



Winston Qin

Locomotives Lead

Electrical
Engineering
Workshop

Content:



**1. Basic Electrical Engineering
Concepts**

2. Electrical Safety

**3. Electronics Design
(Arduinos, MCUs, PCBs)**

4. Railway electrical systems

**5. Locomotives electrical
systems**

6. Motor Control

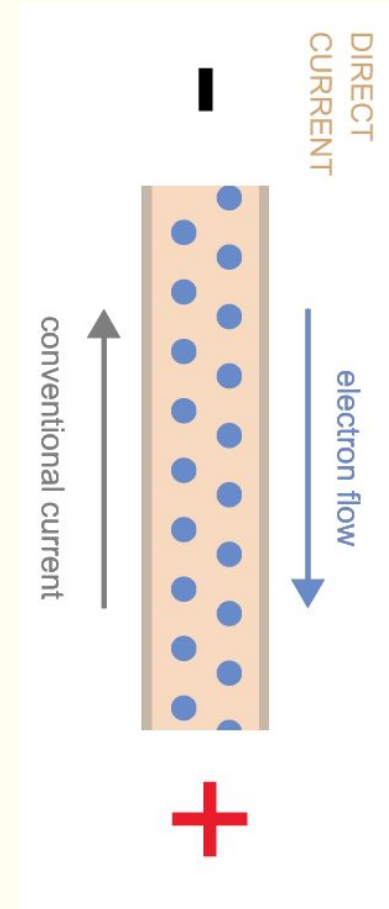


1. Basic Electrical Engineering Concepts



What is electricity?

- Electricity is a form of energy resulting from the flow (current) of charged particles (electrons)
- Electricity can be used to do *work*, such as turn on lights and move a locomotives



Fundamentals: Voltage



- Voltage: Electrical “pressure” or potential difference
- ~strength of the buildup of charge, ex. a battery
- Units: [v] = volts
- Symbol: V

Fundamentals: Current



- Current: Flow of electrons through a point/wire/etc
- Units: [A] = Amperes
- Symbol: i

Fundamentals: Power



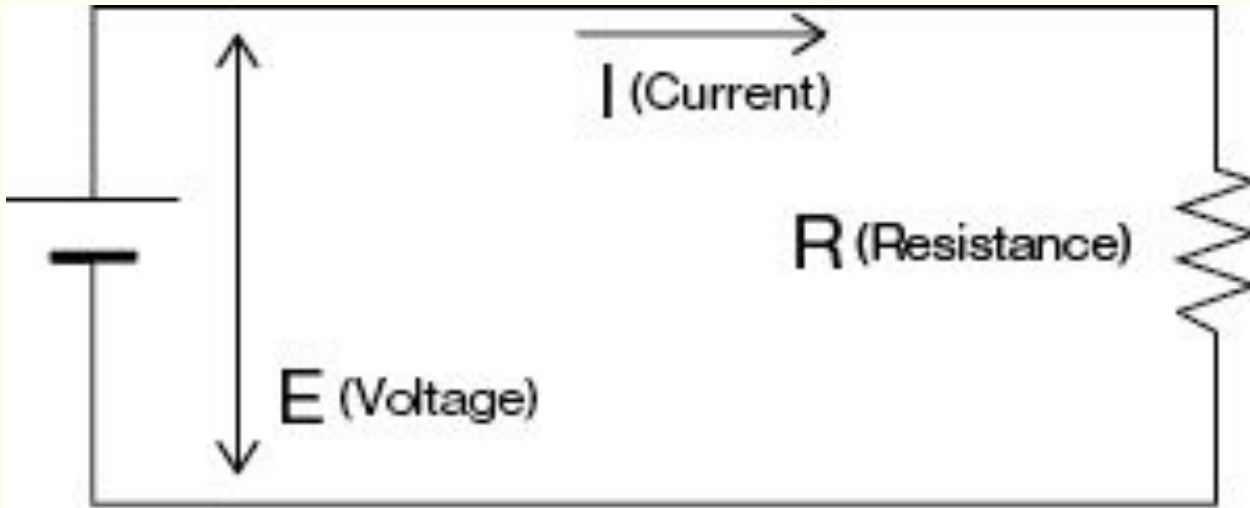
- Power: instantaneous measure of rate of electrical energy production/consumption
- Units: [w] = Watts
- Symbol: P
- Instantaneous $P = V * I$

Fundamentals: Resistance



- Resistance: measure of resistance to flow of current through an element
- Units: $[\Omega]$ = ohms
- Symbol: R
- Through a resistive element,
 $V = I \cdot R$
- Path of least resistance”

Fundamentals: Circuit

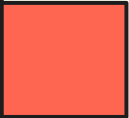


Ohm's law

$$\text{Voltage} = \text{Current} \times \text{Resistance}$$

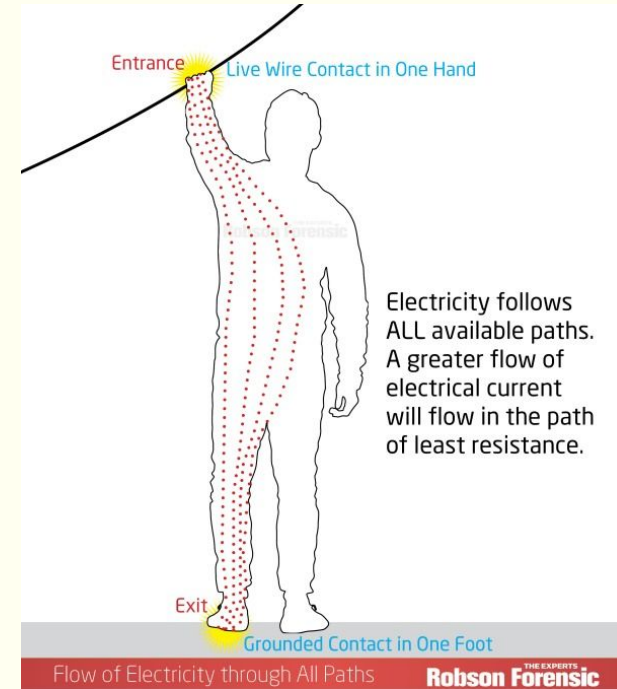


2. Electrical Safety



Is electricity dangerous?

