EECS192 Lecture 9
Mar. 17, 2020

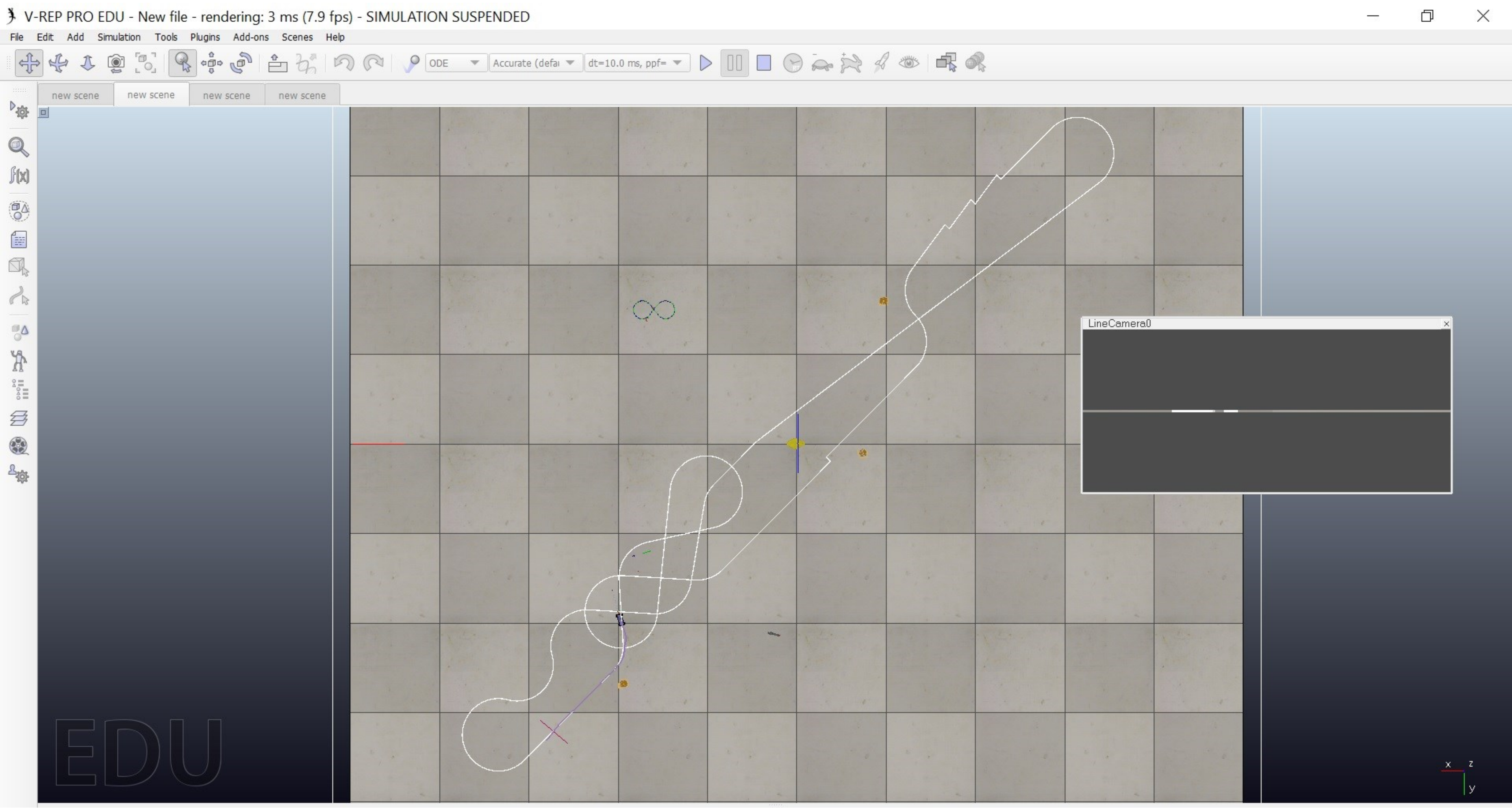
Notes:

1. Check off- PCB Design Review I
2. Progress Report due Tues 4/7 before class in bcourses
3. HW 2 due Fri 4/3, 6 pm in bcourses

Topics

- Upcoming checkpoints
- HW 2
- Progress Report
- Linear regulator –recap
- Buck converter
- Flyback Diode for Motor Inductor
- Discrete Time control/timing

V-rep simulation- HW2



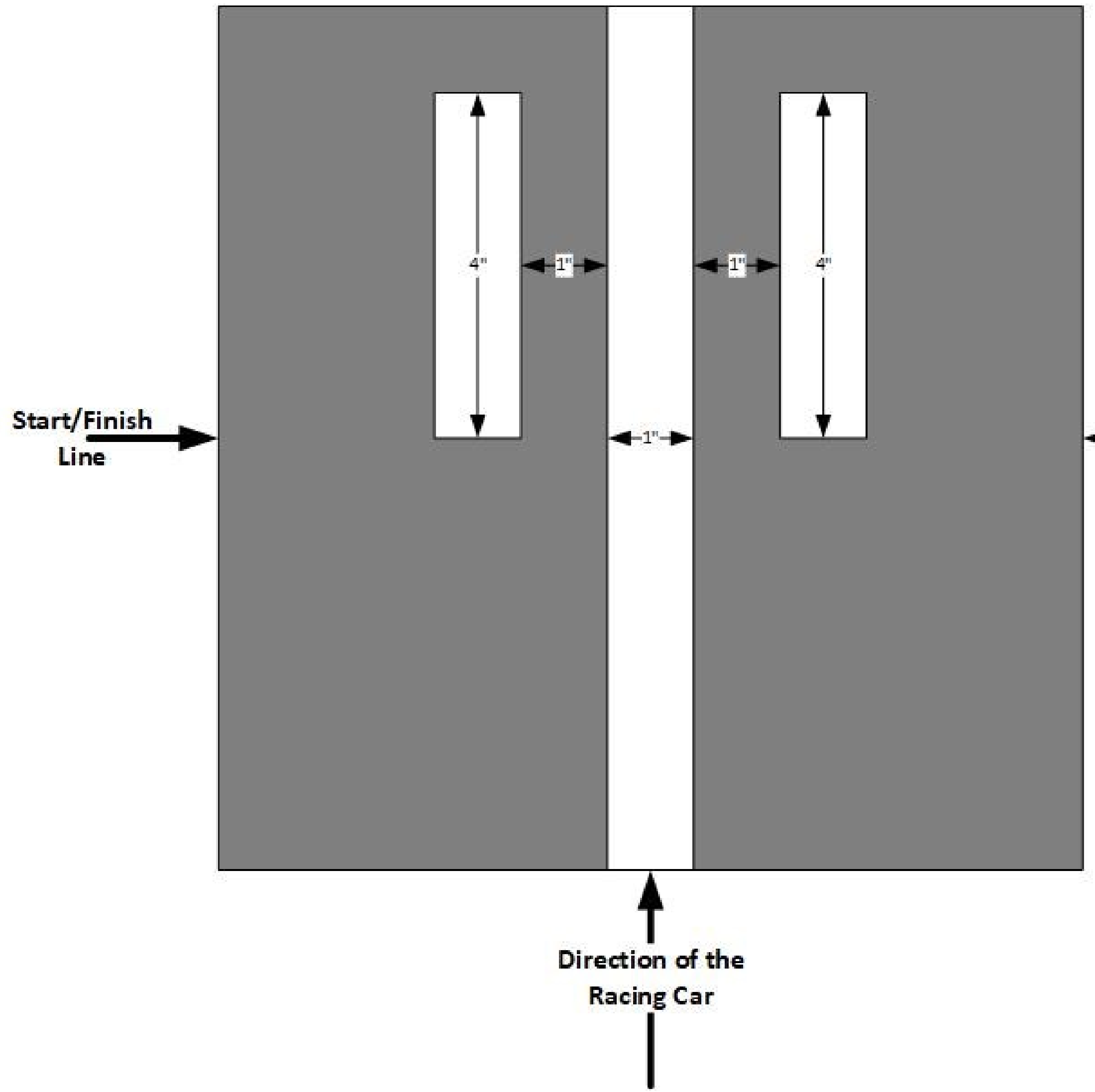
demo

NATCAR Notes

Cones +2 second
Finish line:The start/finish line will be marked with two 4-inch-long segments of 1-inch-wide white tape that are parallel to the track with 1-inch spacing, as shown in the figure below.

