Fundamentals of Electronics
Week 1

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EECE–4646
Northeastern University

Sep 2024

Week 1 Agenda

- Introductions
- Administrivia: Website, Syllabus, Course Components
- Electronic Components
- Review of Circuits

Me

- Education
  - 1969: BS in Engineering Physics, University of Maine
  - 1973: MS in Physics, WPI
  - 1996: Ph.D. in Electrical Engineering, Northeastern
- Employment
  - 1973 — 1987: Raytheon Company (Laser Radar)
  - 1983 — 1987: Northeastern (Part–Time Lecturer)
  - 1987 — 2000: Northeastern (Research Scientist)
  - 2000 — Present: Northeastern ECE Faculty (MIE/BioE)
  - 2014 — 2020: Topical Editor for *Optics Letters*
  - 2014 — 2016: Associate Chair of ECE
- Home: Cambridge, with my Wife, Sheila
- Family: 2 Children, 3 Grandchildren
- Home Ski Area: Killington, Vermont

Personal History

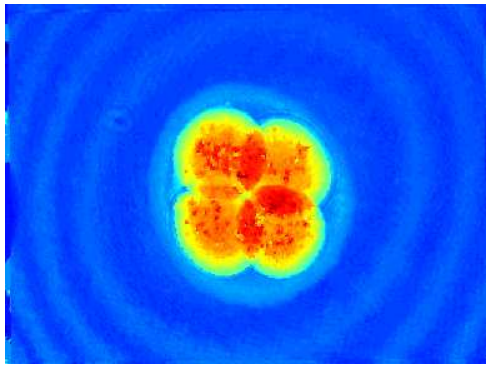
- Raytheon (Jelalian)
  - Aircraft Wake LIDAR
  - Airborne LIDAR
- Northeastern University
  - LIDAR
  - MOKE Sensors
  - Landmine Detection
  - Hyperspectral Imaging (Biomed)
  - Light and Sound
  - Optical Quadrature
  - Multi-Modal Microscopy



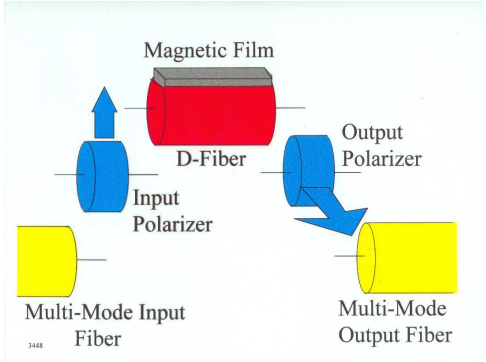
Severe Storms



Coal–Dust Lidar



Cell Counting



Magnetic Sensor

Communication

- I am hearing impaired.
- I can understand you better if I can see your face.
- I hear better on my right side.
- I hear better in a quiet environment.
- I hear better if one person speaks at a time.
- I have a portable microphone that can help.
- Do not let this stop you from asking questions.



You

EE	11
EE/Phys	1
EE/Music	1
	13
ECE	5
CE	7
CE/CS	4
CS	1
	12

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Syllabus and Webiste

http://www.ece.neu.edu/courses/eece2412/dimarzio/

Course Components

- Lectures (Synchronously and Recorded)
- Slides (Available on the Website)
- Textbook Reading
- Recitation
- Homework
- Two Midterm Exams
- Final Exam
- Participation
- EECE2413 to be Taken Concurrently
- Office Hours

Weekly Schedule

- Before Monday Read the Text Assigned
- Monday Lecture
- Tuesday Lab for Some
- Wednesday Lecture
- Homework Due on Last Week's Material
- Thursday Lecture and In–Class Exercise
- Lab for The Rest

A Note About the Slides

These slides are not meant to be complete. They are intended to support the lectures, and not to replace them.

They provide reminders to me and to you.

I encourage you to save the slides to paper or pdf, and take notes on them.

Week 1 Agenda

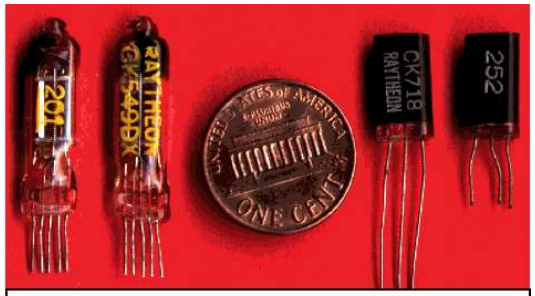
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Back Then

Real equipment glows in the dark!







TRANSISTORS REPLACE TUBES

On the left are submini tubes used in a Zenith Royal hearing aid. The 201 date code represents week 1, 1952. On the right are examples of CK718 junction transistors used in a Zenith Royal "T" hearing aid, with 252 representing week 52, 1952. In less than one year transistors had replaced the dominant vacuum tube technology in hearing aids.

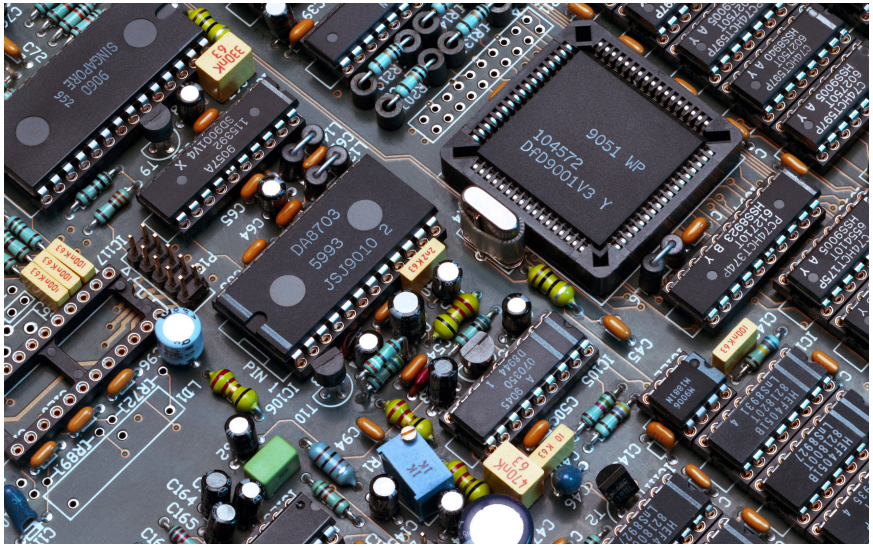




Now



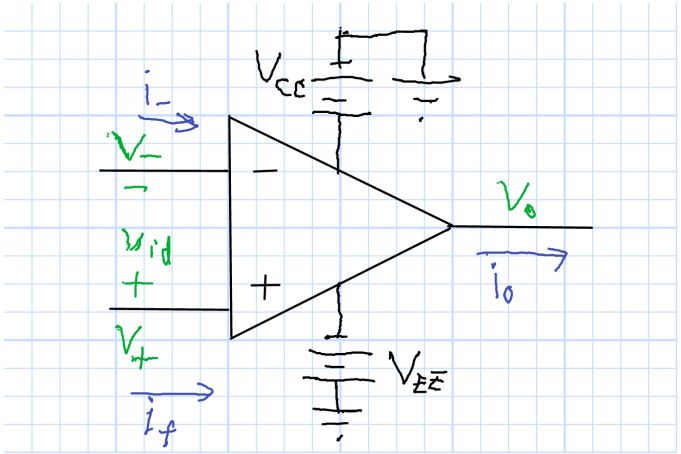
elwagon.com



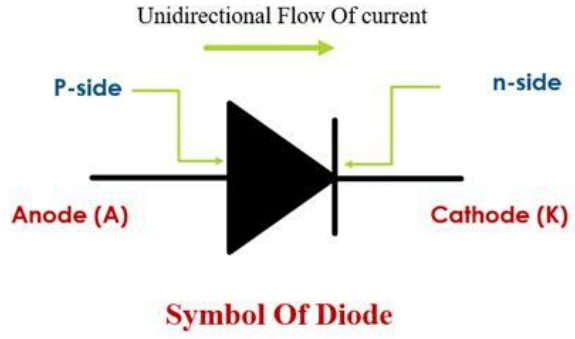
wallpapersafari.com

Find: Resistor, Variable Resistor, Capactor, Electrolytic Capacitor, Transistor, Chips.

