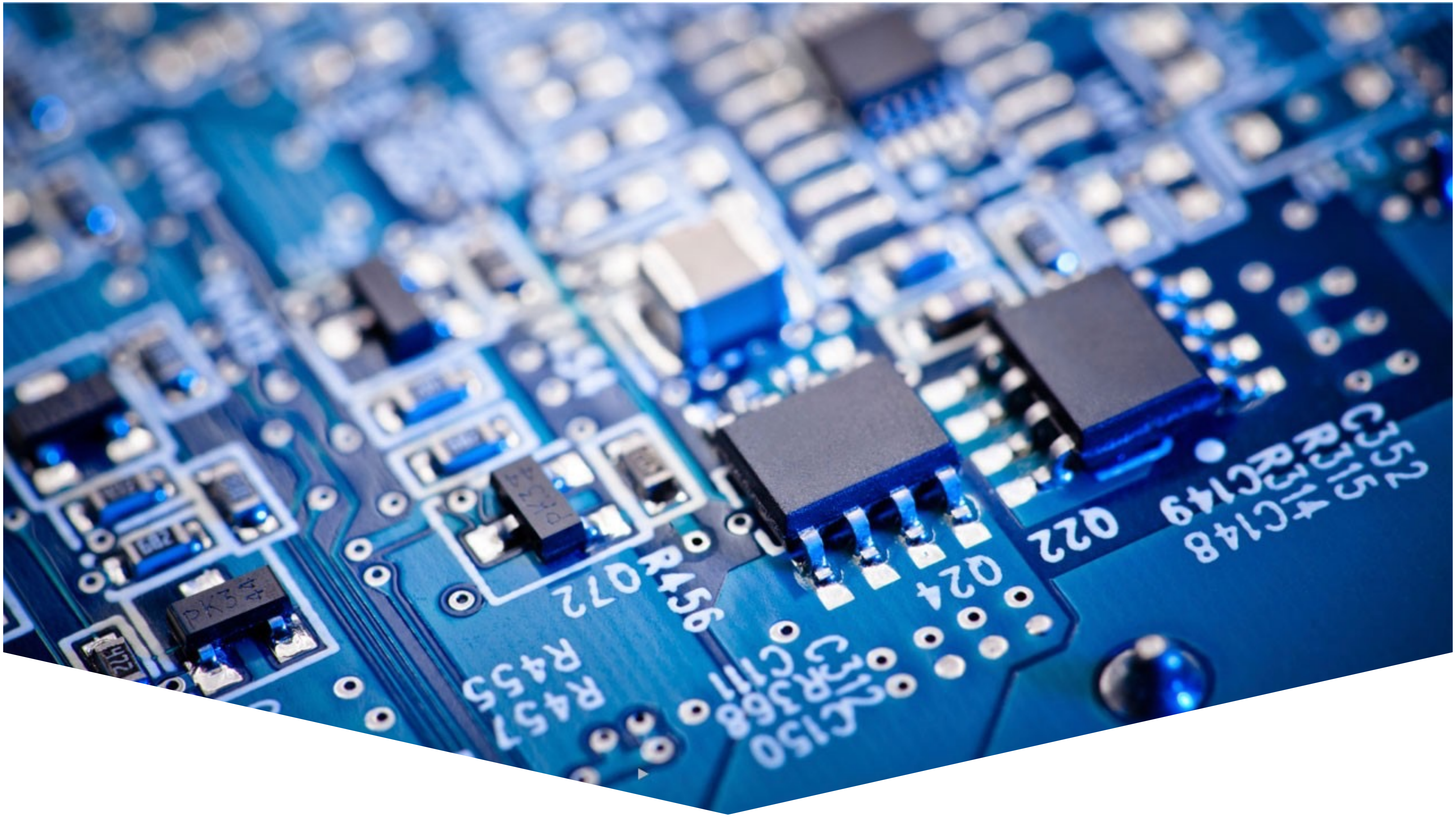

ANALOGE ELEKTRONICA 2

VOLTAGE REGULATORS

overtref jezelf

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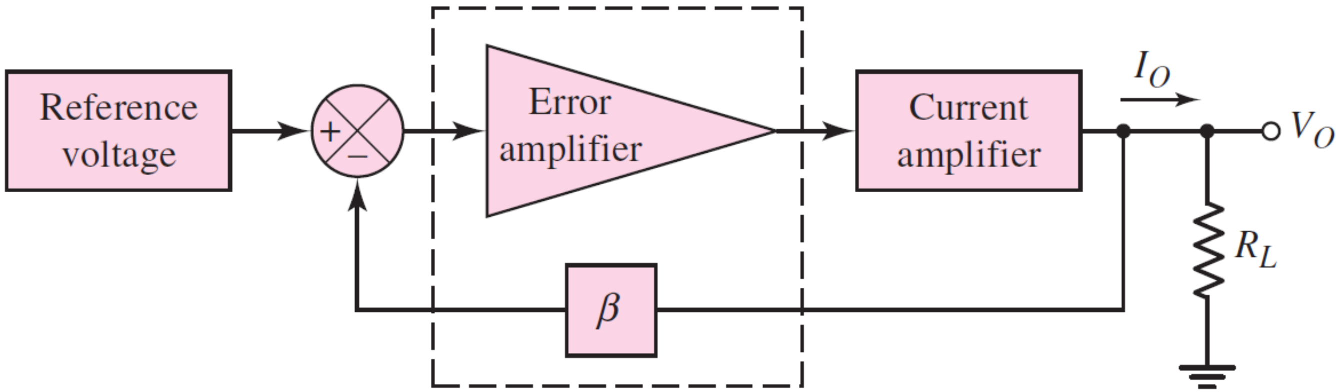
Overzicht

- Linear Voltage Regulators
- Current Limiting
  - Constant current limiting
  - Foldback current limiting
- Integrated Voltage Regulators

Voltage Regulator

- **Voltage Regulator**:
  - A circuit or device that provides a constant voltage to a load
  - Output voltage (relatively) independent of load-current
- **Line regulation**: ratio of change in output voltage to a change in input supply voltage: $\mathrm{LR} = \frac{\Delta V_o}{\Delta V_{in}}$



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Voltage Regulator definitions

- **Output Resistance**: Rate of change of output voltage with output current $R_{of} = -\frac{\Delta V_o}{\Delta I_o}$
- **Load regulation and ripple rejection:**
  - Change in output voltage between no-load current condition and a full-load current condition
  - Load Regulation $= -\frac{V_o(no\ load) - V_o(Full\ load)}{V_o(no\ load)} * 100\ \%$
  - Ripple rejection ratio = $20.\,log_{10}(\frac{V_{ripple,out}}{V_{ripple,in}})$
- **Example:**
  - A 5.0 V voltage regulator has a load-current of 5 mA at full load
  - At a load-current of 1.5 A, voltage is 4.96 V at no load
  - Calculate output-resistance and the load-regulation
  - Ripple rejection ratio = -62 dB, voltage ripple at input = 0.5 V
  - Calculate voltage ripple at output

Exercise problem

EXERCISE PROBLEM

Ex 15.14: The reference voltage for a constant-voltage source is established by the simple combination of V^+, R_1, and D_I, as shown in the regulator circuit in Figure 15.48. If the Zener diode resistance is $R_Z = 10\ \Omega$ and the zero-current diode voltage is $V_{Zo} = 5.6$ V, determine the line regulation of the voltage regulator. Assume an ideal op-amp. (Ans. 0.454%)

