Experiment 11
Oscillators (Hartley/Colpitts)

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May 5, 2020

Abstract

In this Report we are going to exploit about two types of oscillators : hartley and colpitts ,we are going to study how they work in reality and compare with theoretical values.

1 Introduction

Hartley Oscillator:

The Hartley oscillator is an electronic oscillator circuit in which the oscillation frequency is determined by a tuned circuit consisting of capacitors and inductors, that is, an LC oscillator. The circuit was invented in 1915 by American engineer Ralph Hartley. The distinguishing feature of the Hartley oscillator is that the tuned circuit consists of a single capacitor in parallel with two inductors in series (or a single tapped inductor), and the feedback signal needed for oscillation is taken from the center connection of the two inductors.

Colpitts Oscillator:

A Colpitts oscillator, invented in 1918 by American engineer Edwin H. Colpitts, is one of a number of designs for LC oscillators, electronic oscillators that use a combination of inductors (L) and capacitors (C) to produce an oscillation at a certain frequency. The distinguishing feature of the Colpitts oscillator is that the feedback for the active device is taken from a voltage divider made of two capacitors in series across the inductor.

2 Theoritical Background

Hartley oscillator

The Hartley Oscillator design uses two inductive coils in series with a parallel capacitor to form its resonance tank circuit producing sinusoidal oscillations

In the Hartley Oscillator the tuned LC circuit is connected between the collector and the base of a transistor amplifier. As far as the oscillatory voltage is concerned, the emitter is connected to a tapping point on the tuned circuit coil.

The feedback part of the tuned LC tank circuit is taken from the centre tap of the inductor coil or even two separate coils in series which are in parallel with a variable capacitor, C as shown.

The Hartley circuit is often referred to as a split-inductance oscillator because coil L is centre-tapped. In effect, inductance L acts like two separate coils in very close proximity with the current flowing through coil section XY induces a signal into coil section YZ below.

An Hartley Oscillator circuit can be made from any configuration that uses either a single tapped coil (similar to an autotransformer) or a pair of series connected coils in parallel with a single capacitor as shown below.

