ECE/ENGRD 2100

Introduction to Circuits for ECE

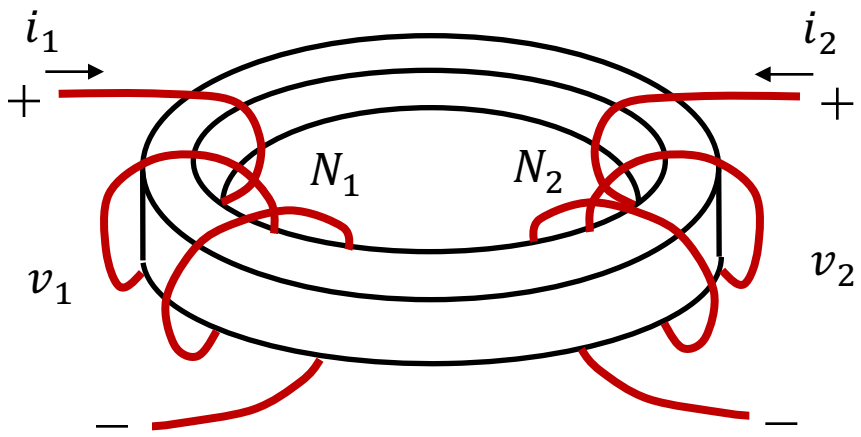
Lecture 40

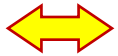
DC-DC Power Converters

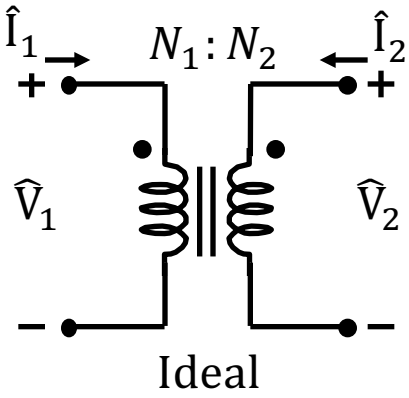
Announcements

- Upcoming due dates:
  - Lab report 6 due by 11:59 pm on Friday May 3, 2019
  - Homework 6 due by 11:59 pm on Thursday May 9, 2019

