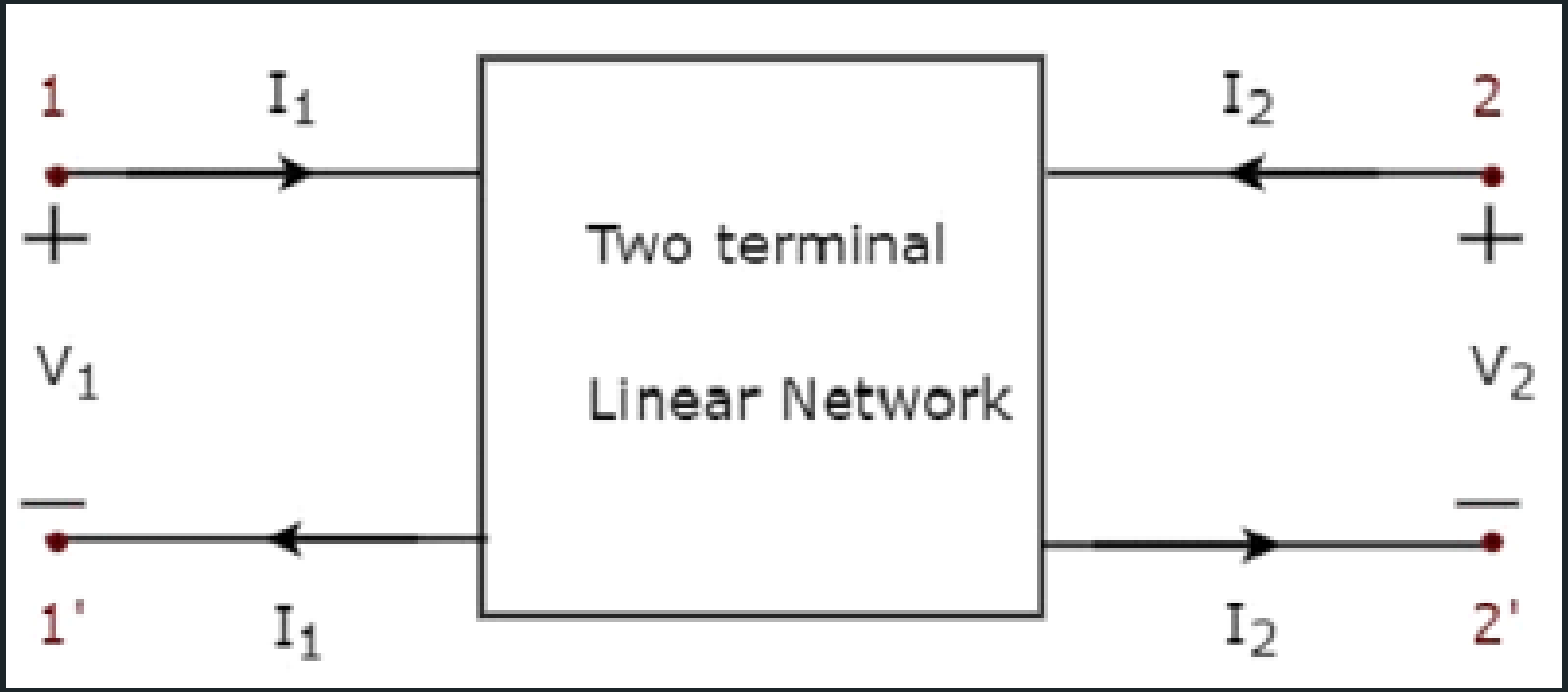
NAS PROJECT PRESENTATION



TWO PORT NETWORKS & IT'S APPLICATION

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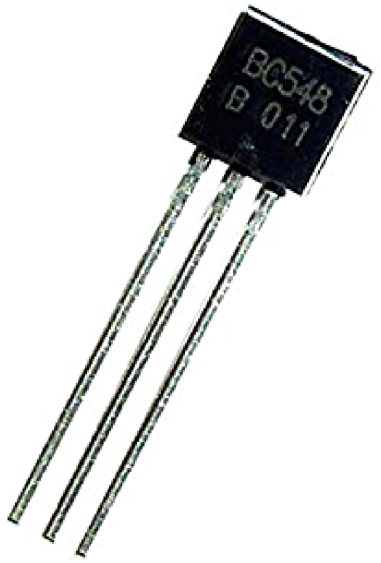


