UNIVERSITY OF MICHIGAN-DEARBORN

Safely Charging EV and PHEV from the Electricity Grid

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Facts about Lithium Ion Batteries

- Lithium ion batteries do not like over charge or over discharge
  - Potential damage and hazards/risks
- Construction of lithium ion battery
  - Very thin metal (15 to 50 um),
    - Cu for anode, Al for cathode
  - Metal oxides, powder
  - Plastic material for packaging
  - Flammable acidic liquids
- Highly sensitive to defects, process impurity, improper packaging, and improper handling

Source of Hazard/Risks

- Oxygen
  - Released from layered cathode during over charge
  - Oxygen access to cells after rupture/opening via gas pressure buildup or external impact
- Combustibles
  - Lithium
  - Electrolyte (solvents and salts)
  - Gasses (hydrogen rich)
- Heat/Energy release via anode and cathode decomposition
  - Cell short, internal or external

Safety: A Major Concern

- Battery safety
- Electricity safety

Before

After

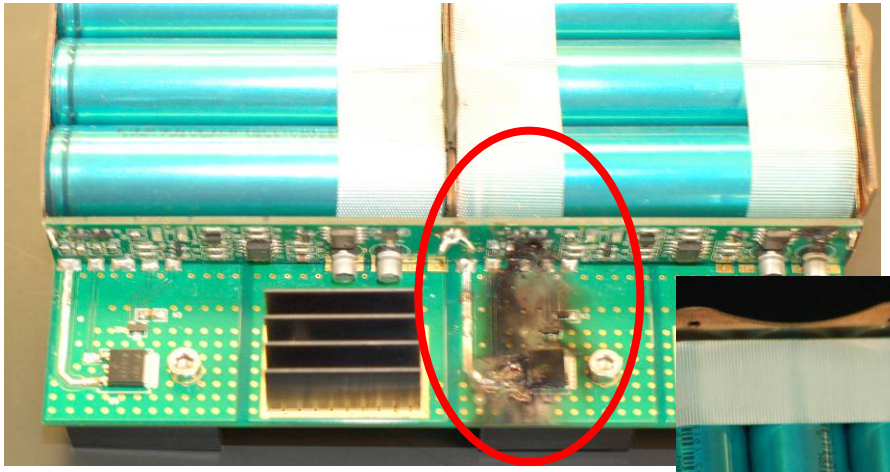
Fire Damaged PHEV Prius

Issues of Lithium Batteries

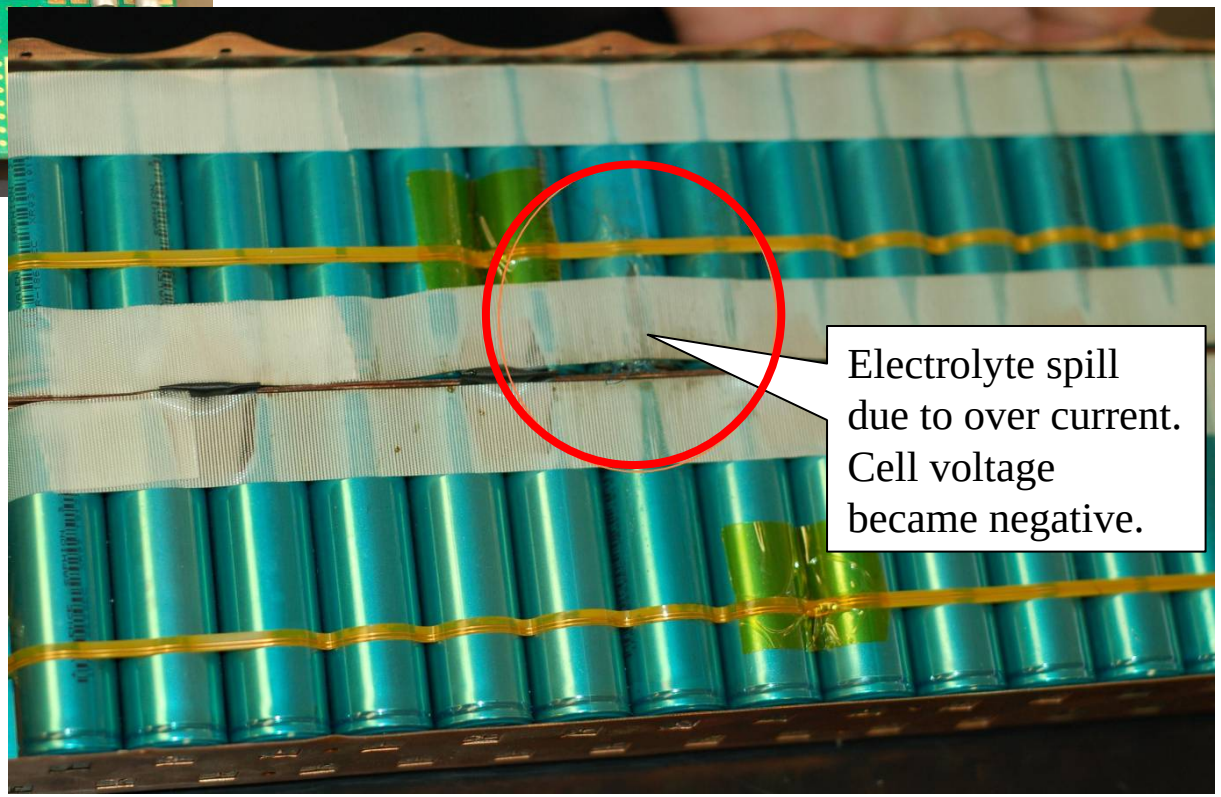
- Safety
  - Electrolyte spill
  - Smoke
  - Fire
  - Explosion
- Capacity fade
  - Less miles every month
- Life cycle
  - Battery end of life earlier than expected
  - Deep discharge, charge sustain, vs. battery life

