Battery 101

Types, Usage and Charging

What are Batteries?

- *Batteries* are devices that convert stored chemical energy into useful electrical energy
- *Batteries* produce voltage to run an electronic circuit.
- *Batteries* have a capacity to run the electronic circuit for a given amount of time.
- *Batteries* have a useful life do to the chemical reaction and reduction of it over usage.

What does a Batteries have?

- Voltage
  - Is the potential difference from Negative to the Positive terminals of the battery.
- Capacity/Current Rating(mAh, Ah, C)
  - Is the amount of energy @ the battery voltage stored to run the electronic circuit.
- Resistance (IR)
  - Is the internal limiter of the amount of capacity we can get at any instance in time. Max current output without dropping voltage.

What does all that stuff mean?

- Lets relate Voltage and Capacity to 55 Gallon Drum.

55 Gallons

110 Gallons

Voltage

1X Capacity

2X Capacity

What happens when we use them?

- Unscrew cap to drain 1 Gallon/Minute.

110 Gallons/110 Minutes

55 Gallons/55 Minutes

1X Capacity

2X Capacity

What about Resistance?

- What is resistance related to in the drum?
  - Drain Hole size
    - Small hole is 1 Gallons/Minute
    - Large Hole is 4 Gallons/Minute
- I can't get any more out then 1 Gallon/Minute or 4 Gallon/Minute
- Not unless I make a bigger hole or open two drums at the same time. (Parallel Batteries 2p)

What happen to a battery over its life?

- Loses it's capacity
  - Reduced flight time. Reduced number of flight before needing recharge.
    - Chemicals are building up on Cathode and Anode terminals.
- Loses it's ability to maintain Voltage.
  - Internal Resistance (IR) rises.
    - 10 mOhm @ 50 Amps = .500 Volt drop
    - 20 mOhm @ 50 Amps = 1.000 Volt drop

Battery Life

- Let relate battery life to our drum.

- Drum reducing (Capacity)
- Drum Output is closing (Rising Resistance)

Questions

- Do we understand what batteries are?
- Do we understand what Voltage is?
- Do we understand what Capacity is?
- Do we understand what IR is?
- Do we understand how these are effected over its life?
- Can we determine total capacity by measuring voltage? “No”
- Can we determine remaining capacity by measuring voltage after use? “Yes and No”

Terms we'll use before we start

- Voltage
  - Define in Volts
- Capacity
  - Defined in mAh (Milli Amp Hours),Ah (Amp Hour). How many Milliamps/Amps we can we can use in 1 hour.
  - 1000 mAh = 1 Ah = Draw 1 Amp for 1 Hour
- Cell Configuration
  - 2s1p. 2 Cells, 1 Parallel. Xs = X*Cell Voltage
  - 1s2p. 1 Cell, 2 Paralleled. Xp= X*Cell Capacity
- C Rating
  - Output current capacity in relationship to cell capacity.
  - 10C for a 2200mAh Cell = 2,200 * 10 = 22,000 mA = 22 Amps
  - 20C for a 5000mAh Cell = 5,000 * 20 = 100,000 mA = 100 Amps

Radio Control usage Battery Types

- Nickel Cadmium (Ni-Cd)
  - Sayno,
- Sealed Lead Acid (SLA)
  - Power Sonic
- Nickel Metal Hydride (Ni-MH, NiMH)
  - Sayno
- Nickel Metal Hydride (Low Lose)
  - Eneloop
- Lithium Ion (Li-Ion)
  - A123, LiFe
- Lithium Polymer (Li-Po)
  - Thunder Power, Turnigy Nano Tech

Ni-Cd

- Cell Voltage
  - Nominal 1.20v, Charged(1.40v-1.60v),Discharged 1.00v
- Discharge Curve
  - Gradual Slope
- Charge Type
  - Slow Constant Current (CC) 1/10C
  - Fast Constant Current/Voltage Drop (CC/VD) 1C
- Power Density
  - 40-60 Wh/kg (Watt = Volts * Amps)
  - (1.2v * 1,100mA = 1.32 W) @ 24 grams = 55 Wh/kg (KR-1100AAU)
- Self Discharge
  - 10%/Month
- Life Cycles
  - 2000 Cycles

