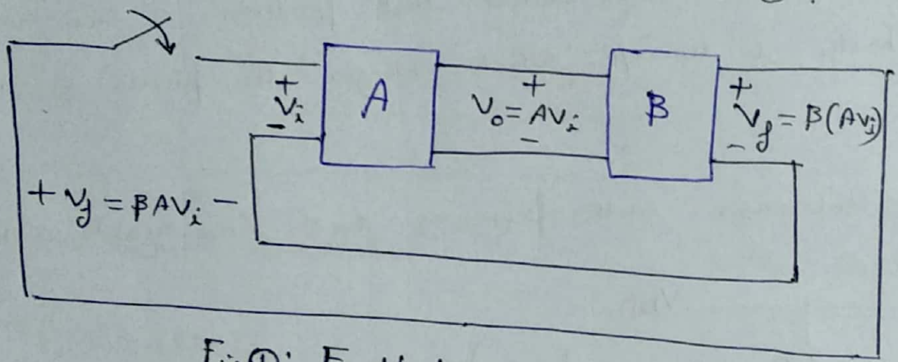
OSCILLATOR

* The use of positive feedback that results in a feedback amplifier having closed-loop gain $|A_f|$ greater than 1 and satisfies the phase condition will result in operation as an Oscillator Circuit
* If the o/p signal varies sinusoidally, the circuit is referred; sinusoidal Oscillator
* If the o/p voltage rises quickly to one voltage level and later drops quickly to another voltage level, the circuit is reffered as a pulse or Square-wave Oscillator.

Consider a feedback circuit as shown in Fig. 1:



Feedback gain

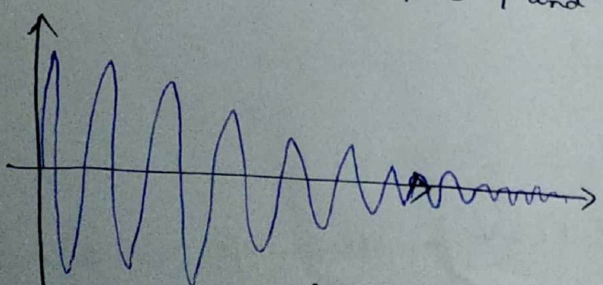
$$\boxed{A_f = \frac{A}{1+\beta A}}$$

Fig 1: Feedback Circuit used as an oscillator

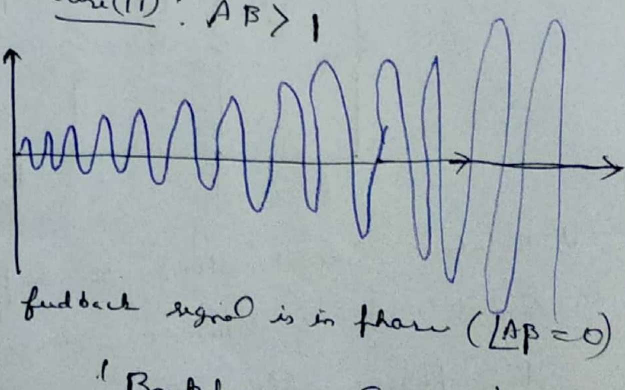
* When the switch at the amplifier input is open, no oscillation occurs.
* Consider that we have a 'fictitious voltage' (imaginary) input 'V_i'. This results in an output voltage $V_o = AV_i$ after the amplifier stage and in a voltage $V_f = \beta(AV_i)$ after the feedback stage.

Thus, we have a feedback voltage $V_f = \beta AV_i$, where βA is called loop gain.

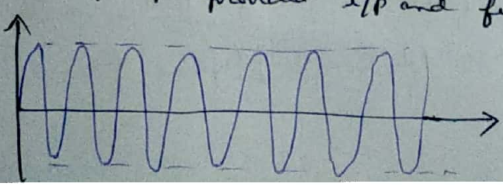
Case(i): $A\beta < 1$ (Eg: $A\beta = 0.9$ and $V_i = 2V$)



Case(ii): $A\beta > 1$



When $A\beta = 1$ provided i/p and feedback signal is in phase ($\angle A\beta = 0$)



'Barkhausen Criteria'

