Microelectronic Circuits Assignment 1

Sai Kartik (2020A3PS0435P)
Manpreet Singh (2020A3PS0419P)
Rajeev Rajagopal (2020A3PS1237P)

February, 2022

Question 1

Value of components (resistor/capacitor) present in the circuit:

Table 1: Calculated values for question 1

Sl. No.	Component Name	Value
1	R1(kΩ)	15kΩ
2	C1 (nF)	1nF

Circuit as on LT SPICE

Graphs

Miscellaneous calculations

DC operating point

Given the overdrive voltage of the MOSFET as 0.2V and the threshold voltage as 0.6696061V, to calculate the DC operating point, we must take $V_{GS} = V_{TH} + V_{OV} = 0.8696061$V. With this value of V_{GS}, the simulation yields the following values:

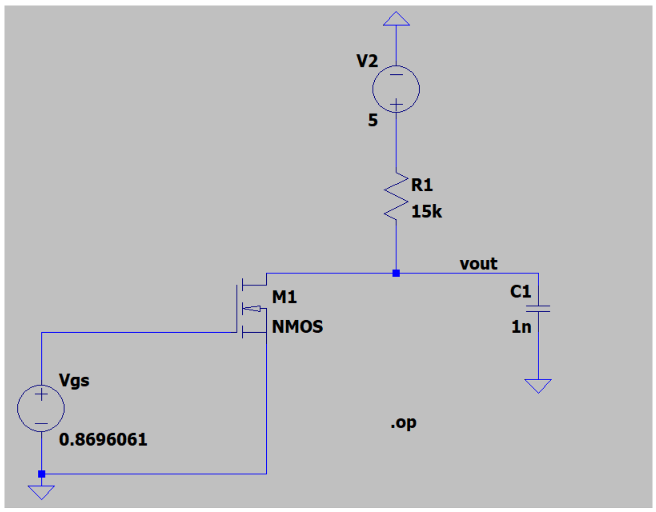

Figure 1: DC operating point circuit

```
       --- Operating Point ---

V(n002):         0.869606       voltage
V(n001):         5              voltage
V(vout):         4.99329        voltage
Id(M1):          4.47302e-007   device_current
Ig(M1):          0              device_current
Ib(M1):          -5.00329e-012  device_current
Is(M1):          -4.47297e-007  device_current
I(C1):           -4.99329e-021  device_current
I(R1):           4.47302e-007   device_current
I(V2):           -4.47302e-007  device_current
I(Vgs):          0              device_current
```

Figure 2: DC operating point parameters

Question 2

Value of components (resistors/gain) present in the circuit

Table 2: Calculated values for question 2

Sl. No.	Component Name	Value
1	R_1(kΩ)	30kΩ
2	R_2(kΩ)	17kΩ
3	R_3(kΩ)	30kΩ
4	R_4(kΩ)	50kΩ
5	k	18 V/V

Circuit as on LT SPICE

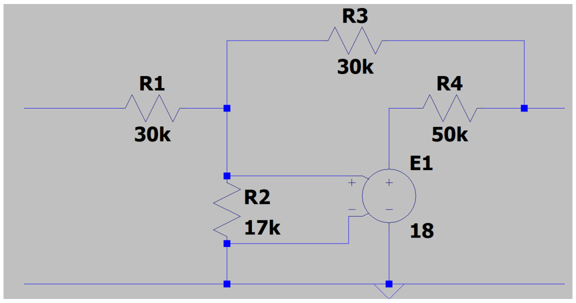

Figure 3: Original 2 port network simulated on LT SPICE

Z, Y and H Parameters

Z parameters

Z parameters as obtained from LT SPICE

$$Z = \begin{bmatrix} 23.492822k\Omega & -4.0669856k\Omega \\ -47.99043k\Omega & -11.24402k\Omega \end{bmatrix}$$

Y parameters

Y parameters as obtained from LT SPICE

$$Y = \begin{bmatrix} 24.479166\mu\mho & -8.8541665\mu\mho \\ -104.47916\mu\mho & -51.145835\mu\mho \end{bmatrix}$$

H parameters

$$H = \begin{bmatrix} 40.851062k\Omega & 361.70211m\mathrm{V/V} \\ -4.268085\mathrm{A/A} & -88.936169\mho \end{bmatrix}$$

Calculations

Z parameters

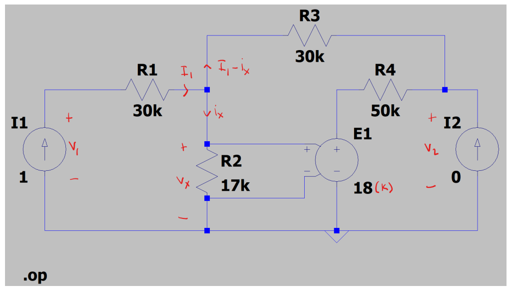

Figure 4: Z parameter circuit 1 (for z_{11} and z_{21})

