SPACE FACULTY

Let’s learn about **satellites**!

Space mission and **satellite** design course

Hands-on Slides

2NDSpace

Satellite Design & Integration

DAY 1

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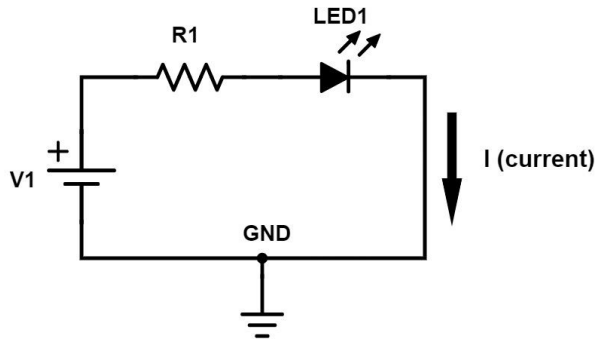
Satellite Design & Integration

Designing a satellite requires expertise in several fields of engineering:

- Mechanical
- Electrical
- Aerospace

Introduction to Electronics

An electronic circuit is a closed loop or pathway through which electric current flows, allowing the controlled movement of electrons. It comprises interconnected electronic components that work together to perform specific functions.



Fundamental Electronics Components

Resistors (“R” in schematics)

- Definition: Resistors are electronic components that introduce resistance to the flow of electric current in a circuit.
- Function: They control the amount of current flowing through a circuit, limit voltage, and protect components from excessive current.



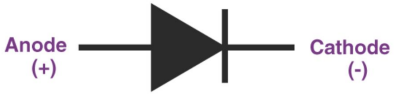
Capacitors (“C” in schematics)

- Definition: Capacitors store and release electrical energy in the form of an electric field between two conductive plates separated by an insulating material.
- Function: They are used for timing, filtering, and energy storage. Capacitors can smooth voltage fluctuations and filter out unwanted frequencies.


Fundamental Electronics Components

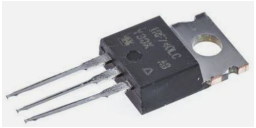
Diodes (“D” in schematics)

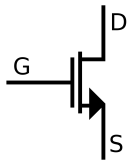
- Definition: Diodes are semiconductor devices that allow current to flow in one direction only.
- Function: They serve as electronic valves, permitting the flow of current under certain conditions.



Transistors (“Q” in OUR schematics)

- Definition: Transistors are semiconductor devices that amplify or switch electronic signals.
- Function: They are the building blocks of modern electronics, serving roles in amplification, signal processing, and digital logic. Transistors are fundamental to the operation of integrated circuits.





Current, Voltage, and Resistance in Circuits

Current (I):

- Current is the flow of electric charge through a conductor. It is measured in Amperes (A).

Voltage (V):

- Voltage, also known as electric potential difference, is the force that drives the electric current. It is measured in Volts (V).

Resistance (R):

- Resistance is the opposition to the flow of electric current in a circuit. It is measured in Ohms (Ω).

Analogy: Water Flow from a Bottle to the Ground

Current is like the steady stream of water flowing from the bottle. The rate at which water leaves the bottle mirrors the electric current in the circuit.

Voltage is like the height from which water falls. Higher voltage corresponds to a more significant potential energy difference.

Resistance is comparable to obstacles or narrowings in the path. Resistance impedes the flow of both water and electric current. Imagine obstacles in the path of falling water – they resist the flow.

Ohm’s Law

Ohm's Law is a fundamental principle in electrical engineering and physics, describing the relationship between voltage (V), current (I), and resistance (R) in an electrical circuit. It is named after the German physicist Georg Simon Ohm, who first formulated the law.

Ohm’s Law

Ohm's Law is expressed as: $\mathbf{V=I \cdot R}$

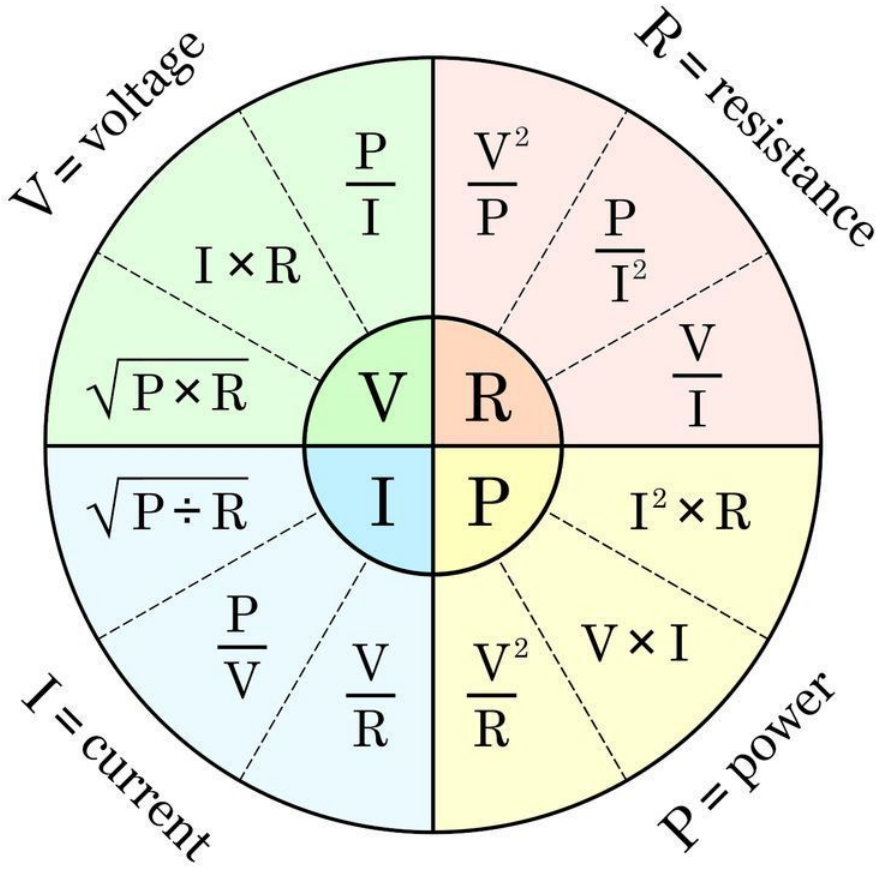
Where:

- **V** is the voltage across the component (measured in volts, V).
- **I** is the current flowing through the component (measured in amperes, A).
- **R** is the resistance of the component (measured in ohms, Ω).

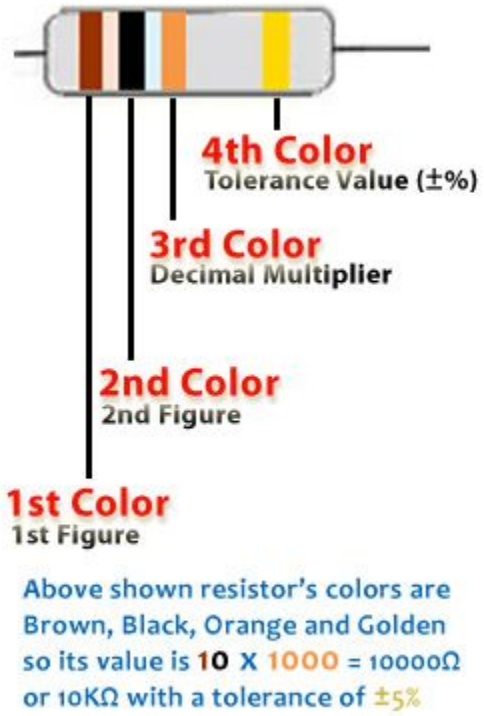
Ohm’s Law: Key Points

- **Direct Proportionality:** According to Ohm's Law, if you double the voltage (V), the current (I) will also double, assuming the resistance (R) remains constant. Similarly, if you increase the resistance, the current decreases for a given voltage.
- **Linear Relationship:** Ohm's Law holds true for many passive electrical components, such as resistors, at a constant temperature. The relationship is linear, meaning a graph of voltage against current is a straight line.
- **Applicability:** While Ohm's Law is a fundamental principle, it may not apply to all electrical components, especially in more complex circuits with non-linear elements like diodes and transistors.
- **Power Equation:** Ohm's Law can be extended to include power (P) using the formula $\mathbf{P=V \cdot I}$

