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ABSTRACT

This individualized learning module on radio frequency (RF), intermediate frequency (IF), and video amplifiers 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) RF, IF, and Video Amplifier Characteristics; (2) RF Amplifiers; (3) IF Amplifiers; and (4) Video Amplifiers. Each lesson follows a typical format including a lesson overview, a list of study resources, and lesson summary. (Progress checks and other supplementary material are provided for each lesson in a student's guide, CE 026 587.) (LRA)

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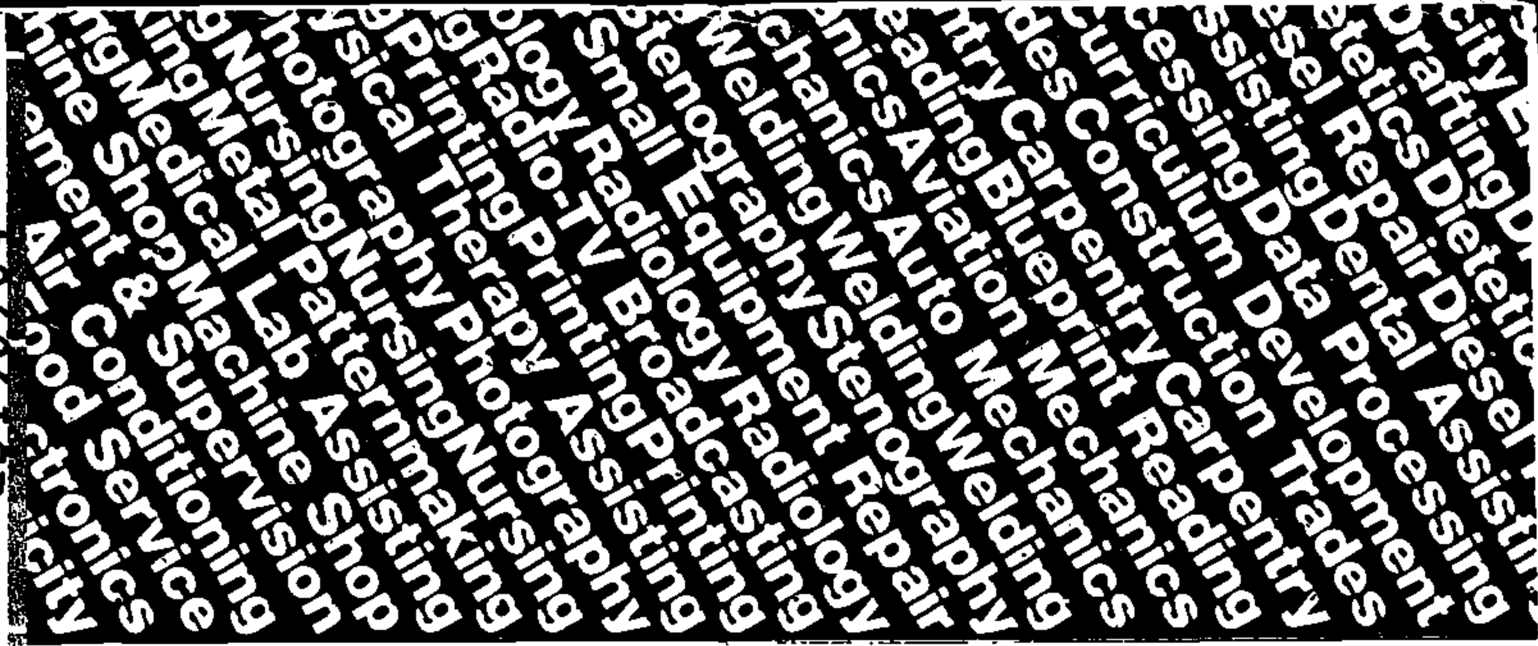

Military Curricula for Vocational & Technical Education

CHIEF OF NAVAL EDUCATION AND TRAINING

CNTT-E-053

JULY 1980

BASIC ELECTRICITY AND ELECTRONICS.

MODULE 31. RF, IF, AND VIDEO AMPLIFIERS.

STUDY BOOKLET.

CE 026 589

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
Director
100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

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 THIRTY ONE

RF, IF AND VIDEO AMPLIFIERS

PREPARED BY

NAVAL EDUCATION AND TRAINING

PROGRAM DEVELOPMENT CENTER DETACHMENT

GREAT LAKES NAVAL TRAINING CENTER

GREAT LAKES, ILLINOIS 60088

STUDY BOOKLET
JULY 1980

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OVERVIEW
BASIC ELECTRICITY AND ELECTRONICS
MODULE THIRTY ONE

RF, IF, and Video Amplifiers

In this module you will learn about different types of amplifiers that operate at frequencies above and below the audio frequency range. You will determine the characteristics of these amplifiers and study their operation. You will learn new terms and definitions, and you will apply your knowledge of basic amplifiers and electronics to troubleshoot them.

This module has been divided into four lessons:

Lesson 1 RF, IF, and Video Amplifier Characteristics
Lesson 2 RF Amplifiers
Lesson 3 IF Amplifiers
Lesson 4 Video Amplifiers

BASIC ELECTRICITY AND ELECTRONICS

MODULE THIRTY ONE

LESSON 1

RF, IF, AND VIDEO AMPLIFIER CHARACTERISTICS

JULY 1980

OVERVIEW
LESSON 1

RF, IF, and Video Amplifier Characteristics

In this lesson you will be introduced to different types of amplifiers that operate at frequencies above and below the audio frequency range. You will become familiar with some important operating characteristics of these amplifiers. You will learn to use amplifier frequency response curves. You also will learn how to find amplifier gain by using decibel conversion charts and graphs.

The learning objectives of this lesson are:

TERMINAL OBJECTIVE(S):

31.1.52 When the student completes this lesson, (s)he will be able to IDENTIFY basic operating characteristics of RF, IF, and video amplifiers to include selecting definitions of terms, determining amplifier frequency response curve values, and determining amplifier voltage and power decibel gain, by selecting statements or values from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVE(S):

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

31.1.52.1 DEFINE the general characteristics of an amplifier, to include center frequency (fo), cutoff frequency (fco), frequency response, and bandwidth, which are shown in a frequency response curve, by selecting the correct definition from a choice of four. 100% accuracy is required.

31.1.52.2 DETERMINE the frequency response characteristics of an amplifier, given its frequency response curve, by selecting the correct statement from a choice of four. 100% accuracy is required.

31.1.52.3 DEFINE the term "selectivity" as it applies to RF, IF, and video amplifiers by selecting the correct definition from a choice of four. 100% accuracy is required.

31.1.52.4 IDENTIFY the general operating characteristics of RF, IF, and video amplifiers, including frequency range, selectivity, and tuning, by selecting the correct statement from a choice of four. 100% accuracy is required.

31.1.52.5 CONVERT given amplifier voltage and power gain ratios to decibels (dB), and vice versa, given a decibel conversion chart/graph, by selecting the correct value(s) from a set of four choices. 100% accuracy is required.

31.1.52.6 DETERMINE total gain and output levels (in terms of voltage, power, or decibels) for a given single or cascaded amplifier circuit when provided a decibel conversion chart/graph and input data, by selecting the correct value(s) from a set of four choices. 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 1

RF, IF, and Video Amplifier Characteristics

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:

Summary
Progress Check

Additional Material(s):

35 mm sound/slide Thirty One-1 "RF, IF, and Video Amplifier Characteristics"

Enrichment Material(s):

NAVSHIPS 0967-000-0120 "Electronic Circuits" Electronics Installation and Maintenance Book (EIMB) Naval Ship Engineering Center, Washington, D.C.: U.S. Government Printing Office 1965.

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

SUMMARY
LESSON 1

RF, IF, and Video Amplifier Characteristics

RF, IF, and video amplifiers are important in communication and radar electronic equipment. Two major categories of information in a basic transmit-receive system are audio signals (20 Hz to 20,000 Hz) and video signals (0 Hz to 6 MHz). Amplifiers you have studied were in the audio frequency response range and were designed to amplify about equally well any signal within that range.

This lesson describes some important operating characteristics of amplifiers. Recall that frequency response is expressed as two numbers, the upper Fco (cut-off frequency) and lower Fco, while bandwidth is expressed as the difference between them. The amplitude of an output signal has its maximum (100%) gain at the center, or resonant frequency (Fo). The upper and lower Fcos, or half-power points, define the two frequencies at which the output voltage amplitudes are reduced to 70.7% of the maximum gain.

These amplifier characteristics can be presented in a frequency response curve as shown in Figure 1.

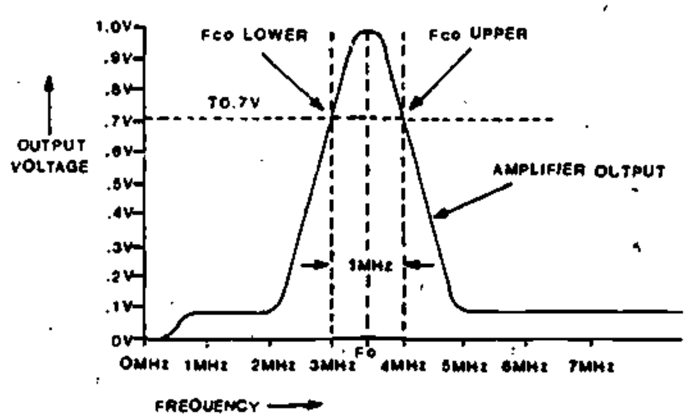


Figure 1

FREQUENCY RESPONSE CURVE

In this example, the voltage output at Fo equals .1 volt input X gain of 10, or 1 volt. Therefore voltage output at the half-power points equals .707 volts. The frequency response is 3 MHz to 4 MHz and the bandwidth 1 MHz. Signal amplification outside of the frequency response is normally considered as an unusable output.

RF amplifiers have about any frequency response characteristic and bandwidth within the frequency range 30 kHz to 300 GHz (G is giga and means 10^9). They are either untuned producing a broad bandwidth, or variable tuned producing a narrow bandwidth over chosen center frequencies. The amplifier's selectivity separates and amplifies a chosen signal and excludes most others.

IF amplifiers are basically fixed-tuned RF amplifiers with a relatively narrow bandwidth. The frequency range is similar to RF amplifiers. Video amplifiers are untuned with a frequency response from about 0 Hz to near 6 MHz and are useful in amplifying square or sawtooth waveforms.

In electronics, a measurement unit called the decibel (dB) is used to simplify solving such problems as combining amplifier gains (i.e., the ratio of output over input). Voltage and power gains can be converted to equivalent decibel values by the use of charts and/or graphs as shown in Figure 2.

VOLTAGE RATIO	DECIBELS	POWER RATIO
1.0	0.0	1.0
1.06	0.5	1.12
1.12	1	1.26
1.26	2	1.59
1.41	3	2.0
1.59	4	2.51
1.78	5	3.16
2.0	6	4.0
2.4	7	5.01
2.5	8	6.31
2.8	9	7.94
3.16	10	10
5.62	15	31.62
10	20	100
17.78	25	316.22
31.6	30	1000
100	40	10,000
316	50	100,000
1000	60	1.000.000
3160	70	10.000.000
10.000	80	100.000.000
31,600	90	1.000.000.000
100,000	100	10.000.000.000

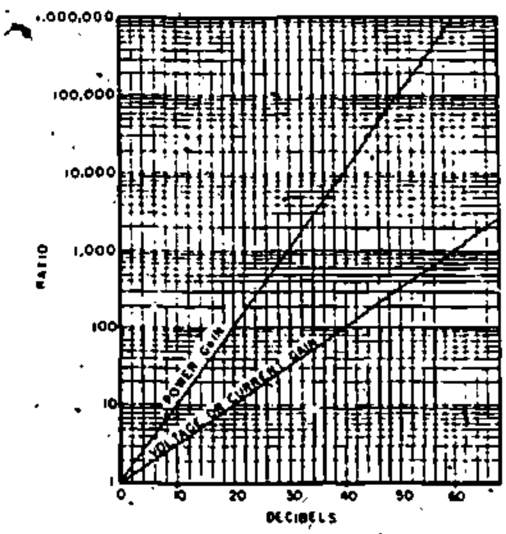


Figure 2

DECIBEL CHART/GRAPH

Inspection of Figure 2 shows that voltage and power ratios convert to different decibel values.

A typical problem which involves combining decibels is to find the total circuit voltage gain of several amplifiers connected in series, or "cascade", as shown in Figure 3.

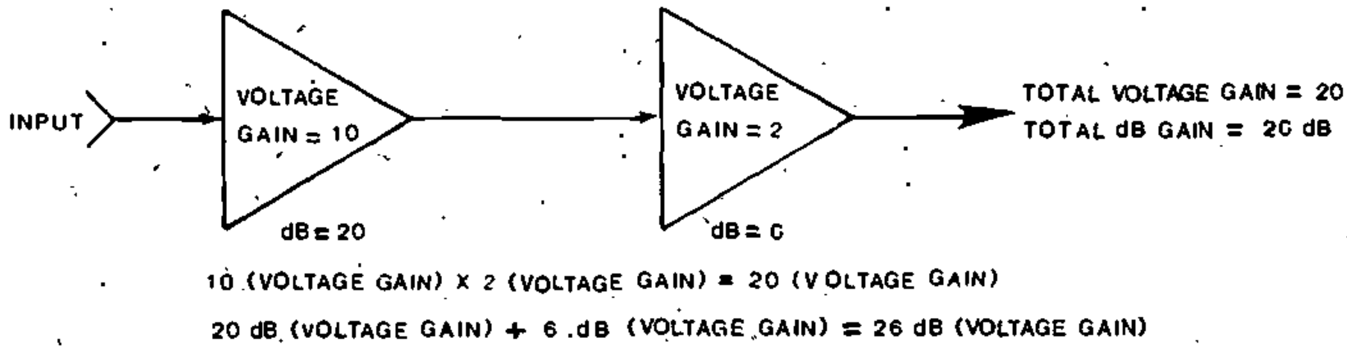


Figure 3

CASCADED VOLTAGE AMPLIFIERS--VOLTAGE AND DECIBEL GAIN

In the example, the total circuit voltage gain equals the product of the individual amplifier voltage gains or 20 as shown. If the individual amplifier voltage gains are first converted to their decibel values, the total circuit voltage gain equals the sum of the individual amplifier dB gains. The identical procedure of converting gains to decibels and summing decibels can be used to find total circuit output power gain.

Another common decibel application is to find an amplifier voltage or power output signal, given the input signal and decibel gain. A diagram of a simple problem is shown in Figure 4.

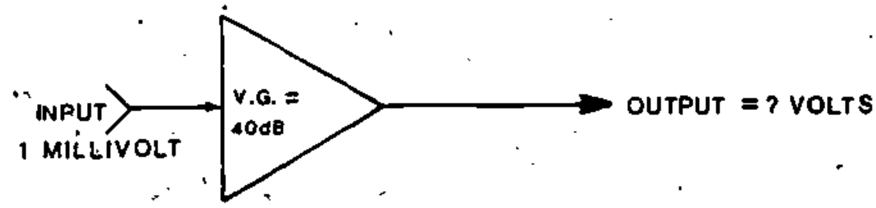


Figure 4

VOLTAGE OUTPUT VS INPUT USING DECIBLES

In this example, the dB gain is converted back to a voltage gain of 100. The product of 100 X 1 millivolt input equals the output, or 100 millivolts. The same procedure is followed to find an amplifier output signal, given the input signal and decibel power gain.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, YOU MAY TAKE THE LESSON TEST. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON 1

RF, IF, and Video Amplifier Characteristics

TEST FRAMES ARE 8, 16, AND 24. PROCEED TO TEST FRAME 8 FIRST AND SEE IF YOU CAN ANSWER THE QUESTION. FOLLOW DIRECTIONS GIVEN AFTER THE TEST FRAME.

(1.) Radio Frequency (RF), Intermediate Frequency (IF), and Video amplifiers are used in communication and radar equipments. Before you can understand some of the more important characteristics of amplifiers, you need to know how they function in electronic equipment.

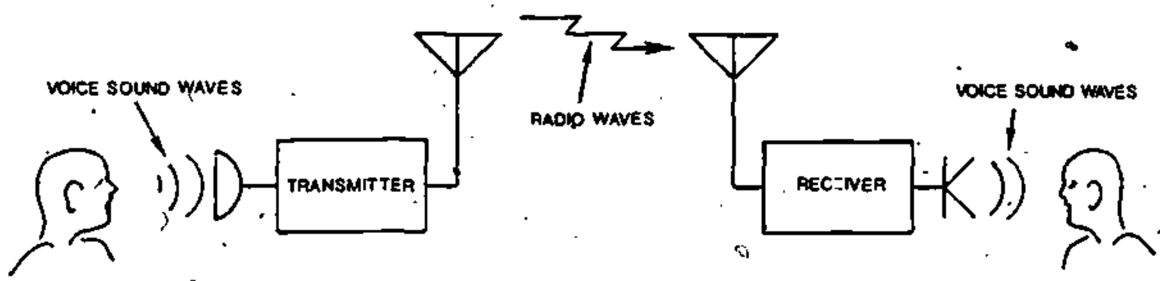


Figure 1

TRANSMIT-RECEIVE SYSTEM

A basic transmit-receive system is shown in Figure 1. Information such as spoken words may be sent, or transmitted, between two points using radio waves. A transmitter generates highly amplified radio frequency energy containing the information so that it may be sent over long distances. This radio frequency energy may be greatly weakened by the time it is picked up by a receiver. The receiver then amplifies the desired radio frequency signals and converts them into the original information that was transmitted.

Radio frequency signals must be ________ at both transmitter and receiver so that communication may take place over long distances.

---

amplified

(2.) Two major categories of information transmitted in a system are audio (sound) and video (image) signals. Examples of these are shown in Figure 2.

Audio Information	Video Information
Voice	Television Pictures
Music	Radar
Code	

Figure 2

ELECTRONIC INFORMATION

Audio signals contain frequencies in the range of the human ear, and range from about 20 Hz to 20,000 Hz. Video signals contain frequencies required to convey images, and range from about 0 Hz to 6 MHz. These two frequency ranges will have an important effect on the amplifier circuits used to send and receive these signals.

Audio signals contain frequencies in the range of ________ Hz to ________ Hz, while video signals contain frequencies in the range of ________ Hz ~~to~~ ________ MHz.

20, 20,000 - 0, 6

(3.) Amplifiers must be able to amplify the highest and lowest frequencies contained in the audio or video signals or a loss of information may result. The amplifiers you studied in earlier modules were designed to amplify signals in the audio range (20 Hz to 20,000 Hz). This means that those amplifiers had a frequency response of 20 Hz to 20,000 Hz, and therefore could amplify just about equally well any signal in that frequency range.

An amplifier designed to amplify audio signals has a ________ ________ in the range of 20 Hz to 20,000 Hz.

---

frequency response

(4.) Now you will apply some of the terms you have learned to determine some important operating characteristics of amplifiers. Recall that in your study of resonance you learned that bandwidth is the lower Fco (cut-off frequency) subtracted from the upper Fco. The basic difference between frequency response and bandwidth is that frequency response is always expressed as two numbers which are the upper Fco and lower Fco, while bandwidth is expressed as the frequency difference between the upper and lower Fco's.

Bandwidth is the ________ ________ subtracted from the ________ ________.

---

lower Fco, upper Fco

(5.) Generally speaking, an amplifier has an output signal that is unchanged from the input signal except for amplitude and phase. The amplitude of the output signal is maximum for a particular amplifier at the center, or resonant, frequency (Fo). This amplitude at Fo is equal to the amplifier input voltage at Fo multiplied by the amplifier gain. For example:

Amplifier Fo = 3 MHz

Amplifier gain = 5

Amplifier input at Fo = 2 V

Amplifier output at Fo = amplifier input x gain

= 10 V

If the amplifier gain is 10 and the input is .5 V at the center frequency of the amplifier, the output voltage is ________.

---

5 volts

(6.) If our input frequency varies either above or below the center frequency of the amplifier, the signal will still be amplified, but to a lesser amount than at Fo. Figure 3 shows the amplitude of the output voltages at various frequencies of the input voltage.

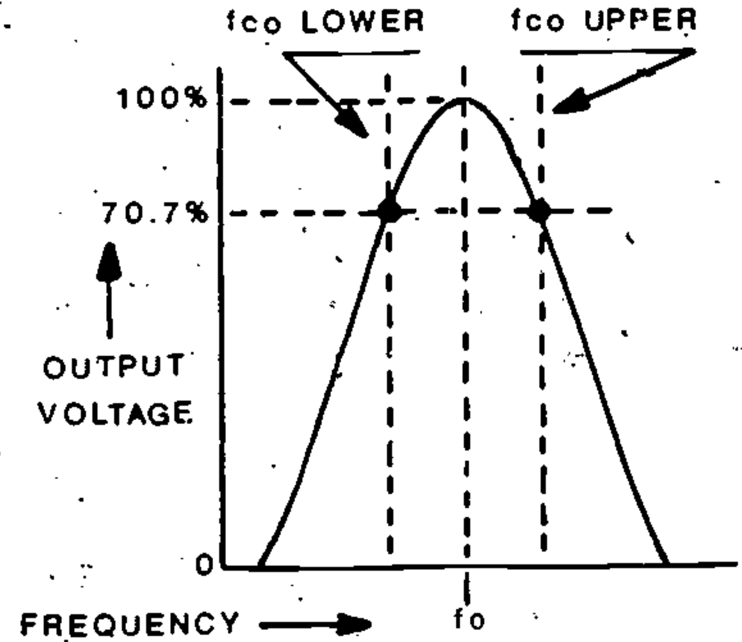


Figure 3

FREQUENCY RESPONSE CURVE

Notice that at the center frequency the amplitude of the output voltage is at 100%. This means that the input voltage at Fo is amplified the maximum amount for the amplifier. You can see that the amplitude of output voltages are lower when the input frequency is <u>either higher or lower</u> than Fo. You also can easily find the two points where the amplitude of the output voltage is only 70.7% as high as the amplitude at Fo. These two 70.7% points, also called half-power points, define the upper and lower Fco's for the amplifier.

If the input signal frequency is <u>increased above</u> the center frequency of the amplifier until the output voltage falls to 70.7% of maximum, the amplifier is operating at its upper Fco. If the frequency is <u>decreased below</u> the center frequency until the output falls to 70.7% of maximum, the amplifier is operating at its lower Fco.

The two frequency points at which the amplitudes of the output voltages of an amplifier are 70.7% of the maximum amplitude at Fo, are called the

________ ________ and the ________ ________.

---

upper Fco, lower Fco

23

(7.) The amplifier characteristics you have covered can be presented in a frequeny response curve as shown in Figure 4.

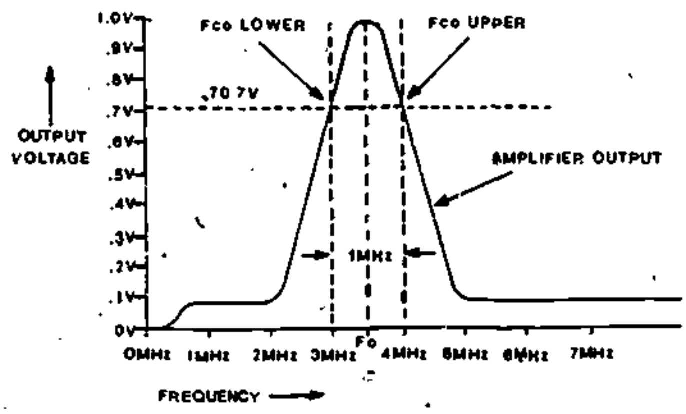


Figure 4

FREQUENCY RESPONSE CURVE

Frequency response curves will be common in your study of electronics. Figure 4 shows a frequency response curve for an amplifier with an input of .1 volt and a gain of 10. The frequencies of the input voltage are divided along the horizontal (or X) axis. The amplifier output voltages are divided along the vertical (or Y) axis. The curve of the amplifier output shows the output voltages which go with different frequencies of the input voltage. Recall that the maximum output for amplifiers = gain X input voltage at Fo. In this example, the maximum output = 10 X .1 volt, or 1 volt. Now you can see that the upper and lower Fco's, or half-power points, are located at the frequency points on the response curve at which the output voltage is only 70.7% of the output voltage at the center frequency. In this example, 70.7% of the maximum output voltage = .707 X 1 volt, or .707 volts.

Upper and lower Fco's are found first by locating the .707 volt division point on the vertical axis, and by reading across until the two points on the response curve are found. Then read down from those points on the curve and identify the two frequency division points on the horizontal axis. These are the lower and upper Fco's for the amplifier, and are located at 3 MHz and at 4 MHz. Recall that the bandwidth is the difference between the upper and lower Fco's. Therefore, for this example, the bandwidth = 4 MHz - 3 MHz, or 1 MHz. You will notice that the amplifier may still amplify signals outside its bandwidth. However anything less than 70.7% of full gain is normally considered to be an unusable output.

In Figure 5 below, the shaded area represents the ________ of the amplifier.

bandwidth

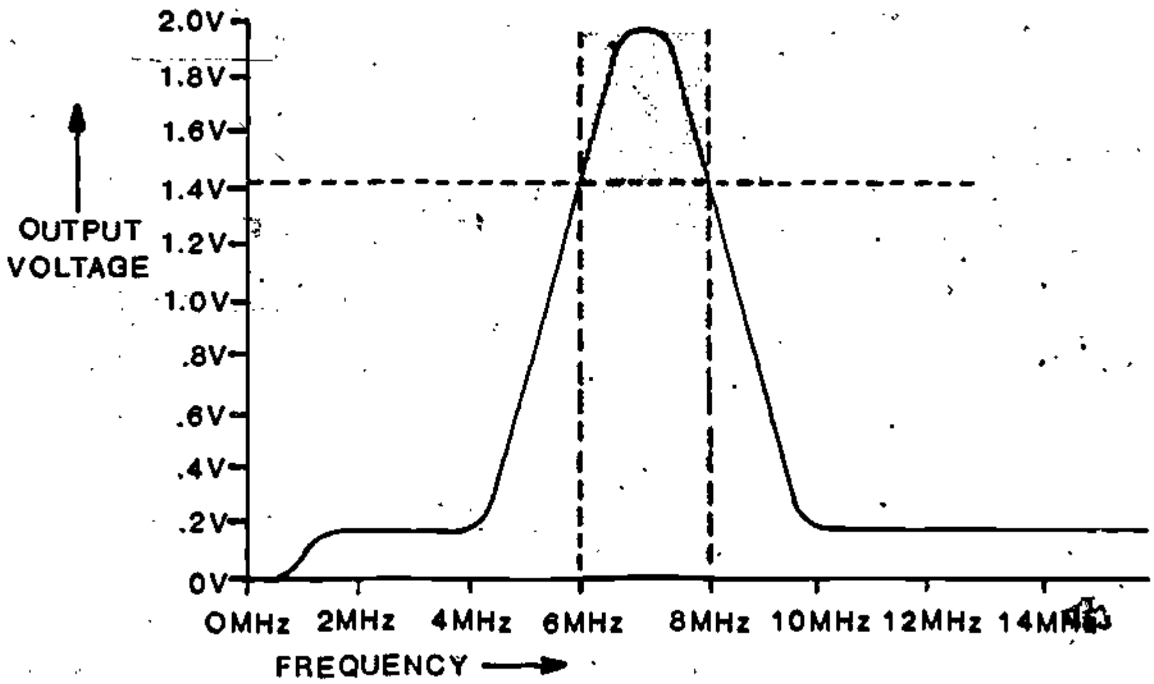


Figure 5

FREQUENCY RESPONSE CURVE

(8.) THIS IS A TEST FRAME. ANSWER THE TEST QUESTIONS AND COMPARE YOUR ANSWERS WITH THE ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE TEST QUESTIONS. REFER TO FIGURE 6. STUDY THE FREQUENCY RESPONSE CURVE FOR AN AMPLIFIER WITH A GAIN OF 5 AND AN INPUT VOLTAGE OF .4 VOLTS, IN ORDER TO ANSWER THE QUESTIONS THAT FOLLOW.

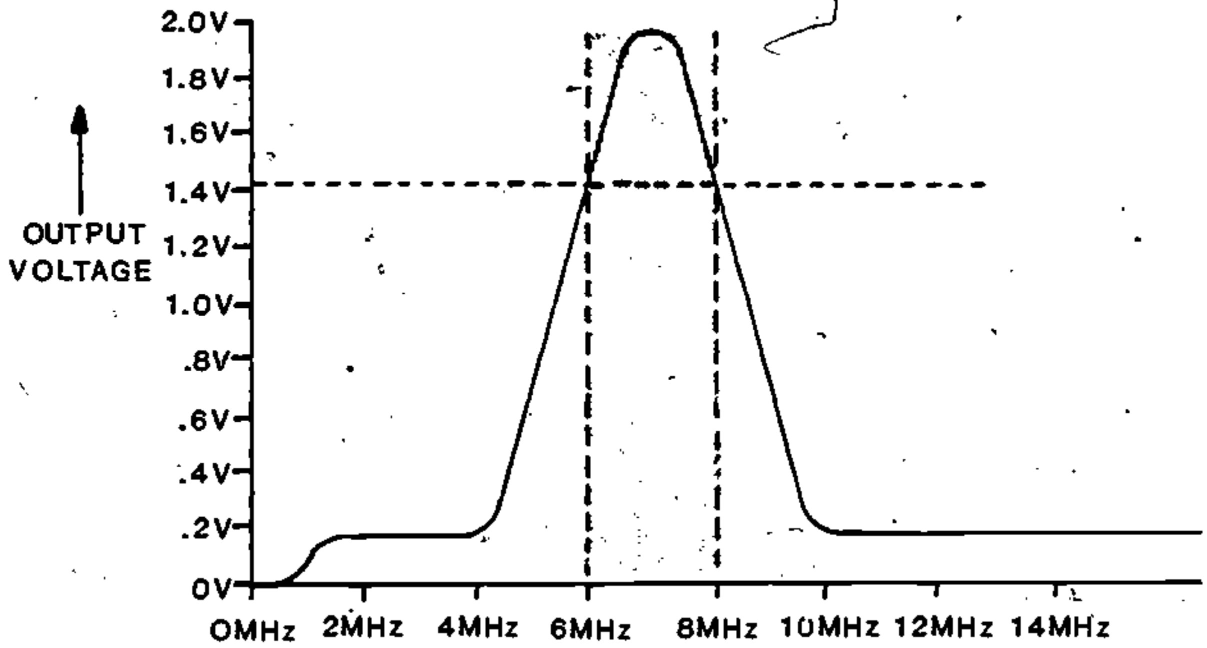


Figure 6

1. The upper Fco for this amplifier is __________.
2. The lower Fco for this amplifier is __________
3. The output voltage for this amplifier at the center frequency is __________.
4. The bandwidth for this amplifier is _________.
5. The output voltage at the half-power points is ________.

COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN ON THE TOP OF THE NEXT PAGE.

1. 8 MHz
2. 6 MHz
3. 2 volts
4. 2 MHz
5. 1.414 volts, or approximately 1.4 volts

IF ALL YOUR ANSWERS MATCH, GO ON TO TEST FRAME 16. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 8 AGAIN.

(9.) The amplifiers you have studied had a frequency response of 20 Hz to 20,000 Hz. Other types of amplifiers may have frequency responses above or below this level. Radio frequency (RF) amplifiers amplify any signals within the frequency range from 30 kHz to 300 GHz (G is pronounced Giga and means 10^9). These amplifiers may have just about any frequency response characteristics and bandwidth within this frequency range.

A circuit which amplifies a frequency or band of frequencies between 30 kHz and 300 GHz can be called a/an ______________ amplifier.

---

radio frequency or RF

(10.) The bandwidth of an RF amplifier, as with any amplifier, must be broad enough to amplify the lowest to the highest information frequencies contained in the signal. For example, an RF amplifier in a communication radio receiver designed to reproduce voice frequency radio transmissions would have a minimum bandwidth of about 3000 Hz. In contrast to this, an RF amplifier in a television set would have a minimum bandwidth of about 6 MHz to pass frequencies required for picture information transfer.

---

no response required

(11.) An important term related to bandwidth size is tuning. Recall that an amplifier is designed to operate within a certain frequency range. Untuned RF amplifiers are used to amplify RF signals over a relatively wide bandwidth within their frequency range. Therefore untuned RF amplifiers will amplify about equally well any frequencies within their frequency range.

What type of RF amplifier will amplify RF signals over a relatively wide bandwidth within their frequency range?

a. tuned

b. untuned

---

b. untuned

(12.) On the other hand, tuned amplifiers are used to amplify RF signals over a relatively narrow bandwidth within their frequency range. In most cases, tuning is variable so you may choose any desired frequency within the frequency range to be amplified. This means that with tuned RF amplifiers you pick a desired frequency and the amplifiers, due to the narrow bandwidth, will amplify that frequency and exclude most others. This ability to separate wanted from unwanted signals is called selectivity. Both tuned and untuned RF amplifiers find many applications in radio, television, radar, and communication equipment.

The ability for tuned RF amplifiers to amplify a desired signal and exclude most others is called ______________

---

selectivity

(13.) Intermediate frequency (IF) amplifiers are special types of tuned RF amplifiers. A major difference is that IF amplifiers are usually tuned to a fixed frequency whereas RF amplifiers can be tuned to different frequencies within their frequency ranges.

IF amplifiers usually have __________ tuning.

a. fixed

b. variable

---

a. fixed

30

(14) The bandwidth of IF amplifiers, just as in tuned RF amplifiers, must be wide enough to amplify, or pass, the lowest to highest information frequencies contained in the signal at or above the 70.7% power points. Also, the bandwidth must be narrow enough so that unwanted frequency signals will be eliminated. Now recall that bandwidth represents the range of signals we want to amplify. We can say that IF amplifiers provide large amounts of amplification over a relatively narrow bandwidth. This means that IF amplifiers are designed to pass desired signals that are relatively close to their center frequencies. Of course some equipment IF amplifier bandwidths may be wider than others because of the particular type of information to be amplified. Figure 7 shows a list of common IF amplifier center frequencies, the range of bandwidths, and typical electronic equipment applications. The bandwidth and amplification characteristics of IF amplifiers make them important in the selectivity, sensitivity and gain of superheterodyne type receivers.

IF (center frequency)	Range of Bandwidths	Application
455 kHz	2.5-20 kHz	FM/AM Broadcast and Communication receivers
4.5 MHz	100 kHz	Television audio
10.7 MHz	10-200 kHz	FM/AM Broadcast and Communication receivers
30 MHz	1-10 MHz	Military and Commercial Radar
45 MHz	3-5 MHz	Television Picture-Video IF
60 MHz	1-10 MHz	Military and Commercial Radar

Figure 7

COMMON IF AMPLIFIER CHARACTERISTICS AND APPLICATIONS

IF amplifiers are usually designed to pass signals over a __________ bandwidth relative to their center frequency.

a. narrow

b. broad

---

a. narrow

(15.) Video amplifiers are untuned and usually have a frequency response from about 0 Hz (DC) to near 6 MHz. They are used in equipments that require amplification of waveforms that contain high and low frequency information such as square or sawtooth waves. Some equipments that use video amplifiers are radar, television and oscilloscopes. A common element in all of these is the visual display of information.

---

no response required

(16.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

1. RF amplifiers usually amplify signals in the frequency range from

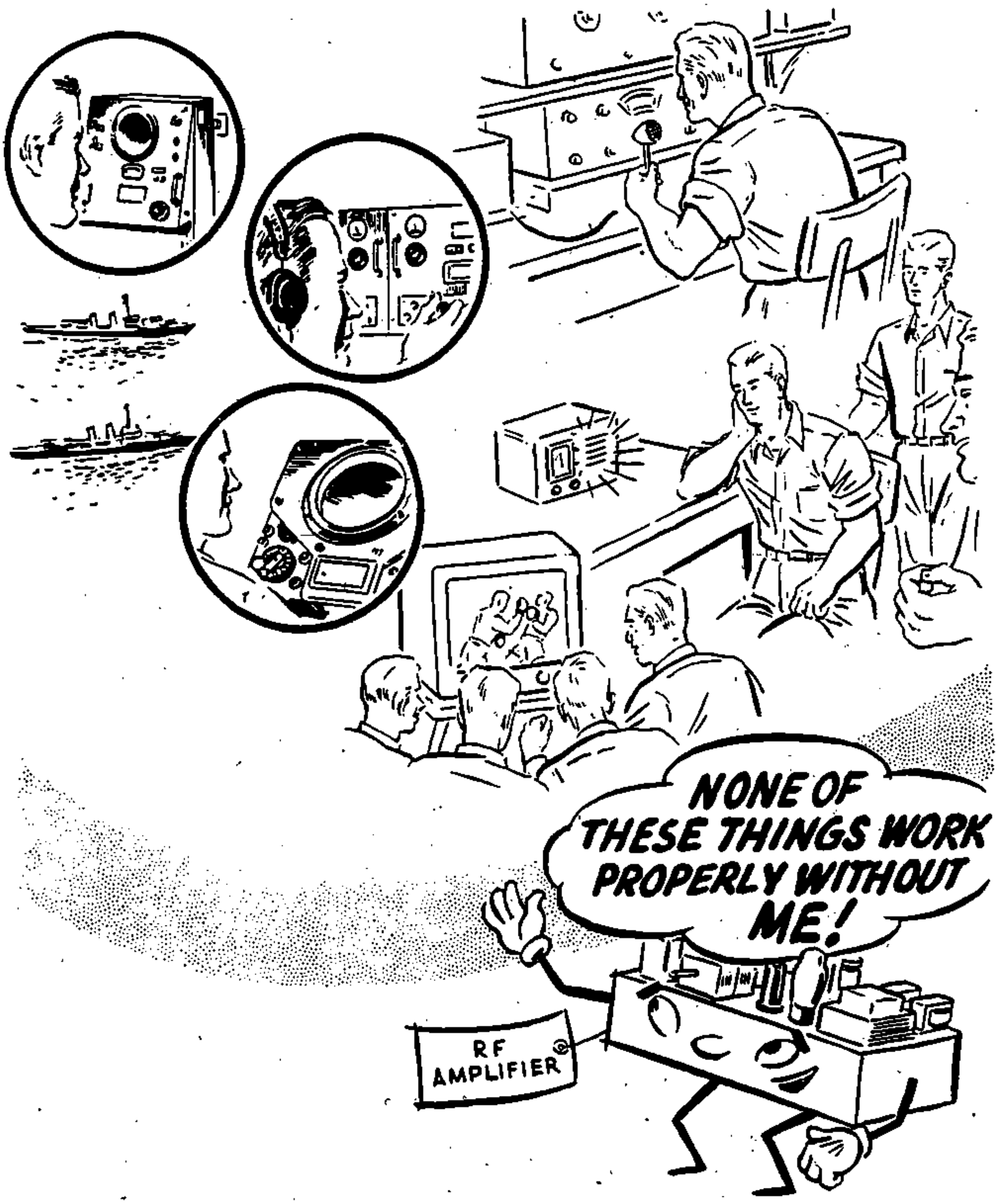
   a. 0 Hz to 20 Hz
   b. 0 Hz to 20 kHz
   c. 20 Hz to 20 kHz
   d. 30 kHz to 300 GHz

2. Untuned RF amplifiers are used to amplify over a __________ bandwidth.

   a. narrow
   b. wide
   c. relative

3. The ability of an amplifier to separate wanted from unwanted input signals is called
   a. selectivity
   b. amplification
   c. bandwidth
   d. sensitivity

4. IF amplifiers usually have
   a. variable tuning, wide bandwidth
   b. variable tuning, narrow bandwidth
   c. fixed tuning, low gain
   d. fixed tuning, high gain


NONE OF THESE THINGS WORK PROPERLY WITHOUT ME!
RF AMPLIFIER

1. d. 30 kHz to 300 GHz
2. b. wide
3. a. selectivity
4. d. fixed tuning, high gain

IF ALL YOUR ANSWERS MATCH GO ON TO TEST FRAME 24 OTHERWISE, GO BACK TO FRAME 9 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 16 AGAIN.

(17.) Often in electronics you will work with voltage and power gains (and losses). A common way to express gain (and loss) is the ratio of $\frac{\text{output}}{\text{input}}$, where output and input are expressed either in voltage or power. For example, if an amplifier has an output voltage of 1 volt with an input voltage of .2 volts, then the gain is $\frac{\text{1 volt output}}{\text{.2 volts input}}$, or 5. Therefore, we can say that the output voltage is 5 times greater than the input voltage, or that the ratio of output voltage to input voltage is 5 to 1.

A common way to express amplifier gain is

a. input x output

b. input/output

c. output/input

---

c. output/input

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(18.) For now we will talk only about gain. Often it is useful to know what is the combined voltage or power gain of several amplifiers working together. You will learn how to do this a little later on. But in order to make a point, let us just mention that the answer requires multiplying voltage or power gain ratios. This multiplication can be a very clumsy procedure, and is unnecessary. A unit of measurement exists which changes the gain ratios into other numbers which can be simply added to find the answer. As you know, addition is easier than multiplication. The unit we use is related to the bel, named after the inventor of the telephone, Alexander Graham Bell. However, in electronics, the bel often is too large to use in many applications. Therefore, we actually use the unit called the decibel which is one-tenth (1/10) of a bel. The decibel is expressed as the letters "dB".

A unit of measurement in electronics which is an expression of the power or voltage ratio is called the ________________.

---

decibel (or dB)

(19.) Voltage and power ratios, or gains, can be easily converted to their equivalent decibel (dB) value by the use of charts and/or graphs. Figure 8 shows a typical dB chart and graph.

VOLTAGE RATIO	DECIBELS	POWER RATIO
1.0	0.0	[illegible]
1.06	0.5	1.12
1.12	1	1.26
1.26	2	1.59
1.41	3	2.0
1.59	4	[illegible]
1.78	5	[illegible]
2.0	6	4.0
2.24	7	5.01
2.5	8	6.31
2.8	9	7.94
3.16	10	10
5.62	15	31.62
10	20	100
17.78	25	316.22
31.6	30	1000
100	40	10,000
316	50	100,000
1000	60	1,000,000
3160	70	10,000,000
10,000	80	100,000,000
31,600	90	1,000,000,000
100,000	100	10,000,000,000

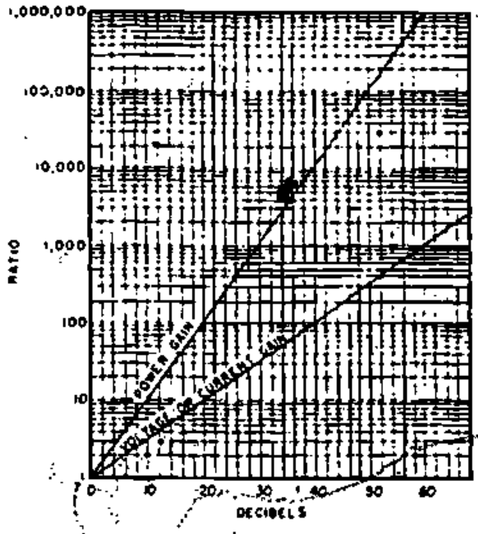


Figure 8

DECIBEL CHART/GRAPH

To use the dB chart, first notice that voltage ratios convert to different decibels than do power ratios. For example, a voltage ratio of 2.0 (that is, output voltage is 2 times greater than input voltage) converts to 6 dB. A power ratio of 2.0 converts to only 3 dB. The mathematical reason for the difference will not be mentioned. Just remember to read down the correct column on the chart in order to find the voltage or power ratio you want to convert, and then read across to find the decibel unit. To use the dB graph, first find the power or voltage ratio you want to convert along the division points of the vertical, or "Y" axis. Then read across until you find the intersection point with the "power" or "voltage" diagonal line, depending on whether you are converting a power or a voltage ratio. Then read down from that point to the decibel unit along the division points of the horizontal, or "X" axis. For example, a voltage ratio of 100 converts to a decibel unit of 40. A power ratio of 100 converts to a decibel unit of 20.

Using either the dB chart or dB graph in Figure 8, find the decibel conversions for the following voltage and power ratios:

a. voltage ratios = 10, 2.5, 200

b. power ratios = 10, 2.0, 300

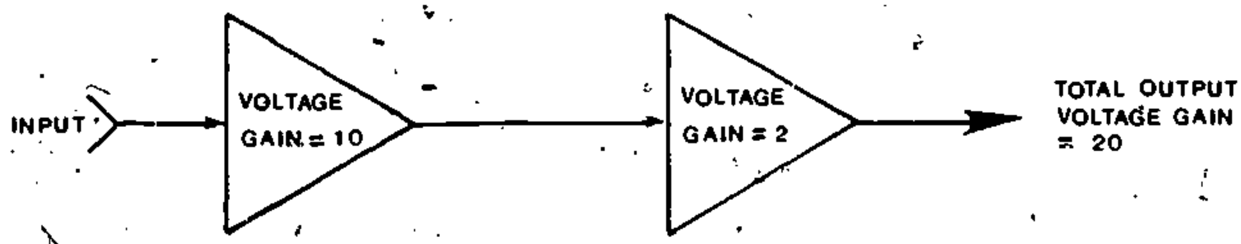
---

a. 20 dB, 8 dB, approximately 46 dB

b. 10 dB, 3 dB, approximately 25 dB

---

(20) Now that you can convert gain ratios to decibels, let's see how useful decibels are in solving some typical problems. A common problem is to find out what is the total voltage gain in a circuit containing more than one amplifier. Figure 9 shows a diagram of a circuit containing two amplifiers connected in series, or "cascaded".



10 (VOLTAGE GAIN) X 2 (VOLTAGE GAIN) = 20 (VOLTAGE GAIN)

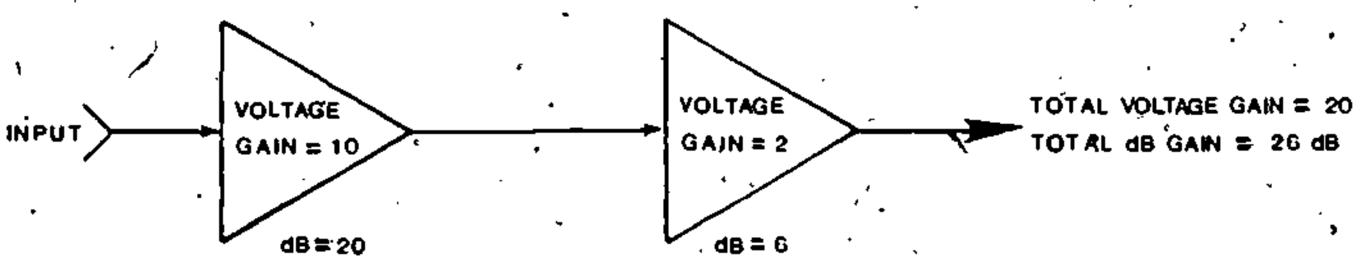
Figure 9

CASCADED VOLTAGE AMPLIFIERS - VOLTAGE GAIN

The voltage gain ratio (VG in Figure 9) for the first amplifier is 10 and for the second amplifier is 2.

This arrangement gives a total circuit voltage gain equal to the <u>product</u> of the individual amplifier voltage gains, or in this case a gain of 20. Now decibels could also be used to express this gain.

Figure 10 shows the same set-up including the decibel conversions for the voltage gain of each amplifier.



10 (VOLTAGE GAIN) X 2 (VOLTAGE GAIN) = 20 (VOLTAGE GAIN)

20 dB (VOLTAGE GAIN) + 6 dB (VOLTAGE GAIN) = 26 dB (VOLTAGE GAIN)

Figure 10

CASCADED VOLTAGE AMPLIFIERS - VOLTAGE AND DECIBEL GAIN

As an exercise use Figure 11 and verify that voltage gain ratios of 10 and 2 convert to dB gains of 20 and 6 respectively. Now the punch line is that the total circuit voltage gain in <u>decibels</u> equals the <u>sum</u> of the individual amplifier voltage gains in decibels, or 26 dB.

Use Figure 11 again and verify that the total circuit voltage gain ratio of 20 converts to a total circuit voltage gain of 26 dB.

VOLTAGE RATIO	DECIBELS	POWER RATIO
1 0	[illegible]	
1 06	0 [illegible]	[illegible]
1 12	1	[illegible]
1 21	2	[illegible]
1 41	[illegible]	[illegible]
1 5[illegible]	4	[illegible]
1 [illegible]	[illegible]	[illegible]
2 0	[illegible]	4 [illegible]
2 4	[illegible]	[illegible]
2 5	[illegible]	[illegible]
2 8	[illegible]	[illegible] 94
3 1[illegible]	10	[illegible]
5.62	15	31.62
10	20	[illegible]
17.78	25	316.22
31 [illegible]	[illegible]	[illegible]
100	[illegible]	[illegible]
3[illegible]	50	[illegible]
1000	60	1,000,000
3160	70	1[illegible],000,0[illegible]
10,000	80	10,000,000
31,600	90	1,00[illegible],000,0[illegible]
100 000	100	10,0[illegible] 000,00[illegible]

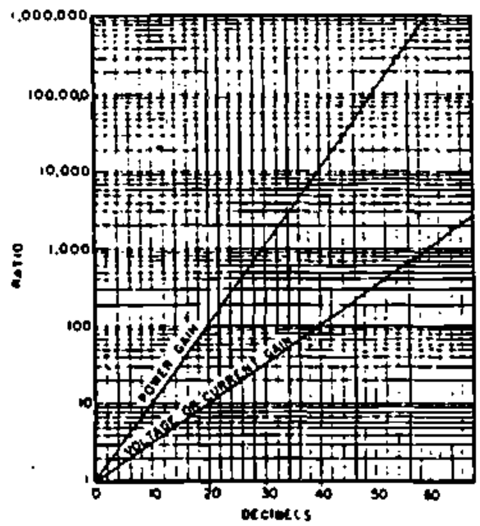


Figure 11

DECIBEL CHART/GRAPH

The total circuit voltage gain in decibels for the two cascaded amplifiers shown in Figure 12 is ________________ dB.

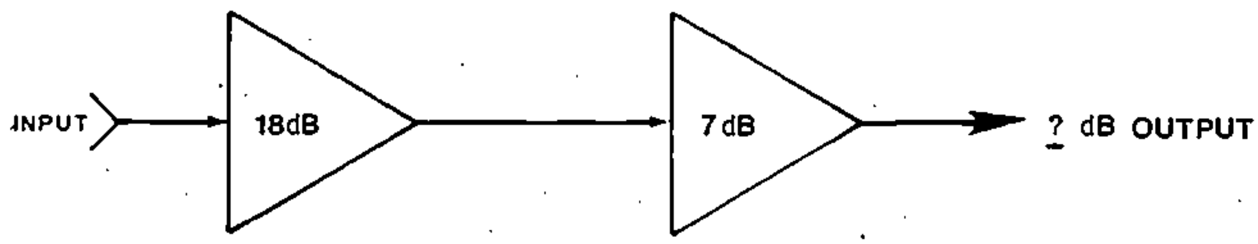


Figure 12

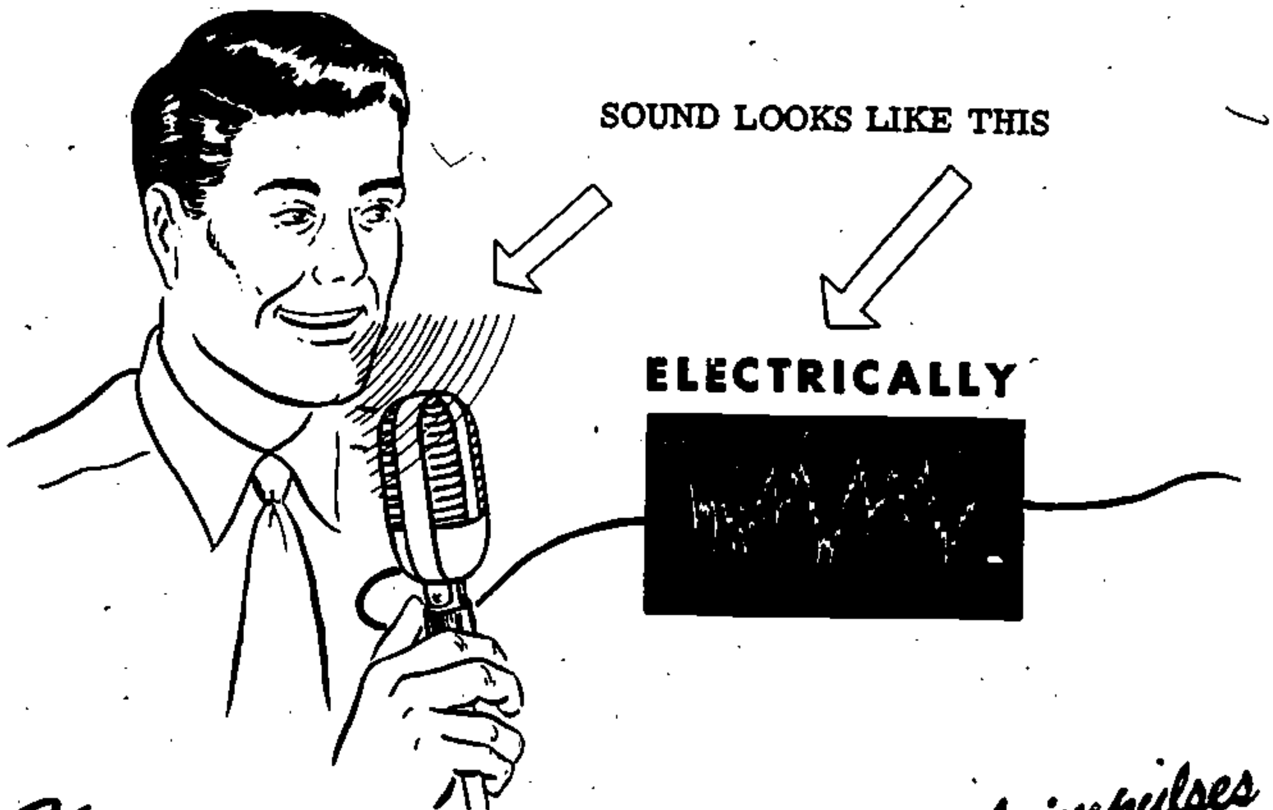
---

25 dB

---

(21) You have learned to convert voltage gain ratios and power gain ratios to decibels using charts and graphs. You have also learned to use decibels to find the total voltage gain in some simple circuits. Now let's try a problem in which you will be combining power gain ratios instead of voltage gain ratios. The procedure is the same. The only difference is that power gain ratios convert to different decibel numbers than do voltage gain ratios. The decibel conversion chart and graph are repeated in Figure 13.

42



Changing sound waves into electrical impulses

VOLTAGE RATIO	DECIBELS	POWER RATIO
1.0	0.0	1.0
1.06	0.5	1.12
1.12	1	1.25
1.26	2	1.58
1.41	3	2.0
1.58	4	2.51
1.78	5	3.16
2.0	6	4.0
2.24	7	5.01
2.5	8	6.31
2.8	9	7.94
3.16	10	10
5.62	15	31.62
10	20	100
17.78	25	316.22
31.6	30	1000
100	40	10,000
316	50	100,000
1000	60	1,000,000
3160	70	10,000,000
10,000	80	100,000,000
31,600	90	1,000,000,000
100,000	100	10,000,000,000

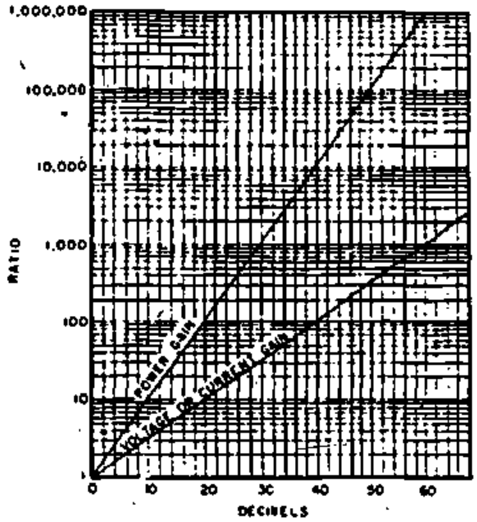
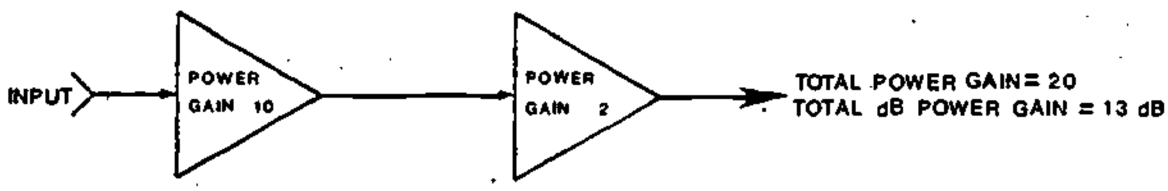


Figure 13

DECIBEL CHART/GRAPH

Figure 14 shows a diagram of a circuit containing two cascaded amplifiers.



10 (POWER GAIN) X 2 (POWER GAIN) = 20 (POWER GAIN)

10 dB (POWER GAIN) + 3 dB (POWER GAIN) = 13 dB (POWER GAIN)

Figure 14

CASCADED POWER AMPLIFIERS - POWER AND DECIBEL GAIN

The power gain ratio in Figure 14 for the first amplifier is 10, and for the second amplifier is 2. The total circuit power gain equals the <u>product</u> of the individual amplifier power gains, or in this case a gain of 20. You will notice that decibels can also be used to express this gain. Figure 14 also shows that the decibel conversions for the power gain ratios of 10 and 2 are 10 dB and 3 dB respectively. As an exercise, verify the decibel conversions by using Figure 13. Remember to read down the "power ratio" column on the dB chart; or read across to the "power gain" diagonal line on the dB graph. As you can see, the total circuit power gain in decibels equals the sum of the individual amplifier power gains in decibels, or 13 dB. Use Figure 13 again and verify that the total circuit power gain ratio of 20 converts to a total circuit power gain of 13 dB.

The total circuit power gain in decibels for the two cascaded amplifiers shown in Figure 15 is ____________ dB.

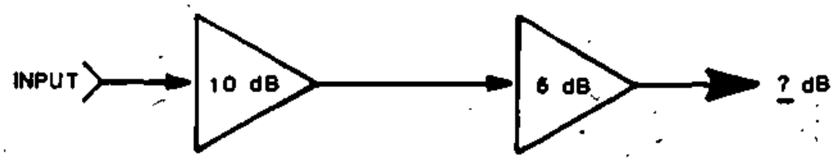


Figure 15

---

15 dB

(22.) You have learned to convert voltage and power gain ratios to decibels, and to combine decibels to find the total voltage and power gain in some simple circuits. One other type of problem is quite common. Suppose you are given an amplifier input in terms of voltage or power, and are also given the amplifier voltage or power gain expressed in decibels. Your problem is to find the amplifier voltage output or power output. To make it easy, let's first solve a problem for voltage output. Figure 16 shows a diagram of a typical problem involving voltage output.

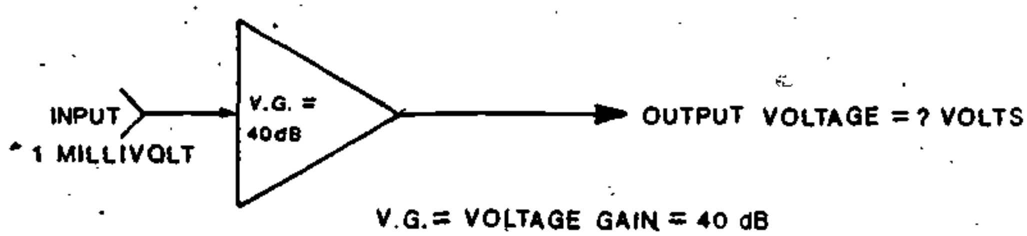


Figure 16

VOLTAGE OUTPUT VS INPUT USING DECIBELS

46

This amplifier has an input signal of 1 millivolt RMS, and a 40 dB voltage gain. What is the voltage output? The answer is easy to find by using the dB gain chart or graph shown in Figure 17.

VOLTAGE RATIO	DECIBELS	POWER RATIO
1.0	0.0	1.0
1.06	0.5	1.12
1.12	1	1.26
1.26	2	1.59
1.41	3	2.0
1.58	4	2.51
1.78	5	3.16
2.0	6	4.0
2.24	7	5.01
2.5	8	6.31
2.8	9	7.94
3.16	10	10.0
5.62	15	31.62
10	20	100
17.78	25	316.22
31.6	30	1000
100	40	10,000
316	50	100,000
1000	60	1,000,000
3160	70	10,000,000
10,000	80	100,000,000
31,600	90	1,000,000,000
100,000	100	10,000,000,000

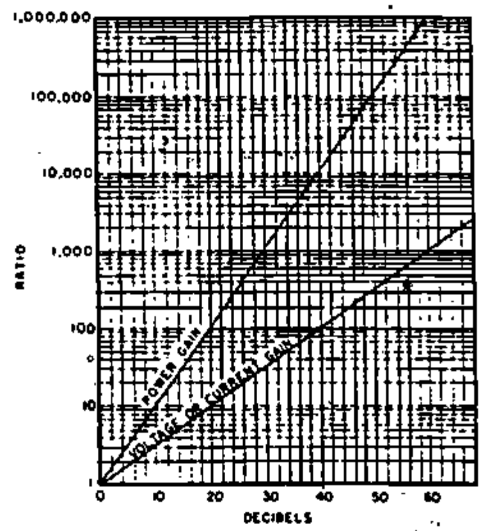


Figure 17

DECIBEL CHART/GRAPH

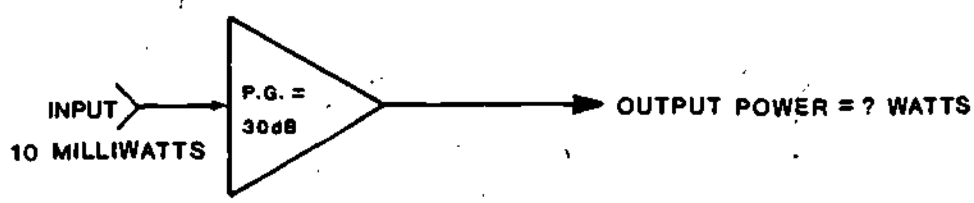
First find the 40 dB entry down the middle column of the dB chart. Now read across to your left and find the voltage ratio related to 40 dB, which in this example equals 100. Now recall that a voltage ratio of 100 means that the ratio $\frac{\text{voltage output}}{\text{voltage input}} = 100$. Therefore, a little simple math shows you that voltage output = 100 X voltage input. In this example, voltage output equals 100 times 1 millivolt, or 100 millivolts. You can also solve this problem by using the dB graph. First find the 40 dB entry along the horizontal axis. Then read up until you find the "voltage gain" diagonal line. Finally, read across to your left from that point and read the ratio value (that is, 100) found on the vertical axis.

An amplifier has an input signal of 2 millivolts and a 20 dB voltage gain. Using the dB chart or graph in Figure 17, the voltage output is ____________

---

20 millivolts output

(23.) A similar problem looking for power output is shown in Figure 18.



P.G. = POWER GAIN = 30 dB

Figure 18

POWER OUTPUT VS INPUT USING DECIBELS

This amplifier has an input signal of 10 milliwatts and a power gain of 30 dB. What is the output power? Again the solution is easy. First find the 30 dB value on the dB chart of the dB graph in Figure 17. If you use the dB chart, read across to your <u>right</u> to find the power ratio, which in this example equals 1000. If you use the dB graph, read up until you find the "power gain" diagonal line, and then read across to your left to find the ratio value on the vertical axis. We now know that the ratio of output to input is 1000. Therefore the power output equals 1000 x 10 millwatts or 10,000 milliwatts. However, since "milli" is the metric prefix for the ratio 1/1000, the most correct way to state the power output would be 10 watts, which is 10,000 divided by 1000.

An amplifier has an input signal of 5 milliwatts and a 20 dB power gain. Using the dB chart or graph in Figure 17, the power output is ____________.

---

500 milliwatts (or .5 watts) output

ELECTRICITY

COMMANDS

RESPECT

NOT

FEAR

CARELESSNESS KILLS

(24) THIS IS A TEST FRAME. ANSWER THE TEST QUESTIONS AND COMPARE YOUR ANSWERS WITH THE ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE TEST QUESTIONS. WHERE NEEDEO USE THE OECIBEL CHART/GRAPH SHOWN IN FIGURE 19 TO FINO YOUR ANSWERS.

VOLTAGE RATIO	DECIBELS	POWER RATIO
1.0	0	1.0
1.06	0.5	1.12
1.12	1	1.26
1.26	2	1.59
1.41	3	2.0
1.59	4	2.51
1.78	5	3.16
2.0	6	4.0
2.4	7	5.01
2.5	8	6.31
2.8	9	7.94
3.16	10	10
5.62	15	31.62
10	20	100
17.78	25	316.22
31.1	30	1000
100	40	10,000
316	50	100.000
1000	60	1.000.000
3160	70	10.000.000
10,000	80	100.000.000
31,600	90	1.000.000.000
100.000	100	10.000.000.000

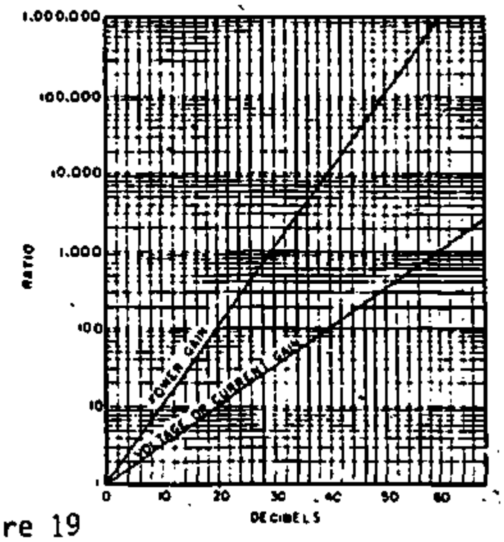


Figure 19

DECIBEL CHART/GRAPH

1. A voltage ratio of 100 converts to the same dB value as does a power ratio of 100.

   a. true
   b. false

2. A voltage ratio of 1.40 converts to ____________ dB.

3. A power ratio of 4.0 converts to ______________ dB.

4. Amplifiers A and B are wired in series (that is, cascaded) in a circuit. Amplifier A has a voltage gain of 30 dB. Amplifier B has a voltage gain of 10 dB. The total circuit amplifier gain is __________ dB.

5. Amplifiers A and B are wired in series (cascade) in a circuit. Amplifier A has a voltage gain ratio of 100. Amplifier B has a voltage gain ratio of 2. The total circuit amplifier gain is

________________ dB.

6. An amplifier has an input power of 10 milliwatts and a power gain of 3 dB. The output power for this amplifier is __________ milliwatts.

1. b. false
2. approximately 3 dB
3. 6 dB
4. 40 dB
5. 46 dB
6. 20 milliwatts output

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON 1, MODULE THIRTY ONE. OTHERWISE GO BACK TO FRAME 17 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 24 AGAIN.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE LESSON TEST. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON 1

RF, IF, and Video Amplifier Characteristics

RF, IF, and video amplifiers have important functions in communication and radar electronic equipment. An application in communication is shown in the basic transmit-receive system diagram in Figure 1.

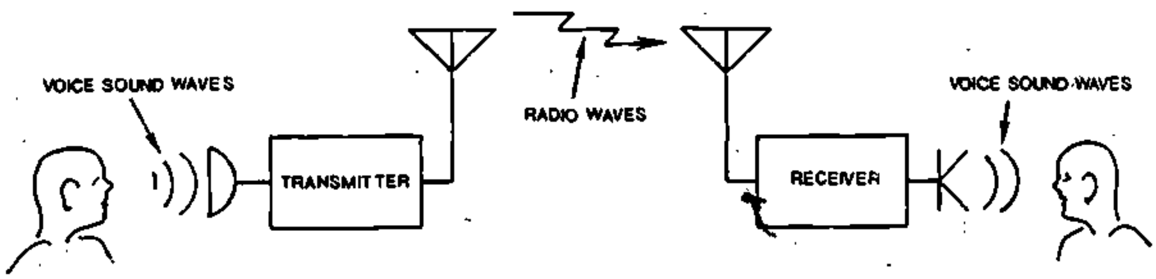


Figure 1

TRANSMIT-RECEIVE SYSTEM

Information such as spoken words may be transmitted between two relatively distant points using highly amplified radio frequency energy waves containing the information. A receiver then amplifies the desired radio frequency signals and converts them into the original information that was transmitted.

Two major categories of information transmitted in a system are audio and video signals. Examples of these are shown in Figure 2.

Audio Information	Video Information
Voice	Television Pictures
Music	Radar
Code	

Figure 2

ELECTRONIC INFORMATION

This lesson describes some important operating characteristics of amplifiers. In your study of resonance you learned that frequency response is expressed as two numbers, the upper Fco (cut-off frequency) and lower Fco, while bandwidth is expressed as the frequency difference between these two numbers. For example, an amplifier is said to have a frequency response from 8 MHz to 9 MHz but a bandwidth of 1 MHz. Within the frequency response of an amplifier, the amplitude of the output signal is at maximum (or 100%) at the center, or resonant frequency (Fo). The maximum amplitude at Fo equals the amplifier input voltage at Fo multiplied by the amplifier gain. For example:

Amplifier Fo = 3 MHz

Amplifier gain = 5

Amplifier input at Fo = 2 V

Amplifier output at Fo = amplifier input x gain = 10 V.

Audio signals contain frequencies ranging from about 20 Hz to 20,000 Hz. Video signals contain frequencies ranging from about 0 Hz to 6 MHz. These two frequency ranges have an important effect on the amplifier circuits in transmitters and receivers. Amplifiers you have studied in earlier modules were in the audio frequency response range, and were designed to amplify about equally well any signal within that range. Amplifiers will still amplify input signals above and below the center frequency, but at less than maximum gain.

Figure 3 shows an amplitude curve of output voltages at various input frequencies around Fo.

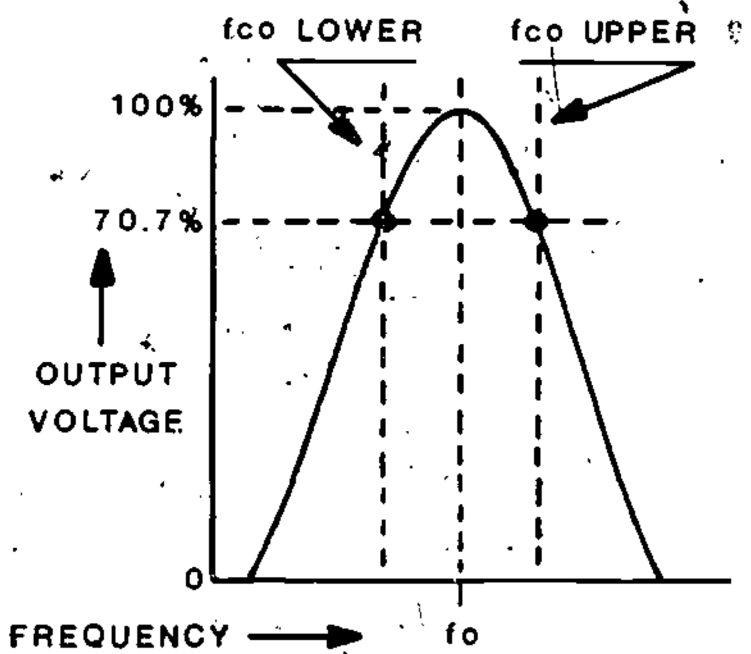


Figure 3

FREQUENCY RESPONSE CURVE

The amplitude of the output voltage is at maximum (100%) at Fo, but is reduced to 70.7% of maximum at the upper and lower Fco, or half-power points. The half-power points indicate the two frequencies at which the amplitudes of the output voltages are 70.7% of the maximum amplitude at Fo.

These amplifier characteristics can be presented in a frequency response curve as shown in Figure 4.

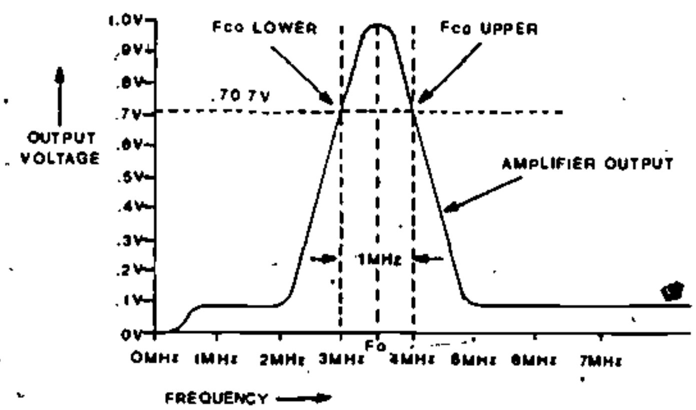


Figure 4

FREQUENCY RESPONSE CURVE

Such curves will be common in your study of electronics. In this example, the maximum voltage output at Fo equals .1 volt input X a gain of 10, or 1 volt. The output voltage at the half-power points equals .707 volts. The two input frequencies which produce this output voltage are 3 MHz and 4 MHz. Therefore, the frequency response for this amplifier is 3 MHz to 4 MHz and the bandwidth is 1 MHz. Any signal amplification outside of the frequency response is normally considered an unusable output.

Radio frequency amplifiers may have just about any frequency response characteristic and bandwidth within the frequency range from 30 kHz to 300 GHz (G is pronounced giga and means 10^9). Untuned RF amplifiers amplify RF signals over a relatively wide bandwidth, whereas tuned RF amplifiers amplify RF signals over a relatively narrow bandwidth. Tuning of RF amplifiers is variable which allows you to choose the frequency to be amplified within the frequency range. The amplifier selectivity will amplify the chosen signal and exclude most others.

Intermediate frequency (IF) amplifiers are basically tuned RF amplifiers with fixed rather than variable tuning. IF amplifiers in AM receivers have a relatively narrow bandwidth, which means that they are designed to pass desired signals that are relatively close to their center frequencies. The center intermediate frequency has a wide range of possibilities, but each IF amplifier has a relatively narrow bandwidth when compared to its own center frequency.

Figure 5 shows a list of common IF amplifier center frequencies, the range of bandwidths, and typical electronic equipment applications. The bandwidth and amplification characteristics of IF amplifiers make them important in the selectivity, sensitivity, and gain of superheterodyne type receivers.

IF (center frequency)	Range of Bandwidths	Application
455 kHz	2.5-20 kHz	FM/AM Broadcast & Communication receivers
4.5 MHz	100 kHz	Television audio
10.7 MHz	10-200 kHz	FM/AM Broadcast and Communication receivers
30 MHz	1-10 MHz	Military and Commercial Radar
45 MHz	3-5 MHz	Television Picture-Video IF
60 MHz	1-10 MHz	Military and Commercial Radar

Figure 5

COMMON IF AMPLIFIER CHARACTERISTICS AND APPLICATIONS

Video amplifiers are untuned and usually have a frequency response from about 0 Hz (DC) to near 6 MHz. They are used in equipment that require amplification of waveforms that contain high and low frequency information such as square or sawtooth waves. Some equipments that use video amplifiers are radar, television and oscilloscopes.

One common way to express voltage or power amplifier gain is the ratio of output divided by input. As an example, 1 volt output divided by .2 volts input equals a gain of 5. Often it is useful to know the combined voltage or power gain of several amplifiers in a circuit. In electronics, the procedure for combining gains is greatly simplified by first converting each amplifier gain to a measurement unit called the decibel (dB). The decibel equals 1/10 of a bel. The basic unit is named after Alexander Graham Bell, and is called a "bel".

Voltage and power ratios, or gains, can be easily converted to their equivalent decibel (dB) value by the use of charts and/or graphs. Figure 6 shows a typical dB chart and graph.

VOLTAGE RATIO	DECIBELS	POWER RATIO
1.0	0.6	1.[illegible]
1.06	0.5	1.12
1.12	1	1.2[illegible]
1.26	2	1.5[illegible]
1.41	[illegible]	2.0
1.58	4	2.5[illegible]
1.[illegible]	[illegible]	[illegible]
2.0	[illegible]	4.0
2.4	[illegible]	5.01
2.[illegible]	[illegible]	[illegible]
2.8	[illegible]	[illegible].94
3.11	10	10
5.62	15	31.62
10	20	100
17.78	25	316.22
31.[illegible]	[illegible]	1000
100	[illegible]	10,000
[illegible]	5[illegible]	100,000
1000	60	1,000,000
316[illegible]	70	10,000,000
10,000	80	10,[illegible],000
31,600	90	1,00[illegible]
100,000	100	10,000,000,000

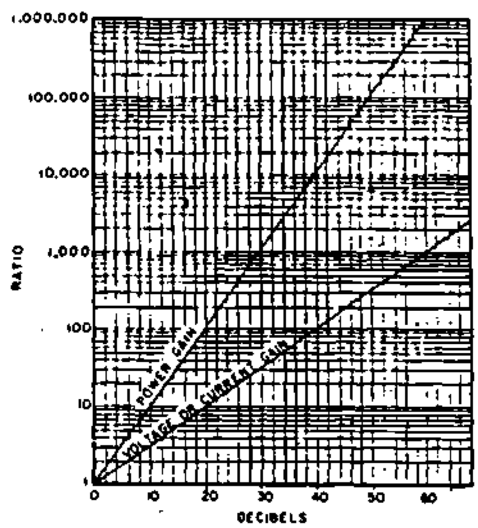
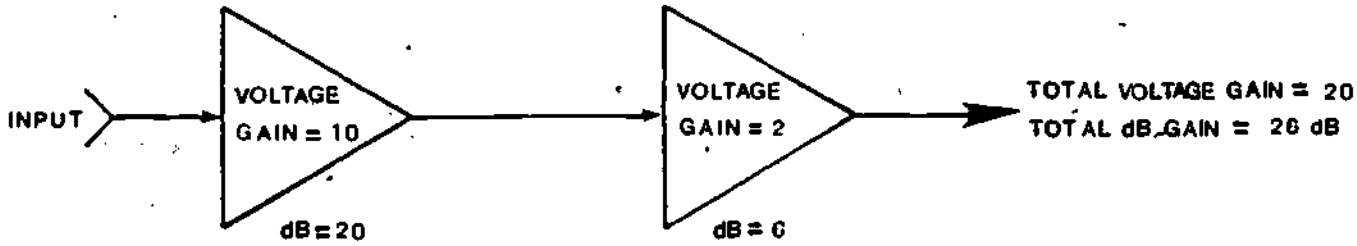


Figure 6

DECIBEL CHART/GRAPH

Note that voltage ratios and power ratios convert to different decibel values. To use the dB chart, locate the voltage or power gain you wish to convert under the "voltage ratio" or "power ratio" column, and read across to the decibel value in the center. To use the dB graph, first locate the gain ratio along the vertical axis, and read across to the correct diagonal line. Then read down to the decibel value on the horizontal axis. For example, a voltage gain of 100 converts to 40 dB and a power gain of 100 converts to 20 dB.

Figure 7 shows a diagram of a circuit containing two amplifiers connected in series, or "cascaded". That is, the collector (plate) of the first stage is connected to the base (grid) of the second stage.



10 (VOLTAGE GAIN) X 2 (VOLTAGE GAIN) = 20 (VOLTAGE GAIN)

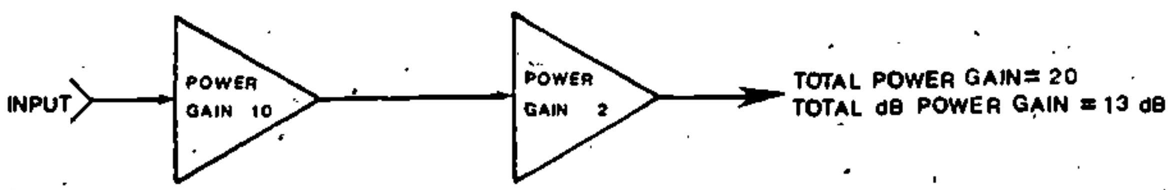
20 dB (VOLTAGE GAIN) + 6 dB (VOLTAGE GAIN) = 26 dB (VOLTAGE GAIN)

Figure 7

CASCADED VOLTAGE AMPLIFIERS VOLTAGE AND DECIBEL GAIN

The voltage gains shown in Figure 7 are 10 and 2, respectively. The total circuit output voltage gain equals the product of the individual amplifier voltage gains, or 20 in this example. If the individual amplifier voltage gains are first converted to their decibel values of 20 dB and 6 dB using the decibel charts/graphs, the total circuit output voltage gain in dB equals the sum of the individual amplifier dB voltage gains, or 26 dB. the decibel chart/graph verifies that the total voltage gain ratio of 20 converts to 26 dB.

The same procedure is used to find the total power gain in cascaded circuits as shown in Figure 8.



10 (POWER GAIN) X 2 (POWER GAIN) = 20 (POWER GAIN)

10 dB (POWER GAIN) + 3 dB (POWER GAIN) = 13 dB (POWER GAIN)

Figure 8

CASCADED POWER AMPLIFIERS-POWER AND DECIBEL GAIN

The power gains (PG in Figure 8) are 10 and 2, respectively. The total circuit output power gain equals the product of the individual amplifier gains (i.e., 20), or the sum of the individual amplifier dB gains (i.e., 13 dB). Figure 6 again verifies that the total power gain ratio of 20 converts to 13 dB.

Another common application of decibels is to find amplifier voltage or power output signal levels, given the input signal and decibel gain. Figure 9 shows a diagram of a typical problem involving voltage output.

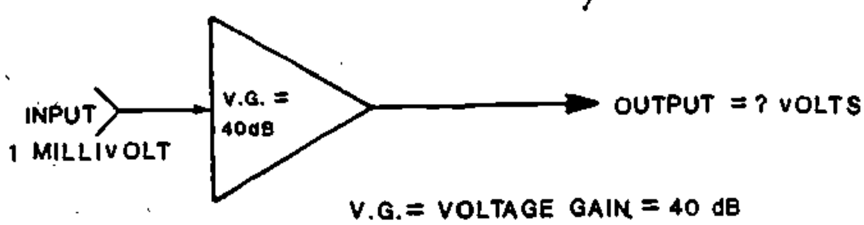


Figure 9

VOLTAGE OUTPUT VS INPUT USING DECIBELS

This amplifier has an input signal of 1 millivolt RMS, and a 40 dB voltage gain. Referring to the dB chart or graph in Figure 10, 40 dB converts back to a voltage ratio of 100. This gain of 100 means that the output signal is 100 times greater than the input signal. Therefore, the voltage output equals 1 millivolt X 100, or 100 millivolts.

VOLTAGE RATIO	DECIBELS	POWER RATIO
1.0	[illegible]	1.0
1.06	0.5	1.12
1.12	1	1.26
1.26	2	1.59
1.41	3	2.0
1.59	4	2.51
1.78	5	3.16
2.0	6	4.0
2.4	7	5.01
2.[illegible]	8	6.31
2.8	9	7.94
3.16	10	10
5.62	15	31.62
10	20	100
17.78	25	316.22
31.6	30	1000
100	40	10,000
316	50	100,000
1000	60	1,000,000
3160	70	10,000,000
10,000	80	100,000,000
31,600	90	1,000,000,000
100,000	100	10,000,000,000

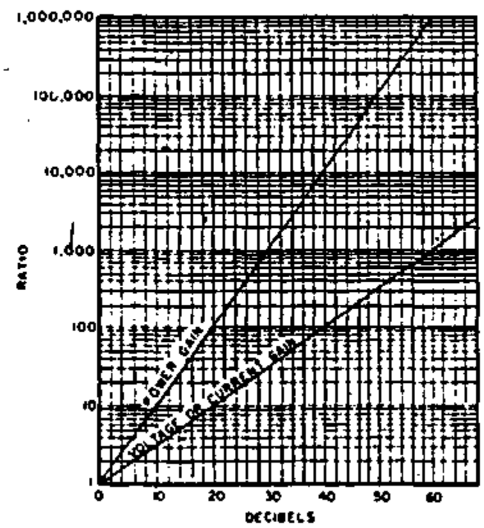
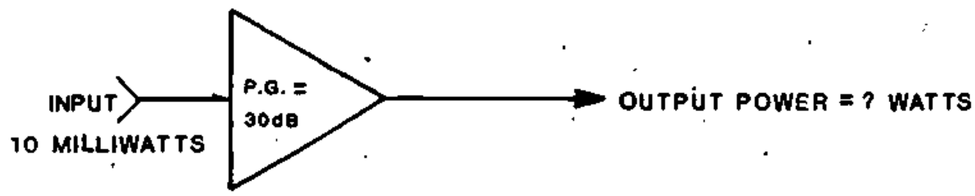


Figure 10

DECIBEL CHART/GRAPH

Figure 11 shows a similar problem involving power output.



P.G. = POWER GAIN = 30 dB

Figure 11

POWER OUTPUT VS INPUT USING DECIBELS

This amplifier has an input signal of 10 milliwatts, and a 30 dB power gain. Again referring to the dB chart or graph in Figure 10, 30 dB converts back to a power ratio of 1000. The power output equals 10 milliwatts X 1000, or 10,000 milliwatts, or 10 watts.

That sums up dB for this lesson. Of course there are other applications for dBs in electronics. You will learn more about these additional uses as you continue your study of electronics. Good luck!

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, YOU MAY TAKE THE LESSON TEST. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

BASIC ELECTRICITY AND ELECTRONICS

MODULE THIRTY ONE

LESSON 2

RF AMPLIFIERS

JULY 1980

OVERVIEW
LESSON 2

RF Amplifiers

In this lesson you will learn the functions of RF amplifier components, and some important operating characteristics of RF amplifiers. You will be able to look at RF amplifier diagrams and identify the types and functions of transformer couplings. You will understand how important the resonant circuit property called "Q" is to amplifier operation. You will become familiar with the function of neutralization components. You will learn the differences in operation between the classes of amplifiers. You will understand how the tank circuit flywheel effect shapes amplifier output waveforms. You will become acquainted with the functions of the sweep frequency generator, and you will determine amplifier frequency response curve characteristics using test equipment.

The learning objectives of this lesson are:

TERMINAL OBJECTIVE(S):

31.2.53 When the student completes this lesson (s)he will be able to IDENTIFY the component functions and operating characteristics of RF amplifier circuits, including types of input and output transformer coupling, factors affecting and affected by Q in resonant circuits, response characteristics of different classes of amplifier operation, and one method for testing the frequency response of an amplifier, by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVE(S):

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

31.2.53.1 IDENTIFY the components which accomplish tuning in a tuned, transformer-coupled RF amplifier circuit, given a schematic diagram, by selecting the correct component(s) from a set of four choices. 100% accuracy is required.

31.2.53.2 IDENTIFY the type of tuning (single, ganged, capacitive, inductive) used in a tuned, transformer-coupled RF amplifier circuit, given a schematic diagram, by selecting the correct type from a choice of four. 100% accuracy is required.

31.2.53.3 IDENTIFY or CALCULATE the effect of changes in inductive reactance, capacitive reactance, or resistance on the Q of a coil or tank circuit, by selecting the correct statement or value from a choice of four. 100% accuracy is required.

31.2.53.4 IDENTIFY or CALCULATE the effect of changes in Q on the bandwidth of a tank circuit, by selecting the correct statement or value from a choice of four. 100% accuracy is required.

31.2.53.5 IDENTIFY the effect of loading on the Q of a tank circuit by selecting the correct statement from a choice of four. 100% accuracy is required.

31.2.53.6 IDENTIFY the function of components and circuit operation (including neutralization of oscillation) in a tuned RF amplifier circuit by selecting the correct statement from a choice of four. 100% accuracy is required.

31.2.53.7 IDENTIFY the conduction time, operation, output waveforms, and relative efficiency of class A, B, AB, and C amplifiers by selecting the correct amplifier class, waveform, or statement from a choice of four. 100% accuracy is required.

31.2.53.8 IDENTIFY the effect of adding tuned tanks to transistor outputs (flywheel effect) on class AB, B, and C RF amplifier circuits by selecting the correct statement from a choice of four. 100% accuracy is required.

31.2.53.9 IDENTIFY the sweep frequency generator method of testing the frequency response of an amplifier by selecting the correct statement from a choice of four. 100% accuracy is required.

31.2.53.10 MEASURE and COMPARE frequency response curve characteristics of an RF amplifier, given a training device, circuit boards, test equipment and proper tools, schematic diagrams, and a job program containing references for comparison. Recorded data must be within limits stated in the job program.

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 2

RF Amplifiers

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:

- Summary
- Progress Check
- Telonic 1232A Sweep Generator I.S.
- Job Program Thirty-2 "RF Amplifiers and the Sweep Frequency Generator"

Additional Material(s):

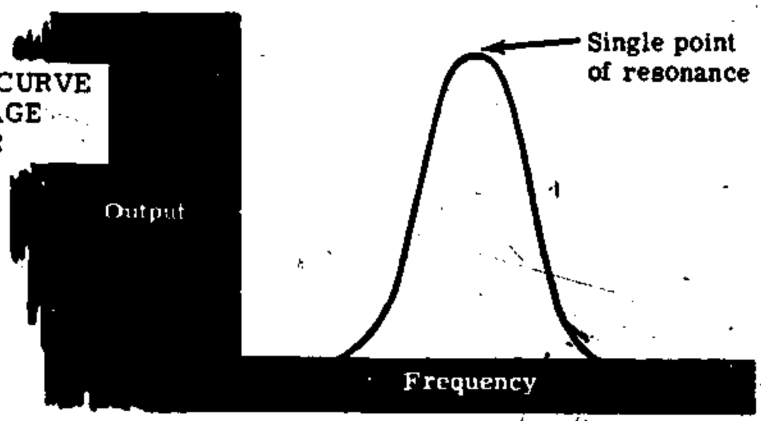
Enrichment Material(s):

NAVSHIP 0967-000-0120 "Electronic Circuits" Electronics Installation and Maintenance Book (EIMB) Naval Ship Engineering Center, Washington, D.C.: U.S. Government Printing Office 1965.

NAVSHIP 0967-LP-000-0130 "Test Methods and Practices" Electronics Installation and Maintenance Book (EIMB) Naval Ship Engineering Center, Washington, D.C.: U.S. Government Printing Office 1970.

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

SELECTIVITY CURVE
OF A TWO-STAGE
RF AMPLIFIER



SUMMARY
LESSON 2

RF Amplifiers

Amplifiers are called RF amplifiers only because they have untuned or tuned input and output coupling with a frequency response in the RF range. Tuned coupling is more common because we are usually interested in the RF amplifier's selectivity when we tune to a specific station on a radio receiver.

Transformers can be made into tuned parallel resonant coupling circuits by placing a capacitor across either or both windings. An example using tuned coupling transformers in a basic amplifier circuit is shown in Figure 1.

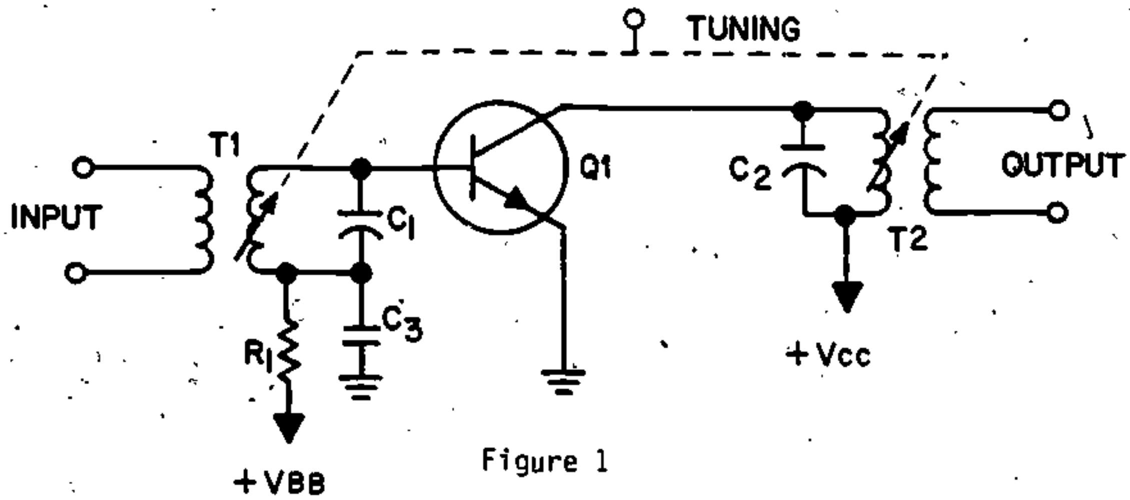


Figure 1

TUNED RF AMPLIFIER

If all the resonant circuits are tuned to the same frequency, the signal input to Q1 and signal output from T2 will be maximum at that Fo.

66

Amplifier selectivity is directly related to the number of circuits tuned to the same frequency in the amplifier's signal path. This relationship is shown in Figure 2.

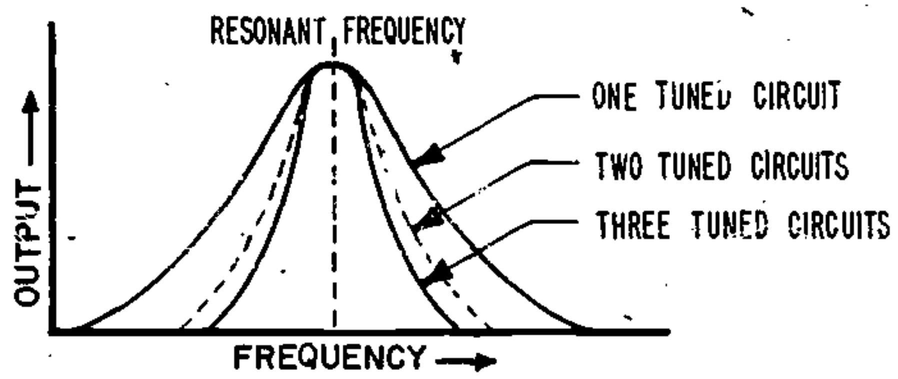


Figure 2

RF AMPLIFIER FREQUENCY RESPONSE CURVES

The input and output coupling tanks can be variable tuned at the same time if the capacitors or inductors are connected together, or "ganged". Figure 3 shows a circuit with ganged variable capacitors.

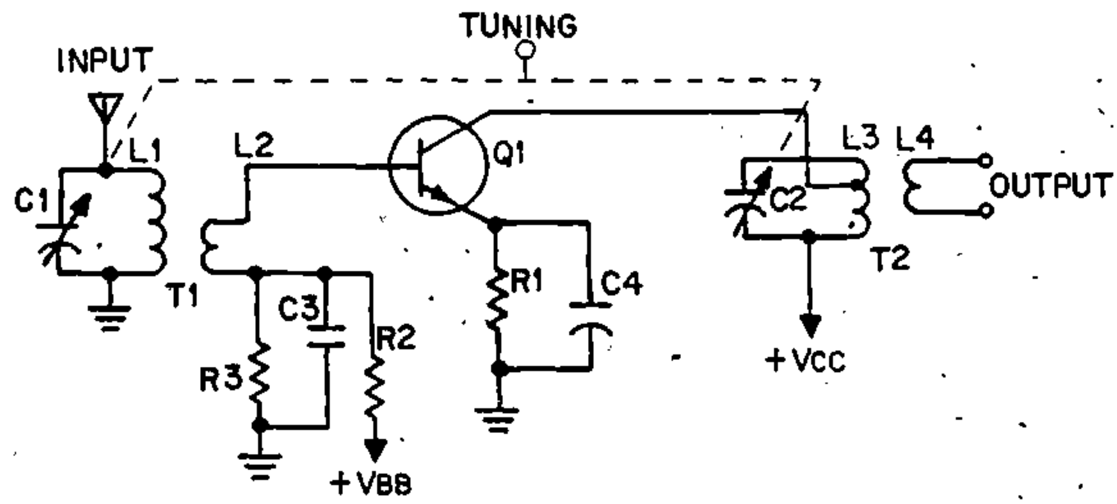


Figure 3

GANGED CAPACITIVE TUNING

Capacitors may be ganged by gears, pulleys, and most often by a common shaft.

Figure 4 shows schematics and a pictorial view of an individual inductive tuned RF transformer.

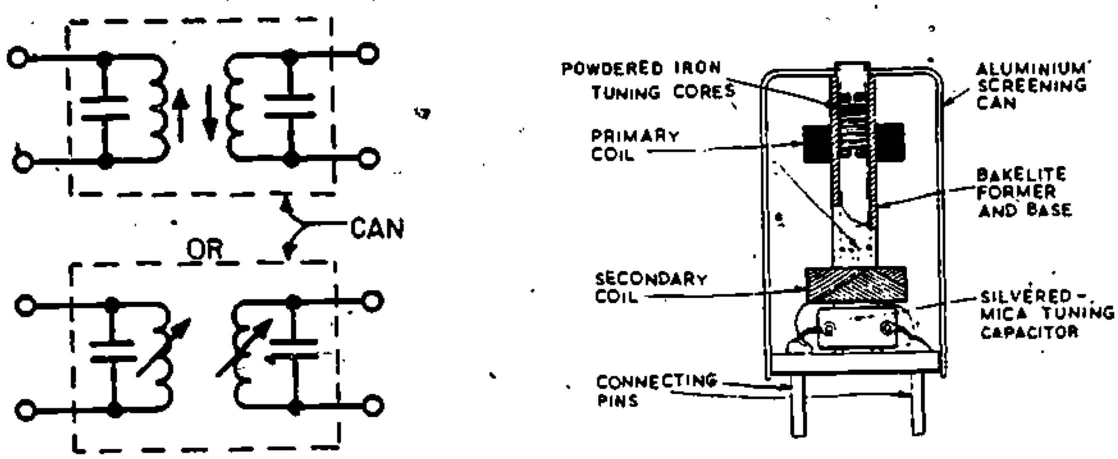


Figure 4

INDUCTIVE TUNED RF TRANSFORMER

The primary and secondary windings can be independently tuned. The entire unit is completely enclosed within a metallic shield. This device is very common in radio receivers and transmitters.

Transformer coupling is inefficient for higher RF signals. To get around this problem, the modified coupling circuit in Figure 5 retains the selectivity advantages of the parallel resonant circuit. C3 provides additional coupling between L1 and L2.

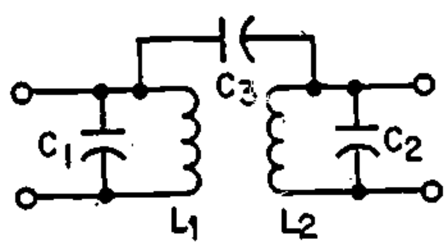


Figure 5

CAPACITIVE COUPLED TUNED TANKS

The Q of an inductor, tank, or loaded circuit expresses the relationships between inductive reactance (XL), capacitive reactance (XC), and resistance (R). The Value Q, or quality, represents the ratio of "energy stored/energy used". Figure 6 shows the inductor equivalent for XL and Rc (coil resistance).

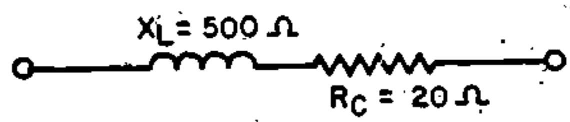


Figure 6

INDUCTOR EQUIVALENT

The formula for Q of a coil is Qcoil = XL divided by Rc, or 25 in the example. Figure 7 shows a simple LC tank circuit.

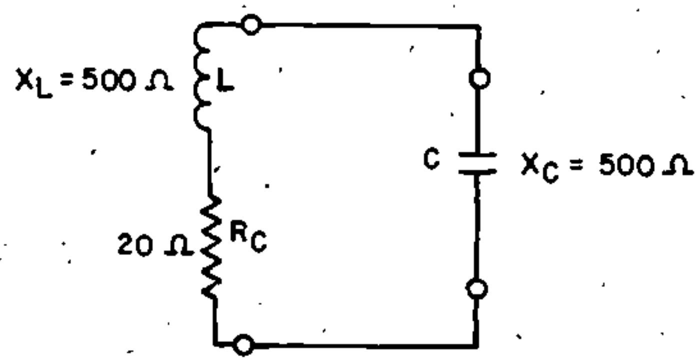


Figure 7

TANK CIRCUIT

In the tank, both XL and XC are equivalent expressions for energy stored. Therefore, the formula for Q of the tank is Qtank = XL (or XC) divided by Rc, or 25 in the example.

Bandwidth can be determined by the formula BW = Fo divided by Q tank. The relationship between the Q of a tank and bandwidth can be seen in the tank circuit diagram and tank frequency response curve in Figure 8.

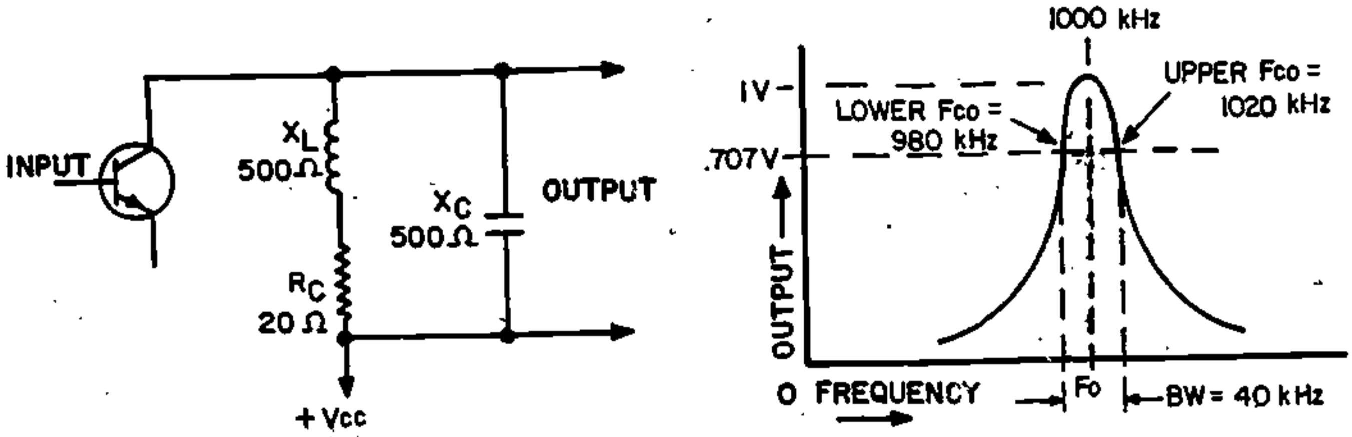


Figure 8

TANK Q vs BANDWIDTH

The figure shows a 40 kHz bandwidth. You can calculate the bandwidth by plugging the circuit diagram values into the formula for Q and bandwidth. In the example, Q equals 25, and bandwidth equals 1000 kHz divided by Q, or 40 kHz. The steep sides, or skirts, on the frequency response curve indicate that the Q of the tank produces high selectivity. If the coil resistance in the tank increases while XL, XC, and Fo remain constant, the Q would lower and the bandwidth would widen. Coil resistance can be increased by winding coils of the same XL with smaller diameter wire.

Figure 9 shows a loaded circuit which includes a tank, switch, and parallel load (Rp).

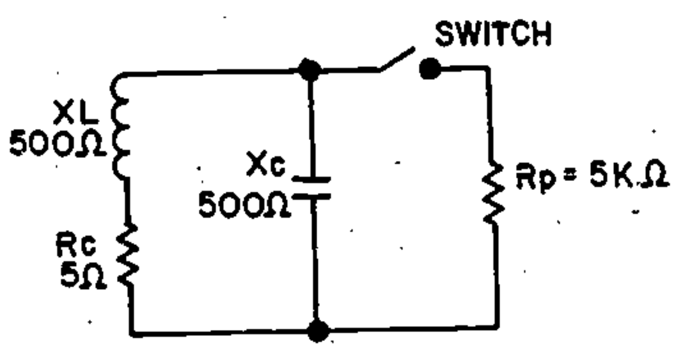


Figure 9

LOADED CIRCUIT

When the switch is open, the Q of the unloaded tank is expressed by the familiar ratio XL (or XC) divided by Rc, or 100 in the example. When the switch is closed, the Q of the loaded tank circuit is Q ckt = Rp divided by XL (or XC), or 10 in the example. The Q of the circuit will be lower when a load is placed on a tank than the Q of the tank without a load. In wideband RF amplifiers, "swamping" resistors sometimes are placed across tank circuits to purposely lower the Q of the circuit and widen the bandwidth.

Figure 10 shows a typical RF amplifier input stage in a broadcast band radio receiver.

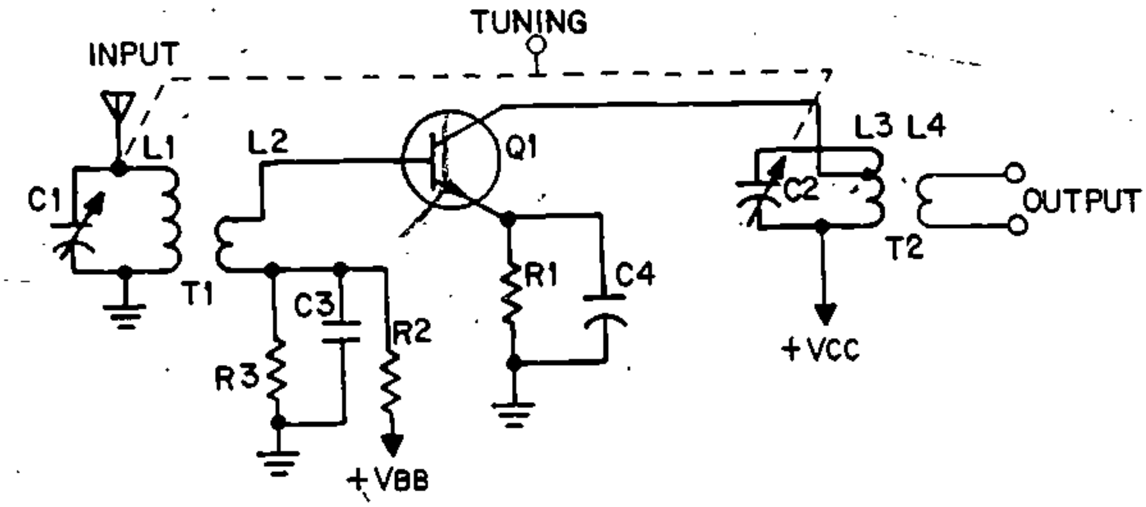


Figure 10

TYPICAL TUNED RF AMPLIFIER

R2 and R3 form a voltage divider to provide forward bias for Q1. C3 places the bottom of L2 at RF ground potential and ensures all signal development is across L2. TI is a step-down transformer with the low impedance winding L2 connected to the base of QI. This impedance match provides for maximum energy transfer between the antenna and base of Q1, and also preserves the Q of the LI-CI tank.

Both the Q and selectivity of tank L3-C2 are preserved in a similar manner. The technique of tapping L3 provides a good impedance match between the collector of Q1 and tank L3-C2. Therefore maximum energy transfer occurs between the output of Q1 and the input to the following stage. Note that V_{BB} and V_{CC} are often one and the same source.

In Figure 10, tank L1-C1 selects one of the many frequencies received by the antenna. The signal then is coupled to L2, fed into the base of QI, amplified, and coupled by T2 to the next stage.

Figure 11 shows one of the many different ways the amplifier circuits in Figure 10 can be drawn.

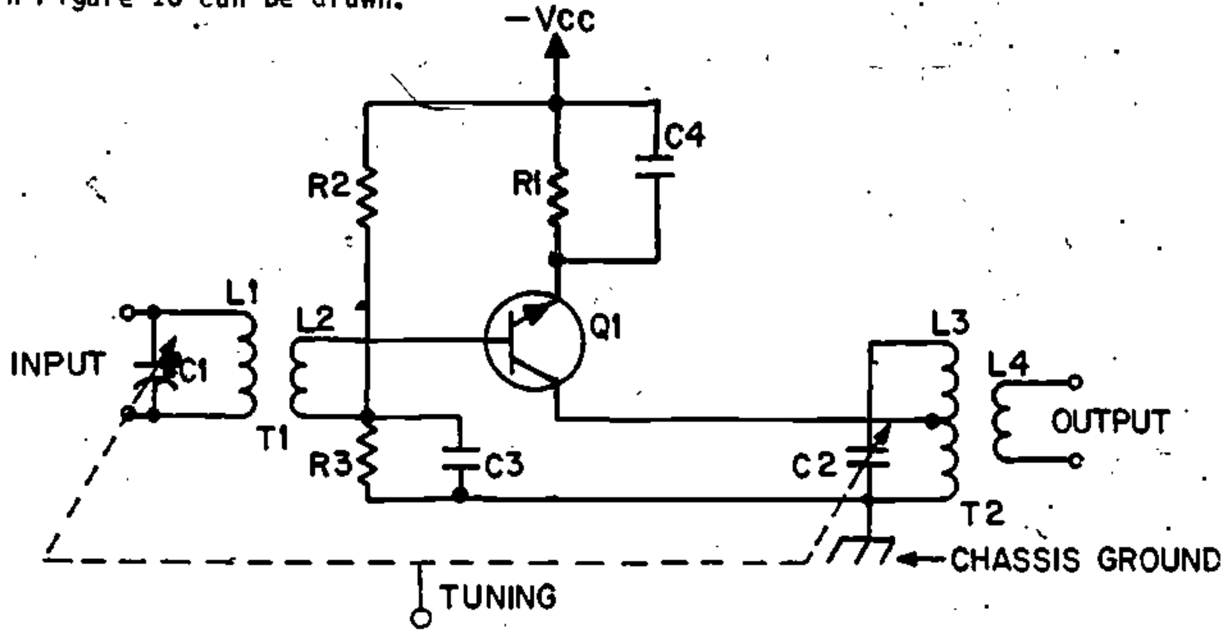


Figure 11

TUNED RF AMPLIFIER

One minor difference is that the tank L3-C2 in Figure 11 is grounded on one side allowing easy attachment of the capacitor frame to the chassis.

Transistors in tuned RF amplifiers have an internal regenerative feedback circuit which may cause oscillation at the higher frequencies. This internal regenerative feedback path is shown in the shaded area of Figure 12.

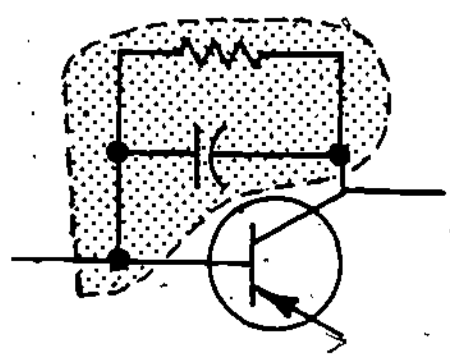


Figure 12

TRANSISTOR INTERNAL FEEDBACK

We can neutralize this internal feedback, and prevent oscillation, by connecting an external feedback circuit which produces a voltage equal in amplitude and opposite in polarity to the internal feedback voltage. Figure 13 shows two types of amplifier neutralization circuits, each labeled Cn.

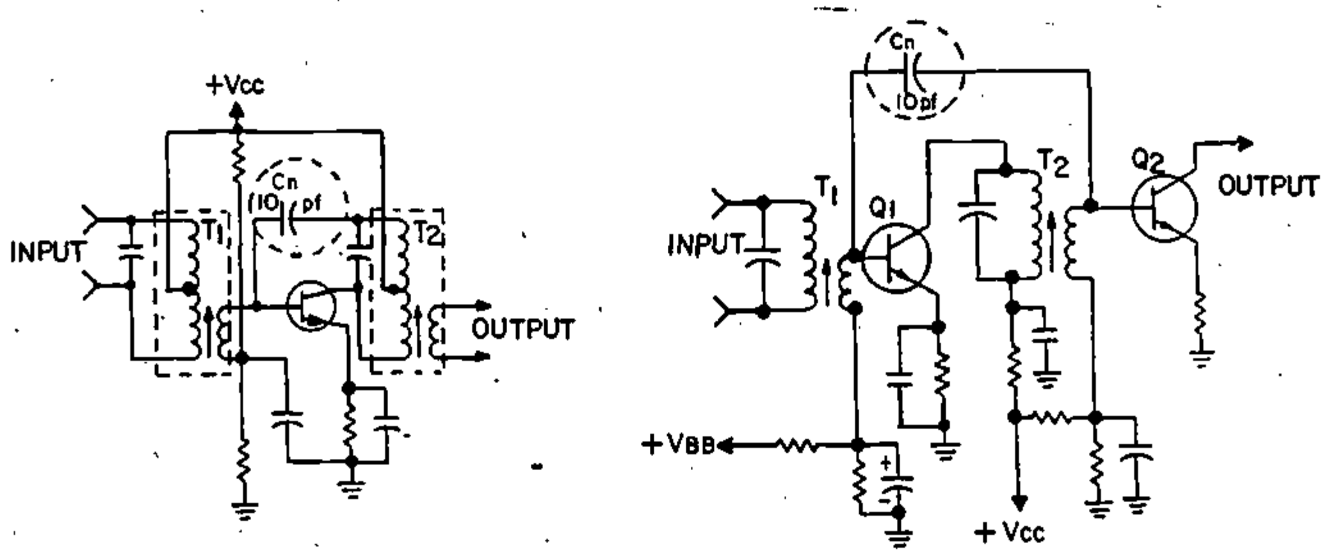


Figure 13

TYPICAL NEUTRALIZING CIRCUITS

RF amplifiers are designed to take into consideration any "stray reactances" at high frequencies caused by the position of wires and components in relation to the chassis. The capacitances Co and Cin in Figure 14 are examples of stray reactances.

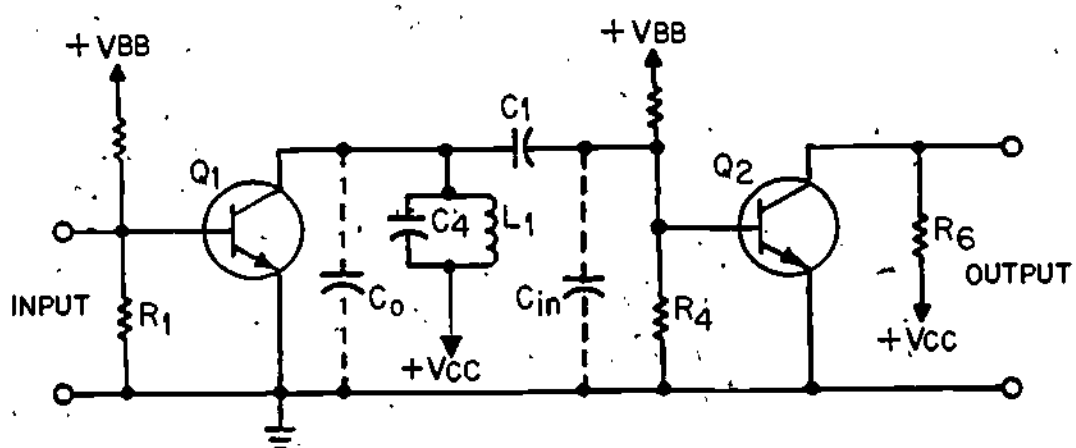


Figure 14

STRAY REACTANCES IN RF AMPLIFIER CIRCUIT

You must be neat and cautious when you repair a circuit so that replaced components will be positioned as they were before repair. Otherwise you may cause a frequency change or oscillation in the amplifier.

Amplifiers can be biased to operate either Class A, B, AB, or C. Figure 15 shows the signal input, transistor conduction waveform and time, and signal output for one cycle in Class A and Class B common emitter (CE) amplifiers with resistive loads.

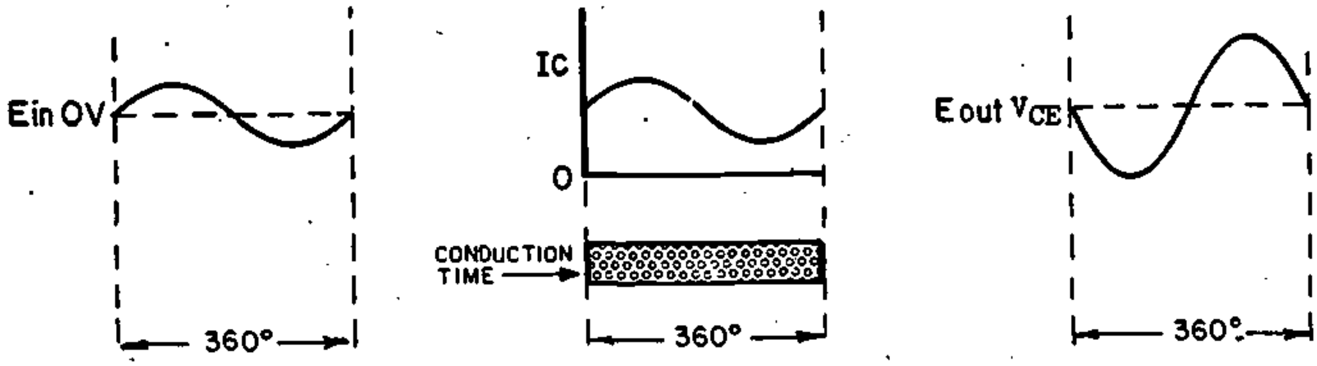


Figure 15

CLASS A OPERATION

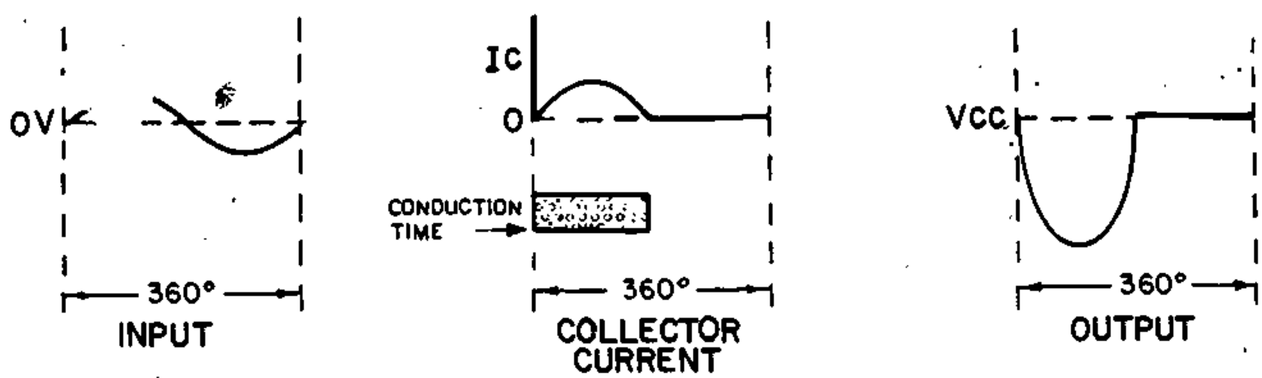


Figure 15

CLASS B OPERATION

In Class A amplifiers, the forward bias is set high enough so that the transistor conducts over the entire input cycle. In Class B amplifiers, the bias is set near zero which causes the transistor to conduct for about half the input cycle. This produces a clipped, or distorted, output signal. The reduced conduction time makes Class B amplifiers more efficient than Class A amplifiers.

Figure 16 shows the operation for Class AB and Class C amplifiers with resistive loads.

In Class AB amplifiers, the bias is set to cause the transistor to conduct for between 180° and 360° of the input cycle. Class AB amplifiers have less output distortion, but lower efficiency, than Class B amplifiers.

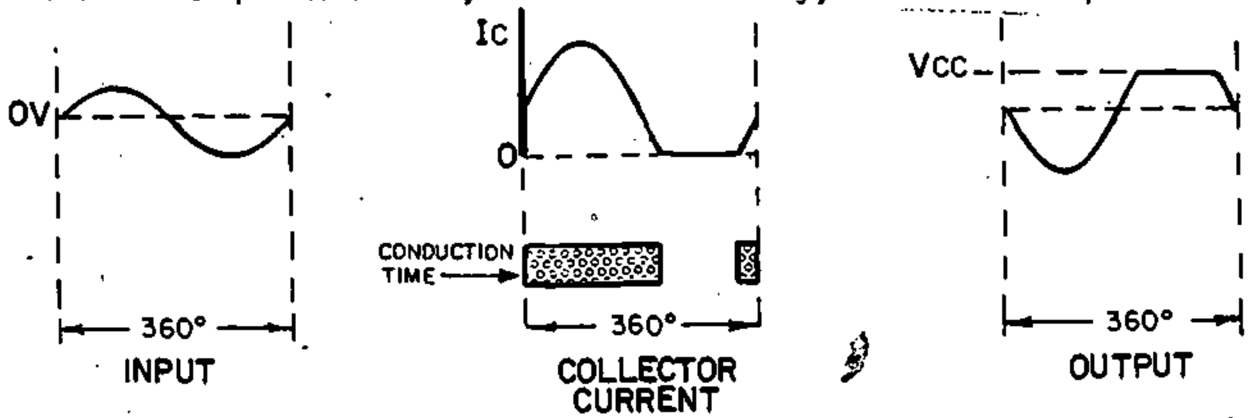


Figure 16

CLASS AB OPERATION

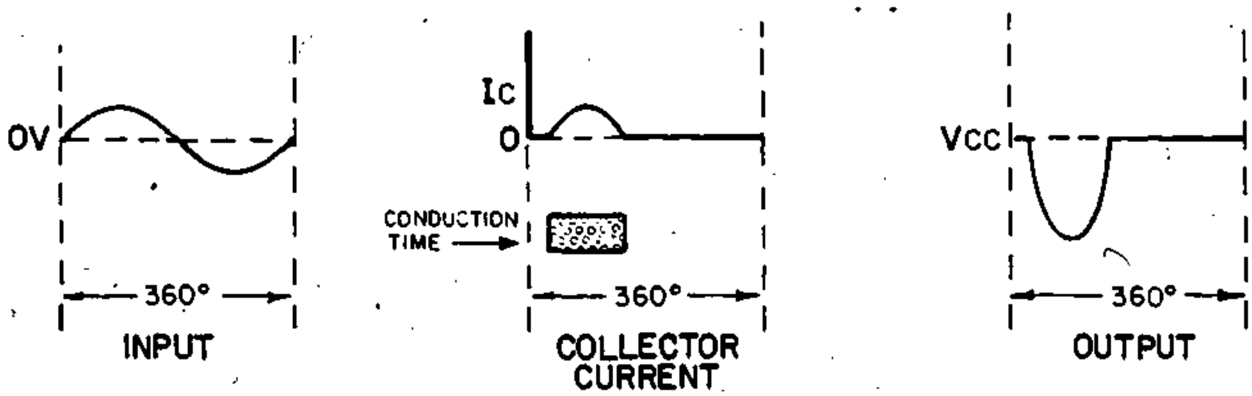


Figure 16

CLASS C OPERATIONS

In Class C amplifiers, the reverse bias causes the transistor to conduct for about 120° of the input cycle.

Class C amplifiers have the greatest output signal distortion, but the greatest efficiency of the four operating classes. Figure 17 shows an application of a Class C amplifier circuit.

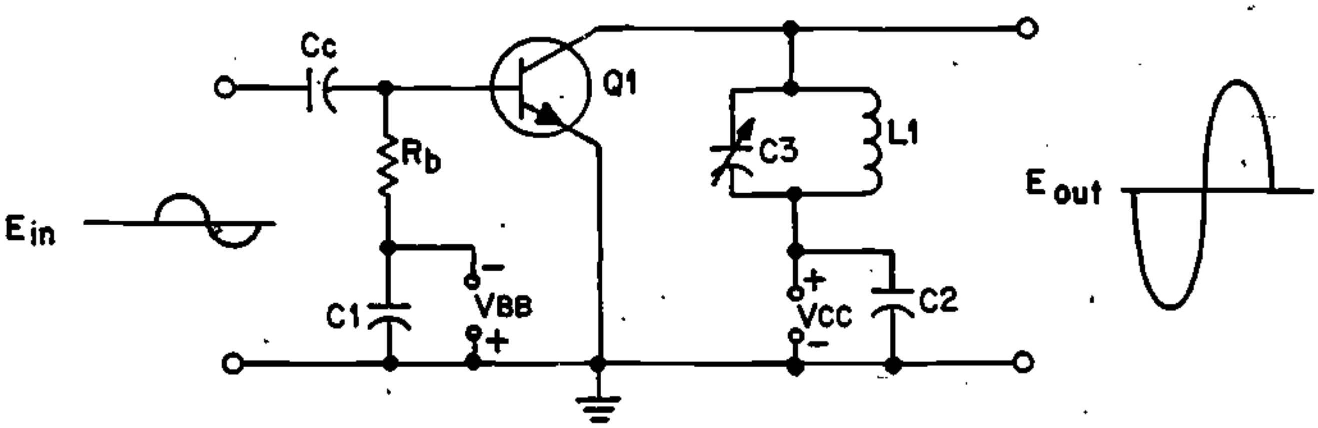


Figure 17

CLASS C RF AMPLIFIER

The actual output wave in Figure 17 is not the expected clipped wave which is characteristic of Class C RF amplifier circuits. The flywheel effect of the tank produces a damped sine wave output signal for each current pulse from the transistor. In Class C RF amplifier circuits, the tank receives the current pulse as shown in Figure 18.

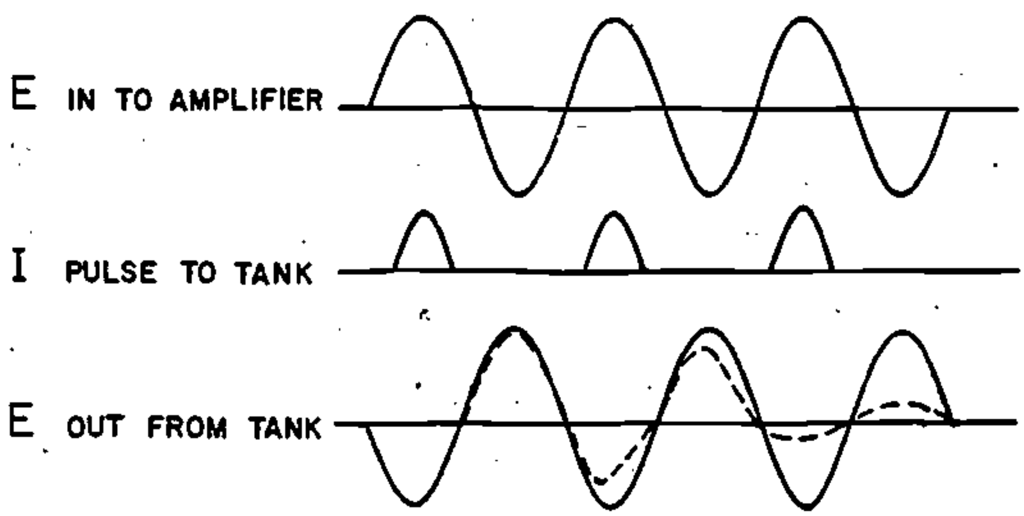


Figure 18

TANK OUTPUT FROM CLASS C AMPLIFIER OPERATION

The repeated current pulses change the damped output wave (shown by the dotted line) to resemble the reasonably good sine-wave (shown by the solid line). The flywheel effect is often used in Class AB, B, and C RF/IF amplifiers to provide a non-distorted sine wave output.

Amplifier efficiency is inversely related to the amount of operating power, and therefore, the amount of operating current. Class C amplifiers are the most efficient, and are used in applications which require large amounts of output power such as the final output amplifier of a ratio transmitter.

One method to test an amplifier's frequency response is to inject each frequency value from a standard signal generator into an amplifier, and then graph each output signal as displayed on an oscilloscope. A more efficient and accurate test method is to use a sweep frequency generator as input to the amplifier, and then directly observe the frequency response curve output on the oscilloscope. The sweep frequency generator produces a variable FM signal that sweeps back and forth over a section of the frequency spectrum.

Figure 19 shows a typical sweep frequency generator/oscilloscope set-up.

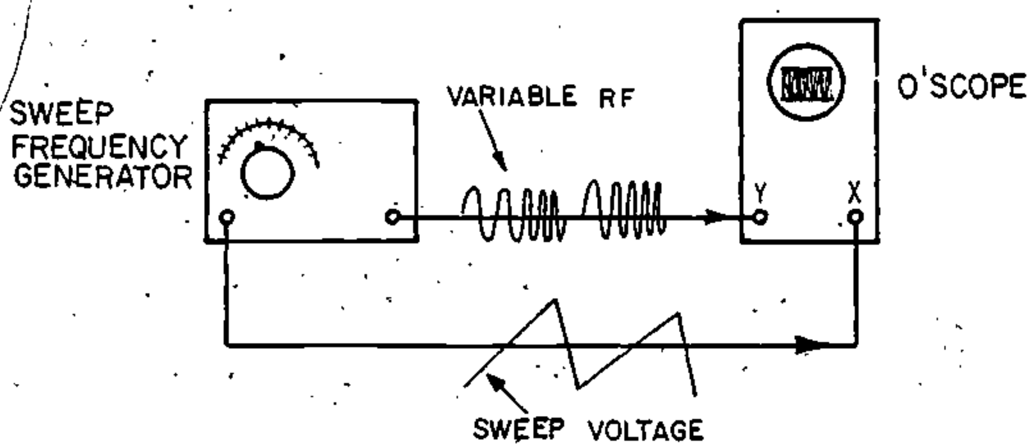


Figure 19

FREQUENCY SWEEP

The variable frequency signals from the generator are fed to the vertical input (Y) terminal of the oscilloscope. The CRT produces a rectangular display which is a combination of the sine waves from the input frequencies, and is often called a "frequency sweep". The generator also produces a horizontal sweep sawtooth wave output that is synchronized with the variable frequency output signal. The horizontal sweep output is connected to the X terminal of the oscilloscope. Since the oscilloscope inputs are synchronized, the CRT display is based on frequency and not on time.

A typical CRT display is shown in Figure 20.

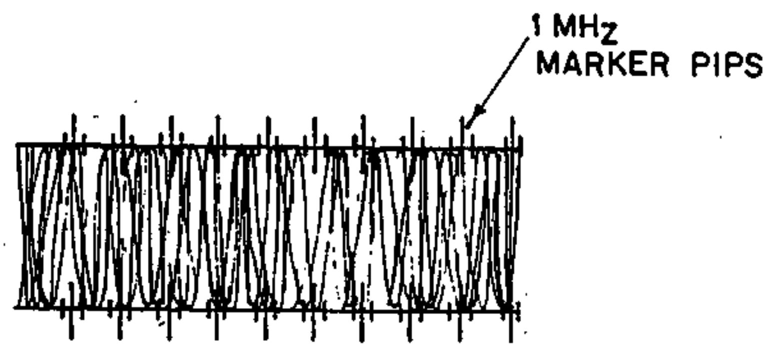


Figure 20

FREQUENCY SWEEP WITH MARKERS

In the figure, the frequency marker pips show a sweep of 5 MHz on either side of an Fo of 5 MHz.

Figure 21 shows a typical sweep frequency generator test set-up.

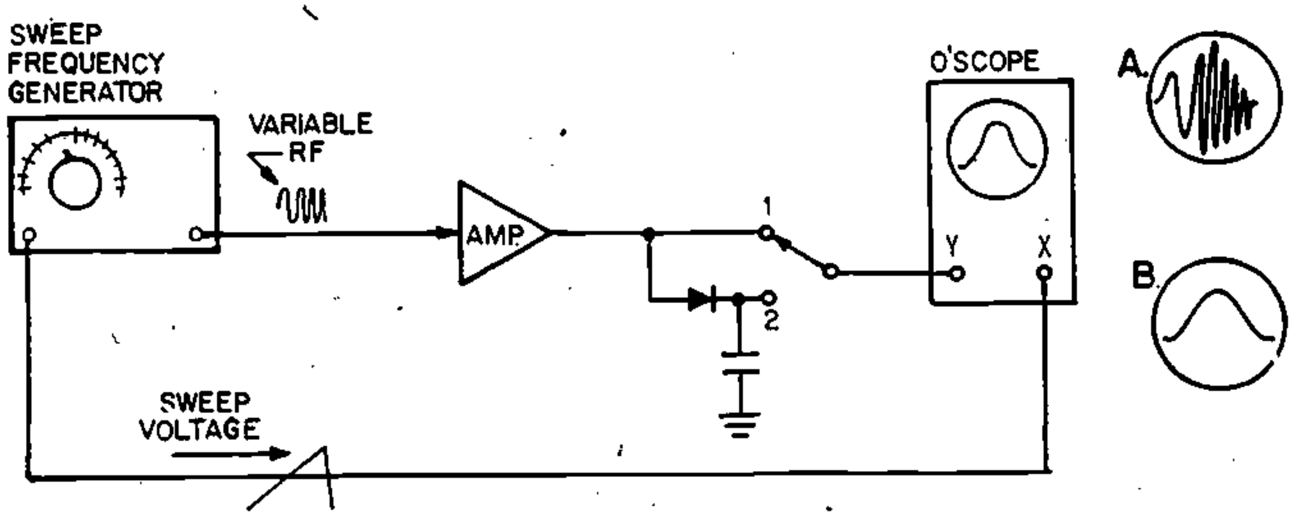


Figure 21

SWEEP FREQUENCY GENERATOR METHOD

In switch position #1, the CRT displays insert A. In switch position #2, the rectifier-filter demodulator converts the CRT display to the frequency response curve in insert B.

You will have the opportunity to use the sweep frequency generator in the job program for this lesson. With this device, you will measure the frequency response of an RF amplifier in the NIDA trainer.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, YOU MAY TAKE THE JOB PROGRAM. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON 2

RF Amplifiers

TEST FRAMES ARE 6, 11, 20, 29, 36 AND 41. PROCEED TO TEST FRAME 6 FIRST AND SEE IF YOU CAN ANSWER THE QUESTIONS. FOLLOW DIRECTIONS GIVEN AFTER THE TEST FRAME.

(1.) You know that radio frequency (RF) amplifiers are circuits commonly used in most electronic equipments. Some equipment examples are radios, television sets, and radars. All the information you learned about basic amplifiers can be applied to these circuits. For example, you can still use PNP or NPN transistors in any of the three basic configurations: Common Emitter, Common Collector, or Common Base. In this lesson you will take a closer look at the operation of the input, conversion, and output sections of RF amplifier circuits.

---

no response required

(2.) You recall that the bandwidth of amplifiers must be wide enough to pass the highest information frequency in the signal. For example, video information requires a bandwidth of about 6 MHz, and audic information requires a bandwidth of about 5 kHz. Now amplifiers are called RF amplifiers only because they have a frequency response within the radio frequency range. The same basic amplifier can be set up to amplify whatever frequency response we desire. We change the frequency response by modifying the input and output coupling.

In amplifiers, we modify the input and output ____________ to achieve desired frequency responses.

---

coupling

(3.) We may use tuned or untuned coupling circuits in amplifiers. Tuned coupling circuits are far more common, and will be covered later on in this lesson. For now, look at Figure 1 and see if you remember this type of circuit from your study of basic amplifiers.

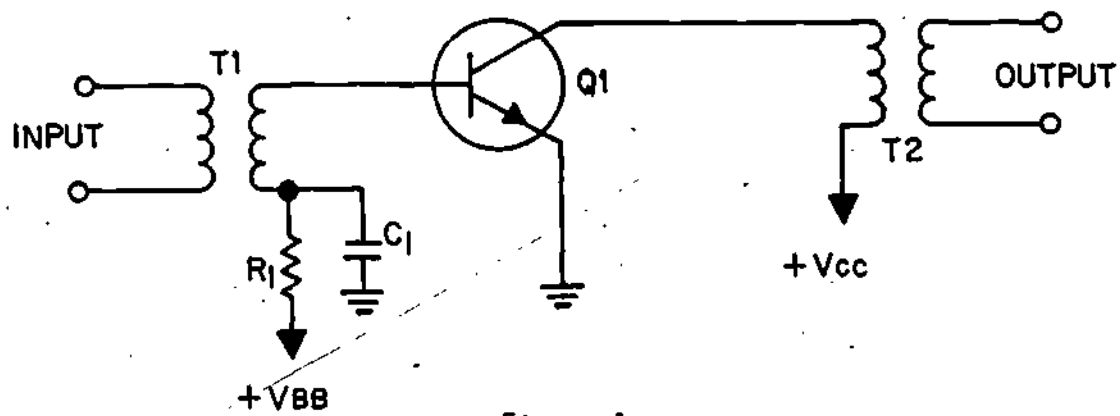


Figure 1

BASIC RF AMPLIFIER

The coupling devices T1 and T2 are untuned, air-core transformers. They will pass a wide band of radio frequencies. This would make the amplifier in Figure 1 an untuned RF amplifier.

The RF amplifier in Figure 1 is (tuned/untuned) which allows it to pass a (wide/narrow) band of radio frequencies.

a. tuned, narrow

b. tuned, wide

c. untuned, narrow

d. untuned, wide

---

d. untuned, wide

(4.) When we amplify RF signals, as in a radio receiver, we also are concerned with selectivity. In other words, we want to amplify only the frequency of the radio station that we select. Since a transformer is actually two coupled inductors, we can put a capacitor across either or both windings, as shown in Figure 2, to make the coupling circuit selective.

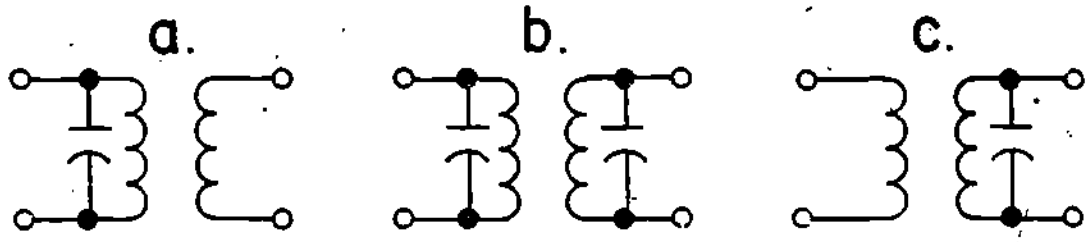


Figure 2

TUNED TRANSFORMER COUPLING

The capacitors parallel to the windings in Figure 2 make the transformer a parallel resonant circuit.

The capacitors in transformers a, b, and c, of Figure 2 make these circuits ________________.

a. parallel capacitive

b. parallel resonant

c. series resonant

d. untuned

---

b. parallel resonant

(5.) If we put these transformers into our basic amplifier, we have the circuit shown in Figure 3.

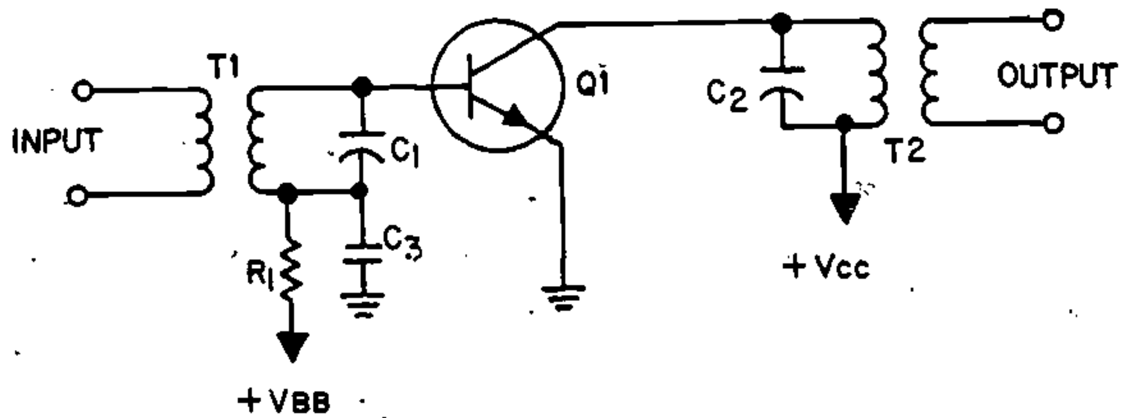


Figure 3

TUNED RF AMPLIFIER

Our basic amplifier now has an input and an output that are tuned to specific frequencies. If both resonant circuits are tuned to the same frequency, the input signal level to Q1 and the output signal level from T2 will be maximum at that resonant frequency (Fo). At frequencies above or below the resonant frequency, these tuned circuits will develop less than maximum voltage to be coupled through transformer action.

Which transformer(s) in Figure 3 is/are tuned?

a. input only

b. output only

c. both input and output

d. neither input nor output

---

c. both input and output

(6.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

Study the diagram below to answer question 1.

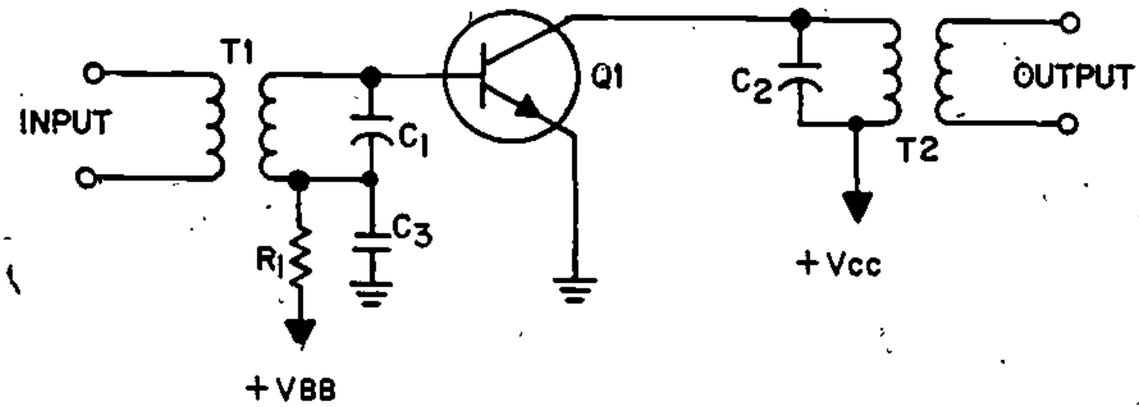


Figure 4

1. Which components of this circuit make it a tuned RF amplifier?

   a. C1 and C2

   b. V_{BB} and V_{CC}

   c. R1 and C3

   d. Q1 and T1

2. RF amplifiers achieve desired frequency response characteristics by the selection of the proper

   a. transistors

   b. coupling circuits

   c. configuration (CB - CC - CE)

   d. bias

...The Only Thing Between You and The Deep Six!

1. a. C1 and C2

2. b. coupling circuits

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 11, OTHERWISE GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 6 AGAIN.

(7.) When we add more resonant circuits tuned to the same frequency in the signal path of an RF amplifier, we get a narrower bandwidth (that is, more selectivity). Figure 5 shows the relationship between the number of tuned circuits and frequency response.

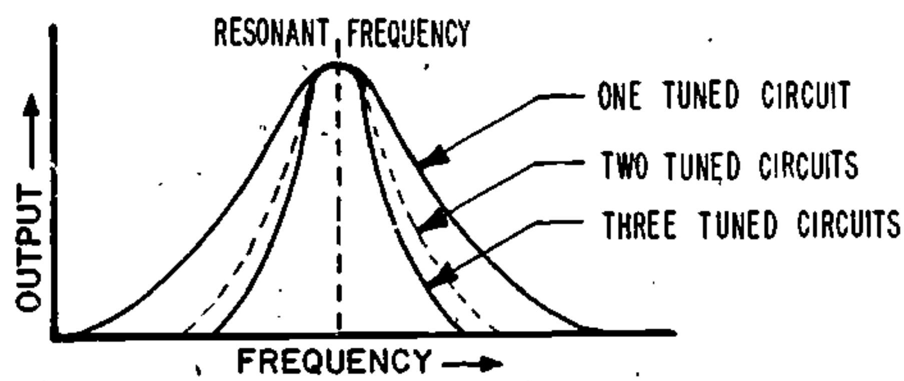


Figure 5

RF AMPLIFIER FREQUENCY RESPONSE CURVES

Adding more resonant circuits tuned to the same frequency increases the ________________ of an RF amplifier.

---

selectivity

(8.) You know that we can amplify a desired frequency in an amplifier by making the input and output coupling circ its parallel resonant. We then have a frequency selective amplifier. However, our amplifier is now tuned to only one frequency. If we desire another frequency, we must retune both the input and outout coupling circuits. The problem is how do we retune without physically replacing components? Also, how can we tune the input coupling at the same time as the output coupling? Figure 6 shows a diagram of one solution to the problem.

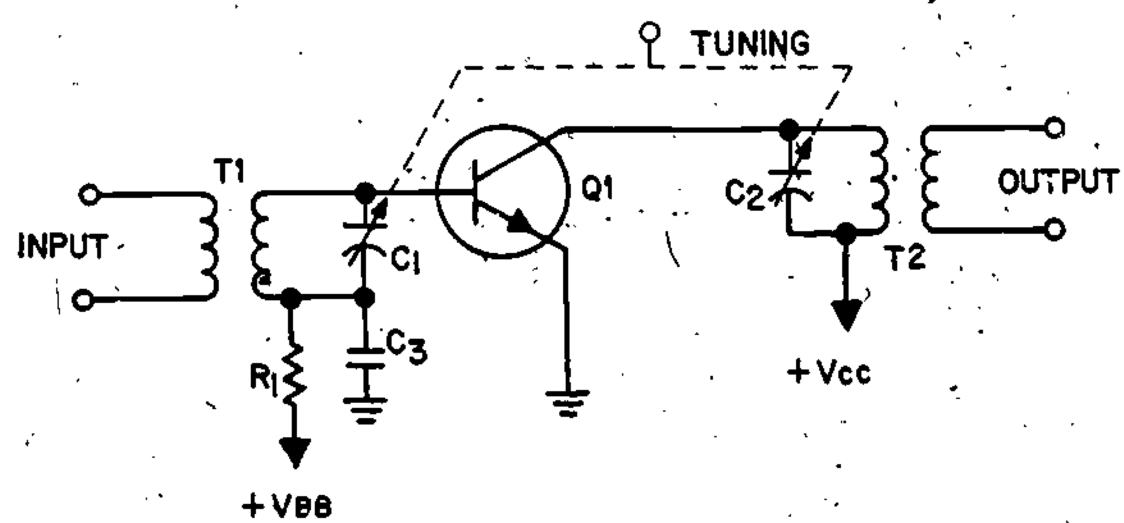


Figure 6

GANGED CAPACITIVE TUNING

In this circuit, the two tuned sections, or "tanks", are both tuned for high selectivity. Some circuits may have only one tank, but this decreases amplifier selectivity. In the diagram, the arrows through C1 and C2 mean that the capacitors are variable. The dotted line connecting them means they also are mechanically connected together, or "ganged".

Capacitors may be ganged in any one of several ways such as by gears or by pulleys. They are most often ganged by a common shaft as shown in Figure 7.

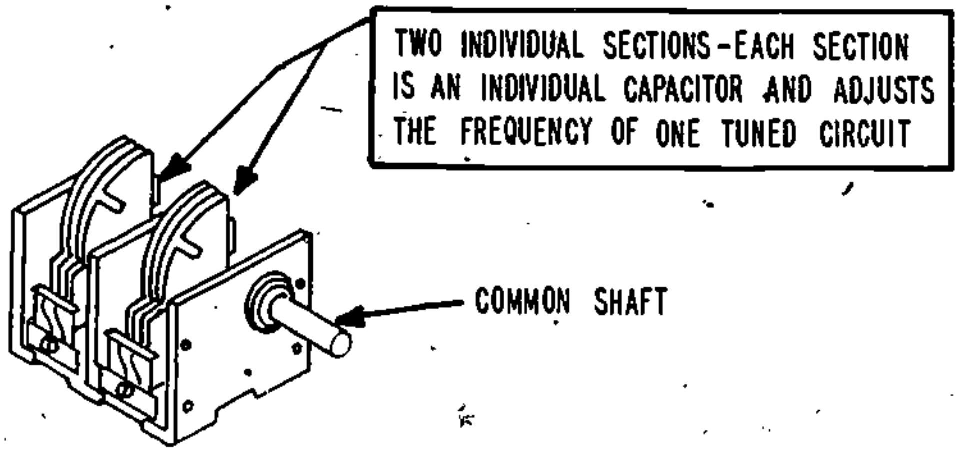


Figure 7

TWO SECTION-AIR VARIABLE CAPACITOR

In Figure 7, a (1/2) section variable capacitor is ganged using a (shaft/pulley).

2, shaft

(9.) Figure 8 shows another way to retune, at the same time, both the input and output coupling circuits in an amplifier.

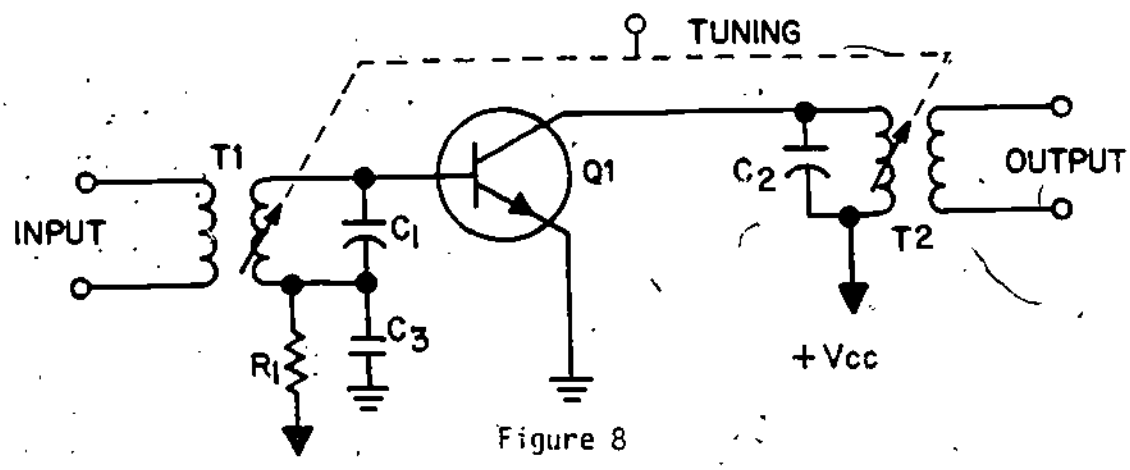


Figure 8

GAN D INDUCTIVE TUNING

In the diagram, the arrows through the windings in T1 and T2 mean that the inductors are variable.

Inductively tuned RF/IF transformers are in common use in electronic equipment. Figure 9 shows two schematics, and a pictorial view of an individual inductive tuned RF transformer.

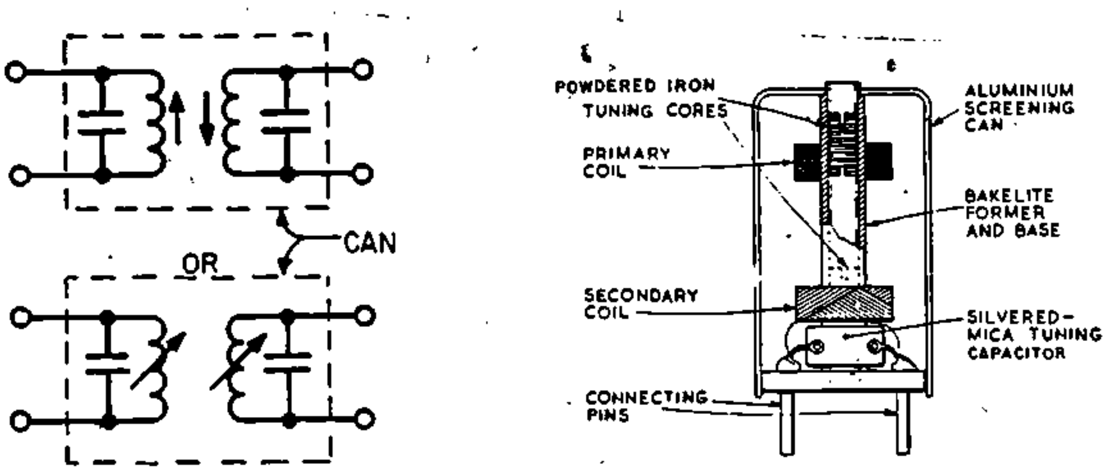


Figure 9

INDUCTIVE TUNED RF TRANSFORMER

In both schematics, notice that the capacitors are fixed. The primary and secondary windings are each single tuned by moving the powdered iron cores inside the transformer coils with special non-metallic tuning wands (see pictorial). The upper core tunes the primary winding, and the lower core tunes the secondary winding. The entire unit is completely enclosed within a metallic shield or can to prevent stray electromagnetic fields from affecting the tuned circuits.

The components which are variable in Figure 8 are the________.

a. capacitors

b. transformers

c. inductors

d. transistors

---

c. inductors

(10.) We have been talking about tuned transformer coupling, which is very good for many applications. However, the transformer's efficiency is considerably reduced when we try to couple signals at the higher RF frequencies. To get around this problem, we can use a coupling circuit like the one shown in Figure 10.

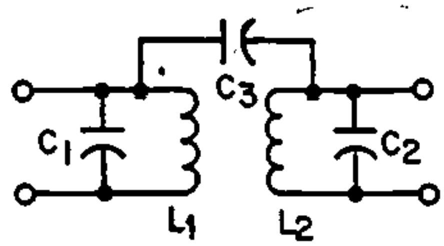


Figure 10

CAPACITIVE COUPLED TUNED TANKS

The coupling is done by capacitor C3. This type of coupling circuit allows us to keep the selectivity advantages of the parallel resonant circuit.

In Figure 10, coupling is done by component________________.

C_3

(11) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

1. If resonant circuits tuned to the same frequency are added to an amplifier, the bandwidth will

   a. remain the same

   b. become wider

   c. become narrower

USE THE DIAGRAM BELOW TO ANSWER QUESTION 2.

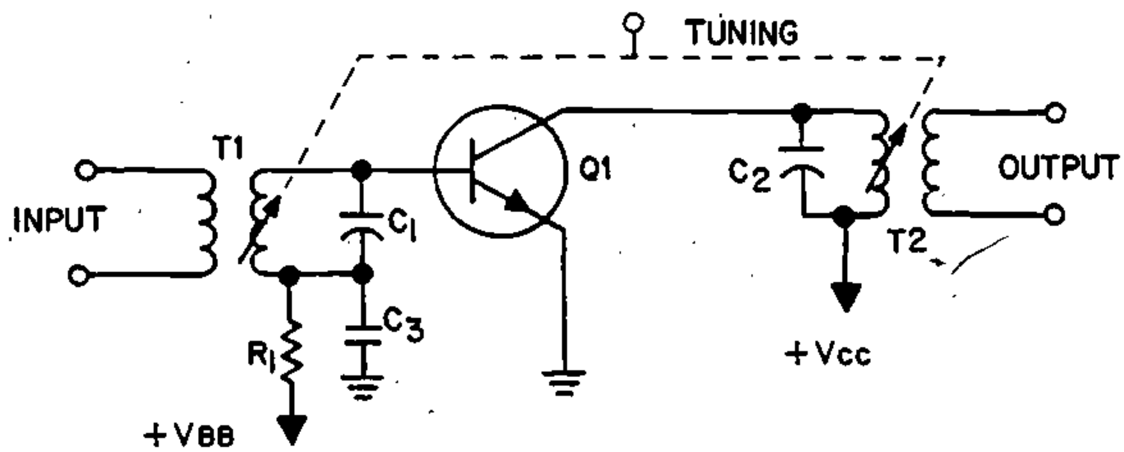


Figure 11

2. The RF amplifier circuit in the diagram has ______________________ ____________________ tuning.

   a. ganged capacitive

   b. ganged inductive

   c. single capacitive

   d. single inductive

USE THE DIAGRAM BELOW TO ANSWER QUESTIONS 3 AND 4.

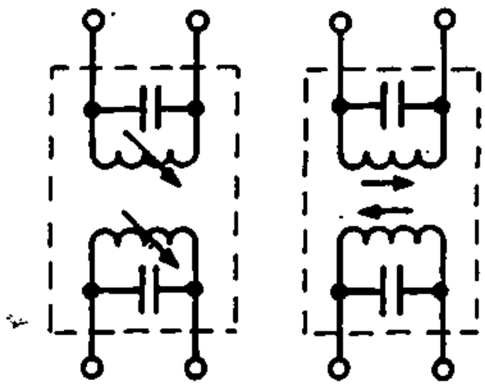


Figure 12

3. The RF transformer has ________________ tuning.

   a. capacitive

   b. inductive

4. The tuning in the primary and secondary is ___________.

   a. single

   b. ganged

1. c. become narrower
2. b. ganged inductive
3. c. inductive
4. a. single

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 20. OTHERWISE GO BACK TO FRAME 7 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 11 AGAIN.

(12.) You have learned about inductive reactance (XL) and capacitive reactance (XC), and how they are related in a resonant circuit. You also are familiar with resistance (R). You now will learn some important new applications of these properties.

In electronics, it is useful to express in measurable values the relationships between properties of circu..s. For example, you are familiar with "gain" which is a measure of the ratio of $\frac{\text{output}}{\text{input}}$. Because a resonant circuit is so common in electronic equipment, it is often useful t(express the property called "Q" of a resonant circuit and its components. Now Q, or quality, represents the ratio of $\frac{\text{energy stored}}{\text{energy used}}$. You can see in this ratio that Q becomes larger as the amount of energy stored becomes larger, or as the amount of energy used becomes smaller.

The letter "Q" in a resonant circuit represents:

a. energy stored times ener used

b. energy stored minus energy used

c. $\frac{\text{energy used}}{\text{energy stored}}$

d. $\frac{\text{energy stored}}{\text{energy used}}$

93

---

d. energy stored divided by energy used

(13) In this lesson, we are concerned with the Q of the inductor (or coil), the tank, and a loaded circuit. First we will talk about the Q of a coil.

You know that all wire has resistance. Since inductors are made by winding wires on a form, inductors have resistance. Therefore, inductors have two oppositions to AC current flow, inductive reactance (XL) and coil resistance (Rc). The Q of a coil is expressed as the ratio of inductive reactance (energy stored) to coil resistance (energy used). The formula is $Q_{coil} = \frac{XL}{Rc}$. Figure 13 shows the inductor equivalent for the two components XL and Rc.

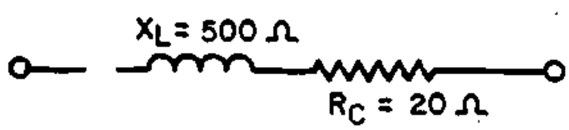


Figure 13

INDUCTOR EQUIVALENT

In Figure 13, XL equals 500 ohms and Rc equals 20 ohms. The Q equals $\frac{500 \text{ ohms}}{20 \text{ ohms}}$ or 25. A Q of 25 simply indicates that this coil has a 25 to 1 ratio of reactance to resistance. The Q figure is useful in comparing one coil or inductance with another.

The Q of a coil is the ratio of ______________ to ______________.

XL to Rc, (or inductive reactance to coil resistance)

(14) We now will talk about the Q of a tank in which the coil is a component. Figure 14 shows a simple tank.

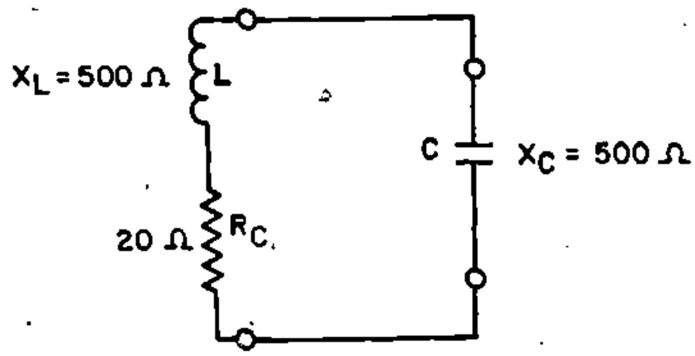


Figure 14

TANK CIRCUIT

In Figure 14, the tank is a resonant circuit containing a coil (L) and a capacitor (C). Within these two components, XL is the inductive reactance of the coil, XC is the capacitive reactance of the capacitor, and Rc is the resistance of the coil. Energy is stored in the magnetic and electric fields of the coil and capacitor. Energy is used in the form of heat caused by resistance. Now in a resonant circuit, the inductive reactance equals the capacitive reactance. Therefore XC can replace XL in the expression for Q. We can define the Q of this tank as the ratio of inductive or capacitive reactance to the coil resistance. The formula is

$$Q_{tank} = \frac{XL}{Rc} \text{ or } \frac{XC}{Rc}$$

The tank in Figure 14 has a Q equal to $\frac{XL}{Rc}$ or $\frac{XC}{Rc}$, which equals $\frac{500 \text{ ohms}}{20 \text{ ohms}}$, or 25.

What is the Q of a tank with Rc equal to 10 ohms and XL equal to 100 ohms?

10

(15.) Resonant circuits in electronics are seldom found in the isolated situation we have just used to present the principles of Q. Tanks are found in circuits connected to other components and devices. These external components and devices load the tank and affect the tank circuit. We will talk about some of these affects in a later frame. Now we are interested in some useful applications of Q.

An important application of Q in a tank circuit is the relationship between the Q of a tank and bandwidth (BW). You remember that a narrow bandwidth is related to good selectivity, or the ability to select a desired frequency and reject others. We can say that a high Q tank has a narrow bandwidth, and therefore, produces good selectivity. The relationship between bandwidth and Q of the tank is expressed in the formula Bandwidth (BW) = $\frac{Fo}{Qtank}$. You can see from this formula that as Q of the tank increases, the bandwidth around the resonant frequency (Fo) becomes narrower.

The relationship between bandwidth, Fo, and Q_{tank} is expressed in which formula?

a. $BW = \frac{Qtank}{Fo}$

b. $BW = \frac{Fo}{Q_{tank}}$

c. $BW = Fo \times Q_{tank}$

d. $BW = Fo + Q_{tank}$

96

---

b. $BW = \frac{Fo}{Q_{tank}}$

(16.) Figure 15 shows both a diagram of a tank circuit, and the frequency response curve for the tank.

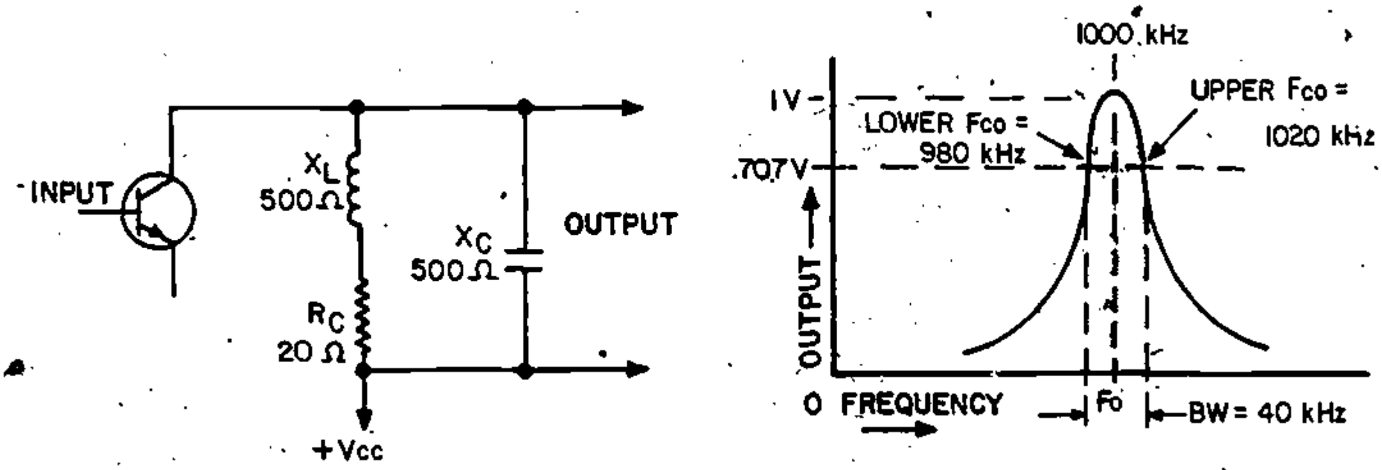


Figure 15

TANK Q VS BANDWIDTH

In Figure 15, the tank has a resonant frequency (Fo) of 1000 kHz, a frequency response of 980 kHz to 1020 kHz, and a bandwidth of 40 kHz. Now you can calculate the bandwidth by plugging values into the formulas for both Q and bandwidth. From Figure 15, Q of the tank equals $\frac{XL\ (or\ XC)}{Rc}$ or $\frac{500\ ohms}{20\ ohms}$, or 25. Since Fo equals 1000 kHz, the bandwidth equals $\frac{Fo}{Q_{tank}}$, or $\frac{1000\ kHz}{25}$, or 40 kHz. In Figure 15, notice that the frequency response curve at the upper and lower Fco points has steep sides, or skirts. This indicates that the Q of this tank produces high selectivity.

A tank circuit with an Fo of 500 kHz and a Q of 10 has a bandwidth equal

to ____________.

---

50 kHz

---

(17) Now let's examine the tank circuit diagram and frequency response curve shown in Figure 16.

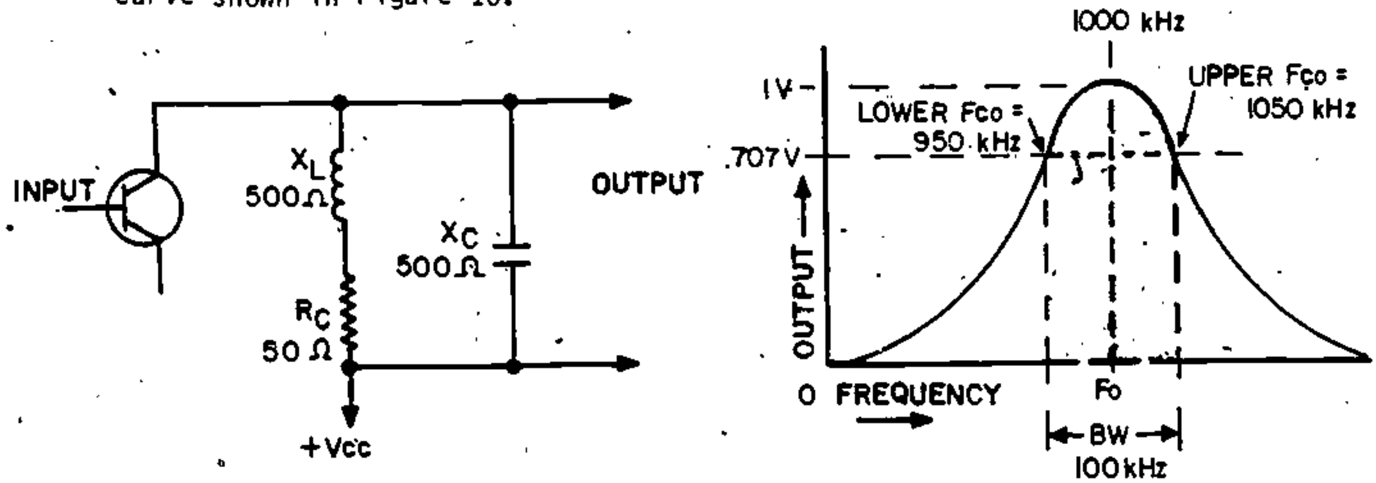


Figure 16

TANK Q VS BANDWIDTH

The only value difference on the tank diagrams between Figures 15 and 16 is that the coil resistance (Rc) is increased from 20 ohms to 50 ohms. The Q of the tank in Figure 16 now equals $\frac{500 \text{ ohms}}{50 \text{ ohms}}$, or 10. Since Fo still equals 1000 kHz, the bandwidth now equals $\frac{1000 \text{ kHz}}{10}$, or 100 kHz. You can see that Q changes as resistance changes. It is obvious from the previous examples that an increase in the resistance in series with a tank produces a decrease in Q, and also a wider bandwidth.

Resistance in tank circuits is related to the resistance of the coil wire and any other series resistance. The resistance of the coil will be determined by the diameter of the wire used to make it. Thus coils with the same inductive reactance (XL) but made with larger wire, should have a smaller resistance, and higher Q. Coils with the same XL but made with smaller wire, should have a larger resistance, and a lower Q.

In a tank, an increase in Rc produces (an increase/a decrease) in Q of the tank.

---

a decrease

(18) You have learned to apply Q to tank circuits. Now you will learn to apply Q to a loaded circuit in which the tank is a part. Figure 17 shows a loaded circuit which includes a tank, a switch, and a parallel load. (Rp).

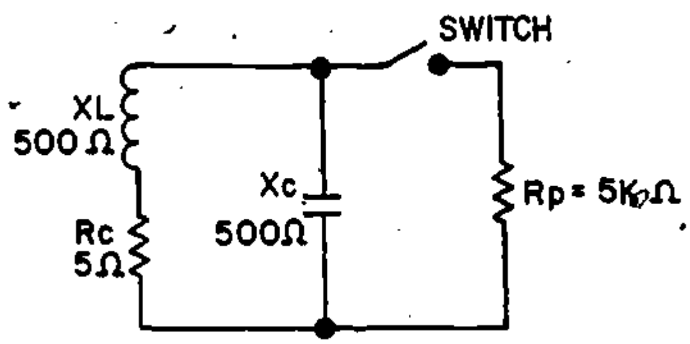


Figure 17

LOADED CIRCUIT Q

The resonant tank in Figure 17 relates Q to a practical circuit. The Q of the tank with the switch open is calculated by a method with which you are familiar, and equals $\frac{500 \text{ ohms}}{5 \text{ ohms}}$, or 100. However, when the switch is closed, the tank will deliver energy to the parallel load which is expressed as the parallel resistance, Rp. Now the tank is not isolated any more, but becomes part of the total loaded circuit. Therefore, when the switch is closed, we are interested in the Q of the circuit. The important point is that the Q of the circuit will be lower when a load is placed on a tank than the Q of the tank without a load.

When a load is placed on a tank, the Q of the circuit will be (higher/lower) than the Q of the unloaded tank.

---

lower

(19) Figure 18 again shows the loaded tank circuit from Figure 17.

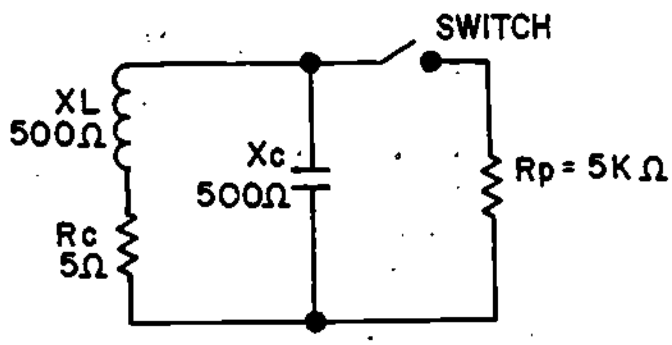


Figure 18

LOADED CIRCUIT Q

The formula for the Q of the loaded tank circuit is expressed as $Q_{ckt} = \frac{Rp}{XL}$ or $\frac{Rp}{XC}$. This formula is different from the formula for Q of a tank. In Figure 18, XL equals XC which equals 500 ohms, and Rp equals 5 kilohms. The Q of the circuit with the switch closed equals $\frac{5 \text{ kilohms}}{500 \text{ ohms}}$, or 10.

Remember that the Q of the tank with the switch open equals 100. Therefore, you can see that the loaded tank circuit has a lower Q, and a wider bandwidth, than the unloaded tank circuit. In wideband RF amplifiers, resistors sometimes are placed across tank circuits to widen the bandwidth. Resistors that are used to lower the Q of the circuit and widen bandwidth are called "swamping" resistors. In narrow-band RF amplifiers, circuits are designed to preserve the Q of the tank.

In a tank circuit, resistors may be placed in parallel in order to (increase/decrease) the bandwidth.

---

increase

(20) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

1. In an inductor, XC is 2000 ohms and Rc is 50 ohms. The Q of the coil is ______________.

2. Coil A has a Q of 10 and coil B has a Q of 20. Each coil is used in a different tank circuit with the same Fo. Which tank circuit has the wider bandwidth?

   a. tank circuit using coil A

   b. tank circuit using coil B

3. Complete the formula: Q_{tank} = ____________________.

   a. $\frac{Rc}{XL}$

   b. Rc x RL

   c. $\frac{XL}{Rc}$

   d. $\frac{XL + RL}{Rc}$

4. In a tank, the Fo is 5 MHz and the Q is 100. The bandwidth is ______________.

5. The loaded tank has a ____________ Q and ____________ bandwidth than an unloaded tank.

   a. lower, wider

   b. lower, narrower

   c. higher, wider

   d. higher, narrower

1. 40
2. a. tank circuit using coil A
3. c. XL/Rc
4. 50 kHz
5. a. lower, wider

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 29. OTHERWISE, GO BACK TO FRAME 12 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 20 AGAIN.

(21) The circuit shown in Figure 19 is a typical RF amplifier input stage in a broadcast band radio receiver.

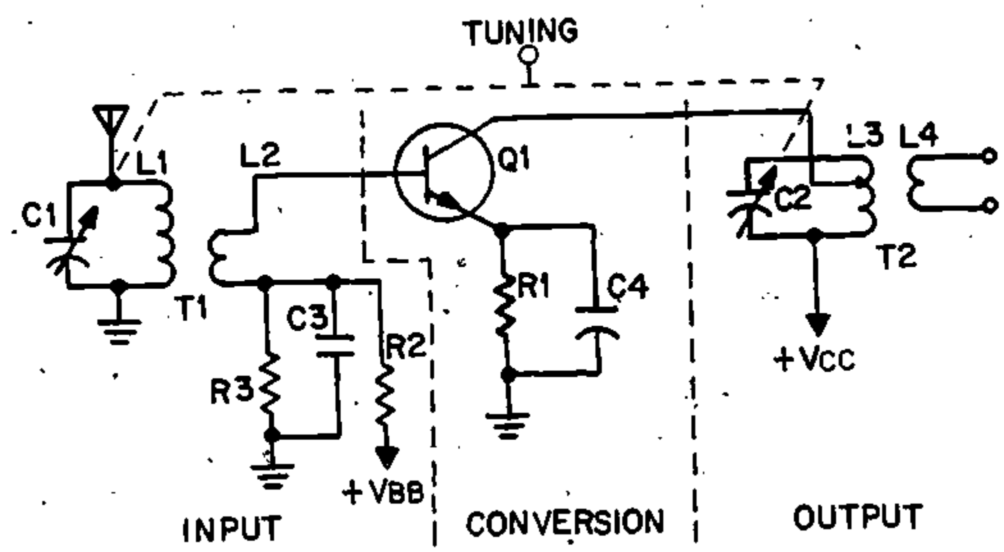


Figure 19

TYPICAL TUNED RF AMPLIFIER

You are familiar with the biasing and stabilizing components, and with the ganged capacitive tuning. You will now become familiar with the function of components not already discussed.

In Figure 19, R2 and R3 form a voltage divider to provide forward bias for Q1. C3 places the bottom of L2 at RF ground potential and ensures all signal development is across L2. T1 is a step-down transformer with the low impedance winding L2 connected to the base of Q1. This impedance match provides for maximum energy transfer between the antenna and base of Q1, and also preserves the Q of the L1-C1 tank.

Maximum energy transfer between antenna and the base of Q1 is provided by the low impedance winding of ___________.

L2

(22.) In Figure 19, both the Q and selectivity of the tank L3-C2 are preserved in a similar manner. The collector of Q1 is connected to a tap on L3. This technique provides a good impedance match between the collector of Q1 and the tank L3-C2. Therefore maximum energy transfer occurs between the output of Q1 and the input to the following stage. Of course R1 and C4 make up the familiar emitter stabilization resistor and bypass capacitor. You should note that V_{BB} and V_{CC} often are one and the same source.

In Figure 19, the Q and selectivity of tank L3-C2 are preserved by a connection between the__________of Q1 and a________on L3.

---

collector, tap

(23) Now let's trace a signal through the entire amplifier, shown again in Figure 20, to see how it operates.

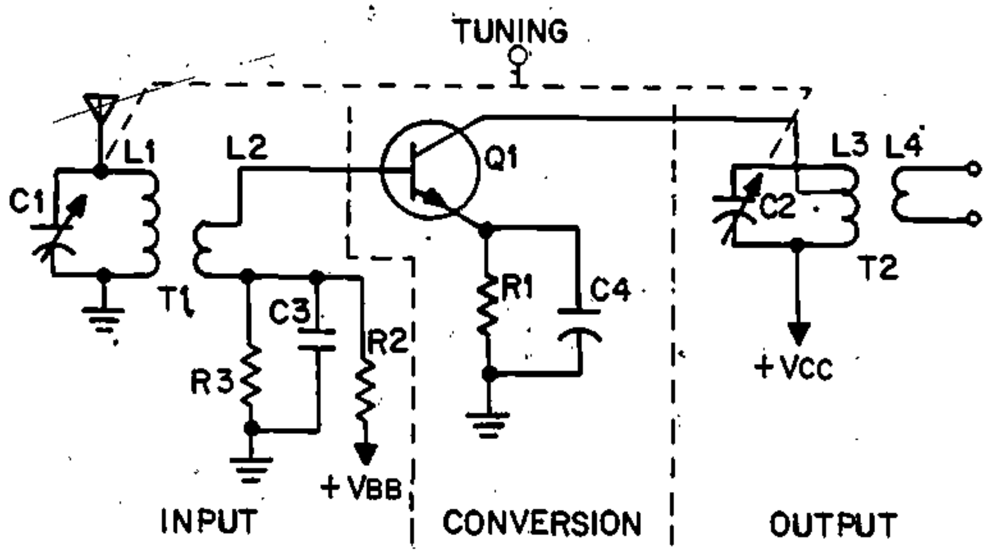


Figure 20

TYPICAL TUNED RF AMPLIFIER

First, a number of received frequencies are present as an input to the antenna circuit. When we tune L1-C1 to the frequency we want, that frequency will be developed by the tank. Since the tank is tuned, it will develop maximum voltage at that frequency only. The signal is then coupled by transformer action to L2. Our desired frequency is fed into the base of Q1 and amplified. This amplified signal is then passed to the next amplifier through the coupling transformer T2. We achieve additional selectivity by tuning the primary of T2 in tank L3-C2. Therefore, we can say that this RF amplifier has a relatively narrow bandwidth.

In Figure 20, the tuned signal is coupled to L2 by________ ________.

---

transformer action

(24.) Look carefully at Figure 21 and compare it to Figure 20.

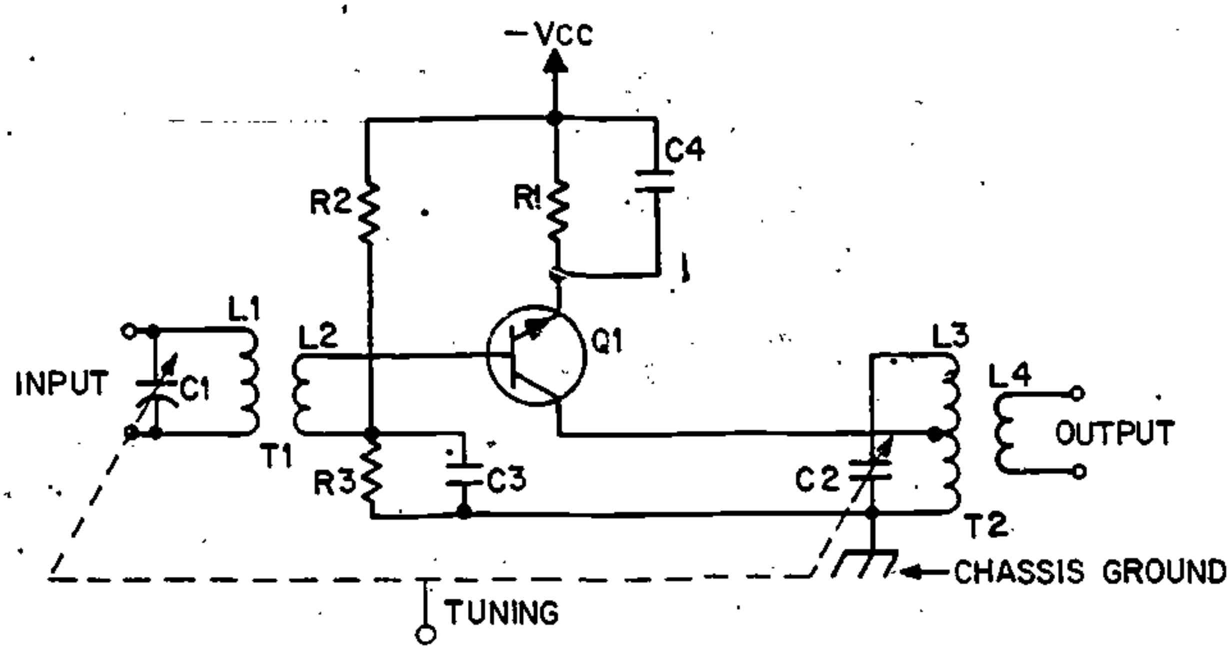


Figure 21

TUNED RF AMPLIFIER

The circuit in Figure 21 is another way of drawing the circuit in Figure 20. At first glance they may appear different to you. After some study, you should see the similarities. Often in your electronics career, you will see what first appears to be a strange circuit. However, on closer examination, it will be just a different way of drawing a common circuit.

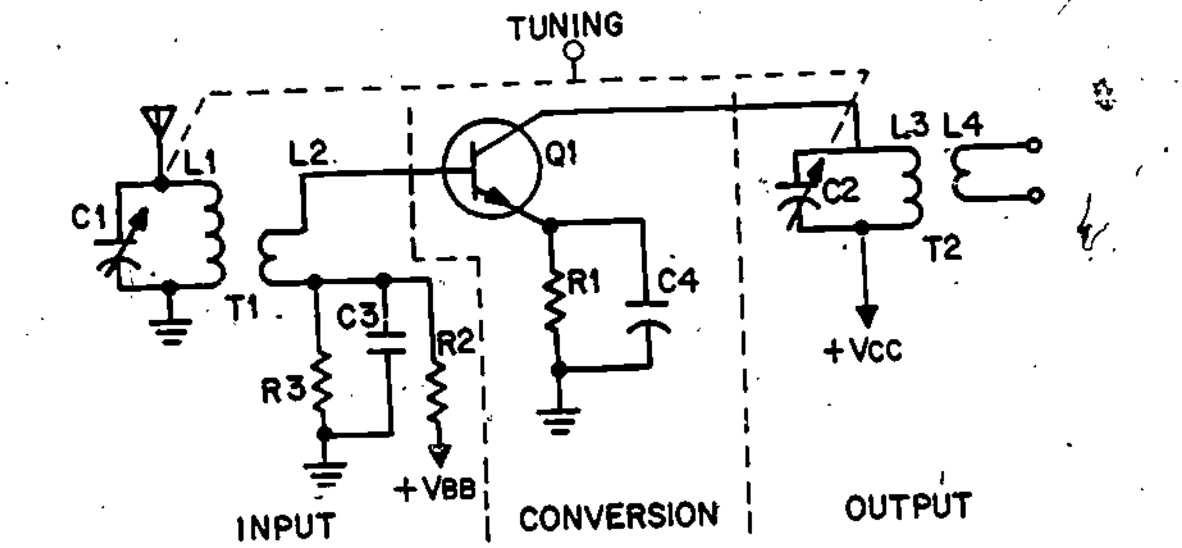


Figure 20

TYPICAL TUNED RF AMPLIFIER

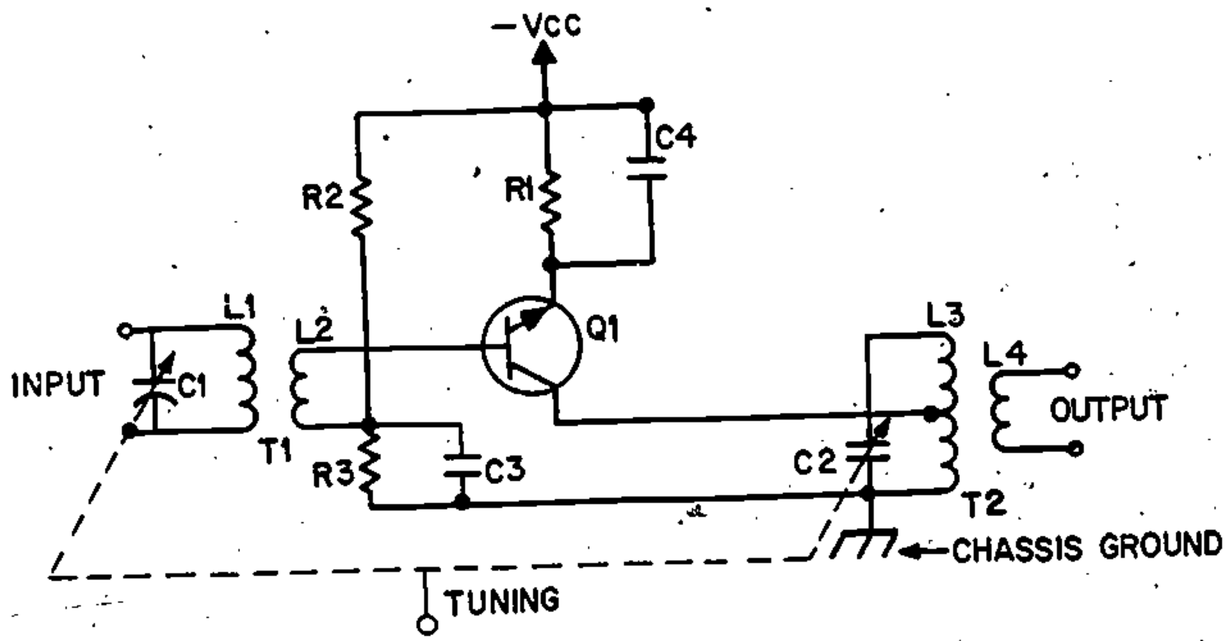


Figure 21

TUNED RF AMPLIFIER

One minor difference between the two circuits is that the tank L3-C2 in Figure 20 is grounded on one side. The circuit arrangement as drawn in Figure 21 provides an easy way to place tank capacitor C2 on chassis ground. Chassis ground connections can be an advantage with large, variable, air capacitors which have large metal frames for easy chassis mounting. This technique also reduces hand-capacity effects when tuning the capacitor.

How are identical circuits in different diagrams drawn?

a. always the same

b. sometimes differently

---

b. sometimes differently

(25) RF amplifiers may have some minor problems. One problem that sometimes occurs with RF amplifiers is that they may tend to oscillate. This tendency increases as the amplified frequency increases. You may easily understand this principle if you recall your study of basic oscillators (Module 22). There you learned that an oscillator is nothing more than an amplifier, a tuned tank, and a regenerative feedback circuit connected as in Figure 22.

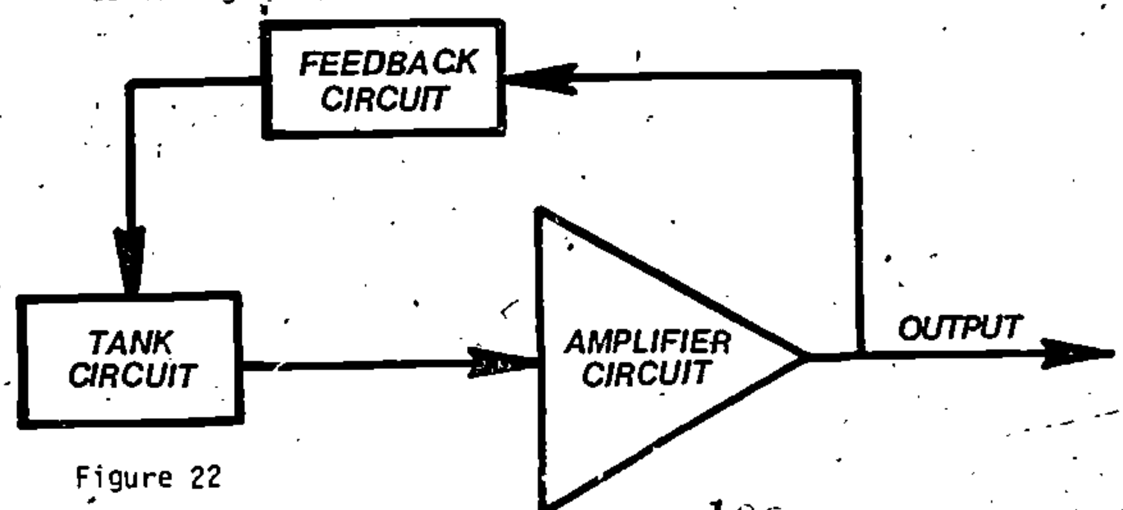


Figure 22

BASIC OSCILLATOR CIRCUIT

Now we will take a good look at the schematic diagram of an RF amplifier circuit shown in Figure 23.

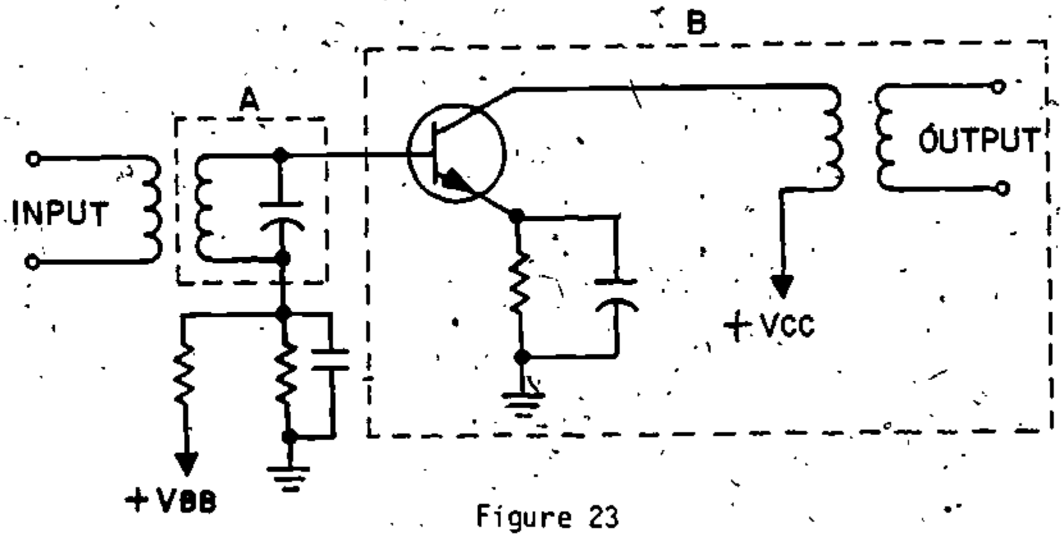


Figure 23

RF AMPLIFIER SECTIONS

In the figure, the outlined area "A" is the tank circuit. The outlined area "B" is the amplifier circuit. If we added a regenerative feedback circuit, we would have an RF oscillator.

In Figure 23, the section missing that would make the diagram an RF oscillator is the regenerative __________ circuit.

---

feedback

(26.) Transistors in tuned RF amplifiers have a built in, or internal, feedback circuit which can cause oscillation problems. The feedback is caused by the design of the transistor. Figure 24 shows the way the transistor looks electrically when it is amplifying a signal.

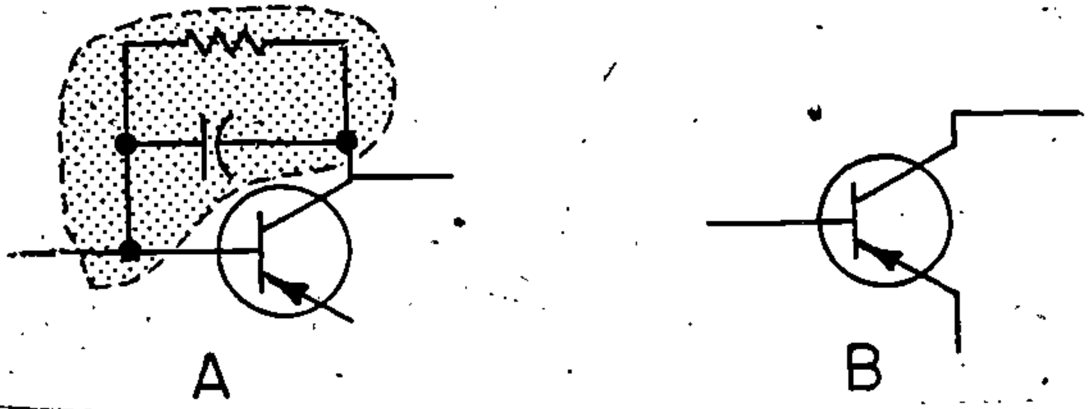


Figure 24

TRANSISTOR INTERNAL FEEDBACK

The shaded area on side "A" represents some of the internal resistances and capacitances of an operating transistor. Side "B" represents the transistor diagram as you normally see it. The internal feedback is caused when part of the signal at the collector is passed to the base of the transistor. The result is that the tuned RF amplifier tends to oscillate near the resonant frequency of the tuned tank.

Transistors have a built in ________ circuit which makes them tend to oscillate in RF amplifiers.

---

feedback

110

(27) We want an RF amplifier to amplify rather than to oscillate. To prevent oscillation, we can supply another feedback circuit which is external to the transistor. If this feedback is exactly equal in voltage and opposite in polarity to the internal feedback, the two feedbacks will cancel each other. No oscillations will occur because we have neutralized the amplifier's tendency to oscillate. The circuits in Figure 25 show two ways an amplifier can be neutralized. The neutralization component is labelled Cn.

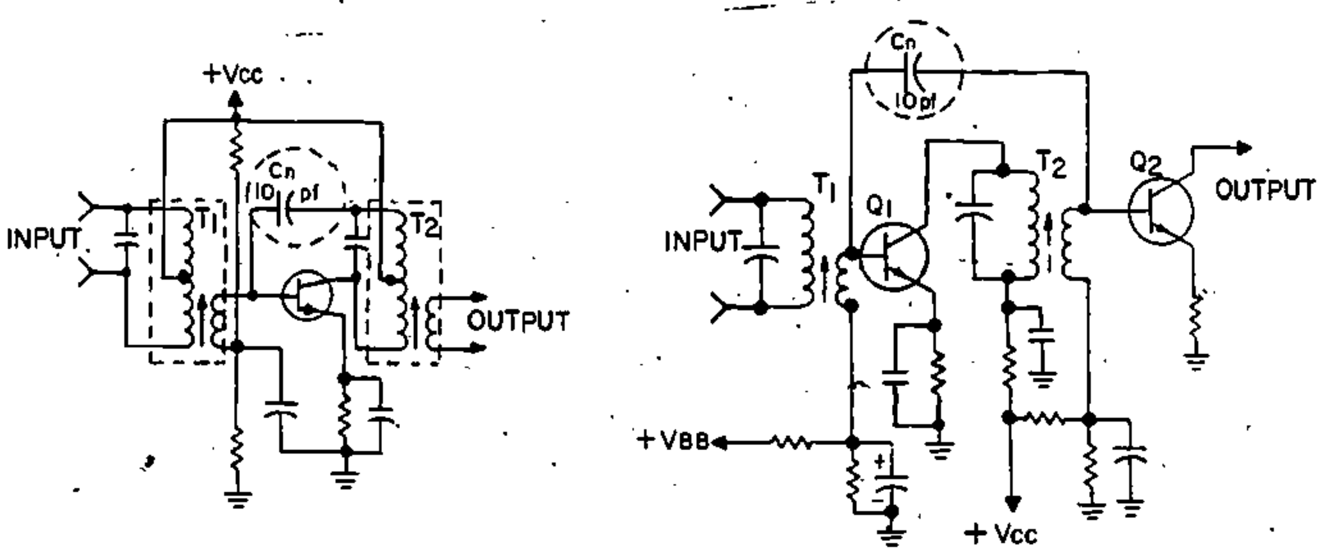


Figure 25

TYPICAL NEUTRALIZING CIRCUITS

A transistor's internal feedback can be cancelled by adding a ____________ component.

---

neutralization (or neutralizing)

(28) At high frequencies, even a straight piece of wire has some of the characteristics of an inductor or capacitor. When an engineer designs an RF amplifier, he takes these "stray reactances" into consideration. The major concern for you to remember when working with RF circuits is "neatness and caution". Wires should not be physically moved. A repaired circuit should be made to look as nearly as possible like the original circuit. Just moving a wire a small amount may change the Fo of an amplifier by several kHz or make it oscillate. An example of the effect of stray reactance is shown in the amplifier circuit in Figure 26.

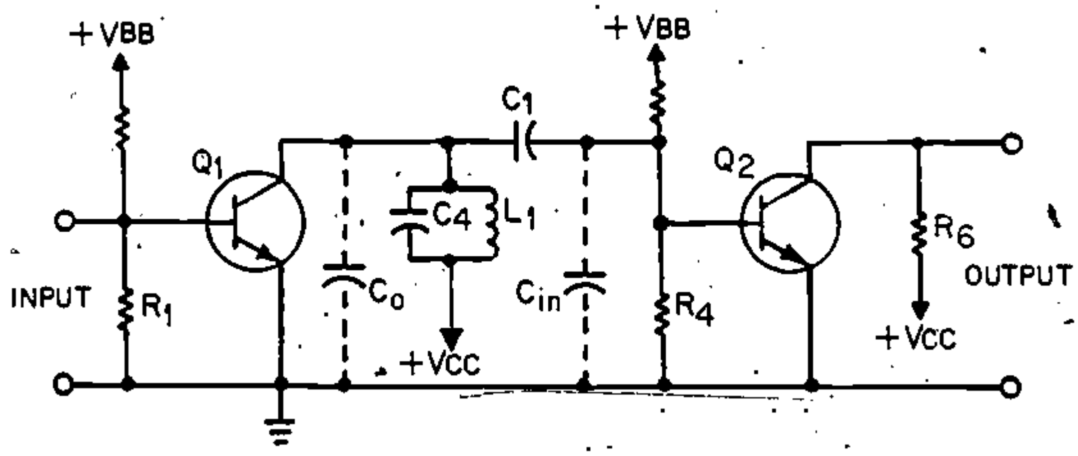


Figure 26

STRAY REACTANCES IN RF AMPLIFIER CIRCUIT

The capacitances (Co and Cin) shown with dotted lines represent the accumulation of reactances due to the position of wires and components in relation to the chassis. These stray capacitive reactances are shown across the signal path and directly influence amplifier gain.

If you move wires or components in an RF amplifier circuit, you may cause stray________to change the Fo of the amplifier or make it oscillate.

---

reactances

(29) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

USE THE DIAGRAM BELOW OF A TYPICAL TUNED RF AMPLIFIER CIRCUIT TO ANSWER QUESTIONS 1 AND 2.

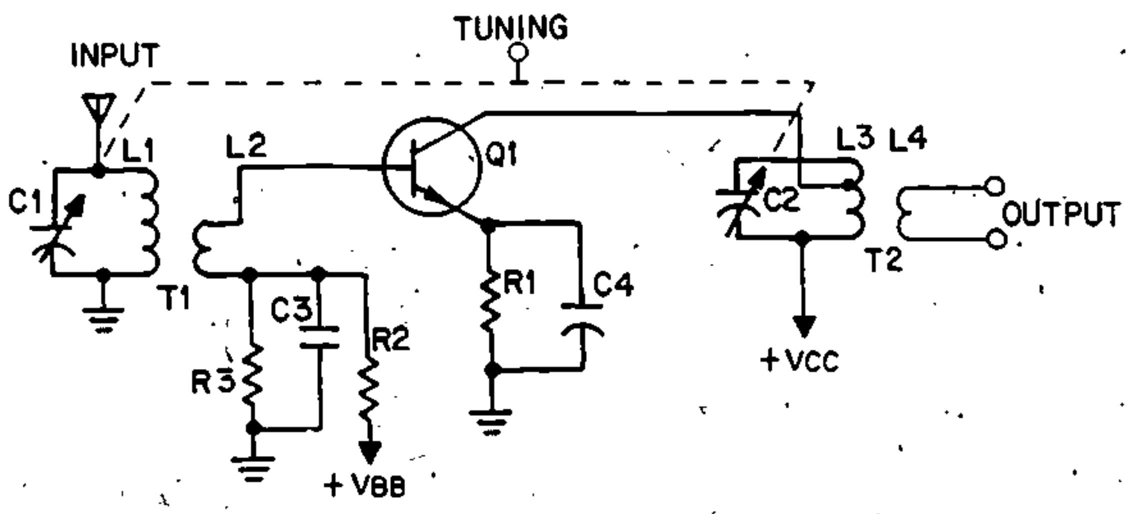


Figure 27

1. Which component places the bottom of L2 at RF ground potential?

   a. R2

   b. R3

   c. C3

   d. T1

2. The tap on L3 provides a good impedance match between the collector of QI and

   a. C2

   b. L3-C2

   c. R1

   d. L4

3. A common RF amplifier circuit may be drawn__________way(s).

   a. one

   b. two

   c. five

   d. many

4. Neutralization components are placed in RF amplifier circuits to

   a. reduce heat buildup in circuits

   b. prevent amplifiers from becoming oscillators

   c. increase the Q of coupling transformers

   d. increase the bandwidth of resonant tanks

5. You can best eliminate the effect of stray reactances during circuit repair by

   a. adding compensating reactances to the circuit

   b. shielding replaced components

   c. retuning any affected LC components

   d. replacing components as they were before removal

1. c. C3
2. b. tank L3-C2
3. d. many
4. b. prevent amplifiers from becoming oscillators
5. d. replacing components as they were before removal

IF ALL YOUR ANSWERS MATCH GO TO TEST FRAME 36. OTHERWISE, GO BACK TO FRAME 21 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 29 AGAIN.

(30.) You have learned that amplifiers can be biased to operate either Class A or Class B. We will now continue our discussion about classes of amplifier operation. Figure 28 shows the operation of Class A amplifiers.

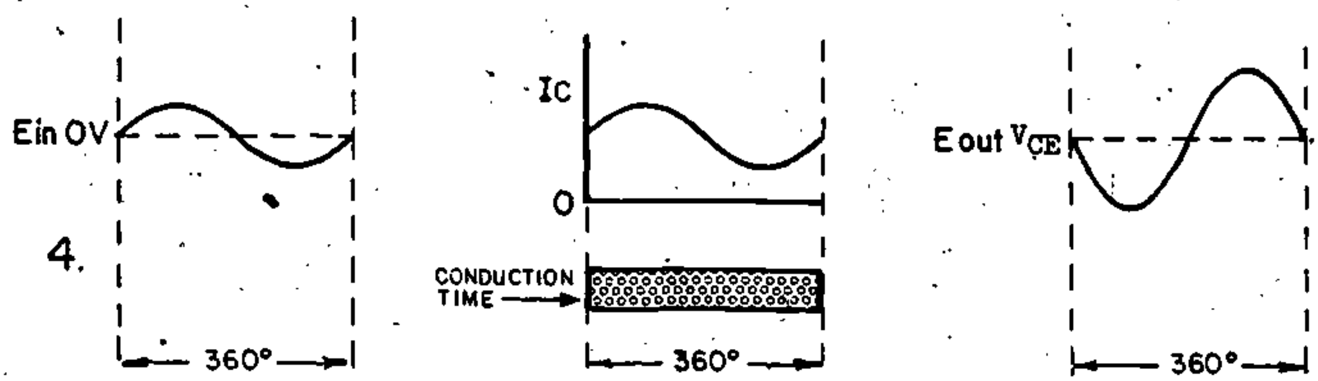


Figure 28

CLASS A OPERATION

In the figure, the left diagram labelled "E_{in}" is the input signal voltage waveform for one cycle, or 360°. The center diagram labelled "Ic" includes both the collector current waveform and a bar chart of transistor conduction time. The right diagram labelled "E out" is the amplified output voltage waveform. The output waveforms are from a CE transistor amplifier using a collector load resistor. In Class A amplifiers, the transistor conducts for the entire duration of the input cycle, or 360°.

In the center diagram of Figure 28, the bar chart shows the duration of time the transistor conducts during one cycle of the input signal. This same diagram also shows that Class A amplifiers have forward bias, and therefore will conduct even when no input signal is present. An important feature of Class A amplifiers is that the bias is set high enough so that conduction will occur over the entire input cycle. Notice that the output signal is 180° out of phase with the input signal. This is a typical output from common emitter amplifiers.

Class A amplifiers conduct for (part/all) of the input cycle.

---

all

(31.) Figure 29 shows the operation of Class B amplifiers.

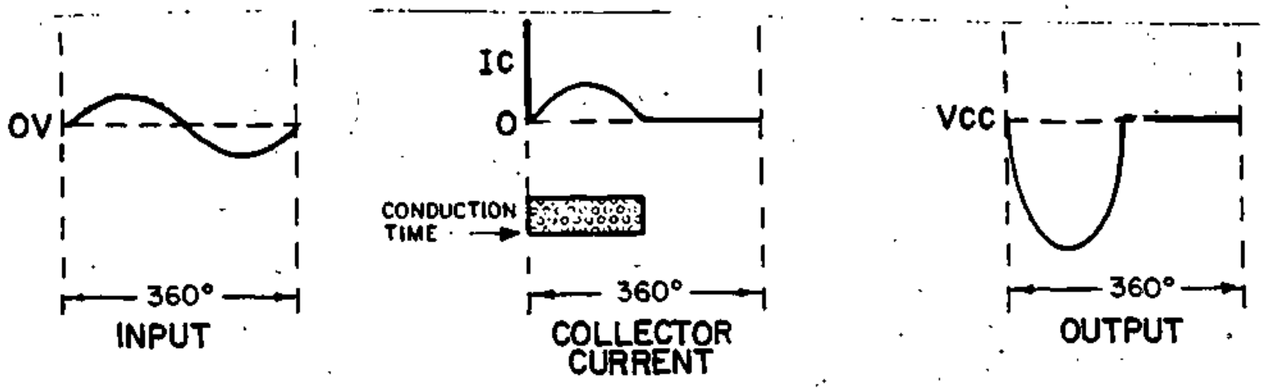


Figure 29

CLASS B OPERATION

In Class B amplifiers, the transistor conducts for half the duration of the input cycle, or 180°. In the center diagram of Figure 29, the bar chart shows that the transistor conducts for half of the cycle. Notice that Class B amplifiers have near zero bias which causes the transistor to cut off.

In Figure 29, the output waveform is clipped for 180° due to no transistor conduction. Therefore, the clipped output signals of Class B amplifiers are distorted when compared to the output signals of Class A amplifiers. However, Class B amplifiers are more efficient due to the reduced conduction time. We will discuss more about efficiency in a later frame.

Class B amplifiers conduct for (half/all) of the input cycle.

---

half

(32.) A third class of amplifier combines the best features of both class A and B amplifiers, and is Class AB. Figure 30 shows the operation of Class AB amplifiers.

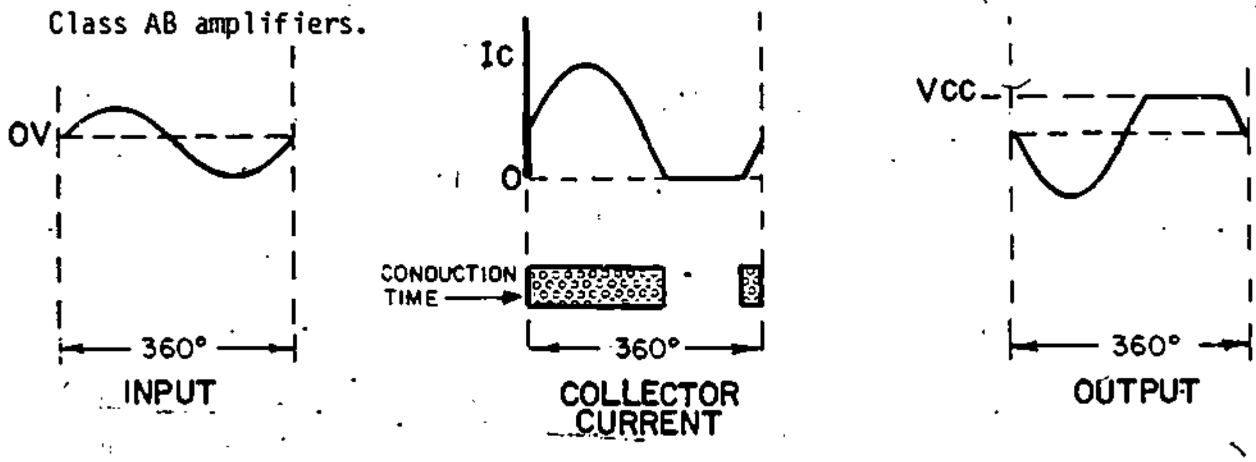


Figure 30
CLASS AB OPERATION

In Class AB amplifiers, the transistor conducts for a longer duration than in Class B amplifiers, but for a shorter duration than Class A amplifiers. In the center diagram of Figure 30, the bar chart shows that the transistor conducts for one complete half-cycle, and for parts of the other half-cycle. Notice that the bias in Class AB amplifiers is set to cause the transistor to cutoff for less than half of the input cycle. The output waveform in Figure 30 is clipped off slightly, and is less distorted than for Class B amplifiers. The efficiency of Class AB amplifiers is between Class A and Class B amplifiers.

Class AB amplifiers conduct for ____________ of the input cycle.

a. all

b. half

c. between half and all

d. less than half

---

c. between half and all

(33.) The concluding class of amplifier biasing is Class C. Figure 31 shows the operation of Class C amplifiers.

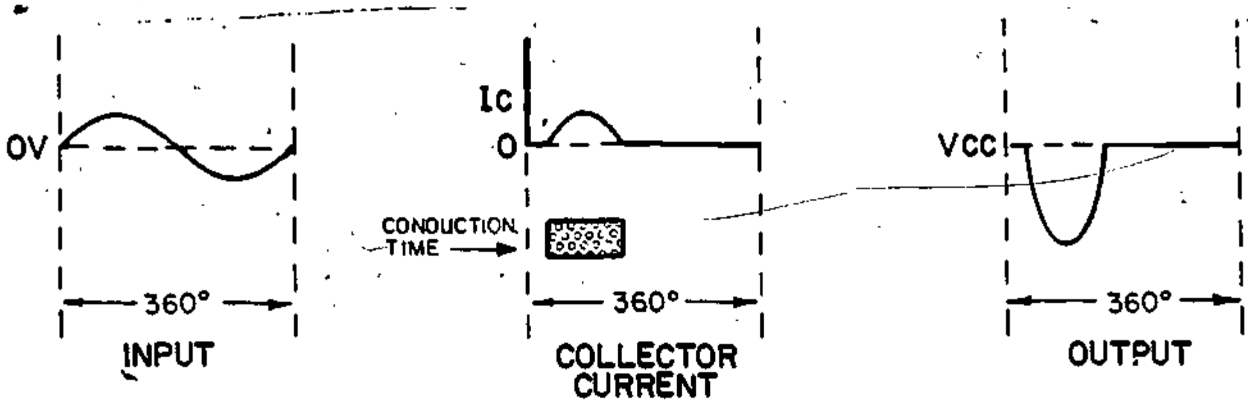


Figure 31

CLASS C OPERATION

In Class C amplifiers, the transistor conducts for the shortest duration of the four amplifier classes. In the center diagram of Figure 31, the bar chart shows that the transistor conducts for less than a half of the input cycle, or about 120°. Class C amplifiers are reverse biased which causes the transistor to cutoff for over half of the input cycle. The output waveform in Figure 31 is the most distorted of all amplifier classes. However, Class C amplifiers are also the most efficient because they conduct for the shortest time duration.

The transistor in Class ________ amplifiers conducts for less than half of an input cycle.

C

(34.) It doesn't look like the voltage and current outputs of Class C amplifiers would do much good, does it? Now let's look at an actual circuit in Figure 32, and see how Class C bias is used.

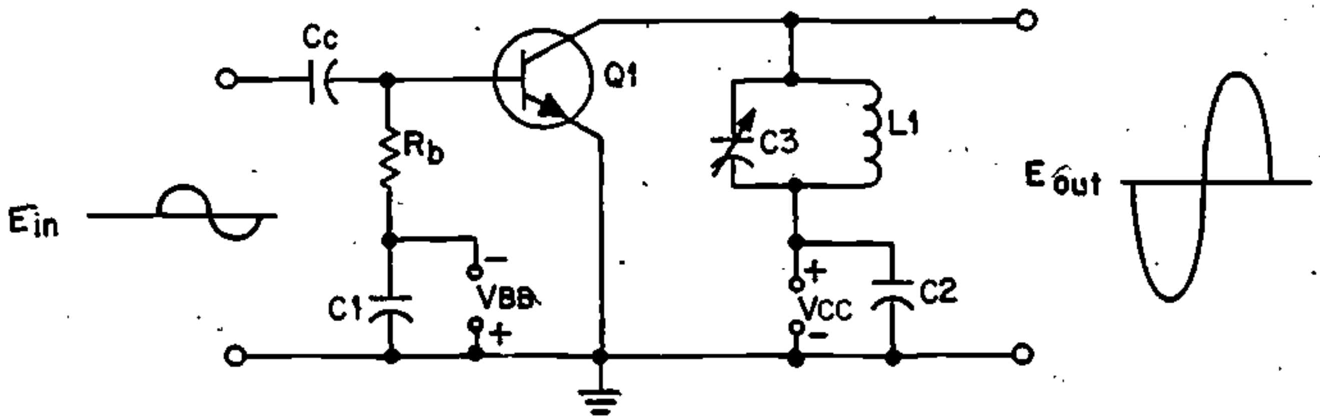


Figure 32

CLASS C RF AMPLIFIER

In the figure you can see the reverse bias on QI as $-V_{BB}$. Therefore, you would expect the output signal to resemble class C as shown in Figure 31. However, as shown in Figure 32 the output signal actually looks like an amplified version of the sine-wave input signal.

The reason for the modification becomes clear when you apply some facts you already know. Remember that when you put a pulse into a tank, the flywheel effect causes the tank to oscillate for a short time. The tank's output resembles the "damped" sine wave shown in Figure 33.

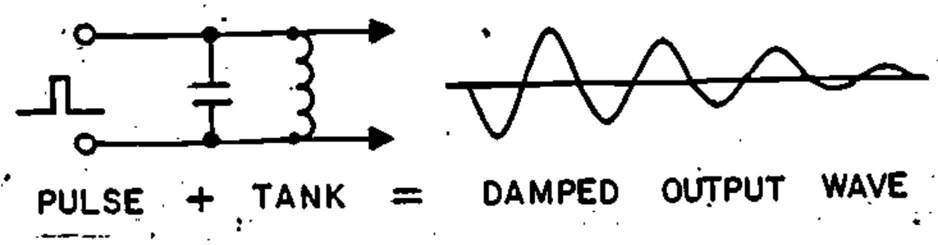


Figure 33

FLYWHEEL EFFECT

The output frequency will be the resonant frequency of the tank. In a Class C amplifier, the tank will get a current pulse from the transistor collector one time for each input cycle. You just learned that these pulses occur above the transistor cutoff, near an input signal peak.

Figure 34 shows the effect of Class C amplifier operation on tank output.

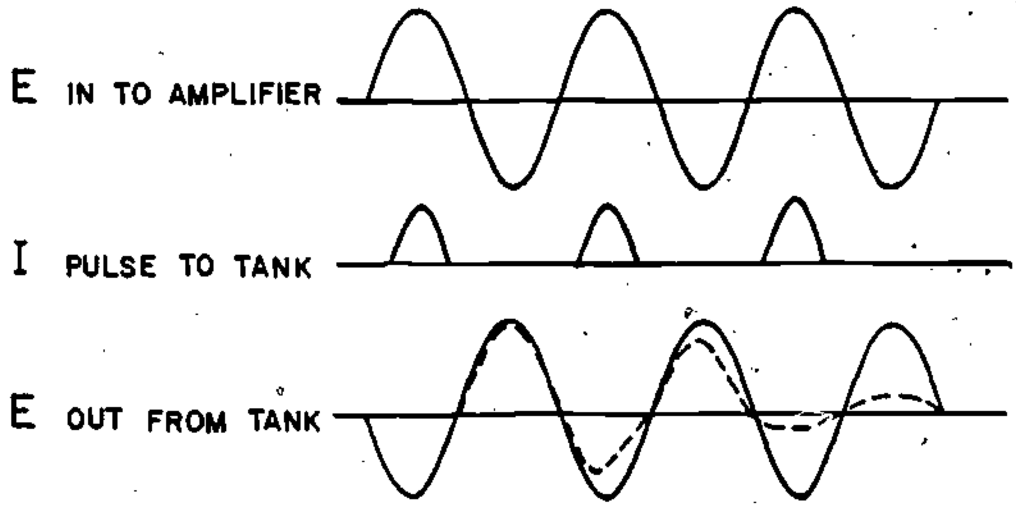


Figure 34

TANK OUTPUT FROM CLASS C AMPLIFIER OPERATION

In Figure 34, the first current pulse starts the tank oscillating. If there were no more pulses, the tank flywheel effect would make the tank output resemble the dotted lines. However, there will be another pulse on the next cycle when the transistor conducts. Therefore, the next current pulse will make the tank output actually resemble a reasonably good sine wave as shown by the solid line. The flywheel effect is often used in Class AB, B and C RF/IF amplifiers to provide a non-distorted sine wave output.

In Class C amplifiers, the output from a resonant tank resembles a good sine wave because of the tank's ____________ effect.

---

flywheel

(35.) We will now continue our discussion on efficiency of the amplifier operating classes. Efficiency relates to the amount of AC power output compared to the DC input power of an amplifier. Amplifiers which require more DC power to produce the same AC output power are less efficient. You know that power equals "current x voltage." Therefore, amplifiers which require more operating current need more power, and are less efficient. Class A amplifiers have a continuous current flow through their transistors, and are the least efficient to operate. Both Class AB and B amplifiers use less current and power than Class A amplifiers, and are more efficient to operate. Class C amplifiers use the least amount of current and power, and are the most efficient to operate. Because of their efficiency, Class C amplifiers are used in applications where large amounts of output power are required, such as the final output amplifier of a radio transmitter. A large amount of power is produced because the transistor is not conducting for most of the output waveform, and the tank supplies the output voltage and current.

Class __________ amplifiers use the least amount of operating power.

C

(36.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

USE THE DIAGRAMS BELOW SHOWING THE INPUT AND OUTPUT WAVEFORMS OF FOUR AMPLIFIER CLASSES OF OPERATION TO ANSWER QUESTIONS 1 THROUGH 4.

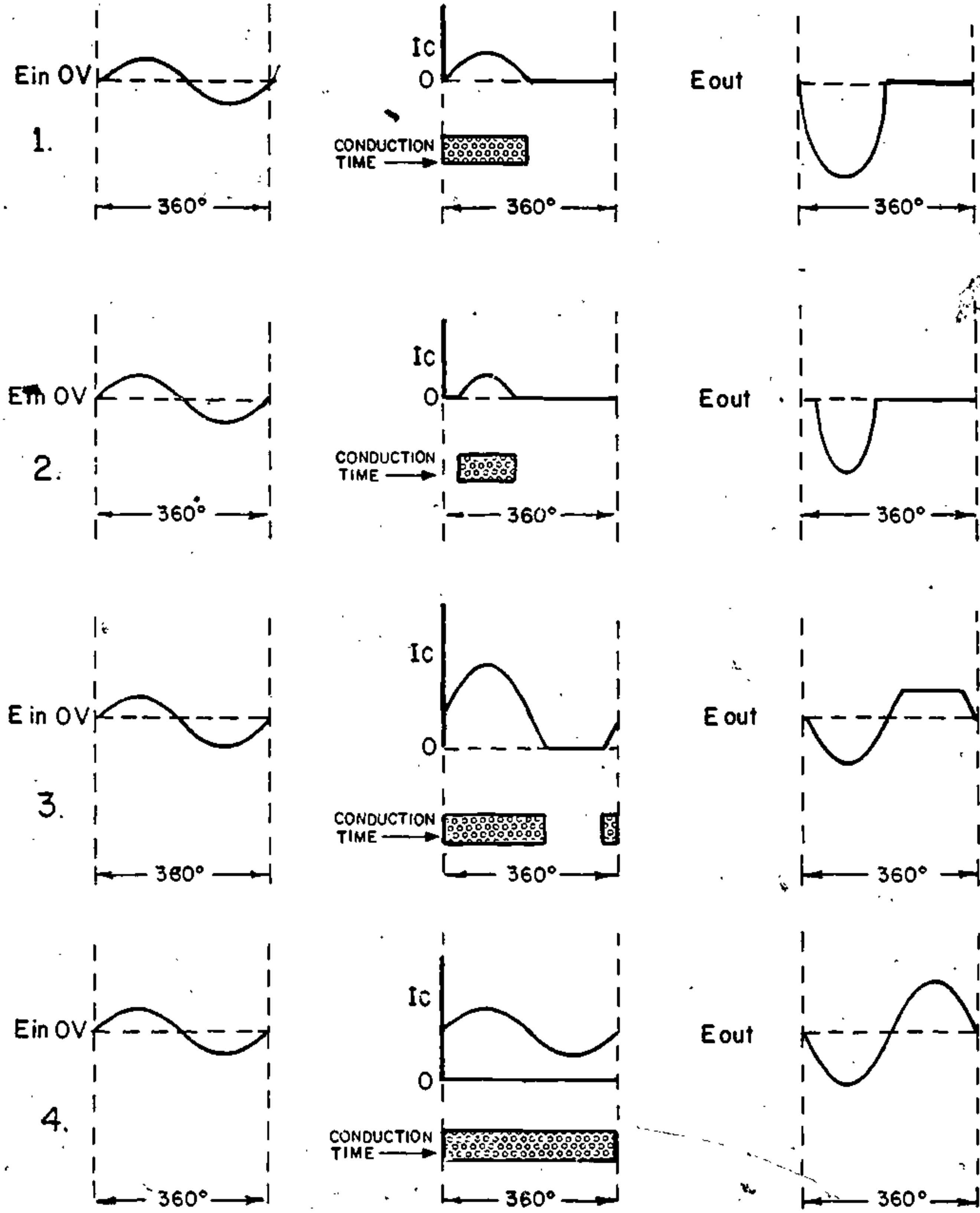


Figure 35

1. Diagram 1 shows the operation of class ___________ amplifiers.

   a. A

   b. B

   c. C

   d. AB

2. Diagram 2 shows the operation of class ___________ amplifiers.

   a. A

   b. B

   c. C

   d. AB

3. Diagram 3 shows the operation of class ___________ amplifiers.

   a. A

   b. B

   c. C

   d. AB

4. The least efficient class of amplifier operation is class _______.

   a. A

   b. B

   c. C

   d. AB

5. Current flows through the transistor during the entire input cycle in class ___________ amplifiers.

   a. A

   b. B

   c. C

   d. AB

1. b. B
2. c. C
3. d. AB
4. a. A
5. a. A

IF ALL YOUR ANSWERS MATCH GO ON TO TEST FRAME 41. OTHERWISE, GO BACK TO FRAME 30 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 36 AGAIN.

(37) In the first lesson in this module, you learned that amplifiers must amplify signals in the audio or video frequency range. Therefore, you must be able to determine whether an amplifier is actually amplifying the required frequencies. We now will discuss a method to test the frequency response of any amplifier. Figure 36 shows a diagram of one test method.

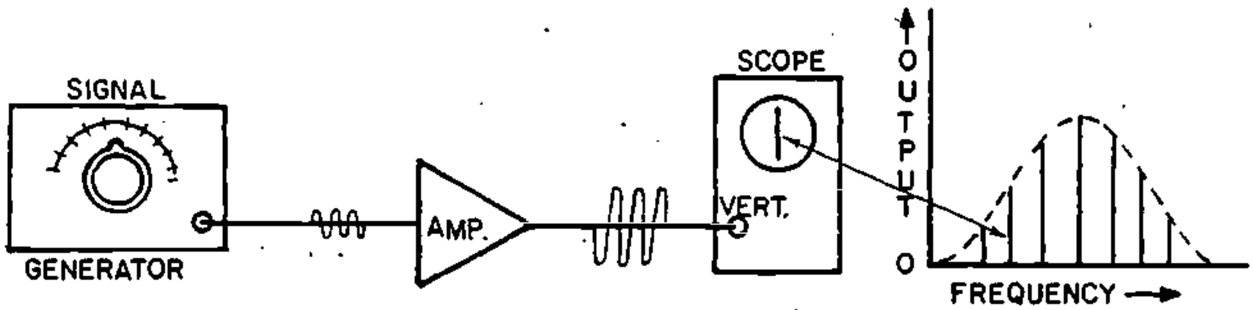


Figure 36

MANUAL FREQUENCY RESPONSE CURVE

The test equipment includes a standard signal generator and an oscilloscope. To perform the test, you first set the signal generator to exact frequency values within the frequency range of the test amplifier. The amplifier's output is then measured on the oscilloscope. In Figure 36, the height of the vertical line on the oscilloscope's CRT shows the amplitude of the output from the amplifier at one test frequency. You can plot a graph of the vertical lines for all test frequencies as shown in the figure. You then get a frequency response curve by connecting the top of the vertical lines on the graph with a smooth curve.

In Figure 36, the image on the oscilloscope represents the ______________ of the signal output at any input frequency.

---

amplitude

(38.) The test method previously described is slow work. It is also inaccurate because you guessed at the shape of the curve between test frequencies when you drew the graph. A far better test method is to use a piece of test equipment called a sweep frequency generator. A sweep frequency generator is a special type of frequency generator. It is capable of producing an output signal that varies back and forth over a section of the frequency spectrum. For example, it can be set to generate a frequency band from 5 to 15 MHz. This means that the sweep frequency generator would produce all frequencies within the 5-15 MHz range, but not at the same time. Rather, the generator "sweeps" across the frequency spectrum like a broom sweeps across the floor. The changing frequency signal is often called a frequency modulated (FM) signal which is so popular in high fidelity radio broadcast.

The sweep frequency generator produces a sawtooth voltage waveform output and an RF output which varies at a sawtooth rate. The sawtooth voltage waveform is fed to an internal RF oscillator and controls its frequency.

The most negative portion of the sawtooth causes the output from the oscillator to be at its lowest frequency. As the sawtooth goes positive, the frequency of the oscillator increases. At the most positive portion of the sawtooth the oscillator will produce its highest frequency. Thus the output of the sweep frequency generator "sweeps" across the frequency spectrum at a sawtooth rate.

Figure 37 shows a typical sweep frequency generator/oscilloscope set-up.

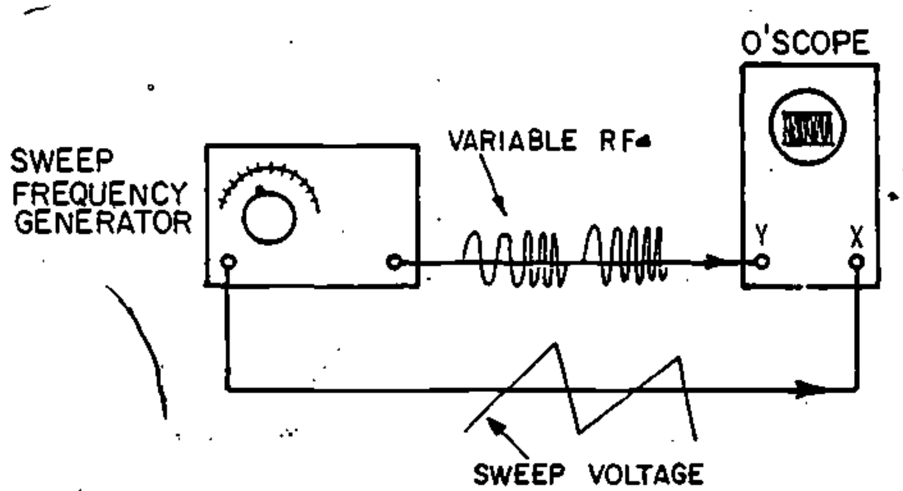


Figure 37

FREQUENCY SWEEP

In the figure, the variable frequency signals from the generator are fed to the vertical input (Y) terminal of the oscilloscope. The CRT produces a rectangular display which is a combination of the sine waves from the many input frequencies.

Actually, the display would show each sine wave if the output frequency of the sweep generator were slow enough. An important point to remember is that the display produced from the sweep generator is different from the normal scope display you have studied. The display from the sweep generator is based on frequency instead of on time, and is often called a "frequency sweep".

The rectangular display on an oscilloscope produced by the input from a sweep frequency generator is based on (time/frequency).

---

frequency

(39) Figure 38 again shows the sweep frequency generator/oscilloscope set-up.

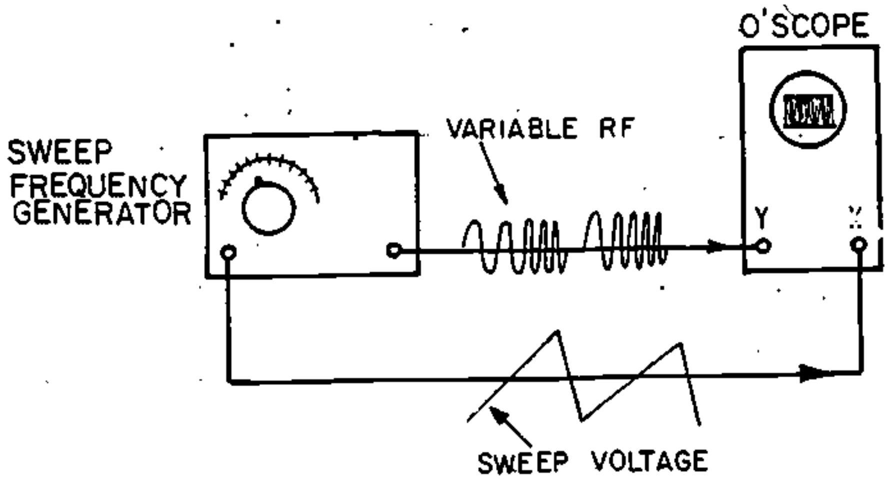


Figure 38

FREQUENCY SWEEP

You recall that variable radio frequencies (RF) are input into the Y terminal of the oscilloscope. The CRT displays the amplitude of all frequencies within the range you have chosen. We now will briefly discuss how the horizontal frequency sweep is produced.

The sweep generator has circuits which generate a linear sweep signal. This output is called a sawtooth sweep voltage.

The sweep generator is designed so that the sawtooth horizontal sweep voltage also determines the variable radio frequency (RF) output signal. In Figure 38, the sweep generator's horizontal sweep (sawtooth wave) output is connected to the horizontal plates of the oscilloscope through the X terminal. Since the inputs to the oscilloscope's X and Y terminals are synchronized, the CRT display will be based on frequency, and not on time. A typical display is shown in Figure 39.

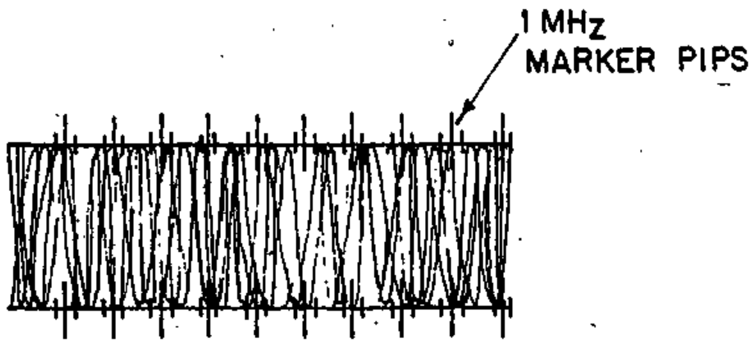


Figure 39

FREQUENCY SWEEP WITH MARKERS

The pips on the frequency sweep in Figure 39 are the result of marker frequencies added to the variable radio frequency signal. Technicians use markers to set the desired limits on the variable frequency signal coming from the sweep generator. A wide range of marker frequencies is usually available to allow precise settings of the sweep generator variable frequency output about a center frequency. In the example in Figure 39, the sweep generator is sweeping frequencies from 0 to about 10 MHz. In other words, the sweep is 5 MHz each side of the center frequency of 5 MHz.

In a sweep generator, a sawtooth sweep voltage generates the________

________on the CRT.

---

horizontal sweep

(4U.) Now let's use the sweep-frequency generator to test the frequency response curve of an amplifier. Figure 40 shows a typical test set-up.

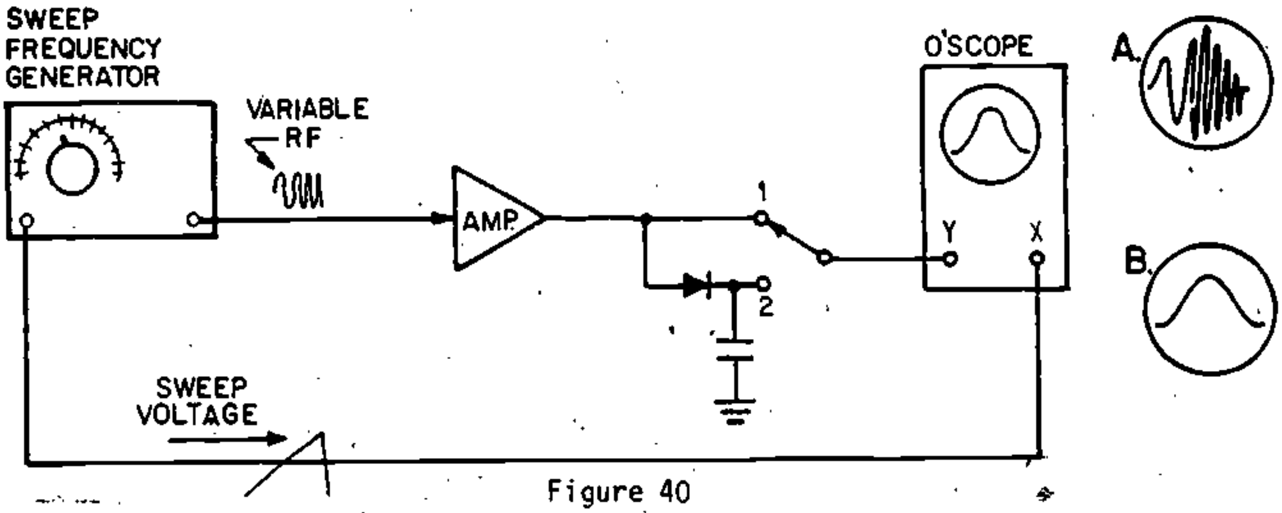


Figure 40

SWEEP FREQUENCY GENERATOR METHOD

In this test method, the sweep generator is used to produce a band of frequencies that varies back and forth over the amplifier's frequency range. The amplifier will then amplify the variable input frequencies according to its ability at any point in the frequency spectrum. The result of this amplification is shown in insert A of Figure 40. Although this display does provide some indication of the amplifier's response, it is not the smooth curve desired.

In the figure, notice a two-position switch. In position #1 as shown, you get the display in insert A. If the switch is placed in position #2, you get the desired smooth frequency response curve (shown in B). The rectifier-filter combination placed in the circuit is called a "demodulator". This test method permits direct observation of amplifier frequency response curves. You will have the opportunity to use the sweep frequency generator in the job program for this lesson. With this device, you will measure the frequency response of an RF amplifier in the NIDA trainer.

The test method using a sweep frequency generator allows you to directly observe the frequency__________ ________ of amplifiers.

---

response curves

(41.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

1. A characteristic of a sweep frequency generator is a ________ frequency output.

   a. single

   b. variable

2. Which test equipment allows you to directly observe an amplifier's frequency response curve?

   a. VOM

   b. DVM

   c. sweep frequency generator

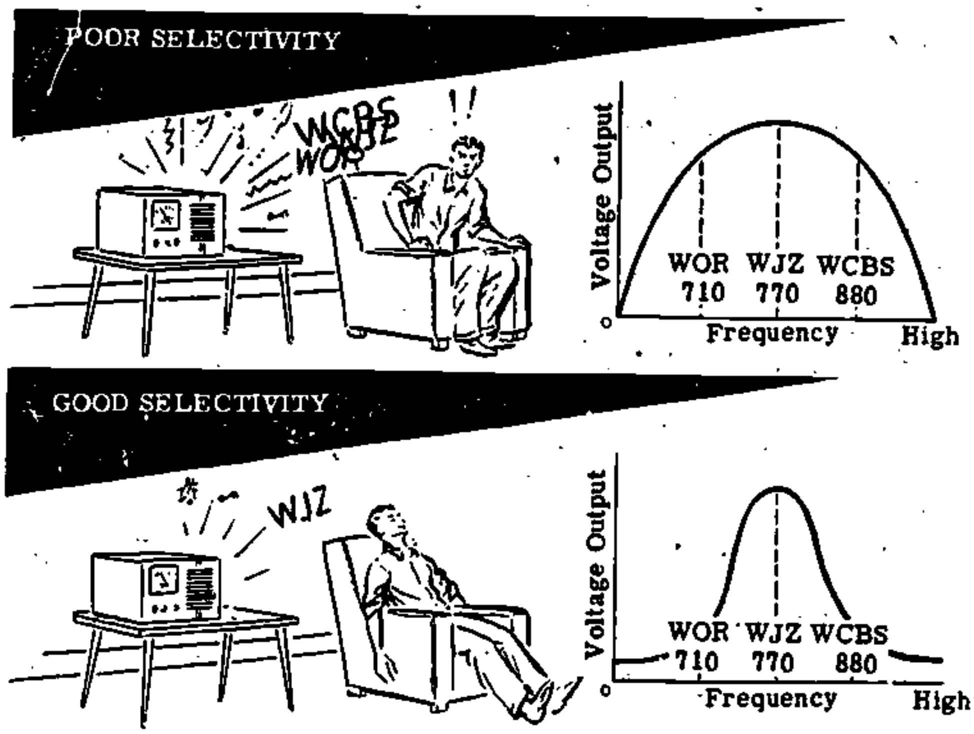
   d. standard RF signal generator

3. The marker pips on a sweep signal generator display are used to indicate divisions of

   a. time

   b. frequency

   c. amplitude



$$Q = \frac{\text{REACTANCE OF COIL}}{\text{RESISTANCE OF COIL}} = \frac{X_L}{R_L}$$

High Q → Sharp tuning → Good separation of stations

Low Q → Broad tuning → Poor separation of stations

1. b. variable

2. c. sweep frequency generator

3. b. frequency

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON 2, MODULE 31. CONGRATULATIONS! OTHERWISE GO BACK TO FRAME 37 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 41 AGAIN.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON 2

RF Amplifiers

Radio frequency (RF) amplifiers are circuits commonly used in electronic equipment including radios, television sets, and radars. All the information you learned about basic amplifiers can be applied to these circuits. You can still use PNP or NPN transistors in any of the three configurations: common emitter, common collector, or common base.

Amplifiers are called RF amplifiers only because they have a frequency response within the radio frequency range. The frequency response is determined by modifying the input and output coupling which may be tuned or untuned. Tuned coupling is more common, and will be covered later in this lesson.

An untuned basic RF amplifier diagram is shown in Figure 1.

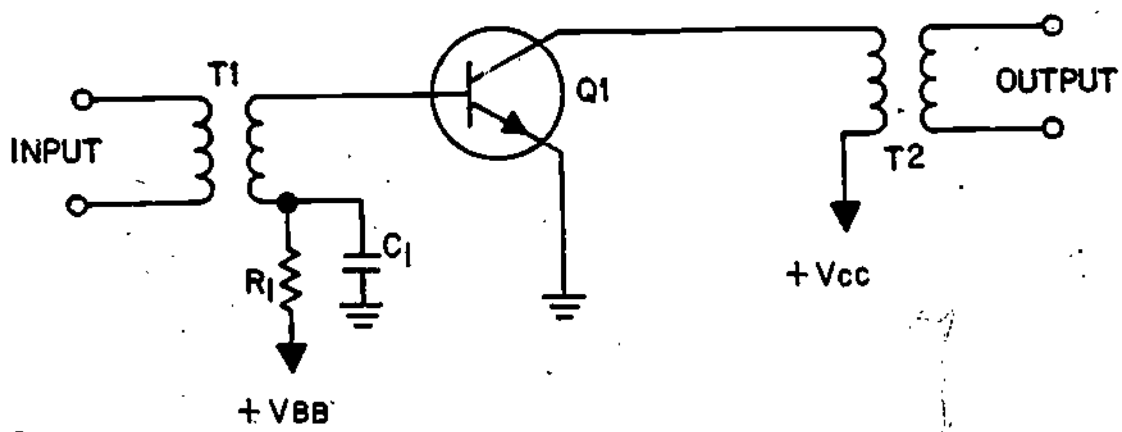


Figure 1

BASIC AMPLIFIER

The coupling circuits T1 and T2 are untuned, air-core transformers which pass a wide band of radio frequencies.

When amplifying RF signals, as in a radio receiver, you want to amplify only the frequency of the desired radio station. Therefore, you are concerned with the amplifier's selectivity. Since a transformer is actually two coupled inductors, you can put a capacitor across either or both windings, as shown in Figure 2, to make the coupling circuit selective.

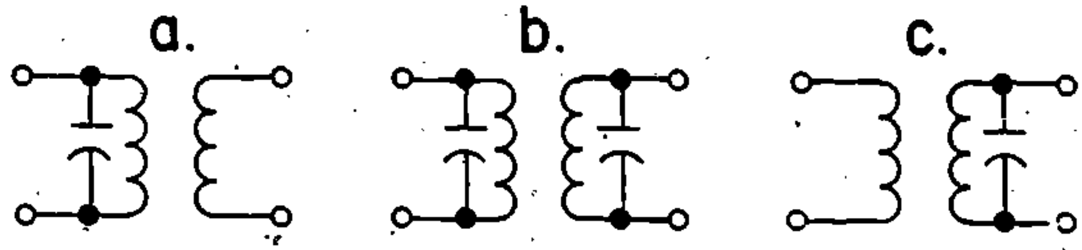


Figure 2

TUNED TRANSFORMER COUPLING

The capacitors parallel to the windings in Figure 2 make the transformer a parallel resonant circuit.

Placing the coupling transformers from Figure 2 into the amplifier of Figure 1, will produce the tuned amplifier shown in Figure 3.

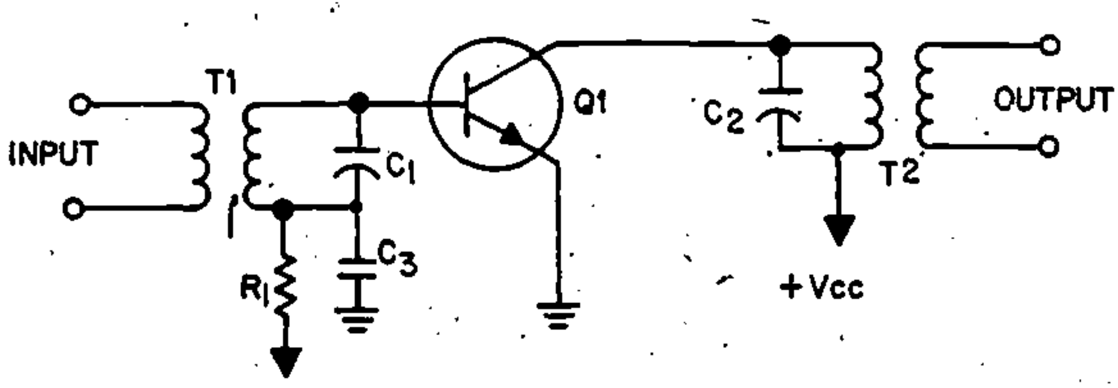


Figure 3

TUNED RF AMPLIFIER

The amplifier in Figure 3 has an input and an output that are tuned to specific frequencies. If all the resonant circuits are tuned to the same frequency, the input signal level to Q1 and the output signal level from T2 will be maximum at that resonant frequency (Fo). At frequencies above or below Fo, these tuned circuits will develop less than maximum voltage to be coupled through transformer action. If more resonant circuits tuned to the same frequency are added in the signal path of an RF amplifier, the result is a narrower bandwidth (that is, more selectivity). Figure 4 shows the relationship between the number of tuned circuits and frequency response.

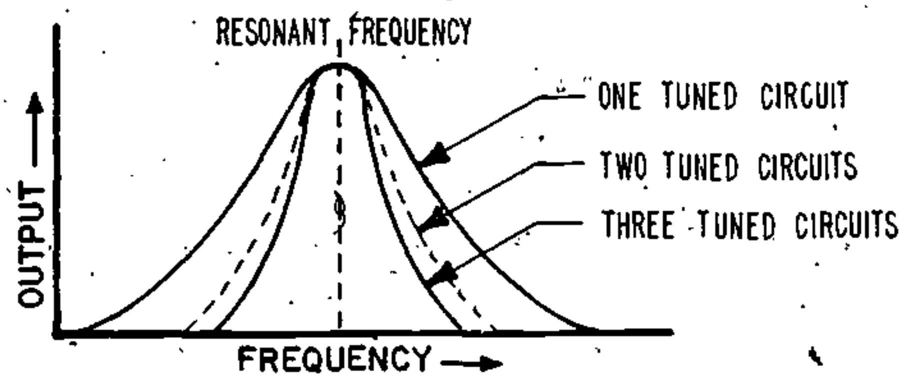


Figure 4

RF AMPLIFIER FREQUENCY RESPONSE CURVES

We have shown amplifiers tuned to one frequency. The problem is how to retune both the input and output coupling circuits at the same time? Figure 5 shows a diagram of one solution.

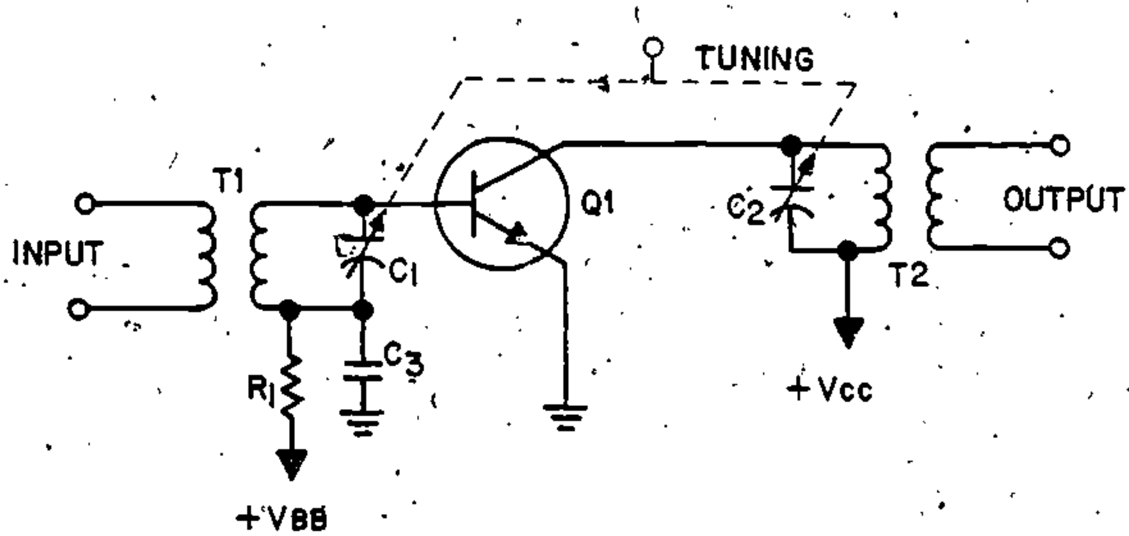


Figure 5

GANGED CAPACTIVE TUNING

In Figure 5, the two tuned sections, or "tanks", are both tuned which provides high selectivity. The arrows through C1 and C2 mean that the capacitors are variable. The dotted line means they are mechanically connected together, or "ganged". Capacitors may be ganged by gears, by pulleys, and most often by a common shaft as shown in Figure 6.

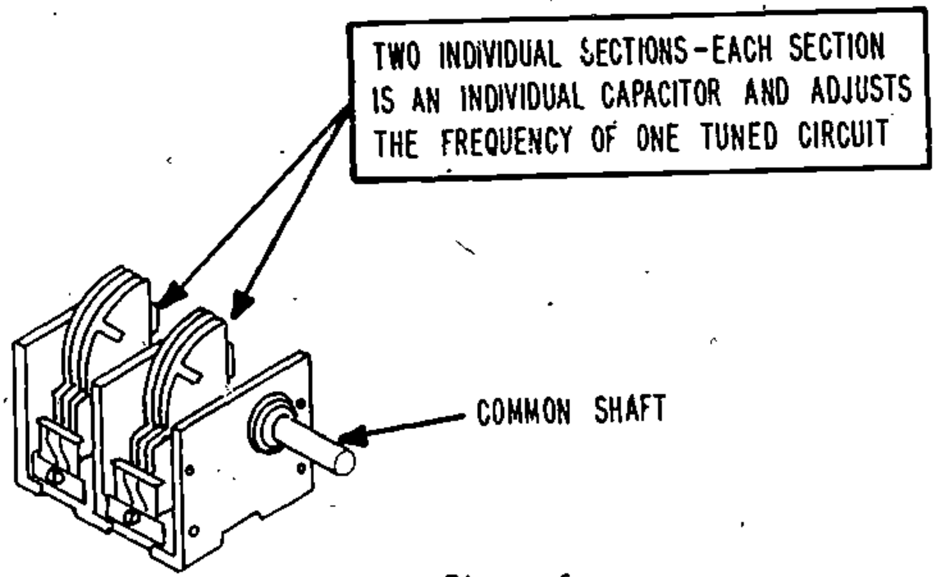


Figure 6

TWO SECTION-AIR VARIABLE CAPACITOR

Another method to retune both input and output coupling circuits is shown in Figure 7.

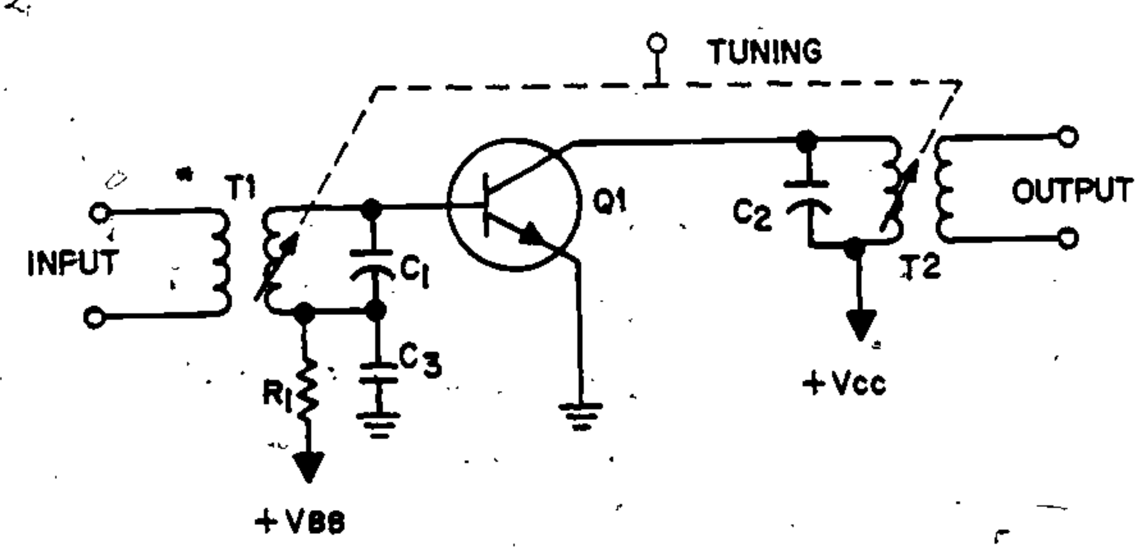


Figure 7

GANGED INDUCTIVE TUNING

In Figure 7, the arrows through the windings in T1 and T2 mean that the inductors are variable, and the dotted line means they also are ganged.

Figure 8 shows two schematics and a pictorial view of an individual inductive tuned RF transformer.

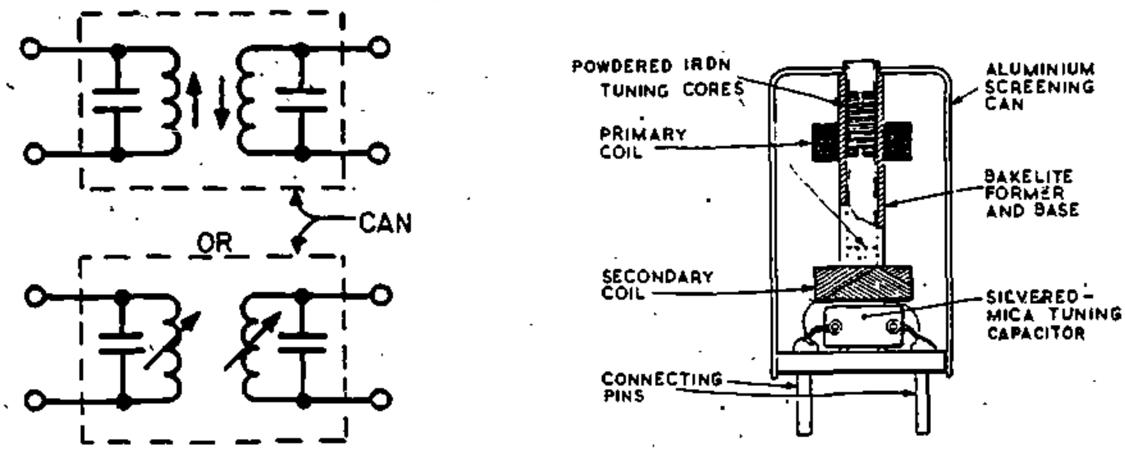


Figure 8

INDUCTIVE TUNED RF TRANSFORMER

In the figure, the primary and secondary windings are each tuned by moving the powdered iron cores inside the transformer coils with special non-metallic tuning wands. The entire unit is completely enclosed within a metallic shield or can to prevent stray electromagnetic fields from effecting the tuned circuits.

Transformer coupling has many applications. However, transformer coupling efficiency is considerably reduced at higher radio frequencies. Figure 9 shows a coupling method which gets around this problem.

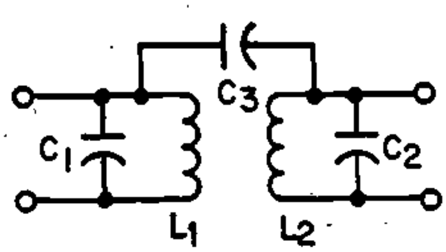


Figure 9

CAPACITIVE COUPLED TUNED TANKS

Coupling capacitor C3 provides a low reactance path to the signal and thus retains the selectivity advantages of the double-tuned parallel resonant coupling circuit.

In electronics, it is useful to express in measurable values the relationships between such resonant circuit properties as inductive reactance (XL), capacitive reactance (XC), and resistance (R). One important property derived from these relationships is called "Q", or quality, of a resonant circuit. The value Q represents the ratio of energy stored/energy used. In this lesson, we are concerned with the Q of the inductor (or coil), the tank, and a loaded resonant circuit.

Inductors have internal resistance since they are made of wire. Therefore, two oppositions to AC current flow in inductors are XL and coil resistance (Rc). The Q of a coil is expressed as the ratio of XL (energy stored) to Rc (energy used). The formula is: Q coil = XL divided by Rc.

Figure 10 shows a diagram of the inductor equivalent for XL and Rc.

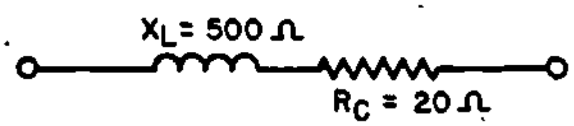


Figure 10

INDUCTOR EQUIVALENT

By applying the formula for Q of a coil, Q equals 500 ohms divided by 20 ohms, or 25. The Q is useful in comparing one coil or inductance with another.

Fact

HE HAS AN AMPLIÆIED IMAGINATION

The Q of a tank is very similar to the Q of a coil. Figure 11 shows a simple tank.

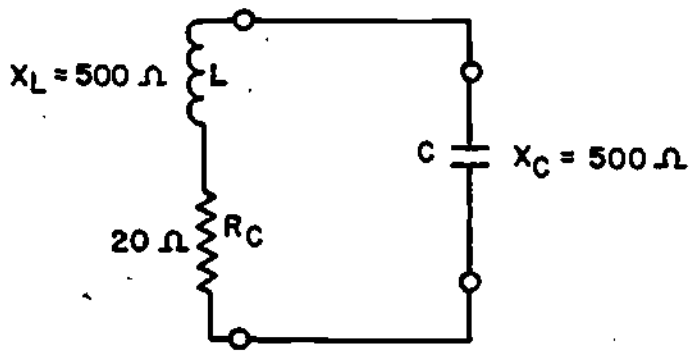


Figure 11

TANK CIRCUIT

The tank is a basic LC resonant circuit with the properties of XL, XC, and Rc. Energy is stored in the magnetic and electric fields of the coil and capacitor. Energy is used or dissipated in the form of heat due to resistance. In a resonant circuit, the capacitive reactance equals the inductive reactance. Therefore, XC can replace XL in the expression for Q. The formula is Q tank = XL (or XC) divided by Rc. The Q of the tank in Figure 11 equals 500 ohms (capacitive or inductive reactance) divided by 20 ohms, or 25.

An important application of the Q of a tank is the relationship between Q and bandwidth (BW). The formula for bandwidth is BW = Fo divided by Q tank. The formula indicates that as the Q of a tank increases, the bandwidth about a center frequency becomes narrower. A high Q tank has a narrow bandwidth, and therefore produces good selectivity (rejects adjacent frequencies).

The relationship between the Q of a tank and bandwidth can be shown using the tank circuit diagram and related tank frequency response curve in Figure 12.

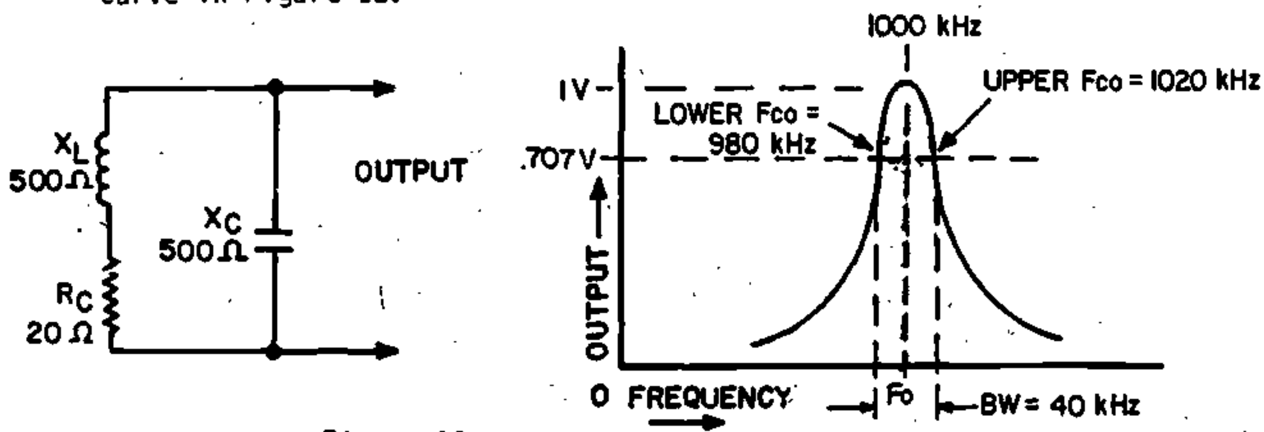


Figure 12

TANK Q vs BANDWIDTH

In the figure, the tank has a 40 kHz bandwidth. You can calculate the bandwidth by plugging the circuit diagram values into the formula for both Q and bandwidth. The Q of the tank equals XL (or XC) divided by Rc or 500 ohms divided by 20 ohms, or 25. The bandwidth equals Fo divided by Q tank, or 1000 kHz divided by 25, or 40 kHz. In the figure, the frequency response curve at the upper and lower Fco points has steep sides, or skirts. This indicates that the Q of this tank produces high selectivity.

If Rc is increased in the circuit shown in Figure 12 from 20 ohms to 50 ohms, the tank circuit diagram and tank frequency resonse curve are as shown in Figure 13.

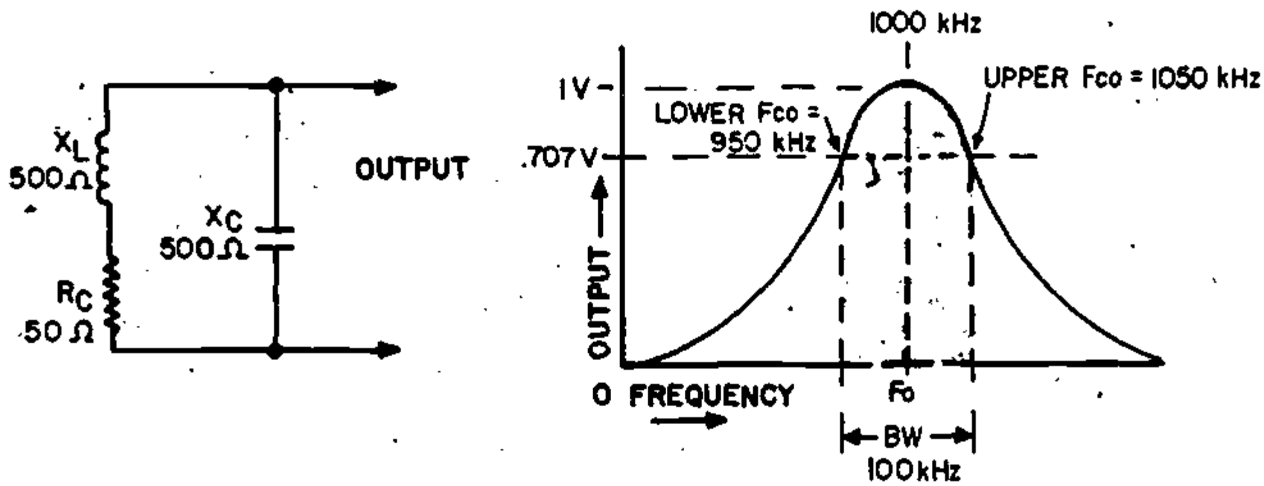


Figure 13

TANK Q vs BANDWIDTH

By applying the formulas, the Q of the tank in Figure 13 equals 10, and the bandwidth equals 100 kHz. The increase in Rc has produced a tank with a lower Q and a wider bandwidth.

Resistance in tank circuits is related to the resistance of the coil wire and any other series resistance. Coils with the same XL made with larger diameter wire should have smaller resistance, and higher Q, than coils made with similar diameter wires.

We now will apply Q to a loaded resonant circuit in which the tank is a part. Figure 14 shows a loaded circuit which includes a tank, switch and parallel load (Rp).

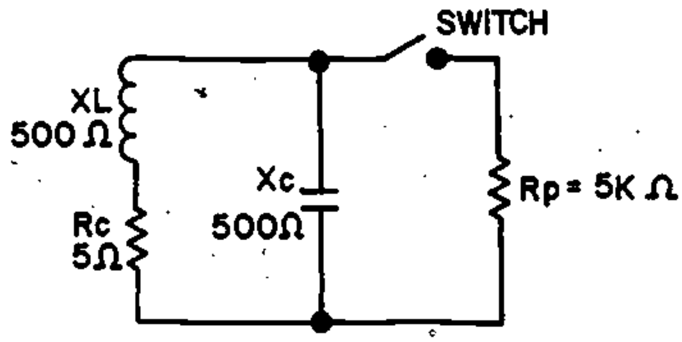


Figure 14

LOADED TANK CIRCUIT Q

In the Figure, the tank is unloaded when the switch is open. The Q of the unloaded tank equals the familiar XL (or XC) divided by Rc, or 100. The tank is loaded when the switch is closed, and delivers energy to the parallel resistance, Rp. The important point is that the Q of the circuit will be lower when a load is placed on a tank than the Q of the tank without a load.

The formula for the Q of a loaded tank circuit is Q ckt = Rp divided by XL, or Rp divided by XC. In Figure 14, XL equals XC which equals 500 ohms, and Rp equals 5 K ohms. the Q of the circuit equals 5 K ohms divided by 500 ohms, or 10. Since the Q of the unloaded tank was 100, the loaded tank circuit has a lower Q, and a wider bandwidth, than the unloaded tank. In wideband RF amplifiers, "swamping" resistors sometimes are placed across tank circuits to purposely lower the Q of the circuit and widen the bandwidth.

Figure 15 shows a typical RF amplifier input stage in a broadcast band radio receiver.

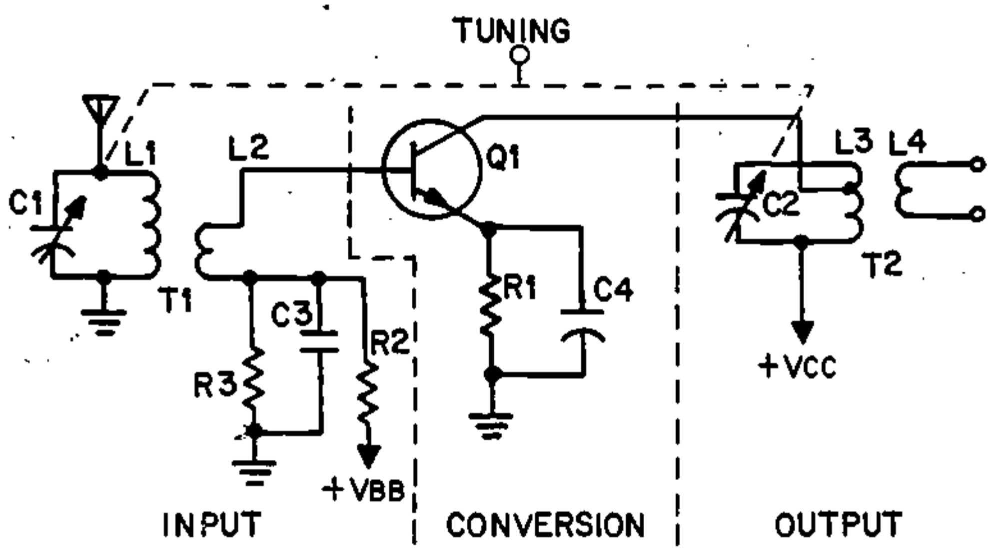


Figure 15

TYPICAL TUNED RF AMPLIFIER

The function of the circuit components will now be discussed. In Figure 15, R2 and R3 form a voltage divider from V_{BB} to ground to provide forward bias for Q1. C3 places the bottom of L2 at RF ground potential and ensures all signal development is across L2. T1 is a step-down transformer with the low impedance winding L2 connected to the base of Q1. This impedance match provides for maximum energy transfer between the antenna and base of Q1, and also preserves the Q of the L1-C1 tank.

Both the Q and selectivity of the tank L3-C2 are preserved in a similar manner. The technique of tapping L3 provides a good impedance match between the collector of Q1 and the tank L3-C2. Therefore maximum energy transfer occurs between the output of Q1 and the input to the following stage. The components R1 and C4 make up the emitter stabilization resistor and bypass capacitor. Note that V_{BB} and V_{CC} often are one and the same source.

In Figure 15, tank L1-C1 is tuned to select one of the many frequencies received by the antenna. This signal is transformer coupled by T1 into the base of Q1. The amplified signal is coupled by T2 to the next amplifier. We achieve additional selectivity by tuning the tank in the primary circuit of T2.

There are many different ways to draw circuits. Figure 16 shows another way to draw the RF amplifier circuit shown in Figure 15.

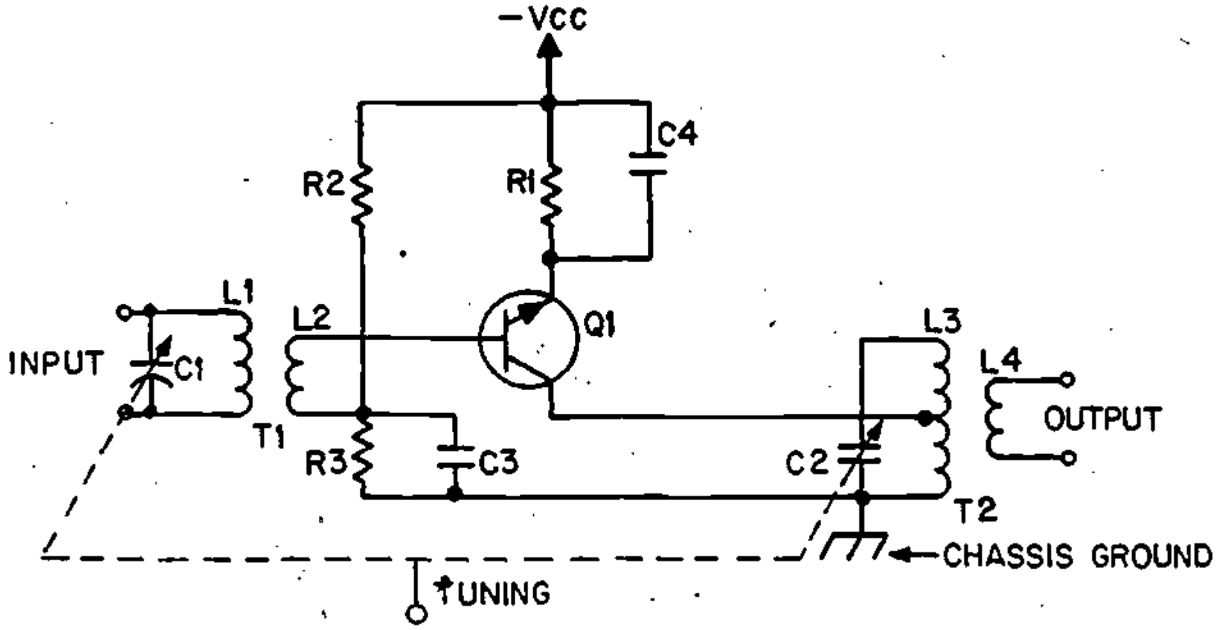


Figure 16

TUNED RF AMPLIFIER

One minor difference between the two diagrams is that the tank L3-C2 in Figure 16 is grounded on one side thus allowing one side of the capacitor to be attached directly to the chassis.

RF amplifiers sometimes tend to oscillate as the amplified frequency increases. Transistors in tuned RF amplifiers have an internal regenerative feedback circuit which may have caused this oscillation. The shaded area in Figure 17 represents the internal regenerative feedback path of an operating transistor.

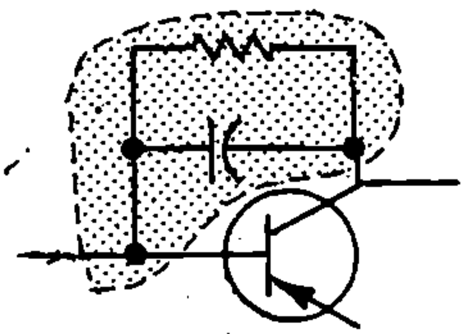


Figure 17

TRANSISTOR INTERNAL FEEDBACK

We can neutralize this oscillation by connecting an external feedback circuit which is exactly equal in voltage and opposite in polarity to the internal feedback. Figure 18 shows two ways an amplifier can be neutralized. The neutralization circuit is labelled Cn.

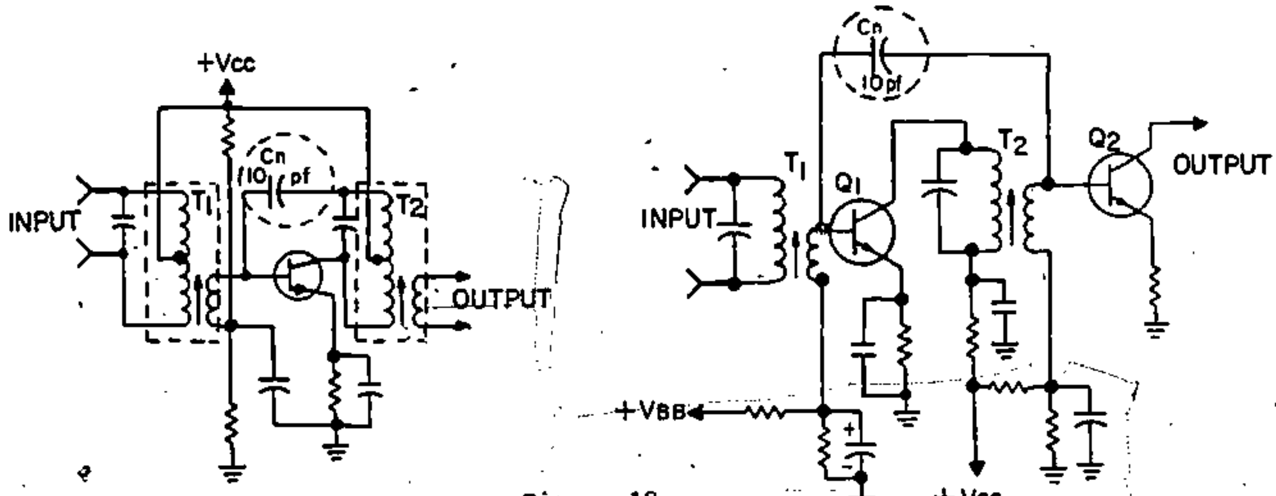


Figure 18

TYPICAL NEUTRALIZING CIRCUITS

RF amplifiers are designed to take into consideration any "stray reactances" which may result at high frequencies. An example of the effect of stray reactances is shown in Figure 19.

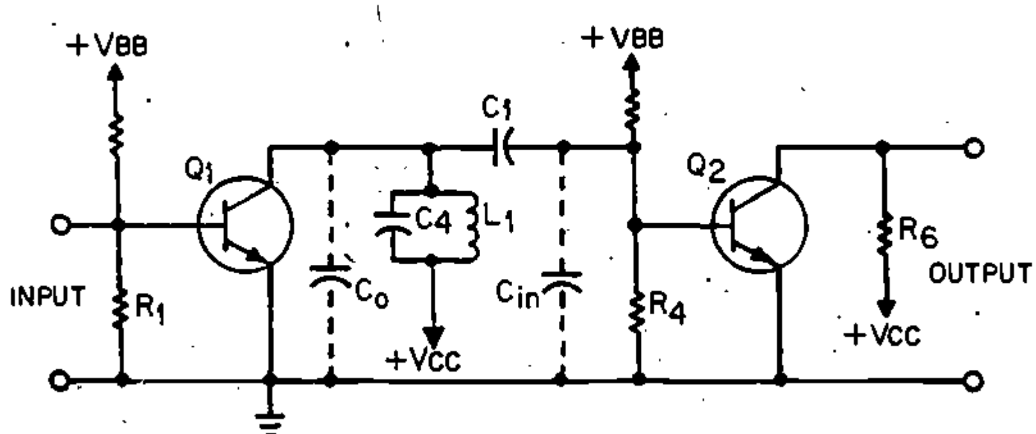


Figure 19

STRAY REACTANCES IN RF AMPLIFIER CIRCUIT

The capacitances Co and Cin represent the accumulation of reactances due to the position of wires and components in relation to the chassis. When you repair a circuit, you must be neat and cautious so that replaced components will be positioned as they were before repair. Otherwise you may cause a frequency change or oscillation in the amplifier.

Amplifiers can be biased to operate either Class A, Class B, Class AB, or Class C. Figure 20 shows Class A amplifier operation.

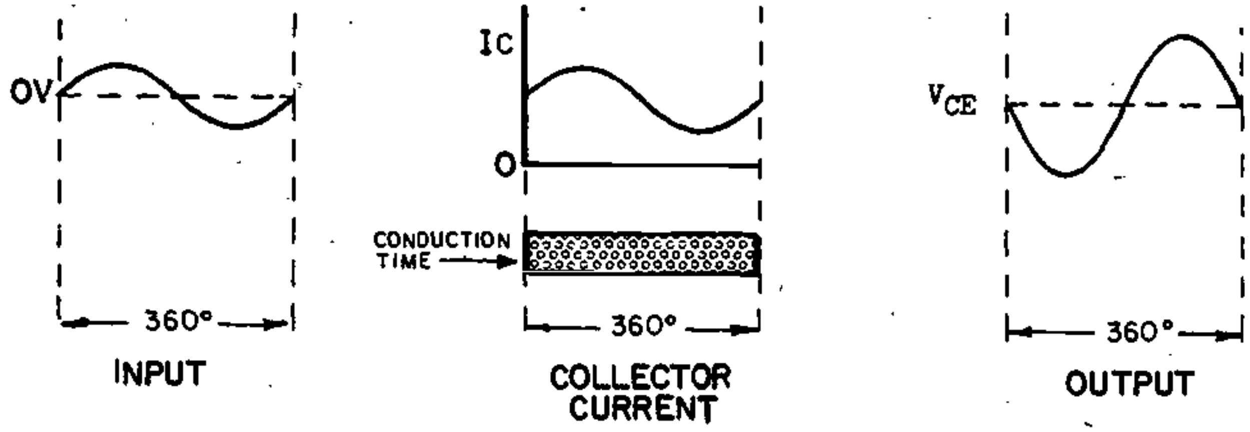


Figure 20

CLASS A OPERATION

In the figure, the left diagram is the input signal voltage for one cycle. The center diagram includes both the collector current waveform and a bar chart of the transistor conduction time. The right diagram is the amplifier output voltage waveform from a CE transistor amplifier using a collector load resistor. In Class A amplifiers, the transistor conducts for the entire duration of the input cycle. The forward bias is set high enough so that conduction will occur over the entire input cycle. The amplified output waveform is a non-distorted image of the input waveform.

Figure 21 shows Class B amplifier operation.

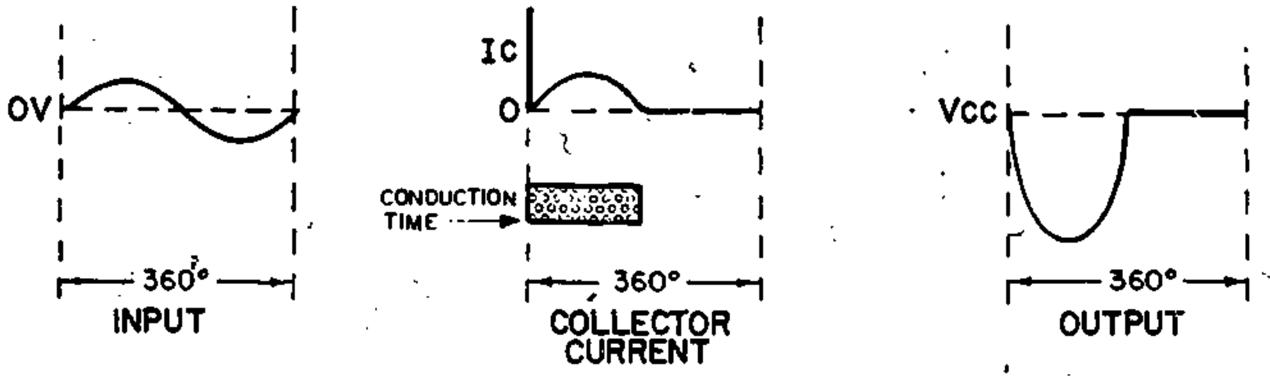


Figure 21

CLASS B OPERATION

In Class B amplifiers, the transistor conducts for half the duration of the input cycle. The bias is set near zero which causes the transistor to cut off and to produce a clipped, or distorted, output signal. Class B amplifiers are more efficient than Class A amplifiers due to the reduced conduction time.

Figure 22 shows Class AB amplifier operation.

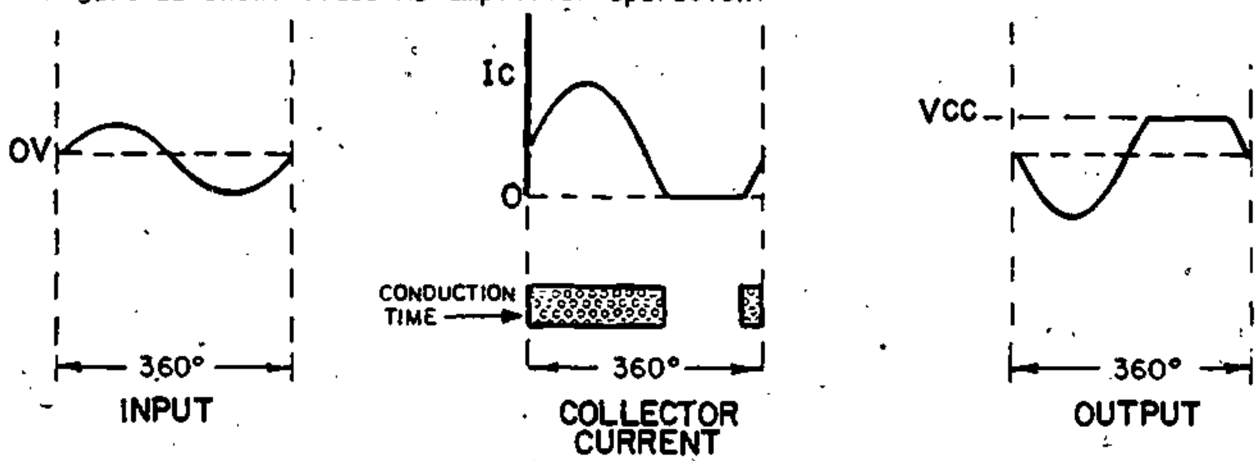


Figure 22

CLASS AB OPERATION

In Class AB amplifiers, the transistor conducts between 180° and 360° of the input cycle. The conduction time is greater than for Class B, and less than for Class A amplifiers. The bias in Class AB amplifiers is set to cause the transistor to cut off for less than half of the input cycle. Class AB amplifiers have less output distortion than Class B amplifiers, but also are less efficient than Class B amplifiers due to the increased conduction time.

Figure 23 shows Class C amplifier operation.

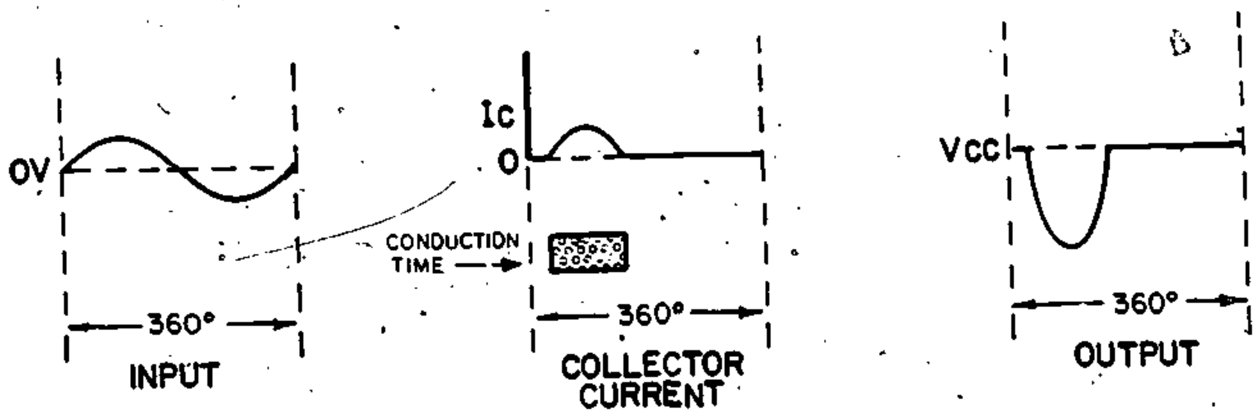


Figure 23

CLASS C OPERATION

In Class C amplifiers, the transistor conducts for about 120° of the input cycle. The reverse bias causes the transistor to cut off for over half of the input cycle. Class C amplifiers have the greatest output signal distortion, but are the most efficient to operate because they have the shortest conduction time.

Figure 24 shows an application of a Class C amplifier circuit.

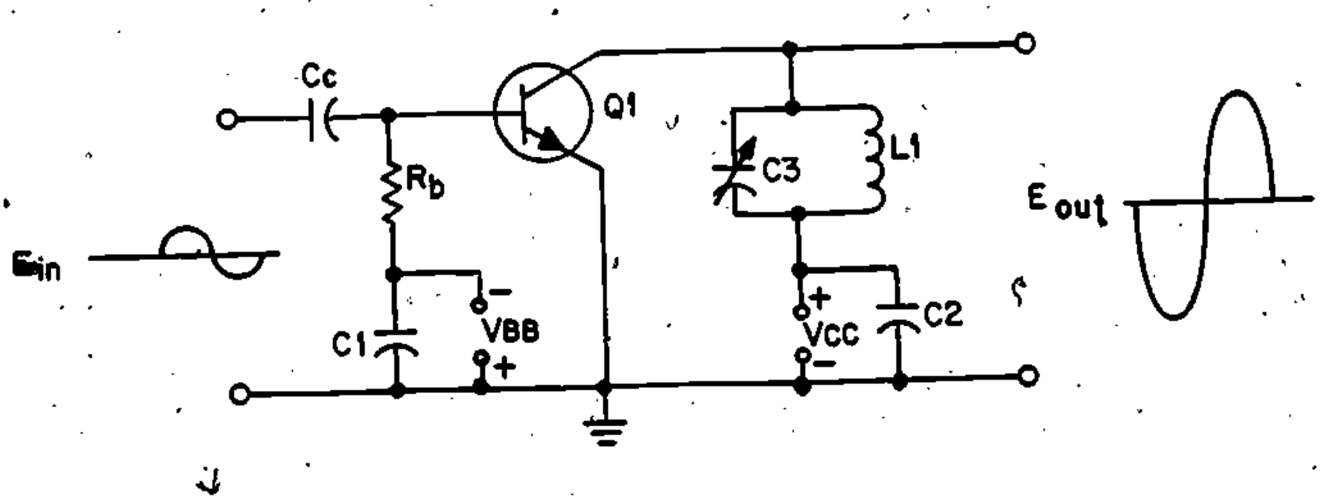


Figure 24

CLASS C RF AMPLIFIER

The reverse bias on Q1 is shown as $-V_{BB}$. The expected output wave is shown in Figure 23, and the actual output wave is shown in Figure 24. The modified output wave is caused by the flywheel effect of the tank. A single pulse put into a tank produces the "damped" sine wave shown in Figure 25.

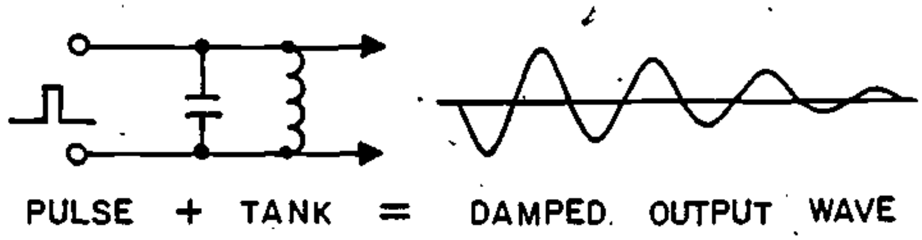


Figure 25

FLYWHEEL EFFECT

In class C operation, the tank will get a current pulse from the transistor collector one time for each input cycle as shown in Figure 26:

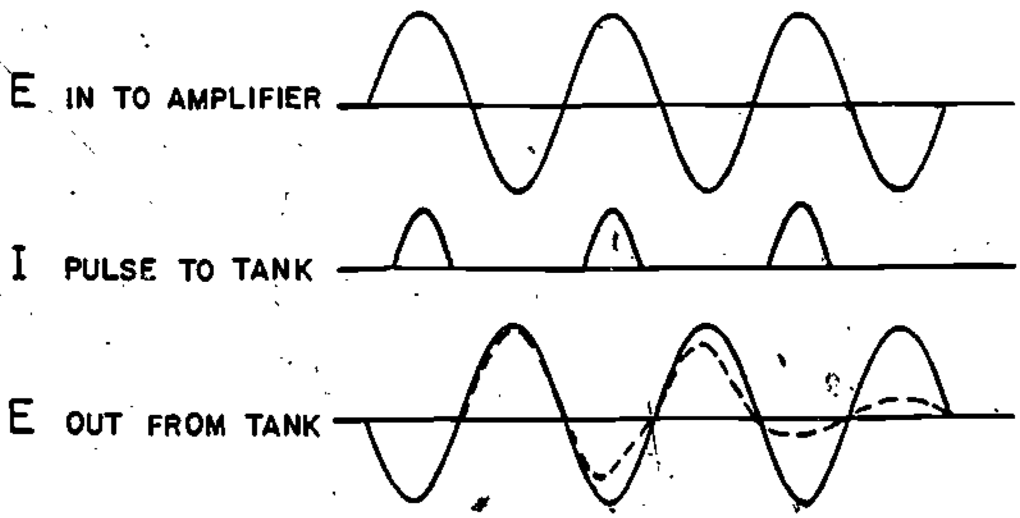


Figure 26

TANK OUTPUT FROM CLASS C AMPLIFIER OPERATION

The repeated current pulses change the damped output wave (shown by the dotted line) to resemble the reasonably good sine wave (shown by the solid line). The flywheel effect is often used in Class AB, B, and C RF/IF amplifiers to provide a non-distorted sine wave output.

Amplifier efficiency increases as the amount of DC operating power decreases. Since operating power is directly related to operating current, the efficiency of each amplifier class is affected by the transistor conduction time. Class A amplifiers have continuous transistor conduction, and are the least efficient to operate. Class C amplifiers are the most efficient to operate, and are used in applications which require large amounts of output power such as the final output amplifier of a radio transmitter.

One method to test the frequency response of an amplifier includes a standard signal generator and an oscilloscope as shown in Figure 27.

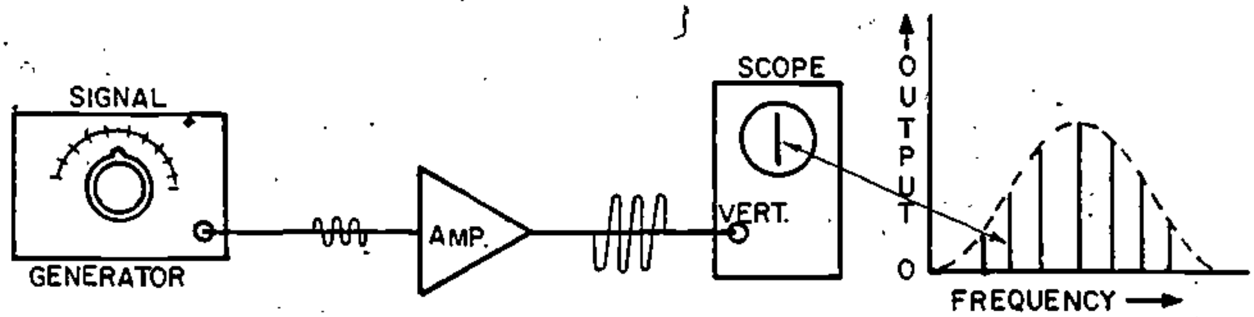


Figure 27

MANUAL FREQUENCY RESPONSE CURVE

The signal generator is manually set to exact frequency values. The height of the vertical line on the CRT shows the amplitude of the amplifier's output signal at one test frequency. You get a frequency response curve by drawing a smooth curve connecting the top of each line, for a number of different input test frequencies.

A more efficient and accurate method to test the frequency response of an amplifier is to use a sweep frequency generator. It produces a frequency modulated (FM) signal that varies back and forth, or sweeps, over a section of the frequency spectrum. Figure 28 shows a typical sweep frequency generator/oscilloscope set up.

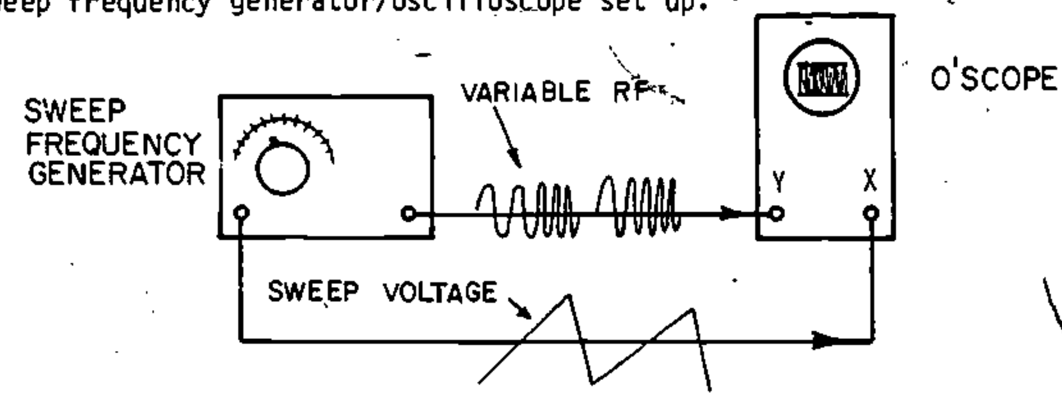


Figure 28

FREQUENCY SWEEP

The variable frequency signals from the generator are fed to the vertical input (Y) terminal of the oscilloscope. The CRT produces a rectangular display which is a combination of the sine waves from the many input frequencies. The display from the sweep generator is based on frequency rather than on time, and is often called a "frequency sweep".

A second generator output is called a sawtooth sweep voltage. The sweep generator is designed so that the sawtooth horizontal sweep voltage also generates the variable frequency output signal. In Figure 28, the sweep generator's horizontal sweep (sawtooth wave) output is connected to the horizontal plates of the oscilloscope through the X terminal.

Since the inputs to the oscilloscope's X and Y terminals are synchronized, the CRT display will be based on frequency, and not on time. Typical display is shown in Figure 29.

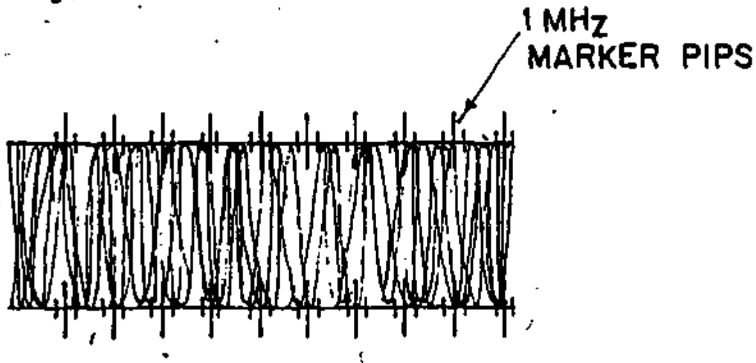


Figure 29

FREQUENCY SWEEP WITH MARKERS

The pips on the frequency sweep are the result of marker frequencies added to the sweep frequency signal. A wide range of marker frequencies are usually available to allow precise control of the sweep generator output frequency. In Figure 29, the sweep is 5 MHz each side of the center frequency of 5 MHz.

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Figure 30 shows a typical sweep frequency generator test set-up.

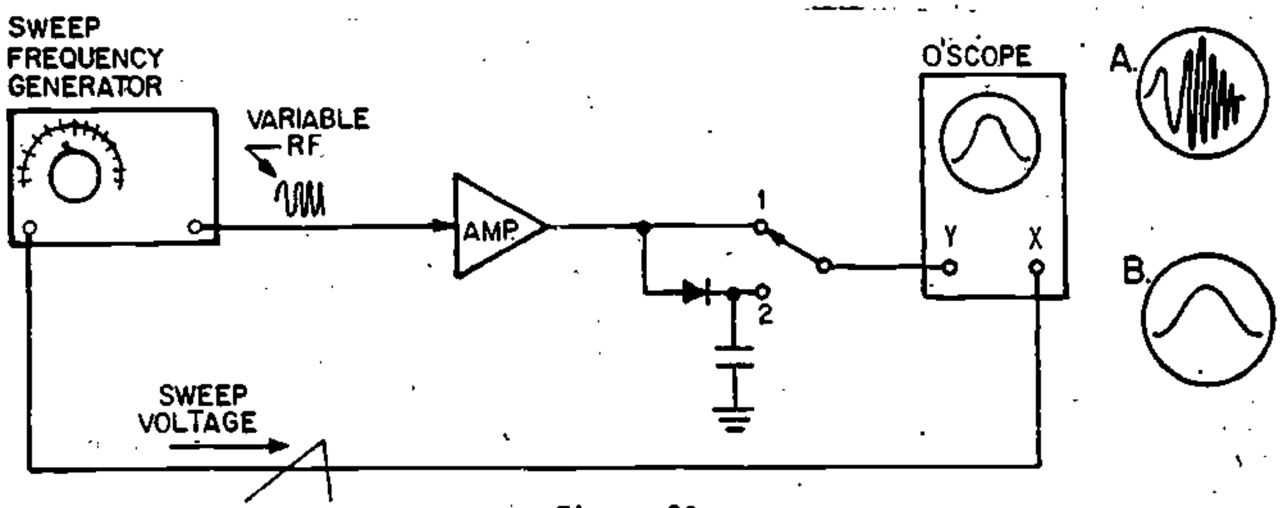

Figure 30

SWEEP FREQUENCY GENERATOR METHOD

The sweep frequency generator sweeps a band of frequencies over the amplifier's frequency range. When the switch is in position #1, as shown in Figure 30, the amplifier's output resembles insert A on the CRT. When the switch is in position #2, the rectifier - filter demodulator is placed into the circuit and converts the amplifier output to resemble insert B on the CRT. This test method permits direct observation of amplifier frequency response curves.

You will have the opportunity to use the sweep frequency generator in the job program for this lesson. With this device, you will measure the frequency response of an RF amplifier in the NIDA trainer.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. 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 THIS LESSON, SELECT AND USE ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS (IF APPLICABLE), OR CONSULTATION WITH THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

BASIC ELECTRICITY AND ELECTRONICS

MODULE THIRTY ONE

LESSON 3

IF AMPLIFIERS

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JULY 1980

OVERVIEW
LESSON 3

IF Amplifiers

In this lesson you will learn some important operating characteristics of IF amplifiers. You will learn how synchronous and stagger tuning relate to IF amplifier frequency response. You will be able to identify the function of IF amplifier components using schematic diagrams. You will find out how an amplifier becomes overdriven, and how gain control circuits prevent overdriving by changing transistor forward bias. You will learn how a built-in "S" meter on a superheterodyne receiver can help you locate a faulty receiver stage. You will determine IF amplifier frequency response curve characteristics, and troubleshoot an IF amplifier using test equipment.

The learning objectives of this lesson are:

TERMINAL OBJECTIVE(S):

31.3.54 When the student completes this lesson, (s)he will be able to TROUBLESHOOT and IDENTIFY faulty components and/or circuit malfunctions in solid state IF amplifiers when given a training device, prefaulted circuit board, necessary test equipment, schematic diagram and instructions. 100% accuracy is required.

ENABLING OBJECTIVE(S):

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

31.3.54.1 IDENTIFY the function of IF amplifier circuits in a superheterodyne receiver by selecting the correct statement from a choice of four. 100% accuracy is required.

31.3.54.2 IDENTIFY the functions, characteristics and applications of synchronous and stagger tuned IF amplifier circuits by selecting the correct statement from a choice of four. 100% accuracy is required.

31.3.54.3 IDENTIFY the function of components and circuit operation of a common-emitter IF amplifier stage, given a schematic diagram, by selecting the correct statement from a choice of four. 100% accuracy is required.

31.3.54.4 IDENTIFY the output signal characteristics of an overdriven amplifier by selecting the correct statement from a choice of four. 100% accuracy is required.

31.3.54.5 IDENTIFY the gain characteristics of a transistor biased in the linear and non-linear operating regions by selecting the correct statement from a choice of four. 100% accuracy is required.

31.3.54.6 IDENTIFY the functions of an AGC circuit by selecting the correct statement from a choice of four. 100% accuracy is required.

31.3.54.7 IDENTIFY the components, component functions, and circuit operation of an AGC circuit, given a schematic diagram, by selecting the correct list or statement from a choice of four. 100% accuracy is required.

31.3.54.8 IDENTIFY the faulty stage(s) in a superheterodyne receiver, given a block diagram showing "S" meter location and failure symptoms, by selecting the correct fault from a choice of four. 100% accuracy is required.

31.3.54.9 MEASURE and COMPARE frequency response and gain characteristics of IF amplifier circuits given a training device, circuit boards, test equipment and proper tools, schematic diagrams, and a job program containing reference data for comparison. Recorded data must be within limits stated in the job program.

31.3.54.10 IDENTIFY the faulty component or circuit malfunction in a given IF amplifier circuit, given a schematic diagram and failure symptoms, by selecting the correct fault from a choice of four. 100% accuracy is required.*

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*This objective is considered met upon successful completion of the terminal objective.

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 3

IF Amplifiers

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

Summary
Progress Check
Job Program Thirty-3 "IF Amplifiers"
Fault Analysis I.S.
Performance Test I.S.

Additional Material(s):

Enrichment Material(s):

*. NAVSHIP 0967-000-0120 "Electronic Circuits" Electronics Installation and Maintenance Book (EIMB) Naval Ship Engineering Center, Washington, D.C.: U.S. Government Printing Office 1965.

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

SUMMARY
LESSON 3

IF Amplifiers

IF amplifiers are commonly found in both receivers and transmitters. IF amplifiers provide the required signal gain and selectivity in superheterodyne receivers such as radio, television, and radar.

An IF amplifier is basically a tuned, high gain, fixed frequency RF amplifier with transformer coupling. Ideally, the IF amplifier will select and amplify with constant gain only the desired signal containing all the information needed for good signal reproduction. Therefore, the ideal IF amplifier should have the rectangular frequency response curve shown in Figure 1.

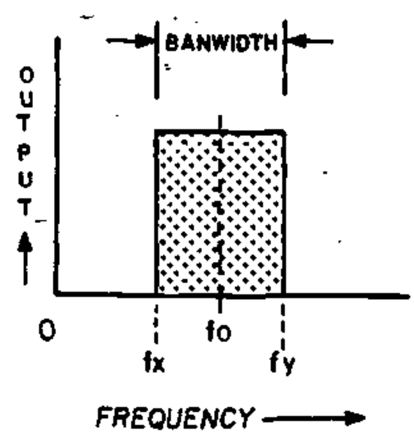

Figure 1

IDEAL IF RESPONSE CURVE

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An actual IF amplifier with tuned-primary transformer coupling has a frequency response curve which more closely resembles Figure 2.

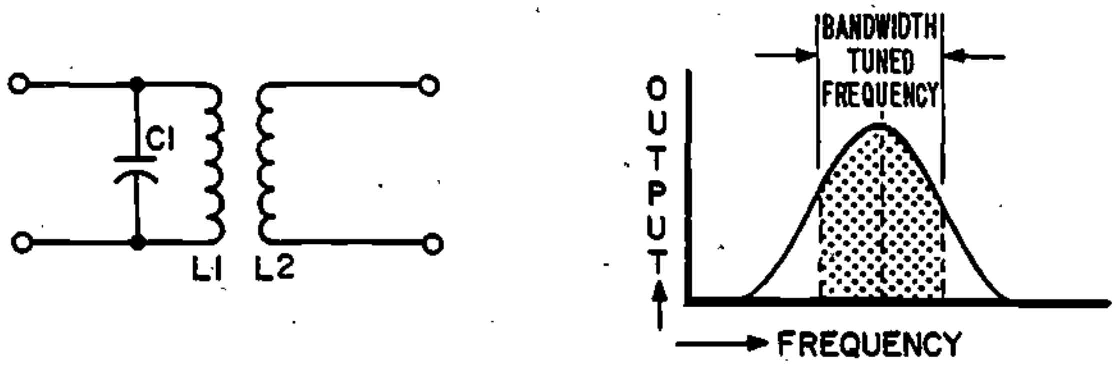


Figure 2

SINGLE TUNED TRANSFORMER COUPLING

There are ways to make the frequency response curve of an IF amplifier resemble the ideal curve and thus improve amplifier operation. One method is to tune all circuits in the signal path to the same frequency, or synchronous tune. A tuned circuit may be added to the secondary of the transformer coupling in Figure 2. If the two tuned tanks are synchronous tuned to the IF center frequency, the resulting frequency response curve is shown in Figure 3.

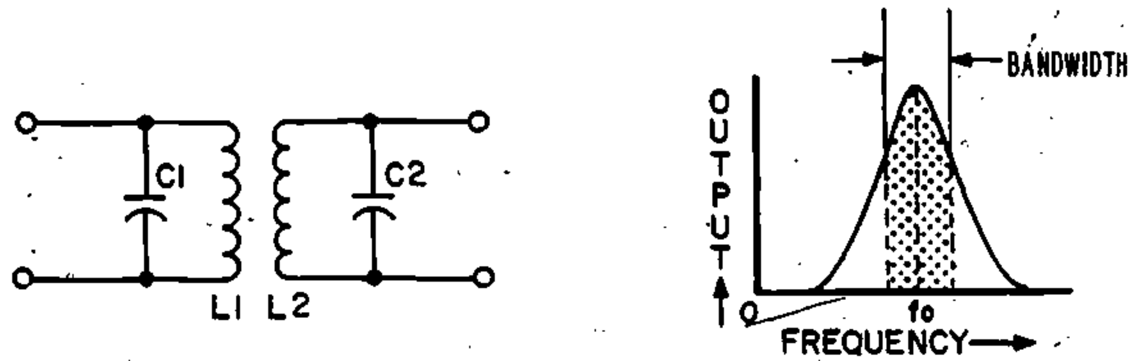


Figure 3

SYNCHRONOUS DOUBLE-TUNED TRANSFORMER COUPLING

In the figure, the bandwidth has become narrower and selectivity has increased.

Synchronous tuning may cause the bandwidth to become too narrow to properly amplify all of the desired signal. For example, television and radar signals require relatively broad bandwidth amplification.

One method to increase the bandwidth of an IF amplifier is to tune each tuned coupling circuit to a slightly different frequency, or stagger tune. The resulting frequency response curve for an amplifier with three stagger-tuned circuits is shown in Figure 4.

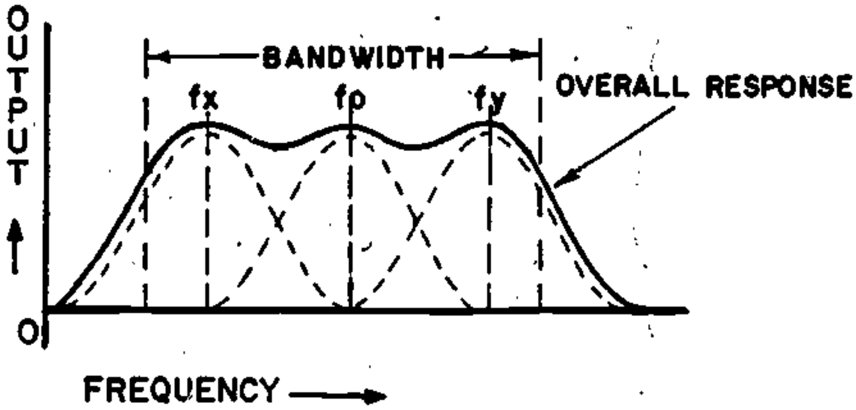


Figure 4

STAGGER-TUNED RESPONSE CURVE

You can see that stagger tuning resonant coupling circuits widens amplifier bandwidth.

Synchronous and stagger tuning can be applied to the operation of a typical common-emitter IF amplifier stage shown in Figure 5.

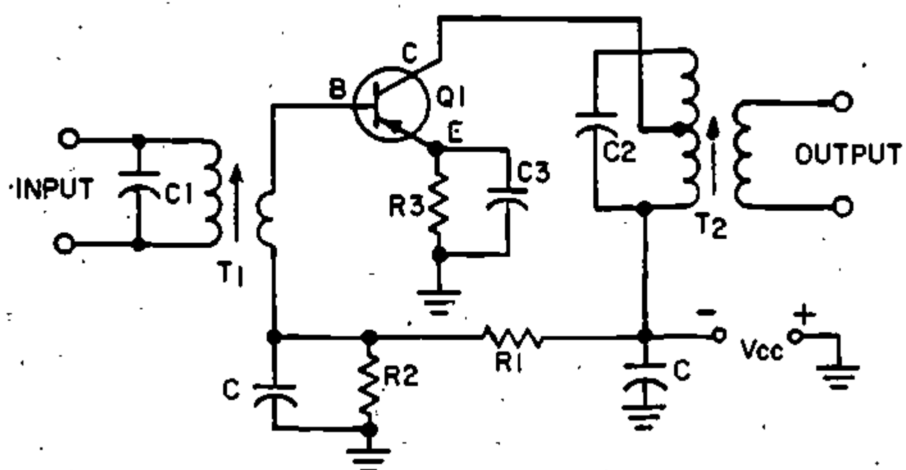
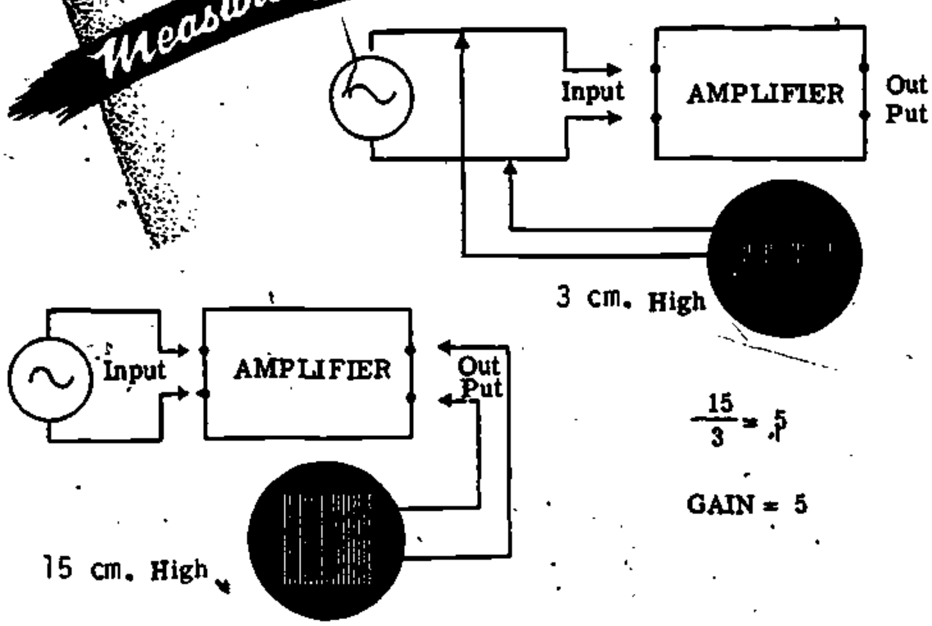


Figure 5

TYPICAL COMMON-EMITTER IF STAGE

This circuit contains two single-tuned interstage coupling transformers. T1 and T2 can be synchronous slug-tuned to provide a narrow bandwidth amplifier with good selectivity. T1 and T2 can also be stagger tuned to increase amplifier bandwidth. Proper tuning in a string of IF amplifiers will produce just about any gain and selectivity required in the receiver.

Measuring Gain with a 'Scope



$$\frac{15}{3} = 5$$

GAIN = 5

The NIDA trainer IF amplifier stage is shown in Figure 6.

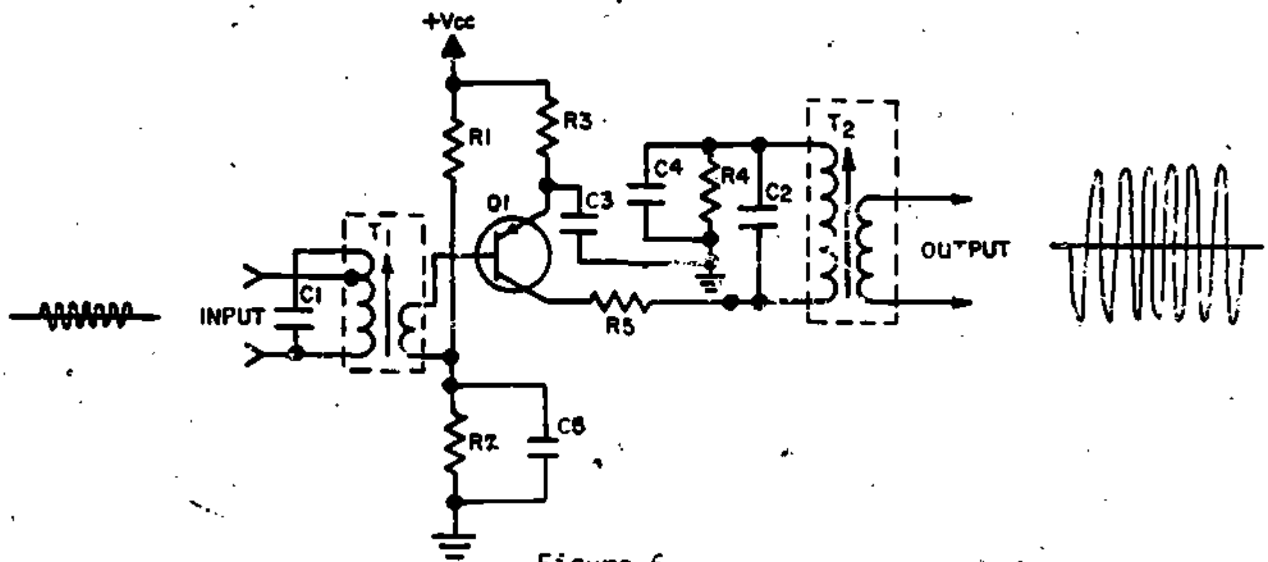


Figure 6

NIDA IF AMPLIFIER

The input signal is applied to coupling transformer T1. The tap on T1 provides an impedance match with the collector circuit in the previous stage. This type of transformer is often enclosed in an aluminum shield to prevent unwanted coupling to nearby wires and transformers. Inductive tuning is done by a tuning slug. The step-down secondary on T1 provides a low impedance match to the Q1 base circuit. R1 and R2 provide forward bias to Q1.

Decoupling capacitor C5 ensures all signal voltage is developed across the secondary of T1, and does not enter the power supply.

In the Q1 collector circuit, the output tank in coupling transformer T2 is tuned to the operating center frequency of 10.7 MHz. C4 and R4 are decoupling components which act to ensure that all signal voltage is developed across the tank, and does not enter the power source. R5 reduces the tendency for strong signals to forward bias the collector-base junction of Q1, which might cause oscillation.

IF amplifiers are usually cascaded to perform their function in a receiver or transmitter. As the number of cascaded amplifiers increases, the gain may become high enough to cause one or more amplifier stages to be overdriven. Severe signal distortion would result as the design capabilities of the circuit and power supply would be exceeded. Therefore, some type of gain control is needed.

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The amount of forward bias on the transistor's base-emitter junction (V_{BE}) affects the static operating level of the transistor which, in turn, affects the amount of gain. The transistor produces a reasonably constant gain within a certain bias range called the linear operating region for the transistor. When the forward bias is significantly above or below the linear region, the transistor is operating in the non-linear operating regions. In these regions, the transistor produces lower gain and, with large signals, possible distortion.

The relationship between bias, conduction, and gain are found in the transistor characteristic curve in Figure 7.

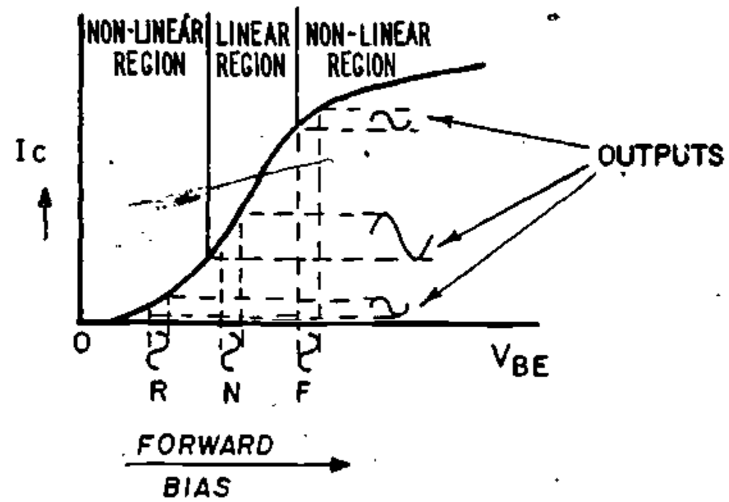

Figure 7

TRANSISTOR CHARACTERISTIC CURVE

The curve is used to determine the amount of gain related to bias and conduction levels for a given input signal. Figure 7 shows examples of three identical input signals applied to a transistor at bias levels within each of the regions. The amplitudes of the input signals are shown above the region labels. The differences in the resulting output amplitudes demonstrate that gain is reduced by applying forward bias either in the "R" region (reverse bias gain control) or in the "F" region (forward bias gain control). You should note that distortion in the non-linear regions is minimized with small signal levels.

A manual method of controlling transistor gain can be shown for the NIDA trainer IF amplifier stage in Figure 8.

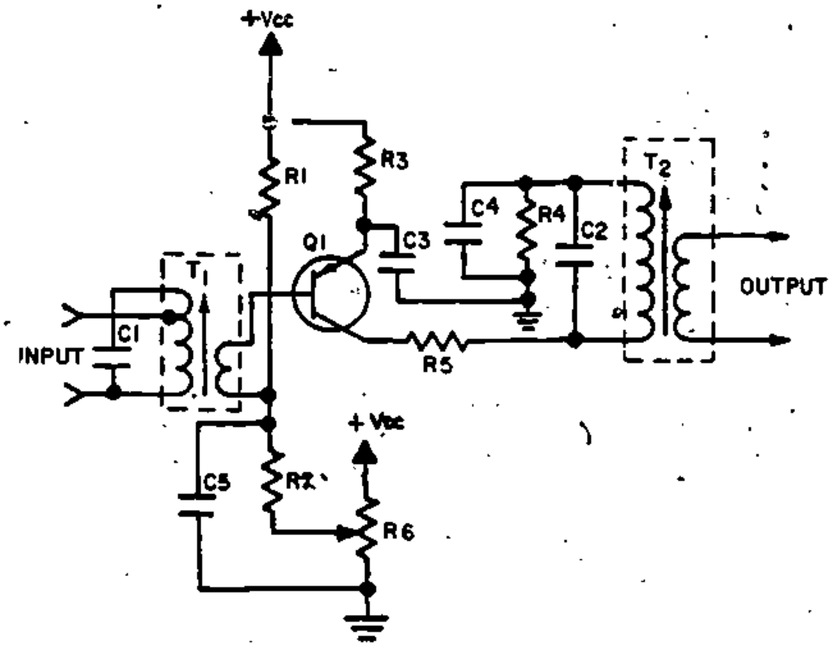

Figure 8

MANUAL IF GAIN CONTROL

In the figure, forward bias is provided by R1, R2, and R6. As the arm of R6 is moved upward, a more positive voltage is placed on the base of Q1 which reduces the forward bias on Q1. If the arm of R6 is moved upward high enough, reverse bias gain control will result.

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An automatic gain control (AGC) circuit provides a more constant output from the audio or video equipment in which it is used. Figure 9 shows the addition of an AGC circuit to the IF amplifier stage in Figure 8.

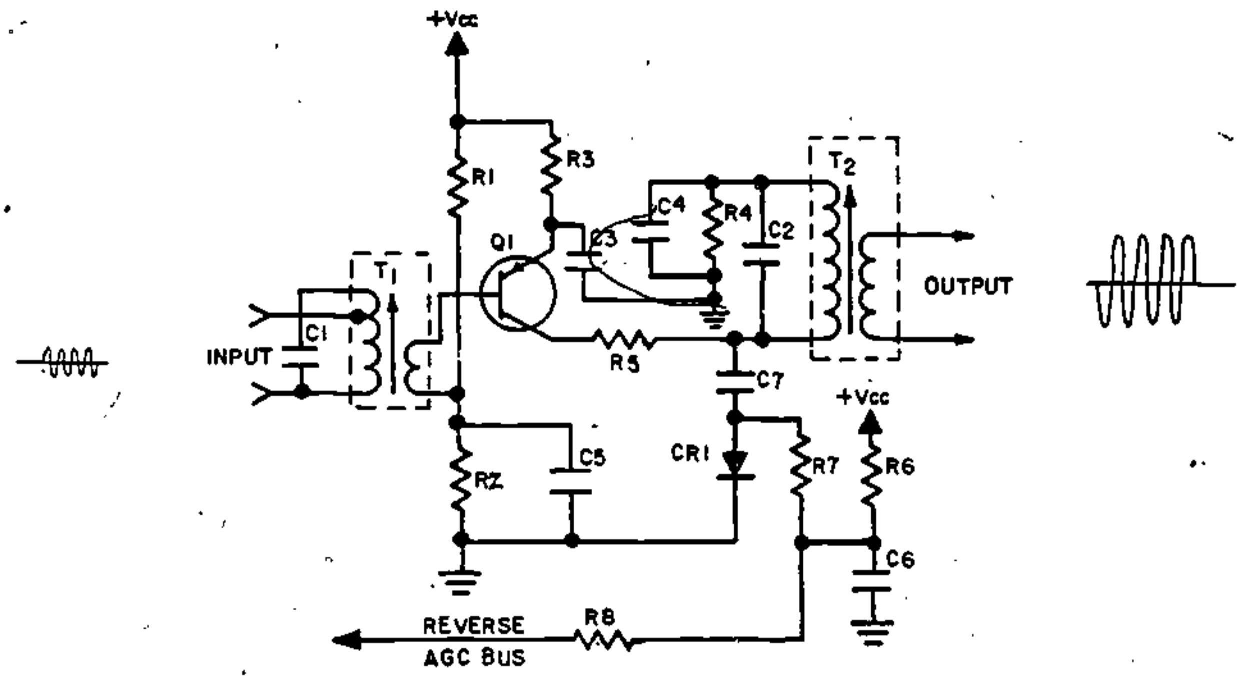

Figure 9

AUTOMATIC GAIN CONTROL (AGC)

The AGC components provide an automatic reverse bias gain control over previous RF and IF amplifier stages. The AGC voltage in a receiver is usually tied to an AGC "bus" which provides feedback to previous stages on the same bus.

In the figure, C7 couples a part of the IF output signal to CR1. This leaves a rectified small positive average DC voltage at the junction of CR1, C7, and R7. This small positive voltage decreases toward zero as the amplitude of the IF signal increases enough in strength. R6 and R7 form a voltage divider between + V_{CC} and the AGC output voltage. As the positive voltage at the CR1, C7, and R7 junction decreases (but never becomes negative), the AGC output voltage becomes less positive. This lowers the AGC bias voltage on the bus and reduces the gain of previous stages. R8 and C6 filter the AGC voltage to produce a smooth DC level.

You will be using the "S" meter in the NIDA trainer as part of the Job Program for this lesson. The meter is often used in superheterodyne receivers to indicate the strength of received signals, and to help center-tune the receiver. Calibration for "S" meters can be in "S" units, decibels, or some other numerical scale units. In the NIDA trainer, calibration is on a scale from 0 to 10. The "S" meter on the NIDA trainer is found in the second IF amplifier stage.

Figure 10 shows the "S" meter circuit components in the NIDA trainer.

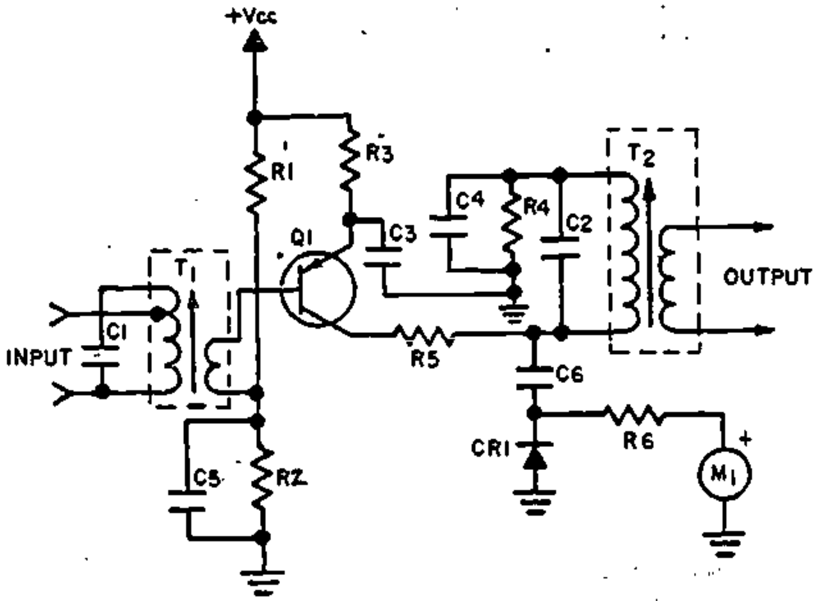

Figure 10

IF AMPLIFIER STAGE WITH "S" METER

For the meter circuit to operate, part of the IF signal is tapped off the Q1 collector circuit. The pulsating +DC voltage across the half-wave rectifier CR1 is applied to dropping resistor R6, and meter M1. The meter pointer indicates the average DC voltage level across CR1.

Technicians often use the "S" meter as a piece of built-in test equipment (BITE) to aid in troubleshooting. When a signal is tuned in, an "S" meter deflection indicates that receiver circuit problems are likely to be located in stages following the meter. If no deflection occurs, receiver problems are likely to be located in stages somewhere leading up to and including the meter circuit.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON 3

IF Amplifiers

TEST FRAMES ARE 7, 14, 24, and 28. PROCEED TO TEST FRAME 7 AND SEE IF YOU CAN ANSWER THE QUESTIONS. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. IF amplifiers are common circuits found in both receivers and transmitters. You now will learn some operating characteristics of IF amplifiers in superheterodyne receivers. Most modern radio, television, and radar receivers are of the superheterodyne type. You have worked with this type of receiver in Module 18, Basic Troubleshooting Techniques, and Module 19, Troubleshooting the Amplifier Stage in a Radio Receiver. In a superheterodyne receiver, the incoming signal is mixed, or heterodyned, with a signal produced by a local oscillator. This mixing action produces a continuous fixed frequency output signal called the Intermediate Frequency, or IF. The IF contains all the information of the original antenna signal. All superheterodyne receivers must amplify these IF signals. Therefore, IF amplifiers are used to provide whatever signal gain and selectivity are required in a receiver.

An IF signal is produced when an incoming signal is ____________ with a local oscillator signal.

---

heterodyned (or mixed)

(2.) An IF amplifier is basically a tuned, high gain, RF amplifier with transformer coupling. You recall that one difference between RF and IF amplifiers is that IF amplifiers are tuned to a fixed frequency. The input signal into an IF amplifier has been converted to a fixed frequency by the converter stage in the receiver. Once an IF amplifier has been tuned to a center frequency at or near the fixed input frequency, no more retuning is necessary.

IF amplifiers are basically RF amplifiers with (fixed/variable) tuning.

---

fixed

(3.) IF amplifiers commonly use tuned transformer coupling. In the previous lesson, you learned that amplifier coupling is important in determining amplifier bandwidth and selectivity. Now let's look at a practical situation which shows how coupling affects amplifier operation.

Suppose you tune in your favorite rock station at 790 kHz on the AM radio dial. In order to get good sound reproduction, your radio receiver will be tuned to select a center frequency of 790 kHz with a 10 kHz bandwidth as shown in Figure 1.

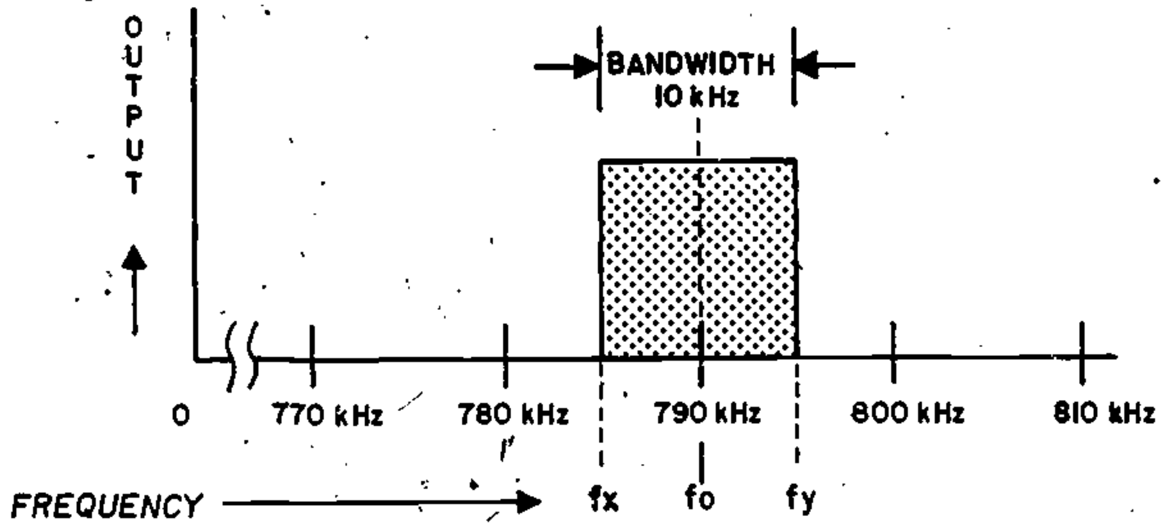

Figure 1: IDEAL RECEIVER FREQUENCY RESPONSE CURVE

Ideally, your radio receiver should select and amplify only the signal which contains the necessary information, and completely reject all other signals. To do this, an ideal receiver would need the rectangular frequency response curve shown in Figure 1. In the figure, the flat top indicates that the receiver should have constant gain within the 10 kHz bandwidth. The vertical sides at Fx and Fy indicate that frequencies on either side of these points would not be amplified.

In Figure 1, the flat top shows that the ideal receiver has constant ____________ within the bandwidth around a selected Fo.

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gain (or amplitude)

(4.) The converted input signal into an IF amplifier in your radio receiver contains all the original information needed for good sound reproduction. Therefore, the ideal IF amplifier should have the rectangular frequency response curve shown in Figure 2.

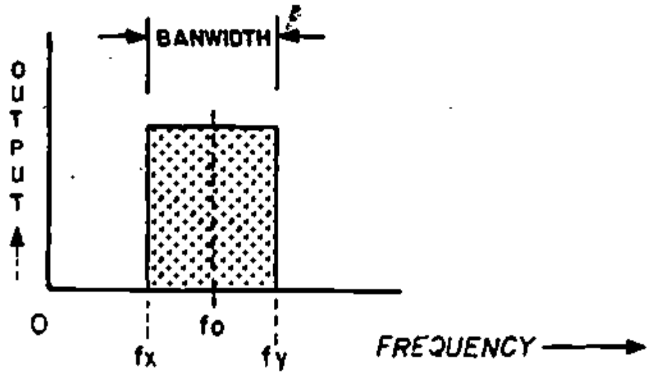

Figure 2

IDEAL IF RESPONSE CURVE

Notice that the shape of the response curve in Figure 2 is the same as for the ideal receiver response curve in Figure 1. Therefore, the ideal IF amplifier should have constant gain within its bandwidth, and no gain beyond the bandwidth limits as Fx and Fy as shown in Figure 2.

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As you have learned, an actual IF amplifier with tuned transformer coupling has a frequency response curve which more closely resembles Figure 3.

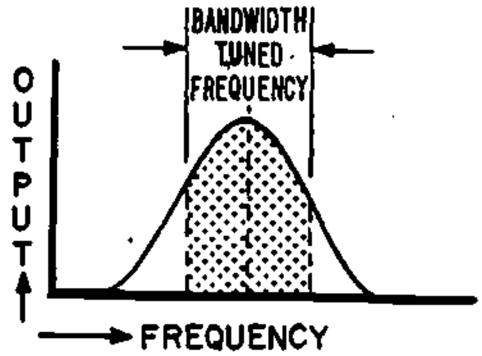

Figure 3

TYPICAL FREQUENCY RESPONSE CURVE

The sloped sides indicate that the gain does not stay constant within the bandwidth, and that some amplification occurs beyond the limits of the bandwidth.

The frequency response curve of an IF amplifier has (vertical/sloped) sides which indicate that (no/some) amplification occurs beyond the bandwidth limits.

---

sloped, some

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(5) There are ways to make the frequency response curve of an IF amplifier resemble the ideal curve in order to improve amplifier operation. You recall that amplifier selectivity increases as more resonant circuits tuned to the same frequency are added in the signal path. Figure 4 shows a coupling circuit with a tuned primary, L1, and related amplifier frequency response curve.

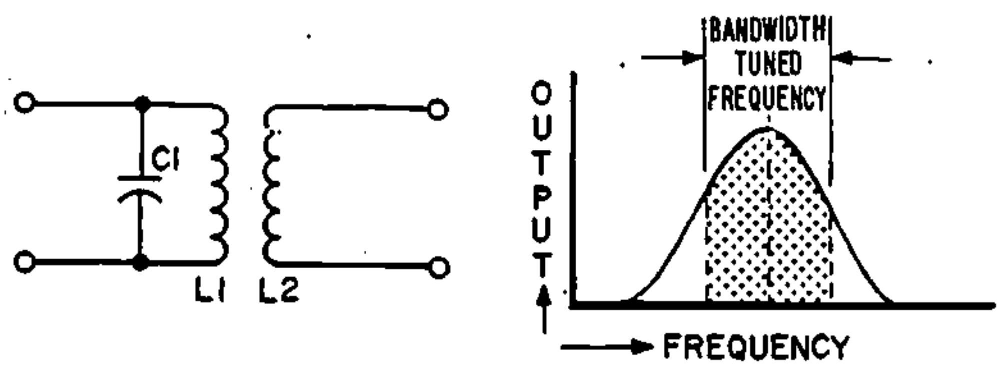

Figure 4

SINGLE-TUNED TRANSFORMER COUPLING FREQUENCY RESPONSE CURVE

A tuned circuit may be added to the secondary, L2, as shown in Figure 5.

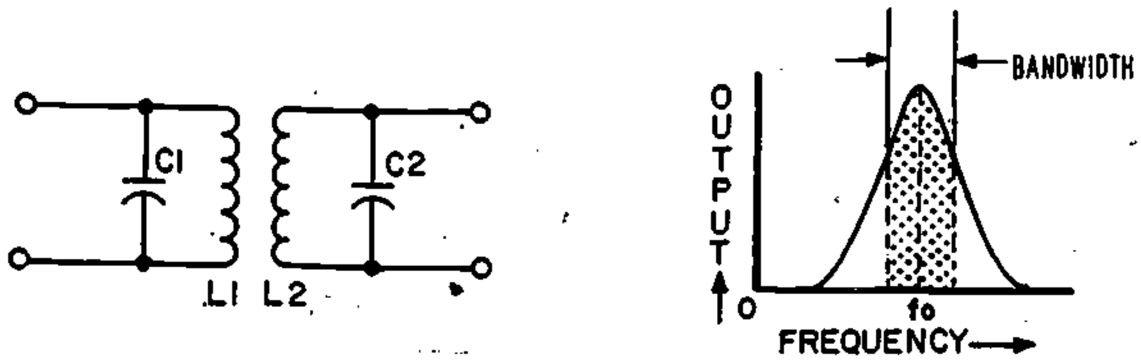

Figure 5

DOUBLE-TUNED TRANSFORMER COUPLING FREQUENCY RESPONSE CURVE

Both primary and secondary can be tuned to the same frequency. This is called synchronous tuning. Synchronous tuning occurs when all tuned circuits in the signal path are tuned to the same frequency. If the two tuned tanks are synchronous tuned to the IF center frequency, the resulting frequency response curve is shown in Figure 5. Notice that the sides are relatively steep and the bandwidth has become narrower. This indicates good selectivity.

The selectivity of an amplifier increases if resonant circuits are added in the signal path and ______________ tuned to the IF center frequency.

---

synchronous

(U.) You know how to increase amplifier selectivity. However, as selectivity increases, the bandwidth becomes more and more narrow. If the bandwidth becomes too narrow, part of the desired signal may not receive enough amplification and the result will be a distorted output (sound, picture, etc.) For example, a television or radar signal has a very broad bandwidth. Radar and TV receivers use IF amplifiers which must have a wide enough bandwidth to receive and amplify this broadband signal.

One method to increase the bandwidth of an IF amplifier is to use stagger tuning. In stagger tuning, each tuned coupling circuit is tuned to a slightly different frequency. The resulting amplifier frequency response curve for an amplifier with three stagger-tuned circuits is shown in Figure 6.

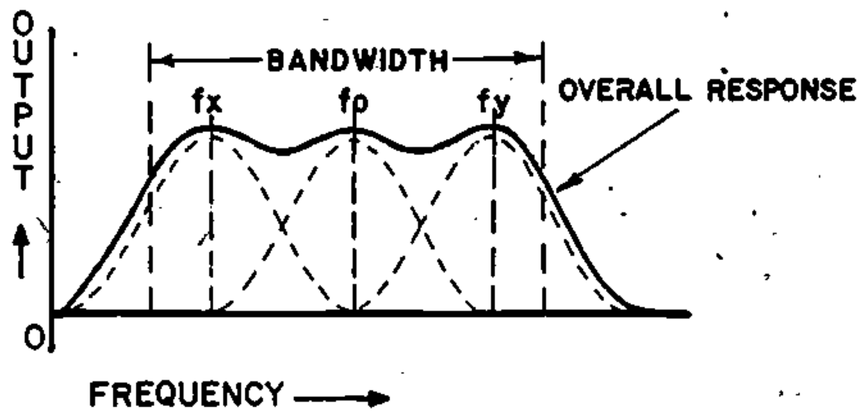

Figure 6

STAGGER-TUNED RESPONSE CURVE

In the figure, the curve now has a fairly flat top which indicates that the gain is at a relatively constant level across the bandwidth. The sides of the curve are sloped, however the shape resembles the ideal response. You can see that adding and tuning resonant coupling circuits affect amplifier bandwidth and selectivity.

One way to widen the bandwidth of an IF amplifier is to __________ tune the resonant coupling circuits.

---

stagger

(7.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

1. The flat-top part of the frequency curve for an ideal IF amplifier indicates

   a. good selectivity

   b. constant gain

   c. narrow bandwidth

   d. amplifier efficiency

2. Synchronous tuning of an IF amplifier

   a. widens the bandwidth

   b. increases the center frequency

   c. heterodynes the input signal

   d. increases selectivity

3. The bandwidth of an IF amplifier is widened by

   a. stagger tuning

   b. synchronous tuning

   c. adding tuned circuits in the signal path

   d. increasing selectivity


INCREASES
RECEIVER
SENSITIVITY
TO
weak
signals
AVC
DECREASES
RECEIVER
SENSITIVITY
TO
strong
signals

1. b. constant gain

2. d. increases selectivity

3. a. stagger tuning

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 14. OTHERWISE GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 7 AGAIN.

(8.) Now let's look at the diagram of a typical common-emitter IF amplifier stage shown in Figure 7.

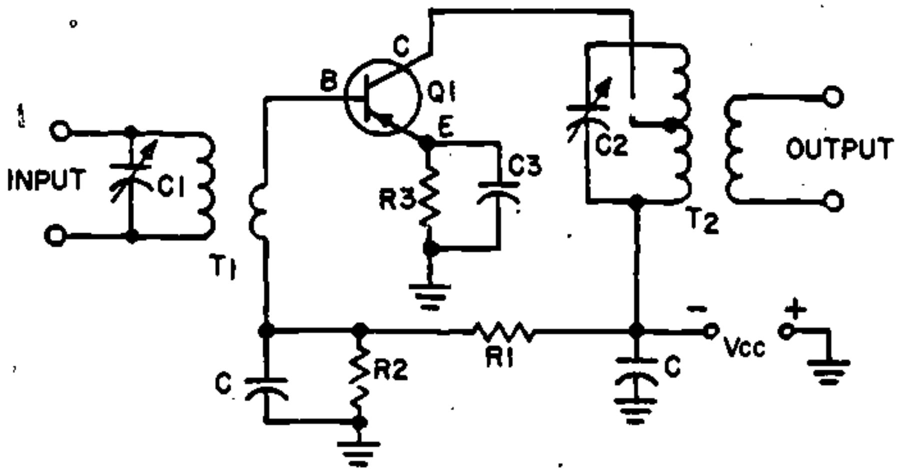

Figure 7

TYPICAL COMMON-EMITTER IF STAGE

You recall that single-tuned transformer coupling has only one tuned tank, and that double-tuned transformer coupling has two tuned tanks. Double-tuned transformers are quite common in IF stages when a narrow bandwidth is desired. However, the bandwidth requirements for the circuit in Figure 7 are best provided by the single-tuned tanks. In the figure, neutralization components have not been included. You will find that neutralization components are often added to amplifiers operating at high intermediate frequencies.

In Figure 7, the coupling circuits are (single/double) - tuned, and the amplifier has (some/no) neutralization components.

---

single, no

(9.) You have learned how both synchronous and stagger tuning improve amplifier operation. Let's apply this knowledge to the operation of the coupling components in the common-emitter IF amplifier stage shown again in Figure 8.

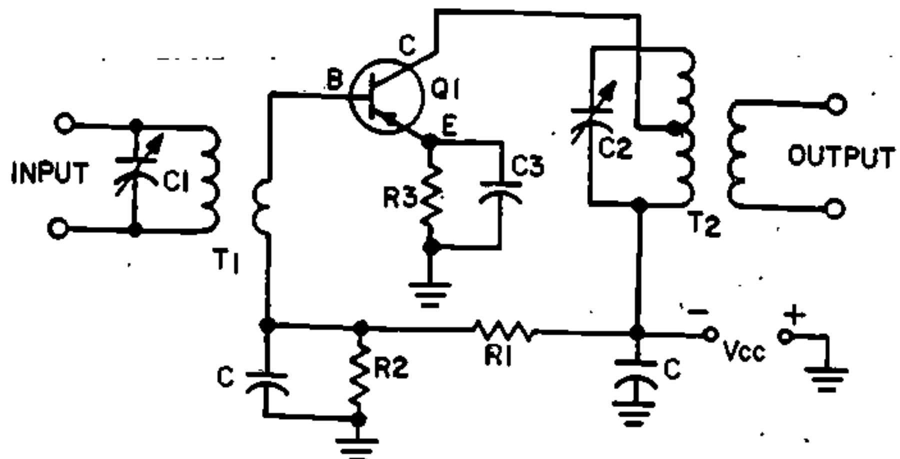

Figure 8

TYPICAL COMMON-EMITTER IF STAGE

In the figure, C1 tunes the primary of T1, and C2 tunes the primary of T2. If a narrow bandwidth amplifier is desired, C1 and C2 can be tuned to the same frequency, or synchronous tuned. If a wide bandwidth amplifier is desired, C1 and C2 can be tuned to a slightly different frequency, or stagger tuned.

If C1 and C2 in Figure 8 are stagger tuned, the IF amplifier bandwidth will become (wider/narrower).

---

wider

(10). The overall amplification of a receiver can be increased by using a string of IF amplifier stages. Just about any frequency response characteristic can be achieved by properly tuning the various stages. An IF amplifier therefore accomplishes two major functions in any receiver. It establishes gain, and controls bandwidth which affects selectivity.

Two frequency response characteristics affected by tuning IF amplifier

________________ and ________________.

---

gain, bandwidth (or selectivity)

(11.) You are familiar with the circuit diagram of a typical IF amplifier. Now let's look at the IF amplifier circuit that you will study on the NIDA trainer. The circuit is shown in Figure 9.

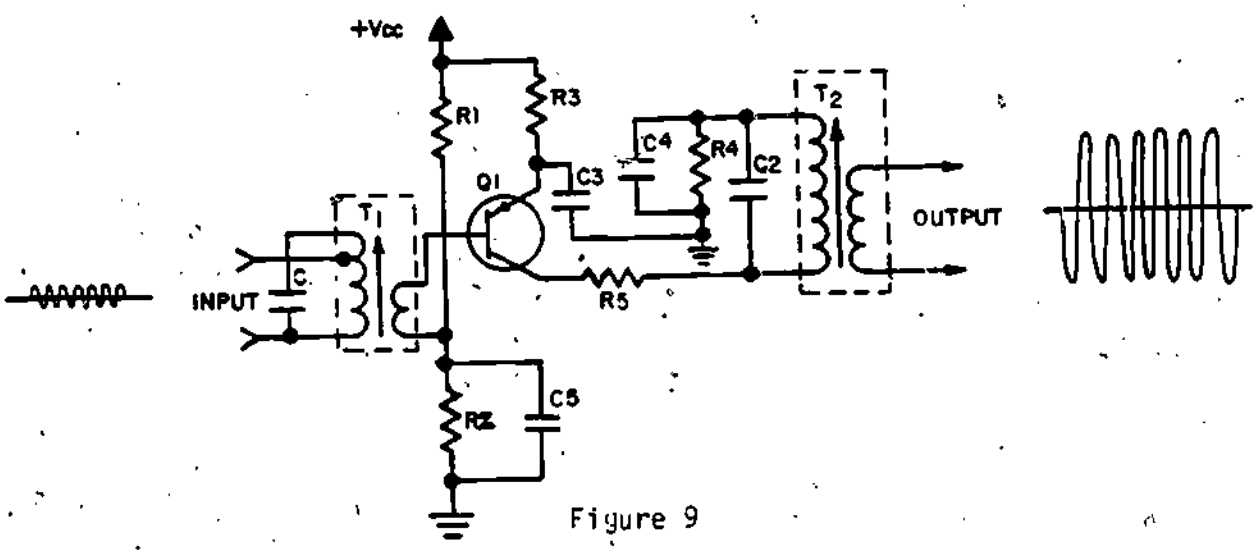

Figure 9

NIDA IF AMPLIFIER

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At first glance, this circuit may appear totally different to you from the typical common-emitter IF amplifier stage you have been studying which is shown again in Figure 10.

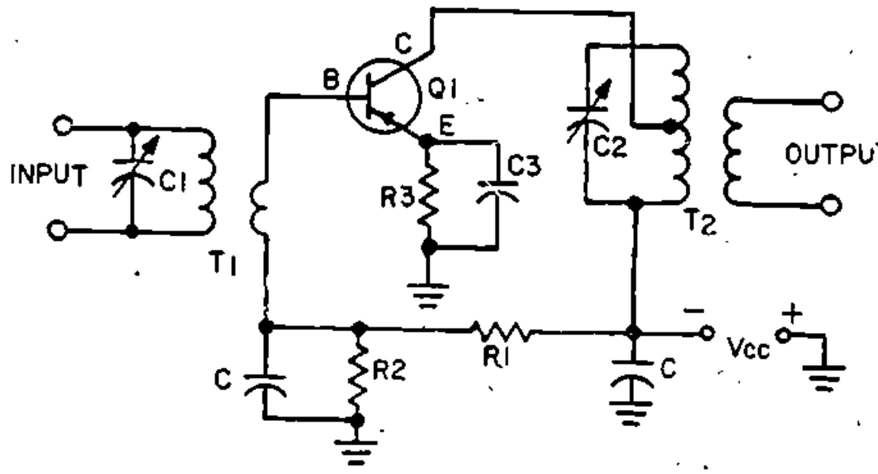

Figure 10

TYPICAL COMMON-EMITTER IF STAGE

However, on closer inspection, you will see that the diagrams in Figures 9 and 10 are basically the same common-emitter IF amplifier circuit. The types of coupling transformers at T1 and T2 are different between the figures (inductive vs capacitive tuning). Also, the V_{CC} source voltage is applied to the emitter in Figure 9, whereas it is applied to the collector in Figure 10. However, these differences do not change the circuit operation or the function of the components.

The NIDA IF amplifier circuit shown in Figure 9 is basically different from the typical common-emitter IF amplifier circuit shown in Figure 10.

a. true

b. false

---

b. false

(12) Let's take another look at the NIDA IF amplifier circuit in Figure 11, and check out the operation of the base-emitter circuit components.

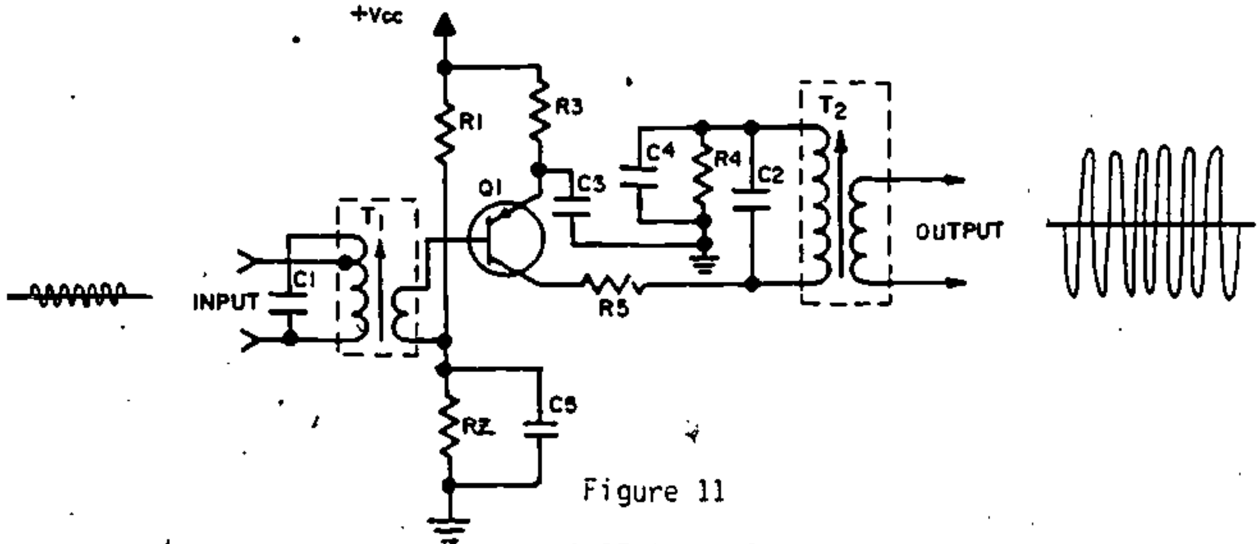

Figure 11

NIDA IF AMPLIFIER

The input signal is applied to the first IF transformer, T1. Notice that T1 is a single-tuned transformer with a tap on the primary. This tap provides an impedance match with the collector circuit in the previous stage. This type of transformer is often enclosed in an aluminum shield to prevent unwanted coupling to nearby wires and transformers. Inductive tuning is done by a tuning slug. T1 has a stepdown secondary to provide a low impedance match to the base circuit of Q1. Forward bias is provided to Q1 by R1 and R2 to establish Class A operation. Decoupling capacitor C5 ensures all signal voltage is developed across the secondary of T1. Emitter stabilization is provided by R3 and C3.

Which components in Figure 11 provide forward bias to Q1?

R1, R2

(13). Now we will cover the operation of the collector circuit components in the NIDA IF amplifier circuit.

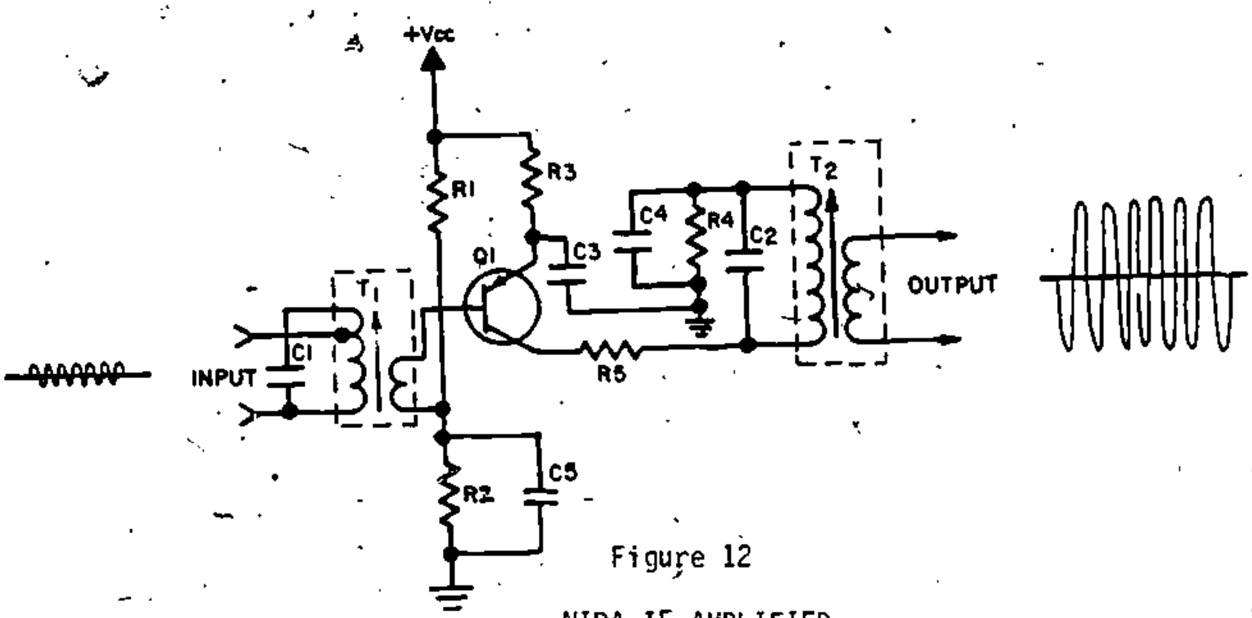

Figure 12

NIDA IF AMPLIFIER

In Figure 12, T2 is a single-tuned transformer. The primary of T2 and C2 make up the output tank circuit which acts as the collector load for Q1. This tank is tuned to the center operating frequency of the IF amplifier which is 10.7 MHz. C4 and R4 acts as a decoupling circuit to ensure that all signal voltage is developed across the tank, and therefore does not enter the power supply. R5 is the main reason why additional neutralization is not required in this circuit. R5 reduces the tendency for the collector-base junction of Q1 to become forward biased on strong signals. Such forward bias could produce enough positive feedback to cause oscillation.

Which component in Figure 12 reduces the possibility of amplifier oscillation?

R5

(14.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

USE THE DIAGRAM BELOW OF AN IF AMPLIFIER CIRCUIT TO ANSWER QUESTIONS 1 THRU 4.

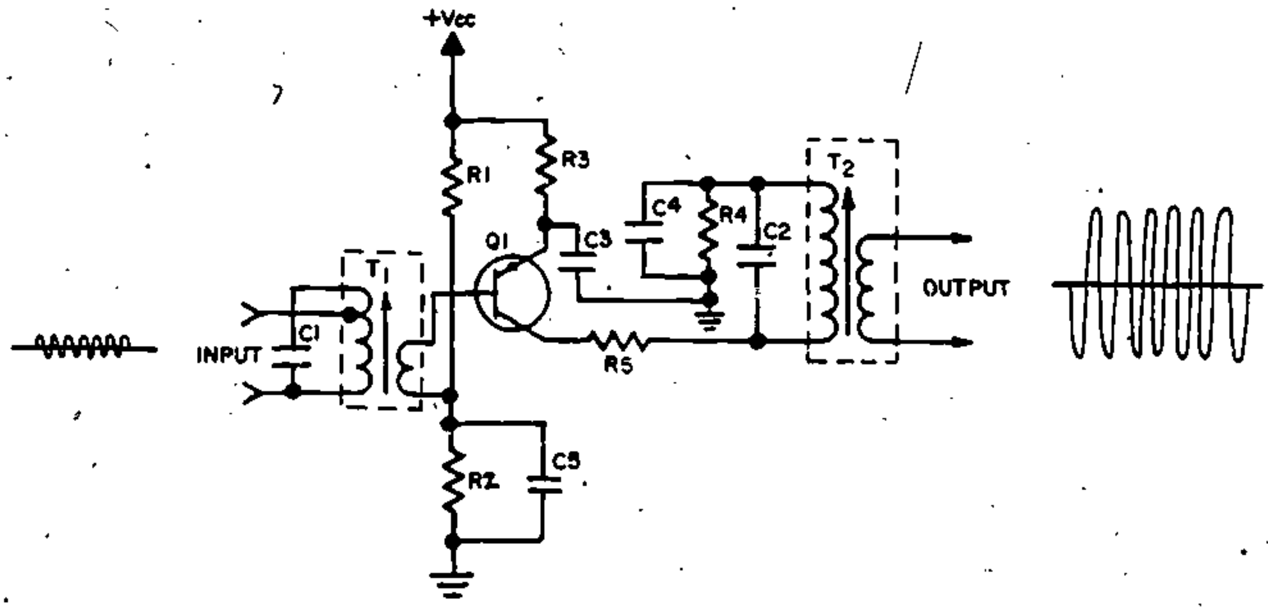

Figure 13

1. If the inductive coupling circuits are stagger tuned, the amplifier's bandwidth would
   a. remain the same
   b. become wider
   c. become narrower

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2. The transformers T1 and T2 are each

   a. double-tuned

   b. single-tuned

3. T1 has a step-down secondary in order to

   a. neutralize the effect of stray reactances

   b. change the Fo of the tank in T1

   c. provide emitter stabilization to Q1

   d. provide an impedance match with Q1

4. R5 is used to reduce the possibility of amplifier

   a. oscillation

   b. degeneration

   c. neutralization

   d. decoupling

1. b. become wider
2. b. single-tuned
3. d. provide an impedance match with Q1
4. a. oscillation

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 24. OTHERWISE GO BACK TO FRAME 8 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 14 AGAIN.

(15.) IF amplifiers are usually found connected together in series to perform their function in a receiver or transmitter. In other words, the output from one IF amplifier stage becomes the input into the next stage. You recall from your study of decibels that amplifiers connected in series, or cascaded, can produce a very high total gain. An example of three cascaded amplifiers is shown in Figure 14.

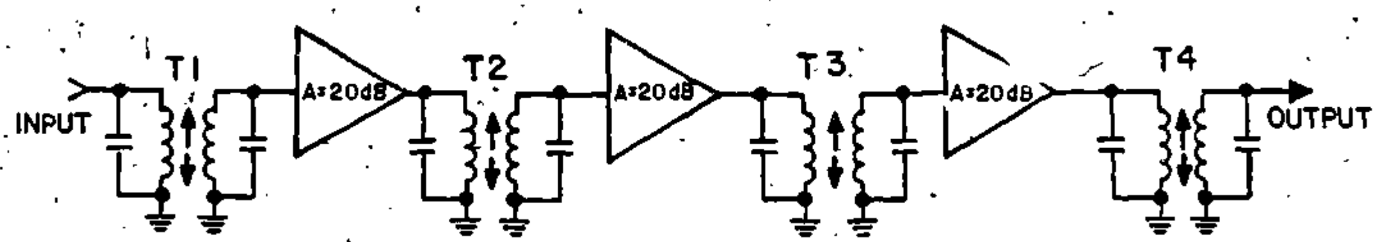


Figure 14

HIGH GAIN IF AMPLIFIERS

Each amplifier in the figure has a 20 dB gain. Therefore, the total gain is the sum of the dB gains for each amplifier, or 60 dB. You can use the familiar dB chart and graph, shown in Figure 15, to find the voltage ratio conversion for a 60 dB gain.

VOLTAGE RATIO	DECIBELS	POWER RATIO
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	1	[illegible]
1.2[illegible]	[illegible]	[illegible]
1.41	3	2.0
[illegible]	4	[illegible]
1.78	5	[illegible]
2.0	6	4.0[illegible]
2.[illegible]	7	[illegible].01
2.5[illegible]	8	6.31
2.[illegible]	9	7.94
[illegible]	10	10
[illegible]	15	31.62
10	20	100
17.78	25	316.22
31.6	30	1000
10[illegible]	40	10,000
[illegible]	50	100,000
1000	60	1,000,000
31[illegible]	70	10,000,000
10,0[illegible]	80	100,000,000
31,62[illegible]	90	1,000,000,000
100,00[illegible]	100	10,000,000,000

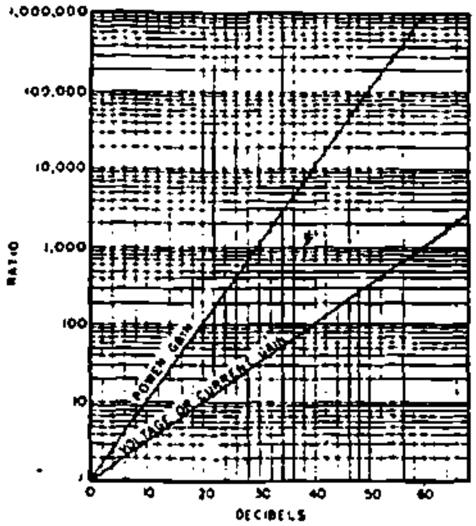


Figure 15

dB CHART/GRAPH

From the chart, you find that 60 dB converts to a voltage ratio of 1000. This means that the output signal from the third amplifier is 1000 times greater than the input signal into the first amplifier. For example, a one millivolt input produces a total output signal amplitude of 1 volt.

Several cascaded amplifiers produce a voltage gain of 100. This means that an input signal of 2 millivolts produces a total output signal of________.

.2 volt (or 200 millivolts)

185

(10.) Suppose that several cascaded IF amplifiers have a normal operating input signal of one millivolt into the first stage, and a total voltage gain of 1000. If a relatively strong input signal of one volt were applied, you might think that the total output would equal 1000 volts. Of course this large an output signal will not happen because it exceeds the design capability of the circuits and power supply. However, severe limiting, or clipping, of the signal would occur and produce unwanted distortion. Each IF amplifier stage has a normal operating input signal voltage. If this voltage is exceeded enough to cause clipping of the output signal, the amplifier stage is said to be <u>overdriven</u>.

An IF amplifier is ____________ when the input signal voltage is high enough to cause clipping of the output signal.

---

overdriven

(17) Some type of gain control is needed to avoid overdriving an IF amplifier. To understand how the gain of an IF amplifier may be controlled, we first must examine the effect of bias on transistor amplification. You recall that transistors require a certain amount of operating DC current to function. The amount of forward bias on the transistor's base-emitter junction (V_{BE}) affects the level of operating DC current in the transistor. As an example, Figure 16 shows the effect of forward bias on transistor operation in a Class A amplifier.

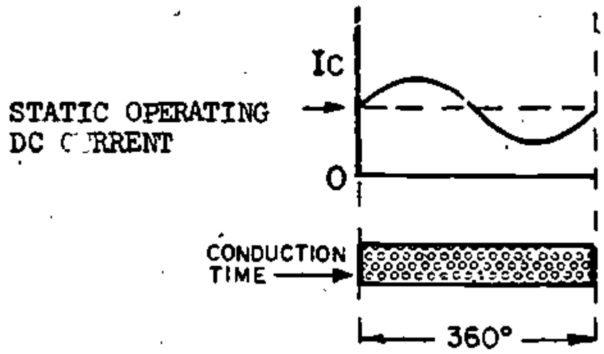


Figure 16

CLASS A AMPLIFIER OPERATION

You remember that Class A amplifiers conduct even when no signal is present. This is called the transistor's static operating level, and is shown by the dotted line in Figure 16. When the transistor receives an input signal, the transistor produces a current waveform that varies about this static operating level. This waveform is shown by the sine wave in the figure. If the forward bias is changed, the static operating level of the transistor is changed.

The amount of ________ ________ affects the static operating level of the transistor.

---

forward bias

(18.) The amount of transistor gain is related to the transistor's static operating level. Since the static operating level is affected by the amount of forward bias, gain is also affected by the amount of forward bias. Within a certain range of bias levels, the transistor produces a reasonably constant gain. This range is called the linear operating region for the transistor. When the forward bias is significantly above or below the linear region, the transistor is operating in what are called the "non-linear" operating regions. A transistor operating in the non-linear operating regions produces lower gain, and possible distortion.

A transistor produces reasonably constant gain when conducting within the (linear/non-linear) operating regions.

---

linear

(19.) The relationship between bias, conduction, and gain are found in the transistor characteristic curve in Figure 17.

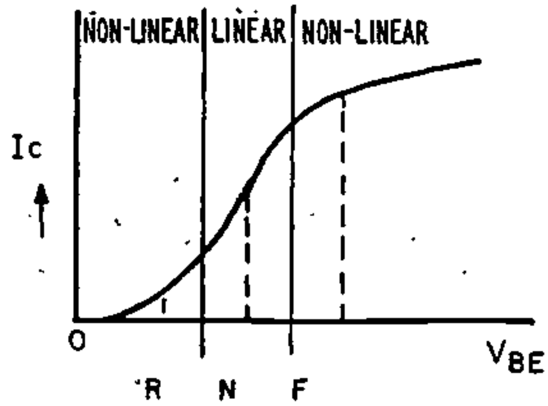


Figure 17

TRANSISTOR CHARACTERISTIC CURVE

The horizontal axis (V_{BE}) is the amount of forward bias applied to the transistor. The vertical axis (Ic) is the amount of collector current. The curve is used to determine the amount of transistor output, or gain, related to bias and conduction levels for a given input signal.

In the figure, a transistor biased at any point within the linear operating region "N" will produce maximum gain. If the bias is reduced to any point within the non-linear operating region "R", the transistor will produce less gain. The transistor also will produce less gain if the bias is increased to any point within the non-linear operating region "F". The dashed lines in the figure represent specific bias points in the "R", "N", and "F" regions. The heights of the dashed lines represent the static operating levels for a tra tor at these specific points.

The transistor characteristic curve is used to determine the amount of transistor ____________ related to specific bias and conduction levels.

---

gain (or output)

(20.) Figure 18 shows examples of three identical input signals applied to a transistor at bias levels within the "R", "N", and "F" regions.

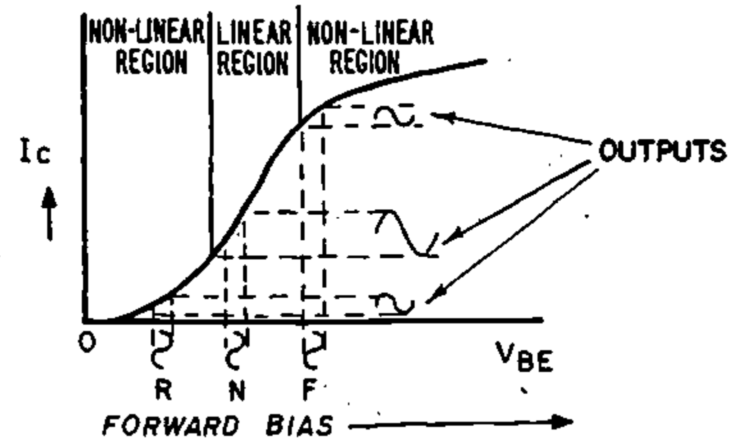


Figure 18

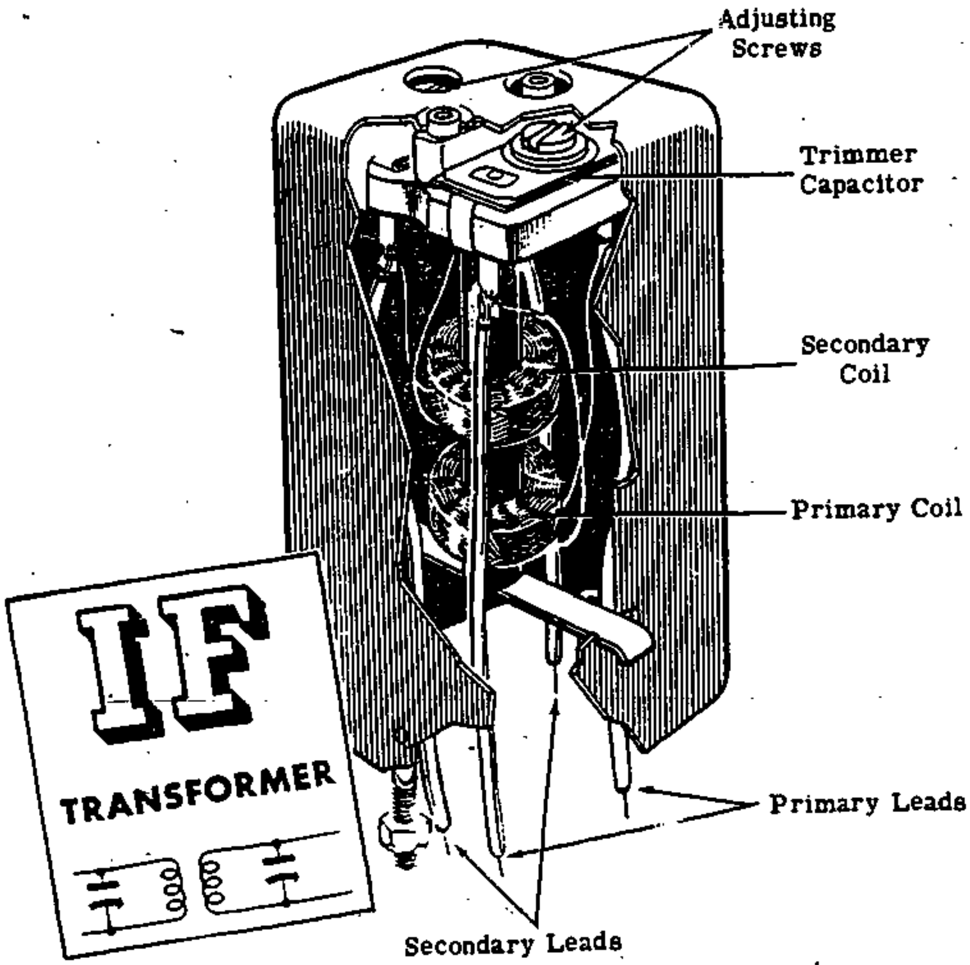
TRANSISTOR CHARACTERISTIC CURVE

In the figure, the amplitudes of the input signals are shown above the region labels. The vertical lines extend from the input signal amplitude limits to the points where they meet the characteristic curve. The horizontal lines represent the upper and lower amplitude limits of the transistor output signals. Notice the difference in the output amplitudes between the three regions. It is now obvious that the gains related to bias levels within the non-linear operating regions are smaller than gains within the linear operating regions. Therefore, amplifier gains can be reduced by applying forward bias at levels within either the "R" or "F" regions. The technique of reducing gain by applying forward bias in the "R" region is called reverse-bias gain control. The technique of reducing gain by applying forward bias in the "F" region is called forward bias gain control.

In reverse bias gain control, the transistor bias is set at a level (below/above) the bias levels which produce maximum gain.

---

below


Adjusting
Screws
Trimmer
Capacitor
Secondary
Coil
Primary Coil
IF
TRANSFORMER
Primary Leads
Secondary Leads

(21) Now that you know the principle for controlling transistor gain, lets's apply your knowledge to the components in a typical IF amplifier circuit. Figure 19 shows the familiar IF amplifier stage from the NIDA trainer.

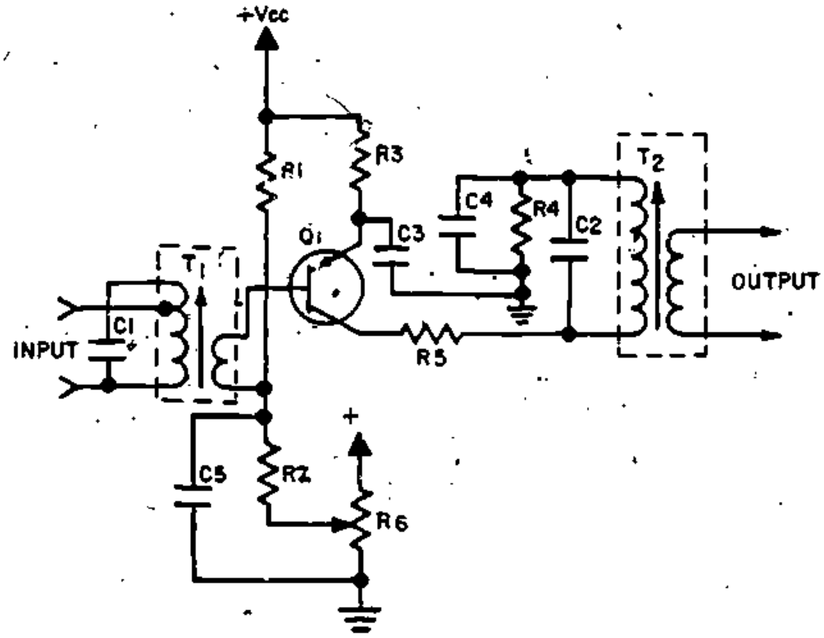


Figure 19

MANUAL IF GAIN CONTROL

In the figure, the one addition to the diagram is potentiometer R6. Forward bias is provided by components R1, R2, and R6. As you can see, the amount of forward bias can be manually controlled by varying R6. When the arm of R6 is in the bottom position, the forward bias in the circuit is in the normal linear operating region. Transistor gain is at a maximum in this region. However, as the arm of R6 is moved upward, a more positive voltage is placed on the base of Q1. This positive voltage reduces the forward bias on Q1. If the arm of R6 is moved upward high enough, the reduced level of forward bias would enter a non-linear operating region. In this region, the transistor would produce less gain. You can see that manual operation of R6 is an example of reverse bias gain control.

In Figure 19, manual operation of potentiometer R6 provides ______________ ____________ gain control to the IF amplifier circuit.

---

reverse bias

(22) Manual gain control might be fine if there are a lot of extra people with nothing to do but run around adjusting "pots" to compensate for weak and strong RF and IF amplifier signals. Happily, there is an automatic gain control (AGC) circuit which does the job quite nicely. AGC provides a more constant output from the IF amplifier stages, and from the audio or video equipment in which AGC is used.

Figure 20 shows the IF amplifier stage from Figure 19 with the addition of the AGC components.

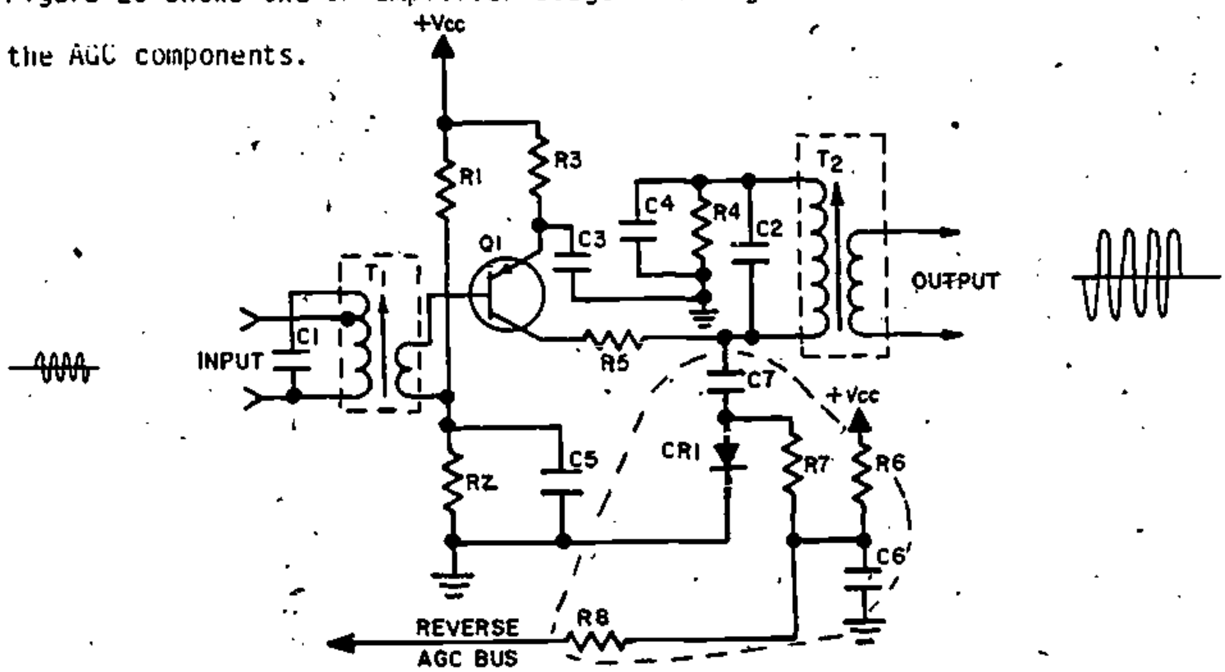


Figure 20

AUTOMATIC GAIN CONTROL (AGC)

In the figure, the additional components are located within the oval, and are labeled CR1, C6, C7, R6, R7, and R8. The AGC components provide an automatic reverse bias gain control over RF and IF amplifier stages which are previous to this stage. As the signal level within the stage in Figure 20 starts to overdrive the amplifier, a reduced positive AGC voltage is automatically fed back to limit the gain of previous stages. This will cause a reduction in the signal level input to this stage, and prevent overdriving. The AGC voltage in a receiver is usually tied to a common interconnecting line, sometimes called an AGC "bus". This AGC bus provides feedback from the AGC circuit to previous stages on the same bus.

In Figure 20, the ______________________ components provide a reduced bias voltage which is fed back to previous amplifier stages.

AGC

(23.) Now that you know the purpose of AGC circuit components, let's see how they function in an IF amplifier. Figure 21 shows the IF amplifier with AGC components added.

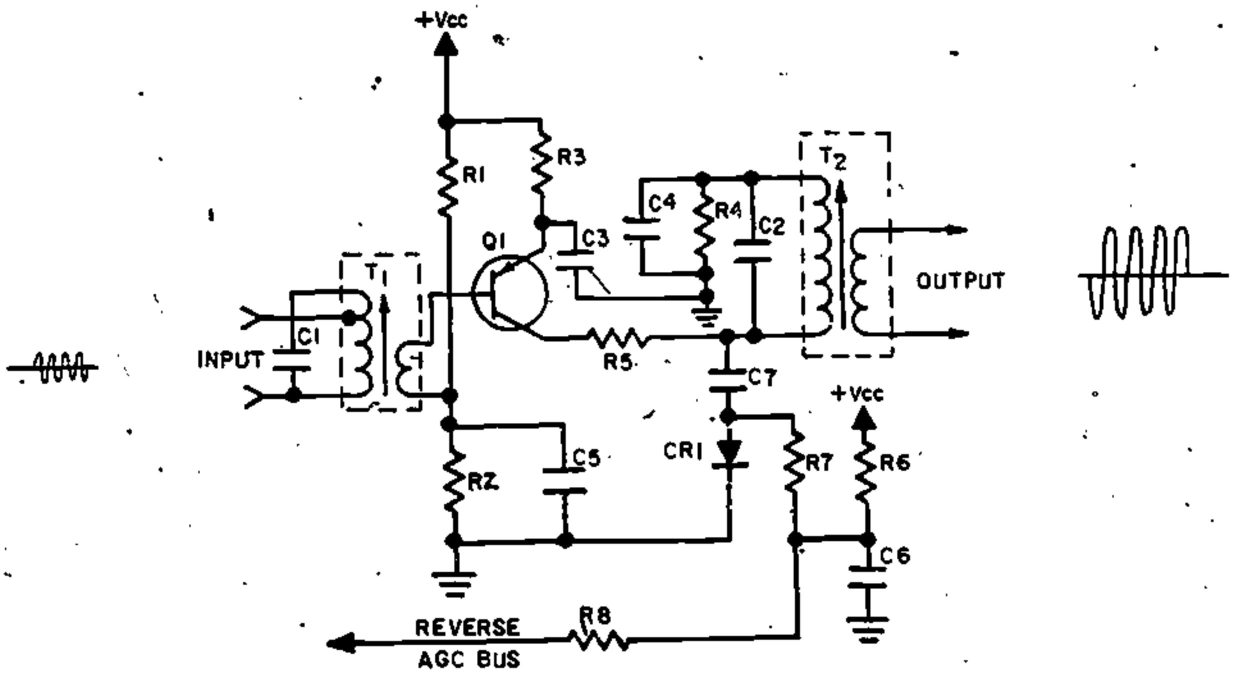


Figure 21

AUTOMATIC GAIN CONTROL (AGC)

In the figure, the IF output signal from Q1 is felt across the output coupling tank (C2-T2 primary). C7 is a small value capacitor that couples a sample of the IF output signal to the AGC diode CR1. CR1 has a static operating level of about +.7 DCV. This diode rectifies the IF signal and leaves a small positive voltage at the junction of CR1, C7, and R7. When the IF signal increases enough in amplitude, the DC voltage across CR1 reduces.

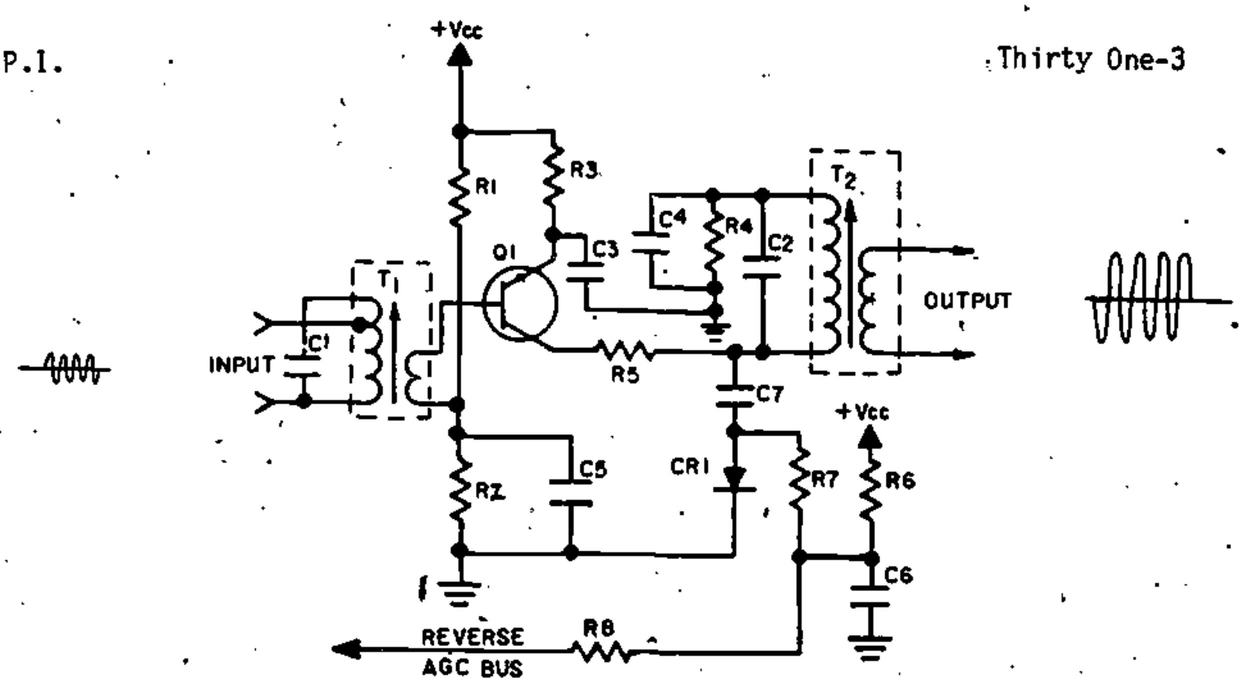


Figure 21

AUTOMATIC GAIN CONTROL (AGC)

This reduced voltage approaches zero, but is never negative. In other words, as the IF output signal gets stronger, the voltage at the junction gets smaller. Now R7 and R8 form a voltage divider between +VCC d the AGC output voltage. Therefore, the AGC output is a small positive DC voltage. As the voltage at the junction of CR1, C7, and R7 decreases, the AGC output voltage also decreases. This lowers the bias voltage on the AGC bus, thus reducing the gain of previous stages. R8 and C6 provide filtering of the AGC voltage to produce a smooth DC level.

When the voltage decreases at the junction of CR1, C7, and R7 in Figure 21, the AGC output voltage becomes

a. less positive

b. more positive

c. less negative

---

a. less positive

(24.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

1. The purpose of IF amplifier gain control is to
   a. improve selectivity
   b. tune coupling tanks
   c. prevent overdriving
   d. limit the number of cascaded stages

2. The IF amplifier produces__________ __________gain within the linear operating region.
   a. fairly constant
   b. relatively small

3. In reverse bias gain control, the amount of forward bias applied to an IF amplifier is in the__________ __________operating region of the amplifier.
   a. normal linear
   b. upper non-linear
   c. lower non-linear

USE THE DIAGRAM BELOW OF AN IF AMPLIFIER TO ANSWER QUESTIONS 4 AND 5.

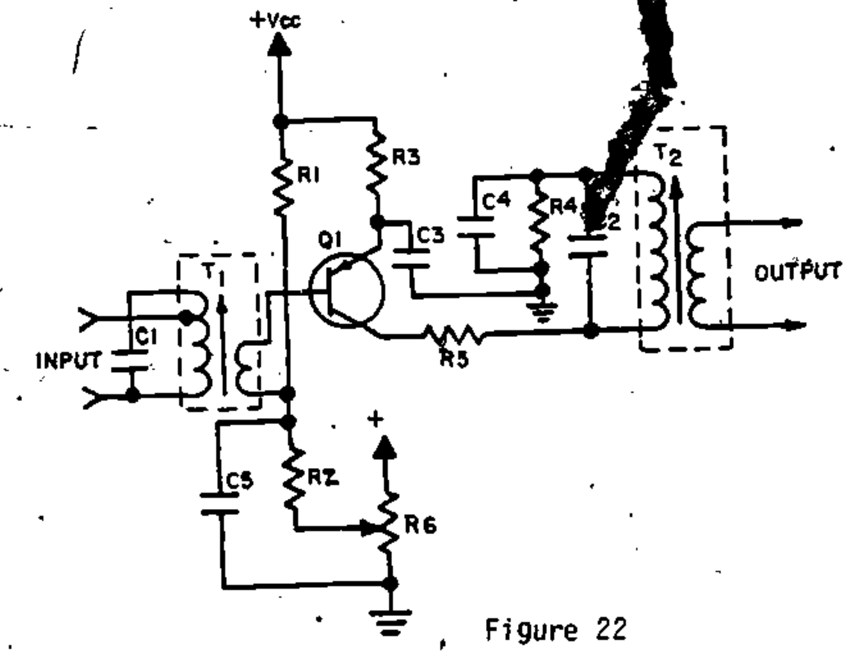


Figure 22

4. By moving the arm of the potentiometer upward, forward bias on Q1

   a. remains the same

   b. is reduced

   c. is increased

5. By moving the arm of the potentiometer upward high enough, what function is performed?

   a. forward bias gain control

   b. reverse bias gain control

   c. increased selectivity

   d. decreased selectivity

USE THE DIAGRAM BELOW OF AN IF AMPLIFIER TO ANSWER QUESTIONS 6 THROUGH 8.

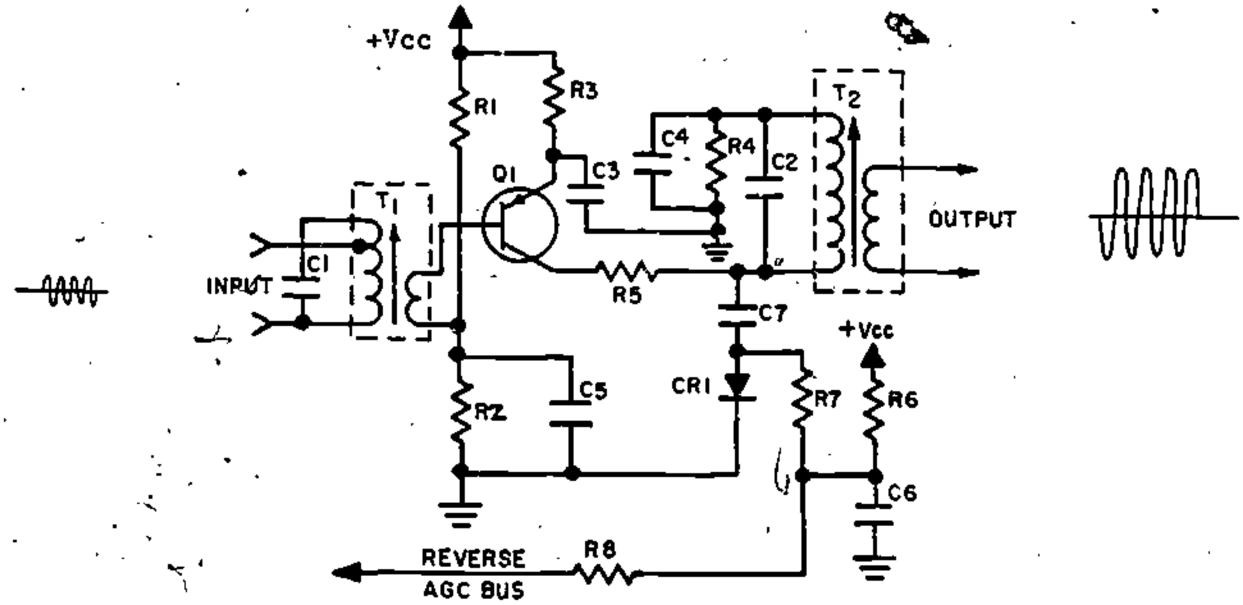


Figure 23

6. Which six labeled components are part of the AGC circuit?

7. As the IF amplifier output signal level becomes <u>weaker</u>, the AGC output level becomes <u>more</u>

a. rectified

b. negative

c. affective

d. positive

8. The AGC circuit affects the gain of

a. previous amplifier stages

b. this amplifier stage

c. the following amplifier stages

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1. c. prevent overdriving
2. a. fairly constant
3. c. lower non-linear
4. b. is reduced
5. b. reverse bias gain control
6. CR1, C6, C7, R6, R7, R8
7. d. positive
8. a. previous amplifier stages

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 28. OTHERWISE GO BACK TO FRAME 15 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 24 AGAIN.

(25) You will be working with the NIDA trainer as part of the job program activity for this lesson. You will need to use the built-in meter on the trainer. Figure 24 shows the meter location on the block diagram of the NIDA trainer.

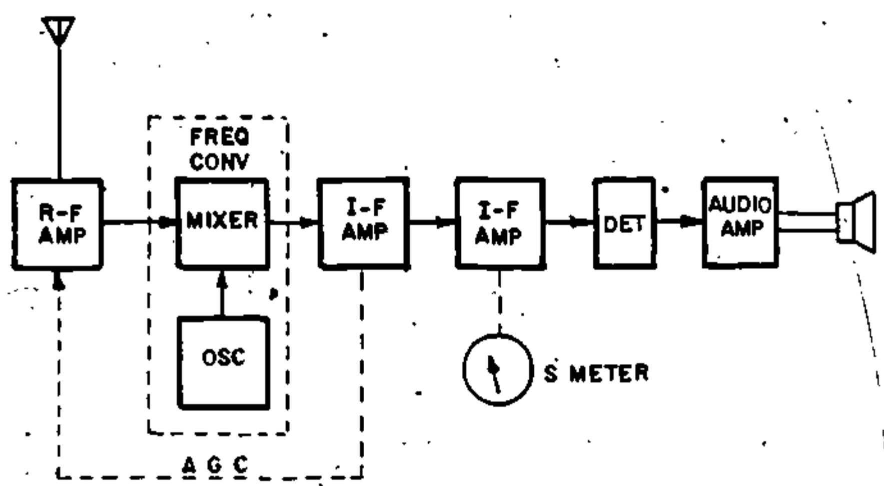

Figure 24

BLOCK DIAGRAM OF NIDA TRANSCEIVER TRAINER

The block diagram in the figure is similar to that of a typical superheterodyne receiver. Many communication-type receivers use some method to indicate the strength of received signals. This indicator is usually called an "S" meter and is calibrated in either "S" units, decibels, or some other numerical scale units. In the NIDA trainer, the scale units range from 0 to 10. The meter is used to indicate the relative strength of received signals, and is helpful for center-tuning the receiver to a desired signal. You probably have seen a similar type of meter on a CB transceiver or hi-fi set.

A function of an "S" meter in a transceiver is to indicate the

a. voltage output from power supply

b. relative strength of received signals

c. current output from power supply

d. amount of transistor collector current

---

b. relative strength of received signals

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(26.) Let's look at the operation of an "S" meter in a circuit. Figure 25 shows the components for the "S" meter circuit in the NIDA trainer IF amplifier stage.

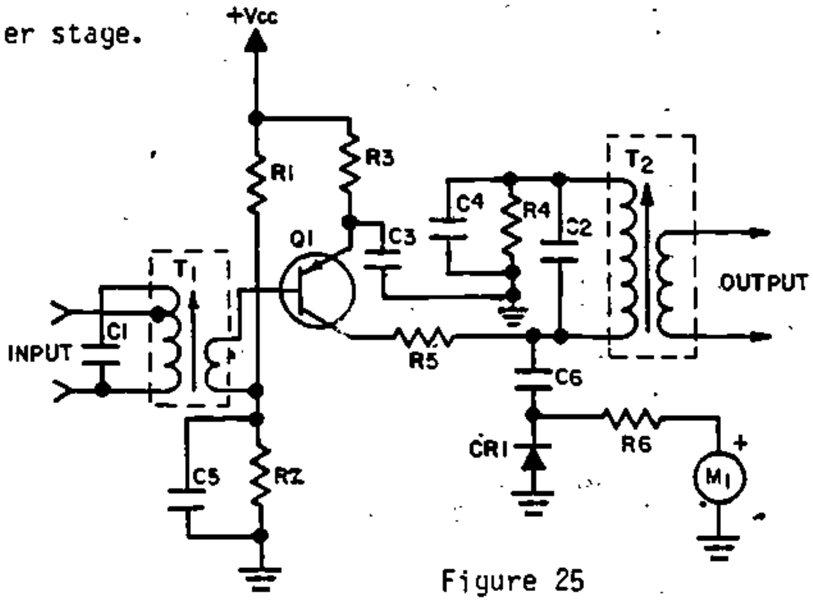

Figure 25

IF AMPLIFIER STAGE WITH "S" METER

In the figure, the meter circuit components are labelled M1, CR1, C6, and R6. For the meter circuit to operate, a small part of the IF output signal is tapped off the Q1 collector circuit. This IF signal is fed to the half-wave rectifier CR1 which, in this case, eliminates the negative alternations of the cycle. The pulsating +DC across CR1 is applied to the meter dropping resistor R6, and then is fed to the meter M1. The meter pointer indicates the average DC level of voltage across CR1. Therefore, as the IF signal amplitude increases, M1 will show a greater deflection, or movement, of the pointer across the scale.

As the IF signal amplitude increases, the pointer on the "S" meter in Figure 24 will show __________ movement across the scale.

a. greater

b. no

c. lesser

a. greater

(27) Technicians often use the "S" meter as a piece of built-in test-equipment (BITE) to aid in troubleshooting.

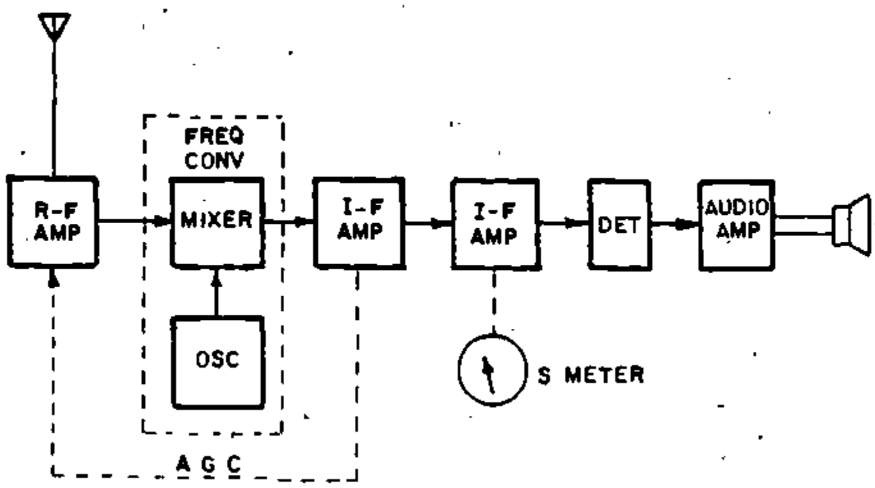

Figure 26

BLOCK DIAGRAM OF SUPERHETERODYNE RECEIVER

Using Figure 26, when a signal is tuned in, a meter deflection indicates that all circuits prior to and including the meter are functioning. Any receiver circuit problems are then located in stages following the meter. If no meter deflection occurs, receiver circuit problems are then located in circuits leading up to and including the meter. This is true wherever an "S" meter might be located in a receiver. Therefore, an "S" meter is a definite aid in isolating a faulty receiver stage.

An "S" meter on a radio receiver shows no deflection as you tune across the dial. This indicates that the receiver has circuit problems in stages (before/after) the meter.

before

(28.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWER WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTION.

USE THE BLOCK DIAGRAM BELOW OF A RADIO RECEIVER TO ANSWER QUESTION 1.

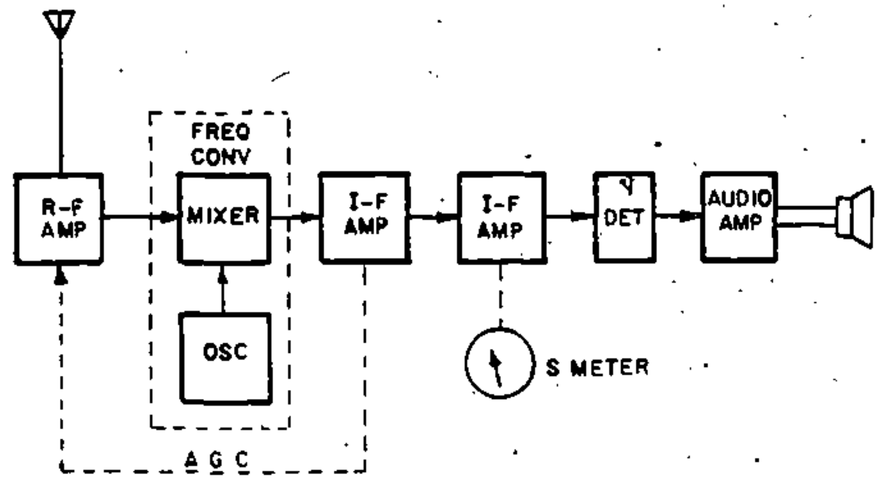

Figure 26

1. You notice that the "S" meter on your radio receiver deflects as you tune across the receiving range. However, there is no audio output. Using the block diagram, you suspect a fault in either the________ or__________.

a. RF amplifier, mixer

b. IF amplifier, oscillator

c. audio amplifier, detector

d. mixer, oscillator

1. c. audio amplifier, detector

IF YOUR ANSWER MATCHES THE CORRECT ANSWER YOU HAVE COMPLETED LESSON 3, MODULE 31. CONGRATULATIONS! OTHERWISE GO BACK TO FRAME 25 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 28 AGAIN.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON 3

IF Amplifiers

IF amplifiers are commonly found in both receivers and transmitters. Most modern radio, television, and radar receivers are of the superheterodyne type which you have studied in Module 18, Basic Troubleshooting Techniques, and Module 19, Troubleshooting the Amplifier Stage in a Radio Receiver. In this type of receiver, the incoming signal is mixed, or heterodyned, with a local oscillator to produce a continuous fixed frequency output called the Intermediate Frequency, or IF. IF amplifiers are used to provide the required signal gain and selectivity in the receiver

An IF amplifier is basically a tuned, high gain, RF amplifier with transformer coupling. IF amplifiers are tuned to a fixed frequency. The input signal into the IF amplifier has been converted to a fixed frequency by earlier receiver circuits. Once the IF amplifier is tuned to a center frequency at or near this fixed input frequency, no more tuning is necessary.

IF amplifier transformer coupling is important in determining amplifier bandwidth and selectivity. The converted input signal into an IF amplifier contains all the information needed for good signal reproduction. Ideally, the IF amplifier will select and amplify with constant gain only the desired signal and completely reject all others falling outside the bandwidth limits. Therefore, the ideal IF amplifier should have the rectangular frequency response curve shown in Figure 1.

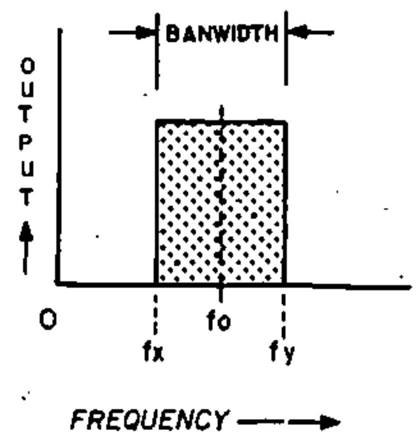

Figure 1

IDEAL IF RESPONSE CURVE

Note the straight sides which indicate ideal selectivity, and the flat top which indicates constant amplification within the bandwidth.

An actual IF amplifier with tuned-primary transformer coupling has a frequency response curve which more closely resembles Figure 2.

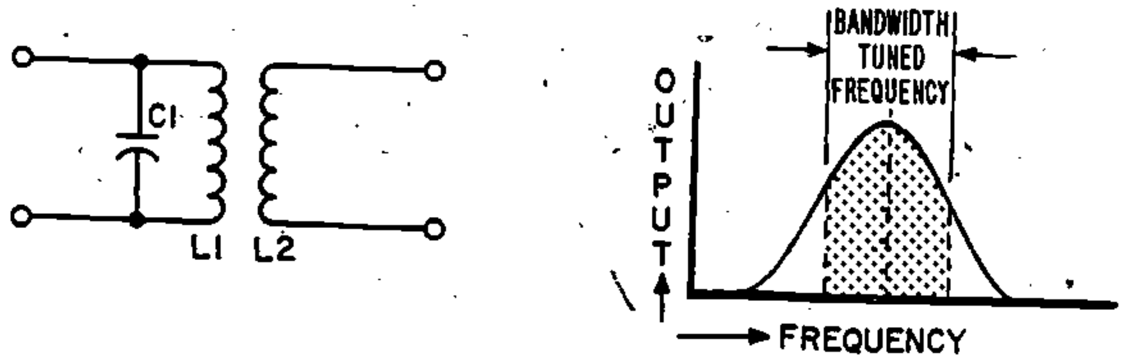

Figure 2

SINGLE TUNED TRANSFORMER COUPLING

There are ways to make the frequency response curve of an IF amplifier resemble the ideal curve and thus improve amplifier operation. For example, a tuned circuit may be added to the secondary of the transformer shown in Figure 2. Both primary and secondary then can be tuned to the same frequency, or synchronous tuned. If the two tuned tanks are synchronous tuned to the IF center frequency, the resulting frequency response curve is shown in Figure 3.

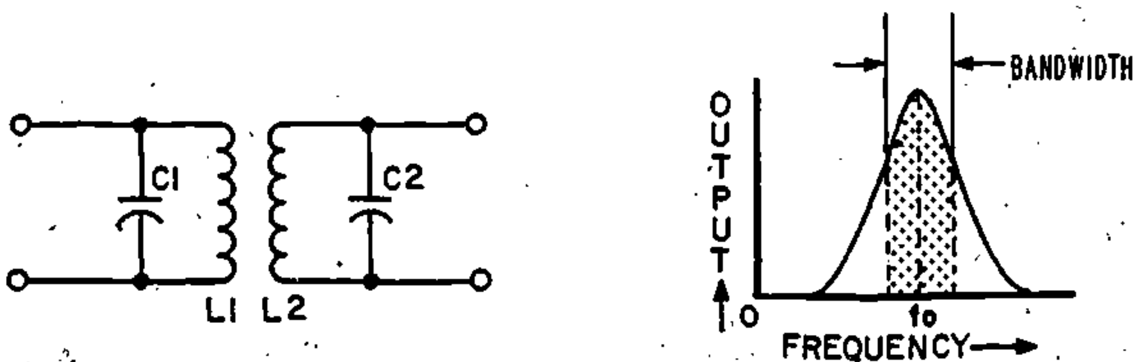

Figure 3

SYNCHRONOUS DOUBLE TUNED TRANSFORMER COUPLING

Synchronous tuning occurs when all tuned circuits in the signal path are tuned to the same frequency. In Figure 3, notice that synchronous tuning has caused the bandwidth to become narrower and selectivity to increase.

As amplifier selectivity increases, bandwidth becomes narrower. However, if the bandwidth becomes too narrow, part of some desired signals may not receive proper amplification. For example, a television or radar signal requires a relatively broad bandwidth to pass all the information contained in the signal. One method to increase the bandwidth of an IF amplifier is to use stagger tuning. In stagger tuning, each tuned coupling circuit is tuned to a slightly different frequency. The resulting frequency response curve for an amplifier with three stagger-tuned circuits is shown in Figure 4.

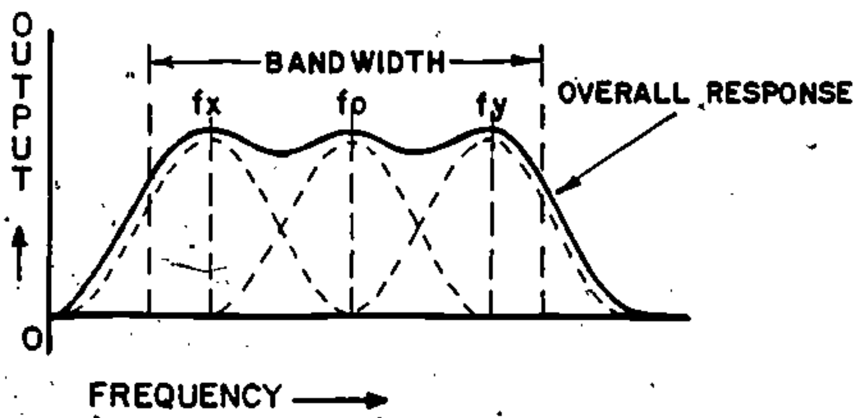

Figure 4

STAGGER TUNED RESPONSE CURVE

In the figure, the curve has a fairly flat top indicating relatively constant gain within the bandwidth. Also, the sides of the curve are sloped. The curve in the figure resembles the ideal curve. You can see that adding and tuning resonant coupling circuits affect amplifier bandwidth and selectivity.

Let's apply the methods of synchronous and stagger tuning to the operation of a typical common-emitter IF amplifier stage shown in Figure 5.

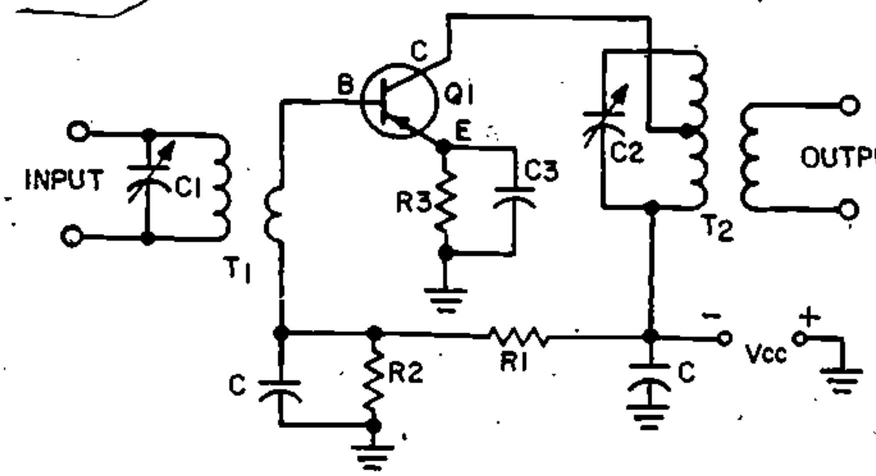

Figure 5

TYPICAL COMMON-EMITTER IF STAGE

This particular circuit requires a bandwidth best provided by the single-tuned tanks as shown. However, double-tuned coupling circuits are also common. Neutralization components are not included in the figure. However, they often are added to amplifiers operating at high-intermediate frequencies. In the Figure, both C1 and C2 can be synchronous tuned to provide a narrow bandwidth amplifier with good selectivity. If a wider bandwidth amplifier is desired, C1 and C2 can be stagger tuned. Stagger tuning tends to decrease the selectivity for the particular stage to which the method is applied. However, proper tuning in a string of IF amplifiers will produce just about any gain, bandwith, or selectivity required in the receiver.

The common-emitter IF amplifier stage described above, and shown in Figure 5, is very similar to the NIDA trainer IF amplifier stage you will be studying.

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Figure 6 shows the NIDA IF amplifier stage diagram.

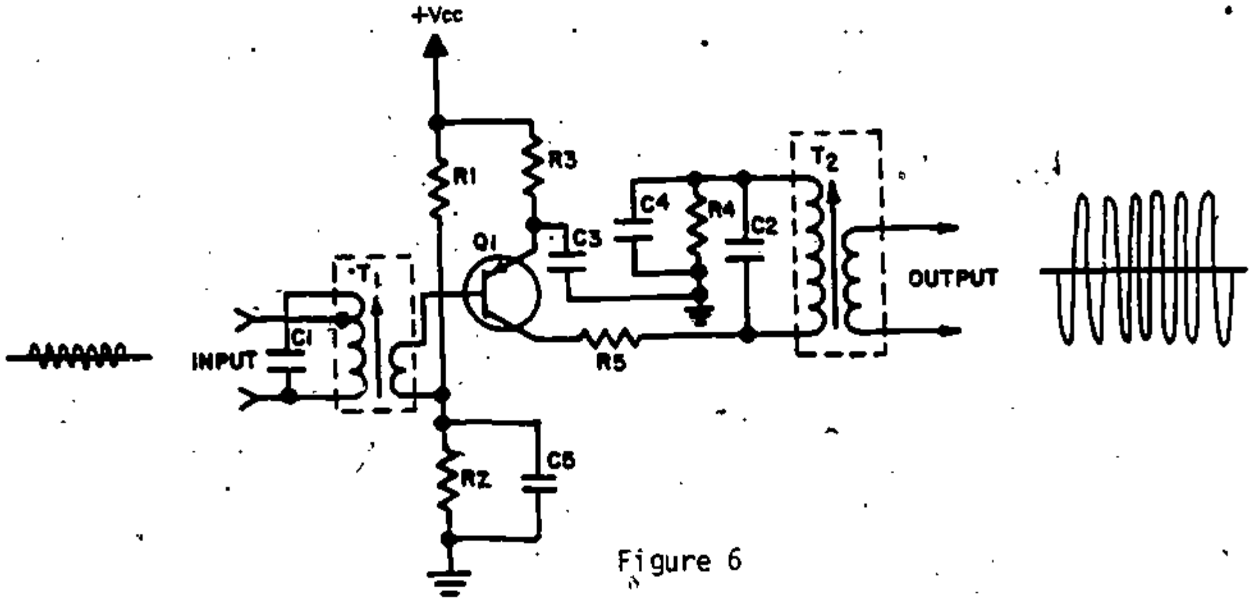

Figure 6

NIDA IF AMPLIFIER

One minor difference between the two IF amplifiers is that the circuit in Figure 6 has tuned inductive coupling instead of tuned capacitive coupling. Another minor difference is that the Vcc source voltage in Figure 6 is applied to the emitter rather than to the collector of Q1. These differences change neither the circuit operation nor the component functions.

The input signal is applied to single-tuned transformer T1 which couples the signal into the base-emitter circuit of Q1. The tap on T1 provides an impedance match with the collector circuit in the previous stage. This type of transformer is often enclosed in an aluminum shield to prevent unwanted coupling to nearby wires and transformers. Inductive tuning is done by a tuning slug. T1 has a step-down secondary to provide a low impedance match to the Q1 base circuit. R1 and R2 provide forward bias to Q1 for Class A operation (about .6 V). Decoupling capacitor C5 ensures all signal voltage is developed across the secondary of T1.

In the collector circuit of Q1, T2 is a single-tuned transformer. The output tank (T2 primary-C2) is the main load for QI. The tank is tuned to the operating center frequency of this IF amplifier which is 10.7 MHz. R4 and C4 are decoupling components which act to ensure that all signal voltage is developed across the tank, and does not enter the power source. R5 is the main reason why additional neutralization is <u>not</u> required in this circuit. R5 reduces the tendency for the collector-base junction of Q1 to become forward biased on strong signals and cause oscillation.

IF amplifiers are usually connected together in series, or cascaded, to perform their function in a receiver or transmitter. As the number of cascaded amplifiers increases, the main gain may become very high. An amplifier stage can become overdriven when the normal operating input signal voltage level is exceeded enough to cause clipping, or distortion, of the output signal. Therefore, some type of gain control is needed to avoid overdriving an IF amplifier.

An example of a high gain IF amplifier is shown in Figure 7.

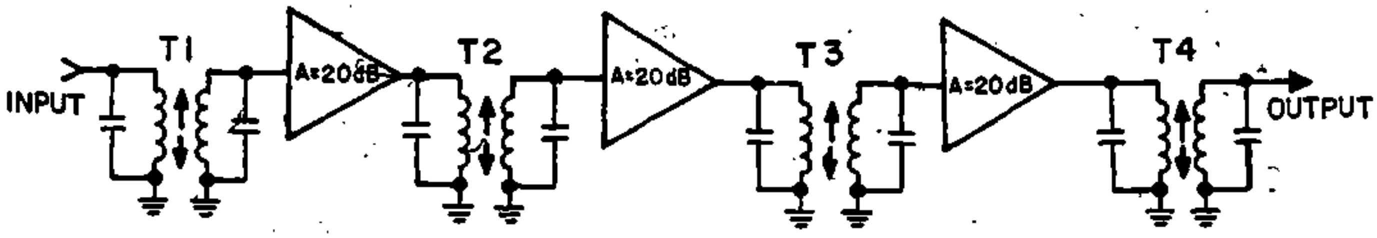

Figure 7

HIGH GAIN IF AMPLIFIERS

Each amplifier in the figure has a 20 dB gain. The total gain of the three stages is the sum of the individual dB gains, or 60 dB. You can use the familiar dB chart and graph, shown in Figure 8, to find the voltage ratio conversion for a 60 dB gain.

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VOLTAGE RATIO	DECIBELS	POWER RATIO
1.0	0.0	1.0
1.06	0.5	1.12
1.12	1	1.26
1.26	2	1.59
1.41	3	2.0
1.59	4	2.51
1.78	5	3.16
2.0	6	4.0
2.4	7	5.01
2.5	8	6.31
2.8	9	7.94
3.10	10	10
5.62	15	31.62
10	20	100
17.78	25	316.22
31.6	30	1000
100	40	10,000
316	50	100,000
1000	60	1,000,000
3160	70	10,000,000
10,000	80	100,000,000
31,600	90	1,000,000,000
100,000	100	10,000,000,000

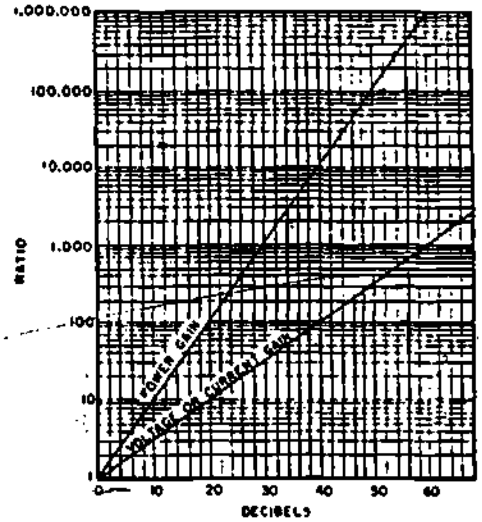

Figure 8

dB CHART/GRAPH

From the chart, 60 dB converts to a voltage ratio of 1000. Therefore, the total output signal from the cascaded amplifiers is 1000 times greater than the initial input signal. If the normal input signal is 1 mV, the total output signal is 1V. Now if a relatively high initial input signal of 1V were applied, you might expect a 1000 V total output signal. However, the design capabilities of the circuit and power supply would be exceeded. Severe signal clipping, or distortion, would occur as the cascaded amplifiers become overdriven. Some type of gain control is needed.

Amplifier gain is related to the transistor's static operating level. The static operating level is the amount of DC current needed by the transistor in order to function as an amplifier. The amount of forward bias on the transistor's base-emitter junction (V_{BE}) affects the static operating level, and therefore, affects transistor gain. The transistor produces a reasonably constant gain within a certain range of bias levels. This range is called the linear operating region for the transistor. When the forward bias is significantly above or below the linear region, the transistor is operating in what are called the non-linear operating regions. In these regions, the transistor produces lower gain, and possible disortion. Small signal levels tend to minimize the distortion produced in these non-linear operating regions.

The relationship between bias, conduction, and gain are found in the transistor characteristic curve in Figure 9.

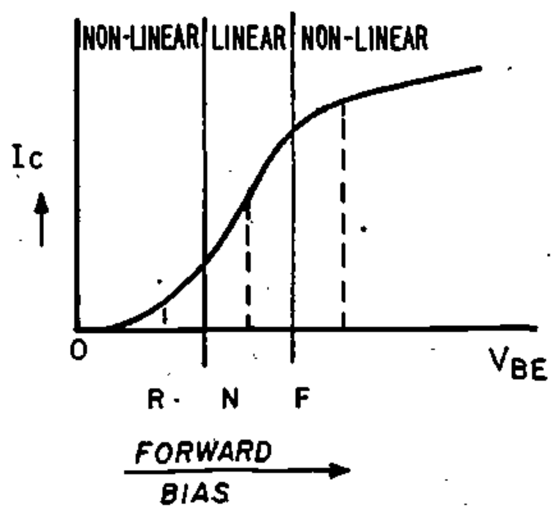

Figure 9

TRANSISTOR CHARACTERISTIC CURVE

The curve is used to determine the amount of transistor output. or gain, related to bias and conduction levels for a given input signal. In the figure, a transistor biased at any point within the linear operating region "N" produces maximum gain. A transistor biased at any points within the non-linear operating regions "R" and "F" produces less gain. The heights of the dashed lines represent the static operating levels for a transistor at specific points within the operating regions.

Figure 10 shows examples of three identical input signals applied to a transistor at bias levels within each of the three regions.

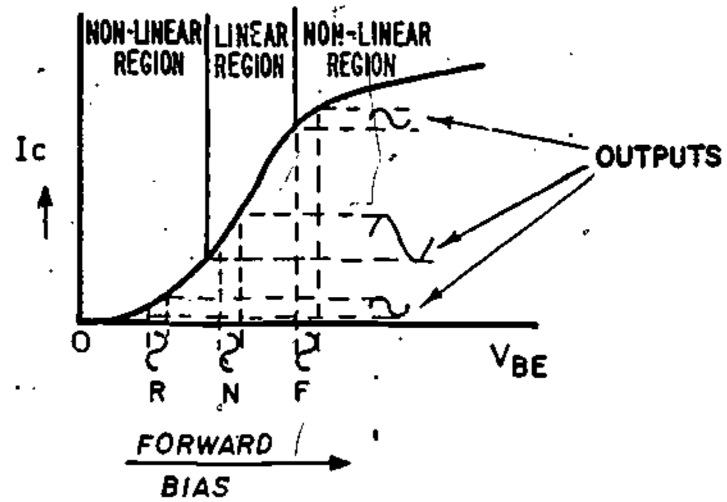

Figure 10

TRANSISTOR CHARACTERISTIC CURVE

In the figure the amplitudes of the input signals are shown above the region labels. (Note the low amplitude signals). The vertical lines extend from the input signal amplitude limits to the points where they meet the characteristic curve. The horizontal lines represent the upper and lower amplitude limits of the transistor output signals. Notice the difference in the output amplitudes between the three regions. It is now obvious that the gains related to bias levels within the non-linear operating regions are smaller than gains within the linear operating region. Therefore, amplifier gains can be reduced by applying forward bias at levels within either the "R" or "F" regions. Application of forward bias in the "R" region is called reversed bias gai control, and in the "F" region is called forward bias gain control.

Let's apply a manual method of controlling transistor gain in an IF amplifier. Figure 11 shows the NIDA trainer IF amplifier stage with the addition of potentiometer R6.

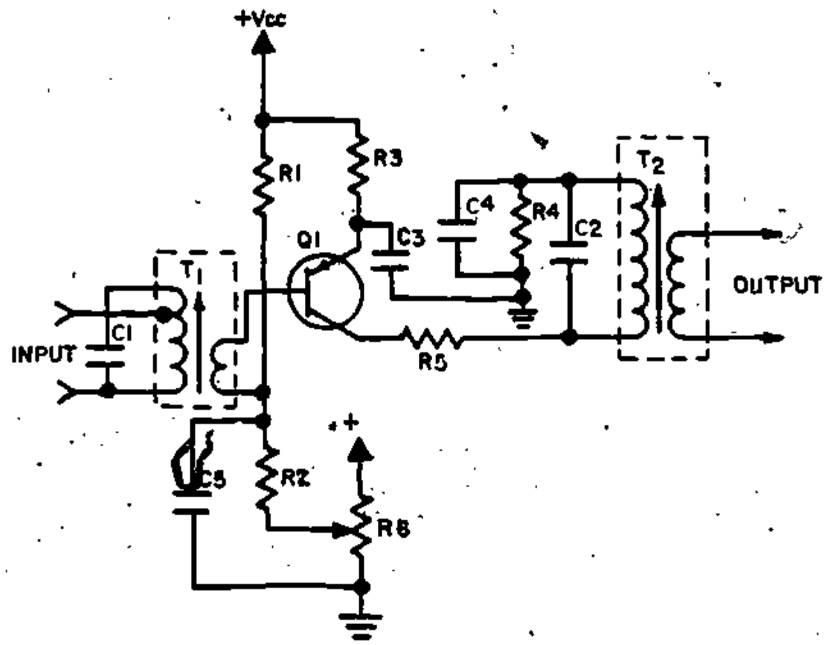

Figure 11

MANUAL IF GAIN CONTROL

Forward bias is provided by components R1, R2, and R6. When the arm of R6 is in the bottom position, the forward bias is in the normal linear operating region. Transistor gain is at a maximum. However, as the arm of R6 is moved upward, a more positive voltage is placed on the base of Q1 which reduces the forward bias on Q1. If the arm of R6 is moved upward high enough, the forward bias would be reduced to a non-linear operating region causing less transistor gain. This manual procedure is an example of reverse bias gain control.

Now let's apply an automatic method of controlling transistor gain in an IF amplifier. The automatic gain control (AGC) circuit provides a more constant output from the audio or video equipment in which AGC is used. Figure 12 shows the addition of an AGC circuit to the IF amplifier stage in Figure 11.

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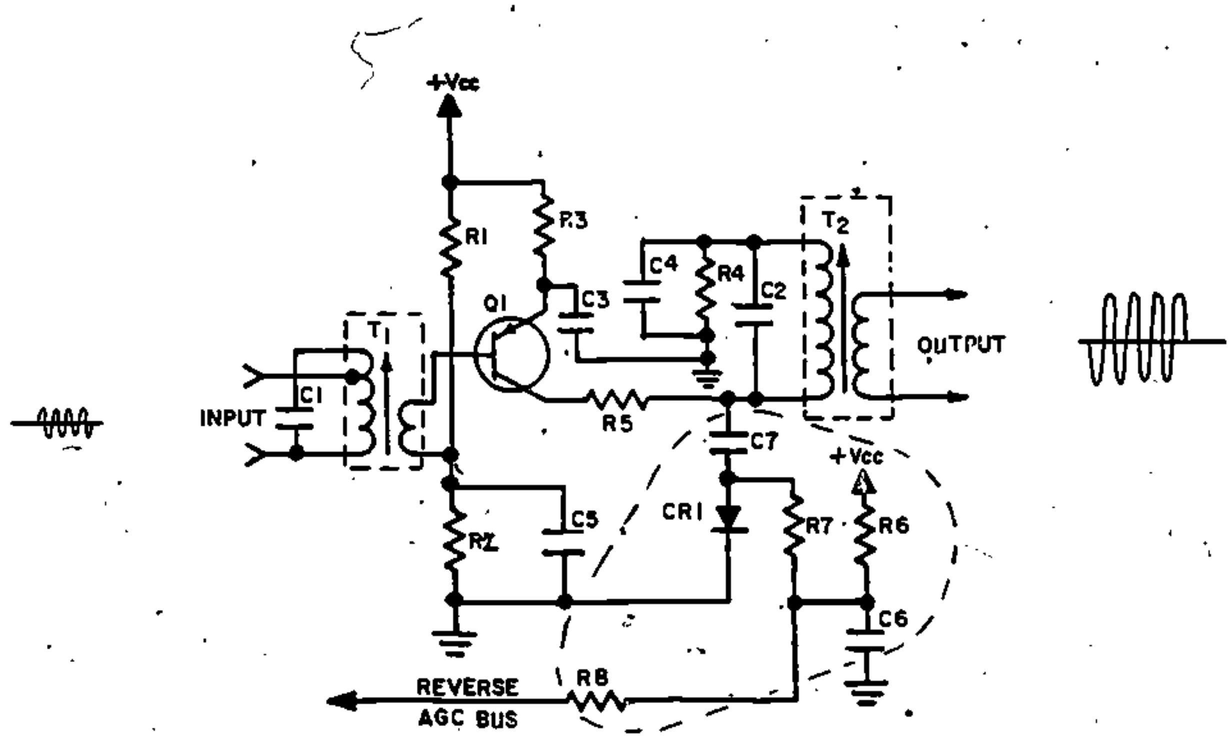

Figure 12

AUTOMATIC GAIN CONTROL (AGC)

In the figure, the AGC components are located within the oval and are labeled CR1. C6, C7, R6, R7, and R8. The AGC components provide an automatic reverse bias gain control over RF and IF amplifier stages which are previous to this stage. As the signal level within the stage starts to overdrive the amplifier, a reduced positive AGC voltage is fed back to limit the gain of previous stages. This causes a reduced signal level input to this stage, and prevents overdriving. The AGC voltage in a receiver is usually tied to a common interconnecting line called an AGC "bus". The AGC bus provides feedback from the AGC circuit to previous RF or IF stages on the same bus.

The function of the AGC components in the IF amplifier now will be explained. In Figure 12, the IF output signal from Q1 is felt across the output coupling tank (C2-T2 primary). C7 couples a part of the IF output signal to the AGC diode CR1. CR1 rectifies this signal and leaves a small positive average DC voltage level at the junction of CR1, C7, and R7. This positive voltage level decreases toward zero as the amplitude of the IF signal increases enough in strength. Now R7 and R8 form a voltage divider between + V_{CC} and the AGC output voltage. Therefore, the AGC output is a small positive DC voltage. As the positive voltage at the junction of CR1, C7, and R7 decreases (but never becomes negative), the AGC output voltage becomes less positive. This lowers the AGC bias voltage on the bus and reduces the gain of previous stages connected to the bus. R8 and C6 filter the AGC voltage to produce a smooth DC level.

You will be using a built-in "S" meter in the NIDA trainer as part of the Job Program for this lesson. Many superheterodyne communication-type receivers, such as the NIDA trainer, use an "S" meter to indicate the strength of received signals. The "S" meter also is helpful for center-tuning the receiver to desired signals. CB transceivers and hi-fi sets often use "S" meters. Calibration for the "S" meter is in either "S" units, decibels, or some other numerical scale units. In the NIDA trainer, the "S" meter calibration is on a scale from 0 to 10. The "S" meter circuit in the NIDA trainer is found in the second IF amplifier stage. Figure 13 shows the block diagram of the NIDA trainer which represents a typical superheterodyne receiver.

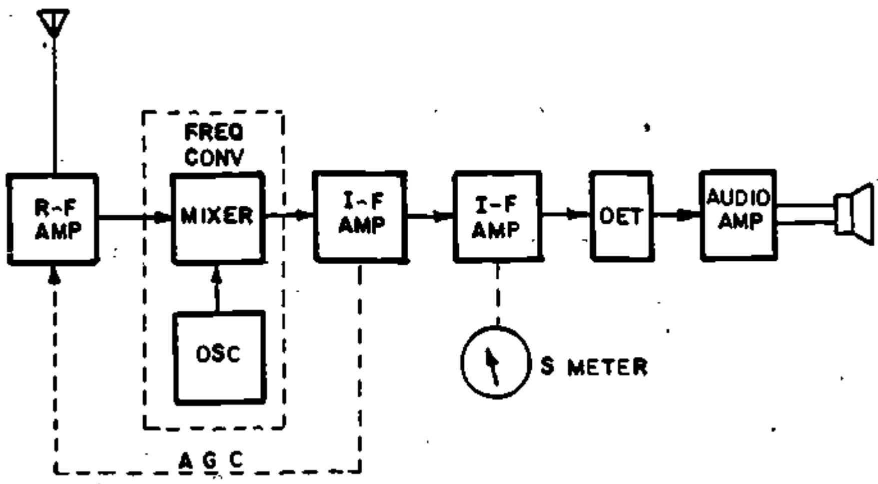

Figure 13

BLOCK DIAGRAM OF NIDA TRANSCEIVER TRAINER

Figure 14 shows the components of the "S" meter circuit in the NIDA trainer.

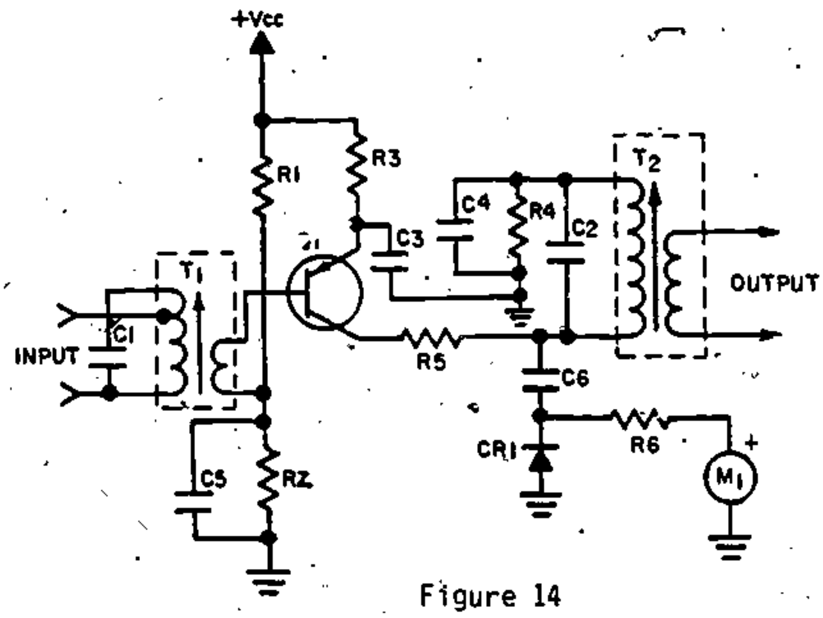

Figure 14

IF AMPLIFIER STAGE WITH "S" METER

In the figure, the meter circuit components are labeled MI, CR1, C6 and R6. For the meter circuit to operate, part of the IF output signal is tapped off the Q1 collector circuit. The half-wave rectifier CRI elimates the negative alternations of the IF signal. The pulsating +DC across CR1 is applied to the dropping resistor R6 and the meter M1.

The meter pointer indicates the average voltage DC level across CR1. As the IF signal amplitude increases, the meter pointer will have a greater deflection across the scale.

Technicians often use the "S" meter as a piece of built-in test equipment (BITE) to aid in troubleshooting. When a signal is tuned in, a deflection on the "S" meter usually indicates that receiver circuit problems are located in stages following the meter. If no deflection occurs, there are receiver circuit problems somewhere in stages leading up to and including the meter. The "S" meter is a definite aid in isolating a faulty receiver stage.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

BASIC ELECTRICITY ANO ELECTRONICS

MOOULE THIRTY ONE

LESSON 4

VIOEO AMPLIFIERS

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JULY 1980

OVERVIEW
LESSON 4

Video Amplifiers

In this lesson you will learn some important operating characteristics of video amplifiers. You will be able to identify the reasons why basic RC coupled amplifiers have losses in gain at low and high frequencies. You will find out what components are added to RC coupled amplifiers to improve their frequency response, and allow them to operate as video amplifiers. You will be able to identify the function of components in video amplifier circuits using schematic diagrams. You will determine video amplifier frequency response curve characteristics, and troubleshoot a video amplifier using test equipment.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

31.4.55 When the student complete this lesson (s)he will be able to TROUBLESHOOT and IDENTIFY faulty components and/or circuit malfunctions in solid state video amplifiers when given a training device, prefaulted circuit board, necessary test equipment, schematic diagram and instructions. 100% accuracy is required.

ENABLING OBJECTIVE(S):

When the student complete this lesson (s)he will be able to:

31.4.55.1 IDENTIFY the causes of low frequency response losses in a basic RF coupled amplifier circuit by selecting the correct statement from a choice of four. 100% accuracy is required.

31.4.55.2 IDENTIFY the components which accomplish low frequency compensation in an AC equivalent video amplifier circuit, given a schematic diagram, by selecting the correct list of components from a choice of four. 100% accuracy is required.

31.4.55.3 IDENTIFY the causes of high frequency response losses in a basic RC coupled amplifier circuit by selecting the correct statement from a choice of four. 100% accuracy is required.

31.4.55.4 IDENTIFY the components which accomplish high frequency compensation in an AC equivalent video amplifier circuit, given a schematic diagram, by selecting the correct list of components from a choice of four. 100% accuracy is required.

31.4.55.5 IDENTIFY the function of components that improve frequency response in a video amplifier circuit, given a schematic diagram, by selecting the correct statement from a choice of four. 100% accuracy is required.

31.4.55.6 IDENTIFY the frequency response deficiency (high or low) indicated by output waveforms from a video amplifier, given illustration of output waveforms, by selecting the correct indication from a choice of four. 100% accuracy is required.

31.4.55.7 MEASURE AND COMPARE frequency response and gain characteristics of video amplifier circuits given a training device, circuit boards, test equipment and proper tools, schematic diagrams, and a job program containing references for comparison. Recorded data must be within limits stated in the job program.

31.4.55.8 IDENTIFY the faulty component or circuit malfunction in a given video amplifier circuit, given a schematic diagram and failure symptoms, by selecting the correct fault from a choice of four. 100% accuracy is required*.

Footnote *This objective is considered met upon successful completion of the terminal objective.

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 4

Video Amplifiers

To learn the materials 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

Module Booklet:

- Summary
- Programmed Instruction
- Narrative

Student's Guide:

- Summary
- Progress Check
- Job Program Thirty-4 "Video Amplifiers"
- Fault Analysis (Paper Troubleshooting) I.S.
- Performance Test I.S.

Additional Material(s):

Enrichment material(s):

NAVSHIP 0967-000-0120 "Electronic Circuits" Electronics Installation and Maintenance Book (EIMB) Naval Ship Engineering Center, Washington, D.C.. U.S. Government Printing Office 1965.

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

SUMMARY
Lesson 4

Video Amplifiers

Any electronic equipment producing a visual display on a CRT requires the use of video amplifiers. The ideal video amplifier should have a frequency response curve resembling Figure 1.

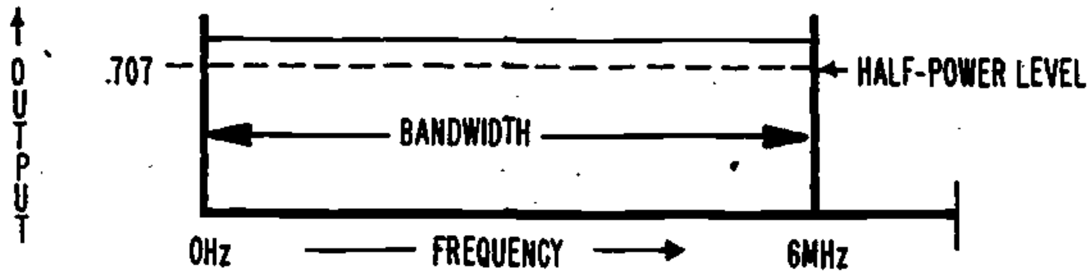

FIGURE 1

IDEAL VIDEO AMPLIFIER RESPONSE CURVE

Figure 2 shows the typical response curves for actual transformer-coupled and resistance-capacitive (RC) coupled amplifiers.

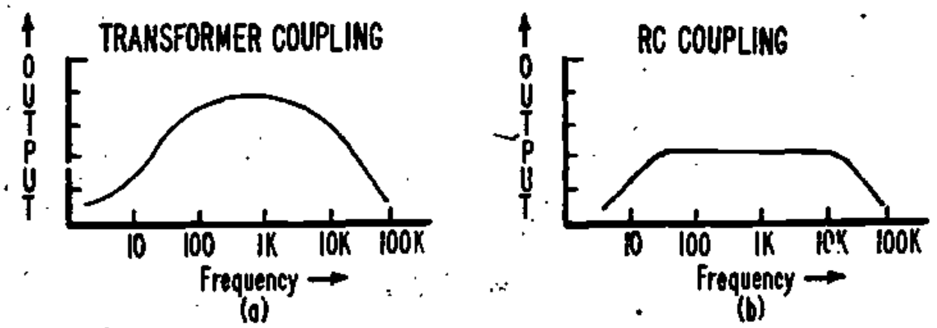

FIGURE 2

AMPLIFIER RESPONSE CURVES

Although RC coupled amplifiers provide the wider bandwidth, they fall short of the wide bandwidth requirements of video amplifiers.

Figure 3 can be referenced to show what limits RC amplifier low frequency response.

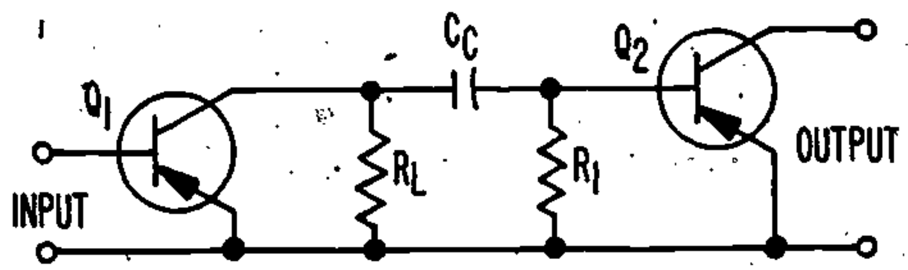

FIGURE 3

AC EQUIVALENT-RC COUPLED AMPLIFIER

At low frequencies, the capacitive reactance (Xc) of Cc is relatively high causing some signal voltage to drop across Cc instead of across RL. Thus, less voltage is felt across R1 which reduces overall amplifier gain at low frequencies.

One method to partially compensate for low frequency response loss is to use a larger value coupling capacitor. A more effective method is to add the RC network shown in Figure 4.

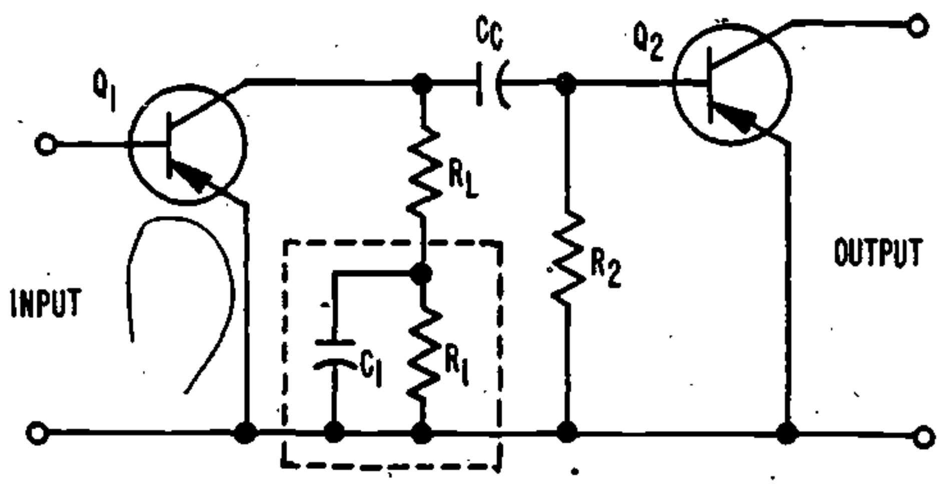

FIGURE 4

AC EQUIVALENT - LOW FREQUENCY COMPENSATION CIRCUIT

At low frequencies, the Xc of C1 is large enough so that C1 acts as an open. Therefore, the RC network has an impedance equal to R1. This makes the total load impedance for Q1 equal to RL + R1, which increases amplifier gain by compensating for the Cc voltage drop. At high frequencies, C1 acts to short the RC network, which returns the gain from QI to that produced by RL alone. Another method for amplifying low frequencies uses DC coupling (direct coupling) between stages. This method will be discussed in Module 34.

Figure 5 shows what limits video amplifier high frequency response.

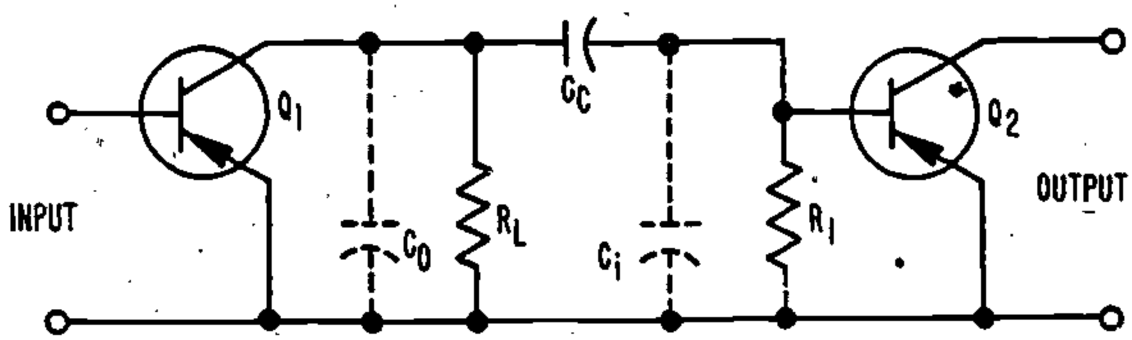

FIGURE 5

AC EQUIVALENT - STRAY CAPACITANCE

The input and output stray capacitances Co and Ci have low reactances at high frequencies, and shunt the signal to ground. These stray capacitances result from the close spacing between wires, foils, components, and the input/output capacity of active devices.

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One method to compensate for high frequency signal loss is to place an inductor in parallel with Co and Ci as shown in Figure 6.

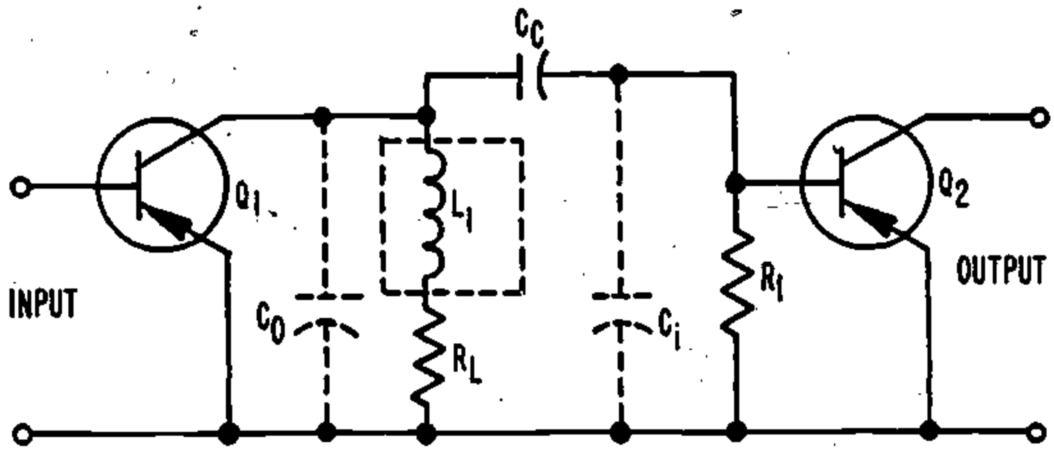

FIGURE 6

"SHUNT" HIGH FREQUENCY COMPENSATION (AC EQUIVALENT)

At high frequencies, Co, Ci and L1 form a parallel resonant circuit which, at resonance, develops an increased output impedance from Q1. This type of high frequency compensation is called shunt compensation, or shunt peaking. The shunt compensation circuit has a wide bandwidth, and an Fo above the frequency response of the uncompensated amplifier circuit.

Shunt type compensation may not improve the high frequency response of video amplifiers enough for some applications. The circuit can be further improved by adding an inductor in series with the signal path and Ci as shown in Figure 7.

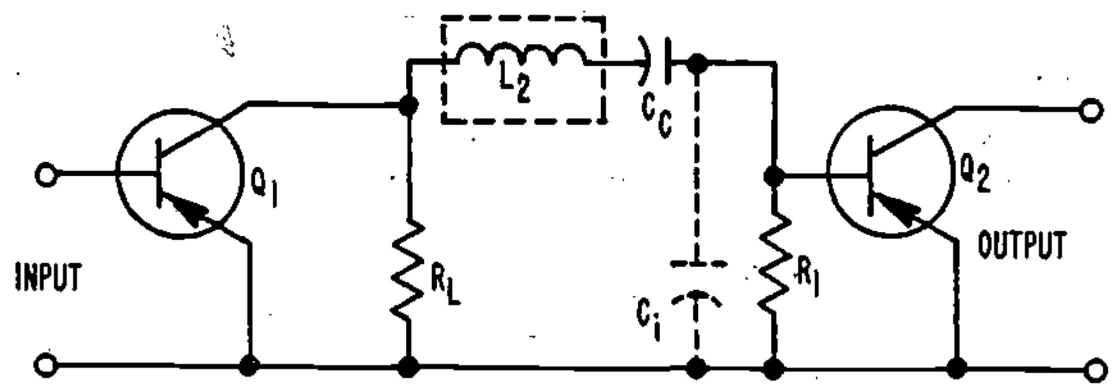

FIGURE 7

"SERIES" HIGH FREQUENCY COMPENSATION (AC EQUIVALENT)

At high frequencies, the combination L2 - Ci forms a series resonant circuit to the signal path. At resonance, the impedance in this LC circuit is at a minimum and the voltage across the reactive components are at a maximum. Therefore, the voltage developed by Ci is maximum at Fo and will be felt across R1 and fed to the base of Q2. This method of increasing amplifier gain is called series compensation, or series peaking. If the value of L2 is chosen properly, the Fo of the series compensation circuit will occur above the frequency response of the shunt compensation circuit. This will further increase the amplifier's frequency response.

Figure 8 shows the frequency response curve for a video amplifier with combined low and high frequency compensation added.

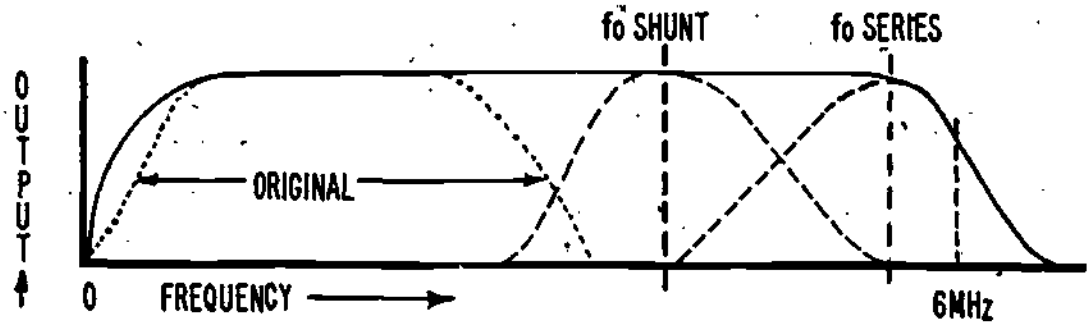

FIGURE 8

COMPENSATED VIDEO AMPLIFIER RESPONSE

This fully compensated RC coupled video amplifier has a frequency response from about 30 Hz to 6 MHz.

Figure 9 shows the schematic diagram of a two-stage video amplifier as found in the NIDA trainer. A description of component functions now follows.

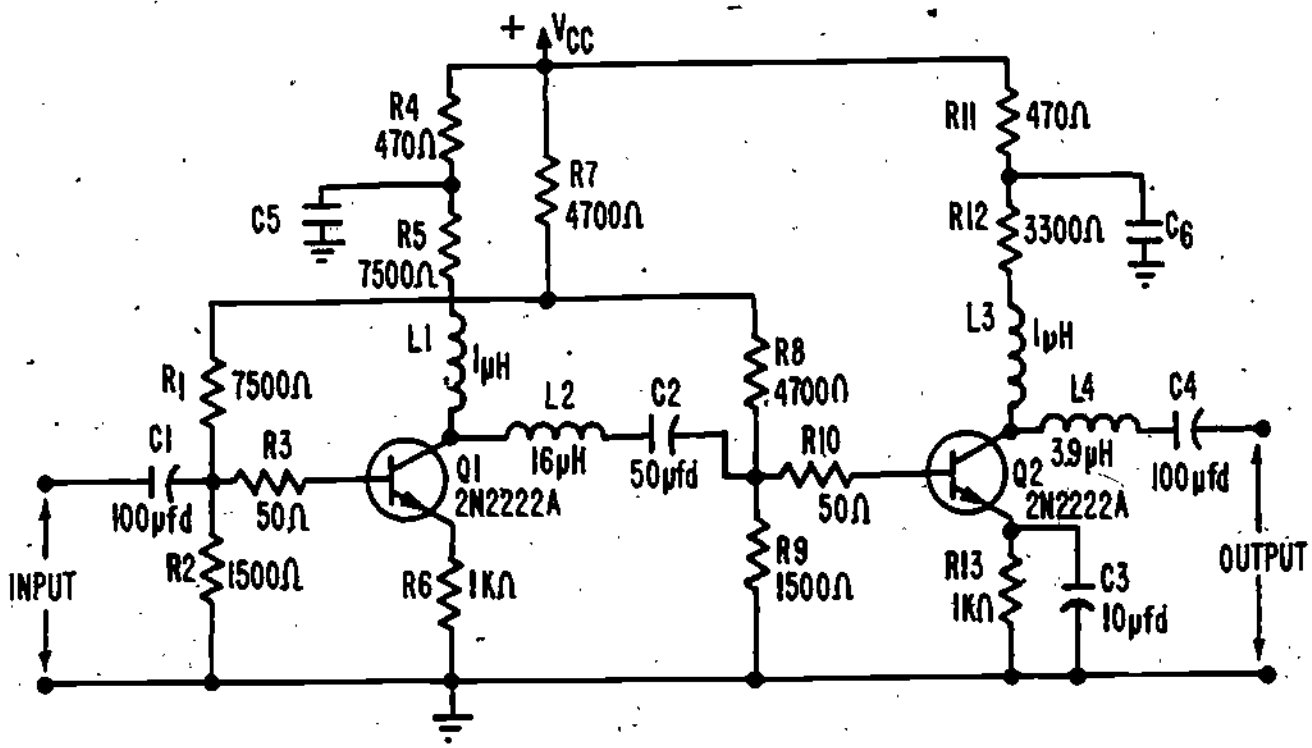

FIGURE 9

2-STAGE VIDEO AMPLIFIER-ACTUAL CIRCUIT

Class A forward bias is provided for Q1 by R1 and R2, and for Q2 by R8 and R9. R7 completes the voltage divider from Vcc with these networks. Emitter stabilization is provided by R6 and R13. R13 is bypassed by C3 to prevent degeneration and loss of gain. R6 is not bypassed to improve low and high frequency response at the cost of some gain.

The interstage video signal coupling C1, C2, and C4 have large values to improve low frequency response. The R4-C5 and R11-C6 decoupling components separate the signal path from the DC power supply, and prevent the amplifier from becoming an oscillator. The shunt high frequency peaking coils L1 and L3 are connected to the normal collector load resistors R5 and R12. The series high frequency peaking coils are L2 and L4.

R10 acts to reduce the Q, and broaden the bandwidth, of the L2-C2 series compensation network. R3 acts to perform a similar function in a previous amplifier stage.

The frequency response for a video amplifier can be measured using a sweep frequency generator as shown in the test set-up in Figure 10.

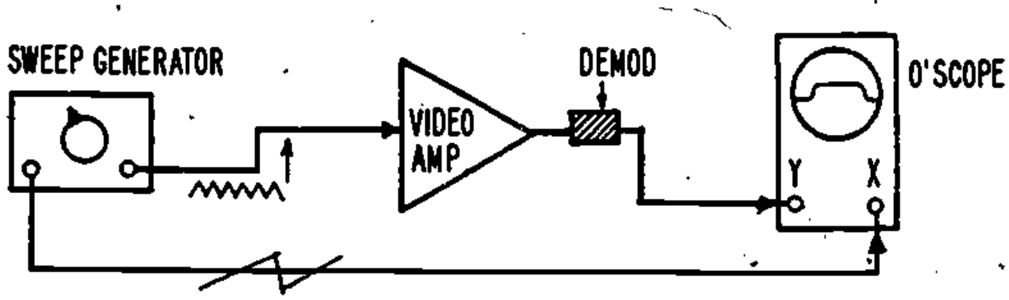

FIGURE 10

VIDEO AMPLIFIER FREQUENCY RESPONSE TEST

If the generator is set to sweep from 0 Hz to 10 MHz, the output signal from a test amplifier would resemble the display on the oscilloscope shown in the figure. A technician can troubleshoot the video amplifier by comparing the actual frequency response curve with the expected normal frequency response curve. Deficiencies in either high or low frequency responses indicate which components may be faulty.

The frequency response for a video amplifier also can be measured using a square wave generator as shown in the test set-up in Figure 11.

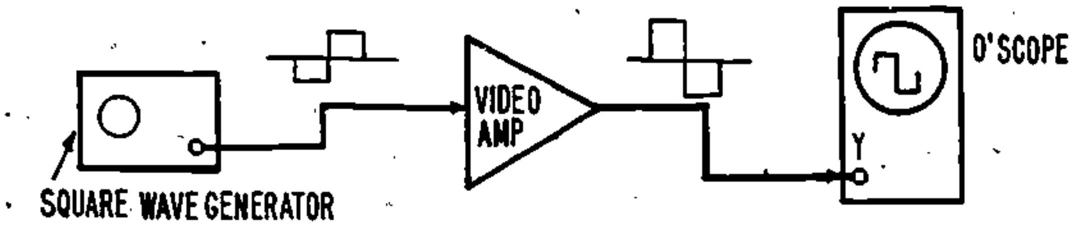

FIGURE 11

SQUARE WAVE-AMPLIFIER TEST

Accurate reproduction of the square wave indicates good frequency response in a video amplifier. Any distortion of the square wave indicates a problem in frequency response.

In theory, a square wave is the result of combining a fundamental sine wave frequency with an infinite number of odd-numbered harmonic frequencies. In practice, a video amplifier which accurately reproduces a square wave is capable of amplifying a fundamental frequency and at least the first 10 odd-numbered harmonics. The display produced by a video amplifier with good and poor frequency responses are shown in Figure 12.

FIGURE 12

SQUARE WAVE DISPLAYS AND FREQUENCY RESPONSE

You will have the opportunity to operate and troubleshoot a video amplifier in the Job Program for this lesson.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

PROGRAMMED INSTRUCTION
LESSON 4

Video Amplifiers

TEST FRAMES ARE 8, 16, 21, and 28. PROCEED TO TEST FRAME 8 AND SEE IF YOU CAN ANSWER THE QUESTIONS. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

(1.) Most electronic equipment that has a cathode-ray tube (CRT) display requires video amplifiers. The picture tube in a television set and the screen on an oscilloscope are two good examples of CRTs. Both of these electronic equipments also utilize video amplifiers.

Video amplifiers, like any other amplifier, must be able to amplify all the information contained in the input signal. The frequency range of video information signals is 0, or a few Hertz, to about 6 MHz. As you can see, video amplifiers are required to amplify a wide range of frequencies. Now the ideal video amplifier should be able to amplify with constant gain all signals within the video frequency range. Therefore, the bandwidth of a video amplifier must be as wide as the frequency range. The bandwidth and response curve for the ideal video amplifier are shown in Figure 1.

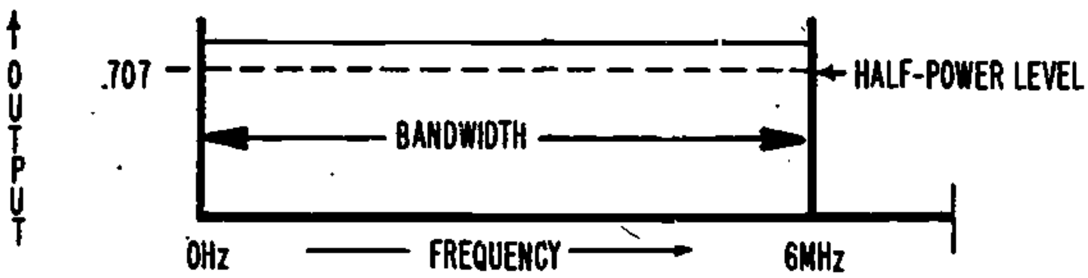

Figure 1

IDEAL VIDEO AMPLIFIER RESPONSE CURVE

In the figure you can see the same rectangular shaped frequency response curve used in the previous lesson to show the ideal frequency response for an IF amplifier. The difference between the amplifiers is that in the case of a video amplifier, raw information in the frequency range between 0 and 6 MHz is being amplified, while in the case of IF and RF amplifiers, a radio frequency carrier signal containing the video information is being amplified. For example, an RF amplifier for a channel 2 television signal would have a frequency response of 56 to 62 MHz and a bandwidth of 6 MHz.

A video amplifier has a (wide/narrow) frequency response from about 0 Hz to about __________.

---

wide, 6 MHz

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(2.) You might wonder whether the audio amplifiers you have studied can be modified to produce the wide bandwidth required of video amplifiers. As you know, bandwidth is related to the types of coupling used in amplifiers. Two types of coupling you have studied are transformer coupling and resistive capacitive (RC) coupling. The frequency response of a typical transformer coupled amplifier is similar to Figure 2a, and the frequency response for a typical RC coupled amplifier is similar to Figure 2b.

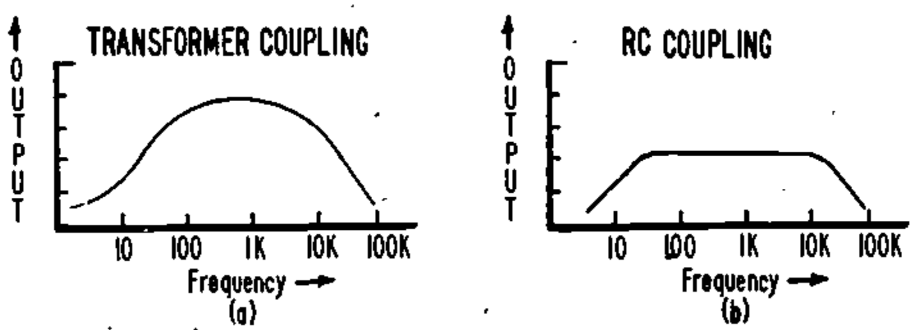

Figure 2

AMPLIFIER RESPONSE CURVES

It is obvious that neither type of coupling meets the frequency response requirements of video amplifiers. However, the frequency response of RC coupled amplifiers come closer to what is required than do the frequency response of transformer coupled amplifiers.

In Figure 2, the typical RC coupled amplifier has a (narrower/wider) bandwidth than does the typical transformer coupled amplifier.

---

wider

3. How can the bandwidth of RC coupled amplifiers be made wide enough to cover the low and high frequencies needed in video amplifiers? To answer this question, you must learn what limits the frequency response of RC coupling. First, let's discuss what limits amplification at low frequencies. Look at Figure 3 which shows a simplified diagram of an RC coupled, two stage amplifier. The bias voltages and some components are omitted for clarity.

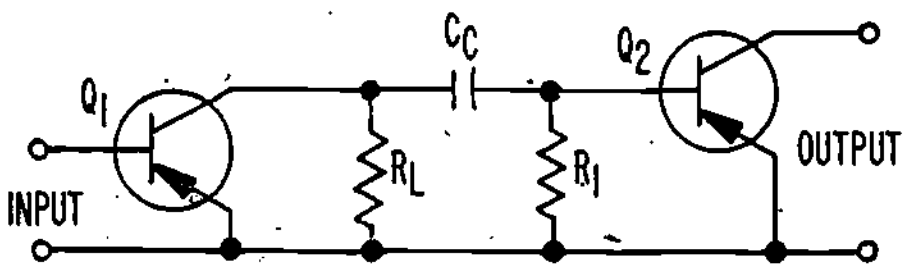

Figure 3

AC EQUIVALENT-RC COUPLED AMPLIFIER

In the figure, the output of Q1 is developed by RL, and then coupled through Cc to be developed across R1. Since R1 and Cc are in parallel with RL, any voltage developed by RL will be divided between R1 and Cc. The voltage dropped across R1 and Cc is related to the resistance and reactance, respectively, of these two components. You know that the resistance of R1 is constant. However the reactance of Cc changes with the applied frequency. As frequency decreases, the capacitive reactance (Xc) increases. As the reactance of Cc increases at low frequencies, the signal voltage divider, Cc and R1, has more voltage dropped across Cc and less across R1. Now the voltage dropped across R1 is the voltage fed to the base of Q2. Therefore, at low frequencies, less voltage is fed to Q2 than at higher frequencies and the overall low frequency response of the amplifier decreases.

In Figure 3, when the input signal frequency is low, the reactance of Cc is (low/high) and the voltage fed to the base of Q2 is (low/high).

---

high, low

(4.) Now that you know why the RC coupled amplifier doesn't amplify low frequency signals, what can be done about it? Refer to Figure 4 which is the same as Figure 3.

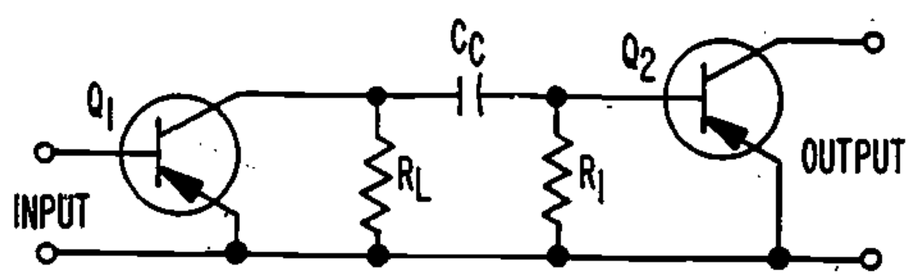

Figure 4

AC EQUIVALENT-RC COUPLED AMPLIFIER

If Cc has a large capacitance, its reactance (Xc) at low frequencies will decrease. The decreased low frequency reactance will cause Cc to drop less signal voltage. Therefore, more signal voltage will be developed across RI and be fed into the base of Q2, increasing the low frequency gain. However, the circuit will become unstable if the value of Cc is increased beyond a certain point. This limits the value of Cc, and thus RC coupled amplifiers cannot amplify very low frequencies, e.g. 0 Hz.

To partially compensate for poor low frequency response in Figure 4, a (larger/smaller) value coupling capacitor can be used.

---

larger

(5.) Since the coupling capacitor's increased capacitance only partially makes up for low frequency losses, more compensation is needed. Figure 5 shows the same diagram as in Figure 4 with the addition of low frequency compensation components.

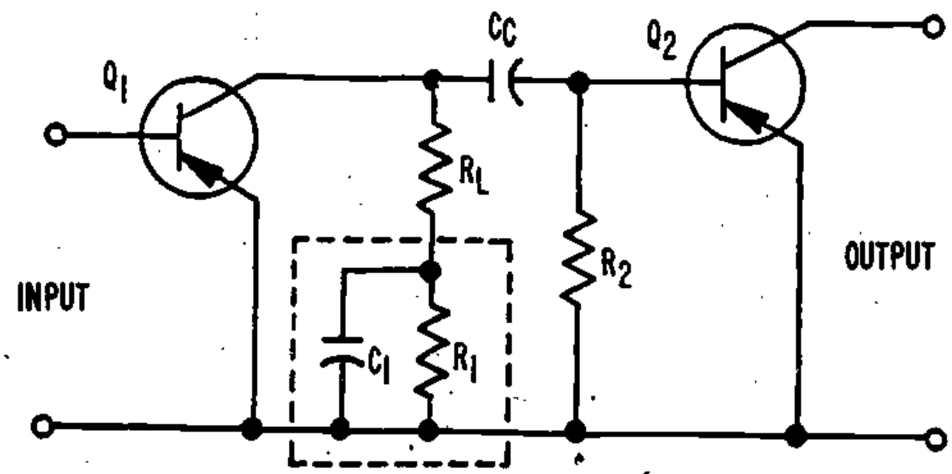

Figure 5

AC EQUIVALENT - LOW FREQUENCY COMPENSATION CIRCUIT

As you know, the gain of a transistor amplifier is directly related to the value of the collector load resistance. If a means could be devised to increase the size of the load resistance at the low frequencies only, then the loss of gain due to the coupling capacitor could be compensated for.

In Figure 6, the collector load for Q1 at low frequencies equals the resistance of ____________ plus the resistance of ______________ .

R1, RL

(7.) The effect of low frequency compensation on the overall circuit frequency response is shown in Figure 7.

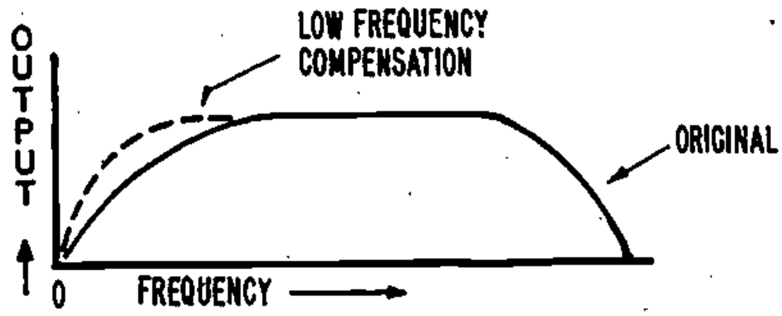

Figure 7

LOW FREQUENCY COMPENSATION RESPONSE

Notice that the low frequency end of the curve has been extended beyond the original uncompensated curve. You can see that adding parallel RC components in the collector circuit and making Cc as large as possible improves the response at the low end, but not at the high end. However, the improved response still is not taken down to the zero frequency point.

A type of amplifier circuit using direct coupling (DC) between stages may be used to improve the frequency response down to 0 Hz. In fact, this type of coupling is becoming very common with the latest state-of-the-art devices such as integrated circuits. Direct coupled amplifier stages were used in Module 30 power supply circuits and will be found again in Module 34, Integrated Circuits.

The addition of a parallel RC circuit in the collector circuit of an RC coupled amplifier improves (high/low) frequency response.

---

low

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(8.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

1. The frequency response and bandwidth of the ideal video amplifier most closely approximates ____________ and __________.

   a. 0 - 20 kHz, 20 kHz

   b. 0 - 600 kHz, 500 kHz

   c. 0 - 2 MHz, 2 MHz

   d. 0 - 6 MHz, 6 MHz

USE THE DIAGRAM BELOW OF AN AC EQUIVALENT, TWO-STAGE AMPLIFIER CIRCUIT TO ANSWER QUESTIONS 2 AND 3.

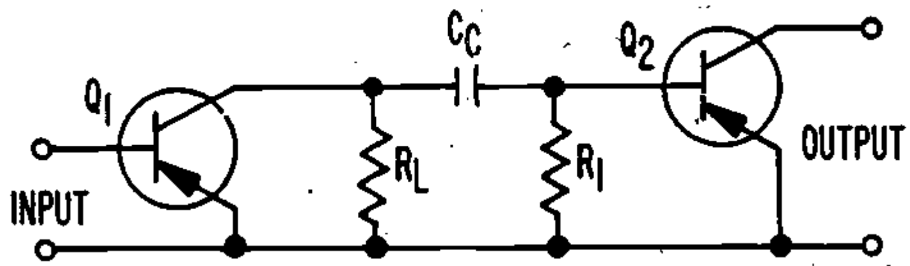

Figure 8

2. At low input frequencies, the reactance of Cc (decreases/increases), causing a (larger/smaller) voltage drop across Cc.

3. The amplifier's frequency response may be improved somewhat at ____________ frequencies by ____________ the capacitance of Cc.

   a. low, decreasing

   b. high, decreasing

   c. low, increasing

   d. high, increasing

USE THE DIAGRAM BELOW OF AN AC EQUIVALENT, TWO-STAGE AMPLIFIER CIRCUIT TO ANSWER QUESTIONS 4 AND 5.

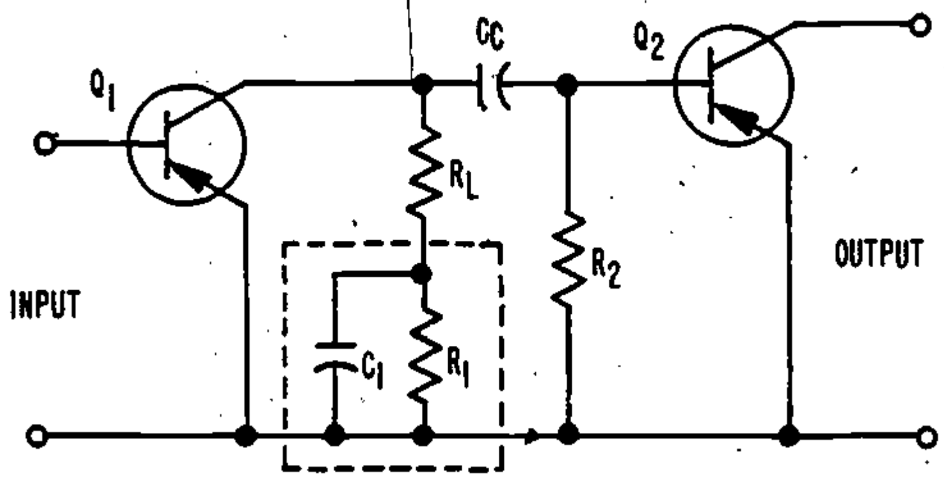

Figure 9

4. At high input frequencies the R1-C1 parallel circuit can be considered to be (a short/an open).

5. The R1-C1 parallel circuit has the effect of increasing the gain of Q1 at ________ frequencies.

   a. all

   b. low

   c. high

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1. d. 0-6 MHz, 6 MHz
2. increases, larger
3. c. low, increasing
4. a short
5. b. low

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 16. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 8 AGAIN.

(9.) You know how to improve gain at low frequencies in video amplifiers. Now you will find out what limits gain at high frequencies, and what can be done about it.

Any transistor circuit at high frequencies will have a definite amount of stray capacitance in both the input and output. These stray capacitances can be caused by any number of things. One major cause is the wiring of the circuit. A wire or printed circuit foil can act as one plate of a capacitor when close to another wire or foil which can act as the other plate. Another reason for the capacitance is the transistor itself, since each junction has capacity associated with it. These stray capacitances are not components, as such. However, they affect the circuit as if they were actual components. Therefore, they can be drawn into the simplified AC equivalent amplifier circuit as shown in Figure 10.

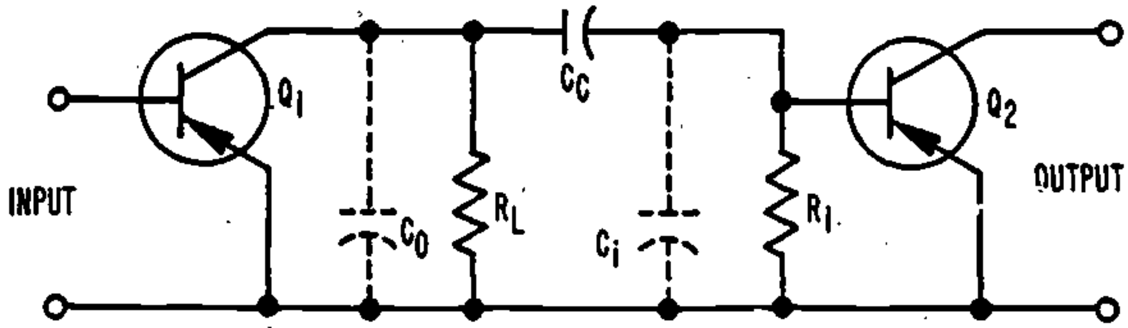

Figure 10

AC EQUIVALENT - STRAY CAPACITANCE

In the figure Co represents stray output capacitance and Ci represents stray input capacitance. The value of these equivalent capacitors is very small (that is, in the picofarad range).

In Figure 10, Co and Ci represent ______________ at the input and output of amplifiers.

---

equivalent capacitances or words to that effect.

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(10.) How do stray capacitors limit gain at high frequencies? Refer to the amplifier circuit shown in Figure 11.

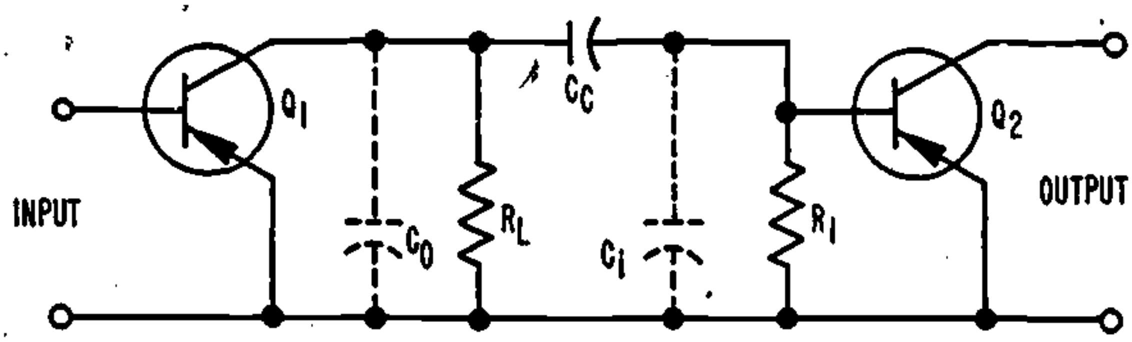


Figure 11

AC EQUIVALENT - STRAY CAPACITANCE

In the figure, Co is in parallel with the output of Q1, and Ci is in parallel with the input to Q2. You know that the reactances of Co and Ci are low at high frequencies. Therefore, at high frequencies. Co and Ci act as signal shorts to ground. This causes the output signal from Q1 and the input signal to Q2 to be shunted to ground. When this occurs, the high frequency signals are effectively shorted out and lost.

In Figure 11, the (high/low) reactances of Co and Ci shunt the high signal frequencies to ground.

---

low

(11.) Now that you know why a standard audio amplifier has poor high frequency response, what can be done to improve it? Since it is not possible to remove Co and Ci, they must be compensated for in some way. An inductor can be added in parallel with Co and Ci to improve high frequency gain of the amplifier. Such a set-up is shown in Figure 12.

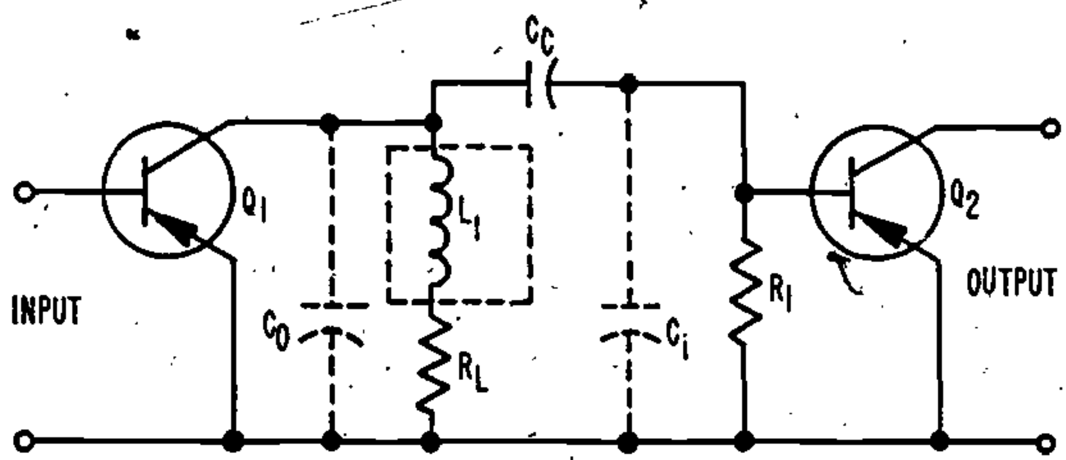


Figure 12

"SHUNT" HIGH FREQUENCY COMPENSATION (AC EQUIVALENT)

How does the added inductor L1 improve high frequency gain? Well, if L1 is the proper value, Co, Ci, and L1 will form a parallel resonant circuit at the high frequencies where the frequency response would normally drop. Cc will not affect the operation of this parallel resonant circuit because Cc has a very large capacitance, and appears as a short at high frequencies.

Now as the frequency applied to the circuit containing L1 increases, the impedance represented by the inductor-resistor combination (L1-RL) increases also. This increased collector load impedance causes the gain of the transistor amplifier to increase. With careful selection of L1, the rise in gain can be made to compensate for the roll-off in gain that would have occurred without L1. Now as the frequency applied to the amplifier increases further, the parallel resonance frequency for L1-Co/Ci will be reached. The gain of this parallel resonant circuit is maximum and further increases amplifier gain. At frequencies above the resonant point, amplifier gain will decrease rapidly. Since L1 is in parallel with Co and Ci (that is "shunts" the input and output equivalent capacitors), this type of compensation is called shunt compensation, or shunt peaking.

In Figure 12, L1 (increases/decreases) the gain and output of Q1 at (high/low) frequencies.

---

increases, high

(12.) Figure 13 shows how shunt compensation improves video amplifier frequency response.

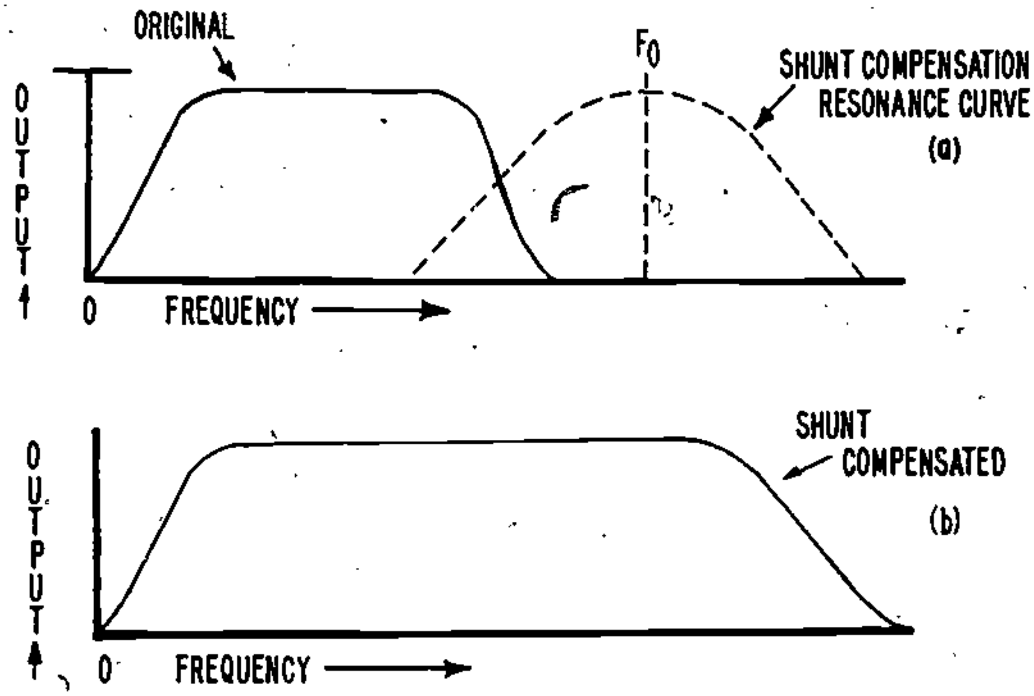


Figure 13

SHUNT HIGH FREQUENCY RESPONSE CURVES

In Figure 13a, the dashed lines show the frequency response curve for the tuned shunt compensation circuit. Notice that the center frequency (Fo) is at a point higher than the frequency response of the original video amplifier. Also notice that the shunt compensation resonance curve has a wide bandwidth. The wide bandwidth occurs because the circuit resistance lowers the circuit Q, which increases the bandwidth (using the formula $BW=Fo/Q$). In Figure 13b, the overall frequency response curve for the video amplifier is shown. This curve is the result of combining the original video amplifier curve and the shunt compensation, or shunt peaking, resonance curve.

The shunt compensation resonant circuit has a relatively (high/low) Fo, and a (narrow/wide) bandwidth.

---

high, wide

(13) Shunt type compensation has improved the high frequency response of the basic video amplifier. However, the improved frequency response still may not be high enough for some applications. Fortunately, there is another way to improve the high frequency response of a video amplifier. This is done by adding an inductor in series with the signal path and Ci as shown in Figure 14.

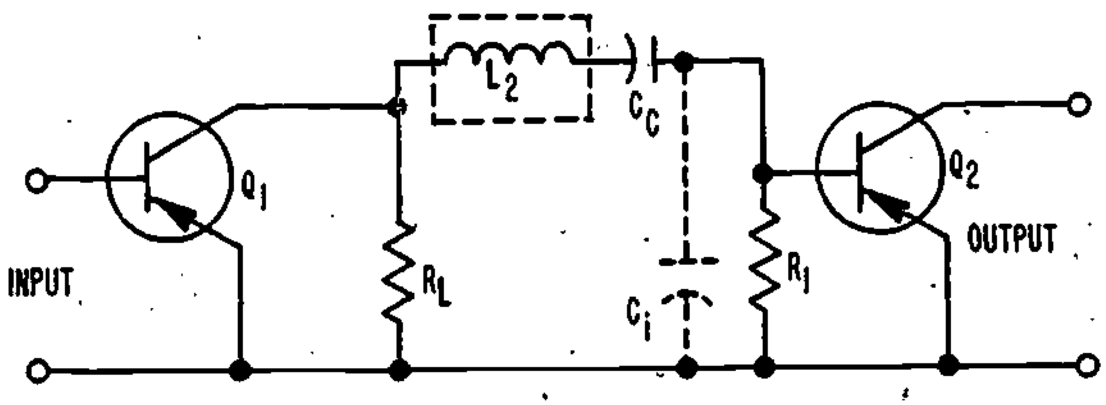


Figure 14

"SERIES" HIGH FREQUENCY COMPENSATED (AC EQUIVALENT)

How does the added inductor L2 improve high frequency gain? Well, L2 is in series with both Cc and the small equivalent capacitor Ci. As you know, Cc appears as a short at high frequencies. Now if L1 is the proper value, the combination L2 and Ci form a series resonant circuit to the signal path at high frequencies. You recall that impedance in a series resonant circit decreases to a minimum at resonance. Therefore, the series resonant circuit composed of L2 and Ci provides a low impedance path to the signal path from Q1 to Q2.

In addition, a fundamental property of series resonant circuits is the increase in voltage across the reactive components. In this case, the reactive components are L2 and Ci. This allows the voltage across L2 and Ci to be a maximum at the resonant frequency. Since Ci is in parallel with R1, any voltage developed by Ci will be felt across R1 and fed to the base of Q2. This method increases amplifier gain, at the previous roll-off point and is called series compensation, or series peaking.

In Figure 14, the L2-Ci circuit at resonance (maximizes/minimizes) the impedance between Q1 and Q2 and (increases/decreases) the voltage applied to Q2.

---

minimizes, increases

(14.) Figure 15 shows how series compensation further improves the video amplifier's frequency response.

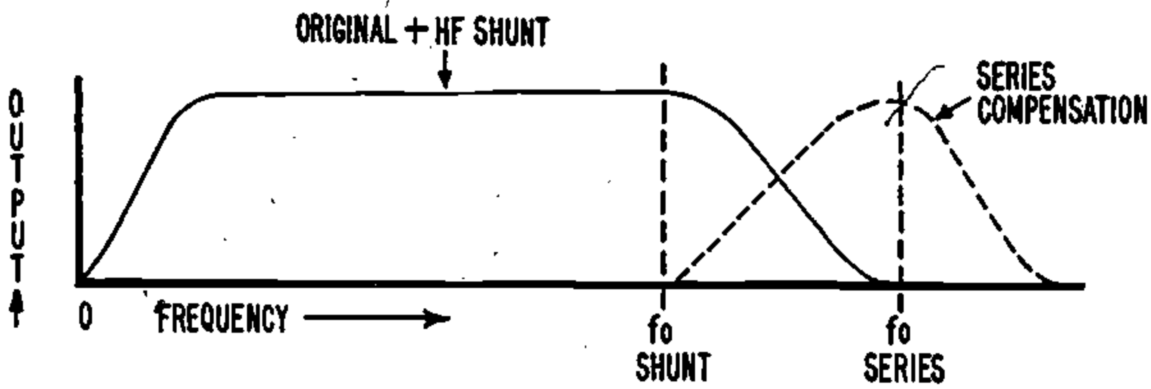


Figure 15

SERIES HIGH FREQUENCY COMPENSATION RESPONSE

In the figure, the dashed lines show the frequency response curve for the tuned series compensation circuit. Proper design of this circuit will make the series peaking center frequency occur above the frequency response of the combined original video amplifier and shunt compensation circuits. The input voltage to the second amplifier stage will increase within the bandwidth of the series compensation circuit and cause a "boost" in the high frequency response.

A series compensation circuit extends an amplifier's response at (low/high) frequencies.

---

high

(15.) Figure 16 shows the result of combining RC low frequency compensation and both shunt and series high frequency compensation to the original video amplifier.

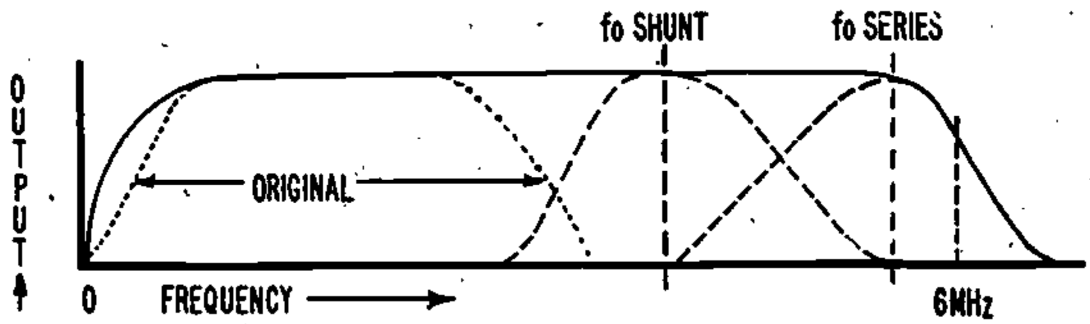


Figure 16

COMPENSATED VIDEO AMPLIFIER RESPONSE

As you study Figure 16, you can see the total effect of frequency compensation (low and high) by the solid line frequency response curve. The dotted lines indicate the original response curve before compensation is applied. The dashed lines indicate the individual resonance curves for shunt and series high frequency compensation. The overall improvement is significant, and extends the frequency response of the video amplifier from about 30 Hz to 6 MHz.

A video amplifier's high frequency response is improved by adding both ___________ and ___________ compensation circuits.

---

shunt, series

(16.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

1. The frequency response of a video amplifier is limited at high frequencies by the
   a. value of the coupling capacitor
   b. stray capacitance

USE THE DIAGRAM BELOW OF AN AC EQUIVALENT, TWO-STAGE VIDEO AMPLIFIER TO ANSWER QUESTION 2.

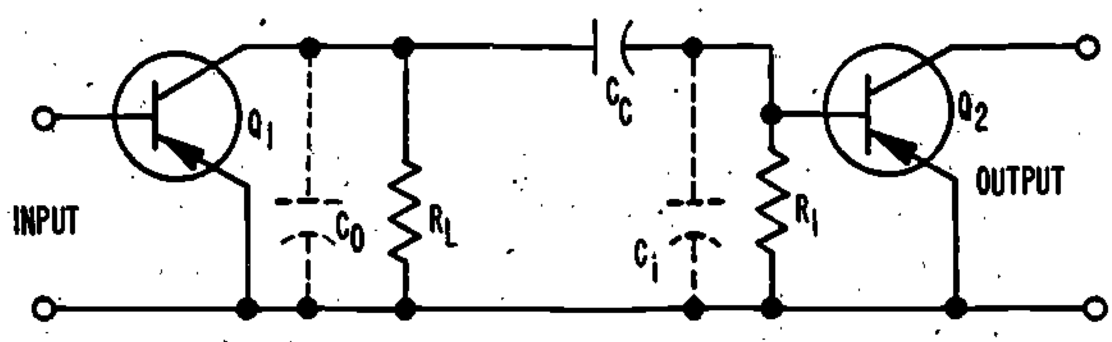


Figure 17

2. At high frequencies, the reactances of Co and Ci are (low/high) causing them to act as (shorts/opens) to ground.

USE THE DIAGRAM BELOW OF AN AC EQUIVALENT, TWO STAGE VIDEO AMPLIFIER TO ANSWER QUESTIONS 3 AND 4.

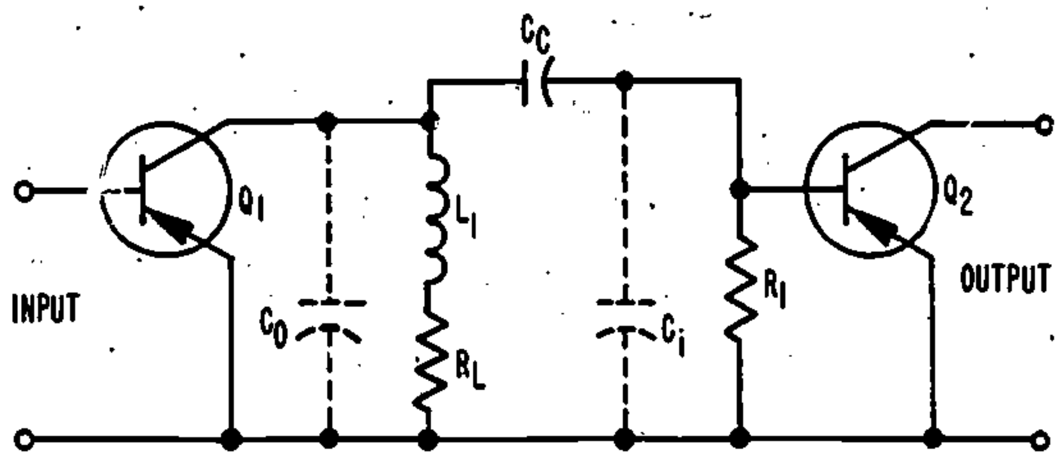


Figure 18

3. The high frequency of this amplifier has been improved by a method called

   a. series compensation

   b. shunt peaking

   c. capacitive bypassing

4. At high frequencies, L1 increases the

   a. capacitances of Co and Ci

   b. resistance of R1

   c. output impedance of Q1

   d. center frequency of Q2

USE THE DIAGRAM BELOW OF AN AC EQUIVALENT, TWO-STAGE VIDEO AMPLIFIER TO ANSWER QUESTIONS 5, 6, AND 7.

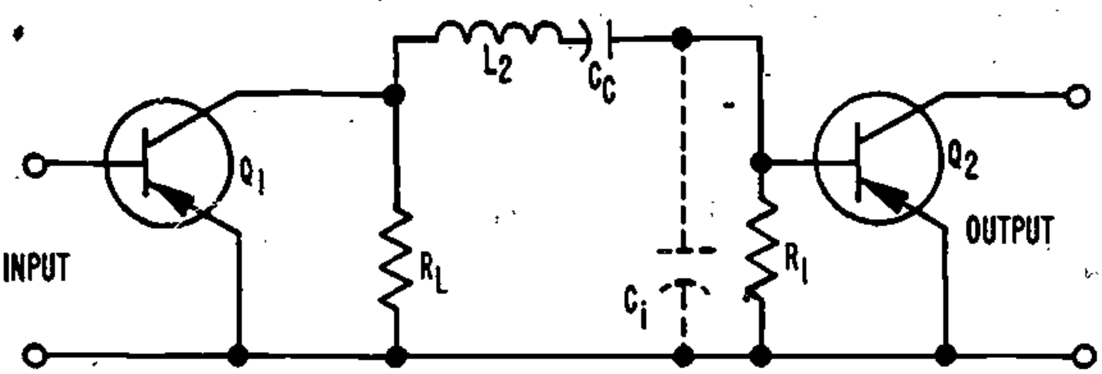


Figure 19

5. Components L2-Ci form a (parallel/series) resonant circuit at (low/high) frequencies.

6. At resonance, the purpose of L2-Ci is to (decrease/increase) the impedance between Q1 and Q2, and to (decrease/increase) the voltage developed across Ci.

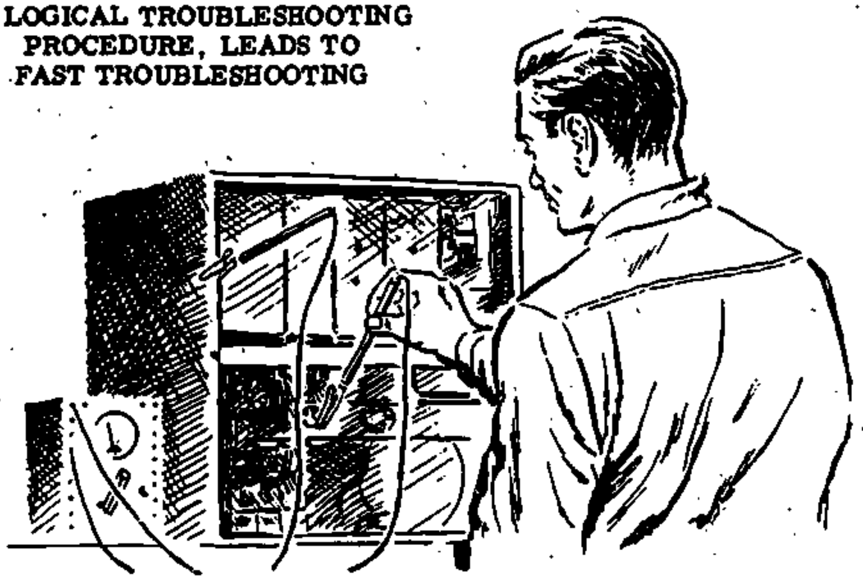
7. In order to improve the amplifier's frequency response, the L2-Ci circuit should be tuned to a frequency which is _______________ the amplifier's high frequency half-power point.

   a. above

   b. at

   c. below

255



A LOGICAL TROUBLESHOOTING PROCEDURE, LEADS TO FAST TROUBLESHOOTING

1. b. stray capacitance
2. low, shorts
3. b. shunt peaking
4. c. output impedance of QI
5. series, high
6. decrease, increase
7. a. above

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 21. OTHERWISE, GO BACK TO FRAME 9 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 16 AGAIN.

(17) You have learned how to improve the frequency response of video amplifiers at low and high frequencies by adding low frequency, shunt, and series compensation circuits. Figure 20 shows an AC equivalent diagram of a video amplifier which includes all three types of compensation circuits.

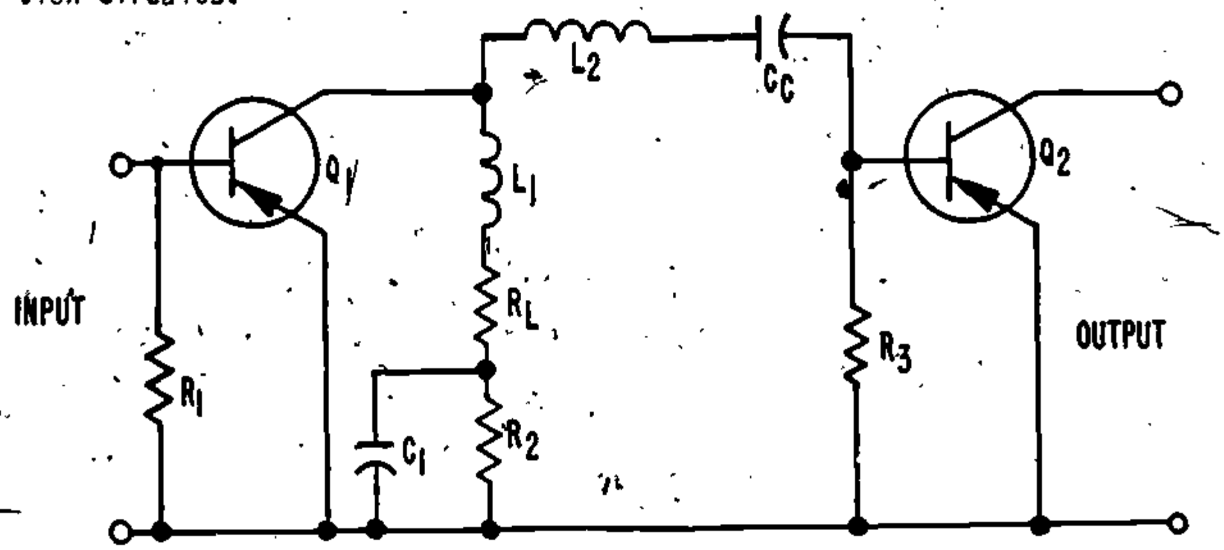


Figure 20

FULLY COMPENSATED VIDEO AMPLIFIER-EQUIVALENT CIRCUIT

In the figure, low frequency compensation is provided by R2-C1. At high frequencies, L1 provides shunt peaking and L2 provides series peaking to extend the high frequency response. These added inductors have little effect on low frequency response since inductors have low reactance at low frequencies.

In Figure 20, low frequency compensation is provided by components

a. L1 and L2

b. L2 and Cc

c. R3 and Cc

d. R2 and C1

---

d. R2 and C1

(18.) Up until now in this lesson, the high and low frequency compensation circuits have been shown in equivalent circuit form. Now let's place them in an <u>actual</u> video amplifier circuit with biasing components present. Figure 21 shows a two-stage video amplifier circuit from the NIDA trainer.

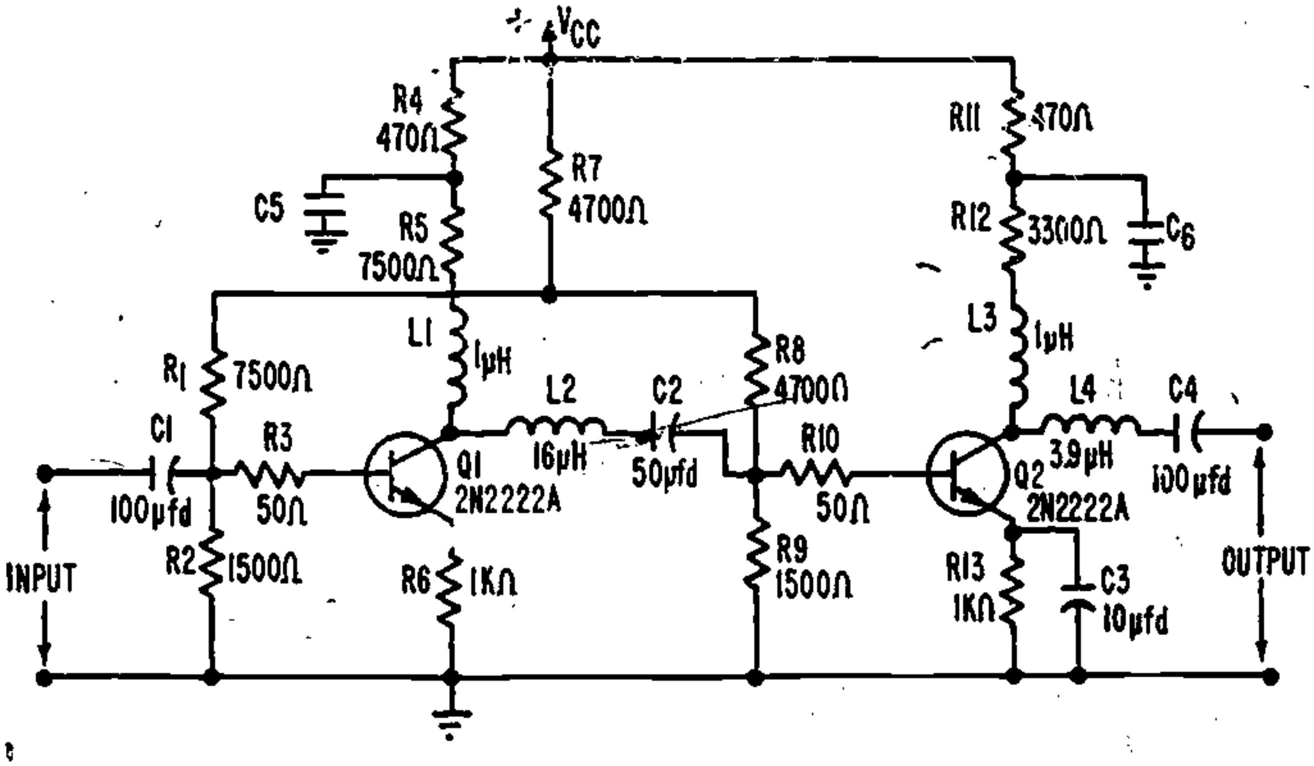


Figure 21

TWO-STAGE VIDEO AMPLIFIER-ACTUAL CIRCUIT

Both stages use a common-emitter circuit arrangement. In the figure, interstage coupling of the video signal is provided by capacitors C1, C2, and C4. These capacitors have large values and help to improve the low frequency response. In the collector circuits, you will find the shunt high frequency peaking coils L1 and L3. These are connected to the normal collector load resistors R5 and R12, respectively. The series high frequency coils are L2 and L4. The output video signal from each stage passes through these two coils. As you know, shunt peaking coils resonate with the output (Co) and input (Ci) equivalent capacitances, while the series peaking coils resonate with the input capacity. These capacitances normally are not shown on a circuit schematic diagram since the physical capacitors do not exist. However, the effects of the capacitances definitely exist!

If Figure 21, the two components which provide high frequency series peaking are _________ and _________.

L2, L4

(19.) Let's take another look at the two-stage video amplifier circuit shown in Figure 22 and examine the components which provide forward bias and emitter stabilization.

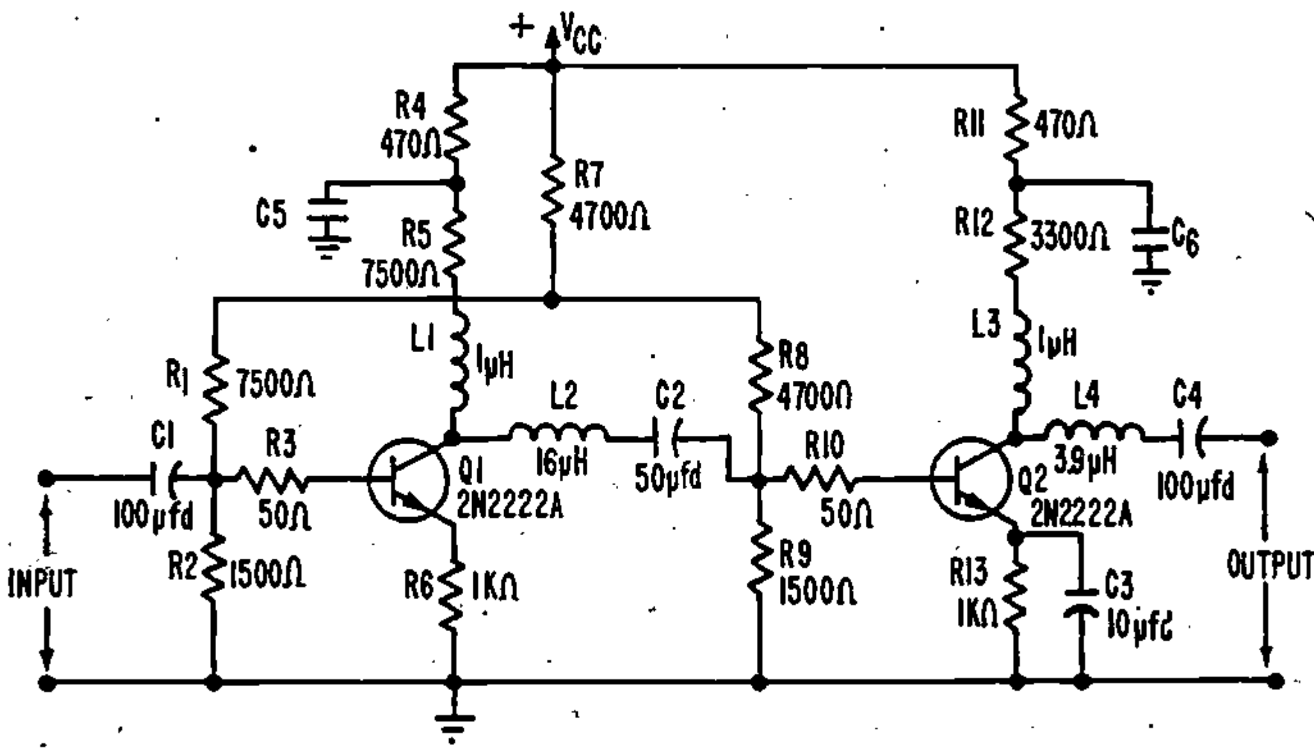


Figure 22

TWO-STAGE VIDEO AMPLIFIER-ACTUAL CIRCUIT

In the figure, R1 and R2 provide Class A forward bias for Q1 as do R8 and R9 for Q2. Both of these forward bias networks are connected to R7 to complete the voltage divider from Vcc. R6 and R13 provide emitter stabilization for the transistors. Notice that R13 has a bypass capacitor C3, whereas R6 does not. The unbypassed emitter in the first stage improves the low and high frequency response at the cost of some gain. The bypassed emitter in the second stage prevents signal degeneration and loss of gain.

In Figure 22, Class A forward bias for Q2 is provided by components __________ and __________, and emitter stabilization for Q1 is provided by component __________.

R8, R9, R6

(20.) Now let's examine the function of the remaining components in the two-stage video amplifier circuit shown in Figure 23.

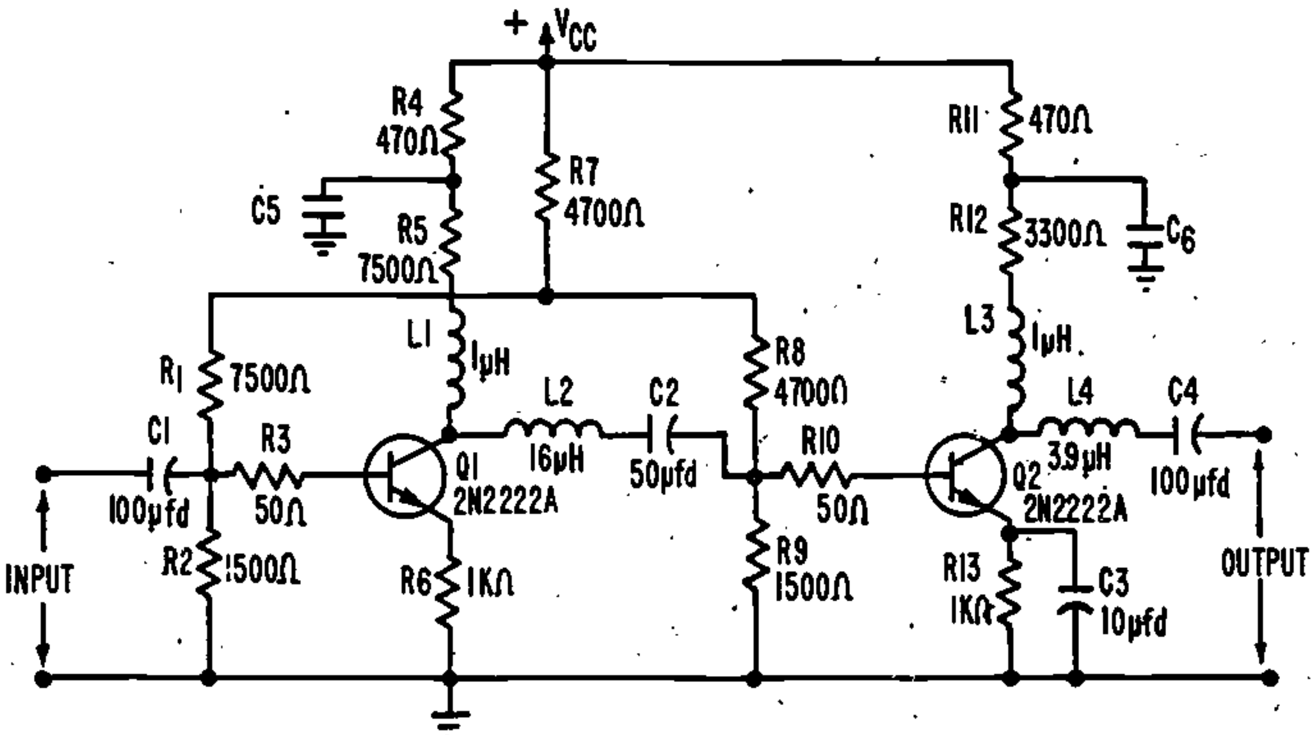


Figure 23

TWO-STAGE VIDEO AMPLIFIER-ACTUAL CIRCUIT

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(21.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

USE THE DIAGRAM BELOW BELOW OF A TWO-STAGE VIDEO AMPLIFIER CIRCUIT TO ANSWER QUESTIONS 1 THROUGH 5.

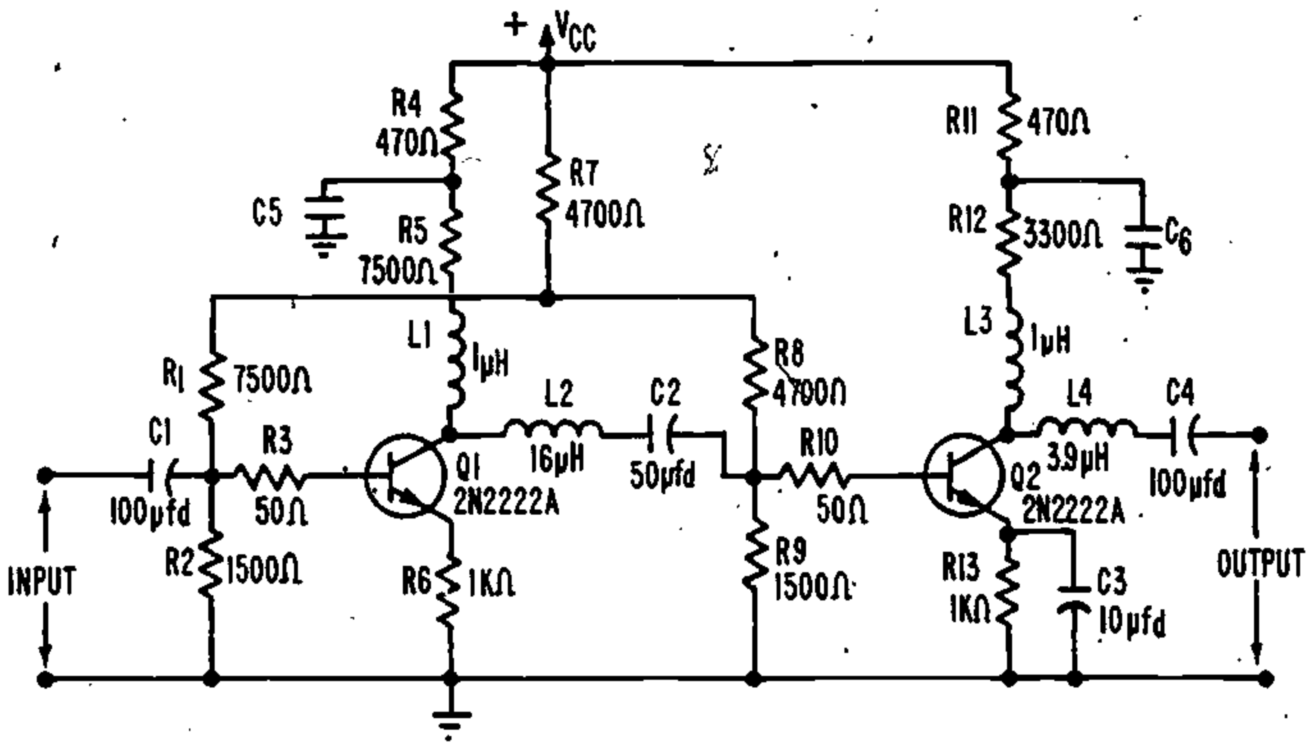

Figure 24

1. The two components which provide series high frequency peaking are ________ and ________.

2. R7 acts as a voltage divider between Vcc and which component networks?

   a. shunt compensation

   b. forward bias

   c. coupling

   d. decoupling

3. Emitter stabilization is performed by which two resistors?

4. The purpose of the R11-C6 network in the second stage is to

   a. decouple the signal from the power supply.

   b. improve the high frequency response.

   c. stabilize the forward bias to Q2.

   d. increase the output impedance of Q2.

In the collector circuits, R4-C5 and R11-C6 provide decoupling of the video signal. Each decoupling network provides the signal with a low impedance path to ground at the junction of the resistor and capacitor. This low impedance path serves to separate the signal from the DC power supply, and keeps signal-related components out of the power supply. If the signal voltage entered the power supply and caused variations in V_{CC}, the amplifier could oscillate instead of amplify.

R10 is in series with the signal path and the L2-C1 series high frequency compensation network. R10 acts to reduce the Q of this network and broaden its bandwidth. R3 also is in series with the signal path. It performs the same type of function as R10 on the series compensation network which would be located in a previous stage.

In Figure 23, R4-C5 and R11-C6 act to prevent the amplifier from (decoupling/oscillating), and R10 acts to (narrow/broaden) the bandwidth of the series compensation network.

---

oscillating, broaden

1. L2, L4
2. b. forward bias
3. R6, R13
4. a. decouple the signal from the power supply

IF ALL YOUR ANSWERS MATCH GO ON TO TEST FRAME 28. OTHERWISE, GO BACK TO FRAME 17 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 21 AGAIN.

(22.) You know the frequency response curve and component operation of the basic video amplifier. Now let's look at two methods for measuring the frequency response of a video amplifier circuit. These methods are useful in troubleshooting circuit problems.

The first method uses the sweep frequency generator. You should recall from the previous lesson that a sweep frequency generator provides a wide range of output frequencies. Figure 25 shows an equipment set-up for measuring frequency response using the sweep frequency generator.

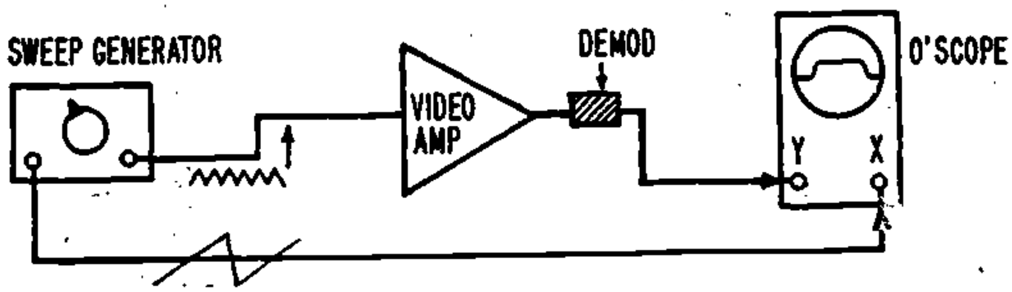

Figure 25

SWEEP FREQUENCY GENERATOR FREQUENCY RESPONSE TEST

If you set the generator to sweep from 0 Hz to 10 MHz and apply this signal to a video amplifier, you get a frequency response curve as shown on the CRT of the oscilloscope. The video amplifier will amplify each frequency according to its ability. The display on the CRT is an accurate indication of the video amplifier's frequency response curve.

In Figure 25, the display on the oscilloscope is the video amplifier's ________ ________ ________.

---

frequency response curve

(23.) A technician can use the sweep frequency generator to test a video amplifier by comparing the actual frequency response curve to the normal, or expected, curve. As an example, Figure 26 shows both actual and normal frequency response curves for a test video amplifier.

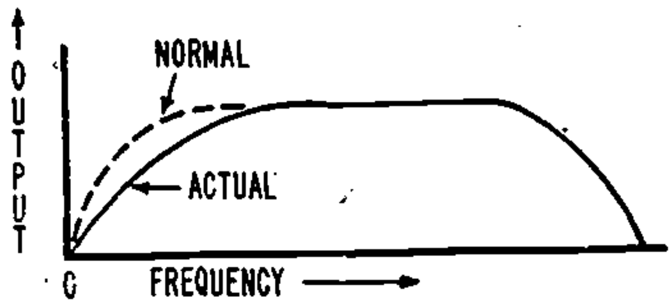

Figure 26

ACTUAL VS NORMAL FREQUENCY RESPONSE

In the figure, you can see that the actual curve (shown by the solid line) displays less gain at low frequencies than indicated by the normal curve (shown by the dotted line). The technician would suspect some problem in low frequency response components. He then would check the coupling capacitors and low frequency RC network components for defects.

The display in Figure 26 was produced by injecting a signal from a ______________ generator into a test video amplifier.

sweep generator

24. The second method for measuring the frequency response of a video amplifier circuit uses the square wave generator. This test method is less accurate than the one previously described, but is effective in troubleshooting. Figure 27 shows an equipment set-up for measuring frequency response using the square wave generator.

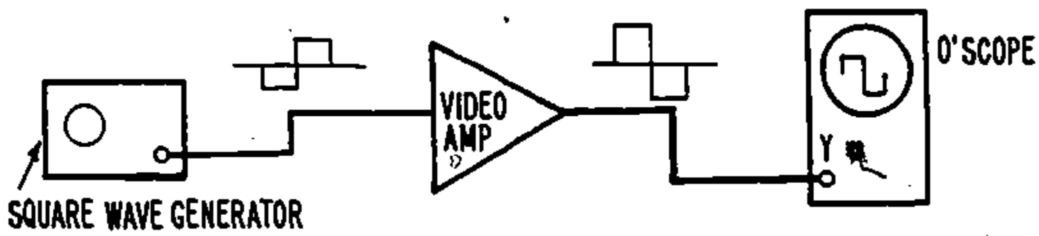

Figure 27

SQUARE-WAVE GENERATOR FREQUENCY RESPONSE TEST

This type of signal generator produces square shaped waveforms which are the input into a test video amplifier as shown in the figure. If the CRT on the oscilloscope accurately displays the square wave, the video amplifier is functioning properly. Any distortion of the square wave signal indicates a lack in the frequency response for the video amplifier.

In Figure 27, the displays on the oscilloscope indicates that the test video amplifier

a. is functioning properly

b. has a lack in frequency response

---

a. is functioning properly

(25) No doubt the question in your mind is "how does an amplifier's frequency response relate to its ability to accurately reproduce a square wave?" The answer requires a brief discussion about what frequencies make up a square wave. In theory, a square wave is the result of combining a basic sine wave frequency with an infinite number of frequencies that are multiples of that frequency. The basic frequency is called the fundamental frequency, and the multiple frequencies are all called the harmonics. In a square wave, the only harmonics we are interested in are the odd-numbered harmonics. For example, if the fundamental frequency is 10 kHz, the third harmonic equals 3 times 10 kHz, or 30 kHz. The fifth harmonic of 10 kHz equals 5 times 10 kHz, or 50 kHz. The square wave related to the fundamental frequency of 10 kHz is the waveform that results from combining 10 kHz with a large quantity of odd-numbered harmonic frequencies.

A square wave is produced by combining a __________ frequency with many of its odd-numbered __________ frequencies.

---

fundamental, harmonic

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(26.) Figure 28 shows the effect of combining a typical fundamental frequency with its third and fifth harmonics.

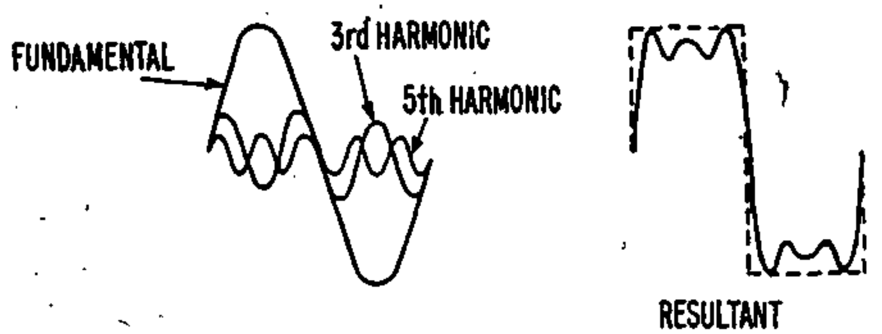

Figure 28

COMPOSITION OF SQUARE WAVE

The left side of the figure shows the individual waveforms for the fundamental frequency, and for the third and fifth harmonics. The right side shows the combination of these frequencies. Notice that the figure closely resembles a square wave when only three frequencies are combined. In actual practice, an almost perfect looking square wave is produced by combining a fundamental frequency with all the odd-numbered harmonics up through the 21st harmonic. Another way to say this is that a square wave is the combination of a fundamental and its first 10 odd-numbered harmonics.

A good square wave can be produced by combining a fundamental frequency with the first 10 (even/odd)-numbered harmonics.

---

odd

(27.) Now that you know the composition of a square wave, let's see how it relates to the frequency response of a video amplifier. If a video amplifier can accurately reproduce a square wave signal, then it can amplify the signal's fundamental frequency and at least the first 10 odd-numbered harmonics. Thus any distortion of the square wave signal indicates that the video amplifier is not amplifying some of the frequencies which compose the square wave. The type of distortion produced by the amplifier relates to those frequencies which are not properly amplified. Figure 29 shows examples of good and distorted square wave reproductions.

GOOD FREQUENCY RESPONSE — POOR HIGH FREQUENCY RESPONSE — POOR LOW FREQUENCY RESPONSE

Figure 29

SQUARE WAVE DISPLAY AND FREQUENCY RESPONSE

A video amplifier which produces the left waveform in the figure has a good frequency response. If it produces the center waveform, there are problems in the high frequency response. If it produces the right waveform, there are problems in the low frequency response. You will be using the square wave generator in the Job Program for this lesson to troubleshoot a video amplifier.

The square wave display from a test amplifier appears as Figure 30 below.

Figure 30

This indicates that the video amplifier's frequency response is poor at __________ frequencies.

---

low

(26.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS GIVEN AT THE TOP OF THE PAGE FOLLOWING THE QUESTIONS.

USE THE FIGURE BELOW TO ANSWER QUESTION 1.

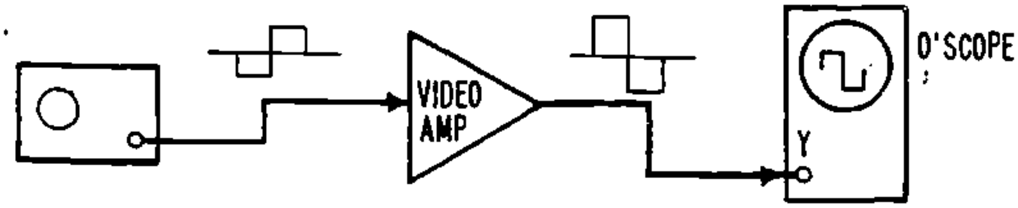

Figure 31

1. You are using this set-up to test the frequency response for a video amplifier. In order to produce the display on the oscilloscope, the input signal to the amplifier comes from a piece of test equipment called ______ ______ ______.

USE THE FIGURE BELOW TO ANSWER QUESTION 2.

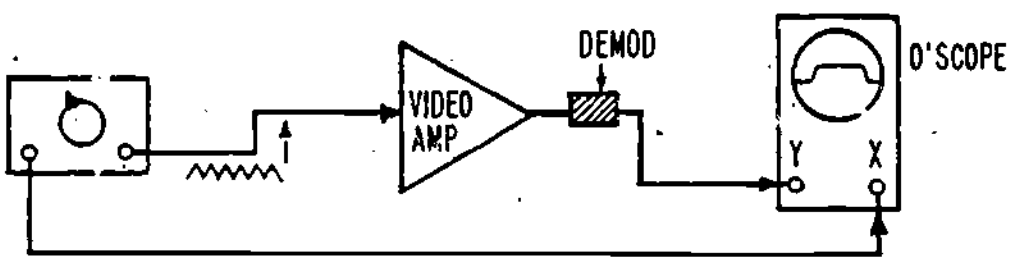

Figure 32

2. You are using this set-up to test the frequency response for a video amplifier. In order to produce the display on the oscilloscope, the input signal to the amplifier comes from a piece of test equipment called a ______ ______ ______.

USE THE FIGURE BELOW TO ANSWER QUESTION 3.

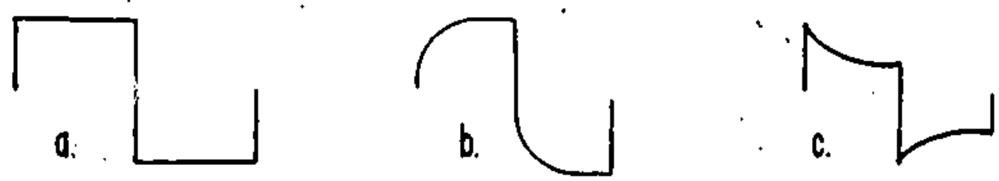

Figure 33

3. A test video amplifier with poor high frequency response will reproduce a square wave that resembles which waveform?

a. a

b. b

c. c

1. square wave generator

2. sweep frequency generator

3. b. b

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU HAVE COMPLETED LESSON 4, MODULE 31. CONGRATULATIONS! IF YOUR ANSWERS DO NOT MATCH GO BACK TO FRAME 22 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 28 AGAIN.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.

NARRATIVE
LESSON 4

Video Amplifiers

Most electronic equipment that produces a visual display on a Cathode Ray Tube (CRT) requires the use of video amplifiers. Examples of this type of equipment include radars, television sets, and oscilloscopes.

To amplify the types of signals used to produce visual displays, a video amplifier must have a frequency response that will allow it to amplify a frequency from 0, or a few Hertz, to about 5 or 6 MHz. The ideal video amplifier should be able to amplify all these frequencies with equal gain, so its bandwidth must be as wide as its frequency response.

The frequency response curve for an ideal video amplifier is shown in Figure 1.

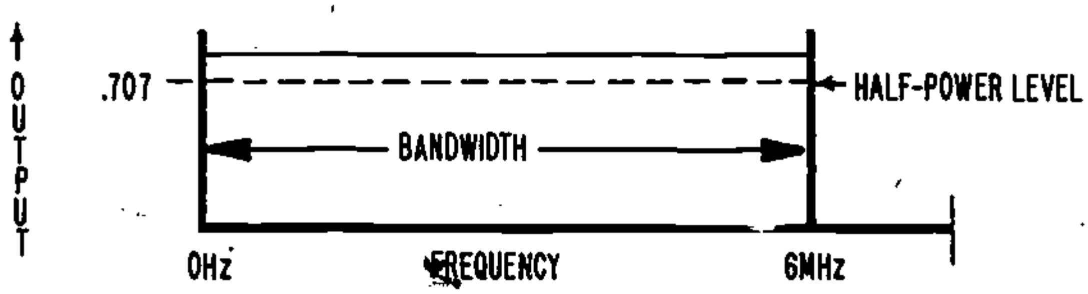

FIGURE 1

IDEAL VIDEO AMPLIFIER RESPONSE CURVE

Amplifiers you have studied will not reproduce the low and high frequencies required of video amplifiers. Figure 2 shows the typical response curves for actual transformer coupled and resistance-capacitance (RC) coupled amplifiers.

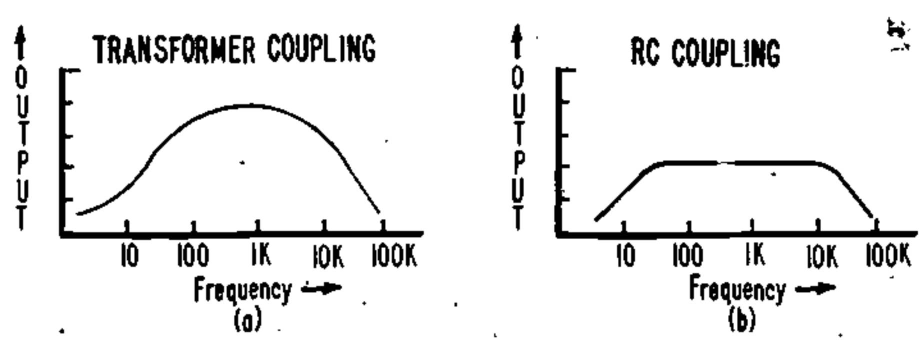

FIGURE 2

AMPLIFIER RESPONSE CURVES

As you can see, amplifiers with RC coupling provide a slightly wider bandwidth. However, even these amplifiers fall short of the wide bandwidth requirements for video amplifiers.

Figure 3 can be used to show what limits the low frequency response of RC coupled amplifiers.

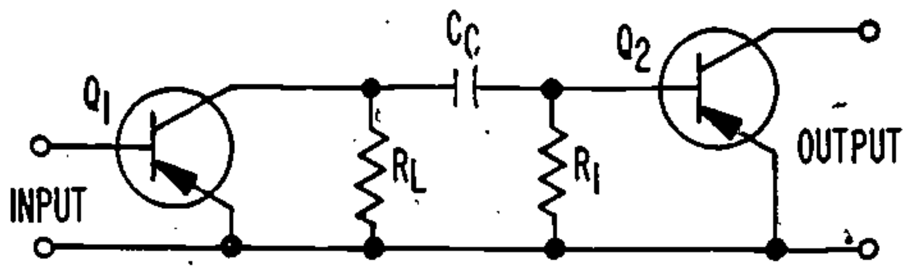

FIGURE 3

AC EQUIVALENT-RC COUPLED AMPLIFIER

The circuit in Figure 3 is a simplified schematic of an RC coupled, two-stage amplifier, with bias voltages and some components omitted for clarity. In the figure, the output of Q1 is developed by RL. Therefore, the signal voltage fed to the input (base) of Q2 is equal to the voltage across RL minus any signal voltage dropped by Cc. When the input frequency decreases, the voltage dropped across Cc will increase due to the increased capacitive reactance (Xc). This leaves less voltage felt across R1 and the base of Q2, thus reducing the overall gain at low frequencies.

One method to compensate for this loss of gain is to increase the value of the coupling capacitor (Cc) in order to lower its impedance at low frequencies. However, if the coupling capacitor value is too large, the circuit becomes unstable and would not work at all. Fortunately, there is another way to compensate for loss of low frequency gain as shown in the simplified circuit of Figure 4.

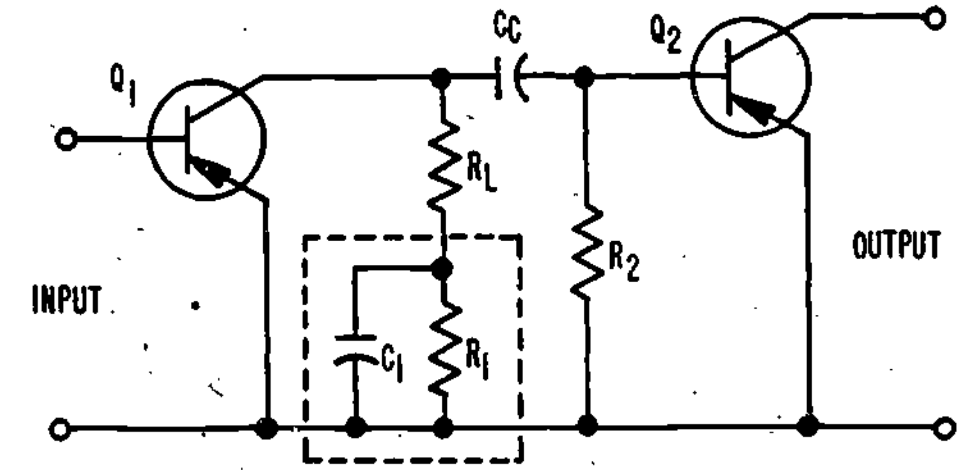

FIGURE 4

AC EQUIVALENT - LOW FREQUENCY COMPENSATION CIRCUIT

In the figure, C1 and R1 have been added. At low frequencies, the Xc of C1 is large enough so that C1 acts as an open. Thus the parallel circuit C1-R1 has an impedance equal to the the resistance of R1. The load for Q1 then would equal the sum of resistances RL and R1 at low frequencies. This larger collector load impedance increases the gain, or output voltage, from the amplifier at these low frequencies. The increased gain makes up for the voltage loss caused by Cc. At high frequencies, the C1-R1 circuit does not affect circuit gain because the reactance of C1 decreases, and effectively shorts out R1. Therefore, the gain from Q1 returns to that produced by RL alone.

The effect of low frequency compensation on the overall circuit frequency response is shown in Figure 5.

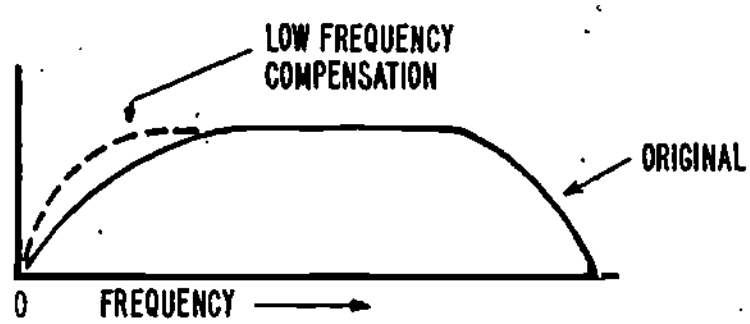

FIGURE 5

LOW FREQUENCY COMPENSATION RESPONSE

In the figure, you will notice that the low frequency end of the curve has been extended beyond the original uncompensated curve. Although the technique of adding a parallel RC network in the collector circuit improves the low frequency response, it does not extend the response to the zero frequency point. A type of amplifier coupling called DC (direct coupling) does not use a capacitor between stages. You may remember this type of amplifier from the lesson on transistor voltage regulators, Module 30-2. A DC amplifier extends the low frequency response down to 0 Hz and is extensively used in integrated circuits. You will study more about integrated circuits in Module 34.

Figure 6 can be used to show what limits high frequency response of video amplifiers.

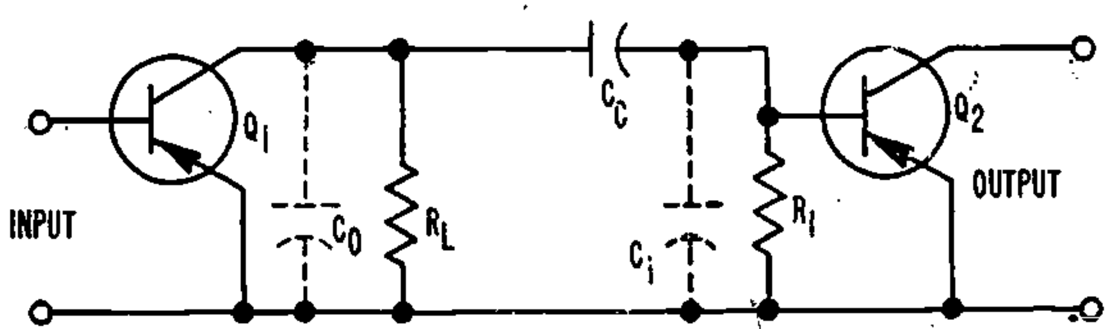

FIGURE 6

AC EQUIVALENT - STRAY CAPACITANCE

In any transistor circuit, there is a definite amount of stray capacitance present in both the input and output stages. This is due to a number of factors including proximity of wires, active device input/output capacity, printed circuit board foils, etc. The input stray capacitance (Ci) and outout stray capacitance (Co) can be drawn into the basic circuit as shown in Figure 6. The values of these equivalent capacitors are in the picofarad range. At high frequencies, Co and Ci have low impedances and act as signal shorts to ground. The stray capacity shunts the signal to ground and prevents them from being fully amplified.

Since it is not possible to physically remove Co and Ci, they must be compensated for in some way.

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One method to compensate for high frequency signal loss is to place an inductor of the proper value in parallel with Co and Ci as shown in Figure 7.

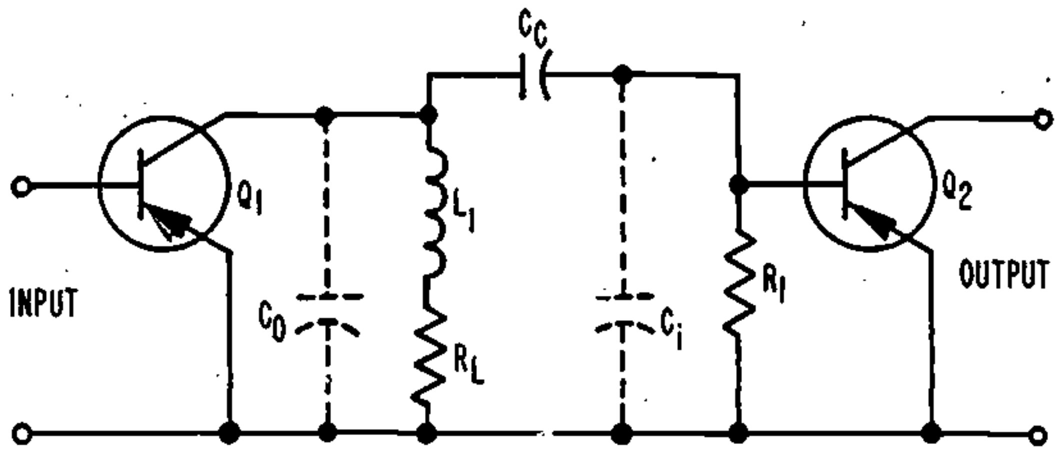

FIGURE 7

"SHUNT" HIGH FREQUENCY COMPENSATION (AC EQUIVALENT)

In the figure, Co, Ci, and L1 form a parallel resonant circuit at high frequencies where the frequency response would normally drop. Cc will not affect the operation of this resonant circuit since Cc appears as a short at high frequencies.

In the amplifier, the addition of L1 increases the output impedance of Q1 at high frequencies because impedance in the parallel resonant circuit increases at resonance. With this increased output impedance, the gain of the amplifier increases at high frequencies thus compensating for the losses that would occur without L1. Since L1 is in parallel ("shunts" the input and output capacitance), this type of compensation is called shunt compensation, or shunt peaking.

Figure 8 shows how shunt compensation improves RC coupled amplifier high frequency response.

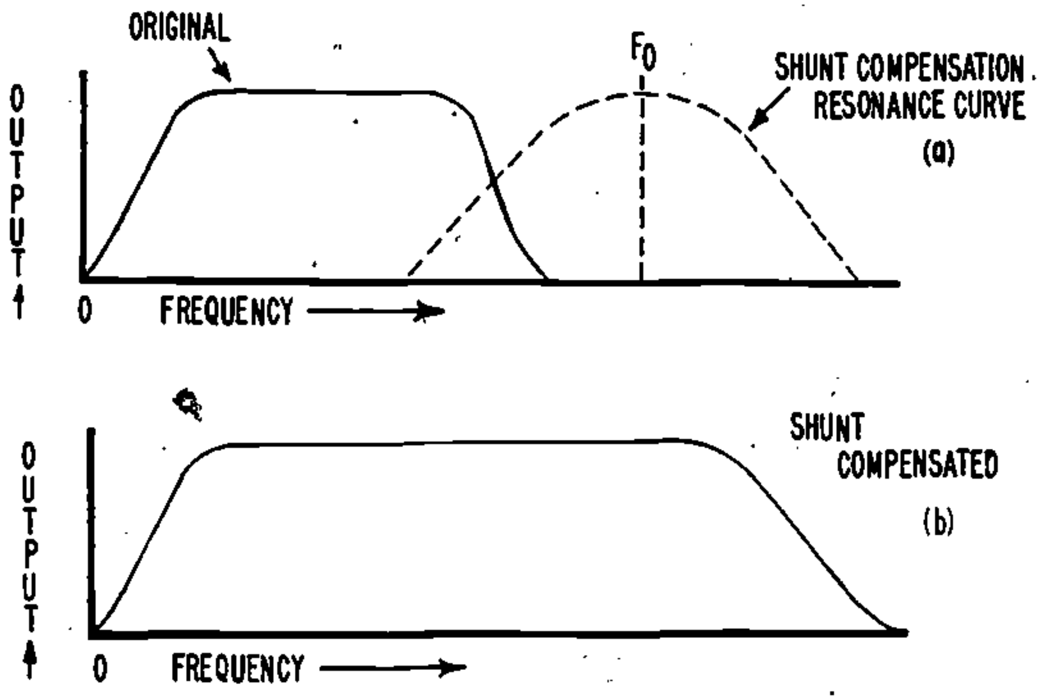

FIGURE 8

SHUNT HIGH FREQUENCY RESPONSE CURVES

In Figure 8a, notice that the resonant curve of the shunt compensation circuit is higher in frequency than the original RC coupled amplifier curve. The wide bandwidth of the shunt compensation circuit occurs because the collector load (RL) lowers the resonant circuit Q and increases the bandwidth (using the formula BW = Fo/Q). In Figure 8b, the overall frequency response curve is obtained by combining the original curve and the shunt compensation curve.

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Shunt type compensation has improved the high frequency response of the basic video amplifier. However, this response still may not be high enough for some applications. The circuit can be further improved by adding an inductor in series with the signal path and Ci as shown in Figure 9.

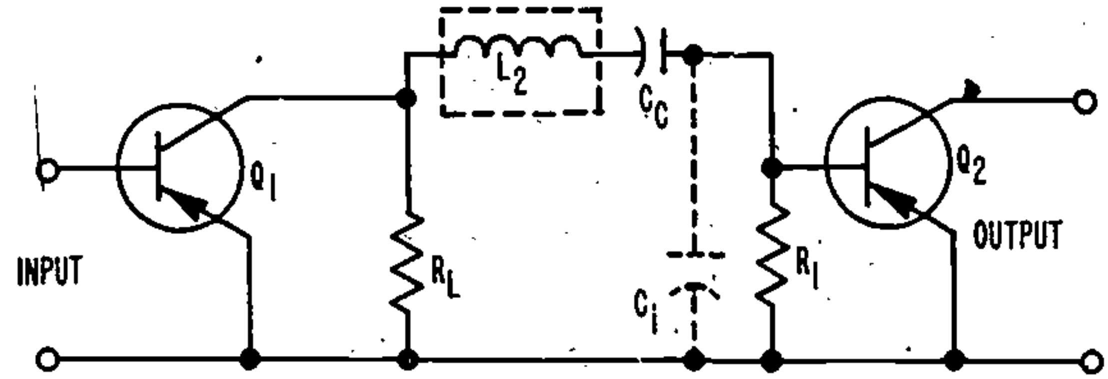


FIGURE 9

"SERIES" HIGH FREQUENCY COMPENSATION (AC EQUIVALENT)

Series high frequency compensation uses the principle of series resonance to improve high frequency response. In the figure, L2 is in series with both Cc and Ci. Since Cc acts as a short at high frequencies, the combination of L2 and Ci form a series resonant circuit to the signal path if the value of L2 is properly chosen. You recall that the voltage across a coil and capacitor in series is maximum at resonance because impedance is at a minimum. Therefore, the voltage developed by Ci is maximum at Fo and will be felt across R1 and fed to the base of Q2. This method of increasing amplifier gain is called series compensation, or series peaking.

Figure 10 shows how series compensation further improves video amplifier frequency response.

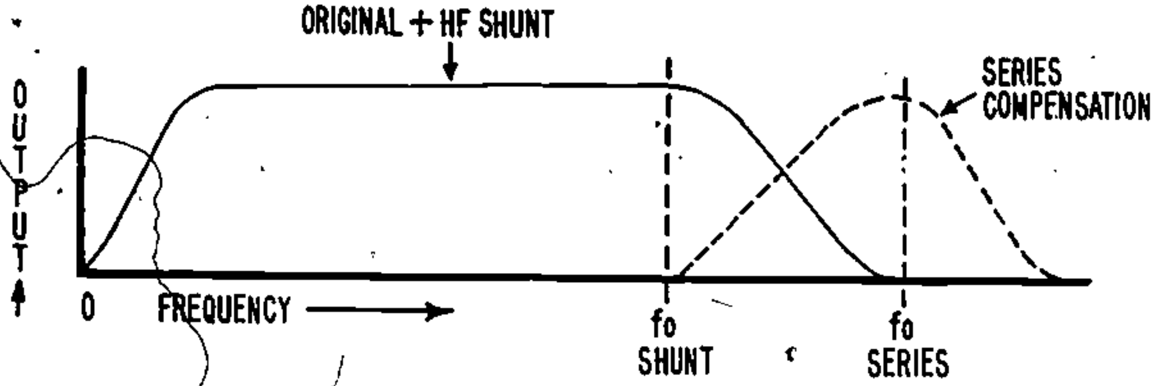


FIGURE 10

SERIES HIGH FREQUENCY COMPENSATION RESPONSE

In the figure, proper design of the resonant series compensation circuit will place its Fo above the frequency response of the combined original RC amplifier and shunt compensation circuits. The input voltage to the second amplifier stage in Figure 9 will receive a "boost" when the signal frequency occurs within the bandwidth of the series compensation circuit.

Figure 11 shows the result of combining RC low frequency compensation and both shunt and series high frequency compensations to the original video amplifier.

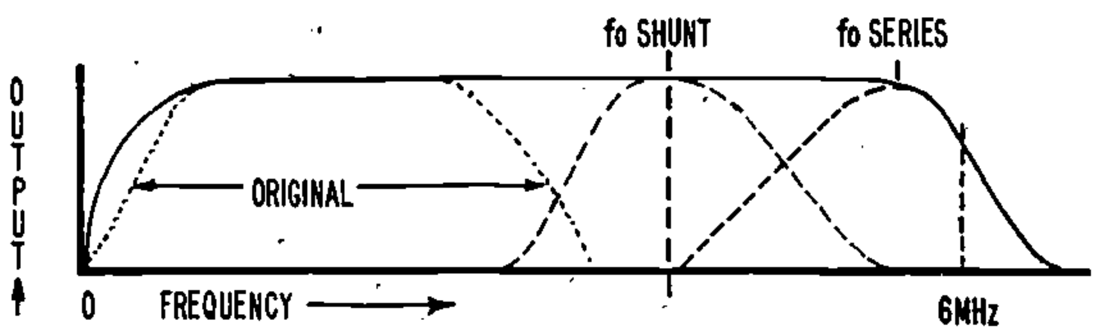


FIGURE 11

COMPENSATED VIDEO AMPLIFIER RESPONSE

As you can see, the total improvement (shown by the solid line) is significant. The frequency response for the fully compensated video amplifier is about 30 Hz to 6 MHz.

Figure 12 shows a simplified diagram of a fully compensated video amplifier.

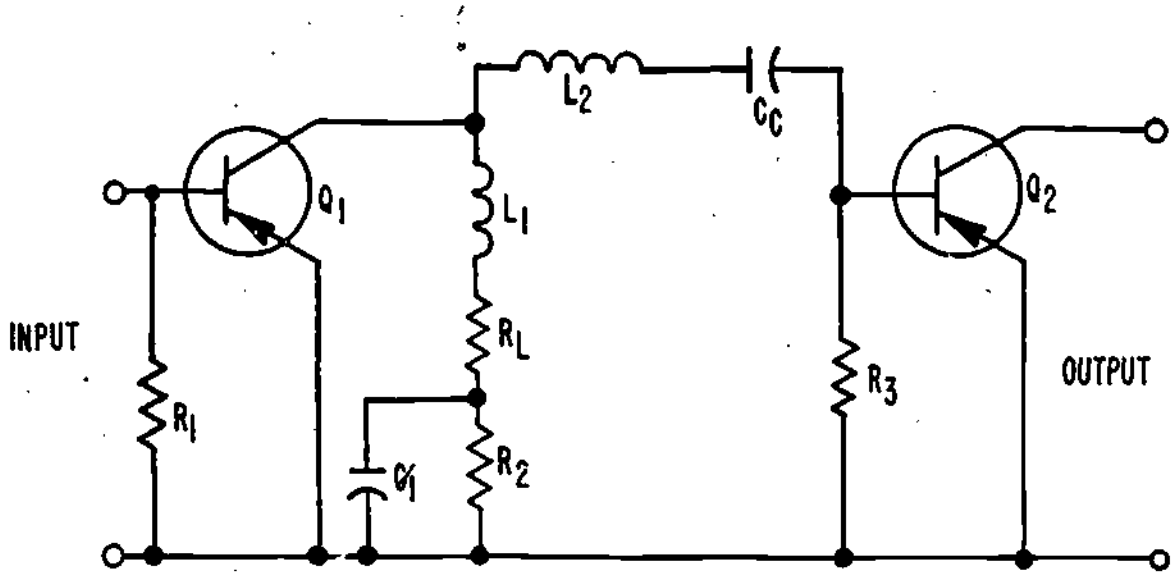


FIGURE 12

COMPENSATED VIDEO AMPLIFIER-EQUIVALENT CIRCUIT

Low frequency compensation is provided by the R2-C1 circuit. High frequency compensation is provided by both L1 (shunt peaking) and by L2 (series peaking)

Now that the high and low frequency compensation circuits have been presented in equivalent circuit form, let's place them into a real circuit. Figure 13 shows the schematic diagram of a two-stage video amplifier as found in the NIDA trainer.

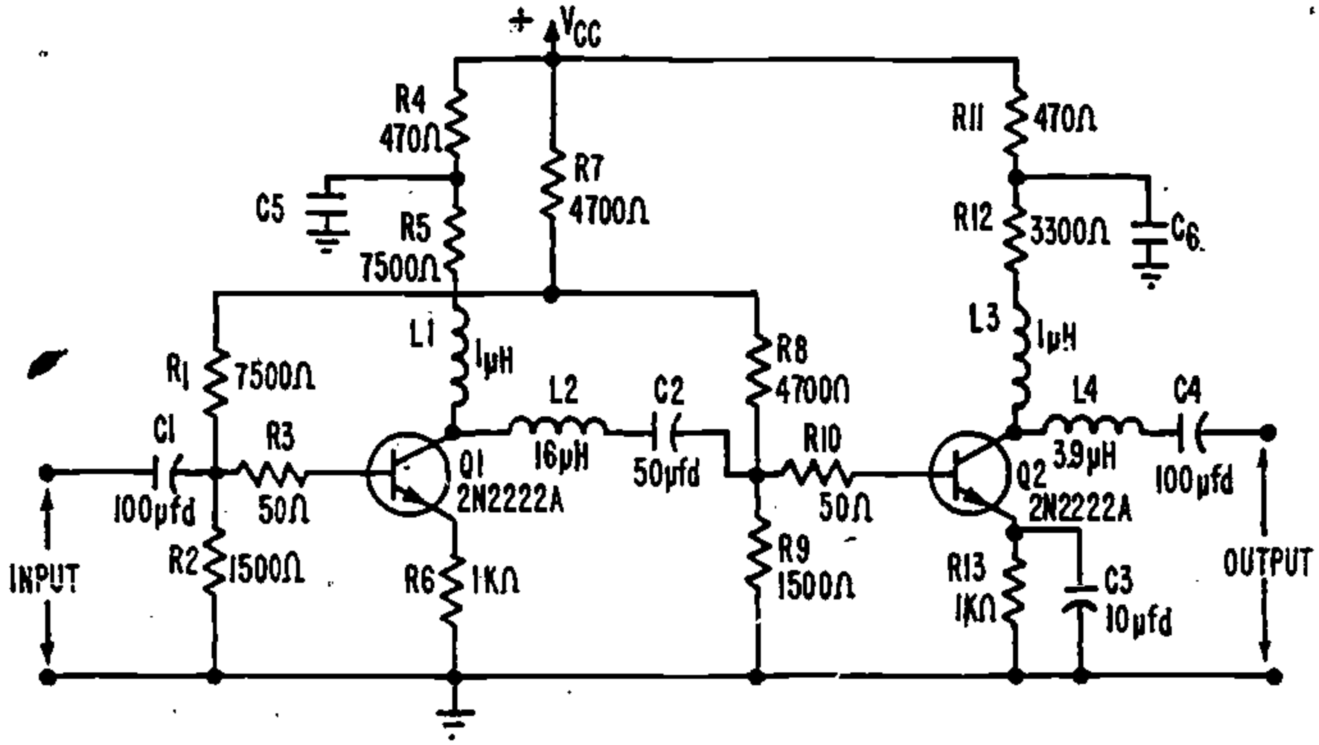


FIGURE 13

2-STAGE VIDEO AMPLIFIER-ACTUAL CIRCUIT

The functions of components in this circuit now will be discussed. R1 and R2 provide Class A forward bias for Q1, as do R8 and R9 for Q2. Both of these networks are connected to R7 to complete the voltage divider from Vcc. R6 and R13 provide emitter stabilization. In the second stage, R13 is bypassed by C3 to prevent degeneration and loss of gain. Notice that R6 is not bypassed. This unbypassed emitter in the first stage provides improvement to the low and high frequency response at the expense of some gain.

Interstage coupling of the video signal is provided by C1, C2, and C4. These capacitors have large values and help improve the low frequency response. In the collector circuits, the R4-C5 and R11-C6 networks provide decoupling of the video signal. Decoupling is a term that indicates the signal sees a low impedance path to ground at the junction of the resistor and capacitor. This low impedance path serves to separate the signal path from the DC power supply, and is necessary to keep signal components out of the supply. If the signal voltage should cause variations in Vcc, the amplifier could oscillate instead of amplify.

Also in the collector circuits, you find the shunt high frequency peaking coils L1 and L3 together with the normal collector load resistors R5 and R12. The output video signal from each stage passes through the series high frequency peaking coils L2 and L4. Of course, the series and shunt peaking coils resonate with the output (Co) and input (Ci) capacities which are not normally shown on a circuit schematic diagram.

R3 and R10 are in series with the signal path. R10 acts to reduce the Q of the L2-Ci series compensation network and to broaden its bandwidth. R3 acts to perform a similar function in a previous amplifier stage.

Now let's look at two methods for measuring the frequency response for a video amplifier. The first method uses a sweep frequency generator. The test set up is shown in Figure 14.

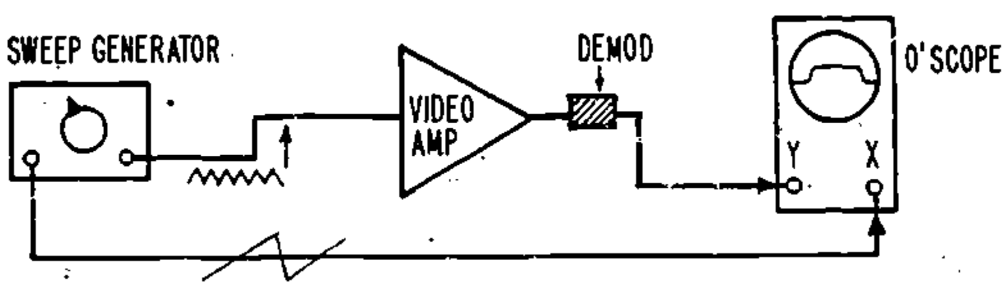


FIGURE 14

VIDEO AMPLIFIER FREQUENCY RESPONSE TEST

Recall that a sweep frequency generator provides a wide band of output frequencies. The generator can be set up to sweep from 0 Hz to 10 MHz, and this signal can be applied to a video amplifier. The output frequency response curve from the amplifier would resemble the display on the oscilloscope in Figure 14. This display would accurately indicate the amplifier's ability to amplify each frequency.

As an example of a test situation, assume the frequency response curve shown in Figure 15 is produced on the CRT of an oscilloscope.

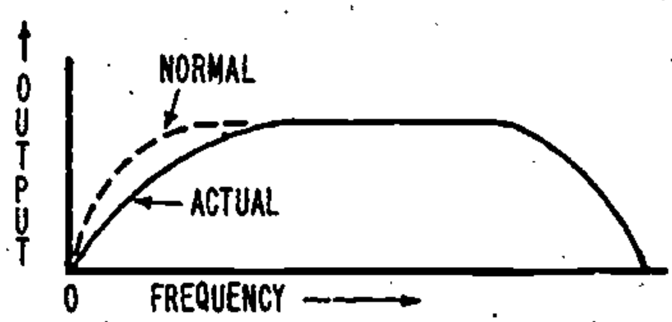


FIGURE 15

ACTUAL VS NORMAL FREQUENCY RESPONSE

In the figure, a technician can determine faulty components in the video amplifier circuit by comparing the actual frequency response curve (solid line) with the expected normal curve (dotted line). In this example, the actual curve indicates some defect in the low frequency response components of the amplifier. The technician would then proceed to check the coupling capacitors and low frequency RC network parts as likely suspects.

The second method for determining video amplifier frequency response uses a square wave generator. This type of generator produces square shaped waveforms particularly suitable for testing frequency response. However, this method is less accurate than the method using the sweep generator. Figure 16 shows the test set-up for measuring video amplifier frequency response with a square wave generator.

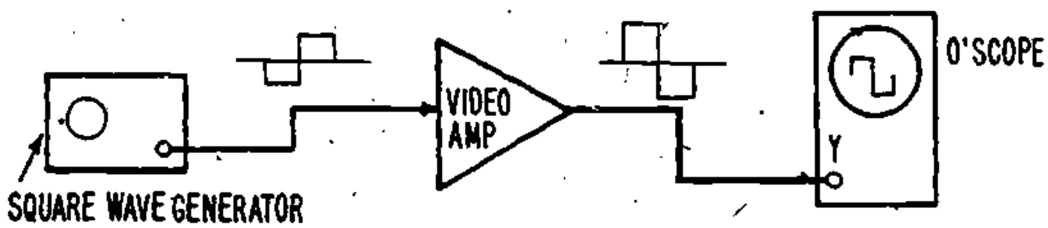


FIGURE 16

SQUARE WAVE-AMPLIFIER TEST

If a video amplifier can accurately reproduce a square wave input signal, it has a good frequency response. Any distortion of the square wave indicates a problem in the amplifier.

The relationship between frequency response and the ability to reproduce a square wave is due to the types of frequencies which make-up a square wave. In theory, a square wave is the result of combining a fundamental sine wave frequency with an infinite number of odd-numbered harmonic frequencies. A harmonic is just a multiple of the fundamental frequency. For example, the third harmonic for a fundamental frequency of 10 kHz is 30 kHz, and the fifth harmonic is 50 kHz.

Figure 17 illustrates the composition of a square wave made by combining a typical fundamental frequency with its third and fifth harmonics.

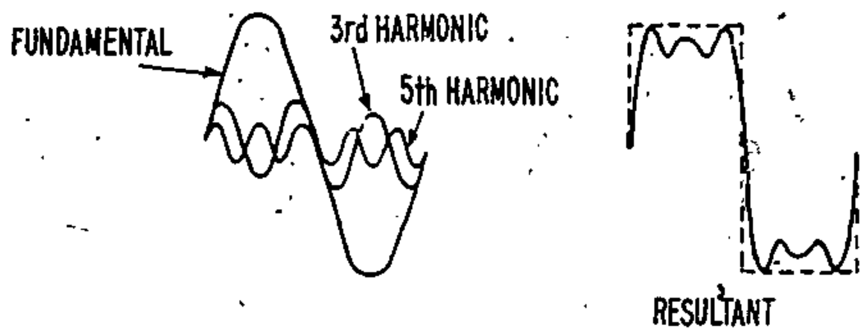
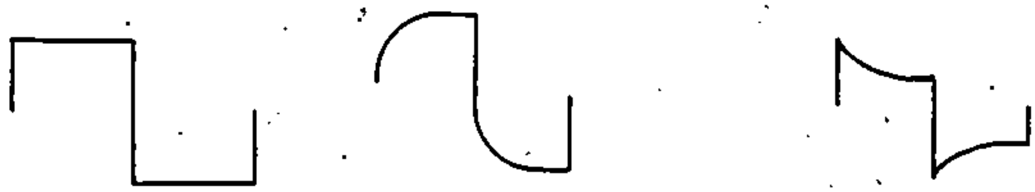


FIGURE 17

COMPOSITION OF SQUARE WAVE

In the figure, the individual frequency waveforms are on the left, and the combination waveform is on the right. Notice that a fairly good square wave results. In actual practice, the combination of a fundamental frequency and the first 10 odd-numbered harmonics produces an excellent square wave.

Now if a video amplifier can accurately reproduce a square wave signal, then it is capable of amplifying the fundamental frequency and at least the first 10 odd-numbered harmonics. Thus, any distortion of the square wave signal is a direct indicator of a lack in frequency response. Examples of this situation are shown in Figure 18.



GOOD FREQUENCY RESONSE POOR HIGH FREQUENCY RESPONSE POOR LOW FREQUENCY RESPONSE

FIGURE 18

SQUARE WAVE DISPLAYS AND FREQUENCY RESPONSE

In the figure, a video amplifier with a good frequency response reproduces the square wave on the left. An amplifier which reproduces the center waveform has poor high frequency response. The waveform on the right indicates poor low frequency response. This test method is simple and provides information suitable for troubleshooting video amplifier circuits. You will be given the opportunity to operate and troubleshoot a video amplifier in the Job Program for this lesson.

AT THIS POINT, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOU ANSWER ALL SELF-TEST ITEMS CORRECTLY, PROCEED TO THE JOB PROGRAM. 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 THE LEARNING CENTER INSTRUCTOR, UNTIL YOU CAN ANSWER ALL SELF-TEST ITEMS ON THE PROGRESS CHECK CORRECTLY.