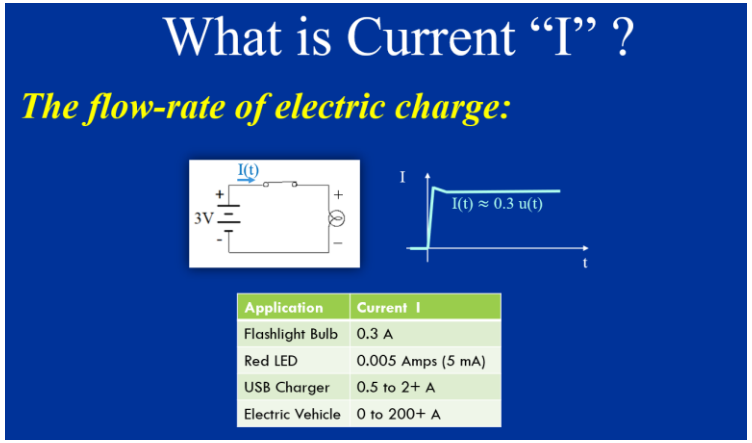
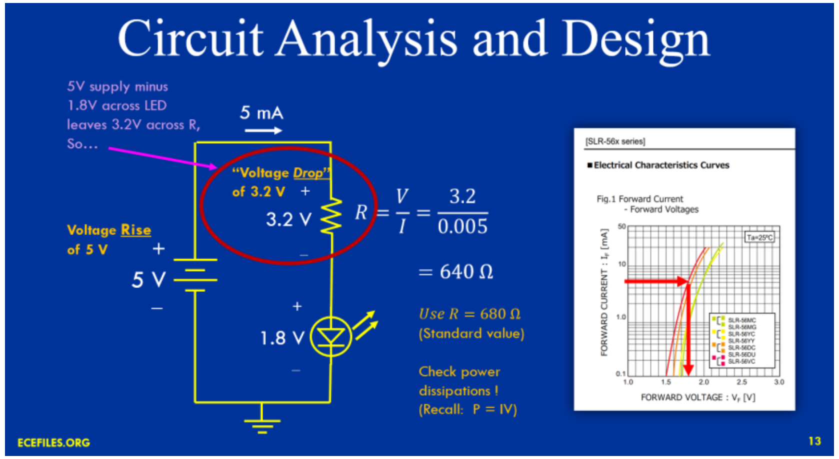
ECE Topics #1 -- Voltage, Current, Resistance, and Power

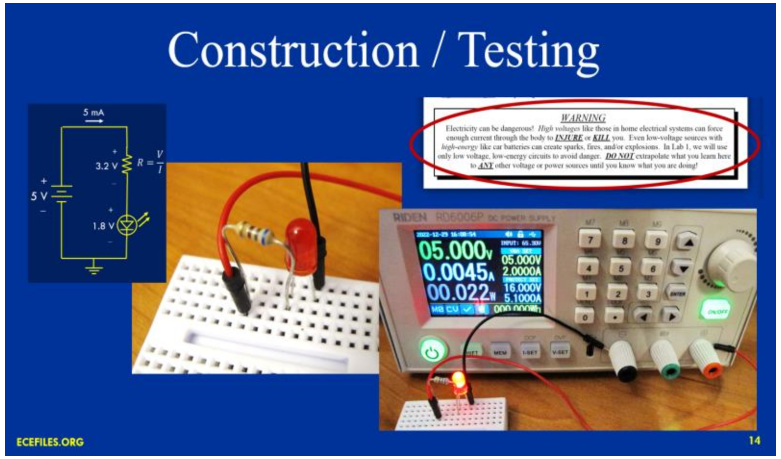
Slides downloaded from: https://ecefiles.org/ece-topics/

Companion video at: https://www.youtube.com/watch?v=2kJbzG6z_tU

This first video in the ECE Topics Series provides an introduction to what voltage, current, power, and resistance are. Going beyond basic theory, we present real-world examples of each. In addition to classic topics like Ohm's Law, we introduce device datasheets and show how such information can be used to design, build, and test a simple circuit.



