POWERING PROTOTYPES

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OVERVIEW

Powering Your Prototype

- Prototyping
- Battery Power
  - Voltage
  - Current
  - Capacity
  - DC-DC Converters
  - Using multiple power sources

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POWERING YOUR PROTOTYPE

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COMMON METHODS

AC to DC power supplies

Variable DC bench power supply

Batteries

USB cable

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MB102 BREADBOARD POWER SUPPLY MODULE ADAPTER SHIELD

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BREADBOARD POWER SUPPLY

Prototypes where 5V, 3.3V, or both, are required

Connect DC power supply unit that has 6.5-12 VDC power output from a barrel jack

Has 2 independent channels of power output for breadboards.

- power channels can be independently configured for 3.3V, 0V, and 5V.

Also USB input with two 5V, two 3.3V, and 4 GND pinout for additional power pin requirements.

Suitable for prototyping, but not for your final project – use batteries

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BATTERY POWER

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IMPORTANT QUESTIONS

How much voltage do I need? And how many different voltages?

How much current do I need?

How long do I need power for?

Is recharging an option?

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HOW MUCH VOLTAGE DO I NEED?

This depends on the components in the circuit

Atmega 328p = 2.7 to 5.5V (technically 2.2-6)

If you use a voltage regulator, you can supply a voltage in a specified range above or below the regulated voltage (with DC-DC converters).

- Some development boards run at 3.3 or 5V, but have DC-DC converters that can handle 6V to 12V.
- You might have to supply 5v and 3.3v to separate parts of the circuit – some components are sensitive.

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HOW MUCH CURRENT DO I NEED?

This also depends on the components in the circuit

Check the datasheets and estimate what the different components need.

- It's best to round up

Or use a multimeter to measure the current going to your circuit while it's running – remember to do this in series and on load

If your circuit includes components that require large amounts of current, like motors or lots of LEDs, you will need a large or (preferably) separate power supply

Not enough current = brown-out

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WHICH BATTERY? HOW LONG DO I NEED POWER FOR?

Battery capacity is measured in ampere-hours (Ah) or milliampere-hours (mAh)

- E.g., a 2000mAh battery can supply 2A (2000mA) for one hour.

From wikipedia

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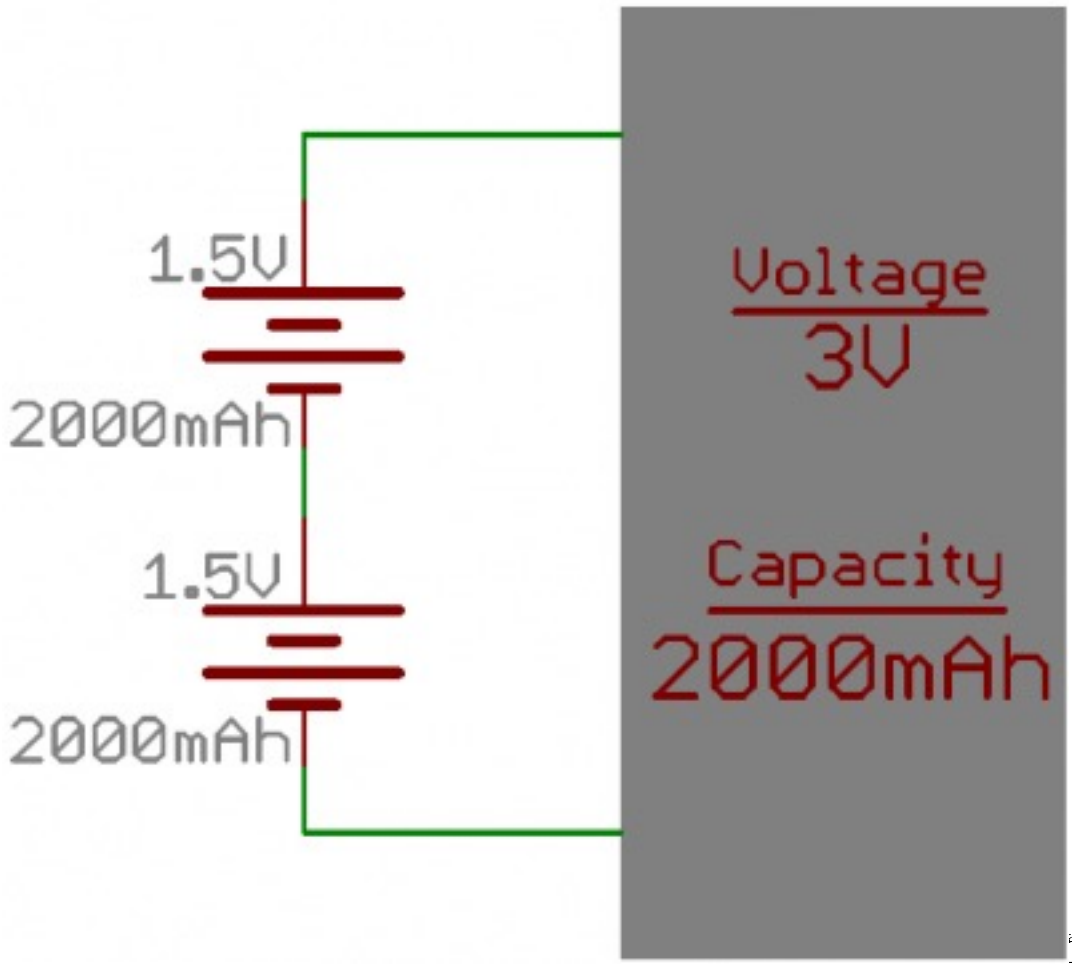
BATTERIES IN SERIES

