MALVINO & BATES

Electronic PRINCIPLES

SEVENTH EDITION

Chapter 3

Diode Theory

Topics Covered in Chapter 3

- Basic ideas
- The ideal diode
- The second approximation
- The third approximation
- Troubleshooting
- Up-down circuit analysis

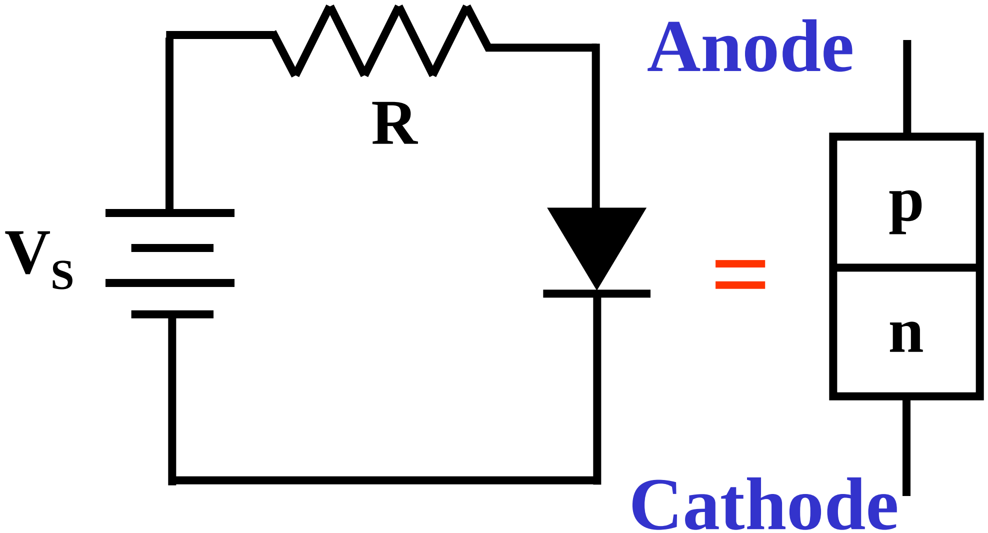
Topics Covered in Chapter 3 (Continued)

- Reading a data sheet
- How to calculate bulk resistance
- DC Resistance of a diode
- Load lines
- Surface-mount diodes

Diode

- A nonlinear device
- The graph of current vs. voltage is <u>not</u> a straight line
- The diode voltage must exceed the barrier voltage to conduct

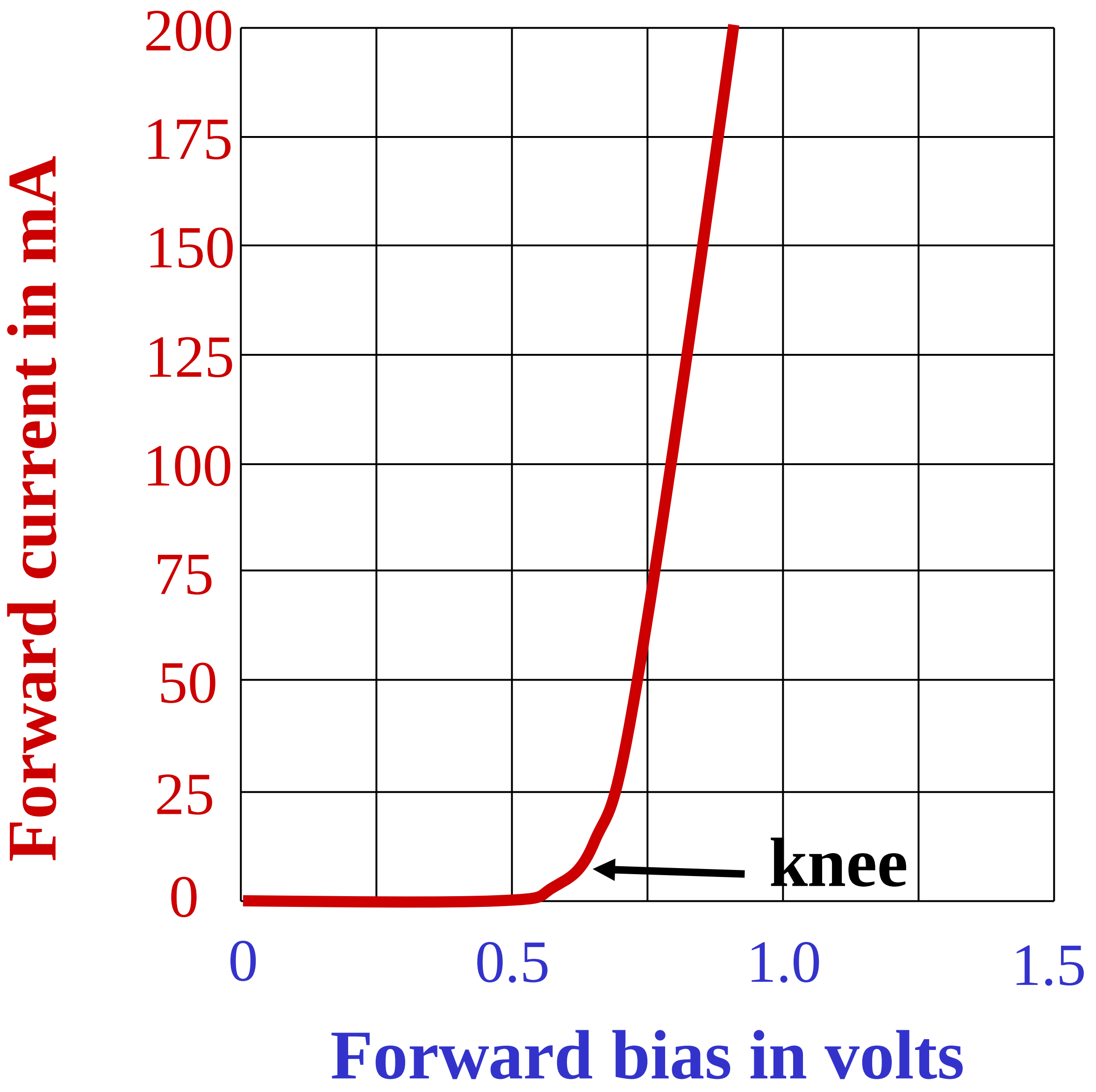
The diode symbol looks like an arrow that points from the p side to the n side.



