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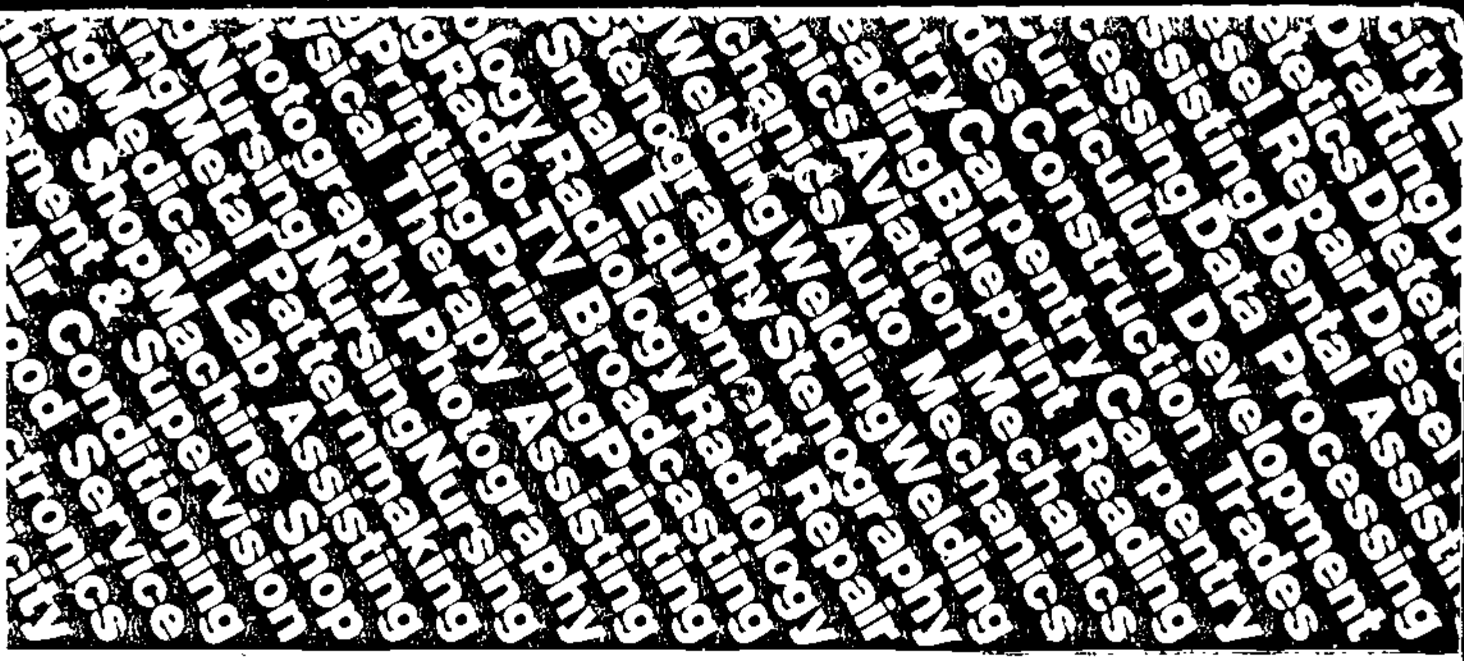
ABSTRACT

This individualized learning module on oscillators is one in a series of modules for a course in basic electricity and electronics. The course is one of a number of military-developed curriculum packages selected for adaptation to vocational instructional and curriculum development in a civilian setting. Four lessons are included in the module: (1) Functional Analysis, (2) Parallel Resonance Circuits, (3) Measuring Frequency with an Oscilloscope, and (4) Oscillator Operation. Each lesson follows a typical format including a lesson overview, a list of study resources, the lesson content, a programmed instruction section, and a lesson summary. (Progress checks are provided for each lesson in a separate document, CE 026 582.) (LRA)




# Military Curricula for Vocational & Technical Education



THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
THE OHIO STATE UNIVERSITY

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

# Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director



# What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

| | |
|---|---|
| Agriculture | Food Service |
| Aviation | Health |
| Building & Construction Trades | Heating & Air Conditioning |
| Clerical Occupations | Machine Shop |
| Communications | Management & Supervision |
| Drafting | Meteorology & Navigation |
| Electronics | Photography |
| Engine Mechanics | Public Service |

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

# How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

**EAST CENTRAL**
Rebecca S. Douglass
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Springfield, IL 62777
217/782-0759

**NORTHWEST**
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Building 17
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**SOUTHEAST**
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Mississippi State, MS 39762
601/325-2510

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# The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION

# Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

PREPARED FOR

BASIC ELECTRICITY AND ELECTRONICS

CANTRAC A-100-0010

MODULE TWENTY TWO

OSCILLATORS

PREPARED BY

INDIVIDUALIZED LEARNING DEVELOPMENT GROUP

SERVICE SCHOOL COMMAND, NTC, SAN DIEGO, CA 92133

STUDY BOOKLET

1 APRIL 1977

8

OVERVIEW
BASIC ELECTRICITY AND ELECTRONICS
MODULE TWENTY TWO

## Oscillators

Any technician will tell you that oscillator circuits are an important part of electronic equipment. Most students studying oscillators for the first time discover that they are amazing circuits -- they have an output signal but no input signal (something for nothing?). Actually they only convert electrical energy from one form to another -- from DC to AC. There are many types of oscillators, but this module will limit itself to oscillators that utilize parallel resonant tank circuits.

This module has been divided into the following four lessons:

Lesson I Functional Analysis
Lesson II Parallel Resonant Circuits
Lesson III Measuring Frequency with an Oscilloscope
Lesson IV Oscillator Operation

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY TWO

LESSON I

FUNCTIONAL ANALYSIS

1 APRIL 1977

# OVERVIEW
# LESSON I

## Functional Analysis

In this lesson you will study and learn about the function of oscillators, the function of the tank circuit, the function of the amplifier circuit, and the function of the feedback circuit.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

22.1.44 When the student completes this course, he will be able to TROUBLESHOOT an oscillator circuit, given a training device, required test equipment, technical manuals, schematics, and a practice board. Fault diagnosis to be 100% correct and any repair work completed on a practice board to pass a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

22.1.44.1 DEFINE the function of a basic oscillator by selecting the correct statement from a list of four statements. 100% accuracy is required.

22.1.44.2 IDENTIFY the tank, amplifier, and feedback components in a basic oscillator given a training device oscillator circuit and its schematic diagram or technical manual and a job program. 100% accuracy is required.

22.1.44.2.1 DEFINE the function of the tank circuit in an oscillator by selecting the correct statement from a list of four choices. 100% accuracy is required.

22.1.44.2.2 DEFINE the function of the amplifier section in an oscillator circuit by selecting the correct statement from a list of four choices. 100% accuracy is required.

22.1.44.2.3 DEFINE the function of the feedback section or "loop" in an oscillator by selecting the correct statement from a list of four statements. 100% accuracy is required.

BEFORE YOU START THIS LESSON, READ THE LESSON LEARNING OBJECTIVES AND PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON I

FUNCTIONAL ANALYSIS

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following study resources:

Written Les    sentation in:

Module Boo  ::

Summary
Narrative

Student's Guide:

Audio/Visual Response Sheet Twenty Two - I
Progress Check

Additional Material(s):

Audio/Visual Program Twenty Two - I "Functional Analysis of Basic Oscillators"

Enrichment Material(s):

Basic Electronics, Vol. I, NAVPERS 10087C
Electronics Installation and Maintenance Book, Electronic Circuits, NAVSHIPS 0967-000-0120, section 6

YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, INCLUDING THE LEARNING SUPERVISOR; HOWEVER, ALL MATERIALS LISTED ARE NOT NECESSARILY REQUIRED TO ACHIEVE LESSON OBJECTIVES. THE PROGRESS CHECK MAY BE TAKEN AT ANY TIME.

SUMMARY
LESSON I

Functional Analysis

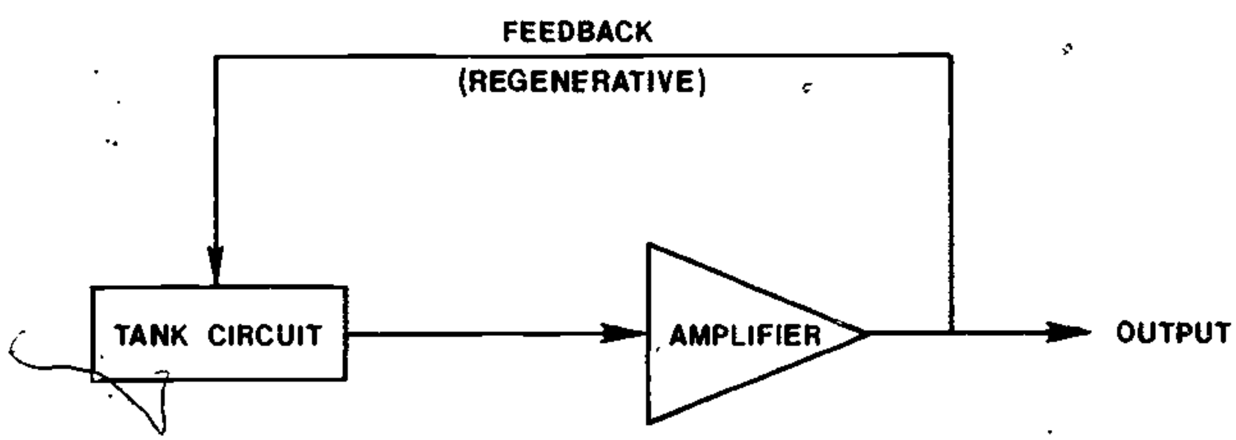
Oscillators must be considered in some detail in the study of electronics, since most electronic equipments employ them.

An oscillator is a non-rotating device for producing alternating current from a direct current supply, at a frequency determined by the characteristics of the device.

Alternators and generators (rotating devices) can produce AC at a variety of frequencies, but they are not classified as oscillators.

Electronic oscillators may not always produce sinewave AC, but only those that do will be considered in this module.

The figure illustrated below shows the block diagram for the basic oscillator:




The functions of the circuits are:

Tank Circuit: Develops the desired AC frequency.

Amplifier Circuit: Amplifies the tank circuit output to a usable level and compensates for energy losses in the components of the oscillator.

Feedback Circuit: Returns part of the oscillator output signal back into the tank circuit to insure that the tank circuit will continue to oscillate.

The output of the basic oscillator circuit is a sinewave at a constant amplitude and frequency.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE COPRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

# NARRATIVE
# LESSON I

## Functional Analysis

In the study of electronics, oscillators must be considered in some detail, since the list of equipments employing oscillators is a long one. Included are equipments such as radio transmitters and receivers, radar, sonar, guided missiles, test equipment, and television.

The question "what is an oscillator?" can be answered best by determining what an oscillator does. An oscillator generates a waveform at a constant amplitude and specific frequency.

Although all oscillators do not produce sine waves, in this lesson we will only be concerned with oscillators that do. The function of all oscillators is basically the same, regardless of the waveshape produced.

By definition, an oscillator is a non-rotating device for producing alternating current from a direct current supply, the output frequency of which is determined by the characteristics of the device.

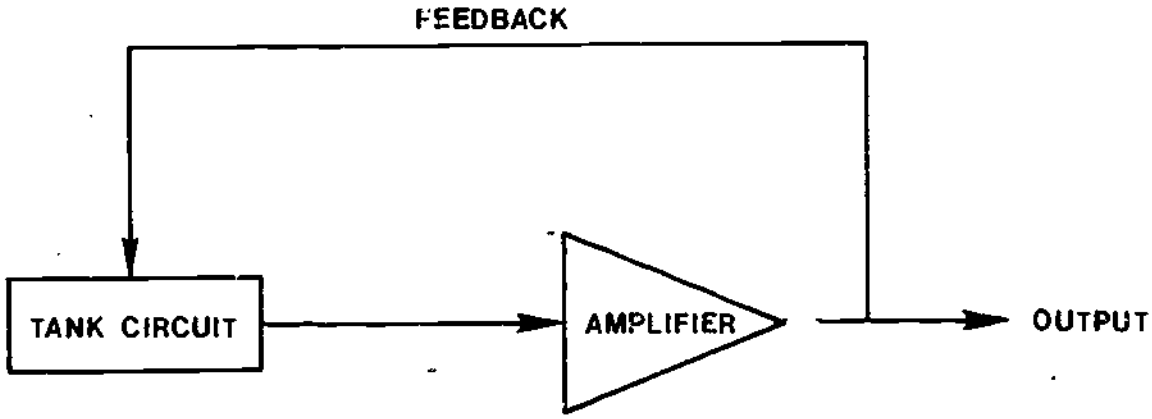
The definition contains the word non-rotating in order to eliminate the possibility of classifying an alternator or a generator as an oscillator. Although an alternator or generator can produce a sinewave at a given frequency (such as 60 Hz for the AC power line), they are not classified as oscillators.

An oscillator circuit produces a given (1) ____________
at a constant (2) ____________________.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

1. frequency
2. amplitude

The figure illustrated below is a block diagram which shows the three essential sections of a basic oscillator circuit.




The three essential sections of any oscillator circuit are:

(1) ____________
(2) ____________
(3) ____________

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

1. Feedback
2. Amplifier
3. Tank Circuit (in any order)

As discussed earlier, the power supply's function is to convert AC to DC.

The oscillator's function is just the opposite. It converts DC into AC. The tank circuit is a basic oscillator and when supplied with a DC voltage can convert it to AC.


Wait a minute! If we started with AC and needed a power supply to convert it to DC, why go to the trouble of converting it back to AC? Remember, the AC line voltage was only 60 Hz. In electronics, many different frequencies are required, and the tank circuit can convert DC to any frequency. The frequency might range, for example, from 1 to $1 \times 10^{12}$ Hz depending on the value of components in the tank circuit.

The oscillator's function is to convert DC to the required AC. The Tank circuit establishes the ______________________.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

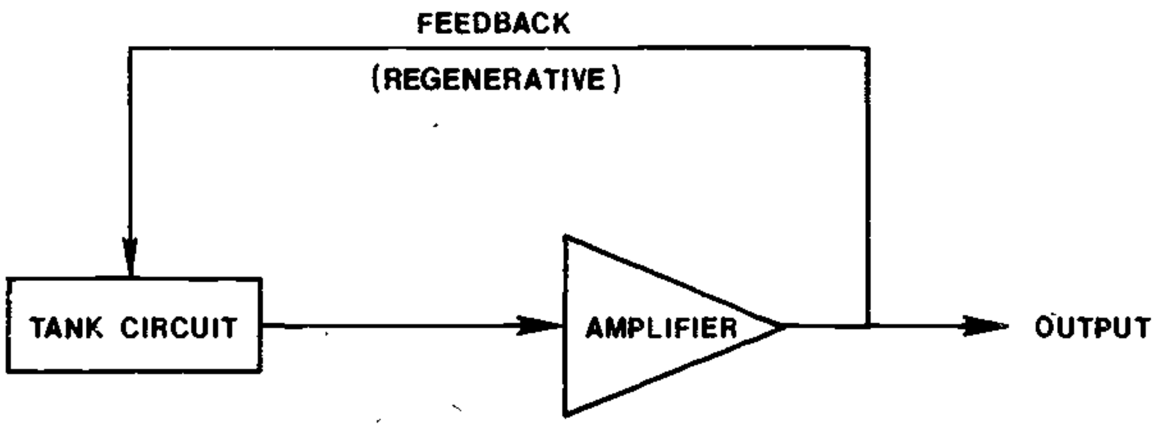
frequency of the oscillator

The tank circuit can convert DC to AC by itself but due to energy losses of the components that make up the oscillator, it can only sustain oscillations for short periods of time. In order for the output to be useful, the oscillator must maintain the required frequency and amplitude. By adding an amplifier and a feedback circuit to the tank circuits, a constant amplitude and frequency can be maintained.

This amplifier is the same as the basic amplifier you have already studied. Its function is to amplify the output of the tank circuit. This is necessary to compensate for component energy losses and to ensure that the output is of the required amplitude.

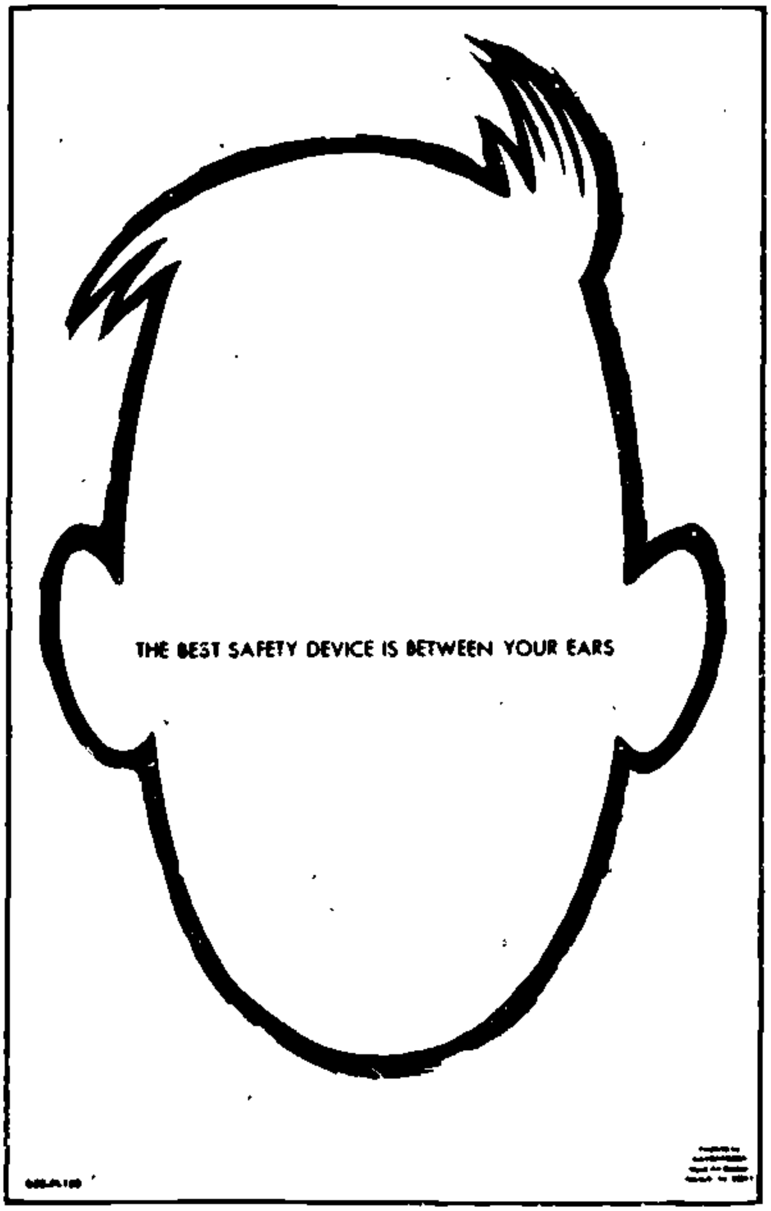
The feedback takes part of the amplifier's output and returns it to the tank in phase with the oscillation of the tank to sustain oscillations. In oscillators we call the type of feedback regenerative or positive feedback.

We say that the signal is fed back into the tank to prevent the oscillations from dying out.




The blocks shown in the illustration must work together to provide an output usable by the rest of the equipment. In short, the tank circuit establishes the frequency of oscillations but, because of component losses, it alone is not capable of maintaining the required output. The amplifier performs two functions. The first is to increase the tank's output to an amplitude sufficient for equipment operation; the second is to provide power for the feedback circuit. The feedback circuit replaces the energy lost in the tank. As you can see, each stage is dependent upon the other stages and failure of one function disables the total oscillator.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.


THE BEST SAFETY DEVICE IS BETWEEN YOUR EARS

BASIC ELECTRICITY AND ELECTRONICS

# MODULE TWENTY TWO

## LESSON II

## PARALLEL RESONANT CIRCUITS

1 APRIL 1977

OVERVIEW
LESSON II

## Parallel Resonant Circuits

In this lesson you will study and learn about flywheel effect, damping, and various methods for changing frequency of tank circuit.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

22.2.44 When the student completes this course, he will be able to TROUBLESHOOT an oscillator circuit, given a training device, required test equipment, technical manuals, schematics, and a practice board. Fault diagnosis to be 100% correct and any repair work completed on a practice board to pass a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

22.2.44.3 IDENTIFY the output waveform of a tank circuit operating at resonance by selecting an illustration of the correct waveform from a set of four illustrations. 100% accuracy is required.

22.2.44.4 IDENTIFY the waveform that represents a "damped" sinewave by selecting the correct waveform from a set of four. 100% accuracy is required.

22.2.44.4.1 OBSERVE a damped waveform given an oscilloscope, a training device, and a job program. 100% accuracy is required.

