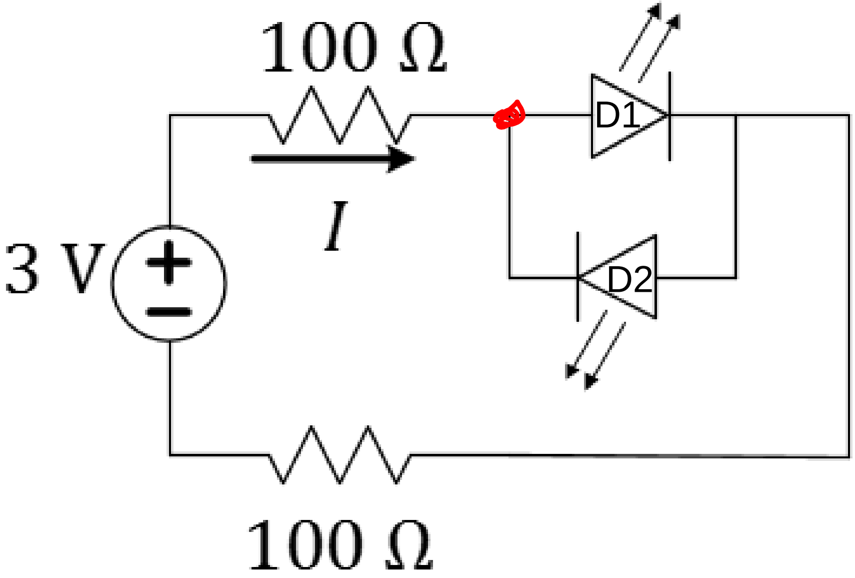
Lecture 17: Diode Circuits

- Guess-and-check for diode circuits
- Current-limiting resistors and power dissipation
- Voltage-limiting (clipping) diode circuits

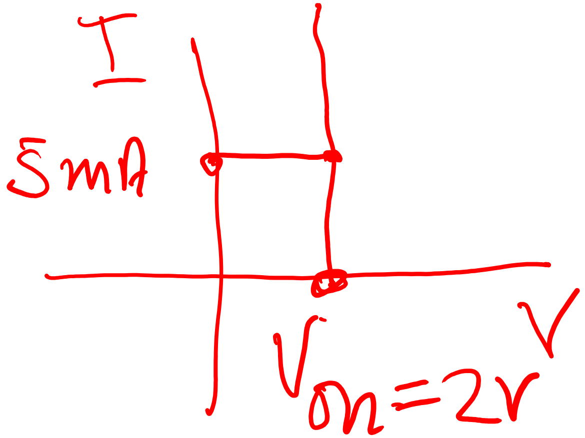
Guess-and-check example



Assume OIM with V_{ON} = 2 V (red LED)

Q: What is the current supplied by the voltage source?

$$\frac{3 - V_{D1}}{200} = \frac{3 - 2V}{200} = 5mA$$

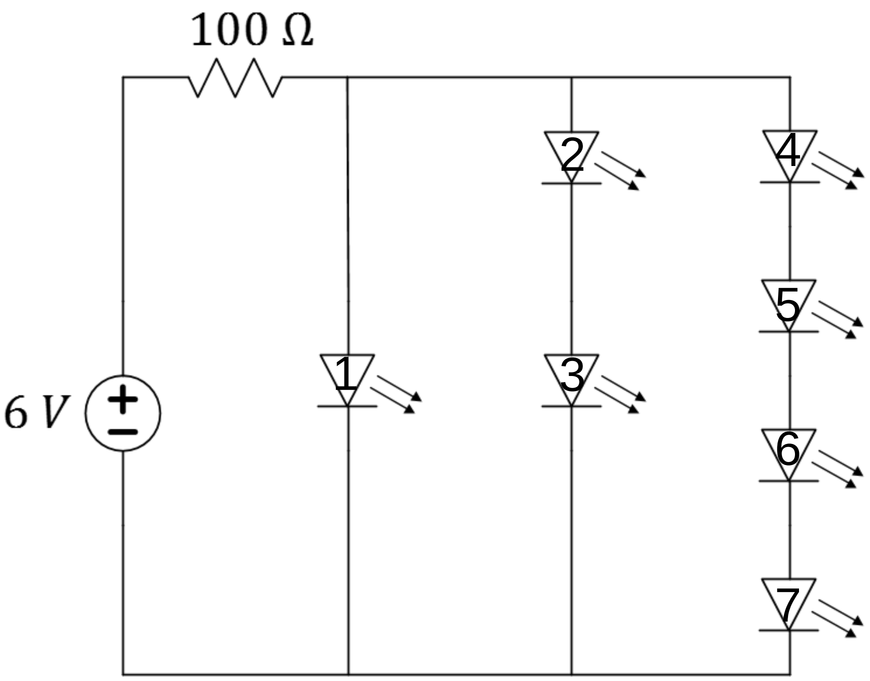


Q: What is the power dissipated in each diode?

