Feedback Circuit and Oscillator

Dharmendra Kumar Pandey

Department of Physics,
P. P. N. (PG) College,
Kanpur – 208 001, U.P., India
Email: pandeydrdk@rediffmail.com,
dr.dkpandey@gmail.com
Website: dkpandey.weebly.com

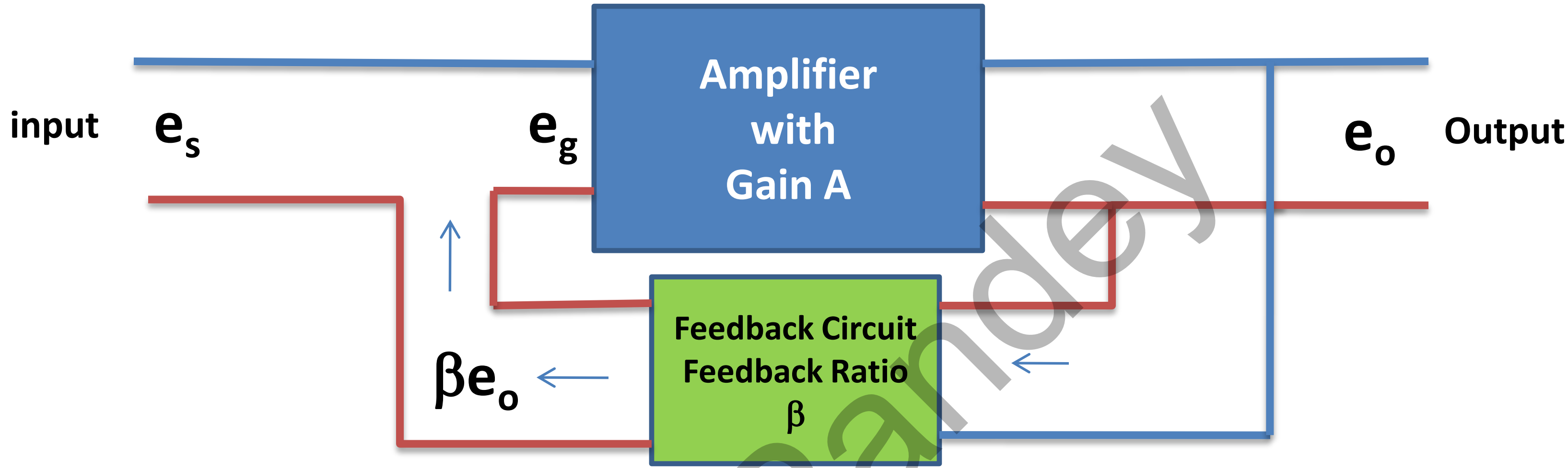
Concept of Feedback Principle

1. ***The Process of injecting a fraction of output energy/voltage/current of some device back to the input is known as feedback.***
2. ***An amplifier working on the principle of feedback is called as feedback amplifier.***
3. ***The circuit which transfers fraction of output voltage/current to the input is called as feedback circuit. On the basis of voltage and current feedback, amplifier is termed as voltage/current feedback amplifier.***
4. ***There are two types of feedback circuit.***

   a. Positive Feedback: When the input voltage/current and feedback voltage/current are in same phase then feedback is called as positive feedback. Such feedback is used in oscillators.

   b. Negative Feedback: When the input voltage/current and feedback voltage/current are in opposite phase then feedback is called as negative feedback. Such feedback is used in amplifiers.

Concept of Feedback Principle



$$\text{Voltage gain} = \frac{\text{Output voltage}}{\text{Input voltage}}$$

$$\text{Output voltage} = \text{Voltage gain} \,.\, \text{Input voltage}$$

$$e_o = A \,.\, e_g$$

$$e_o = A \,.\, (e_s + \beta e_o)$$

$$e_o - \beta A e_o = A \,.\, e_s$$

$$e_o(1 - \beta A) = A \,.\, e_s$$

$$\frac{e_o}{e_s} = \frac{A}{(1 - \beta A)}$$

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

A_f : Gain with feedback or Closed loop gain

βA : Open loop gain: feedback factor

Concept of Feedback Principle

Depending upon the nature of β, there are two types of feedback.

1. when β is Positive: Then feedback is called as positive feedback.

Input voltage/current and feedback voltage/current are in same phase.

$$1 - \beta A < 1 \Rightarrow A_f > A$$

After positive feedback, Gain of Amplifier increases.

If positive feedback is too large such that,

$$\beta A = 1$$

This condition is called as Barkhausen Criterion for sustained oscillation. In this condition,

$$1 - \beta A = 0 \Rightarrow A_f = \infty \Rightarrow e_s = 0$$

Amplifier generates maximum output without taking any input signal. Therefore, this feedback is used in oscillators.

2. when β is Negative: Then feedback is called as negative feedback.

$$A_f = \frac{A}{(1 + \beta A)} \Rightarrow A_f < A$$

Effect of Negative Feedback to the amplifiers

1. **Increase in Stability:** *If feedback is done in such away that -*

$$\beta A >> 1 \Rightarrow A_f = \frac{A}{(1+\beta A)} = \frac{A}{\beta A} = \frac{1}{\beta}$$

A_f becomes independent of supply voltage and transistor parameters. Therefore stability of amplifier increases with negative feedback.

2. **Reduction in amplitude Distortion:** *Distortion is the change in shape of output voltage by internal or external means. It may be in size/amplitude or frequency or phase. If D_n (=e_{on}/e_{o1}) and D'_n are the amplitude distortion with and without feedback to the amplifier then -*

$$D'_n = \frac{D_n}{1+\beta A} \Rightarrow D'_n < D_n$$

Therefore distortion reduces after negative feedback to amplifier.

3. **Reduction in frequency Distortion:** *The change in shape of output voltage by due to change in frequency by internal or external means is called as frequency Distortion.*

$$\frac{A_{f1}}{A_{f2}} = \frac{A_1}{(1+\beta A_1)} \times \frac{(1+\beta A_2)}{A_2} = \frac{A_1}{\beta A_1} \times \frac{\beta A_2}{A_2} = 1 \Rightarrow A_{f1} = A_{f2}$$

A_f becomes frequency independent .

Effect of Negative Feedback to the amplifiers

4. ***Increase in input impedance:*** ***After negative feedback, input impedance increases.***

$$Z_{if} = Z_i(1+\beta A) \Rightarrow Z_{if} > Z_i$$

5. ***Decrease in output impedance:*** ***After negative feedback, output impedance reduces.***

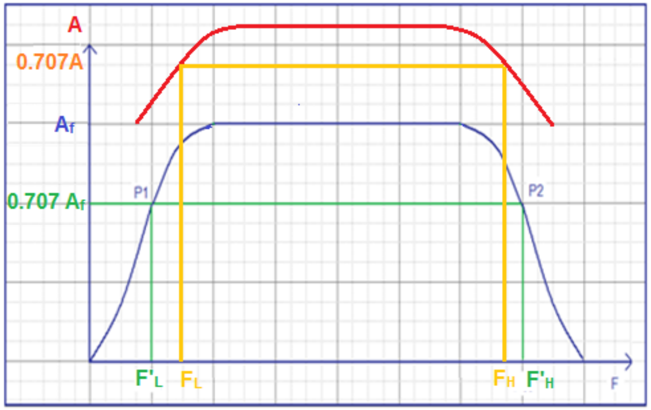
$$Z_{of} = \frac{Z_o}{1+\beta A} \Rightarrow Z_{of} < Z_o \quad \textit{as} \quad (1+\beta A) > 1$$

6. ***Decrease in voltage gain:*** ***Due to increase in input impedance and decrease in output impedance, the net voltage gain of negative feedback amplifier decreases.***

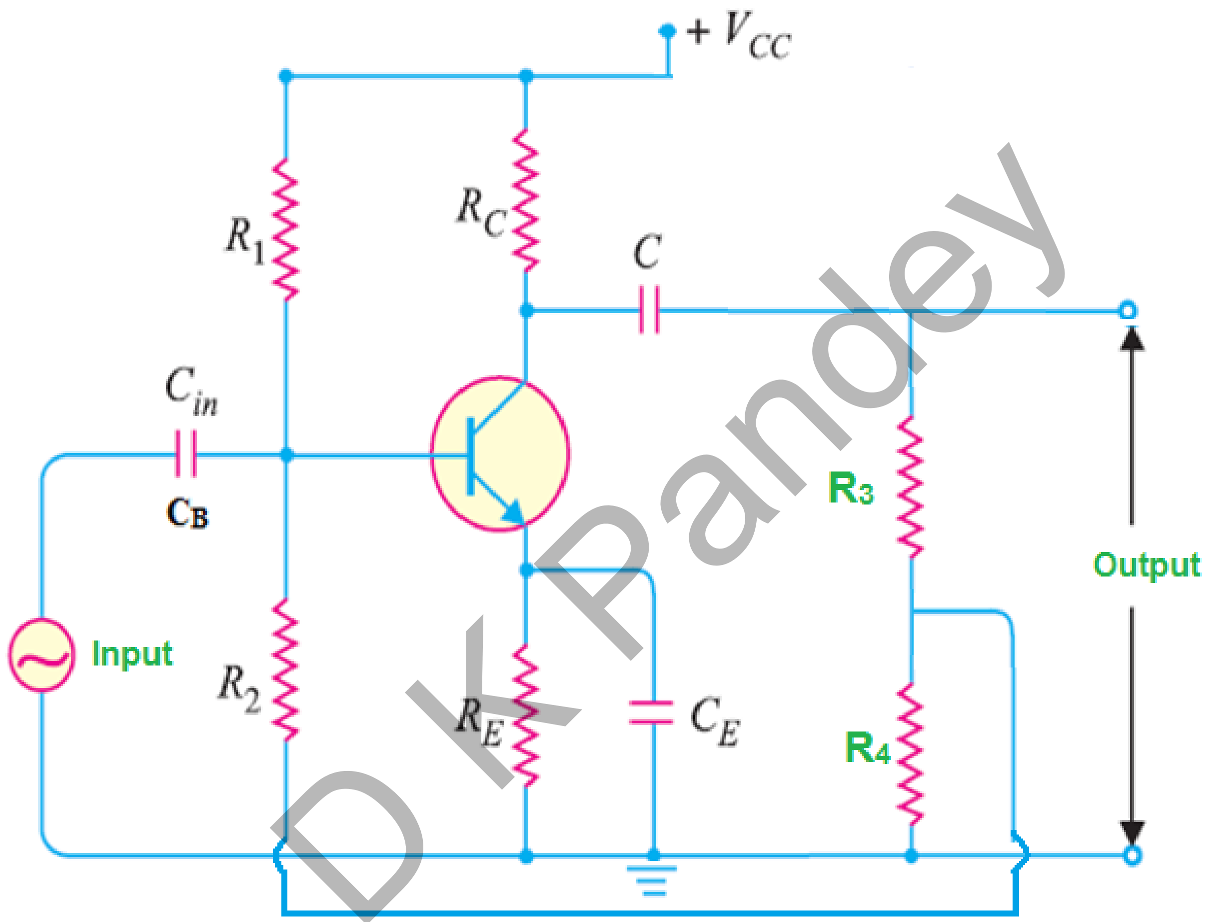
$$A_f = \frac{A}{1+\beta A} \Rightarrow A_f > A \quad \textit{as} \quad (1+\beta A) > 1$$

