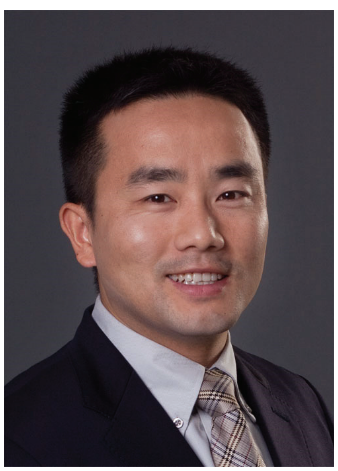
Announcements

- TBC: Design comparison due Friday
  - Afterwards, begin PCB layout (as group)
    - Due Friday, Nov. 2nd
- Guest lecture this Friday

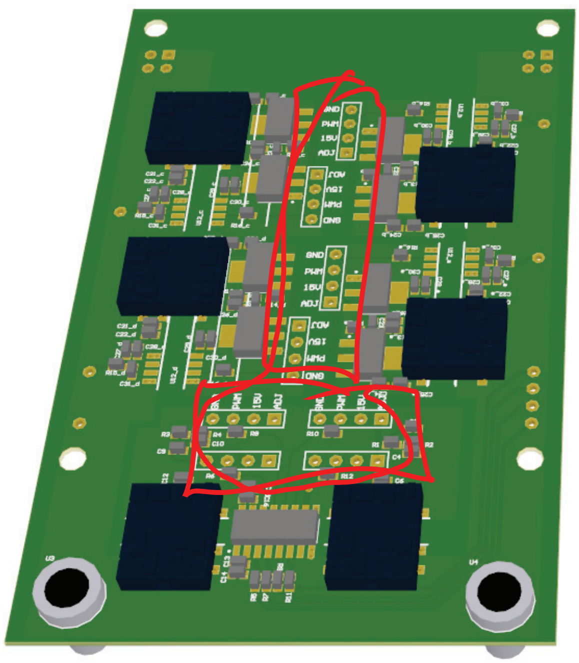
Guest Lecture Friday 10/26

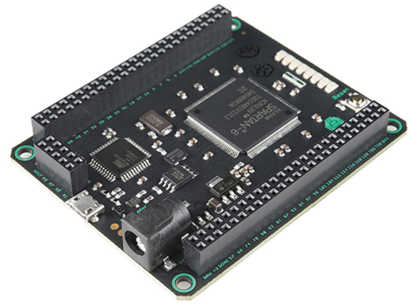


This presentation summarizes our activities in the areas of energy management and megahertz wireless power transfer, especially at system-level designs and control aspects. Modeling and control of a hybrid energy system are fist explained. Multi-agent modeling and game theory-based control are proposed and combined as a general solution for the energy management of such multi-source energy systems. This unique solution fully respects and balances different preferences of components, and thus improves scalability and performances at both component-level and system-level. Problem of managing a larger energy system, such as a microgrid with renewable energy, energy storage, and plugged-in electric vehicles (EVs), is further formulated to reflect EV's charging priority, driver's price sensitivity and range anxiety. A new direction on demand-side management of spatial and temporal distributions of EV fleet charging and its framework will also be mentioned.

Chengbin Ma received the B.S. degree in industrial automation from East China University of Science and Technology, Shanghai, China, in 1997, and the M.S. and Ph.D. degrees in electrical engineering from The University of Tokyo, Tokyo, Japan, in 2001 and 2004, respectively. From 2004 to 2006, he was an R&D Researcher with the Servo Motor Laboratory, FANUC Limited, Japan. Between 2006 and 2008, he was a Postdoctoral Researcher with the Department of Mechanical and Aeronautical Engineering, University of California, Davis, USA. He joined the University of Michigan–Shanghai Jiao Tong University Joint Institute, Shanghai Jiao Tong University, Shanghai, China, in 2008, and currently an Associate Professor of electrical and computer engineering. His research interests include energy management, megahertz wireless power transfer, dynamics and motion control, and wide applications in electronic devices, electric vehicles, microgrids, smart grids, etc.

