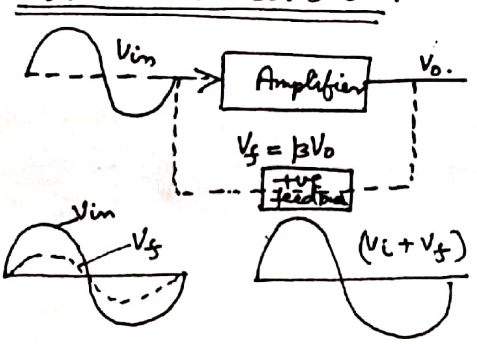
Feedback The process of injecting a fraction of output voltage of an amplifier into the input, ~~the~~ so that it becomes a part of the input is known as feedback. An amplifier ckt consists of two sections (a) The amplifier proper & (b) The feedback network

The amplifier produces the amplification of the "Actual input Voltage" fed between its input terminals. The "feed back network" returns a fraction (or entire) output voltage back to the input side.

Feedback are of two types

(a) Positive or Regenerative feedback. ~~and~~ or Direct feedback and
(b) Negative or degenerative (or inverse) feedback.

Positive Feed back.

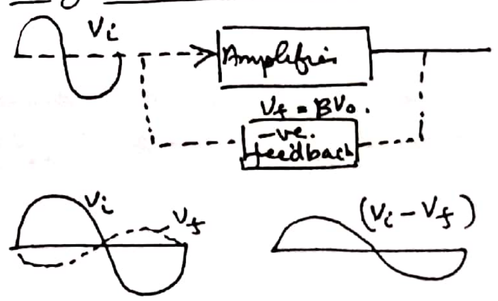


In this case the feed back. Voltage is in phase with the input from the Source. It reinforces the original input signal.

In this case the resultant input signal is "Sum" of input and feed back. Signal

i.e $V_p = V_i + V_f$.

Negative Feed back

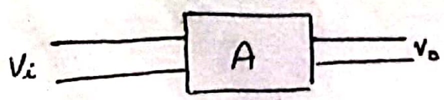


In this case the feedback. Voltage is opposite in phase with the input from the Source. It opposes the original input.

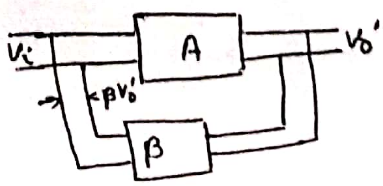
In this case the resultant input signal is "difference" of input and feedback. signal

i.e $V_d = V_i - V_f$.

Mathermatically



Amplification without feedback.
fig (a)



Amplifier with feedback.

Now as per figure (a)

$A = \frac{V_o}{V_i}$ —① open loop gain

As per figure (b)

If β is feedback ratio then

a fraction β of output voltage V_0' i.e $\beta V_0'$ is applied to the input voltage which becomes $(V_i \pm \beta V_0')$ depending wether the feedback is +ve (in phase) or −ve (out of phase)

Assuming +ve feedback the input voltage becomes $(V_i + \beta V_0')$ This is then amplified A times when it becomes $A(V_i + \beta V_0')$

Thus $V_0' = A(V_i + \beta V_0')$

$$V_0' = AV_i + A\beta V_0'$$

$$V_0'(1 - A\beta) = AV_i$$

Thus amplification gain A' with feedback is given by

$$\boxed{A' = \frac{V_0'}{V_i} = \frac{A}{1-\beta A}} \quad (\text{+ve feedback})$$

and

$$\boxed{A' = \frac{A}{1+\beta A}} \quad (\text{−ve feedback})$$

as feedback factor is $-\beta A$.

Here β is "feedback Ratio"

& βA is "feedback factor"

also $(1 \pm \beta A)$ is "loop gain"

A is "open loop gain"

A' is "Closed loop gain"

characterstic features with example

(a) Negative Feedback.