6. ***Increase in bandwidth:*** ***The frequency difference between lower and upper cut off frequencies is called as bandwidth.***

$$F'_H - F'_L > F_H - F_L$$



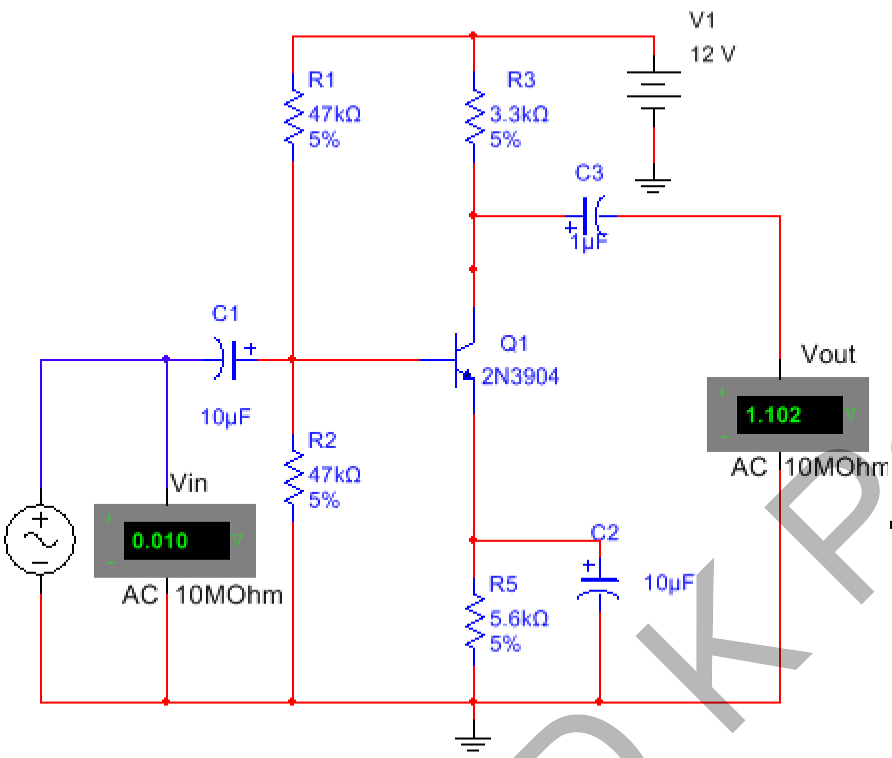
Voltage Negative Feedback amplifiers

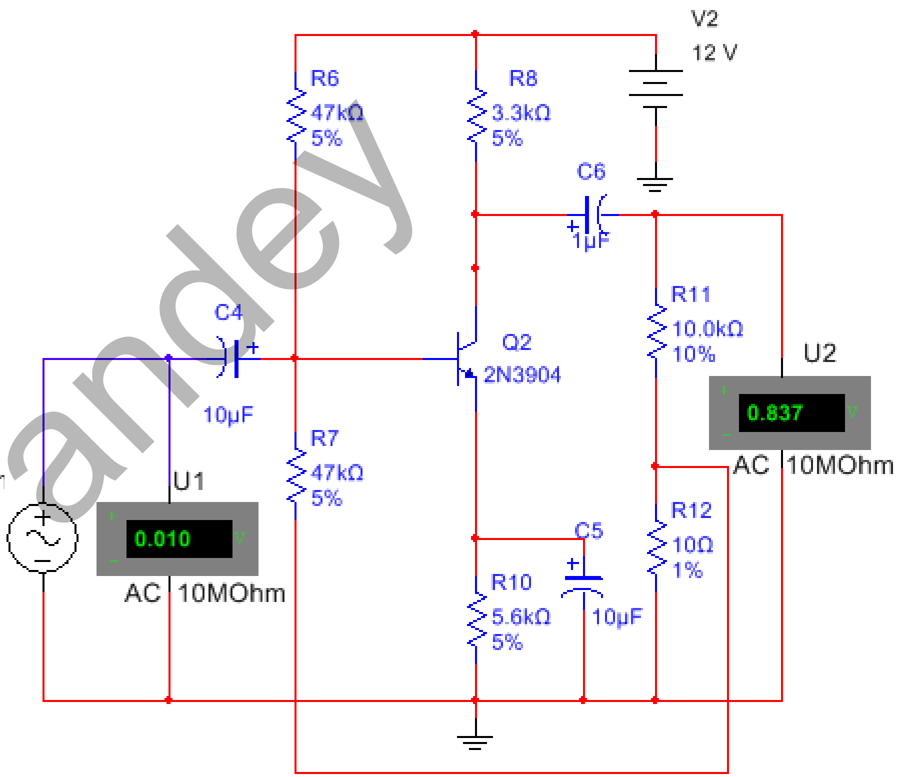


$$\text{Feedback Voltage} = \text{Voltage across } R_4 = \frac{R_4}{R_3 + R_4} \text{output voltage}$$

$$\Rightarrow \beta = \frac{R_4}{R_3 + R_4}$$

Voltage Negative Feedback amplifiers





$$A = \frac{1.102}{0.010} = 110.2$$

$$A_f = \frac{0.837}{0.010} = 83.7$$

Current Negative Feedback amplifiers

$$V_{be} = e_s - i_e R_E$$

$$\because i_c \approx i_e$$

$$\therefore V_{be} = e_s - i_c R_E$$

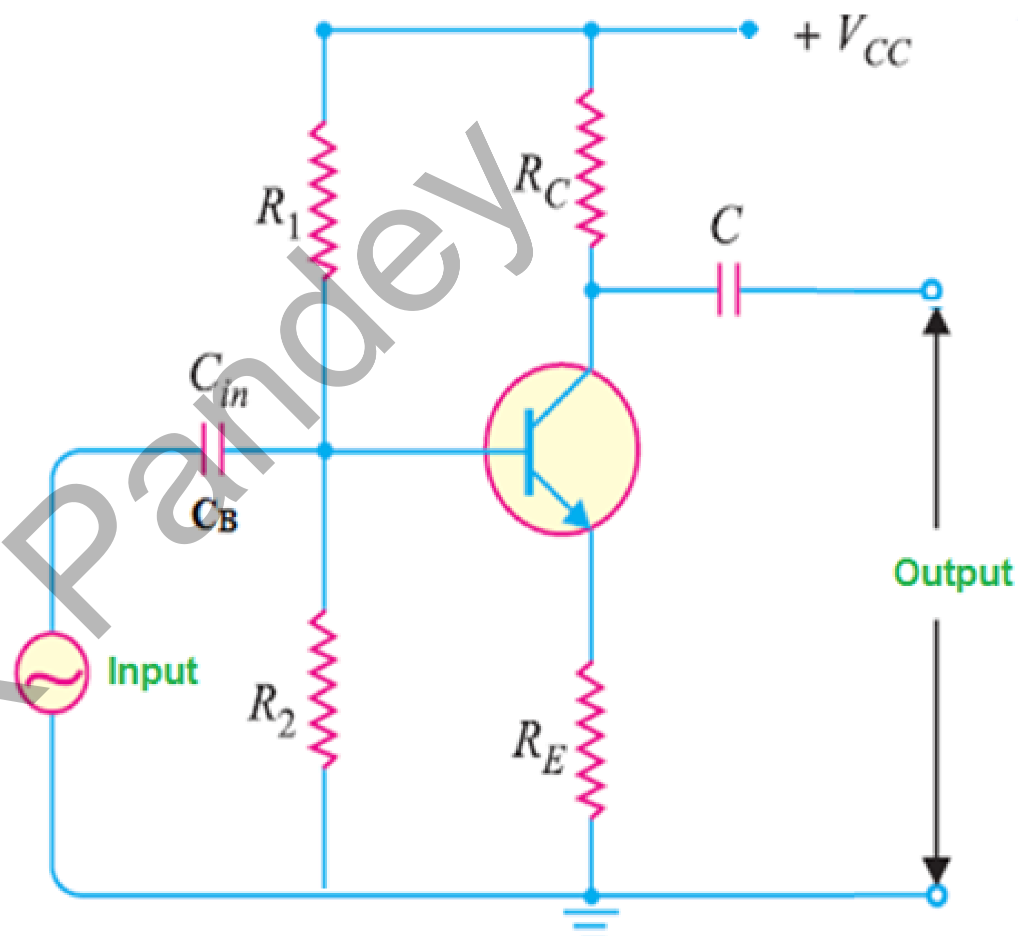
$$\because e_o = -i_c R_C$$

$$\therefore V_{be} = e_s + \frac{R_E}{R_C} e_0$$

$$V_{be} = e_s + \beta e_0$$

$$\Rightarrow \quad \beta = \frac{R_E}{R_C}$$

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



If, $\beta A > 1$ $\Rightarrow$ $A_f = \frac{A}{\beta A} = \frac{1}{\beta}$ $\Rightarrow$ $A_f = \frac{R_C}{R_E}$

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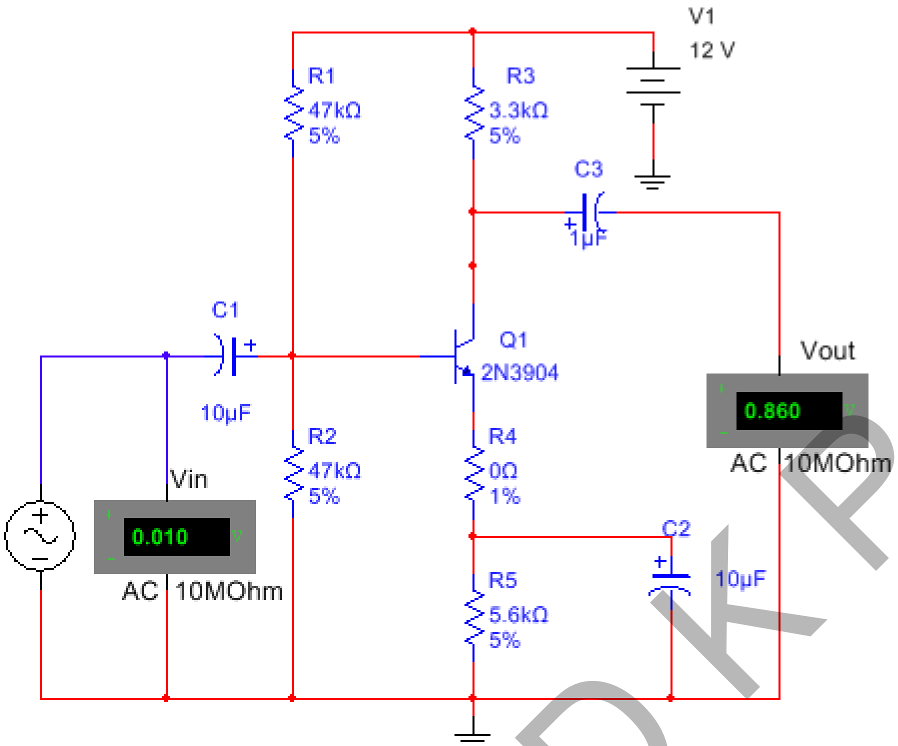
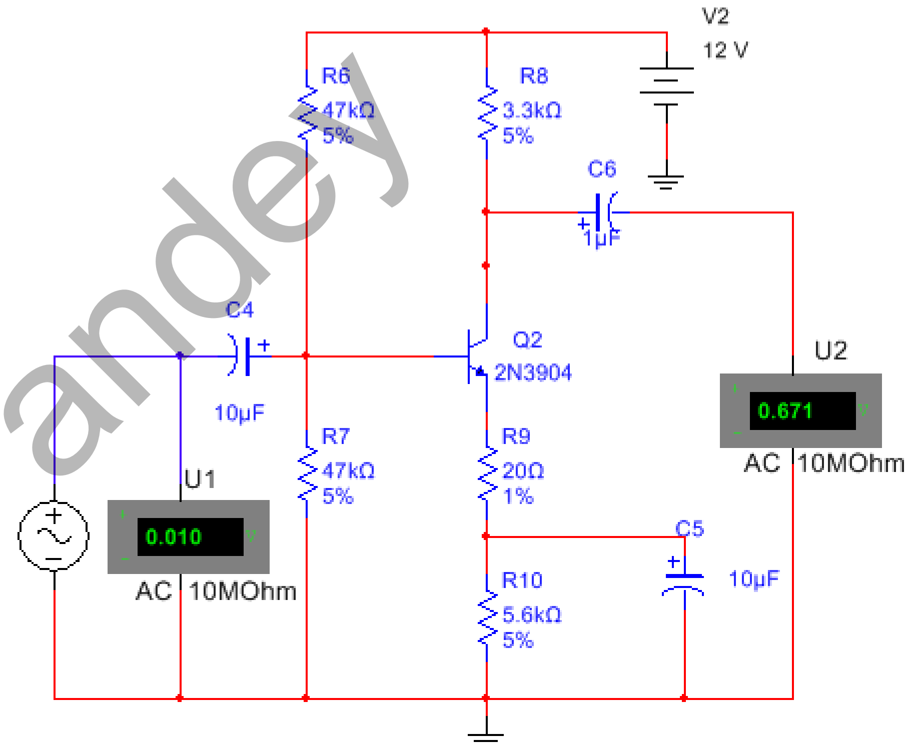
Current Negative Feedback amplifiers





$$A = \frac{0.872}{0.010} = 87.2$$

$$A_f = \frac{0.671}{0.010} = 67.1$$

Numerical

1. *The voltage gain of an amplifier with negative feedback is 75. If feedback ratio is 0.01. Then find the without feedback.*