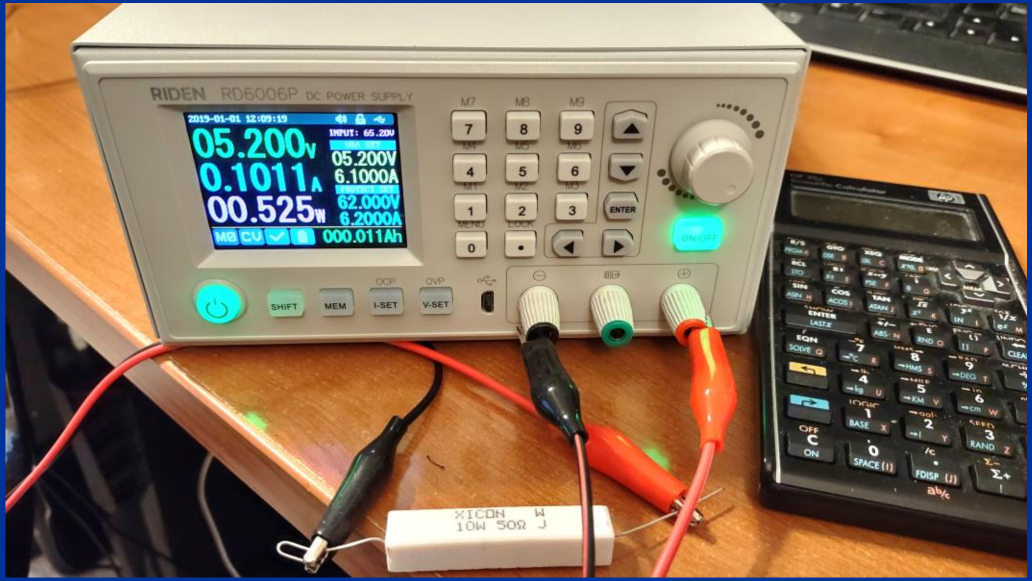




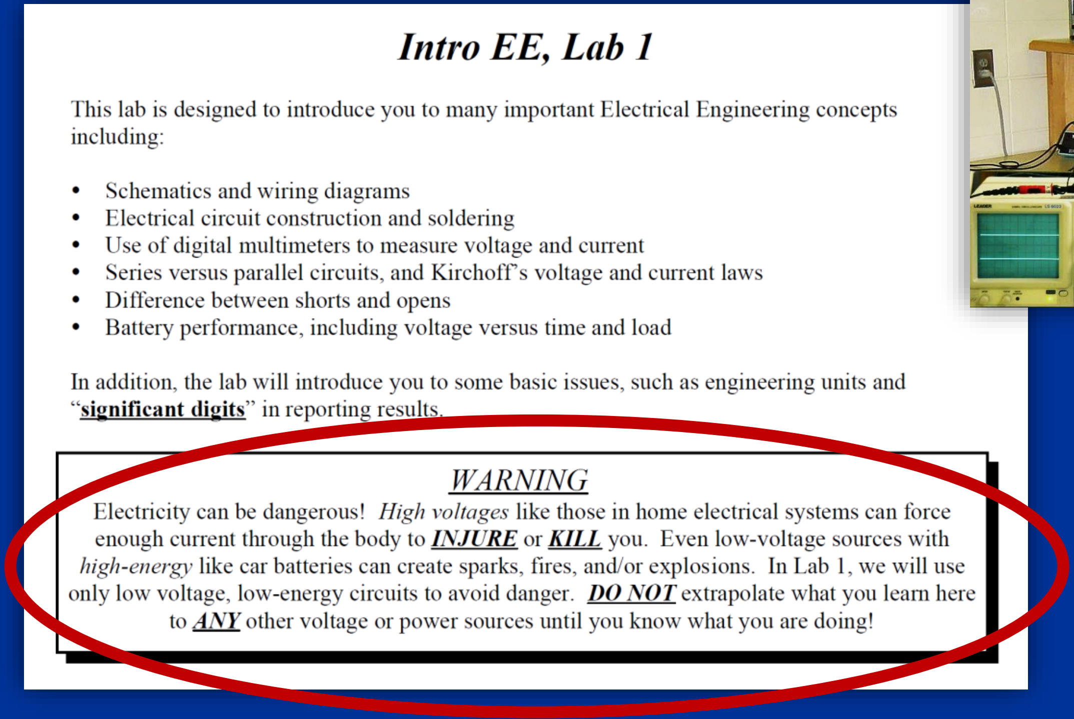
Topics in ECE #1

Voltage, Current, ^ and Power

Resistance,



Based on University Courses



Intro EE, Lab 1

This lab is designed to introduce you to many important Electrical Engineering concepts including:

- Schematics and wiring diagrams
- Electrical circuit construction and soldering
- Use of digital multimeters to measure voltage and current
- Series versus parallel circuits, and Kirchoff's voltage and current laws
- Difference between shorts and opens
- Battery performance, including voltage versus time and load

In addition, the lab will introduce you to some basic issues, such as engineering units and "**significant digits**" in reporting results.

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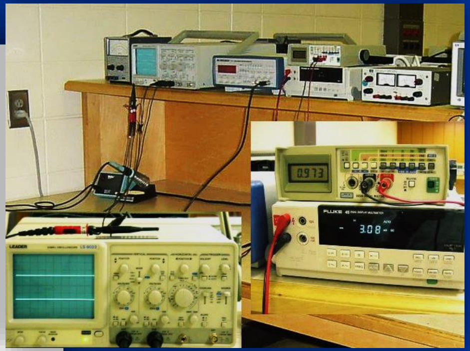
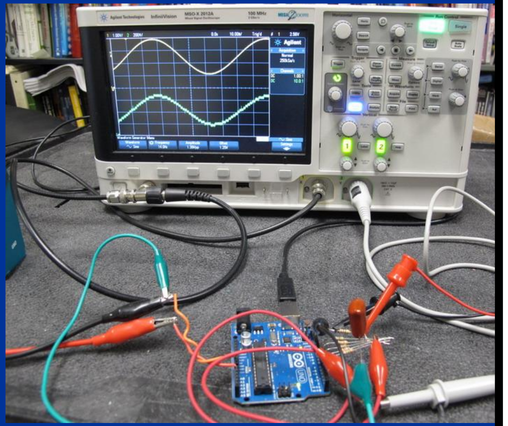
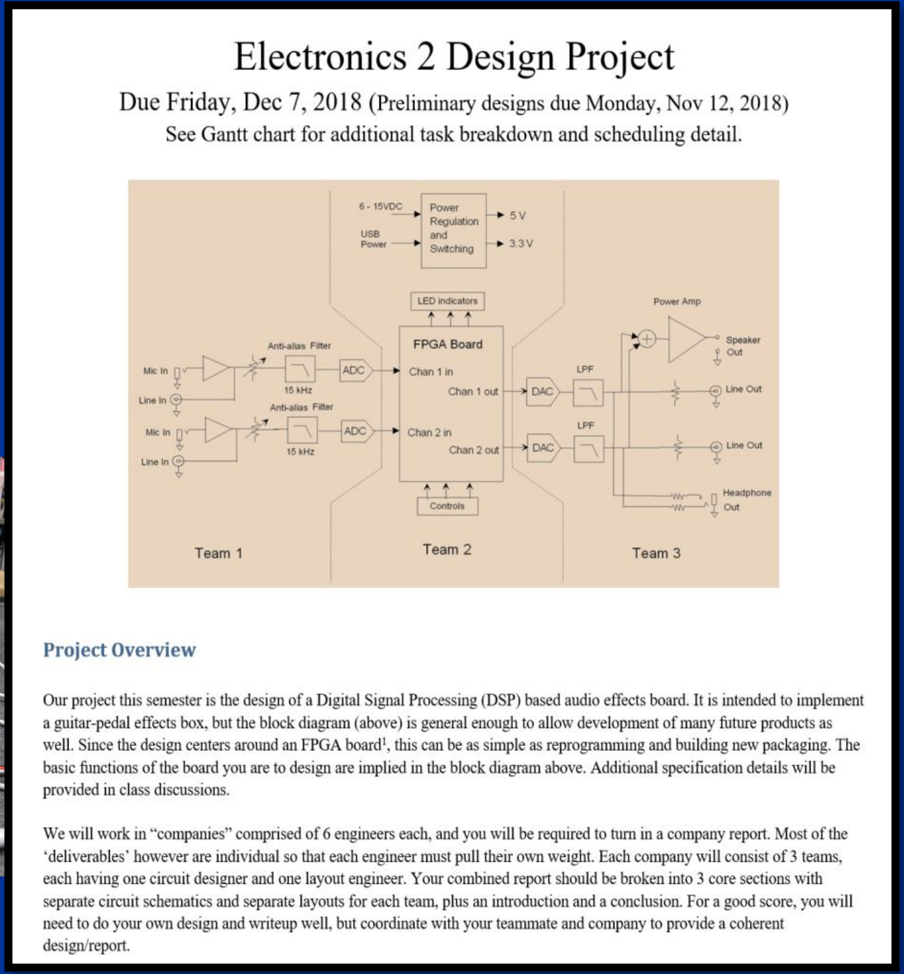






Electronics 2 Design Project

Due Friday, Dec 7, 2018 (Preliminary designs due Monday, Nov 12, 2018)

See Gantt chart for additional task breakdown and scheduling detail.

Project Overview

Our project this semester is the design of a Digital Signal Processing (DSP) based audio effects board. It is intended to implement a guitar-pedal effects box, but the block diagram (above) is general enough to allow development of many future products as well. Since the design centers around an FPGA board[1], this can be as simple as reprogramming and building new packaging. The basic functions of the board you are to design are implied in the block diagram above. Additional specification details will be provided in class discussions.

