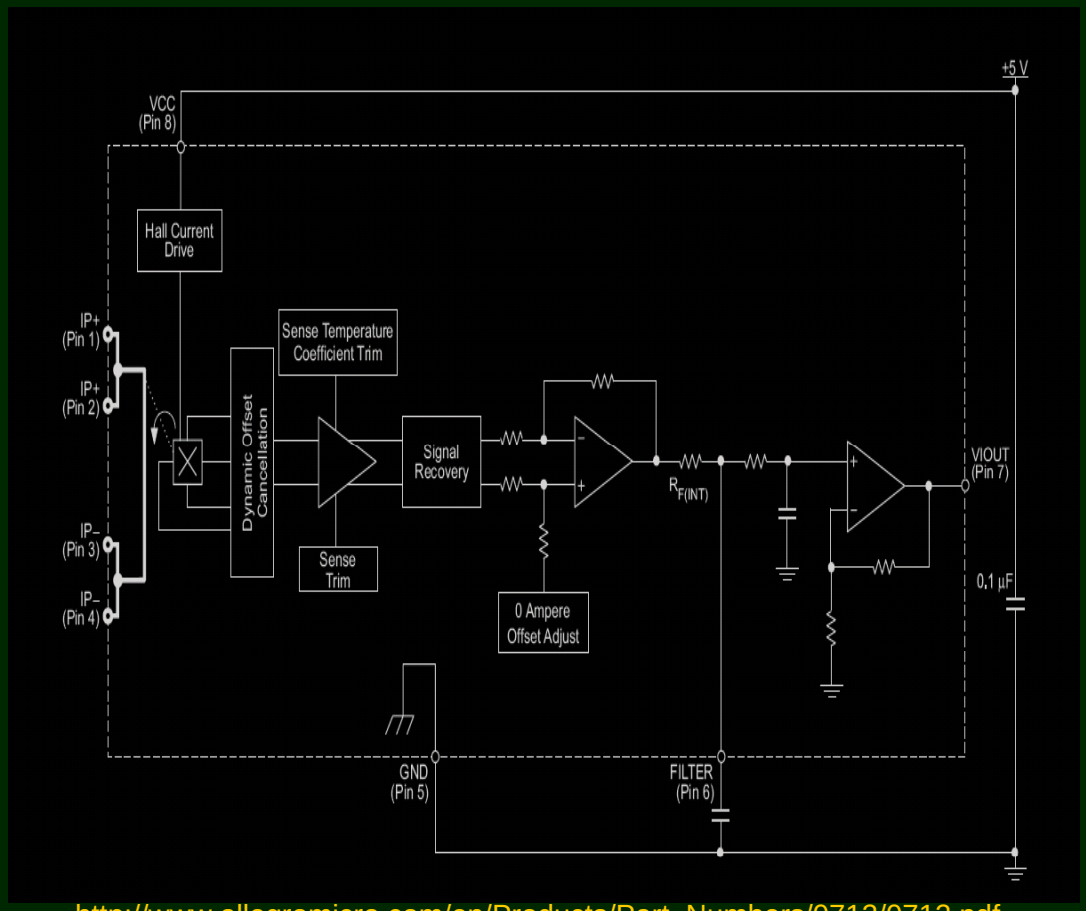
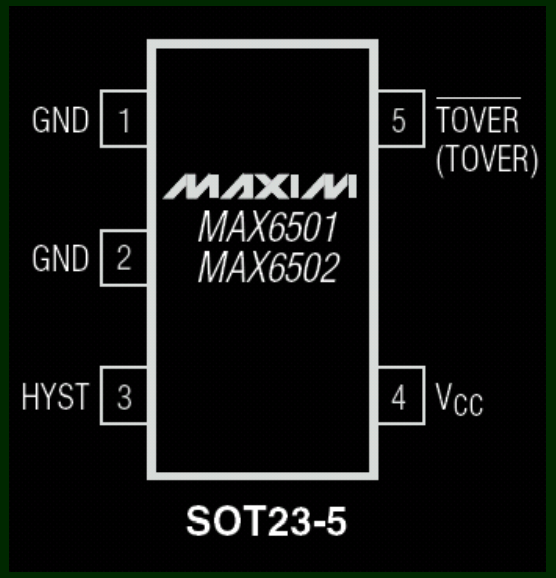
# Amplifier Protection




http://www.allegromicro.com/en/Products/Part_Numbers/0712/0712.pdf

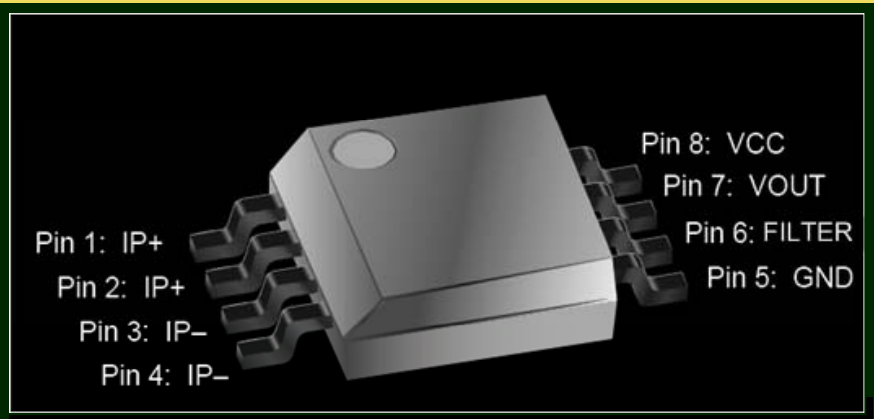


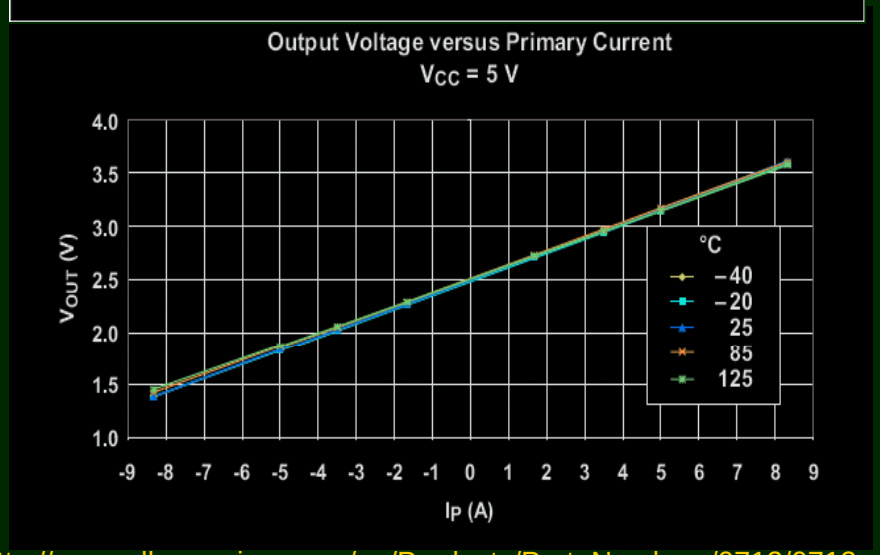

http://datasheets.maxim-ic.com/en/ds/MAX6501-MAX6504.pdf

# Overview

- Over Current Protection
  - Hall Effect Sensor
  - Current Limiting
- Temperature Sensor
  - Case temperature
  - IC switch

# Over Current Protection – Hall Effect Sensor

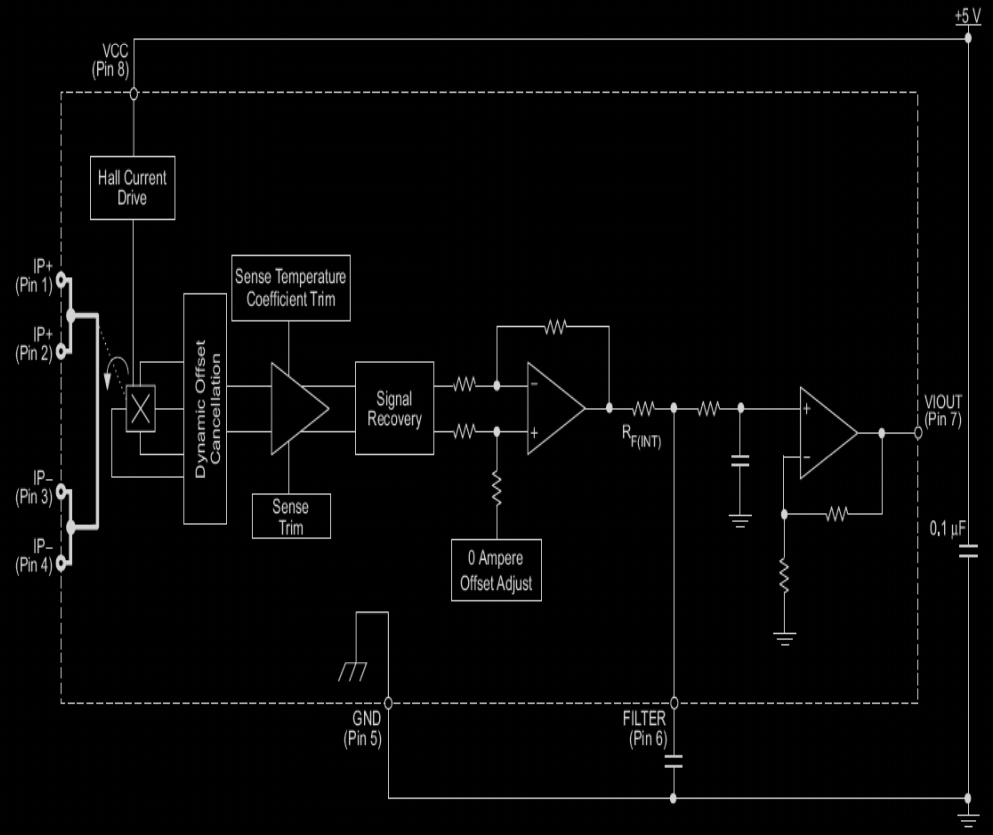



http://www.allegromicro.com/en/Products/Part_Numbers/0712/0712.pdf

- ACS712ELCTR-05B-T
- $r_{IP+ \text{ to } IP-} = 0.0012\ \Omega$
- $V_{out\ @IP\ =\ 0} = 2.5$ V
- Sensitivity = 185 mV/A