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Ni-MH

- Cell Voltage
  - Nominal 1.20v, Charged(1.40v-1.60v),Discharged 1.00v
- Discharge Curve
  - Gradual Slope
- Charge Type
  - Slow Constant Current (CC) 1/10C
  - Fast Constant Current/Voltage Drop (CCVD) 1C
- Power Density
  - 60-120 Wh/kg (Watt = Volts * Amps)
  - (1.2v * 1,600mA = 1.92 W) @ 31 grams = 62 Wh/kg (HHR160AA/B)
  - (1.2v * 2,300mA = 2.76 W) @ 30 grams = 90 Wh/kg (NH15-2300)
- Self Discharge
  - 1.2% (Low Lose), 10%/Month
- Life Cycles
  - 500-1000 Cycles

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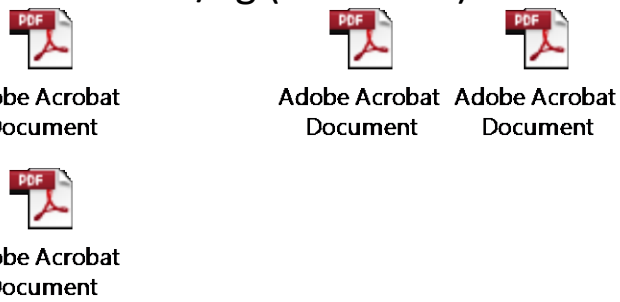
Sealed Lead Acid

- Cell Voltage
  - Nominal 2.10v, Charged(2.25v),Discharged 1.75v
- Discharge Curve
  - Gradual Slope
- Charge Type
  - Constant Voltage/Current Limited (CV)
- Power Density
  - 30-40 Wh/kg (Watt = Volts * Amps)
- Self Discharge
  - 3%-20%/Month
- Life Cycles
  - 500-800 Cycles

Lithium Ion

- Cell Voltage
  - Nominal 3.30v-3.70v, Charged(3.60v-4.20v),Discharged (3.00v-3.30v)
- Discharge Curve
  - Flat Slope / Sharp drop-off at end
- Charge Type
  - Constant Current/Constant Voltage (CC/CV) 1C-5C / (3.60v-4.20v)
  - Should use Balancing Charger
- Power Density
  - 100-250 Wh/kg (Watt = Volts * Amps)
  - (3.3v * 1,100mA = 3.63 W) @ 39 grams = 93 Wh/kg (APR18650) 25C
  - (3.7v * 2,300mA = 8.51 W) @ 48 grams = 177 Wh/kg (ICR18650) 2C
- Self Discharge
  - 5%-10%/Month
- Life Cycles
  - 400-1200 Cycles



Lithium Polymer

- Cell Voltage
  - Nominal 3.70v, Charged 4.20v,Discharged 3.00v, Safe Discharge 3.30v
- Discharge Curve
  - Flat Slope / Sharp drop-off at end
- Charge Type
  - Constant Current/Constant Voltage (CC/CV) 1C-5C / 4.20v
  - ALWAYS!!! Balancing Charger (I will explain why later)
- Power Density
  - 150-400 Wh/kg (Watt = Volts * Amps)
  - 3.7v * 950mA = 3.51 W) @ 25 grams = 140 Wh/kg (Nano-Tech)
  - 3.7v * 850mA = 3.14 W) @ 20 grams = 155 Wh/kg (Cell)
- Self Discharge
  - <5%/Month
- Life Cycles
  - 500-1000 Cycles

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Typical usages of different types of Batteries.

- Ni-Cd
  - Receiver pack
  - Transmitter pack
- Ni-MH
  - Receiver pack
  - Transmitter pack
- Sealed Lead Acid
  - Starter Box
  - Glow Driver Panels

Battery Usages

- Lithium Ion
  - Receiver Packs
    - With and Without regulators (Diode Drop)
  - Transmitter Packs
  - Motor Packs
- Lithium Polymer
  - Receiver Packs
    - With Regulator
  - Motor Packs
  - Motor and Receiver Pack Combo
    - (ESC with BEC) Electronic Speed Control with Battery Elimination Circuit

Questions on Types of Batteries?

