Description

This is a document containing the answers to most of the exercises in the course Analog IC Design. There is no solutions provided, this document is intended as guideline during yours (the students) effort to learn the scope of this course. Also some of the derivations and longer answers containing plots have been excluded.
IMPORTANT: In most of the answer where process parameters have been used they are taken from the process of this course and **NOT** from the tables referred to in the textbook.

Exercise 1

1.1 a) ψ_0=750 mV, W=W_1+W_2=1.0 μm and ϵ_{max}=-11.4 MV/m.
b) V_{rev}=-0.3 V, ψ_0=750 mV, W=W_1+W_2=0.28 μm and ϵ_{max}=-3.2 MV/m.
b) V_{rev}=0 V, ψ_0=750 mV, W=W_1+W_2=0.61 μm and ϵ_{max}=-4.2 MV/m.

1.2 $C_j(V_{rev} = 5\,V)$=209 fF, $C_j(V_{rev} = 0\,V)$=577 fF and $C_j(V_{rev} = -0.3\,V)$=744 fF.

1.15 a) See output curves in the textbook.
b) See curves in the textbook.

1.16 C_{sb}=12.8 fF, C_{db}=8.7 fF, C_{gs}=30.8 fF, C_{gd}=2.0 fF, C_{gb}=5 fF, g_m=724 μS, g_{mb}=15.60 μS and r_o=128 kΩ.

2.12 V_t=0.48 V and k_n=191 μA/V^2.

2.17 Derive it and see if it checks out!

2.18 Derive it and see if it checks out!

2.19 The answers are 'sensitive' to how the diagrams are reed.
a) Two chips are cheaper.
b) It is hard to tell. One and two chips are rather close.
c) Two chips are cheaper.

Exercise 2

2.1 a) in p-type. See figure 2.2 $\Rightarrow$ N_A=1.5$\cdot$10^{16} cm^{-3}.
b) in n-type. See figure 2.2 $\Rightarrow$ N_D=6.0$\cdot$10^{15} cm^{-3}.

2.2 R_{square}=2000 $\Omega/square$.

EXAM The rest of this weeks exercises is old examination problems. For answers/solutions look at the exam at question on the course homepage.

Exercise 3

3.4 a) V_o=0.68 V and V_i=1.28 V at the triode region limit an a_v=-$g_m R_D$
b) Then $|a_v|$=1 V/V, V_i=0.7 V and V_o=2.95 V.
c) $a_{v,max}$=-6.8 V/V.

3.7 R_{in}=500 Ω if R_D=1 MΩ then R_{in}=999.5 Ω. Check if $R_{in} < 1/g_m$.

3.9 a) V_o=1.93 V and a_v=$\frac{v_o}{v_i}$=1 V/V.
b) V_o=1.93 V and a_v=$\frac{v_o}{v_i}$=0.85 V/V.
c) V_o=1.93 V and a_v=$\frac{v_o}{v_i}$=0.84 V/V.
d) V_o=1.93 V and a_v=$\frac{v_o}{v_i}$=0.76 V/V.

3.14 R_i=∞ Ω, G_m=2.4 mS, R_o=4.3 MΩ and a_v=$\frac{v_o}{v_i}$=10 kV/V.

3.15 R_o=3.47 GΩ.

3.24 I_{tail}=166 μA and W=52.3 μm.

3.26 V_{os}=-2.1 mV.

4.3 L=1.8 μm and W=39.1 μm.

4.5 R_o=460 MΩ.

4.7 L=0.35 μm and W=30.4 μm.

4.10 A_v=-{131.9; 417.1; 1318.9; 4170.6} V/V when I_{ref}={1 m; 100μ; 1 μ}A.

4.17 R_o=420 MΩ and A_v=-320 kV/V.

Exercise 4

7.2 f_{-3dB}=19.5 MHz and p_2=-19.1 Grad/s.