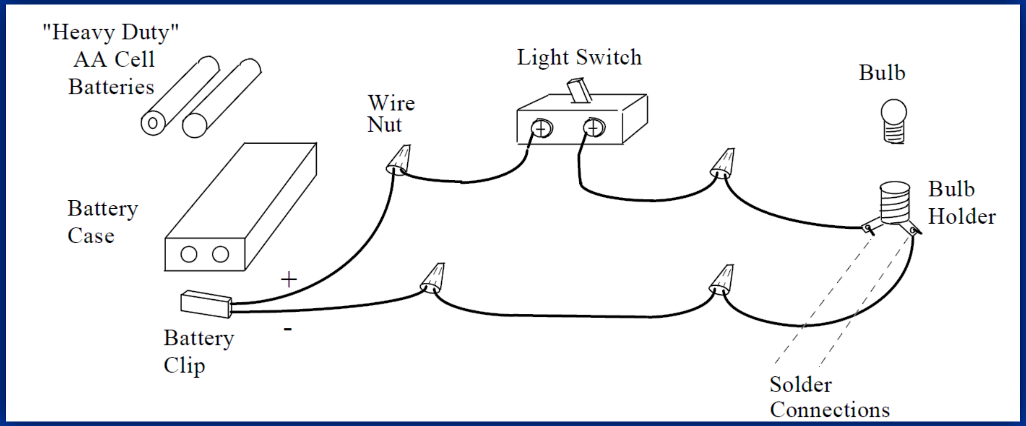
We will work in "companies" comprised of 6 engineers each, and you will be required to turn in a company report. Most of the 'deliverables' however are individual so that each engineer must pull their own weight. Each company will consist of 3 teams, each having one circuit designer and one layout engineer. Your combined report should be broken into 3 core sections with separate circuit schematics and separate layouts for each team, plus an introduction and a conclusion. For a good score, you will need to do your own design and writeup well, but coordinate with your teammate and company to provide a coherent design/report.

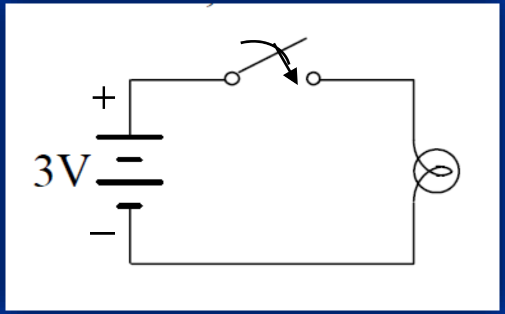
Episode 1 Topics

- The Basics
  - What are current, voltage, and power ?
  - Real world applications and example values
- Ohms Law vs Device IV Curves
- Circuit Analysis and Design
- Protoboard Construction / Testing

What is Current "I" ?

The flow-rate of electric charge in Amperes





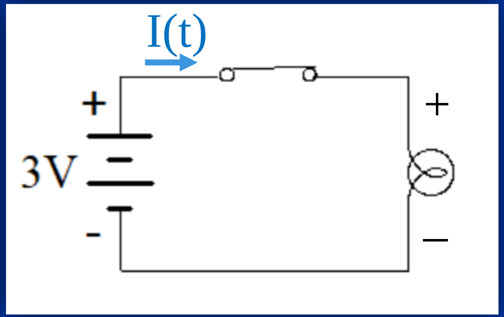
Charge in Coulombs

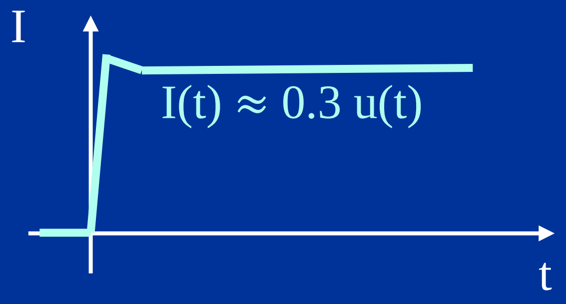
$$I = \frac{Q}{t} \quad \text{or} \quad I = \frac{\Delta Q}{\Delta t} \quad \text{or} \quad i(t) = \frac{dq}{dt}$$

Time in seconds

What is Current "I" ?

The flow-rate of electric charge:

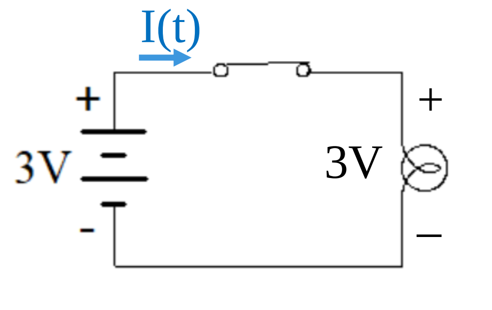




Application	Current I
Flashlight Bulb	0.3 A
Red LED	0.005 Amps (5 mA)
USB Charger	0.5 to 2+ A
Electric Vehicle	0 to 200+ A

OK – So what is Voltage ?

This is more complicated…
It's kinda like the "pressure" behind the flow…



But actually, it's ***energy (a.k.a. work) per unit charge, in Volts***

Work (energy) in Joules

$$V = \frac{W}{Q} \quad \text{or} \quad V = \frac{\Delta W}{\Delta Q}$$

Charge in Coulombs

Application	Voltage V
Flashlight Bulb	3 Volts
Red LED	1.8 V
USB Charger	5 V (5-20V for PD)
Electric Vehicle	200 to 800 V

Measuring I and V

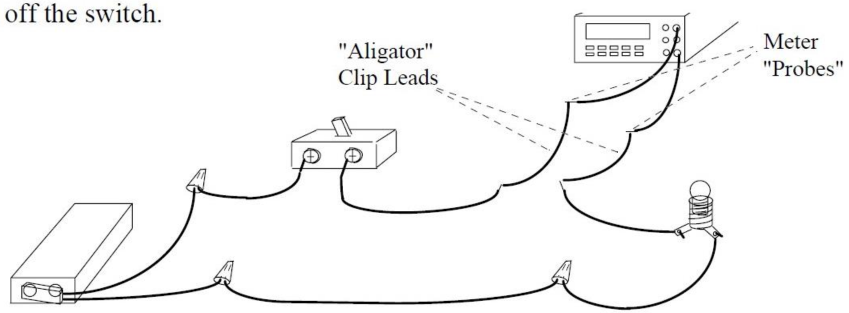
Small Currents

III. Measuring Current

Recall from class that current is a “through variable”, whereas voltage is an “across variable”. To measure voltage, all we needed to do was place the DMM test leads “across” the battery. **To measure current, we must put the meter in the path of the current so that the current passes *through* the DMM**. The following steps will walk you through this procedure.

1. It is almost always good practice to “de-energize” a circuit before working on it. To do this here, disconnect the clip from the battery holder.
2. Undo the connection between the switch and the bulb (at the wire nut).
3. “Hook-up” the meter as shown in the figure below to measure current. ***Be sure to use the 10A current input on the meter***, and to configure the meter to read DC amps (ask your instructor if you are not sure!).
4. With the switch off, re-energize your circuit (hook up the batteries again).