- Do we know what is different for the different battery types?
- Do we know why a different type is better in some application then others?
- Is there any other types anyone has used for radio control?

Charging “Doing it Correctly” and “Safely”

- Ni-Cd
  - Constant Current (CC) 1/10C
    - Wall Wart with Radio System
    - Charger System
  - Constant Current / Voltage Drop (CC/VD) 1C (Some Vendors)
    - Charger System Needed to sense VD to turn off charging cycle.
  - Over Charging
    - Limited 1/10C
    - Possible @ 1C
  - Cycling
    - To determine Capacity after long term use.
    - 3-5 Charge/Discharge Cycles @ 1/2C Discharge (Charger System)

Charging Your Batteries

- Ni-MH
  - Constant Current (CC) 1/10C
    - Wall Wart with Radio System
    - Charger System
  - Constant Current / Voltage Drop (CC/VD) 1C
    - Charger System Needed to sense VD to turn off charging cycle.
  - Over Charging
    - Limited 1/10C
    - Possible @ 1C
  - Cycling
    - To determine Capacity after long term use.
    - 3-5 Charge/Discharge Cycles @ 1/2C Discharge (Charger System)

Charging Your Batteries

- Sealed Lead Acid
  - Constant Voltage (CV)
    - Wall Wart with Battery
    - Charger System
  - Over Charging
    - Limited
  - Cycling
    - Not Normally done.

Charging Your Batteries

- Lithium Ion
  - Constant Current/Constant Voltage (CC/CV) 1-25C
    - Charger System Only
    - Can be Charged with Balancer or not.
      - » Balancer keep all Cells in Pack within set range (+-10mV)
  - Over Charging
    - Limited if Charger System Set Correct.
    - Possible if Charging with the incorrect settings on Charger
    - Limited danger if over charged.
  - Cycling
    - Not Normally done. Discharge current to simulate usage is to high for most Charger System.

