Wave Shaping Circuits with Diodes

Background: Clipping circuits allow that portion of the input waveform which lies above or below some reference voltage level. Broadly, clippers are classified into two categories:

a) Shunt clipper
b) Series clippers

Shunt clipper: The shunt clippers are the circuits in which the diode is connected across the load. The operation of the shunt clipper shown in Fig. 1(a) can be well understood using piecewise linear approximation model.

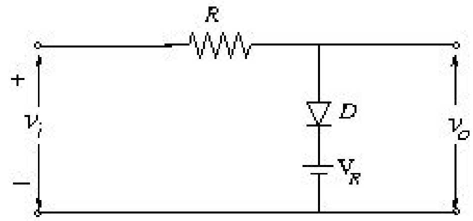

Figure 1(a)

In Fig. 1 (a), the cathode of the diode D is held at $+V_R$. Hence, for the diode to conduct, the input signal has to be greater than $V_R + V\gamma$, where $V\gamma$ is the cut-in voltage of the diode.

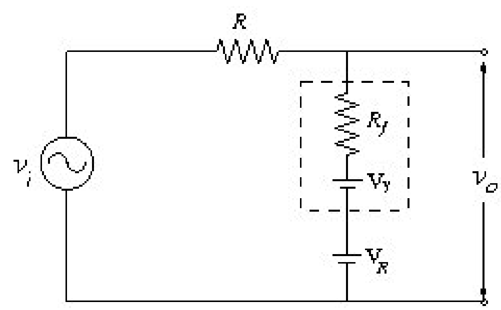

Figure 1(b)

Replacing the diode by its equivalent circuit shown in fig. 1(b) and applying KVL, we get

$V_i = i.R + V_o$ -- (1)

$V_i = i.R + i.R_f. + V\gamma + V_R$ -- (2)

$i = \frac{V_i - V_\gamma - V_R}{R + R_f}$

This gives,

$V_o = \frac{Rf}{Rf+R}(Vi - V\gamma - V_R) + V_R + V\gamma$ --------------------------------- (3)

Simplifying this, we get,

$V_o = \frac{Rf}{Rf+R} Vi + \frac{R}{Rf+R} (V_{R+} V\gamma)$ -- (4)

i) When input signal V_i is less than (V_R+ $V\gamma$), D is OFF (i=0).
Hence, from Eq. 1, we get $V_o = V_i$.

ii) For the diode D to conduct, V_i should be greater than $V_R + V\gamma$. When the diode conducts, the output signal is given by the Eq. 4.

