MALVINO & BATES

Electronic PRINCIPLES

SEVENTH EDITION

Chapter 5

Special-Purpose Diodes

Topics Covered in Chapter 5

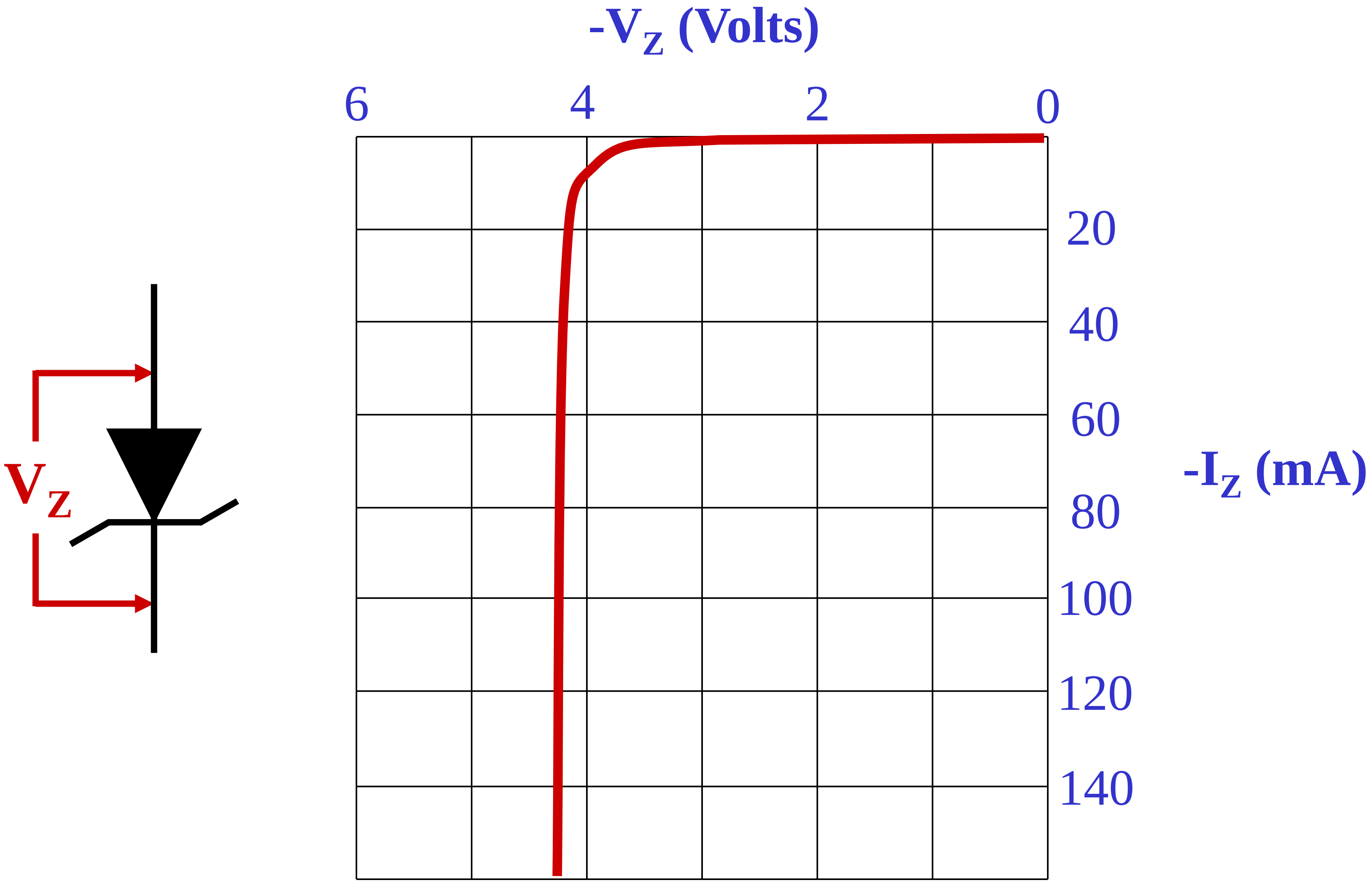
- **Zener diode**
- **Loaded zener regulator**
- **Second approximation of a zener diode**
- **Zener drop-out point**
- **Reading a data sheet**
- **Troubleshooting**

Topics Covered in Chapter 5 (Continued)