* In reality,

feedback gain $A_f = \dfrac{A}{1+\beta A}$ —— ①

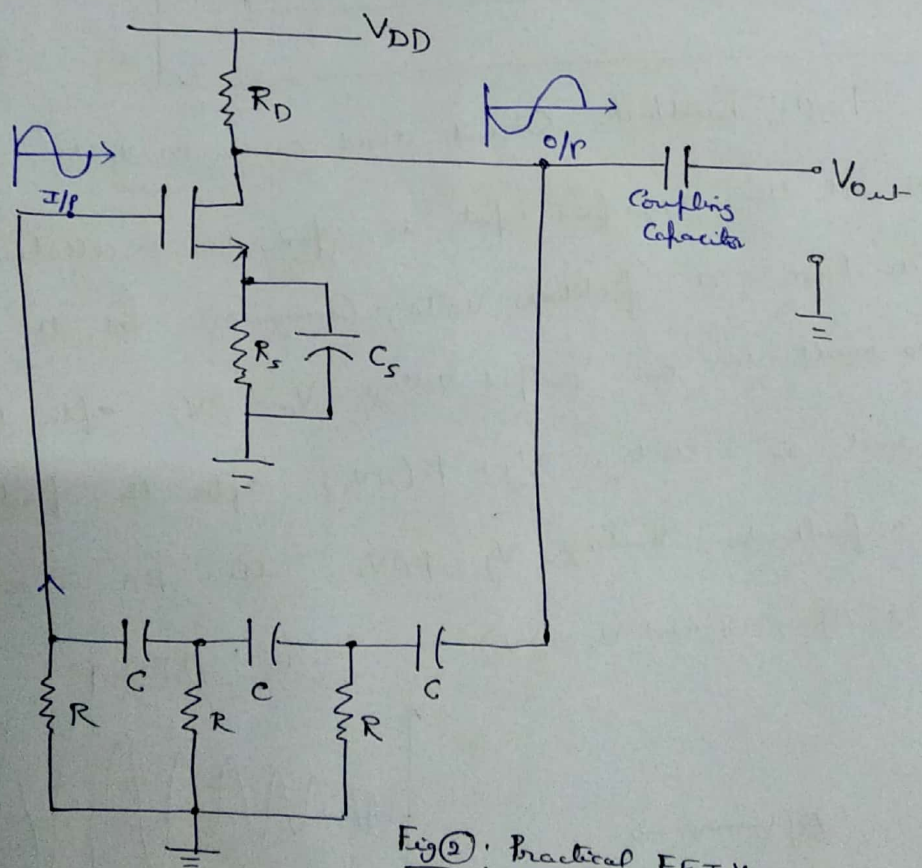
When $\beta A = -1$ or magnitude 1 at a phase of 180°, the denominator of eqⁿ ① becomes 0 and the gain with feedback 'A_f' becomes infinite.

* Thus, an infinitesimal signal (noise voltage) can provide a measurable output voltage, and the circuit acts as an oscillator even without an input signal.

1. Phase Shift Oscillator (RC / Low Freq. Oscillator)

* A phase shift oscillator is a circuit that produces a sine wave.
* The O/P is fed back to the i/P which changes the phase of the waves of the signal.

* The phase shift increases with frequency and can reach a maximum of 180°



Fig②: Practical FET version phase-shift oscillator circuit

* The above circuit shows the amplifier with feedback network. The circuit consists of a common source FET amplifier followed by 3 section RC phase shift network.

* The amplifier stage is self biased with a capacitor which bypass source resistor 'R_S' and a drain biased resistance R_D.
* The O/P of the last section is supplied back to the gate. If the loading of the phase shift network is assumbed to be negliable, a phase shift of 180° between the amplified O/P voltage V_{out} and the input voltage V_{in} at the gate is produced by the amplifier itself.
* The 3 section RC phase shift network produces an additional phase shift of 180° at some frequency of operation. At this frequency, the total phase shift from the gate around the circuit and back to the gate will be exactly zero. (i.e 360°). This particular frequency will be the one at which the circuit will oscillate provided that the magnitude of the amplification is sufficiently large.
* In FET phase shift oscillator, voltage series feedback is used. This feedback network attenuates the output voltage by a factor of $\frac{1}{29}$. This means that the amplifier must have a voltage gain of 29 or above.
* When the amplifier voltage gain is 29 and feedback factor of RC network, $\beta = \frac{1}{29}$, then loop gain is $\beta A = 1$. ('Barkhausen Criterion')
* The amplifier phase shift of $-180°$ combined with a network phase shift of $+180°$ gives a loop phase shift of 0.
* If the amplifier gain is much greater than 29, the oscillator output waveform is likely to be distorted and when output gain is slightly greater than 29, the output is usually a pure sinusoidal signal.

Advantages:

1. It is a Cheap & simple Circuit as it Contains R & C
2. It provides good frequency stability
3. The Output is sinusoidal which is quite distortion free.
4. It has a wide frequency range from Hz to several kHz.
5. RC phase shift Oscillators are suitable for low freq. applications

NOTE:

In phase-shift n/w shown in Fig①, frequency is Calculated at 180° phase shift and given by

$$\boxed{f = \frac{1}{2\pi RC\sqrt{6}}}$$

LC Tank Circuits

- Colpitts' Oscillator
- Hartley Oscillator

Colpitts' Oscillator

a. FET Colpitts' Oscillator: A practical version of an Colpitt's oscillator is shown in below figure.