Assume the convention in the above circuit for the calculations that follow

$$-(I_1 - i_x)(R_3 + R_4) - kV_x + V_x = 0$$
$$(i_x - I_1)(R_3 + R_4) = V_x(k-1)$$
$$(i_x - I_1)(R_3 + R_4) = i_x R_2(k-1)$$
$$i_x(R_3 + R_4 - R_2(k-1)) = I_1(R_3 + R_4)$$
$$\implies i_x = I_1 \frac{(R_3 + R_4)}{R_3 + R_4 - R_2(k-1)}$$
$$V_1 = I_1 R_1 + V_x$$
$$V_1 = I_1 R_1 + i_x R_2$$
$$V_1 = I_1 \left[R_1 + \frac{R_2(R_3 + R_4)}{R_3 + R_4 - R_2(k-1)} \right]$$
$$\implies \frac{V_1}{I_1} = \boxed{z_{11} = R_1 + \frac{R_2(R_3 + R_4)}{R_3 + R_4 - R_2(k-1)}}$$

Also :

$$V_2 = (I_1 - i_x)R_4 + kV_x$$
$$V_2 = (I_1 - i_x)R_4 + k i_x R_2$$
$$V_2 = i_x(kR_2 - R_4) + I_1 R_4$$
$$V_2 = I_1 \left[R_4 + \frac{(kR_2 - R_4)(R_3 + R_4)}{R_3 + R_4 + R_2(k-1)} \right]$$
$$\implies \frac{V_2}{I_1} = \boxed{z_{21} = R_4 + \frac{(kR_2 - R_4)(R_3 + R_4)}{R_3 + R_4 - R_2(k-1)}}$$

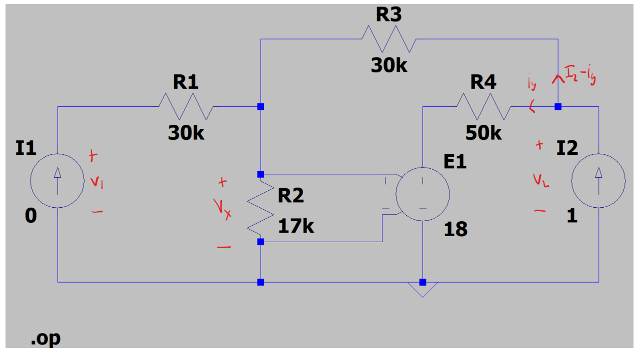

Figure 5: Z parameter circuit 2 (for z_{12} and z_{22})

Assume the convention in the above circuit for the calculations that follow

$$
\begin{gathered}
-R_3(I_2 - i_y) - V_x + kV_x + i_yR_4 = 0 \\
i_yR_4 - R_3(I_2 - i_y) = (1-k)V_x \\
i_yR_4 - R_3(I_2 - i_y) = (1-k)(I_2 - i_y)R_2 \\
i_yR_4 = (I_2 - i_y)[(1-k)R_2 + R_3] \\
(R_4 + R_3 + (1-k)R_2)i_y = I_2[(1-k)R_2 + R_3] \\
\implies i_y = I_2\frac{(1-k)R_2 + R_3}{(1-k)R_2 + R_3 + R_4} \\
V_2 = i_yR_4 + kV_x \\
V_2 = i_yR_4 + k(I_2 - i_y)R_2 \\
V_2 = i_y[R_4 - kR_2] + KI_2R_2 \\
V_2 = I_2\left[\frac{(R_4 - kR_2)\{(1-k)R_2 + R_3\}}{(1-k)R_2 + R_3 + R_4} + kR_2\right] \\
\implies \frac{V_2}{I_2} = \boxed{z_{22} = \frac{(R_4 - kR_2)\{(1-k)R_2 + R_3\}}{(1-k)R_2 + R_3 + R_4} + kR_2} \\
\text{Also :} \\
V_1 = V_x = (I_2 - i_y)R_2 \\
V_1 = I_2R_2\left[1 - \frac{(1-k)R_2 + R_3}{(1-k)R_2 + R_3 + R_4}\right] \\
\implies \frac{V_1}{I_2} = \boxed{z_{12} = R_2\left[1 - \frac{(1-k)R_2 + R_3}{(1-k)R_2 + R_3 + R_4}\right]}
\end{gathered}
$$

Using the corresponding values taken from 2 into the above equations, we get the matrix for the Z parameters:

$$Z = \begin{bmatrix} 23.49282297k\Omega & -4.066985646k\Omega \\ -47.99043062k\Omega & -11.244041914k\Omega \end{bmatrix}$$

Which is in accordance with the values obtained from the simulation.