The car must automatically stop within 6 feet of the finish line after finishing the race.

A penalty of 4 seconds will be added to the lap time for any car that does not automatically stop within the required region.



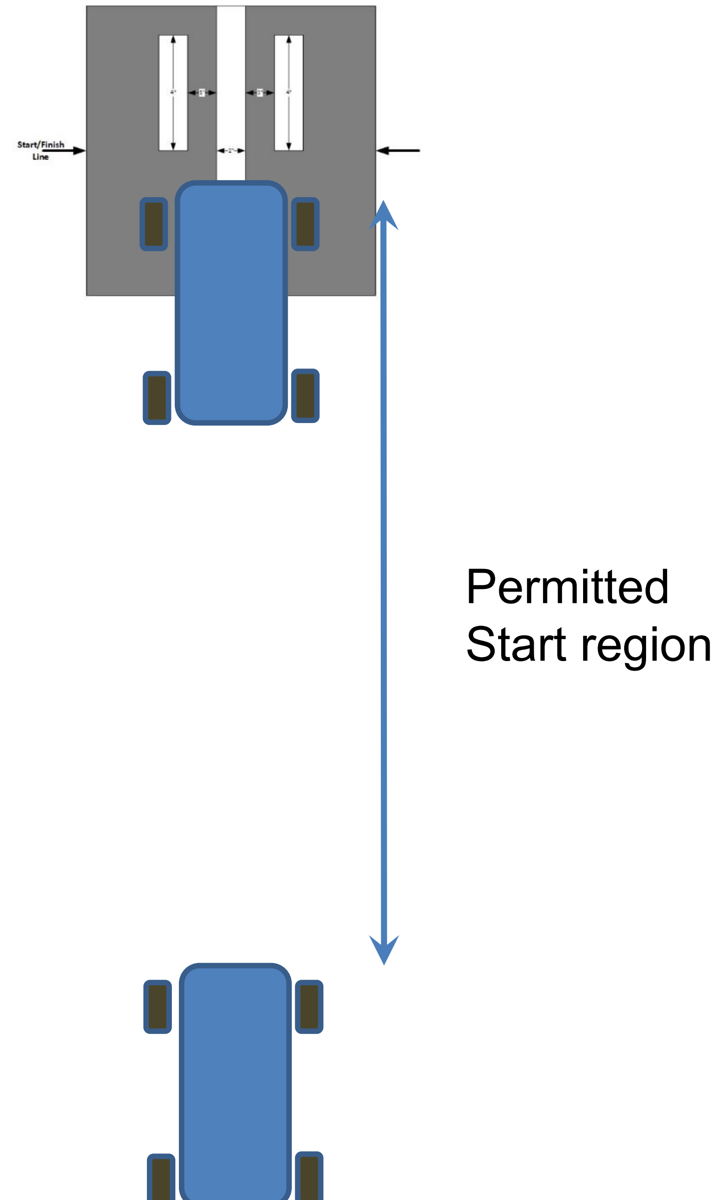
NATCAR Notes

1. Car can start in region shown (running start or avoid seeing stop line…) up to ``several feet” behind start/stop line

2. A running car can continue running for consecutive laps. If car is doing multiple laps without stopping, 4 second penalty is applied to intermediate laps.

The car must automatically stop within 6 feet of the finish line after finishing the race.

A penalty of 4 seconds will be added to the lap time for any car that does not automatically stop within the required region.



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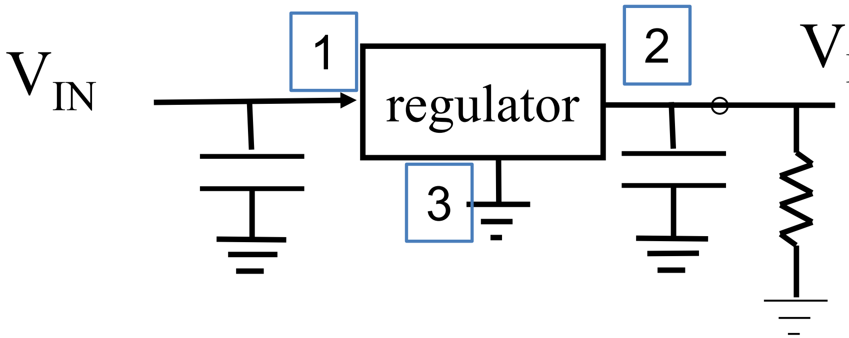
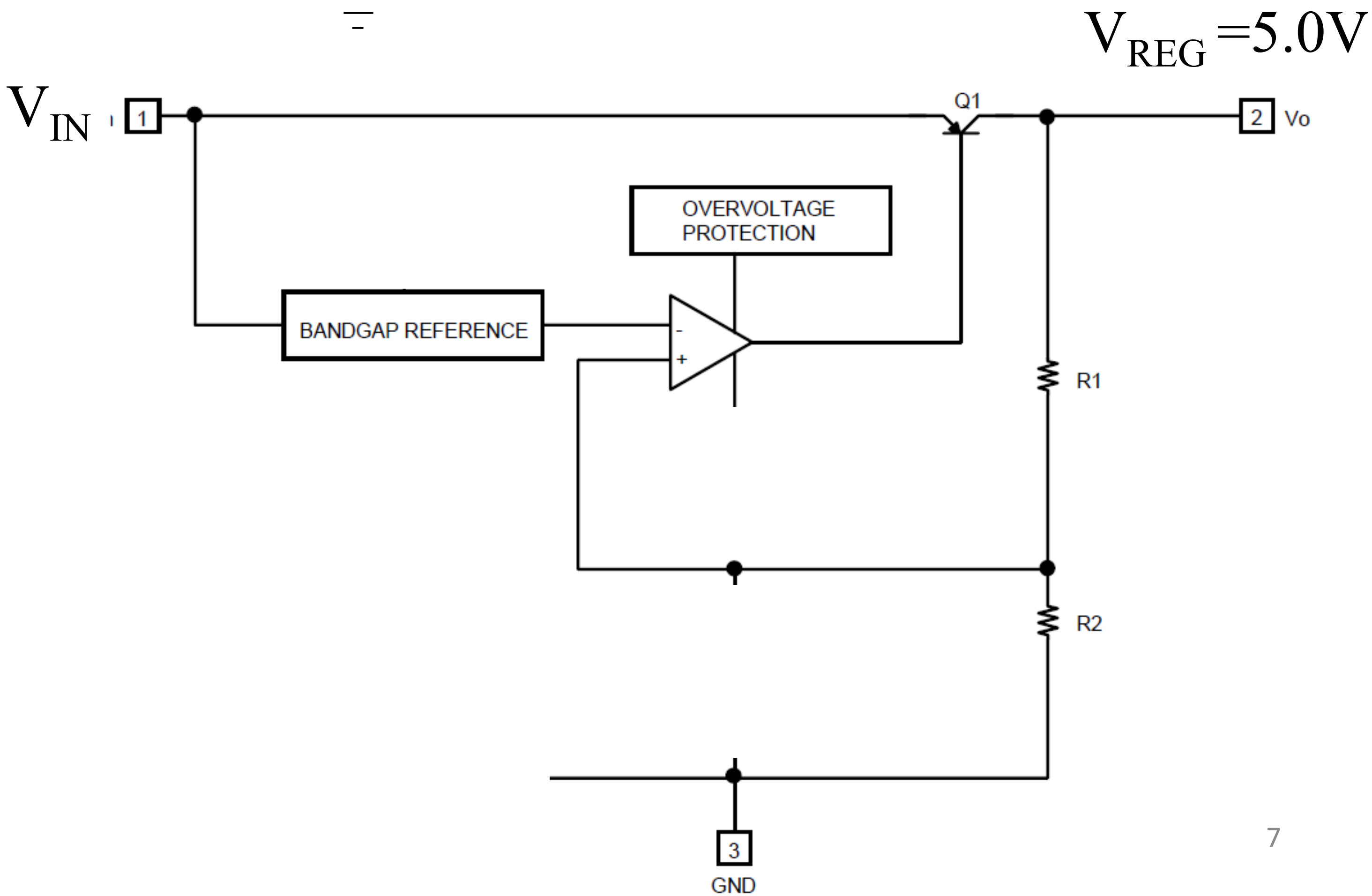
Linear Voltage Regulator



