Graymark

808 Triple Power Supply Breadboard

INTRODUCTION

The Graymark Model 808 Triple Power Supply/Breadboard is a high quality piece of equipment that you build yourself. It is designed to provide 5 Volts for logic devices, and variable positive and negative voltages for analog circuitry. All voltages are regulated, and current limiting is is provided to prevent power supply damage in the event of short circuits or overloads.

The Model 808 has been designed to teach you about electronic theory while you have fun building it. You may use either of two different Modes to build your Power Supply/Breadboard. One Mode contains educational experiences, while the other Mode consists of constructing the 808 without learning how it works.

MODE I

MODE I is comprised of Graymark's Self-Tech system of learning. This unique system allows you to build the project at your own rate, with maximum educational value. By blending meaningful educational experiences with the construction of the Power Supply/Breadboard, the instruction manual creates a pleasant atmosphere for learning power supply theory. The 808 is constructed and tested one section at a time, on its carefully designed printed circuit board. This mode enables you to understand the HOW and WHY of Power Supply circuitry. If you are constructing this project without the supervision of an instructor, you may follow MODE II.

The theory portion of the manual assumes that you have a basic understanding of AC and DC circuits, including:

VOLTAGE
CURRENT
RESISTANCE
CAPACITANCE
INDUCTANCE

Mode I should be used if you are constructing this project with the supervision of an instructor, or if you want to learn the electronics theory that is contained in the instruction manual. To follow Mode I, read all material and perform all of the steps for each section. Check off each section, as you complete it, in the Progress Guide.

MODE II

MODE II provides assembly instructions for the printed circuit board, breadboard and enclosure. The completed Power Supply/Breadboard looks and works as well as one constructed using MODE I.

Mode II should be used if you are constructing this project without the supervision of an instructor, and you do not want to learn any electronics theory. To follow Mode II, read **GRAYMARK CARES ABOUT YOUR SAFETY, TOOLS, HOW TO SOLDER, BUILDING YOUR POWER SUPPLY BREADBOARD, USING AN OHMMETER ON POLARIZED COMPONENTS AND CIRCUITRY,** and the **METRIC MEASUREMENTS** sections. Then, perform all the CONSTRUCTION steps, the FINAL PCB ASSEMBLY steps, the CABINET ASSEMBLY steps and the FINAL TEST.

Depending on your skill level and experience in the construction of electronic equipment, you may wish to perform some or all of the PCB tests that follow some of the construction step sequences.

At the back of this instruction manual you will find sections covering **SERVICING, TEST POINT DESCRIPTIONS, TRANSFORMER COIL RESISTANCES, SPECIFICATIONS, LEARNING EXPERIENCE AND SKILL DEVELOPMENT REVIEW,** and Graymark's **REPAIR POLICY.**

You are now ready to start building your Model 808 Power Supply/Breadboard. Follow the instructions closely and you will have an enjoyable experience as well as a piece of equipment that will enable you to build and test experimental and prototype circuitry quickly and conveniently.

P/N 639222
109876543

TABLE OF CONTENTS

PARTS LIST

Model 808 Triple Power Supply/Breadboard

(✔)	QTY.	SYMBOL	PART #	DESCRIPTION	REPLACEMENT PRICE
	1	TEST	61375	Resistor, ½W, 5%, 10 Ohm	.10
	2	TEST	61413	Resistor, ¼W, 5%, 3.9 kOhm	.10 ea.
	1	TEST	62650	Resistor, ¼W, 5%, 10 kOhm	.10
	1	TEST	63915	Resistor, 5W, 20%, 50 Ohm	.50
	2	R1,2	63837	Resistor, 1W, 5%, 1 Ohm	.25 ea.
	2	R3,5	62577	Resistor, ¼W, 5%, 6.8 kOhm	.10 ea.
	2	R4,6	61410	Resistor, ¼W, 5%, 2.2 kOhm	.10 ea.
	2	R7,9	62855	Resistor, ¼W, 1%, 340 Ohm	.10 ea.
	3	R11,12,TEST	61952	Resistor, ½W, 5%, 1.5 kOhm	.10 ea.
	2	R8,10	63848	Potentiometer, 5 kOhm	2.00 ea.
	2	C1,2	63829	Capacitor, Electrolytic, 1000 mF	.75 ea.
	1	C3	63830	Capacitor, Electrolytic, 4700 mF	1.00
	5	C4–8	63828	Capacitor, Electrolytic, 10 mF	.75 ea.
	1	U1	63823	Integrated Circuit, LM317	3.00
	1	U2	63824	Integrated Circuit, LM337	3.00
	1	U3	63825	Integrated Circuit, LM309	4.00
	8	D1-8	63834	Diode, 1N5393	.50 ea.
	4	D9-12	62155	Diode, 1N4148	.10 ea.
	2	Q1,4	63836	Transistor, 9015	.50 ea.
	2	Q2,3	63835	Transistor, 9014	.50 ea.
	1	T1	63849	Transformer	12.00
	1		63843	Switch, Rocker	2.00
	19		63238	Terminal Post	.10 ea.
	1		63831	Printed Circuit Board	3.00
	1		63832	Heatsink	3.00
	2		63833	Heatsink	2.00 ea.
	1		63844	Fuse Holder	2.00
	1		63845	Fuse	.50
	1		61620	AC Power Cord	1.50
	3		63841	Post, Red	1.00 ea.
	1		63842	Post, Black	1.00
	1		62858	Solder Lug	.15
	1		63916	Wire, Green, 22 Gauge, 650mm	.50
	1		63917	Wire, Red, 22 Gauge, 550mm	.50
	1		63918	Wire, Black, 18 Gauge, 150mm	.50
	1		63919	Wire, Red, 18 Gauge, 150mm	.50
	1		63920	Wire, Orange, 18 Gauge, 150mm	.50
	1		63921	Wire, Gray, 18 Gauge, 150mm	.50
	4		63895	Spacer, 10mm	.25 ea.
	2		63896	Spacer, 40mm	.50 ea.
	4		61433	Foot, Rubber	.15 ea.
	1		61553	Strain Relief	.50
	1		63913	Tubing, 4×25mm	.10
	1		63914	Tubing, 6×50mm	.20
	10		62191	Screw, Self-Tapping, 2.6×5mm	.10 ea.
	4		63911	Screw, Self-Tapping, 3×9mm	.10 ea.
	14		63362	Screw, Machine, 3×8mm	.10 ea.
	4		63894	Screw, Machine, 3×20mm	.10 ea.
	18		63277	Washer, Lock, Split, 3mm	.10 ea.
	6		62629	Nut, 3mm	.10 ea.
	2		63908	Screw, Machine, 3.5×12mm	.10 ea.
	2		63909	Nut, 3.5mm	.10 ea.
	2		63910	Washer, Lock, Split, 3.5mm	.10 ea.
	2		63912	Washer, Lock, Internal Star, 7mm	.10 ea.
	2		63363	Washer, Flat, 3.3mm	.10 ea.
	1		63735	Solder, 1600mm	.75
	1		63840	Breadboard	20.00
	1		BB6	Bus Strip	1.95
	1		63838	Cabinet, Top	10.00
	1		63839	Cabinet, Bottom	5.00
	1		63922	Manual, Instruction	8.00

PARTS IDENTIFICATION AND INVENTORY EXPERIENCE

This experience is provided to acquaint you with the various electronic components and fittings included in this project. Unpack the project carefully and check (✔) each part and fitting against the PARTS LIST In case of incorrect, missing, or damaged parts, please refer to How to Order Replacement Parts and Graymark's Warranty.

To assist you in proper identification of the major parts and fittings, pictorial and schematic illustrations are given in Figure 1.

Upon completion of the parts identification and inventory, have your instructor initial your Progress Guide.

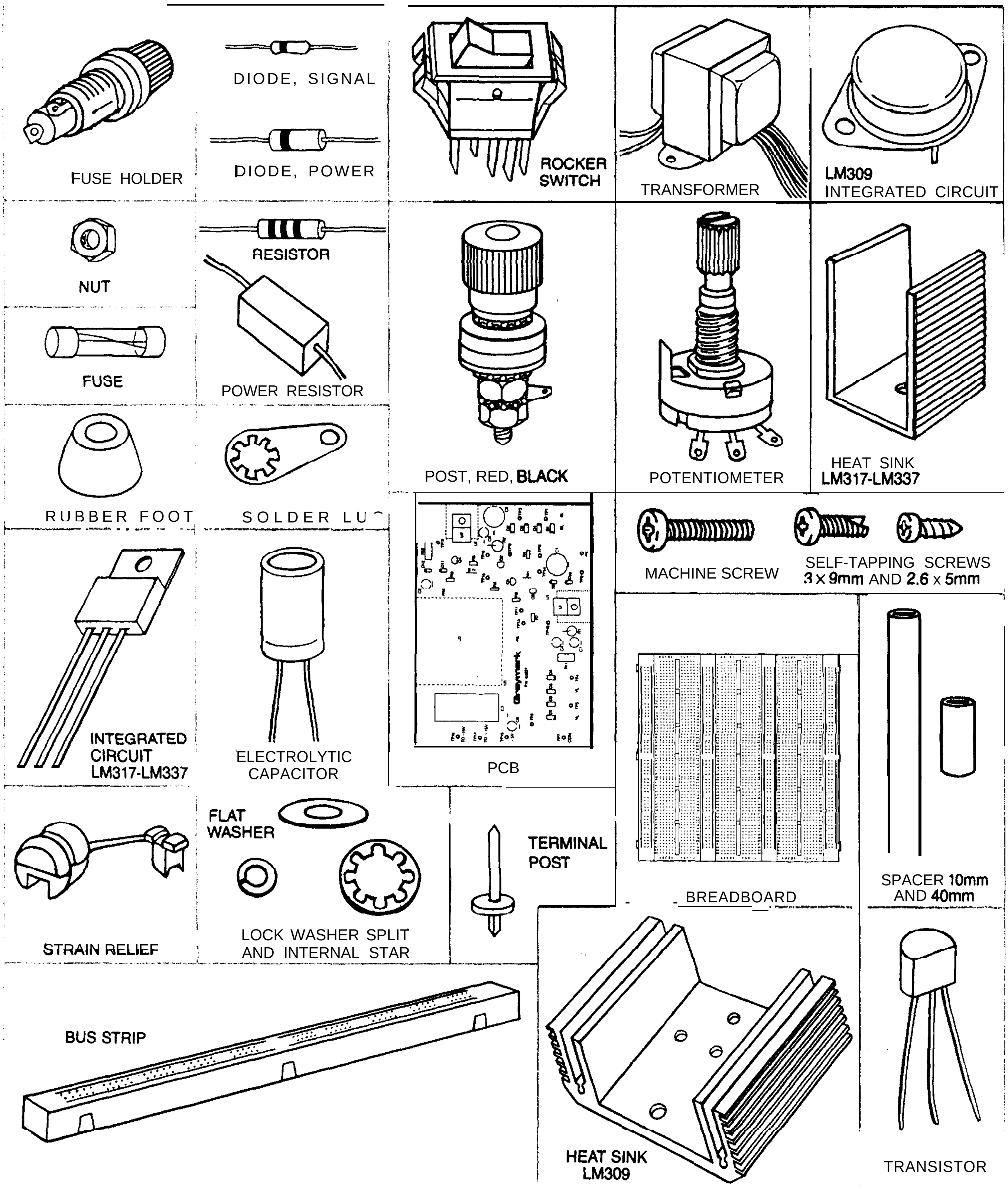


FIG. 1

TOOLS

The proper tools are very important for construction of any kit. Using the wrong tools will slow you down and may damage the project beyond repair. Recommended tools for this kit are:

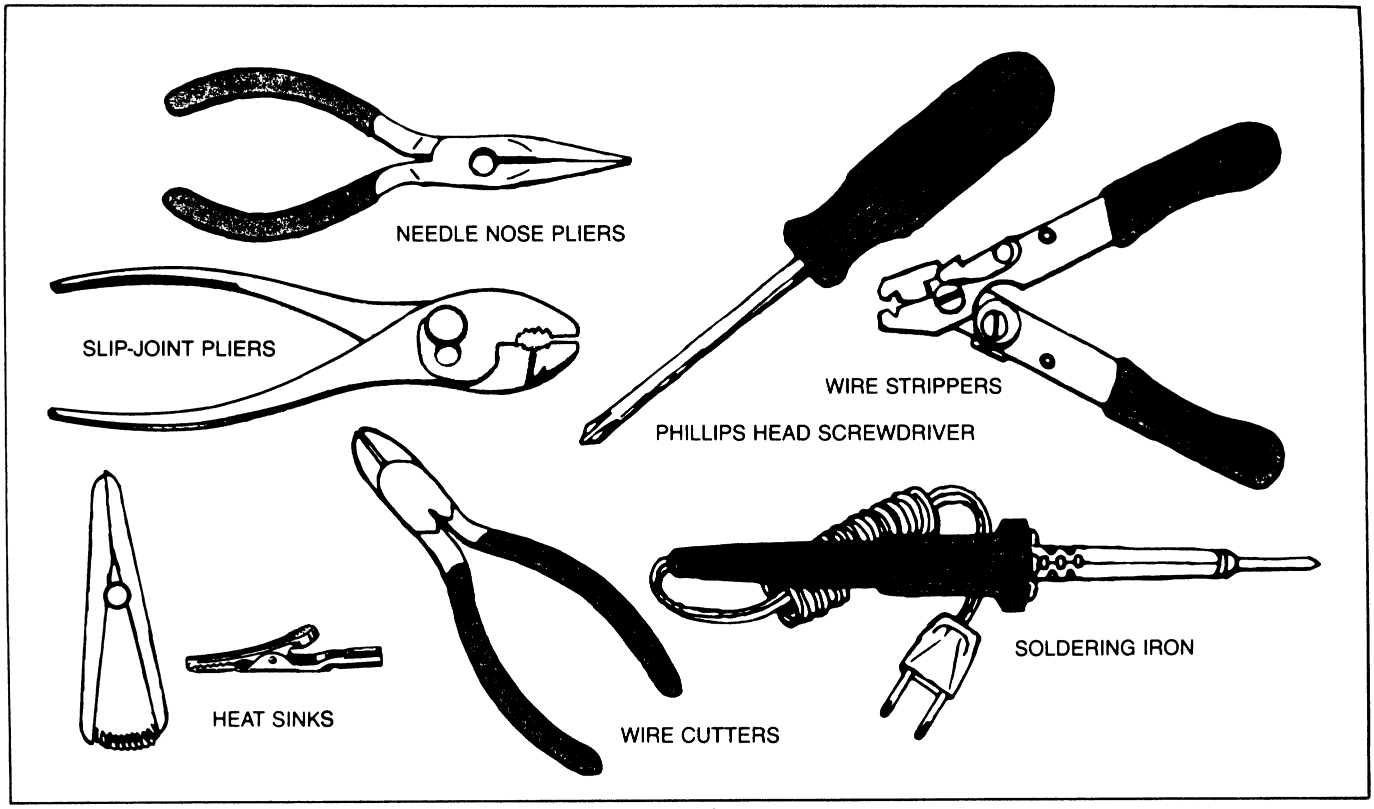


FIG. 2

HOW TO SOLDER

For this project to work properly, you must have good solder connections. If you have not had experience in soldering, it is suggested that before you start assembling this project, you practice making solder connections with odd lengths of wire and used components. Observe the following rules for proper soldering techniques.

1. ***Use a 20-to-30-watt pencil type soldering iron.*** **Do not** use a soldering gun.
2. Use only rosin core solder as supplied with your project. The use of any other types of solder will void your warranty. If additional solder is required, use only 60-40 rosin core, such as Kester 44. DO NOT USE ACID CORE SOLDER or paste fluxes.
3. Be sure the tip of the iron is well tinned (coated with a thin layer of molten solder) so that it will properly conduct heat. To keep the tip clean, wipe it from time to time with a damp sponge or cloth. (See Fig. 3) Do not clean on a sal ammonia block.
4. Before soldering, be sure all connection points such as wire leads, terminal lugs, and printed circuit (p.c.) islands are clean and free of oxidation. Tin wire leads before connecting them into the circuit.
5. Whenever possible, attach wire leads onto terminal lugs by forming tight mechanical connections before you apply solder.
6. Wear safety glasses while unsoldering and soldering to avoid eye injury caused by a hot solder splash or flying bits of wire leads.
7. Position the flat side of the soldering iron firmly against the wire lead and terminal to preheat the metal parts to be soldered. (See Fig. 4). **CAUTION:** ***When soldering semiconductors, such as transistors, use a heat sink to prevent damage to these heat-sensitive devices.***
8. While the connection is being heated, apply the solder. Do not apply the solder directly onto the tip of the iron. Remove the solder feed when enough molten solder has been applied to form a thin coating on all metal parts in the connection. (See Fig. 5).
9. After the solder feed has been removed, continue to heat the connection for an INSTANT. . . this will aid the flow of molten solder and insure against flux pockets. Next, remove the iron from the connection in a smooth motion.
10. Wait until the solder has cooled (solidified) before testing the connection. A properly soldered connection will have a good fillet contour and a smooth bright finish. (See Fig. 6).

Lead dress and placement of components is also important. All wiring or parts placement should be as near as possible. See Figs. 7, 8, 9 and 10 for examples of component placement and solder connections.

CLEANING TIP

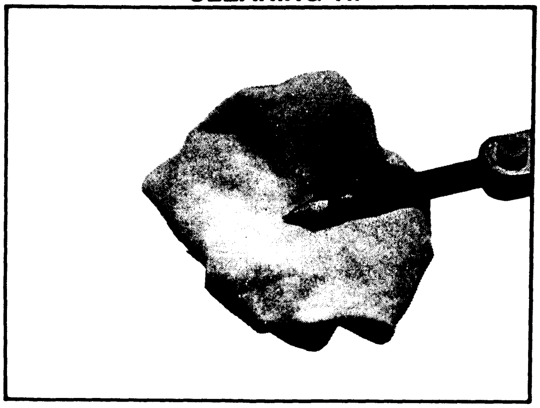


Fig. 3

PREHEAT

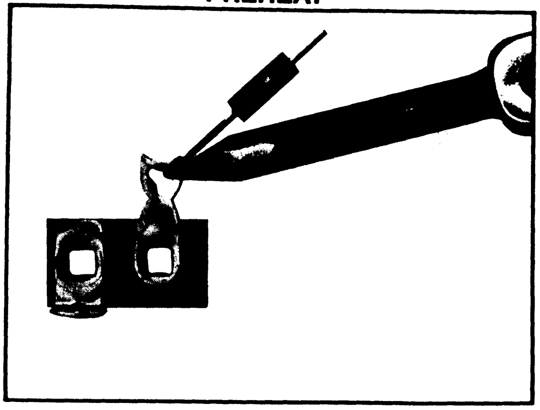


Fig. 4

APPLYING SOLDER

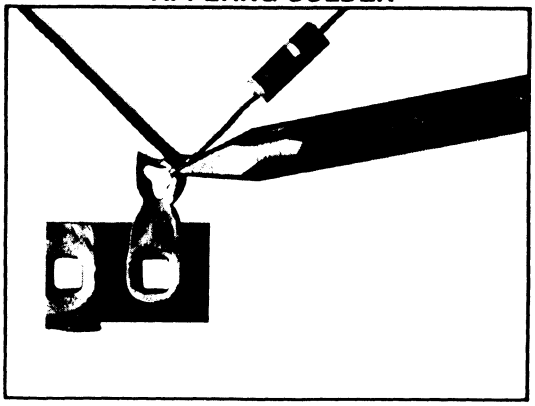


Fig. 5

SOLDER FLOW

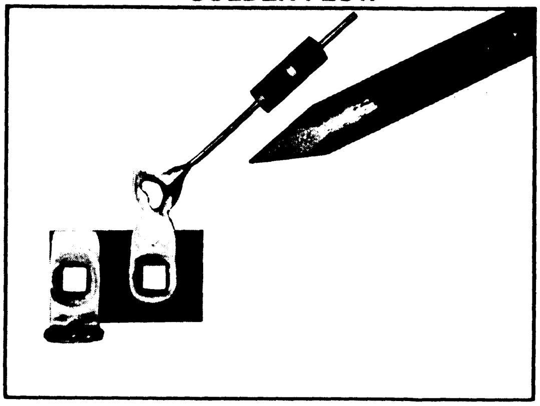


Fig. 6

CORRECT

Fig. 7

INCORRECT

Fig. 8

CORRECT

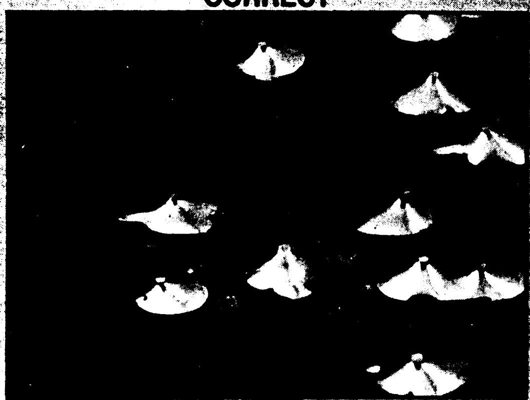


Fig. 9

INCORRECT

Fig. 10

SCHEMATIC

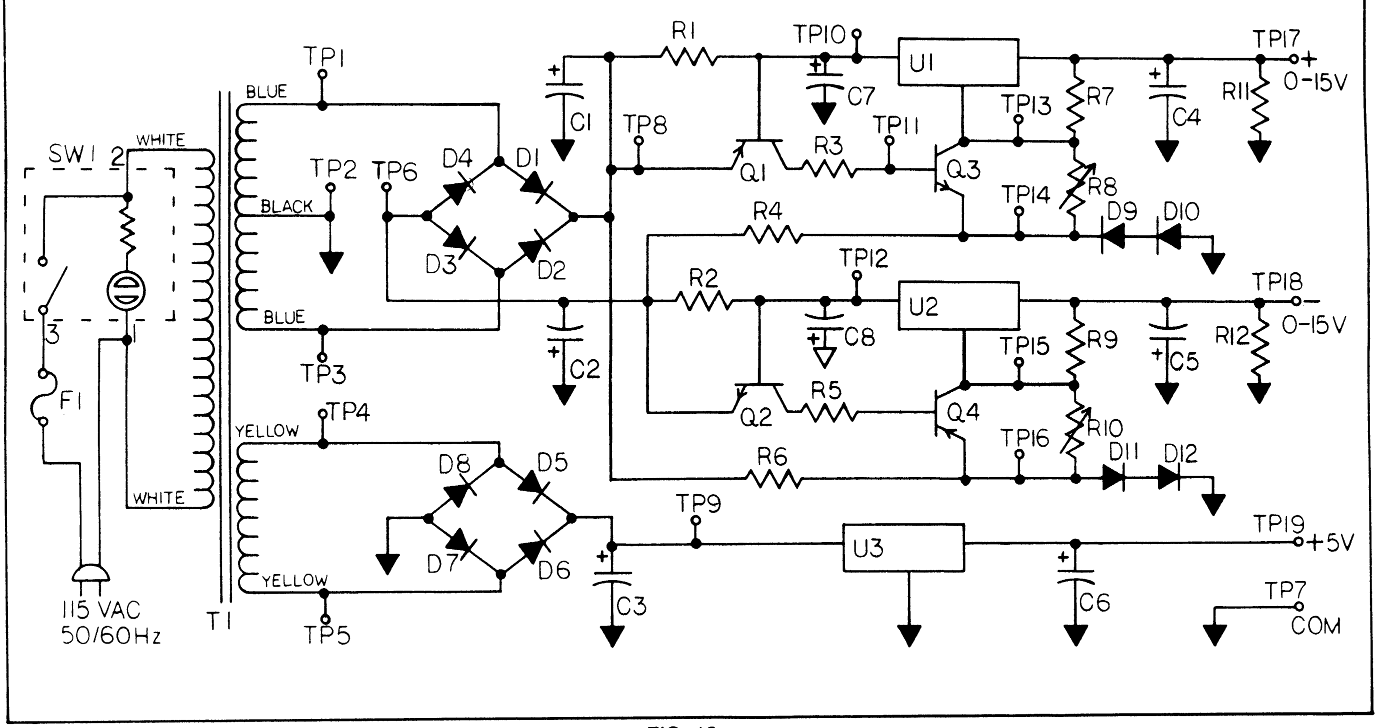


FIG. 13

BLOCK DIAGRAM

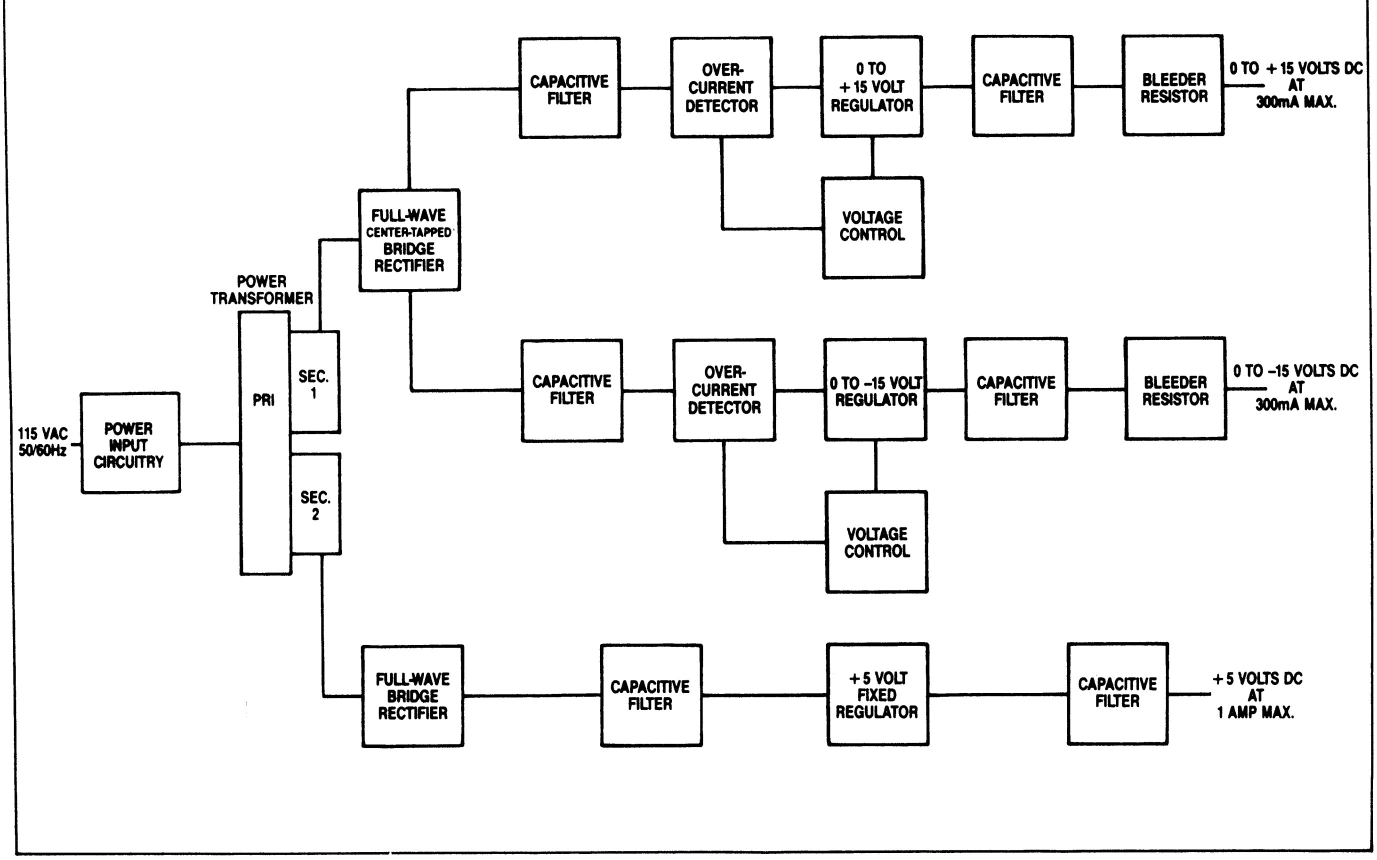


FIG. 14

Check off each experience and test as you complete it. Do not proceed to the next test or experience until you have completed and fully understand the previous one.

COMPLETION DATE	YOUR INITIALS	LEARNING EXPERIENCE	EVALUATION	INSTRUCTOR'S INITIALS
		PARTS IDENTIFICATION AND INVENTORY		
		TRANSFORMER SECTION		
		Winding Resistance Test		
		Winding Isolation Test		
		Construction		
		AC Voltage Observation and Measurement Experience		
		RECTIFIER CIRCUIT SECTION		
		Construction		
		Diode Test		
		Half-Wave Rectifier Experience		
		Full-Wave Center-Tapped Rectifier Experience		
		Construction		
		Full-Wave Bridge Rectifier Experience		
		Construction		
		Center-Tapped Full-Wave Bridge Rectifier Experience		
		FILTER SECTION		
		Capacitive Filter Experience		
		RC Circuit Test		
		Construction		
		PCB TEST		
		VOLTAGE REGULATOR SECTION		
		Construction		
		+15 Volt Regulator Test		
		Construction		
		–15 Volt Regulator Test		
		Construction		
		+5 Volt Regulator Test		
		Overcurrent Protection Experience		
		Temperature Protection Experience		
		EXTERNAL CONTROL AND PROTECTION CIRCUITRY SECTION		
		Adjustment Voltage Experience		
		Construction		
		Overcurrent Protection Circuitry Test		
		Overcurrent Protection Experience		
		Construction		
		Voltage Control Operational Test		
		FINAL PCB ASSEMBLY		
		CABINET ASSEMBLY		
		FINAL TEST		

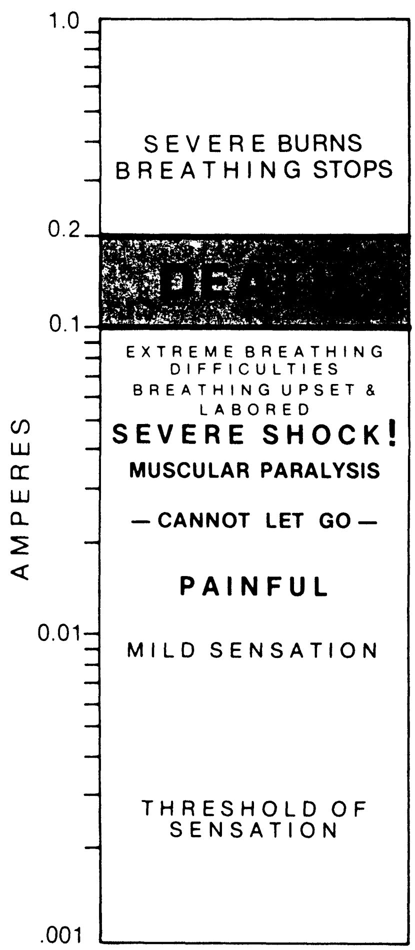
GRAYMARK CARES ABOUT YOUR SAFETY

Through the years, man has developed many useful tools. Two of the most important and powerful tools which we use everyday are the wheel and electricity. Because they are both powerful, they can also be dangerous if we do not understand and respect them.

You would not deliberately lie down in the path of a car, because you know that it could injure you, perhaps fatally, if its wheel passes *over* your body.

With electricity, you must exercise safety precautions to prevent current from passing *through* your body.

A very small amount of electric current passing through your body can injure you, and can even be fatal. Fig11 shows what can occur when different amounts of current pass through your body. Please note that a current as small as .1 amp can cause death. Equally important, notice that even lesser amounts of current can cause physiological effects, ranging from a small sensation to extreme breathing difficulties.



PHYSIOLOGICAL EFFECTS OF ELECTRIC CURRENTS

FIG. 11

These effects can also cause more dangerous events. For example, receiving a mild sensation of only .01 amp would come as a surprise; and, your reaction to it may cause you serious injury. A violent involuntary muscle spasm could cause you to come in contact with an even higher voltage-or hurl your body against a sharp projection, workbench or wall. This is no cause for alarm, for just as you learned and now practice safety precautions with respect to the wheel, you must learn and practice safety precautions for electricity.

UNDERSTANDING THE ELECTRICAL RESISTANCE OF YOUR BODY

Current is forced through the resistance of a circuit by voltage, which is electrical pressure or force. A lower resistance in the circuit allows more current to pass through the circuit for a given amount of voltage.

If you think of the human body as a circuit, then the amount of current that can flow between any two points of the body depends on the resistance between those two points at that time and the amount of voltage or electrical pressure applied. Normally, your skin resistance is high. This high resistance tends to impede the current flowing into and out of your body. However, there are several conditions which can lower skin resistance drastically and which permit a larger amount of current to pass through your body with the same voltage applied.

The average body resistance is over 100,000 ohms. However, if your skin is wet from perspiration or other moisture, or if your pulse rate is high, your body's resistance can be as low as a few hundred ohms.

Also, if your skin is broken with a cut or an abrasion, a lesser voltage is required at that point to force the same amount of current through your body.

PRECAUTIONS TO BE USED WHEN WORKING WITH ELECTRONIC CIRCUITS

1. ***Practice a precaution used by experienced technicians. Try to keep one hand in your pocket or behind you, when you are making voltage and current measurements. If two hands are in contact with the circuit or if one hand is in contact with the circuit and the other hand is in contact with ground (such as a metal panel or the case of a piece of test equipment), the current path is across the chest where the heart, and lungs are located. This is extremely dangerous.***
2. ***Do not work on electronic circuits when the power is on, except when absolutely necessary.***
3. ***Electrolytic and other large capacitors can hold a voltage charge for several hours after the power is removed. Make it a habit to check if they are fully discharged by shorting them with a screwdriver with an insulated handle or clip lead before working on a circuit.***
4. ***Do not work on electronic equipment while standing on a damp floor or when leaning on any metal object.***
5. ***Certain components, such as resistors and vacuum tubes, get quite hot. Give them time to cool off before removing them.***
6. ***Make it a point to know the location of an available fire extinguisher and how to use it.***
7. ***Be sure equipment is in proper working order before you use it. Frayed, cracked, or burnt power cords and cracked or chipped plugs are a major source of accidents.***

SAFETY IS EVERYONE'S RESPONSIBILITY. Where your personal life and good health are concerned, safety becomes your responsibility. Whether you lie in the path of a car or expose yourself to a lethal electrical shock are matters over which you, as an individual, have more control than anyone else.

Familiarize yourself with these safety precautions before working with any electronic circuits, and your experience will be pleasant and rewarding.

We care about your personal safety as much as we care about your learning electronics.

808 Power Supply/Breadboard

BUILDING YOUR POWER SUPPLY/BREADBOARD

ASSEMBLING YOUR POWER SUPPLY/BREADBOARD DOES NOT REQUIRE ANY PREVIOUS ELECTRONIC EXPERIENCE. THE NINE RULES THAT FOLLOW WILL MAKE BUILDING THIS PIECE OF EQUIPMENT FUN AND EASY.

1. Exercise patience. If you rush through your project, chances are that you will forget something, lose a part, or do something wrong. Take your time and you will have a working piece of equipment much sooner than if you rush through the project.
2. Use a clean, large work space. Make sure you have enough room to assemble the project. If your work space is too small or cluttered, you will be likely to misplace parts or get confused. You should have enough room to keep the 808 parts and your tools on the table and still have plenty of room to work.
3. Use the proper tools. Trying to make do with the wrong tool will cause trouble and could cause irreparable damage to the power supply/breadboard.
4. Double check your work. Before proceeding with an instruction, make sure you understand it. After completing an instruction, double check your work to make sure you did what the instruction called for.
5. Pay particular attention to component values. Many parts look similar. If you have any doubts about a part, check to make sure there isn't another part which better fits the description.
6. Make sure your work space is well lit. If you don't have enough light, it is easy to make mistakes. Resistors use painted color bands to identify their value, and it is very easy to mistake one color for another in inadequate light.
7. Neatness is important. Beside the fact that your project will look better if you do a neat job, it will also work better. Sloppy wiring is likely to short or break. Again, take your time to do the job right.
8. Pay close attention to all figures. The figures show how your power supply/breadboard should look as you assemble it. If it doesn't look the same, you've probably made an error.
9. Check for short circuits or other faults after installing components.

The power transformer in your 808 power supply is capable of supplying enough current to quickly overheat and damage diodes, transistors, capacitors, resistors and possibly even the printed circuit board (PCB). This could happen if one or more components have been installed incorrectly, if there excess solder or a stray lead causing a short on the PCB or one of the new components in the kit is defective or incorrectly marked.

To check for faults, when first powering up the 808 after you have installed any parts, turn the power switch on, wait about one second (count "one thousand and one") and then turn the power switch OFF. Feel each component with your finger. (Careful, if there is a fault, the component could be hot enough to burn your finger.) If any of the components feel warm or hot, there is something wrong.

Check your work carefully, and consult with your instructor if necessary. If your power supply passes this one second test, repeat it, keeping the power switch on for about five seconds this time.

Of course, if you have just soldered a part to the PCB, it will be warm. In that case, wait for the part to cool down. If you're in a hurry, blowing on the part will cool it faster.

After being in operation for some time, and especially under full load, it is normal for some components such as diodes, voltage regulators, heatsinks, and some of the resistors to become quite warm or even hot.

