BATTERIES AND WIRING

Winter Workshop

Students' Technical Activities Body

(STAB)

- A battery is a device that converts chemical energy into electrical energy

Battery Basics

- Cells, modules and packs
- Battery Classification
- C- and E- rates
  - A 1C rate means that the discharge current will discharge the entire battery in 1 hour.
  - A 1E rate is the discharge power to discharge the entire battery in 1 hour.

Rechargeable?

- Primary Cells – cannot be recharged
- Secondary Cells – rechargeable

Specifying Battery Condition

- State of Charge (SOC)(%)
- Depth of Discharge (DOD) (%)
  - 80% DOD is generally referred to as ‘Deep Discharge’
- Terminal Voltage (V)
  - The voltage between the battery terminals with load applied
- Open Circuit Voltage (V)
  - The voltage between the battery terminals with no load applied
- Internal Resistance

Battery Specifications

- Nominal Voltage (V)
- Cut-off Voltage
- Capacity (Ah)
- Cycle Life
  - Number of discharge-charge cycles before failure
  - Higher DOD, lower cycle life
- Specific Energy (Wh/kg), Specific Power (W/kg), Energy Density (Wh/L), Power Density (W/L)

Battery Specifications

- Maximum Continuous Discharge Current
- Maximum 30-sec Discharge Pulse Current
- Charge Voltage
  - voltage that the battery is charged to when charged to full capacity
- Charge Current
  - The ideal current at which the battery is initially charged (to roughly 70 percent SOC) under constant charging scheme before transitioning into constant voltage charging.

Types of Batteries

- Lithium Ion
- NiMH
- Lithium Polymer
- Lead Acid
- NiCd

Lithium Ion

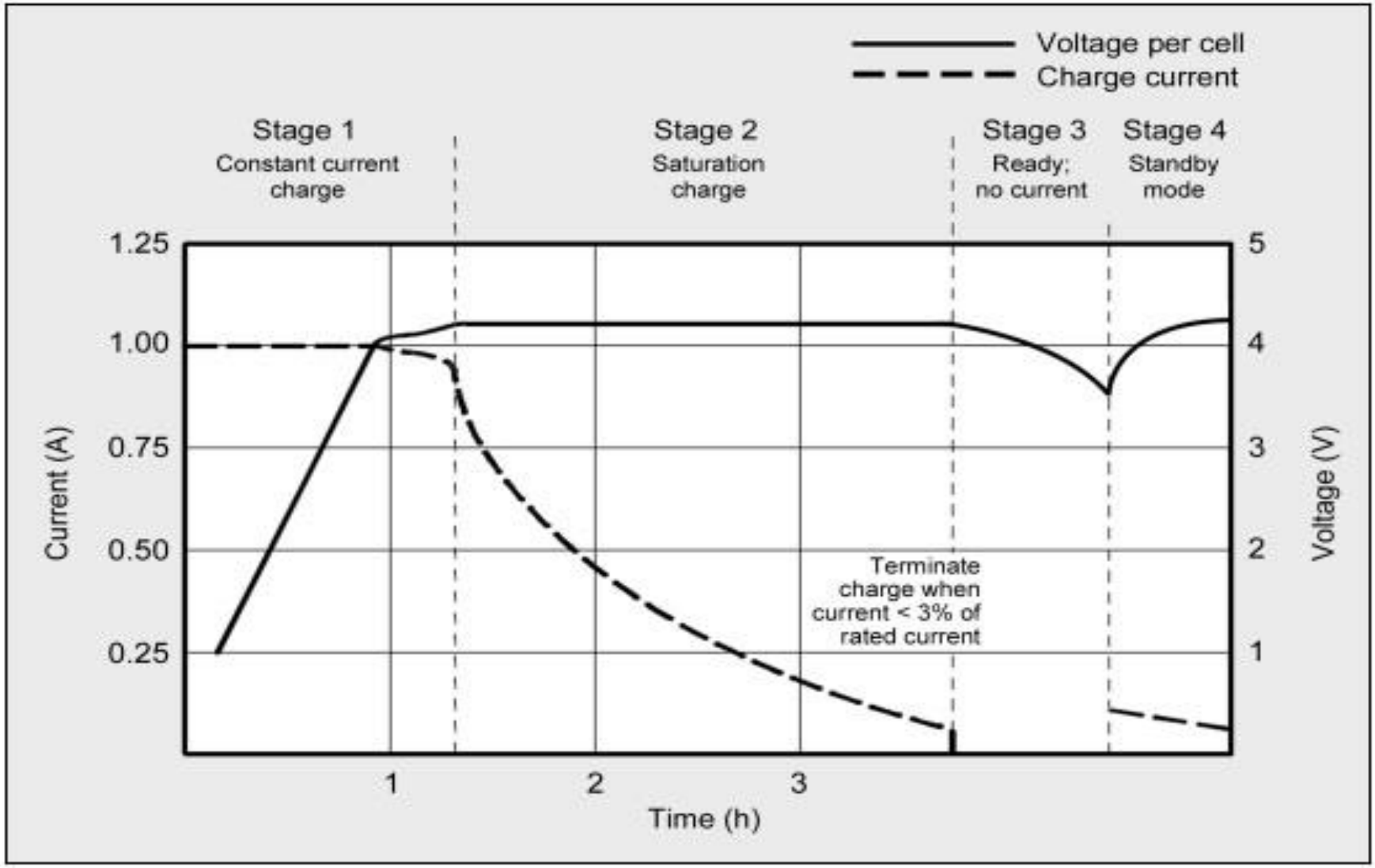
Lithium Ion

- Typical ratings
  - Nominal Voltage: 3.7V
  - Capacity: 2000 mAh

Charging

- A single Li-ion cell is charged in 2 stages:
  - CC
  - CV
- A Li-ion battery (a set of Li-ion cells in series) is charged in 3 stages:
  - CC
  - Balance (not required once a battery is balanced)
  - CV