V_{REG} =5.0V

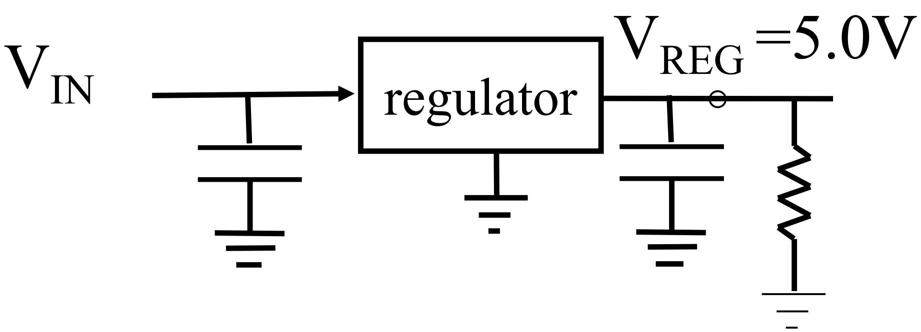
0.5 ohm
(equiv. for 1 amp load)



Linear Regulator for RC servo power

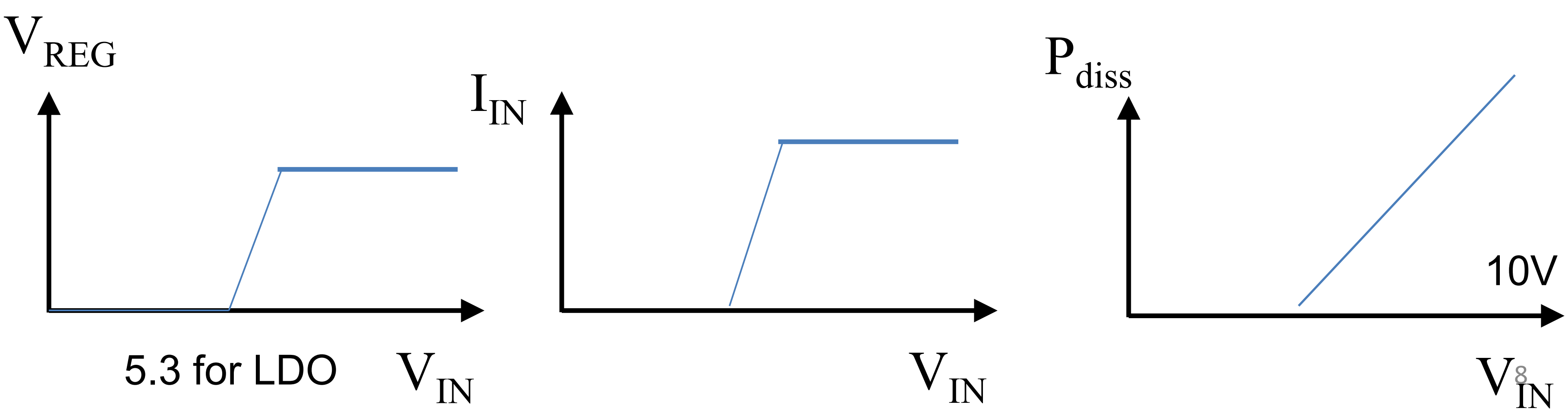
- Power limit? Heat….

Caution: caps required for stability for some voltage regulators



5 ohm
(equiv. for 1 amp load)

$P_{diss} = ?$



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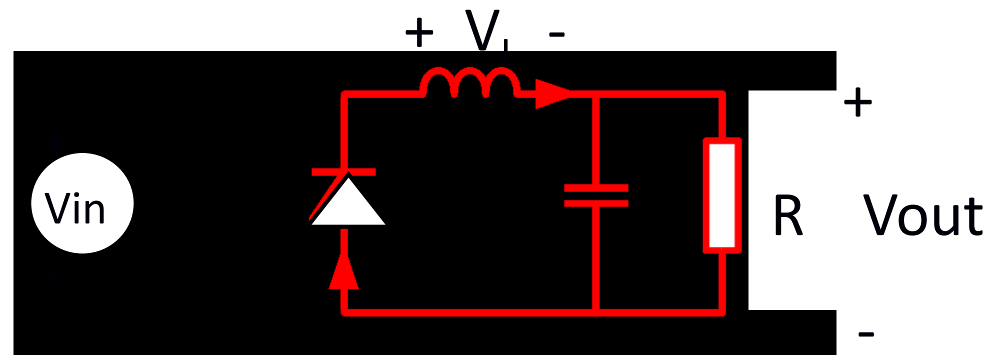
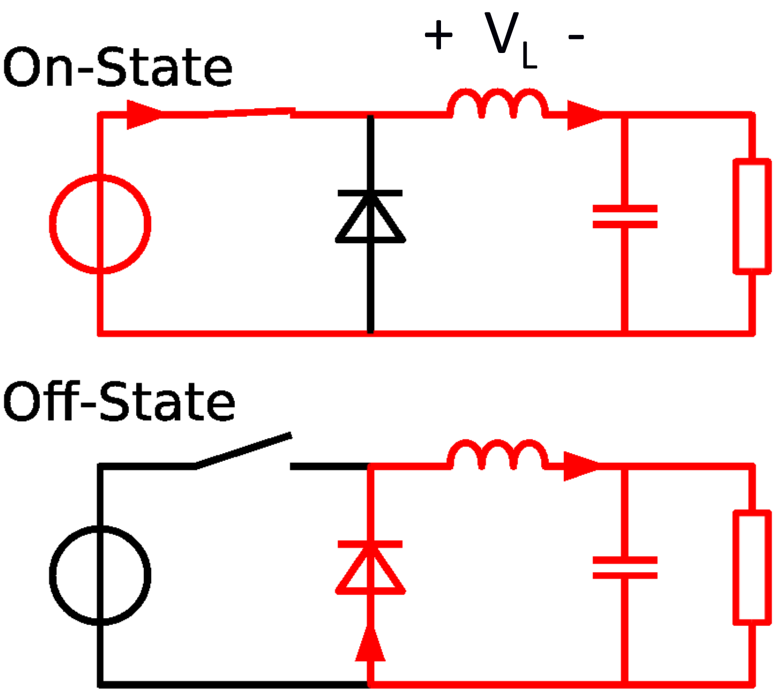
Buck Converter- DC-DC