When batteries are placed in series, the voltages of the batteries are added together.

- When connecting batteries in series, they should be of the same chemistry.

- Many chargers are limited to single-cells, so won't work for batteries in series.



From Sparkfun

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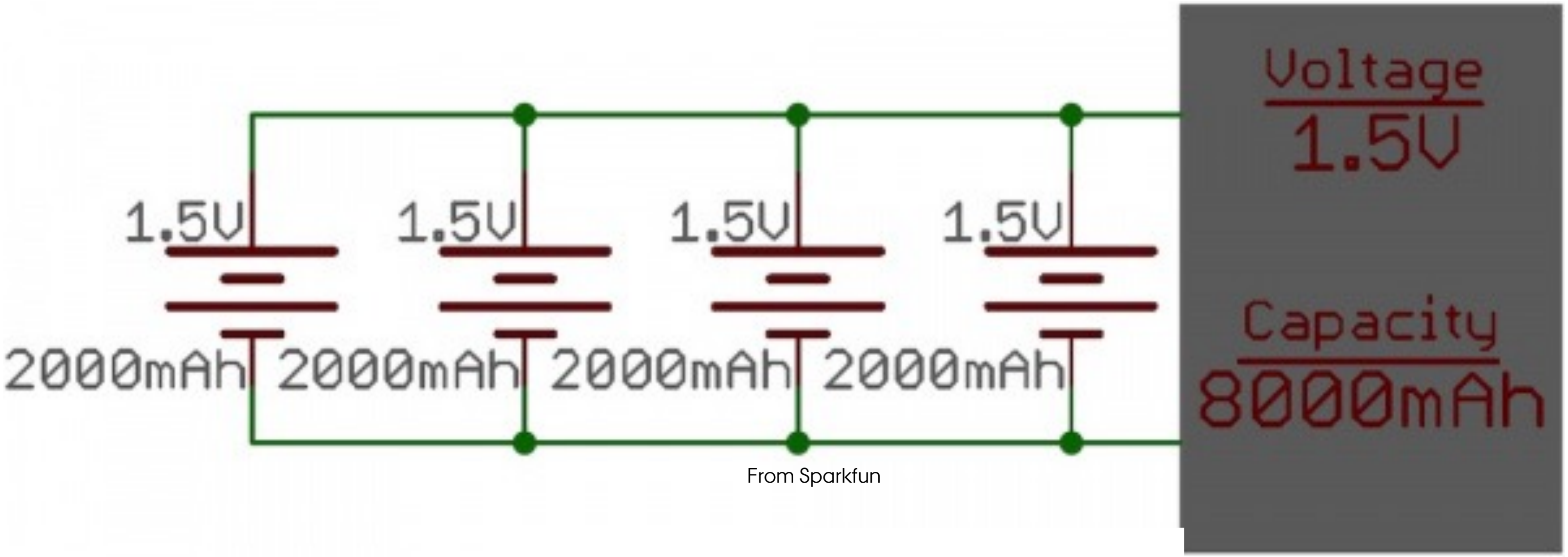
BATTERIES IN PARALLEL

When you connect batteries in parallel, the voltage remains the same, but the capacity increases.