D1:
A. $-20\ mW$
B. $-10\ mW$
C. $0\ mW$
D. $10\ mW$
E. $20\ mW$

D2:
A. $-20\ mW$
B. $-10\ mW$
C. $0\ mW$
D. $10\ mW$
E. $20\ mW$

Another guess-and-check example



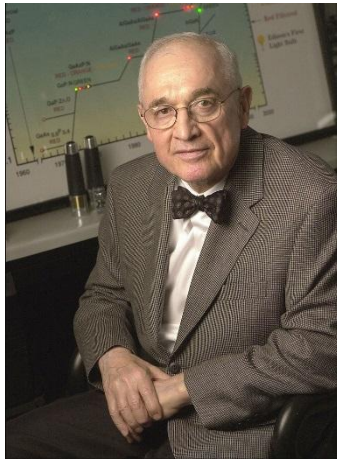
$V_{on} = 2\ V$, all diodes OIM

Q: How many red LEDs are turned on in the circuit?

A. 1
B. 2
C. 3
D. 4
E. 7

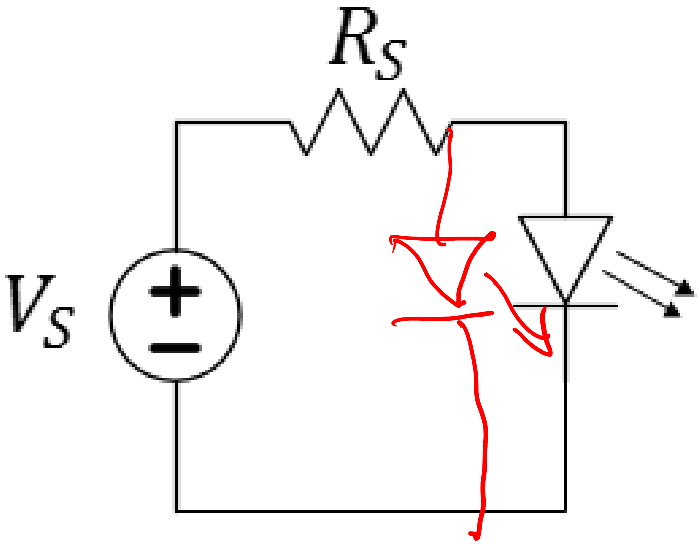
ECE Spotlight…

The first visible-light LED was developed by University of Illinois alumnus (and, later, professor) Nick Holonyak, Jr., while working at General Electric in 1962 with unconventional semiconductor materials.
He immediately predicted the widespread application of LED lighting in use today.



Current-limiting resistors for LEDs

Assume OIM with V_{ON} = 3.3 V (blue LED)



Q: How many 1.5 V batteries are needed to turn on the LED?

A. 1
B. 2
C. 3
D. 4
E. 5

Q: What is the series resistance, R_S, needed to get 16 mA through the LED?

A. 5 Ω
B. 10 Ω
C. 25 Ω
D. 50 Ω
E. 75 Ω

Q: What is the resulting power dissipation in the diode?

