Lecture 2: Linear Regulator

0. Review
1. Op amp feedback
2. Design example
3. Current limiting

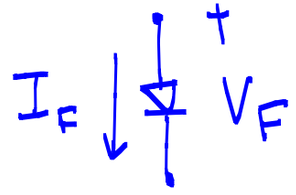
- PreLab1 due Thu (Sep 19) at lab session
- HW1 due Fri (Sep 20) → leave in box outside my office
- Quiz1 next Tue (Sep 24)

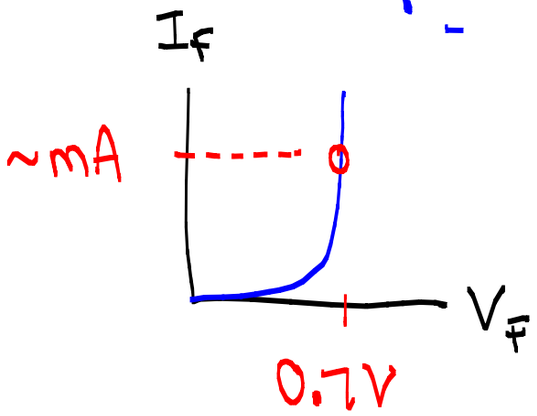
Helpful textbook reading:

Ch 22-1 Power Supply Characteristics
22-3 Series regulators
22-4 Monolithic Linear regulators