8. Note that there is a “voltage drop” from the battery to the bulb due to the DMM that is measuring the current. **This is an example of an important issue in taking measurements. The measurement equipment itself can affect the quantity being measured, to some degree**.
9. Turn off the switch.



Hooking up meter to measure current (meter terminals may not be shown accurately).

Voltages and Large Currents

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How Are V&I Related ?

Through Power (P) in Watts

$$V\,I = \frac{\Delta W}{\cancel{\Delta Q}}\frac{\cancel{\Delta Q}}{\Delta t} = \frac{\Delta W}{\Delta t} = P \qquad or \qquad P = VI$$

Application	Voltage	Current	Power
Flashlight Bulb	3 V	0.3 A	0.9 W
Red LED	1.8 Volts	0.005 Amps	0.009 Watts (9 mW)
USB	5 V	2 A	10 W
Electric Vehicle	800 V	200 A	160 kW (215 HP)

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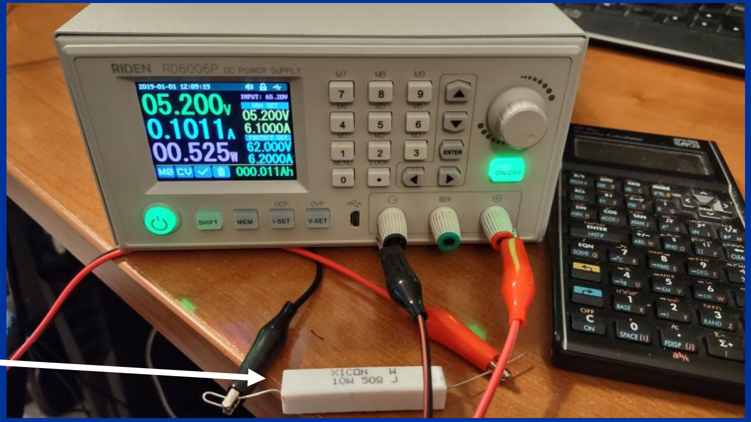
Oh yeah, and thru "Ohms Law"…

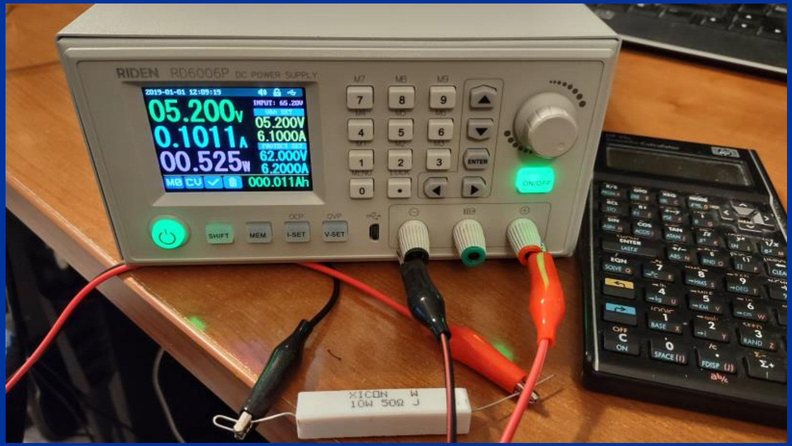
$$I = \frac{V}{R} \qquad => \quad P = \frac{V^2}{R} \qquad P = I^2 R$$

