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Fast Robots

Topics this week…

- Callback functions
- RCL recap
- Electro Magnetic Interference
- Electrostatic Discharge
- Wiring and Routing
  - Lab 3 pre-lab discussion
- Batteries

- Actuators
- Motor drivers
- Oscilloscope

- Grading…

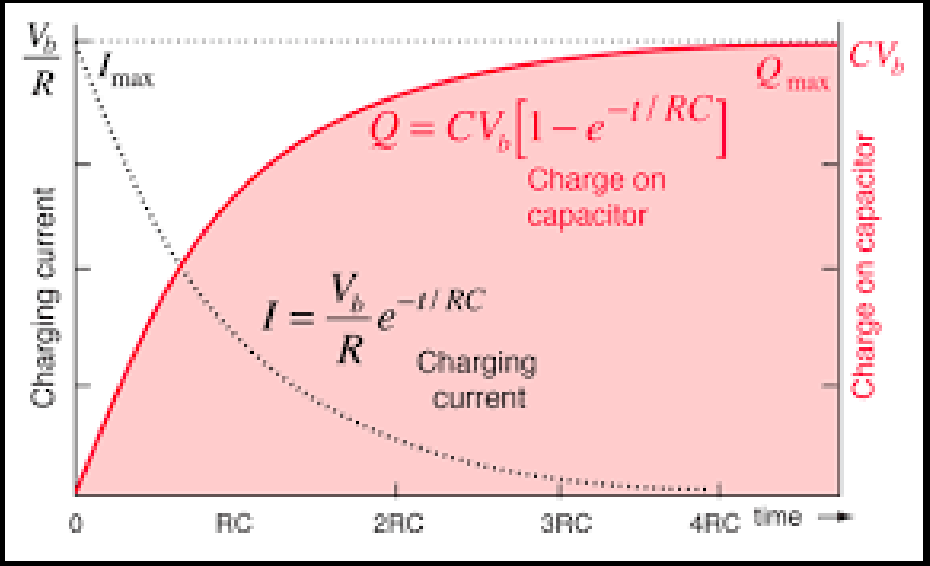
- First in-person lab!
- PH427
- Bring your kit, incl. white box
  - Remainder of the kit
- Computers have Lab 2 SW installed

- Try to finish soldering in your designated lab
- Worst case
  - Saturday open lab hours 12-5pm
    - Aratrika (no class help)
  - Sunday 4-7pm
    - Jade

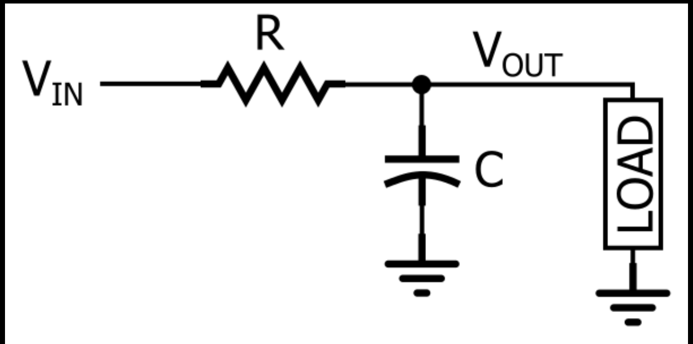
Basics

Hyperphysics.com

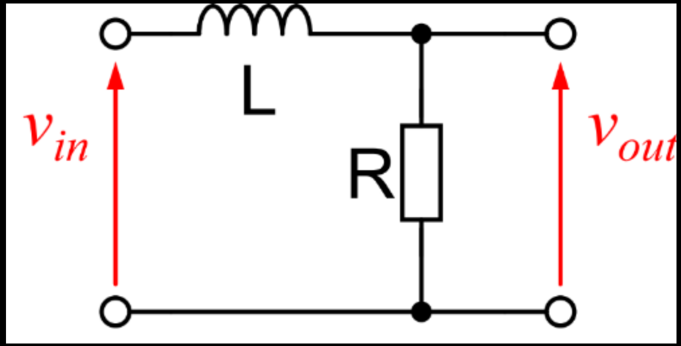
Circuit Element	Symbol	Current-Voltage Relationship in Time	Impedance
Resistor	I → + V −	$V = IR$	R
Capacitor	I → + V −	$I = C\frac{dV}{dt}$	$\frac{1}{j\omega C}$
Inductor	I → + V −	$V = L\frac{dI}{dt}$	$j\omega L$

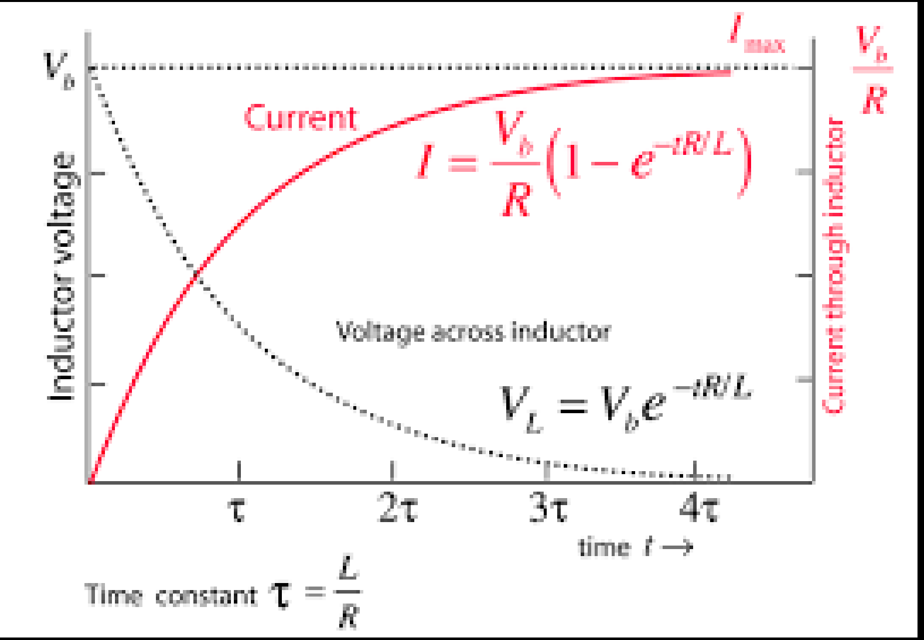


RC low pass filter



RL high pass filter





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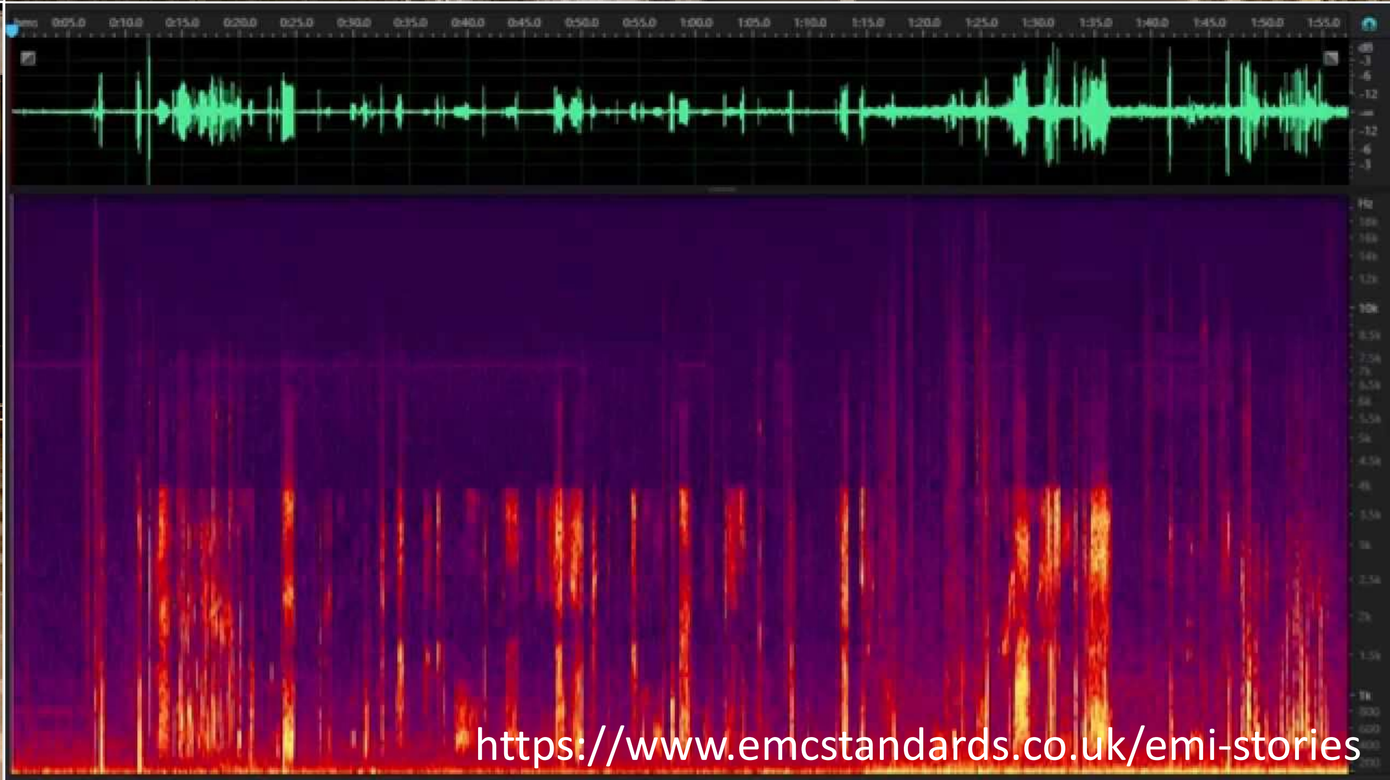
Electro-Magnetic Interference

