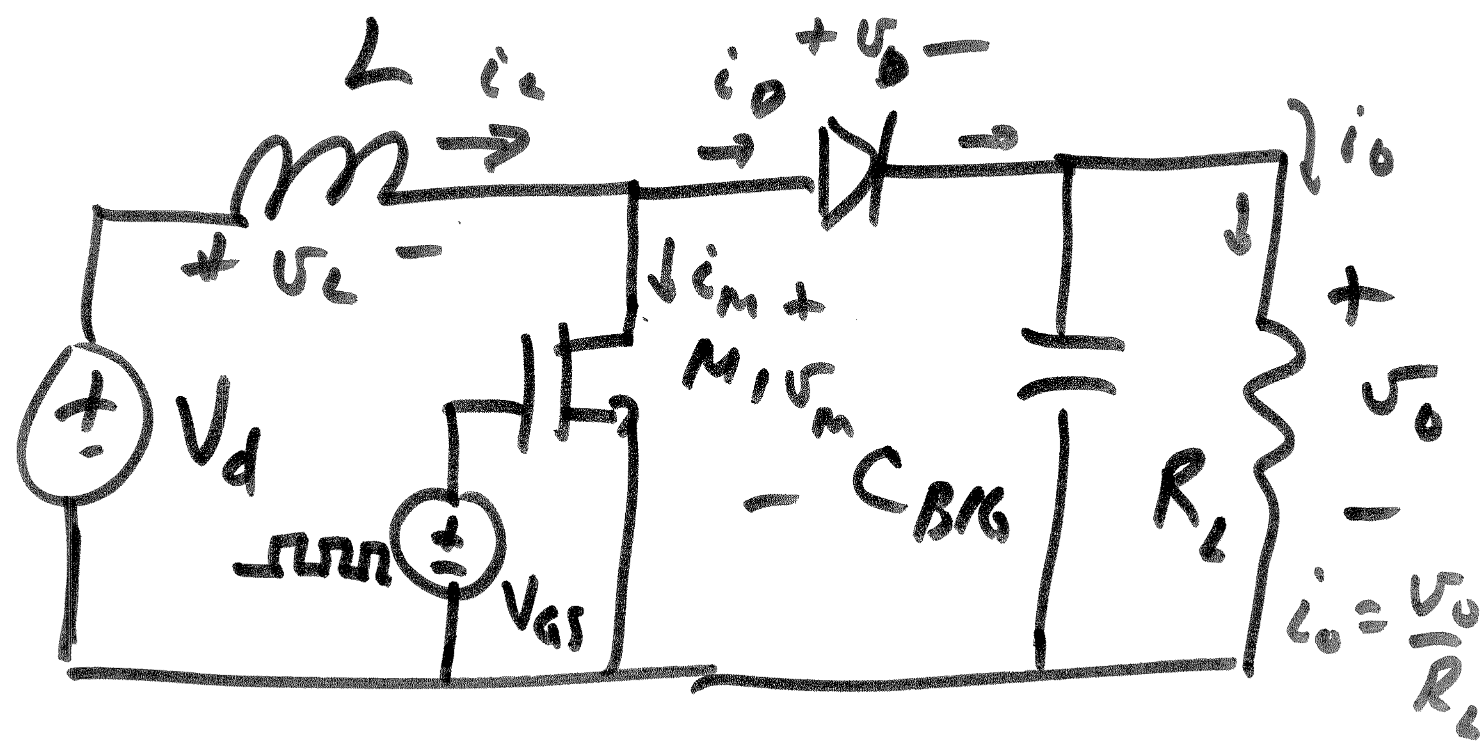
ECE 320 & ECE 329

ENERGY SYSTEMS I

BACKGROUND STUDY IN ENERGY SYSTEMS

SESSION no.   33

BOOST CONVERTER



