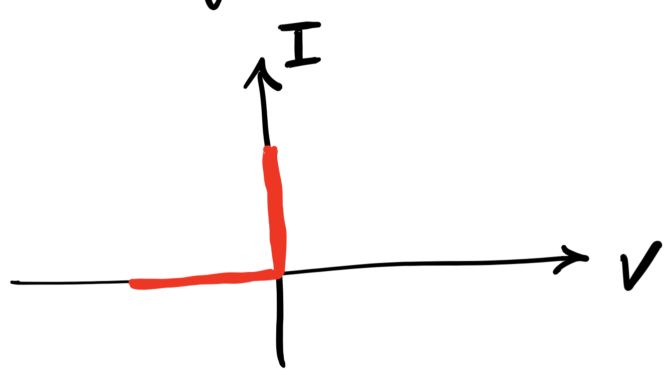
Diode behaviour

There are three approches to model a diode:

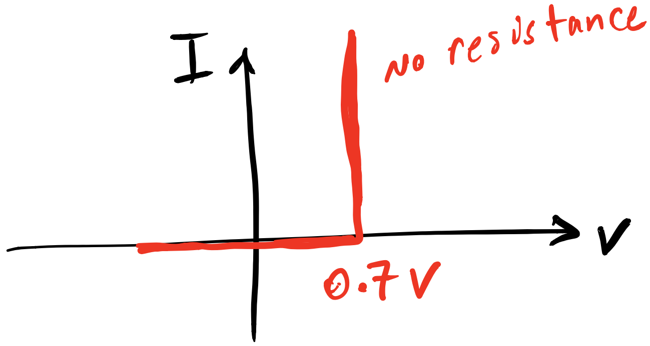
- Ideal model
- Corner model
- Real model

For the one way (ideal) model, the bulk resistance (r_B) and the threshold voltage (V_D) is negligible.



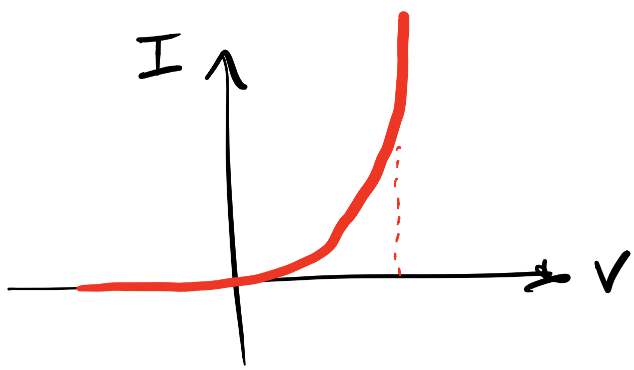
Ideal model

For the corner model V_D exists.
But there are same simplifications:



Corner model

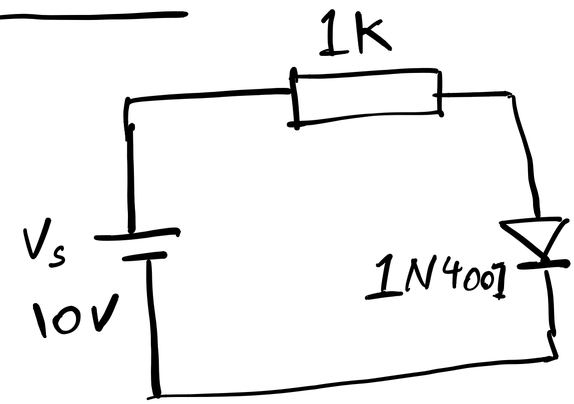
The real model includes bulk resistance and voltage V_D.