AC-AC Voltage Conversion



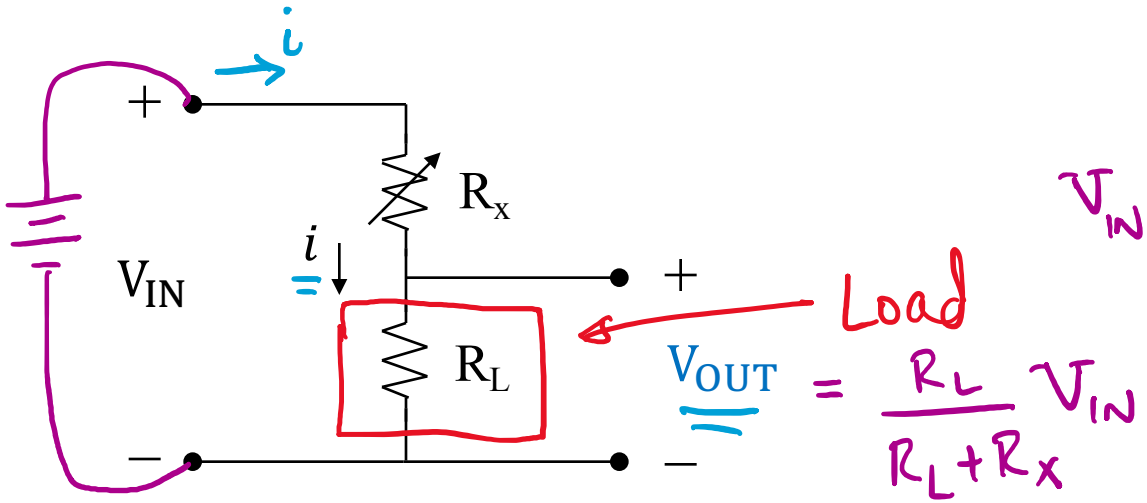


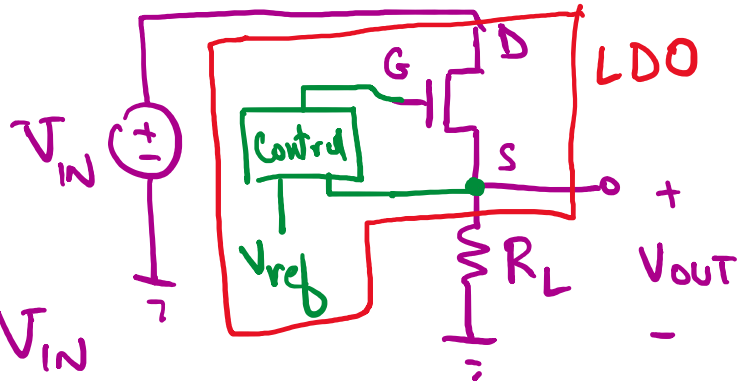


$$\frac{\hat{\mathrm{V}}_2}{\hat{\mathrm{V}}_1} = \frac{N_2}{N_1}$$

$$\frac{\hat{\mathrm{I}}_2}{\hat{\mathrm{I}}_1} = -\frac{N_1}{N_2}$$

DC-DC Voltage Conversion - Linear Regulator



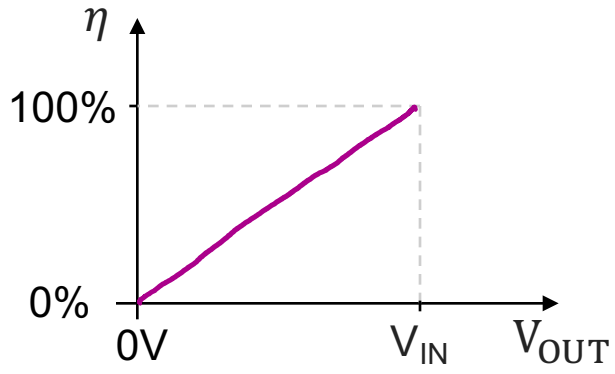


$$\text{Efficiency, } \eta \equiv \frac{\text{Output Power}}{\text{Input Power}} = \frac{V_{OUT}\, i}{V_{IN}\, i}$$

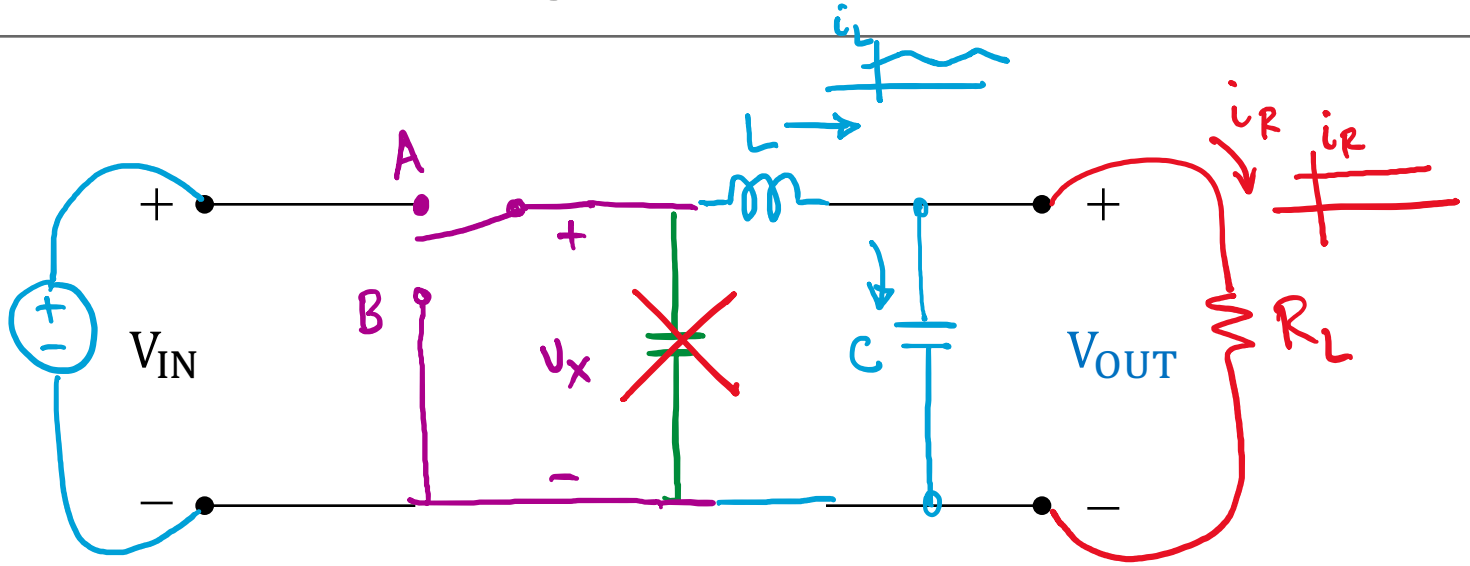
Example: $V_{IN} = 12\ V$

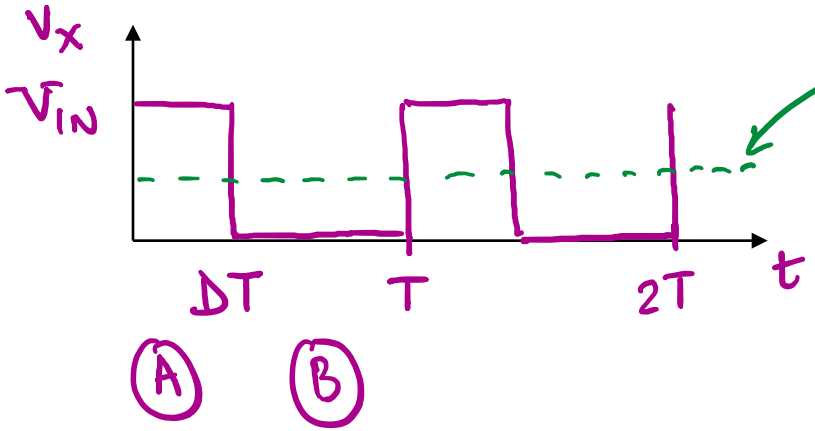
$V_{OUT} = 5\ V \Rightarrow \eta = \frac{5}{12} \approx 42\%$