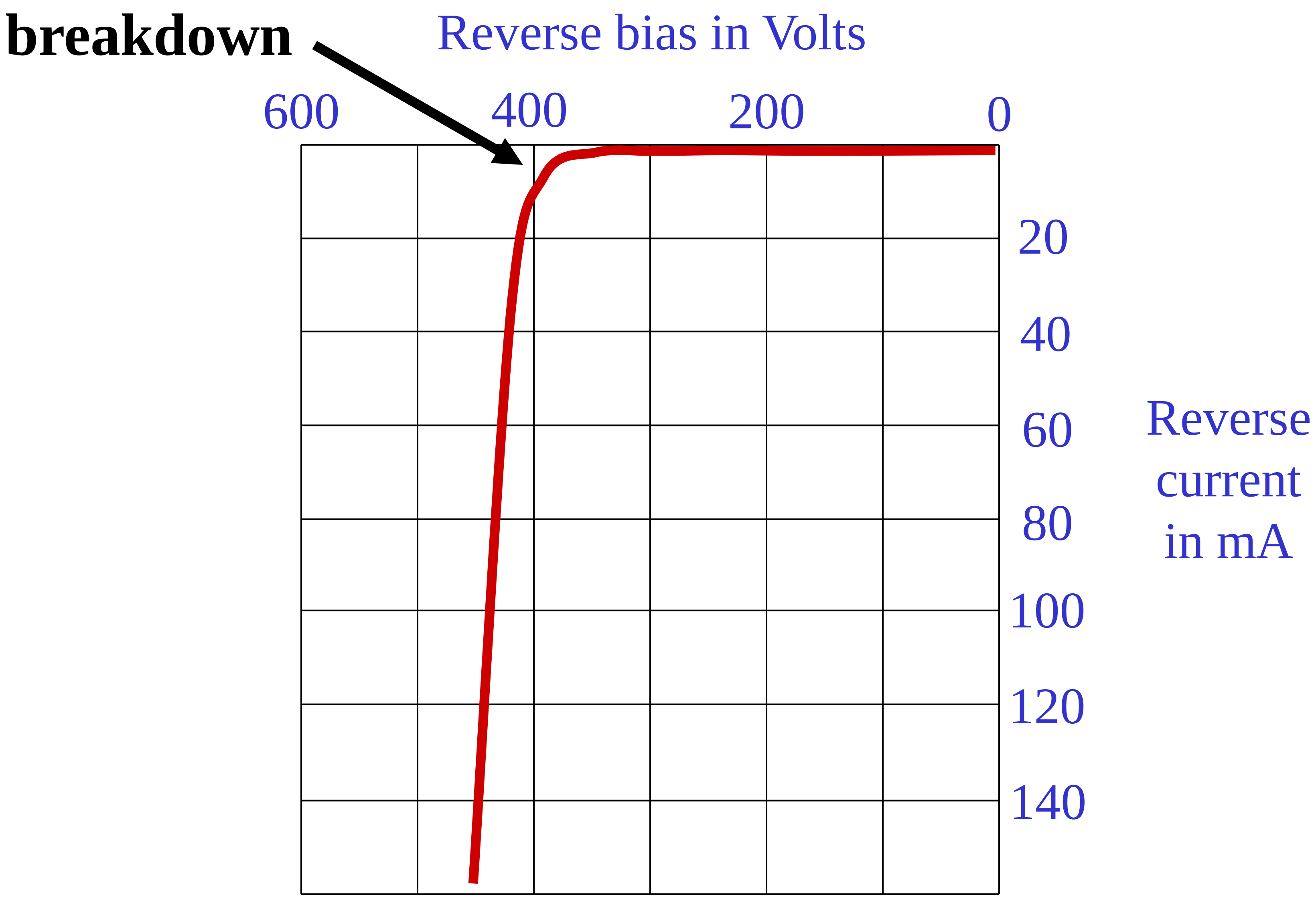
The arrow points in the direction of conventional current flow. This diode is forward biased by V_S.

