Positive Feedback

Varum SM*

Consider the positive-feedback circuit shown in Fig. 0.

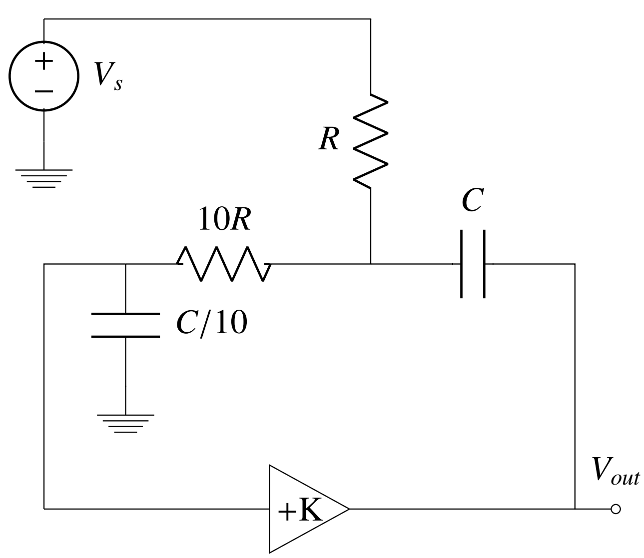

Fig. 0: Positive Feedback Circuit

(a) Find the loop transmission L(s) and the characteristic equation ,find the expressions for resulting pole frequency ω_o and Q factor?
(b) Sketch a Pole-Zero plot for varying K.
(c) For what value of K do the poles coincide? For what value of K does the response becomes maximally flat? For what value of K does the circuit oscillate?

Assume that the amplifier has frequency-independent gain, infinite input impedance, and zero output impedance.

1. Find $L(s)$.
   Solution: To obtain the loop transmission L(s),
   - Short-circuit the signal source V_s.
   - Break the loop at the Amplifier input.
   - Then apply a test voltage V_t and find the returned voltage V_r, as indicated in Figure: 1.

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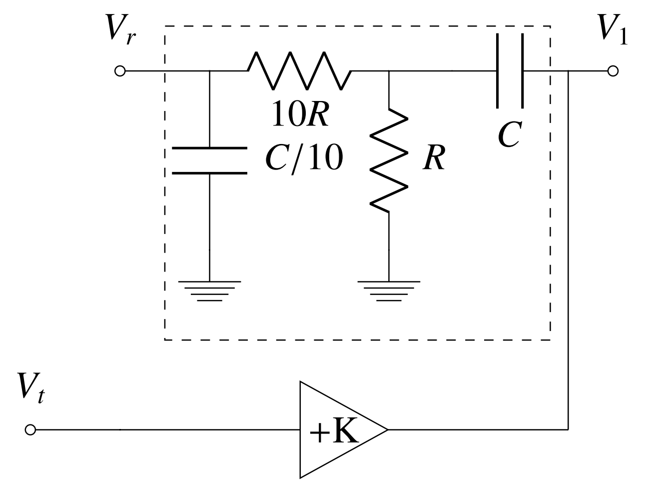

Fig. 1

The loop transmission is given by

$$L(s) = -\frac{V_r(s)}{V_t(s)} = -KT(s) \tag{1.1}$$

where T(s) is the transfer function of the two-port RC network shown inside the broken-line box in Figure: 1.

$$T(s) = \frac{V_r(s)}{V_1(s)} \tag{1.2}$$

Applying KCL at nodes present in the RC network yields

$$T(s) = \frac{s(\frac{1}{CR})}{s^2 + s(\frac{2.1}{CR}) + (\frac{1}{CR})^2} \tag{1.3}$$

Substituting T(s) in Eq: 1.1

$$L(s) = \frac{-s(\frac{K}{CR})}{s^2 + s(\frac{2.1}{CR}) + (\frac{1}{CR})^2} \tag{1.4}$$

