

BASIC ELECTRONICS

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OVERVIEW

Session 1

Electricity is kind of like water

The Components Inside

The Binary Miracle

Session 2

Switches can do all that?

Arrange them just right, and you have a computer

The computer does what you say millions of times a second

Reconnecting to the real world

ELECTRICITY IS LIKE WATER

LEVELS OF UNDERSTANDING

How much do you need to know?

To own a car you do not need to understand the details of internal combustion engines, but the details leak out : gasoline, oil, batteries

To do electronics you don't need a degree in materials science or solid state physics, but the details sometimes leak out : voltage, current, Ohms Law, etc.

This session and the next are what we think you'll need to know to begin to have an intuitive grasp over the field of electronics.

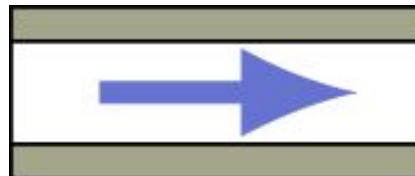
ELECTRICITY

Think of electricity flowing like water in a pipe

The analogy to water is not perfect, but it helps.

Electrons are present and quite moveable in every conductor.

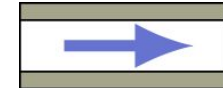
Electricity is the ordered flow of electrons in a conductor.



VOLTAGE AND CURRENT

Voltage is like water pressure

Measured in **Volts, V**



Current is like water volume

Measured in **Amps, A**

1/1000th of an Amp is a milliamp – **mA**

Power is Voltage x Current

Measured in **Watts, W**

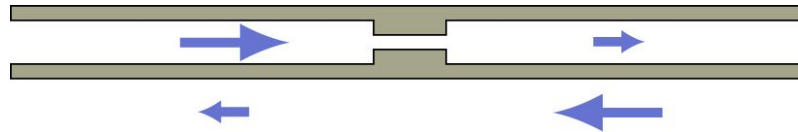
1/1000th of a Watt is a milliwatt - **mW**

RESISTANCE

Almost everything that conducts electricity has a resistance. It doesn't conduct it perfectly.

Resistance is measured in **Ohms** (Ω)

$1000\Omega = 1\text{k}\Omega$ $1,000,000\Omega = 1\text{M}\Omega$



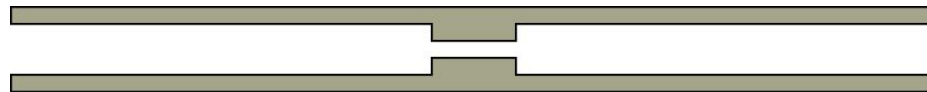
OHMS LAW

Relates Voltage and Current in a simple circuit

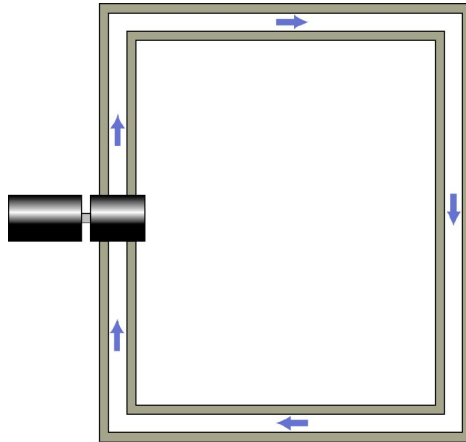
$$V = I R$$

Volts = Current (I) x Resistance (R)

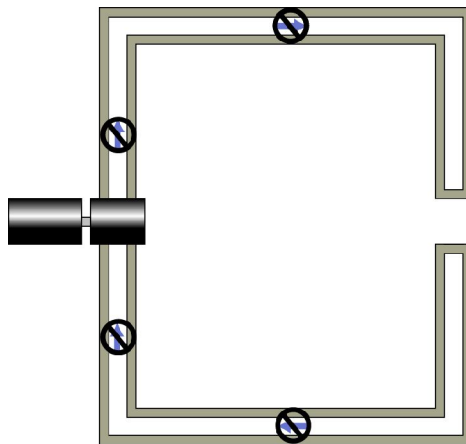
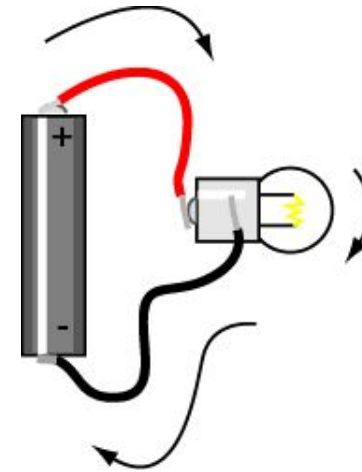
(this means $I = V / R$ and $R = V / I$)