- Load lines
- Optoelectronic devices
- Schottky diode
- Varactor
- Other diodes

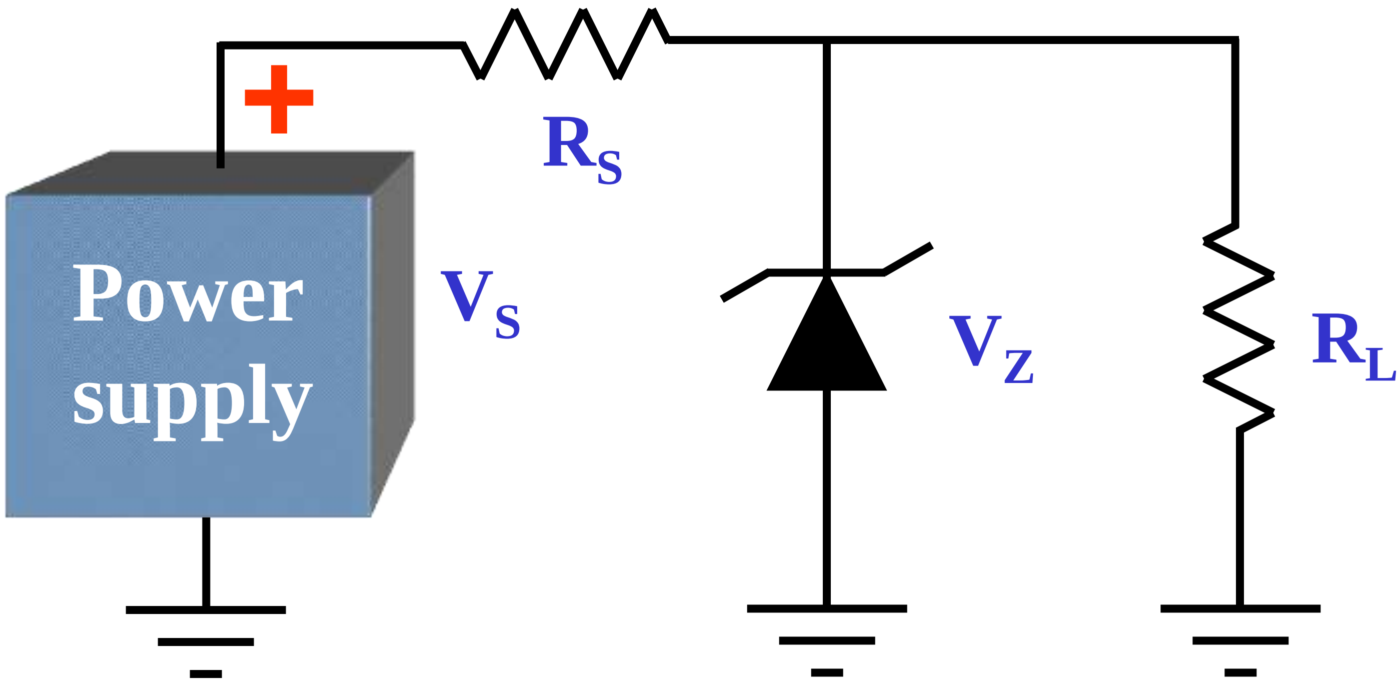
Zener diode

- Optimized for operation in the breakdown region
- Main use: voltage regulation



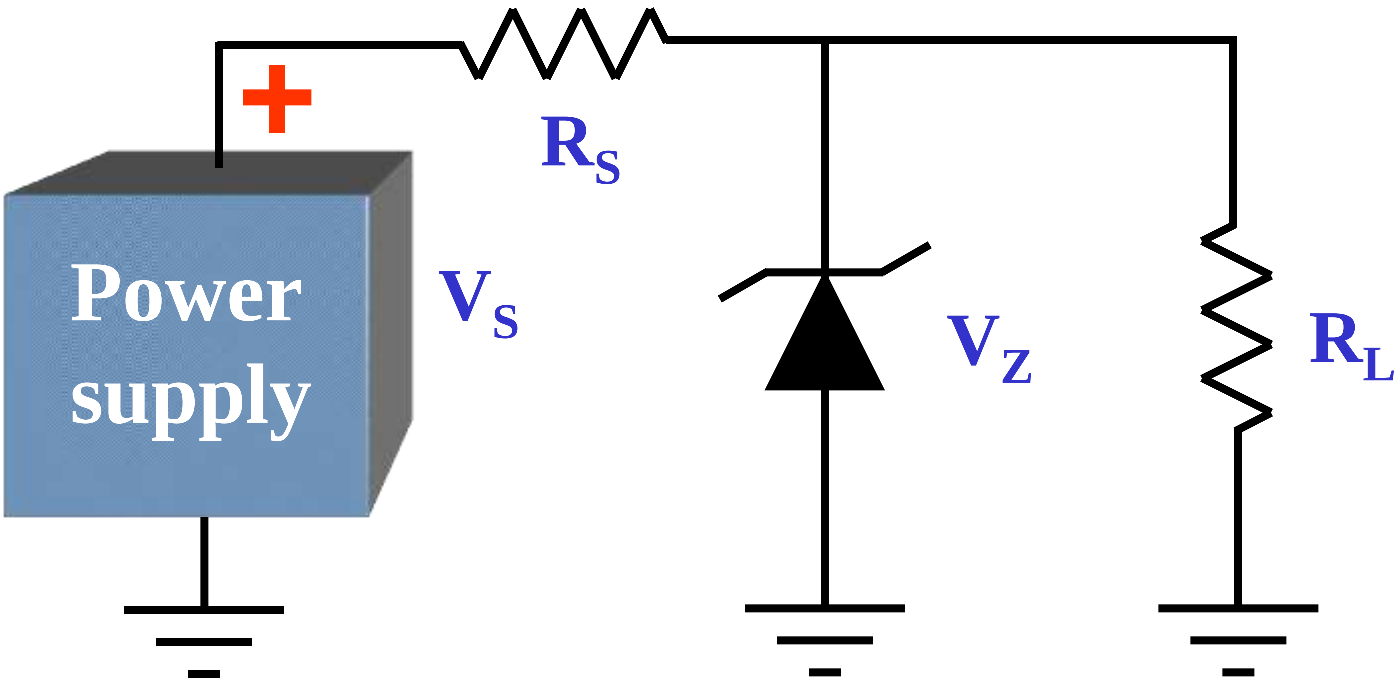
Graph of zener current versus voltage

A zener diode voltage regulator



This circuit will regulate when the Thevenin voltage facing the zener diode is greater than the zener voltage.

$$V_{TH} = \frac{R_L}{R_S + R_L} V_S$$



Assuming the zener is conducting:

$$I_S = \frac{V_S - V_Z}{R_S} \qquad I_L = \frac{V_Z}{R_L} \qquad I_Z = I_S - I_L$$