Solution.

$$A_f = \frac{A}{1+\beta A} \Rightarrow 75 = \frac{A}{1+0.01A} \Rightarrow A = 75 + 0.75A$$

$$\Rightarrow A - 0.75A = 75 \Rightarrow 0.25A = 75 \Rightarrow A = 300$$

2. *An amplifier has voltage gain 100. If on negative feedback, its gain reduces to 20. Find the feedback ratio and feedback percentage.*

Solution.

$$A_f = \frac{A}{1+\beta A} \Rightarrow 20 = \frac{100}{1+100\beta} \Rightarrow 1+100\beta = \frac{100}{20}$$

$$\Rightarrow 1+100\beta = 5 \Rightarrow 100\beta = 4 \Rightarrow \beta = 0.04$$

$$\text{Percentage of feedback} = 0.04 \times 100 = 4\,\%$$

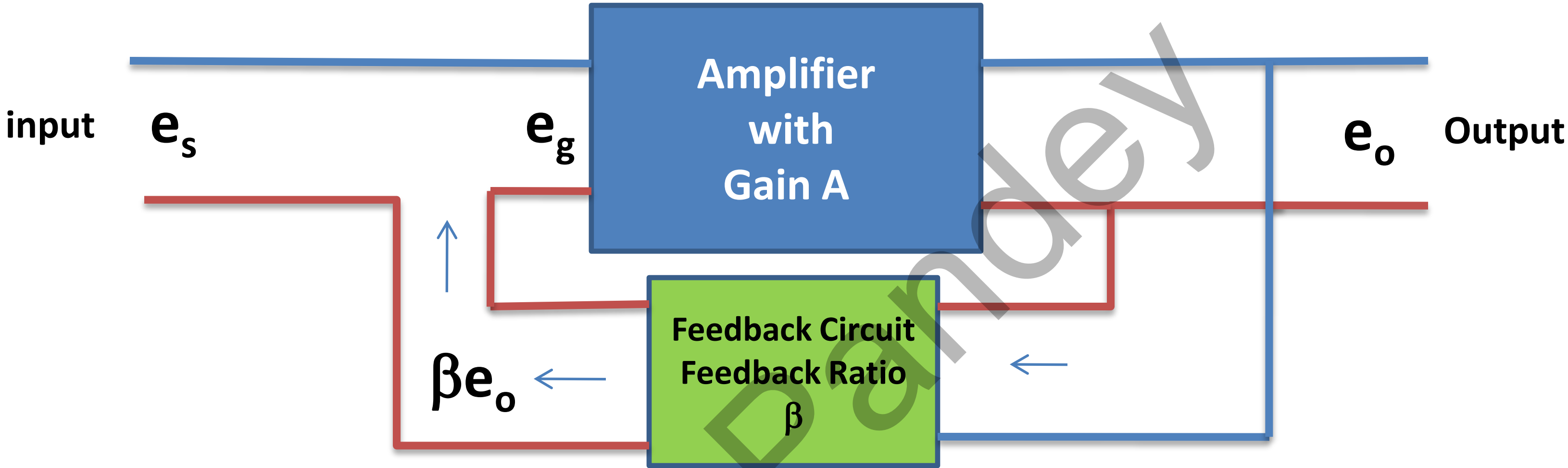
Oscillator

1. The electronic device which generates sinusoidal oscillations of desired frequency is called as oscillator.
2. An oscillator is an electronic circuit associated with transistor that generates alternating output taking dc as input .
3. Since , It converts direct voltage into alternating voltage thus also called as inverter.

Works on the principle of positive feedback amplifiers.

Principle of Oscillator

Oscillator works on the principle of positive feedback amplifiers.



When a fraction of output voltage of an amplifier is injected to its input in same phase then feedback is said to positive feedback. The gain of amplifier under positive feedback is given by-

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

Principle of Oscillator

$$1-\beta A<1 \quad \Rightarrow \quad A_f > A$$

After positive feedback, Gain of Amplifier increases.

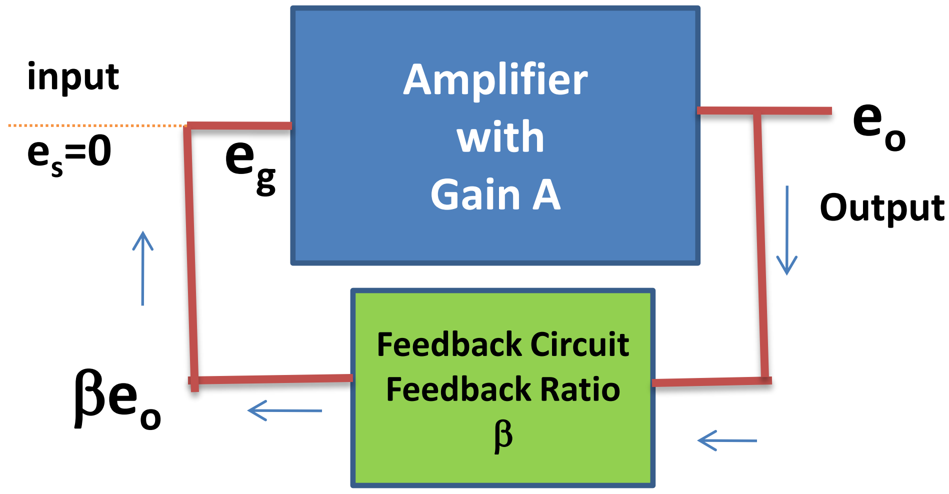
If positive feedback is too large such that,

$$\beta A=1$$

This condition is called as Barkhausen Criterion for sustained oscillation. In this condition,

$$1-\beta A=0 \quad \Rightarrow \quad A_f=\infty \quad \Rightarrow \quad e_s=0$$

Thus under Barkhausen Criterion, the positive feedback amplifier generates an alternating signal without taking any ac input. It requires only dc as input. Hence the circuit receives dc and generates ac. This is the principle of Oscillator.



Component of Oscillator

There are three component of oscillator.

1. **Tank Circuit:**

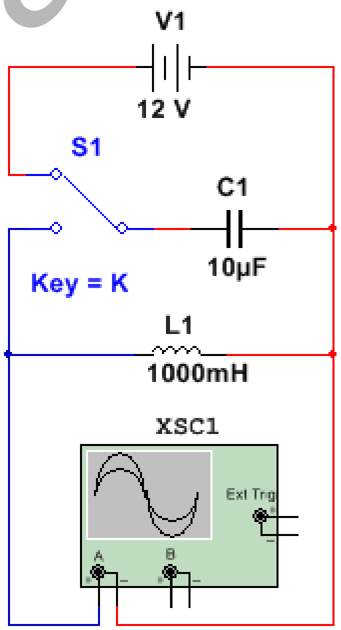
   (a) *It is a simple inductor and capacitor circuit which is used to generates a sinusoidal oscillation or alternating voltage.*

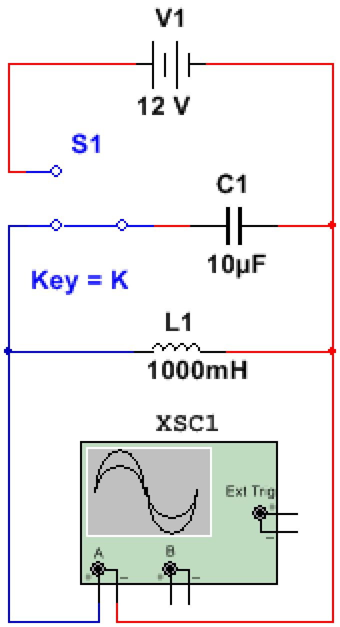
   (b) *When a charged capacitor discharges through an inductor an oscillation of charge/voltage/energy between capacitor and inductor setups. Whose frequency of oscillation depends on the value of L and C.*

$$\frac{d^2q}{dt^2} + \frac{1}{LC}q = 0$$

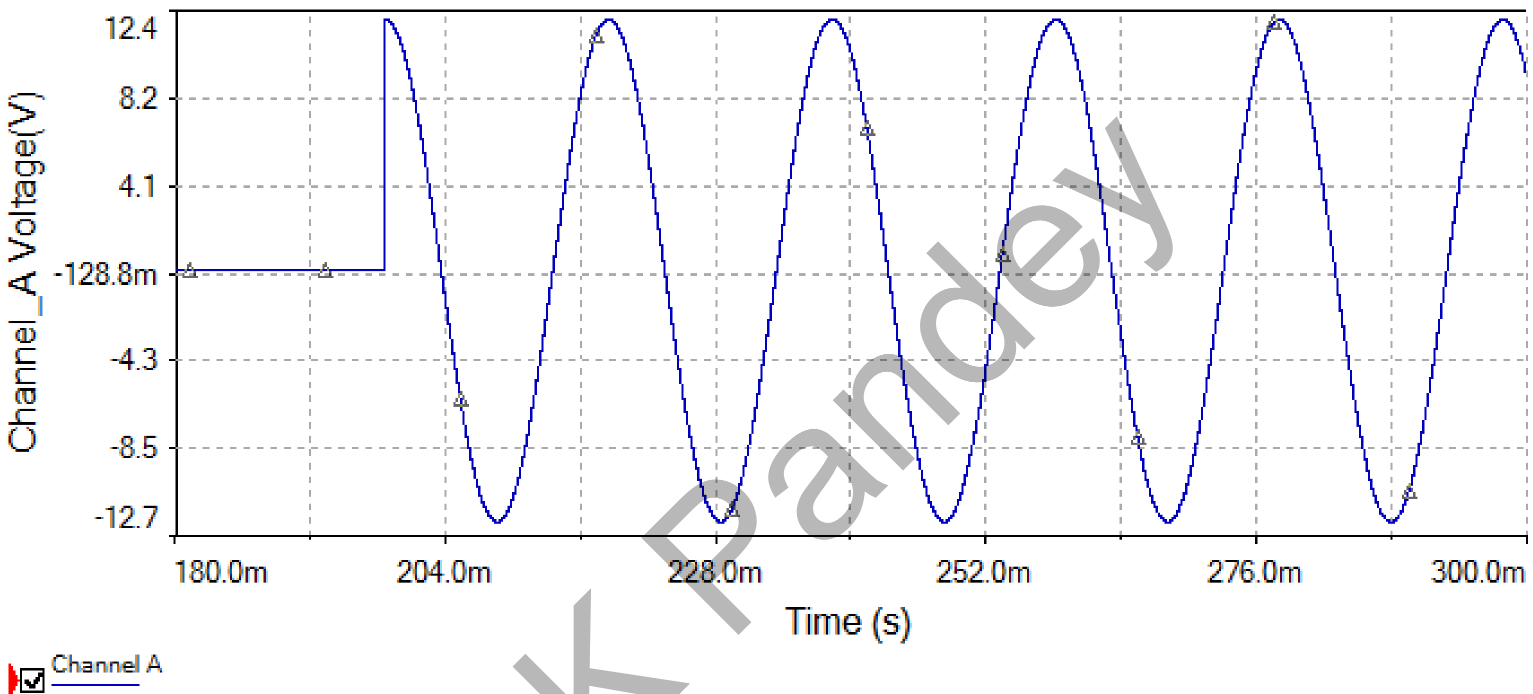
$$\Rightarrow \quad q = q_0 \text{Sin}(\omega t)$$

$$\omega = \frac{1}{\sqrt{LC}} \quad \Rightarrow \quad f = \frac{1}{2\pi\sqrt{LC}}$$