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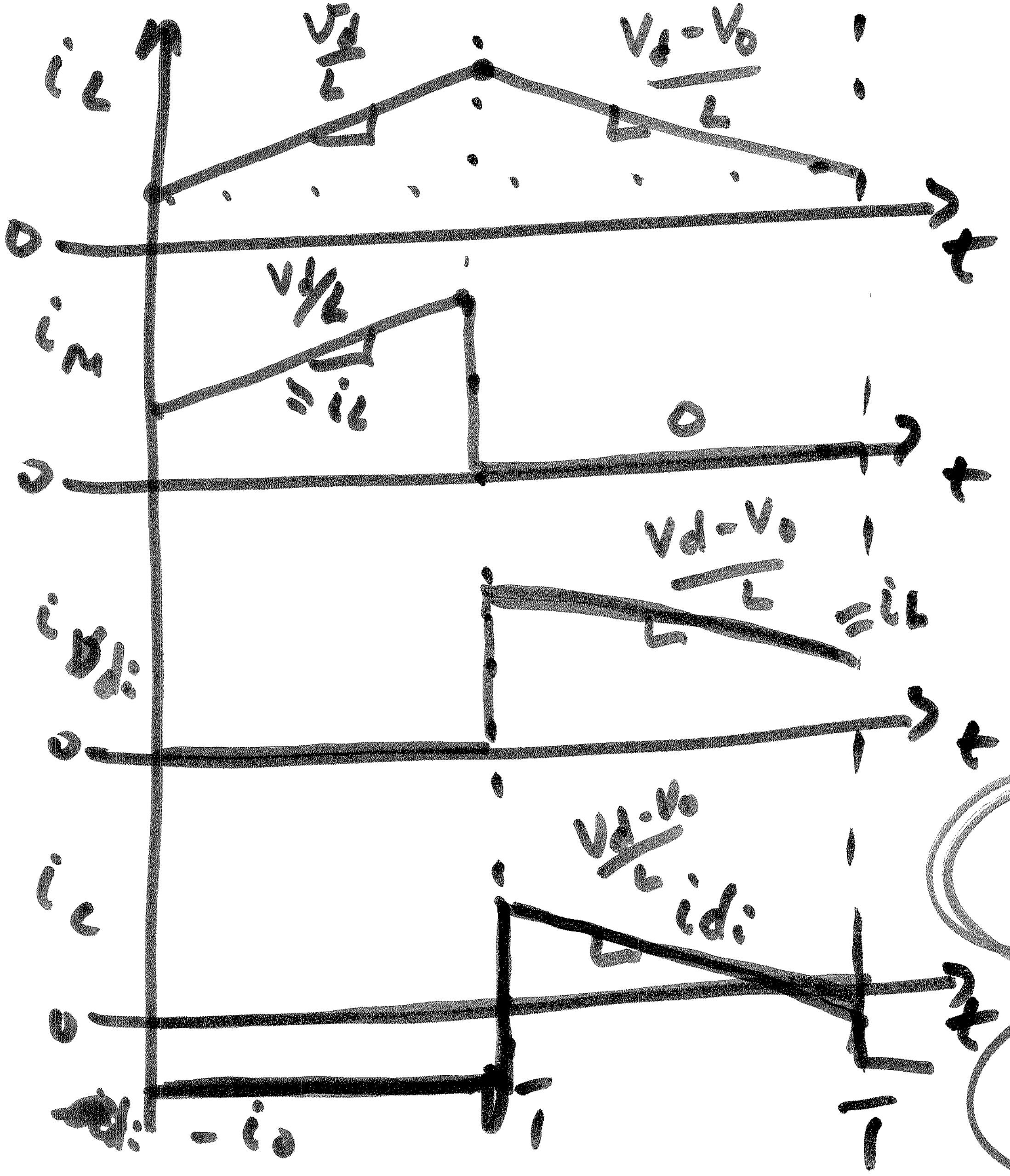
$$\Delta i_L = \int_0^T v_L \, dt = 0$$