https://www.emcstandards.co.uk/emi-stories


Ray-Ban


TELEPHONE



https://www.emcstandards.co.uk/emi-stories

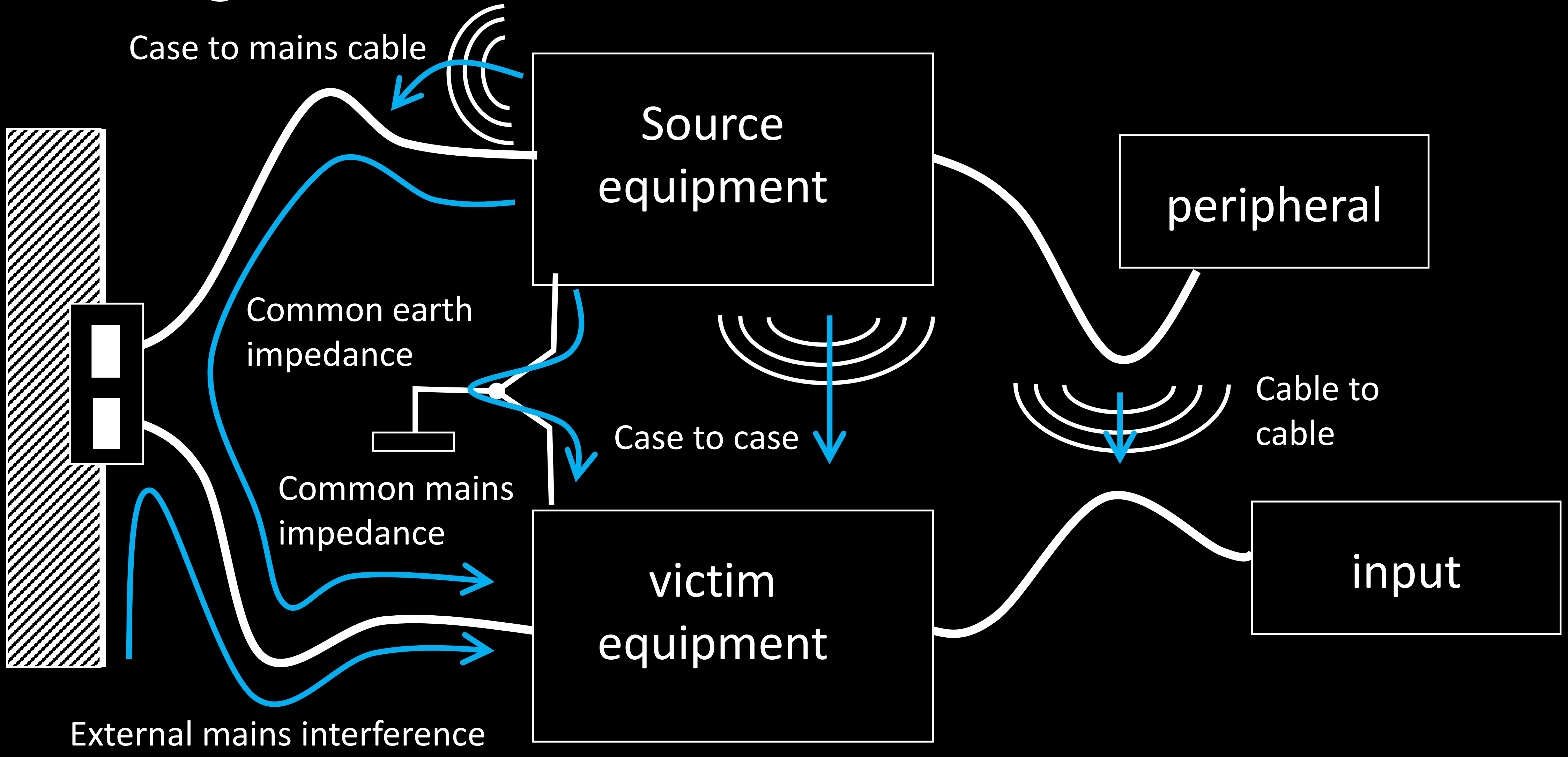
EMC Directive

- The ability of the system to operate without interfering with other systems
- The ability of the system to operate despite interference from other systems
  - Under *typical* conditions (domestic, commercial, industrial)

(not to be confused with…)


SAMSUNG
02 · 01
AFP

Electromagnetic Interference

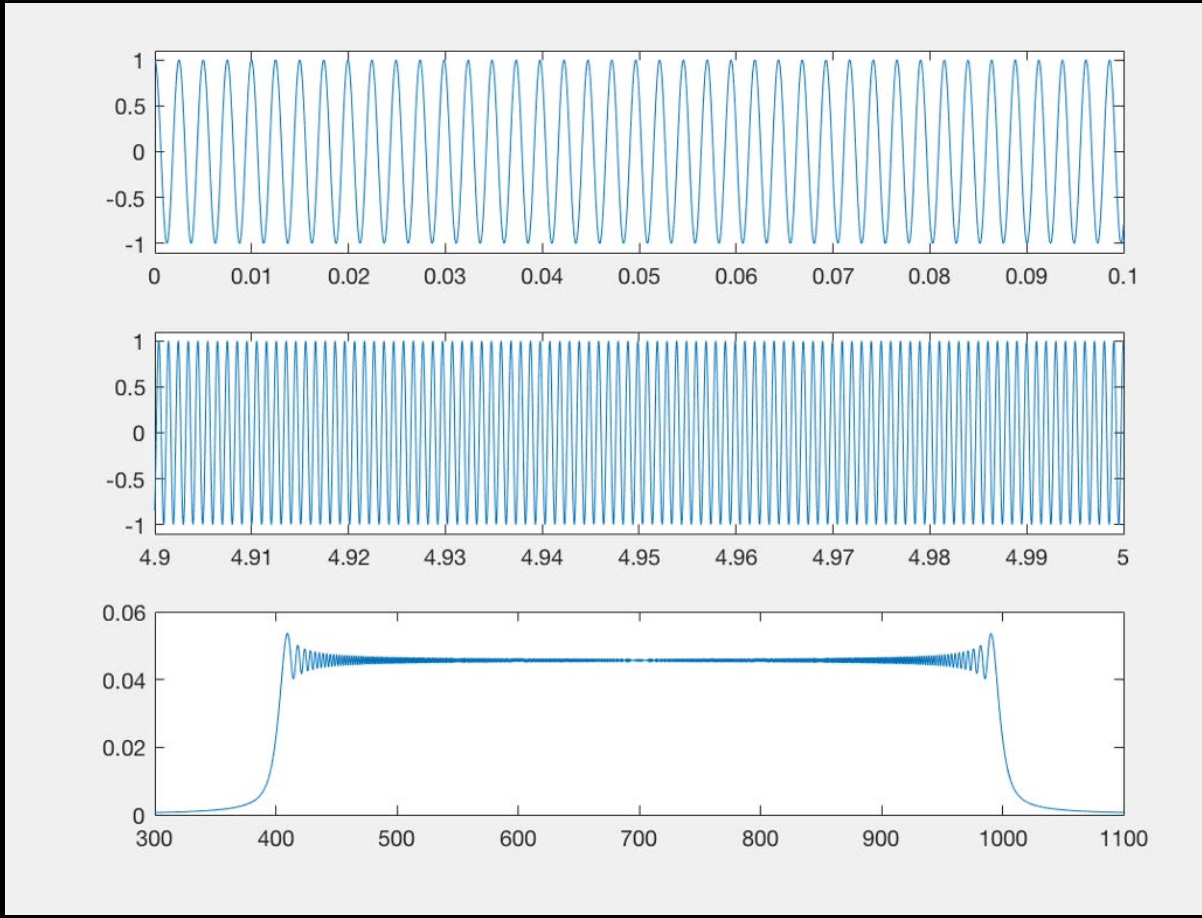


Electromagnetic Interference

What sources of EMI are in your system?

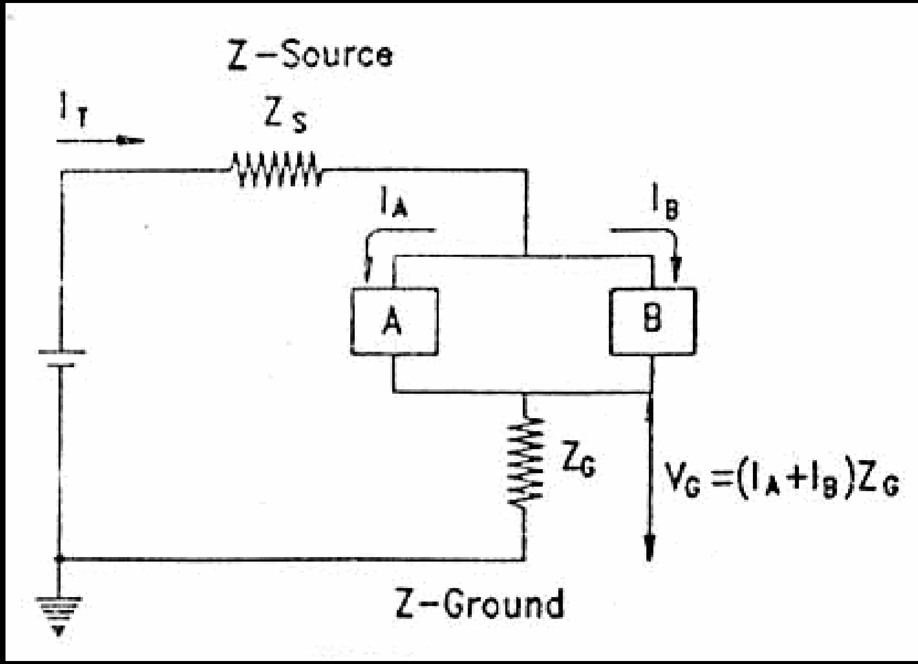
- DC motors
- Switching circuitry (motor drivers)
- Digital signals (I2C, USB)
- Shared power supply (batteries)

