

EE101: Diode circuits



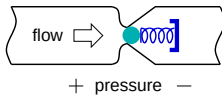
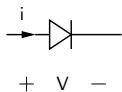
M. B. Patil

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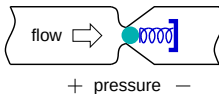
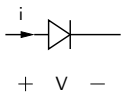
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Department of Electrical Engineering
Indian Institute of Technology Bombay

Diodes

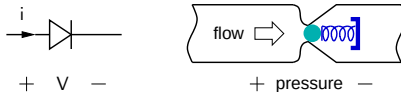


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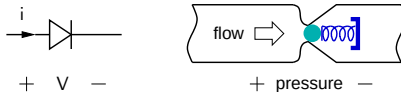
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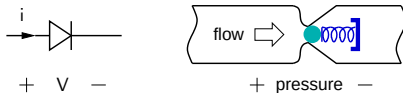
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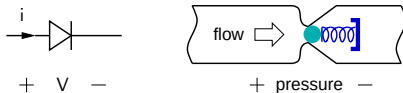


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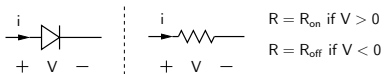


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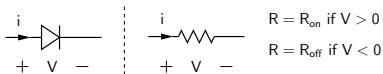


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- * In the forward direction, the diode resistance $R_D = V/i$ would be a function of V . However, it is often a good approximation to treat it as a constant (small) resistance.
- * In the reverse direction, the diode resistance is much larger and may often be treated as infinite (i.e., the diode may be replaced by an open circuit).

Simple models: $R_{\text{on}}/R_{\text{off}}$ model

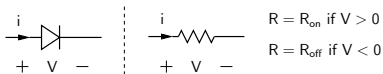


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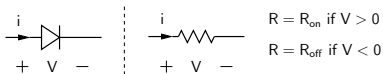
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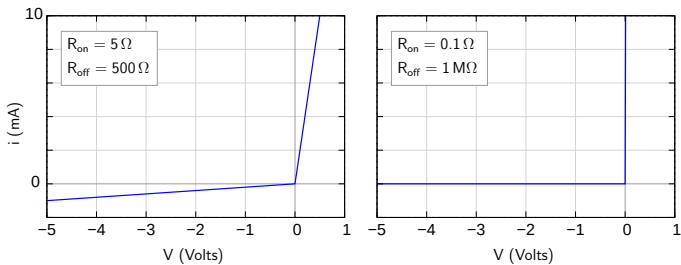


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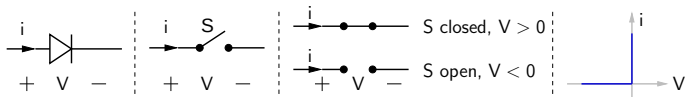
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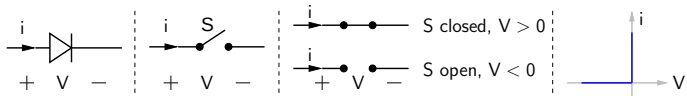
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Simple models: ideal switch

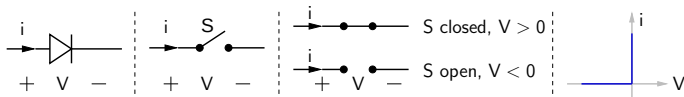


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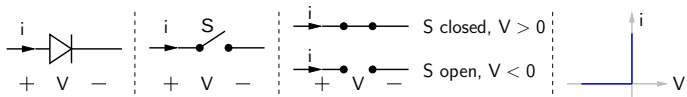
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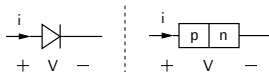
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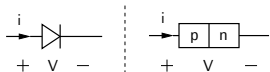


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- * The actual values of V and i for a diode in a circuit get determined by the i - V relationship of the diode *and* the constraints on V and i imposed by the circuit.

Shockley diode equation



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$$i = I_s \left[\exp \left(\frac{V}{V_T} \right) - 1 \right], \text{ where } V_T = k_B T / q.$$

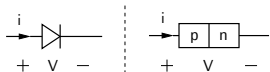
k_B = Boltzmann's constant = $1.38 \times 10^{-23} \text{ J/K}$.

q = electron charge = $1.602 \times 10^{-19} \text{ Coul}$.

T = temperature in $^{\circ}\text{K}$.

$V_T \approx 25 \text{ mV}$ at room temperature (27°C).

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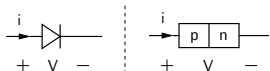
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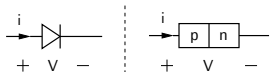
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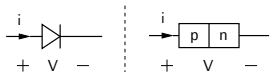
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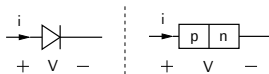
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- * The “turn-on” voltage (V_{on}) of a diode depends on the value of I_s . V_{on} may be defined as the voltage at which the diode starts carrying a substantial forward current (say, a few mA).
For a silicon diode, $V_{\text{on}} \approx 0.7 \text{ V}$.
For a GaAs diode, $V_{\text{on}} \approx 1.1 \text{ V}$.

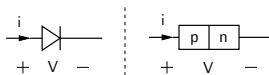
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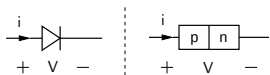


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V	$x = V/V_T$	e^x	i (Amp)
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0.2	7.74	0.229×10^4	0.229×10^{-9}
0.3	11.6	0.110×10^6	0.110×10^{-7}
0.4	15.5	0.525×10^7	0.525×10^{-6}
0.5	19.3	0.251×10^9	0.251×10^{-4}
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0.64	24.8	0.565×10^{11}	0.565×10^{-2}
0.66	25.5	0.122×10^{12}	0.122×10^{-1}
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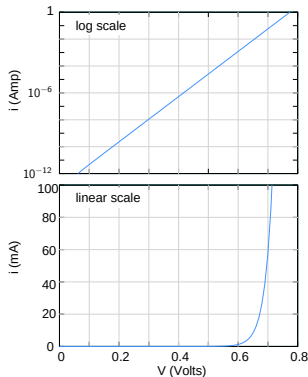
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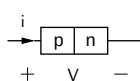
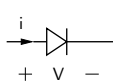
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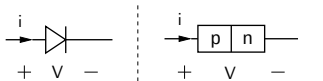


Shockley equation and simple models

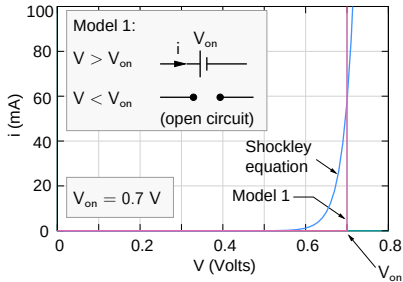


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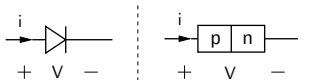
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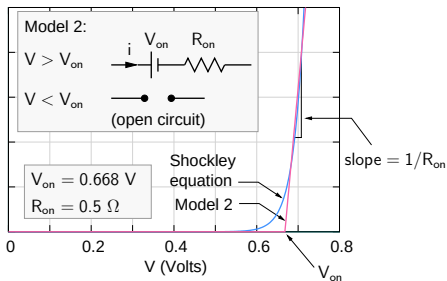
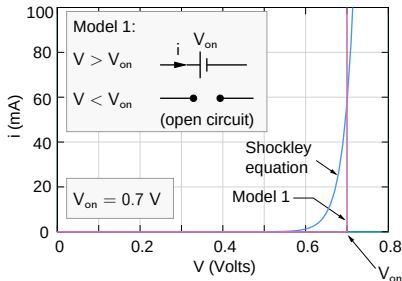
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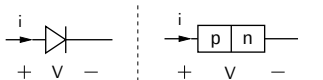
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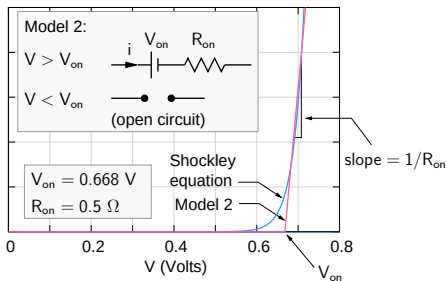
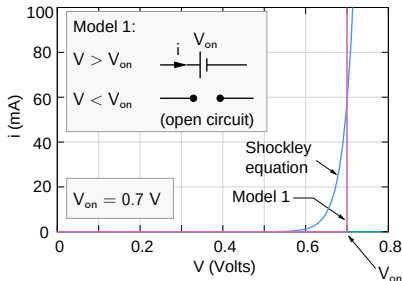
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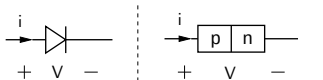