$V_{OUT} = 1\ V \Rightarrow \eta = \frac{1}{12} \approx 8\%$



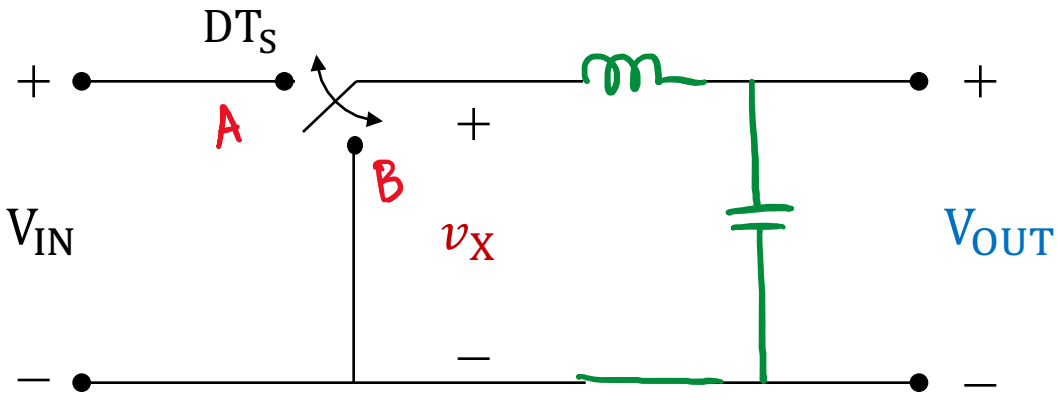
DC-DC Voltage Conversion – Alternate Approach