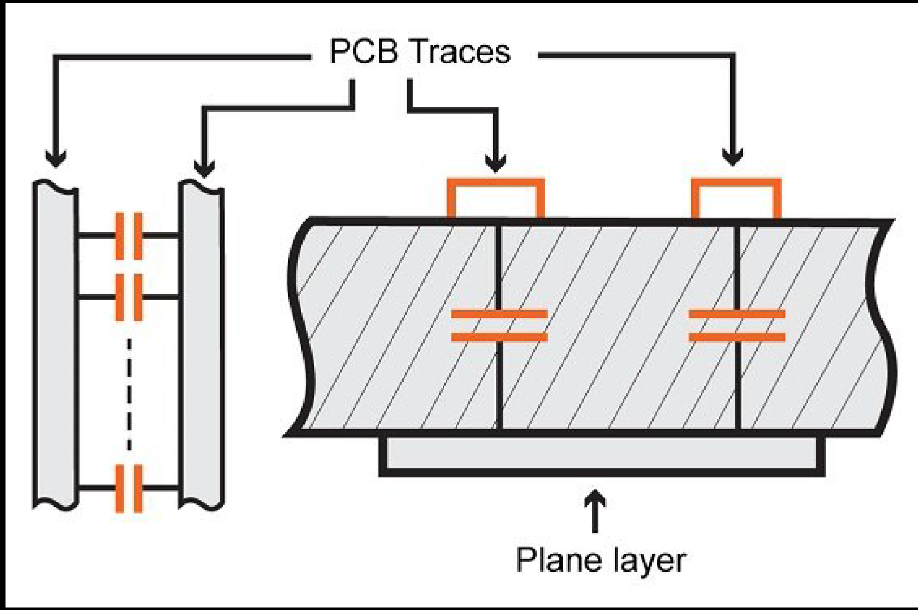
- Two modes of interference
  - Conducted EMI
  - Radiated EMI



Conducted EMI

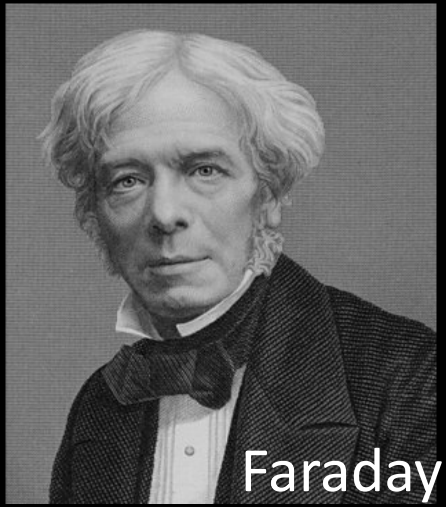
- Shared current paths in resistive wires
  - Ohm's Law
    - U=RI
  - Longer shared paths, higher coupling
- Parasitic Capacitance
  - Electric field over short distances
  - Current in a capacitor
    - I = C dV/dt
  - Higher frequency, higher coupling

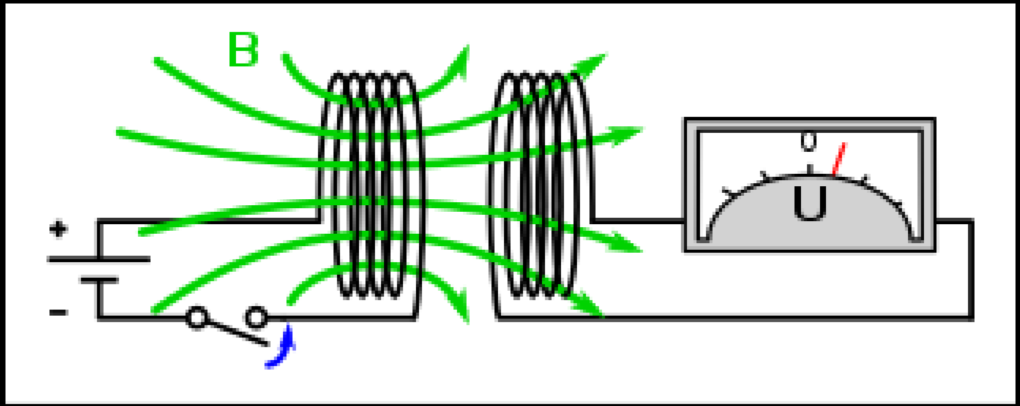


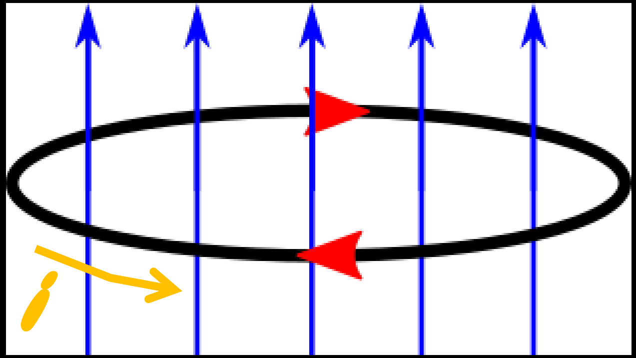


Radiated EMI

https://resources.pcb.cadence.com/blog/2020-lenz-law-vs-faradays-law-how-do-they-govern-crosstalk-and-emi



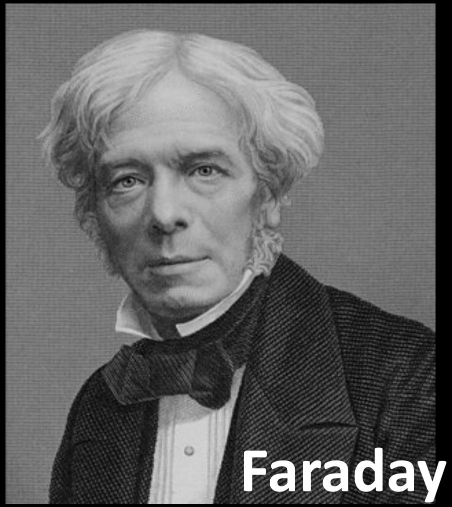


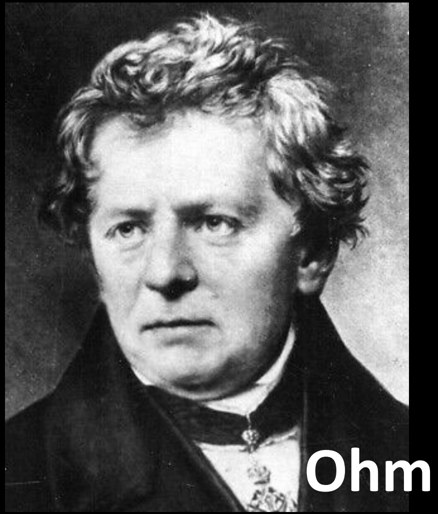


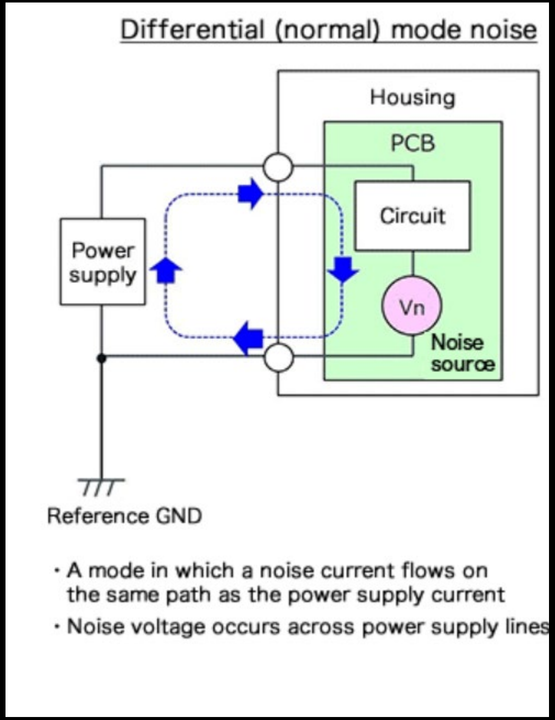
(Fleming's right hand rule)