- **Stage 1: CC**: Apply charging current to the battery, until the voltage limit per cell is reached.
- **Stage 2: Balance**: Reduce the charging current (or cycle the charging on and off to reduce the average current) while the State Of Charge of individual cells is balanced by a balancing circuit, until the battery is balanced.
- **Stage 3: CV**: Apply a voltage equal to the maximum cell voltage times the number of cells in series to the battery, as the current gradually declines asymptotically towards 0, until the current is below a set threshold

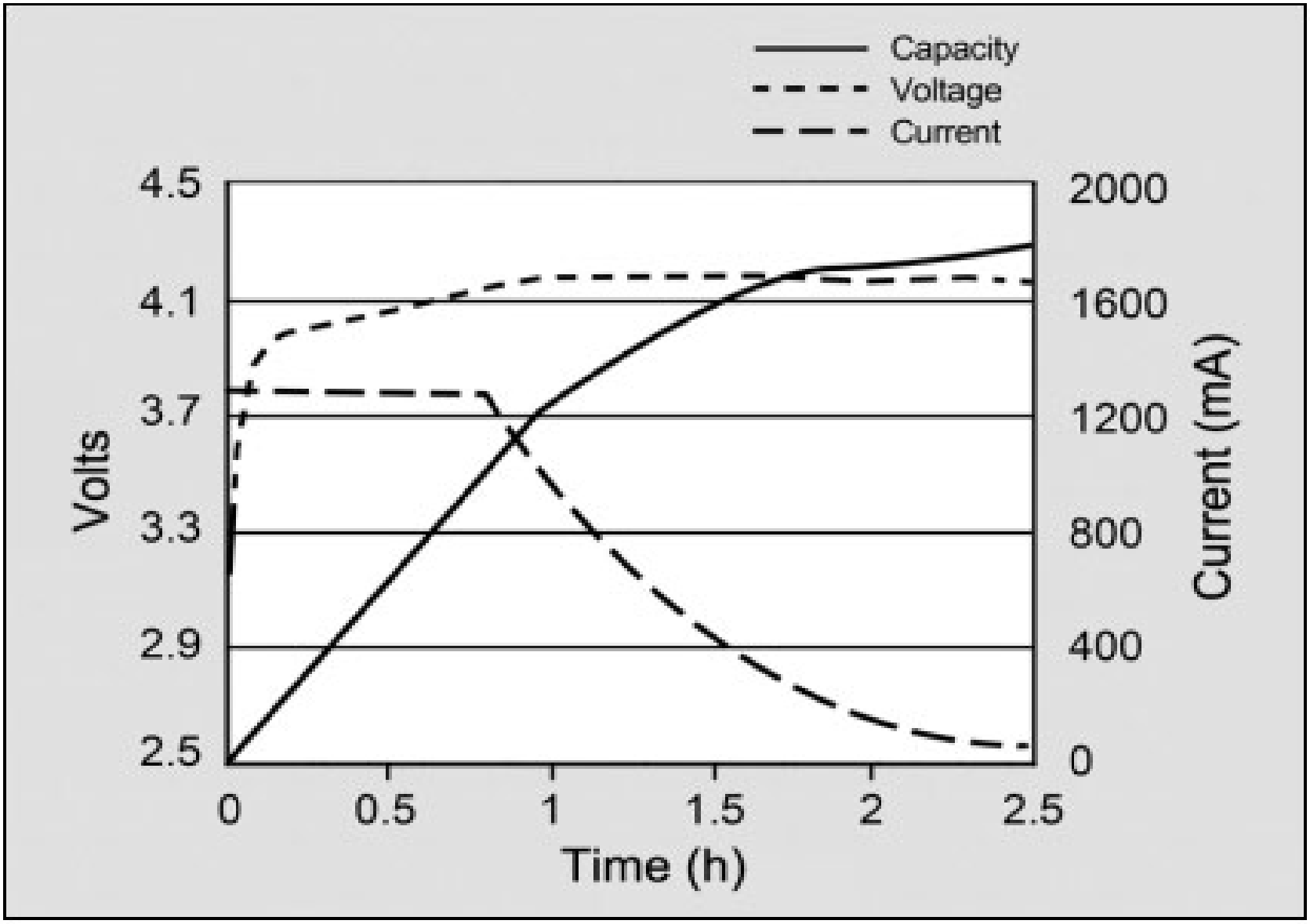


Stage 1
Voltage rises at constant current

Stage 2
Voltage peaks, current decreases

Stage 3
Charge terminates

Stage 4
Occasional topping charge


Capacity
Voltage
Current
4.5
4.1
3.7
3.3
2.9
2.5
Volts
2000
1600
1200
800
400
0
Current (mA)
0
0.5
1
1.5
2
2.5
Time (h)

