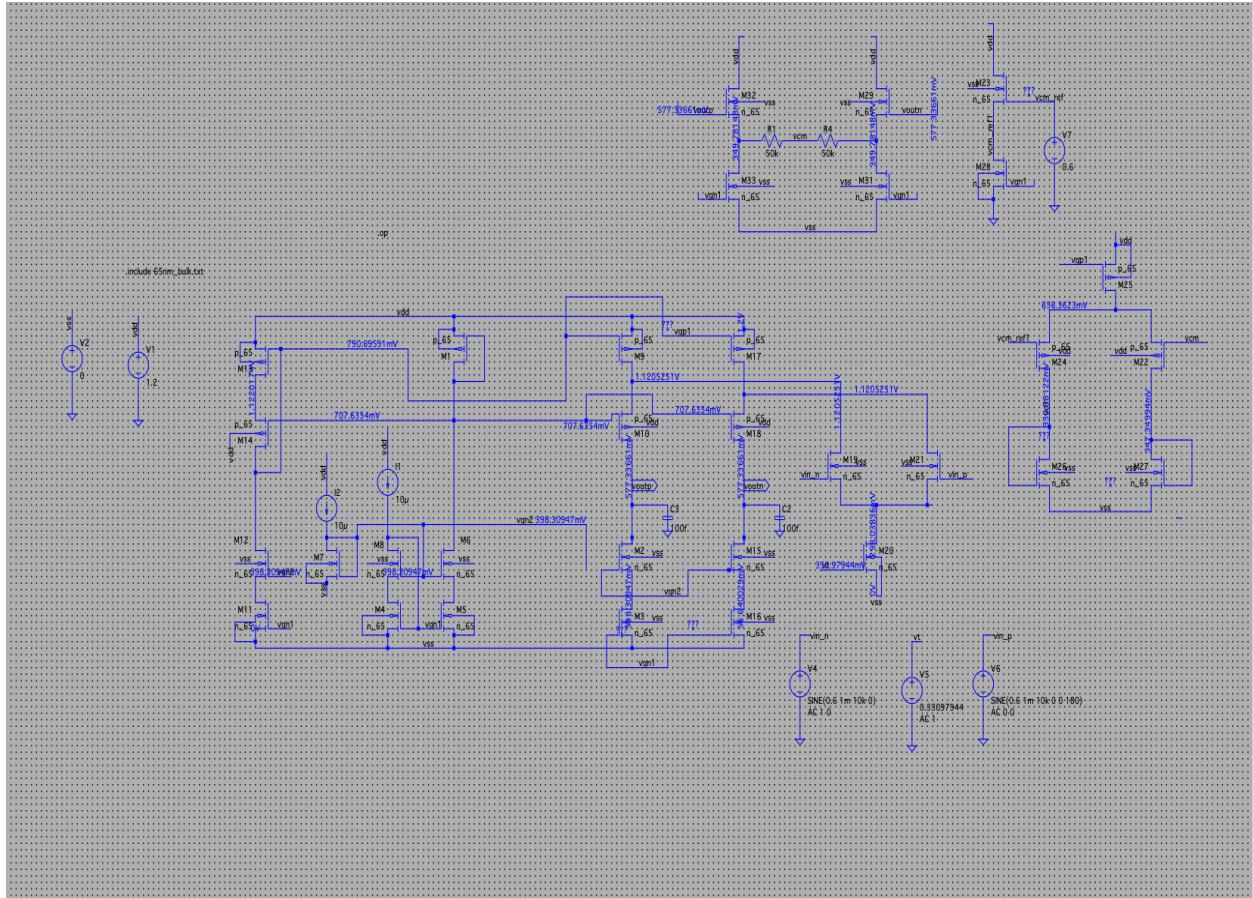


VLSI Summer School Project Documentation 2025

Group Member:Krrish Kumar(23EE10033)
Kushagra Poonia(23EE10036)

Assignment 6: Folded Cascode

- Circuit Diagram:



Assignment 6: Folded Cascode

(i) DC operating point, check DC currents and voltages in all branches.

- Currents and voltages of all different mosfets:

--- BSIM4 MOSFETS ---					
Name:	m1	m9	m10	m13	m14
Model:	p_65	p_65	p_65	p_65	p_65
Id:	-1.01e-05	-2.03e-05	-1.00e-05	-1.01e-05	-1.01e-05
Vgs:	-4.92e-01	-4.09e-01	-4.13e-01	-4.09e-01	-4.14e-01
Vds:	-4.92e-01	-7.95e-02	-5.43e-01	-7.80e-02	-3.31e-01
Vbs:	0.00e+00	0.00e+00	7.95e-02	0.00e+00	7.80e-02
Vth:	-3.64e-01	-3.65e-01	-3.80e-01	-3.65e-01	-3.80e-01
Vdsat:	-1.53e-01	-9.63e-02	-9.15e-02	-9.63e-02	-9.21e-02
Gm:	1.19e-04	3.10e-04	1.77e-04	1.53e-04	1.77e-04
Gds:	1.04e-06	9.96e-05	1.20e-06	5.20e-05	1.44e-06
Gmb:	2.46e-05	6.45e-05	3.48e-05	3.19e-05	3.49e-05
Cbd:	1.10e-15	9.75e-15	4.26e-15	4.88e-15	4.46e-15
Cbs:	2.00e-15	1.60e-14	7.80e-15	8.00e-15	7.80e-15
Name:	m17	m18	m24	m25	m22
Model:	p_65	p_65	p_65	p_65	p_65
Id:	-2.03e-05	-1.00e-05	-1.03e-05	-2.49e-05	-1.45e-05
Vgs:	-4.09e-01	-4.13e-01	-2.90e-01	-4.09e-01	-3.07e-01
Vds:	-7.95e-02	-5.43e-01	-3.25e-01	-5.44e-01	-3.09e-01
Vbs:	0.00e+00	7.95e-02	5.44e-01	0.00e+00	5.44e-01
Vth:	-3.65e-01	-3.80e-01	-4.13e-01	-3.64e-01	-4.15e-01
Vdsat:	-9.63e-02	-9.15e-02	-5.18e-02	-9.71e-02	-5.31e-02
Gm:	3.10e-04	1.77e-04	2.47e-04	4.19e-04	3.42e-04
Gds:	9.96e-05	1.20e-06	3.88e-05	2.89e-06	5.38e-05
Gmb:	6.45e-05	3.48e-05	3.98e-05	8.59e-05	5.49e-05
Cbd:	9.75e-15	4.26e-15	1.63e-14	8.67e-15	1.63e-14
Cbs:	1.60e-14	7.80e-15	2.77e-14	1.60e-14	2.77e-14
Name:	m2	m3	m4	m5	m6
Model:	n_65	n_65	n_65	n_65	n_65
Id:	1.00e-05	1.00e-05	1.00e-05	1.01e-05	1.01e-05
Vgs:	3.42e-01	3.36e-01	3.36e-01	3.36e-01	3.41e-01
Vds:	5.21e-01	5.66e-02	5.56e-02	5.71e-02	6.50e-01
Vbs:	-5.66e-02	0.00e+00	0.00e+00	0.00e+00	-5.71e-02
Vth:	4.35e-01	4.23e-01	4.23e-01	4.23e-01	4.34e-01
Vdsat:	4.93e-02	5.00e-02	5.00e-02	5.00e-02	4.93e-02
Gm:	2.13e-04	2.06e-04	2.05e-04	2.06e-04	2.13e-04
Gds:	1.21e-06	4.73e-05	4.95e-05	4.62e-05	1.17e-06
Gmb:	4.86e-05	4.83e-05	4.81e-05	4.85e-05	4.87e-05
Cbd:	4.30e-15	4.91e-15	4.91e-15	4.91e-15	4.19e-15
Cbs:	7.86e-15	8.00e-15	8.00e-15	8.00e-15	7.85e-15
Name:	m7	m8	m11	m12	m15
Model:	n_65	n_65	n_65	n_65	n_65
Id:	1.00e-05	1.00e-05	1.01e-05	1.01e-05	1.00e-05
Vgs:	3.98e-01	3.43e-01	3.36e-01	3.41e-01	3.42e-01
Vds:	3.98e-01	2.81e-01	5.75e-02	7.33e-01	5.21e-01
Vbs:	0.00e+00	-5.56e-02	0.00e+00	-5.75e-02	-5.66e-02
Vth:	4.23e-01	4.35e-01	4.23e-01	4.34e-01	4.35e-01
Vdsat:	6.34e-02	4.94e-02	5.00e-02	4.93e-02	4.93e-02
Gm:	1.88e-04	2.12e-04	2.07e-04	2.14e-04	2.13e-04
Gds:	1.17e-06	1.44e-06	4.55e-05	1.16e-06	1.21e-06
Gmb:	4.37e-05	4.83e-05	4.85e-05	4.87e-05	4.86e-05
Cbd:	1.12e-15	4.54e-15	4.91e-15	4.13e-15	4.30e-15
Cbs:	2.00e-15	7.86e-15	8.00e-15	7.85e-15	7.86e-15

Assignment 6: Folded Cascode

i) DC operating point, check DC currents and voltages in all branches.