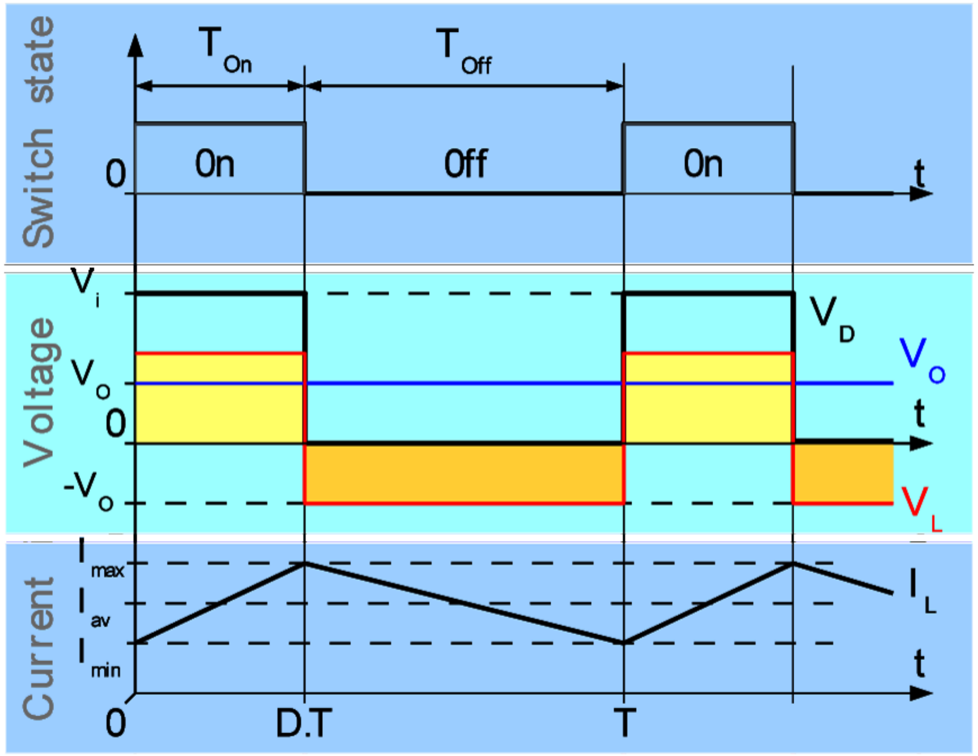


Why? Efficiency ~90%

Waveforms on board (also see buck converter notes.)
Buck: high to low. Boost: low-to-high)