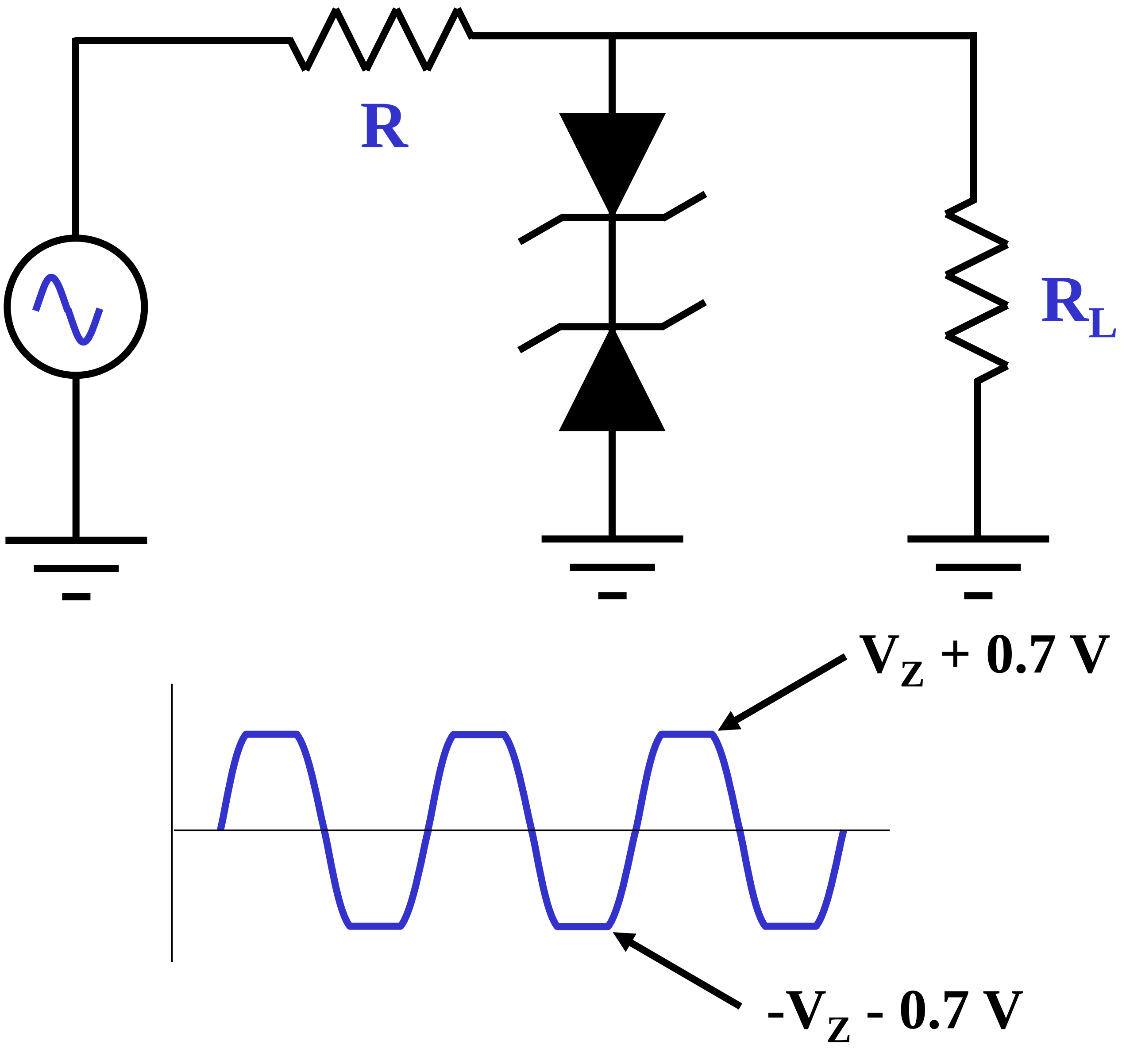
Zener waveshaping

- Back-to-back zeners:

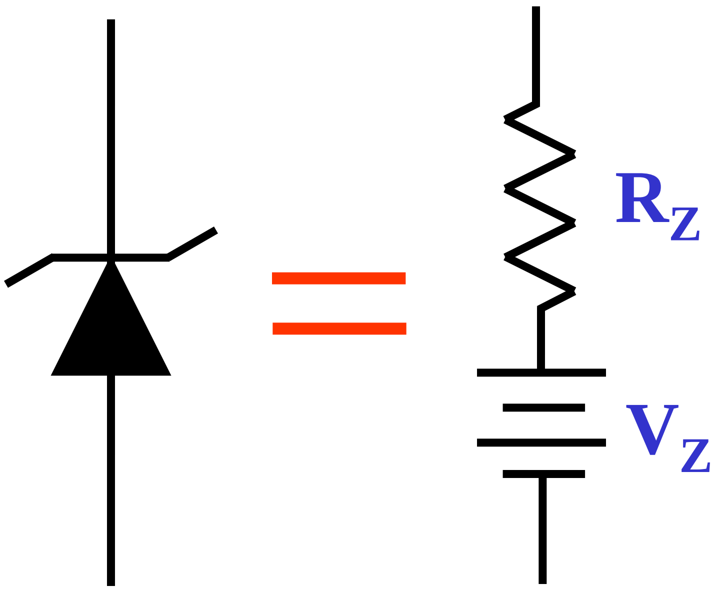
✓ One zener conducts as one breaks down

✓ Clipping results

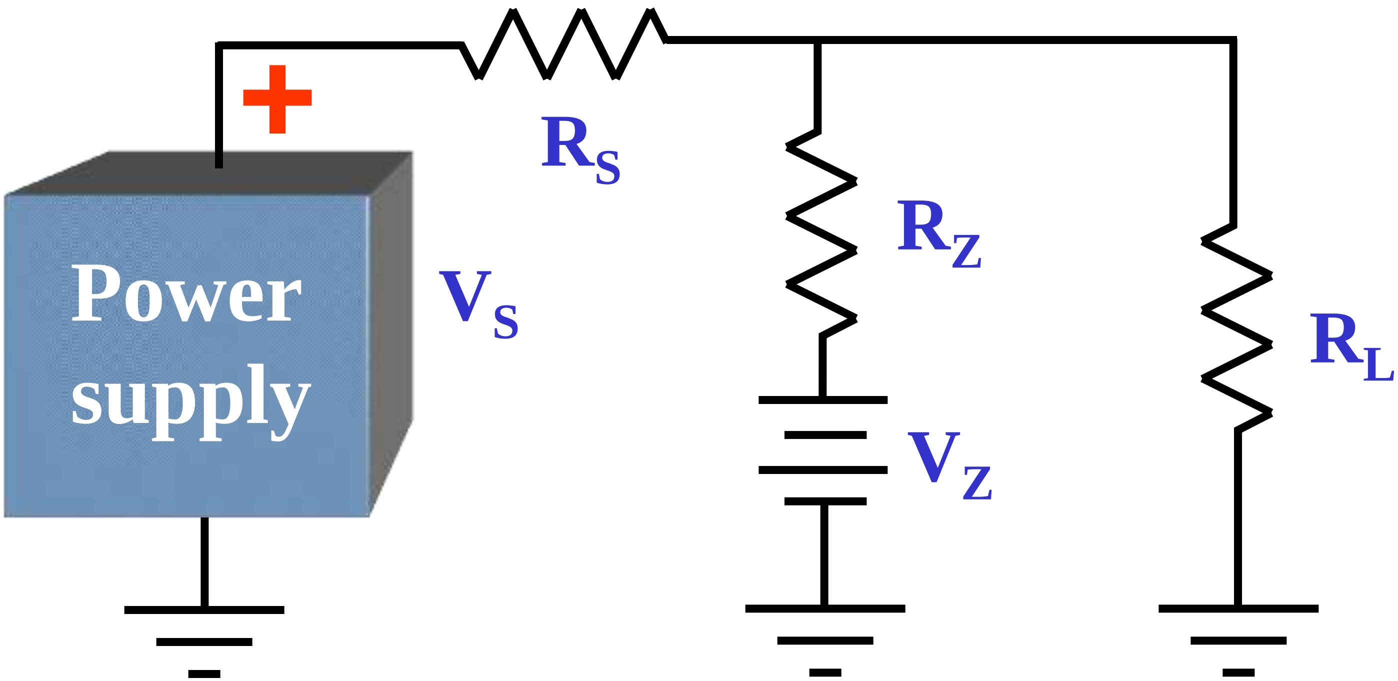
A zener waveshaping circuit



Zener diode
<u>second</u> approximation



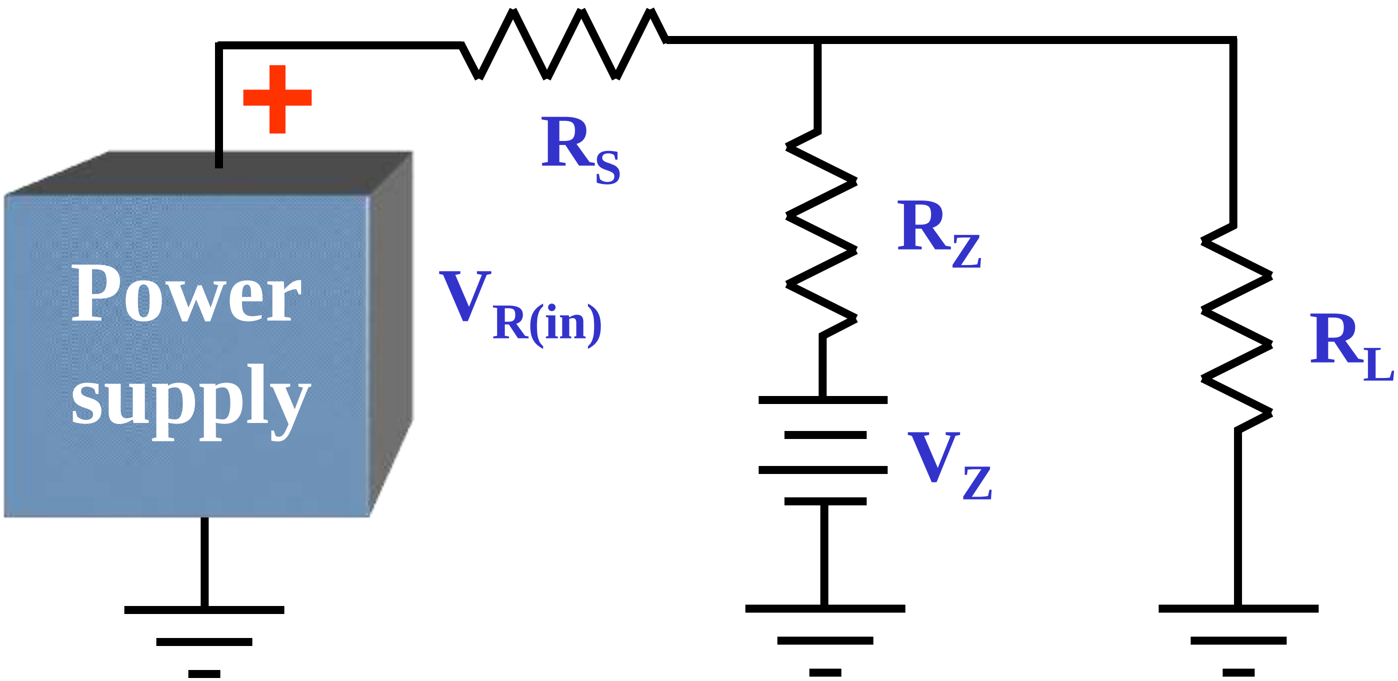
Applying the second approximation



The deviation in load voltage from the ideal case:

$$\Delta V_L = I_Z R_Z$$

The zener regulator also <u>reduces</u> ripple



Assuming that both R_L and R_S >> R_Z:

$$V_{R(out)} \cong \frac{R_Z}{R_S} V_{R(in)}$$

Zener diode ratings

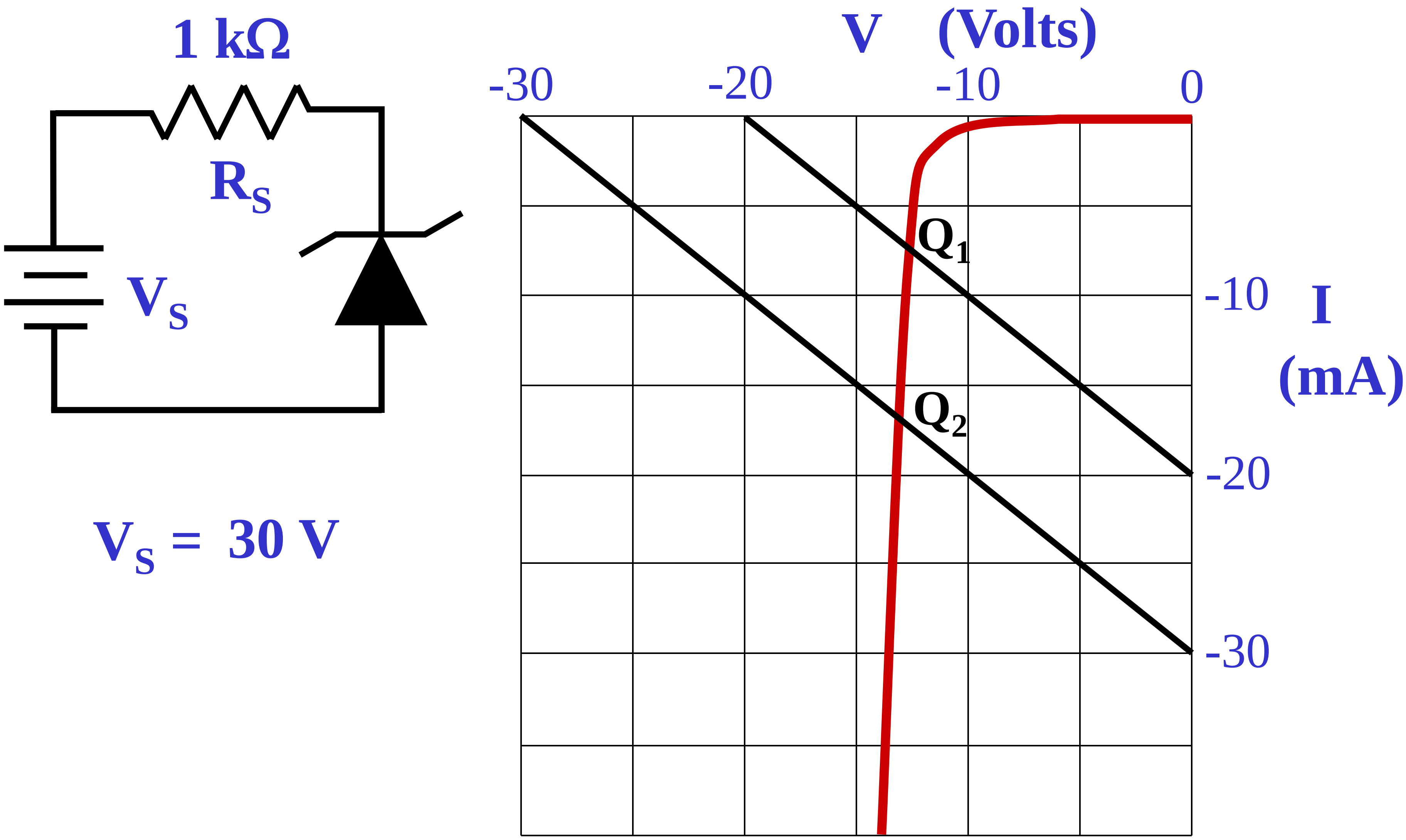
- Maximum power = $P_{Z(max)} = V_Z I_{Z(max)}$
- Available tolerances: 1, 2.5 and 20 percent
- Zener resistance, R_{ZT}, increases at the knee of the characteristic curve
- A derating factor such as 6.67 mW per degree for temperatures above 50 degrees Celsius is typical.