Electronics Formulas



Resistor Color Code



Above shown resistor's colors are Brown, Black, Orange and Golden so its value is 10 X 1000 = 10000Ω or 10KΩ with a tolerance of ±5%

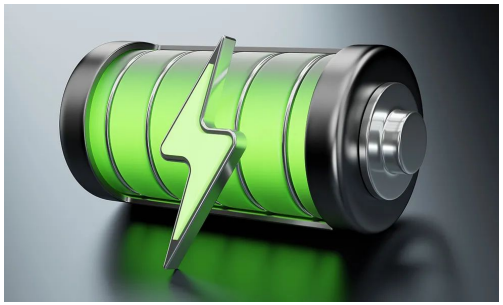
Color Name	Value As Figure	As Decimal Multiplier	Tolerance ±
Black	0	x 1	±20%
Brown	1	x 10^{1}	±1%
Red	2	x 10^{2}	±2%
Orange	3	x 10^{3}	-
Yellow	4	x 10^{4}	±5%
Green	5	x 10^{5}	±0.5%
Blue	6	x 10^{6}	±0.25%
Violet	7	x 10^{7}	±0.1%
Grey	8	x 10^{8}	±0.05%
White	9	x 10^{9}	±10%
Golden	-	x 10^{-1}	±5%
Silver	-	x 10^{-2}	±10%

Power Supply

Power supply is an electronic device or circuit that converts electrical energy from a source (such as an outlet or battery) into a form suitable for powering other devices within a circuit.

There are mainly two types of power supply DC (Direct Current) and AC (Alternating Current).

For our satellite we will use only DC current devices.



Variable Power Supply Unit

A variable power supply unit is an electronic device designed to provide an adjustable output voltage to power various electronic components and circuits. Variable power supplies play a significant role in laboratories, testing environments, and electronic development, contributing to the reliable and effective operation of electronic circuits.

Variable Power Supply Unit

- Let’s check the variable power supplies!
- Set up your variable power supply unit and check the voltage range on the screen.
- When you are done, try to adjust it to 3.3V first and then 5V.

Multimeter

A multimeter is a versatile electronic measuring instrument used to measure various electrical parameters in a circuit. It combines several essential measurement functions into a single device, providing convenience for technicians, engineers, and hobbyists.

Multimeter

The primary modes of a multimeter typically include:

- Voltage measurement
- Current measurement
- Resistance measurement
- Continuity check: find if two points are connected together or not (open circuit).

IMPORTANT INFORMATION! 

It's crucial to pay attention to the voltage and current ratings of electronic components to make sure they work properly and safely in a circuit. Ignoring these specifications can lead to various issues, including **PERMANENT component damage**.

Exceeding Voltage Ratings: Applying a voltage higher than a component's rated voltage can lead to breakdown or failure of insulation, causing permanent damage.
Exceeding Current Ratings: Passing a current beyond a component's rated capacity may result in overheating, leading to component burnout or irreversible damage.

IMPORTANT INFORMATION! 

A **short circuit** is a critical issue in electrical circuits, arising when unintended contact creates an unplanned path for current flow. This can lead to significant damage.

Unintentional short circuits, particularly involving tools like screwdrivers, often result from accidental contact with exposed conductors, damaged insulation, or incorrect wiring.

Pay extreme attention during tool use, follow correct wiring practices meticulously, and **ALWAYS turn off power before engaging with electrical circuits** to avert potential damage to components.

IMPORTANT INFORMATION! 

If you mistakenly tell an INPUT pin to act like an OUTPUT in your Arduino code and it tries to send or receive current, you could end up damaging your Arduino.

Coding Mistake: If you accidentally make an INPUT pin behave like an OUTPUT in your code, it means you're giving it the wrong instructions. INPUT pins are meant to sense signals, while OUTPUT pins are used to send signals or power devices like LEDs. If you mix them up in your code and tell an INPUT pin to send current, it can lead to too much current flowing through the pin, possibly harming your Arduino.

Always double check what code are you uploading on the Arduino!

IMPORTANT INFORMATION!

NEVER switch multimeter modes while actively measuring something, especially avoid measuring resistance under voltage.

Doing so risks damage to the multimeter, compromises accuracy, and may create short circuits, leading to potential harm to the circuit and the multimeter.

Always disconnect the multimeter before switching modes, double-check settings and ranges of measurements based on what you expect to read.

IMPORTANT INFORMATION!

Safety rules summarized:

- Do not exceed components voltage ratings.
- Do not touch electronic boards with tools unless they are completely disconnected from power (no cables and RBF inserted).
- Do not place electronic boards on metallic surfaces.
- Always double check the code you upload on Arduino.
- Do not measure resistance with the multimeter with the power on.
- Do not switch modes on the multimeter while measuring something.

IMPORTANT INFORMATION!

And, most importantly, if you ever feel in doubt, don't hesitate to ask us a million times!

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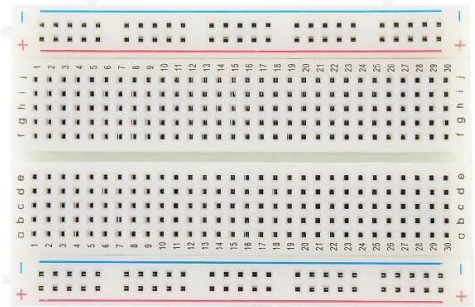
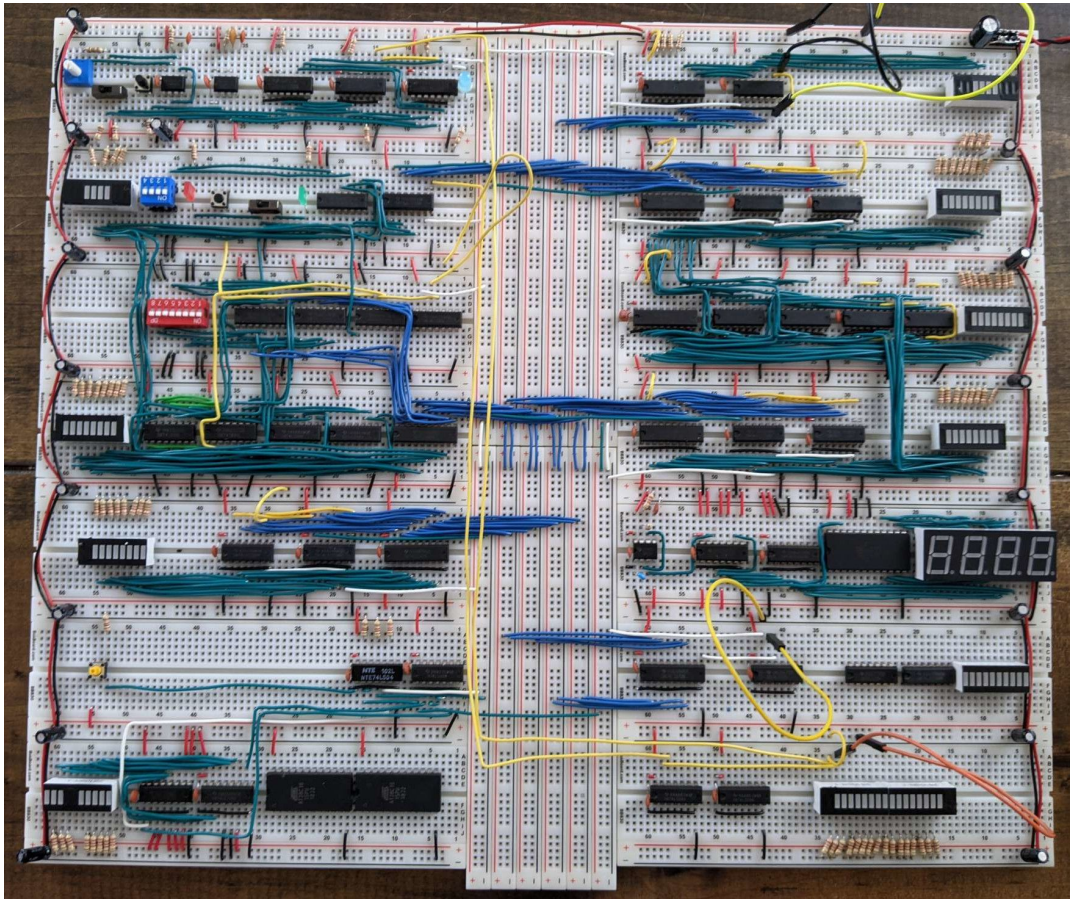
Breadboard

