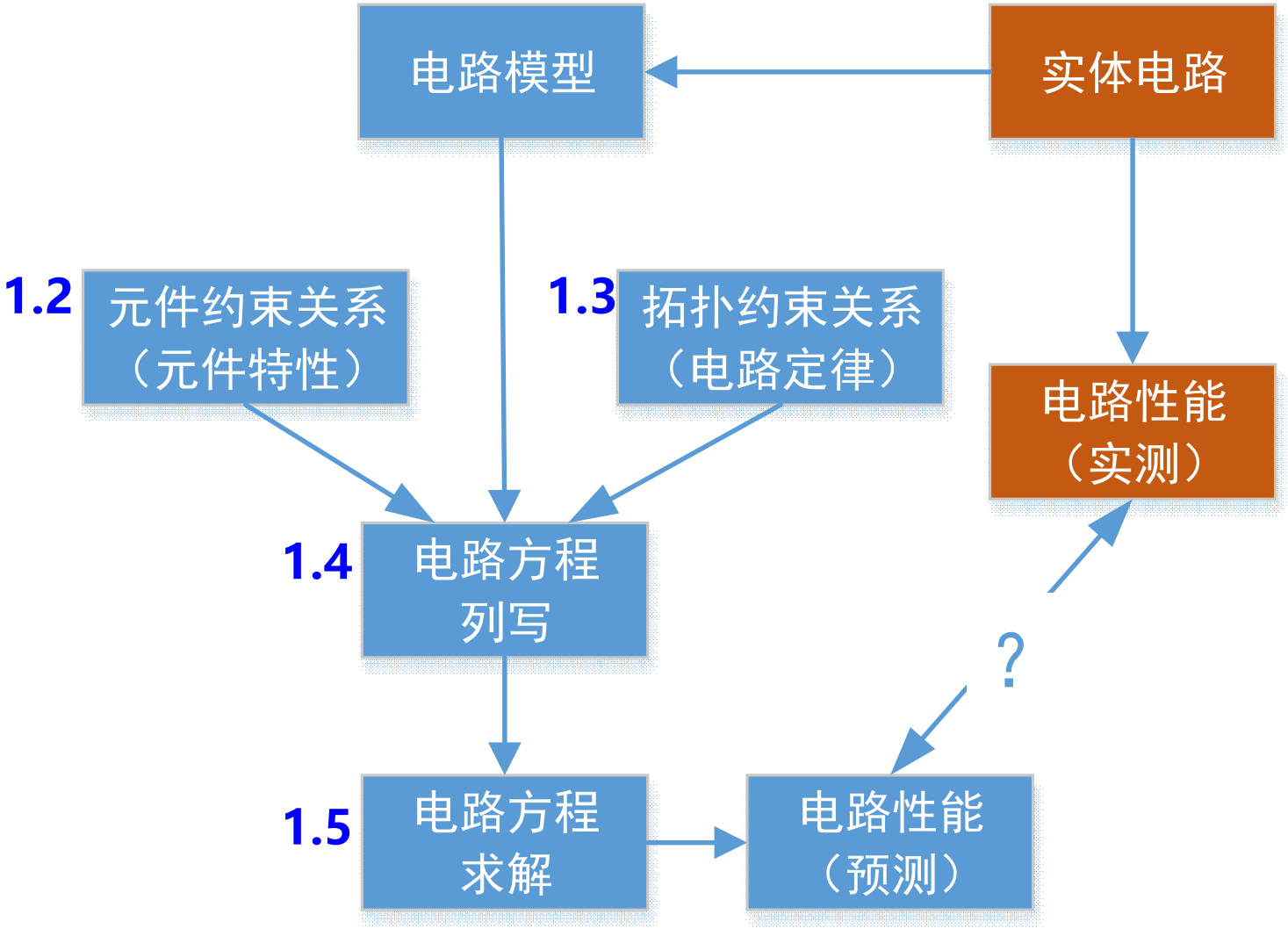
第一章 电路分析方法

1.5 线性电阻电路分析

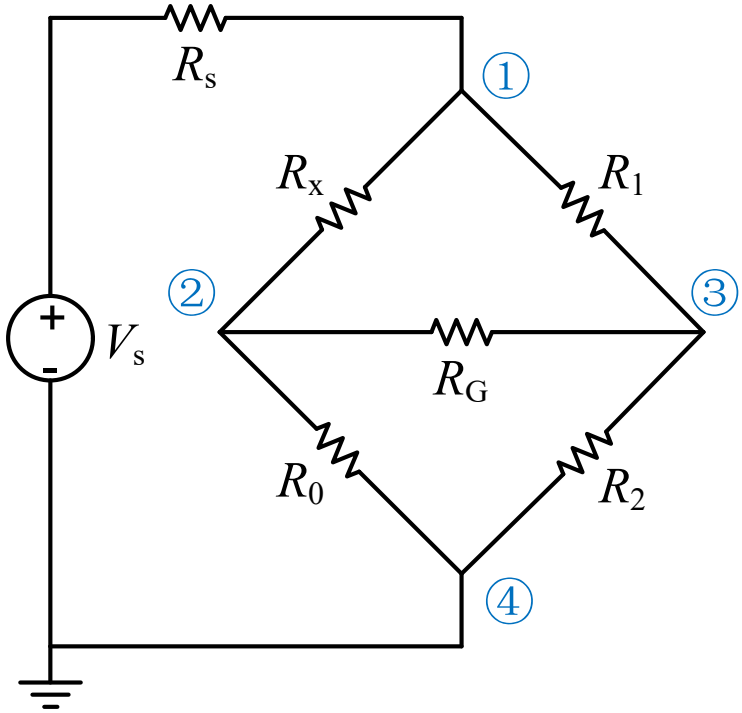
线性电阻电路分析

- Wheatstone bridge circuit
- 惠斯通电桥分析
- 惠斯通电桥应用
- 惠斯通电桥仿真


电路模型
实体电路
1.2
元件约束关系
（元件特性）
1.3
拓扑约束关系
（电路定律）
电路性能
（实测）
1.4
电路方程
列写
?
1.5
电路方程
求解
电路性能
（预测）

惠斯通电桥分析

- 线性电阻电路
  - 由线性电阻与独立电源组成
- 电路变量 V_1 V_2 V_3
- 节点分析法得到电路方程



$$\begin{bmatrix} \frac{1}{R_s}+\frac{1}{R_x}+\frac{1}{R_1} & -\frac{1}{R_x} & -\frac{1}{R_1} \\ -\frac{1}{R_x} & \frac{1}{R_x}+\frac{1}{R_G}+\frac{1}{R_0} & -\frac{1}{R_G} \\ -\frac{1}{R_1} & -\frac{1}{R_G} & \frac{1}{R_2}+\frac{1}{R_G}+\frac{1}{R_1} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} V_s / R_s \\ 0 \\ 0 \end{bmatrix}$$

惠斯通电桥分析

- 惠斯通电桥电路方程
- 改用电导表示 $G = \frac{1}{R}$

$$\begin{bmatrix} G_s + G_x + G_1 & -G_x & -G_1 \\ -G_x & G_x + G_G + G_0 & -G_G \\ -G_1 & -G_G & G_2 + G_G + G_1 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} V_s / R_s \\ 0 \\ 0 \end{bmatrix}$$

