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ABSTRACT

This individualized learning module on linear integrated circuits 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. Two lessons are included in the module: (1) Introduction to Linear Integrated Circuits and (2) Integrated Circuits Operational Amplifiers. Each lesson follows a typical format including a lesson overview, a list of study resources, the lesson content, a programmed instruction section, and a lesson summary. (Progress checks and other supplemental material are provided for each lesson in a separate document, CE 026 590.) (LRA)

Military Curricula for Vocational & Technical Education

CHIEF OF NAVAL EDUCATION AND TRAINING

CNTT-E-056

JULY 1980

BASIC ELECTRICITY AND ELECTRONICS.

MODULE 34. LINEAR INTEGRATED CIRCUITS.

STUDY BOOKLET.

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 Cen. .or 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
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The National Center Mission Statement

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

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

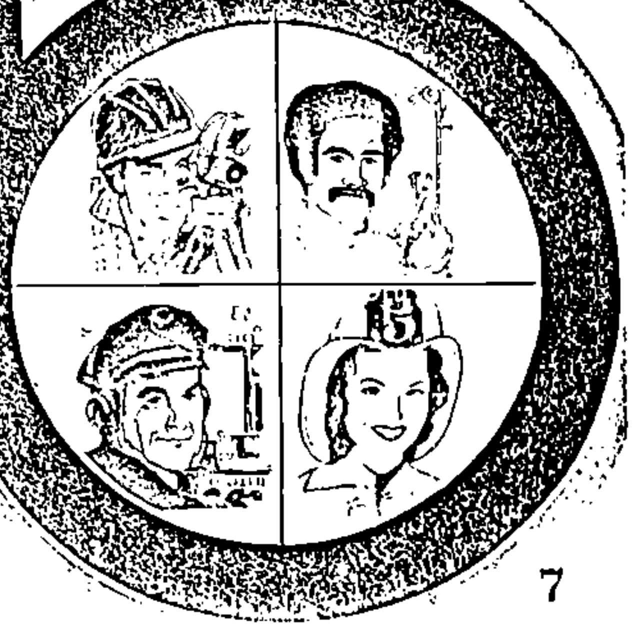
FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except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

THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education



PREPARED FOR

BASIC ELECTRICITY AND ELECTRONICS

CANTRAC A-100-0010

MODULE THIRTY FOUR

LINEAR INTEGRATED CIRCUITS

PREPARED BY

NAVAL EDUCATION AND TRAINING

PROGRAM DEVELOPMENT CENTER DETACHMENT

GREAT LAKES NAVAL TRAINING CENTER

GREAT LAKES, ILLINOIS 60088

STUDY BOOKLET

JULY 1980

OVERVIEW
BASIC ELECTRICITY AND ELECTRONICS
MODULE 34

Linear Integrated Circuits

In this module you will study different types of integrated circuits. You will learn how these devices are constructed and what precautions must be observed when working with them. You will study the base diagrams for many types of integrated circuits and examine data sheets that describe the input and output voltage requirements. You will learn about the characteristics and operation of IC operational amplifiers. You will examine troubleshooting procedures for testing these devices.

This module has been divided into two lessons:

Lesson 1 Introduction to Linear Integrated Circuits

Lesson 2 IC Operational Amplifiers

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BASIC ELECTRICITY AND ELECTRONICS

MODULE THIRTY FOUR

LESSON 1

INTRODUCTION TO LINEAR INTEGRATED CIRCUITS

JULY 1980

10

OVERVIEW
LESSON 1

Introduction To Linear Integrated Circuits

In this lesson you will learn about linear integrated circuits and their applications. You will learn about the specifications of these devices from data sheets, including packaging and lead identification methods. You will also become familiar with special handling precautions for integrated circuits.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

34.1.65 When the student completes this lesson (s)he will be able to IDENTIFY basic characteristics of linear integrated circuits to include definitions of terms, proper handling procedures, pin numbering systems and functions by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVES:

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

34.1.65.1 IDENTIFY the basic characteristics of a linear integrated circuit by choosing the correct set of characteristics from a choice of four. 100% accuracy is required.

34.1.65.2 IDENTIFY proper handling procedures for integrated circuits by choosing the correct statement from a choice of four. 100% accuracy is required.

34.1.65.3 IDENTIFY the set of integrated circuit (IC) packages that have have their leads properly numbered, given IC package drawings, by choosing the correct drawing or pin number from a choice of four. 100% accuracy is required.

34.1.65.4 DETERMINE the function of a given pin on an IC, given the IC's part number, data sheet, package type and pin number, by selecting the correct statement from a choice of four. 100% accuracy is required.

34.1.65.5 IDENTIFY the proper procedures for soldering and replacing ICs by selecting the correct statement from a choice of four. 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

Introduction To Linear Integrated Circuits

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 in:

Module Booklet:

Summary
Programmed Instruction
Narrative

Student's Guide:

Summary
Progress Check

Additional Material(s):

None.

Enrichment Material(s):

Robert G. Hibbert, A Basic Course in Integrated Circuits (Cleveland: Penton Publishing Company, 1968-69), Lessons 1, 2, 3, 4, 9, 10, 12, 13 and 14.

YOU MAY USE ANY, OR ALL, RESOURCES LISTED ABOVE, AND ALSO 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

Introduction To Linear Integrated Circuits

Linear Integrated Circuits (linear IC's) are devices that integrate (combine) discrete (single) components into one package.

Most linear IC's are amplifiers. Their outputs will be proportional to their inputs. The internal circuitry is complete with very few required external components. Feedback networks, compensation networks, and LC tanks are added where needed.

The size of the IC is made up mostly of packaging materials; the actual circuit is a paper-thin wafer of silicon called the substrate (see Figure 1).

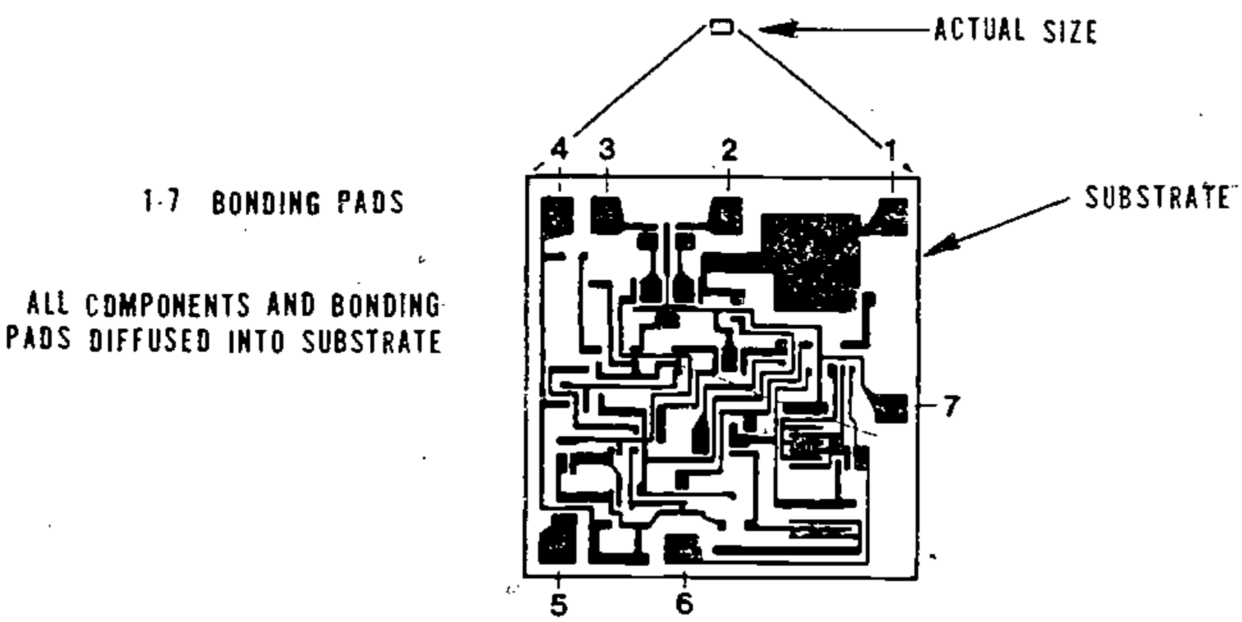
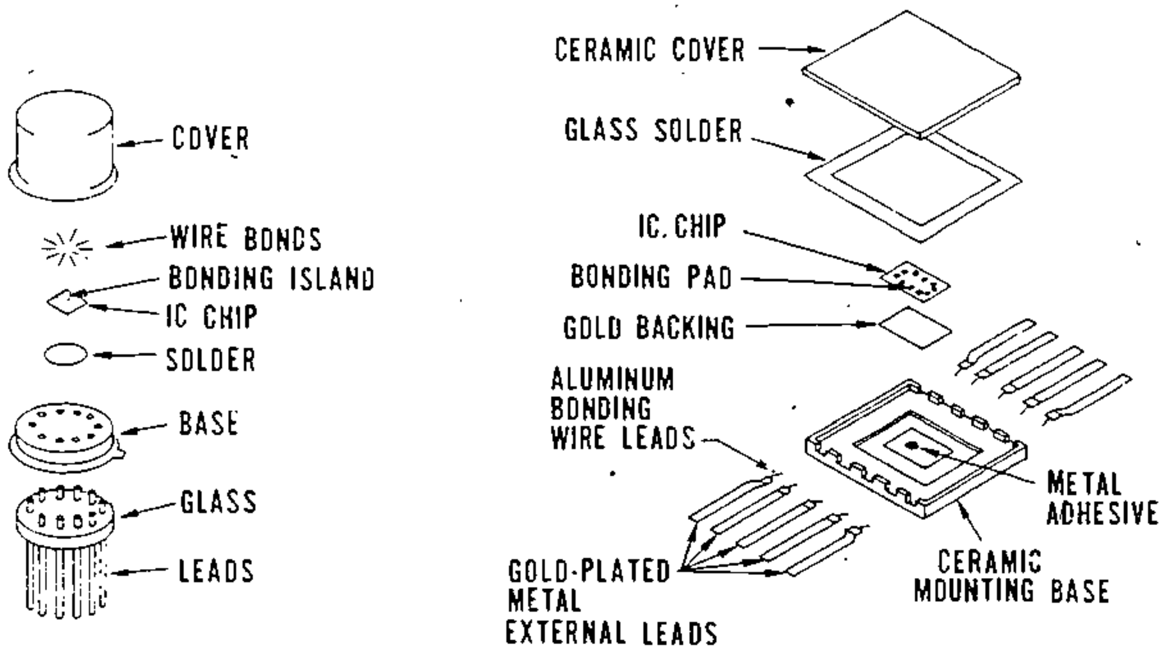


Figure 1

MAGNIFIED VIEW OF AN IC CHIP

The circuit's components are formed by a diffusion process (forcing molecules of other materials into the silicon). The completed circuit is called an "IC Chip". The IC chip is then mounted in a rugged package, like those shown in exploded views in Figure 2.



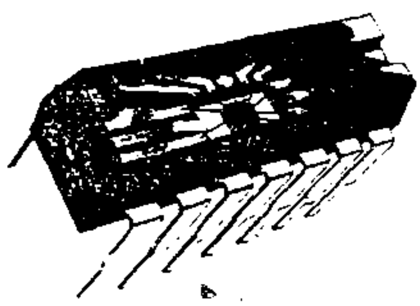


Figure 2

VARIOUS IC PACKAGES

The IC chip is soldered or cemented to a base and fine gold or aluminum wires are bonded to pads on the IC chip as shown in Figure 3.

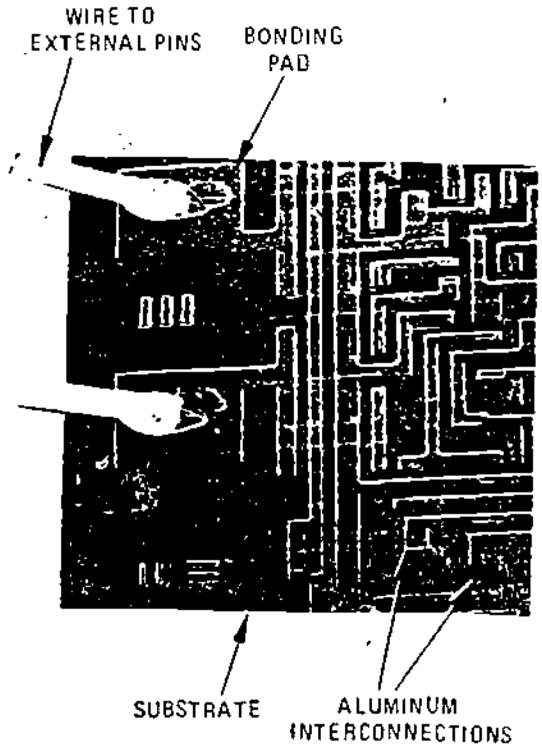


Figure 3

IC LEAD BONDING

The bonded wires are attached to the external pins, the cover is installed, and the IC package is then hermetically sealed. A hermetic seal is a seal that will not allow air, dust, or moisture to pass.

The result is a small, rugged device (see Figure 4).

Figure 4

IC RELATIVE SIZE

Even though installed IC's are very rugged devices, they may be damaged while being handled. One of the things that can destroy an IC circuit is the static electricity that builds up on your body. To prevent static electricity from damaging the IC, ground yourself for a couple of seconds before handling the IC. An IC's shipping wrapper is made of a material designed to protect the IC from static electricity. Therefore, you should keep an IC in its shipping wrapper until you are ready to install it in a piece of equipment.

An IC may be mounted by soldering it onto a printed circuit board. The pads on the board should be spaced to accept the IC, but sometimes the IC leads do not line up with the holes in the pads. When this problem occurs, you must carefully bend the IC leads to make them line up properly. To do this you should use two small needlenose pliers: one to support the IC's leads, the other to make the bend (see Figure 5).

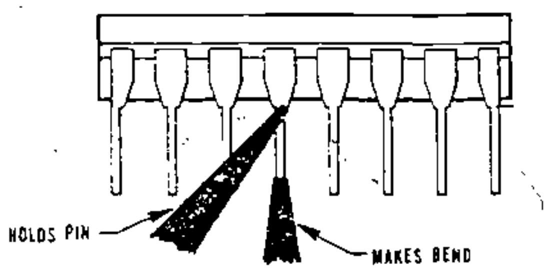


Figure 5

STRAIGHTENING IC LEADS

You must be careful not to bend a lead where it enters the IC as you do not want to break the hermetic seal. If this seal did break, the IC circuit might eventually short out from dust and moisture which could enter through the break.

Plug-in type IC's are attached to a printed circuit board by plugging them into an IC socket (see Figure 6).

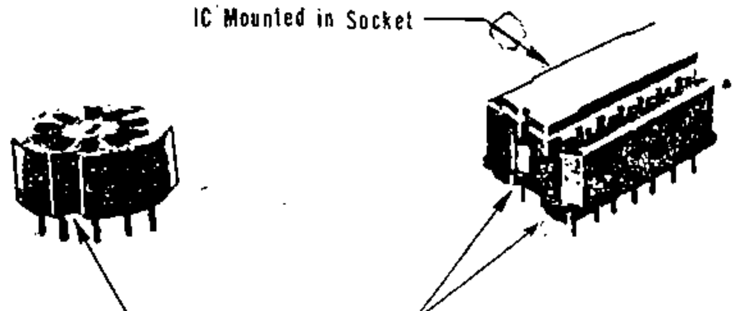


Figure 6

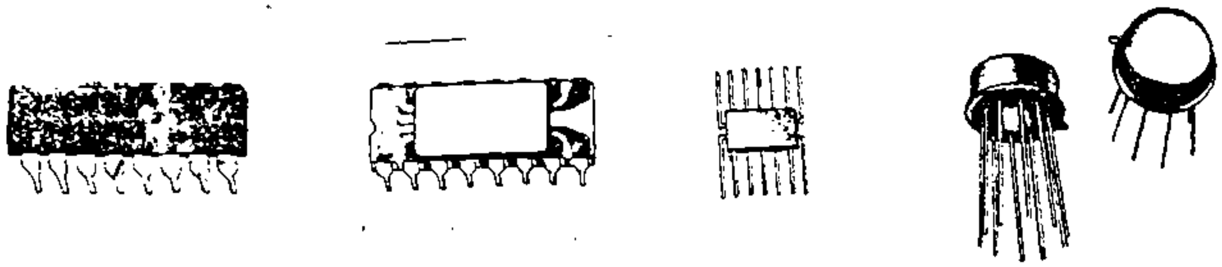
IC SOCKETS

To remove an IC from its socket, the equipment must first be deenergized. Removal is accomplished through the use of an IC removal tool called a DIP puller or package puller. If this tool is unavailable, grasp the IC between your thumb and forefinger and gently rock the IC out of the socket.

To put an IC into a socket, first make sure the pins line up with the socket's holes. If they don't, line up the leads by bending them with the two needle-nose pliers. Next, line up the reference mark on the IC (a notch, dot, impression, hole, or tab) with the socket's reference mark (a notch or cut off corner). Then, with the IC's leads lined up with the socket's holes, and the equipment deenergized, hold the IC between your thumb and forefinger and gently rock it into place.

One last handling precaution: Be carfeul not to drop or strike an IC; either the hermetic seal or one of the fine internal connecting wires may be broken.

IC's are manufactured in various package shapes (see Figure 7).

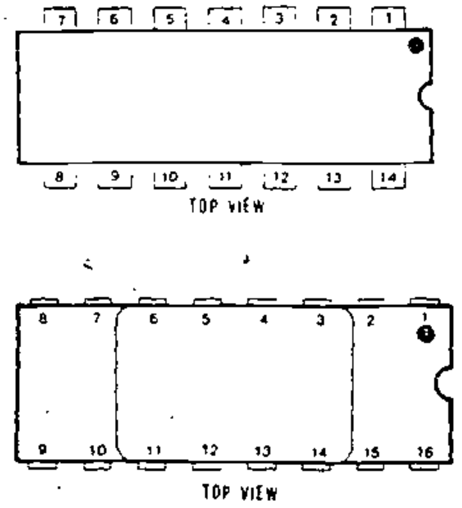


16-PIN DUAL-IN-LINE PLASTIC PACKAGE (DIP) 16-PIN DUAL-IN-LINE CERAMIC PACKAGE (DIP) 14-PIN FLAT PACK 10-PIN TO-5 CAN

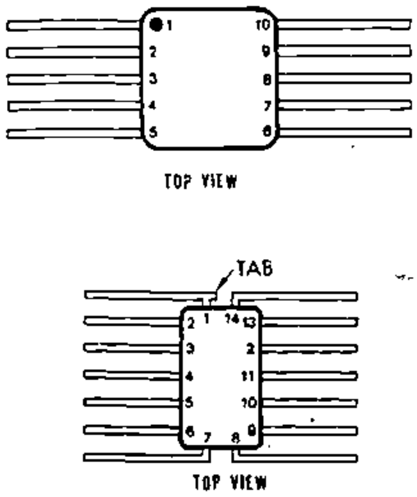
Figure 7

IC CASE STYLES

Each IC has a reference mark. The dual-in-line package or DIP (both plastic and ceramic) and the flat pack will have a notch, dot or impression on the package. When viewed from the top, pin 1 will be the first pin in a counter-clockwise direction directly next to the reference mark. Pin 1 may also be marked directly by a hole or notch in it or a tab on it (in this case pin 1 is the counting reference). When viewed from the top, all other pins are numbered consecutively in a counterclockwise direction from pin 1 (see Figure 8).



DIP Packages



Flat Pack Packages

Figure 8

IC PIN NUMBERING

The TO-5 can has a tab for the reference. When numbering the leads you must view the TO-5 can from the bottom. Pin 1 will be the first pin in a clockwise direction from the tab. All other pins will be numbered consecutively in a clockwise direction from pin 1 (see Figure 9).

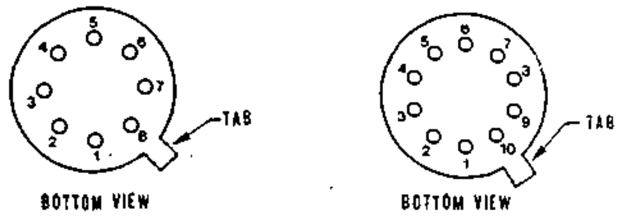


Figure 9

IC PIN NUMBERING

The schematic symbol for a linear IC is a triangle (most common) or a rectangle, as shown in Figure 10.

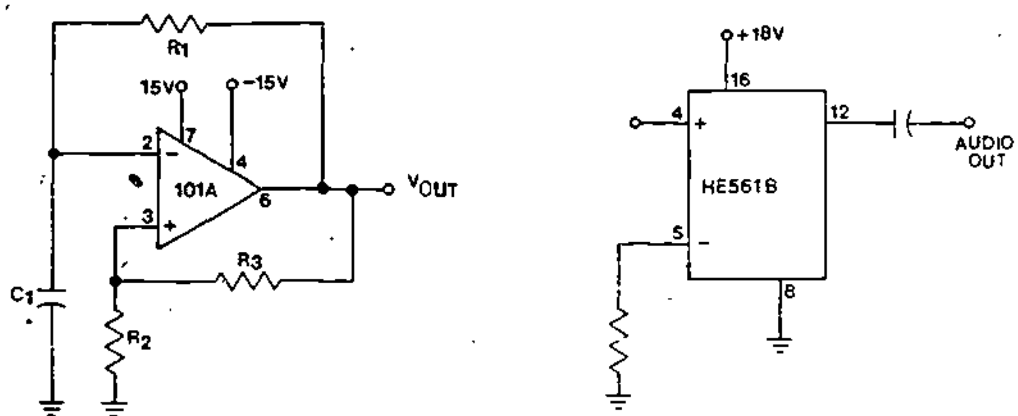


Figure 10

IC SCHEMATIC SYMBOLS

The IC's type number will be printed in the middle of the circuit symbol (101A, HE 561 B). The pin numbers will be printed outside the schematic symbol. The (+) and (-) in the triangle or rectangle indicate a non-inverting input (+) and an inverting input (-). These inputs plus the outputs and power supply connections are the only pin functions that are identified. To find the function of the other pins you must use a data sheet.

A data sheet may be just a schematic of the IC's internal circuitry with the pin functions labeled (see Figure 11).

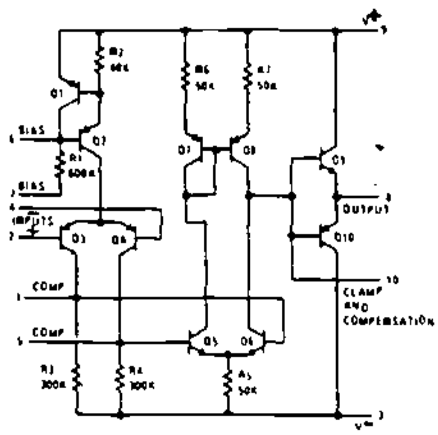


Figure 11

LH0001 SCHEMATIC DIAGRAM

The data sheet may also be a Manufacturer's Data Sheet as shown in Figure 12 on the next page. This data sheet is for a type of linear IC called an operational amplifier.

LH101 LH201 OPERATIONAL AMPLIFIER

FOR AMPLIFIERS, VOLTAGE COMPARATORS, LOW DRIFT SAMPLE-AND-HOLD

Features

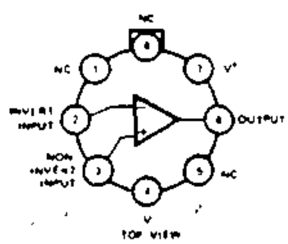
- Low Offsets and Temperature Drift
- Internal 30 pF Capacitor for Frequency Compensation
- Operation from ±5 to ±20 Volt Power Supplies
- Low Current Drain, 1.8 mA at ±20 Volts Typical
- Continuous Short-Circuit Protection
- No Latch Up When Common Mode Range Is Exceeded
- Same Pin Configuration as 709 Amplifier

Description

The LH101/LH201 is stable for all feedback configurations, even with capacitive loads, with no external compensation capacitors. Low power dissipation permits high voltage operation across the full temperature range.