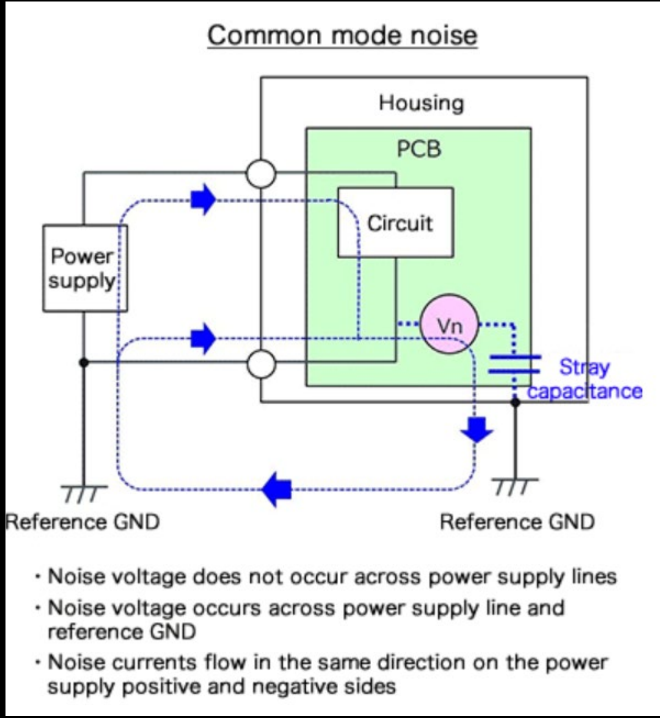
- Faraday's Law
  - Electromotive "force" [V]
  - $EMF = -N\frac{\Delta\Phi}{t}$; where $\Phi = BA$
- Lenz' Law
  - Induced current creates a magnetic field that opposes the source
- The radiated EMI increases with…
  - Magnetic field strength
  - Loop area
  - Signal frequency

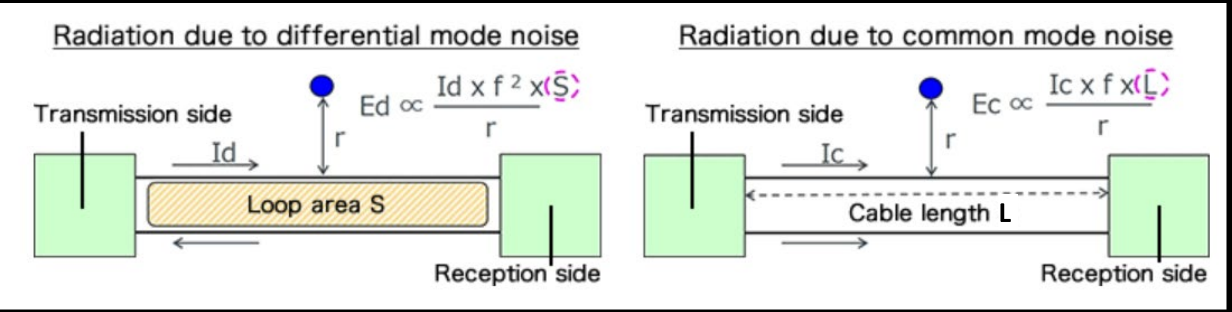
Common Mode Noise and Differential Mode Noise





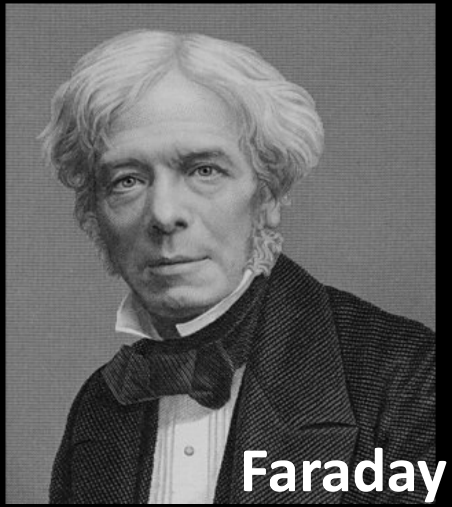




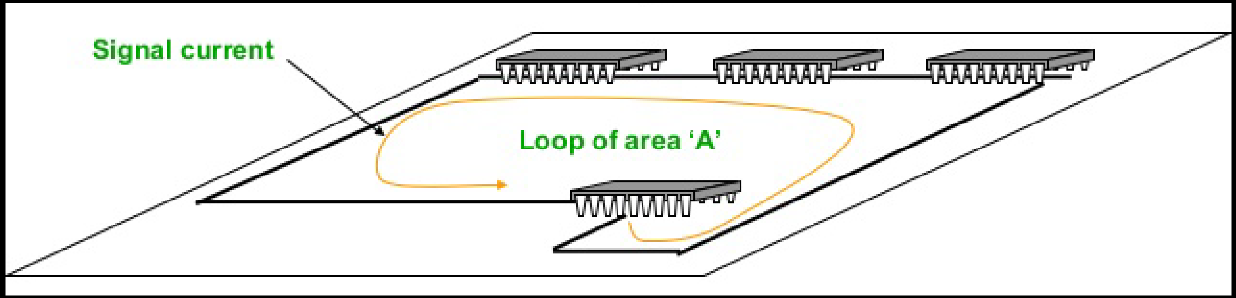


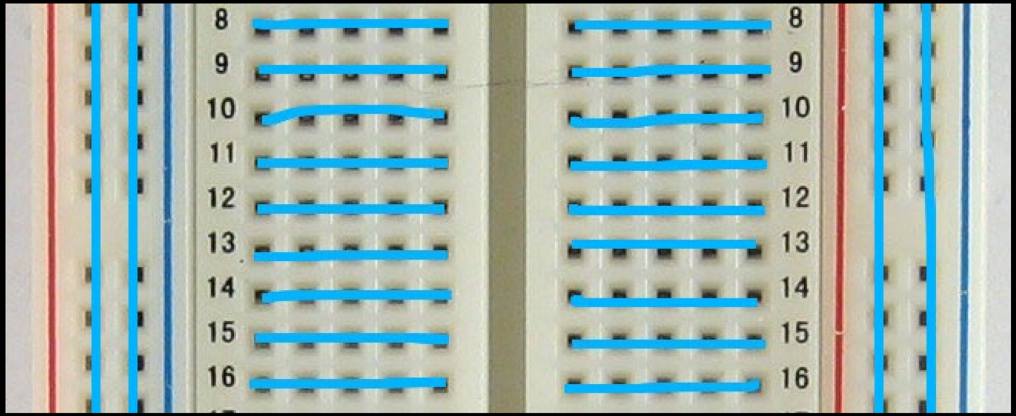
https://techweb.rohm.com/knowledge/emc/s-emc/01-s-emc/6899

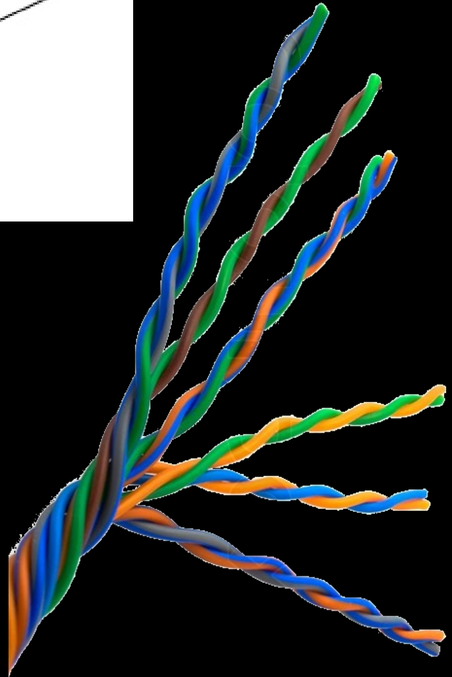
Common Mode Noise and Differential Mode Noise

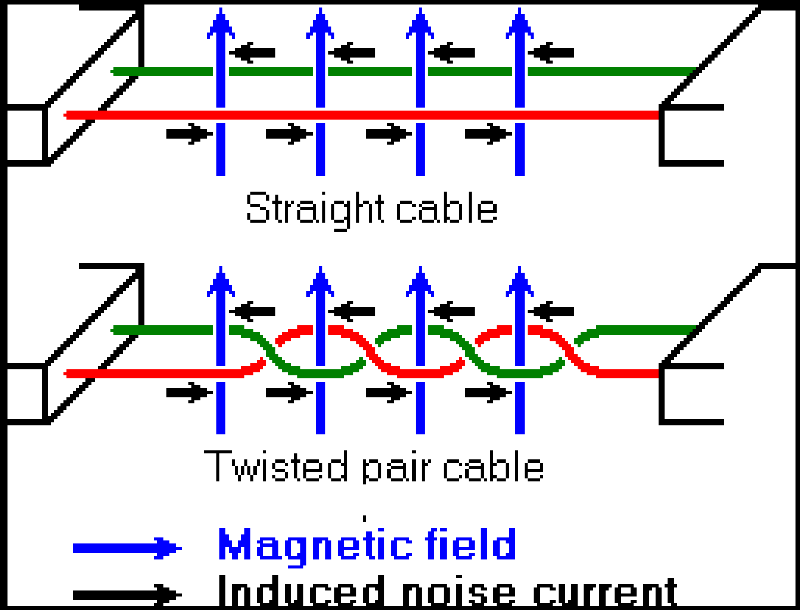


- ***How to suppress noise?***
  - Use lower frequencies when possible
  - Use shielded cables
  - Minimize common impedances
    - Short, thick wires
  - Lower loop area
  - Twist out/return cables