Troubleshooting

- Usually begin by measuring voltages
- Analyze symptoms
- Ask "what if" on the way to a solution

Load lines

- The intersection of the load line and the zener diode is the Q (operating) point
- When the source voltage changes, a different load line appears with a different Q point

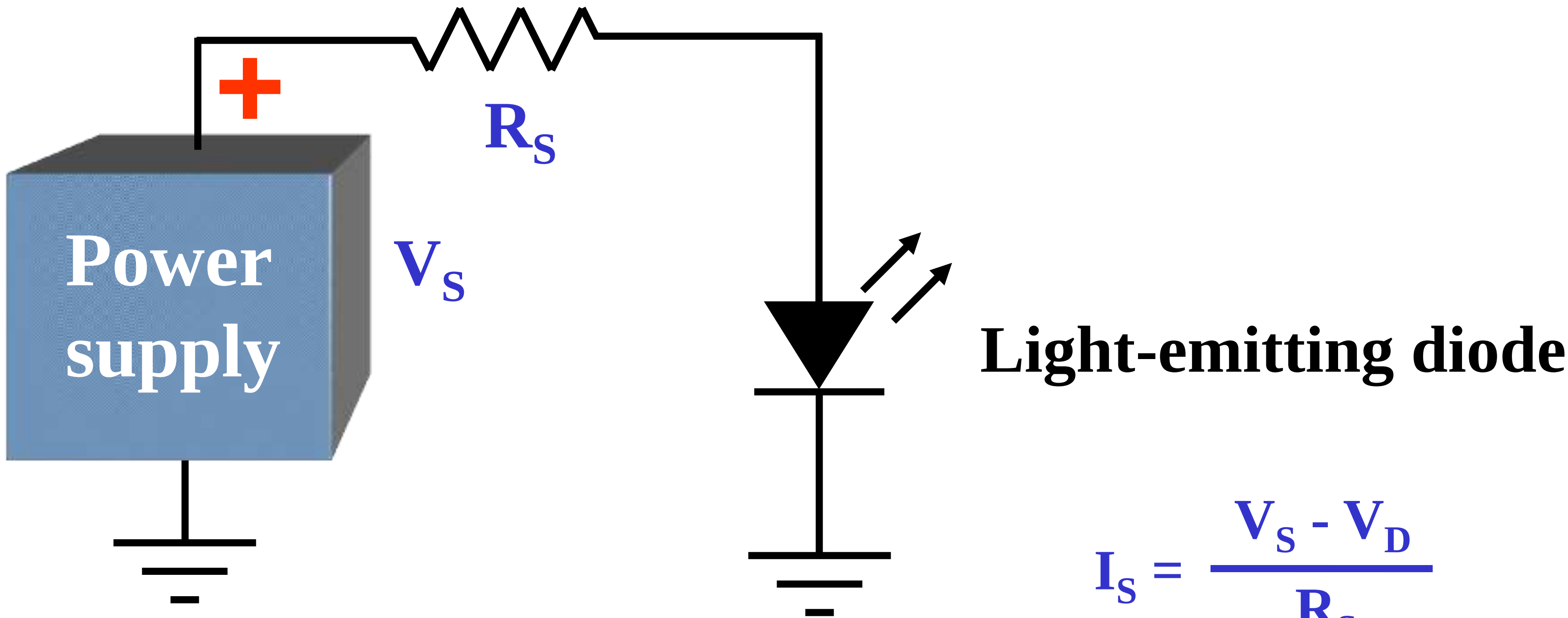


What happens to V_Z when V_S <u>varies</u> from 20 to 30 volts?

Load lines provide a <u>graphical</u> solution.

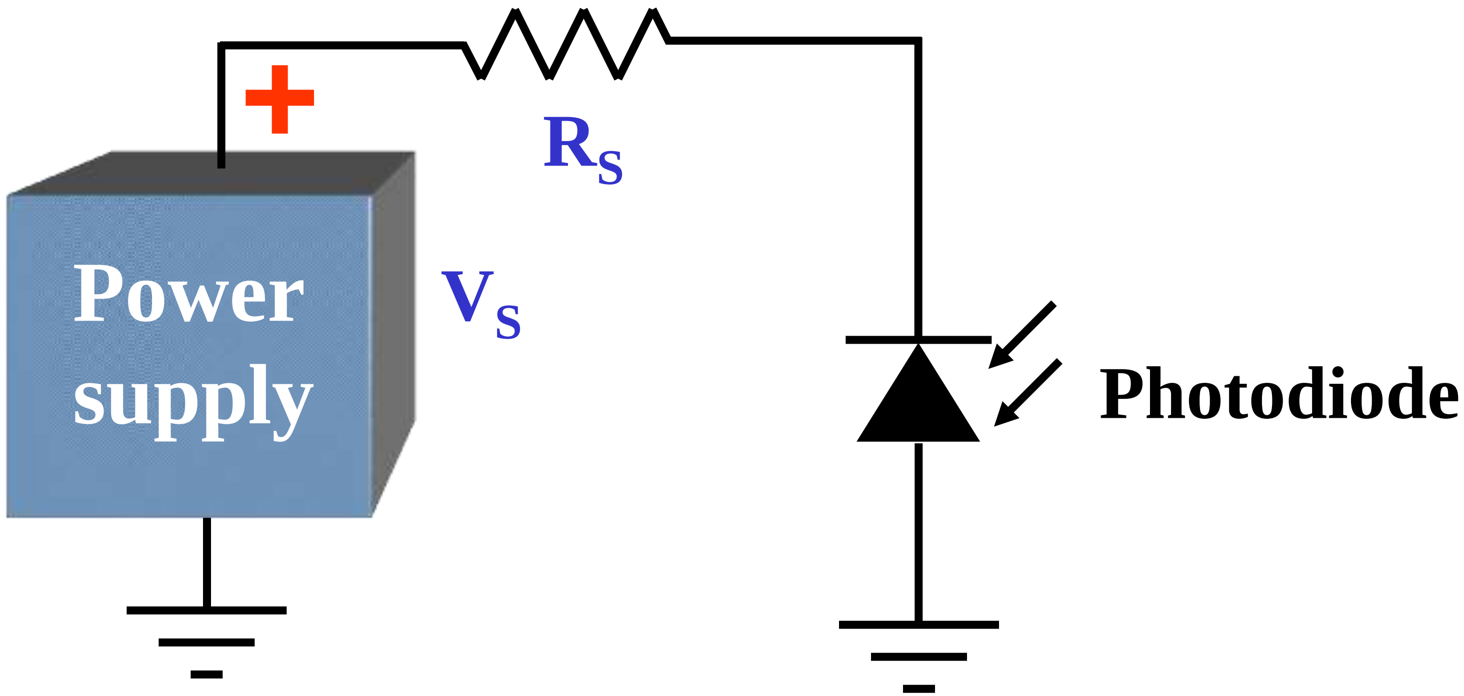
Optoelectronics

- Technology of optics and electronics
- LEDs
- Photodiodes
- Optocouplers
- Laser diodes

