

1 RLC circuits

$\tau = RC$, or $\tau = L/R$, or $\tau = 1/\sqrt{LC}$, is the time it takes to decay to $1/e$ times the original. This is only valid for undamped circuits; damped circuits oscillate at $\sqrt{1/LC - (R/2L)^2}$.

The general form of the equation is $i'' + 2\alpha i' + \omega_0^2 i = 0$; the solutions then are $s = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$; with $i = Ae^{s_1 t} + Be^{s_2 t}$. The Q-factor, $Q = \omega_0/2\alpha$, is such that

At low frequencies or long timescales, an inductor is like a short and a capacitor is open. At high frequencies and short timescales, the other way around.

When computing timescales, voltage sources act like shorts.

Bandwidth is twice the distance between the resonant frequency and when it's half at resonance; bandwidth is equal to 2α ; also, $\delta\omega/\omega_0 = 1/Q$. In an RC circuit, voltage lags current. In an RL circuit, voltage leads current. In an RLC circuit, something. This can be seen by noting that $V = IZ$, and so $I/V = 1/Z$. So if ImZ is positive (inductive), current lags. If ImZ is negative (capacitive), current leads.

2 Solving circuits

DON'T PANIC

Set up equations and solve them.

Remember the properties of voltage dividers.

Remember that elements in series can be combined.

Assume that if you get a really messy equation, you're doing something wrong. Thevenin equivalent: V_{TH} is the voltage you get with no input. To find R_{TH} , short voltage sources and open current sources, apply a test voltage V_T and compute $R_{TH} = V_T/I_T$.

Remember that current sources constrain the current to be equal to them, and so do voltage sources. But the voltage across a current source and the current across a voltage source can be arbitrary.

Remember that all state variables are finite.

Try to make shit look like voltage dividers or whatever. Remember that open ports don't matter!

MESSY EQUATIONS MEAN YOU'RE DOING SOMETHING WRONG.

Remember that parallel 'branches' are 'independent'.

When dealing with non-linear elements, find the Thevenin equivalent of the rest of the circuit, or solve 'around' it.

To calculate power, remember that $P = IV = V^2/R = I^2R$.

2.1 Dividers

A voltage going across resistors in series divides in proportion to the amount of resistance it has yet to 'pass through'. A current going through R_x divides into

$I_x = IR_T/(R_X + R_T)$ where R_T is the resistance of everything else.

3 MOSFETs

The fundamental law of a MOSFET is that $I_{DS} = K/2(V_{GS} - V_T)^2$ when $V_{GS} > V_{th}$ and $V_{DS} > V_{GS} - V_{th}$. When $V_{DS} < V_{GS} - V_{th}$, $I_{DS} = K((V_{GS} - V_T)V_{DS} - V_{DS}^2/2)$.

Current into gate is zero.

For a FET-like thing, where $i_{DS} = f(v_{GS}, v_{DS})$, the general model is a voltage source of gain $g_m = f_{v_{GS}}(v_{GS}, v_{DS})$ in parallel with a resistor of conductance $f_{v_{DS}}(v_{GS}, v_{DS})$, so $i_d = g_m v_{gs} + v_{ds}/r$.

4 Small-circuit analysis

- Voltage sources become shorts.
- Circuit sources become open.
- Resistors stay the same.
- A MOSFET becomes a current source $i_{ds} = K(V_{GS} - V_T)v_{gs}$.
- More generally, a large-signal thing $i_A = f(v_A)$ becomes $i_a = f'(V_A)v_a$.