Real model

Example for ideal model:

Use an ideal model to calculate the load current, voltag, power, diode power, and total power.



$$I_L = \frac{V_s}{R_L} = \frac{10V}{1 K\Omega} = 10 \text{ mA} = \frac{10}{1000} A$$

$$V_L = 10 V$$ ← $V_L = V_R + V_D$, $V_D = 0$ in ideal model

$$P_L = V_L \times I_L = 10 \times \frac{10}{1000} A = 0.1 \text{ watt}$$

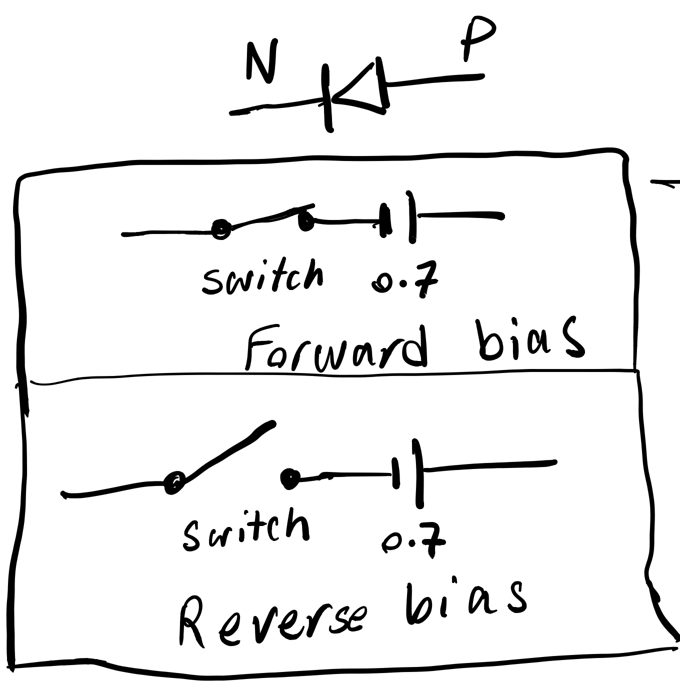
$$P_D = V_D \times I_L = 0 \times I_L = 0 \text{ watt}$$

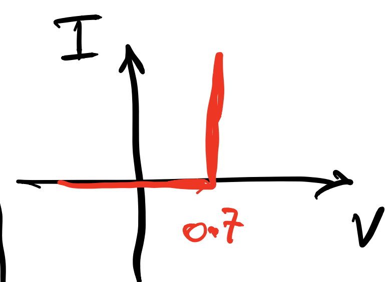
$$P_T = P_L + P_D = 0.1 + 0 = 0.1 \text{ watt}$$

Corner Model

The corner model can be simulated using a power supply (0.7V) and switch with zero resistance.

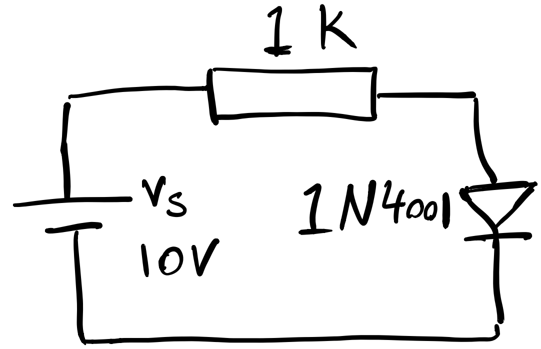
The switch is closed in the forward bias, and open in the reverse biasing:





Example

Use the corner model to calculate the load current, voltage, power, diode power and total power.



$$I_L = \frac{(V_S - V_D)}{R_L}$$

$$= \frac{(10 - 0.7)}{1\,k\Omega} = 9.3\,mA$$

$$V_L = I_L R_L = 9.3\,mA \times 1\,k\Omega = 9.3\,V$$

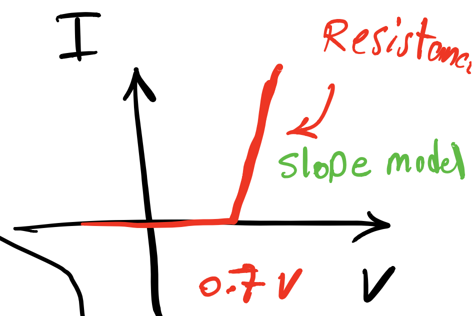
$$P_L = V_L I_L = 9.3 \times 9.3\,mA = 86.5\,mW$$