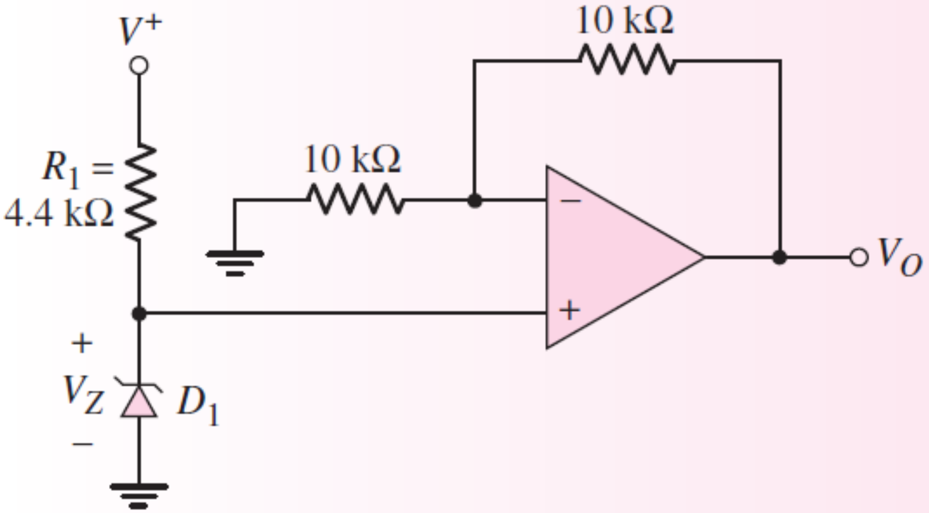


Figure 15.48 Figure for Exercise Ex15.14

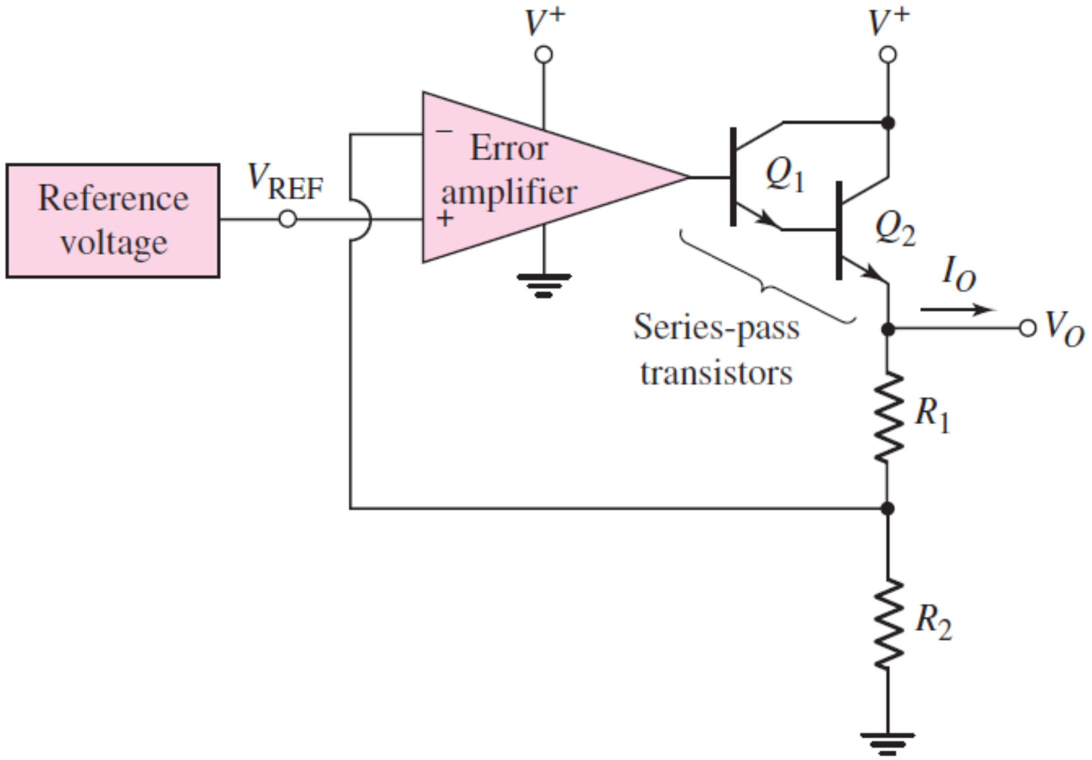
Simple Series-Pass Regulator

$$\frac{R_2}{R_1 + R_2} V_o = V_{ref}$$

Or:

$$V_o = \left(1 + \frac{R_1}{R_2}\right) . V_{ref}$$

$$A_{CL} = \frac{V_o}{V_{REF}} = 1 + \frac{R_1}{R_2}$$



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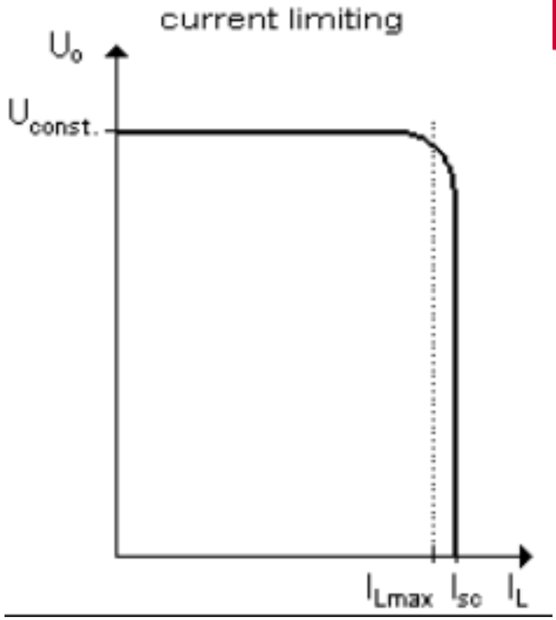
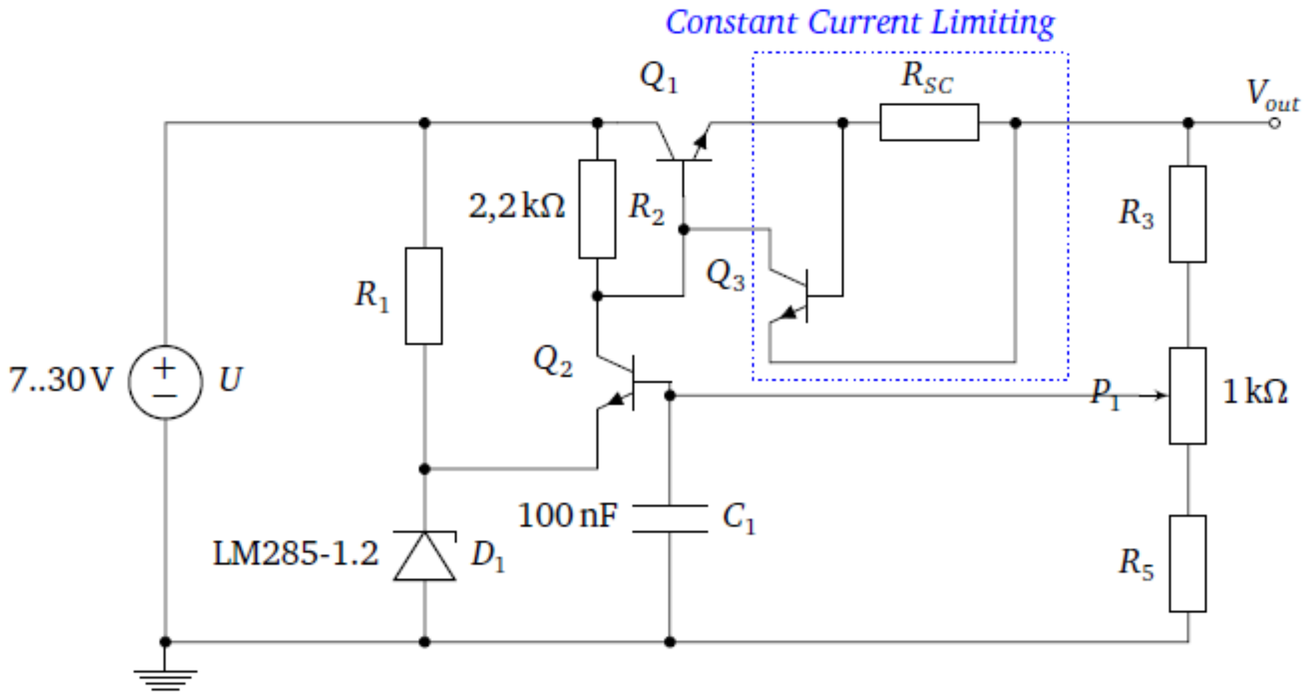
Voltage Regulator with Constant current-limiting





$$I_{L,max} = \frac{V_{BE3}}{R_{SC}}$$

- Q_2 acts as an error-amplifier
- V_{REF} is 1.2 V + 0.7 V = 1.9 V
- Adjust R_3, P_1 and R_5 voltage divider to correct value
- Q_3 conducts if voltage over R_{SC} > 0.7 Volts
  - Q_1 base is shorted with output => Q_1 stops conducting
- Heatsink needed!