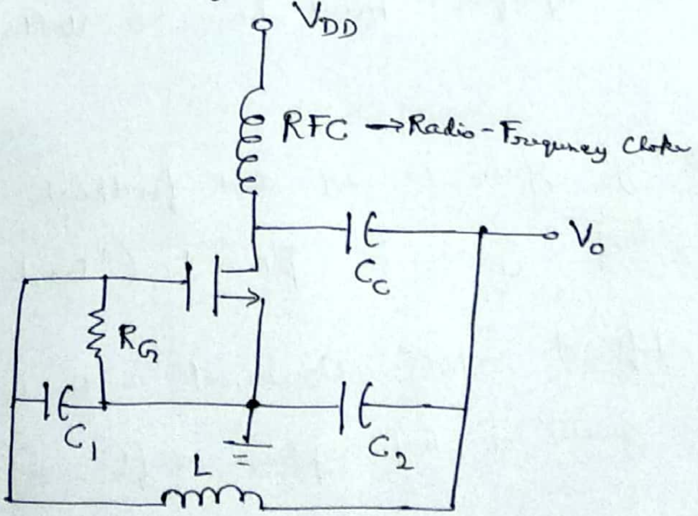


Fig ③ FET Collpits Oscillator

* The Configuration of the FET amplifier is of a Common Source amplifier with the output signal 180° out of phase with regards to the input signal.

* The additional 180° phase shift require for oscillation is achieved by the fact that the two capacitors are connected together in series but in parallel with the inductive coil resulting in overall phase shift of the circuit being zero or 360°.
* The amount of feedback depends on the values of C_1 and C_2. Therefore, by changing the values of capacitors, C_1 and C_2 we can adjust the amount of feedback voltage returned to the tank circuit. This ratio is called 'Feedback Fraction' and given by,

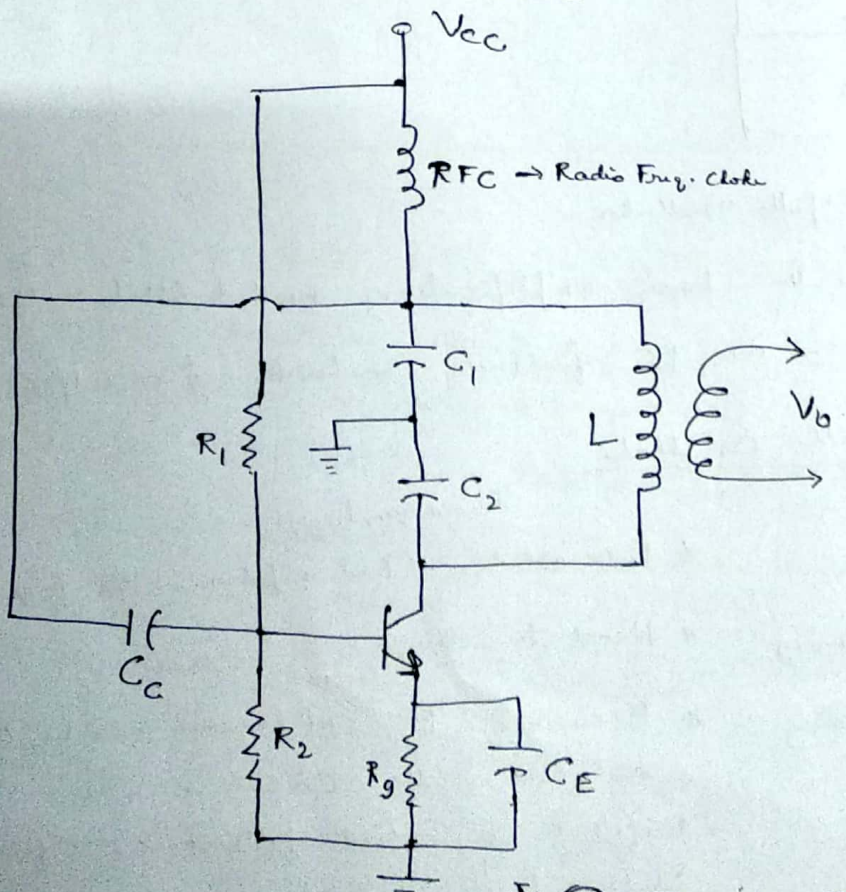
$$\text{Feedback Fraction} = \frac{C_1}{C_2}\ \%$$

The oscillator frequency is given by,

$$\boxed{f_o = \frac{1}{2\pi\sqrt{LC_{eq}}}}$$

where $C_{eq} = \dfrac{C_1 C_2}{C_1 + C_2}$

<u>Transistor Colpitt's Oscillator</u>



The ckt freq. of oscillator is,

$$f_o = \frac{1}{2\pi\sqrt{LC}}$$

Transistor – MOSFET
C – D
E – S
B – G

Fig (4): Transistor Colpitts Oscillator

* Transistor Colpitts' Oscillator also Consist of a parallel LC resonator tank Circuit whose feedback is achieved by way of a Capacitive divider.