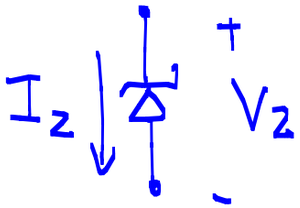
0. Review

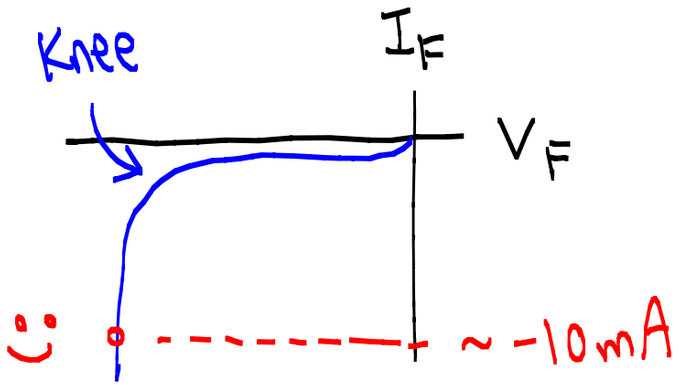
- **Diode**



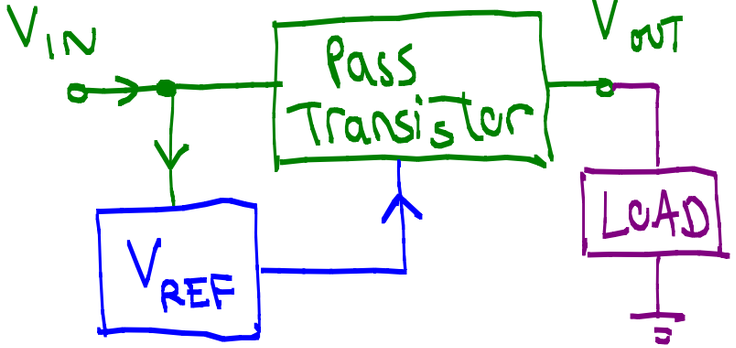


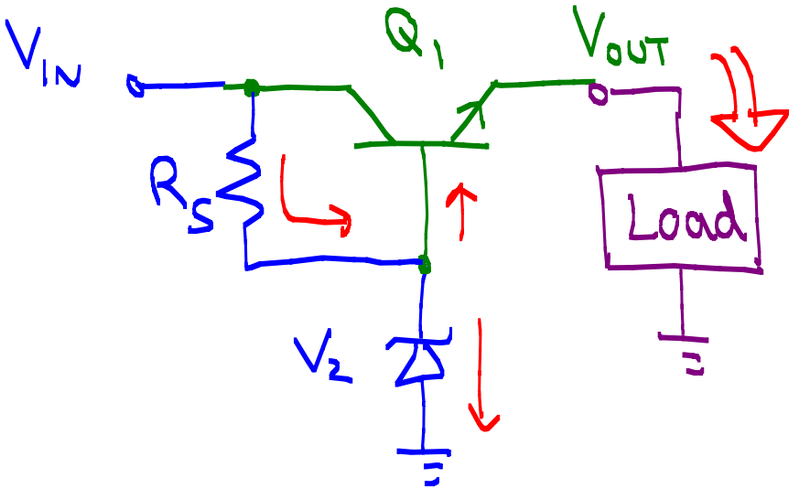
- **Zener**





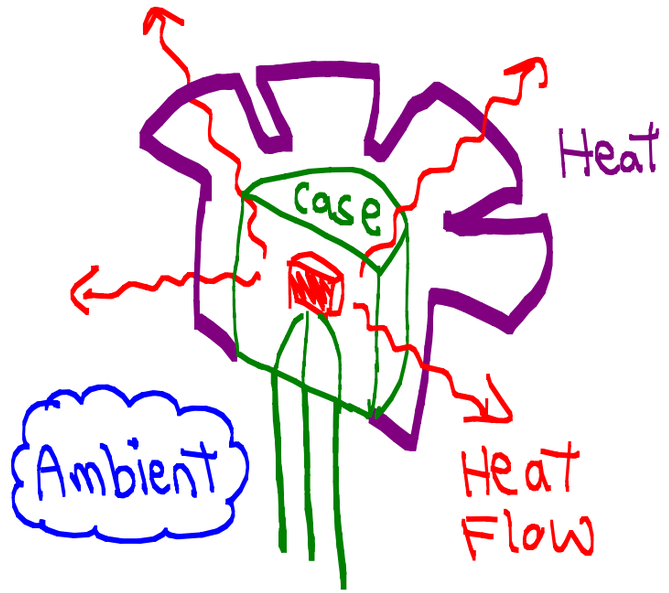
Zener Follower





$$V_{out} = V_Z - V_{BE}$$

- **Heat Sinks**



$$T_J = T_A + P \times \left[\overbrace{\theta_{JC} + \theta_{CS} + \theta_{SA}}^{\theta_{JA} \text{ w/ heat sink}} \right]$$

Junction to case — Case to sink — sink to Ambient

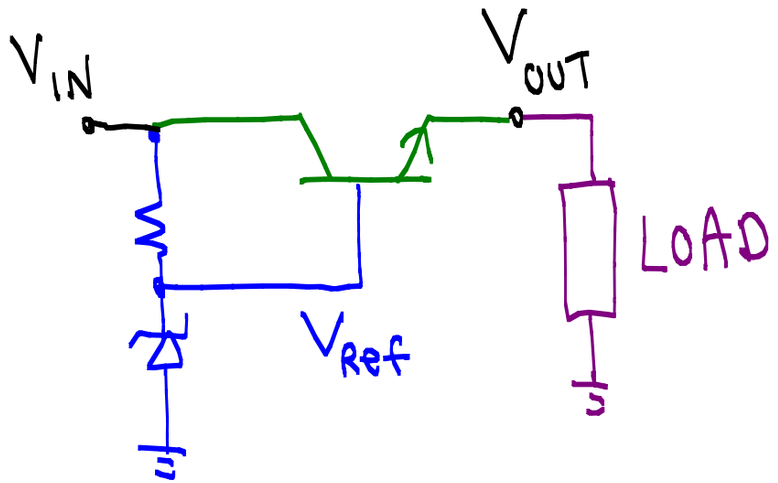
1. Negative Feedback

- Zener follower problems:

1.

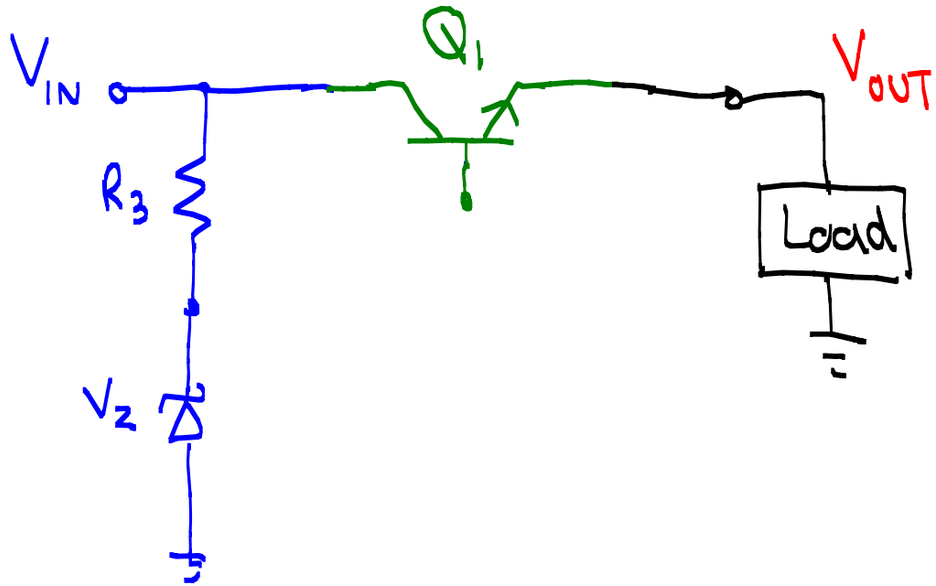
2.