Linearity

- The volt-ampere characteristic curve for a resistor is a straight line (linear).
- A diode has a non-linear characteristic curve.
- The barrier potential produces a knee in the diode curve.
- The knee voltage is about 0.7 volts for a silicon diode.



Silicon diode volt-ampere characteristic curve



Silicon diode reverse bias characteristic curve

Bulk resistance

- The ohmic resistance of the p and n material is called the bulk resistance.
- The bulk resistance is often less than 1 Ω.
- With forward bias, diode current increases rapidly beyond the knee voltage.
- Small increases in voltage cause large increases in current.

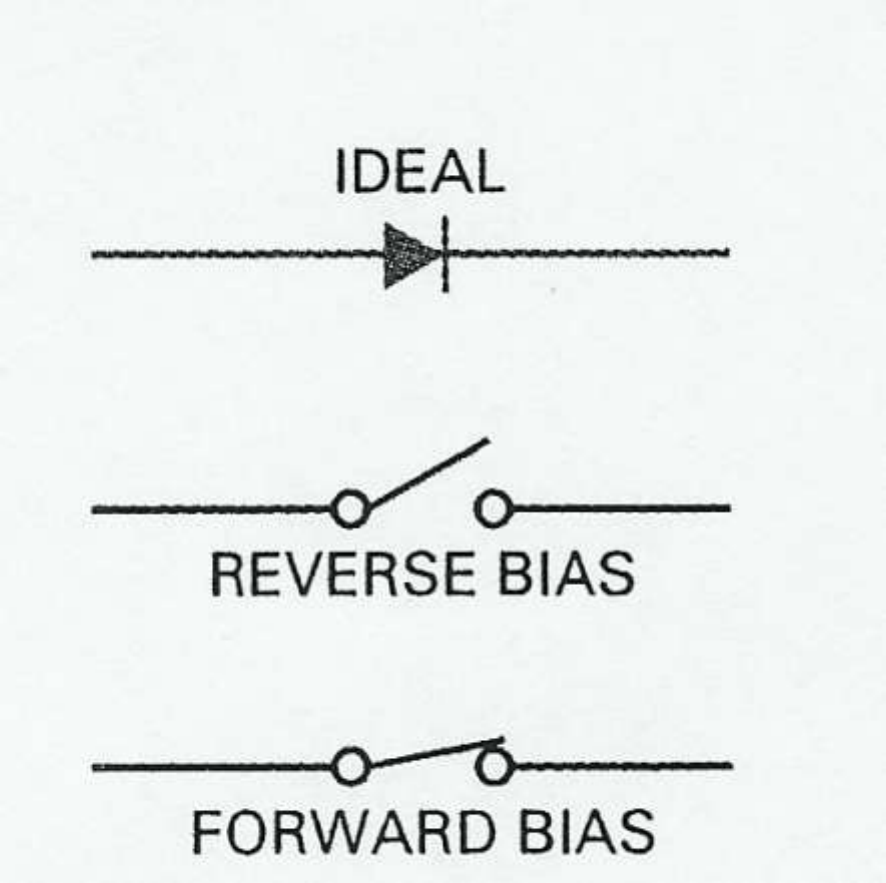
Diode ratings

- Specified on manufacturers' data sheets
- The maximum reverse bias rating must not be exceeded.
- The maximum forward current rating must not be exceeded.
- The power rating of a diode is determined by its maximum current rating and the forward voltage drop at that current flow.