Y parameters

From the above matrix for Z parameters, we can calculate the Y parameters as follows:

$$\Delta Z = z_{11}z_{22} - z_{12}z_{21}$$
$$\implies \Delta Z = [(23.49282297 \times -11.244041914) - (-47.99043062 \times -4.066985646)] \times 10^3$$
$$\Delta Z = -459.326 \times 10^6$$
$$Y = \begin{bmatrix} \dfrac{z_{22}}{\Delta Z} & -\dfrac{z_{12}}{\Delta Z} \\ -\dfrac{z_{21}}{\Delta Z} & \dfrac{z_{11}}{\Delta Z} \end{bmatrix}$$

Simplifying the above matrix, we get the Y parameters:

$$Y = \begin{bmatrix} 2.448 \times 10^{-5}\mu\mho & -8.8541 \times 10^{-6}\mu\mho \\ -1.104480 \times 10^{-4}\mu\mho & -5.11 \times 10^{-5}\mu\mho \end{bmatrix}$$

H parameters

Similarly, we can calculate the H parameters as follows:

$$H = \begin{bmatrix} \dfrac{\Delta Z}{z_{22}} & -\dfrac{z_{12}}{z_{22}} \\ -\dfrac{z_{21}}{z_{22}} & \dfrac{1}{z_{22}} \end{bmatrix}$$

Simplifying the above matrix, we get the H parameters:

$$H = \begin{bmatrix} 40.8507k\Omega & -0.3617\text{V/V} \\ -4.2681\text{A/A} & -88.9363\mho \end{bmatrix}$$

Load resistance value at port 2

Varying the output resistance at the terminals of port 2 and by calculating the voltage and current across the resistance, we can calculate the maximum power dissipated across the resistance. This can be seen in the following figure:

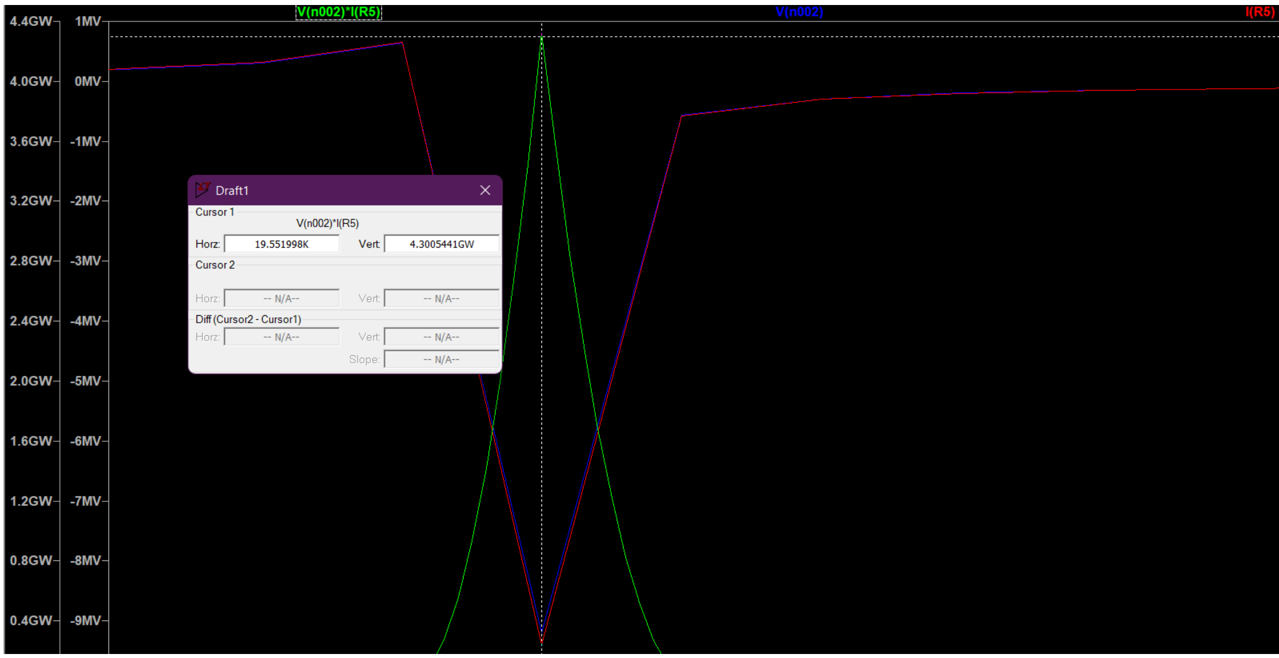

Figure 6: Load resistance value at port 2

According to the simulation results shown above, the value for the resistance at which maximum power transfer occurs is $19.551998K\Omega$ and the maximum power transferred is $4.3005441G$W.