Recap

What is the Internet of Things?

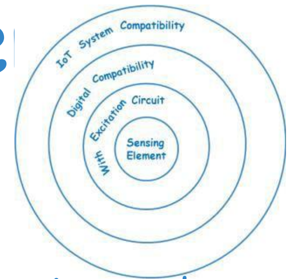
- Start with a traditional device

- Add computational intelligence to improve the functions

- Add a network connection to further enhance functions – IOT fridge

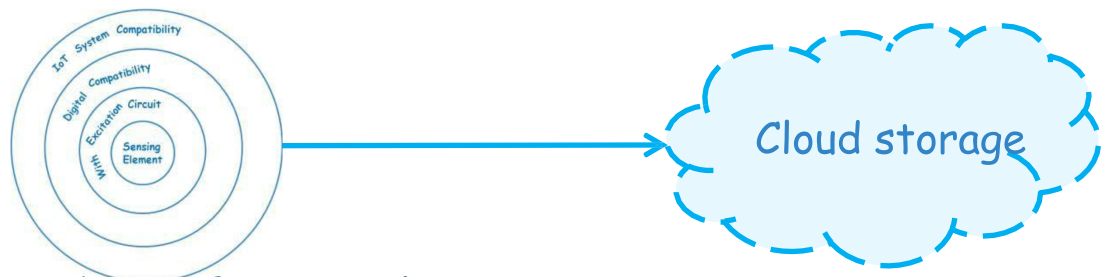
Types of IoT Syste

Level 1



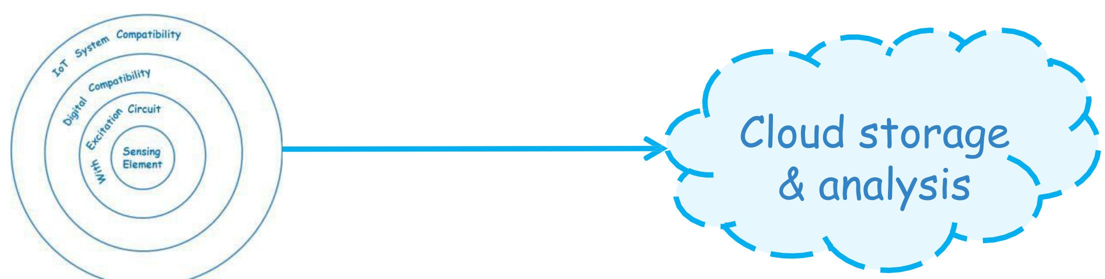
Monitoring node, performs analysis, stores data

Level 2



Monitoring node, performs analysis

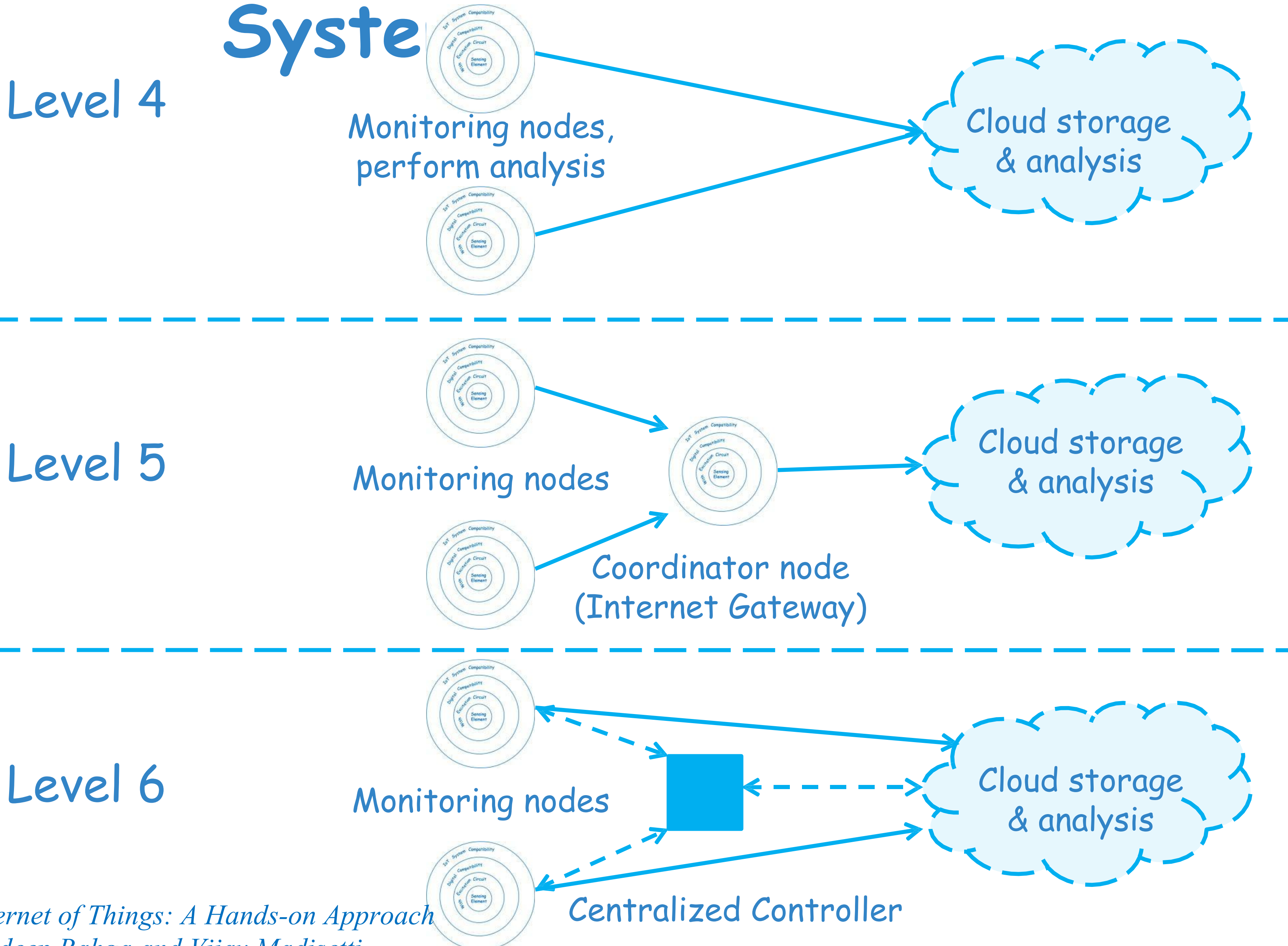
Level 3



Monitoring node

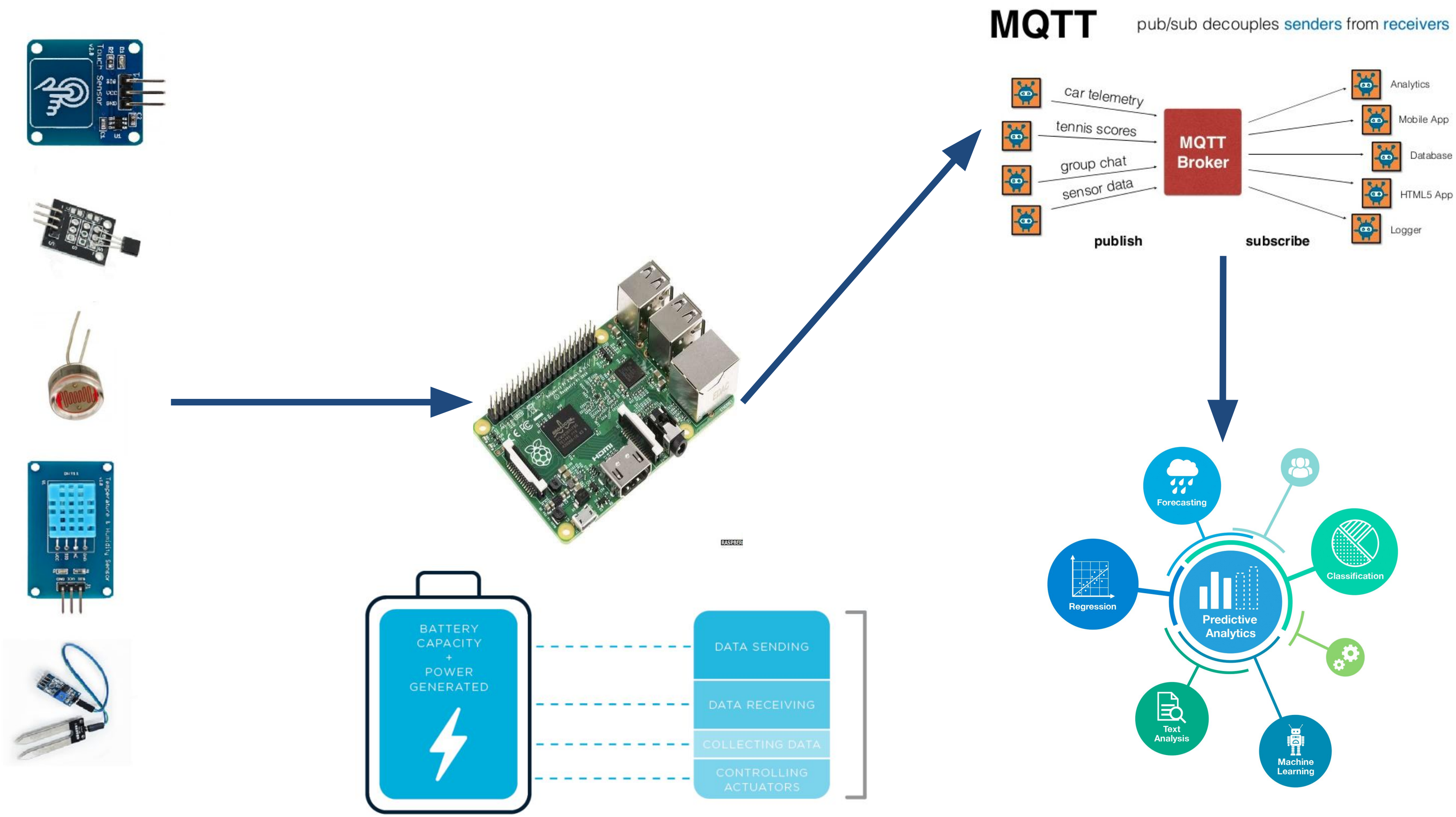
Ref: Internet of Things: A Hands-on Approach
By Arshdeep Bahga and Vijay Madisetti