Name:	m16	m19	m21	m20	m26
Model:	n_65	n_65	n_65	n_65	n_65
Id:	1.00e-05	1.03e-05	1.03e-05	2.06e-05	1.03e-05
Vgs:	3.36e-01	3.02e-01	3.02e-01	3.31e-01	3.31e-01
Vds:	5.66e-02	8.22e-01	8.22e-01	2.98e-01	3.31e-01
Vbs:	0.00e+00	-2.98e-01	-2.98e-01	0.00e+00	0.00e+00
Vth:	4.23e-01	4.83e-01	4.83e-01	4.23e-01	4.23e-01
Vdsat:	5.00e-02	4.40e-02	4.40e-02	4.94e-02	4.94e-02
Gm:	2.06e-04	2.47e-04	2.47e-04	4.33e-04	2.17e-04
Gds:	4.73e-05	1.28e-06	1.28e-06	2.87e-06	1.38e-06
Gmb:	4.83e-05	5.23e-05	5.23e-05	1.02e-04	5.10e-05
Cbd:	4.91e-15	3.12e-14	3.12e-14	9.18e-15	4.55e-15
Cbs:	8.00e-15	5.87e-14	5.87e-14	1.60e-14	8.00e-15
Name:	m27	m29	m31	m32	m33
Model:	n_65	n_65	n_65	n_65	n_65
Id:	1.45e-05	2.33e-05	2.32e-05	2.33e-05	2.32e-05
Vgs:	3.47e-01	2.28e-01	3.36e-01	2.28e-01	3.36e-01
Vds:	3.47e-01	8.50e-01	3.50e-01	8.50e-01	3.50e-01
Vbs:	0.00e+00	-3.50e-01	0.00e+00	-3.50e-01	0.00e+00
Vth:	4.23e-01	3.97e-01	4.23e-01	3.97e-01	4.23e-01
Vdsat:	5.17e-02	3.98e-02	5.01e-02	3.98e-02	5.01e-02
Gm:	3.00e-04	5.49e-04	4.86e-04	5.49e-04	4.86e-04
Gds:	1.89e-06	6.75e-05	3.04e-06	6.75e-05	3.04e-06
Gmb:	7.00e-05	1.11e-04	1.14e-04	1.11e-04	1.14e-04
Cbd:	4.53e-15	7.71e-15	9.06e-15	7.71e-15	9.06e-15
Cbs:	8.00e-15	1.45e-14	1.60e-14	1.45e-14	1.60e-14
Name:	m23	m28			
Model:	n_65	n_65			
Id:	2.33e-05	2.33e-05			
Vgs:	2.33e-01	3.36e-01			
Vds:	8.33e-01	3.67e-01			
Vbs:	-3.67e-01	0.00e+00			
Vth:	4.02e-01	4.23e-01			
Vdsat:	3.99e-02	5.01e-02			
Gm:	5.51e-04	4.87e-04			
Gds:	6.77e-05	3.00e-06			
Gmb:	1.10e-04	1.14e-04			
Cbd:	7.71e-15	9.02e-15			
Cbs:	1.44e-14	1.60e-14			

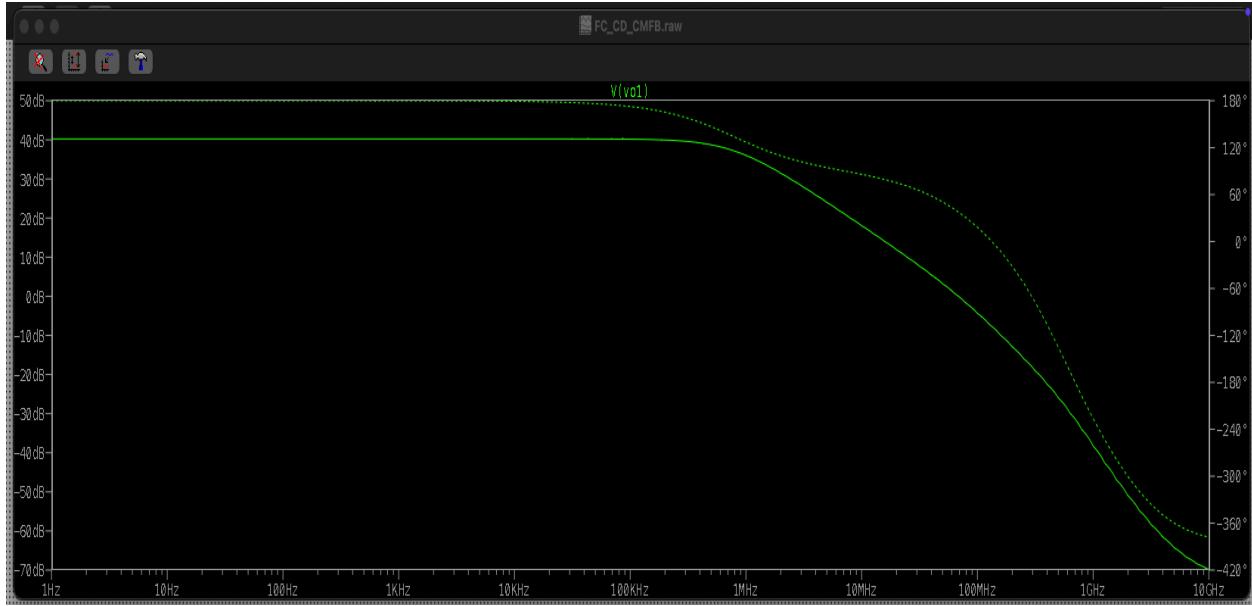
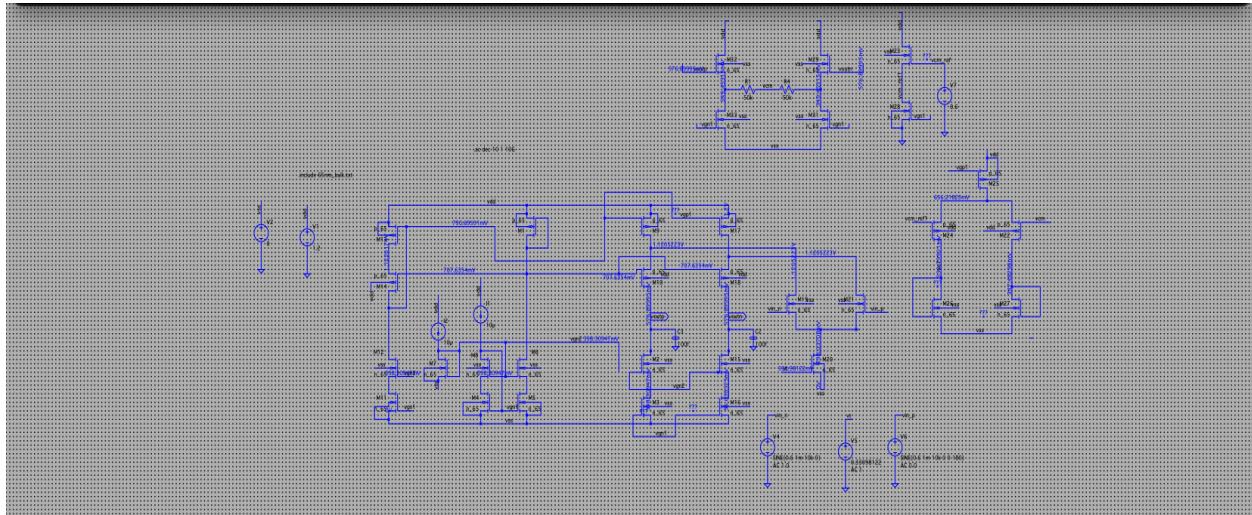
- DC voltages at different input and output nodes:

Operating Bias Point Solution:		
V(n004)	0.707635	voltage
V(vdd)	1.2	voltage
V(voutp)	0.577337	voltage
V(vgn2)	0.398309	voltage
V(n014)	0.05664	voltage
V(vss)	0	voltage
V(vgn1)	0.336499	voltage
V(n012)	0.0556403	voltage
V(n013)	0.0571415	voltage
V(n005)	1.12053	voltage
V(vgp1)	0.790696	voltage
V(n011)	0.0574549	voltage
V(n007)	1.12202	voltage
V(voutn)	0.577337	voltage
V(n015)	0.05664	voltage
V(n006)	1.12053	voltage
V(vin_n)	0.6	voltage
V(n009)	0.298038	voltage
V(vin_p)	0.6	voltage
V(vt)	0.330979	voltage
V(vo1)	0.330981	voltage
V(vcm_ref1)	0.366833	voltage
V(n003)	0.656362	voltage
V(n008)	0.34735	voltage
V(n002)	0.349781	voltage
V(n001)	0.349781	voltage
V(vcm)	0.349782	voltage
V(vcm_ref)	0.6	voltage

Assignment 6: Folded Cascode

ii) CMFB open loop analysis for diode load and current mirror load in error amplifiers.

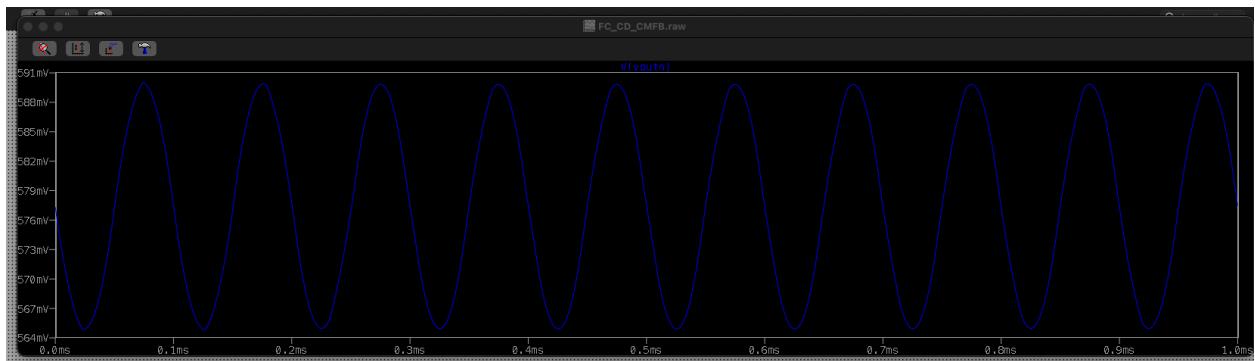
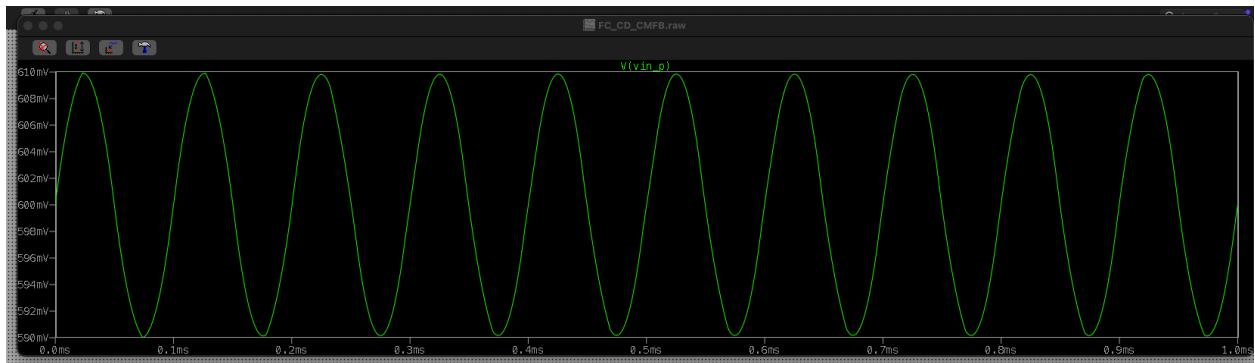
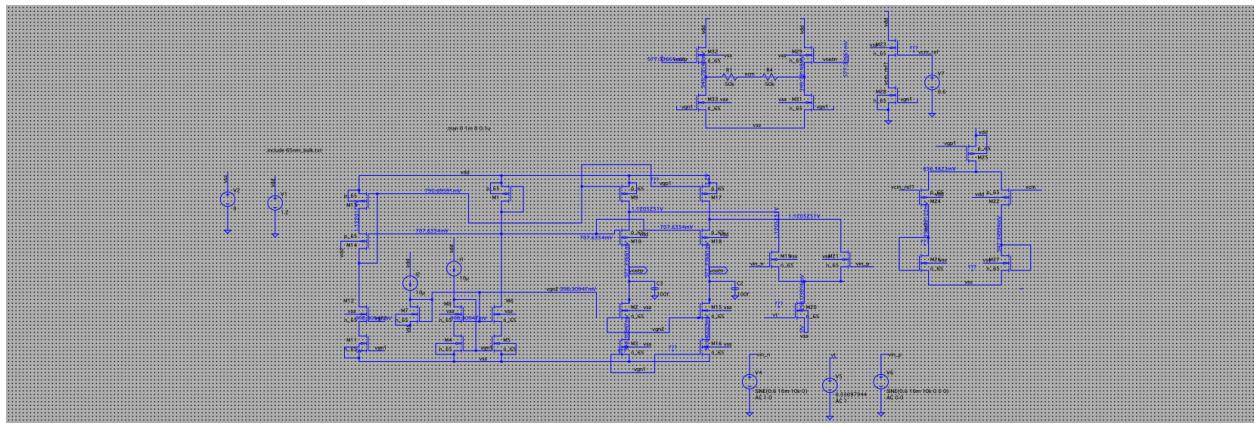
For diode connected load.(AC analysis)