* The Centre tapping of the Circuit (tank sub-circuit) is made at the junction of a "Capacitive Voltage divider" network to feed a fraction of the output signal back to the emitter of the transistor.

* The two Capacitor (C_1, C_2) in series produce a 180° phase shift which is inverted by another 180° to produce the required positive feedback.

* The Oscillating frequency which is a pure sine-wave Voltage is determined by the resonance frequency of the tank Circuit.

IC Colpitts' Oscillator

* An Op-amp Colpitts' Oscillator Circuit is shown in Fig (5).

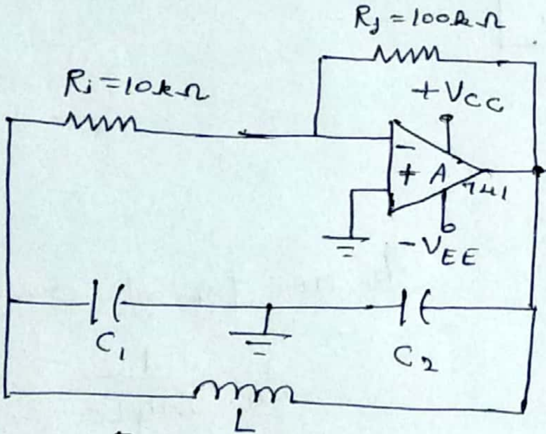


Fig (5): Op-amp Colpitts oscillator

* Again, the Op-amp provides the basic amplification needed while the Oscillator frequency is set by an LC feedback network of a Colpitts Configuration.

Colpitts Oscillator

Advantages

* Good sine wave purity
* Fine performance at high frequency
* Good stability at high frequency
* Wide operating range 10 kHz – 300 MHz

Disadvantages

* Poor isolation (bad impedance V/s frequency)
* Hard to design
* Because of 'L', Ckt becomes more bulky and Cost of the Circuit is more
* Difficult to adjust feedback as Capacitor Values to be changed.

Hartley Oscillator

* If the elements in the basic resonant circuit are X_1 and X_2 (inductors) and X_3 (capacitor), the circuit is a Hartley Oscillator.