A breadboard serves as a fundamental instrument in electronics, facilitating the prototyping and testing of circuits without the necessity of soldering. It offers a platform that enables convenient connection and disconnection of electronic components, providing users the flexibility to experiment with circuit designs prior to committing to a permanent version on a printed circuit board (PCB).

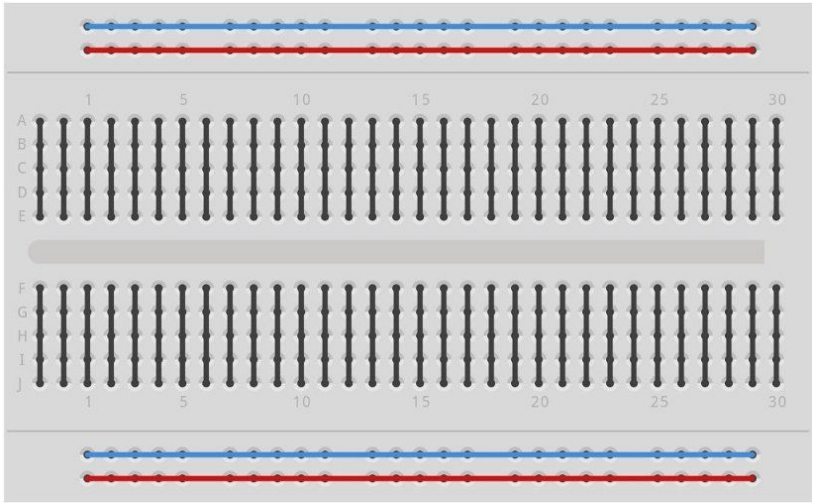


Breadboard



Breadboard

- **Internal Connections:** Holes within the same row and column are internally connected, forming continuous conductive paths.
- **Bus Strips on the Sides:** Bus strips along the sides provide external connections for **power** and **ground**, running parallel to the rows but not internally connected to them.

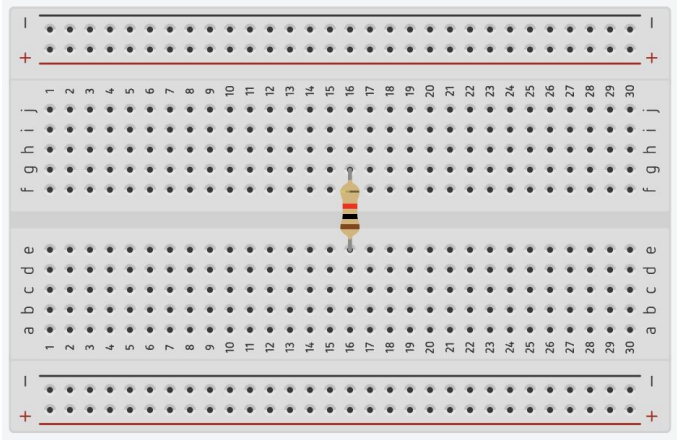


Power: Vxx, positive, +
Ground: GND, negative, -

Let’s Measure!

Set up the following circuit on the breadboard:

- Find the value of the resistance with the Resistor Color Code.
- Measure the resistance value with the multimeter and see the differences .



Resistors: Series and Parallel

Resistors in Series: Resistors are connected end-to-end, creating a single path for current flow. Total resistance in series is the sum of individual resistances.

$$R_{total} = R_1 + R_2 + \ldots + R_n$$

Resistors in Parallel: Resistors are connected across the same two points, providing multiple paths for current. Total resistance in parallel is the reciprocal of the sum of the reciprocals of individual resistances.

$$\frac{1}{R_{total}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$$

Let’s Measure!

Set up the resistance series and parallel circuit on the breadboard:

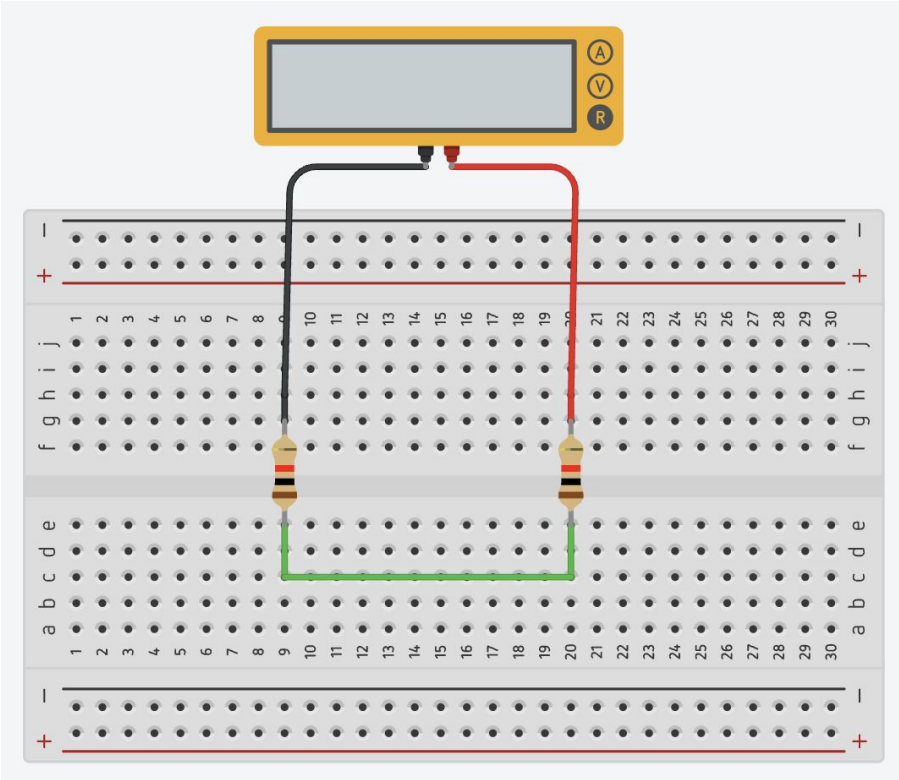
- Calculate the value of the total resistance with the formulas for both cases.
- Measure the resistance value with the multimeter and see the differences .
- Calculate also the amount of current that would flow in the two circuits in case 3.3V and 5V are applied.

