Subject: Electronic Devices and Circuits

(a) Course Objectives:

- To provide an overview of the principles and operation of electronic devices.
- To explore use of electronic devices for various applications in electronic circuits.
- To analyze various electronic circuits.

(b) Course Outcomes(Proposed):

After successfully completing the course, the students will be able to

- **CO1:** Comprehend the knowledge of semiconductor devices(Diode, BJT, JFET, MOSFET, UJT), rectifiers, filters, amplifiers & oscillator circuits
- **CO2:** Understand basics of Diode, BJT, JFET, MOSFET, UJT, Rectifier, filters, Amplifiers, Oscillators with analysis of their characteristics and operational parameters.
- **CO3:** To understand Biasing, feedback concept, topologies and their applications.
- **CO4:** Implement and analyze various electronic circuits..

Subject: Electronic Devices and Circuits

Unit-2

Wave shaping* : *Analysis of RC low pass and high pass filters for sinusoidal, step, pulse, square signal. *Analysis of clipping and clamping circuits using diodes*

Unit-II: WAVE SHAPING CIRCUITS-

Lectures required	Topic	Books
	Wave shaping circuits	
L1-L3	RC low pass and high pass circuits-	T1,T2
L4-L5	Clippers-	T2, T1
L6-L7	Clampers	

Subject: Electronic Devices and Circuits

Unit2: WAVE SHAPING CIRCUITS

Part-I WAVE SHAPING CIRCUITS: **RC CIRCUITS**

- ✓ Definition of wave shaping circuit
- ✓ Purpose of wave shaping circuits
- ✓ Types of wave shaping circuits
- ✓ Analysis of High pass & low pass RC circuits

Part-II CLIPPER CIRCUITS

- ✓ Definition of Clipping circuit
- ✓ Purpose of Clipping circuits
- ✓ Types of Clipping circuits
- ✓ Analysis of Clipping circuits

Part-III CLAMPING CIRCUITS

- ✓ Definition of Clamping circuit
- ✓ Purpose of Clamping circuits
- ✓ Types of Clamping circuits
- ✓ Analysis of Clamping circuits

Waveshaping circuits

Prerequisite

- Fundamentals of PN Junction Diode
- Biasing and Operation of the Diode
- VI Characteristics of Diode
- Ideal and Practical Parameters
- Basics of standard signals
- Basics about Electrical circuit elements (R,L,C)

Wave shaping circuits-

Wave shaping circuits means:

A process by which non-sinusoidal waveforms are altered in passing through the circuit elements (such as diodes, resistors, inductors, capacitors) is called wave shaping and circuit used for this purpose is referred as wave shaping circuits.

The wave shaping is used to perform following functions:

i) To generate one wave from the other

ii) To limit the voltage level of the waveform to some preset value and suppressing all other voltage levels in excess of the preset level

iii) To cutoff the positive and negative portions of the input waveforms

iv) To hold the waveform to a particular dc level

The wave shaping is important in most of the signal processing systems…

Wave shaping circuits

The wave shaping is performed by the circuits known as-

- **Low pass RC circuit(LPF, Integrators when τ >> T)**
- **High pass RC circuit(HPF, Differentiators when τ << T)**
- Limiters circuits
- Clipper circuits
- Clamper circuits

Wave shaping circuits

The wave shaping is performed by the circuits known as-

- Low pass RC circuit(LPF, Integrators)- To generate a voltage, which increases or decreases linearly with time (ramp signal)
- High pass RC circuit(HPF,Differentiators)- To generate sharp narrow pulses either from rectangular waveforms or distorted pulse waveforms
- Limiters circuits-To limit the voltage level of the waveform to some some preset value and suppressing all other voltage levels in excess of this preset levels, it is also called amplitude limiters
- Clipper circuits- To cut-off the positive and negative portion of an input waveforms
- Clamper circuits- It is used to hold or restore the waveform to a particular dc level or used to change average value of sinusoidal signal

Wave shaping circuits

Different non-sinusoidal signal wave shapes or waveforms used in signal processing systems

non-sinusoidal signal wave shapes or waveforms are nothing but any waveform whose shape is different from that of a standard **sinusoidal wave**

Important non-sinusoidal signal waveforms:

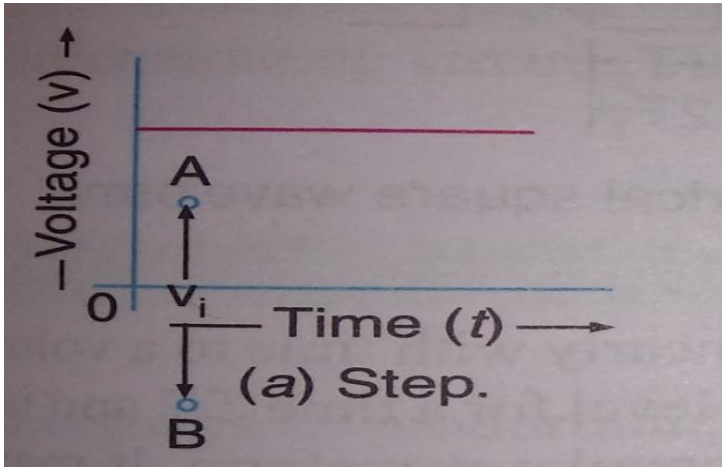
- Step waveforms
- Pulse waveforms
- **Square waveforms**
- Symmetrical square waveforms
- Triangular waveforms
- Saw tooth waveforms

All these waveforms are a part of standard voltage or current signal such as step, ramp and exponential signals

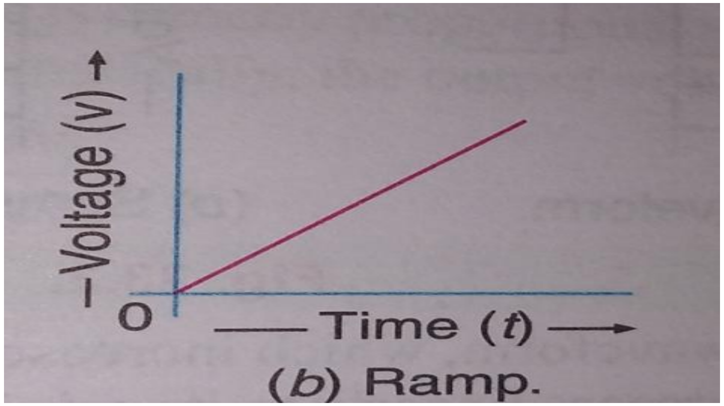
Wave shaping circuits

Standard voltage or current signal such as-

- Step signal- maintains V = 0 for all times t < 0 and maintains voltage level V for all times t > 0(V = some value), transition takes place at t = 0



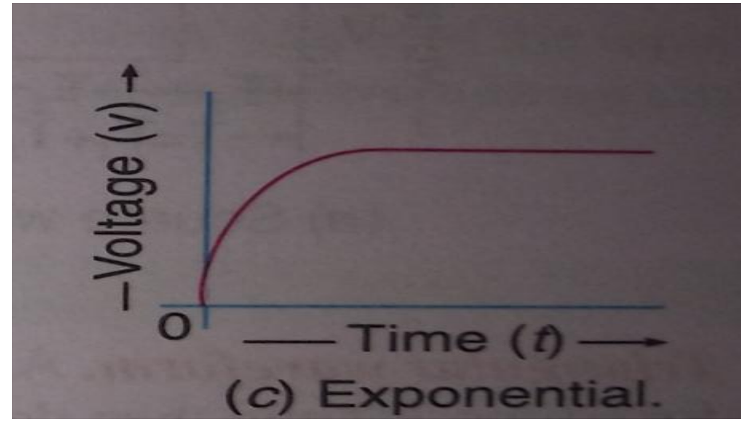
- Ramp signal- maintains zero voltage level for t < 0(V = 0) and increases linearly with time for t > 0 (V = α . t)



Wave shaping circuits

Standard voltage or current signal such as-

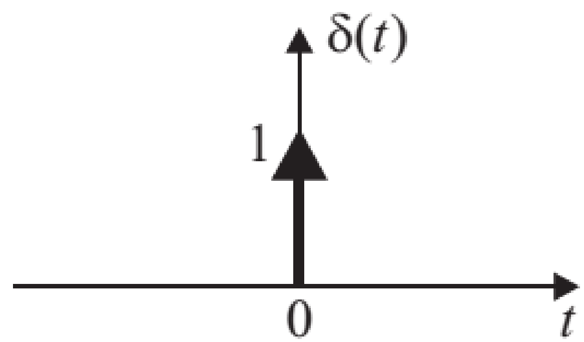
- Exponential signals- maintains $V = 0$ for $t < 0$ and increases nonlinearly with time for $t > 0$ that is $V = V_i e^{-t/\tau}$



(c) Exponential.

- The impulse signal is a signal with infinite magnitude and zero duration, but with the unit area.

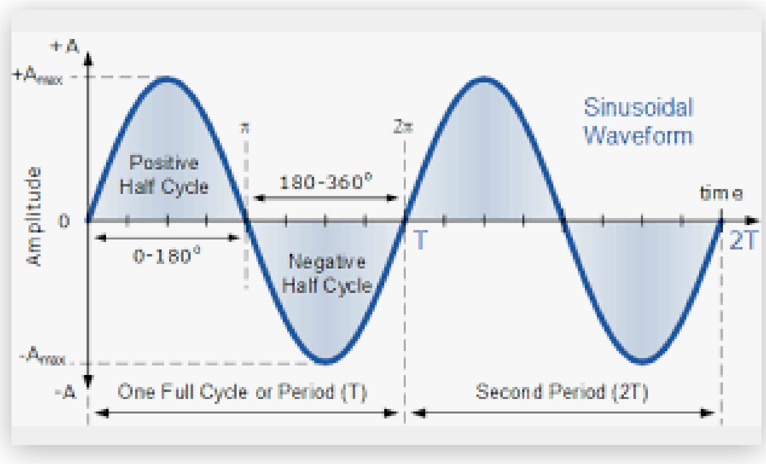
  The unit impulse function is also known as the Dirac delta function.



$$\delta(t) = \begin{cases} \infty & \text{at} \quad t = 0 \\ 0 & \text{at} \quad t \neq 0 \end{cases} \quad \text{and} \quad \int_{-\infty}^{\infty} \delta(t)\,dt = 1$$

Wave shaping circuits

Sinusoidal signals: Sine waves,



Important non-sinusoidal signal waveforms

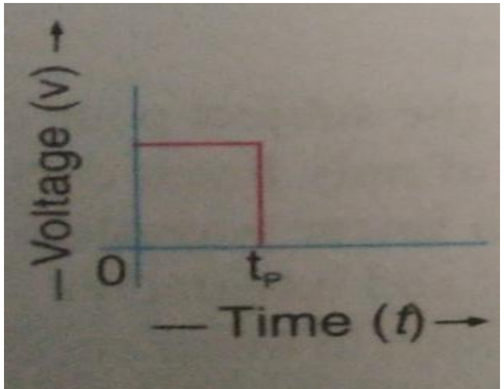
- Pulse waveforms-
- Square waveforms-
- Symmetrical square
- Triangular waveforms-
- Sawtooth waveforms-

Wave shaping circuits

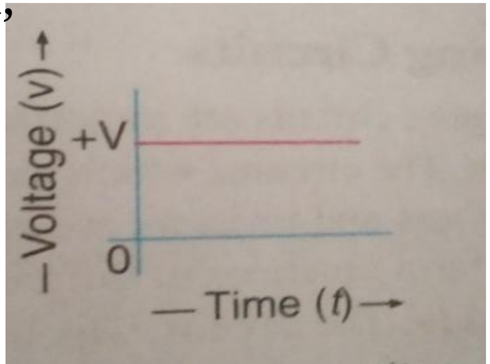
Important non-sinusoidal signal waveforms:

Pulse waveforms-

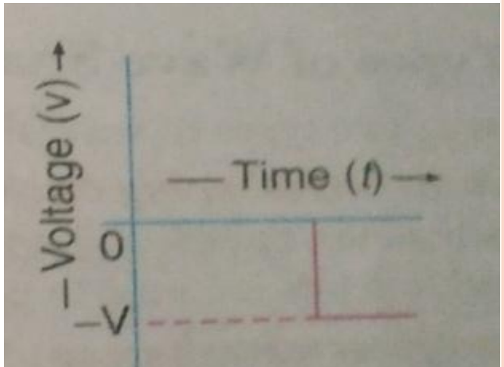
- Pulse amplitude is V and Pulse duration is tp,
- It is sum of the Positive and Negative step signal,
- used in communication, computers, defence equipments, etc



(a) Pulse.



(b) Positive step voltage.



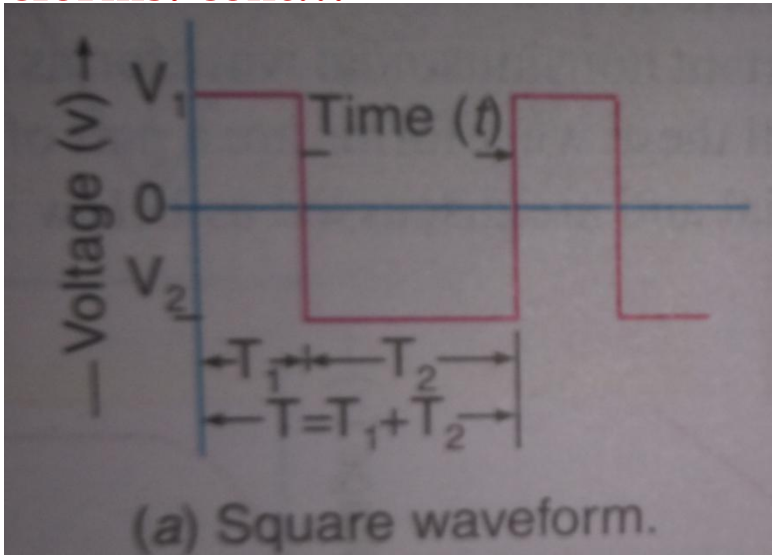
(c) Negative step voltag

Wave shaping circuits

Important non-sinusoidal signal waveforms: cont…

- **Square waveforms-**

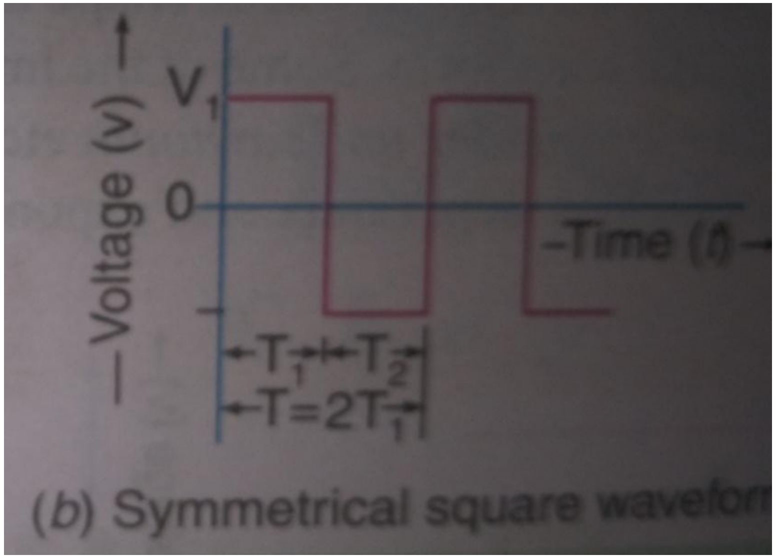
It maintains one constant voltage level(+V for t=T1) and another constant voltage level(-V2 for t=T2), it is a periodic waveform with t=T1+T2, used in Digital electronics circuits, radars, Television



(a) Square waveform.

