Lecture # 8, 10/18/2021

Last time

- S.S. Analysis w nonideal ckt elements (Ch 3)
  - $\hookrightarrow$ continue today

Today

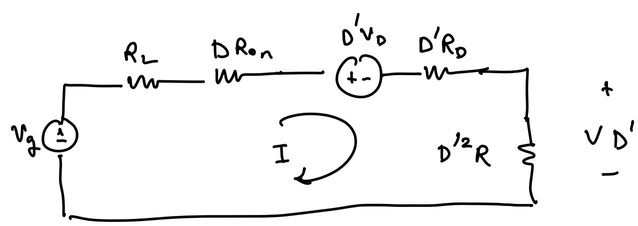
- Realistic η curves from ckt nonidealities
- Might start Ch 4

Tips

- Don't be a calculator monkey! Algebra is more impt. Learn to do math symbolically.
- Pros use computers w/ symbolic formulas

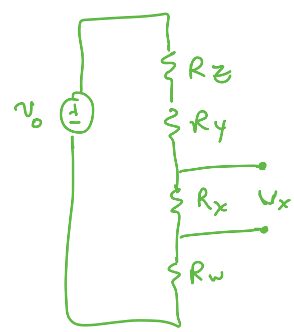
- Boost example contd.

Push load R to LHS



Easy to find I

$$I = \frac{V_g - V_D D'}{R_L + D R_{on} + D' R_D + D'^2 R}$$



$$V_x = V_o \frac{R_x}{R_w + R_x + R_y + R_z}$$

Lecture #9, 10/20/2021

- HW2, gave 24 hr extension

Today

↳ Continue ch 3 analysis

↳ Start Ch 4 → devices

voltages easy to get w/ divider formula

$$D'V = (V_g - D'V_D)\frac{D'^2 R}{R_L + D R_{on} + D'R_D + D'^2 R}$$

look @ output/input ratio

$$\frac{V}{V_g} = \frac{1}{D'}\left(1 - \frac{D'V_D}{V_g}\right)\left(\frac{1}{1 + \frac{R_L + D R_{on} + D'R_D}{D'^2 R}}\right) \qquad (1)$$

- Efficiency ?

$P_{in} = V_g I$ & $P_{out} = V(ID')$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V\cancel{I}D'}{V_g \cancel{I}} = \frac{VD'}{V_g} = \text{* rearrange (1)}$$

$$= \left(1 - \frac{D'V_D}{V_g}\right)\left(\frac{1}{1 + \frac{R_L + D R_{on} + D'R_D}{D'^2 R}}\right)$$

How to get high $\eta \to 1$?

pick $\frac{V_g}{D'} \gg V_D$ => supply V_g much higher than diode drop

$D'^2 R \gg R_L + D R_{on} + D'R_D$ => want small resistances in $\underbrace{\text{inductor, MOSFET, diode}}_{\text{in converter}}$

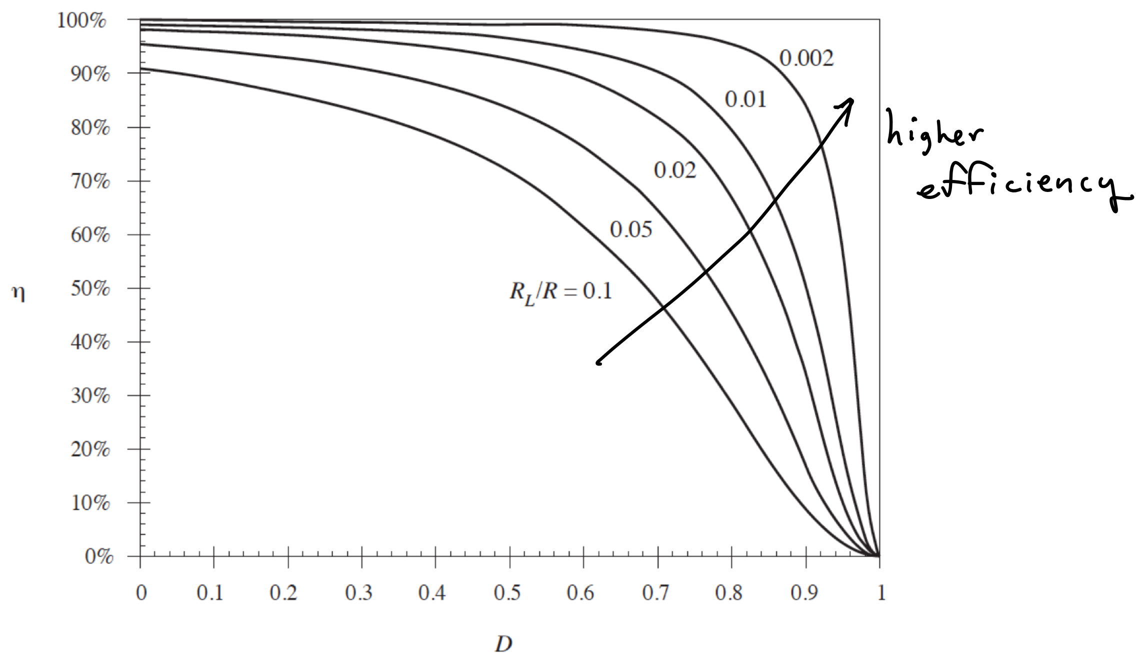
- Simplify to get cleaner result
  - ignore diode drop V_d
  - ignore R_D & R_{on} in MOSFET & diode
- keep R_L

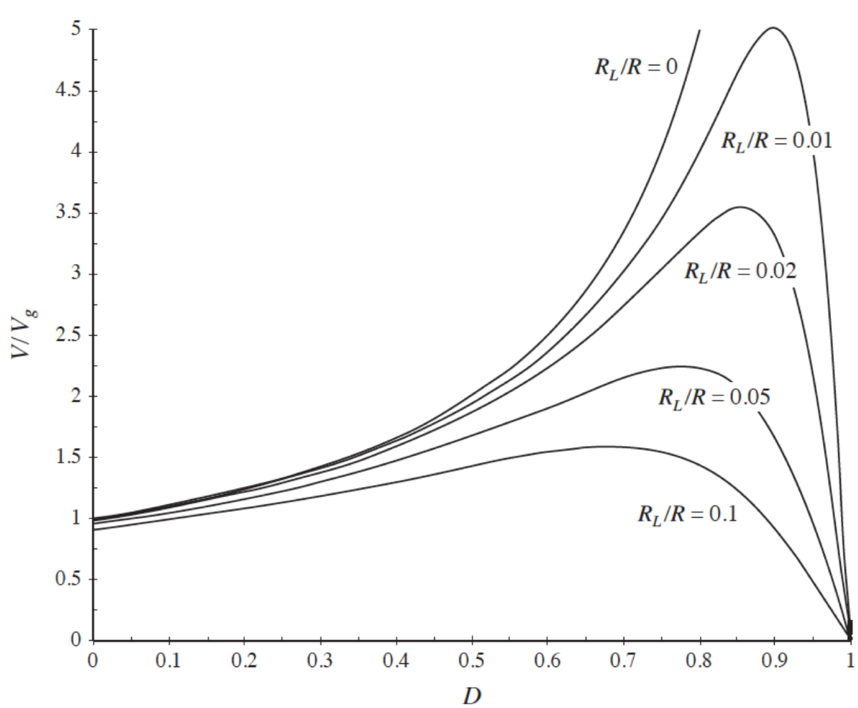
get

$$\Rightarrow \quad \eta \approx \frac{1}{1 + \frac{R_L}{D'^2 R}}$$

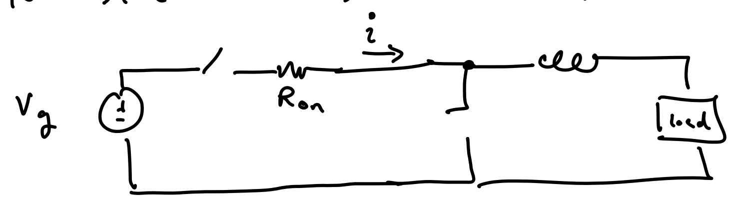
$$\frac{V}{V_g} \approx \frac{1}{D'} \frac{1}{1 + \frac{R_L}{D'^2 R}}$$

For boost example

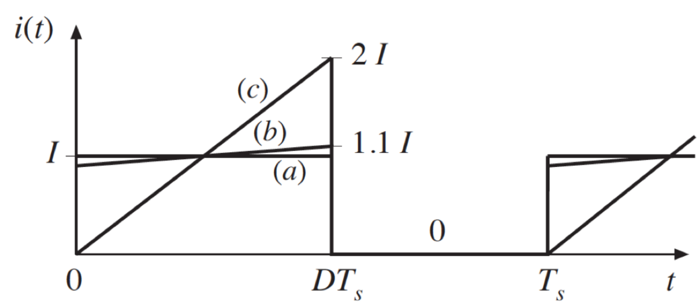




- How Accurate is SRA?