Remember the formula **V = R*I**

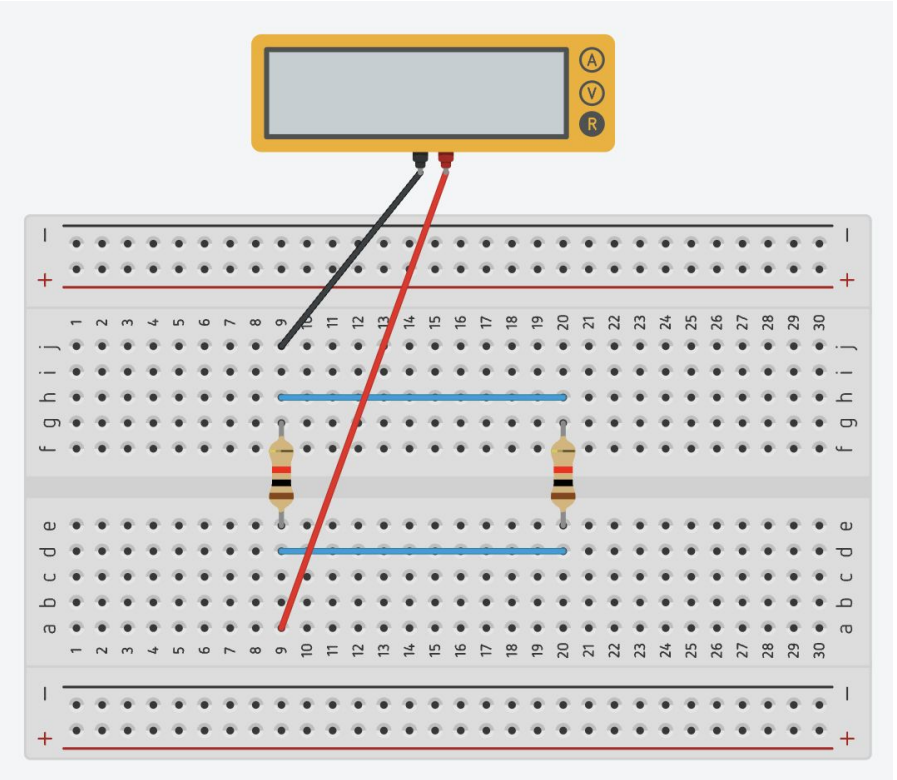
Use jumper wires to make connections!

Resistors: Series and Parallel - Solution

Resistors in Series



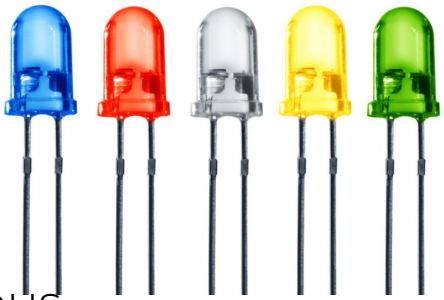
Resistors in Parallel



Light-Emitting Diodes: LEDs

An LED is a semiconductor device that emits light when an electric current flows through it. It is a diode, allowing current to flow in one direction, and it emits light in the process.

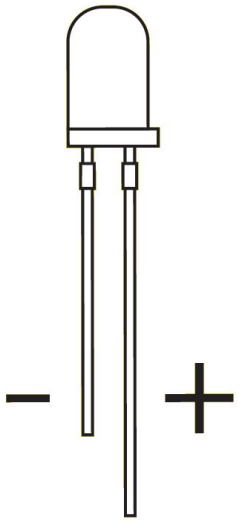
The color of the emitted light is determined by the material used in the LED.

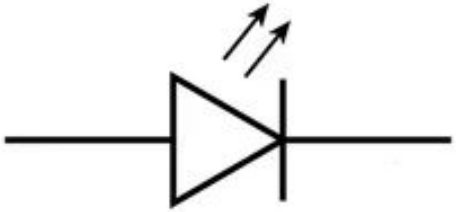


LEDs are OUTPUT devices, commonly used in various applications, such as indicator lights, display screens, and lighting systems, due to their energy efficiency, long lifespan, and compact size.

Light-Emitting Diodes: LEDs

LEDs have a short (cathode, GND) and a long (anode, V+) leg, and proper polarity is crucial for correct functioning. Always check it!





Let’s Use LEDs!

Set up a breadboard with one LED connected to a resistor in series, so to limit the current flowing through the circuit.

- Before connecting the power supply to it through the jumpers, set the voltage to 3.3V. Connect the power through the side bus.
- Check what happens if you increase the voltage to 5V.
- By reading how much current is flowing through the circuit from the power supply screen, try to determine the internal resistance of the LED.
- Check different resistor setups (series, parallel) to the LED.
- Determine the voltage drop across the LED with a multimeter.

Add a Button!

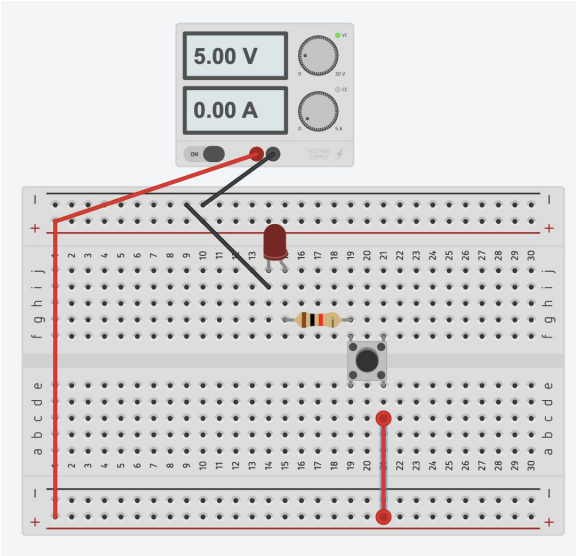
We now want to add a button to the circuit we realized:

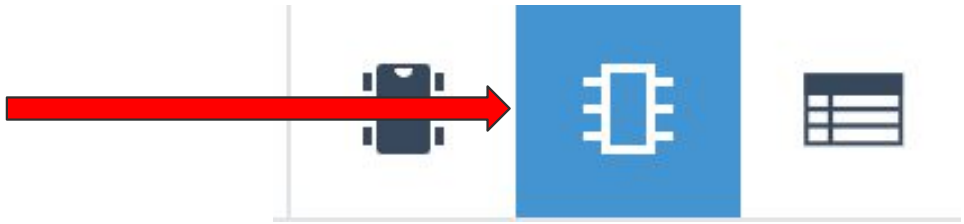
- Use continuity function on the multimeter to find the right pinout of the button.
- Set up the circuit and then play with it a bit!

Tinkercad

Recreate this circuit in Tinkercad:

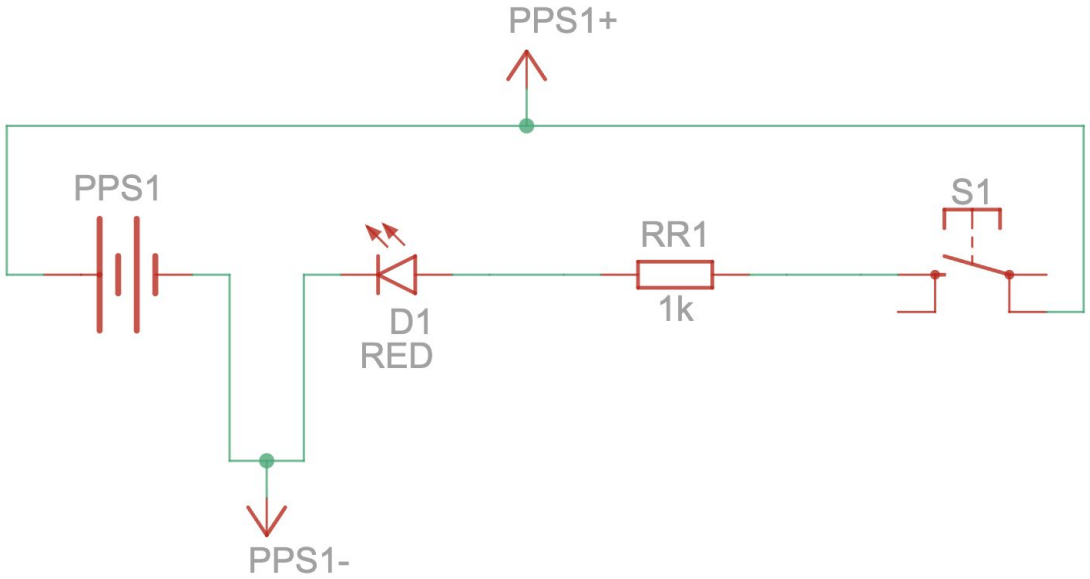
- Let’s go on www.tinkercad.com
- Login with your Google account
- Click on “Create” then “Circuit”
- Pick the components and make the circuit
- When done, click on the top right corner icon that shows you the schematic view