PROJECT OUTLINE

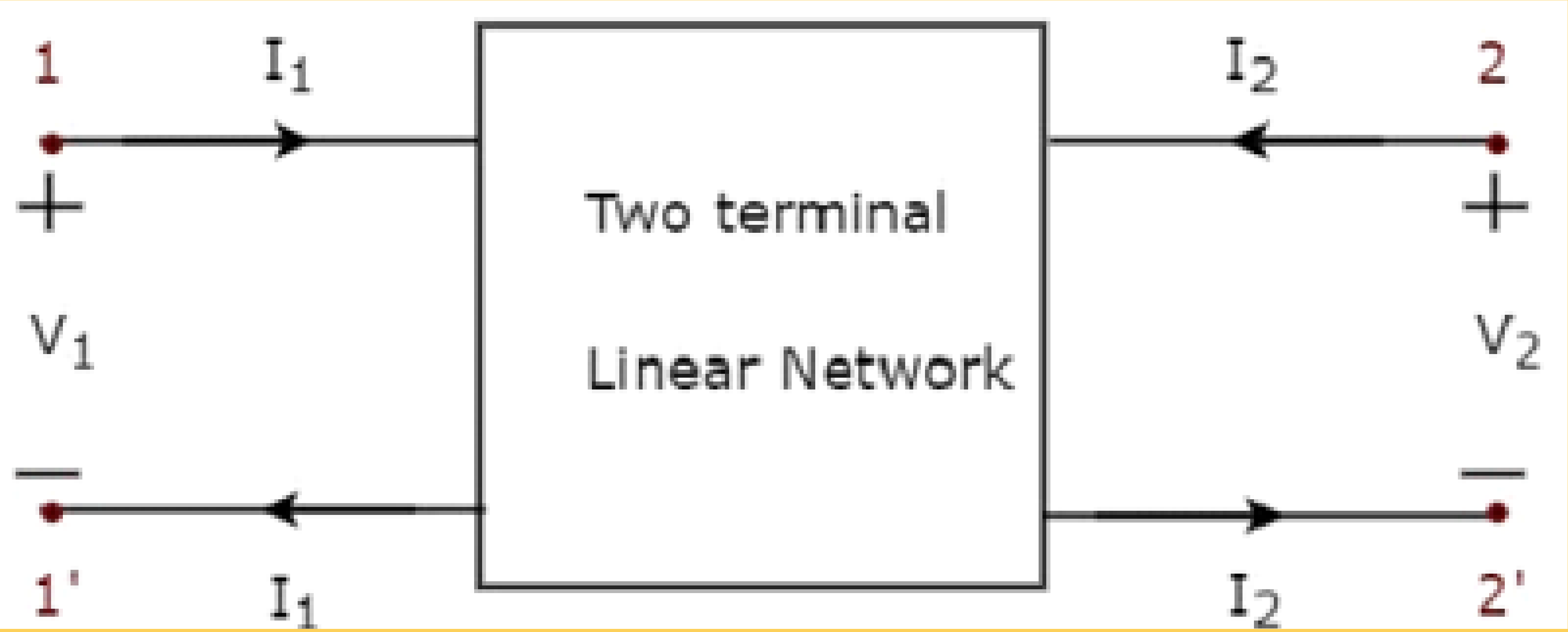
POINTS FOR DISCUSSION

- INTRODUCTION- TWO PORT NETWORKS
- TWO PORT NETWORK PARAMETERS
- APPLICATION
- Two port network analysis for Wireless Power Transfer Systems (WPT)
- SIMULATIONS
- Two port network parameters using Proteus

INTRODUCTION- TWO PORT NETWORKS

- A two port network is an electrical network model with one pair of input terminals and one pair of output terminals.
- Commonly used to model the voltage and current characteristics of complex electrical networks.
- When an electrical signal is applied across the input ports, there would be an electrical signal across output ports.
- The relation between input and output signals of the network can be determined by transferring various network parameters.

- **V1, voltage across port 1.**
- **I1, current into port 1.**
- **V2, voltage across port 2.**
- **I2, current into port 2.**



TWO PORT NETWORKS PARAMETERS

$$z_{11} \stackrel{\text{def}}{=} \left.\frac{V_1}{I_1}\right|_{I_2=0} \qquad z_{12} \stackrel{\text{def}}{=} \left.\frac{V_1}{I_2}\right|_{I_1=0}$$

$$z_{21} \stackrel{\text{def}}{=} \left.\frac{V_2}{I_1}\right|_{I_2=0} \qquad z_{22} \stackrel{\text{def}}{=} \left.\frac{V_2}{I_2}\right|_{I_1=0}$$

Z Parameters

- Also known as impedance parameters.
- The voltages are represented as the function of currents.
- They are also known as open-circuit impedance parameters.

The voltages are represented as-

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} z_{11} & z_{12} \\ z_{21} & z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

Y Parameters

$$y_{11} \overset{\text{def}}{=} \frac{I_1}{V_1}\bigg|_{V_2=0} \qquad y_{12} \overset{\text{def}}{=} \frac{I_1}{V_2}\bigg|_{V_1=0}$$

$$y_{21} \overset{\text{def}}{=} \frac{I_2}{V_1}\bigg|_{V_2=0} \qquad y_{22} \overset{\text{def}}{=} \frac{I_2}{V_2}\bigg|_{V_1=0}$$

- Y parameter of is an admittance matrix.
- Matrix gives the relationship between input, output current and voltage of the network.
- Also known as short circuit admittance parameter.

In Y parameter, the current and voltage related by the following equations,

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix}$$

H PARAMETER

$$h_{11} \stackrel{\text{def}}{=} \left.\frac{V_1}{I_1}\right|_{V_2=0} \qquad h_{12} \stackrel{\text{def}}{=} \left.\frac{V_1}{V_2}\right|_{I_1=0}$$

$$h_{21} \stackrel{\text{def}}{=} \left.\frac{I_2}{I_1}\right|_{V_2=0} \qquad h_{22} \stackrel{\text{def}}{=} \left.\frac{I_2}{V_2}\right|_{I_1=0}$$

- **Also known as hybrid parameters.**
- **Voltage gain, current gain, impedance and admittance are used to determines relation between current and voltage of two port network.**

Hence;

$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$

ABCD PARAMETER

$$A \stackrel{\text{def}}{=} \left.\frac{V_1}{V_2}\right|_{I_2=0} \qquad B \stackrel{\text{def}}{=} -\left.\frac{V_1}{I_2}\right|_{V_2=0}$$

$$C \stackrel{\text{def}}{=} \left.\frac{I_1}{V_2}\right|_{I_2=0} \qquad D \stackrel{\text{def}}{=} -\left.\frac{I_1}{I_2}\right|_{V_2=0}$$

- The ABCD-parameters are known variously as chain, cascade, or transmission line parameters.
- For reciprocal networks A.D-B.C=1.
- For symmetrical networks A=D.