# Over Current Protection – Hall Effect Sensor




http://www.allegromicro.com/en/Products/Part_Numbers/0712/0712.pdf

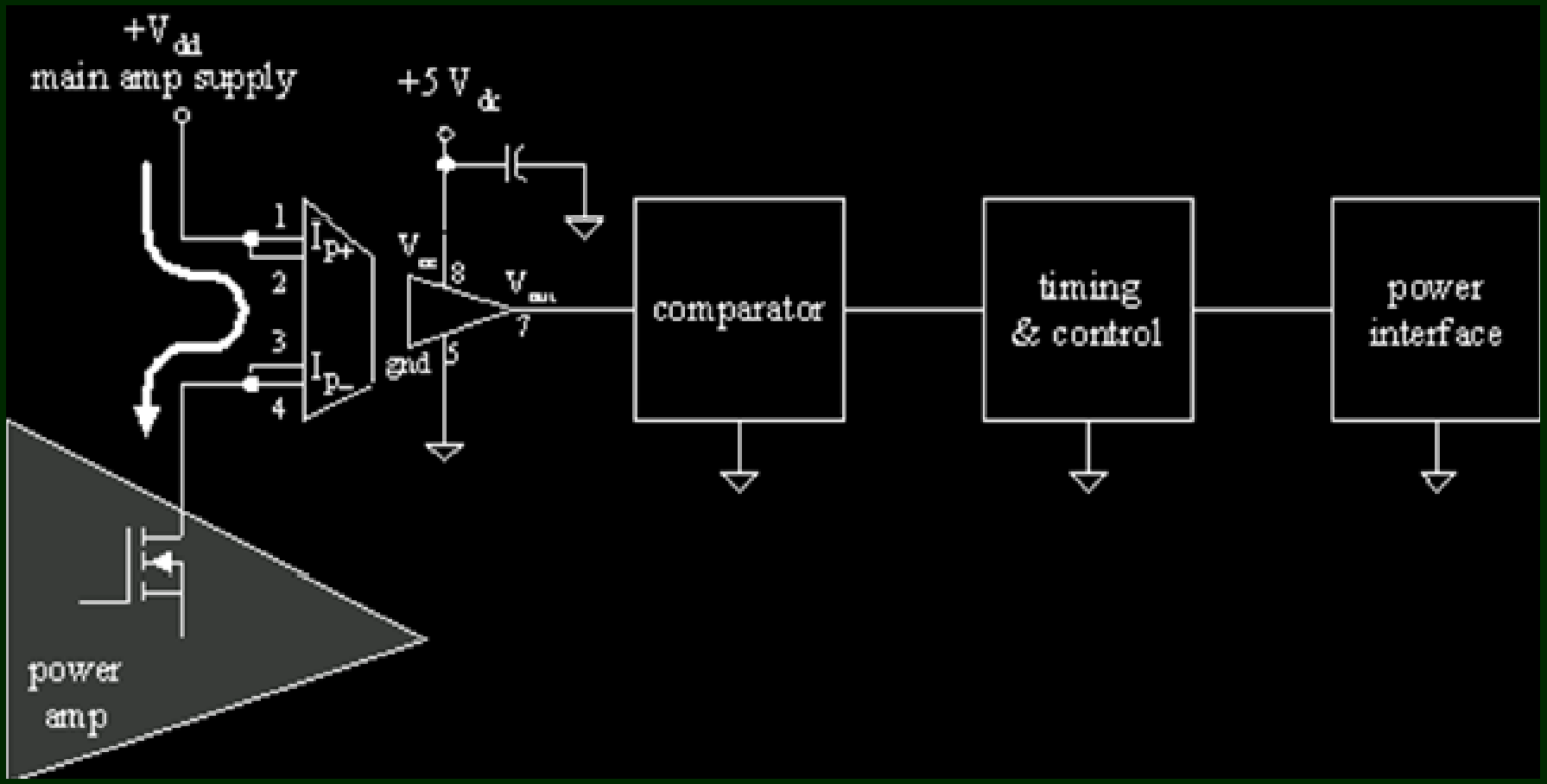
- ACS712ELCTR-05B-T
- $I_{P+}$ & $I_{P-}$ isolated from $V_{cc}$, $V_{out}$, & GND
- Pins 3 & 4 = $I_{out}$
- Pins 1 & 2 = $I_{in}$
- Filter: $t_{rise} = 0.35/f_{-3dB}$

| $C_F$ (nF) | $t_r$ (µs) |
|---|---|
| 0 | 6.6 |
| 1 | 7.7 |
| 4.7 | 17.4 |
| 10 | 32.1 |
| 22 | 68.2 |
| 47 | 88.2 |
| 100 | 291.3 |
| 220 | 623.0 |
| 470 | 1120.0 |

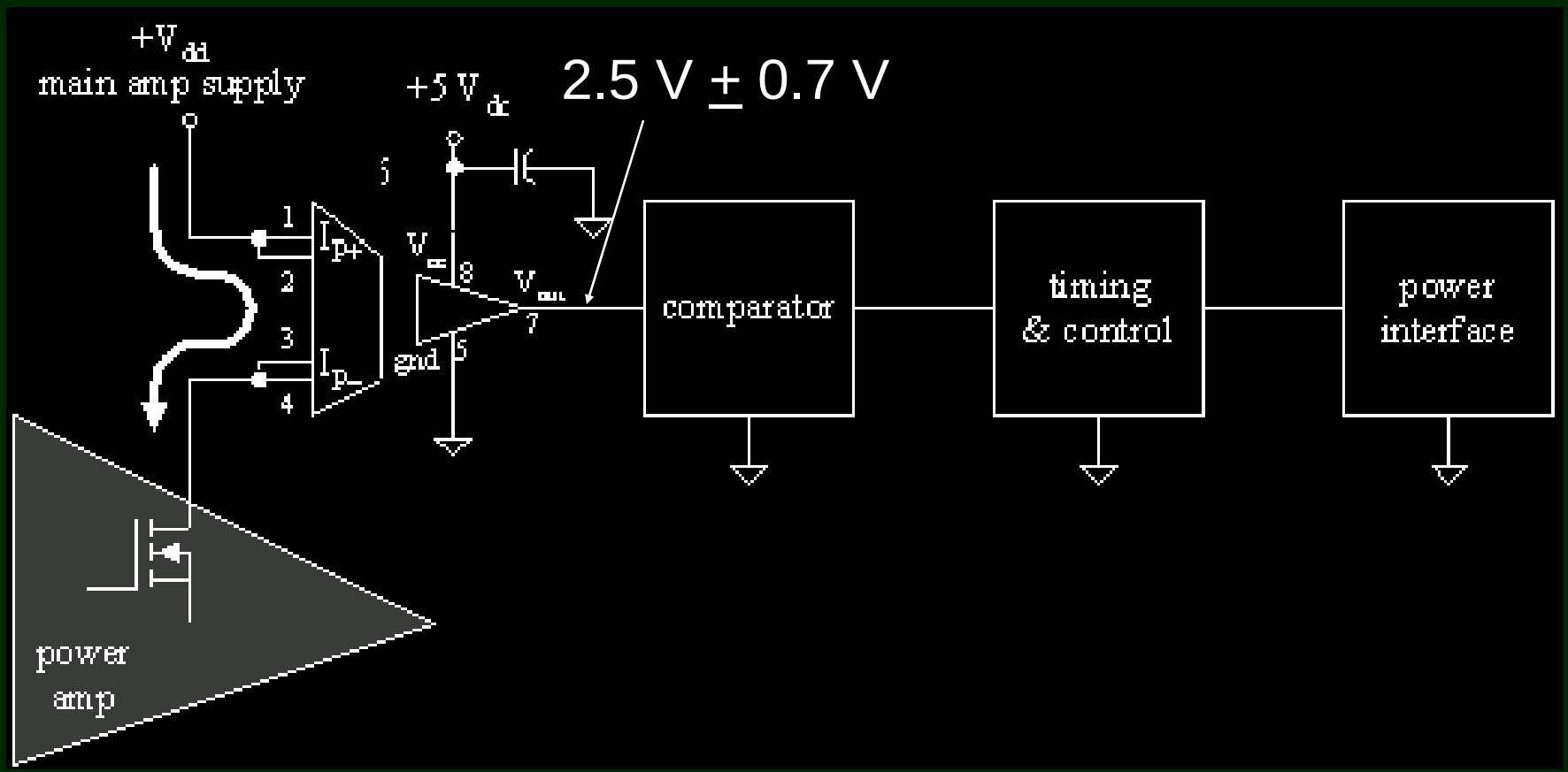
$f_{-3dB}$ = 20 kHz

$C_f$ = ?