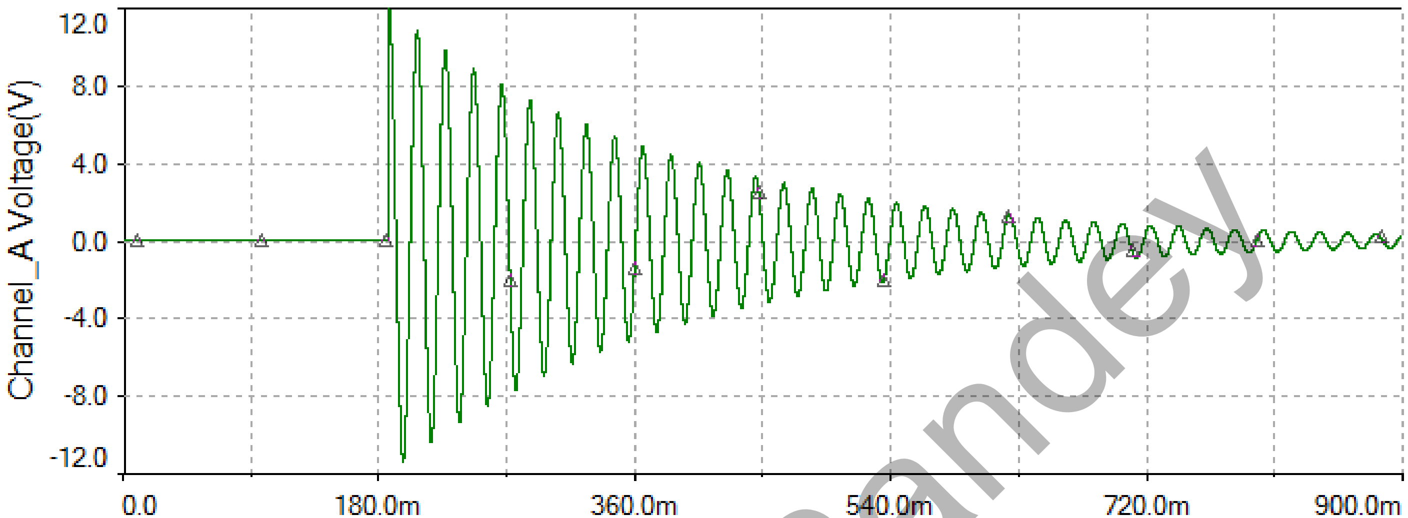
Component of Oscillator

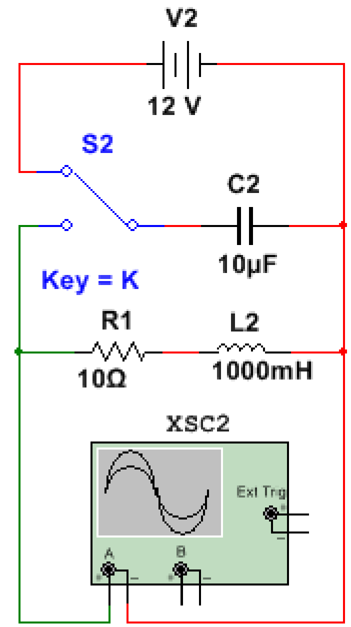


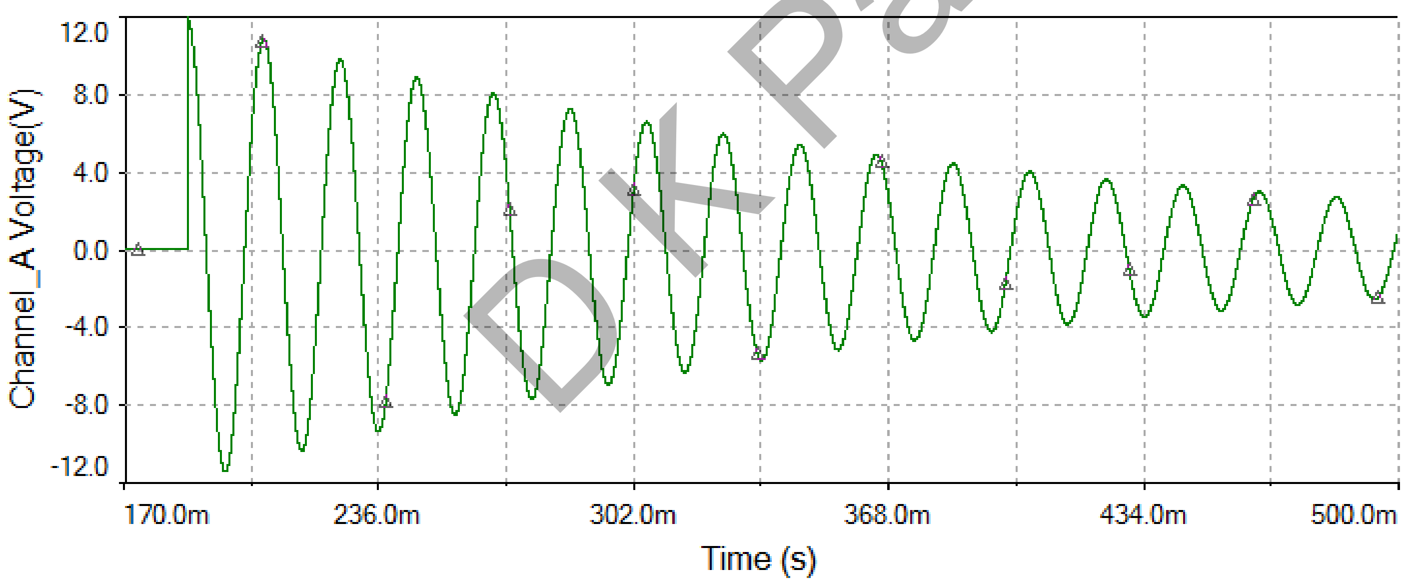
(C) The oscillation may go for a long time if inductor have no resistance. But due to finite resistance in inductor, the oscillation in tank circuit becomes damped. The frequency of oscillation is slightly changed while amplitude of oscillation decreases exponentially.

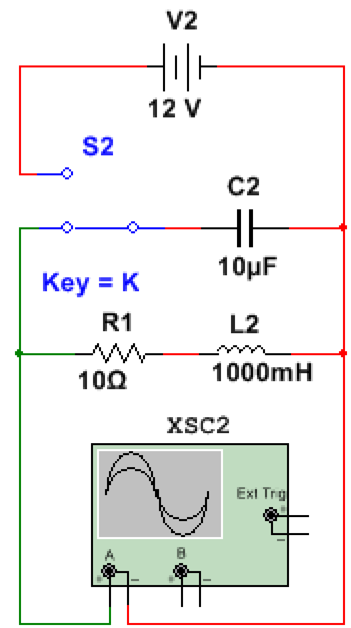
$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{4L^2}}$$

Component of Oscillator









(d) To maintain these oscillations, an amplifier is used.

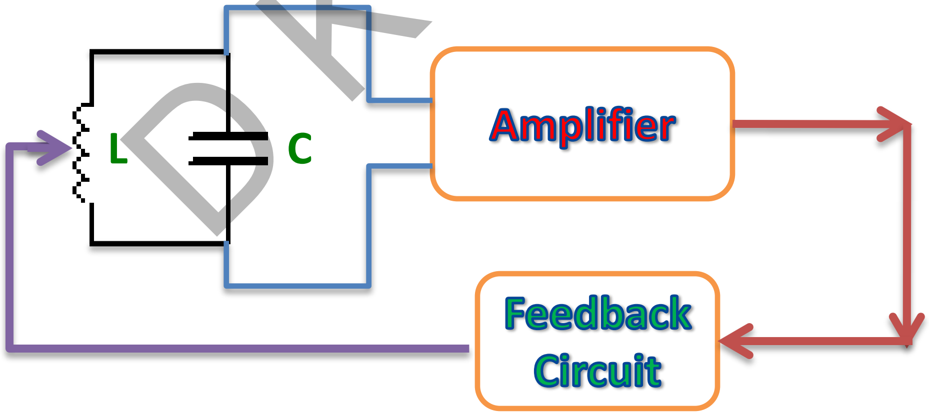
Component of Oscillator

(2) An amplifier:

Since the oscillation in tanks circuit becomes damped due to non zero resistance of the inductor therefore an amplifier is needed to amplify the reducing amplitude of voltage and to maintain it for long time. To maintain stable and sustained oscillation, the amplifier is made in positive feedback condition.

(3) Feedback circuit:

It is a circuit with transfer a fraction of output voltage to the input. It is done in such a way that the feedback voltage is in same phase of input voltage.



Types of Oscillator

(1) Depending upon the method of producing oscillations:

- ***(a) Feedback Oscillators***
- ***(b) Negative resistance Oscillators***

(2) Depending upon the generated voltage wave form:

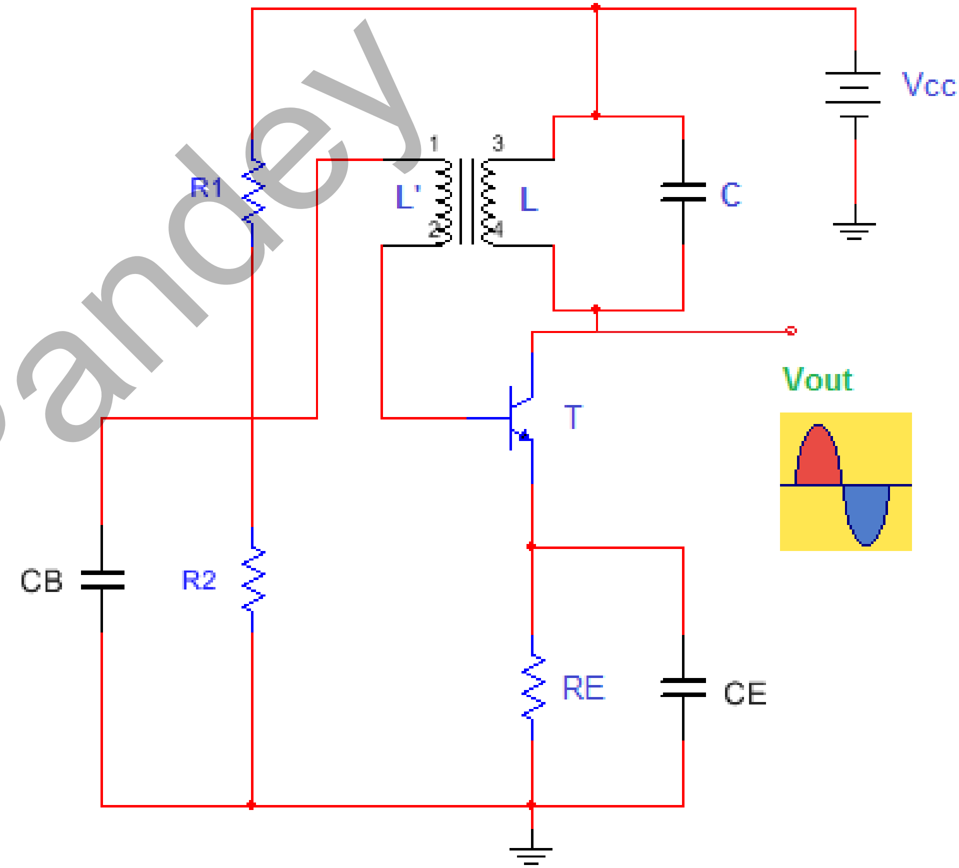
- ***(a) Sinusoidal Oscillators***
  - ***(i) Tuned collector oscillator***
  - ***(ii) Hartley oscillator***
  - ***(iii) Colpits oscillator***
  - ***(iv) Crystal oscillator***
  - ***(v) R-C oscillators***
  - ***(vi) Weins Bridge oscillator***
- ***(b) Non-sinusoidal (Relaxation) Oscillators***
  - ***(i) Multivibrator***
  - ***(ii) Blocking oscillator***

(3) Depending upon the frequency of generated voltage:

- ***(a) Audio frequency Oscillators***
- ***(b) Radio frequency Oscillators***

Tunes collector Oscillator

Tuned collector oscillation is a type of transistor LC oscillator where the tuned circuit (tank) consists of a transformer and a capacitor is connected in the collector circuit of the transistor. Tuned collector oscillator is of course the simplest and the basic type of LC oscillators. The tuned circuit connected at the collector circuit behaves like a purely resistive load at resonance and determines the oscillator frequency. **The common applications of tuned collector oscillator are RF oscillator circuits, mixers, frequency demodulators, signal generators etc.**



Tuned collector Oscillator -components

1. Resistor R_1 and R_2 forms a voltage divider bias for the transistor.
2. R_E is the emitter resistor which is meant for thermal stability. It also limits the collector current of the transistor.
3. C_E is the emitter by-pass capacitor. It is to by-pass the amplified oscillations. If C_E is not there, the amplified AC oscillations will drop across R_E and will add on to the base-emitter voltage (V_{be}) of the transistor and this will alter the DC biasing conditions.
4. Capacitor C and primary of the transformer L forms the tank circuit.
5. C_B is the by-pass capacitor for resistor R_2.
6. L' is inductance of secondary of transformer.
7. T is transistor.
8. Vcc is dc power source.

