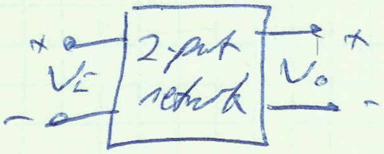
Waveform shaping circuits

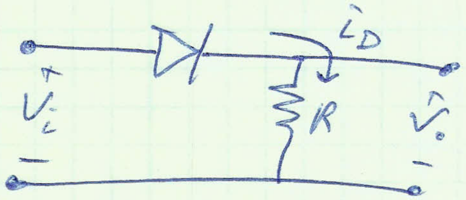
- Consider a 2-port network.



- We are interested in the transfer function, v_o as func. of v_i
- We are used to this circuit →

- Assume $R_L \to \infty$
  (openloop transfer function)

Rectifier Circuits



for "openloop"
the entire diode current
flows through the resistor

$$\left.\begin{aligned} v_i &= v_D + R i_D \\ v_o &= R i_D \end{aligned}\right\} \text{KVL}$$

Diode OFF : $i_D = 0$, $v_D < V_{D0}$

$$v_o = R i_D = 0$$

$$v_i = v_D + R i_D \rightarrow v_i = v_D < V_{D0}$$

Diode is only off when $v_i < V_{D0}$, then $v_o = 0$

Diode ON : $v_D = V_{D0}$, $i_D \geq 0$

$$v_i = v_D + R i_D \longrightarrow v_o = R i_D \longrightarrow \underline{v_o = v_i - V_{D0}}$$

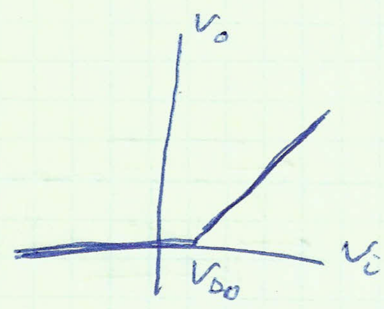
$$i_D = \frac{v_i - V_{D0}}{R} \quad i_D \geq 0 \text{ for } v_i \geq V_{D0}$$

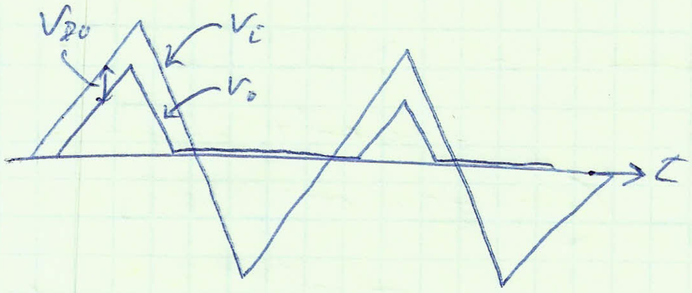
Diode is on when $v_i \geq V_{D0}$, then $v_o = v_i - V_{D0}$

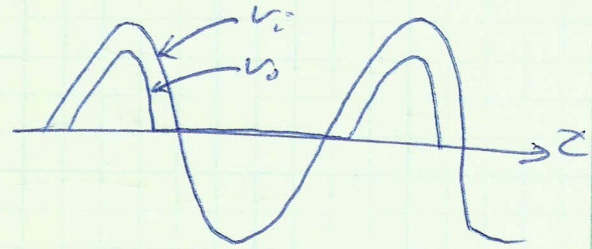
Transfer function:

$V_i < V_{D0} \rightarrow OFF \rightarrow V_o = 0$

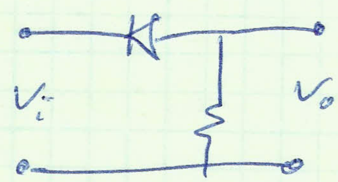
$V_i \geq V_{D0} \rightarrow ON \rightarrow V_o = V_i - V_{D0}$