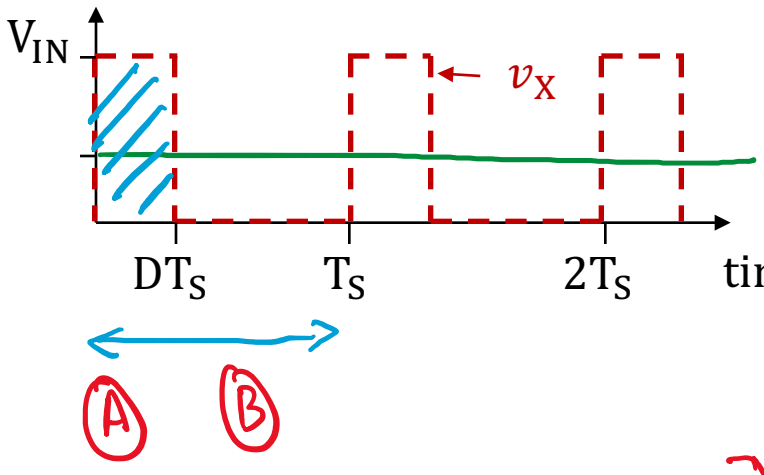




V_{OUT} ⇐ $\frac{1}{T}\int v_x\,dt$ ⇐ average of v_x

Switching Power Converter



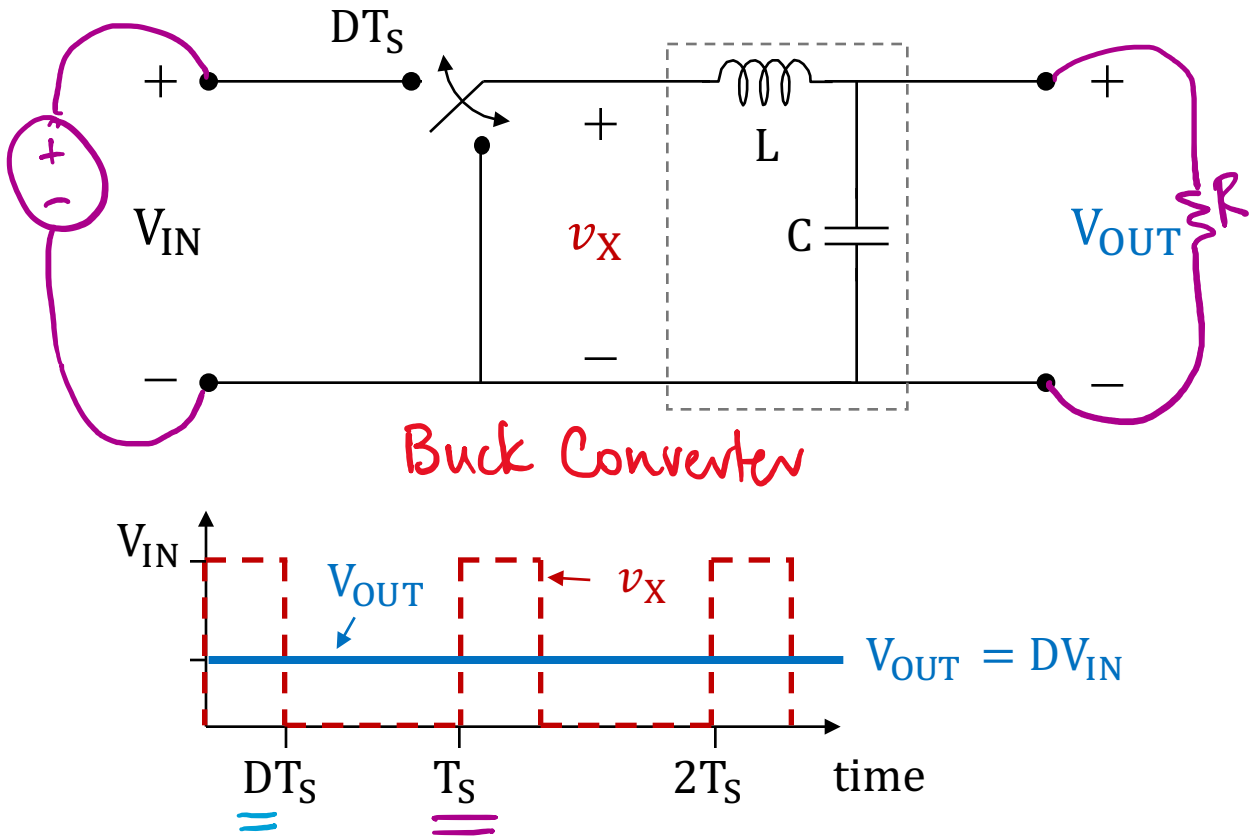


$$V_{OUT} = \frac{1}{T_s}\int_0^T v_x\,dt = \frac{1}{T_s}\,DT_s V_{IN}$$

$$DT_s V_{IN}$$

$$V_{OUT} = DV_{IN}$$

Switching Power Converter with Low Pass Filter



D = switch duty cycle

$0 \le D \le 1$

T_S = switching period

f_S = switching frequency

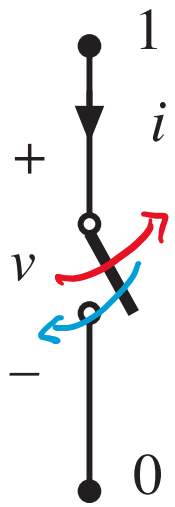
$= 1/T_S$

f_0 = filter cutoff frequency

$= 1/2\pi\sqrt{LC}$

- Choose filter cutoff frequency f_0 much smaller than switching frequency f_S
- This circuit is known as the "buck converter"