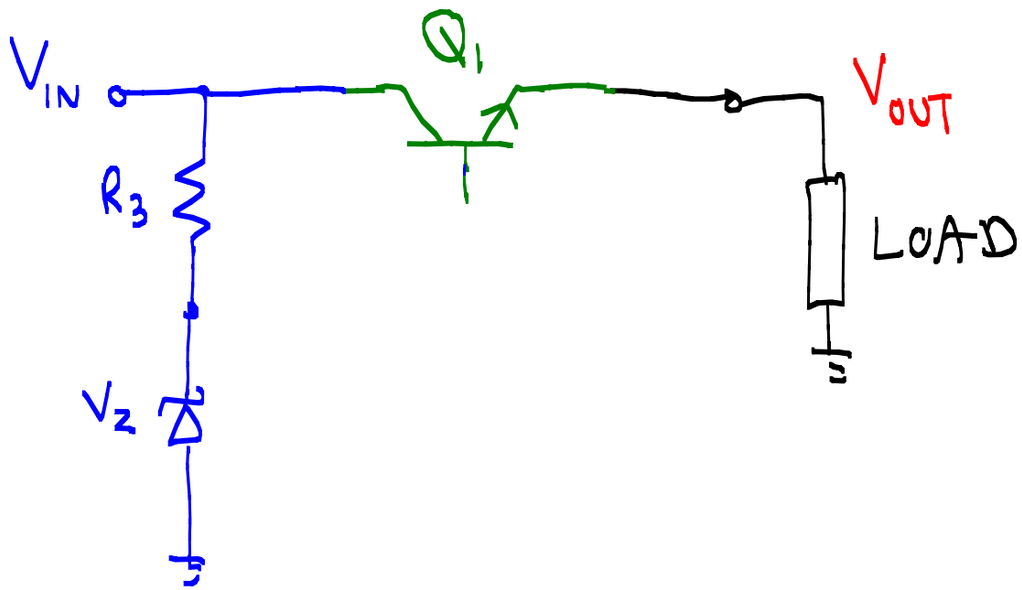
3.



- A voltage regulator actively stabilizes V_{out} using _____ !

☆ Use an op amp with negative feedback!





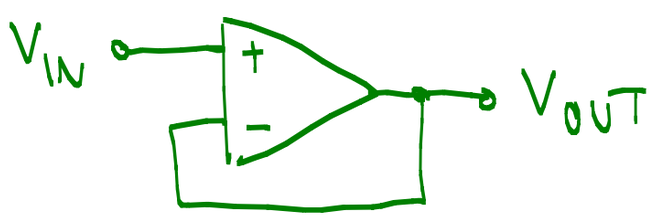
• Op Amp Review

Ideal op amp with (-) feedback obeys two Golden Rules:

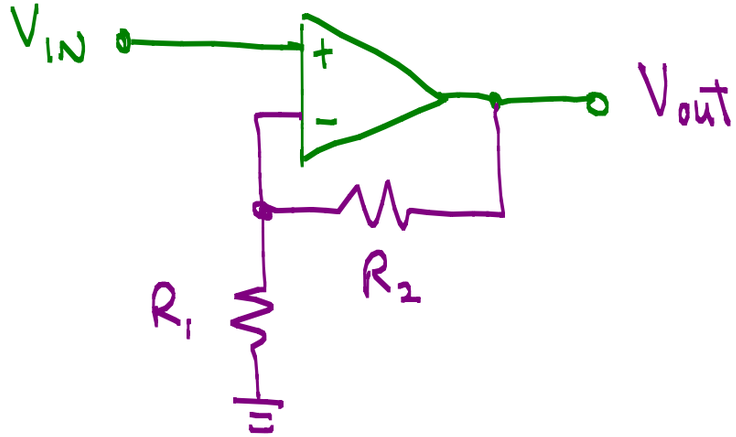
1.

2.

Ex. 1 Voltage Buffer

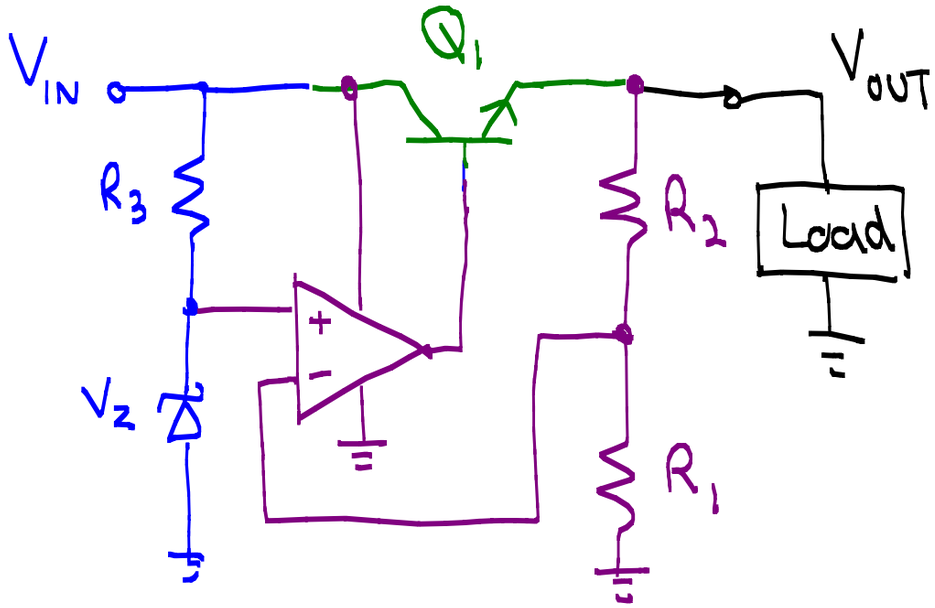


Ex. 2 Non-inverting Amplifier



Q: How does the op amp do this?

