

Energy supply and distribution

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ELEC518, Spring 2011

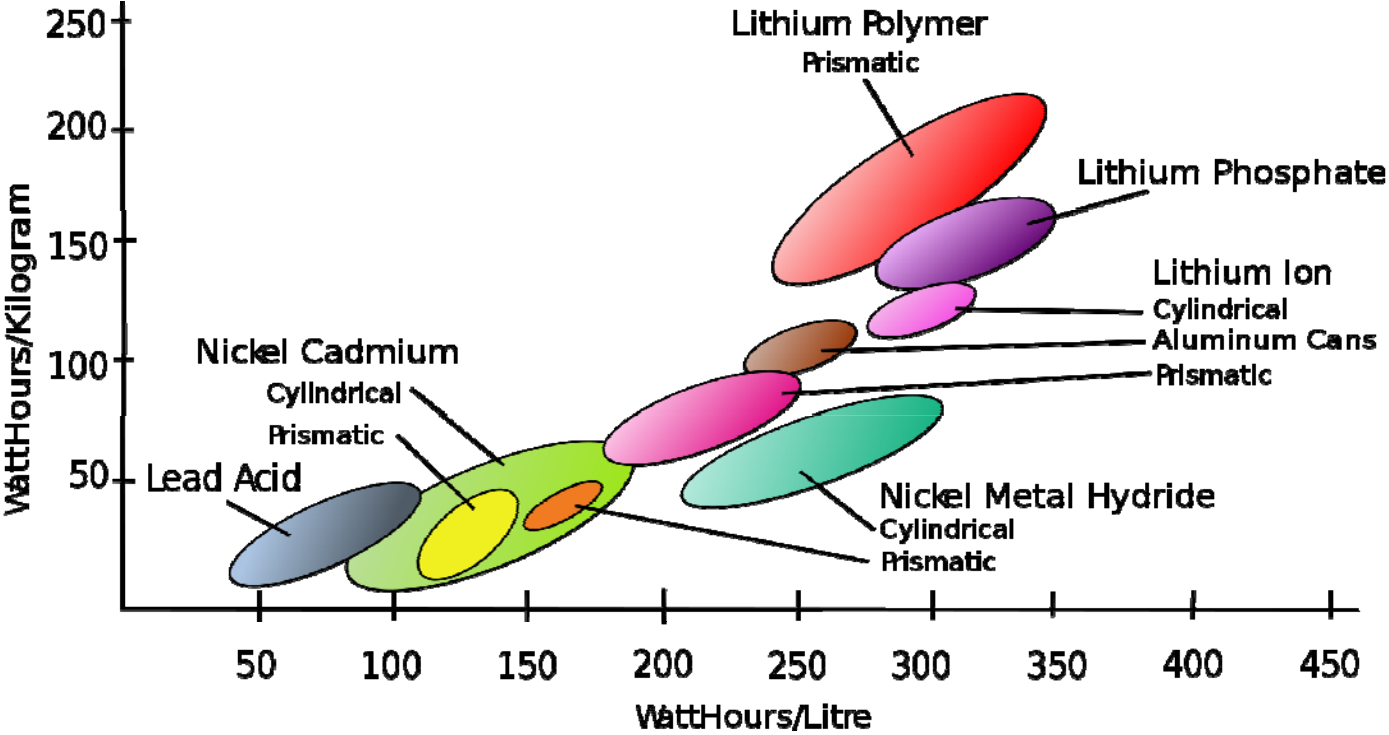
Outline

- Battery technologies
 - Battery properties
 - Fuel cell batteries
 - Smart battery interface
- Power distribution

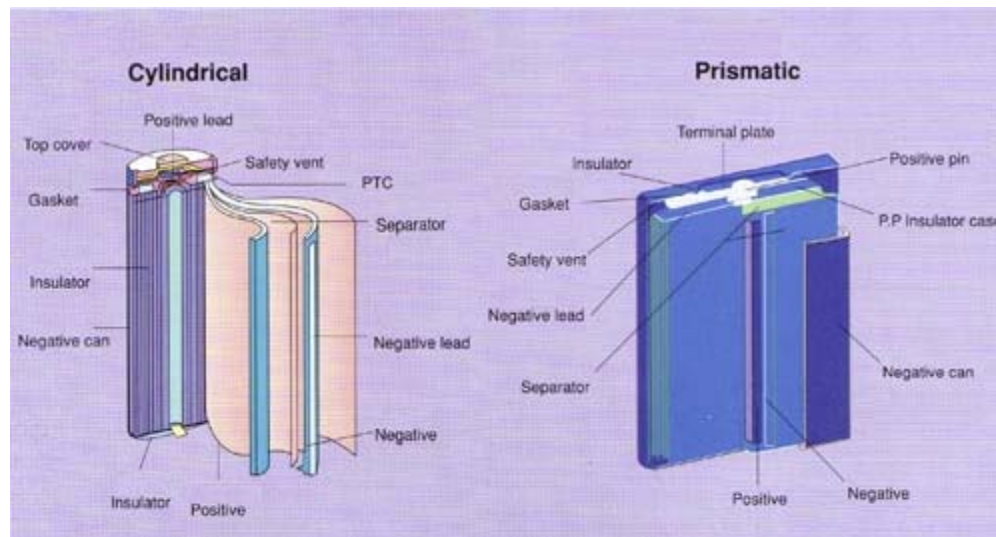
Brief history of batteries

- Battery density increases about 10% annually
 - 1950 Nickel Cadmium (NiCd) (banned in EU from 2006)
 - 1990 Nickel-metal Hydride (NiMH)
 - 1991 Lithium Ion (Li-ion)
 - 1999 Li-ion Polymer
- Most devices have battery capacity within 1500mAh, typically slightly more than 1000mAh (@3-5V)
 - Nokia 9500 communicator: 1300mAh (@3-5V) Li-ion Polymer, 172 grams
 - Dell Latitude D610: 4700mAh (@11V) Li-ion, 2300 grams