A. 19 mW
B. 32 mW
C. 53 mW
D. 100 mW
E. 320 mW

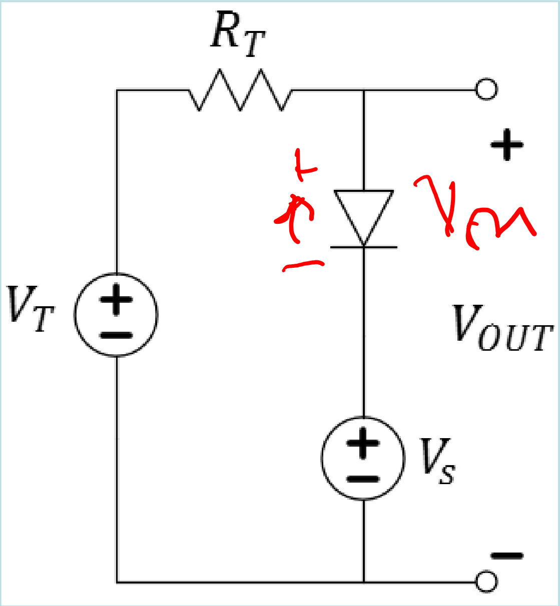
$\frac{4.5 - 3.3}{R_S} = 16mA$

$R_S = \frac{1.2}{16} \times 10^3 = 75\Omega$

Power = $3.3 \times 16mA = 52.8mW$

Setting voltage limits with diodes

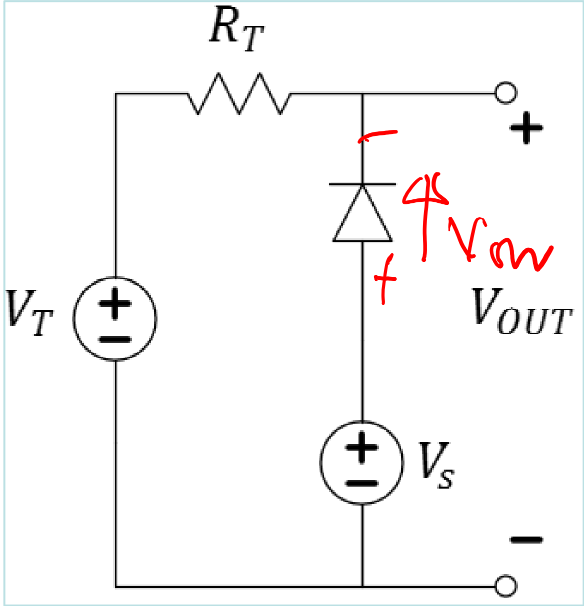
Assume OIM model with V_{ON} = 0.3 V (Ge diode)



Q: What is the possible range of the output voltages?

$V_{out} \in$

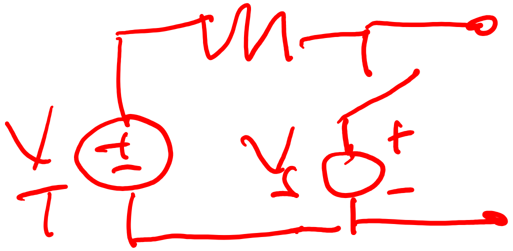
A. $(-\infty, V_S + 0.3]$
B. $[V_S + 0.3, 0]$
C. $[V_S - 0.3, V_S + 0.3]$
D. $[V_S - 0.3, \infty)$
E. $[V_S + 0.3, \infty)$



Q: What is the possible range of the output voltages?

$V_{out} \in$

A. $(-\infty, V_S + 0.3]$
B. $[V_S + 0.3, 0]$
C. $[V_S - 0.3, V_S + 0.3]$
D. $[V_S - 0.3, \infty)$
E. $[V_S + 0.3, \infty)$