Assignment 6: Folded Cascode

ii) CMFB open loop analysis for diode load and current mirror load in error amplifiers.

For diode connected load(transient analysis)

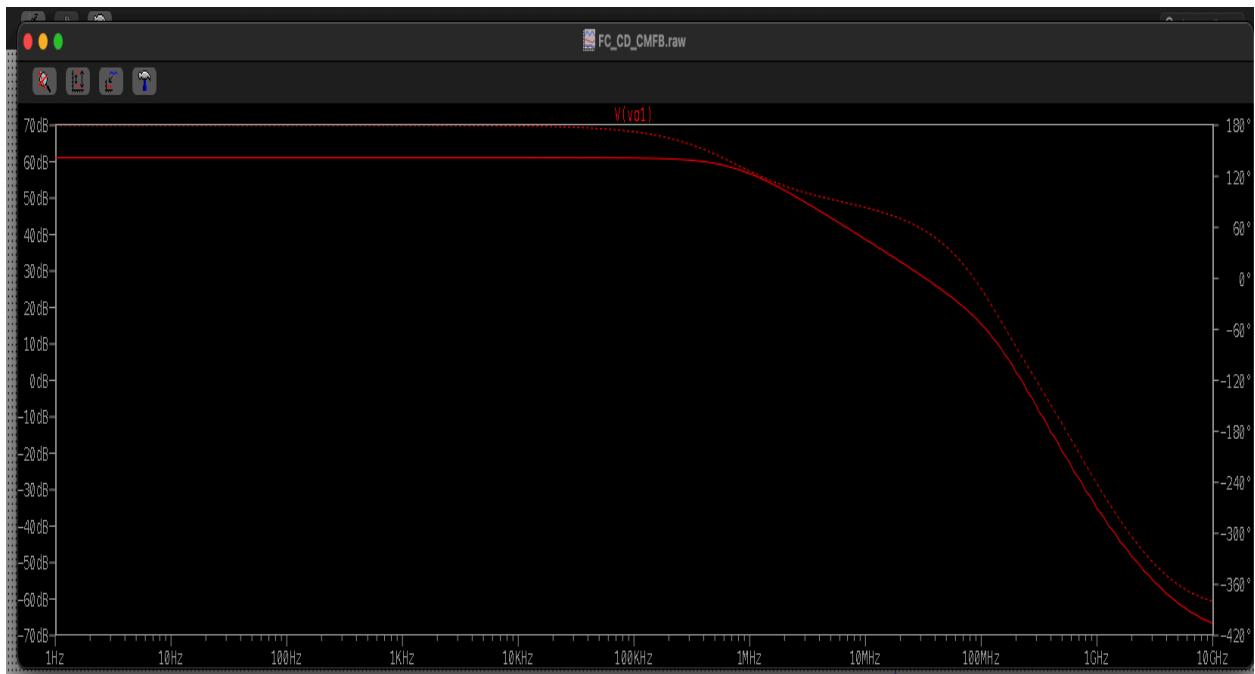
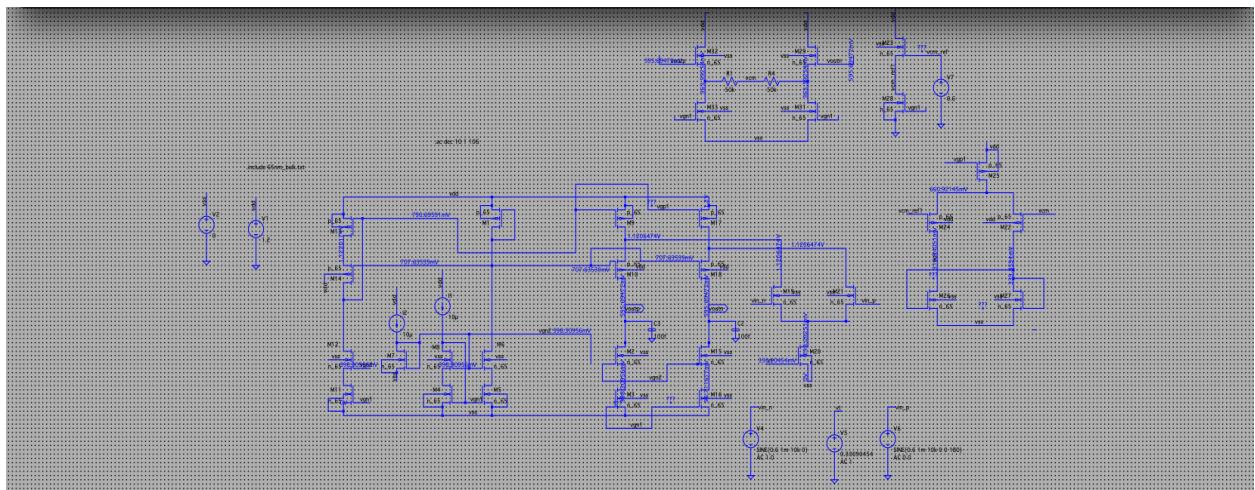


V_{in_p} (green) and V_{out_p} (blue).

Assignment 6: Folded_Cascode

ii) CMFB open loop analysis for diode load and current mirror load in error amplifiers.

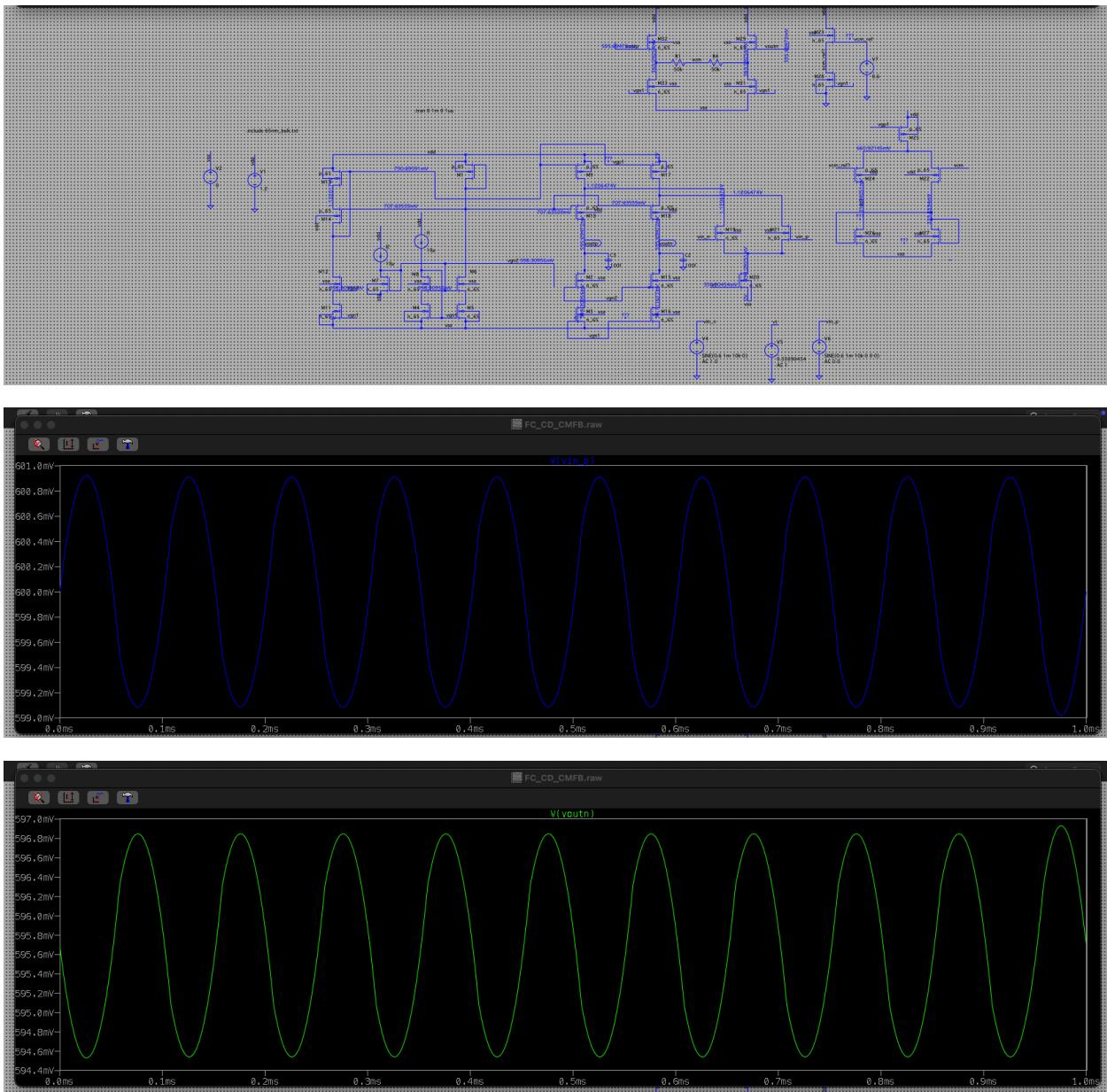
For current mirror load in error amplifiers.(AC analysis)



Assignment 6: Folded_Cascode

ii) CMFB open loop analysis for diode load and current mirror load in error amplifiers.