- E.g., 4 AA parallel batteries will produce 1.5V, but the capacity will be quadrupled.
- Parallely connected LiPos can run on the same BMS.



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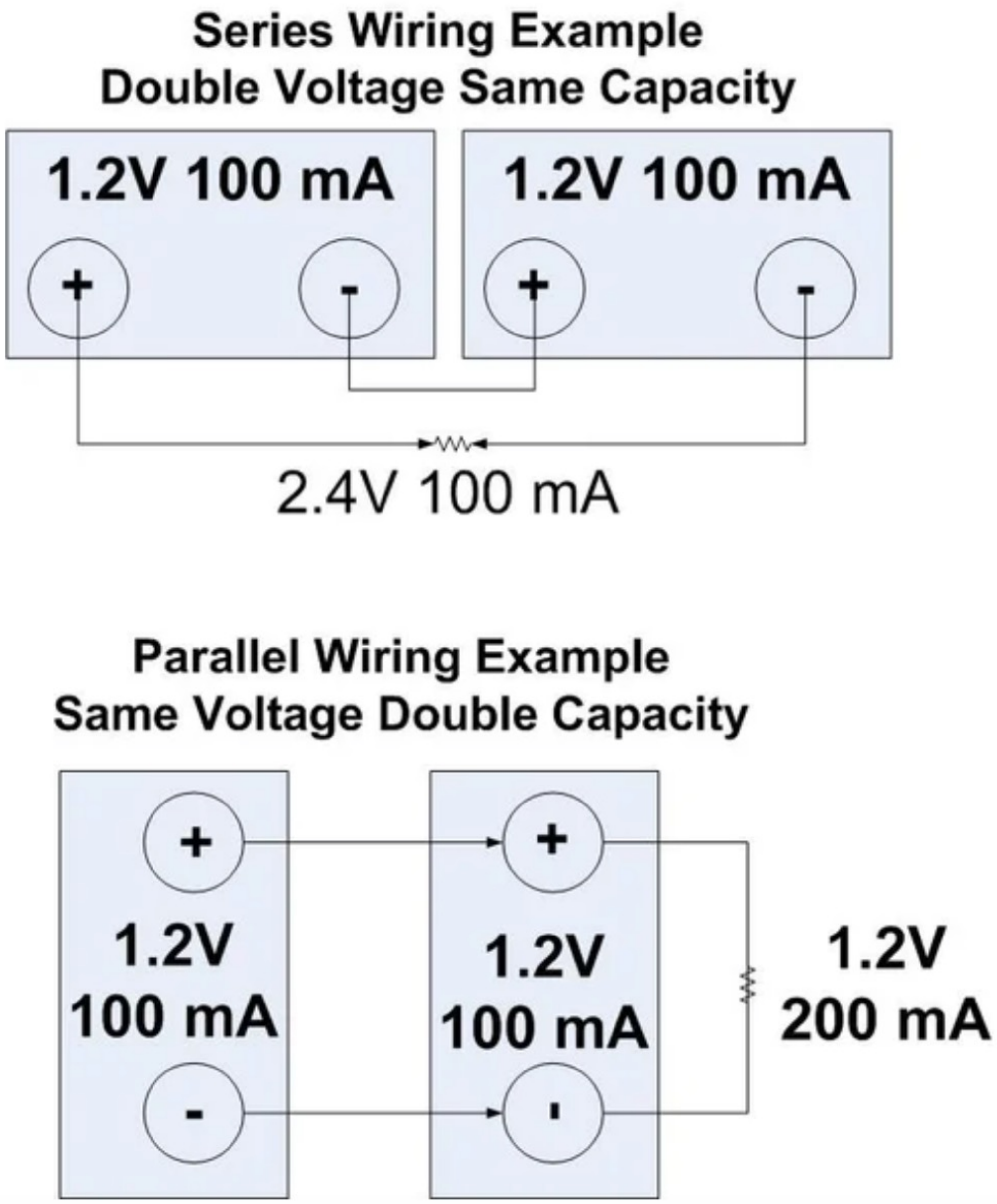

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IS RECHARGING AN OPTION?