NiMH

NiMH

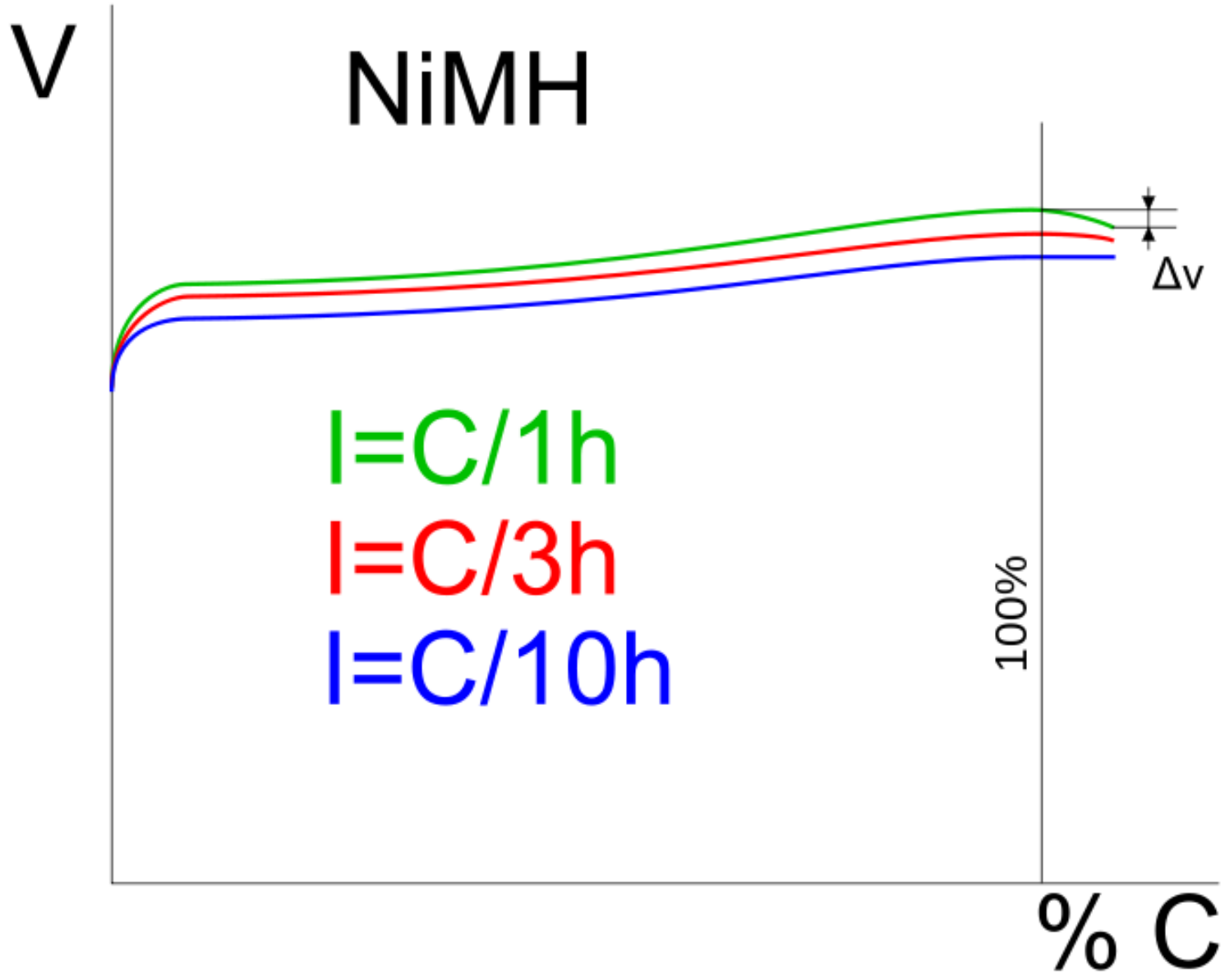
- Rechargeable battery similar to the nickel–cadmium cell
- uses a hydrogen-absorbing alloy for the negative electrode instead of cadmium
- 2 or 3 times the capacity of same sized NiCd battery

Charging Techniques

- Trickle Charging
  - The simplest way to safely charge a NiMH cell
  - Charge with a fixed low current, with or without a timer.
  - Currents below 0.1C
  - At this rate, could take 10 to 20 hours