Power Loss in an Ideal Switch



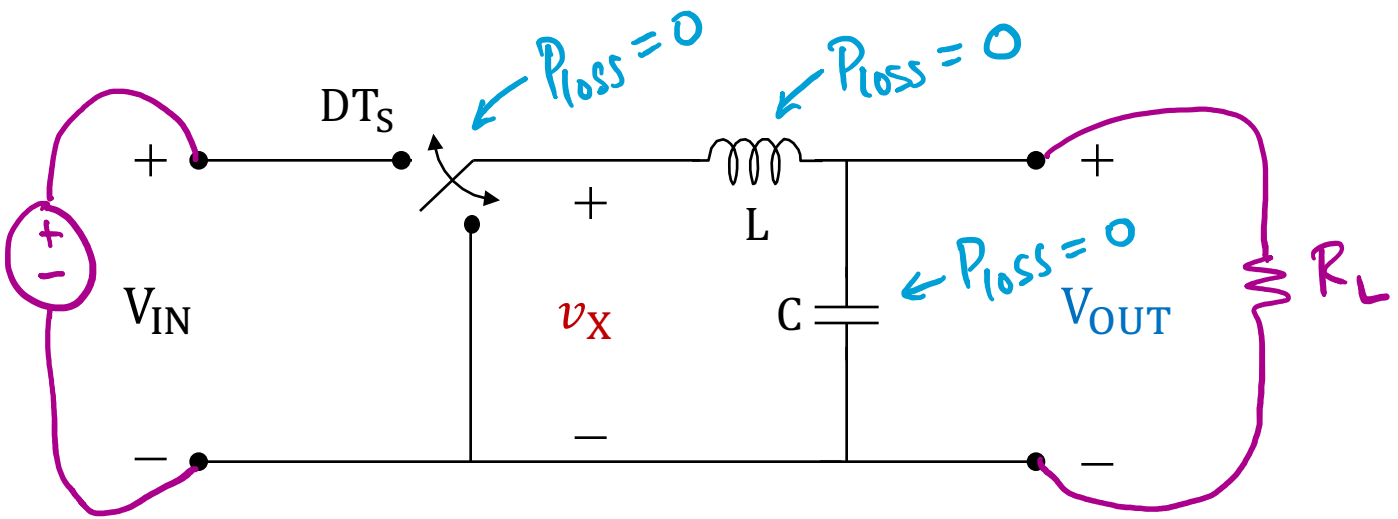
Switch closed: $v(t) = 0$

Switch open: $i(t) = 0$

closed open

Power loss: $p(t) = v(t)\,i(t) = 0(I) + V(0) = 0 + 0 = 0$

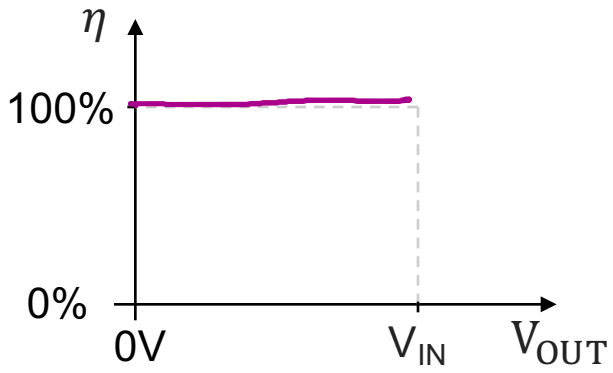
Efficiency of Switching Power Converter



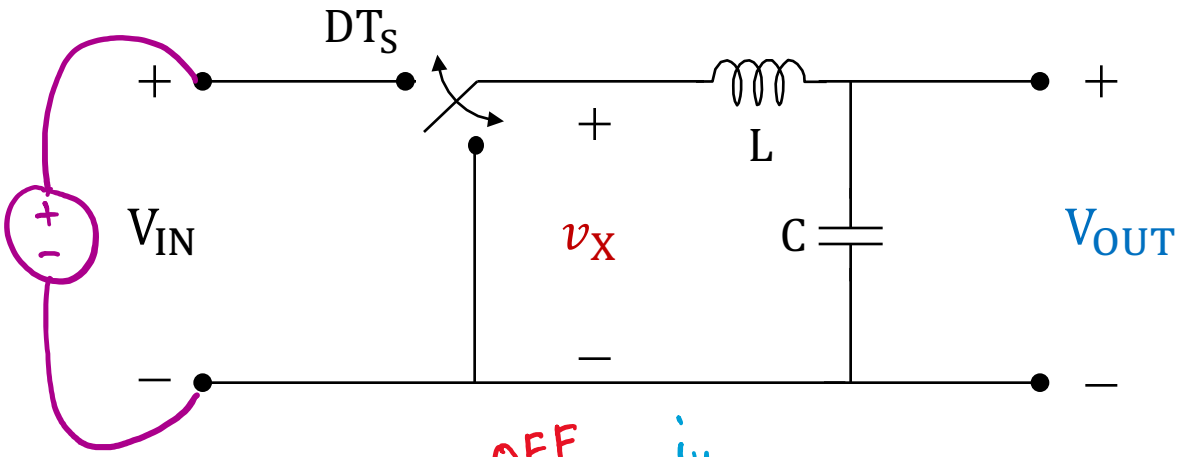
$$\eta = \frac{P_{OUT}}{P_{IN}} = \frac{P_{OUT}}{P_{OUT} + \underbrace{P_{LOSS}}_{=0}} = \frac{P_{OUT}}{P_{OUT}} = 100\%$$