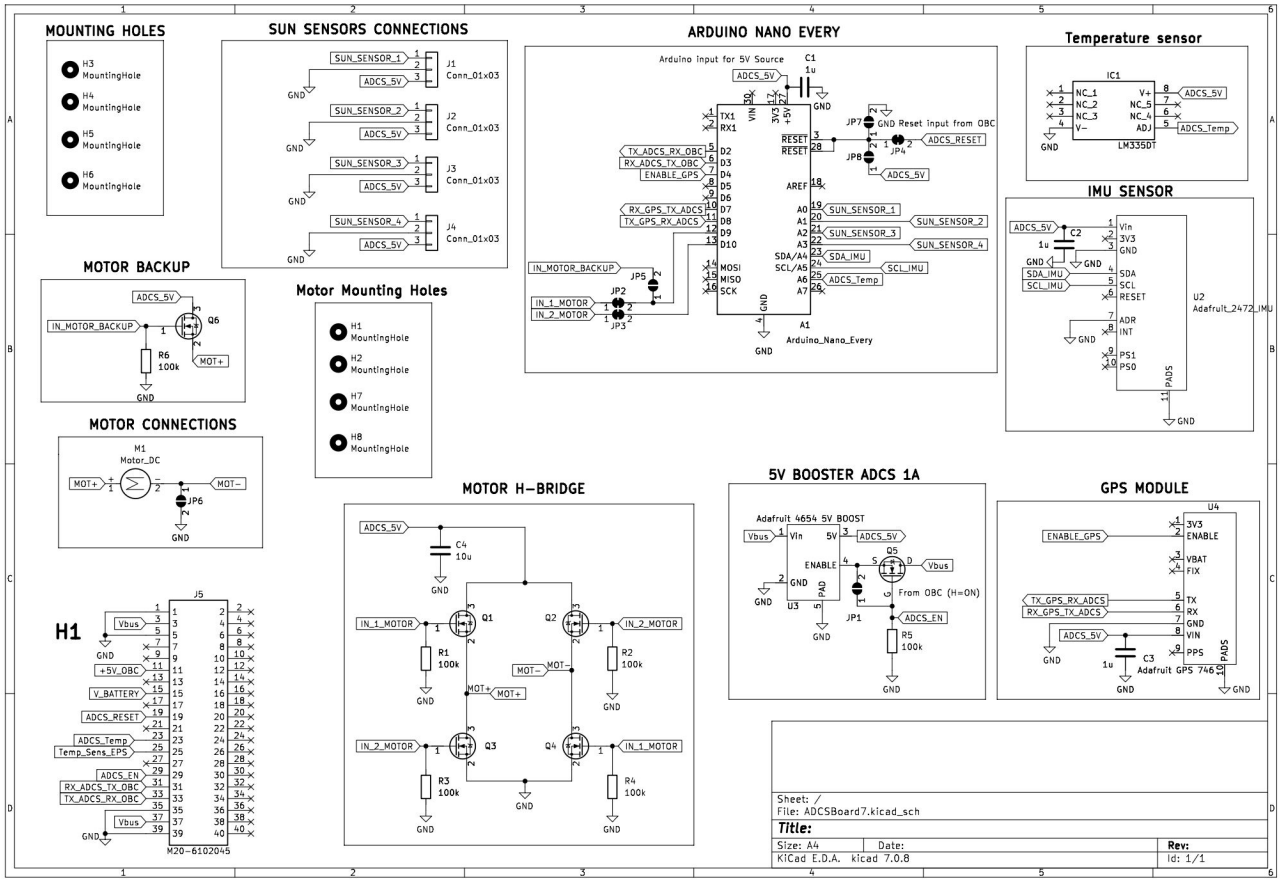


Schematics of an LED, Resistor and Button Circuit

This is how the circuit we created can be drawn from an electrical point of view (schematics).



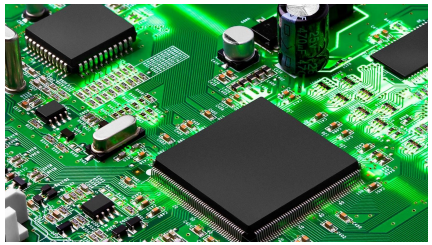
Satellite Boards Schematics



Electrical Schematics

Electrical schematics, utilizing symbols and lines to represent components and connections, offer a detailed abstraction of a circuit's functionality, but they do not visually represent the physical layout of the PCB board.

The schematics serve as a guide for understanding electrical relationships, guiding the subsequent design of the physical layout during the PCB design and manufacturing stages.

