Electrical Engineering Fundamentals I Lab

Laboratory 6
Input/Output Resistance and Δ-Y Conversion

Instructor

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Equipment

- DC Power Supply
- Digital Multimeter
- Components

a. 1.1 kΩ ×2, 2.2 kΩ×2, 3.3 kΩ×2, Variable Resistor R_T ×1

b. 1 kΩ ×2, 3 kΩ ×4, 6 kΩ ×1

Learning Objectives

- To learn to use the "proportional measurement method" for input and output resistance measurement
- To learn the experimental measurement for Wheatstone bridge and the analysis and application of Δ-Y Conversion

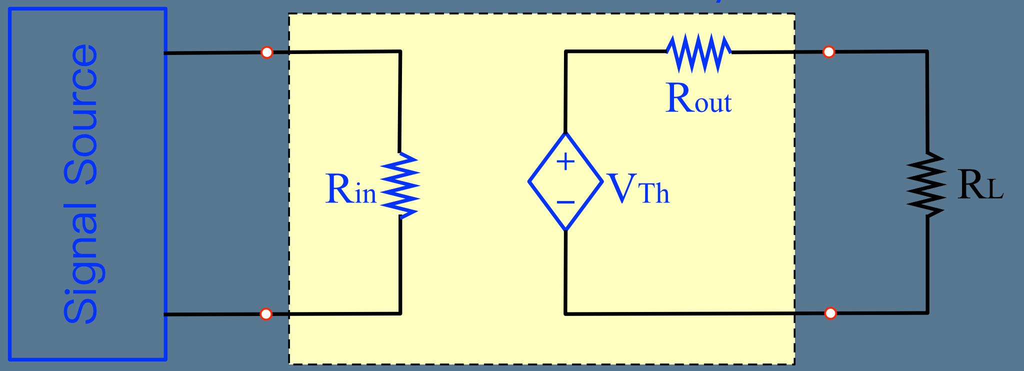
Background

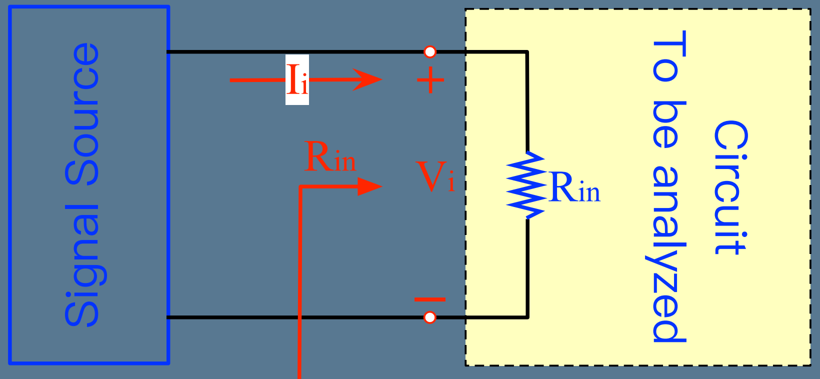
Input/Output Resistance Measurement

By Definition

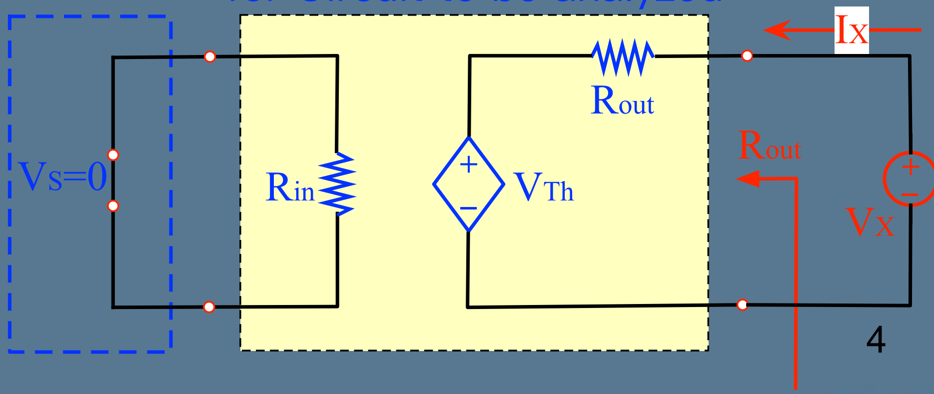
- **Input Resistance Measurement**
  - Measure the current I_i flow into the circuit, and the voltage V_i across the circuit.
  - $R_{in} = {}^{V_i}/_{I_i}$
- **Output Resistance Measurement**
  - Turn off the voltage source (V_S=0), and leave R_L open
  - Measure output current I_X & output voltage V_X.
  - $R_{out} = {}^{V_X}/_{I_X}$