For current mirror load in error amplifiers.(transient analysis)

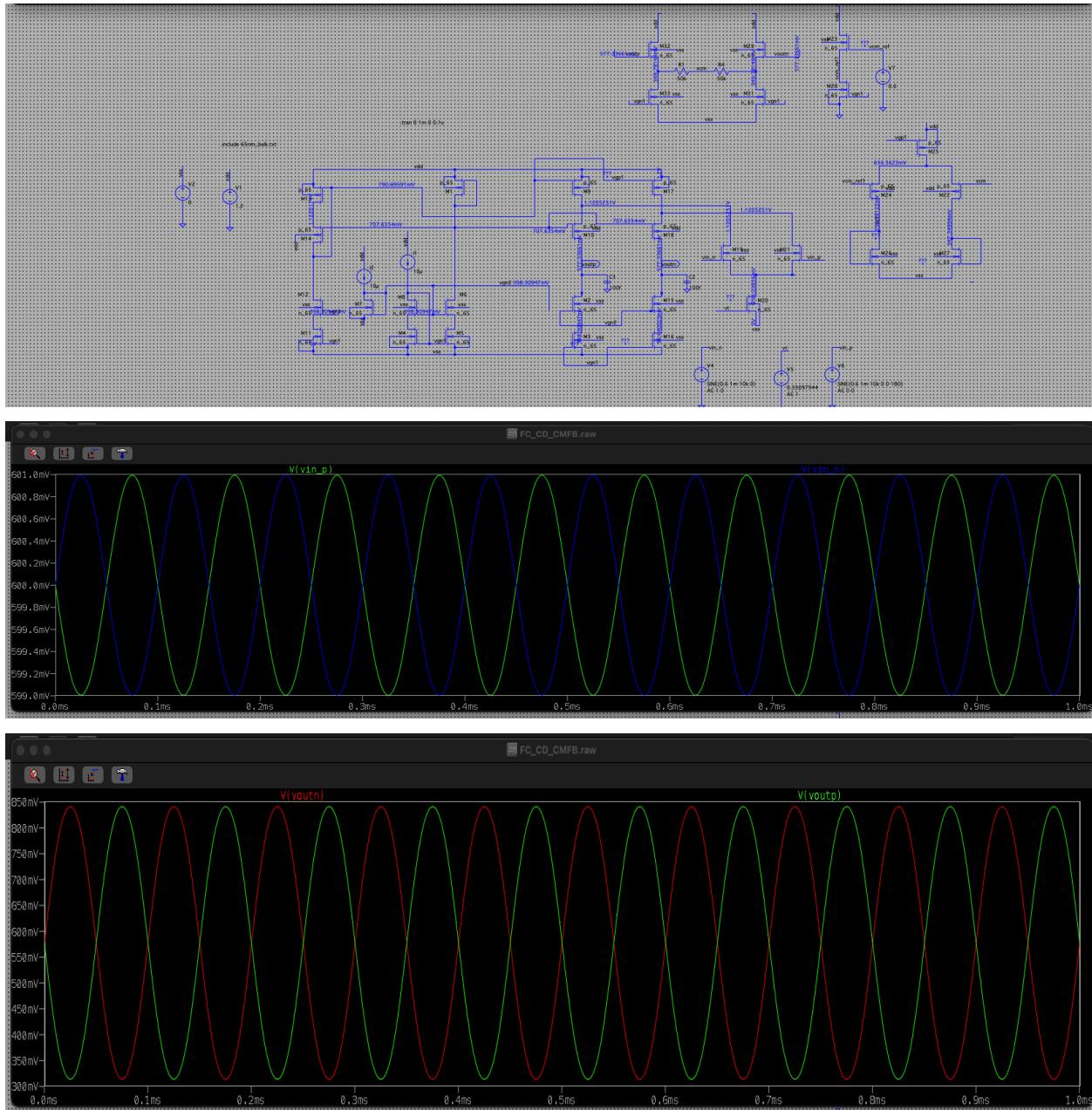


\$Vin_p\$(blue) and \$Vout_p\$(green).

Assignment 6: Folded Cascode

(iii) Differential open loop transient simulation, for estimating the open loop gain.

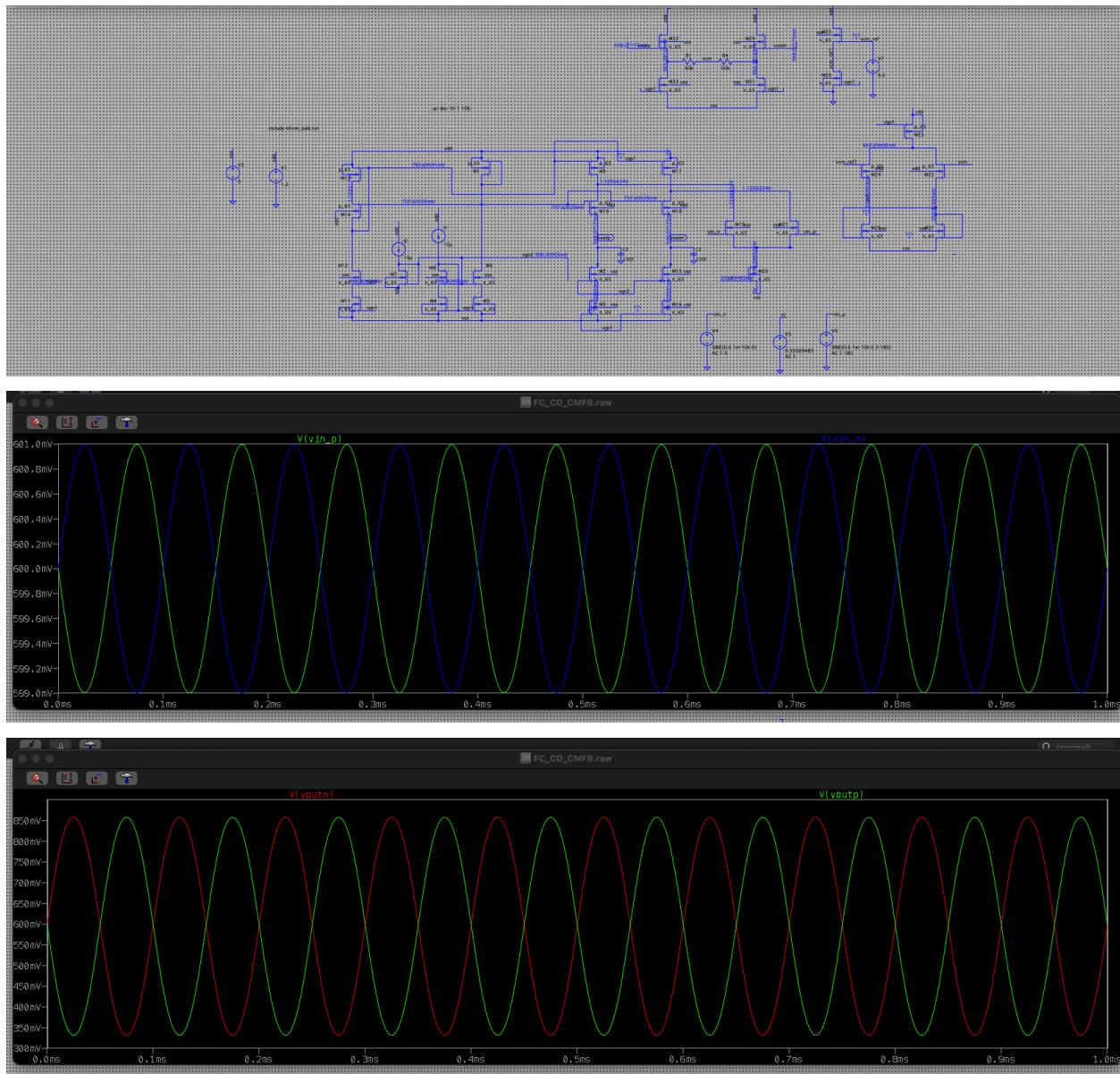
a) For diode connected load in error amplifier.