Battery Shape	Chemistry	Nominal Voltage	Rechargeable?
AA, AAA, C, and D	Alkaline or Zinc-carbon	1.5V	No
9V	Alkaline or Zinc-carbon	9V	No
Coin Cell	Lithium	3V	No
Silver Flat Pack	Lithium Polymer (LiPo)	3.7V	Yes
AA, AAA, C, D (Rechargeable)	NiMH or NiCd	1.2V	Yes
Car Battery	Six-cell lead acid	12.6V	Yes

From Sparkfun

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BATTERY CALCULATION EXAMPLES

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CALCULATING CIRCUIT CURRENT

Simple circuit with 5v, no step up/down.

Circuit includes:

- ATmega 328p = 14mA (active, 16MHz) (rounded up to 20mA)
- 3 red LED's with 330 ohm resistors = 10mA per LED
- 2 motors = 25mA each

Total possible current is:

$$20mA + (3 \ * 10mA) + (2 \ * 25mA) = 100mA$$

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HOW LONG WILL IT LAST? (SIMPLE VERSION)

Let's choose a standard alkaline AA battery - 2Ah, 1.5V, for our 100mA circuit

To calculate how long a circuit will last on battery power, we use the following equation:

$$\frac{BatteryCapacity(Amphours)}{CurrentDraw(Amps)} = BatteryLife(Hours)$$

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$$\frac{2Ah}{100mA} = \frac{2000mAh}{100mA} = 20\ hours$$

3 AA BATTERIES IN PARALLEL

3 AA's in parallel connected to a circuit with a constant 100mA current draw

$$\frac{(3 * 2Ah)}{100mA} = \frac{6000mAh}{100mA} = 60h$$

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DC-DC CONVERTERS

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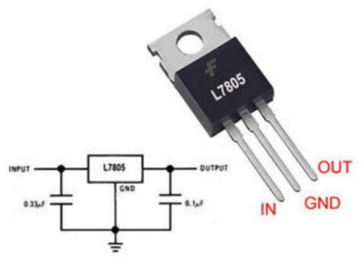
DC-DC CONVERTERS



Can be used to convert an input direct current (DC) from one voltage to another

2 types:

- Step-down (buck converter) - output voltage is lower than the input voltage

- Step-up (boost converter) - outputs a voltage higher than the input voltage
  - E.g. a step-up can be used to provide 5V from an AA battery

NB: there's always some loss – 20 to 30% loss per step-up/step-down stage is a good and very conservative estimate.

- Check datasheets – XL6009 (boost) gives a rough nominal estimate (92%), LM2596 (buck) has efficiency curves for each voltage (e.g 20v stepped to 3.3v is 74% efficiency)

BATTERY CALCULATION EXAMPLES

Simple circuit, 5v as example, no stepping other than battery source:

Circuit current draw at 5v: 100mA

Power source = 3.7v 800 mAh (LiPo battery)

Boost converter (step up) efficiency = 92% (XL6009)

Calculating battery capacity:
3.7 (battery voltage) / 5 (stepped up voltage) = 0.74 * 0.92 = 0.68.

Converter must draw proportionally more/less from battery to deliver higher/lower output.

Basically every mAh in the unstepped battery results in 0.68mAh when boosted and including efficiency.

Battery capacity: 800*0.68 = 544.64

Prototype will last: 545/100 = 5.45 hours

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EXAMPLE REVISITED

Complex circuit, multiple voltages.

Circuit current draw: 100mA from 5v, 200mA from 9v, 500mA from 18v.

Power source = 3.7v 800 mAh (LiPo battery)

Boost converter (step up) efficiency = 92% (XL6009)

Calculating battery capacity (conversion efficiency uses nominal estimated value of 92% efficiency):
Battery wattage: 3.7 (volts) * 0.8 (amps) = 2.96 watt hours

5v circuit section wattage: 0.5 watts = 0.54 watts due to 8% energy loss from inefficient conversion

9v circuit section wattage: 1.8 watts = 1.944 watts due to 8% energy loss from inefficient conversion

18v circuit section wattage: 9 watts = 9.72 watts due to 8% energy loss from inefficient conversion

Total wattage of circuit = 11.3 = 12.204 watts including conversion efficiency loss

Battery lasts 2.96/12.204 = 0.242 hours = 14.5 minutes

USING MULTIPLE POWER SOURCES

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MULTIPLE POWER SOURCES

Many components you use need a higher voltage, and current, than the one handled by the ATMega, e.g.