- **Symmetrical sq. waveforms**

A square wave with T1=T2=T/2 and V1= -V2, 50% duty cycle, it is a periodic waveform with t=T1+T2 ,used in Digital electronics circuits



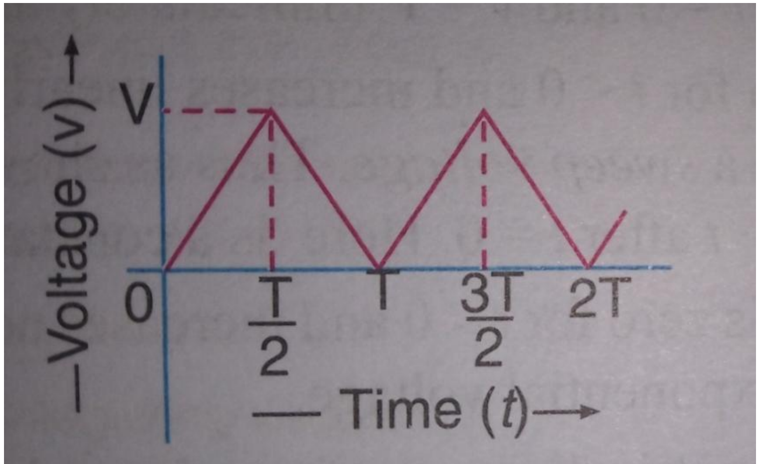
(b) Symmetrical square wavefor

Wave shaping circuits

Important non-sinusoidal signal waveforms: cont…

- **Triangular waveforms-**

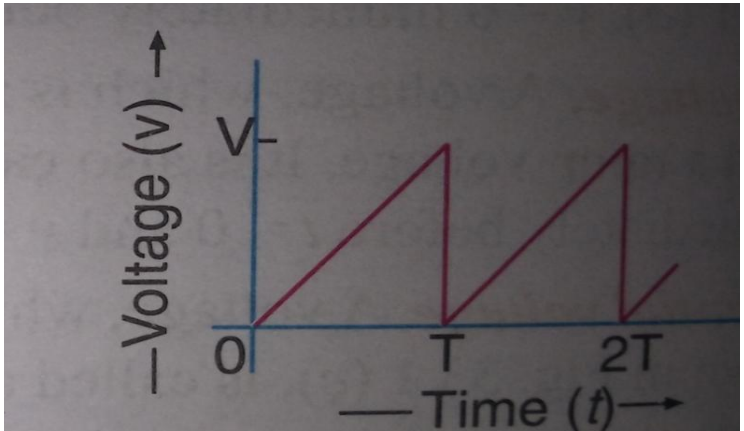
Increases linearly with time to a voltage level V for t=T/2 and then decreases linearly to its original level for t=T/2, it is a sum of positive and negative ramp signal, it is a periodic waveform with t=T1+T2 ,use as timing circuits for electronics applications



(a) Triangular waveform.

- **Sawtooth waveforms-**

Increases linearly with time to a voltage level V for t=T/2 and then changes abruptly to its original level, it is a periodic waveform with t=T1, it is referred as sweep or time base waveforms.



(b) Sawtooth wavefor

Types of Wave shaping circuits

Types of Wave shaping circuits: Linear & Non Linear

- **Linear wave shaping circuits-**
  - The process in which the form of nonsinusoidal signals(such as step, pulse, square wave, ramp and exponential signals) gets altered by transmission through a linear circuit(described by linear differential equation, $Vo = Ri(t)+L\,di/dt+1/C \int idt$) is called linear wave shaping
  - Using only linear circuit elements(Resistors, Capacitors, Inductors)
  - Use to perform functions of Integration & differentiation
- Non linear wave shaping circuits-
  - Using non linear circuit elements(diode, transistors)
  - Use to perform functions of amplitude limiting, clipping and clamping

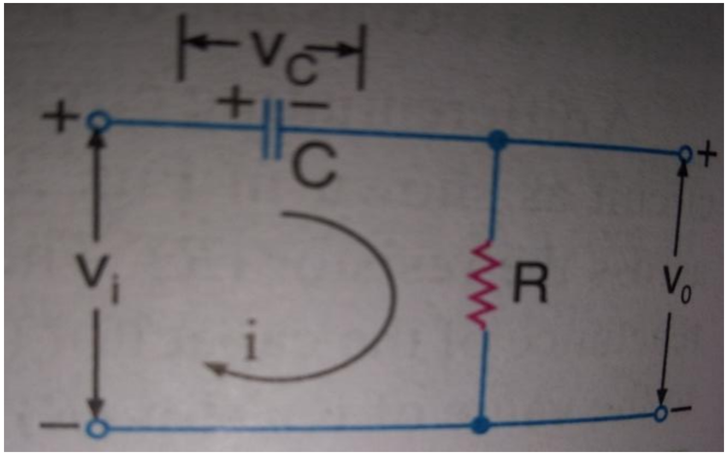
Subject: Electronic Devices and Circuits

Unit2: WAVE SHAPING CIRCUITS :Part-I

- ✓ Introduction to waveshaping circuits
- ✓ Definition of wave shaping circuit
- ✓ Purpose of wave shaping circuits
- ✓ Standard signal waveforms
- ✓ Derived signal waveforms
- ✓ Types of wave shaping circuits
- ✓ Analysis of High pass RC Circuits
- ✓ Analysis of Low pass RC circuits

Linear wave shaping circuits

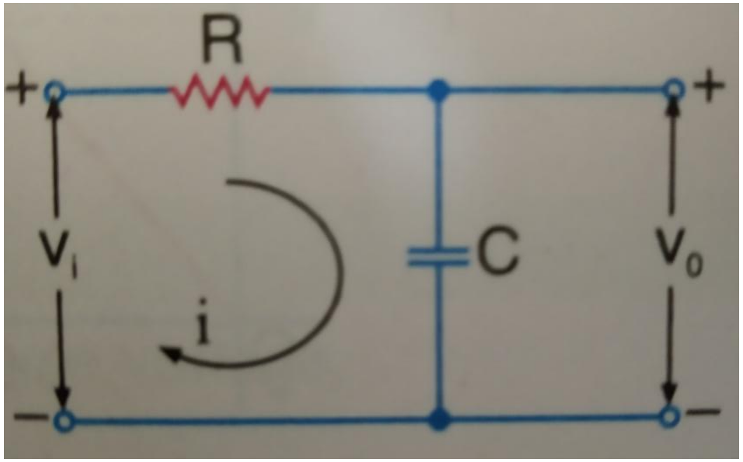
- **High pass RC circuits**
  - High Pass Filter,
  - as Differentiator- τ(RC) << T



$$Xc = \frac{1}{2\pi fC}$$

- f = 0, f = ∞

- **Low pass RC circuits**
  - Low pass filters
  - Use to perform functions of Integration, τ (RC)>> T

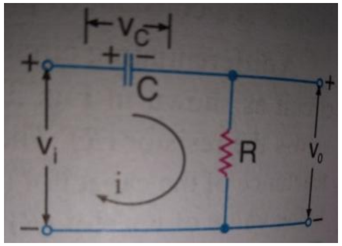


$$Xc = \frac{1}{2\pi fC}$$

f = 0, f = ∞

$\int idt$

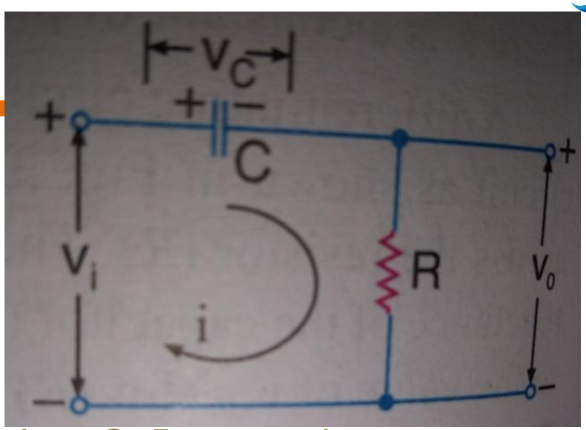
Linear wave shaping circuits



- **High pass RC circuits**
  - High Pass Filter,
  - as a Differentiator- **τ** (RC) << T

$\int idt$

Linear wave shaping circuits

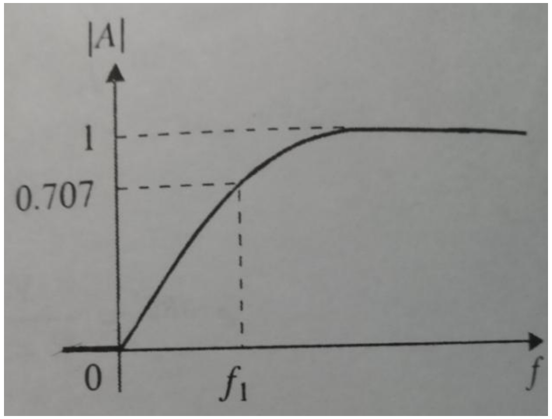


- **High pass RC circuits**
- **Low pass RC circuits**
- Referred as High pass and
  Low pass filters also
- Use to perform functions of differentiation & Integration

- 1. High pass RC circuits(hpf , use as differentiation (τ >T, ie low f))

$$Xc = \frac{1}{2\pi fC}$$

- $f = 0, Xc \rightarrow \infty$ acts as open circuit or blocks dc signal and
  $f = \infty, Xc \rightarrow 0$ as short circuit, that is it pass ac components
- as f increases, Xc decreases, o/p and magnitude of gain increases
- High frequency components in the i/p signal appears at the o/p with less attenuation as compare to low frequency components
- For HF capacitor acts as a short circuit and all the i/p appears at the o/p such behavior of the circuit referrers as High pass filter (HPF)



$\int idt$

High pass RC circuits: Sinusoidal Input

1. Sinusoidal Input

Expression for the lower cutoff frequency-

- **Vi = Vmsinωt**
- **i = Vi/(R-jXc)**
- **Vo = iR = Vi*R/(R-jXc)**

$$|A| = \left|\frac{Vo}{Vi}\right| = \frac{R}{R - jXc} = \frac{1}{1 - jXc/R}$$

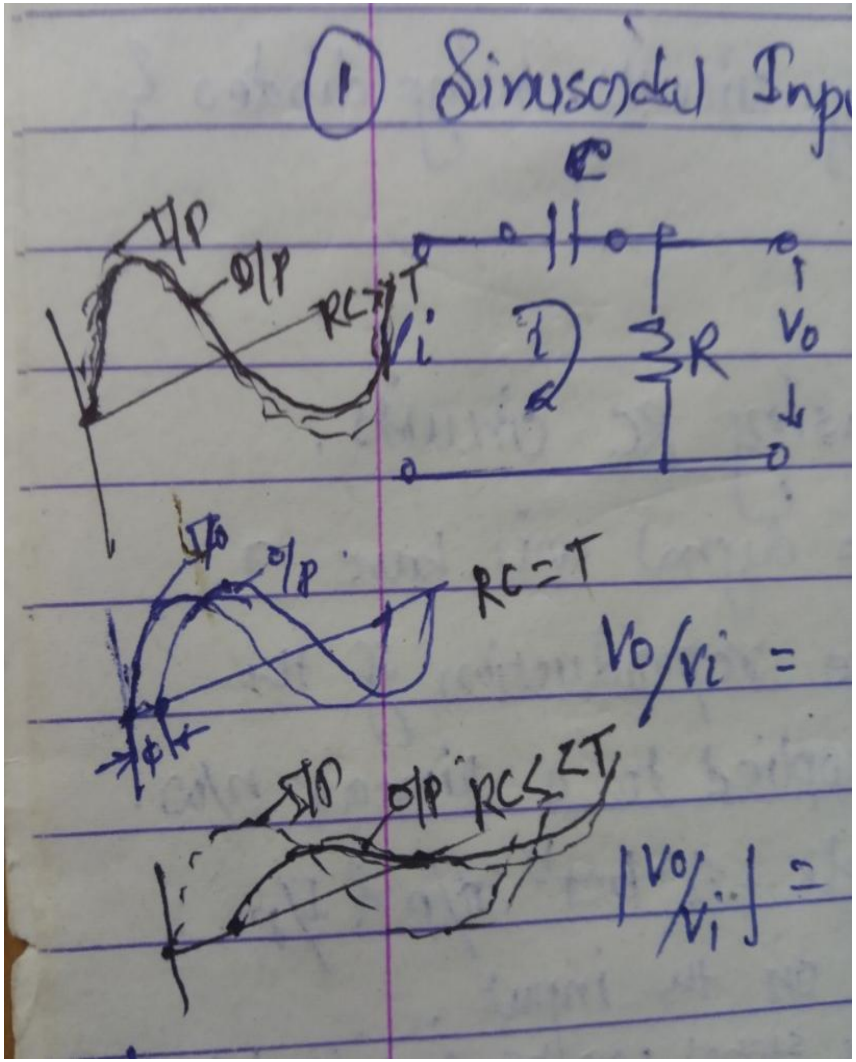
$$\left|\frac{Vo}{Vi}\right| = |A| = \frac{1}{\sqrt{1 + (Xc/R)^2}}$$

$$= \frac{1}{\sqrt{1 + (f1/f)^2}}$$

$$\theta = \tan^{-1}\frac{f1}{f}$$

$$f1 = \frac{1}{2\pi RC}$$

3db lower cutoff freq.