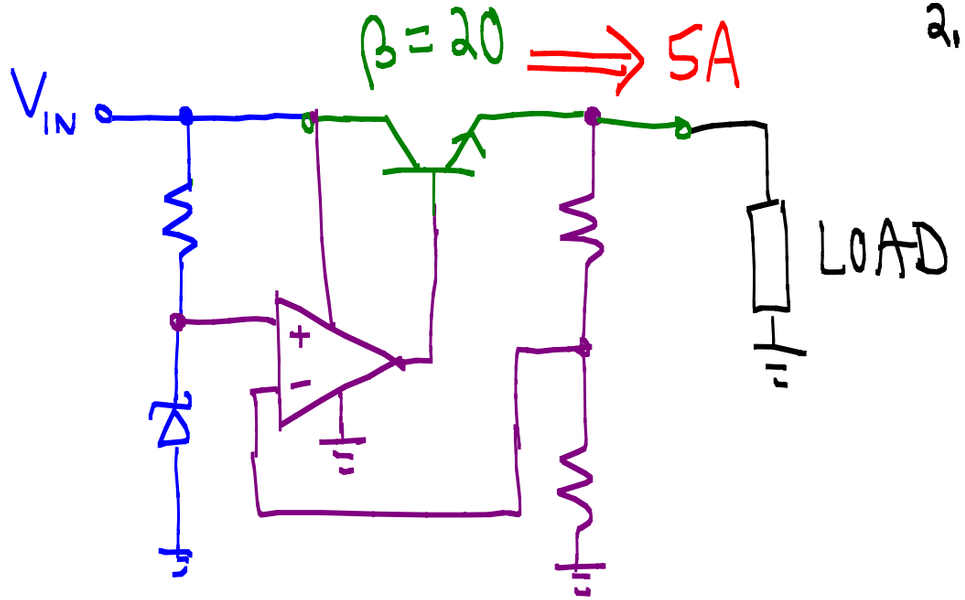
An op amp is basically a _____ amplifier with _____



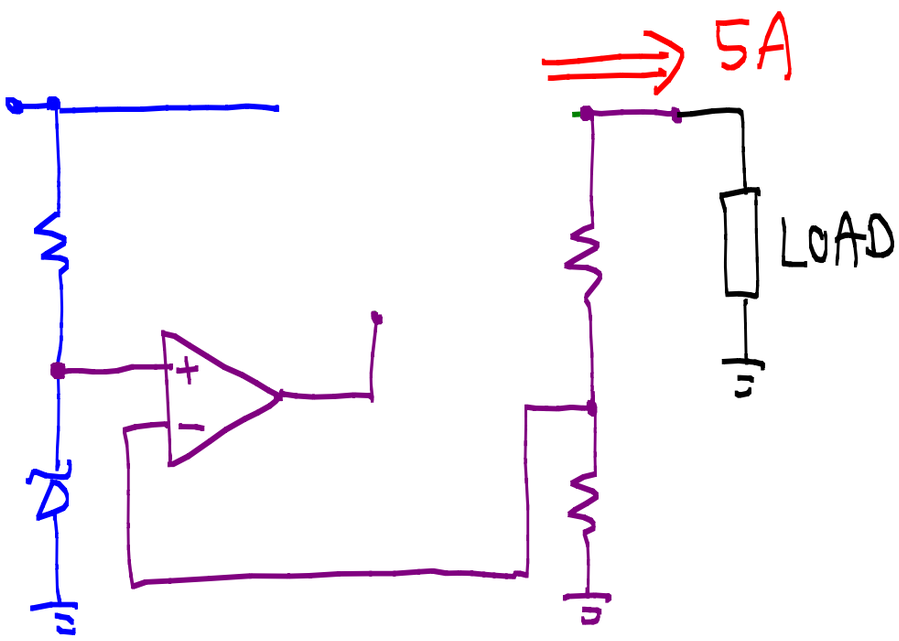
$\Rightarrow V_{out} =$

- Negative feedback greatly improves V_{OUT} regulation.
- Need to be careful with large I_{OUT}

Ex:

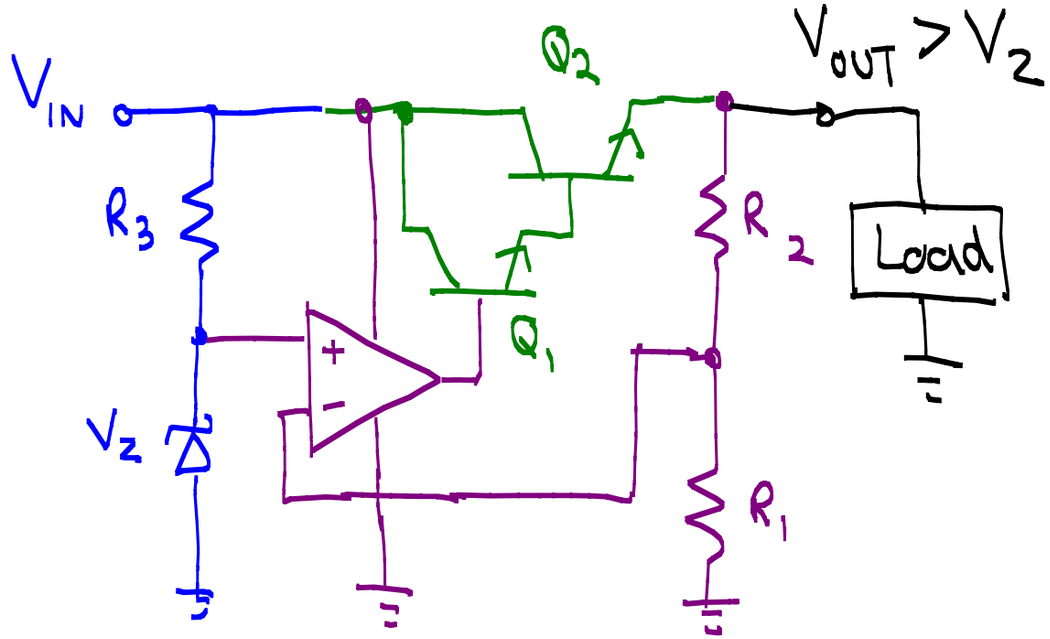


Ex: V_{IN}



3. Design Guidelines for Linear Regulator

- Minimum I_2
- Max Q_1 base current
- R_1 and R_2
- Make sure
- Don't fry



Example: $V_{in} = 19\text{-}22\,V$, $V_{out} = 15\,V$, $R_L > 20\,\Omega$

① Choose $V_z =$

② $I_{L,max} =$

Need to choose Q_2 and Q_1! Q_2:

	Max I_C	Max P ($T_A = 25°C$)	Max P ($T_C = 25°C$)
2N3904	200 mA	.625W	
2N4401	600 mA	.625W	1.5W
TIP31	3 A	2W	40W
2N3055	15 A		115W

Q_1: I_{E1} =

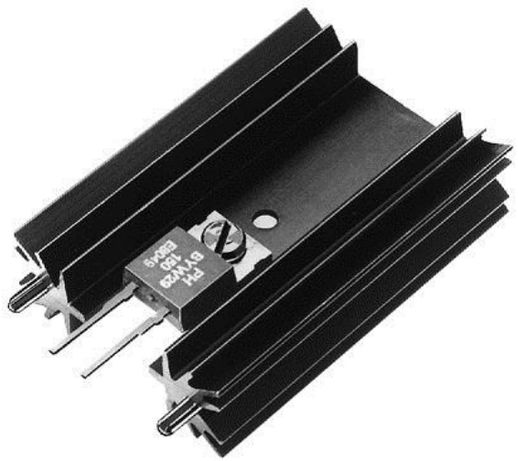
③ V_{OUT} =

④ Minimum V_{IN}

⑤ Power ratings

R_3: Max P =

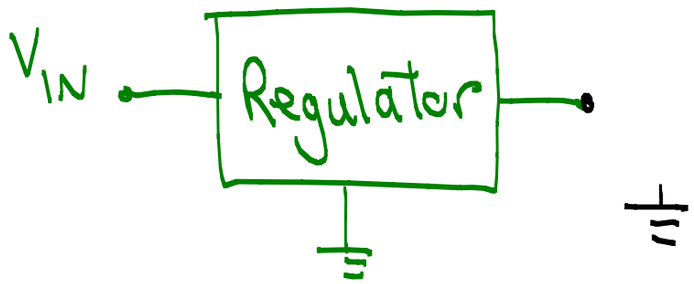
Q_2: TIP31 needs a heat sink! Let's assume: $\begin{cases} T_A = \\ \text{Max } T_J = \end{cases}$



R_1 and R_2:

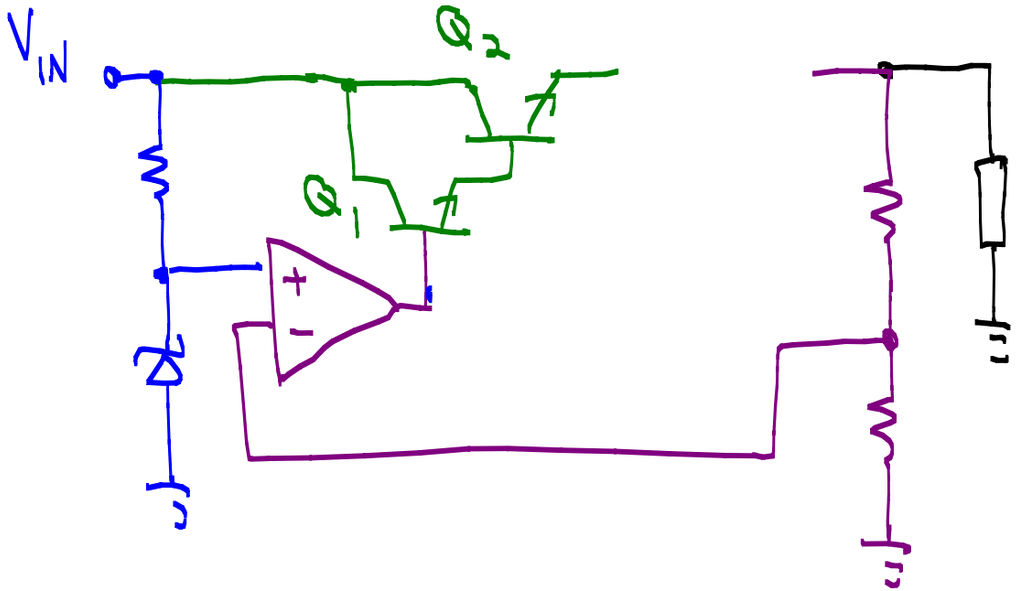
3. Current Limiting

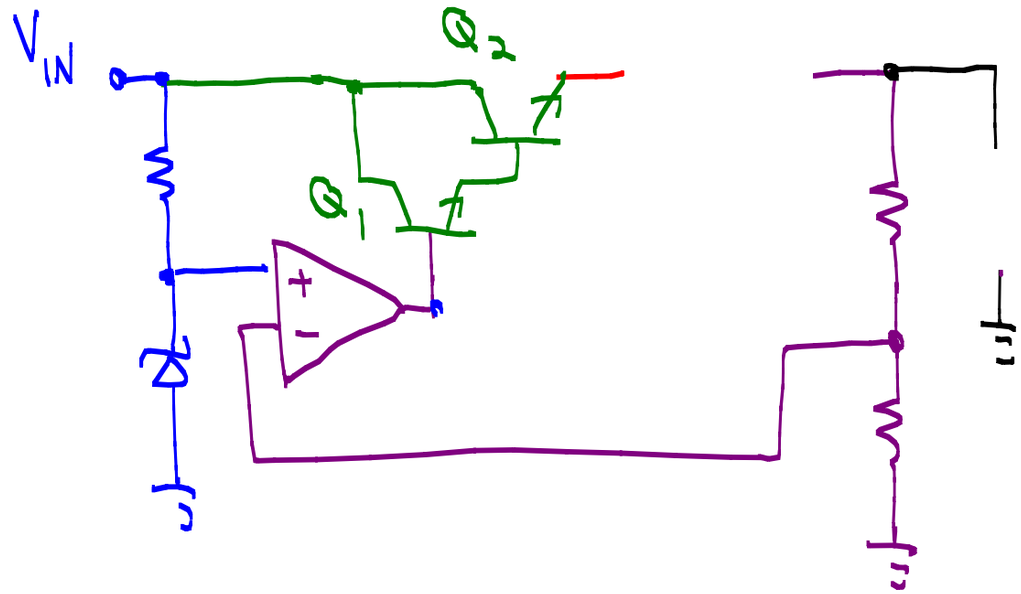
- Any regulator needs protection from short circuited output
- Simple method:



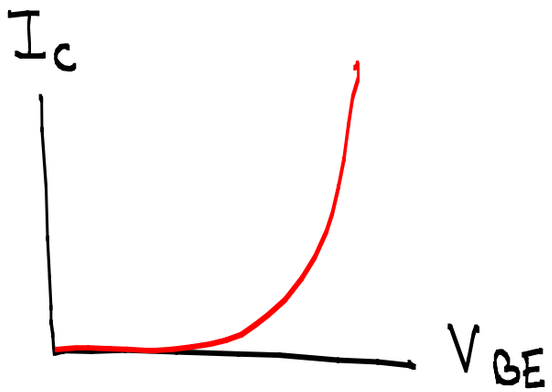
Normal Operation

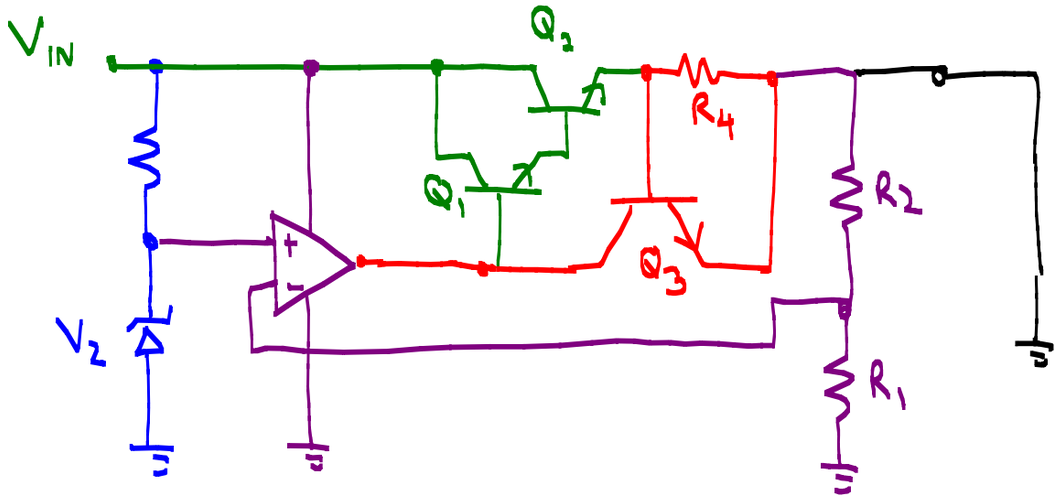
Short Circuit



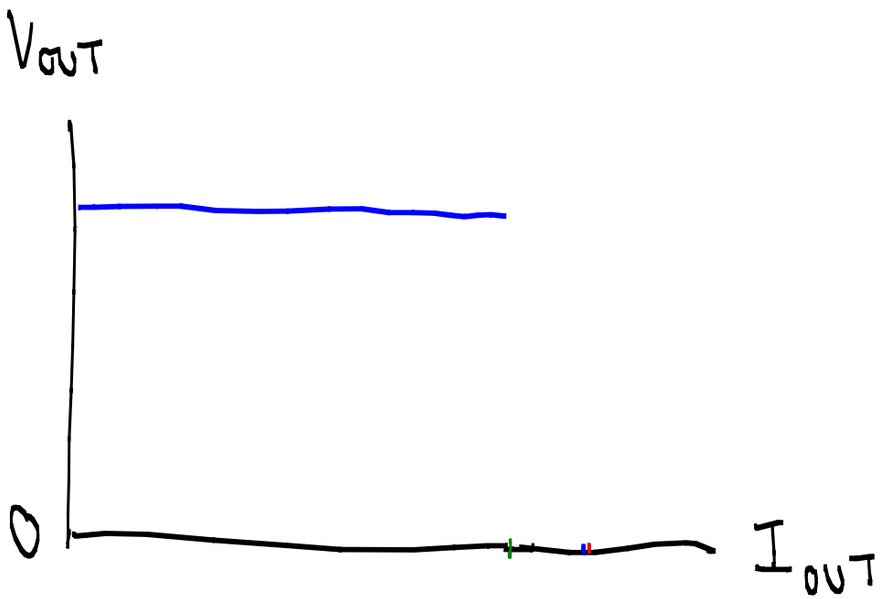


NOTE #1: Q_3 does not abruptly turn ON.





