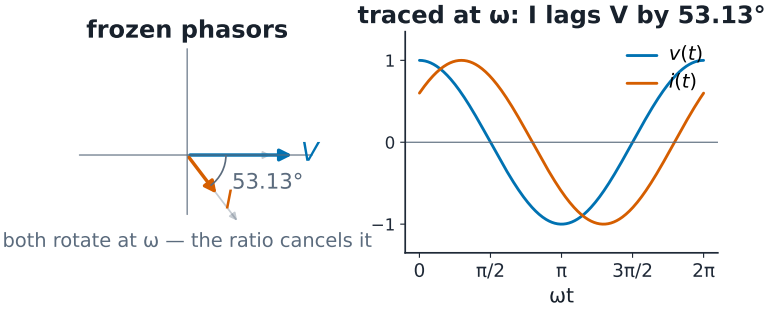
Circuit Analysis II (AC)

Curated undergraduate study track (not accredited, no external exam). Original explanations and practice only, following the reviewed course handout.

The AC toolkit opens

- EE02 complex numbers, ODEs and Laplace now pay for themselves.
- Every **phasor** answer verifies in a second representation.

The rotating picture behind the frozen phasor

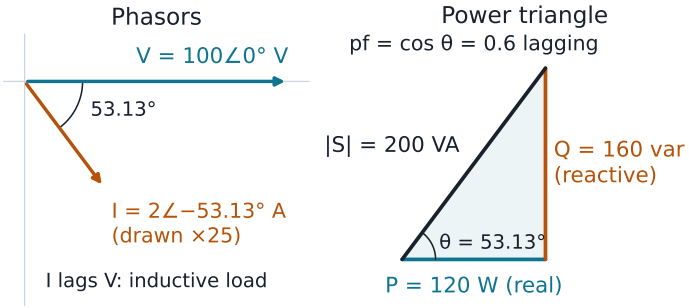


A **phasor** is a snapshot of a rotating arrow; the traced sinusoid is its projection, and ratio questions cancel the rotation.

Sinusoidal steady state and phasors: verify in the other form

1. **Series** 30 + j40 = 50 at 53.13 degrees under 100 V: I = 2 A at -53.13 - current lags.
2. **Check** Rectangular: I = 1.2 - j1.6; |I| = 2 and atan2(-1.6, 1.2) = -53.13 - agrees.
3. **Parallel** 30 || j40 = (48000 + j36000)/2500 = 19.2 + j14.4 = 24 at 36.87: smaller than either branch.

The RL load: lag becomes a power triangle

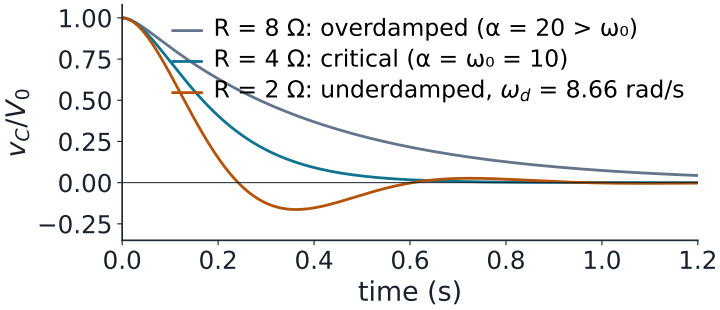


V = 100 at 0 with I = 2 A at -53.13 lagging; the triangle reads P = 120 W, Q = 160 var, |S| = 200 VA, pf 0.6.

AC power and three-phase: two routes agree

1. **Load** 120 W, 160 var, 200 VA, pf 0.6 - both cross-check routes agree.
2. **Correct** 50.9 uF cancels the 160 var at 100 V, 50 Hz; source current 2 A drops to 1.2 A.
3. **Motor** Star, 415 V line, 10 + j10 per phase: 239.6 V, 16.94 A, P = 8611 W per phase and by the line formula.

One circuit, three resistors

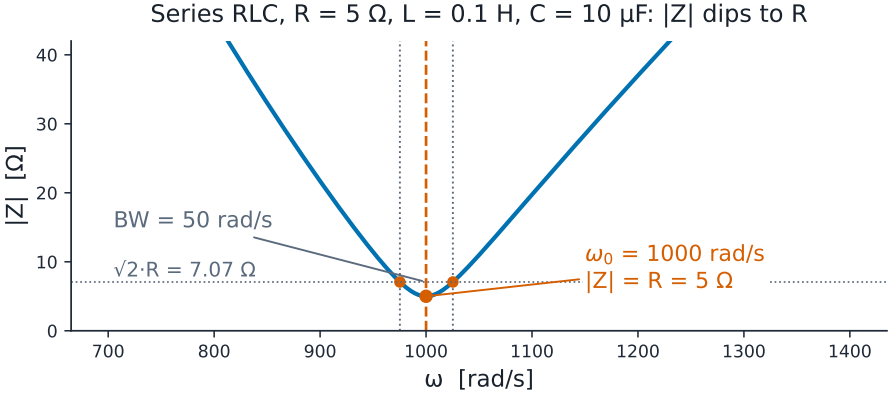


L = 0.2 H, C = 0.05 F released from 1 V: R = 8 **overdamped**, R = 4 critical, R = 2 **underdamped** - the same omega0 = 10 with alpha 20, 10, 5.