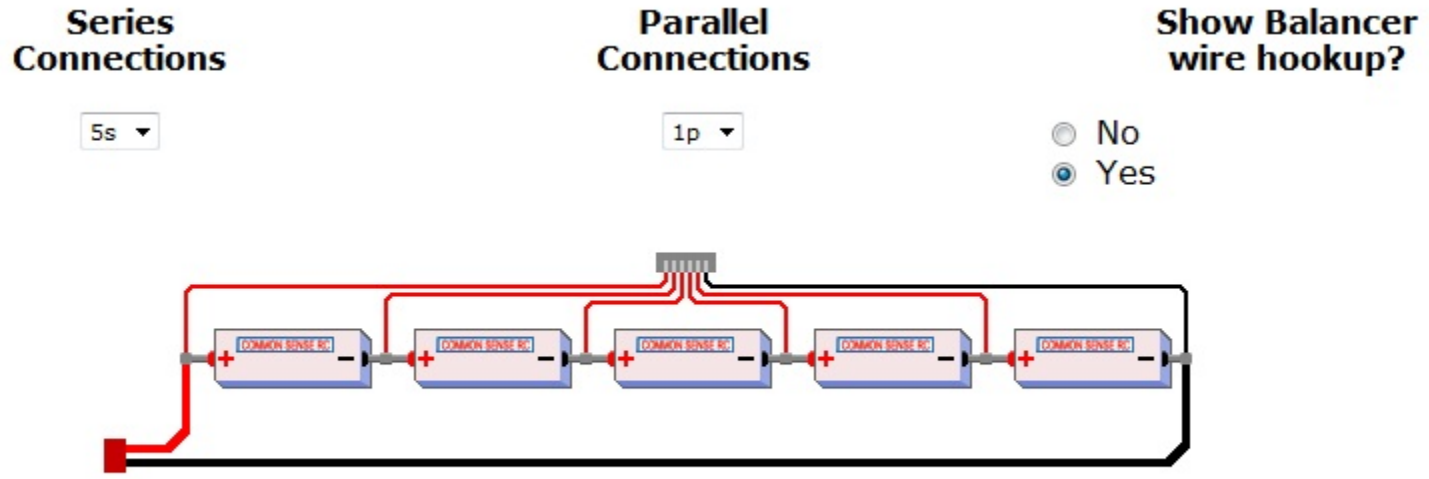
Charging Your Batteries

- Lithium Polymer
  - Constant Current/Constant Voltage (CC/CV) 1-25C
    - Charger System Only
    - !! MUST !! be Charged with Balancer to be SAFE.
      - » Balancer keep all Cells in Pack within set range (+-10mV)
  - Over Charging
    - Limited if Charger System Set Correct.
    - Possible if Charging with the incorrect settings on Charger
    - Very Dangerous if over charged.
  - Cycling
    - Not Normally done. Discharge current to simulate usage is to high for most Charger System.

What is Balancing and Why?

- What
  - Balancing is when the Charger System monitors all the different cells in a packs voltage individually and matches them with-in +- 10 mV.
- Why
  - This prevent the different cells in a pack from rising in voltage and causing other cells in the pack to become uncharged.
- What causes this voltage difference?
  - Difference in Internal Resistance (IR) of the different cells in the pack causes different charge rates per cell.

Balancing what it is



Why is it important?

- So you don’t Burn the House Down !!!
- How could this happen?
  - 5 Cell pack with one bad cell @ (0v)
  - 5 Cell Pack should be 18.50v. With bad cell 14.80v.
  - Charging 4 good cells to 21.0v (4.2*5). 21.0/4 = 5.25v
    - 1.05V over the max voltage per cell. (Over Charged)
- Balancing during charging will prevent this.
- !! NEVER !! Charger Li-Po without Balancing during charging.

Question on Charging and Balancing?

- Do we understand the different type of chargers systems needed for the different types of batteries?
- Do we understand why the balancing of Li-Po during charging is VERY important?
- Can measuring the voltage of our battery pack tell us if it's charged? “Yes and No”
- Can measuring the voltage of our battery pack tell us how much capacity we have left? “No”

Charger Systems what's on Market?

- AC/DC Input
  - Wall Plug powered/12V DC powered.
- Single Output
  - 4s, 6s, 10s
- Multi Output
  - Dual Output, Quad Output
- Different Wattage
  - 50W, 100W, 200W 400W, 1,000W, 50W/Output
- Different Battery types in same Charger

Chargers

- Single Output 50W

- Single Output 400W

- Dual Output 200W Each

- Single/Dual Output 260W Total

What else should we know about our Batteries?

- Li-Po Break-In, Should we?
  - Yes, Max 60-70% discharge @ 80% Rated Current Max Short Burst, 50% Rated Current Normally.
  - 5 Cell @ 5,000mAh @ 20C
    - 80 Amp Max, 50 Amp Normal, Cell ending voltage 3.75v-3.85v
  - 7-10 Flights as above. Note Charge put into Pack during charging.
- Storage Charge, Should we?
  - Yes if you want to or use same as above for last flight before storage.
  - 3.85v Storage charge. Some chargers have this mode.

What else should we know about our Batteries?

- Should we Cycle our Ni-Cd's and Ni-MH's?
  - Yes, To determine their capacity and reduce memory effect of Ni-Cd's
- Should we record or know what amount of charge we are putting into our Li-Po's
  - Yes, This will help not over Dis-Charging them and help maximize their usefully life.
  - Shouldn't Dis-Charge over 85%-90%
    - 4,250mA for 5,000mAh pack

What else should we know about our Batteries?

- Should we know our IR for each Cell on our Li-Po's.
  - Some Chargers Report these values
  - It's helpful in knowing when the Pack is getting near its end of life.
  - IR(Internal Resistance) will increase as cell life depletes.
- Should we know the number of cycles on each pack?
  - It's nice in determining number of flight we have gotten from each pack. Also help determine the best pack to buy, cost / flight vs. cost.
  - Help us know when we will need to start looking at replacing our packs.

Battery 101 Wrap-Up

- Pick the battery that best fits your need.
- Pick the correct Cell size and Cell configuration and output capacity rating. (10C vs. 20C)
- Don’t !! EVER !! charge Li-Po’s without a Balancer or Balance Charger.
- Know what you’re doing to your packs so you don’t damage them or reduce their life.

Questions?

- Thank You