Resistance in Ohms

50 Ohm Resistor
(actually 51.4 Ω)

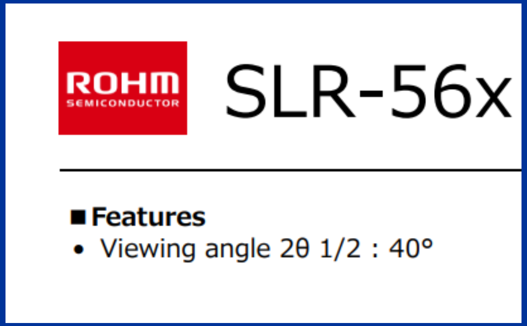


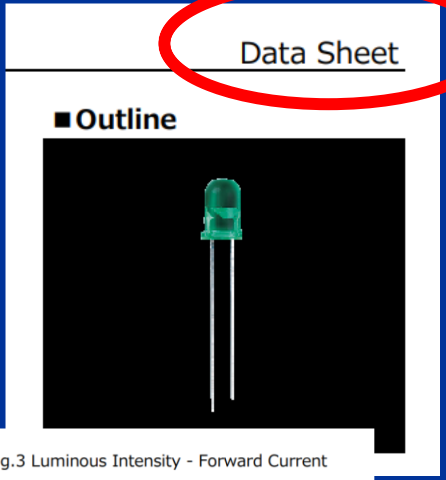
Ohms Law vs Device IV Curves

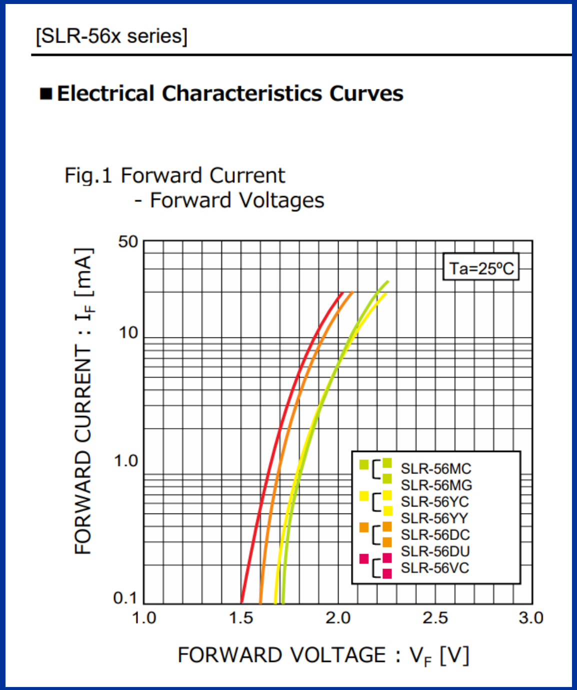


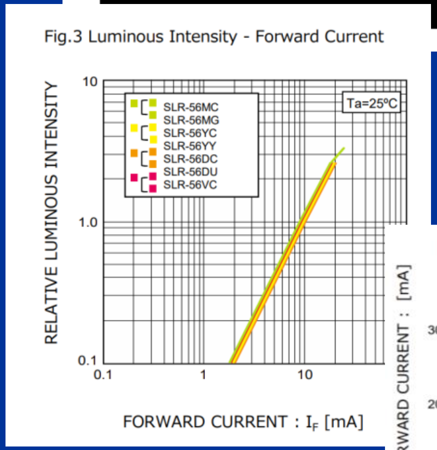
$$I = \frac{V}{R}$$

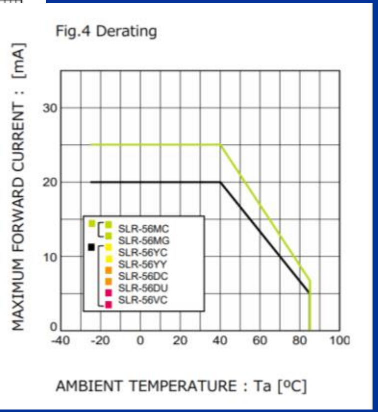
$$R = \frac{V}{I} \qquad V = IR$$



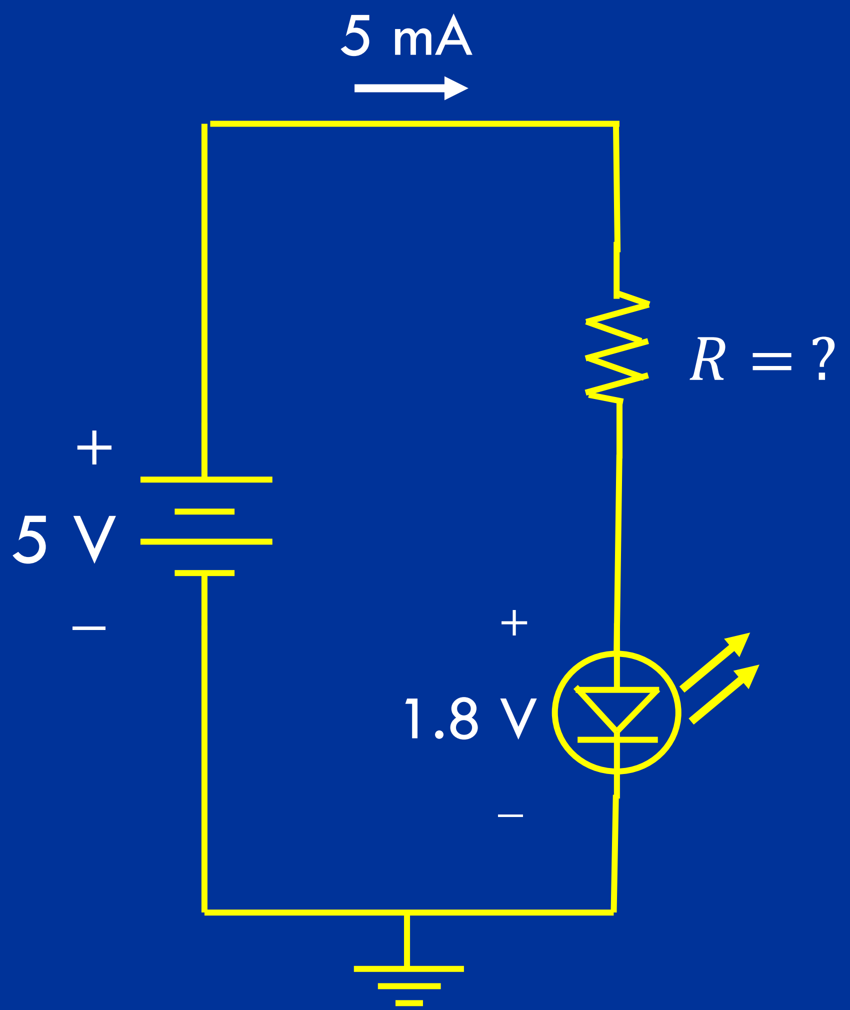




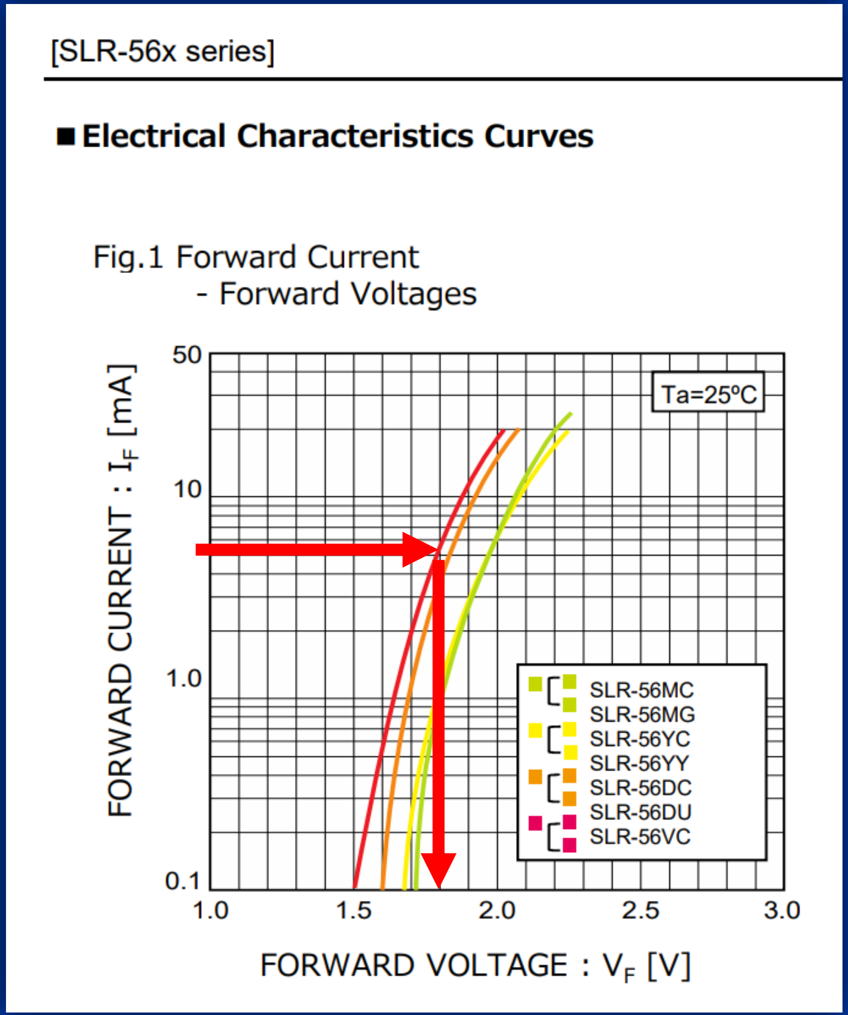




Circuit Analysis and Design