Assignment 6: Folded Cascode

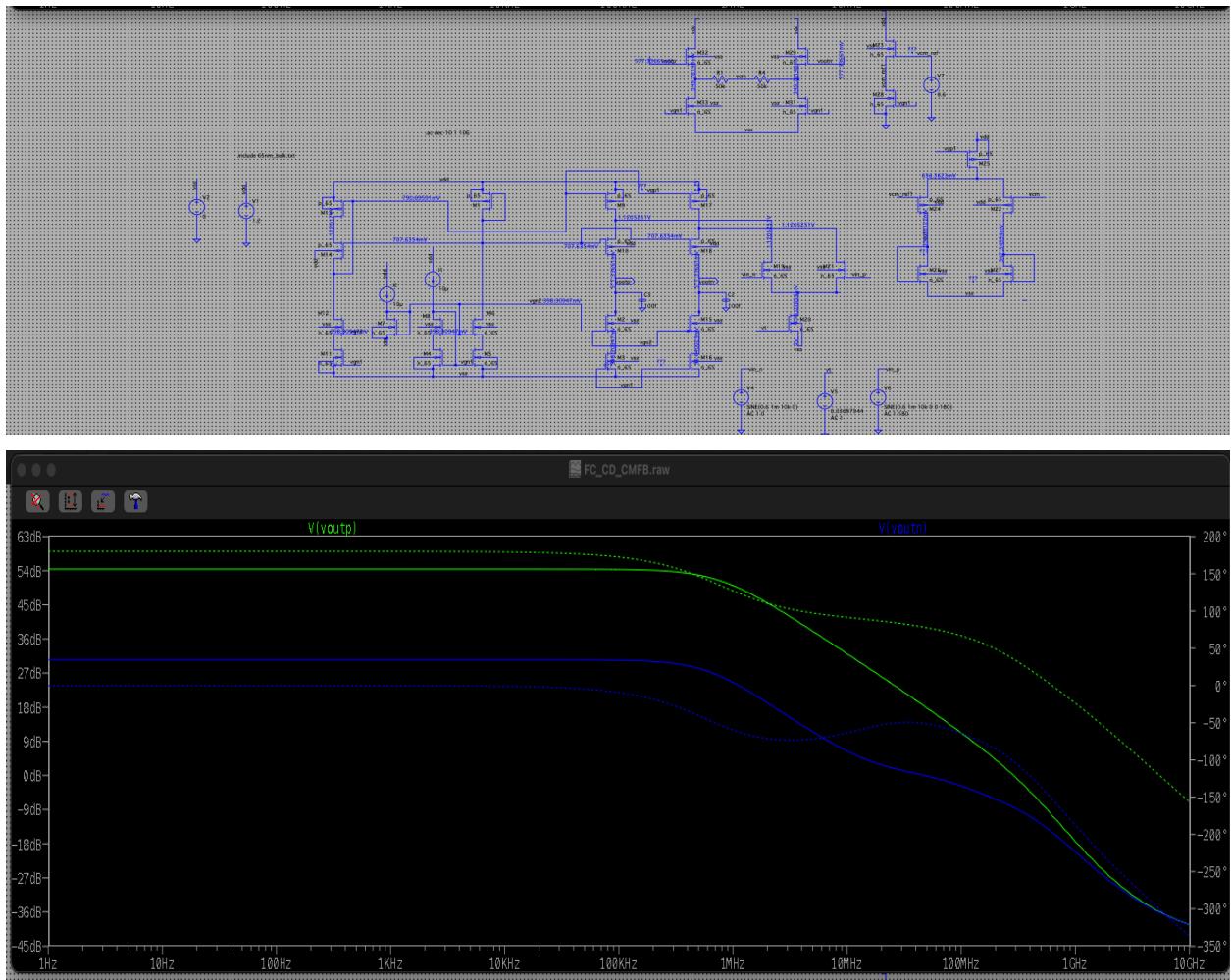
(iii) Differential open loop transient simulation, for estimating the open loop gain.

b) For current mirror load in error amplifier.



Assignment 6: Folded Cascode

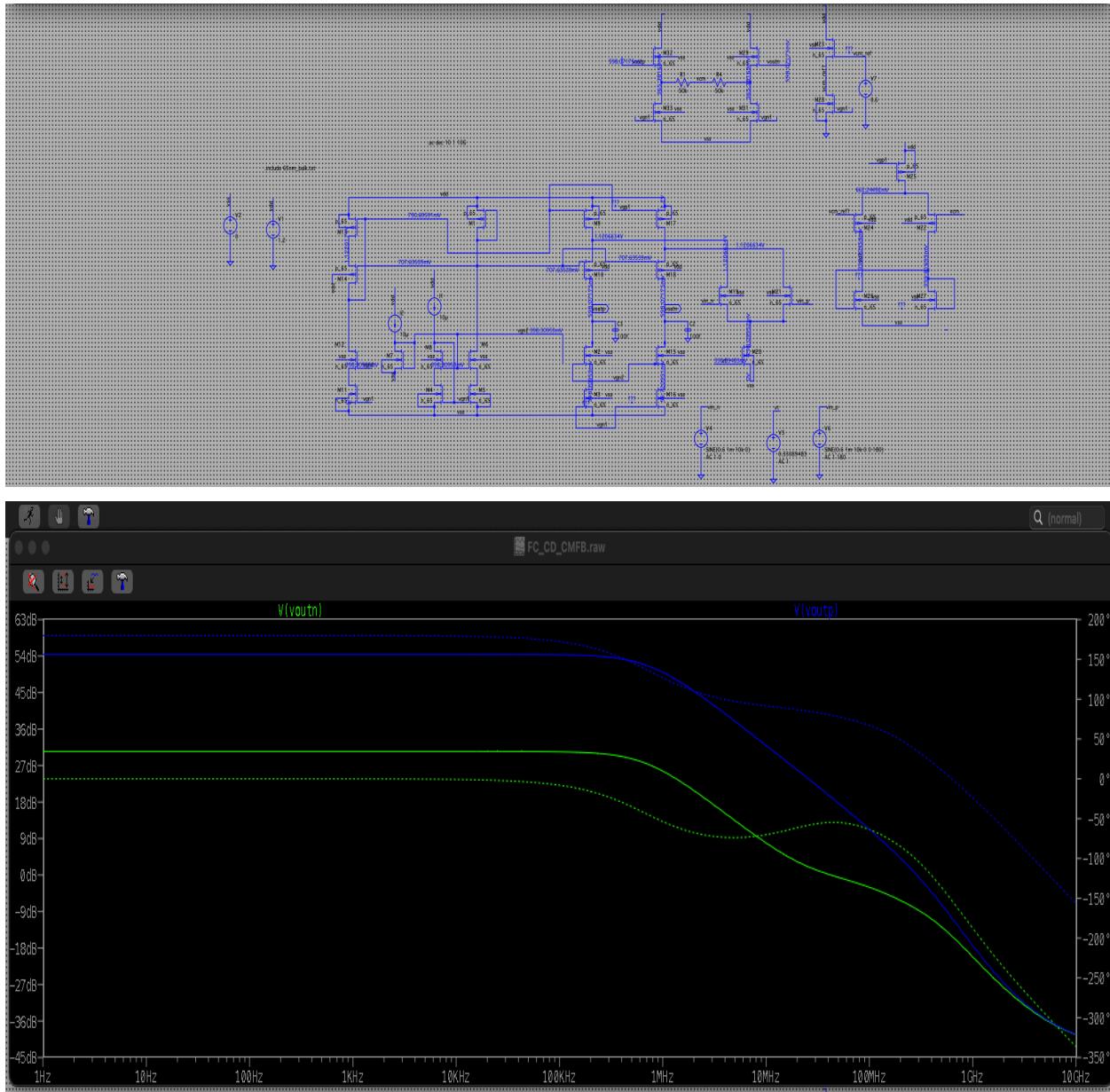
- (iii) Differential open loop AC simulation, for estimating the open loop gain.
c) For diode connected load in error amplifier.



Assignment 6: Folded Cascode

(iii) Differential open loop AC simulation, for estimating the open loop gain.

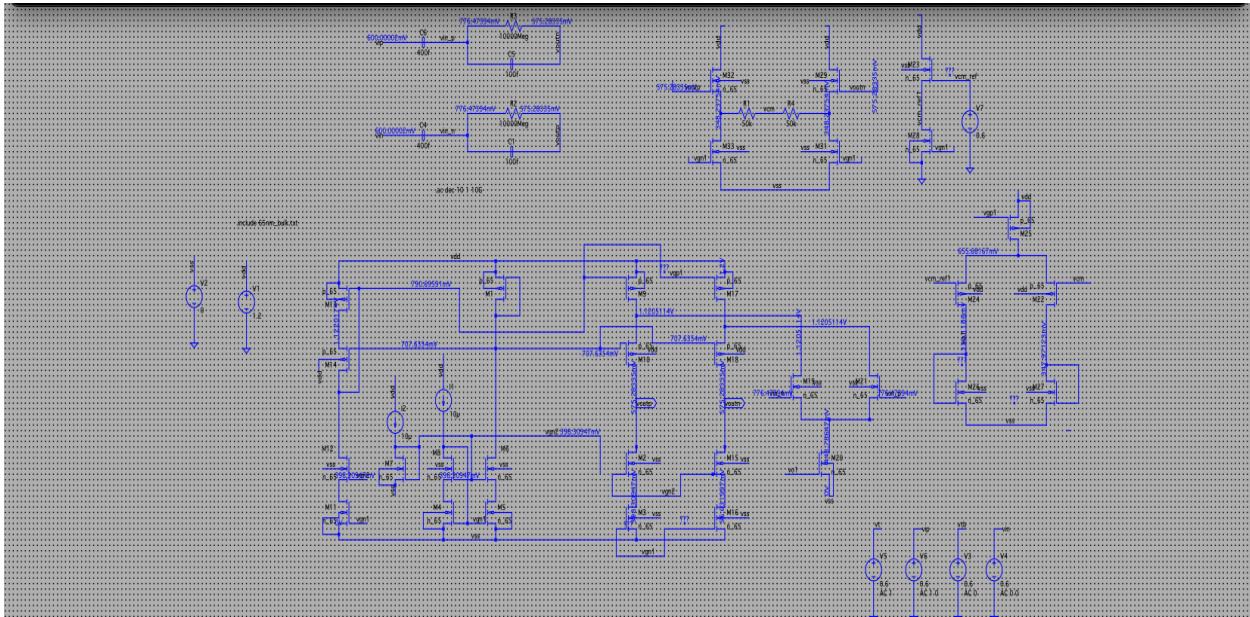
d) For current mirror load in error amplifier.



