Announcements

- Tiny Box Competition
  - Begins today
  - Form teams of 2-3
    - First assignment is individual
- Midterm
  - Tentatively Nov 5-9

Competition Specifications

The **winning converter** will be the unit which achieves the **highest power density**, i.e. fits in the smallest rectangular volume, while meeting the following specifications.

Parameter	Requirement	Comment
Voltage Input	48 Vdc	
Maximum Output Power	12 W	
Output Voltage	1.2 ± 0.1 Vdc	
Output Ripple Voltage	< 2%	Measured as $V_{pk\text{-}pk}/V_{avg}$ from the DC supply, in steady state, at full output power
TPE Efficiency	> 85%	Measured using TPE method[1]
No-load Power Loss	< 3W	Measured with load disconnected, but output voltage within specified range
Volume	< 6 in^3	Volume of minimum rectangle enclosing power stage

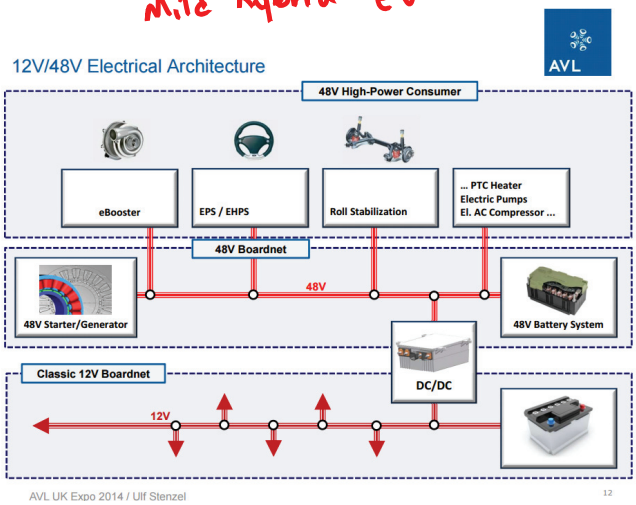
[1]Tennessee Power Electronics (TPE) efficiency is a weighted power efficiency defined as:

$$\eta_{TPEF} = 0.1\eta_{P_{out}=0.25\cdot P_{max}} + 0.15\eta_{P_{out}=0.5\cdot P_{max}} + 0.25\eta_{P_{out}=0.75\cdot P_{max}} + 0.5\eta_{P_{out}=P_{max}}$$