This Course

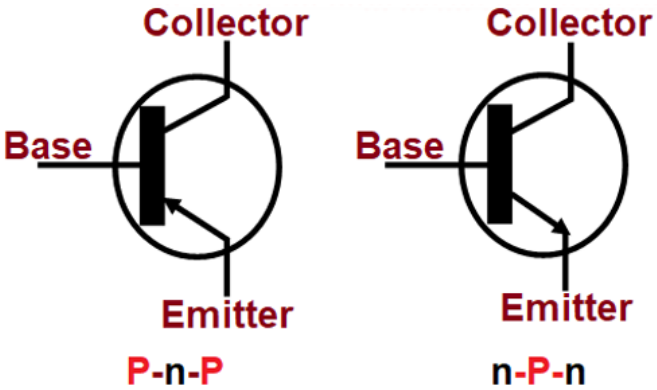


Op Amp



quick-learn.in

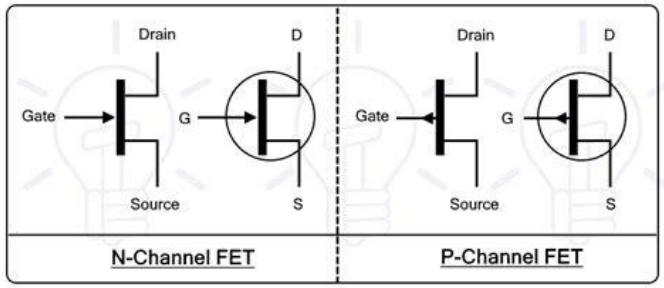
Diode



webmapflicker.com

BJT

Bipolar Junction Transistor



electricaltechnology.org

FET

Field–Effect Transistor

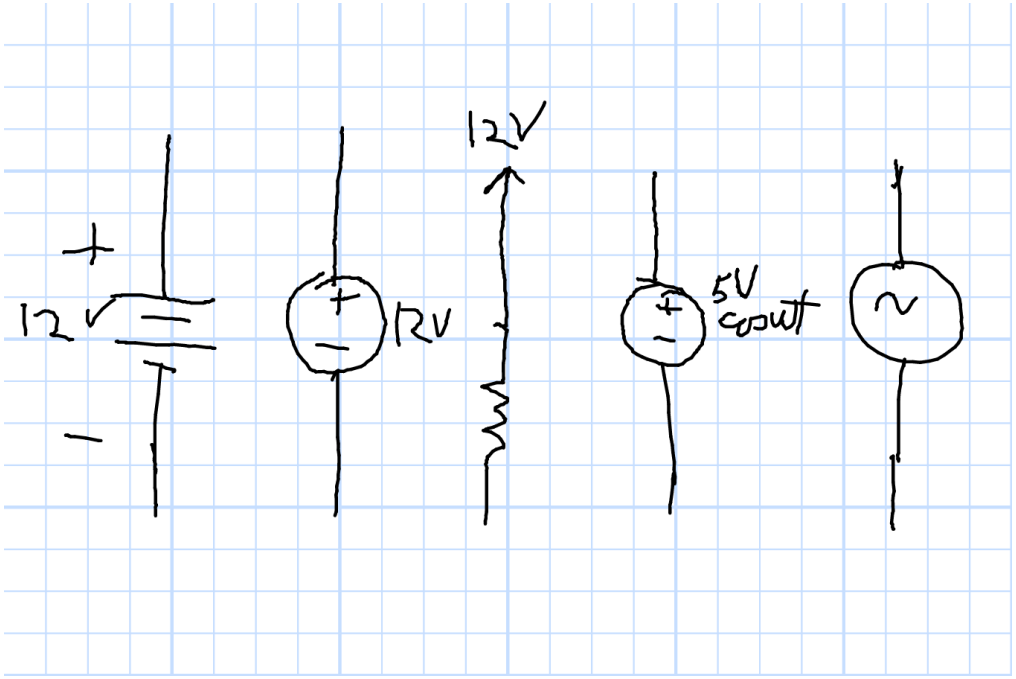
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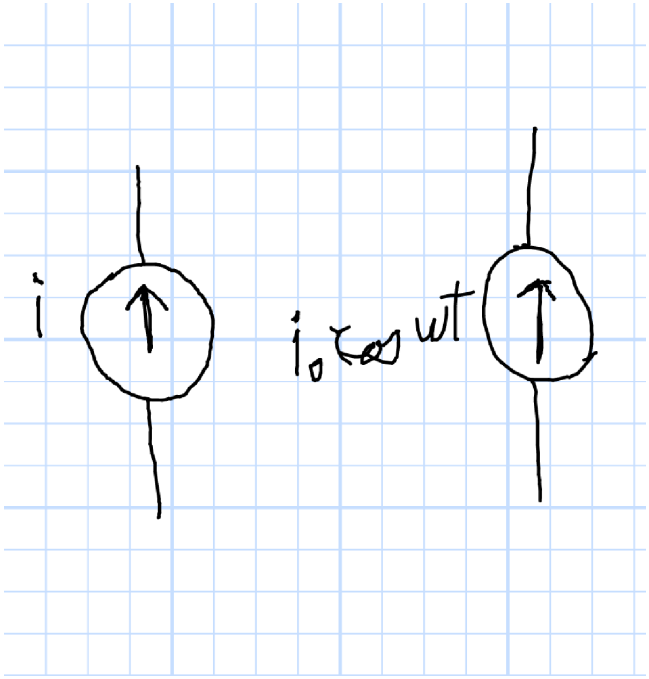
Circuits Review

- Sources, Resistors, Capacitors, Inductors
- Kirchoff's Current and Voltage Laws (KCL, KVL)
- Analysis and Design Problems
  - Node and Mesh Analysis
  - Series and Parallel
  - Current and Voltage Dividers
  - Superposition
  - Thévenin and Norton Equivalent Circuits
  - DC, Transients, Sinusoids

Voltage/Current Sources



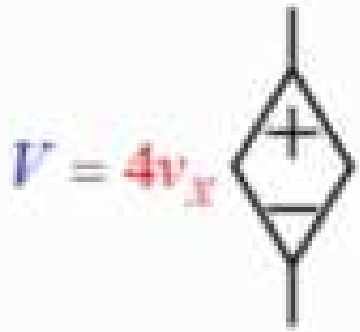
Some Voltage Sources



Current Sources

Dependent Sources

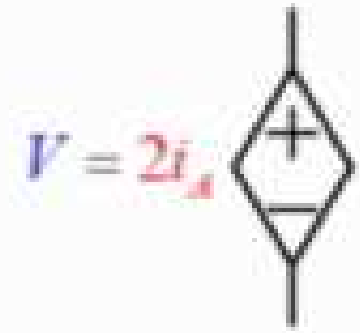
Voltage controlled voltage source

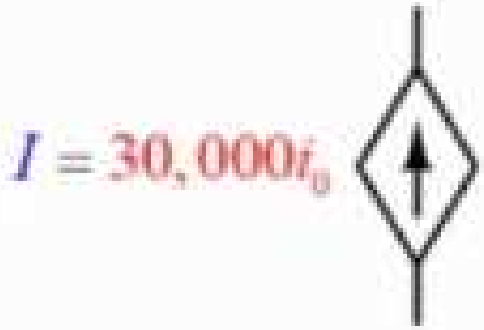




Voltage controlled current source

Current controlled voltage source





Current controlled current source

Be Careful About the Units on These Sources

comidoc.com

Passive Components

	DC	Time Domain	Frequency Domain
Resistor	$v = iR$	$v = iR$	$V = Ir$
Capacitor	$i = 0$	$i = C\frac{dv}{dt}$	$V = I\frac{1}{j\omega C}$
Inductor	$v = 0$	$v = L\frac{di}{dt}$	$V = Ij\omega L$
Any Above		$V = Iz$	

Coming Soon:
Diode

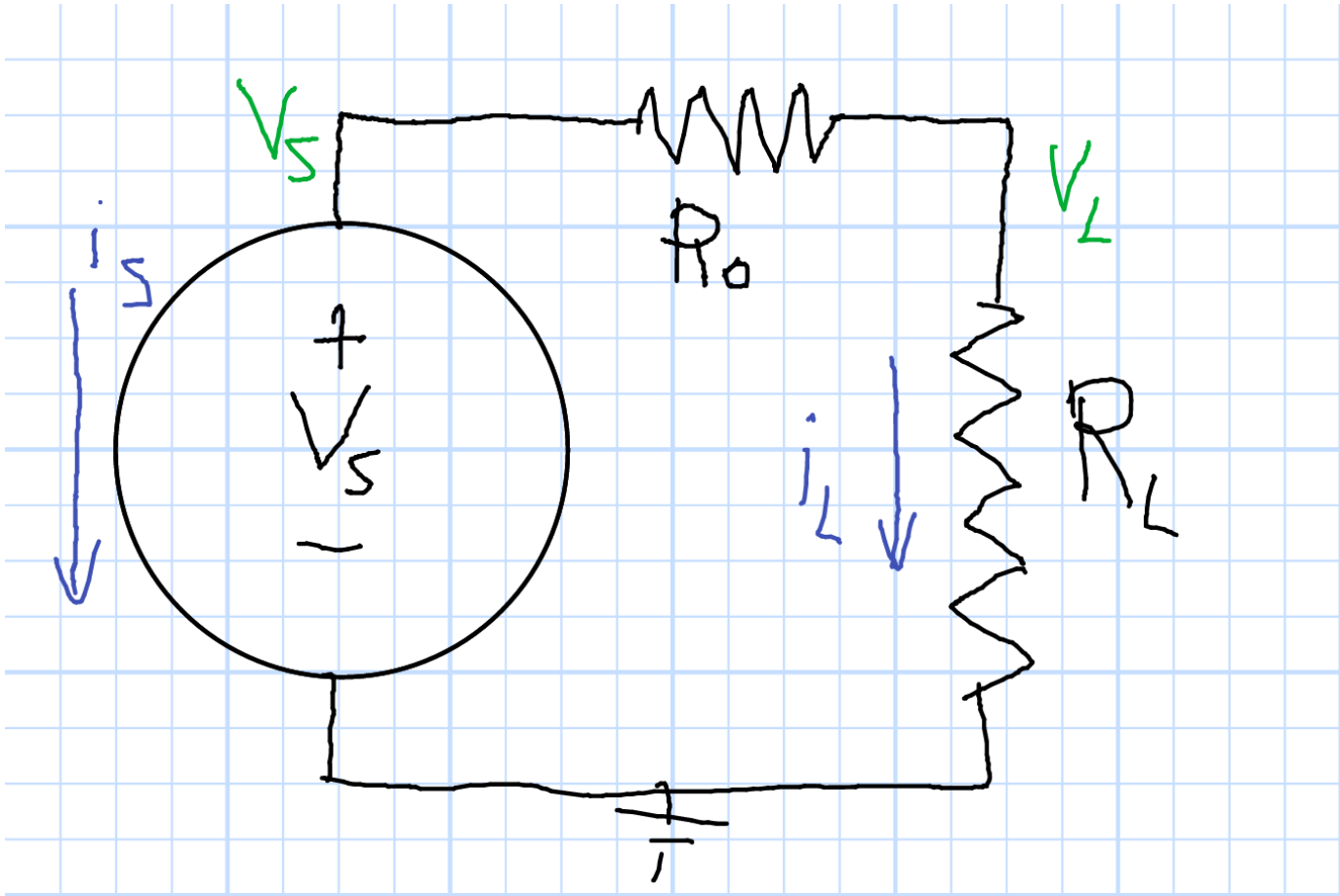
Later:
BJT (1)
FET (2)

1. Bipolar Junction Transistor
2. Field Efect Transistor

A Circuit with Passive Sign Convention

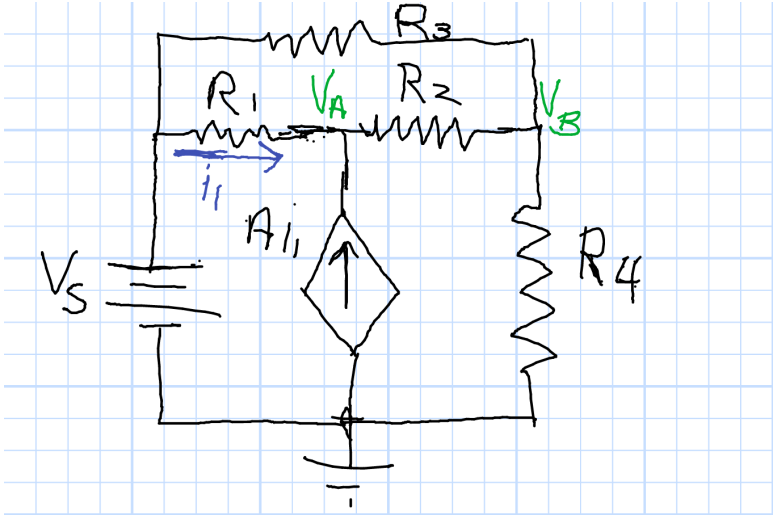
Power Absorbed $P = iv$

$P < 0$ $P > 0$

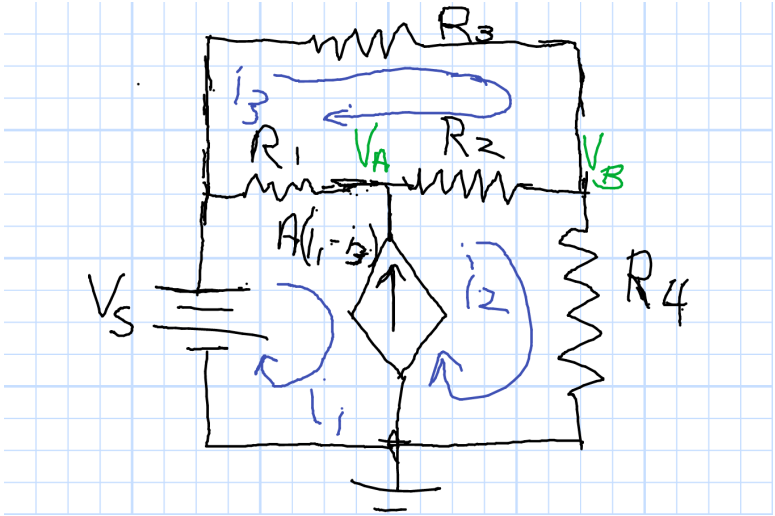


Solving Circuits

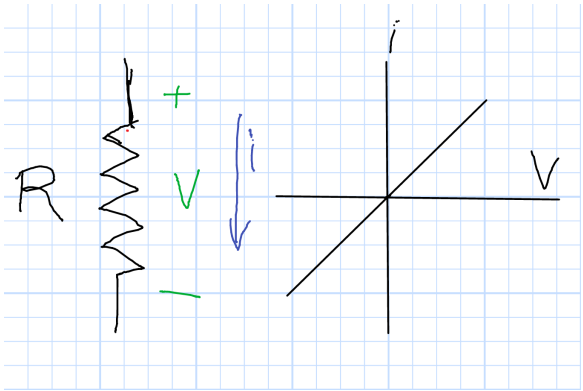
Node Analysis
($\sum i = 0$)



or Mesh Analysis
($\sum v = 0$)