The pain is exacerbated in large lithium ion battery systems

Batteries Fail due to Many Reasons



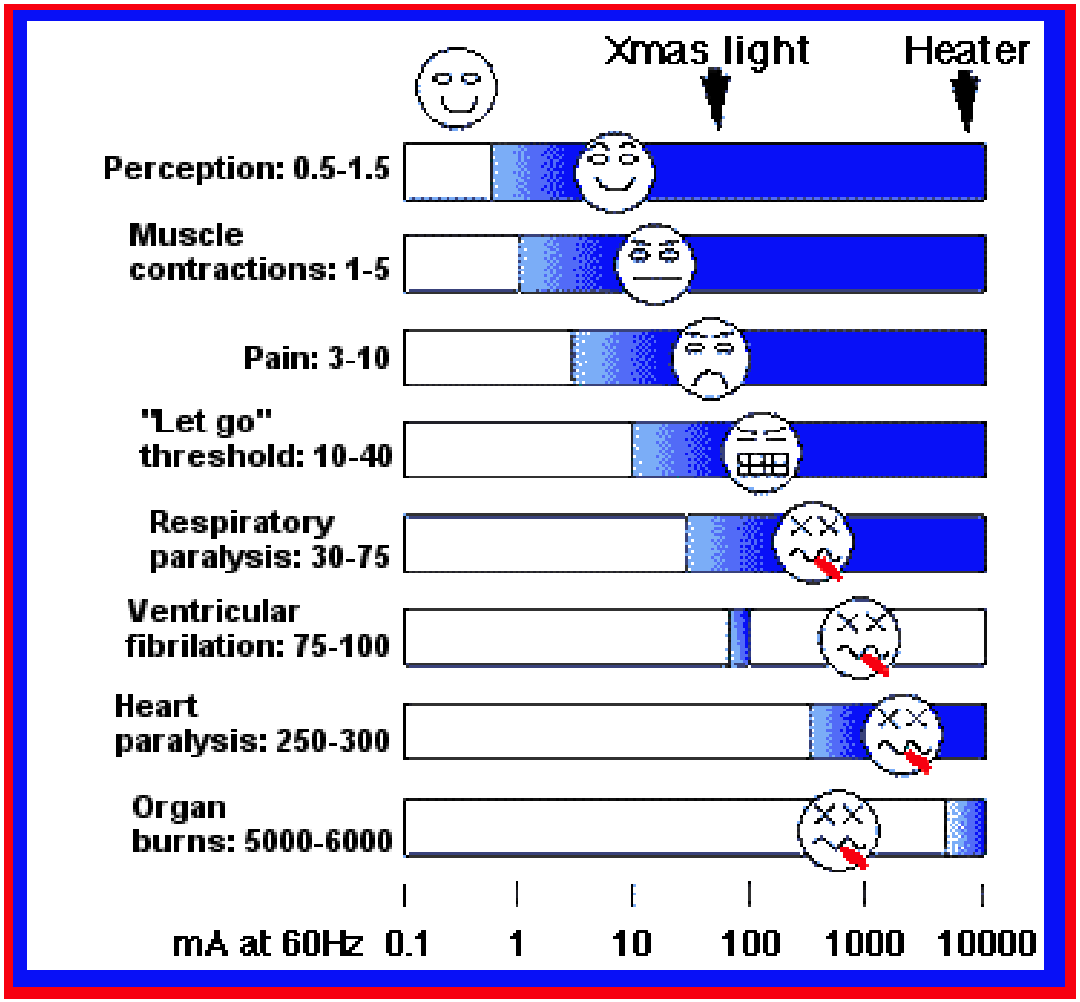
- Unbalanced charge
- Over charge



- Over heating
- Over current
- Over discharge

Battery charging and management is one key aspect of battery/Ev safety

What Can Electricity Do?



In the US, per year, due to electricity

600 death

3600 disabling injury

4,000 non-disabling injuries

9% of all industrial fatalities

Electric Shock

Arcing

Blast

EV Needs to be charged from the utility grid

http://ehs.okstate.edu/modules/electric/index.htm

Risks of High Voltage Batteries

- Electric
  - Electric shock: manufacturing personnel, service personnel, emergency responders, owner
- Thermal
  - Smoke
  - Fire
  - Explosion
- Chemical
  - Acid spill
  - Toxic gas
  - Burns

Risks of High Voltage Batteries

- Low/short term risks
  - Injury: burns, electric shocks,
  - Market risks (bad image)
- Medium/middle term risks
  - Loss of property
  - Disability
- High/long term risks
  - Loss of life
  - Loss of business/income
  - Loss of opportunity
  - Dead of EV industry (another era of EV…)

Charging Technology

- Direct charging, or conductive charging
  - There is direct electrical contact between the batteries and the charger. Conductive charging is achieved by connecting a device to a power source with plug-in wires.
- Inductive charging
  - Energy is transferred through electromagnetic coupling, not direct wire connection – close proximity
- Wireless charging – through a distance

Advantages of Inductive Charging

- Low risk of electric shock
- All weather proof due to no exposed wire
  - Especially in public charging stations
  - Prevent water flow in so as to prevent short circuits due to water

