Analog Circuits

For

EC / EE / IN

By

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Syllabus for Analog Circuits

Small Signal Equivalent Circuits of Diodes, BJTs, MOSFETs and Analog CMOS. Simple Diode Circuits, Clipping, Clamping, Rectifier. BIASING and Bias Stability of Transistor and FET Amplifiers. Amplifiers, Single-and Multi-Stage, Differential and Operational, Feedback, and Power. Frequency Response of Amplifiers. Simple Op-Amp Circuits. Filters. Sinusoidal Oscillators, Criterion for Oscillation, Single-Transistor and Op-Amp Configurations. Function Generators and Wave-Shaping Circuits, 555 Timers. Power Supplies.

Previous Year GATE Papers and Analysis

GATE Papers with answer key

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Subject wise Weightage Analysis

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"Live as if you were to die tomorrow.
Learn as if you were to live forever."
.... **M. K. Gandhi**

CHAPTER 1 Diode Circuits - Analysis and Application

Learning Objectives

After reading this chapter, you will know

1. Wave Shaping Circuit
2. Clippers and Champers
3. Rectifiers and Power Supplies
4. Efficiency, Regulation, Ripple Frequency, Form Factor, Ripple Factor

Wave Shaping Circuits

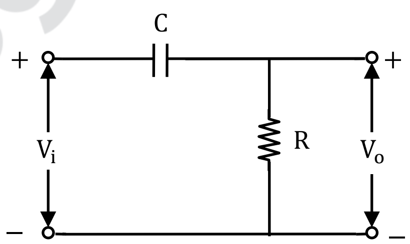
Wave shaping circuits are of two types

(A) Linear wave shaping circuits
(B) Non linear wave shaping circuits

Linear Wave Shaping Circuits

The process by which the wave form of non-sinusoidal signal is altered by passing it through the linear network is called the linear wave shaping.

High Pass Circuit



High Pass Circuit

This circuit is called the high pass filter because it passes the high frequency components and attenuates the low frequency components.
For low frequency, the reactance of the capacitance is large.

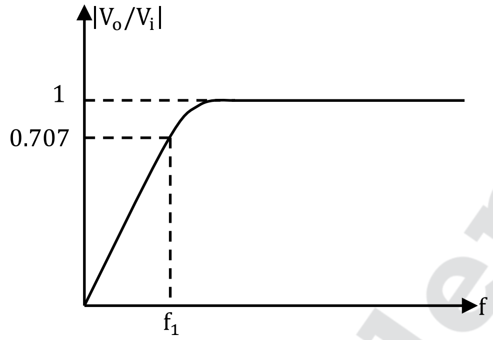
(a) Sinusoidal Input:

$$\frac{V_o}{V_i} = \frac{R}{R + 1/j\omega C} = \frac{1}{1 - j\frac{1}{\omega RC}}$$

$$\frac{V_o}{V_i} = \frac{1}{1 - j\left(\frac{f_1}{f}\right)}$$

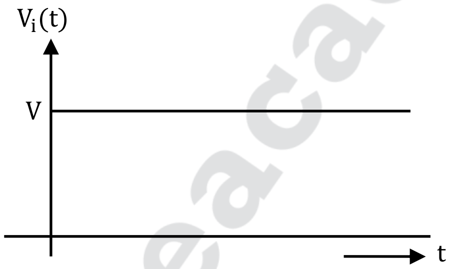
Where, $f_1 = \frac{1}{2\pi}RC$

$$\left|\frac{V_o}{V_i}\right| = \frac{1}{\sqrt{1 + \left({f_1}/{f}\right)^2}}, \angle\frac{V_o}{V_i} = -\tan^{-1}(-f_1/f) = \tan^{-1}(f_1/f)$$



Gain-Frequency Plot of High Pass Circuit

(b) Step Input:



Step Input

$V_i\,(t) = V_c(t) + V_o(t)$, ... (1)

$V_i(t) = 1/C \int i\,dt + V_o(t) = iR$, ... (2)

So $V_i(t) = 1/RC \int V_o(t)\,dt + V_o(t) = V\,u(t)$.......... (3)

For step input $V_i(t) = \begin{cases} V \text{ for } t \geq 0 \\ 0 \text{ other wise} \end{cases}$

It is a single time constant circuit and a first order equation is obtained.