MOSFET current waveforms, for various ripple magnitudes:



Inductor current ripple	*MOSFET rms current*	*Average power loss in R_{on}*
(a) $\Delta i = 0$	$I\sqrt{D}$	$D\,I^2\,R_{on}$
(b) $\Delta i = 0.1\,I$	$(1.00167)\,I\sqrt{D}$	$(1.0033)\,D\,I^2\,R_{on}$
(c) $\Delta i = I$	$(1.155)\,I\sqrt{D}$	$(1.3333)\,D\,I^2\,R_{on}$

$= \langle i \rangle^2 R_{on}$

i^2_{rms}

indicate lower accuracy of SRA for larger Δi values.

- What is avg power lost in R_{on}?

• instantaneous

$$p(t) = i(t)\,v(t)$$
$$= i^2(t)\,R_{on}$$

• Cycle avg power lost

$$\langle p \rangle = \frac{1}{T_s}\int_0^{T_s} i^2(t)\,R_{on}\,dt$$

$$= R_{on}\boxed{\frac{1}{T_s}\int_0^{T_s} i^2(t)\,dt}$$

Familiar? RMS Definition!

$$= i^2_{rms}\,R_{on}$$

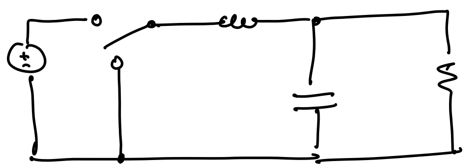
... but our prior analysis was for avg dc component only

turns out

$$\underbrace{\langle i \rangle^2}_{\text{based on SRA}} R_{on}$$

— Chapter 4: Switch Realization & Devices

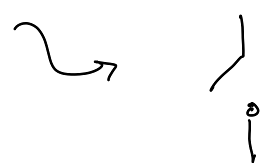
we started out with $\underbrace{\text{Single Pole Double Throw}}_{\text{SPDT}}$ model



Buck

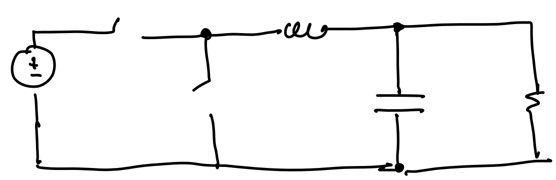
... but all power semiconductors act like

Single Pole Single Throw (SPST) switches



= SPST

Redraw to get same functionality



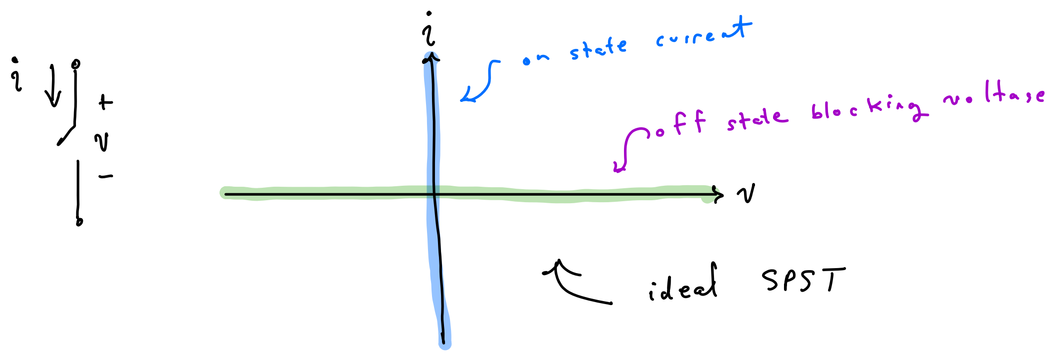
Problems with real world

→ Devices aren't perfect switches

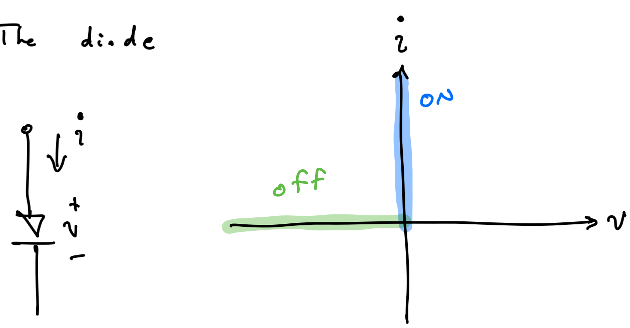
→ Some can conduct current in one direction only

→ - - - - - - block voltages in one polarity only

— Look at v-i "quadrants" each device can handle



The diode



- A single quadrant device

  ⊕ i, ⊖ v only