EE215 – FUNDAMENTALS OF ELECTRICAL ENGINEERING

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WEEK 5
CIRCUIT ANALYSIS (III) & OPERATIONAL AMPLIFIERS

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QUESTIONS TO ANSWER

- Thévenin and Norton Equivalents
  - What are the Thevenin and Northon equivalents?
  - How to simplify electric circuits to those equivalents?
- Maximum Power Calculation
  - What is the condition of a resistive network to deliver maximum power?
  - How to calculate the maximum power delivered by the network?
- Operational Amplifier
  - What is an op amp and its circuit symbol?
  - What are the common configurations of op amps and their gains?

THÉVENIN AND NORTON EQUIVALENTS

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THÉVENIN AND NORTON EQUIVALENTS

- Every network consisting of independent and dependent sources and resistors with two terminals a and b can be replaced with equivalent circuits of the following form:

THÉVENIN AND NORTON EQUIVALENTS

- Thévenin and Norton equivalents are very useful if we are only interested in the effect on a load.
  - Example: home power outlet, car battery, …
- How do we determine v_{Th} and R_{Th}?
  - Open circuit
    ➔
  - Short circuit
    ➔
  - Dead network resistance
    ➔

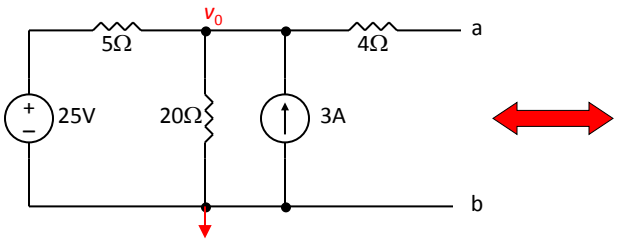
THÉVENIN AND NORTON EQUIVALENTS

- Therefore, we know the Thévenin equivalent if we know the open circuit voltage, the short circuit current, or dead network resistance.
  - Don't try this at home!

EXAMPLE (1)

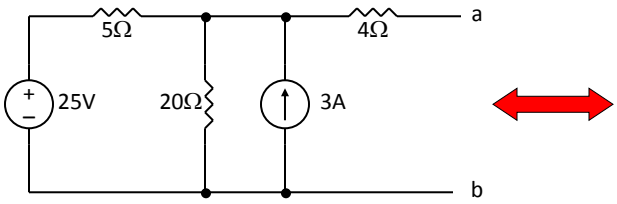
- Open circuit:

EXAMPLE (1)



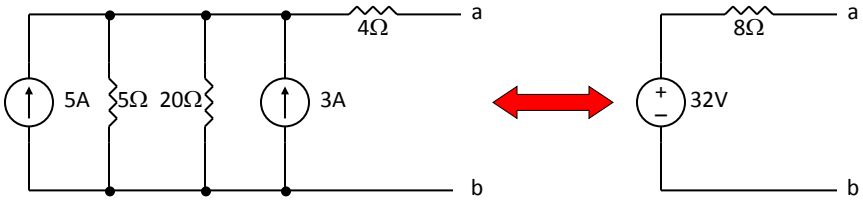
- Short circuit:

EXAMPLE (2A)



- We could have obtained the same result with source transformations

EXAMPLE (2B)



Replace combined current source with Thévenin equivalent:

EXAMPLE (2C)

MAXIMUM POWER TRANSFER

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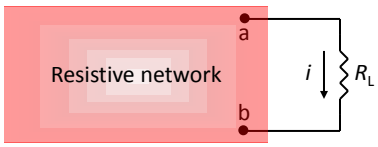
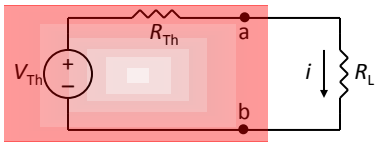
MAXIMUM POWER TRANSFER (1)

- For what output load R_L is the power maximized?
- General resistive network:



- Find Thévenin equivalent:



MAXIMUM POWER TRANSFER (2)

- Calculate output power p:

- Find load R_{L} such that p is maximized:

- Max. power if load is equal to Thévenin resistance

OPERATIONAL AMPLIFIER

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OPERATIONAL AMPLIFIER (1)

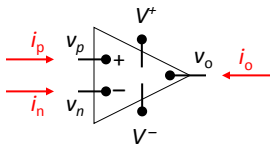
- The operational amplifier, or op amp for short, is a fundamental building block in circuit design. Stuffed inside a chip are a bunch of transistors and other elements that make up a near-ideal voltage controlled voltage source (VCVS) with near-infinite gain. Of course, we'll start by assuming it is ideal…

OPERATIONAL AMPLIFIER (2)

- **Circuit Symbol:**
  - The op amp has a special circuit symbol, a triangle with two inputs and one output

OPERATIONAL AMPLIFIER (3)

- Voltage transfer characteristic:



OPERATIONAL AMPLIFIER (4)

- **Slew Rate:**
  - At this point we should probably note that another departure from ideality in the op amp is that the slew rate, is also limited. This affects how fast the op amp responds to a step change in input, and how high a frequency it can operate at.

OPERATIONAL AMPLIFIER (5)

- Operation in the linear region:
  -
  -
  -
  -
    -
- Op amps have very high input resistance.
  -
  -
  -

OPERATIONAL AMPLIFIER (6)

- **Ideal Op Amps Relationships:**
  - An ideal op amp is an ideal voltage controlled voltage source. We can think of the op amp symbol being replaced as follows:

OPERATIONAL AMPLIFIER (7)

- Negative feedback can be used to ensure operation in the linear region.
  - –
  - –

OPERATIONAL AMPLIFIER (8)

- Inverting Amplifier:

OPERATIONAL AMPLIFIER (9)

- Summing Amplifier:

OPERATIONAL AMPLIFIER (10)

- Non-inverting Amplifier:

OPERATIONAL AMPLIFIER (11)

- Differential Amplifier:

OPERATIONAL AMPLIFIER (12)

Remember:

- Input current: $i_p = i_n = 0$
- Virtual short condition (in linear region): $v_p = v_n$
- First assume op amp operates in linear region.
  - If this leads to a contradiction, then op amp is in saturation.