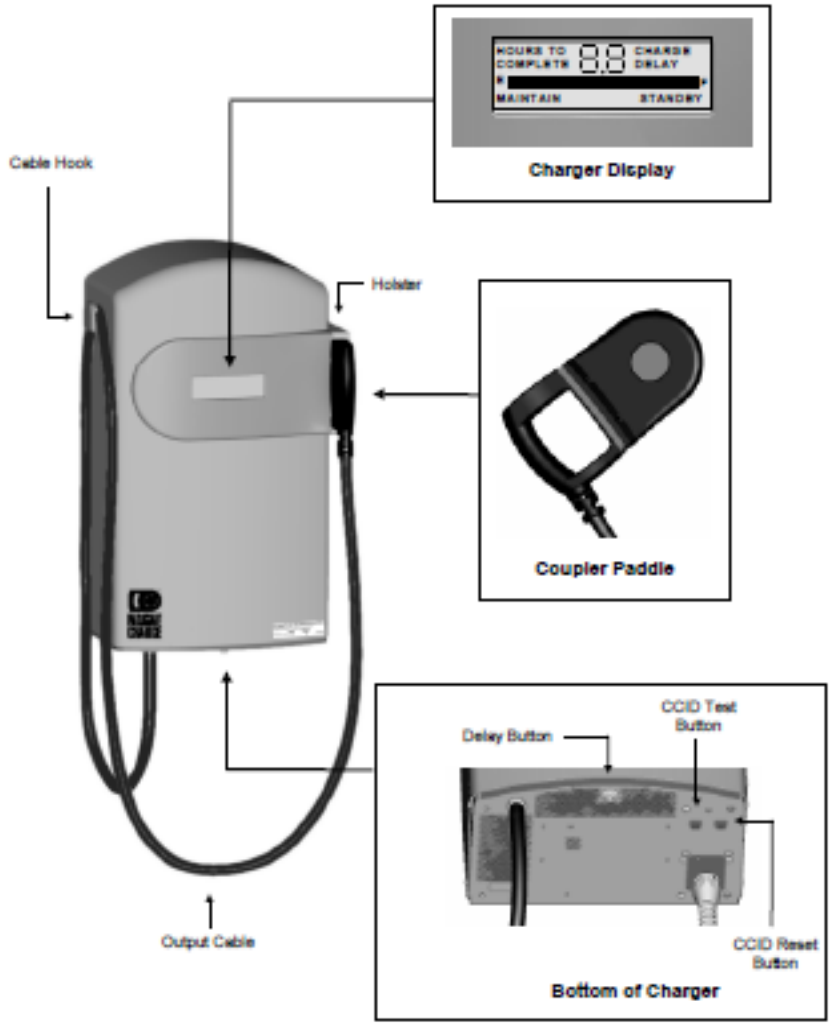
Disadvantages of Inductive Charging

- Low efficiency
- Low power
- Manufacturing complexity
- High cost
- Equipment specific (no exchangeability)
- Charge station is needed