- LEDs
- Motors

You need a separate power source to handle these

This is a common scenario – '*I want to connect my 12V powered LED strip to my PCB but I can't get it to communicate. All connections are fine. I have a 12V power supply for the LEDs and the PCB is powered by batteries*

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YOU NEED SHARED (COMMON) GND

What is Ground?

- A name given to a point in your circuit.
- 0 volt reference point.

The 5V pin of the ATMega isn't actually 5V – it is 5V *with respect to* the ground pin.

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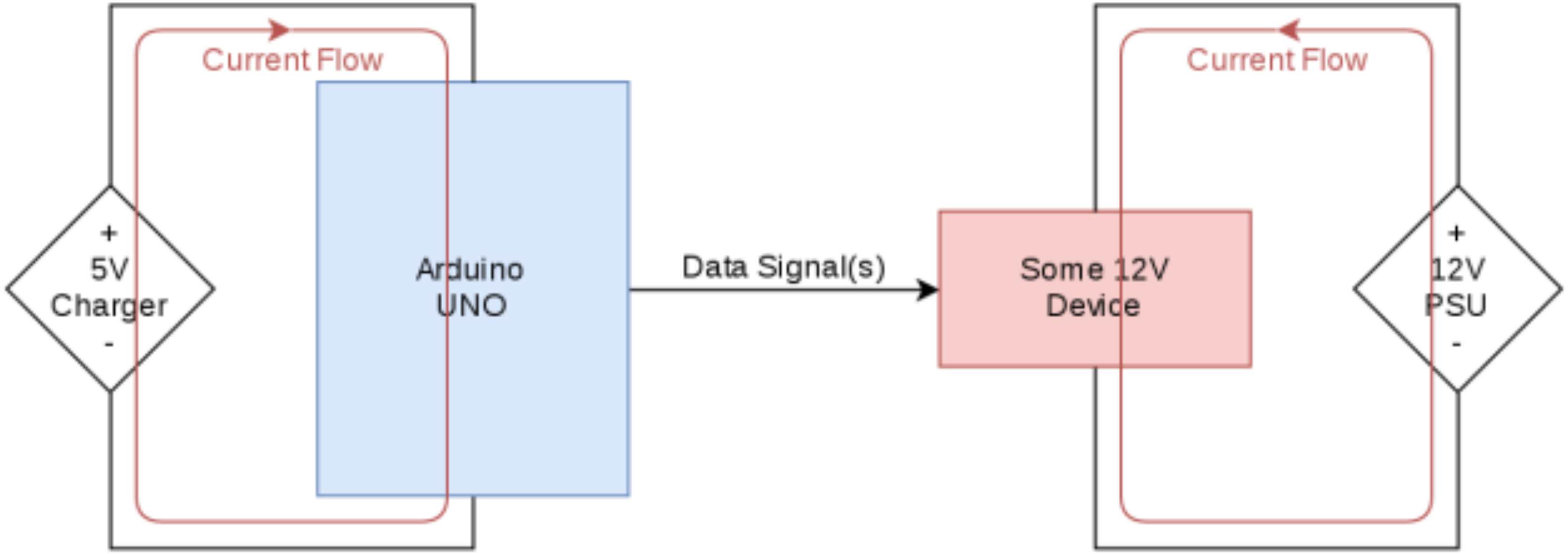
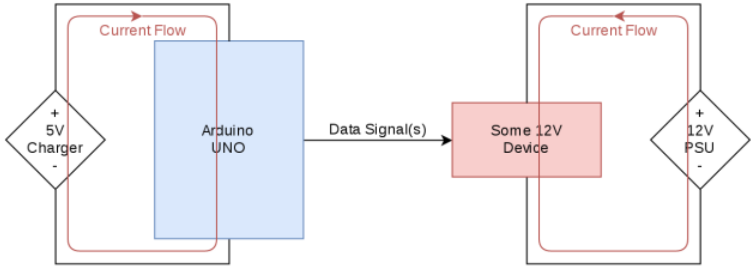


From https://hackingmajenkoblog.wordpress.com/

GROUND



From the ATMega's point of view ground is the bottom line of it's power circuit (charger -).