Equivalent Circuit
for Circuit to be analyzed





Equivalent Circuit
for Circuit to be analyzed



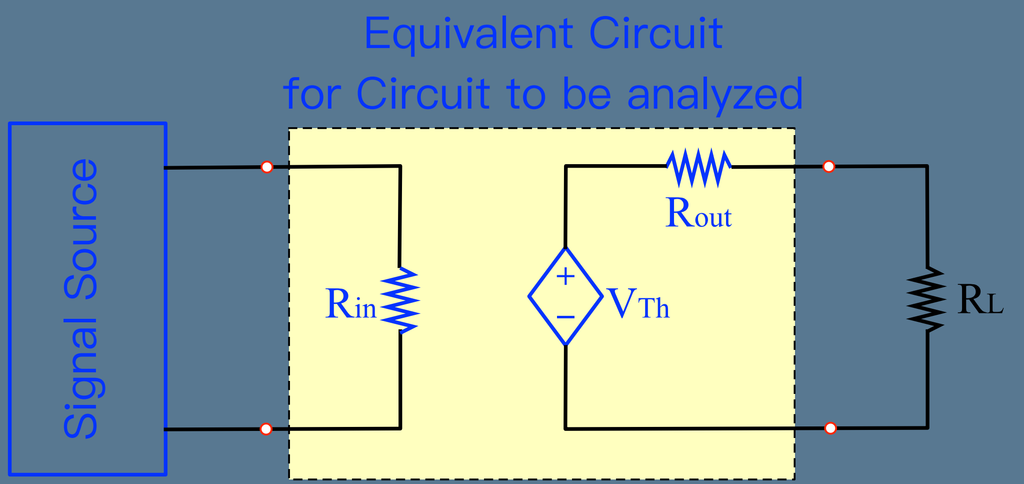
Background

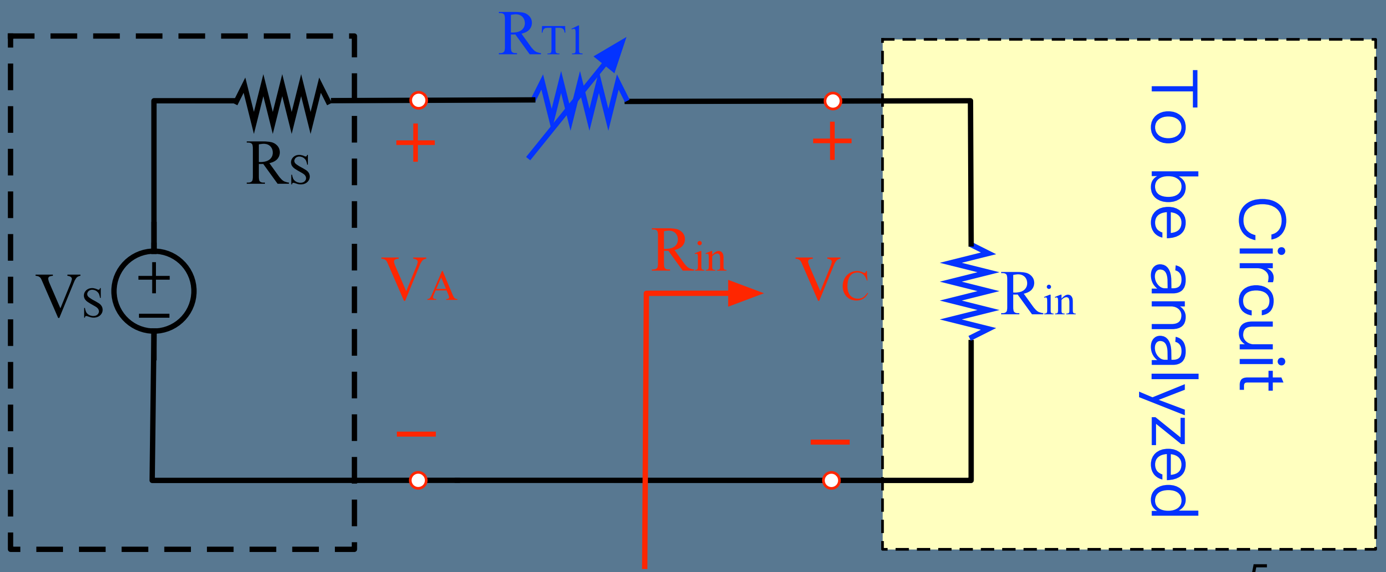
Input/Output Resistance Measurement

Proportional Method

■ Input Resistance Measurement

- Connect a variable resistor (R_{T1}) in series
- Adjust R_{T1} until $V_C = \frac{1}{2} V_A$
- Measure $R_{T1} \Rightarrow R_{in} = R_{T1}$