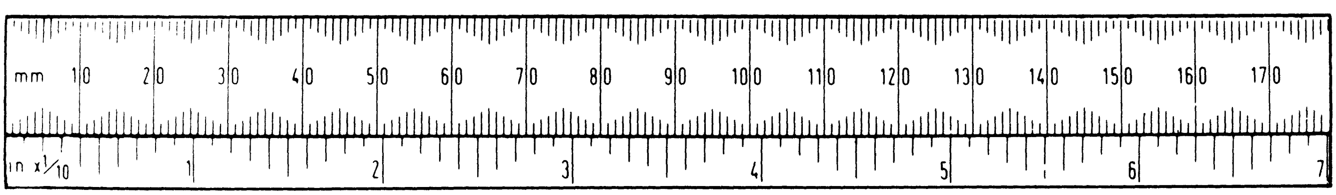
If at any time you see smoke coming from any part of your power supply, immediately turn OFF the power switch and remove the power plug from the power outlet.

USING AN OHMMETER ON POLARIZED COMPONENTS AND CIRCUITRY

All ohmmeter ranges on VOMs and DMMs (digital multi meters) measure resistance by either passing a current through or applying a voltage to the component or circuit under test, and measuring the resulting voltage or current.

METRIC MEASUREMENTS

All measurements in the manual are metric, the international measurement language. For your convenience, a metric ruler is printed occasionally throughout the manual.



A battery inside the VOM or DMM is used to provide the power necessary for making resistance measurements. When measuring the resistance of non-polarized components, such as resistors or transformer windings, the polarity of the voltage and current provided by the measuring instrument makes no difference in the resistance reading obtained. But when measuring the resistance of a polarized component, such as a diode, the polarity of the voltage or current from the measuring instrument does affect the measured resistance. This is caused by the fact that the device being measured actually responds differently to different polarities of applied voltage or current.

Most DMMs are designed so that the negative voltage from the internal battery appears on the negative test lead, which is the lead plugged into the meter jack marked Negative (-) or COM.

Many VOMs, including Graymark Models 206A and 212, are designed so that the positive voltage from the internal battery appears on the negative test lead.

If you are not sure which way the internal battery is connected in the meter you are using, you can easily find out with a diode that is correctly marked with a band on the cathode lead end of the diode body. See Fig. 38.

Use the lowest ohmmeter range, unless there is another range marked with a diode symbol or the word "diode". If so, then use that range. Connect the negative test lead of the meter to the diode lead coming out of the banded end of the diode body. Connect the positive test lead to the other diode lead.

If the ohmmeter indicates an infinite reading, then the negative battery voltage is appearing on the positive test lead. If you get a resistance reading on the meter, typically from one third to two thirds full scale on a VOM, then the negative battery voltage is appearing on the negative test lead.

In some of the tests that you will make using an ohmmeter during the construction of the 808, the ohmmeter test leads will be referred to as positive*, or negative*. The asterisk after the word "positive" indicates that you should use the test lead that has the positive voltage from the ohmmeter battery appearing on it. The asterisk after the word "negative" indicates that you should use the test lead that has the negative voltage from the ohmmeter appearing on it.

PRINTED CIRCUIT BOARDS

Modern printed circuit technology offers substantial reductions in both size and weight over discrete hook-up wire circuits. Without the use of printed circuit boards, engineering triumphs such as the Apollo moon landings would not have been possible. Your Model 808 Power Supply/Breadboard uses a printed circuit board that serves as the foundation for mounting and connecting the various components which form the units circuitry. The printed circuit board (PCB) has been silkscreened on the non-copper side to show you exactly where each component is mounted. The copper circuit side has a special flux coating which protects the copper from oxidation and helps produce good solder connections. Assembly of the PCB gives you an opportunity to develop skills in soldering, lead dress, component identification and the use of hand tools.

SCHEMATICS AND BLOCK DIAGRAMS

All electronic circuits can be graphically illustrated in two ways: the schematic diagram and the block diagram. A schematic diagram is a drawing in which each circuit element is represented by a graphic symbol, and wires are represented by lines. A block diagram is a drawing in which principal sections are represented by geometrical figures to show functions and illustrate functional relationships.

BREADBOARDS AND POWER SUPPLIES

In the early days of electronics, flat pieces of wood, often plywood, were used as the physical foundations for experimental and prototype electronic circuits. Often these pieces of wood were about the size of a kitchen breadboard. Terminal strips, vacuum tube sockets, transformers and other electronic components were attached to the piece of wood using screws, and occasionally nails. Parts such as small resistors and capacitors were soldered to the terminal strips. Bus wire or insulated hook-up wire was used to connect the various components together.

With the development of the transistor and later the integrated circuit, along with miniaturization of other components, the space needed to breadboard even a complex electronic circuit dropped dramatically. But the number of interconnections required in a given amount of space increased even more dramatically.

Along with the developments mentioned above, several standards were becoming common. A pin spacing of 2.54 mm (.100 inch) is used on most integrated circuits. Several popular families of digital logic and memory ICs operate on 5 Volt dc power. Many analog ICs require both positive and negative power supplies. Voltages of +/-6 Volts, +/-12 Volts or +/-15 Volts are often required.

Your Graymark 808 Power Supply/Breadboard is well suited to support modern integrated circuitry by meeting the standards mentioned above. It provides the following regulated voltages:

+5 Vdc FIXED
0 TO +15 Vdc ADJUSTABLE
0 TO -15 Vdc ADJUSTABLE

The maximum output current for the +5Vdc supply is 1.0 Ampere. The maximum output current for the 0 to +15 Vdc supply and 0 to -15 Vdc supply is 300 mA each. All three supplies can deliver currents up to their maximum ratings simultaneously.

A complete schematic diagram of the 808 Power Supply is shown in Fig. 13.

Electronically, The 808 consists of the following types of circuit blocks and components. Refer to Fig. 14.

INPUT CIRCUITRY
TRANSFORMER
FULL WAVE BRIDGE RECTIFIER
CENTER-TAPPED (or DUAL COMPLEMENTARY) FULL WAVE BRIDGE RECTIFIER
CAPACITIVE FILTERS
VOLTAGE REGULATOR INTEGRATED CIRCUITS
EXTERNAL CONTROL AND PROTECTION CIRCUITRY
BLEEDER RESISTORS

The 808 will be studied and built in stages that will follow the BLOCK DIAGRAM of Fig. 14. We will begin with the discussion of the INPUT CIRCUITRY and TRANSFORMER blocks.

INPUT CIRCUITRY SECTION

Refer to Fig. 15.

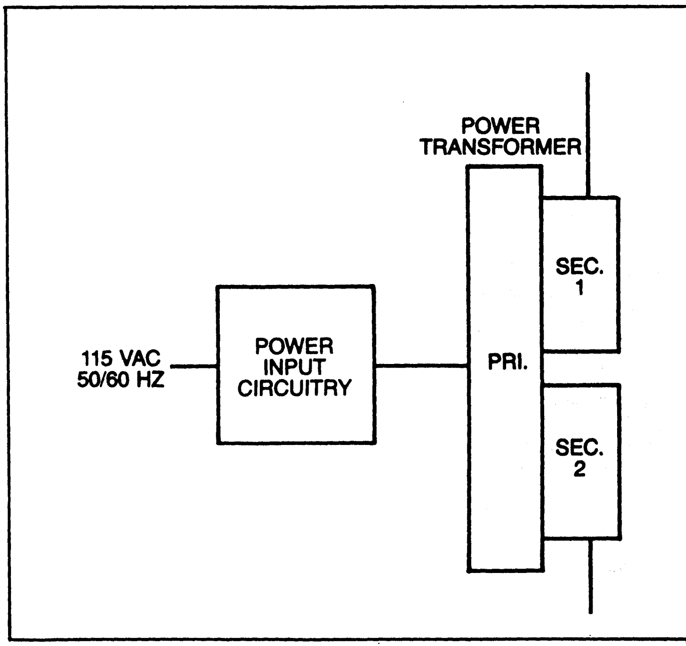
The input circuitry of the 808 consists of the following components.

AC POWER CORD - provides the means of getting the AC power from the 115 VAC outlet to the 808 power supply.

FUSE - used for circuit protection. It will interrupt current flow when the input circuitry is overloaded. When the current rating of the fuse is exceeded, the thin metal filament within the glass envelope will melt, thereby opening the circuit, which will interrupt current flow. The fuse itself has a voltage and current rating marked on the outside casing.

POWER SWITCH - a single pole switch. When placed in the "ON" position, it connects the AC power provided through the AC Power Cable to the transformer primary winding.

The power switch has a built in neon lamp that serves as a "Power On" indicator. The neon lamp consists of two electrodes and an atmosphere of neon gas enclosed in a glass envelope. When the electrodes are connected to a low voltage the gas will not conduct, and the resistance between the electrodes is extremely high. When the voltage is increased to a high enough point, the the gas between the electrodes will ionize, that is, the atoms of gas will gain or lose electrons. The ionized neon gas will conduct electricity and in doing so gives off orange colored light. When the gas is ionized, the voltage drop across the electrodes will remain constant regardless of any increase in the current flowing through the lamp. To limit the current to a safe value for the lamp, a ballast resistor is connected in series with the lamp electrodes.



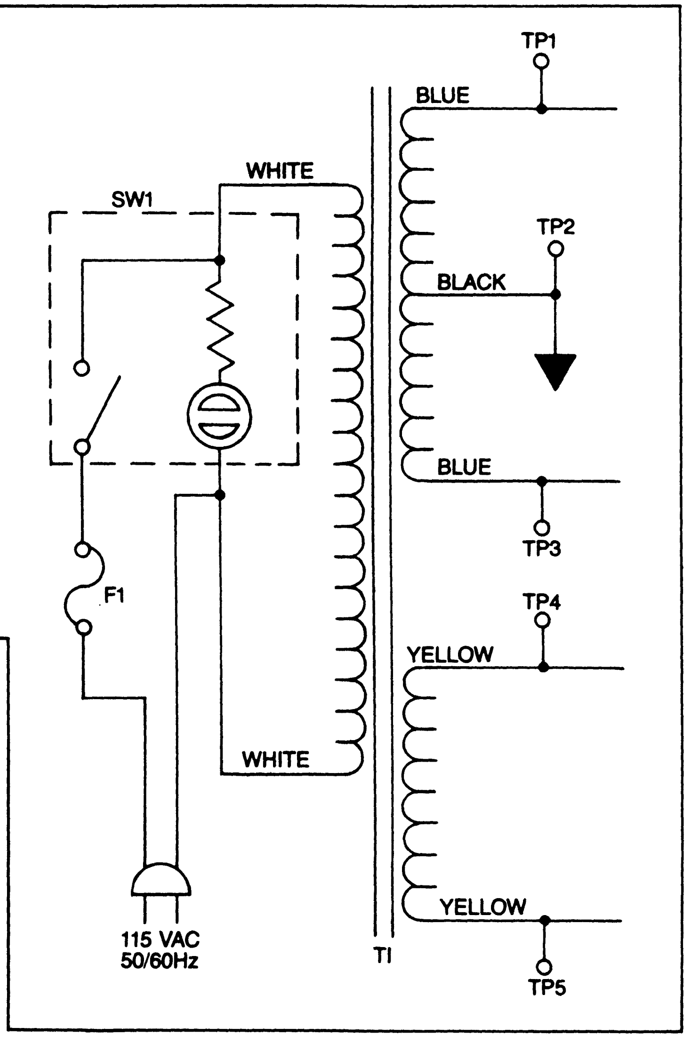


FIG. 15

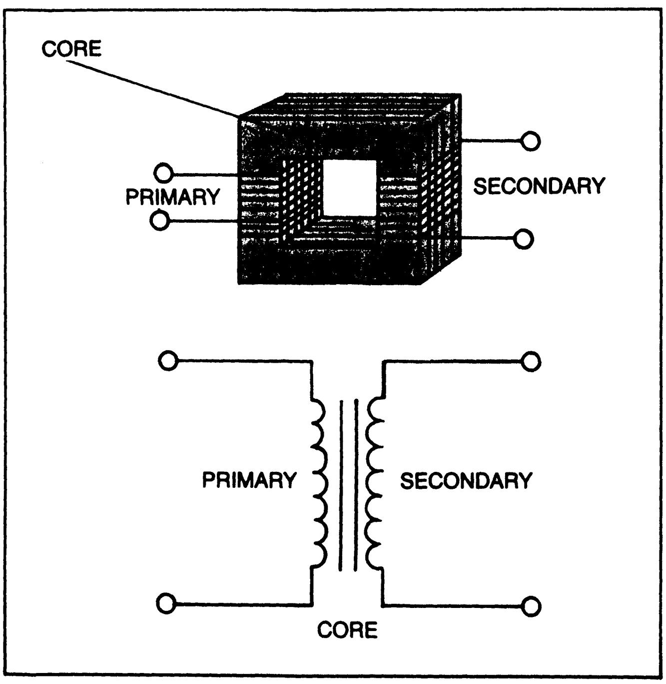


FIG. 16

TRANSFORMER SECTION

DISCUSSION

Refer to Fig. 16 for this discussion.

A transformer is an alternating current (AC) device that transfers electrical energy from one circuit to another. In its basic form, the transformer consists of two coils of wire wound around a magnetic core. The core is used to strengthen the magnetic field. (There are different types of core material; the most common is iron.) One coil is connected to an AC Voltage source and is called the PRIMARY winding; the second coil is called the SECONDARY winding. The words WINDING and COIL are interchangeable. The words PRIMARY and SECONDARY are sometimes abbreviated PRI and SEC.

The SECONDARY coil receives electrical energy from the PRIMARY coil; this is done through mutual induction. The mutual induction process is explained below.

The following is a brief discussion of the physical laws of electricity and magnetism which makes transformers possible:

The transformer is based on FARADAY'S LAW OF INDUCTION. Current flowing in a conductor will produce a magnetic field around the conductor. The conductor can be any shape or size. We can intensify the magnetic field of a current carrying wire by forming the wire into a coil of many turns. We can further strengthen the magnetic field by placing an iron core in the center of the coil. When two coils are close together a current in one coil will produce a magnetic field around it and this magnetic field will induce a Voltage across the second coil which will cause a current flow in the second coil. The current flow in the second coil will produce a magnetic field around it. This process is called induction or mutual induction. As stated earlier, the transformer consists of two coils place close together to achieve mutual induction. This mutual induction process causes a magnetic coupling effect (to link or unite the two magnetic fields of the two coils) and this is strengthened by the iron core.

Refer to Figs. 17, 18 and 19.

One of the characteristics of a transformer is it's ability to either STEP UP or STEP DOWN an AC Voltage. When the Voltage across the PRIMARY coil is equal to the Voltage across the SECONDARY coil, it's called a ONE-to-ONE. When we speak of STEP UP or STEP DOWN, we mean that the Voltage at the output (secondary coil Voltage) is either increased (STEP UP) or decreased (STEP DOWN). The STEP UP or STEP DOWN Voltage is proportional to the ratio of the number of turns in each coil (see mathematical formula below). That is, when the number of turns in the SECONDARY coil is GREATER than the number of turns in the PRIMARY coil, it's a STEP UP transformer. When the number of turns in the SECONDARY coil is LESS than the number of turns in the PRIMARY coil, it's a STEP DOWN transformer. When the number of turns in the PRIMARY coil is EQUAL to the number of turns in the SECONDARY coil, it's a ONE-to-ONE transformer.

The mathematical formula for determining the secondary coil Voltage is:

$$V_s = V_p \times N_s/N_p$$

where: V_s = secondary voltage

V_p = primary voltage

N_s = number of turns of the secondary coil

N_p = number of turns of the primary coil

Another way of writing this formula is:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

In addition to the basic transformer with two windings and

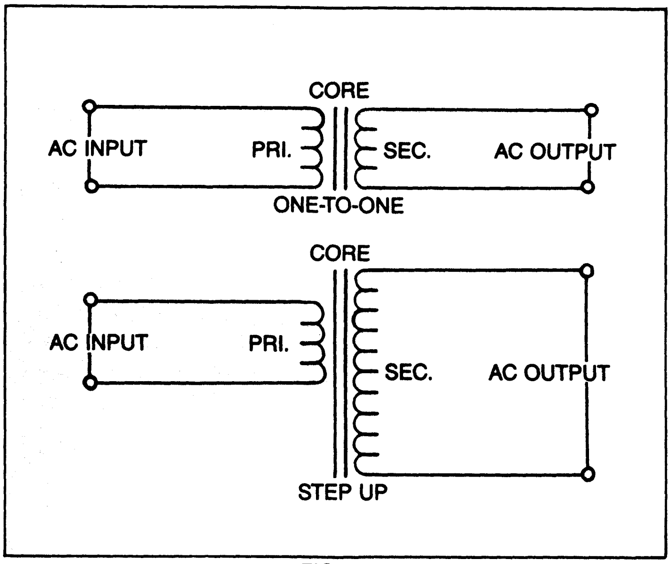


FIG. 17

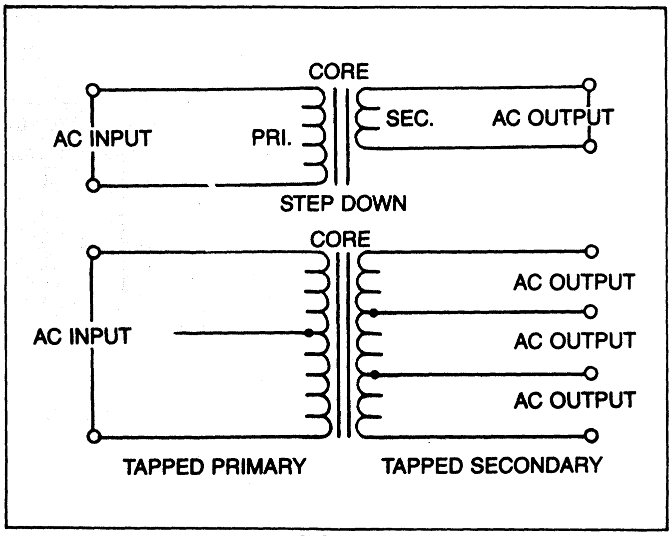


FIG. 18

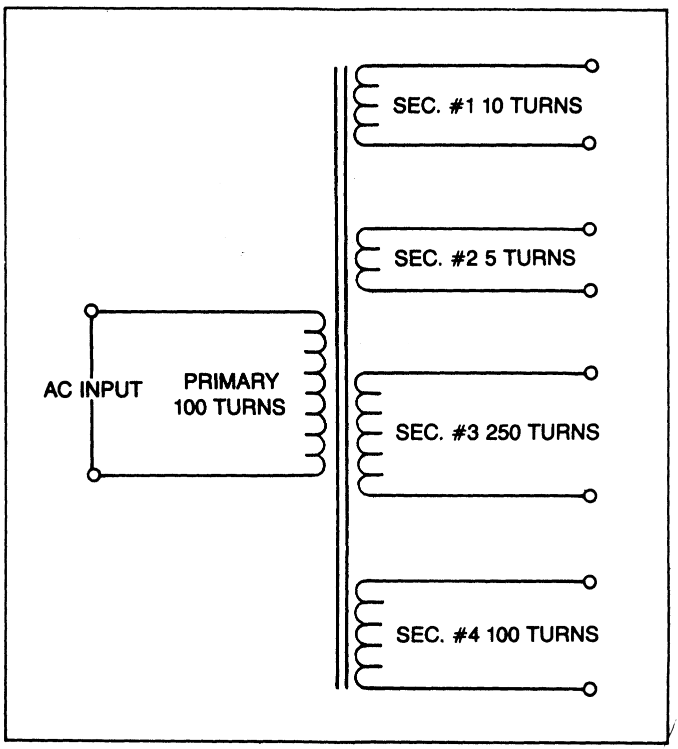


FIG. 19

four terminals, other winding configurations are often used.

Figure 18 is the schematic of a transformer with TAPPED windings.

Some transformers have either tapped primaries or tapped secondaries and in some cases both the primary and the secondary are tapped. The reason for tapping is to obtain different Voltages using the same coil. The voltage depends upon how many turns make up the section the coil that you tap into. Because the Voltage is proportional to the ratio of turns (N_p/N_s), you may tap into as many turns of the coil as is necessary to obtain the Voltage that you need. You may use more than one tap on a coil. The number of taps you use depends on your circuit design.

Figure 19 illustrates a MULTI-WINDING transformer.

Some transformers can have more than one primary and secondary windings, these are called MULTI-WINDING transformers. You can use the formula given previously for calculating the voltages of any of the secondary windings. For example, let's calculate the output voltage across the top secondary winding of Fig. 19.

TRANSFORMER VOLTAGE CALCULATIONS

$$V_p = 110 \text{ VAC}$$
$$N_s = 10\text{T}$$
$$N_p = 100\text{T}$$

substituting these values into the formula for determining

PRIMARY		SECONDARY			
TURNS	VOLTAGE	NUMBER (#)	TURNS	VOLTAGE	FUNCTION*
100	110	1	10	11	STEP DOWN
100	110	2	5		
100	110	3	250		
100	110	4	100		

*Function will be either step-up, step-down or one-to-one

FIG. 20

secondary voltage:

$$V_s = 110 \text{ VAC} \times \frac{10\text{T}}{100\text{T}}$$

$$V_s = 11 \text{ VAC}$$

Calculate the other secondary winding voltages and record the results of your calculations in the space provided in Fig. 20. Also indicate for each secondary what function it is performing (step up, step down or one-to-one).

The transformer used in your 808 Power Supply/Breadboard is a multi winding, step down transformer. In Fig. 21 the block diagram symbol and the schematic of this transformer are highlighted.

This transformer has two separate secondary windings. One of these windings is center tapped, and provides two equal voltages of 21.5 Volts AC for the + and - 0 to 15 Volt supplies. The other secondary winding provides 11.4 Volts AC for the + 5 Volt fixed supply.

TRANSFORMER TESTS

DISCUSSION

There are a number of faults that can develop in a transformer, either when it is being manufactured or during its service lifetime. To locate some kinds of transformer faults require specialized test equipment and fixtures. Other kinds of faults can be found by using the ohmmeter function of a VOM.

With the use of an ohmmeter we can determine that:

> Each winding has electrical continuity, and is not an open circuit. Each color coded lead wire is internally connected to the correct winding or winding tap.
>
> All the windings are electrically isolated from each other, and from the transformer core.

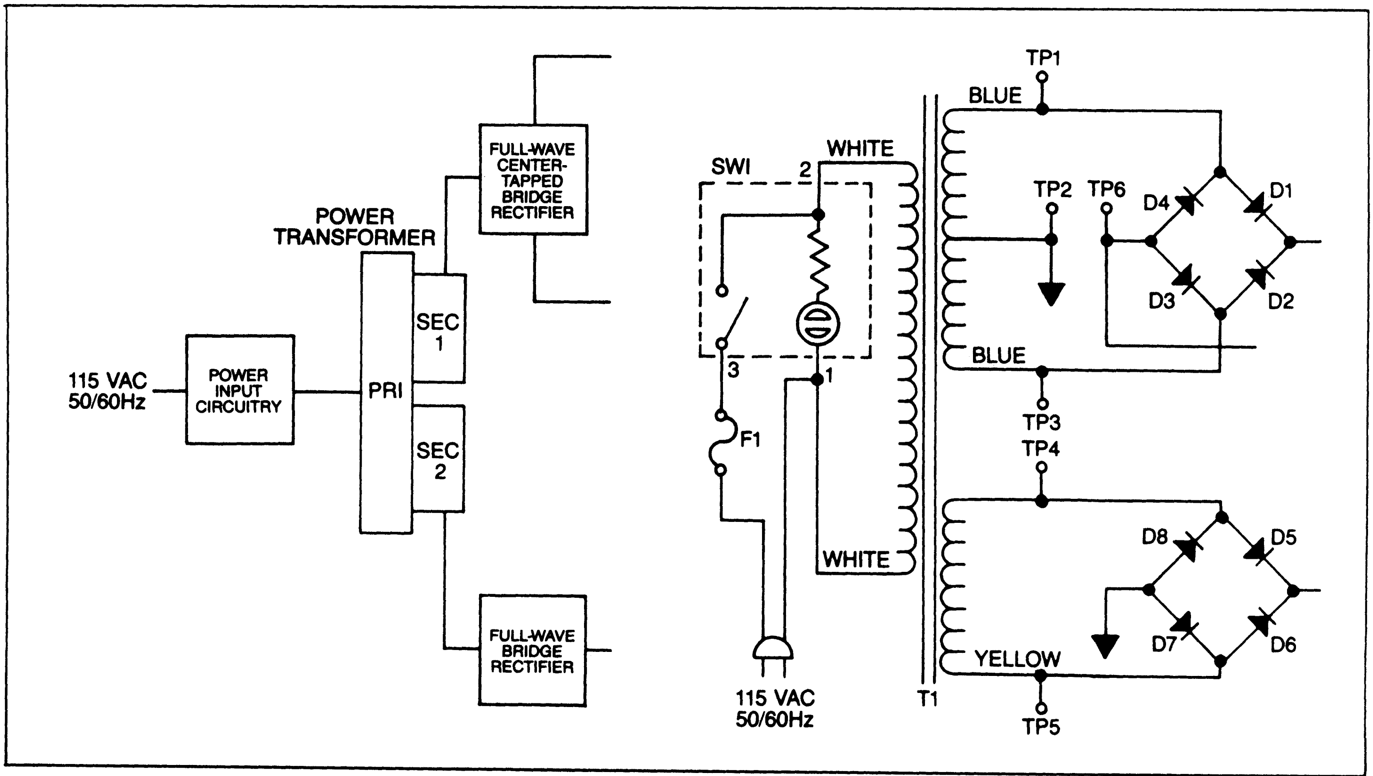


FIG. 21

WINDING RESISTANCE TEST

Purpose: To determine that all of the transformer windings have continuity, and that the lead wire color codes are correct.

Equipment: VOM or DMM

Figure 21A is a schematic of the transformer used in your 808 Power Supply. it shows the color code of each transformer lead, along with the voltage and approximate resistance of each winding.

____ 1. Set the meter you are using to its lowest resistance range.

____ 2. Connect the meter test leads to the white leads of the transformer.

____ 3. Write the resistance reading in the first "Measured" column box of Fig. 22.

____ 4. Repeat steps 2 and 3, using the yellow and the blue leads of the transformer.

____ 5. Connect the meter test leads to the black lead and one of the blue leads of the transformer. Write the resistance reading in the last "Measured" column box of Fig. 22.

____ 6. Verify that the resistance values you measured for the primary and secondary number 2 are within +/- 25% of the values specified in Fig. 22. For secondary number 1, the measured the measured value should be less than 1 Ohm.

____ 7. If any of your measured winding resistance values were not within the above limits, then STOP, recheck your test set up, and if necessary consult your instructor.

WINDING ISOLATION TEST

Purpose: To determine that all the transformer windings are electrically isolated from each other, and from the transformer core.

Equipment: VOM or DMM

Refer to Fig. 21A. There should not be any current path between any of the windings, or from any winding and the transformer core. The core and windings are coupled magnetically; any electrical connection between any of them indicates a faulty transformer.

____ 1. Set the meter you are using to its highest resistance range.

____ 2. Connect one of the meter test leads to either of the white transformer leads.

NOTE: In the following tests, don't hold both of the wires in contact with the meter test leads with your fingers. Your body and skin resistance is low enough to give false readings.

____ 3. Check for an infinite resistance reading on the meter while connecting the other meter test lead to the following: A. Either of the yellow transformer leads. B. Either of the blue transformer leads. This tests for current leakage between the primary and either of the two secondary windings.

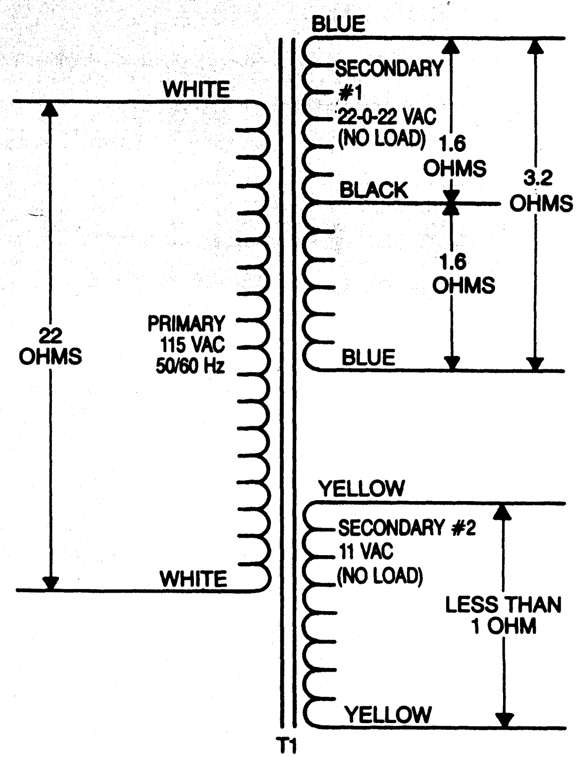
____ 4. Move the meter test lead connected to the white lead in step 2 to either of the yellow transformer leads.

____ 5. Check for an infinite resistance reading on the meter while connecting the other meter test lead to either of the blue transformer leads. This tests for current leakage between the two secondary windings.

____ 6. Move the meter test lead connected to the yellow lead in step 4 to the metal housing of the transformer.

____ 7. Check for an infinite resistance reading on the meter while connecting the other meter test lead to the following: A. Either of the white transformer leads. B. Either of the yellow transformer leads. C. Either of the blue transformer leads. This tests for current leakage between the transformer core and any of the windings.

____ 8. If any of your Winding Isolation Test resistance readings were not infinite, then STOP, recheck your test set up, and if necessary consult your instructor.



POWER TRANSFORMER SPECIFICATIONS

FIG. 21A

WINDING	LEAD COLOR CODE	RESISTANCE SPECIFIED	RESISTANCE MEASURED
PRIMARY	WHITE-WHITE	22 OHMS	
SECONDARY #1	YELLOW-YELLOW	LESS THAN 1 OHM	
SECONDARY #2	BLUE-BLUE	3.2 OHMS	
SECONDARY #2 CENTER TAP	BLACK-EITHER BLUE	1.6 OHMS	

FIG. 22

CONSTRUCTION

Refer to Fig. 23 for the following steps.

____ 1. With the cabinet top positioned top side up, insert the power switch into the hole marked POWER, with terminal 1 (the terminal that has the largest hole in it) to your right. The POWER switch does not require any mounting hardware. Press down hard on the bezel of the switch until it is firmly seated in the cabinet top.

____ 2. To assure that the POWER switch is installed correctly: A. Turn the power switch ON by pressing on the end of the switch rocker that is closest to the word "ON" on the cabinet top. B. Set your VOM or DMM to its lowest resistance range. C. Connect the meter test leads to the POWER switch terminals 2 and 3 Refer to Fig. 26. You should have a meter reading of zero Ohms. D. Turn the POWER switch OFF. You should now have a meter reading of infinite resistance. E. Disconnect the meter test leads from the POWER switch.

____ 3. Take the Black Terminal Post and remove the two hex nuts, the terminal lug, the lock washers, the flat metal washer and the two plastic washers from the smaller diameter part of the metal terminal post.

____ 4. Make sure that the threaded metal washer under the plastic binding nut is against the unthreaded part of the metal terminal post as shown in Fig. 24. Then turn the plastic binding nut down against the threaded metal washer.

____ 5. Install the Black Terminal Post in the cabinet top in the hole marked COM as shown in Fig. 25. Tighten the hex nut securely so that Terminal Post can't rotate when the plastic binding nut is tightened or loosened.

____ 6. Repeat steps 2 through 5, using the three Red Terminal Posts, mounting them in the cabinet top holes marked +5V, 0 to -15V and 0 to +15V.

____ 7. Place a solder lug, a lock washer and a second hex nut on each of the four terminal posts. Position the solder lugs as shown in Fig. 26 and tighten the hex nuts.

____ 8. Remove the mounting nut from the Fuse Holder. Insert the Fuse Holder into the largest hole in the

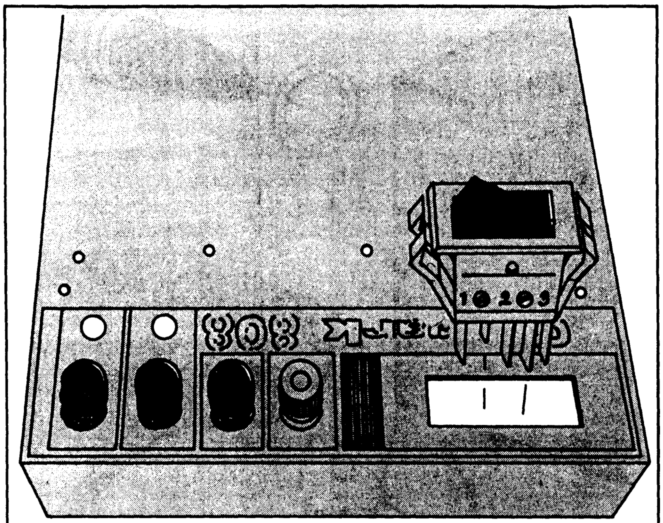


FIG. 23

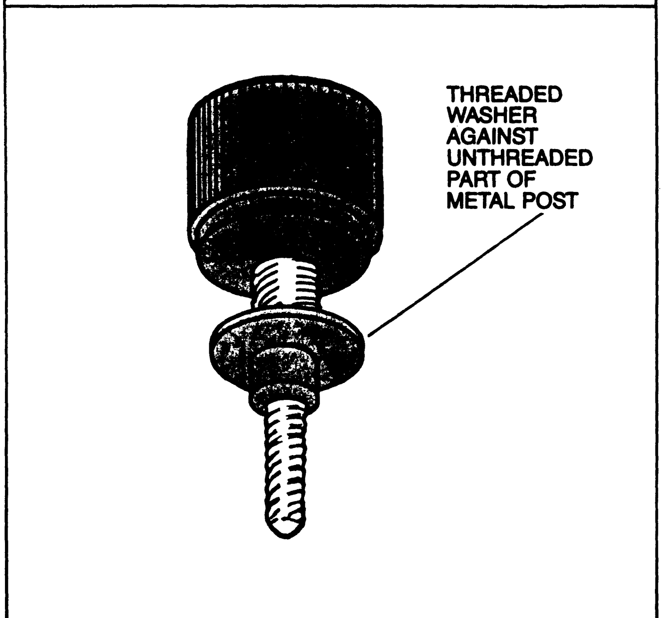


FIG. 24

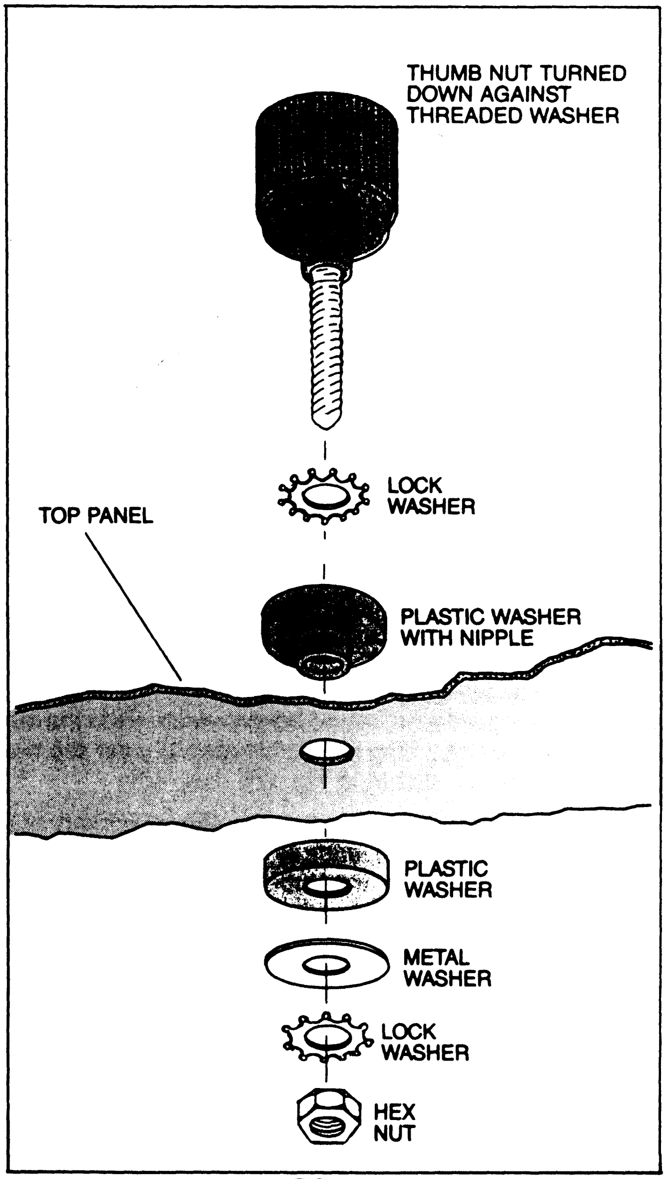


FIG. 25

back of the cabinet top.

____ 9. Position the Fuse Holder so that the side solder lug is facing towards the top of the cabinet as shown in Fig. 27. Place the nut on the Fuse Holder and tighten the nut. If the Fuse is not already in the Fuse Holder, install it at this time.

____ 10. Separate the two leads of the AC Power Cord 50mm from the end opposite the plug.

____ 11. Strip about 8mm of insulation from the end of each lead. Twist the conducting strands of each lead together, and tin (coat with a thin layer of solder).

____ 12. Insert the two leads of the AC Power Cord through the hole in the back of the cabinet top that is next to the Fuse Holder.

____ 13. Cut a 12mm length of the 4.5mm diameter insulation tubing, and place it on one of the leads of the AC Power Cord.

____ 14. Connect and solder this power cord lead to terminal at the end of the Fuse Holder. Slide the insulation tubing over the soldered connection.

