

Electrical engineering Basics

ETIA06
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Energy

- Energy is measured in Joules [J]
- Not possible to generate or destroy

- Usually ends up as heat.

- Electricity:
 - From wallplug
 - Stored in batteries

Energy densities

- Li-Ion battery 0.4-0.9 MJ/kg
- NiMH battery 0.2-0.9 MJ/kg
- Lead-Acid battery 0.6 MJ/kg
- Alkaline battery 0.4-0.5 MJ/kg

- TNT 4.6 MJ/kg

- Gasoline 46.4 MJ/kg

More on energy

- Energy to boil 1 liter of water
 - 10 degrees to 100 degrees = $90 \times 4200 \times 1 = 378 \text{ kJ}$
 - Using NiMH cells: $0.378 \text{ MJ} / 0.5 \text{ MJ/kg} = 756 \text{ g}$
 - Using propane: $0.378 \text{ MJ} / 13.8 \text{ MJ / kg} = 27 \text{ g}$
- This is why camping stoves are still using propane/buthane.

Power

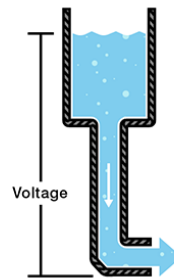
- Power = energy per time [J/s]
- Measured in Watts [W]=[J/s]
- In electricity:
 - Power = Current x Voltage
 - [W]=[A] x [V]

Current

- “Number of electrons that passes a point in a conductor per second.”
- 1 A = 6.242×10^{18} electron per second.
 - The same as 1 Columb per second.
- Generates a magnetic field
- Generates heat in a loss

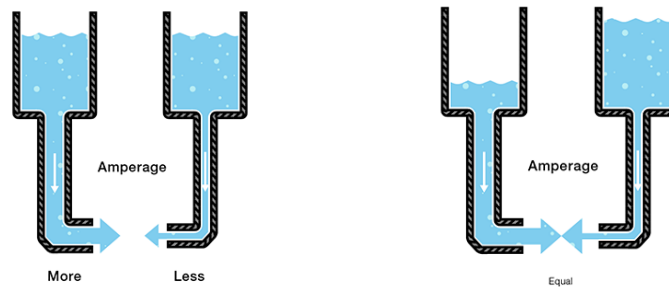
Voltage

- Voltage is the “pressure” of electrons coming from the power source.
- Water analog:
 - Voltage is the pressure.



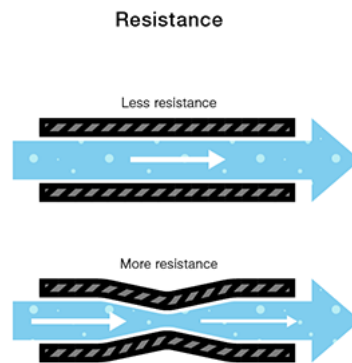
Water analog

- Current is the flow



Water analog

- Flow restrictions are resistance



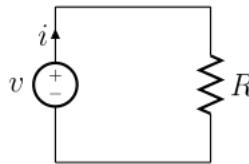
<https://learn.sparkfun.com/tutorials/voltage-current-resistance-and-ohms-law/electricity-basics>

Ohm's law

- Voltage = current x resistance
- $[V] = [A] \times [Ohm]$

Internal resistance

- A battery has an internal resistance
 - NiMH 0.02 Ohm
 - Alkaline 1-2 Ohm
 - Lead-Acid 0.003-0.005 Ohm



<http://www.learningaboutelectronics.com/Articles/Battery-internal-resistance>

Back to energy

- Batteries
 - Measured in mAh = milli-Ampere-Hours
 - But: [A]x[s] not equal to [J]
 - [A]x[V]x[s] = [W]x[s] = [J]
- Energy given on a battery in mAh is assuming the voltage of the battery!
- A 12 V battery of 5000 mAh has 8 times the energy of a 1.5 V battery of 5000 mAh!