Diode first approximation

- This represents the diode as being ideal.
- The first approximation ignores leakage current, barrier potential and bulk resistance.
- When an ideal diode is forward biased, the model is a closed switch.
- When an ideal diode is reverse biased, the model is an open switch.

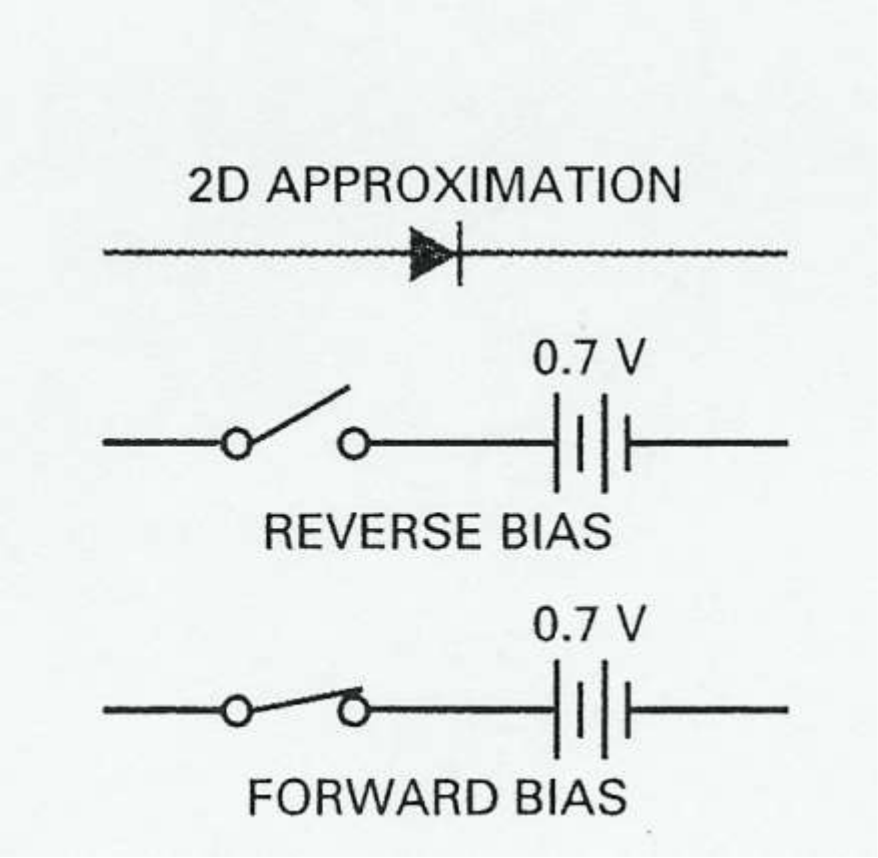
First (ideal) approximation



Diode second approximation

- This model assumes that no diode current flows until the forward bias across the diode reaches 0.7 volts.
- This model ignores the exact shape of the knee.
- This model ignores the diode's bulk resistance.

Second approximation

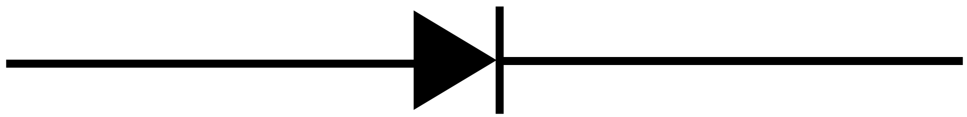


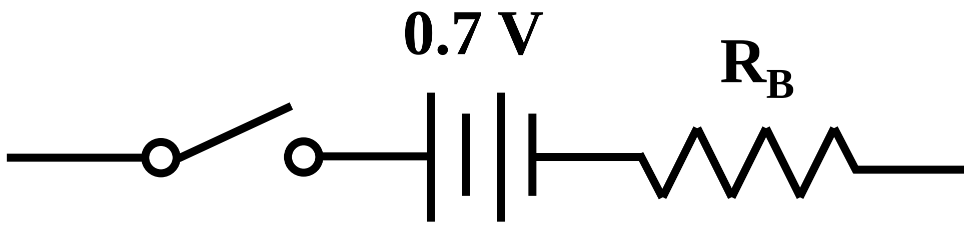
Diode third approximation

- This model assumes that no diode current flows until the forward bias across the diode reaches 0.7 volts.
- This model ignores the exact shape of the knee.
- This model does account for the diode's bulk resistance.

