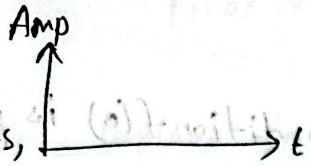
Control Systems
EEE 313

Control Systems Laboratory
EEE 314

Laploce transformation:



time domain.

A signal is, Fourier transformable if

→ In a fixed period, no. of minima and maxima has/is finite ★
→ " no. of discontinuity has to be finite.
→ Integral of the signal has to be finite.

$$L\{f(t)\} = F(s) = \int_0^\infty f(t)\, e^{-st}\, dt$$

$$L^{-1}[F(s)] =$$

$$L\{e^{-at}u(t)\} = \frac{1}{s+a}$$

Time shifting property:

$$f(t) \longleftrightarrow F(s)$$

$$f(t-a)\, u.(t-a) \longleftrightarrow e^{-as} . F(s)$$

Time integration:

$$\int f(t)\, dt \longleftrightarrow \frac{F(s)}{s}$$

$$\int u(t)\, dt \longleftrightarrow \frac{1}{s^2}$$

Time differentiation:

$$\frac{d}{dt} f(t) \longrightarrow sF(s) - f(0)$$

It, initial condition $f(0)$ is given.

$$\star \ \frac{d^2}{dt^2} f(t) \longrightarrow s[sF(s) - f(0)] - f'(0)$$
$$\longrightarrow s^2 F(s) - sf(0) - f'(0)$$

$$\star \ \frac{d^3}{dt^3} f(t) \longleftrightarrow s^3 F(s) - s^2 f(0) - sf'(0) - f''(0)$$

General form:

$$L\left[\frac{df(t)^n}{dt^n}\right] =$$

$$L[t] = \frac{1}{s^2}$$

$$L[t^n] = \frac{n!}{s^{n+1}}$$

$$L\{t e^{-at}\} = \frac{1}{(s+a)^2}$$

$$L\{t^4 . e^{-2t}\} = \frac{4!}{(s+2)^5}$$

$$L\{t^n . e^{-at}\} = \frac{n!}{(s+a)^{n+1}}.$$

$$L\{\sin(\omega t)\} = \frac{\omega}{s^2+\omega^2}$$

$$L\{\cos(\omega t)\} = \frac{s}{s^2+\omega^2}$$

$$e^{-at} \sin(\omega t) = \frac{\omega}{(s+a)^2+\omega^2}$$

$$e^{-at} \cos(\omega t) = \frac{s+a}{(s+a)^2+\omega^2}$$

$$L\{u(t)\} = \frac{1}{s}$$

$$L\{e^{-at}\} = \frac{1}{s+a}$$

Theorem : Initial value theorem
Final value theorem.

Q. Find the laplace transform of $t^2 . e^{-5t}$

Q. Find the inverse Laplace transform of $F(S) = \frac{10}{S(S+2)(S+3)^2}$

$$F(S) = \frac{A}{S} + \frac{B}{(S+2)} + \frac{C}{(S+3)} + \frac{D}{(S+3)^2} = \frac{10}{S(S+2)(S+3)^2}$$

$$\Rightarrow 10 = A(S+2)(S+3)^2 + B.S(S+3)^2 + Cs(S+2)(S+3) + Ds(S+2)$$

Putting, $S = 0$

$A = \frac{5}{9}$ | $B = -5$ | $C = \frac{40}{9}$ | $D = \frac{10}{3}$

Inverse

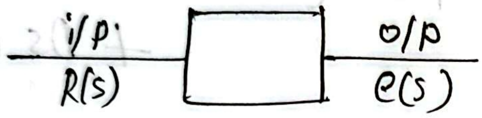
Mathematical Modeling of Transfer Function:

1) Transfer function
2) State space representation.

★ What is model?

$\longrightarrow$ is a simplified representation or abstraction of reality.

★ Transfer function:



$$T.F.,\ G(s) = \frac{output(s)}{input(s)}$$

<u>Exercise: 2.3</u> Find the transfer function, $G(s) = \dfrac{C(s)}{R(s)}$ corresponding to differential equation:

$$\frac{d^3c}{dt^3} + 3\cdot\frac{d^2c}{dt^2} + 7\cdot\frac{dc}{dt} + 5c = \frac{d^2r}{dt^2} + 4\cdot\frac{dr}{dt} + 3r \text{ — (i)}$$