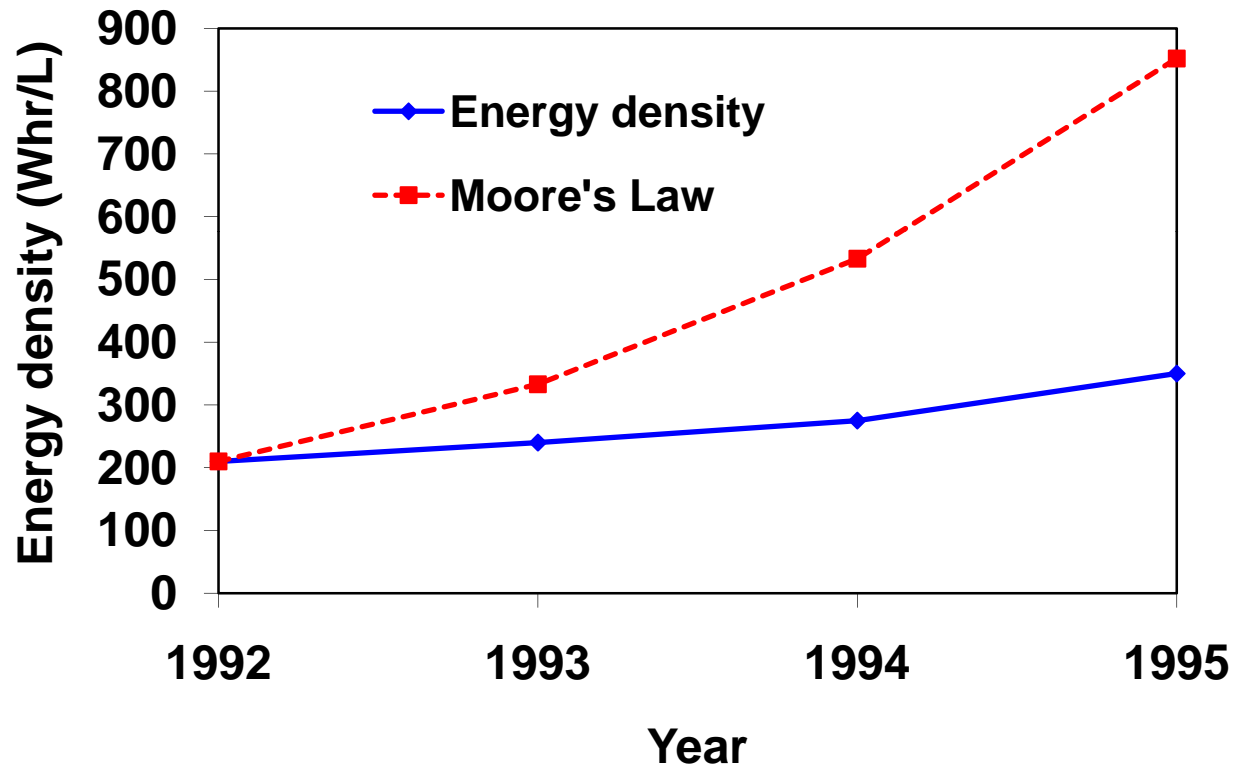
Energy density



Cell structures

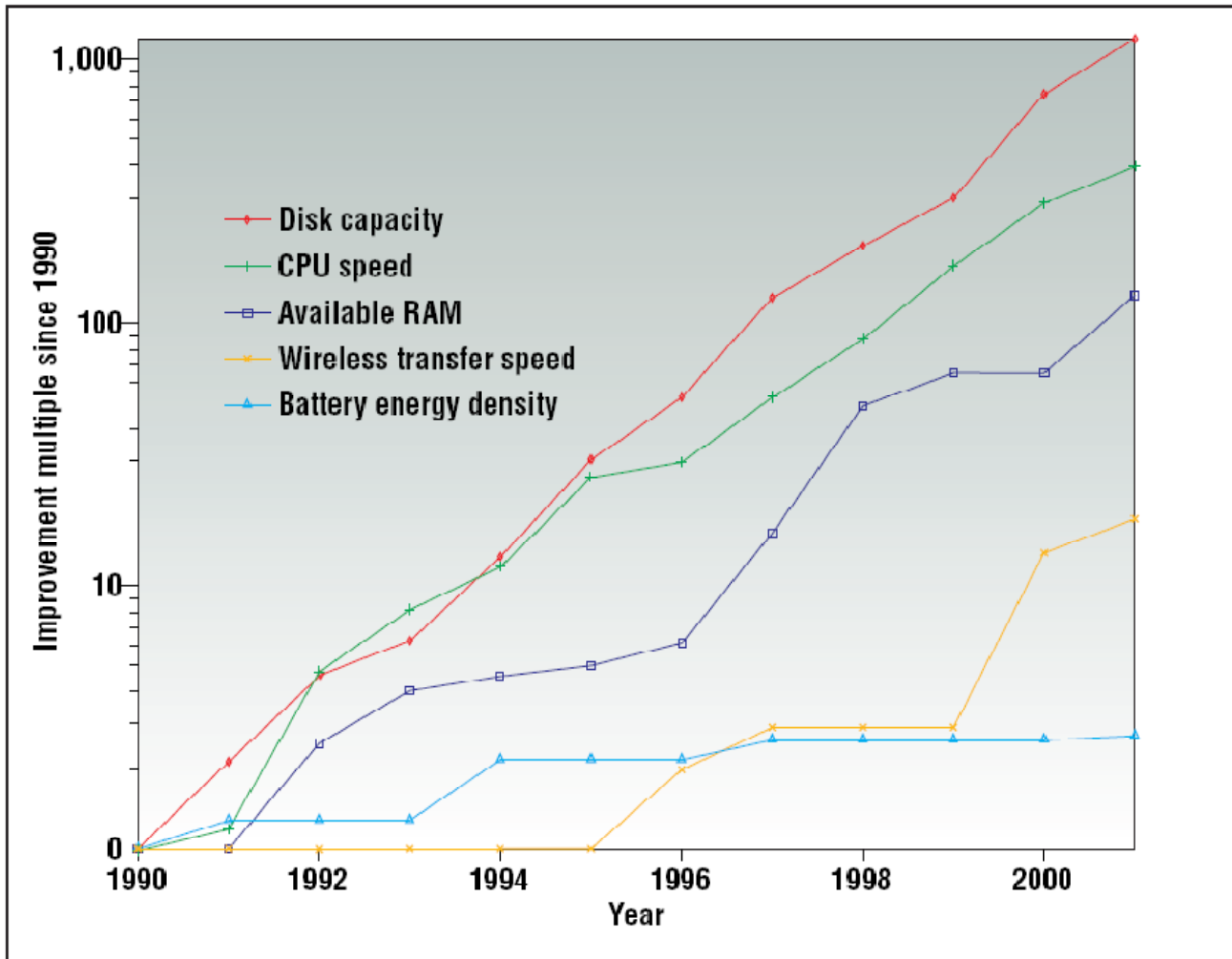


Battery properties I



Volumetric energy density for Li-Ion cells Powers,
1994

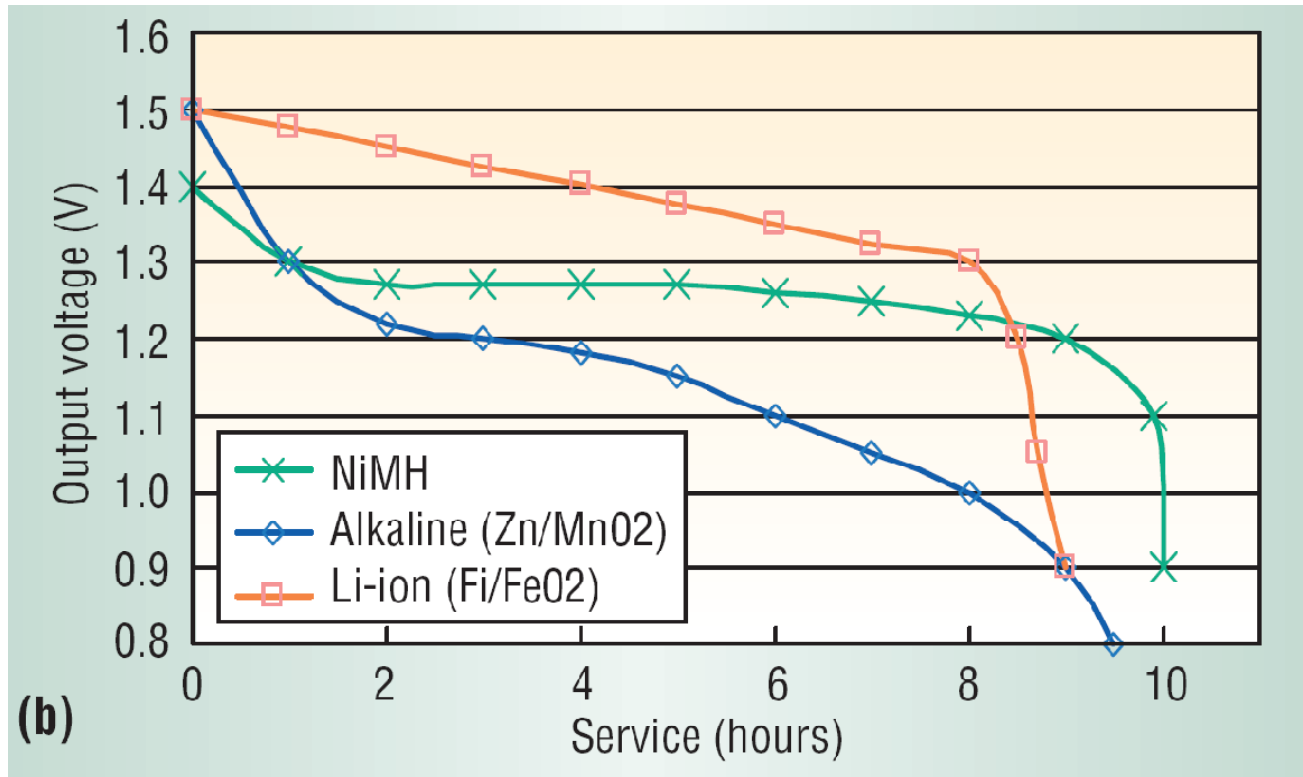
Battery properties I (Contd.)



Starner, 2003
(IEEE Pervasive)

Figure 1. Improvements in laptop technology from 1990–2001.