Types of IoT Syste



Ref: Internet of Things: A Hands-on Approach
By Arshdeep Bahga and Vijay Madisetti

What's Next?



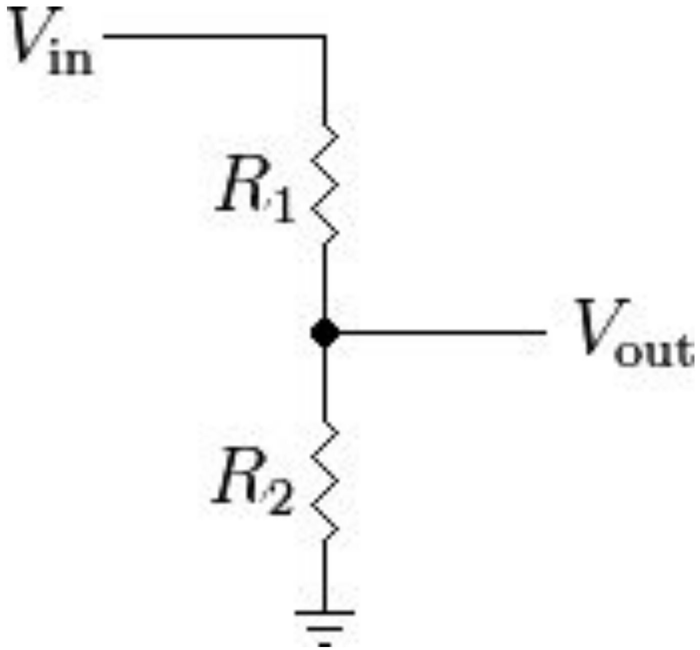
MQTT
pub/sub decouples senders from receivers
car telemetry
tennis scores
group chat
sensor data
MQTT Broker
Analytics
Mobile App
Database
HTML5 App
Logger
publish
subscribe
BATTERY CAPACITY + POWER GENERATED
DATA SENDING
DATA RECEIVING
COLLECTING DATA
CONTROLLING ACTUATORS
Forecasting
Classification
Regression
Predictive Analytics
Text Analysis
Machine Learning

Power Management & Batteries

Power Management

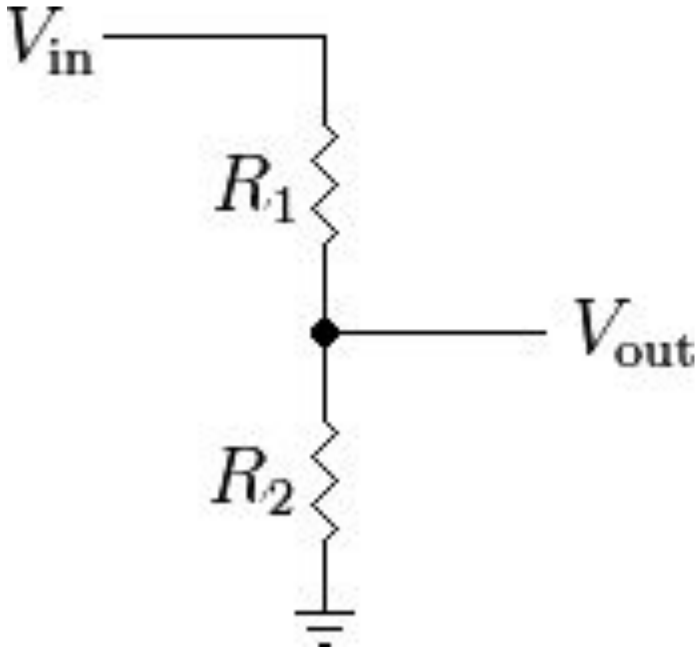
- Voltage supply / Power source
- Non-idealities, imperfections
- Power rating
- Real life design challenges
- Efficiency
- USB power supply
- Voltage regulator

Question 1



$V_{out} = ?$

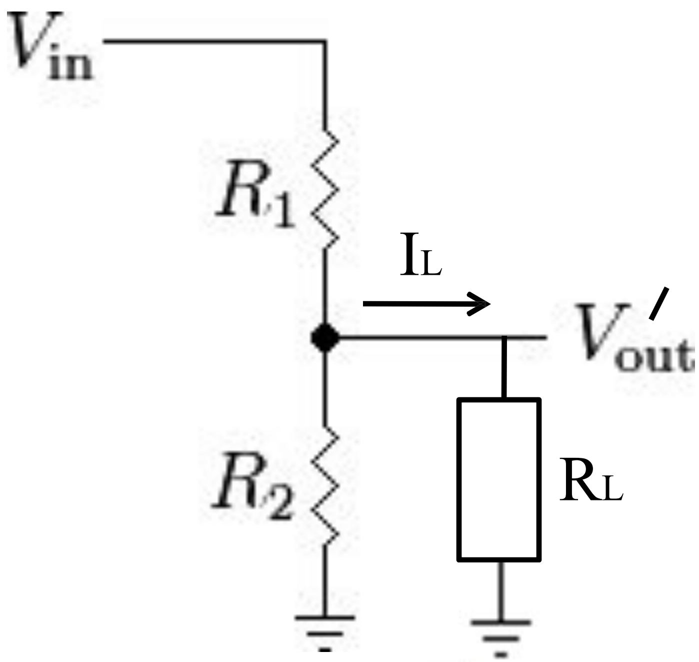
Question 1



$V_{out} = ?$

$$V_{out} = \frac{R_2}{R_1 + R_2} \cdot V_{in}$$

Question 2



$V_{out}' = ?$

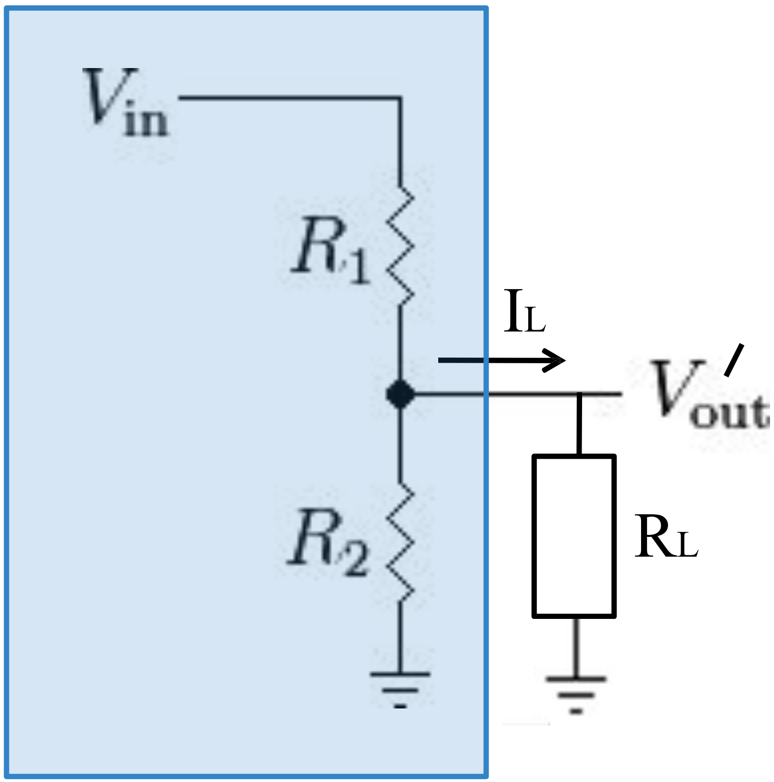
$V_{out}', I_L (R_L \rightarrow 0) = ?$

$V_{out}', I_L (R_L \rightarrow \infty) = ?$

Question 3

- What is an ideal DC voltage source / power supply ?
- What are the common non idealities of a typical DC voltage source ?
- Now go back to Q2 and give reason for drop in Vout with load.