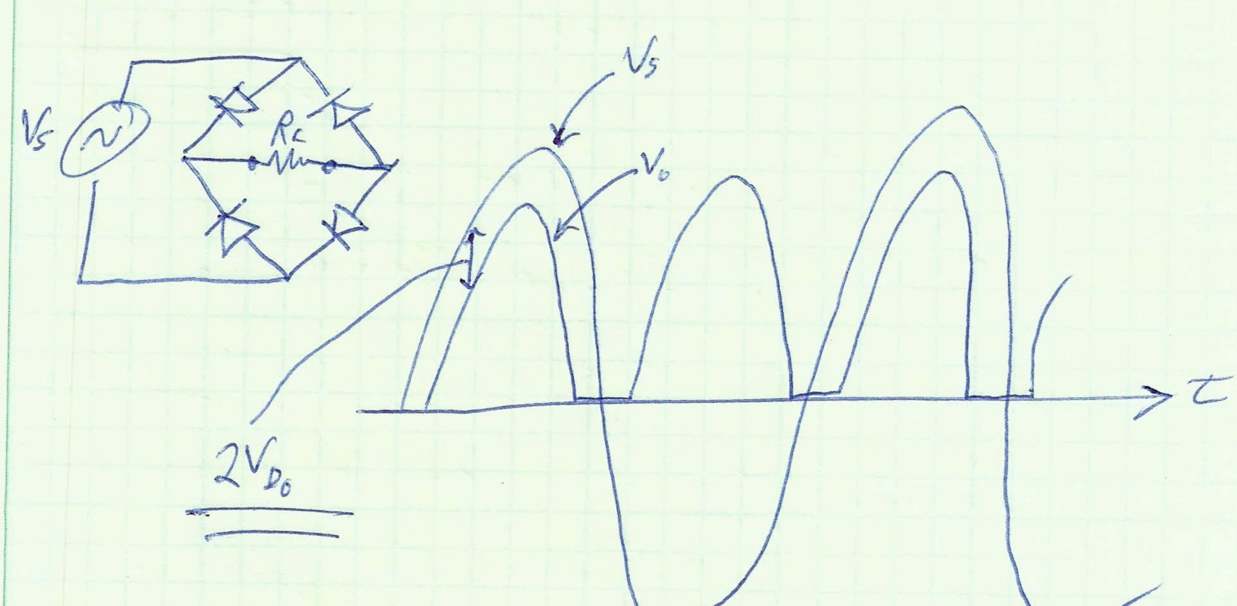


If diode is turned around, still rectifies, but with negative output

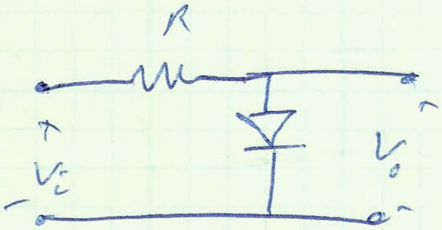


Both are known as "half-wave" rectifier circuits.

Full-wave rectifier circuit:



Clipper Circuits

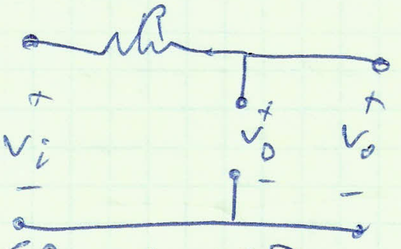


KVL: $v_i = R i_D + v_D$, $v_o = v_D$

Diode OFF: $v_o = v_i \rightarrow$ for $v_i < V_{D0}$

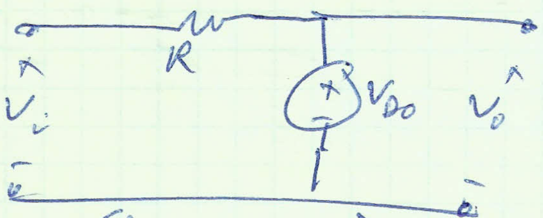
Diode ON: $v_O = V_{D0} \rightarrow i_D = \frac{v_i - V_{D0}}{R} \geq 0 \rightarrow v_i \geq V_{D0}$

OFF



(for $v_D < V_{D0}$)