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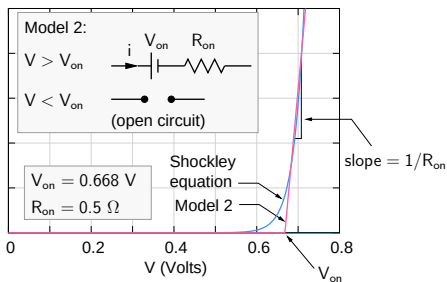
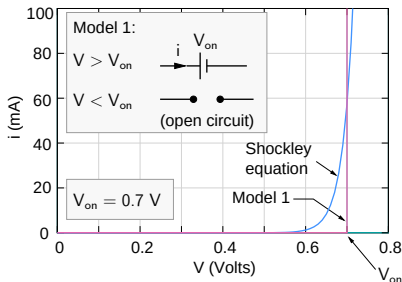


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Shockley equation and simple models

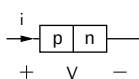
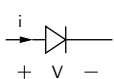


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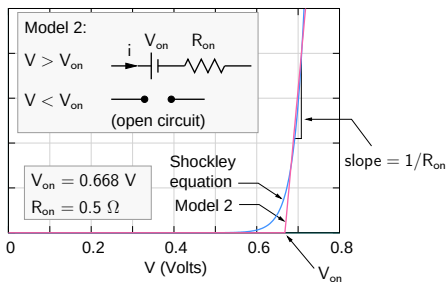
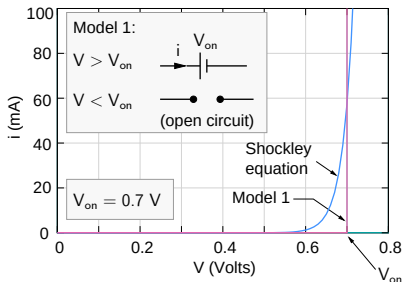


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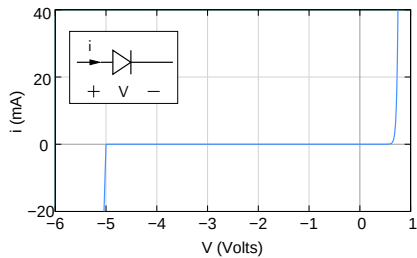


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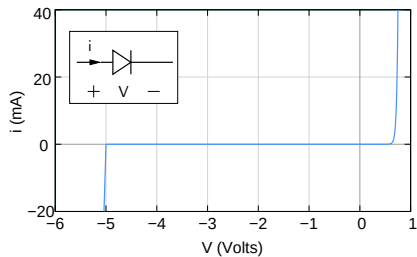


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- * Note that the “battery” shown in the above models is not a “source” of power! It can only absorb power (see the direction of the current), causing heat dissipation.

Reverse breakdown

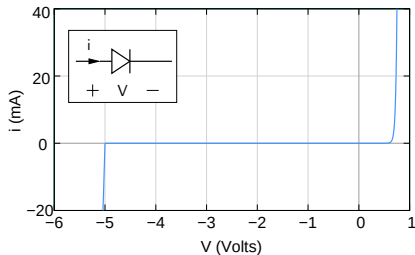


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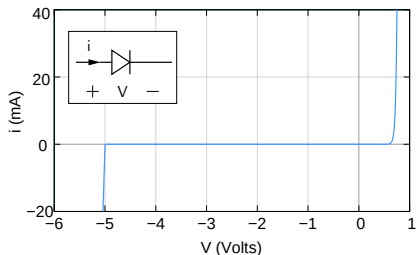
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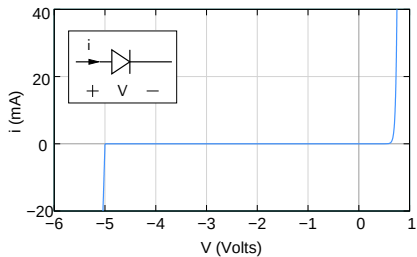
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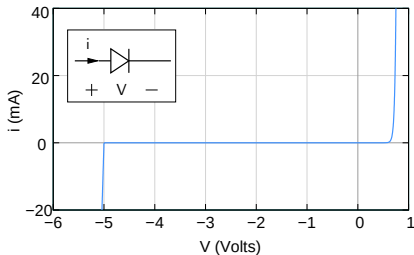
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- * When the reverse bias $V_R > V_{BR}$, the diode allows a large amount of current. If the current is not constrained by the external circuit, the diode would get damaged.

Reverse breakdown



Symbol for a Zener diode

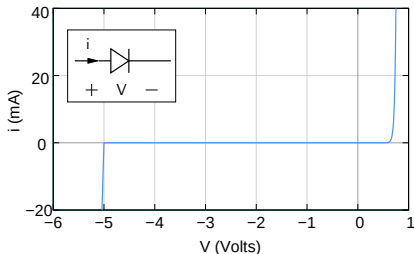
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- * A wide variety of diodes is available, with V_{BR} ranging from a few Volts to a few thousand Volts! Generally, higher the breakdown voltage, higher is the cost.

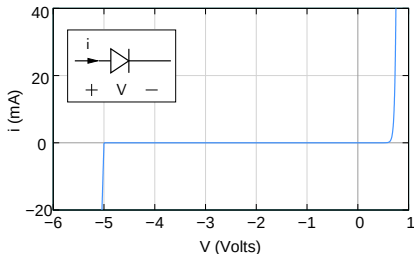
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- * Diodes with high V_{BR} are generally used in power electronics applications and are therefore also designed to carry a large forward current (tens or hundreds of Amps).

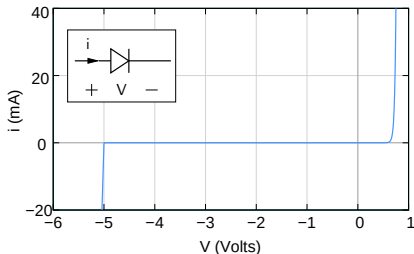
Reverse breakdown



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- * “Zener” diodes typically have V_{BR} of a few Volts, which is denoted by V_Z . They are often used to limit the voltage swing in electronic circuits.

Diode types

Apart from their use as switches, diodes are also used for several other purposes. The choice of materials used, fabrication techniques, and packaging depend on the functionality expected from the device.

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An LED emits light of a specific wavelength (e.g., red, green, yellow, blue).

White LEDs combine individual LEDs that emit the three primary colors (red, green, blue) or use a phosphor material to convert monochromatic light from a blue or UV LED to broad-spectrum white light.

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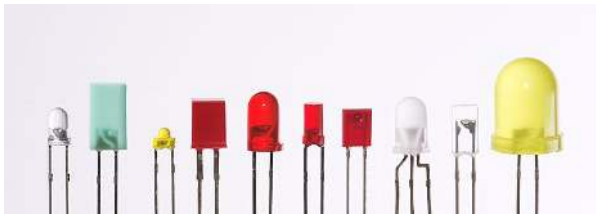
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(source: wikipedia)

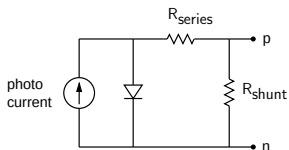
Diode types

- * **Solar cells** are generally silicon diodes designed to generate current efficiently when solar radiation is incident on the device. A “solar panel” has a large number of individual solar cells connected in series/parallel configuration. A solar cell can be modelled as a diode in parallel with a current source (representing the photocurrent). In addition, parasitic series and shunt resistances need to be considered.

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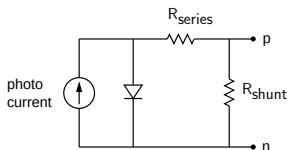
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A solar cell can be modelled as a diode in parallel with a current source (representing the photocurrent). In addition, parasitic series and shunt resistances need to be considered.



