Prelab Problem 6.1: Op-Amp Gain-Bandwidth Product

Assume you have an op-amp with the following s-domain model:

$$V_{out}(s) = \left(V_{in}^{+}(s) - V_{in}^{-}(s)\right)\frac{A_o}{1 + s/\omega_c}$$

which is to say:

$$A_V(s) = \frac{A_o}{1 + s/\omega_c}$$

where $s = j\omega$ for a sinusoidal drive with radial frequency ω.

(a) Assuming $A_o \gg 1$, at what frequency ω (in rad/s) is the magnitude of the gain $|A_V(j\omega)| = 1$?

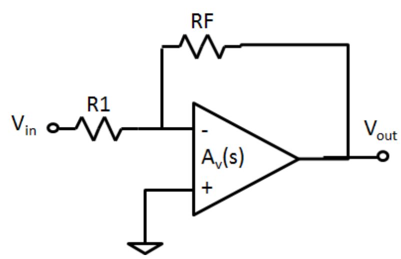


Fig. 1. Inverting amplifier.

(b) If this op-amp is used to build an inverting amplifier (as shown in Fig 1), what is the transfer function of the amplifier gain $G(s) \equiv V_{out}/V_{in}$ in the s-domain? Write your solution in terms of R_1, R_F, A_o and ω_c. What is the value of the pole?

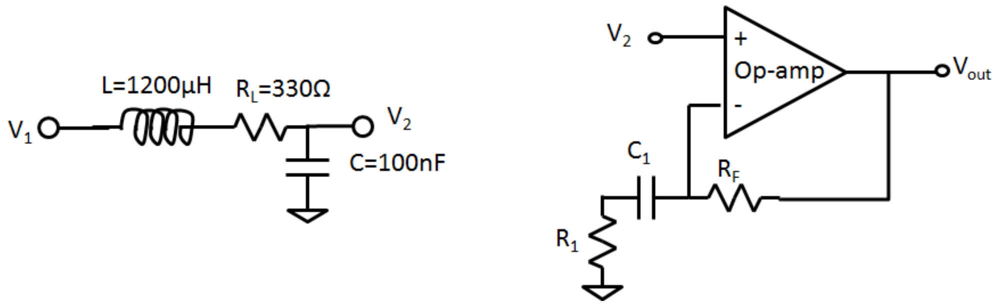
(c) Given that $A_o = 10^5$ and $\omega_c = 62.8\,\text{rad/s}$, sketch (by hand) the magnitude Bode plot for $R_F/R_1 = 100$, and $R_F/R_1 = 10$.

Prelab Problem 6.2: Equalization

One of the problems in digital communications is equalization. The "channel" (often just a wire) over which bits are sent is imperfect, and, so, distorts one's signal between transmitter and receiver. However, if you know the properties of the channel, you can build a circuit that cancels those properties (or at least the most egregious ones), increasing the bandwidth of the channel.

(a) Model the channel as a wire (as shown in Fig. 2a) with the following properties: $L = 1.2$ mH, $R = 330\ \Omega$, $C = 100$ nF. This is a fairly reasonable first-order model for a 500-meter long, 0.1 mm thick wire. What is $H(s) \equiv V_2(s)/V_1(s)$? Where are its poles?

(b) Sketch a magnitude Bode plot for this "wire" from 100 Hz to 1 MHz. What is its 3-dB bandwidth?



(a) (b)

Fig. 2. (a) Channel model, and (b) equalizer circuit.

Our goal is to use an equalizer circuit to cancel the lowest-frequency pole of the channel by placing a zero at the same frequency.

(c) For the equalizer circuit shown in Fig. 2b (assuming that the op-amp is ideal), find $G(s) \equiv \mathrm{V_{out}}(s)/\mathrm{V_2}(s)$ in terms of $\mathrm{R_F}$, $\mathrm{C_1}$ and $\mathrm{R_1}$. What is the location (in terms of $\mathrm{R_F}$, $\mathrm{C_1}$ and $\mathrm{R_1}$) of the pole and zero of $G(s)$?

(d) Choose $\mathrm{R_F}$, $\mathrm{C_1}$ and $\mathrm{R_1}$ so that the zero of the equalizer cancels the pole of the "wire", and the pole of the equalizer corresponds to a frequency of 50 kHz. Sketch a magnitude Bode plot of the equalizer's response $G(s)$.

(e) What is the combined transfer function of the wire plus equalizer (as shown in Fig. 3) $\mathrm{V_{out}}/\mathrm{V_1} = H(s)G(s)$? Sketch the combined magnitude Bode plot. What is the (approximate) 3-dB bandwidth of this equalized channel?

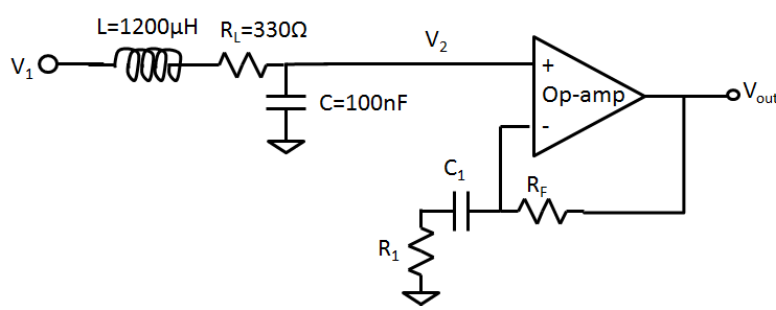


Fig. 3. Combined circuit: wire plus equalizer.