LMC ELECTRONICS

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- **Read instruction manual carefully.**
- **The graphical variations shown are exemplary and the numerical values may differ.**
- **Connect the circuit step by step as written in the procedure.**
- **Check the circuit again carefully before switching ON the power supply.**

OPERATING INSTRUCTIONS MANUAL
FOR
THE STUDY OF HARTLEY OSCILLATOR SERIES & PARALLEL FED

MODEL: LMC-151

Connection leads Red-2 & Black-2 (2mm).

HARTLEY OSCILLATOR

OBJECT: - To Study Series and Parallel Fed Hartley Oscillator Circuits.

APPARATUS: - LMC Experimental Board, CRO.
Connection leads Red-2 & Black-2 (2mm).

THEORY: - An electronic oscillator is a device which converts dc power into ac power. The commonly used oscillators are:

1. Sine wave or sinusoidal oscillators
2. Non sinusoidal oscillators.

An amplifier with proper +Ve feedback is used to sustain oscillations. The Hartley oscillator produces high frequency sinusoidal oscillations ranging from about 100 kHz to tens of MHz. Commonly parallel LC resonant circuits are used in conjunction with an active device (transistor, FET, Op amp) to generate high frequency oscillations. The resonant frequency of a parallel resonant circuit is given by following relation:

$$f = \frac{1}{2\pi\sqrt{LC}} \ldots (1)$$

where with L in henry (H) and C in farad (F), the f is given in hertz (Hz).

The basic working of an LC oscillator of which the Hartley oscillator is very important member requires to know the following:

(i) Production of damped oscillations by a parallel resonant LC circuit.

(ii) The proper amount of positive feedback to counterbalance the damping by an active electronic device to sustain oscillations. This is usually referred as Barkhausen condition of oscillations.

(iii) In Hartley oscillator the inductance L of the resonant or tank circuit is divided into two parts. One part of which from the output is returned back to the input in proper phase and amount in order to sustain oscillations. This properly phased amount of output to input satisfies the Barkhausen condition.

Let us briefly consider these points stepwise with the help of fig. (1a, 1b &1c).

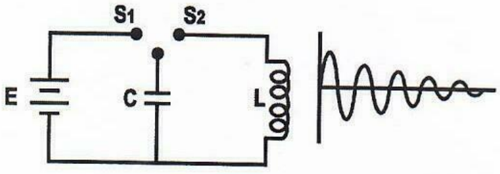


Fig (1a): Damped electromagnetic oscillations produced by a parallel resonant LC circuit

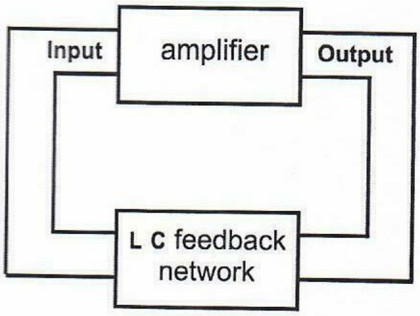


Fig (1b): Positive feedback condition to sustain oscillations by countering the damping

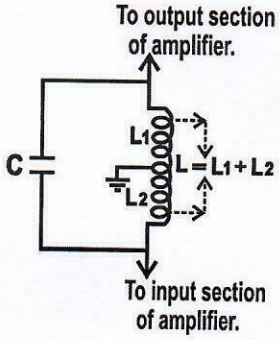


Fig (1c): The splitted L to provide proper feedback to sustain oscillations.

The fig (1a) shows a parallel resonant LC circuit and the damped oscillations produced by such a circuit. Consider following mechanism to produce damped oscillations by the circuit. Switch S_1 on and off it. This charges C to peak value instantaneously. Now switch on S_2. The capacitor C discharges through L immediately and thereby produces a variable magnetic field around the coil L. The decreasing magnetic field tries to hold the current and charges the C with polarity opposite to the previous one. This process of the back and forth charging and discharging of capacitor C produces electromagnetic oscillations of decreasing amplitude till the stored energy on C is annihilated. The energy loss causing the damping is due to ohmic resistance of the coil L. Hence R of a coil must be as low as possible to reduce damping. This loss is compensated by proper +Ve feedback by an amplifier using transistor or op amp circuit.