7.5 $Z_o=\frac{1-s/n_1}{(1-s/p_1)(1-s/p_2)}$, there n_1=-649.4 Mrad/s, p_1=-337.2 Mrad/s and p_2=-30.3 Grad/s.

7.7 A_{dm}=-$\frac{9.68(1-s\cdot 7.23p)}{1+s\cdot 2.97n+s^2\cdot 9.8\cdot 10^{-20}}$ V/V, $A_{cm}=-8.33m(1+s\cdot 0.6\mu)$ V/V and $CMRR=\left|\frac{9.68(1-s\cdot 7.23p)}{(1+s\cdot 2.97n+s^2\cdot 9.8\cdot 10^{-20})\cdot 8.33m(1+s\cdot 0.6\mu}\right|$.

7.17 A_v=-$\frac{19.36}{1+s\cdot 1.03n}$ V/V and f_{-dB}=155 MHz.

7.28 A_v=-$\frac{527.5}{1+s\cdot 12.3n}$ V/V and f_{-dB}=12.97 MHz.

7.33 A_i=-$\frac{1-s\cdot 7.5p}{1+s\cdot 261p}$ V/V, f_{-dB}=610 MHz and τ_{rise}=0.6 ns.

7.37 a) A_v=-5$\frac{1+s\cdot 66p}{(1+s\cdot 307p)(1+s\cdot 121p)}$ V/V and f_{-dB}=370 MHz.
b) A_v=-3.9$\frac{1+s\cdot 83.7p}{(1+s\cdot 306.7p)(1+s\cdot 284p)}$ V/V and f_{-dB}=269 MHz.

7.40 f_{3dB}=321 MHz and f_T= 2.4 GHz.

7.43 a) p_1=-1.1 kHz.
b) p_2=-289 kHz.

7.46 a) p_1=-1.0 krad/s and p_2=1.0 Trad/s. b) Compare with Spice.

7.49 Z=-20 Grad/s and p=-10 Grad/s.

Exercise 5

6.1 I_{out}=V_{in}/R.

6.2 Like a V symmetrical round the y-axis.

6.4 $a \geq$2 MV/V.

6.5 $CMRR$=20 000.

6.7 v_o=2 mV.

6.10 $PSRR^+$=-$g_m R$ and $PSRR^-$=-$\frac{g_m r_o}{1+g_m r_0}$.

6.11 a) A_v=-$g_{m1}(r_{o1}||r_{o4})g_{m6}(r_{o6}||r_{o7})$.
b) $V_{ov7}-V_{SS}\leq V_o \leq V_{DD}-|V_{o6}|$.
c) $V_{OS(SYS)}=(V_{ov3}+V_{t3}-\frac{V_{DD}+V_{SS}}{2})/A_v$.
d) $CMRR$=2$g_{m1}r_{tail}g_{m3}(r_{o1}||r_{o3})$.
e) $V_{IC,max}=V_{DD}-|V_{t3}|-|V_{ov3}|-V_{t1}$.
f) $PSRR^+$=$\frac{A_{dm}}{A^+}$=-$\frac{4}{|V_{ov1}||V_{ov6}|}\left(\frac{|V_{A2}||V_{A4}|}{|V_{A2}|+|V_{A4}|}\right)|V_{A6}|$.

6.13 a) $V_{OS(RAND)}$=10m$\sqrt{115/40}$=17.0 mV.
b) $V_{OS(RAND)}$=10m$\sqrt{40/115}$=5.9 mV.
c) b) has the lowest offset.

6.15 A_v=80 kV/V, -1.44 V$\leq V_{ic} \leq$0.48 V, A^+=0 and A^-=1/2.

6.18 $-V_{SS} + 1.2\,V < V_{IC} < V_{DD} - 1.4\,V$.

Exercise 6

9.2 The feedback should be smaller than 0.065 to be stable. A phase margin of 60 degree is achieved with a feedback of 0.011.

9.5 a) $1 \cdot p_1$=$A_0 \cdot p_D \Rightarrow p_D$= 60 Hz.
b) A_o=500 $\Rightarrow p_D$= 600 Hz. Bandwidth of the feedback circuit $\approx p_1$.