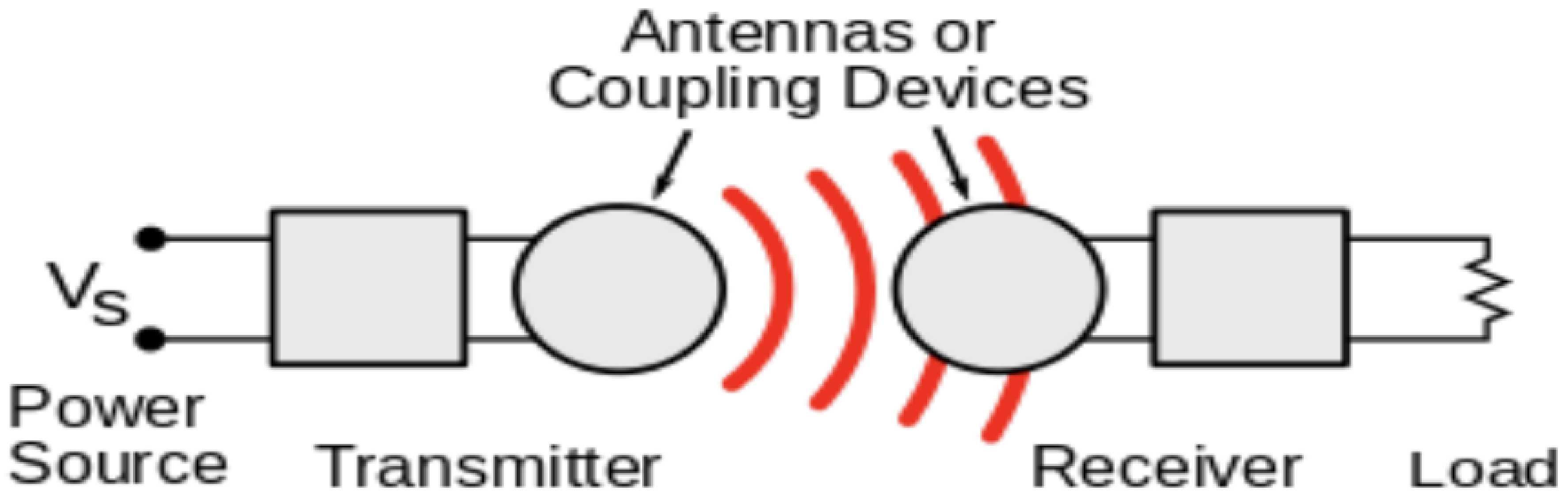
In matrix form it can be written as,

$$\begin{bmatrix} V_1 \\ I_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_2 \\ -I_2 \end{bmatrix}$$

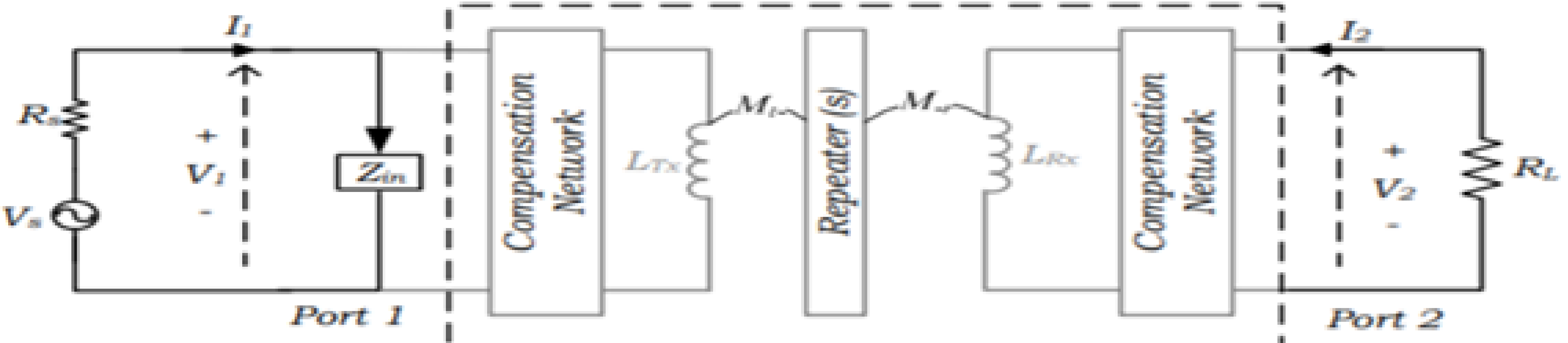
APPLICATION

WIRELESS POWER TRANSFER (WPT) SYSTEMS

- **WPT is transmission of electrical energy without wires as a physical link.**
- **A transmitter device, driven by electric power generates a time-varying electromagnetic field, which transmits power across space to a receiver device.**



- **Regardless of the complexity of the WPT system, any single-Tx – single-Rx WPT system can be represented as a two-port network.**



- The two-port network can be modelled using the impedance parameter matrix where Z11, Z12, Z21, and Z22 are impedance parameters.

$$\begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix}$$

- The input impedance, Zin, seen at port 1, can be determined using,

$$Z_{in} = \frac{V_1}{I_1} = Z_{11} - \frac{Z_{12} Z_{21}}{Z_{22} + R_L}$$

- The input power (Pin) flowing into the two-port network, and the output power (Pout) received at the load are calculated.

$$P_{in} = |I_1|^2 \operatorname{Re}\{Z_{in}\} = \frac{|V_s|^2}{|Z_{in} + R_s|^2} \operatorname{Re}\{Z_{in}\}$$

and

$$P_{out} = |I_2|^2 R_L = \frac{|Z_{21}|^2 |V_s|^2}{|(Z_{in} + R_s)(Z_{22} + R_L)|^2} R_L$$

- The powers Pin, and Pout are dependent on the source voltage, Therefore, a number of gain parameters have been defined to represent normalized performance indices.
- Power gain (Gp), available gain (Ga) and transducer gain (Gt)

$$G_P = \frac{P_{out}}{P_{in}} = PTE$$

$$G_A = \frac{P_{out-\max}}{P_{s-\max}} = \frac{P_{out-\max}}{|V_s|^2/8R_s}$$

$$G_T = \frac{P_{out}}{P_{s-\max}} = \frac{P_{out}}{|V_s|^2/8R_s}$$

- Gp represents power transfer efficiency (PTE) of the WPT systems.