We know,

$$f(t) \longrightarrow F(s)$$

$$\frac{df(t)}{dt} \longrightarrow sF(s) - f(0)$$

$$\frac{d^2f(t)}{dt^2} \longrightarrow s^2F(s) - sf(0) - f'(0)$$

from (i)

$$s^3C(s) + 3s^2C(s) + 7sC(s) + 5C(s) = s^2R(s) + 4sR(s) + 3R(s)$$

$$\Rightarrow C(s)\{s^3 + 3s^2 + 7s + 5\} = R(s)\{s^2 + 4s + 3\}$$

$$\Rightarrow \frac{C(s)}{R(s)} = \frac{s^2 + 4s + 3}{s^3 + 3s^2 + 7s + 5}$$

Exercise 2.4 Find the differential equation corresponding to the transfer function,

$$G(s) = \frac{2s+1}{s^2+6s+2}$$

Given,

$$G(S) = \frac{C(S)}{R(S)} = \frac{2s+1}{s^2+6s+2}$$

$$\Rightarrow C(s)s^2 + C(s)\,6s + C(s)\,2 = R(s)\,2s + R(s)$$

$$\Rightarrow \frac{d^2c}{dt^2} + 6\frac{dc}{dt} + 2c = 2\frac{dr}{dt} + r$$

$$\xrightarrow[R(S)]{i/P} \boxed{G(s)} \xrightarrow[C(S)]{O/P}$$

$$G(S) = \frac{C(S)}{R(S)}$$

$$\Rightarrow C(S) = G(S) \cdot R(S).$$

Exercise 2.5 Find the ramp response for a system whose transfer function is $G(S) = \frac{S}{(S+4)(S+8)}$

$$L(t) \longrightarrow \frac{1}{s^2}$$

$$L\{u(t)\} \longrightarrow \frac{1}{s}$$

$$r(t) = t\,u(t)$$

$$\therefore R(S) = \frac{1}{s^2}$$

Therefore,

$$C(S) = G(S) \cdot R(S)$$

$$= \frac{1}{s^2} \cdot \frac{S}{(S+4)(S+8)}$$

$$= \frac{1}{S(S+4)(S+8)}$$

$$\frac{1}{S(S+4)(S+8)} = \frac{A}{S} + \frac{B}{(S+4)} + \frac{C}{(S+8)}$$

$$A = \frac{1}{32},\quad B = -\frac{1}{16},\quad C = \frac{1}{32}$$

$$C(s) = \frac{1}{32s} - \frac{1}{16(s+4)} + \frac{1}{32(s+8)}$$

$$= 32u(t) - \frac{1}{16} \cdot e^{-4t} + \frac{1}{32} \cdot e^{-8t}$$

$V = IR$

$\Rightarrow R = \frac{V}{I}$

$= \text{Imped} = -$

Electrical Network Transfer functions:

Systems
- i) → Electrical Systems.
- ii) → Mechanical Systems.
  - → i) Linear System
  - → ii) Rotational system.

Electrical System:

→ Passive element (doesn't store charge)

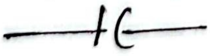
→ Active element (can store charge)

Resistor → Passive.

Capacitor, Resistor → Active

Voltage- Current relationship:

voltage across capacitor, $V_C(t) = \frac{1}{C} \int i(t)\,dt$



V

voltage across inductor, $V_L(t) = L \frac{di(t)}{dt}$

$$\frac{df(t)}{dt} \longleftrightarrow sF(s)$$

$$\int f(t)\,dt \longleftrightarrow \frac{1}{s} F(s)$$

Capacitor:

$$V_c(t) = \frac{1}{c}\int i(t)\,d(t)$$

LT

$$V_c(s) = \frac{1}{c} \cdot \frac{1}{s} I(s) = \frac{1}{cs} I(s)$$

$$V_c(s) = \frac{1}{cs} \cdot I(s)$$

$$\Rightarrow \frac{V_c(s)}{I(s)} = \frac{1}{cs}$$

$$\Rightarrow Z(s) = \frac{1}{cs}$$

$\hookrightarrow$ impedence.

Inductor:

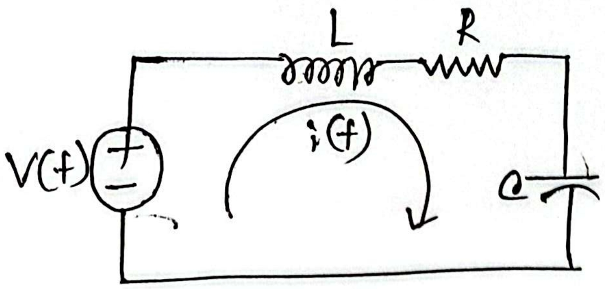
$$V_L(t) = L\frac{di(t)}{dt}$$

$$\Rightarrow V_L(s) = L.S.I(s)$$

$$\Rightarrow \frac{V_L(s)}{I(s)} = Ls$$

Resistor:

$$\frac{V_R(s)}{I(s)} = R$$ (as passive element)



