Matze, December 2013

Stability and performance of Cherry's NDFL 60W amplifier

For this little stude, I have taken Cherry's example 60W amplifier from ETI 1983, but changed the VAS to a darlington configuration.
Nevertheless, the stability margins still look OK, if one accepts the ULGF values of around 10 Mhz, The high ULGF can be reduced e.g. by increasing the 33p capacitors around the drivers or higher VAS degeneration; perhaps the other loops will have to be re-checked in this case. A small capacitor around the VAS emitter degeneration helps in the critical innermost loop, as well Cherry's two 33p. Usage of faster output transistors like MJL3281 seems not to be a majour problem. I also tried it with the much slower MJL21193/4, with not much change (at least for the stability margins).

In order to really benefit from the higher gain of the Darlington VAS, the load of the intermediate Rush amplifier would have been changed to a constant-current source. As first approximation, I have introduced inductivity L2, which creates the high impedance at all frequencies of interest.

With my modifications, the amp of course will not be robust against clipping / output short-circuit.

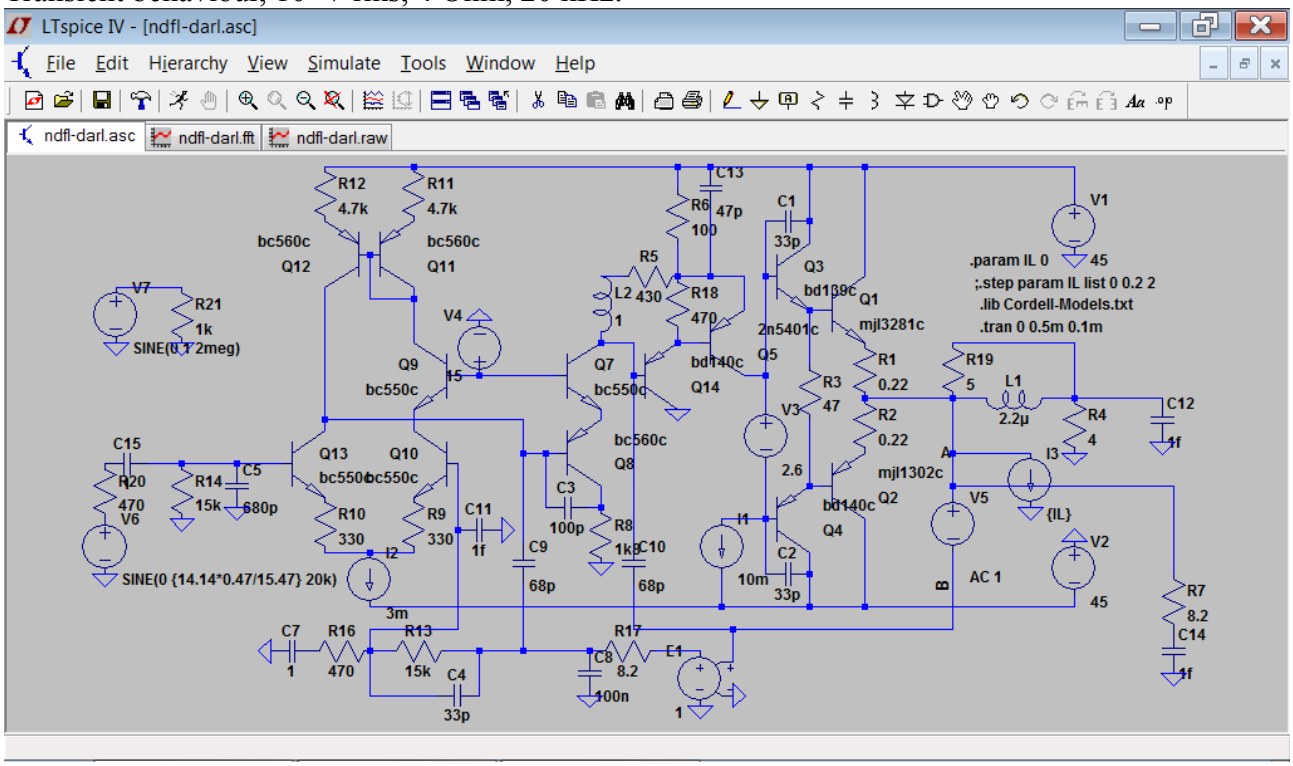
As I did not feel comfortable with the Zobel and how to correctly insert it into the loop gain measurements, I included the controlled voltage source E1 between the amp output and the feedback network. In a real implementation I would opt for increased values of the RC network, so that it does not load the amp output that much. Additionally, I have chosen a lower output inductor and a parallel resistor to damp resonances with a load capacity (cable and so on).

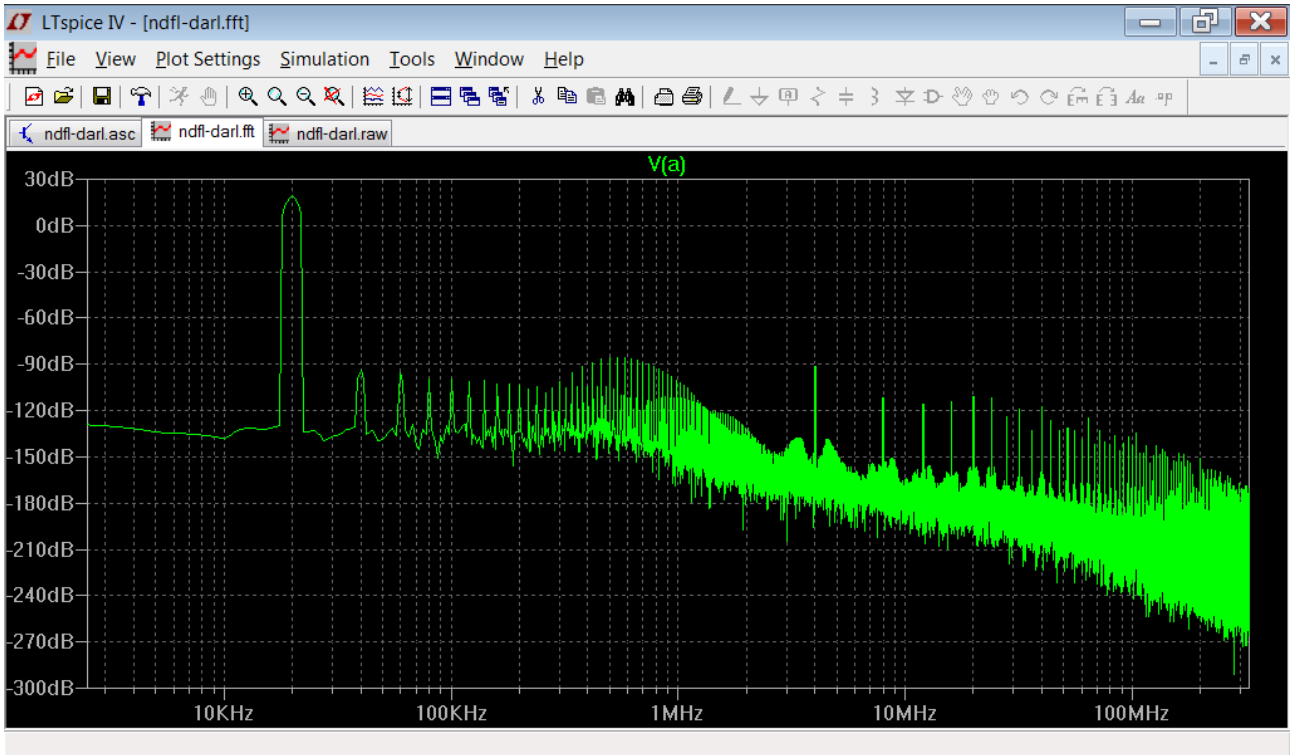
Accepting the high ULGF, the amplifier seems to perform quite well: TDH20k in the ppm range, also in critical transition range between class A and class B, with an OPS bias current of about 90 mA. Total NFB around the OPS is a bit more than 100 dB at 20 kHz.