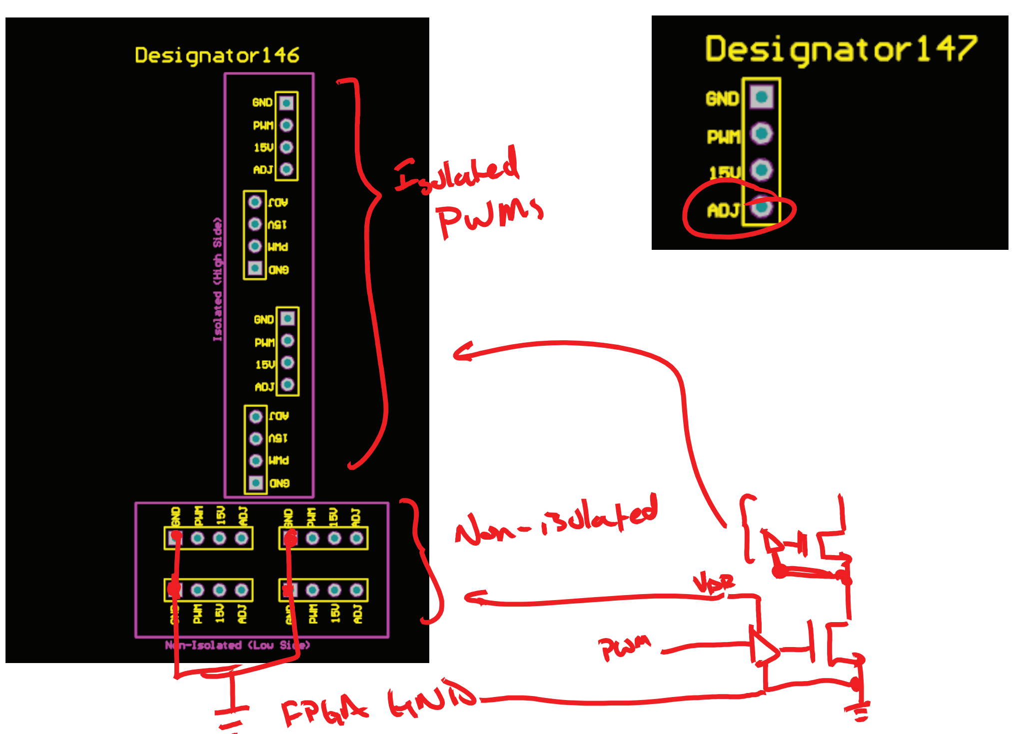
Modulation Signal Board



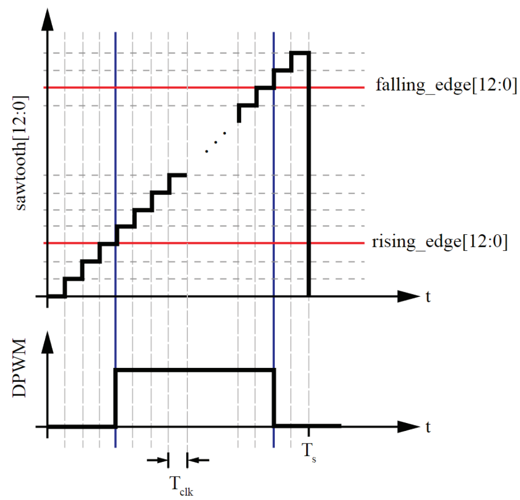


- Mates on Mojo v3 (stacked headers)
- 4-pin (male) header connections
- Layout in Altium starter package on course website

Starter File Footprints



FPGA Code



Further tutorial:

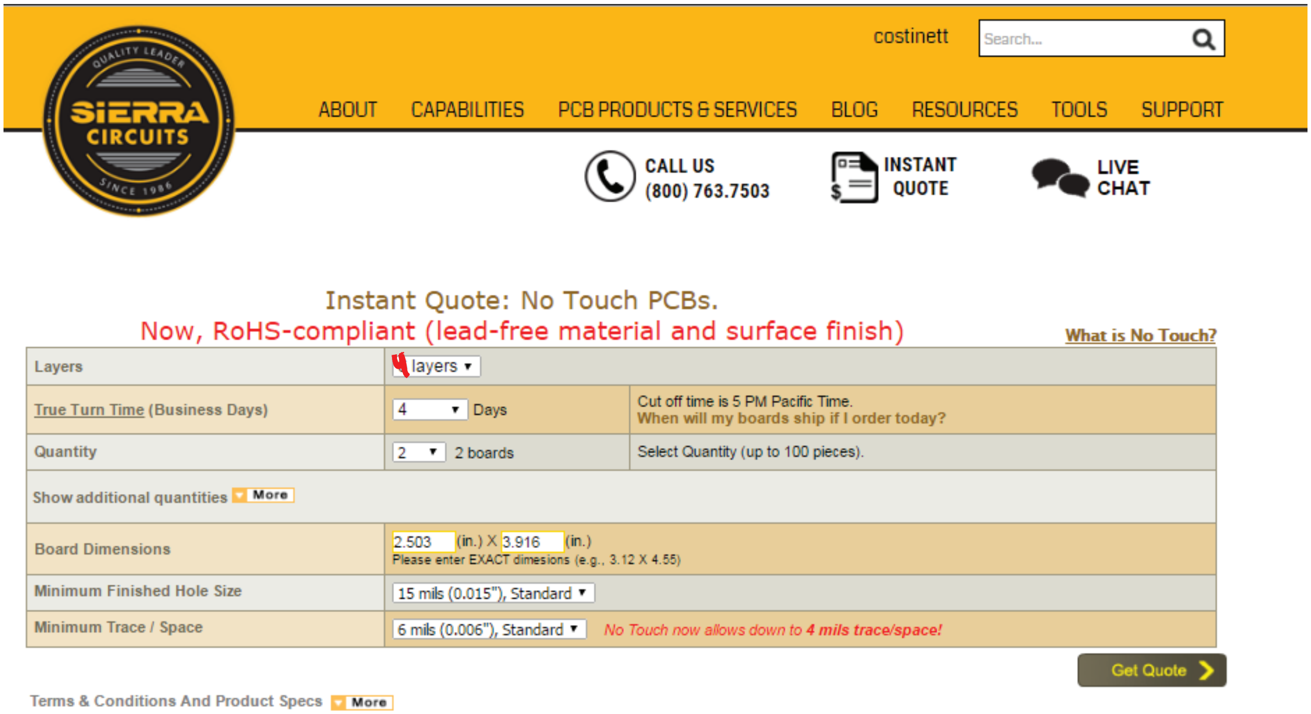
http://web.eecs.utk.edu/~dcostine/ECE581/Fall2018/TinyBox/FPGA/