$$P_D = V_D I_L = 0.7 \times 9.3\,mA = 6.51\,mW$$

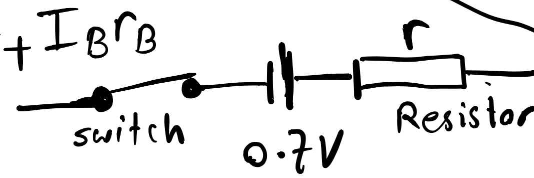
$$P_T = P_L + P_D = 6.51 + 86.5 = 93\,mW$$

Real model

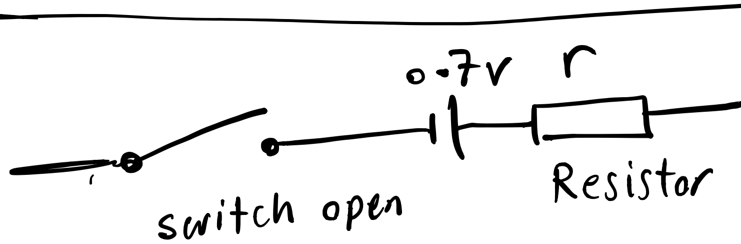
The real model can be simulated using a power supply (0.7 V), serial resistor and switch. The switch is closed in the Forward bias, and open in the reverse biasing.



$V_D = 0.7 + I_B r_B$



Forward bias



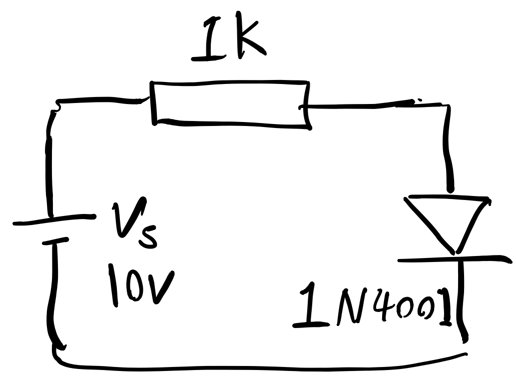
Reverse bias

Example

use the slope model to calculate the load current, voltage, power, diode power, and total power.

The 1N4001 diode has a bulk resistance of 0.23 ohm.

$$I_L = \frac{(V_S - V_D)}{(R_L + r_B)} = \frac{10 - 0.7}{1K - 0.23}$$



$$I_L = 9.3 \text{ mA}$$

$$V_L = I_L \times R_L = 9.3 \text{ mA} \times 1K = 9.3 \text{ V}$$

$$P_L = V_L \times I_L = 9.3 \times 9.3 \text{ mA} = 86.5 \text{ mW}$$

$$V_D = 0.7 + (9.3 \text{ mA} \times 0.23) = 0.702 \text{ V}$$

$$P_D = V_D \times I_L = 0.702 \times 9.3\,mA = 6.53\ mW$$

$$P_T = P_L + P_D = 6.53 + 86.5 = 93.03\ mW$$

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which model should I use?

- In troubleshooting or preliminary analysis when large error is acceptable use ideal model.

- If the circuit uses precision resistors (±1%), real model should be used (However, carner model approximation is acceptabe)

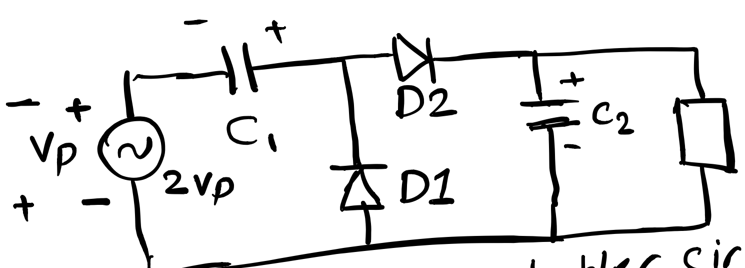
The following formula can be used for calculating the diode current.

$$I_F = \frac{(V_S - 0.7)}{r_B + R_L}$$

Applications of Diodes:

- Voltage doubler:

To undrestand the operation of the circuit, we need to look at the halfcycles of the ac input.



