S2014, BME 101: Applied Circuits study sheet 1

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May 22, 2014

Abstract

There is very little to memorize in this class. Here are the few concepts that are worth having instantly available in your memory. Your studying should not be memorizing these few formulas, but using them repeatedly to solve design and analysis problems.

1 Physics

$$Q = CV$$

$$I(t) = \frac{dQ(t)}{dt}$$

$$V = IR, \text{Ohm's Law}$$

2 Math

$$j = \sqrt{-1}$$

$$e^{j\theta} = \cos(\theta) + j\sin(\theta)$$

$$\frac{de^{j\omega t}}{dt} = j\omega e^{j\omega t}$$

$$\omega = 2\pi f$$

where ω is angular frequency in radians/sec,
and f is frequency in Hz

3 Op amps

For the generic op-amp amplifier in Figure 1, only the approximations when gain $G \to \infty$ are worth memorizing:

Inverting:

$$V_{out} - V_p \approx \frac{Z_f}{Z_i}(V_p - V_m)$$

Non-inverting:

$$V_{out} - V_m \approx \frac{Z_f + Z_i}{Z_i}(V_p - V_m)$$

Transimpedance (set $Z_i = 0$ and look at I_m from amplifier into input node V_m):

$$V_{out} - V_p \approx Z_f I_m$$

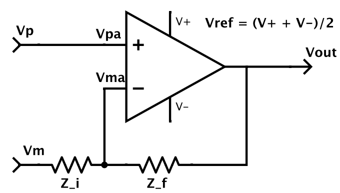

Figure 1: Generic negative-feedback op amp circuit, used for inverting and non-inverting amplifiers. $V_{out} - V_{ref} = G(V_{in+} - V_{in-}) = G(V_p - \frac{V_m Z_f + V_{out} Z_i}{Z_f + Z_i})$, where $V_{ref} = (V_+ + V_-)/2$ is the voltage midway between the power rails of the op amp. The negative feedback tries to keep the plus and minus inputs of the op amp at the same voltage.

4 Impedance

$$v(t) = i(t)Z$$

$$Z = R, \text{resistor}$$

$$Z = \frac{1}{j\omega C}, \text{capacitor, angular frequency} = \omega$$

$$Z = j\omega L, \text{inductor, angular frequency} = \omega$$

$$Z_{series} = Z_1 + Z_2$$

$$Z_{parallel} = Z_1 \parallel Z_2 = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2}} = \frac{Z_1 * Z_2}{Z_1 + Z_2}$$

$$\text{gain} = \frac{V_{out}}{V_{in}} = \frac{Z_{down}}{Z_{up} + Z_{down}}, \text{for voltage divider}$$

$$2\pi f = \omega = \frac{1}{RC}, \text{corner frequency for RC circuit}$$

$$2\pi f = \omega = \frac{1}{\sqrt{LC}}, \text{corner frequency for LC circuit}$$

Gain of simple RC circuit (one R, one C) is $\sqrt{2}/2$ at the corner frequency.