Question 2



$V_{out}' = ?$

$V_{out}', I_L (R_L \to 0) = ?$

$V_{out}', I_L (R_L \to \infty) = ?$

Question 4

- Why there is drop in voltage during peak summer / winter ?
- Why are you supposed to increase your meter wattage if you install an *AC* in your house?

AC Supply @Your Home

- You receive fixed *AC* voltage 240V (Ideal scenario)
- What about "current". Is current also fixed?
- Who decides the upper limit of current?
- What parameters help in deciding the upper limit of current?

Power Handling in Electronic Circuits

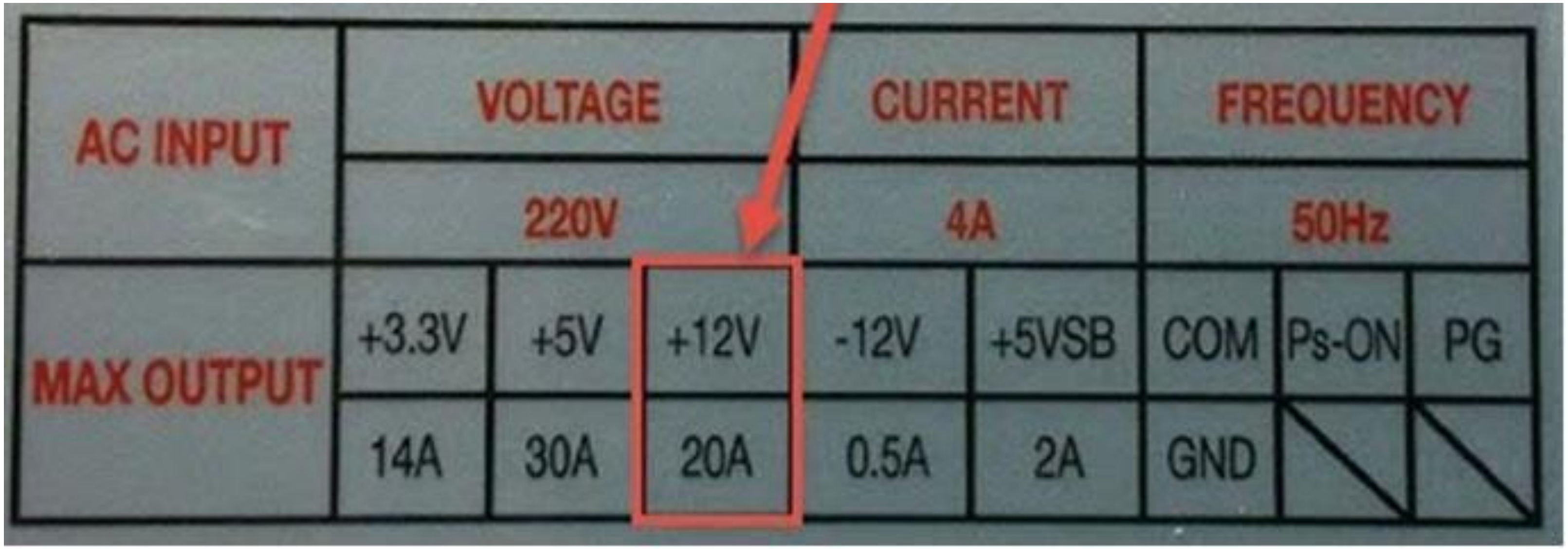
- AC to DC conversion
- Cellphone charger is an excellent example
- Switching Mode Power Supply (SMPS) of your PC:

  Accepts 240V AC input and gives out +5, -5, +12,

  -12, 3.3V

  – Is this information about an SMPS enough?

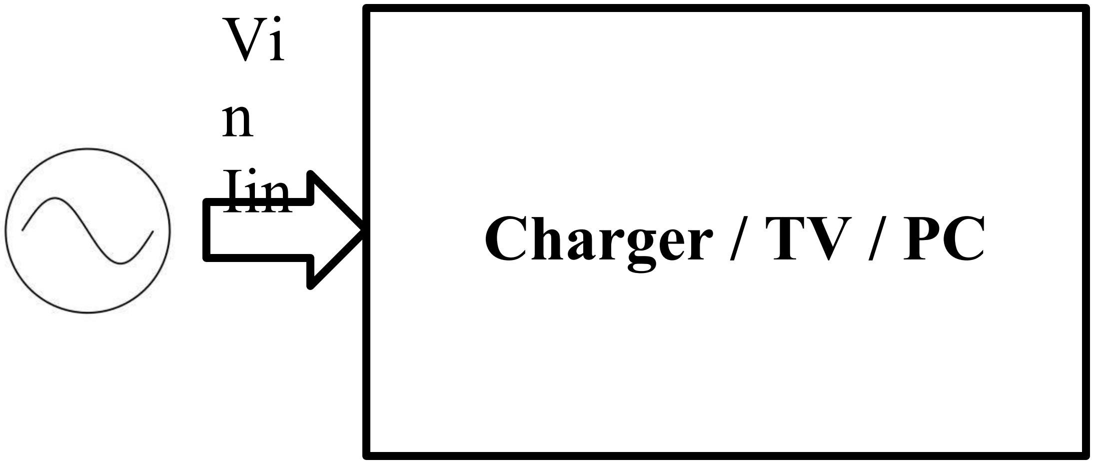
Power Rating of an SMPS



AC INPUT	VOLTAGE			CURRENT		FREQUENCY		
	220V			4A		50Hz		
MAX OUTPUT	+3.3V	+5V	+12V	-12V	+5VSB	COM	Ps-ON	PG
	14A	30A	20A	0.5A	2A	GND		

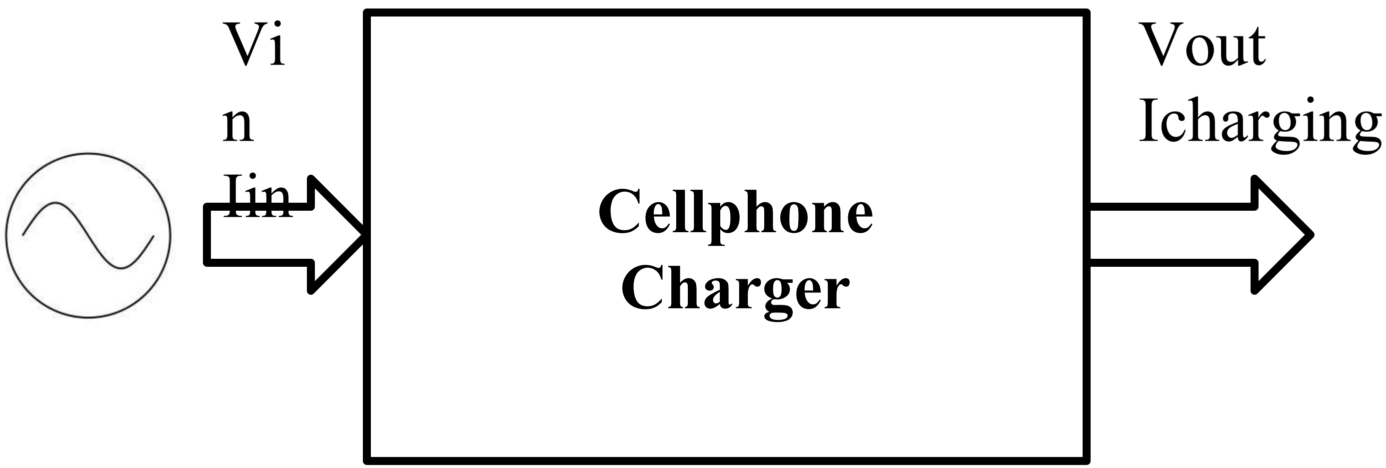
Current rating is very important !