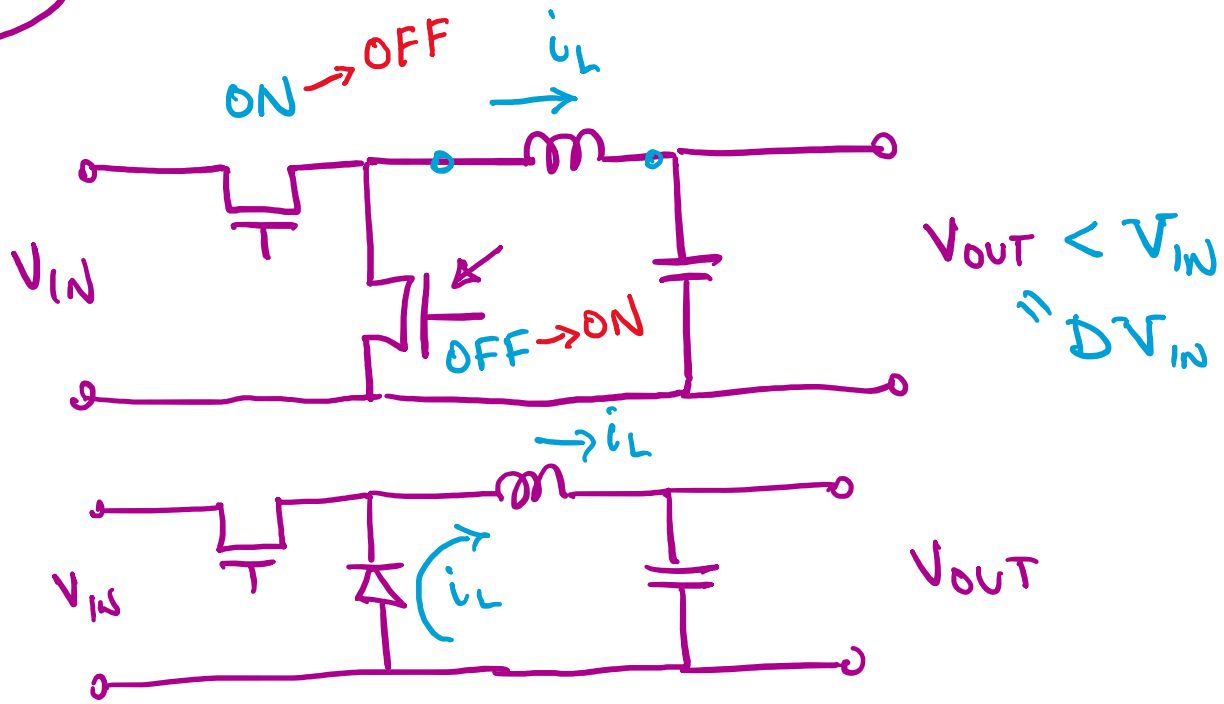
$$P_{OUT} = P_{IN}$$

$$V_{OUT} I_{OUT} = V_{IN} I_{IN}$$

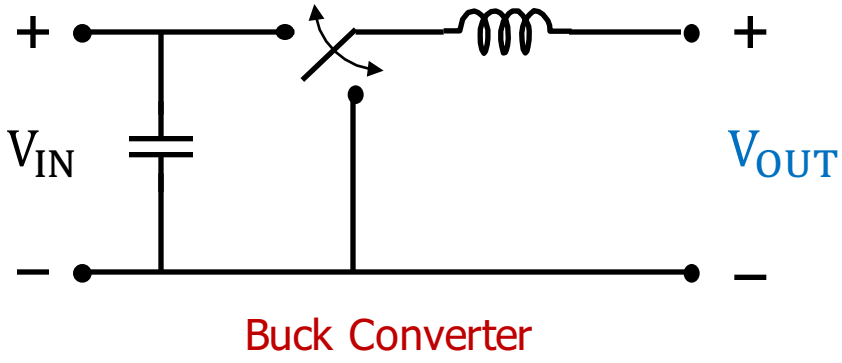


Switch Implementation of Buck Converter



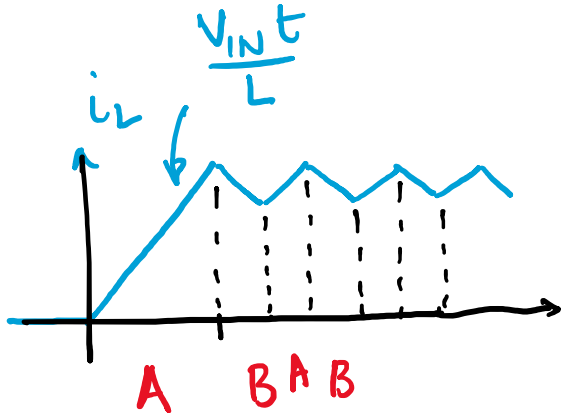


Boost Converter

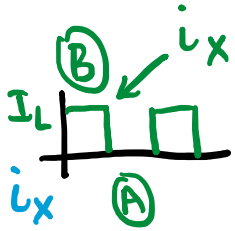


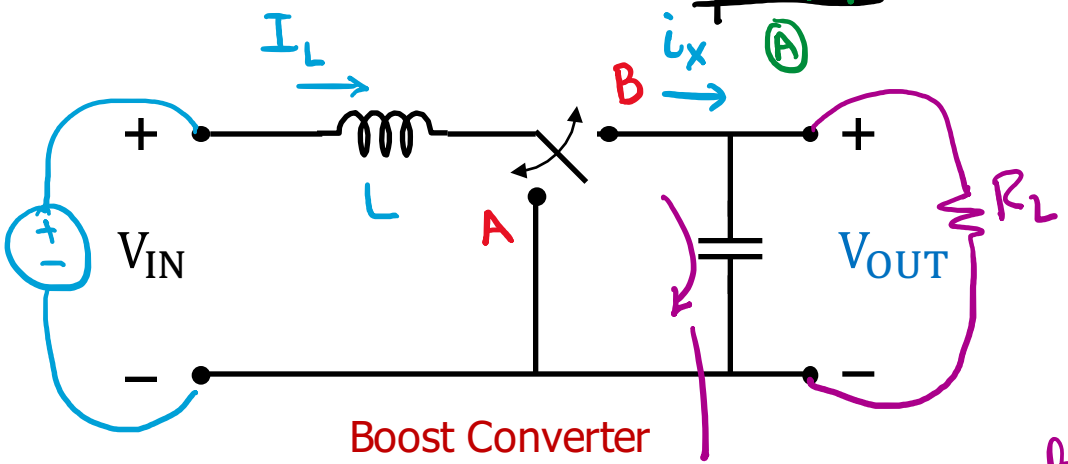
Buck Converter

$v_L = L\frac{di_L}{dt}$



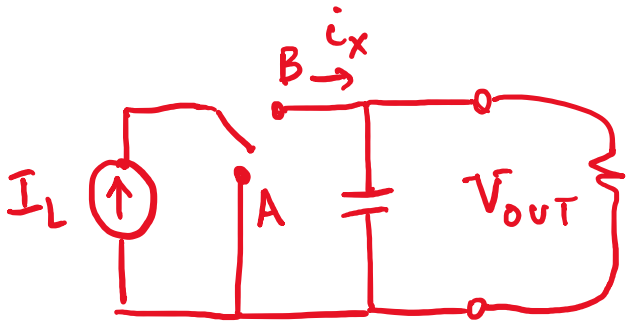
- Swap source and load