(i) $\frac{V_c(s)}{V(s)} = ?$ (Transfer function)

$$V(t) = L.\frac{di(t)}{dt} + R.i(t) + \frac{1}{C}\int i\,dt$$

We know,

$$i(t) = C.\frac{dV_c(t)}{dt}$$

$$V(t) = LC\frac{d^2V_c(t)}{dt^2} + RC.\frac{dV_c(t)}{dt} + \frac{1}{C} \times \int C.\frac{dV_c(t)}{dt}$$

$$= LC.\frac{d^2V_c(t)}{dt^2} + RC.\frac{dV_c(t)}{dt} + V_c(t)$$

Applying laplace transformation,

$$V(s) = LC.s^2V_c(s) + RC.s.V_c(s) + V_c(s)$$

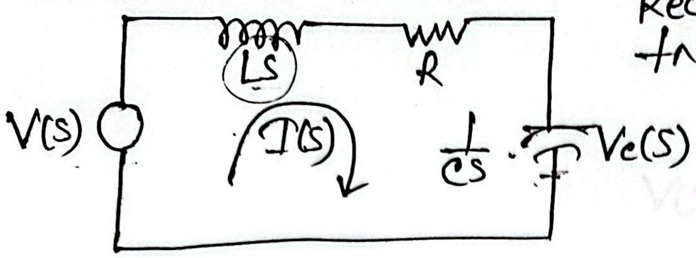
$$\Rightarrow V(s) = V_c(s)\left[s^2LC + s.RC + 1\right]$$

$$\Rightarrow \frac{V_c(s)}{V(s)} = \frac{1}{s^2LC + s.RC + 1}$$

ii) Using mesh analysis:

Redraw circuit with laplace transform:

$$\frac{V_c(S)}{V(S)} \quad KVL$$



Applying KVL:

$$V(s) = Ls \times I(s) + R \times I(s) + I(s) \times \frac{1}{Cs}$$

$$= I(s)\left[Ls + R + \frac{1}{Cs}\right]$$

We know,

$$\frac{V_c(s)}{I(s)} = \frac{1}{Cs}$$

For $V = IR$

$\Rightarrow I = \frac{V}{R}$

$\Rightarrow V_c(s) = I(s) \cdot \frac{1}{Cs}$

$$\Rightarrow I(s) = Cs \cdot V_c(s)$$

Therefore,

$$V(s) = Cs \cdot V_c(s) \cdot \left[Ls + R + \frac{1}{Cs}\right]$$

$$\Rightarrow \frac{V(s)}{V_c(s)} = Cs\left[Ls + R + \frac{1}{Cs}\right]$$

$$\Rightarrow \frac{V(s)}{V_c(s)} = s^2CL + RCs + 1$$

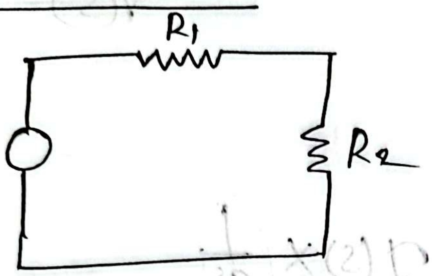
$$\Rightarrow \frac{V_c(s)}{V(s)} = \frac{1}{1 + RCs + s^2CL}$$

iii) **Ohm's law:**

$$\boxed{I \propto V}$$

$\boxed{\begin{matrix}KVL\\KCL\end{matrix}}$

Voltage divider:



$$V_2 = \frac{R_2}{R_1+R_2} \times V$$

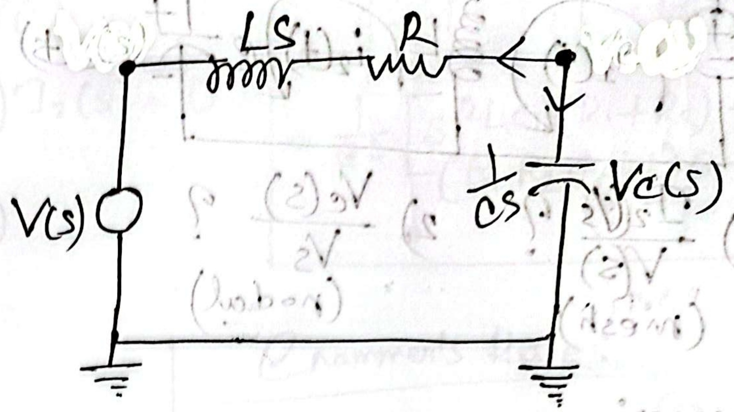
$$\frac{V_c(S)}{V(S)} = ?$$

$$V_c(S) = V(S) \cdot \frac{1/cs}{Ls+R+\frac{1}{cs}}$$

$$\Rightarrow \frac{V_c(S)}{V(S)} = \frac{\frac{1}{cs}}{\frac{s^2Lc+Rcs+1}{cs}}$$

$$= \frac{1}{1+Rcs+s^2Lc}$$

iv) Nodal Analysis:



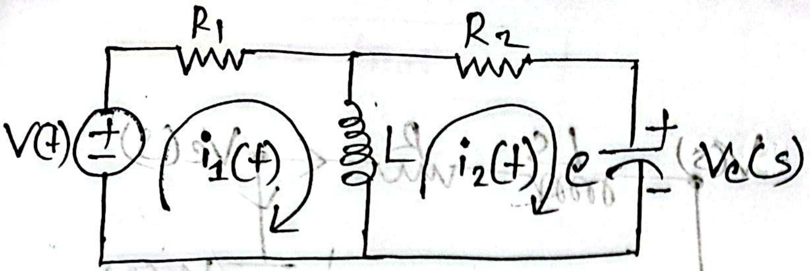
$$\frac{Vc(S)-0}{1/CS} + \frac{Vc(S)-V(S)}{LS+R} = 0$$

$$\Rightarrow CS\,Vc(S) + \frac{Vc(S)}{LS+R} = \frac{V(S)}{LS+R}$$

$$\Rightarrow Vc(S)\left[CS + \frac{1}{LS+R}\right] = \frac{V(S)}{LS+R}$$

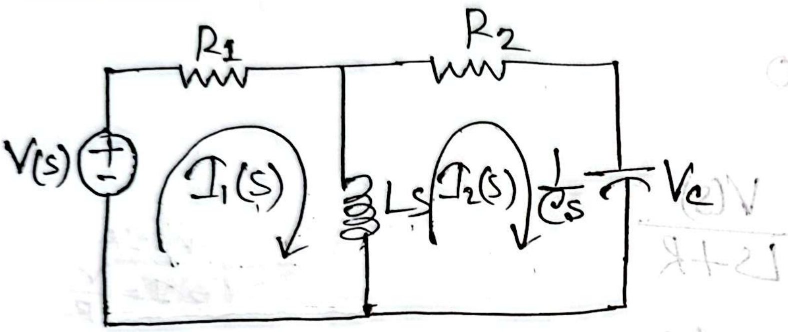
$$\Rightarrow \frac{Vc(S)}{1} \cdot \left[\frac{S^2LC+RCS+1}{LS+R}\right] = \frac{V(S)}{LS+R}$$

$$\Rightarrow \frac{Vc(S)}{V(S)} = \frac{1}{S^2LC+RCS+1}$$



1) $\frac{I_2(s)}{V(s)}$? (mesh) 2) $\frac{V_C(s)}{V_s}$? (nodal)

Answer:



$$R_1 I_1(s) + Ls\, I_1(s) - Ls\, I_2(s) = V(s)$$

$$\Rightarrow I_1(s)(R_1 + Ls) - Ls\, I_2(s) = V(s) \longleftarrow (i)$$

$$R_2 I_2(s) + \frac{1}{Cs} I_2(s) + Ls\, I_2(s) - Ls\, I_1(s) = 0$$

$$\Rightarrow I_2(s)\left(R_1 + \frac{1}{Cs} + Ls\right) - Ls\, I_1(s) = 0 \longleftarrow (ii)$$

from (i) we can write

[sum of impedence around mesh 1] $I_1(s)$ − [sum of impedendence around mesh (1) and (2)] $I_2(s)$

= [sum of applied source in mesh 1]

from (ii)

[sum of impedence around mesh 2] $I_2(s)$ − [sum of impedence around mesh (1) and (2)] $I_1(s)$

= [sum of applied source in mesh 2]

From (i) and (ii)

$$(R_1+Ls)I_1(s) - Ls\,I_2(s) = V(s)$$

$$-Ls\,I_1(s) + \left(R_2+\frac{1}{Cs}+Ls\right)I_2(s) = 0$$

$$\Delta = \begin{vmatrix} (R_1+Ls) & -Ls \\ -Ls & \left(R_2+\frac{1}{Cs}+Ls\right) \end{vmatrix}$$

$$= \frac{1}{Cs}\left[s^2LC(R_1+R_2) + (R_1R_2C+L)s + R_1\right]$$

Now, transfer function, $G(s)$

$$G(s) = \frac{I_2(s)}{Vs}$$

$$I_2(s) = \frac{\begin{vmatrix} (R_1+Ls) & V(s) \\ -Ls & 0 \end{vmatrix}}{\Delta}$$