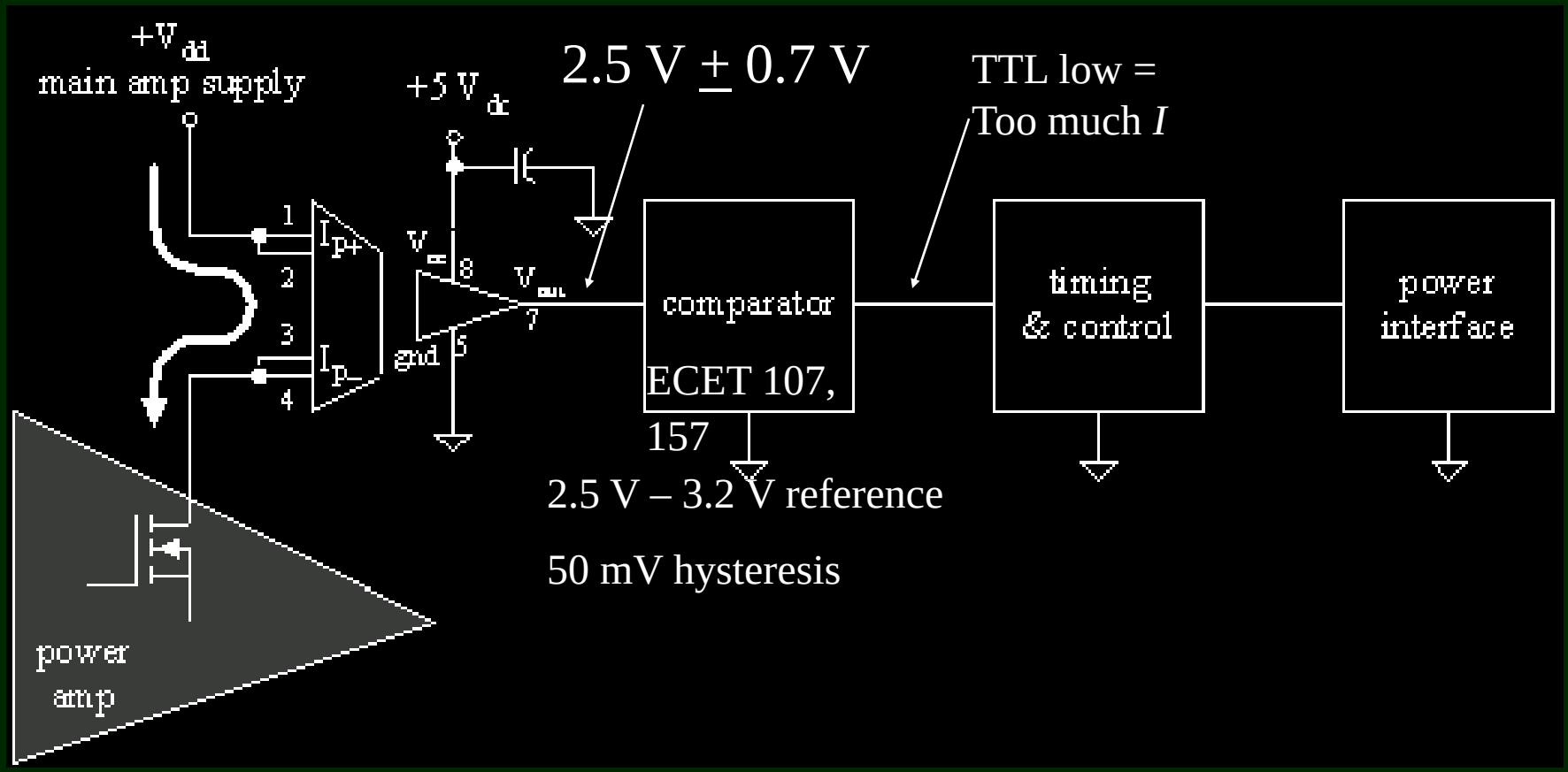
# Over Current Protection – Signal Processing



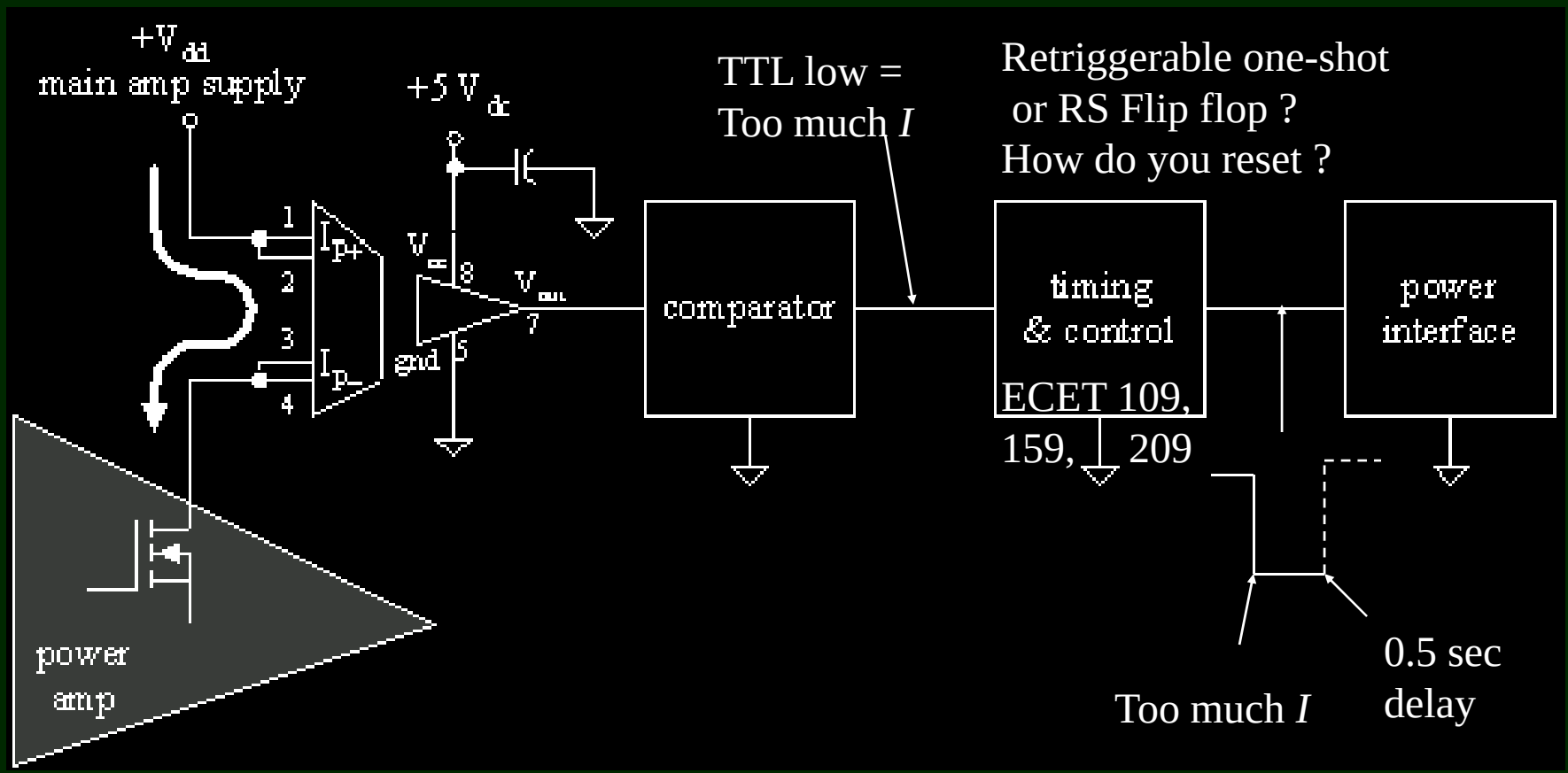
# Over Current Protection – Signal Processing