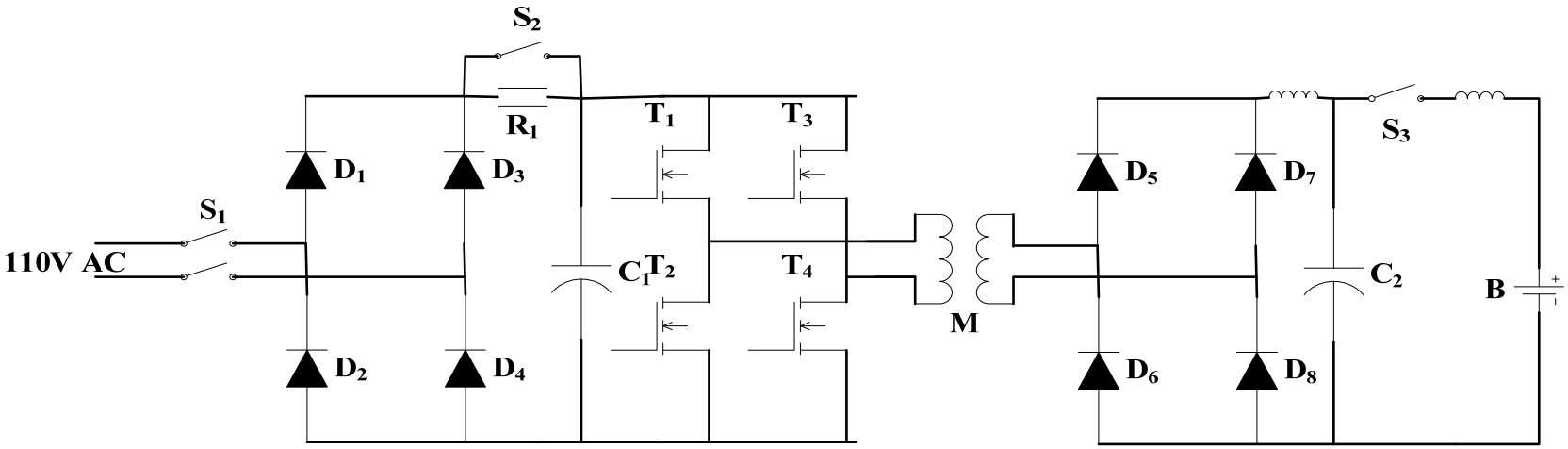
GM EV1 Magne Charger

- 208-240V/32A input
- 60Hz
- 6.6kW
- 25kg (55 lb)
- Efficiency 86% at peak power

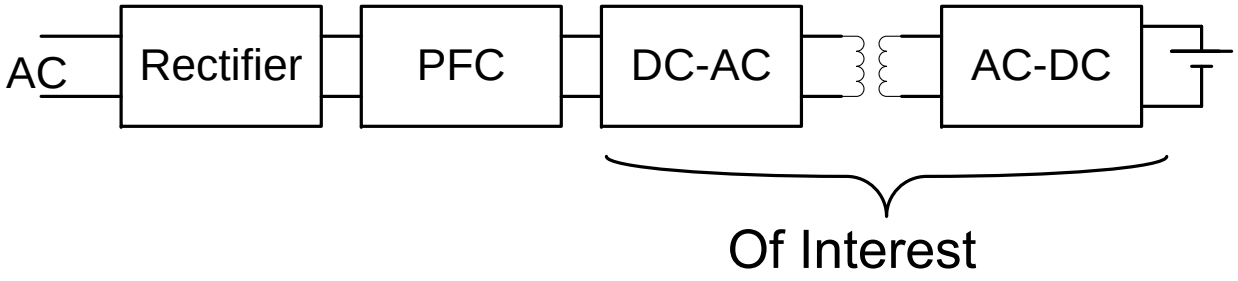
http://www.evchargernews.com/miscfiles/gm%20atv%20wm7200%20owners%20manual.pdf