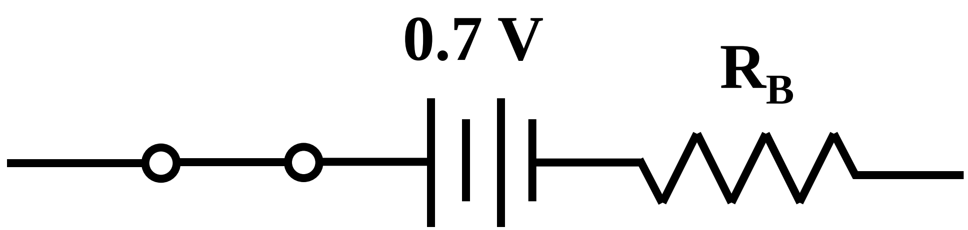
However, bulk resistance that is less than 1 Ω can be ignored.

Third approximation





Reverse bias



Forward bias

Appropriate approximation

- The first approximation is adequate for most troubleshooting situations.
- The second approximation is often used if more accurate values for load current and voltage are required.
- The third approximation improves accuracy when the diode's bulk resistance is more than 1/100 of the Thevenin resistance facing the diode.

Silicon diode testing using an ohmmeter

- **Low resistance in both directions: the diode is <u>shorted</u>.**
- **High resistance in both directions: the diode is <u>open</u>.**
- **Relatively low resistance in the reverse direction: the diode is <u>leaky</u>.**
- **If the ratio of reverse to forward resistance is > 1000: the diode is <u>good</u>.**

Silicon diode testing using a DMM

- Set DMM to diode test function
- A connected forward-biased diode will display the pn-junction's forward voltage (~0.5V to 0.7V)
- When the diode is reversed-biased by the test leads, meter displays over-range indication such as "OL" or "1"

Silicon diode testing using a DMM (continued)

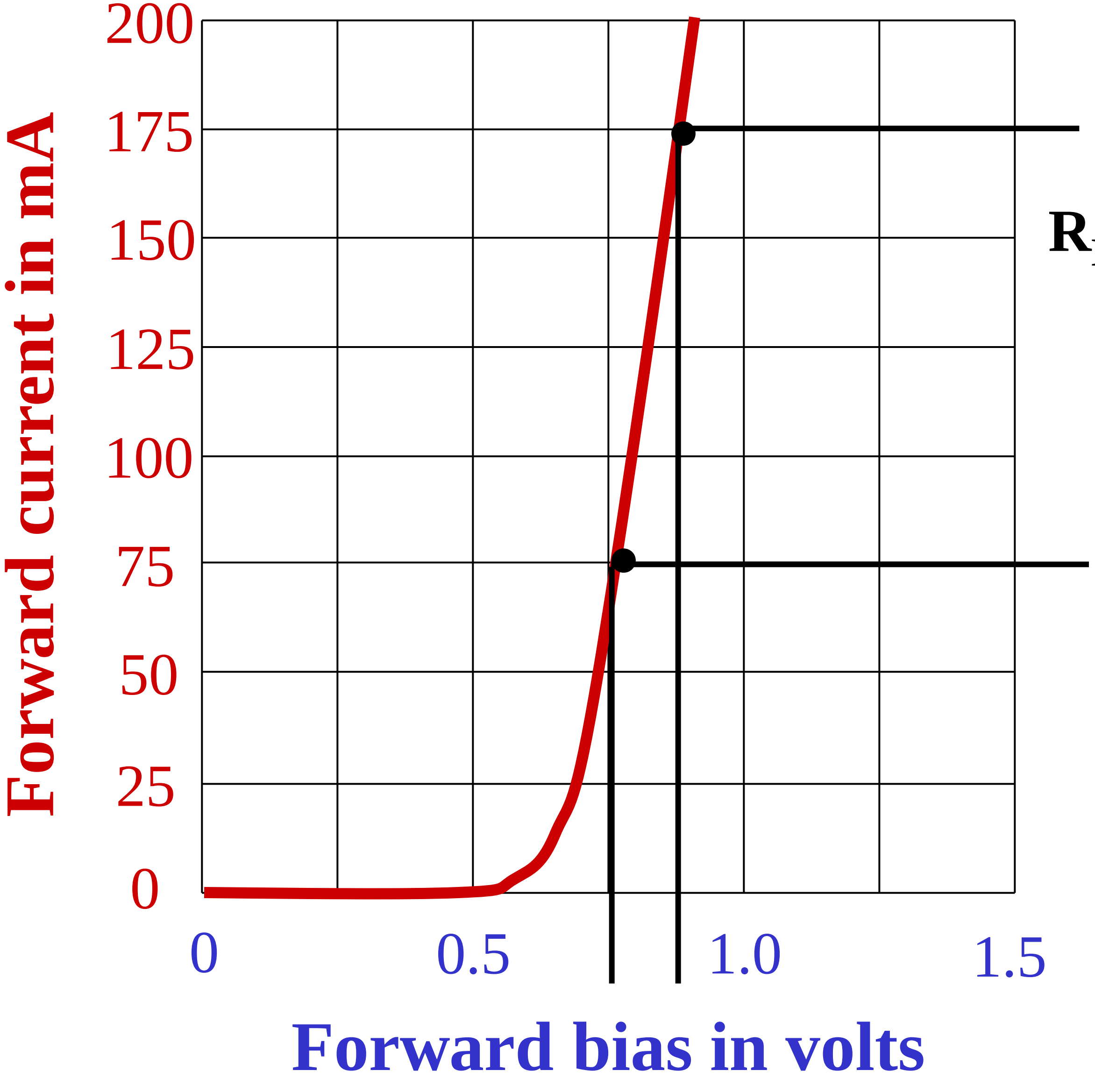
- A shorted diode displays a voltage less than 0.5V in both directions
- An open diode would be indicated by an over-range display in both directions
- A leaky diode would display a voltage less than 2.0V in both directions