D off = $V_{out} = V_T$

D on $V_{out} = V_s + V_{on}$

$V_T < V_{on} + V_s$ D on

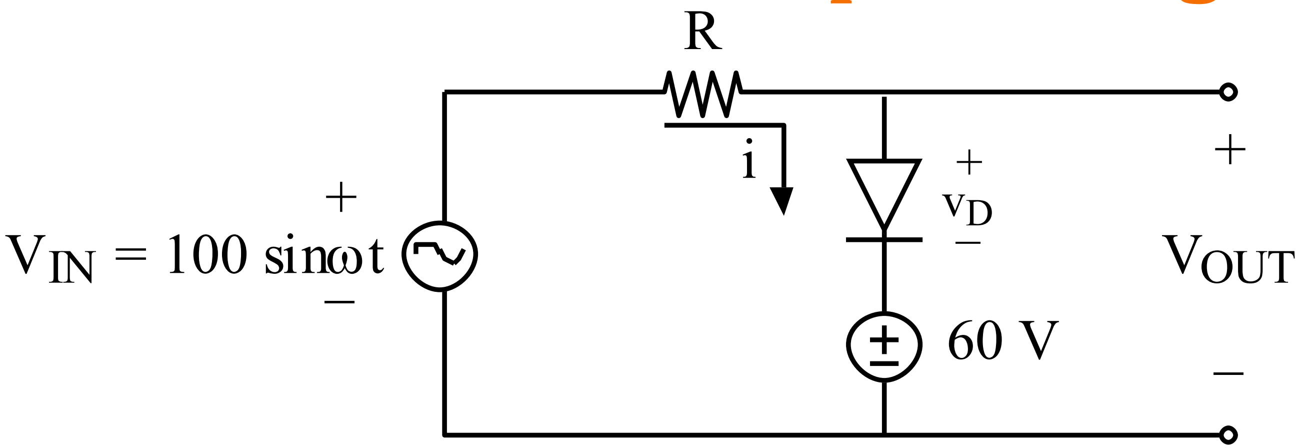
L17 Learning Objectives

a. Solve circuit analysis problems involving sources, resistances, and diodes
b. Estimate power dissipation in diode circuits
c. Select appropriate current-limiting resistors
d. Determine voltage limits and waveforms at outputs of diode voltage-clipping circuits

Lecture 18: Diode Applications

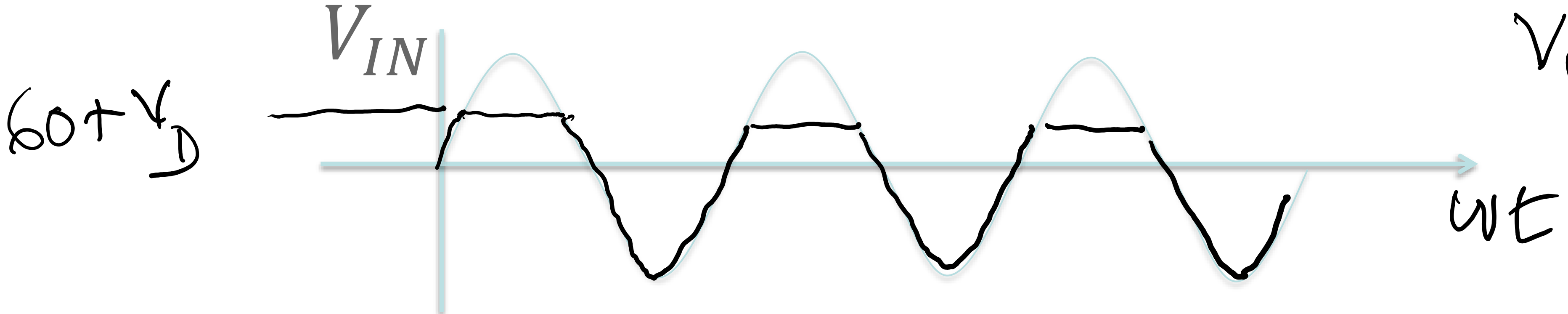
- Voltage clipping
- Rectifiers
- Flyback diode (lab)
- Instructor option…

A voltage-clipping circuit sets maximum or minimum output voltage



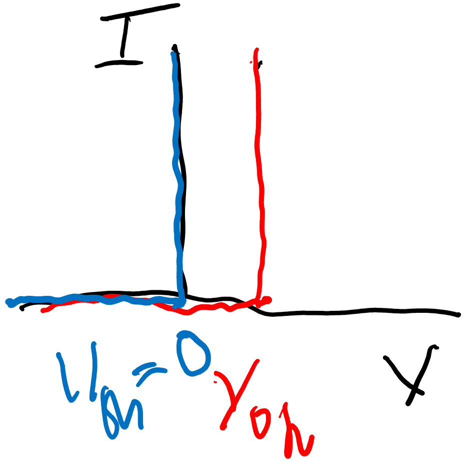
KVL:

$V_{OUT} = 60 + v_D$



Q: If the input voltage waveform is shown, what is the output waveform, assuming an ideal diode model (V_{ON} = 0 V)?

