Analog Electronic Circuits (UEC301)

By

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THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Subject: Analog Electronic Circuits (UEC301)

Faculty name: Dr. Mayank Kumar Rai (Associate Professor & Course Coordinator)

Topic of today's Lecture : Oscillator

Key points

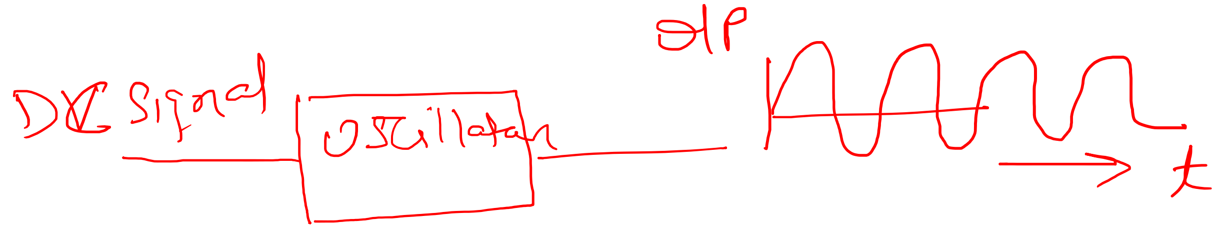
- ✓ **Oscillator**
- ✓ **Types of Oscillator**
- ✓ **RC Phase shift Oscillator**
- ✓ **Hartley and Colpitts Oscillators**

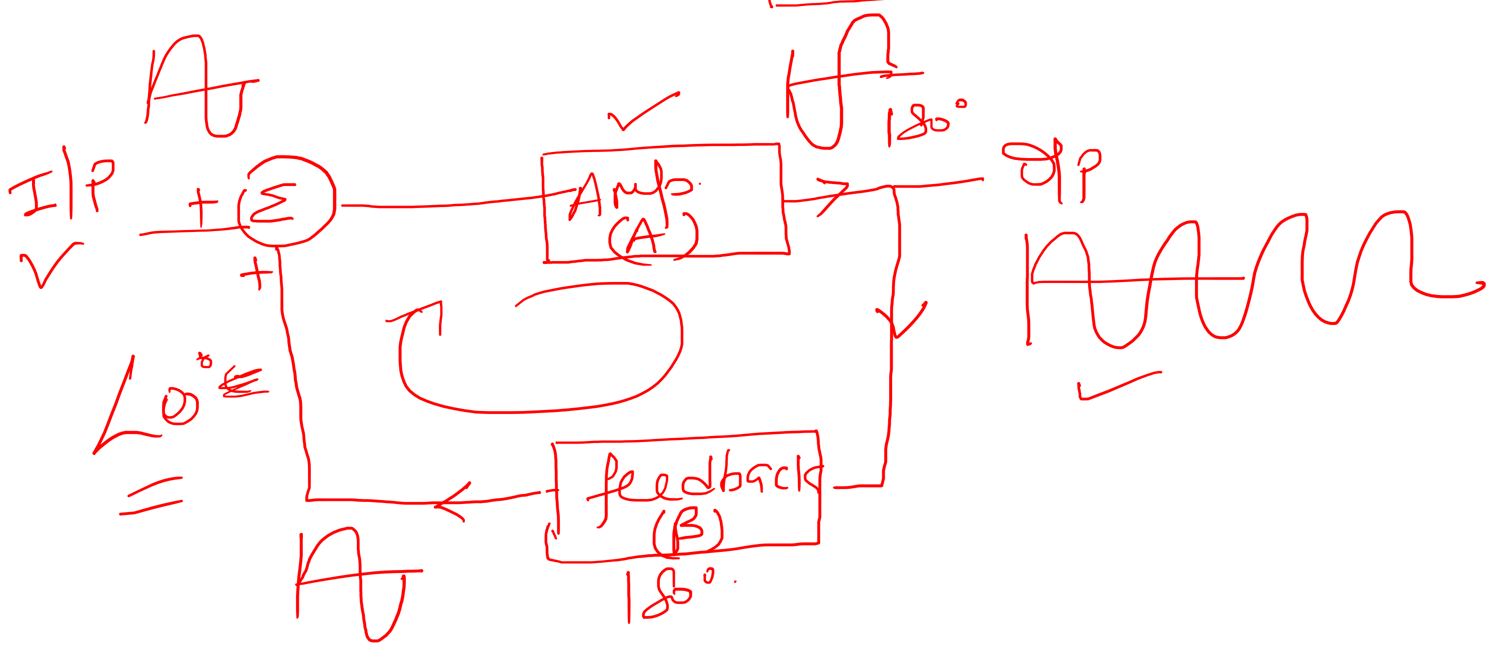
Contents of this lecture are based on the following books:

- *Jacob Milman & and C.C.Halkias, **"Integrated Electronics Analog and Digital Circuit and Systems"**Second Edition.*
- *Adel S. Sedra & K. C. Smith, **"MicroElectronic Circuits Theory and Application"** Fifth Edition.*
- *Robert L. Boylestad & L. Nashelsky, **"Electronic Devices and Circuit Theory"** Eleventh Edition.*

Oscillator

The Oscillator is an amplifier with positive feedback ,which accepts the DC voltage and generates the periodic time varying waveform of desired frequency.