#1 $A' = \frac{A}{1+\beta A}$.

clearly $A' < A$ as $|1+\beta A| > 1$

If $A = 90$ & $\beta = \frac{1}{10} = 0.1$ then gain with feedback becomes.

$$A' = \frac{A}{1+\beta A} = \frac{90}{1+0.1\times 90} = 9.$$

i.e −ve feedback reduces the gain hence also called as "Degenerative feedback". when $|\beta A| \gg 1$ then $A' \simeq \frac{A}{\beta A} = \frac{1}{\beta}$

Thus A' only depends upon β.

No doubt a lot of voltage is sacrificed but the −ve feedback amplifier is very stable as it is not effected by changes in temperature, device parameters, supply voltage & ageing of ckt. components. Thus highly precise and stable gain is possible with negative feedback.

#2 Advantages of −ve feedback.

Against the disadvantage of reduced gain, the −ve feedback has numerous advantages namely

1. Higher fidelity i.e more linear operation
2. highly stabilized gain.
3. increased bandwidth i.e improved frequency response.
4. less amplitude distortion.
5. less harmonic distortion.
6. less phase distortion
7. reduced noise
8. Input and output impedances can be modified as desired.

#3 Gain stability

Now for −ve feedback gain is given as $A' = \frac{A}{1+\beta A}$ —(1)

taking log on b/s.

$$\log A' = \log A - \log(1+\beta A)$$

diff. b/s.

$$\frac{dA'}{A'} = \frac{dA}{A} - \frac{\beta\, dA}{1+\beta A}$$

$$= dA\left(\frac{1}{A} - \frac{\beta}{1+\beta A}\right)$$

$$\frac{dA'}{A'} = \frac{1}{1+\beta A} \cdot \frac{dA}{A}$$

If $\beta A \gg 1$ then above eq^n becomes

$$\frac{dA'}{A'} = \frac{1}{\beta A} \cdot \frac{dA}{A}.$$

#4. Decreased distortion

Let harmonic distortion voltage generated within the amplifier change from D to D' with -ve feedback.

Suppose $D' = xD$ —— ①

The fraction of the output distortion voltage which is fed back to the input is

$= \beta D' = \beta x D$

After amplification this becomes $\beta x D A$ and gets amplified in antiphase with original voltage D. Hence, the new distortion voltage D' which appears in the output is $D' = D - \beta x D A$ —— ②

From eqn's ① & ② we get

$xD = D - \beta x D A$

$x = \frac{1}{1+\beta A}$

Substituting this value of x in eqn ① we get

$D' = \frac{D}{1+\beta A}$ —— ③

obviously from above eqn $D' < D$

Thus the -ve feedback reduces the amplifier distortion by the amount of loop gain i.e by a factor of $(1+\beta A)$

This improvement in distortion is possible only when the distortion is produced by the "Amplifier itself" and not when it is already present in the input signal.

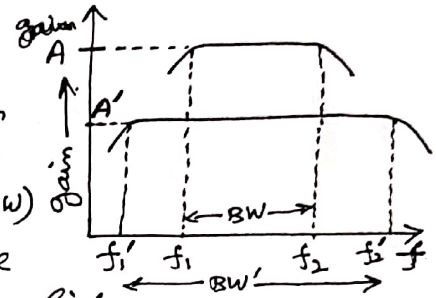
#5 Increased Bandwidth

The bandwidth of an amplifier without feedback is equal to the seperation between the 3-dB frequencies f_1 and f_2.

$\therefore BW = f_2 - f_1$ where

$f_1 \rightarrow$ lower 3dB frequency and

$f_2 \rightarrow$ upper 3dB frequency



If A is the gain then the gain-bandwidth product is $(A \times BW)$

Now when -ve feedback is applied the amplifier gain is reduced. Since the product gain x Bandwidth should remain the same hence.

Thus

If $A \times BW = A' \times BW'$

as $A' < A$ hence $BW' > BW$

Thus for a -ve feed back amplifier the lower and upper 3dB frequencies become.

$f_1' = \frac{f_1}{(1+\beta A)}$

and $f_2' = f_2(1+\beta A)$ s.t.

