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Experiment 1-B
Reciprocity Theorem

Aim: To verify the reciprocity theorem.

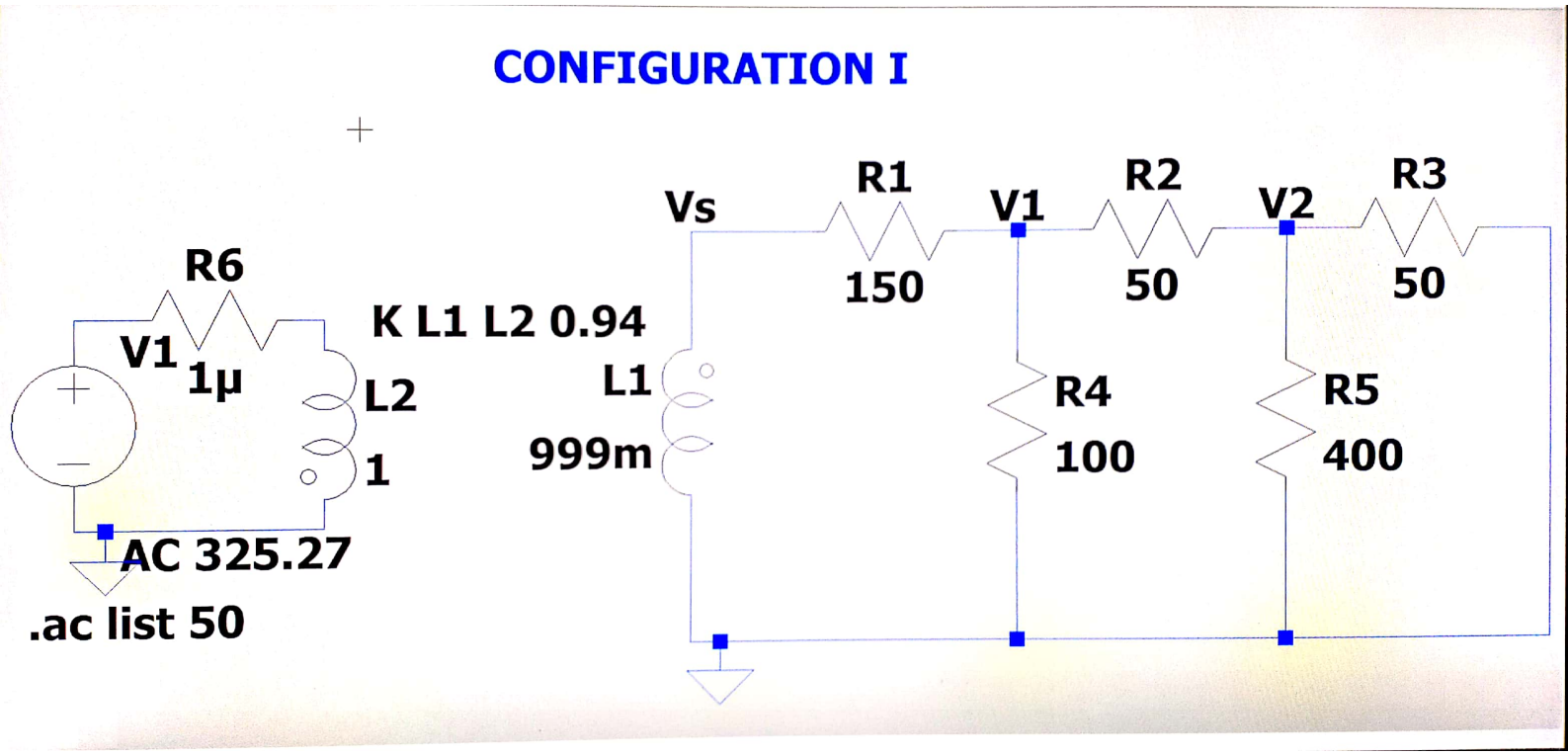
Theory: Consider 2-port (4-terminal) linear bilateral passive networks. Apply a voltage V_s accross the first two terminals, say 1-1' and hence a current I flows through the shorted other two terminals say 2-2'. Next interchange the positions of the ammeter and the source voltage. The magnitude of the sourcd voltage in the new position is set to V_s' and the corresponding current is I'.
The reciprocity theorem states that for passive bilateral network,

$$\frac{V_s}{I} = \frac{V_s'}{I'}$$

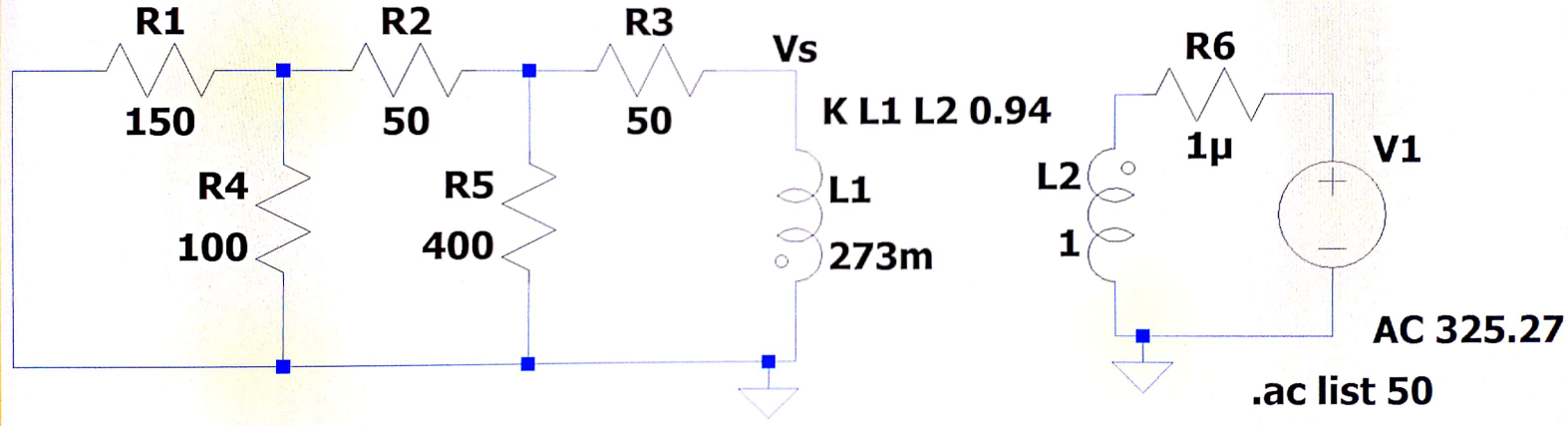
LTSpice Circuit Diagrams:

The diagrams for this experiment follows from the next page.

Note that the currents flowing throw R_1, R_2, R_3, R_4 and R_5 are labelled as I_1, I_2, I_3, I_4, I_5 and as I_1', I_2', I_3', I_4', I_5' in the first and the second configuration respectively, for the entire report.



CONFIGURATION II



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Observation Table:

(V_s: input voltage in Config 1; V_s': in Config 2)

S.No.	V_s (V)	I_3 (mA)	V_s/I_3	V_s' (V)	I_1' (mA)	V_s'/I_1'
01.	212.52	489	0.435	112.67	259	0.435
02.	186.66	430	0.434	161.89	373	0.434
03.	170.46	392	0.435	187.11	431	0.434

Inference / Sample Calculations:

In the observation table, for almost all the readings the ratio V_s/I_3 was observed equal to V_s'/I_1'. This verifies the reciprocity theorem.

I Configuration 1 - when voltage source is connected to 1-1' and ammeter to 2-2'.

$$R_{eff} = R_1 + (R_4 \,||\, (R_2 + R_3 \,||\, R_5))$$

$$= R_1 + R_4 \,||\, \left(R_2 + \frac{R_3 \cdot R_5}{R_3 + R_5}\right)$$

$$= 150 + 100 \,||\, \left(50 + \frac{50 \cdot 400}{50 + 400}\right)$$

$$= 150 + 100 \,||\, 94.44 = 198.57\ \Omega$$

I_1 = 212.52 / 198.57

(∵ by ohm's law, $I_1 = V_s / R_{eff}$)

= 1.07 A.

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$$I_2 = I_1 \times \frac{100}{100 + 50 + 400 \| 50}$$

$$= I_1 \times 0.514 = 0.55\ A$$

$$I_4 = I_1 - I_2 = 0.52\ A.$$

$$I_3 = I_2 \times \frac{400}{400 + 50} = 0.49\ A$$

$$I_5 = I_2 - I_3 = 0.06\ A.$$

$V_1 = V_S - R_1 I_1$ (junction of R_1, R_2, R_4)
$= 212.52 - 150 \times 1.07 = 52.02\ V$

$V_2 = V_1 - R_2 I_2$ (junction of R_2, R_3, R_5)
$= 52.02 - 50 \times 0.55 = 24.52\ V$

★ $I_1 = 1.07\ A$, $I_2 = 0.55\ A$, $I_3 = 0.49\ A$
$I_4 = 0.52\ A$, $I_5 = 0.06\ A$
$V_1 = 52.02\ V$, $V_2 = 24.52\ V$.

II Configuration 2 - when voltage source is connected to 2-2' and ammeter to 1-1'.

$$R'_{eff} = R_3 + (R_5 \| (R_2 + (R_1 \| R_4)))$$

$$= 50 + \left(400 \| \left(50 + \frac{150 \cdot 100}{150 + 100}\right)\right)$$

$$= 50 + 400 \| 110 = 136.27\ \Omega$$

$I_3' = V_{S'} / R'_{eff}$ (by ohm's law)
$= 112.67 / 136.27 = 0.83\ A$

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$I_3' = I_3' \times \frac{400}{480 + 50 + 100 \parallel 150}$

$= I_3' * 0.784 =$ ~~1.11A~~ $0.65\,A$

$I_5' = I_3' - I_2' =$ ~~0.31A~~ $0.18\,A$

$I_1' = I_2' \times \frac{100}{100 + 150}$

$= I_2' \times 0.4 = 0.26\,A$

$I_4' = I_2' - I_1' = 0.39\,A$

$V_3 = V_5' - R_3 I_3'$ (junction of R_2, R_3, R_5)
$= 112.67 - 50 \times 0.83 = 71.17\,V$

$V_4 = V_3 - R_2 I_2'$ (junction of R_1, R_2, R_4)
$= 71.17 - 50 \times 0.65 = 38.67\,V$

$I_1' = 0.26\,A$, $I_2' = 0.65\,A$ $I_3' = 0.83\,A$
$I_4' = 0.39\,A$, $I_5' = 0.18\,A$
$V_3 = 71.17\,V$, $V_4 = 38.67\,V$

Discussion: The values of the ratios V_5/I_3 and V_5'/I_1' are very similar for all the readings recorded in the table. Therefore the experiment was successful in verifying the reciprocity theorem. Besides, the values of branch currents for the two configurations corresponding to the first reading were calculated theoretically using ohm's law.

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and Kirchhoff's rules. The values of the branch currents I_3 and I_1' were extremely close to the values that were predicted theoretically through calculations.