- * **Photodiodes** are used to detect optical signals (DC or time-varying) and to convert them into electrical signals which can be subsequently processed by electronic circuits. They are used in fibre-optic communication systems, image processing, etc.

A photodiode works on the same principle as a solar cell, i.e., it converts light into a current. However, its design is optimized for high-sensitivity, low-noise, or high-frequency operation, depending on the application.

- * In DC situations, for each diode in the circuit, we need to establish whether it is on or off, replace it with the corresponding equivalent circuit, and then obtain the quantities of interest.

Diode circuit analysis

- * In DC situations, for each diode in the circuit, we need to establish whether it is on or off, replace it with the corresponding equivalent circuit, and then obtain the quantities of interest.
- * In transient analysis, we need to find the time points at which a diode turns on or off, and analyse the circuit in intervals between these time points.

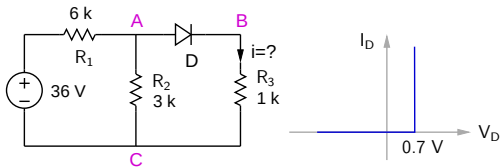
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- * In AC (small-signal) situations, the diode can be replaced by its small-signal model, and phasor analysis is used. We will illustrate this procedure for a BJT amplifier later.

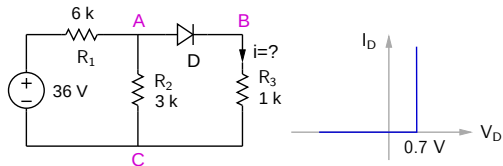
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- * In AC (small-signal) situations, the diode can be replaced by its small-signal model, and phasor analysis is used. We will illustrate this procedure for a BJT amplifier later.
- * Note that there are diode circuits in which the exponential nature of the diode I-V relationship is made use of. For these circuits, computer simulation would be required to solve the resulting non-linear equations.

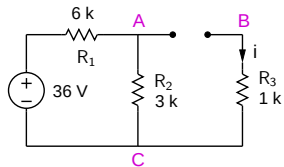
Diode circuit example



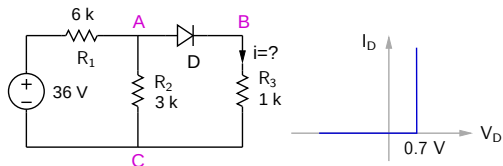
Diode circuit example



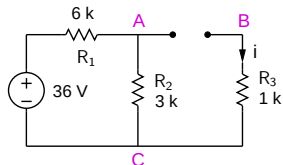
Case 1: D is off.



Diode circuit example



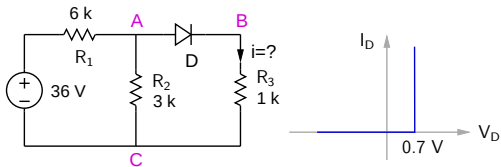
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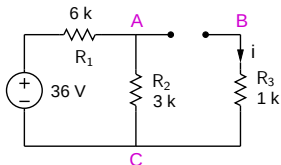
$$V_{AB} = V_{AC} = \frac{3}{9} \times 36 = 12 \text{ V},$$

which is not consistent with our assumption of D being off.

Diode circuit example



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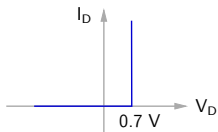
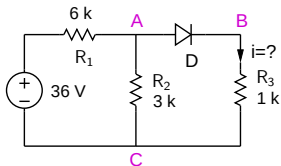


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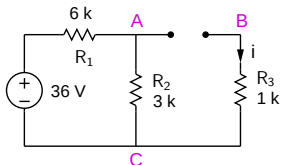
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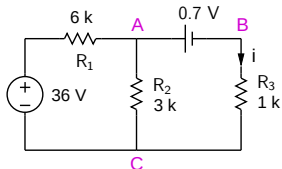


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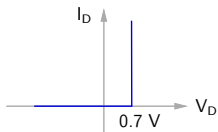
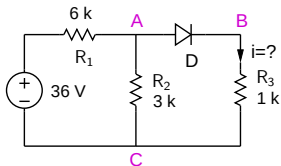
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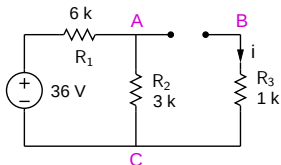
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Diode circuit example



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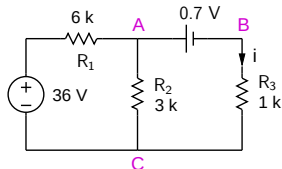


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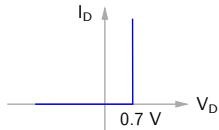
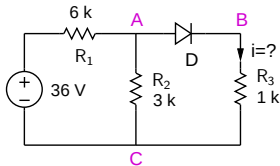


Taking $V_C = 0 \text{ V}$,

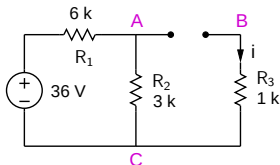
$$\frac{V_A - 36}{6 \text{ k}} + \frac{V_A}{3 \text{ k}} + \frac{V_A - 0.7}{1 \text{ k}} = 0,$$

$$\rightarrow V_A = 4.47 \text{ V}, i = 3.77 \text{ mA}.$$

Diode circuit example



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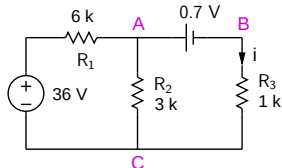


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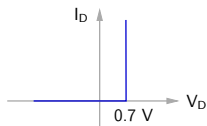
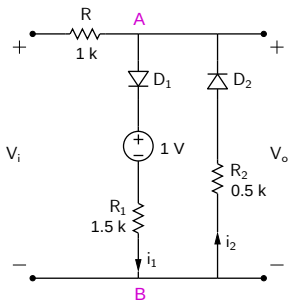
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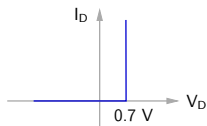
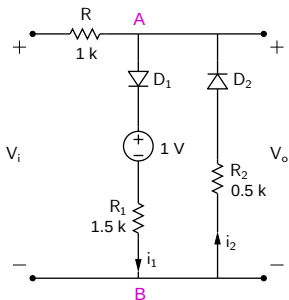
Remark: Often, we can figure out by inspection if a diode is on or off.

Diode circuit example



- (a) Plot V_o versus V_i for $-5\text{ V} < V_i < 5\text{ V}$.
- (b) Plot $V_o(t)$ for a triangular input:
 -5 V to $+5\text{ V}$, 500 Hz .

Diode circuit example

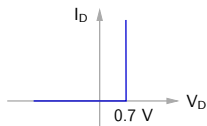
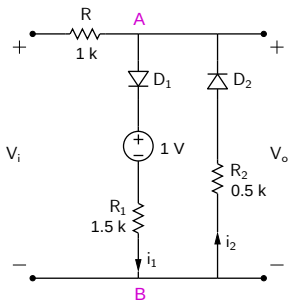


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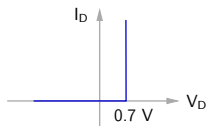
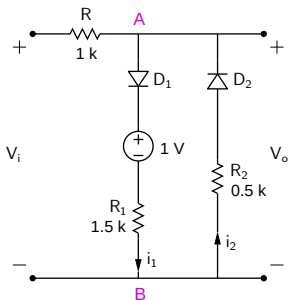
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Consider D_1 to be on $\rightarrow V_{AB} = 0.7 + 1 + i_1 R_1$.

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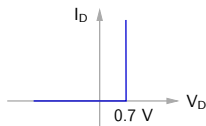
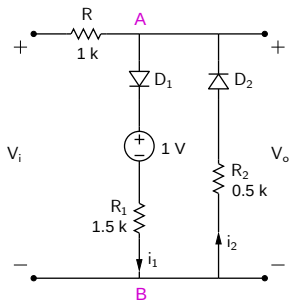
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Note that $i_1 > 0$, since D_1 can only conduct in the forward direction.