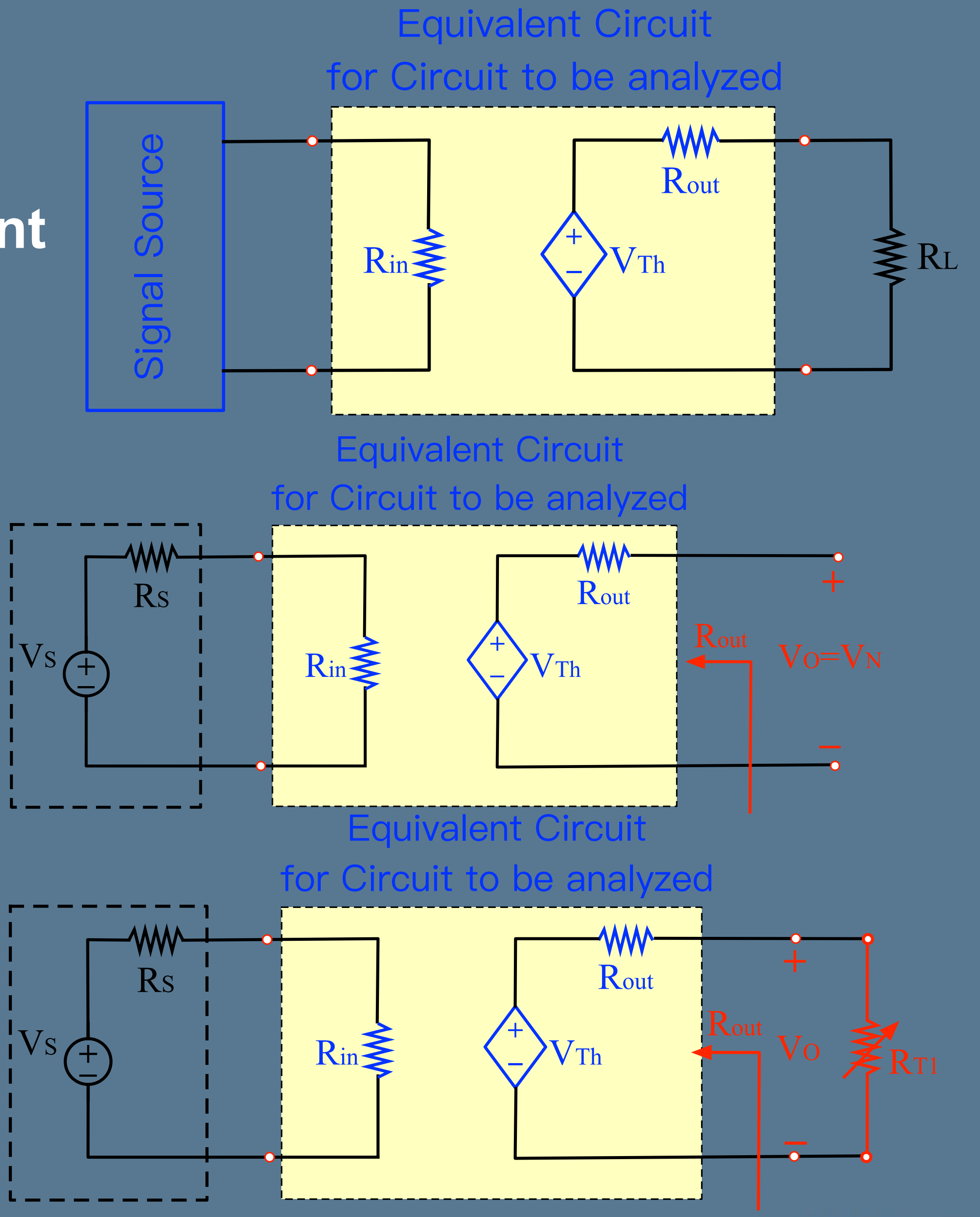
Background

Input/Output Resistance Measurement

Proportional Method

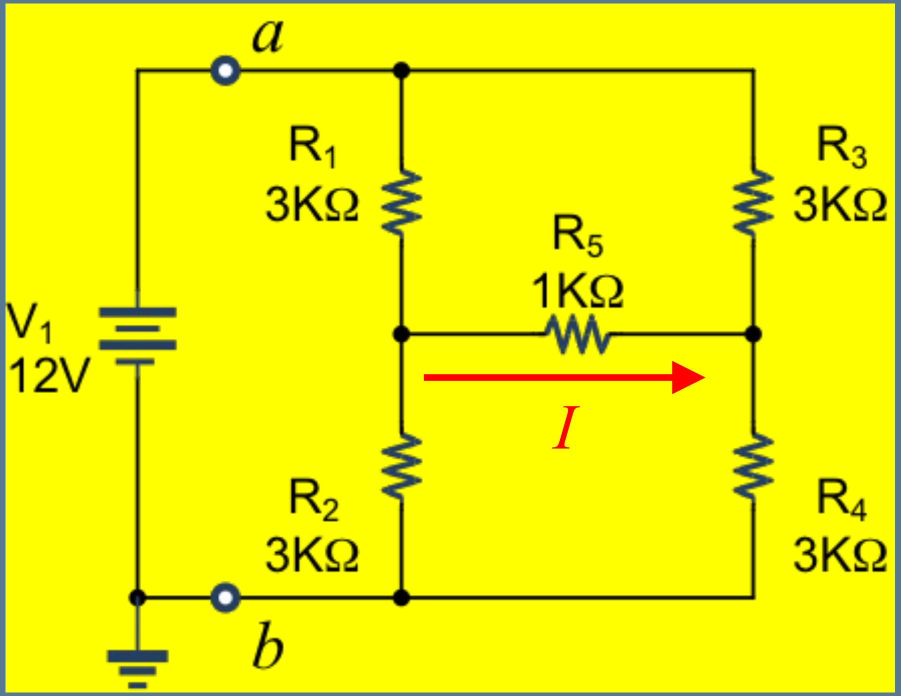
■ Output Resistance Measurement

- With Vs applied, set $R_L = \infty$ (open circuit)
- measure output voltage Vo and set it to be V_N
- Connect R_{T1} in series as output load
- Adjust R_{T1} until $V_O = ½\, V_N$
