UNIVERSITY OF HERTFORDSHIRE
School of Engineering and Technology

COURSEWORK ASSIGNMENT

Module Title: Mixed-Mode and VLSI Technologies	**Module Code:** 7ENT1008
Assignment Title: Design and Simulation of CMOS OTA-C Filters	**Individual Assignment**
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Student ID Number **ONLY**:	Year Code:
17019396	

Marks Awarded %:	Marks Awarded after Lateness Penalty applied %:

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Lab Answer Sheet on

Design and Simulation of CMOS OTA-C Filters

ID number: 17019396

(a)Determine the minimum value of bias voltage V_b, showing the workings. Choose bias voltage V_b= -1.6V and compute OTA transconductance, g_m, using the formula and parameter values given in the lab sheet.

(20%)

For the minimum value of V_b we should equal the g_m to 0 in the equation,

$$g_m = \mu_n c_{ox}\sqrt{\frac{1}{2}\left(\frac{W}{L}\right)_{1,2}\left(\frac{W}{L}\right)_9}\,(V_b - V_{ss} - V_{Tn}) \qquad g_m = 0$$

$0=(V_b-V_{ss}-V_{Tn})$ where $V_{ss}= -2.5V$ and $V_{Tn}=0.8V$

So minimum value of V_b= -1.7V

With V_b given finding g_m,

$$g_m = \mu_n c_{ox}\sqrt{\frac{1}{2}\left(\frac{W}{L}\right)_{1,2}\left(\frac{W}{L}\right)_9}\,(V_b - V_{ss} - V_{Tn})$$

Parameter values given in the lab sheet;

$$\mu_n = 700\, {cm^2}/{V\_s}, C_{ox} = 3.45\, {fF}/{\mu m^2}, V_{Tn} = 0.8V, V_{ss} = -2.5V$$

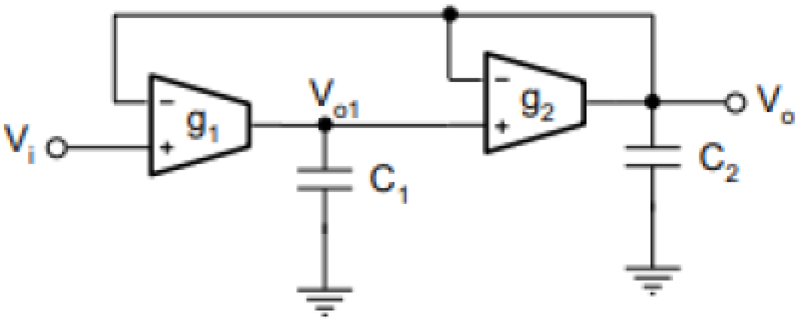
gm= $(0.07) * (3.45) * \frac{10^{-15}}{10^{-12}} * \sqrt{\frac{1}{2}\left(\frac{50}{5}\right)_{1,2}\left(\frac{25}{5}\right)_9} * (-1.6 + 2.5 - 0.8)$

$=(0.07) \times (3.45) \times 10^{-3} \times 5 \times 10^{-1}$
$=1.20175 \times 10^{-4}$
$=12.0175 \times 10^{-5}$ simens

(b)For the OTA-C filter, at V_b= -1.6V, assuming $g_1=g_2=g_m$, calculate C_1 and C_2 for the given filter specifications f_o=10MHz and Q=1. Give the formulas used and the process.

(20%)

$K_{LP}=1$



$$H_{lp}(s) = \frac{g_1 g_2 / C_1 C_2}{s^2 + s\left(g_2/C_2\right) + g_1 g_2/C_1 C_2} = \frac{K_{LP} W_o^2}{s^2 + s\left(W_o/Q\right) + W_o^2}$$

$$\boldsymbol{Q = \sqrt{\frac{g1 * C2}{g2 * C1}}}$$

where

$Q=1$ and assuming $g1 = g2 = gm$

from here $C1 = C2 = C$

$$\boldsymbol{wo = \sqrt{\frac{g1 * g2}{C1 * C2}}}$$

from here

$$\boldsymbol{wo = \frac{gm}{C}}$$

It is known that $\boldsymbol{wo = 2\pi fo}$ and **f_o=10MHz**

$$= 2 \times 3.14 \times 10 \times 10^6$$
$$= 62.8 \times 10^6 \text{ Hz}$$

$$C = \frac{gm}{wo} = \frac{12.0175\times10^{-5}}{62.8\times10^{-6}} = 0.191 \times 10^{-11}$$

$$= 1.91 \times 10^{-12} F$$
$$= \ 1.91\ pF$$

(c)Give the transistor level schematic of the whole CMOS OTA-C filter with V_b= -1.6V you actually used in your lab simulation. Give the simulated amplitude and phase frequency responses of the filter at V_b= -1.6V only, which were obtained in the lab experiment.

(20%)

