YILDIZ TEKNİK ÜNİVERSİTESİ
ELEKTRİK ELEKTRONİK FAKÜLTESİ / ELEKTRONİK VE HABERLEŞME MÜHENDİSLİĞİ BÖLÜMÜ

Öğrencinin Adı Soyadı: Alirıza Bilir	**Öğrenci No:18014125**	**İmza:**
Dersin Adı: EHM2122 Elektronik Devreler 1-Gr2	**Son Teslim Tarihi/Saati:** 08/06/2022 23:59	
Sınav Türü:	Ödev 2	
Unvan Ad-Soyad: Doç. Dr. Revna ACAR VURAL **(Ders Yürütücüsü)**		

Design Specification of GainxBandwidth (GBW), by means of MHz, is provided according to last two digits of the student number (XX).

GainxBandwidth= $= \left(5 + \frac{XX}{5}\right)$ **MHz**

Gain by means of Volts/Volts, Bandwidth by means of Hertz.

5% of tolerance for GBW at most is acceptable.

Design steps:

*** Use a cascaded two-stage MOSFET amplifier.**

* Bias your design by using any bias topology. Magnitude of supply voltage should be an integer between 10 and 15V. Make sure that MOSFETs operate in saturation mode.

***Determine all external capacitor values as 100 µF and external resistor values according to design specifications. W/L value must be an integer, the smallest possible value for L is 1.5 µm.**

* For your design homework, refer to TUBITAK YITAL 1.5µm MOSFET model parameters:

(.model nmos nmos level=3 tox=230e-10 ld=0.125e-6 wd=0.6e-6 uo=570 vto=0.7

+theta=0.05 rs=75 rd=75 delta=0.4 nsub=1.2e16 xj=0.15e-6 vmax=2.3e5

+eta=0.0022 kappa=0.5 nfs=7e11 gamma= 0.46 phi=0.35

.model pmos pmos level=3 tox=230e-10 ld=0.06e-6 wd=0.6e-6 uo=230 vto=-0.66

+theta=0.17 rs=120 rd=120 delta=0.4 nsub=1.2e16 xj=0.3e-6 vmax=0

+eta=0.016 kappa=0.06 nfs=1e12 gamma=0.48 phi=0.35)

*Determine the threshold voltage and (μ*Cox) parameter for MOSFET and the parasitic capacitances of MOSFET from 1.5 μm model parameters.

(Hint: in saturation region→ $C_{gs} = \frac{2}{3} WLC_{ox} + WL_{ov}C_{ox}$, $C_{gd} = WL_{ov}C_{ox}$, $L_{ov}: overlap\ length$)

$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$ $\varepsilon_{ox} = 3.9\varepsilon_0$ $\varepsilon_o = 8.85x10^{-14}$ [F/cm] L_{ov}=0.05L

Last two digits of your student number: 25

Your GBW specification : 10

$W = 100u$ $L = 10u$

$Cox = \varepsilon ox/tox$, $\varepsilon_{ox} = 3.9\varepsilon 0$, $\varepsilon_o = 8.85x10^{-14}$ [F/cm] = $8.85x10^{-12}$ [F/m] , $tox = 230x10^{-10}$

$Cox = 3.9x8.85x10^{-12} /230x10^{-10}$

L_{ov}=0.05L =0.05x10u = 0.5 u

C_{gs} =2/3WLC$_{OX}$+WL$_{ov}$ C$_{ox}$=2/3.100u.(30u).[$3.9x8.85x10^{-12} /230x10^{-10}$]+2/3.100u.(0.5u).[$3.9x8.85x10^{-12} /230x10^{-10}$]=1,05x$10^{-12}$