$\Rightarrow V_{AB} > 1.7 \text{ V} \Rightarrow D_2$ cannot conduct.

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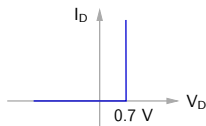
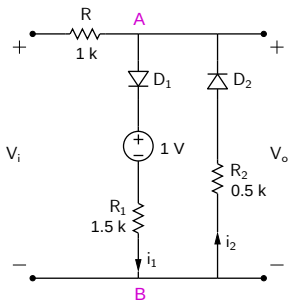
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Similarly, if D_2 is on, $V_{BA} > 0.7 \text{ V}$, i.e., $V_{AB} < -0.7 \text{ V} \Rightarrow D_1$ cannot conduct.

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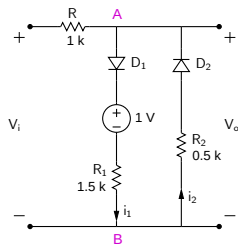
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Clearly, D_1 on $\Rightarrow D_2$ off, and D_2 on $\Rightarrow D_1$ off.

Diode circuit example (continued)

- * For $-0.7 \text{ V} < V_i < 1.7 \text{ V}$, both D_1 and D_2 are off.
→ no drop across R , and $V_o = V_i$.

(1)



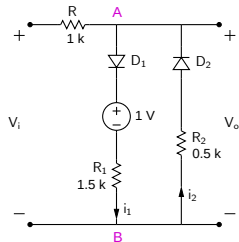
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Use KVL to get i_2 : $V_i + i_2 R_2 + 0.7 + R i_2 = 0$.

$$\rightarrow i_2 = -\frac{V_i + 0.7}{R + R_2}, \text{ and}$$

$$V_o = -0.7 - R_2 i_2 = \frac{R_2}{R + R_2} V_i - 0.7 \frac{R}{R + R_2}. \quad (2)$$

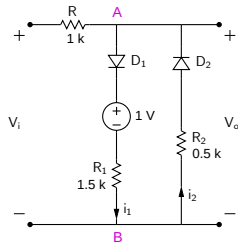


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- * For $V_i > 1.7 \text{ V}$, D_1 conducts. → $V_o = 0.7 + 1 + i_1 R_1$.
Use KVL to get i_1 : $-V_i + i_1 R + 0.7 + 1 + i_1 R_1 = 0$.
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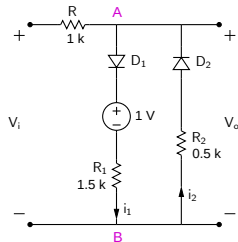
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- * Using Eqs. (1)-(3), we plot V_o versus V_i .
 (SEQUEL file: ee101_diode_circuit_1.sqproj)



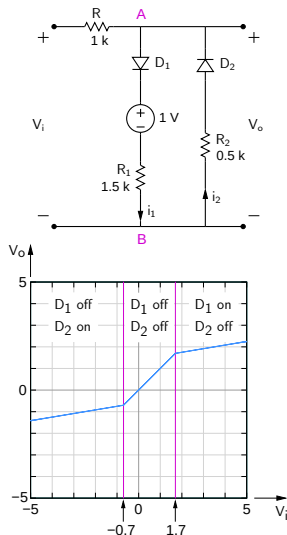
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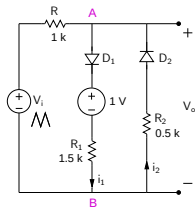
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- * For $V_i > 1.7 \text{ V}$, D_1 conducts. $\rightarrow V_o = 0.7 + 1 + i_1 R_1$.
 Use KVL to get i_1 : $-V_i + i_1 R + 0.7 + 1 + i_1 R_1 = 0$.
 $\rightarrow i_1 = \frac{V_i - 1.7}{R + R_1}$, and
 $V_o = 1.7 + R_1 i_1 = \frac{R_1}{R + R_1} V_i + 1.7 \frac{R}{R + R_1}$. (3)

- * Using Eqs. (1)-(3), we plot V_o versus V_i .
 (SEQUEL file: ee101_diode_circuit_1.sqproj)

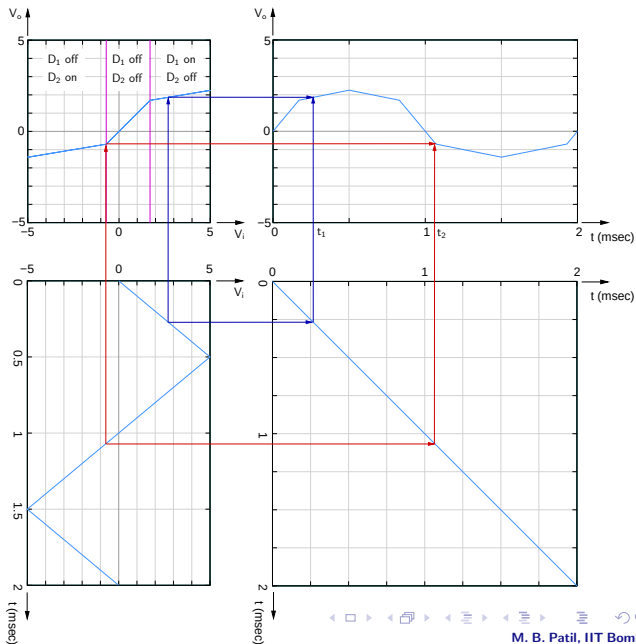


Diode circuit example (continued)

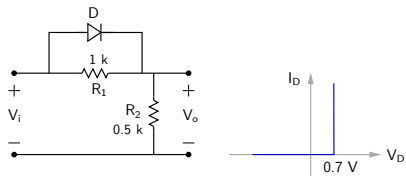


Point-by-point construction of V_o versus t :

Two time points, t_1 and t_2 , are shown as examples.

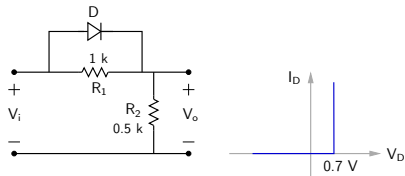


Diode circuit example

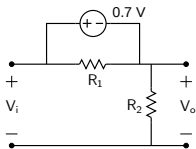


Plot V_o versus V_i for $-5 \text{ V} < V_i < 5 \text{ V}$.

Diode circuit example

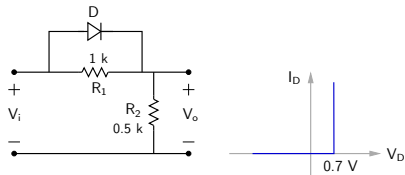


Plot V_o versus V_i for $-5 \text{ V} < V_i < 5 \text{ V}$.

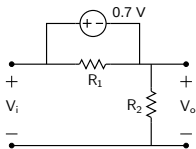


D on
 $V_o = V_i - 0.7$

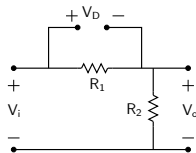
Diode circuit example



Plot V_o versus V_i for $-5\text{ V} < V_i < 5\text{ V}$.

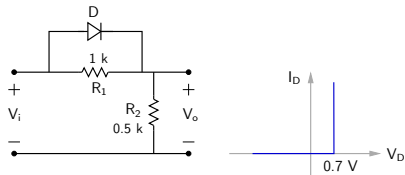


D on
 $V_o = V_i - 0.7$

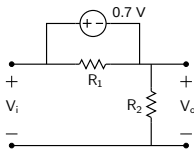


D off
 $V_o = \frac{R_2}{R_1 + R_2} V_i$

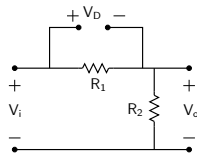
Diode circuit example



Plot V_o versus V_i for $-5\text{ V} < V_i < 5\text{ V}$.



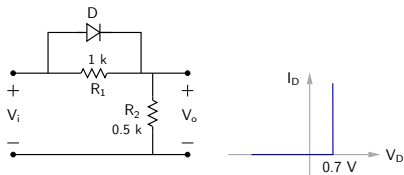
D on
 $V_o = V_i - 0.7$



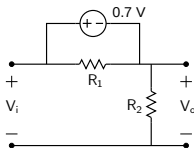
D off
 $V_o = \frac{R_2}{R_1 + R_2} V_i$

At what value of V_i will the diode turn on?