22.2.44.5 IDENTIFY the component that, when changed, will (will not) vary the resonant frequency of a paralled tank circuit by selecting from a list of four statements the component that, when changed, will (will not) change the resonant frequency. 100% accuracy is required.

BEFORE YOU START THIS LESSON, READ THE LESSON LEARNING OBJECTIVES AND PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

# LIST OF STUDY RESOURCES
## LESSON II

## Parallel Resonant Circuits

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following study resources:

Written Lesson presentation in:

Module Booklet:

Summary
Programmed Instruction
Narrative

Student's Guide:

Audio/Visual Response Sheet Twenty Two - II
Job Program Twenty Two - II "Damped Oscillations"
Progress Check

Additional Materials(s):

Audio/Visual Program Twenty Two - II "Parallel Resonant Circuits"

Enrichment Material(s):

Basic Electronics, Vol. 1, NAVPERS 10087-C

YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, INCLUDING THE LEARNING SUPERVISOR; HOWEVER, ALL MATERIALS LISTED ARE NOT NECESSARILY REQUIRED TO ACHIEVE LESSON OBJECTIVES. THE PROGRESS CHECK MAY BE TAKEN AT ANY TIME.

# SUMMARY
# LESSON II

## Parallel Resonant Circuits

The tank circuit determines the frequency of the oscillator. Tank circuits store electrical energy in the electrostatic field of the capacitor and in the electromagnetic field of the inductor. Energy is transferred from capacitor to inductor and back again producing a sine wave output at a specific resonant frequency. This automatic energy transfer is called the flywheel effect.

If components were perfect, the flywheel effect would continue forever; however, because of internal losses of the components and wiring, the tank loses energy. This loss in energy lowers the amplitude of the sine wave until all energy of the tank is dissipated. This sine wave of decreasing amplitude is known as damped oscillations.

A fixed tank circuit has only one resonant frequency. The formula for the resonant frequency of the tank is $f_o = \frac{.159}{\sqrt{LC}}$. Therefore, the resonant frequency may be changed by adding inductors or capacitors to the tank. If capacitance or inductance is increased, the resonant frequency is decreased. They are indirectly proportional. Variable components are frequently used to change the resonant frequency over a range of frequencies.

In order to use a tank as a frequency producer, some method must be used to overcome the losses that cause damped oscillations. This method will be covered in Lesson IV.

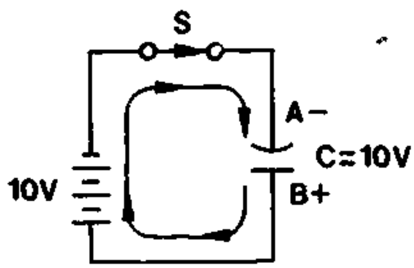
AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON II

## Parallel Resonant Circuits

TEST FRAME IS FRAME 11. GO FIRST TO TEST FRAME 11 AND SEE IF YOU CAN ANSWER THE QUESTIONS. FOLLOW THE DIRECTIONS AT THE END OF THE TEST FRAME.

1. The "heart" of an oscillator is a parallel resonant circuit commonly called a tank circuit. It is known as a tank circuit because it has the ability to store energy just as a gas tank has the ability to store fuel. Capacitors and inductors are the components used in tank circuits. These components hold or store electrical energy. For example:




When the switch is closed, electrons accumulate on one plate of the capacitor (A) and are taken off the other plate (B).

Figure 1

A difference in potential between plate A and plate B soon matches the source voltage. When the potential of the capacitor equals the potential of the battery, current flow stops.

If the battery voltage increased to 20 VDC, to what level would the capacitor charge or discharge?

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

The capacitor would charge to 20 VDC.

2. The inductor holds energy in the form of an electromagnetic field. For example:

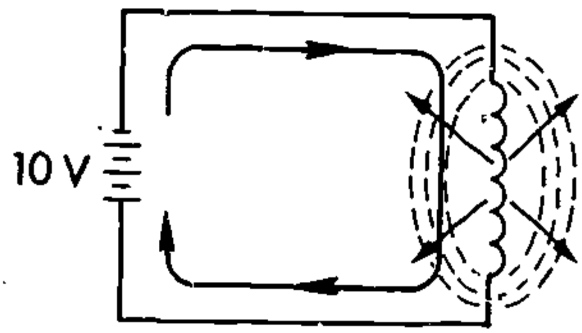



Figure 2

If the battery shorts out, the electromagnetic field of the inductor would start to collapse. The collapsing electromagnetic field induces a voltage in the inductor that would tend to keep current flowing in the same direction.

In the circuit shown, switch S1 is placed to the B position. Will current flow be up or down through resistor R?

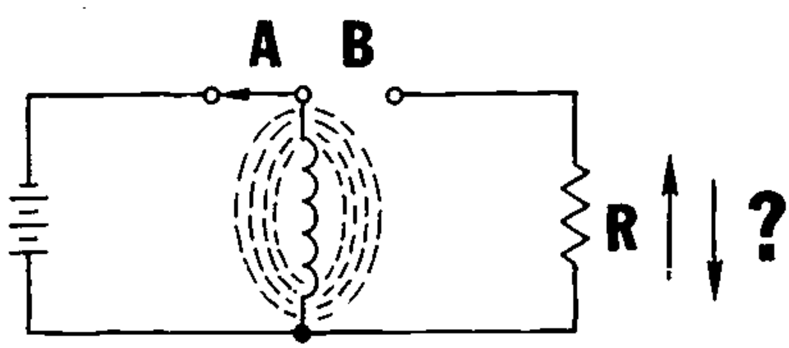



Figure 3

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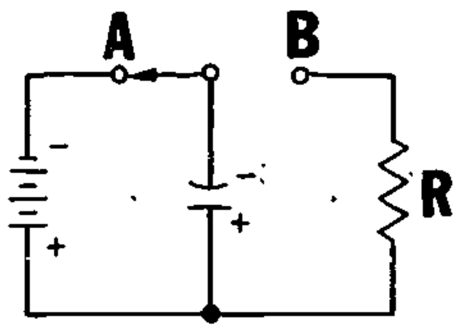
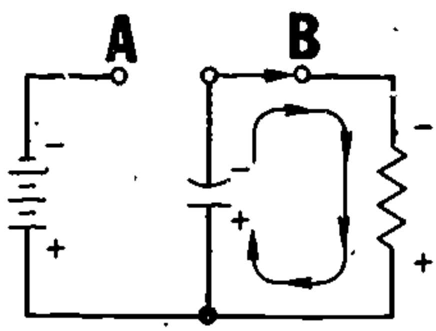
Up. Inductors try to maintain current flow in the same direction when their fields collapse.

3. Capacitors, unlike inductors, will change the direction of current flow when the source is disconnected.




CAPACITOR FULLY CHARGED
Figure 4




CAPACITOR DISCHARGES
Figure 5

a. Capacitors charge in one direction of current flow and discharge in the ____________________ direction.
b. Inductor's field expands in one direction of current flow and collapses in the ________________ direction.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

a. opposite
b. same

4. When these two components are put in the same circuit and parallel to each other, the circuit becomes a tank circuit. Let's examine what happens.

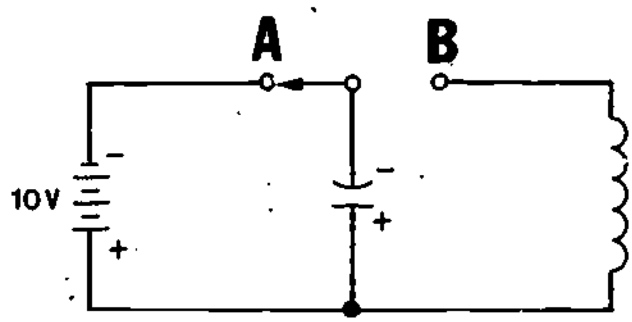



Figure 6

In Figure 6 the capacitor is fully charged.

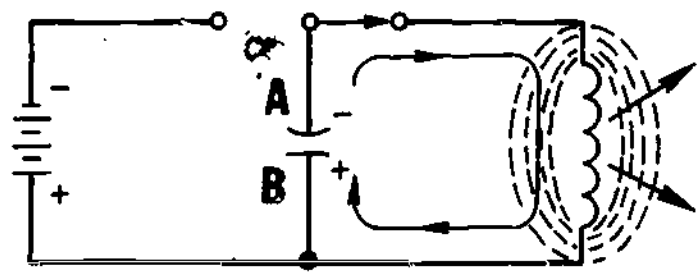



Figure 7

In figure 7 the capacitor starts to discharge and at the same time the electromagnetic field of the inductor starts to build. When the capacitor's charge is exhausted, what happens to the inductor's electromagnetic field?

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It starts to collapse.

5. The collapsing inductor field maintains current flow through the inductor in the same direction as the current that built up the field.

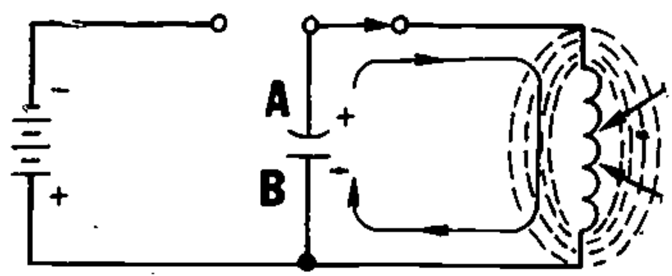



Figure 8

In Figure 8, the induced voltage in the inductor keeps current flowing after the capacitor has been fully discharged. The electrons that were on plate A have now been transferred to plate B. The capacitor has switched polarity as compared to its initial charge.

The capacitor has again become fully charged but with polarity opposite to its initial charge. At the same time the inductor's field is completely exhausted.

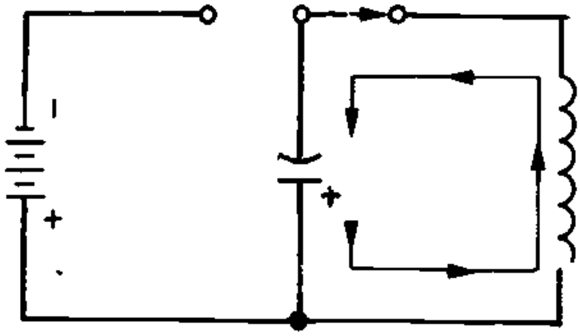
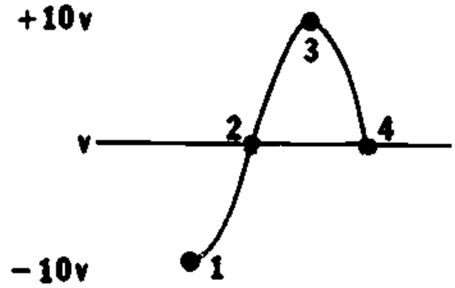


Figure 9

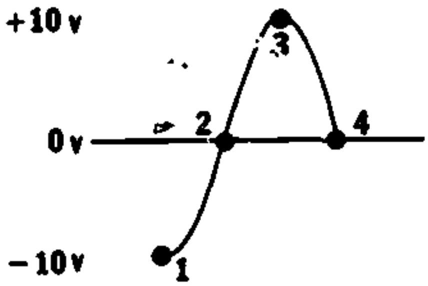
In Figure 9 the capacitor starts to discharge, causing current to flow through the inductor in the opposite direction. Let's stop now and see what the voltage across the tank has been doing.




Frame 4 describes the generation of the waveform section from point 1 to point 2. This frame, so far, covers from point 2 to point 3. Between points 3 and 4 the capacitors discharge current will build up a magnetic field around the inductor while the circuit voltage drops to zero.

In the next step of the process, the magnetic field around the inductor collapses keeping current flowing through the circuit in the same direction.

Complete the waveform below to show tank circuit voltage during the magnetic field's collapse (after point 4).

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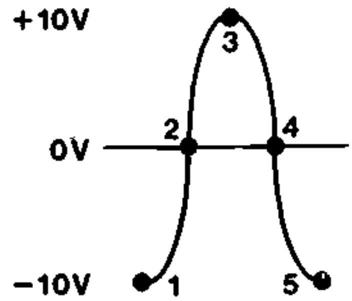
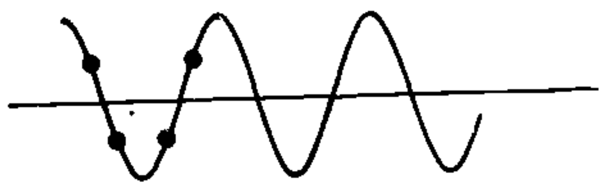



6. This transfer of energy between capacitor and inductor is called the flywheel effect. If this sequence were to be continued, the output of the tank would be a sine wave.




The function of a tank circuit then is to produce this flywheel effect You have just observed how this is done. What component action causes the tank circuit to switch direction of current flow?

---

The capacitor switches polarity. (or words to that effect)

7. As we all know, perfect (no loss) components are not possible and as a result, some energy is lost in each transfer of energy between the capacitor and inductor. Energy is lost through the resistance of the wire, leakage in the capacitor's dielectric, etc. This results in a continually decreasing amplitude of the oscillator's sine wave output until finally all energy is dissipated.

The term for this effect is damped oscillations.

Why can't a tank circuit be used as an oscillator?

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Damped oscillations make the output unusable - or - the amplitude is not constant. (or words to that effect)

8. You have been told the tank circuit is the frequency determiner of the oscillator. The frequency or rate of exchange between the components is determined by the relationship of the values of capacitance and inductance used in the tank. The easiest way to show this relationship is with the use of the following formula:

$$f_o = \frac{1}{2\pi\sqrt{LC}} \text{ or } \frac{.159}{\sqrt{LC}}$$

What we are concerned with is the effect an increase or a decrease of capacitance or inductance has on the resonant frequency.

For example:

$$f_o = \frac{.159}{\sqrt{LC}}$$

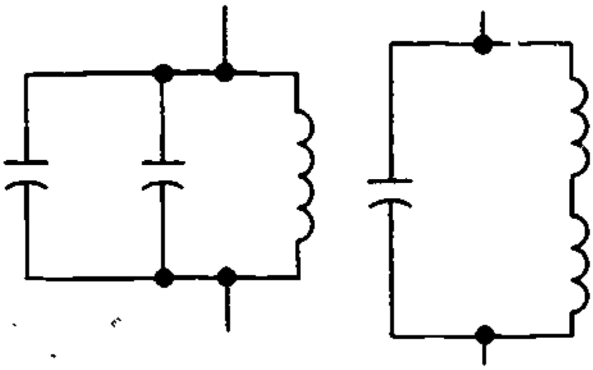
If C increases, the square root of L times C increases. This gives us a larger number divided into .159. The result of this division of a larger number into a constant number must be a lower resonant frequency.

What would happen if the L (inductance) of a tank circuit increased?

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

The resonant frequency ($f_o$) would decrease.

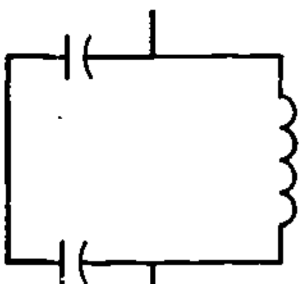
9. It can be seen then, if capacitance or inductance is added to a tank circuit, the frequency must decrease



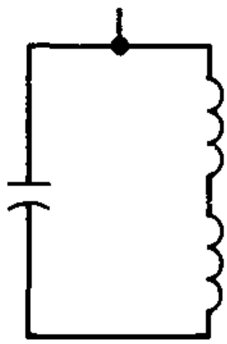
To lower the frequency of a tank circuit, add capacitance or inductance.

*Remember - to increase capacitance, capacitors must be added in parallel. To increase inductance, inductors must be added in series.

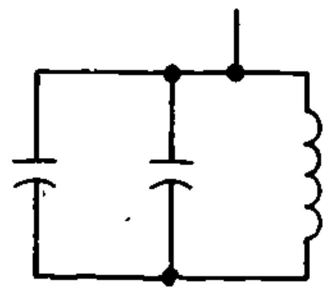
Which two circuits will increase the resonant frequency of a tank circuit?



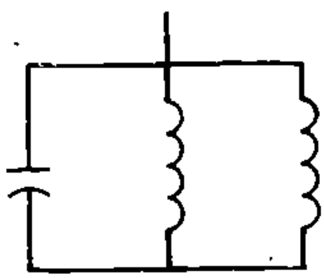
a.



b.



c.

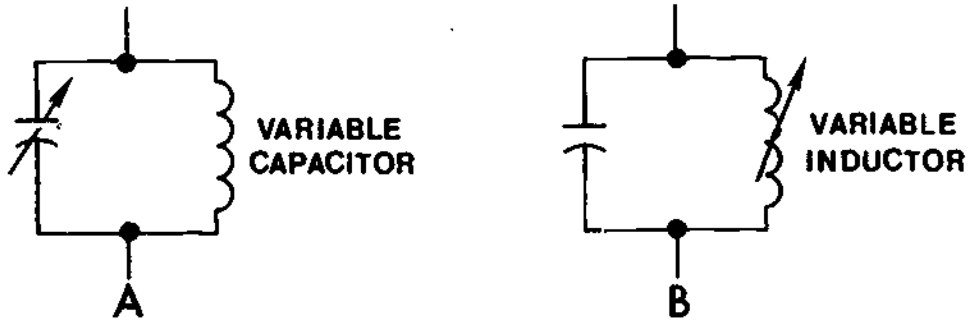


d.

---

a, d

10. Often we desire a range of frequencies from a tank circuit. This is easily done by using variable components.




The range of capacitance in A, or the range of inductance in B, determines any number of possible frequencies.

If the inductance in B is reduced, the frequency will (increase/decrease).

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

increase

11. TEST FRAME

a. The ______ ________ is a term used to describe the transfer of energy within a resonant tank.

b. If the frequency of a tank increases, the value of either the capacitor or inductor must have (increased/decreased).

c. What is meant by "damped oscillations"?

d. Variable inductors are used in tank circuits to ______________ __________?

e. What kind of waveform is produced by a tank circuit? ____________ ________________

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS AT THE TOP OF THE NEXT PAGE.

a. flywheel effect

b. decreased

c. Damped oscillations means that amplitude of each successive waveform from a tank circuit gets smaller because of the internal losses of the components within the tank. (or words to that effect)

d. change the frequency of the tank

e. Sine wave.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON II

## Parallel Resonant Circuits

In Lesson I, the functional block diagram explained the purpose of tank circuits. In this lesson we will examine the operation of various tank circuits used in oscillators. All tank circuits are comprised of capacitors and inductors. These components, as you recall, have the ability to store electrical energy.

To simplify the explanation of tank circuit operation, we will show only the capacitor (tank voltage) waveforms.

The tank circuit can convert DC voltage to AC voltage. To initiate tank circuit operation, we must first charge the capacitor.

In figure 1-a, the switch is in position B. The capacitor is fully charged to source potential and the circuit has stabilized.

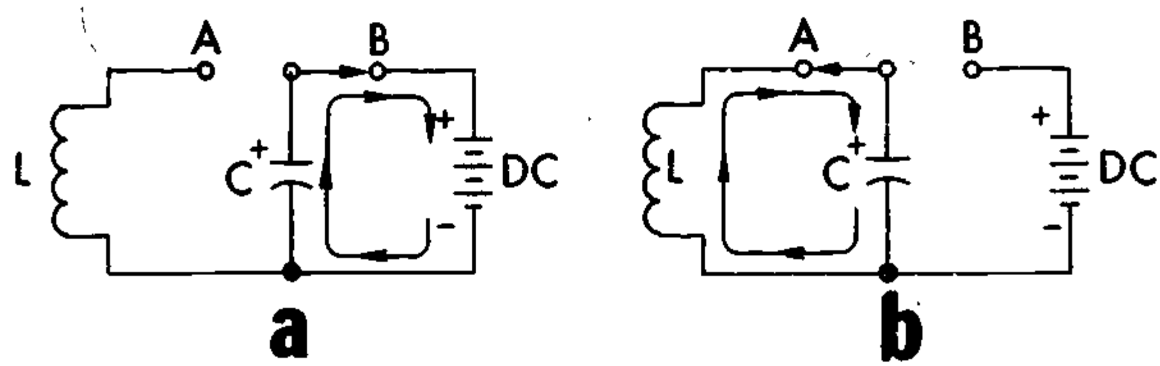
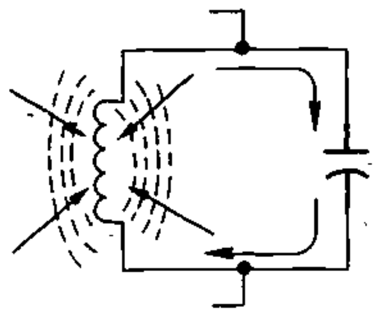



Figure 1

Source voltage is now removed by placing the switch in position A (Figure 1-b). At this instant, all tank energy is stored in the electrostatic field of the capacitor. The capacitor acts as a source and discharges through the inductor, producing an expanding magnetic field around the inductor. While the capacitor continues to discharge, the inductor's field enlarges.