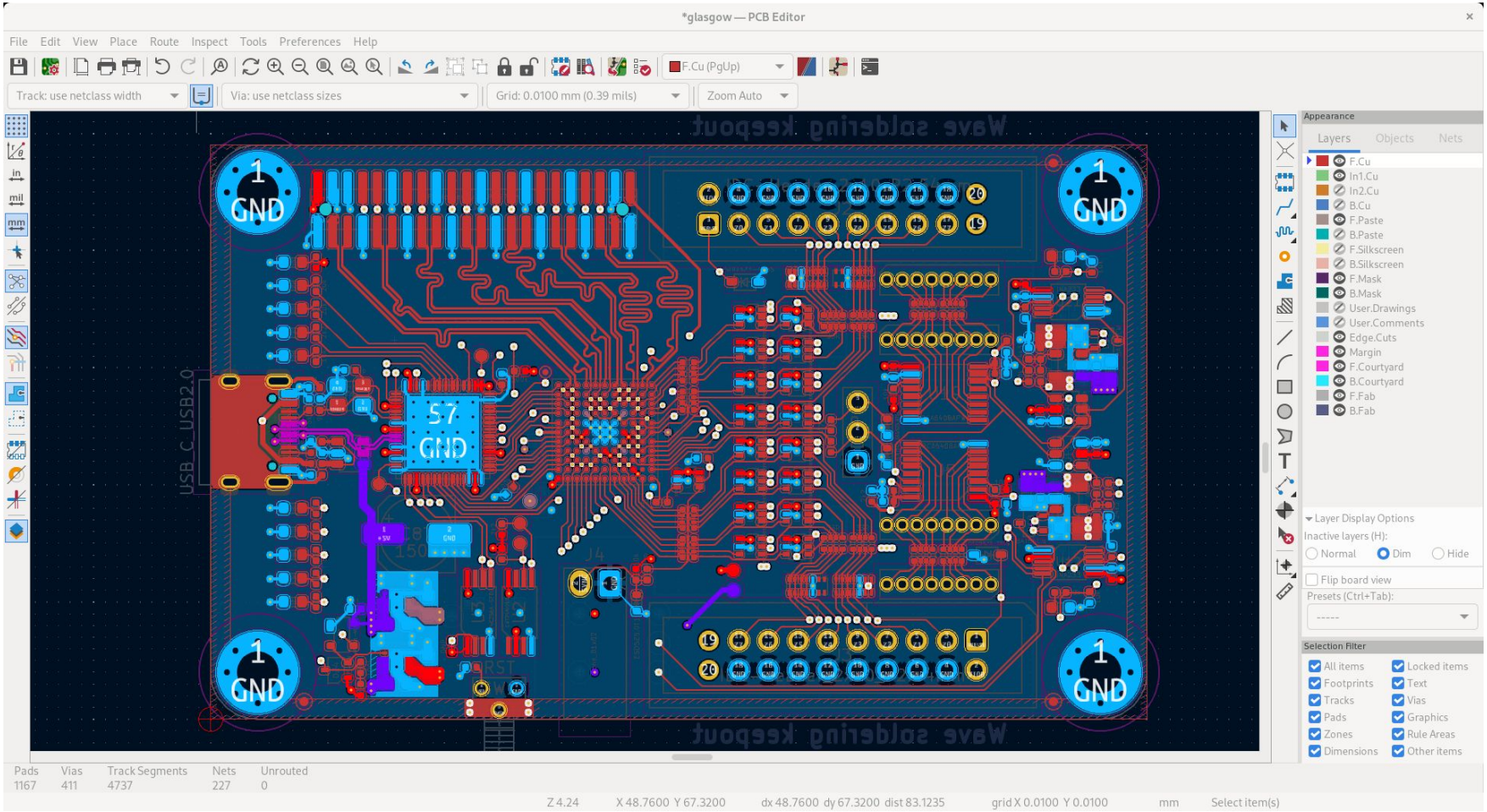


From Electrical Schematics to PCBs

From schematic to PCB, engineers meticulously plan components and connections, associating them with physical footprints. Utilizing PCB design software, they strategically arrange components and route traces in harmony with the schematic.

The process culminates in the creation of construction files detailing PCB features, which are then sent to a manufacturer for fabrication. The final stage involves populating the fabricated PCB with electronic components through either automated precision or manual assembly.

From Electrical Schematics to PCBs



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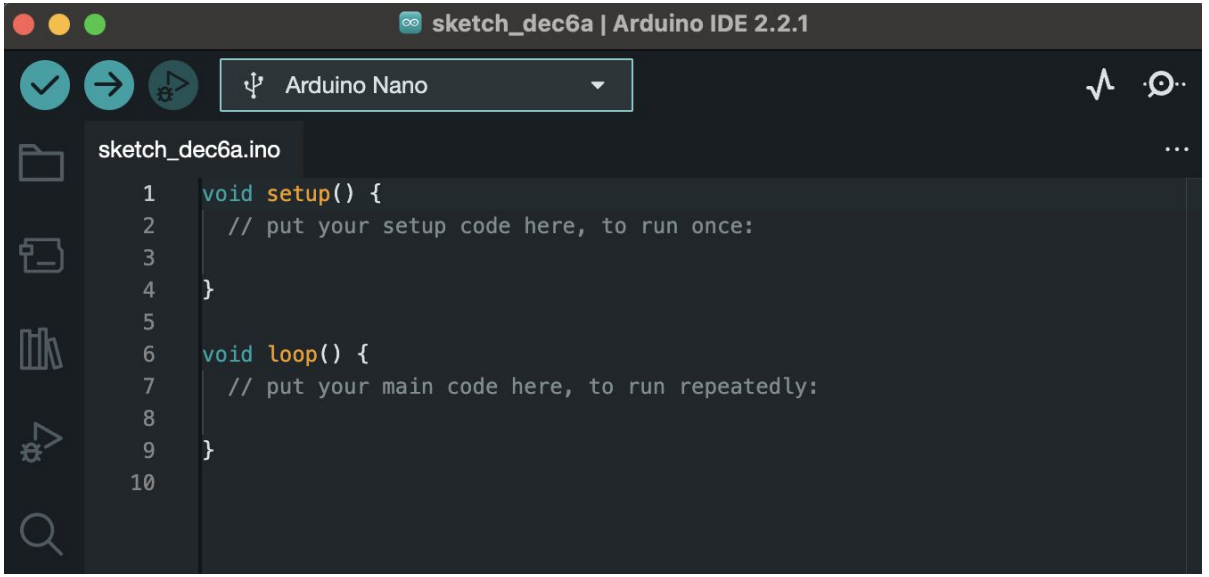
GS, OBC, EPS and ADCS Schematics

Let’s have a look at the schematics of the electronic boards we are going to use:

- Can you recognize the components?

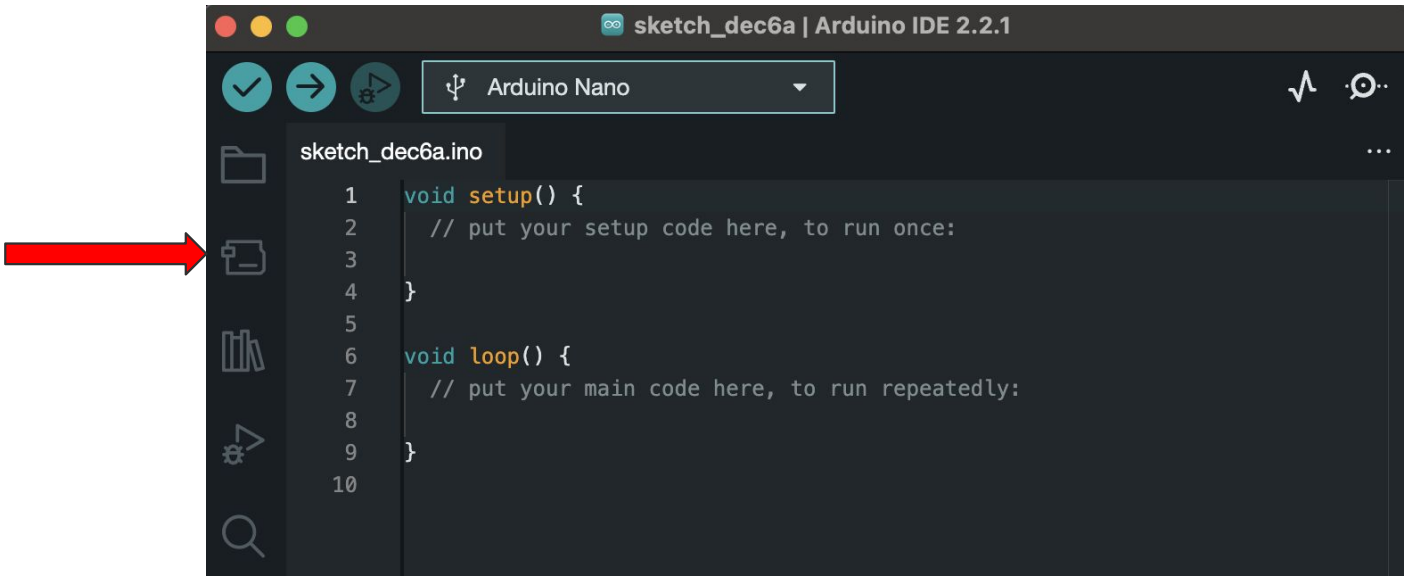
Arduino Programming Set Up

- Let’s go on Arduino website, find the software download section and install the latest Arduino IDE version for either Mac or Windows.