Tuned collector Oscillator -working

1. When the **power supply is switched ON**, the transistor starts conducting and the capacitor C starts charging.
2. When the **capacitor is fully charged, it starts discharging through the primary coil L**. When the capacitor is fully discharged, the energy stored in the capacitor as electrostatic field will be moved to the inductor as electromagnetic field. Now there will be no more voltage across the capacitor to keep the current through the coil starts to collapse. In order to oppose this **the coil L generates a back emf** (by electromagnetic induction) and **this back emf charges the capacitor again**. Then capacitor discharges through the coil and the cycle is repeated.
3. In this way **a transient current setups in the circuit and this charging and discharging sets up a series of oscillations in the tank circuit.**

Tuned collector Oscillator -working

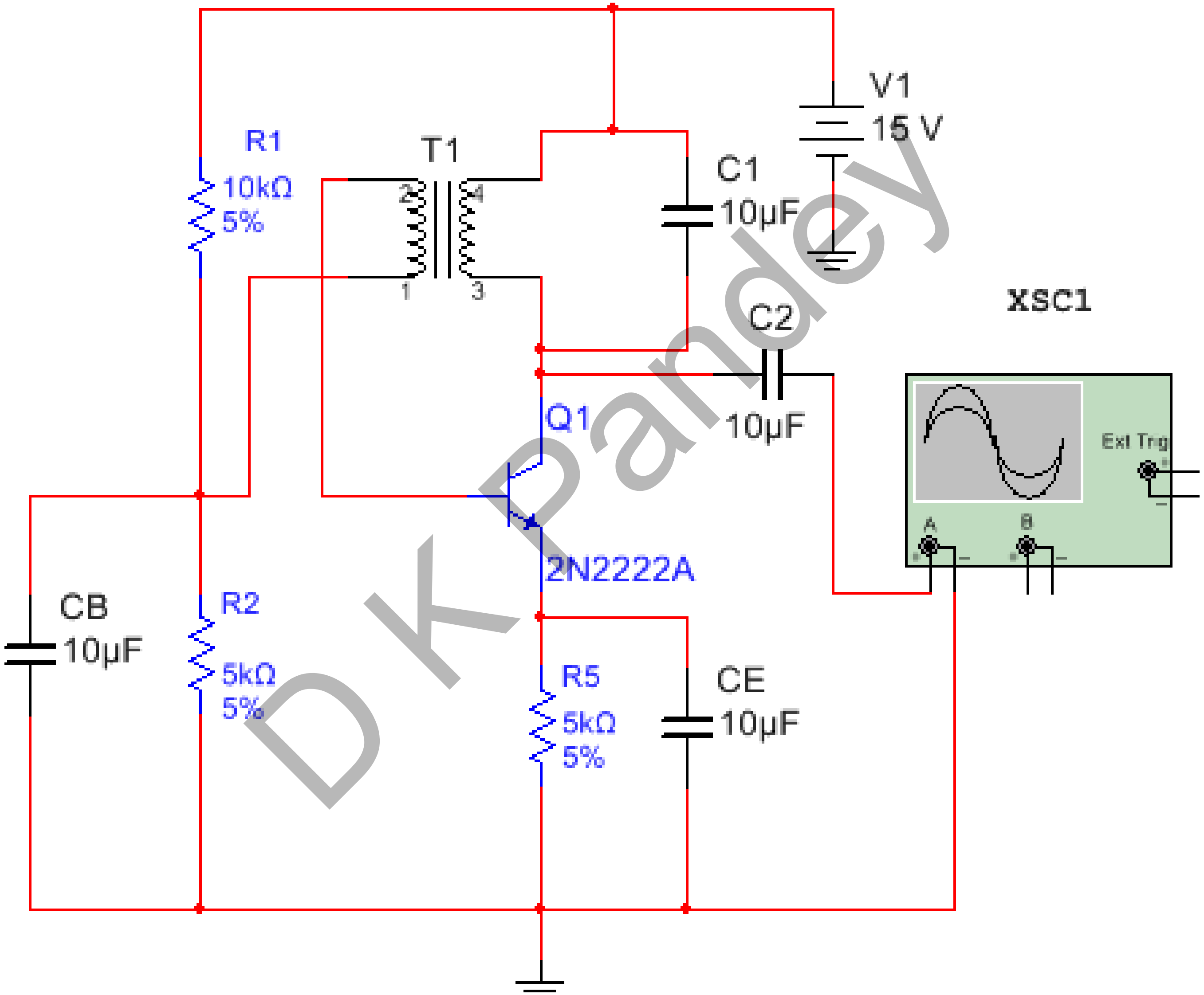
4. The oscillations produced in the tank circuit is fed back to the base of transistor T by the secondary coil by inductive coupling. The amount of feedback can be adjusted by varying the turns ratio of the transformer. **The winding direction of the secondary coil (L') is in such a way that the voltage across it will be 180° phase opposite to that of the voltage across primary (L).** Thus **the feedback circuit produces a phase shift of 180° and the transistor alone produces a phase shift of another 180°. As a result a total phase shift of 360° is obtained between input and output** and it is a very necessary condition for positive feedback and sustained oscillations.

5. The **collector current of the transistor compensates the energy lost in the tank circuit**. This is done by taking a small amount of voltage from the tank circuit, amplifying it and applying it back to the tank circuit. Capacitor C can be made variable in variable frequency applications.

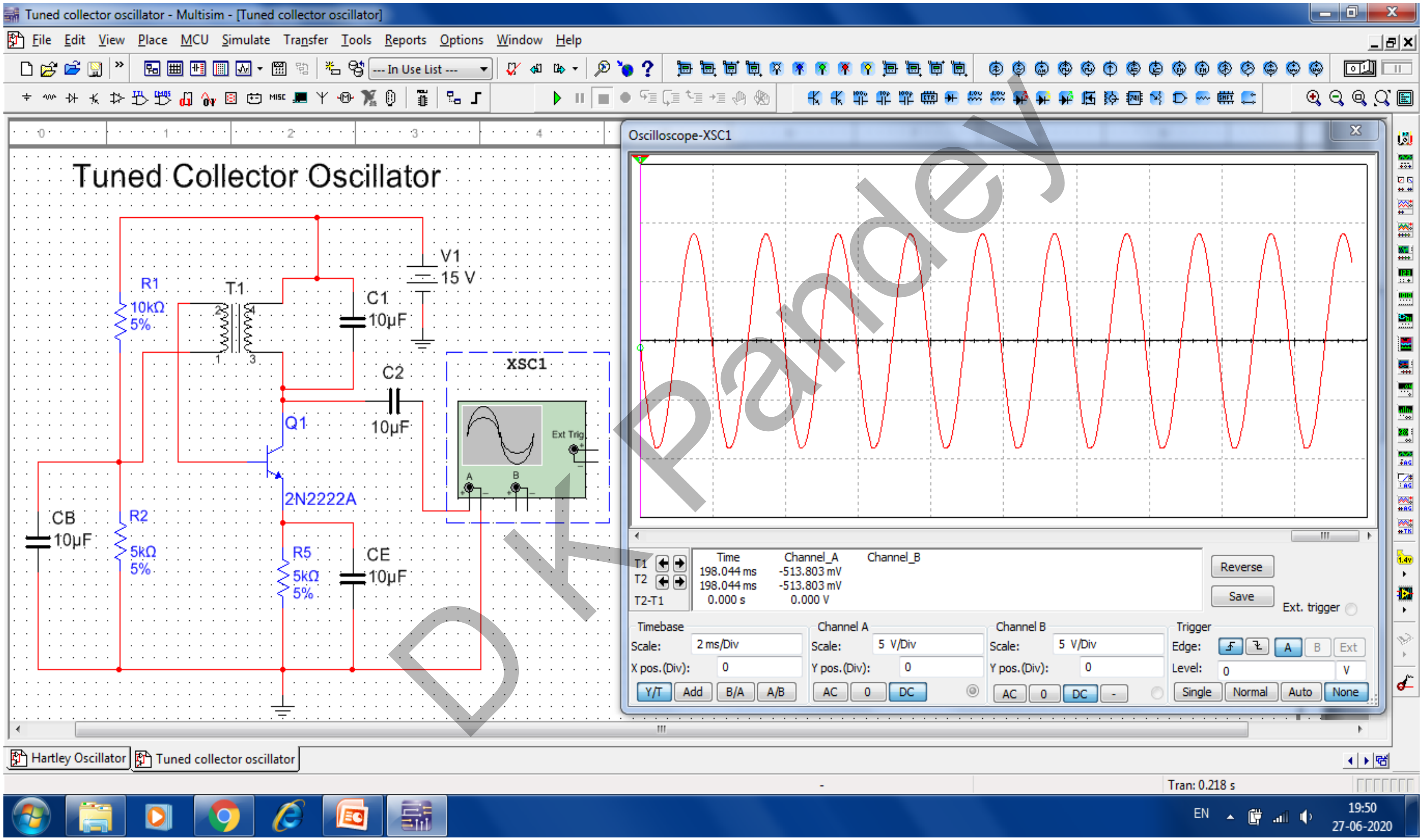
The frequency of oscillations of the tank circuit can be obtained by sustained oscillation condition as-

$$Z_1 + Z_2 = 0 \Rightarrow j\omega L + \frac{1}{j\omega c} = 0 \Rightarrow \omega^2 = \frac{1}{LC} \Rightarrow \omega = \frac{1}{\sqrt{LC}} \Rightarrow f = \frac{1}{2\pi\sqrt{LC}}$$

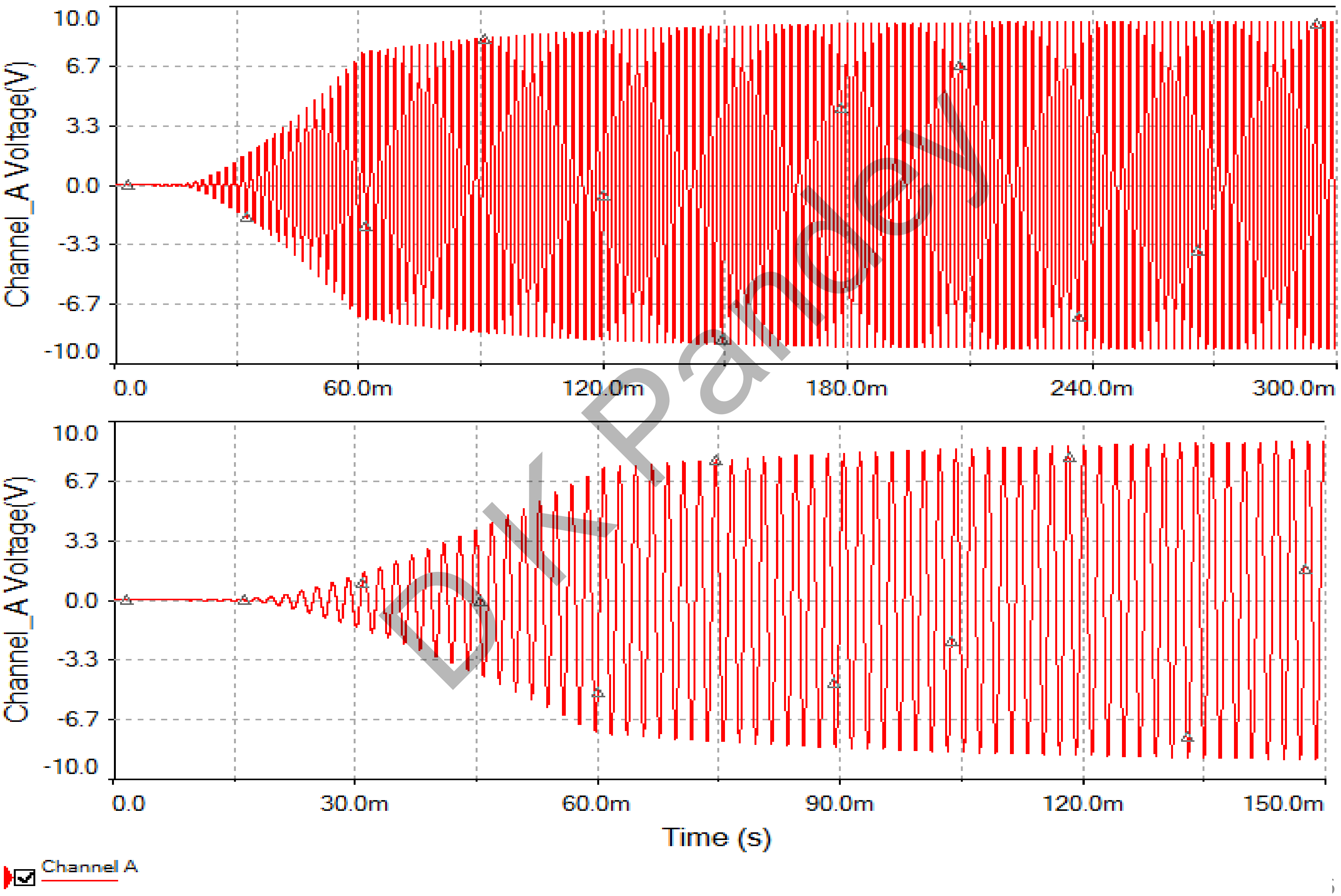
Tuned collector Oscillator –Practical simulation circuit