- Not necessarily!
- Safety is usually a function of voltage
- 120Vdc is a moderately liberal upper threshold
- 20mA is enough to cause cardiac arrest



How do I stay safe?

- Inspect elements of a circuit carefully—**particularly** around batteries and capacitors
- Make sure any conductors you touch are not at a high potential!
- Locomotives battery is safe: 72V
FSAE EV battery is not nearly as safe (450V!)



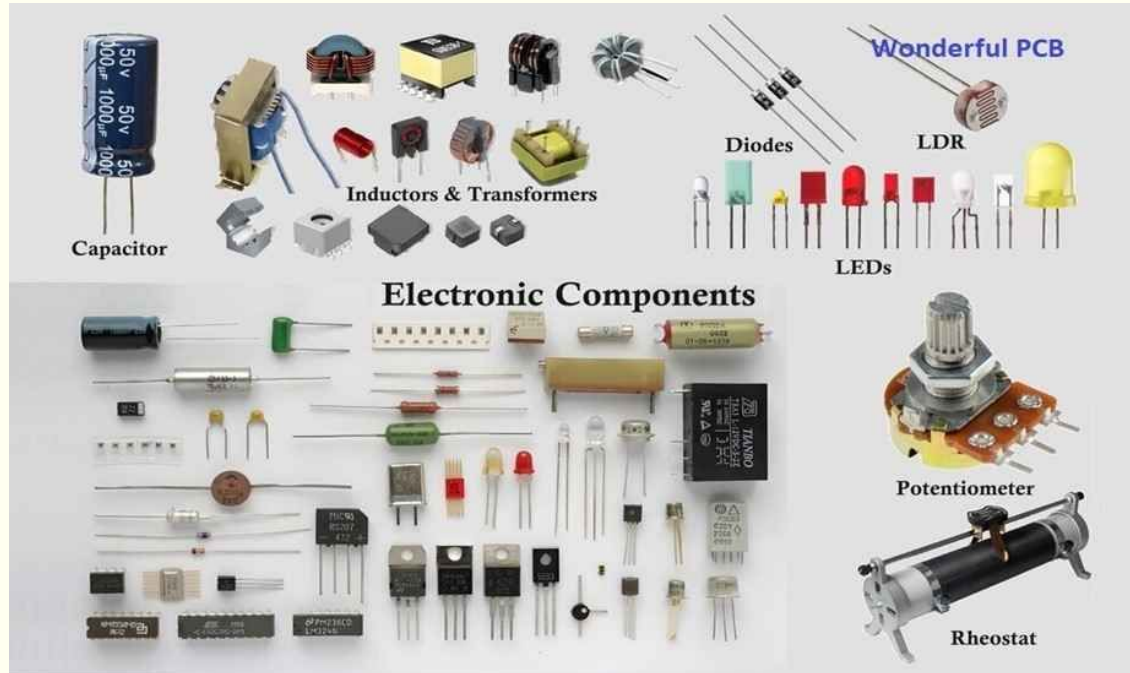