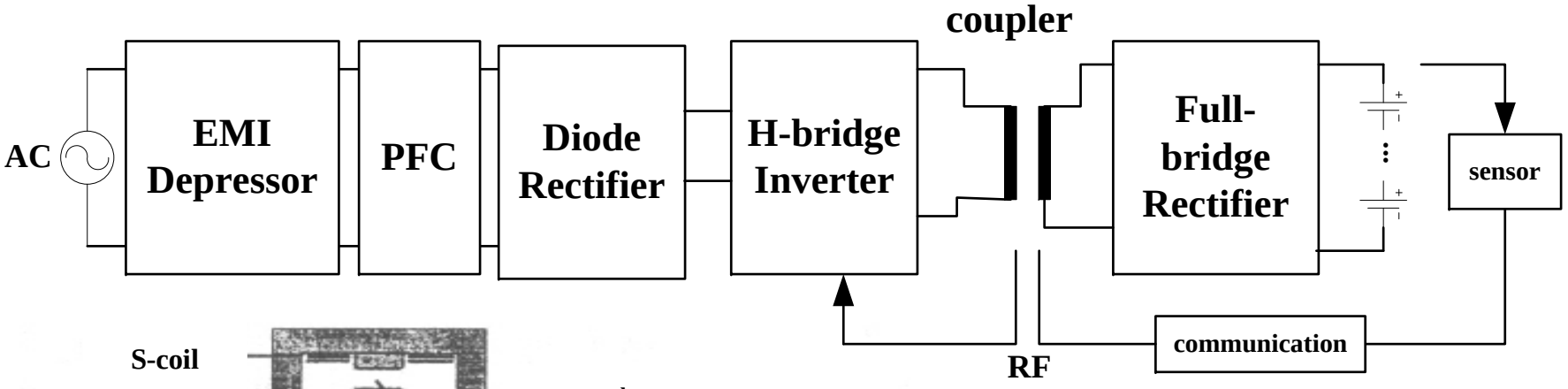
Isolated Charger Topology

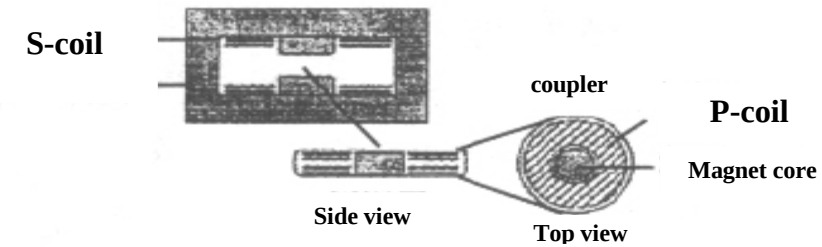


- Isolated architecture
- Phase shifted control

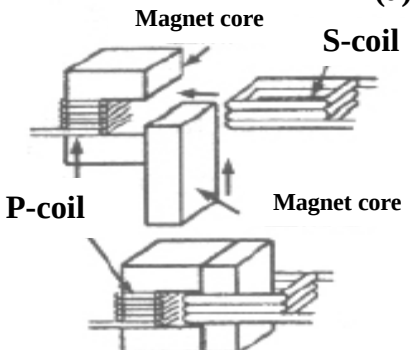


Inductive charging techniques

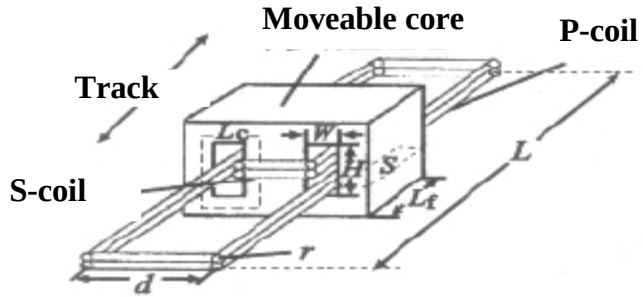




(a) GM Hughes



(b) Separable type



(c) linear type

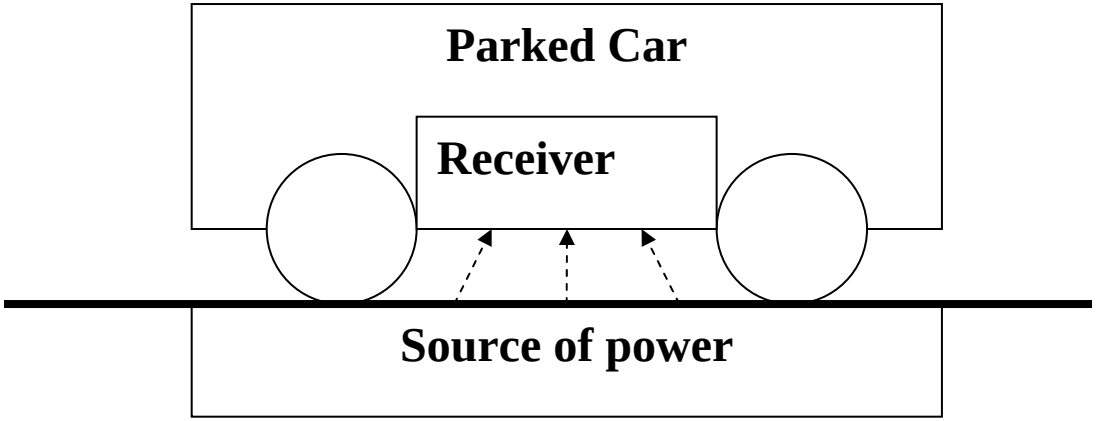
There are three types of inductive couplers.