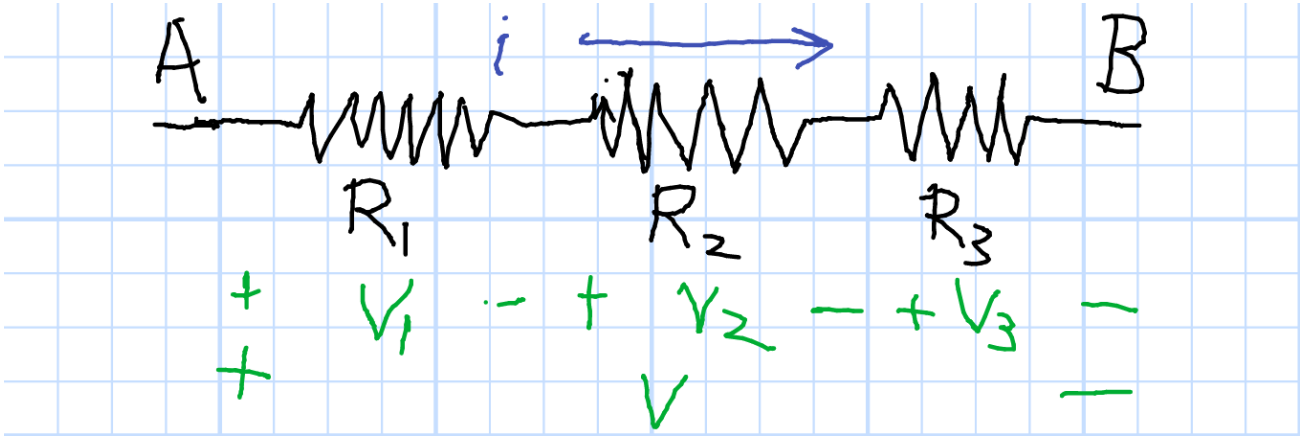
Components I–V Equations



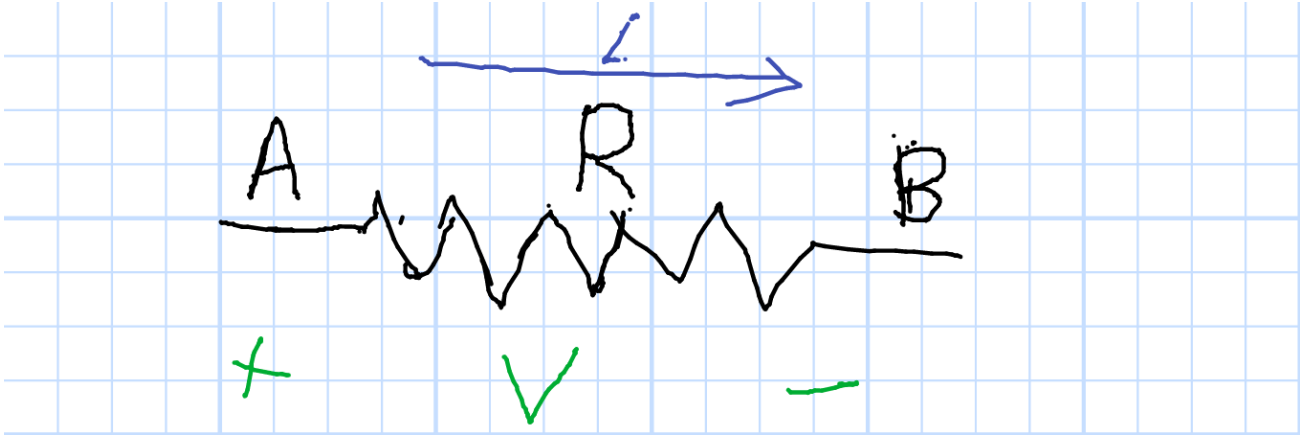
or Bag of Tricks

Series/Parallel
Voltage/Current Divider
Superposition

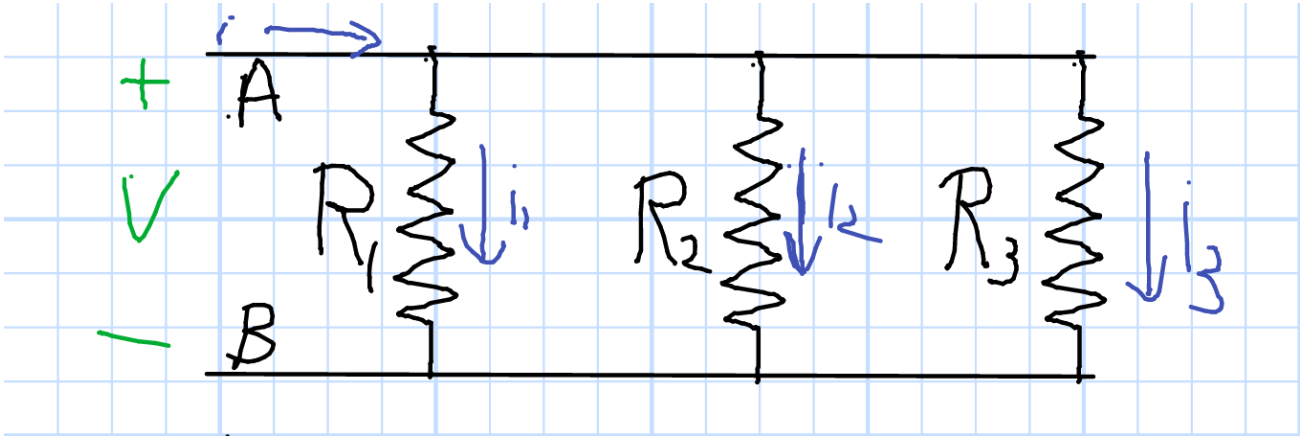
Resistors in Series



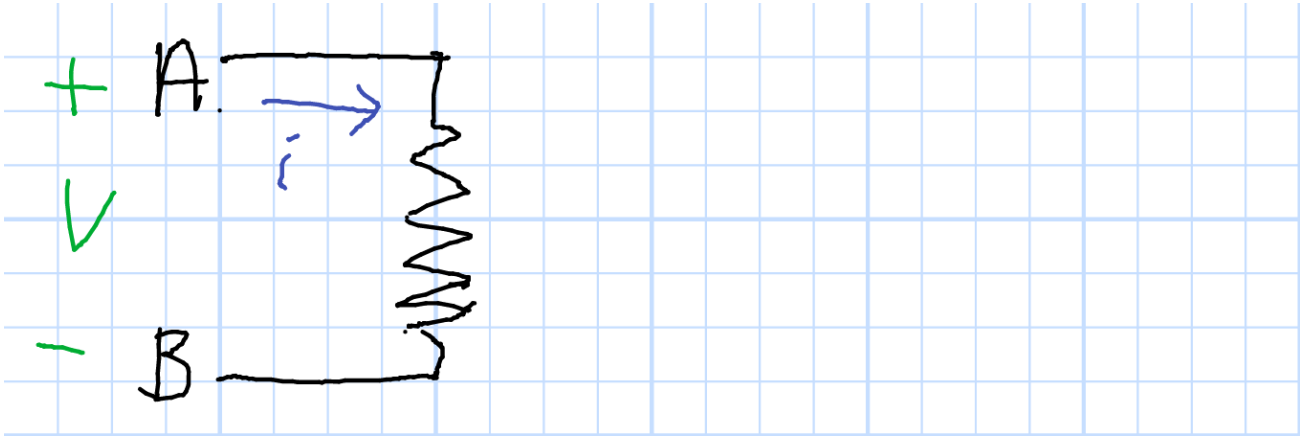
$$R = R_1 + R_2 + R_3$$



Resistors in Parallel



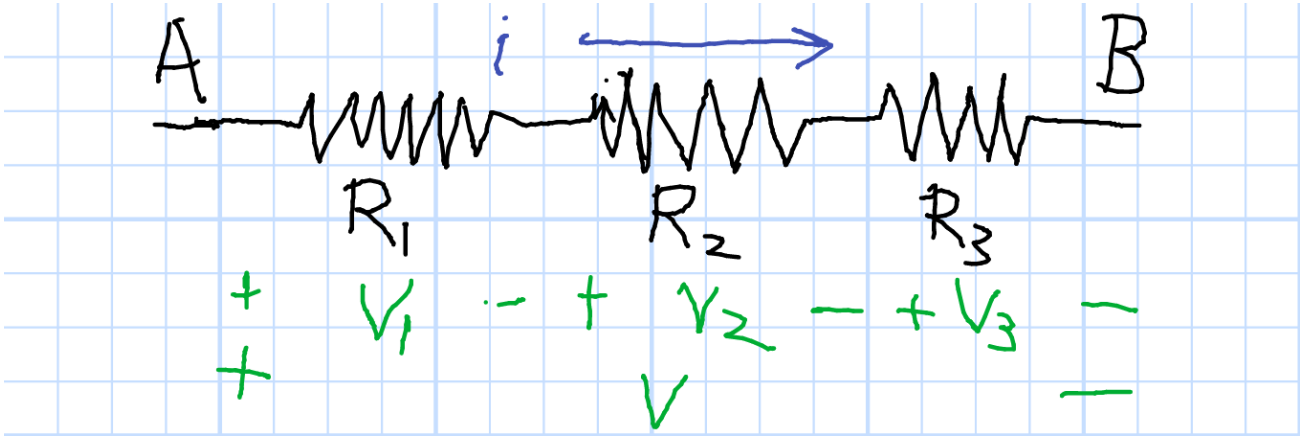
$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$



Parallel/Series Summary

	Series	Parallel
Voltage Sources	$v = \sum v_n$	Contradictory
Current Sources	Contradictory	$i = \sum i_n$
Resistors	$R = \sum R_n$	$\frac{1}{R} = \sum \frac{1}{R_n}$
Inductors	$L = \sum L_n$	$\frac{1}{L} = \sum \frac{1}{L_n}$
Capacitors	$\frac{1}{C} = \sum \frac{1}{C_n}$	$C = \sum C_n$
R, L, C	$Z = \sum Z_n$	$\frac{1}{Z} = \sum \frac{1}{Z_n}$