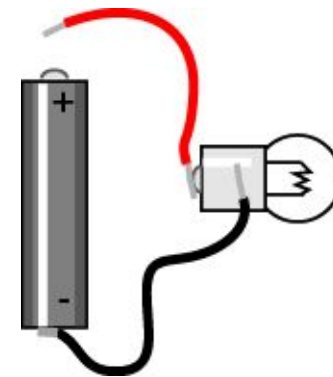
CIRCUITS – WATER AND ELECTRICITY



A circuit needs a complete path, and a source of energy



Electricity, like water, flows only when it can.

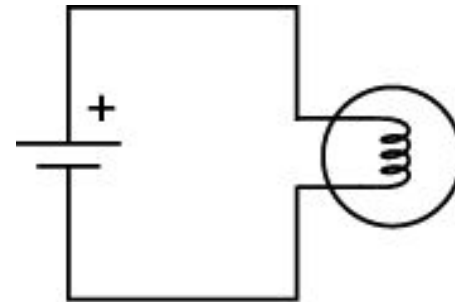
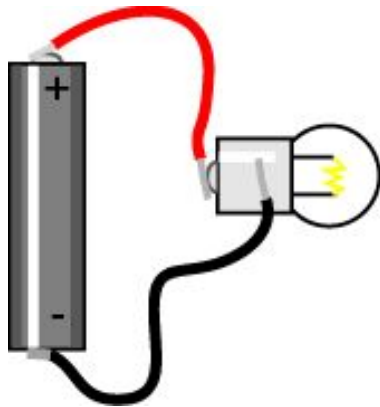


CIRCUIT DIAGRAMS I

Circuit Diagrams (also called Schematics) are a compact easy way to represent circuits.

Only the essential details are represented.

Like the London Underground – drawn for human use



CIRCUIT DIAGRAMS II

More realistic diagram

Vcc & Gnd Connections

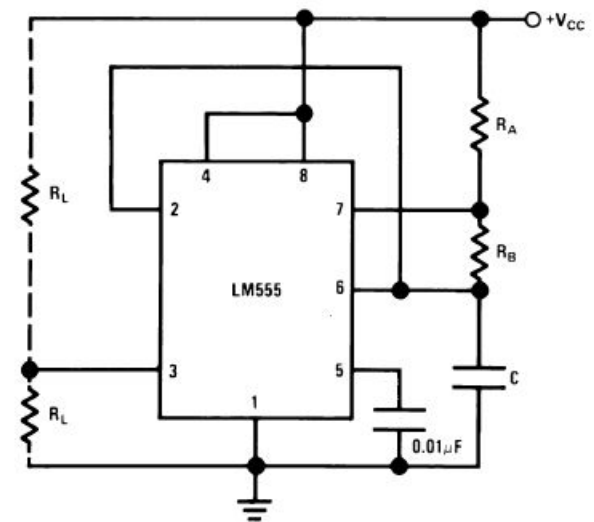
Many paths

Chip (**LM555**)