Example Applications

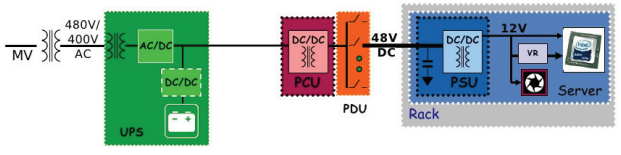
EV 48V Architectures

Mild hybrid EV

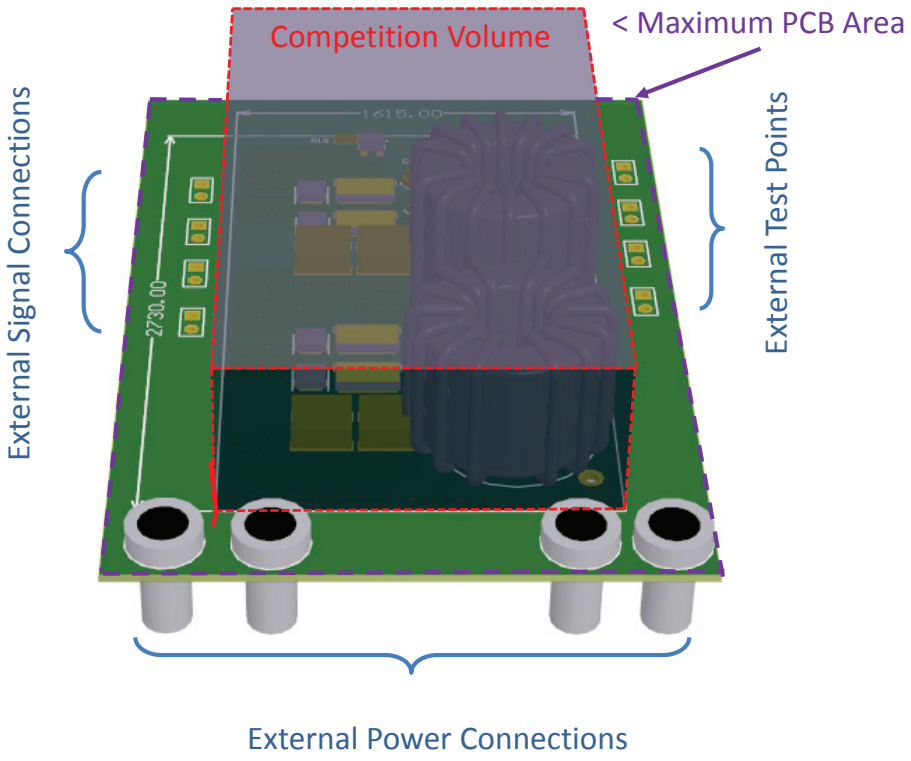


Data Centers / Telecom

{ 48V VRM – Voltage Regulation module
  48V POL – Point of load



How Volume is Measured



Additional Details

- Full competition specifications and example testing report on course webpage
- No regulation requirements
- First Deliverable: Friday October 26th
  - Design comparison of 3 topologies
  - Due per individual
  - All other deliverables as a team

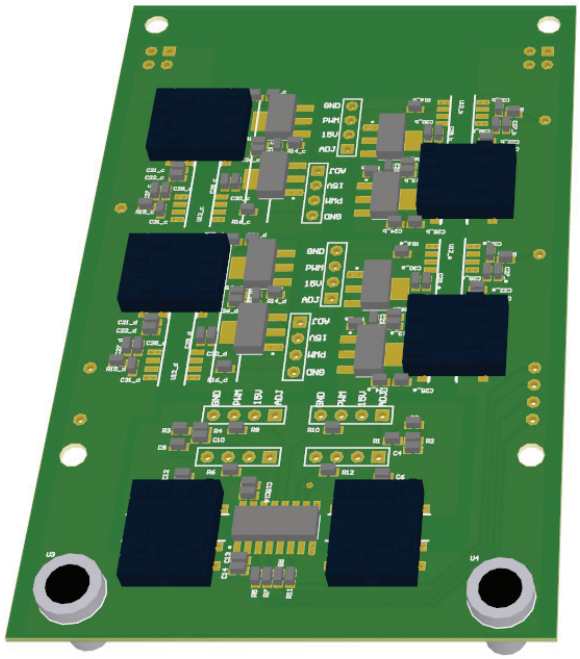
Design and Comparison Report (10/26)

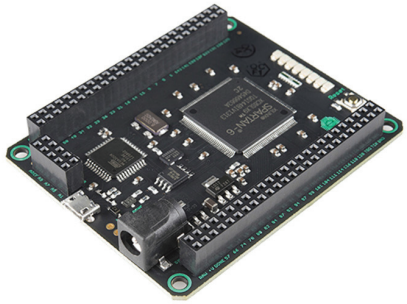
1. Select three topologies from the table and compare based on
   I. Efficiency at full power
   II. Power loss at zero load
   III. Output voltage ripple
   IV. Volume of main passive components

	Class I	Class II	Class III	Class IV
Definition	Two-switch PWM topologies	Isolated variants of PWM topologies	AC-link topologies	Any topology not conforming to Class I-III
Examples	Buck, Boost, Buck-Boost, Cuk, SEPIC, etc.	Flyback, Forward, push-pull, half-bridge, full-bridge	DAB, DAHB, SRC, LLC, Full Bridge, etc.	Switched capacitor, sigma-delta, multilevel, etc.
Required number	--	--	≥ 1	≥ 1

2. Select (and justify) one topology, and provide a complete design including (but not limited to)
   I. Power Devices
   II. Gate Driver Circuitry
   III. Passive Devices and implementation
   IV. Switching Frequency

Modulation Signal Board





- FPGA + PWM isolation
  - 4 low-side (common ground)
  - 4 high-side (isolated grounds)
- Reference code to generate open-loop PWM signals
- Layout in Altium starter package on course website

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Schedule

- Select teams of 2-3 — M 10/15
- Paper Design and Comparison — F 10/26
- PCB Layout and BOM — F 11/2
- Testing Report — F 11/30