____ 15. Cut a 70mm length of red 22 gauge wire, and strip 6mm of insulation from each end.

____ 16. Connect and solder one end of this wire to the terminal on the side of the fuse holder. Cut a 12mm length of the 4.5mm diameter insulation tubing, and slide it over the red wire so that it covers the fuse holder terminal.

____ 17. Cut three 15mm lengths of the 6mm diameter insulation tubing. Slide one of them over the free end of the red wire going to the Fuse Holder.

____ 18. Solder the free end of the red wire to terminal 3 of the Power Switch, and slide the insulation tubing over the soldered connection.

____ 19. Slide the second length of 6mm diameter tubing over one of the Power Transformer primary leads. The primary leads are white, and have thicker insulation than the secondary leads.

____ 20. Connect and solder this primary lead to terminal 2 of the Power Switch. Terminal 2 is the middle terminal. Slide the tubing over the soldered connection.

____ 21. Place the remaining transformer primary lead along side the free power cord lead. Slide the last length of tubing you cut in step 17 over the two leads as shown in Fig. 28.

____ 22. Connect and solder the transformer primary and the power cord leads to terminal 1 of the Power Switch. Slide the tubing over the soldered connection.

____ 23. To assure that the input circuitry wiring has been connected correctly: A. Turn the power switch ON. B. Set your VOM or DMM to its lowest resistance range. C. Connect the meter test leads to the two prongs of the power plug. You should have a meter reading of approximately 23 Ohms. D. Turn the power switch OFF. You should now have meter reading of infinite resistance. E. Dis-

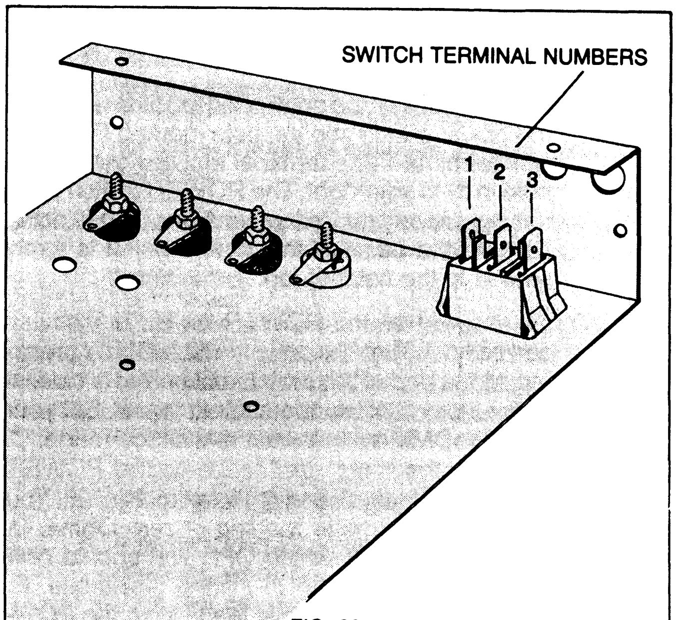


FIG. 26

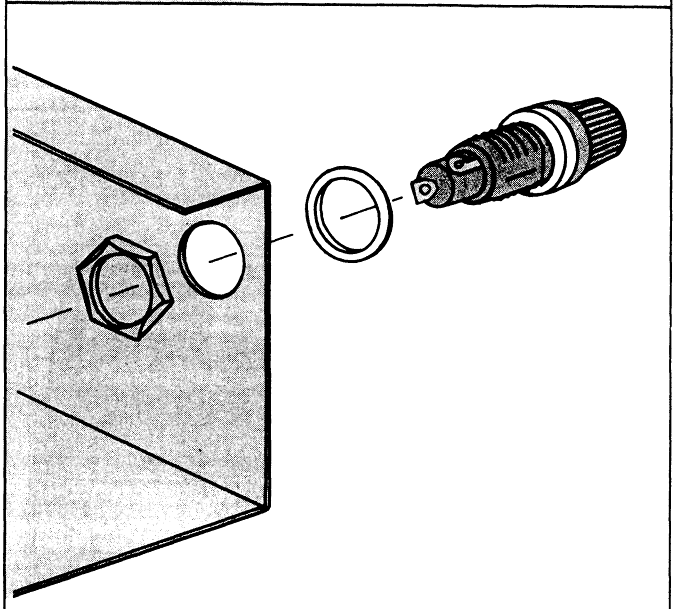


FIG. 27

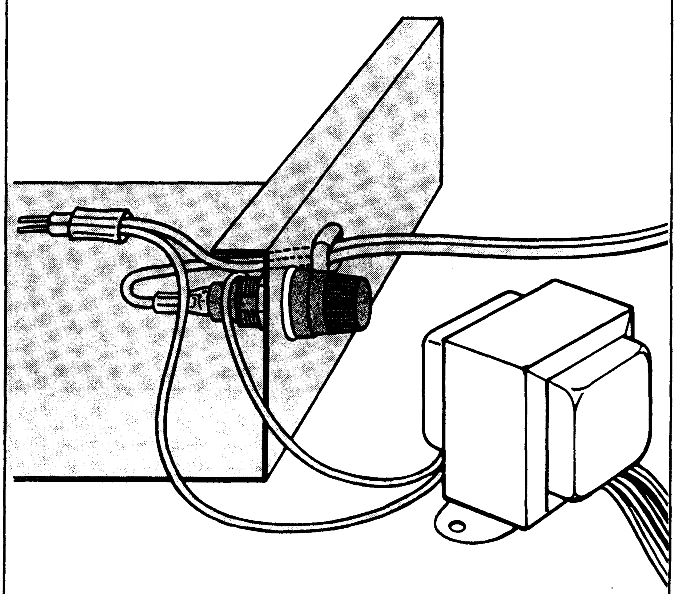


FIG. 28

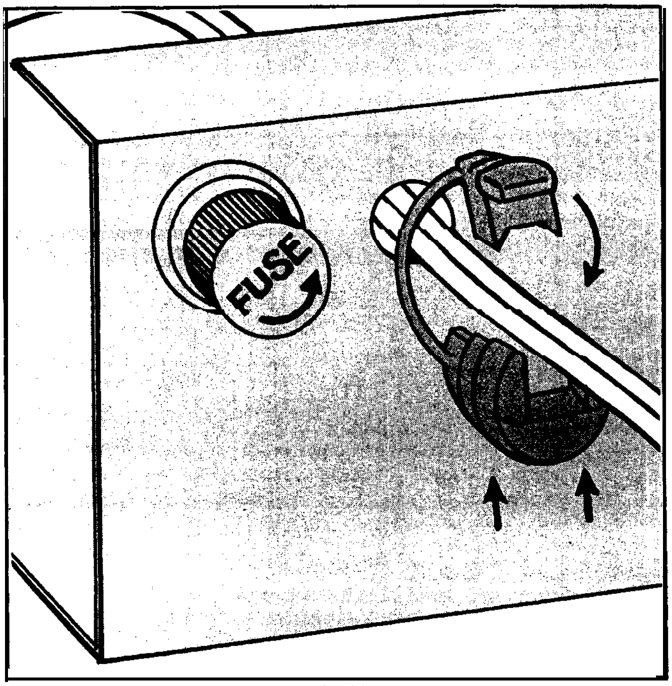


FIG. 29A

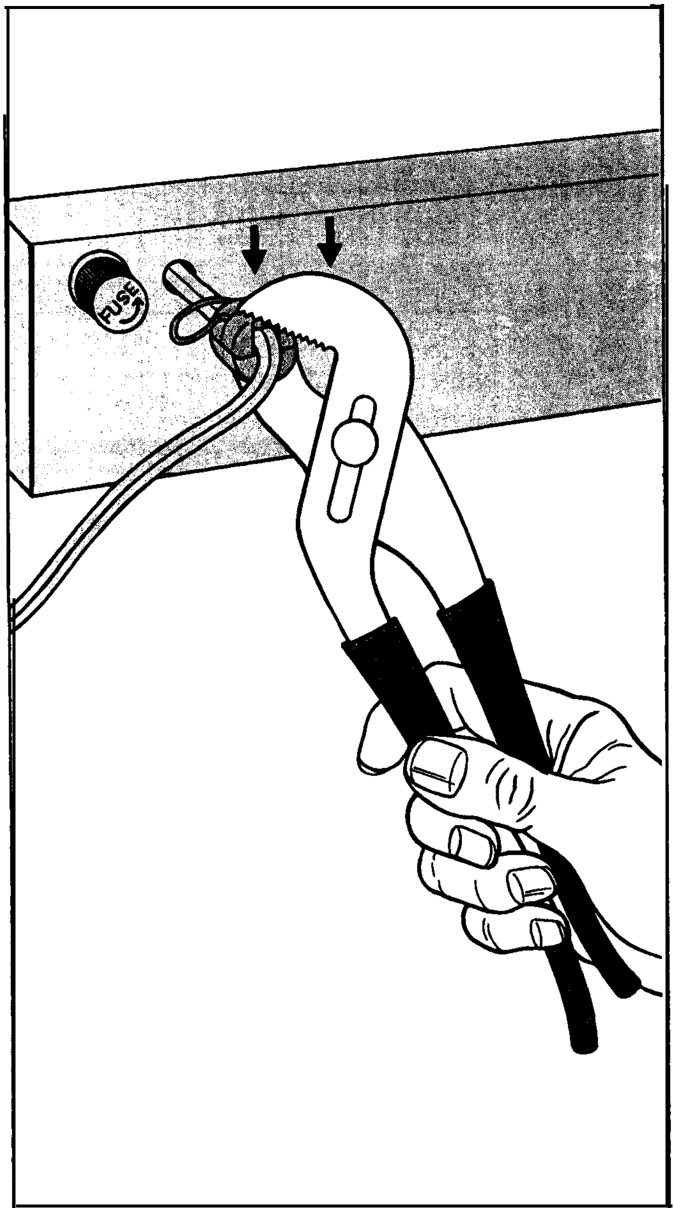


FIG. 29B

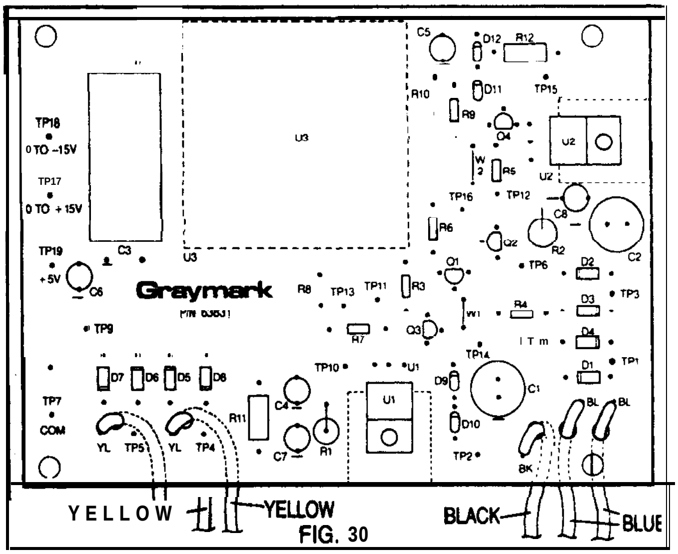


FIG. 30

connect the meter test leads from the power **plug.**

____ 24. Position the two portions of the AC power cord grommet around the cord where it extends out of rear of the cabinet top, as shown in Fig. 29A. Using slip-joint pliers, insert the grommet into the hole in the rear of the cabinet top as shown in Fig. **29B. You** will have to squeeze the grommet quite hard with the pliers so that the power cord is formed into a “U” inside the grommet, and the grommet is compressed enough to fit into the hole.

____ 25. Locate the Printed Circuit Board (PCB) and the test points. Insert and solder **TP1** through **TP19** into the PCB. The test points are inserted from the component side of the PCB and soldered to the copper on the solder side of the **PCB.** Refer to Fig. 30 and the the silkscreened legend orthe component side of the PCB for the test point locations.

____ 26. From the solder side (bottom) of the PCB thread the transformer leads through the holes in the PCB as shown in Fig. **30. Then,** from the component side (top) of the PCB, thread the stripped and tinned wire ends through the holes marked YL, BL and **BK.** Solder these five wires to the PCB, and cut off any excess lead length. Note: This is done so when the board is handled during component installation and testing, the wires won’t bend and break at the weak points where the wire insulation stops and the tinned copper wire goes through the PCB.

AC VOLTAGE WAVEFORMS AND VALUES

DISCUSSION

Measuring a DC voltage is simple and straight forward. Shown on a graph, the voltage of an automobile battery would appear as a straight horizontal line. In Fig. **31** the **vertical** axis shows the magnitude of the voltage being measured, and the horizontal axis represents time. The time shown on the graph would be in the order of several **seconds,** the time it takes for the meter pointer to stabilize and for you to accurately read the **meter. The** graph shows that the meter test probes were connected to the the battery at time (T) 0, and removed immediately after the meter was read.

To show an AC voltage, we need to change our graph in two ways. It will have to indicate voltages of both polarities, positive and negative, and we will have to make the horizontal axis cover a much smaller period of time.The public utility companies in the United States provide 60 Hertz power. Hertz, abbreviated Hz, means cycles per second. 60 Hz means that the polarity of the voltage is reversing 120 times a second.

Figure 32 is a graph of the voltage at a waloutlet.The horizontal axis only covers 1/60 of a second of time, or 16.67 milliseconds (mS).To observe what this graph shows, you will have to use an oscilloscope.The AC voltage ranges of a VOM will indicate the rms voltage, but the meter cannot respond to the rapid changes of the 60 Hz. AC voltage, and even if it could your eye could not read the rapidly moving meter pointer.

AC VOLTAGE OBSERVATION and MEASUREMENT EXPERIENCE

Purpose: To observe and measure PEAK, PEAK-TO-PEAK, and RMS Voltages.

Equipment: OSCILLOSCOPE
VOM or DMM

____ 1. Refer to Fig. 33. Mount the 1 Omm spacers on the solder side of the PCB, using the four 20 x 3mm machine screws, the two 40mm spacers, and two 3mm nuts.

____ 2. Place the cabinet top assembly, the powertransformer and the PCB on a work surface as shown in Fig. 34.

____ 3. Set the oscilloscope power switch to On.

____ 4. Adjust the Oscilloscope to 10 Volts/div. Set the sweep rate to 5mS/div. Adjust the input controls to display an AC signal, and vertical positioning at the CENTER line.

____ 5. Connect the scope ground lead to TP2 of the PCB, and the probe to TP1.

____ 6. Connect the power plug of the 808 to a 115 VAC power outlet.

____ 7. Set the power switch to ON.

____ 8. Record your peak-to-peak reading __________

____ 9. If your reading is about 60 Volts peak to peak, then proceed to the next step. If your reading is not about 60 Volts peak-to-peak, stop, and check your test set up or consult your instructor.

____ 10. Remove the scope probe.

____ 11. Adjust the VOM or DMM to read 19 Volts AC.

____ 12. Connect one meter test lead toTP2 of the PCB, and the other test lead to TP1.

____ 13. Record your reading __________________.

____ 14. If your reading is about 21 Volts AC, proceed to the next step. If your reading is not about 21 Volts AC, then stop and check your test set up or consult your instructor.

____ 15. Remove the test leads.

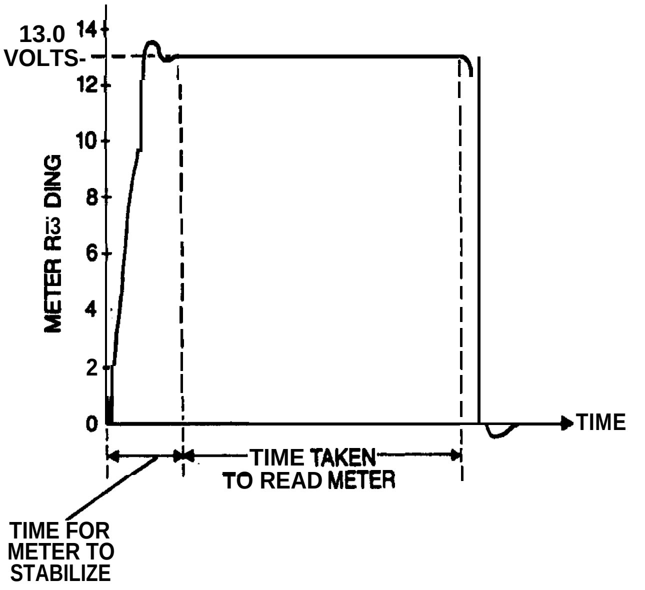


FIG. 31

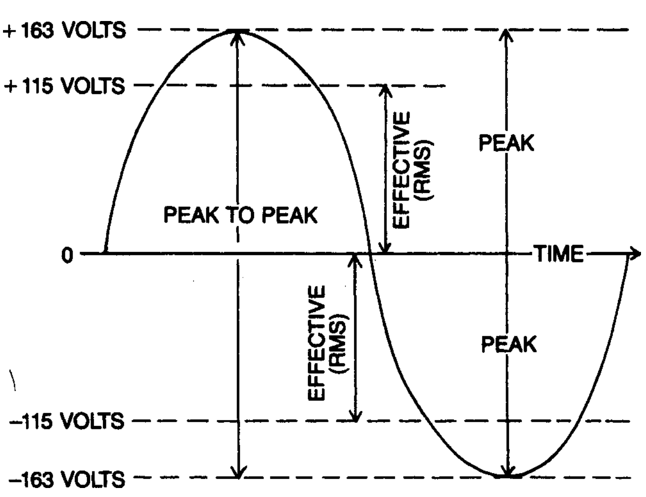


FIG. 32

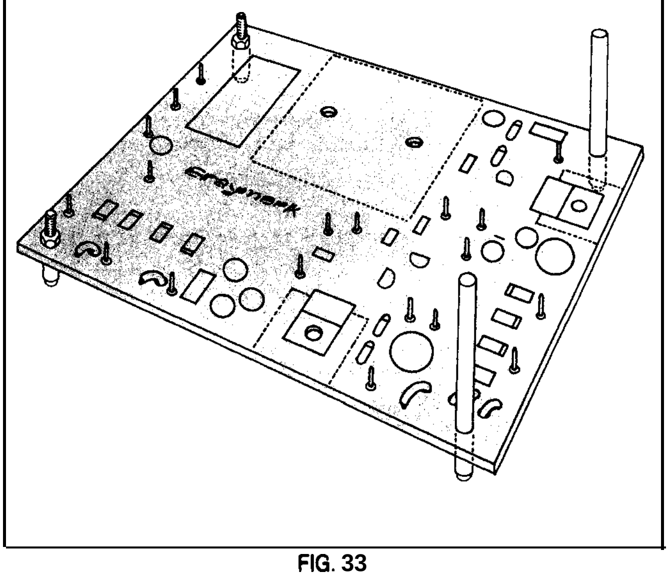


FIG. 33

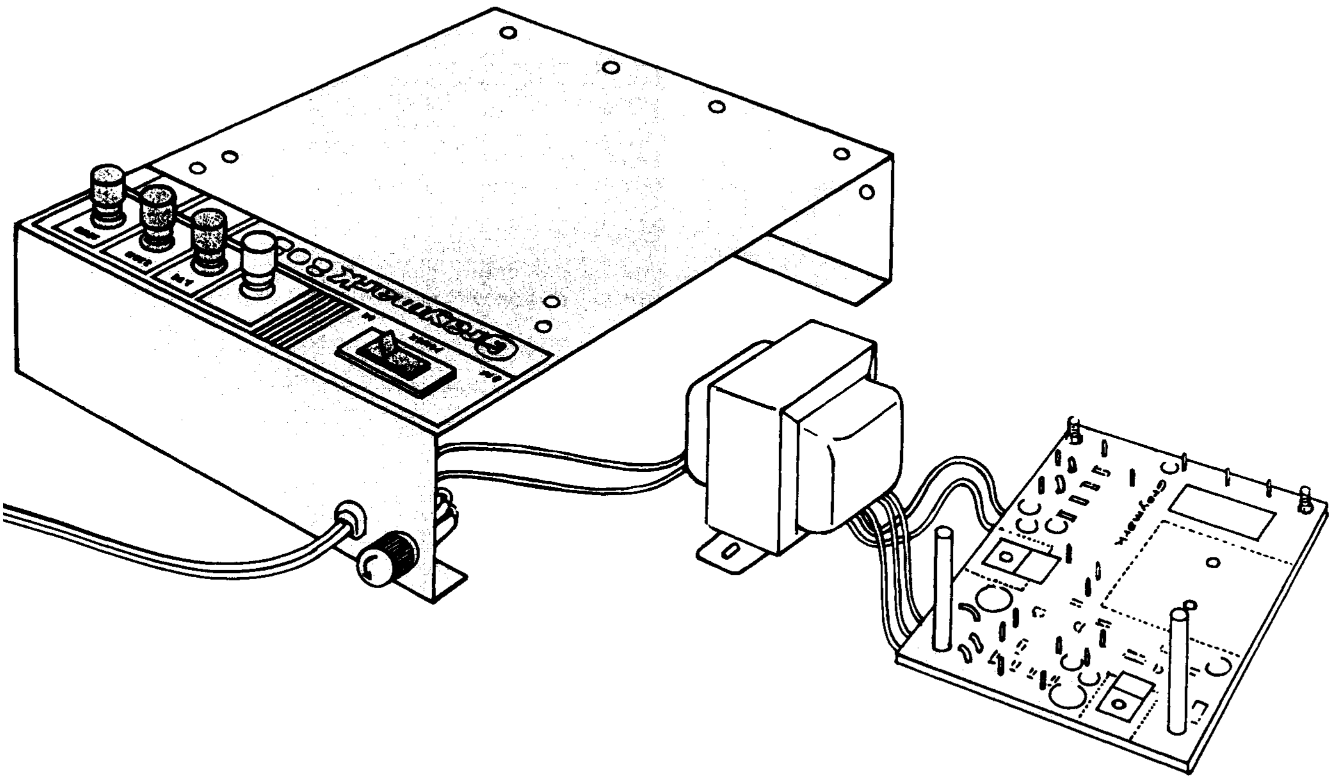


FIG. 34

MATHEMATICAL CALCULATIONS AND DEFINITIONS

Purpose: To demonstrate that the previous experience is in agreement with the mathematical formulas

The following formulas are used to calculate ROOT MEAN SQUARE, PEAK and PEAK-to-PEAK AC sine wave Voltages, Refer to Fig. 32.

$$V_p = 1.414 \times V_{rms}$$
$$V_p = .5 \times V_{p\text{-}p}$$
$$V_{p\text{-}p} = 2.828 \times V_{rms}$$
$$V_{p\text{-}p} = 2 \times V_p$$
$$V_{rms} = .707 \times V_p$$
$$V_{rms} = .3536 \times V_{p\text{-}p}$$

PEAK VALUE (p): The amplitude of a voltage measured from zero or reference axis to its maximum value, when the voltage alternates between positive and negative half cycles.

PEAK-to-PEAK (p-p): The amplitude of a voltage measured from maximum positive peak to maximum negative peak, when the voltage alternates between positive and negative half cycles.

ROOT MEAN SQUARE (RMS): The effective or RMS value of a voltage is the SQUARE ROOT of the average (MEAN) of the squares of all the instantaneous values of the voltage over one cycle. For a sine voltage, the RMS value is equal to 0.707 times the maximum peak value of the voltage.

INSTANTANEOUS VALUE: The exact value of the amplitude of a voltage at a particular instant in time.

Using the above formulas, calculate the unknown voltages in Fig. 35.

This completes the AC VOLTAGE OBSERVATION and MEASUREMENT EXPERIENCE. Have your instructor initial your progress guide.

MEASURED VALUE	RMS	PEAK-TO-PEAK	PEAK
54 V p-p			
115 V rms			
163 V p			
326 V p-p			

FIG. 35

RECTIFIER CIRCUIT SECTION

DISCUSSION

Figure 36 is a partial block diagram and schematic of the 808 Power Supply, showing the rectifiers and associated circuitry.

There are three basic types of rectifier circuits: the half-wave, the full-wave center-tapped, and the full-wave bridge. Each of these rectifier circuits uses a different number of diodes and requires a transformer winding with a different rating. Figures 36A and 37 identify some of the differences between these three types of circuits.

The first column in Fig. 37 contains the three types of rectifier circuits. The number of diodes used by each circuit is listed in the second column. The average diode current is shown in the third column. This value has significance because diodes with a higher current rating are required for half-wave circuits, as compared to those required by the other two circuits. The Transformer Power Rating column is also important, since each type of circuit requires a transformer or a transformer winding with a different power capacity. And, the larger the power capacity required, the greater the size and the cost of the transformer.

The Ripple column refers to the percentage of ac voltage contained in the DC output of the rectifier circuit. A decrease in the percentage of ripple offers a corresponding decrease in the amount of capacitance required in the Filtering Stage. Since lower value capacitors are smaller in size and cost less, a low percentage of ripple from the rectifier circuit is desirable.

Finally, the Conversion Efficiency column indicates the efficiency of each Rectifier Circuit in converting alternating current to direct current. Notice that the full-wave rectifier circuits are twice as efficient as the half wave circuit.

The heart of the rectifier circuit is the diode. Most diodes are made from silicon or germanium, both of which are semiconductors. Silicon is used for almost all diodes used in power supply rectifier circuits, as it is capable of operating a higher temperature than germanium. For a given size of device, a silicon diode can pass more current than a germanium diode. A diode is a component which will allow current to flow in one direction - from cathode to anode. Refer to Fig. 38.

Alternating current flows first in one direction, then the opposite direction, then reverses direction again. This alternating action occurs continuously. Direct current, on the other hand, flows in only one direction. A diode can be put in the path of an alternating current to block the current flow in one direction and permit the current flow in the opposite direction. It is in this manner that alternating current is rectified or converted into pulsating direct current.

The Graymark Model 808 Power Supply uses four silicon diodes in a full-wave bridge rectifier circuit, and four more silicon diodes in a center-tapped full-wave bridge rectifier circuit.

The center-tapped full-wave rectifier circuit combines features of the center-tapped full-wave and the full-wave bridge rectifier circuits. It is used in the 808 Power Supply to provide power for the 0 to + 15 Volt and the 0 to - 15 Volt outputs. Before going on to the FILTERING section, you will build and test four types of rectifier circuits.

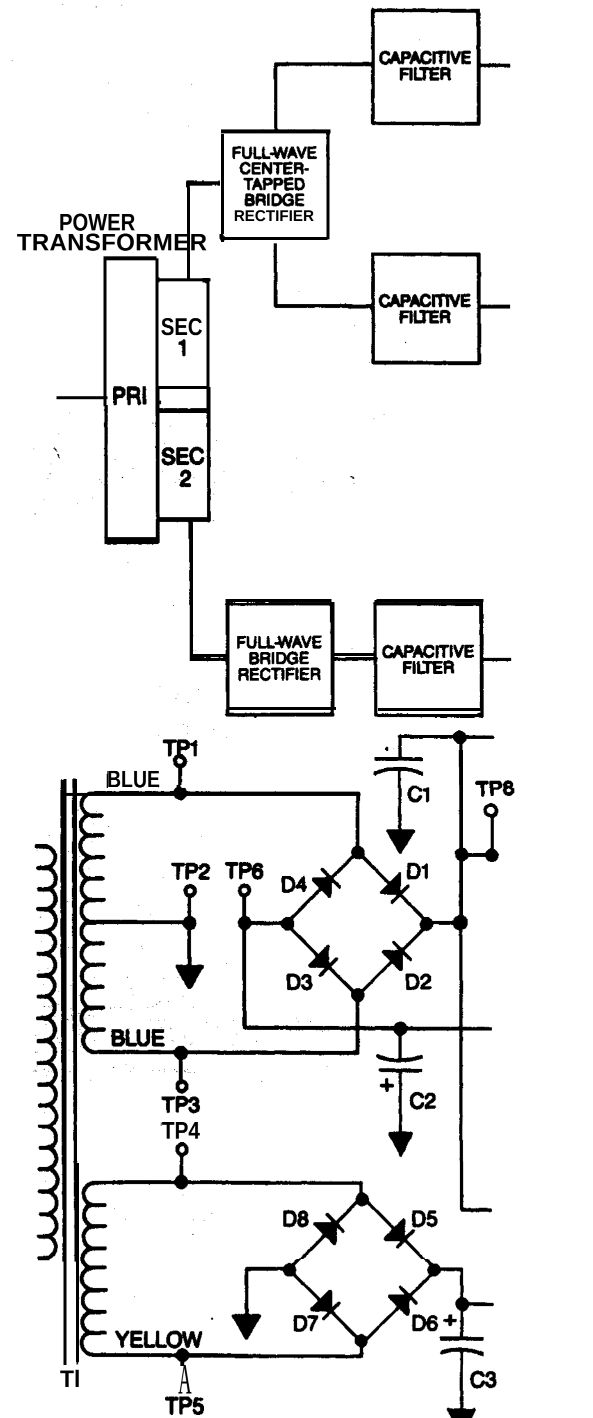


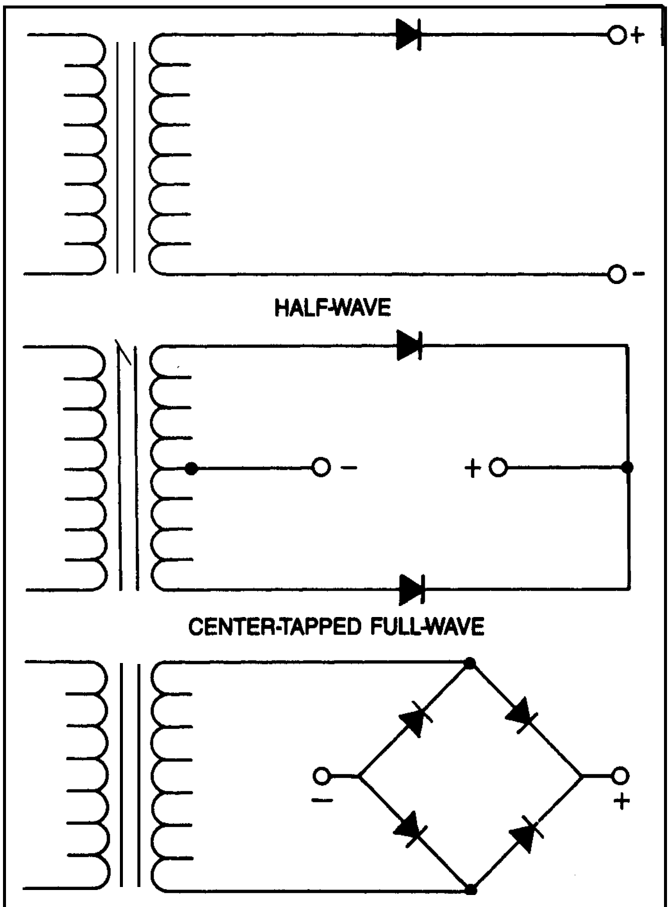
FIG. 36

HALF-WAVE RECTIFIERS

DISCUSSION

Half-wave rectifier circuits are sometimes used where the current requirements are low, in the order of 10 to 100 microamps, and voltages of 1 kV (1000 Volts) or higher are needed. Photomultiplier tubes and Ion chambers, which are used to detect and measure radiation, are examples of devices requiring this type of DC power. Utility power supplies, such as your Graymark 808, which are generally used to power solid state analog and digital devices, do not usually use half-wave rectifier circuits.

In the HALF-WAVE RECTIFIER TEST, you will be viewing the output of a half-wave rectifier on an oscilloscope. A 1.5K Ohm resistor (RI 1) is connected across the output of



TYPES OF RECTIFIER CIRCUITS

FIG. 36A

SIGNIFICANT RECTIFIER CIRCUIT CHARACTERISTICS

TYPE OF RECTIFIER CIRCUIT	NUMBER OF DIODES REQUIRED	AVERAGE DIODE CURRENT	TRANSFORMER POWER RATING	RIPPLE (%)	CONVERSION EFFICIENCY (%)
HALF-WAVE	1	2	1	121	40.6
FULL-WAVE CENTER-TAPPED	2	1	.5	48.2	81.2
FULL-WAVE BRIDGE	4	1	.35	48.2	81.2

FIG. 37

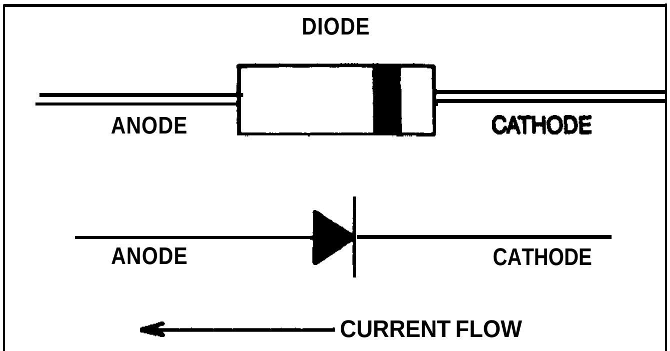


FIG. 36

the rectifier circuitry. Figure 43 is a schematic of this circuit. Without this resistor, stray circuit capacitances could distort the waveform displayed on the scope. In the completed Power Supply **R1** 1 serves as a bleeder resistor.

One of the functions of a bleeder resistor is to discharge or "bleed off" the electrical energy remaining in the filter capacitors **after** the power supply is turned off. In high voltage supplies, the bleeder resistor is an important safety device.

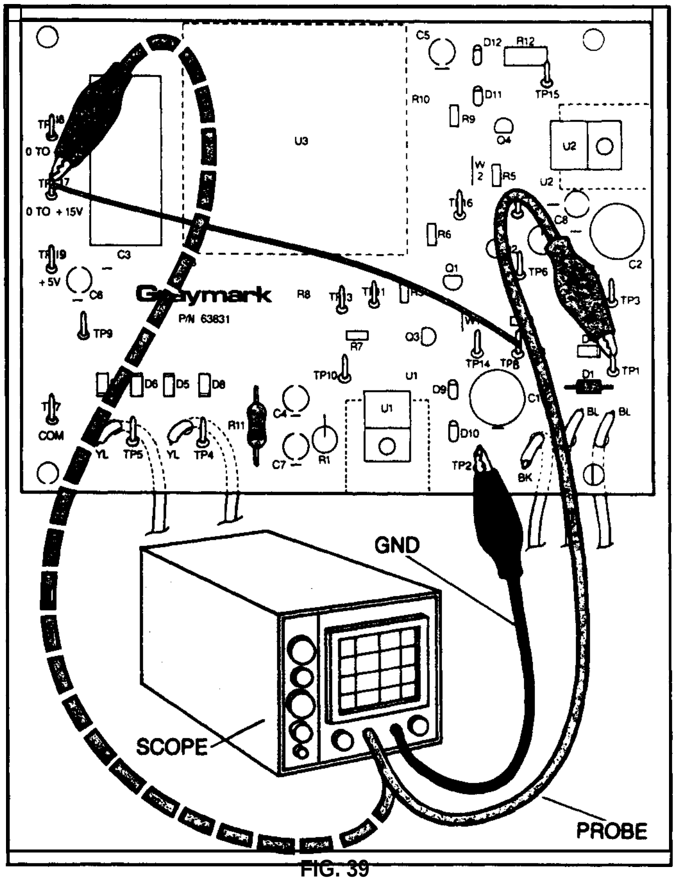


FIG. 39

Without it, dangerously high voltages could remain present long after the input power has been turned off or disconnected.

The output voltages of the Model 808 Triple Power Supply are not high enough to be hazardous to the person using it, but it is disconcerting when a power supply that has been turned off earlier generates a spark if an output is accidentally shorted. In the 808 Power Supply, bleeder resistors, along with the voltage regulators, serve to discharge the filter capacitors within seconds after the input power has been switched off or disconnected.

When you are building your 808, you will be instructed to install some components long before they are used in an **experience. This** is to provide a discharge path for the filter capacitors before the voltage regulators are installed.

In unregulated power supplies the bleeder resistor is is often designed to draw 10**%** or more of the rated output **current. This** is to improve the voltage regulation of the supply under changing load conditions.

CONSTRUCTION

Refer to Fig. 39 for the following steps.

____ 1. Be sure the 808 power plug is **NOT connected** to a power outlet.

____ 2. Mount diode DI on the PCB. Besure that the banded end of the diode is oriented the same as the diode outline that is silkscreened onthe PCB. Using a heat sink as shown in Fig. 40, solder the diode leads to the PCB. cut off any excess lead length.

____ 3. Mount resistor **R11,** 1 SK Ohm **(brown-green-**red) **.5** Watt, on the PCB. Solder the leads to the PCB and cut off any excess length.

DIODE EXPERIENCE

Purpose: To observe the current blocking capability of a diode.

Equipment: VOM or DMM

____ 1. Be sure the 808 power plug is **NOT connected** to a power outlet.

____ 2. Set the meter you are using to its lowest ohmmeter range. If your meter has an range marked with a diode symbol or the word “diode”, use that range instead. Connect the positive* meter test lead to TP8 and the negative* meter test lead to **TP1**, (If your uncertain what the asterisks after the words “positive” and “negative” mean, review the last paragraph of the section titled USING **AN** OHMMETER ON POLARIZED CIRCUITS AND CIRCUITRY) Record the resistance reading.

____

____ 3. Reverse the meter test leads and record the **resistance** reading. __________ Disconnect the meter test leads from the test points.

