Discussion 3

10/14/2016

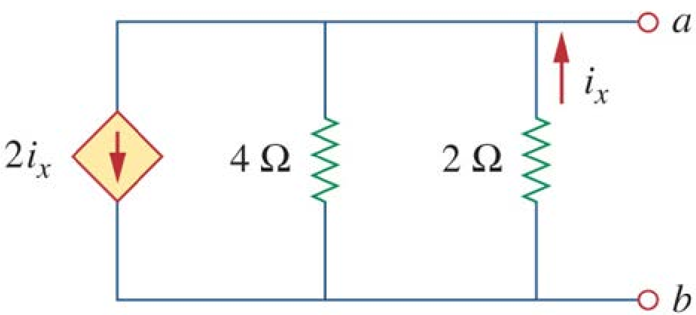
Reading: Chapter 4 and Chapter 5

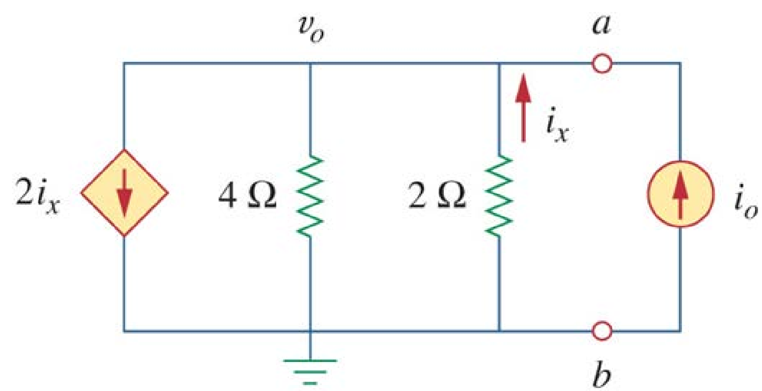
Part one: Circuit Theorems

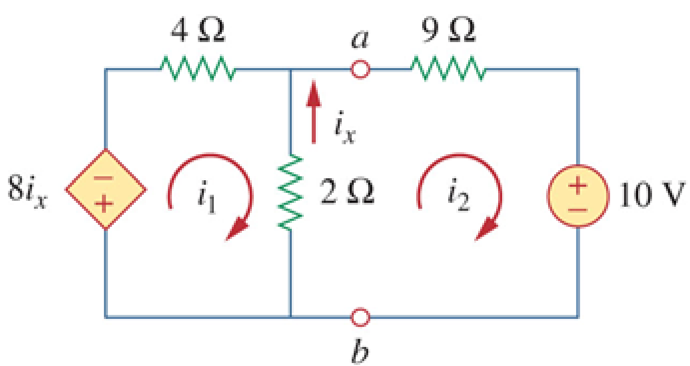
- What you have learned in class:
- Linearity Property
- Superposition
- Thevenin's Theorem
- Source Transformation
- Norton's Theorem

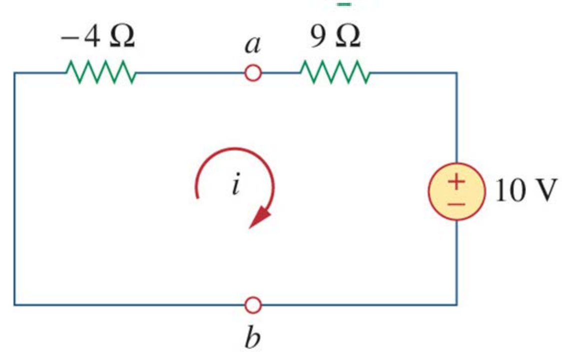
Something puzzles you

- It is possible for the result of this analysis to end up with a negative resistance;
  - This implies the circuit is supplying power
  - This is reasonable with dependent sources





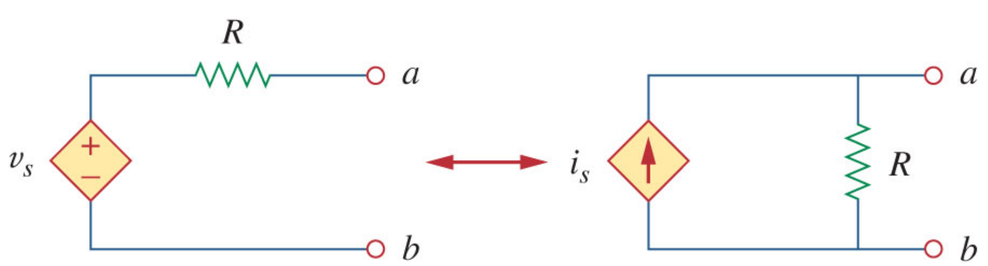




$$R_{Th} = -4\Omega$$

Dependent Sources

- Source transformation also applies to dependent sources
- The same relationship between the voltage and current holds here:



Example

Find v_x in Fig. 4.20 using source transformation.