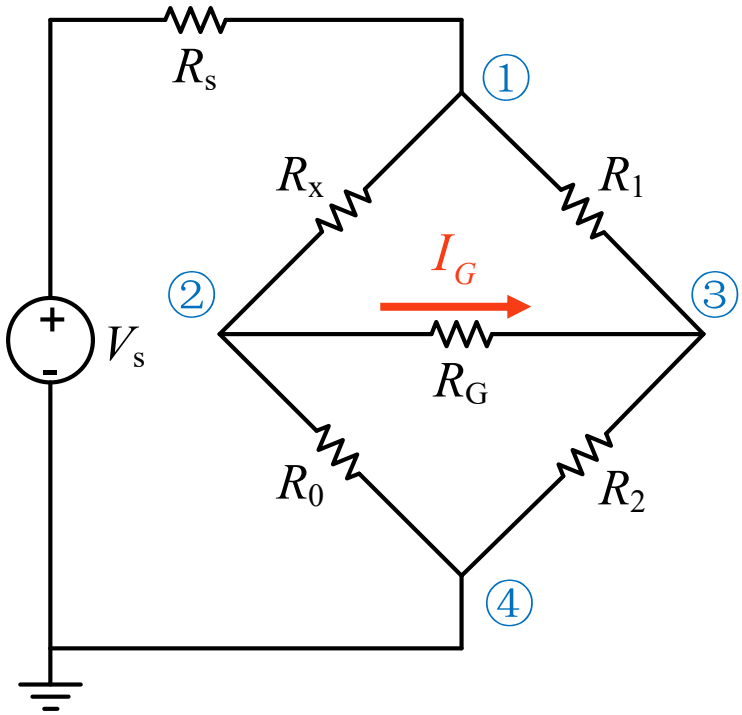
$$AX=B$$
$$X=A^{-1}B$$

惠斯通电桥分析

- Matlab符号数学工具辅助求解

```
% Wheatstone bridge circuit
syms Gs Gx G1 G2 G0 GG Vs Rs;

A = ...
    [(Gs + Gx + G1), -Gx, -G1; ...
     -Gx, (Gx + GG + G0), -GG; ...
     -G1, -GG, (G2 + GG + G1)];

B = [Vs/Rs; 0; 0];

V = inv(A) * B;

IG = (V(2) - V(3)) * GG
```

$$I_G = \frac{V_2 - V_3}{R_G}$$



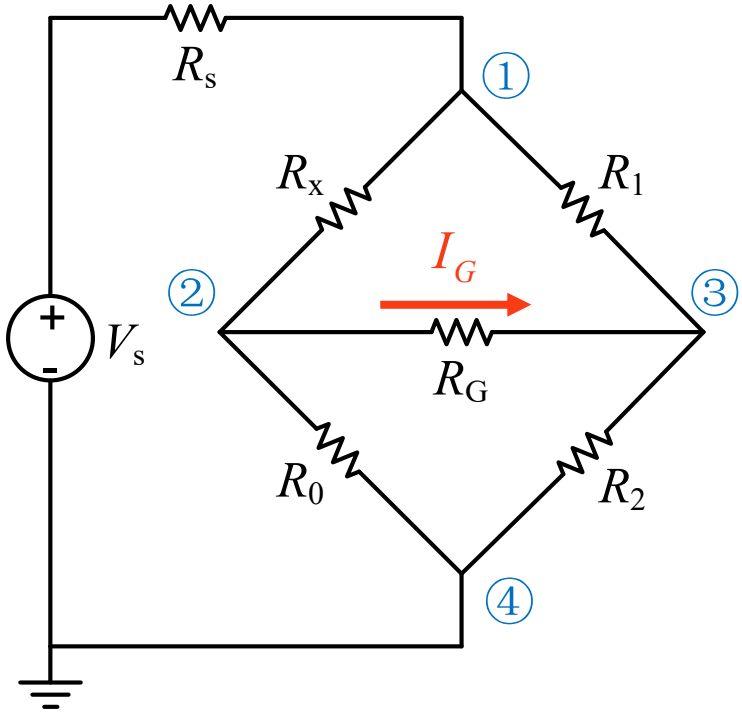
惠斯通电桥分析

- Matlab符号数学工具辅助求解

$$V_2 = \frac{G_1G_G + G_1G_x + G_2G_x + G_GG_x}{f(G_s,G_1,G_2,G_x,G_0,G_G)}V_s$$

$$V_3 = \frac{G_0G_1 + G_1G_G + G_1G_x + G_GG_x}{f(G_s,G_1,G_2,G_x,G_0,G_G)}V_s$$

