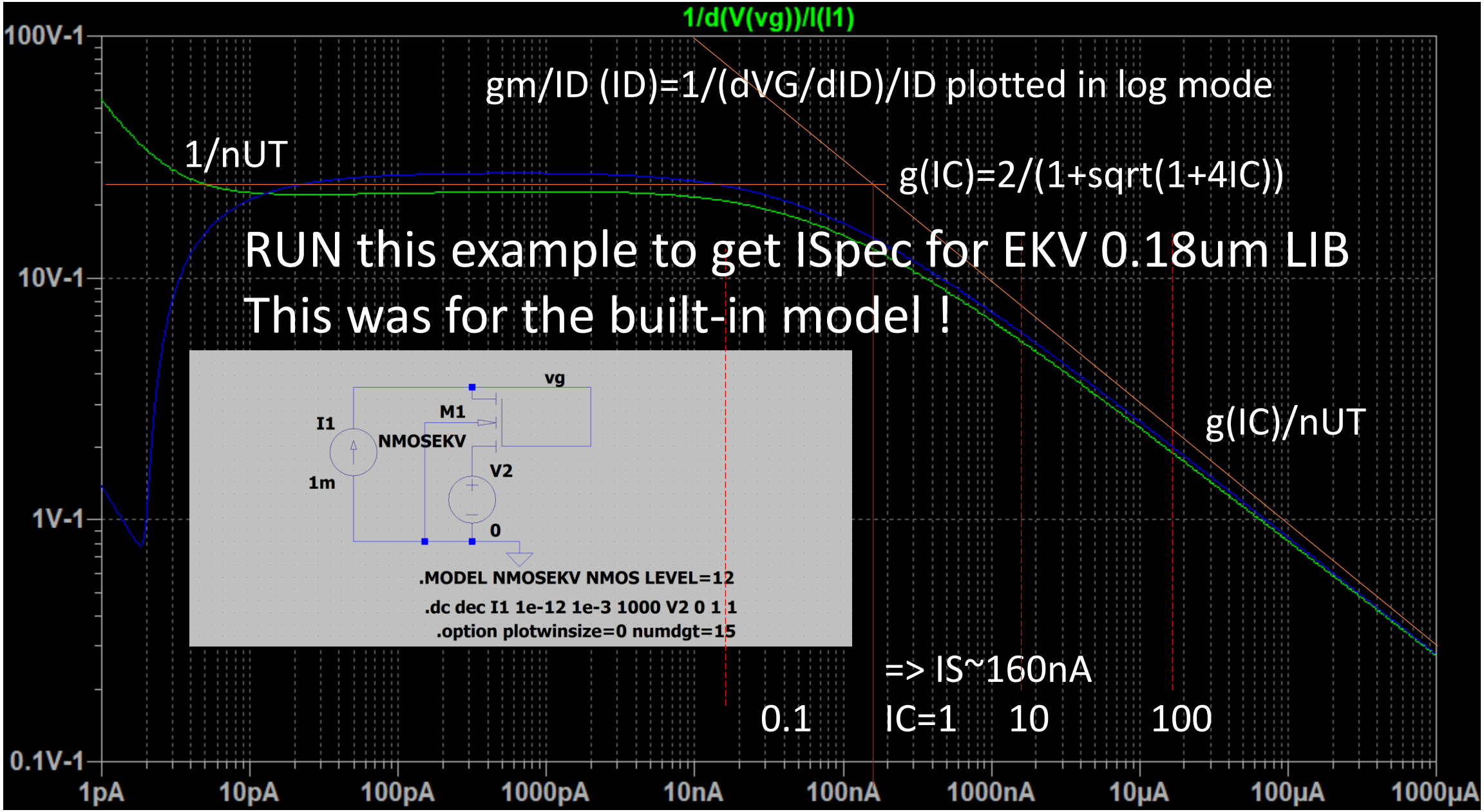
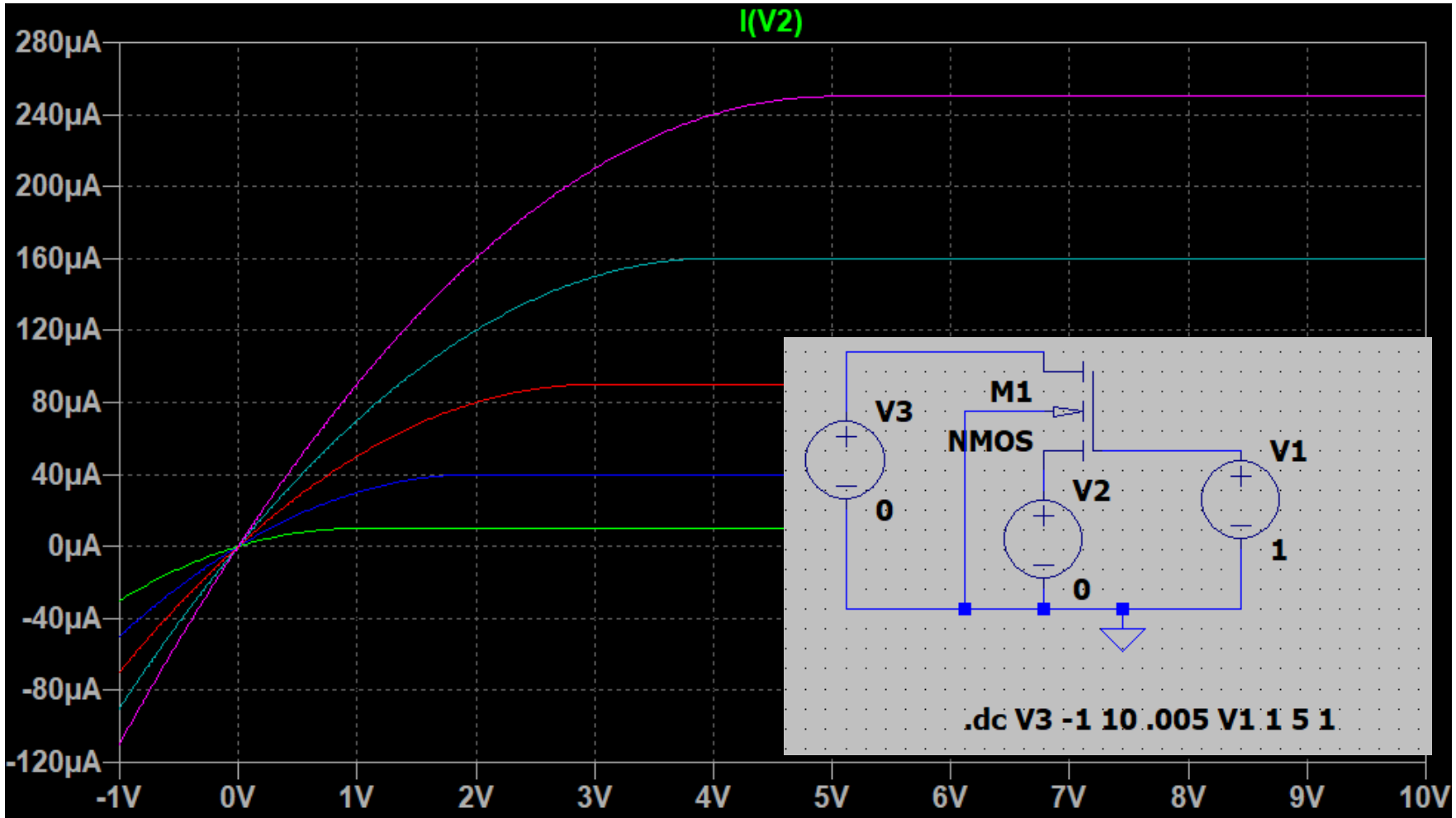
