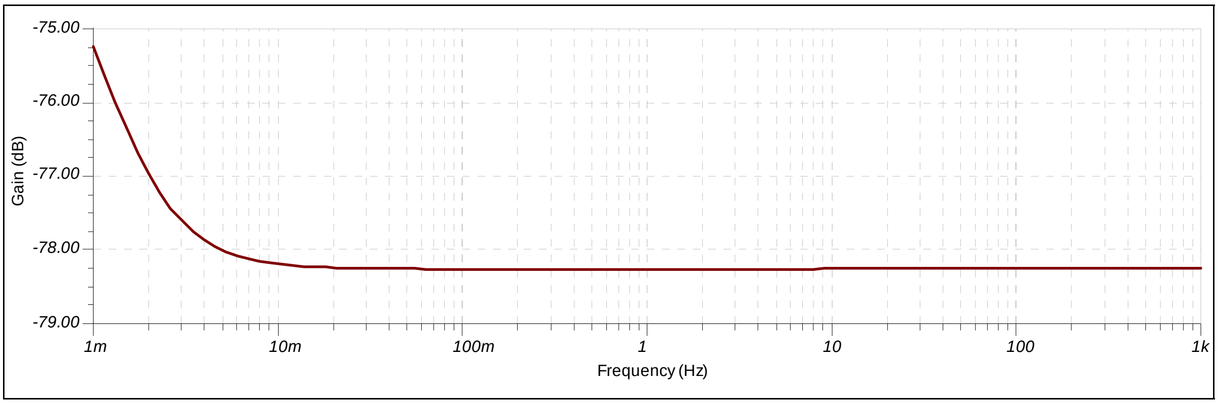

fig. 7

A better amplifier input configuration III

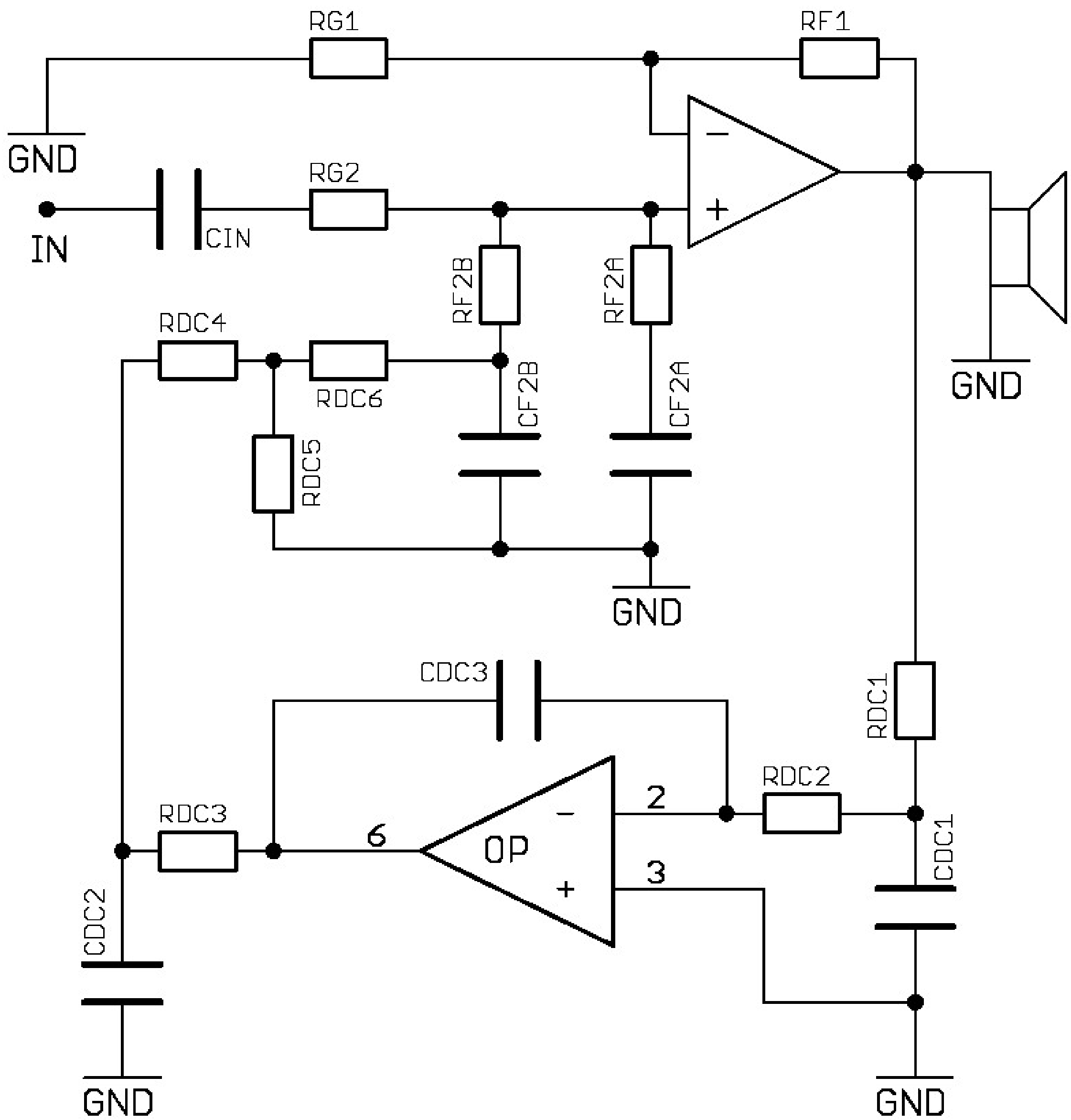

fig. 8

Goal reached:

The feedback capacitor is replaced by a DC servo circuit.
This makes it possible to reduce the values of RG1 and RF1 (as long as the **ratio** remains the same) dramatically without affecting low frequency roll off.
The common mode rejection ratio (CMRR) is improved.

Gain:

The AC and DC gain are the same: $\mathbf{g = R_{F1} / R_{G1}}$

DC-Servo:

OP1 forms a DC Servo with first Lowpass R_{DC1} / C_{DC1}, R_{DC2} and C_{DC3} as integrator and R_{DC3} / C_{DC2} as first Lowpass. The OPs Output Voltage is scaled down by R_{DC4} / R_{DC5} and isolated by R_{DC6}.
The DC gain of the amp is g = R_{F1} / R_{G1} and therefore the same as AC-Gain.
Typical DC output voltages should be in the range +5/-5V (else, something is wrong completely). To reach +5V DC, there must be ~ 5V/g, so e.g. when g=20 then there must be 0.25V DC at the input. To scale the noise of the OP down, RDC4 and RDC5 form an voltage divider. If you consider that Ops output can easily achieve +/-5V, then the voltage divider can scale down by 20. A good advice is to scale down Ops output voltage by g, therefore making the attenuation of the DC control voltage the same as the overall gain is.
R_{DC6} resistance can (by theory) be as high as possible, but a value of 470k seems almost ok.

Calculations:

Gain: $g = R_{F1} / R_{G1}$

C: $C_{F0} = C_{in} / g$

$C_{F2A} + C_{F2B} = C_{F0}$

R: $R_{F2} = R_{G2} * g$

$R_{F2A} // R_{F2B} = R_{F2}$

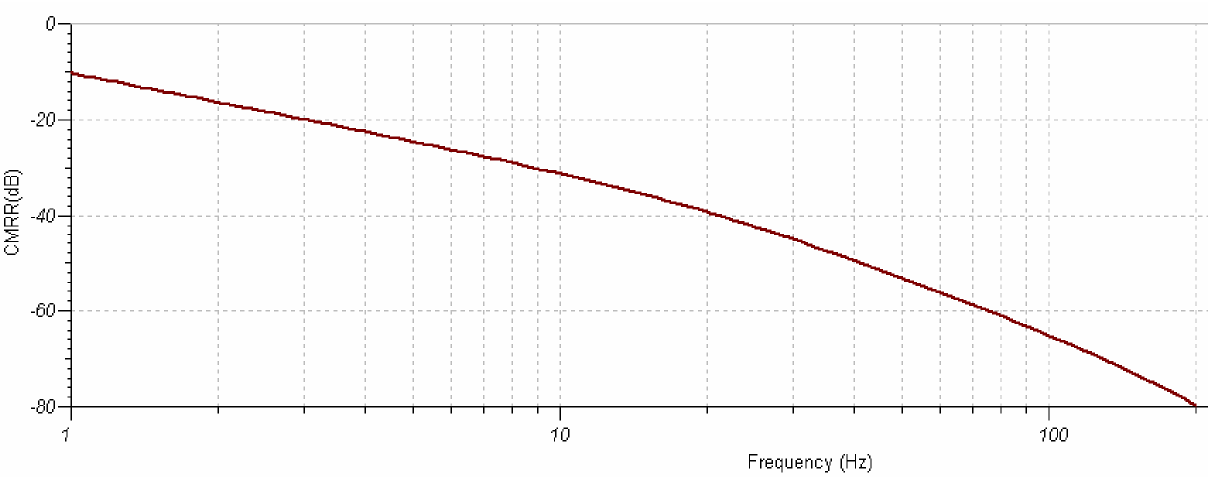