Voltage Divider



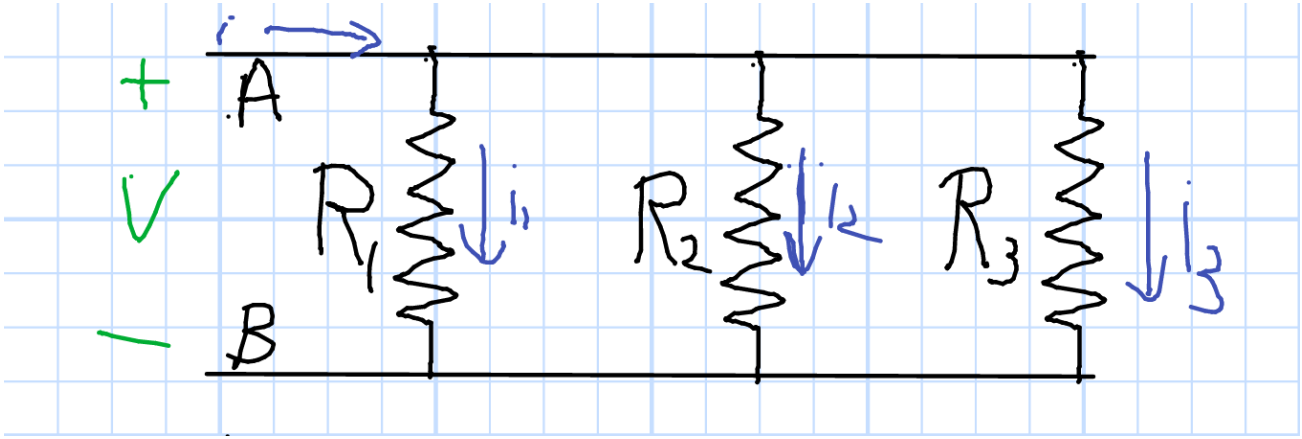
$$v_1 = iR_1 \qquad v = iR = i\left(R_1 + R_2 + R_3\right)$$

$$v_1 = v\frac{R_1}{R_1 + R_2 + R_3}$$

Some Applications:

- Using a Voltmeter
- Understanding Battery Failure
- Making a Volume Control

Current Divider

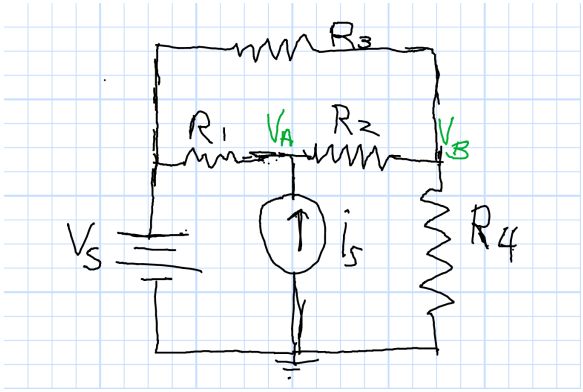


$$v = i_1 R_1 \qquad v = iR = i\frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}}$$

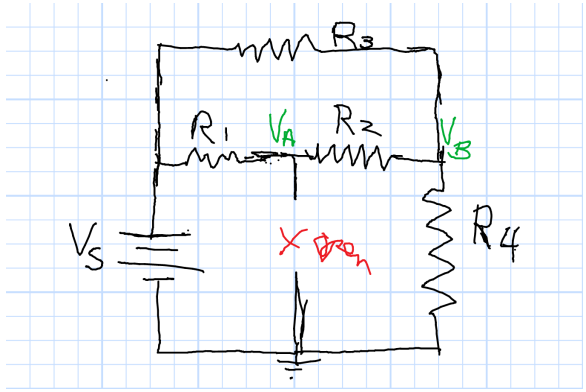
$$i_1 = i\frac{\frac{1}{R_1}}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}}$$

$$i_1 = \frac{G_1}{G_1+G_2+G_3}$$

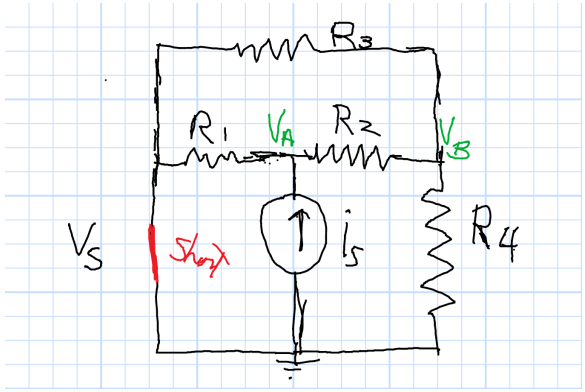
Zeroing Sources for Superposition



Original



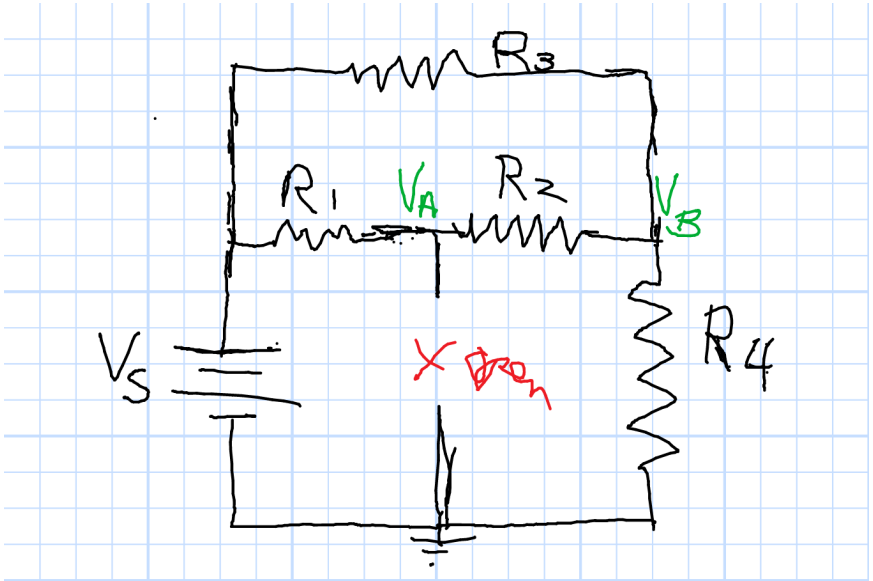
Zero Current Source
Open



Zero Voltage Source
Short

- Zero the Sources One at a Time
- Solve the Circuit for All Unknowns in Each Case
- Sum the Results

Superposition Solution



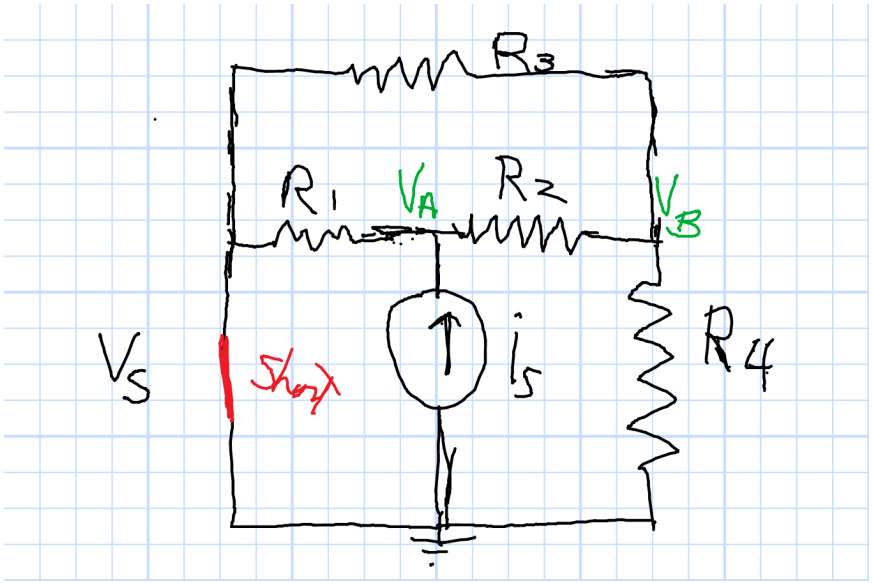
Series–Parallel Solution

$$i = v_s / \left[(R_1 + R_2) \parallel R_3\right] + R_4$$

$$v_B = iR_4$$

Voltage Divider

$$v_A = v_s + (v_B - v_s)\frac{R_1}{R_1 + R_2}$$



Series–Parallel Solution

$$v_A = i_s \left\{R_1 \parallel \left[R_2 + (R_3 \parallel R_4)\right]\right\}$$

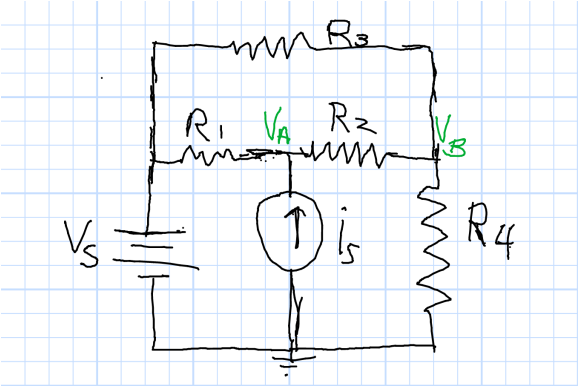
Current Divider (i_2 to the right)

$$i_2 = i_s \frac{R_1}{R_1 + R_2 + (R_3 \parallel R_4)}$$

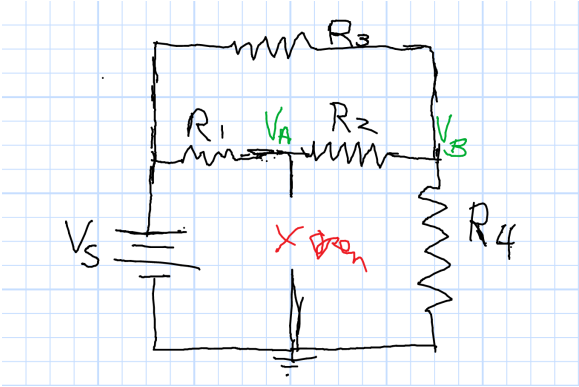
$$v_B = i_2 \left(R_3 \parallel R_4\right)$$

Conclusion

$V_s = 12\text{V}, i_s = 6\text{mA},\ R_1 = R_2 = 1k\Omega,\ R_3 = 5k\Omega, R_4 = 200\Omega$

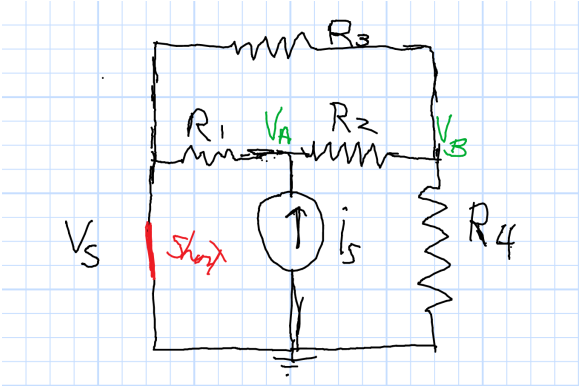


V_{total} $=$



v_1 $+$

$v_A = 6.74\text{V}$
$v_B = 1.47\text{V}$



v_2

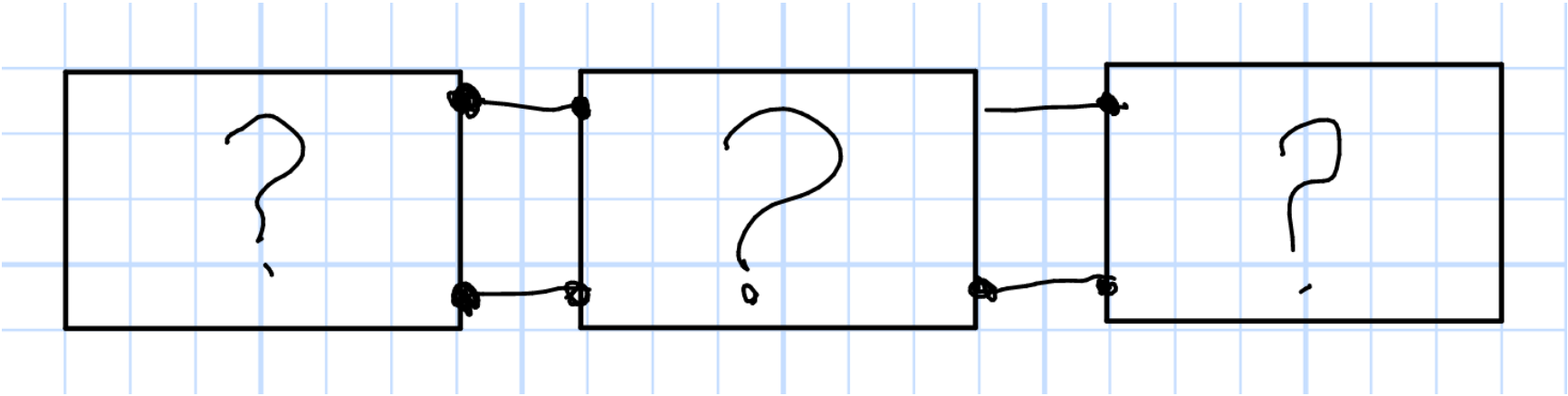
$v_A = 3.26\text{V}$
$v_B = 0.53\text{V}$