3. Electronics Design (Arduinos, MCUs, PCBs)

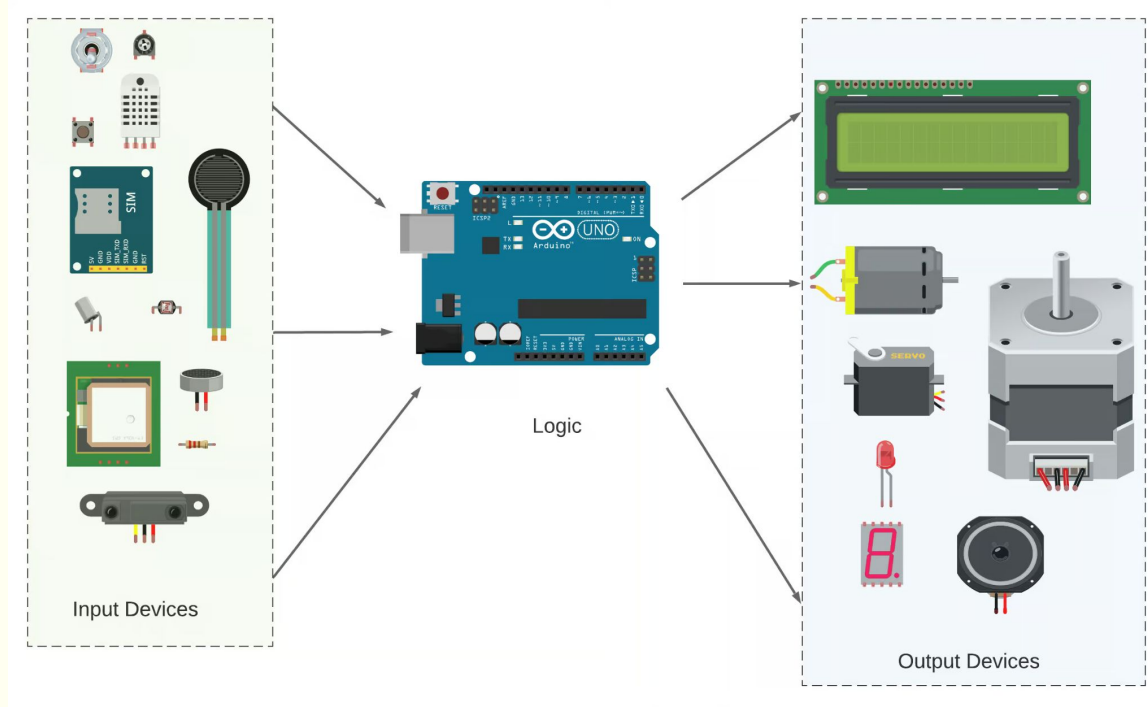
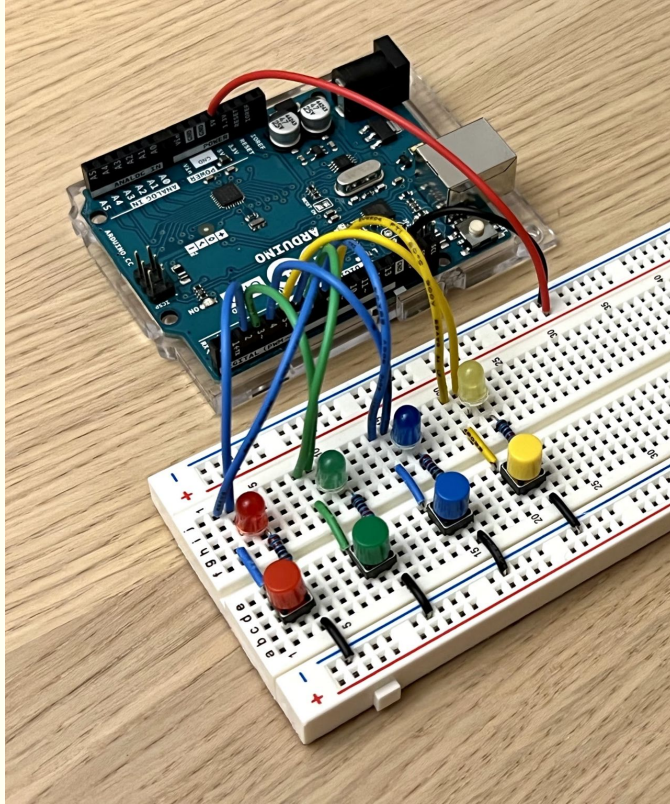


What is *electronics*?

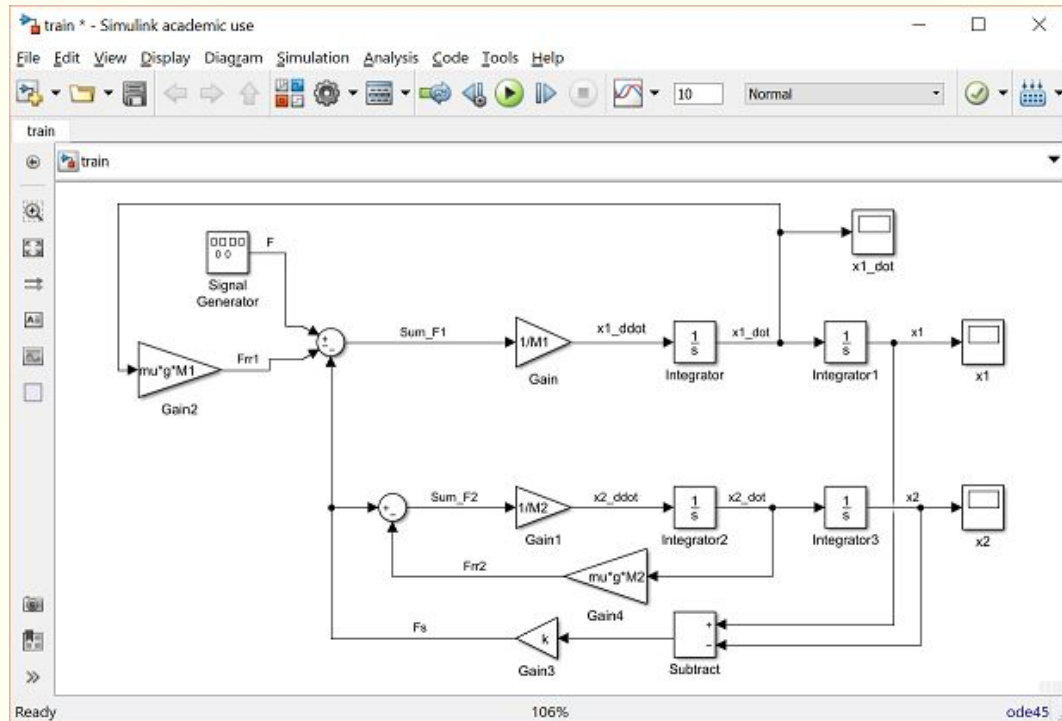
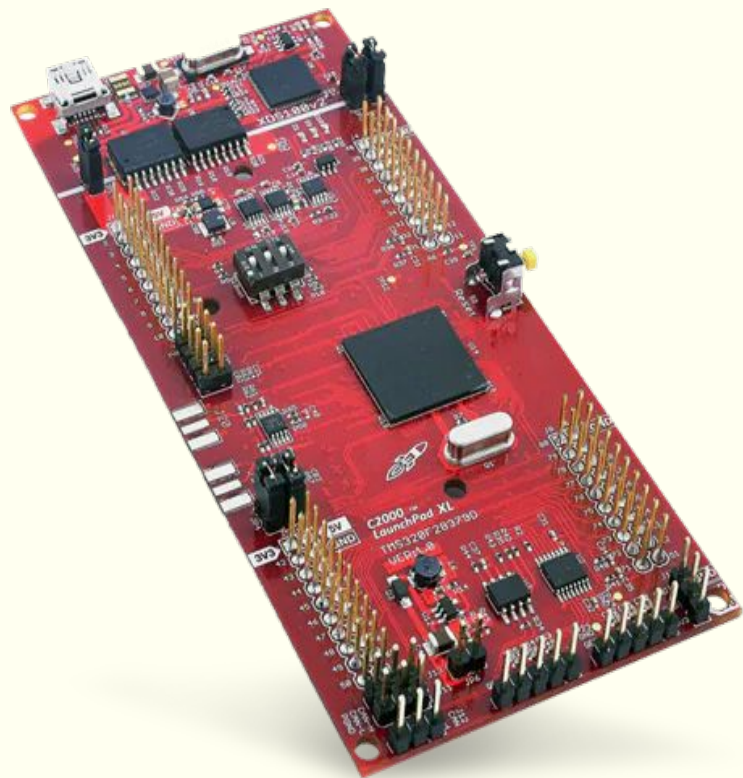
“The branch of physics and technology concerned with the design of circuits using transistors and microchips, and with the behavior and movement of electrons in a semiconductor, conductor, vacuum, or gas.”