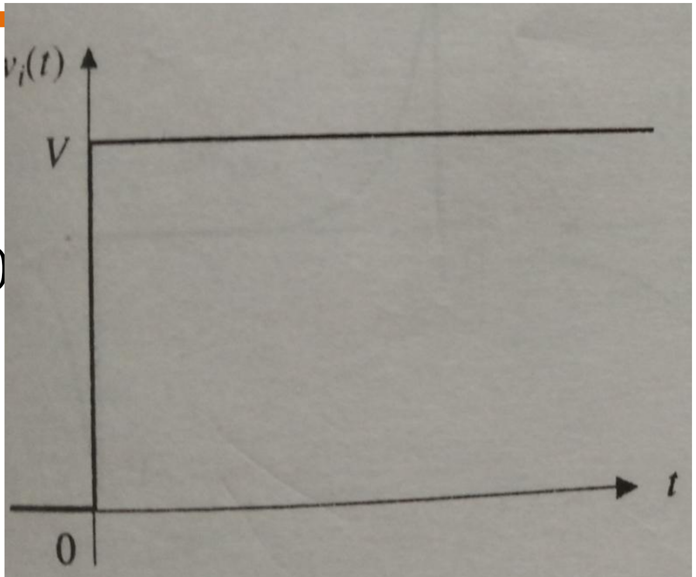
$\int idt$

High pass circuits: Step Input

2. Step Input

Vi = 0, t < 0 and Vi = V, t > 0

The transition between two voltage levels takes place at t = 0 Voltages at(t=0+,t=0-)



(a)

The response of High pass RC circuit is exponential with RC = τ and

$V0 = B1+B2e^{-t/\tau}$

Constant B1-steady state value of V0 as t--∞,

V0 = B1 = Vf

Constant B2 derived from

The initial value of V0 at t=0

V0 = Vi = B1 + B2

B2 = Vi – Vf

$V0 = Vf + (Vi - Vf)\, e^{-t/\tau}$

at steady state $V0 = V e^{-t/\tau}$

High pass circuits

cont…

i. Capacitor C blocks DC and input is constant for $t > 0$, therefore $Vo = Vf = 0$

ii. Voltage across capacitor Vc

$$Vc = \frac{1}{C}\int_{0}^{t1} i\,dt$$

iii. At $t= 0$ Vi changes abruptly from 0 to V value and hence output must also changes abruptly by this same amount

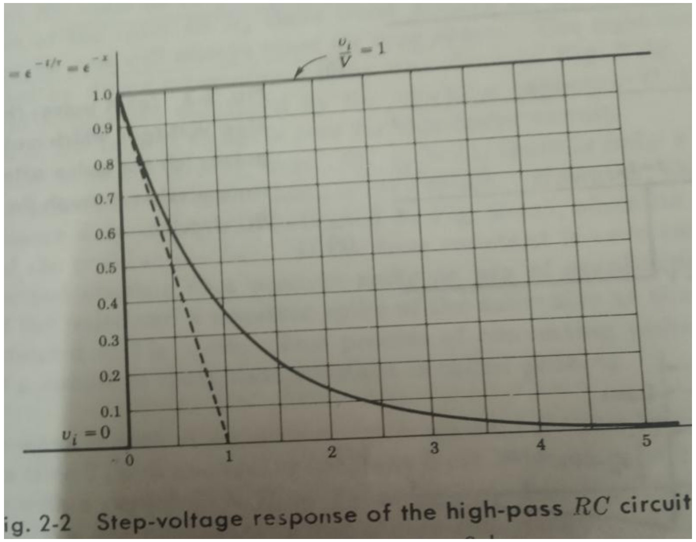


Fig. 2-2 Step-voltage response of the high-pass RC circuit

iv. Initially capacitor is fully uncharged
Therefore $V0 = Vinitial = 0$, at $t = 0+$ $Vi = V$

The response of High pass RC circuit is exponential with RC = τ and $V0 = Vf + (Vi - Vf)\, e^{-t/\tau}$

Therefore $V0 = 0 + (V - 0)\, e^{-t/\tau}$ so $V0 = Ve^{-t/\tau}$

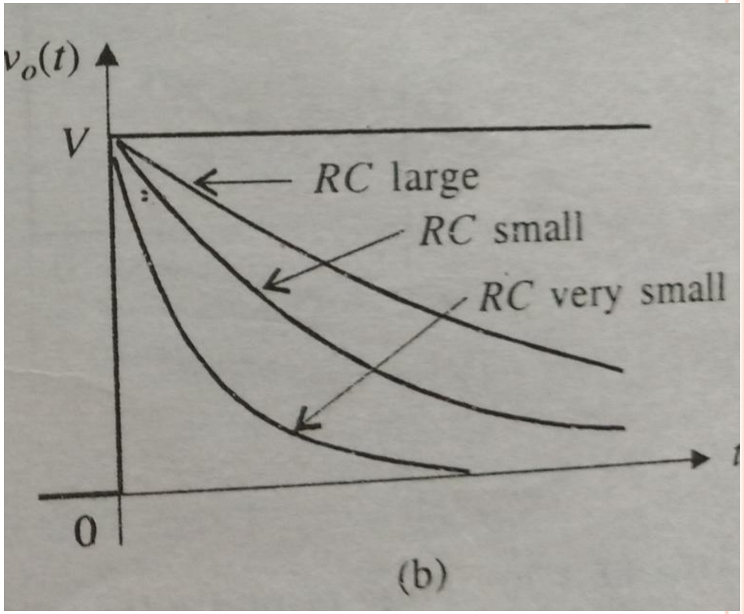
High pass circuits

cont…

i. RC >>

ii. RC comparable

iii. RC <<



The response of High pass RC circuit is exponential with RC = τ

Initially capacitor is fully uncharged

Therefore V0 = Vinitial = 0, at t = 0+ Vi = V

$V0 = Vf + (Vi – Vf)\, e^{-t/\tau}$

Therefore $V0 = 0 + (V – 0)\, e^{-t/\tau}$ so $V0 = Ve^{-t/\tau}$

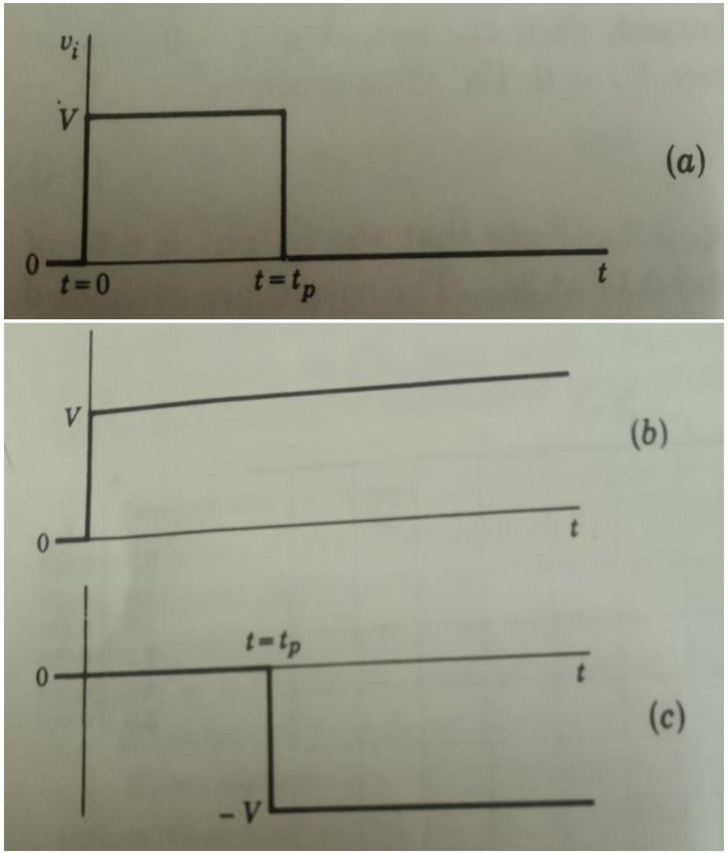
High pass circuits: Pulse Input

3. Pulse Input

- Pulse with Amplitude and Pulse duration tp
- It is the combination of +ve and Negative Step input

or

Pulse input signal is the Sum of +V step voltage whose discontinuity occurs at t=0 and –V step voltage whose discontinuity occurs t= tp



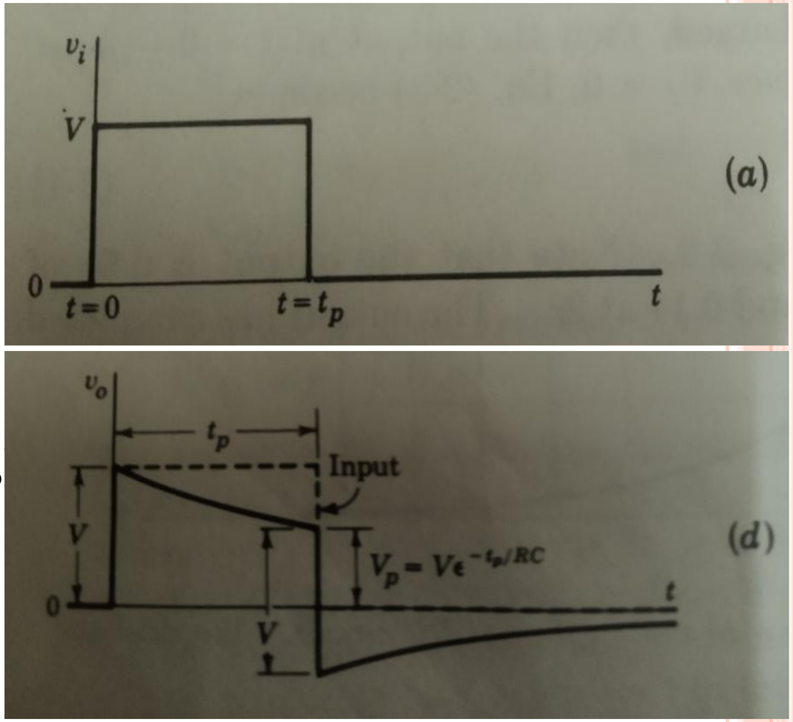
High pass circuits: Pulse Input

3. cont….

- pulse input is applied to High pass RC circuit then Response
  - i) for t < tp is similar to that for step input voltage

    V0 = $Ve^{-t/\tau}$

    = $Ve^{-tp/\tau}$ = Vp at t = tp
  - ii) at the end of pulse i/p falls abruptly by an amount V but the capacitor voltage cannot changes instantaneous finite current flow therefore output must drop by same amount ie V at t = tp, Vo = Vp-V (V > Vp)
  - iii) Vo is negative and then it decreases exponentially to zero with Vo= V($e^{-tp/RC}$ -1) = $Ve^{-(t-tp)/RC}$



$$Vc = \frac{1}{C}\int_0^{t1} idt$$

High pass circuits: Pulse Input

3. cont….

- **Pulse input is applied to High pass RC circuit then Response for Various Circuit Time constant RC**

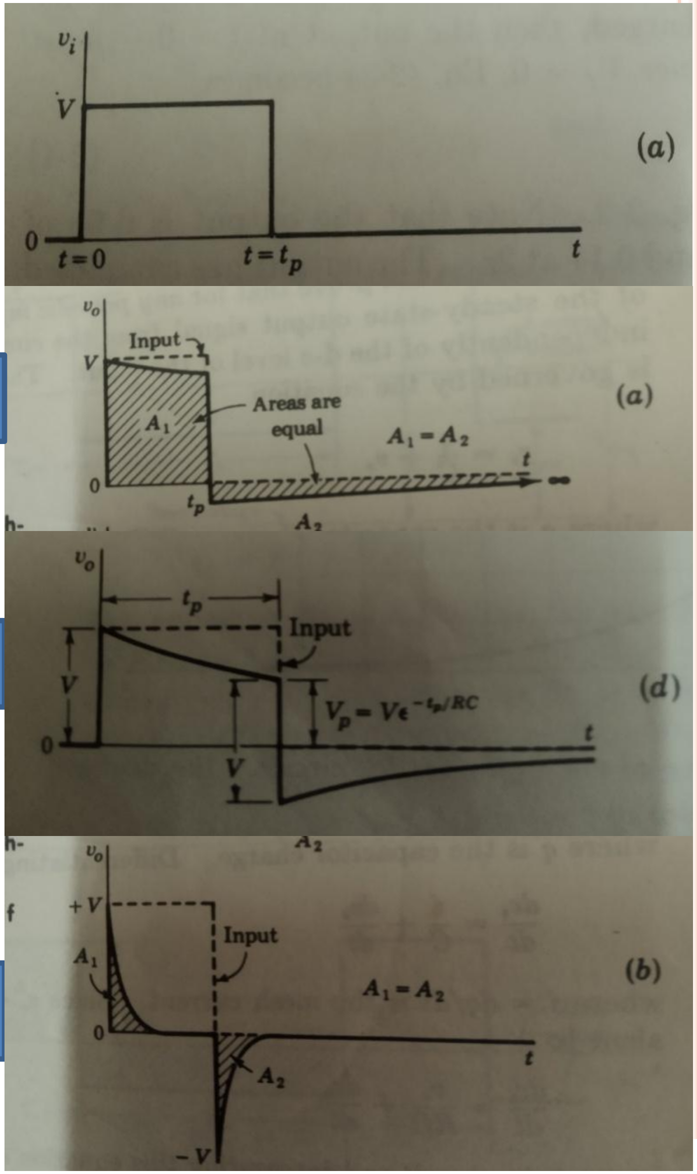
- ($V0 = Ve^{-t/\tau}$)
- at t = tp,
  $Vo = Vp - V$ ($V > Vp$)
- $Vo = V(e^{-tp/RC} - 1)\, Ve^{-(t-tp)/RC}$

RC >> tp

RC ~ tp

- i) RC >> Tp
- ii) RC comarable with Tp
- iii) RC<< Tp

RC<< tp



High pass circuit: Square wave Input

Square wave input:

One constant level V’ for t = T1,

and at another constant level V”

for t = T_2

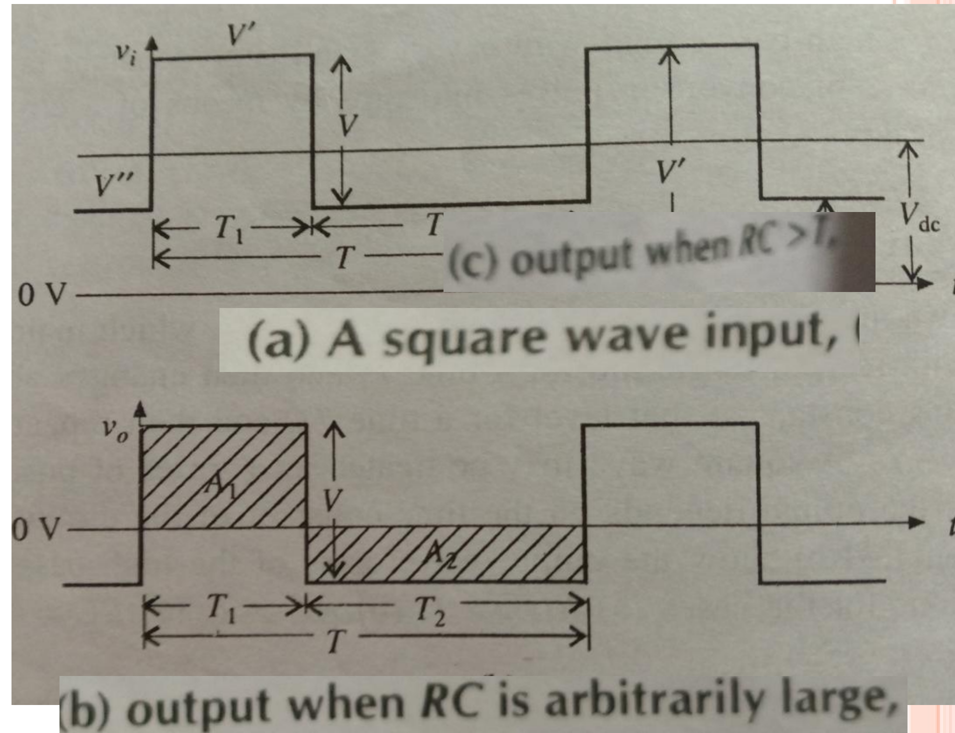
Which is repetitive with a period

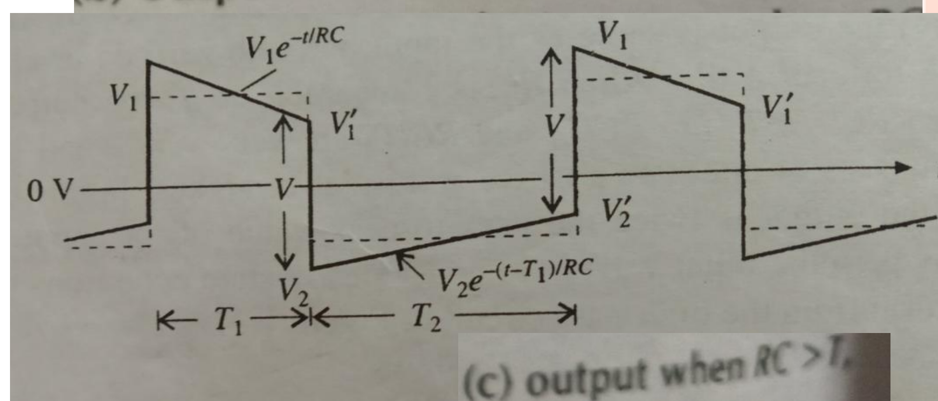
$T = T_1 + T_2$

The response of RC high pass circuit for

i. RC >> T_1 and RC >> T_2,
ie RC >> T

the output wave will be identical to the input except that the dc component will be lacking(as an average value is zero