$$I_G = G_G\frac{G_2G_x - G_0G_1}{f(G_s,G_1,G_2,G_x,G_0,G_G)}V_s$$

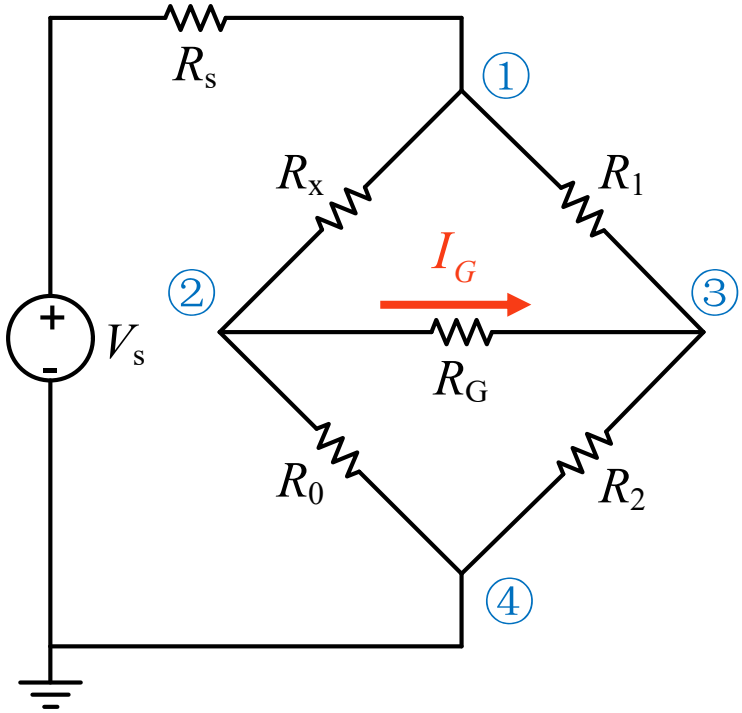


$$\begin{aligned} f(G_s,G_1,G_2,G_x,G_0,G_G) = R_s(&G_0G_1G_2 + G_0G_1G_G + G_1G_2G_G + G_0G_1G_s + G_0G_2G_s \\ &+ G_0G_1G_x + G_0G_2G_x + G_1G_2G_x + G_0G_GG_s + G_1G_GG_s \\ &+ G_2G_GG_s + G_0G_GG_x + G_2G_GG_x + G_1G_sG_x + G_2G_sG_x + G_GG_sG_x) \end{aligned}$$