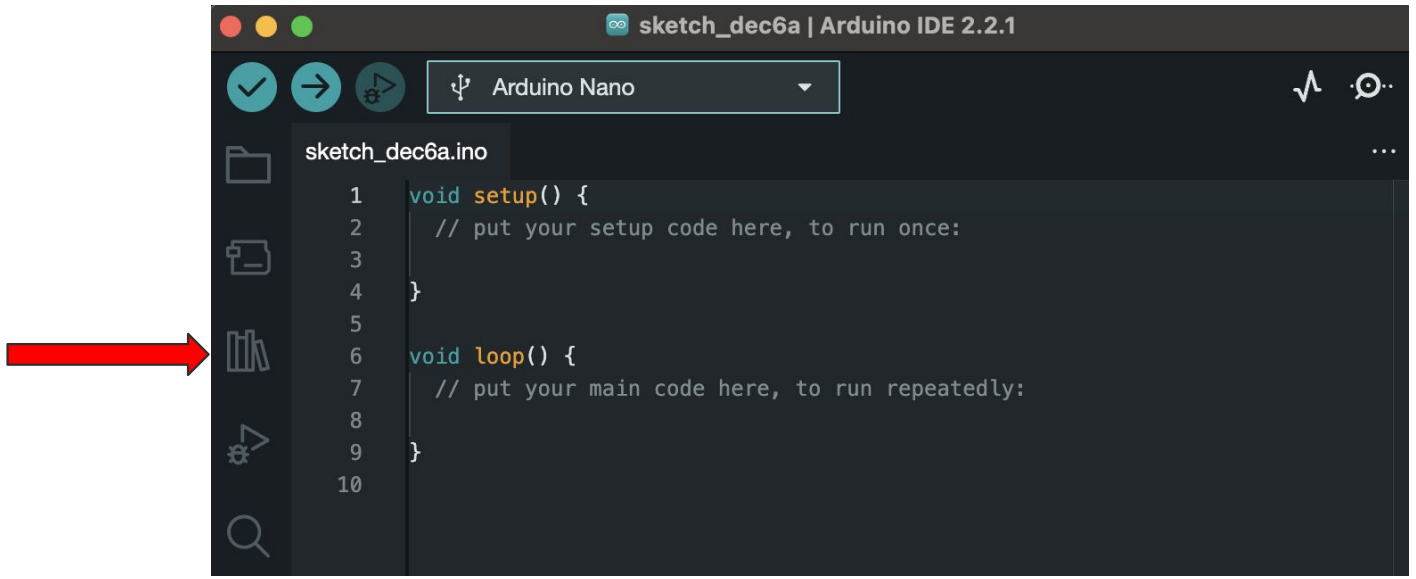
Arduino Programming Set Up

- Go on “Boards Manager”.
- Search “megaAVR” and install it.



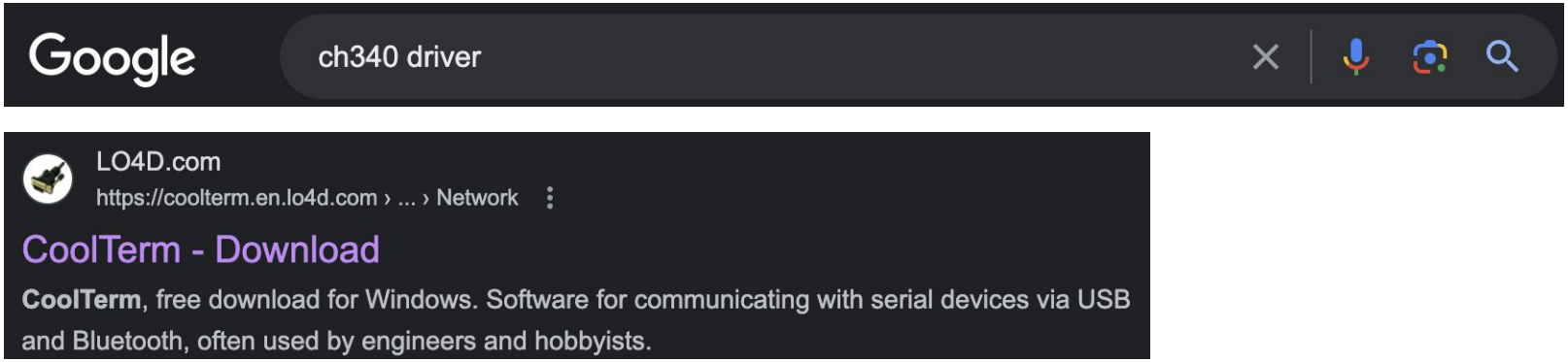
Arduino Programming Set Up

- Go on “Library Manager”.
- Install the first library you see appearing.

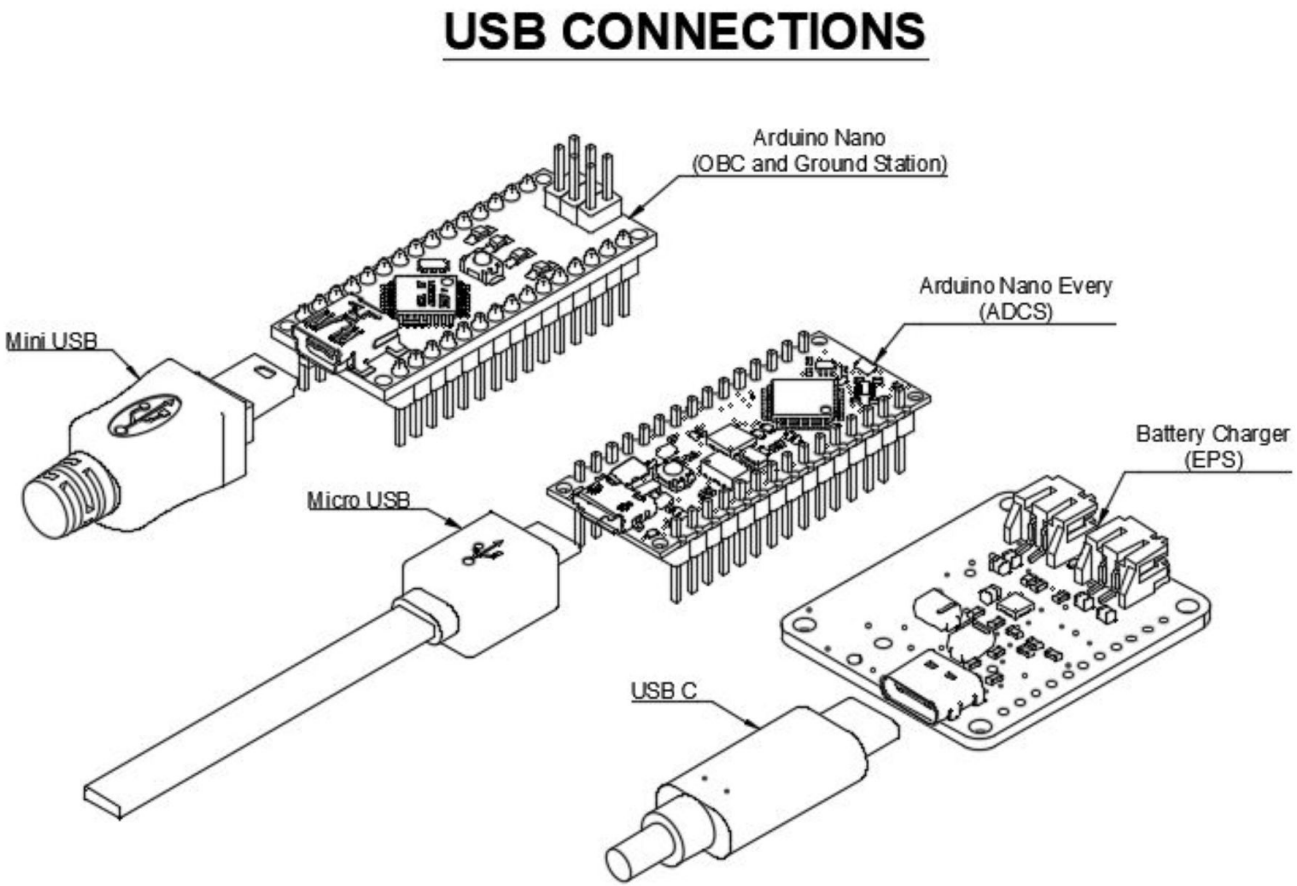


Arduino Programming Set Up

- Now locate your “libraries” folder inside the “Arduino” folder in that got installed with the IDE.
- Copy and paste there the library folders we are going to use in programming the satellite.
- For Windows users, install a driver called “CH340” online to recognize Arduino Nano.
- Search and install a program called “CoolTerm”.