$V_A = 10.0\text{V}$ $\quad$ $V_B = 2.0\text{V}$

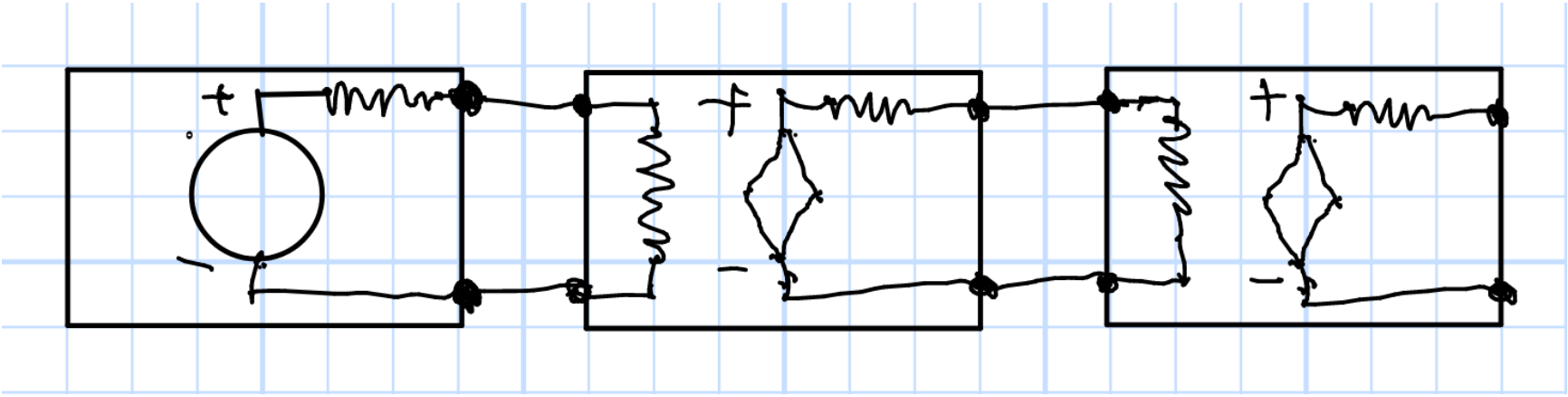
Same Result We Had Before.

Why Equivalent Circuits

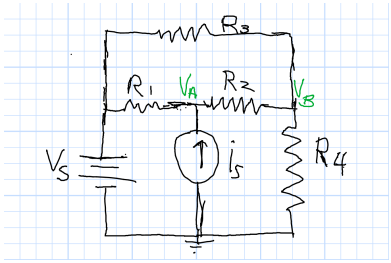
Each box contains a complicated Circuit. . .



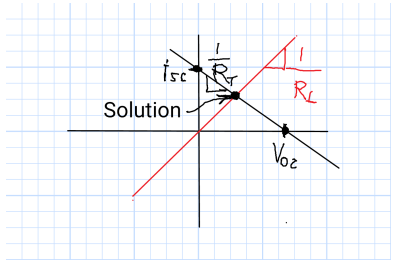
. . . but we don't really care what is in them.



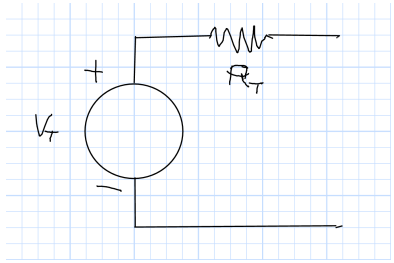
Equivalent Circuits



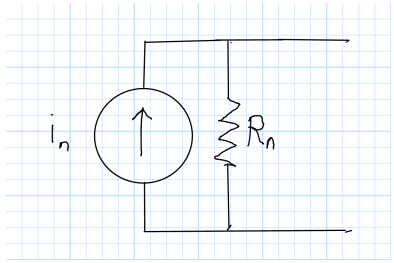
A Circuit



I-V PLots



Thévenin



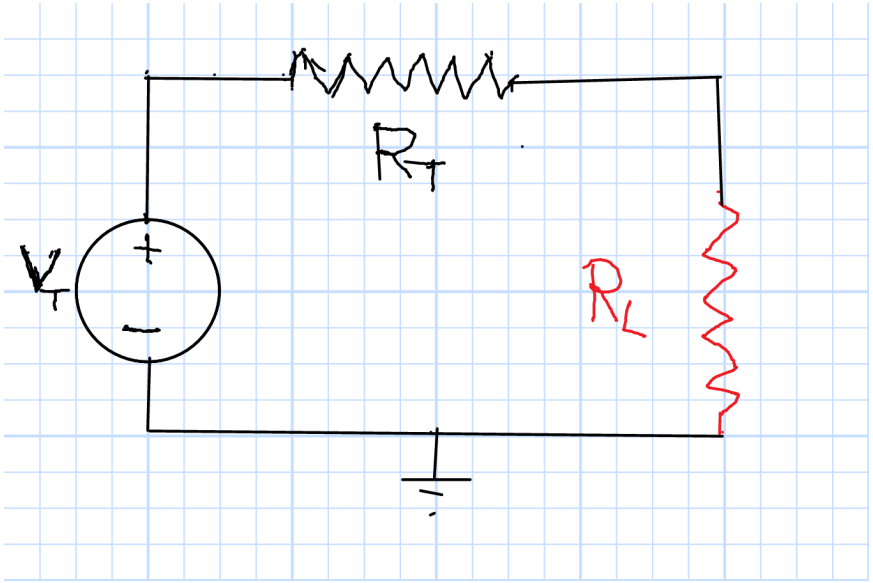
Norton

R_4 is the Load: Analyze everything else.

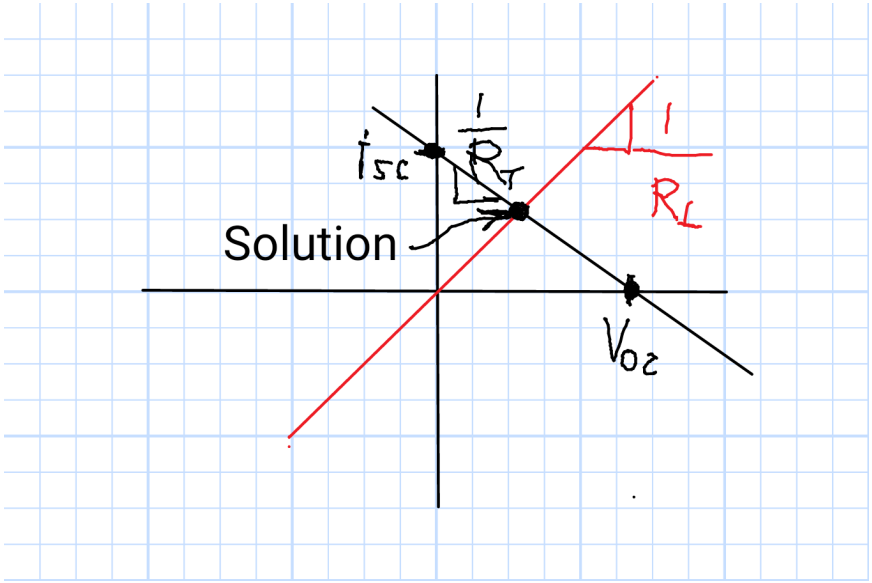
For a linear circuit, i vs. v is a straight line. Need two of v_{oc}, i_{sc}, R_T

- Calculation Options: Use any one.
  - Calculate V_{oc} and i_{sc}
  - Calculate V_{oc} and R_T
  - Calculate R_T and i_{sc}
- Equivalent Circuits
  - Thévenin: Voltage Source, V_{oc}, with Series R_T
  - Norton: Current Source, i_{sc}, with Parallel $R_N = R_T$

Thévenin Concept



Circuit Equation



Load Equation

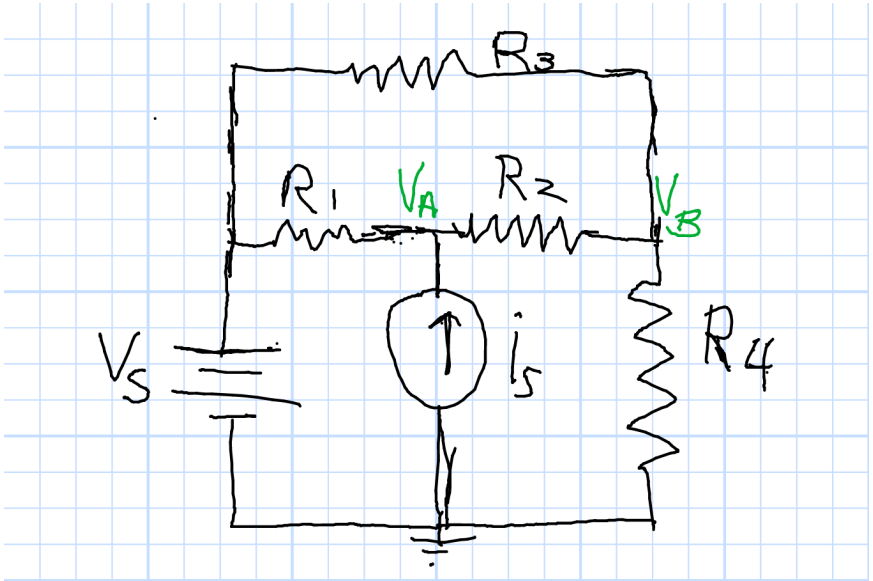
$$i = \frac{v_T - v}{R_T}$$

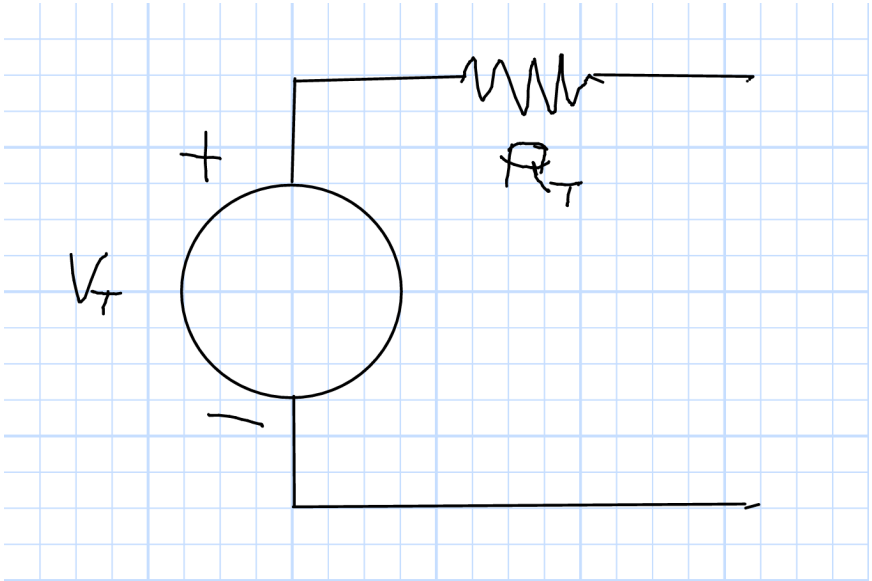
Load Line

$$i = \frac{v}{R}$$

Solution is at the interesection.