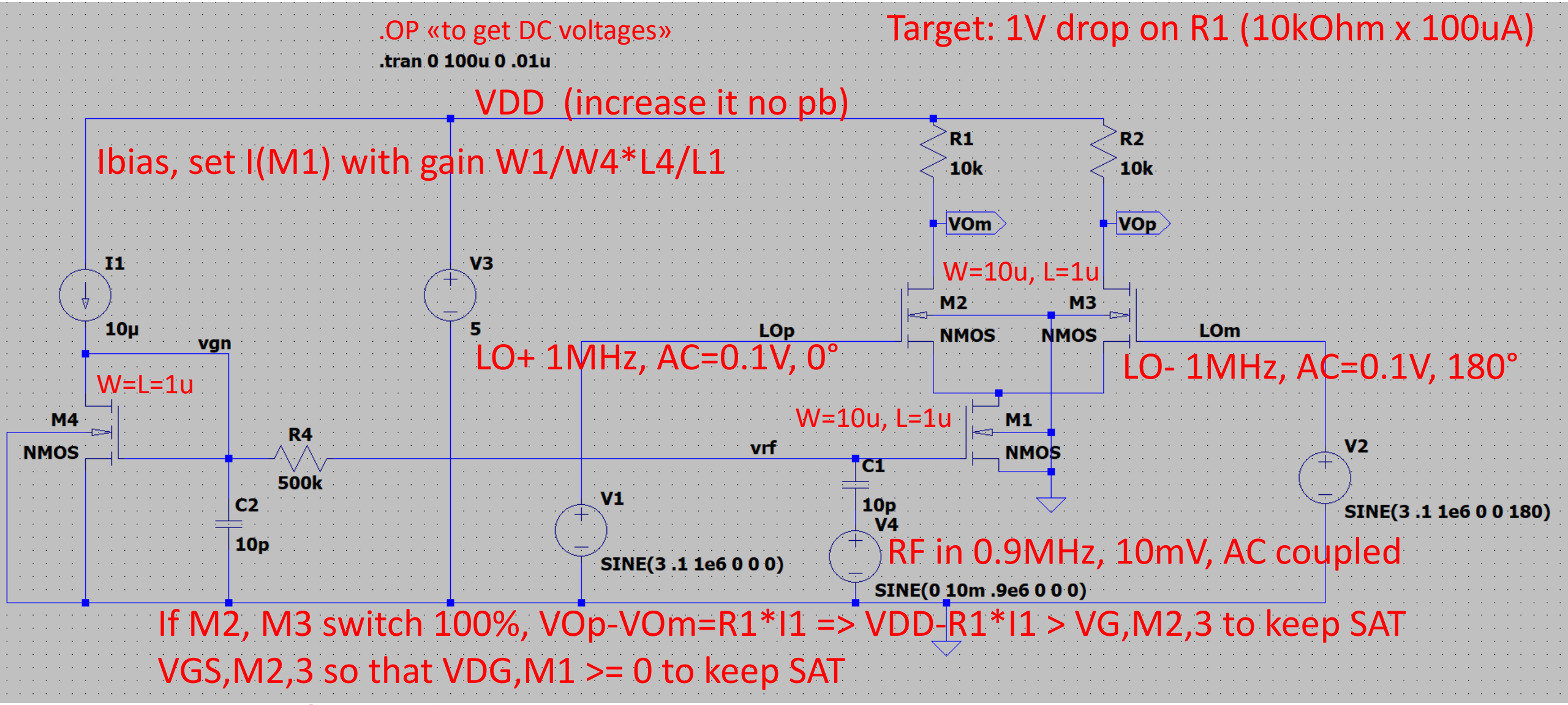