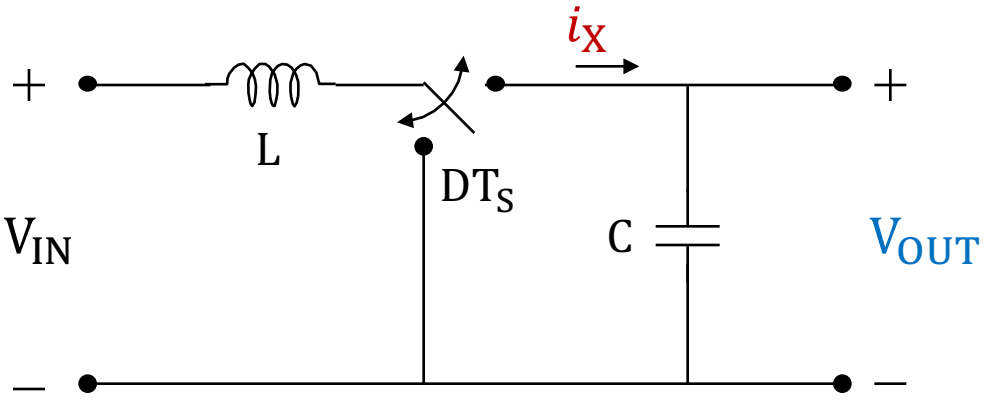


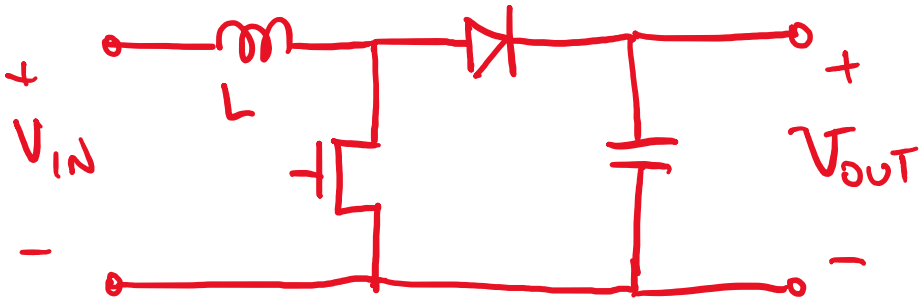
Boost Converter

high freq current



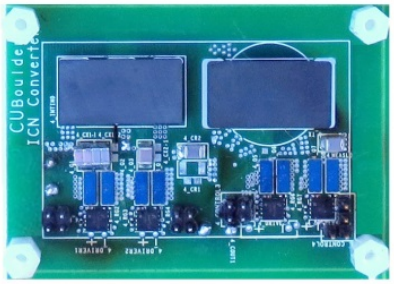
Switch Implementation of Boost Converter





Sample Power Converters

DC-DC Power Converter

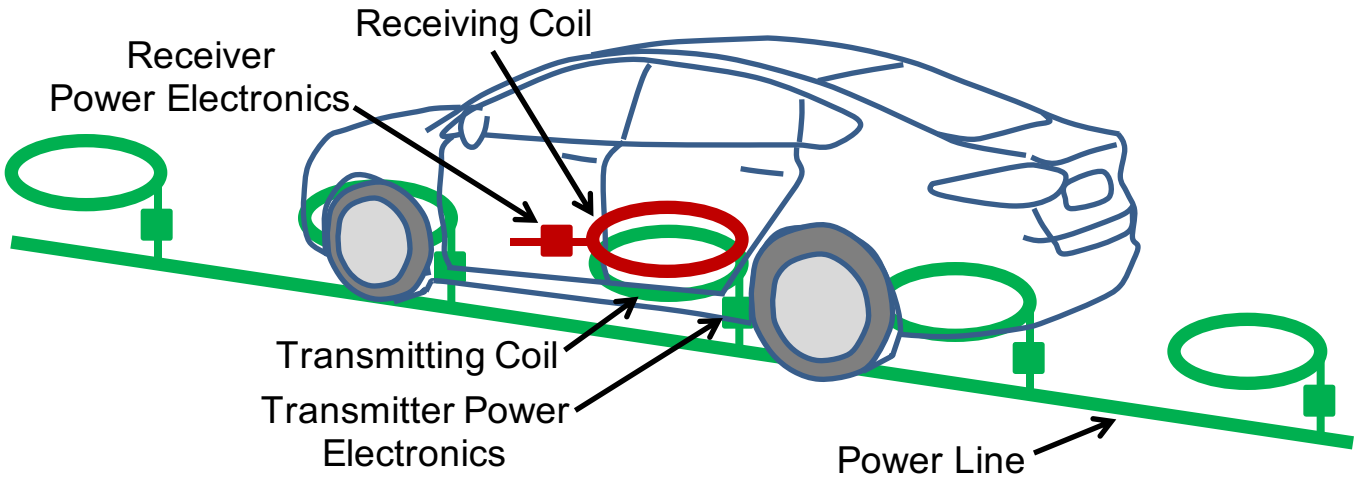


550-W quarter-brick telecom intermediate bus dc-dc converter

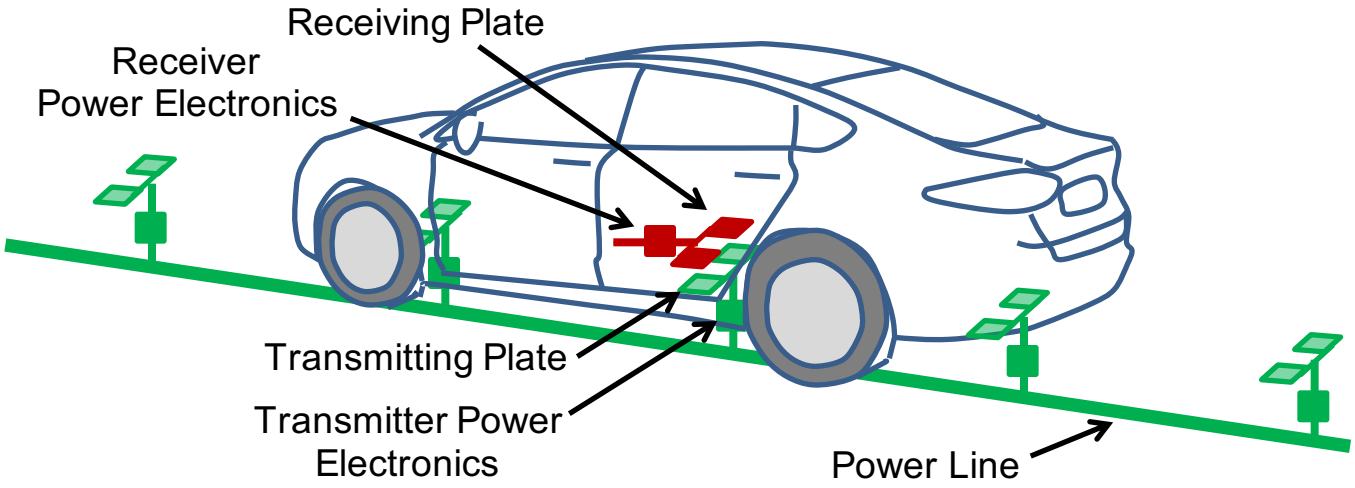
AC-DC Converter (Rectifier)