Resistors, Capacitors

Non-literal line connections

Optional parts

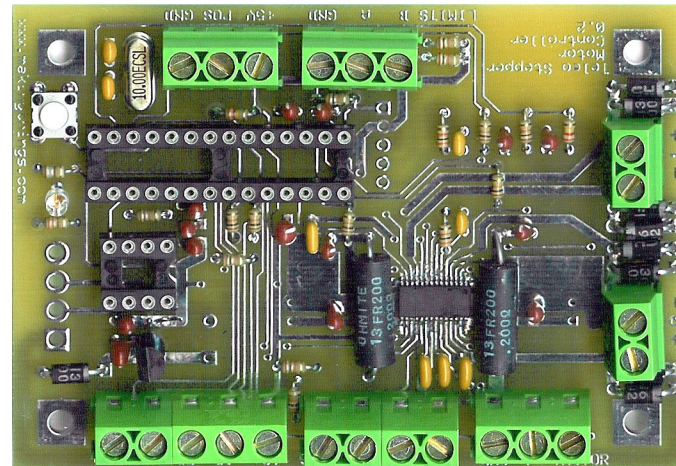
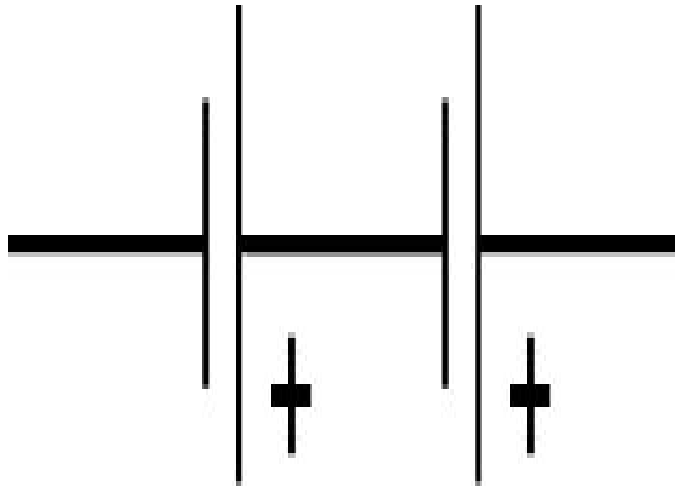


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PRINTED CIRCUIT BOARDS

When wiring-up circuits with wires is too much work

Each trace (thin strip of copper) replaces one wire



DEMONSTRATION - CIRCUITS

Objectives

Show a simple circuit

Measure voltages & current

Materials

Battery and Lamp

Multimeter

COMPONENTS

The components that make up a circuit

CONDUCTORS

Connections are very important

Many things are conductive – car chassis / salty water

Stranded vs. Solid Core

Solid core is much more likely to break when flexed

AWG (American Wire Gauge) Standard

AWG 16 – Larger Power Connections

AWG 18 – Power Connections

AWG 22 – Good Interconnection Size

AWG 30 – Very fine – breaks easily



CELLS & BATTERIES

Chemical Reactions creating electricity

Lead-acid (car battery approx 2V)

Alkaline (regular cells approx 1.5V)

Lithium Ion (latest rechargeable approx 3.6V)

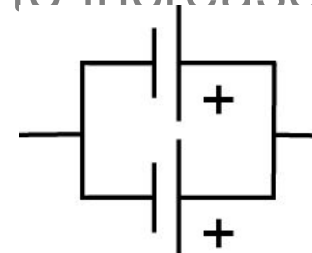
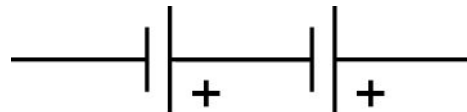
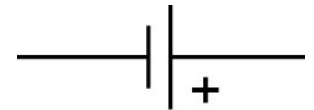
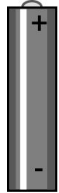
Fuel Cells (new technology)

Solar Cells (light converted into electricity)

Fruit! (lemons with copper and zinc electrodes)

Can put them in series (end to end) to increase voltage

Can put them in parallel (side by side) to increase current



POWER SUPPLIES

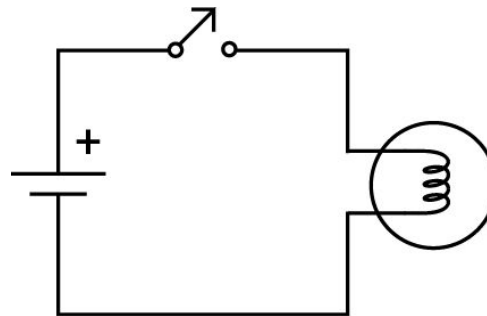
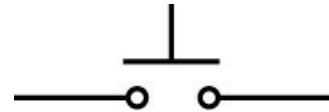
Connect to 110V AC to provide electricity in a different form.