C_{gd}= WL$_{ov}$C$_{ox}$=100u.0.5u.(0.0015)=0.75x10^{-11}

μ = 570 $cm^2 /V.s$ = $570x10^{-4}$ m^2/V. S

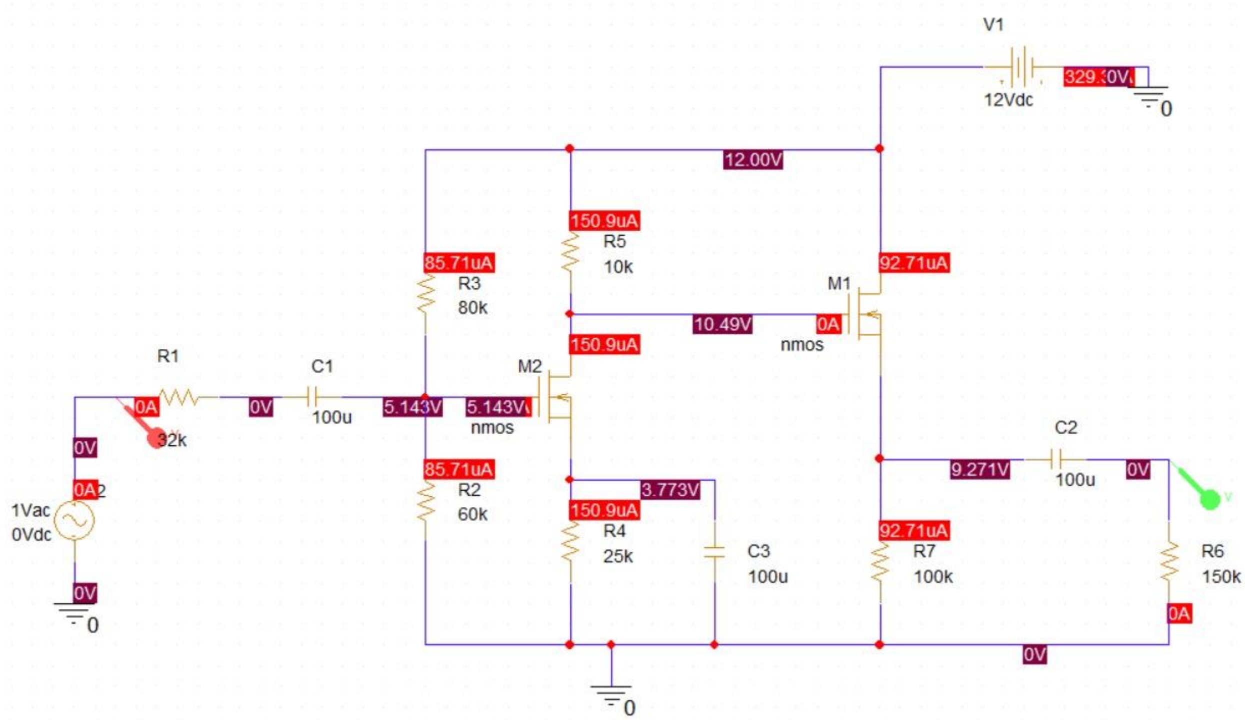
μ. Cox = $570x10^{-4}$. (0,0015)= 0.000085

K = μ. Cox W/L=850u

V_{t}=0.7

λ=0

a) Give your schematic circuit design below with the numerical values of passive components (i.e., R and C). Determine the width to length ratios of your MOSFETs on the schematic.



```
* source ALIRIZAED1ODEV2
R_R5         N15394 N15282  10k TC=0,0
R_R4         0 N15522  25k TC=0,0
C_C2         N15472 N15536  100u  TC=0,0
R_R3         N15408 N15282  80k TC=0,0
R_R6         0 N15536  150k TC=0,0
R_R2         N15408 0  60k TC=0,0
V_V2         N15476 0 DC 0Vdc AC 1Vac
C_C3         0 N15522  100u  TC=0,0
V_V1         N15282 0 12Vdc
C_C1         N15486 N15408  100u  TC=0,0
R_R1         N15476 N15486  32k TC=0,0
R_R7         0 N15472  100k TC=0,0
M_M1         N15282 N15394 N15472 N15472 nmos
+ L=10u
+ W=100u
M_M2         N15394 N15408 N15522 N15522 nmos
+ L=10u
+ W=100u

**** RESUMING alirizaac.cir ****
.END
```

```
****     MOSFET MODEL PARAMETERS
******************************************************************************

           nmos
           NMOS
      LEVEL    3
         L  100.000000E-06
         W  100.000000E-06
        LD  125.000000E-09
        WD  600.000000E-09
       VTO     .7
        KP  85.577910E-06
     GAMMA     .46
       PHI    .35
    LAMBDA    0
        RD  75
        RS  75
        IS  10.000000E-15
        JS  0
        PB    .8
      PBSW     8
        CJ  352.822200E-06
      CJSW    0
      CGSO    0
      CGDO    0
      CGBO    0
      NSUB   12.000000E+15
       NFS  700.000000E+09
       TOX   23.000000E-09
        XJ  150.000000E-09
        UO  570
     UCRIT   10.000000E+03
      VMAX  230.000000E+03
     DELTA     4
     THETA     .05
       ETA   2.200000E-03
     KAPPA     .5
    DIOMOD     1
       VFB   0
      LETA    0
      WETA    0
        U0   0
      TEMP    0
       VDD   5
     XPART    0
```

b) Determine operating point with theoretical DC Analysis.