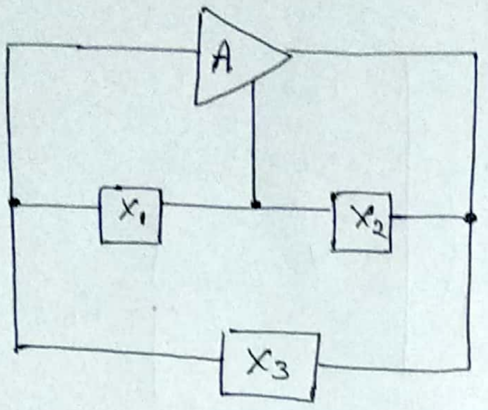


Fig ⑥ : Basic Configuration of resonant circuit Oscillator

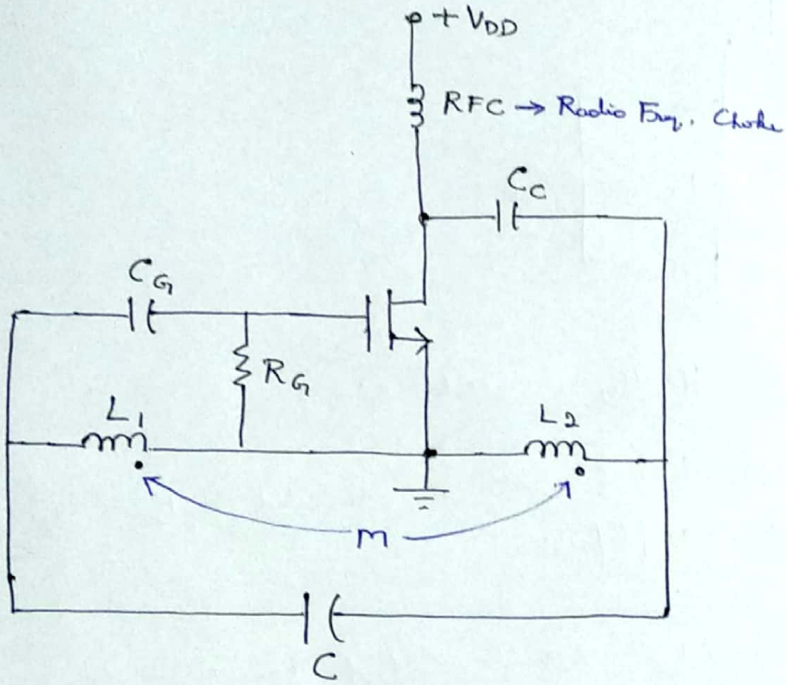


Fig ⑦ : FET Hartley oscillator

* Hartley oscillator consist of a parallel LC resonator tank circuit whose feedback is achieved by way of an inductive divider.
* Inductors 'L_1' and 'L_2' have a mutual coupling M, which must be taken into account determining the equivalent inductance for the resonant tank circuit.
* The circuit frequency of oscillation is given by,

$$\boxed{f_o = \frac{1}{2\pi\sqrt{L_{eq} C}}}$$

with

$$\boxed{L_{eq} = L_1 + L_2 + 2M}$$

Transistor Hartley Oscillator

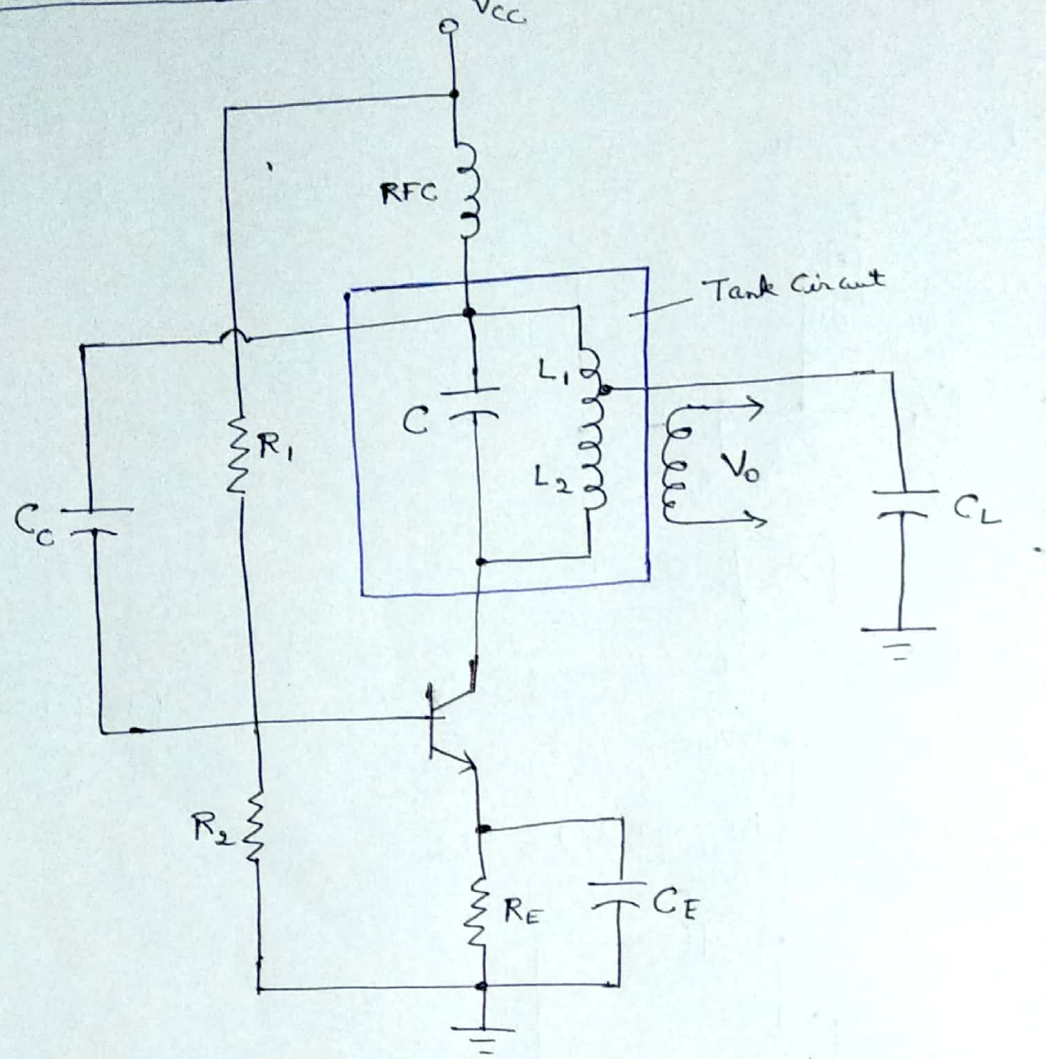


Fig ⑧ : Transistor Hartley Oscillator Circuit

* Hartley Oscillator the tuned LC Circuit is Connected between the Collector and the base of a transistor amplifier.