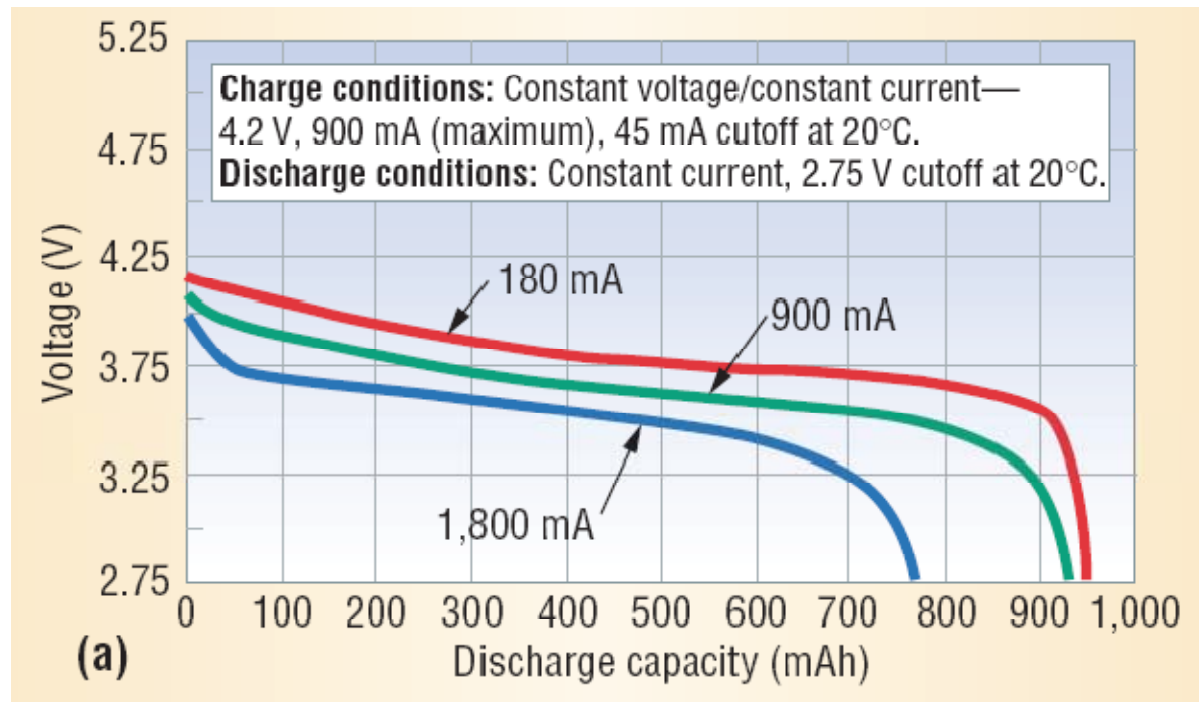
Battery properties II



Voltage drop

Casas & Casas, 2005 (Energizer batteries)