Thévenin Equivalent Circuit





R_4 is the Load: Draw a circuit for everything else.

Linear Circuits: i *vs.* v is a straight line.

We need two points to determine the line.

$i = 0$: Open Circuit Voltage. $v = 0$: Short–Circuit Current

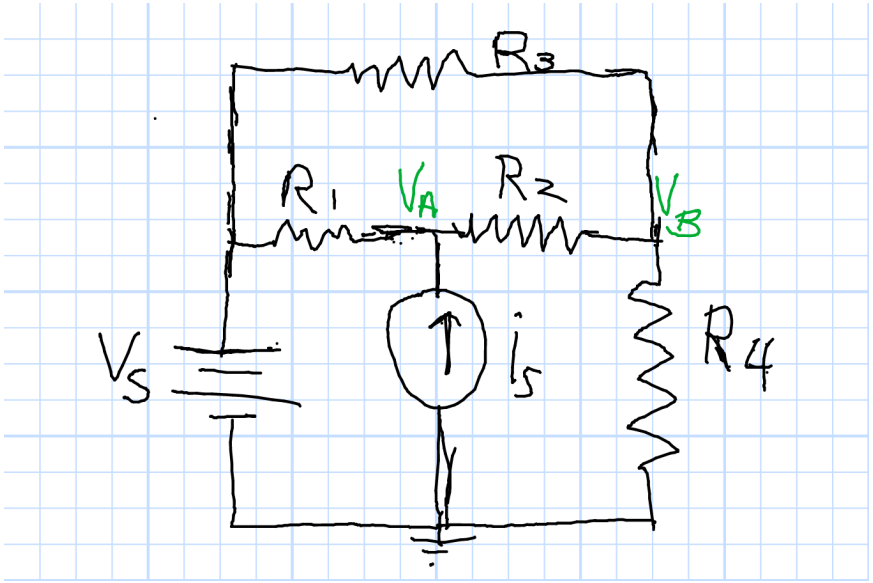
$R_T = v_{oc}/i_{sc}$

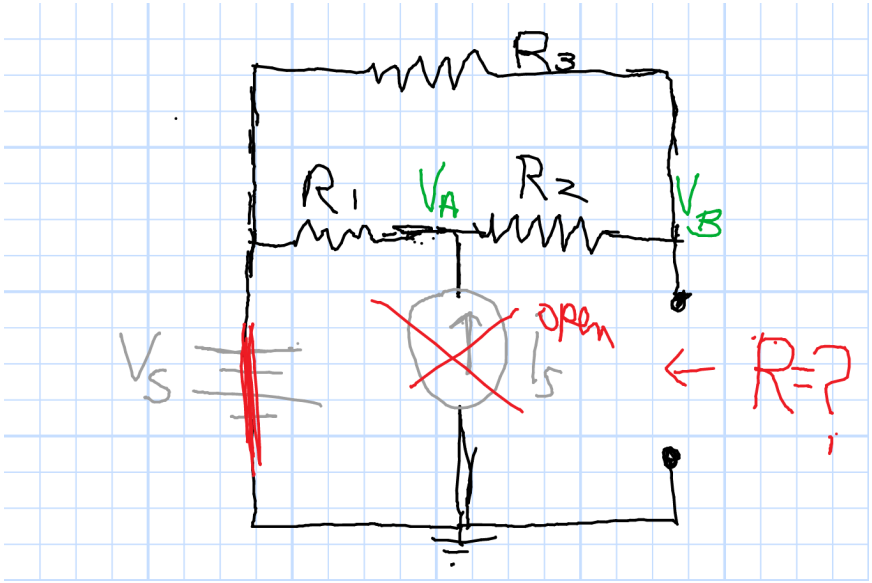
Solution: Voltage Divider

Load Resistor: $i = \frac{v}{R_4}$

Everything Else: $i = \frac{v_T - v}{R_T}$

Alternative: Find R_T





Zero the Sources:

Voltage Sources Shorted ($v = 0$)

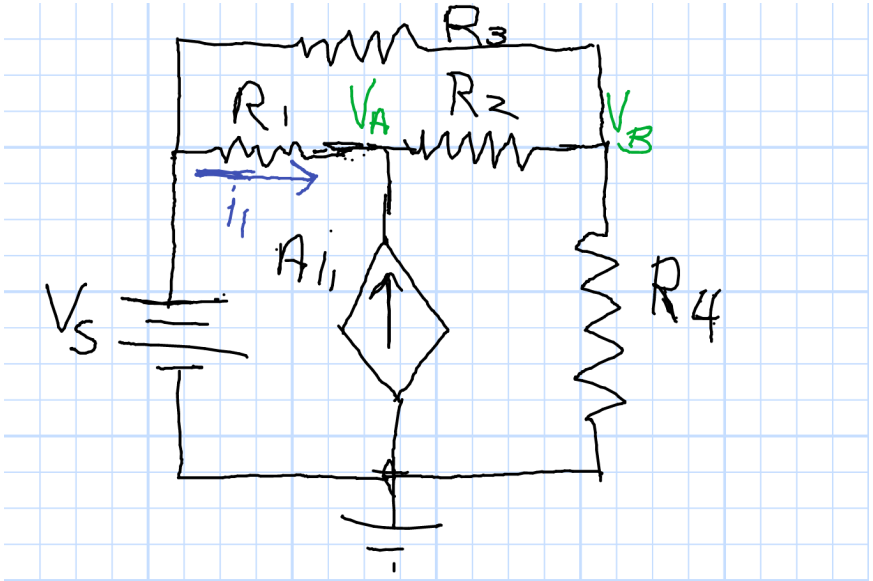
Current Sources Opened ($i = 0$)

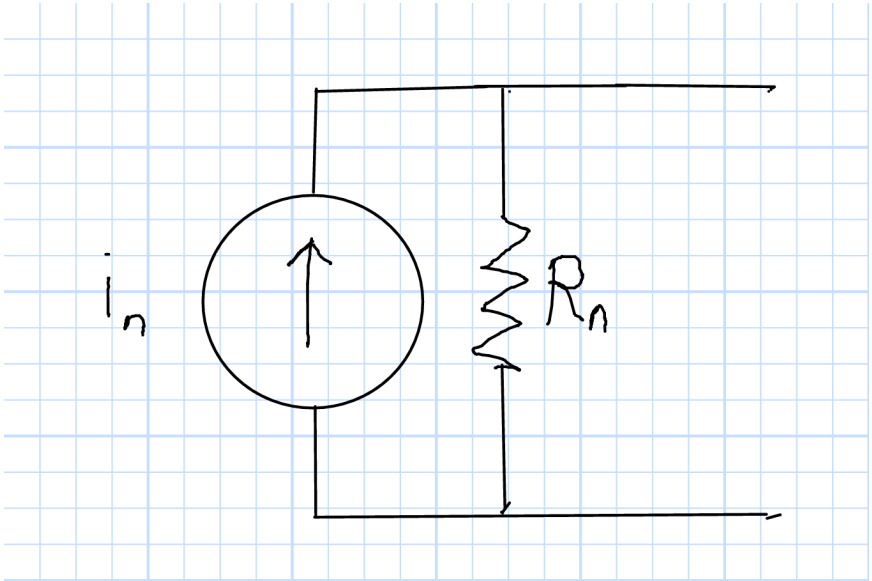
Use Series and Parallel Combinations

Do This if v_{oc} or i_{sc} Looks Messy.

In This Example, $R_T = (R_1 + R_2) \parallel R_3 = 1430$ Ohms

Norton Equivalent Circuit





R_4 is the Load: Draw a circuit for everything else.

Linear Circuits: i *vs.* v is a straight line.

We need two points to determine the line.

$i = 0$: Open Circuit Voltage. $v = 0$: Short–Circuit Current

Load Resistor: $i = \frac{v}{R_4}$

Solution: Current Divider

Everything Else: $i = i_N - \frac{v}{R_N}$

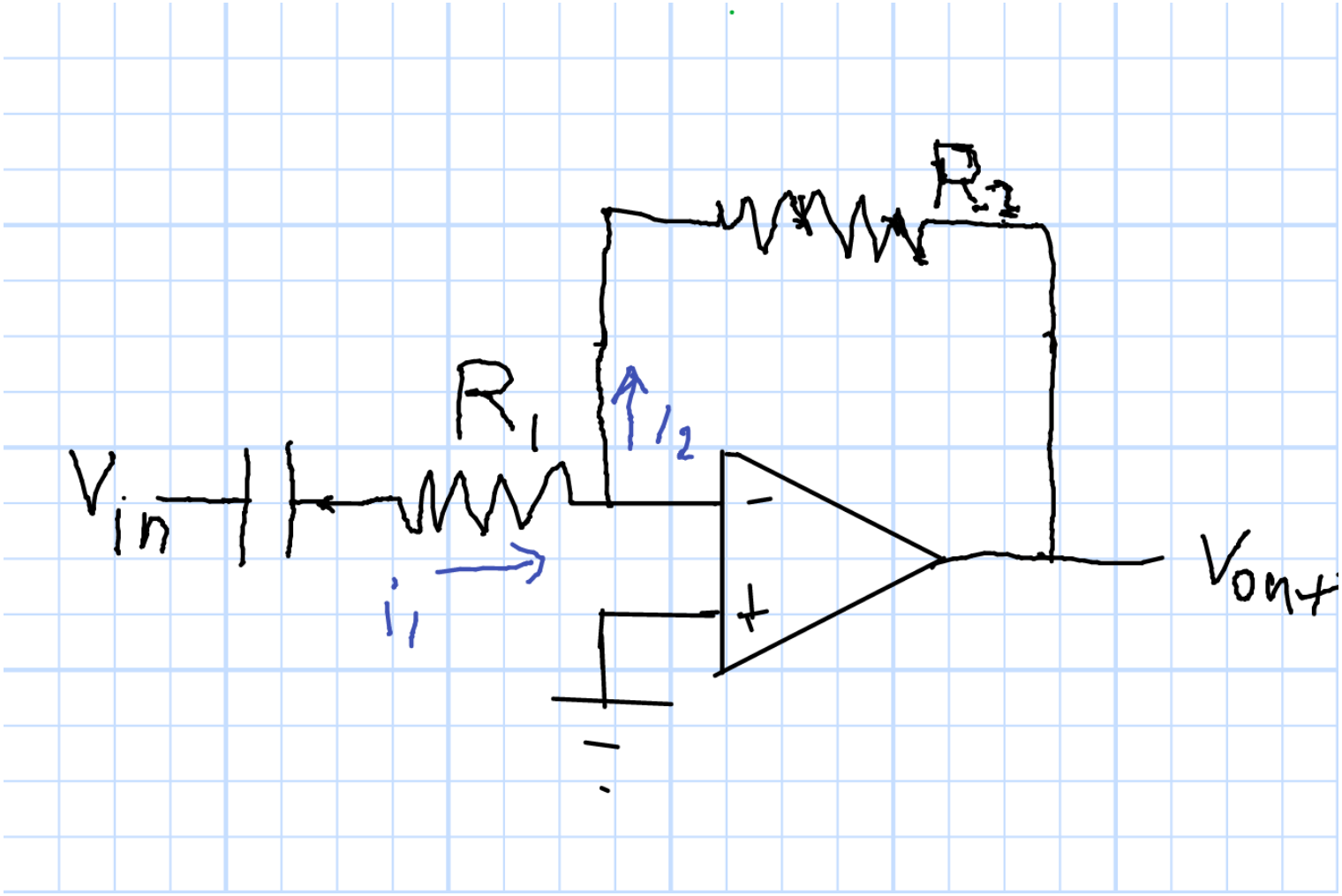
Steady State

- DC Sources, Resistors, Capacitors, Inductors
- $t \to \infty$
- $\frac{d\text{anything}}{dt} \to 0$
- Specifically $\frac{dv_{capacitor}}{dt} \to 0$
- Therefore $i_{capacitor} = 0$
- Treat Capacitors as Open and Solve