12V of the external circuit is 12V *with respect to* the – side of the 12V PSU

- the ground is the lower side of the 12V circuit – the "PSU -" connection.

Look at the data signal going from the ATMega to the 12V device, what voltage is that at?

It's impossible to know.

- From the ATMega's point of view, it is a 5V signal, but what voltage is that signal with respect to the 12V circuit ground?

Given that voltages aren't absolute – they are only relative to a reference point within the same circuit, it is impossible to know what the voltage is there.

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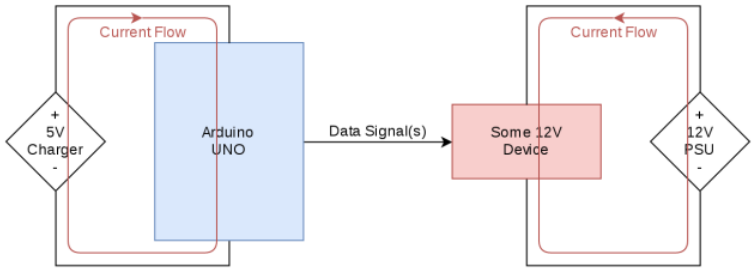
CURRENT



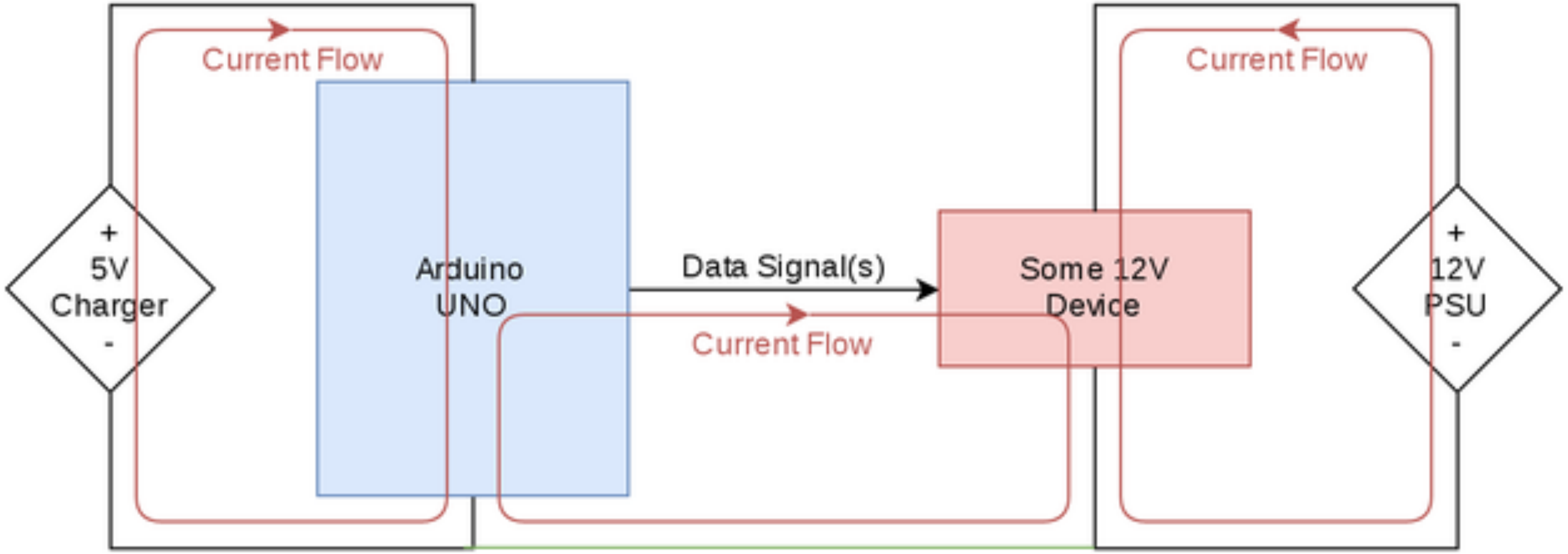
The red arrows are the flow of the current around the circuit

Current has to flow out of a supply, through a circuit, and back to the supply from where it came.