The fig (1b) shows the block diagram to sustain oscillations. The output of amplifier is made the input of a feedback network as shown by another block. A properly phased amount from the feedback network is again applied at the input of the amplifier. If β is the feedback factor and A is the internal gain of the amplifier, then the gain A_f with +Ve feedback is given by following relation:

$$A_f = \frac{A}{1 - A\beta} \ldots (2)$$

The $A_f \rightarrow \infty$ as $A\beta \rightarrow 1$ and the condition $A\beta = 1$ implies A_f to become infinitely large. Such an amplifying system becomes an oscillator. The condition $A\beta = 1$ is called the Barkhausen condition of oscillations. In practice $A\beta \geq 1$ initially.

In case of Hartley oscillator the fig (1c) shows that a drop of voltage across the amplifier is divided into two parts of L shown as L_1 and L_2 with respect to the ground. The voltage drop across L_2 is fedback to the input. If its amount and phase are as per Barkhausen condition, then the amplifier turns into oscillator, where frequency is exclusively governed by LC value in this case.

At present transistorized amplifier and operational amplifier are commonly used to make oscillators. The Hartley oscillator has two versions, namely:

1. Series Fed Type.

2. Parallel or Shunt Fed Type.

In series fed type both ac and dc thread through the transistor; while in parallel fed type the paths of ac and dc are different. The circuits of interest are shown in fig (2a, 2b &2c).

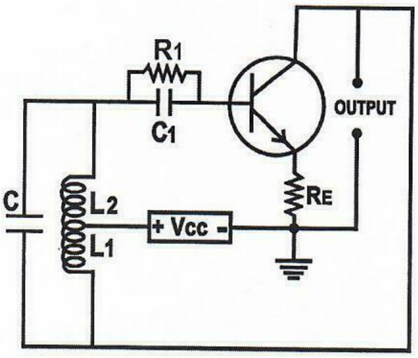


Fig (2a): Series Fed Hartley oscillator.

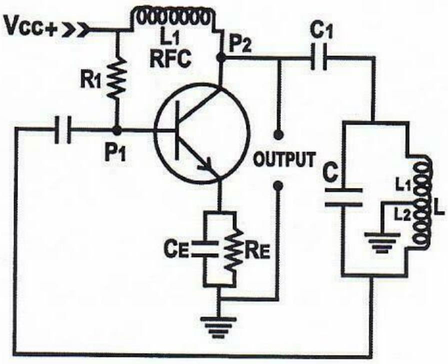


Fig (2b): Shunt Fed Type Hartley oscillator

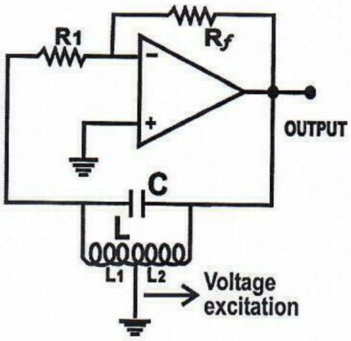


Fig (2c): Op amp based Hartley oscillator.

In fig (2a) note that oscillatory current and biasing current follow the same path.

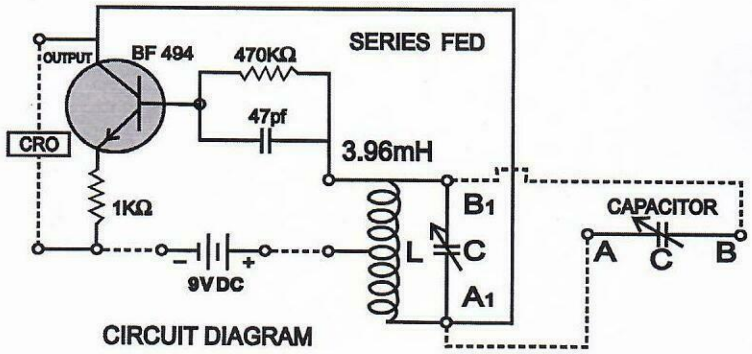
In fig (2b) the biasing current and oscillatory current have separate path due to radio frequency choke (RFC).