Power Consumption



Input Power = Vin x Iin

Cellphone Charger



$$\text{Efficiency } (\eta) = \frac{\text{Power Out}}{\text{Power In}}$$

Cellphone Charger

AC ~240V

VUSB = ?

Wall Charger

DC / AC ?

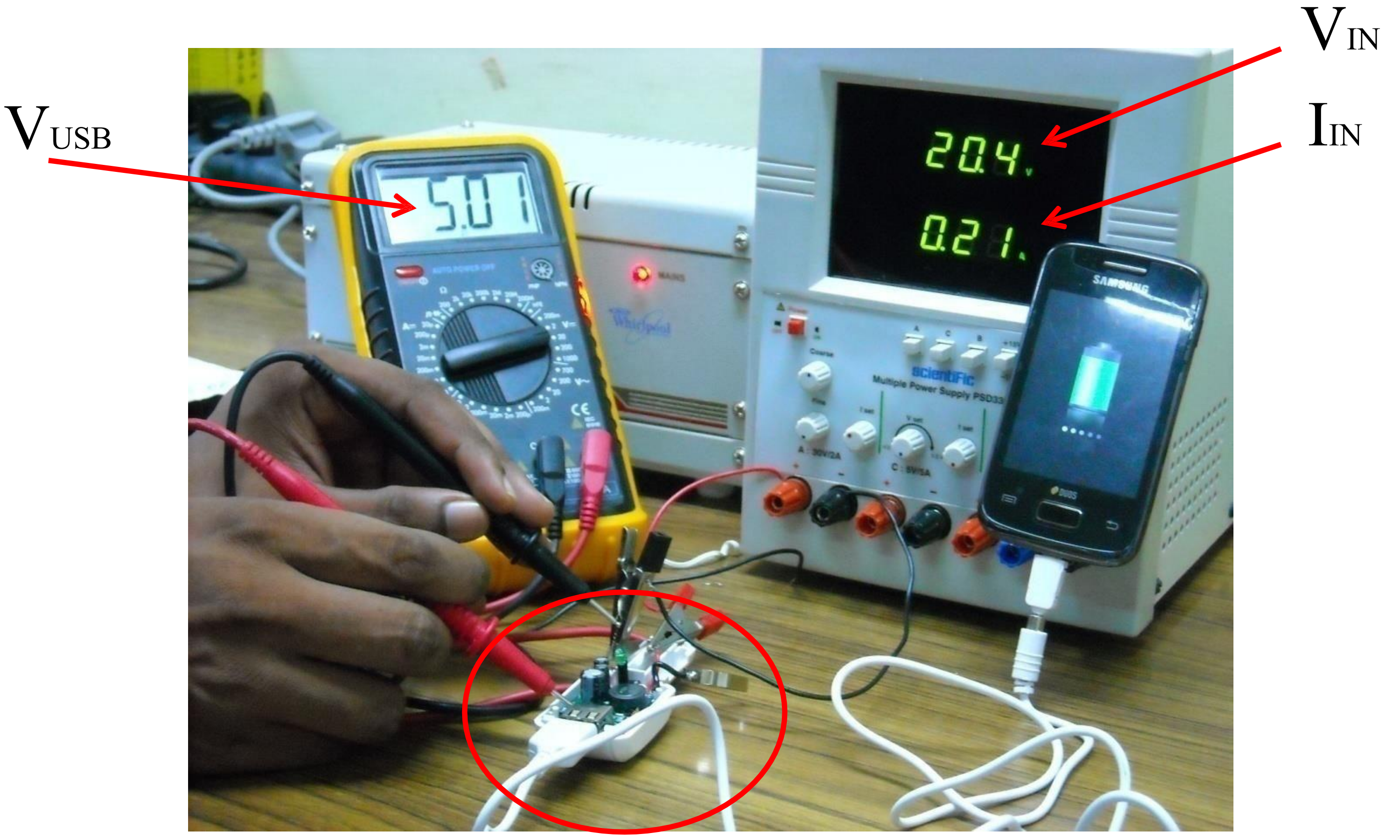
VUSB = ?

Car Charger

Car Charger

- From where does the car charger derive its power?
- DC / AC ?
- Battery chemistry?
- Terminal voltage?

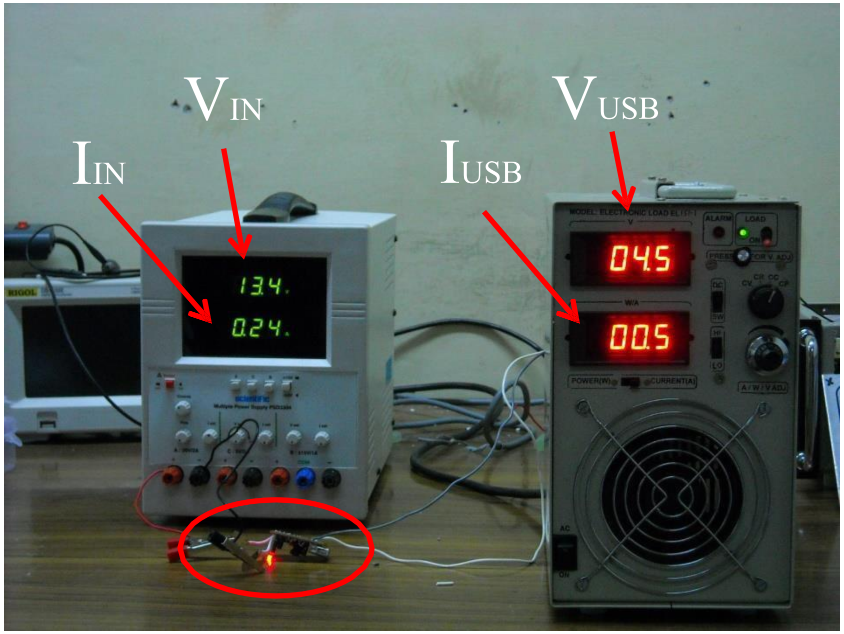
Efficiency of a Cellphone Charger



Q: What is the power efficiency of the charger if the charging current here is 600 mA ?

Image courtesy: GT Silicon Pvt Ltd

Benchmarking



ABC GT Silicon

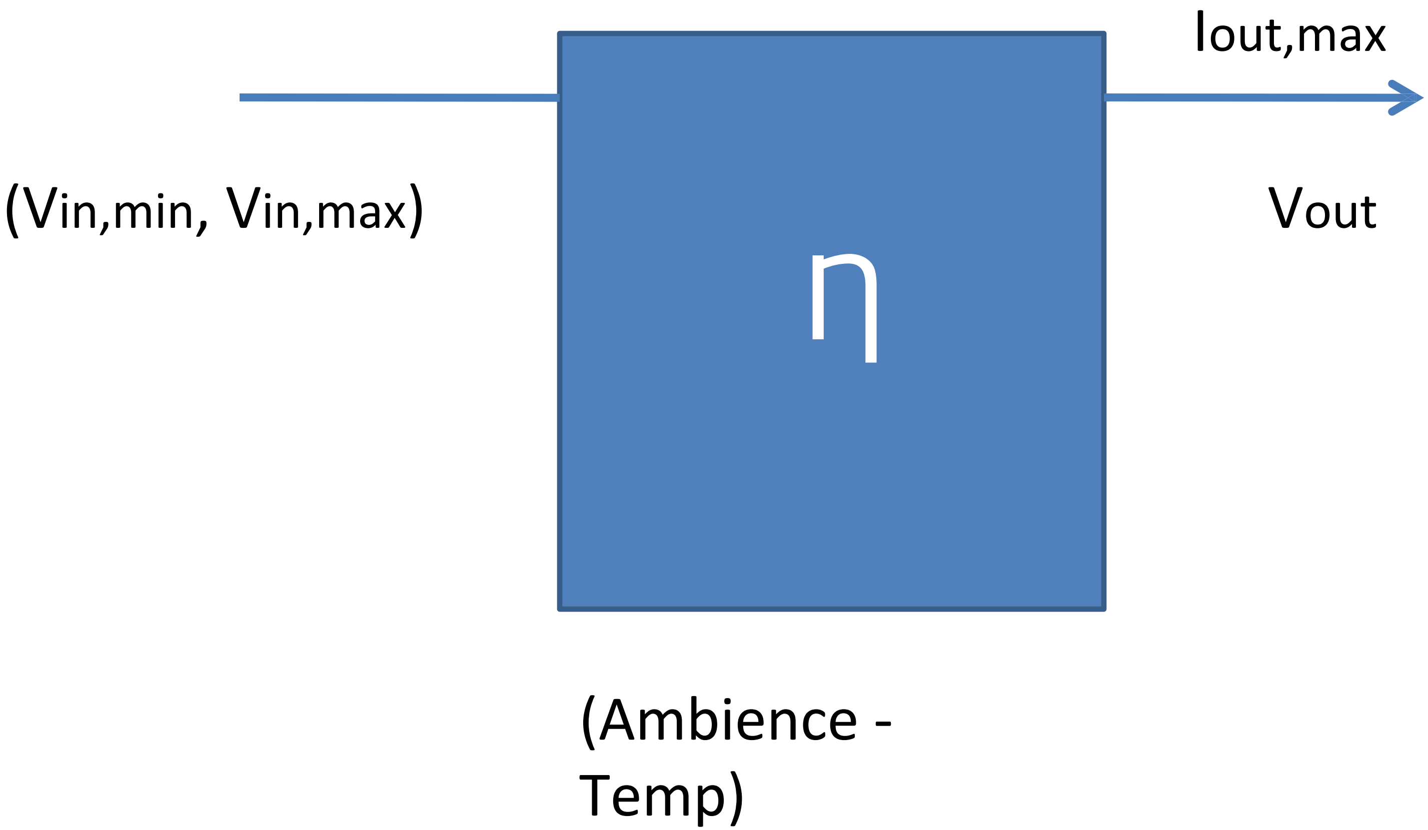
Q: What is the power efficiency of GT Silicon's charger in this case ?