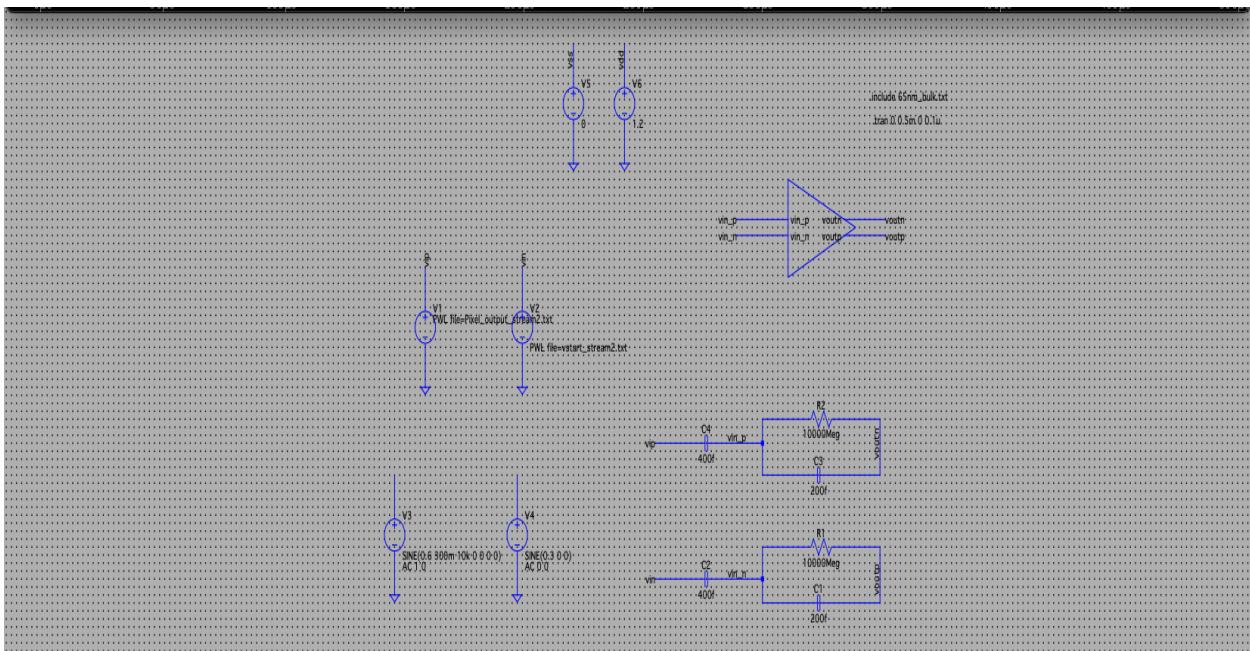
Assignment 6: Folded Cascode

- Including RC feedback:

Circuit Diagram:



With symbol implementation circuit:



Assignment 6: Folded_Cascode

- Including RC feedback: Operating points

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FC_CD_CMFB.log
Search

---- BSIM4 MOSFETS ----

Name: m1      m9      m10     m13     m14
Model: p_65    p_65    p_65    p_65    p_65
Id: -1.01e-05 -2.03e-05 -1.00e-05 -1.01e-05 -1.01e-05
Vgs: -4.92e-01 -4.09e-01 -4.13e-01 -4.09e-01 -4.14e-01
Vds: -4.92e-01 -7.95e-02 -5.45e-01 -7.80e-02 -3.31e-01
Vbs: 0.00e+00  0.00e+00  7.95e-02  0.00e+00  7.80e-02
Vth: -3.64e-01 -3.65e-01 -3.80e-01 -3.65e-01 -3.80e-01
Vdsat: -1.53e-01 -9.63e-02 -9.15e-02 -9.63e-02 -9.21e-02
Gm: 1.19e-04  3.10e-04  1.77e-04  1.53e-04  1.77e-04
Gds: 1.04e-06  9.96e-05  1.20e-06  5.20e-05  1.44e-06
Gmb: 2.46e-05  6.45e-05  3.48e-05  3.19e-05  3.49e-05
Cbd: 1.10e-15  9.75e-15  4.26e-15  4.88e-15  4.46e-15
Cbs: 2.00e-15  1.60e-14  7.80e-15  8.00e-15  7.80e-15

Name: m17     m18     m24     m25     m22
Model: p_65    p_65    p_65    p_65    p_65
Id: -2.03e-05 -1.00e-05 -1.01e-05 -2.49e-05 -1.47e-05
Vgs: -4.09e-01 -4.13e-01 -2.89e-01 -4.09e-01 -3.07e-01
Vds: -7.95e-02 -5.45e-01 -3.26e-01 -5.44e-01 -3.08e-01
Vbs: 0.00e+00  7.95e-02  5.44e-01  0.00e+00  5.44e-01
Vth: -3.65e-01 -3.80e-01 -4.13e-01 -3.64e-01 -4.15e-01
Vdsat: -9.63e-02 -9.15e-02 -5.17e-02 -9.71e-02 -5.32e-02
Gm: 3.10e-04  1.77e-04  2.43e-04  4.19e-04  3.46e-04
Gds: 9.96e-05  1.20e-06  3.81e-05  2.89e-06  5.45e-05
Gmb: 6.45e-05  3.48e-05  3.92e-05  8.59e-05  5.55e-05
Cbd: 9.75e-15  4.26e-15  1.63e-14  8.66e-15  1.63e-14
Cbs: 1.60e-14  7.80e-15  2.77e-14  1.60e-14  2.77e-14

Name: m2      m3      m4      m5      m6
Model: n_65    n_65    n_65    n_65    n_65
Id: 1.00e-05  1.00e-05  1.00e-05  1.01e-05  1.01e-05
Vgs: 3.42e-01  3.36e-01  3.36e-01  3.36e-01  3.41e-01
Vds: 5.19e-01  5.66e-02  5.56e-02  5.71e-02  6.50e-01
Vbs: -5.66e-02 0.00e+00  0.00e+00  0.00e+00  -5.71e-02
Vth: 4.35e-01  4.23e-01  4.23e-01  4.23e-01  4.34e-01
Vdsat: 4.93e-02 5.00e-02  5.00e-02  5.00e-02  4.93e-02
Gm: 2.13e-04  2.06e-04  2.05e-04  2.06e-04  2.13e-04
Gds: 1.21e-06  4.73e-05  4.95e-05  4.62e-05  1.17e-06
Gmb: 4.86e-05  4.83e-05  4.81e-05  4.85e-05  4.87e-05
Cbd: 4.30e-15  4.91e-15  4.91e-15  4.91e-15  4.19e-15
Cbs: 7.86e-15  8.00e-15  8.00e-15  8.00e-15  7.85e-15

Name: m7      m8      m11     m12     m15
Model: n_65    n_65    n_65    n_65    n_65
Id: 1.00e-05  1.00e-05  1.00e-05  1.01e-05  1.01e-05
Vgs: 3.98e-01  3.43e-01  3.36e-01  3.41e-01  3.42e-01
Vds: 5.38e-01  2.81e-01  5.75e-02  7.33e-01  5.19e-01
Vbs: 0.00e+00  -5.56e-02 0.00e+00  -5.75e-02  -5.66e-02
Vth: 4.23e-01  4.35e-01  4.23e-01  4.34e-01  4.35e-01
Vdsat: 6.34e-02 4.94e-02  5.00e-02  4.94e-02  5.00e-02
Gm: 1.88e-04  2.12e-04  2.12e-04  2.12e-04  2.07e-04
Gds: 1.17e-06  1.44e-06  1.44e-06  1.44e-06  1.44e-06
Gmb: 4.37e-05  4.83e-05  4.81e-05  4.85e-05  4.87e-05
Cbd: 1.12e-15  4.54e-15  4.91e-15  4.13e-15  4.91e-15
Cbs: 2.00e-15  7.86e-15  8.00e-15  7.85e-15  7.86e-15

Name: m16     m19     m21     m20     m26
Model: n_65    n_65    n_65    n_65    n_65
Id: 1.00e-05  1.03e-05  1.03e-05  1.03e-05  1.01e-05
Vgs: 3.36e-01  3.31e-01  3.31e-01  3.31e-01  3.31e-01
Vds: 5.66e-02  4.01e-02  5.00e-02  4.12e-02  5.00e-02
Vbs: 0.00e+00  -4.38e-01 0.00e+00  -4.38e-01  -4.38e-01
Vth: 4.23e-01  4.35e-01  4.23e-01  4.34e-01  4.35e-01
Vdsat: 6.34e-02 4.94e-02  5.00e-02  4.94e-02  5.00e-02
Gm: 2.06e-04  2.50e-04  2.50e-04  2.50e-04  2.33e-04
Gds: 4.73e-05  1.31e-06  1.31e-06  1.31e-06  2.55e-06
Gmb: 4.83e-05  5.00e-05  5.00e-05  5.00e-05  1.02e-04
Cbd: 4.91e-15  3.12e-14  3.12e-14  8.87e-15  4.55e-15
Cbs: 8.00e-15  5.68e-14  5.68e-14  1.68e-14  8.00e-15

Name: m27     m29     m31     m32     m33
Model: n_65    n_65    n_65    n_65    n_65
Id: 1.47e-05  2.32e-05  2.32e-05  2.32e-05  2.32e-05
Vgs: 3.48e-01  2.27e-01  3.36e-01  2.27e-01  3.36e-01
Vds: 3.48e-01  8.52e-01  3.48e-01  8.52e-01  3.48e-01
Vbs: 0.00e+00  -3.48e-01 0.00e+00  -3.48e-01  0.00e+00
Vth: 4.23e-01  3.97e-01  4.23e-01  3.97e-01  4.23e-01
Vdsat: 5.18e-02 3.98e-02  5.01e-02  3.98e-02  5.01e-02
Gm: 3.03e-04  5.49e-04  5.49e-04  5.49e-04  5.49e-04
Gds: 1.91e-06  6.75e-05  3.04e-06  6.75e-05  3.04e-06
Gmb: 7.08e-05  1.11e-04  1.14e-04  1.11e-04  1.14e-04
Cbd: 4.53e-15  7.71e-15  9.06e-15  7.71e-15  9.06e-15
Cbs: 8.00e-15  1.45e-14  1.60e-14  1.45e-14  1.60e-14

Name: m23     m28
Model: n_65    n_65
Id: 2.33e-05  2.33e-05
Vgs: 2.33e-01  3.36e-01
Vds: 8.33e-01  3.67e-01
Vbs: -3.67e-01 0.00e+00
Vth: 4.02e-01  4.23e-01
Vdsat: 3.99e-02  5.01e-02
Gm: 5.51e-04  4.87e-04
Gds: 6.77e-05  3.00e-06
Gmb: 1.10e-04  1.14e-04
Cbd: 7.71e-15  9.02e-15
Cbs: 1.44e-14  1.60e-14

```

Assignment 6: Folded_Cascode

- Including RC feedback: Operating points