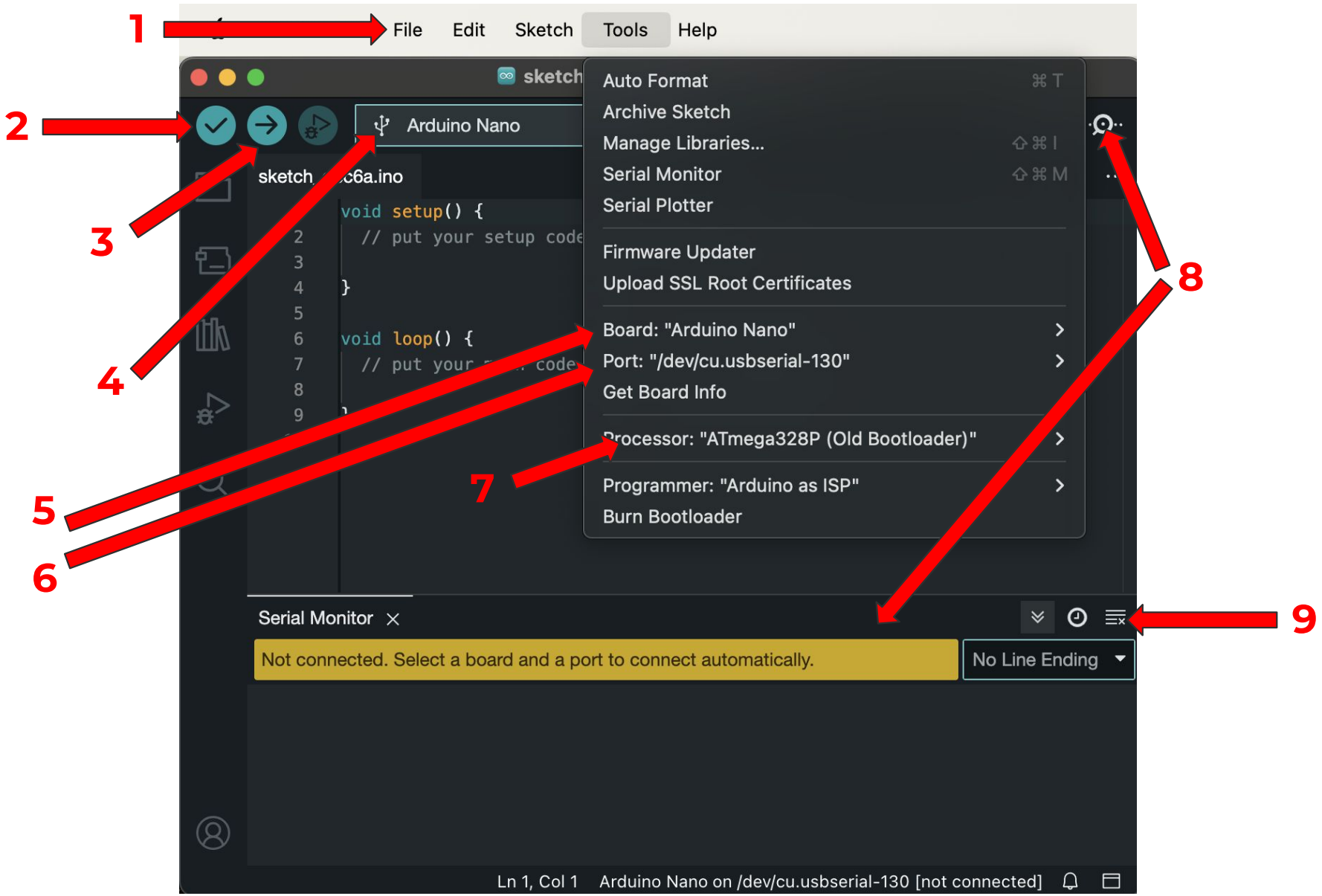
Arduino Nano vs Arduino Nano Every



Introduction to Arduino IDE

Basic interface:

1. Create a new sketch, save, open examples.
2. "Verify" checks the syntax and compiles the code to identify errors without uploading it to the board.
3. “Upload” transfers the compiled code from your computer to the Arduino board, making it ready to execute the program on the hardware.
4. Board and COM Port selection
5. Board selection (either Arduino Nano or Nano Every)
6. COM Port selection
7. For Arduino Nano (GS and OBC), select “Old Bootloader”.
8. Open/Close Serial Monitor
9. Clear Serial Monitor


1
2
3
4
5
6
7
8
9
File
Edit
Sketch
Tools
Help
sketch
Arduino Nano
Auto Format ⌘T
Archive Sketch
Manage Libraries... ⇧⌘I
Serial Monitor ⇧⌘M
Serial Plotter
Firmware Updater
Upload SSL Root Certificates
Board: "Arduino Nano"
Port: "/dev/cu.usbserial-130"
Get Board Info
Processor: "ATmega328P (Old Bootloader)"
Programmer: "Arduino as ISP"
Burn Bootloader
void setup() {
// put your setup code
}
void loop() {
Serial Monitor
Not connected. Select a board and a port to connect automatically.
No Line Ending
Ln 1, Col 1
Arduino Nano on /dev/cu.usbserial-130 [not connected]

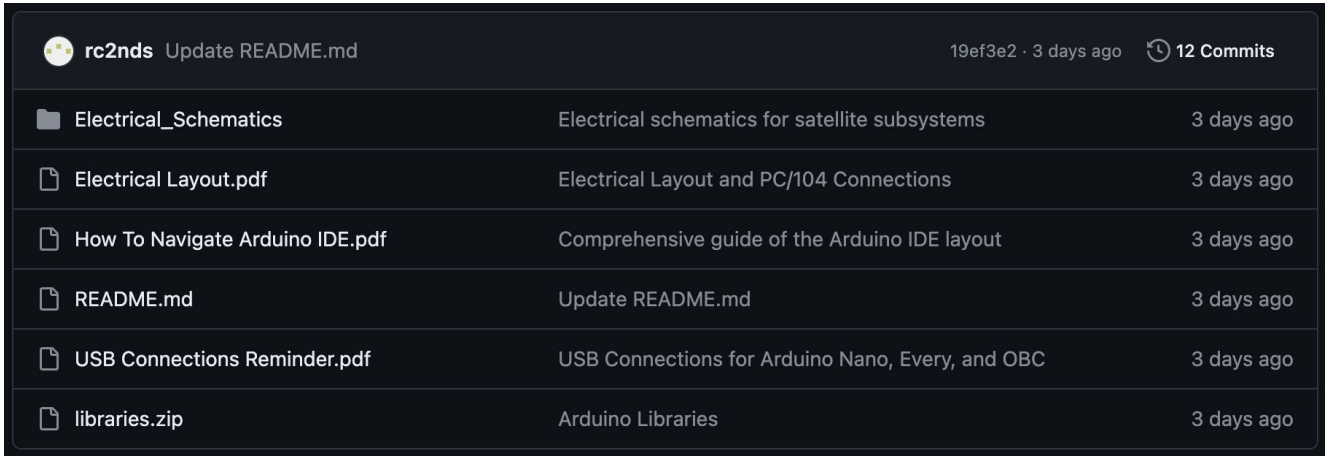
GitHub Resources Available!

GitHub is a web-based platform for hosting and collaborating on software development projects. It offers features like code hosting, issue tracking, code review, and project management.

GitHub Resources Available!

You can find valuable information about our satellite workshop on our GitHub page, accessible through the following link:

https://github.com/rc2nds/2NDS-SpaceFaculty-HandsOn



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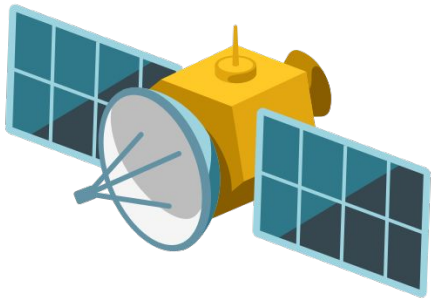
Satellite Design & Integration

END of DAY 1



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