The current can flow out of the 5V, through the ATMega, and back to the 5V again

Same for the 12V loop

There's no loop for the signal from the ATMega to the 12V; it needs to get back to the ATMega GND again.



From https://hackingmajenkoblog.wordpress.com/

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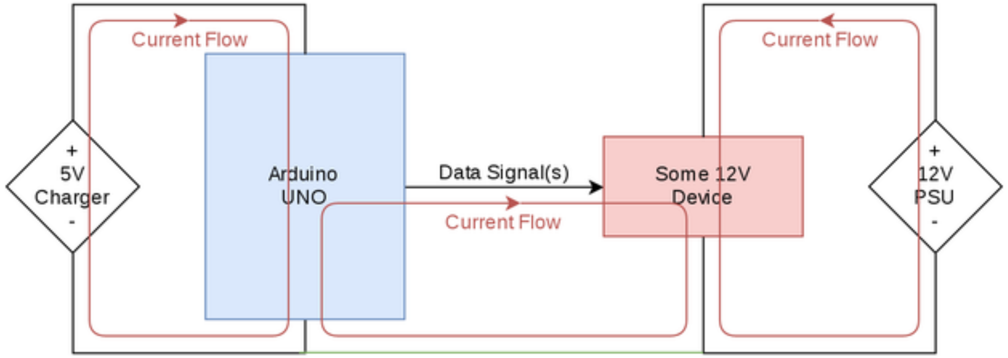
SHARED GND



Now there's a loop where the current from the IO pin can flow through the 12V device, out of the ground connection of the device, along the green wire, and back up through the ground connection of the ATMega.

Also, now, since the ground of the 5V section and the ground of the 12V section are the same, any signals generated from the 5V side are recognisable by the 12V side as 5V since the reference point (ground) is the same for every point in the circuit.

SUMMARY

Powering Your Prototype

- Battery Power
  - Voltage
  - Current
  - Capacity
  - DC-DC Converters
  - MB102 Breadboard Power Supply Module Adapter Shield
  - Using multiple power sources

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PRACTICAL EXERCISE 4

Actuation

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MAIN GOALS

Using actuators

Reacting to sensor data

You will need:

- Batteries:
  - Go to Føtex or check your kits… ☺
  - We have some LiPos by the component table
- Transistor: MOSFET or NPN BJT, plus a 1k resistor or the transistor will burn out
- Diode (for flyback)
- Your voltage divider circuit.

ACTUATION

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MOTOR SPEED CONTROL TASK

Measure an input with your ADC voltage divider (FSR, Potmeter, LDR)

Map the ADC value to a PWM value

- map(val, 0, 1023, 0, 255)

Control the speed of the motor using the mapped PWM value through a transistor (e.g. the more light that shines on the LDR, the faster the motor spins)

https://www.arduino.cc/reference/en/language/functions/math/map/

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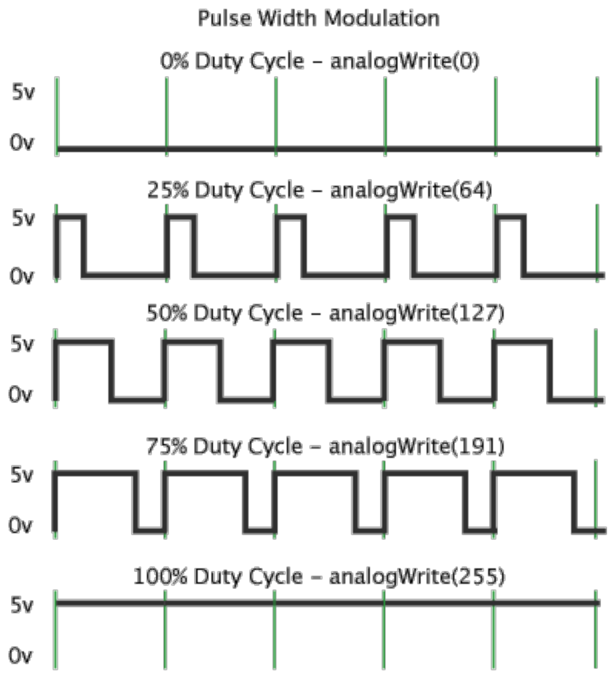
PWM - PULSE WIDTH MODULATION