Time–Varying Sources

- Transient Analysis (Now)
  - Differential Equations
  - First Order for RL, RC
  - Second Order for RLC
  - Circuits Usually Involve Switches
  - Transient and Steady–State Solutions
- Sinusoidal Solution
  - Phasor Analysis ($\frac{d}{dt} = j2\pi f$)
  - Complex Impedance
  - "Easy" Solutions
  - Fourier Series and Transforms

AC Coupled Amplifier



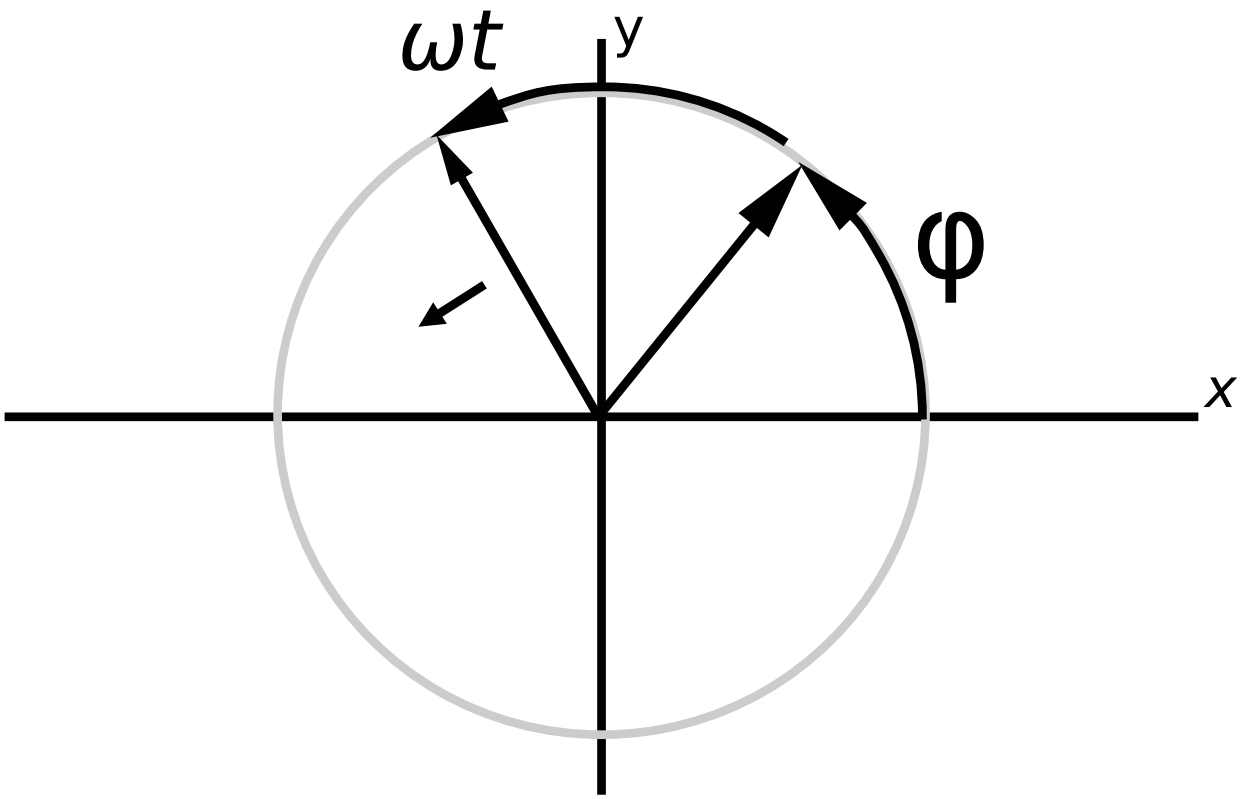
Steady–State Sinusoids

Resistors		
$v = iR$		$\vec{V} = \vec{I}R$
Capacitors		
$i = C\frac{dv}{dt}$	$\vec{I} = j\omega C\vec{V}$	$\vec{V} = \frac{1}{j\omega C}\vec{I}$
Inductors		
$v = L\frac{di}{dt}$		$\vec{V} = j\omega L\vec{I}$

Easy? . . .

Easy!

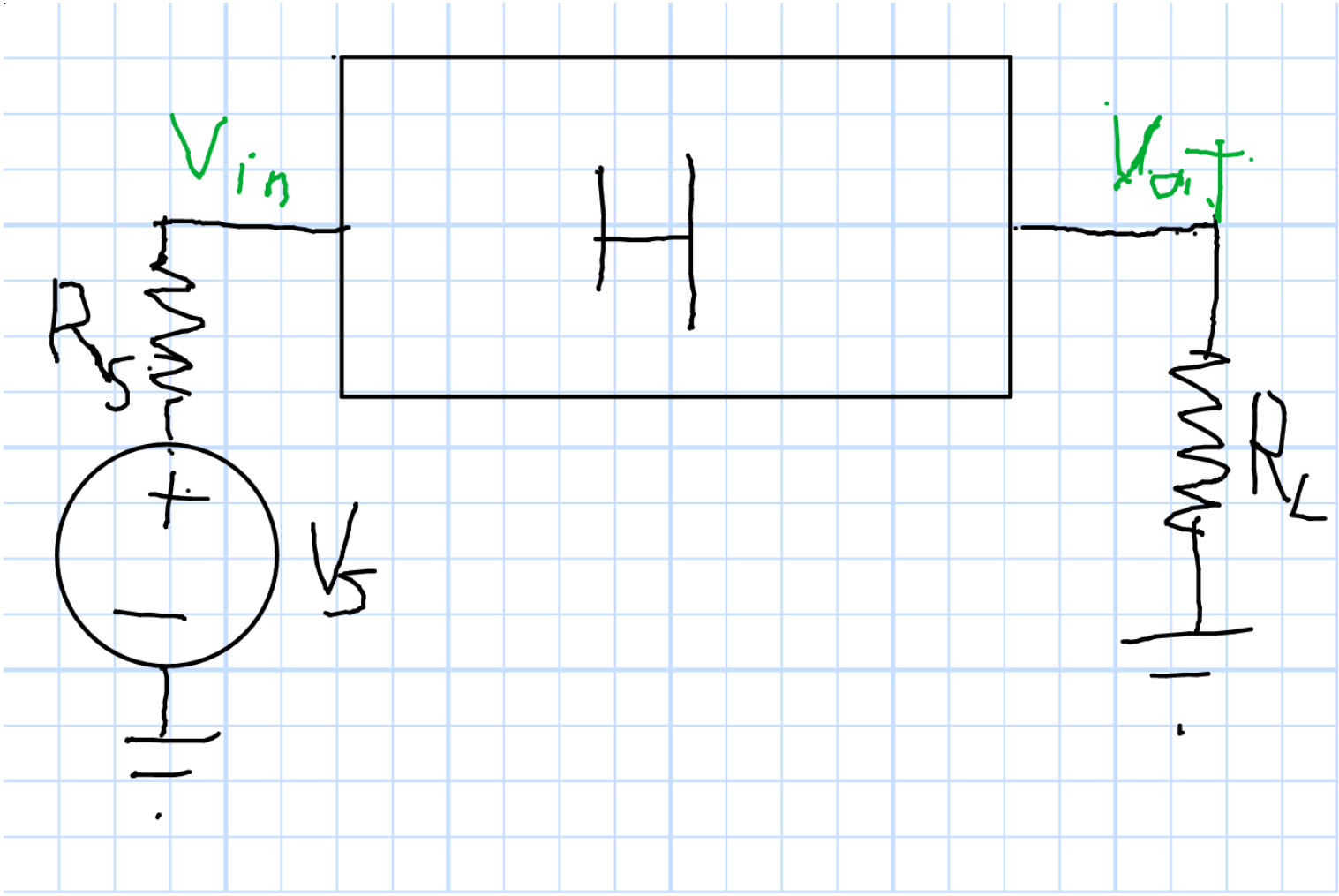
Phasors



$$x = Re(z) = |z| \cos\phi$$

$$y = Im(z) = |z| \sin\phi$$

Transfer Function Concept



$\vec{V}_{out}(\omega) = H(\omega)\,\vec{V}_{in}(\omega)$ and No Coupling

DeciBels, dB

- Always Refers to a Ratio

$$\frac{|V_{out}|}{|V_{in}|} \qquad \text{Or} \qquad \frac{P_{out}}{P_{in}} =? \left|\frac{V_{out}}{V_{in}}\right|^2$$

- Log Base 10

$$\log_{10} \frac{P_{out}}{P_{in}}$$

- But That's too Coarse; Multiply by 10

$$R_{dB} = 10 \log_{10} \frac{P_{out}}{P_{in}} = 20 \log_{10} \frac{|V_{out}|}{|V_{in}|} \qquad \frac{|V_{out}|}{|V_{in}|} = 10^{R_{dB}/20}$$

- lower case d, Capital B (Named for Alexander Graham Bell)

Some Ratios in dB

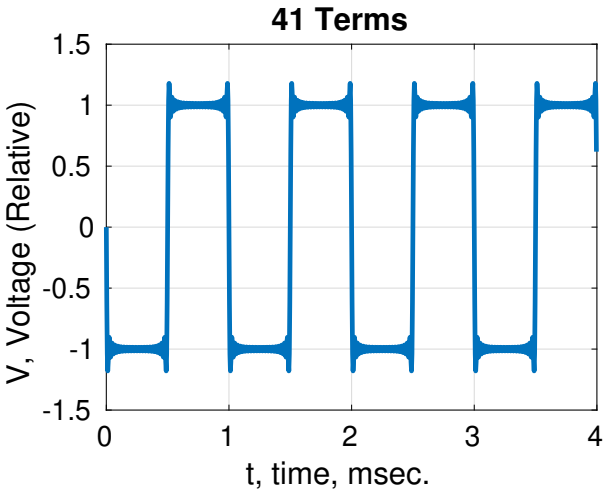
dB	Power Ratio	Voltage Ratio
-40	0.0001	0.01
-30	0.001	$\sqrt{0.001} \approx 0.032$
-20	0.01	0.1
-10	0.1	$\sqrt{0.1} \approx 0.32$
-6	0.25	0.5
-3	0.5	$\sqrt{0.5} \approx 0.71$
0	1	1
3	2	$\sqrt{2} \approx 1.4$
6	4	2
10	10	$\sqrt{10} \approx 3.2$
20	100	10
30	1000	$\sqrt{1000} \approx 32$
40	10000	100

The cool thing is that they add.