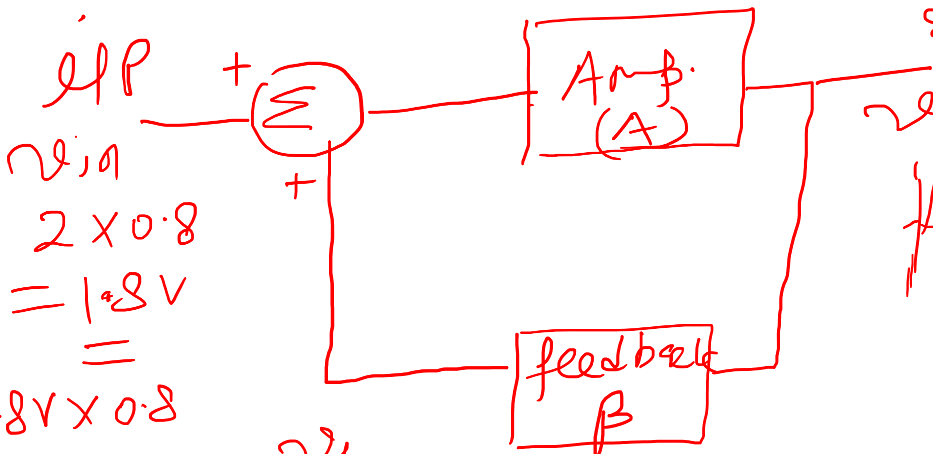




Oscillator

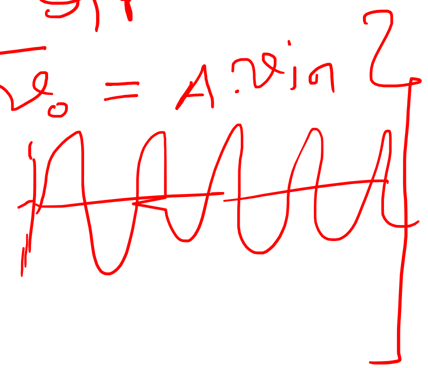
Mathematical Analysis

β = feedback fraction



2×0.8
$= 1.8V$
$=$
$1.8V \times 0.8$
$=$
$=$

$v_o = A \cdot v_{in}$



$v_f = \beta \cdot v_o = A \cdot \beta \cdot v_{in}$

$v_f = A \cdot \beta \cdot v_{in} \rightarrow (1)$

$A \cdot \beta$ = loop gain

Barkhausen criteria:

$\boxed{A \cdot \beta = 1}$

$v_f = v_{in}$

$\boxed{A\beta = 1}$

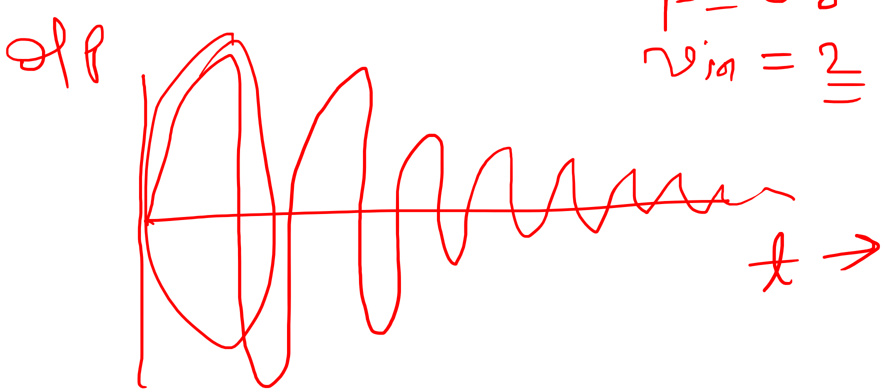
$v_{in} = 2V$

$= 1.2$

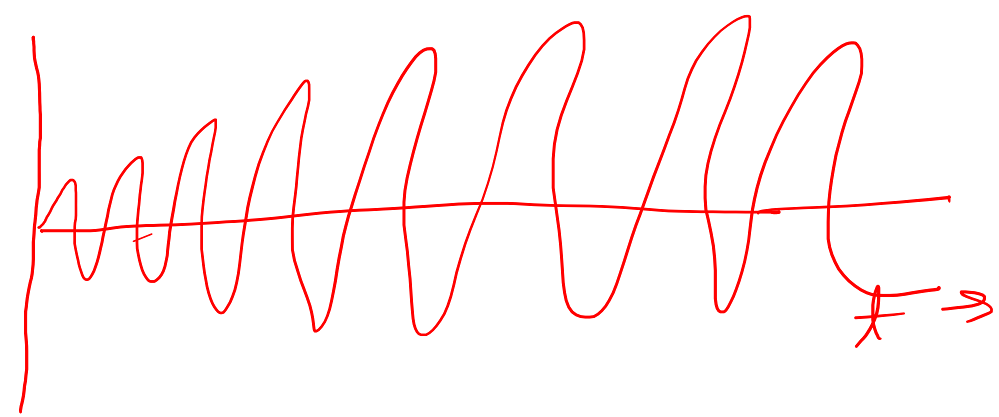
Case 1: $A \cdot \beta < 1 \Rightarrow \beta < 1$