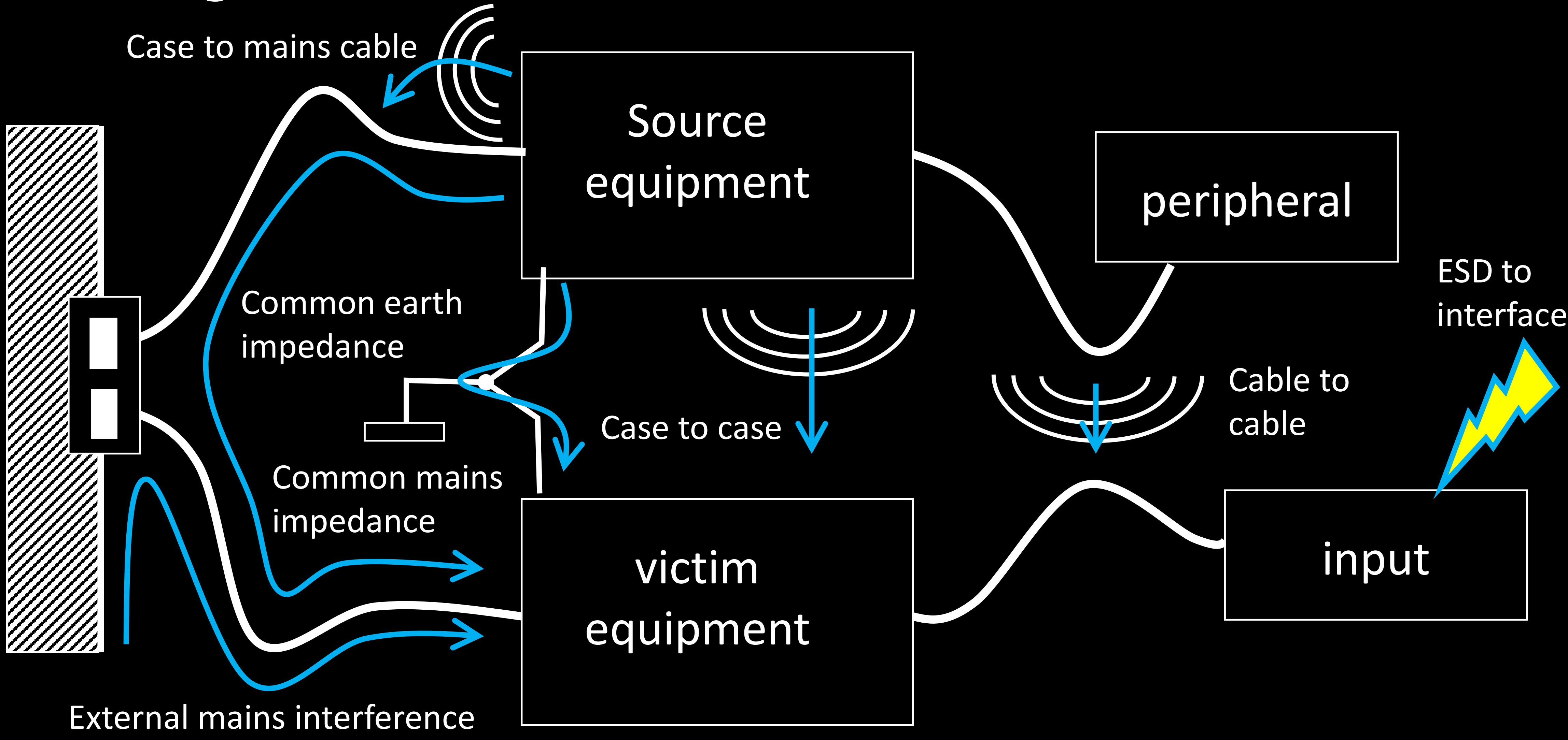








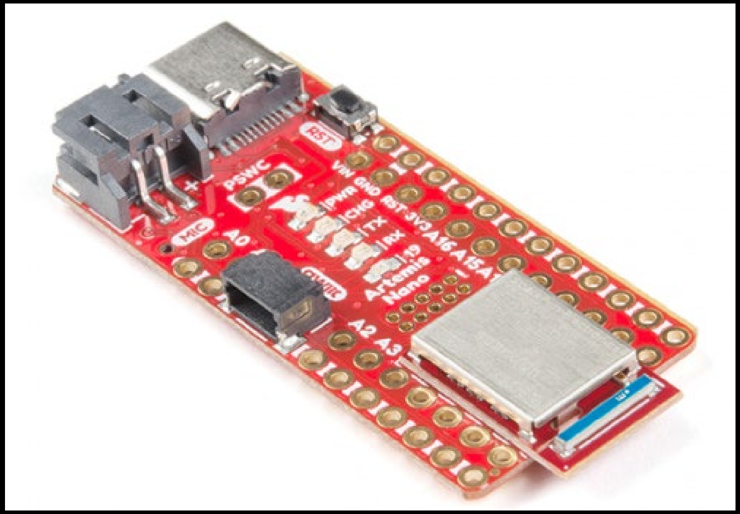
Electromagnetic Interference

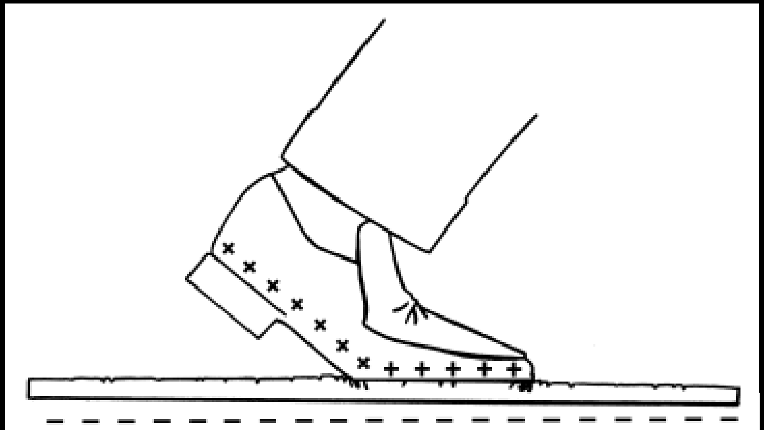


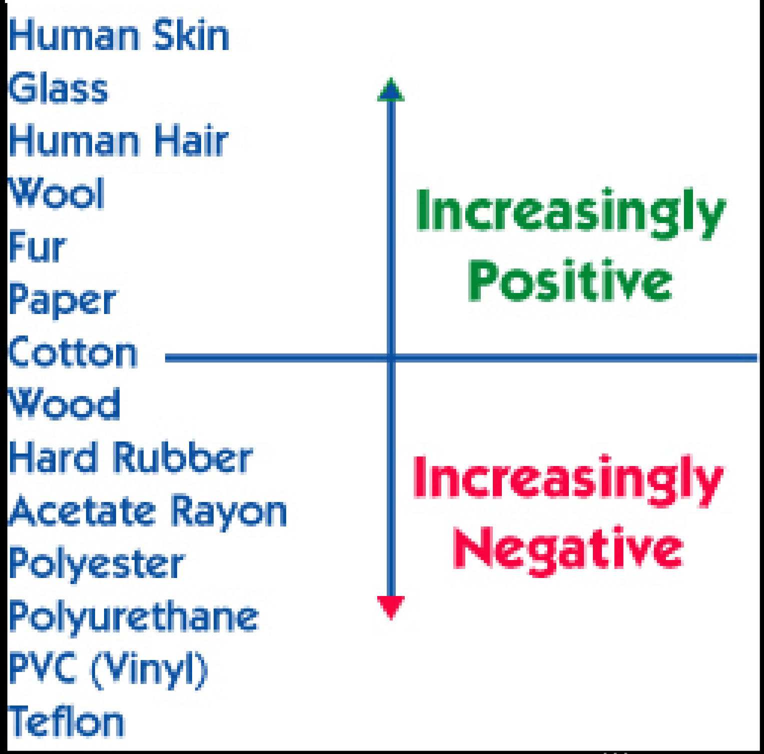
Electrostatic Discharge

Static Voltage Generation at different Relative Humidity (RH) levels		
Generation Method	10-25% RH	60-90% RH
Walking across a carpet	35,000Volts	1,500Volts
Walking across vinyl tiles	12,000Volts	250Volts
Worker at a workbench	6,000Volts	100Volts
Poly bag picked up from workbench	20,000Volts	1,200Volts
Sitting on chair with urethane foam	18,000Volts	1,500Volts

- *Always discharge through ground!*







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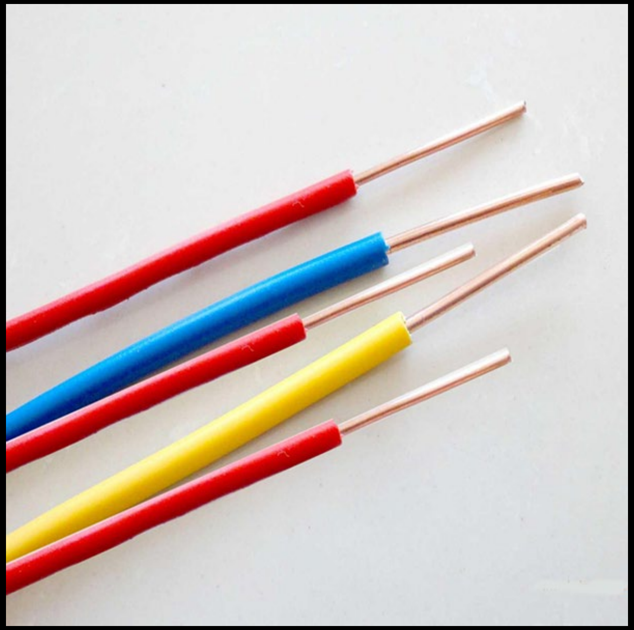
WIRING AND ROUTING