- Gain terms, Ga and Gt represent the maximum available output power (Pout-max) and output power (Pout) at a given operating point normalized to the maximum available input power at the source (Ps-max), respectively.

- The source impedance is negligibly small (i.e., a nearly ideal voltage source).
- Square voltage gain represents the ratio between the output power of the WPT system and the output power when the load is directly connected to the source.

$$PTE = \frac{P_{out}}{P_{in}} = \frac{|Z_{21}|^2}{|Z_{22} + R_L|^2} \frac{R_L}{(R_{in} + R_s)}$$

$$G_{V^2} = \left|\frac{V_2}{V_1}\right|^2 = \frac{|Z_{21}|^2 R_L^{\ 2}}{|(Z_{in} + R_s)(Z_{22} + R_L)|^2}$$

- Therefore, it compares the power capability of the WPT system with the direct wired connection with the source. Hence, the source impedance is neglected for the subsequent analysis.

- The equivalent impedance parameters are written as where rij and xij are the real and imaginary parts, respectively.

$$Z_{11} = r_{11} + jx_{11}, Z_{22} = r_{22} + jx_{22}$$

$$Z_{12} = Z_{21} = r_{12} + jx_{12}$$

- The optimum value of x22 which gives maximum PTE, is computed by equating the derivative to zero, as

$$\frac{\partial(PTE)}{\partial x_{22}} = 0 \rightarrow x_{22,PTE\_\max} = \frac{r_{12}x_{12}}{r_{11}}$$

- The respective maximum PTE is found using-

$$PTE = \frac{r_{11}\left(x_{12}^2 + r_{12}^2\right)R_L}{\left(r_{11}\left(R_L + r_{22}\right) + x_{12}^2\right)\left(r_{11}\left(R_L + r_{22}\right) - r_{12}^2\right)}$$

- For a classical 2-coil WPT, x22 represents the reactive impedance of the Rx coil. Accordingly, for the classical 2-coil WPT, x22,PTE_max is zero, since the value of r12 is made zero for to coincides with the well-known relation of maximum PTE at the resonance frequency of Rx.

- Since, x11 determines the reactive component of the input impedance. Therefore, the value of x11 can be chosen to make Zin purely real,

$$\Im(Z_{in}) = 0 \rightarrow$$

$$x_{11,\Im(Z_{in})=0} = \frac{x_{22}\left(x_{12}^{2} - r_{12}^{2}\right) + 2r_{12}x_{12}\left(R_L + r_{22}\right)}{\left(R_L + r_{22}\right)^2 + x_{22}^{2}}$$

- With the optimal values of x11 and x22, Gv2 reduces to-

$$G_{V^2} = \frac{\left(r_{12}^2 + x_{12}^2\right)\left(r_{12}^2 x_{12}^2 + r_{11}^2\left(R_L + r_{22}\right)^2\right)R_L^2}{\left(x_{12}^2 + r_{11}\left(R_L + r_{22}\right)\right)^2\left(r_{11}\left(R_L + r_{22}\right) - r_{12}^2\right)^2}$$

- The optimal load which gives maximum efficiency can be derived as-

$$R_{22,PTE\_max} = \frac{\sqrt{\left(r_{11}r_{22} + x_{12}^2\right)\left(r_{11}r_{22} - r_{12}^2\right)}}{r_{11}}$$

- If the load is assumed to be at its optimal value, the maximum efficiency (PTEmax) can be derived as-

$$PTE_{max} = 1 - \frac{2}{1 + \sqrt{1 + \left(\frac{x_{12}^2 + r_{12}^2}{r_{11}r_{22} - r_{12}^2}\right)}}$$