$\beta = 0.8$

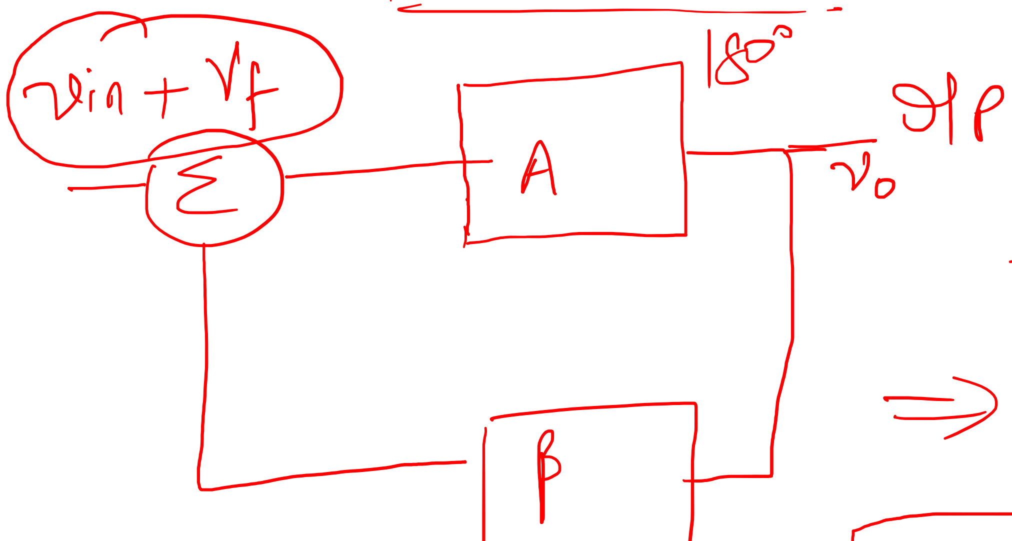
$v_{in} = 2$



Case 2: $A\beta > 1 \Rightarrow \beta > 1$



By Considering v_{in}



$v_f = \beta \cdot v_o$ 180°

In first cycle

$v_o = A v_{in}$

IInd Cycle

$\Rightarrow v_o = A(v_{in} + v_f)$

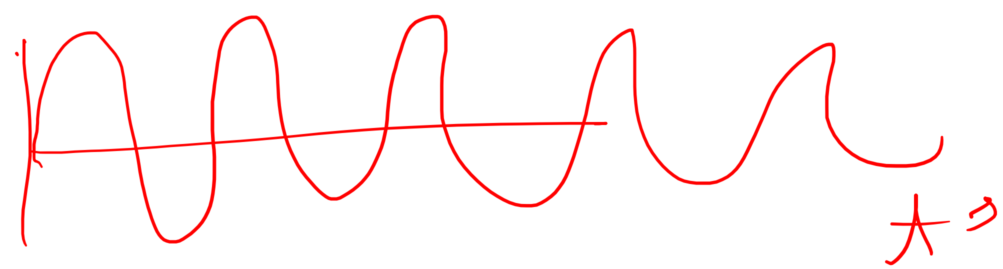
$v_o = A(v_{in} + \beta \cdot v_o)$

$$\boxed{\frac{v_o}{v_{in}} = \frac{A}{1 - A \cdot \beta}}$$

$v_{in} = 0$

$\boxed{A\beta = 1}$

$\angle \phi = 0°$



Types of Oscillator

Depending on the type of feedback

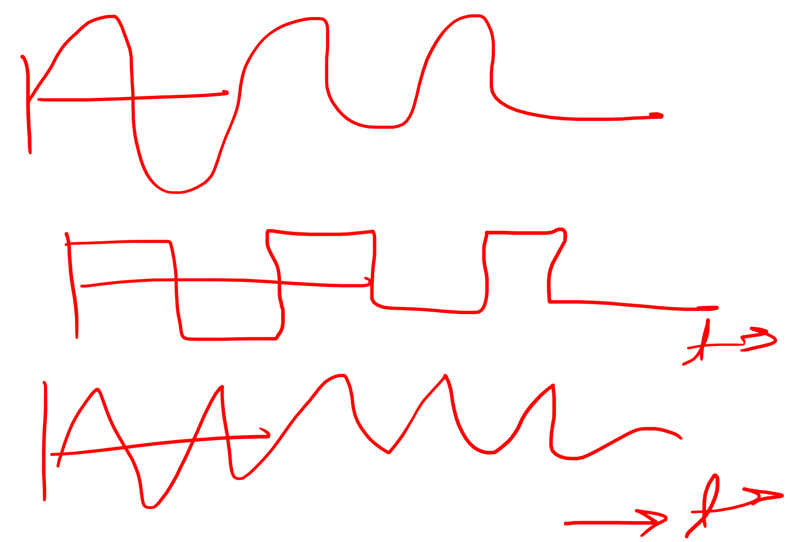
- i ✓ RC Oscillator
- ii ✓ LC Oscillator
- iii ✓ Crystal Oscillator

Depending on the arrangement of R, L and C components:

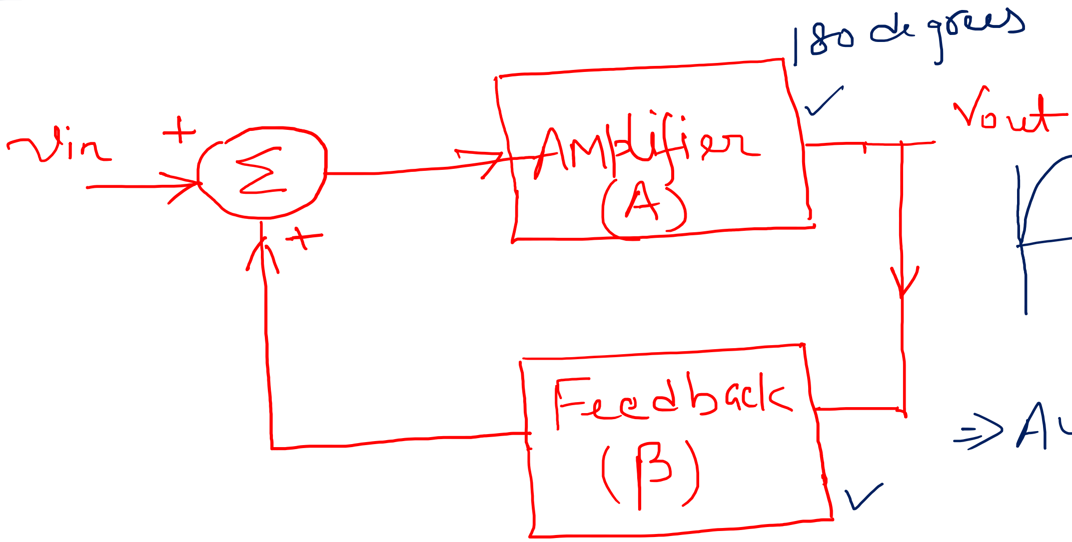
- **RC Phase shift Oscillator**
- **Colpitts Oscillator**
- **Hartley Oscillator**

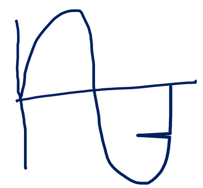
Depending on the output of Oscillator

- **Harmonic Oscillator** (Sinusoidal)
- **Relaxation Oscillator** (Non Sinusoidal)



RC Phase shift Oscillator





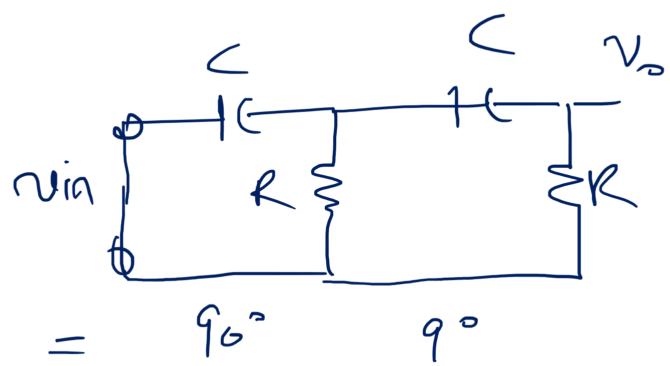
⇒ Audio frequencies

RC Stages

⇒ 180 degrees

$\boxed{A\beta = 1}$

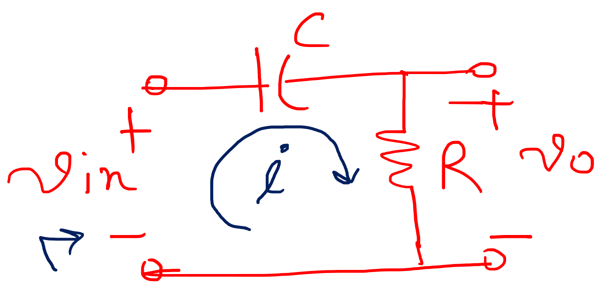
$\angle A\beta = 0^\circ$ or 360°



$R = 0$

voltage gain $= 0$

RC Stage



Transfer function $\left(\frac{v_o}{v_{in}}\right)$

$$i = \frac{v_{in}}{\frac{1}{j\omega C} + R}$$

$$v_o = i \cdot R = \frac{v_{in}}{R + \frac{1}{j\omega C}} \cdot R \rightarrow \boxed{\frac{v_o}{v_{in}} = \frac{R}{R + \frac{1}{j\omega C}}}$$

$$\boxed{\frac{v_o}{v_{in}} = \frac{1}{1 + 1/j\omega CR}} \rightarrow (1)$$

, Phase shift $\angle A\beta$ or $\angle\phi$

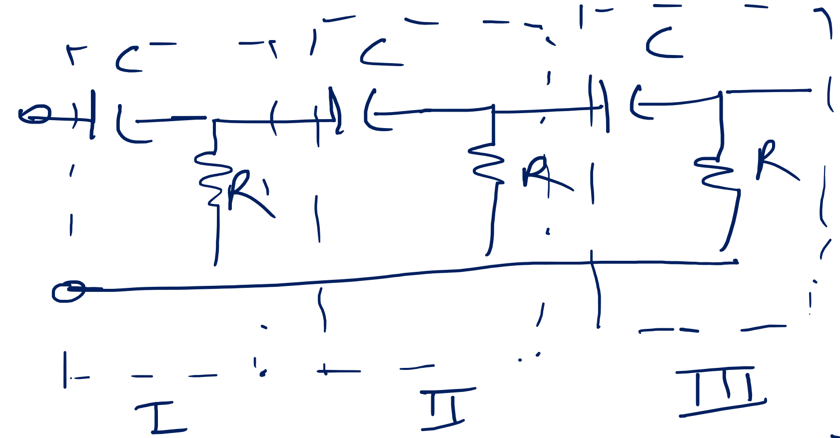
$$\boxed{\angle\phi = 0 - \tan^{-1}\left(-\frac{1}{\omega CR}\right) = \tan^{-1}\left(\frac{1}{\omega CR}\right)}$$