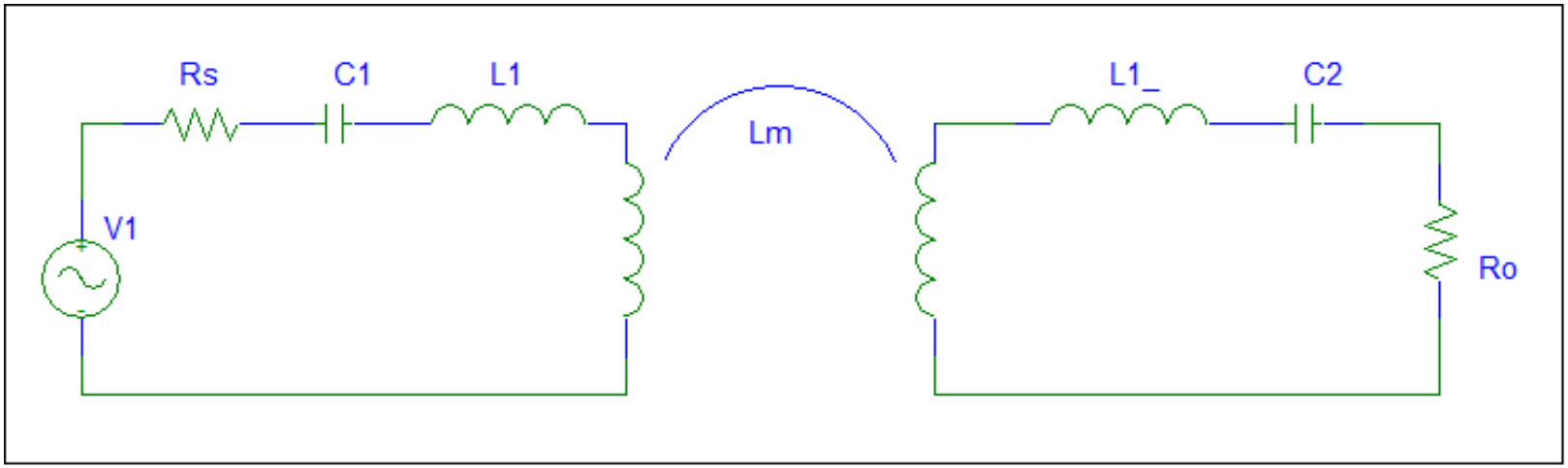
Wireless Charging

- Wireless changing is different from inductive charging, and information transmission, such as radio signal
- Wireless means transferring power and energy in a great distance.
- It is typically done through electromagnetic resonance
- MIT and University of Tokyo, some of the leaders in this area.