**Be very careful with 110V! It can kill you.
Anything over 50V is dangerous.**



SWITCHES AND PUSH BUTTONS

Connect and disconnect circuits



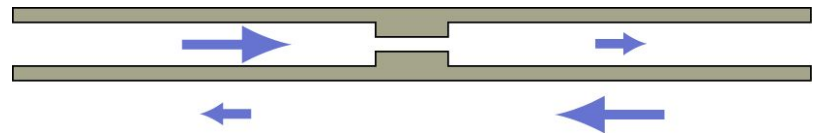
RESISTORS

As the name suggests - tend to present a partial barrier to electricity flow

Recall, Resistance is measured in **Ohms** (Ω)

$1000\Omega = 1\text{k}\Omega$ $1,000,000\Omega = 1\text{M}\Omega$

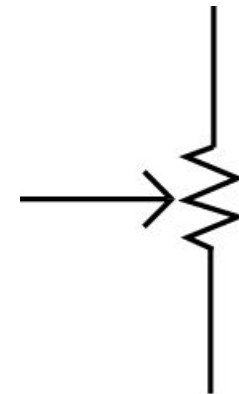
Also need to note rated power (e.g. 1/8W, 5W)



POTENTIOMETERS

Variable Resistors

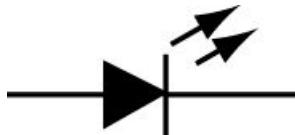
Have a resistance that varies according to the mechanical position of one of its **wiper**.



LIGHT EMITTING DIODES (LEDs)

Tiny light sources – come in a variety of colors

Require very small current – but will take all you offer – always use a resistor! Values between 300Ω and $1K\Omega$ are useful.



DEMONSTRATION - LEDs

Objectives

Show how to use an LED

Show how it only works one way round

Show how you need a resistor

Show how different resistors give different brightnesses, potentiometers

Materials

Soldering iron / solder / wire

LED

Resistor / Potentiometer

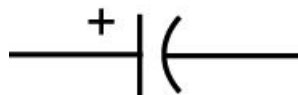
CAPACITORS

As the name suggests - tend to store electricity
- like a mini-battery

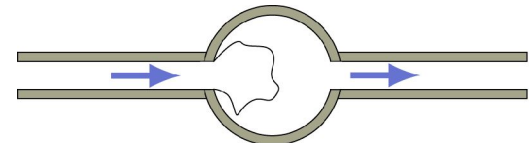
Measured in **Farads (F)**

$$0.000001\text{F} = 1\mu\text{F} \quad 0.000000001 = 1\text{pF}$$

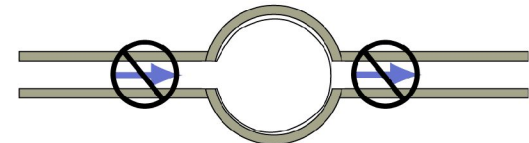
Also need to note rated voltage



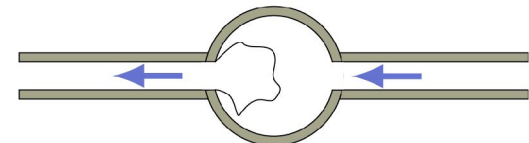
Charging



Charge
d



Discharging



DEMONSTRATION - CAPACITORS

Objectives

To show charging and discharging capacitors

Show charge with LED / resistor

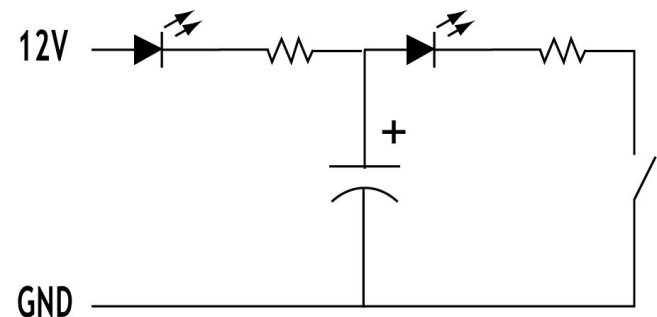
Show discharge with LED / resistor

Materials

Capacitor (large value)