Arduino

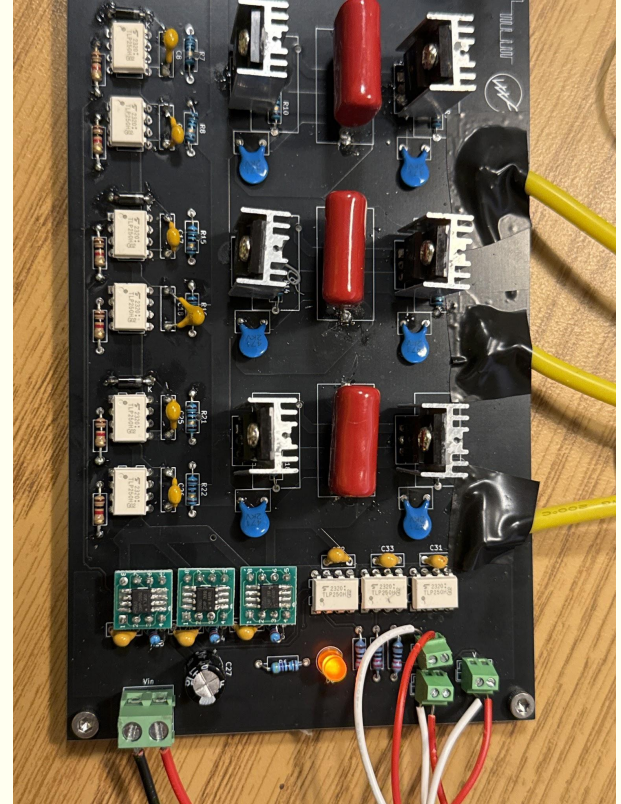
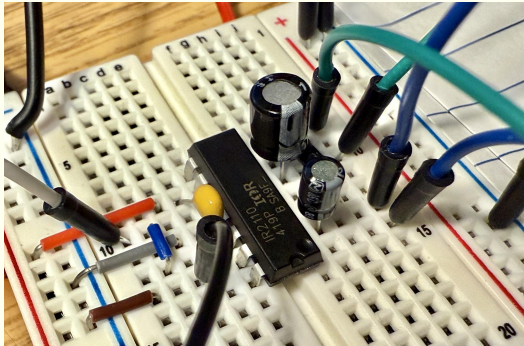
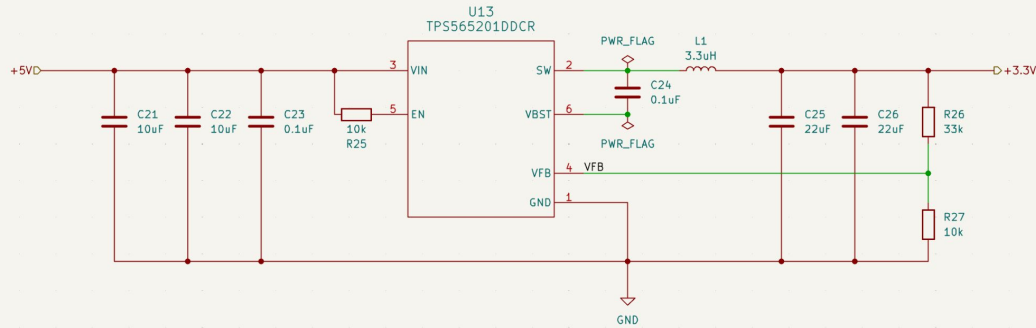