```
FC_CD_CMFB.log
Search

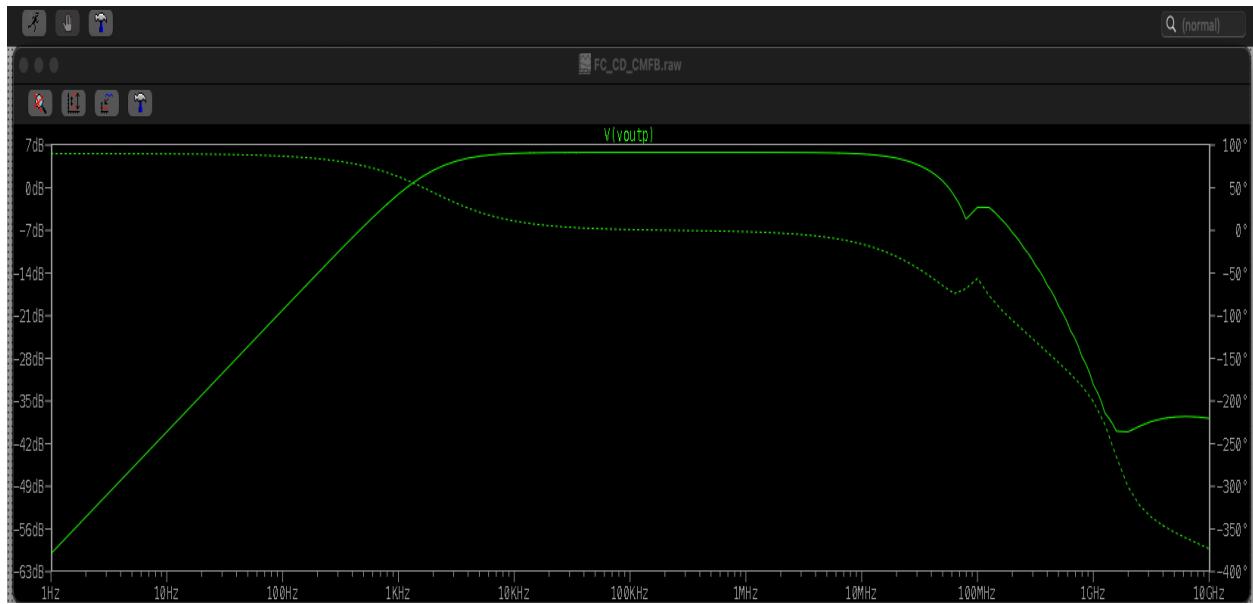
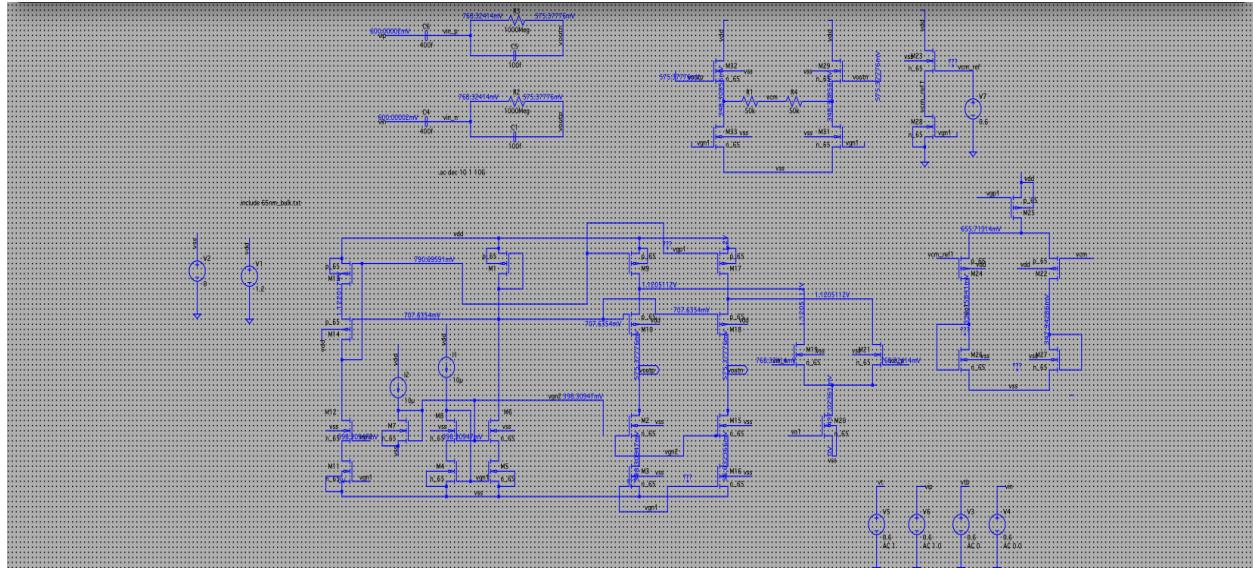
Vbs: 0.00e+00 -3.48e-01 0.00e+00 -3.48e-01 0.00e+00
Vth: 4.23e-01 3.97e-01 4.23e-01 3.97e-01 4.23e-01
Vdsat: 5.18e-02 3.98e-02 5.01e-02 3.98e-02 5.01e-02
Gm: 3.03e-04 5.49e-04 4.86e-04 5.49e-04 4.86e-04
Gds: 1.91e-06 6.75e-05 3.04e-06 6.75e-05 3.04e-06
Gmb: 7.08e-05 1.11e-04 1.14e-04 1.11e-04 1.14e-04
Cbd: 4.53e-15 7.71e-15 9.06e-15 7.71e-15 9.06e-15
Cbs: 8.00e-15 1.45e-14 1.60e-14 1.45e-14 1.60e-14

Name: m23 m28
Model: n_65 n_65
Id: 2.33e-05 2.33e-05
Vgs: 2.33e-01 3.36e-01
Vds: 8.33e-01 3.67e-01
Vbs: -3.67e-01 0.00e+00
Vth: 4.02e-01 4.23e-01
Vdsat: 3.99e-02 5.01e-02
Gm: 5.51e-04 4.87e-04
Gds: 6.77e-05 3.00e-06
Gmb: 1.10e-04 1.14e-04
Cbd: 7.71e-15 9.02e-15
Cbs: 1.44e-14 1.60e-14