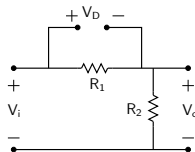
Diode circuit example



Plot V_o versus V_i for $-5\text{ V} < V_i < 5\text{ V}$.



D on
 $V_o = V_i - 0.7$

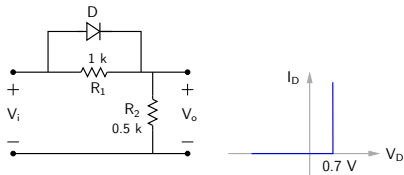


D off
 $V_o = \frac{R_2}{R_1 + R_2} V_i$

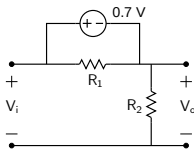
At what value of V_i will the diode turn on?

In the off state, $V_D = \frac{R_1}{R_1 + R_2} V_i$.

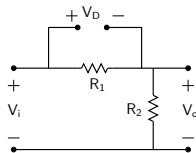
Diode circuit example



Plot V_o versus V_i for $-5\text{ V} < V_i < 5\text{ V}$.



D on
 $V_o = V_i - 0.7$



D off
 $V_o = \frac{R_2}{R_1 + R_2} V_i$

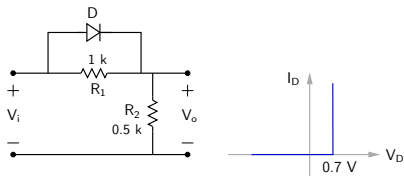
At what value of V_i will the diode turn on?

In the off state, $V_D = \frac{R_1}{R_1 + R_2} V_i$.

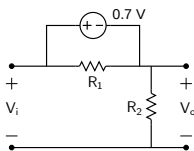
For D to change to the on state, $V_D = 0.7\text{ V}$.

i.e., $V_i = \frac{R_1 + R_2}{R_1} \times 0.7 = 1.05\text{ V}$.

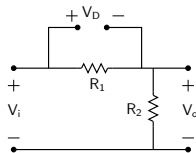
Diode circuit example



Plot V_o versus V_i for $-5\text{ V} < V_i < 5\text{ V}$.



D on
 $V_o = V_i - 0.7$



D off
 $V_o = \frac{R_2}{R_1 + R_2} V_i$

At what value of V_i will the diode turn on?

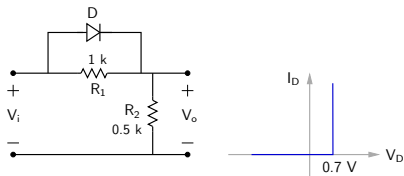
In the off state, $V_D = \frac{R_1}{R_1 + R_2} V_i$.

For D to change to the on state, $V_D = 0.7\text{ V}$.

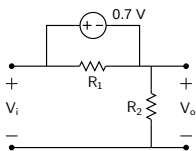
i.e., $V_i = \frac{R_1 + R_2}{R_1} \times 0.7 = 1.05\text{ V}$.

(SEQUEL file: ee101_diode_circuit_2.sqproj)

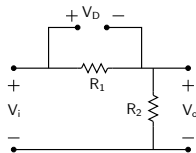
Diode circuit example



Plot V_o versus V_i for $-5\text{ V} < V_i < 5\text{ V}$.



D on
 $V_o = V_i - 0.7$



D off
 $V_o = \frac{R_2}{R_1 + R_2} V_i$

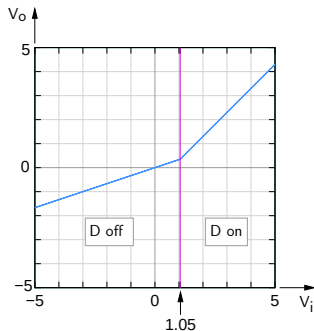
At what value of V_i will the diode turn on?

In the off state, $V_D = \frac{R_1}{R_1 + R_2} V_i$.

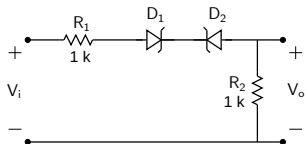
For D to change to the on state, $V_D = 0.7\text{ V}$.

i.e., $V_i = \frac{R_1 + R_2}{R_1} \times 0.7 = 1.05\text{ V}$.

(SEQUEL file: ee101_diode_circuit_2.sqproj)



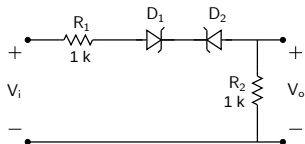
Diode circuit example



$$V_{on} = 0.7\text{ V}, V_Z = 5\text{ V}.$$

Plot V_o versus V_i .

Diode circuit example

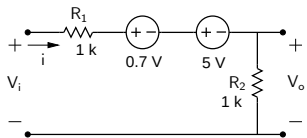


$$V_{on} = 0.7 \text{ V}, V_Z = 5 \text{ V}.$$

Plot V_o versus V_i .

For a current to flow, we have two possibilities:

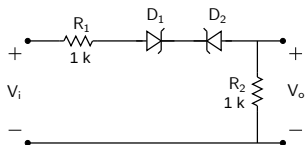
D_1 on (forward), D_2 in reverse breakdown



$$V_o = iR_2 = \frac{V_i - 5.7}{R_1 + R_2} R_2$$

Since $i > 0$, this can happen only when $V_i > 5.7 \text{ V}$.

Diode circuit example

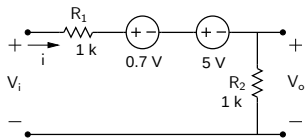


$$V_{on} = 0.7 \text{ V}, V_Z = 5 \text{ V}.$$

Plot V_o versus V_i .

For a current to flow, we have two possibilities:

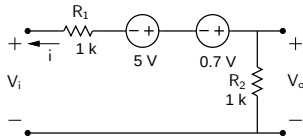
D_1 on (forward), D_2 in reverse breakdown



$$V_o = iR_2 = \frac{V_i - 5.7}{R_1 + R_2} R_2$$

Since $i > 0$, this can happen only when $V_i > 5.7 \text{ V}$.

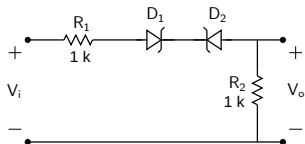
D_2 on (forward), D_1 in reverse breakdown



$$V_o = -iR_2 = \frac{V_i + 5.7}{R_1 + R_2} R_2$$

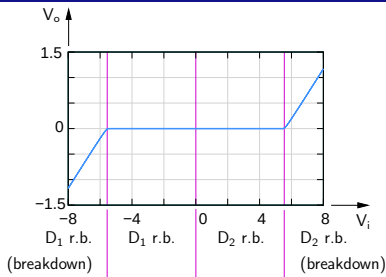
Since $i > 0$, this can happen only when $V_i < -5.7 \text{ V}$.

Diode circuit example



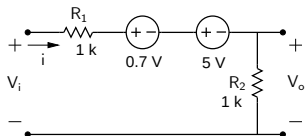
$$V_{on} = 0.7 \text{ V}, V_Z = 5 \text{ V}.$$

Plot V_o versus V_i .



For a current to flow, we have two possibilities:

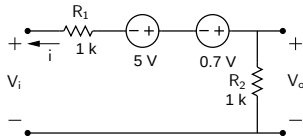
D_1 on (forward), D_2 in reverse breakdown



$$V_o = iR_2 = \frac{V_i - 5.7}{R_1 + R_2} R_2$$

Since $i > 0$, this can happen only when $V_i > 5.7 \text{ V}$.

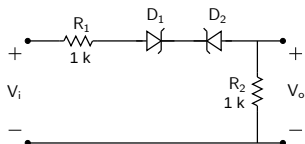
D_2 on (forward), D_1 in reverse breakdown



$$V_o = -iR_2 = \frac{V_i + 5.7}{R_1 + R_2} R_2$$

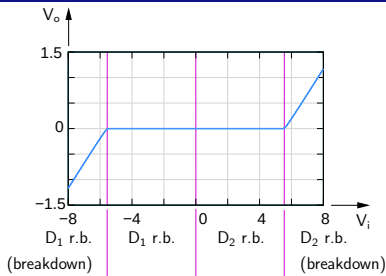
Since $i > 0$, this can happen only when $V_i < -5.7 \text{ V}$.