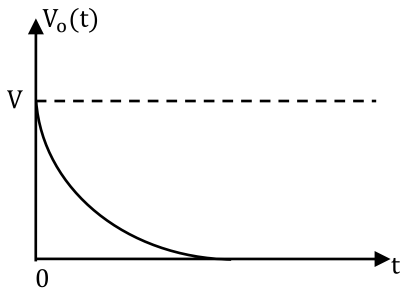
The general solution of any single time constant circuit can be written as,

$V_o(t) = V_f + (V_i - V_f)e^{-t/\tau}$, ... (4)

Here, $V_f = 0$; $V_i = V$, $V_o\,(t) = Ve^{-\frac{t}{\tau}}$

Where $\tau = 1/RC$

For the circuit in high pass circuit fig, $V_f = 0$ and $V_i = V$substituting in E.q., (4), we have

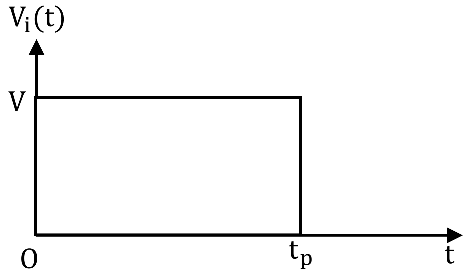


Output Voltage of High Pass Circuit When Input is a Step Voltage

(c) Pulse Input:

$V_i(t) = V[u(t) - u(t - t_p)]$

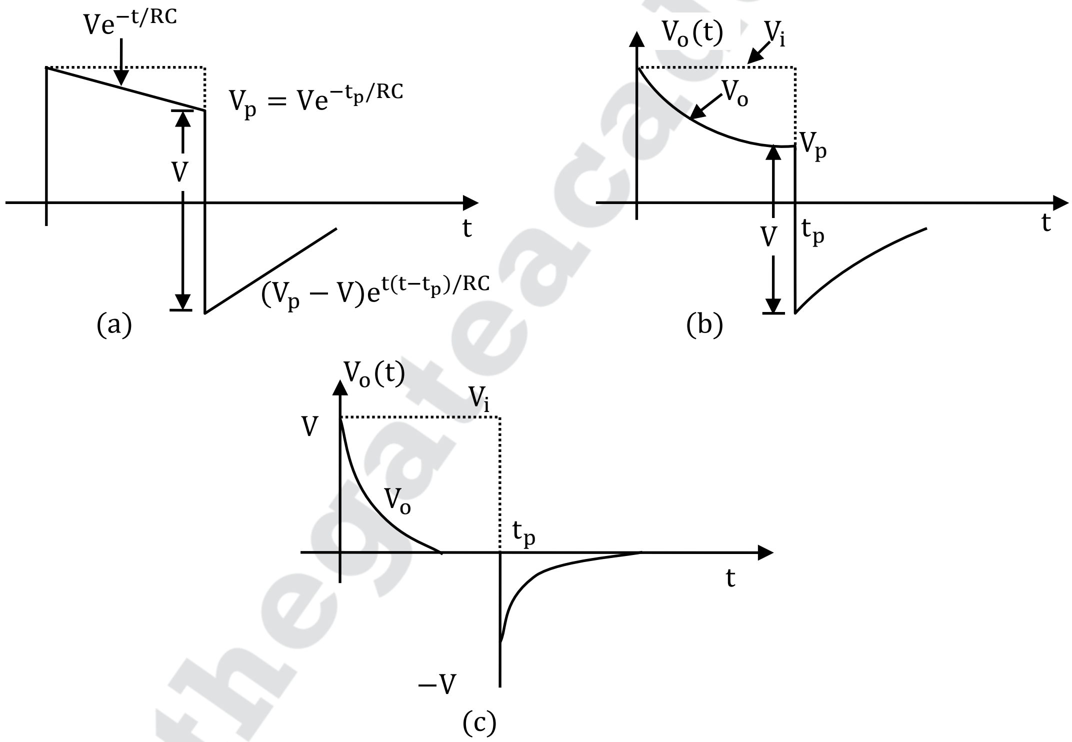
1. $V_o = Ve^{-t/\tau}, V_p = Ve^{-t_p/\tau}$
2. $V_o = V_2 e^{-(t-t_p)/\tau}, V_2 = V_p - V$



Pulse Input Signal

τ large $\Rightarrow$ Slow response and

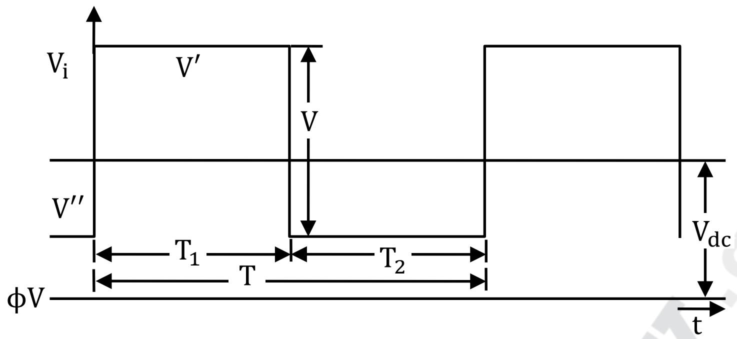
τ small $\Rightarrow$ Fast response



Output of High Pass Filter, When Input is a Pulse

For a low time constant the peak – to – peak amplitudes will be double. The process of converting pulses into spikes by means of a low time constant is called peaking. In high pass RC circuit, the average level of the output is always zero. The area above the zero axis should be equal to the area below the zero axis, $A_1 = A_2$.