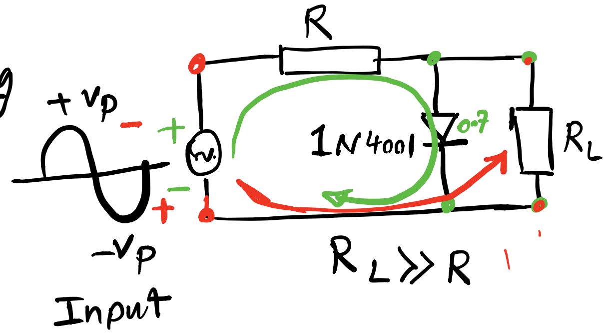
Voltage doubler circuit

During the first negative half-cycle, D1 will be forward biased and will hold the right end of C1 at ground.

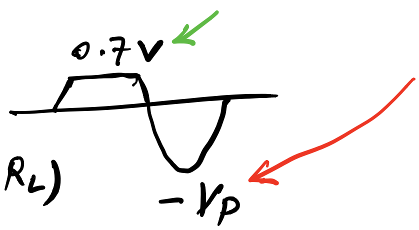
During the following positive half cycle, D1 will be reverse biased and therfore will not conduct current. The voltage on C1 will add to the output voltage, so 2Vp apear at the left end of D2. Since C2 is not yet charged, this will forward bias D2 and allow the voltage at the right end of C1 to be applied to the top of C_2. C2 will charge as C1 discharges. until the two capacitors can no longer forward-bias D2. For the first positive half-cycle, the Voltage C_2 will be equal to Vp and C1 will be completely discharged.

– Limiters

Positive voltag limiter

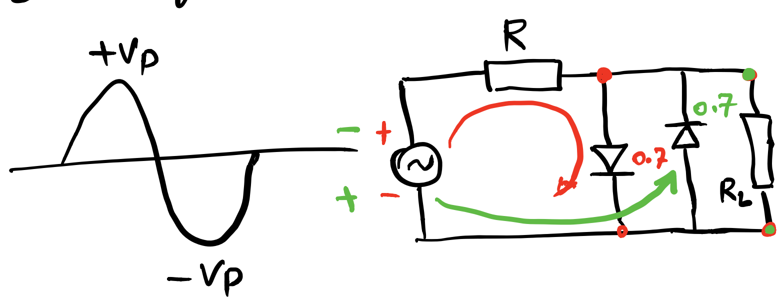


output
(voltage across R_L)