Advantages:

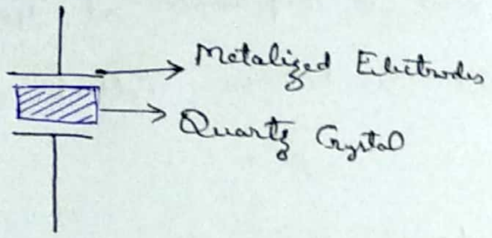
* Instead of two seperate Coils L_1 & L_2, a single Coil of bare wire Can be used & the Coil grounded at any desired point along it.
* By using a Variable Capacitor, or by making Core movable, freq. of Oscillation Can be Varied.
* Very few Components required, including either two fixed inductors or a tapped Coil.
* The amplitude of the O/P remains Constant over the working frequency range.

Disadvantages:

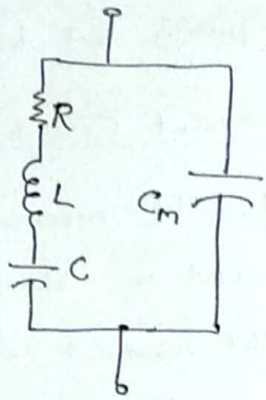
* It Cannot be used as a low freq. Oscillator since the Value of inductors become large & the size of the inductors become large.
* The harmonic Content in the O/P of the oscillator is Very high & hence it is not suitable for the applications which require a pure sine wave.

Crystal Oscillator

* A Crystal Oscillator is basically a tuned-Circuit Oscillator using a piezoelectric Crystal as a resonant tank Circuit.
* The Crystal (usually quartz) has a greater stability in holding Constant at whatever frequency the Crystal is originally Cut to Operate.
* Crystal Oscillators are used whenever great stability is required, such as in Communication transmitters and receivers.



(a) Symbol



(b) Electrical Equivalent Circuit of a Crystal

where inductor 'L' and Capacitor 'C' represent electrical equivalents of Crystal mass and Compliance
'R' is the electrical equivalent of Crystal structure's internal friction
'C_M' shunt Capacitance due to mechanical mounting of the Crystal.

Series-resonant Circuits

* To excite a Crystal for operation in the series-resonant mode, it may be Connected as a series element in a feedback path.
* At the series-resonant frequency of the Crystal, its impedance is smallest and the amount of (positive) feedback is largest.

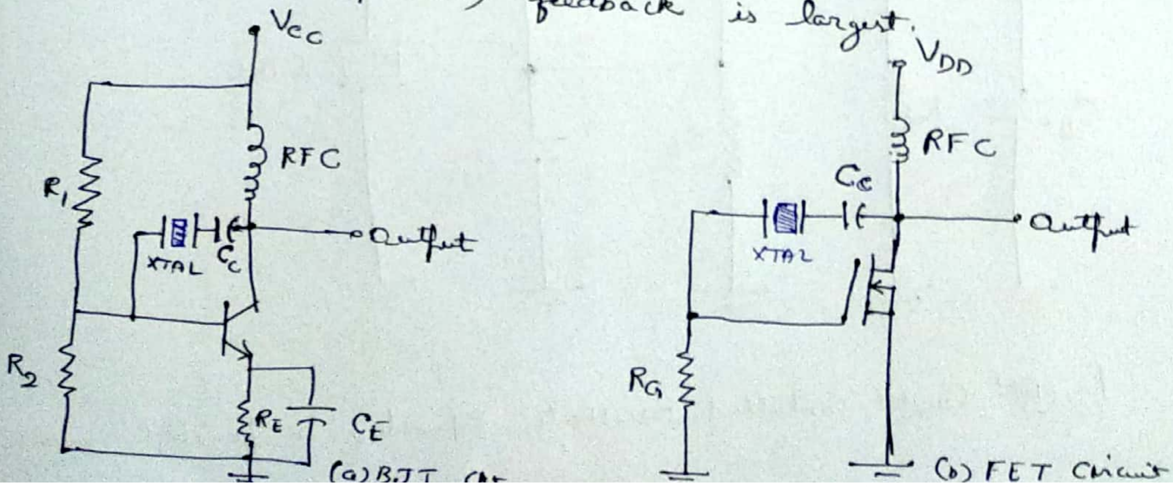


Fig 9 (a) BJT Ckt (b) FET Circuit

* A typical transistor circuit is shown in Fig (9). Resistors R_1, R_2 and R_E provide a voltage-divider stabilized dc bias circuit.
* Capacitor C_E provides ac bypass of the emitter resistor, and the RFC coil provides for dc bias while decoupling any ac signal on the power lines from affecting the output signal.
* The voltage feedback from collector to base is a maximum when the crystal impedance is minimum (in series-resonant mode).
* The coupling capacitor C_C has negligible impedance at the circuit operating frequency but blocks any dc between collector and base.