- Measure $R_{T1} \Rightarrow R_{out} = R_{T1}$



Background

Wheatstone bridge

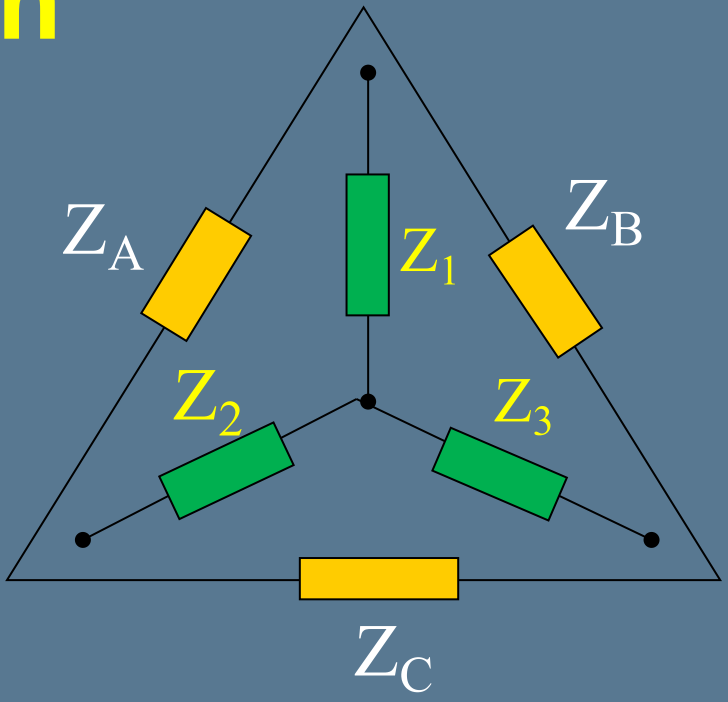


- The Wheatstone bridge circuit is often used in a sensor circuit application.
- Once the unbalance is occurred within the bridge, the current, whose amount depends on the amplitude of the unbalance, will flow through the branch that connecting the bridge.