The characteristic equation is

$$1 + L(s) = 0 \tag{1.5}$$

$$s^2 + s(\frac{2.1-K}{CR}) + (\frac{1}{CR})^2 = 0 \tag{1.6}$$

The standard characteristic equation of a second order network can be written as

$$s^2 + \frac{\omega_o}{Q}s + \omega_o^2 = 0 \tag{1.7}$$

ω_o is called pole frequency , Q is called pole Qfactor. By comparing the Eq:1.6 with the standard characteristic equation Eq:1.7

$$\omega_o = \frac{1}{RC}; Q = \frac{1}{2.1 - K} \tag{1.8}$$

2. Equivalent control system model of Fig. 1
Solution:

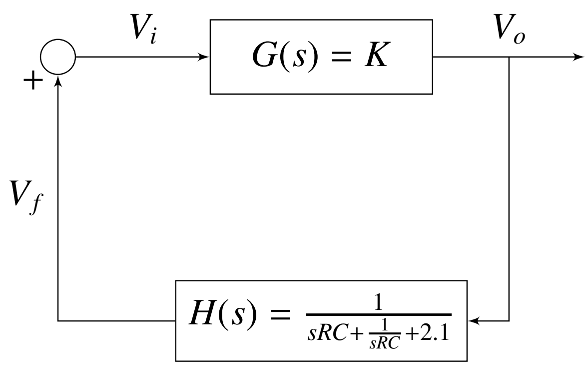

Fig. 2: Positive Feedback Circuit

Closed Loop gain

$$T = \frac{k(s^2 + s(\frac{2.1}{RC}) + (\frac{1}{RC})^2)}{s^2 + s(\frac{2.1-K}{CR}) + (\frac{1}{CR})^2} \tag{2.1}$$

3. Sketch the Normalised closed loop gain of T for various Q values
Solution:

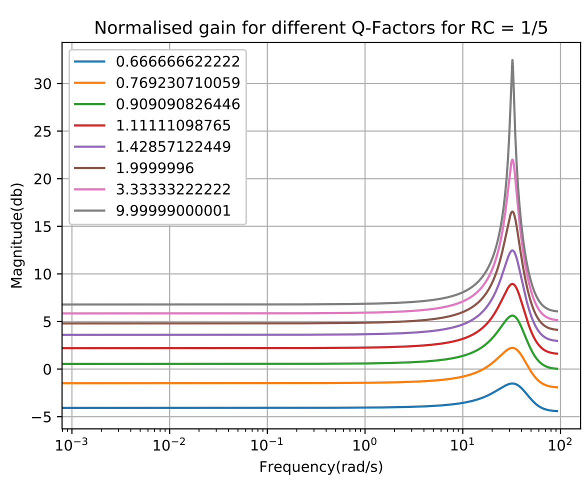

Fig. 3

The following is code for the plot

codes/ee18btech11030/ee18btech11030.py

From Figure:3 ,

- It is observed that maximally flat response is obtained when Q = 0.71
- It will be seen that response of the feedback amplifier under consideration shows almost no peaking for Q≤ 0.71

4. Sketch a Pole-Zero Plot to Eq:2.1 for a varying K
Solution: :

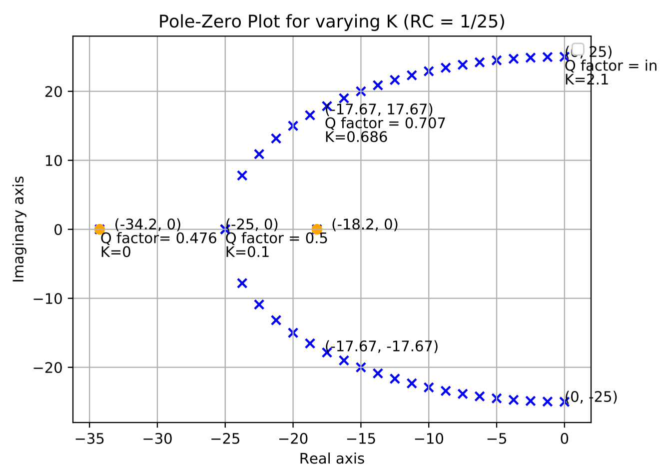

Fig. 4

The following is code for the plot

codes/ee18btech11030/ee18btech11030_1.py

From Figure : 4

- For K = 0,the poles have Q = 0.476 and therefore located on negative real axis.
- As K increases poles are brought closer together and eventually coincide at K = 0.1 and Q = 0.5
- Further increase in K results in poles becoming complex conjugate
- Maximally flat response is obtained when Q = 0.707,which results when K = 0.686.In this case poles are at 45°.
- Oscillating response is obtained when poles are completely imaginary when Q = inf which results when K = 2.1

5. Building gain K in spice simulation for circuit Fig: 1
Solution: :

Q-Factor	K	Requirement
0.5	0.1	Poles are coincident
0.707	0.686	Maximally flat response
∞	2.1	Oscillatory response

TABLE 4

- For K greater than 1(K = 2.1),the gain block is built using LM741 op-amp.

