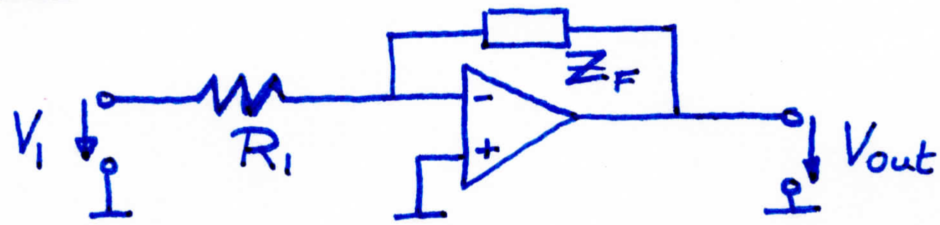
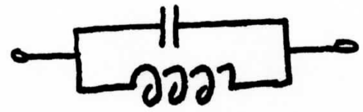
ITE – Homework 03 – Solution

Problem 01 Operational amplifier



(a) Feedback 

$$Z_F = \left(\frac{1}{j\omega L} + j\omega C\right)^{-1} = \left(\frac{1 + j^2\omega^2 LC}{j\omega L}\right)^{-1}$$

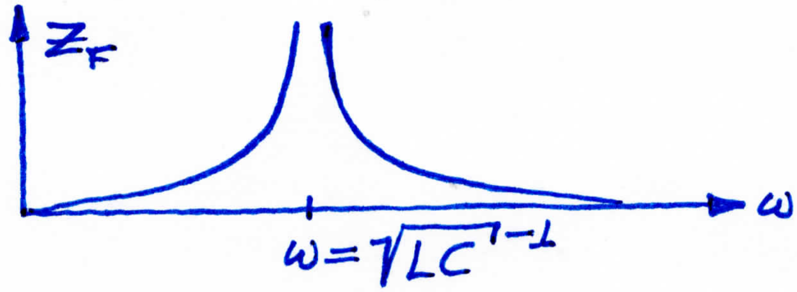
$$= \frac{j\omega L}{1 - \omega^2 LC}$$

$\omega \to 0 \Rightarrow Z_F \to 0$

$\omega = \frac{1}{\sqrt{LC}} \Rightarrow Z_F \to \infty$

$\omega \to \infty \Rightarrow Z_F \to 0$

Sketch



(b) Resonance angular frequency $\omega_0 = 1/\sqrt{LC}$

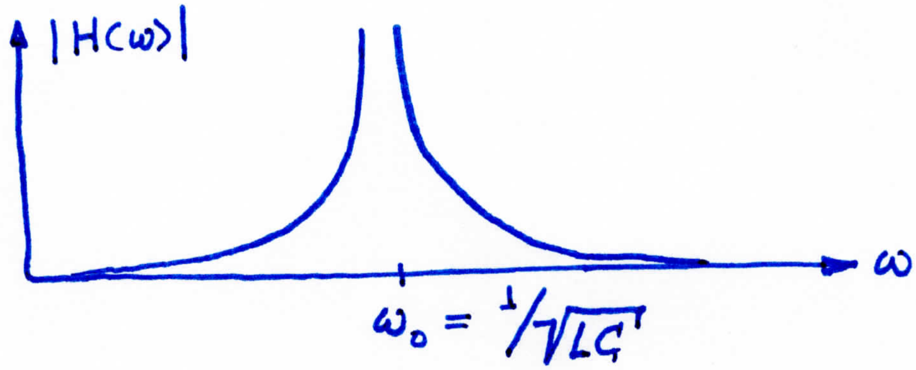
(c) Recall $A_{voc} = -\dfrac{Z_F}{R_1}$

$$= -\frac{1}{R_1}\,\frac{j\omega L}{1-\omega^2 LC} = \frac{V_{out}}{V_1}$$

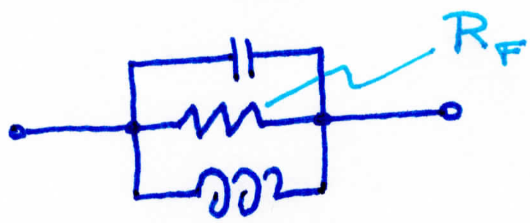
$$H(\omega) = \frac{V_{out}}{V_1} = -\frac{1}{R_1}\,\frac{j\omega L}{1-\omega^2 LC}$$

$$\Rightarrow \quad |H(\omega)| = \frac{1}{R_1}\,\frac{\omega L}{1-\omega^2 LC}$$

Sketch



(d) Addition of R_F



Impedance

$$Z_F = \left(\frac{1}{j\omega L} + j\omega C + \frac{1}{R_F}\right)^{-1}$$

$$= \left(\frac{R_F + j^2\omega^2 LCR_F + j\omega L}{j\omega L R_F}\right)^{-1}$$

$$= \frac{j\omega L R_F}{R_F - \omega^2 LCR_F + j\omega L}$$

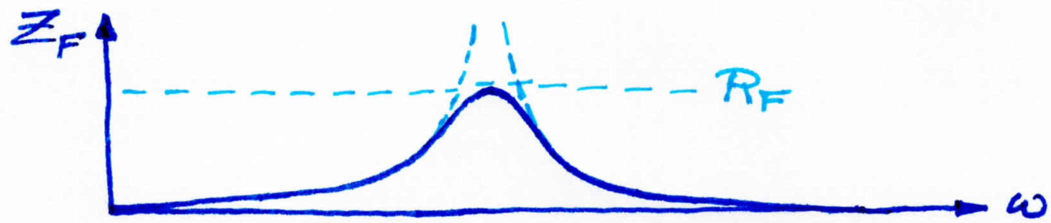
(e) Impedance at resonance frequency

$$\omega = \omega_0 = 1/\sqrt{LC}$$

$$\Rightarrow Z_F = \frac{j\omega_0 L R_F}{R_F - \frac{1}{LC} LC R_F + j\omega_0 L}$$

$$= \frac{j\omega_0 L R_F}{j\omega_0 L} = R_F$$

Sketch



(f) At resonance $Z_F = R_F$

$$\Rightarrow A_{voc} = -\frac{Z_F}{R_1} = -\frac{R_F}{R_1} = -1$$

Problem 02

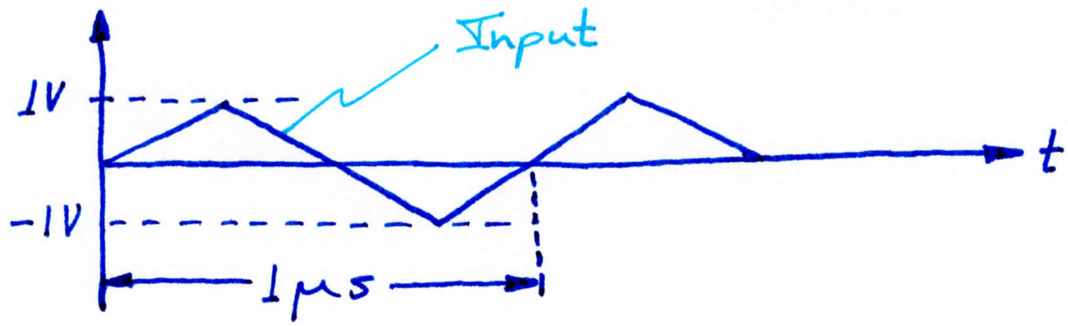
Slew rate = $SR = 1\,\frac{V}{\mu s}$

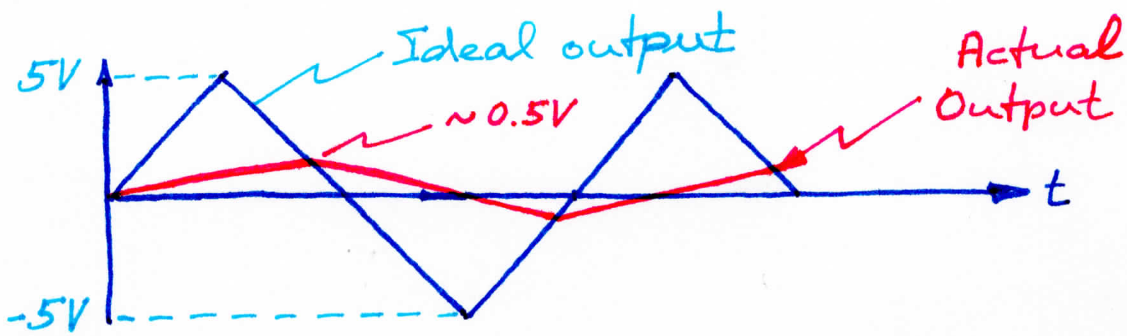
(a) Slew rate is maximum of $\frac{dV_{out}}{dt}$

Slew rate applies to Op Amp's output voltage.

(b) Triangular wave $T = 1\mu s$ $V_o = 1V$

$A_{voc} = 5$ $V_{out} = 5V$





⇒ Output signal is strongly distorted

(c) $V_{0,In} = 0.1V$ $A_{voc} = 1$ $V_{0,out} = 0.1V$

$$\text{Slew rate} = \frac{\Delta V}{\Delta t} = \frac{100mV}{T/4} = \frac{400mV}{T} = \underbrace{1\,V/\mu s}_{\text{Op Amp value}}$$

Solve for $T \Rightarrow T = 400mV / 1\,V/\mu s = 0.4\mu s$

$$\Rightarrow f = \frac{1}{T} = \frac{1}{0.4\mu s} = \underline{\underline{2.5\,MHz}}$$

(d) $V_{0,In} = 0.1V \qquad A_{voc} = 10 \qquad V_{0,out} = 1V$

$$\text{Slew rate} = SR = \frac{\Delta V}{\Delta t} = \frac{1V}{T/4} = \frac{4V}{T} = 1\frac{V}{\mu s}$$

$$\text{Solve for } T \Rightarrow T = 4V/1\tfrac{V}{\mu s} = 4\ \mu s$$

$$\Rightarrow f = \frac{1}{T} = \frac{1}{4\mu s} = \underline{\underline{0.25\ MHz}}$$

(e) $V_{0,In} = 0.1V \qquad A_{voc} = 100 \qquad V_{0,out} = 10V$

$$\text{Slew rate} = SR = \frac{\Delta V}{\Delta t} = \frac{10V}{T/4} = \frac{40V}{T} = 1\frac{V}{\mu s}$$

$$\Rightarrow T = \frac{40V}{1V/\mu s} = 40\ \mu s$$

$$\Rightarrow f = \frac{1}{T} = \frac{1}{40\mu s} = \underline{\underline{0.025\ MHz}}$$

(f) Gain × Bandwidth

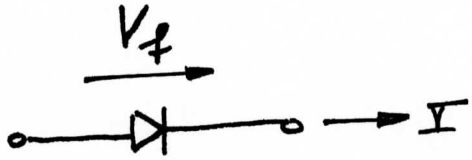
$$\left.\begin{array}{lll} (c): & 1 \times 2.5\ MHz & = 2.5\ MHz \\ (d): & 10 \times 0.25\ MHz & = 2.5\ MHz \\ (e): & \underbrace{100}_{\text{Gain}} \times \underbrace{0.025\ MHz}_{\text{Bandwidth}} & = 2.5\ MHz \end{array}\right\} \text{In each case: } 2.5\ MHz$$

⇒ We see that Gain × Bandwidth = constant

(g) Yes, the present problem shows that this is indeed the case.

Problem 3

(a) True.



Power dissipated in the diode is $P = V_f I$

(b) True.

Reverse current is very small. $\Rightarrow P = V I$ is very small as well.