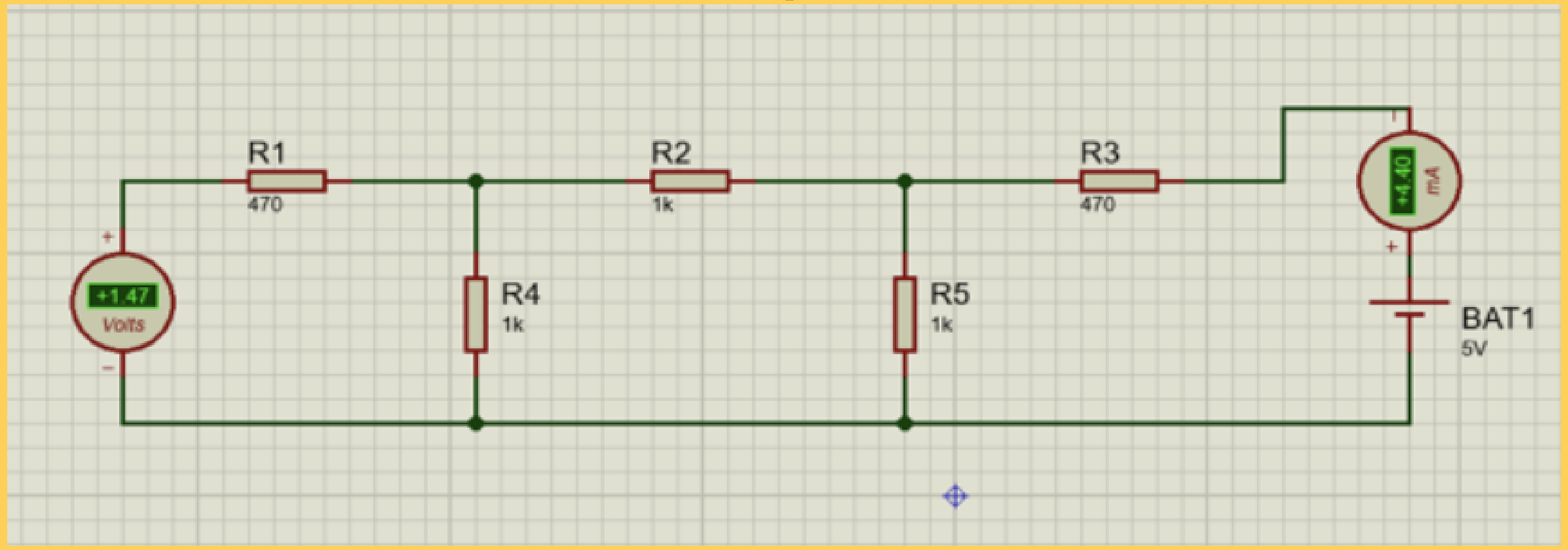
CONCLUSION

- It is observed from the above equations that GV2 is monotonically increasing with the increase of load resistance.
- Therefore, in terms of high Gv2, higher load resistance is always better. However, in practice, it is not required to maximize the voltage ratio.
- Instead, it is only required to keep the voltage ratio at a realistic value close to unity.
- One cannot maximize both PTE and the voltage ratio at the same time. The maximum efficiency condition may result in a lower voltage ratio.
- Therefore, a balance between PTE and GV2 should be considered.