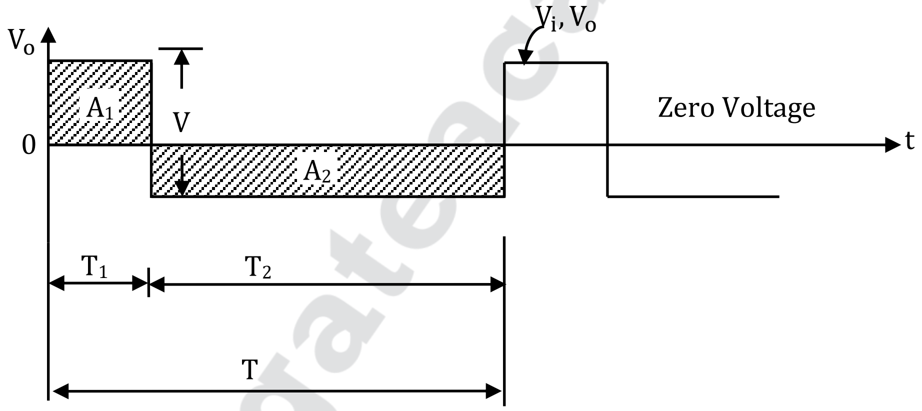
(d) Square Wave Input:



(a) Square Wave Input

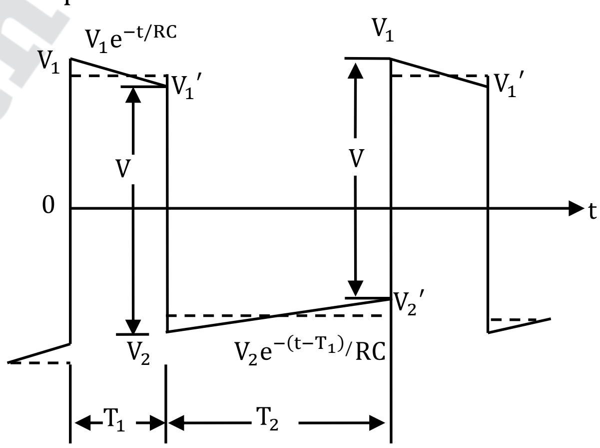
A square wave is a waveform as shown in fig (a) which is periodic with time period T such that it maintains a level V' for time T_1 and $V''$for time T_2 where $T = T_1 + T_2$.
Figure (b) (c) (d) and (e) show output wave forms of the high pass RC circuit under steady-state conditions for the cases (i) RC>>T (ii) RC>T (iii) RC=T and (iv) RC<<T

Case (i): For arbitrarily large time constant value, the output is same as that of input but with zero dc level.



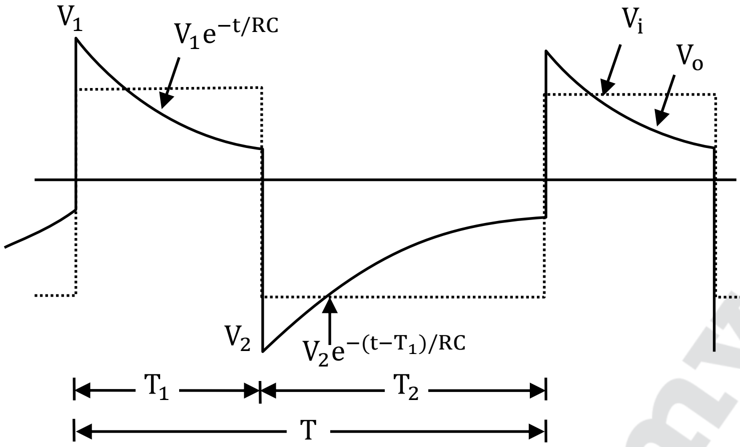
(b) Output When RC is Very Large

Case (ii): When RC>T, the output is in the form of a tilt.



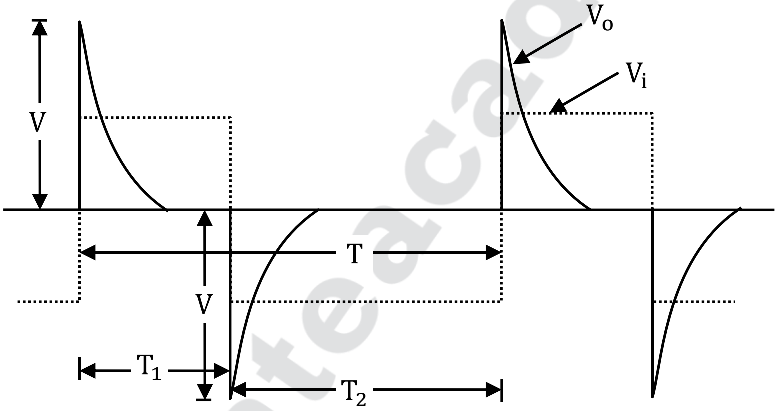
(c) Output When RC>T

Case (iii): When RC is comparable to T, the output rises and falls exponentially.



