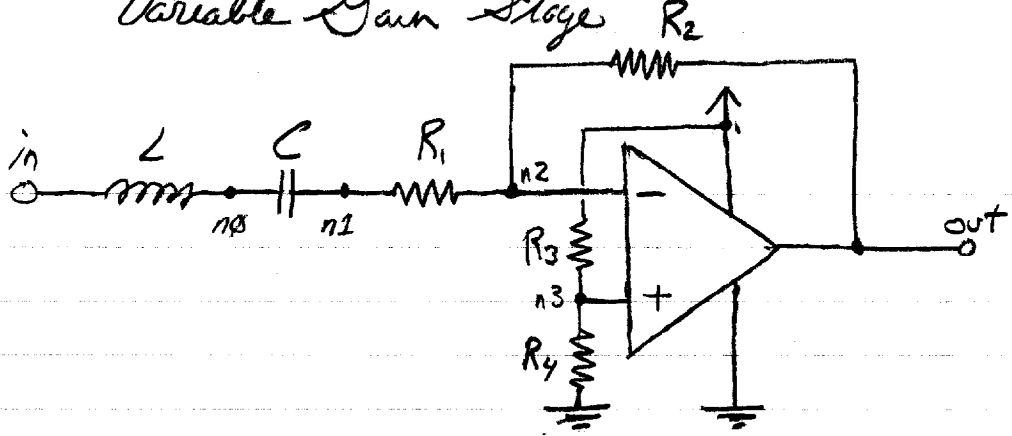
Variable Gain Stage



KCL at node n2: $\dfrac{V_{IN} - V_2}{Z_{LCR}} = \dfrac{V_2 - V_{OUT}}{R_2}$

For an ideal op-amp, $v_2 = v_3 = \text{Constant}$, so from AC point of view

$$V_2 = \emptyset$$

and we are left with $\dfrac{V_{IN}}{Z_{LCR}} = \dfrac{-V_{OUT}}{R_2}$

or

$$\frac{V_{OUT}}{V_{IN}} = \frac{-R_2}{Z_{LCR}}$$

The series impedance of L, C, and R_1 is

$$Z_{LCR} = j\omega L + \frac{1}{j\omega C} + R_1 = R_1 + j\left(\omega L - \frac{1}{\omega C}\right) = R_1\left(1 + j\left(\frac{\omega L}{R_1} - \frac{1}{\omega R_1 C}\right)\right)$$

$$= R_1\left(1 + j\left(\frac{\omega}{\omega_{HP}} - \frac{\omega_{LP}}{\omega}\right)\right) = R_1\sqrt{1 + \left(\frac{\omega}{\omega_{HP}}\right)^2 + \left(\frac{\omega_{LP}}{\omega_{LP}}\right)^2}\; e^{j\tan^{-1}\left(\frac{\omega}{\omega_{HP}} - \frac{\omega_{LP}}{\omega}\right)}$$

So for this op-amp stage, the gain and input impedance are

$$\boxed{\frac{V_{OUT}}{V_{IN}} = \frac{-R_2}{R_1}\left(\frac{1}{\sqrt{1 + \left(\frac{\omega_{LP}}{\omega}\right)^2 + \left(\frac{\omega}{\omega_{HP}}\right)^2}}\right) \cdot e^{-j\tan^{-1}\left(\frac{\omega}{\omega_{HP}} - \frac{\omega_{LP}}{\omega}\right)}}$$

and

$$\boxed{|Z_{in}| = R_1\sqrt{1 + \left(\frac{\omega_{LP}}{\omega}\right)^2 + \left(\frac{\omega}{\omega_{HP}}\right)^2}}$$

where

$$\boxed{\omega_{LP} = \frac{1}{R_1 C} \quad \text{and} \quad \omega_{HP} = \frac{R_1}{L}}$$

The input impedance should be set so as not to heavily load the prior stage.

$$\boxed{R_1 \geq 10 \cdot R_{out}}$$

Then the two reactive coupling components are set

$$C = \frac{1}{2\pi R_1 f_{LP}}$$

$$L = \frac{R_1}{2\pi f_{HP}}$$

In practice we usually want $f_{LP} \leq \frac{1}{10} f_{min}$ and $f_{HP} \geq 10 f_{max}$, so

$$f_{LP} \leq \frac{1}{10} f_{min} \qquad f_{HP} \geq 10 f_{max}$$

$$\omega_{LP} \leq \frac{2\pi}{10} f_{min} \qquad \omega_{HP} \geq 20\pi f_{max}$$

$$\frac{1}{R_1 C} \leq \frac{2\pi}{10} f_{min} \qquad \frac{R_1}{L} \geq 20\pi f_{max}$$

$$R_1 C \geq \frac{10}{2\pi f_{min}} \qquad \frac{L}{R_1} \leq \frac{1}{20\pi f_{max}}$$

$$\boxed{C \geq \frac{10}{2\pi f_{min} R_1} \quad \text{and} \quad L \leq \frac{R_1}{20\pi f_{max}}}$$

Within the bandpass region, the desired gain is achieved with

$$\boxed{R_2 = \frac{Gain}{R_1}}$$

Also FYI, the output resistance of the opamp stage is that of the op-amp itself, in parallel with R_2

$$R_{out} = R_{o(op\text{-}amp)} \parallel R_2 \approx R_{o(op\text{-}amp)}$$