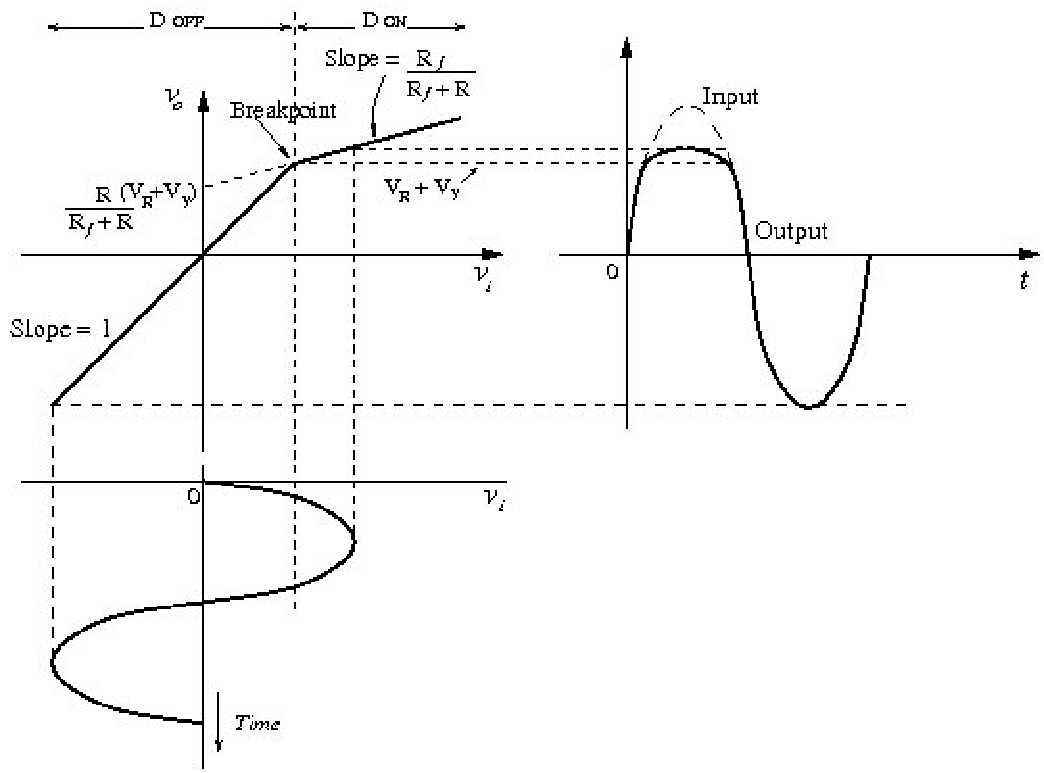

Figure 1(c)

The transfer characteristics can be drawn to illustrate both the conditions as shown in Fig. 1(c).

The transfer characteristics indicate an abrupt change in slope at V_i= V_R+ $V\gamma$ (breakpoint). When the input voltage is less than (V_R+ $V\gamma$), diode D is OFF and V_o= V_{in}, indicated by slope 1. When the input voltage is greater than (V_R+ $V\gamma$) (to the right of the breakpoint), the characteristics is a line with slope $\frac{Rf}{Rf+R}$ given by the Eq. 4.

Since $R_f << R$ and $V\gamma << V_R$. Eq. 4 reduces to

$V_o = V_R + V\gamma$.

Thus the output waveform is found to have “clipped off” the positive peak above (V_R+ $V\gamma$).

Series clipper: These are the clipping circuits in which the diode is connected in series with the load (see Fig. 2(a)).

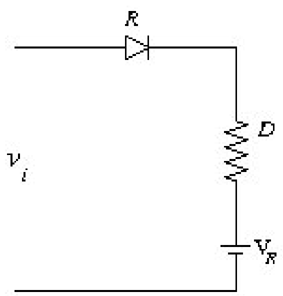

Figure 2(a)

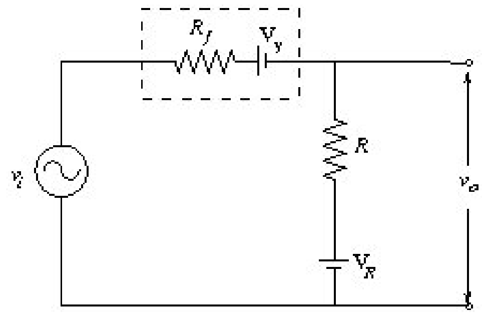

Figure 2(b)

Here, the cathode of the diode is held at V_R. .So, the diode conducts for $V_i > V_R + V\gamma$. Applying KVL to the circuit in Fig. 2(b),

$V_i =$ i. $(R_f + R) + V\gamma + V_R$

$i = \frac{V_i - V_\gamma - V_R}{R + R_f}$

$V_o = i.R + V_R$

$V_o = \frac{Vi - V\gamma - V_R}{R + Rf} . R + V_R$

$V_o = \frac{R}{Rf+R} V_i + \frac{Rf}{Rf+R} V_R - \frac{R}{Rf+R} V_\gamma$

Since $R >> R_f$, $\frac{Rf}{Rf+R} V_R \approx 0$, and $\frac{R}{Rf+R} \approx 1$

Hence, $V_o = V_i - V\gamma$.

For $V_i < V_R + V\gamma$ the diode does not conduct (i = 0),

$Vo = V_R$.

Thus, that portion of the waveform is transmitted which lies above V_R.