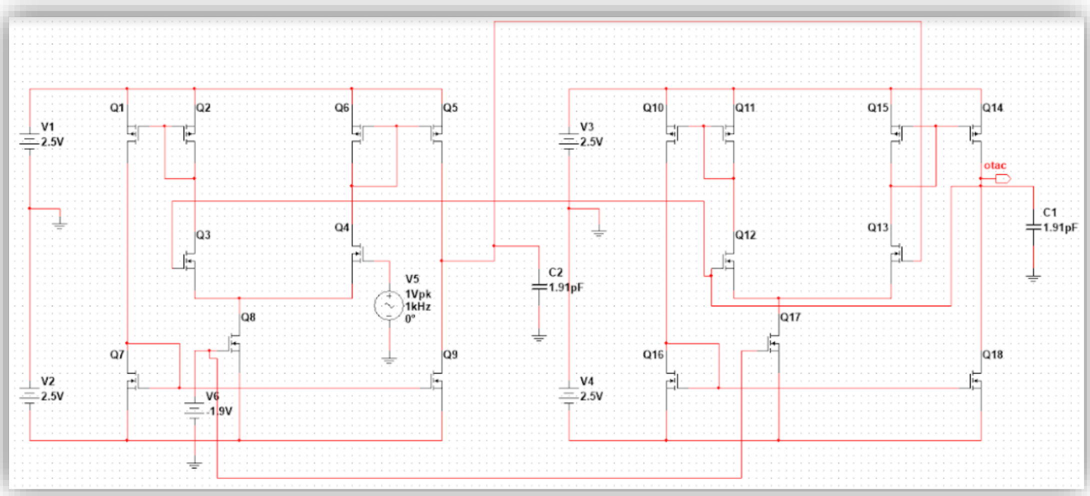


Figure 1 Schematic of the whole CMOS OTA-C filter

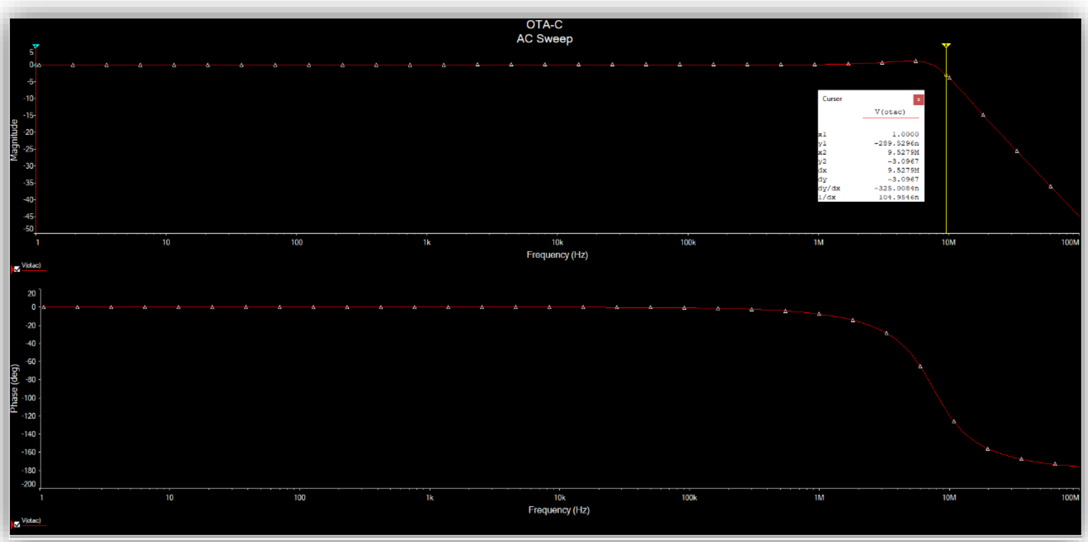
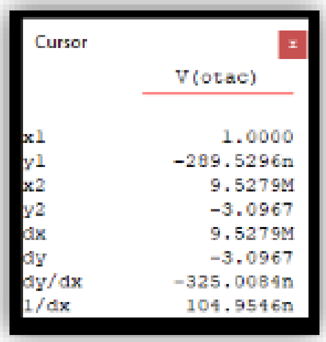


Figure 2 simulated amplitude and phase frequency responses of the filter at Vb= -1.6



For V_b= -1.6

(d)Comment on the simulated results given above by comparing the simulated cut-off frequency with its ideal value. Discuss deviation if any and what OTA nonidealities may have caused the deviation and why.

(40%)

When changing V_b to other values to observe how the filter cutoff frequency fo is tuneable by the bias voltage, the results we got are below.

V_b	f_o
-1.3	12.7896M
-1.4	11.710M
-1.5	10.7277M
-1.6	**9.5279M**
-1.7	8.4768M
-1.8	7.3187M
-1.9	6.3188M
-2.0	5.2543M

As V_b decreases, cut off frequency decreases.

When V_b is equal to -1.6V;
fo=9.5279MHz as a result of the simulation although fo is specified 10MHz. This result shows that there is a deviation due to OTA nonideality.

An ideal OTA which is a voltage controlled current source has infinite input,output impedances and constant transconductance. Moreover, the OTA has tunable transconductance. It can work high frequencies. It is one of the most important features for fully integrated high-frequency filter design. In addition, practical OTA has finite input and output impedances. The transconductance of OTA is frequency-dependent at very high frequencies. Nonideal characteristics will decrease frequency performances of OTA-C filters.

The input conductance of the CMOS operational transconductance amplifier is very small so it may be neglected. OTA input and output capacitances rises the total capacitances or cause parasitic poles.Both can decrease the operation frequency. Parasitic capacitances can be absorbed into the grounded circuit capacitances. This approach specifies the real component values by removing the parasitic caused increases from the nominal values.

The finite OTA output resistance Ro or finite OTA DC voltage gain decrease Q and filter gain. This impact can require to be removed by using negative resistance in high-Q applications.The OTA frequency dependent transconductance causes instability at higher frequencies, limiting the operation frequency. Transconductance frequency dependence or excess phase has a Q increase effect. The impact can be compensated when connecting a resistor in series with the capacitor. This resistor is normally achieved utilizing a MOSFET in the triode or ohmic region in IC design. The equivalent resistance value may be set by voltage VB.

REFERENCES

- Sun, Y., Ebooks Corporation, Books24x7, I. & Institution of Electrical Engineers 2002, *Design of High Frequency Integrated Analogue Filters,* The Institution of Engineering and Technology, Stevenage.

- Lecture Notes