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Course Schedule

L24 - Oct. 22	**L25** - Oct. 24	**L26** - Oct. 26 *TBC Design Comparison Due*
L27 - Oct. 29	**L28** - Oct. 31	**L29** - Nov. 2 *TBC PCB Layout Due*
L30 - Nov. 5	**L31** - Nov. 7 *Midterm Exam*	**L32** - Nov. 9
L33 - Nov. 12	**L34** - Nov. 14	**L35** - Nov. 16
L36 - Nov. 19	**L37** - Nov. 21	Nov. 23
L38 - Nov. 26	**L39** - Nov. 28	**L40** - Nov. 30 *TBC Testing Report Due*

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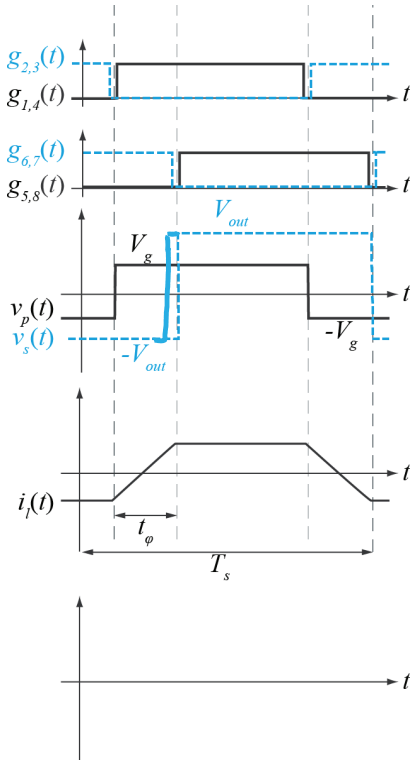
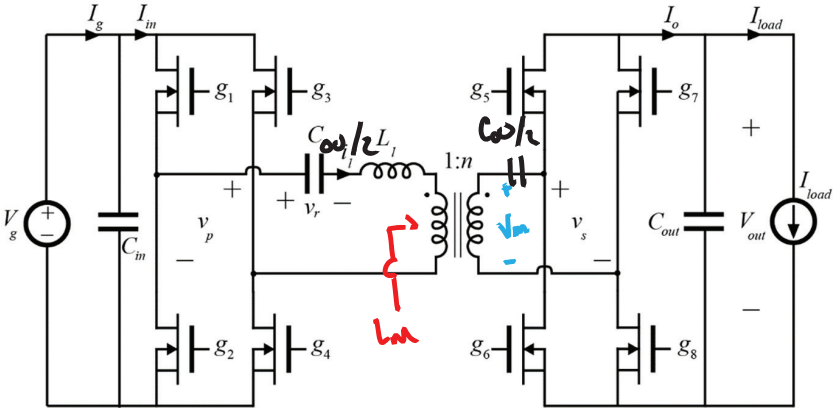
DAB: Transformer Saturation



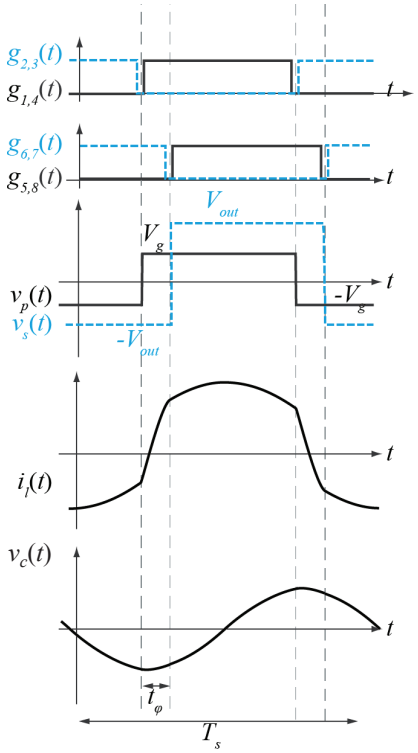


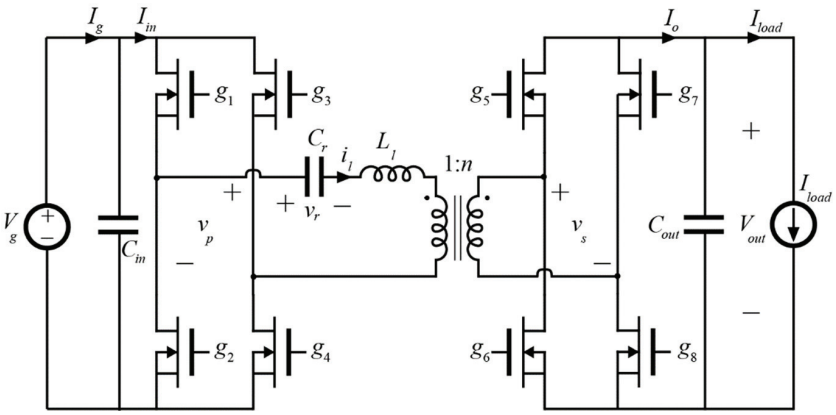
To prevent XF saturation
(1) current sensing / control
(2) ZVS dynamics (if t_{dt}, t_g large $\sim \frac{T_s}{2}$)
(3) DC blocking capacitor