At the instant the capacitor is fully discharged, the inductor's field is maximum. The stored energy of the capacitor's electrostatic field has been transferred to the inductor's electromagnetic field.

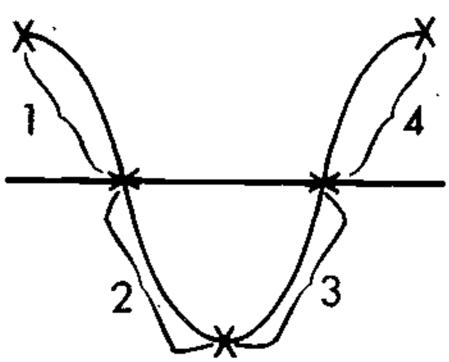
With no current to maintain it, the inductor's field begins to collapse. This collapsing field maintains current flow in the same direction (Figure 2).



NOTE: The capacitor is now charging with opposite polarity.

Figure 2

The more the inductor's field collapses, the more the capacitor charges. Once again, all circuit energy is transferred between the components of the tank. During the next transfer of energy, the polarity is reversed and the direction of current is opposite to that in the first energy cycle (Figure 3).




1 - Initial charge maximum positive -- capacitor starts to discharge through the inductor.
2 - Inductor maintains current flow in same direction -- capacitor charges in opposite direction.
3 - Capacitor discharges for the second time -- in the opposite direction.
4 - Inductor maintains current flow -- capacitor charges back up to maximum positive.

Figure 3

The transfer of energy between the capacitor and inductor will continue and the waveform read on an oscilloscope will be a sine wave (Figure 4).

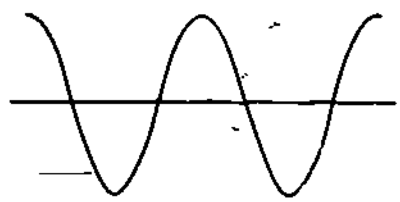


Figure 4

The alternation of energy between the capacitor's electrostatic field and the inductor's magnetic field is known as the flywheel effect. The flywheel effect would continue to generate a sine wave indefinitely if the tank had perfect (no loss) components. Unfortunately, this is not the case.

A small amount of energy is lost on each cycle of the flywheel effect. These losses are caused by the resistance of the inductor's wire, by the leakage of the capacitor's dielectric, and in numerous other places. The result of the losses is a decreasing amplitude waveform out of the tank, until all output is finally dissipated. This phenomenon is referred to as damped oscillations (Figure 5).

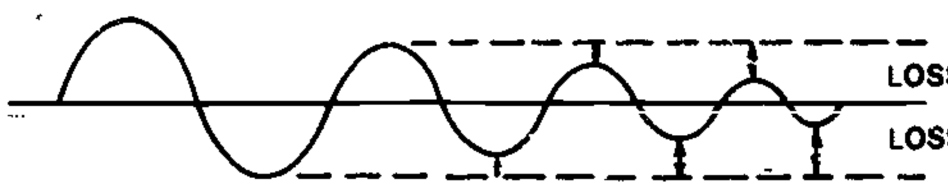



Figure 5

The frequency of oscillation is determined by the relationship of capacitance and inductance values of the tank components. This relationship is best shown by the formula for determining the resonant frequency of the tank.

$$f_o = \frac{1}{2\pi\sqrt{LC}} \text{ or } \frac{.159}{\sqrt{LC}}$$

The importance of this formula for technicians is: when L or C increases, the resonant frequency decreases. Inductance and capacitance are inversely proportional to the resonant frequency.

The flywheel effect relates to:

a. The reduced amplitude of the oscillations due to internal losses of the tank.
b. The transfer of energy between the capacitor and inductor at resonance.
c. The ratio of inductance tc capacitance.

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b.

So far we have explored a tank circuit that has only one resonant frequency. Often we require a tank circuit to operate at different frequencies. This is very easily accomplished by using a variable capacitor or a variable inductor.

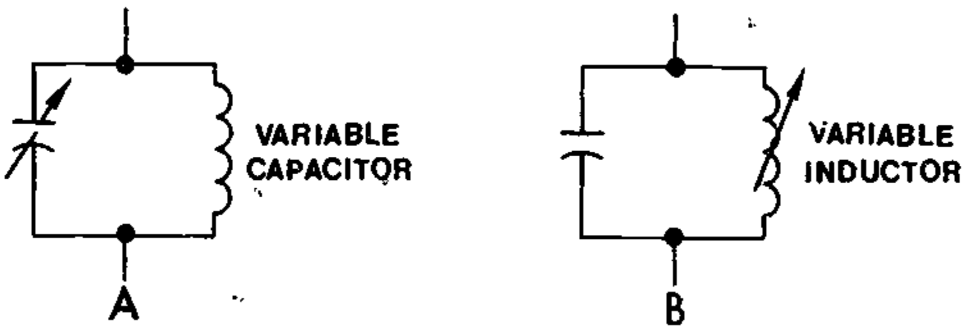


Figure 6

Varying the value of either L or C in Figure 6 will change the output frequency of the tank.

The inductance of the circuit in Figure 6b is decreased. What happens to the resonant frequency of the tank?

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The resonant frequency will increase.

Another method for changing frequency is to add capacitors or inductors in series or in parallel. To lower the frequency refer to Figure 7.

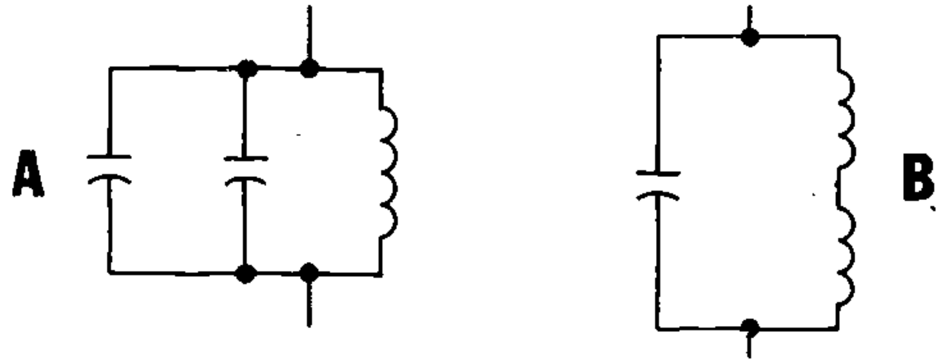



Figure 7

Remember, capacitance in parallel is additive, like inductors in series. The major disadvantage of this method of changing resonant frequency is that you can change it to only one lower frequency at a time.

To raise the resonant frequency of the tank circuit, you must:

a. add capacitors in parallel and/or inductors in parallel.
b. add capacitors in series and/or inductors in parallel
c. add capacitors in series and/or inductors in series
d. add capacitors in parallel and/or inductors in series.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

b.

The problem encountered when using the tank as an oscillator is the damped oscillation effect. Tank circuits cannot sustain oscillations by themselves. In Lesson IV you will learn how the oscillator circuit overcomes these losses.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.


BEAT THE FRIZZIES
DO NOT PLUG IN!
PULL and TAG the
PLUG or CIRCUIT BREAKER
Before Working on Equipment!

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY TWO

LESSON III

FREQUENCY MEASUREMENT WITH AN OSCILLOSCOPE

1 APRIL 1977

# OVERVIEW
# LESSON III

## Frequency Measurement With An Oscilloscope

By now, you're becoming quite familiar with using an oscilloscope. Up to this time, however, it hasn't been necessary for you to determine the frequency of the various waveforms you have seen. Now it is important that you be able to determine the output frequency of an oscillator. This lesson will show you how to do it.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

22.3.44 When the student completes this course, he will be able to TROUBLESHOOT an oscillator circuit, given a training device, required test equipment, technical manuals, schematics, and a practice board. Fault diagnosis to be 100% correct and any repair work completed on a practice board to pass a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

22.3.44.6 DETERMINE the frequency of a signal, given an oscilloscope, a job program, and a test signal generator set to a frequency unknown to the students, to within a tolerance of ± 5%.

22.3.44.6.1 IDENTIFY an illustration of a waveform with one cycle correctly marked by selecting the correct choice from a set of four illustrations. 100% accuracy is required.

22.3.44.6.2 DETERMINE, by calculation, the period of a waveform, given an illustration of a waveform on a graticule and a sweep time control position setting. 100% accuracy is required.

# OVERVIEW

22.3.44.6.3 DETERMINE, by calculation, the frequency of waveform, given the period of the waveform. 100% accuracy is required.

22.3.44.6.4 DETERMINE, by calculation, the frequency of a waveform, given an illustration of a waveform on a graticule and a sweep time control position setting. 100% accuracy is required.

BEFORE YOU START THIS LESSON, READ THE LESSON LEARNING OBJECTIVES AND PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

# LIST OF STUDY RESOURCES
## LESSON III

## Frequency Measurement With An Oscilloscope

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following study resources:

Written Lesson presentation in:

Module Booklet:

Summary
Programmed Instruction
Narrative

Student's Guide:

Job Program Twenty Two - III "Frequency Measurement Using an Oscilloscope"

Progress Check

Additional Material(s):

Audio/Visual Program Twenty-Two "Measuring Frequency With An Oscillosco

Enrichment Material(s):

Oscilloscope Technical Manual (Applicable Model Manual).

YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, INCLUDING THE LEARNING SUPERVISOR; HOWEVER, ALL MATERIALS LISTED ARE NOT NECESSARILY REQUIRED TO ACHIEVE LESSON OBJECTIVES. THE PROGRESS CHECK MAY BE TAKEN AT ANY TIME.

SUMMARY
LESSON III

## Frequency Measurement With An Oscilloscope

To use an oscilloscope in order to measure frequency, you must be familiar with the terms "frequency", "cycle", and "period".

Frequency is the number of cycles for waveforms that occur in a specific unit of time.

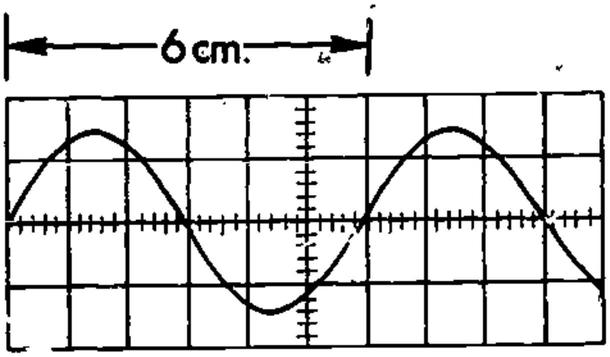
A cycle is a complete sequence of events. In our case, a repeating waveform that moves through one positive deflection, one negative deflection and returns to the point of origin.

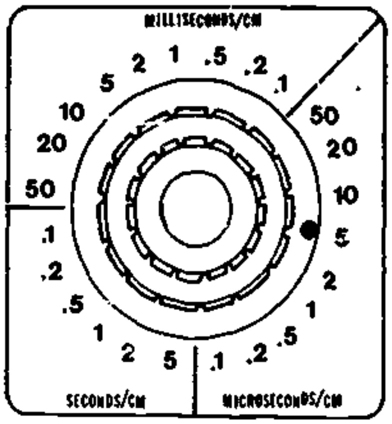
A period is the time required to complete one cycle of a waveform.

Once the period of a signal is measured, the equation $f = \frac{1}{t}$ may be used to evaluate the frequency.

Most oscilloscopes have a <u>SWEEP TIME CONTROL</u>. This control allows you to vary the number of complete cycles displayed on the oscilloscope screen. To increase the accuracy of measurement, you should display the <u>smallest</u> number of complete cycles possible in one sweep.

To determine the period of a waveform, first count the number of centimeters of <u>one</u> complete cycle. Multiply this number of centimeters by the setting of the <u>SWEEP TIME CONTROL</u>.




t = 6 cm X 5 μsec/cm

t = 30 μsec

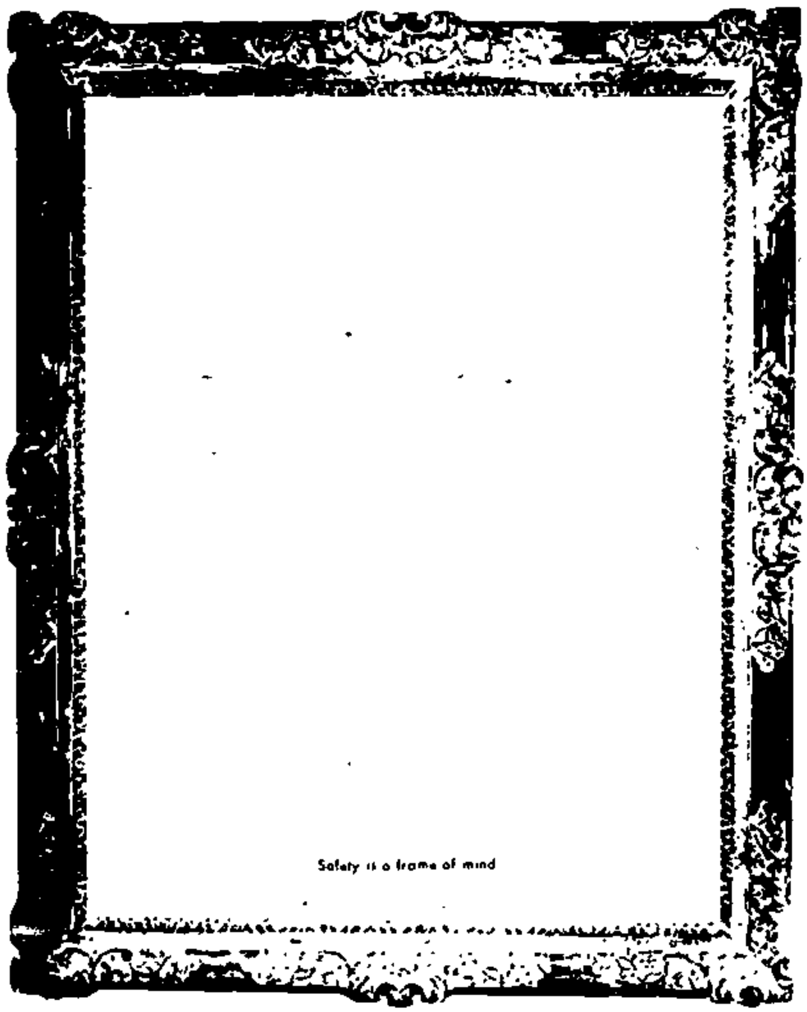
The period (t) is then inserted into the formula $f = \frac{1}{t}$.

$$f = \frac{1}{30\mu sec}$$

$$f = 33.3 \text{ KHz}$$

Another control, TRIGGER LEVEL, can be used to move the starting point of the waveform in either a positive or negative position. The HORIZONTAL POSITION control moves the signal left or right with respect to the scope graticule. These will help you to more easily "read" the complete cycle.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.



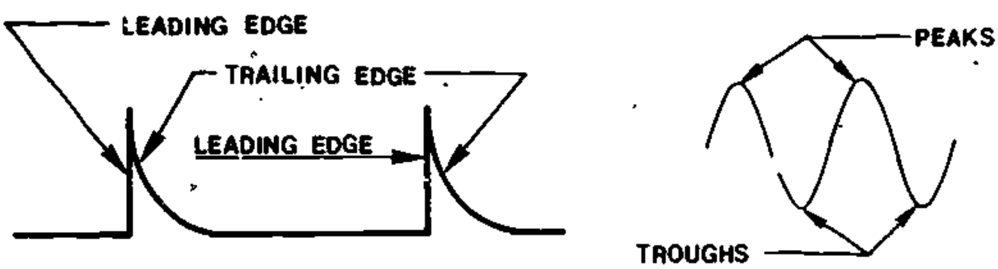

*Get the picture?*

PROGRAMMED INSTRUCTION
LESSON III

Frequency Measurement With An Oscilloscope

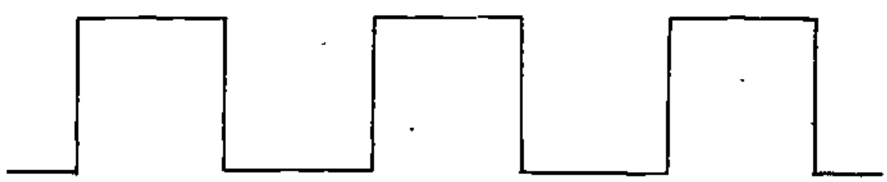
TEST FRAMES ARE 5, 9, AND 11. GO FIRST TO TEST FRAME 5 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. To measure frequency with an oscilloscope, you must understand the different parts of a waveform. Look at the illustration.




Most waveforms have leading and trailing edges. Many also have crests and troughs.

In the below illustration, identify the leading edges of the waveforms.



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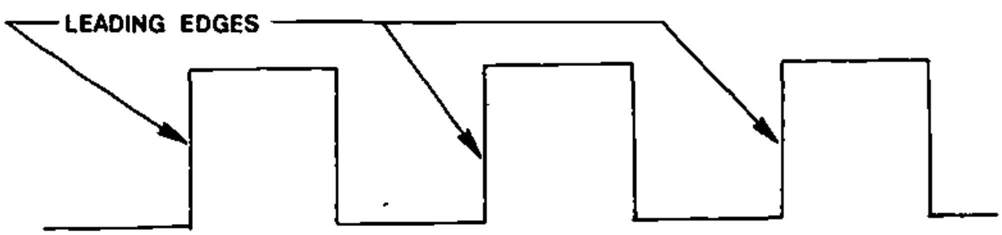
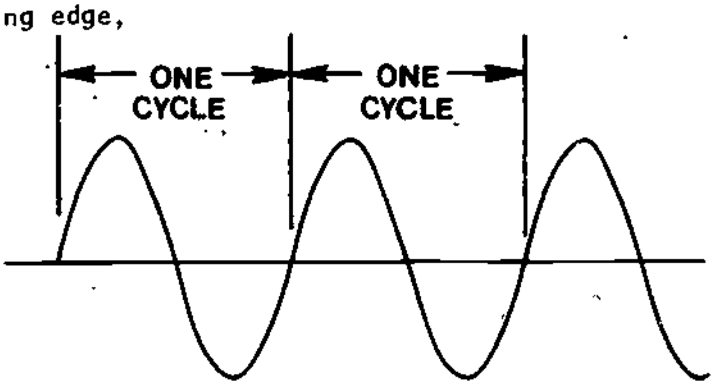
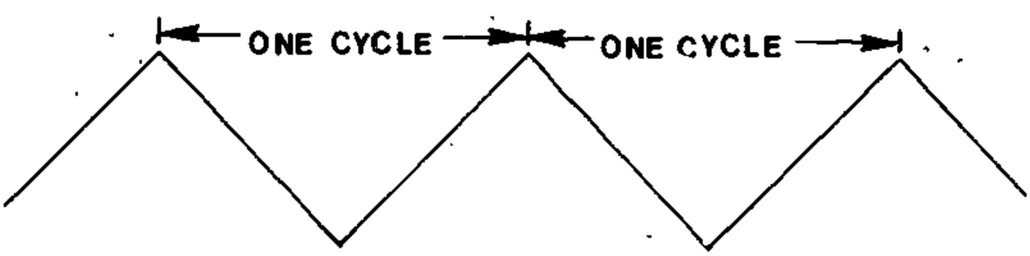



2. Another part of a waveform that must be identified is the CYCLE. A cycle is a complete sequence of events, a repeating waveform that moves through one positive deflection, one negative deflection, and returns to the point of origin. A cycle can be measured from leading edge to leading edge,

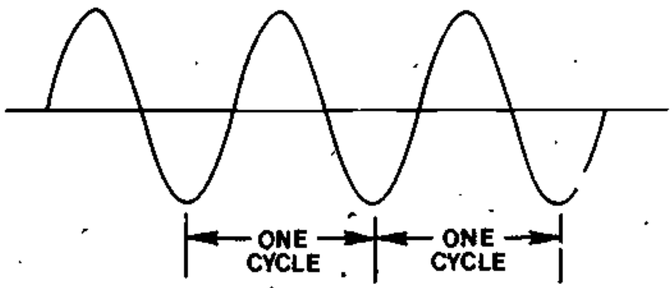



- OR -

From crest to crest,

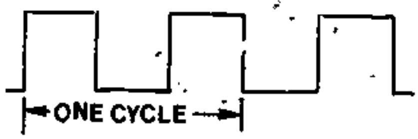


from trough to trough.

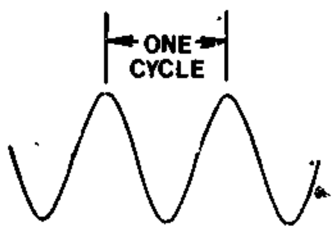



Which of the below illustrated correctly depicts one cycle?