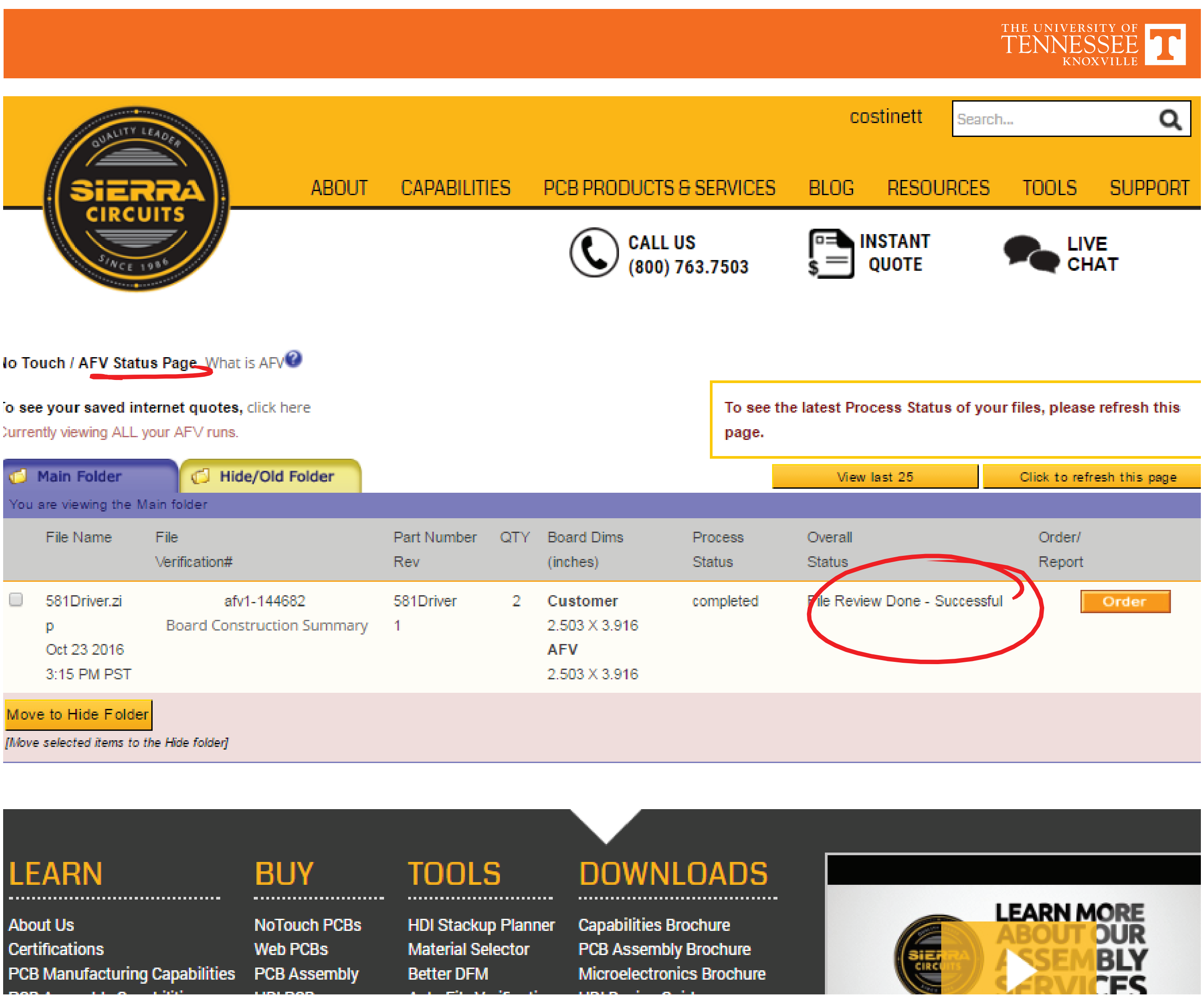
```
//Digital sawtooth generator.  One is shared by all
modulator to ensure the sawtoothes themselves are in
phase
sawtooth_gen sawtooth_gen (
      .max_mod_value(300),
      .rst(rst),
     .clk(clk300),
      .sawtooth(sawtooth)
      );

//8 individual PWM modulators.  To turn any of them
off, just change
//       .rst(rst),
//to
//       .rst(~rst),

//FPGA pin 124
modulator_single gL0 (
      .sawtooth(sawtooth),
      .falling_edge(298),
      .rising_edge(152),
      .rst(rst),
      .clk(clk300),
      .DPWM(gL[0])
      );

//FPGA pin 127
modulator_single gL1 (
      .sawtooth(sawtooth),
      .falling_edge(150),
      .rising_edge(1),
      .rst(rst),
      .clk(clk300),
      .DPWM(gL[1])
      );

…
```