For a real try I would

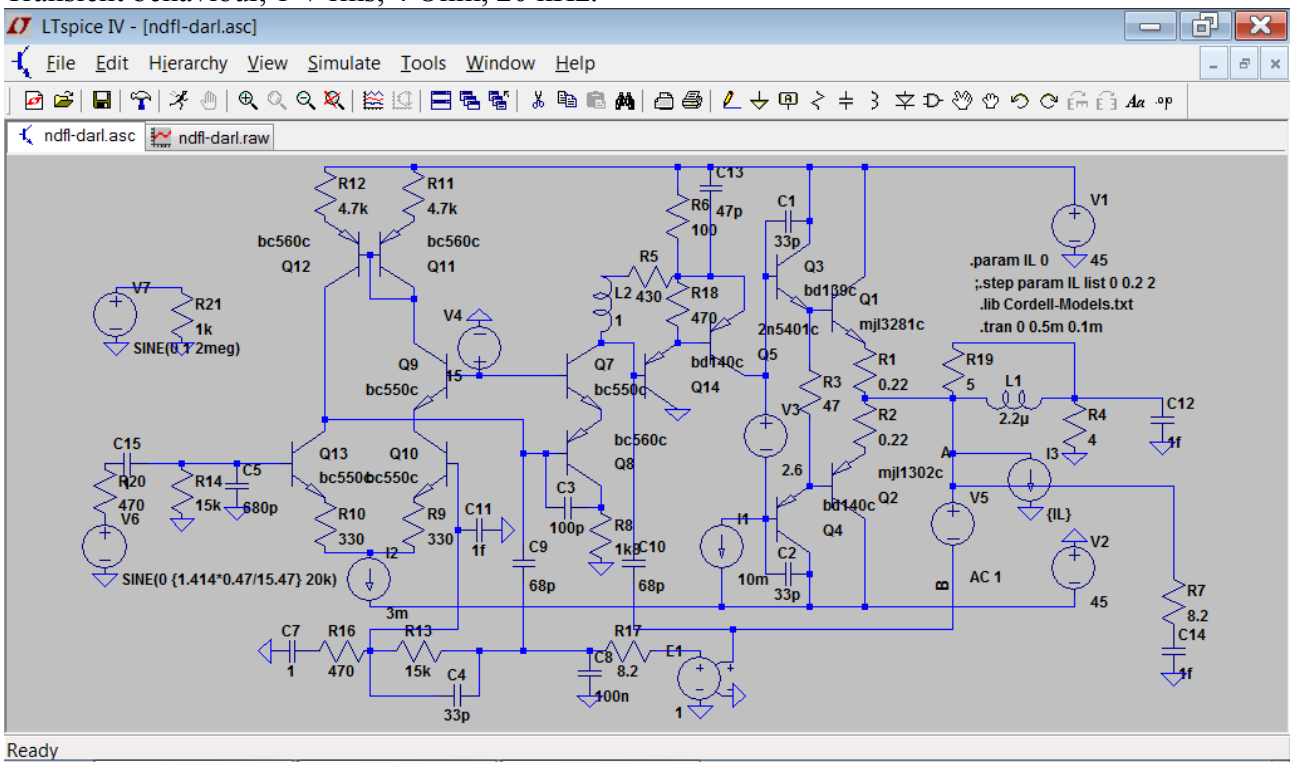
- scale down the frequencies a bit (OPS ULGF of 2 to 3 Mhz are probably easier to manage)
- replace the Rush amplifier with a degenerated version as in my amplifier project with nested Miller compensation (pleased to understand that I innocently re-invented it for the n plus first time ;-).
- fiddle with the ULGF of global loop and intermediate loop. Both are relatively low, especially the low NFB around the IPS is critical. Once one has accepted the high ULGF in the OPS, one could do this also for the other stages. Of course, one needs to keep enough margin to eventually roll out to 20dB per decade.