Background

Δ-Y Conversion

$$\begin{cases} Z_1 = \dfrac{Z_A \cdot Z_B}{Z_A + Z_B + Z_C} \\ Z_2 = \dfrac{Z_A \cdot Z_C}{Z_A + Z_B + Z_C} \\ Z_3 = \dfrac{Z_B \cdot Z_C}{Z_A + Z_B + Z_C} \end{cases}$$



$$\begin{cases} Z_A = \dfrac{Z_1 \cdot Z_2 + Z_2 \cdot Z_3 + Z_3 \cdot Z_1}{Z_3} \\ Z_B = \dfrac{Z_1 \cdot Z_2 + Z_2 \cdot Z_3 + Z_3 \cdot Z_1}{Z_2} \\ Z_C = \dfrac{Z_1 \cdot Z_2 + Z_2 \cdot Z_3 + Z_3 \cdot Z_1}{Z_1} \end{cases}$$

Experiments

Experiment 6

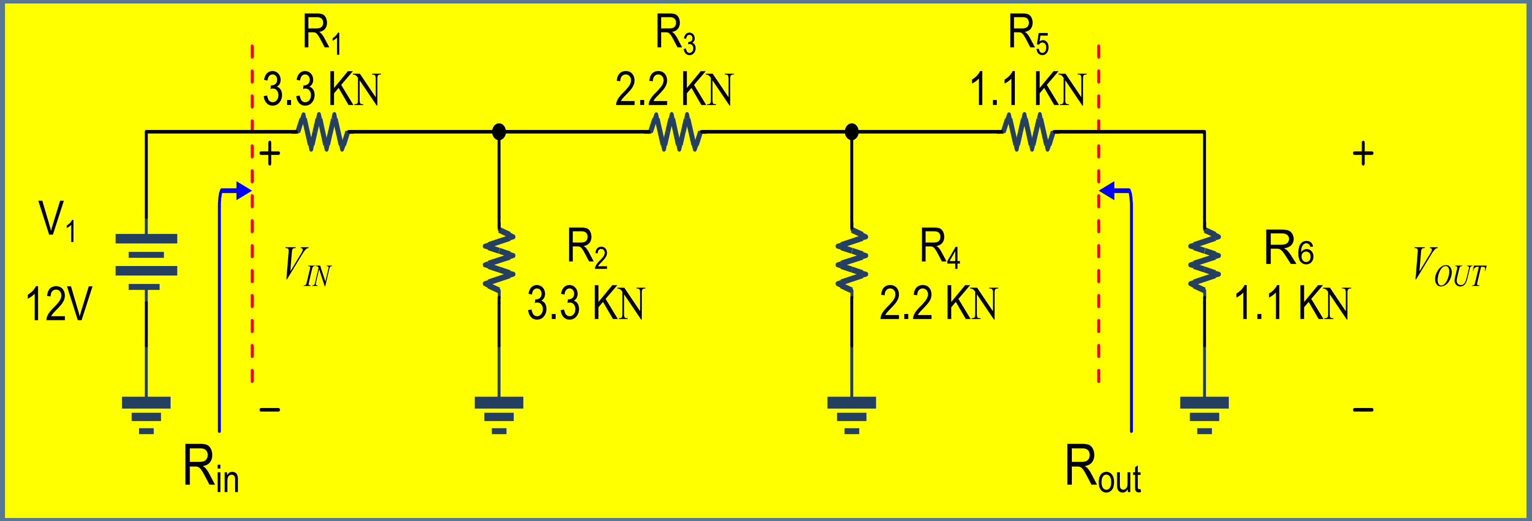
Input/Output Resistance Measurement
& Δ-Y Conversion

- **Experiment 6.a**
  Input/Output Resistance Measurement
- **Experiment 6.b**
  Δ-Y Conversion

Experiment 6.a
Input/Output Resistance Measurement
6.a.1 Input Resistance

- Determine the input resistance R_{in} of the circuit with Proportional Method
- Determine the input resistance R_{in} with direct measurement
- Calculate the input resistance R_{in} of by theorem
- Compare the results with % error