$A(f_2 - f_1) = A'(f_2' - f_1)$

#5

Forms of -ve feedbacks. (Done) 4 types

(b) Positive Amplifier for it we have.

$A' = \frac{A}{1-\beta A}$.

If $A = 90$ $\beta = \frac{1}{100} = 0.01$ then with feedback $A' = \frac{90}{1-(0.01 \times 90)} = 900$

clearly $A' > A$. hence also called as "Regenerative feedback." When $\beta A = 1$ then $A' = \infty$ i.e there is an output without an input thus the amplifier becomes an oscillator.

→ Discuss Barkhausen Criterion

whereas the voltage feedback to the input of the amplifier is proportional to the output current in negative current feedback.

Oscillators

It is an device which incorporates active and passive circuit elements to generate sinusoidal or other repetitive wave forms.

Def is one of the following four.

ⓐ It is a ckt. which converts dc energy into ac energy at a high frequency

ⓑ It is an electronic source of a.c current capable of having Sine, Square, or sawtooth etc wave forms (eg. function generator)

ⓒ It is an electronic circuit which generates an ac output signal without requiring any externally applied input signal
(Define here Barkhausen Carteria for amplifier to become Oscillator)

ⓓ It is an unstable amplifier (+ve feed back amplifier).

Types of oscillators

ⓐ Sinusoidal or Harmonic Oscillator:- It is capable of producing sinusoidal wave form of desired frequency(s)

ⓑ Relaxation Oscillator:- This produces non-sinusoidal wave forms (i/e Square, rect, sawtooth) of desired frequency(s)

Types of Sinusoidal or Harmonic oscillators

(1) Negative Resistance Oscillators
These use some active device such as Tunnel diode which have current-voltage characteristics of curve of negative slope. for a given definite range.

(B) (14)

② **Feedback Oscillators.** These are esentially regenerative (+ve feedback) amplifiers in which the loop gain (βA) is so adjusted st overall gain is ~~∞~~. infinty

~~Sinusoidal Oscillators are further classified as~~

3) Tuned ckt oscillators or LC feedback oscillators such as Hartly, colpitts etc.

4) RC-phase shift oscillators such as Wein bridge oscillator

5) Crystal oscillators such as. Pierce Oscillators

6) Hetradyne or Beat-frequency oscillator (BFO)

What are conditions of feedback amplifier to become an oscillator

The two necessary conditions are.

ⓐ The feed back must be regenerative or +ve.

ⓑ The loop gain must be adjusted such that the total gain is infinty

Now for an oscillatory (Amplifier) ckt

$$A' = \frac{A}{1 - A\beta}$$

$A \rightarrow$ voltage gain without feedback.

$A' \rightarrow$ " " with feedback.

$\beta \rightarrow$ feedback ratio

$\beta A \rightarrow$ feedback factor.

for +ve feedback $A' > A$.

If $(1 - A\beta) = 0$ then $A' = \infty$ in which case there will be an output without any input i.e. the amplifier provides its own input thus becomming an oscillator.

$\rightarrow$ Barkhausen Critria

How oscillations become steady

To start the oscillations, it is supposed that an initial switching surge occurs in the output ckt. A part of amplified output is fed back to the input. which again appears at the output after amplification. Thus the voltage slowly builds up. Thus the Voltage gain A will begin to decrease as the amplifier works into the saturation or cut off region of its characterstics. At this stage there is no further increase in amplitude and a steady-state oscillations continue. As $|\beta|$ is less than Unity $|A|$ must be $\geq$ one.

Frequency determination

Necessity It is highly necessary to determine the frequency of an oscillator as it has to be predicted as well as adjusted. even though ~~because the~~ it is determined by the amplifier ckt. parameters. any LC or RC ckt network helps us in this regard.

Tank Ckt It is an ckt capable of producing electrical oscillations of any desired frequency.