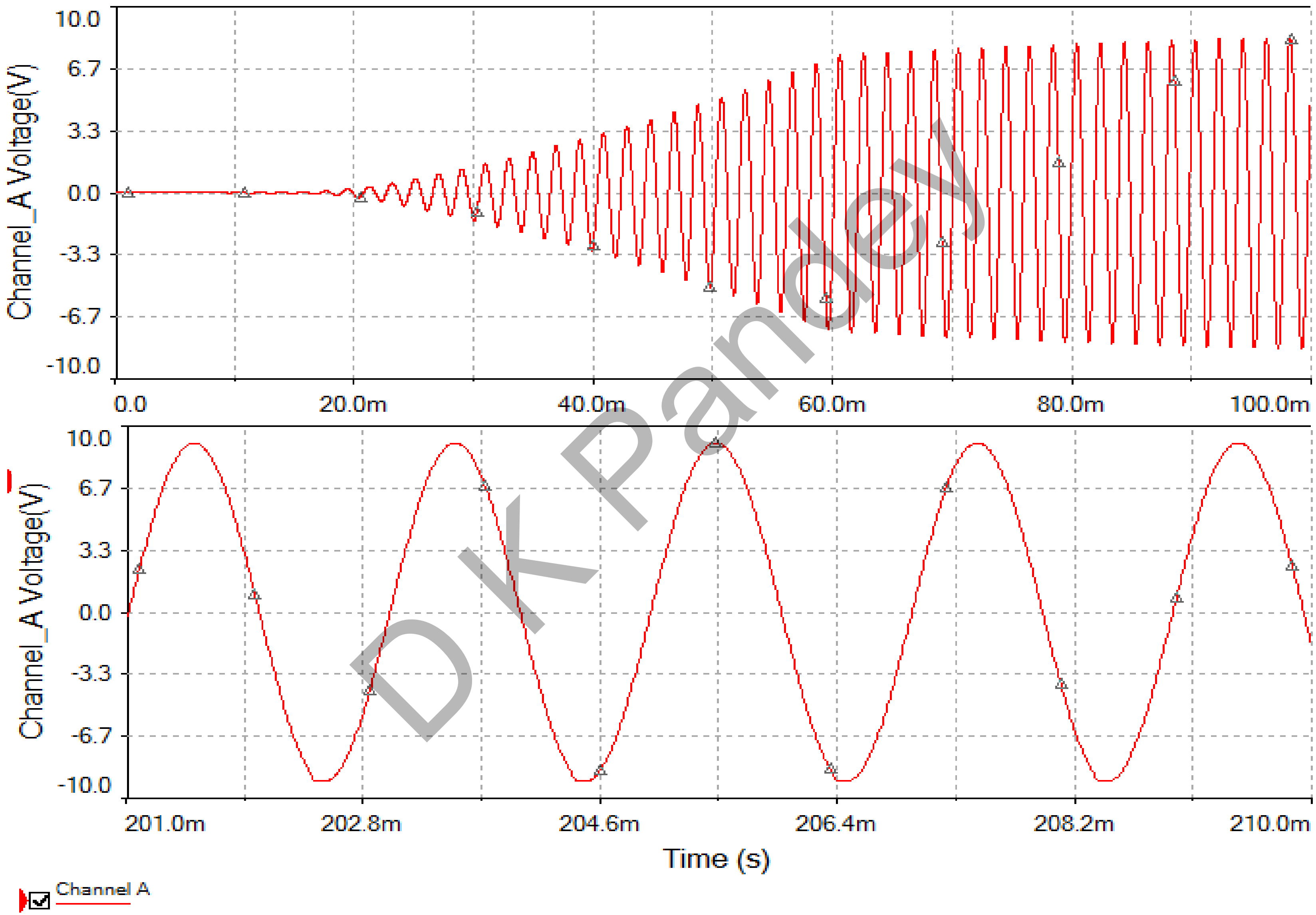
Tuned collector Oscillator –Practical circuit and output



Tuned collector Oscillator -output



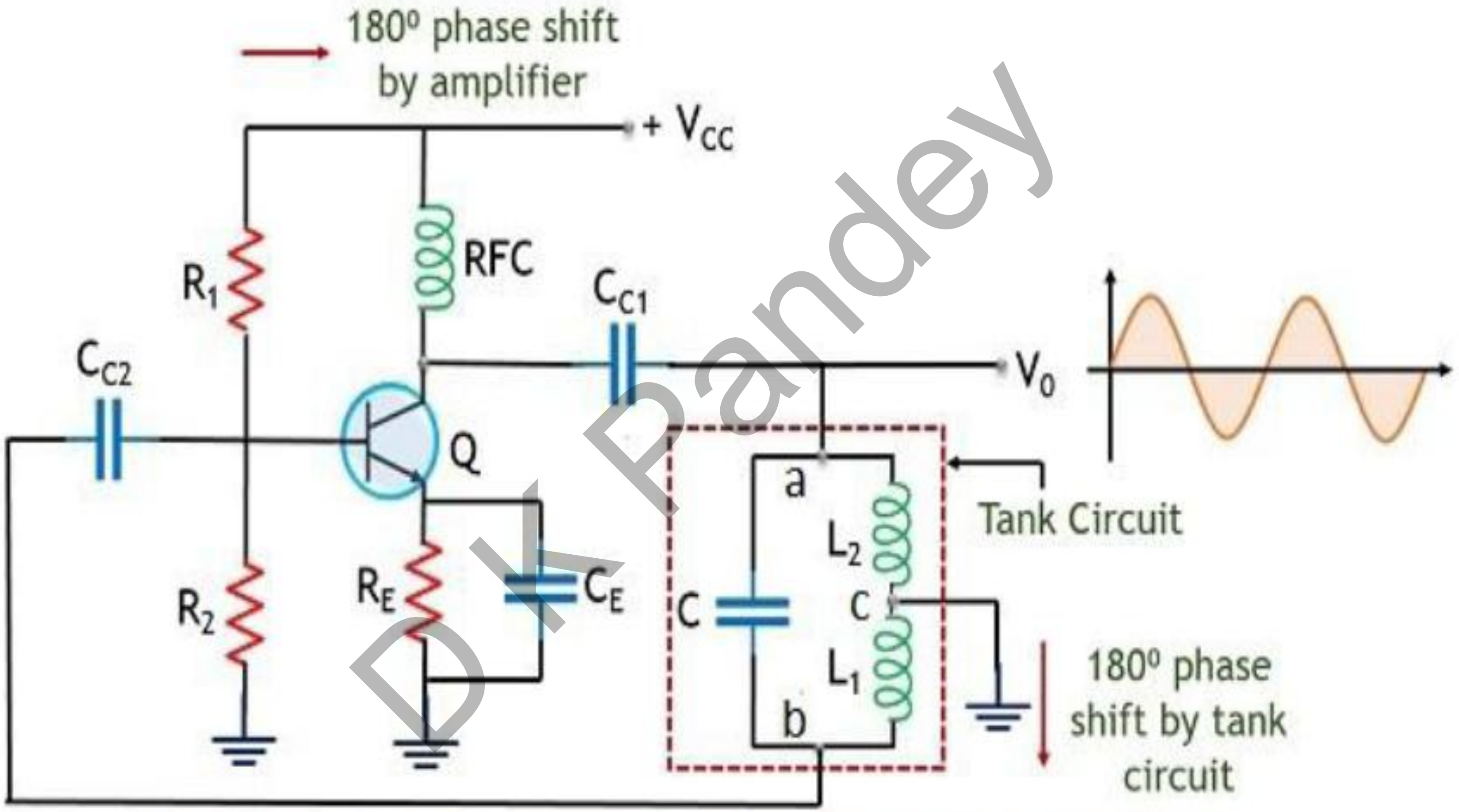
Tuned collector Oscillator -output



Hartley Oscillator

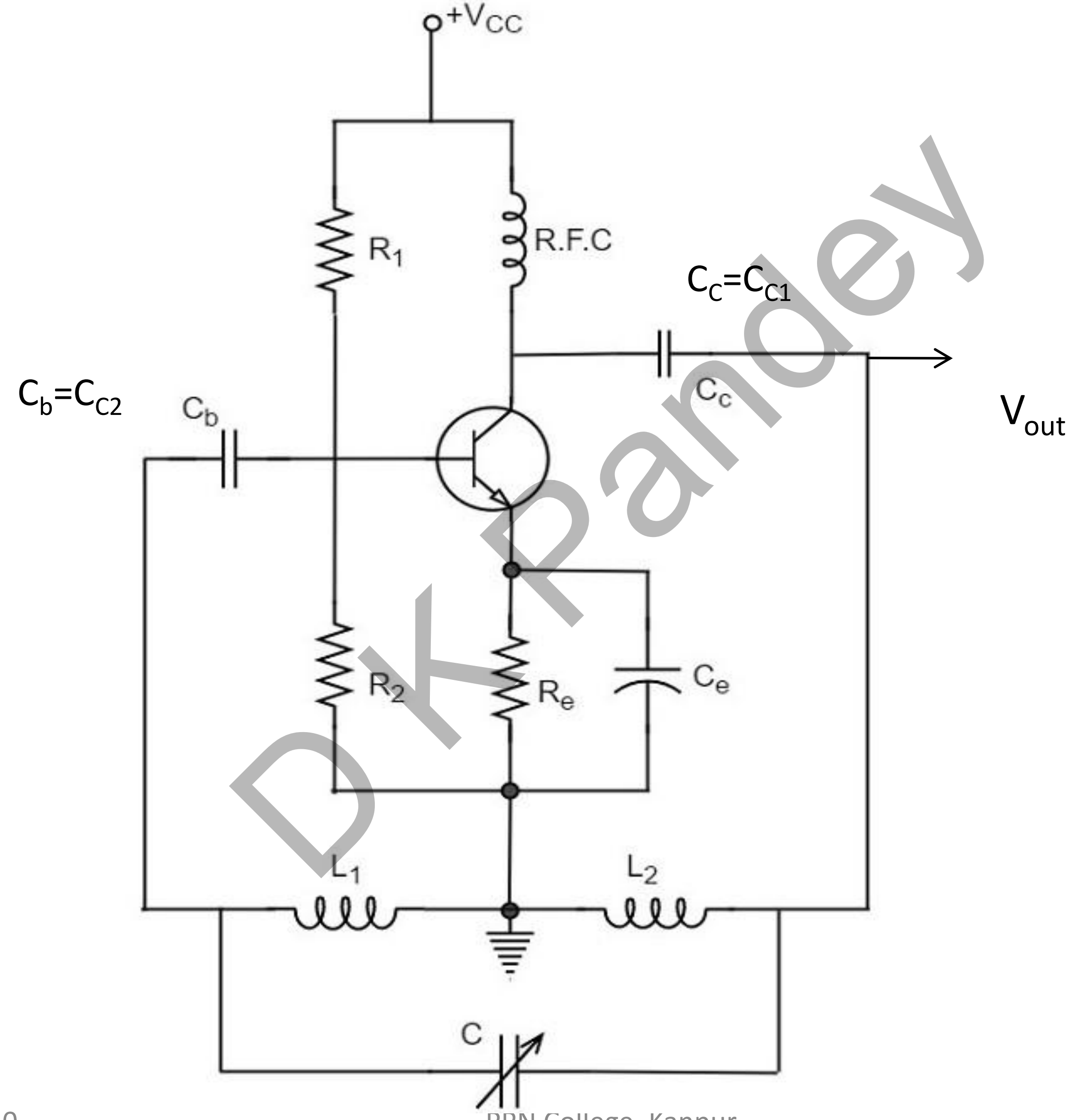
- Hartley oscillator is a type of LC oscillator that generates undamped sinusoidal oscillations whose tank circuit consists of 2 inductors and a capacitor.
- In the tank circuit, the two inductive coils are serially connected together forming a parallel combination with the capacitor.
- Hartley Oscillator was invented by Ralph Hartley in 1915 and hence named so.
- In normal LC oscillator, the amplitude of the oscillations generated by the circuit is uncontrollable. Along with that tuning to a particular frequency is quite difficult.
- So unlike normal LC oscillator, the Hartley oscillator uses an LC parallel feedback configuration that has self-tuning base oscillator circuit.