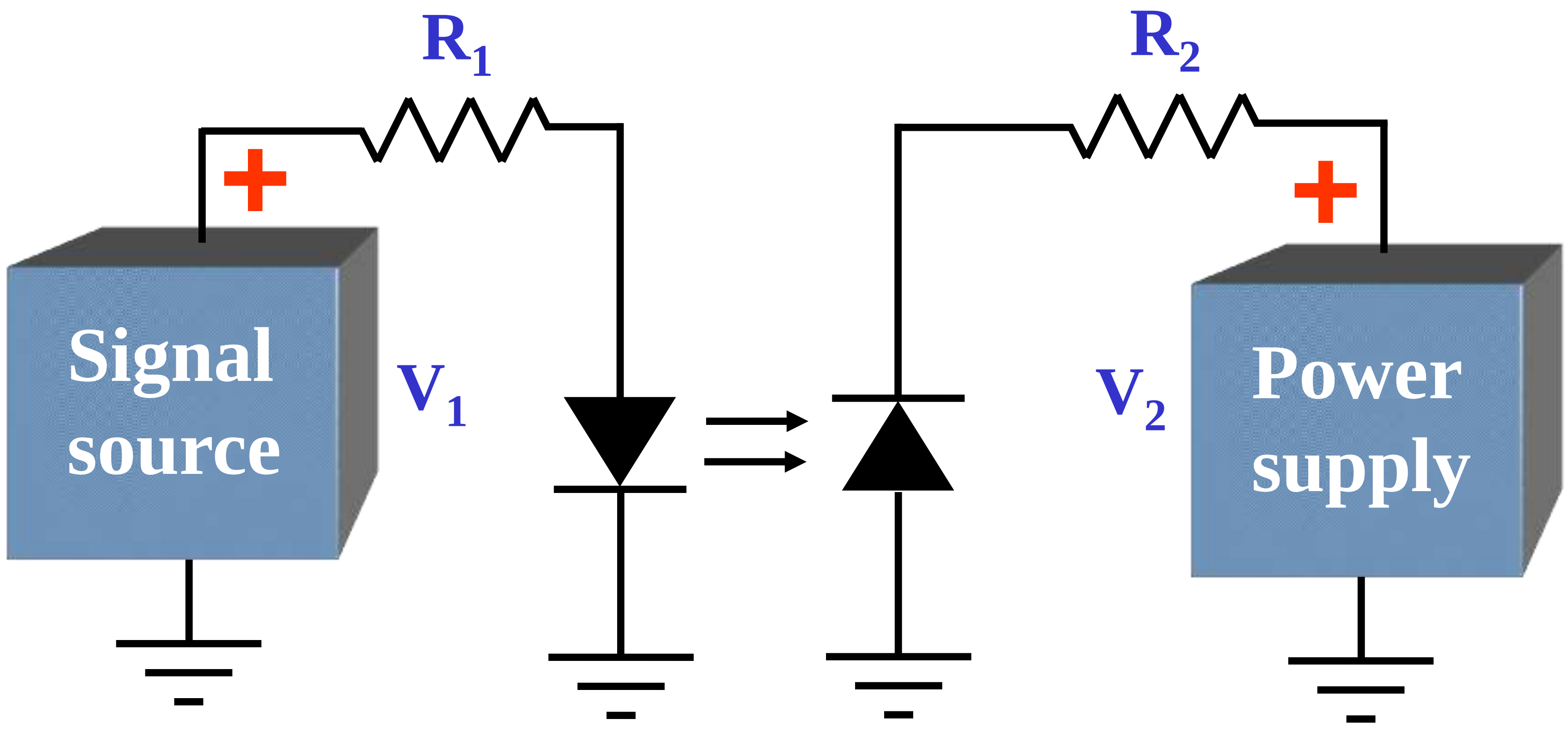


$$I_S = \frac{V_S - V_D}{R_S}$$

The typical voltage drop for most LEDs is from 1.5 to 2.5 V.



Photodiodes are reverse biased and conduct when struck by light

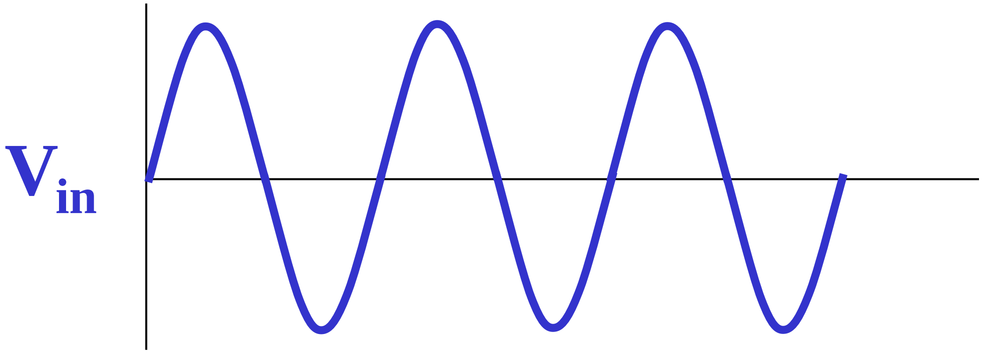


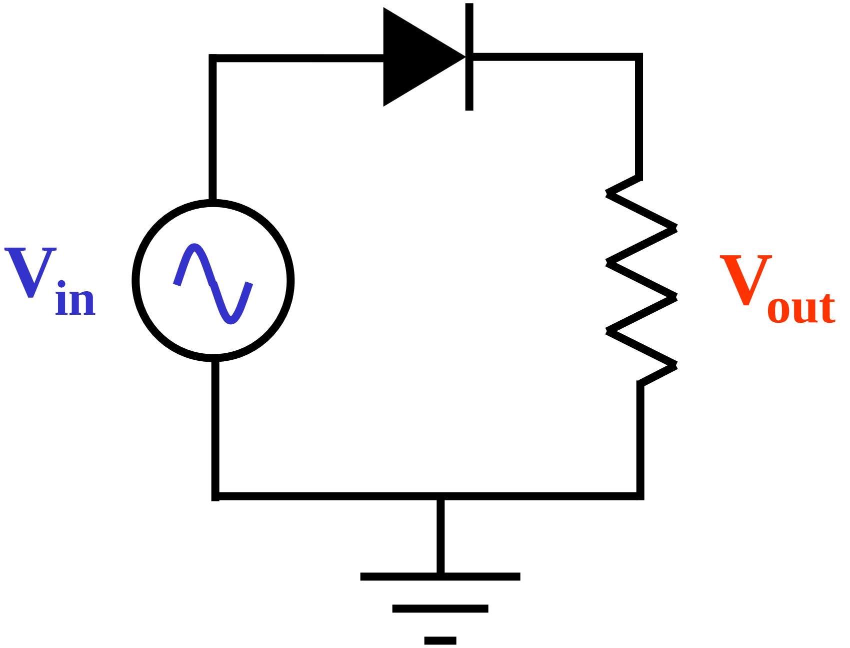
<u>Optocoupler</u> combines an LED and a photodiode