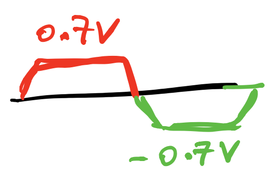


Negative voltage limiter

Input

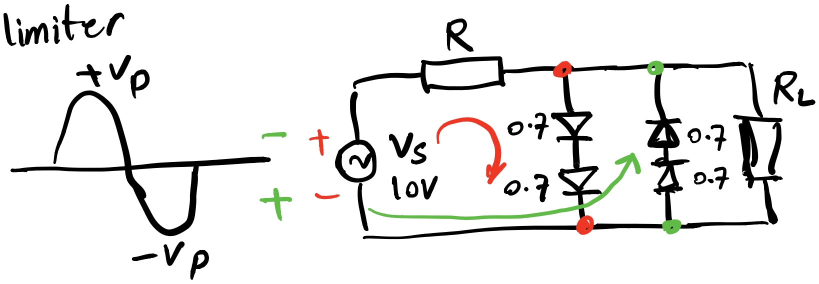


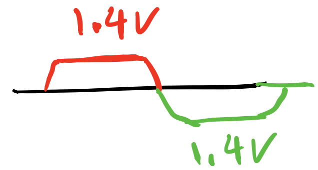
The output voltag across R_L



Muli limiter

Input

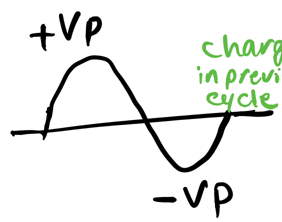


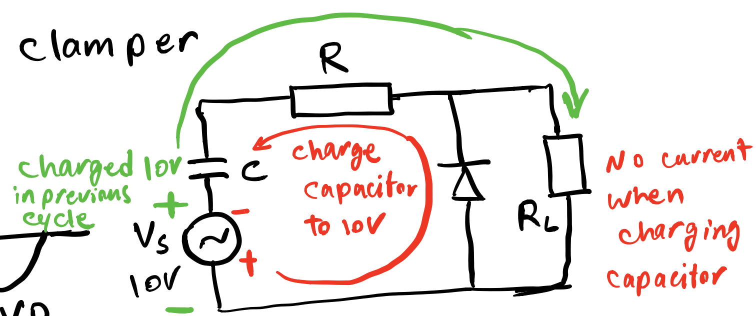
The voltag across R_L 

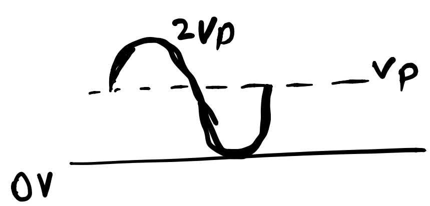
Clampers

Diode clampers add a DC level to an AC signal and are sometimes known as dc restorers.

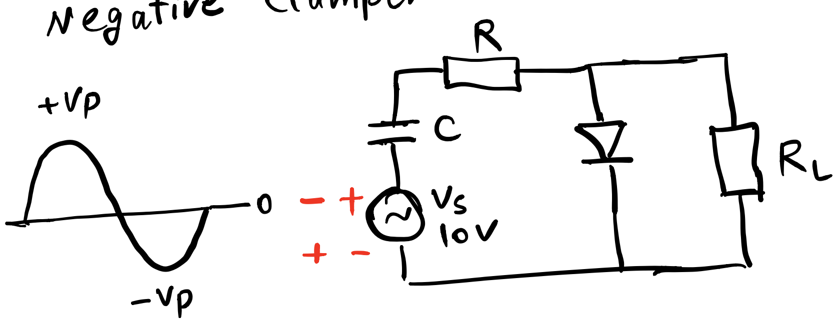
Positive clamper



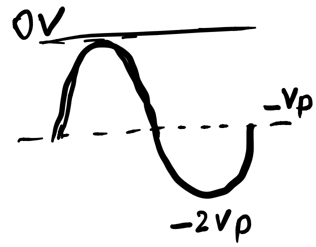


The voltage output 

Negative clamper

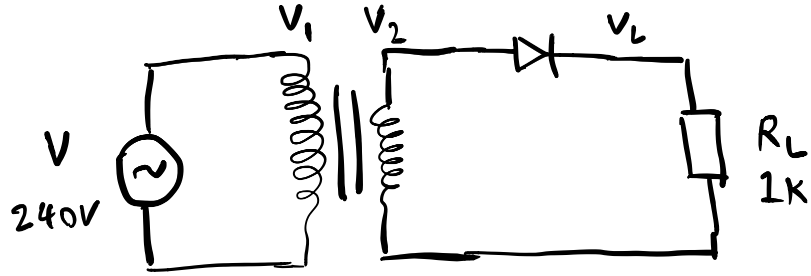


Voltage across the R_L



Rectifiers

A half wave rectifier is special case of a clipper. In half-wave rectification, either the positive or negative half of the AC wave is passed easily, while the other half is blocked, depending on the polarity of the rectifier. Because only one half of the input waveform reaches the output, it is very inefficient if used for power transfer. Half wave rectification can be achieved with a single diode in a one phase supply.