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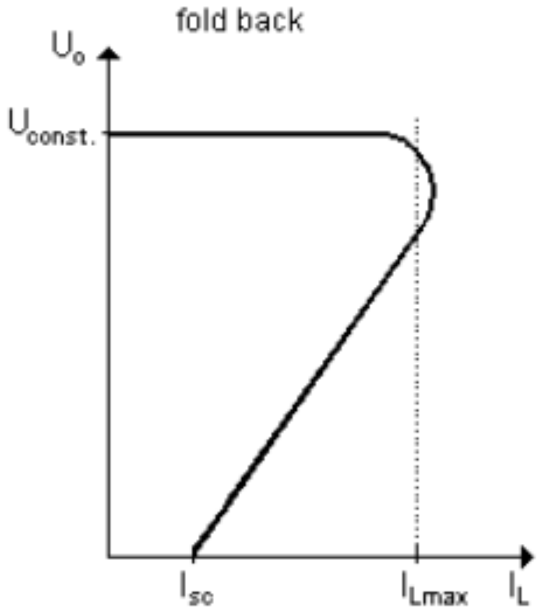
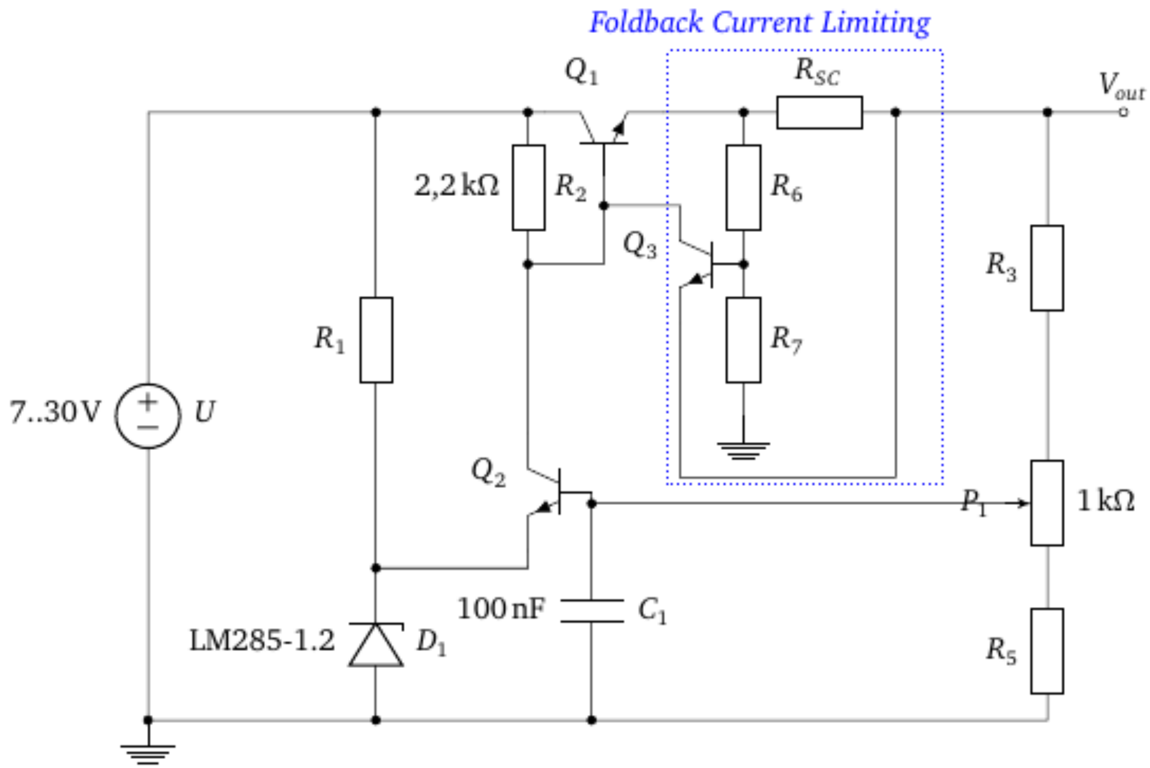
Voltage regulator with foldback-current limiting





- Q_3 turns on when a short-circuit occurs
- Current through Q_1 << maximum pass current
- Generally no heatsink needed

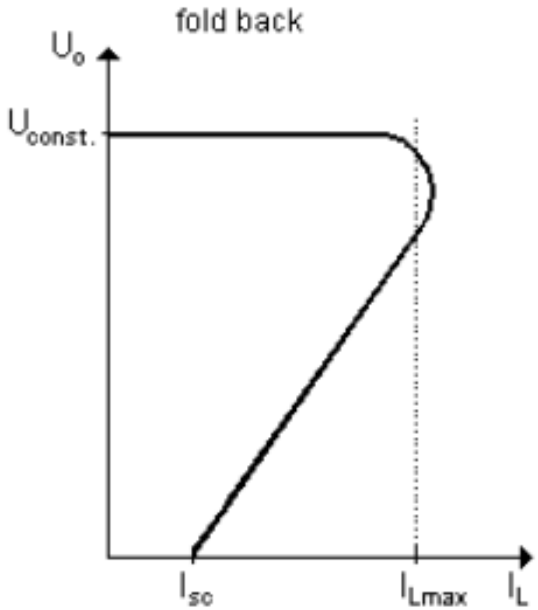
Foldback-current limiting: I_{SC} derivation

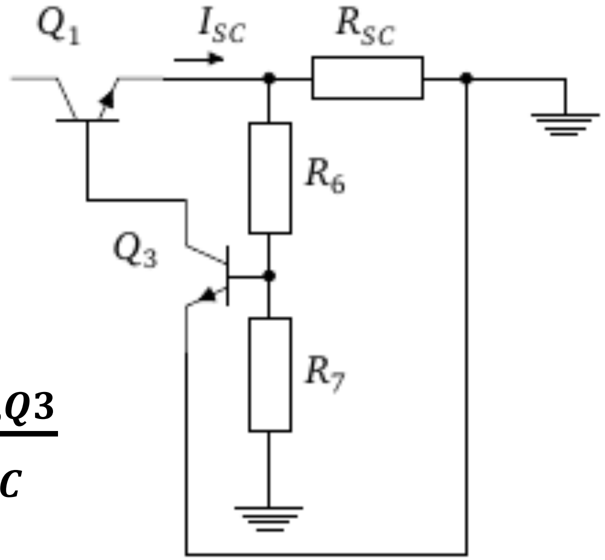
- I_{SC} is the short-circuit current when V_o = 0 V

$$V_{BE,Q3} = \frac{R_7}{R_7+R_6} \cdot V_{E,Q1}$$

$$V_{E,Q1} = \left(1 + \frac{R_6}{R_7}\right) \cdot V_{BE,Q3}$$

$$I_{SC} = \frac{V_{E,Q1}}{R_{SC}} = \left(1 + \frac{R_6}{R_7}\right) \cdot \frac{V_{BE,Q3}}{R_{SC}}$$