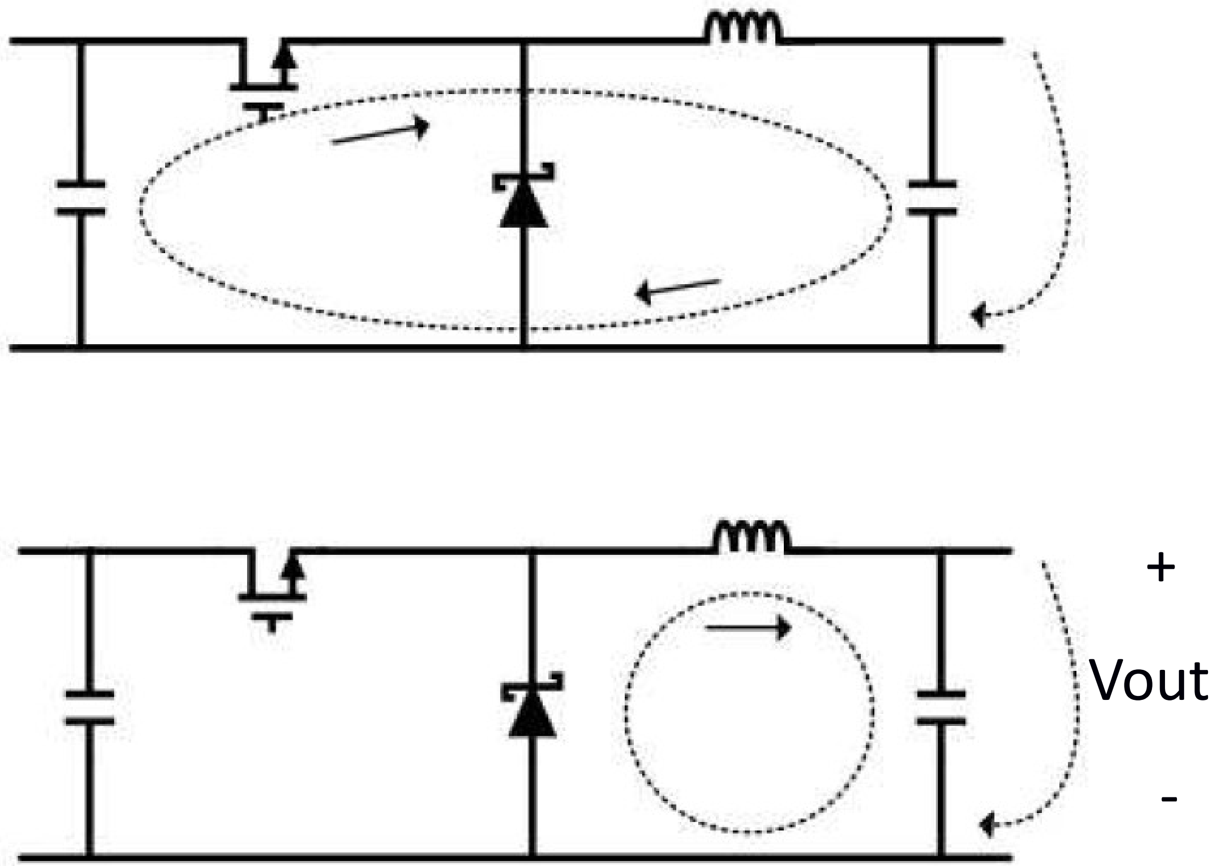
Buck Converter



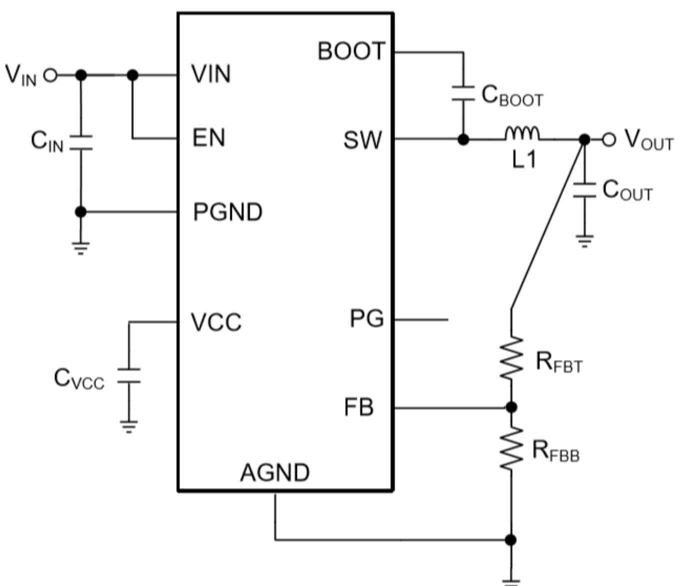


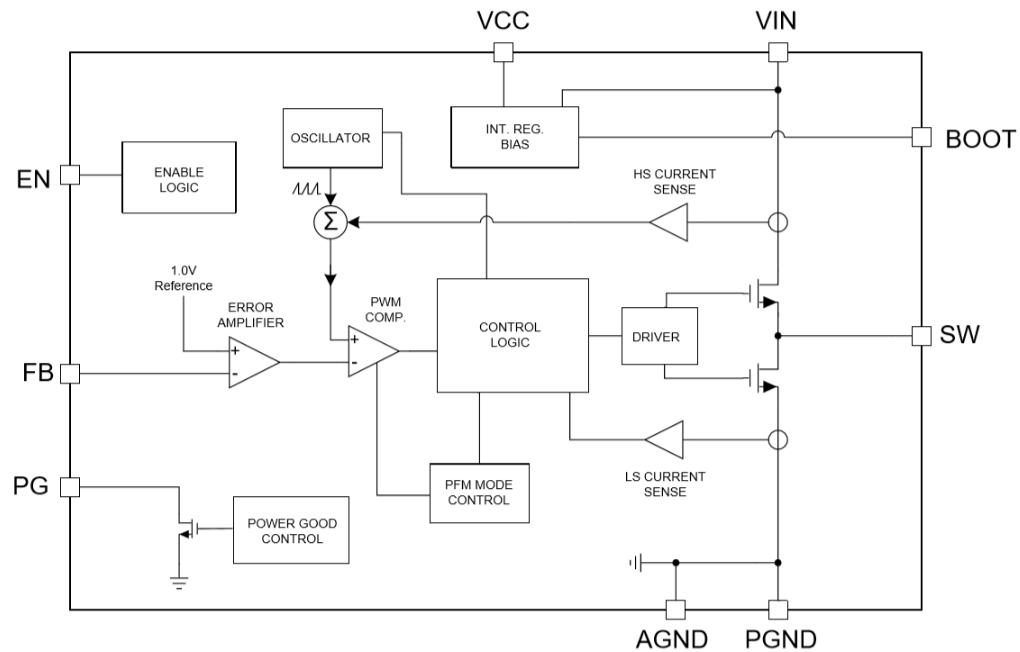
https://en.wikipedia.org/wiki/Buck_converter

Buck Converter LM2678



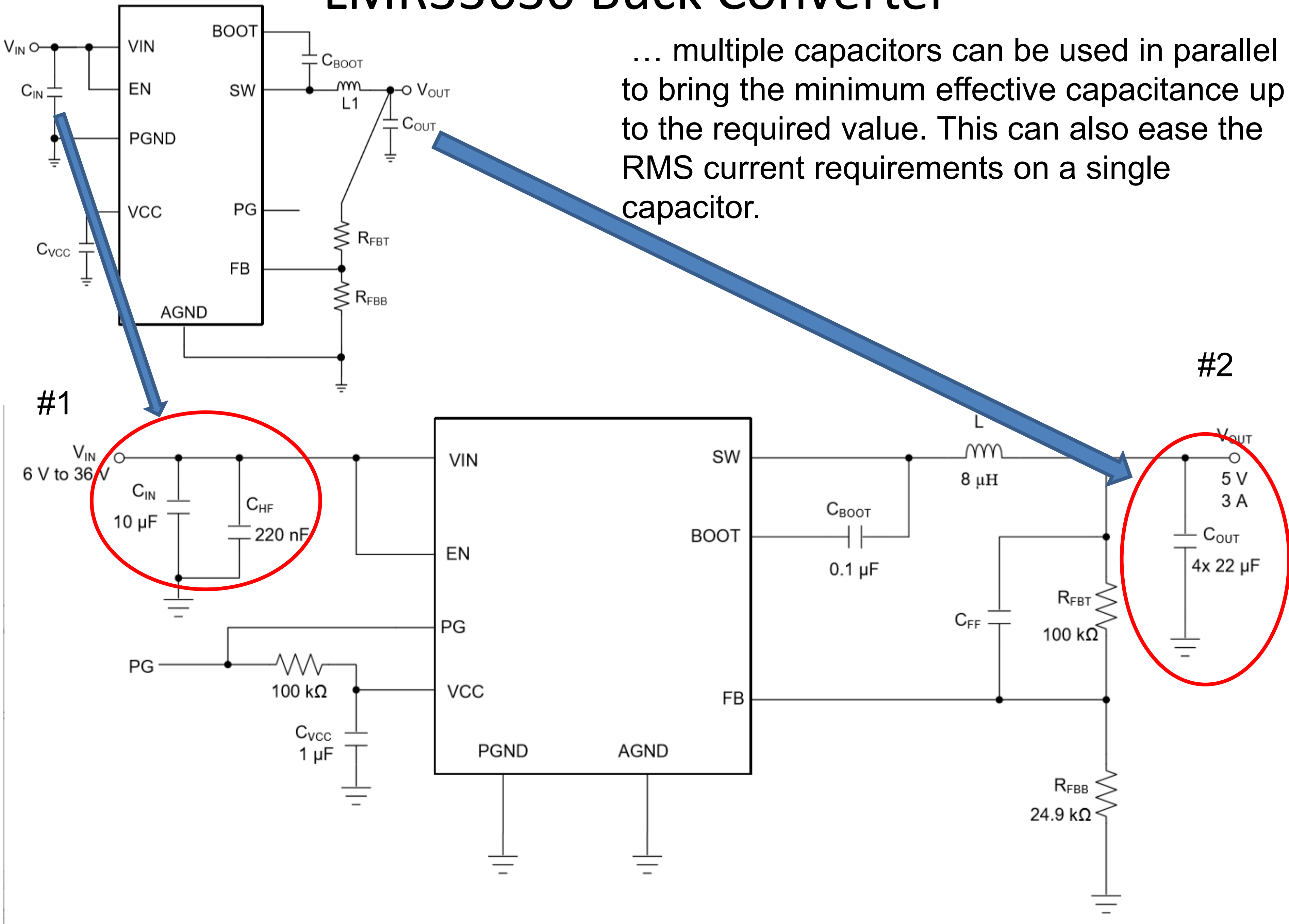
LMR33630 Buck Converter





LMR33630 Buck Converter

… multiple capacitors can be used in parallel to bring the minimum effective capacitance up to the required value. This can also ease the RMS current requirements on a single capacitor.