Image courtesy: GT Silicon Pvt Ltd

Voltage Regulator

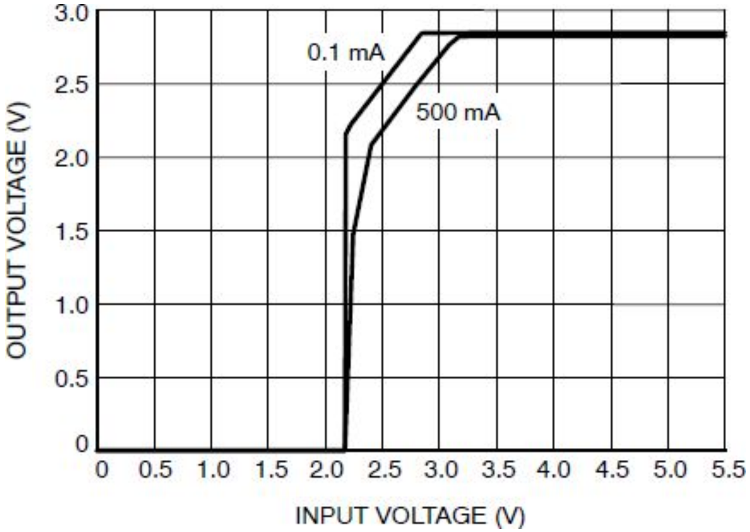
- Provides voltage at certain level (1.8V, 2.5V, 3.3V, 5V etc)
- Maintains the voltage despite variation in input voltage, output current, temperature etc
- The max load current, maximum input voltage range and ambient temperature range for stable output are important specifications

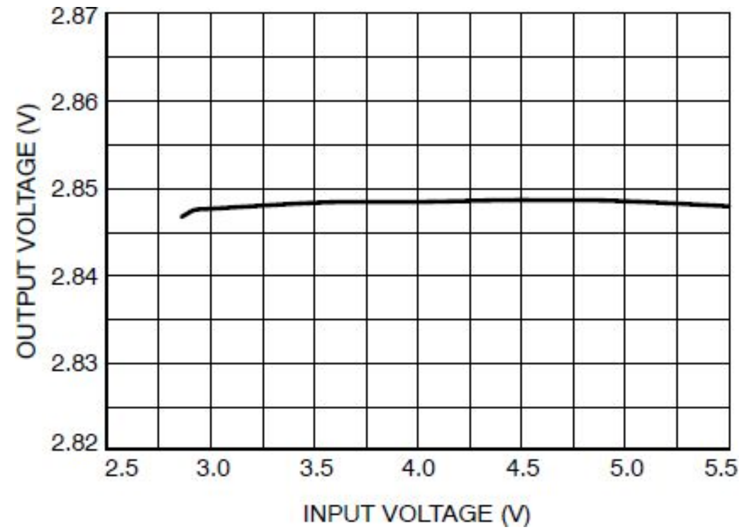
Specifications of a Voltage Regulator



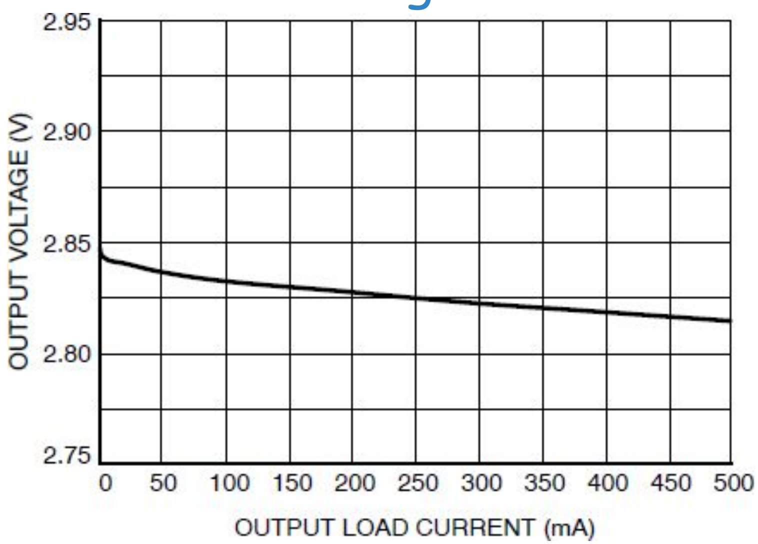
Specifications of CAT6219 (2.85V, 500mA)

Dropout characteristicLine regulation

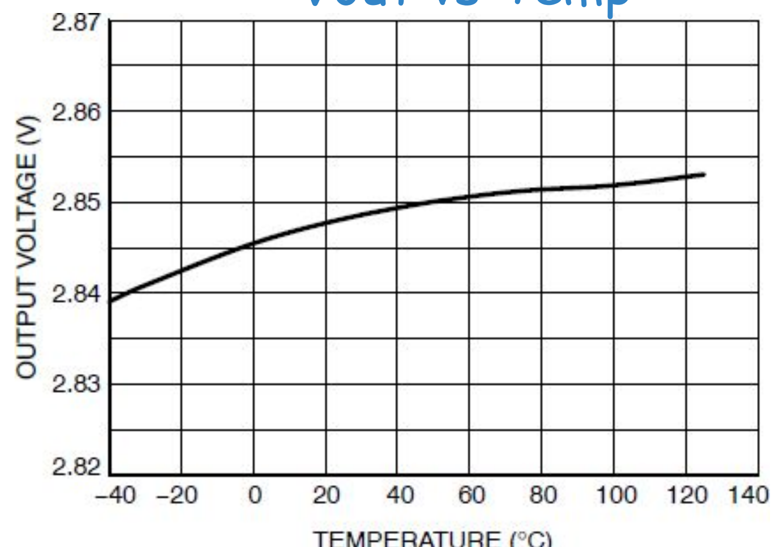




Load regulation



Vout vs Temp



Summary

- Voltage supply / Power source
- Variation in voltage due to current withdrawn
- Non-idealities, imperfections of a voltage supply
- Current rating (typical, max) of a system
- Real life design challenges due to imperfections
- Efficiency of a power mgmt unit
- USB power supply (current limit)
- Voltage regulator
  - Stability of output voltage, Range of input voltage
  - Efficiency, Effect of ambient and operating conditions

Batteries

- Battery chemistry
- Non idealities
- Li-polymer battery
- Charging & Discharging
- Series & Parallel combination
- Protection circuit

Power Source: Mains / Battery ?