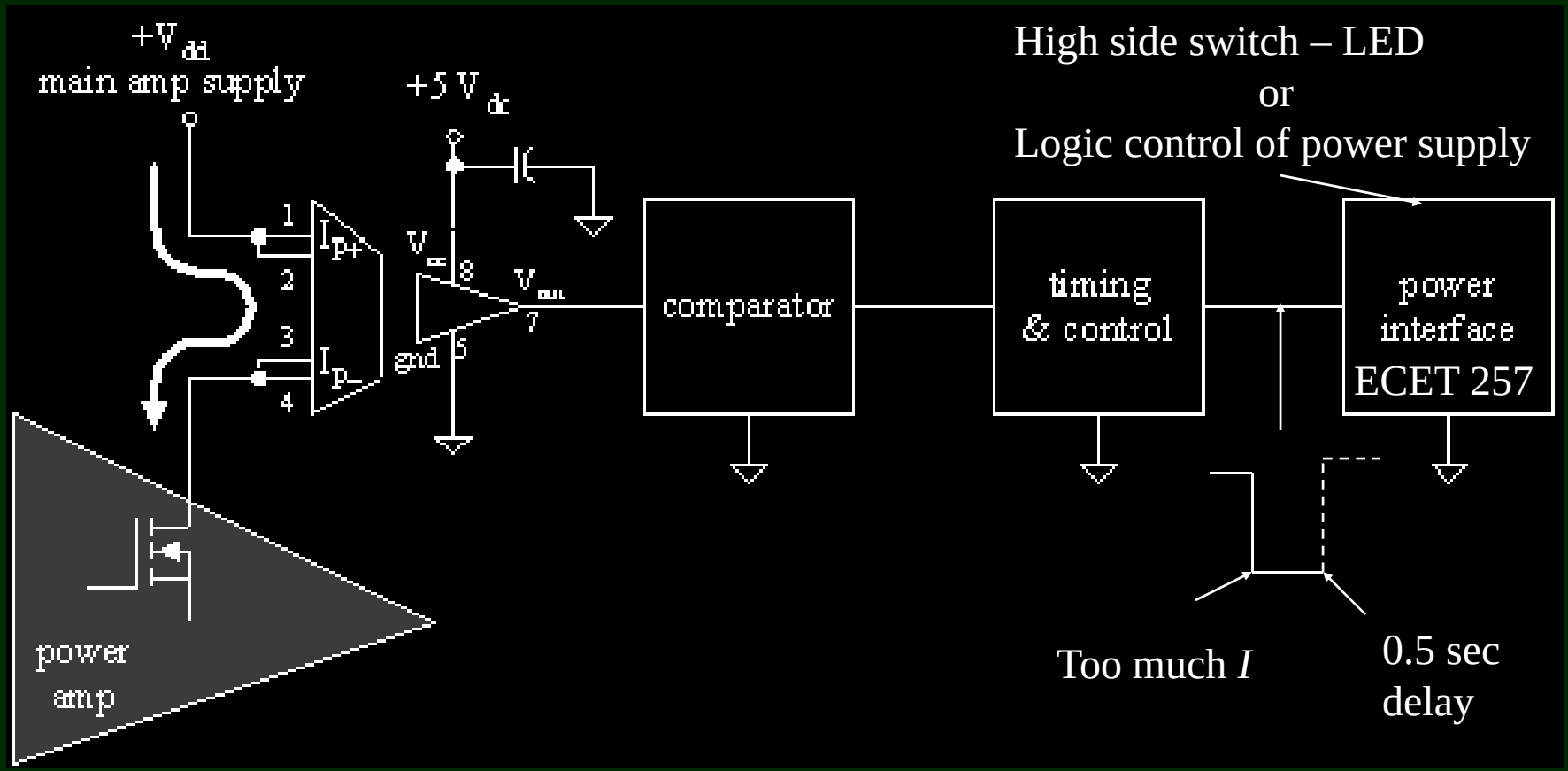
# Over Current Protection – Signal Processing



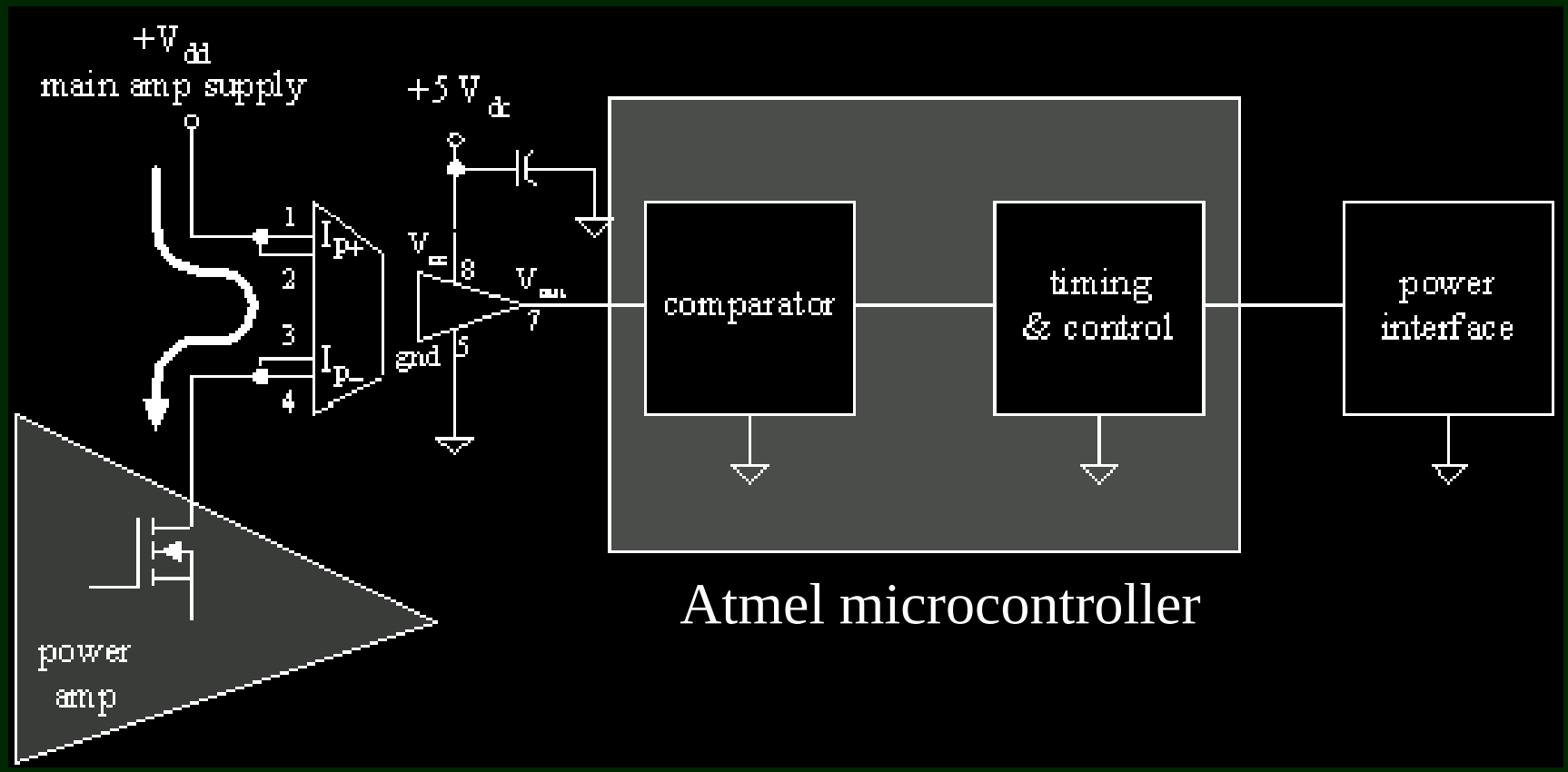
# Over Current Protection – Signal Processing



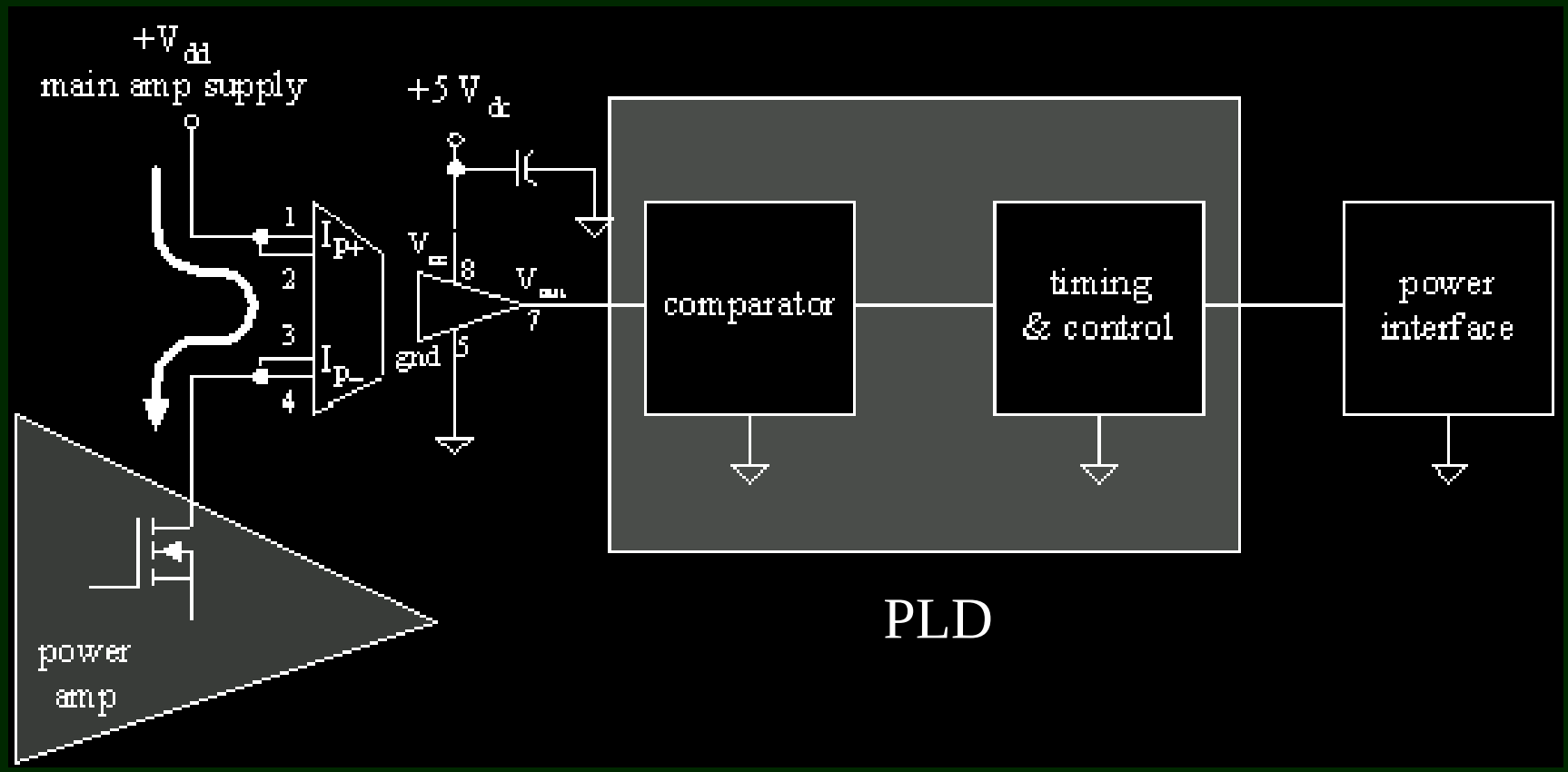
# Over Current Protection – Signal Processing