High pass circuit: Square wave Input

Square wave input:

ii. $RC \approx T_1$ and $RC \approx T_2$, ie $RC \approx T$

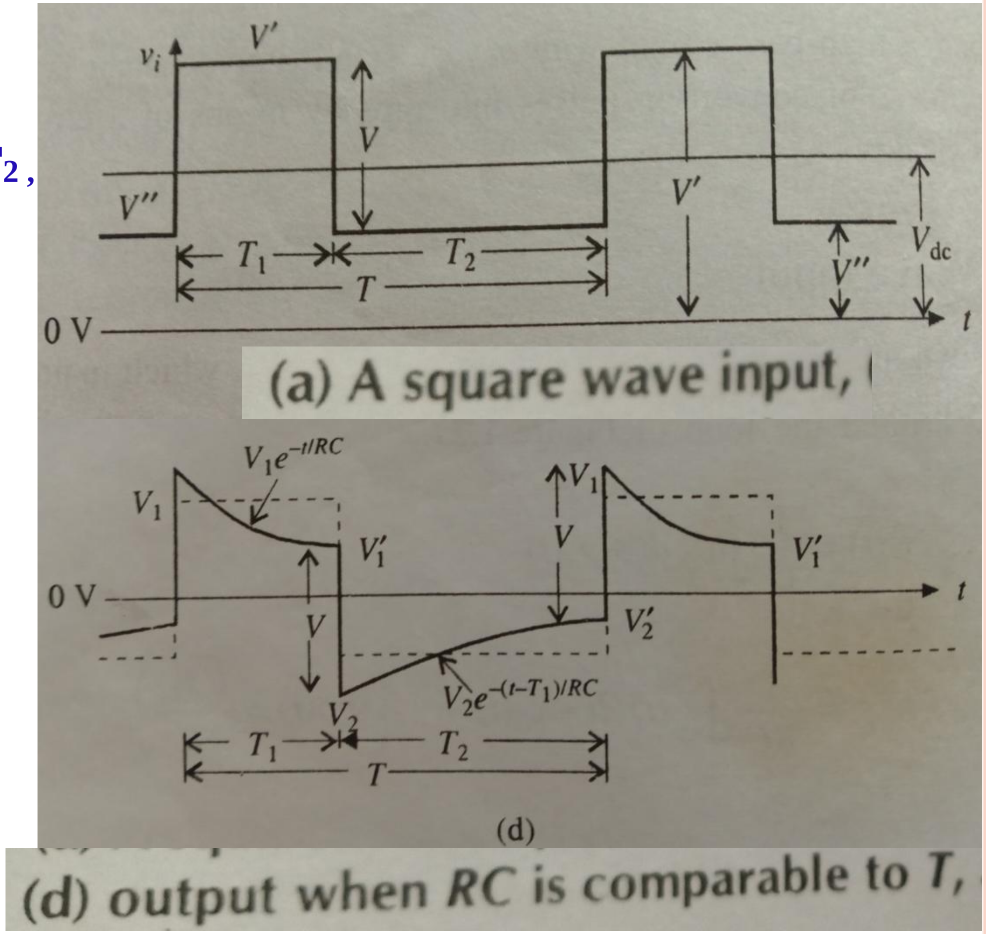
$$V_1' = V_1 e^{-T_1/RC},$$

$$V_1' - V_2 = V$$

$$V_2' = V_2 e^{-T_2/RC},$$

$$V_1 - V_2' = V'$$

iii.



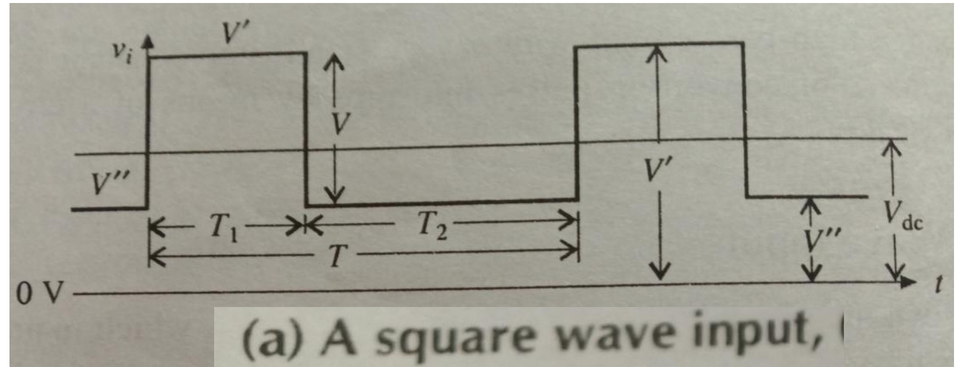
(a) A square wave input,

(d) output when RC is comparable to T,

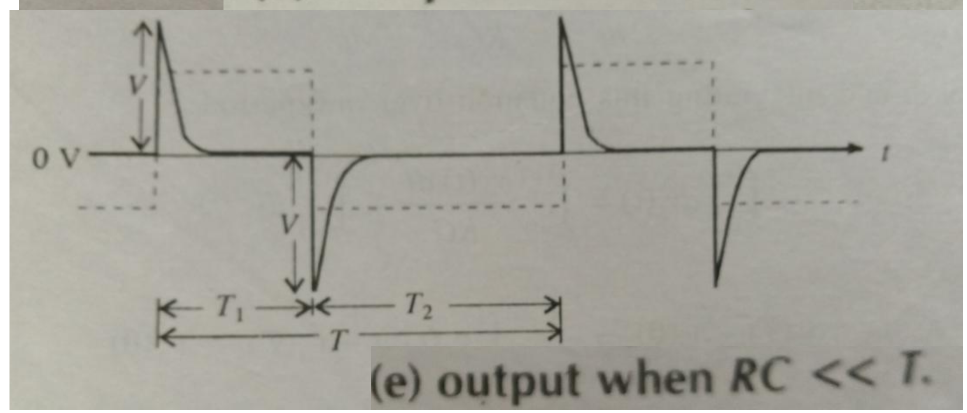
High pass circuit: Square wave Input

Square wave input:

iii. RC << T_1 and RC << T_2 , ie RC << T
the output wave will consists of alternate +ve and –ve peaks, peak to peak amplitude of the output is double then the peak-to peak amplitude of the input



(a) A square wave input,



(e) output when RC << T.

High pass circuit: Square wave Input

Square wave input:

i. $RC >> T_1$ &$RC >> T_2$,
ie $RC >> T$

ii. $RC \approx T_1$&$RC \approx T_2$,
ie $RC \approx T$

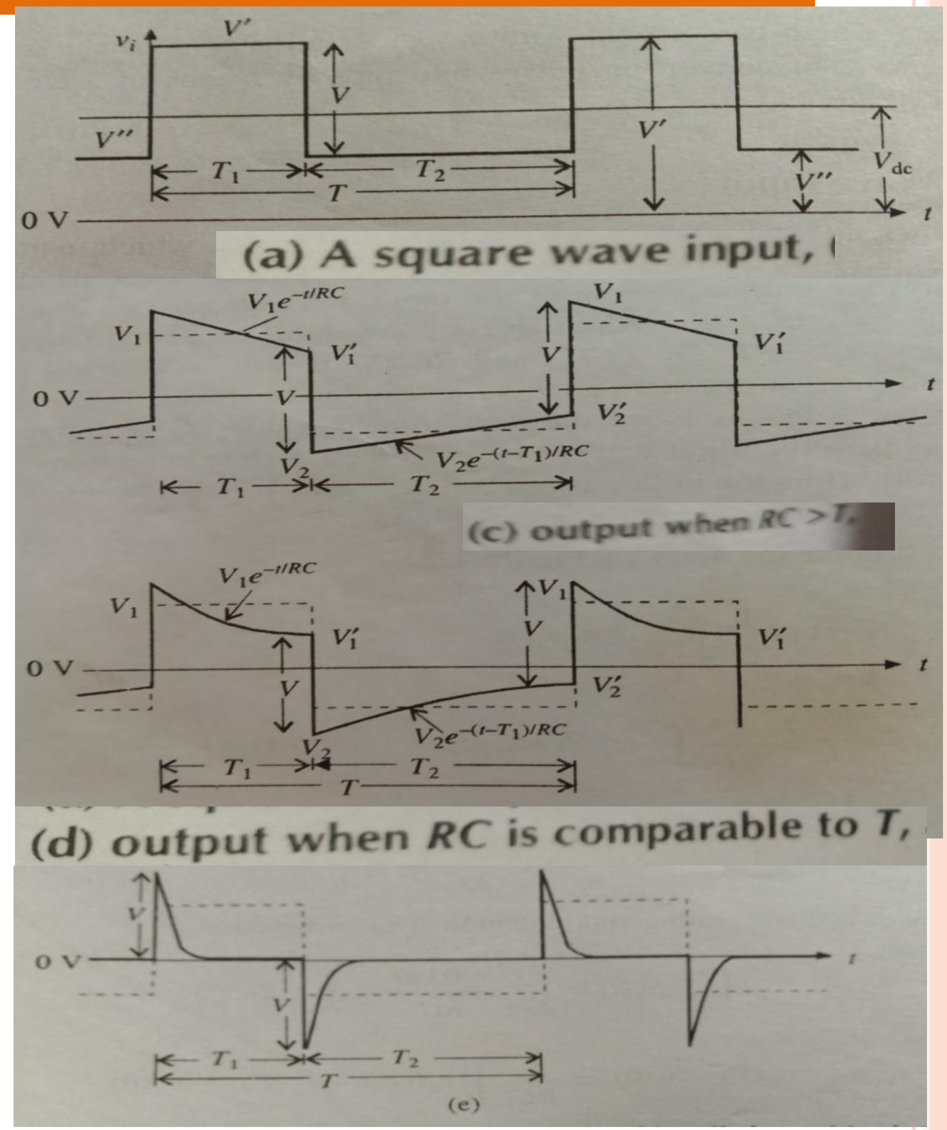
$V_1' = V_1 e^{-T_1/RC}$,

$V_1' - V_2 = V$

$V_2' = V_2 e^{-T_2/RC}$,

$V_1 - V_2' = V$

iii. $RC << T_1$ &$RC << T_2$,
ie $RC << T$



High pass circuits: Pulse Input cont…

When $\tau << tp$ where $\tau = RC$
Pulse is converted into spikes
The process of converting pulses into spikes(pips) by means of RC circuit of very short time constant ($RC << tp$) is called peaking circuit

Or

Differentiator
If the time constant is very very small as compare to the time required for the input signal to make an appreciable change , the circuit is called a differentiator

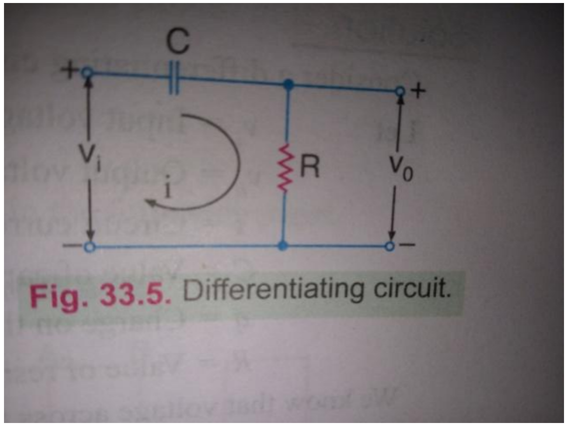
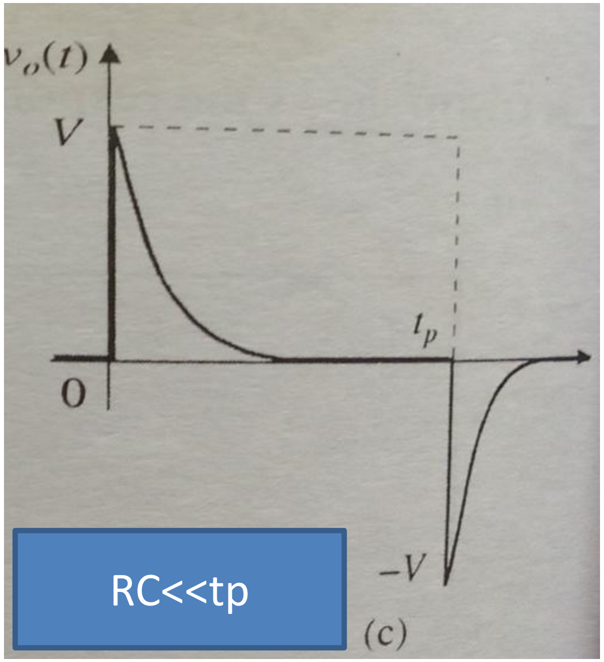


Fig. 33.5. Differentiating circuit.