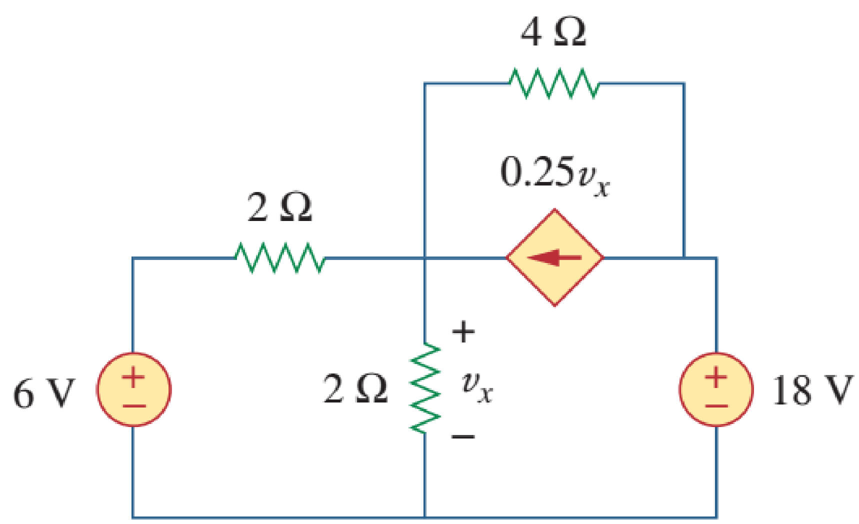
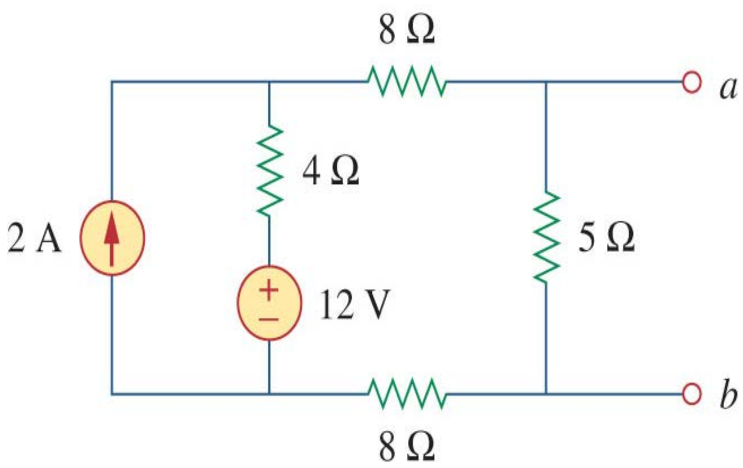
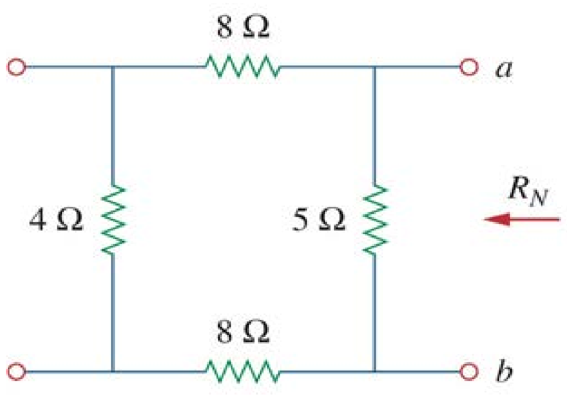


Figure 4.20
For Example 4.7.