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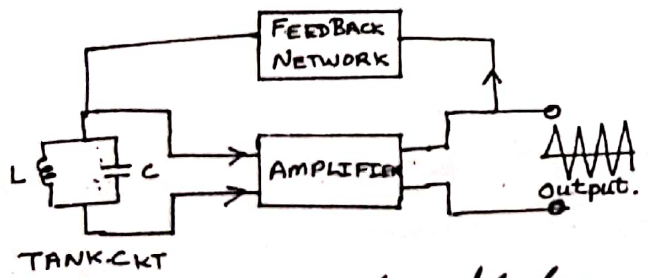
In order to have sustained oscillations. The feedback LC oscillator (tank ckt) must have the following features

i) A resonator consisting of an LC ckt. i.e a tank circuit

ii) An amplifier which amplifies these oscillations

iii) A +ve feedback network which transfers a part of output energy to the resonant LC ckt in "PROPER PHASE" s.t the energy fed back is sufficient to meet I^2R losses in the LC ckt as shown in the block diagram



Moreover in the above ckt for oscillations to be sustained one.

(i) Feedback factor for loop must be. $|\beta A| = 1$.

(ii) Net phase shift around the loop must be $0°$ (i.e. integral multiple of $360°$) s.t the feedback is positive.

Some basic ckts are.

(a) Tuned-Base oscillator also called as Armstrong or Tickler ckt. This employs inductive feedback from collector to the tank ckt in the base of transistor

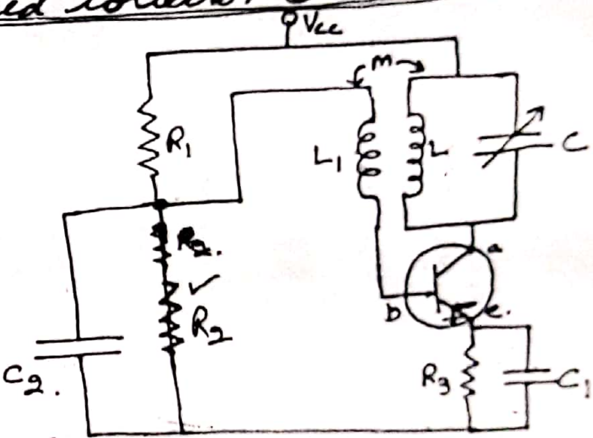
(b) Tuned collector Oscillator:- This also employs inductive coupling but the LC tuned ckt in its collector ckt.

(c) Hartley Oscillator. in this case feedback is supplied inductively

(d) Colpitts Oscillator in this case the feedback is supplied capacitively.

(e) Clapp Oscillator:- It is virtually an Colpitts Oscillator with slight modification.

Tuned Collector Oscillator



A CE (p-n-p) transistor as Tuned Collector Oscillator is as shown in figure its components are.

(a) Supply voltage V_{cc}.

(b) Resistors R_1, R_2 and R_3 for dc bias of transistor by voltage division method s.t trans. is in Q pt.

(c) Variable Capacitor C in parallel to inductor L acting as tank ckt.

(d) capacitors C_1 and C_2 to act as bypass for resistances R_3 and R_2 respectively so that these have no effect on ac operation of ckt. Moreover C_2 also provides ac ground for transformer secondary L_1

(e) The positive feedback between Collector-Emitter & base-emitter.

circuit is provided by the transformer secondary winding L_1, which is mutually coupled to L.

The ac. signals ~~…~~ of L_1, are connected to emitter via low-reactance capacitors C_1 & C_2.

Now as transistor in CE mode provides a phase shift of 180°. between its input and output ckts, another phase shift of 180° is provided by the transformer thereby producing a total phase shift of 360° between the output and input voltages resulting in "POSITIVE FEEDBACK"

(f) The transistor amplifier in CE mode provides sufficient gain for oscillator action to take place ie $|\beta A| = 1$.