Last Two Digits of Student Number = 25

$W = 100u$ $L = 10u$ Student Number = 25. $Gbw = 10$

DC Analysis

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Thevenin Theorems

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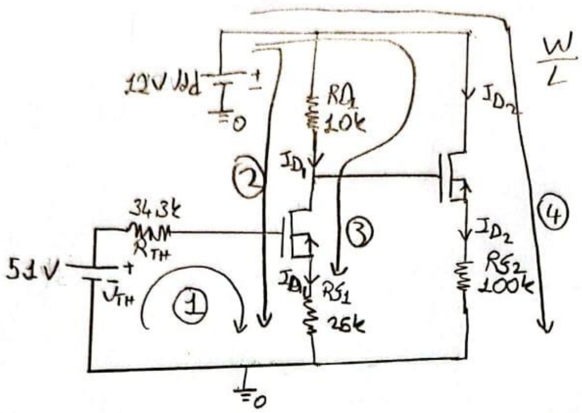
$\frac{60 \times 80}{60+80} = R_{TH} \approx 34.3k$ $\frac{60 \times 12}{60+80} = V_{TH} \cong 5.1\ Vdc$



$\frac{W}{L} = \frac{100u}{10u} = 10$

Let's admit Saturation

① $-V_{TH} + \cancel{I_{G1} \cdot R_{TH}} + V_{GS1} + I_{D1} \cdot R_{S1} = 0$

$V_{GS1} + I_{D1} \cdot R_{S1} = 5.1 \Rightarrow V_{GS1} + \frac{1}{2} K (V_{GS1} - V_T)^2 \cdot R_{S1} = 5.1$