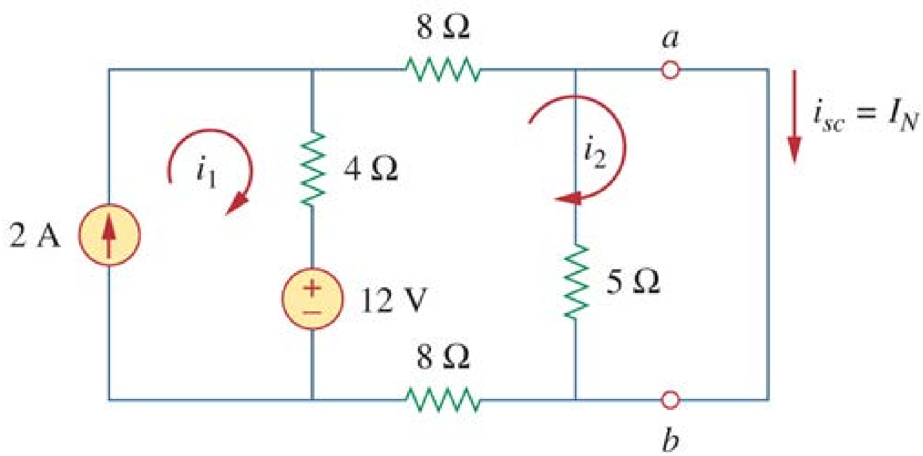
$$v_s = 7.5V$$

Exercise Find I_N and R_N

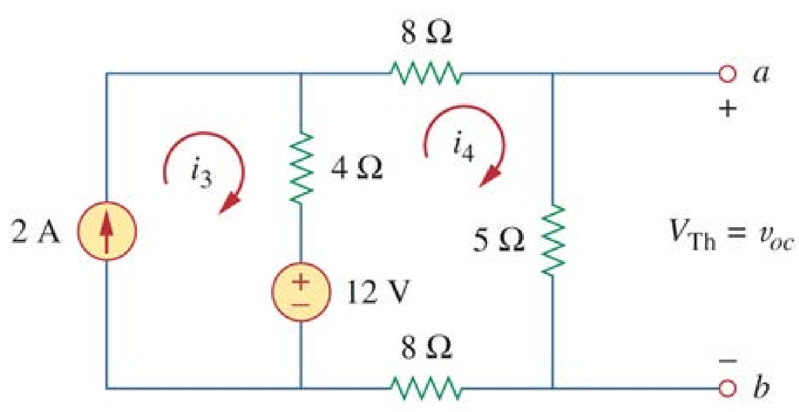




$$R_N = 4\Omega$$



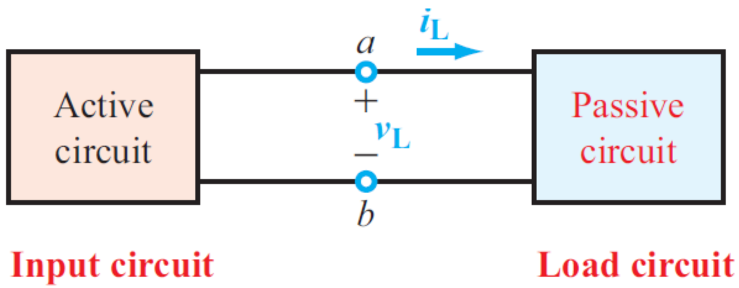
i_{sc}=1A



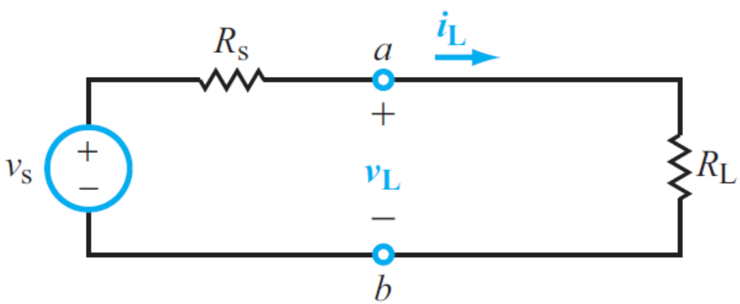
$$v_{TH} = 4V$$

Extention1: Maximum Power Transfer

- In many situations we want to transfer maximum power to the load

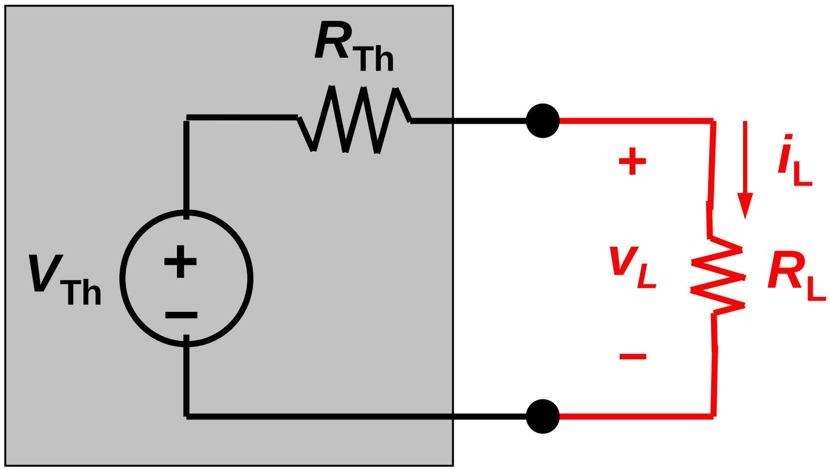


(a) Source and load circuits

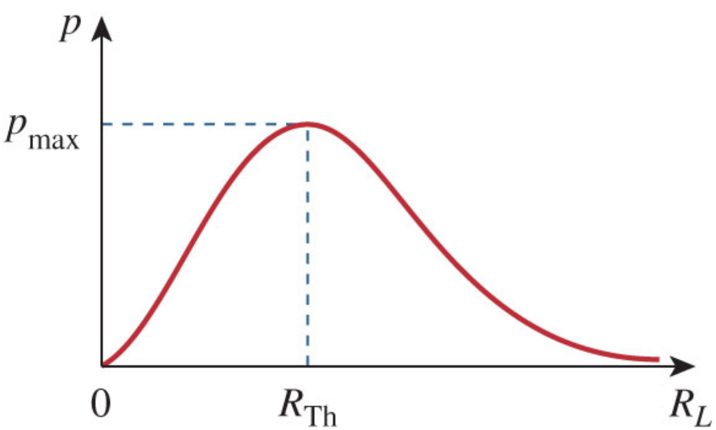


(b) Replacing source and load circuits with their Thévenin equivalents

For realistic circuits ,we often find their Thévenin equivalent circuit to define which RL makes maximum load power