Deliverables Next Friday

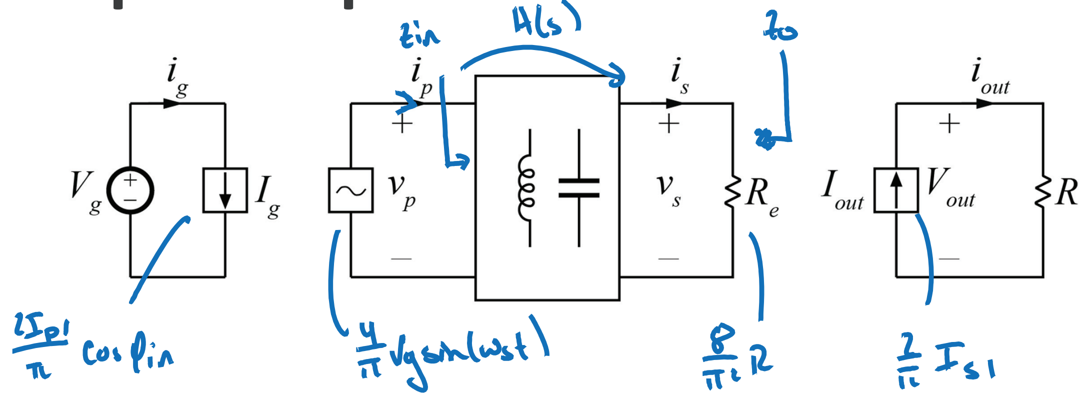
- Login info to account with PCB layout that has passed Sierra Circuits' AFV with
  - 6 mil spacing
  - 15 mil holes
  - 4-day turn
  - 2 boards
  - Up to 4 layers
- Excel spreadsheet of all parts, showing $100 requirements met
- Total $300 for components & PCB
- **Actionable** ordering links/quotes for all parts

Quote Specifications





Complete Equivalent Circuit



φ_{in}, I_{p1}, I_{s1} determined by complete circuit

$$M = \frac{V_{out}}{V_g} = \frac{V_{out}}{I_{out}} \cdot \frac{I_{out}}{I_{s1}} \cdot \frac{I_{s1}}{V_{s1}} \cdot \frac{V_{s1}}{V_{p1}} \cdot \frac{V_{p1}}{V_g}$$

$$M = R \cdot \frac{2}{\pi} \cdot \frac{1}{\frac{8}{\pi^2} R} \cdot \| H(j\omega_s) \| \cdot \frac{4}{\pi}$$