NOTE #2: When $I_{OUT} = I_{SC}$,



Ex: $R_4 = 0.8\Omega$, $V_{IN} = 22V$

Appendix #1

TIP31

Typical $\beta \sim 70$

0.75A

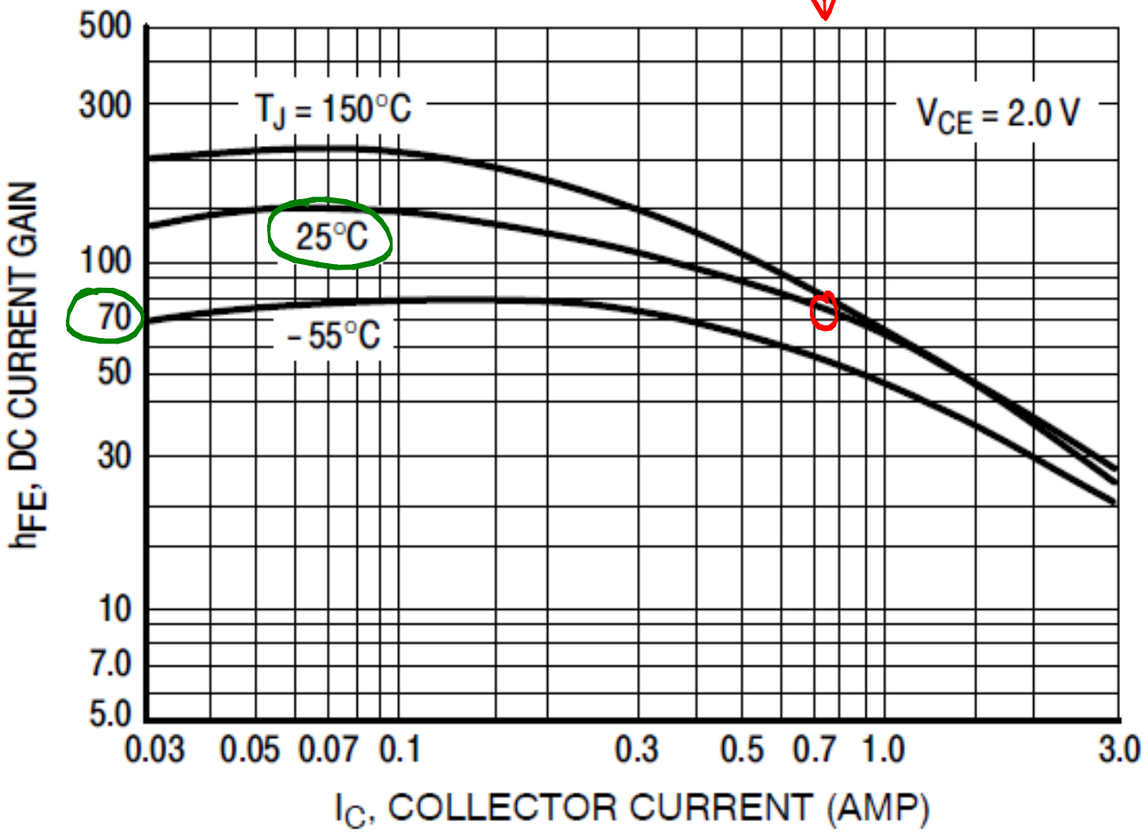


Figure 9. DC Current Gain

For BJT Switch

BJT active mode

$V_{BE} \sim 0.8V$

0.75A

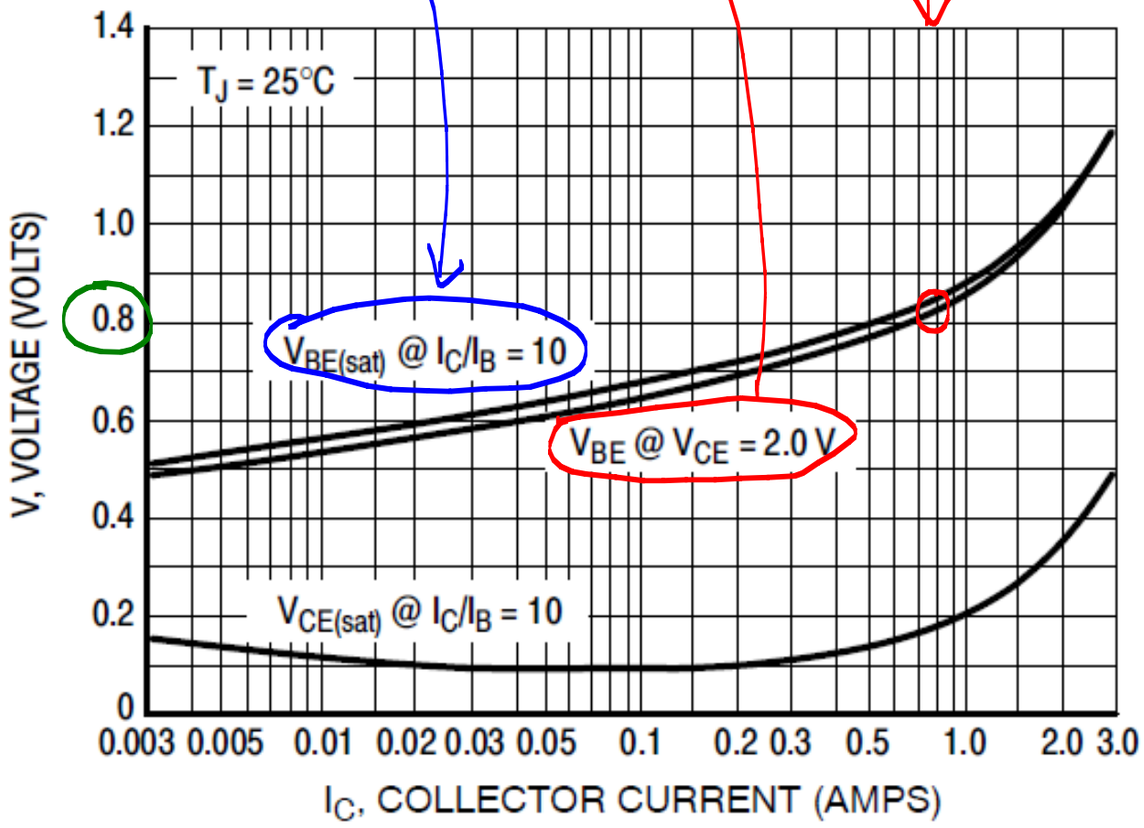


Figure 11. "On" Voltages

2N3904

β~225

10mA

~0.72V