Half-Wave Rectifier

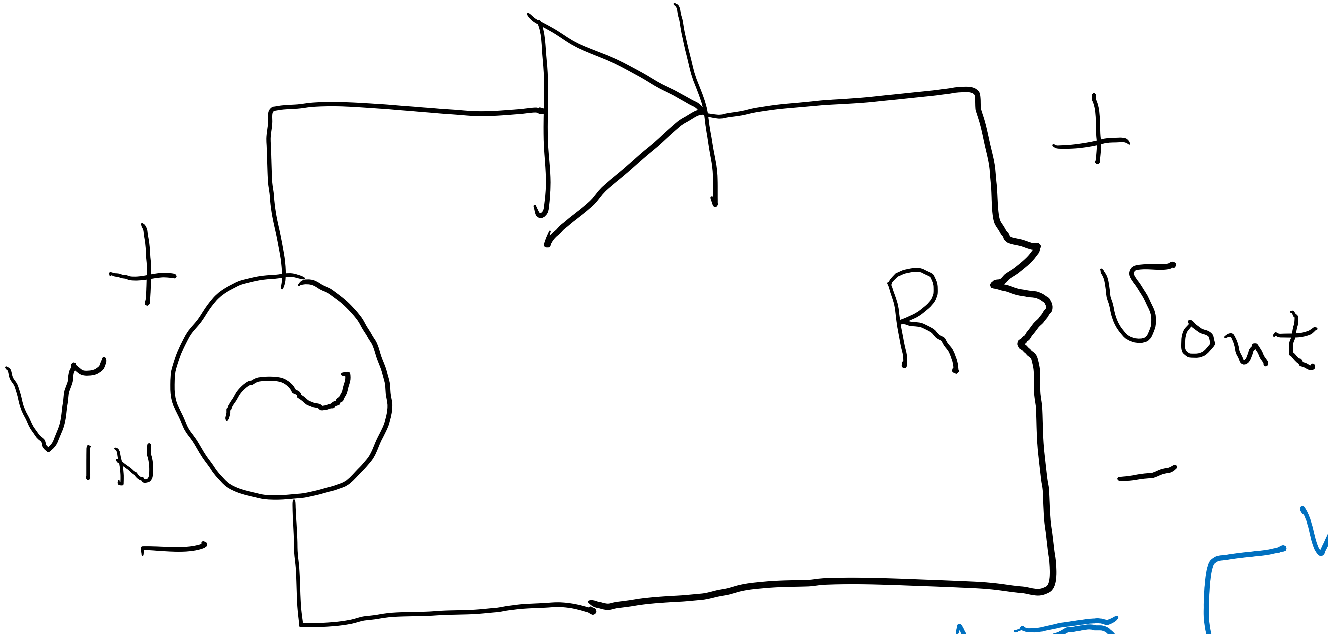


Q: Assume $V_{on} = 0\,V$.
Then $V_{out} = 0$ when

A. v_{in}>0.

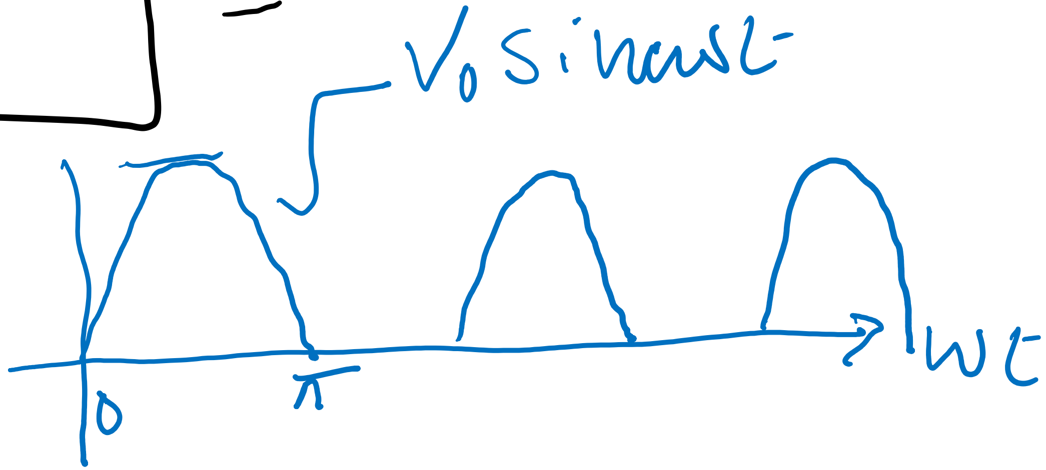
B. v_{in}<0.