$V_{GS1} + \frac{1}{2}\ 850u\ (V_{GS1} - 0{,}7)^2 \cdot 25k = 5{,}1$

$V_{GS1} \approx 1{,}28$ $I_{D1} \approx 142\ uA$

② $-V_{DD} + I_{D1} \cdot R_{D1} + V_{DS1} + I_{D1} \cdot R_{S1} = 0$

$142u \cdot 10k + V_{DS1} + 142u \cdot 25k = 12$ $V_{DS1} \approx 7{,}03$

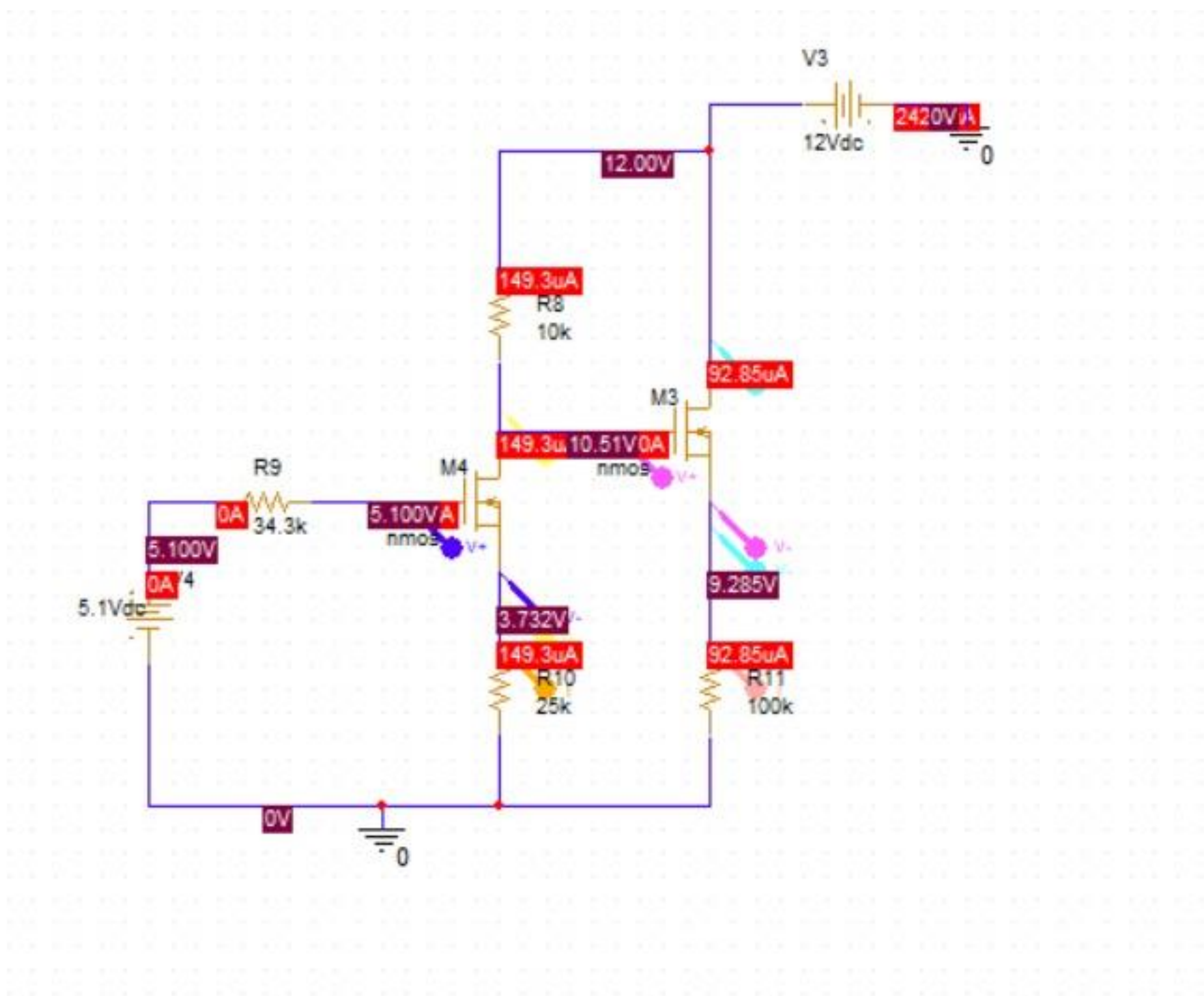
③ $-V_{DD} + I_{D1} \cdot R_{D1} + V_{GS2} + I_{D2} \cdot R_{S2} = 0$ $V_{GS2} \approx 1{,}66$

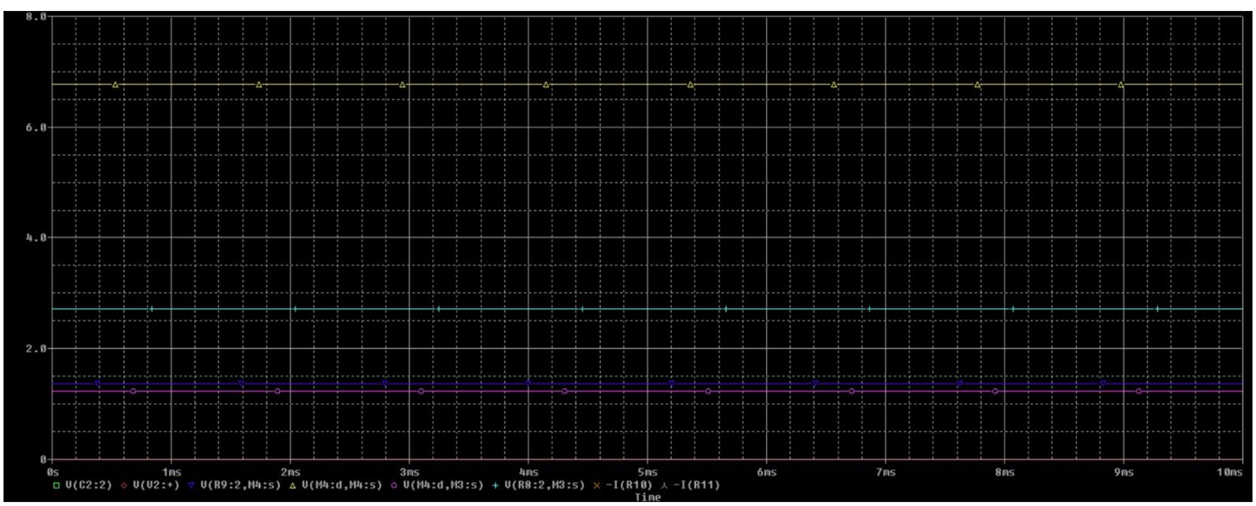
$142u \cdot 10k + V_{GS2} + \frac{1}{2} \cdot 850u\ (V_{GS2} - 0{,}7)^2 \cdot 20k = 12$ $I_{D2} \approx 92u$