2 x Resistor / LED combo

Soldering Iron, Solder

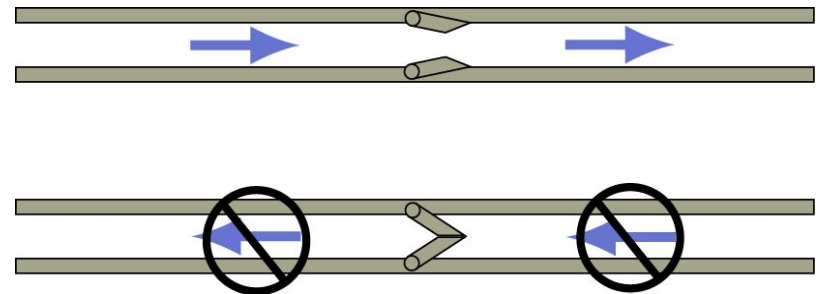
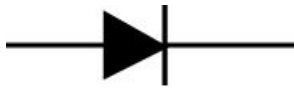


DIODES

Family of components which only let electricity flow one way

Many different kinds – each with different characteristics

Main characteristic to note is power (W)



DEMONSTRATION - DIODES

Objectives

To show diodes blocking current

Materials

Power supply

Diode

12V Lamp

Solder / Soldering Iron

SOLENOIDS

Electromagnets

Current is passed through the coil and a magnetic field is created

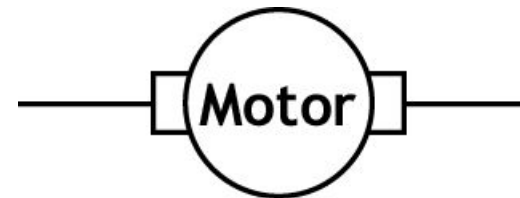
Used to release latches, lock parts in place, etc.



MOTORS

Family of components that use sequenced electricity and magnetism to make movement

Voltage, Current, Torque & RPM often specified



RELAYS

Electromechanical Switches – Apply a current to the coil and the connected switches are connected and disconnected.

Cars use relays to switch 12V, 500A!

Silicon Relays also available with no moving parts



DEMONSTRATION

SOLENOIDS / MOTORS / RELAYS

Objectives

To show solenoids, motors and relays running

Materials

Solenoid / Motor / Relay

Power Supply

VOLTAGE DIVIDERS I

Simple and vital part of electronics. Used throughout electronics.

Vital in the connection of sensors to computers.

Take a resistor and connect it to a power source.

The voltage on one side is 5V, and on the other is 0V

What would it be in the middle of the resistor?



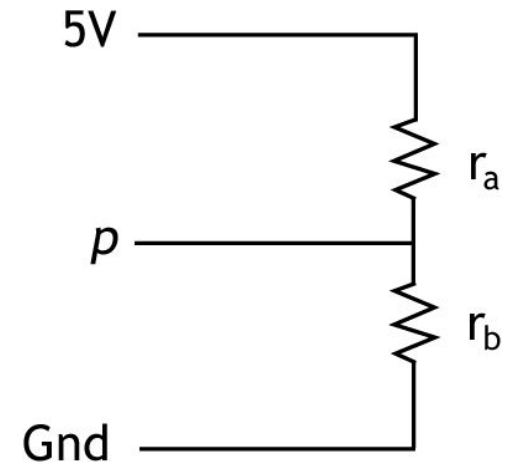
VOLTAGE DIVIDERS II

Can set this up:

Take two resistors of equal value in series and connect them to a power source.

We can guess that the voltage at p is 2.5V if $r_a = r_b$.

Each resistor does half the work.