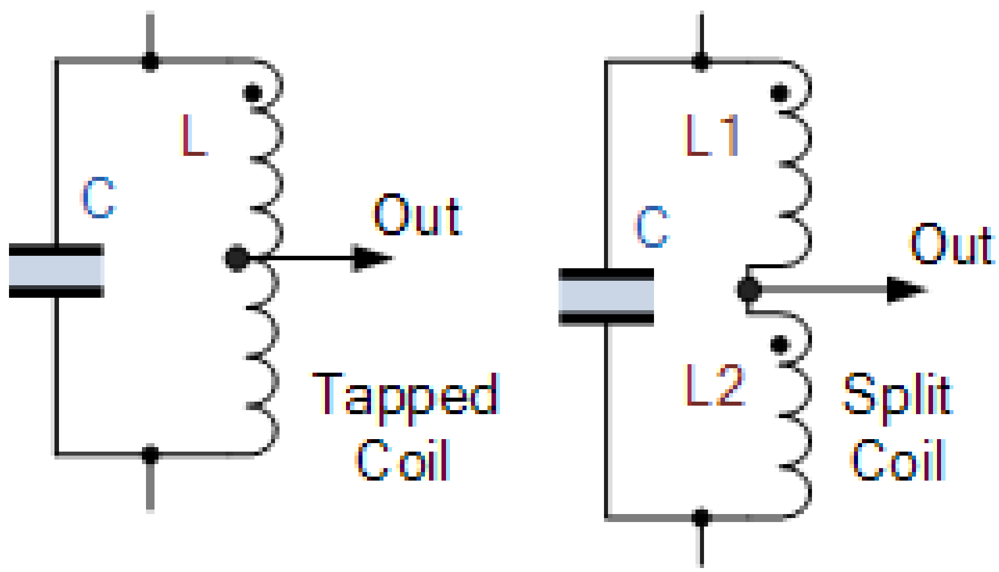
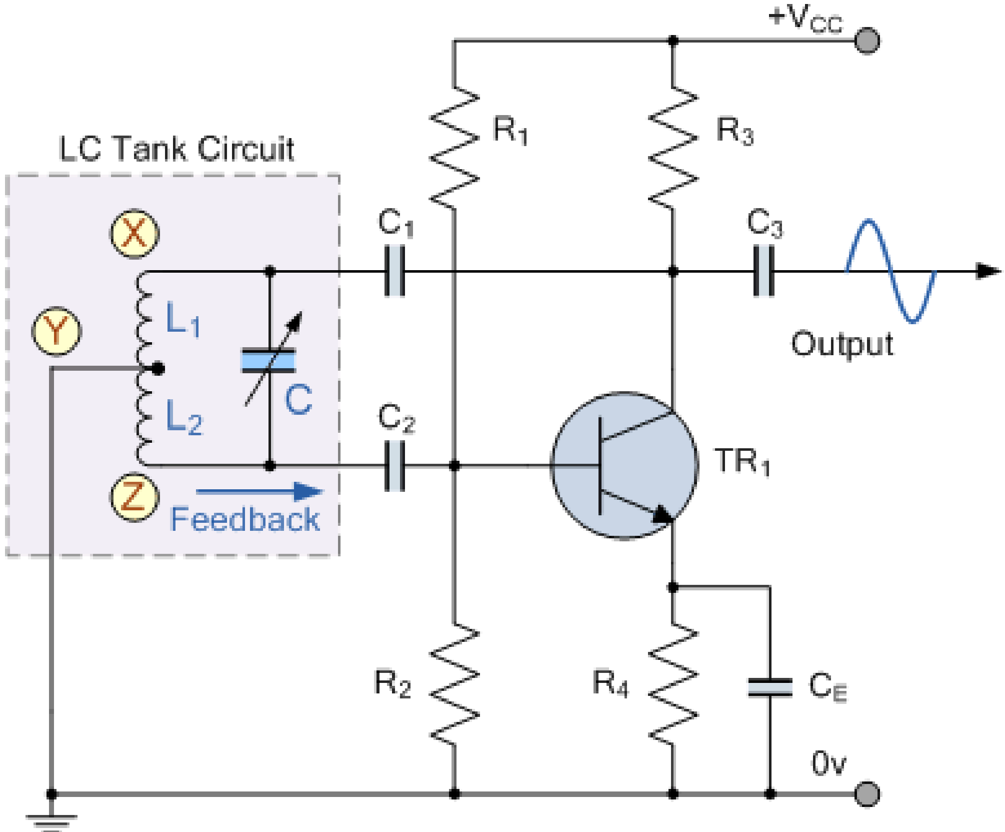


Figure: Hartley Oscillator Tank Circuit

Basic Hartley Oscillator Design



When the circuit is oscillating, the voltage at point X (collector), relative to point Y (emitter), is 180° out-of-phase with the voltage at point Z (base) relative to point Y. At the frequency of oscillation, the impedance of the Collector load is resistive and an increase in Base voltage causes a decrease in the Collector voltage.

Thus there is a 180° phase change in the voltage between the Base and Collector and this along with the original 180° phase shift in the feedback loop provides the correct phase relationship of positive feedback for oscillations to be maintained.

The amount of feedback depends upon the position of the tapping point of the inductor. If this is moved nearer to the collector the amount of feedback is increased, but the output taken between the Collector and earth is reduced and vice versa. Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the capacitors act as DC-blocking capacitors.

In this Hartley Oscillator circuit, the DC Collector current flows through part of the coil and for this reason the circuit is said to be Series-fed with the frequency of oscillation of the Hartley Oscillator being given as.

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

Where L_T=L_1+L_2+2M, Note: L_T is the total cumulatively coupled inductance if two separate coils are used including their mutual inductance, M.

The frequency of oscillations can be adjusted by varying the tuning capacitor, C or by varying the position of the iron-dust core inside the coil (inductive tuning) giving an output over a wide range of frequencies making it very easy to tune. Also the Hartley Oscillator produces an output amplitude which is constant over the entire frequency range.