$$\angle\phi = \tan^{-1}\left(\frac{X_C}{R}\right) \longrightarrow (2)$$

if $X_C \Rightarrow 0$, $\angle\phi \cong 0$

$R \Rightarrow 0$, $\angle\phi \cong 90°$

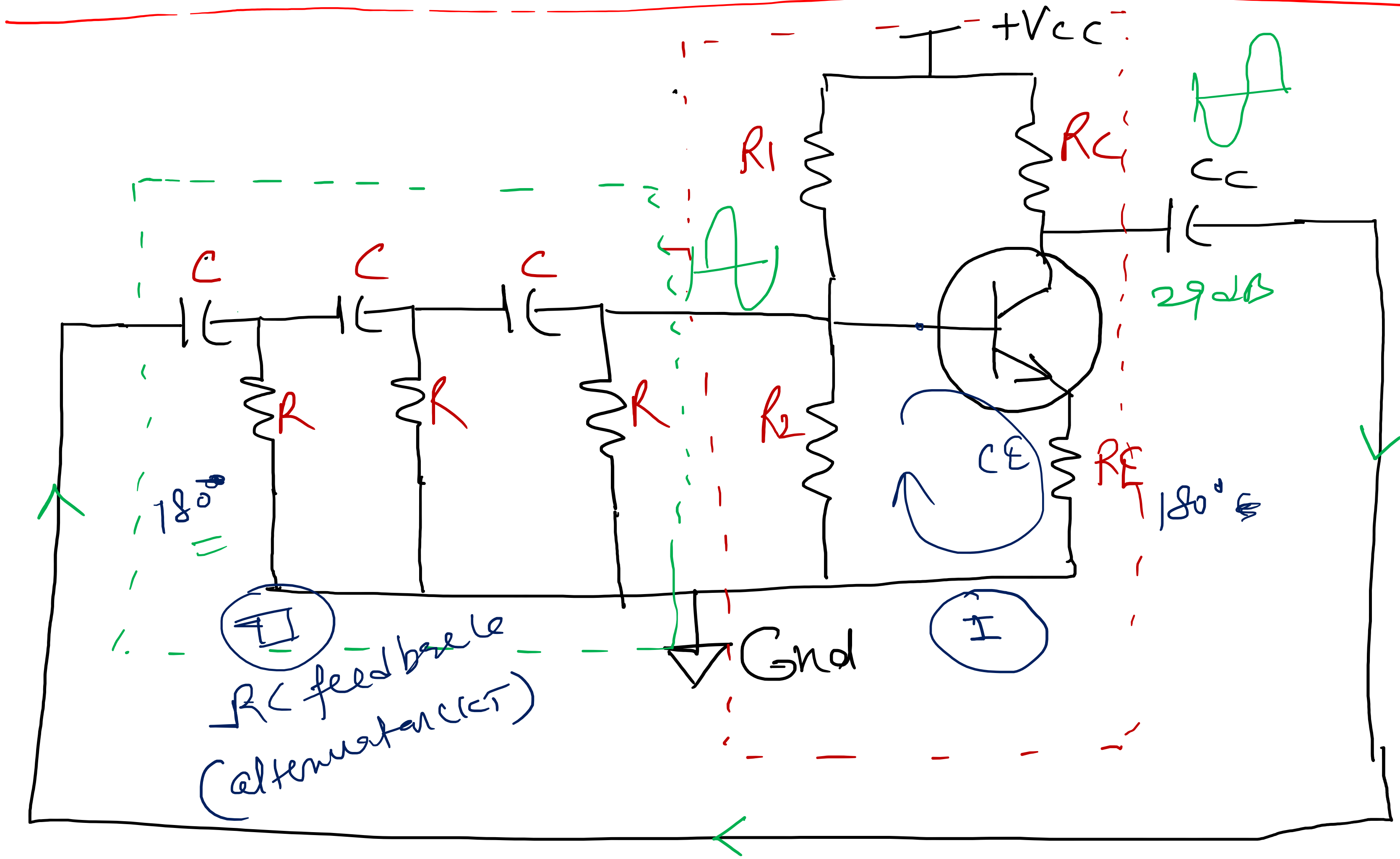
Cascade Stages of RC Network



$\Rightarrow$ feedback block

$$60° + 60° + 60° = 180°$$

Circuit level implementation of RC phase shift oscillator



$\angle A\cdot\beta = 0^\circ$ $\quad \frac{1}{29}$ dB

$$A\cdot\beta = 1$$

$$\boxed{29 \cdot \frac{1}{29} = 1}$$

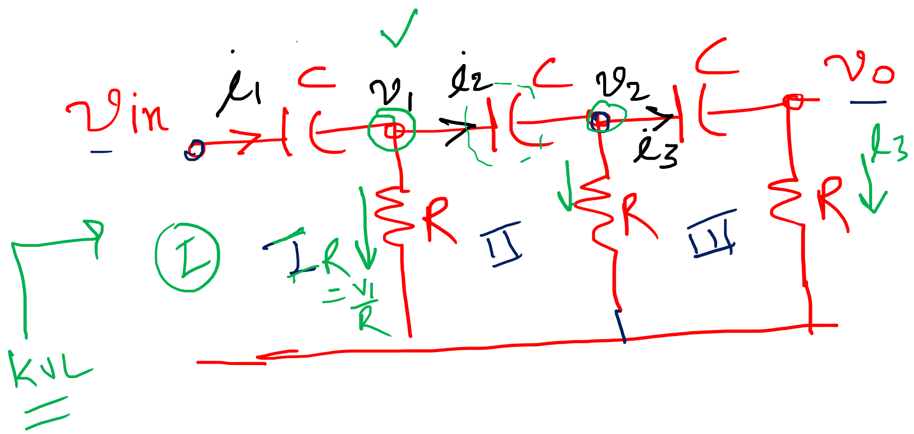
$$\boxed{A\cdot\beta = 1}$$

$$\left\{\begin{array}{l} \beta = -\frac{1}{29}\,dB \\ A = 29\,dB \end{array}\right\} \Rightarrow \boxed{A\cdot\beta = 1}$$

$$\boxed{f = \frac{1}{2\pi RC\sqrt{2\cdot N}}}$$

N = No. of Stages of RC Network

Mathematical Analysis



feedback ckt

At node v_2

$$v_2 = \frac{i_3}{j\omega C} + v_0 \rightarrow (1), \quad i_3 = \frac{v_0}{R}$$

$$v_2 = \frac{v_0}{j\omega RC} + v_0$$

$$\boxed{v_2 = v_0\left\{1 + \frac{1}{j\omega RC}\right\}} \rightarrow (2)$$

By applying KCL at node v_2

$$i_2 = i_3 + \frac{v_2}{R} \rightarrow (3)$$

from Eqn (2)

$$i_2 = \frac{v_0}{R} + \frac{v_0}{R}\left\{1 + \frac{1}{j\omega RC}\right\}$$

$$\boxed{i_2 = \frac{v_0}{R}\left\{2 + \frac{1}{j\omega RC}\right\}} \rightarrow (4)$$

at node v_1

$$v_1 = v_2 + \frac{i_2}{j\omega C} \rightarrow (5) \quad \rightarrow X_C$$