$C_{oss} \rightarrow$ large $\quad \frac{1}{2\pi\sqrt{C_{oss} L_l}} \ll f_s$

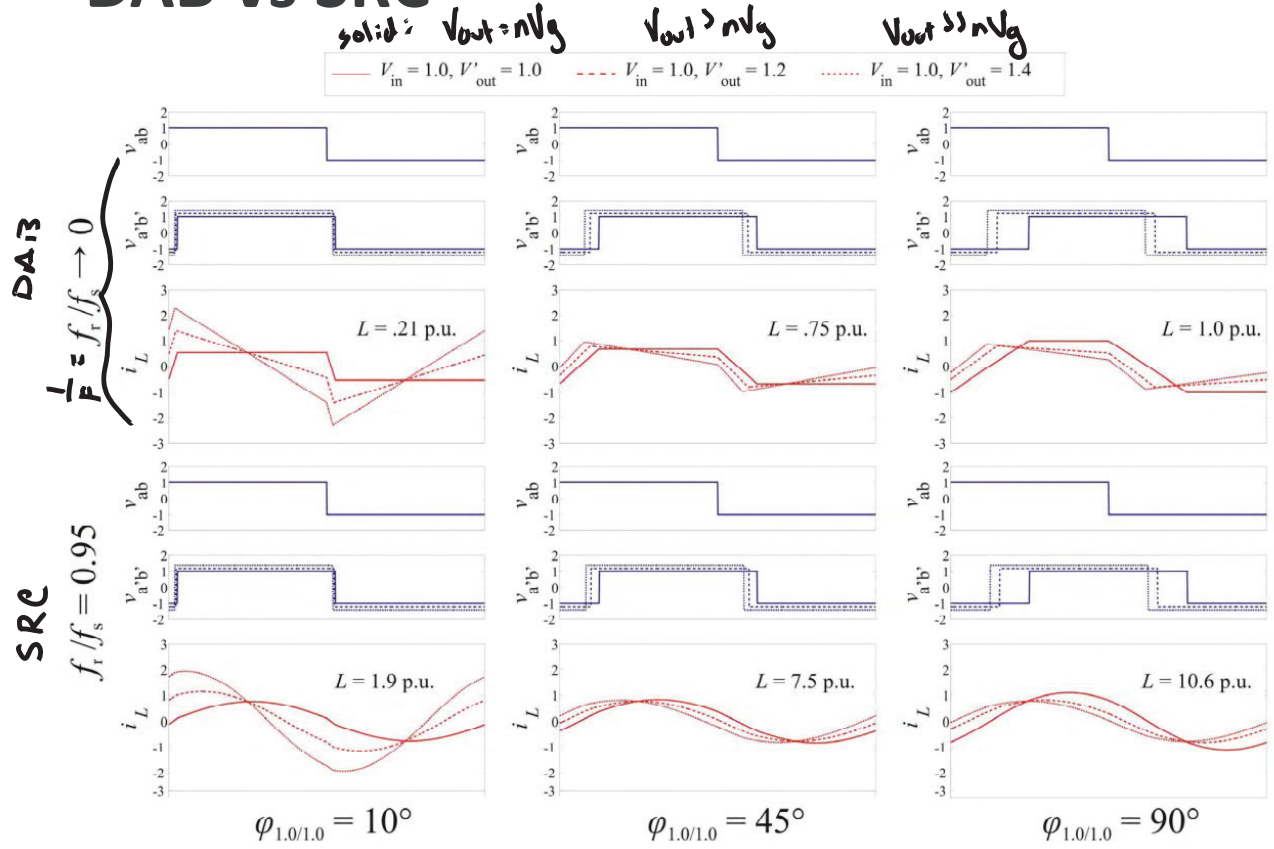
Series Resonant Converter

$\frac{1}{2\pi\sqrt{C_r L_l}} \approx f_s$





DAB vs SRC



R. Lenke, F. Mura and R. W. De Doncker, "Comparison of non-resonant and super-resonant dual-active ZVS-operated high-power DC-DC converters,"