Colpitts Oscillator

In many ways, the Colpitts oscillator is the exact opposite of the Hartley Oscillator we looked at in the previous tutorial. Just like the Hartley oscillator, the tuned tank circuit consists of an LC resonance sub-circuit connected between the collector and the base of a single stage transistor amplifier producing a sinusoidal output waveform.

The basic configuration of the Colpitts Oscillator resembles that of the Hartley Oscillator but the difference this time is that the centre tapping of the tank sub-circuit is now made at the junction of a capacitive voltage divider network instead of a tapped autotransformer type inductor as in the Hartley oscillator.

The Colpitts oscillator uses a capacitive voltage divider network as its feedback source. The two capacitors, C1 and C2 are placed across a single common inductor, L as shown. Then C1, C2 and L form the tuned tank circuit with the condition for oscillations being: $X_{C1} + X_{C2} = X_L$, the same as for the Hartley oscillator circuit.

The advantage of this type of capacitive circuit configuration is that with less self and mutual inductance within the tank circuit, frequency stability of the oscillator is improved along with a more simple design.

As with the Hartley oscillator, the Colpitts oscillator uses a single stage bipolar transistor amplifier as the gain element which produces a sinusoidal output. Consider the circuit below.

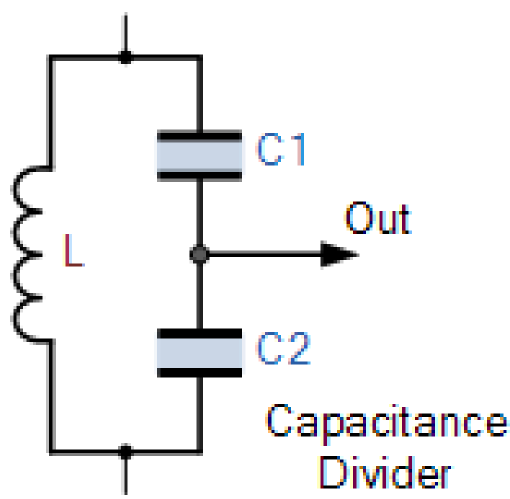
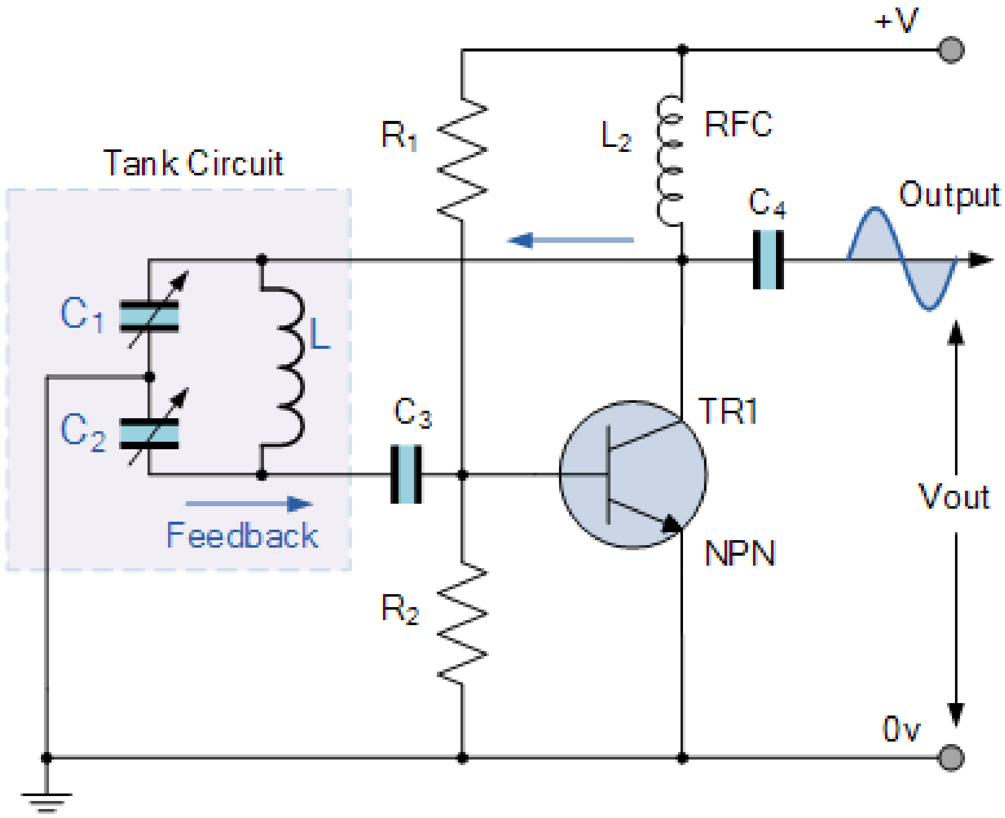