A.

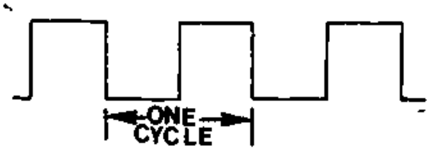



B.

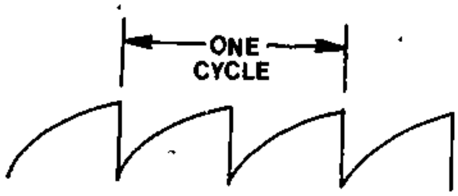



C.


D.




E.



B, C, and D

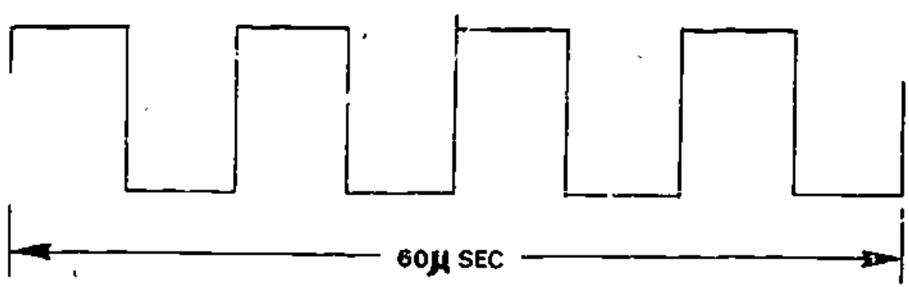
3. Another term that may need explaining is PERIOD. A period is the time required to complete one (1) cycle. Period and frequency are inversely proportional. If the frequency is increased, the period is decreased. Here is the equation to use when calculating frequency

$$f = \frac{1}{t}$$

when "f" is the frequency in Hertz and "t" is time of one period in seconds.

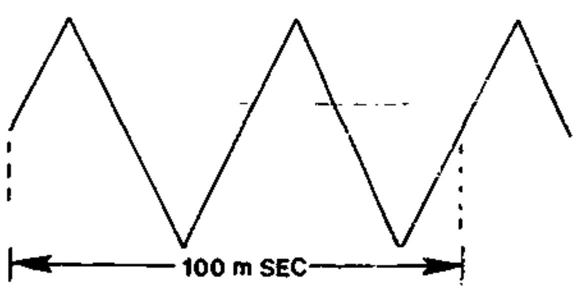
What are the periods of these illustrations?

A.

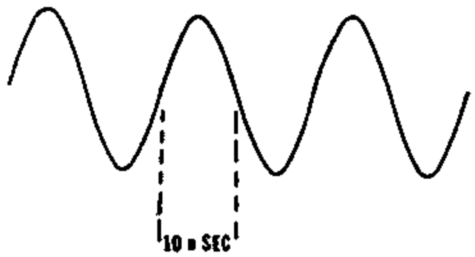



PERIOD = ________________ μsec

B.




PERIOD = ________________ msec

C. 


PERIOD = ________________ μsec

---

A. 15 μsec; B. 50 msec; C. 20 μsec

4. If a waveform has a period of 15 msec, the frequency of the waveform can be calculated with the equation:

$$f = \frac{1}{t}$$

$$f = \frac{1}{15 \text{ msec}}$$

$$f = \frac{1}{15 \times 10^{-3}}$$

$$f = 66.667 \text{ Hz}$$

What are the frequencies of the periods given below?

A. 1 msec
B. 50 μsec
C. 1000 μsec

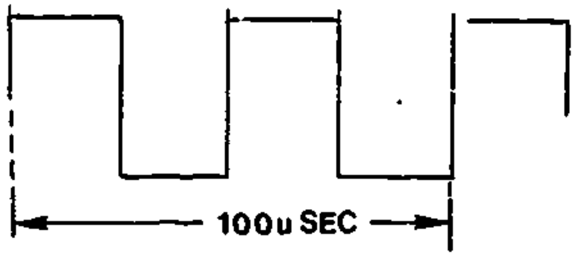
---

A. 1 KHz; B. 20 KHz; C. 10 KHz

5. TEST FRAME

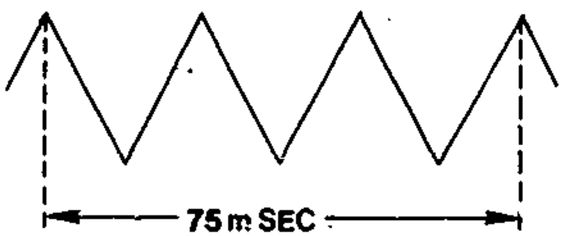
What are the frequencies of the below waveforms?

**A.**



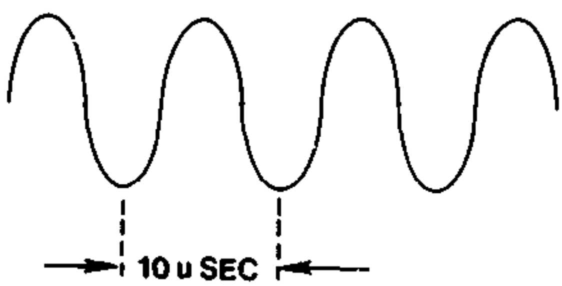

FREQUENCY = _____ Hz

**B.**



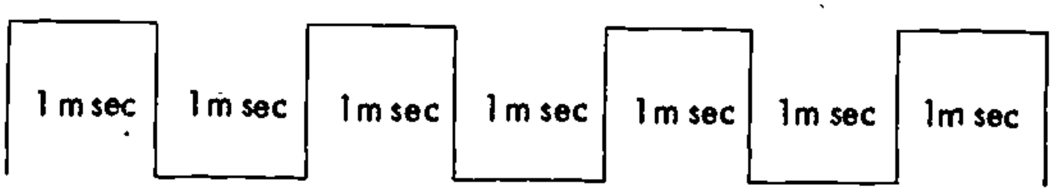

FREQUENCY = _____ Hz

**C.**




FREQUENCY = _____ Hz

**D.**




FREQUENCY = _____ Hz

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

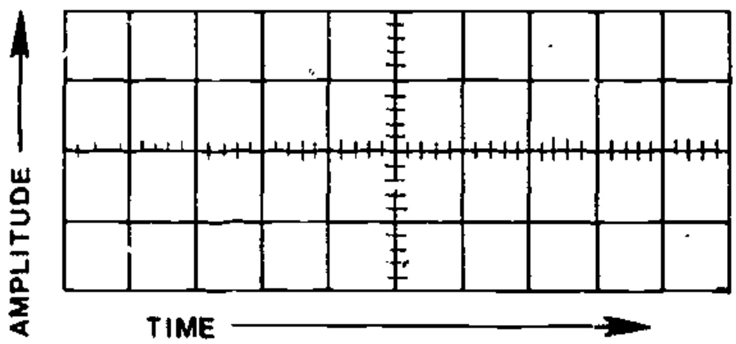
(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

A. f = 1/50 μsec, f = 20 KHz.
B. f = 1/25 μsec, f = 40 Hz.
C. f = 1/10 μsec, f = 100 KHz.
D. f = 1/2 μsec, f = 500 Hz.

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO TO TEST FRAME 9. OTHERWISE GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 5 AGAIN.

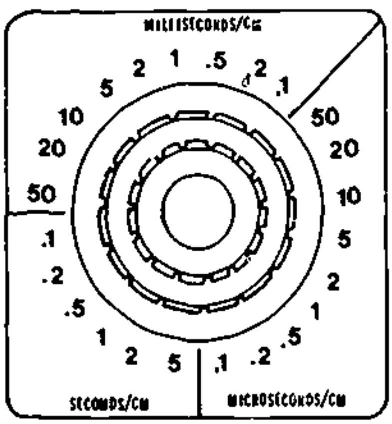
6. Using the oscilloscope to measure frequency is just a matter of applying the principles you have just learned.

An oscilloscope is a device that will display amplitude versus time. The amplitude is displayed on the vertical axis and time is displayed on the horizontal axis.




Most oscilloscope time bases are divided into centimeters.

The number of cycles that are displayed is dependent upon the SWEEP TIME CONTROL. This is a representative example of a SWEEP TIME CONTROL.

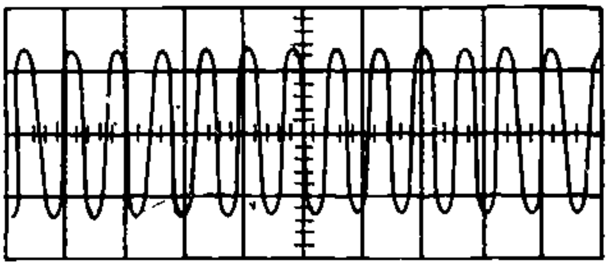



NOTE: MAKE SURE THE VERNIER CONTROL IS IN THE "CAL" POSITION.

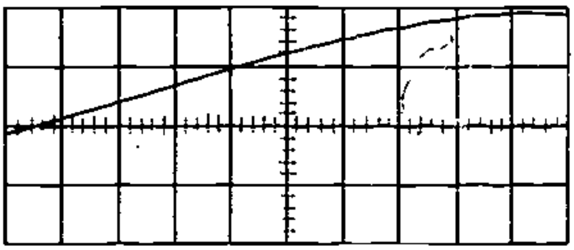
Decrease the sweep time by turning the SWEEP TIME CONTROL clockwise (CW) to display a smaller number of cycles on the screen of the oscilloscope. For the most accurate measurement, the smallest possible number of complete cycles should be displayed.

Which of the following illustrations would give the most accurate measurement?

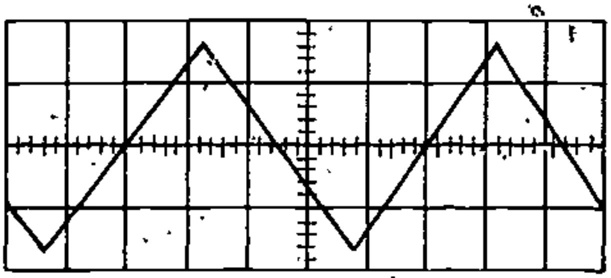
a



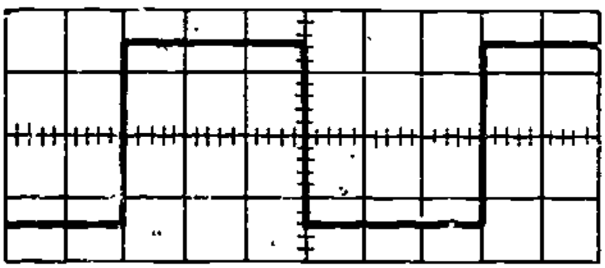
b



c



d



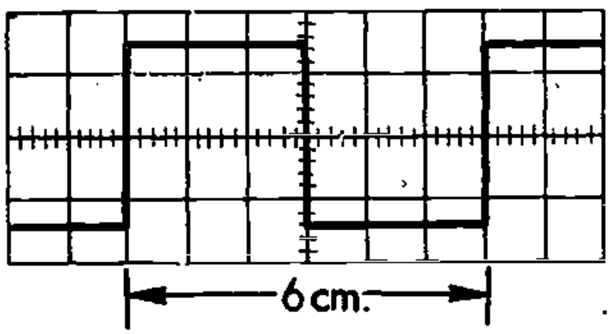
D

7. In each of the drawings in Frame 6, what must be done to the sweep time to obtain the most accurate reading?

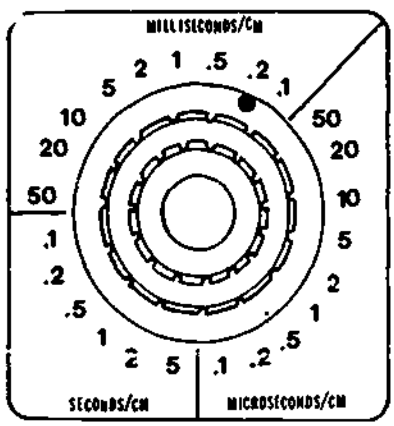
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

A. Decrease the sweep time.
B. Increase the sweep time.
C. Decrease the sweep time.
D. Nothing. This is the most correct time base.

8. Once the smallest number of complete cycles are displayed on the oscilloscope, the number of centimeters for ONE COMPLETE cycle can be counted.




In the illustration above one complete cycle covers 6 cm. Now multiply the number of centimeters by the setting of the SWEEP TIME CONTROL In this example the SWEEP TIME CONTROL is set on .2 milliseconds/cm.




This will give you the period (time) of the waveform.

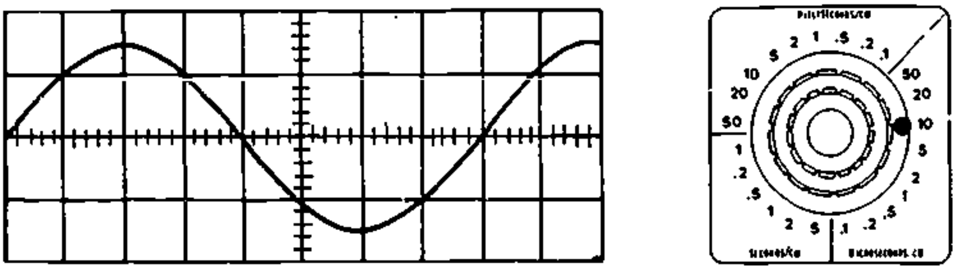
1 Period = 6 centimeters X .2 milliseconds/cm

1 Period = 1.2 milliseconds.

9. TEST FRAME

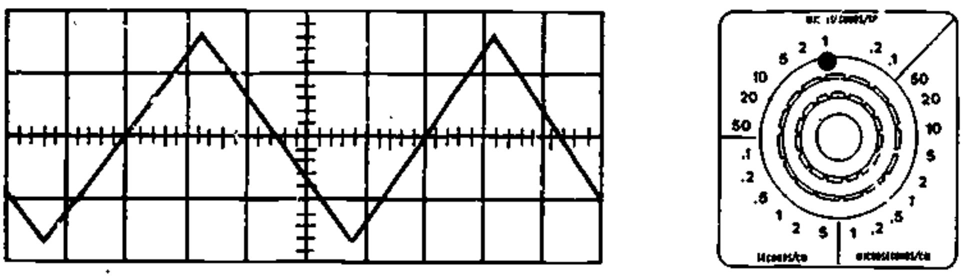
What are the periods of the below examples?

A.



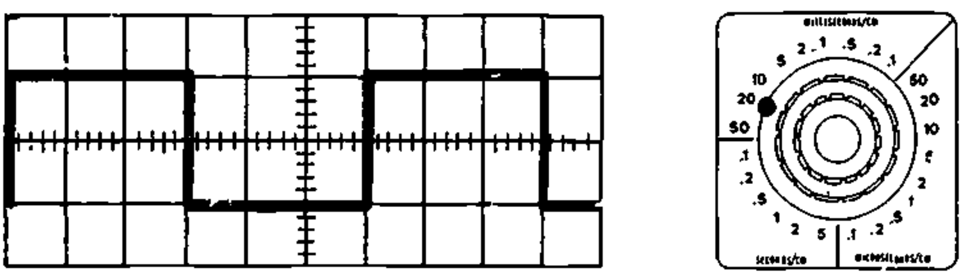
PERIOD = ______________

B.



PERIOD = ______________

C.



PERIOD = ______________

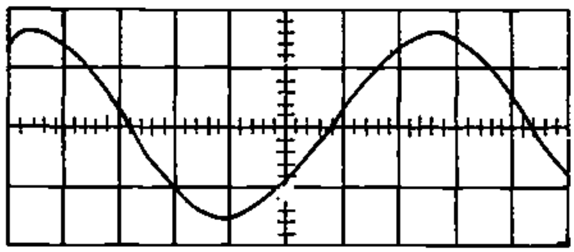
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

(THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

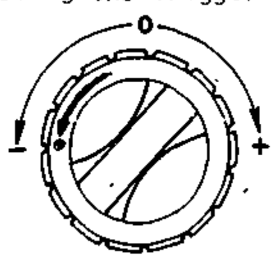
A. 80 µsec
B. 5 msec
C. 120 msec

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO ON TO TEST FRAME 11. IF ANY OF YOUR ANSWERS ARE INCORRECT, GO BACK TO FRAME 6 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 9 AGAIN.

10. On most oscilloscopes, there are 2 other controls that will aid you in frequency measurement -- the TRIGGER LEVEL CONTROL. If you have a waveform that looks like this --

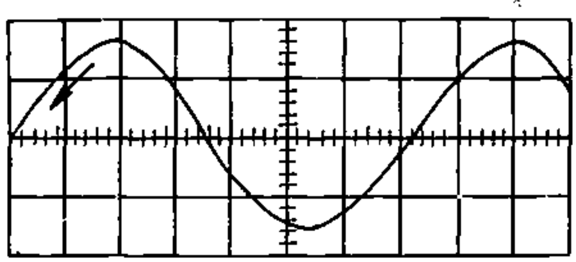


You can't see both leading edges. The TRIGGER LEVEL CONTROL allows you to move the starting point of the waveform -- either in a positive or negative direction. Moving the trigger level control --




TRIGGER LEVEL

will move the starting point in a negative direction.



This enables you to more easily "sight" the starting point of the waveform; makes it easier to locate measurement points on the waveform.

The <u>HORIZONTAL POSITION CONTROL</u> is also useful to move the entire waveform left or right so that you can more easily "sight" the distance in centimeters between your measurement points.

Finally, to measure frequency with an oscilloscope, use the equation $f = \frac{1}{t}$, and the period you have determined.

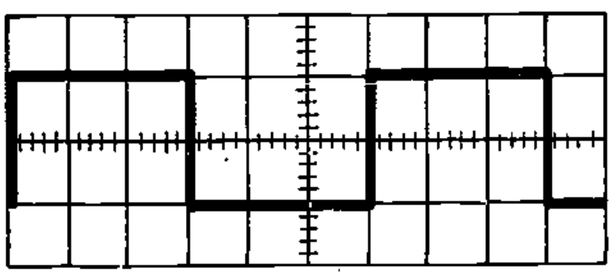
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

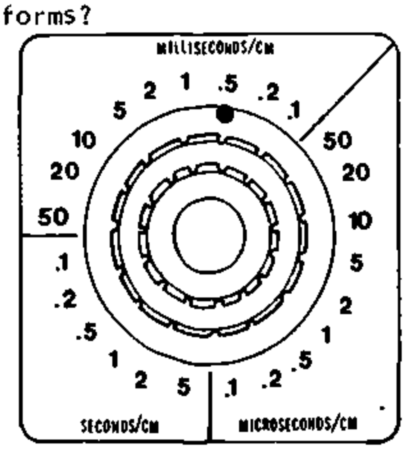
No Response Required

11. TEST FRAME

What is the frequency of each of the following waveforms?

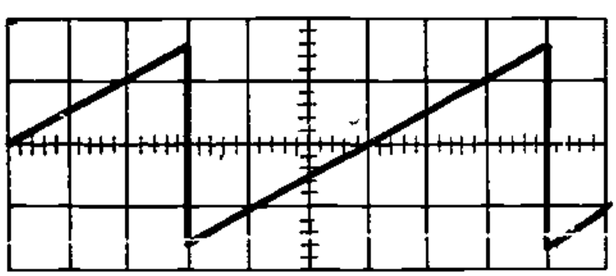
A.

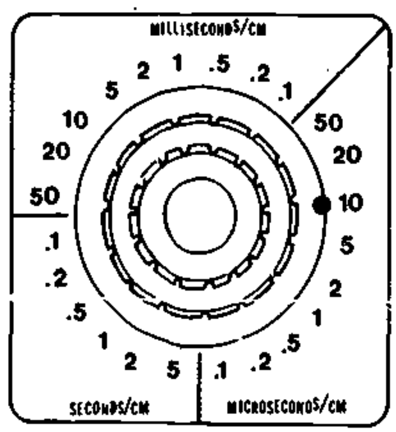




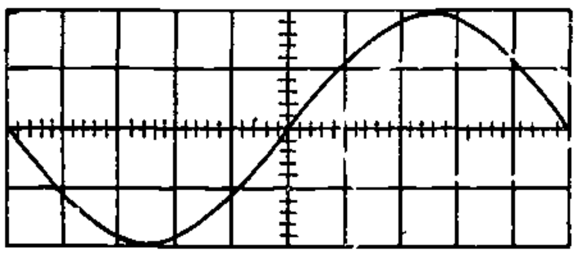

f = ________________

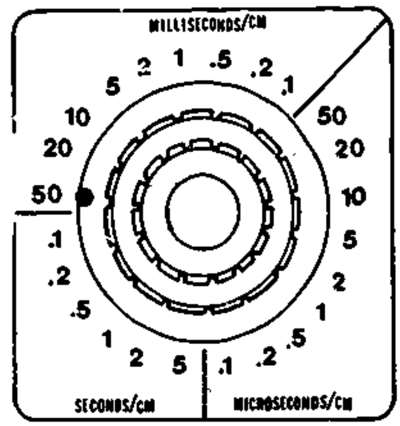
B.






f = ________________






f = ________________

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

(THIS IS A TEST FRAME, COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.)