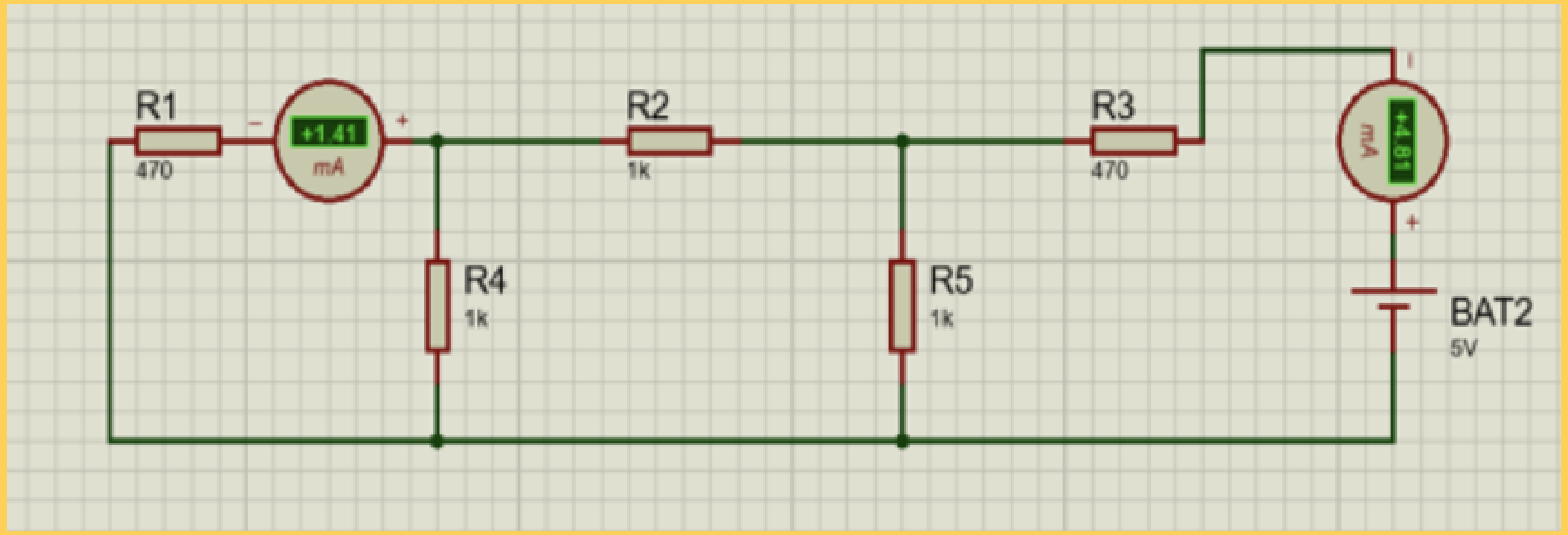
SIMULATIONS

Two port network parameters using Proteus

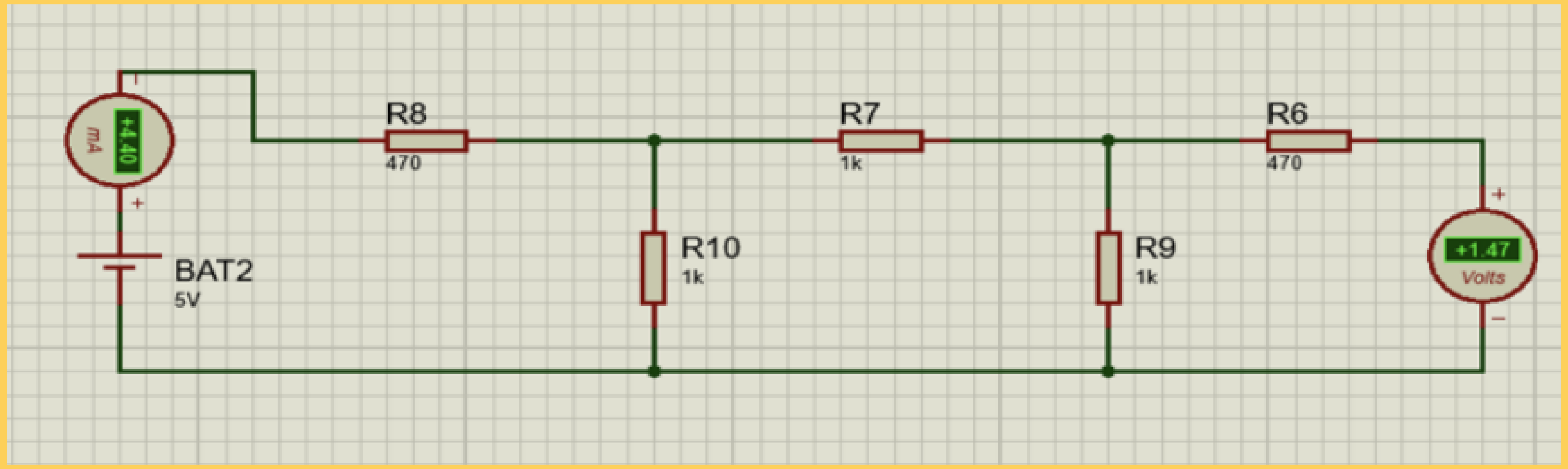
Z Parameter I/P is Open circuit



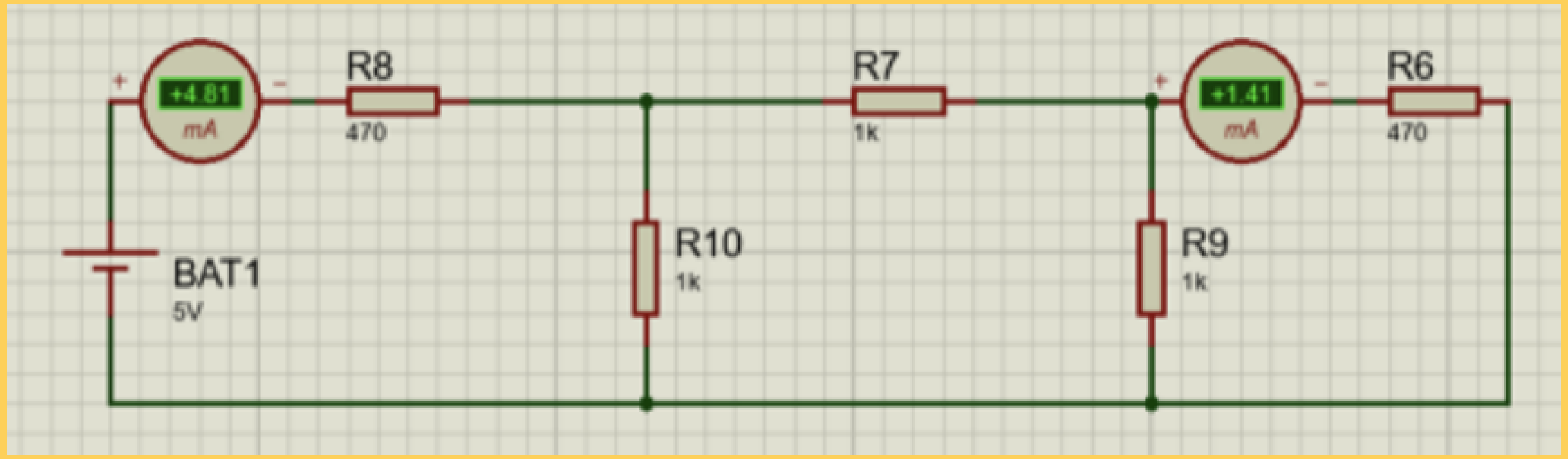
Y Parameter I/P is Short Circuit



Z Parameter O/P is Open circuit



Y Parameter O/P is Short Circuit



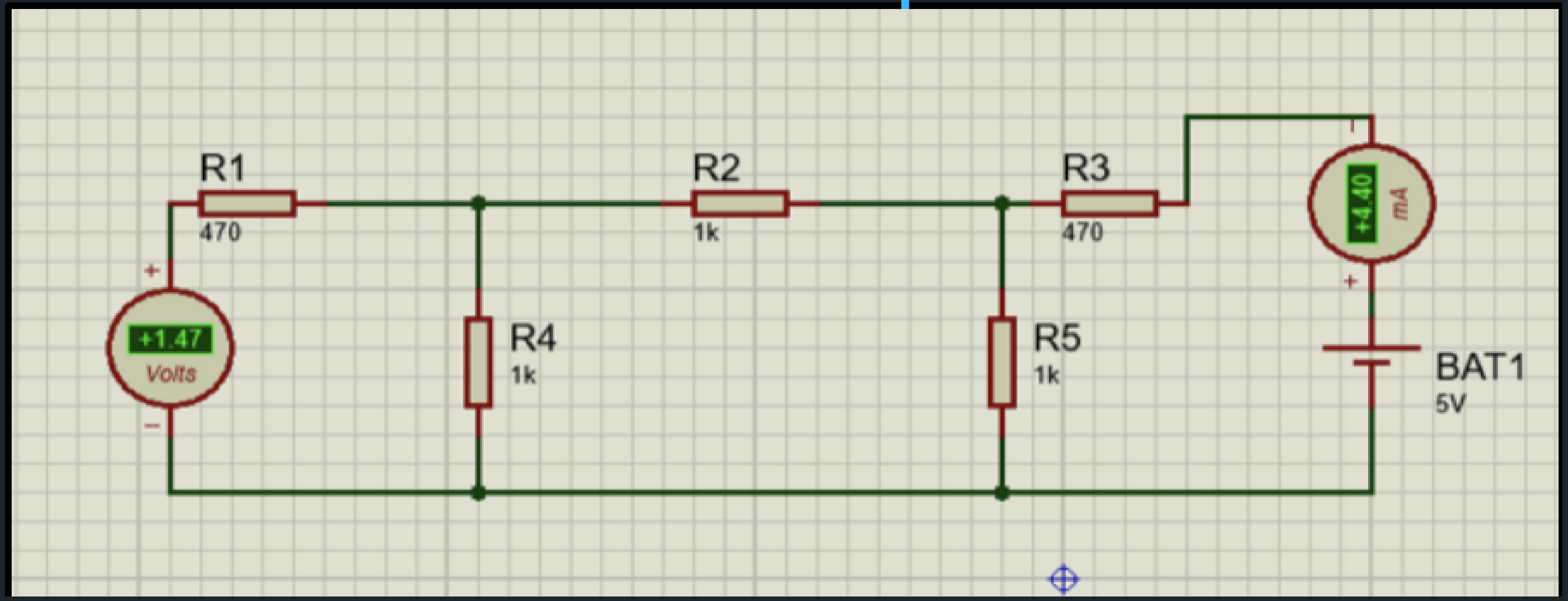
I/P Open Circuit			O/P Open Circuit		
V2	V1	I2	V2	V1	I1
5 V	1.47 V	4.40 mA	1.47 V	5 V	4.40 mA