- Application decides the primary source of power
- **Non portable appliances** use Mains as the main power source and battery for backup
  - Your TV / PC are not portable items. Those are meant to operate on main supply. Battery/inverter is used as backup power. (Give more examples)
- **Portable appliances** use battery as the main power source and mains for charging or backup
  - Oblu (wearable sensor) runs on battery. It uses USB power for charging battery and also as an alternate power source. (Give more examples)

Typical Power Source for Electronic Gadgets

- AC Mains (Converted to DC internally)
- Batteries
- USB* (?)

*USB is not a source of power. It is just a form of connector

USB Port as Power Source (?)

- Fixed voltage – 5V DC
- Maximum current limit of a USB port (which also supports USB data transfer)
  - 100 mA
  - 500 mA

- Cellphone chargers use USB connectors
- Those are just physical connectors for charging only
- There is no USB data transfer support in chargers
- Charger circuit controls the charging current
- Charging current is chosen as per battery specifications
- Use only the charger specified by phone manufacturer !

Image source: Internet

How would you explain this to a 2 yrs old

Image source: Internet

Phone is eating food!

Image source: Internet

Do these appliances also eat food?

Image source: Internet

Do these appliances also eat food?

They do! But they don't have stomach!

Image source: Internet

Batteries and Human Beings

- A perfect analogy to understand
- Form of energy – Chemical in both the cases

- Source of energy
- Energy storage
- Charge rate and time
- Discharge rate and time
- Energy draining beyond a limit
- Recovering some energy after some rest
- Recovering from a fatal state

Types of Batteries

- Commonly used rechargeable batteries
  - Li-ion / Li-Poly (Lithium ion / Lithium polymer)
  - Pb-Acid (Lead Acid)
  - NiCd (Nickle Cadmium)
  - NiMH (Nickle Metal Hydride)
- Different chemistries,   different terminal voltages
- Somewhat similar characteristics (like humans)
- Li-ion / Li-Poly: most popular for portable and wearable IoT
  - Highest energy density
  - Low maintenance
  - Ease of handling

Reference - http://batteryuniversity.com/learn/archive/whats_the_best_battery

Important Factors for Wearable / Portable

- Small size
- High energy density
- Low price
- Longevity is least bothered

Li-ion Battery

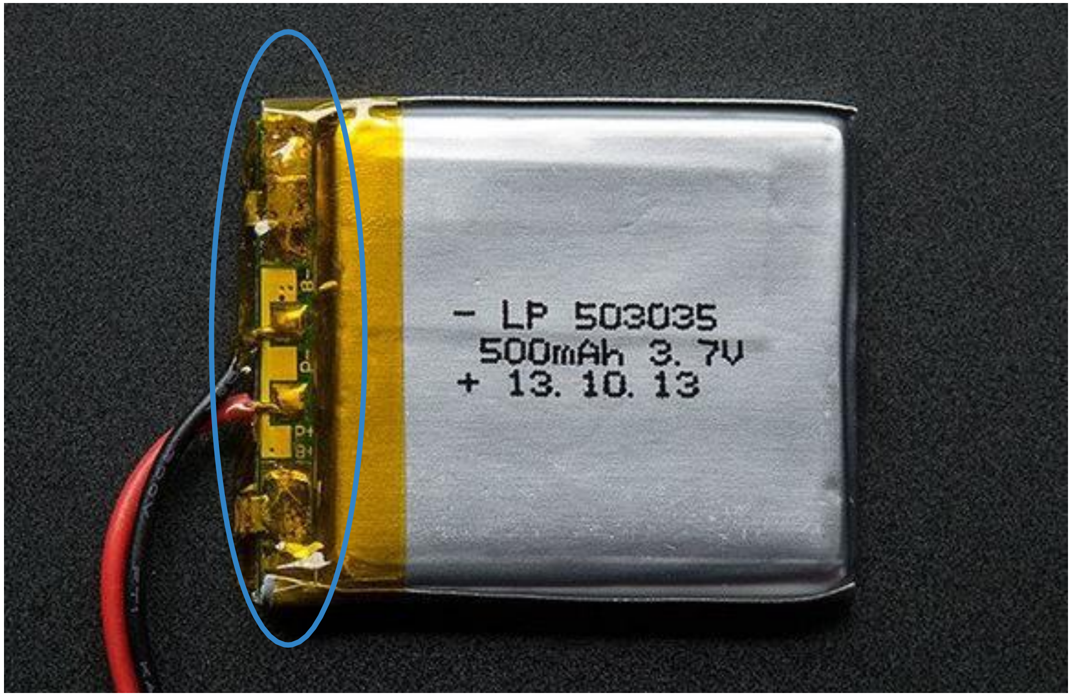
- Typical terminal voltage of a unit cell (3.7V)
- Battery capacity (milli-Amp-Hours or mAH or C)
- Charging current
  - Recommended C/2 for best performance
  - Charging time with C/2 is ~2 hours
- Fast charging (2C, max limit)
  - Typical is 2C
  - Max limit of charge current
  - Must not be used on regular basis

Li-ion Battery

C-rate	Time
5C	12 min
2C	30 min
1C	**1h**
0.5C or C/2	2h
0.2C or C/5	5h
0.1C or C/10	10h
0.05C or C/20	20h

Table 1: C-rate and service times when charging and discharging batteries of 1Ah (1,000mAh)

Protection Circuit Module



- Over charging protection voltage (~4.2 V)
- Over discharging protection voltage (~2.7 V)
- Max discharging current protection
- Over current protection
- Short circuit protection