High pass circuits: Differentiating Circuit

cont…

$$Vo \ \alpha \ \frac{dVi}{dt}$$

High pass RC circuit as a Differentiator:

$$Vo = k\frac{dVi}{dt}$$

If the time constant is very very small as compare to the time required for the input signal to make an appreciable change , the circuit is called a differentiator

Actually

When $\tau << tp$ (where $\tau = RC$, $tp = T$),

$V_R << V_C$ (for low freq Xc is high $Xc = \frac{1}{2\pi fC}$),

Therefore total input voltage Vi appears across capacitor C and hence the total current i is determined entirely by the Capacitor

$$i = C\frac{dVc}{dt}$$

$$= C\frac{dVi}{dt}$$

$$iR = RC\frac{dVi}{dt}$$

$$Vo = RC\frac{dVi}{dt}$$

$$Vo \ \alpha \ \frac{dVi}{dt}$$

Hence the output is proportional to the derivative of the input

High pass circuits: Sq.wave Input

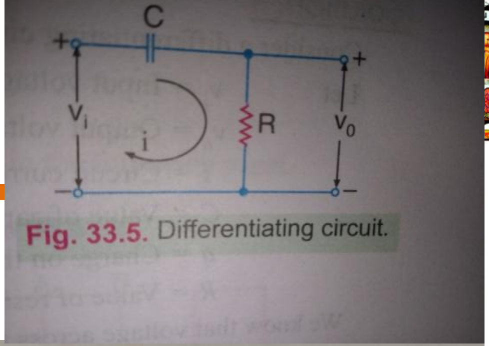


Fig. 33.5. Differentiating circuit.

cont…

When τ << tp where τ = RC

+ve Pulse and –ve Pulse is converted into spikes

The process of converting pulses into spikes(pips) by means of RC circuit of very short time constant (RC << tp) is called peaking circuit

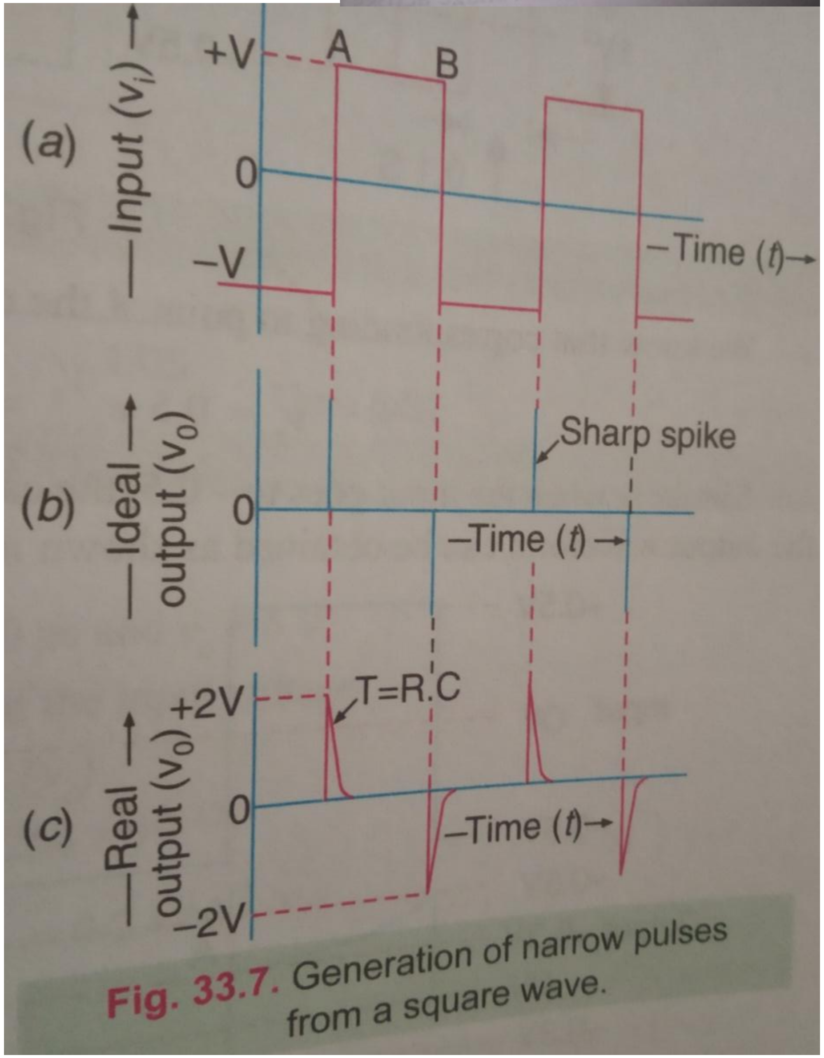
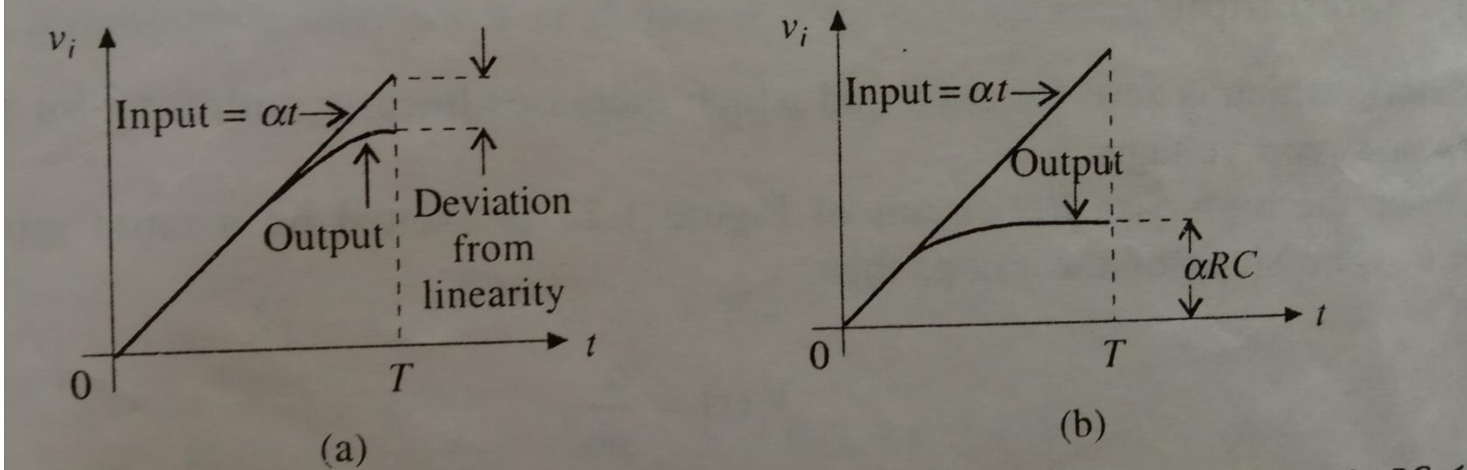


Fig. 33.7. Generation of narrow pulses from a square wave.

Or Differentiator

If the time constant is very very small as compare to the time required for the input signal to make an appreciable change , the circuit is called a differentiator

High pass circuits: Ramp Input



Response of the high-pass circuit for a ramp input when (a) $RC >> T$ and (b) $RC << T$.

High pass circuits:

Response of High pass RC circuits for exponential input

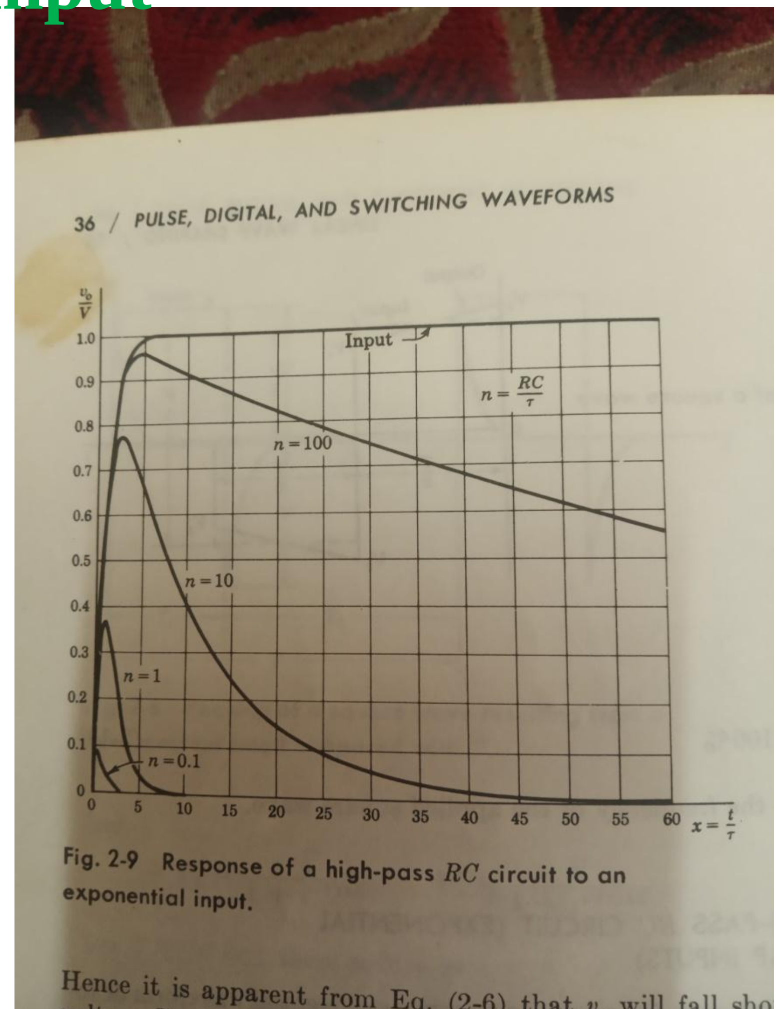

36 / PULSE, DIGITAL, AND SWITCHING WAVEFORMS

Fig. 2-9 Response of a high-pass RC circuit to an exponential input.

Hence it is apparent from Eq. (2-6) that v_o will fall sho

Types of Wave shaping circuits

Types of Wave shaping circuits

- **Linear wave shaping circuits-**
  - **It use the transient properties of Resistors, Capacitors, Inductors to realize the mathematical operations of Integration & differentiation**
- **Differentiating Circuit:**

$$Vo \ \alpha \frac{dVi}{dt}$$

$$Vo = k \frac{dVi}{dt}$$

- **It is realised by a simple RC series circuit**
- **Output is taken across R and Xc >>R**

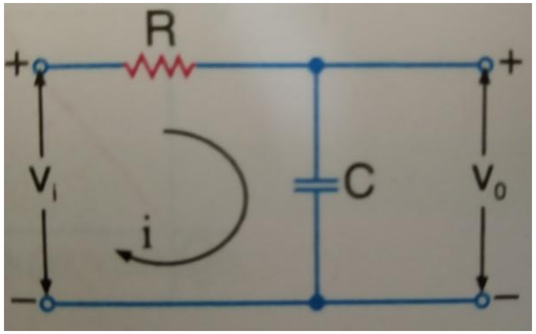
$$Xc = \frac{1}{2\pi fC}$$

$$R << \frac{1}{2\pi fC}, \qquad f << \frac{1}{2\pi RC}, \quad \frac{1}{T} << \frac{1}{2\pi RC}$$

$$2\pi RC << T, \ \tau << T \qquad Vo = RC \frac{dVi}{dt} = \tau \frac{dVi}{dt}$$

Low pass RC circuits

Linear wave shaping circuits



- **Low pass RC circuits**
  - Low Pass Filter,
  - as an Integrator – τ (RC) >> T

$\int idt$

Linear wave shaping circuits

- **Low pass RC circuits**
  - Low pass filters
  - Use to perform functions of Integration, τ (RC)>> T

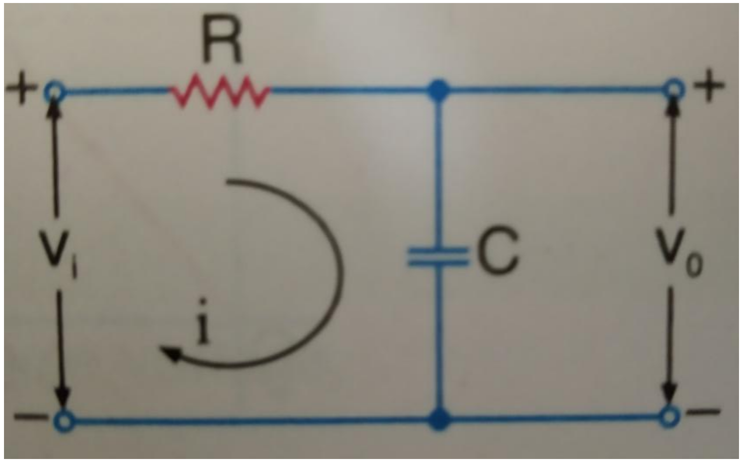
$$Xc = \frac{1}{2\pi fC}$$

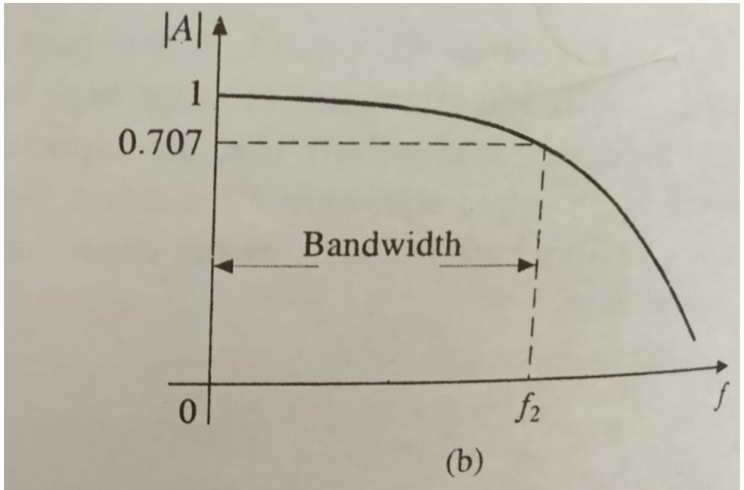
f = 0, f = ∞ Xc--∞, Xc– 0 resp

- as f increases, Xc decreases, o/p and magnitude of gain decreases

- low frequency components in the i/p signal appears at the o/p with less attenuation as compare to high frequency components

- For HF, capacitor acts as a short circuit and the o/p decreases to zero





low-pass *RC* circuit and (b) its frequency response.

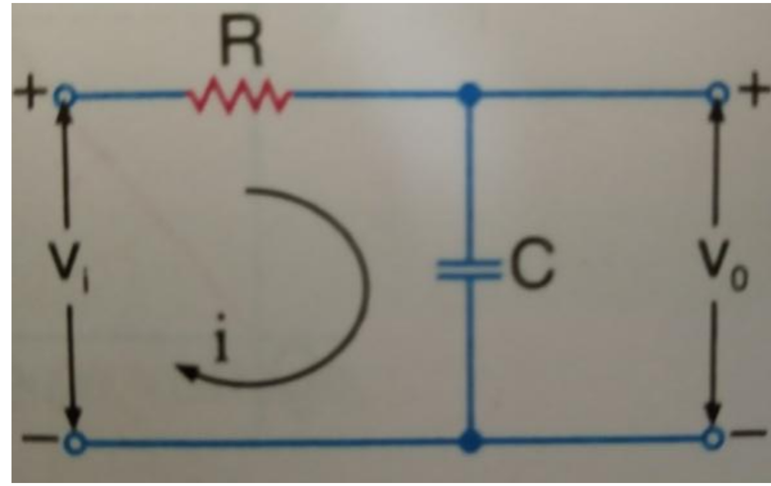
$\int idt$

Low pass RC circuits: Sinusoidal Input

1. Sinusoidal Input

Expression for the lower cutoff frequency-

- $Vi = Vm\sin\omega t$
- $i = Vi/(R-jXc)$
- $Vo = i(-jXc)$
  $= Vi*(-jXc)/(R-jXc)$



$$|A| = \left|\frac{Vo}{Vi}\right| = \frac{-jXc}{R-jXc} = \frac{1}{R/jXc-1}$$

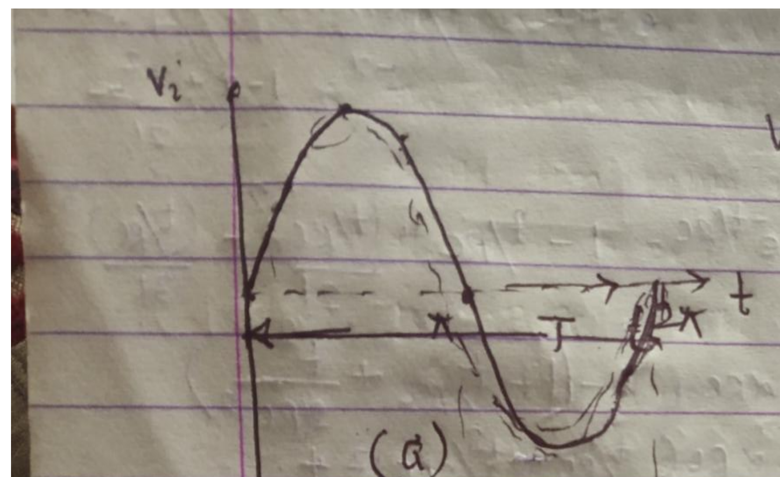
$$\left|\frac{Vo}{Vi}\right| = |A| = \frac{1}{\sqrt{1+(R/Xc)^2}}$$