If I = 5 mA flows ***through*** LED

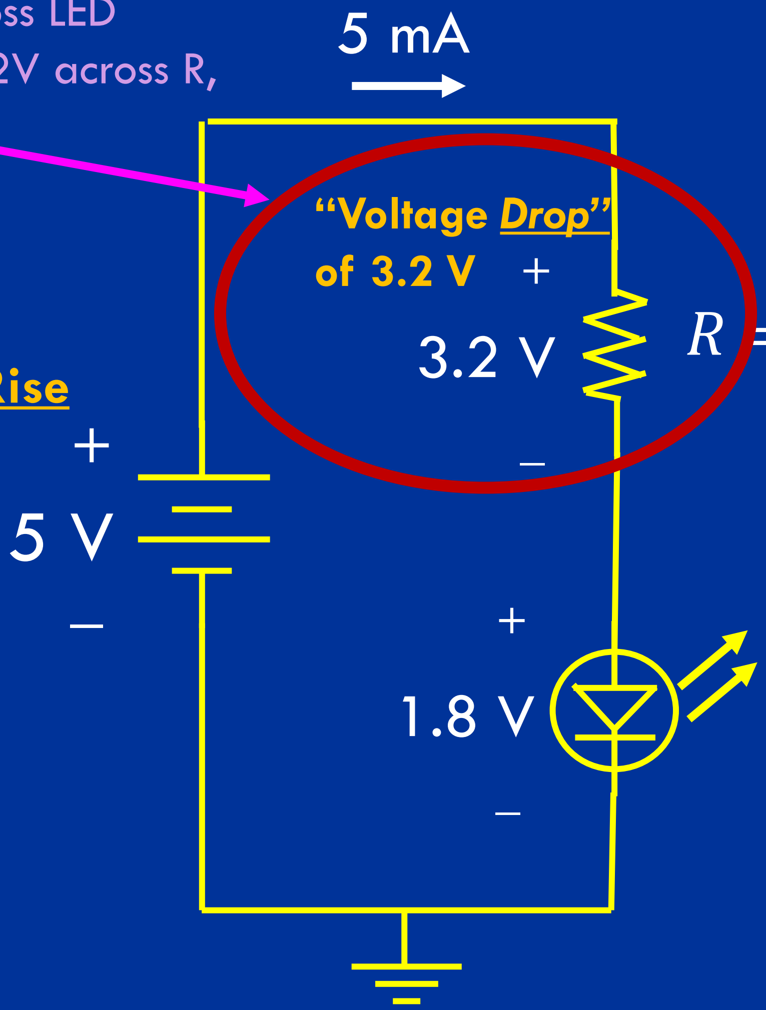


LED will have V=1.8 V ***across*** it

Circuit Analysis and Design

5V supply minus
1.8V across LED
leaves 3.2V across R,
So…

Voltage Rise
of 5 V

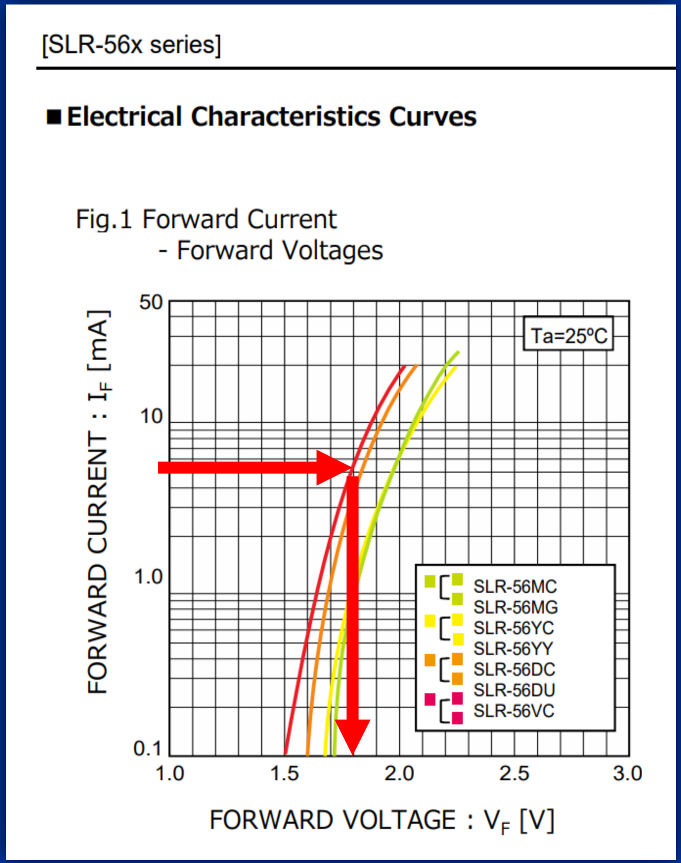


$$R = \frac{V}{I} = \frac{3.2}{0.005}$$

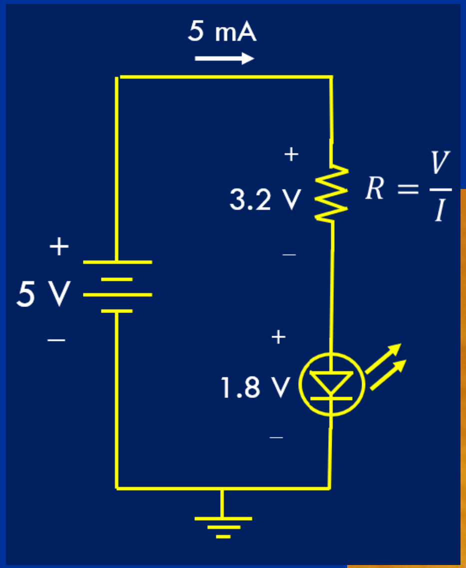
$$= 640\ \Omega$$

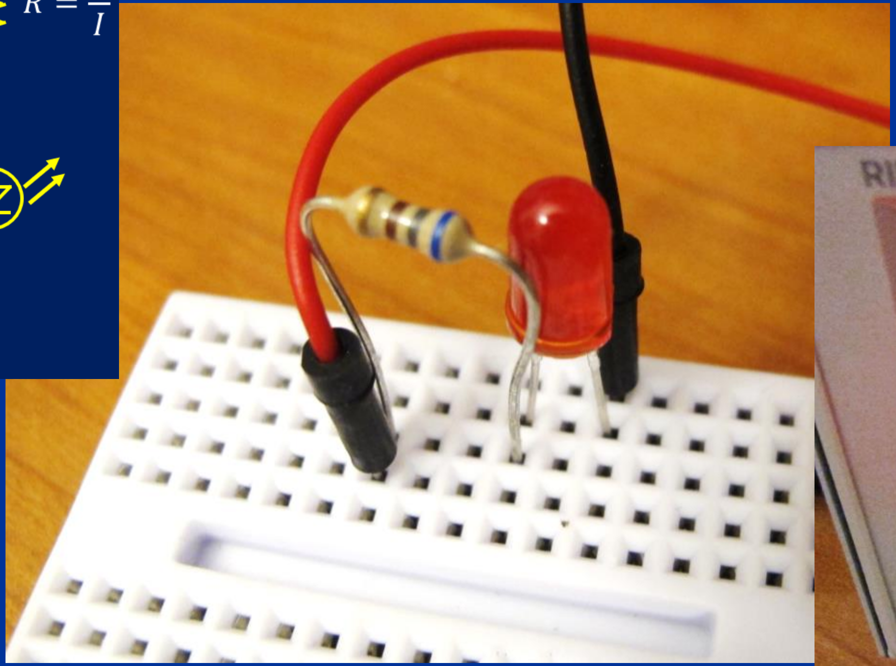
Use $R = 680\ \Omega$
(Standard value)