Data sheets

- Useful to circuit designers
- Useful to repair technicians
- Typical entries include:

✓ Breakdown voltage
✓ Maximum forward current
✓ Forward voltage drop

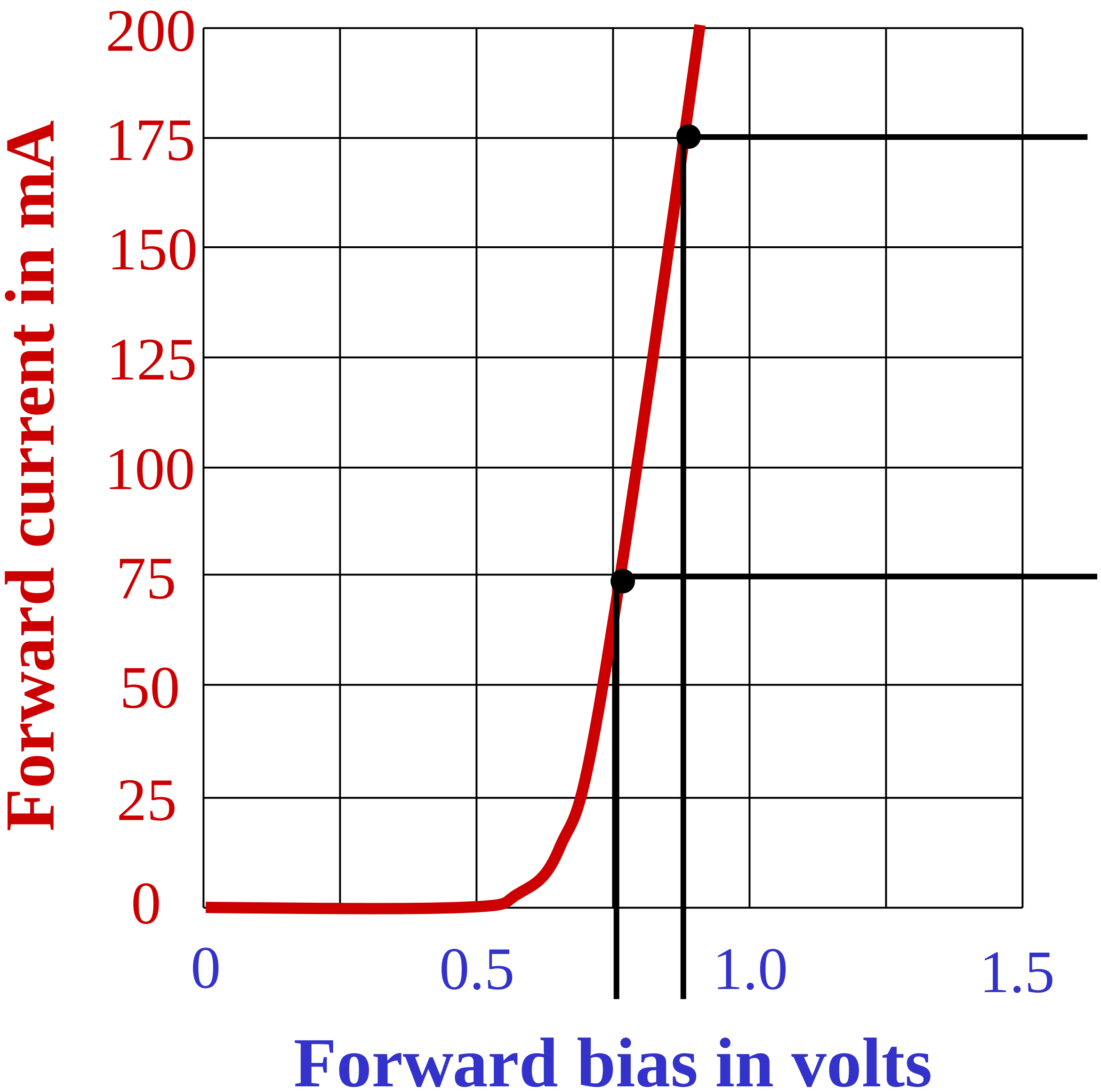
Bulk resistance calculation



$$R_B = \frac{0.875\text{ V} - 0.75\text{ V}}{175\text{ mA} - 75\text{ mA}}$$

$$= 1.25\ \Omega$$

DC resistance



$$R_F = \frac{0.875\ V}{175\ mA}$$

$$= 5\ \Omega$$

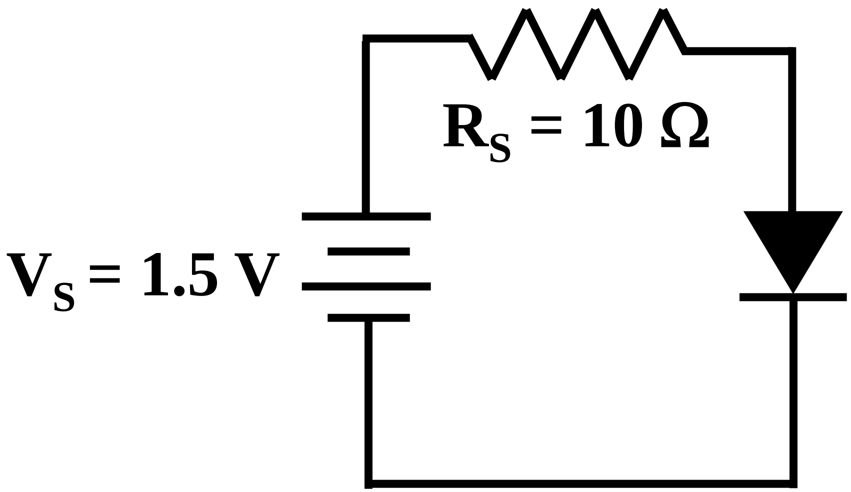
$$R_F = \frac{0.75\ V}{75\ mA}$$