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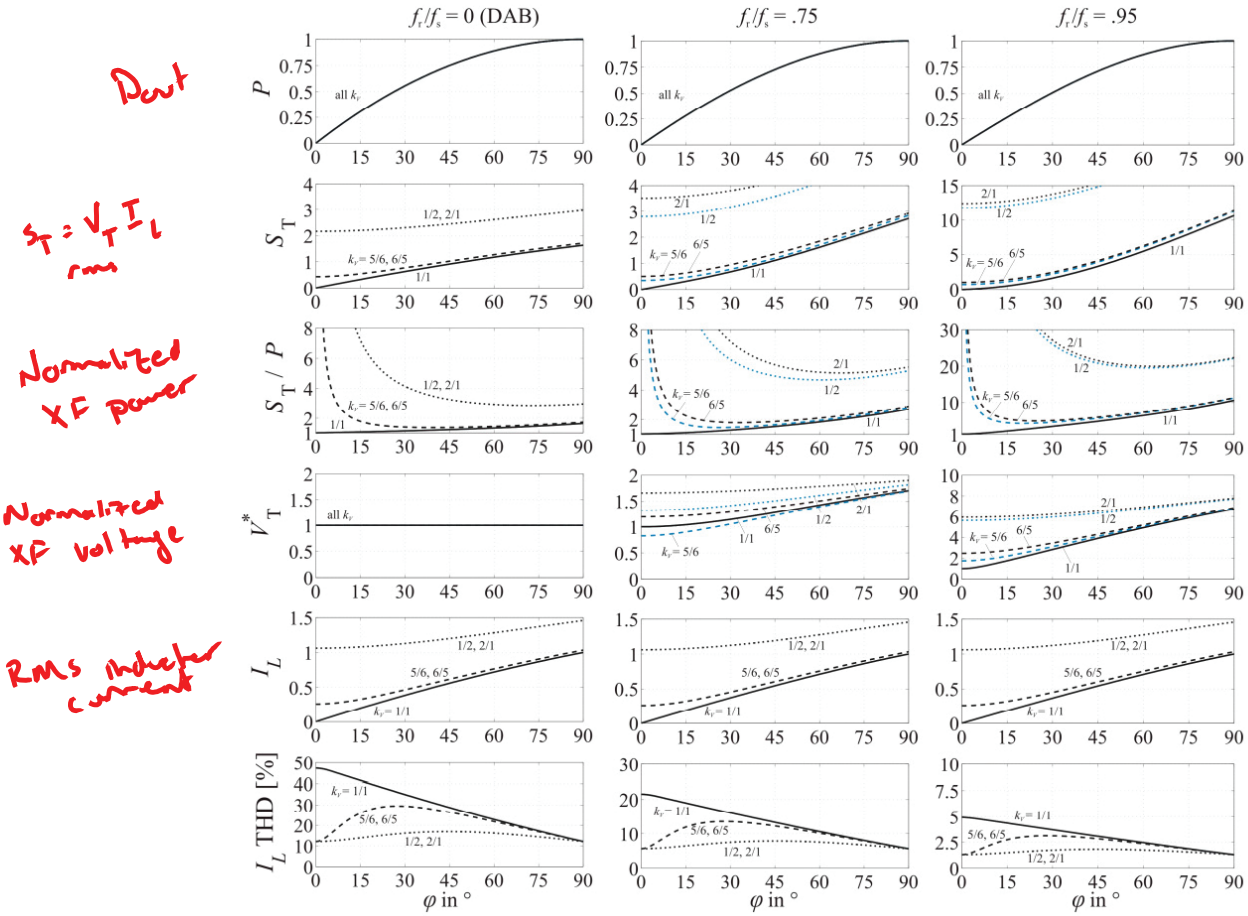

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DAB vs SRC: Conclusions

DAB

+ Smaller resonant tank (physically)
+ Smaller RMS currents
+ Wider Soft-switching range

SRC

+ Can be designed with larger XF inductance
+ Lower AC winding losses
+ Reduced device turn-off losses

R. Lenke, F. Mura and R. W. De Doncker, "Comparison of non-resonant and super-resonant dual-active ZVS-operated high-power DC-DC converters,"