C. Neither of these conditions cause $V_{out} = 0$.

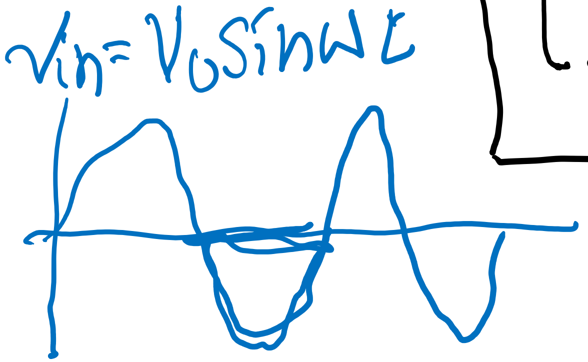


$V_{in} = V_0 \sin \omega t$

V_{out}



Full-Wave Rectifier



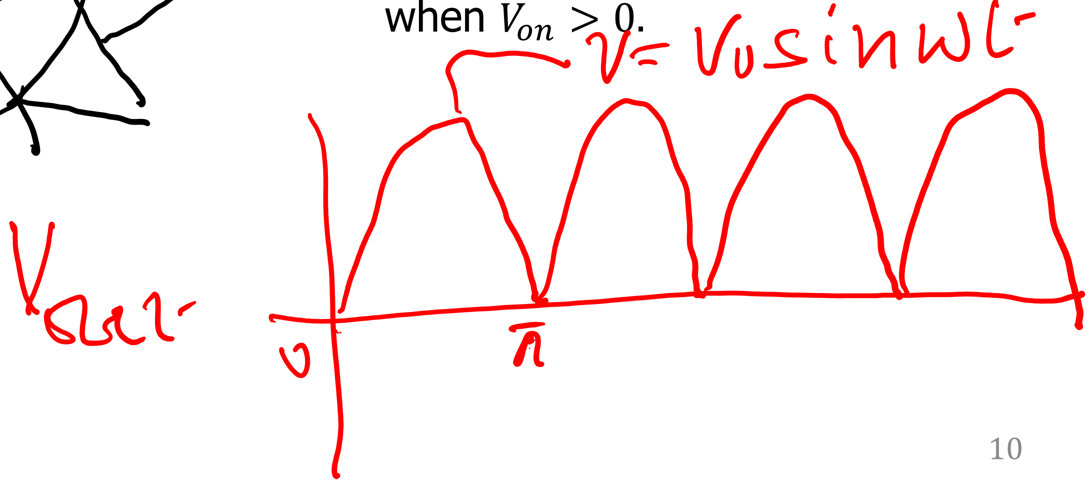
Q: Assume $V_{on} = 0\ V$ for both diodes. Then $V_{out} = 0$ when

A. v_{in}>0.

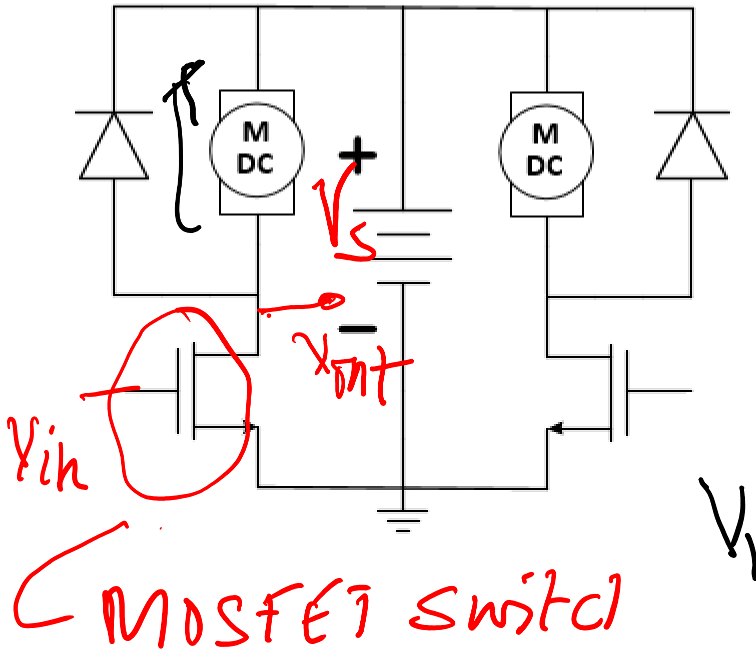
B. v_{in}<0.