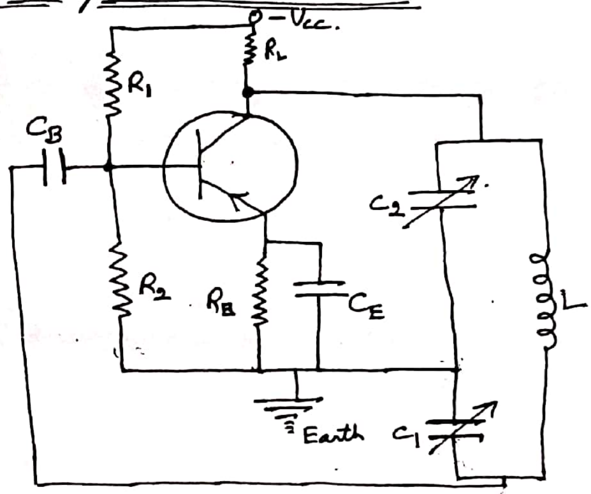
(g) <u>Working</u>

When the supply voltage V_{cc} is switched on, a transient current is developed in the tuned LC ckt. as the collector current rises to its quiescent value. This transient current initiates natural oscillations in the tank ckt. These oscillations induce a small emf into L_1 by mutual induction causing a corresponding variations in base current. These variations in I_B are amplified β times and ~~appear in~~ appear in the collector circuit. Part of this amplified energy is used to meet the losses taking place in the tank ckt and the balance is radiated out in form of e.m waves.

The frequency of oscillatory currents is almost equal to the resonant frequency of the tuned ckt.

ie $f_0 = \frac{1}{2\pi\sqrt{LC}}$

Colpitts Oscillator



It consists of.

(a) p-n-p transistor in CE mode. acting as an amplifier having sufficient amplification so as to meet the oscillator conditions $|\beta A| = 1$.

(b) The tank (oscillatory ckt) consisting of variable capacitors C_1, C_2 in ~~p~~ series and parallel to inductor L.

(c) The bypass capacitors C_E (base-emitter ckt) ~~for~~ for R_E providing feedback fun from collector to base ckt. and C_B (base ckt) for R_2.

(d) The capacitor C_E provides ground for ac signal

(e) The capacitors C_1 & C_2 form the necessary voltage divider for providing the necessary feedback voltage. The feedback fraction is C_1/C_2. Also the minimum value of amplifier gain for maintaining oscillations is

$$A_{(min)} = \frac{1}{C_1/C_2} = \frac{C_2}{C_1}$$

~~(f) The resistances R_1, R_2 & R_3 form a voltage~~

(f). Working when the supply voltage is switched on a sudden surge of collector circuit "Shock Excites" the tank ckt. into oscillations which are sustained by the +ve feedback. The feed back is positive as 180° phase is due to transistor in CE mode and another 180° phase is due to the capacitive feedback. thereby a net phase shift of 360° occurs.

The colpitts oscillators are widely used in commercial signal generators upto 1MHz. The freqnency of oscillations is varied by the gang-tuming of the two capacitors C_1 & C_2.

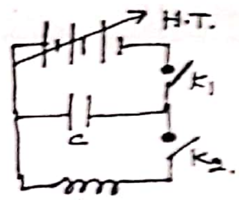
Also $f = \dfrac{1}{2\pi\sqrt{LC}}$

where $C = \dfrac{C_1 C_2}{C_1 + C_2}$. [~~Colpitts~~]

as. $C_1 \parallel C_2$.

Basic Tank or Oscillatory Circuit

It consists of a capacitor C in parallel to an inductor L.



Step I Key K_1 is closed, K_2 is open. This leads to the charging up of the capacitor C. s.t it stores up energy in form of Electric field given as $\frac{1}{2}CV^2$ or $\frac{1}{2}\frac{Q^2}{C}$.

Step-II Key K_1 is opened while key K_2 is closed. Due to it the ckt gets coupled through L and as such the energy of capacitor gets discharged through L. As the current through L rises due to self induction it stores up energy in form of magnetic field given as $\frac{1}{2}LI_0^2$.