Power from wall-plug

- In Europe: 230 V
- Typically fused to 10A
 - Maximum power from an outlet 2300 W
 - Plug supports 16A x 230 V = 4160 W
- In North Americas: 110 V
- If we want the same power: $2300 / 110 = 21$ A
 - Twice as large area of cables to keep losses the same!
 - Typically plug is rated to 15 A.
 - Maximum power is 1650 W



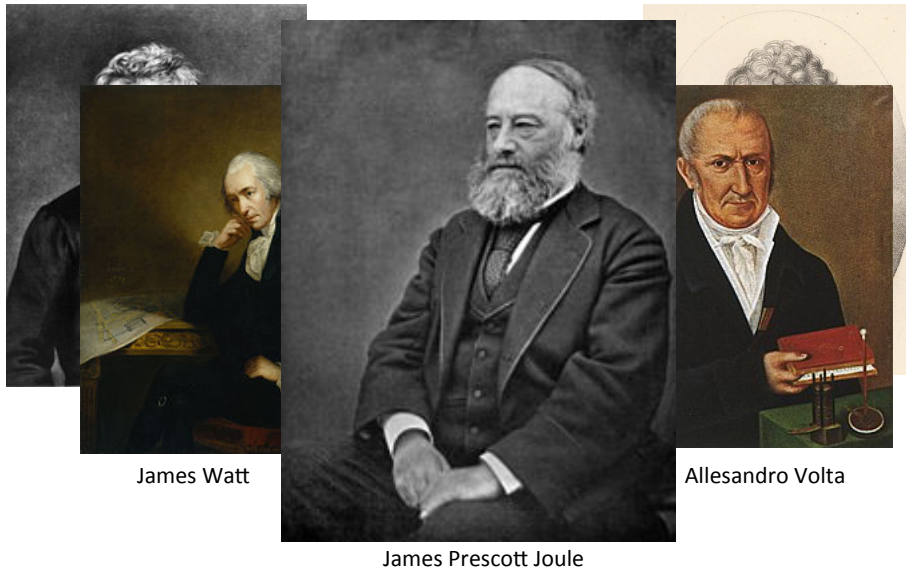
- Flat plug
 - Rated to 2.5 A
 - Maximum power $2.5 \times 230 = 575$ W



Water-Heater

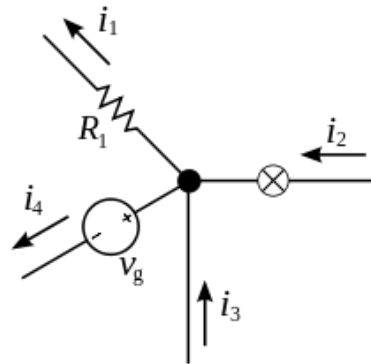
- My old summer house
 - 6A fuses
 - 230V from grid
- New water heater
 - 2200W
- Fuse breaks...
- Why?
- Solution?

Kirchoff's laws



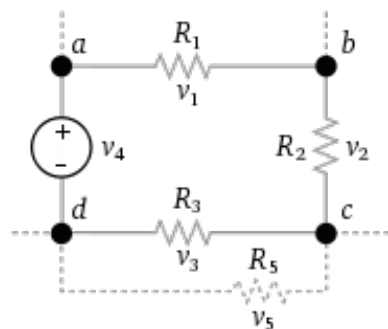
Current law

- Sum of all currents in a connection is zero.