____ 4. In the 2nd step, you should have had an infinite resistance reading, indicating that the direct current from the ohmmeter was being blocked. In the 3rd step, there should have been a much lower resistance reading, indicating that the current was passing through the diode. This illustrates the ability of a diode to permit current to flow in one direction, and to restrict its flow in the opposite direction. The difference between the two conditions depends upon the polarity of the voltage applied to the diode. The anode of a diode has to be at a more positive potential than the cathode for current to flow to occur.

HALF-WAVE RECTIFIER EXPERIENCE

Purpose: To observe the voltage waveform produced by a Half-Wave Rectifier circuit.

Equipment: Oscilloscope

Refer to Fig. 39 for the following steps.

____ 1. Be sure the 808 power plug is **NOT connected** to a power outlet.

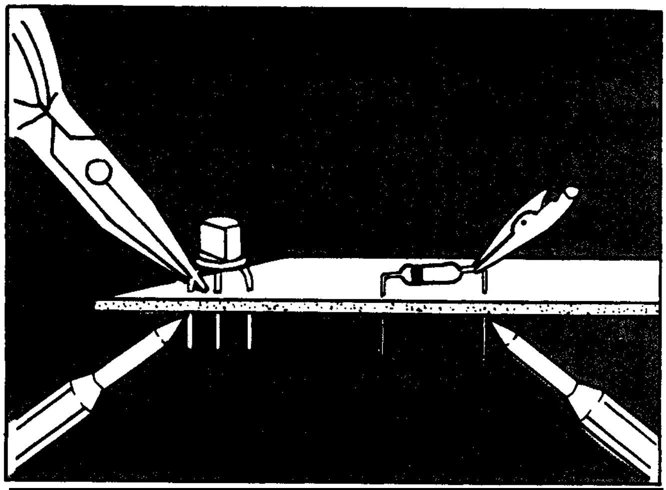
____ 2. Cut a **125mm** length of red 22 gauge wire, and strip 6mm of insulation from each end.

____ 3. Solder one end of the red wire to TP8, and the other end toTP17. Because these are temporary connections for testing purposes, its not necessary to make mechanical connections.

____ 4. Turn the oscilloscope ON and let it warm up. Adjust it to display a 60 Volt (peak to peak) 60 Hertz **(60Hz)** signal. Set the vertical (Y) input coupling to DC.

____ 5. Connect the oscilloscope (scope) ground lead to TP2, and the scope input probe to **TP1**.

____ 6. Plug the 808 Power Supply plug into a power **outlet. Turn** the power switch ON. **Observe** the waveform displayed on the scope. It should look like Fig. 41 . **This** is ac voltage which is present at the secondary winding of the transformer.



TRANSFORMER SECONDARY

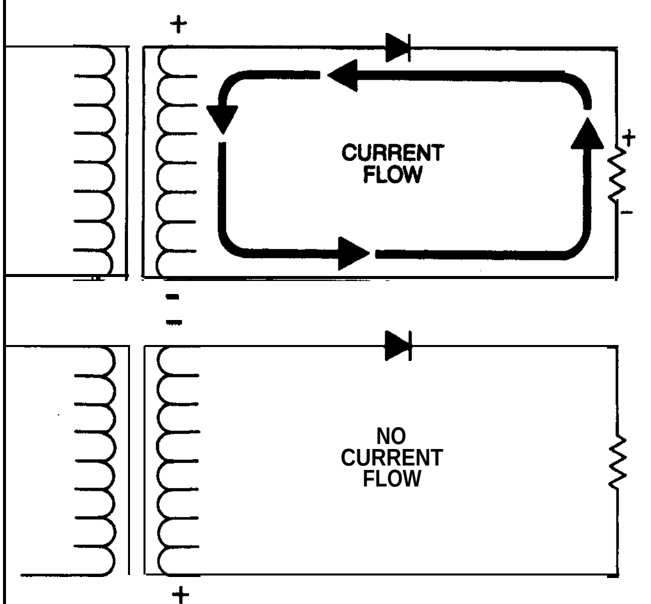
AC VOLTAGE

FIG. 41

CATHODE OF DI

HALF-WAVE RECTIFICATION

FIG. 42



HALF WAVE RECTIFIER CIRCUIT

FIG. 43

____ 7. Move the scope probe to TP17. The waveform should look like Fig. **42. This** waveform is the **result** of diode DI rectifying the ac voltage. DI clips off the negative half of the waveform, leaving only the positive half. This is called **half-** wave rectification. Current flow in a half-wave rectifier circuit is illustrated in Fig. 43.

____ 8. Turn the 808 Power switch Off and disconnect the power plug from the outlet. Disconnect the scope common lead and input Probe. Leave the red wire that is soldered to TP8 and **TP17** in place.

____ 9. This completes the **Half-Wave** Rectifier Experience. Have your instructor initial your Progress Guide.

FULL-WAVE CENTER-TAPPED RECTIFIERS

DISCUSSION

A **Full-Wave** center-tapped rectifier circuit requires a transformer with a secondary winding which has a tap halfway between both ends of the winding (a center-tap). secondary number 2 of the 808 Power Supply transformer is a **center-**tapped winding. You have already used one half of this winding in the **Half-Wave** Rectifier section.

FULL-WAVE CENTER-TAPPED RECTIFIER EXPERIENCE

Purpose: To observe the voltage waveform produced by a Full-Wave Center-Tapped Rectifier circuit.

Equipment: Oscilloscope

Refer to Fig. 44 for the following steps.

___ 1. Be sure that the 808 power plug is **NOT connect**-ed to a power outlet.

___ 2. Solder the cathode lead of a **1N5393** diode to TP8 of the **PCB,** and the anode lead toTP3. Do not cut the diode leads, or remove the red wire soldered to TP8. This is a temporary installation of D2. This diode will be removed after the **full-**wave filter test and installed later in its permanent location. Since the long leads isolate the heat of soldering from the diode itself, it is not necessary to use a heat sink.

___ 3. Turn the scope ON and let it warm up. Adjust it to display a 60 Volt (peak to peak) 60 Hz signal. Set the vertical input (Y) coupling to DC.

___ 4. Connect the scope ground lead toTP2, and the input probe to **TP17.**

___ **5.** Connect the 808 Power Supply plug to a power outlet. Turn the power switch ON. The waveform displayed on the scope should look like Fig. 45. Both halves of the ac cycle are now being rectified. Refer to Fig. 46. **Diode D1** rectifies the current from one half of the secondary winding, and diode D2 rectifies the current from the other half of the winding. Since the diode cathodes are connected together, both their waveforms are joined together to produce a composite waveform. This composite waveform is composed of two sets of positive voltage half cycles. One set is from Dl ,and the other set, which is 180 degrees out of phase with the first set, is from **D2.** This is called full-wave rectification.

___ 6. Turn the 808 Power switch OFF and disconnect the power plug from the outlet. Disconnect the scope common lead and input probe. Leave diode D2 and the red wire in place.

___ 7. This completes the Full-Wave Center-Tapped Rectifier Test. Have your instructor initial your Progress Guide.

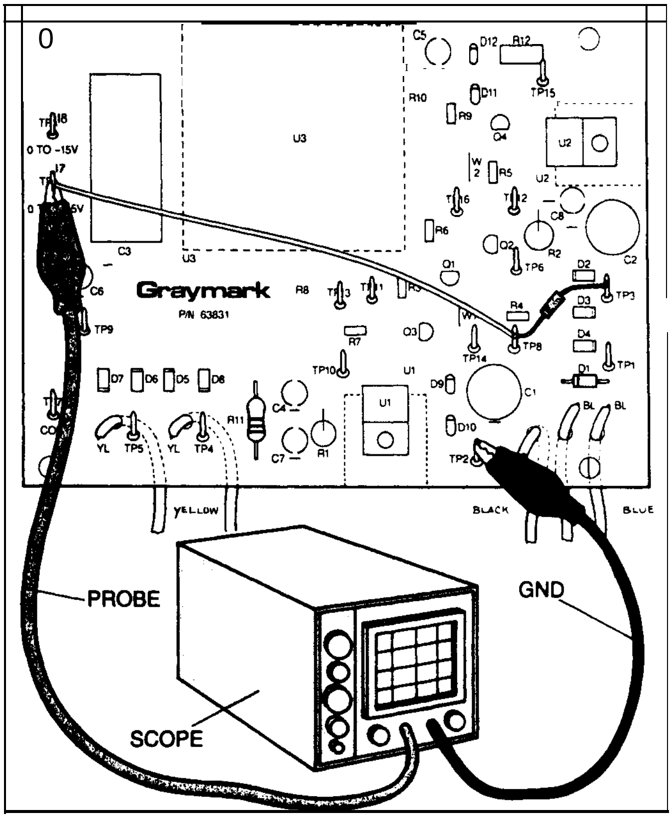
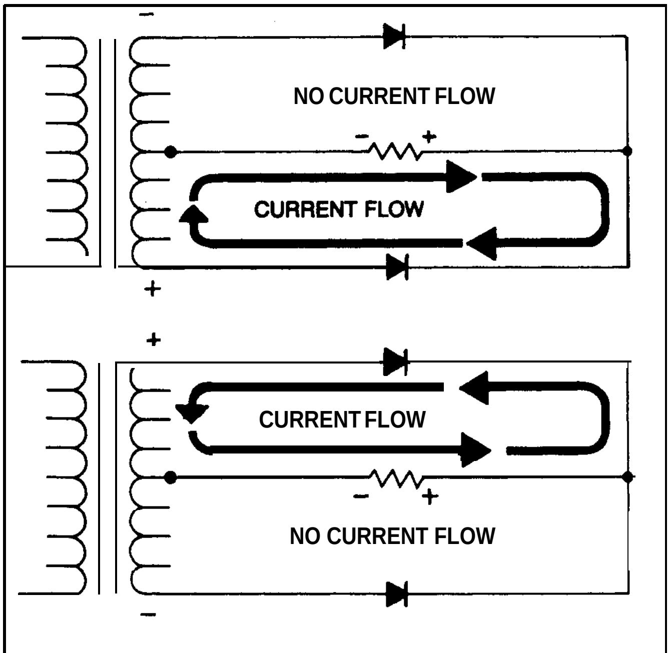


FIG. 44

FULL-WAVE RECTIFICATION, POSITIVE OUTPUT

FIG. 45



FULL-WAVE CENTER-TAPPED RECTIFIER CIRCUIT

FIG. 46

FULL-WAVE BRIDGE RECTIFIERS

DISCUSSION

Full-Wave bridge rectifiers are used in a wide range of power supplies. These rectifier circuits are among the most efficient and cost effective for many applications.

CONSTRUCTION

Refer to Fig. 47 for the following steps.

____ 1. Be sure the 808 power plug is Not connected to a power outlet.

____ 2. Mount diodes **D5,** D6, D7 and D8 on the PCB Be sure the banded ends of the diodes are oriented the same as the diode outlines that are silk screened on the PCB. Using a heat sink, solder each diode lead to the **PCB,** and cut off any excess lead length.

FULL-WAVE BRIDGE RECTIFIER EXPERIENCE

Purpose: To observe the voltage waveform produced by a Full-Wave Bridge Rectifier circuit.

Equipment: Oscilloscope

____ 1. Be sure the ***808*** power plug is Not connected to a power outlet.

Refer to Fig. ***47*** for steps 3 through 6.

____ ***2.*** Solder a 1.5 **kOhm** (brown-green-red) **.5** Watt resistor toTP7 and **TP9.** Cut the leads off close to the test points. This resistor is for testing purposes and will be left in place until the 5 Volt regulator is **installed.**

____ ***3.*** Adjust the scope to display a 30 Volt (peak to peak) 60 **Hz.** signal. Set the vertical (Y) input coupling to DC.

____ **4.** Connect the scope ground lead to TP7 and the input probe to **TP 9.**

____ 5. Plug the 808 Power Supply plug into an outlet. Turn the Power Switch ON. Observe the waveform displayed on the scope. **It** should look like Fig. 45. Both the **Full-Wave Center-Tapped** and the **Full-Wave** Bridge produce the same waveform. Figure 48 illustrates current flow in a **Full-**Wave Bridge Rectifier circuit.

____ 6. Turn the 808 Power switch Off and disconnect the power plug from the outlet. Disconnect the scope ground lead and input probe from the test points.

____ 7. This completes the **Full-Wave** Bridge Rectifier Test. Have your instructor initial your progress guide.

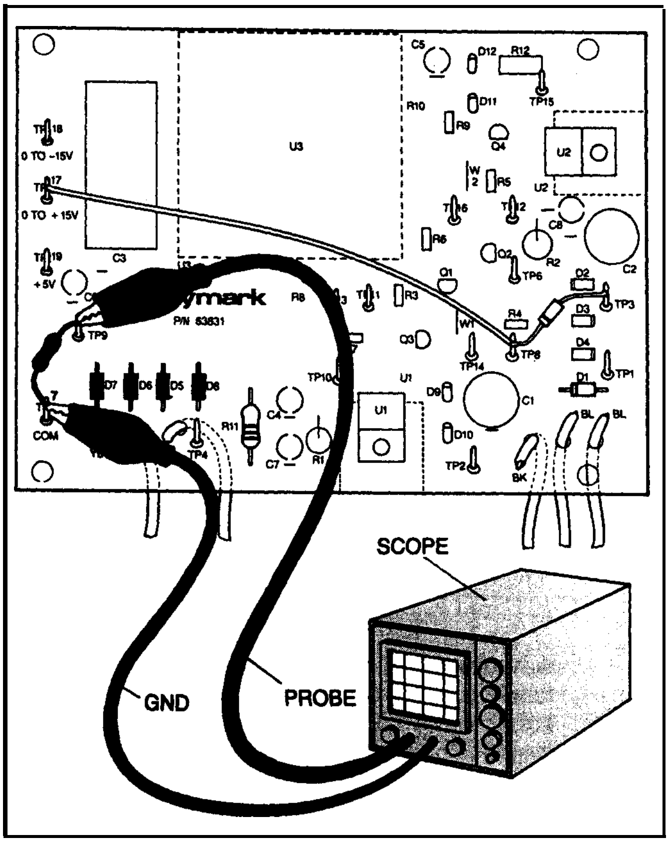
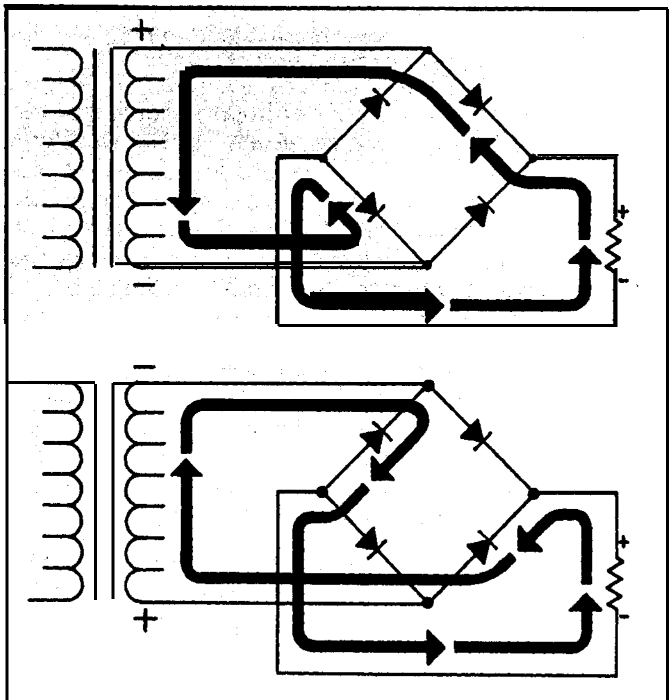
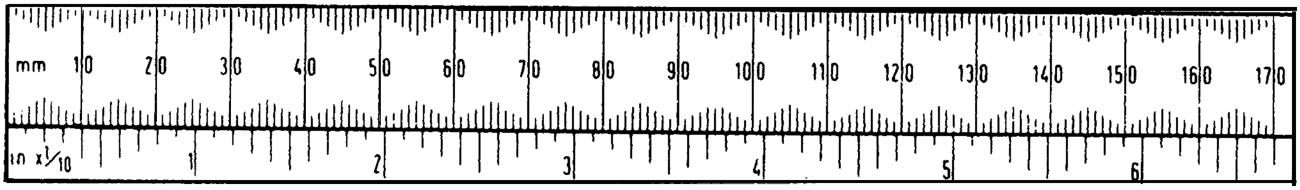


FIG. 47



FULL-WAVE BRIDGE RECTIFIER CIRCUIT

FIG. 48



CENTER-TAPPED FULL-WAVE BRIDGE RECTIFIERS

DISCUSSION

As mentioned before, the center-tapped full-wave bridge rectifier circuit combines features of both the center-tapped full-wave and the full-wave bridge rectifier circuits. It has two equal voltage outputs of opposing polarity as referred to the transformer secondary center tap. Figures 49A and 49B are schematics of the same rectifier circuit. Figure 49A is drawn to illustrate that a center-tapped full-wave bridge rectifier is made by connecting two center-tapped full-wave rectifiers to a common center tapped transformer secondary winding. Figure 49B shows the same circuit, drawn differently to illustrate that a center-tapped full-wave bridge rectifier can also be considered to be a full-wave bridge rectifier with a added center-tap on the transformer winding.

CONSTRUCTION

Refer to **Fig. 50 tor** the following steps.

____ 1. Be sure the 808 power plug is not connected to a power outlet.

____ 2. Mount diodes D3 and D4 to the PCB. Be sure the banded ends of the diodes are oriented the same as the diode outlines that are silk screened on the PCB. Using a heat sink, solder each diode lead to the PCB, and cut off any excess lead

____ 3. Mount resistor **R12, 1.5K** Ohm **(brown-green-**red), **.5** Watt, on the PCB. Solder the resistor leads to the PCB and cut off any excess length.

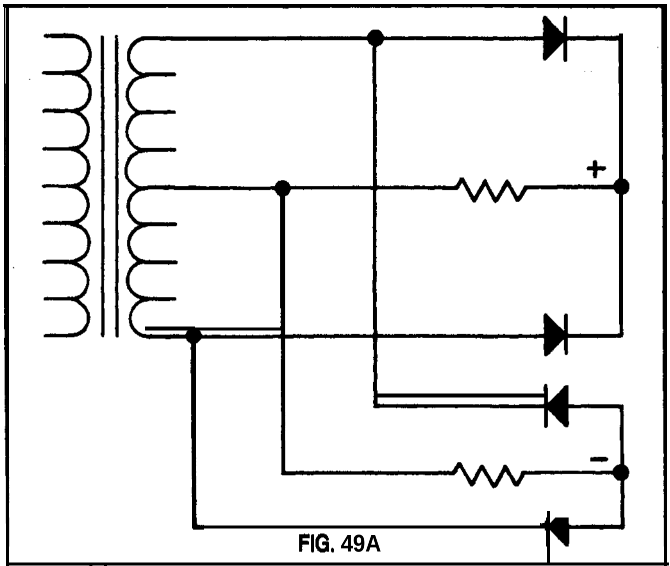


FIG. 49A

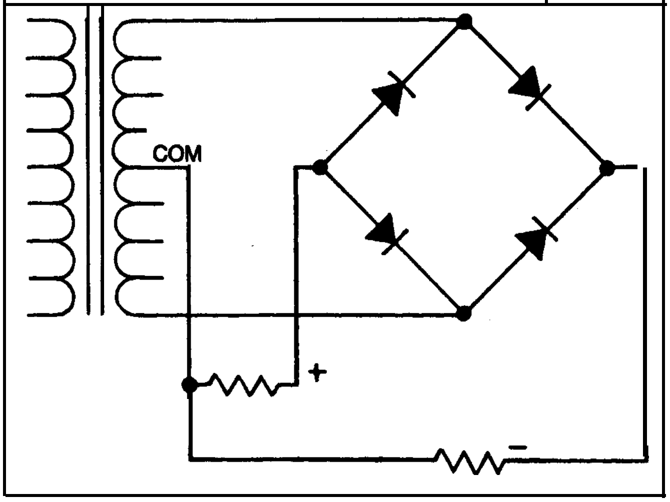


FIG. 49B

CENTER-TAPPED FULL-WAVE BRIDGE RECTIFIER EXPERIENCE

Purpose: To observe the voltages and waveforms produced by a Full-Wave Center-Tapped Bridge Rectifier Circuit

Equipment: Oscilloscope

Refer to Fig. ***50*** for the following steps.

____ **1.** Be sure the ***808*** power plug is **NOT connected** to a power outlet.

____ 2. Cut a **125mm** length of green ***22*** gauge wire, and strip 6mm of insulation from each end.

____ 3. Solder one end of the green wire toTP6, and the other end **to TP18.** Because these are temporary connections for testing purposes, it is not necessary to make mechanical connections.

____ ***4.*** Adjust the scope to display a ***60*** Volt (peak to peak) 60 **Hz.** signal. Set the vertical (Y) input coupling to DC.

____ ***5.*** Connect the scope ground lead to TP7 and the input probe to **TP17.**

____ 6. Connect the 808 Power Supply plug to a power **outlet. Turn** the Power Switch **ON. The** waveform displayed on the scope should look like Fig. ***45.*** This is the same waveform being produced by the same circuitry as in the Full-Wave **Center-Tapped** Rectifier Test that you did earlier.

____ 7. Move the scope input probe **to TP18.** The waveform displayed on the scope now should look like

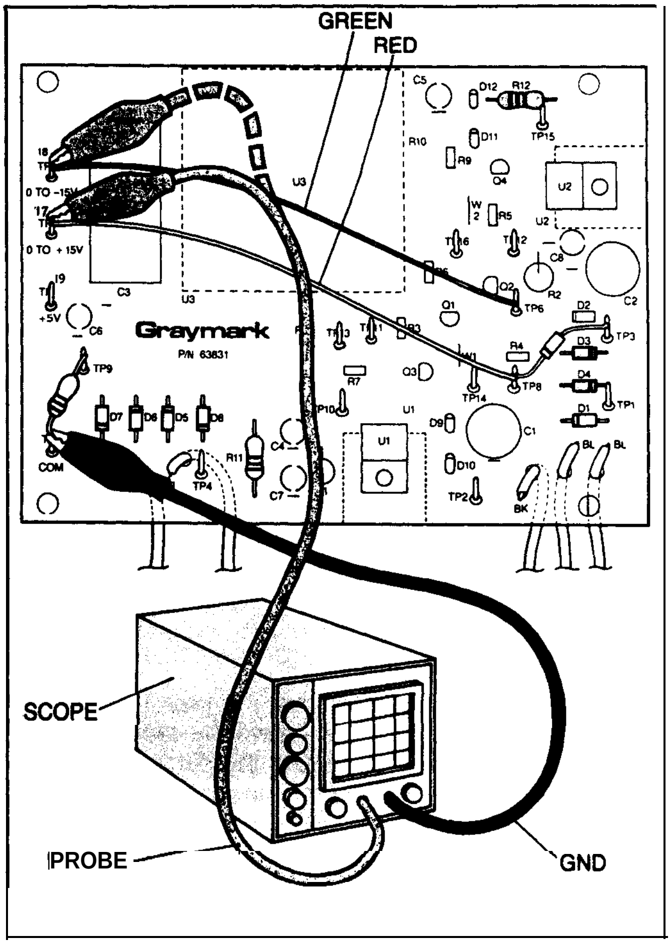


FIG. 50

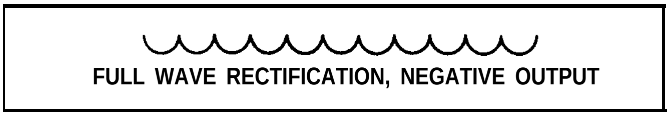
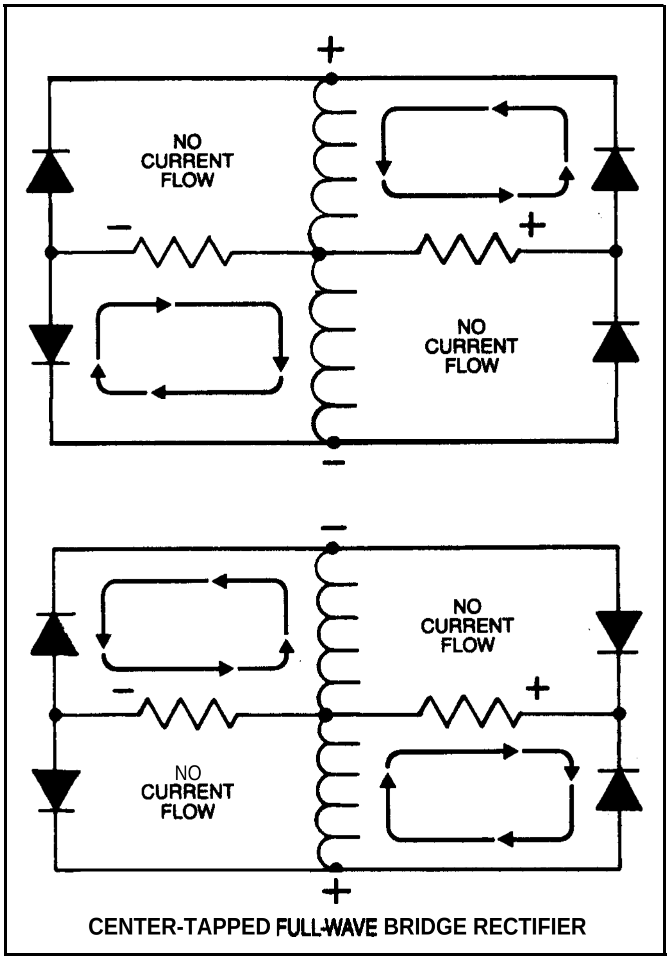


FIG. 51



CENTER-TAPPED FULL-WAVE BRIDGE RECTIFIER

FIG. 52

Fig. 51. Diodes D3 and **D4,** along with the **center-**tapped secondary winding that also is connected to diodes Dl and D2, form a Full-Wave **Center-**Tapped Rectifier the output of which is negative in respect to the transformer center-tap. These two complimentary Full-Wave Center-Tapped Rectifiers, sharing the same transformer winding, can also be correctly calleda Center-Tapped **Full-Wave** Bridge Rectifier. Figure 52 shows the current flow in this type of **rectifier.The** transformer primary winding and core symbol have been omitted so that the current flow in the rest of **circuit** can be shown clearly, but apart from that, it is the same as Figs. 49A and 49B.

____ 8. Turn the power switch Off and disconnect the power plug from the outlet. Disconnect the scope leads.

____ 9. Unsolder and remove the green wire running from TP6 to **TP18**. Leave the red wire running from **TP8** to TP17 and the diode connected to TP3 and **TP8** in place, as you will be using them later in another test.

____ 10. This completes the CENTER-TAPPED FULL WAVE BRIDGE RECTIFIER EXPERIENCE. Have your instructor initial your Progress Guide.

FILTER SECTION

DISCUSSION

In general, a filter is an electronic device used to pass a certain frequency or band of frequencies while rejecting or blocking another frequency or band of frequencies.

There are four types of filters commonly used in electronics:

LOW PASS	**BANDPASS**
HIGH PASS	**BANDSTOP**

A LOW PASS filter will pass all frequencies from DC to a cutoff frequency. All frequencies above this cutoff are attenuated. DC has a frequency of zero Hz; it is a straightline on an oscilloscope.

A HIGH PASS filter will pass all frequencies above a cutoff frequency, and attenuate all frequencies below that cutoff frequency.

A **BANDPASS** filter will pass a band or group of frequencies, and attenuate all frequencies outside that band.

A **BANDSTOP** filter will attenuate a particular band of frequencies and will pass all other frequencies.

To remove the ripple from the output of the rectifier circuit, most power supplies use a resistance/capacitance filter (also called a **RC** filter) of the low pass type.The resistance part of the **RC** filters in most DC power supplies is provided by the resistance of the diode **circuitry** and the power transformer secondary winding, along with the reactance of the power transformer. The term reactance applies to devices operating on alternating current and varying (pulsating) **direct current. The** output of a rectifier circuit is an example of pulsating direct current.

The resistance and reactance in a**RC** filter used in a DC power supply serves to limit the peak current flowing through the rectifier diodes to a value that the particular diodes being used can handle safely. The**"R"** part of the filter does not directly enter into the filter's effectiveness.

Figure 53 shows part of the block diagram and schematic of the 808 Power Supply, with the capacitive filters highlighted. Notice that **R1/C7** and **R2/C8** are not highlighted. These components appear to be**RC** low pass filters, but are not. the resistors **R1** and **R2** are current sensing resistors used in the overcurrent detectors of the variable positive and negative power supplies. If **R1** and **R2** were not in the circuit, capacitors C7 and C8 would not be **necessary.This** is due to the characteristics of the integrated circuit voltage regulators Ul and U2, And will be discussed in the External Control and Protection Circuitry Section. Capacitors C4, **C5** and C6 are also required because of other characteristics of the voltage regulators. This will be explained later in the section on voltage regulators.

CAPACITIVE FILTERS

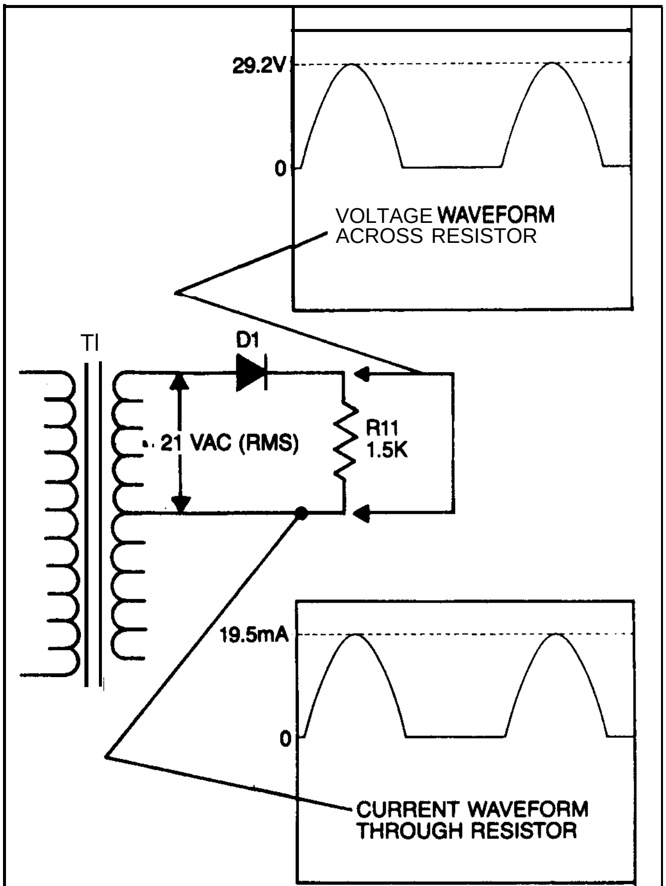
DISCUSSION

No half-wave rectifier circuits are used in the **Graymark 808.This** experience included tests using a half-wave rectifier because, when done along with tests using a full wave rectifier, they will help you to understand the operation of capacitive filters.

Figure 54 shows the circuit you built earlier for the **half-**wave rectifier test. The voltage waveform across resistor

R1 1 is what you saw in step 7 (Fig. 42). If we could connect the scope so that it would display the current flowing through **R1** 1, we would see that current waveform is the same as the voltage waveform. We can say that the current flowing through a resistor is in phase with the voltage across the resistor, and is proportional to this voltage. Ohms Law expresses this proportionality in the formula I = E/R or, current = voltage/resistance.

This direct correspondence of current and voltage are not true with other components such as **capacitors. We** can display the waveform and magnitude of the current passing through a capacitor by using the test set up shown schematically in Fig. **55. The** voltage developed across the test resistor is proportional to the current flowing through it. As **long** as the resistance value of the test resistor is small compared to the resistances in the circuit being tested, the measurement error because of the added resistance will be small as **well. The** high sensitivity of the oscilloscope allows the current sensing test resistor to have a small resistance value.



$21\ V_{RMS} \times 1.414 = 29.7Vp - .5V$ (FORWARD VOLTAGE DROP ACROSS D1) $= 29.2Vp$ ACROSS R11.

$Ip = \frac{Ep}{R}$ $\quad I = \frac{29.2}{1500} = .0195$ AMPERES OR 19.5mA

FIG. 54

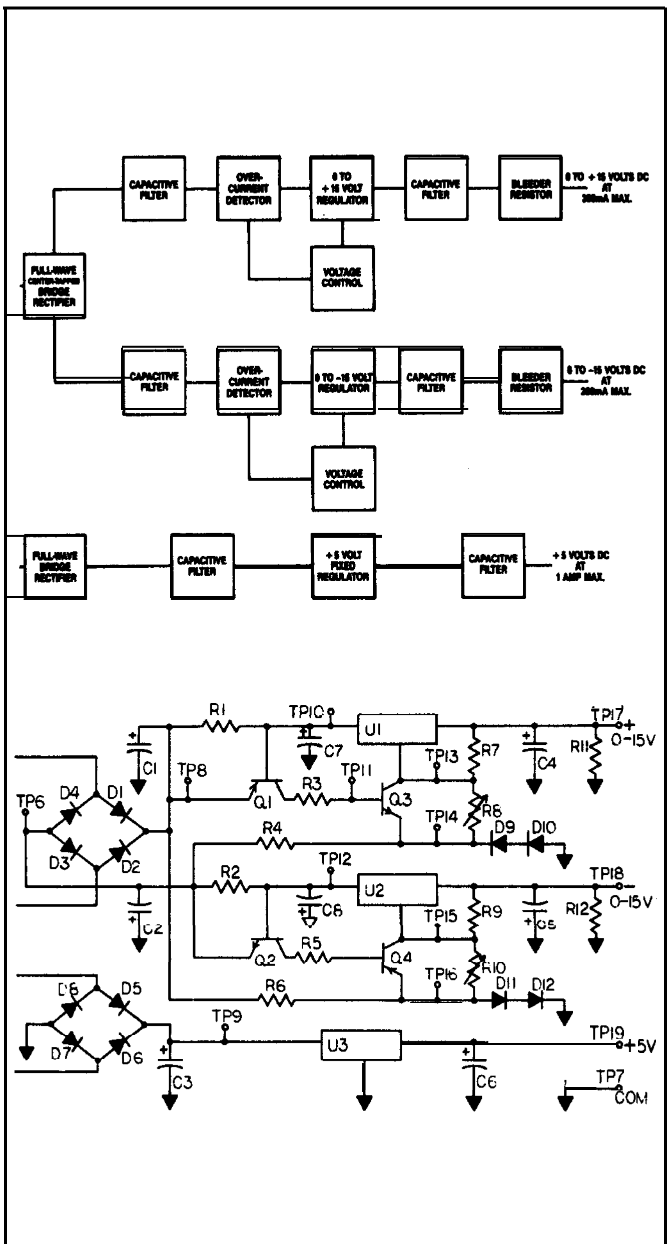


FIG. 53

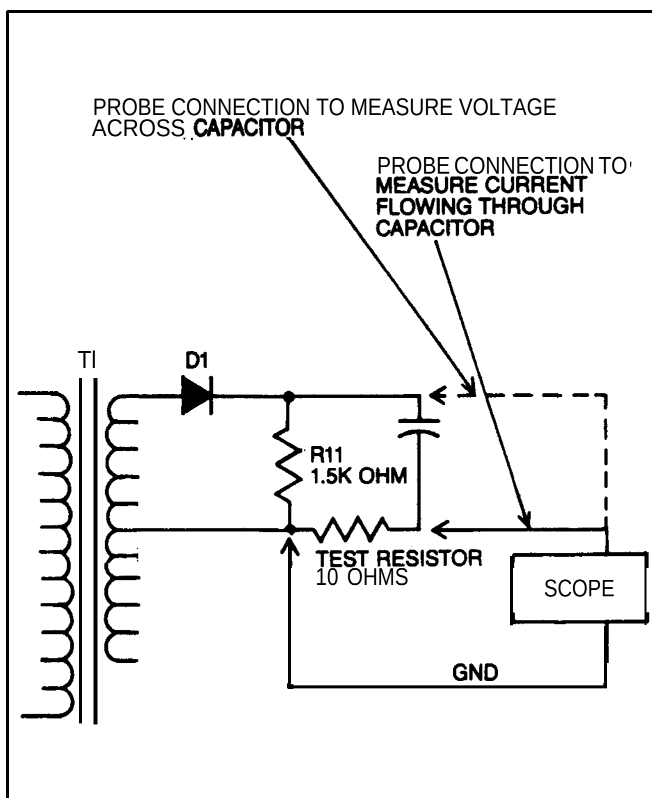


FIG. 55

CAPACITIVE FILTER EXPERIENCE

Purpose: To obsetve the current through and the voltage across a capacitor when it is connected to a half wave rectifier circuit.

Equipment: Oscilloscope
Clip Lead
1000 **mF** Capacitor
Test Resistor

Refer to Fig. 56 for the following steps.

____ 1. Be sure the ***808*** power plug is **NOT connected** to a power outlet.

____ ***2.*** Unsolder from TP3 the anode lead of the diode that was installed **between TP3** and TP8 during the Full-Wave Center-Tapped Rectifier Test. Bend the anode lead so that is not touchingTP3 or any of the other parts or the PCB.

____ ***3.*** Solder the positive lead of a 1000 **mF** 35 Volt capacitor toTP17. Make sure that the red wire from TP8 remains soldered to TP17.

NOTE: **The capacitors supplied in your 808 kit ail are of the electrolytic type, and have both leads coming out of one end of the body of the capacitor. On the side of the capacitor there will be one or more minus signs printed. The lead that is closest to these minus signs is the negative lead of the capacitor; the other lead is the positive lead. Also, the capacitors are supplied with the positive leads longer than the negative leads as a further means of determining polarity.**

It is important to observe polarity when using electrolytic capacitors. Failure to do so may result in damage to the capacitor and other components.