Step III When the inductor is fully charged (capacitor discharged) the process of discharging of inductor occurs through capacitor which again gets charged up but in reverse order.

Step IV This process is repeated resulting in damped e.m. oscillations.

Mathematically

E_T = Electric energy + magnetic energy

$$E_T = \frac{1}{2}\frac{Q^2}{C} + \frac{1}{2}LI^2.$$

If losses are assumed to be zero.

Then $\dfrac{dE_T}{dt} = 0$.

$$\frac{Q}{C}\cdot\frac{dQ}{dt} + L\frac{dI}{dt} = 0.$$

$$\frac{Q}{C}\frac{dQ}{dt} + L\frac{d^2Q}{dt^2} = 0.$$

$$\frac{d^2Q}{dt^2} + \frac{1}{LC}Q = 0. \quad -(1)$$

Comparing it with eqn $\dfrac{d^2x}{dt^2} + \omega^2 x = 0$.

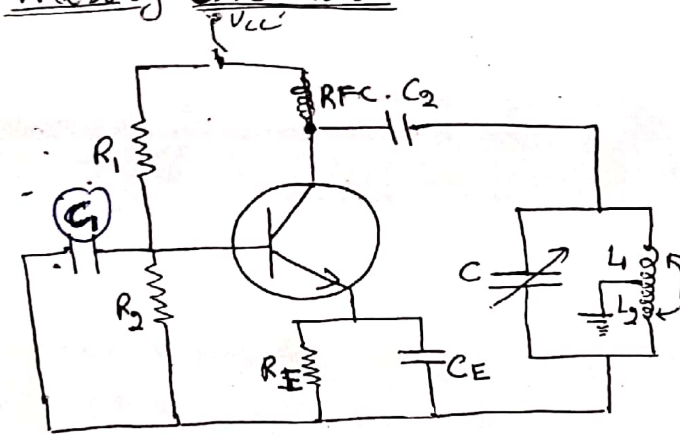
$\omega = \dfrac{1}{LC}$. or $f = \dfrac{1}{2\pi}\dfrac{1}{\sqrt{LC}}$.

also sol. of eqn (1) to $Q = Q_0 \sin\omega t$.

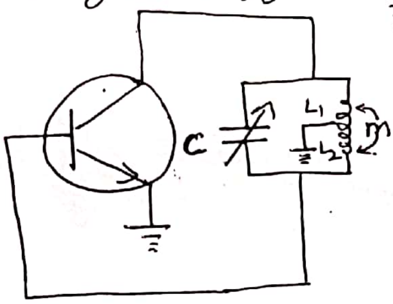
or $\dfrac{dQ}{dt} = I = Q_0\omega \cos\omega t$.

or $I = I_0 \cos\omega t$ where $I_0 = Q_0\omega$.

Hartley Oscillator



Hartley Oscillator using CE Configuration



AC equivalent ckt.

~~Design~~ construction

① It consists of Input coupling capacitor C_1

② A transistor in CE configuration

③ An LC tank ckt in which we have inductively-coupled two parts of the same inductor called as auto-transformer or Split Tank inductor.

④ Bypass capacitor CE providing temperature stability and preventing degeneration of ac signal.

⑤ R_1, R_2, V_{cc} providing the necessary biasing conditions for transistor.

⑥ RFC (Radio frequency choke) providing dc load for the collector and also providing an isolation by keeping ac currents out of the dc supply V_{cc}.

⑦ The Blocking Capacitor or output Coupling capacitor C_2.