$$M = \frac{V_{out}}{V_g} = \| H(j\omega_s) \|$$

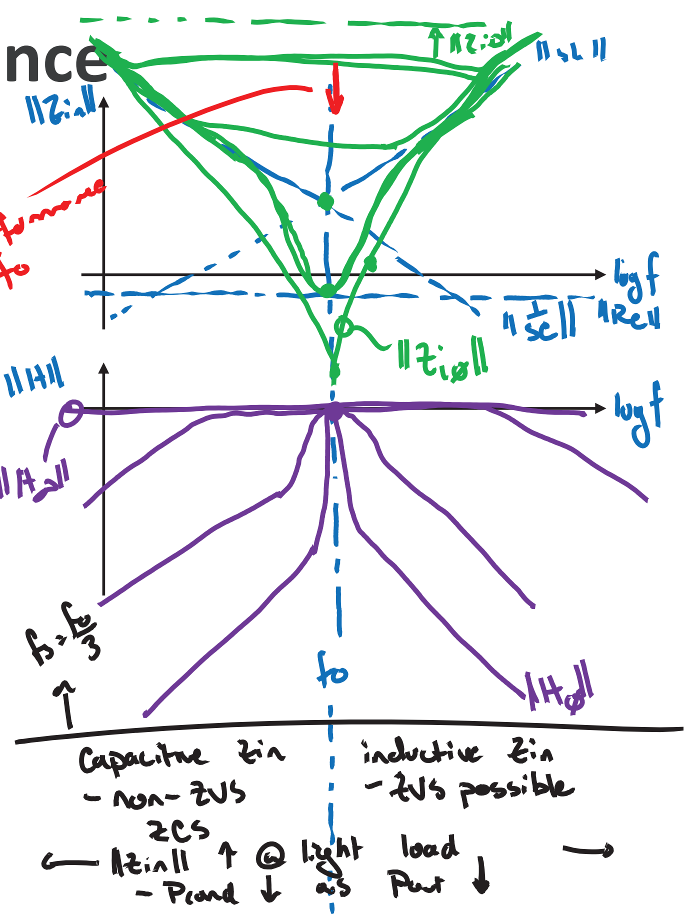
keep in mind Z_{in}, $H(s)$, Z_o depend on R_e

Tank Input Impedance

SRC example

$$Z_{in}(s) = sL_r + \frac{1}{sC_r} + R_e$$

$$H(s) = \frac{R_e}{Z_{in}(s)}$$



poor short circuit performance if $f_s \approx f_o$

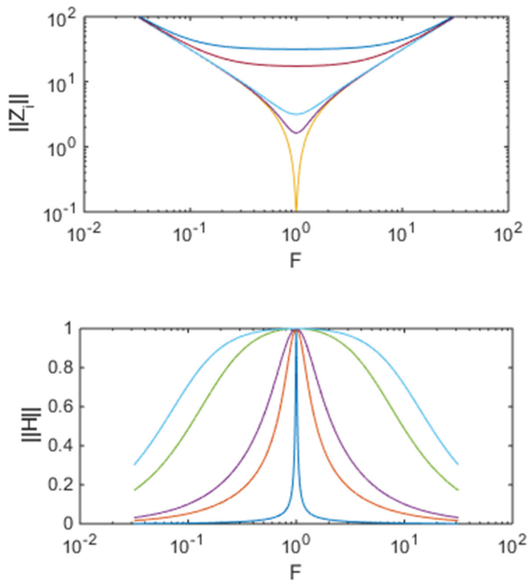
$\|Z_{i0}\| \rightarrow \|Z_{i, R_e \rightarrow 0}\|$

$\|Z_{i\infty}\| \rightarrow \|Z_{i, R_e \rightarrow \infty}\|$

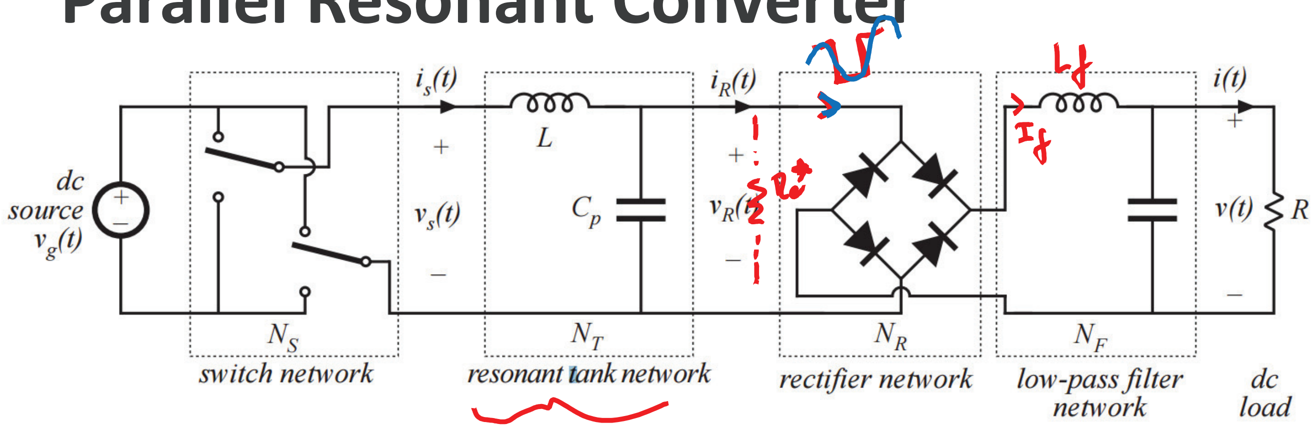
Sinusoidal approximation valid when
- $R_e << \infty$
- $f_s \gtrsim f_o$