Schottky diode

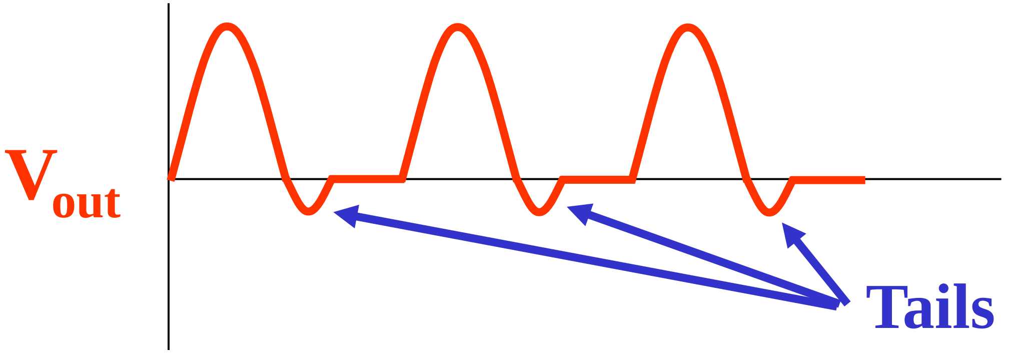
- A special diode with <u>almost zero</u> reverse recovery time
- Useful at <u>high</u> frequencies where short switching times are needed

High-frequency rectification

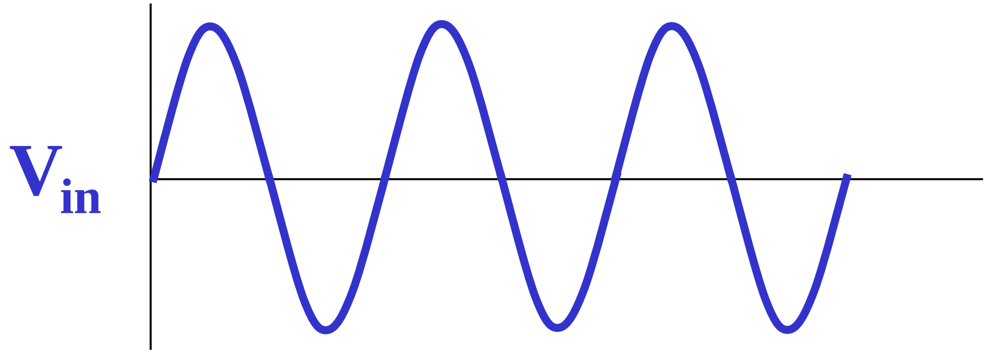


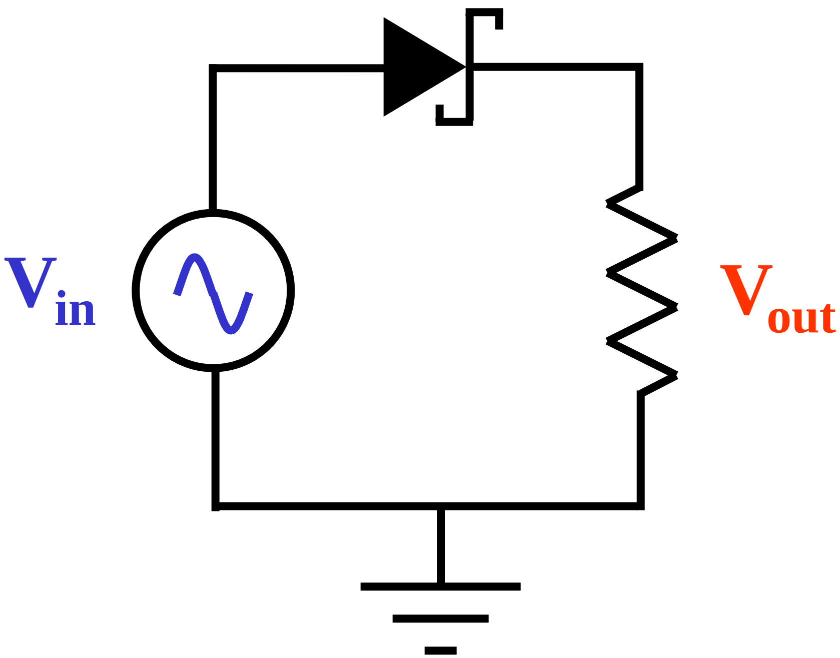


Charge storage can cause <u>poor</u> performance at <u>high</u> frequencies.

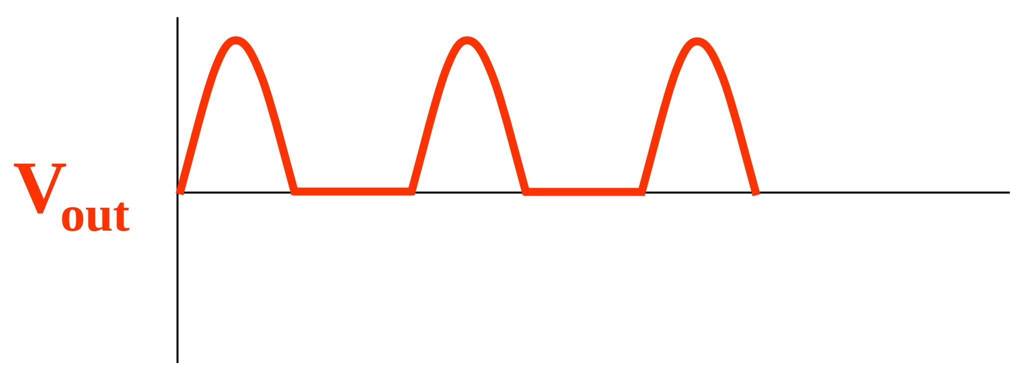


Hot-carrier rectifier



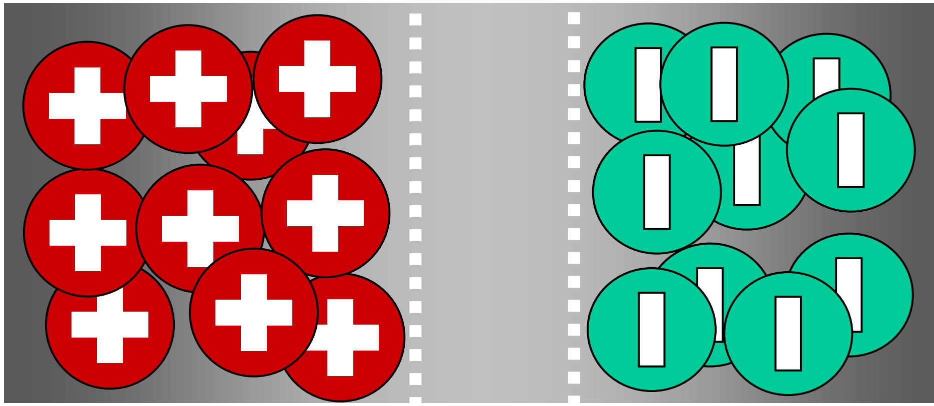


Schottky diodes eliminate tails at high frequencies.