C. Neither of these conditions cause $V_{out} = 0$.

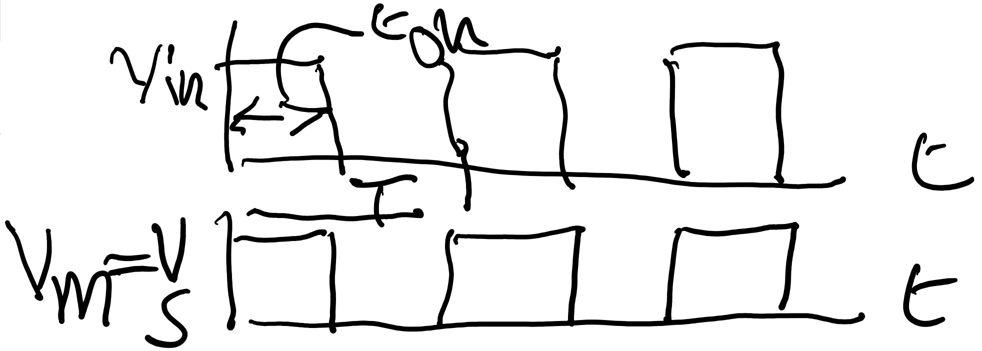
Q: Discuss limitations on this device when $V_{on} > 0$.



Fly back Diode: Motor protection



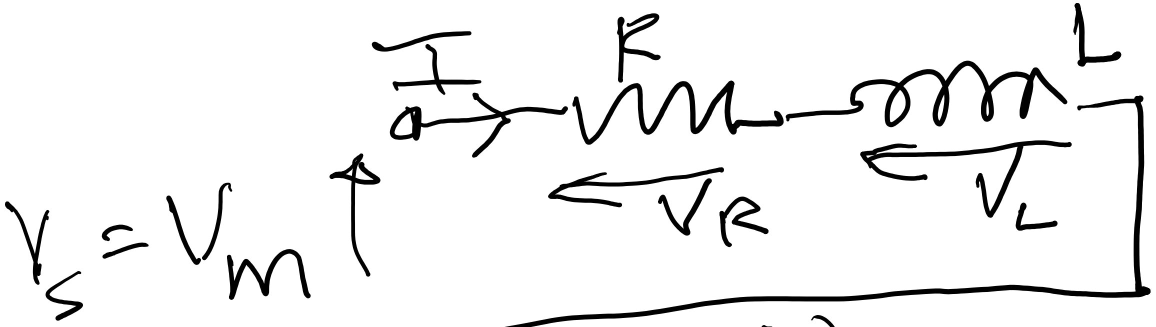
If we consider motor to be a power consuming element like a resistor



$$V_{M_{pwm}} = \sqrt{\frac{t_{on}}{T} V_s^2}$$

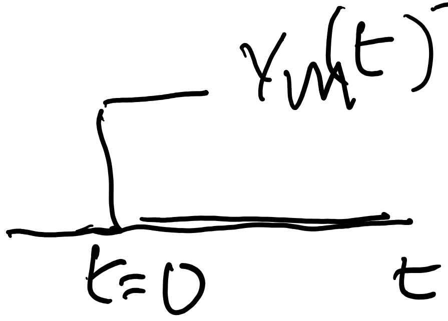
This diode is known by many other names, such as kickback diode, snubber diode, commutating diode, freewheeling diode, suppression diode, clamp diode, or catch diode. -Wikipedia on Flyback Diode