____ **4.** Solder the positive lead of a 10 **mF 50** Volt capacitor to the positive lead of the 1000**mF** capacitor that you soldered to TP17 in step 3. Solder one of the leads of the 10 Ohm**(brown-black-**black) **1/2** Watt test resistor **toTP7.The** other lead of this 10 Ohm resistor and the negative leads of the two capacitors are not connected to anything at this time.

____ 5. Adjust the scope to display a 30 Volt (peak) 60 Hz signal. Set the **vertical (Y)** input coupling to DC**.**

____ 6. Connect the scope ground lead toTP7, and the scope input probe to TP17.

____ 7. Connect the 808 Power Supply plug to a power **outlet. Turn** the Power Switch **ON. The** scope display should look like Fig. 57. You've seen this waveform before, its the output of a half wave rectifier.

____ 8. Using a clip lead, connect the negative lead of the 10 **mF** test capacitor to the free lead of the 10 Ohm test **resistor. The** scope should now display the waveform shown in Flg. 58. Adjustthe sweep and trigger controls as necessary to make the scope display closely match the waveform as shown in Fig. 58. Notice that the peak voltage is about 30 Volts, and the minimum voltage is about 9 **Volts. The** peak to peak ripple voltage is the difference between these two voltages, that is, about 21 **Volts. This** is a very large amount of ripple. If your stereo system were powered by a supply with this much ripple, you would hear a very loud 60 Hz tone whenever it was turned on.

____ 9. Remove the 808 power plug from the outlet for

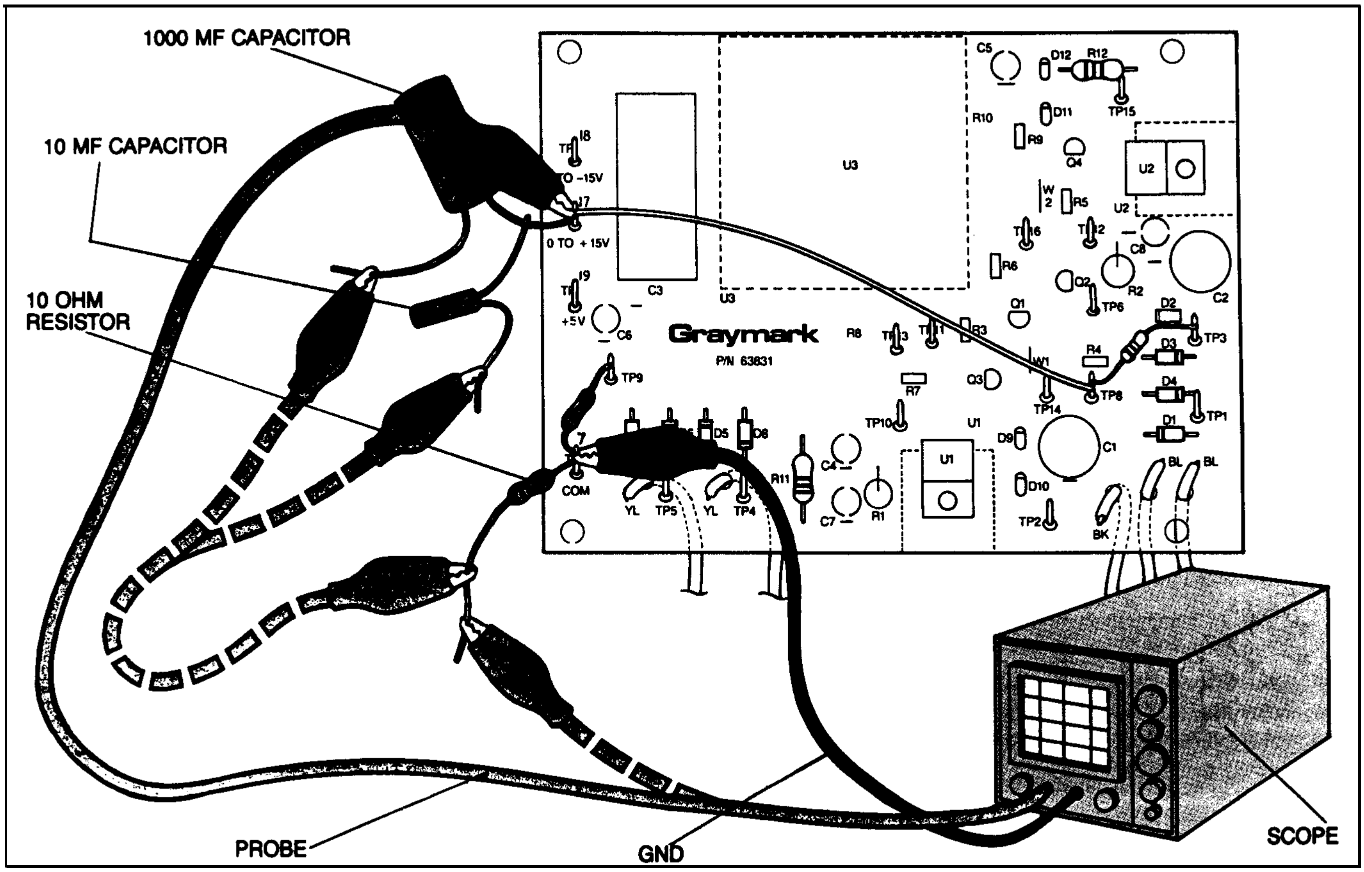


FIG. 56

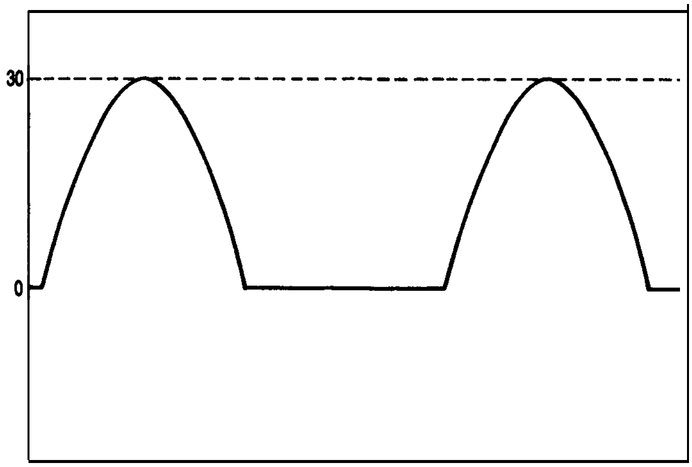


FIG. 57

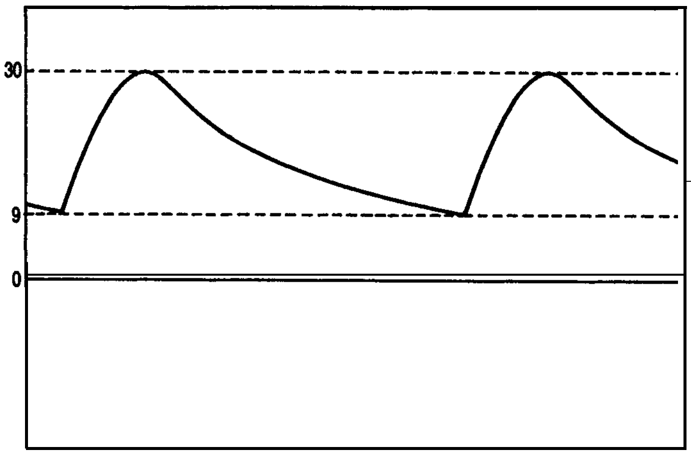


FIG. 58

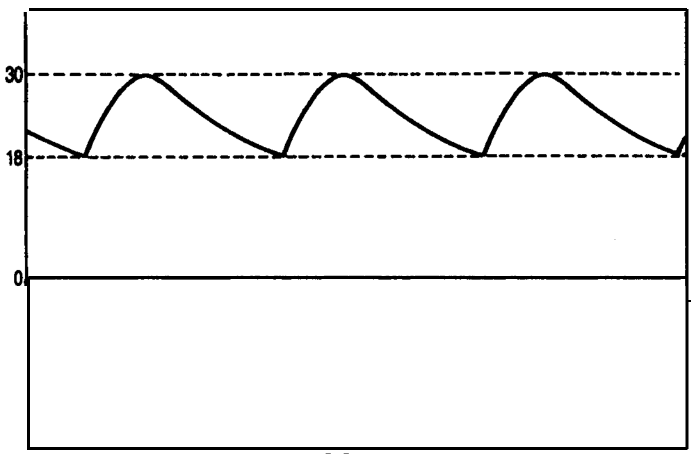


FIG. 59

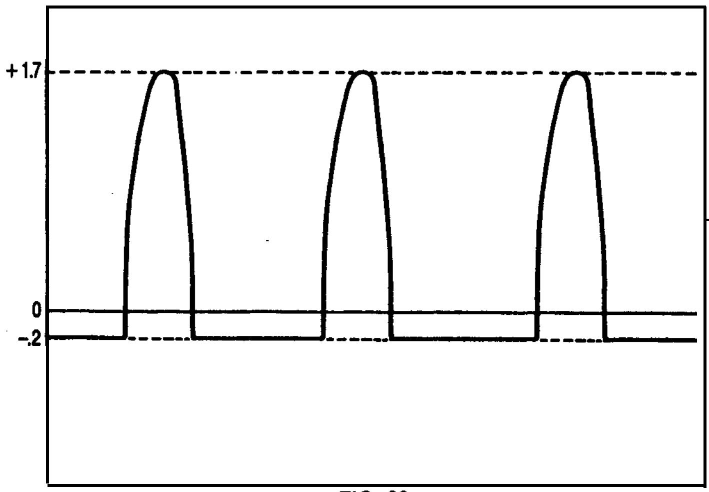


FIG. 60

this step. Resolder the anode lead of the temporary D2 diode toTP3. Do not change the test set **up.**

____ 10. Plug the 808 power plug back into the outlet. The waveform on the scope should now look Fig. 59. The peak voltage is still about 30 Volts, but the minimum voltage has gone up to 18 Volts, and the peak to peak ripple has gone down to 12 Volts. This shows that the output of a full wave rectifier is more easily filtered than the output of a half wave rectifier.

____ **11.** Disconnect the end of the clip lead that is connected to the negative lead of the 10 **mF** test capacitor, and connect it to the negative lead of the 1000 **mF** test capacitor. Observe the scope display. (You may need to readjust the scope trigger control.) Using a colored pencil, draw this waveform on Fig. 59, over the printed **waveform.What** is the approximate peak to peak ripple voltage now? ____________

____ 12. Move the Scope probe to the **10** Ohm test resistor lead that is connected to the 1000 **mF** capacitor negative lead by the clip lead. You will need to change the scope vertical Volts/cm control to a more sensitive setting, as the voltage developed across the 10 Ohm resistor by the current flowing through the test capacitor is quite low. The waveform displayed on your scope should look like the one shown in Fig. 60. Notice that the current flows through the capacitor in short positive pulses. These current pulses occur when the instantaneous voltage from the rectifier diodes exceed the the relatively constant voltage across the capacitor. It is during these pulses that the capacitor is charged or, to say it in another way, that electrical energy is stored in the capacitor. During the longer periods between the positive current pulses the capacitor discharges, or gives up electrical energy to the load resistor **R1** 1 and the 10 Ohm current sensing resistor.

____ 13. We can use Ohm's law to calculate the current flowing through the capacitor during the charging and discharging periods. The formula **I** = E / **R** will give us the current **(I)** if the voltage (E) is divided by the resistance **(R).** Using -0.2 Volts, the voltage developed across across the current sensing test resistor during capacitor discharge periods, and 10 Ohms, the resistance value of the current sensing resistor, calculate the **capacitor**current. __________ Amps. Calculate the peak capacitor current during the capacitor charging period. __________ Amps. Hint: the voltage is +1.7 Volts.

____ **14.** Disconnect the 808 power plug from the power outlet and the scope probe and ground lead from your test setup. Unsolder the two capacitors, the test resistor, the diode and the red wire that were soldered to test points on the PCB. This completes the Capacitive Filter Experience. Have your instructor initial your progress guide.

CAPACITIVEFILTERCALCULATIONS

PERCENT OF RIPPLE

This term is often used to express how "clean" or free from periodic voltage variations a power supply output is. The voltage output of a battery supplying power to a constant load, such a fixed resistor, has a percent of ripple of 0.

To calculate the percent of ripple, the following formula is used:

$$\% \text{ Ripple} = \frac{V_{rms}}{V_{average}} \times 100$$

Where: V_{rms} = the rms value of the peak to peak ripple voltage

We can use .707 times the peak to peak ripple voltage to determine the rms ripple voltage. While this conversion is only exact for sine waveforms, it is reasonably accurate for full-wave ripple waveforms.

$V_{average}$ = the average dc voltage output of the power supply.

The dc voltage ranges of a VOM or a DMM read the average value of a pulsating dc voltage input.

Using the above formula, calculate the percentage of ripple in the voltage waveform shown in Fig. 59. Use 24.4 Volts for $V_{average}$.

Hint: the peak to peak ripple voltage can be calculated from the voltage values given in Fig. 59. The positive peak of the ripple voltage is 30 Volts. The negative peak of the ripple voltage is 18 Volts. Both of these voltages are positive in respect to ground. The peak to peak ripple voltage is the difference between these two voltages, that is, 12 Volts.

Write your answer here. ________

CAPACITANCE REQUIRED FOR A PARTICULAR APPLICATION

If we were designing a power supply, ho.w would we determine the value of capacitance needed for the capacitance filter? Lets go through the process step by step, using the positive 0 to 15 Volt power supply of the 808 as an example. Figure 61 is the schematic of this power supply.

1. Determine the current required from the capacitive filter. The rated output is 15 Volts at 300 mA. Bleeder resistor R1 1 has a resistance value of 1500 Ohms. Using Ohm's law, (I = E/R), we find the current through this resistor is .OIO Amps, or 10 mA.

   To calculate the current flowing through the R7, R8, D9 and D10 circuit, we will have to get some values from the ELECTRICAL CHARACTERISTICS OF THE LM317 table in the VOLTAGE REGULATOR SECTION of this manual. These values are the "Reference Voltage", which appears across R7, and the "Adjustment Pin Current". The Reference Voltage is 1.30 Volts maximum. R7 is a 340 Ohm resistor. Using Ohm's law again, the same formula as above, the current through R7 calculates to be 3.8 mA. Since the Adjustment Pin Current is a relatively low 100 uA (or .I mA) we will ignore it. If we wanted to include it, it would be added to the current flowing through R7. Since a current of 300 mA is not enough to turn on the overcurrent protection circuitry,(Q1, R3 and Q3), there is no current flowing through these three components. Its as if they were not there.

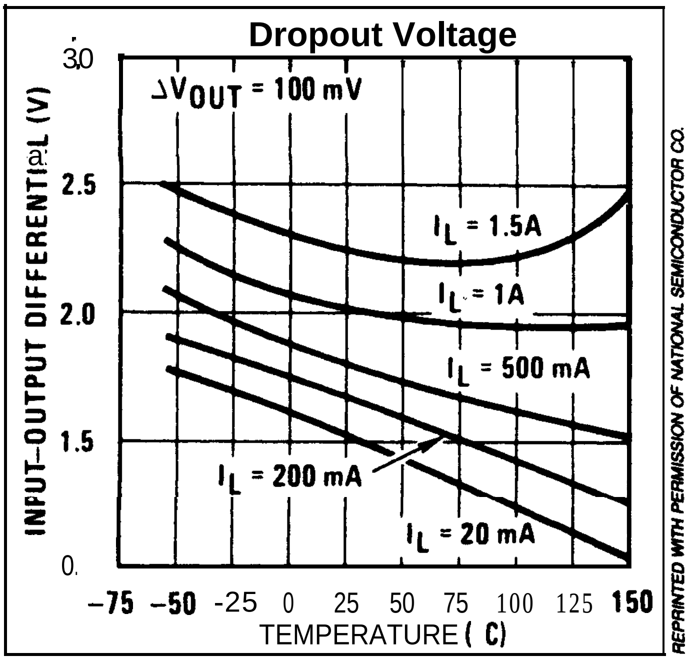


FIG. 60A

   Adding these three currents gives us the total current that the filter capacitor (Cl) must provide during the time periods that the rectifier is not supplying current. See Fig. 60.

Rated output current:	300.0 mA
Bleeder (R1 1) current:	10.0 mA
Voltage control circuit current:	3.8 mA
Total current:	313.8 mA

2. Determine the voltage required from the capacitive filter. The rated output is 15 Volts. To this we must add the "Drop Out" voltage of the voltage regulator, and the voltage drop across the overcurrent sensing resistor Rl. The drop out voltage of a regulator is the lowest voltage across its input to output terminals that can exist with the voltage regulator still functioning as a regulator. We will get voltage from the Dropout Voltage graph, from the National Semiconductor specification sheets for the LM 317. This graph is shown in Fig. 60A. Using a current of 500 mA and a temperature of 25 C, the graph indicates the input/output differential to be about 1.8 Volts.

   Ohm's law (E = I x R) indicates the voltage drop across 1 Ohm R1 to be .314 Volts.

Rated output voltage:	15.0
Volts Regulator dropout voltage:	1.8
Volts R1 voltage drop:	0.314 Volts
Total Voltage:	17.114 Volts

   This is the minimum voltage that Cl has to maintain between the time periods the rectifier is supplying current if the output voltage is to be maintained at 15 Volts with a current of 300 mA.

3. If complete specifications for the power transformer and rectifier diodes are available, the peak voltage at the bridge rectifier output can be calculated. These specifications would have to include winding resistances, turn ratios,. and core losses at different power levels for the power transformer and forward voltage drops at different current levels for the rectifier diodes.

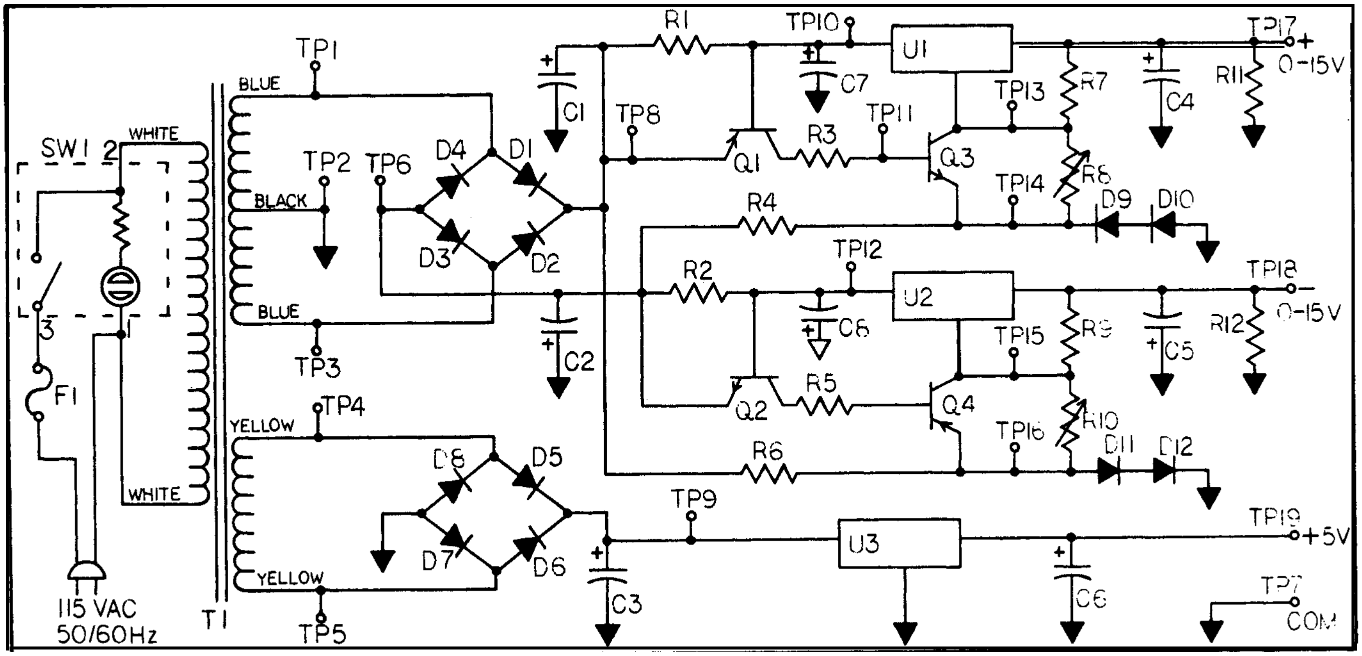


FIG. 61

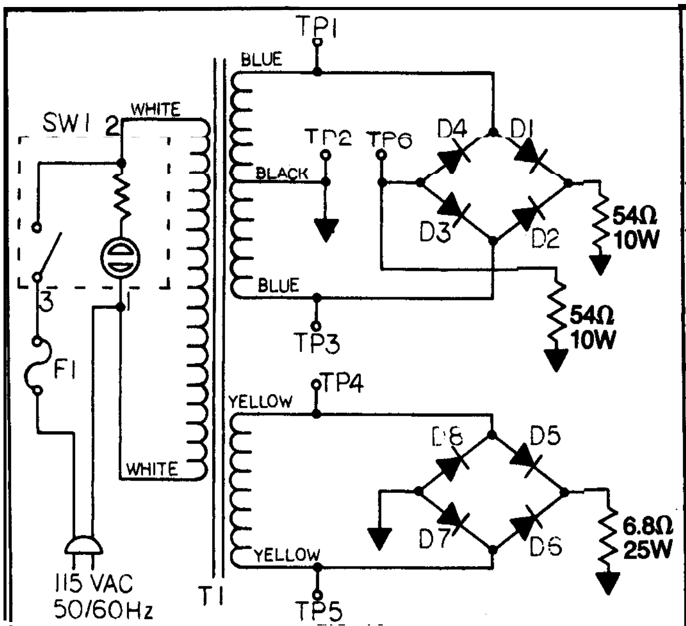


FIG. 62

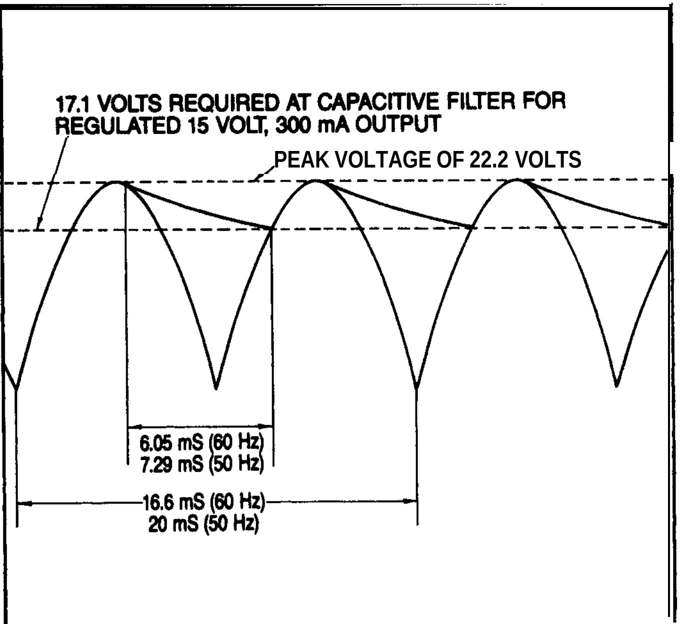


FIG. 63

A less math-intensive, more empirical method would be to provide resistive loads for each rectifier output, and measure the peak D.C. voltage available to charge the filter capacitor with an oscilloscope. (The word **"empirical"** relates to information gained by observation and experimentation.) All the outputs need to be loaded **because,** due to the primary winding resistance and core losses of the transformer, increasing the load on one winding will decrease the voltage output of the other windings. Figure 62 shows schematically how this measurement would be made. The load resistor values are calculated with the formula: **R =** E/I. For the variable supplies, we use the values of 17.1 Volts and 314 **mA** that we calculated earlier. The two load resistors have a resistance value of 54 Ohms each. The load **resistor** for the fixed **5** Volt supply was calculated in a similar manner, and has a resistance value of 6.8 Ohms.

The input voltage to the power transformer is reduced to 95 Volts, as this is the minimum input voltage specified for the 808 Power Supply. Under these test **conditions** the measured peak output voltage of the rectifier is 22.2 Volts. We need to maintain a voltage of at least 17.1 Volts (which is 77% of the peak voltage) at **all** times to maintain a regulated power supply output of 15 Volts at 300 **mA.** How big a capacitor will be needed to do this?

4. Through calculation and measurement, we have determined that the power transformer and rectifier are capable of providing a full wave pulsating DC voltage of 22.2 Volts at full rated current with a line input voltage of 95 **Volts. We** have also determined that to maintain a regulated plus 15 Volts at a current of 300 **mA** at the variable positive output of the 808 Power Supply, the voltage from rectifier will have to be at least 17.1 Volts at all times. Figure 63 shows this information graphically, along with the period of time that the capacitive filter **will** have to supply power during each cycle of the rectifier **output. To** calculate the size of the capacitor needed, we will be using **RC** time constant formulas.

RC TIME CONSTANT EXPERIENCE

DISCUSSION

The time constant of the discharge of a capacitor through a resistor is the time required for the voltage or current to drop to **1/e of its** value at the time the discharge began. The symbol "e" **is the** base of the natural or Napierian logarithm. **It** value **is 2.718.** The reciprocal of e (l/e) is 0.3679.

Consider the formulas:

$$E_c = E_p \times e^{-t/T}$$

or;

$$E_c = E_p \times (1/e)^{t/T}$$

Where: E_c is the voltage across the capacitor at the end of the discharge time period,

E_p is the voltage across the capacitor at the beginning of the discharge period,

e **is 2.718,**

t is the discharge time in seconds,

T = **R** x C, in seconds,

R is resistance in Ohms,

and C is capacitance in Farads.

If **R** is expressed in **kOhms,** C in **uF, T and t** in milliseconds **(mS);** the formula is a little easier to handle.

Using a 1000 **uF** capacitor and a 10 **kOhm** resistor, T (that is, **RxC)** is **10,000 mS,** or **10** seconds. If E_p is 10 Volts, and **t is 10** seconds,

then E_c = **10 x 0.3679' = 3.679** Volts.

Figure 64 is a graph of E_c versus time, using the values giv-**en above.**

Calculate the values for E_c at **t/T of** 0.5 and 2.0. Record your answers. ______________________

Compare your answers with the values you read from Fig. 64.

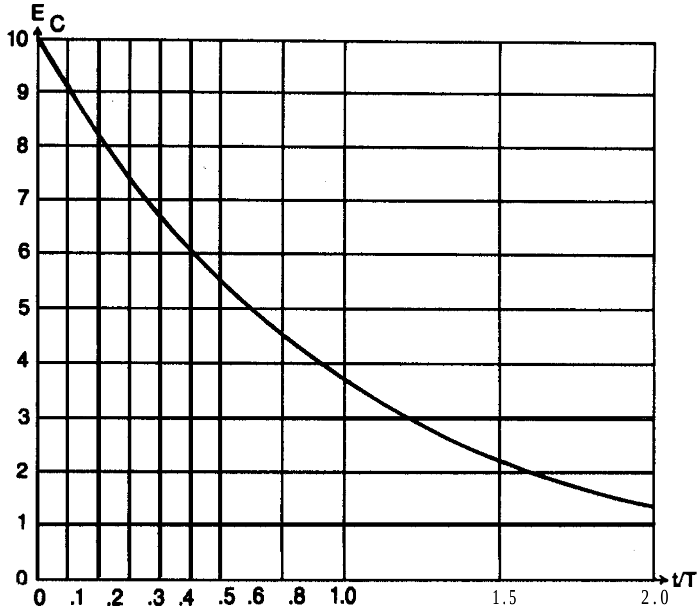


FIG. 64

RC CIRCUIT TEST

Purpose: To observe the action of an actual (hardware) RC circuit.

Equipment: **VOM** or **DMM**
DC Power Supply
Two Clip Leads
Watch With Second Hand or Digital Readout

____ **1.** A completed **Graymark** 808 or 803 Power Supply, or any power supply capable of supplying 10 Volts at approximately 25 **mA** or more may be used. Be sure the power supply power plug is Not connected to a outlet, and that the voltage control is set for minimum voltage output. Refer to Fig. 65 for the following steps.

____ 2. Connect a **1000 uF** capacitor and the **10 kOhm** (brown-black-orange) test resistor from your 808 kit to the **VOM** or **DMM** as shown in Fig. 65. Solder the capacitor leads to the resistor leads. Do not make a mechanical connection of the leads before soldering, as these parts will be unsoldered at the end of this experience. Be sure to **observe** the capacitor polarity when connecting the **power** supply and meter.

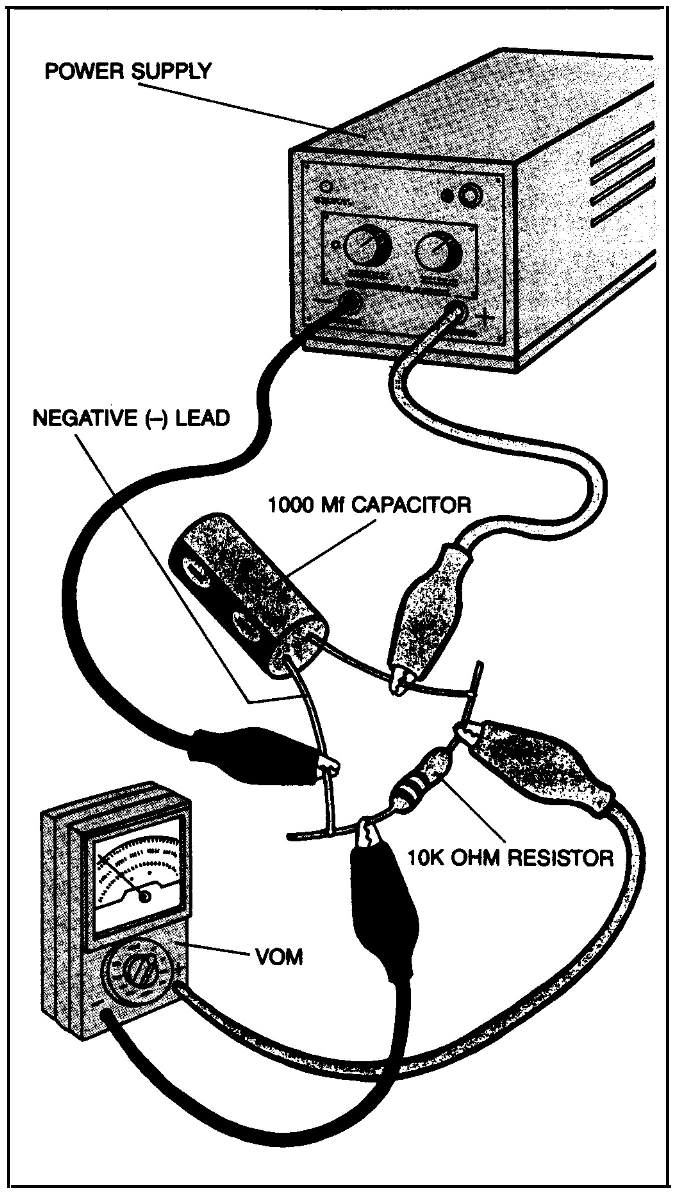


FIG. 65

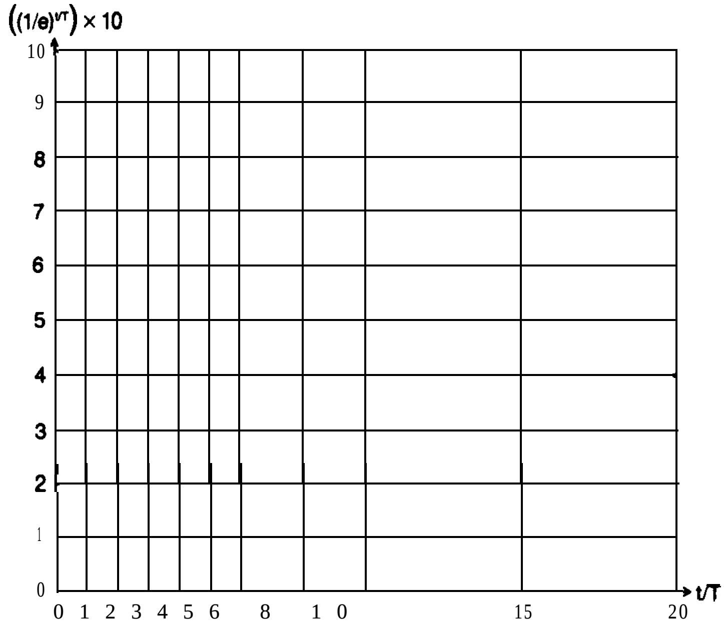


FIG. 66

___ 3. Set the test meter to read a voltage of 10 Volts DC. Connect the power supply plug to an outlet and adjust the power supply for a meter reading of 10 Volts.

___ 4. Disconnect one of the clip leads from the power supply, wait 20 seconds and then read the meter. Put a dot on the blank graph in Fig. 66 where the voltage you read from the meter andthe time you waited intersect.

___ 5. Reconnect the clip lead (that was disconnected in step 4) to the power supply. Notice how rapidly the capacitor is charged to 10 Volts. This is because the resistance, or **R,** is now only the clip lead resistances plus the internal resistance of the power **supply. The** total of these resistances is probably less than 100 Ohms.

___ 6. Repeat steps 4 and 5, using waiting periods of **15, 10, 8, 6, 5, 4, 3, 2** and 1 seconds. Place a dot in the appropriate place on the graph in Fig. 66 each time you repeat steps 4 and 5.

___ **7.** Connect the dots on the graph with a pencil line, using a **french** curve if possible. Does the graph you just drew look like the one in Fig. **64?** Because of the difficulty in reading the meter **accurately** when the voltage is changing rapidly, the dots you place near the left edge of the graph will be the least accurate. Also, the capacitance tolerances of electrolytic capacitors are large, **typically -20%** to **+ 50%. This** could affect the vertical location of the curve you generated on the graph, but not necessarily its slope.

___ 8. Remove the power supply plug from the outlet. Disconnect the clip leads and the meter test leads Unsolder the capacitor and resistor leads. This completes the **RC** Time Constant Experience- Have your instructor initial your progress guide.

CAPACITANCE REQUIRED FOR A PARTICULAR APPLICATION(continued)

With some understanding of **RC** time constants, we can continue with the capacitive filter calculations that were begun **earlier. The** power transformer and rectifier circuitry for the positive variable power supply of the 808 are capable of supplying a full wave pulsating DC voltage of 22.2 peak Volts at full rated current with a line input voltage of 95 Volts.

For the voltage regulator and overcurrent protection circuitry to maintain an output of **15** Volts at a current of 300 **mA,** the voltage from the rectifier will have to be at least 17.1 Volts at all times.The length of time that the capacitive filter will have to periodically supply power to maintain this minimum voltage is 7.29 **mS.** for **50** Hz input power. Refer to Fig. 63 to review this information. The equivalent load resistance of the fully loaded voltage regulator and overcurrent circuitry is 54 Ohms.

The formula: $E_c = E_p\,(1/e)^{t/RC}$

can be rewritten to solve for **C.**

$$C = \frac{t}{R \times \ln(E_p/E_c)}$$

In is the natural log of, in this case, E_p/E_c. It can be found by using a table of natural logarithms or a scientific calculator.

By expressing **t** in milliseconds and **R** in **kOhms,** C will be in microfarads. Plugging in these values and solving for C, we get:

$$\frac{7.29}{0.054 \times \ln(22.2/17.1)} = 517\ \mu F$$

Is this the value that should be used for the capacitive filter for the positive variable supply in the **808?** Because of one factor that we were not able to evaluate in our empirical design approach, the answer to that question has to be "no". Look at Fig. 60 again. This figure shows the voltage drop across a current sensing resistor connected between the rectifier and the capacitive filter. Because of the winding resistance and core losses of the power transformer, and losses in the rectifier circuitry, the spikes of current that occur when the capacitive filter is charging will reduce the voltage available at the rectifier output.

Figure 67 shows the full wave rectifier output for the positive variable supply of the **808. The** solid line shows the voltage waveform with a resistive load and no capacitive filter. The dashed line shows the voltage waveform when a capacitive filter is added. Notice how the voltage peaks are reduced with the addition of the filter.

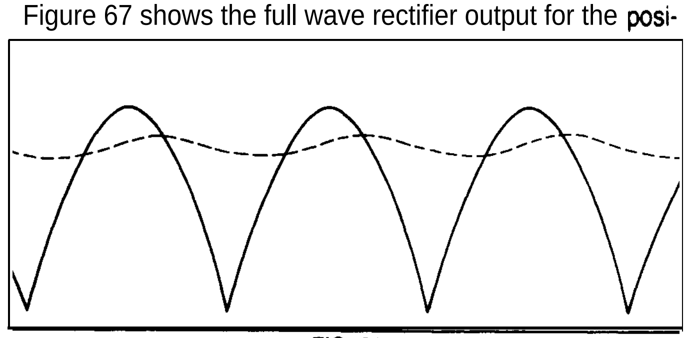


FIG. 67

To determine the values for the capacitive filters empirically, trial values for the capacitors must be connected and the power supply outputs evaluated under load until **satisfactory** capacitance values are found. Most engineering companies use a mathematical approach for the initial design work, and then verify the design by building and testing a prototype. Developments in computers and software allow tests using computer simulated prototypes, with savings in engineering time and expense.