fig. 9 CMMR of fig. 8 / fig. 10

Example

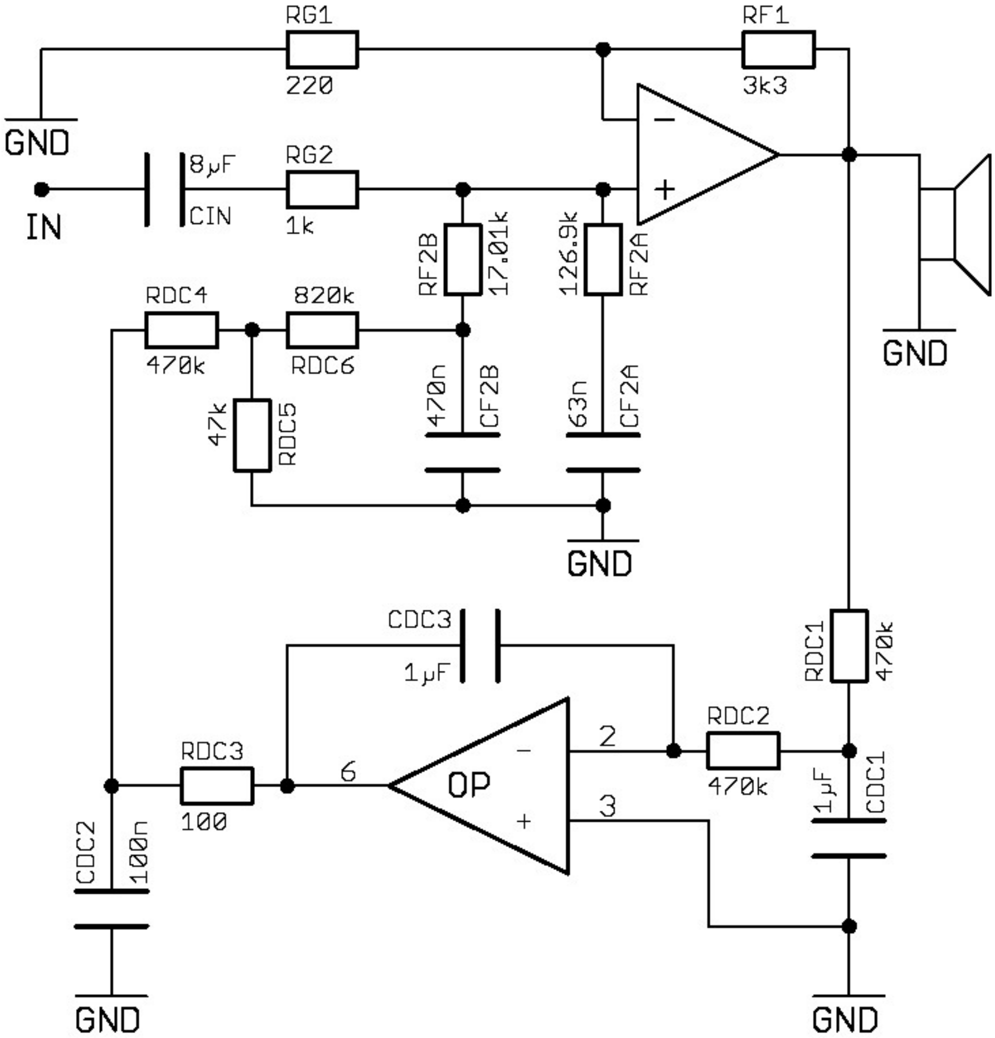

fig. 10

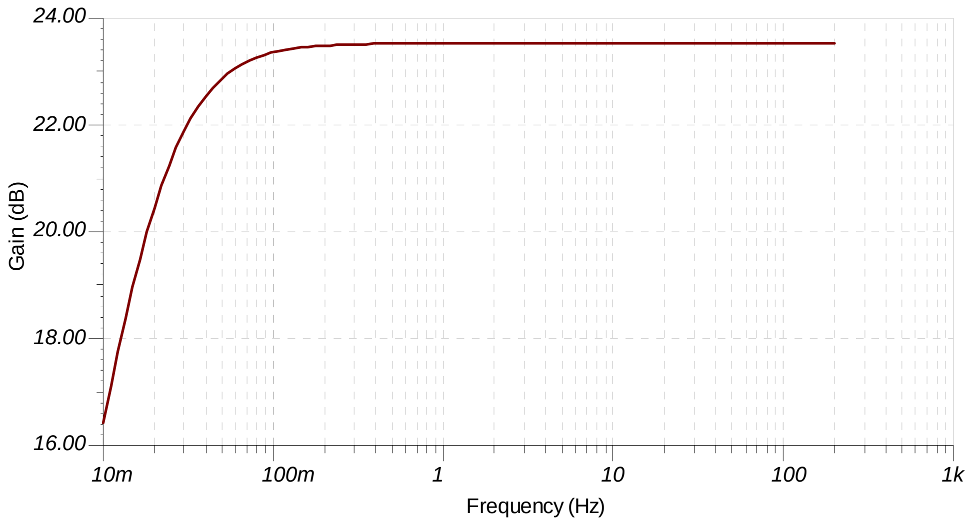

fig. 11 Gain of fig. 10

How to connect the source and layout GND

Variant A:

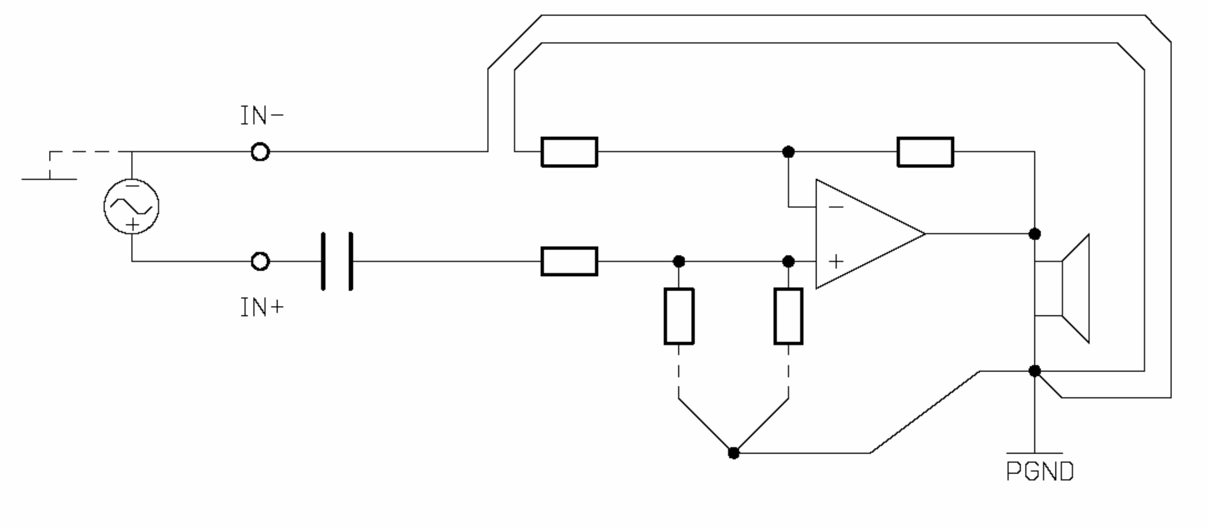

fig. 12

Variant B:

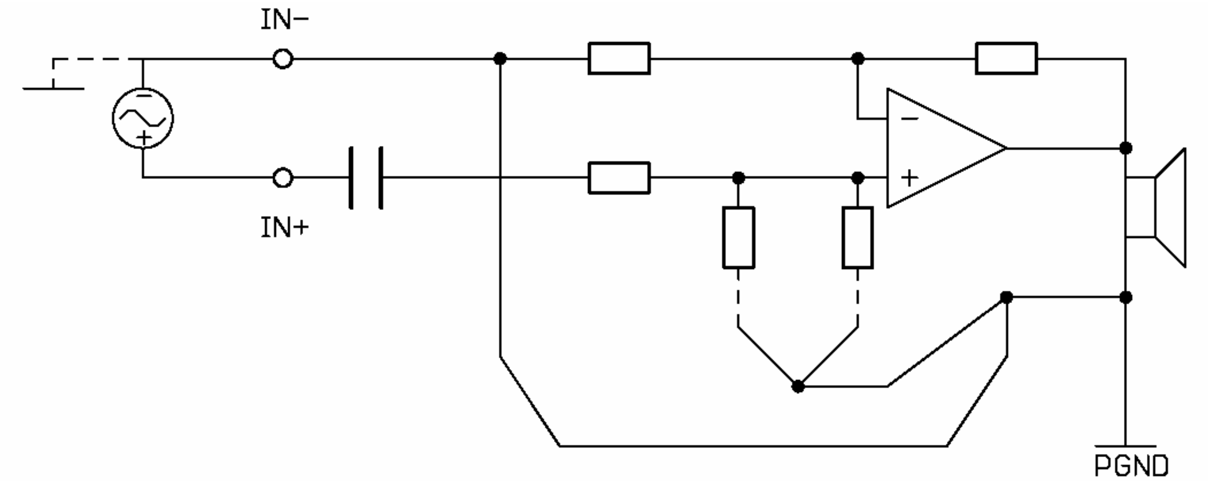

fig. 13

Variant A is preferred and should be used whenever possible.
The feedback network is directly connected to the PGND (at best where Speaker GND is connected) because of "high" currents in the feedback path (some mA).
The incoming signal GND is also connect to the same point but via an additional path because of that the feedback currents now couldn't distort the signal GND.
The currents at the Amps + input are normally so small that they can connect via a 3rd track to the **same** GND point as the other ones.
GND tracks for **decoupling** purposes (DC-Servo OP Power, Filter, Limiter, …) should be separated from the **signal** GNDs and connected to PGND as the other ones.

Don't try to power further GND related electronics thru a 2nd cable from the Power Supply which is **not directly** connected to the star/sum point.

Conclusion

The artefacts of using CIN can only be eleminated theoreticaly, but real-life results can be achieved which are widely better than a “standard” input stage.

Grounding schemes and careful Layout and separating Power and Signal grounds gives a low noise, low THD amplifier.

Only a small amount of additional components are needed to satisfy modern amplifier needs.