1/d(V(vg))/I(I1)
100V-1
10V-1
1V-1
0.1V-1
gm/ID (ID)=1/(dVG/dID)/ID plotted in log mode
1/nUT
g(IC)=2/(1+sqrt(1+4IC))
RUN this example to get ISpec for EKV 0.18um LIB
This was for the built-in model !
g(IC)/nUT
vg
M1
I1
NMOSEKV
1m
V2
0
.MODEL NMOSEKV NMOS LEVEL=12
.dc dec I1 1e-12 1e-3 1000 V2 0 1 1
.option plotwinsize=0 numdgt=15
=> IS~160nA
0.1
IC=1
10
100
1pA
10pA
100pA
1000pA
10nA
100nA
1000nA
10µA
100µA
1000µA

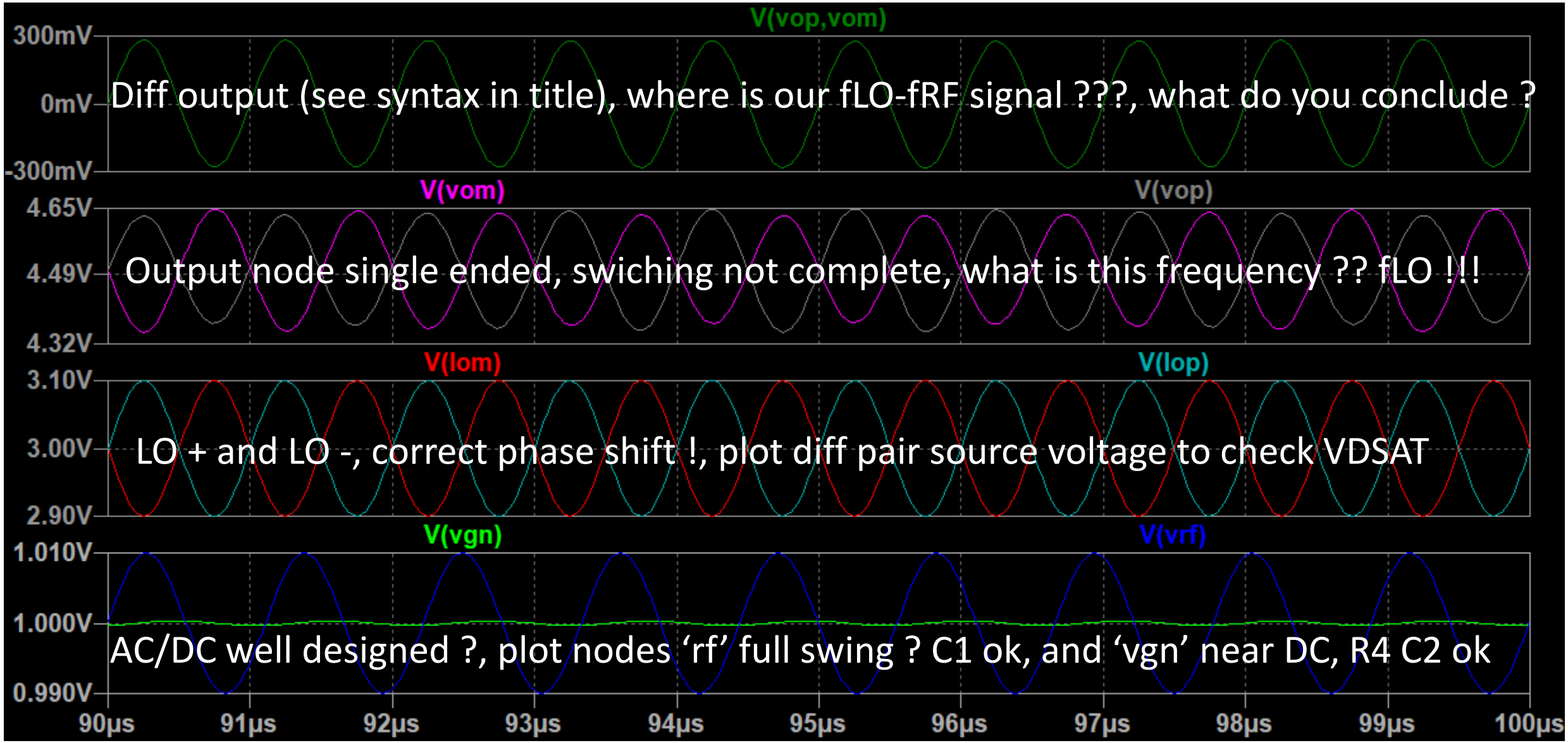
Determine VDSAT (normally (VG-VT)/n)
Redo this with EKV 0.18um model VDD=1.8V

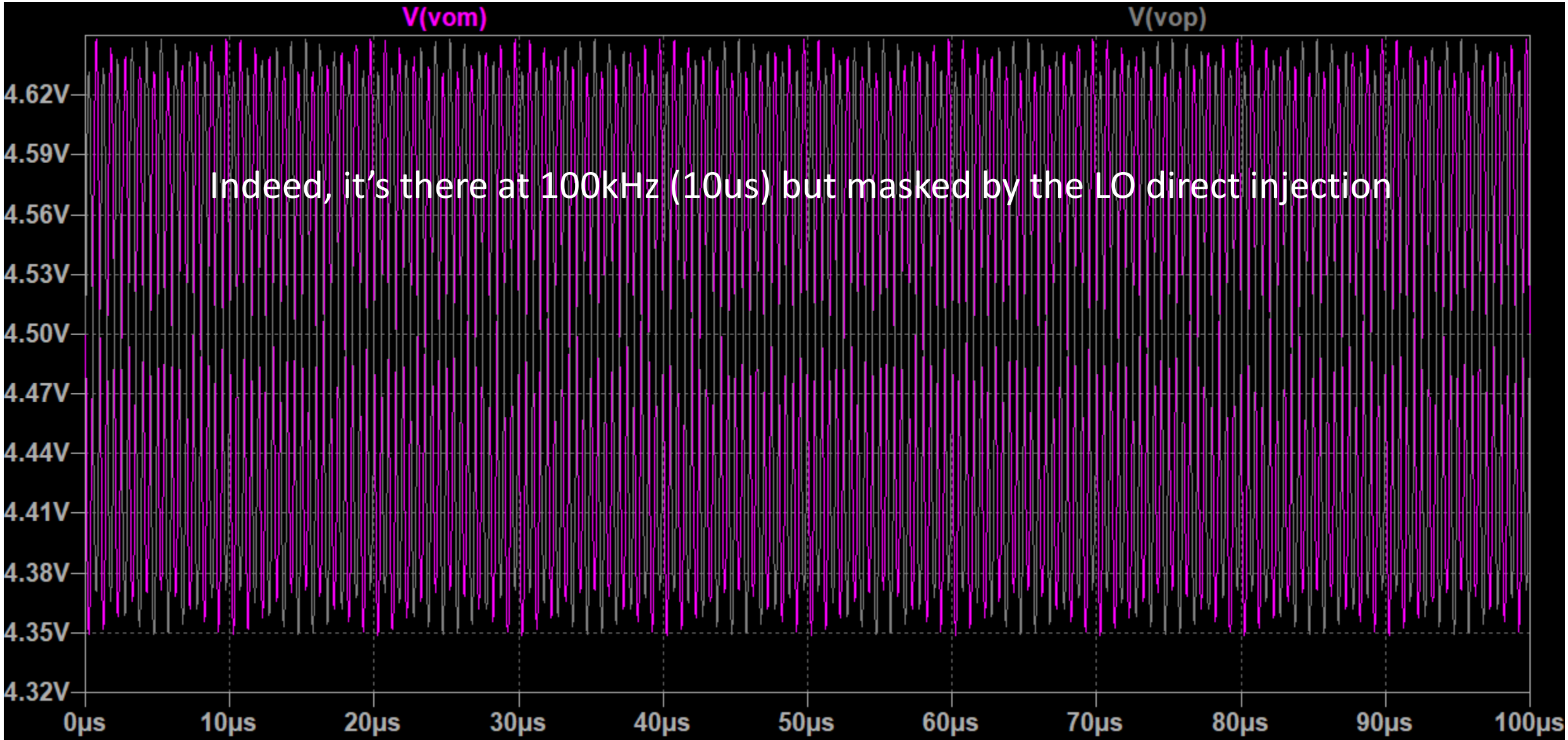
- Sweep -1V<VD<10V, 1st sweep is X-axis
- VS=0, I(VS)>0 (plt)
- VG=1, 2, .., 5V
- VT=0, n=1 =>
  - VDSAT=VG
  - VDG>=0 !
- Mirror ok !