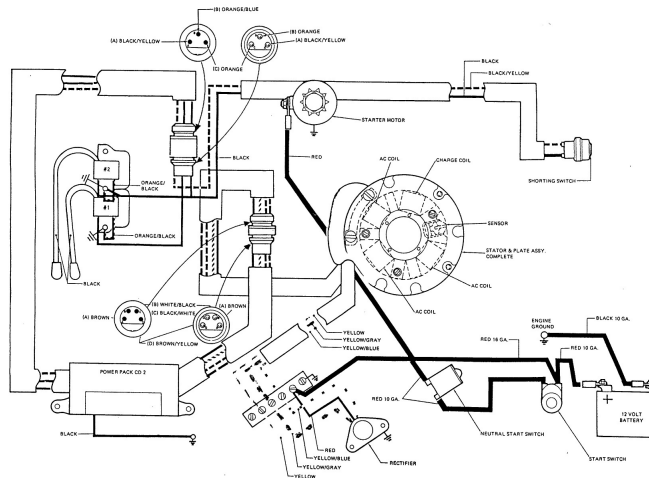


Voltage law

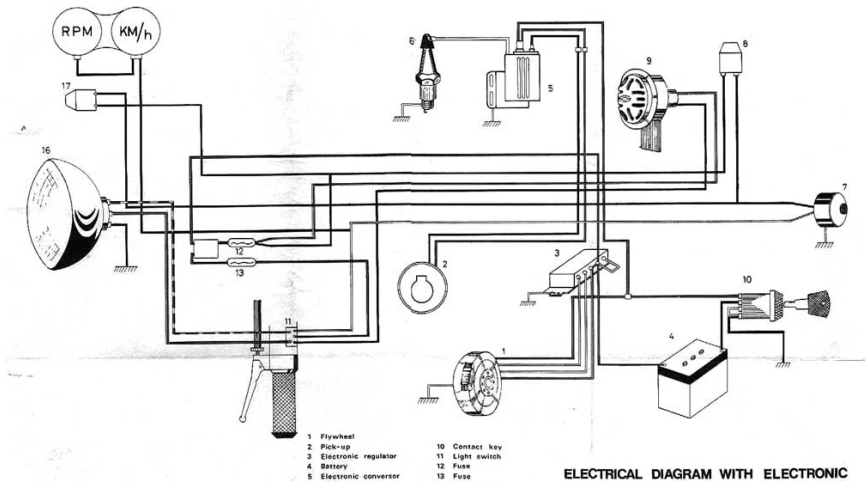
- Sum of all voltages in a loop is zero.



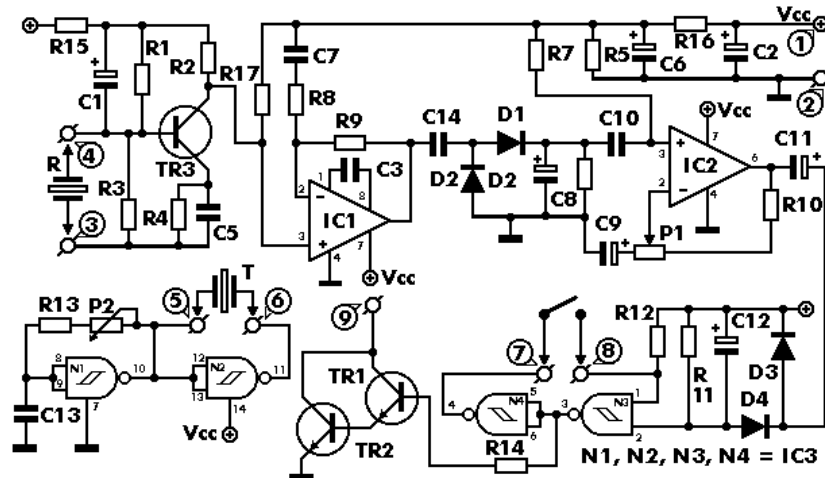
Wiring diagram



Wiring diagram



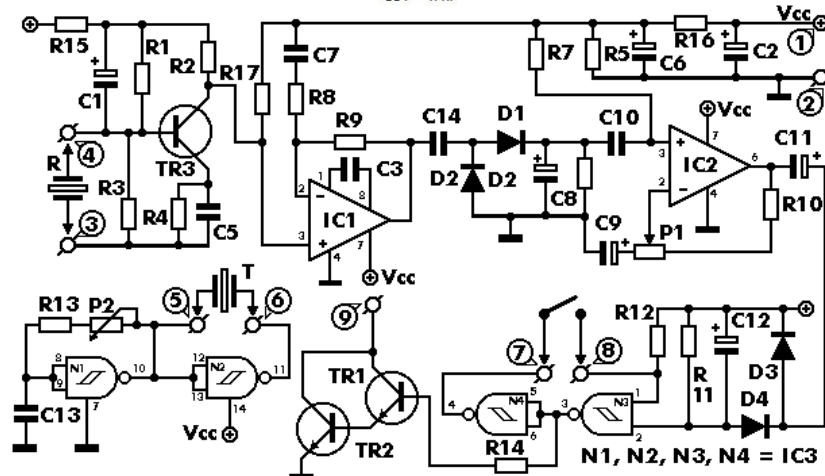
Circuit Diagram



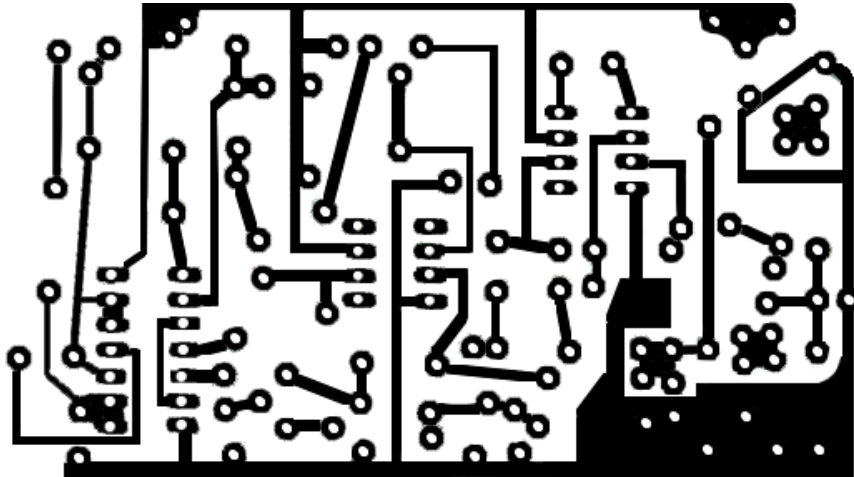
R1 = 180 KOhm
 R2 = 12 KOhm
 R3, 8 = 47 KOhm
 R4 = 3,9 KOhm
 R5, 6, 16 = 10 KOhm
 R7, 10, 12, 14, 17 = 100 KΩ
 R9, 11 = 1 MOhm
 R13, 15 = 3,3 KOhm