A value of 1000 **uF** was selected for the capacitive filter of the positive variable supply in the **Graymark** 808. The selection of this value was based on further calculations.

CONSTRUCTION

Refer to Fig. 68 for the following steps.

____ 1. Be sure the 808 power **plug** is **NOT connected** to a power outlet.

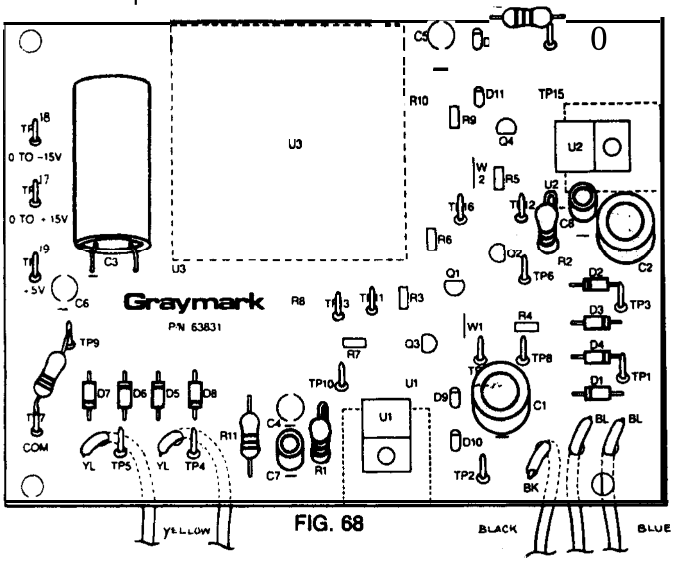


FIG. 68

____ 2. Mount diode D2 on the **PCB.** Be sure that the banded end of the diode is oriented the same as the diode outline that is silkscreened on **the PCB.** Using a heat sink as shown in Fig. 40, solder the diode leads to the PCB. Cut off any excess lead length.

____ **3.** Mount the following capacitors on the PCB, **making** sure that the negative **(-)** leads are inserted into the holes marked **"-"**.

- A . C I , **1000 uF** ____ D. **C7, 10 uF**

____ B. **C2, 1000 uF** ____ E. **C8, 10 uF**

____ C. **C3, 4700 uF**

____ **4.** Solder all the capacitor leads to the PCB and cut off any excess lead lengths.

____ 5. Mount resistors RI and **R2** on the PCB. Both **resistors** are 1 Ohm **(brown-black-gold),** 1 Watt. Solder the resistor leads to the PCB and cut off any excess lead length.

NOTE: The following components are being mounted on the PCB at this time to serve as bleeder resistors for capacitors Cl and C2 until the variable voltage regulators are installed. The 1.5 kOhm test resistor which was connected to TP7 and TP9 earlier serves as a bleeder for capacitor C3 until regulator U3 is installed.

____ 6. Mount and solder resistors **R4** and **R6, 2.2 kOhm** (red-red-red), **.25** Watt, on the PCB. Cut off the excess lead length. Save one of these leads for the next step.

____ 7. Bend the piece of wire saved from the last step into a "U" shape, and use it for Jumper **W2.** insert this jumper wire from the component side of the PCB. Solder and cut off any excess lead length.

____ 8. Mount the **1N4148** diodes **D9, D10,** Dll and D12 on the PCB. These diodes are smaller than the rectifier diodes installed earlier. Be sure that the banded ends of the diodes are oriented as shown on the diode outlines printed on the PCB. Using a heat sink, as shown in Fig. 40, solder the diodes to the PCB. Cut off any excess lead

PCB TEST

Purpose: To determine that the PCB has been assembled correctly up to this point.

Equipment: VOM or **DMM**
Watch with second hand or digital readout. (Counting out loud "One thousand one, one thousand two . . . one thousand thirteen" etc., would be accurate enough for these tests.)

____ 1. Review rule 9 of BUILDING YOUR POWER SUPPLY BREADBOARD that appears earlier in this manual.

____ 2. With the 808 power plug connected to a power outlet, turn the 808 power switch ON, wait 1 **second,** and turn it **OFF. Touch** all the diodes and **capacitors** C7 and C8 with your finger to tell if any of them are warm or hot. Bigger components take longer to heat up if something is wrong. By checking smaller components after a short power ON period, even if something is wrong the components probably will not be damaged, and will work satisfactorily after the fault is wrrected. If any of the wmponents called out above are warm, something is wrong. Check the PCB carefully, and consult with your instructor if necessary.

____ 3. Repeat step 2, leaving the power ON for **5 seconds.** Recheck all the diodes, and capacitors C7 and C8 to tell if they are warm. In addition, touch capacitors Cl, C2 and C3 to tell if they aregetting warm.

____ 4. Repeat step 2 again, leaving the power ON for **15 seconds** this time. Recheck all diodes and **capacitors** for heating.

____ 5. If none of the diodes or capacitors heated up in steps two through four, power up the 808 again and measure the dc voltage between the pairs of test points listed below. For an input line voltage of from 105 to 125 Volts, the voltages you measure should be within the ranges listed below.

____ A. TP7 and TPQ (TPQ should be positive), **13** to 16 Volts dc.

____ B. TP7 and **TP10 (TP10** should be **positive**), 25 to 31 Volts dc.

____ C. TP7 and TP12 (TP12 should be **negative**), 25 to 31 Volts dc.

____ 6. Turn OFF the power switch of the 808 Power Supply, and remove its power plug from the **outlet. This completes** the FILTER SECTION. Have your instructor initial your progress guide.

VOLTAGE REGULATOR SECTION

DISCUSSION

The 808 uses three voltage regulators as follows. The **LM309** and **UA7805** are interchangeable devices for the + **5** VDC supply.

LM317 (UI) for the + **15** VDC supply

LM337 (U2) for the **-15** VDC supply

LM309 (or **UA7805)** (U3) for the + 5 VDC supply

The **LM317** is a three terminal adjustable positive voltage regulator. Refer to Fig. 69. Its output is adjustable from + **1.2** to + 37 Volts. As used in the **Graymark 808,** its output is guaranteed to be adjustable upward to a minimum of a regulated 15 Volts under worst case conditions, that is, 300 **mA** output current and low input line voltage (95 Volts AC). The output voltage is adjustable down to 0 Volts. This is made possible by the design of the external control circuitry. This will be discussed in the EXTERNAL CONTROL AND PROTECTION CIRCUITRY section.

The **LM317** is an integrated circuit **(IC).** All of the circuitry for the **LM317** to do it's job, with the exception of the voltage divider **circuitry** that controls the the output voltage, is contained within the **IC.** Current limiting is also included in the design of the **IC** to limit the output current to a safe value. The **LM317** also has internal thermal shutdown circuitry to prevent the **IC** from overheating. When the regulator reaches its maximum safe operating temperature, the regulator will shutdown to prevent damage to itself by excessive heating. All protection circuitry remains fully functional even if the adjustment terminal becomes disconnected.

The LM337 is similar to the **LM317,** except that its output is adjustable from -1.2 to -37 Volts. Itis used in the negative variable supply of the **Graymark 808.The** specifications for the **LM337** are shown in Fig. 70.

The **LM309** is a nonadjustable three terminal device, and is used to regulate the **+** 5 VDC supply so the output voltage is constant under varying load and line **conditions.The LM309** is an integrated circuit, and all of the circuitry to do it's job is contained within the **IC.** Current limiting is also included in the design of the **LM309** to limit the output current to safe value. The **LM309** also has internal thermal shutdown protection circuitry to prevent it from overheating. If the internal power dissipation becomes too great, the **regulator** will shutdown to prevent damage to itself. Figure**71** shows the specifications for the **LM309.**

The three voltage regulators will be installed and tested one at a time. Some of the associated circuit components have already been installed so that tests could be performed, and some of the voltage control components will be installed **at this** time so that the regulators can be tested.

CONSTRUCTION

Refer to Fig. 72 for the following steps.

____ 1. **Be** sure the 808 power plug is not connected to a power outlet.

____ 2. Mount resistor **R7,** 340 Ohm **(orange-yellow-**black-black) **.25** Watt **1%,** on the PCB. Solder the leads to the PCB and cut off any excess length.

____ 3. Solder the leads of a 3.9**kOhm (orange-white-**red) **.25** Watt test resistor to test pointsTP13 and **TP14.This** resistor temporarily takes the place of variable resistor **R8** for test purposes.

LM317 SPECIFICATIONS

Absolute Maximum Ratings

Power Dissipation	internally limited
Input - Output Voltage Differential	4ov
Operating Junction Temperature Range	
LM117	−55°C to +150°C
LM217	−25°C to +150°C
LM317	0°C to +125°C
Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

Preconditioning

Burn-In in Thermal Limit	100% Ail Devices

Electrical Characteristics (Note 1)

PARAMETER	CONDITIONS	LM117/2 MIN	LM117/2 TYP	LM117/2 MAX	LM317 MIN	LM317 TYP	LM317 MAX	UNITS
Line Regulation	$T_A = 25°C$, $3V \le V_{IN} - V_{OUT} \le 40V$ (Note 2)		0.01	0.02		0.01	0.04	%/V
Load Regulation	$T_A = 25°C$, $10\ mA \le I_{OUT} \le I_{MAX}$							
	$V_{OUT} \le 5V$, (Note 2)		5	15		5	25	mV
	$V_{OUT} \ge 5V$, (Note 2)		0.1	0.3		0.1	0.5	%
Thermal Regulation	$T_A = 25°C$, 20 ms Pulse		003	0.07		0.04	0.07	%/W
Adjustment Pin Current			50	100		50	100	µA
Adjustment Pin Current Change	$10\ mA \le I_L \le I_{MAX}$ $2.5V \le (V_{IN} - V_{OUT}) \le 40V$		0.2	S		0.2	5	µA
Reference Voltage	$3 \le (V_{IN} - V_{OUT}) \le 40V$, (Note 3) $10\ mA \le I_{OUT} \le I_{MAX}$, $P \le P_{MAX}$	1.20	1.25	130	1.20	12s	1.30	V
Line Regulation	$3V \le V_{IN} - V_{OUT} \le 40V$, (Note 2)		0.02	0.05		0.02	0.07	W V
Load Regulation	$10\ mA \le I_{OUT} \le I_{MAX}$, (Note 2)							
	$V_{OUT} \le 5V$		m	50		20	70	mV
	$V_{OUT} \ge 5V$		0.3	1		0 3	1 5	%
Temperature Stability	$T_{MIN} \le T_j \le T_{MAX}$		1			1		%
Minimum Load Current	$V_{IN} - V_{OUT} = 40V$		3.5	5		3.5	10	mA
Current Limit	$V_{IN} - V_{OUT} \le 15V$							
	K and T Package	1.5	2.2		1 5	2.2		A
	H and P Package	0.5	0.8		0 5	0.8		A
	$V_{IN} - V_{OUT} = 40V$							
	K and T Package		0.4			0.4		A
	H and P Package		0.07			0.07		A
RMS Output Noise, % of V_{OUT}	$T_A = 25°C$, $10\ Hz \le f \le 10\ kHz$		0.003			0.003		%
Ripple Rejection Ratio	$V_{OUT} = 10V$, $f = 120\ Hz$		65			65		dB
	$C_{ADJ} = 10\mu F$	66	80		66	80		dB
Long-Term Stability	$T_A = 125°C$		0.3	1		0.3	1	%
Thermal Resistence, Junction to Case	H Package		12	15		12	15	°C/W
	K Package		2 3	3		2.3	3	°C/W
	T Package					4		°C/W
	P Package					12		°C/W

Note 1: Unless otherwise specified, these specifications apply: $-55°C \le T_j \le +150°C$ for the LM117, $-25°C \le T_j \le +150°C$ for the LM217 and $0°C \le T_j \le +125°C$ for the LM317; $V_{IN} - V_{OUT} = 5V$ and $I_{OUT} = 0.1A$ for the TO-5 and TO-202 packages and $I_{OUT} = 0.5A$ for the TO-3 package and TO-220 package. Although power dissipation is internally limited, these specifications are applicable for power dissipations of 2W for the TO-5 and TO-202 and 20W for the TO-3 and TO-220. I_{MAX} is 1.5A for the TO-3 and TO-220 package and 0.5A for the TO-5 and TO-202 package.

Note 2: Regulation is measured at constant junction temperature, using pulse testing with J tow duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

Note 3: Selected devices with tightend tolerance reference voltage available.

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FIG. 69

LM337 SPECIFICATIONS

Absolute Maximum Ratings

Power Dissipation	Internally limited
Input-Output Voltage Differential	40V
Operating Junction Temperature Range	
LM137	-55°C to + I 50°C
LM237	−25°C to 150°C
LM337	0°C to +125°C
Storm Temperature	−65°C to +150°C
Load Temperature (Soldering, 10 seconds)	300°C

Preconditioning

Burn-In in Thermal Limit	100% All Devices

Electrical Characteristics (Note1)

PARAMETER	CONDITIONS	LM137/LM237 MIN	LM137/LM237 TYP	LM137/LM237 MAX	LM337 MIN	LM337 TYP	LM337 MAX	UNITS
Line Regulation	$T_A = 25°C$, $3V \le \lvert V_{IN} - V_{OUT} \rvert \le 40V$ (Note 2)		0 01	0 02		0 01	0 04	% V
Load Regulation	$T_A = 25°C$, $10\ mA \le I_{OUT} \le I_{MAX}$							
	$\lvert V_{OUT} \rvert \le 5V$ (Note 2)		15	25		15	50	mv
	$\lvert V_{OUT} \rvert \ge 5V$ (Note 2)		0 3	0 5		0 3	1 0	%
Thermal Regulation	$T_A = 25°C$, 10 ms Pulse		0 002	0 07		0 003	0 04	% W
Adjustment Pin Current			65	100		65	100	µA
Adjustment Pin Current Change	$10\ mA \le I_L \le I_{MAX}$ $2.5V \le \lvert V_{IN} - V_{OUT} \rvert < 40V$, $T_A = 25°C$		1	5		1	5	µA
Reference Voltage	$T_A = 25°C$ (Note 3)	1225	-1250	1 275	1 213	1 250	-1 287	V
	$3 \le \lvert V_{IN} - V_{OUT} \rvert \le 40V$, (Note 3) $10\ mA \le I_{OUT} < I_{MAX}$, $P < P_{MAX}$	-1 200	-1250	1300	1 200	1 250	-1 300	V
Line Regulation	$3V \le \lvert V_{IN} - V_{OUT} \rvert \le 40V$ (Note 2)		0 07	0 05		0 02	0 07	% V
Load Regulation	$10\ mA \le I_{OUT} \le I_{MAX}$ (Note 2)							
	$\lvert V_{OUT} \rvert \le 5V$		20	50		20	70	mv
	$\lvert V_{OUT} \rvert \ge 5V$		0 3	1		0 3	1 5	%
Temperature Stability	$T_{MIN} \le T_j \le T_{MAX}$		0 6			0 6		%
Minimum Load Current	$\lvert V_{IN} - V_{OUT} \rvert \le 40V$		2 5	5		2 5	10	mA
	$\lvert V_{IN} - V_{OUT} \rvert \le 10V$		1 2	3		1 5	6	mA
Current Limit	$\lvert V_{IN} - V_{OUT} \rvert \le 15V$							
	K and T Package	1 5	2 2		1 5	2 2		A
	H and P Package	0.5	0 8		0 5	0 8		A
	$\lvert V_{IN} - V_{OUT} \rvert = 40V$							
	K and T Package		0 4			0 4		A
	H and P Package		0 17			0 17		A
RMS Output Noise, % of V_{OUT}	$T_A = 25°C$, $10\ Hz \le f \le 10\ kHz$		0 003			0 003		%
Ripple Rejection Ratio	$V_{OUT} = -10V$, $f = 120\ Hz$		60			60		dB
	C_{ADJ} 10 µF	66	77		66	77		dB
Long Term Stability	$T_A = 125°C$, 1000 Hours		0 3	1		0.3	1	%
Thermal Resistance, Junction to Case	H Package		12	15		12	15	°C/W
	K Package		2 3	3		2 3	3	°C/W
	T Package					4		°C/W
	P Package					12		°C/W

Note 1: Unless otherwise specified, these specifications apply $-55°C \le T_j \le +150°C$ for the LM137, $-25°C \le T_j \le +150°C$ for the LM237 and $0°C \le T_j \le +125°C$ for the LM337; $V_{IN} - V_{OUT} = 5V$; and $I_{OUT} = 0.1A$ for the TO-5 package and TO-202 package and $I_{OUT} = 0.5A$ for the TO-3 package and TO-220 package. Although power dissipation is internally limited, these specifications are applicable for power dissipations of 2W for the TO-5 and TO-202 and 20W for the TO-3 and TO-220. I_{MAX} is 1.5A for the TO-3 and TO-220 package and 0.5A for the TO-5 package and TO-202 package.

Note 2: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation. Load regulation is measured on the output pin at a point 1/8" below the base of the TO-3 and TO-5 packages.

Note 3: Selected devices with tightened tolerance reference voltage available

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FIG. 70

____ 4. Mount 10 **mF** capacitor C4 on the PCB, making sure that the negative lead is inserted in the hole marked **"-"**. Solder the capacitor leads to the PCB and cut off any excess length.

____ 5. Locate the positive variable voltage regulator, U 1 **(LM317)**, one of the small heat sinks, a 3 x 8mm machine screw, a 3mm split lock washer and a 3mm hex nut.

____ 6. Bend the three leads of the **LM317** regulator as shown in Fig. 73. A long nose pliers is **a good** tool to use for this.

____ 7. Refer to Fig. 74. Mount the **LM317** regulator and heat sink on the **PCB**, using the hardware called out in step 5. **Graymark** recommends the use of heat sink compound on the surfaces of the voltage regulators and heat sinks where they contact each other.

____ 8. Before tightening the machine screw and nut that holds the heat sink and regulator to the PCB, **ro**tate the heat sink on the machine screw so that its cooling fins are oriented as shown in Fig. 72. Then tighten the machine screw and nut.

____ 9. Solder the regulator leads to the PCB, using a small alligator clip heat sink on each lead between the plastic regulator package and the top surface of the PCB. Cut off any excess lead length.

+ 15 VOLT REGULATOR TEST

____ 1. Connect the 808 power plug to a power outlet.

____ 2. Turn the 808 power switch ON, wait 1 second and turn it **OFF. Touch** the components that were installed in the construction steps that were just completed. If any of these components are warm, there is something wrong. Check the PCB and components carefully, and consult with your instructor if necessary.

____ 3. Repeat step 2, leaving the power ON for 5 **sec**onds this time.

Absolute Maximum Ratings

Input Voltage	35 V
Power Dissipation	Internally Limited
Operating Junction Temperature Range	
LM109	-55°C to +150°C
LM209	-25°C to +150°C
LM309	0°C to +125°C
Storage Temperature Range	-65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

LM309 SPECIFICATIONS

Electrical Characteristics

PARAMETER	CONDITIONS	LM109/LM209 MIN	LM109/LM209 TYP	LM109/LM209 MAX	LM309 MIN	LM309 TYP	LM309 MAX	UNITS
Output Voltage	$T_j = 25°C$	47	5.05	5.3	4.8	5.05	5.2	V
Line Regulation	$T_j = 25°C$, $7V \le V_{IN} \le 25V$		4.0	50		4.0	50	mV
Load Regulation	$T_j = 25°C$							
TO-5 Package	$5mA \le I_{OUT} \le 0.5A$		15	50		15	50	mV
TO-3 Package	$5mA \le I_{OUT} \le 1.5A$		15	100		15	100	mV
Output Voltage	$7V \le V_{IN} \le 25V$, $5mA \le I_{OUT} \le I_{MAX}$, $P < P_{MAX}$	4.6		5.4	4.75		5.25	V
Quiescent Current	$7V \le V_{IN} \le 25V$		5.2	10		5.2	10	mA
Quiescent Current Change	$7V \le V_{IN} \le 25V$			0.5			0.5	mA
	$5mA \le I_{OUT} \le I_{MAX}$			0.8			0.0	mA
Output Noise Voltage	$T_A = 25°C$, $10Hz \le f \le 100kHz$		40			40		µV
Long Term Stability				10			20	mV
Ripple Rejection	$T_j = 25°C$	50			50			dB
Thermal Resistance, Junction to Case	(Note 2)							
TO-5 Package			15			15		°C/W
TO-3 Package			2.5			2.5		°C/W

Note 1 Unless otherwise specified, these specifications apply for $-55°C \le T_j \le +150°C$ for the LM109, $-25°C \le T_j \le +150°C$ for the LM209, and $0°C \le T_j \le +125°C$ for the LM309. $V_{IN} = 10V$ and $I_{OUT} = 0.1A$ for the TO-5 package or $I_{OUT} = 0.5A$ for the TO-3 package. For the TO-5 package, $I_{MAX} = 0.2A$ and $P_{MAX} = 2.0W$. For the TO-3 package, $I_{MAX} = 1.0A$ and $P_{MAX} = 20W$.

Note 2 Without a heat sink, the thermal resistance of the TO-5 package is about 150°C/W, while that of the TO-3 package is approximately 35°C/W. With a heat sink, the effective thermal resistance can only approach the values specified, depending on the efficiency of the sink.

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FIG. 71

____ 4. Repeat step 2 again, this time leaving the power ON for **15 seconds.**

____ 5. If none of the components heated up in the previous **steps**, power up the 808 again. Measure the dc voltage between test points TP7 and TP17. TP17 should be positive, and the voltage should be between 12.7 and 15.8 **Volts. The** reason that a range of voltages is given is that the tolerances of a number of components can affect the regulator output voltage. If the voltage is not in this range, check resistor **R7** and the 3.9 **kOhm** resistor installed temporarily between TP13 and TP14. Make sure they are the correct resistors for these locations. Consult with your instructor if necessary.

____ 6. Turn OFF the 808 power switch and remove the power plug from the power outlet.

CONSTRUCTION

Refer to Fig. 72 for the following steps.

____ 1. Be sure the 808 power plug is not connected to a power outlet.

____ 2. Mount resistor **R9**, 340 Ohm **(orange-yellow-black-black) .25** Watt 1%, on the PCB. Solder the leads to the PCB and cut off any excess length.

____ 3. Solder the leads of a 3.9 **kOhm (orange-white-**red) **.25** Watt test resistor to test points TP15 and **TP16. This** resistor temporarily takes the place of variable resistor **R10** for test purposes.

____ 4. Mount 10 **mF** capacitor C5 on the PCB, making sure that the negative lead is inserted in the hole marked **"-"**. Solder the capacitor leads to the PCB and cut off any excess length.

____ 5. Locate the negative variable voltage regulator (U2, **LM337)**, one of **the** small heat sinks, a 3 x 8mm machine screw, a 3mm split lock washer and a 3mm hex nut.

____ 6. Bend the three leads of the LM337 regulator as shown in Fig. 73. A long nose pliers is a good tool to use for this.

____ **7.** Refer to Fig 74. Mount the LM337 regulator and heat sink on the PCB, using the hardware called out in step 5. **Graymark** recommends the use of

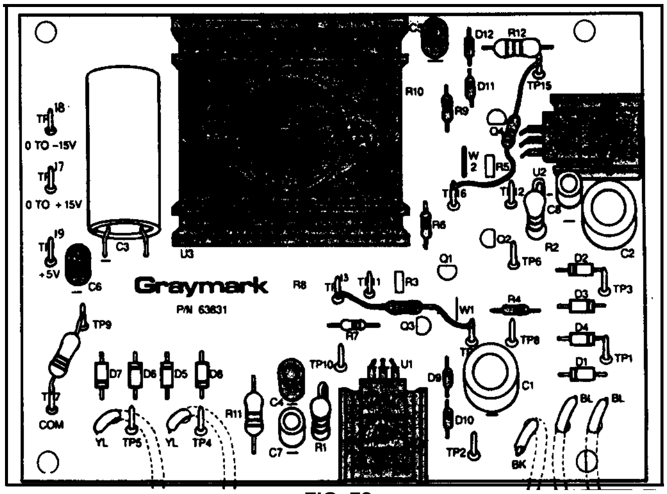


FIG. 72

heat sink compound on the surfaces of the voltage regulators and heat sinks where they contact each other.

____ **8.** Before tightening the machine screw and nut that holds the heat sink and regulator to the **PCB**, rotate the heat sink on the machine screw so that its cooling fins are oriented as shown in Fig. 72. Then tighten the machine screw and nut.

____ **9.** Solder the regulator leads to the PCB, using a small alligator clip heat sink on each lead between the plastic regulator package and the top surface of the **PCB**. Cut off any excess lead length.

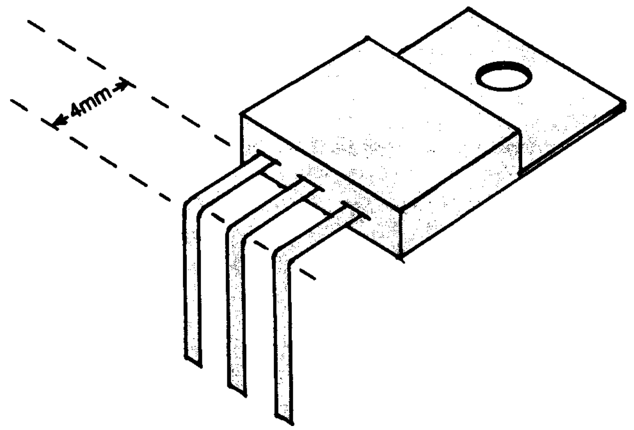


FIG. 73

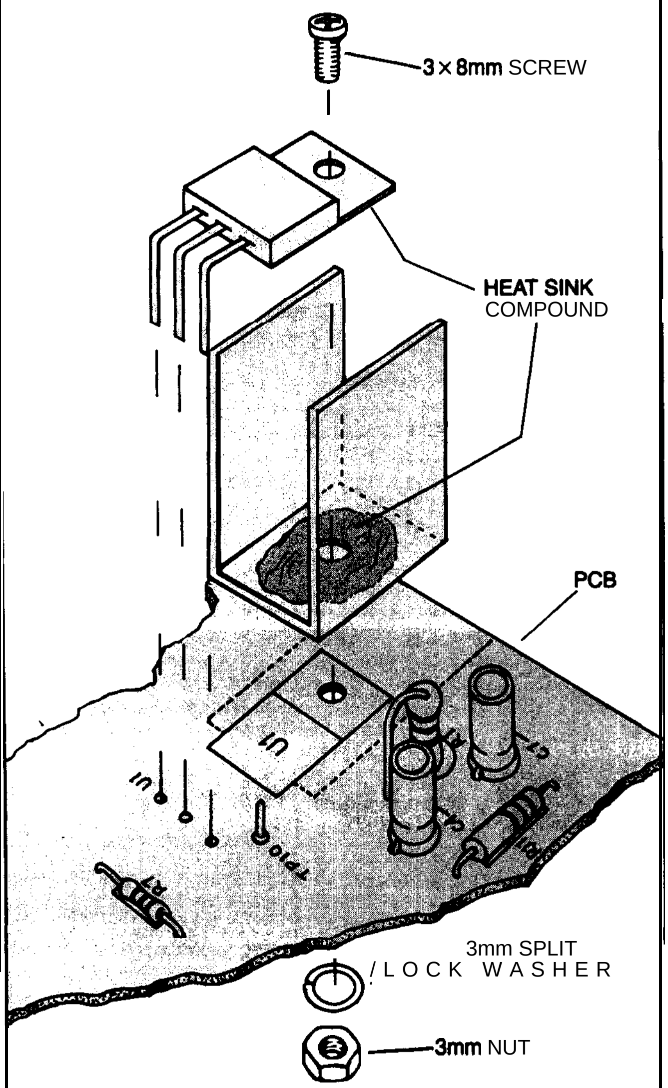


FIG. 74

-15 VOLT REGULATOR TEST

____ 1. Connect the **808** power plug to a power outlet.

____ 2. Turn the 808 power switch ON, wait **1** second and turn it **OFF. Touch** the components that were installed in the construction steps that were just completed. If any of these components are warm, there is something wrong. Check the PCB and components carefully, and consult with your instructor if necessary.

____ 3. Repeat step 2, leaving the power ON for **5** seconds this time.

____ 4. Repeat step 2 again, this time leaving the power ON for 15 seconds.

____ 5. If none of the components heated up in the previous steps, power up the **808** again. Measure the dc voltage between test points TP7 and TP18. **TP18** should be negative, and the voltage should be between 12.7 and 15.8 Volts. The reason that a range of voltages is given is that the tolerances of a number of components can affect the regulator output voltage. If the voltage is not in this range, check resistor **R7** and the 3.9 **kOhm** resistor installed temporarily between TP15 and **TP16.** Make sure they are the correct resistors for these locations. Consult with your instructor if necessary.

____ 6. Turn OFF the 808 power switch and remove the power plug from the power outlet.

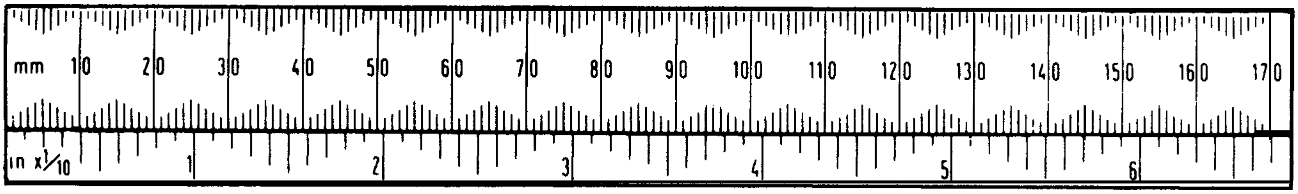
CONSTRUCTION

Refer to Fig. 72 for the following steps.

____ 1. Be sure the 808 power plug is not connected to a power outlet.

____ 2. Mount 10 **mF** capacitor C6 on the PCB, making sure that the negative lead is inserted in the hole marked **"-".** Solder the capacitor leads to the PCB and cut off any excess length.

____ 3. Locate the positive fixed voltage regulator **(U3, LM309),** the large heat sink, two 3.5 x **12mm** machine screws, two **3.5mm** split lock washers



and two 3.5mm nuts.

____ 4. Refer to Fig. 75. Mount the LM309 regulator and heat sink on the PCB, using the hardware called out in step 3. Graymark recommends the use of heat sink compound on the surfaces of the voltage regulators and heat sinks where they contact each other. Be sure that the larger machine screws (3.5mm diameter) are used to fasten the IC and heat sink to the PCB. If you use the smaller 3mm diameter screws for this purpose, it is possible for the heat sink to short to the IC leads.

____ 5. Solder the regulator leads tothe PCB. Cut off any excess lead length.

+5 VOLT REGULATOR TEST

____ 1. Connect th8 808 power plug to a power outlet.

____ 2. Turn th8 808 power switch ON, wait 1 second and turn it OFF. Touch the components that were installed in the construction steps that were just completed. If any of these components are warm, there is something wrong. Check the PCB and components carefully, and consult with your instructor if necessary.

____ 3. Repeat step 2, leaving the power ON for 5 seconds this time.

____ 4. Repeat step 2 again, this time leaving the power ON for 15 seconds.

____ 5. If none of the components heated up inthe previous steps, power up the 808 again. Measure the dc voltage between* test points TP1 9 and TP7. TP19 should be positive, and the voltage should be between 4.6 and 5.4 Volts. This range of voltages allows for the specified output voltage tolerance (4.7 to 5.3 Volts), plus approximately 2 % measurement error. If the voltage is not in this range, check your work carefully, and consult with your instructor if necessary.

____ 6. Turn OFF the 808 power switch and remove the power plug from the power outlet.

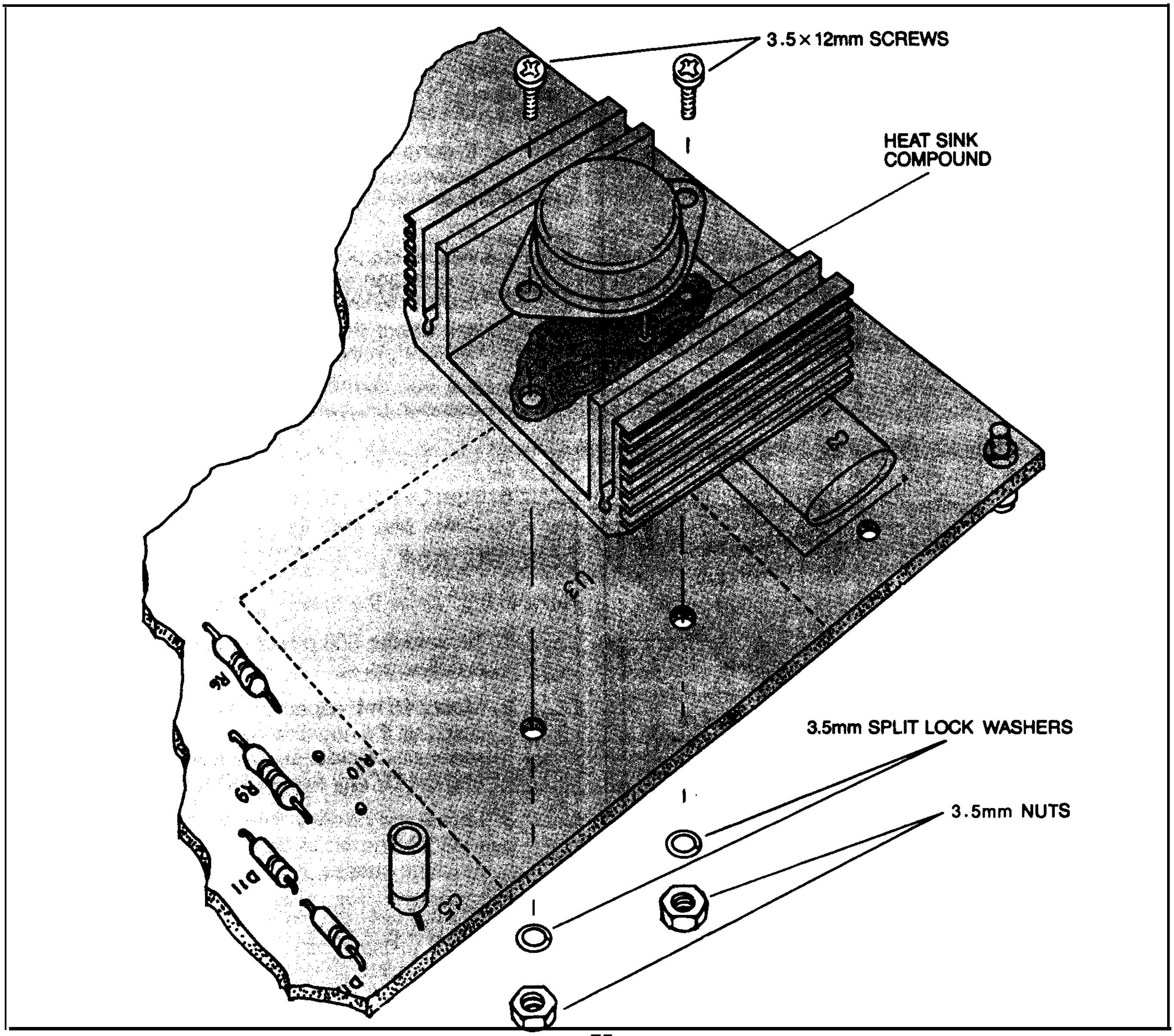


FIG. 75

VOLTAGE REGULATOR OPERATION

DISCUSSION

Figure 76 is a partial block diagram and schematic of the 808 Power Supply, showing the voltage regulators and associated circuitry.

A power supply requires regulation to maintain a constant voltage level with variations in load, AC line voltage, and environmental conditions. Voltage regulators provide the regulation which will enable the supply to maintain a constant output voltage under these changing conditions. The **Graymark** 808 is voltage regulated triple power supply.

The following are the definitions of load, and line regulation:

LOAD REGULATION: Load regulation is a supply's ability to maintain a constant voltage or current output level with changes in a resistive load.

If the value of FULL LOAD voltage is equal to the value of NO LOAD voltage, the LOAD VOLTAGE REGULATION is 0%, which is the ideal **value.This** value means the power supply is a true voltage source, where the output voltage is independent of the current drawn from the supply.

In an UNREGULATED power supply the output voltage decreases as the amount current drawn from the supply increases.This is because of the internal resistance of the power supply. When the load resistance decreases, the load current increases, causing a proportional increase in the voltage drop across the internal resistance of the power supply. This results in a decrease in the voltage at the power supply output. Refer to Fig. 78.

LINE **REGULATION:** Line regulation is a supply's ability to maintain a constant voltage or current output level with changes in the input AC line voltage.

Figure 77 shows four voltage graphs plotted with a common X axis, representing the passage of time.The top graph is of AC line voltage. It appears that some other large loads on this line are being switched on and off, resulting in variations of the AC line voltage.