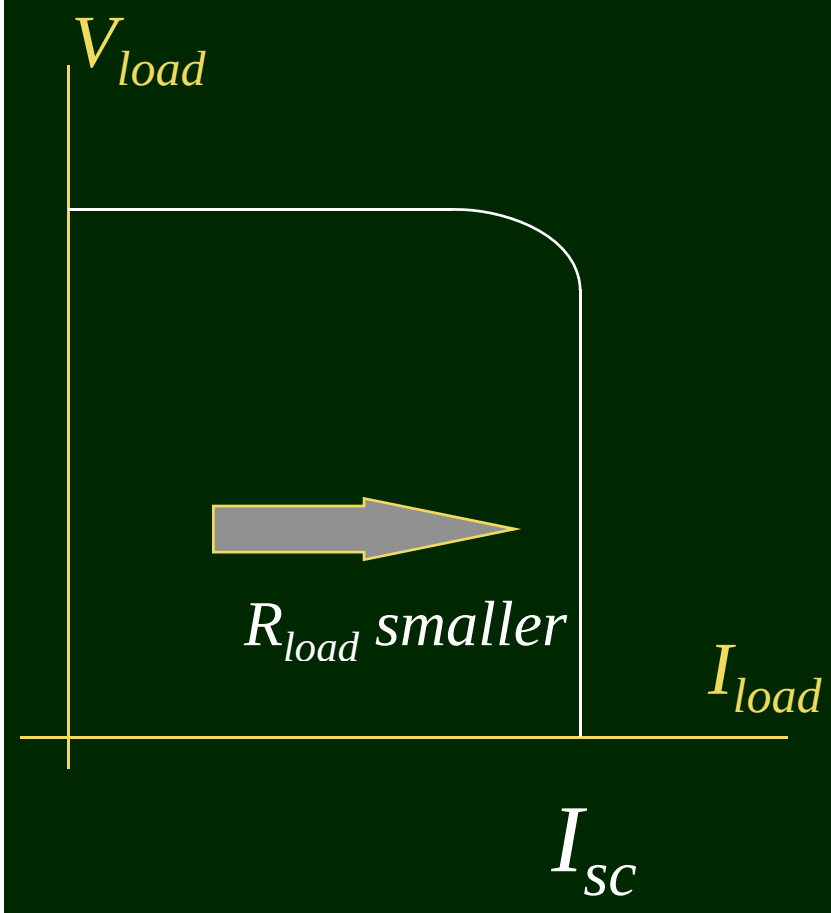
# Over Current Protection – Signal Processing