Hartley Oscillator



Circuit Diagram of Hartley Oscillator

Hartley Oscillator



Hartley Oscillator- components

- The required biasing of the circuit is provided by resistors R_1, R_2 and R_E. While C_{C1} and C_{C2} are the coupling capacitors.
- An **radio frequency choke coil** (RFC) is present in the circuit.
- In high-frequency applications, the reactance of RFC becomes very large. Thus can be considered as open-circuited.
- While RFC exhibits almost zero reactance in DC condition, hence do not cause any issue for DC capacitors. Therefore, maintains ac and dc conditions in the circuit.
- Also, a phase shift of 180^o is provided by the transistor amplifier present in the circuit.
- The oscillating frequency relies on the components of tank circuit L_1, L_2 and C.

Hartley Oscillator - working

- So when dc supply voltage V_{cc} is provided to the circuit, then with the increase in the collector current of the transistor, the capacitor in the tank circuit starts charging. The capacitor stores charge in the form of the electric field.
- So, the capacitor continues its charging until it gets fully charged.
- But once it gets fully charged then the capacitor begins to discharge through inductor L_1 and L_2.
- This discharging of the capacitor results in charging of the inductor. The inductor stores the charge in the form of the magnetic field.
- So, the complete discharging of the capacitor will automatically cause the charging of the inductor and vice-versa.

Hartley Oscillator-working

- This continuous **charging** and **discharging** will provide sinusoidal oscillations at the output.
- However, it is noteworthy here that these oscillations are damped oscillations, as amplitude is decreasing continuously.
- This decrease in amplitude is the result of internal resistance of inductor that causes heat loss in the circuit and is denoted by $\mathbf{I^2R}$.
- It is to be noted here that between point **a** and **b** in the circuit, a phase shift of 180^o is provided by the tank circuit.
- As here point **c** is grounded.
- Thus, for a particular time instant when **a** is positive then **b** will be negative wrt **c** and vice-versa.
- Therefore, the **tank circuit** provides a **phase shift of** $\mathbf{180^o}$.

Hartley Oscillator-working

- the tank circuit generates damped sinusoidal oscillations. Thus it is required to be amplified otherwise the oscillations will die out after a certain point of time.
- So, the output of the tank circuit is provided as input to the CE configuration transistor.
- The sinusoidal signal when provided to the transistor, gets amplified. The feedback energy is taken by the mutual inductance between inductive coils L_1 and L_2.
- The amplified output from the transistors then provides the charging energy to the capacitor in the tank circuit to produce further sinusoidal oscillations.
- This amplified output compensates for the losses generated by the tank circuit.
- Thus the tank circuit provides continuous sinusoidal oscillations of constant amplitude at the output.
- In this way, a tank circuit works.

Hartley Oscillator-working

The frequency of oscillations of the tank circuit can be obtained by sustained oscillation condition as-

$$Z_1 = j\omega L_1 + j\omega M$$

$$Z_2 = j\omega L_2 + j\omega M$$

$$Z_3 = \frac{1}{j\omega c}$$

$$\Rightarrow \quad Z_1 + Z_2 + Z_3 = 0$$

$$\Rightarrow \quad j\omega L_1 + j\omega M + j\omega L_2 + j\omega M + \frac{1}{j\omega c} = 0$$

$$\Rightarrow \quad L_1 + L_2 + 2M = \frac{1}{\omega^2 c}$$

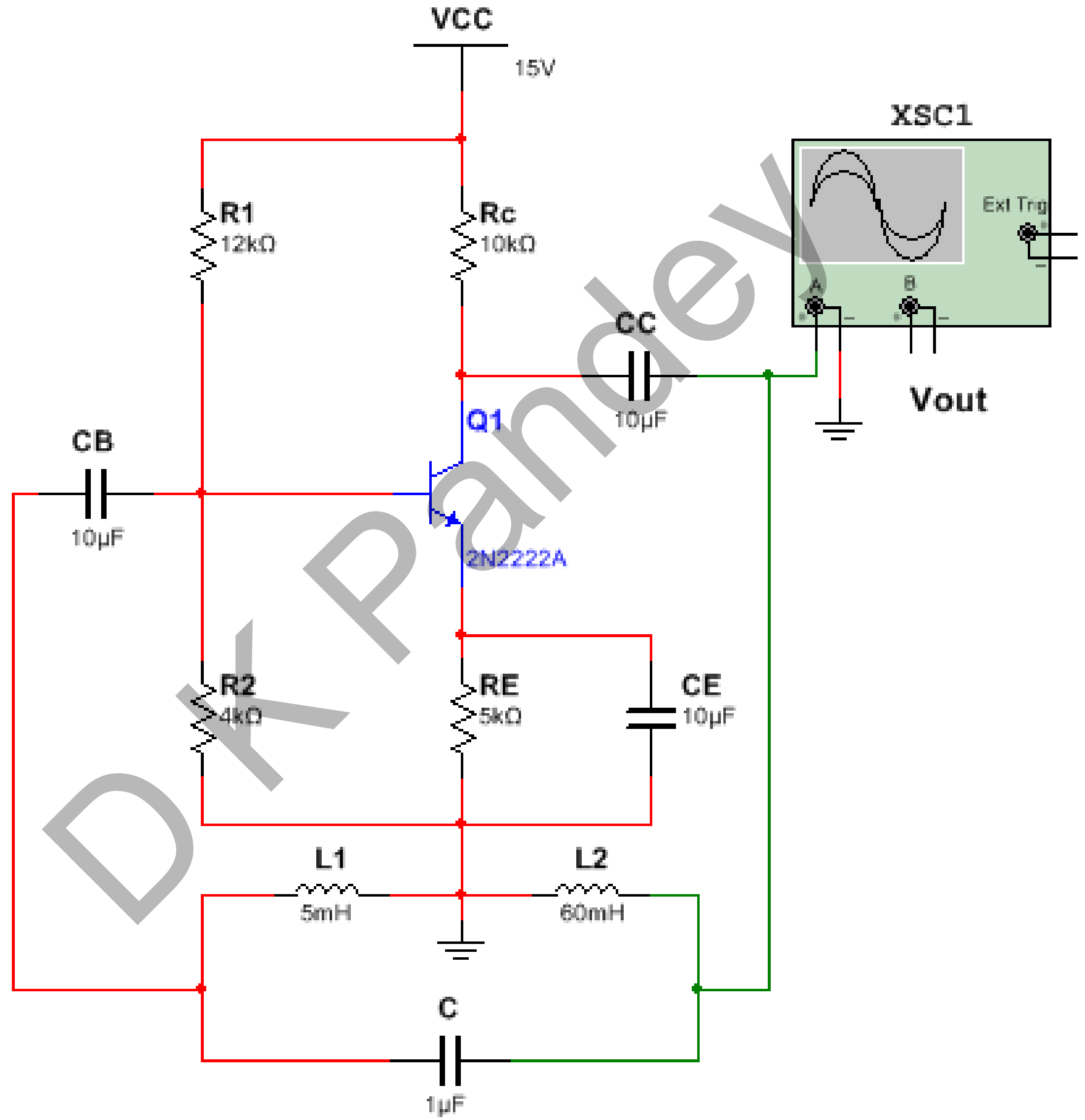
$$\Rightarrow \quad \omega = \frac{1}{\sqrt{(L_1 + L_2 + 2M)C}} \Rightarrow f = \frac{1}{2\pi\sqrt{(L_1 + L_2 + 2M)C}}$$

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

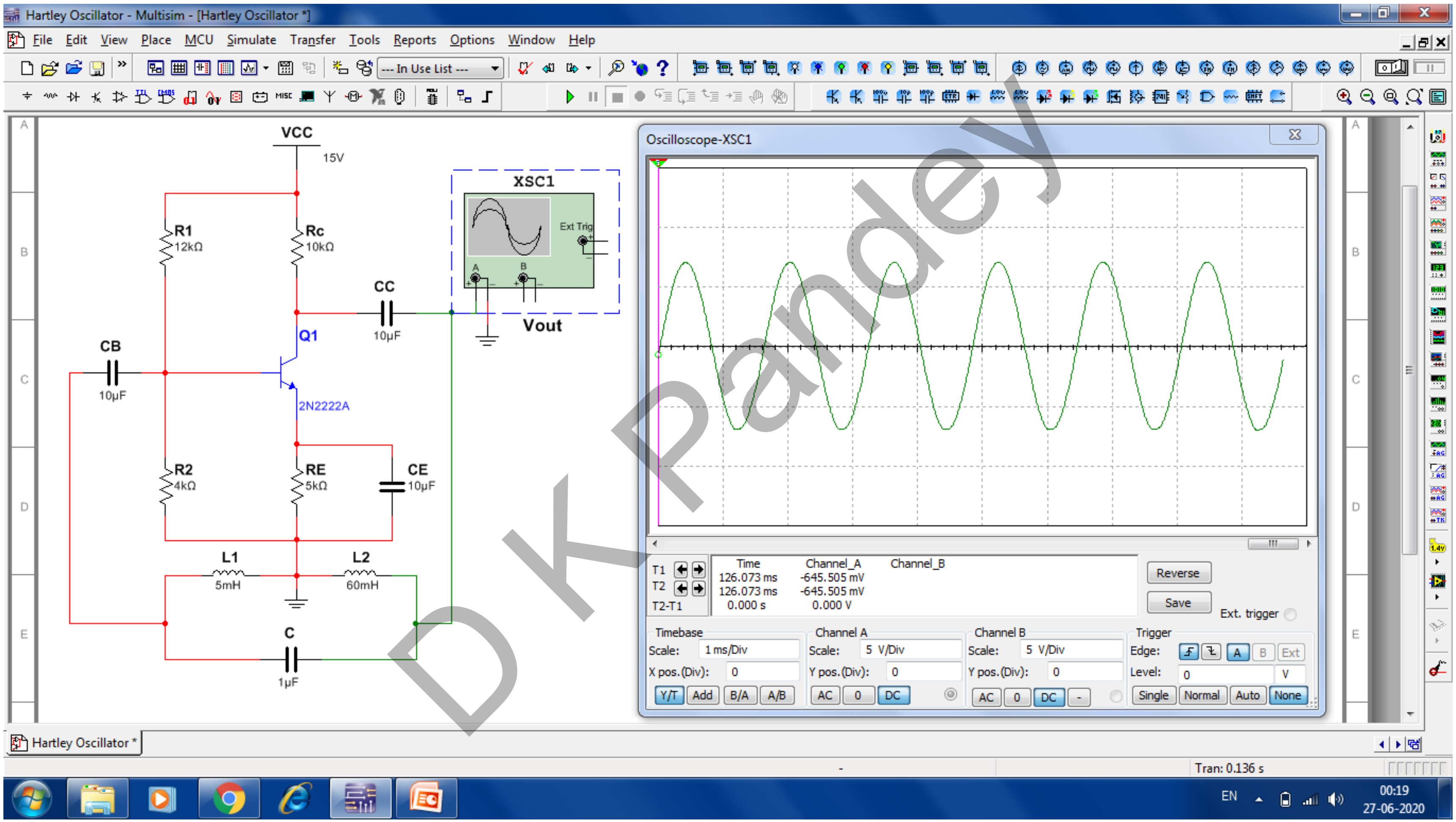
Hartley Oscillator-working

- Advantages of Hartley Oscillator
  - It provides sinusoidal oscillations of constant amplitude.
  - The oscillating frequency can be changed by the use of a variable capacitor.
  - The circuit is not complex.
  - Practically a single tapped coil can also be used in place of two inductors in the circuit.
- Disadvantages of Hartley Oscillator
  - Due to the presence of harmonics, sometimes distorted sinusoidal oscillations are generated.
  - It does not find use in low-frequency applications.
- Applications of Hartley Oscillator
  - Hartley oscillators widely used in the generation of sinusoidal waveforms of a certain frequency. Thus these are suitable for radio-frequency applications, thus find their use in radio receivers.

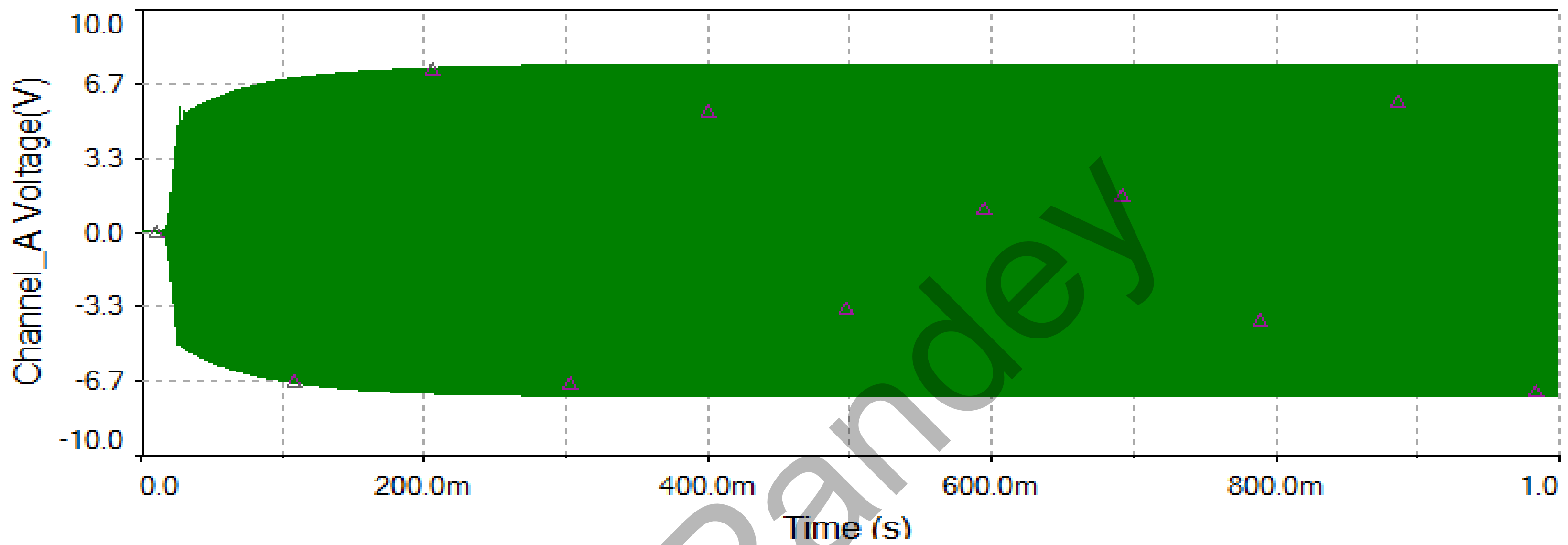
Hartley Oscillator-Practical Circuit at Multisim Software

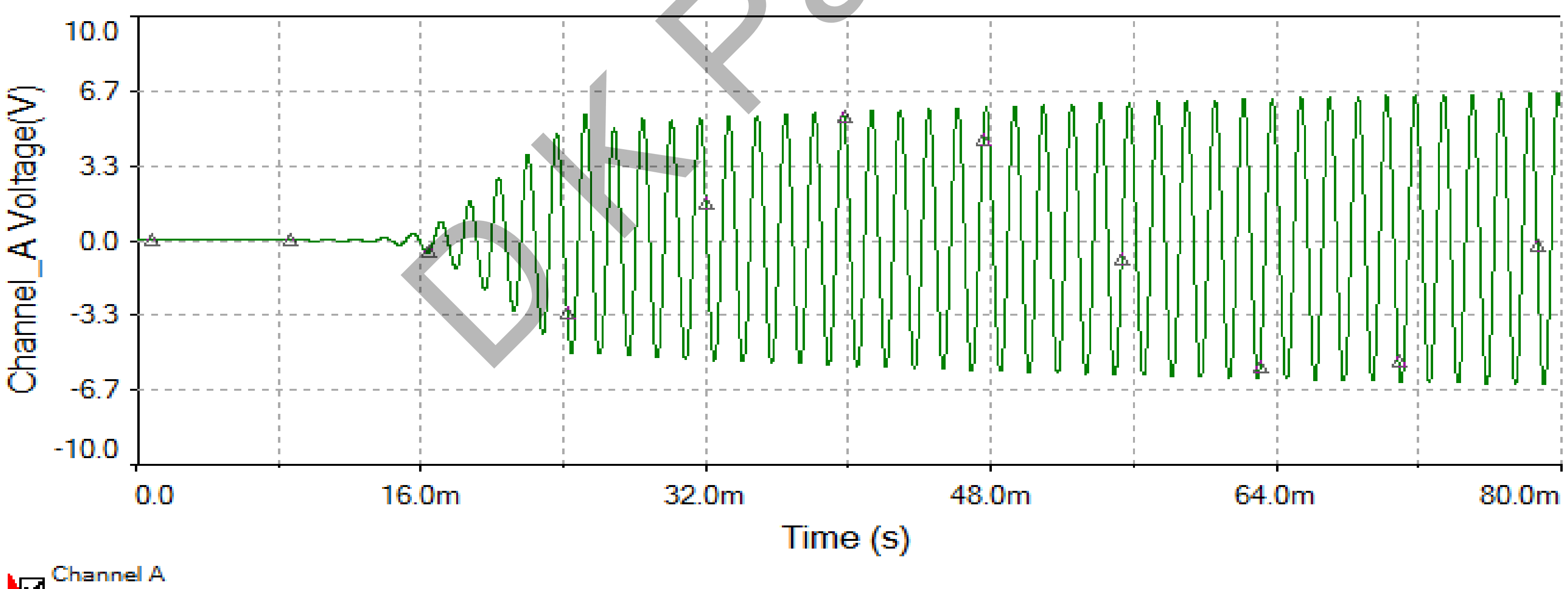


Hartley Oscillator-Practical Circuit

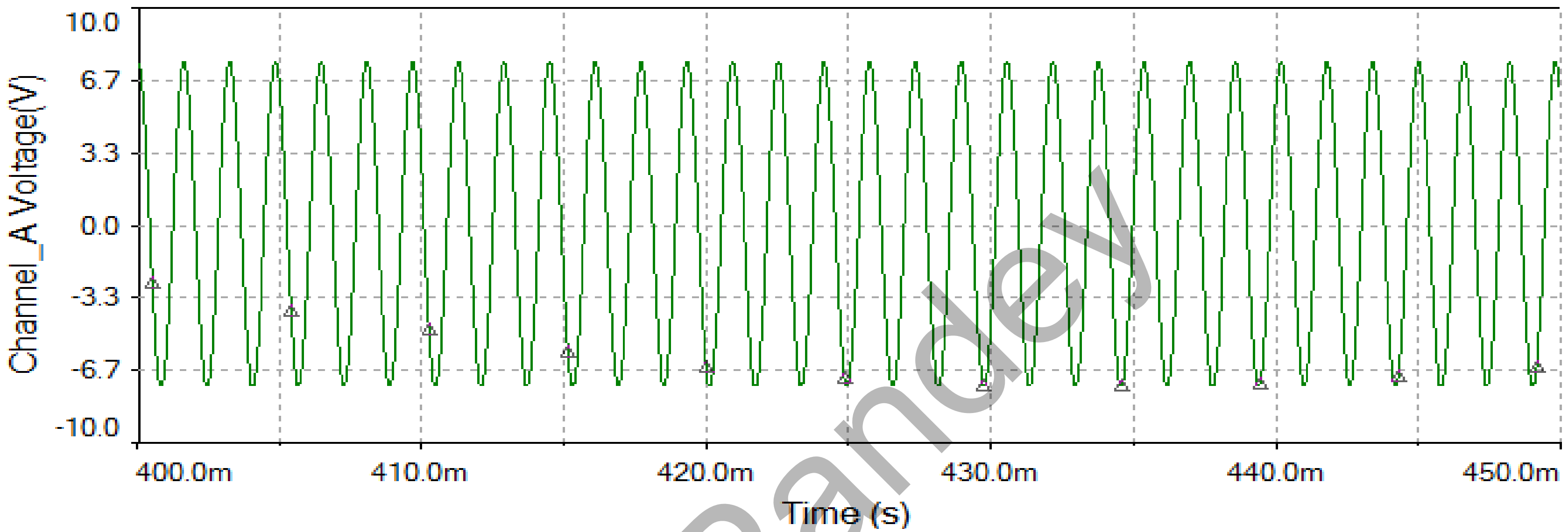


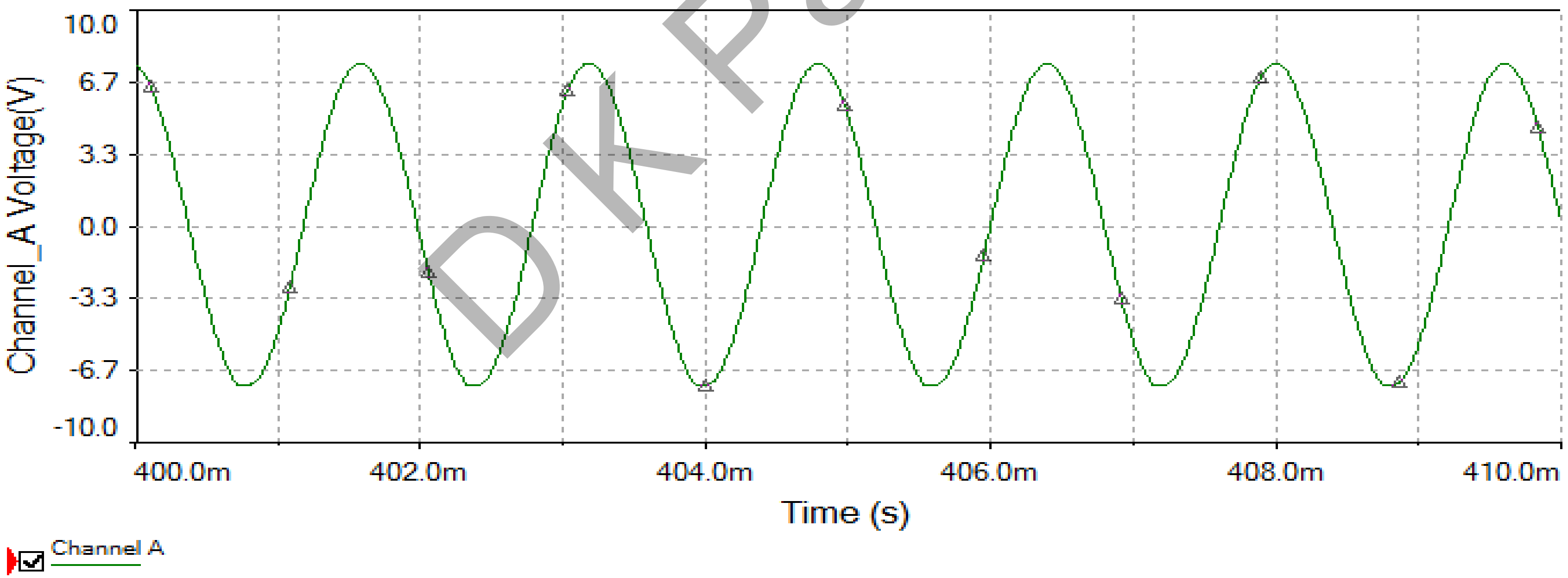
Hartley Oscillator-output





Hartley Oscillator-output





A Lot of Thanks

for kind attention