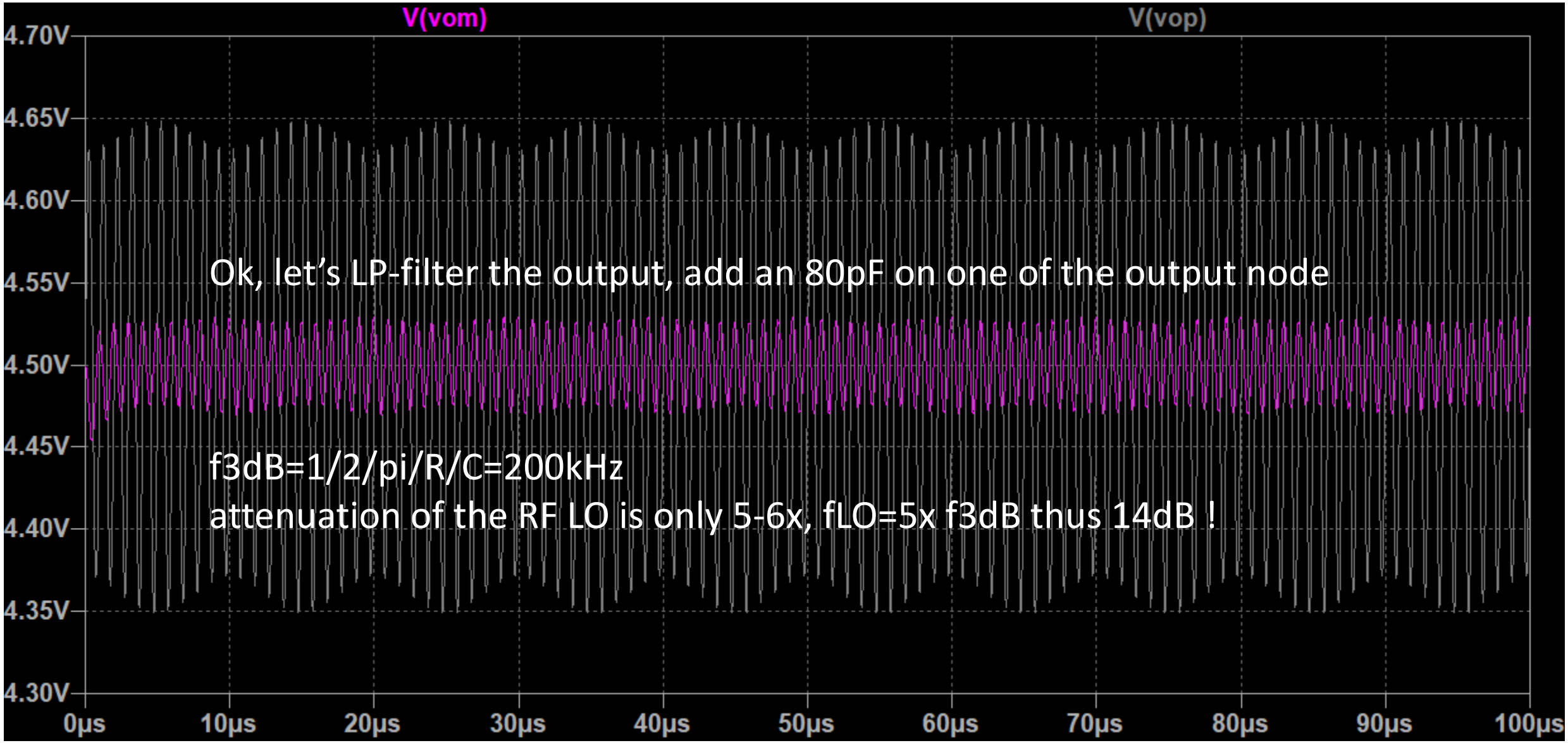


Mixer schematic (use EKV L=0.18um LIB, VDD=1.8V)