Crammer's Rule:

$$a_1x + b_1y = c_1 \quad \text{(i)}$$

$$a_2x + b_2y = c_2 \quad \text{(ii)}$$

$$x = \frac{\begin{vmatrix} c_1 & b_1 \\ c_2 & b_2 \end{vmatrix}}{\Delta}$$

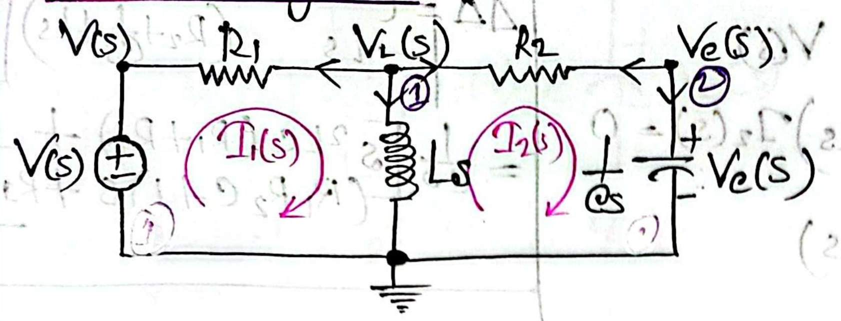
$$y = \frac{\begin{vmatrix} a_1 & c_1 \\ a_2 & c_2 \end{vmatrix}}{\Delta}$$

$$\Delta = \begin{vmatrix} a_1 & b_1 \\ a_2 & b_2 \end{vmatrix} = a_1b_2 - a_2b_1$$

$$\frac{I_2(s)}{V(s)} = \frac{Ls \times Cs}{s^2LC(R_1+R_2) + (R_1R_2C+L)s + R_1}$$

$$= \frac{LCs^2}{s^2LC(R_1+R_2) + (R_1R_2C+L)s + R_1}$$

Nodal analysis:



For node ①

$$\frac{V_L(s)-V(s)}{R_1}+\frac{V_L(s)-0}{Ls}+\frac{V_L(s)-V_c(s)}{R_2}=0$$

$$\Rightarrow \frac{V_L(s)}{R_1}-\frac{V(s)}{R_1}+\frac{V_L(s)}{Ls}+\frac{V_L(s)}{R_2}-\frac{V_c(s)}{R_2}=0$$

$$\Rightarrow V_L(s)\left[\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{Ls}\right]+V_c(s)\left(-\frac{1}{R_2}\right)=\frac{V(s)}{R_1}$$

$$\Rightarrow V_L(s)\left[G_1+G_2+\frac{1}{Ls}\right]-V_c(s)\,G_2=V(s).G_1$$

For node ②

$$\frac{V_c(s)-V_L(s)}{R_2}+\frac{V_c(s)-0}{\frac{1}{Cs}}=0$$

$$\Rightarrow \frac{V_c(s)}{R_2}-\frac{V_L(s)}{R_2}+\frac{V_c(s)}{\frac{1}{Cs}}=0$$

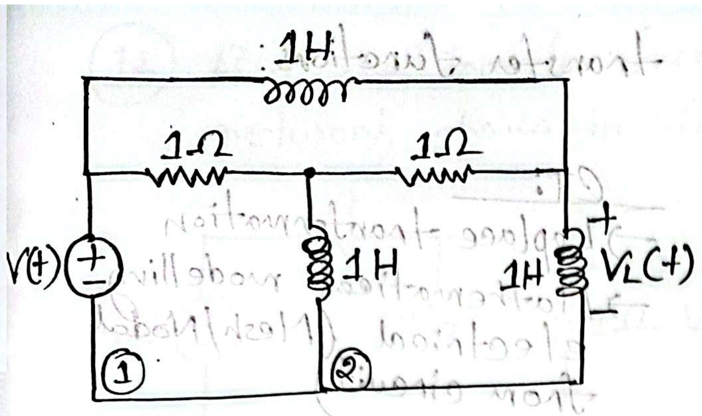
$$\Rightarrow V_L(s)\left[-\frac{1}{R_2}\right]+V_c(s)\left[\frac{1}{R_2}+Cs\right]=0$$

