.

EE1101: Circuits and Network Analysis

Lecture 15: Time-varying Signals

September 1, 2025

Topics :

1. Step and Impulse Signals

2. Periodic Signals

Time-varying signals - Introduction

goal: Compute circuit response for time-varying scenarios (or signals)

a) understanding time-varying signals.

b) circuit elements under time-varying scenarios

c) circuit laws under time-varying scenarios

⇓

dependent on the nature of response of interest ⟶ d) develop Eqns of a ckt using ckt laws.

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e) mathematical methods to solve the circuits.

function :- mapping from set of i/ps to set of o/p's

a) analytical representation : $f(x)$ ⟶ independent variable.

b) graphical representation

Signal : Equivalent of a function in the context of circuits

lower-case : $v(t)$ or $i(t)$

a) analytical representation ($v(t)$) ⟶ independent variable ⟶ time (t)

b) graphical representation ⟶ waveform.

focus for the rest of the course : Computing circuit responses where sources are time-varying signals

Step Signal

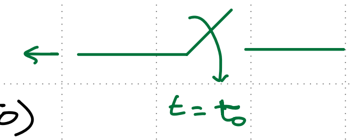
$v(t) \longrightarrow$ time-varying signal (also ref to as AC signal)

$\Downarrow$ general implication

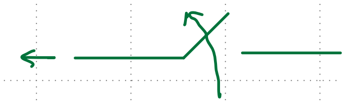
Sinusoidal signal (x for this course)

① Step signal : Time varying signal characterized by finite jump at an instant of time } appears in ckts with switching elements

Switch closing at specified time instant (t_0)



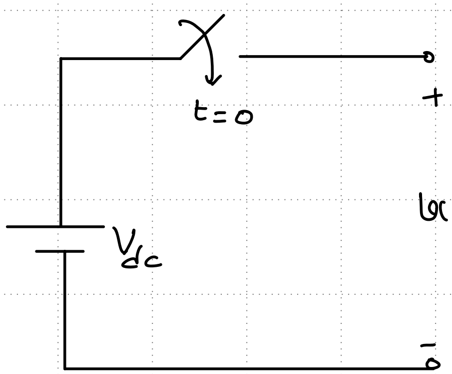
Switch opening at specified time instant (t_0)



Unit step signal $u(t)$:

$$u(t) = \begin{cases} 0 & \text{for } t < 0 \\ 1 & \text{for } t \geq 0 \end{cases}$$

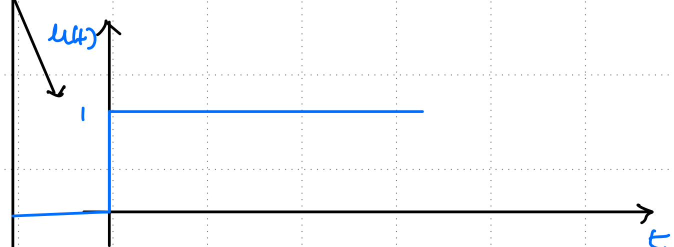
Ex:-



$v(t) = V_{dc}\, u(t)$.

waveform

waveform of $u(t)$:-



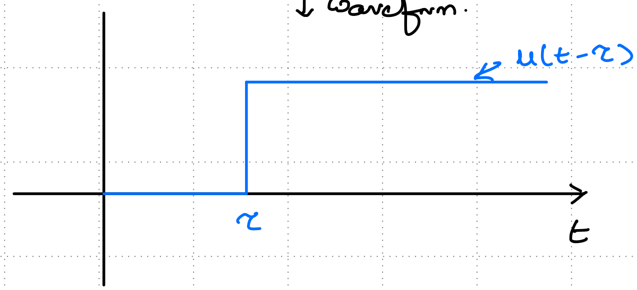
Step Signal

Shifted unit step signal:

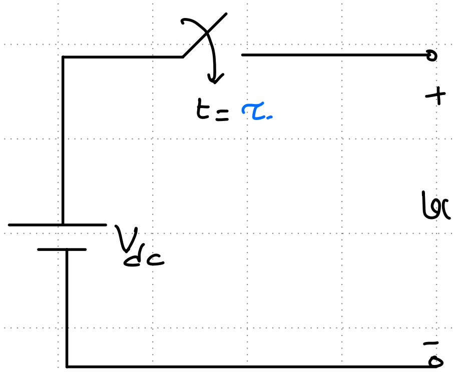
$$u(t-\tau) = \begin{cases} 0 & \text{for } t < \tau \\ 1 & \text{for } t \geq \tau. \end{cases}$$

jump at τ

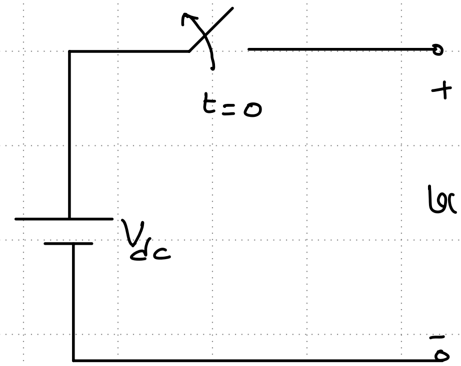
↓ waveform.



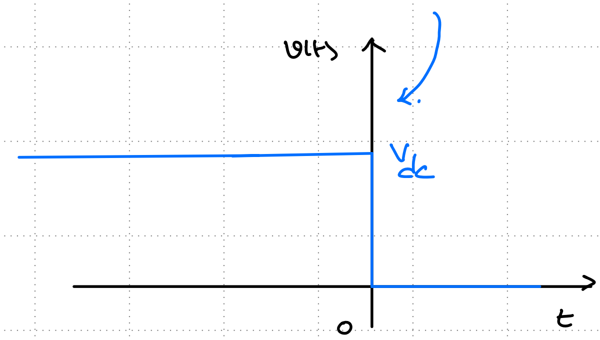
Ex:-



$v(t) = V_{dc}\, u(t-\tau)$.



$v(t) = V_{dc}\, u(-t)$



$V_{dc}\, u(-t)$.

Response to a step signal → used to characterize the dynamic response of a ckt.

Impulse Signal ($\delta(t)$)

for this Course: $\delta(t) \longrightarrow \boxed{\int} \longrightarrow u(t)$

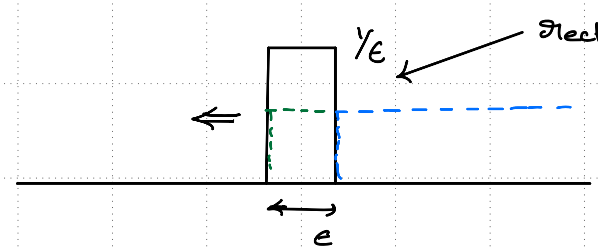
Integrator (bec it is the basic building block of a CT system)

$\delta(t)$: $\int_{-\infty}^{t} \delta(t)\,dt = u(t) \longrightarrow$ can be Considered as a limiting case of two signals

Note that a rectangular pulse $s(t)$ can be rep as

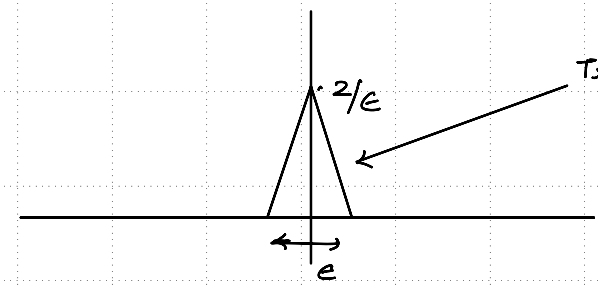
$$s(t) = \frac{1}{\varepsilon}\left[u(t+\varepsilon/2) - u(t-\varepsilon/2)\right]$$

a)



$$\delta(t) = \lim_{\epsilon \to 0} s(t).$$

b)



$$\delta(t) = \lim_{\epsilon \to 0} s_{\Delta}(t).$$

Significance of impulse :-

a) Impulse response is key to studying stability of a system/ckt

b) useful to deal with initial conditions in circuit elements.

Impulse Signal

more fundamental definition

$\delta(t)$: $\int_{-\infty}^{\infty} f(t)\,\delta(t)\,dt = f(0)$ ← appears like sampling | value picking

⇓ extended to

$\delta(t)$: $\int_{-\infty}^{\infty} f(t)\,\delta(t-\tau)\,dt = f(\tau)$

shifted impulse.

$\delta(t)$ as a distribution

how it operates on other functions

representation of an impulse: