ELECTRIC CIRCUITS
ECSE-2010

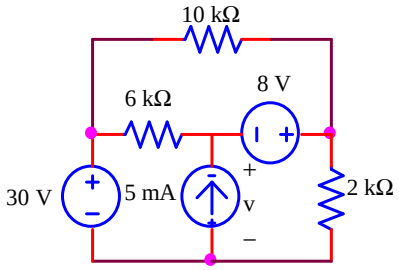
Lecture 4.1

Rensselaer

LECTURE 4.1 AGENDA

- Linearity
- Superposition Principle
- Superposition Example
- Dependent Sources

ACTIVITY 5-1A



4 Nodes – 2 Voltage Sources – 1 Ref
1 Unknown Node Voltage, v

LINEARITY

- If have multiple inputs
- Input = $x_1 + x_2 + x_3$
- Output must be additive
- $y = k_1x_1 + k_2x_2 + k_3x_3$
- Leads to Superposition Principle
  - Can use only for multiple inputs to a linear circuit

SUPERPOSITION

- Technique to use when there is more than 1 Independent Source in a Linear Circuit:
  - Not always the best technique to use
  - Will learn lots of techniques; Experience helps us learn which technique to choose

SUPERPOSITION

- Find Output due to <u>each independent source with all other independent sources set = 0; then Add to find Total Output</u>:
  - Source of 0 is called a "dead source"
  - "Dead" voltage source = 0 V = Short Circuit
  - "Dead" current source = 0 A = Open Circuit

ELECTRIC CIRCUITS
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Lecture 4.2

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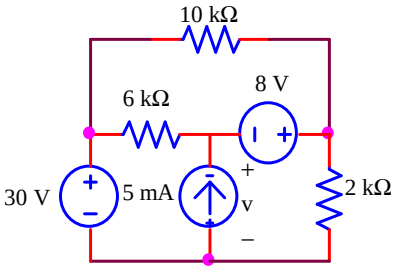
LECTURE 4.2 AGENDA

- Dependent sources overview
- Dependent sources example

ACTIVITY 5-1A



4 Nodes – 2 Voltage Sources – 1 Ref
1 Unknown Node Voltage, v

DEPENDENT SOURCES

- 2 Types of sources for circuit models:
  - Independent Sources
    - Both voltage and current sources
    - Usually model with ideal sources
  - Dependent Sources
    - Also called controlled sources
    - Both voltage and current sources

DEPENDENT SOURCES

- Dependent/Controlled Source:
  - Voltage or current source whose value depends on the v or i at some other point in the circuit
  - Cannot buy a dependent source!
  - Used to model the behavior of electronic devices
  - Almost all interesting or useful circuits contain Dependent Sources

DEPENDENT SOURCES

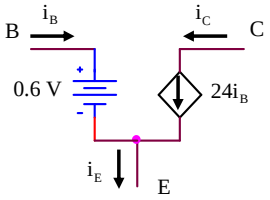
- Dependent source cannot be the only source of energy in a complete circuit
  - Need an Independent Source to create the controlling current or voltage
- All circuit models for transistors and other electronic devices involve Dependent Sources
  - Whole field of analog electronics is based on dependent sources

EXAMPLE

BJT Transistor

$i_C = 24 i_B$

$v_{BE} = 0.6$ V



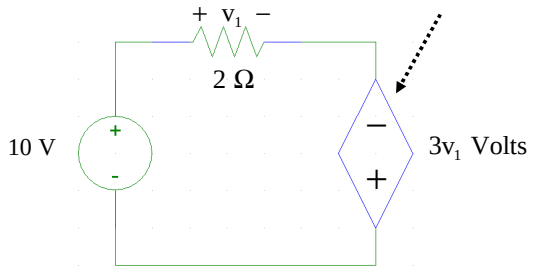
Circuit Model for a BJT

DEPENDENT SOURCES

- Symbol:
  - Diamond = Symbol for Dependent Source
  - Circle = Symbol for Independent Source
- 4 Types of Dependent Sources
  - Voltage Controlled Voltage Source (VCVS), E
  - Current Controlled Current Source (CCCS), F
  - Voltage Controlled Current Source (VCCS), G
  - Current Controlled Voltage Source (CCVS), H

VCVS

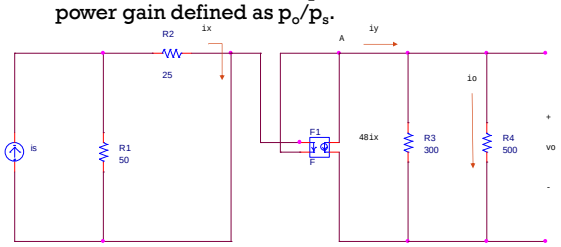
Symbol for Dependent Source



Voltage Controlled Voltage Source (VCVS)

EXAMPLE 4-1

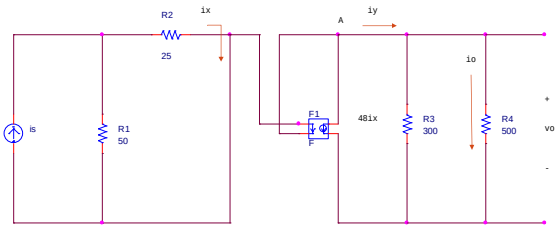
- Determine the current, voltage, and power delivered to the 500-Ω output load. Then find the power gain defined as p_o/p_s.



- Current Controlled Current Source (CCCS), F

EXAMPLE 4-1

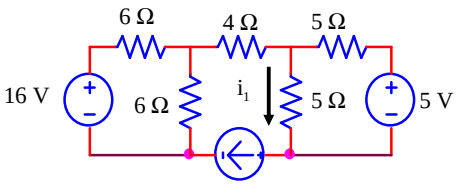
- Current Controlled Current Source (CCCS), F



SUPERPOSITION

- Total Output = Sum of all Outputs due to each independent source with all other independent sources "dead":
  - Simply Add them
  - Works only for Linear Circuits; Only kind we will consider

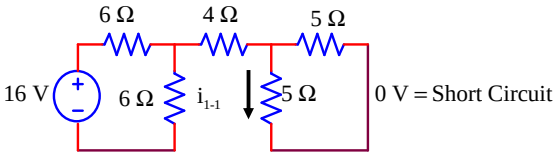
EXAMPLE



Find i_1 using Superposition

EXAMPLE

Output Due to 16 V Source

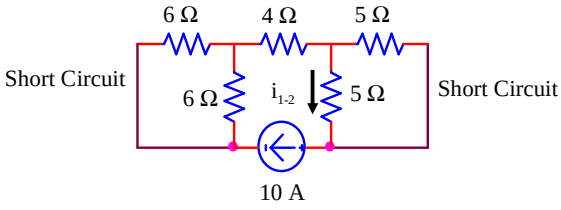


0 A = Open Circuit

$i_{1-1} = 0$

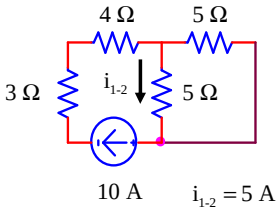
EXAMPLE

Output Due to 10 A Source



EXAMPLE

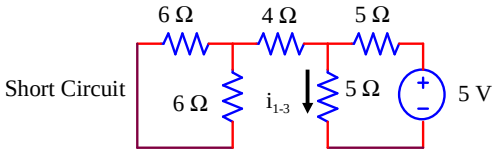
Output Due to 10 A Source



$i_{1-2} = 5$ A

EXAMPLE

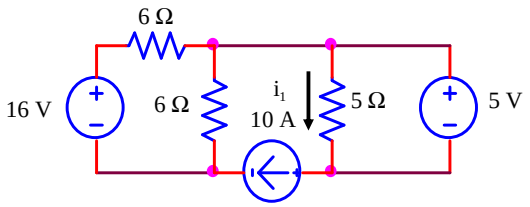
Output Due to 5 V Source



Open Circuit

$$i_{1-3} = \frac{5}{5+5} = .5 \text{ A}$$

EXAMPLE



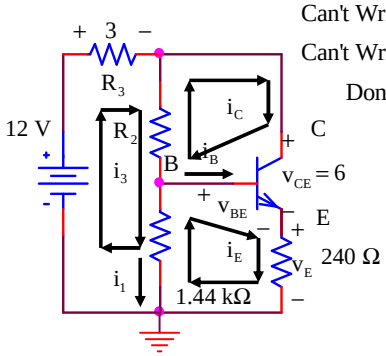
$i_1 = 0 + 5 + .5 = 5.5$ A

ACTIVITY 5-2

Can't Write KVL around i_3

Can't Write KVL around i_C

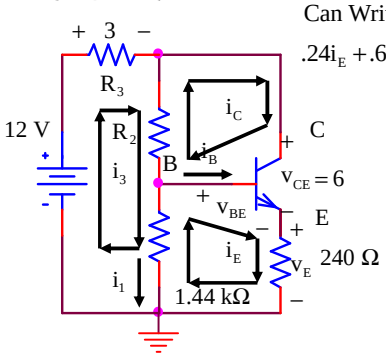
Don't know R_2



ACTIVITY 5-2

Can Write KVL around i_E

$.24i_E + .6 + 1.44(i_E - i_3) = 0$



ACTIVITY 5-2

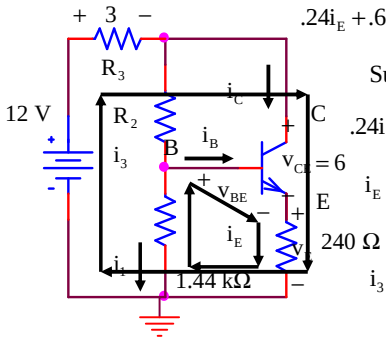
$.24i_E + .6 + 1.44(i_E - i_3) = 0$

Supermesh

$.24i_E + 6 + 3 - 12 = 0$

$i_E = \frac{3}{.24} = 12.5$ mA

$i_3 = \frac{21.6}{1.44} = 15$ mA



ACTIVITY 5-2

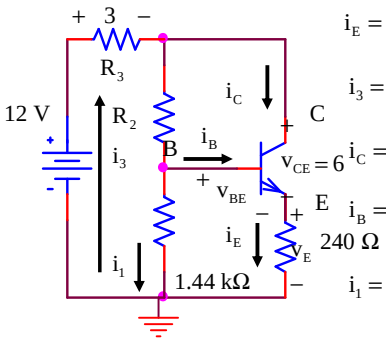
$i_E = \frac{3}{.24} = 12.5$ mA

$i_3 = \frac{21.6}{1.44} = 15$ mA

$i_C = \frac{24}{25} i_E = 12$ mA

$i_B = \frac{i_C}{24} = .5$ mA

$i_1 = i_3 - i_E = 2.5$ mA



ACTIVITY 5-2

$i_E = 12.5$ mA $i_B = .5$ mA

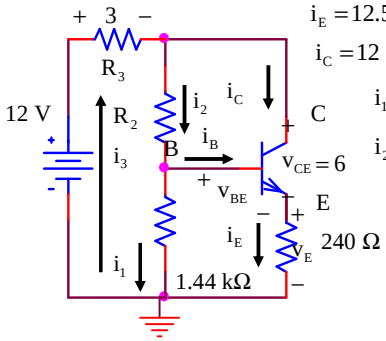
$i_C = 12$ mA $i_3 = 15$ mA

$i_1 = 2.5$ mA

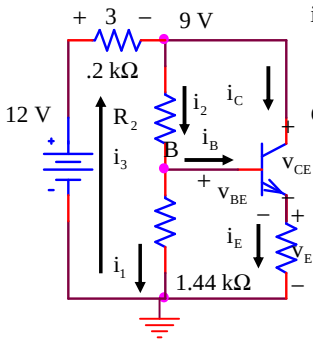
$i_2 = i_1 + i_B = 3$ mA

$3 = i_3 R_3$

$R_3 = \frac{3}{15} = .2$ kΩ



ACTIVITY 5-2



$i_E = 12.5$ mA $i_B = .5$ mA

$i_C = 12$ mA $i_3 = 15$ mA

$i_1 = 2.5$ mA $i_2 = 3$ mA

$v_B = 1.44 i_1 = 3.6$ V

$i_2 R_2 = 9 - 3.6 = 5.4$ V

$R_2 = \frac{5.4}{3} = 1.8$ kΩ

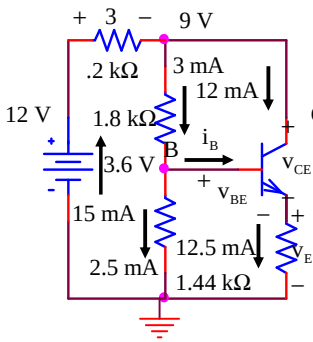
ACTIVITY 5-2

$P_1 = 2.5(3.6) = 9$mW

$P_2 = 3(5.4) = 16.2$ mW

$P_3 = 15(3) = 45$ mW

$P_E = 12.5(3) = 37.5$ mW



$P_T = 107.7$ mW