Battery properties III

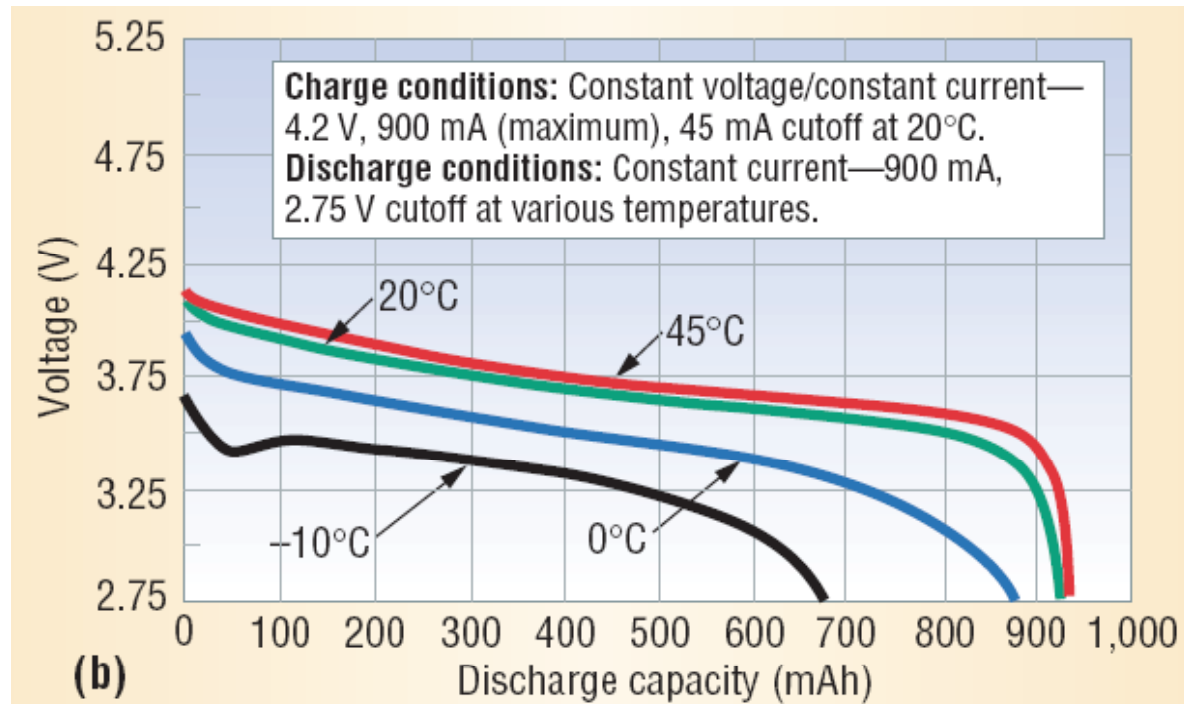


Rate dependent

Lithium-Ion battery

Rao et al 2003

Battery properties IV

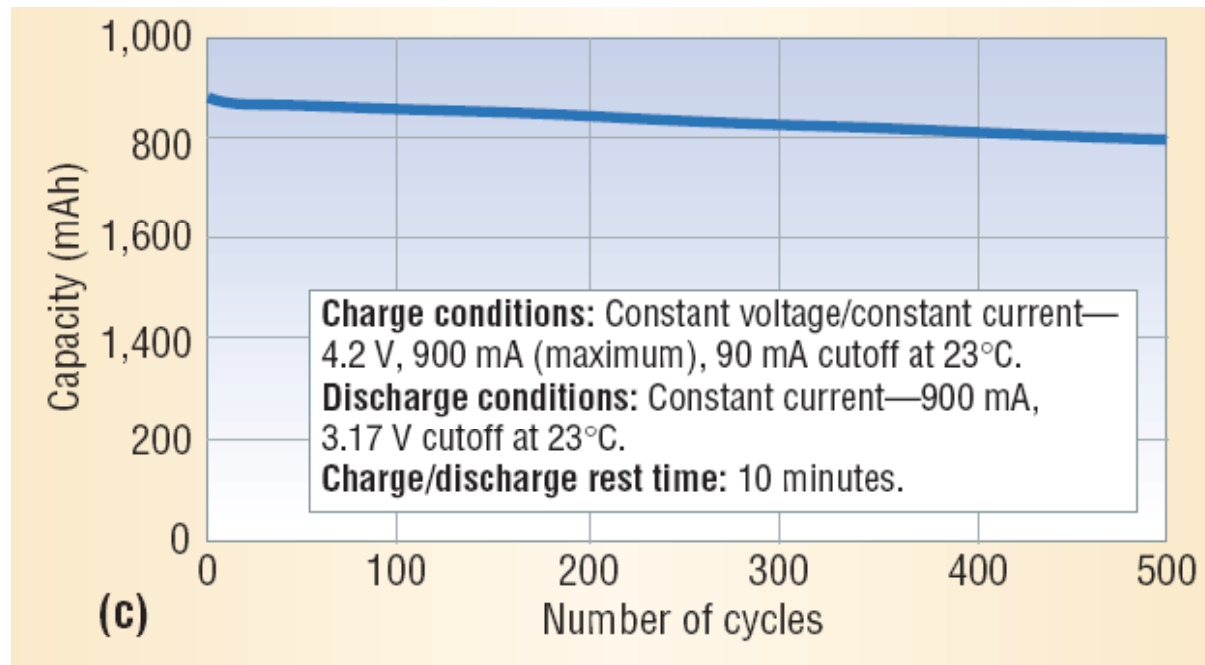


Temperature dependent

Lithium-Ion battery

Rao et al 2003

Battery properties V

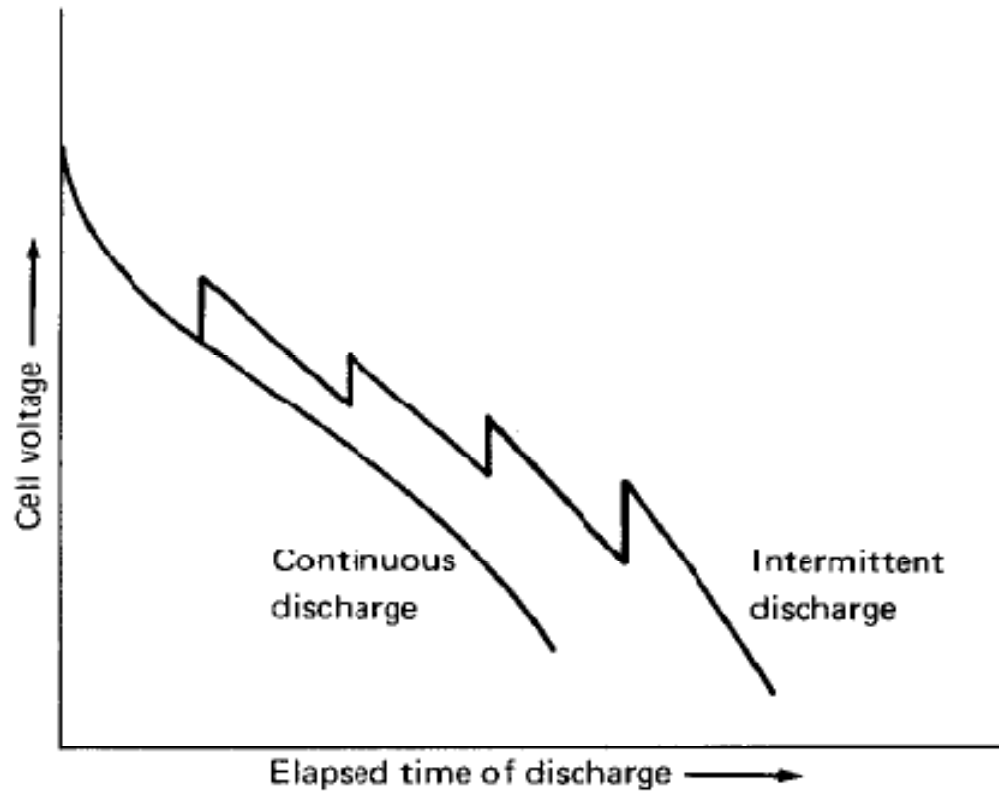


Capacity loss (aging)

Lithium-Ion battery

Rao et al 2003

Battery properties VI



Recovery effect

Martin, 1999

Wireless charging



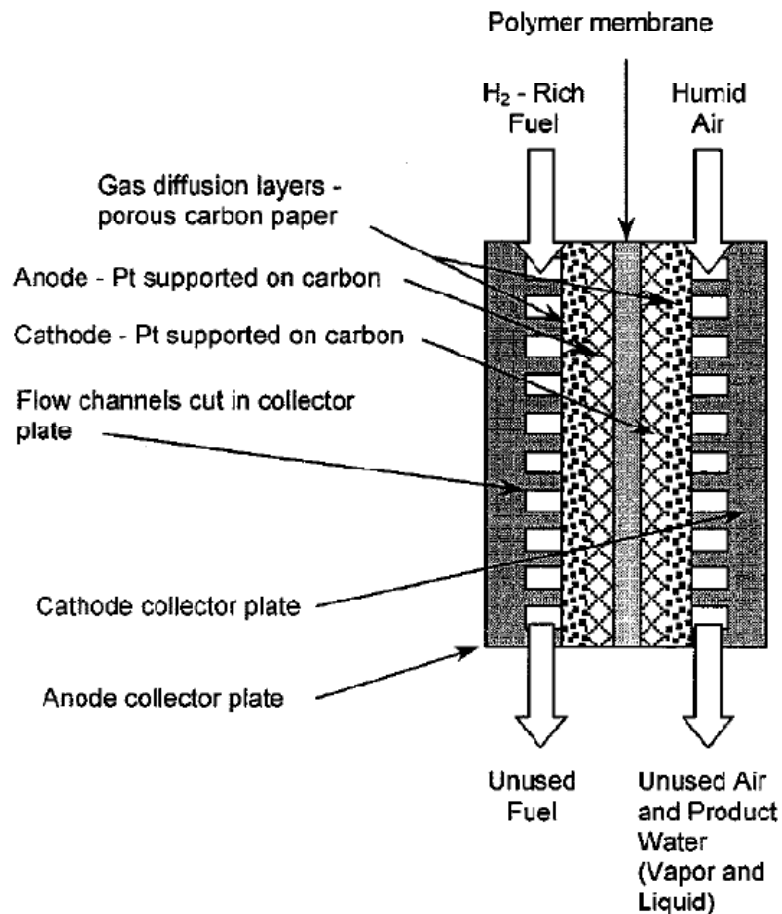
The Latitude Z on wireless charging station, and wireless dock adapter on the right. (Credit: Erica Ogg/CNET)

Wireless charging (Contd.)



Palm Pre™ Touchstone™ Charging Dock

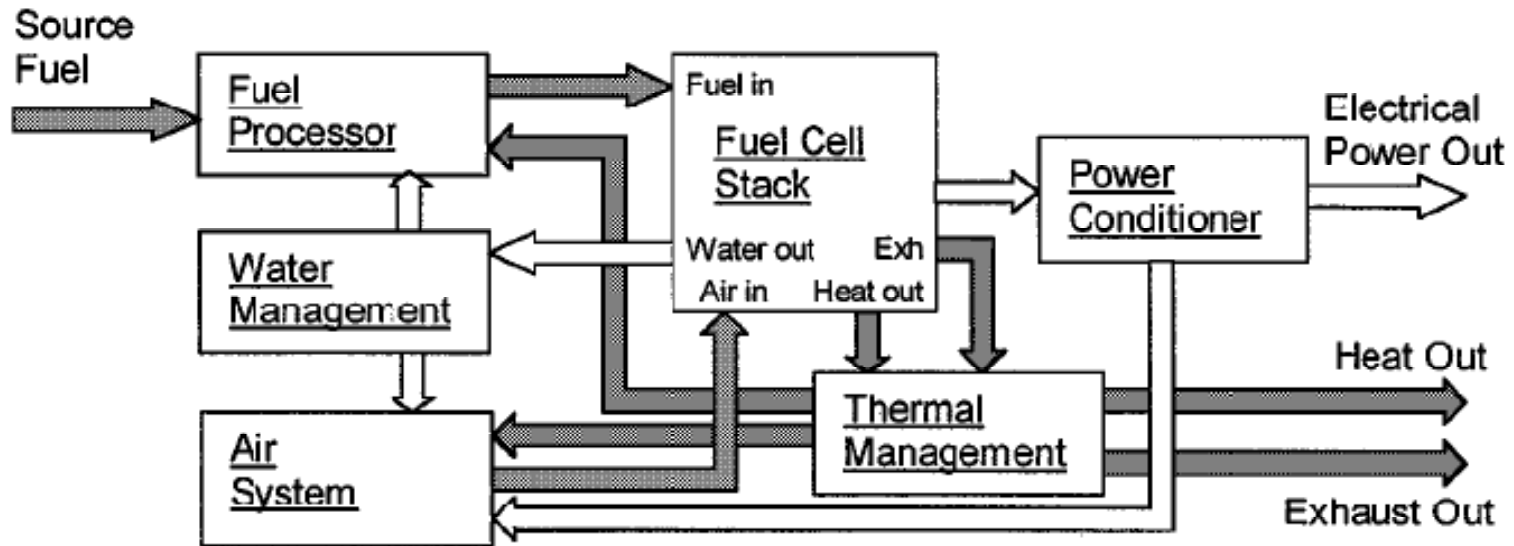
Fuel cell for portable power



- Proton exchange membrane (PEMFC)
- Direct methanol (DMFC)
- Low operating temperature (60-80 degree C)