Charging Profile

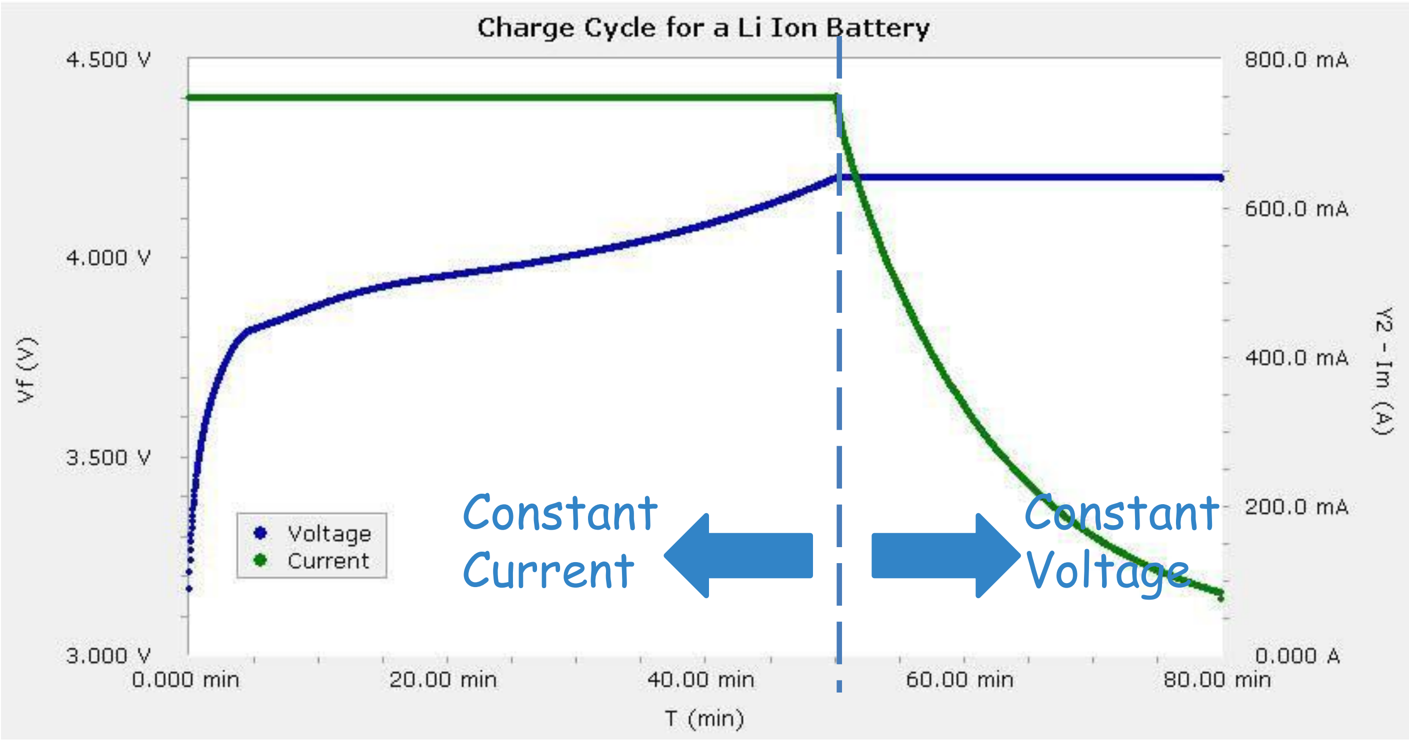
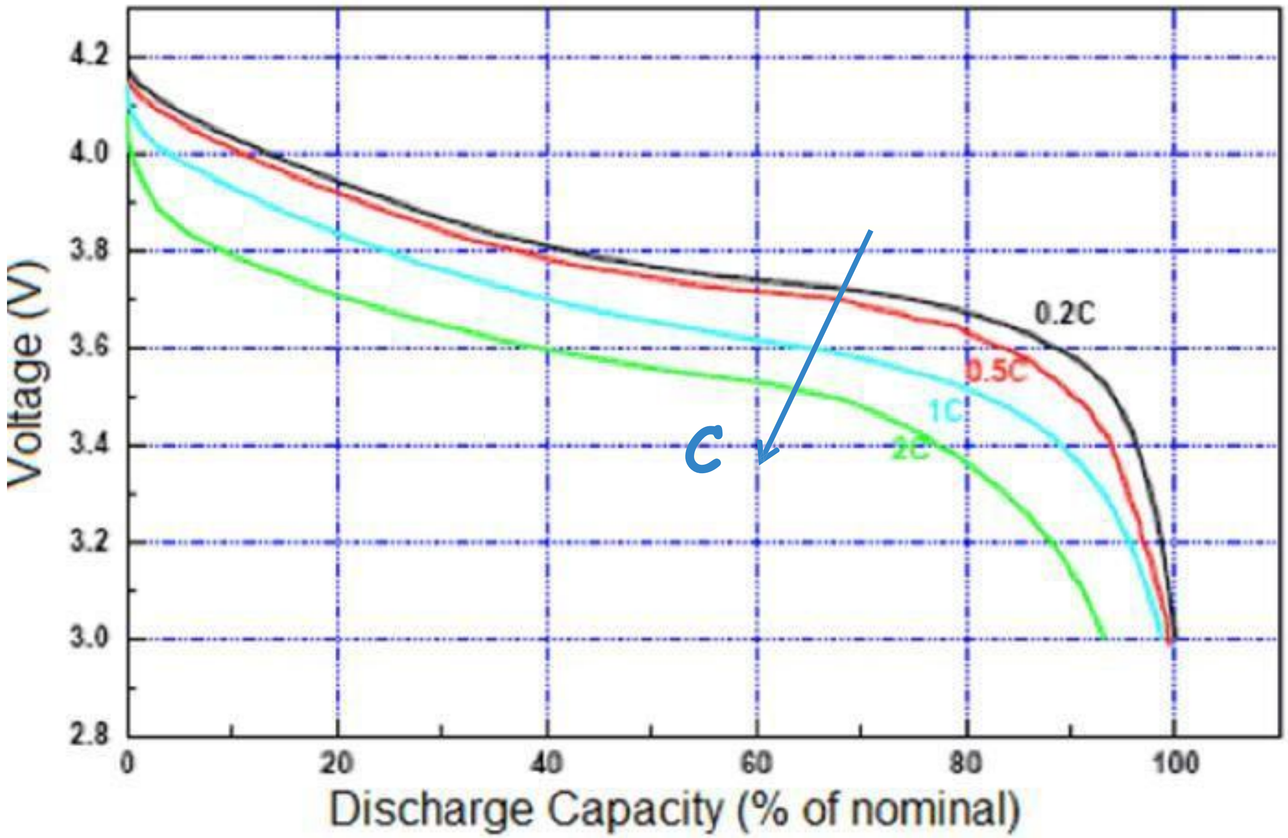


Image source: Internet

- Terminal voltage profile
  - Varies nonlinearly. Faster variation near empty and slower at near completion
  - Approximated as linear for indication purpose
  - Typically varies from 3.2V (full discharge) to 4.2V (full charge)

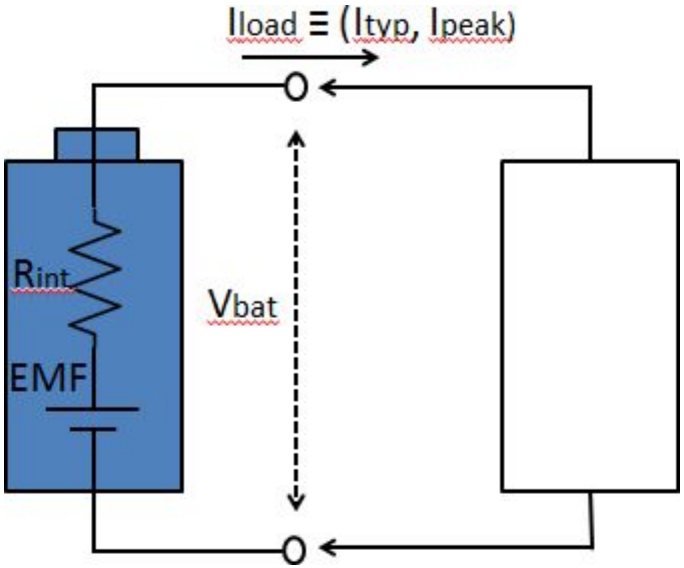
Discharging Profile



- Cutoff voltage (3.0 V) at room temperature
- Faster discharge results in reduced capacity
- Charging cycles of a battery are limited

Image source: Internet

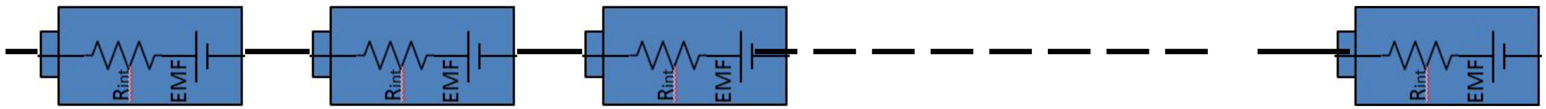
InternalResistance



- OCV or EMF (Li-ion): 2.7 (min), 3.7 (typ), 4.2 (max)
- Rint: ~500 mOhms
- Vbat = EMF – Iload * Rint

- Non idealities can be modeled as internal resistance
- Remember momentary current surge of 1A can cause terminal voltage drop by 0.5V !!
- Internal resistance limits battery backup of a system!

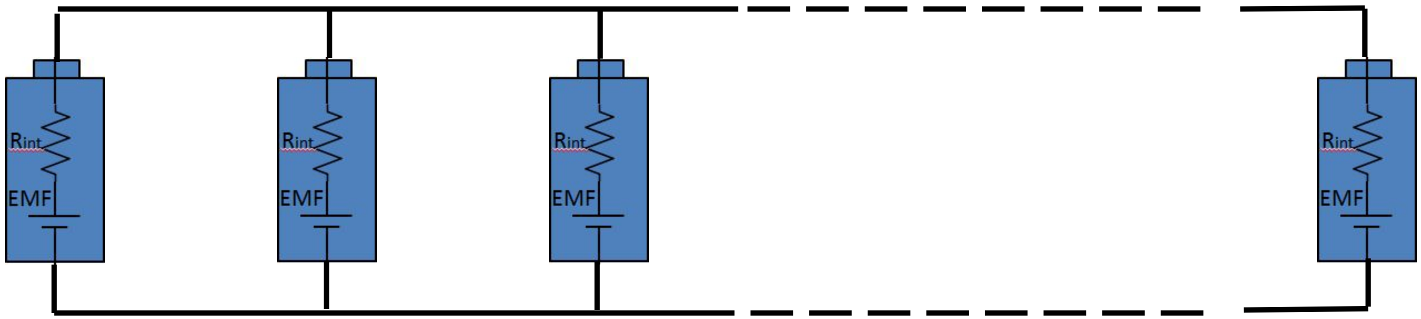
Series Combination



$EMF = \sum EMF_i$ $R_{int} = \sum R_{int,i}$

- For increasing the terminal voltage (V, 2V, …)
- Results in increased internal resistance (r1+r2+…)
- Capacity remains unchanged of the resultant battery (C)
- Use batteries from the same manufacturer, same model

Parallel Combination



Capacity = ∑ Capacity$_i$ **$1/R_{int} = \sum 1/R_{int,i}$**

- For increasing the capacity (C1+C2+…)
- Results in reduced internal resistance (r1||r2||…)
- Terminal voltage remains unchanged (V)
- Use batteries from the same manufacturer
- Defect in any one battery of the combination gets distributed in the resultant battery system

Elasticity (The ability toself recover)