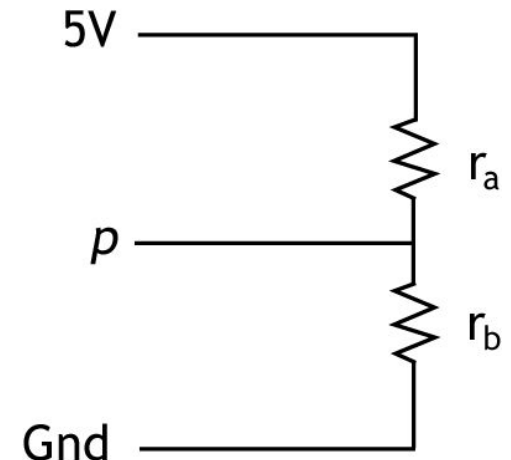


VOLTAGE DIVIDERS III

And to extend this further:

What if the resistors are not the same?

We can guess that the voltage at p will be greater than 2.5V if $r_a < r_b$. Less resistance \Rightarrow less **voltage drop**

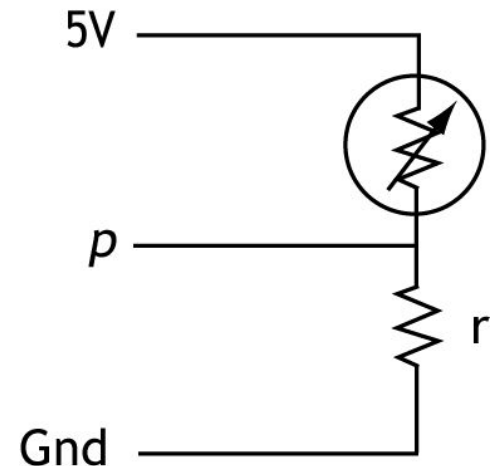


VOLTAGE DIVIDERS IV

Now we have something useful

What if we substitute one of the resistors for a resistive sensor of some kind?

We can guess that the voltage at p will be dependent on the quality sensed.

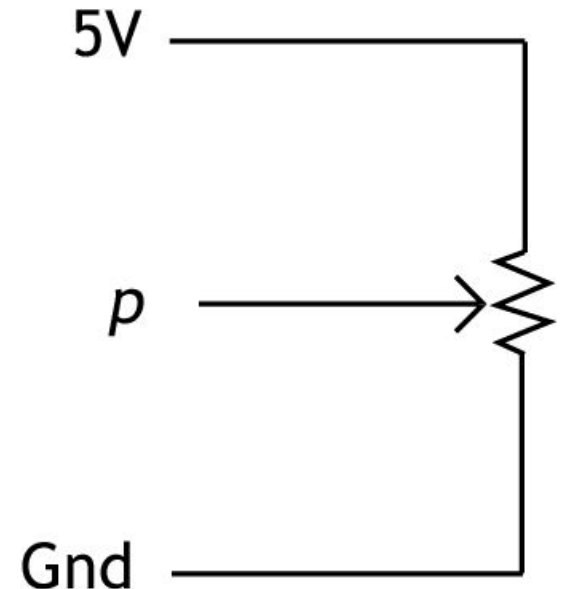


VOLTAGE DIVIDERS V

Variable Resistors can work like this too

With this circuit, we can sense the rotational position of a shaft or a linear position

The voltage at p will be dependent on the position of the wiper.