Figure: Colpitts Oscillator Tank Circuit

Basic Colpitts Oscillator Circuit



The emitter terminal of the transistor is effectively connected to the junction of the two capacitors, C1 and C2 which are connected in series and act as a simple voltage divider. When the power supply is firstly applied, capacitors C1 and C2 charge up and then discharge through the coil L. The oscillations across the capacitors are applied to the base-emitter junction and appear in the amplified at the collector output.

Resistors, R1 and R2 provide the usual stabilizing DC bias for the transistor in the normal manner while the additional capacitors act as a DC-blocking bypass capacitors. A radio-frequency choke (RFC) is used in the collector circuit to provide a high reactance (ideally open circuit) at the frequency of oscillation, (f_r) and a low resistance at DC to help start the oscillations.

The required external phase shift is obtained in a similar manner to that in the Hartley oscillator circuit with the required positive feedback obtained for sustained undamped oscillations. The amount of feedback is determined by the ratio of C1 and C2. These two capacitances are generally ganged together to provide a constant amount of feedback so that as one is adjusted the other automatically follows.

The frequency of oscillations for a Colpitts oscillator is determined by the resonant frequency of the LC tank circuit and is given as:

$$f_r = \frac{1}{2\pi\sqrt{L_T C}} \tag{2}$$

where C_T is the capacitance of C1 and C2 connected in series and is given as:

$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} \tag{3}$$

The configuration of the transistor amplifier is of a Common Emitter Amplifier with the output signal 180o 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 C1 and C2. We can see that the voltage across C1 is the the same as the oscillators output voltage, Vout and that the voltage across C2 is the oscillators feedback voltage. Then the voltage across C1 will be much greater than that across C2.