C2000

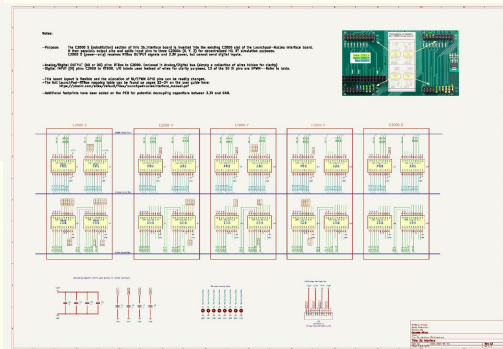
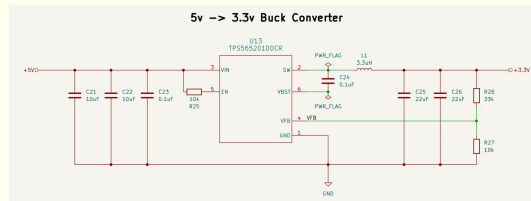
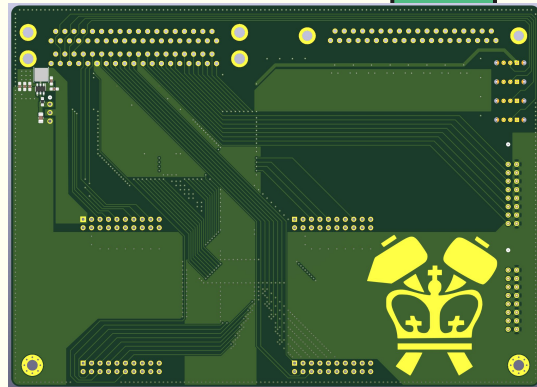
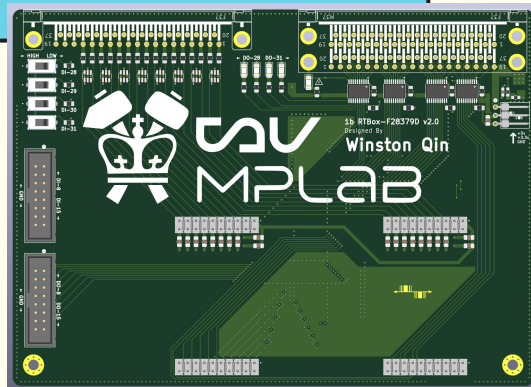
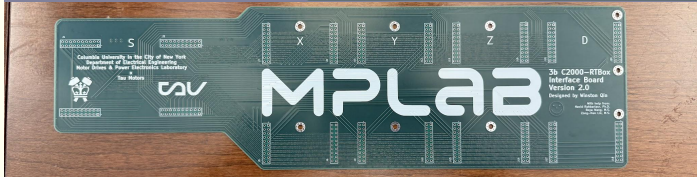
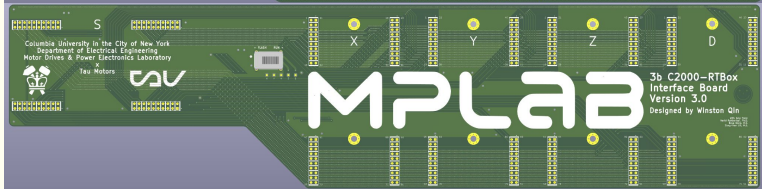
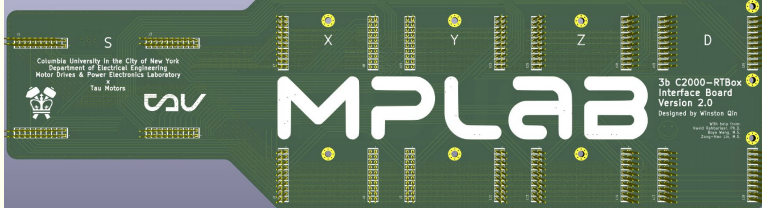
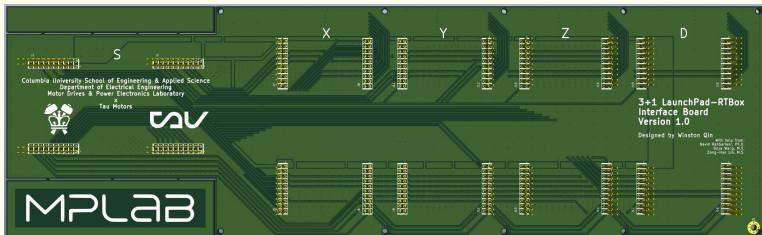