A. f = 333. Hz
B. f = 16.666 KHz
C. f = 2.0 Hz

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON III, MODULE 22. OTHERWISE, GO BACK TO FRAME 10 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 11 AGAIN.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

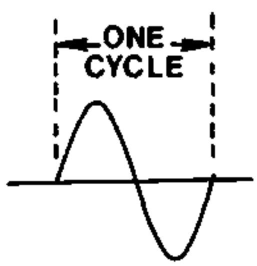
MODULE TWENTY TWO
LESSON III

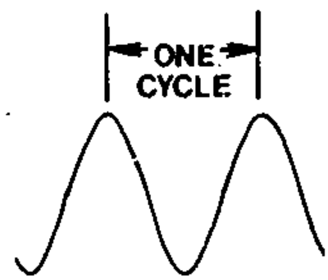
## Frequency Measurement With An Oscilloscope

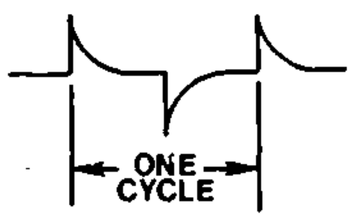
Now that you have mastered voltage measurement with an oscilloscope it's time to learn how to measure frequency with an oscilloscope.

You are probably pretty familiar with the term "frequency". You have worked with Hertz, KiloHertz and MegaHertz. You have seen examples of sine waves, square waves and triangular waves displayed on an oscilloscope. To determine the frequency of these waveforms, you first have to measure the time duration of one cycle.

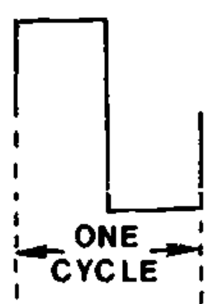
What is the definition of a cycle? A cycle is defined as a complete sequence of events; in our case, a repeating waveform that moves through one positive deflection, one negative deflection, and returns to the point of origin. Let's look at some illustrations.



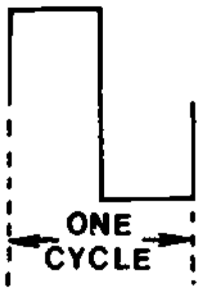



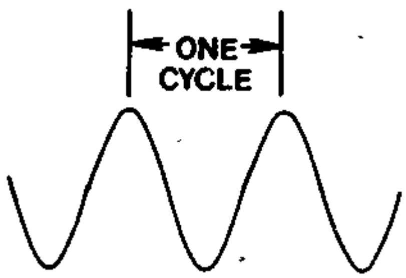




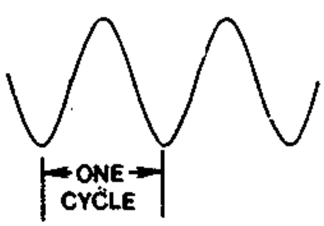
A cycle can be measured at several different places -- from leading edge to leading edge.



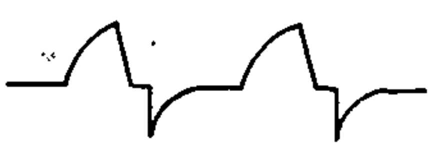

- or from crest to crest,



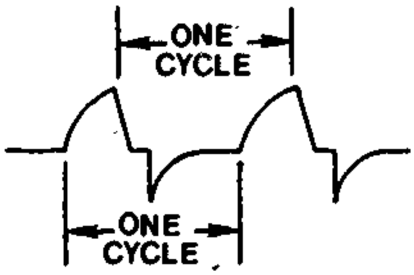

- or from trough to trough.

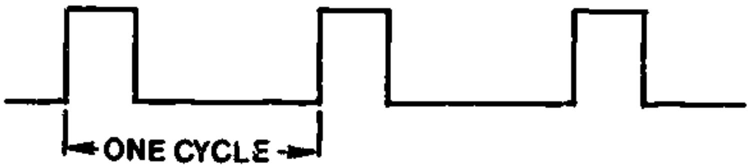



What about waveforms that have different positive and negative shapes? How would you determine the cycle of these waveforms?



Of course, you could measure from crest to crest, from trough to trough, or from leading edge to leading edge.




There is another term you will need to understand to measure frequency -- "PERIOD". A period is the time required to complete one cycle of a waveform. The period of a waveform is inversely proportional to its frequency. The shorter the period of a waveform the higher the frequency. In terms of an equation:

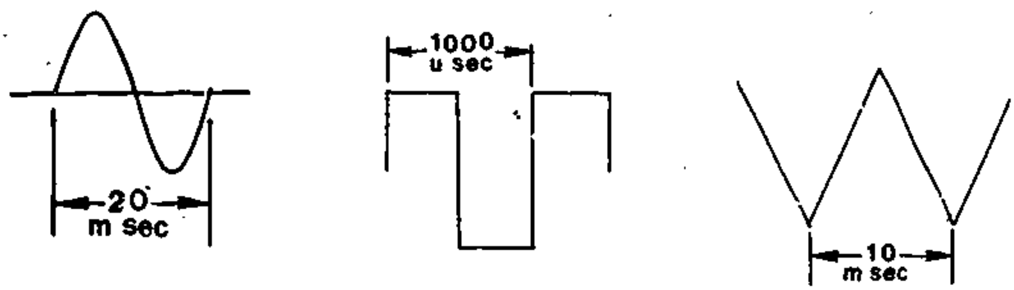
$$f = \frac{1}{t} \quad \text{and} \quad t = \frac{1}{f}$$

where "f" is the frequency in Hertz, and "t" is the time of the period of one cycle in seconds. This will be the equation you will use for frequency calculations.

63

Let's try a few examples just for practice.

You will measure the period, t, in seconds and then <u>calculate</u> the frequency, f:

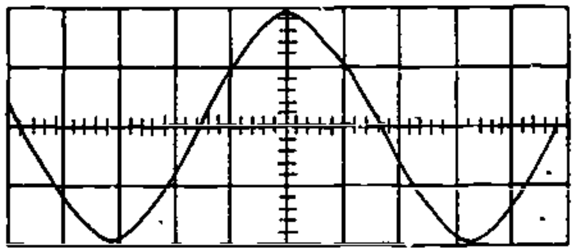



| | | |
|---|---|---|
| $f = \frac{1}{20 msec}$ | $f = \frac{1}{1000 \mu sec}$ | $f = \frac{1}{10 msec}$ |
| $f = \frac{1}{20 \times 10^{-3}}$ | $f = \frac{1}{1000 \times 10^{-6}}$ | $f = \frac{1}{10 \times 10^{-3}}$ |
| f = 50 Hz | f = 1000 Hz | f = 100Hz |

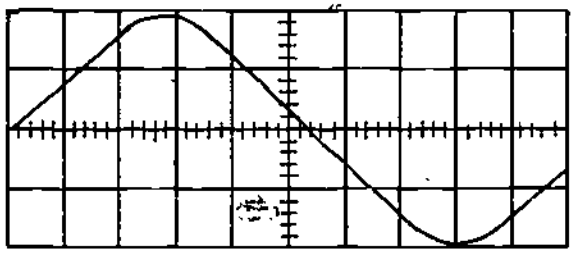
Well, now that we can find the frequency when we know the period, all we have left to do is learn how to use an oscilloscope to measure the period of a waveform.

The first thing to do is get the waveform correctly displayed on the scope. The smallest number of COMPLETE cycles displayed will give you the most accurate measurement. In the below illustrations, which would allow you to most accurately measure the waveform?

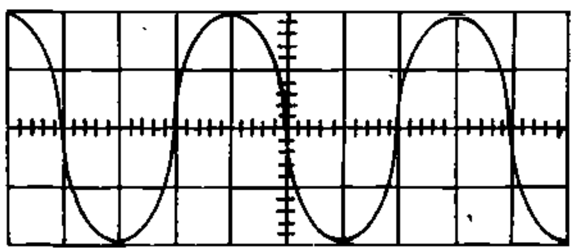
A.



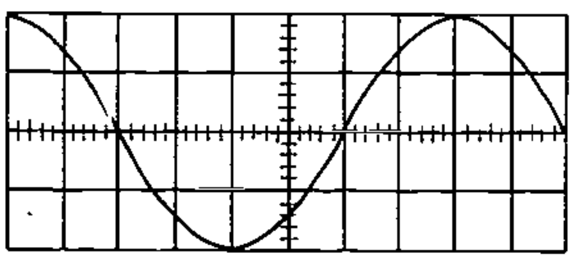
B.



C.



D.



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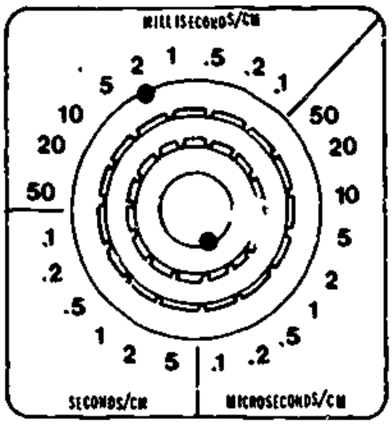
D. (B doesn't quite make one complete cycle)

Now, the question arises, "How do you get the smallest number of cycles?" The answer is, "Use the SWEEP TIME control." This control allows you to select how many cycles are displayed on the oscilloscope.

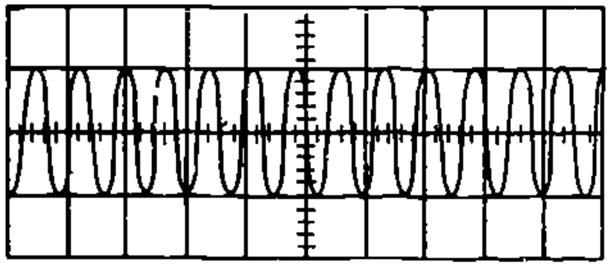
NOTE: NEVER take the Vernier control out of its calibrated position.




Notice that the sweep time dial is divided into microseconds/centimeter, milliseconds/centimeter and seconds/cm. Also notice that within the divisions of time per cm there are the numbers .1, .2, .5, 1, 2, 5, 10, 20, and 50. Increasing the sweep time will allow you to view more cycles on the oscilloscope.

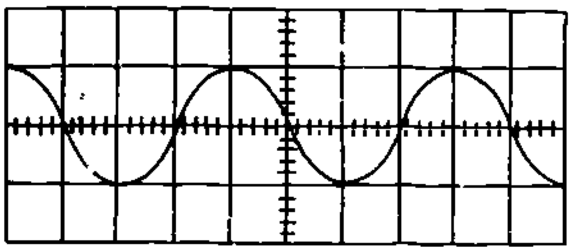
In the below illustrations, what would you have to do to display the smallest number of complete cycles?

A.



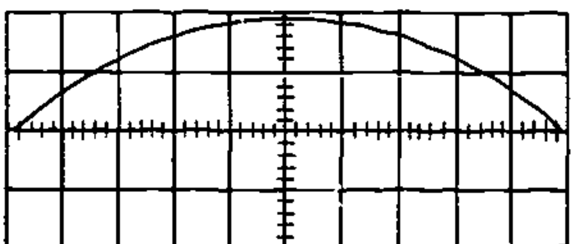
______________________

B.



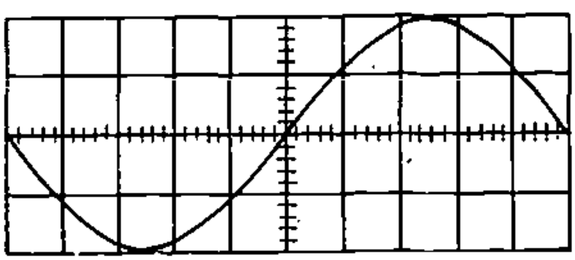
______________________

C.



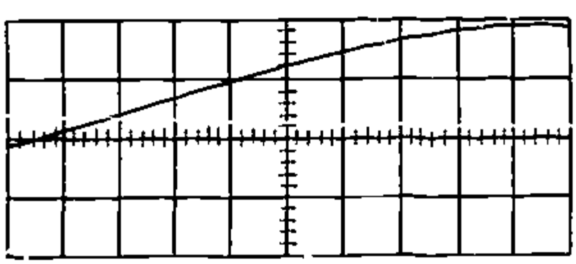
______________________

D.



______________________

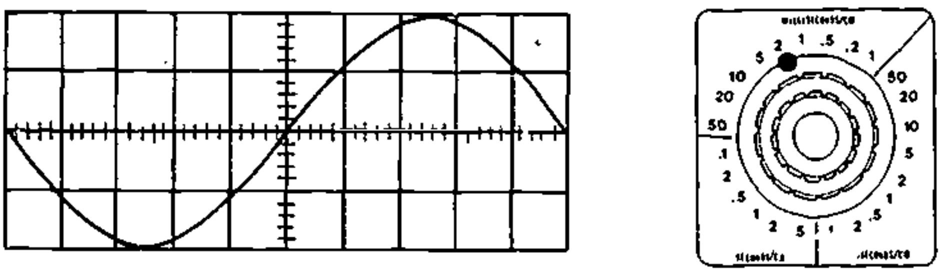
E.



______________________

A. Decrease sweep time
B. Decrease sweep time
C. Increase sweep time
D. Nothing (This is what you want.)
E. Increase sweep time

Now that you have the smallest number of cycles displayed on the oscilloscope, you are ready to determine the frequency. How? Well, you have to determine the period of the waveform. To do this you have to count the number of centimeters that <u>one complete</u> cycle covers on the oscilloscope face. Then multiply that number of centimeters by the setting of the <u>SWEEP TIME</u> control.

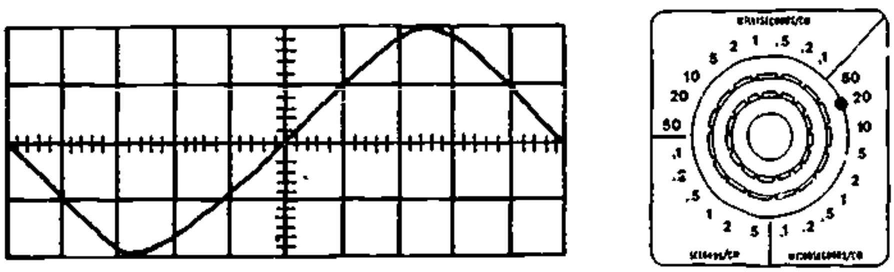


In this case:

t = 10 cm X 2 msec/cm

t = 20 msec

What are the periods of the below waveforms?



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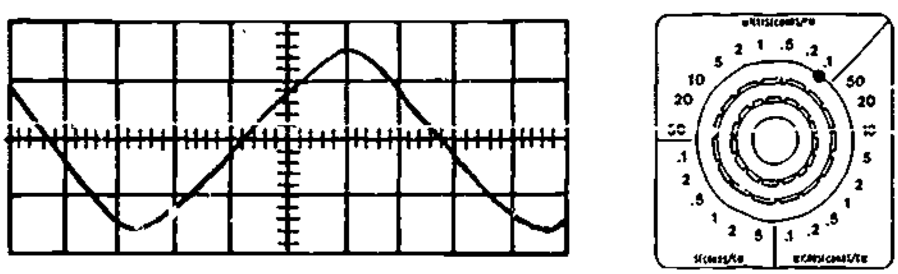
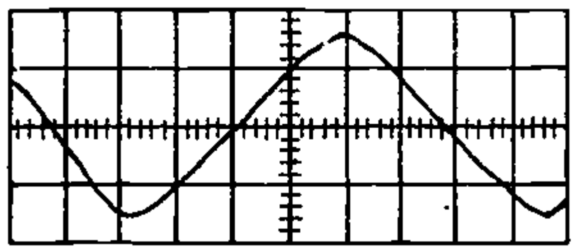


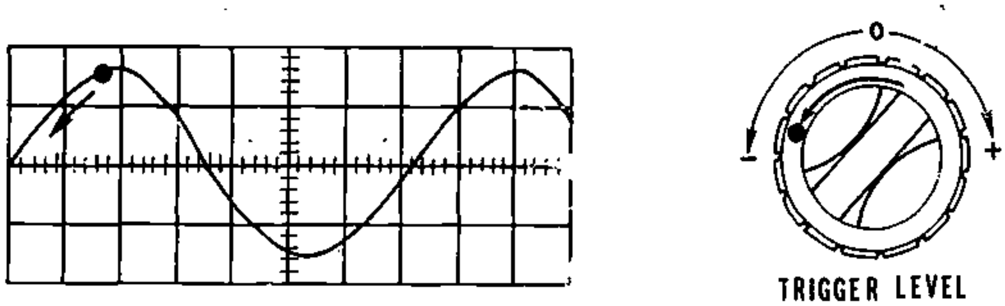
______________

A. 200 μsec
B. 0.72 msec

There is one other control that proves to be useful in frequency measurement -- the TRIGGER LEVEL control. Suppose you have a waveform that looks like this:

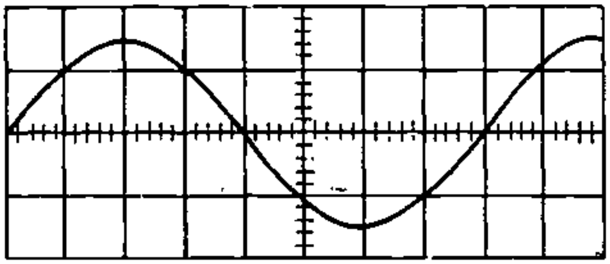


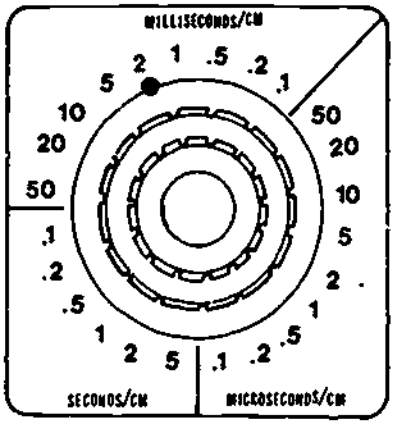
The TRIGGER LEVEL control allows you to move the starting point of the waveform in either a positive or negative direction. Moving the TRIGGER LEVEL control in the negative direction will cause the starting point to move in a negative direction.




Doing this will enable you to more easily sight the starting point of the waveform. Bear in mind that you can also measure the distance between crest to crest and trough to trough. Don't forget that you may use the HORIZONTAL control to shift the waveform horizontally for this purpose.

The final step in measuring frequency is to use the equation $f = \frac{1}{t}$. Take the time of the period you have calculated and divide this into 1. Let's try one together.






1 cycle covers 8 cm

Sweep Time set on 2μsec/cm

1 period (t) = 8cm x 2μsec/cm

1 period = 16μsec

$$f = \frac{1}{16\mu sec}$$

$$f = \frac{1}{16 \times 10^{-3}}$$

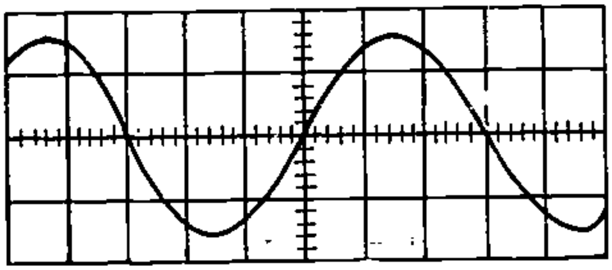
f = 62.5 Hz

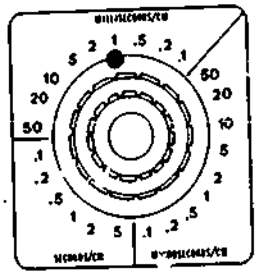
Narrative

Now you try some:

What are the frequencies of the below illustrated waveforms?