THE UNIVERSITY OF TENNESSEE KNOXVILLE

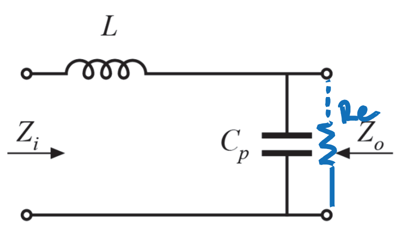
Series Resonant Tank



Parallel Resonant Converter

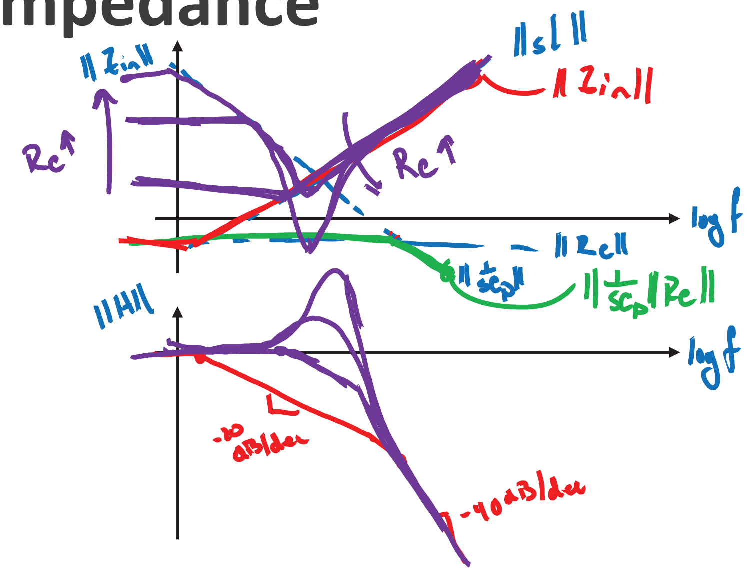


PRC Tank Input Impedance



$Z_{in} = sL + \left(\frac{1}{sC_p} \| R_e\right)$

$H(s) = \frac{R_e \| \frac{1}{sC_p}}{Z_{in}}$

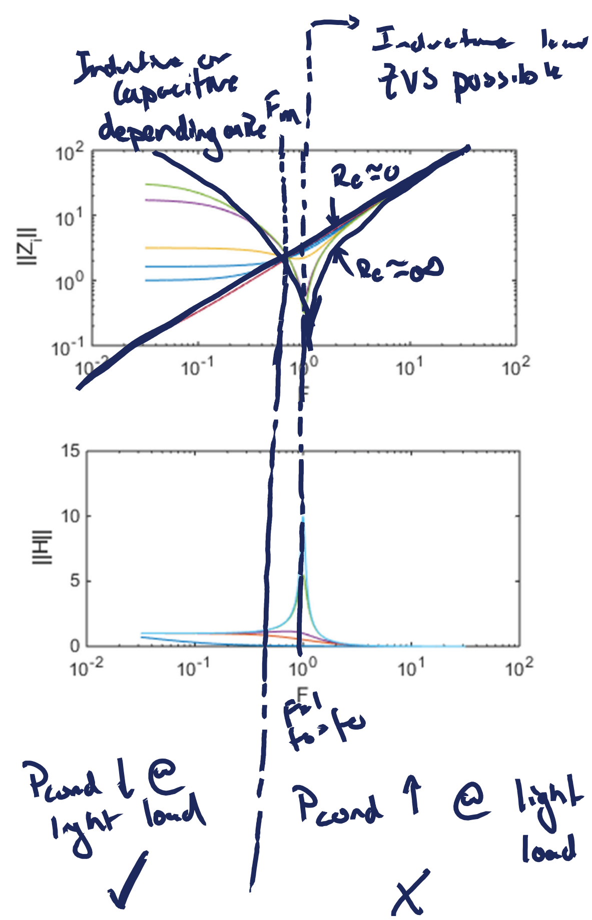


PRC Tank

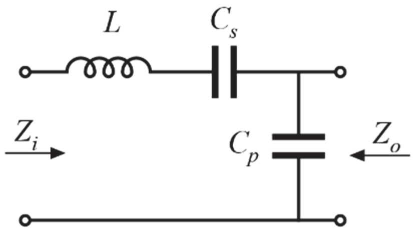
→ very high currents @ open circuit output if $f_s \approx f_o$