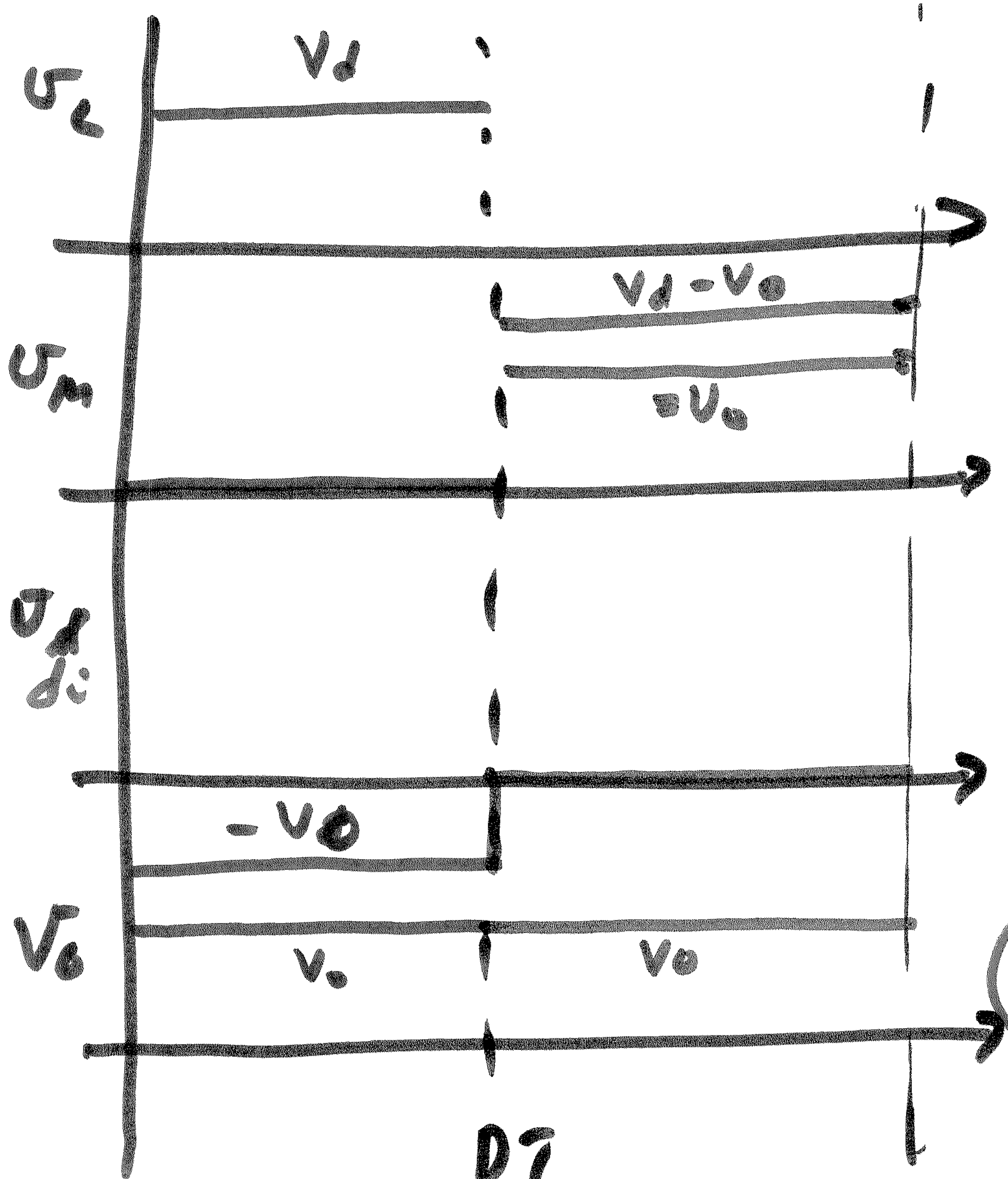
$$0 = \int_0^{DT} V_d \, dt + \int_{DT}^{T} (V_d - v_o) \, dt$$

$$\frac{v_o}{v_d} = \frac{1}{1-D}$$



$i_c = i_{di} - i_o$

$i_{c_{Av}} = 0$



$$V_0 = \frac{V_d}{1-D}$$

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EXAMPLE

BOOST CONVERTER

IDEAL DIODE & SWITCH

$P_{in} = 10W$ $\Delta i_L = 2A$ $P_{out} = 10W$

$f_{sw} = 200kHz$ FIND L, i_L WAVEFORM

$$\frac{V_o}{V_{in}} = \frac{1}{1-D} = \frac{12\,V}{5\,V}$$

$$(1-D)\frac{12}{5} = 1$$

$$2.4 - 2.4D = 1$$

$$3.4 = 2.4D$$

D = [illegible]