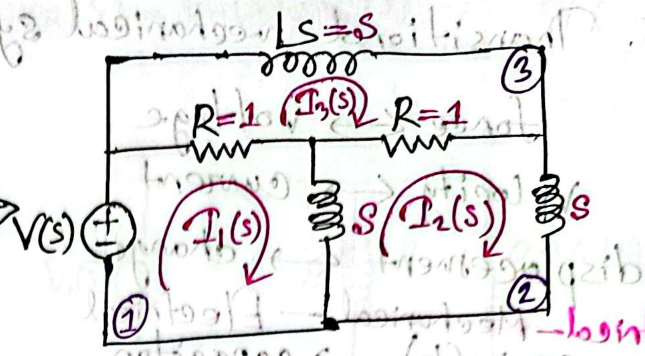
$$\Delta=\begin{vmatrix} G_1+G_2+\frac{1}{Ls} & -G_2 \\ -G_2 & G_2+Cs \end{vmatrix}$$

$$=(G_2+Cs)\left(G_1+G_2+\frac{1}{Ls}\right)-G_2^2$$

$$\therefore V_c(s)=\frac{\begin{vmatrix} G_1+G_2+1/Ls & G_1V(s) \\ -G_2 & 0 \end{vmatrix}}{(G_2+Cs)\left(G_1+G_2+\frac{1}{Ls}\right)-G_2^2}=\frac{G_1G_2V(s)}{(G_2+Cs)\left(G_1+G_2+\frac{1}{Ls}\right)-G_2^2}$$

$$\therefore \frac{V_c(s)}{V(s)}=\frac{G_1G_2}{(G_2+Cs)\left(G_1+G_2+\frac{1}{Ls}\right)-G_2^2}$$





For loop 1

$$(1+s)I_1(s) - sI_2(s) - I_3(s) = V(s) \quad \text{--- (i)}$$

For loop 2

$$(1+2s)I_2(s) - s.I_1(s) - I_3(s) = 0 \quad \text{--- (ii)}$$

For loop 3

$$(2+s)I_3(s) - I_1(s) - I_2(s) = 0 \quad \text{--- (iii)}$$

$$\Delta = \begin{vmatrix} (1+s) & -s & -1 \\ -s & (1+2s) & -1 \\ -1 & -1 & (2+s) \end{vmatrix} = s^3+5s^2+2s$$

$\frac{V_L(S)}{V(S)} = ?$

$\frac{I_3(S)}{V(S)} = ?$

$$V_L(S) = I_3(S) \times \frac{1}{s} \Rightarrow I_3(S) = s.V_L(S)$$

$$I_3(S) = \frac{\begin{vmatrix} (1+s) & -s & V(s) \\ -s & (1+2s) & 0 \\ -1 & 1 & 0 \end{vmatrix}}{s^3+5s^2+2s}$$

2.5. Transitional mechanical system transfer functions:

force $\leftrightarrow$ voltage
velocity $\leftrightarrow$ current
displacement $\leftrightarrow$ charge

Mechanical — Electrical
spring(k) $\longrightarrow$ capacitor
mass (m) $\longrightarrow$ inductor
viscous damper (f_{sv}) $\longrightarrow$ resistor.

CT:
→ Laplace transformation
→ Mathematical modelling electrical (Mesh/Nodal from circuit)

Representation:

Spring $\longrightarrow k$
viscous damper $\longrightarrow f_s v$
mass $\longrightarrow ms^2$

force $\leftrightarrow$ voltage.

Mesh ①

$$\left[M_1 s^2 + (K_1+K_2) + s\,(f_{v_1}+f_{v_3})\right] x_1(s) - (K_2 + f_{v_3} s)\, x_2(s) = F(s)$$

Mesh ②

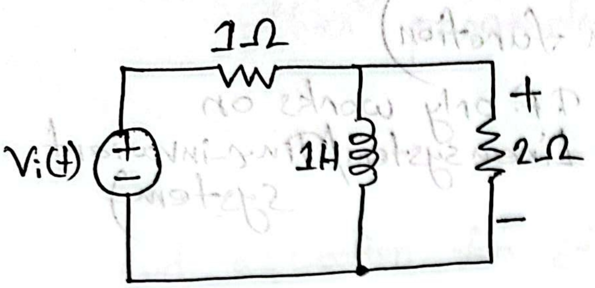
$$\left[M_2 s^2 + (K_2+K_3) + s.\,(f_{v_2}+f_{v_3})\right] x_2(s) - (K_2 + s.f_{v_3})\, x_1(s) = 0$$

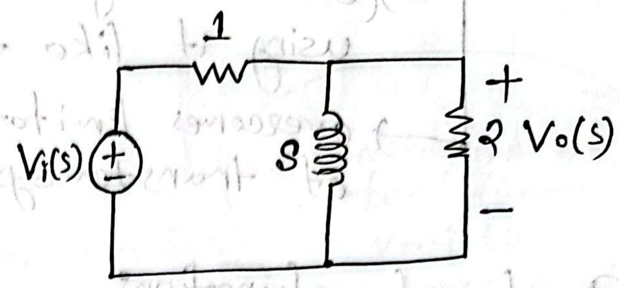
Transfer function → Analyses behaviour of system
→ Linear system / Time-invariant system.
interal

$$T(s) = \frac{C(s)}{X(s)}$$

$$\Rightarrow C(s) = T(s) . X(s)$$

(17) Find the transfer function, $G(s) = V_o(s)/V_i(s)$, for each network shown in figure