Two power supplies are connected to this power line. One is unregulated, the other is a regulated power supply. Both of these power supplies have nominal output ratings of **15** Volts DC at 300 **mA.** Both power supplies are driving identical loads. These loads periodically change between no load (infinite resistance), **1/2** load (100 Ohms resistance)

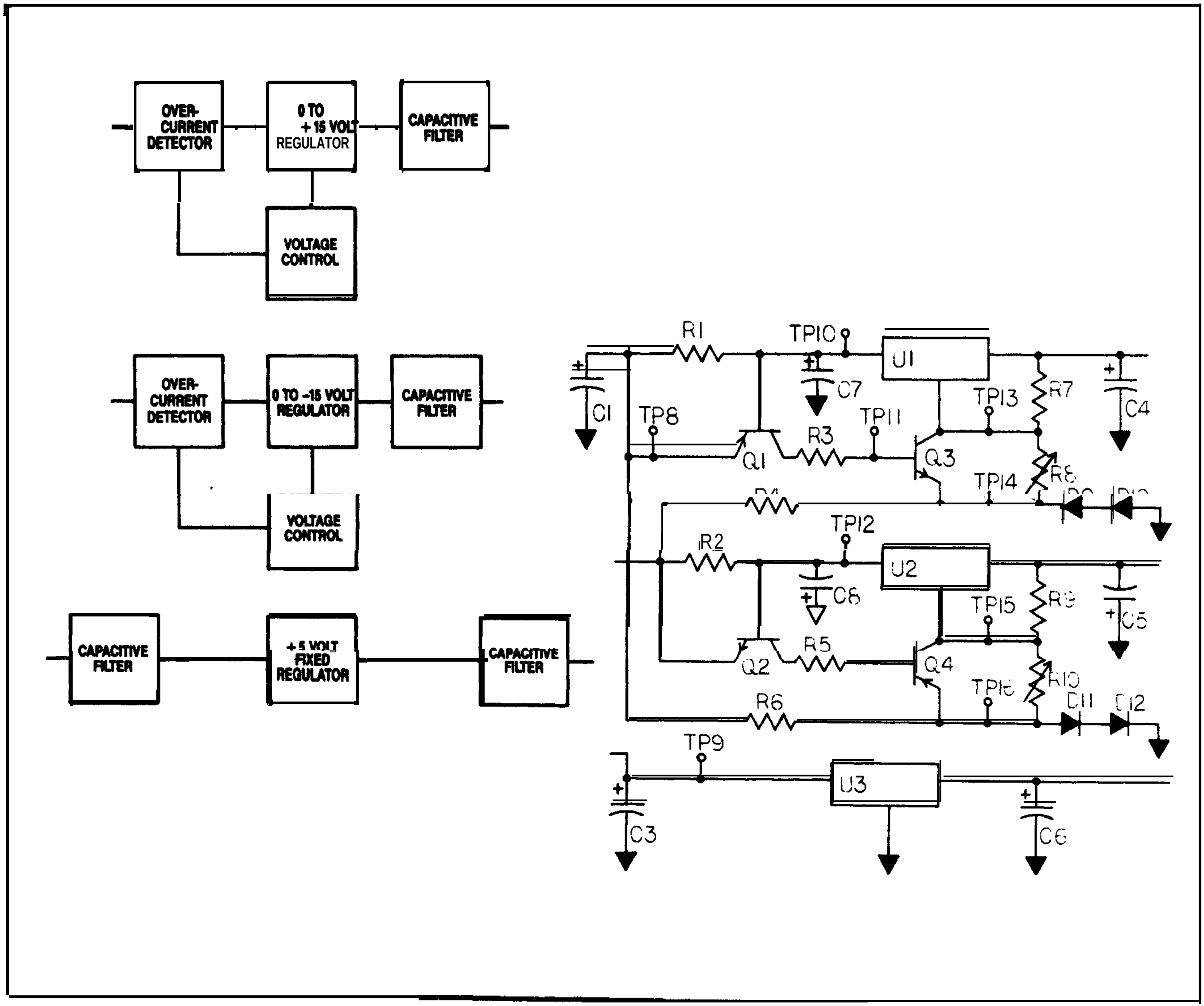


FIG. 76

and full load (50 Ohms resistance). The changing condition of these loads is shown by the second graph.

Figure 78 is the equivalent circuits of the unregulated and the regulated power supplies. The boxes labeled INPUT, POWER CONDITIONING represent the input circuitry, power transformer, rectifiers and input filters. The resistors labeled R_{int} represent all the losses and resistances in the components mentioned above.

In the equivalent circuit of the regulated power supply, the variable resistor labeled R_{dtr} represents the Darlington transistor in the voltage regulator that controls the current that flows through the regulator to the load resistors. The load resistors are shown with push-button switches, ganged together between the two loads. With this setup, the load conditions shown in the second graph could be duplicated by manipulating the switches.

How voltage regulators actually work will be discussed in more detail a little later. Right now we just want to see the differences in the output voltages of unregulated and regulated power supplies with varying line input voltages and loads.

The third graph from the top shows the output voltage of the unregulated power supply. What is the worst case voltage variation in Volts? ______________

Under what conditions is the output voltage the highest?

________________ Input line. ________________ Load.

Under what conditions is the output voltage the lowest?

________________ Input line. ________________ Load.

To calculate the % load voltage regulation, use the following formula:

$$\%\ \text{load voltage regulation} = \frac{V_{out}\,(\text{no load}) - V_{out}\,(\text{full load})}{V_{out}\,(\text{full load})} \times 100$$

At the nominal line input voltage of 115 Volts.

V_{out} (no load) occurs at the point on the Unregulated Power Supply Output graph that is marked with the letter A.

V_{out} (full load) occurs at the point marked with the letter B.

Calculate the % load voltage regulation for this power supply and write your answer in the space provided.

______________ %

The bottom graph in Fig. 77, shows the regulated power supply output voltage. The little "glitches' appearing on this graph indicate that the voltage regulator cannot instantly compensate for input voltage and load changes. More about that later.

Most real life regulators won't provide the zero percent regulation shown on the graph, but the voltage regulators in your Graymark 808 Power Supply will provide considerably better than 1% combined line and load regulation.

Figure 79 shows the schematic diagram of the LM317 voltage regulator. Transistors, resistors, Zener diodes and capacitors are formed in a small piece of silicon, often called a "chip". To help understand how a voltage regulator functions, we will be using a functional schematic, which is shown in Fig. 80.

The operation of all three of the IC voltage regulators used in the Graymark 808 Power Supply is based on the same general principles. The following discussion applies to the

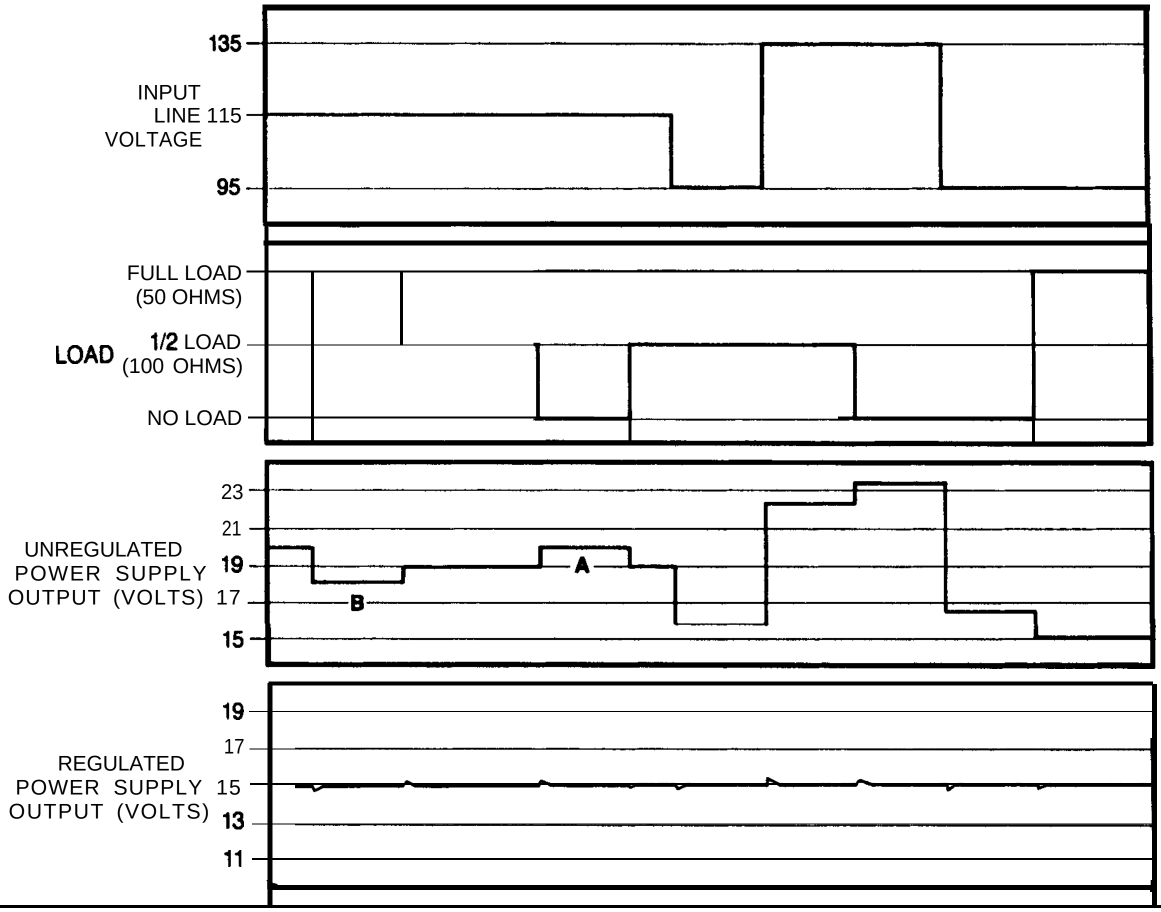


FIG. 77

LM309, the **LM317** and the LM337. The LM337 is a negative **regulator,that** is, its input and output voltages are negative in respect to ground. This results in different polarities inside the **IC**, but it operates according to the same principles as the **LM309** and **LM317**.

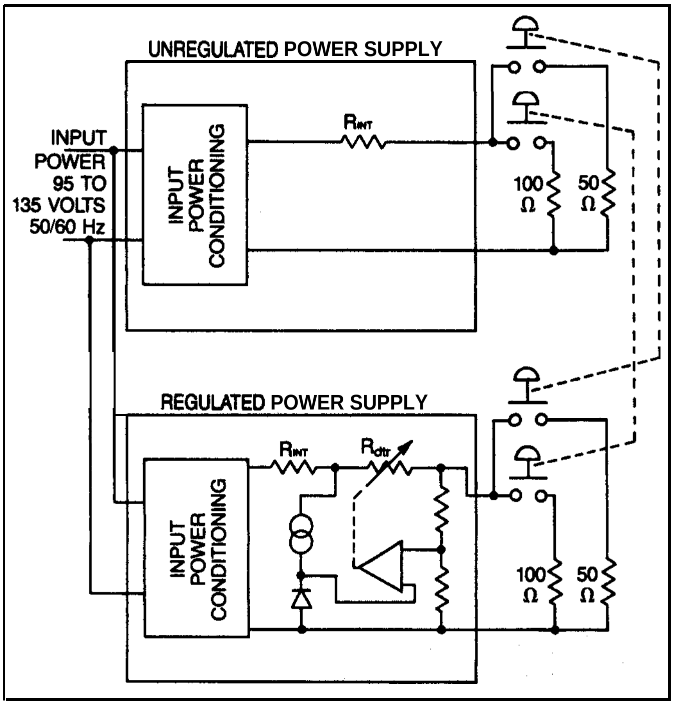


FIG. 78

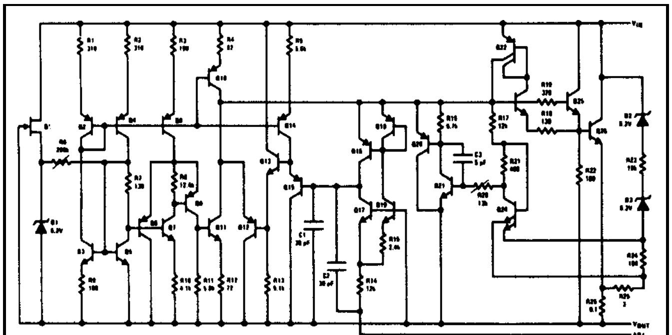


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FIG. 79

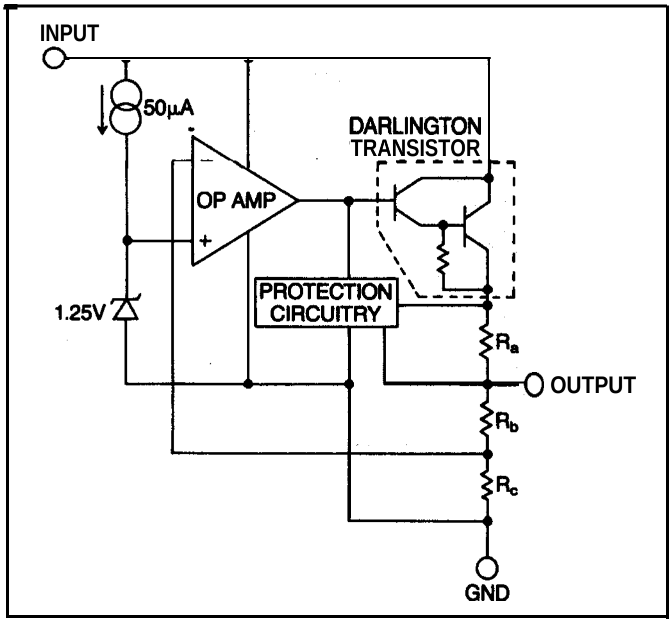

FIG. 80

The two overlapping circles and the arrow in the upper left hand corner of the schematic form the symbol for a current source. A current source will pass a constant current, in this case **50 uA**, despite variations of the voltage appearing across its terminals. This current source provides a constant current for the **1.25** Volt Zener diode that supplies the reference voltage for the regulator.

Resistors R_a and R_b form a voltage divider. R_b has three times the resistance in Ohms of R_a, so when the voltage at the regulator output terminal is **5** Volts, the voltage at the junction of R_a and R_b is 1.25 **Volts.The** operational amplifier (op amp) compares this portion of output voltage of the regulator to the 1.25 Volt reference voltage. As long as the two input terminals of the op amp are at the same voltage, there is very little current flowing either into or out of the op amp output terminal.

The adjustable voltage regulators are a little different. R_a and R_b are external to the **regulators.This** will be discussed later in the EXTERNAL CONTROL AND PROTECTION CIRCUITRY section.

If we increase the voltage regulator load by connecting a resistor between the regulator output and ground, the additional current flowing through the regulator will cause the output voltage to drop below 5 **Volts.The** voltage at the op amp input terminal marked with the minus sign drops as well. The op amp responds to this input change by moving its output in a positive direction, causing an increase in the base current of the Darlington transistor shown at the right side of Fig. **80**.

The Darlington transistor is named after the person who invented this particular way of connecting two transistors and a resistor together to form the equivalent of one transistor. A Darlington transistor requires very little base input current to control the collector output current, and can respond to rapid changes of the base current.

A transistor can be thought of as a valve that controls the flow of electrons, that is, the current in a circuit. The "valve handle" of the transistor is its base. The amount of current flowing through the transistor from emitter to collector is controlled by a much smaller current flowing from the emitter to the base.

Another way of looking at a transistor is to consider it as a variable resistor, where an increase in the base current causes a decrease in the resistance.

At this point, the output of the voltage regulator is below **5** Volts because an additional load resistor was connected between its output terminal and ground. This lowered output voltage caused the voltage at the inverting input of the op amp to become lower as **well.The** op amp responds to this input voltage change by by moving its output in a positive direction, increasing the base current of the Darlington transistor.

The resulting decrease of resistance between the Darlington transistor's emitter and collector causes an increase in the current flowing through the voltage regulator and the load resistors. In accordance with Ohm's law, (voltage = current x resistance), the output voltage of the voltage regulator heads back up to 5 Volts.

Figure 81 shows the effects of connecting a load resistor to the output of a voltage regulator. The conditions shown in the right portion of the figure occur after the load resistor is connected, but before the voltage regulator. is able to compensate for this change in load resistance.

It takes much longer to describe the operation of a voltage regulator than it takes for the regulator to operate. There is some time delay from the instant that a load change or input voltage change takes place and causes the output voltage to change until the voltage regulator is able to compensate and restore the correct output voltage. This time delay occurs mostly in the op amp and Darlington transistor circuitry. Figure 82 is from the LM309 specification sheets, and illustrates the time required for the LM309 regulator to respond to a load change. Notice that it is a very short time, about 1 micro second.

The output filter capacitor for the fixed supply, C6, reduces the amplitude of these voltage spikes. C6 has a capacitance of 10 mF. It does not need to have a large capacitance like C3, the input filter capacitor, because of the short periods of time it must provide or absorb electrical energy to keep the output voltage constant. Look again at Fig. 63. The time that the input filter capacitor must provide electrical energy is about 6 milliseconds, which is 6000 times as long as 1 microsecond.

The circuitry symbolized by the rectangle labeled PROTECTION CIRCUITRY can divert the op amp output current away from the base of the Darlington transistor. Normally, when the op amp output moves in the positive direction, we want to increase the current flowing through the voltage regulator and load resistor. But when this current reaches the maximum value the regulator can safely handle, we don't want it to increase any more.

The voltage across resistor R_c is directly proportional to the current flowing through it. (Ohm's law again, voltage = current x resistance. As the output current of the regulator increases, the voltage across R_c increases as well. When this voltage reaches a level that indicates the maximum safe current is flowing, the protection circuitry begins to divert current away from the Darlington transistor base.

OVERCURRENT PROTECTION EXPERIENCE

Purpose: To observe the operation of the internal overcurrent limiting function of a voltage regulator.

Equipment: **DVM** or **DMM**
Clip Lead

1. Be sure that the 808 power plug is NOT connected to a power outlet. Refer to Fig. 83 for the following steps.

___ 2. Remove the 1.5 **kOhm** test resistor which is soldered toTP7 and **TP9.**

___ 3. Connect the positive meter lead toTP8 and the negative meter lead **toTP10. The** meter will read the voltage across the current sensing resistor **R1.** Set the meter range selector to read a DC voltage of 2.5 Volts.

4. Connect the 808 power plug to a power outlet.

___ **5.** Turn the 808 power switch ON. While observing the meter, connect the clip lead from TP7 to TP17. This is a short circuit across the positive variable regulator, **LM317.** This represents a heavy overload for the power transformer and current sensing resistor **R1** . Read the meter and quickly remove the clip lead. Write down the meter reading here. ________________ Volts

___ 6. Using Ohm's law, calculate how much current is flowing through the regulator. ____________________ Amps. Notice that when using a 1 Ohm current sensing resistor, The voltage across the resistor in Volts is the same as the current flowing through the resistor in Amps. The same correspondence occurs when voltage is in millivolts, the current is then in milliamps. How does the current you measured compare to the value given on the National Semiconductor Electrical Characteristics specification sheet for the **LM317?**

___ 7. Turn OFF the 808 power switch and remove the power plug from the power outlet. Disconnect the clip lead and the meter test leads.

Just how hot a voltage regulator becomes when it is operating depends on a number of variables. The input

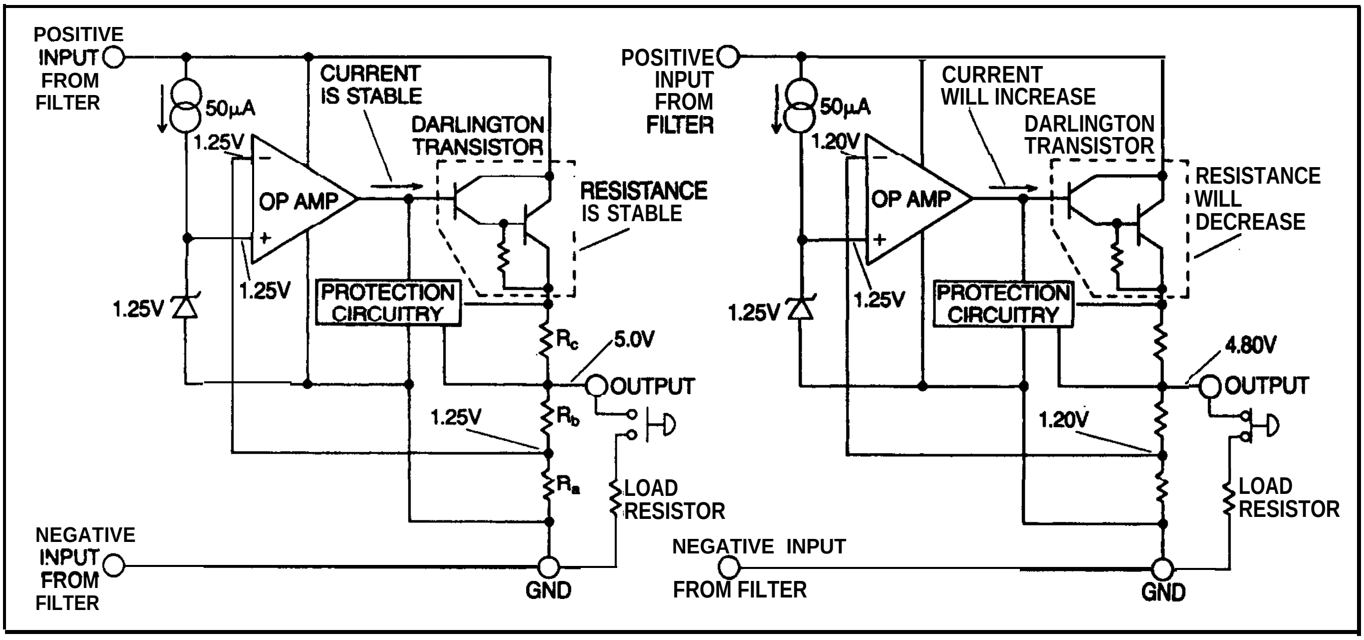

FIG. 81

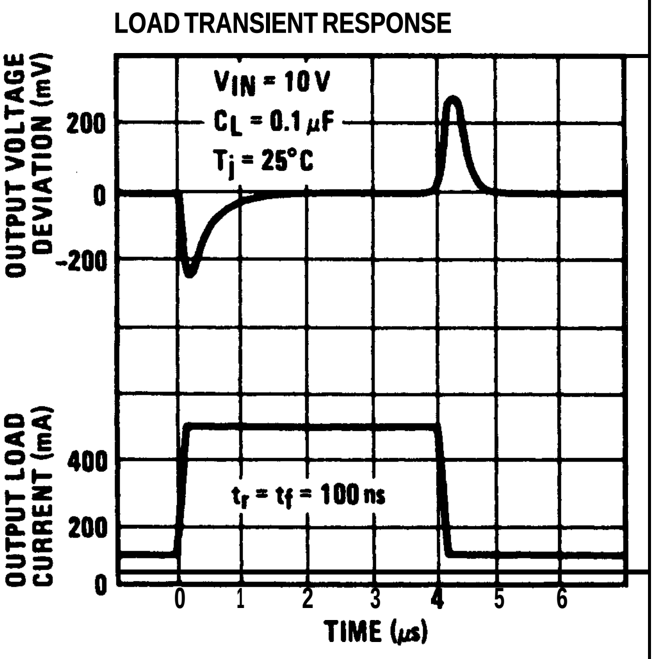

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FIG. 82

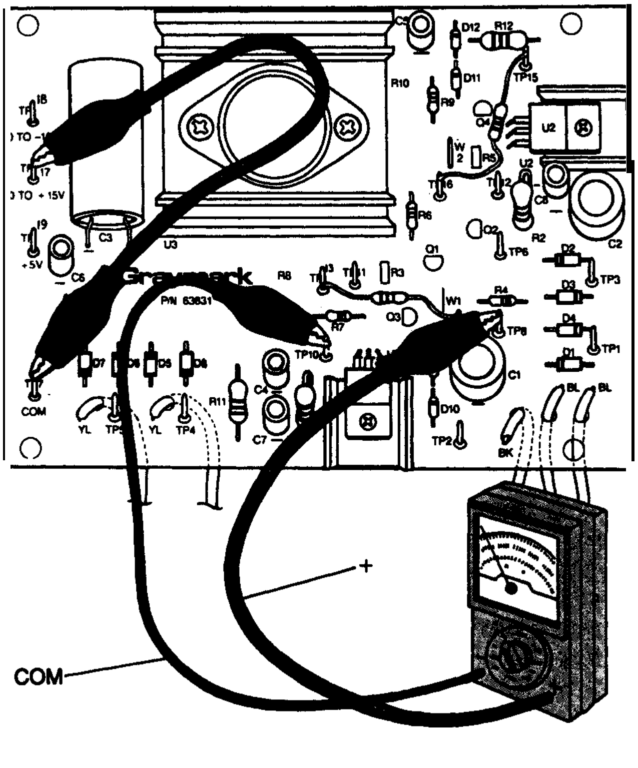


FIG. 83

voltage, along with the output current and voltage, affect the amount of power that theregulator has to dissipate.The size of the heat sink and the amount air flow around it affects how much the temperature of the regulator must rise to dissipate this power.

If a voltage regulator gets too hot, it will be damaged, even though the current flowing through it is within safe limits.

The protection circuitry on the voltage regulator chip includes a temperature sensor. When the chip temperature reaches its maximum safe limit, the protection circuitry begins to divert some of the op amp output current from the Darlington transistor base, just as it did when the regulator output current reached its maximum safe value, as we discussed earlier.

OVER TEMPERATURE PROTECTION

DISCUSSION

To force the **LM317** voltage regulator into its over temperature protection mode without risking damage to other power supply components, the regulator will be operated without a heat sink attached while supplying approximately the maximum rated current of the power supply. The 50 Ohm 5 Watt test resistor that will be used for a load draws between 254 and 316 **mA** with the regulator output voltage between 12.7 and **15.8** Volts. The 3.9 **kOhm** test resistor that was installed in place of variable resistor **R8** sets the regulator output within this range. If you wish to, refer back to step 5 of the **+15** VOLT **REGULATOR** TEST

TEMPERATURE PROTECTION EXPERIENCE

Purpose: To observe a voltage regulator and its output when if is in the over temperature protection mode.

Equipment: Oscilloscope
VOM or **DMM**
50 Ohm 5 Watt Test Resistor
Drinking Straw

___ 1. Be sure that the 808 power plug is NOT connected to a power outlet.

Refer to Fig. 84 for the following steps.

___ 2. Temporarily remove the mounting hardware and heat sink for the **LM317** regulator from the **PCB**.

___ 3. Solder the 50 Ohm test resistor leads toTP7 and TPI7.

___ 4. Connect the ground lead of the scope and the negative lead of the DVM or the **DMM** to the test resistor lead going to TP7. Connect the scope probe and the positive lead of the meter to the test resistor lead going **toTP17.** Adjust the meter and scope to read and display a 15 Volt DC signal.

___ 5. Connect the **808** power plug to a power outlet.

___ 6. Turn the 808 power switch ON. Watch the meter and scope display. Depending on the ambient temperature and the power line voltage, it may take a minute or more for the voltage regulator to reach the temperature at which the over

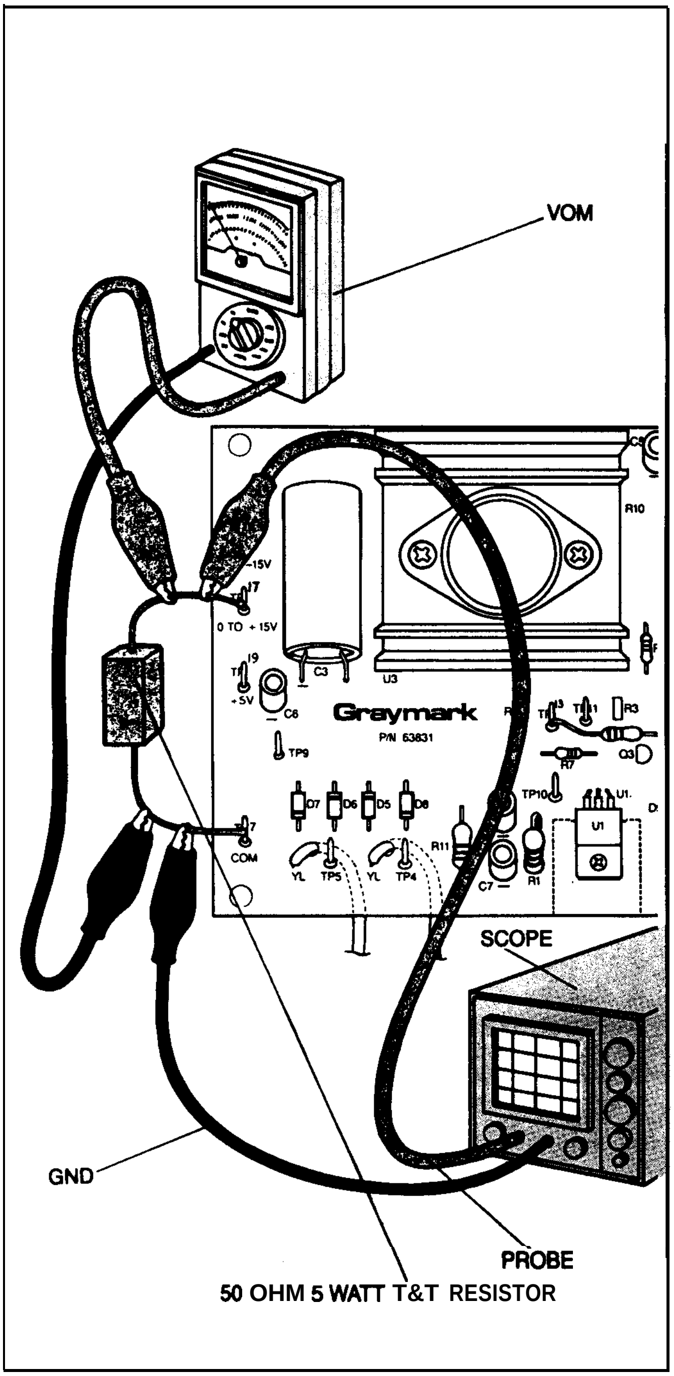


FIG. 84

temperature protection circuitry begins to operate. When the over temperature circuit is activated, the voltage across the test resistor will begin to drop. Wait approximately 1/2 minute longer. What is the meter reading? _____ Volts

____ 7. While watching the meter and scope display, use the drinking straw to blow on the **LM317** regulator. What happens?

____ 8. Turn OFF the 808 power switch and remove the power plug from the power outlet. Disconnect the test equipment and unsolder the test resistor. Replace the heat sink and mounting hardware that was removed in step 2.

This completes the TEMPERATURE PROTECTION EXPERIENCE. Have your instructor initial your progress chart.

EXTERNAL CONTROL AND PROTECTION CIRCUITRY SECTION

VOLTAGE CONTROL

DISCUSSION

Figure 85 is a partial block diagram and schematic of the **Graymark** 808 Power Supply, with the external voltage control circuitry highlighted.

Figure 86 is a functional diagram of the positive adjustable regulator and its external voltage control circuitry. The negative adjustable regulator is similar, but with reversed voltage polarities. Comparing this schematic with the functional schematic of the fixed voltage regulator shown in Fig. 80, we see that resistors **Ra** and **Rb** are now outside the regulator, and that the ground terminal has become the adjustment terminal.

Because the adjustment **terminal** Is the control Input of the voltage regulator, the current necessary to operate the op amp and protection circuitry inside the regulator must flow from the input **terminal,through** the regulator circuitry and through the output **terminal. This** is why there needs to be some output current flowing whenever the regulator is operating. The bleeder resistor and the voltage control resistors, **Ra** and Rb, provide the load needed to cause this current flow.

ADJUSTMENT VOLTAGE EXPERIENCE

The voltage that is applied to the adjustment terminal of a voltage regulator determines the output voltage of that regulator. The op amp inside the regulator adjusts the resistance of the Darlington transistor so that the voltage at the op amp's inverting input (marked with a minus **(-)** sign) is the same as the voltage at its non-inverting input (marked with a plus **(+)** sign).

Purpose: To demonstrate how an adjustable voltage regulator's output responds to different voltages at the adjustment terminal.

Equipment: **VOM** or **DMM**
Clip Lead

____ **1.** Be sure the 808 power plug is not connected to a power outlet.

Refer to Fig. 87 for the following steps.

____ 2. Connect the negative meter lead **to TP** 7 and the positive meter lead **to TP** 17. Set the meter to a range that will read up to 20 Volts DC.

____ 3. Connect the 808 power plug to an outlet and turn the power switch ON. Write the voltmeter reading down in Fig. 88 in the "Output Voltage" column and the Clip Lead Connections "None" row (in the box marked **#** 1). Move the negative meter lead **to TP** 13 and write the voltmeter reading in the "Output to Adjustment Voltage Difference" column and the Clip Lead Connections "None" row (box **#** 2). Set the meter range selector to a lower range if necessary for an accurate reading.

____ 4. Connect the clip lead **to TP** 13 and TP 2. Write the meter reading down in box **#** 3. Move the negative meter lead back to TP 7 and write the meter reading down in box **#** 4.

____ **5.** Disconnect the negative meter lead from TP 7

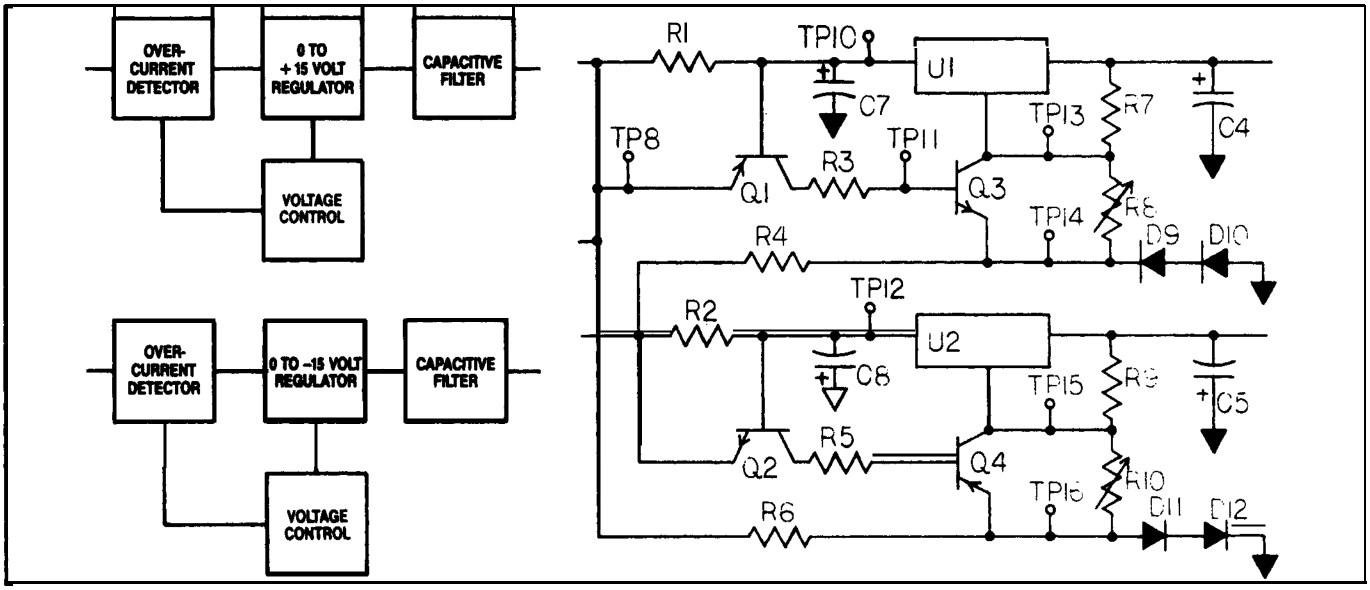


FIG. 85

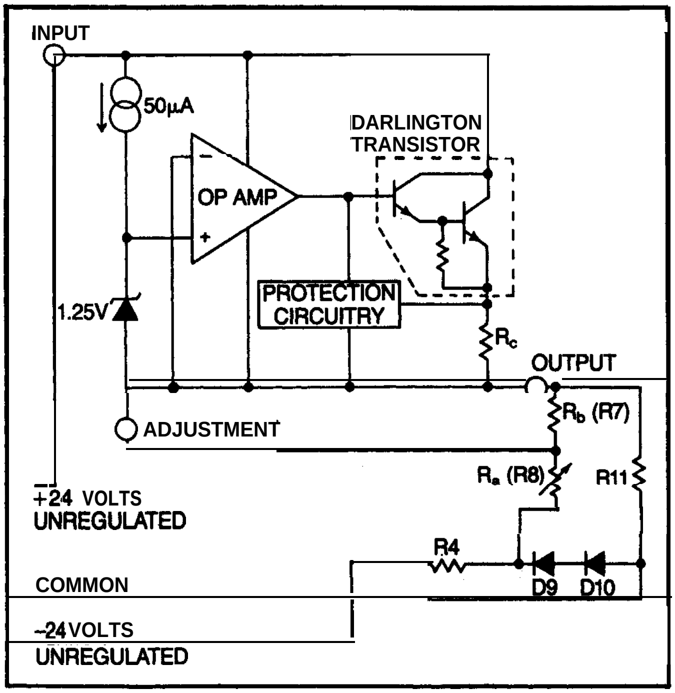


FIG. 86

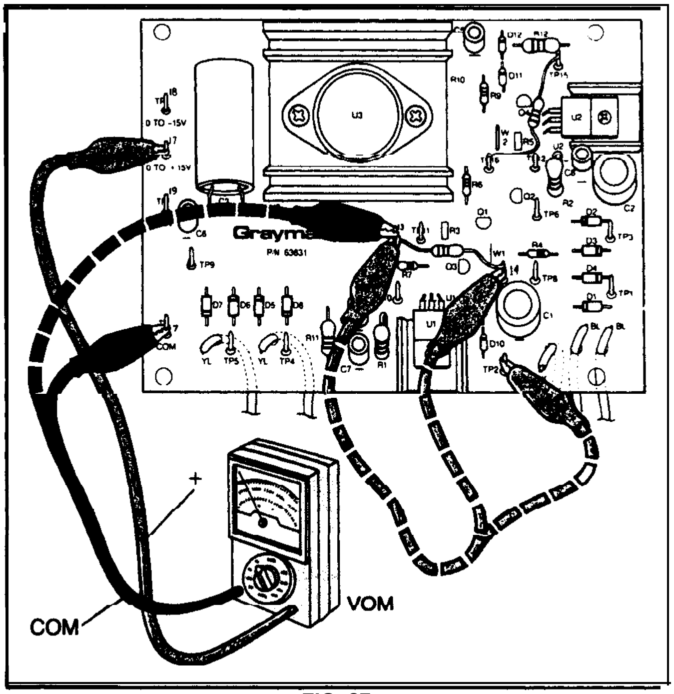


FIG. 87

while you change one end of the clip lead from TP 2 to TP 14. Reconnect the negative meter lead to TP 7 and write the meter reading in box **# 5.** Move the the negative meter lead from TP 7 to TP 13 and write down the meter reading in box # 6.