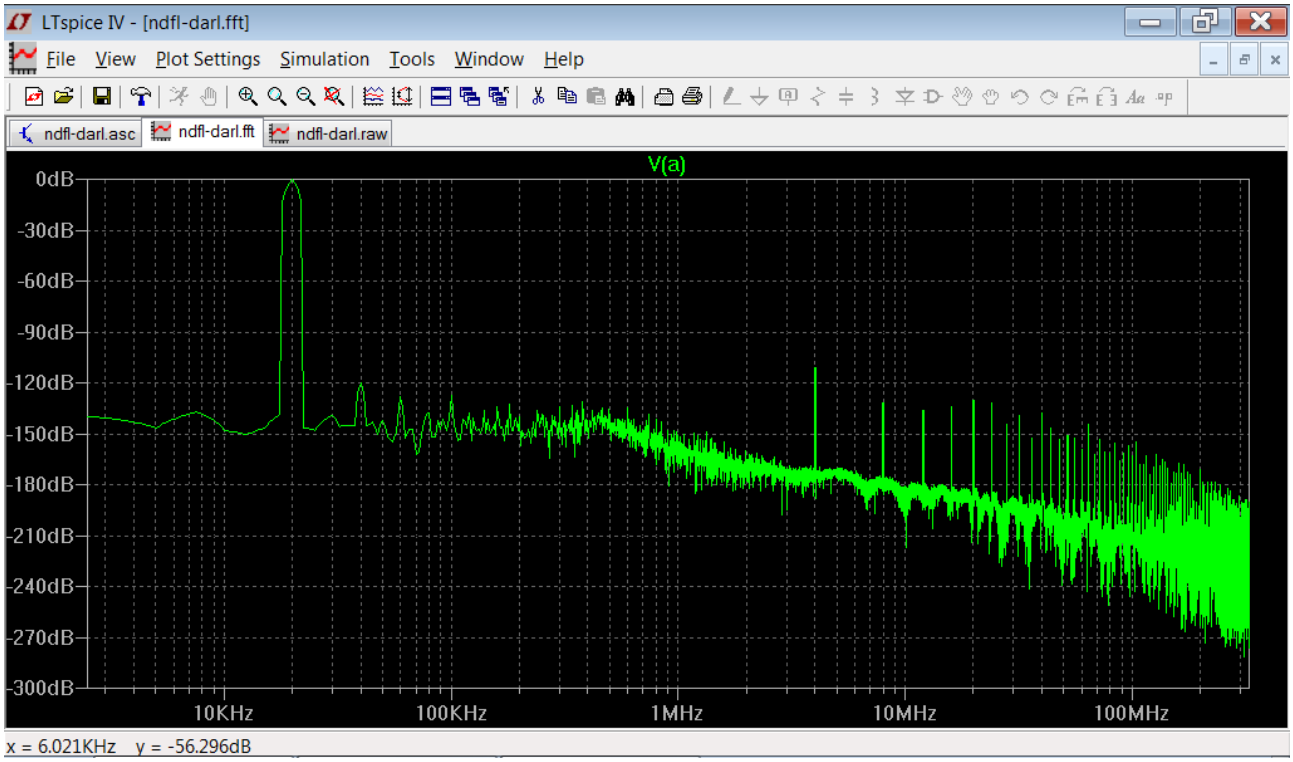
Transient behaviour, 10 V rms, 4 Ohm, 20 kHz:



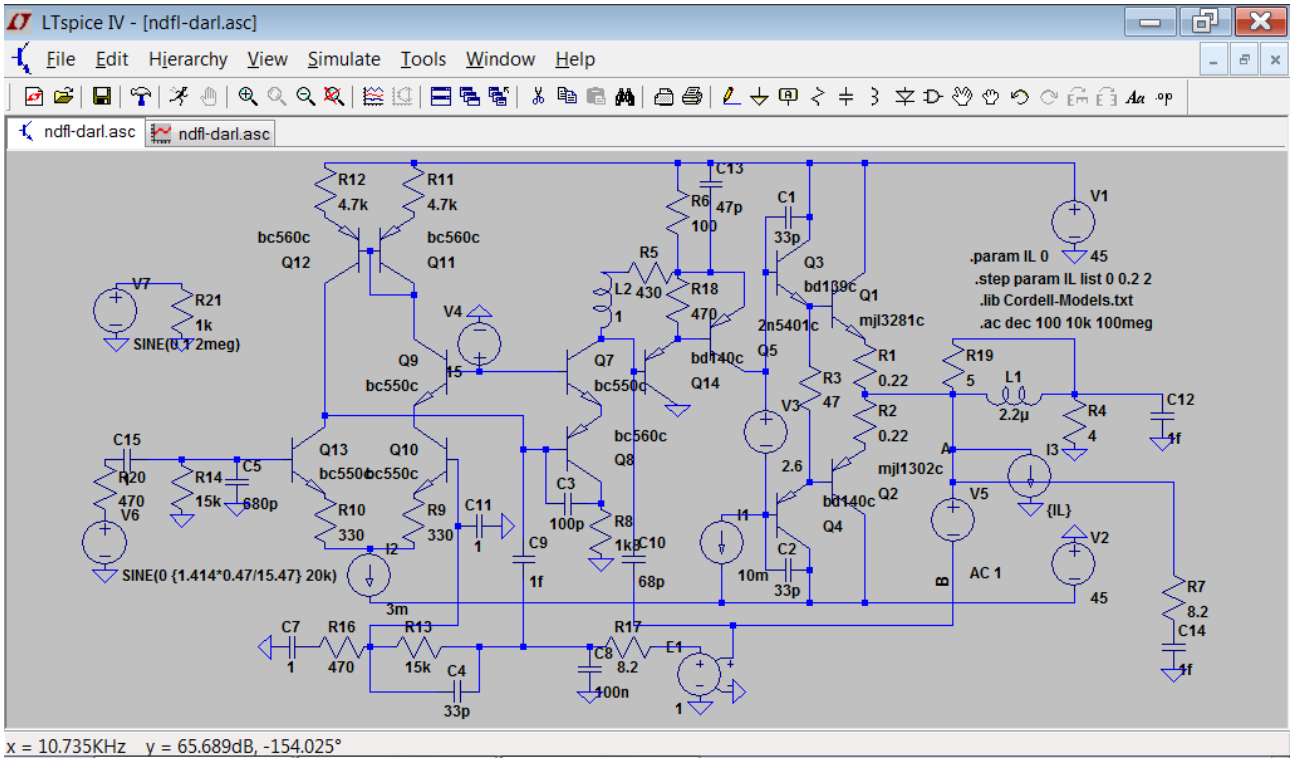


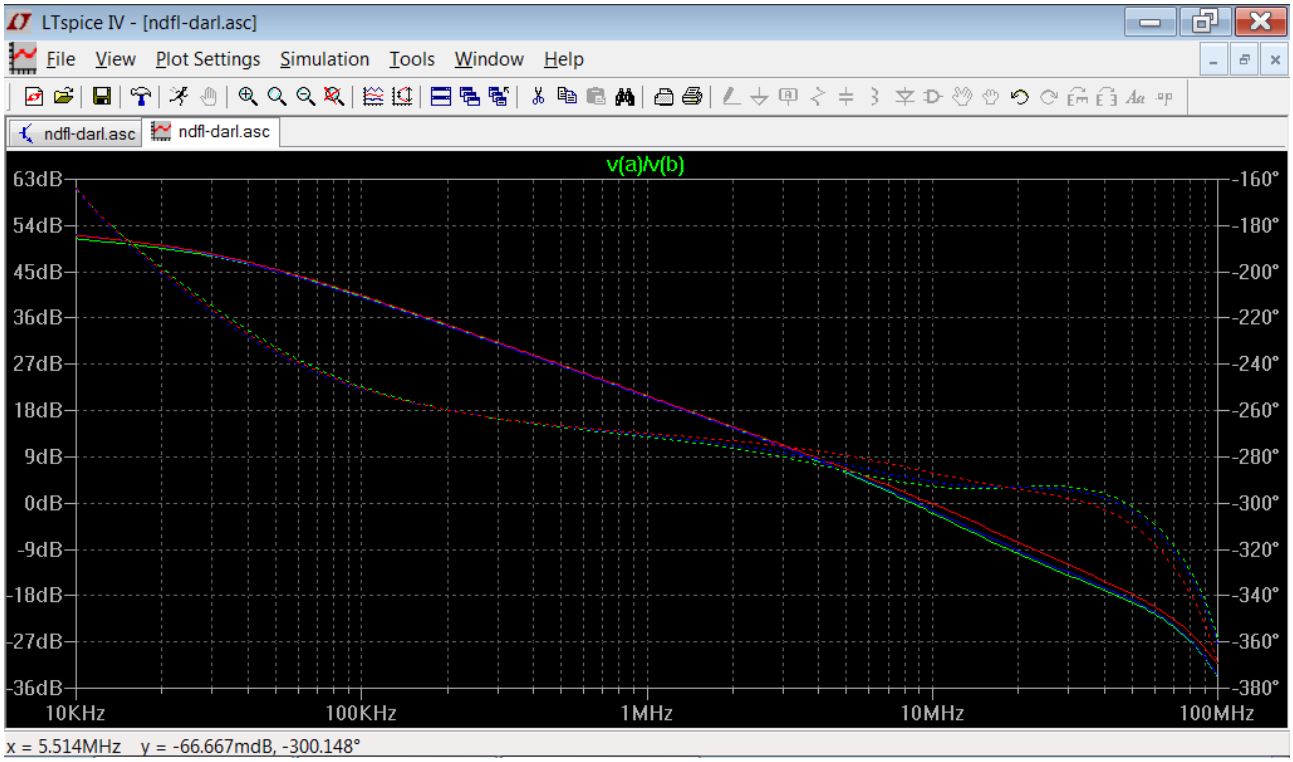
Transient behaviour, 1 V rms, 4 Ohm, 20 kHz:





Loop gain of innermost loop; with global loop and intermediate loop disengaged:
- ULGF around 10 Mhz, phase margin around 70 degrees
- different colors correspond to different load currents (other polarity brings little change)





Total loop gain around OPS, with additionally engaged intermediate stage:

[[(I have changed the capacitor at rush stage input (originally 470p) to C3=100p, still with enough margins in this loop, and with increased NFB at audio frequencies)
but see further below: this has perhaps a price, phase margins for intermediate and global loops become worse
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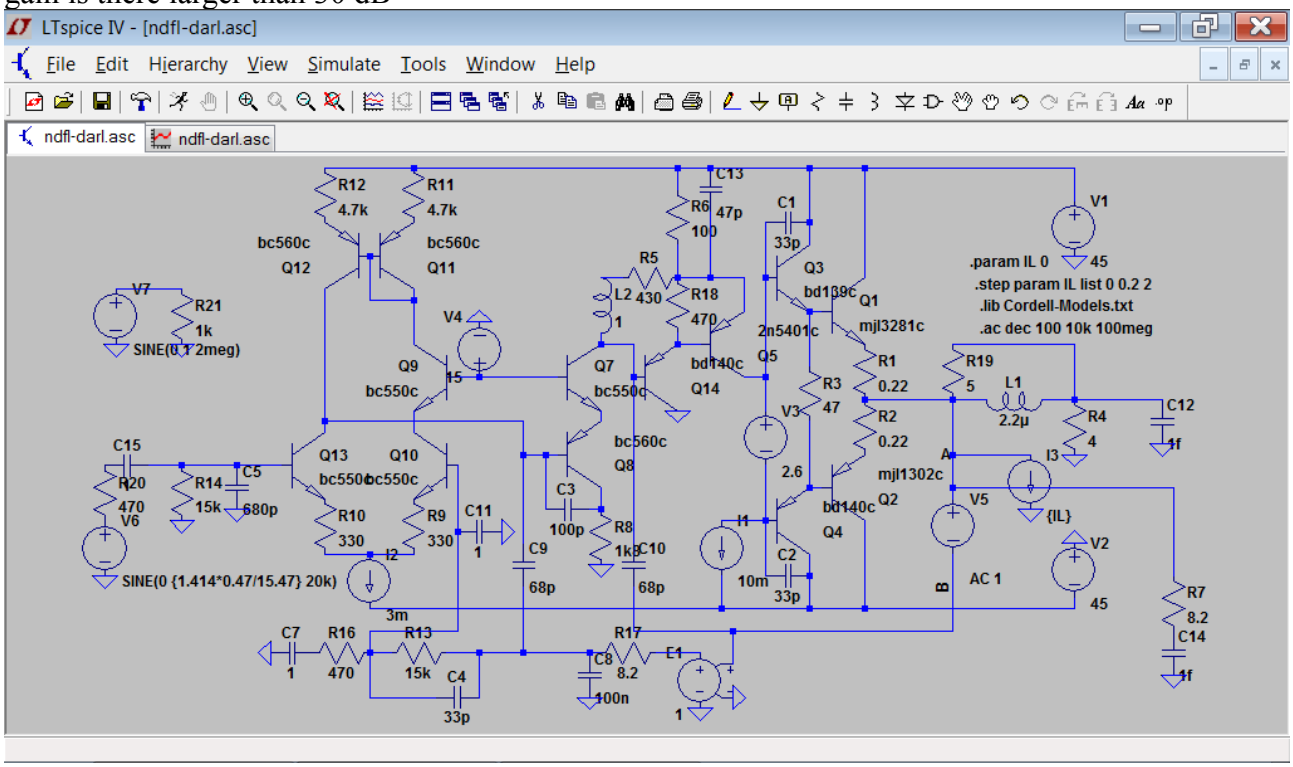
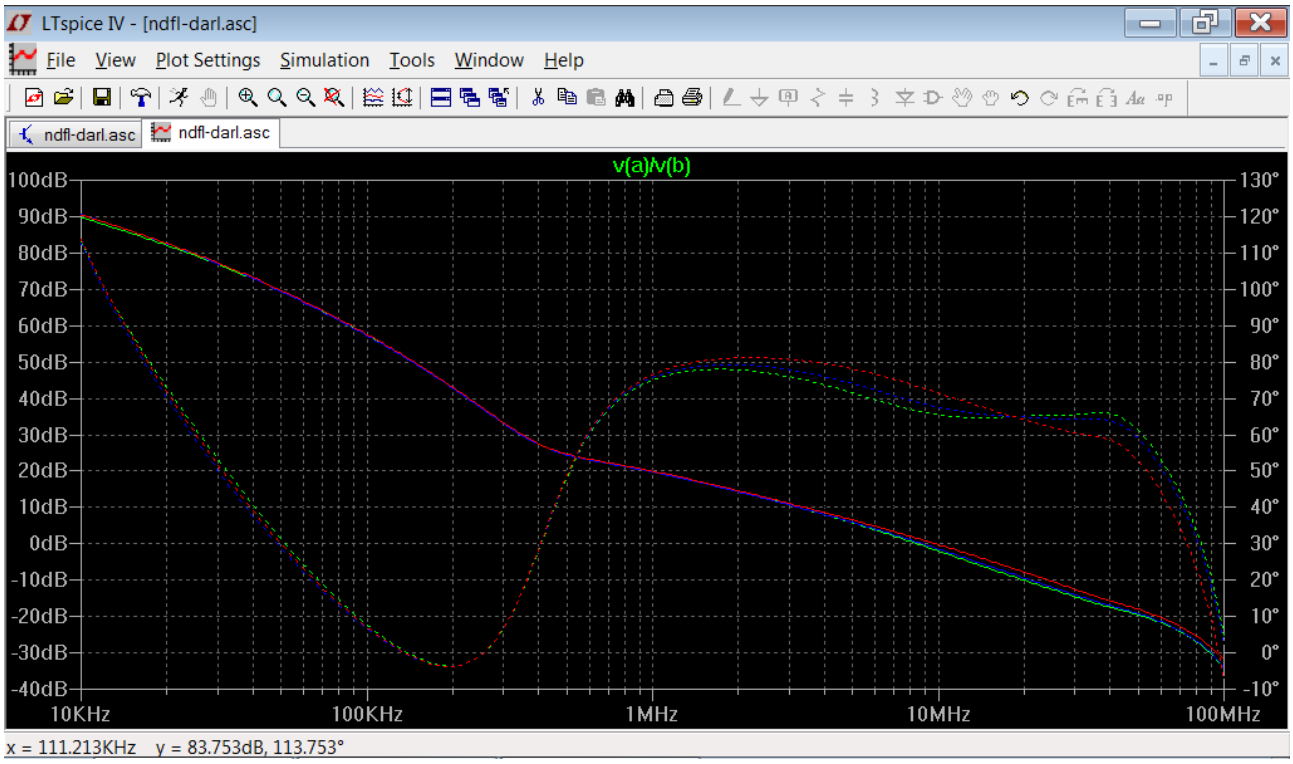
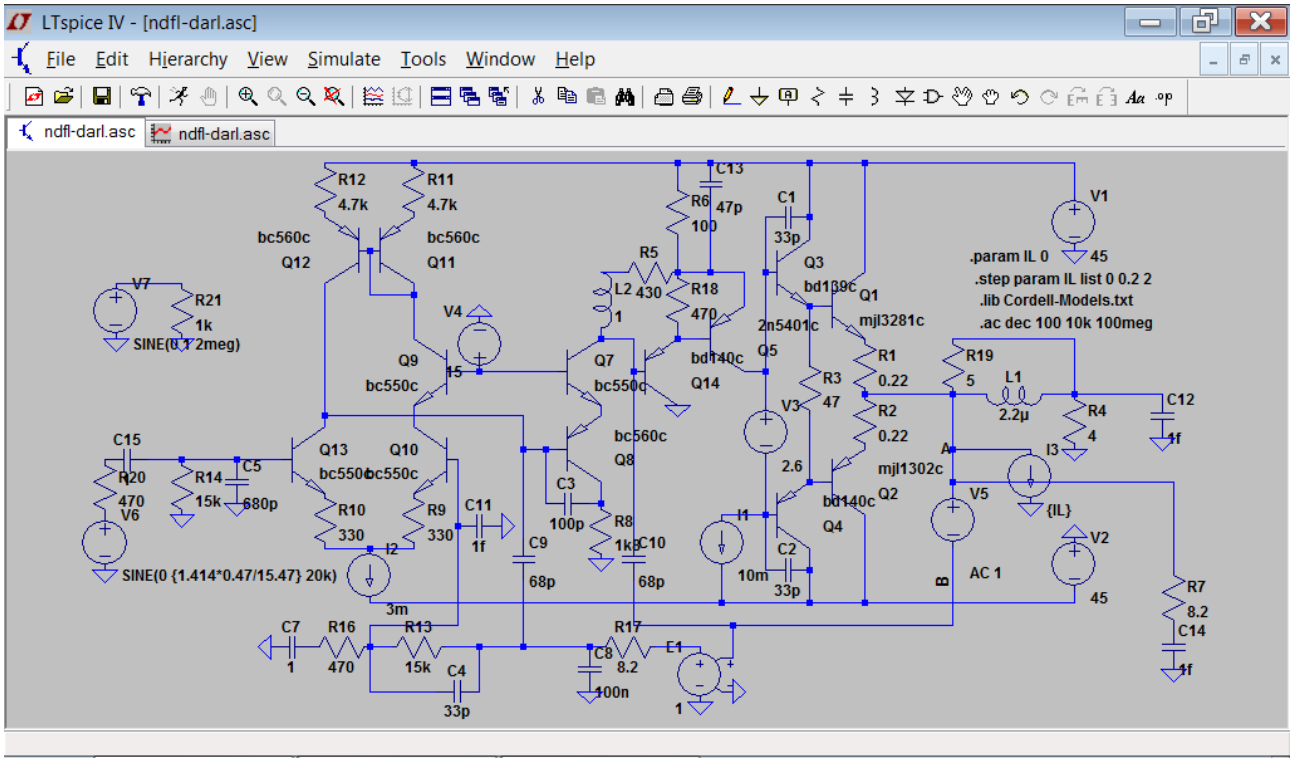
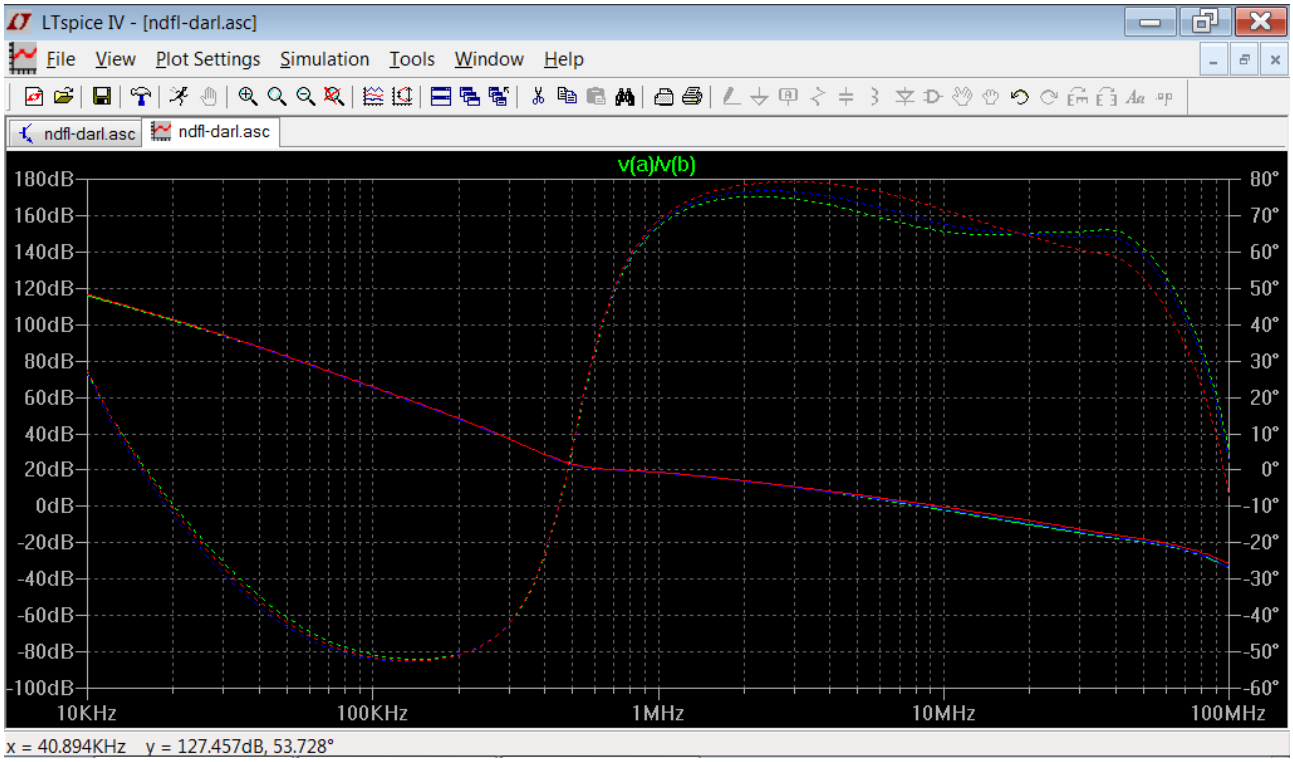
margins at high frequencies do not change, loop gain phase of 0 degrees at around 250 kHz, but gain is there larger than 30 dB