from Eqns (2) & (4)

$$v_1 = v_0\left\{1 + \frac{1}{j\omega RC}\right\} + \frac{v_0}{j\omega RC}\left\{2 + \frac{1}{j\omega RC}\right\} \rightarrow (6)$$

$$\boxed{v_1 = v_0\left\{1 + \frac{3}{j\omega RC} - \frac{1}{\omega^2R^2C^2}\right\}} \rightarrow (7)$$

Applying KCL at v_1

$$i_1 = i_2 + \frac{v_1}{R} \rightarrow (8)$$

from Eqn (4) & (7)

$$\boxed{i_1 = \frac{v_0}{R}\left\{2 + \frac{1}{j\omega RC}\right\} + \frac{v_0}{R}\left\{1 + \frac{3}{j\omega RC} - \frac{1}{\omega^2R^2C^2}\right\}} \rightarrow (9)$$

Finally

$$v_{in} = v_1 + \frac{i_1}{j\omega C}$$

from Eqns (7) & (9)

$$v_{in} = v_0\Big\{\underbrace{1 - \frac{5}{\omega^2R^2C^2}}_{\text{Real}} + \underbrace{\frac{6}{j\omega RC} - \frac{1}{j\omega^3R^3C^3}}_{\text{Img.}}\Big\} \rightarrow (M)$$

Img.

$$\frac{6}{j\omega RC} - \frac{1}{j\omega^3R^3C^3} = 0$$

$$\omega^2R^2C^2 = \frac{1}{6}$$

$$\omega = \frac{1}{\sqrt{6}\,RC} \Leftarrow \omega = 2\pi f$$

$$\boxed{f = \frac{1}{2\pi RC\sqrt{6}}} \rightarrow (10)$$

for N of RC stages

$$\boxed{f_N = \frac{1}{2\pi RC\sqrt{2\cdot N}}} \rightarrow (11)$$

N = No. of RC stages

Gain of the feedback CKT

Real term from Eqn (M)

$$v_{in} = v_o \left\{ 1 - \frac{5}{\omega^2 R^2 C^2} \right\} \rightarrow (12)$$

$$\Rightarrow v_{in} = v_o \left\{ 1 - \frac{5}{\frac{1}{6R^2C^2} \times R^2C^2} \right\}, \quad \omega = \frac{1}{RC\sqrt{6}}$$