Charging Techniques

- ΔV charging method
- ΔT charging method


V
NiMH
Δv
I=C/1h
I=C/3h
I=C/10h
100%
% C

Lithium Polymer

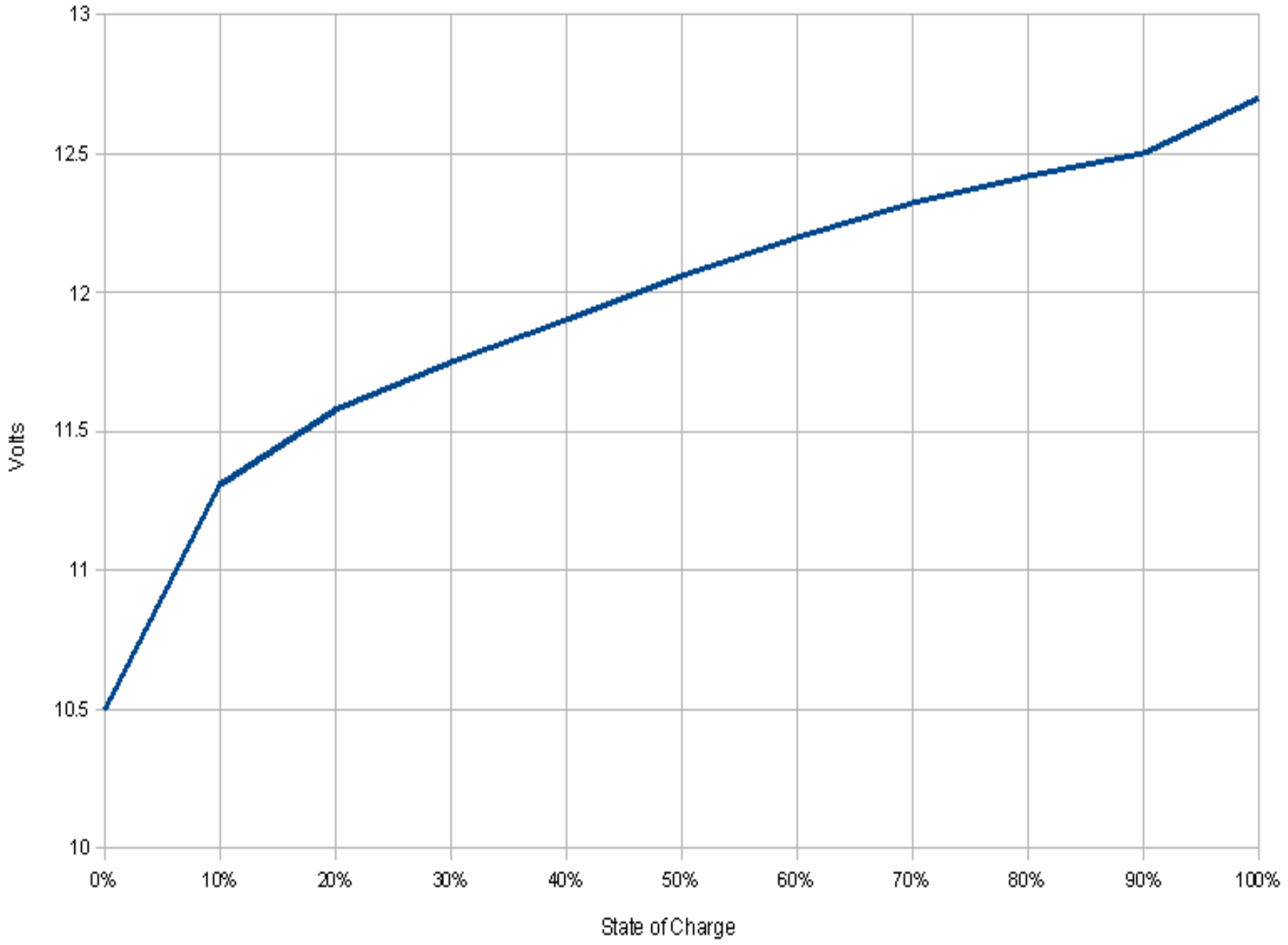
- Nominal 3.7V at 1000mAh

- 7.4V 2-cell pack
- 1000mAh of charge
- 25C continuous discharge rate

- Trickle charging is not recommended for lithium batteries
- Dedicated lithium polymer chargers
  - Use charge timers for safety
- Maximum and minimum voltage of 4.23 and 3.0 volts per cell

Lead Acid

- Low energy-to-weight ratio
- Low energy-to-volume ratio
- Supply high surge currents
- Open-circuit voltage can be used to estimate the state of charge


13
12.5
12
11.5
11
10.5
10
Volts
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
State of Charge

NiCd

- Presence of cadmium
- Ni–Cd batteries may suffer from a memory effect if they are discharged and recharged to the same state of charge hundreds of times
- Battery remembers the point in its charge cycle where recharging began and during subsequent use suffers a sudden drop in voltage at that point, as if the battery had been discharged.

WIRING

Why is a wire used?

- Supply electricity/ power
- Transmission of electric signals

Common cables

- Coaxial cables
  - RG59
- DVI
- HDMI

Ideal cables

- Cables connecting different types of equipment should ideally behave as "shorts“
- An ideal cable should behave as an ideal "transmission line", having no effect on the signal.

Why cables do not behave ideally?

- First, cables do not behave as ideal transmission lines with known impedance due to flaws in cable design and production.
- Second, due to imperfection in cable design, stray (parasite) capacitance and inductance appear along the cable
- Long cable = more problem

Standards

- **Wire gauge** is a measurement of how large a wire is, either in diameter or cross sectional area. This determines the amount of electric current a wire can safely carry, as well as its electrical resistance
- Standards
  - **British Standard Wire Gauge**
  - **American wire gauge** (**AWG**)
- Example: No. 36 AWG is 0.0050 inches in diameter, and No. 0000 is 0.4600 inches in diameter

Allowable amperage of conductors under 50 Volts with 105° C insulation			
AWG Wire Size	Metric Wire Size	Amperage Outside Engine Spaces	Amperage Inside Engine Spaces
18	.8	20	17
16	1	25	21.3
14	2	35	29.8
12	3	45	38.3
10	5	60	51
8	8	80	68
6	13	120	102
4	19	160	136
2	32	210	178.5
0	50	285	242.3
00	62	330	280.5
000	81	385	327.3
0000	103	445	378.3

Some tips

- R = rho l by a
- No matter what you are trying to power you must always use a wire that can handle the current flow.
- Always use a bigger wire than you need. Your wires should never get hot even during heavy loads.
- Solid core wire has a tendency to break with vibrations and impacts. Multi-stranded always provides better current flow especially when using D/C power. More strands – better the wires