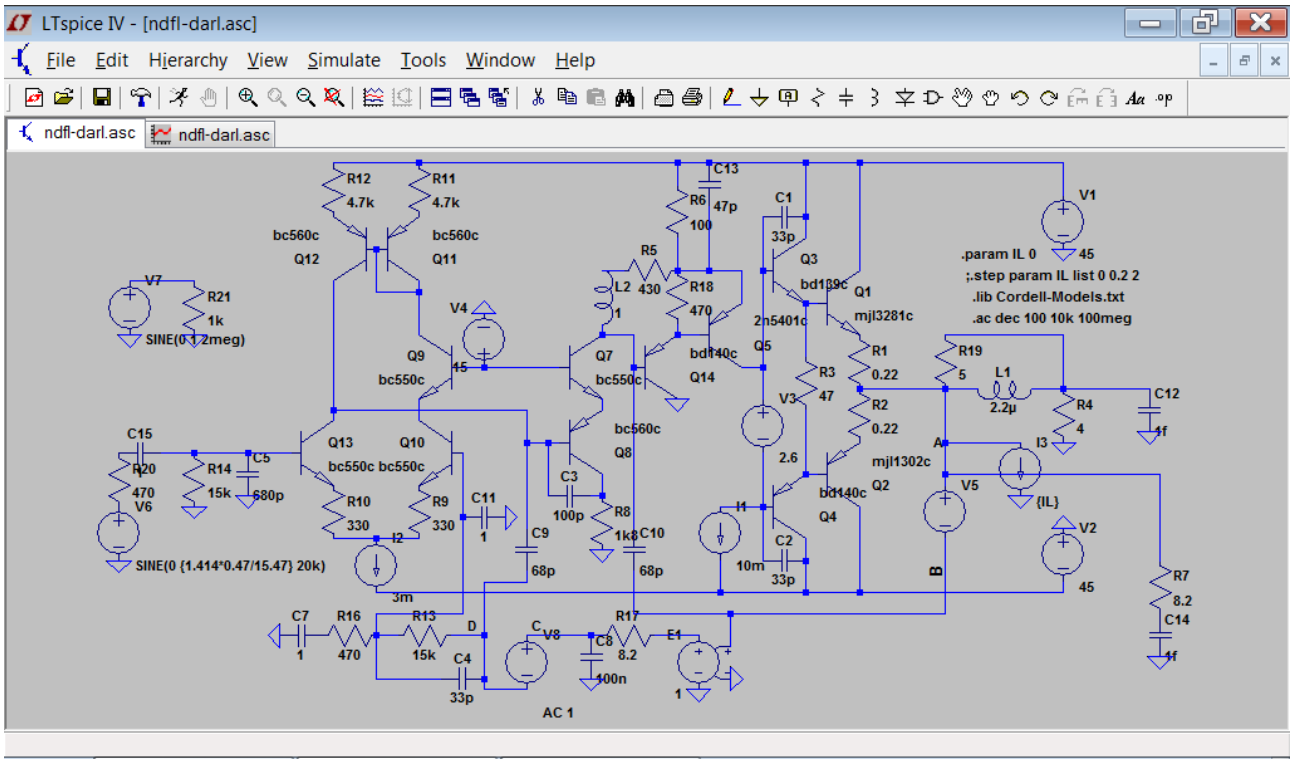


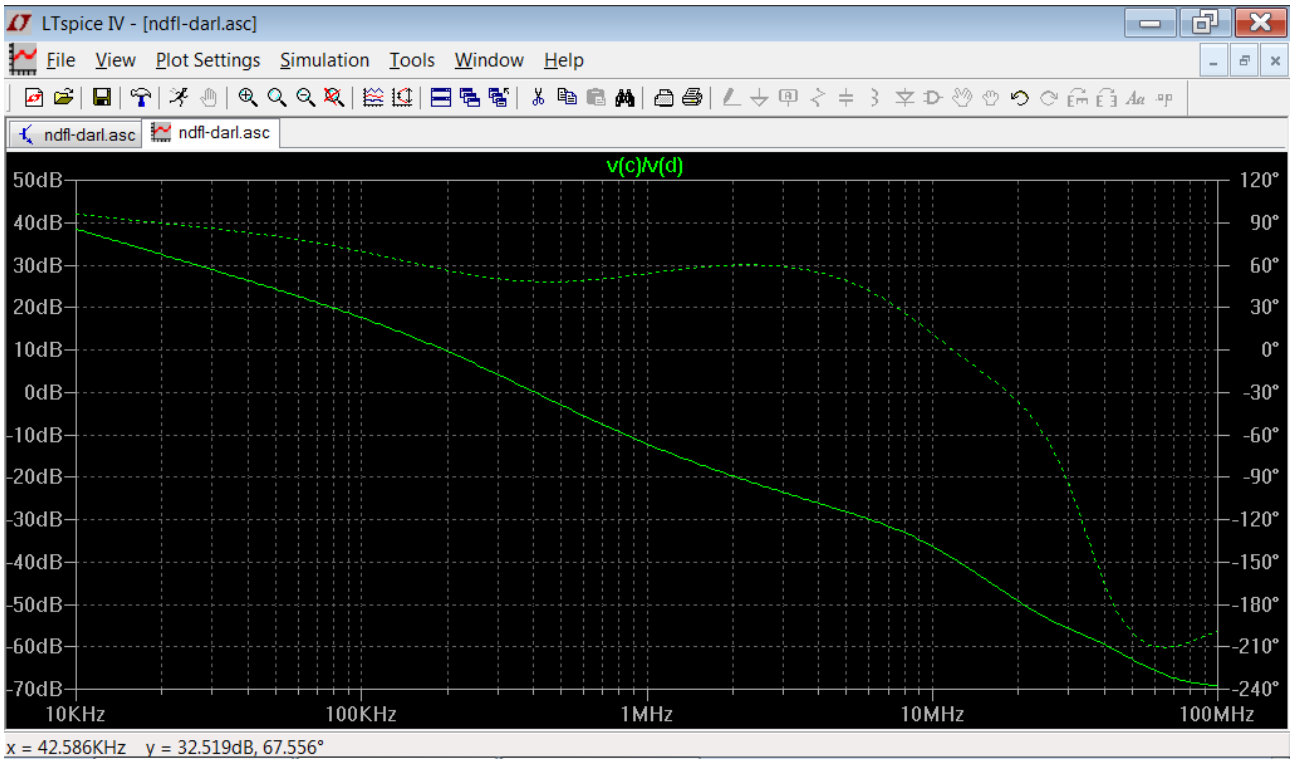
Total gain around OPS, now all loops active:
behaviour at HF only a little bit worse, at lower frequency a 0-degree-point now at around 450 kHz, but loop gain at this point is still larger than 20 dB



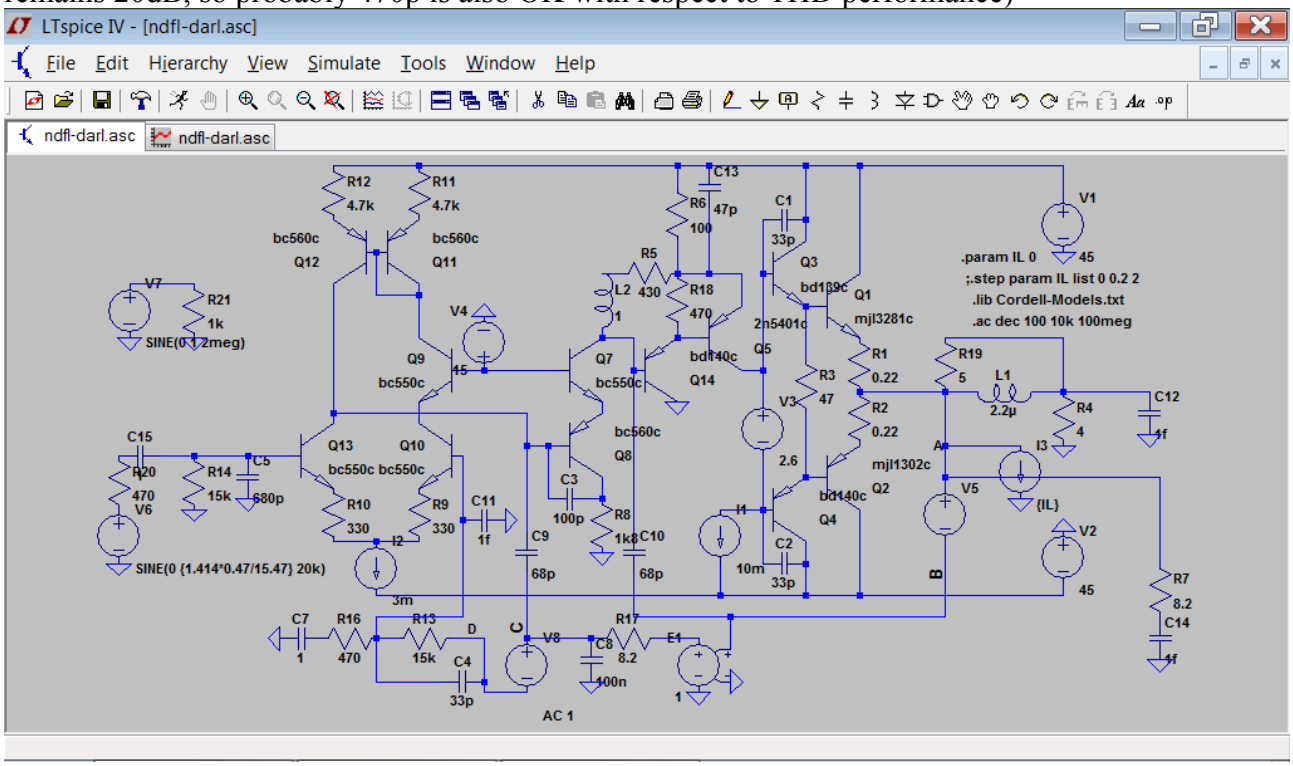


Loop gain in intermediate loop, global loop not active:
relatively low ULGF of 400 kHz, phase margin below 50 degrees
→ reason is the change of the capacitor at the rush stage (470 → 100p): with 100p, the phase margin is much larger, the ULGF much lower