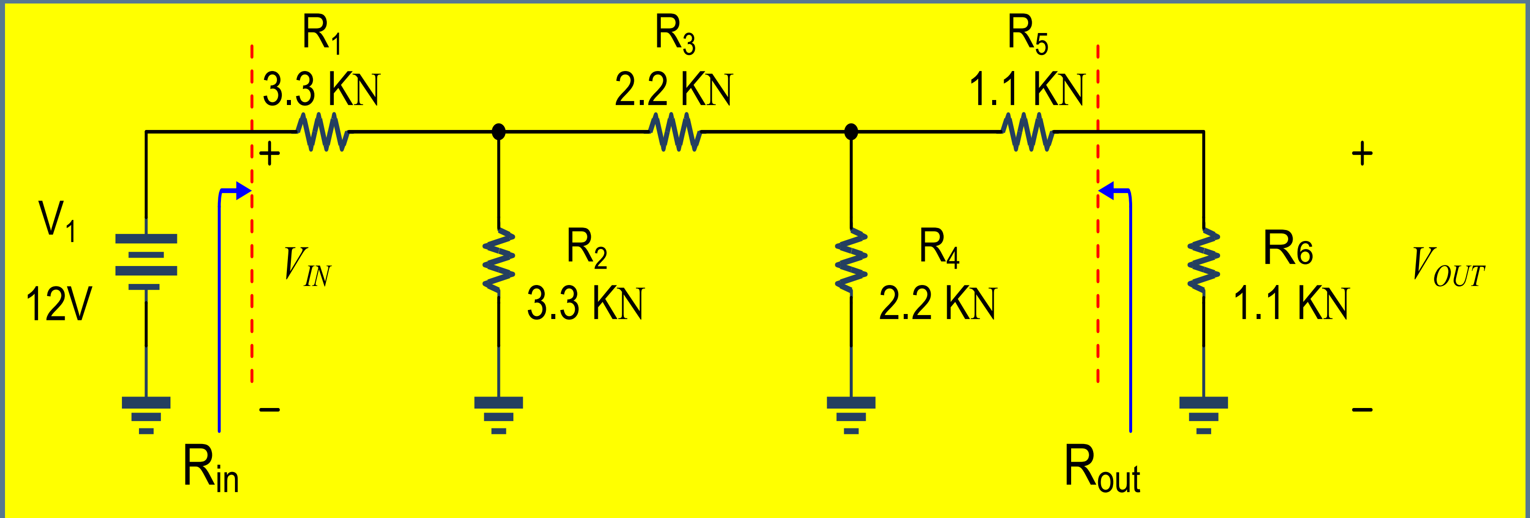
$$
\begin{cases}
R_1 = & 3.3\ k\Omega \\
R_2 = & 3.3\ k\Omega \\
R_3 = & 2.2\ k\Omega \\
R_4 = & 2.2\ k\Omega \\
R_5 = & 1.1\ k\Omega \\
R_6 = & 1.1\ k\Omega
\end{cases}
$$



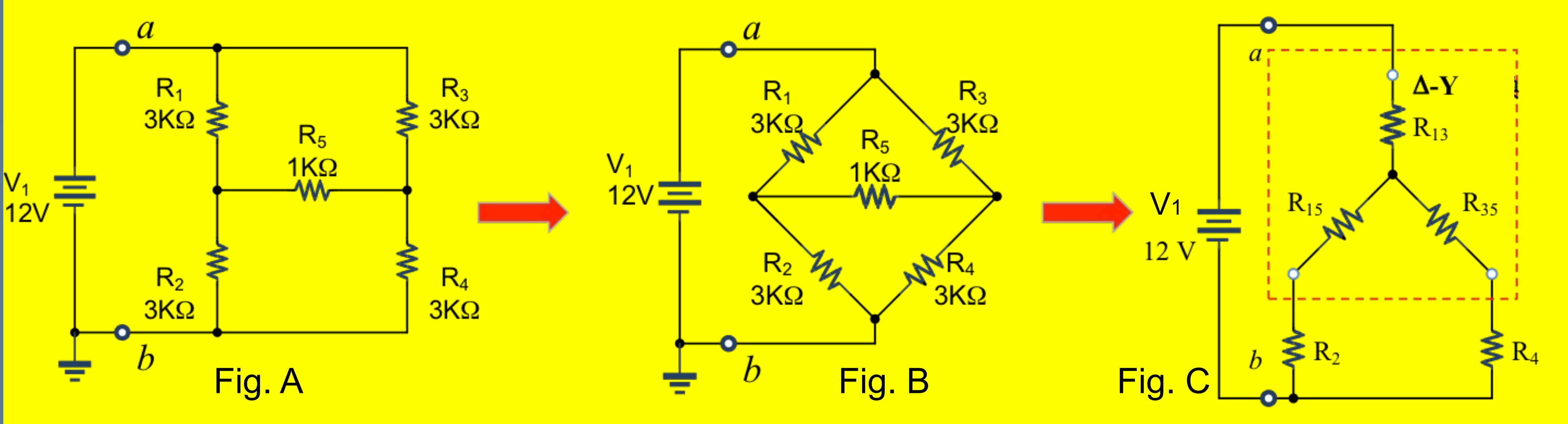
Experiment 6.a
Input/Output Resistance Measurement
6.a.2 Output Resistance

- Determine the output resistance R_{out} of the circuit with Proportional Method
- Determine the input resistance R_{out} with direct measurement
- Calculate the input resistance R_{out} of by theorem
- Compare the results with % error

$$\begin{cases} R_1 = & 3.3\ k\Omega \\ R_2 = & 3.3\ k\Omega \\ R_3 = & 2.2\ k\Omega \\ R_4 = & 2.2\ k\Omega \\ R_5 = & 1.1\ k\Omega \\ R_6 = & 1.1\ k\Omega \end{cases}$$