In fig (2c), the proper gain is provided by R_f / R_1 and voltage excitation at L is needed to start oscillations.

PROCEDURE: - Series Fed Circuit.

NOTE:- The variations shown in graphs are exemplary & the numerical values may differ due to physical conditions and individual's working.

- **Keep power switch in off position.**
- **Remove all the connections, if any, on the exp. board.**



CIRCUIT DIAGRAM

1. Connect terminals 1 - 1, 2 - 2, A - A_1 & B - B_1.
   Connect CRO across the output terminals. Switch on the power supply.
2. Record the value of inductor L of the LC circuit (given on the exp. board).

   L =...mH =...H

   Adjust variable capacitor C at 40 pF(pico farad) by the rotary switch.
3. Calculate & record the frequency (f_{cal}) of oscillations by following relations:

   $$f_{\text{cal}} = \frac{1}{2\pi\sqrt{LC}} = \ldots \text{ Hz} = \ldots \text{kHz}$$

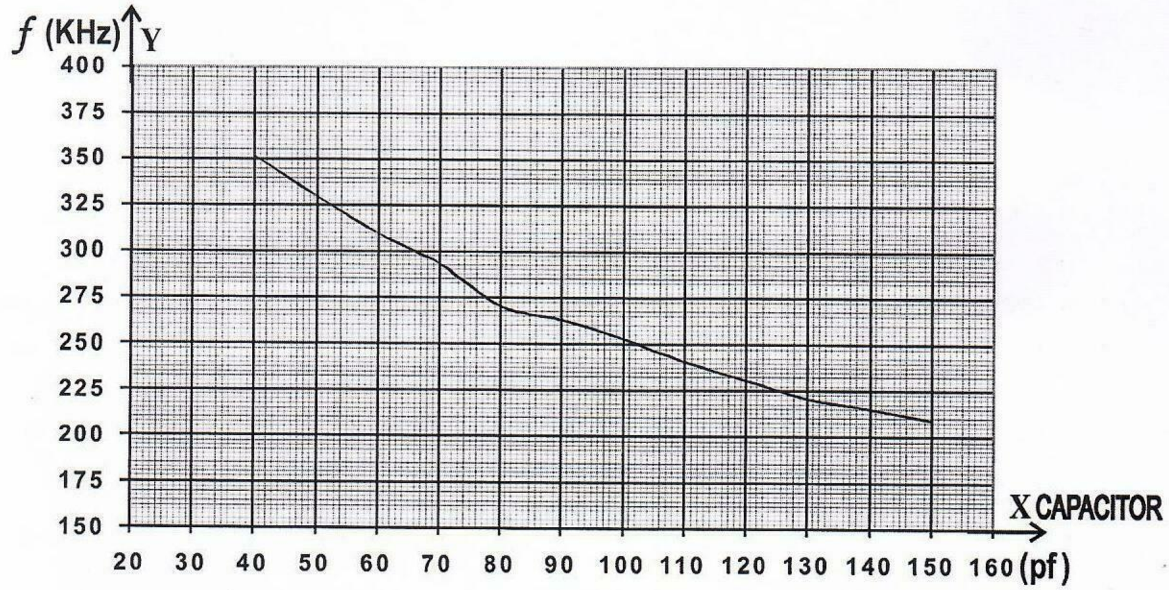
   With given L in henry (H) and C in farad (F).
4. Now measure & record the value of experimental frequency (f_{exp}) and the output voltage peak-peak ($V_{\text{p-p}}$) of the oscillations given by the oscillator for C= 40pF.
5. Repeat steps **3 & 4** for other step values of **C** given on the Experimental Board. Record the experimental observations and subsequently calculated values of frequency (f_{cal}) in table (1).
6. Calculate the difference in f_{exp} and f_{cal} as Δf i.e. ($f_{\text{exp}} \sim f_{\text{cal}}$) in kHz. Now calculate the % Δf with respect to f_{exp} by following relation for each step:

   $$\% \Delta f = \Delta f \times 100 / f_{\text{exp}} = \ldots$$

Table (1): Series Fed Hartley Oscillator.

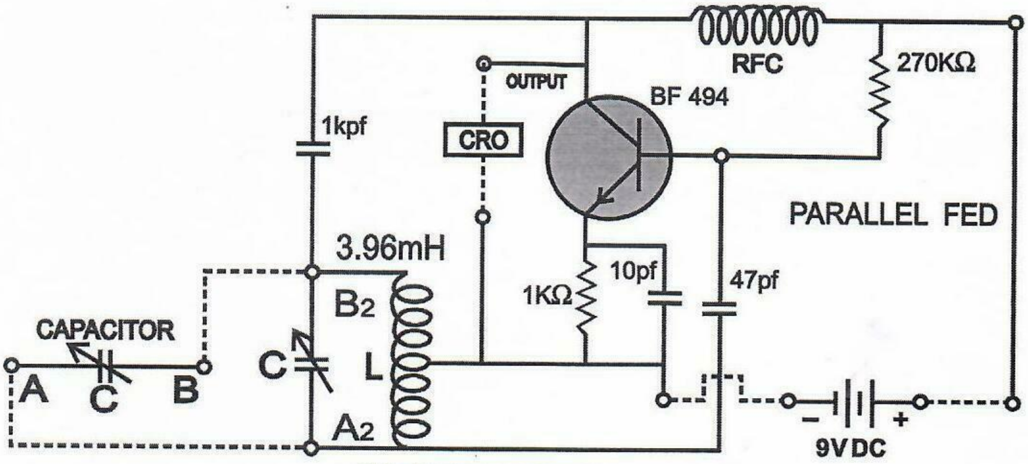
Sl. no	Capacitor C pF	V_{out} p-p	f_{exp} kHz	f_{cal} kHz	$\Delta f = (f_{\text{exp}} \sim f_{\text{cal}})$ kHz	$\% \Delta f = \Delta f \times 100 / f_{\text{exp}}$

7. Use the values recorded in table (1) to plot graph between capacitor C and frequency f_{exp}. Take C values in pF on x-axis with zero origin and f_{exp} values in kHz on y-axis. The typical variation is shown below.



PROCEDURE: - **Parallel Fed Circuit:**

- **Keep power switch in off position.**
- **Remove all the connections, if any, on the exp. board.**



CIRCUIT DIAGRAM

1. Connect terminals 3 - 3, 4 - 4, A - A_2 & B - B_2. Connect CRO across the output terminals. Switch on the power supply.

2. Record the value of inductor L of the LC circuit (given on the exp. board).

L =...mH =...H

Adjust variable capacitor C at 40 pF(pico farad) by the rotary switch.

3. Calculate & record the frequency (f_{cal}) of oscillations by following relations:

$$f_{cal} = \frac{1}{2\pi\sqrt{LC}} = \ldots \text{ Hz} = \ldots \text{kHz}$$

With given L in henry (H) and C in farad (F).

4. Now measure & record the value of experimental frequency (f_{exp}) and the output voltage peak-peak ($V_{p\text{-}p}$) of the oscillations given by the oscillator for C= 40pF.

5. Repeat steps **3 & 4** for other step values of **C** given on the Experimental Board. Record the experimental observations and subsequently calculated values of frequency (f_{cal}) in table (2).