Diode circuit example



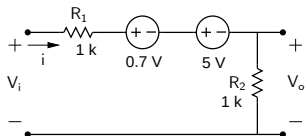
$$V_{on} = 0.7 \text{ V}, V_Z = 5 \text{ V}.$$

Plot V_o versus V_i .



For a current to flow, we have two possibilities:

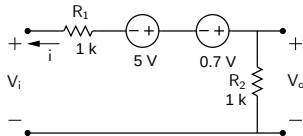
D_1 on (forward), D_2 in reverse breakdown



$$V_o = iR_2 = \frac{V_i - 5.7}{R_1 + R_2} R_2$$

Since $i > 0$, this can happen only when $V_i > 5.7 \text{ V}$.

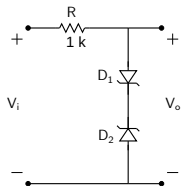
D_2 on (forward), D_1 in reverse breakdown



$$V_o = -iR_2 = \frac{V_i + 5.7}{R_1 + R_2} R_2$$

Since $i > 0$, this can happen only when $V_i < -5.7 \text{ V}$.

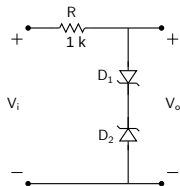
Diode circuit example (voltage limiter)



$V_{\text{on}} = 0.7\text{ V}$, $V_Z = 5\text{ V}$.

Plot V_o versus V_i .

Diode circuit example (voltage limiter)

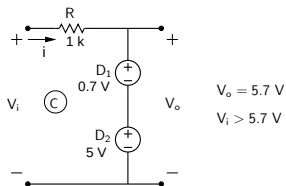


$$V_{\text{on}} = 0.7\text{ V}, V_Z = 5\text{ V}.$$

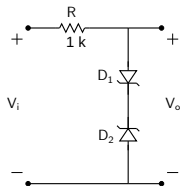
Plot V_o versus V_i .

For a current to flow, we have two possibilities:

D_1 on (forward), D_2 in reverse breakdown



Diode circuit example (voltage limiter)

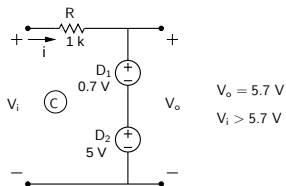


$$V_{on} = 0.7 \text{ V}, V_Z = 5 \text{ V}.$$

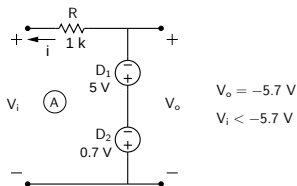
Plot V_o versus V_i .

For a current to flow, we have two possibilities:

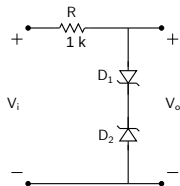
D_1 on (forward), D_2 in reverse breakdown



D_2 on (forward), D_1 in reverse breakdown



Diode circuit example (voltage limiter)

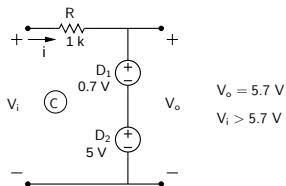


$$V_{on} = 0.7 \text{ V}, V_Z = 5 \text{ V}.$$

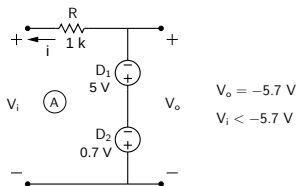
Plot V_o versus V_i .

For a current to flow, we have two possibilities:

D_1 on (forward), D_2 in reverse breakdown

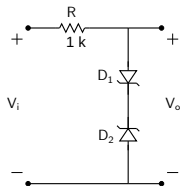


D_2 on (forward), D_1 in reverse breakdown



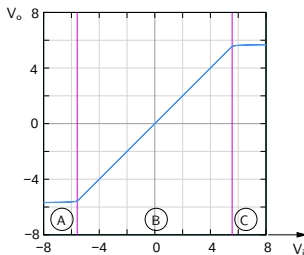
In the range, $-5.7 \text{ V} < V_i < 5.7 \text{ V}$, no current flows, and $V_o = V_i$. (B)

Diode circuit example (voltage limiter)



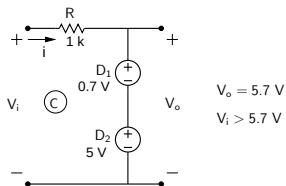
$$V_{on} = 0.7 \text{ V}, V_Z = 5 \text{ V}.$$

Plot V_o versus V_i .

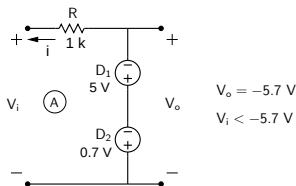


For a current to flow, we have two possibilities:

D_1 on (forward), D_2 in reverse breakdown

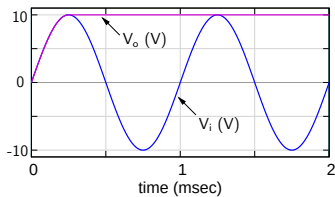
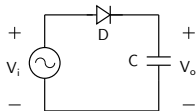


D_2 on (forward), D_1 in reverse breakdown

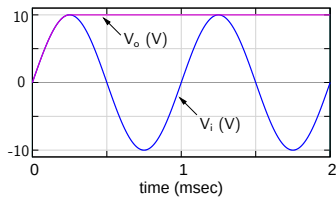
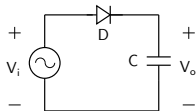


In the range, $-5.7 \text{ V} < V_i < 5.7 \text{ V}$, no current flows, and $V_o = V_i$. (B)

Peak detector

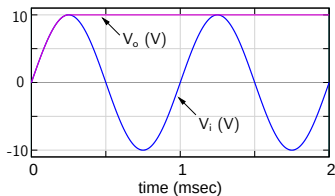
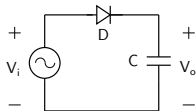


Peak detector



Let $V_o(t) = 0$ V at $t = 0$, and assume the diode to be ideal, with $V_{on} = 0$ V.

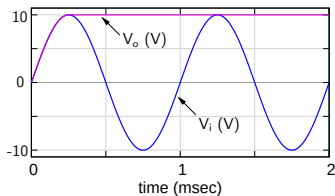
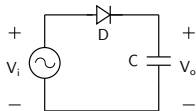
Peak detector



Let $V_o(t) = 0$ V at $t = 0$, and assume the diode to be ideal, with $V_{on} = 0$ V.

For $0 < t < T/4$, V_i rises from 0 to V_m . As a result, the capacitor charges.

Peak detector

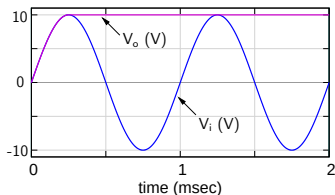
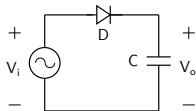


Let $V_o(t) = 0$ V at $t = 0$, and assume the diode to be ideal, with $V_{on} = 0$ V.

For $0 < t < T/4$, V_i rises from 0 to V_m . As a result, the capacitor charges.

Since the on resistance of the diode is small, time constant $\tau \ll T/4$; therefore the charging process is instantaneous $\Rightarrow V_o(t) = V_i(t)$.

Peak detector



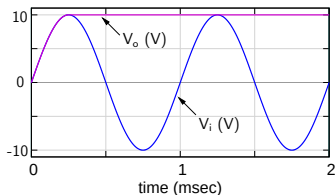
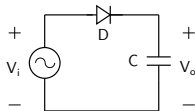
Let $V_o(t) = 0$ V at $t = 0$, and assume the diode to be ideal, with $V_{on} = 0$ V.

For $0 < t < T/4$, V_i rises from 0 to V_m . As a result, the capacitor charges.

Since the on resistance of the diode is small, time constant $\tau \ll T/4$; therefore the charging process is instantaneous $\Rightarrow V_o(t) = V_i(t)$.

For $t > T/4$, V_i starts falling. The capacitor holds the charge it had at $t = T/4$ since the diode prevents discharging.