惠斯通电桥分析

- Matlab符号数学工具辅助求解

$$I_G = G_G \frac{G_2 G_x - G_0 G_1}{f(G_s, G_1, G_2, G_x, G_0, G_G)} V_s$$



当 $G_2 G_x = G_0 G_1$ 或 $R_2 R_x = R_0 R_1$ 时，IG=0

$$R_x = \frac{R_0 R_1}{R_2}$$

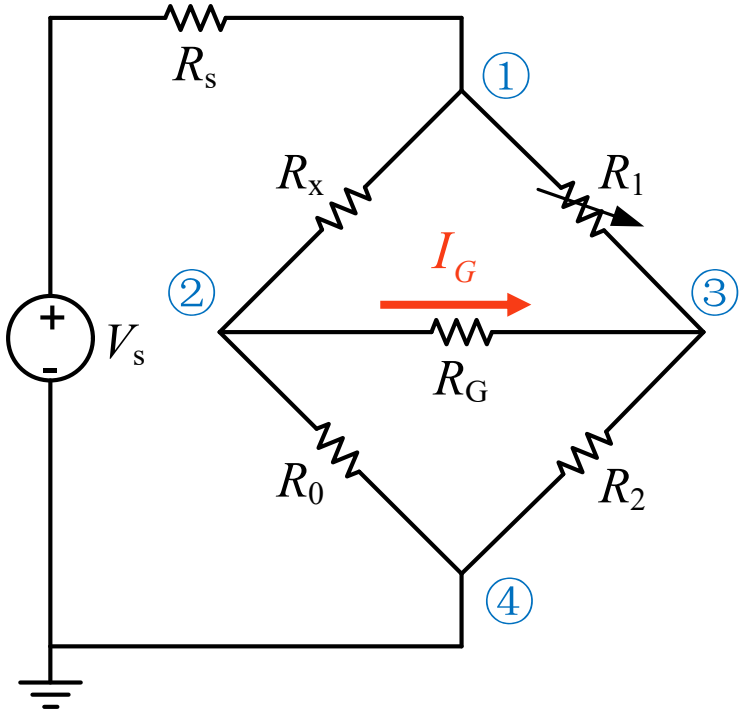
电路处于平衡状态Balanced

惠斯通电桥应用

- 当 $R_2R_x = R_0R_1$ 时，IG=0

- 未知电阻Rx测量
  - 已知R0，R2
  - 调节R1，使IG=0

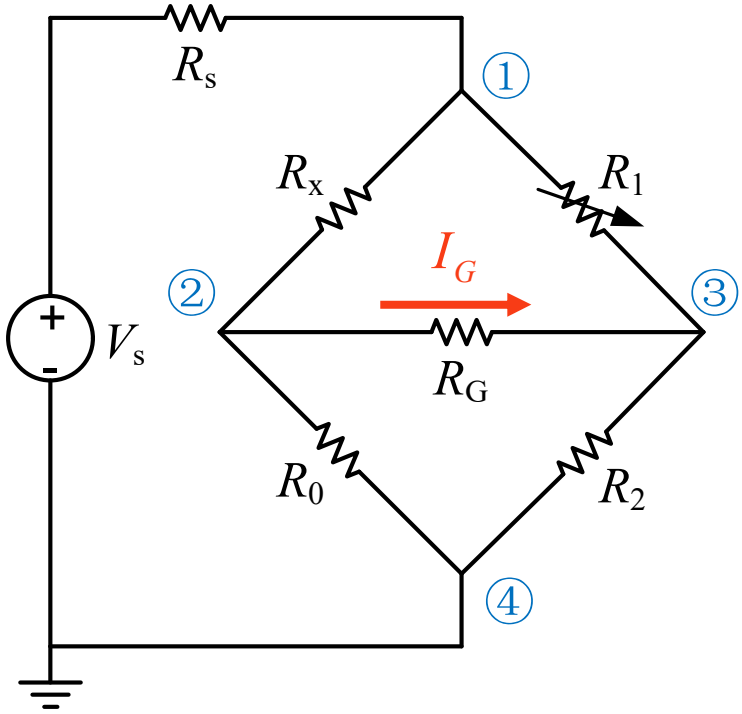
$$R_x = \frac{R_0R_1}{R_2}$$



惠斯通电桥应用

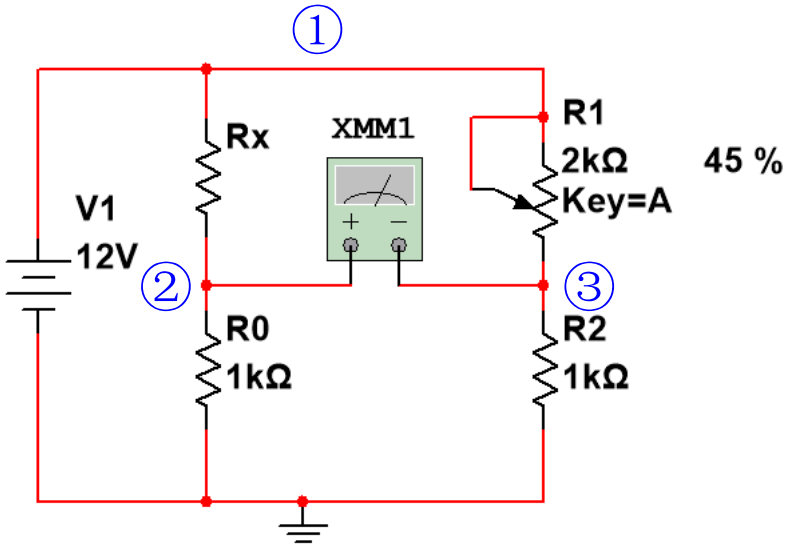
- 当 $R_2R_x = R_0R_1$ 时，IG=0

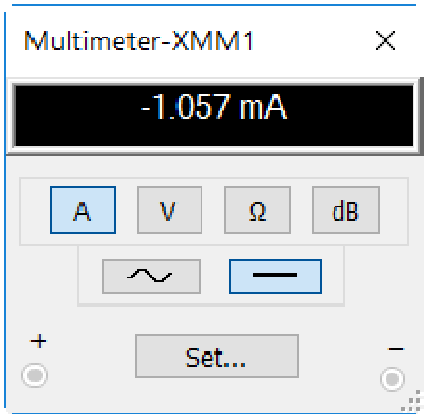
- 电阻Rx变化监测
  - （如热敏电阻随温度变化）
  - 初始条件：调节R1，使IG=0
  - 如果IG变化，说明Rx变化