Parallel- Resonant Circuits

* Since the parallel-resonant impedance of a crystal is a maximum value, it is connected in shunt.
* At parallel-resonant operating frequency, a crystal appears as an inductive reactance of largest value.
* Fig (10) shows a crystal connected as the inductor element in a modified Colpitts circuit.

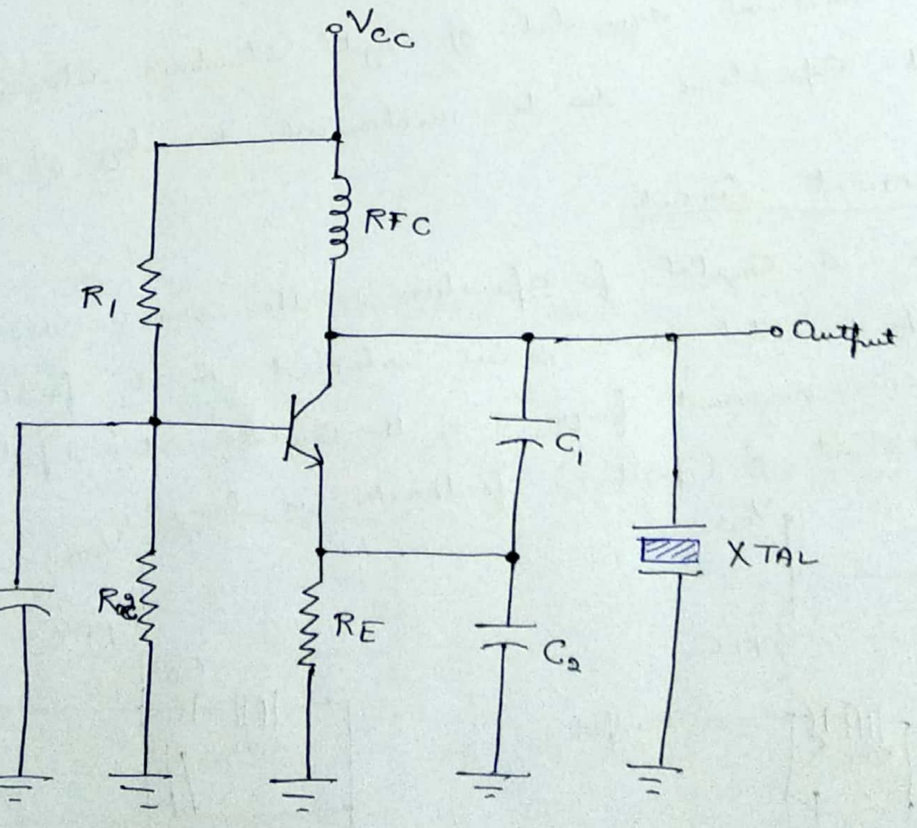


Fig (10): Crystal-controlled oscillator operating in parallel-resonant mode

* The basic dc bias Circuit should be evident
* The maximum Voltage is developed across the Crystal at its parallel-resonant frequency.
* The Voltage is Coupled to the emitter by a Capacitor Voltage divider C_1 & C_2.
* A Miller Crystal-Controlled Oscillator Circuit is shown in Fig (11).
* A tuned LC Circuit in the drain section is adjusted near the Crystal parallel-resonant frequency.
* The maximum gate-source signal occurs at the Crystal antiresonant frequency, Controlling the Circuit Operating frequency.