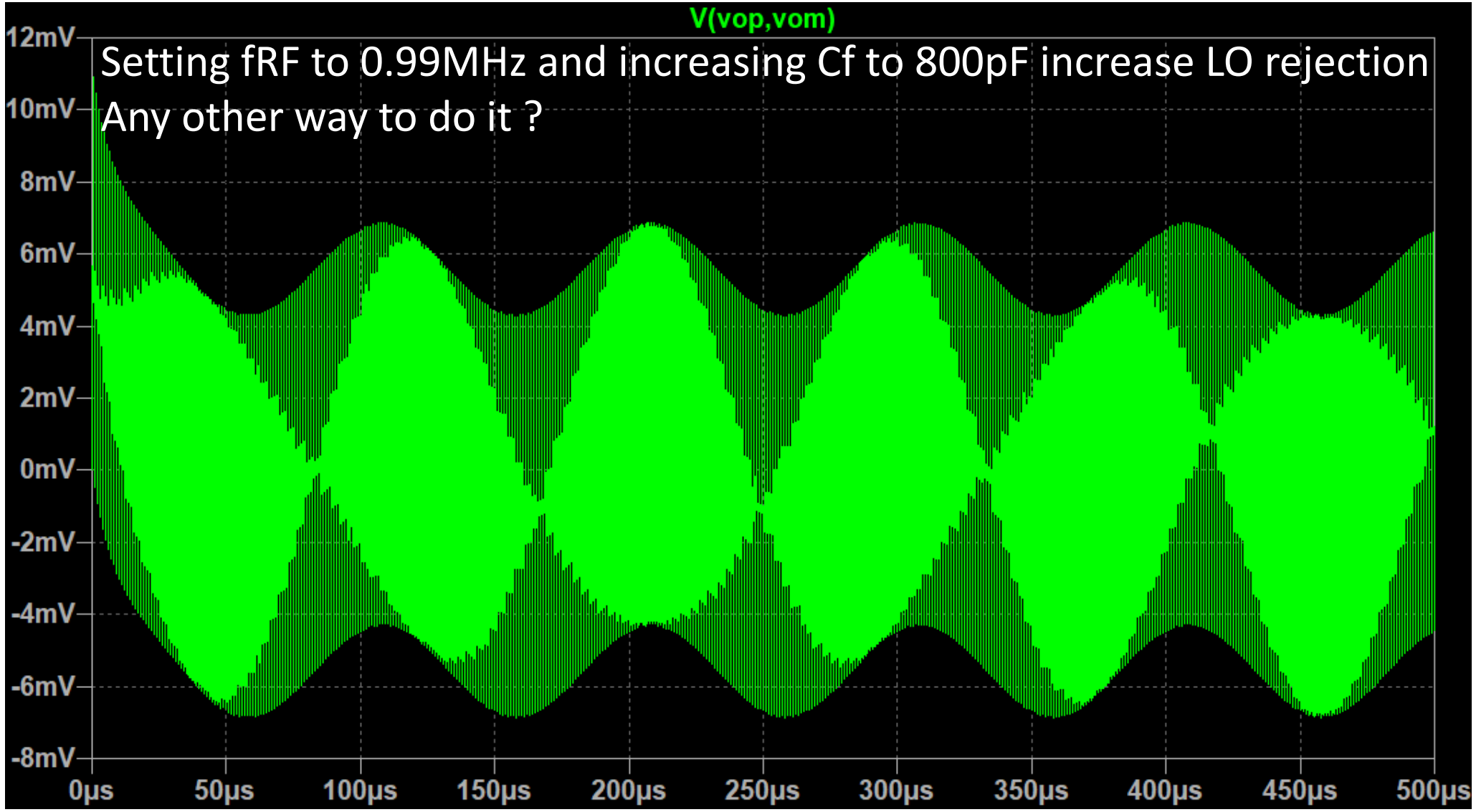



V(vop,vom)
300mV
0mV
-300mV
Diff output (see syntax in title), where is our fLO-fRF signal ???, what do you conclude ?
V(vom)
V(vop)
4.65V
4.49V
4.32V
Output node single ended, swiching not complete, what is this frequency ?? fLO !!!
V(lom)
V(lop)
3.10V
3.00V
2.90V
LO + and LO -, correct phase shift !, plot diff pair source voltage to check VDSAT
V(vgn)
V(vrf)
1.010V
1.000V
0.990V
AC/DC well designed ?, plot nodes ‘rf’ full swing ? C1 ok, and ‘vgn’ near DC, R4 C2 ok
90µs
91µs
92µs
93µs
94µs
95µs
96µs
97µs
98µs
99µs
100µs

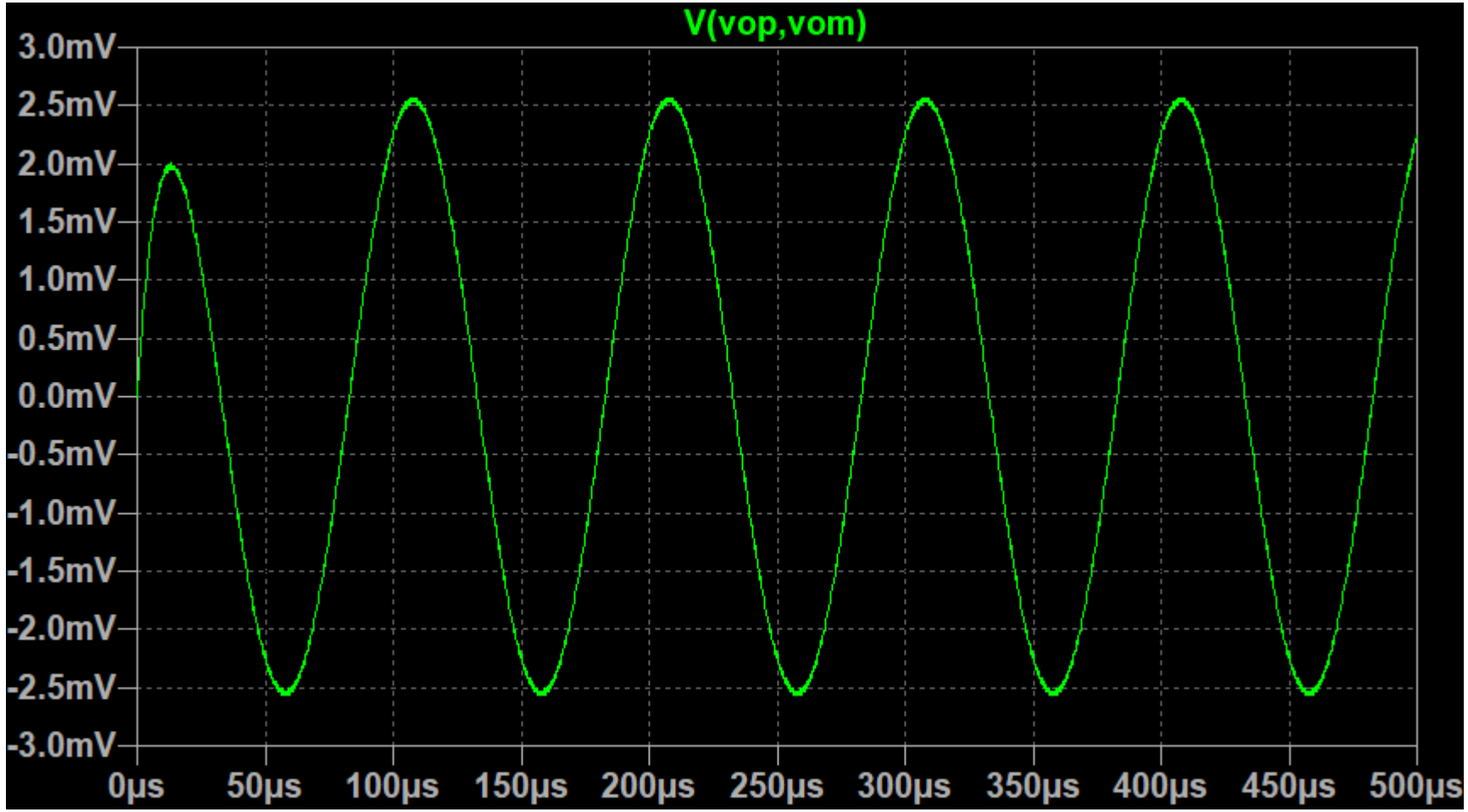

V(vom)
V(vop)
4.62V
4.59V
4.56V
4.53V
4.50V
4.47V
4.44V
4.41V
4.38V
4.35V
4.32V
0µs
10µs
20µs
30µs
40µs
50µs
60µs
70µs
80µs
90µs
100µs
Indeed, it’s there at 100kHz (10us) but masked by the LO direct injection


V(vom)
V(vop)
4.70V
4.65V
4.60V
4.55V
4.50V
4.45V
4.40V
4.35V
4.30V
0µs
10µs
20µs
30µs
40µs
50µs
60µs
70µs
80µs
90µs
100µs
Ok, let’s LP-filter the output, add an 80pF on one of the output node
f3dB=1/2/pi/R/C=200kHz
attenuation of the RF LO is only 5-6x, fLO=5x f3dB thus 14dB !

Lowering fIF/fLO ratio



Yes ! Double-balanced mixers !