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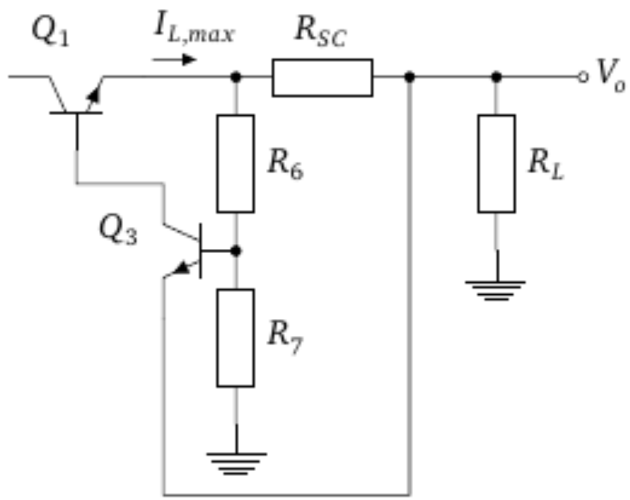
Foldback-current limiting: $I_{L,max}$ derivation



- Start with Kirchhoff voltage loop:

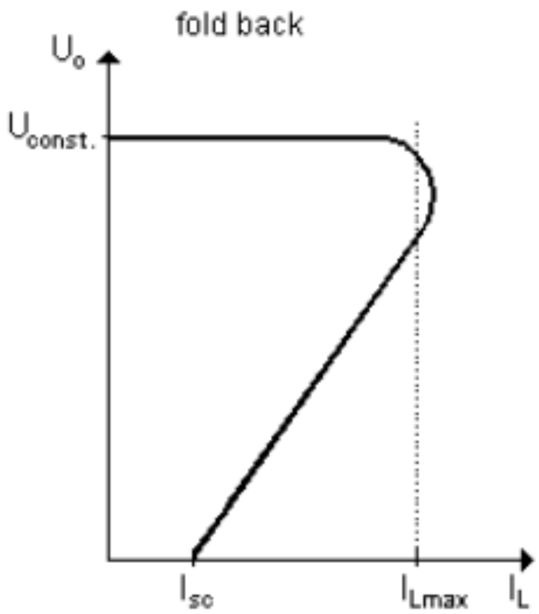
$$\boxed{V_{BE,Q3} - V_{R_{SC}} + V_{R6} = 0}$$

$$V_{BE,Q3} = I_{L,max}.R_{SC} - (V_o + R_{SC}.I_{L,max}).\frac{R_6}{R_7 + R_6}$$

$$V_{BE,Q3}.(R_7 + R_6) = (R_7 + R_6).I_{L,max}.R_{SC} - R_6.V_o - R_6.R_{SC}.I_{L,max}$$

$$V_{BE,Q3}.(R_7 + R_6) + R_6.V_o = I_{L,max}.\left((R_7 + R_6).R_{SC} - R_6.R_{SC}\right)$$