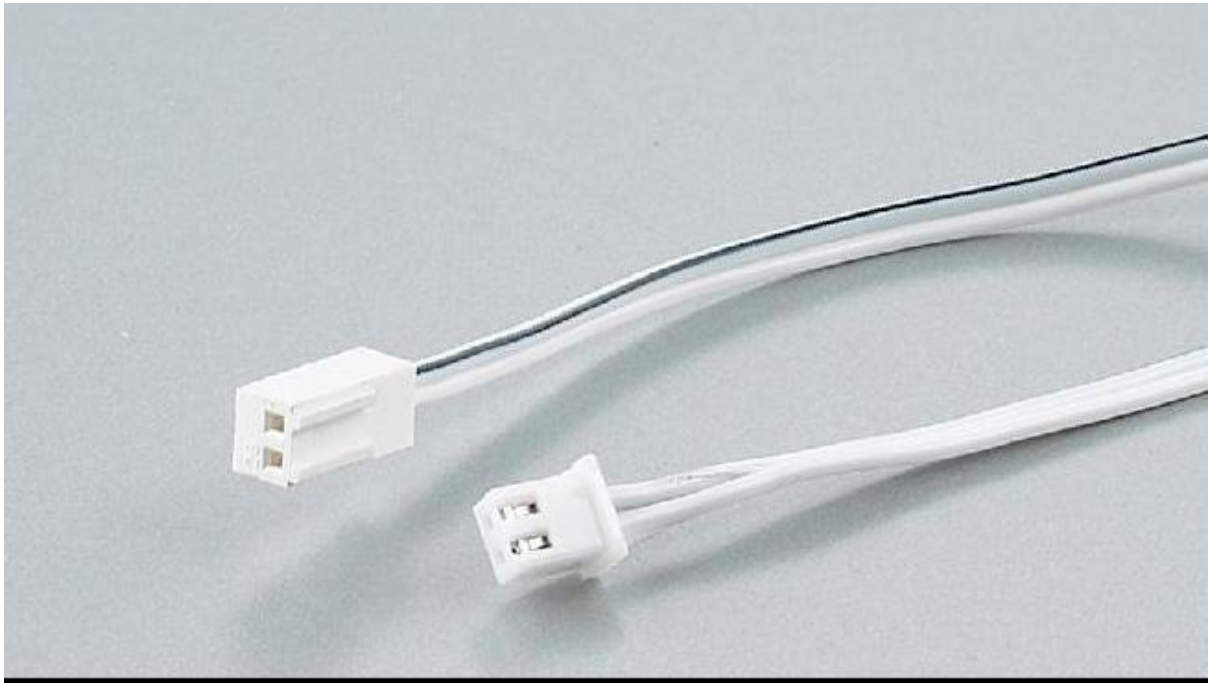
Wires we use

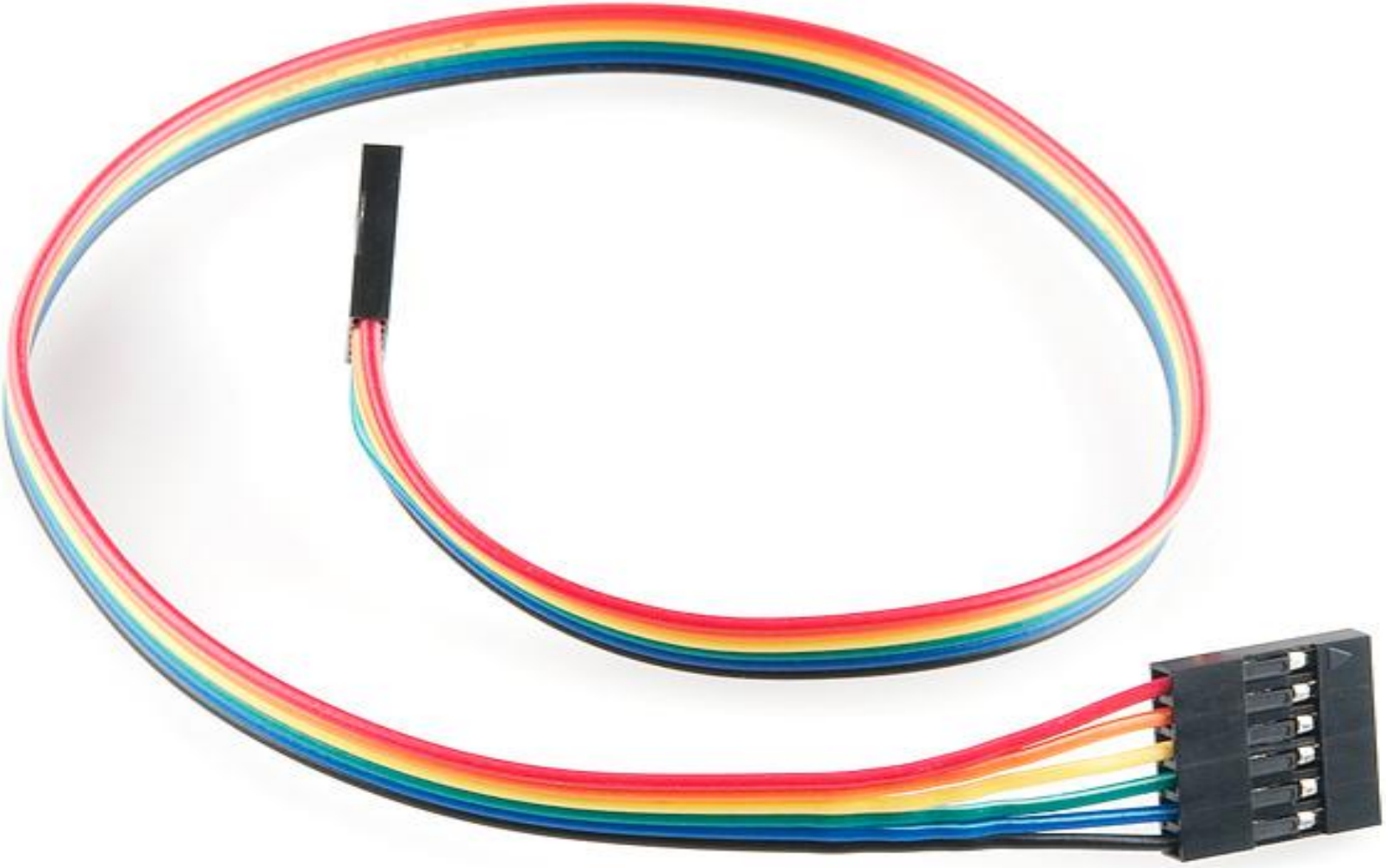
- Single Strand
- Multi Strand

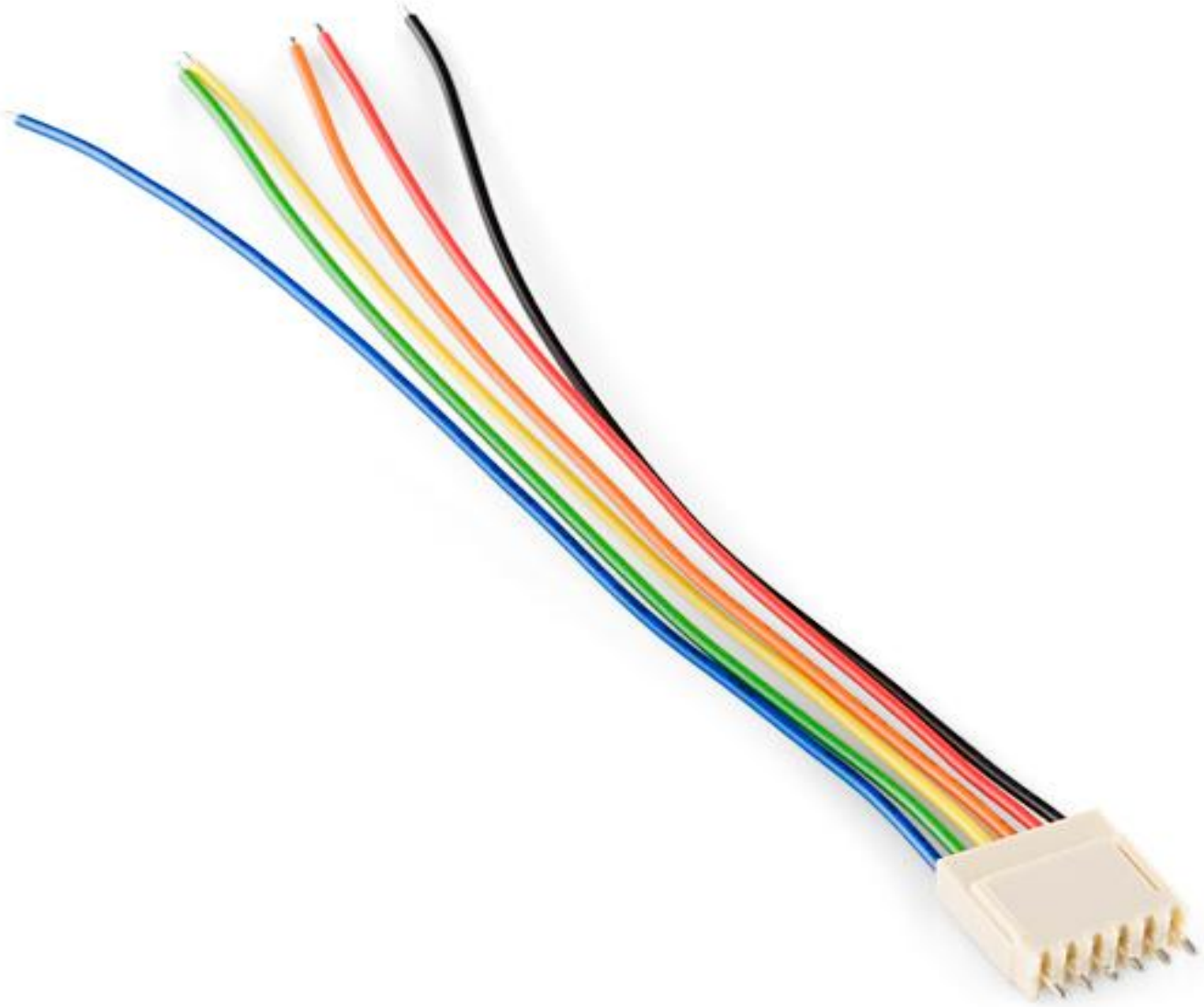
Single Strand Wires