惠斯通电桥仿真

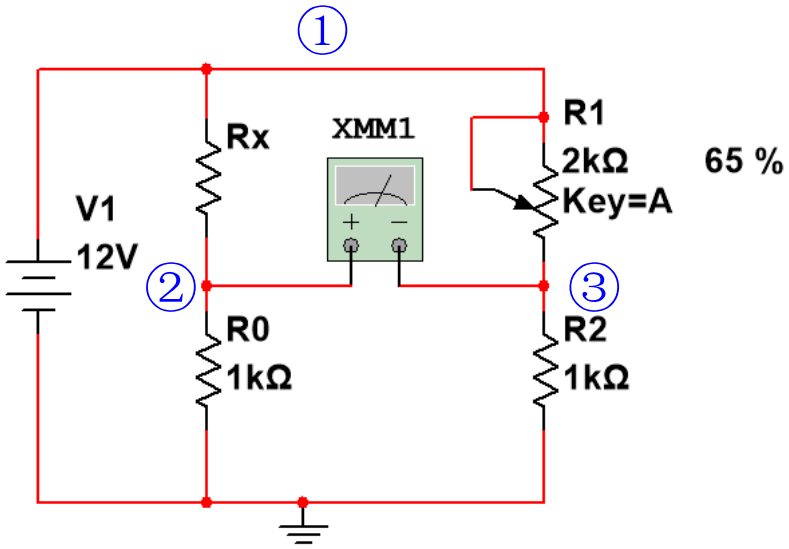
- R1=900Ω

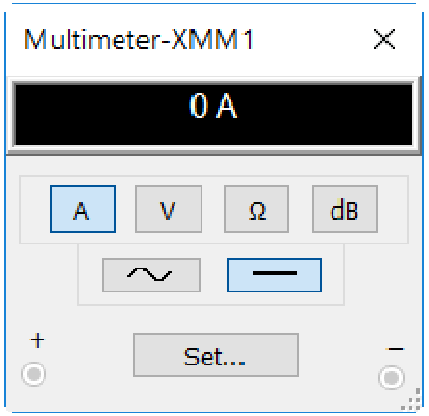




惠斯通电桥仿真

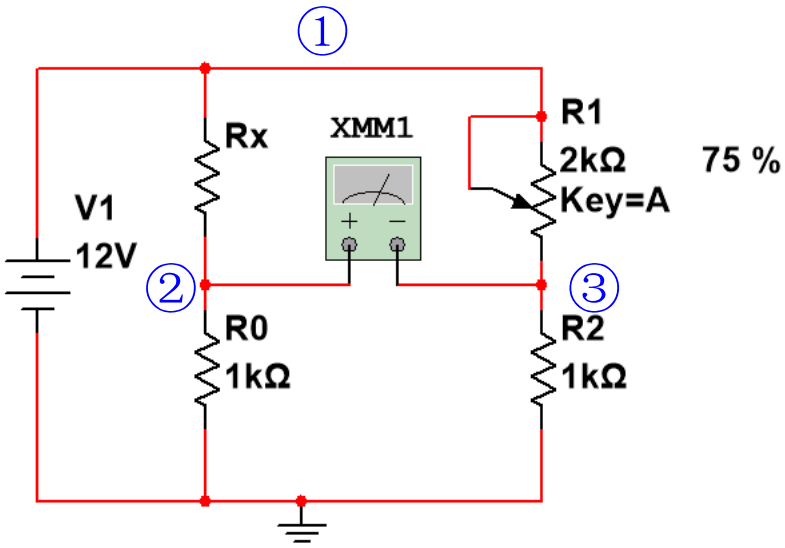
- R1=1.3kΩ

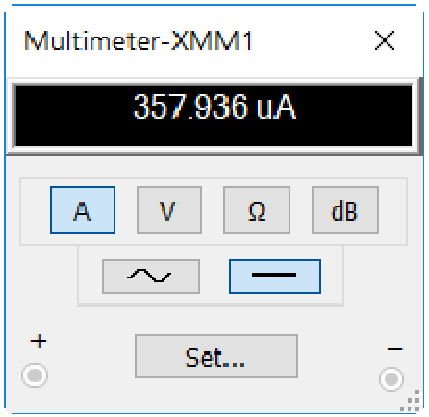




惠斯通电桥仿真