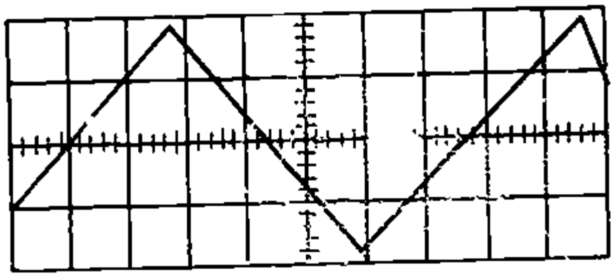
**A.**

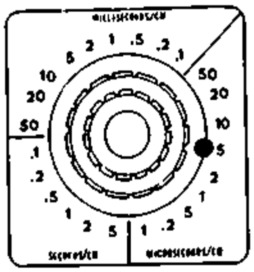




**F:** ______

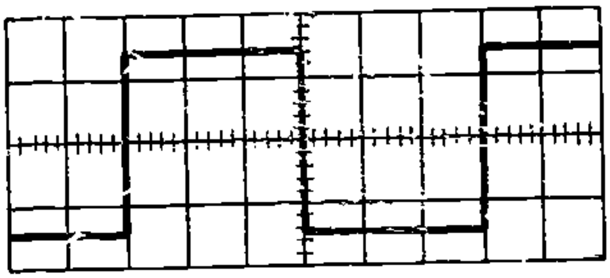
**B.**

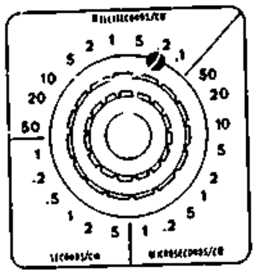




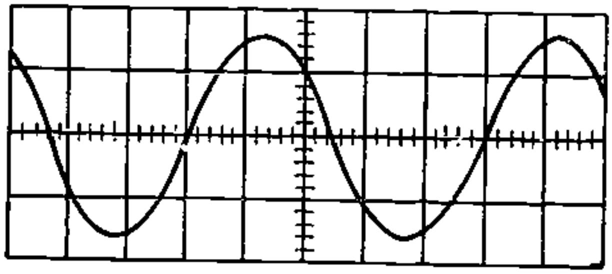
**F:** ______

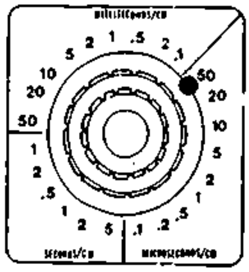
**C.**





**F:** ______

D. 



F: ______

---

| | |
|---|---|
| A. | 167 Hz 166.66 Hz |
| B. | 29 KHz 29.41 Hz |
| C. | 833 Hz 833.33 $H_3$ |
| D. | 4 KHz |

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.


Time waits for no man. . .
ACCIDENTS
WAIT
FOR
EVERYONE
COMPLACENCY KILLS!

BASIC ELECTRICITY AND ELECTRONICS

MODULE TWENTY TWO

LESSON IV

OSCILLATOR OPERATION

1 APRIL 1977

# OVERVIEW
# LESSON IV

## Oscillator Operation

In this lesson you will study and learn about the operation of an Armstrong oscillator, the operation of a Colpitts oscillator, the operation of a Clapp oscillator, and electronic voltmeters (EVM).

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

22.4.44 When the student completes this course, he will be able to TROUBLESHOOT an oscillator circuit, given a training device, required test equipment, technical manuals, schematics, and a practice board. Fault diagnosis to be 100% correct and any repair work completed on a practice board to pass a Learning Supervisor's visual and physical check.

ENABLING OBJECTIVE(S):

When the student completes this lesson, he will be able to:

22.4.44.7 IDENTIFY the schematic diagrams of three basic (Armstrong, Colpitts, and Clapp) oscillators, by selecting the correct name for each schematic from a set of four schematic drawings and a list of names. 100% accuracy is required.

22.4.44.7.1 IDENTIFY the purpose of the two series capacitors in the tank circuit of a Colpitts oscillator by selecting the correct statement, given a schematic and four statements about the tank circuit. 100% accuracy is required.

22.4.44.7.2 IDENTIFY the sections of an Armstrong oscillator (tank, amplifier, or feedback), given a schematic of an Armstrong oscillator and labeled components in each of the sections by selecting the correct statement from a set of four statements. 100% accuracy is required.

# OVERVIEW

22.4.44.8 OBSERVE the change in frequency of a tank circuit when changing certain components given an oscilloscope a training device and a job program. 100% accuracy is required.

22.4.44.9 IDENTIFY a commonly used voltage measuring device that should not be used to make voltage measurements on an oscillator circuit, given a list of test equipment. 100% accuracy is required.

22.4.44.10 OBSERVE and RECORD the loading effects which occur when a VOM is connected to measure voltage in an oscillator circuit, given an oscilloscope, a VOM, a job program, and a device containing an oscillator circuit. All measurements to fall within tolerances stated in the experiment sheet.

22.4.44.11 MEASURE and RECORD voltages in an oscillator circuit, given an EVM, oscillator training device, schematics, a job program and technical manual. Measurements to be within tolerances given in technical manual or progress check answer section.

22.4.44.12 IDENTIFY a malfunctioning component in a prefaulted oscillator circuit, given the necessary tools, job program, a prefaulted training device, an oscilloscope and the appropriate technical manual or schematic. Fault diagnosis to be 100% correct.

BEFORE YOU START THIS LESSON, READ THE LESSON LEARNING OBJECTIVES AND PREVIEW THE LIST OF STUDY RESOURCES ON THE NEXT PAGE.

LIST OF STUDY RESOURCES
LESSON IV

Oscillator Operation

To learn the material in this lesson, you have the option of choosing, according to your experience and preferences, any or all of the following:

Written Lesson presentation in:

Module Booklet:

Summary
Programmed Instruction
Narrative

Student's Guide:

Audio/Visual Response Sheet Twenty Two-IV-1
Job Program Twenty Two-IV-1 "Oscillator Operation"
Job Program Twenty Two-IV-2 "Loading Effects of Meters"
Job Program Twenty Two-IV-3 "Colpitts/Armstrong Oscillators"
Job Program Twenty Two-IV-4 "Troubleshooting Oscillators"
Progress Check

Additional Material(s):

Audio/Visual Program Twenty Two-IV-1 "Oscillator Operation"
Audio/Visual Program Twenty Two-IV-2 "AN/USM 116 EVM Operation"

Enrichment Material(s):

Electronics Installation and Maintenance Book, Electronic Circuits, NAVSHIPS 0967-000-0120, section 6
AN/USM 116 Technical Manual

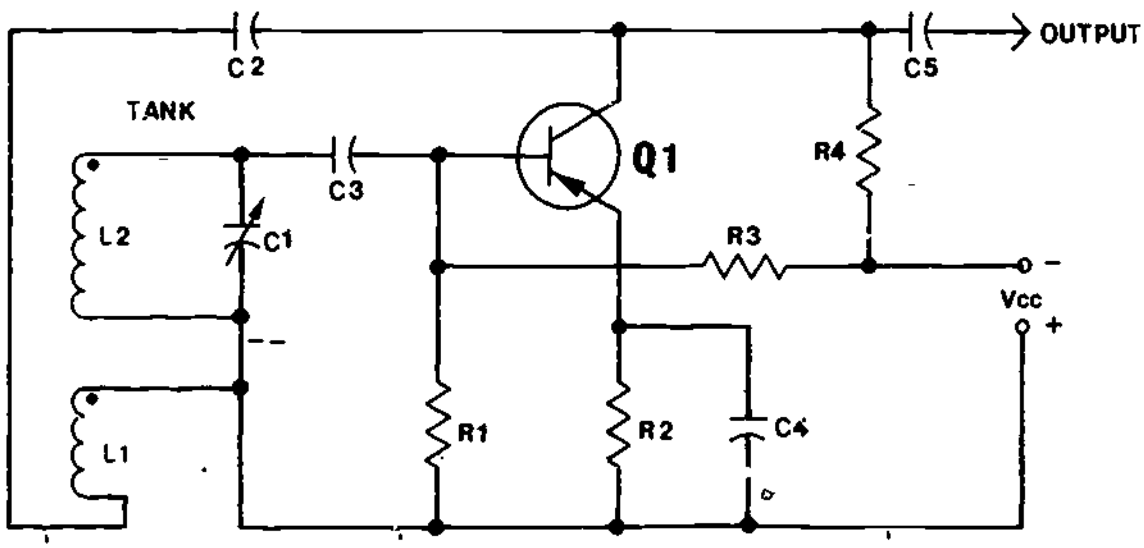
YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, INCLUDING THE LEARNING SUPERVISOR; HOWEVER, ALL MATERIALS LISTED ARE NOT NECESSARILY REQUIRED TO ACHIEVE LESSON OBJECTIVES. THE PROGRESS CHECK MAY BE TAKEN AT ANY TIME.

SUMMARY
LESSON IV

## Oscillator Operation

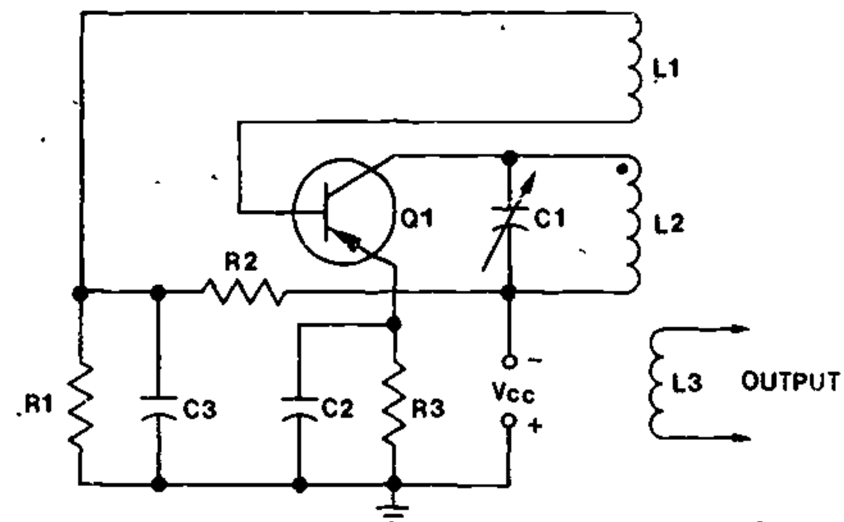
A feedback path and an amplifier must be added to a tank circuit in order to sustain oscillations. The amplifier will typically be a common-emitter amplifier which has a 180° phase shift. In order to replenish the losses in the tank circuit at the correct phase, there must also be 180° of phase shift in the feedback path. This type of feedback is called positive or regenerative.

An Armstrong oscillator uses a common-emitter amplifier and inductive feedback.



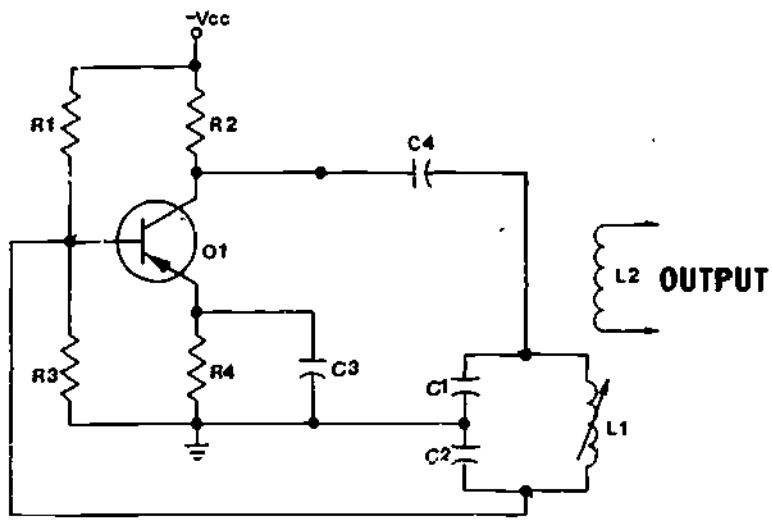

Sine wave oscillations are established in the tank circuit consisting of L2 and C1. These oscillations are fed through coupling capacitor C3 to the base of transistor amplifier Q1. The transistor amplifies the sine wave and part of the energy is coupled through C5 to the output. The remainder of the energy is fed back through C2 to "tickler" coil L1. L1 puts energy back into the tank through mutual induction with L2. Oscillations are thus sustained.

A variation of the Armstrong oscillator is shown on the next page:



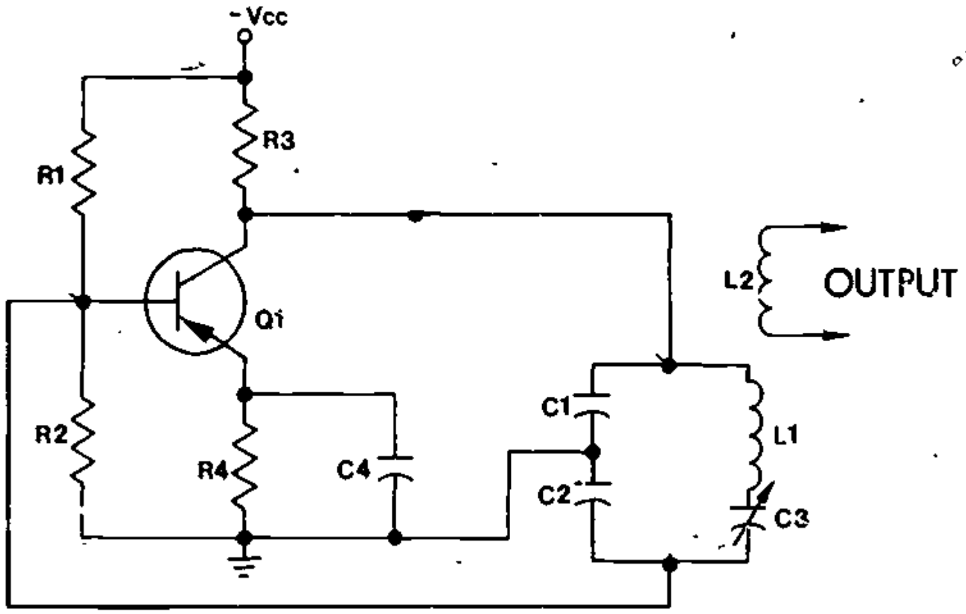

Energy from the tank circuit (L2 and C1) is coupled to the output via L3 and to the feedback path via L1. Transistor Q1 amplifies the energy from L1 and injects the energy right back into the tank.

A Colpitts oscillator utilizes two capacitors and a variable inductor in the tank.




Part of the sinewave energy is taken from capacitor C2, amplified, and fed back to capacitor C1. Inductor L1 is used to vary the frequency of oscillation. The oscillator output is taken from coil L2 which is wound on the same core with L1.

A variation of the Colpitts oscillator is the Clapp oscillator:




Here the tank consists of C1, C2, C3, and L1, and the frequency of oscillation can be changed by varying C3.

When measuring voltages in an oscillator circuit with a meter rather than an oscilloscope, an electronic voltmeter (EVM, DMM or VTVM) must be used to prevent circuit loading (frequency change and loss of amplitude).

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

# PROGRAMMED INSTRUCTION
## LESSON IV

## Oscillator Operation

TEST FRAMES ARE 7, 11, 13, AND 17. GO FIRST TO TEST FRAME 7 AND SEE IF YOU CAN ANSWER ALL THE QUESTIONS THERE. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

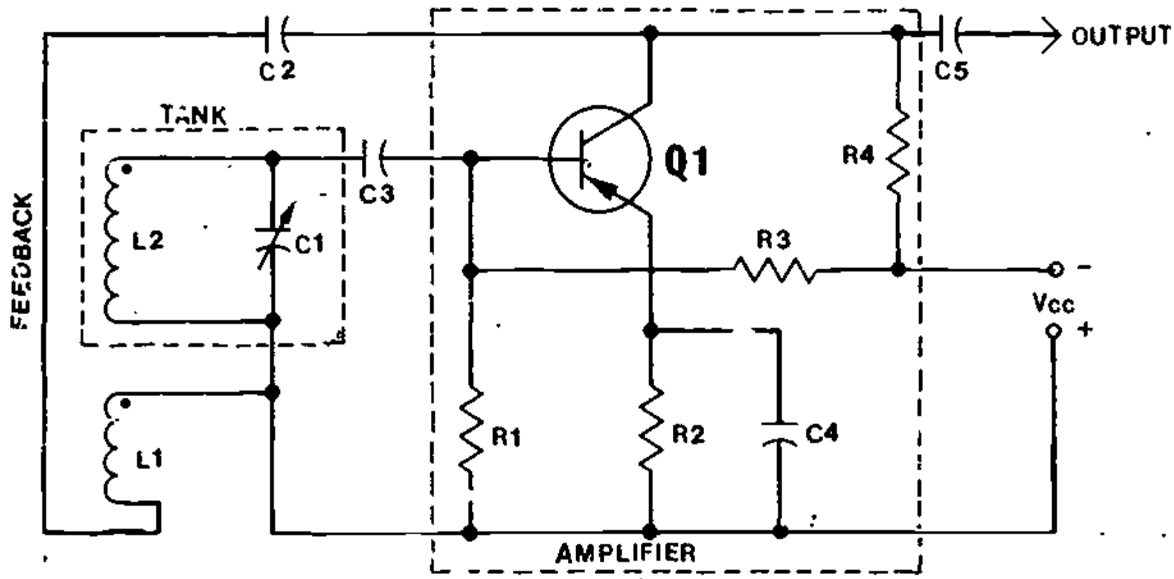
1. The operation of some actual oscillator circuits will be explored in this lesson. As you know, an amplifier and a feedback path must be added to a resonant circuit to sustain oscillations. The feedback to the tank circuit must be of the proper phase and amplitude to replenish the losses in the tank circuit. This type of feedback is called positive or regenerative feedback. In other words, there must be no difference in phase between the energy that leaves the tank circuit and the energy that is fed back to the tank circuit. The total phase shift in the amplifier and feedback path must be 0° or 360° (which is equivalent to 0°). The most common type of amplifier used in oscillators is a common-emitter amplifier. Feedback can be accomplished in various ways: inductive, capacitive, or direct.

Since a common-emitter amplifier has a 180° phase shift, how much additional phase shift will be necessary in the feedback path to obtain a positive feedback?

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

180°

2. An example of an oscillator using a common-emitter amplifier and inductive feedback is shown below.



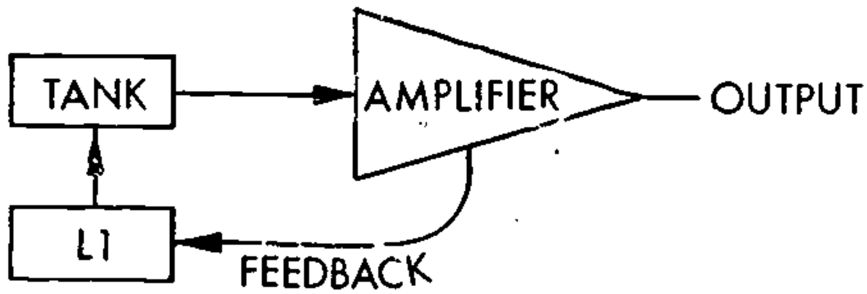

The tank circuit consists of inductor L2 and capacitor C1. The sine wave output of the tank is fed through coupling capacitor C3 to the base of transistor amplifier Q1. Transistor Q1 amplifies the sine wave which is coupled to the output through C5. What would happen to the sine wave if there were no feedback?

---

The sine wave would be damped because of losses in the tank (or words to that effect).

3. Part of the sine wave output is fed back through coupling capacitor C2 to inductor L1. Inductor L1 and L2 are wound on a common core. Part of the sine wave energy on L1 is induced into L2. The transistor amplifie will invert the sine wave by 180° and the mutual inductance between L1 and L2 will also invert the sine wave by 180°. Therefore the sine wave induced from L1 and L2 will reinforce the oscillations in the tank.

The sequence of energy can be shown as:




The purpose of L1 is to:

a. Establish oscillator frequency.
b. Provide coupling for the feedback path.
c. Couple the energy out of the tank.
d. Provide a DC path to ground.

---

b. Provide coupling for the feedback path.

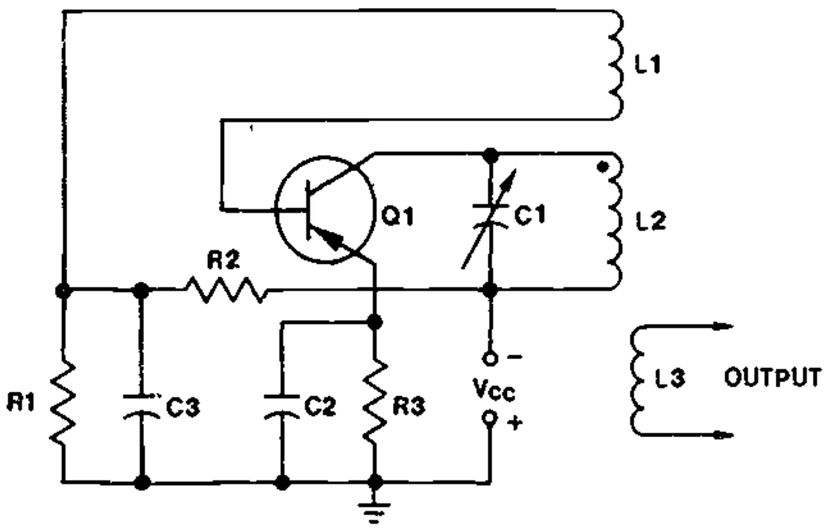
4. The type of oscillator shown in frame 2 is called an Armstrong oscillator - named after the man who invented it. An Armstrong oscillator is characterized by a "tickler" coil that feeds energy back into the tank.