DEMONSTRATION – VOLTAGE DIVIDERS

Objectives

To mirror the foregoing voltage divider discussion with voltage divider examples

Materials

Multimeter

Soldering Iron and Solder

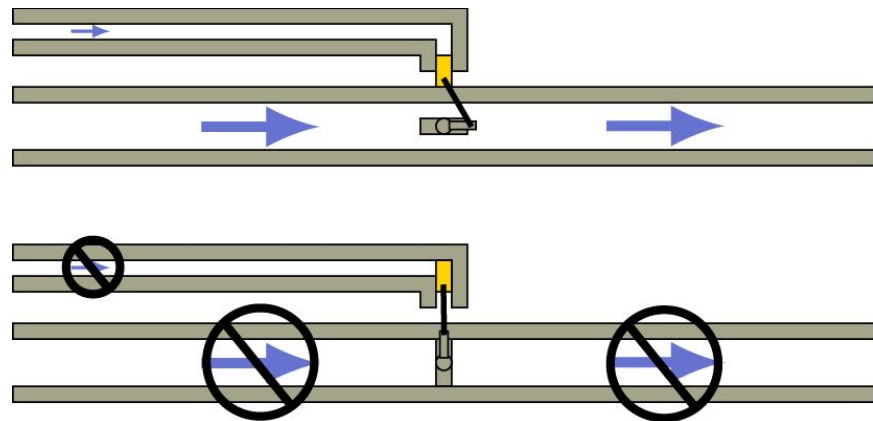
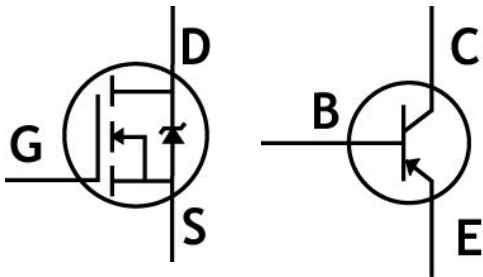
Resistors

Resistive Sensors (Bend / Light)

TRANSISTORS I

Developed to switch and amplify

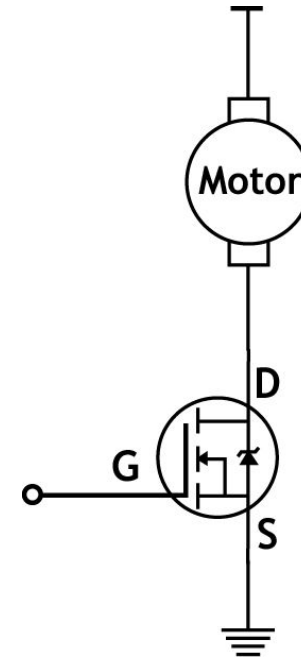
Come in a large number of different varieties, shapes and sizes



TRANSISTORS II

MOSFETs are transistors that make very good switches

A very small signal on the gate can switch very large loads on and off thousands of times a second.



DEMONSTRATION – TRANSISTORS

Objectives

To show the operation of a transistor

Materials

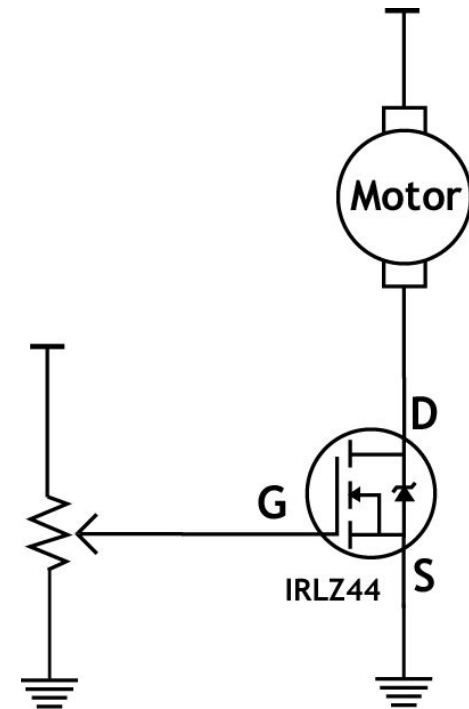
Multimeter

Soldering Iron and Solder

Motor / Halogen

Big MOSFET

MOSFET datasheet



BINARY

The gateway to digital electronics

THE DECIMAL NUMBER SYSTEM

At the risk of stating the obvious...

We count by going through our list of number symbols until we run out...

0, 1, 2, 3, 4, 5, 6, 7, 8, 9, ...

When we run out, we mark that fact with a digit in another column and start again

... 8, 9, 10, 11, 12, 13, 14, 15, ...

When we run out again, we use another column

... 98, 99, 100, 101, 102, 103, ...

THE BINARY NUMBER SYSTEM

Binary is identical, except we only have **0** and **1**

We count by going through our list of number symbols until we run out...

0, 1, ...

When we run out, we mark that fact with a digit in another column and start again

... 0, 1, 10, ...

When we run out again, we use another column

... 10, 11, 100, 101, 110, 111, ...