# Over Current Protection – Signal Processing



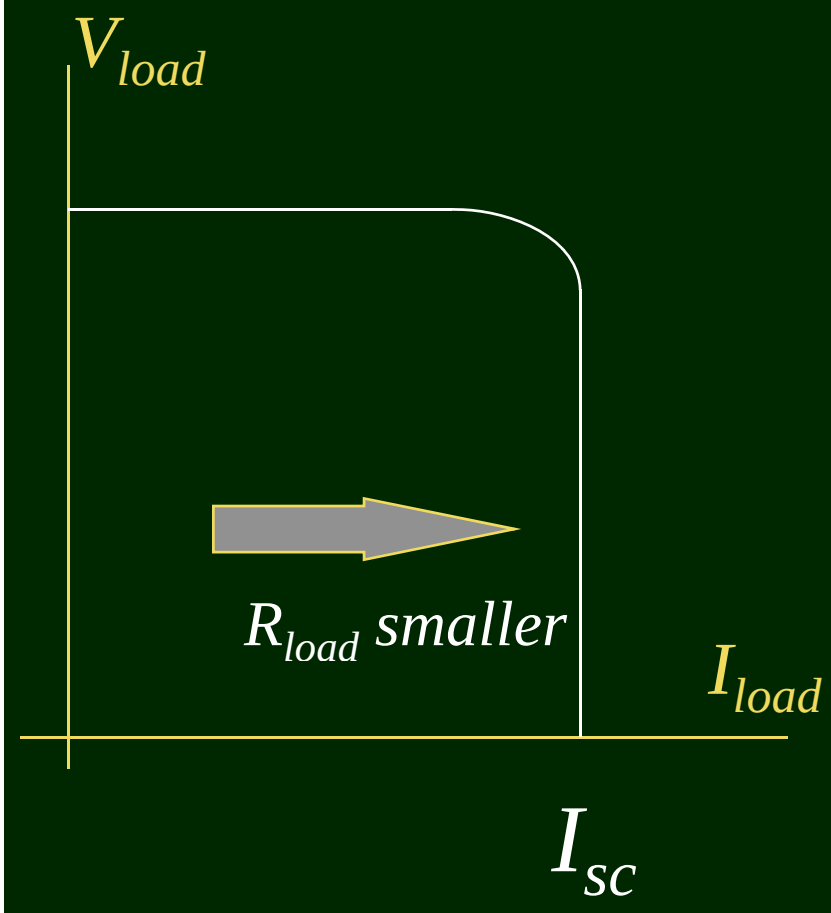
# Current Limiting - performance




low voltages out

=> whatever current $R_{load}$ needs

# Current Limiting - performance

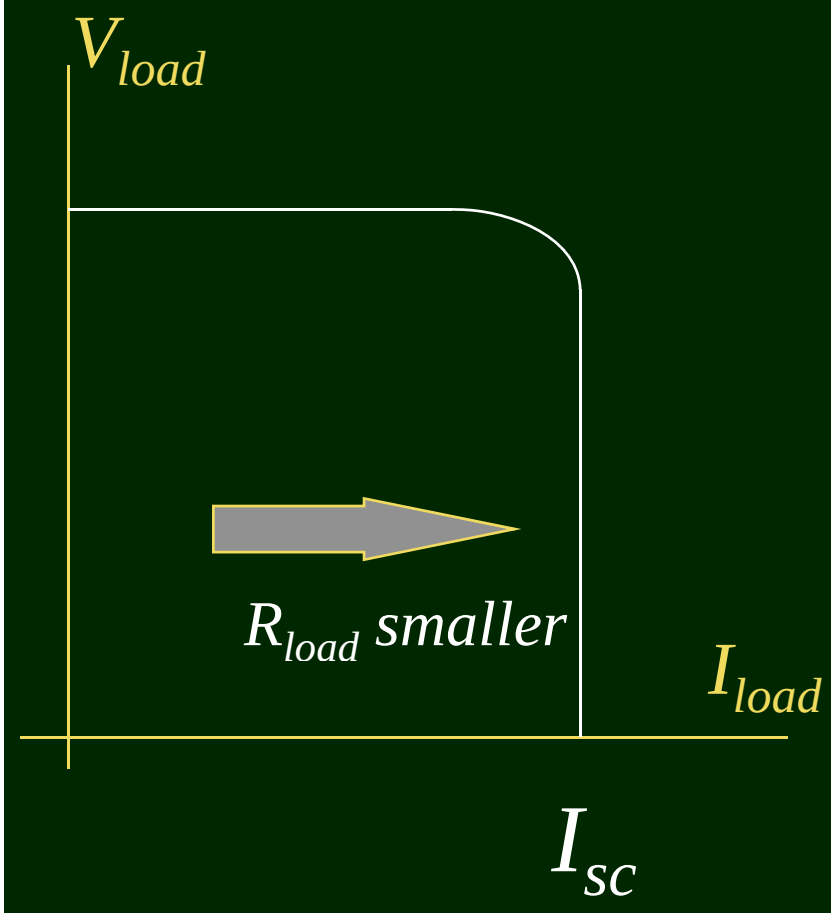



low voltages out

=> whatever current $R_{load}$ needs

I demand too high

# Current Limiting - performance



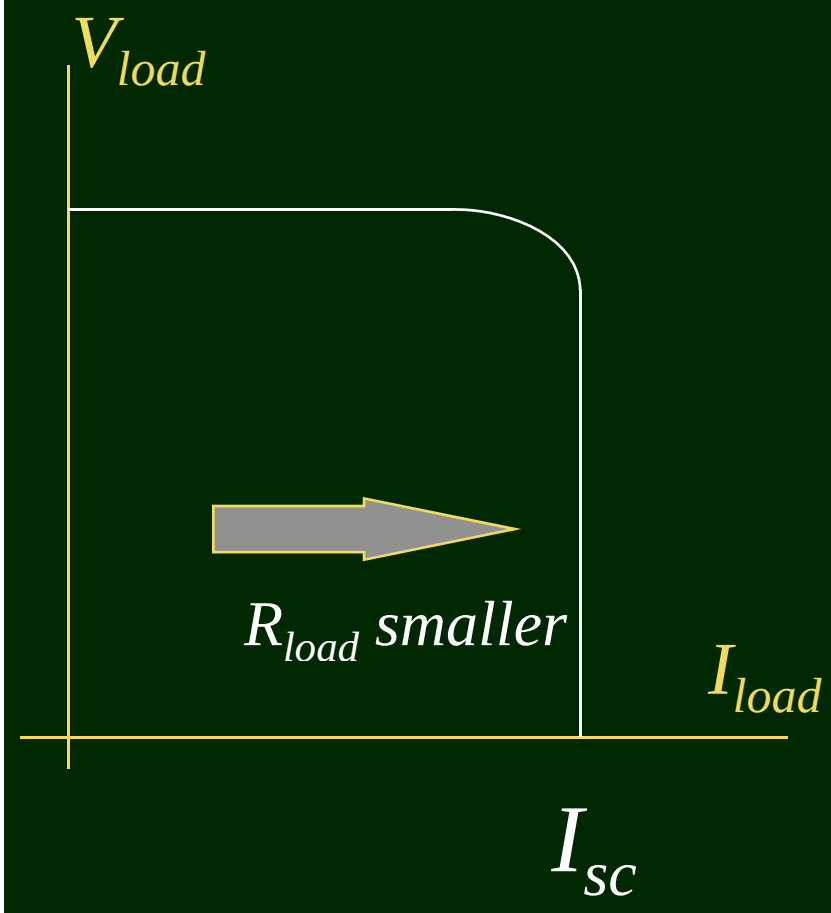

low voltages out

=> whatever current $R_{load}$ needs

I demand too high

=> $I_{load}$ limited to $I_{SC}$

# Current Limiting - performance




low voltages out

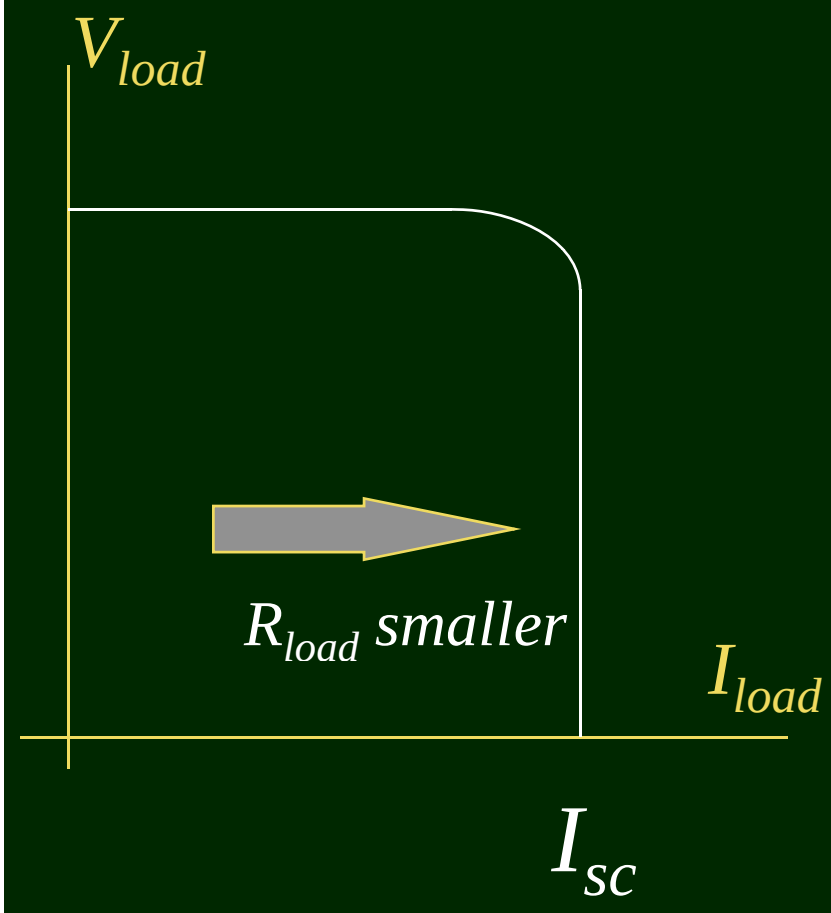
=> whatever current $R_{load}$ needs

I demand too high

=> $I_{load}$ limited to $I_{SC}$

& $V_{load}$ dropped as set by $R_{load}$

# Current Limiting - performance




low voltages out

=> whatever current $R_{load}$ needs

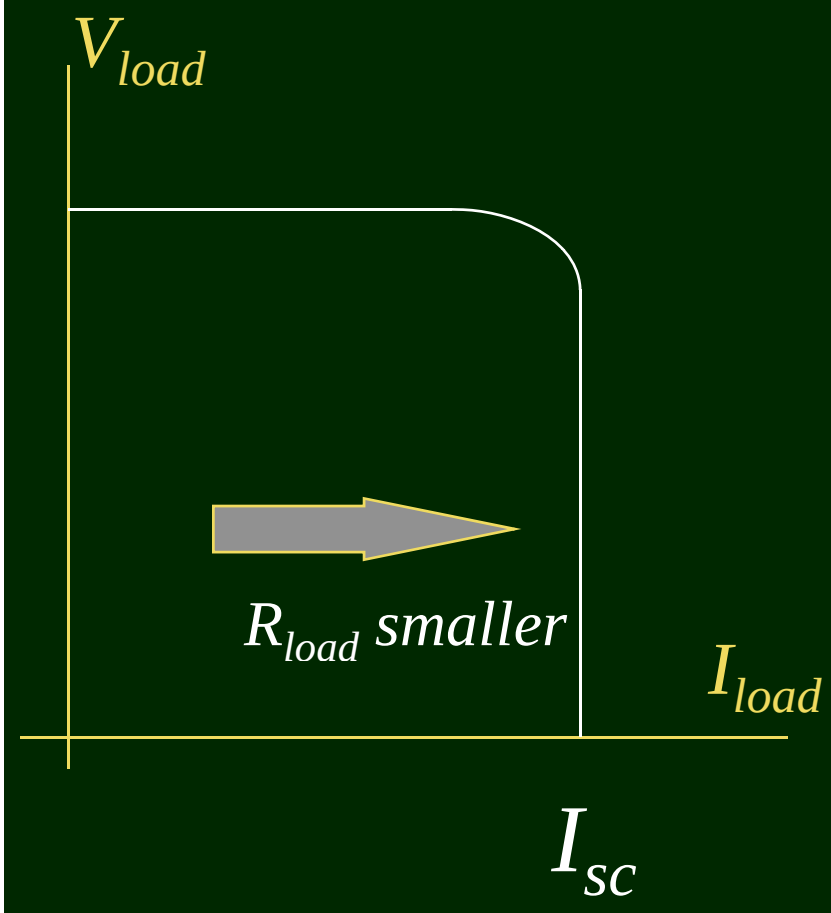
I demand too high

=> $I_{load}$ limited to $I_{SC}$

& $V_{load}$ dropped as set by $R_{load}$

$V_{load} = I_{sc} * R_{load}$

# Current Limiting - performance




low voltages out

=> whatever current $R_{load}$ needs

I demand too high

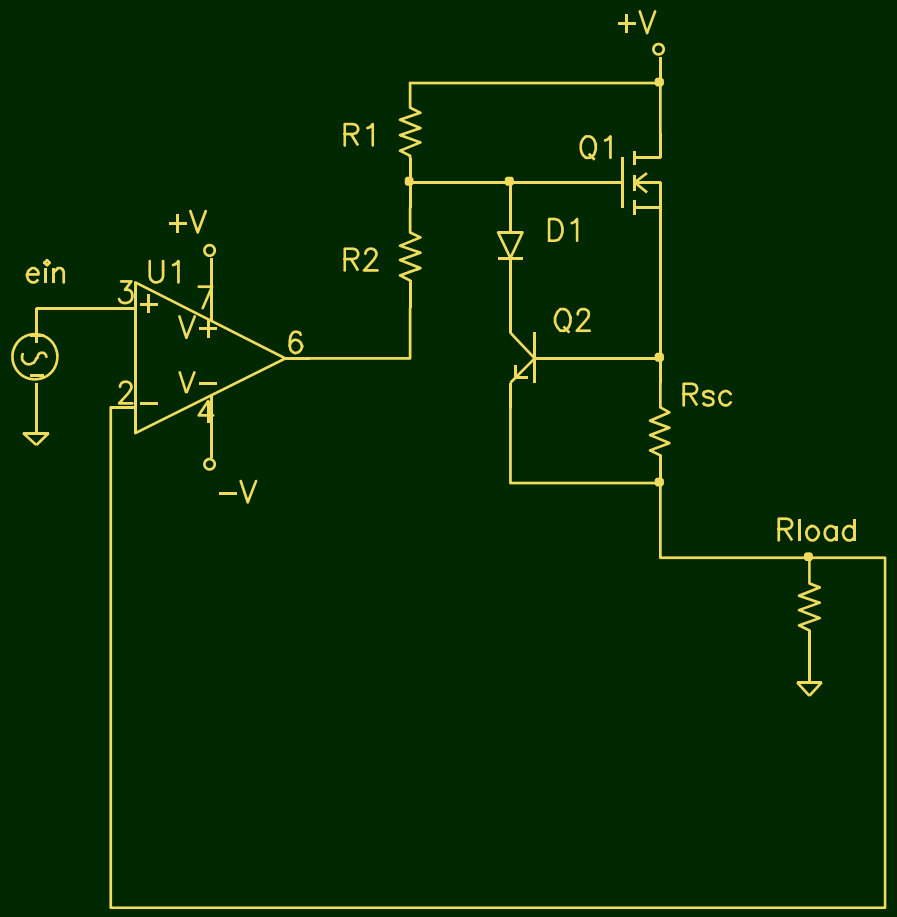
=> $I_{load}$ limited to $I_{SC}$

& $V_{load}$ dropped as set by $R_{load}$

$V_{load} = I_{sc} * R_{load}$

constant

# Current Limiting - Positive side schematic



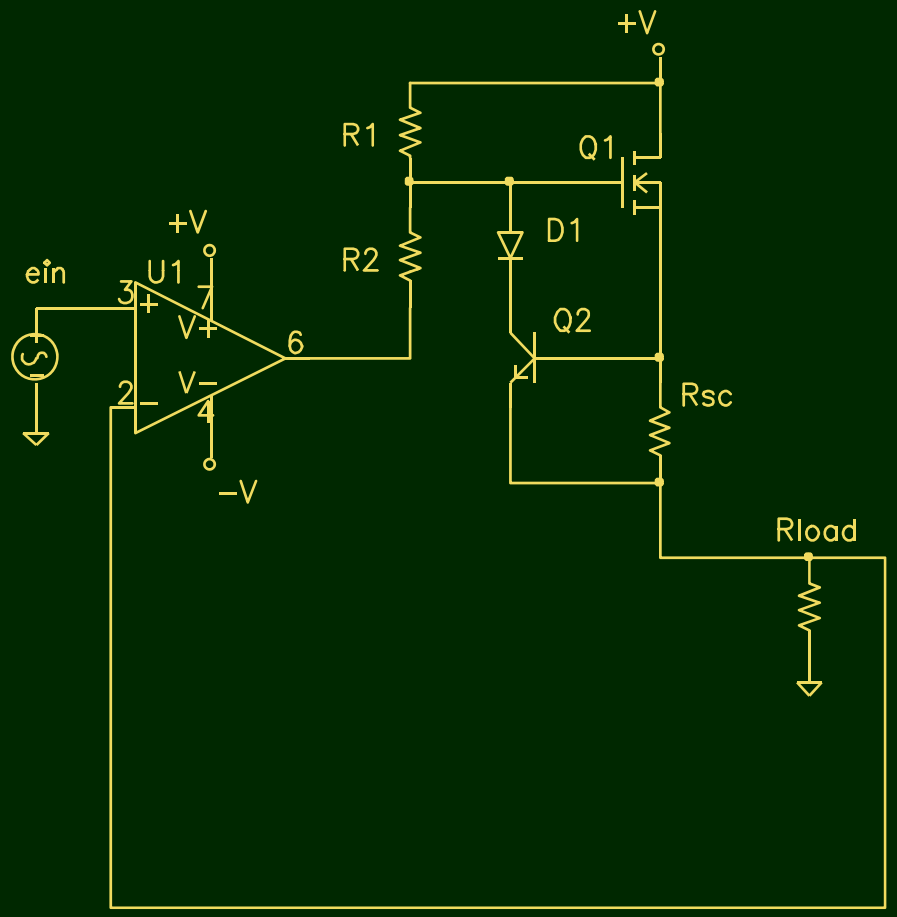