Second-order RLC: $\omega 0$ and alpha decide

1. **Classify** R=4, L=0.2, C=0.05: alpha = omega0 = 10, critical; R=2 gives alpha = 5, **underdamped**, wd = 8.66.
2. **Roots** R=8: alpha = 20, roots -20 +/- sqrt(300) = -2.68 and -37.32 per second (machine-verified).
3. **Constants** From 1 V with zero slope: A = 37.32/34.64 = 1.077, B = -0.077 - the slow root owns the tail.

|Z| dips to R at resonance

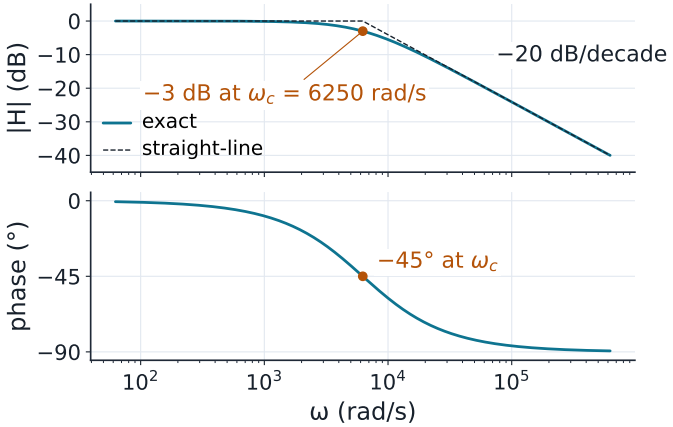


|Z| bottoms at R = 5 ohm at 1000 rad/s; the half-power band is 975 to 1025.

Resonance: magnification and selectivity

1. **Numbers** R=5, L=0.1, C=10 uF: omega0 = 1000 rad/s, Q = 20, BW = 50 rad/s.
2. **Magnify** I = 2 A; V_L = V_C = 200 V on a 10 V source - verified on both elements, 180 degrees apart.
3. **Select** Half-power at 975.3 and 1025.3 rad/s (difference 50.0); at 900 rad/s the current is 10/21.7 = 0.46 A.

The RC low-pass against its asymptotes



At the 6250 rad/s corner: −3 dB and −45°, then −20 dB per decade.

Filters and Bode plots: the high-pass mirror

1. **Corner** 1.6k x 0.1u: wc = 6250 rad/s (995 Hz); at 10wc the exact gain is -20.04 dB.
2. **Mirror** High-pass: -20.04 dB at +84.3 degrees for 0.1wc; -3.01 dB at +45 at wc; -0.04 dB at +5.7 for 10wc.
3. **Design** -40 dB at 10 kHz forces wc <= 628 rad/s; passband 1 dB at 400 Hz needs wc >= 4940 - one section cannot do both.

The s-domain toolkit

The s-domain models: impedance plus initial-condition source

Resistor $Z = R$ no initial energy — nothing extra

Inductor $Z = sL$ plus series source $Li(0^-)$

Capacitor $Z = 1/(sC)$ plus parallel source $Cv(0^-)$

Then every DC method (divider, mesh, Thévenin) applies in s — with the sources carrying the past

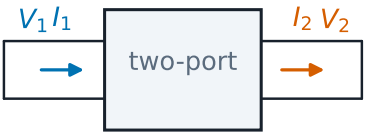
Each element drawn twice: its **impedance** R, sL or 1/(sC), and beside it the initial-condition source - L i(0) volts in series, C v(0) amperes in parallel.

Laplace circuit analysis: the poles are alpha and omega_d

1. **RC** vC(0) = 1 V on a 9 V step: V_C = 9/s - 8/(s+1), so vC(t) = 9 - 8 e^(-t) - the wave-1 answer by algebra.
2. **RLC** R=2, L=0.2, C=0.05 with i(0) = 1 A: (0.2s + 2 + 20/s) I = 0.2, so I(s) = s/(s^2 + 10s + 100).
3. **Match** Poles -5 +/- j8.66 - exactly alpha = 5 and wd = 8.66 from the time-domain regime arithmetic.

Ports hide the interior

port conventions



ABCD: current OUT of port 2

elementary ABCD blocks

series Z $(1,\ Z;\ 0,\ 1)$
impedance in the line

shunt Y $(1,\ 0;\ Y,\ 1)$
admittance across

cascade = matrix multiply

A box with port 1 (V1, I1 in) and port 2 (V2, I2 out) beside the two elementary ABCD blocks: series Z as (1, Z; 0, 1), shunt Y as (1, 0; Y, 1).

Two-port networks: cascades and reciprocity

1. **L-section** Shunt -j0.1 then series j10: product (1, j10; -j0.1, 2); det = 2 - 1 = 1 - reciprocal.
2. **Convert** z11 = A/C, z12 = det/C, z21 = 1/C, z22 = D/C: z11 = z12 = z21 = j10, z22 = j20 (machine-verified).
3. **Read** Port 2 open: V1 = z11 I1 = j10 I1 - a pure inductive 10 ohm at the input.

Check yourself

- **Phasor**: 30 + j40 across 100 V draws? (2 A at -53.13 degrees.)
- **Resonance**: Q = 20 on 10 V gives V_C? (200 V.)
- **Two-port**: a reciprocal cascade has AD - BC? (1.)