④ $-V_{DD} + V_{DS2} + I_{D2} \cdot R_{S2} = 0$ $V_{DS2} + 92u \cdot 25k = 12$

$V_{DS2} \approx 2{,}3$ DC Points $Q_1(142uA, 7{,}03, 1{,}28)$ $Q_2(92u, 2{,}3, 1{,}66)$

Simulation c) Using OrCAD Capture or PSpice A/D, find DC operating point of the circuit. (Indicate necessary currents and voltages with probes on the schematic)





d) Calculate theoretical voltage gain (V/V) using mid-frequency AC analysis.
Calculate upper 3dB cut-off frequency using open circuit time constant method.

for $\lambda = 0$, $r_d \to \infty$

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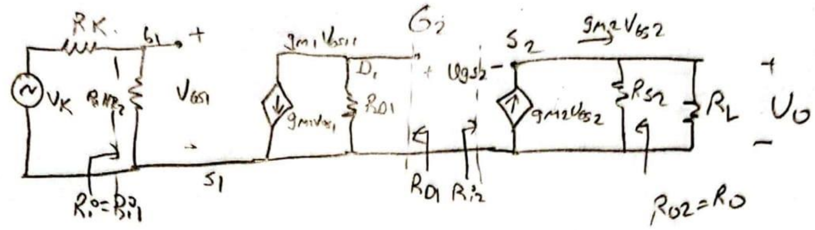
$g_{m1} = \sqrt{2 \cdot K \cdot I_D} = \sqrt{2 \times 850u \times 142u} = 4{,}91 \cdot 10^{-4}$

$g_{m2} = \sqrt{2 \times 850u \times 92u} = 3{,}95 \cdot 10^{-4}$

AC Analysis



① $V_o = g_{m2} V_{gs2} (R_{S2} // R_L)$ ★

$\Rightarrow V_{D1} = V_{G2} = V_{gs2} + V_o = V_{gs2}\left(1 + g_{m2}(R_{S2} // R_L)\right)$

$\Rightarrow V_{G2} = -g_{m1} V_{gs1} R_{D1} = V_{gs2}\left(1 + g_{m2}(R_{S2} // R_L)\right)$

$$V_{GS2} = \frac{-g_{m1} R_{D1}}{1 + g_{m2}(R_{S2} // R_L)} \cdot V_{gs1} \quad ★$$

② $$V_{gs1} = \frac{R_1 // R_L}{R_1 // R_2 + R_K} \cdot V_K \quad ★$$

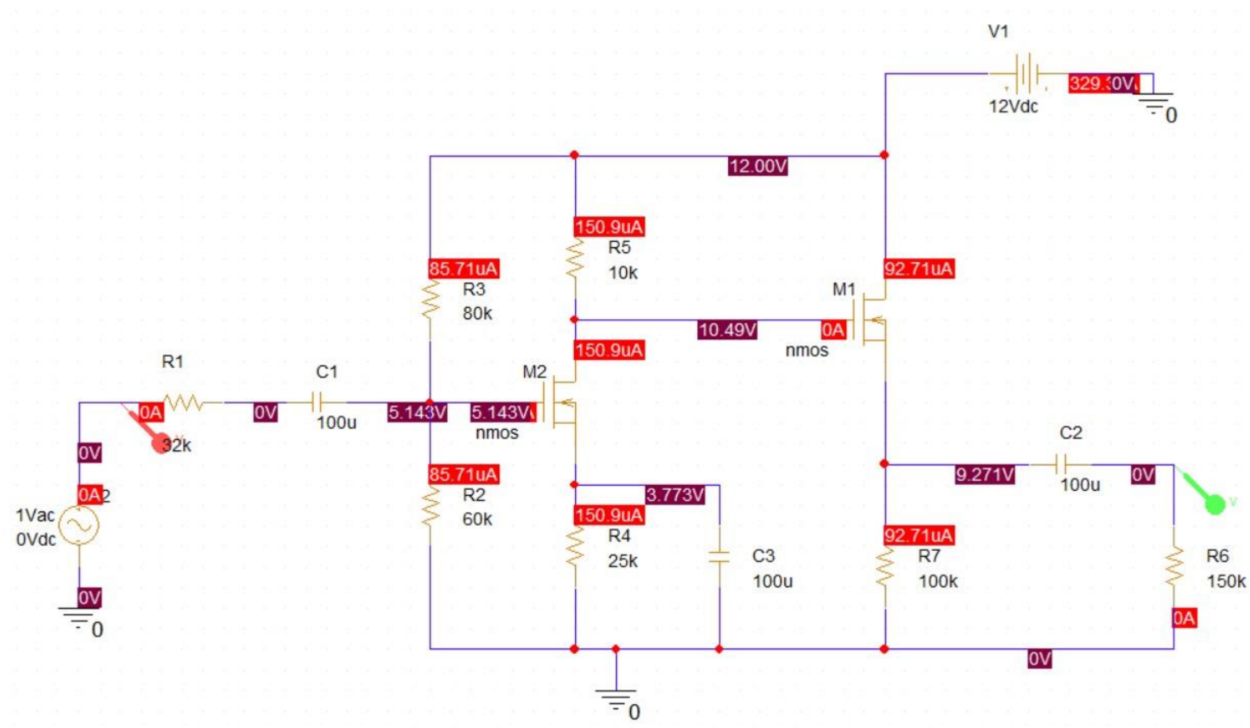
$$A_{vs} = \frac{V_o}{V_K} = \frac{V_o}{V_{gs2}} \cdot \frac{V_{gs2}}{V_{gs1}} \cdot \frac{V_{gs1}}{V_K}$$