Laptop charger

Dynamic Wireless Charging of Electric Vehicles

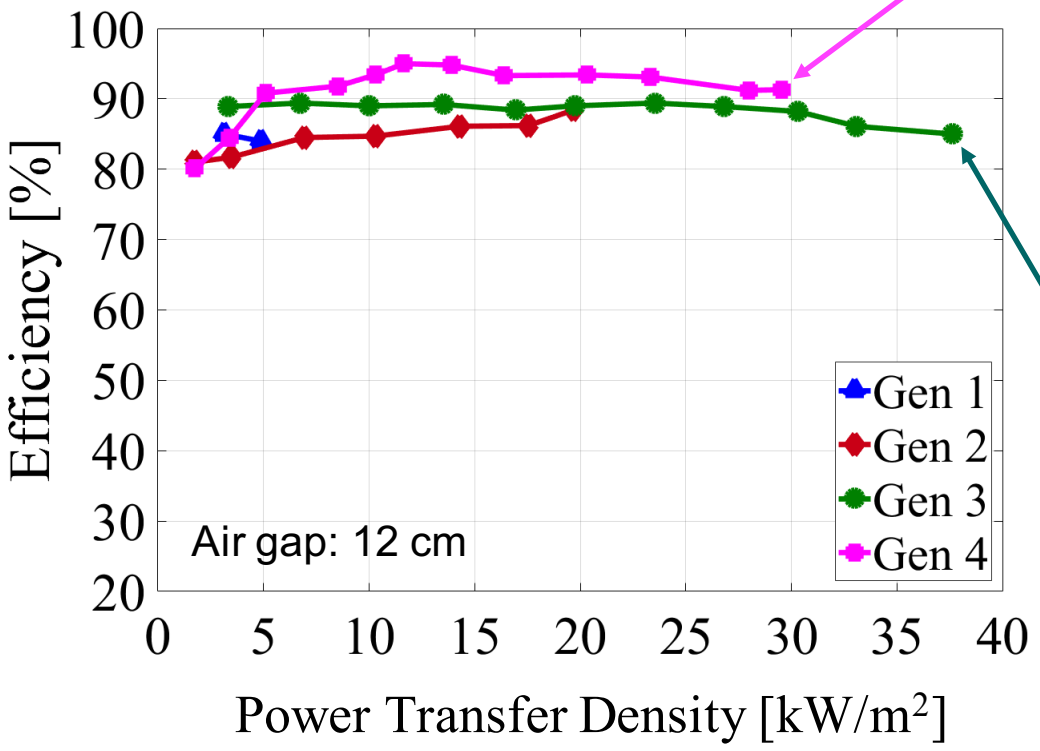


Dynamic Capacitive Wireless Charging

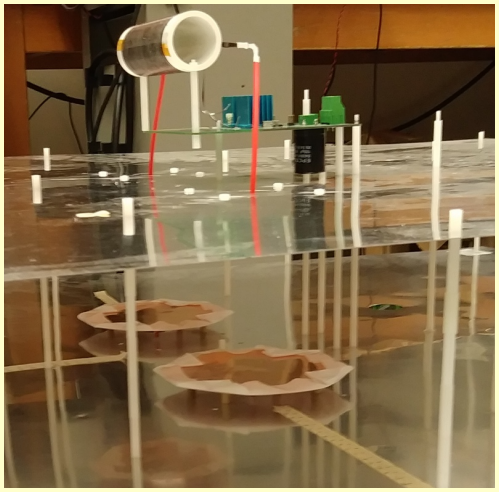


- Capacitive WPT systems do not have ferrites and can be:
  - Less expensive
  - More efficient
  - Smaller
  - Lighter
  - Easier to embed in roadway

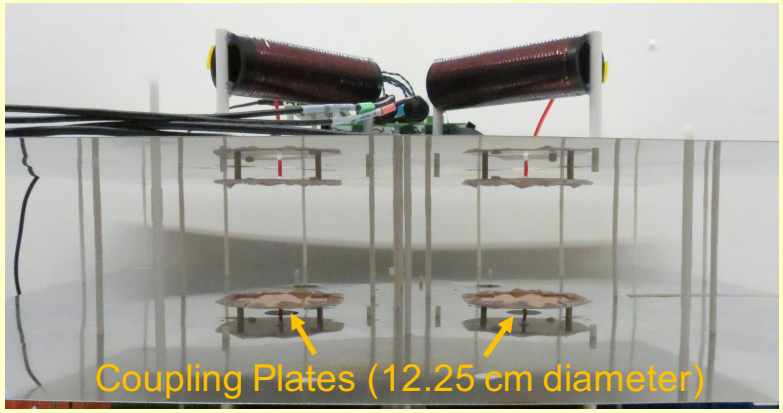
Capacitive Wireless Charging Prototypes



Gen 4 System:
13.56-MHz 0.9-kW



Gen 3 System: 6.78-MHz 1.2-kW



Power Electronics – ECE 4950

Title:	Power Electronics
Course Number:	ECE 4950
Credits:	4
Next Offering:	Fall 2019
Lecture:	MWF 10:10-11:00 am
Discussion:	W 1:25-2:15 pm
Prerequisite:	ECE 3150 (Microelectronics) or equivalent
Instructor:	Khurram Afridi