$$= \frac{1}{\sqrt{1+(f/f2)^2}}$$

$$\theta = -\tan^{-1}\frac{f}{f2}$$

$$f2 = \frac{1}{2\pi RC}$$

3db lower cutoff frequency



$\int idt$

Low pass RC circuits: Sinusoidal Input

1. Sinusoidal Input

$$\left|\frac{Vo}{Vi}\right| = |A| = \frac{1}{\sqrt{1+(R/Xc)^2}}$$

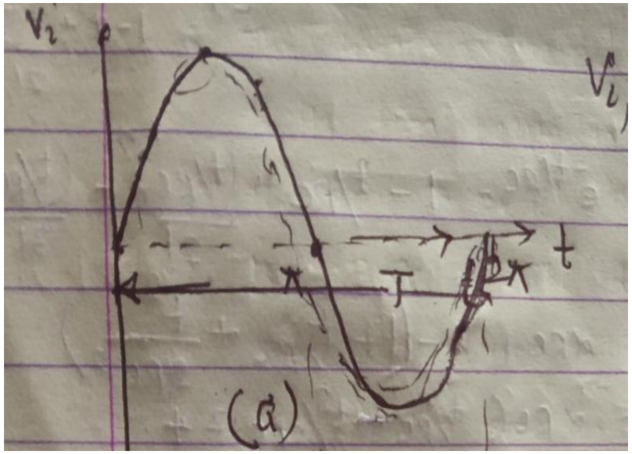
$$= \frac{1}{\sqrt{1+(f/f2)^2}}$$

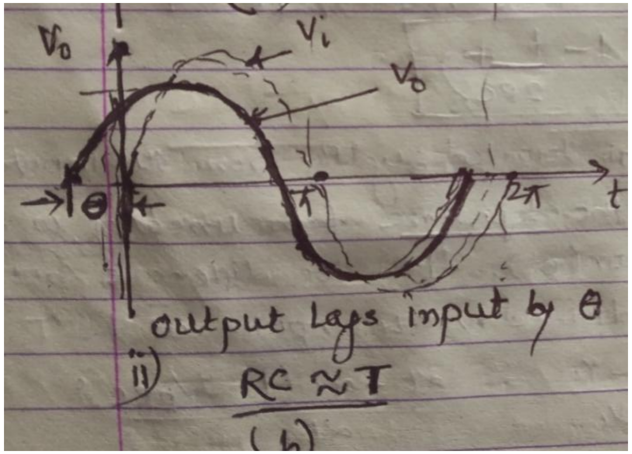
$$\theta = -\tan^{-1}\frac{f}{f2}$$

$$f2 = \frac{1}{2\pi RC}$$

a. Sinusoidal Input(Vi)
b. Sinusoidal output (V0)

Output waveform Nature is same but amplitude reduced and output lags input by θ





Low pass RC circuits: Sinusoidal Input

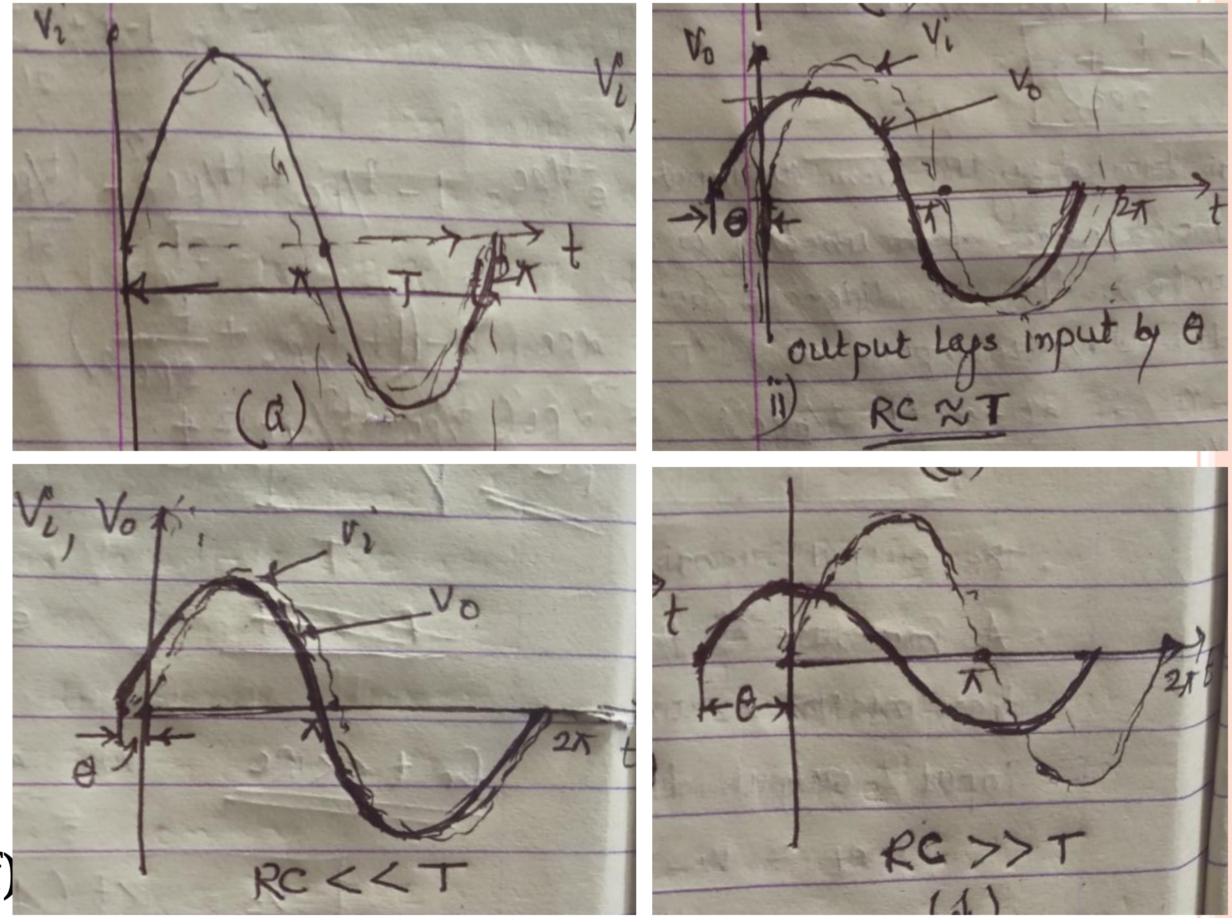
1. Response of Low pass RC circuit for Sinusoidal Input with Various circuit time constant(RC)

$$\left|\frac{Vo}{Vi}\right| = |A| = \frac{1}{\sqrt{1+(R/Xc)^2}}$$

$$= \frac{1}{\sqrt{1+(f/f2)^2}}$$

$$\theta = -\tan^{-1}\frac{f}{f2}$$

$$f2 = \frac{1}{2\pi RC}$$



Input-Vi (fig.a)
Output-V0

b. **RC << T, (low f)**
c. RC ≈ T, (f = f2)
d. **RC >> T (High f)**

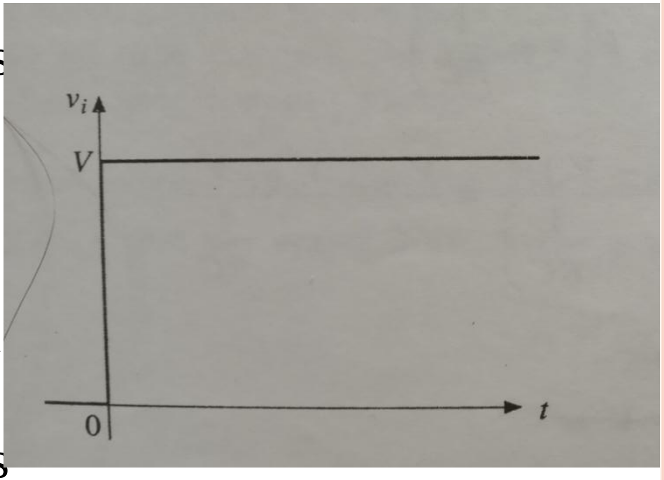
$\int idt$

Low pass circuits: Step Input

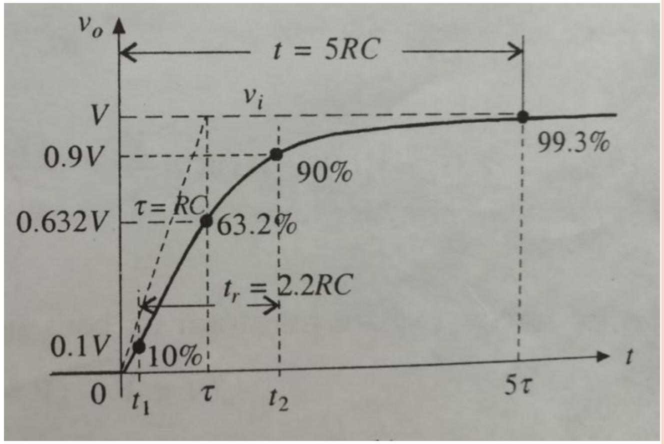
2. Step Input

Vi = 0, t < 0 and Vi = V, t > 0

The transition between two voltage levels takes place at t = 0 , Voltages at (t=0+ , t=0-)



- The response of low pass RC circuit is exponential with time constant RC = τ since the Vc cannot changes instantaneously
- The output(V0=Vc) starts from zero and rises towards the steady state value V,
  V0 = Vf = V,
- The initial value of V0 at t=0
  V0 = Vi = 0
- , V0 = Vf + (Vi – Vf) $e^{-t/\tau}$
  = V + (0 – V) $e^{-t/\tau}$
  = V(1 – $e^{-t/\tau}$)

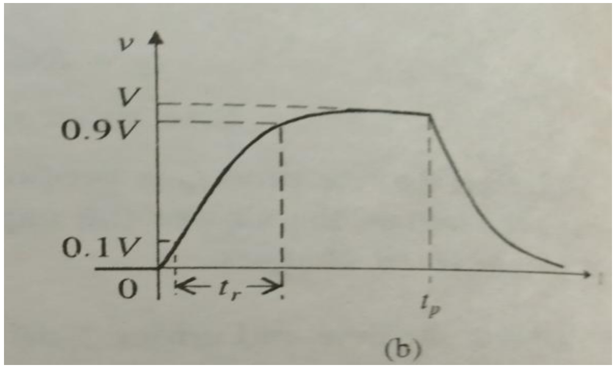


Rise time tr = 2.3RC – 0.1RC =2.2 RC
= 0.35/f2

Low pass circuits: Pulse Input

3. Pulse Input

- **If the pulse input is applied to low pass RC circuit then Response**



i) **for $t < tp$ is similar to that for step input voltage and** $V_{01} = V(1- e^{-t/\tau})$

ii) At the end of pulse i/p falls abruptly by an amount V but the capacitor voltage cannot changes instantaneously for finite current flow therefore output decreases exponentially

$$\text{at } t = tp,\ Vo1 = Vp = V(1- e^{-tp/\tau}))$$

iii) At $t > tp$ capacitor discharges exponentially,

at $t = tp$, $Vo = V(1- e^{-tp/\tau}))$

after tp ($t> tp$) the output Vo decreases exponentially to zero from $V0 = Vp$ with time constant RC For $t > tp$,

$Vo_2 = 0 + (Vp – 0)\ e^{-}(t\text{-}tp)/RC$

$= Vpe^{-}(t\text{-}tp)/RC$

Low pass circuits: Pulse Input

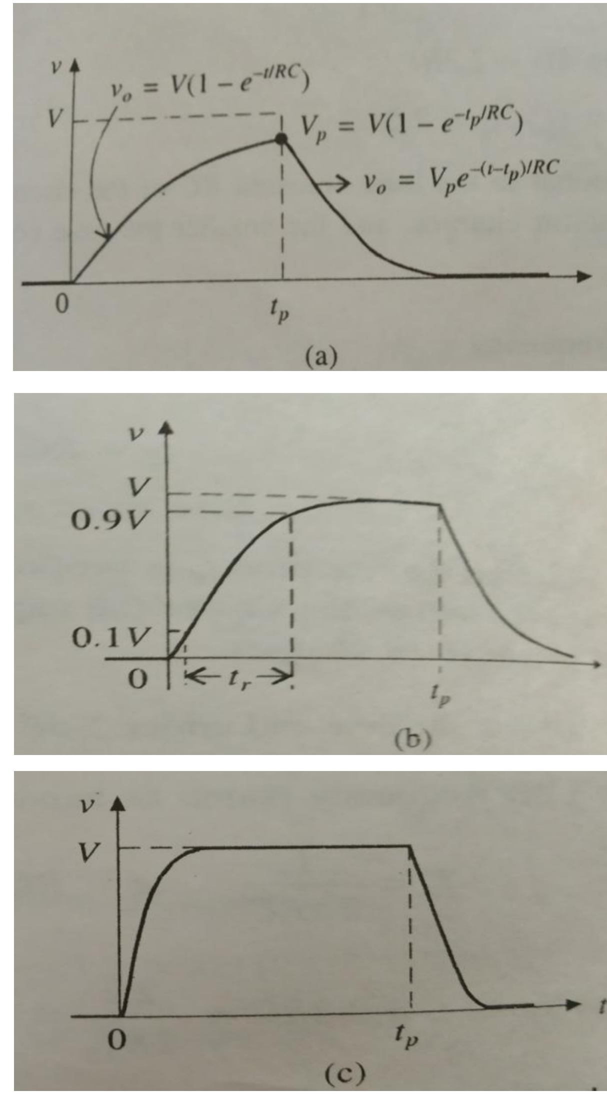
3. Pulse Input

- **Response of low pass RC circuit for pulse input with various RC**

i) RC >> Tp (high f)

ii) RC = Tp

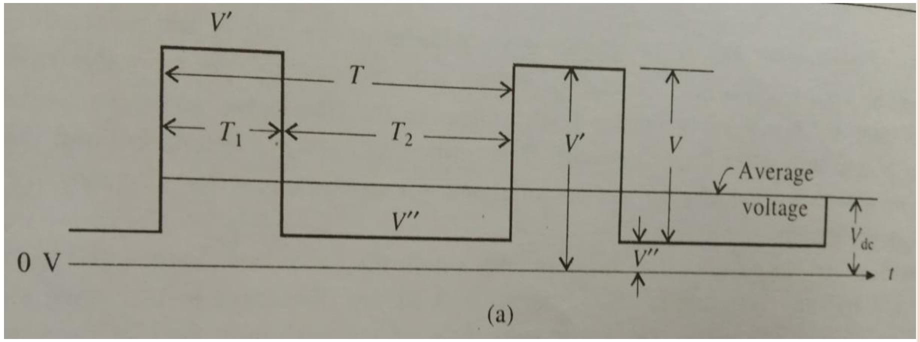
iii) RC << TP (low f)