$$D = \frac{1.4}{2.4} = \underline{\underline{0.583}}$$

$$\Delta i_L = \frac{V_{in}}{L} D T$$

$$2A = \frac{5V}{L} (0.583) \frac{1}{200kHz}$$

$$L = \frac{5V}{2A} (0.583) (5 \mu s)$$

$$L = 7.3 \mu H$$

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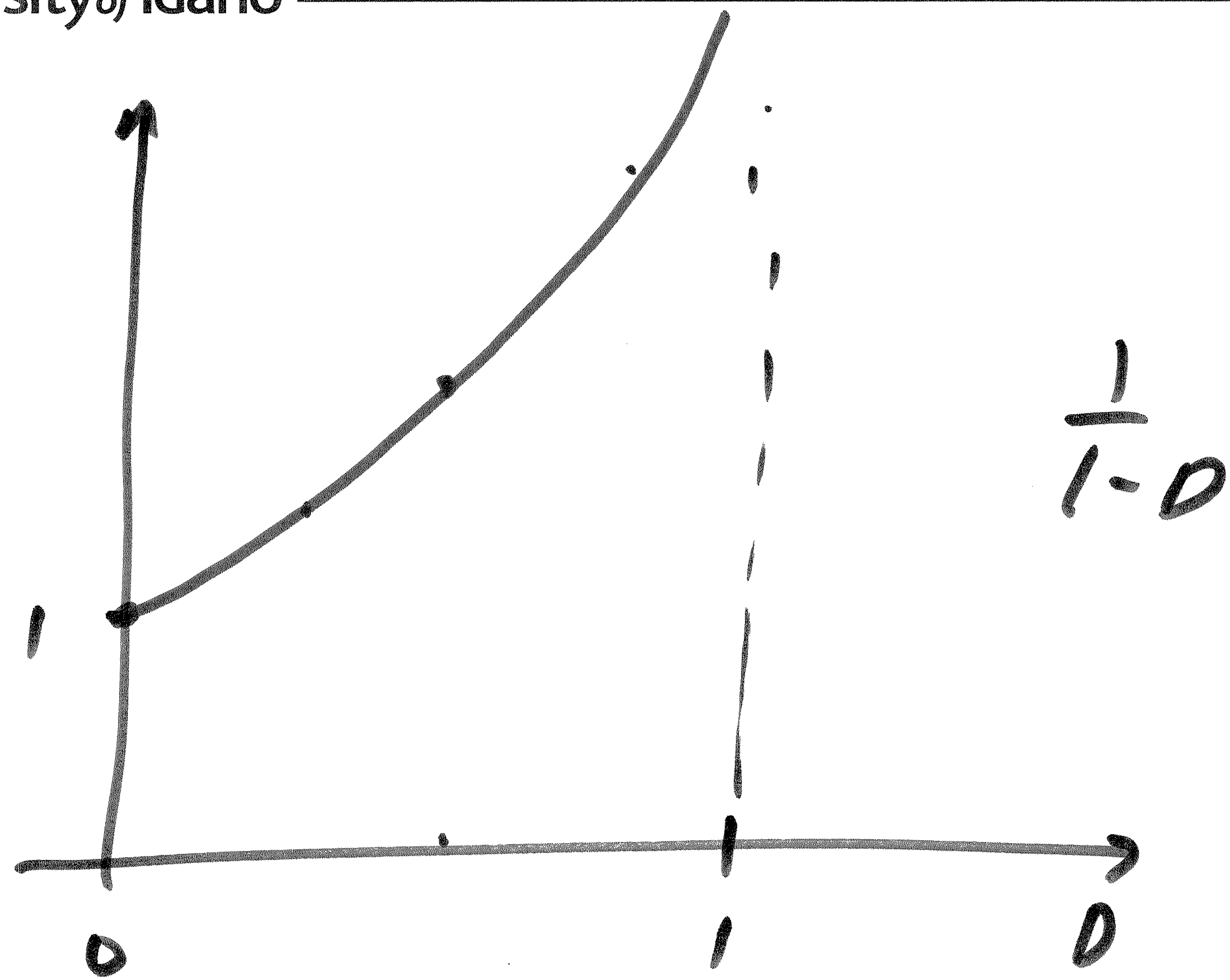