10-core wires – each core multi-strand

JST Connectors

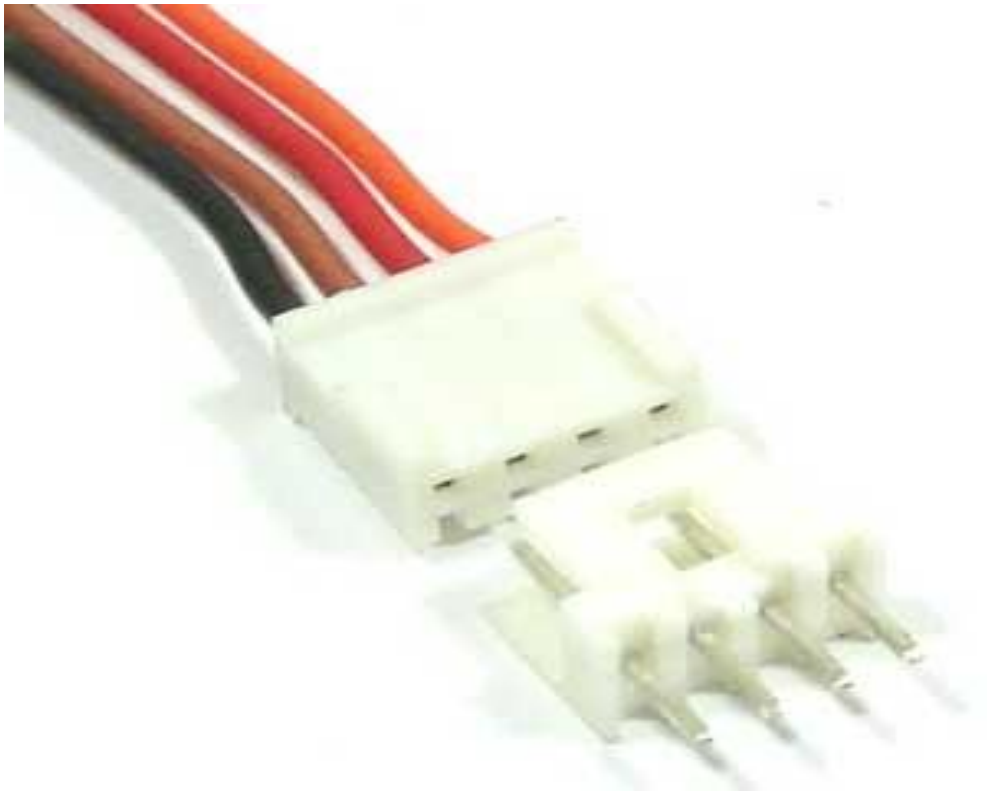


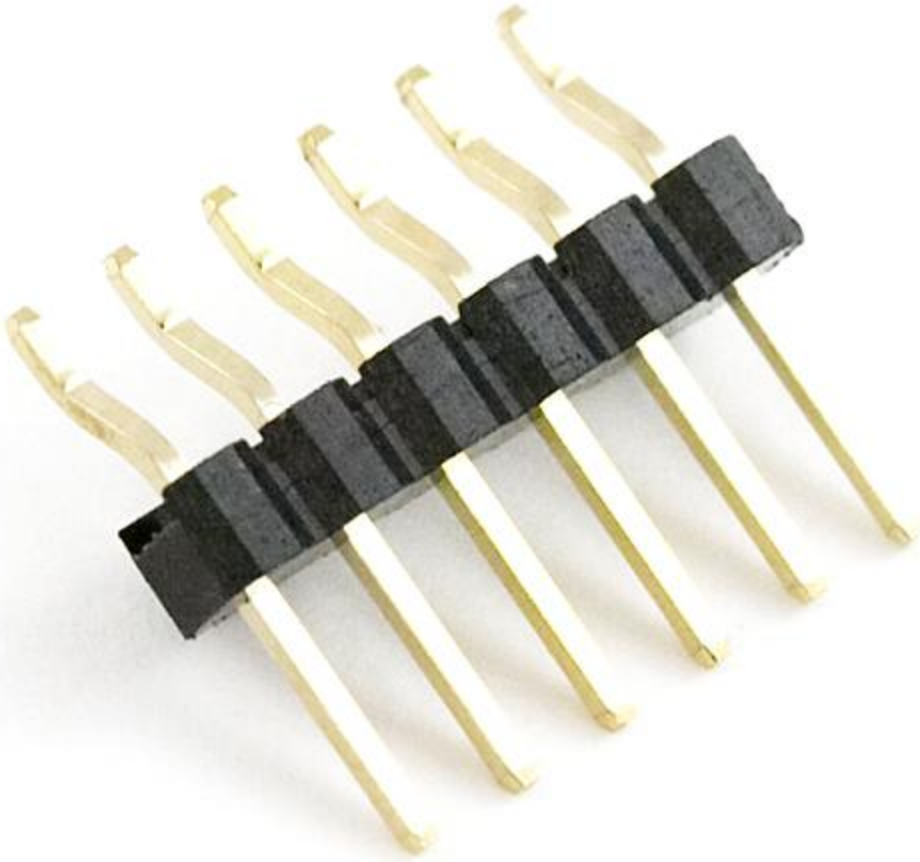


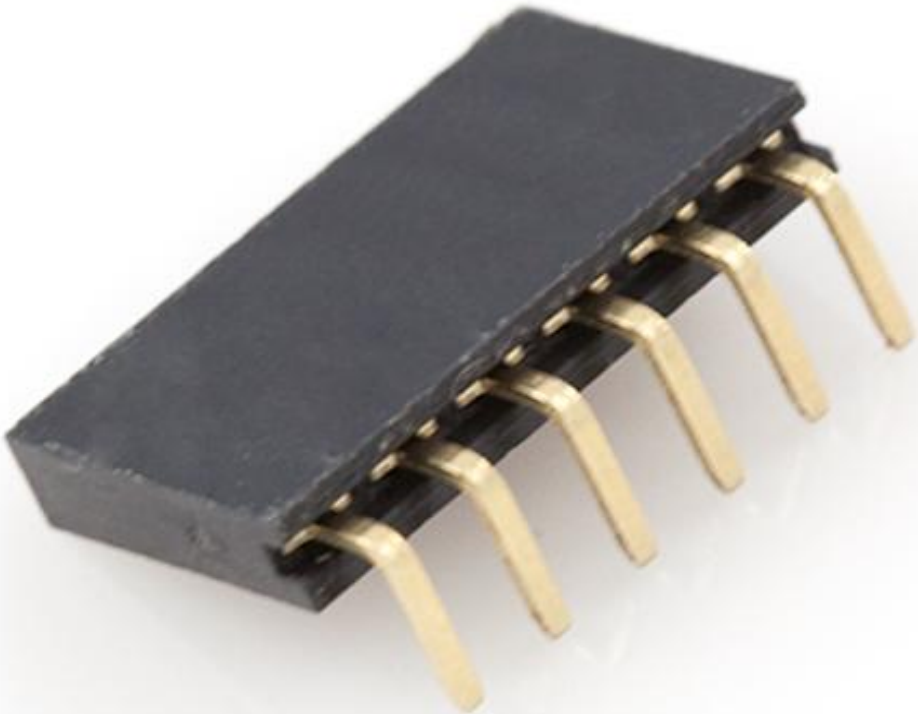