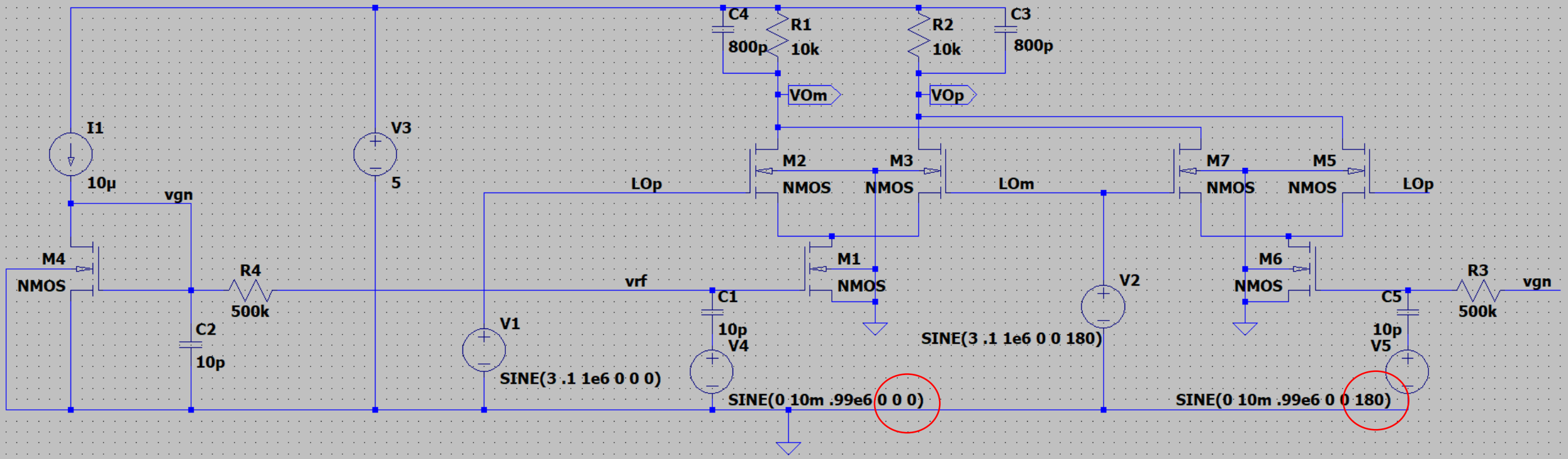


Differential RF input and duplicated diff pair !

Issue is DC current from RF input MOS M1 which is steered by M2,3 and >> IRF

Solution: inject that same DC current on opposite node and AC with -1 gain (hence 180° RF)

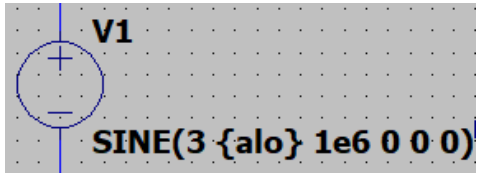
Same total current and load if M1,2,3,5,6,7 W is reduced by 2x

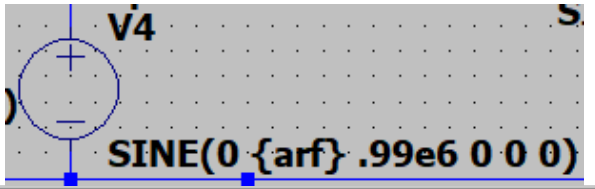


Replicate that structure and vary RF, LO swings to extract gain, compression (☺?)

- Check the .measure help in LTSpice or use below syntax directives

```
.PARAM arf=10m alo=100m
.step param arf list 1m 2m 4m 8m 16m 32m 64m 128m 256m 512m
.step param alo list 100m 200m 400m   800m 1.6
.meas TRAN if_amp MAX V(VOp,VOm)
```





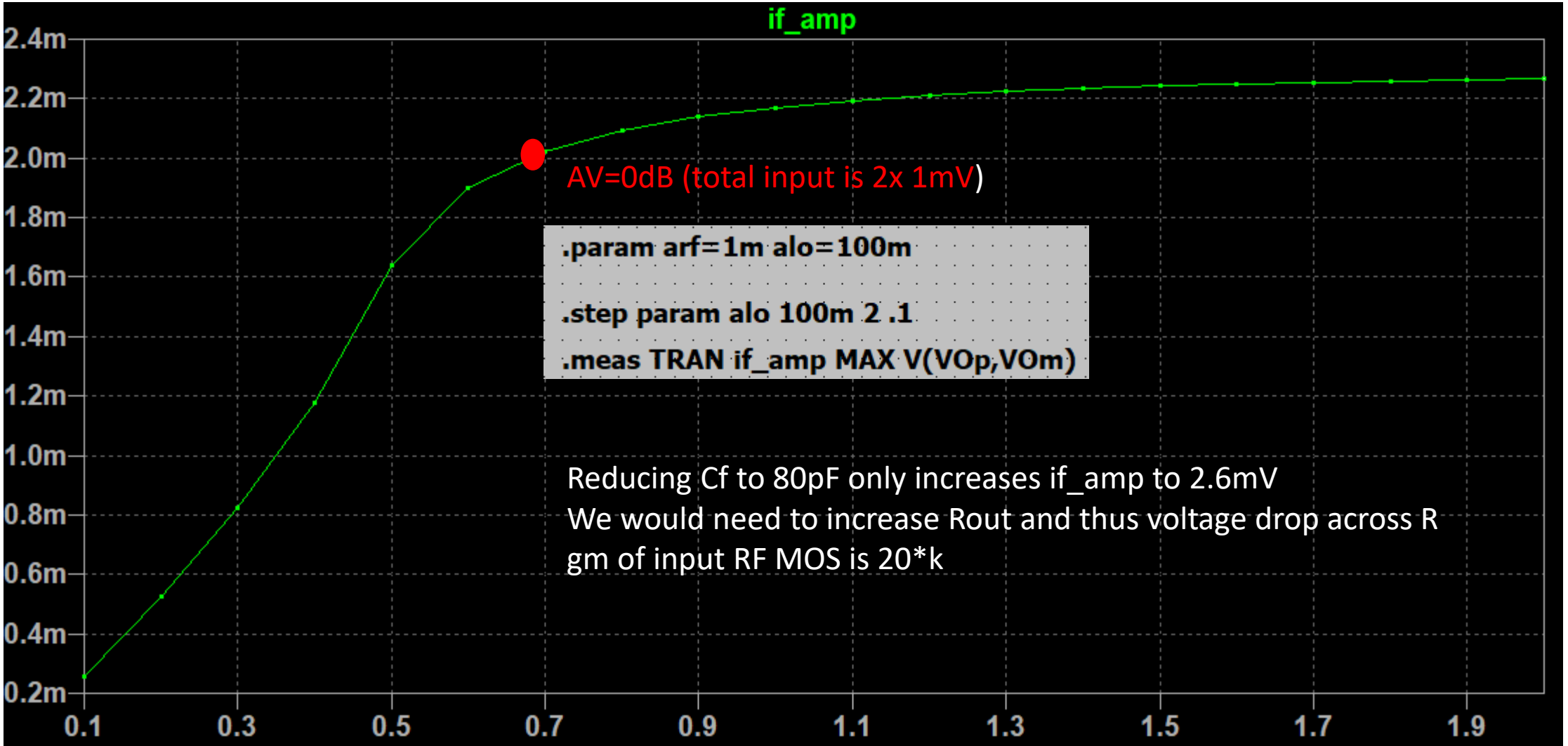
- Select View -> Spice Error Log
- Right clik inside window
- Select Plot stepped meas data