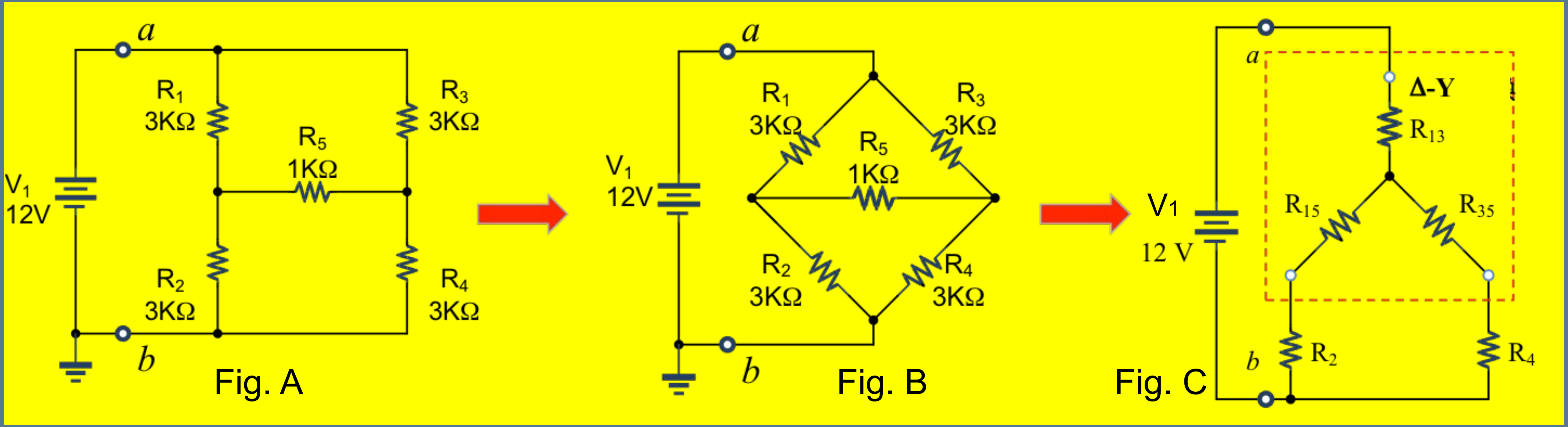
Experiment 6.b Δ-Y Conversion



I. Based on Direct Measurement

1. Use the specified resistors to set up the circuit of Fig. A. V_1=12 V, $R_1 = R_2 = R_3 = R_4 = 3k\Omega$, $R_5 = 1k\Omega$
2. Measure the practical resistance of the resistors:
   R_1 = ______ R_2 = ______ R_3 = ______ R_4 = ______ R_5 = ______.
3. Measure the equivalent resistance of R_{ab} with DMM

Experiment 6.b Δ-Y Conversion



II. Based on Theoretical Calculation

1. Apply Δ-Y Conversion, convert Fig. A & B, into Fig. C.
2. Calculate the resistances of the equivalent circuit in Fig. C:

   R_{13} = ________ R_{15} = ________ R_{35} = ________.

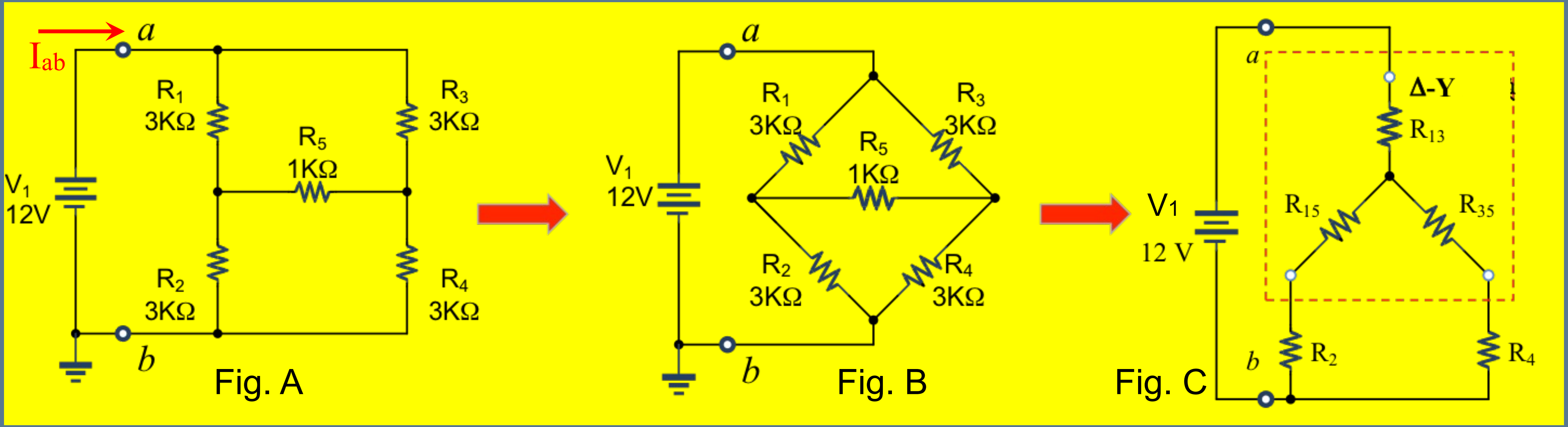
3. Calculate the equivalent resistance of R_{ab} with different R_4