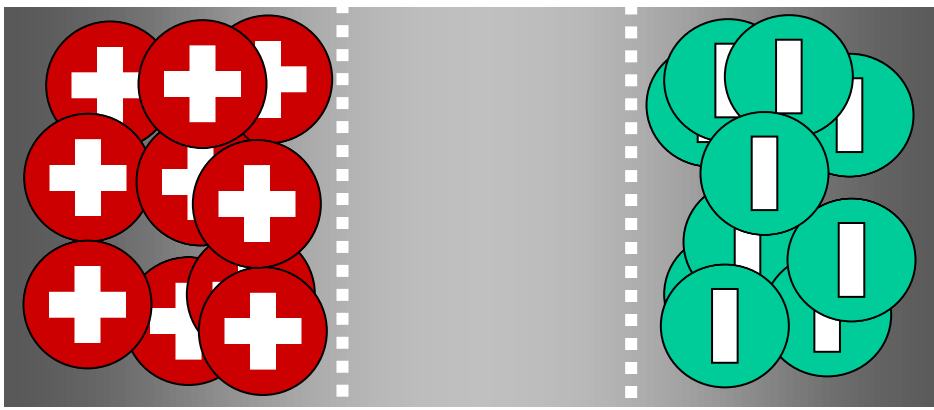
Varactor diode

- Exhibits variable capacitance
- Can tune resonant circuits
- Applications include radio and television tuning



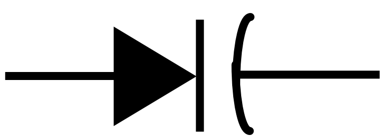
Less reverse bias

(more capacitance)



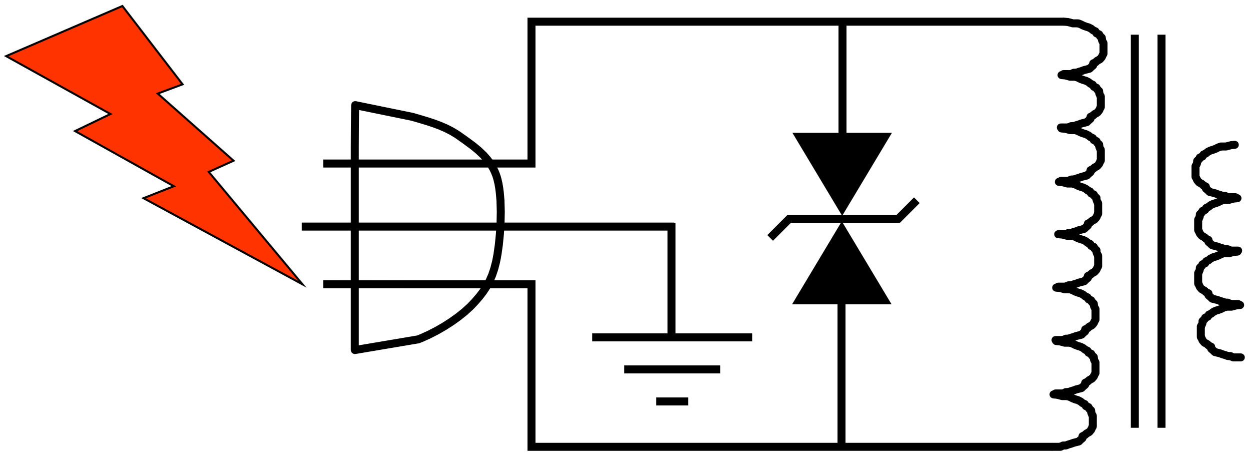
More reverse bias

(less capacitance)

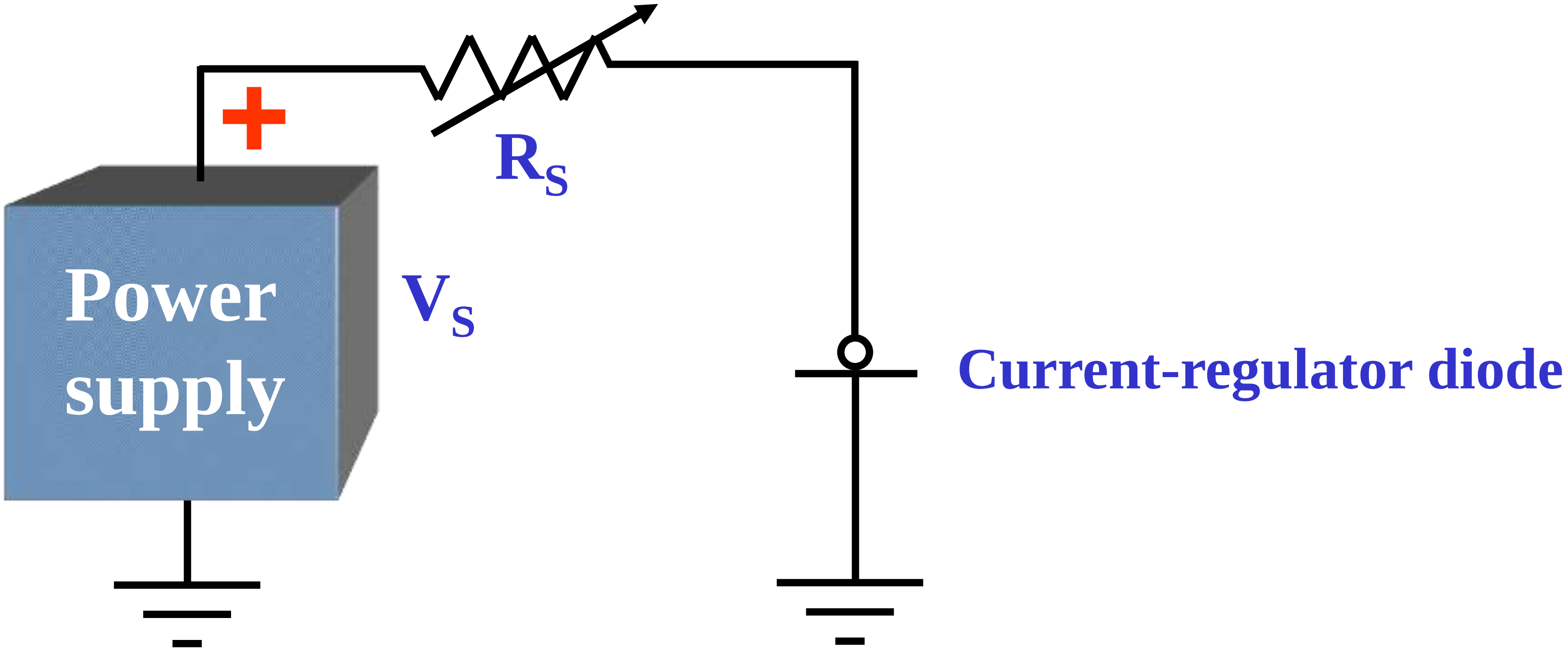


Varactor symbol

A varistor diode can be used to protect line-operated equipment from voltage surges.



A varistor diode is also called a transient suppressor



R_S can vary over a wide range and the current stays the same

Other diode types

- Laser: emits coherent light
- Step-recovery: snaps off when reverse biased
- Back: conducts better when reverse biased
- Tunnel: has a negative resistance region
- PIN: operates as a variable resistor at RF and microwave frequencies

Other diode applications

- Laser: CD players, communications
- Step-recovery: Frequency multipliers
- Back: Small-signal rectifiers
- Tunnel: High-frequency oscillators
- PIN: RF and microwave modulator circuits