for three stages of RC network

$$v_{in} = v_o \left\{ 1 - 30 \right\}$$

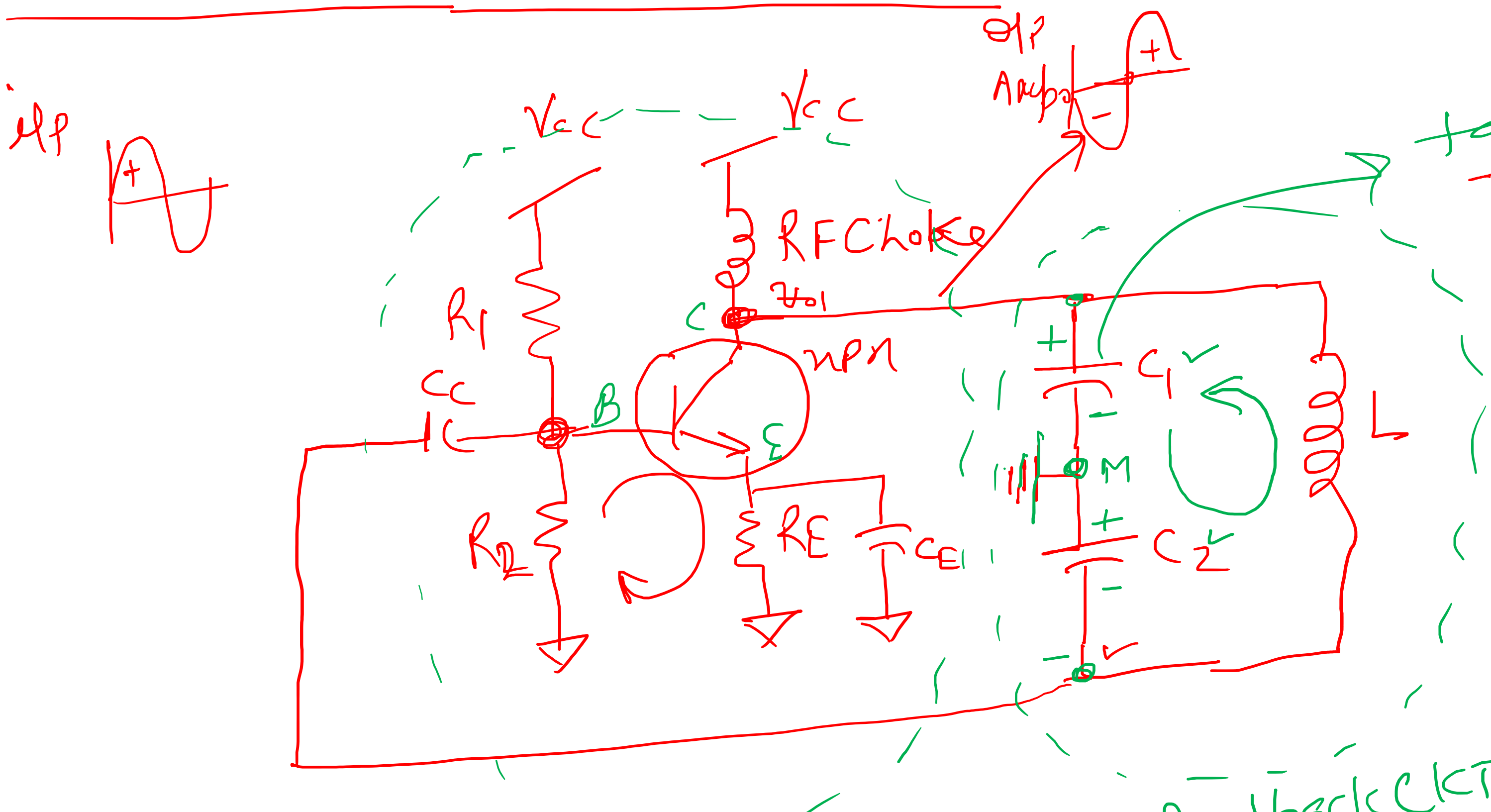
$$\boxed{\frac{v_o}{v_{in}} = -\frac{1}{29}} \rightarrow (13)$$

"-ve" Sign ⇒ 180° phase shift

Close loop gain $(A \cdot \beta) = 1$

⇒ Attenuator CKT = feedback RC CKT

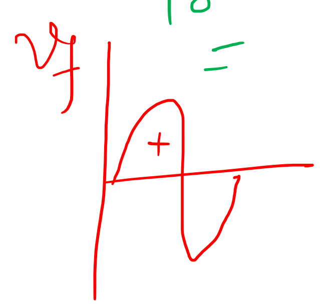
Colpitt's oscillator



Single stage Amp ckt

180°

180°

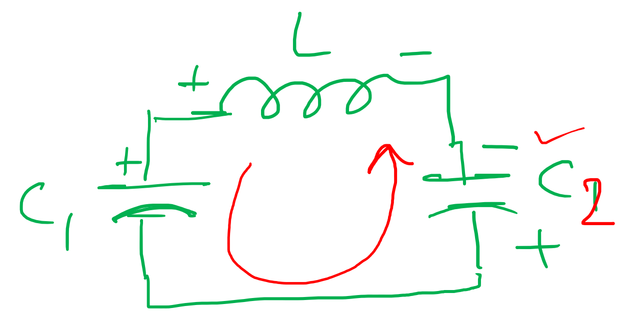


tapped Cap. Conf.

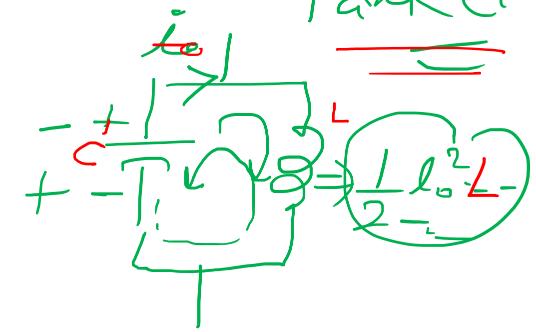
$$\boxed{f = \frac{1}{2\pi\sqrt{L \cdot C_T}}}$$