Ellis, Spakovsky & Nelson, 2001

Fuel cell system



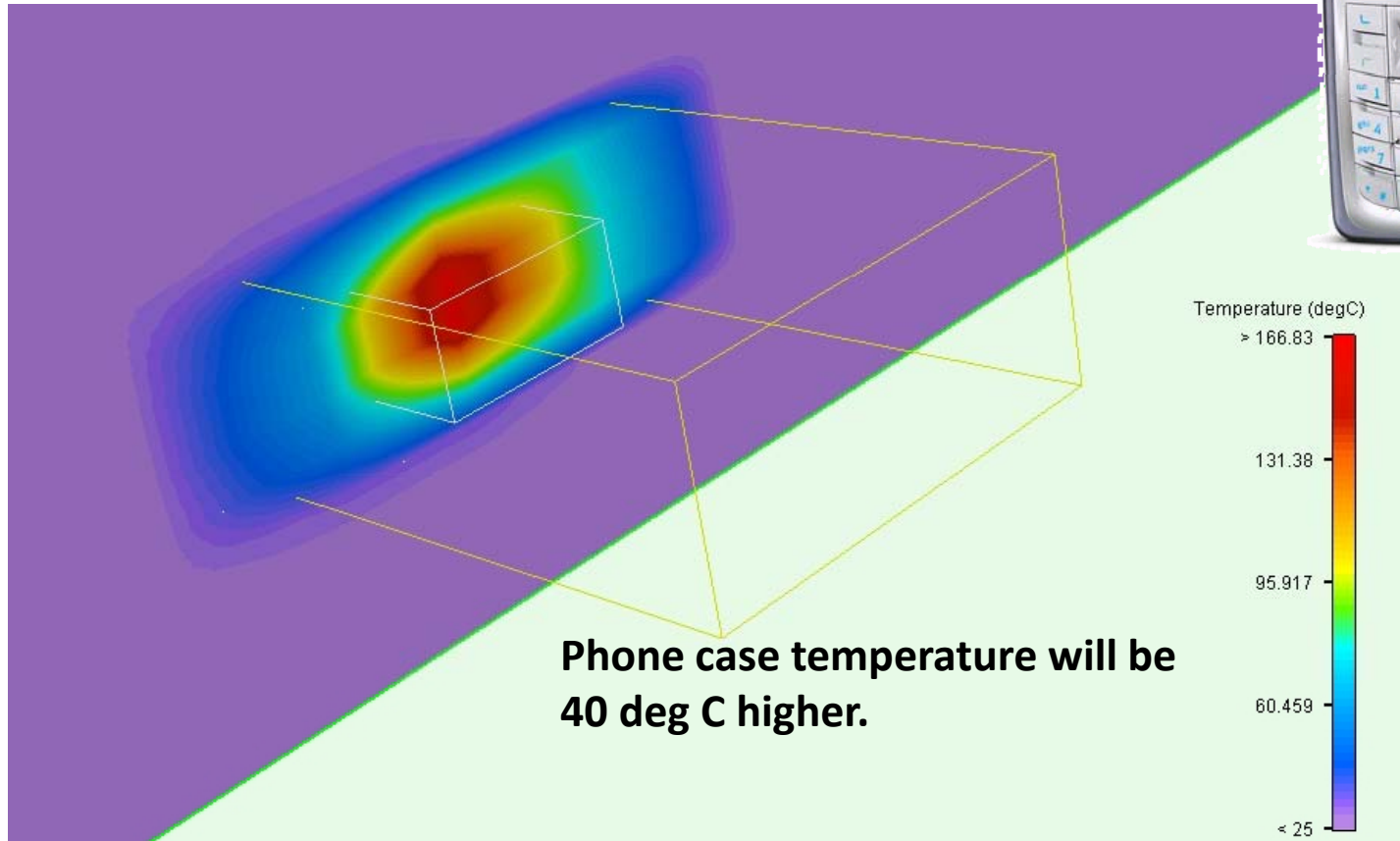
Fuel cell system schematics

40-50% efficiency

Ellis, Spakovsky & Nelson, 2001

A hot case: 3-Watt Nokia 3120

Every One Watt increases surface temperature by about 13 deg C



Phone case temperature will be 40 deg C higher.

Applications



\$39---3300mAh
fuelcellstore.com

- Portable energy storage (charger)
- Refillable fuel cell



Motorola: under development

Hitachi prototypes (2005)

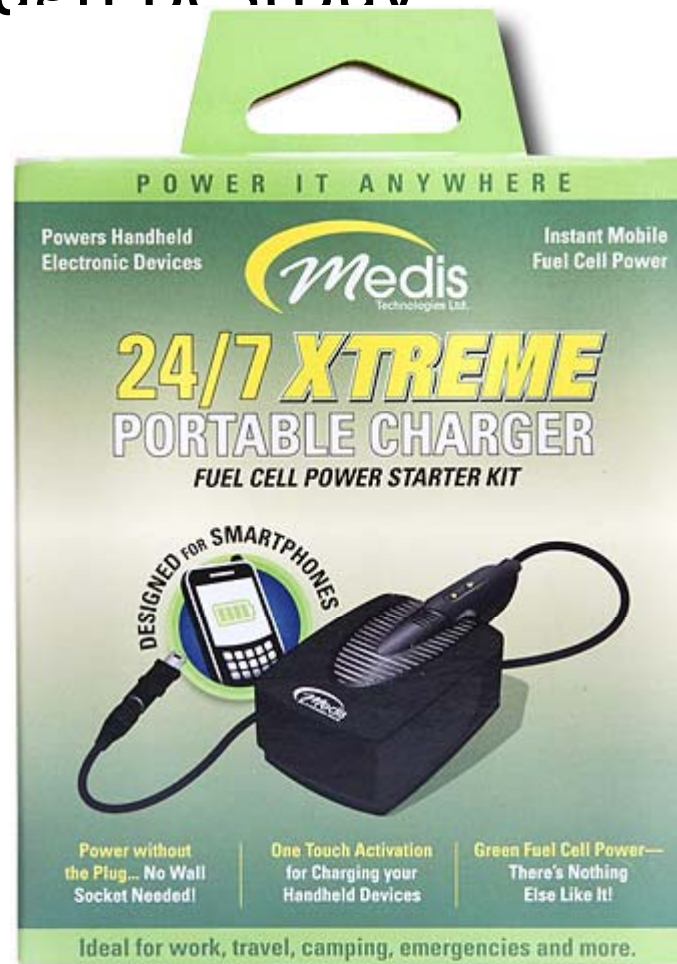


Toshiba prototypes (2005)



Medis (2008)

- Available through BestBuy



Supercapacitors/Ultracapacitors

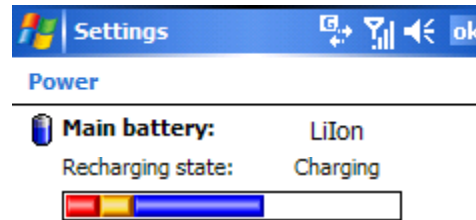
- Fast charging
- More cycles
- High power density
- Low energy density