Peak detector



Let $V_o(t) = 0$ V at $t = 0$, and assume the diode to be ideal, with $V_{on} = 0$ V.

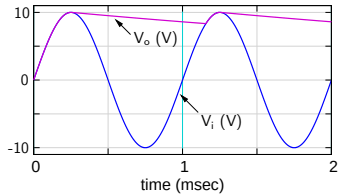
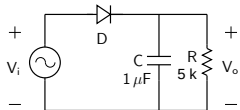
For $0 < t < T/4$, V_i rises from 0 to V_m . As a result, the capacitor charges.

Since the on resistance of the diode is small, time constant $\tau \ll T/4$; therefore the charging process is instantaneous $\Rightarrow V_o(t) = V_i(t)$.

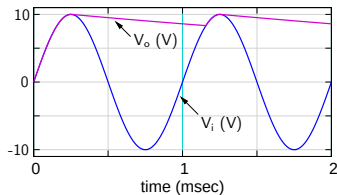
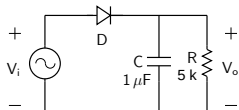
For $t > T/4$, V_i starts falling. The capacitor holds the charge it had at $t = T/4$ since the diode prevents discharging.

SEQUEL file: ee101.diode.circuit_5.sqproj

Peak detector (continued)

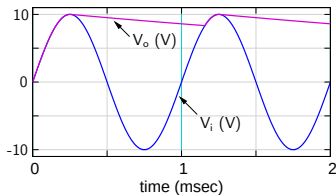
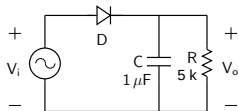


Peak detector (continued)



If a resistor is added in parallel, a discharging path is provided for the capacitor, and the capacitor voltage falls after reaching the peak.

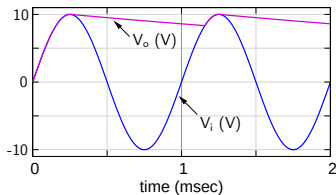
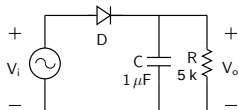
Peak detector (continued)



If a resistor is added in parallel, a discharging path is provided for the capacitor, and the capacitor voltage falls after reaching the peak.

When $V_i > V_o$, the capacitor charges again. The time constant for the charging process is $\tau = R_{Th}C$, where $R_{Th} = R \parallel R_{on}$ is the Thevenin resistance seen by the capacitor, R_{on} being the on resistance of the diode.

Peak detector (continued)

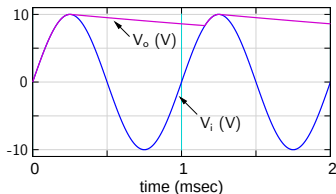
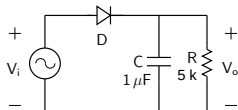


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Since $\tau \ll T$, the charging process is instantaneous.

Peak detector (continued)



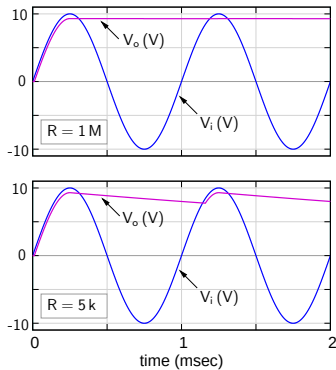
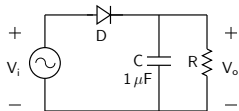
If a resistor is added in parallel, a discharging path is provided for the capacitor, and the capacitor voltage falls after reaching the peak.

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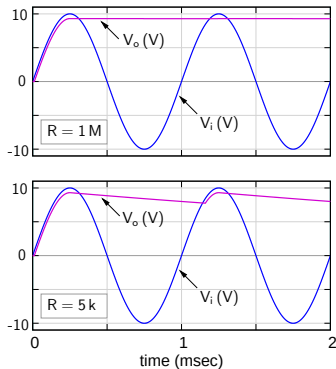
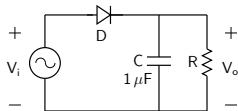
Since $\tau \ll T$, the charging process is instantaneous.

SEQUEL file: ee101_diode_circuit_5a.sqproj

Peak detector (with $V_{on} = 0.7\text{ V}$)

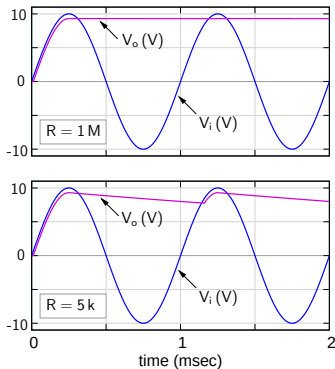
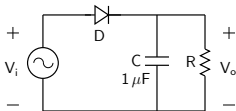


Peak detector (with $V_{on} = 0.7 \text{ V}$)



With $V_{on} = 0.7 \text{ V}$, the capacitor charges up to $(V_m - 0.7 \text{ V})$.

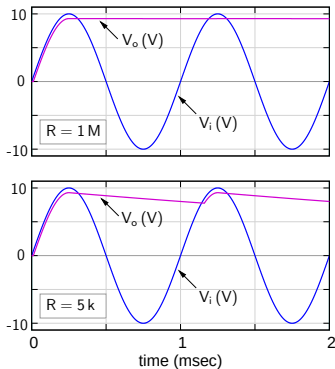
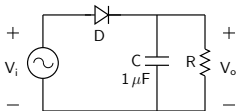
Peak detector (with $V_{on} = 0.7 \text{ V}$)



With $V_{on} = 0.7 \text{ V}$, the capacitor charges up to $(V_m - 0.7 \text{ V})$.

Apart from that, the circuit operation is similar.

Peak detector (with $V_{on} = 0.7 \text{ V}$)

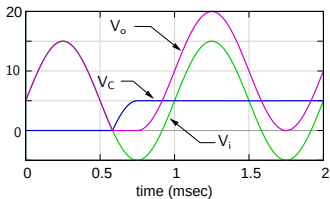
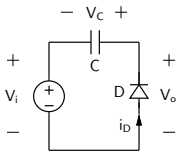


With $V_{on} = 0.7 \text{ V}$, the capacitor charges up to $(V_m - 0.7 \text{ V})$.

Apart from that, the circuit operation is similar.

SEQUEL file: ee101_diode_circuit_5a.sqproj

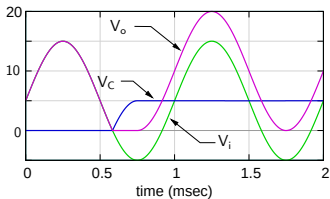
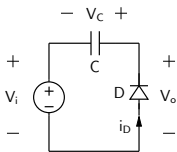
Clamped capacitor



* Assume $V_{on} = 0$ V for the diode.

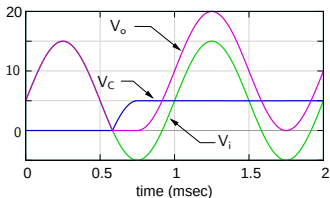
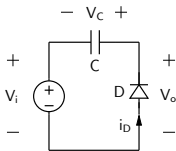
When D conducts, $V_D = -V_o = 0 \Rightarrow V_C + V_i = 0$, i.e., $V_C = -V_i$.

Clamped capacitor



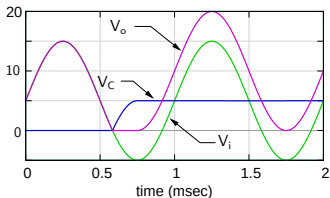
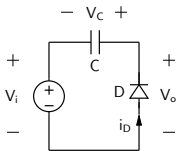
- * Assume $V_{on} = 0$ V for the diode.
When D conducts, $V_D = -V_o = 0 \Rightarrow V_C + V_i = 0$, i.e., $V_C = -V_i$.
- * V_C can only increase with time (or remain constant) since i_D can only be positive.