SPICE Error Log: C:\Users\dru\OneDrive - CSEM S.A\Documents\LTspiceXVII\mixer.log

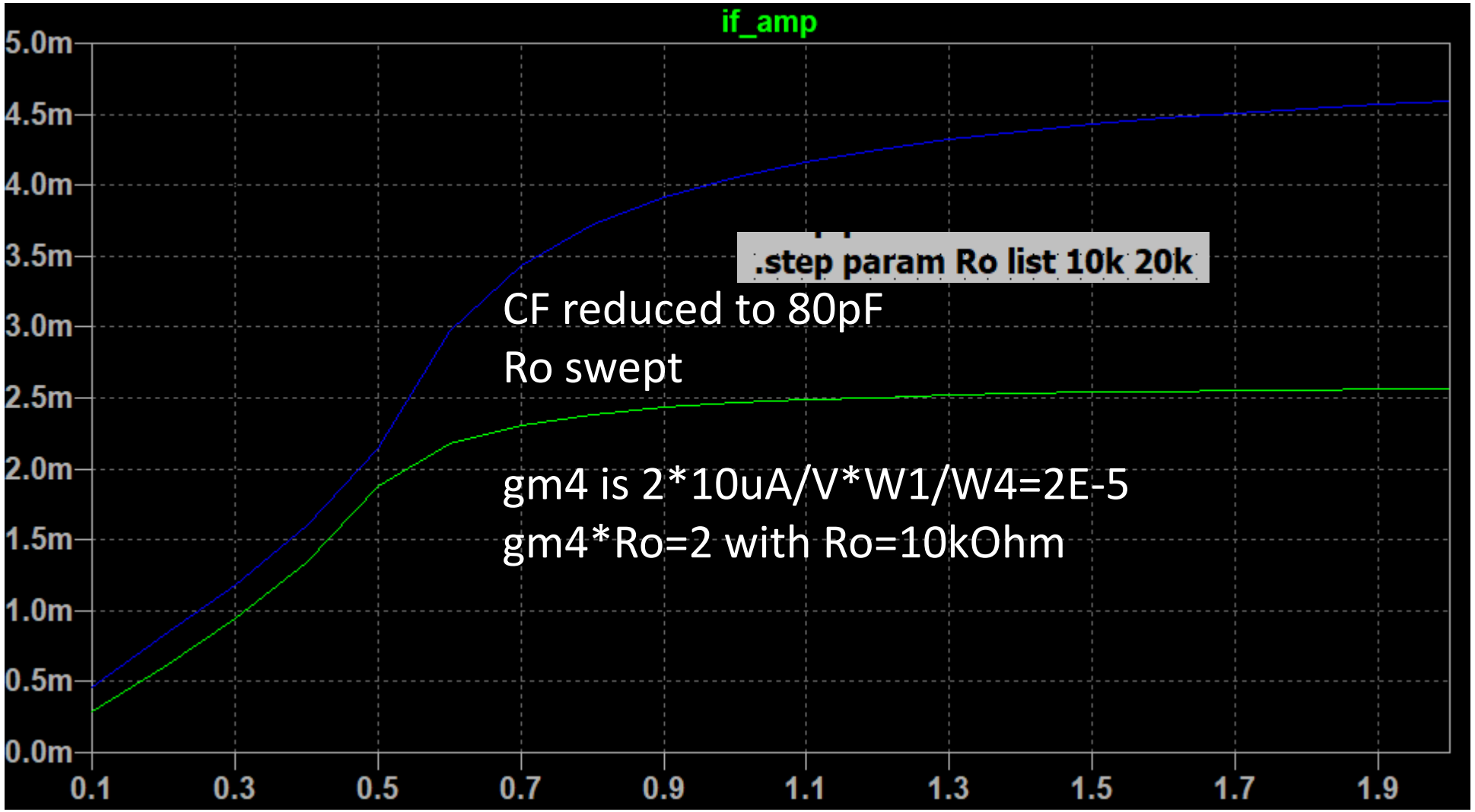
```
.step arf=0.256 alo=1.6
.step arf=0.512 alo=1.6


Measurement: if_amp
  step             MAX(v(vop,vom))     FROM                TO
     1             0.000257492         0                   0.0005
     2             0.000514984         0                   0.0005
     3             0.00102901          0                   0.0005
     4             0.00205851          0                   0.0005
     5             0.00411749          0                   0.0005
```