Buck Converter Waveforms

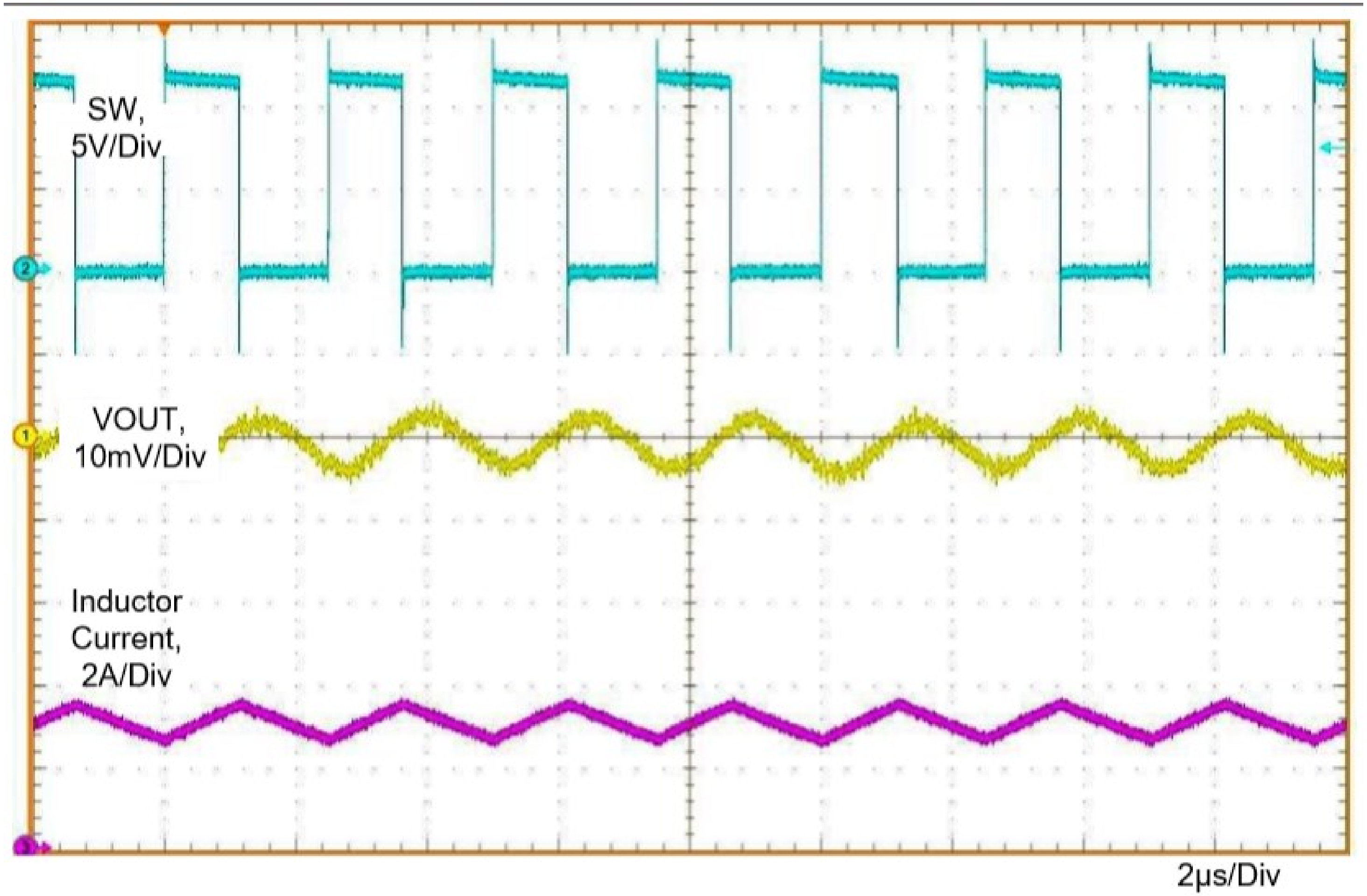


Figure 14. Typical PWM Switching Waveforms
V_{IN} = 12 V, V_{OUT} = 5 V, I_{OUT} = 3 A, f_S = 400 kHz

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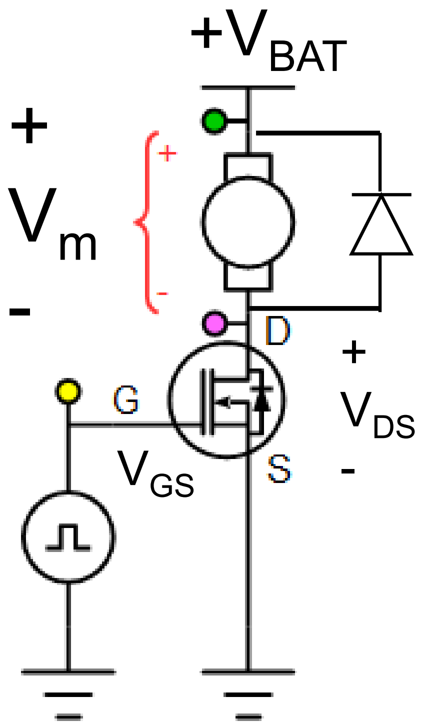
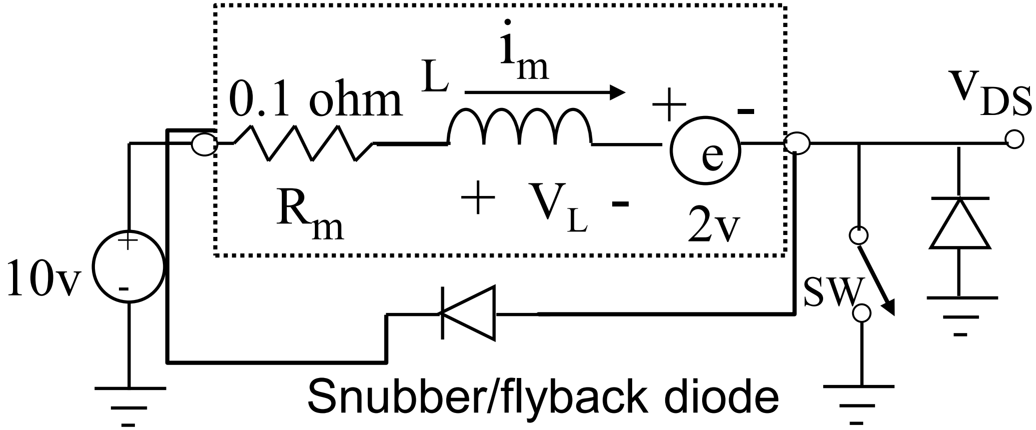
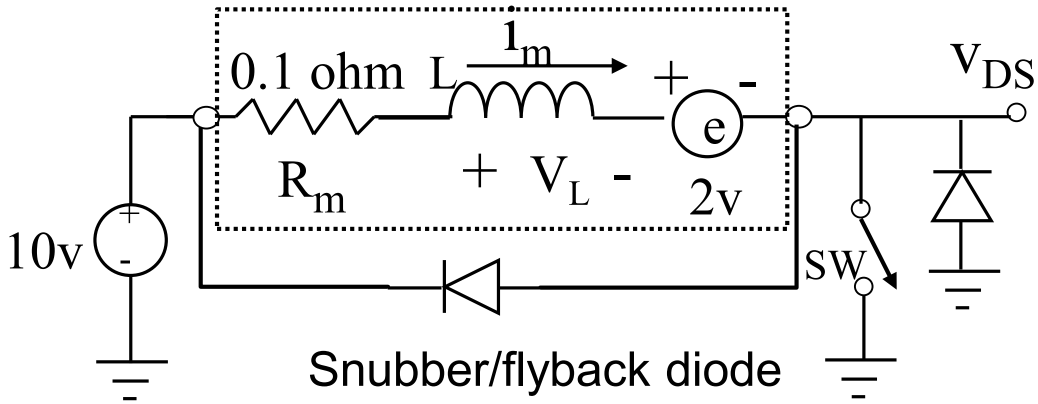
Low side motor drive