Z11	Z12	Z21	Z22
1136.7	334.1	334.1	1136.7

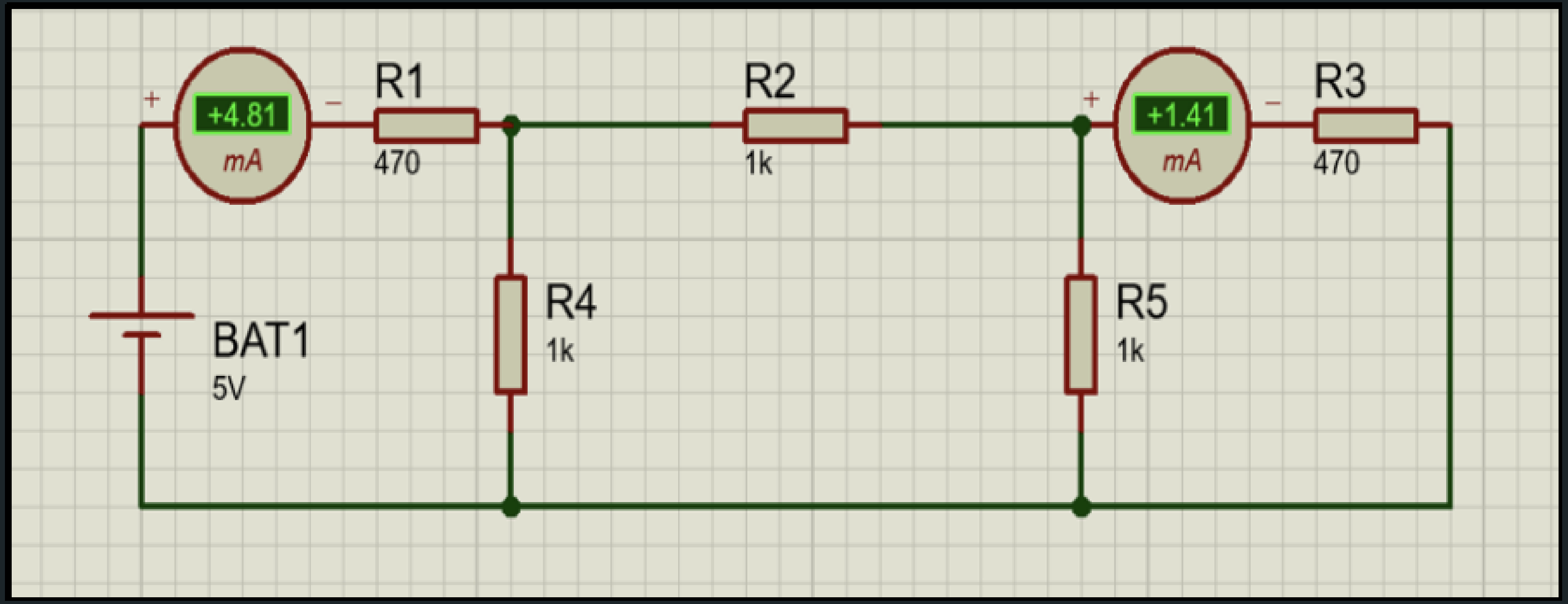
I/P Short Circuit			O/P Short Circuit		
V2	I1	I2	V1	I1	I2
5 V	1.41 mA	4.81 mA	5 V	4.81 mA	1.41 mA