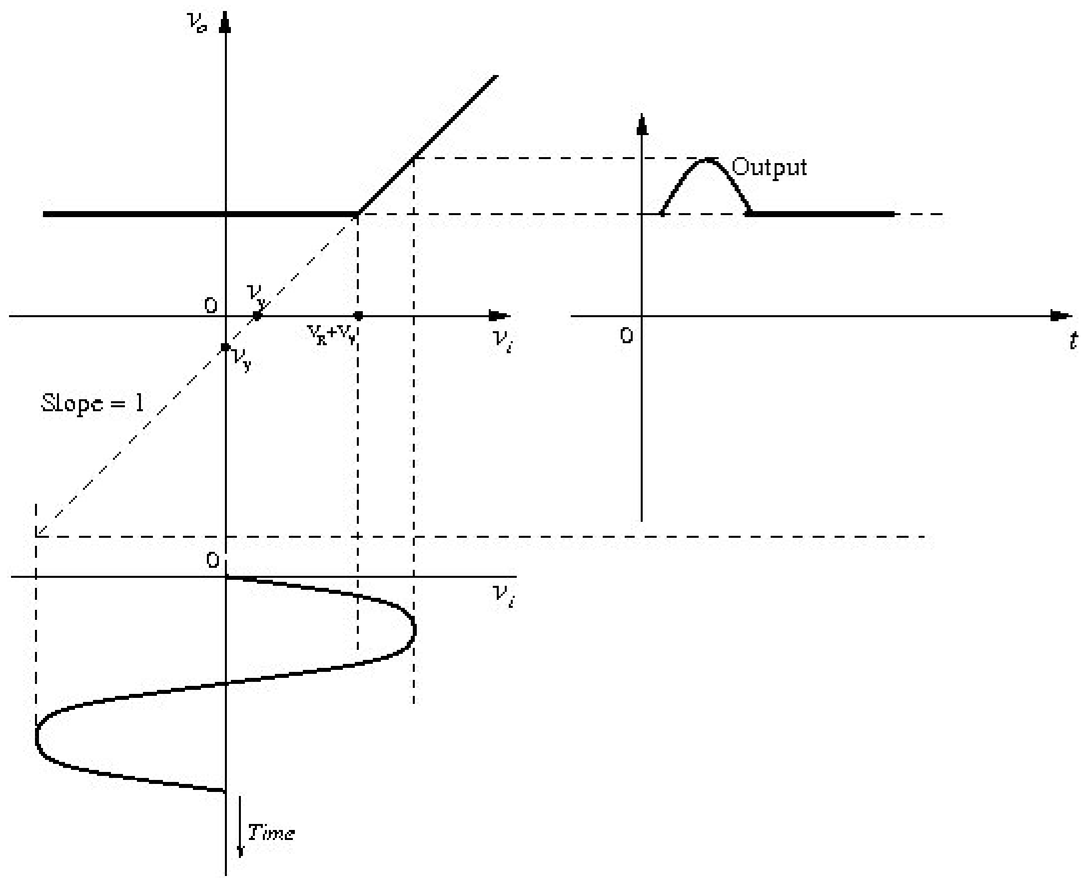

Figure 2(c)

Clamper Circuit

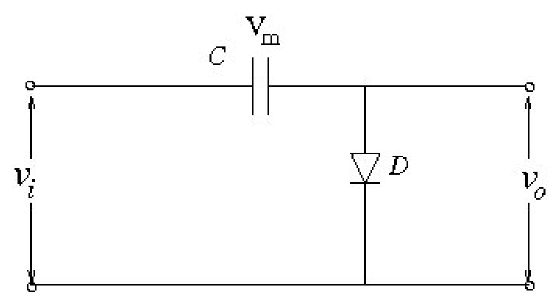

Figure 3(a)

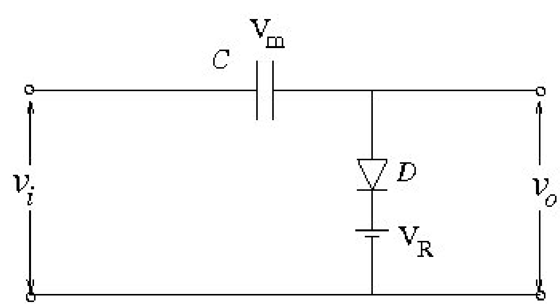

Figure 3(b)

Clamping circuits are used to hold either positive or negative extremity to a reference voltage level. Fig. 3(a) shows the clamper circuit that clamps the positive peak at zero level. The capacitor charges to V_m i.e. the peak value of the input signal during the first quarter positive cycle of the input signal. After the first positive peak, the input voltage starts falling. Since the capacitor has no path for discharge, it will hold $+V_m$ across it preventing the diode to conduct. The output voltage is then given by $V_O = V_{in} - V_m$. Thus, whenever positive peak occurs, ($V_{in} = V_m$), the output is clamped to zero volts.

In Fig. 3(b), by inserting a reference voltage between the cathode of the diode and common, the positive extremity is held at $+V_R$ level. In this case, the capacitor charges to voltage $V_m - V_R$. This gives rise to $V_O = V_{in} – (V_m - V_R)$.