- Tendency of battery to gain some strength given rest from the normal operation.
- Measure terminal voltage when in operation. Stop using it for few minutes. Measure the voltage again.
- Fully drained out cellphone also becomes alive for few minutes, after sometime

Battery's shape

Cylindrical

Prismatic

Coin Cell

- Form factor, energy density, charge cycles

Image source: Internet

Flexible Li-ion Batteries for IoT, Wearables

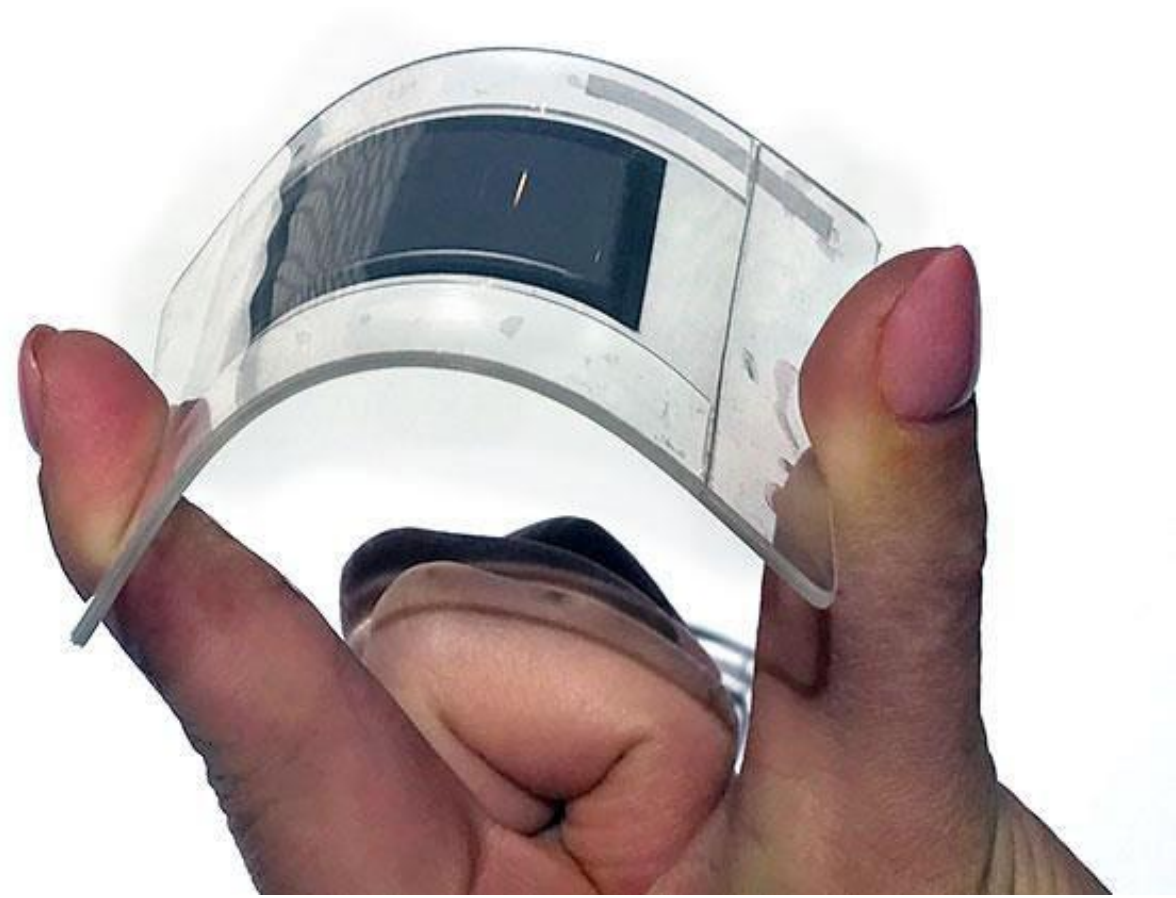


Image source - http://spectrum.ieee.org/tech-talk/consumer-electronics/portable-devices/ces-2017-panasonic-shows-off-bendable-lithiumion-battery-for-iot-wearables

Universal Battery Charger

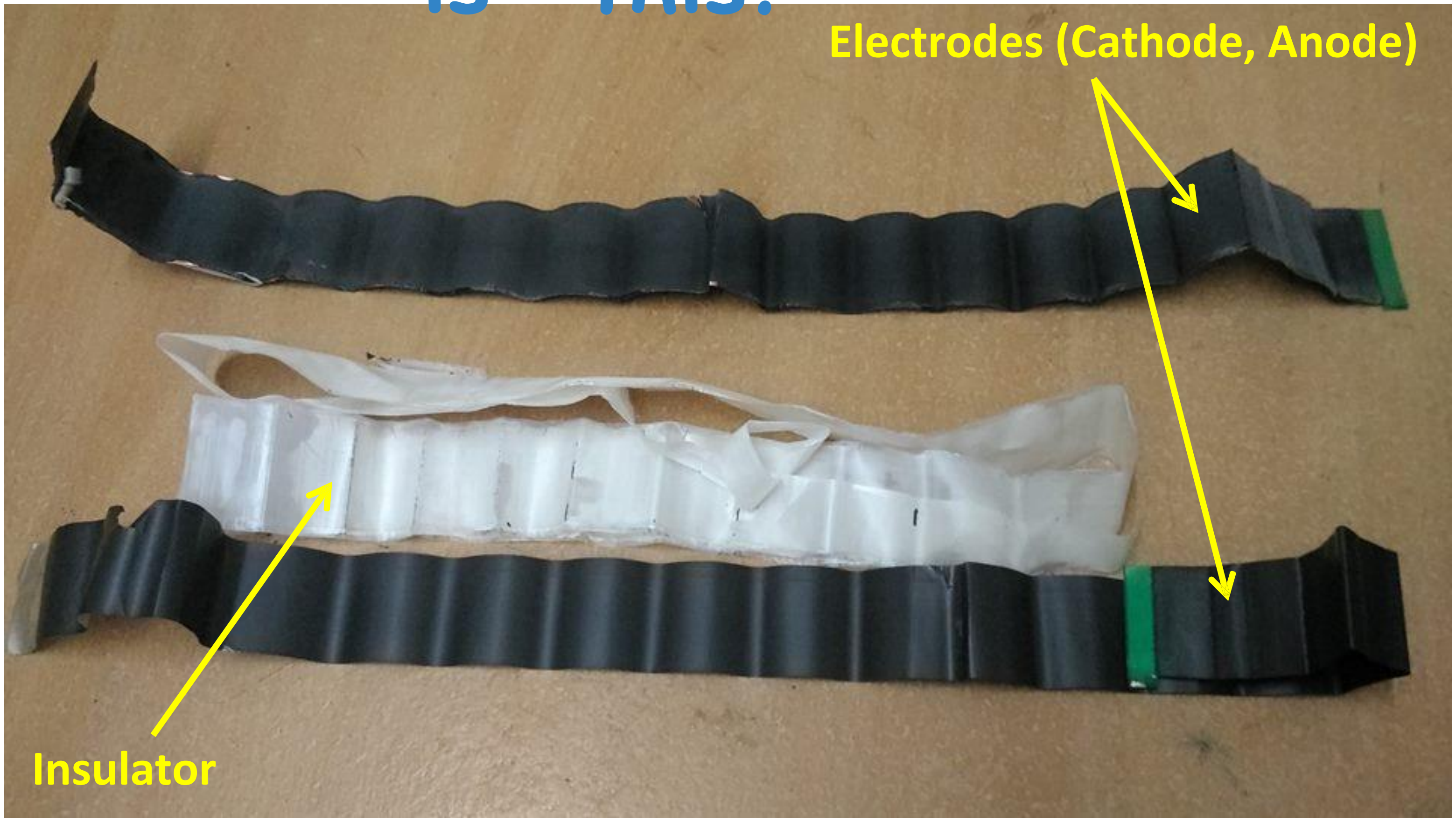
Image source:

Flex Your Neurons

We were shocked when we measured thickness of this coin cell using this vernier caliper, without much thinking. Can you tell why did it happen?

Flex Your Neurons: What is this?

Flex Your Neurons What is this?



Li-ion battery unpacked!

Summary

- Similar to human beings
- Energy storage (food)
- Internal resistance (weakness, immunity)
- Li-poly rechargeable battery
  - Capacity 3.7V XXXXmAH (milli Ampere Hours)
- Terminal voltage's variation with charge/discharge
- Max. charging & discharging rates (2 hrs charging)
- Serial & parallel combinations
- Protection circuit - Min and max cut-off voltages

Thank You