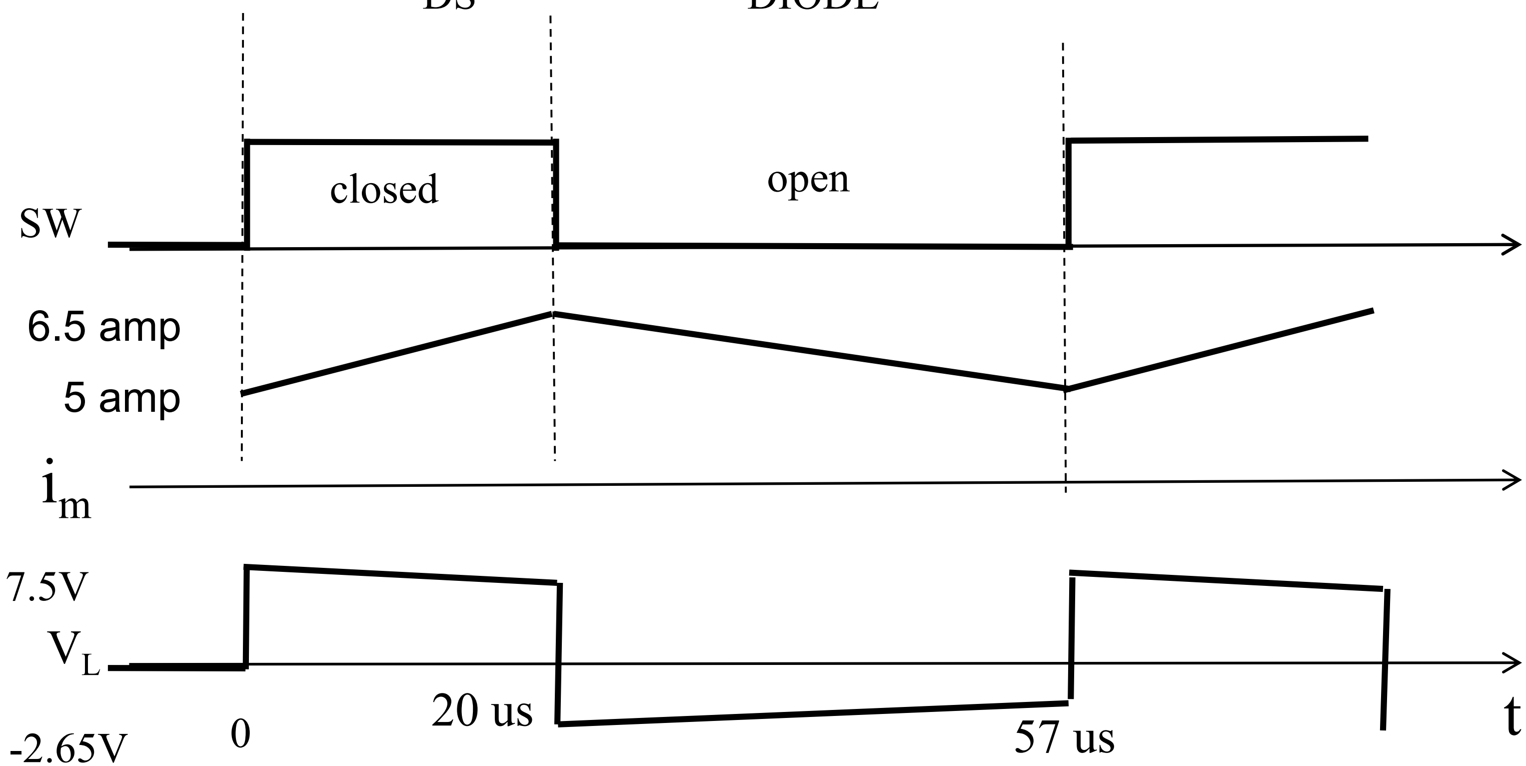
What about motor inductance?





Motor inductance~100 uH (?)
Time constant?
L/R= 10^{-4}H / 0.1 ohm = 1 ms

$$V_{DS} = 10V - V_{DIODE}$$



Flyback diode with motor model

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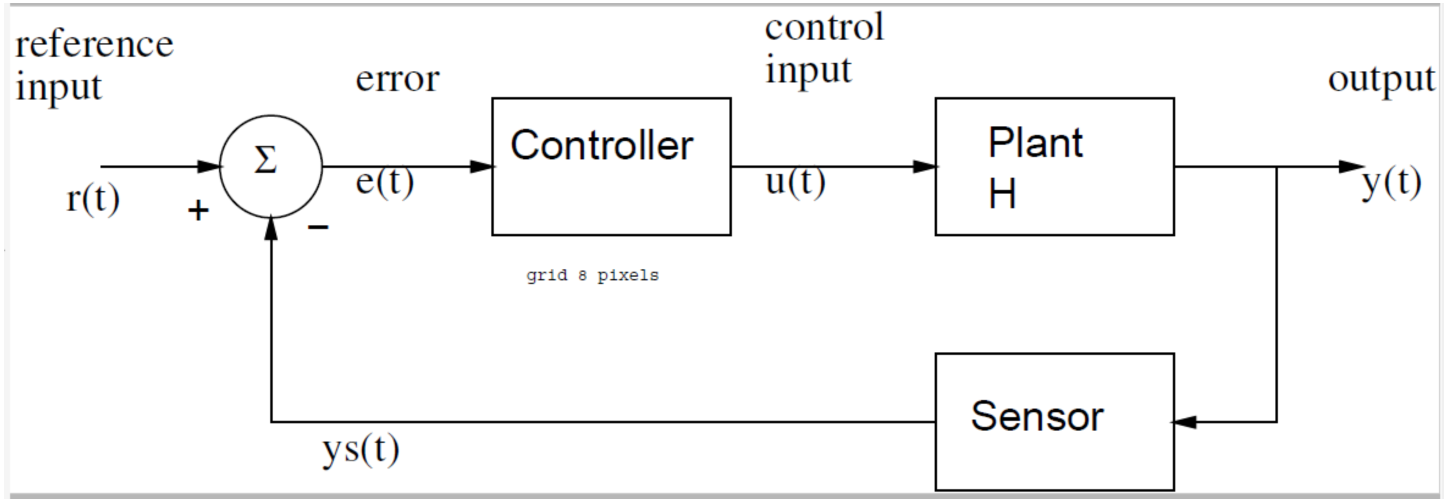
Control Synopsis



State equations: $$\dot{x}(t) = ax(t) + bu(t)$$

Output equations: $$y(t) = cx(t) + du(t)$$

Control Law (P): $$u(t) = k_p e(t) = k_p(r(t) \; - \; y(t)).$$

Control Synopsis

Control Law (P): $$u(t) = k_p e(t) = k_p(r(t) \; - \; y(t)).$$

New state equations:

$$\dot{x} = ax + bk_p e(t) = ax + bk_p(r - x) = (a - bk_p)x + bk_p r.$$

Zero Input Response (non-zero init condx):

$$x(t) = x(0)e^{(a-bk_p)t} \quad for \quad t \geq 0.$$

$a' = a - b\,k_p$ $\qquad$ $b' = b\,k_p$

Total Response (non-zero init condx) by convolution:

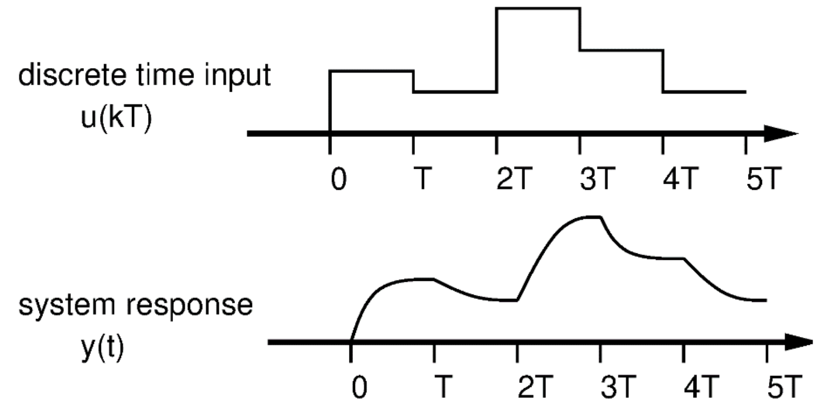
$$x(t_o) = e^{a't_o}x(0) + \int_0^{t_o} e^{a'(t_o-\tau)}b'r(\tau)d\tau \; . \tag{10}$$

Step Response (zero init condx) by convolution:

$$x(t_o) = b' \int_0^{t_o} e^{a't_o}e^{-a'\tau}d\tau \; = \; \frac{-b'e^{a't_o}}{a'}e^{-a'\tau}|_0^{t_o} \; = \frac{b'}{a'}(1 - e^{-a't_o}) \; . \tag{11}$$

Control Synopsis- Discrete Time

Superposition of Step Responses



$$x((k+1)T) = e^{a(k+1)T}x(0) + e^{a(k+1)T}\int_0^{(k+1)T} e^{-a\tau}bu(\tau)d\tau \ . \qquad (15)$$

$$x(kT) = e^{akT}x(0) + e^{akT}\int_0^{kT} e^{-a\tau}bu(\tau)d\tau \ . \qquad (14)$$

$$x((k+1)T) = e^{aT}x(kT) + e^{a(k+1)T}\int_{kT}^{(k+1)T} e^{-a\tau}bu(\tau)d\tau \ = e^{aT}x(kT) + \int_0^T e^{a\lambda}bu(kT)d\lambda \ , \quad (16)$$

Control Synopsis- Discrete Time

$$G(T) \equiv e^{aT} \quad and \quad H(T) \equiv b \int_0^T e^{a\lambda} d\lambda \ . \tag{17}$$

State equations:

$$x((k+1)T) = G(T)x(kT) + H(T)u(kT) \tag{18}$$

Output equations:

$$y(kT) = Cx(kT) + Du(kT) \ . \tag{19}$$

Total Response (non-zero init condx) by convolution:

$$x(k) = G^k x(0) + \sum_{j=0}^{k-1} G^{k-j-1} H u(j) \ . \tag{23}$$

Control Synopsis- Discrete Time

Control Law (P): $U(kT) = k_p\,[r(kT) - x(kT)]$

New state equations:

$$x((k+1)T) = G(T)x(kT) + H(T)k_p(r(kT) - x(kT)) = [G - Hk_p]x(kT) + Hk_p r(kT)\ . \quad (24)$$

$$x((k+1)T) = [e^{aT} + \frac{k_p}{a}(1 - e^{aT})]x(kT) + Hk_p r(kT) \ = \ G'x(kT) + Hk_p r(kT) \ . \quad (25)$$

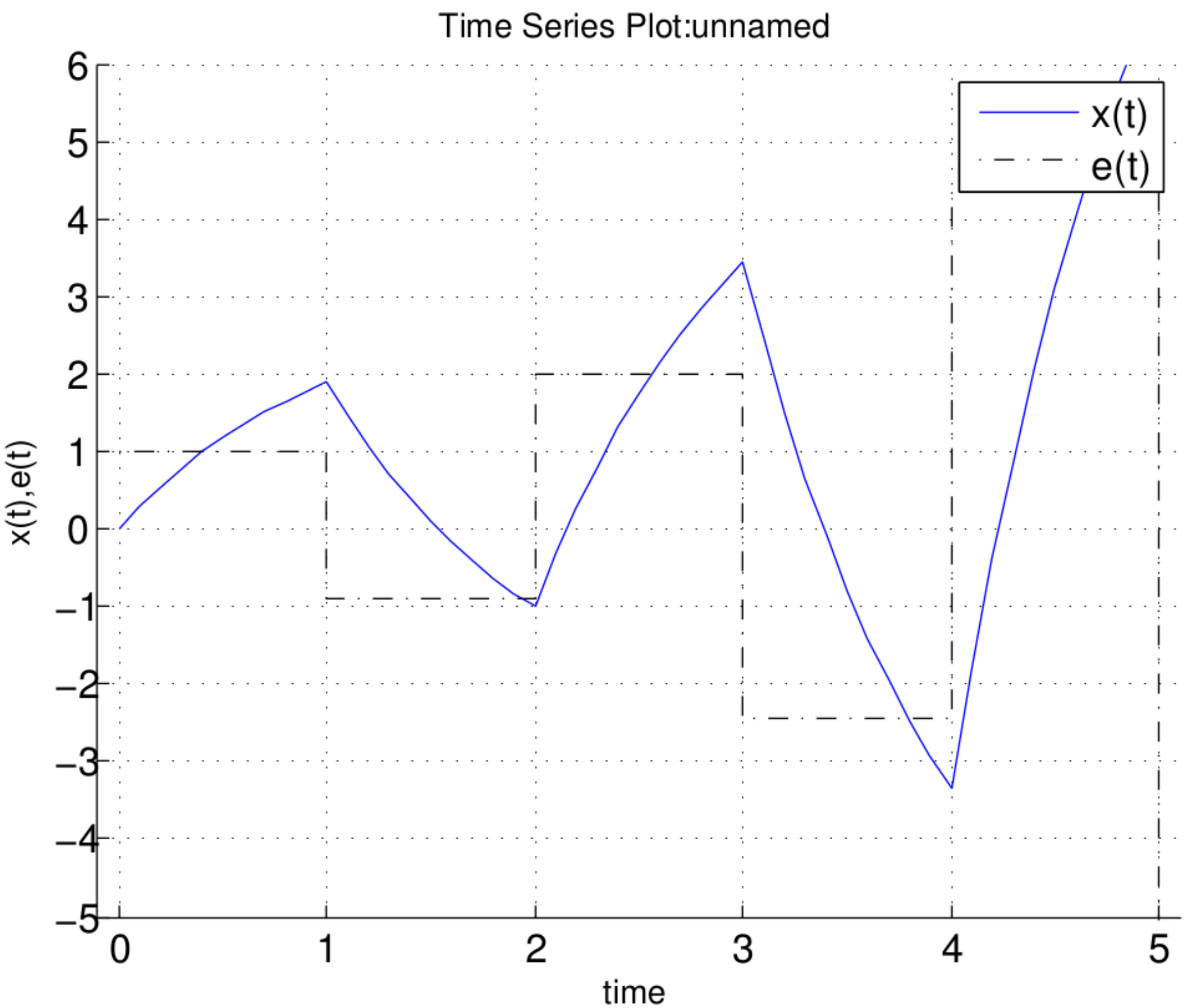
For stability:

$$|e^{aT} - \frac{k_p}{a}(e^{aT} - 1)| < 1. \quad (26)$$

Notes: stability depends on gain **and** T!

Discrete Time Control

u[k] = kp*(r[k]-x[k])



On board