http://news.cnet.com/8301-11128_3-10363496-54.html

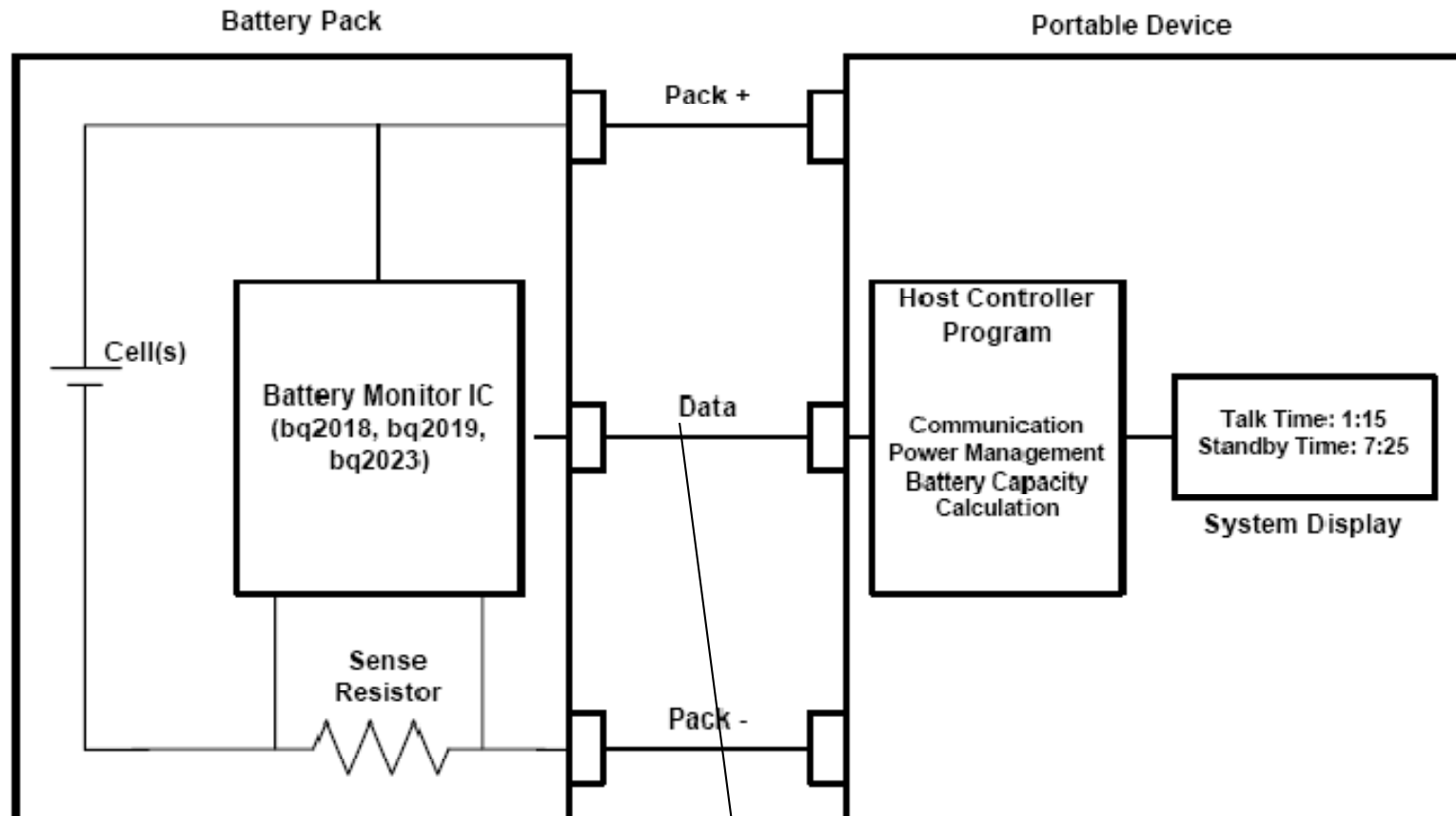
Battery management

- Accurate battery capacity monitoring



- TI BQ2023
 - Coulomb (Charge) counting-based monitoring
 - Single-wire advanced battery monitor IC

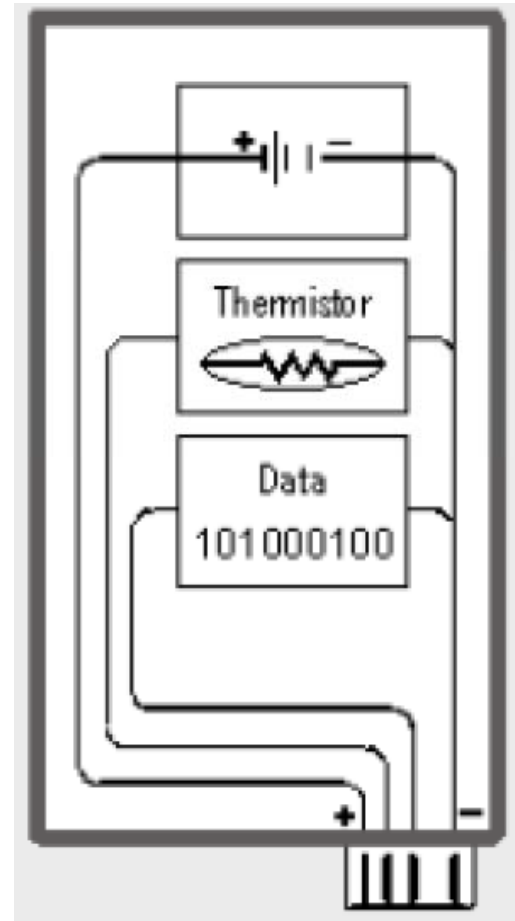
Battery gas (fuel) gauge



SDQ single-wire serial communications interface

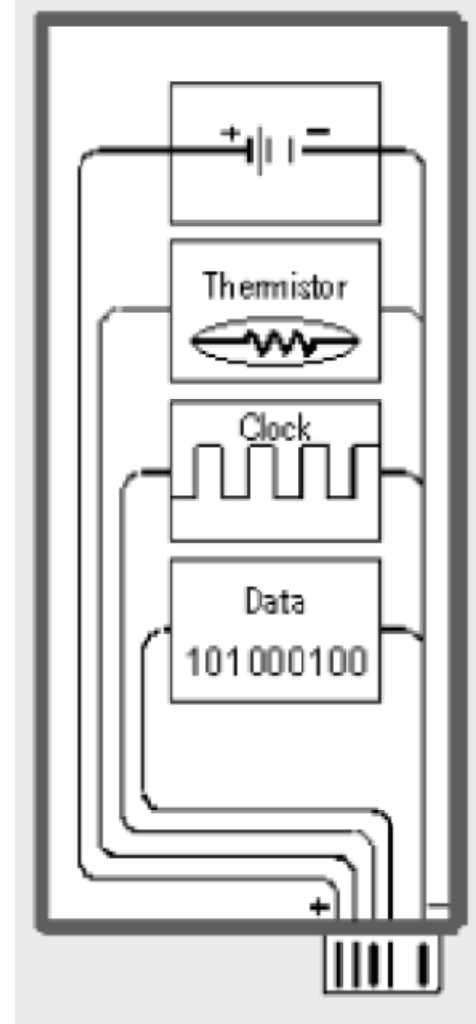
Smart battery interface

- Single wire
 - Embedded clock



Smart battery interface (Contd.)