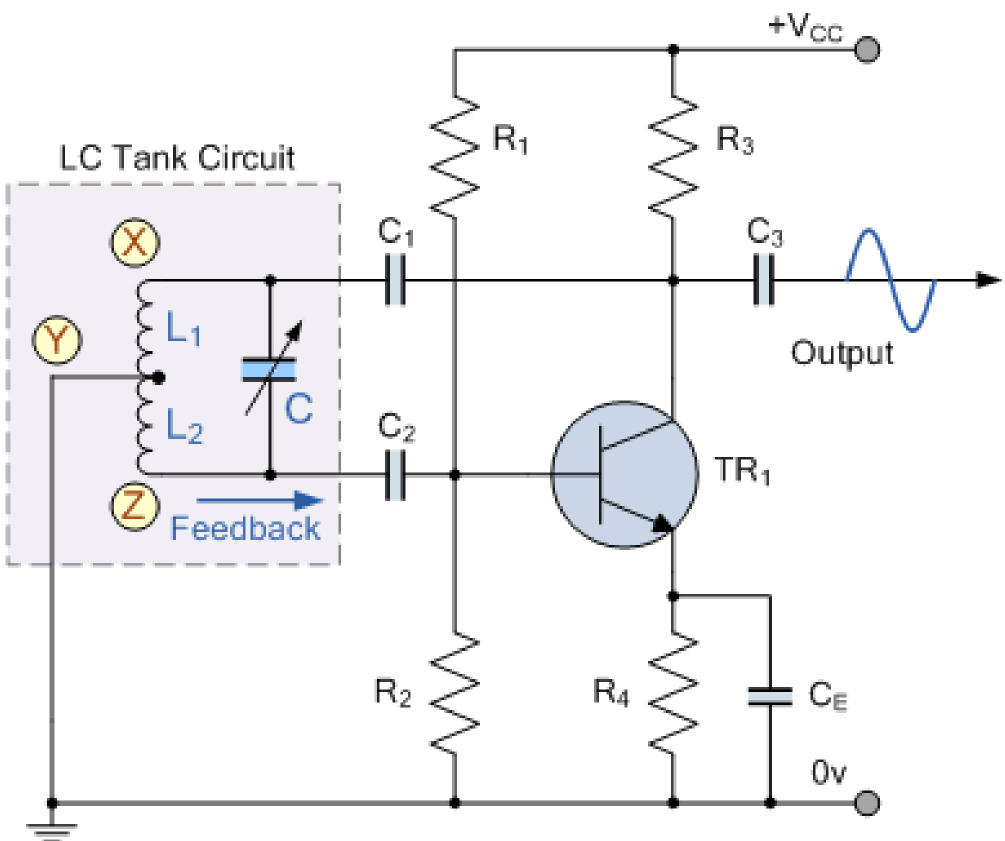
Therefore, by changing the values of capacitors, C1 and C2 we can adjust the amount of feedback voltage returned to the tank circuit. However, large amounts of feedback may cause the output sine wave to become distorted, while small amounts of feedback may not allow the circuit to oscillate.

Then the amount of feedback developed by the Colpitts oscillator is based on the capacitance ratio of C1 and C2 and is what governs the the excitation of the oscillator. This ratio is called the feedback fraction and is given simply as:

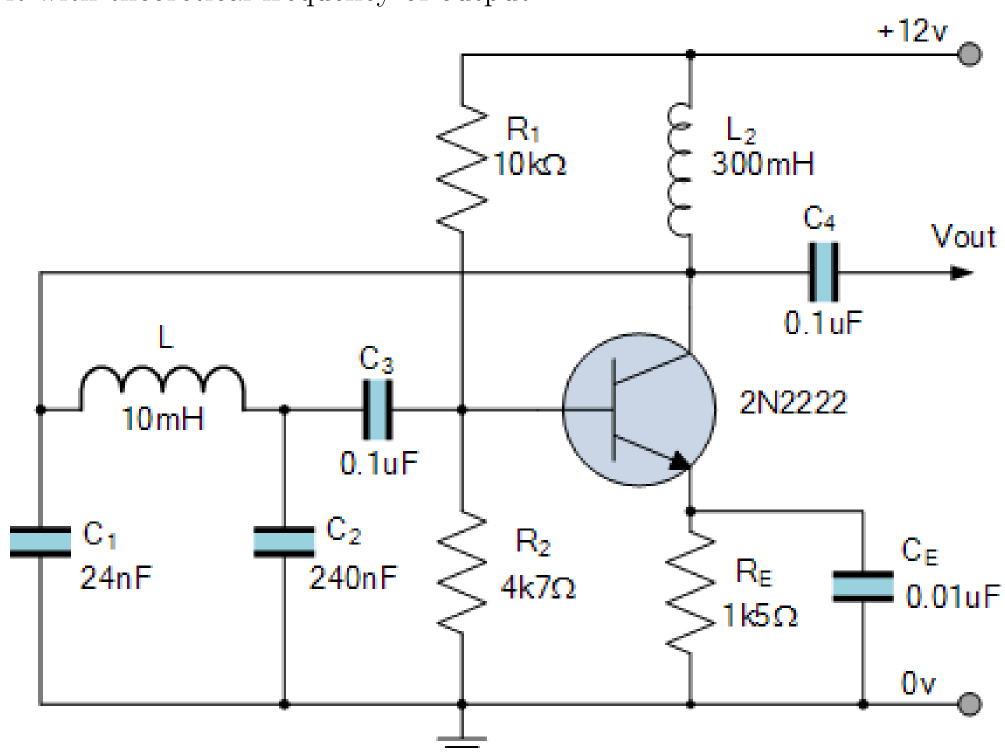
Feedback fraction = $\frac{C_1}{C_2}$ (4)