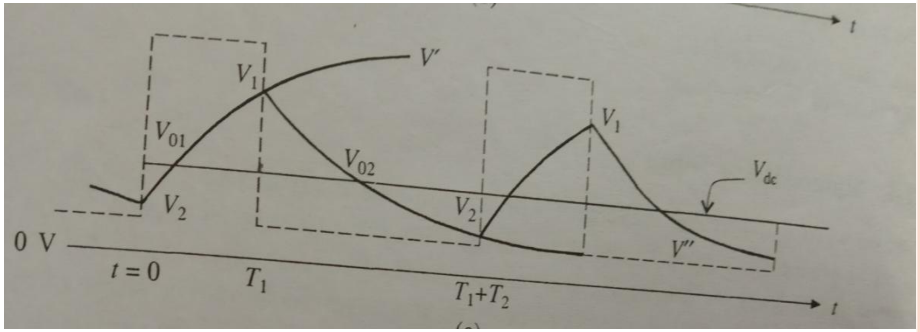


Low pass circuit: Square wave Input

Square wave input:

level V’ for t = T1, & level V” for t = T2
Which is repetitive with a T = T1 + T2





The response of RC low pass circuit for

i. For T_1, the equation for rising portion

$$V_{01} = V' - (V' - V_2)\, e^{-t/RC}$$

Where V2 = Vc at t =0, and V’is the level upto which capacitor may charge

ii. For T_2, the equation for falling portion

$$V_{02} = V'' - (V'' - V_1)\, e^{-(t - T1)/RC}$$

Where V1 = Vc at t =T1, & V” is the level upto which capacitor may charge

Low pass circuit: Squa

Square wave input:

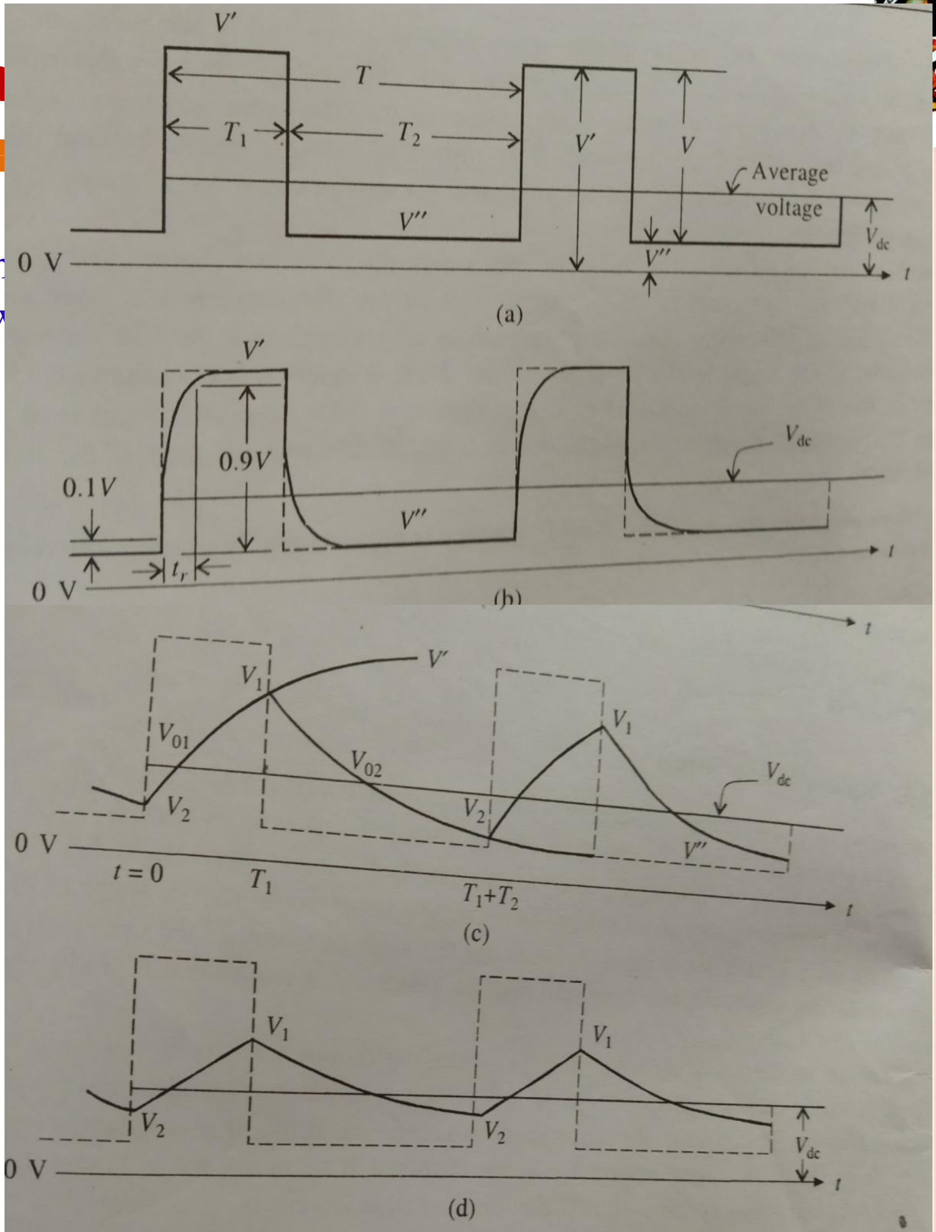
One constant level V' for t = T1, & at ar
level V'' for t = T2 Which is repetitive w
Time period T = T1 + T2

The response of
RC low pass circuit for

i. $RC << T_1$ &
$RC << T_2$, ie $RC << T$

ii. $RC \approx T_1$ &
$RC \approx T_2$, ie $RC \approx T$

iii. $RC >> T_1$ &
$RC >> T_2$, ie $RC >> T$



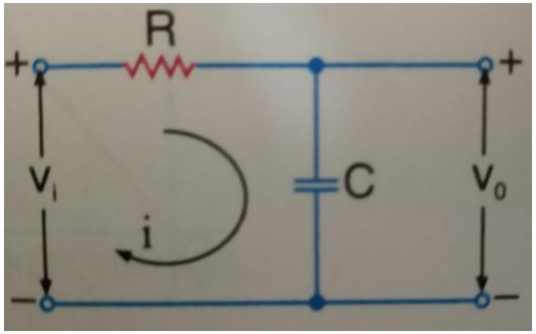
6 Response of a low-pass *RC* circuit to a square wave input: (a) square-wave input waveform, (b) output waveform for $RC << T$, (c) output waveform for $RC \approx T$, and (d) output waveform for $RC >> T$.

Low pass circuits: Integrating Circuit

Low pass RC circuit
as an Integrator:

$$Vo \; \alpha \int Vidt$$

$$Vo = k\int Vidt$$



If the circuit time constant is very large as compare to the time required for the input signal to make an appreciable change , the circuit is called an integrator

$$Vi = V_R + Vc = V_R$$

$$i = \frac{V_R}{R} = \frac{V_i}{R}$$

$$Vo = \frac{1}{C}\int_0^T idt$$

$$= \frac{1}{RC}\int_0^T Vidt$$

$$so\ Vo \; \alpha \int_0^T Vidt$$

Actually
When τ >> tp
(where τ = RC, tp = T),
V_c << V_R
(for high freq Xc is small $Xc = \frac{1}{2\pi fC}$),

Therefore total input voltage
Vi appears across resistor R
and hence the total current
i is determined entirely by the resistor

Hence the o/p(V0) is proportional
to the integration of the input(Vi)

RC circuits

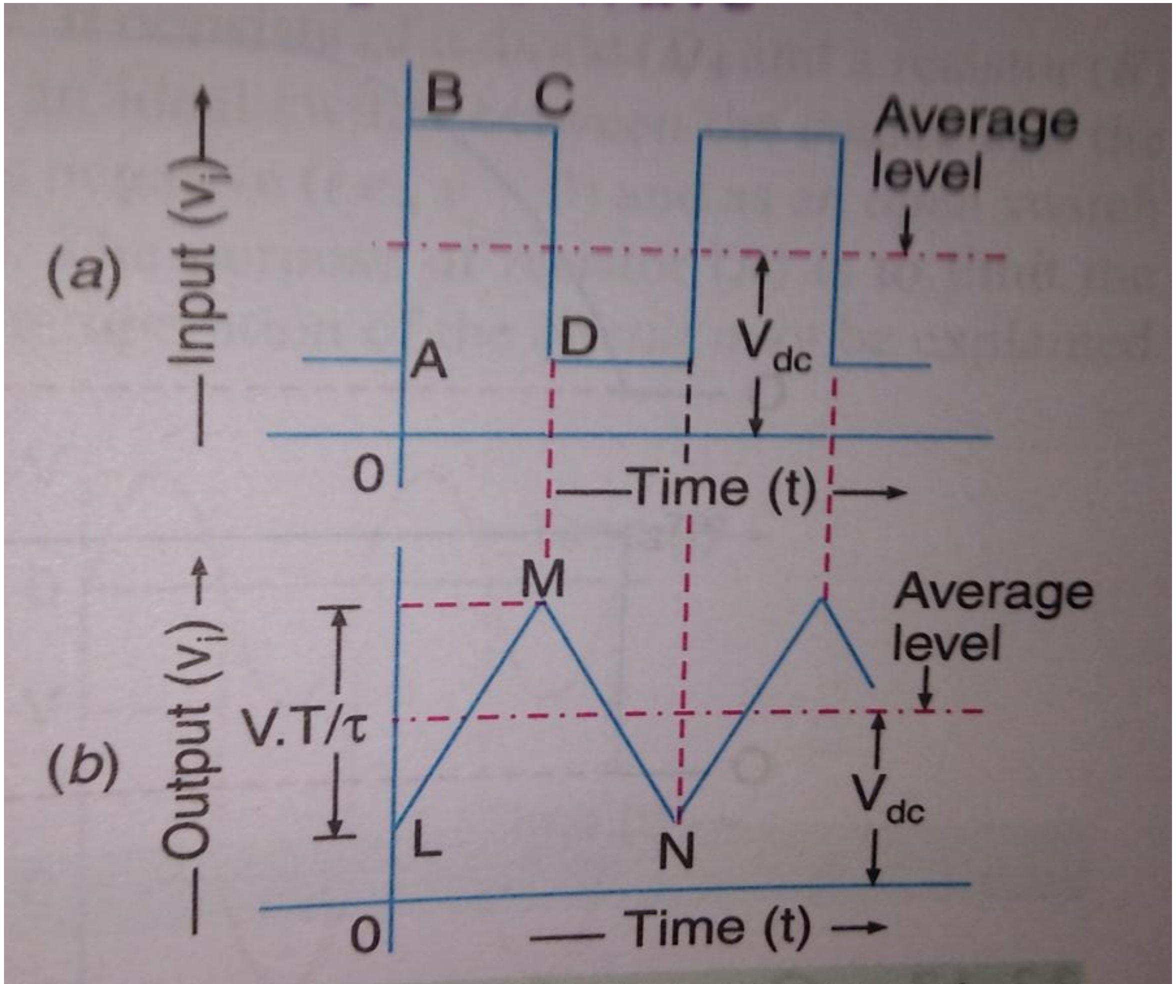


Fig. 33.14. Generation of a triangle wave from a square wave.

RC circuits

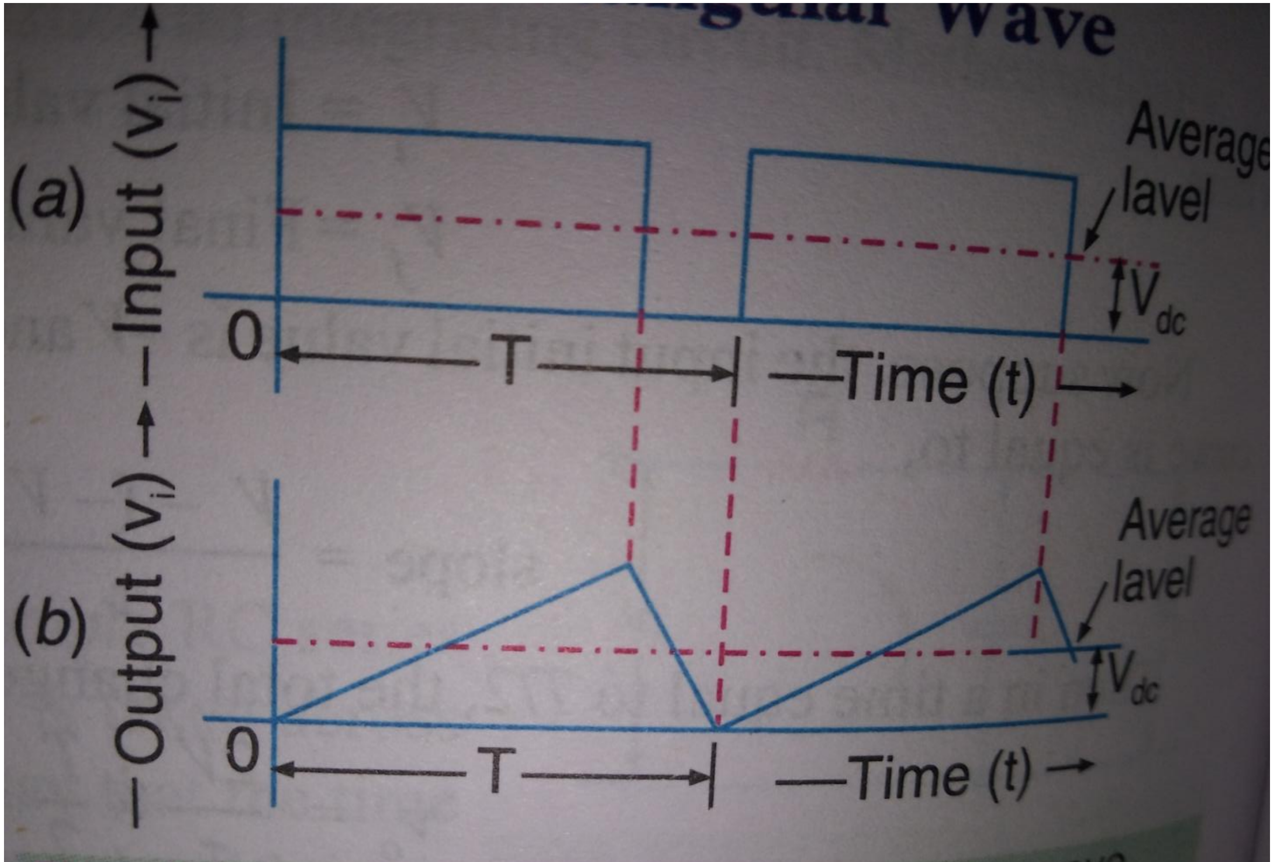


Fig. 33.17. Generation of a sawtooth wave from a rectangular wave.