$R_{sc}$ small 0.x Ω

normal operation

$I_{load} < I_{SC}$

Q2 off => no effect

# Current Limiting - Positive side schematic




$R_{sc}$ small 0.x Ω

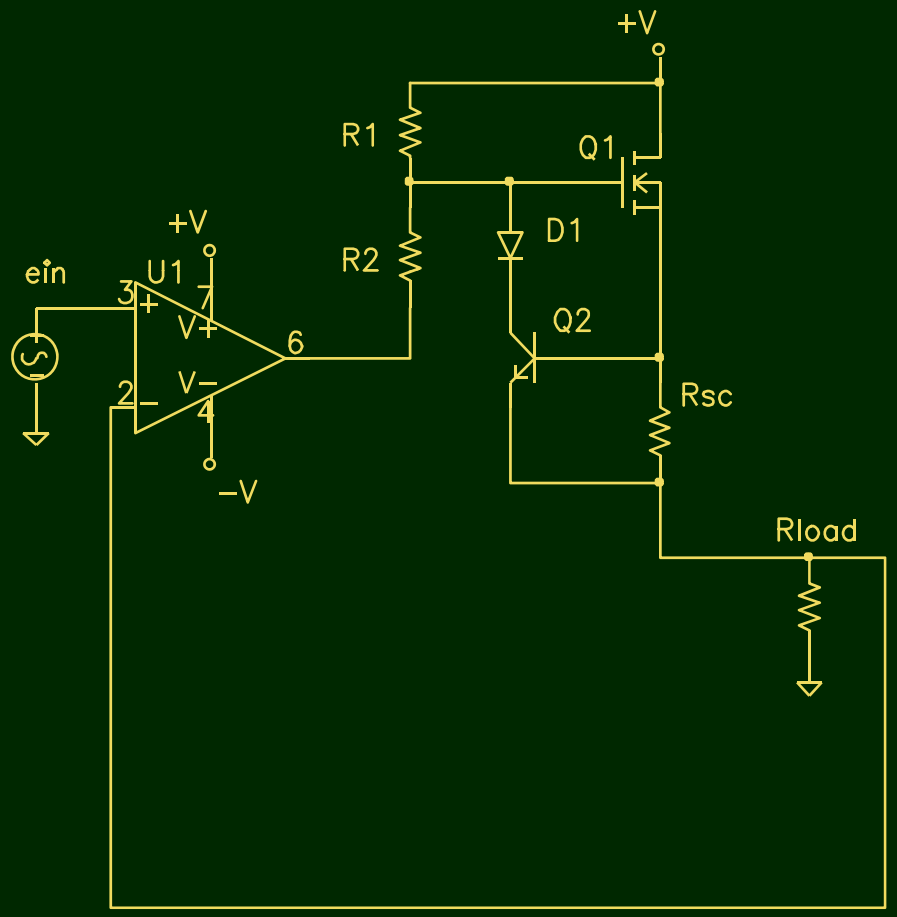
normal operation

$I_{load} < I_{SC}$

Q2 off => no effect

$I_{load}$ ↑ => $V_{R\ sc}$ ↑

# Current Limiting - Positive side schematic




$R_{sc}$ small 0.x Ω

normal operation

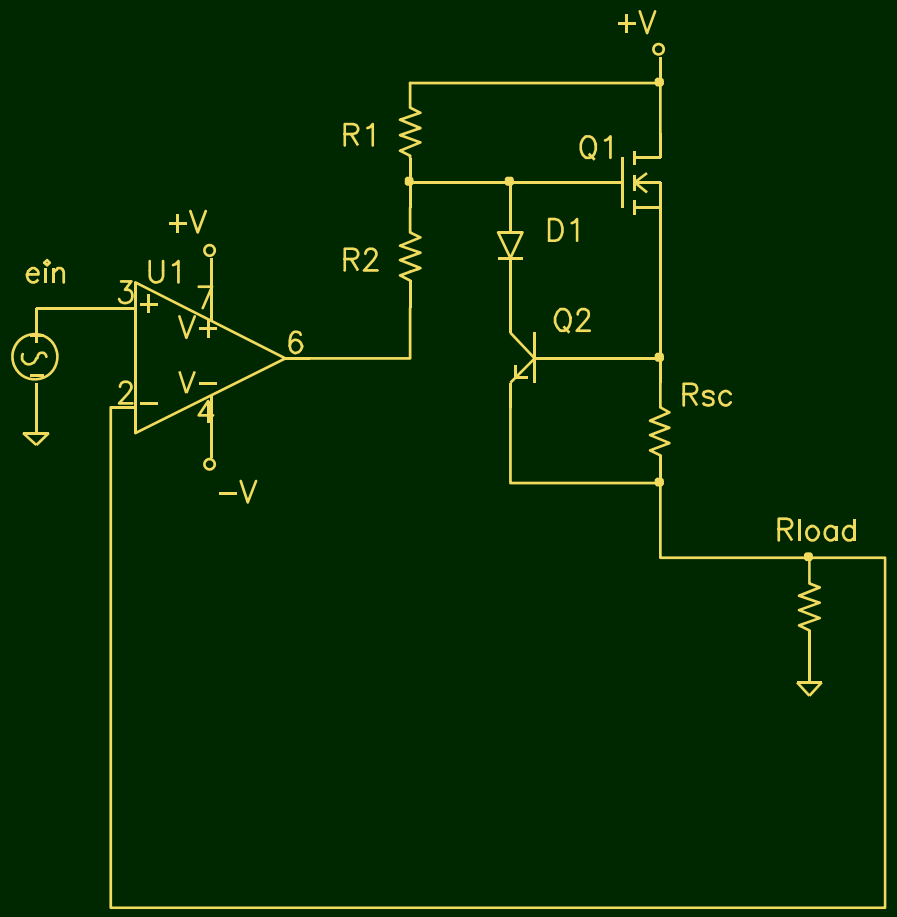
$I_{load} < I_{SC}$

Q2 off => no effect

$I_{load}$ ↑ => $V_{R\,sc}$ ↑

$V_{R\,sc} = 0.7V$ =>

# Current Limiting - Positive side schematic




$R_{sc}$ small 0.x Ω

normal operation

$I_{load} < I_{SC}$

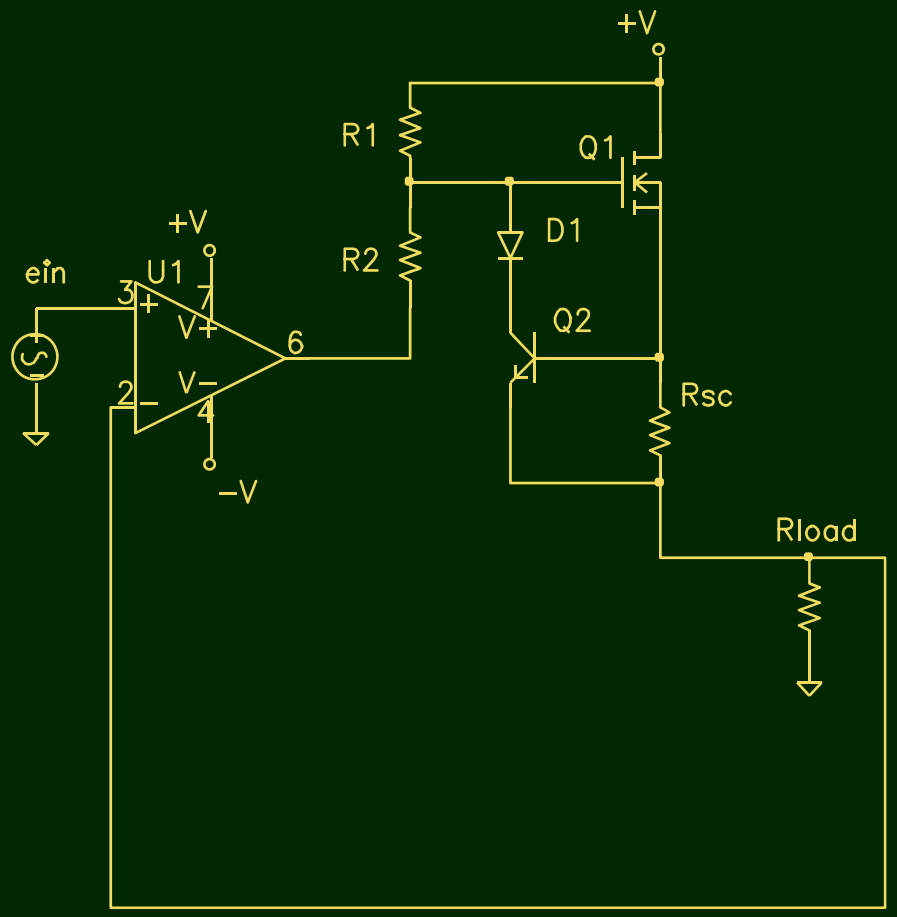
Q2 off => no effect

$I_{load}$ ↑ => $V_{R\,sc}$ ↑

$V_{R\,sc} = 0.7V$ =>

Q2 on => Q1 $V_{GS}$ shorted

# Current Limiting - Positive side schematic




$R_{sc}$ small 0.x Ω

normal operation

$I_{load} < I_{SC}$

Q2 off => no effect

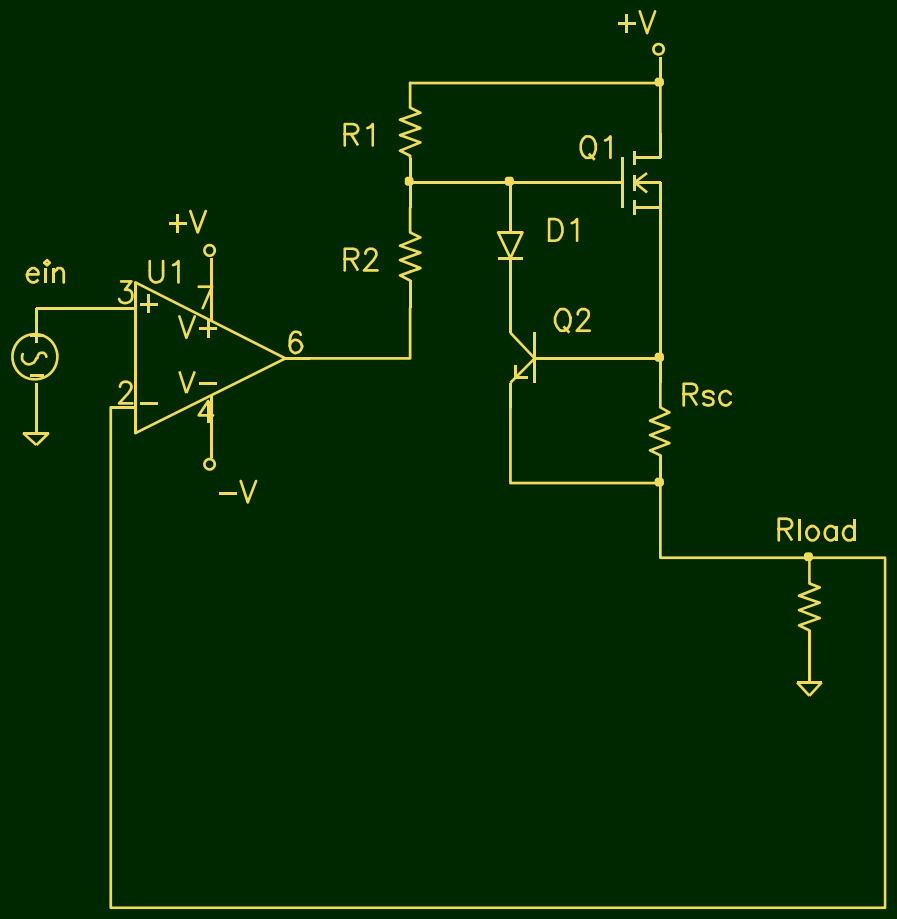
$I_{load}$ ↑ => $V_{R\,sc}$ ↑

$V_{R\,sc}$ = 0.7V => ↓

Q2 on => Q1 $V_{GS}$ shorted

Q1 off => $I_{load}$ ↓

# Current Limiting - Positive side schematic




$R_{sc}$ small 0.x Ω

normal operation

$I_{load} < I_{SC}$

Q2 off => no effect

$I_{load}$ => $V_{R\,sc}$

$V_{R\,sc}$ = 0.7V =>

Q2 on => Q1 $V_{GS}$ shorted

Q1 off => $I_{load}$

# Current Limiting - Problem

$V_{supply} = 30V$
$R_{load} = 8\Omega$