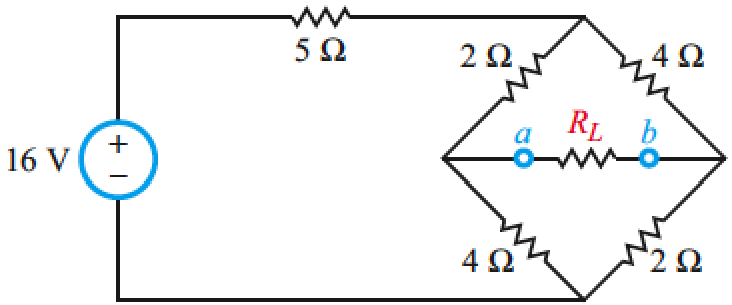
$$p = i_L^2 R_L = \left(\frac{V_{Th}}{R_{Th} + R_L} \right)^2 R_L$$



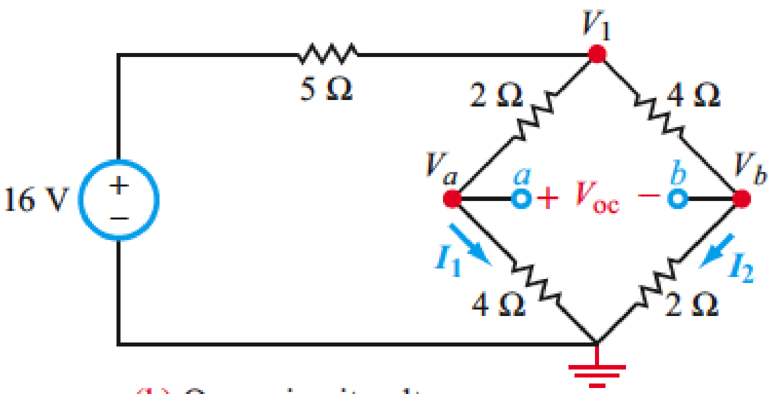
$$\frac{dp}{dR_L} = V_{Th}^2 \left[\frac{(R_{Th} + R_L)^2 - R_L \times 2(R_{Th} + R_L)}{(R_{Th} + R_L)^4} \right] = 0$$

$$\Rightarrow R_{Th} = R_L$$

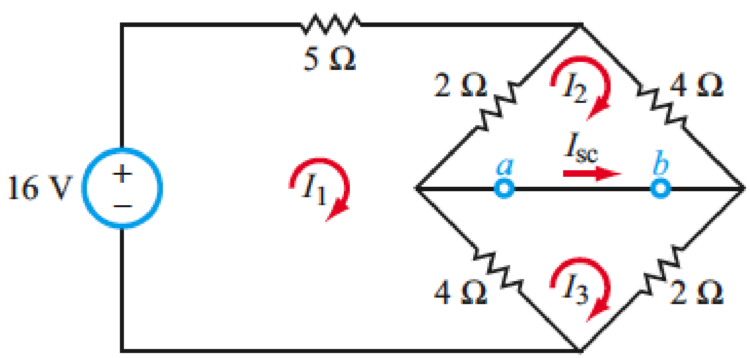
Exercise : Find RL that makes the load power maximum



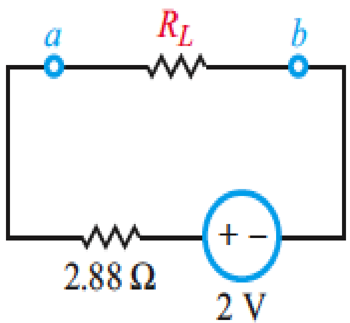
(a) Original circuit



(b) Open-circuit voltage



(c) Short-circuit current

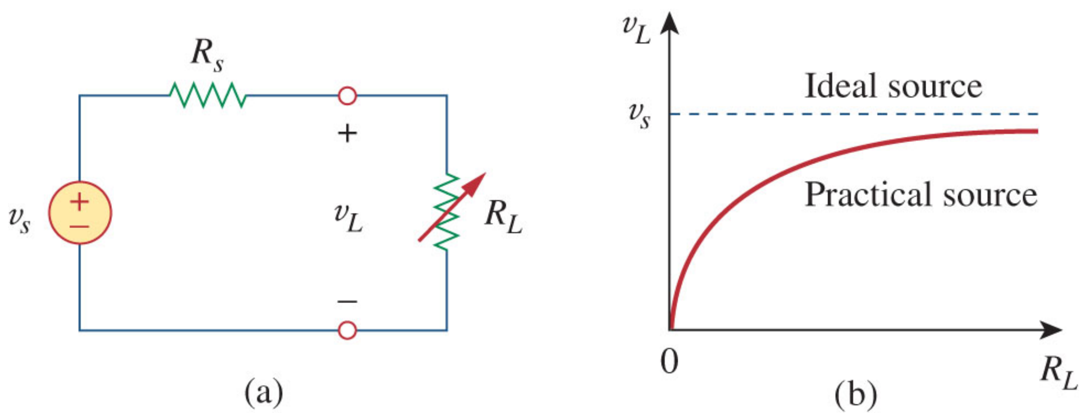


(d) Thévenin equivalent circuit

Extension2: Applications of equivalent theorem

1. Source modeling I

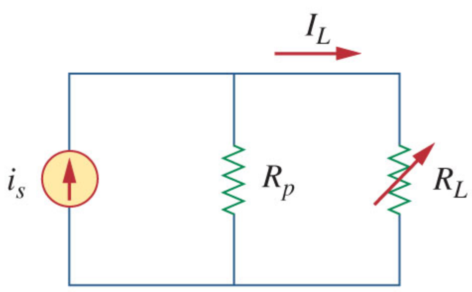
- An active source such as a battery is often characterized by its Thevenin or Norton Equivalent circuit
- Take the Thevenin circuit with load resistor:



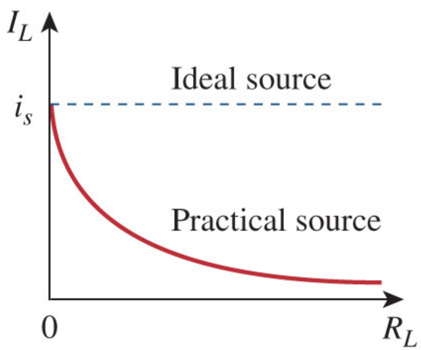
As the load resistance increases, the voltage source comes closer to operating like the ideal source.

Source modeling II

- Similarly, with a realistic current source, the internal resistor in parallel with the ideal source acts to siphon away current that would otherwise go to the load.



(a)

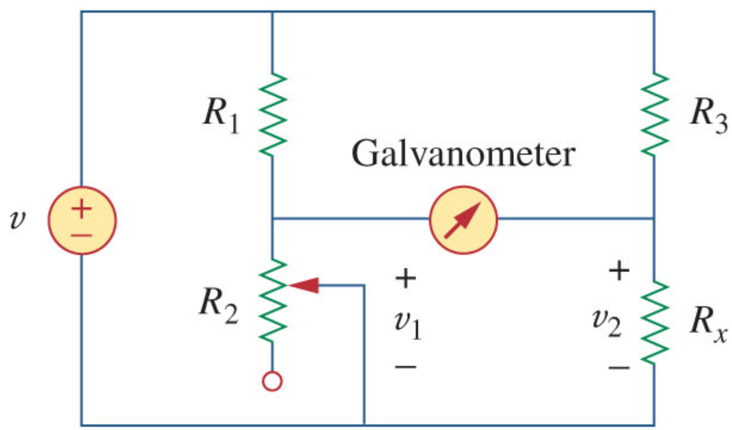


(b)

As the load resistance decreases, the current source comes closer to operating like the ideal source.

2. Resistance Measurement

- Wheatstone bridge : high accuracy
- It is based on the principle of the voltage divider



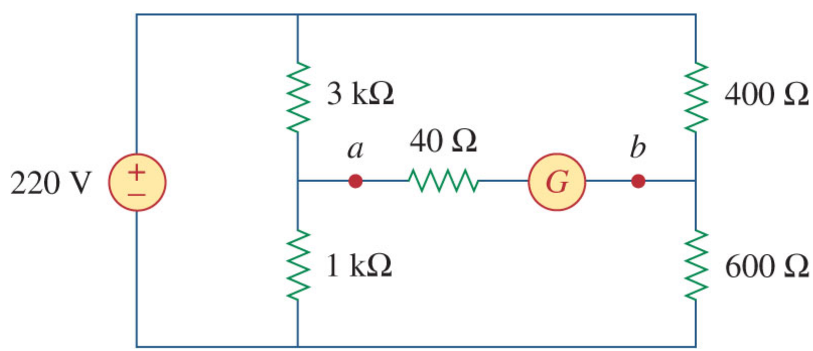
- The key to the high accuracy lies in the fact that any slight difference in the voltage dividers will lead to a current flow

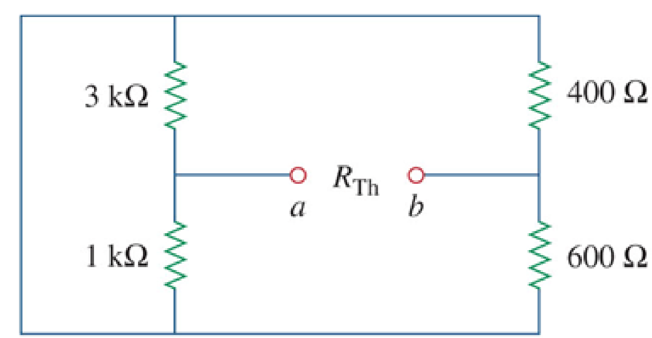
$$I = \frac{V_{Th}}{R_{Th} + R_m}$$

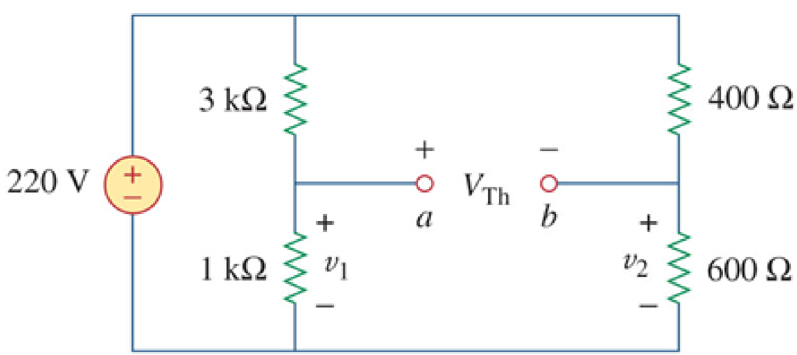
where the terminals of the bridge is reduced to its Thevenin equivalent.

