Oscillator

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1. For the circuit in Fig. **??**, break the loop at node X and find the loop gain (working backward for simplicity to find V_X in terms of V_O). For R = 10 kΩ, find C and R_f to obtain sinusoidal oscillations at 10 kHz.

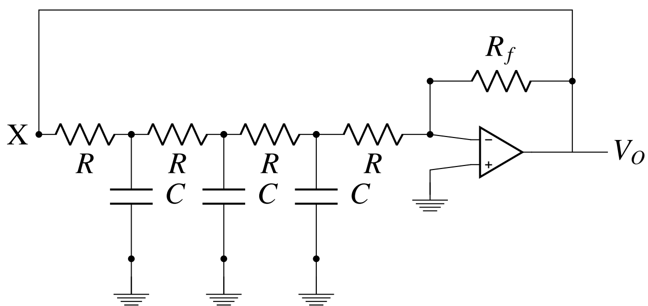

Fig. 1

2. **Solution:** We first calculate the relation between I_4 and V_X in fig **??** by using the relation between the currents and the fact that the inverting terminal of the Op-Amp is virtually grounded as follows:

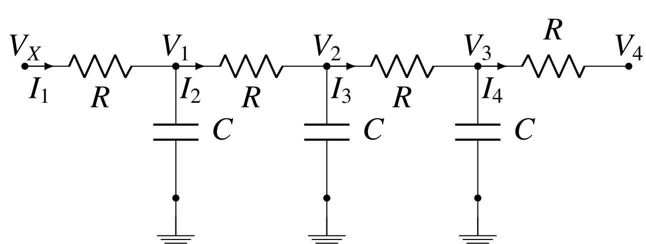

Fig. 2

Here, V_4 has zero voltage. Applying KVL between V_3 and V_4, we get

$$V_3 = I_4 R \tag{2.1}$$

Starting at node V_3 to node V_X, applying KCL and KVL sequentially, and substituting the previous two equations gives:

$$I_3 = I_4 + V_3 sC \implies I_3 = I_4(1 + sRC) \tag{2.2}$$

$$V_2 = V_3 + I_3 R \implies V_2 = I_4 R(2 + sRC) \tag{2.3}$$

$$I_2 = I_3 + V_2 sC \implies I_2 = I_4(1 + 3sRC + (sRC)^2) \tag{2.4}$$

$$V_1 = V_2 + I_2 R \implies V_1 = I_4 R(3 + 4sRC + (sRC)^2) \tag{2.5}$$

$$I_1 = I_2 + V_1 sC \implies I_1 = I_4(1 + 6sRC + 5(sRC)^2 + (sRC)^3) \tag{2.6}$$

$$V_X = V_1 + I_1 R \implies V_X = I_4 R(4+10sRC+6(sRC)^2+(sRC)^3) \tag{2.7}$$

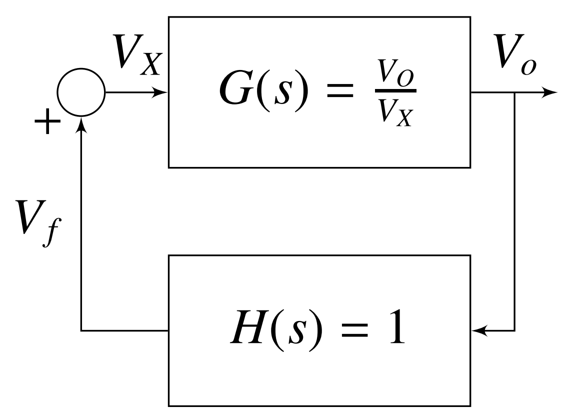

Fig. 2

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