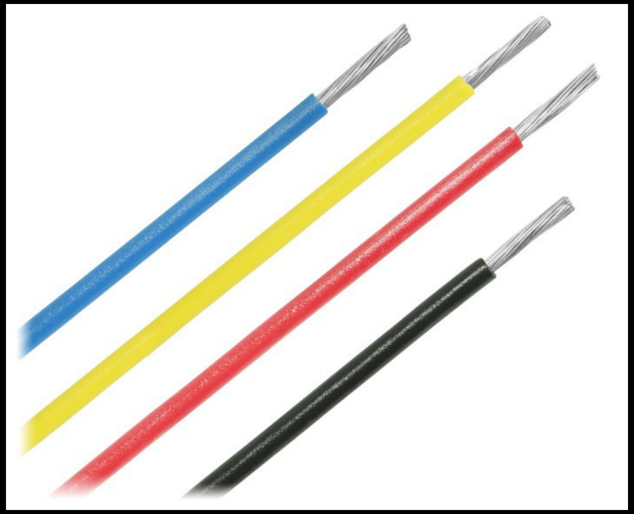
Wiring and Routing

- Power transmission wires
  - Sized according to power
- Signal wires
  - Carry little wire, but are more susceptible to EMI

- Solid core
  - Holds shape, but is brittle
- Stranded
  - Use anywhere the position is not permanent
  - More strands, more flexible

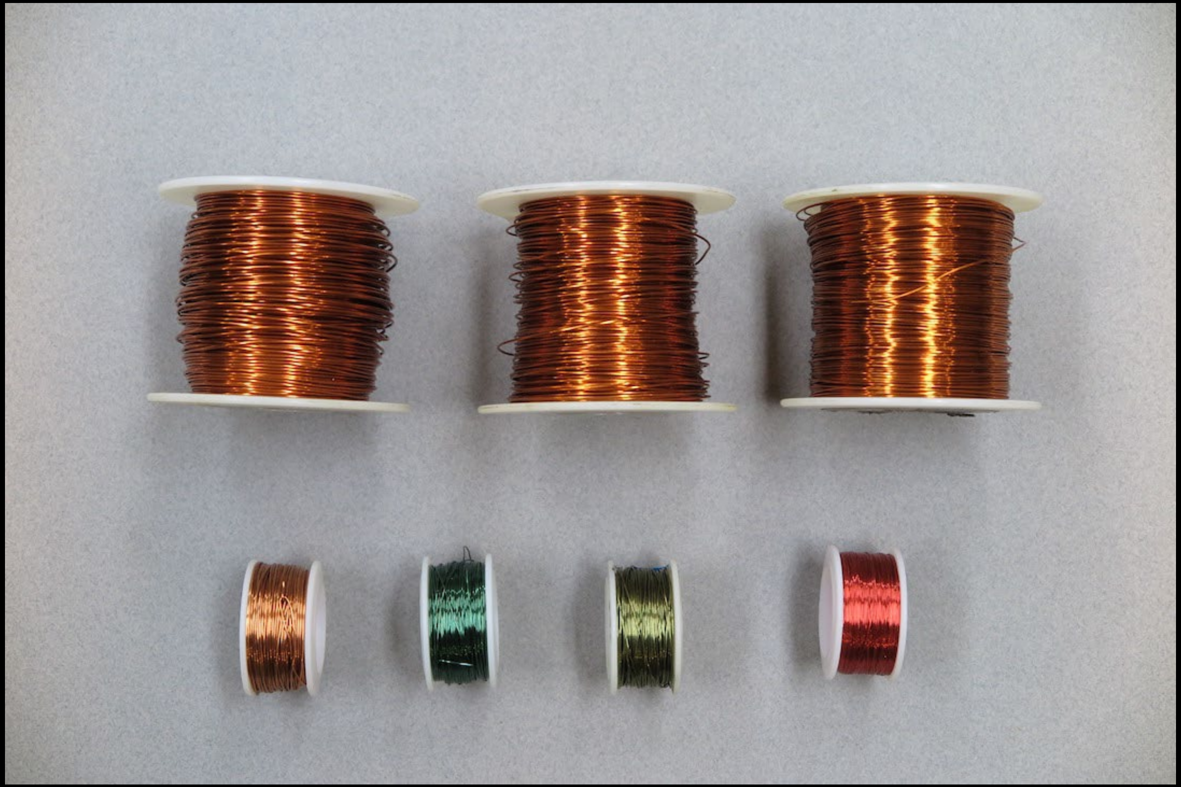
- Insulation
  - Most common: polyviny chloride
  - Polyethylene, polyester, rubber, and Teflon
  - PH427: Silicone
  - Copper tin coating





Wiring and Routing

- Magnet Wire
  - Use in motors, transformers where high density routing is needed
  - Thin enamel-like, tough coating
    - 100-1000s V and 100s of degrees C.
    - Removal with heat or solvent
  - Cannot tolerate repeated bending



Wiring and Routing

Wire Gauge

- US standard is American Wire Gauge (AWG)
- The large the gauge, the smaller the wire
  - AWG 16 and lower are for power transmission
  - AWG 18-22 can be used for low-power motor supplies
  - AWG 22 signals
- Stranded wire
  - AWG 16 26/30

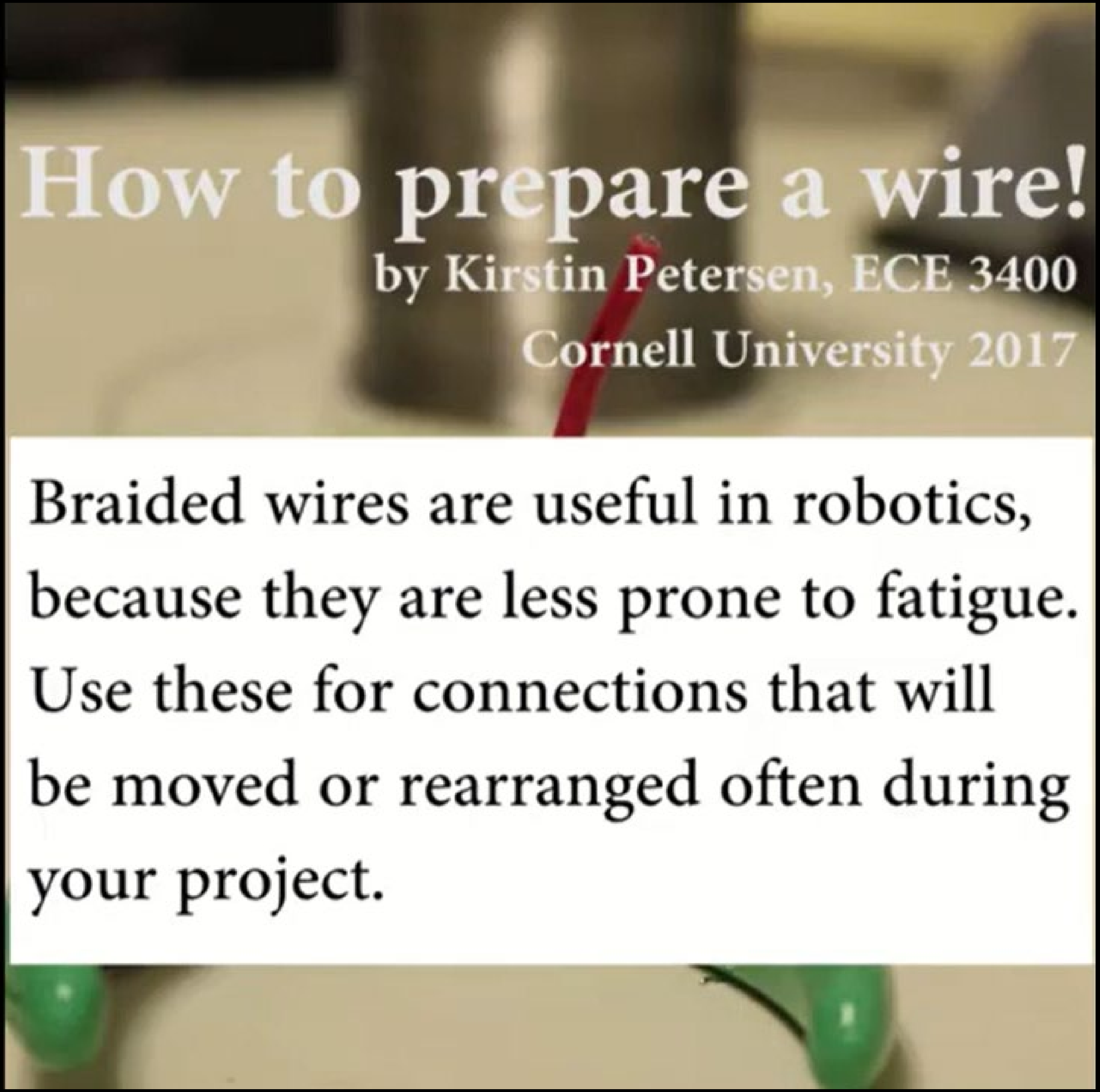
AWG gauge	Conductor Diameter Inches	Conductor Diameter mm	Conductor cross section in mm^2	Ohms per 1000 ft.	Ohms per km	Maximum amps for chassis wiring	Maximum amps for power transmission
0000	0.46	11.684	107	0.049	0.16072	380	302
000	0.4096	10.40384	84.9	0.0618	0.202704	328	239
00	0.3648	9.26592	67.4	0.0779	0.255512	283	190
0	0.3249	8.25246	53.5	0.0983	0.322424	245	150
1	0.2893	7.34822	42.4	0.1239	0.406392	211	119
2	0.2576	6.54304	33.6	0.1563	0.512664	181	94
3	0.2294	5.82676	26.7	0.197	0.64616	158	75
4	0.2043	5.18922	21.1	0.2485	0.81508	135	60
5	0.1819	4.62026	16.8	0.3133	1.027624	118	47
6	0.162	4.1148	13.3	0.3951	1.295928	101	37
7	0.1443	3.66522	10.6	0.4982	1.634096	89	30
8	0.1285	3.2639	8.37	0.6282	2.060496	73	24
9	0.1144	2.90576	6.63	0.7921	2.598088	64	19
10	0.1019	2.58826	5.26	0.9989	3.276392	55	15
11	0.0907	2.30378	4.17	1.26	4.1328	47	12
12	0.0808	2.05232	3.31	1.588	5.20864	41	9.3
13	0.072	1.8288	2.63	2.003	6.56984	35	7.4
14	0.0641	1.62814	2.08	2.525	8.282	32	5.9
15	0.0571	1.45034	1.65	3.184	10.44352	28	4.7
16	0.0508	1.29032	1.31	4.016	13.17248	22	3.7
17	0.0453	1.15062	1.04	5.064	16.60992	19	2.9
18	0.0403	1.02362	0.823	6.385	20.9428	16	2.3
19	0.0359	0.91186	0.653	8.051	26.40728	14	1.8
20	0.032	0.8128	0.519	10.15	33.292	11	1.5
21	0.0285	0.7239	0.412	12.8	41.984	9	1.2
22	0.0253	0.64516	0.327	16.14	52.9392	7	0.92

https://www.powerstream.com/Wire_Size.htm

Connection Points

- Solder permanent connection points
- Minimize connection points
    - BUT use for modularity