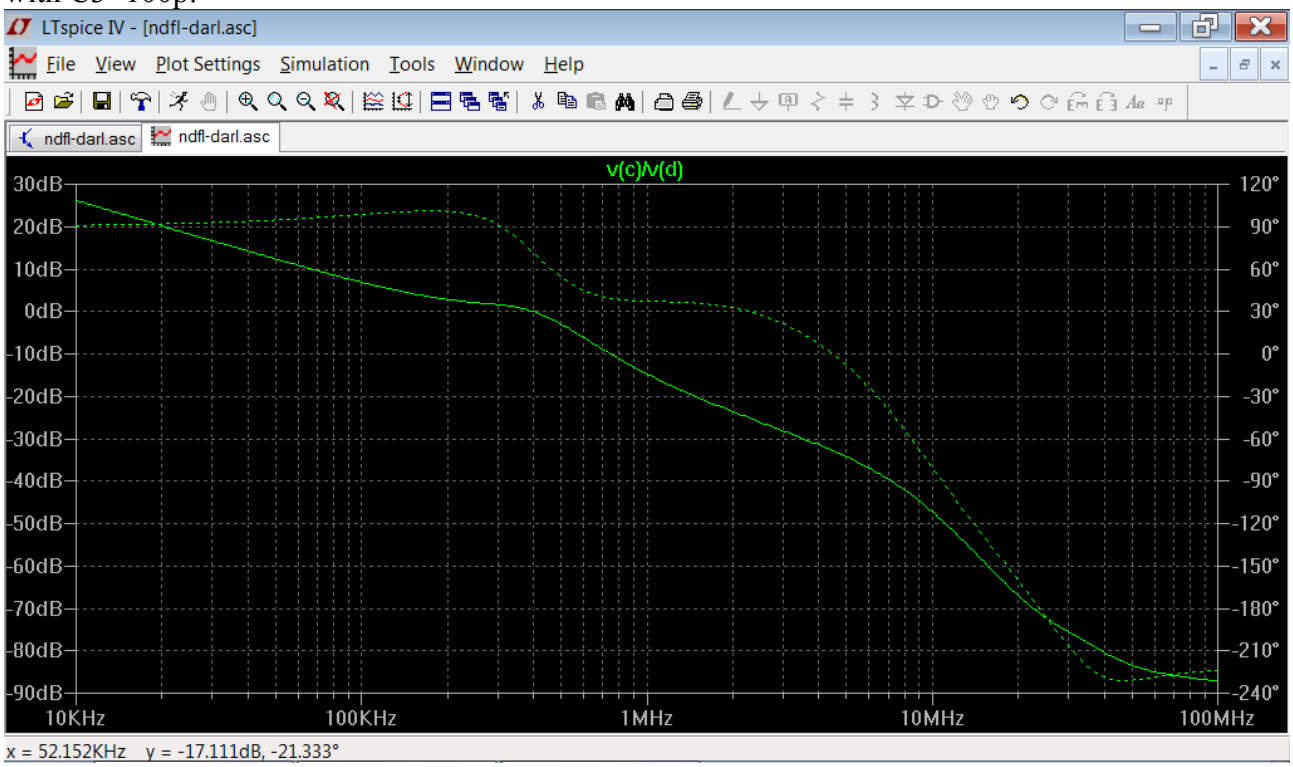




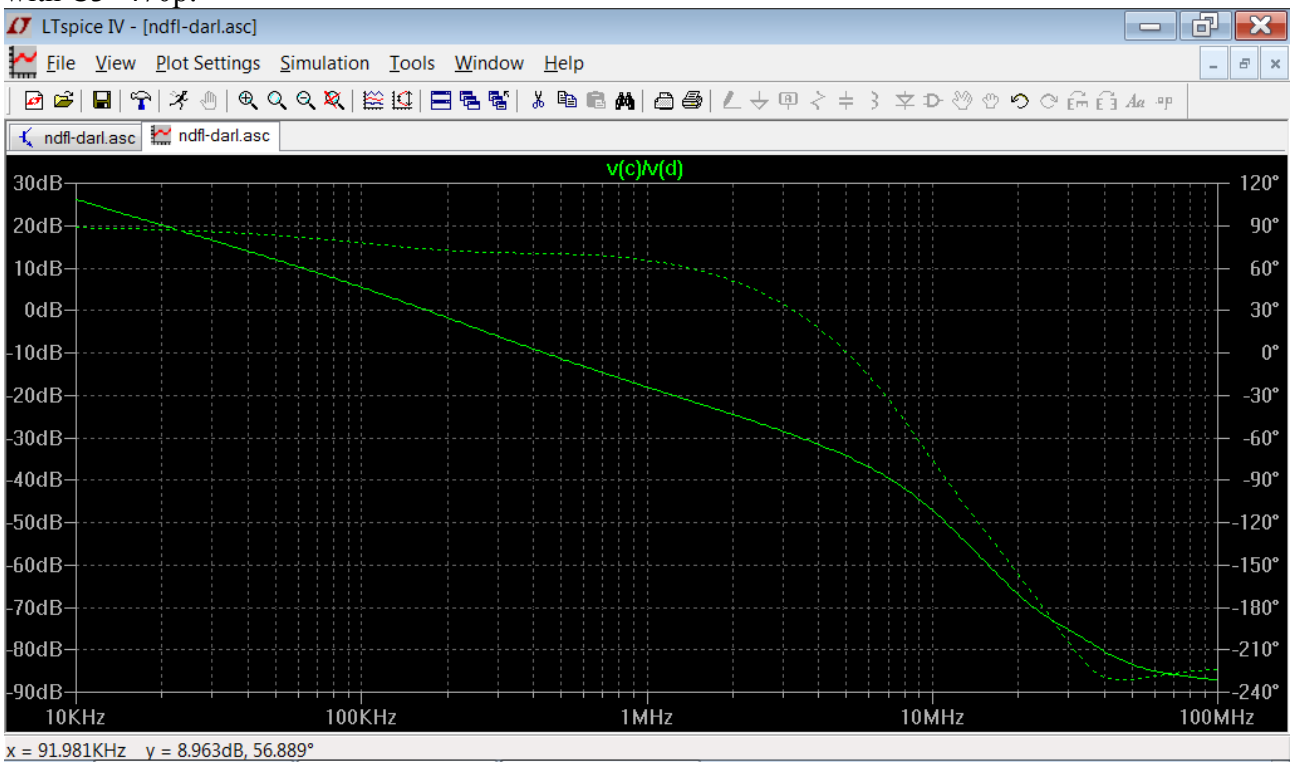
Global NFB loop:
relatively low ULGF of only 400 kHz, phase margin around 70 degrees
The strange behaviour vansihs if the capacitor at the Rrush stage is set to 470p (but NFB at 20kHz remains 20dB, so probably 470p is also OK with respect to THD performance)



with C3=100p:



with C3=470p:


LTspice IV - [ndfl-darl.asc]
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V(c)/V(d)
30dB
20dB
10dB
0dB
-10dB
-20dB
-30dB
-40dB
-50dB
-60dB
-70dB
-80dB
-90dB
120°
90°
60°
30°
0°
-30°
-60°
-90°
-120°
-150°
-180°
-210°
-240°
10KHz
100KHz
1MHz
10MHz
100MHz
x = 91.981KHz y = 8.963dB, 56.889°