Motor Model when Stationary/starting



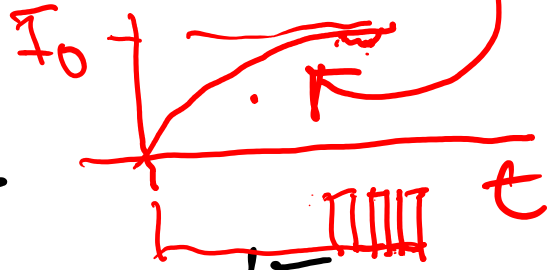
L = Magnetic Flux linkages per Amp

$$L = \frac{N\Phi}{I}$$



$$I_0 = V_s / R$$

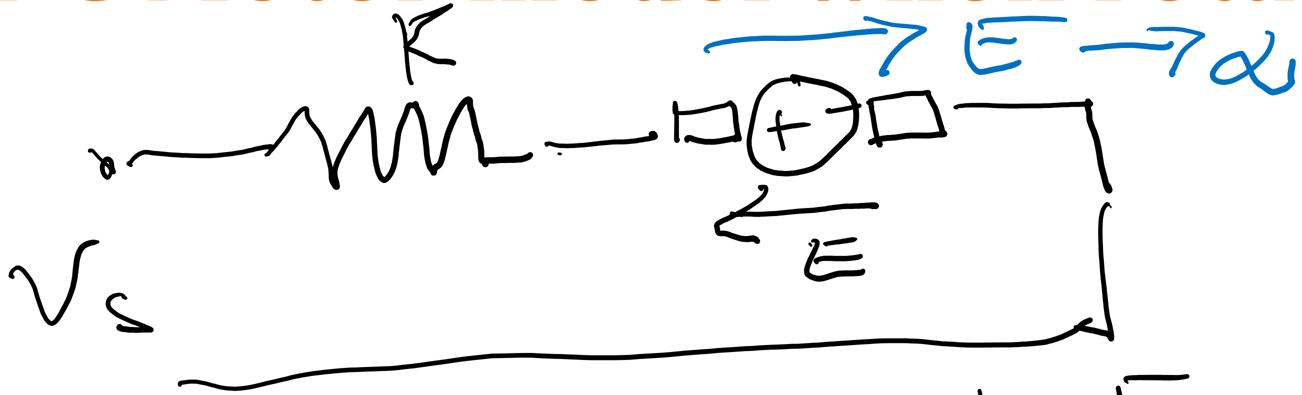
$$I(t) = I_0\left(1 - e^{-\frac{tR}{L}}\right)$$



$$V_s = V_m = V_R + V_L = IR + L\frac{dI}{dt}$$

$$\frac{dV_s}{dt} = 0 = R\frac{dI}{dt} + L\frac{d^2I}{dT^2} \quad \therefore \quad \frac{d^2I}{dt^2} = -\frac{R}{L}\frac{dI}{dt}$$

DC Motor model when rotating in steady state



$E = K\Phi\omega$, motor speed in rad s^{-1}

Φ mag. flux

If $L >> R$ then $V_s \simeq E$

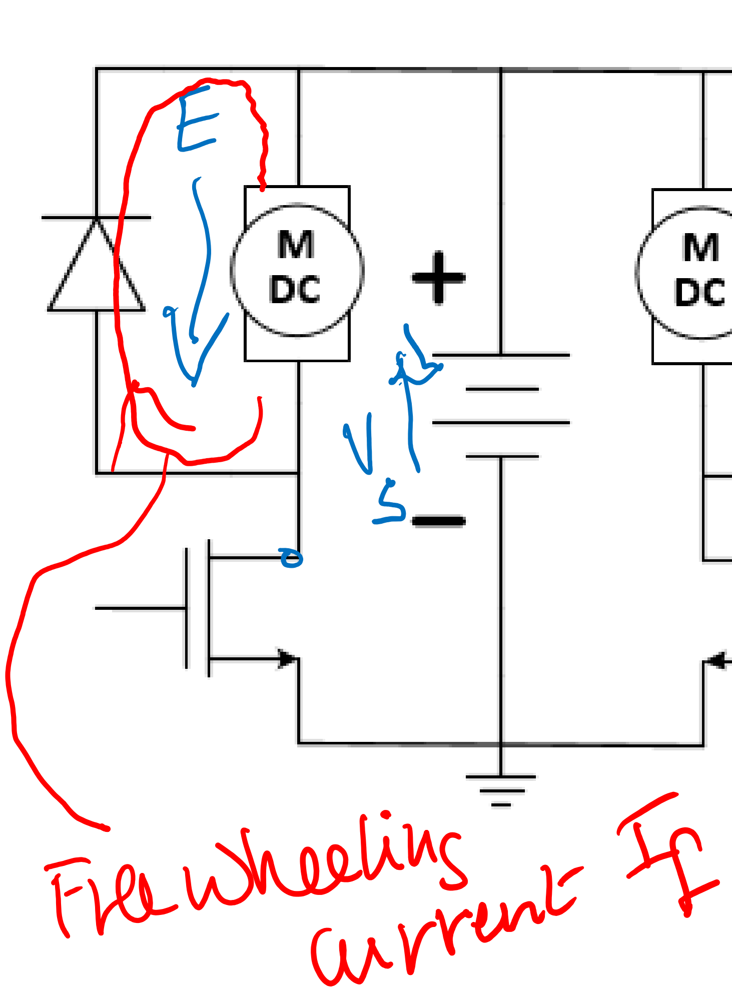
$V_s \simeq E \quad V_s \propto \omega$

If V_{pwm} such that $\frac{2\pi}{T} = 2\pi f >> \omega$ (motor speed)

then $V_{s\,pwm}$ can be used to control motor

What if motor suddenly stops?

Fly back (freewheeling) diode action



When motor stops
Free wheeling diode avoids E becoming very large.
When $E > V_s$ Diode turns on

L18 Learning Objectives

a. Determine voltage limits and waveforms at outputs of diode voltage-clipping circuits