- Connectors
    - Signal transfer
    - Power transfer

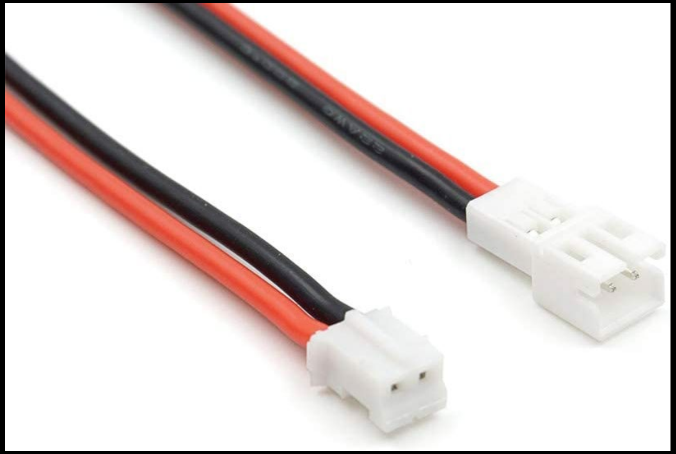


Connection Points

- Solder permanent connection points
- Minimize connection points
    - BUT use for modularity

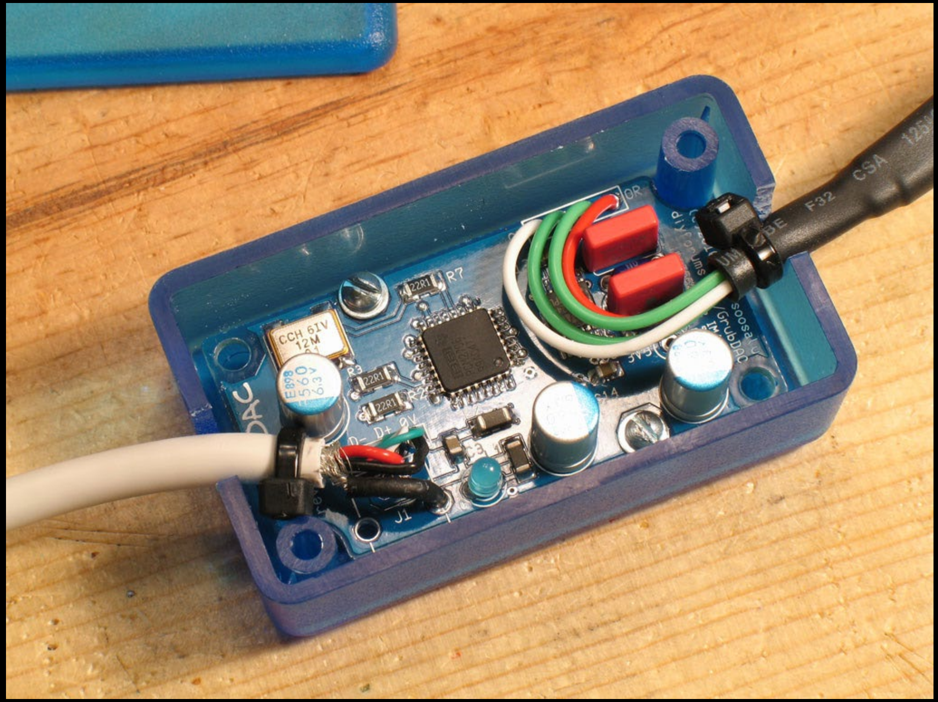
- Connectors
    - Signal transfer
    - Power transfer
    - Female: hot side
    - Male: Receiver
    - Reversible

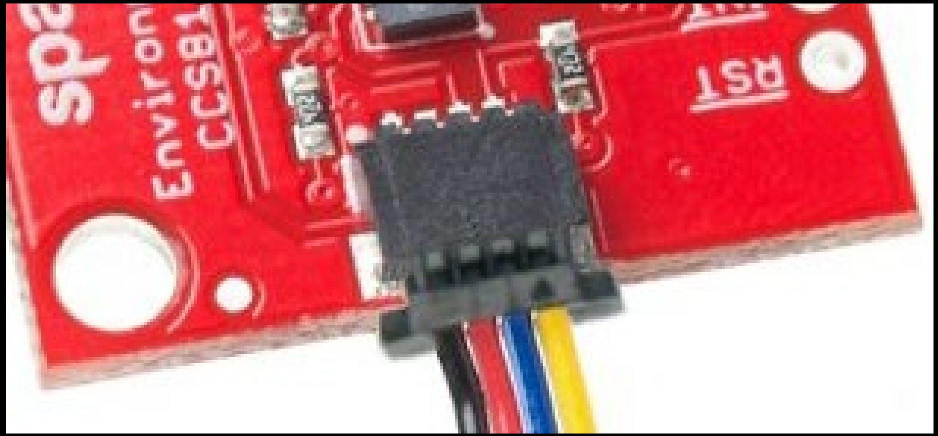
    - General
    - Protocol


Good practices

- Use color convention
  - Red/Black: Vcc/Gnd
  - Purple: V+ (raw power or battery voltage)
  - Green/white/yellow/orange: signal wires
- Fastening
  - Fasten wires on permanent components
  - Avoid pinch points
  - Service loops
  - Strain relief
  - Hot glue
    - Good for semi-permanent connections
    - Becomes brittle over time
- Heat shrink
  - Electrical tape ages and leaves residue



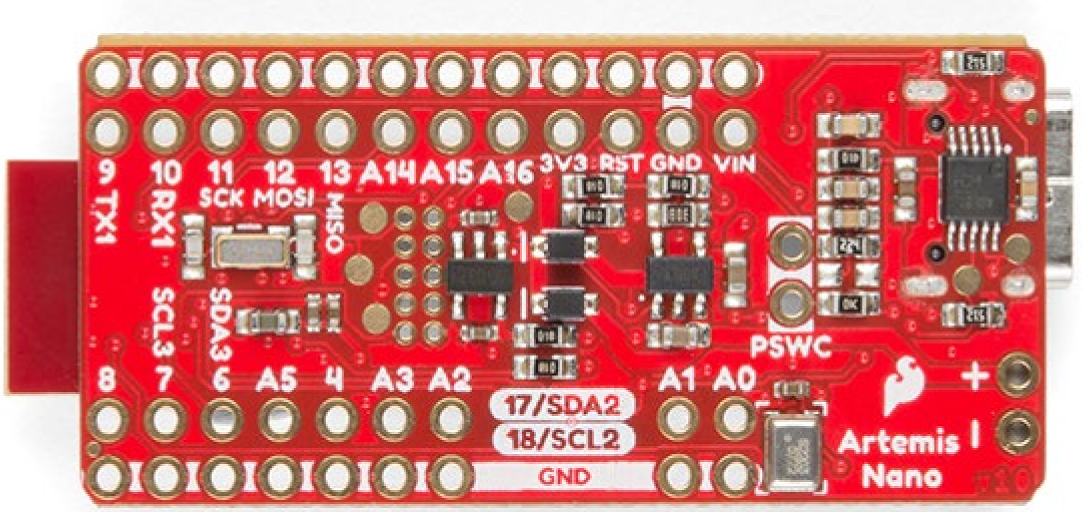


Lab 3: Sensors

- Connect to TOF sensors and IMU
- Understand and process data
- Things to consider…
    - Color coding
    - Permanent solder joints / Detachable connections?
    - Single core or braided wires?
    - Routing of TOF sensors, IMU, Artemis, battery
    - Routing for motor drivers and battery for the motors
    - How will you deal with two TOF sensors on one I2C line?
    - Mechanical mounting components (optional)

Lab 3: Sensors (pre-lab)

Draw the connection diagram that you intend to use



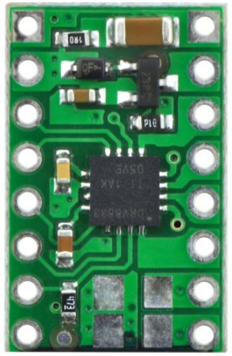
Sensors

VDD (2.8V out)
VIN (2.6–5.5V)
GND
SDA
SCL
XSHUT
GPIO1

VDD (2.8V out)
VIN (2.6–5.5V)
GND
SDA
SCL
XSHUT
GPIO1

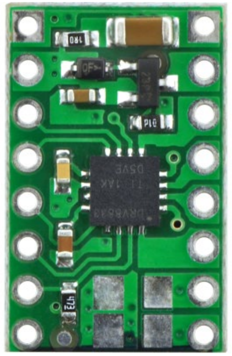
Motor drivers (optional until Lab 4)