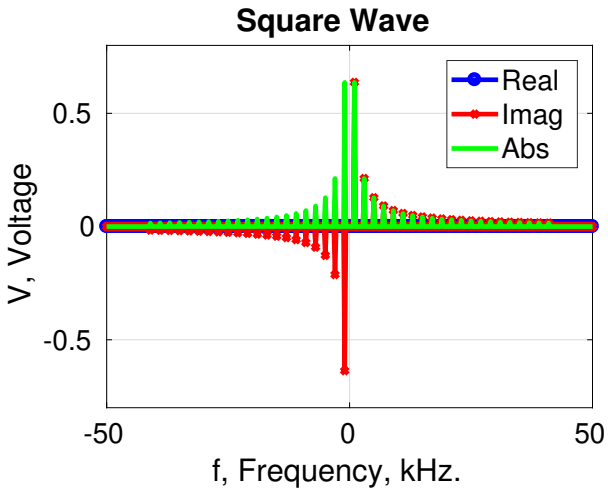
Power

- Power: $P = iv$
- Average Power: $\overline{p} = \frac{1}{T}\int_0^T iv \ dt$
- Resistor: $\overline{p} = \frac{1}{T}\int_0^T \frac{v^2}{R} \ dt \ v_{rms} = \frac{1}{T}\int_0^T v^2 \ dt$
- Sinusoids: $v_{rms} = \frac{1}{\sqrt{2}} v_{peak} = \frac{1}{2\sqrt{2}} v_{pp}$

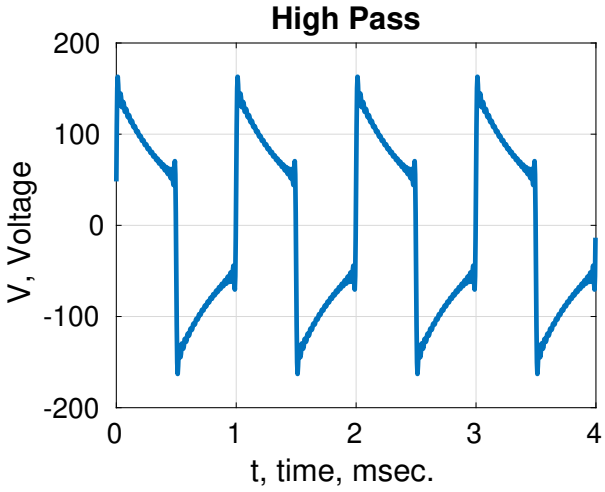
High–Pass Filter/Amplifier



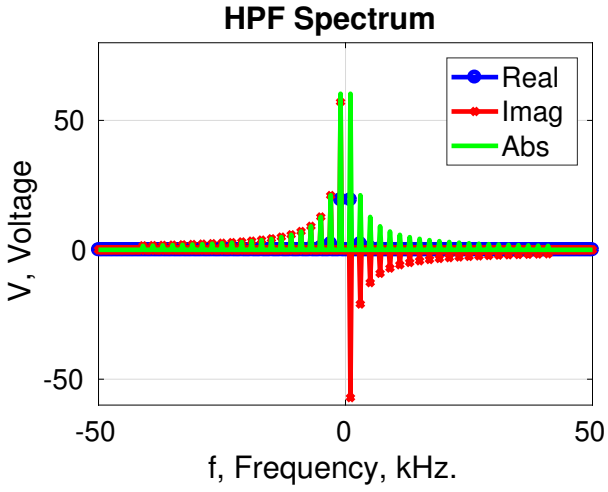
Input



Fourier Series

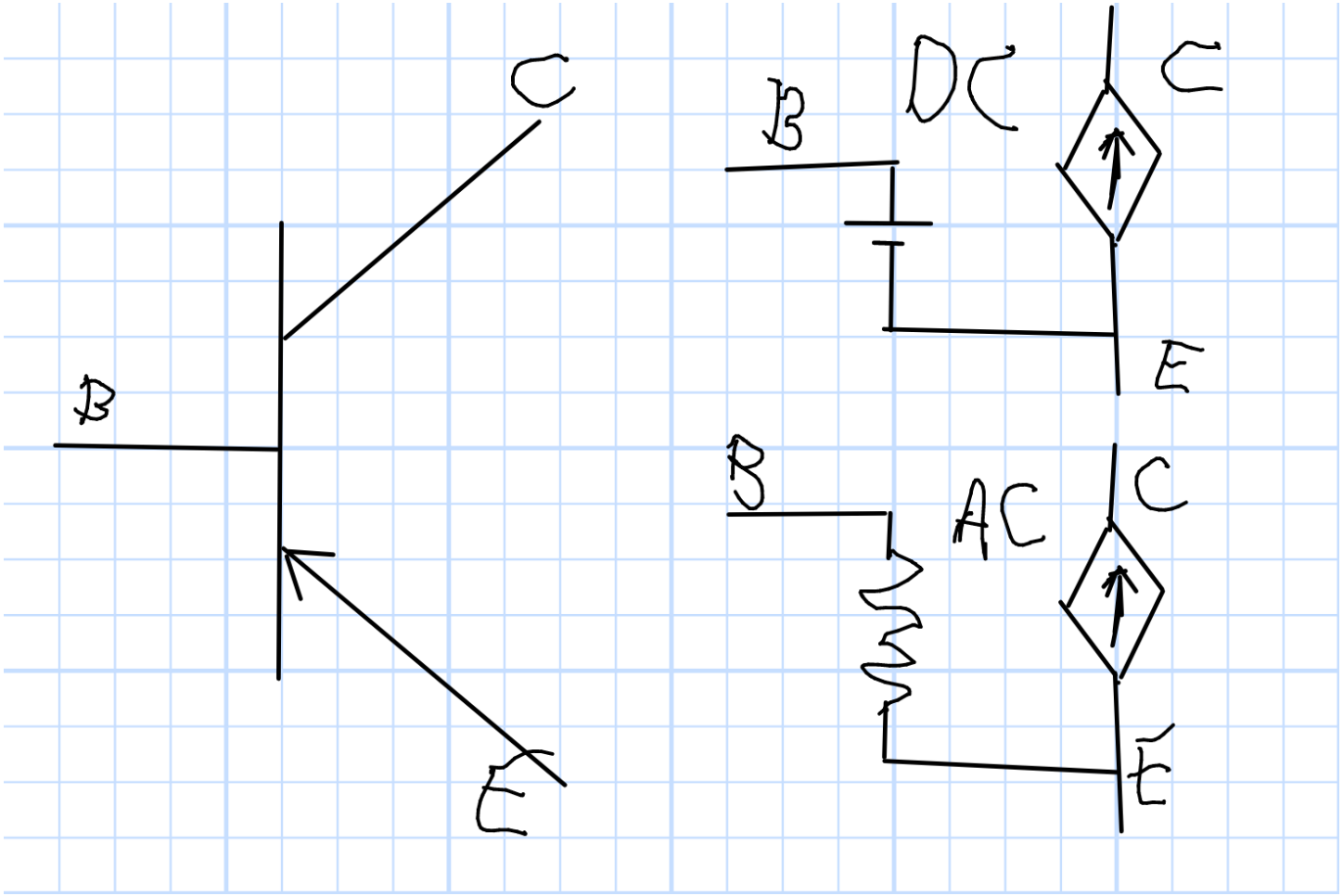


HPF Output



Fourier Series

Some Transistor Models

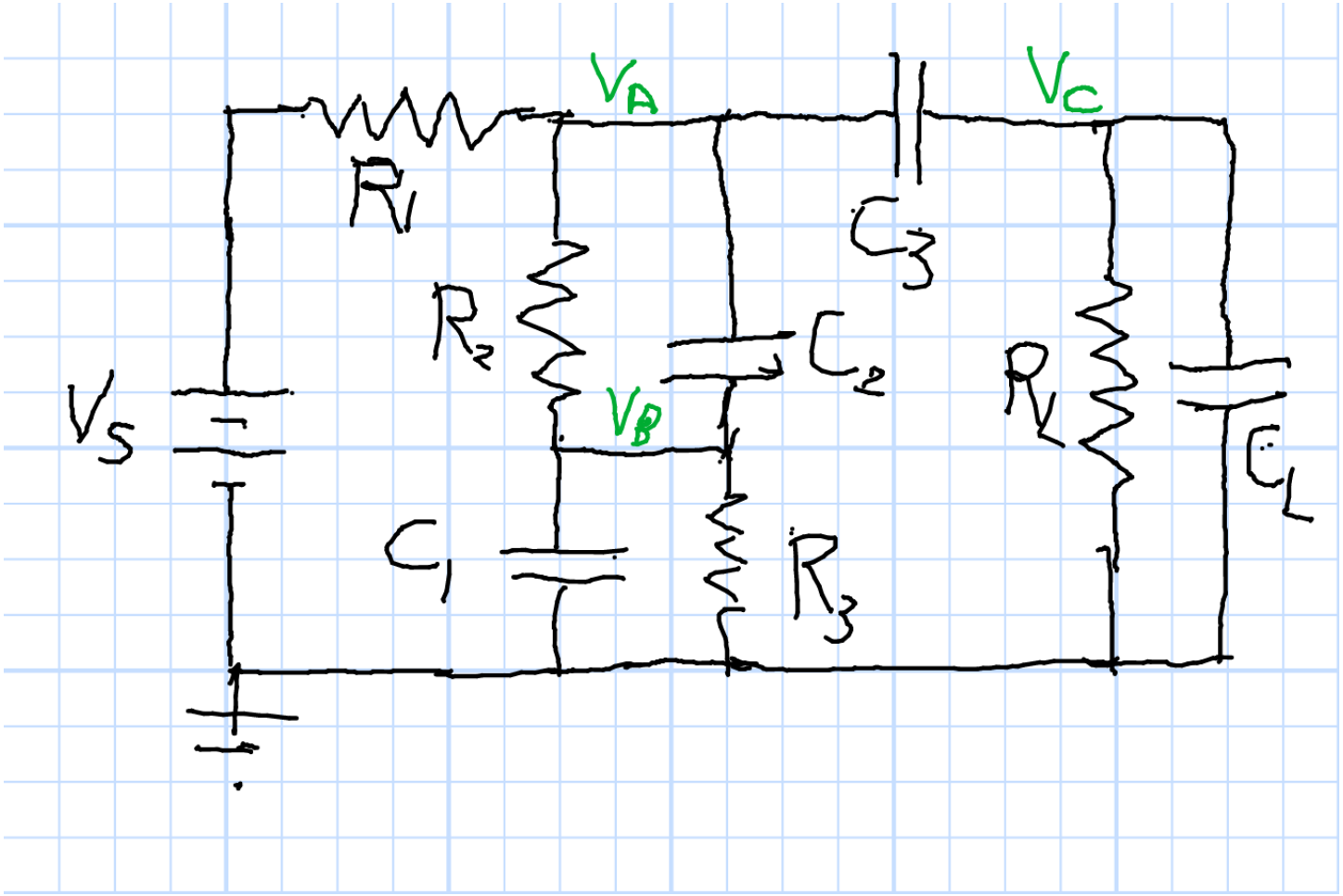


Electronic Components Can Be Described by Concepts We Already Know, *eg.* Sources and Resistors.

In–Class Examples

To be solved in class.

Steady–State Example



Steady State: $v_A =?$ $v_B =?$ $v_C =?$ $P_{RL} =?$

Superposition Example