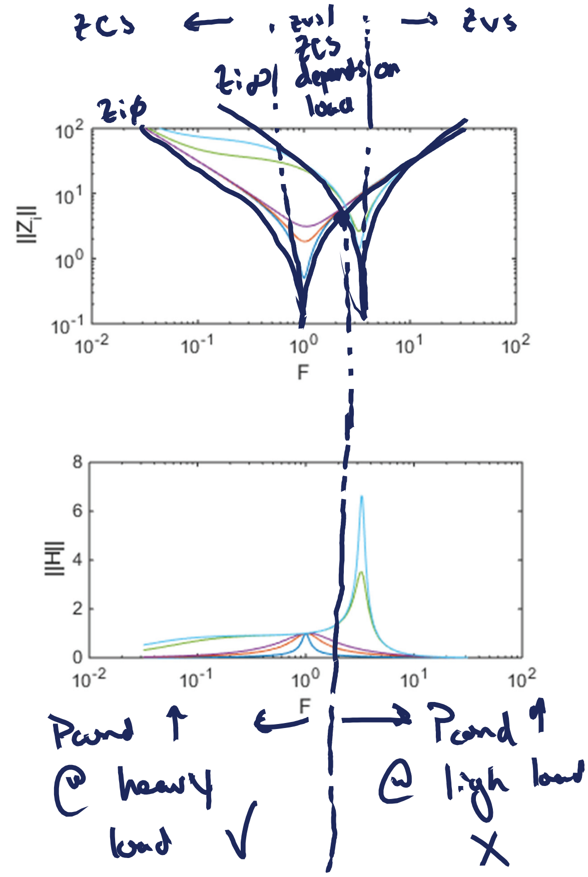
Theorem 1 from textbook Sec 19.4.2

If tank is purely reactive, $\|Z_i(j\omega_x)\|$ is a <u>monotonic</u> function of Re