Clamped capacitor



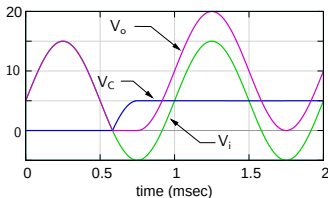
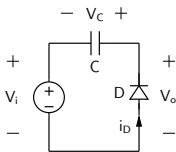
- * Assume $V_{on} = 0$ V for the diode.
When D conducts, $V_D = -V_o = 0 \Rightarrow V_C + V_i = 0$, i.e., $V_C = -V_i$.
- * V_C can only increase with time (or remain constant) since i_D can only be positive.
- * The net result is that the capacitor gets charged to a voltage $V_C = -V_i$, corresponding to the maximum negative value of V_i , and holds that voltage thereafter. Let us call this voltage V_C^0 (a constant).

Clamped capacitor



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When D conducts, $V_D = -V_o = 0 \Rightarrow V_C + V_i = 0$, i.e., $V_C = -V_i$.
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- * $V_o(t) = V_C(t) + V_i(t) = V_C^0 + V_i(t)$, which is a “level-shifted” version of V_i .

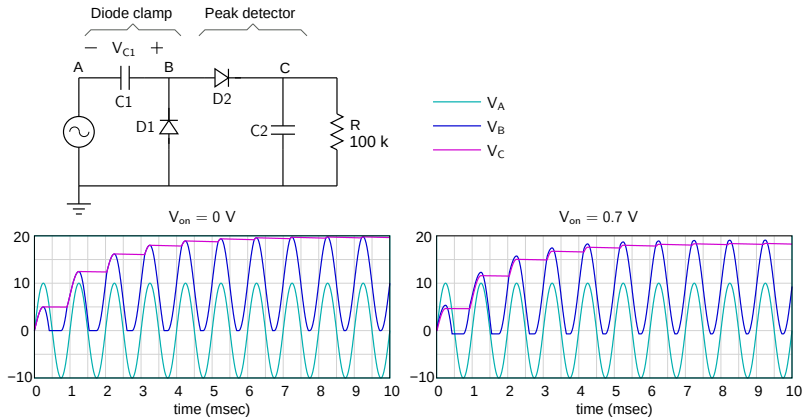
Clamped capacitor



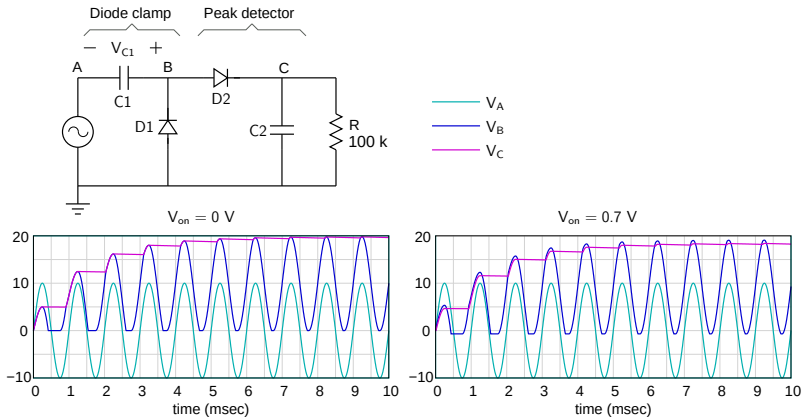
- * Assume $V_{on} = 0$ V for the diode.
When D conducts, $V_D = -V_o = 0 \Rightarrow V_C + V_i = 0$, i.e., $V_C = -V_i$.
- * V_C can only increase with time (or remain constant) since i_D can only be positive.
- * The net result is that the capacitor gets charged to a voltage $V_C = -V_i$, corresponding to the maximum negative value of V_i , and holds that voltage thereafter. Let us call this voltage V_C^0 (a constant).
- * $V_o(t) = V_C(t) + V_i(t) = V_C^0 + V_i(t)$, which is a “level-shifted” version of V_i .

(SEQUEL file: ee101_diode_circuit_6.sqproj)

Voltage doubler

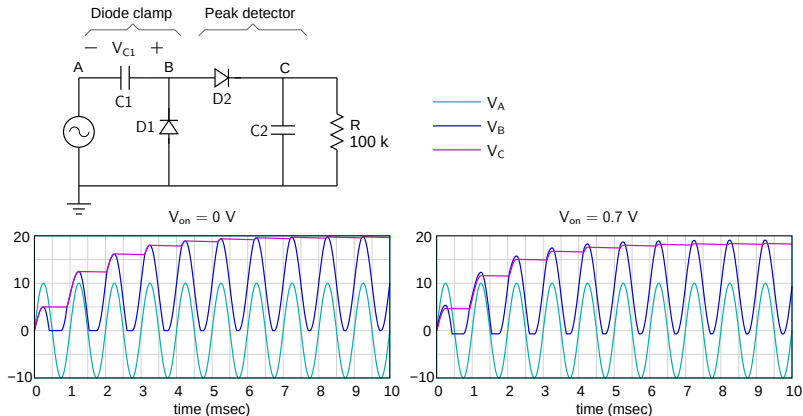


Voltage doubler



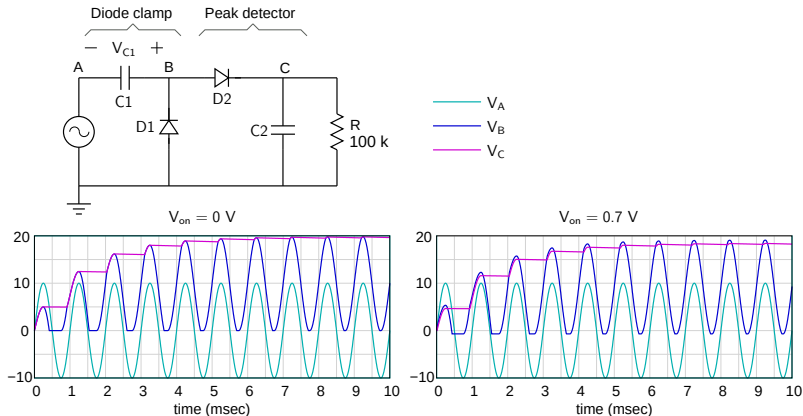
- * The diode clamp shifts V_A up by V_m (the amplitude of the AC source), making V_B go from 0 to $2 V_m$.

Voltage doubler



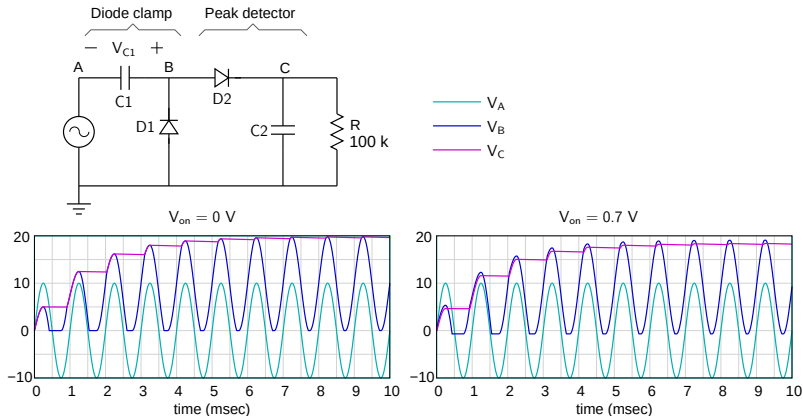
- * The diode clamp shifts V_A up by V_m (the amplitude of the AC source), making V_B go from 0 to $2 V_m$.
- * The peak detector detects the peak of V_B ($2 V_m$ w.r.t. ground), and holds it constant.

Voltage doubler



- * The diode clamp shifts V_A up by V_m (the amplitude of the AC source), making V_B go from 0 to $2V_m$.
- * The peak detector detects the peak of V_B ($2V_m$ w.r.t. ground), and holds it constant.
- * Note that it takes a few cycles to reach steady state. Plot V_{C1} , i_{D1} , i_{D2} versus t and explain the initial behaviour of the circuit.

Voltage doubler



- * The diode clamp shifts V_A up by V_m (the amplitude of the AC source), making V_B go from 0 to $2 V_m$.
- * The peak detector detects the peak of V_B ($2 V_m$ w.r.t. ground), and holds it constant.
- * Note that it takes a few cycles to reach steady state. Plot V_{C1} , i_{D1} , i_{D2} versus t and explain the initial behaviour of the circuit.

(SEQUEL file: ee101.voltage-doubler.sqproj)