JUST LIKE A REAL NUMBERING SYSTEM

You can convert to decimal, since you know how big each column is – 32, 16, 8, 4, 2, 1

$$1100_2 = 1 \times 8 + 1 \times 4 + 0 \times 2 + 0 \times 1 = 12_{10}$$

You can add and subtract binary numbers (and all other arithmetical operations)

$$\begin{array}{r} 0010 \\ + 0110 \\ \hline 1000 \end{array} \qquad \begin{array}{r} 1000 \\ - 0110 \\ \hline 0010 \end{array}$$

Each column is called a **bit**. Eight bits are called a **byte**.

THE BIG STEP

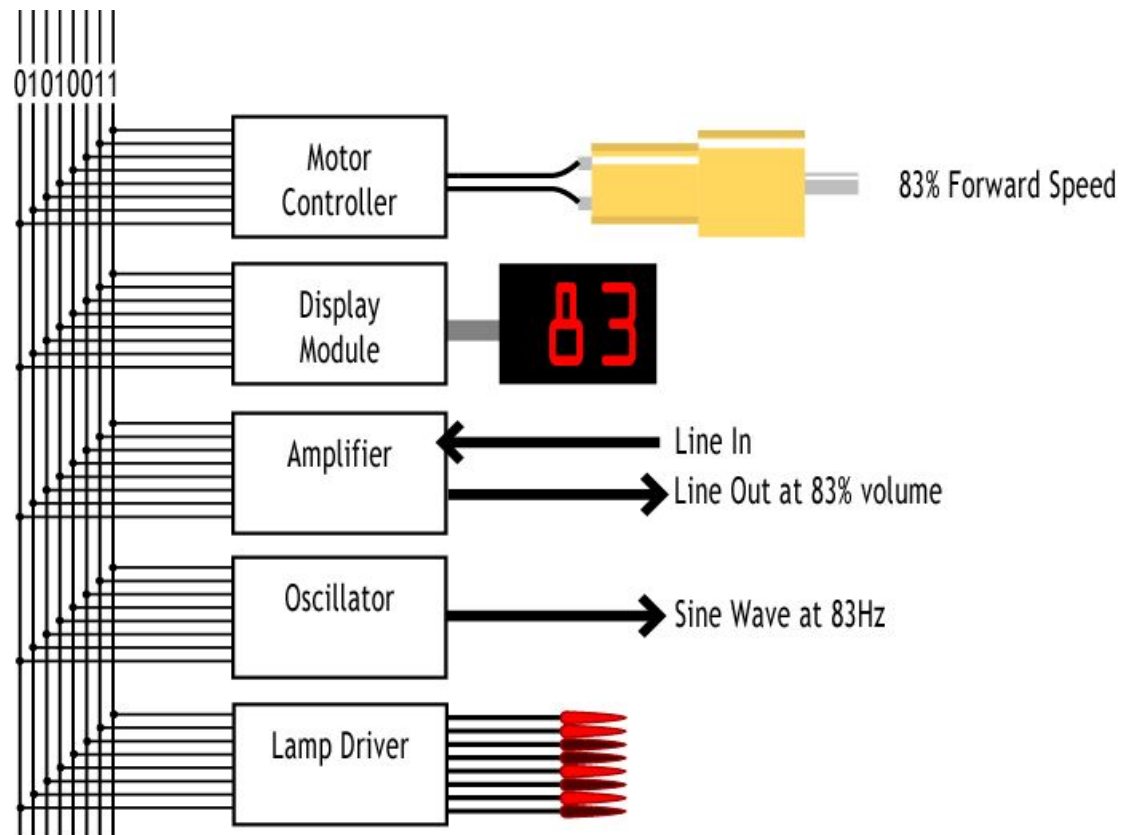
So what's so cool about a numbering system that only has 2 digits?

Each digit can be unambiguously represented by a voltage on a wire.

And you can do whatever you want with it.

83

What is 83_{10} or 01010011_2 ?



MATERIALS

Materials

Power Supply

1.5V Cell

Wire

Solder

Soldering Iron

LEDs

Resistors (1K & 500 Ω)

Potentiometer

Diodes (high-ish current)

Bend Sensor

Photocell

Bend sensor

MOSFET & Datasheet

Motors

Halogens