GND, VMM, BIN1, BIN2, AIN2, AIN1, nSLEEP, nFAULT



GND, VIN, BOUT1, BOUT2, AOUT2, AOUT1, AISEN, BISEN

GND, VMM, BIN1, BIN2, AIN2, AIN1, nSLEEP, nFAULT

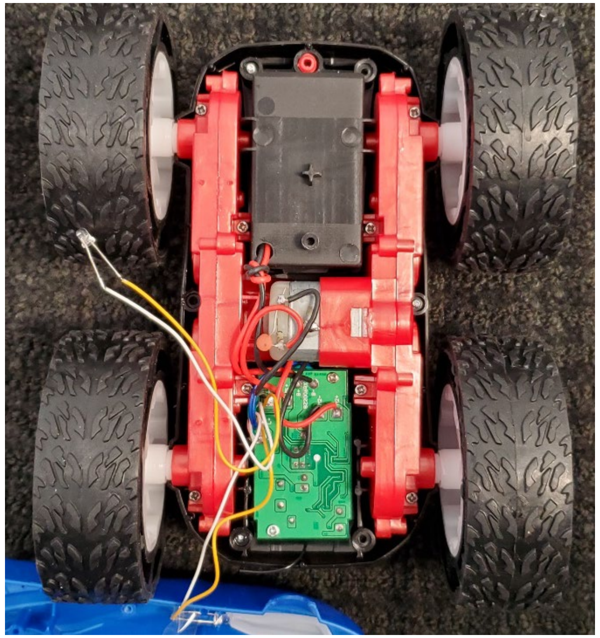


GND, VIN, BOUT1, BOUT2, AOUT2, AOUT1, AISEN, BISEN

Lab 3: Sensors (pre-lab)

Think about the placement of components and batteries



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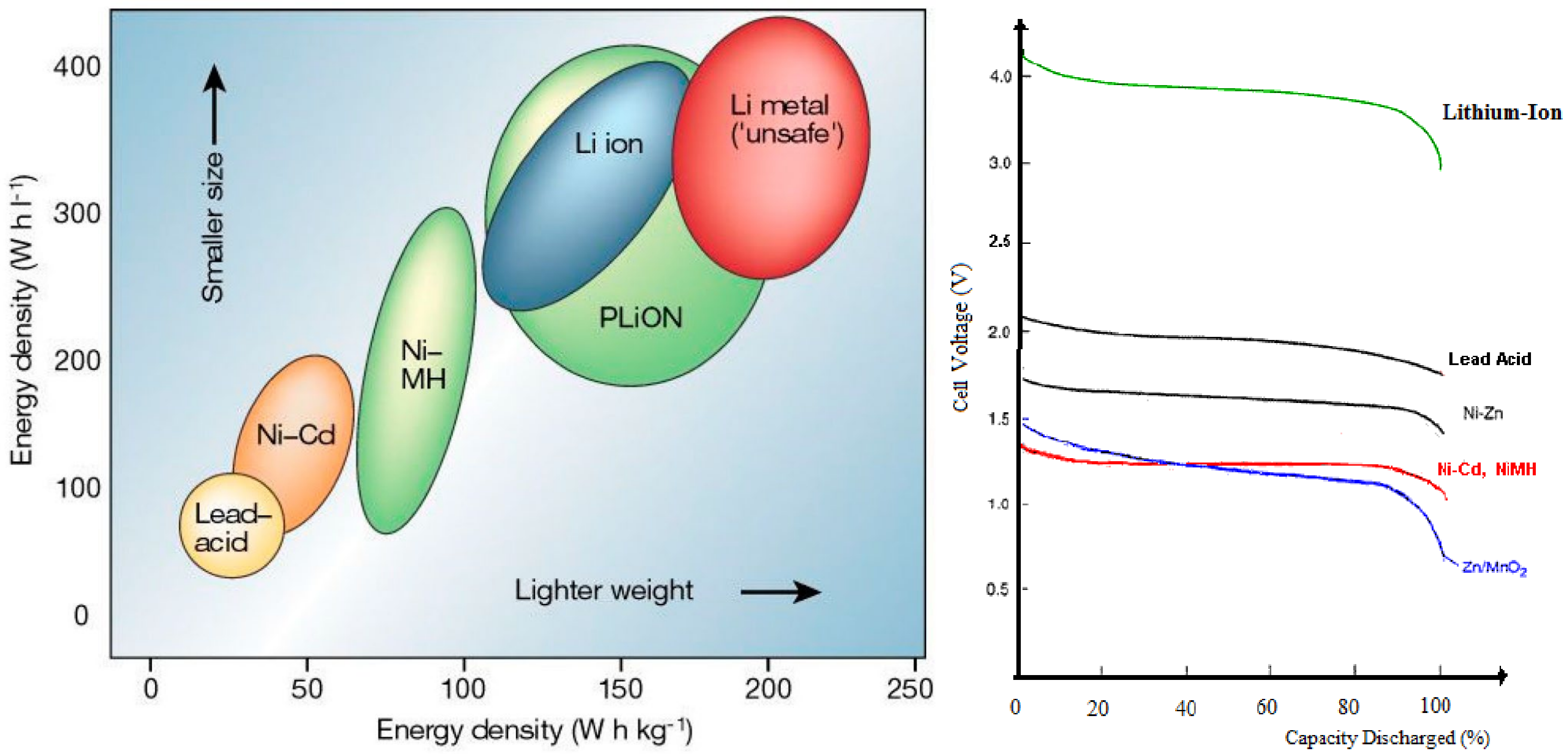
(Rechargeable) Batteries

https://batteryuniversity.com/article/whats-the-best-battery

Important properties

- Battery capacity
- Cell voltage
- Discharge curve
- Discharge rate (C)
- Charge rate
- Cycle times
- Aging
- Safety
- Form factor/weight
- Cost

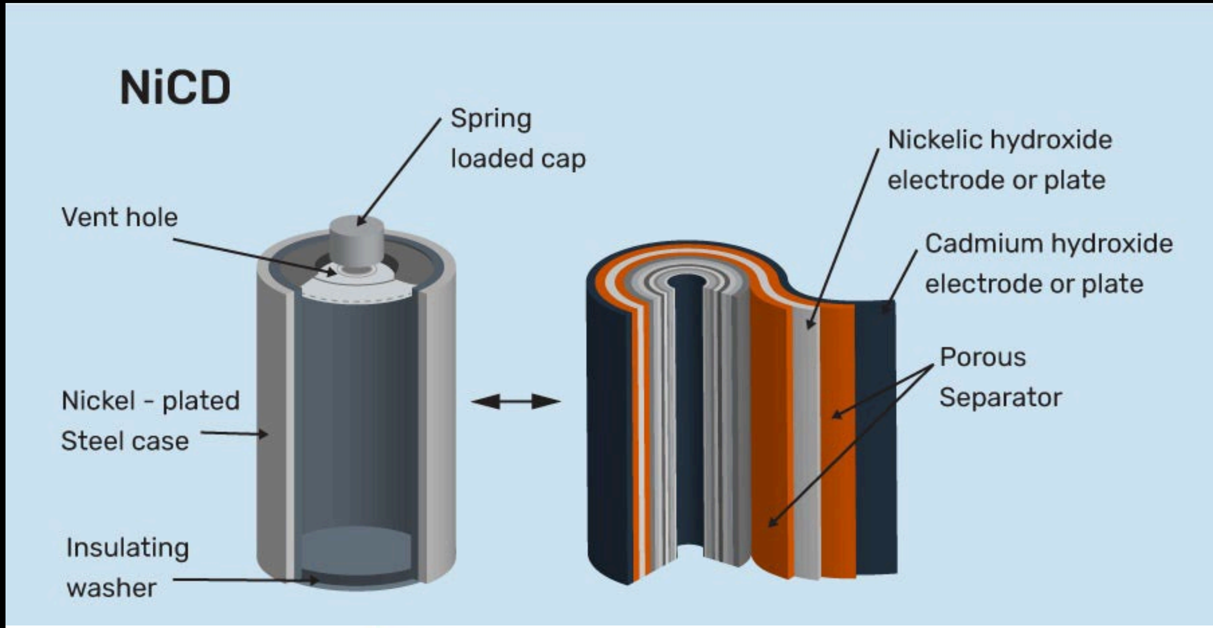
MDPI, Energies



https://batteryuniversity.com/article/whats-the-best-battery

Rechargeable Batteries

- Nickel Cadmium (NiCd)
  - Mature tech, affordable
  - Pretty low in energy density
  - High discharge rate
  - Long cycle life
  - Better in rigorous working conditions
  - Periodic full discharge/charge is critical
  - Contains toxic metals
- Nickel-Metal Hydride (NiMH)
  - Higher capacity than NiCd
  - Higher energy density
  - Higher discharge rate than NiCd
  - No toxic metals
  - Reduced cycle life
  - More expensive than NiCd
- Lead Acid (SLA)
  - Cheap
  - Large power applications
  - Low energy density



Rechargeable Batteries

- Lithium Ion (Li-Ion)
  - High energy density
  - Light weight
  - Low maintenance battery
  - Max discharge rate: 1-2C
  - High cell voltage (single cell batteries)
  - Low self-discharge
  - Protection circuits for charge/discharge
  - Aging
- Lithium Polymer (Li-Po)
  - Light weight
  - Free form-factor
  - More robust
  - Max discharge rate: 3-60C
  - Lower energy density than Li-Ion
  - Cost more than Li-Ion