GATE 2027 EC, Section 2A

Network theory

Circuit laws and theorems, sinusoidal steady state, RL/RC/RLC transients, Laplace methods and two-port networks.

37 formulas in 6 topics. Equations are numbered section.topic.formula, for example (2A.1.1).

2A.1 Basics

Ohm's law and power (2A.1.1)

$V = IR$; $P = VI = I^2R = V^2/R$

Series / parallel R (2A.1.2)

$R_s = \Sigma R$; $1/R_p = \Sigma 1/R$; two in parallel: $R_1R_2/(R_1 + R_2)$

Capacitors, inductors (2A.1.3)

C: series like parallel R, parallel adds; L: combine like R

Dividers (2A.1.4)

$V_1 = V \cdot R_1/(R_1 + R_2)$; $I_1 = I \cdot R_2/(R_1 + R_2)$

Capacitor (2A.1.5)

$i = C\, dv/dt$; energy $\frac{1}{2}CV^2$; voltage cannot jump

Inductor (2A.1.6)

$v = L\, di/dt$; energy $\frac{1}{2}LI^2$; current cannot jump

Star ↔ delta (2A.1.7)

$R_a = R_{ab}R_{ca}/(R_{ab} + R_{bc} + R_{ca})$; $R_{ab} = (R_aR_b + R_bR_c + R_cR_a)/R_c$

Equal: $R_Y = R_\Delta/3$

2A.2 Theorems

Thevenin (2A.2.1)

V_{th} = open-circuit voltage; $R_{th} = V_{oc}/I_{sc}$ (or with sources killed)

Norton (2A.2.2)

I_N = short-circuit current; $R_N = R_{th}$

Superposition (2A.2.3)

Valid for voltage/current in linear circuits, not for power

Max power (DC) (2A.2.4)

$R_L = R_{th}$; $P_{max} = V_{th}{}^2/(4R_{th})$; efficiency 50%

Max power (AC) (2A.2.5)

$Z_L = Z_{th}{}^*$ (conjugate); if only R_L can vary: $R_L = |Z_{th}|$

Reciprocity (2A.2.6)

Linear bilateral networks: swapping source and meter gives the same reading

Tellegen (2A.2.7)

$\Sigma\, v_k i_k = 0$ over all branches

2A.3 Transients

First-order response (2A.3.1)

$x(t) = x(\infty) + [x(0^+) - x(\infty)]\, e^{-t/\tau}$

Time constants (2A.3.2)

RC circuit $\tau = RC$; RL circuit $\tau = L/R$

Series RLC (2A.3.3)

$s^2 + (R/L)s + 1/(LC) = 0$; $\omega_0 = 1/\sqrt{(LC)}$; $\zeta = (R/2)\sqrt{(C/L)}$

Parallel RLC (2A.3.4)

$\zeta = (1/2R)\sqrt{(L/C)}$

Damping (2A.3.5)

$\zeta > 1$ overdamped; $\zeta = 1$ critically damped; $\zeta < 1$ underdamped (rings at $\omega_d = \omega_0\sqrt{(1 - \zeta^2)}$)

2A.4 Sinusoidal steady state

Impedances (2A.4.1)

$Z_R = R$; $Z_L = j\omega L$; $Z_C = 1/(j\omega C)$

RMS and average (2A.4.2)

Sine: $V_{rms} = V_m/\sqrt{2}$, full-wave average $2V_m/\pi$; square ($\pm V_m$): $V_{rms} = V_m$

Complex power (2A.4.3)

$S = V_{rms} I_{rms}^* = P + jQ$; $|S|$ in VA; $pf = \cos\varphi = P/|S|$

Series resonance (2A.4.4)

$f_0 = 1/(2\pi\sqrt{(LC)})$; $Q = \omega_0 L/R = (1/R)\sqrt{(L/C)}$; $BW = f_0/Q$; Z minimum = R

Parallel resonance (2A.4.5)

$Q = R\sqrt{(C/L)}$; Z maximum = R

Half-power frequencies (2A.4.6)

$f_1 f_2 = f_0^2$; $f_2 - f_1 = BW$

2A.5 Laplace methods

Common pairs (2A.5.1)

$u(t) \to 1/s$; $t \to 1/s^2$; $e^{-at} \to 1/(s+a)$; $\sin\omega t \to \omega/(s^2+\omega^2)$; $\cos\omega t \to s/(s^2+\omega^2)$

Derivative, integral (2A.5.2)

$f' \to sF(s) - f(0^-)$; $\int f \to F(s)/s$

Shifts (2A.5.3)

$f(t-a)u(t-a) \to e^{-as}F(s)$; $e^{-at}f(t) \to F(s+a)$

Initial / final value (2A.5.4)

$f(0^+) = \lim_{s\to\infty} sF(s)$; $f(\infty) = \lim_{s\to 0} sF(s)$ (all poles of $sF(s)$ in left half-plane)

Initial-condition models (2A.5.5)

Capacitor: $1/(sC)$ in series with V_0/s; inductor: sL in series with source $L\cdot i(0)$

2A.6 Two-port networks

Z parameters (2A.6.1)

$V_1 = z_{11}I_1 + z_{12}I_2$; $V_2 = z_{21}I_1 + z_{22}I_2$

Y parameters (2A.6.2)

$I_1 = y_{11}V_1 + y_{12}V_2$; $I_2 = y_{21}V_1 + y_{22}V_2$; $[Y] = [Z]^{-1}$

h parameters (2A.6.3)

$V_1 = h_{11}I_1 + h_{12}V_2$; $I_2 = h_{21}I_1 + h_{22}V_2$

ABCD parameters (2A.6.4)

$V_1 = AV_2 - BI_2$; $I_1 = CV_2 - DI_2$

Reciprocal (2A.6.5)

$z_{12} = z_{21}$; $y_{12} = y_{21}$; $h_{12} = -h_{21}$; $AD - BC = 1$

Symmetric (2A.6.6)

$z_{11} = z_{22}$; $y_{11} = y_{22}$; $A = D$; $\Delta h = 1$

Interconnections (2A.6.7)

Series → add Z; parallel → add Y; cascade → multiply ABCD

My notes