$$= 10\ \Omega$$

The forward resistance decreases as current increases.

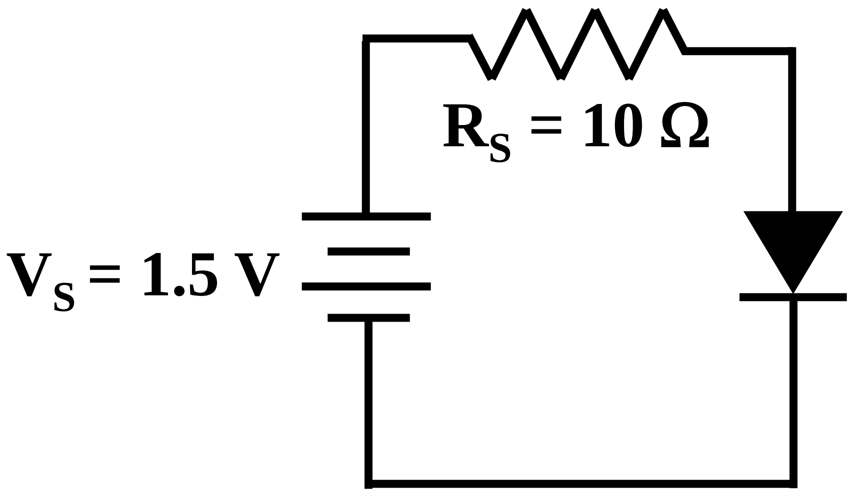
Silicon diode resistance values

- The reverse resistance is very high: typically tens or hundreds of megohms.
- The forward resistance is not the same as the bulk resistance.
- The forward resistance is always greater than the bulk resistance.
- The forward resistance is equal to the bulk resistance plus the effect of the barrier potential.