Low pass RC circuits: ramp Input

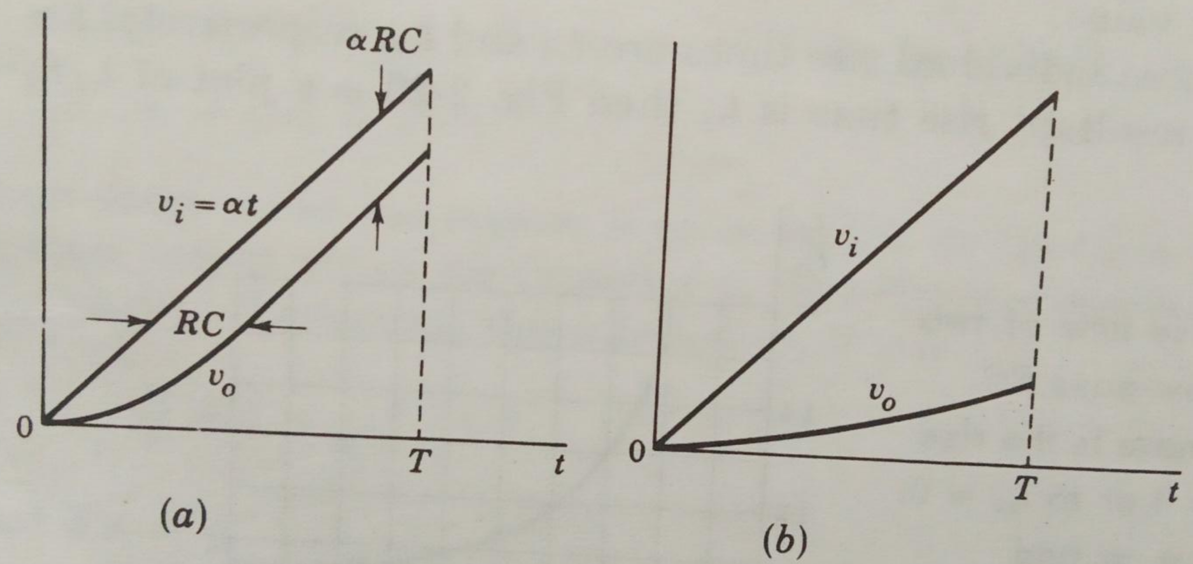


Fig. 2-21 Response of a low-pass RC circuit to a ramp voltage. (a) $RC/T \ll 1$; (b) $RC/T \gg 1$.

Problem on High Pass RC circuits

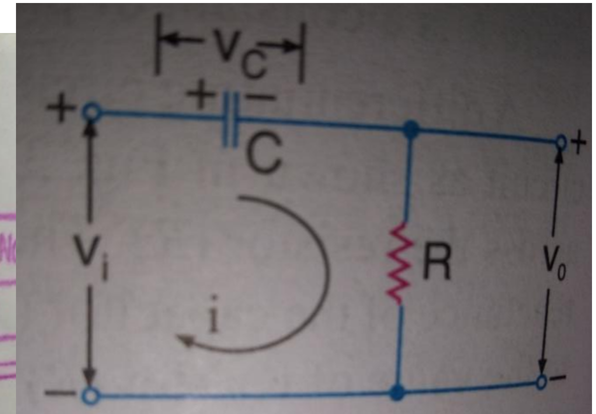
* Expression for the % tilt

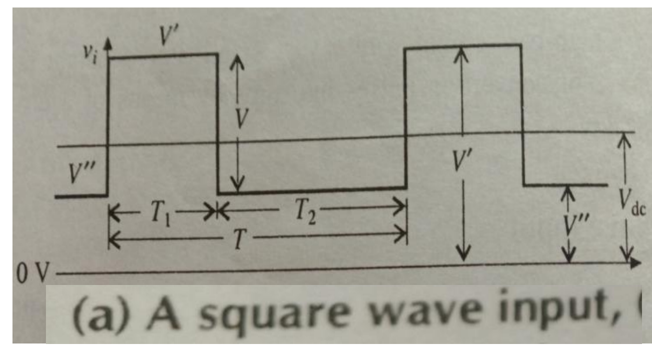
Define % tilt occurring in the output waveform after transmission of symmetrical sq. wave through RC high pass circuit and then show that

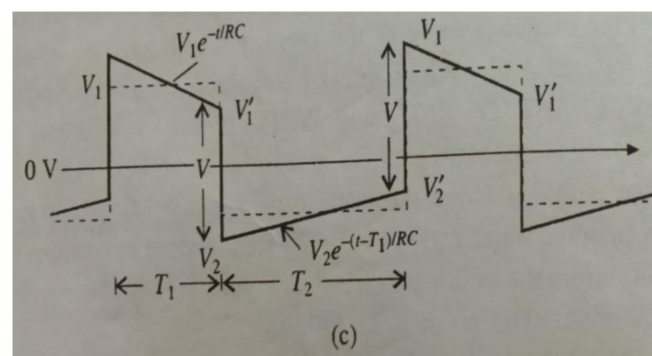
$$\% \text{tilt} \simeq P \cong \frac{T}{2RC} \times 100 \quad \text{or} \quad P = \frac{\pi f_1}{f} \times 100.$$

Def^n: $$\% \text{tilt} = \frac{V_1 - V_1'}{V/2} \times 100$$

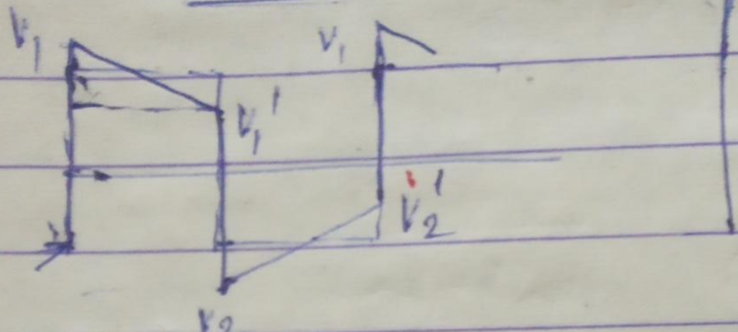
tilt







Problem on High Pass RC circuits



linear when RC↑

for symmetrical square wave

$T_1 = T_2 = T/2$ and Because of the symmetry $V_1 = -V_2$ and $V_1' = -V_2'$.

If RC >> T and the response to a sq. wave have the appearance as shown in fig. and we got the equations as follows.

$V_1' = V_1 e^{-T_1/RC}$ & $V_1' - V_2 = V$ — (1)

$V_2' = V_2 e^{-T_2/RC}$ & $V_1 - V_2' = V$ — (2)

RC circuits

$V_1' = V_1 e^{-T_1/RC}$ & $V_1' - V_2 = V$ — (1)

$V_2' = V_2 e^{-T_2/RC}$ & $V_1 - V_2' = V$ — (2)

for symmetrical sq. wave eqn (1) becomes

$V_1' = V_1 e^{-T/2RC}$

$V_1' - V_2 = V$

or $V_1' = V + V_2 = V - V_1$

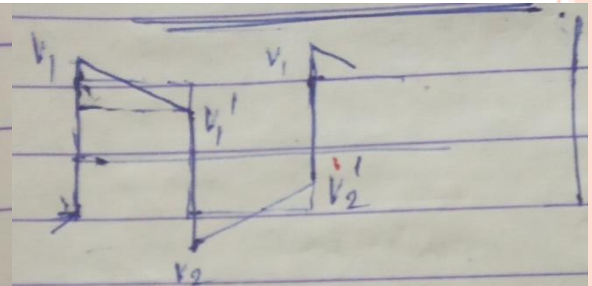
$T_1 = T_2 = T/2$

$V_1 = -V_2$ & $V_1' = -V_2'$

$V_2 = -V_1$

$\therefore V - V_1 = V_1 e^{-T/2RC}$

$$\boxed{V_1 = \frac{V}{1 + e^{-T/2RC}}} \quad \text{— (3)}$$



for symmetrical square w

$T_1 = T_2 = T/2$ a

the symmetry $V_1 = -V_2$

If $RC >> T$ and the

RC cir

Similarly

$$V_1' = V_1 e^{-T/2RC}$$

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$V_1' - V_2 = V$ or $V_1' = V + V_2 = V - V_1$ or $V_1 = V - V_1'$

$$\therefore \quad V_1' = (V - V_1') e^{-T/2RC}.$$

$$V_1' = \frac{V e^{-T/2RC}}{1 + e^{-T/2RC}} = \frac{V}{1 + 1/e^{-T/2RC}}$$

$$\boxed{V_1' = \frac{V}{1 + e^{T/2RC}}} \quad — (4)$$

for $2RC >> T$ or $T/2 << RC$

$$V_1 = \frac{V}{1 + e^{-T/2RC}} \qquad \left(e^{-x} = 1 - x + \frac{x^2}{2!} - \frac{x^3}{3!} \ldots\right.$$

$$1 - T/2RC + \frac{(T/2RC)^2}{2} \ldots$$

RC cir

$$1+e^{T/2RC} \quad \text{— (4)}$$

for $2RC >> T$ or $T/2 << RC$

$$V_1 = \frac{V}{1+e^{-T/2RC}} \qquad \left(e^{-x} = 1 - x + \frac{x^2}{2!} - \frac{x^3}{3!}\right.$$

$$e^{-T/2RC} \cong 1 - T/2RC + \frac{(T/2RC)^2}{2!} - \cdots$$

for $T/2 << RC$ eliminate higher or ter

$$\therefore \; e^{-T/2RC} \cong (1 - T/2RC) \quad \text{— (5)}$$

$$\therefore \; V_1 = \frac{V}{1+1-T/2RC} = \frac{V}{2(1-T/4RC)} = \frac{V}{2}(1-T/$$

$$(1-T/4RC)^{-1} = 1 + \frac{T}{4RC} + (T/4RC)^2 \qquad \left\{ (1-x)^{-1} = 1+x \right.$$

Binomial s expansi

$$\cong (1 + T/4RC)$$

$$\therefore \; V_1 = \frac{V}{2}\left(1+\frac{T}{4RC}\right) \quad \text{— (6)}$$

RC cir

from eqn (4)

$$V_1' = \frac{V}{1+e^{T/2RC}} \qquad \left(e^x = 1 + x + \frac{x^2}{2!}\right.$$

$$e^{T/2RC} = 1 + T/2RC + \frac{(T/2RC)^2}{2!} + \cdots$$

$$\simeq (1 + T/2RC)$$

$$V_1' = \frac{V}{1+1+T/2RC} = \frac{V}{2(1+T/4RC)} = \frac{V}{2}\left(1+\frac{T}{4RC}\right)^{-1} \quad (7)$$

$$(1+x)^{-1} = 1 - x + x^2 - x^3$$

$$(1+T/4RC)^{-1} = \cancel{1-x+x^2-x^3}$$

$$1 - T/4RC + (T/4RC)^2 - \cdots$$

$$\simeq \left(1 - \frac{T}{4RC}\right)$$

$$\therefore V_1' = \frac{V}{2}\left(1 - \frac{T}{4RC}\right) \longleftarrow (8)$$

$$\%\,tilt = P = \frac{V_1 - V_1'}{V/2} \times 100$$

from eqn (6) & (8)

$$P = \frac{V}{2}\left(1+\frac{T}{\ldots}\right) - \frac{V}{2}\left(1-\frac{T}{\ldots}\right)$$

RC cir

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$$\boxed{P = \frac{T}{2RC} \times 100}$$ % tilt

f_1 = lower 3dB frequency = $1/2\pi RC$

$\therefore\ 2RC = 1/\pi f_1$ & $T = 1/f$

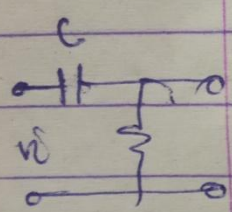
$$\therefore\ \boxed{P = \frac{\pi f_1}{f} \times 100}$$

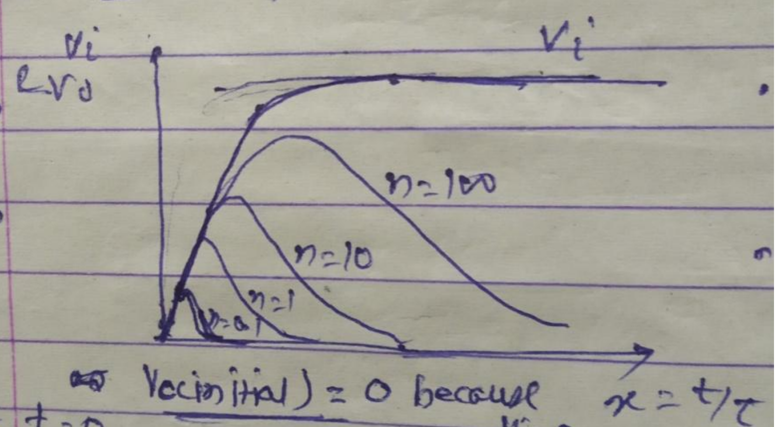
THANKS A LOT

Thanks a lot

RC circ

be narrower, but the … will remain equal to the … the input square wave, pr… has vertical sides which i… impossible, and therefo… rise time of the input … be taken into account.





Vc(initial) = 0 because $v_i = 0$ at $t = 0$, then $V_o(0) = 0$

$$v_i = \frac{1}{C}\int i\,dt + v_o$$

$$v_i = \frac{q}{C} + v_o$$

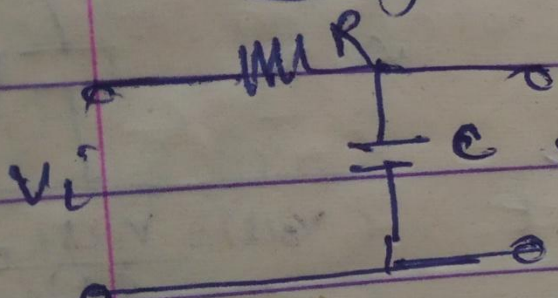
$$\boxed{\frac{dv_i}{dt} = \frac{v_o}{RC} + \frac{dv_o}{dt}}$$

$$i = \frac{dq}{dt} \qquad \frac{1}{C}\frac{dq}{dt}$$

$$\frac{dv_i}{dt} = \frac{1}{C}\frac{dq}{dt} + \frac{dv_o}{dt}$$

$$= \frac{i}{C} + \frac{dv_o}{dt}$$

The Low pass RC circuit as An Integrator



$RC >> T$

The time constant (RC) is very large in comparison with the time required for the input signal to make an appreciable change, the ckt is called an integrator.

when $RC >> T$ the voltage drop across C will be very small in comparison to the drop across R.

$(V_C << V_R)$

$V_i = V_R + V_C \cong V_R$

$\underline{RC >> T}$ to make an appr...

the ckt is called an integrator.

when $RC >> T$ the voltage drop across C will be very small in comparison to the drop across R. ($V_C << V_R$)

$$V_i = V_R + V_C \cong V_R$$

$$\therefore \quad i = V_R/R = V_i/R$$

$$V_o = \frac{1}{C}\int i\,dt$$

$$\boxed{V_o = \frac{1}{RC}\int_0^T v_i\,dt}$$

$V_o \propto \int V_i\,dt$

$$\boxed{v_i = \alpha t, \quad V_o = \frac{\alpha t^2}{2RC}}$$

for output $v_o = V_i - V_R = \alpha t - \alpha RC(1 - e^{-t/RC})$

$$\boxed{v_i = \alpha t, \quad v_o = \frac{\alpha t^2}{2RC}}$$

for Ramp Input

$$v_o = v_i - v_R = \alpha t - \alpha RC(1 - e^{-t/RC})$$

$$v_o = \alpha t - \alpha RC\left[1 - \left(1 - t/RC + t^2/2(RC)^2 - \ldots\right)\right]$$

$$= \alpha t - \alpha RC\left(t/RC - t^2/2(RC)^2\right)$$

$$= \alpha t - \alpha t + \alpha t^2/2RC$$

$$\boxed{v_o = \frac{\alpha t^2}{2RC}}$$

& $$v_o = \frac{1}{RC}\int v_i\,dt = \frac{1}{RC}\int \alpha t\,dt$$

$$= \frac{\alpha}{RC}\int t\,dt = \frac{\alpha t^2}{RC\,2} = \frac{\alpha t^2}{2RC}$$

$$\boxed{v_o = \alpha t^2/2RC}$$