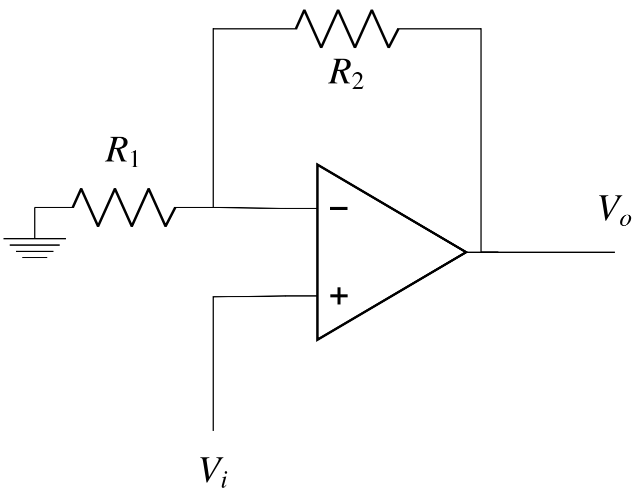

Fig. 5: LM741 op-amp

$$K = 1 + \frac{R_2}{R_1} \implies \frac{R_2}{R_1} = 1.1 \tag{5.1}$$

- For K less than 1, the gain block is built using voltage divider circuit.

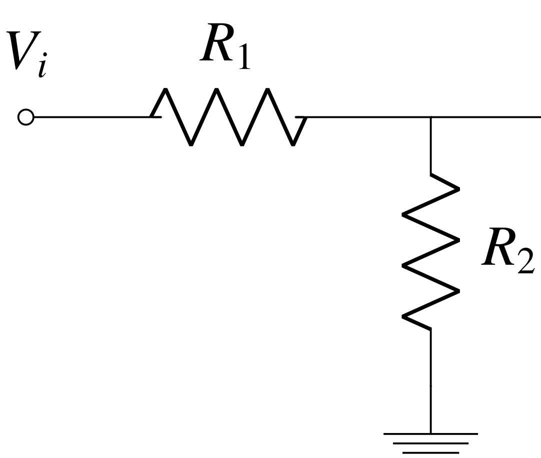

Fig. 5: Voltage Divider

$$K = \frac{R_2}{R_1 + R_2} \tag{5.2}$$

6. Verify the response in time domain using parameters in Table : 7 for K = 2.13
Solution: :

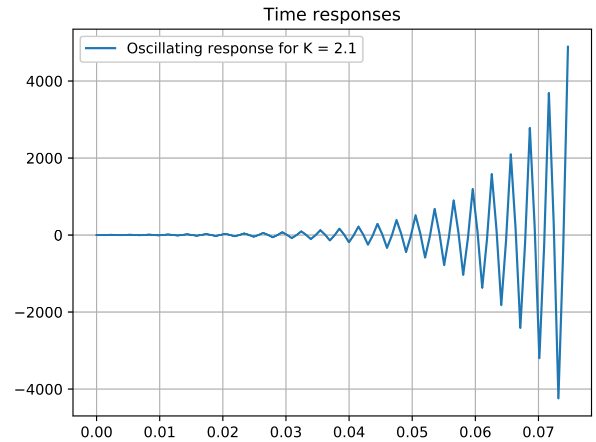

Fig. 6

The following is code for the plot

codes/ee18btech11030/ee18btech11030_2.py

7. Choose the appropriate values of R and C to simulate the circuit for K = 2.1
Solution: :

Parameter	Value
R_1	$10k\Omega$
R_2	$11.3k\Omega$
R	$10k\Omega$
$10R$	$100k\Omega$
$C/10$	$1.6nF$
C	$16nF$

TABLE 7

8. Verify the response using the spice model
Solution: :
   - Figure 8 is the spice simulated output for K = 2.1 using Table 7 parameters.
   - The following is the netlist for simulated circuit.