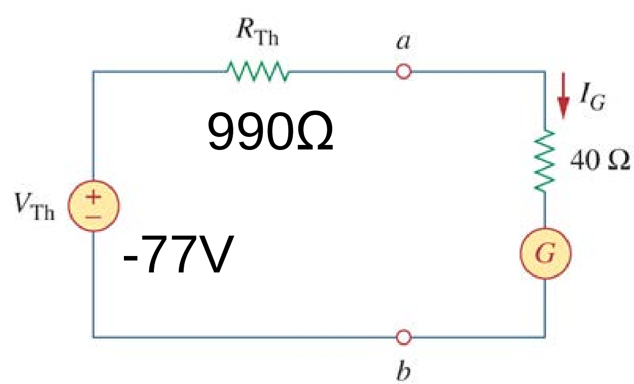
Example

- The circuit below represents an unbalanced bridge. If the galvanometer has a resistance of 40Ω, find the current through the galvanometer.

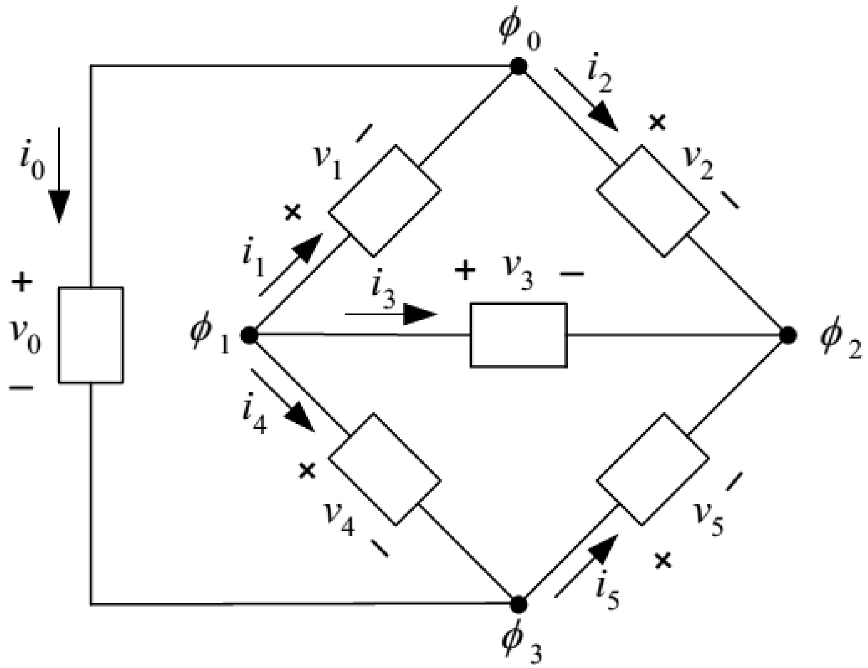








Extension3: Tellegen's Theorem



$$\sum_{n=0}^{5} i_n v_n = 0.$$

It actually shows that the power in a circuit holds.

For specified description ,you can refer to:

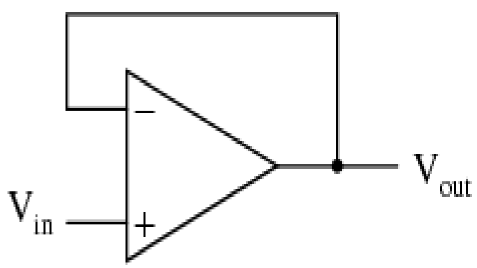
https://en.wikipedia.org/wiki/Tellegen%27s_theorem

Part two : Operational Amplifiers

- What you have learned:
  - What is an Amplifier and its real and ideal models;
  - The characteristic of its inputs and outputs;
  - Several types of applications of OPA;
    including inverting, noninverting, summing, etc;

Extension 1: Positive Feedback

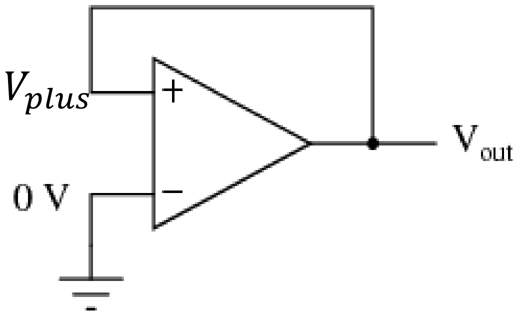
Negative feedback



$V_{in} \uparrow \Longrightarrow$ voltage differential $\uparrow \Longrightarrow V_{out} \uparrow$
$\Longrightarrow$ voltage differential $\downarrow \Longrightarrow V_{out} \downarrow$
$\Longrightarrow \cdots$
$\Longrightarrow V_{out} \rightarrow V_{in}$ but small difference exists

giving the op-amp the capacity to work in its linear (active) mode.