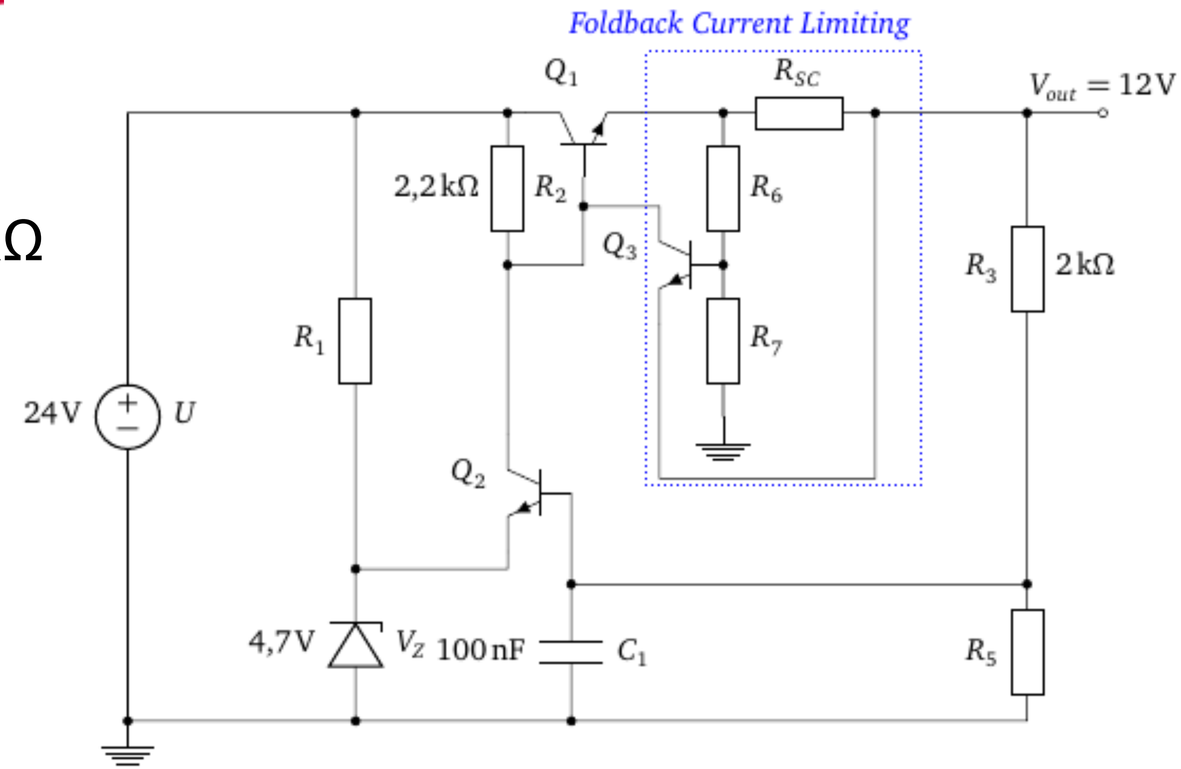
$$V_{BE,Q3}.(R_7 + R_6) + R_6.V_o = I_{L,max}.R_7.R_{SC}$$



$$\boxed{I_{L,max} = \left(1 + \frac{R_6}{R_7}\right).\frac{V_{BE,Q3}}{R_{SC}} + V_o.\frac{R_6}{R_{SC}.R_7} = I_{SC} + V_o.\frac{R_6}{R_{SC}.R_7}}$$

Foldback-current limiting: Example

- Gegeven:
  - V_{in} = 24 V, V_{out} = 12 V
  - R_6 = 1.5 kΩ, R_7 = 8.5 kΩ
  - $V_{BE,Q3}$ = $V_{BE,Q2}$ = 0.7 V
- Gevraagd:
  - Current-limit = 1 A
- Bepaal:
  - Bepaal R_{SC}
  - Bepaal R_5



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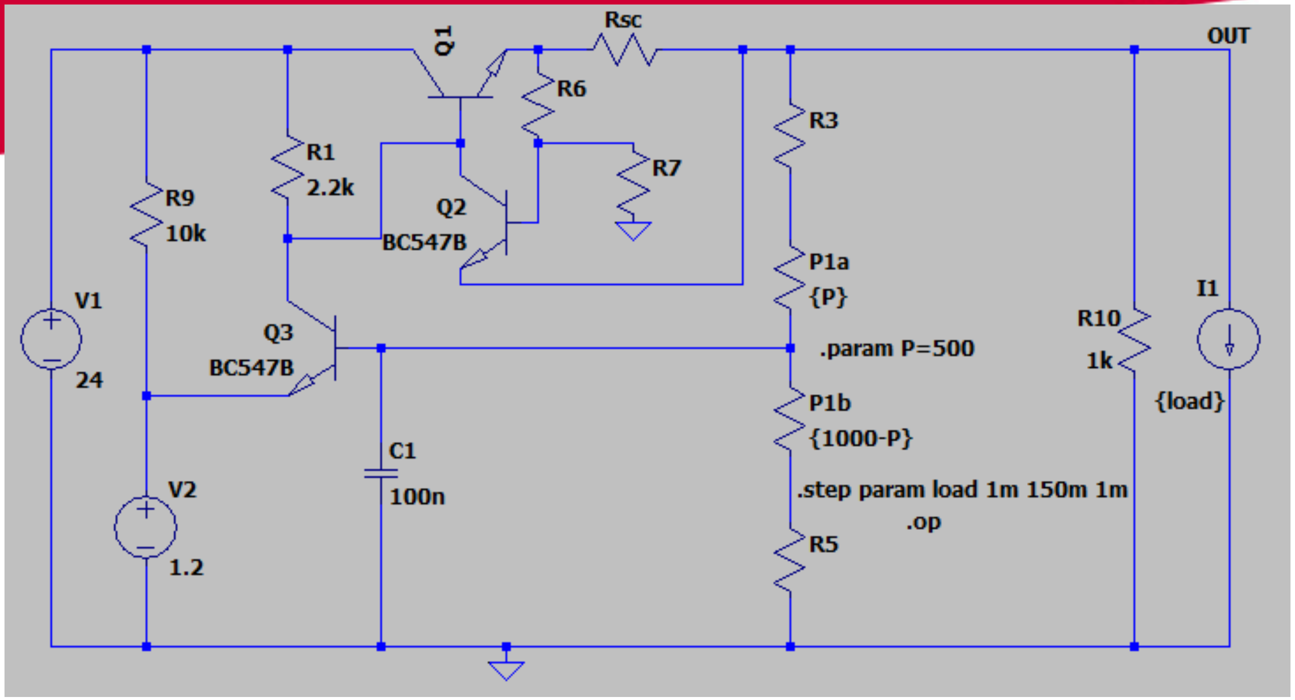
LT-Spice: enkele tips