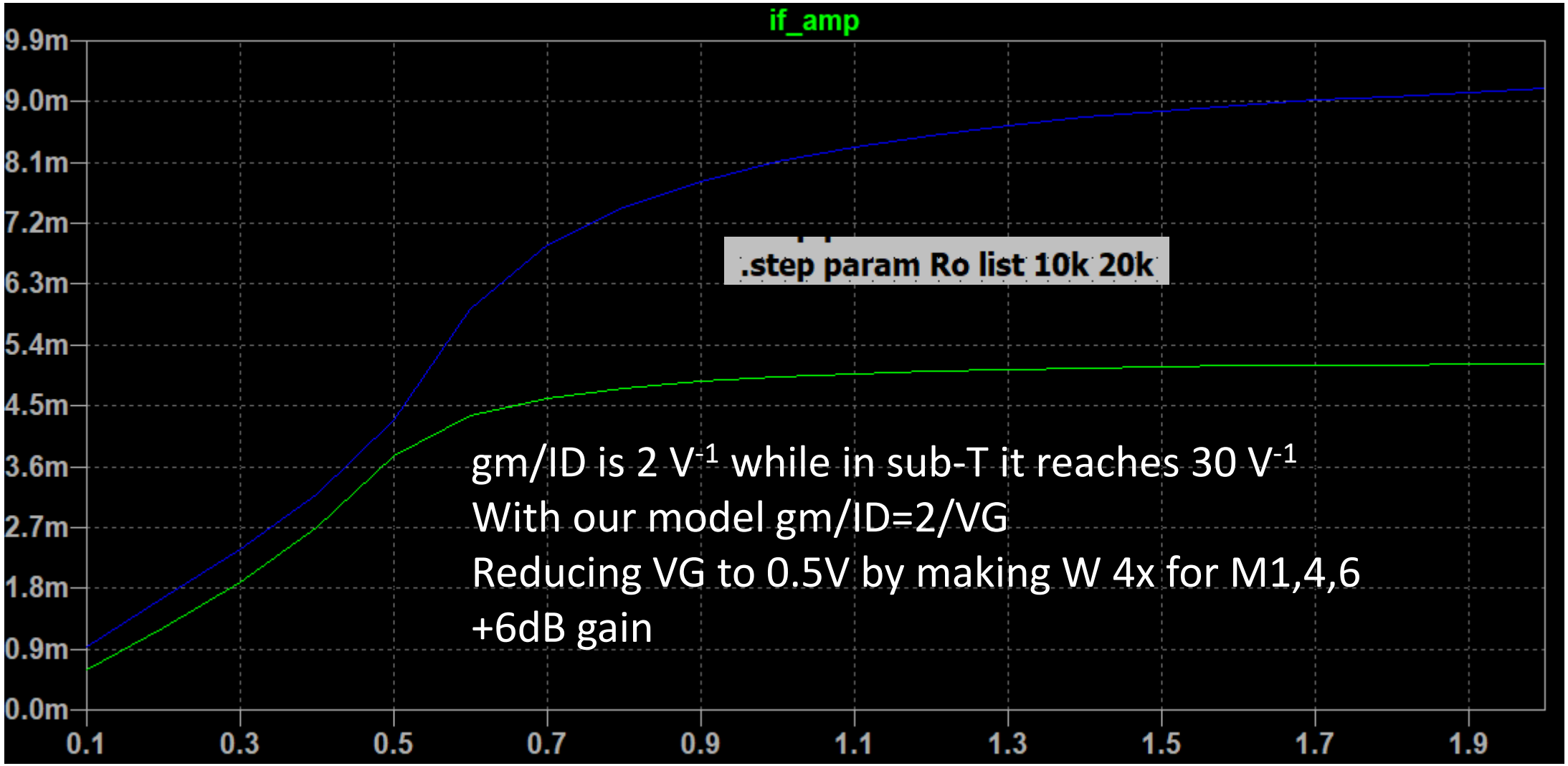
Gain as a function of LO swing

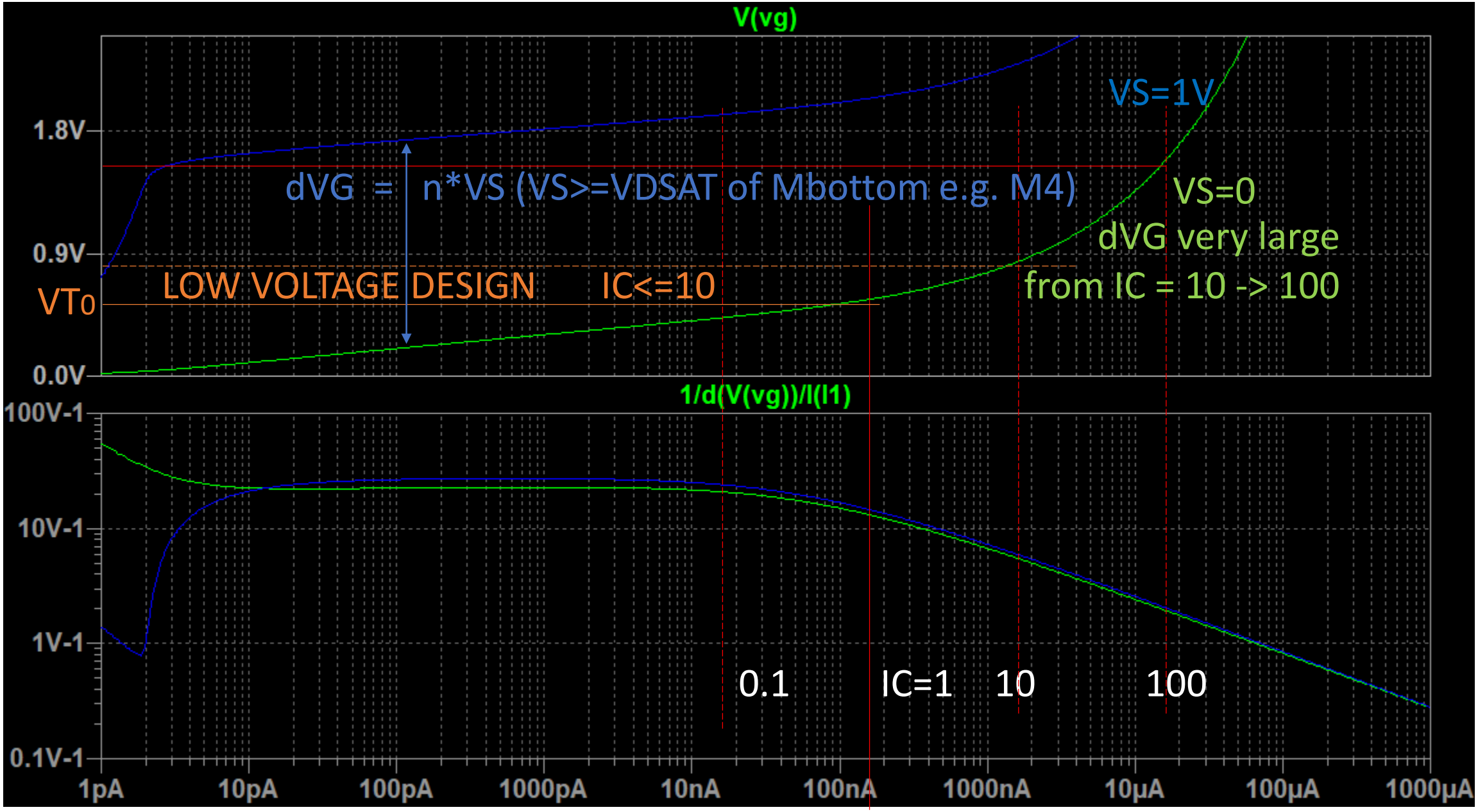


Doubling Ro indeed does increase our gain !



Changing gm/ID (to be updated with EKV!)




V(vg)
1.8V
0.9V
0.0V
VT0
VS=1V
dVG = n*VS (VS>=VDSAT of Mbottom e.g. M4)
VS=0
dVG very large
from IC = 10 -> 100
LOW VOLTAGE DESIGN
IC<=10
1/d(V(vg))/I(I1)
100V-1
10V-1
1V-1
0.1V-1
0.1
IC=1
10
100
1pA
10pA
100pA
1000pA
10nA
100nA
1000nA
10µA
100µA
1000µA

Exercises

- Try to vary the W & L of MOS to vary IC
  - AD(S) is drain, source area, PD(S) perimeter
  - AD(S)=W*1u=1p for W=1u; PD(S)=2W+2*1u
  - You could go with L=.1u to limit cap, likely no effect modelled
    - Try to verify cst W/L curves to check this, plot ID, gn/ID, …
- Study compression of gain especially as you get closer to sub-T
- Try to modulate RF in amplitude or in frequency (fRF=fLO+-10kHz)
  - You may use switches with two voltage sources
  - And look at transient waveforms
- What do you conclude ?