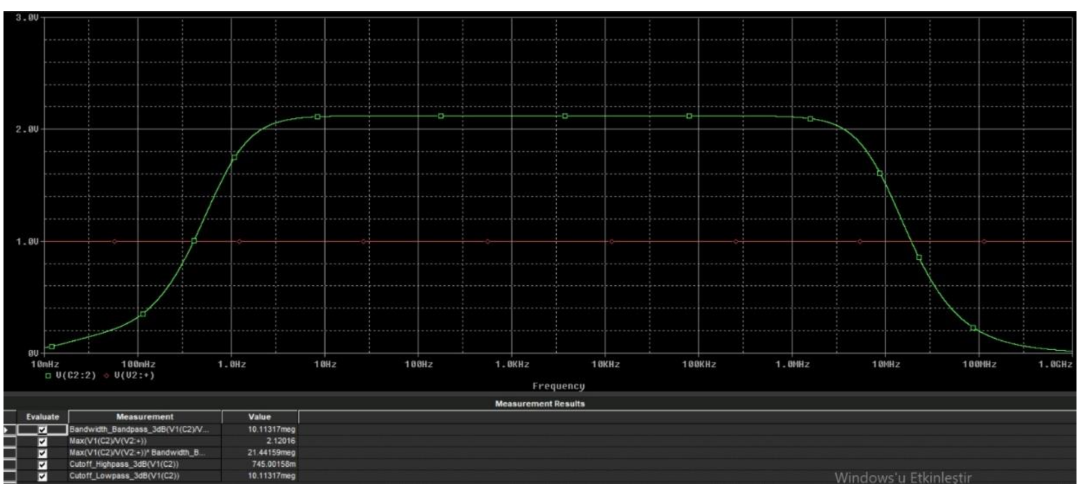
$$= g_{m2}(R_{S2} // R_L) \cdot \frac{-g_{m1} \cdot R_{D1}}{\left(1 + g_{m2}(R_{S2} // R_L)\right)} \cdot \frac{R_1 // R_2}{R_1 // R_2 + R_K}$$

$$= 3{,}95 \cdot 10^{-4} (60) \, \frac{-4{,}96 \cdot 10^{-4} \cdot 10k}{1 + 3{,}95 \cdot 10^{-4}} \cdot \frac{34{,}28}{34{,}28 + 32k} = 2{,}05$$

$V_{vs} = 2{,}05$

Simulation e) Using OrCAD Capture or PSpice A/D, sketch amplitude frequency response by using AC sweep. Indicate mid-frequency voltage gain, upper and lower cut-off frequencies by using cursors.





f) Comment on differences between theoretical and simulation results (if any).
In theory , when we do ac and dc analysis , the result we get is similar to simulation results . As in the gain calculations, I saw about 10 times my input voltage when I measured the output. I've seen the frequencies , W , L and R parameters get wrong how effective they are when rendering the graphs.

Note: Uploaded file type should be <u>.pdf version</u> of this document. Make sure that you use this document as the template for the homework and use the provided spaces for your answers. Submission will be via ONLINE system.