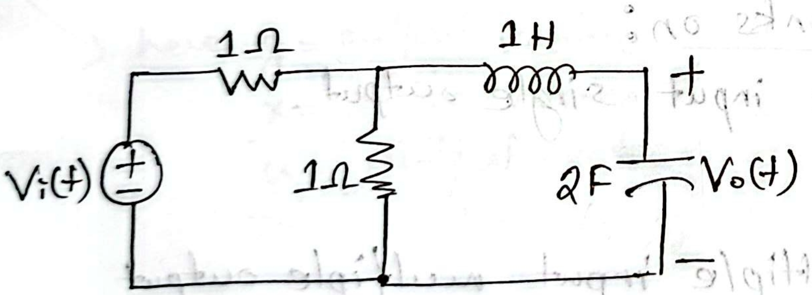


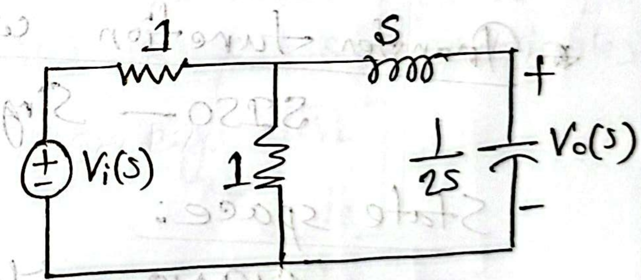


Total impedence $= 1 + s + 2$
$= s + 3$

$$V_o(s) = \frac{V_i(s)}{s+3} \times 2$$

$$\Rightarrow \frac{V_o(s)}{V_i(s)} = \frac{2}{s+3}$$





Total impedence $= 1 + s + \frac{1}{2s}$

$$V_o(s) = \frac{\frac{1}{2s}}{1 + s + \frac{1}{2s}} \times V_i(s)$$

$$\Rightarrow \frac{V_o(s)}{V_i(s)} = \frac{1}{2s^2 + 2s + 1}$$

State space representation:

→ (can be analysed system's behaviour using it like transfer function)

→ overcomes limitation (as T.F. only works on Linear system/Time-invariant system.) of transfer system.

* In transfer function:

output depends on current input

In state-space:

→ output depends on current input as well as previous state variable (past memory) — capacitor and inductor are used for it.

→ it can analyse wide-range of system (not only linear)

* Transfer function works on:

SISO — Single input single output.

State space:

MIMO — Multiple input multiple output

Question: Differentiate between transfer function and state space representation. (it is necessary over tran. func. to analyse a system)

capacitor, inductor — stores energy, works as memory

State variable:

linearly independent variable, doesn't depend on other parameter.

Combination of two/three variable — not a state variable

Required equation for state-space analysis:

derivative of x, $\dot{x} = \frac{dx}{dt}$

i) $\dot{x} = Ax + Bu$ → state equation

ii) $y = Cx + Du$ → output equation

$\dddot{x} = \frac{d^3x}{dt^3}$

$\ddot{x} = \frac{d^2x}{dt^2}$

here, x = state vector
u = input vector

x = vector representation of state variables

here, y = output vector
x = state vector
u = output vector.

e.g. $x = \begin{bmatrix} V_L \\ i_C \end{bmatrix}$

$\dot{x} = \begin{bmatrix} \frac{dV_L}{dt} \\ \frac{di_C}{dt} \end{bmatrix}$

$= \begin{bmatrix} \dot{V}_L \\ \dot{i}_C \end{bmatrix}$

A =

B =

C =

D =

A system is represented in state space by following equation,

$$\dot{x} = Ax + Bu$$
$$y = Cx + Du$$

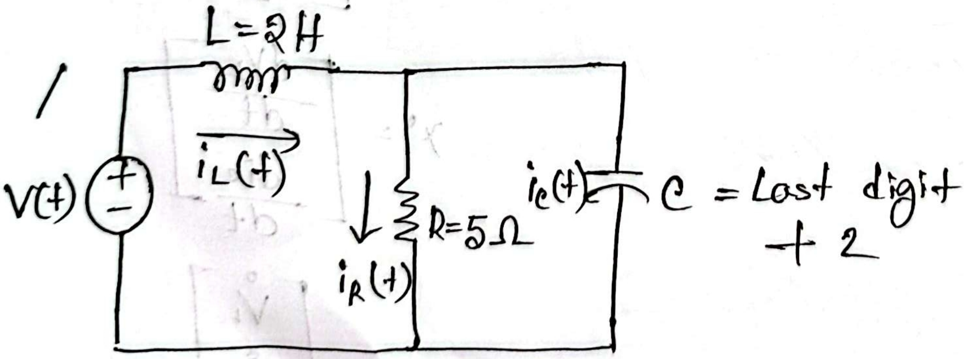
① কোনটা state variable — order যত, no. of state variable তত,