   spice/ee18btech11030/ee18btech11030.net

   - The following is code for generating output

   spice/ee18btech11030/ee18btech11030.py

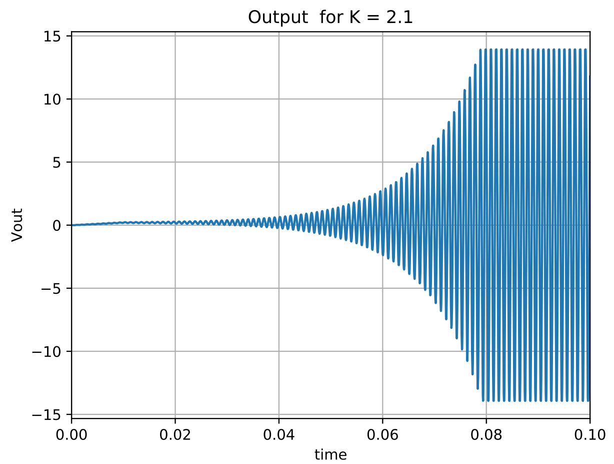

Fig. 8

9. Choose the appropriate values of R and C to simulate the circuit for K = 0.1 and K = 0.686
Solution: :

Parameter	**K = 0.686**	**K = 0.1**
R_1	$4.14k\Omega$	$1k\Omega$
R_2	$6.86k\Omega$	$9k\Omega$
R	$10k\Omega$	$10k\Omega$
$10R$	$100k\Omega$	$100k\Omega$
$C/10$	$1.6nF$	$1.6nF$
C	$16nF$	$16nF$

TABLE 9

10. Verify the response using the spice model
Solution:

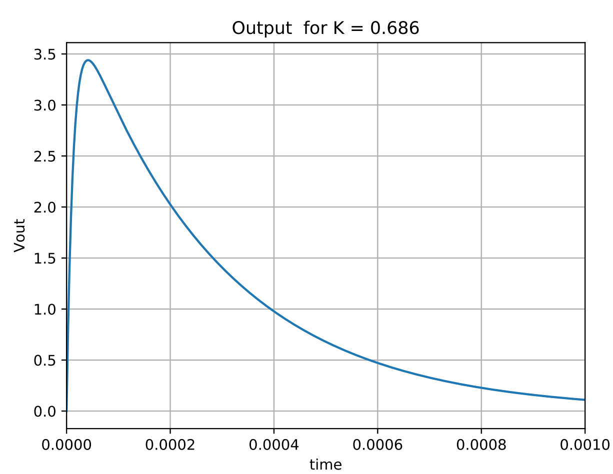

Fig. 10

- Figure 10 is the spice simulated output for K = 0.686 using Table 9 parameters.
- The following is the netlist for simulated circuit.

```
spice/ee18btech11030/ee18btech11030_1.net
```

- The following is code for generating output

```
spice/ee18btech11030/ee18btech11030_1.py
```

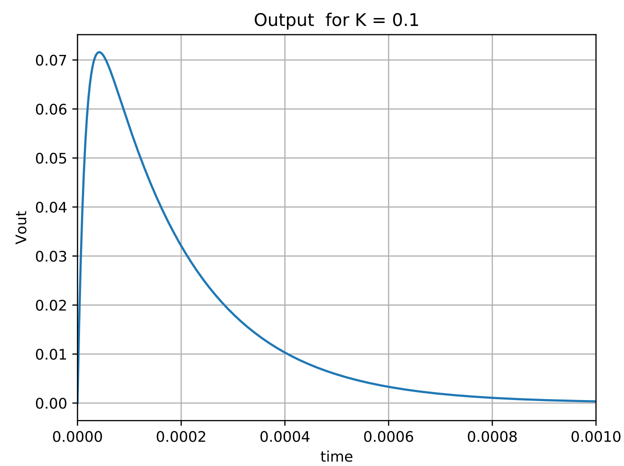

Fig. 10

- Figure 10 is the spice simulated output for K = 0.1 using Table 9 parameters.
- The following is the netlist for simulated circuit.

```
spice/ee18btech11030/ee18btech11030_2.net
```

- The following is code for generating output

```
spice/ee18btech11030/ee18btech11030_2.py
```