A square wave, with constant frequency, where the fraction of the time the signal is on (the duty cycle) can be varied between 0 and 100%



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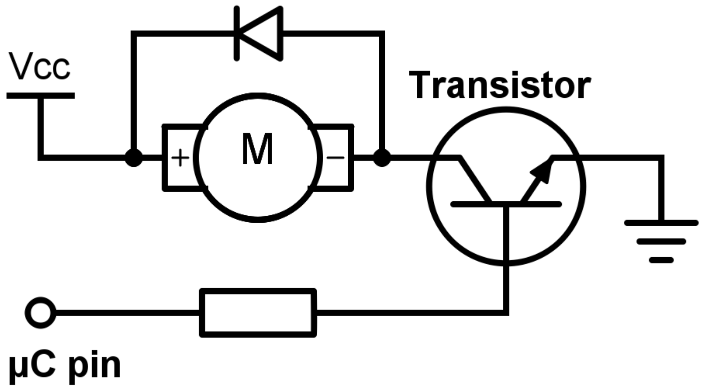
MOTOR SPEED CONTROL EXAMPLE

Recreate this circuit with your Atmega breadboard set-up (in addition to your voltage divider set-up). Remember to add a resistor before the Base.

- You can use a MOSFET or BJT



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BEWARE!!

Some motors require a high voltage, which some transistors cannot handle.

- Big solenoids or motors requires, in some cases, > 30v

When working with inductive load you MUST use a flyback diode - or else you might fry the circuit

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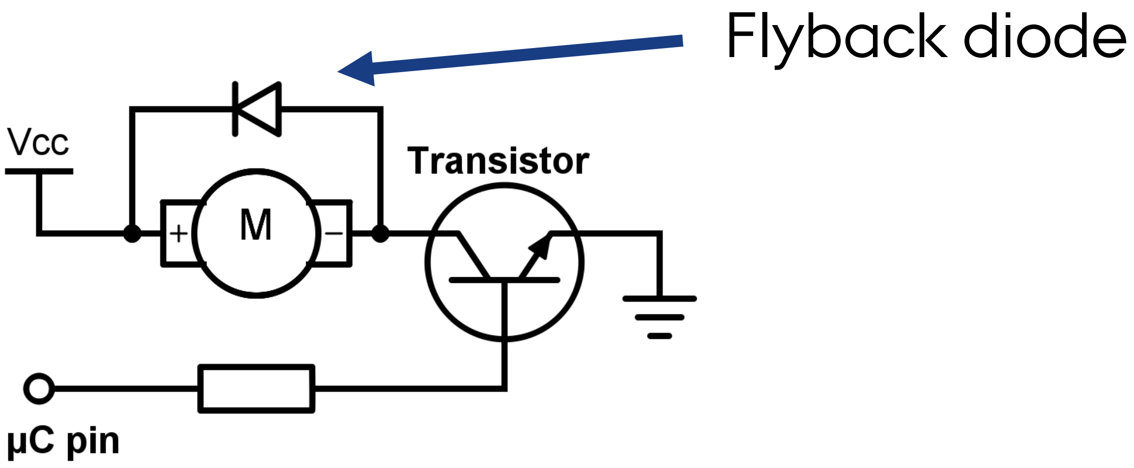
FLYBACK DIODES

A diode connected across an inductor (the motor) used to stop flyback

Flyback is the voltage spike seen across an inductive load when its supply current is suddenly reduced or interrupted.



Adapted from NorwegianCreations.com

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CONNECTING TO VOLTAGE DIVIDER

You can use your LDR circuit to control the speed of the motor e.g. more light equals faster spin

This is done through code –

e.g.

```
void loop()
{
    int reading = analogRead(%your voltage divider output%);
    int spd = map(reading, 0, 1023, 0, 255);
    analogWrite(motor, spd);
    delay(50);
}
```


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TO PASS -

Show your motor set-up to one of us.

Or submit a video of the motor running at different speeds in response to your variable resistor input.

Deadline: 23/09/2025 at 09:00

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