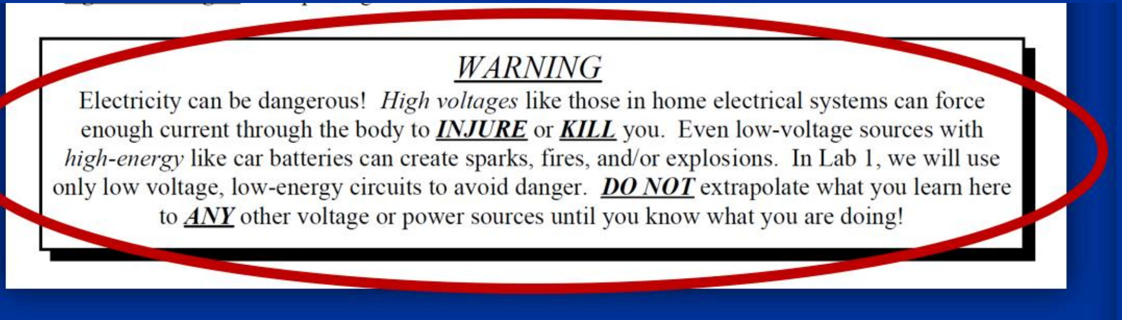
Check power
dissipations !
(Recall: P = IV)



Construction / Testing







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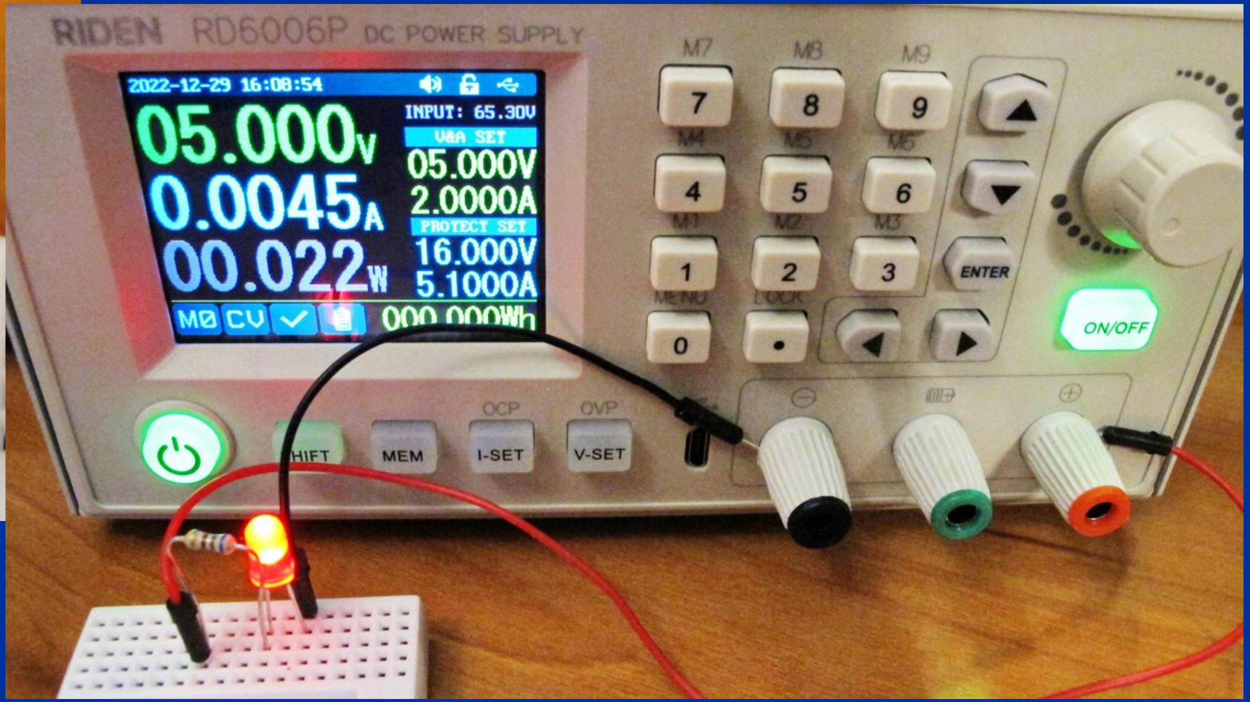


A Little More Theory …

Ohm's Law

$$I = \frac{V}{R}$$

$$V = IR$$

$$R = \frac{V}{I}$$

Kirchoff's Current Law

At a "node":

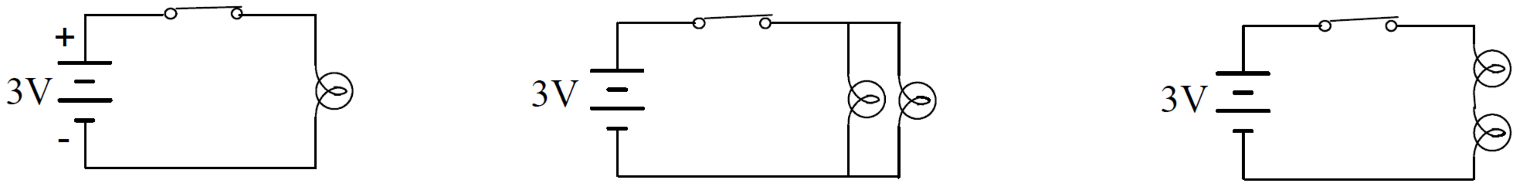
$$\sum I_{entering} = \sum I_{leaving}$$

Kirchoff's Voltage Law

Around a loop:

$$\sum V_{rises} = \sum V_{drops}$$

In this lab, we will build 3 simple circuits, shown in the 3 schematics below.