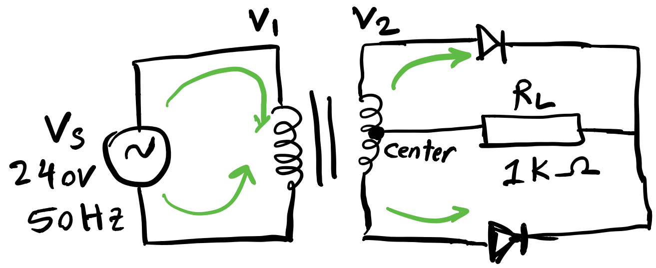


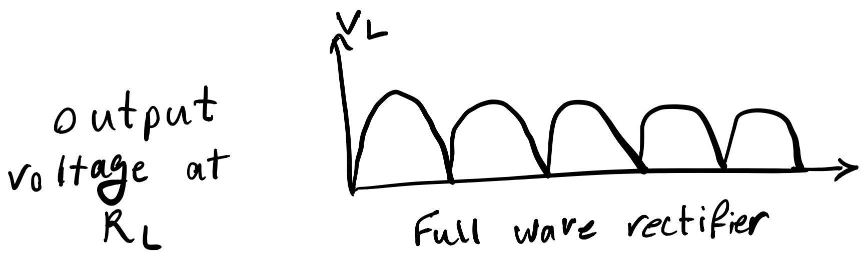
$$V_2 = V_1 (N_2/N_1) \qquad I_2 = I_1 \left(\frac{N_1}{N_2}\right)$$

Full wave rectifier

A Full wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output by reversing the negative (or positive) portions of the alternating current waveform.

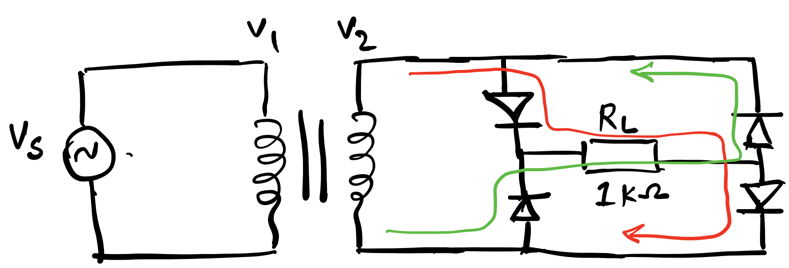
The positive (or negative) portions thus combine with the reversed negative (positive) portions to reduce an entirely positive (negative) voltage/current waveform.

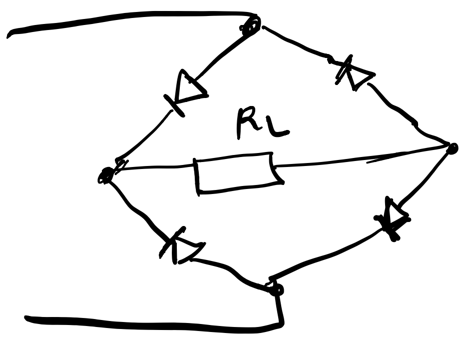


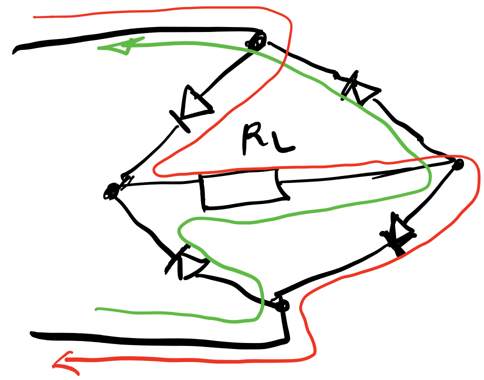


Bridge Rectifier

Full wave rectification converts both polarities of the input waveform to DC, and is more efficient. However, in a circuit with a non-center tapped transformer, four rectifiers required instead of the one needed for half-wave rectification.




RL


RL