Y11	Y12	Y21	Y22
9.62*10^-4	2.82*10^-4	2.82*10^-4	9.62*10^-4

H Parameter I/P is Open circuit



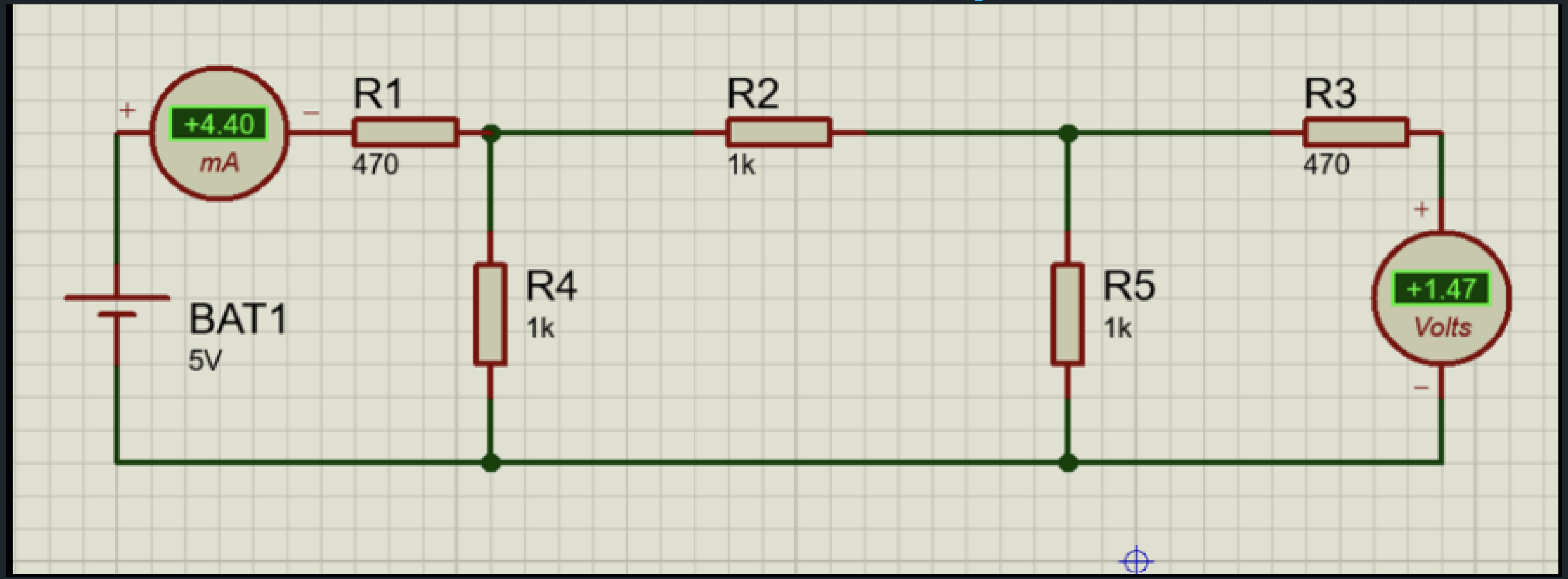
H Parameter O/P is Short circuit



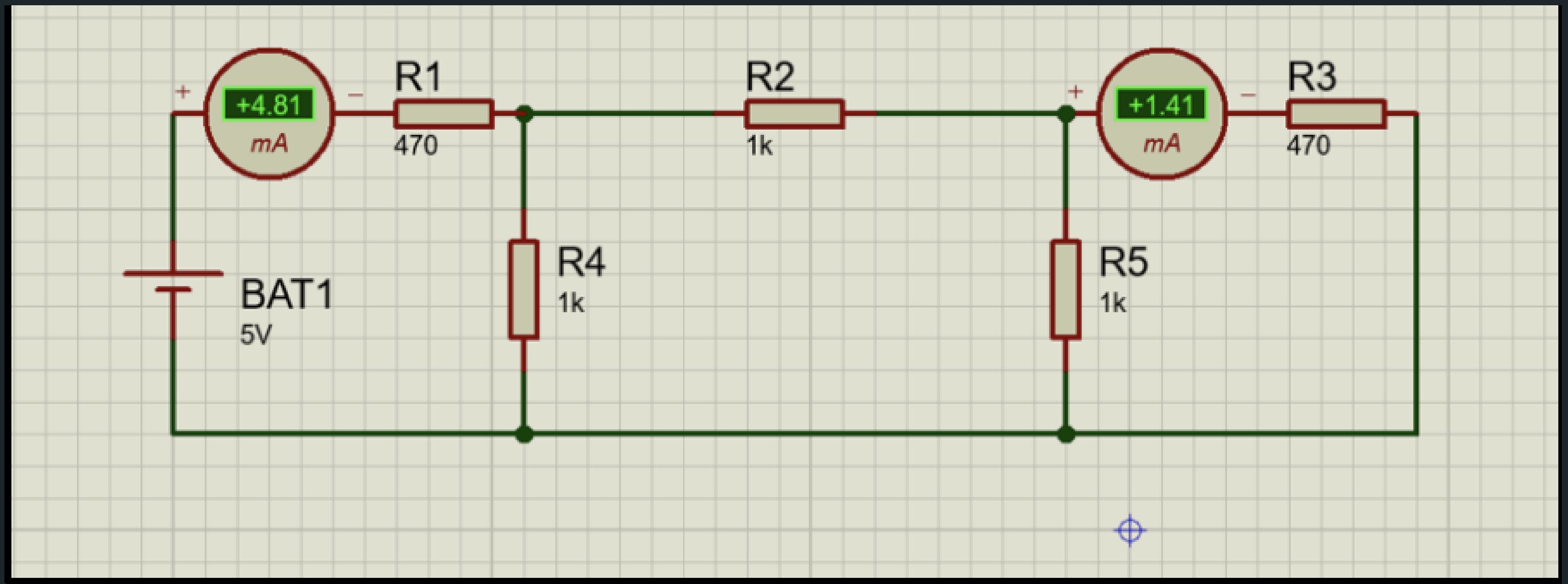
I/P Open Circuit			O/P Short Circuit		
V1	V2	I2	V1	I1	I2
1.47 V	5 V	4.40 mA	5 V	4.81 mA	1.41 mA

H11	H12	H21	H22
1039.5	0.294	0.2931	8.8*10^-4

ABCD Parameter O/P is Open Circuit



ABCD Parameter O/P is Short Circuit



O/P Open Circuit			O/P Short Circuit		
V1	V2	I1	V1	I1	I2
5 V	1.47 V	4.40 mA	5 V	4.81 mA	1.41 mA

A	B	C	D
3.401	-3546.1	2.993*10^-3	-3.411

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