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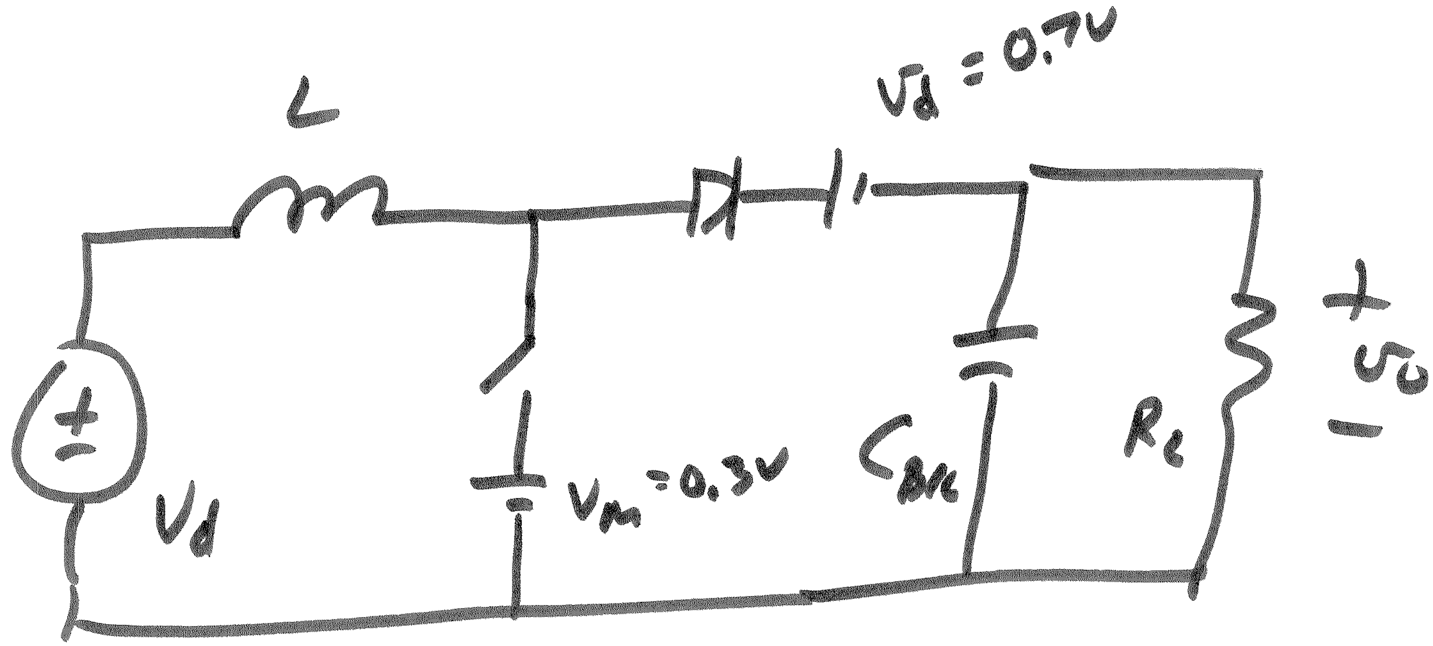


WHAT HAPPENS IF WE CONSIDER Vd & Vm?

Effect of inductor resistance

For boost converter, recall

$$V_o = \frac{V_s}{1 - D}$$

converters are not ideal. Some effects are possible to analyze. for example, inductors have resistance. It is a problem that we are trying to get rid of, but have not yet done so at a reasonable price. So we find,

$$P_{out} + P_{loss} = P_{source}$$

$$V_o \cdot I_o + I_{Lrms}^{2} \cdot r_L = V_s \cdot I_{Lave}$$

We know from our work with the boost converter that

$$I_o = I_{Lave} \cdot (1 - D)$$

$$I_o = \frac{V_o}{R}$$

Combining these two equations,

$$\frac{V_o}{R} = I_{Lave} \cdot (1 - D)$$

$$I_{Lave} = \frac{V_o}{R \cdot (1 - D)}$$

Now go back to the power balance and substitute for the average inductor current.

$$V_o \cdot I_o + I_{Lrms}^{2} \cdot r_L = V_s \cdot I_{Lave}$$

Because we assume a small ripple,

$$I_{Lave} \approx I_{Lrms}$$

$$V_o \cdot \frac{V_o}{R} + \left[\frac{V_o}{R \cdot (1 - D)}\right]^2 \cdot r_L = V_s \cdot \frac{V_o}{R \cdot (1 - D)}$$

Multiply through by $\frac{R}{V_o^{2}}$

$$1 + \frac{r_L}{\left[R \cdot (1 - D)^2\right]} = \frac{V_s}{V_o} \cdot \frac{1}{1 - D}$$

Simplify

$$\frac{V_s}{V_o} = (1 - D) + \frac{r_L}{R \cdot (1 - D)}$$

$$\frac{V_o}{V_s} = \frac{1}{\left[(1 - D) + \frac{r_L}{R \cdot (1 - D)}\right]} = \frac{1 - D}{(1 - D)^2 + \frac{r_L}{R}}$$