C1, 6 = 10uF/16V
 C2 = 47uF/16V
 C3 = 4,7 pF
 C4, 7 = 1 nF
 C5 = 10nF
 C8, 11 = 4,7 uF/16V
 C9 = 22uF/16V
 C10 = 100 nF
 C12 = 2,2 uF/16V
 C13 = 3,3nF
 C14 = 47nF

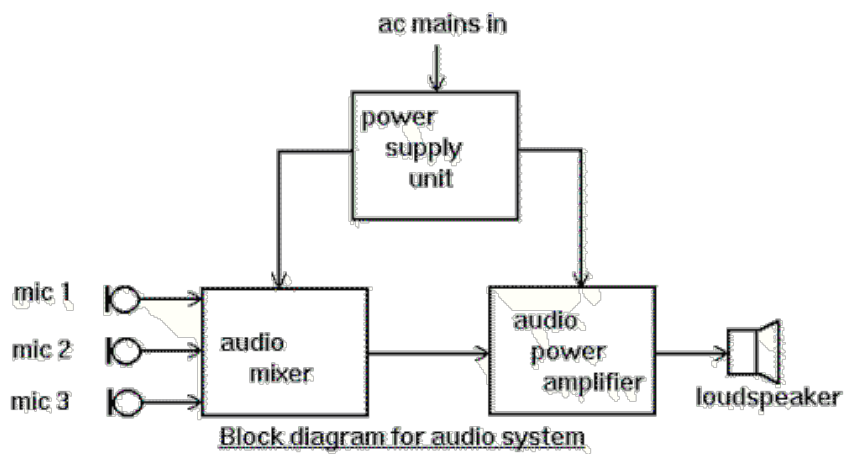
TR1, 2, 3 = BC547, BC548
 P1 = 10 KOhm trimmer
 P2 = 47 KOhm trimmer
 IC1, 2 = 741 OP-AMP
 IC3 = 4093 C-MOS
 R = TRANSDUCER 40KHz
 T = TRANSDUCER 40KHz
 D1, 2, 3, 4 = 1N4148



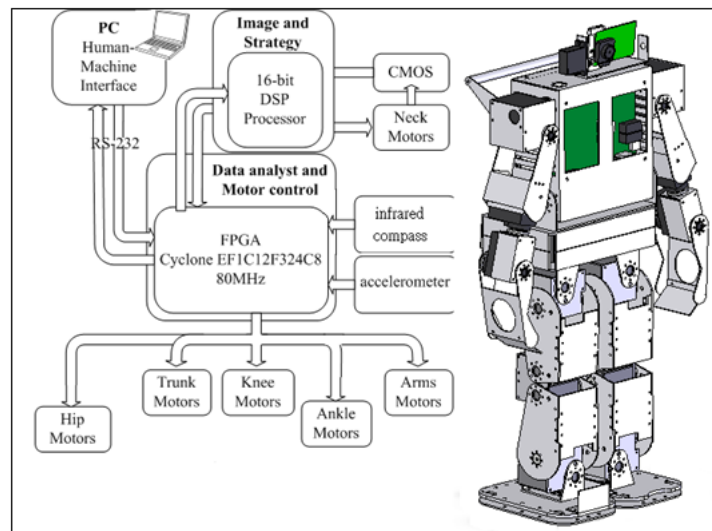
PCB : Printed Circuit Board



Block diagram



Block diagram



Fritzing Demo

Summary

- Energy: Joule
Energy = Power x time
- Power : Watt, or Joule / second
Power = current x Voltage
- Voltage : Volt
- Current: Ampere
- Resistance: Ohm
Voltage = Current x Resistance

Diagrams

- Block diagram
 - Uses squares, show large scale picture of function
- Circuit diagram
 - Uses standardised symbols, shows how to build.
- PCB, wiring diagram
 - Shows how to assemble.