PCBs

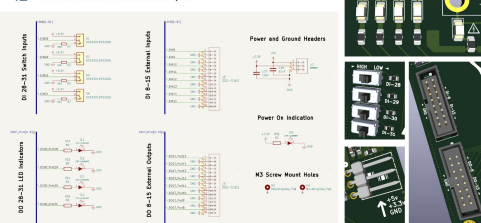
5v → 3.3v Buck Converter



PCBs



42 Schematic: Surface I/O

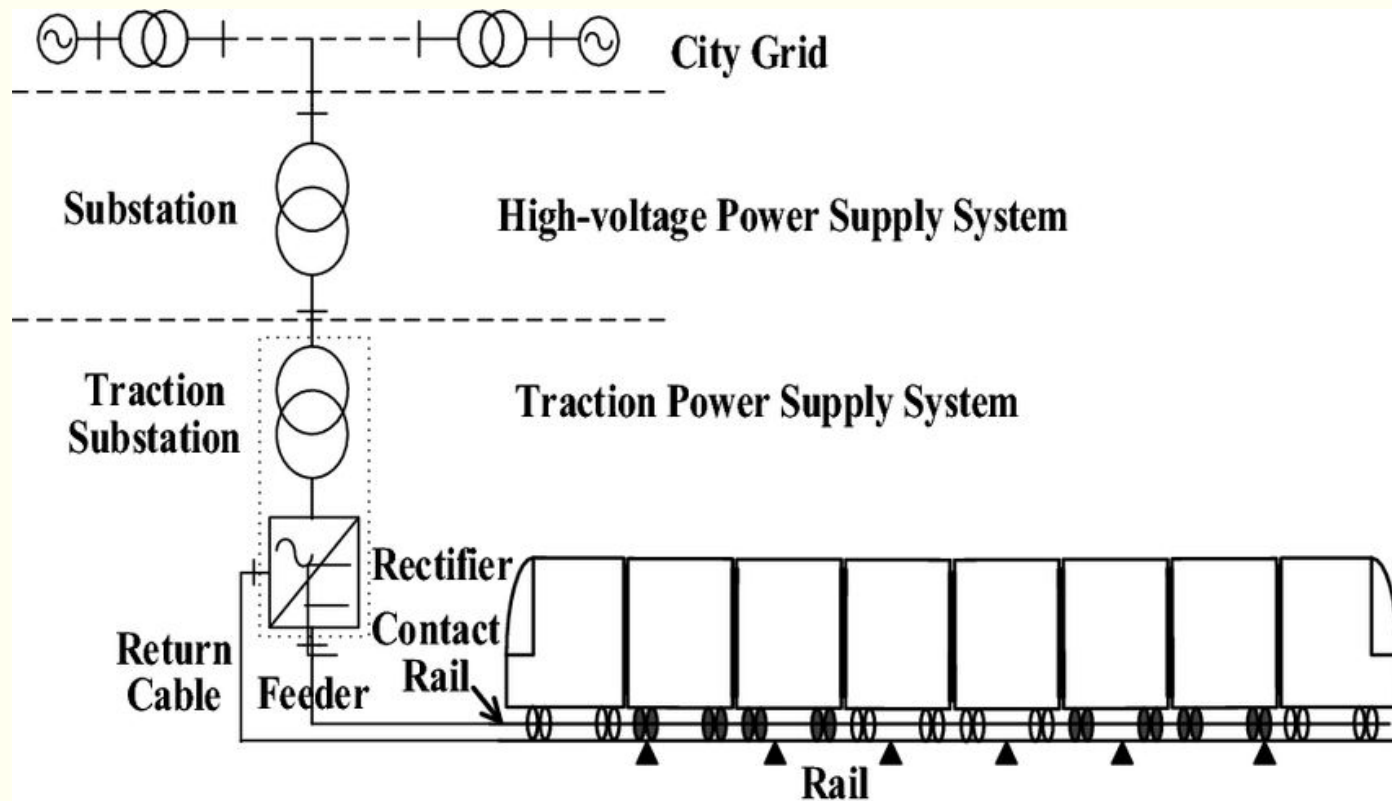




4. Railway Electrical Systems



Overview



The Grid

Color Key:

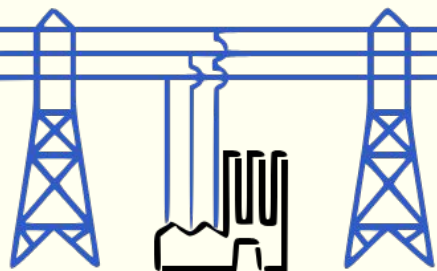
Red: Generation
Blue: Transmission
Green: Distribution
Black: Customer