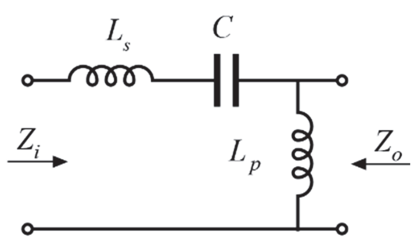


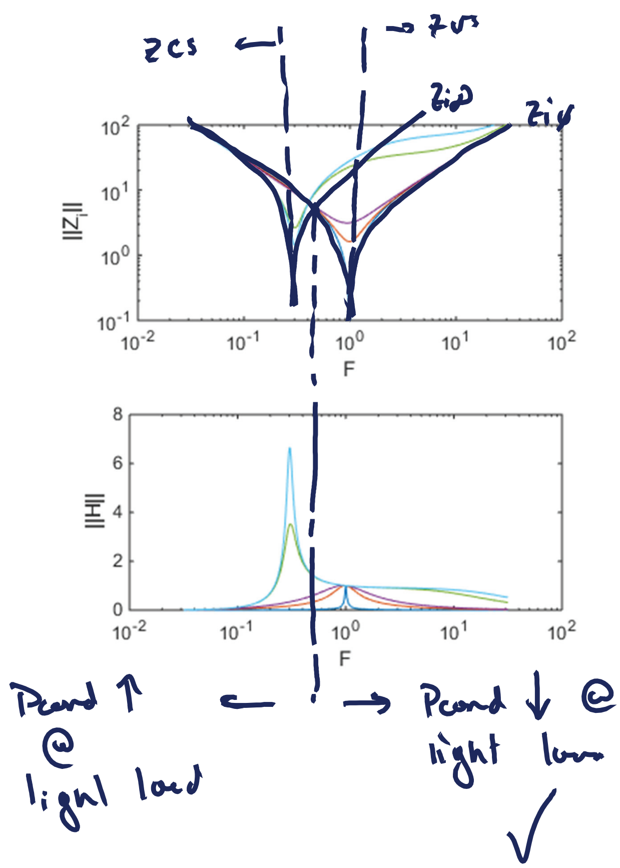
LCC


L
Cs
Zi
Cp
Zo

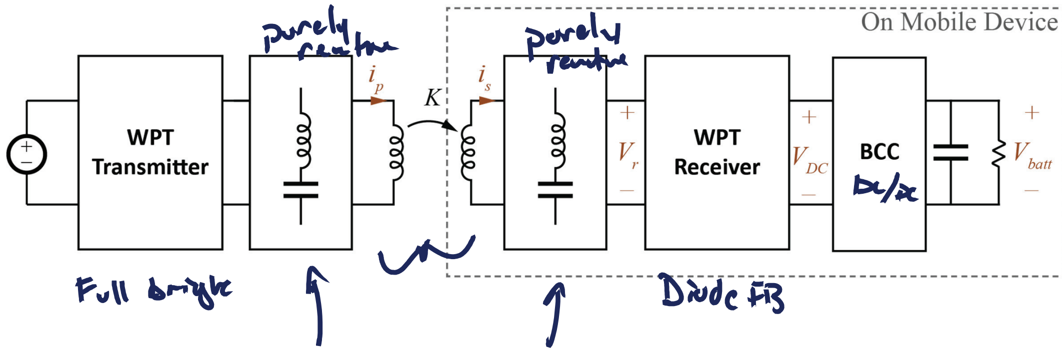

ZCS ←
→ ZVS
ZCS depends on load
||Zi||
F
||H||
Pcond ↑ @ heavy load ✓
Pcond ↑ @ light load X

LLC

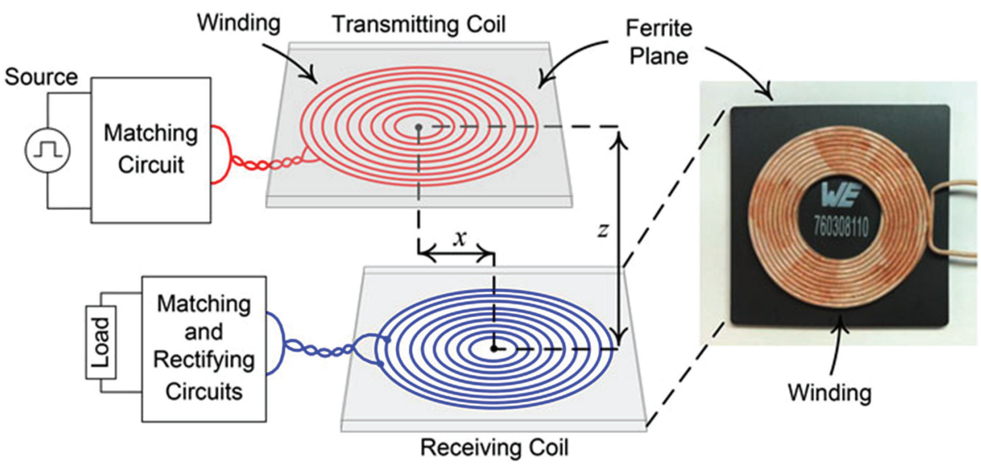

Ls
C
Zi
Lp
Zo


ZCS ←
→ ZVS
||Zi||
F
||H||
Pcond ↑ @ light load
Pcond ↓ @ light load ✓

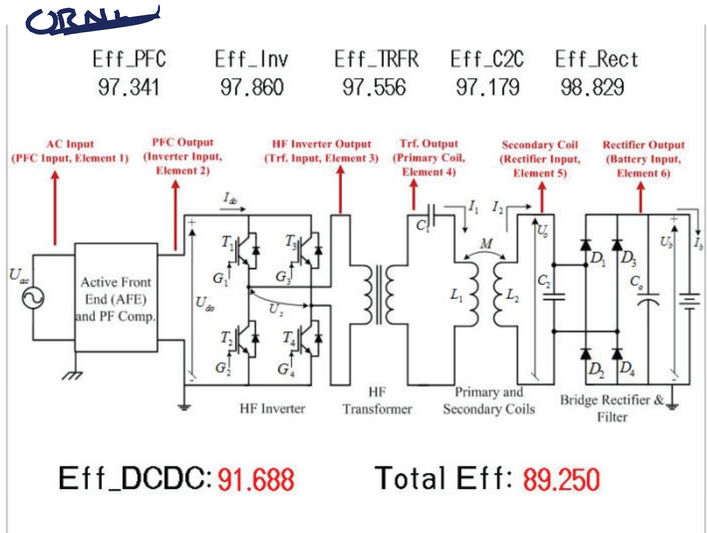
Wireless Power Transfer

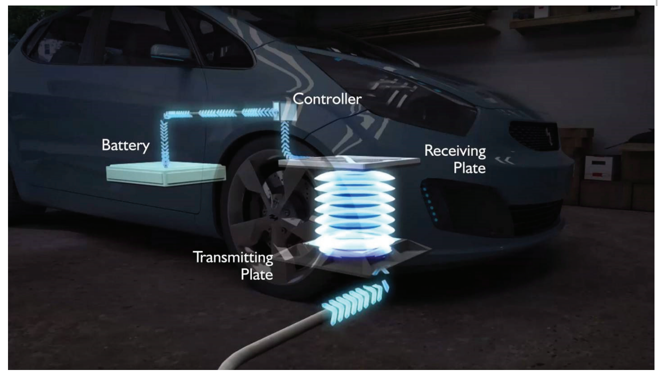


Mobile Device WPT



EV WPT





Class E Topologies