② state variable = no. of energy element (inductor/ capacitor)

Scenario. — $\left\{ \begin{array}{l} \text{series} - ১ \text{ induction} \\ \text{parallel} - ১ \text{ capacitor} \end{array} \right\}$ — considered equivalent

Example 3.1:

Find a state-space representation



Step 1: Label all branch current.

Step 2: Write the derivative of all energy equation.

equation ও দুই state variale আর input প্রকাশে পারছে।

Derivative

$$V_L = L\cdot\frac{di_L}{dt} \qquad \boxed{i_L = \frac{1}{L}\int V_L\,dt}$$

$$\Rightarrow \frac{di_L}{dt} = \frac{1}{L}\cdot V_L \text{ --- (i)}$$

Note: We took the derivative equation, (box are excluded)

$$i_c = C\cdot\frac{dV_c}{dt} \quad\Rightarrow\quad \frac{dV_c}{dt} = \frac{1}{C}\,i_c \text{ --- (ii)}$$

$$\boxed{\Rightarrow V_c = \frac{1}{C}\int i_c\,dt}$$

as, (energy storage element's) which variable can be represent through derivative $\left(\frac{di_L}{dt}, \frac{dV_c}{dt}\right)$ they are state variables.

now,

$$x = \begin{bmatrix} V_c \\ i_L \end{bmatrix}$$

$$\dot{x} = \begin{bmatrix} \frac{dV_c}{dt} \\ \frac{di_L}{dt} \end{bmatrix}$$

Step 3: non-state variable representation through state variable.

In eqn (i)

$$\frac{di_L}{dt} = \frac{1}{L}\cdot V_L$$

$$= \frac{1}{L}(V - V_c)$$

$$= \frac{1}{L}V - \frac{1}{L}V_c \text{ --- (iii)}$$

$$V = V_L + V_R$$

$$\Rightarrow V_L = V - V_R$$

$$i_L = i_R + i_c$$

$$i_c = i_L - i_R$$

$$= i_L - \frac{V_R}{R}$$

$$= i_L - \frac{V_c}{R}$$

[as, V_c and V_R are equivalent for being parallel]

From eqn (ii)

$$\frac{dV_c}{dt} = \frac{1}{c} \cdot i_c$$

$$= \frac{1}{c}\left(i_L - \frac{V_c}{R}\right)$$

$$= \frac{1}{c} i_L - \frac{1}{Rc} V_c$$

$$\frac{dV_c}{dt} = -\frac{1}{Rc} V_c + \frac{1}{c} i_L + 0 \cdot V_i \text{ —— (1)}$$

$$\frac{di_L}{dt} = -\frac{1}{L} V_c + 0 \cdot i_L + \frac{1}{L} V_i \text{ —— (2)}$$

$$\overset{\circ}{x} = \begin{bmatrix} \frac{dV_c}{dt} \\ \frac{di_L}{dt} \end{bmatrix} = \underbrace{\begin{bmatrix} -1/Rc & \cancel{V_c}\ 1/c \\ -1/L & 0 \end{bmatrix}}_{(2\times2)} \underbrace{\begin{bmatrix} V_c \\ i_L \end{bmatrix}}_{(2\times1)} + \begin{bmatrix} 0 \\ 1/L \end{bmatrix} V_i$$

(2×1) — 2 equation (1 and 2)

Output equation:

$$\text{Output, } y = i_R = \frac{V_R}{R} = \frac{V_c}{R}$$

$$i_R = \frac{1}{R} V_c + 0 \cdot i_L + 0 \cdot V_i$$

$$i_R = \begin{bmatrix} 1/R & 0 \end{bmatrix} \begin{bmatrix} V_c \\ i_L \end{bmatrix} + \begin{bmatrix} 0 \end{bmatrix} V_i$$

Mid

Lec1: → Basics of cs

→ open system
Vs
closed system

→ functional block diagram of closed loop system.

→ steps of engineering cs.

Lec2: → Laplace transform (প্রুফ দরকার)

— 3 টা condition

→ Lap. tran. math.

→ Mathematical model
(mechanical mast আসবে)

E

Lec3: State space representation (Theory + Math)