(d) Output When RC is Comparable to T

Case (iv): When RC<<T, the output consists of alternative positive and negative spikes.



(e) Output When RC <<T

More generally the response to a square wave must have the appearance shown below:

The four levels V_1, V_1', V_2, V_2' can be determined from (refer below figure)

$V_1' = V_1 e^{-T_1/\tau}, V_1' - V_2 = V$

$V_2' = V_2 e^{-T_2/\tau}, V_1 - V_2' = V$

For symmetrical square wave

$T_1 = T_2 = T/2$

$V_1 = -V_2, V_1' = -V_2$ and the response is shown below in Fig. (b)

Percentage tilt 'P' is defined by

$$P = \frac{V_1 - V_1'}{V/2} \times 100 \approx \frac{T}{2\tau} \times 100\ \%$$

$$= \frac{\pi f_1}{f} \times 100\ \%$$

Where $f_1 = \dfrac{1}{2\pi\tau}$ and $f = \dfrac{1}{T}$

(e) Ramp Input

$V_i(t) = \alpha\, t\, u(t)$ and $V_o(t) = \alpha\, \tau\, (1 - e^{-t/\tau})$, are shown below,

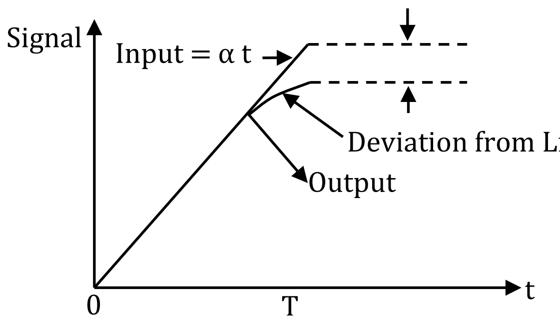


Fig (a)

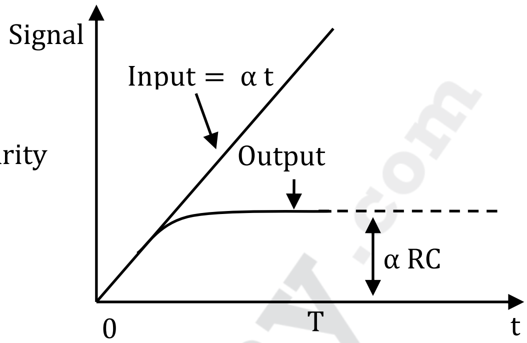


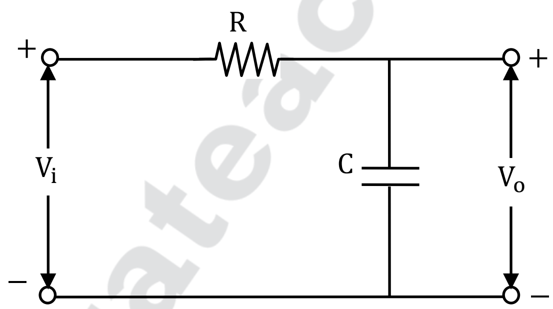
Fig (b)

(a) Response of a High Pass RC Circuit to a Ramp Voltage for RC/T >> 1;
(b) Response to a Ramp Voltage for RC / T << 1

For $t << \tau$, as a measure of departure from linearity, transmission error, e_t is defined as

$$e_t = \frac{V_i - V_o}{V_i}, \quad \text{At } t = T, e_t \approx \frac{T}{2\tau} = \pi f_1 T$$

Low Pass Filter



Low Pass Circuit

This circuit allows the low frequency components and attenuates the high frequency components.

$$X_c = \frac{1}{j\omega c} = \frac{1}{j2\pi fc}$$

At low frequency $(f \rightarrow 0)$; $X_c \rightarrow \infty$

At high frequency $(f \rightarrow \infty)$; $X_c \rightarrow 0$

So at low frequency capacitor behaves like open circuit so low frequency component passes to o/p

(a) Sinusoidal Input

$$\left|\frac{V_o}{V_i}\right| = \frac{1}{\sqrt{1 + (f/f_2)^2}}$$

$$\angle V_o / V_i = -\tan^{-1}\left(\frac{f}{f_2}\right), \text{where } f_2 = 1/(2\pi RC)$$