Generating Station



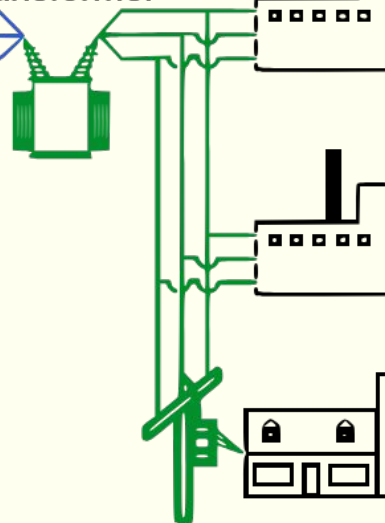
Generating
Step Up
Transformer

Transmission lines
765, 500, 345, 230, and 138 kV



Transmission Customer
138 kV or 230 kV

Substation
Step Down
Transformer



Subtransmission
Customer
26 kV and 69 kV

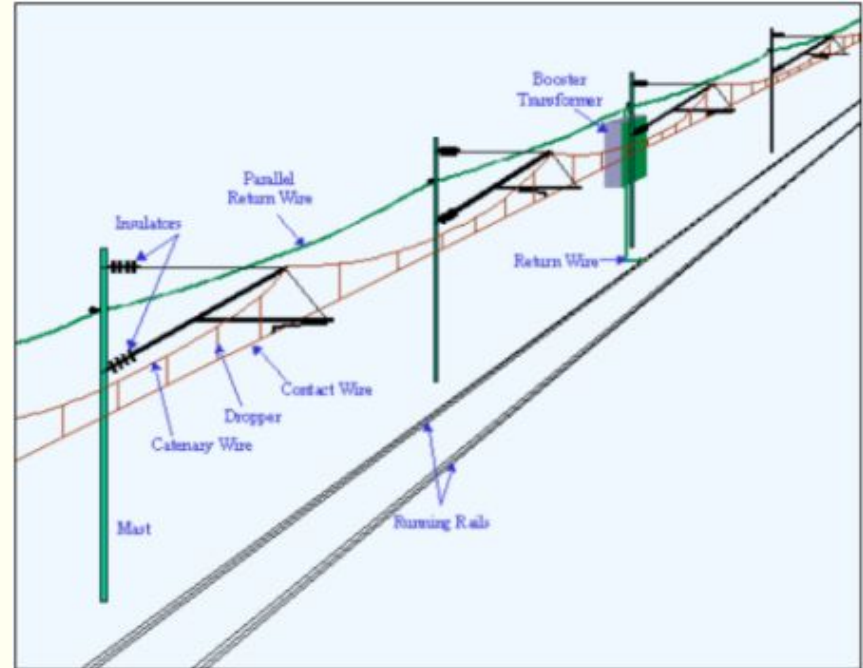
Primary Customer
13 kV and 4 kV

Secondary Customer
120 V and 240 V

Substations



Catenary