- .param commando
- .step commando
- X-as: I(Rsc)
- Y-as: V(out)
  - Begrens op 0V!

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Integrated Circuit Regulators

Type	Iout	Vout	Load Reg.	Ripple Rej.
LM78L05	100 mA	+5 V	0.4 %	62 dB
LM78L12	100 mA	+12 V	0.25 %	54 dB
LM78L15	100 mA	+15 V	0.25 %	51 dB
LM79L05	100 mA	-5 V	0.2 %	60 dB
LM79L12	100 mA	-12 V	0.2 %	55 dB
LM79L15	100 mA	-15 V	0.3 %	52 dB
LM317LZ	100 mA	+1.2 V – 37 V	0.1 %	80 dB
LM317MP	500 mA	+1.2 V – 37 V	0.1 %	80 dB
LM317T	1.5 A	+1.2 V – 37 V	0.1 %	80 dB
LM78MGCP	500 mA	+5V -30 V	1 %	62 dB
LM78GCP	1 A	+5V -30V	1 %	62 dB

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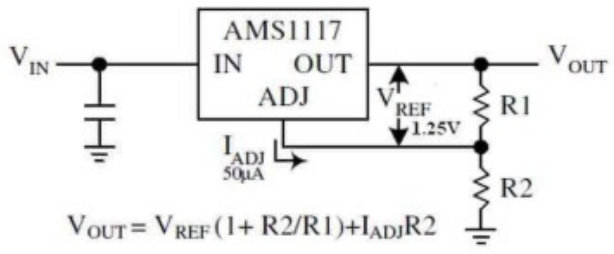
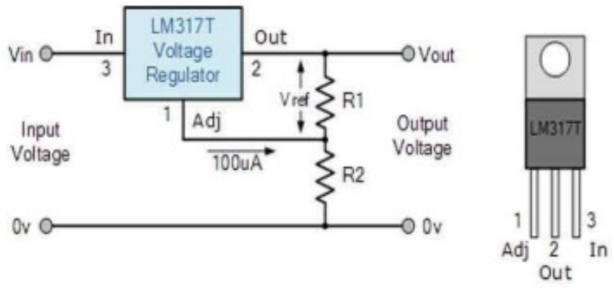
Integrated Circuit Regulators

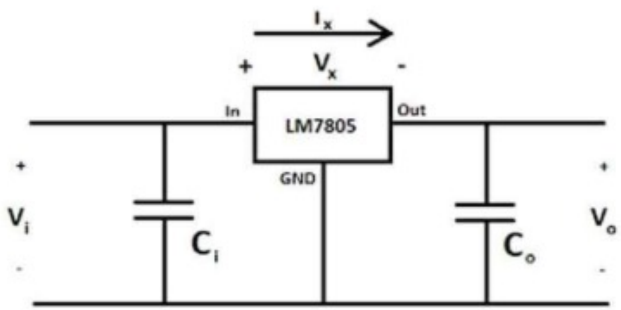
AMS1117



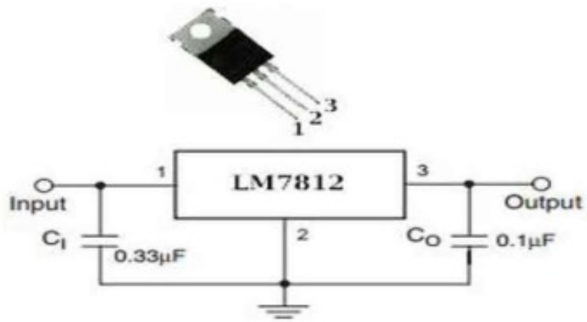
LM317T



LM7805



LM7812



Besproken is:

Voltage Regulators