$V_{load\ max} = 20V_P$
$T_A = 50\ ^oC$
$\Theta_{JA} = 7.5\ ^oC/W$

$I_{SC} = ?$ $R_{SC} = ?$

$P_{Q\ shorted\ load} = ?$
$T_J = ?$

$I_{SC} > V_{load\ P} / R_{load}$
$> 20V_P / 8\Omega = 2.5A_P$
pick $I_{sc} = 2.8A$
$R_{SC} = 0.7V / 2.8A = 0.25\Omega$

$P_{Q\ short} = (30V * 2.8A) / 2 = 42W$
$T_J = 50\ ^oC + 42W * 7.5\ ^oC/W$
$= 365\ ^oC$ => smoke !

# Current Limiting - Problem

$V_{supply} = 30V$
$R_{load} = 8\Omega$
$V_{load\ max} = 20V_P$
$T_A = 50\ ^oC$
$\Theta_{JA} = 7.5\ ^oC/W$

$I_{SC} = ?$ $R_{SC} = ?$

$P_{Q\ shorted\ load} = ?$
$T_J = ?$

$I_{SC} > V_{load\ P} / R_{load}$
pick $I_{sc} = 2.8A$

$T_J = 365\ ^oC$ => smoke !

Why does it not burn up when the load is not shorted?

What are we going to do?

# Overview

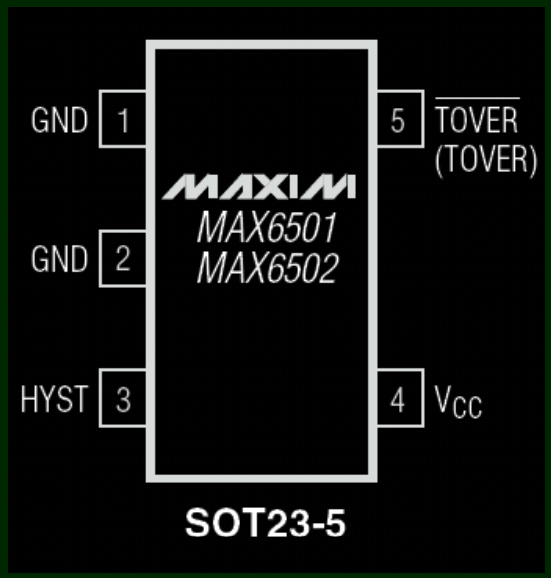
- Current Limiting
  - performance operation
  - positive side schematic problem
- Temperature Sensor
  - Case temperature
  - IC switch

# Temperature Switch

$$T_J = T_S + P(\Theta_{JC} + \Theta_{CS})$$

$$T_S = T_J - P(\Theta_{JC} + \Theta_{CS})$$

$$T_S = 130°C - 19.5W\left(1.9\frac{°C}{W} + 0.2\frac{°C}{W}\right) = 89°C$$




Heat sink temperature = ?

Temperature switch

- MAX6501 - 95ºC
- $T_C$ < 95ºC => output open
  - 3.3kΩ pullup to 5V
- $T_C$ > 95ºC => output low
- Hysteresis pin
  - V+ => 10ºC
  - 85 ºC to go high

Mounting ?

http://datasheets.maxim-ic.com/en/ds/MAX6501-MAX6504.pdf