$$\boxed{C_T = \frac{C_1 \cdot C_2}{C_1 + C_2}}$$

feedback $C_1 \to C_2 \to L$

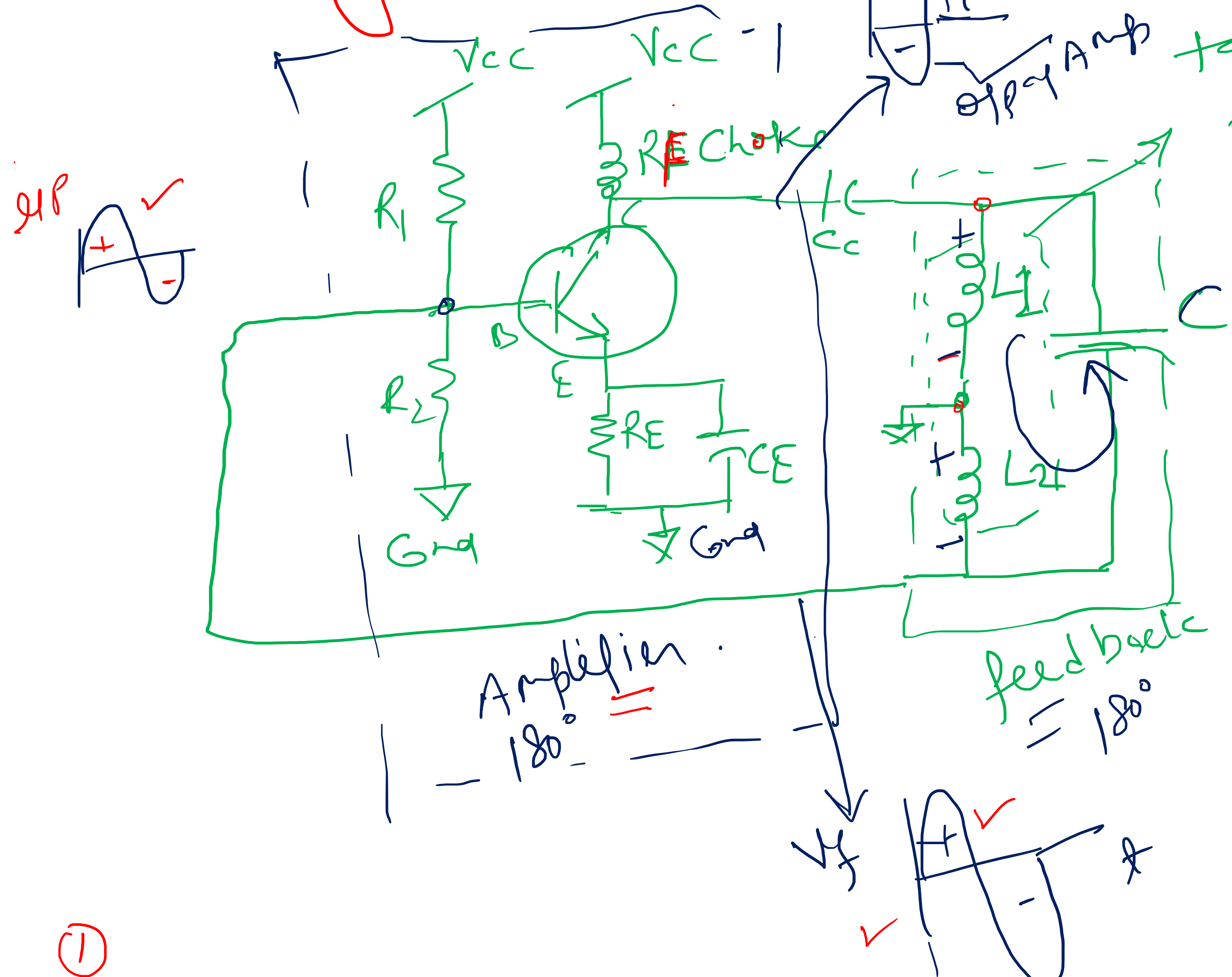


Tank ckt



oscillatory ckt

⇒ Hartley oscillator



tapped inductor

$$\cancel{f = \frac{1}{2\pi C_n \sqrt{L_T}}}$$

$L_T = L_1 + L_2 + 2M$

M = mutual inductance b/w L_1 & L_2

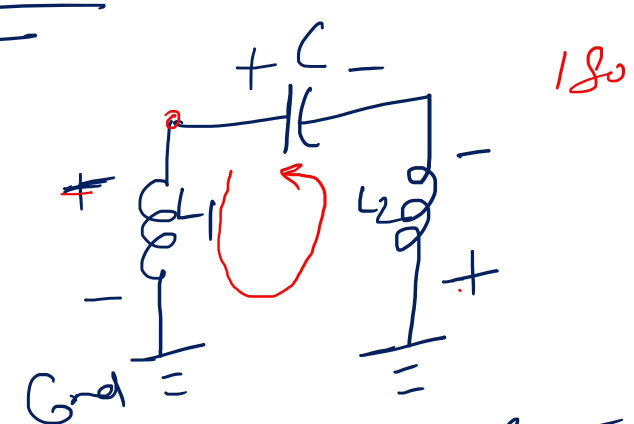
$\boxed{L_1 \rightarrow L_2 \rightarrow C}$ direction of feedback path.

Ckt oph

$\boxed{A \cdot \beta = 1}$

→ feedback fraction

→ open loop gain



feedback CKT

① ② ③

$\boxed{A \cdot \beta = 1}$ ⇒ Barhausen criterion

$$\boxed{f = \frac{1}{2\pi\sqrt{C \cdot L_T}}}$$

Thank You