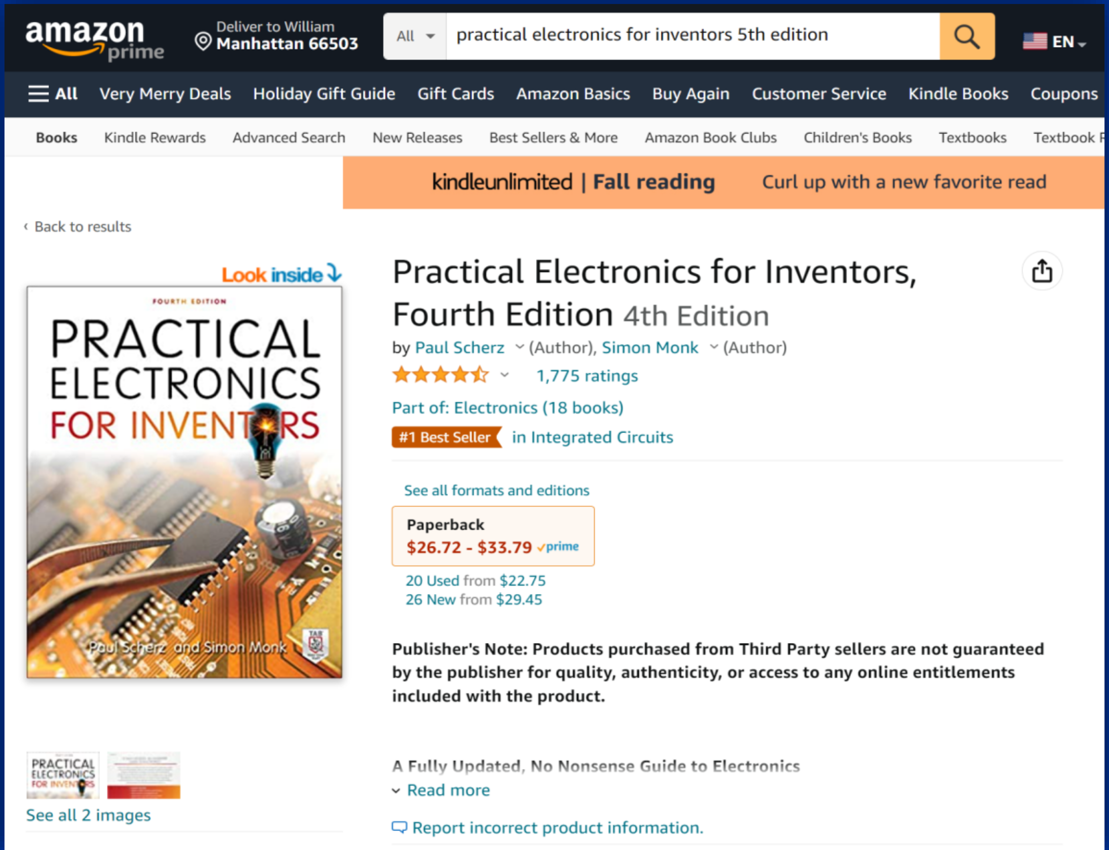


Schematic 1
Ohm's Law Demo

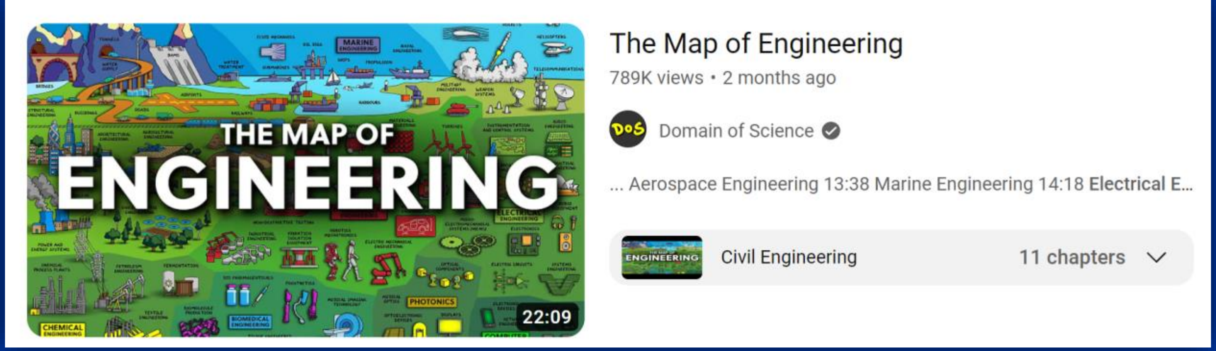
Schematic 2
KCL Demo

Schematic 3
KVL Demo

Suggested References



https://www.amazon.com/Practical-Electronics-Inventors-Fourth-Scherz/dp/1259587541/ref=asc_df_1259587541



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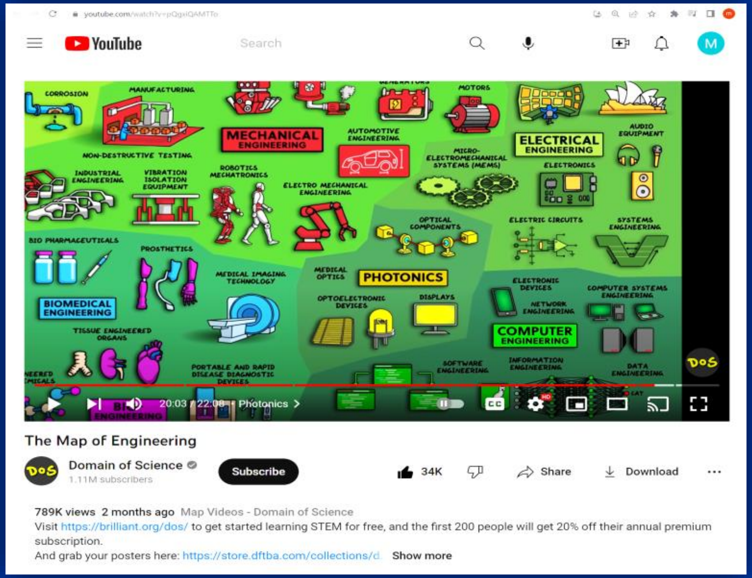

Future Episodes ?

Lecture Topics	*Labs*
Voltage, current, nodes, batteries, resistance,	None
KVL, KCL, Ohm's law, power, AC, peak vs RMS	Circuit construction, V, I measurements with DMM
Circuit analysis and applications	Resistance Measurements, AC Signals, Function generators,
Electricity&magnetism, Faraday's law, applications	Resistor circuits (volume controls, input/output impedance)
Inductors and application circuits	Magnetism, transformers, relays, motors and generators
Capacitors and application circuits	Inductor and capacitor circuits
Frequency response, dB, and sinusoidal circuit analysis	Kit Construction
Semiconductors, diodes and application circuits	Kit Construction
Transistors and amplifier/switching applications	Diodes, rectifiers, transistors and applications
Introduction to Systems (esp. renewable energy)	Project work with solar-cell panels and renewable energy sy
Introduction to complex numbers and impedance	Project work with solar-cell panels and renewable energy sy

From Intro EE Course Syllabus (Fall 2010 offering)

Topics covered include:

Part I (The big picture)

- Review of "signals" and amplifiers. Frequency domain concepts (Fourier theory)
- Mathematical models, including Thevenin models and loading effects
- Opamp review, including application circuits and real-world performance issues
- Additional analog ICs (comparitors, switches, regulators, etc.)
- Systems that include amplifiers, ADCs, DACs, and digital signal processing (DSP).
- Circuit board layout

Part 2 (The details of discrete devices and their applications, and circuits inside ICs)

- Diodes, classic power supplies, and modern switching supplies
- MOSFET structure and operation and switching and amplifier applications
- Amplifier configurations (e.g. CS, CG, CD, and high-frequency behavior)
- Multi-transistor amplifiers, Miller's theorem, and cascoding.
- Comparison of MOSFETs and BJTs.
- Differential amplifiers, power-amp stages, and basics of op-amp internal designs
- Two-port network representations, feedback, and stability

Additional topics will be interwoven as time permits (e.g. Simulators, filter design, noise and coupling

From Electronics 2 Course Syllabus (Fall 2015 offering)

THANKS FOR WATCHING !