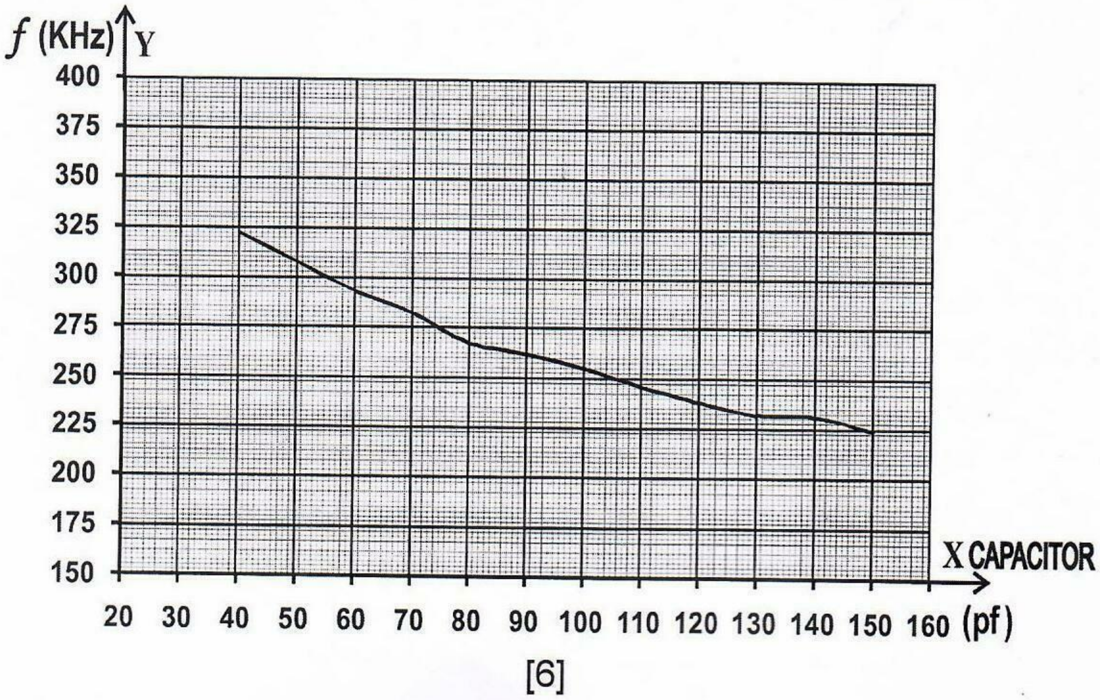
6. Calculate the difference in f_{exp} and f_{cal} as Δf i.e. ($f_{exp} \sim f_{cal}$) in kHz. Now calculate the % Δf with respect to f_{exp} by following relation for each step:

$$\% \Delta f = \Delta f \times 100 / f_{exp} = \ldots$$

Table (2): Parallel Fed Hartley Oscillator.

Sl. No	Capacitor C pF	V_{out} p-p	f_{exp} kHz	f_{cal} kHz	$\Delta f = (f_{exp} \sim f_{cal})$	$\% \Delta f = \Delta f \times 100 / f_{exp}$

7. Use the values recorded in table (2) to plot graph between capacitor C and frequency f_{exp}. Take C values in pF on x-axis with zero origin and f_{exp} values in kHz on y-axis. The typical variation is shown below.



RESULTS:-

(1) The study of two circuits shows that the oscillator frequency is determined by the LC values of the parallel resonant circuit.

(2) The difference between f_{exp} & f_{cal} and their similar variation with C show the similarity of two circuits.

(3) The f_{exp} values widely differ from f_{cal} at low values of C because of comparable capacitance of circuit elements.

(4) At low frequencies the oscillations do not sustain due to inadequate feed back.

COMMENTS :-

(i) The feedback wave and its amplitude may be observed and measured between the base terminal and the ground.

(ii) The plot between C & f_{cal} along with the f_{exp} value with only L gives the value of the lowest value of permissible C.