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Abstract—This manual is an introduction to control systems based on GATE problems. Links to sample Python codes are available in the text.

1	STABILITY
2	ROUTH HURWITZ CRITERION
3	COMPENSATORS
4	NYQUIST PLOT
5	STATE SPACE MODEL
6	OSCILLATOR

Oscillators generate AC output (the waveform), without any external input. Resonant frequency, is the frequency at which oscillator oscillates, it depends on R/L/C components of the circuit it's been fed back through.

Oscillators work because they overcome the losses of their feedback circuit either in the form of a capacitor, inductor or both. In other words, an oscillator is an amplifier which uses feedback that generates an output frequency without the use of an input signal.

Draw the equivalent block diagram of an oscillator.

Solution: Fig. shows the block diagram of the an Oscillator in Fig. 6.1.

6.2. Show that the gain of the oscillator is

$$G = \frac{V_{out}}{V_{in}} = \frac{A}{1 - AB} \quad (6.2.1)$$

Solution: From 6.1 Oscillators gain can be

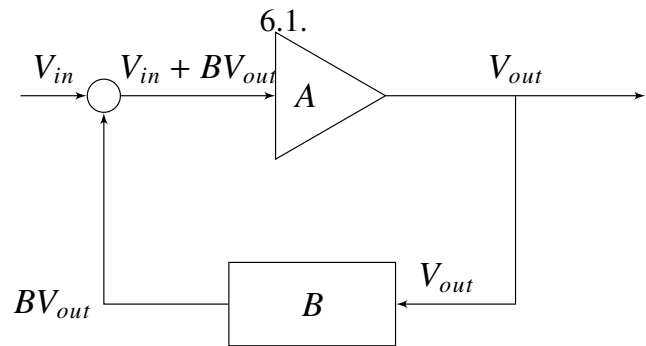


Fig. 6.1: block diagram for oscillator

given as follows:

$$A(V_{in} + BV_{out}) = V_{out} \quad (6.2.2)$$

$$A(V_{in} = (1 - AB)V_{out} \quad (6.2.3)$$

$$\frac{V_{out}}{V_{in}} = \frac{A}{1 - AB} \quad (6.2.4)$$

resulting in (6.2.1).

6.3. State the condition for sustained oscillations. Justify.

Solution: Condition for sustained oscillation is given by

$$AB = 1 \quad (6.3.1)$$

Along with, total phase gain of the circuit should be 0 or 2π

Justification: as, when $AB = 1$, gain becomes infinity, and theoretically we can get output, without actually providing input

Total phase gain should be so, as we want our signal to be in phase after every loop traversal.

6.4. Find A and B.

Solution: Consider the below circuit We know

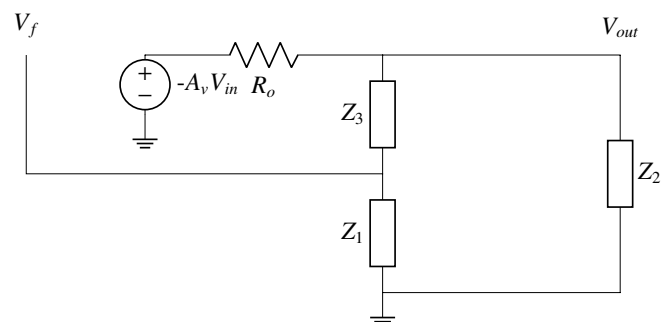


Fig. 6.4: block diagram for oscillator

that feedback gain is B, i.e., $\frac{V_o}{V_f} = B$
Applying voltage divider rule we get

$$B = \frac{Z_1}{Z_1 + Z_3} \quad (6.4.1)$$

$$A = \frac{V_o}{V_{in}} = \frac{AZ_L}{R_o + Z_L} \quad (6.4.2)$$

$$(6.4.3)$$

where, Z_L is equivalent load across output

$$Z_L = \frac{(Z_1 + Z_3)Z_2}{Z_1 + Z_2 + Z_3} \quad (6.4.4)$$

$$(6.4.5)$$

6.5. Find the frequency of oscillation using the condition that $AB = 1$.

Solution: For any LC oscillator, Now, we know that $AB = 1$ for sustained oscillations, putting the above terms in the equation on solving,

$$AB = \frac{Z_1 Z_2 A}{(Z_1 + Z_2 + Z_3)R_o + Z_2(Z_1 + Z_3)} \quad (6.5.1)$$

$$(6.5.2)$$

Hartley oscillator:

The Hartley oscillator is one of the classical LC feedback circuits, i.e. feedback is made of LC components. Below here

$$Z_1 = sL_1 (\text{inductor}) \quad (6.5.3)$$

$$Z_2 = sL_2 (\text{inductor}) \quad (6.5.4)$$

$$Z_3 = \frac{1}{sC} (\text{capacitor}) \quad (6.5.5)$$

putting that in and equating $AB = 1$ we get,

$$1 = \frac{S^2 L_1 L_2 A}{(S L_1 + S L_2 + \frac{1}{sC})R_o + S L_2 (S L_1 + \frac{1}{sC})} \quad (6.5.6)$$

$$S^2 L_1 L_2 A = (S L_1 + S L_2 + \frac{1}{sC})R_o + S L_2 (S L_1 + \frac{1}{sC}) \quad (6.5.7)$$

As we need, to find frequency, put $S = j\omega$

$$\omega^2 L_1 L_2 A = j(\omega L_1 + \omega L_2 - \frac{1}{\omega C})R_o - \omega L_2 (\omega L_1 + \frac{1}{\omega C}) \quad (6.5.8)$$

To satisfy the above equation, equating imaginary term to Zero.

$$\omega L_1 + \omega L_2 = \frac{1}{\omega C} \quad (6.5.9)$$

$$\omega = \frac{1}{\sqrt{(L_1 + L_2)(C)}} \quad (6.5.10)$$

$$f = \frac{1}{2\pi \sqrt{(L_1 + L_2)(C)}} \quad (6.5.11)$$

$$B = \frac{Z_1}{Z_1 + Z_3} = \frac{Z_1}{Z_2} \quad (6.5.12)$$

$$= \frac{L_1}{L_2} \quad (6.5.13)$$

$$A = \frac{L_2}{L_1} \quad (6.5.14)$$

6.6. For Hartley oscillator frequency generated can be given as

$$f = \frac{1}{2\pi \sqrt{(L_1 + L_2)C}} \quad (6.6.1)$$

Fig. 6.6 shows a Hartley oscillator built using opamp.

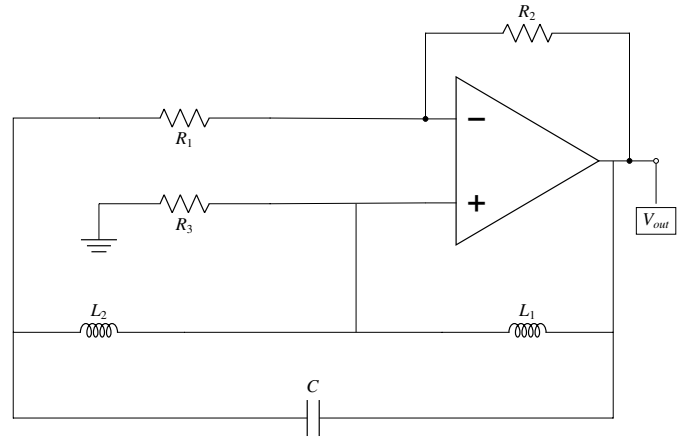


Fig. 6.6: Hartley oscillator

Simulation:

Taking the following values, and applying in 6.6.1

Component	Value
R_1	10K Ω
R_2	100K Ω
R_3	~
L_1	1 μ H
L_2	1 μ H
C	120 pF

We get $f = 103 \text{ MHz}$

Feedback factor for Hartley given by:

$$B = \frac{L_1}{L_2} = 1 \quad (6.7.1)$$

W.K.T, $AB = 1$

\therefore Minimum amplification Gain, $A = 1$