Which inductor would be considered the "tickler" coil in the oscillator shown in Frame 2?

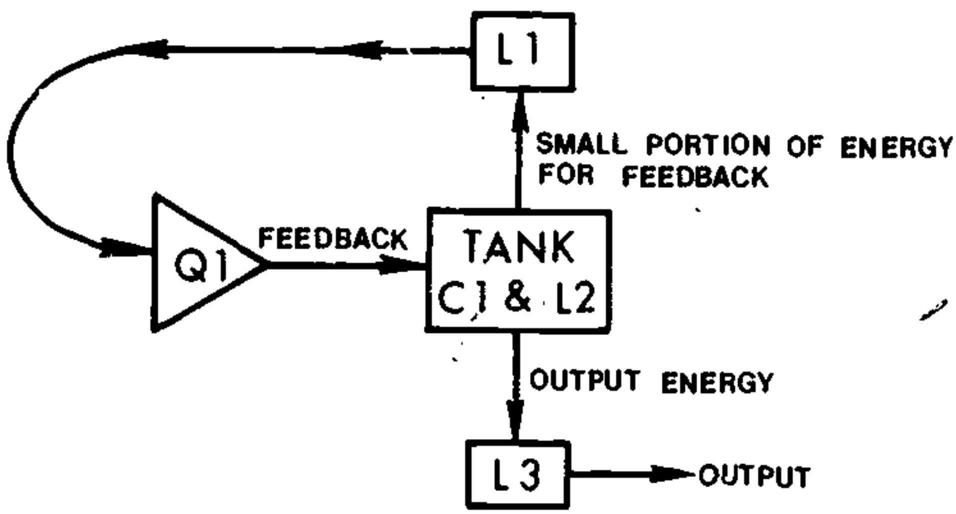
---

L1

5. Another type of Armstrong oscillator couples the energy out of the oscillator by using another inductor:



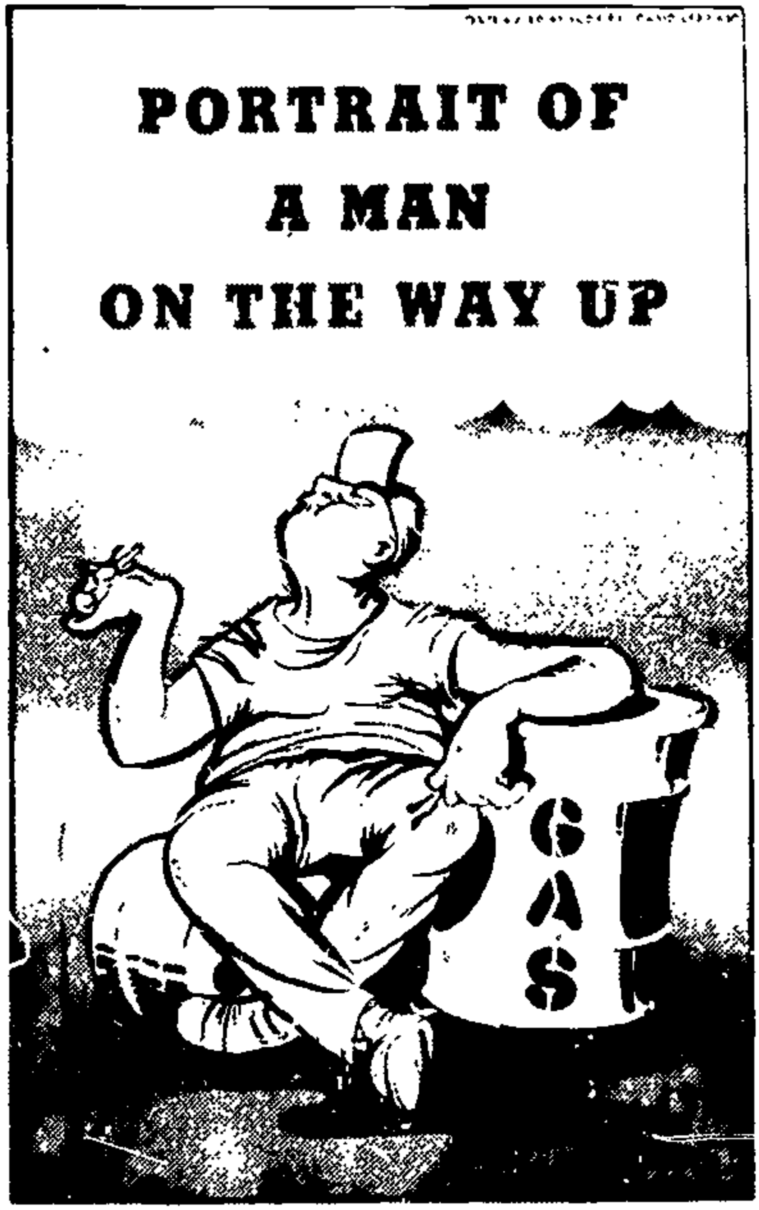

In this oscillator, the sequence of energy flow can be shown as:




A sine wave generated by the tank is induced into both L1 and L3. Inductor L3 couples the energy to the output. Inductor L1, feeds the energy to amplifier Q1. Amplifier Q1 amplifies the sine wave and feeds the amplified energy back to the tank to sustain oscillations.

Which inductor in the oscillator illustrated above will determine the frequency of oscillation?

a. L1
b. L2
c. L3


PORTRAIT OF
A MAN
ON THE WAY UP
GAS

b. L2 since it is part of the tank circuit.

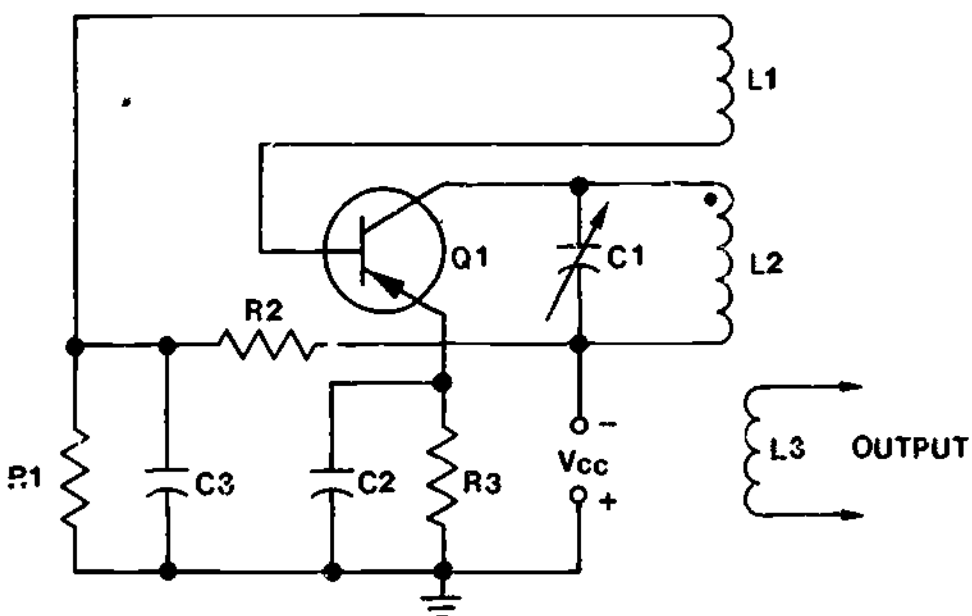
6. The frequency of oscillation in both the Armstrong oscillators covered so far could be changed easily by adjusting variable capacitor C1. Would changing the value of any component other than the inductor or capacitor in the tank change the frequency of oscillation?

---

No, not significantly, although there may be small changes.

7. TEST FRAME

What is the purpose of transistor Q1 in the oscillator illustrated below?




a. To feed energy to the tank circuit to sustain oscillations.
b. To feed energy to L1 for feedback to the tank circuit.
c. To establish the proper frequency of oscillation.
d. To provide a means of coupling the output signal to an external load.

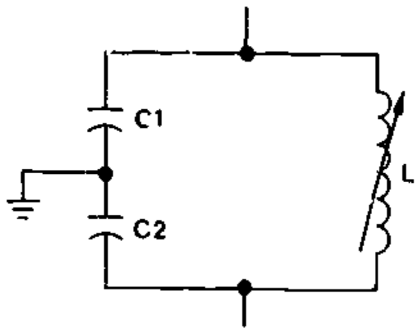
---

THIS IS A TEST FRAME. COMPARE YOUR ANSWER WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE NEXT PAGE.

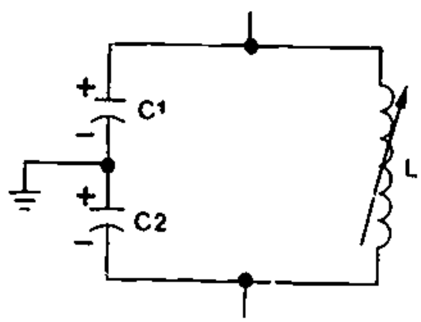
a. To feed energy to the tank circuit to sustain oscillations.

IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 11. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 7 AGAIN.

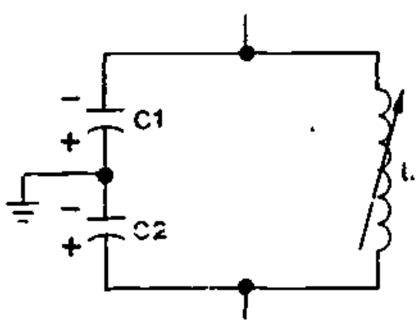
8. Another type of oscillator, called the Colpitts oscillator, uses a tank with two capacitors and a variable inductor.




The point between the two capacitors is connected to ground. With respect to ground, the sine wave at the top of the tank is 180° out of phase with the sine wave at the bottom of the tank. For example, at one instant of time the charges on the capacitors will be:

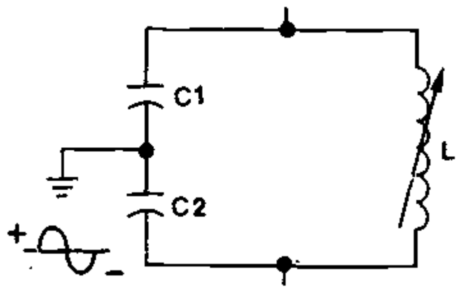


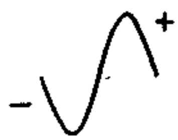

The top of the tank will be positive when the bottom is negative. On the next half cycle, the top of the tank will be negative when the bottom is positive



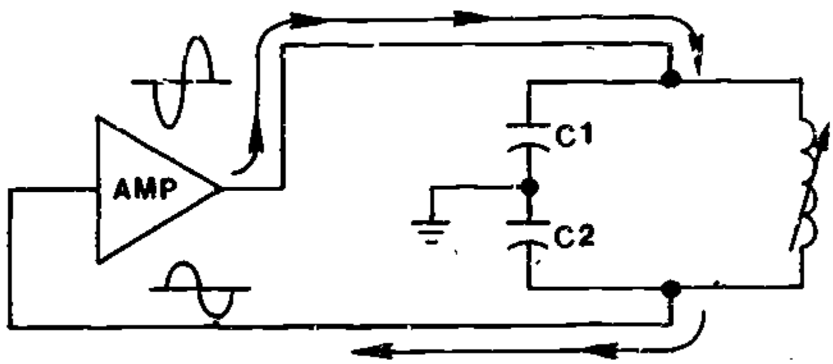

87

Using the tank illustrated below, and given the sine wave at the bottom of the tank, draw the sine wave which you would expect to find at the top of the tank.




9. In the Colpitts oscillator tank circuit, capacitors C1 and C2 act as a capacitive voltage divider across the tank circuit. The voltage across C2 will be the input to the amplifier. The output of the amplifier will be fed back to C1.




Since the voltage across C2 is the input voltage to the amplifier, the amount of feedback depends on the ratio of the values of the two tank capacitors C1 and C2.

If the capacitance of C1 is decreased, the reactance of C1 will increase. This will cause more of the total tank voltage to drop across C1 and less across C2. With less voltage across C2, the input signal to the amplifier will be less; that is, less feedback will occur.

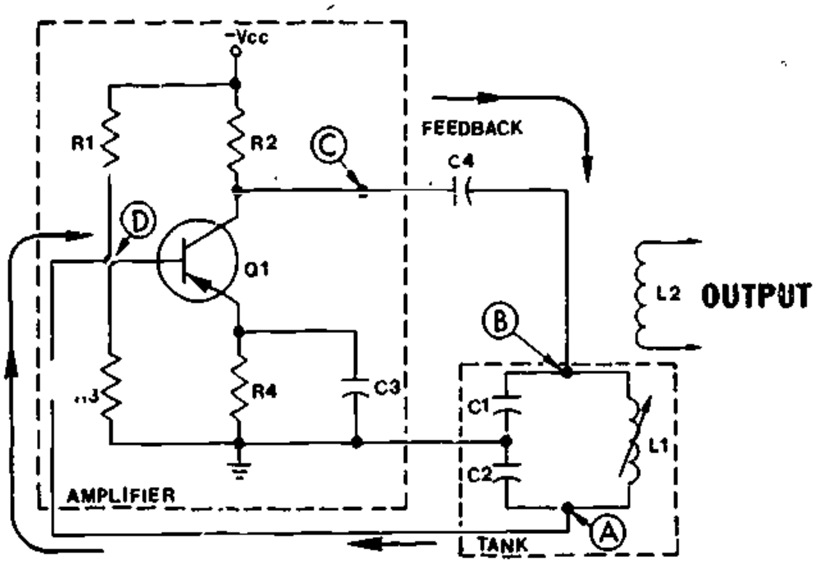
The amount of feedback is very important in establishing oscillations and maintaining stability in the oscillator. If there is too much positive feedback, the signal will grow larger and larger until it exceeds the limits of the amplifier causing the sine wave to be distorted. If there is too little positive feedback, the oscillations will be damped.

A part of (sample) of the tank sine wave is taken from capacitor ________ and the amplified sine wave is fed back to capacitor ____________.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

C2, CI (in that order)

10. A complete Colpitts oscillator circuit is shown below:




Part of the sine wave is taken out of the tank at point A. This energy is amplified by transistor Q1. The amplified sine wave is fed back through capacitor C4 to the tank at point B. The sine wave oscillations are thus sustained. The oscillator output is taken from coil L2 which is wound on the same core with L1. The frequency of oscillation may be varied by adjusting L1.

The flow of energy in the Colpitts oscillator shown above is from point A, to point ______, to point _______, and back to point B.

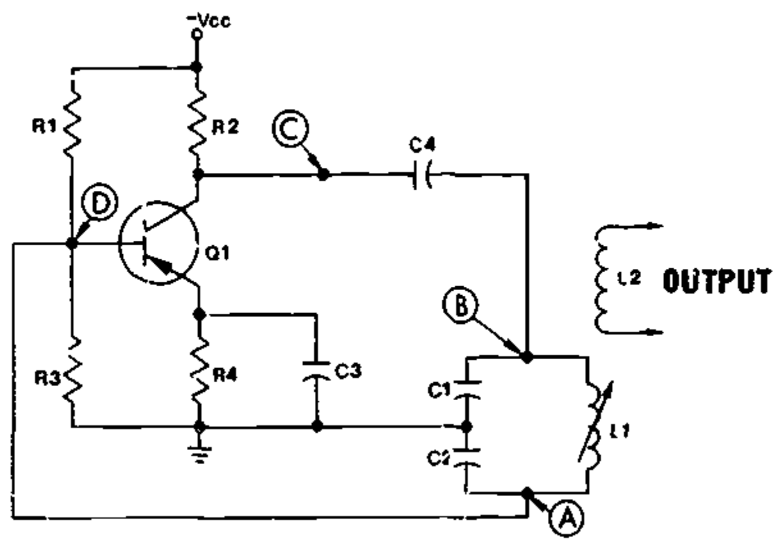
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

D, C, (in that order)

89

II. TEST FRAME

(1) List the components in each functional part of the Colpitts oscillator below:




COMPONENTS

Tank ______________________

Amplifier ______________________

Feedback coupling ______________________

(2) The two capacitors in the tank circuit of a Colpitts oscillator form a (current/voltage) div‘‘er r.:.w_rk and provide

a. two tank circui· ‘als that are in phase.
b. two tank circuit s ls 180° out of phase.
c. one tank circuit sign.l at double the amplitude.
d. source voltage to the emitter of Q1.

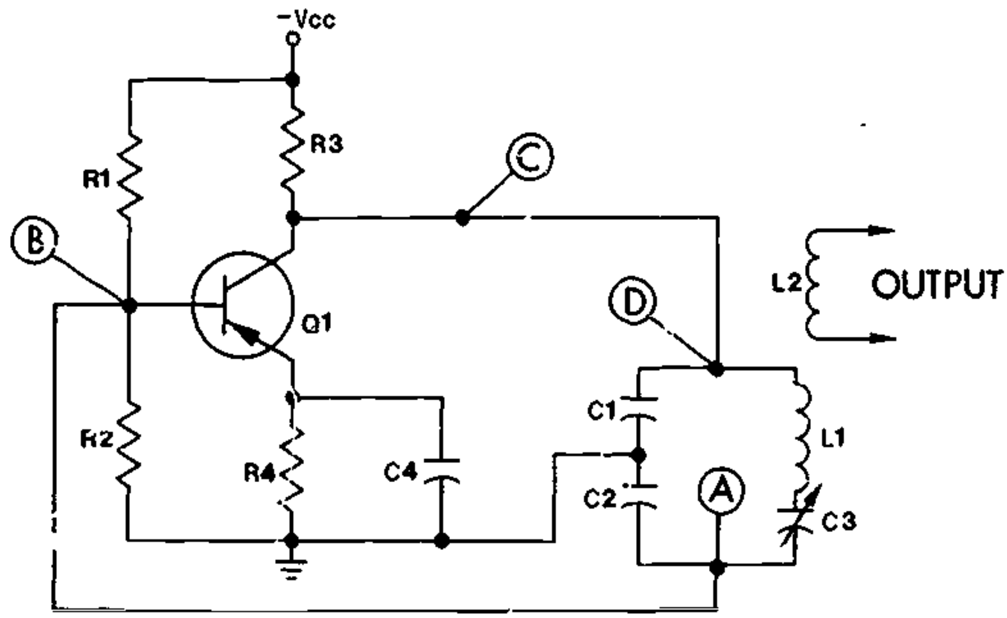
---

THIS IS A TEST FR.ME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.

(1) Tank C1, C2, L1
Amplifier Q1, R1, R2, R3, R4, C3
Feedback coupling C4
(2) Voltage, b. (two tank circuit signals 180° out of phase.)

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 13. OTHERWISE GO BACK TO FRAME 8 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 11 AGAIN.

12. A variation of the Colpitts oscillator is called the Clapp oscillator. The Clapp oscillator has a variable capacitor C3 in series with a fixed inductor L1 in the tank.




The frequency of oscillation can be changed by varying C3. The operation of the Clapp oscillator is basically the same as the Colpitts oscillator. Part of the sine wave energy is taken out of the tank at point A, coupled into the amplifier at point B, is amplified, tapped out of the amplifier at point C, and fed back to the tank at point D. Sine wave energy is also taken out of the tank by the mutual induction between L1 and L2.

List the components that determine the frequency of oscillation in the above circuit.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

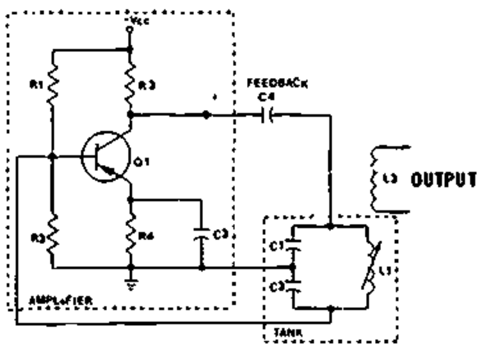
L1, C1, C2 and C3

13. TEST FRAME

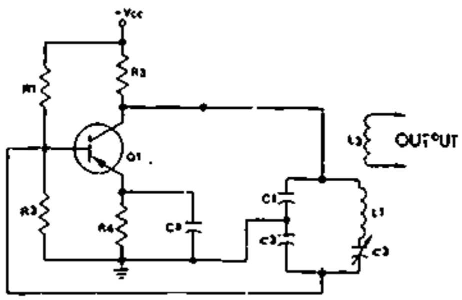
Select the correct name from column B and match it to its respective schematic diagram in column A.