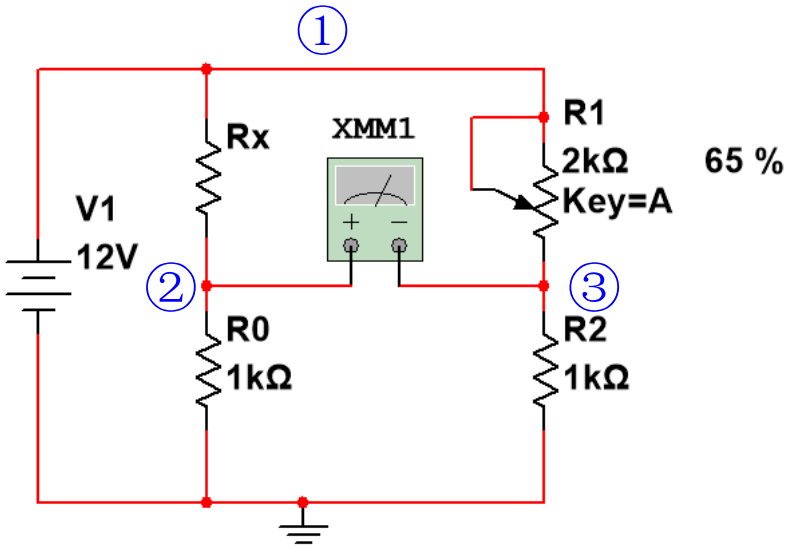
- R1=1.5kΩ

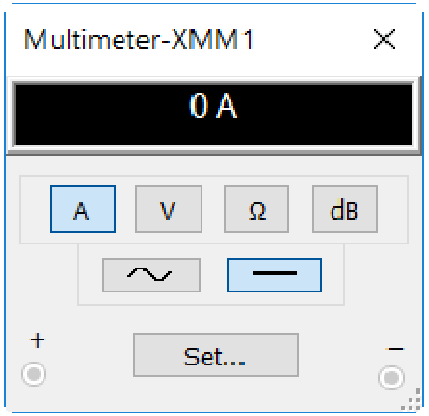




惠斯通电桥仿真

- R1=1.3kΩ





$$R_x = \frac{R_0 R_1}{R_2} = 1.3k\Omega$$

小结

- 以惠斯通电桥为例
- 线性电阻电路分析
  - 节点分析法列写电路方程
  - 电路方程计算机辅助求解
- 线性电阻电路仿真
  - 直流（DC）仿真