Working

1. It has ~~sig~~ single tapped-coil having two parts L_1 & L_2. One side of L_2 is connected to base via C_1 and the other to emitter via ground and C_E. This forms the ~~Input~~ Input Circuit i.e BE circuit.
Similarly One end of L_1 is connected to collector via C_2 and the other to common emitter terminal via C_E. This forms the Output circuit i.e CE circuit

2. These two parts are inductively Coupled forming an Autotransformer or a Split-tank inductor.

3. Feedback between Input and output is accomplished through autotransformer action which also introduces a phase reversal of 180°. (due to the fact that the voltage is tapped at OPPOSITE ENDS of the L_1-L_2 inductor)

4. Since the transistor is in CE mode. It itself induces a phase of 180°. Thus the total phase shift is of 360°, thereby making the feedback positive (regenerative)

5) The amplifier should be such that it has a high gain meeting the Barkhausen Criteria of $|\beta A| = 1$

6) Thus the +ve feedback obtained from the tank ckt. and coupled to the base via C_1 (as Shown in ac equivt ckt).

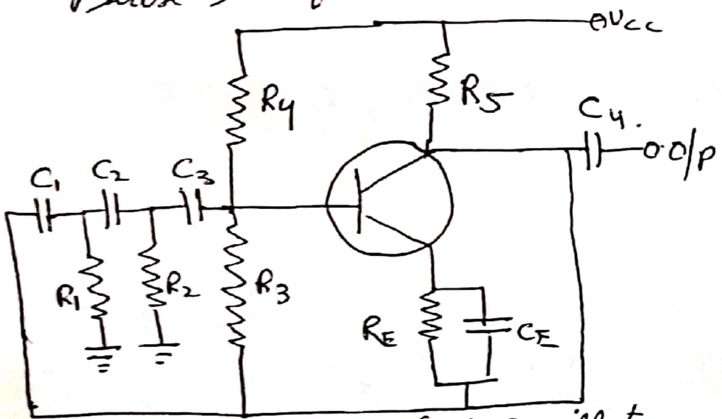
7). When V_{cc} is switched on an initial bias is established by R_1-R_2 and oscillations are produced due to positive feedback from LC Tank Ckt. (L_1 & L_2 constitute L) and the frequency of oscillations is given by

$$f_0 = \frac{1}{2\pi\sqrt{LC}} \quad \text{where } L = L_1 + L_2 + 2M$$

The output of the oscillator is taken out by means of another coil coupled either to L_1 or L_2.

Phase Shift Oscillator

Principle Tuned ckts are not an essential requirement for oscillations. The essential part is that there should be 180° phase shift (another 180° being provided by the active device (transistor) of amplifier). This required 180° phase shift is achieved by using a suitable RC network consisting of three or four RC sections.
The "Sine Wave" oscillators which use R-C feedback network are called as Phase-Shift Oscillators.



Transistor Phase Shift Oscillator

Construction Do yourself

Working
It uses a three section R-C feedback network for producing a total phase shift of 180° (ie 60° per section) in the signal which is fed back to the base.

Also as CE amplifier produces another phase reversal of 180°. The net phase change is 360° ie the feedback becomes +ve or Regenerative. also the amplification factor for transistor should be such that $|\beta A| = 1$

In this case the first three sections of RC produces phase shift of 60° each and the fourth adds stability of oscillator.

Only ⇒ It is seen that the phase shift of 180° and hence oscillation occurs for "Only One Frequency"

Circuit Action

The circuit is set into oscillations by any random or chance variation caused in the base current by
i) Noise inherent in a transistor
or ii) Minor variation in the voltage of the dc source.

These variations in the base current
(a) get amplified in Collector Ckt.
(b) Is then fed back to the RC Network R_1C_1, R_2C_2 and R_3C_3
(c) Is reversed in phase by RC network
(d) The feedback is fed to input in same phase to obtain sustained Oscillations.

The ckt. stops oscillating the moment the phase shift differs from 180°.

Frequency The frequency of oscillation is given as $f_0 = \frac{1}{2\pi\sqrt{6}RC} = \frac{0.065}{RC}$ Hz.

Advantages
1). These are well suited for frequencies below 10KHz
2) These do not require any bulky and expensive high-valued Inductor
3) It produces distortion level of only 5% in input signal
4) Pure sine waves are possible.

Disadvantages
1). It is necessary that a transistor of high β value is used (≃ >29)
2) As oscillations are produced for only one frequency hence it is not suited for variable frequencies
3)

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