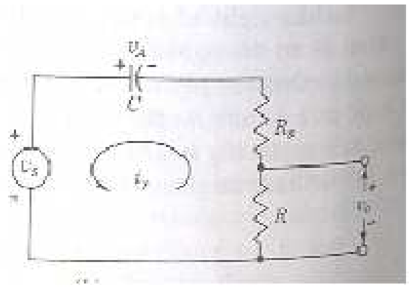
**Expressions for tilts in the output waveform:**
**(relation between tilts in the out put waveform)**

Consider $\Delta f$ & $\Delta r$ are the tilts in the output waveform when the diode is in conducting & non conducting states.

From the output waveform, $\Delta f = V_1 - V_1'$ and $\Delta r = V_2' - V_2$

At $t = 0^-$ , $V_s = V''$ and $V_o = V_2'$ , diode is OFF then the circuit diagram is redrawn as shown below,



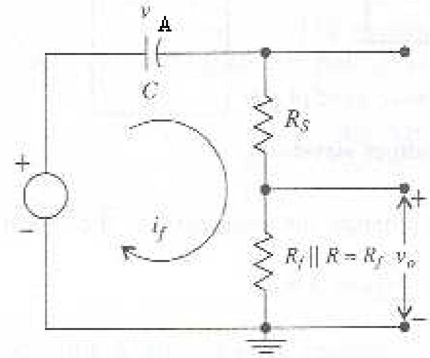

By applying KVL to the loop ,

$-V_s - i_r ( R + R_S) + V_A = 0$

$V_A = V_s - (V_o/R) ( R + R_S)$

So $V_A = V'' - V_2' [ ( R + R_S) /R]$-------(1)

At $t = 0^+$ , $V_s = V'$ and $V_o = V_1$ , diode is ON then the circuit diagram is redrawn as shown below,




By applying KVL to the loop ,

$V_s - i_f ( R_f + R_S) - V_A = 0$

$V_A = V_s - (V_o/R_f) ( R_f + R_S)$

So $V_A = V' - V_1 [ ( R_f + R_S) /R_f]$-------(2)

We know voltage across the capacitor can not changes instataneously. hence Voltage across the capacitor at $t= 0^-$ and at $t = 0^+$ are equal.

From equations (1) & (2),

$V' - V'' = V_1 [ ( R_f + R_S) /R_f] - V_2' [ ( R + R_S) /R]$

Since the peak to peak input amplitude is $V = V' - V''$

Then the above equation will becomes,

$V = V_1 [ ( R_f + R_S) /R_f] - V_2' [ ( R + R_S) /R]$ ----(3)

In a similar manner ,by considering conditions at $t= T^-$ and at $t = T^+$ we obtain

$V = V_1' [ ( R_f + R_S) /R_f] - V_2 [ ( R + R_S) /R]$ ----(4)

Since in the interval $T_1$ the diode is conducting, the output decays with a time constant

$(R_f + R_S)C$. hence

$V_1' = V_1 \, e^{-T1/(Rf + RS)C}$ --------(5)

Similarly, during the interval $T_2$ the diode is reverse biased and the circuit time constant is $(R + R_S)C$. so that

$V_2' = V_2 \, e^{-T2/(R + R_S)C}$ --------(6)

By solving equations 3 to 6 we can obtain all the voltage levels.

Now ,by subtracting equation (3) from (4),

$(V_1 – V_1') \, [(R_f + R_S)/R_f] – (V_2' - V_2) \, [(R + R_S)/R] = 0$

From equations (1)&(2)

$\Delta f \; [(R_f + R_S)/R_f] = \Delta r \, [(R + R_S)/R]$

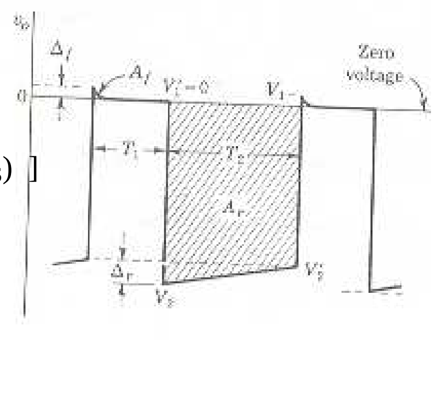
**Practical clamping circuit :**

Clamping circuit does not provide exact clamping in all the cases. In the above analysis we expect that positive edge of input signal should be clamped to zero and also output waveform must be same as input. But as per our analysis we are not getting exact waveform.

In the above analysis ,if $\mathbf{V_1' = V_1 = 0}$ and

$\mathbf{V_2' = V_2 = V}$ then it is said to be perfect clamping.

To achieve perfect clamping the necessary condition is




$\mathbf{(R_f + R_S)C << T_1}$ **and** $\mathbf{(R + R_S)C >> T_1}$

If $(R_f + R_S)C << T_1$ then from equation(5), $\mathbf{V_1' = 0}$
And from equation(4) , $V_2 = -V \, [R/(R + R_S)]$

Generally Rs is small compared to R , so $\mathbf{V_2 = -V}$

If $(R_f + R_S)C >> T_2$ then from equation(6), $\mathbf{V_2' = V_2 = -V}$
and from equation(3) $\mathbf{V_1 = 0}$

**Clamping circuit theorem :**

**statement :** In the steady state, the area $A_f$ under the output voltage waveform in the forward direction (when the diode conducts) is related to the area $A_r$ in the reverse biased direction (when the diode does not conduct) by the relationship

$$\mathbf{A_f / A_r = R_f / R}$$

**Proof:** the necessary circuit diagrams and waveforms are there in the topic of square wave input to the clamping circuit. Refer those.

consider $V_f(t)$ is the output voltage in the forward direction and $V_r(t)$ is the output voltage in the reverse direction.

During the interval 0 to $T_1$ , diode is in conducting state so capacitor will tries to charge.
Here capacitor charging current is $i_f(t) = V_f(t) / R_f$

Therefore the charge acquired by the capacitor during the interval 0 to $T_1$ is

$$Q = \int_0^{T1} i_f(t)\ dt = (1/R_f) \int_0^{T1} V_f(t)\ dt$$

$$Q = A_f / R_f \text{ ------(1)}$$

During the interval $T_1$ to $T_1 + T_2$ , diode is in non conducting state and here capacitor will tries to discharge.
Here capacitor discharging current is $i_r(t) = V_r(t) / R$

Therefore the charge lost by the capacitor during the interval $T_1$ to $T_1 + T_2$ is

$$Q = \int_{T1}^{T1+T2} i_r(t)\ dt = (1/R) \int_{T1}^{T1+T2} V_r(t)\ dt$$

$$Q = A_r / R \text{ ------(2)}$$

In the steady state , the net charge acquired by the capacitor must be zero. Therefore by equating equations(1) &(2) ,

$$\mathbf{A_f / A_r = R_f / R}$$

Hence proved.