# BME 194: Applied Circuits study sheet 2

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February 20, 2013

There is very little to memorize in this class. Here are the few concepts we've had so far that are worth having instantly available in your memory. You should design and analyze enough RC, RL, and LC circuits that you have memorized the formulas as a by-product.

## 1 Physics

$Q = CV$
$I(t) = \frac{dQ(t)}{dt}$
$V = IR$

## 2 Math

$j = \sqrt{-1}$
$e^{j\theta} = \cos(\theta) + j\sin(\theta)$
$\frac{de^{j\omega t}}{dt} = j\omega e^{j\omega t}$
$\omega = 2\pi f$ angular frequency in radians/sec, frequency in Hz

## 3 Impedance

$v(t) = i(t)Z$
$Z_R(\omega, R) = R,$ resistor
$Z_C(\omega, C) = \frac{1}{j\omega C},$ capacitor, $\omega = 2\pi f$
$Z_L(\omega, L) = j\omega L,$ inductor, $\omega = 2\pi f$
$Z_{series} = Z_1 + Z_2$
$Z_{parallel} = Z_1 \parallel Z_2 = \frac{1}{\frac{1}{Z_1}+\frac{1}{Z_2}} = \frac{Z_1 * Z_2}{Z_1+Z_2}$
gain $= \frac{Z_{down}}{Z_{up}+Z_{down}},$ for voltage divider
Gain of simple RC or RL circuit (one R, one C or L) is $\sqrt{2}/2$ at the corner frequency.
$2\pi f = \omega = \frac{1}{RC},$ corner frequency for $RC$
$2\pi f = \omega = \frac{R}{L},$ corner frequency for $RL$
$2\pi f = \omega = \frac{1}{\sqrt{LC}},$ corner frequency for $LC$

## 4 Op amps

$V_{out} - V_{ref} = G(V_+ - V_-)$, for reference voltage $V_{ref}$ (often zero). Open-loop gain $G$ is very large.
In negative feedback loop, the two inputs have the same voltage.
Note: inverting and non-inverting amplifiers are identical, with the $V_{ref}$ and $V_{in}$ labels swapped (Figure 1 and Figure 2).

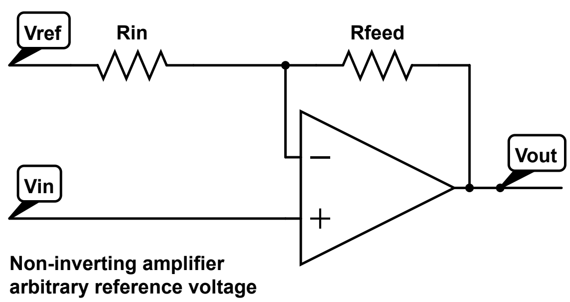


Figure 1: A non-inverting amplifier with gain $1 + R_{feed}/R_{in}$. That is,
$V_{out} - V_{ref} = (1 + R_{feed}/R_{in})(V_{in} - V_{ref})$, since
$V_- = V_{ref} + \frac{R_{in}}{R_{in}+R_{feed}}(V_{out} - V_{ref})$.

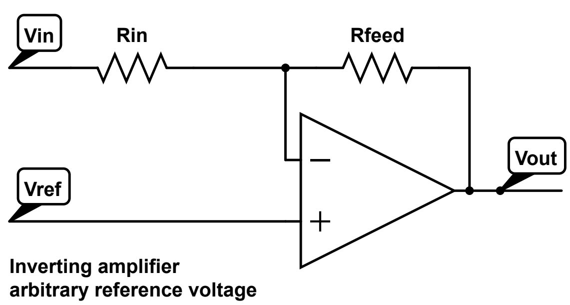


Figure 2: An inverting amplifier with gain $\frac{-R_{feed}}{R_{in}}$. That is,
$V_{out} - V_{ref} = \frac{-R_{feed}}{R_{in}}(V_{in} - V_{ref})$, since
$I_{in} = (V_{in} - V_{ref})/R_{in} = (V_{ref} - V_{out})/R_{feed}$.