Positive feedback

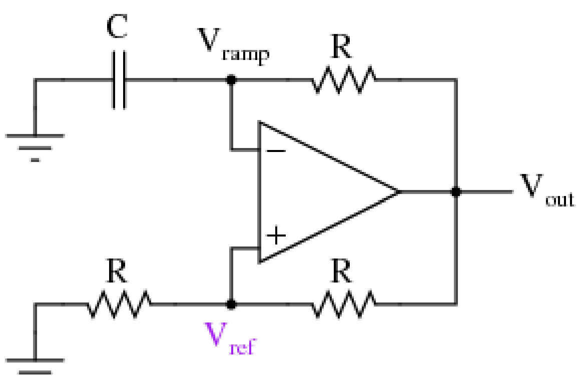


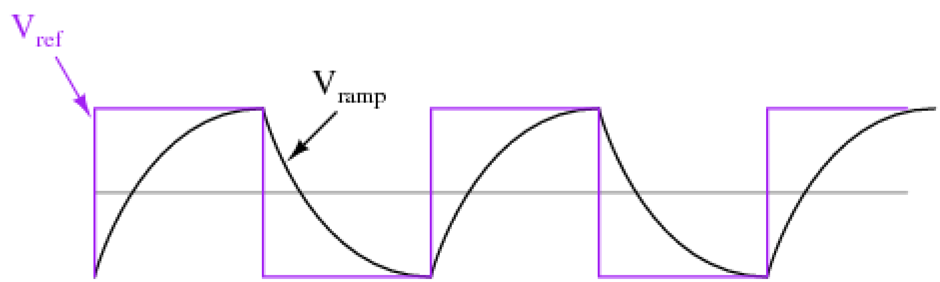
Small $+V_{plus} \Longrightarrow$ large $+V_{out} \Longrightarrow$ full positive output saturation because of feedback

it adds to make the input larger, tends to cause system instability

Simple application of positive feedback

- Oscillator is a device that produces an alternating, or at least pulsing, output voltage.
  - Known as bistable device, no stable output state.

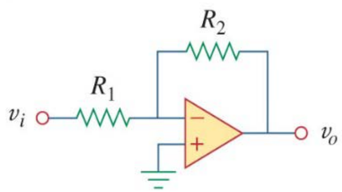




V_{out} is a square wave just like V_{ref}, only taller

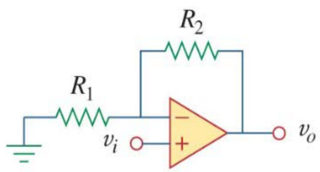
- When V_{out} is saturated positive, V_{ref} is positive, capacitor C charges up.
- When V_{ramp} exceeds V_{ref} by the tiniest margin, V_{out} becomes saturated negative, and C will charge in the opposite direction (polarity).
- Oscillation occurs because
  - positive feedback is instantaneous,
  - negative feedback is delayed by means of an RC time constant.

Several types of amps we have learned



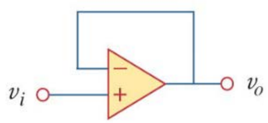
Inverting amplifier

$$v_o = -\frac{R_2}{R_1} v_i$$



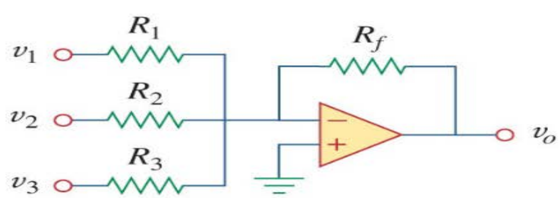
Noninverting amplifier

$$v_o = \left(1 + \frac{R_2}{R_1}\right) v_i$$



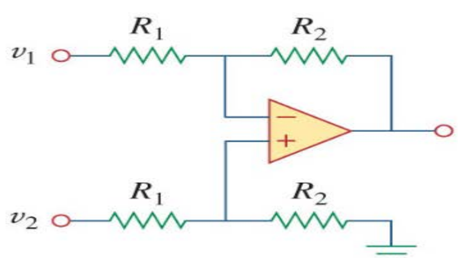
Voltage follower

$$v_o = v_i$$



Summer

$$v_o = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \frac{R_f}{R_3} v_3\right)$$