A circuit like this can be solved in several ways:

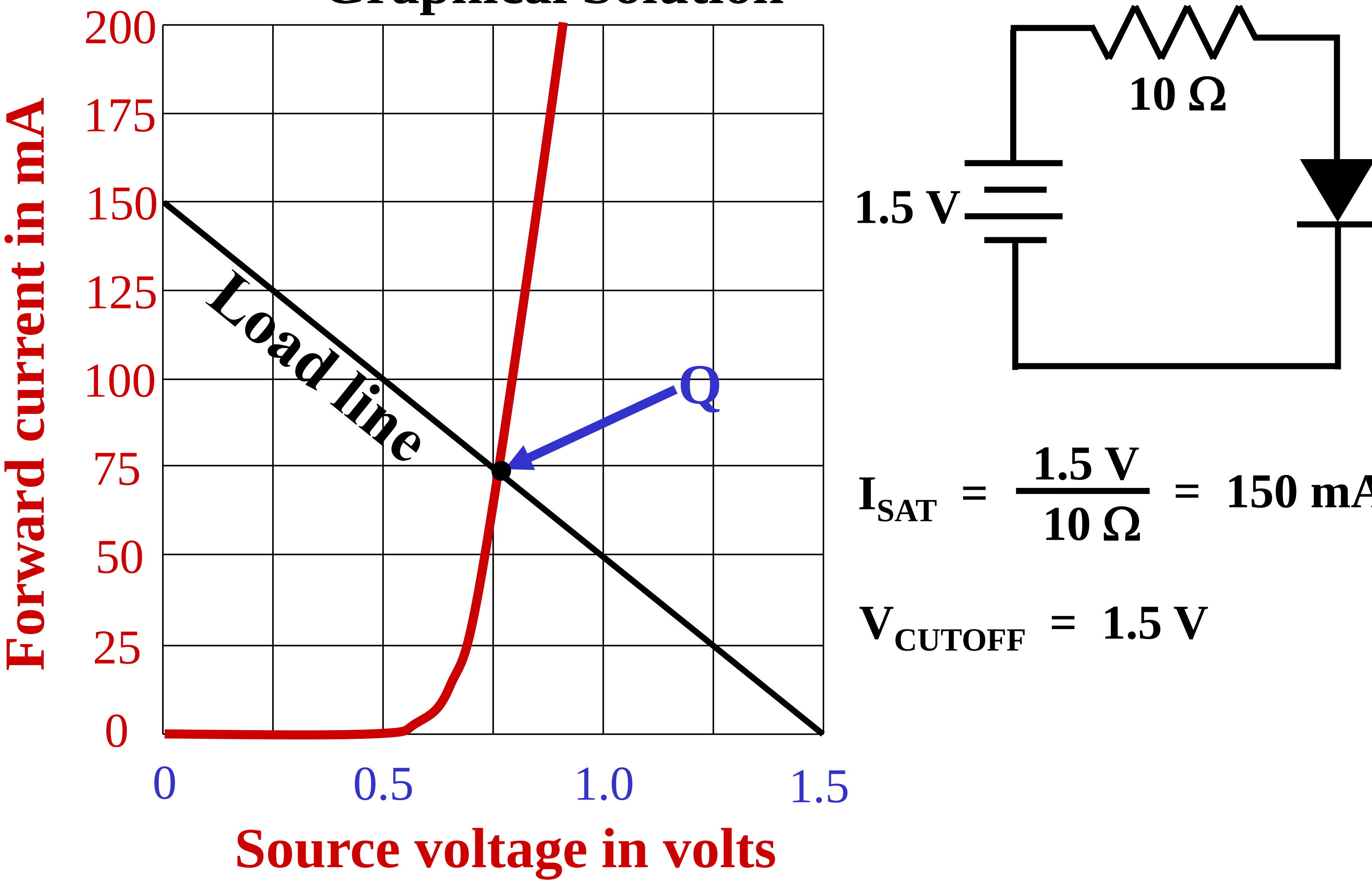
1. Use the <u>first</u> (ideal) approximation.
2. Use the <u>second</u> approximation.
3. Use the <u>third</u> approximation.
4. Use a circuit simulator.
5. Use the diode’s characteristic curve.



Using the characteristic curve is a graphical solution:

1. Find the saturation current using Ohm's law.
2. The cutoff voltage is equal to the supply voltage.
3. Locate these two points on the diode's curve.
4. Connect them with a load line.
5. The intersection is the graphical solution.

Graphical Solution



$$I_{SAT} = \frac{1.5\ V}{10\ \Omega} = 150\ mA$$

$$V_{CUTOFF} = 1.5\ V$$

Q is the operating point