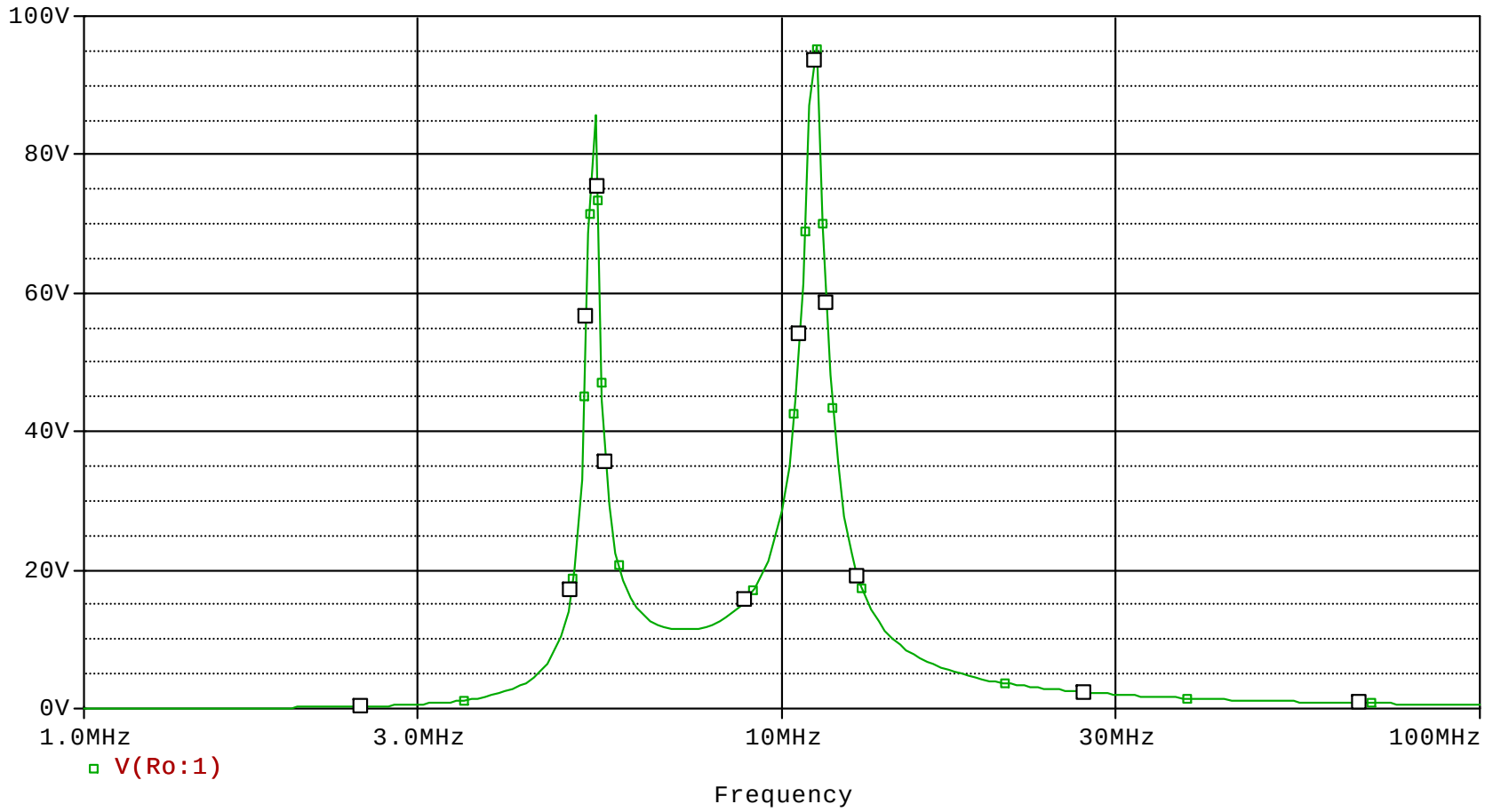
Wireless Charging

Wireless Charging of EV





Resonant Topology



Power is transmitted wirelessly in a distance. Frequency at 10MHz or more

Current Issues and Future of Wireless Charging

- Efficiency is low (20%??)
- Distance is not great (30 cm ??)
- Size is too big
  - For 100W, the size of the coils exceeded 50 cm for distance of 50 cm
- Potential use with ultra cap
- Electrified highway, etc.

A Compromise

- Home charging using conductive charging
- Public charging station using inductive charging
- ???
- This does not seem possible since these are two different technologies, unless each car is equipped with
  - Two different chargers!!!

Costs and forecast how the costs will decrease

- Cost and efficiency are two major factors
- Cost will only decrease as the quantity goes up
- Power semiconductor technology can play a role
- Silicon Carbide devices can further increase switching frequency hence reduce weight of coupling

Prototype PHEVs at UMD

- Three PHEV's were converted
  - Prius PHEV (7kWh, equi. E-range 30 miles)
  - Chrysler Aspen (11kWh, equi. E-range 21 miles
  - Chrysler Minivan (11kWh, equi. E-range 25 miles)
  - Saturn Vue (underway,10kWh, equi. estimated E-range 30 miles)

Work supported by and performed for Chrysler, DTE Energy/GM/Michigan Public Service Commission, DOE and Army