ON

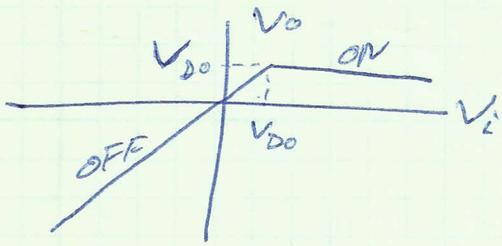


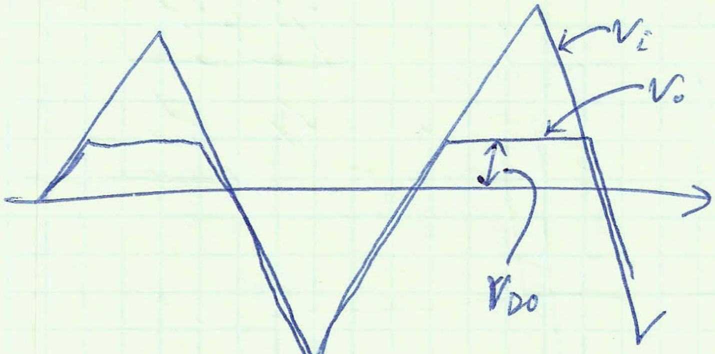
(for $i_D \geq 0$)

Transfer function

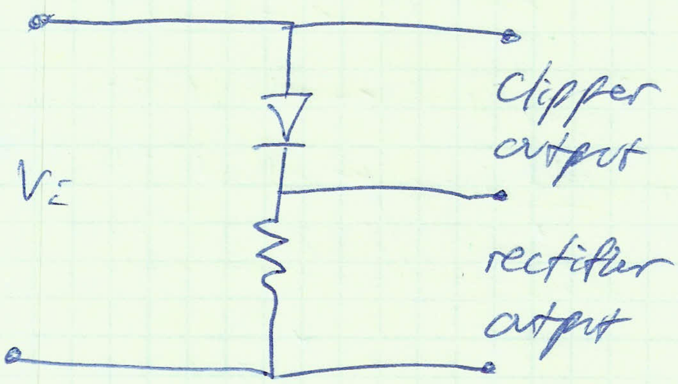
$v_i < V_{D0} \rightarrow$ OFF, $v_o = v_i$

$v_i \geq V_{D0} \rightarrow$ ON, $v_o = V_{D0}$



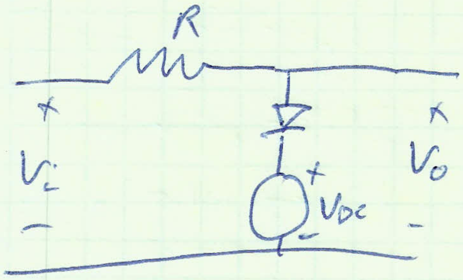


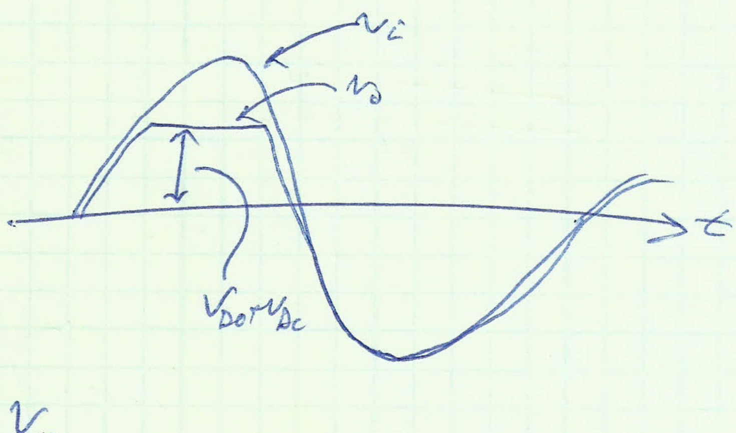
Note that the rectifier and clipper circuits are the same except with output taken at different points



- Voltage across diode can never exceed V_{D0}
- Voltage across resistor can never be negative

Clipper circuits for values other than V_{D0}





KVL
$$\begin{cases} V_o = V_D + V_{DC} \\ V_i = R\,i_D + V_D + V_{DC} = R\,i_D + V_o \end{cases}$$

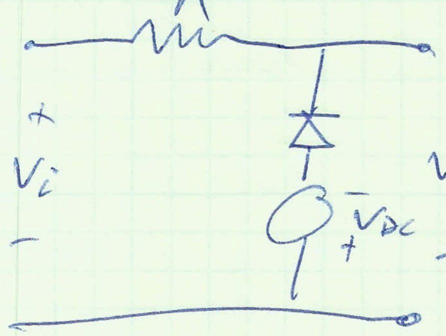
Diode ON:

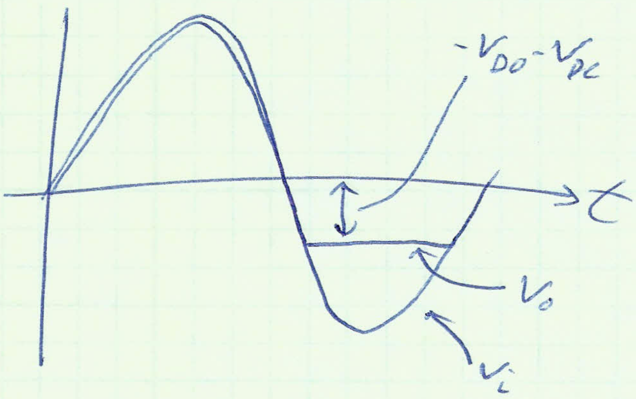
$$V_o = V_{D0} + V_{DC} \rightarrow \quad i_D = \frac{V_i - V_{D0} - V_{DC}}{R} \geq 0 \rightarrow \underline{V_i \geq V_{D0} + V_{DC}}$$

Diode OFF:

$$V_o = V_i - 0 \times R = V_i \,, \quad V_D = V_i - R\,i_D - V_{DC} < V_{D0} \rightarrow \underline{V_i < V_{D0} + V_{DC}}$$

Clipper circuit for negative voltages





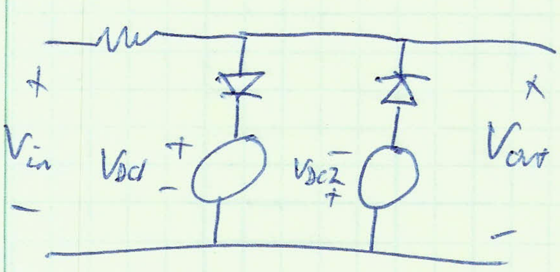
KVL: $v_i = -Ri_D - V_D - V_{DC}$

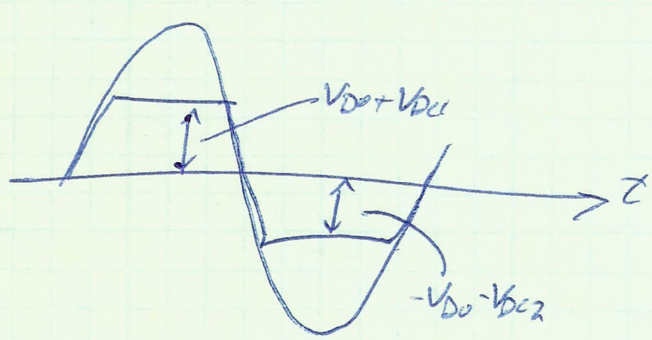
$v_o = -V_D - V_{DC}$

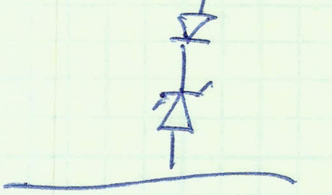
<u>Diode ON:</u> $v_o = -V_{D0} - V_{DC}$, $\quad i_D = \dfrac{v_i + V_{D0} + V_{DC}}{R} \geq 0 \rightarrow \underline{v_i \leq -V_{D0} - V_{DC}}$

<u>Diode OFF</u> $v_o = v_i$, $v_D = -v_i - V_{DC} < V_{D0} \rightarrow \quad v_i > -V_{D0} - V_{DC}$

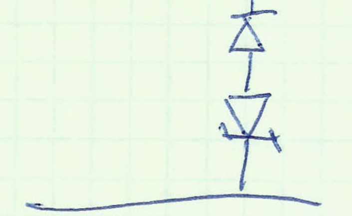
Other Clipper Circuits



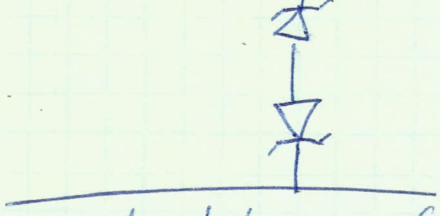




clips $v > V_{Z2} + V_{D01}$



clips $v < -V_{D01} - V_{Z2}$



clips $|v| > V_{D0} + V_Z$

if diodes are identical