O S C I L L A T I O N S A N D D A M P I N G E F F E C T

PART I TRANSIENT RESPONSE TO A SQUARE PULSE

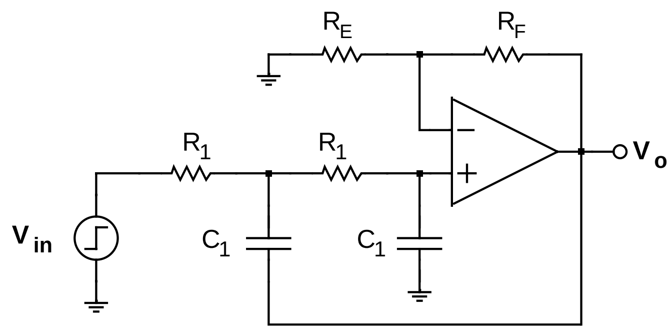
Transfer Function

$$F_{(S)} = \frac{A_o \omega_n^2}{S^2 + 2\zeta\omega_n S + \omega_n^2}$$

$$F_{(S)} = \frac{A_o/(RC)^2}{S^2 + \left(\frac{3-A_o}{RC}\right)S + \frac{1}{(RC)^2}}$$

where $A_o = 1 + \frac{R_F}{R_E}$

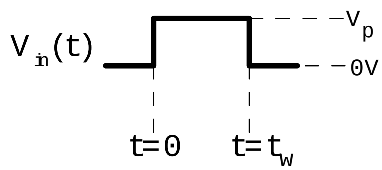
Circuit diagram



$R_1 = 1591.55\Omega$, $C_1 = 0.1\ \mu F$, $R_E = 10K$, R_F variable

PRE-LAB

Input waveform and its corresponding Laplace transform.



$$V_{in(S)} = \frac{V_P}{S}\left(1 - e^{-t_w S}\right)$$

1. Prove that the output waveform is given by the following equation:

$$V_{o(t)} = A_o V_P \left[1 - \left[\frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} SIN\left(\omega_n\sqrt{1-\zeta^2}\,t + \phi\right)\right] - u_{(t-t_w)} + \left[u_{(t-t_w)} \frac{e^{-\zeta\omega_n (t-t_w)}}{\sqrt{1-\zeta^2}} SIN\left(\omega_n\sqrt{1-\zeta^2}\,(t-t_w) + \phi\right)\right]\right]$$

2. Write the equation of $V_o(t)$ with numerical values for all R_F values of 16K, 20K and 22K for an input square pulse of $0{,}1V_P$ and 0,5 ms duration.

3. Fill out the table shown below.

R_F	16K	18K	20K	21K	22K
ζ					
τ					
F_n					
F_{osc}					

4. Write the general equations of the two envelopes for $t < t_w$ using using the equation stated in step #1. The equation of the envelopes for $t > t_w$ are:

$$\left|V_{o(t)}\right| = \pm \frac{A_o V_{in}\, e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} \sqrt{\left[1 + e^{2\zeta\omega_n t_w} - \left(2 e^{\zeta\omega_n t_w} COS\left(\omega_n \sqrt{1-\zeta^2}\, t_w\right)\right)\right]}$$

Plot the envelopes showing all relevant values for R_F = 16K, 20K and 22K. Find $V_o(t=0)$ and $V_o(t=t_w)$ and plot the actual waveforms of $V_o(t)$ inside the envelopes just plotted for t = 0 to 5 ms.

5. R_F = 20K is the ideal condition for constant amplitude oscillations. Prove that if the oscillator is started with a single square pulse whose duration is $1/F_n$, the oscillator will not start.

6. For R_F = 20K and PW=0.5 ms, determine the settled output amplitude of the oscillation as a function of the pulse amplitude.

PROCEDURE

Verify your pre-lab results with Micro-Cap. Do not forget to measure t and F_{osc} for all responses. It is suggested that you simulate with the following parameters:

Simulation time: 0 to 5 ms # of points: 1000

max step size: $\Delta t_{\max} \approx 5 \times \left(\frac{t_{\max} - t_{\min}}{\#\, po\mathrm{int}\, s}\right) = 5 \times \left(\frac{5m - 0}{1000}\right) = 25\,\mu s$

Use stepping option for multiple graphs and zoom in for accurate readings.

1. Simulate steps #2 and #3 of pre-lab. Do one simulation for R_F = 16K, 18K and 20K for 0 to 5 ms. Perform another simulation for R_F = 20K, 21K and 22K for t = 0 to 10 ms.

2. Simulate step #5 of pre-lab.

3. Simulate step #6 of pre-lab for pulses of 0.1V, 0.2V, 0.3V and 0.4V to verify your predictions.

POST-LAB

1. Explain what is the effect of positive damping on oscillations and also explain the effect of negative damping on oscillations.

2. Explain what more damping does to the oscillations. How is the time constant affected by the damping factor?

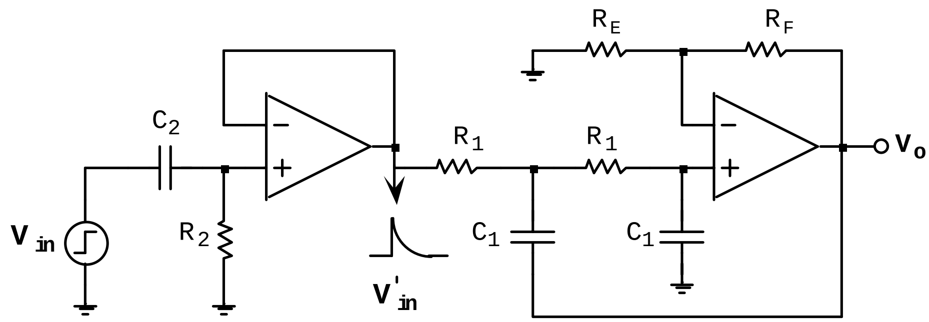
3. When there is no damping, what determines the amplitude of the oscillation? Is the staurtup pulsewidth critical? Explain.

4. Compare all pre-lab results to simulation results where applicable.

PART II TRANSIENT RESPONSE TO AN EXPONENTIAL INPUT PULSE

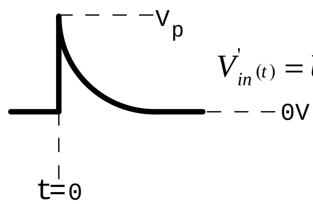
Circuit diagram

R_1 = 1591.55Ω
C_1 = 0.1 μF
R_E = 10K
R_F = 20k
R_2 and C_2 variable



PRE-LAB

The input $V_{in}(t)$ is a single step voltage that is converted to an exponential pulse by R_2 and C_2 which serves as the actual input $V'_{in}(t)$ for the oscillator to kickstart it.



$$V'_{in}(t) = u(t) V_P e^{-t/\tau_2} \Rightarrow V'_{in}(S) = \frac{V_P}{\left(S + \frac{1}{\tau_2}\right)}$$

$$\frac{1}{(S+a)} \times \frac{1}{S^2 + 2\zeta\omega_n S + \omega_n^2} \Rightarrow \frac{e^{-at}}{a^2 + 2\zeta\omega_n a + \omega_n^2} + \frac{e^{-\zeta\omega_n t} SIN\left(\omega_n \sqrt{1-\zeta^2}\, t - \phi\right)}{\omega_n \sqrt{1-\zeta^2} \times \sqrt{a^2 + 2\zeta\omega_n a + \omega_n^2}}$$

where $\phi = ATAN(\omega_n / a)$

1. For ζ=0, prove that the output is given by the following expression using the Laplace transform pair shown above.

$$V_o(t) = \frac{A_o V_P e^{-t/\tau_2}}{1 + (\omega_n \tau_2)^{-2}} + \frac{A_o V_P SIN(\omega_n t - \phi)}{\sqrt{1 + (\omega_n \tau_2)^{-2}}} \quad where \quad \phi = a\tan(\omega_n \tau_2)$$

2 a) For ζ=0 and $\omega_n\tau_2$ >> 1, prove that $V_o(t) = A_o V_P e^{-t/\tau_2} + A_o V_P SIN\left(\omega_n t - \frac{\pi}{2}\right)$

b) Determine the output waveform for τ_2 = 1 ms if the input is a 0.5V step. Draw the envelopes first then sketch in the actual waveforms for 0 to 5 ms.

3 a) For ζ=0 and $\omega_n\tau_2$ << 1, prove that $V_o(t) = (A_o V_P\, \omega_n \tau_2)\, SIN(\omega_n t)$

b) Determine the output waveform for τ_2 = 30 μs if the input is a 0.5V step. Draw the envelopes first then sketch in the actual waveforms for 0 to 5 ms.

PROCEDURE

1. Simulate step 2b of the pre-lab for t = 0 to 15 ms using C_2 = 0.1 μF and R_2 = 10k, 30k and 50k.

2. Simulate step 3b of the pre-lab for t = 0 to 5 ms using C_2 = 1 nF and R_2 = 10k, 30k and 50k.

POST-LAB

1. What time constant is needed in order to make the amplitude of the settled sinewave independant of the time constant?

2. Once a suitable time constant is chosen for the startup pulse, what determines the amplitude of the setted sinewave?

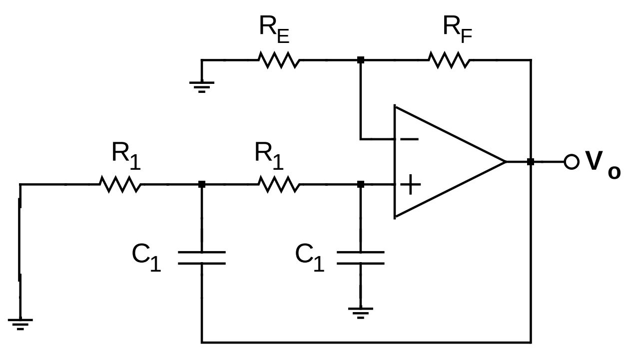
3. Is it possible that oscillations do not start with an exponential pulse? Explain.

4. <u>Compare</u> all simulation results with pre-lab predictions where applicable.

PART III OSCILLATOR START-UP WITHOUT KICK START

Circuit diagram

R_1 = 1591.55Ω
C_1 = 0.1 μF
R_E = 10K
R_F variable



PROCEDURE

Verify how the basic oscillator circuit starts without a kick start pulse for R_F = 20K, 21K, 22k, 23k and 24K. Simulate for at least 100 ms.

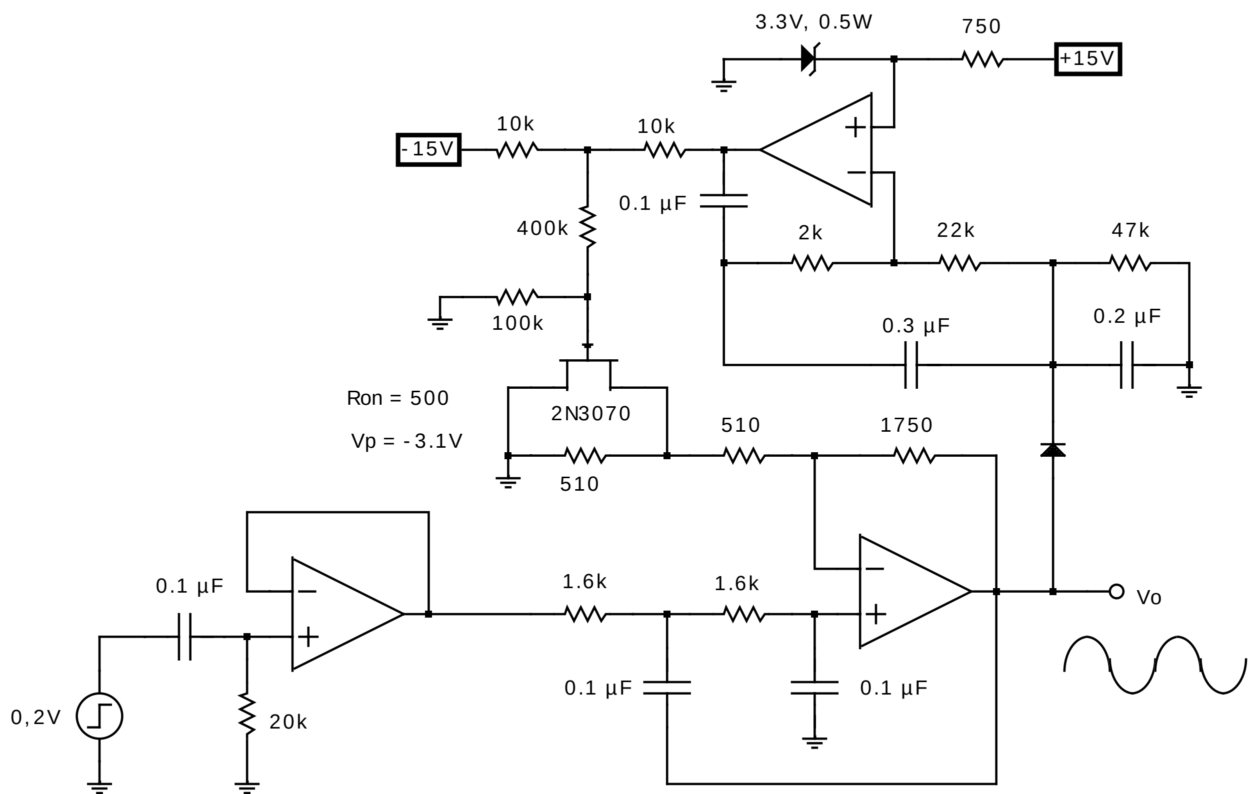
POST-LAB

1. What makes the oscillator start? Is it reliable and predictable? Explain.

2. What is the best way of starting an oscillator according to parts I, II and III of the lab? Explain.

PART IV OSCILLATOR WITH AGC LOOP

Given that it is impossible to have a damping factor of exactly 0 to maintain constant amplitude oscillations, explain how a voltage variable resistor (VVR) as shown below can be used to set ζ exactly to zero and how it can also be used with an AGC loop to regulate the output sinewave amplitude by providing either positive and negative damping as required. What is the output amplitude in the circuit shown below? What range of damping factor does it provide?



PROCEDURE

1. Replace the Zener with an appropriate resistor if a 3.3V Zener is not available. Also ensure that the op amp modeling level is set to 3 and its supplies set to +15V and -15V in the model statement.

2. Simulate the above circuit for 0 to 50 ms and explain the waveforms V_o and V_G of the JFET obtained for the initial start of the oscillator. Explain what happens to the damping factor during this initial phase.

POST-LAB

To make the oscillator more reliable, <u>design a circuit</u> that will detect the absence of oscillations at the O/P and then kickstart the oscillator every time it stops oscillating.