PIN CONFIGURATIONS

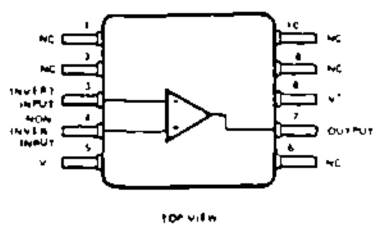
Metal Can Package



NOTE: Pin 4 CONNECTED TO CASE

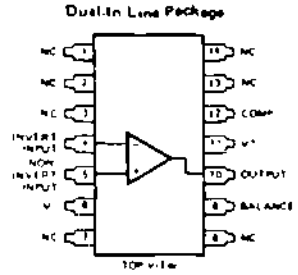
ORDER NUMBERS LH101H OR LH201H
SEE PACKAGE 1

Flat Package



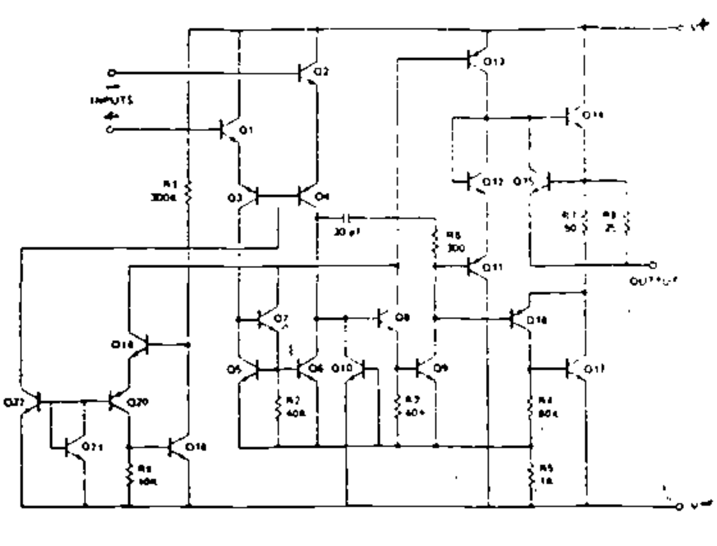
ORDER NUMBERS LH101F OR LH201F
SEE PACKAGE 4

Dual-In Line Package



ORDER NUMBERS LH101D OR LH201D
SEE PACKAGE 11

SCHEMATIC DIAGRAM



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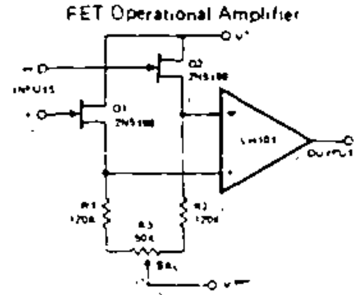
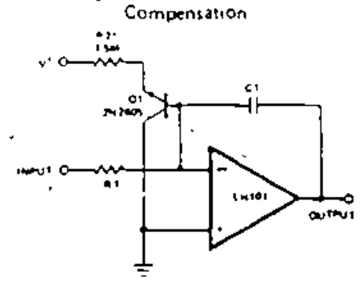
TYPICAL APPLICATIONS*

FET Operational Amplifier



Integrator with Bias Current Compensation



*SELECT FOR ZERO INTEGRATOR DRIFT

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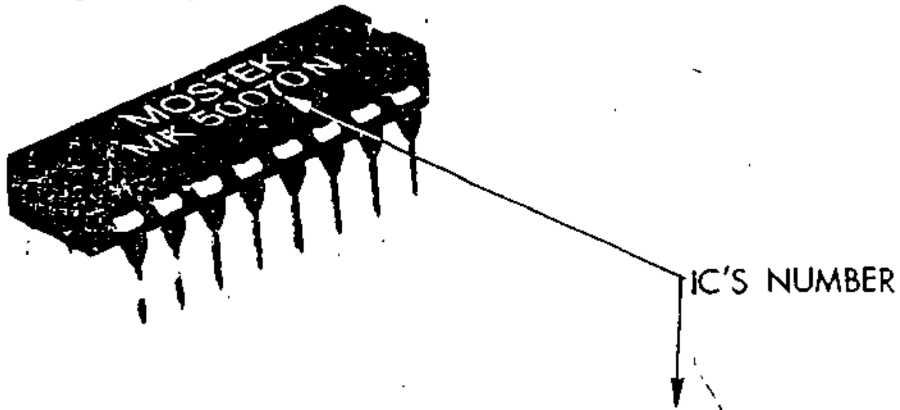
Figure 12

IC DATA SHEET

The manufacturer's data sheet will have either the pin configurations section, a schematic diagram, or both.

The required data sheets will be supplied with the equipment manuals. To select the correct data sheet for an IC, simply match the IC's type number, printed on the IC package or in the IC's circuit symbol, to the data sheet's type number (see Figure 13).



MK 50070 N

CMOS Oscillator and Divider | **MOSTEK**

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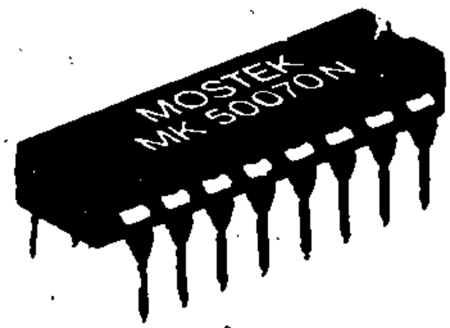
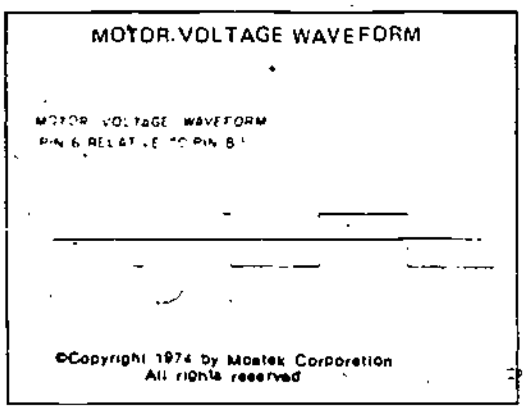
FEATURES.

- Low Power Dissipation
- 4 18 Volt Operating Range
- Internal Zener Regulation
- Internal Oscillator



DESCRIPTION:

The MOSTEK 50070 circuit is an oscillator and divider circuit for specialized applications. An external quartz crystal determines the oscillator frequency and the chip divides this frequency by 49152. The output is buffered by a 4 transistor bridge.



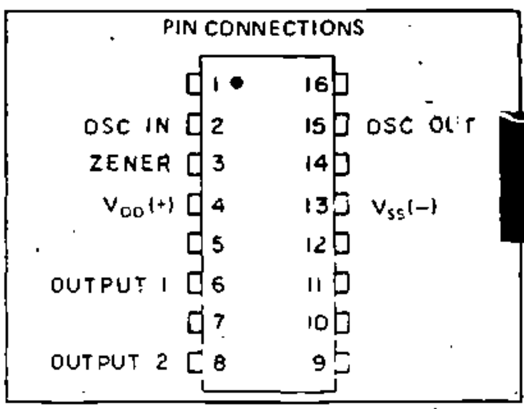


Figure 13

IC DATA SHEET

The information covered in this lesson applies to all ICs. ICs require a little more care in handling than transistors, but once installed in a circuit board they are very rugged and can operate for years without circuit failure.

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.

PROGRAMMED INSTRUCTION
LESSON 1

Introduction to Linear Integrated Circuits

TEST FRAMES ARE 3, 11, 15, 18, AND 21. GO FIRST TO TEST FRAME 3 AND SEE IF YOU CAN ANSWER THE QUESTIONS. FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. You may have heard the term Integrated Circuit, or IC, used before, especially if you have been shopping for a new stereo, television, or calculator. But, you may be thinking, "Just what is an integrated circuit?"

Well, an integrated circuit (IC) is a device which integrates (combines) discrete (single) components (transistors, diodes, resistors, capacitors, etc.) into one single package.

Most linear IC's are amplifiers. The output signal will be proportional to the input signal (the output waveshape is an amplified, and sometimes inverted, version of the input waveshape), as shown in Figure 1.

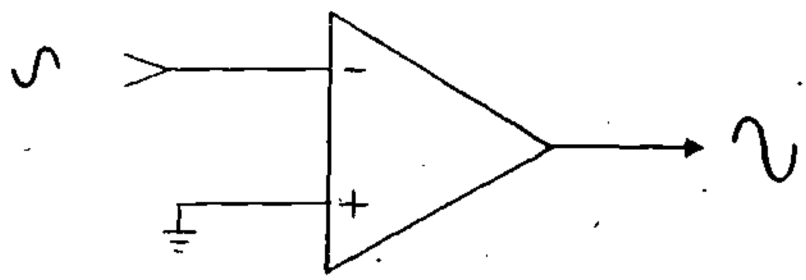


Figure 1

INTEGRATED CIRCUIT
(SCHEMATIC SYMBOL)

With a sine wave applied to the input of a linear IC, the IC's output will be a

a. square wave.

b. sine wave.

c. sawtooth.

---

b. sine wave.

2. Linear IC's are widely used as amplifiers and oscillators in electronic equipment. Some integrated circuits combine these functions to form an entire subsystem as shown in Figure 2.

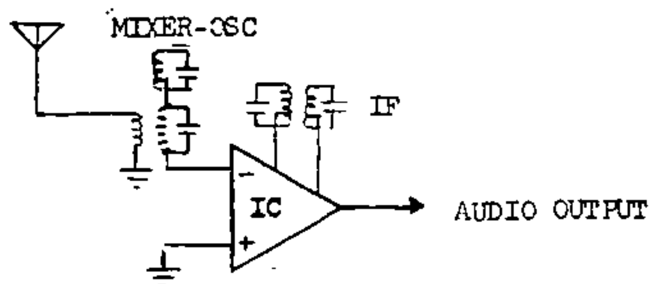


Figure 2

AM RECEIVER INTEGRATED CIRCUIT

Basically, the linear IC is a complete circuit. With the exception of a small number of parts, all of the parts that make up the circuit will be contained within the IC package. The external components are for feedback networks, compensation networks, and LC tanks (when needed). Leaving these parts out of the IC package allows us to use the same IC for a number of different applications. There are some special purpose IC's which have all components in one package. These IC's require only input, output and power connections.

One IC could replace a

a. transistor.

b. resistor.

c. complete circuit containing many components.

d. diode.

---

c. complete circuit containing many components.

3. 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 TEST QUESTIONS.

1. A linear integrated circuit is a device that
   a. is manufactured with actual components and produces a square wave output from any signal applied to its input.
   b. is manufactured with discrete components and has an output that is proportional to its input.
   c. combines a complete circuit into one package and produces a square wave at its output from any signal applied to its input.
   d. combines a complete circuit into one package and has an output that is proportional to its input.
2. What components are likely to be external to an IC?
   a. Diodes
   b. Resistors
   c. Inductors
   d. Transistors

27

1. d. combines a complete circuit into one package and has an output that is proportional to its input.

2. c. Inductors

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 AGAIN BEFORE TAKING TEST FRAME 3 AGAIN.

4. If you could open up an IC, you might be slightly surprised to see what is inside. Instead of a bunch of miniature components, you would see a paper-thin wafer of silicon, called the substrate, whose size is dependent upon circuit complexity. Figure 3 shows a 23 transistor amplifier which measures .14 cm long and .14 cm wide.

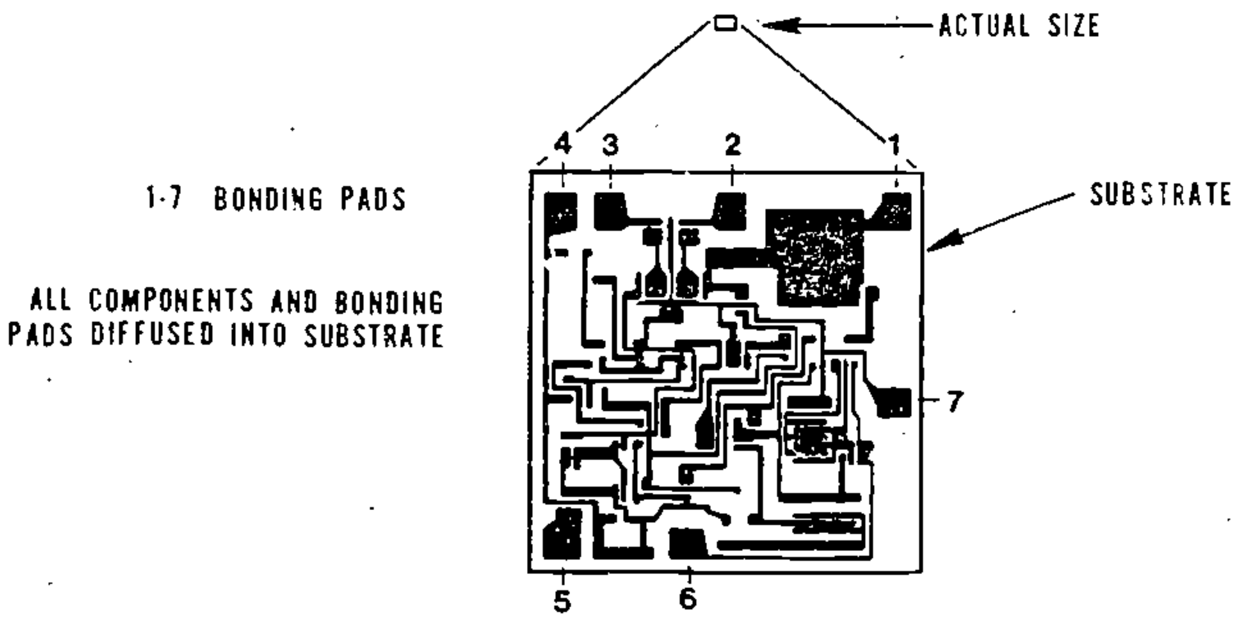


Figure 3

MAGNIFIED VIEW OF AN IC CHIP

The materials that make up the circuit's components and the interconnections are formed in the silicon wafer by diffusion (forcing molecules of other materials into the silicon). The resulting circuit is called an IC "chip".

No response required

(5.) The IC chip must be mounted in a package that is easy to handle and ruggedized to protect the chip. Connections to various points in the chip's circuitry are also provided. Figure 4 shows three of these packages.

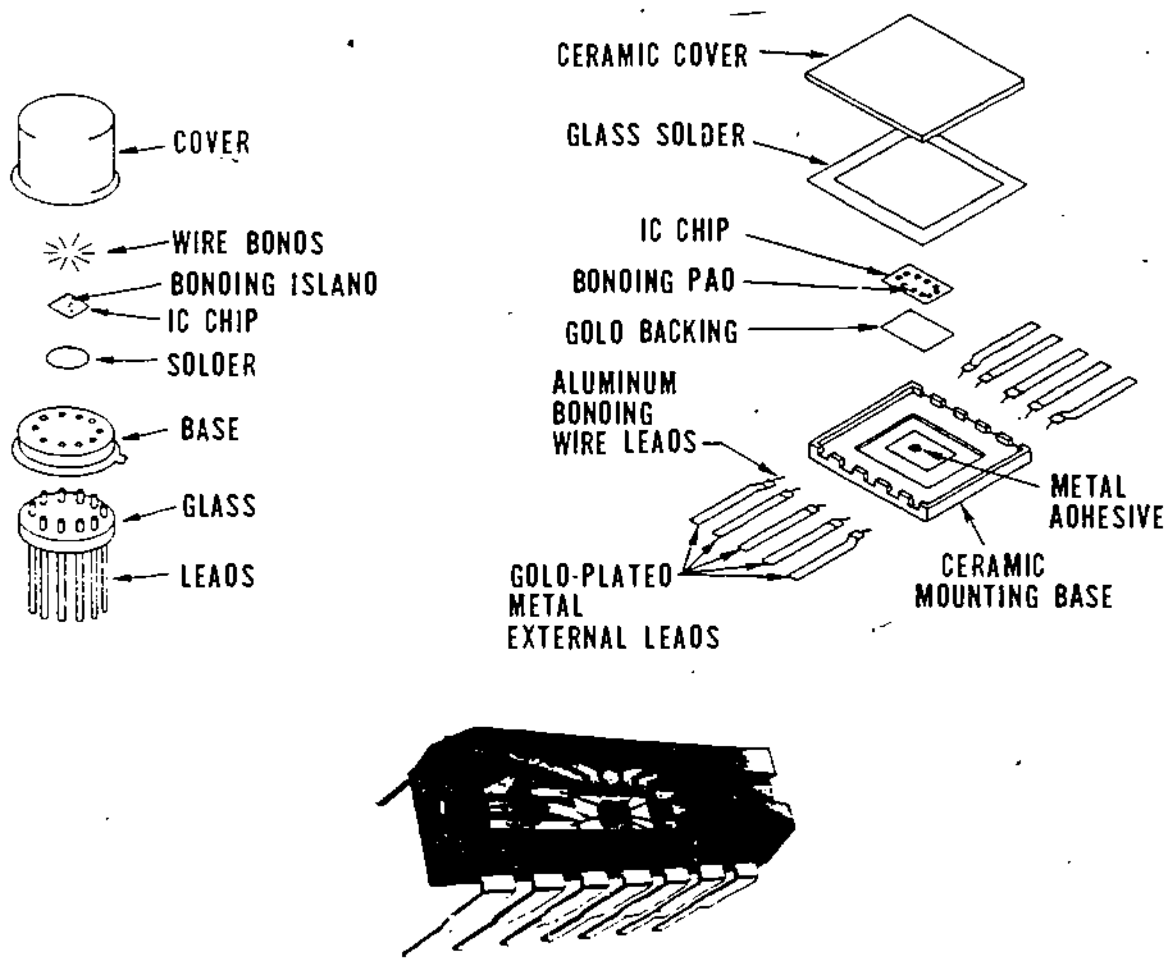


Figure 4

The IC chip is first soldered or cemented to a base which will hold it rigidly in place. Then, fine gold or aluminum wires (as fine as human hair) are bonded to pads on the substrate which are connected to the components (see Figure 5).

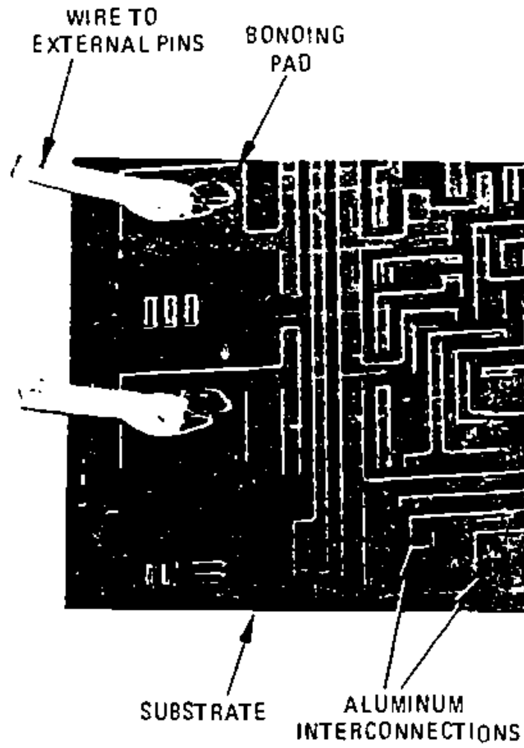


Figure 5

LEAD BONDING IN IC'S

The wires that are bonded to the pads on the substrate are also attached to the external pins. After the cover is installed, the package is hermetically sealed. A hermetic seal is a seal that will not allow air, dust or moisture to pass.

The result is a very small and rugged package. See Figure 6.

Figure 6

RELATIVE SIZE OF IC

(1) The external pins on an IC package are connected to the pads on an IC chip with

a. a printed circuit board.

b. coaxial cable.

c. very fine gold or aluminum wires.

d. standard insulated circuit hook-up wire.

(2) The package the IC chip is mounted in makes the IC package

a. a rugged device.

b. hard to handle because of its large size.

c. a very fragile device.

(3) To protect the IC chip from moisture and dust, the IC package has a

a. substrate.

b. hermetic seal.

c. metal base.

---

(1) c. very fine gold or aluminum wires.
(2) a. a rugged device.
(3) b. hermetic seal.

(6.) On days when the air is very dry (low humidity), you may notice that it is easy to get a shock when you touch metal, especially after walking across carpeting or getting up from a plastic or leather covered chair. This shock is caused by a charge that builds up on your body. The charge is shorted to ground through the metal you touch. This charge is called static electricity.

The voltage potential of the charge that builds up on your body may reach as high as 1000 volts. This voltage potential is high enough to destroy an IC's circuitry. To protect the IC from the static charge, the IC is shipped in a special conductive wrapper. The shipping wrapper is conductive to keep all of the IC's leads at the same potential. With all of the leads at the same potential the static electricity cannot discharge through the IC's circuitry.

When handling and storing an IC, it (is/is not) necessary to keep the IC in its shipping wrapper until you are ready to install it to protect it from static electricity.

---

is

(7.) So, how do you handle an IC to keep from damaging it with the static charge you may have built up? By simply grounding yourself for a couple of seconds to allow any charge to drain off before you touch the IC.

There are plenty of grounding places all around you. Any bare metal surface that is grounded works very well. One excellent source is any bare metal on a piece of test equipment that is plugged in.

If you remember to ground yourself before you pick up an IC and after any large physical movements (such as standing up, sitting down, or walking), you will not have any problems with static electricity while you handle the IC.

Before you pick up an IC that is not in its shipping wrapper, you (will/will not) have to ground yourself to protect the IC from damage by static electricity.

---

will

8. Most IC's are mounted on printed circuit boards and soldered in place. The pads on the boards are placed so that the IC may be mounted easily. However, you may have to bend the IC's leads a small amount to align them with the holes in the pads. To do this you must use two small needlenose pliers; one to hold and support the lead, the other to make the bend. See Figure 7.

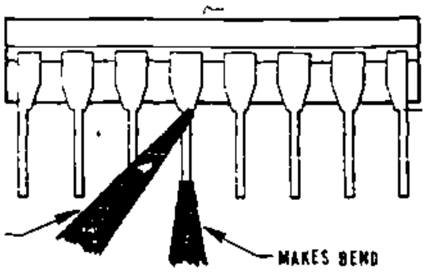


Figure 7

IC LEAD STRAIGHTENING

You must be very careful that you don't bend the lead where it enters the IC package as you may break the hermetic seal.

An IC's leads should be bent with

a. your fingers.

b. two needlenose pliers.

c. one needlenose pliers.

The internal circuitry may develop shorts when exposed to

a. moisture.

b. dust.

c. either moisture or dust.

---

b. two needlenose pliers.
c. either moisture or dust.

---

9. Not all IC's are soldered into place on a printed circuit board; some are plugged into a special IC socket which is soldered into place on the printed circuit board. See Figure 8.

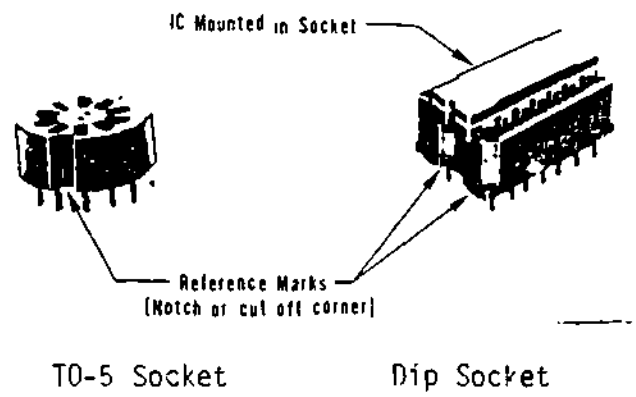


Figure 8

IC SOCKETS

To remove an IC from its socket you must first make sure the equipment is deenergized or the IC may be damaged when you remove it. Removal is accomplished through the use of an IC removal tool, most often called a DIP puller or package puller. This tool is needed in order to handle the IC firmly and securely without damaging it. In the event an IC removal tool is unavailable, grasp the IC between your thumb and forefinger and gently rock it out of its socket.

To put an IC into a socket first make sure that the power is off. Next, line up the IC's reference mark (a notch, hole, dot, or tab) with the socket's reference mark (a notch or cut off corner as shown in Figure 8). Then, holding the IC between your thumb and forefinger, gently rock the IC into the socket (you may have to bend some of the IC's leads to make them match the socket's holes).

(1) When installing or removing an IC from a piece of equipment, the equipment must be (energized/deenergized).

(2) When an IC is removed from an IC socket you should

a. gently rock it while lifting it out.

b. pry it out with a small, flat bladed screwdriver.

c. grasp it and pull it straight out without rocking it.

(3) The reference mark on an IC must be ____________________ the socket's reference mark before the IC is plugged into the socket.

a. at the opposite end from

b. one pin in a clockwise direction from

c. in line with

(1) deenergized
(2) a. gently rock it while lifting it out.
(3) c. in line with

10. While handling an IC, you should be careful that you do not drop or strike the IC. The sudden jarring impact could break the hermetic seal or one of the fine gold or aluminum interconnecting wires. If the IC were dropped, it would be easy to tell if one of the interconnecting wires broke as the IC would not work properly. However, if the hermetic seal broke you wouldn't know it. The IC would work properly, but its life expectancy (the amount of time a device is expected to operate) would be greatly shortened.

To prevent breaking an IC's fine interconnecting wires or hermetic seal, you should not __________ the IC.

a. drop

b. strike

c. jar

d. drop, strike or jar

d. drop, strike or jar

(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 TEST QUESTIONS.

1. When handling an IC you should NOT

   a. bend the leads with two needlenose pliers.

   b. deenergize the equipment in which you are replacing an IC.

   c. ground yourself before touching an IC.

   d. wiggle any of the IC's leads.

2. IC's may be mounted on printed circuit boards by

   a. soldering.

   b. sockets.

   c. stand-offs.

   d. either soldering or sockets.

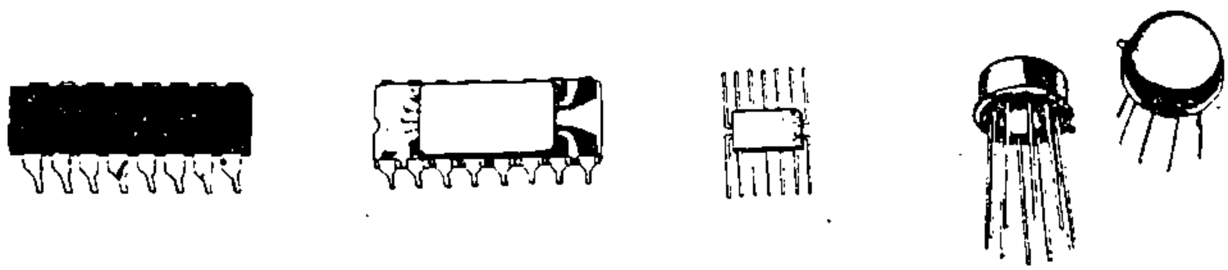
---

1. d. wiggle any of the IC's leads.

2. d. either soldering or sockets.

IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 15. OTHERWISE GO BACK TO FRAME 4 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 11 AGAIN.

(12.) IC packages are manufactured in various shapes and sizes as shown in Figure 9.



16-PIN DUAL-IN-LINE PLASTIC PACKAGE (DIP) | 16-PIN DUAL-IN-LINE CERAMIC PACKAGE (DIP) | 14-PIN FLAT PACK | 10-PIN TO-5 CAN

Figure 9

PIN NUMBERING METHODS

The pin numbering system for each of the packages is standard. The plastic and ceramic Dual-in-line Package (or DIP), will have a reference mark at one end. This reference mark will be either a dot (painted on or an impression), a notch or hole in pin number 1, or a notch in the end of the package. When the IC is viewed from the top, pin number 1 will be the first pin going in a counterclockwise direction next to the impression, dot or notch. If there is no dot, notch, or hole, pin number 1 may be directly identified by a hole or notch in the lead itself.

Once pin number one is located, all other pins are numbered consecutively in a counterclockwise direction from pin 1, see Figure 10.

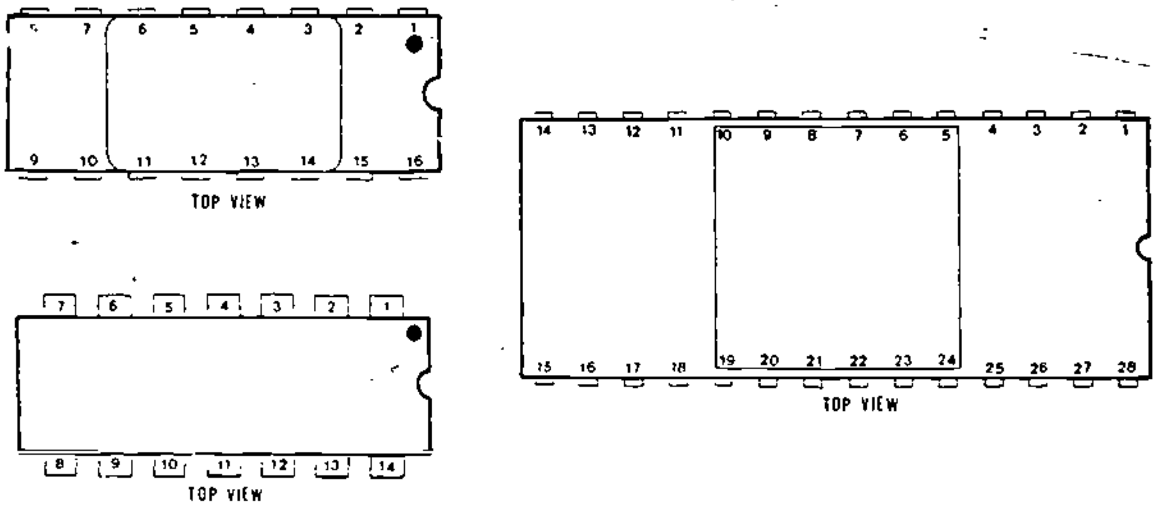


Figure 10

DIP PIN NUMBERING

When the DIP IC is viewed from the bottom, the pins must be numbered going in a (clockwise/counterclockwise) direction from the reference mark.

---

clockwise

---

13. The flat pack IC may have any one of the reference marks used on the DIP (dot, notch, impression, hole or notch in pin 1). There is also one other possible reference mark. Pin 1 may have a tab on it (see Figure 11).

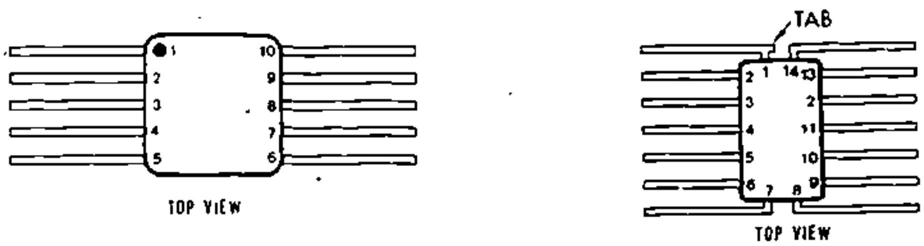


Figure 11

FLAT PACK IC PIN NUMBERING

As with the DIP, when viewed from the top, pin number 1 on the flat pack is the first pin in a counterclockwise direction from the reference mark. Or pin number 1 may be marked directly with a hole, notch, or tab. All other pins are numbered consecutively in a counterclockwise direction from pin 1.

Which of the illustrations below shows the correct path to follow when numbering the leads of a flat pack?

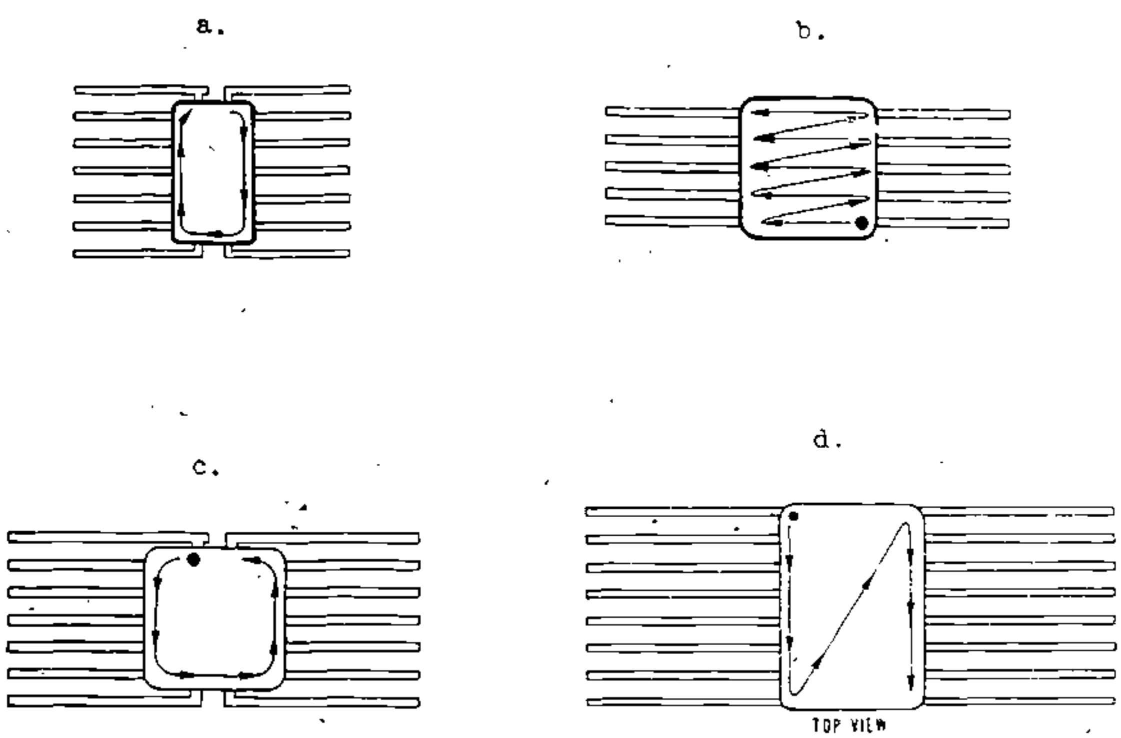
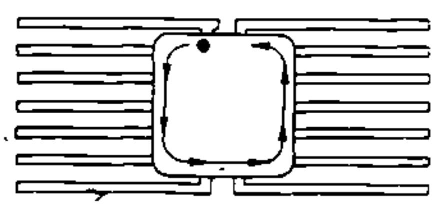


Figure 12

---

c.



(11.) The TO-5 type IC package looks like a transistor package (see Figure 13).

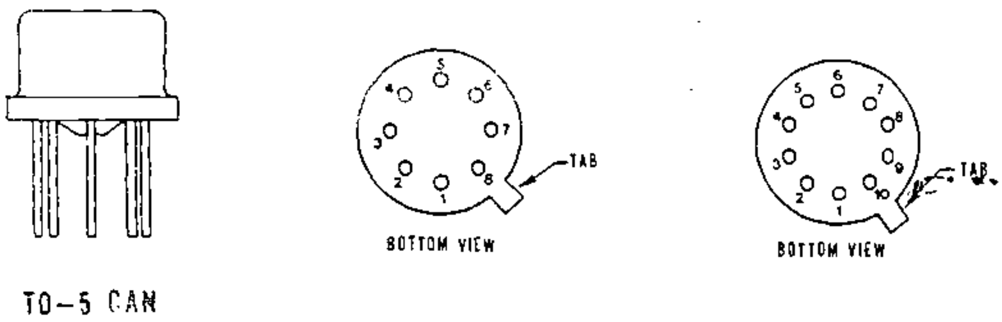


Figure 13

TO-5 PIN NUMBERING

Notice that to number the leads, you view the TO-5 can from the <u>bottom</u>. Also, the tab on the can is the reference and pin 1 will be the first pin in a <u>clockwise</u> direction from the tab. Looking at the <u>bottom</u>, all of the other pins are numbered consecutively in a <u>clockwise</u> direction from pin 1.

Which of the illustrations below shows the correct placement of pin 1 on the TO-5 can (bottom view)?

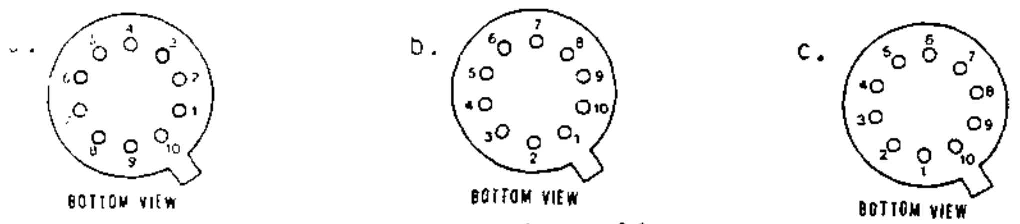
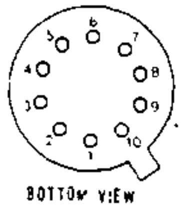


Figure 14

---

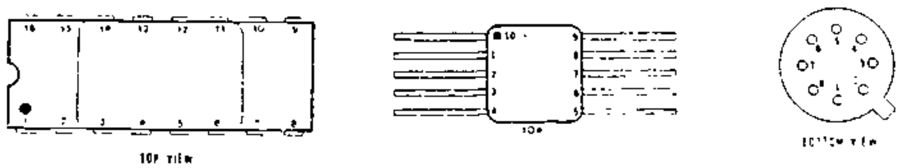
c.



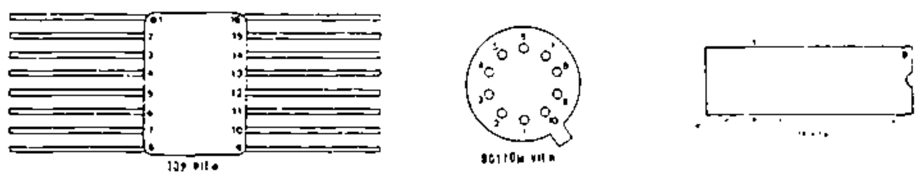
(15.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTION AND COMPARE YOUR ANSWER WITH THE CORRECT ANSWER GIVEN AT THE TOP OF THE PAGE FOLLOWING THE TEST QUESTION.

1. In which of the following sets of IC packages are the leads of all three packages numbered correctly?

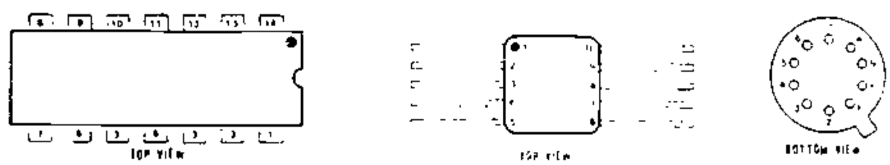
a.



b.



c.



d.

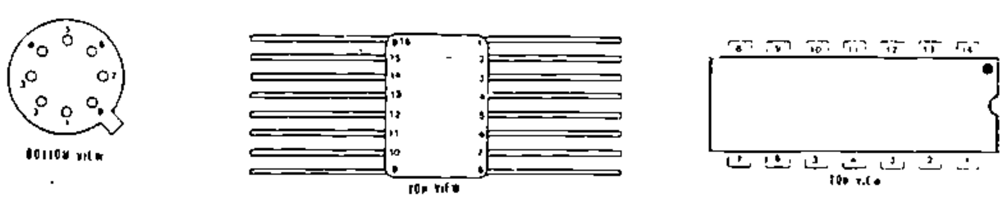
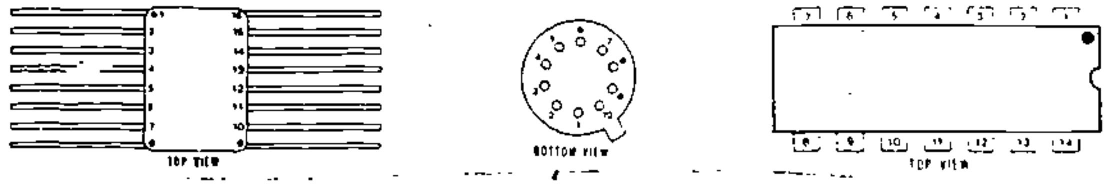


Figure 15

b.



IF YOUR ANSWER MATCHES THE CORRECT ANSWER, YOU MAY GO ON TO TEST FRAME 16. OTHERWISE, GO BACK TO FRAME 12 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 15 AGAIN.

(16.) The linear IC is represented in a schematic by a triangle or rectangle (see Figure 16).

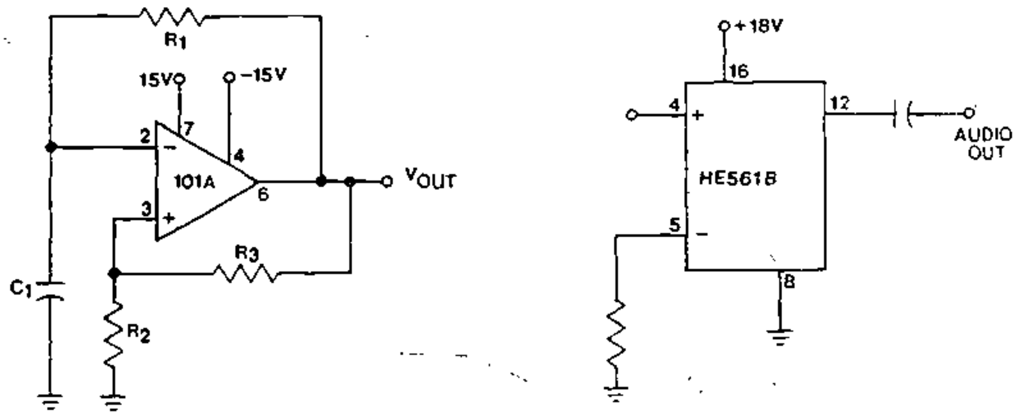


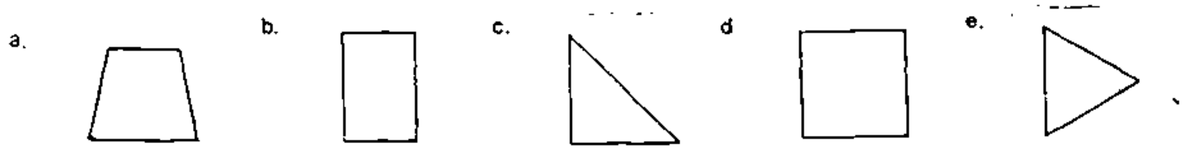
Figure 16

IC SCHEMATIC SYMBOLS

The IC's type number is located in the middle of the triangle (101 A) or rectangle (HE 561 B). The pin numbers are outside the triangle or rectangle. The (+) and (-) in the triangle or rectangle indicate the non-inverting input (+) and the inverting input (-). A signal applied to the (+) input will NOT be inverted at the output (the output will be in phase with the input). A signal applied to the (-) input will be inverted at the output (the output will be 180° out-of-phase with the input).

The inputs are sometimes identified by (+) or (-), but the functions of the other pins may not be shown. To find out what each pin is used for, you must refer to a data sheet.

(1) Which of the geometric shapes below represents a linear IC?



f. a and c

g. b and e

h. b, d and e

i. a, b, c, d and e

(2) The type number of the linear IC will be located (inside/outside) the IC's schematic symbol and the pin numbers will be located on the (inside/outside).

(3) In the circuit symbol for a linear IC, the inputs are

a. labeled "inverting input" and "non-inverting input".

b. pin 1 for inverting and pin 2 for non-inverting.

c. (+) for the non-inverting input and (-) for the inverting input; both (+) and (-) are located inside the circuit symbol.

d. (-) for the non-inverting input and (+) for the inverting input; both (-) and (+) are located outside the circuit symbol.

---

(1) g. b and e

(2) inside, outside

(3) c. (+) for the non-inverting input and (-) for the inverting input; both (+) and (-) are located inside the circuit symbol.

17. Each type of IC will have its own data sheet. Sometimes the data sheet is simply a schematic diagram with the pins shown as terminals and labeled as to their function (see Figure 17).

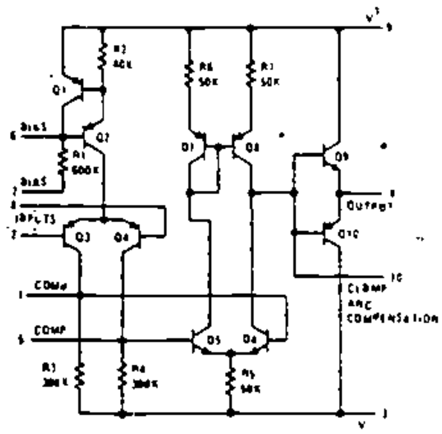


Figure 17

LH 0001 SCHEMATIC DIAGRAM

Although some of the pins may not be labeled in the schematic, the inputs, outputs and power connections are labeled,

Another type of data sheet is the manufacturer's data sheet, shown in Figure 18. This data sheet is for a type of linear IC called an Operational amplifier.

45

LH101 LH201 OPERATIONAL AMPLIFIER

FOR AMPLIFIERS, VOLTAGE COMPARATORS, LOW DRIFT SAMPLE-AND-HOLD

Features

- Low Offsets and Temperature Drift
- Internal 30 pF Capacitor for Frequency Compensation
- Operation from ±5 to ±20 Volt Power Supplies
- Low Current Drain, 1.8 mA at ±20 Volts Typical
- Continuous Short-Circuit Protection
- No Latch Up When Common Mode Range Is Exceeded
- Same Pin Configuration as 709 Amplifier

Description

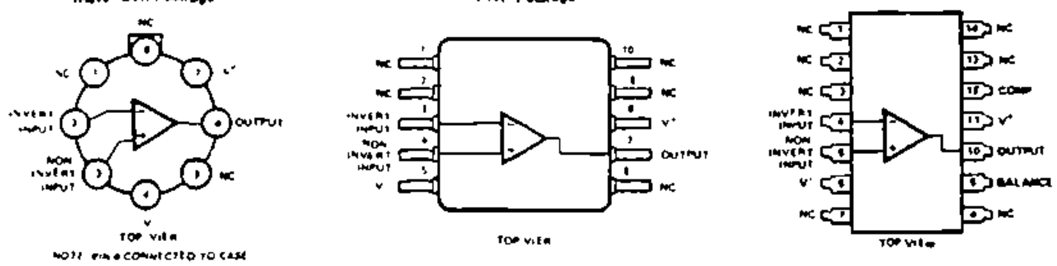
The LH101/LH201 is stable for all feedback configurations, even with capacitive loads, with no external compensation capacitors. Low power dissipation permits high voltage operation across the full temperature range.

PIN CONFIGURATIONS

Metal Can Package

Flat Package

Dual-In-Line Package

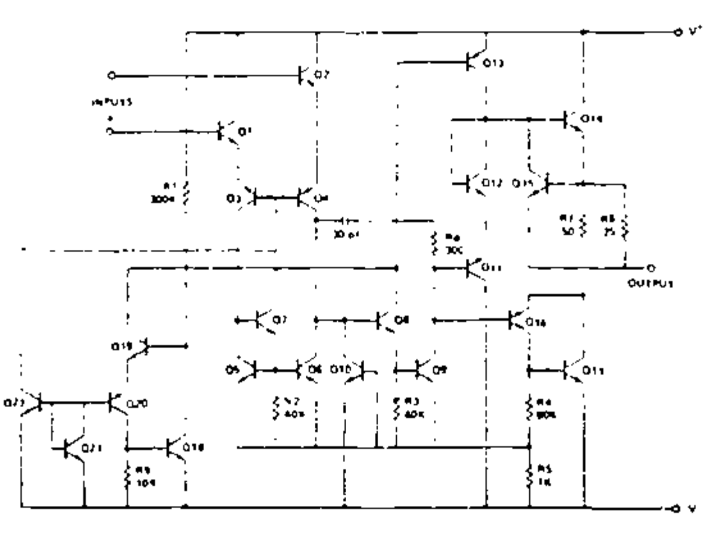


ORDER NUMBERS LH101H OR LH201H
SEE PACKAGE 1

ORDER NUMBERS LH101F OR LH201F
SEE PACKAGE 4

ORDER NUMBERS: LH101D OR LH201D
SEE PACKAGE 11

SCHEMATIC DIAGRAM



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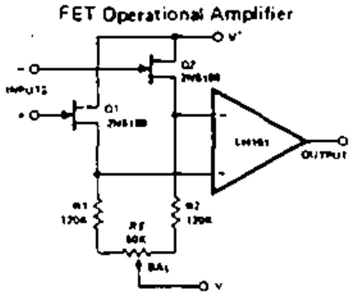
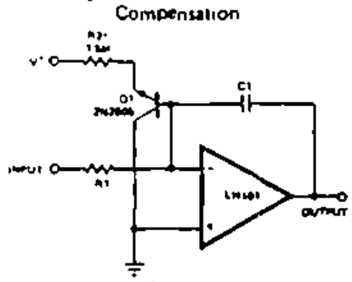
TYPICAL APPLICATIONS

FET Operational Amplifier



Integrator with Bias Current Compensation



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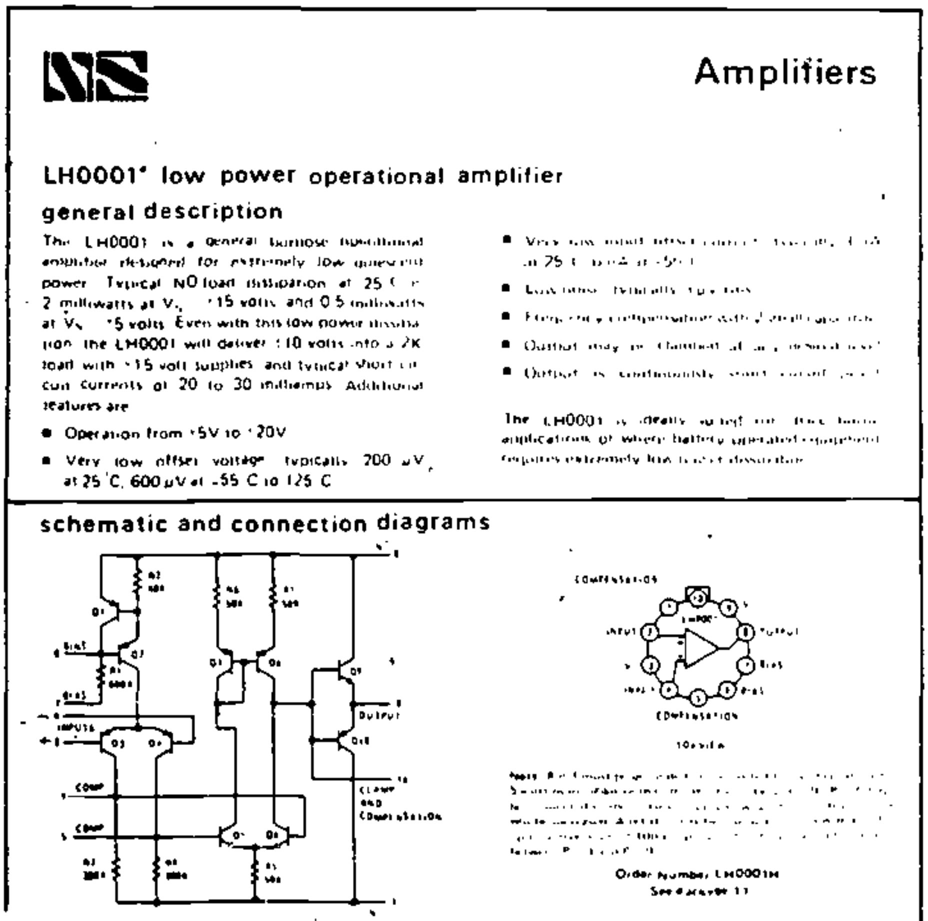
*NC - not connected internally

Figure 18

IC DATA SHEET

This type of data sheet will normally show the pin configurations with all pins labeled. If the pin configurations are not shown, there may be a schematic diagram showing pin functions. Some data sheets give both pin configuration and schematic diagrams as is the case in Figure 19. Figure 19 illustrates another manufacturer's data sheet with all of the pin functions shown.



Amplifiers

LH0001* low power operational amplifier

general description

The LH0001 is a general purpose operational amplifier designed for extremely low quiescent power. Typical NO load dissipation at 25°C is 2 milliwatts at V_S = ±15 volts and 0.5 milliwatts at V_S = ±5 volts. Even with this low power dissipation the LH0001 will deliver ±10 volts into a 2K load with ±15 volt supplies and typical short circuit currents of 20 to 30 milliamps. Additional features are

- Operation from ±5V to ±20V
- Very low offset voltage typically 200 μV at 25°C, 600 μV at -55°C to 125°C
- [illegible]
- [illegible]
- [illegible]
- [illegible]
- [illegible]

The LH0001 is ideally suited for [illegible] applications or where battery operated equipment requires extremely low [illegible] dissipation.

schematic and connection diagrams

Order Number LH0001H

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Figure 19

IC DATA SHEET

No response required.

(18.) 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 TEST QUESTIONS.

REFER TO THE FIGURE BELOW TO ANSWER QUESTION 1.

schematic and connection diagrams

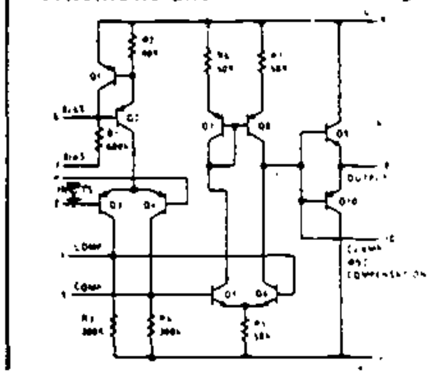

Figure 20

1. The function of pin 4 is

   a. negative power (V-).

   b. inverting input.

   c. non-inverting input.

   d. bias.

REFER TO THE FIGURE ON THE FOLLOWING PAGE TO ANSWER QUESTION 2.

2. Pin 7 on the dual in-line package (DIP) is

   a. the output.

   b. not connected internally.

   c. positive power (V+) in.

   d. negative power (V-) in.

LH101 LH201 OPERATIONAL AMPLIFIER

FOR AMPLIFIERS, VOLTAGE COMPARATORS, LOW DRIFT SAMPLE-AND-HOLD

Features

- Low Offsets and Temperature Drift
- Internal 30 pF Capacitor for Frequency Compensation
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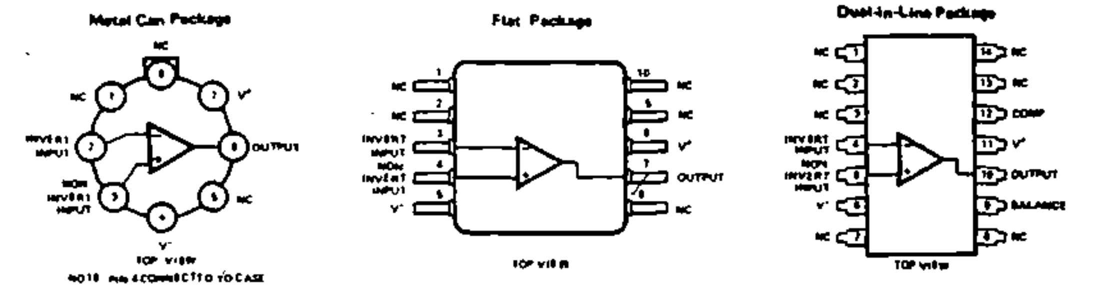
- Same Pin Configuration as 709 Amplifier

Description

The LH101/LH201 is stable for all feedback configurations, even with capacitive loads, with no external compensation capacitors. Low power dissipation permits high voltage operation across the full temperature range.

PIN CONFIGURATIONS

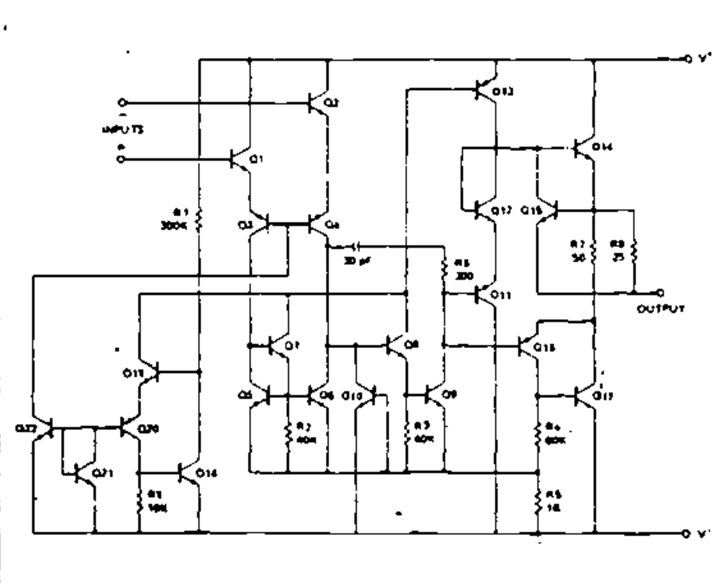


ORDER NUMBERS: LH101H OR LH201H SEE PACKAGE 1

ORDER NUMBERS: LH101F OR LH201F SEE PACKAGE 4

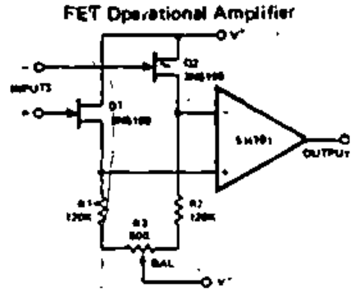
ORDER NUMBERS: LH101D OR LH201D SEE PACKAGE 11

SCHEMATIC DIAGRAM



TYPICAL APPLICATIONS

FET Operational Amplifier



Integrator with Bias Current Compensation

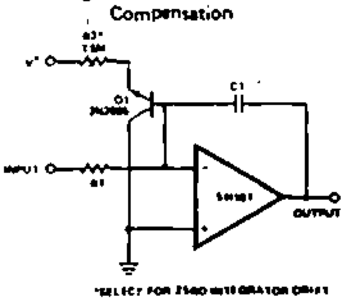


Figure 21

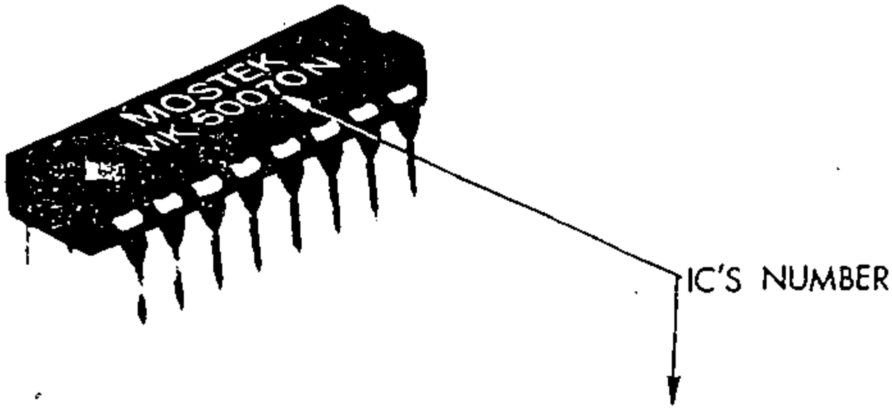
*NC - not connected internally

1. b. inverting input.

2. b. not connected internally.

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU MAY GO ON TO TEST FRAME 21. OTHERWISE GO BACK TO FRAME 16 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 18 AGAIN.

19. Although the required manufacturer's IC data sheets or schematics will be provided with the equipment manuals, you must be able to select the correct data sheet for a particular type of IC. To do this you simply match the IC type number, which is printed on the IC package or in the IC's circuit symbol, to the data sheet type number as shown in Figure 22.



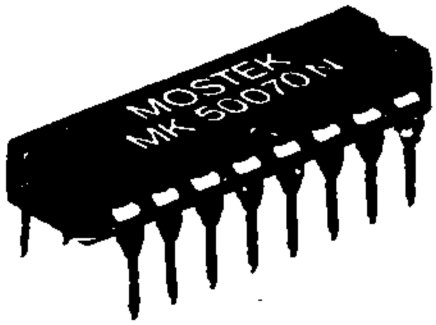
MK 50070 N

CMOS Oscillator and Divider

MOSTEK

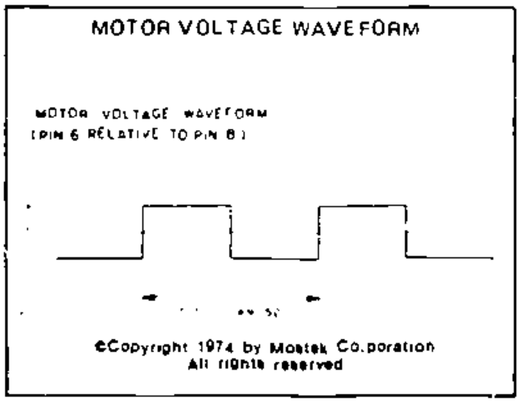
FEATURES

- Low Power Dissipation
- 4 18 Volt Operating Range
- Internal Zener Regulation
- Internal Oscillator



DESCRIPTION:

The MOSTEK 50070 circuit is an oscillator and divider circuit for specialized applications An external quartz crystal determines the oscillator frequency and the chip divides this frequency by 49152 The output is buffered by a 4 transistor bridge



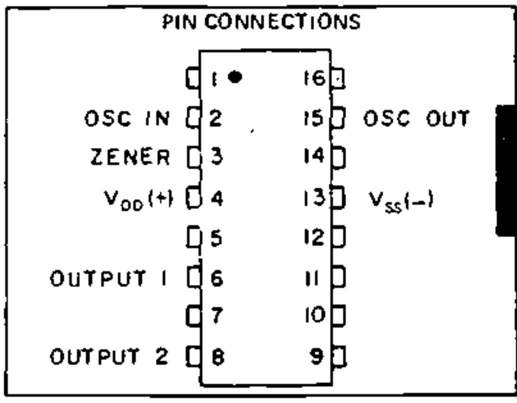


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Figure 22

IC DATA SHEET

How do you choose the correct data sheet to use with a particular IC (in your own words)?

By matching the data sheet type number to the IC type number (or words to that effect).

20. Integrated circuits are becoming very common in modern electronic equipment. You will likely have the opportunity to replace one very early in your Navy career. Read over the list of general soldering precautions and handling considerations below to familiarize yourself with the proper procedures.

a. Always keep the leads of the IC in contact with a conductive material, except when testing or operating the device so as to avoid static charge build-up.

b. Ground the tips of soldering-irons, metal parts of fixtures and tools, and handling devices when working with ICs.

c. Deenergize power to circuits before attempting to insert or remove IC's from them.

d. Do not apply signals to IC devices while the power supply is off.

e. Always use the smallest soldering iron wattage rating possible when soldering to IC's.

f. Never apply molten solder or heat to an IC lead or terminal for longer than 10 seconds, or to a point closer than 1/16 inch from the IC body.

g. Always use a heat sink such as pliers, or alligator clip between the solder connection point and the IC body.

The information we have covered in this lesson applies to all ICs. ICs require a little more care in handling than transistors, but when installed in a circuit board, they are very rugged and can operate for many years without circuit failure.

No response required

21. 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 TEST QUESTIONS.

1. Data sheets for ICs are arranged in equipment tech manuals according to
   a. manufacturer's name.
   b. IC type number.
   c. IC type name.
   d. pin configuration.

2. To work on ICs, you should use a soldering iron that has a(n) (grounded/ungrounded) tip and the (largest/smallest) wattage rating possible.

3. When soldering an IC, a heat sink, such as pliers or (an alligator clip/a solder wick), should (always/never) be used.

1. b. IC type number.
2. grounded, smallest
3. an alligator clip, always

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS, YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON 1, MODULE THIRTY FOUR. OTHERWISE GO BACK TO FRAME 19 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 21 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

Introduction To Linear Integrated Circuits

So far, all the circuits you have experienced have been constructed with discrete (single) components. The components were either mounted on a printed circuit board or you made a circuit by breadboarding (plugging a pre-mounted component into a board to construct a temporary circuit). These circuits used transistors which were fairly small and, until the early 1960's, were thought to be the ultimate in small size and efficiency. However, the aerospace industry needed even smaller, lighter, and more rugged circuits that would use less power. In 1962 these needs were met with the introduction of the Linear Integrated Circuit.

Linear Integrated Circuits (linear IC's) are devices that integrate (combine) discrete (single) components (transistors, resistors, capacitors, diodes, etc.) into one single package.

Most linear IC's are amplifiers. The output signal will be proportional to the input signal (the output waveshape is an amplified, and sometimes inverted, version of the input waveshape).

The circuit inside the package is complete. The only additional components external to the IC are for feedback and compensation networks and LC tanks whenever they are required. These components are intentionally left out of the IC package to allow the same IC to be used for different applications. Also, inductors and large value capacitors are difficult to manufacture into IC circuitry so they are normally external to the IC. However, in some specialized applications, you may find that the IC was manufactured with all components internal to the IC package, thus requiring only input, output, and power connections. Physically, the IC is mostly packaging. The actual electronic circuitry is a paper-thin wafer of silicon, called the substrate, whose size is dependent upon circuit complexity.

Figure 1 shows a 23 transistor amplifier IC whose actual size is .14 cm long and .14 cm wide.

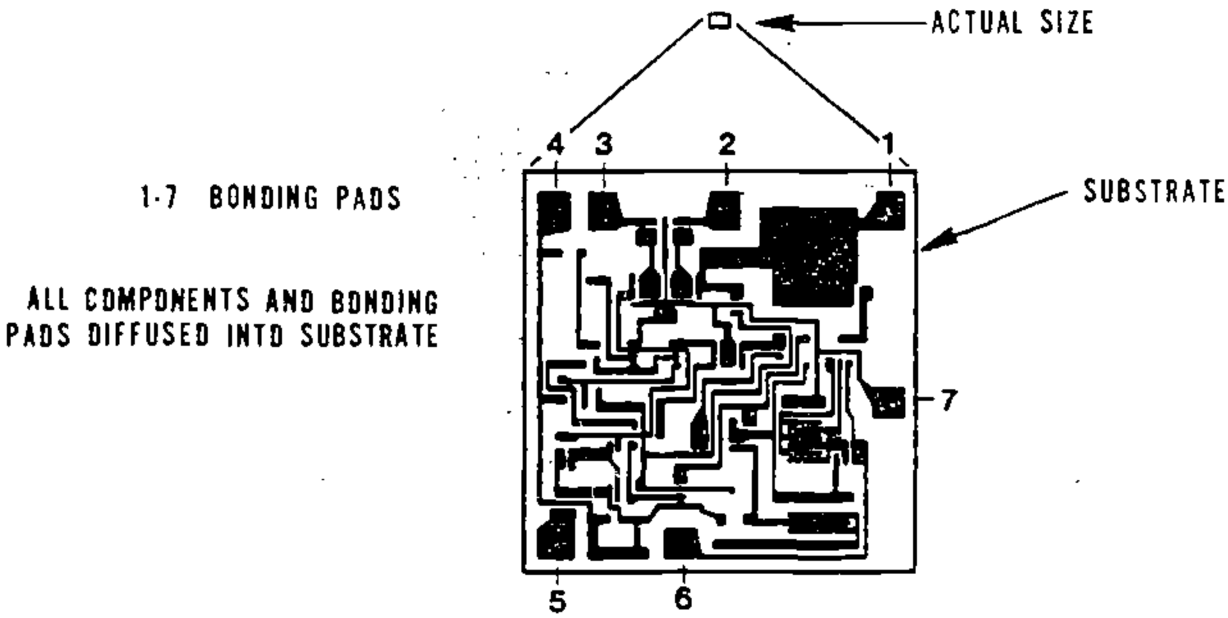

Figure 1

MAGNIFIED VIEW OF AN IC CHIP

The components are formed in the silicon by diffusion (forcing molecules of other materials into the silicon wafer). The resulting circuit is called an "IC Chip".

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The IC chips are mounted in rugged packages as shown in Figure 2.

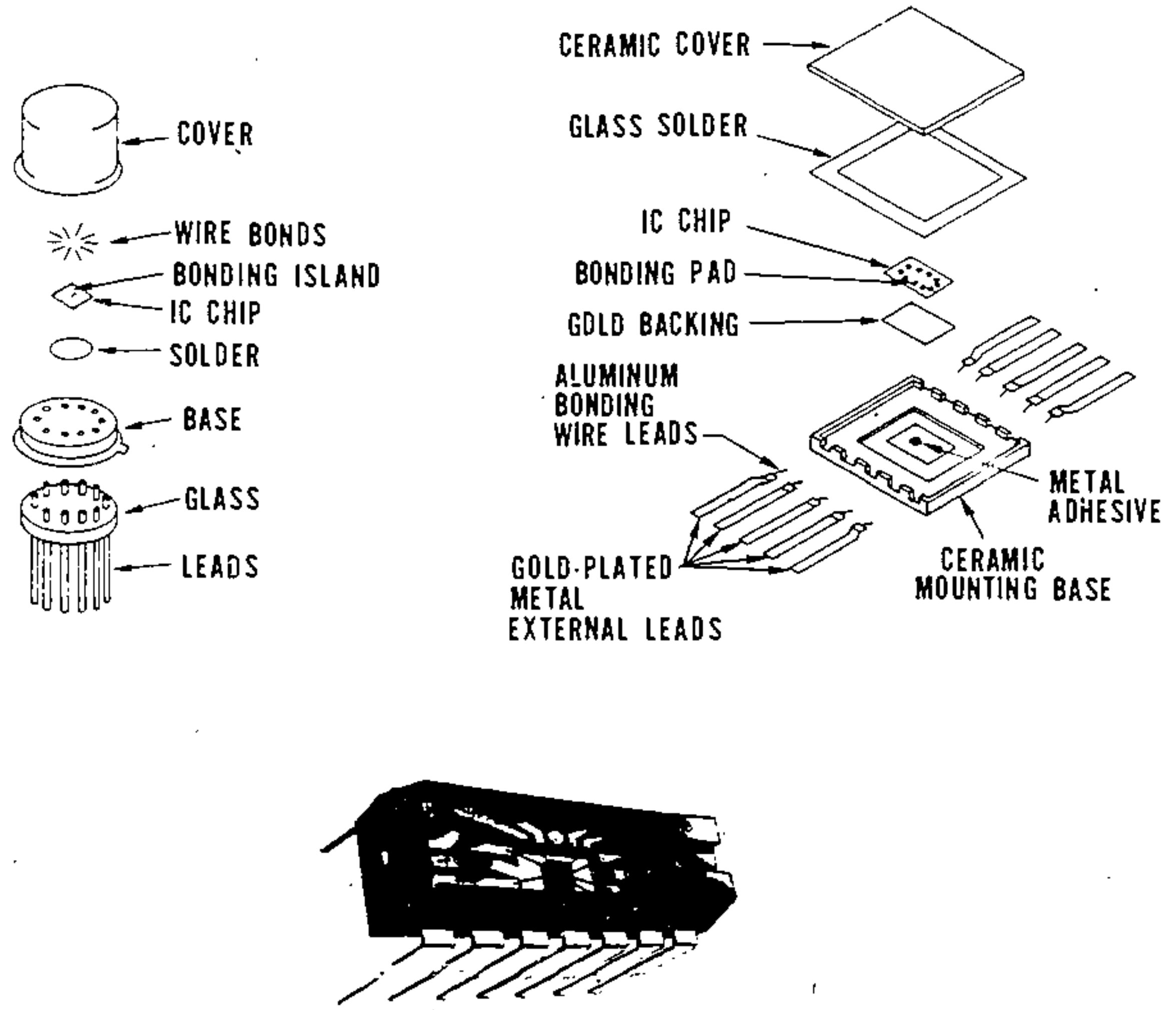


Figure 2

VARIOUS IC PACKAGES

The IC chip is soldered or cemented to a base which will hold it rigidly in place. Then fine gold or aluminum wires 2.54 x 10^{-2} mm in diameter (as fine as human hair!), are bonded to pads on the substrate which are connected to the components, as Figure 3 shows.

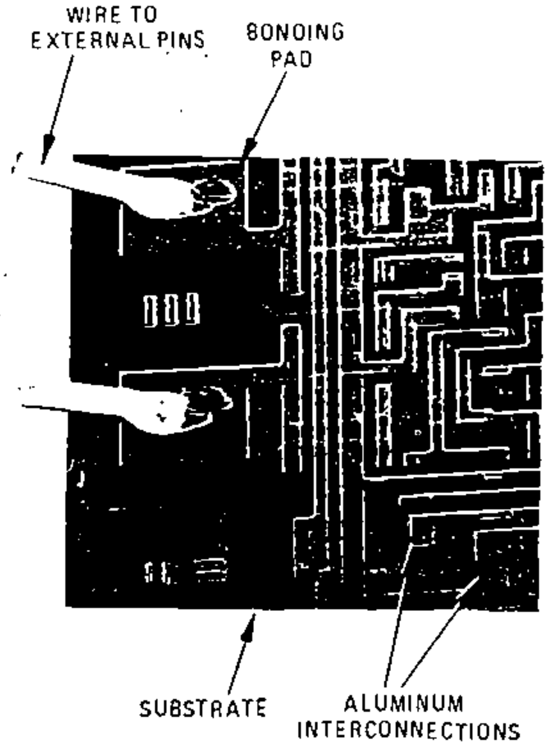


Figure 3

BONDING LEADS

The bonded wires in Figure 3 are attached to the external pins and then the cover is installed. The whole unit is then hermetically sealed. A hermetic seal is a seal which prevents the passage of air, dust, or moisture. The result is a very small, rugged device (see Figure 4).

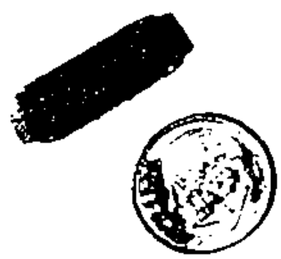


Figure 4

RELATIVE SIZE OF IC

Have you ever walked across a carpeted room or stood up from a chair and received an electrical shock when you touched something that was metal? The shock was caused by an electrical charge that your body picked up from the carpet or chair. This charge is called static electricity. The voltage potential that builds up on your body may reach a potential of 1000 volts. This static charge is high enough in potential to destroy an IC's circuitry. For this reason you should not remove an IC from its shipping wrapper, which protects the IC from static electricity, until you are ready to install it. Then, before you touch the IC you should ground yourself for a few seconds (2 or 3 are sufficient) by touching the carrying handles on a piece of test equipment that is plugged in. In fact, any bare metal surface that is grounded will drain off the static charge from your body. Any movement you make will begin to build up the static charge on your body again, so do not carry the IC when it is out of its shipping wrapper. Remember to ground yourself again after any large movements such as standing up, sitting down or walking.

IC's are normally mounted on printed circuit boards and soldered in place. These printed circuit boards are normally set up to mount an IC on without bending its leads. However, you may have a circuit board with mis-aligned mounting holes. In this case you will have to bend the IC's leads to make them fit. To do this you must use two small needlenose pliers; one to hold the lead and the other to make the bend (see Figure 5).

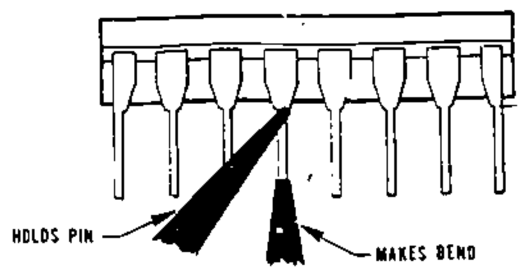


Figure 5

STRAIGHTENING IC LEADS

You must be very careful that you don't bend the lead where it enters the IC package to avoid breaking the hermetic seal. If the seal is broken, dust and moisture may enter the IC and create shorts across the internal circuitry.

Some IC's are not soldered into a printed circuit but are plugged into a special IC socket (see Figure 6).

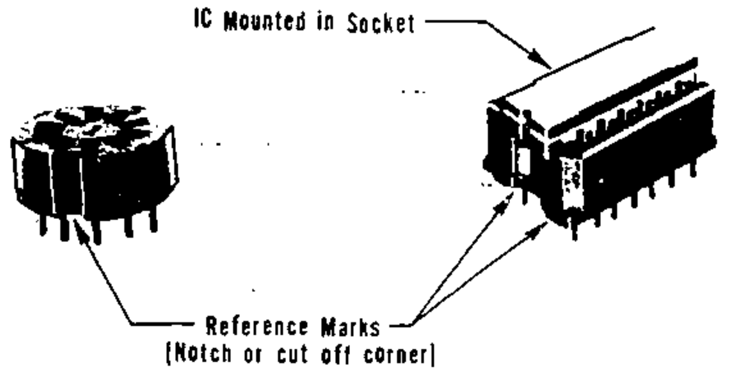


Figure 6

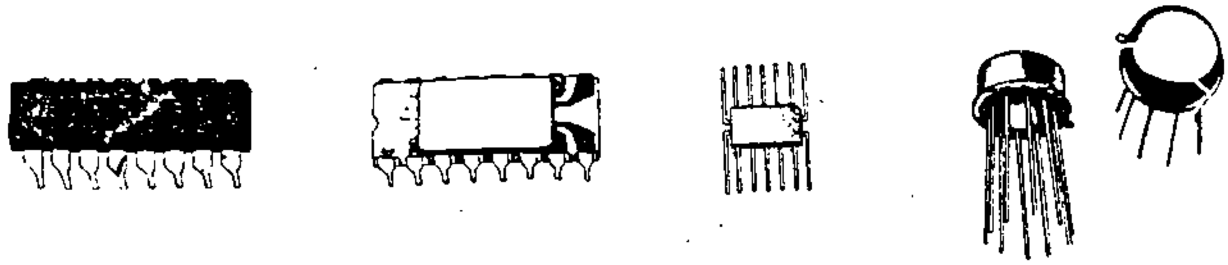
IC SOCKETS

To remove the IC from the socket, first make sure the equipment is deenergized or you will damage the IC when you remove it. Removal is accomplished through the use of an IC removal tool, most often called a DIP puller or package puller. This tool is needed in order to handle the IC firmly and securely without damaging it. In the event an IC removal tool is unavailable, grasp the IC between your thumb and forefinger and gently rock it out of its socket.

To put an IC into a socket, first make sure the equipment is deenergized. Next, line up the reference mark on the IC (a notch, dot, tab or hole) with the socket's reference mark (a notch or cut off corner as shown in Figure 6). Then grasp the IC between thumb and forefinger and gently rock the IC into the socket. You may have to bend the leads slightly with the two needlenose pliers before the IC will go into the socket.

One last handling precaution; do not drop or strike an IC. The sudden jarring impact may break the hermetic seal or one of the fine gold or aluminum interconnecting wires.

IC's are manufactured in various package shapes as shown in Figure 7.



16-PIN DUAL-IN-LINE PLASTIC PACKAGE (DIP)   16-PIN DUAL-IN-LINE CERAMIC PACKAGE (DIP)   14-PIN FLAT PACK   10-PIN TO-5 CAN

Figure 7

IC CASE STYLES

The system of numbering the leads for these packages is standard for each package shape.

With the plastic and ceramic Dual-In-Line Package (DIP), one end will be marked with a painted or impressed dot, a notch or hole in pin 1, or a notch in one end of the package. When viewed from the top, pin number 1 is the first pin going in a counterclockwise direction from, or directly next to, the impression, dot, or notch.

All other pins are numbered consecutively from pin 1 in a counterclockwise direction (see Figure 8).

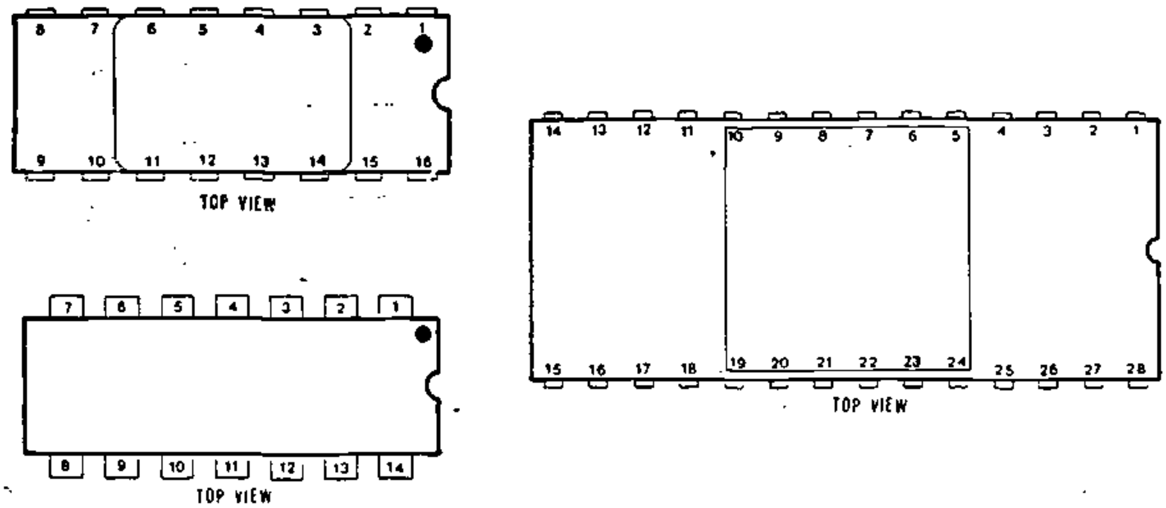


Figure 8

DIP NUMBERING

Notice that no matter how many pins the DIP has, the pins will be numbered consecutively, in a counterclockwise direction from pin 1.

The flat pack will have one end marked in the same manner as the DIP (impression, dot, notch, hole or notch in pin 1), or one other possible marking: Pin 1 may have a tab on it.

As with the DIP, when viewed from the top the pins on the flat pack are numbered consecutively in a counterclockwise direction from the reference mark as shown in Figure 9.

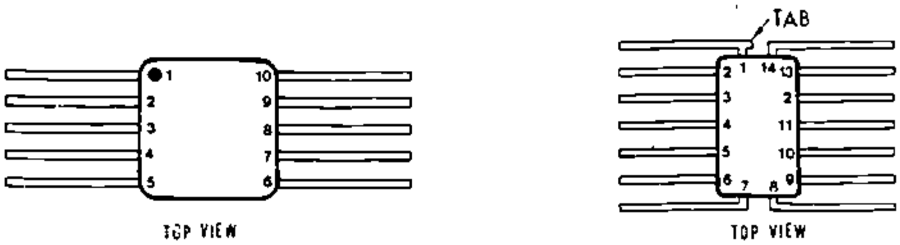


Figure 9

FLAT PACK PIN NUMBERING

The TO-5 can is basically a transistor package with more leads than the common transistor. It is a small metal can that has a tab for a reference mark. When viewed from the bottom, pin number 1 is the first pin in a clockwise direction from the reference tab (the tab is located on the highest number pin) and all other pins are numbered consecutively in a clockwise direction from pin 1 as shown in Figure 10.

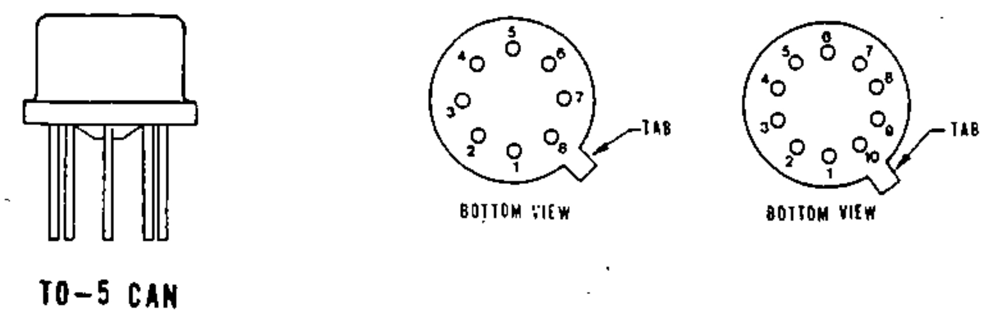


Figure 10

TO-5 PIN NUMBERING

In circuit schematics, the linear IC is normally represented by a triangle or rectangle, as shown in Figure 11.

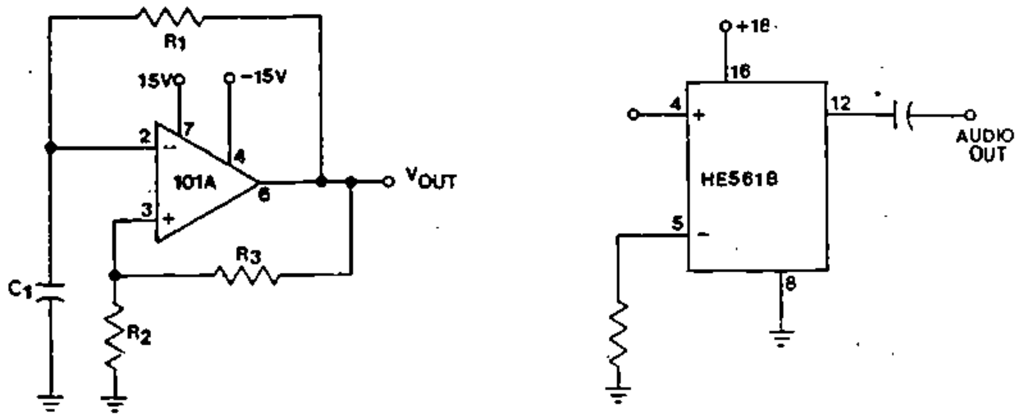


Figure 11

IC SCHEMATIC SYMBOLS

The IC's type number will normally be printed in the center of the triangle (101 A) or rectangle (HE 561 B). The pin numbers will be on the outside of the triangle or rectangle. The (+) and (-) in the triangle or rectangle indicate the non-inverting input (+) and the inverting input (-). A signal applied to the (+) input will <u>not</u> be inverted at the output. A signal applied to the (-) input <u>will</u> be inverted at the output. While the inputs of an IC are sometimes identified by (+) or (-), the other leads are not. To find out the function of each pin of an IC, you must refer to the IC's data sheet.

The data sheet for an IC usually includes a separate schematic of its internal circuitry (see Figure 12).

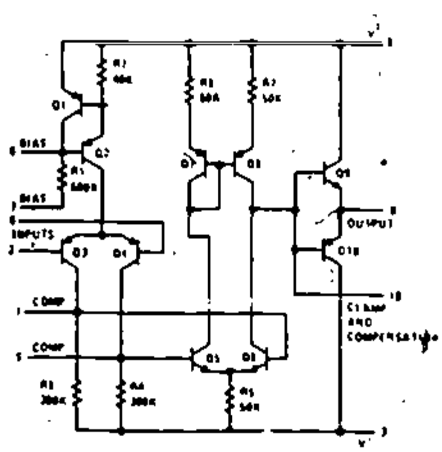


Figure 12

LH0001 SCHEMATIC DIAGRAM

The schematic of the IC will identify the inputs, outputs, and power connections.

Other information that may be on the manufacturer's data sheet is shown in Figure 13 on the next page. This data sheet is for a type of linear IC called an Operational Amplifier.

LH101 LH201 OPERATIONAL AMPLIFIER

FOR AMPLIFIERS, VOLTAGE COMPARATORS, LOW DRIFT SAMPLE-AND-HOLD

Features

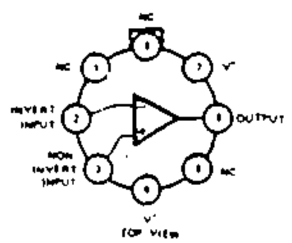
- Low Offsets and Temperature Drift
- Internal 30 pF Capacitor for Frequency Compensation
- Operation from ±5 to ±20 Volt Power Supplies
- Low Current Drain, 1.8 mA at ±20 Volts Typical
- Continuous Short-Circuit Protection
- No Latch Up When Common Mode Range Is Exceeded
- Same Pin Configuration as 709 Amplifier

Description

The LH101/LH201 is stable for all feedback configurations, even with capacitive loads, with no external compensation capacitors. Low power dissipation permits high voltage operation across the full temperature range.

PIN CONFIGURATIONS

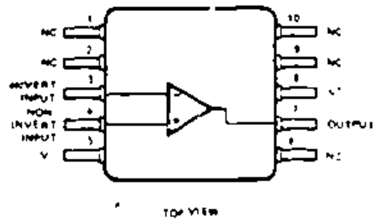
Metal Can Package



TOP VIEW
NOTE: PIN 4 CONNECTED TO CASE

ORDER NUMBERS: LH101H OR LH201H
SEE PACKAGE 1

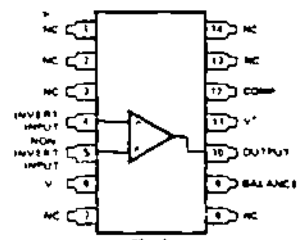
Flat Package



TOP VIEW

ORDER NUMBERS: LH101F OR LH201F
SEE PACKAGE 4

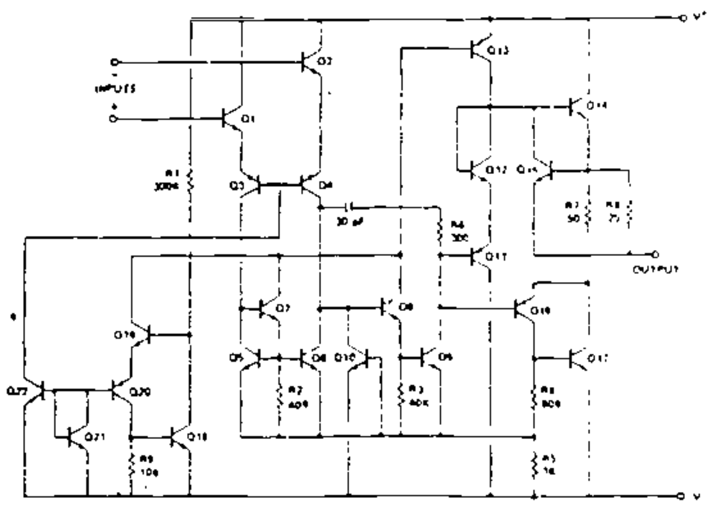
Dual-In-Line Package



TOP VIEW

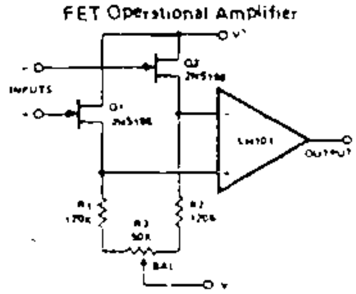
ORDER NUMBERS: LH101D OR LH201D
SEE PACKAGE 11

SCHEMATIC DIAGRAM

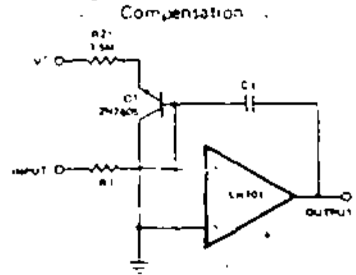


TYPICAL APPLICATIONS

FET Operational Amplifier



Integrator with Bias Current Compensation



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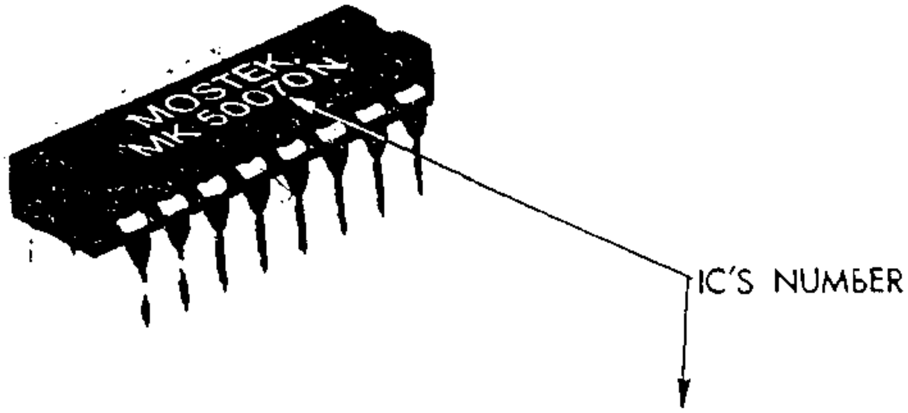
*NC - not connected internally

Figure 13

IC DATA SHEET

Some data sheets may show pin configurations, and others may show a schematic diagram. Still others may show both.

The required manufacturer's data sheets or the IC's schematics will be provided in the equipment technical manual. To select the correct data sheet for an IC, first take the IC's type number from the IC's circuit symbol or the top of the IC. Then match this number to the IC type number of the IC data sheet. Figure 14, on the next page, shows an IC with its part number and its data sheet matched.



PRELIMINARY

MK 50070 N

CMOS Oscillator and Divider

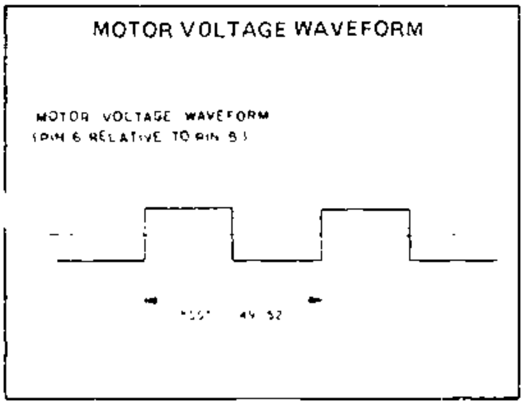
MOSTEK

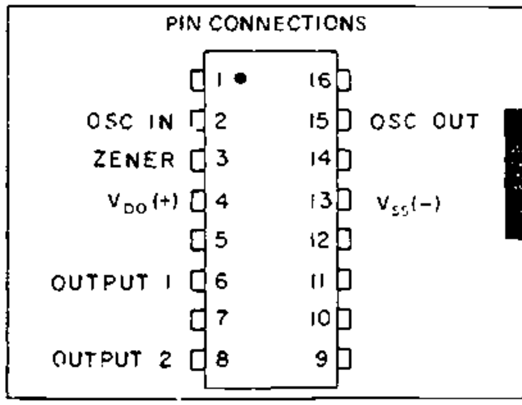
FEATURES:

- Low Power Dissipation
- 4-18 Volt Operating Range
- Internal Zener Regulation
- Internal Oscillator

DESCRIPTION:

The MOSTEK 50070 circuit is an oscillator and divider circuit for specialized applications. An external quartz crystal determines the oscillator frequency and the chip divides this frequency by 49152. The output is buffered by a 4 transistor bridge.





All of the information we have covered in this lesson applies to every type of IC manufactured. An IC requires more care in handling than a transistor, but once installed in a circuit board, it is very rugged and can operate for many years without circuit failure.

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 OR 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 FOUR

LESSON 2

IC OPERATIONAL AMPLIFIERS

JULY 1980

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OVERVIEW
LESSON 2

IC Operational Amplifiers

In this lesson you will learn about a very common type of linear integrated circuit called an operational amplifier. You will study the characteristics of IC operational amplifiers including schematic symbols, input-outputs, and typical circuit operation. You will learn some useful troubleshooting procedures for repairing these devices.

The learning objectives of this lesson are as follows:

TERMINAL OBJECTIVE(S):

34.2.66 When the student completes this lesson (s)he will be able to IDENTIFY basic functional characteristics of operational amplifiers to include using gain formulas to calculate the gain of inverting and non-inverting circuit configurations and listing correct troubleshooting methods, by selecting statements from a choice of four. 100% accuracy is required.

ENABLING OBJECTIVES:

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

34.2.66.1 IDENTIFY the functional characteristics of an IC operational amplifier by selecting the correct statement from a choice of four. 100% accuracy is required.

34.2.66.2 IDENTIFY inverting and non-inverting opamp circuit configurations, given schematic diagrams, by selecting the correct name or diagram from a choice of four. 100% accuracy is required.

34.2.66.3 IDENTIFY the formulas used for computing output voltage in an IC operational amplifier by selecting the correct formula from a choice of four. 100% accuracy is required.

34.2.66.4 CALCULATE the gain of an operational amplifier circuit, given a schematic diagram and necessary circuit values, by selecting the correct gain value from a choice of four. 100% accuracy is required.

34.2.66.5 IDENTIFY proper troubleshooting methods for a given IC opamp circuit by selecting the correct statement from a choice of four. 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 2

IC Operational 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 in:

Module Booklet:

Summary
Programmed Instruction
Narrative

Student's Guide:

Summary
Progress Check

Additional Material(s):

None

Enrichment Material(s):

Robert G. Hibberd, A Basic Course In Integrated Circuits, (Cleveland: Penton Publishing Company, 1968-69), Lessons 1,2,3,4,9,10,12,13, and 14.

YOU MAY USE ANY, OR ALL RESOURCES LISTED ABOVE, AND ALSO 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 2

IC Operational Amplifiers

An IC Operational Amplifier (opamp) is a class "A" amplifier which has two inputs and one output. One of the inputs will have the signal we wish to amplify applied to it. The other input will be connected to a resistor that will develop bias for the IC. The resulting output will be the input multiplied by the gain of the circuit.

Various schematic symbols for an IC opamp are shown in Figure 1.

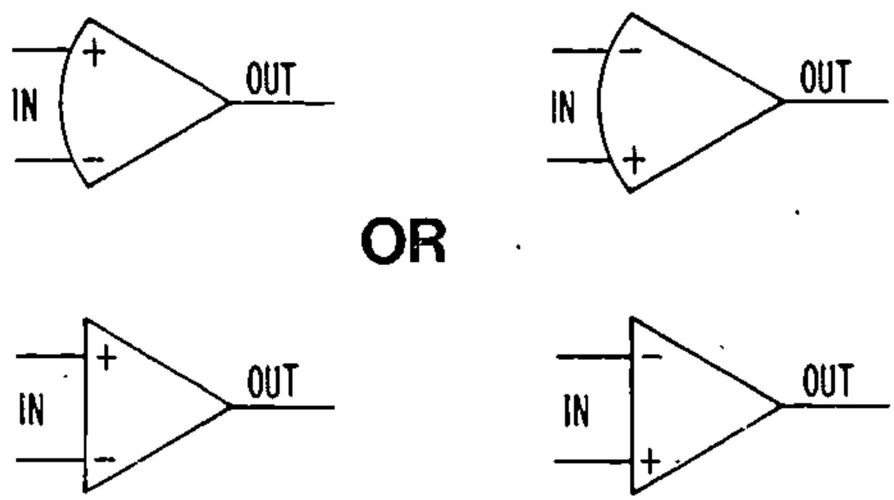


Figure 1

OPAMP SCHEMATIC SYMBOLS

IC opamps are used as either inverting or non-inverting amplifiers. Figure 2 shows an inverting IC opamp amplifier circuit.

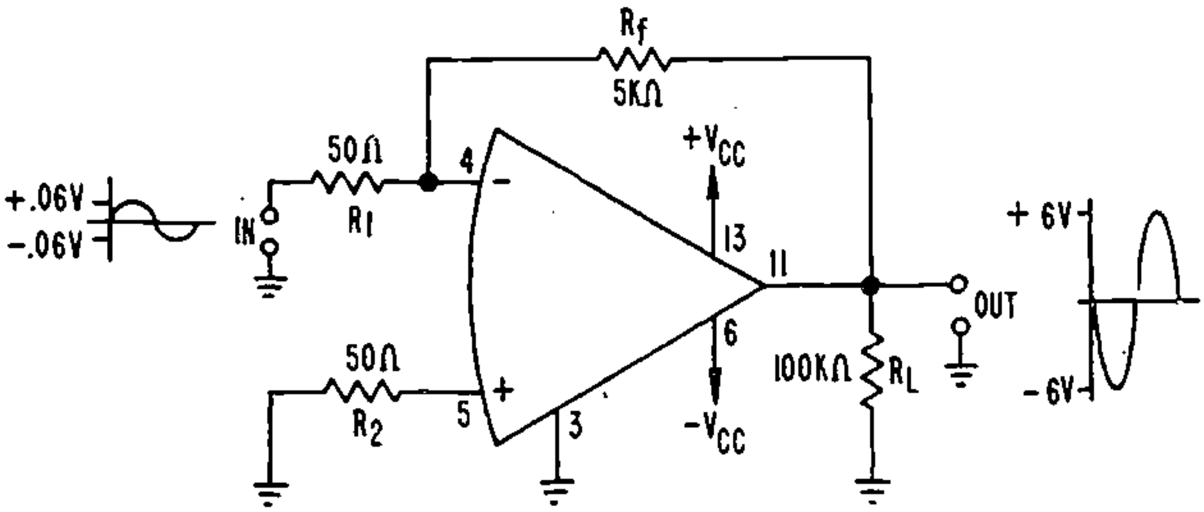


Figure 2

INVERTING OPAMP

In Figure 2, R1 is the input resistor, R2 the bias resistor, Rf the feedback resistor and RL the load resistor. Figure 3 shows a non-inverting IC opamp amplifier circuit.

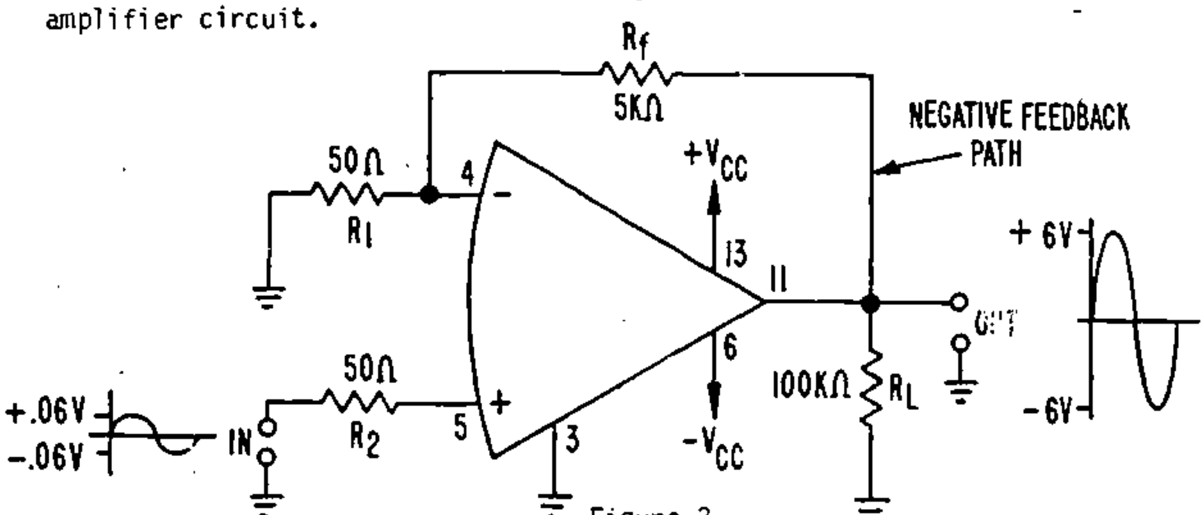


Figure 3

NON-INVERTING OPAMP

This circuit is the same as the inverting amplifier circuit except that the input and bias connections are reversed. Now the input resistor is R2 and the bias resistor is R1.

Operational amplifiers have extremely high gain. Both the inverting and the non-inverting IC opamp amplifier circuits use negative feedback to stabilize the output signal and prevent oscillation. The inverting amplifier has a feedback signal that is 180° out-of-phase with the input signal and, since both signals are applied to the same point, negative feedback is directly provided. See Figure 4.

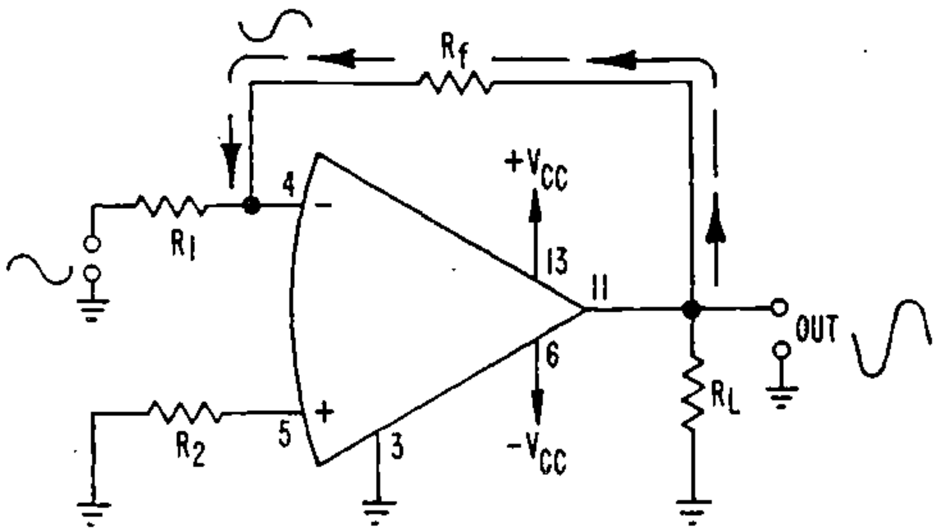


Figure 4

INVERTING IC OPAMP FEEDBACK PATH

The non-inverting amplifier has a feedback signal that is in phase with the input signal which would indicate the use of positive feedback. However, the feedback signal is applied to the inverting input where it is inverted inside the IC. See Figure 5.

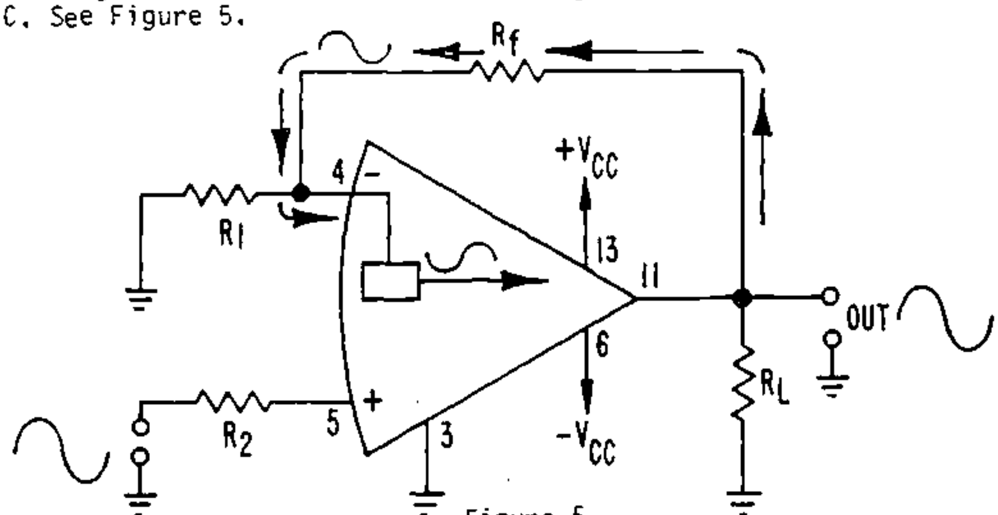


Figure 5

NON-INVERTING IC OPAMP FEEDBACK PATH

The feedback signal on the inverting input terminal (-) acts in opposition to the input signal on the non-inverting terminal (+).

Since the inverted feedback is 180° out-of-phase with the input signal, negative feedback is being used.

To measure the input signal you would use an oscilloscope. But, you must not measure the input signal on the input pin of the IC.

With the inverting amplifier, the negative feedback and the input signal are applied to the IC's input. Since the two signals are 180° out-of-phase, the resultant signal is too small to measure.

With the non-inverting amplifier, the input signal at the IC's input may be smaller than the actual input signal due to the voltage drop across the input resistor.

Therefore you must measure the input signal to either amplifier (inverting or non-inverting) at the points indicated in Figure 6.

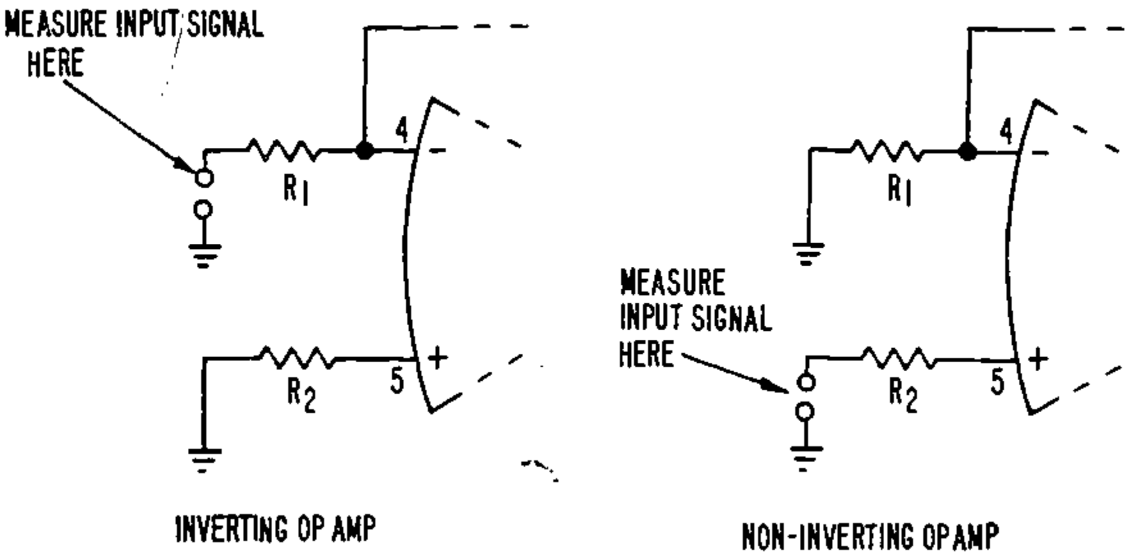


Figure 6

MEASURING OP AMP INPUT SIGNALS

In both the inverting and non-inverting amplifiers, the gain is controlled by the ratio of Rfeedback to Rin or

$$\text{Gain} \cong \frac{R_{feedback}}{R_{in}}.$$

The symbol "$\cong$" means "approximately equal to". This gain is approximate because there are other factors at an engineering level to take into consideration. However, the gain determined by this formula will be close enough to the actual amount for our purposes.

Since the gain of an amplifier is the number of times the input signal is multiplied,

$$V_{out} \cong V_{in} \frac{R_{feedback}}{R_{in}}$$

(NOTE: This formula may be used regardless of how the input is stated, i.e., peak-to-peak, peak, or RMS. However, the output must be stated in the same terms).

The Vout formula is a good troubleshooting aid. With it you can determine whether the output signal has the correct amplitude or not.

You cannot normally test the IC when the amplifier circuit has a bad output signal. However, you can check the supply voltages to the IC and the components external to the IC.

To check supply voltages to the IC, a VOM or VTVM may be used. The IC opamp requires both positive (+VCC or V+) and negative (-VCC or V-) voltages, most commonly between 6 volts and 18 volts. See Figures 4 and 5. The equipment manuals will indicate the correct voltages and the pin numbers where the voltages are applied.

To check resistance of the external components, a VOM may be used. However, multiple current paths through the IC will cause false readings across the external components. Also, the IC can be damaged by the current from the meter; therefore, the IC must be isolated from the components under test. If the IC is plugged into an IC socket, observing proper handling precautions, unplug the IC. If the IC is soldered into the circuit board, you must unsolder and lift out one lead of the component under test to isolate that component from the IC and other circuit components. Therefore, you should have some idea of the possible cause of a symptom to eliminate unnecessary soldering.

To check the output signal of the IC, an oscilloscope is used. Place the oscilloscope probe on the output pin of the IC. The Vout formula will help you determine if the signal amplitude is correct. Remember, when you check the IC opamp amplifier circuit, you must first check the signal input, the DC voltage inputs, and all external components before considering the IC to be faulty.

IC handling precautions are identical with those for MOS devices and are shown in Figure 7.

NOTICE

SPECIAL HANDLING OF MOS DEVICES

The MOS metal oxide semiconductor devices have a fairly high input resistance making them subject to damage from charges of static electricity through improper handling. The thin layer of oxide can be damaged from discharges of static electricity or improper handling in or out of circuit. The damage may be apparent immediately or may show up only after a short operating time. To avoid possible damage, the following procedures should be followed when handling or testing these devices.

1. The use of synthetic clothing such as nylon should be avoided as this will generate static charges. Dry weather (relative humidity less than 30%) also tends to increase static buildup.

2. Keep the leads of the device in contact with a conducting material or shorted, except when testing, inserting or removing from the circuit.

3. A wrist strap with a megohm resistor in series to common ground should be worn by the technician when inserting, removing or testing MOS devices.

4. Do not remove or insert an MOS device with the power to the circuit or test instrument "ON".

5. Do not apply or inject test signals into the circuit when an MOS device is used with the circuit power "OFF".

6. Do not turn the circuit power "ON" with an MOS device removed from the circuit. Charges can build up causing possible damage when the device is replaced in the circuit.

7. Soldering iron tips, metal bench tops, test equipment and tools should be grounded to a common ground along with the chassis of the set being serviced.

8. Soldering guns should not be used in MOS circuits; AC line leakage from the gun tip could cause damage to an MOS device.

9. Do not apply heat for longer than 10 seconds or closer than 1/16 of an inch to any MOS device when soldering. Use of a heat sink is recommended to prevent damage to the advice.

Figure 7

IC HANDLING PRECAUTIONS

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 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

IC Operational Amplifiers

TEST FRAMES ARE 3, 7, 14, AND 19. GO FIRST TO TEST FRAME 3 AND SEE IF YOU CAN ANSWER THE QUESTION(S). FOLLOW THE DIRECTIONS GIVEN AFTER THE TEST FRAME.

1. There are many different types of linear ICs being manufactured. Up to this time, we have discussed information that is common to all types of linear IC's. Now we will discuss a specific type of linear IC called an Operational Amplifier (opamp). The opamp is simply a class "A" amplifier which has two inputs and one output. One input is used as a signal input. The other input has a resistor attached to it that develops bias for the IC opamp. The resultant output is the input voltage multiplied by the gain of the amplifier.

If the gain of an amplifier is 5 and the input signal is .1 volt peak-to-peak, the output signal will be _______________.

0.5 volts peak-to-peak.

(2.) Various schematic symbols for an IC opamp are shown in Figure 1.

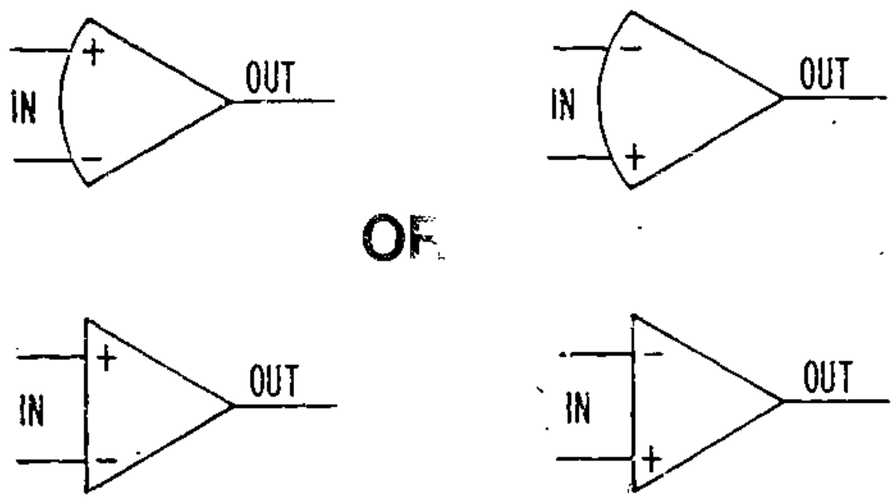


Figure 1

OPAMP SCHEMATIC SYMBOLS

As you may recall, the (+) or (-) at each input in Figure 1 indicates whether the applied signal will or will not be inverted at the output. The (-) indicates an inverting input. If the input signal is applied to the (-) input, the output will be 180° out-of-phase with respect to the input. The (+) indicates a non-inverting input. If the input signal is applied to the (+) input, the output signal will be in-phase with respect to the signal.

A sine wave input signal to an opamp terminal labeled (-) will be ________ ̀he output terminal.

---

inverted, or 180° out-of-phase

3. THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS GIVEN AT THE TOP OF THE NEXT PAGE.

1. An integrated circuit operational amplifier is basically a __________ (Class A/Class B) amplifier with an ____________ (in-phase/out-of-phase/in-phase or out-of-phase) output.

2. Identify the terminals on the IC schematic symbol shown in Figure 2.

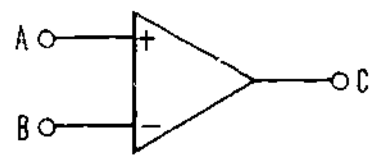


Figure 2

a. A=inverting input, B=output, C=non-inverting input

b. A=non-inverting input, B=inverting input, C=output

c. A=output, B= inverting input, C=non-inverting input

d. A=output, B= non-inverting input, C=inverting input

1. Class A, in-phase or out-of-phase
2. b. A=non-inverting input, B=inverting input,C=output

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 7. OTHERWISE, GO BACK TO FRAME 1 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 3 AGAIN.

4. Now let's take a look at an IC opamp in a circuit. Look at Figure 3, below.

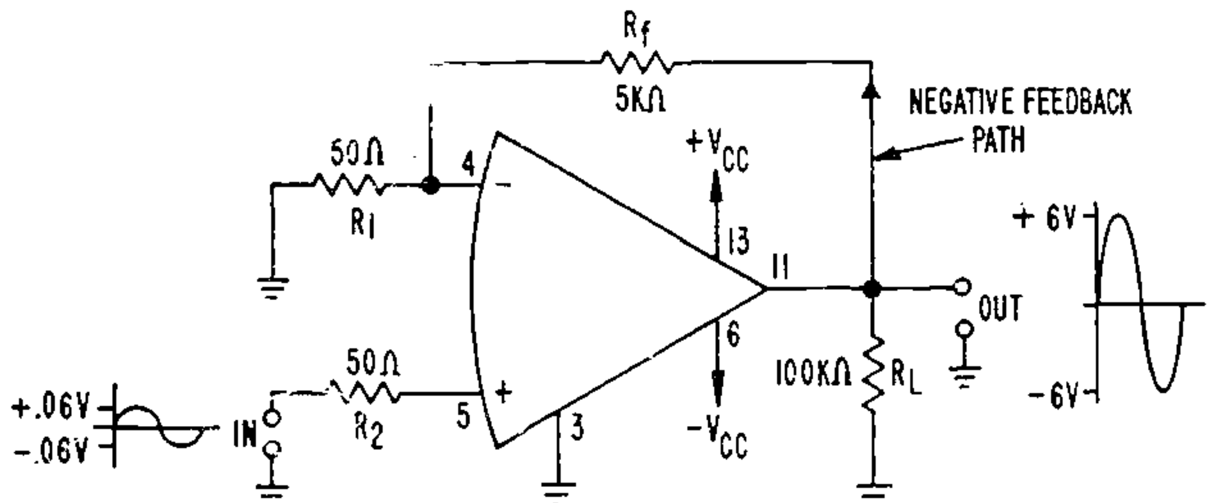


Figure 3

NON-INVERTING IC OPAMP AMPLIFIER

Operational amplifiers have extremely high gain capabilities. Therefore it is often necessary to use negative (degenerative) feedback in the circuit to control ~~this~~ gain and ensure a stable amplifier. As you study this non-inverting amplifier circuit, notice that the input signal is applied to the non-inverting input(+), pin 5, through series input resistance R2. The output signal is taken from pin 11, across load resistor RL, and is an amplified, in-phase version of the input. R1 is the bias resistor.

Resistor Rf is used to provide the negative feedback. Although the feedback appears positive (in-phase with the input signal), it has a negative effect because it is applied to the inverting input(-), pin 4. The opamp internally inverts the phase of the feedback, making it act in opposition to the input signal.

Operational amplifiers use negative feedback to control ________ ________.

---

amplifier gain (or words to that effect)

(5.) An IC opamp may also be connected as an inverting amplif'er (input signal applied to inverting input) as shown in Figure 4.

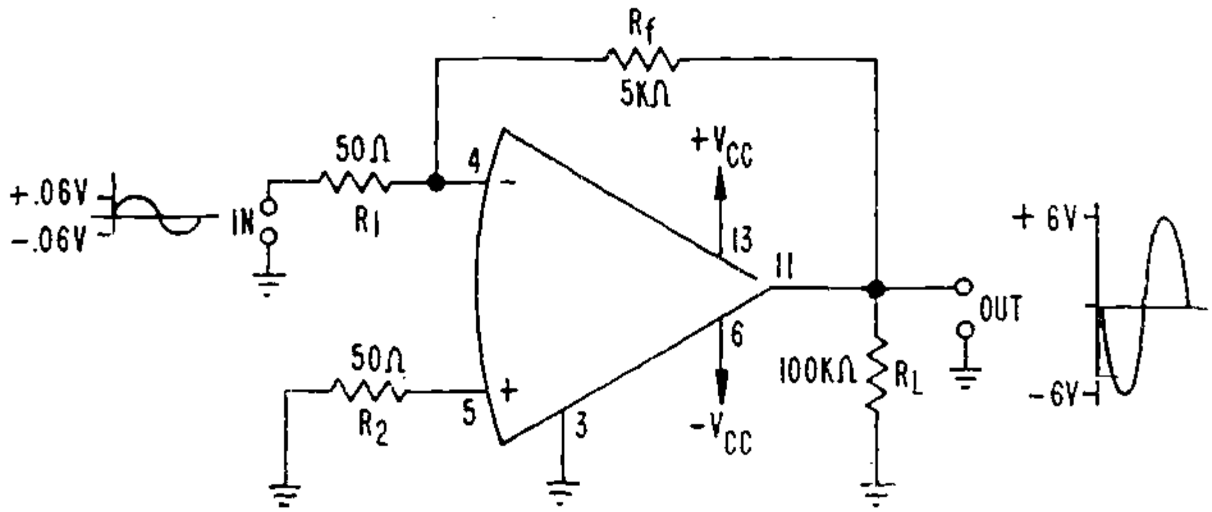


Figure 4

INVERTING IC OPAMP AMPLIFIER

Notice that the only change needed to make a non-inverting amplifier circuit (Figure 3) into an inverting amplifier circuit (Figure 4) is to reverse the ground and input connections. R1 now becomes the input resistor and R2 the bias resistor, as shown i. Figure 4.

Notice t.. the feedback is pplied to the (-) terminal for either circuit configuration. This will ins that negative feedback is provided. Ne..tive feedb..k will stabilize the amplifier's output and keep it from oscillating.

Negative feedback in IC opamp circuits is al ys applied to the ________ (non-inverting(+)/inverting(-)) input.

---

inverting (-)

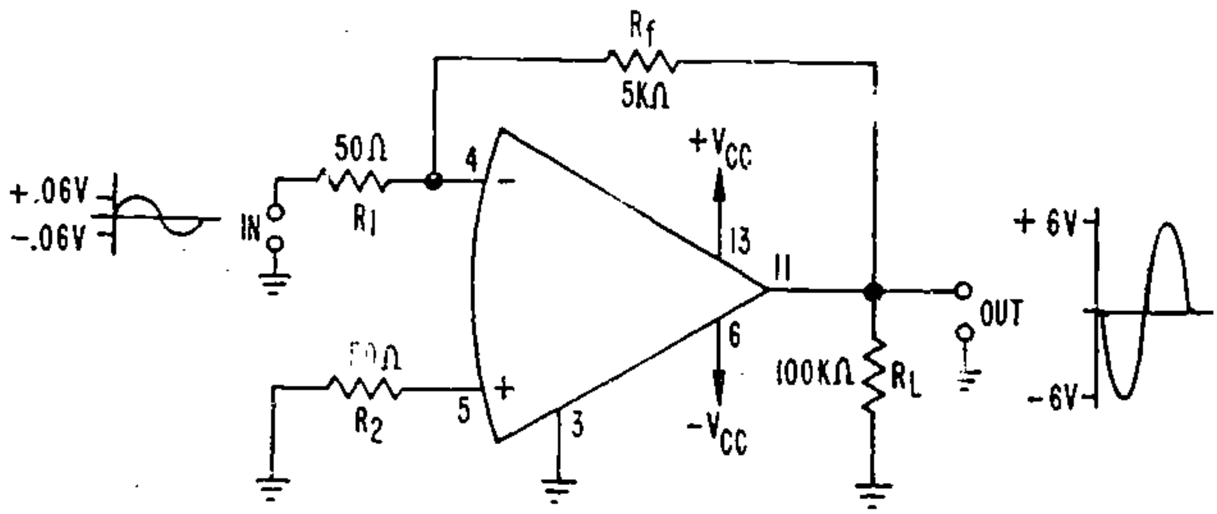


Figure 5

OPAMP GAIN

(6) I ,th inverting and non-inverting amplifier circuits. e gain of the amplifier is controlled by the ratio of the feedback resistance (Rf) to the input resistance (R1 or R2, depending upon which is used for an input resistor). Stated as a formula,

$$\text{Gain} \simeq \frac{R_{feedback}}{R_{in}}.$$

The "≃" symbol means "appr oximately equal to". Thus gain is approximate because the are other factors at an engineering level to take into consideration. However, the gain determined by this formula will be close enough to the actual amount for our purposes. The formula applies to both the inverting and non-inverting amplifier.

For the circuit shown in Figure 5, the gain of the amplifier would be computed as follows:

$$\text{Gain} \simeq \frac{R_{feedback}}{R_{in}} = \frac{5K}{50} = \frac{5000}{50} = 100$$

From the gain formula you can easily determine the voltage of the output signal. Since the gain is the number of times the signal is amplified, it is easy to see that the input voltage (V_{in}) multiplied by the gain would tell you the output voltage (V_{out}). This stated as a formula would be

$V_{out} = \text{Gain}\ (V_{in})$.

(NOTE: This formula may be used regardless of how the input is stated, i.e., peak-to-peak, or RMS. However, the output must be stated in the same terms). Since we know that Gain $\simeq \frac{R_{feedback}}{R_{in}}$ for either amplifier configuration, our formula becomes

$$V_{out} \simeq V_{in}\left(\frac{R_{feedback}}{R_{in}}\right).$$

In Figure 5, V_{out} = .06V (100) = 6V.

In the amplifier shown in Figure 6 below, the gain is approximately ________ and the output signal (is/is not) inverted.

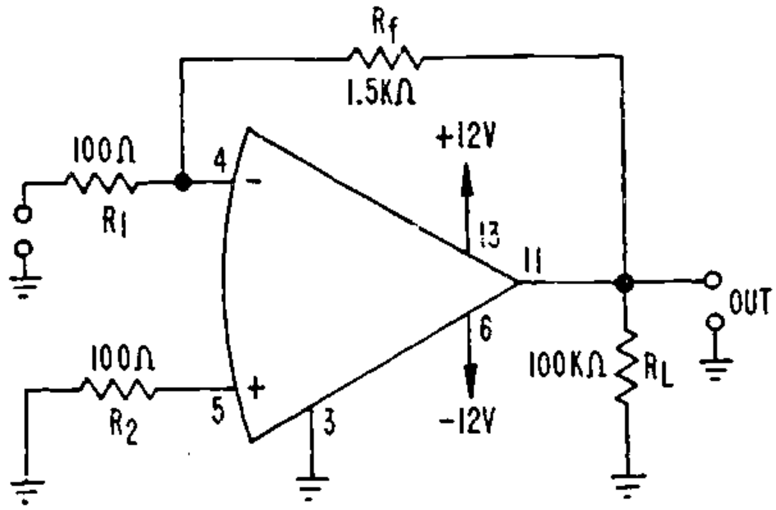


Figure 6

a. 15, is not

b. 15, is

c. 0.067, is not

d. 0.067, is

---

b. 15, is

(7.) THIS IS A TEST FRAME. COMPLETE THE TEST QUESTIONS AND THEN COMPARE YOUR ANSWERS WITH THE CORRECT ANSWERS AT THE TOP OF THE PAGE FOLLOWING THE TEST FRAME. USE FIGURE 7, BELOW, TO ANSWER THE QUESTIONS.

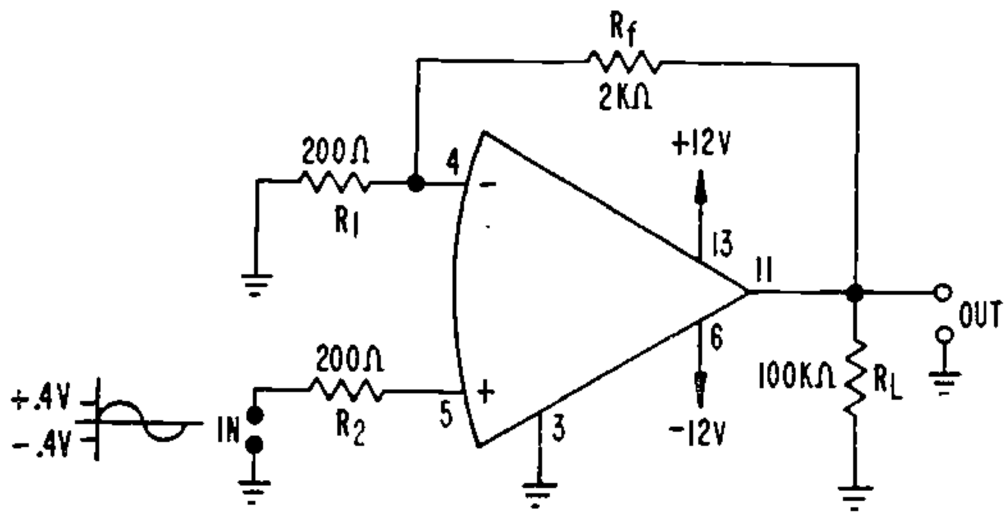


Figure 7

1. This schematic diagram is an example of a(an) ____________ (inverting/ non-inverting) opamp.

2. The gain of the opamp circuit is __________.

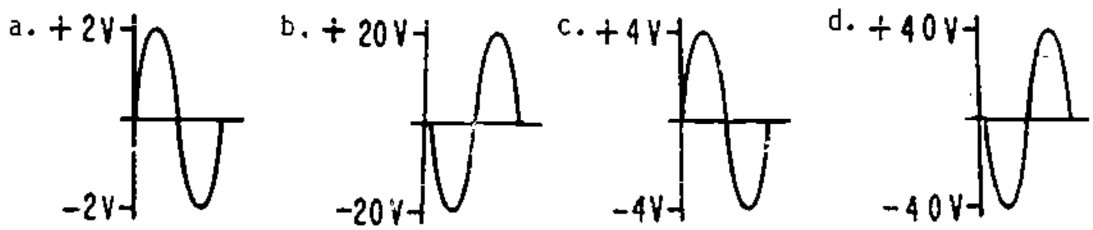
   a. 2000

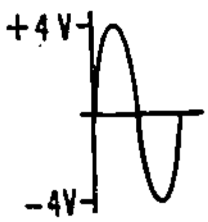
   b. 200

   c. 100

   d. 10

3. With the input shown, the output would appear as



1. non-inverting
2. d. 10
3. c. 

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 14. OTHERWISE GO BACK TO FRAME 4 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 7 AGAIN.

(8.) Being able to determine the output voltage of an IC opamp can be a very helpful troubleshooting aid, especially if you have to determine whether or not the IC is operating properly. But first you have to find out what voltage is being applied at the input.

Let's discuss the inverting opamp first.

If you were to take out your oscilloscope and check the signal at the input to the IC itself, you would find practically no signal (see Figure 8).

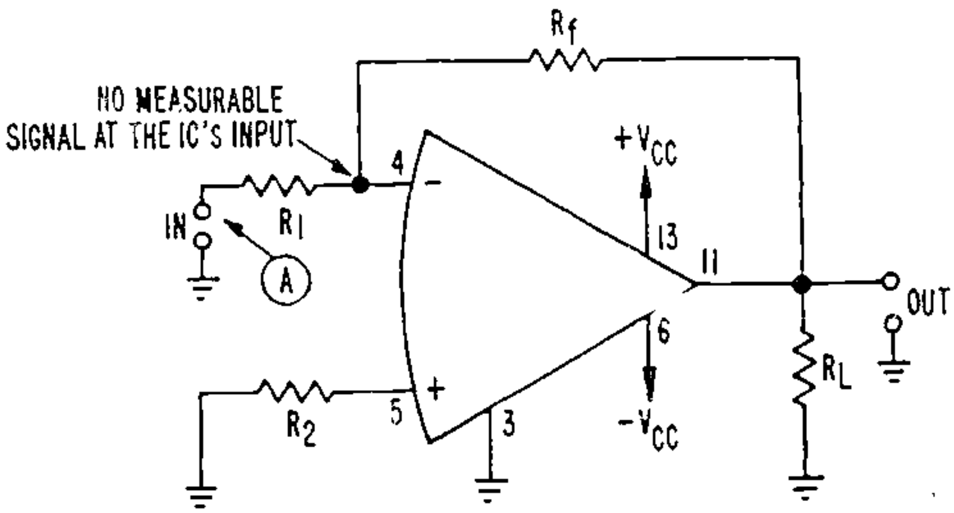


Figure 8

MEASURING IC OPAMP SIGNALS

Further checks show a good input signal at point "A", and an output signal whose amplitude is correct (as determined by the V_{out} formula).

The amplitude of the signal on the input pin of an IC opamp is __________.

a. very large

b. equal to the input signal to the circuit

c. very small

---

c. very small

(9.) So why is this true? The reason for the small signal on the opamp input terminal can be understood by looking at Figure 9.

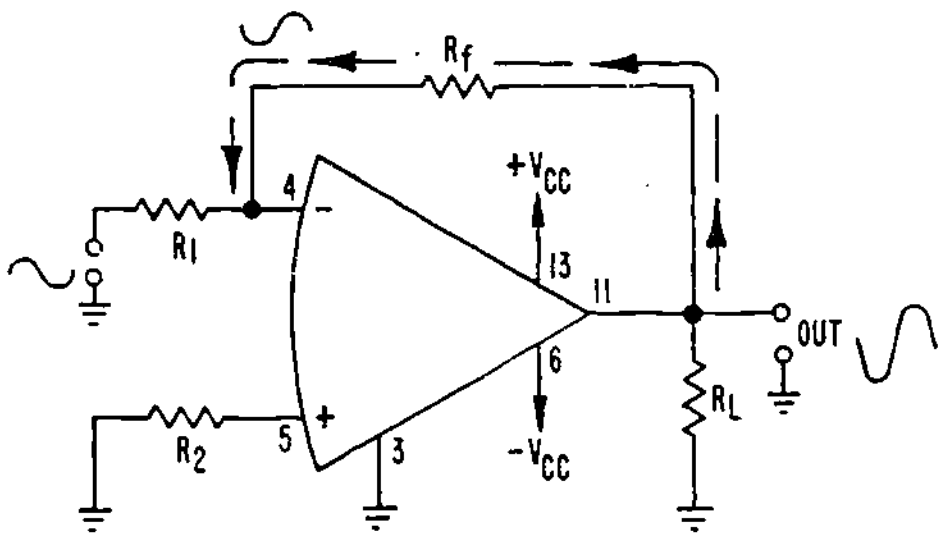


Figure 9

INVERTING OPAMP FEEDBACK SIGNAL PATH

The feedback and input signals are applied to the same point (pin 4 of the IC). Since the feedback signal is negative (180° out-of-phase with the input signal) the two signals at pin 4 act in phase opposition (oppose each-other).

---

no response required

(10.) The net result of combining the input and feedback signals is shown in Figure 10.

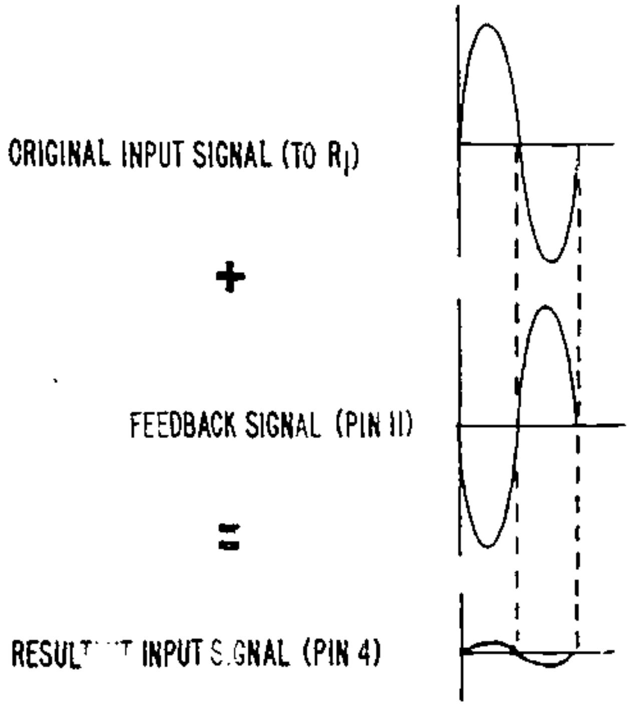


Figure 10

RESULTANT INPUT SIGNAL
INVERTING OPAMP

The feedback and input signals are being applied to the same point (pin 4 of the IC). Since we are using negative feedback (180° out of phase with the input signal), the resulting signal at the IC's input is very small.

The feedback signal (adds to/subtracts from) the original input signal to an IC opamp.

---

subtracts from

(11.) In fact, the input signal applied to Pin 4 of the IC is so small that even the very small loading effect of your oscilloscope will make the signal almost undetectable. Therefore, you must measure the input signal to the inverting circuit at the circuit's input (input side of the input resistor) as shown in Figure 11.

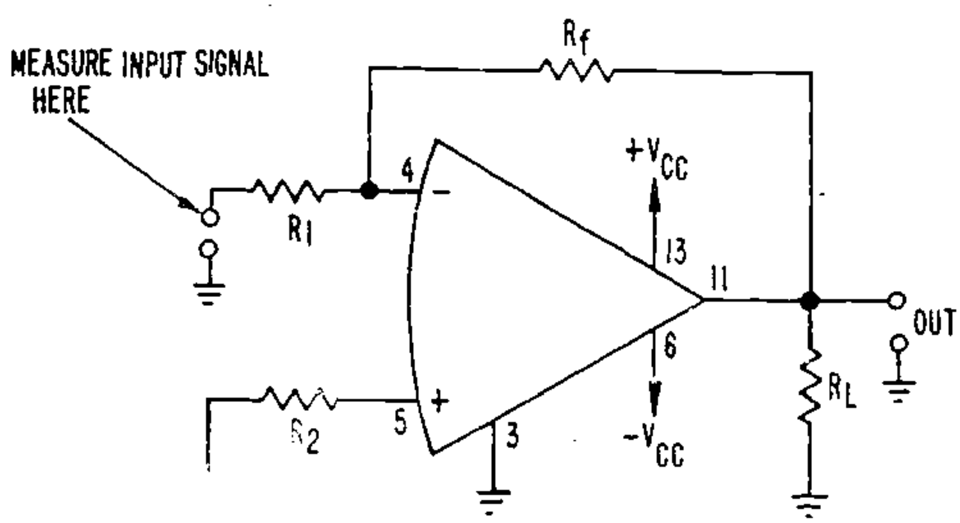


Figure 11

MEASURING INVER..NG OPAMP SIGNALS

When measuring inverting opamp input signals the oscilloscope probes should be placed on the ________ input terminal.

a. IC

b. circuit

---

b. circuit

(12) Now let's look at the situation involved in measuri‑‑ non-inverting opamp signals shown in Figure 12.

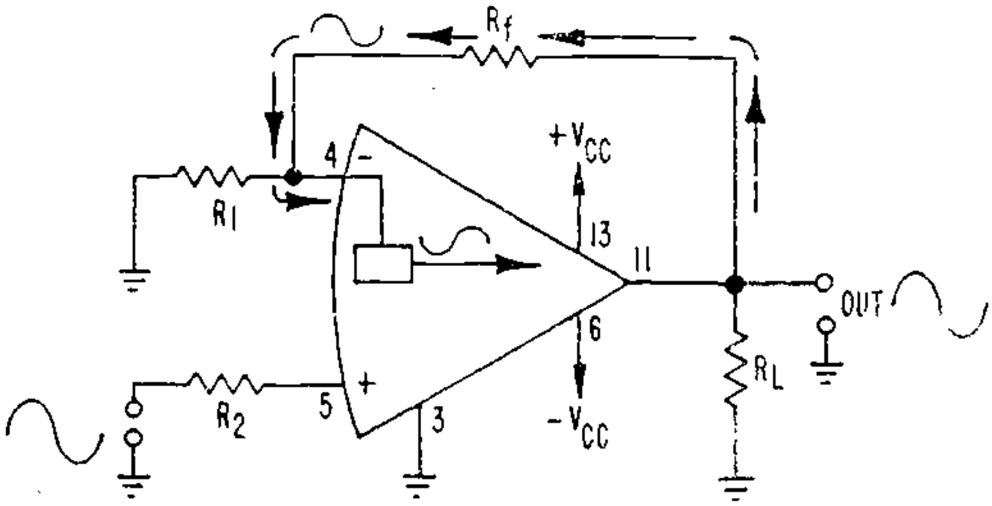


Figure 12

NON-INVERTING OPAMP SIGNALS

In the non-inverting amplifier, the input signal is applied through series resistor R_2 to input terminal 5. The feedback signal is still ed through feedback resistor R_f to terminal 4. Therefore, the combining action of the input and feedback signals occur within the IC itself.

Non-inverting opamps combine input and feedback signals ____________ (outside/within) the IC.

---

within

(13) Although the feedback signal does not externally subtract from the input signal in non-inverting opamps, the input resistor may still cause a signal voltage drop. For this reason, the input signal to a non-inverting IC opamp should also be measured at the circuit's input as shown in Figure 13.

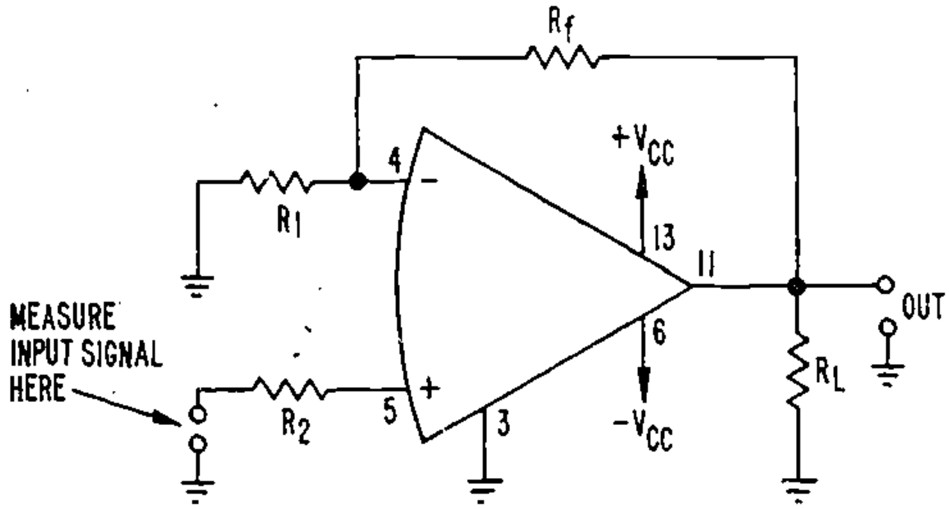


Figure 13

MEASURING NON-INVERTING OPAMP SIGNALS

The input signal to non-inverting opamps is measured at the ______________.

a. IC input terminals

b. circuit input terminals

---

b. circuit input terminals

(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 TEST FRAME.

USE FIGURE 14 BELOW TO ANSWER QUESTIONS 1 AND 2.

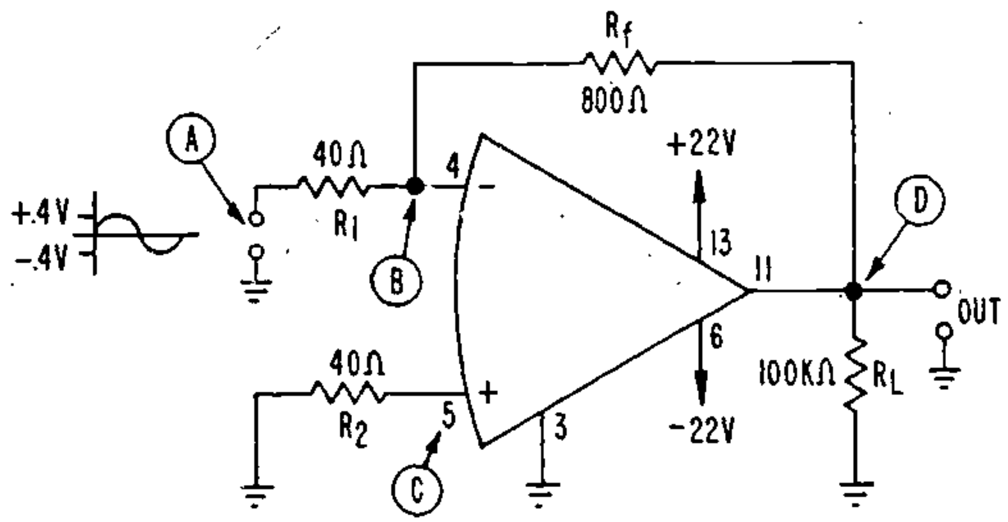


Figure 14

1. The signal at point _________ is smaller than the signal at point ______.
   a. D, A
   b. A, B
   c. D, C
   d. B, A
2. When measuring input signals to the opamp, the oscilloscope probe should be placed at point __________.
   a. A
   b. B
   c. C
   d. D

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3. When measuring input signals in non-inverting opamps, the oscilloscope probe should be placed at the ______________.

   a. IC input terminal

   b. IC output terminal

   c. circuit input terminal

1. d. B,A
2 a. A
3. c. circuit input terminal

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU MAY GO TO TEST FRAME 19. OTHERWISE GO BACK TO FRAME 8 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 14 AGAIN.

15. We have discussed the procedures for checking input signals to an IC. Now let's look at some general IC troubleshooting procedures. Consider the IC operational amplifier chain shown in Figure 15.

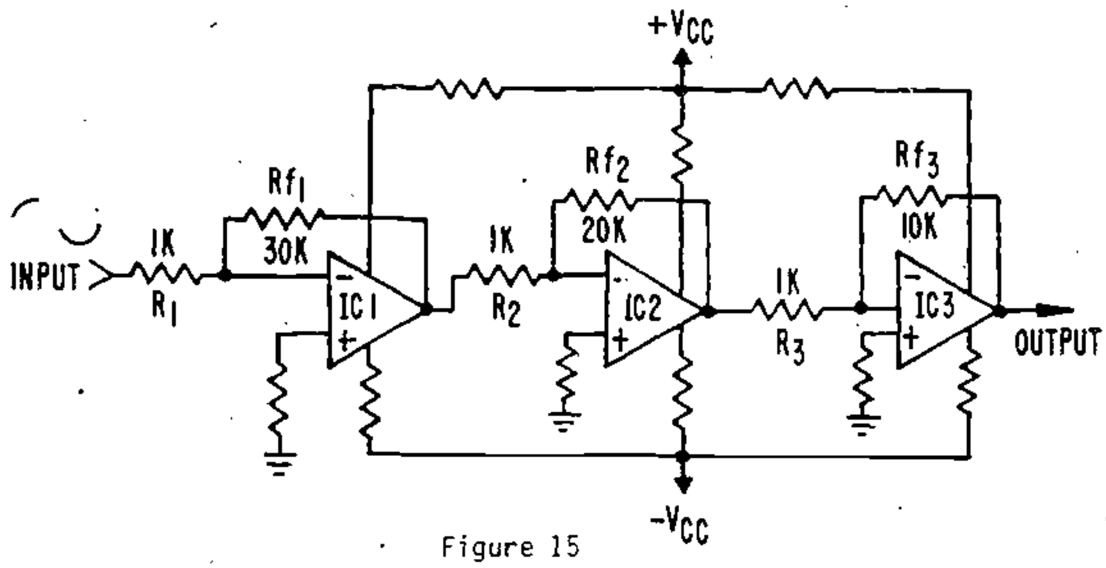

Figure 15

IC TROUBLESHOOTING

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Generally, troubleshooting intergrated circuits follows a definite sequence of events. The first step to take in troubleshooting the equipment, after making obvious fuse and operational checks, is to signal trace with the oscilloscope. In Figure 15, the oscilloscope would be used to check for proper signals at the input and output points. The amplitude of the signal at specific points may be specified in references. If not available there, the correct amplitude may be estimated using the formula:

$$Av \simeq \frac{R_f}{R_{in}}.$$

By applying this formula to each stage in the circuit shown in Figure 15, the gain of each stage becomes as follows:

For IC_1, $Av = \frac{30k}{1k} = 30$; for IC_2, $Av = \frac{20k}{1k} = 20$; for IC_3, $Av = \frac{10k}{1k} = 10$.

A faulty IC stage will be identified as having a good input signal (correct amplitude and shape) and an abnormal output signal (incorrect amplitude or shape).

The first step in troubleshooting IC opamp circuits is to isolate the faulty stage by signal tracing with an __________.

---

oscilloscope

(16) Once the faulty stage is isolated, the next step is to check DC supply voltages at the IC pins as shown in Figure 16.

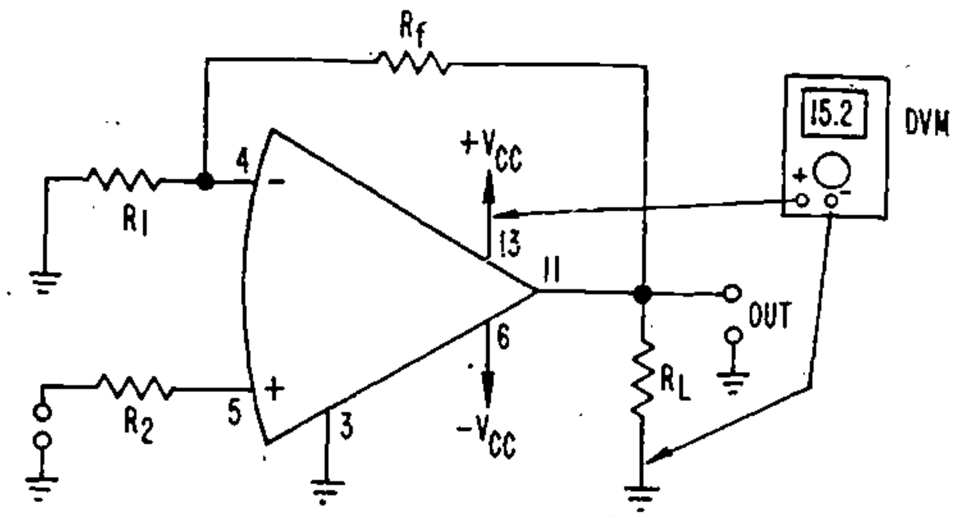

Figure 16

CHECKING IC DC SUPPLY VOLTAGES

IC DC supply voltages range between 5 and 30 volts. IC opamps require a positive (Vcc or V+) and a negative (-Vcc or V-) power supply voltage to operate (see Figure 16). The circuit schematic will usually indicate the voltages and pin numbers where the voltages are applied. Although a digital voltmeter (DVM) is shown in Figure 16, other types of voltmeters may be used (VOM, VTVM, etc.).

After isolating the faulty IC stage, the technician should then check (AC/DC) supply voltages with a (voltmeter/ammeter).

DC, voltmeter

(17) When the supply voltages to a faulty IC stage are normal, the failure is either in stage components external to the IC, or the IC itself. The next step the technician should take is to use the ohmmeter and make resistance checks. However, circuit precautions must be observed. Look at Figure 17.

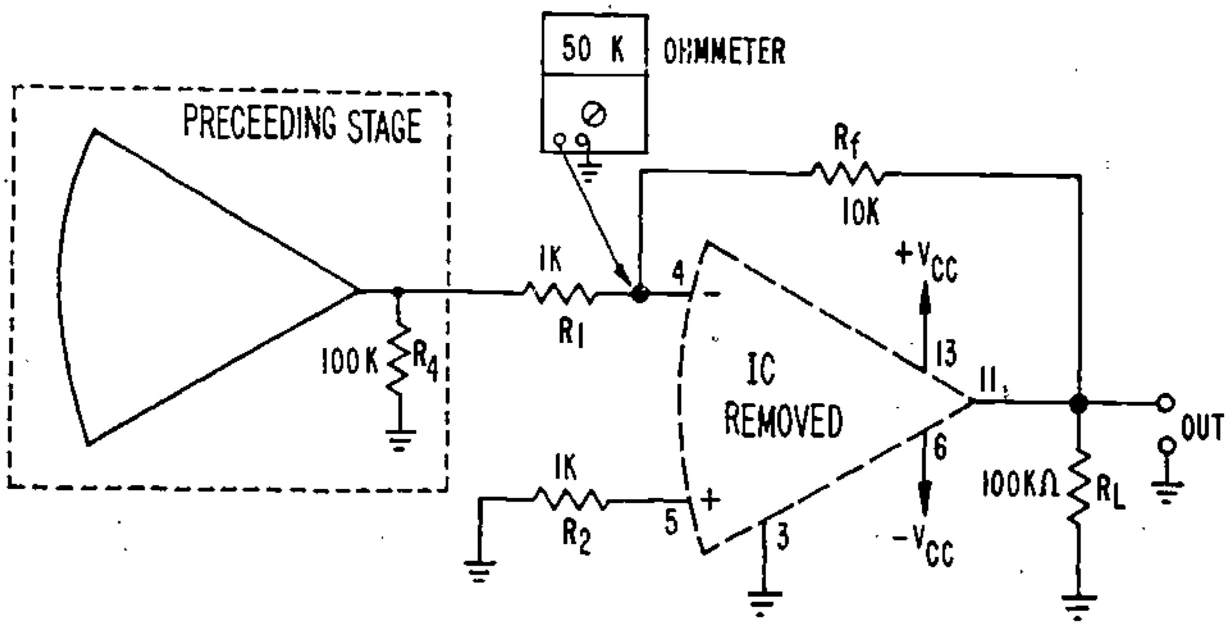

Figure 17

IC RESISTANCE MEASUREMENTS

Technicians making resistance measurements in IC circuits must observe the following precautions:

1. Placing an ohmmeter directly on or across the IC pins may damage the IC, and should be avoided. If socket mounted, the IC should be removed prior to resistance checks.
2. Parallel resistance paths are usually found which must be taken into consideration. (Note the 50K ohm reading in Figure 17).

3. Components may be isolated for measurements by disconnecting one lead.

If an ohmmeter is used to measure resistance in an IC circuit, the IC should be ____________ if possible.

---

removed

18. If resistance checks on the external IC components are normal, the IC may be considered faulty and must be replaced. Since many ICs contain metal oxide semiconductor (MOS) devices, the technician should observe all the handling precautions for MOS devices listed in Lesson 4, Module 33. This list has been reprinted in Figure 18. Study it carefully.

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NOTICE

SPECIAL HANDLING OF MOS DEVICES

The MOS metal oxide semiconductor devices have a fairly high input resistance making them subject to damage from charges of static electricity through improper handling. The thin layer of oxide can be damaged from discharges of static electricity or improper handling in or out of circuit. The damage may be apparent immediately or may show up only after a short operating time. To avoid possible damage, the following procedures should be followed when handling or testing these devices.

1. The use of synthetic clothing such as nylon should be avoided as this will generate static charges. Dry weather (relative humidity less than 30%) also tends to increase static buildup.

2. Keep the leads of the device in contact with a conducting material or shorted, except when testing, inserting or removing from the circuit.

3. A wrist strap with a megohm resistor in series to common ground should be worn by the technician when inserting, removing or testing MOS devices.

4. Do not remove or insert an MOS device with the power to the circuit or test instrument "ON".

5. Do not apply or inject test signals into the circuit when an MOS device is used with the circuit power "OFF".

6. Do not turn the circuit power "ON" with an MOS device removed from the circuit. Charges can build up causing possible damage when the device is replaced in the circuit.

7. Soldering iron tips, metal bench tops, test equipment and tools should be grounded to a common ground along with the chassis of the set being serviced.

8. Soldering guns should not be used in MOS circuits; AC line leakage from the gun tip could cause damage to an MOS device.

9. Do not apply heat for longer than 10 seconds or closer than 1/16 of an inch to any MOS device when soldering. Use of a heat sink is recommended to prevent damage to the advice.

Figure 18

IC HANDLING PRECAUTIONS

When replacing integrated circuits, the technician should unsolder the IC with a ____________ soldering iron.

a. large wattage, grounded tip

b. low wattage, ungrounded tip

c. large wattage, ungrounded tip

d. low wattage, grounded tip

---

d. low wattage, grounded tip

---

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

1. When troubleshooting electronic equipment which uses ICs, the faulty stage is identified as the one with a __________ input and a __________ output.

   a. good, good

   b. bad, good

   c. good, bad

   d. bad, bad

2. IF the DC supply voltages to an IC are normal, you should then take ____________ (voltage/resistance) checks of components ____________ (internal/external) to the IC.

   a. voltage, internal

   b. resistance, external

   c. resistance, internal

   d. voltage, external

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3. When making resistance measurements in IC circuits, you should be careful to _________(remove/replace) the IC and observe ___________ (parallel/series) resistance paths.

   a. remove, series

   b. replace, series

   c. replace, parallel

   d. remove, parallel

1. c. good, bad
2. b. resistance, external
3. d. remove, parallel

IF YOUR ANSWERS MATCH THE CORRECT ANSWERS YOU HAVE COMPLETED THE PROGRAMMED INSTRUCTION FOR LESSON 2, MODULE THIRTY-FOUR. OTHERWISE GO BACK TO FRAME 15 AND TAKE THE PROGRAMMED SEQUENCE BEFORE TAKING TEST FRAME 19 AGAIN.

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.

NARRATIVE
LESSON 2

IC Operational Amplifiers

There are many different types of linear ICs being manufactured. Up to this time, we have discussed information that is common to all types of linear ICs. Now we will discuss a specific type of linear IC called an Operational Amplifier (opamp). The opamp is simply a class "A" amplifier which has two inputs and one output. One input will be used as a signal input. The other input will have a resistor attached to it that will develop bias for the IC opamp. The resultant output is the input voltage multiplied by the gain of the amplifier. Various schematic symbols for an IC opamp are shown in Figure I.

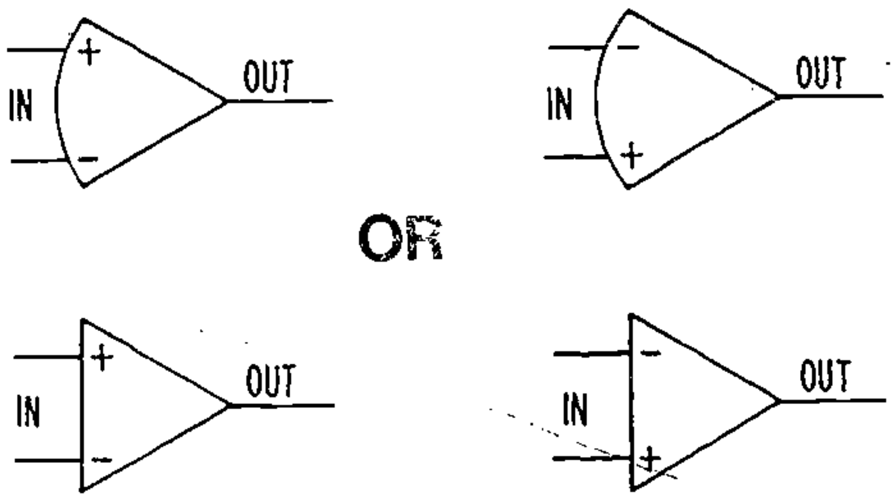

Figure 1

OPAMP SCHEMATIC SYMBOLS

As you may recall, the (+) or (-) at each input in Figure 1 indicates whether the applied signal will or will not be inverted at the output. The (-) indicates an inverting input. If the input signal is applied to the (-) input, the output will be 180° out-of-phase with respect to the input. The (+) indicates a non-inverting input. If the input signal is applied to the (+) input, the output signal will be in-phase with respect to the input signal.

Now let's take a look at an IC opamp in a circuit. See Figure 2.

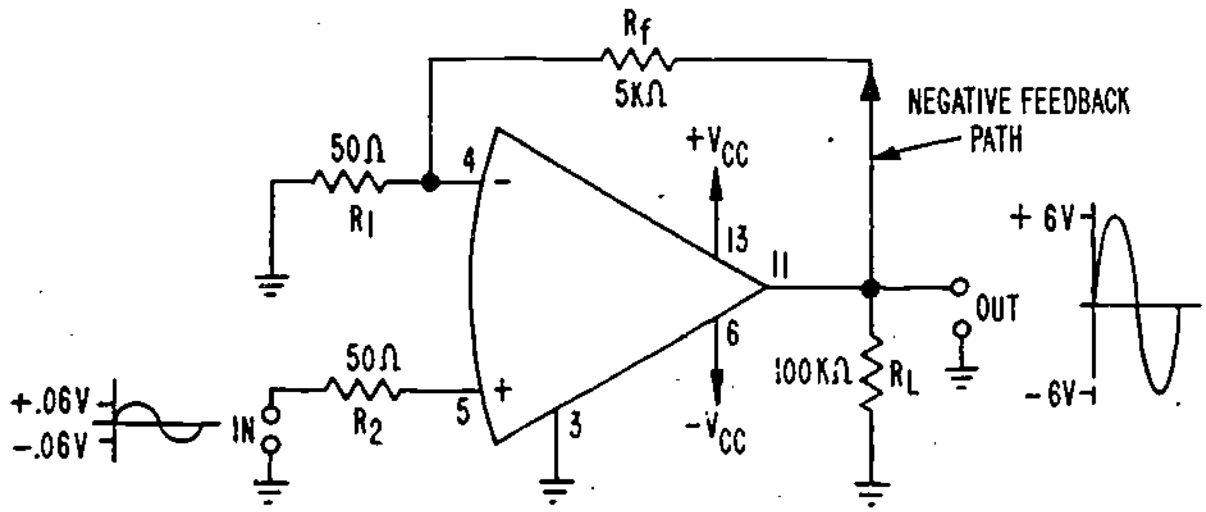

Figure 2.

NON-INVERTING IC OPAMP AMPLIFIER

Operational amplifiers have very high gain. Negative feedback is used to control this gain to usable levels and thus stabilize the amplifier.

The IC opamp in Figure 2 is connected as a non-inverting amplifier (the input signal is applied to the non-inverting input through input resistor R2).

Feedback is applied to the inverting input through Rf (the feedback resistor). Although the feedback appears to be positive (in-phase with the input signal), it is inverted by the (-) input, making it negative feedback. R1 is the bias resistor and RL is the load resistor.

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An IC opamp may also be connected as an inverting amplifier (input signal applied to inverting input) as shown in Figure 3.

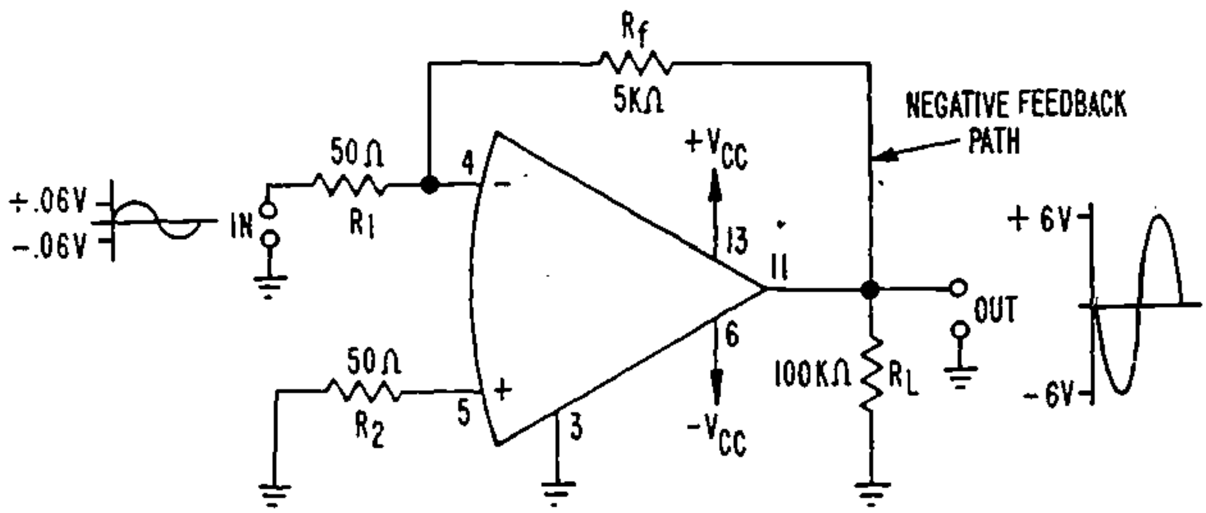

Figure 3

INVERTING IC OPAMP AMPLIFIER

Notice that the only change needed to make a non-inverting amplifier circuit (Figure 2) into an inverting amplifier circuit (Figure 3) is to reverse the ground and input connections. R1 now becomes the input resistor and R2 the bias resistor, as shown in Figure 3.

Notice that the feedback is applied to the (-) terminal for either circuit configuration. This will insure that negative feedback is provided. Negative feedback will stabilize the amplifier's output and keep it from oscillating.

In both circuits the gain of the amplifier is controlled by the ratio of the feedback resistance (Rf) to the input resistance (R1 or R2, depending upon which is used for an input resistor). Stated as a formula,

$$\text{Gain} \simeq \frac{R_{feedback}}{R_{in}}.$$

The " $\simeq$ " symbol means "approximately equal to". This gain is approximate because there are other factors at an engineering level to take into consideration. However, the gain determined by this formula will be close enough to the actual amount for our purposes. The formula applies to both the inverting and non-inverting amplifiers.

In the amplifier in Figure 3 the gain is approximately 100 and the output signal is inverted.

From the gain formula you can easily determine the voltage of the output signal. Since the gain is the number of times the signal is amplified, it is easy to see that the input voltage (Vin) multiplied by the gain would tell you the output voltage (Vout). This stated as a formula would be

$$\text{Vout} \simeq \text{Gain (Vin) or } \frac{\text{Vout}}{\text{Vin}} \simeq \text{Gain.}$$

(NOTE: This formula may be used regardless of how the input is stated, i.e., peak-to-peak, peak, or RMS. However, the output must be stated in the same terms).

Since we know that Gain $\simeq \frac{\text{Rfeedback}}{\text{Rin}}$ for either amplifier configuration,

our formula becomes $$\text{Vout} \simeq \text{Vin} \left(\frac{\text{Rfeedback}}{\text{Rin}}\right).$$

Using the data of Figure 3 we obtain

$$\text{Gain} \simeq \frac{\text{Vout}}{\text{Vin}} = \frac{12 \text{ Volts (p-p)}}{.12 \text{ Volts (p-p)}} = 100 \text{ or}$$

$$\text{Gain} \simeq \frac{\text{Rfeedback}}{\text{Rin}} = \frac{5\text{K ohms}}{50 \text{ ohms}} = 100.$$

Being able to determine the output voltage of an IC opamp can be a very helpful troubleshooting aid; especially if you have to determine whether or not the IC is operating properly. But first you have to find out what voltage is being applied at the input.

Let's discuss the inverting opamp amplifier first.

If you should take out your oscilloscope and check the signal at the input to the IC itself, you would find practically no signal (see Figure 4).

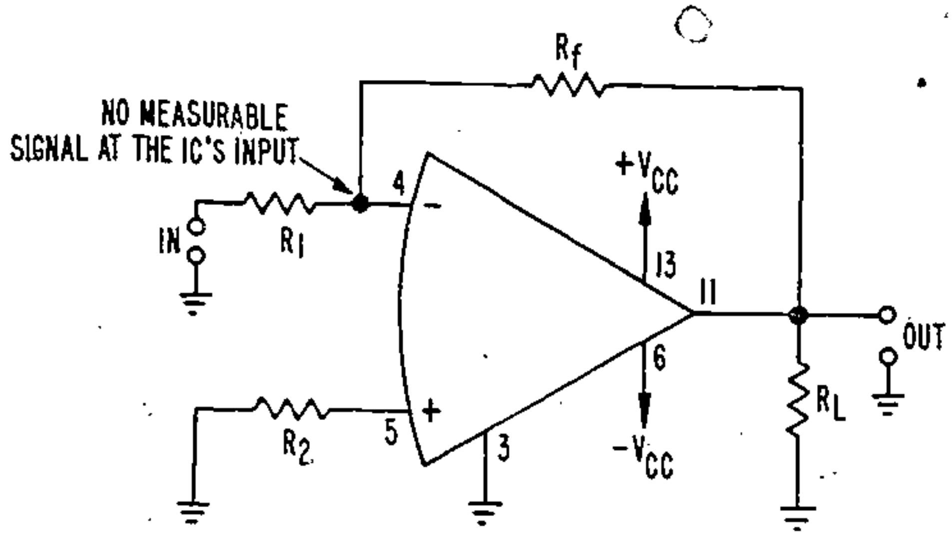

Figure 4

MEASURING OPAMP INPUT

Further checks show a good input signal at the circuit's input (input to the input resistor) and an output signal whose amplitude is correct (as determined by the Vout formula using the input signal applied to Rin for Vin). So what gives? Well, actually those indications were normal for an inverting IC opamp amplifier circuit.

To find out why these indications are normal, let's look at the feedback for the inverting amplifier in Figure 5.

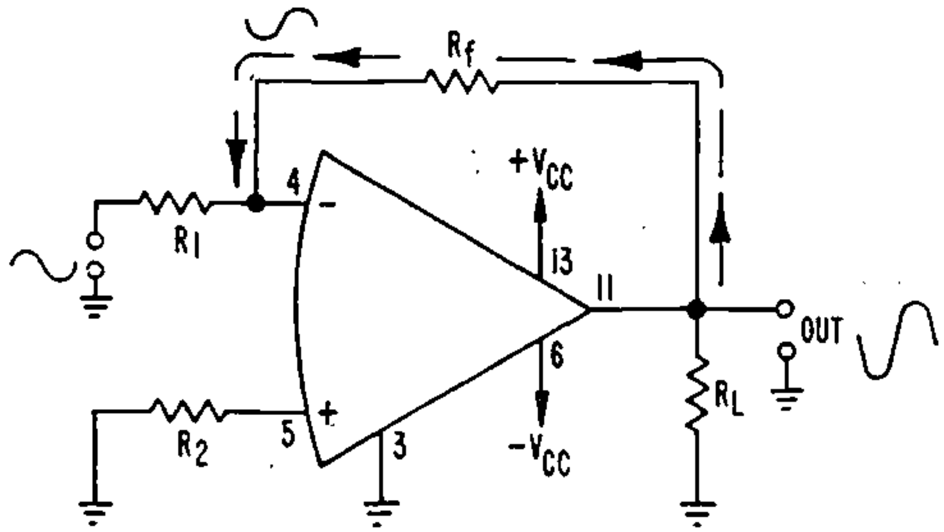

Figure 5

NEGATIVE FEEDBACK INVERTING OPAMP

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The feedback and input signals are being applied to the same point (pin 4 of the IC). Since we are using negative feedback (180° out-of-phase with the input signal), the resulting signal at the IC's input is very small. See Figure 6.

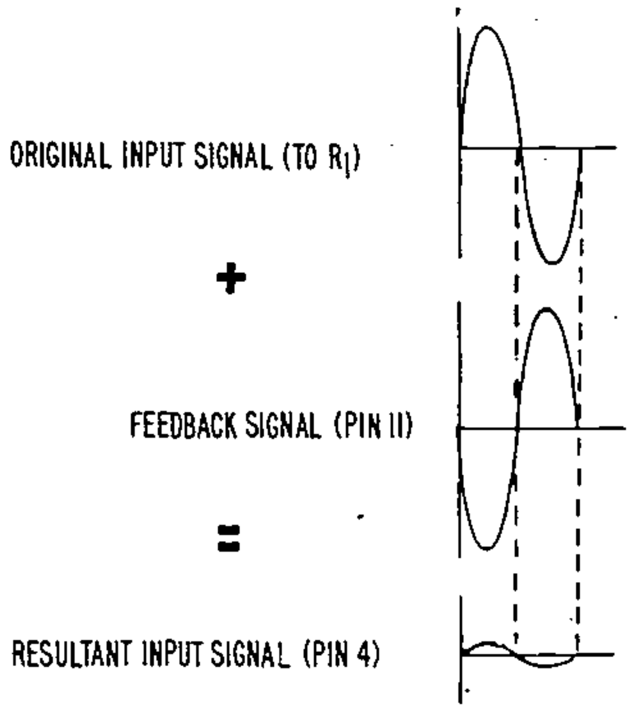

Figure 6

OPAMP SIGNALS

In fact, the input signal applied to Pin 4 of the IC is so small that even the very small loading effect of your oscilloscope will make the signal almost undetectable. Therefore, you must measure the input signal to the inverting circuit at the circuit's input (input side of the input resistor) as shown in Figure 7.

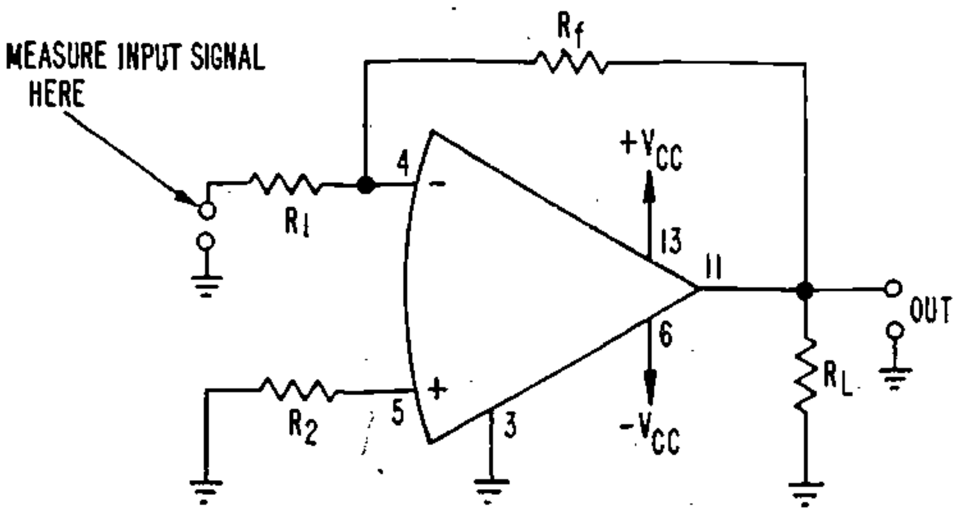

Figure 7

MEASURING INVERTING OPAMP INPUT SIGNAL

The same does not hold true for the non-inverting amplifier shown in Figure 8.

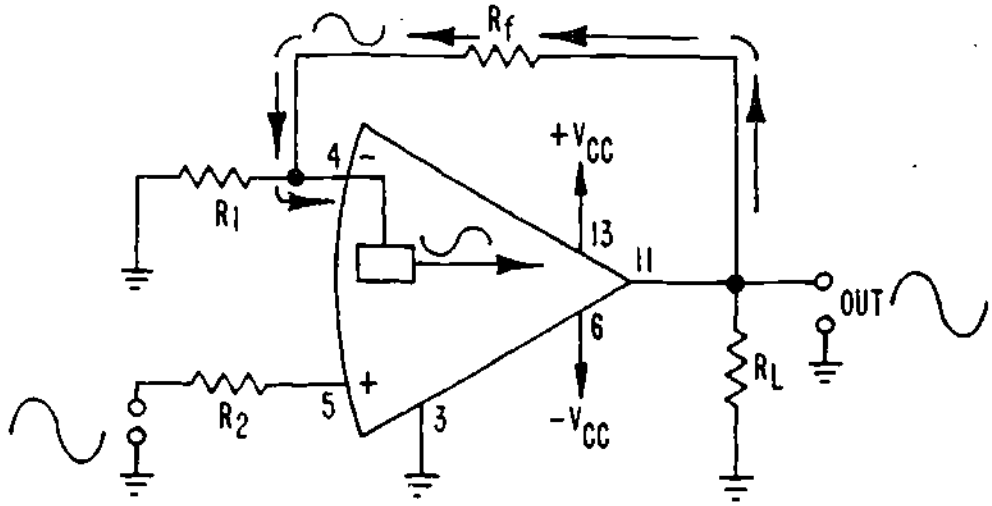

Figure 8

FEEDBACK - NON-INVERTING OPAMP

With the non-inverting amplifier, the feedback is not applied to the same point as the input signal. The feedback signal is inverted, forming the negative feedback inside the IC(see Figure 8). The voltage drop across the input resistor may cause the signal at the ICs input to be smaller than the actual input signal. Therefore, you must measure the input signal to a non-inverting IC opamp amplifier at the circuit's input (see Figure 9).

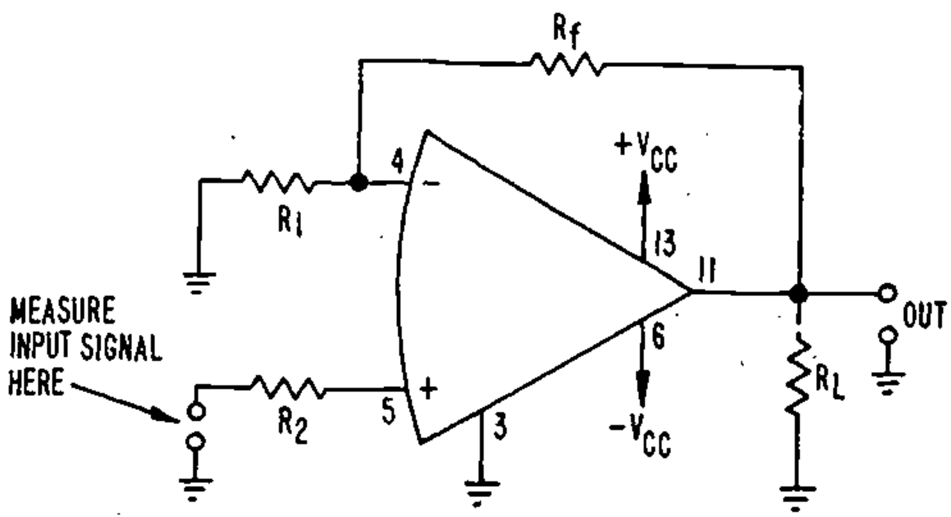

Figure 9

MEASURING NON-INVERTING OPAMP INPUT SIGNAL

We have discussed using an oscilloscope for checking the input signal. But what other checks can you make and which test equipments may you use?

The IC opamp requires a positive (+VCC or V+) and a negative (-VCC or V-) power supply voltage to operate (see Figure 10). The voltages are normally between 6 to 18 volts both positive and negative. The circuit schematic will indicate the voltages and the pin numbers where the voltages are applied. To check these voltages a VOM or VTVM may be used.

You must not measure resistance of an IC; if you do, the meter's current can damage the IC. However, you can measure the resistance of the components external to the IC with an ohmmeter. See Figure 10.

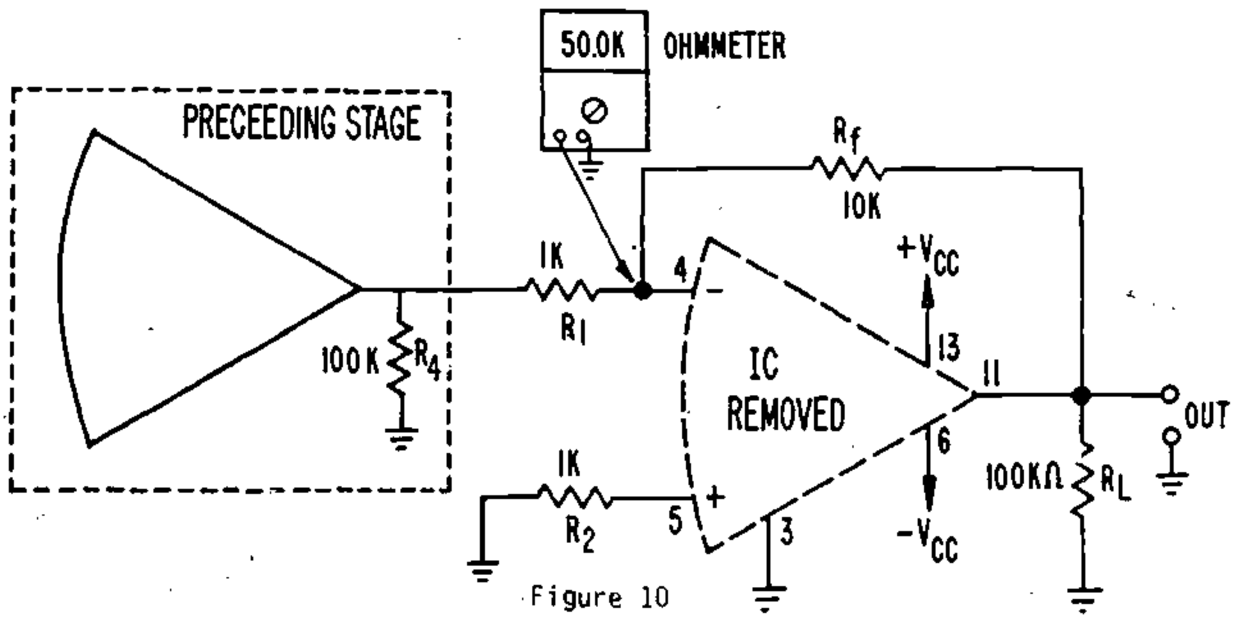

Figure 10

TROUBLESHOOTING OPAMPS

As you can see, there are five resistors in the circuit in Figure 10. If you make a resistance check across any of the resistors, you will be reading across the IC as well. The resistance reading would not only be incorrect, but the IC could be damaged. You must isolate the IC from the component under test.

If the IC is plugged into a socket, a resistance check of the components is simple. Observing the proper handling precautions, take the IC out the make your checks.

If the IC is soldered in place, <u>do not</u> unsolder the IC. Instead, unsolder and carefully lift one lead of each component you wish to check. This isolates the component from the circuit, protects the IC, and gives you an accurate reading of the component's value. One precaution you must observe: Do not unsolder and test more than one component at a time; if you do, you might solder a component back in the wrong place.

To check the output signal of an IC opamp, place your oscilloscope probe on the ICs output pin. The Vout formula, Vout $\simeq$ Vin $(\frac{Rf}{Rin})$, will help you determine if the amplitude of the output signal is correct.

The IC itself cannot easily be checked. If the output signal is <u>incorrect</u> and the input signal, supply voltages, and circuit components check good, the IC may then be considered faulty and must be replaced.

Finally, when replacing ICs, certain precautions must be observed. Since many ICs use metal-oxide semiconductor devices in them, the MOS chart from Lesson 3, Module 33 is reprinted below in Figure 11.

NOTICE

SPECIAL HANDLING OF MOS DEVICES

The MOS metal oxide semiconductor devices have a fairly high input resistance making them subject to damage from charges of static electricity through improper handling. The thin layer of oxide can be damaged from discharges of static electricity or improper handling in or out of circuit. The damage may be apparent immediately or may show up only after a short operating time. To avoid possible damage, the following procedures should be followed when handling or testing these devices.

1. The use of synthetic clothing such as nylon should be avoided as this will generate static charges. Dry weather (relative humidity less than 30%) also tends to increase static buildup.

2. Keep the leads of the device in contact with a conducting material or shorted, except when testing, inserting or removing from the circuit.

3. A wrist strap with a 1 megohm resistor in series to common ground should be worn by the technician when inserting, removing or testing MOS devices.

4. Do not remove or insert an MOS device with the power to the circuit or test instrument "ON".

5. Do not apply or inject test signals into the circuit when an MOS device is used with the circuit power "OFF".

6. Do not turn the circuit power "ON" with an MOS device removed from the circuit. Charges can build up causing possible damage when the device is replaced in the circuit.

7. Soldering iron tips, metal bench tops, test equipment and tools should be grounded to a common ground along with the chassis of the set being serviced.

8. Soldering guns should not be used in MOS circuits; AC line leakage from the gun tip could cause damage to an MOS device.

9. Do not apply heat for longer than 10 seconds or closer than 1/16 of an inch to any MOS device when soldering. Use of a heat sink is recommended to prevent damage to the device.

Figure 11

IC HANDLING PROCEDURES

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 OR 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.