COLUMN A

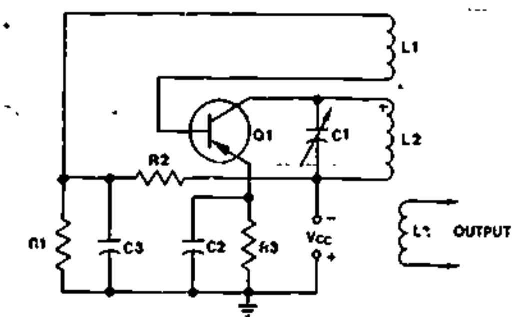
a.




b.




c.




COLUMN B

1. Clapp oscillator
2. Armstrong oscillator
3. Allen oscillator
4. Colpitts oscillator

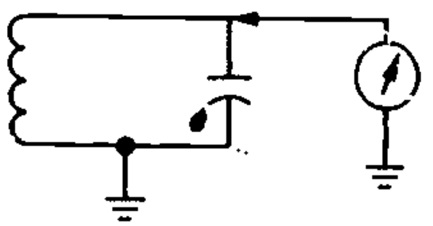
---

THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.

a. 4. Colpitts oscillator
b. 1. Clapp oscillator
c. 2. Armstrong oscillator

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 17. OTHERWISE, RESTUDY FRAME 12 BEFORE GOING ON.

14. Whenever a meter is used for voltage measurement on an oscillator tank circuit, the meter is placed in parallel with the tank.



If the meter is a VOM (AN/PSM-4 or Simpson 260) the energy needed to operate the meter movement will have to come from the circulating current in the tank. What will happen to the amplitude of oscillations in the tank circuit if you connect a VOM to it?

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Oscillation amplitude will decrease.

15. The actual amount of decrease will depend upon how much energy is drawn from the tank.

A second loading effect caused by a standard VOM is a frequency change. The meter leads and the meter itself have some capacitive reactance. How will this added reactance affect the frequency of the oscillator?

$$\left(f_o = \frac{.159}{\sqrt{LC}}\right)$$

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

The frequency will decrease.

93

16. Because of these loading effects (decreased amplitude and change in oscillator frequency), you must use a voltmeter which will not remove much power from the circuit. An electronic voltmeter, often called a VTVM, meets this requirement. The letters VTVM stand for Vacuum Tube Volt Meter, and are generally used for any meter that has an electronic amplifier in it. Some of these meters have some solid state circuitry but are still called VTVMs. (See Note 2.) A more modern term for these meters is EVM for Electronic Volt Meter or DMM for Digital Multi-Meter.

Besides a VTVM, what other piece of test equipment can be used to measure voltage in an oscillator circuit?

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

An oscilloscope

NOTE 1: In order to get the minimum loading effect from an oscilloscope you should use a 10X probe when taking measurements.

NOTE 2: One type of solid state meter uses a field effect transistor in order to achieve high input impedance. This meter is called an F.E.T. meter.

17. TEST FRAME

List two types of test equipment that can be used to measure voltage in an oscillator circuit.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

THIS IS A TEST FRAME. COMPARE YOUR ANSWERS WITH THE ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.

An oscilloscope and a VTVM, EVM, or DMM.

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON IV, MODULE TWENTY TWO. OTHERWISE GO BACK TO FRAME 14 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 17 AGAIN.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON IV

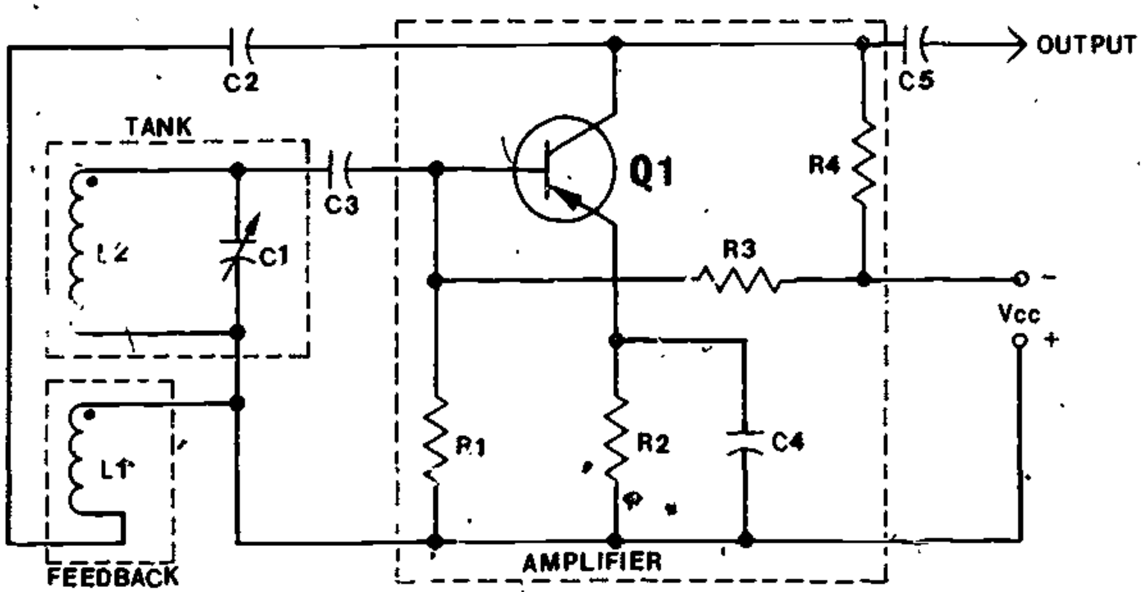
Oscillator Operation

The previous lesson showed how tank circuits establish a given frequency of oscillation. This lesson will indicate how amplifiers and feedback paths are added to tank circuits. The most common type of amplifier used in transistorized oscillators is a common-emitter amplifier. Feedback can be accomplished in various ways: inductive, capacitive, and direct.

The feedback to the tank circuit must be of the proper phase and amplitude to replenish the losses in the tank circuit. This type of feedback is called positive or regenerative. In other words, there must be no difference in phase between the energy that leaves the tank circuit and the energy that is fed back to the tank circuit. The total phase shift in the amplifier and feedback path must be 0° or 360° (which is equivalent to 0°). Since a common-emitter amplifier has a 180° phase reversal, the phase shift in the feedback path must also be 180°. If there is a total phase shift of 360°, the sine wave feedback to the tank circuit will support the oscillations in the tank.

An Armstrong oscillator uses a common-emitter amplifier and inductive feedback.

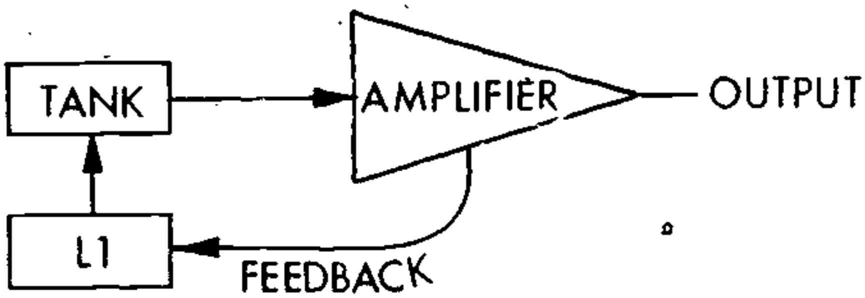
The inductive feedback provides 180° of phase reversal through transformer action. A typical Armstrong oscillator is shown below.



The tank circuit consists of inductor L2 and capacitor C1. The sine wave output of the tank is fed through coupling capacitor C3 to transistor amplifier Q1. Transistor Q1 amplifies the sine wave produced by the tank. Part of the amplified sine wave is connected to the oscillator output through coupling capacitor C5.

The rest of the amplified sine wave is connected through coupling capacitor C2 to inductor L1. Inductor L1 is wound on a common core with L2 (in the tank circuit). L1 is referred to as a "Tickler" coil. By mutual inductance, sine wave energy on L1 is induced into L2 to sustain the oscillations in the tank. The amplifier will invert the sine wave by 180° and the transformer action between L1 and L2 will invert the sine wave by another 180°.

The sequence of energy flow can be shown as:




Armstrong Oscillator

Notice that C1 is a variable capacitor. This allows an easy method of varying the frequency of oscillation.

The purpose of L1 is to

a. establish oscillator frequency.
b. provide coupling of the feedback path.
c. couple the energy out of the resonant tank.
d. provide a DC path to ground.

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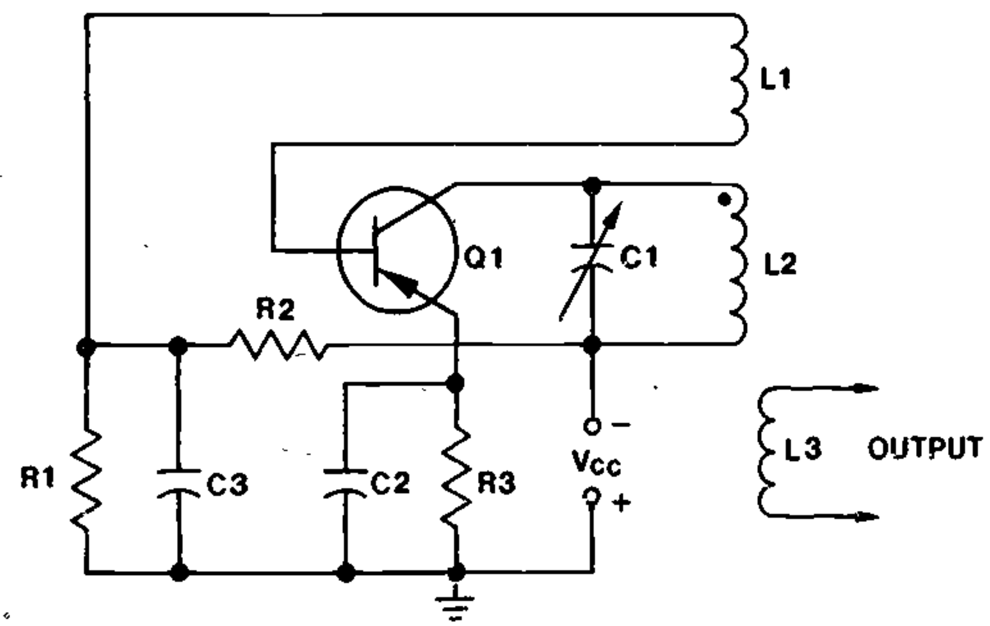
97

b. provide coupling of the feedback path.

The arrangement of the various elements in an oscillator can be changed and we can still have a functioning circuit. For example, the oscillator illustrated below is also an Armstrong oscillator.




The output energy in the Armstrong oscillator is coupled through L3. Inductors L1, L2, and L3 are all wound on the same core.

Which inductor in the Armstrong oscillator will determine the frequency of oscillation?

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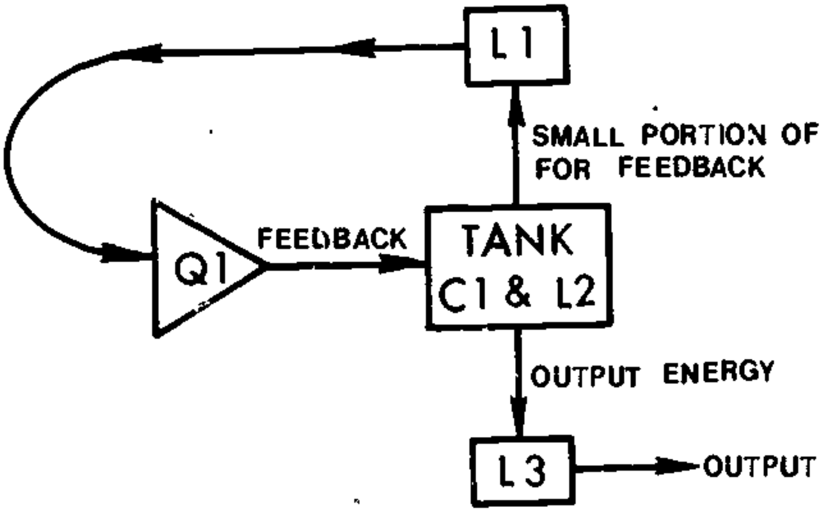
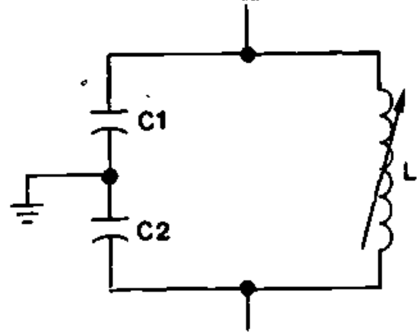
L2, since it is part of the tank circuit.

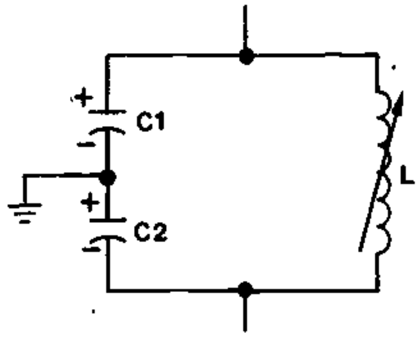



Armstrong Oscillator

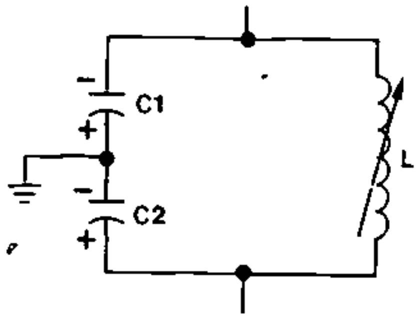
Another type of oscillator, called the Colpitts oscillator, utilizes a special type of tank circuit with two capacitors and a variable inductor:




The point between the two capacitors is connected to ground so that, at one instant of time, the charges on the capacitors will be as shown below: the top of the tank will be positive and the bottom negative.



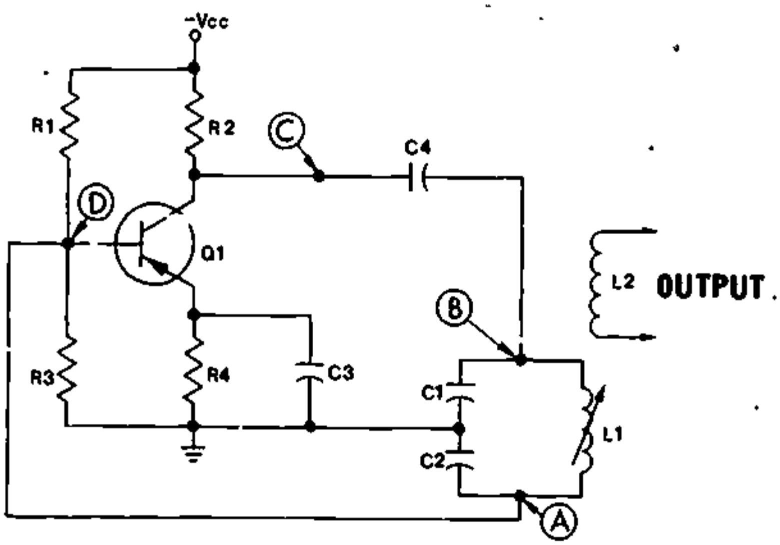
On the next half cycle, the top of the tank will be negative when the bottom is positive, as shown below:




Therefore, the sine wave at the top of the tank will be 180° out of phase with the sine wave at the bottom of the tank.

In the Colpitts oscillator tank circuit, capacitors C1 and C2 act as a capacitive voltage divider across the tank circuit. The voltage across C2 will be the input to the amplifier and the output of the amplifier will be fed back to C1. The amount of feedback depends on the ratio of the values of the two tank capacitors.

A typical Colpitts oscillator circuit is shown below:




Part of the sine wave energy is taken out of the tank at point A. This energy is fed to point D and is amplified by transistor Q1. The amplified sine wave appears at point C and is fed back through capacitor C4 to the tank at point B. The sine wave oscillations are thus sustained The oscillator output is taken from coil L2 which is wound on the same core with L1.

List the components in each functional part of the Colpitts oscillator.

COMPONENTS

Tank ________________________________

Amplifier ________________________________

Feedback coupling ________________________________

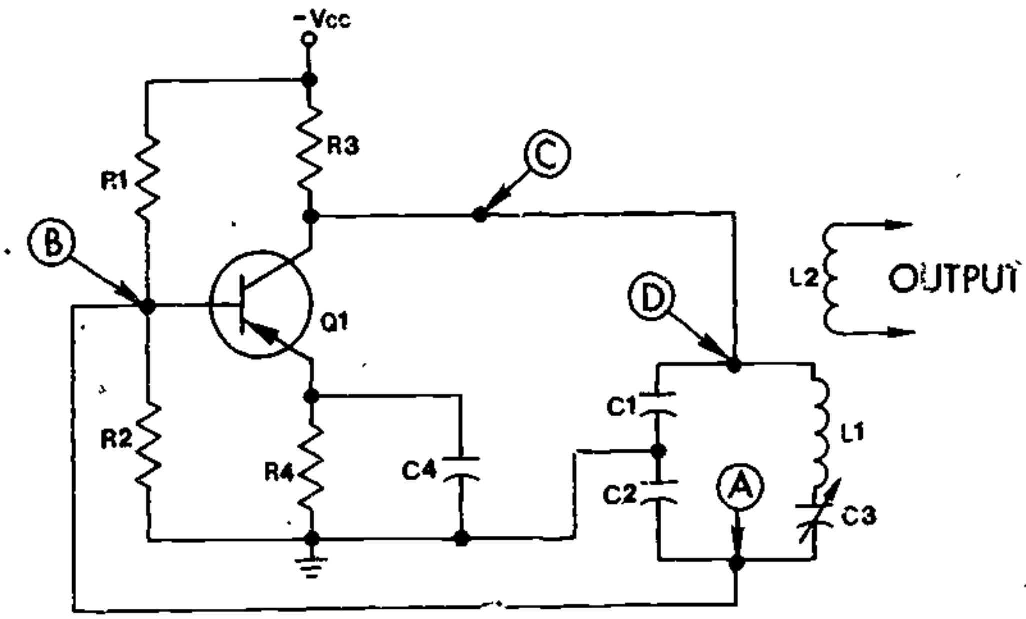
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Tank C1, C2, L1

Amplifier Q1, R1, R2, R3, R4, C3

Feedback coupling C4

A variation of the Colpitts oscillator is called the Clapp oscillator. The Clapp oscillator has a variable capacitor (C3) in series with a fixed inductor (L1) in the tank.




The frequency of oscillation can be changed by varying C3. The operation of the Clapp oscillator is basically the same as the Colpitts oscillator. Part of the sine wave energy is taken out of the tank at point A, coupled into the amplifier at point B, is amplified, tapped out of the amplifier at point C, and fed back to the tank at point D to produce an output and continue oscillations.

Sine wave energy is also taken out of the tank by the mutual induction between L1 and L2.

List all the components of the Clapp oscillator that determine the frequency of oscillation.

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

L1, C1, C2, and C3

The name of the game is troubleshooting and in order to troubleshoot you need test equipment. When troubleshooting oscillators, care must be taken in choosing the correct voltmeter to use.

If you were to connect a standard V O M (i.e., AN/PSM-4 or Simpson 260) to an oscillator circuit, the output frequency and amplitude would change. These loading effects could cause false casualty indications elsewhere in the system. It is even conceivable that actual casualties could be caused by using the wrong meter.

Here is an example of the type of trouble you can get into by using improper test equipment. A technician connects a VOM to an oscillator circuit and he notices the amplitude and frequency in the circuit are wrong so he adjusts them until they are correct. Now when he removes the meter, the loading effect disappears and the amplitude and frequency of the output change. The sad part of this story is that, unless he realizes his mistake, he may go far afield looking for the source of his troubles before he comes back to these adjustments because he has already made them and "they are correct".

The meter that must be used to measure voltage in an oscillator circuit is one which will not load down the circuit. An electronic voltmeter has a high input impedance (Z) and will not load these circuits.

This type of meter is usually referred to as a VTVM (Vacuum Tube Volt Meter) even though some of the newer types have solid state circuitry. A more modern term is EVM (Electronic Volt Meter) or DMM (Digital Multimeter).

NOTE: One type of solid state electronic meter uses a field effect transistor in order to achieve high input impedance. This meter is called an F.E.T. meter.

Another piece of test equipment (other than a meter) that can be used to measure voltages in an oscillator is an oscilloscope. Due to its internal construction, an oscilloscope will generally not load down the circuit under test.

NOTE: In order to get the minimum loading effect from an oscilloscope you should use a 10X probe while taking measurements.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE NEXT LESSON. IF YOU INCORRECTLY ANSWER ONLY A FEW OF THE PROGRESS CHECK QUESTIONS, THE CORRECT ANSWER PAGE WILL REFER YOU TO THE APPROPRIATE PAGES, PARAGRAPHS, OR FRAMES SO THAT YOU CAN RESTUDY THE PARTS OF THIS LESSON YOU ARE HAVING DIFFICULTY WITH. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST, OF THE LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH LEARNING SUPERVISOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.