9.6 a) $A_o p_1'$=$p_2 \Rightarrow p_1'$=400 Hz. Bandwidth is $\approx p_2$.
b) p_1'=4 kHz. Bandwidth is $\approx p_2$.

9.8 R_1=0.1 Ω, R_2=100 Ω and L=3.2 mH.

9.21 S_R=4 MV/s, GB=3.2 MHz and A_o=5.7 GV/V.

9.22 A_o= 87 kV/V, GB=35 MHz and S_R=40 MV/s.

9.25 p_1'=3.18 MHz, g_{m6}= 234.5 μS and C_L=11.7 pF.

9.31 a) C=2.0 pF.
b) C=2.0 pF and R_Z=500 Ω.

11.5 $\sqrt{v_{out}^2}(10)$=11.95 μV/$\sqrt{Hz}$, $\sqrt{v_{in}^2}(10)$=808 nV/$\sqrt{Hz}$, $\sqrt{v_{out}^2}(100k)$=606 nV/$\sqrt{Hz}$ and $\sqrt{v_{in}^2}(100k)$=40.9 nV/$\sqrt{Hz}$, $\sqrt{v_{out}^2}(1G)$=593 nV/$\sqrt{Hz}$, $\sqrt{v_{in}^2}(1G)$=7.7 μV/$\sqrt{Hz}$.

11.8 i_i=2qI_G $\approx$0 and v_i= 4.3 μV_{rms}.

11.25 a) L=8.33 μm and W=0.6 μm.
b) L=8.33 μm and W=0.6 μm.

Exercise 7

12.1 -0.48 V$< V_{o1}; V_{o2}$ <2.3 V, $V_{odp,max}$=2.78 V.

12.2 -2.3 V$< V_{o1}; V_{o2}$ <2.3 V, V_{odp}=4.6 V.

12.5 a) a_{dm}=-134 V/V, R_{od}/2=134 kΩ, a_{cm}=-1.98 V/V, R_{oc}=396 kΩ, R_{oc}/2-R_{od}/4=131 kΩ, G_{md}=0.5 mS, G_{mc}=5 μS and $R_{od}||(-2R_{oc})$=405 kΩ.
b) C_{md}=2.9 pF, C_{mc}=60 fF, Z_{id}/2=(s·2.9pF)$^{-1}$, $Z_{id}||(-2Z_{ic})$=(s·1.4pF)$^{-1}$, Z_{ic}/2-Z_{id}/4=(s·0.12pF)$^{-1}$.

12.9 S_R=40 MV/s.

12.13 a) C_{Ld}=9.5 pF and C_{Lc}=7 pF.
b) C_{Ld}=1.5 pF and C_{Lc}=13 pF.

12.15 a) V_{oc}=1.7 V.
b) a_{dm}=-15.4 V/V and a_{cm}=-1.96 V/V.

12.16 a) a_{dm}=-66.7 V/V and a_{cm}=-66.7 V/V.
b) The DM and CM half circuits are identical thus the same gain.

12.20 a) A_{dm}=-5 V/V, A_{cm}=0 V/V, A_{cm-dm}=0 V/V and A_{dm-cm}=0 V/V.
b) A_{dm} $\approx$-5 V/V, A_{cm}=0 V/V, A_{cm-dm} $\approx$0.017 V/V and A_{dm-cm}=0 V/V.

12.21 v_{s1}=0.2sin(100t) V, v_{s2}=0 V, v_{sc}=0.1sin(100t) V, v_{sd}=0.2sin(100t) V, v_{od}=-sin(100t) V, v_{oc}=0 V, v_{o1}=-0.5sin(100t) V, v_{o2}=0.2sin(100t) V, v_{id}=0 V, $A_{dm} = \infty$ for the op-amp, v_{ic}=0.083sin(100t) V, v_{i1}=0.083sin(100t) V, v_{i2}=0.083sin(100t) V.