- Two-wire SMBus system
 - One wire for clock
 - TI BQ2040



Windows Mobile battery API

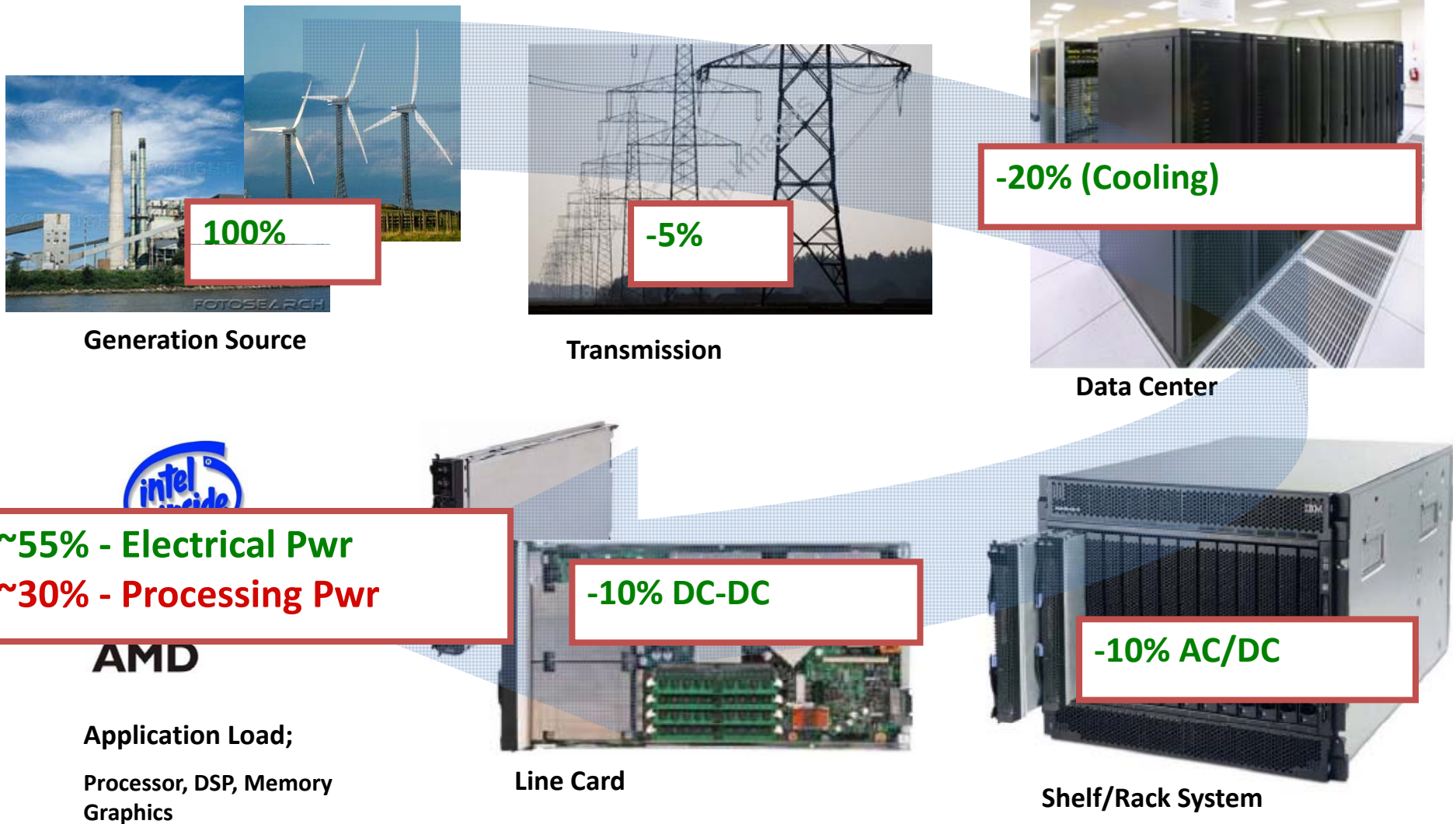
- Battery is treated as a peripheral device
 - Battery driver

```
DWORD GetSystemPowerStatusEx2  
( PSYSTEM_POWER_STATUS_EX2 pSystemPowerStatusEx2,  
DWORD dwLen, BOOL fUpdate );
```

Discussion

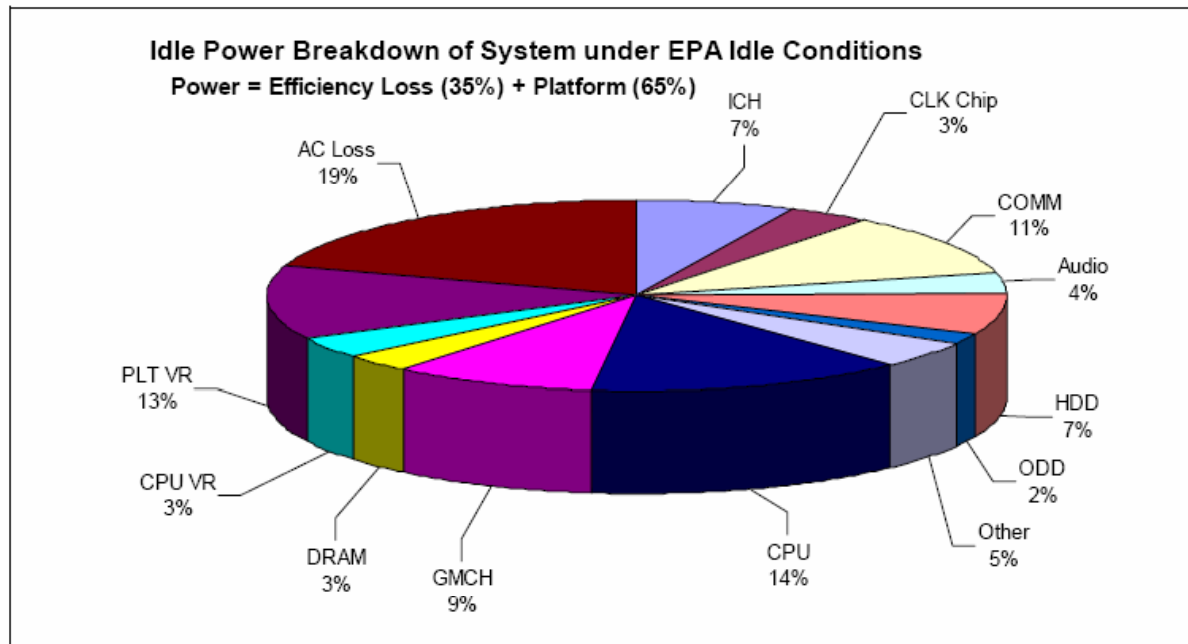
- Why is battery gas gauge difficult?

Power distribution



Power distribution

Typical Notebook Idle Power Breakdown



VR: voltage regulator

ENERGY STAR* System Implementation

Published by Intel with technical collaboration from the U.S. Environmental Protection Agency

Whitepaper

February 2007
Revision -001

Voltage regulator (DC-DC)

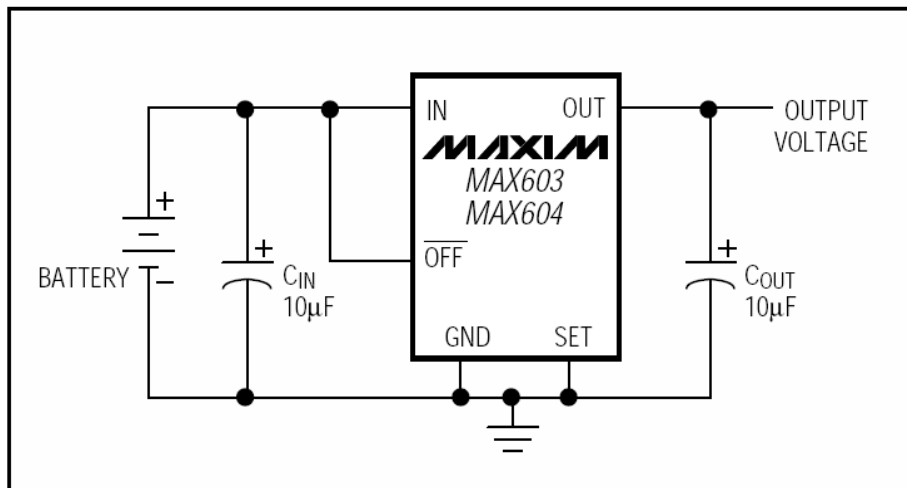
- Maintain a constant voltage output

Property	Linear regulator	Switching regulator
Price	Low for low power	High for low power
Step-up?	No	Yes
Efficiency	Low	High
Output noise	Low	High