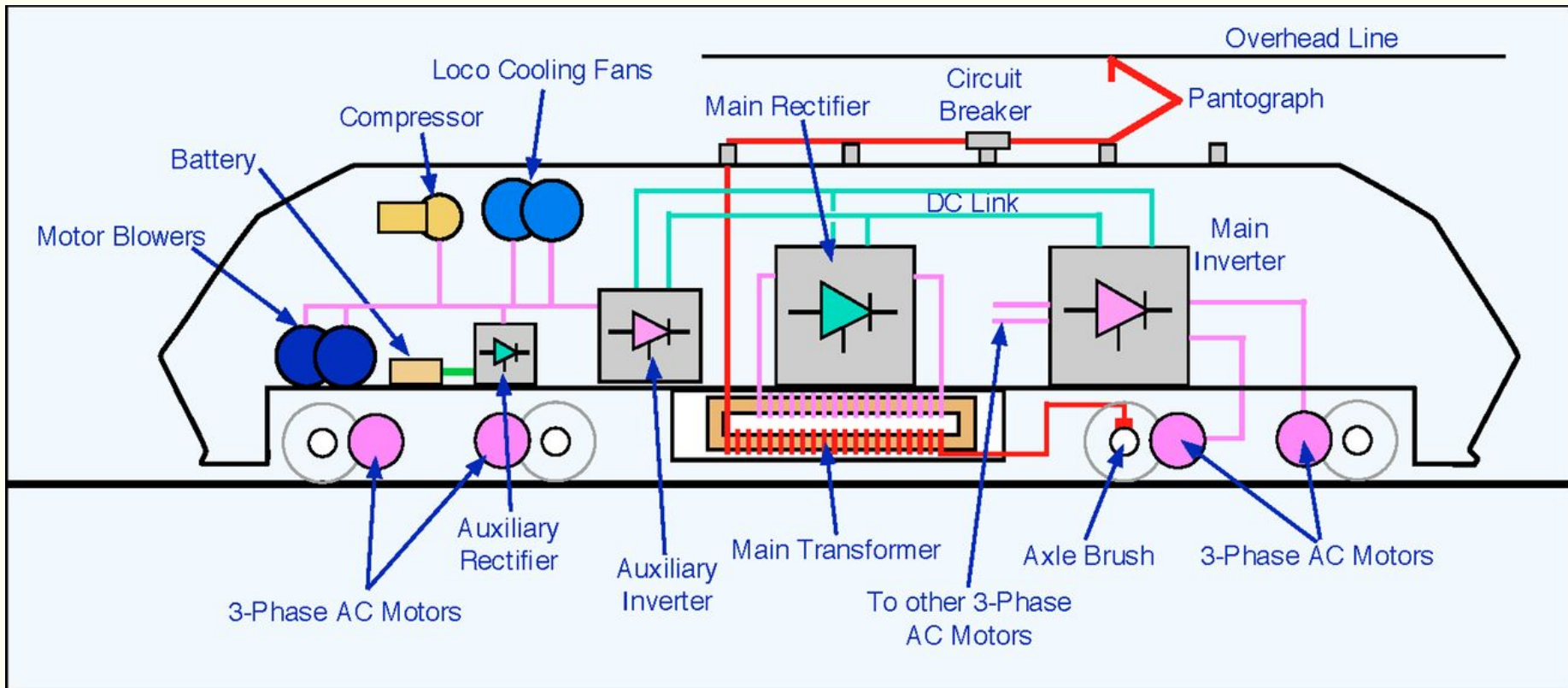




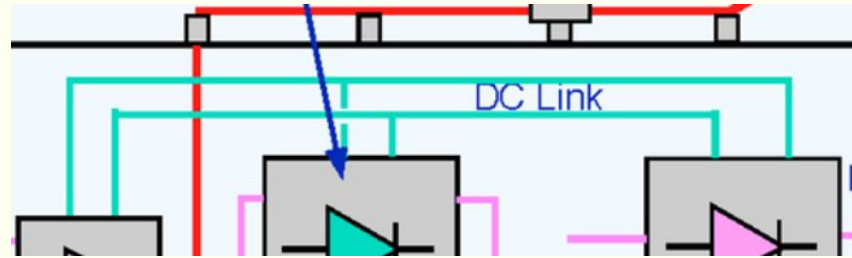
5. Locomotives Electrical Systems



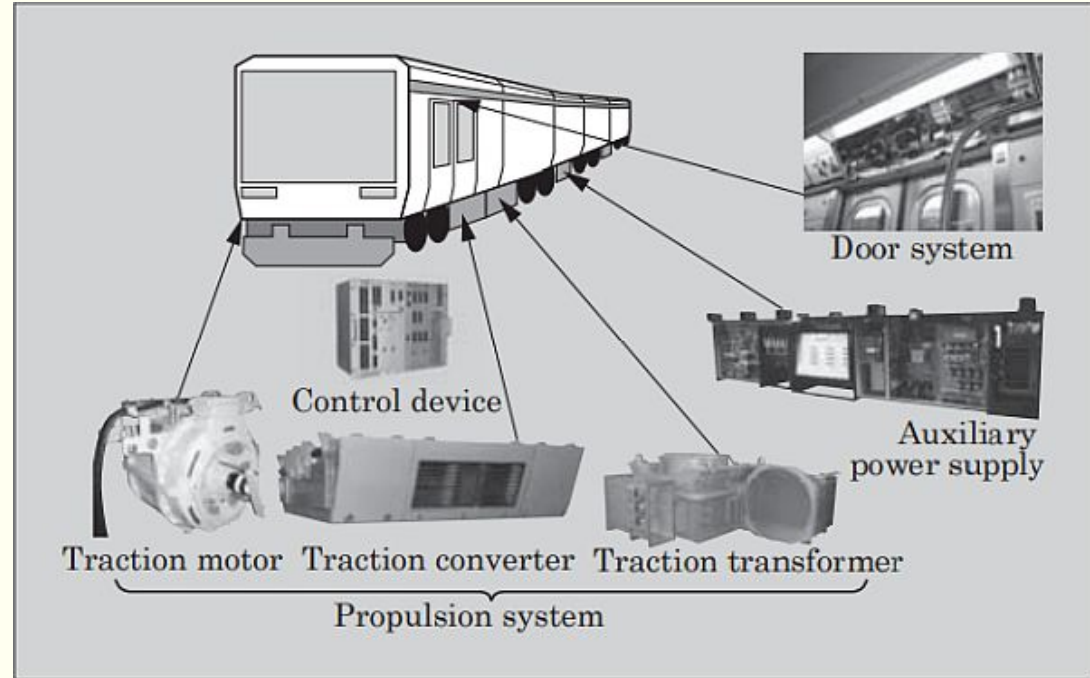
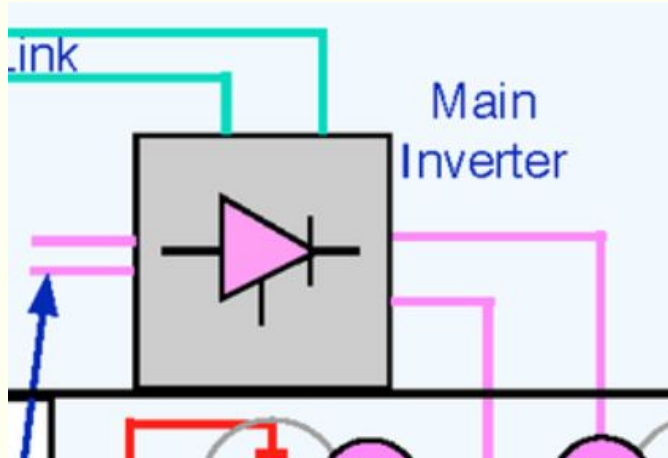
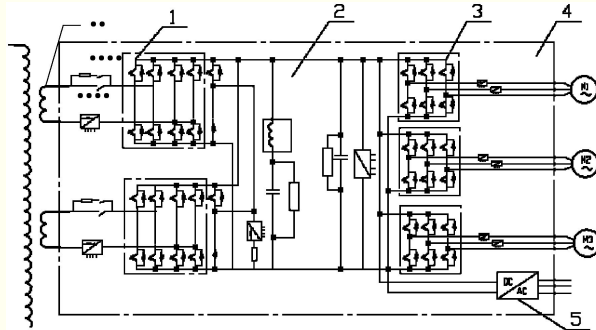
Overview



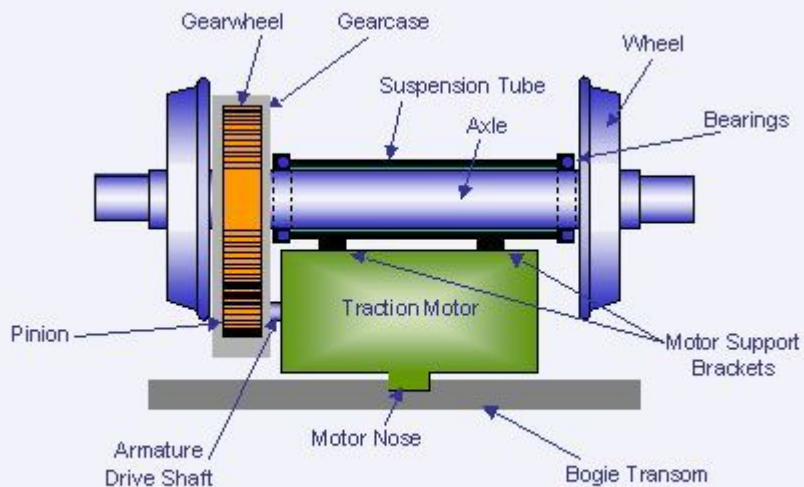
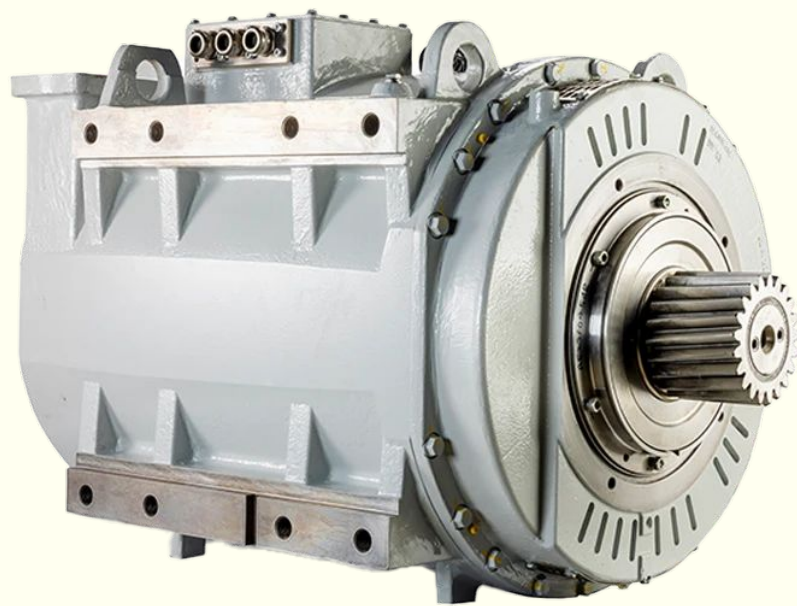
DC Link



Inverter (Controller)



Motor





6. Motor Control



Overview