3 Procedures

Hartley oscillator we are going to check the output of the below circuit and compare it with theoretical frequency of output



Colpitts Oscillator we are going to check the output of the below circuit and compare it with theoretical frequency of output



A Colpitts Oscillator circuit having two capacitors of 24nF and 240nF respectively are connected in parallel with an inductor of 10mH.

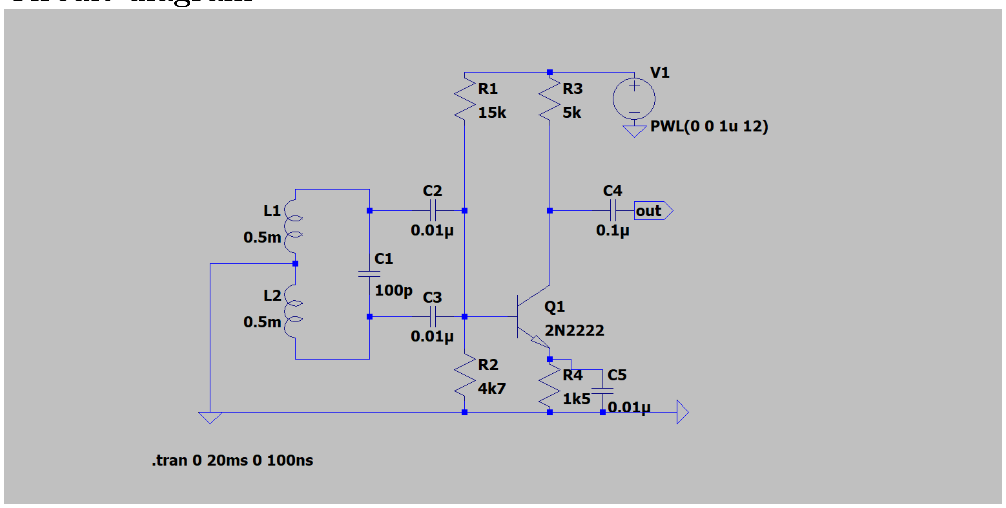
4 Analysis

Hartley Oscillator

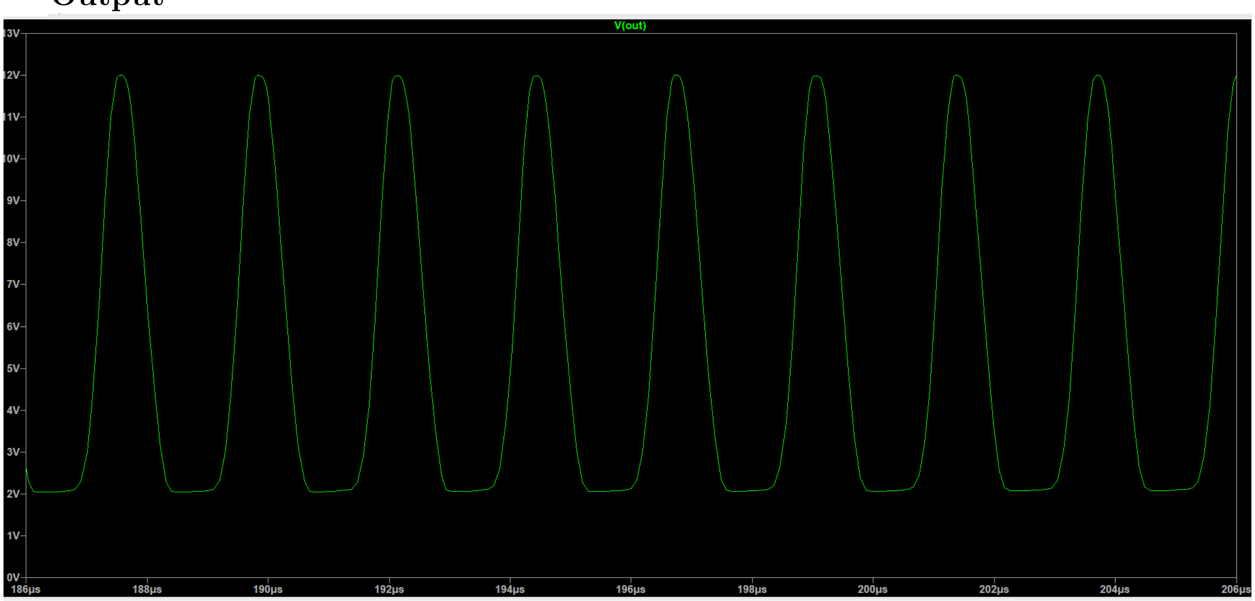
The circuit consists of two inductive coils in series, so the total inductance is given as:

L_T=L_1+L_2=0.5+0.5mH=1mH
C=100pF

Circuit diagram



Output



output frequency is $f_r = \frac{1}{2.36us} = 425KHz$
(5)

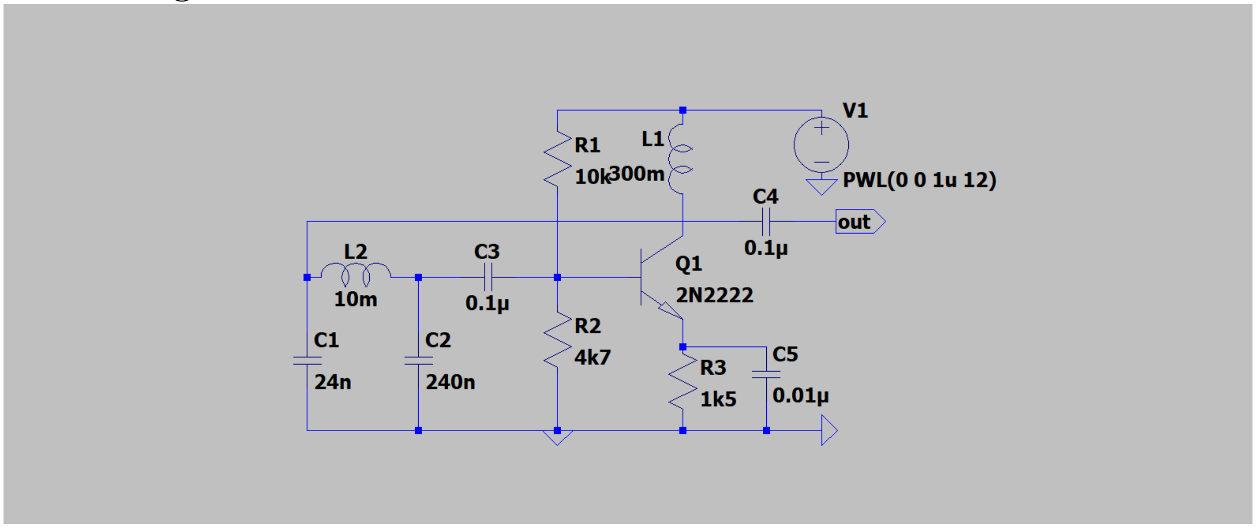
Theoretical frequency is $f_{theoretical} = \frac{1}{2\pi\sqrt{100pF \times 1mH}} = 500KHz(6)$

Colpitts oscillator

A Colpitts Oscillator circuit having two capacitors of 24nF and 240nF respectively are connected in parallel with an inductor of 10mH.
As the colpitts circuit consists of two capacitors in series, the total capacitance is therefore:

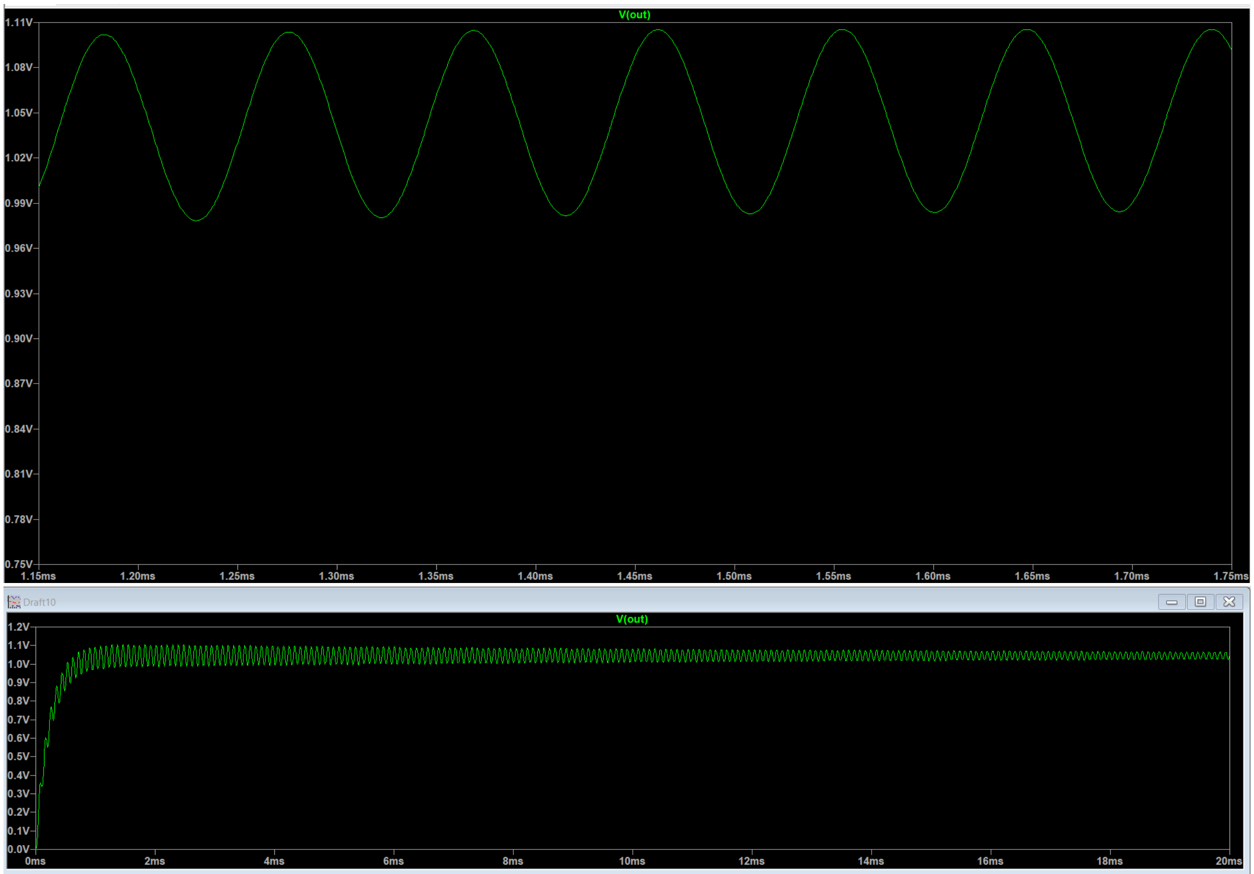
$C_T = \frac{240nF \times 24nF}{240nF + 24nF} = 21.82nF(7)$

Circuit diagram



$$Theoretical\ frequency\ is f_{theoretical} = \frac{1}{2\pi\sqrt{21.82nF \times 10mH}} = 10.8KHz \qquad (8)$$

output



$$output\ frequency\ is\ f_r = 11.1KHz. \tag{9}$$

5 conclusions

Hartley Oscillator
1. It cannot be used as a low frequency oscillator since the value of inductors becomes large and the size of the inductors becomes large.
2.The output is rich in harmonics and therefore not suitable where a pure sine wave is required.

Colpitts oscillator
3. difficult to adjust feedback as capacitor values to be changed.
4.Fine performance at high frequency.

Thank you