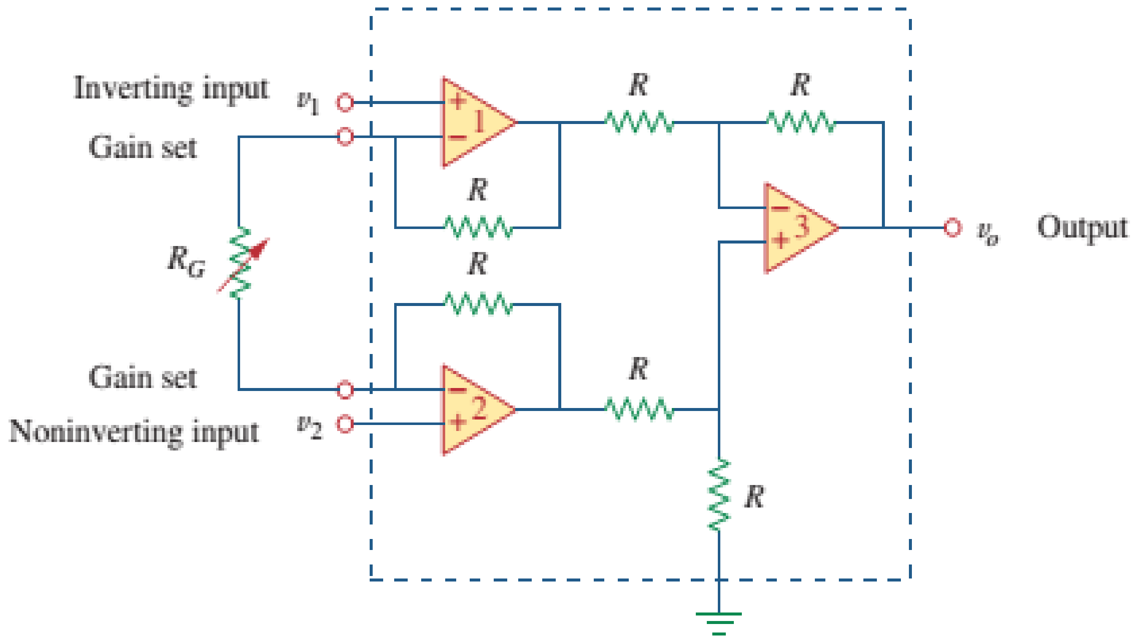


Difference amplifier

$$v_o = \frac{R_2}{R_1}(v_2 - v_1)$$

Extension 2： Instrumentation Amplifier

An extension of the difference amplifier

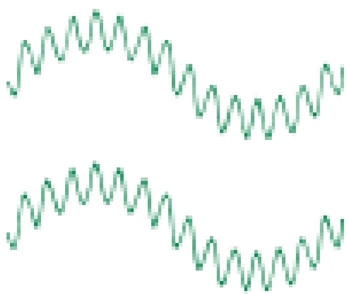


$$v_o = A_v(v_2 - v_1)$$

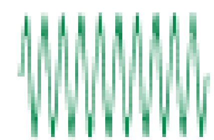
$$A_v = 1 + \frac{2R}{R_G}$$

The IA with an external resistance to adjust the gain，
Can reject common voltages but amplified small signal voltages

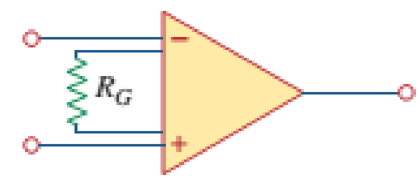
Characteristics of IA



Small differential signals riding on larger common-mode signals



Amplified differential signal, no common-mode signal



Simplified symbol

1.Gain is adjusted by one external resistor RG;
2.The input impedance of both inputs is very high and does not change;
3.Output vo depends on v1,v2 not on the voltage common to them;

Example:

Obtain i_o in the instrumentation amplifier circuit of Fig. 5.27.

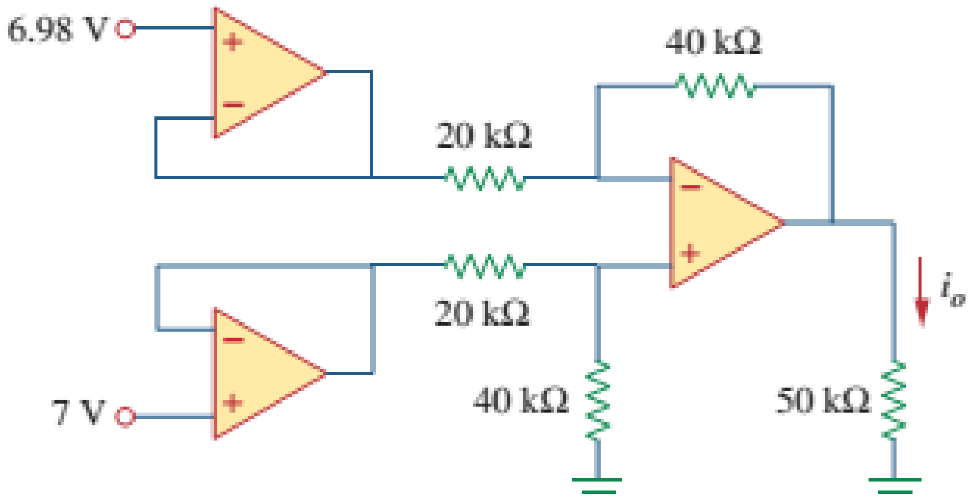


Figure 5.27
Instrumentation amplifier; for Practice Prob. 5.8.

Answer: $-800\ \mu A$.