Efficiency

$$\eta = \frac{P_{out}}{P_{out} + P_{loss}}$$

$$\eta = \frac{\frac{V_o^2}{R}}{\frac{V_o^2}{R} + I_{Lrms}^2 \cdot r_L} = \frac{\frac{V_o^2}{R}}{\frac{V_o^2}{R} + \left[\frac{V_o}{R \cdot (1 - D)}\right]^2 \cdot r_L}$$

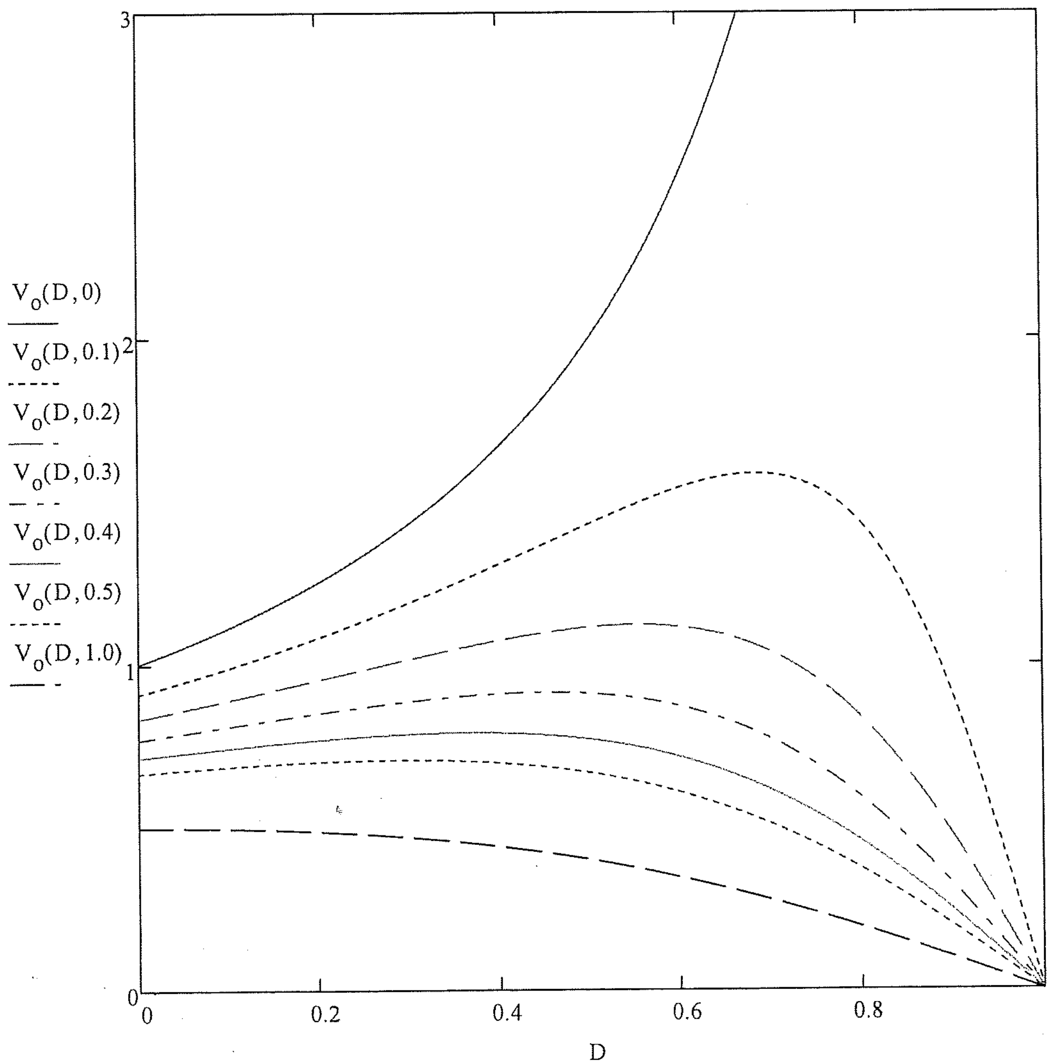
Divide out the $\frac{V_o^2}{R}$

$$\eta = \frac{1}{1 + \frac{r_L}{R \cdot (1 - D)^2}}$$

Now plot this out and see how the inductor resistance really affects the output voltage,

$R := 1$

$$V_o(D, r_L) := \frac{1 - D}{(1 - D)^2 + \frac{r_L}{R}}$$



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Energy Systems I

Lesson 33

Power Electronics

Boost Converter

Adafruit.com

Assignment: look up Limor Fried and Adafruit industries. Find out the background of the Minty Boost converter.