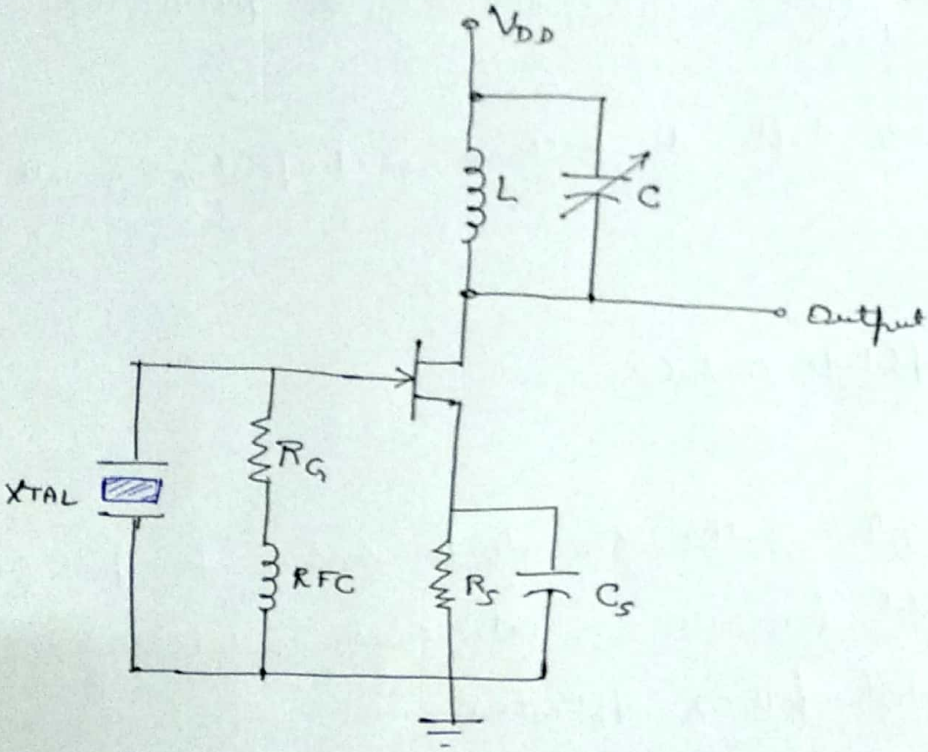


Fig (11): Miller Crystal-Controlled Oscillator

Crystal Oscillator

* An Op-amp Can be used in a Crystal Oscillator as shown in Fig (12).

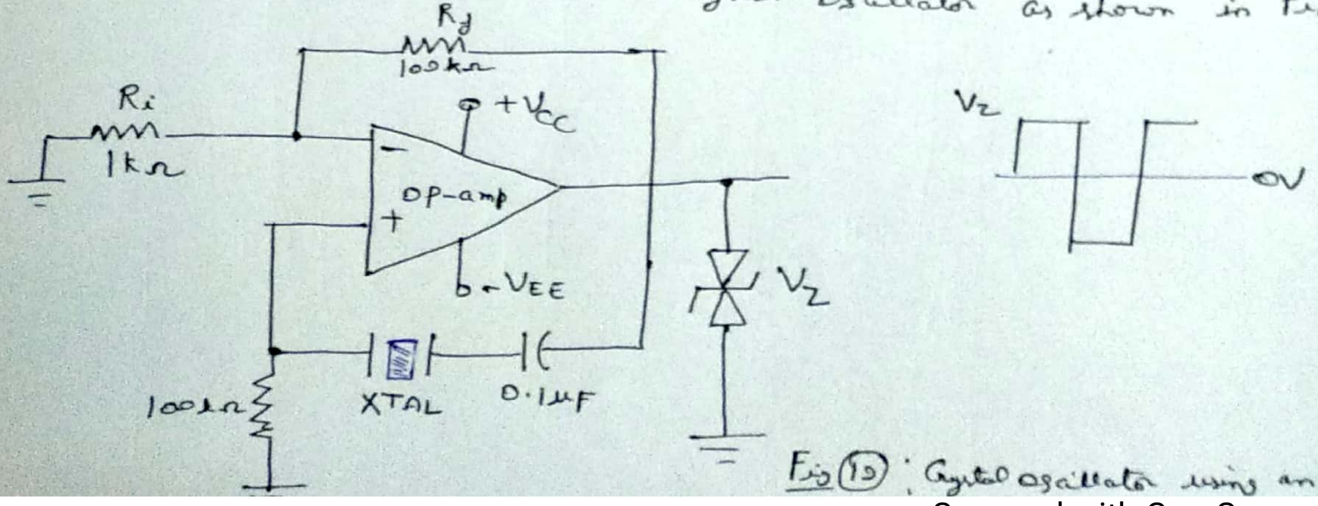


Fig (12): Crystal oscillator using an Op-amp

* The Crystal is Connected in the series - resonant path and operates at the Crystal series - resonant frequency.
* The present Circuit has a high gain, so that an output square-wave signal results as shown in the figure.
* A pair of Zener diodes is shown at the output to provide output amplitude at exactly the Zener Voltage (V_Z).

Crystal Oscillator : Advantages:

* The Crystal Oscillator have Very high frequency stability
* The Crystal Oscillator is possible to Obtain Very high precise and stable frequency of Operation.
* It has Very low frequency drift due to change in temperature & other parameters.
* The 'Q' is Very high
* It has automatic Amplitude Control.

Disadvantages:

* Crystal Oscillators are fragile. So they Can only be used in low power Circuits.
* Crystals of low fundamental frequencies are not easily available.
* These are sitable for high frequency applications.