Operating Bias Point Solution:
V(n004) 0.707635 voltage
V(vdd) 1.2 voltage
V(voutp) 0.575362 voltage
V(vgn2) 0.398309 voltage
V(n014) 0.0566323 voltage
V(vss) 0 voltage
V(vgn1) 0.336499 voltage
V(n012) 0.0556403 voltage
V(n013) 0.0571415 voltage
V(n005) 1.12051 voltage
V(vgp1) 0.790696 voltage
V(n011) 0.0574549 voltage
V(n007) 1.12202 voltage
V(voutn) 0.575362 voltage
V(n015) 0.0566323 voltage
V(n006) 1.12051 voltage
V(vin_n) 0.769413 voltage
V(n009) 0.437927 voltage
V(vin_p) 0.769413 voltage
V(vo1) 0.330152 voltage
V(vcm_ref1) 0.366833 voltage
V(n003) 0.655708 voltage
V(n008) 0.347947 voltage
V(vin) 0.6 voltage
V(vt) 0.6 voltage
V(vip) 0.6 voltage
V(n002) 0.348297 voltage
V(n001) 0.348297 voltage
V(vcm) 0.348297 voltage
V(vcm_ref) 0.6 voltage
V(vtb) 0.6 voltage
V(m1#dbody) 1.2 voltage
V(m1#sbody) 1.2 voltage
V(m9#dbody) 1.2 voltage
V(m9#sbody) 1.2 voltage
V(m10#dbody) 1.2 voltage
V(m10#sbody) 1.2 voltage
V(m13#dbody) 1.2 voltage
V(m13#sbody) 1.2 voltage
V(m14#dbody) 1.2 voltage
V(m14#sbody) 1.2 voltage
V(m17#dbody) 1.2 voltage
V(m17#sbody) 1.2 voltage
V(m17#dbody) 1.2 voltage
```

Assignment 6: Folded Cascode

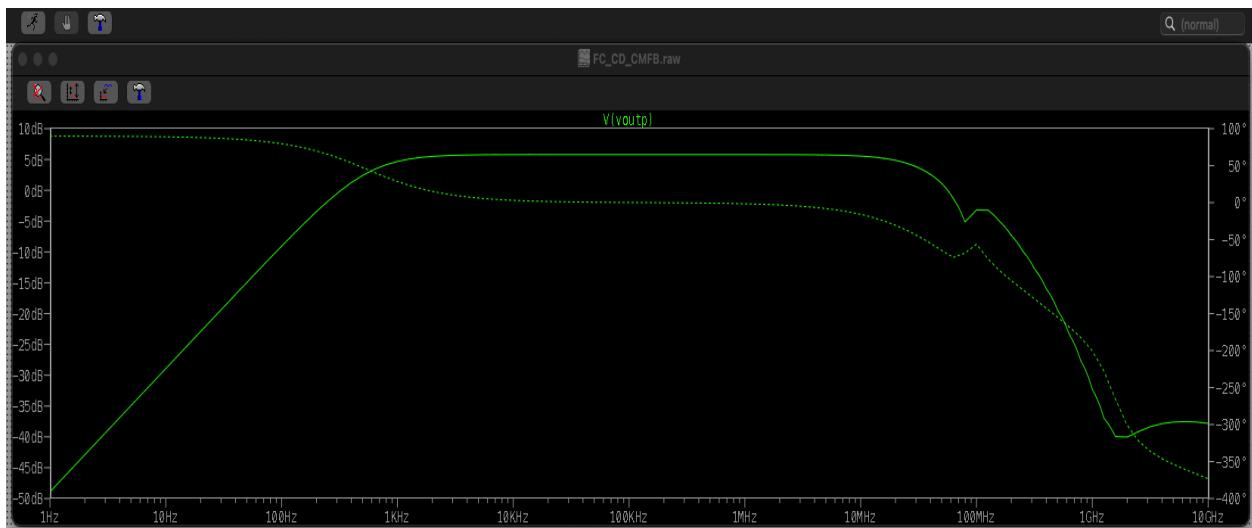
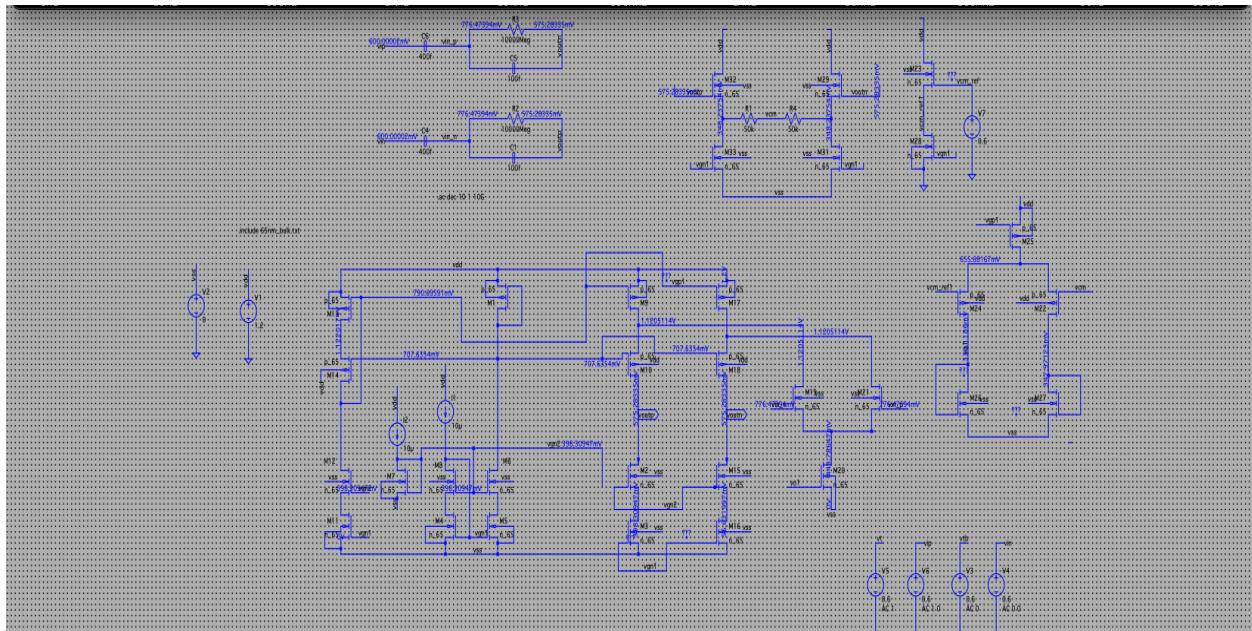
- Including RC feedback: AC analysis
i) $R_f = 1000\text{Meg ohm}$, $C_1 = 100\text{fF}$ and $C_2 = 400\text{fF}$



Gain (dB) ~ 6.8 dB

Assignment 6: Folded Cascode

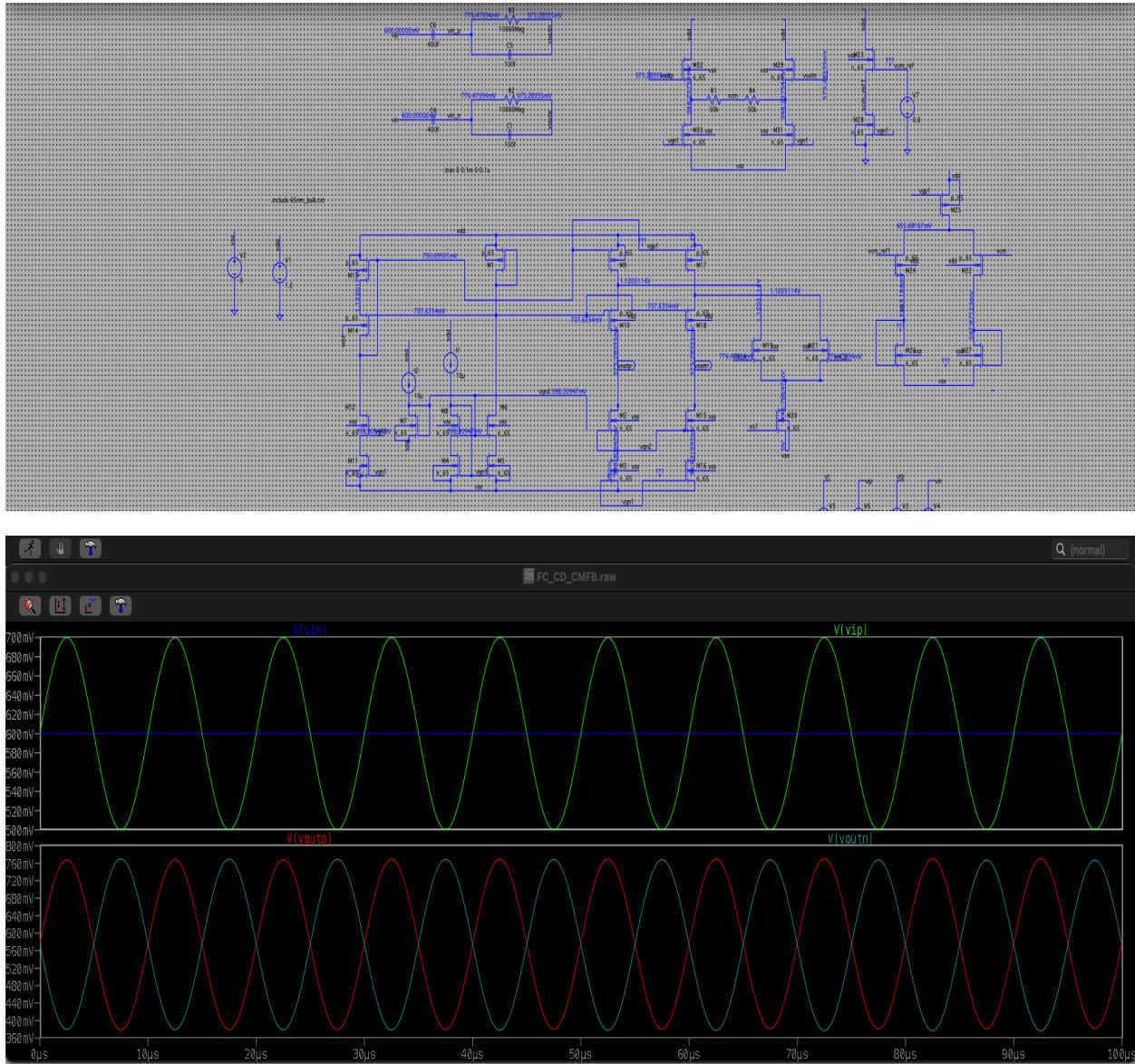
- Including RC feedback: AC analysis
ii) $R_f = 10000\text{Meg ohm}$, $C_1 = 100\text{fF}$ and $C_2 = 400\text{fF}$



$\text{Gain(dB)} \sim 7 \text{ dB}$

Assignment 6: Folded Cascode

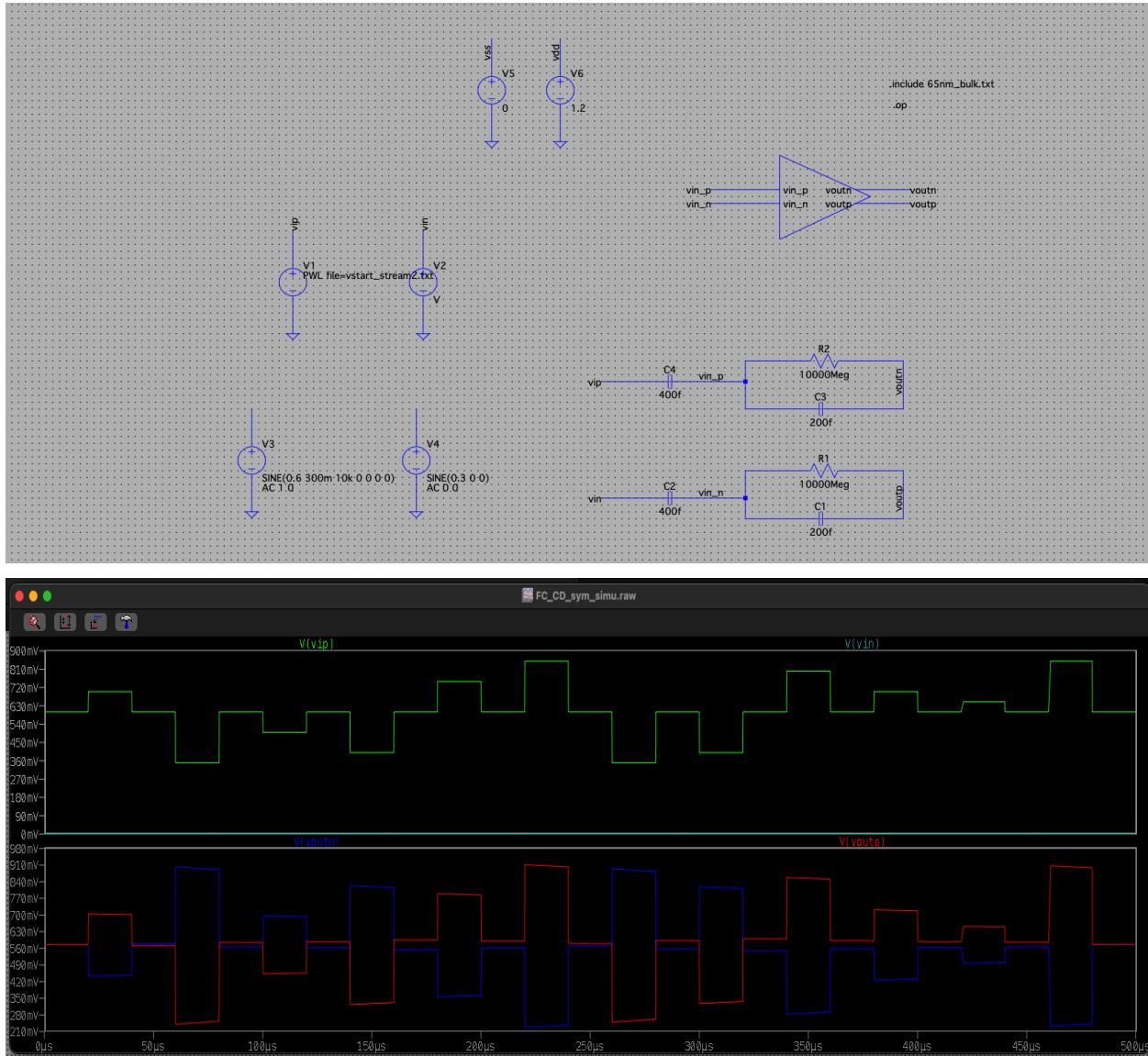
- Including RC feedback: Transient analysis
ii) $R_f = 10000\text{Meg ohm}$, $C_1 = 100\text{fF}$ and $C_2 = 400\text{fF}$



V_{in}(green) , V_{outp}(red) and V_{outn}(peacock green)

Assignment 6: Folded Cascode

- Including RC feedback: Transient analysis(PWL input)
ii) $R_f = 10000\text{Meg ohm}$, $C_1 = 200\text{fF}$ and $C_2 = 400\text{fF}$



V_{in} (green) , V_{outp} (red) and V_{outn} (blue)