Linear regulator

- Output voltage
- Dropout
- Output current limit
- Input voltage range

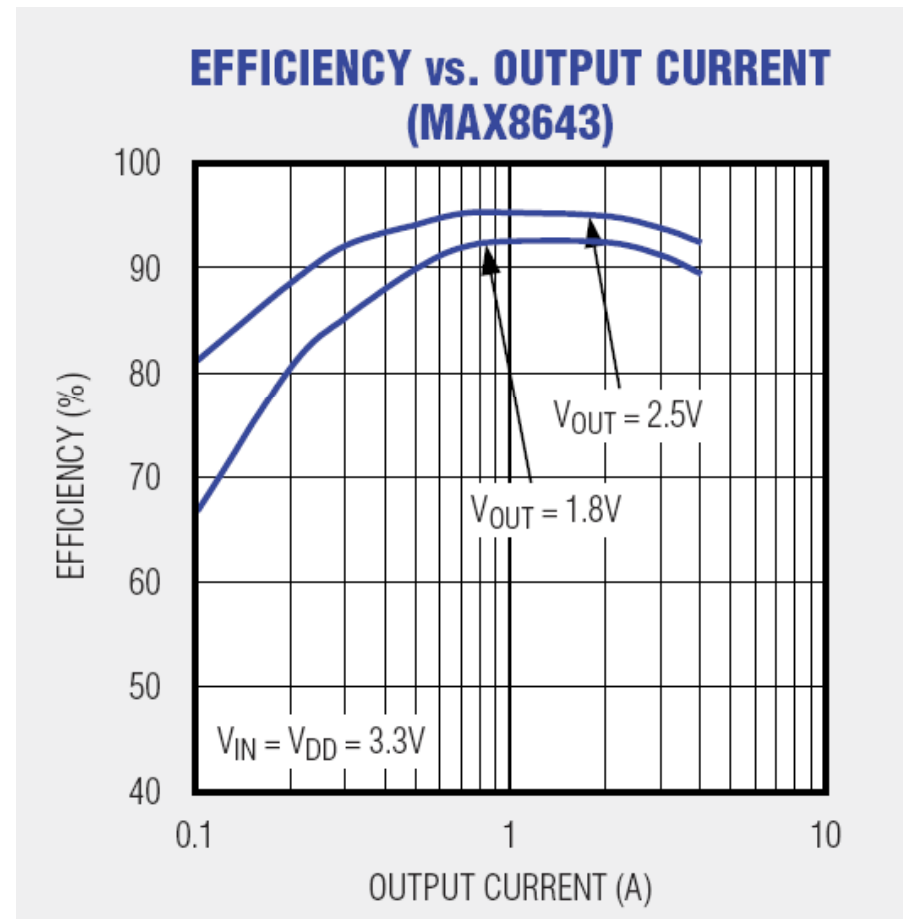
Typical Operating Circuit



Linear regulator (Contd.)

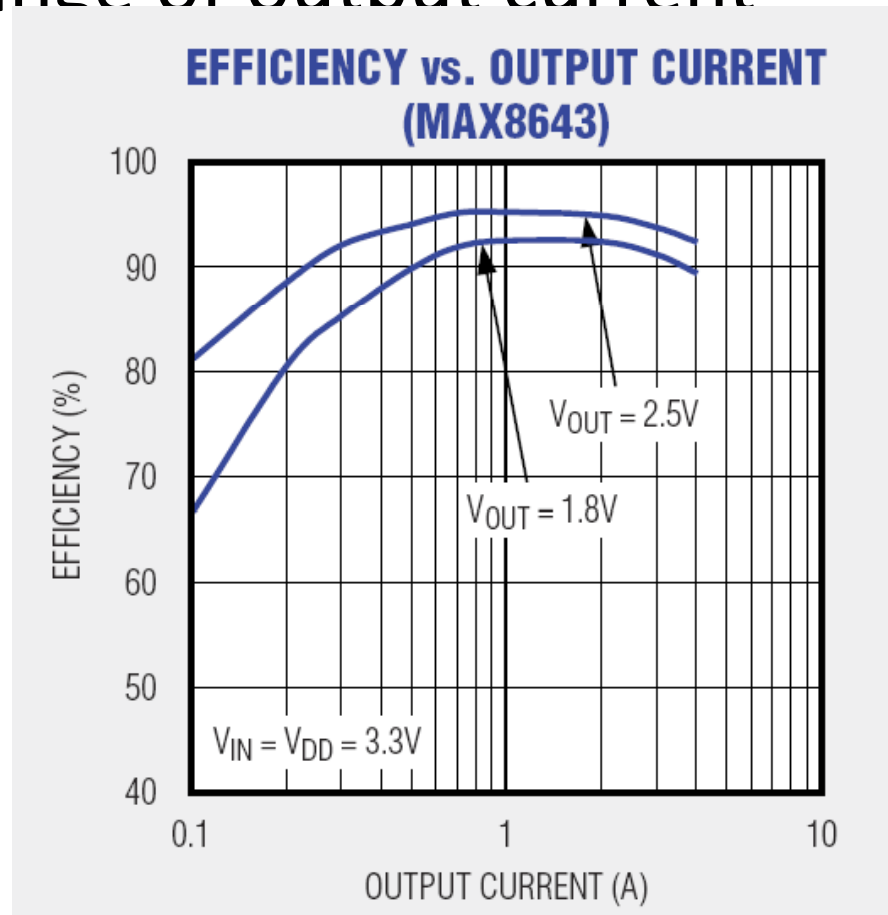
- Efficiency

Power waste $\approx (V_{in} - V_{out}) * I_{load}$



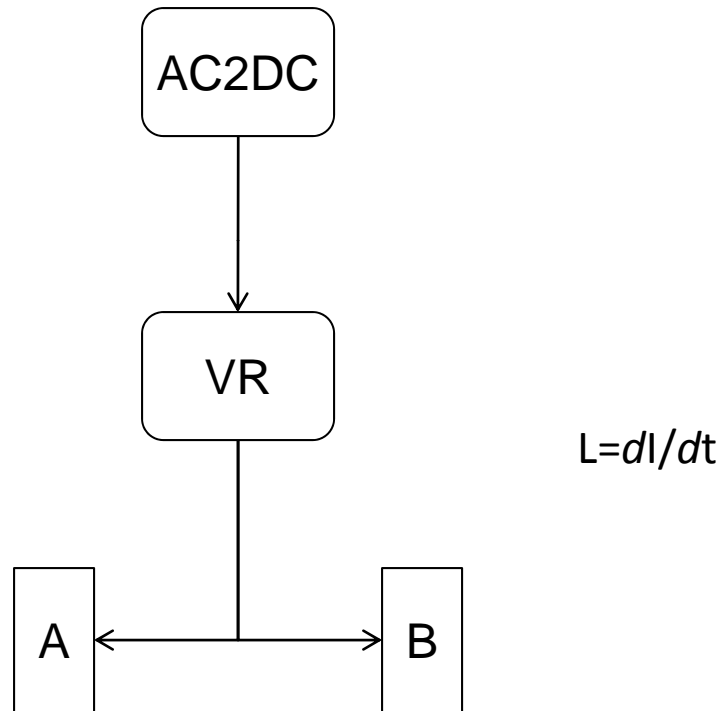
Regulator network

- A regulator achieves best efficiency over a narrow range of output current



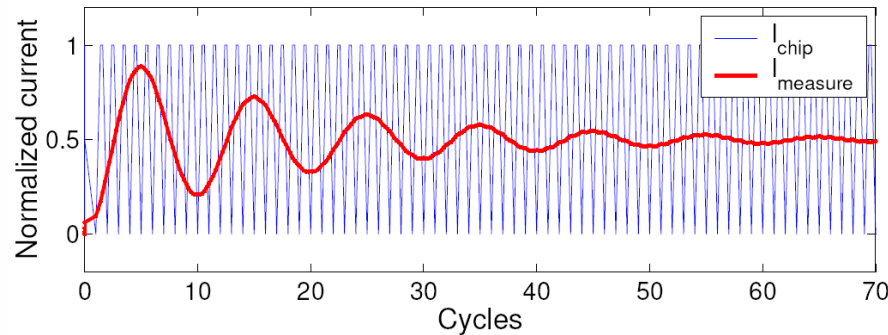
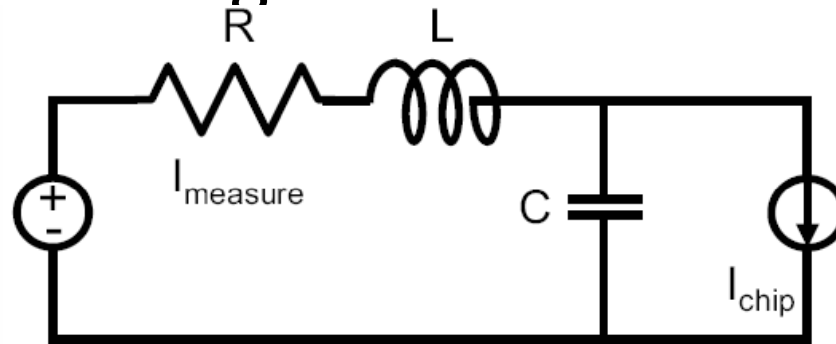
Decoupling capacitors

Bypass capacitors



Impact on power measurement

- Low-pass filtering effect



Quming Zhou, Lin Zhong, and Kartik Mohanram, "Power signal processing: A new perspective for power analysis and optimization," in *Proc. ACM/IEEE Int. Symp. Low Power Electronics and Design (ISLPED)*, August 2007.

<http://batteryuniversity.com/>