   a. $R_4 = 1$ kΩ, R_{ab} = ________ ;

   b. $R_4 = 3$ kΩ, R_{ab} = ________ ;

   c. $R_4 = 6$ kΩ, R_{ab} = ________ .

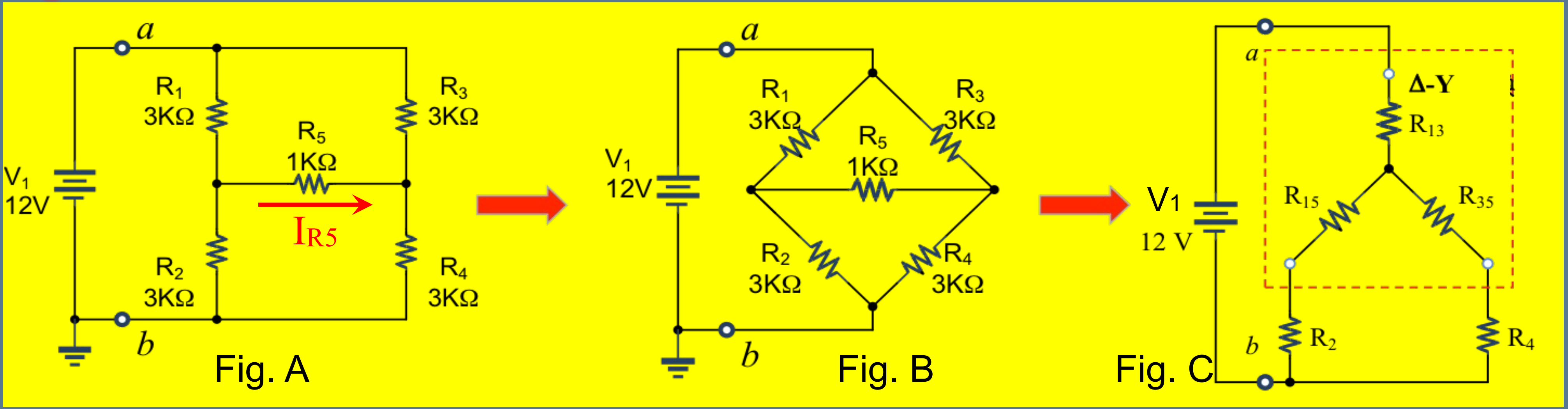
Experiment 6.b Δ-Y Conversion



III. Based on Current-Voltage Measurement

1. Connect an Ammeter in series with node-a of Fig. A to measure the current I_{ab} based on different R_4.
2. Based on the definition of $R_{ab} = V_1/I_{ab}$, calculate the resulted R_{ab}
   a. $R_4 = 1$ kΩ, $I_{ab} =$ __________ ; $R_{ab} = V_1/I_{ab} =$ __________ ;
   b. $R_4 = 3$ kΩ, $I_{ab} =$ __________ ; $R_{ab} = V_1/I_{ab} =$ __________ ;
   c. $R_4 = 6$ kΩ, $I_{ab} =$ __________ ; $R_{ab} = V_1/I_{ab} =$ __________ .

Experiment 6.b Δ-Y Conversion



IV. Bridge Current Measurement

1. Connect an Ammeter in series with R_5 of Fig. A to measure the bridge current I_{R5} based on different R_4.
   a. $R_4 = 1\text{k}\Omega$, $I_{R5} =$ __________ ;
   b. $R_4 = 3\text{k}\Omega$, $I_{R5} =$ __________ ;
   c. $R_4 = 6\text{k}\Omega$, $I_{R5} =$ __________ .
2. Apply Thevenin's beyond R_5 and use the equivalent circuit to calculate for I_{R5} with different R_4, and compare the results with Step 1 for % error.
3. Discuss your results of I~IV with tabulated data.