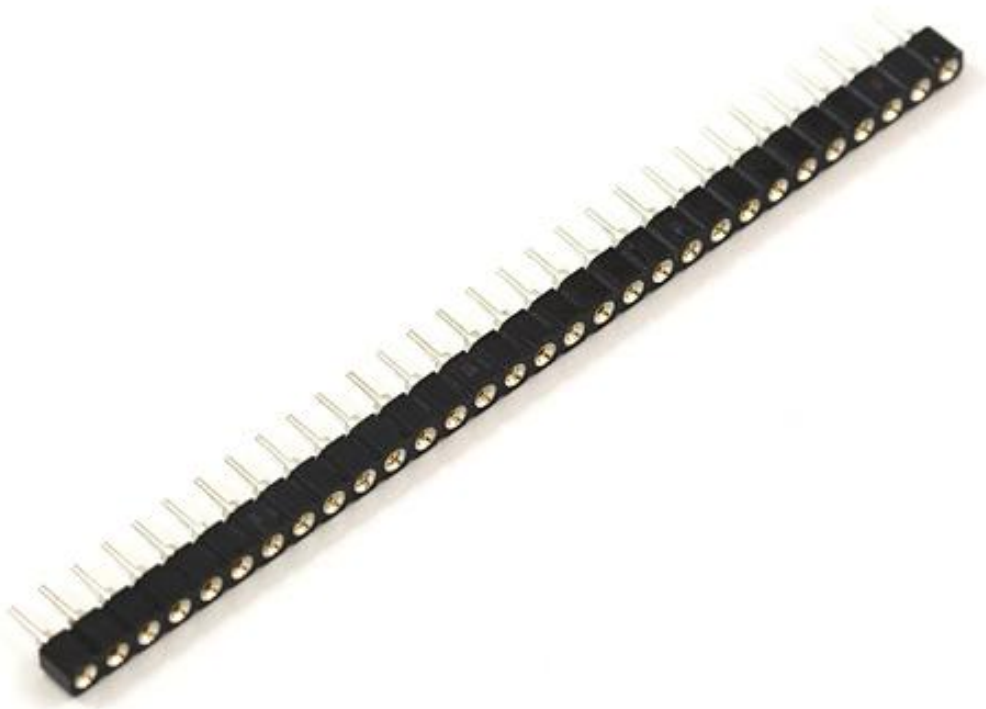
FRC Connectors

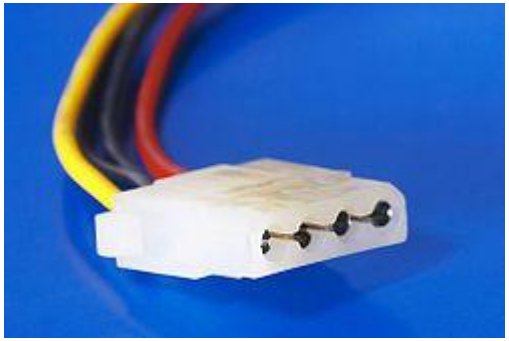
Relimates

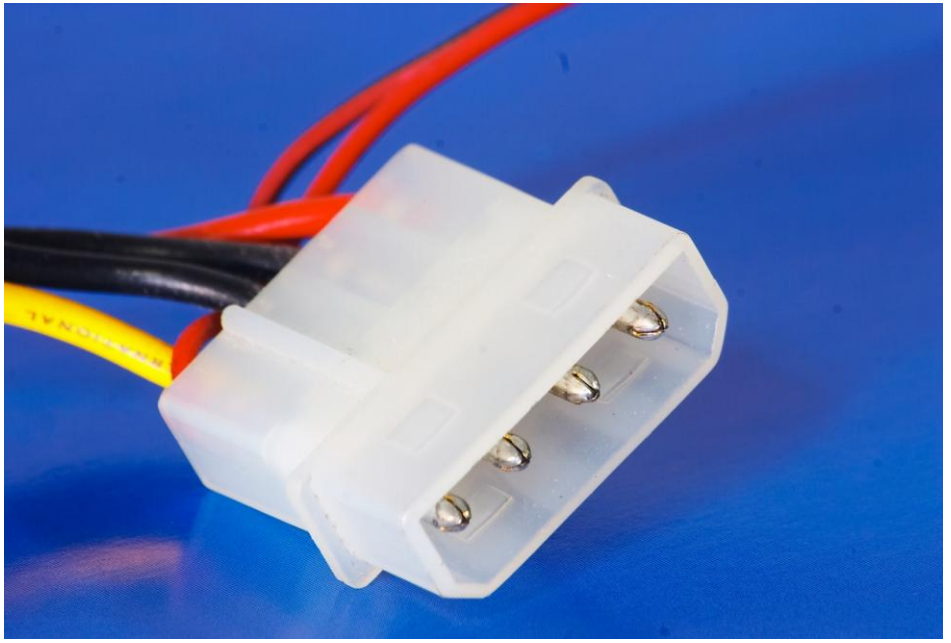












- Use the connectors shown above in your circuit designs!
- Connectors make the circuit robust, more reliable, less messier and more aesthetically pleasing
- More connectors – more convenient for you to use your circuit