Notice that while the output voltage changed when the adjustment terminal of the voltage regulator was connected to different voltages, the output-to-adjustment voltage difference remained the same. The op amp was controlling the Darlington transistor resistance so that the op amp's input terminals remained at the same voltage- The **1.25** Volts across the output and adjustment terminals of the regulator is actually the voltage of the voltage reference inside the regulator.

Later, when you connect potentiometers **R8** and **R10** to the PCB, they will control the adjustable regulator output voltages.

When the adjustment terminal is connected to ground, the regulator output voltage is **1.25** Volts. To be able to adjust the output voltage to 0 Volts, two diodes connected in series are forward biased by the unregulated negative supply, through **R4.** The exact voltage drop across the diodes will vary with the current flowing through them and their temperature, but it is approximately 1.4 Volts, or 0.7 Volts for each diode. This results in the variables supplies being adjustable to and a little beyond zero Volts. With the voltage controls turned all the way down, the

CLIP LEAD CONNECTIONS	OUTPUT VOLTAGE	OUTPUT-TO-ADJUSTMENT VOLTAGE DIFFERENCE
NONE	#1	#2
TP13 TO TP7	#4	#3
TP13 TO TP14	#5	#6

FIG. 88

positive variable supply will have an output of about - 0.2 Volts, and the negative supply an output of about + 0.2 Volts.

This can be useful in some test situations, where it is is helpful if a voltage can be adjusted to zero and a little beyond. If the utmost in stability is required from the adjustable supplies, then the diode pairs D9-10 and D1 l-l 2 could be jumpered. This would make the lowest voltage setting obtainable 1.25 Volts, but the output voltages would be more stable with changes in power line voltage, load, and ambient temperature.

____ 6. Turn OFF the 808 power switch, and remove its power plug from the outlet. This completes the ADJUSTMENT VOLTAGE EXPERIENCE. Have your instructor initial your Progress Guide.

PROTECTION CIRCUITRY

DISCUSSION

Figure 89 is a partial block diagram and schematic of the 808, with the external protection circuitry highlighted.

The overcurrent and over temperature protection circuitry built into the voltage regulators that are used in Your Graymark 808 do a good job of protecting the regulators themselves, but under some conditions over current damage could occur to other power supply components. With this in mind, circuitry has been designed into the 808 to give additional protection.

We have already talked about current sensing resistors R1 and R2 and used them to determine the current flowing through the voltage regulators in tests that were done earlier. Transistors Q1 and Q2 monitor the voltage drop that occurs across these resistors.

The collector current of a transistor depends on the voltage applied from collector to emitter, and the current flowing between the emitter and base. The emitter to base current depends primarily on the voltage applied between the transistors base and emitter, and secondarily on the temperature of the transistor.

At normal operating temperatures, base current starts to flow when the voltage of the base in respect to the emitter is about + 0.50 Volts for an NPN transistor, and about - 0.50 Volts for a PNP transistor. With the transistor base and emitter leads connected across a 1 Ohm resistors, base current begins to flow when the current through the resistors reaches about 500 mA.

As the base current of a transistor increases, the collector current will increase as well. A given change in the base current of a transistor results a larger change in the collector current. We could say that as base current increases in a transistor, resistance between the emitter and collector of that transistor decreases. In the positive adjustable power supply of the 808, the collector current of Q1 flows through R3 and increases the base to emitter voltage of Q3. This results in a drop in the emitter to collector resistance of Q3. Since Q3 is connected in parallel with R8, the result is the same as if the resistance of R8 was reduced, and the output voltage of the LM317 voltage regulator is reduced as well.

The voltage regulators can become unstable and cause rapid changes or oscillations in the output voltage if there is too much resistance or reactance between the filter capacitor, in this case C1, and the regulator input terminal. C7 is provided to prevent this oscillation.

All the polarities are reversed in the over current protection circuit for the negative adjustable power supply, but this circuit operates in the same-manner as the one described above.

CONSTRUCTION

____ 1. Be sure that the 808 power plug is not connected to a power outlet. Refer to Fig. 90 for the following steps.

____ 2. Mount resistor R3 and R5 on the PCB. These resistors are both 6.8 kOhm, (blue-gray-red), .25 Watt. Solder the resistor leads to the PCB and cut off any excess length. Save one of these

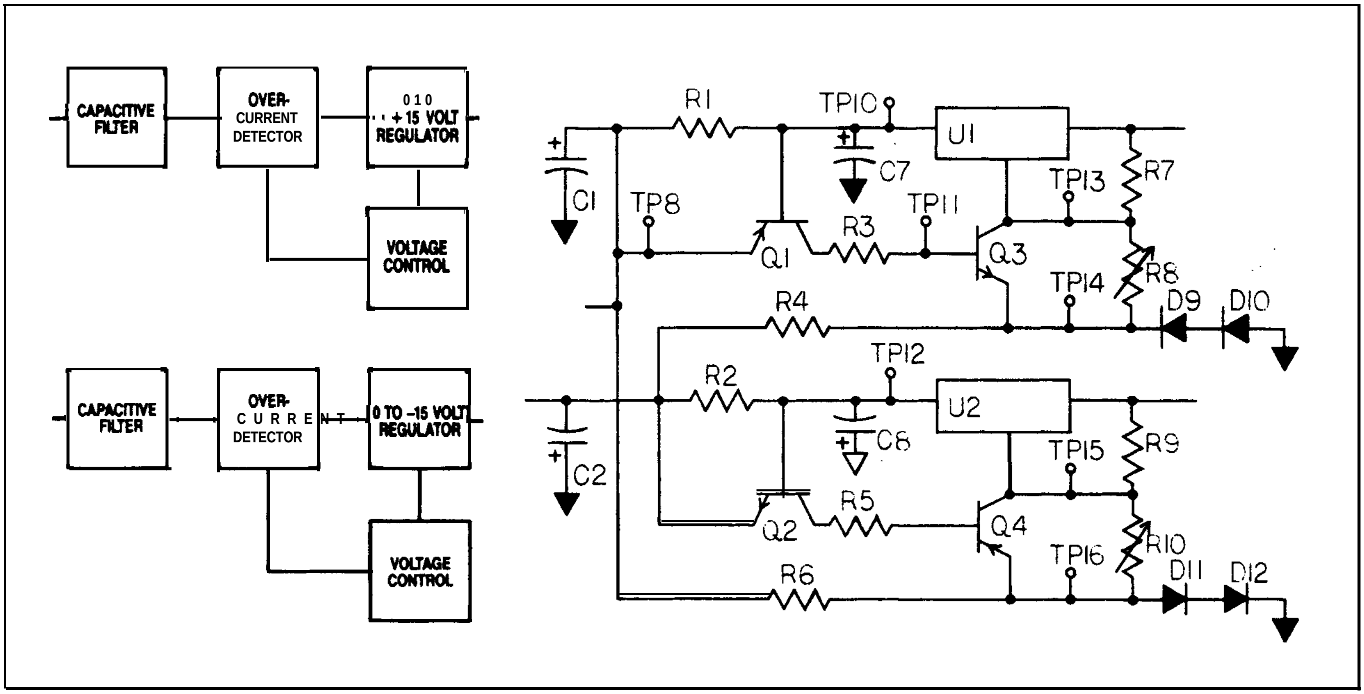


FIG. 89

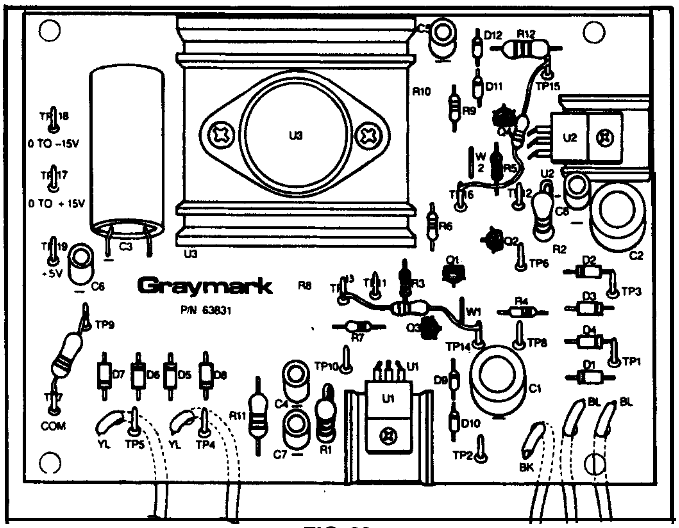


FIG. 90

pieces of wire for the next step.

____ **3.** Bend the piece of wire saved from the previous step into a U shape and use it for jumper wire **W1**. Insert this wire from the component side of the **PCB.** Solder it to the PCB and cut off any excess length.

____ **4.** Locate the two transistors that are marked 9015. There may be other numbers or letter as well, such as **C9015A** QC, but the numbers 9015 will appear within the sequence of **characters. These** are the PNP transistors and are used for **Q1** and **Q4.** Spread the leads to form a triangle, and mount these transistors on the **PCB,** making sure that they are oriented the same as the D shaped transistor outlines that are silk screened on the PCB. Solder the leads to the PCB, using a heat sink as shown in Fig. 40 on each lead as you solder it.

____ **5.** Repeat Step 4, using the transistors marked 9014. These are the NPN transistors and are used for **Q2** and **Q3.**

____ **6.** This completes the construction of the external protection circuitry. Have your instructor initial your progress guide.

OVERCURRENT PROTECTION CIRCUITRY TEST

____ 1. Connect the 808 power plug to a power outlet.

____ 2. Turn the 808 power switch ON, wait 1 second and turn it OFF touch the components that were installed in the construction steps just completed. If any of these components are warm, there is something wrong. Check the PCB and components carefully, and consult with your instructor if necessary.

____ 3. Repeat step 2, leaving the power ON for 5 seconds this time.

____ 4. Repeat step 2 again, leaving the power ON for 15 seconds this time.

____ 5. If none of the components heated up in the previous steps, power up the 808 again. Measure the DC voltage between test points TP7 and TP17. TP17 should be positive, and the voltage should be between 12.7 and 15.8 Volts. Then measure the DC voltage between TP7 and **TP18.** TP18 should be negative and the voltage should again be between 12.7 and 15.8 Volts. If these voltages are not within these ranges, check transistors **Q1** through **Q4** for proper location and orientation. Consult with your instructor if necessary.

OVERCURRENT PROTECTION EXPERIENCE

Purpose: To demonstrate the operation of the external overcurrent protection circuitry used in the Graymark 808 Power Supply

Equipment: **VOM** or **DMM**
Clip Lead

____ 1. Be sure that the 808 power plug is not connected to a power outlet. Refer to Fig. 91 for the following steps.

____ 2. Connect the positive meter lead **to TP** 8 and the negative meter lead to TP 10. Set the meter range selector switch to a range that will read **up** to 1 Volt DC.

____ 3. Connect the 808 power plug to an electrical outlet and turn the power switch ON. What is the meter reading? ________ The meter **is** reading the voltage drop across **R1,** the 1 Ohm current sensing resistor. What is the current flowing through the resistor? Use the short cut way of calculating the current value that was discussed earlier in this manual.

____ 4. Connect the clip lead to TP7 and TP17. This provides a very low resistance load for the positive variable power supply, and will activate its external overcurrent protection **circuitry**. How much current is flowing now? ________ It should be about 500 **mA.**

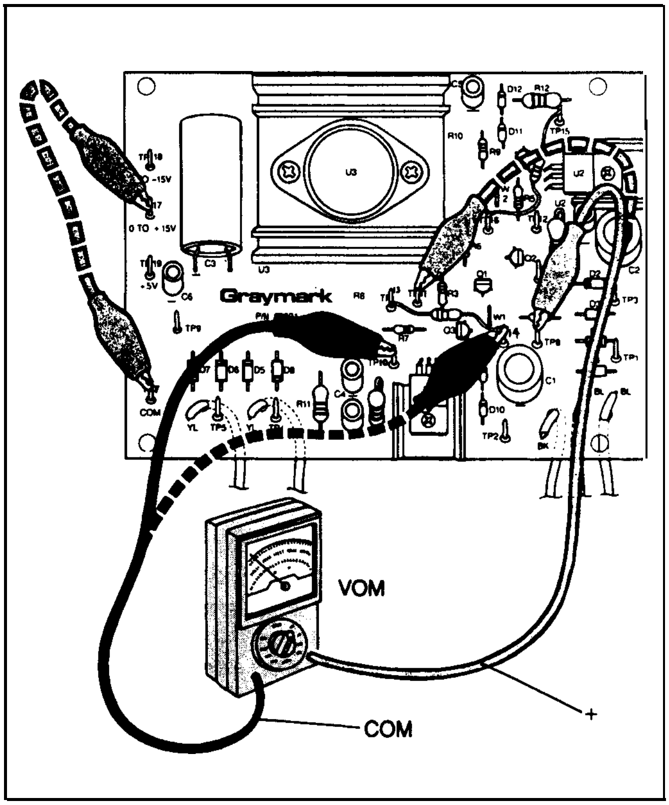


FIG. 91

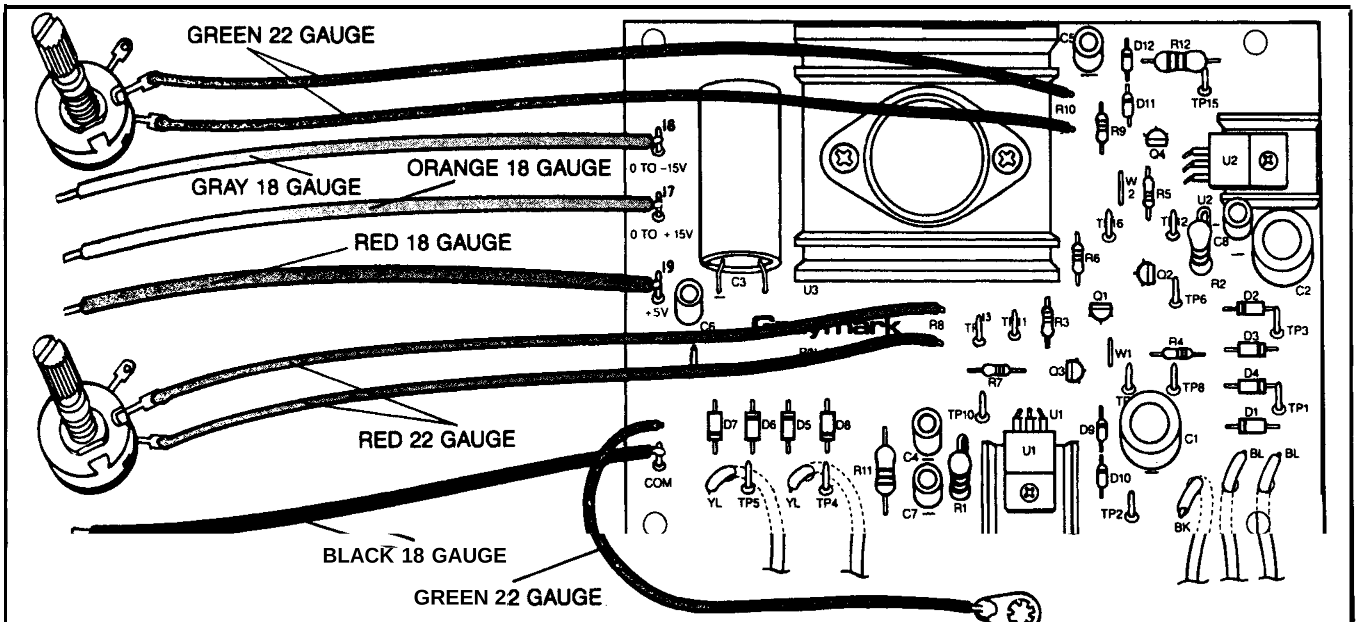


FIG. 92

____ 5. Disconnect both meter leads and reconnect the positive meter lead to TP 11 and the negative lead to TP 14. The meter will now read the voltage between the emitter and base of Q3. What is the meter reading now? ____________________
(The clip lead should still be connected to TP 7 and TP 17.)

____ 6. Remove the clip lead from TP7 and TP 17. What is the voltage across the base / emitter junction of Q3 now? ____________________
In step 5 the voltage across the base / emitter junction was more than 0.5 Volts, and current was flowing from the collector to the emitter. In this step the voltage from the base to the emitter of Q3 was very low, so there was almost no current flowing from the collector to the emitter.

____ 7. Turn OFF the 808 power switch and disconnect the power plug from the power outlet. Remove the test clip and meter leads. Remove the two 3.9 kOhm test resistors from TP13, TP14, TP15 and TP16.

CONSTRUCTION

____ 1. Be sure that the 808 power plug is not connected to a power outlet. Refer to Fig. 92 for the following steps.

____ 2. Cut two 200mm pieces of green 22 gauge wire and strip 6mm of insulation from all four ends. Twist the exposed strands of fine wire together on each end and tin them.

____ 3. Repeat step 2, cutting and preparing two 175mm pieces of red 22 gauge wire.

____ 4. Locate the two 5 kOhm potentiometers. Bend the small metal tab on each potentiometer as shown in Fig. 93 so that it won't interfere when the potentiometer is mounted on the cabinet top.

____ 5. Connect and solder the two green wires prepared in step 2 to one of the potentiometers as shown in Fig. 93. It is important that the correct solder terminals of the variable resistors be used.

____ 6. Repeat step 5, this time using the two red wires and the second potentiometer.

____ 7. Insert the free ends of the green wires in the PCB holes that are nearest to the silk screened designation "R10". Solder the wires to the PCB and cut off any excess length. It doesn't matter which of the two wires goes into which of the two holes.

____ 8. Repeat step 7, this time using the free ends of the two red wires and the two holes on the PCB closest to the designation "R8".

VOLTAGE CONTROL OPERATIONAL TEST

Purpose: To determine that the external voltage control circuitry is working properly

____ 1. During this test be careful not to let the terminals of the potentiometers touch the PCB or any of the components. Rotate the control shafts of both potentiometers to the full counter clockwise position. Adjust the range selector of your VOM or DMM to measure up to 20 Volts DC. Connect the negative meter lead to TP7. Connect the positive meter lead to TP17.

- - 2. Power up the 808. The voltmeter should read between 0 and - 0.3 Volts. Rotate the Shaft of the potentiometer connected to the red wires to the full clockwise position. The voltmeter should now read between 15.5 and 20 Volts.

____ 3. Remove the voltmeter leads from TP17 and TP7. Reconnect the positive meter lead to TP7 and the Negative lead to TP18. The voltmeter should read between 0 and + 0.3 Volts. Rotate the shaft of the potentiometer connected to the green wires to the full clockwise position. The meter should now read between 15.5 and 20 Volts.

____ 4. Turn OFF the 808 power switch and disconnect the power plug from the power outlet.

____ 5. This completes the VOLTAGE CONTROL OPERATIONAL TEST Have your instructor initial your progress guide.

FINAL PCB ASSEMBLY

____ 1. Be sure that the 808 power plug is NOT connected to a power outlet. Refer to Fig. 92 for the following steps.

____ 2. Locate the four 150mm lengths of 18 gauge wire. strip 6mm of insulation from each end of each of the four wires. Twist the fine strands of exposed wire on each of the ends together and tin them. Form one of the tinned ends of each of the wires into a hook shape with a long nose pliers. Connect and solder these hooked wire ends to the following test points on the PCB.

____ A. The black wire to TP 7.

____ B. The red wire to TP 19.

____ C. The orange wire to TP 17.

____ D. The gray wire to TP 18.

____ 3. Cut a 1 00mm piece of green 22 gauge wire. Strip 6mm of insulation from each end. Twist the small strands of wire together, and tin both ends.

____ 4. Connect and solder the 3.5mm solder lug to one end of the green wire that you prepared in the previous step. Connect and solder the other end of this wire to the PCB. Use the unmarked hole near TP 7. Cut off any excess wire.

____ 5. This completes the FINAL PCB ASSEMBLY. Have your instructor initial your progress guide.

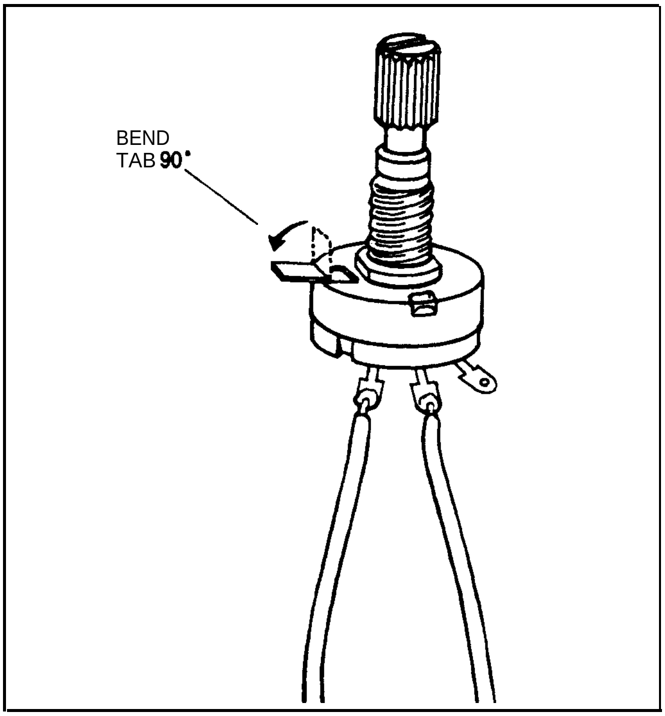


FIG. 93

CABINET ASSEMBLY

CAUTION!

Be sure that the AC Cord is NOT plugged into an electrical outlet during this Cabinet Assem bly Section.

____ 1. Mount two rubber feet to one end of the cabinet bottom, using two 3 x 8mm self-tapping screws. Refer to Fig. 94.

____ 2. Repeat the previous step for the other end of the cabinet bottom.

____ 3. Remove the protective plastic from the breadboard.

____ 4. Place the cabinet top face up on your work surface, so the printing on the cabinet top is readable.

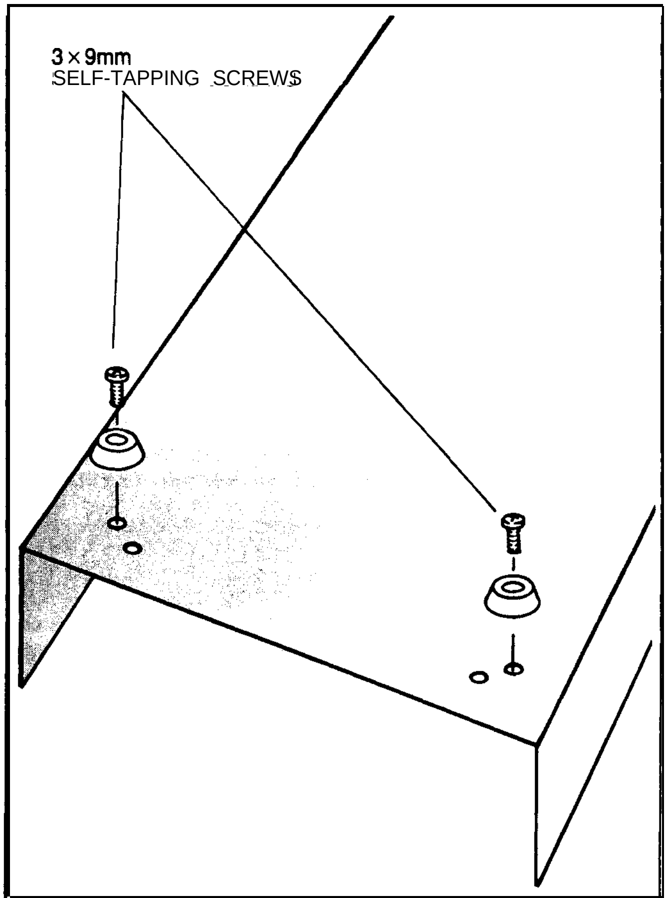
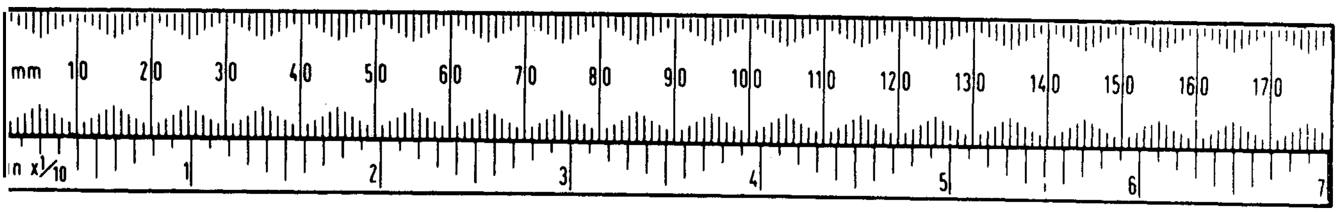


FIG. 94



____ 5. Position the breadboard on the cabinet top, so the printing on the breadboard is readable. While holding the breadboard in place, turn the cabinet top over.

Refer to Fig. 95 for the following steps.

____ 6. Attach the breadboard to the cabinet top using eight 2.6 x 5mm self-tapping screws. Do not over tighten the screws.

____ 7. Attach the breadboard bus strip to the cabinet top using two 2.6 x 5mm self-tapping screws. Do not over tighten the screws.

Refer to Fig. 96 for the following steps.'

____ 8. Position the transformer so the side with the two white wires is next to the cabinet side. Mount the transformer to the cabinet bottom using two 3 x 8mm machine screws, two 3mm flat washers, two 3mm lockwashers, and two 3mm nuts. Place the solder lug which is attached to the green wire from the PCB between the transformer and the cabinet bottom as shown in Fig. 96. This wire provides an electrical connection between Common (ground) on the PCB and the metal cabinet.

____ 9. Unscrew and remove the four screws which are holding the standoffs at each corner of the PCB.

____10. Using the screws, standoffs and nuts removed in the previous step, mount the PCB to the cabinet bottom. Place four 3mm lockwashers between the top of the PCB and the two 3mm nuts and the two long standoffs. Position the PCB so that IC U1 is next to the transformer.

____11. Connect and solder the black wire from TP7 to the solder lug on the black binding post which was installed on the cabinet top earlier, Cut off any excess wire that sticks out beyond the solder lug.

____12. Repeat Step 11, connecting the red wire from TP19 to the red + 5V binding post.

____13. Repeat Step 11, connecting the orange wire from TP17 to the red 0 to +15V binding post.

____14. Repeat Step 11, connecting the gray wire from TP18 to the red 0 to -15V binding post.

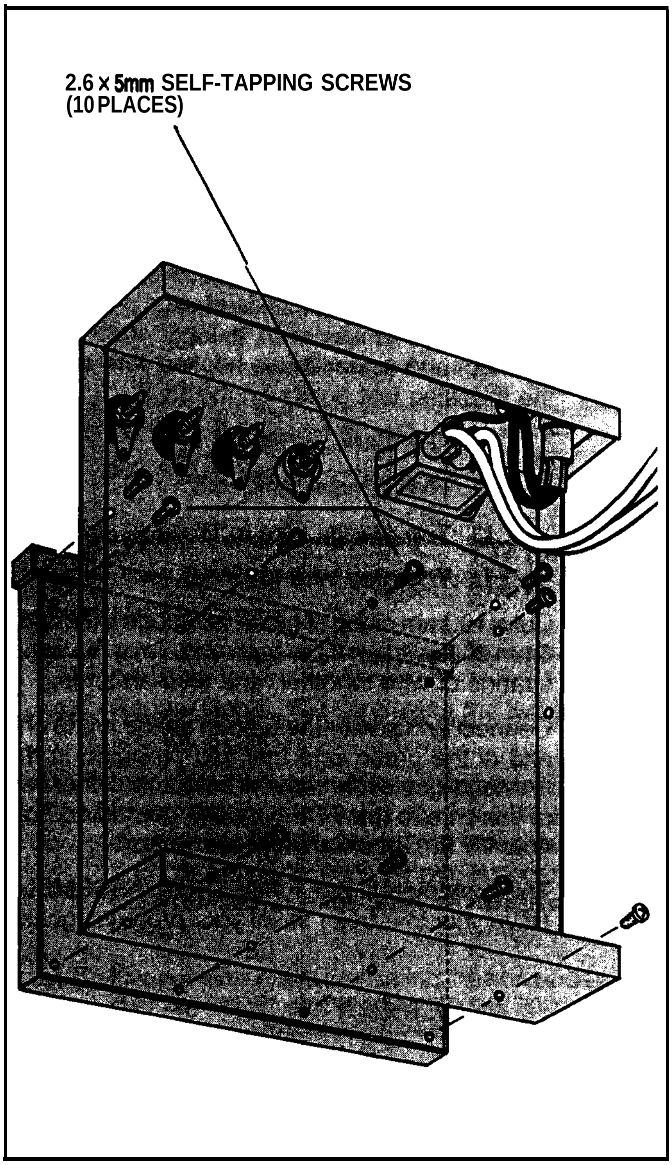
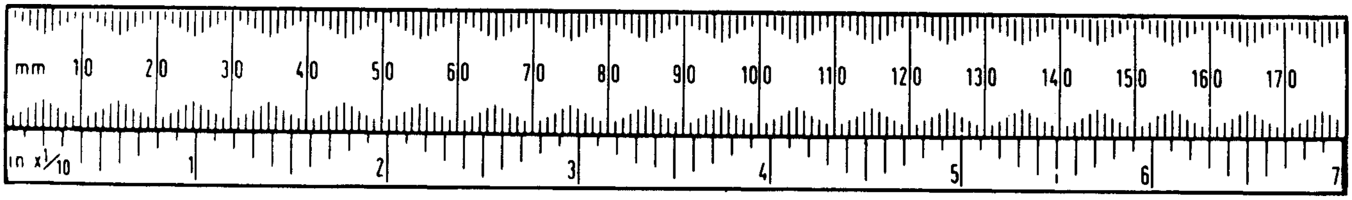


FIG. 95

____15. Place a 7mm lo&washer over the threaded bushing of the potentiometer which is connected to the PCB with two green wires. Mount the potentiometer in the hole in the cabinet top marked 0 to -15V, using a 7mm flat washer and hex nut.

____16. Repeat the previous step using the potentiometer connected to the PCB with two red wires, mounting it in the hole marked 0 to +15V.



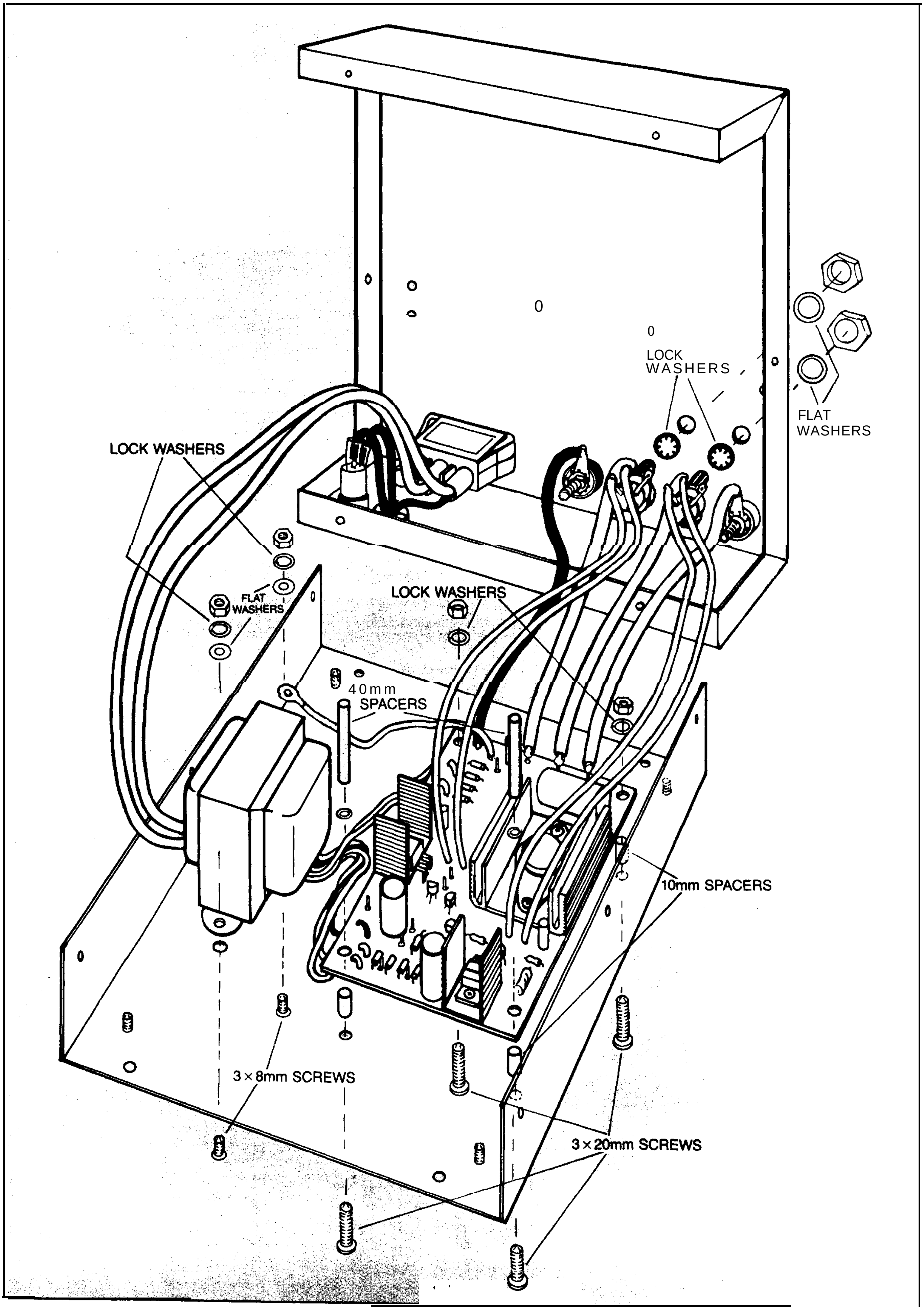

LOCK WASHERS
FLAT WASHERS
LOCK WASHERS
FLAT WASHERS
LOCK WASHERS
40mm SPACERS
10mm SPACERS
3×8mm SCREWS
3×20mm SCREWS

FIG. 96

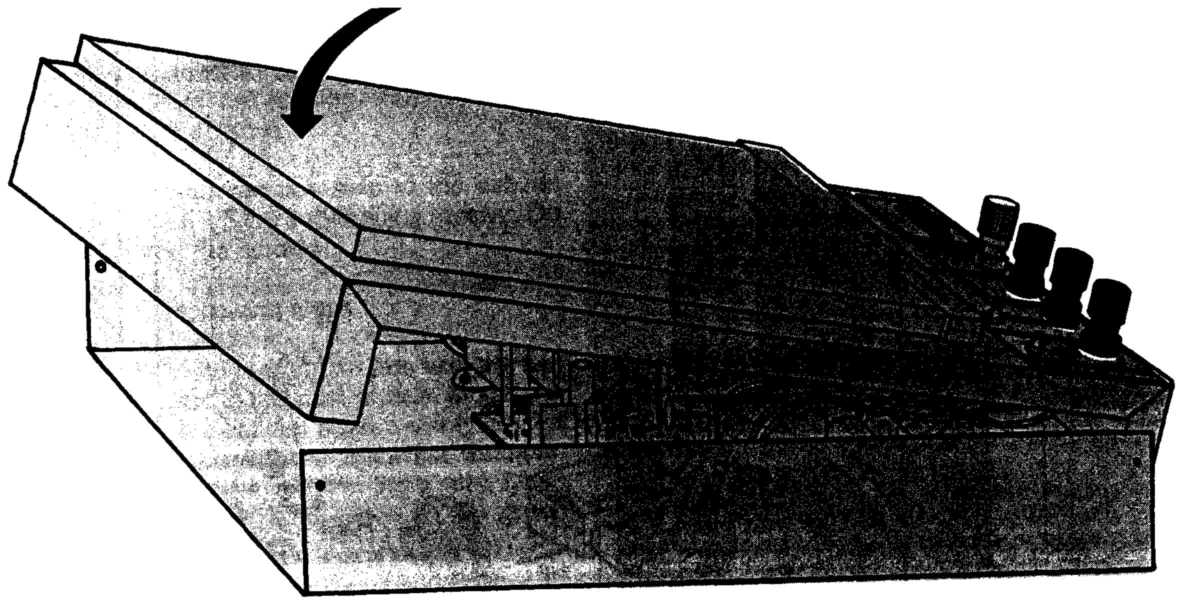


FIG. 97

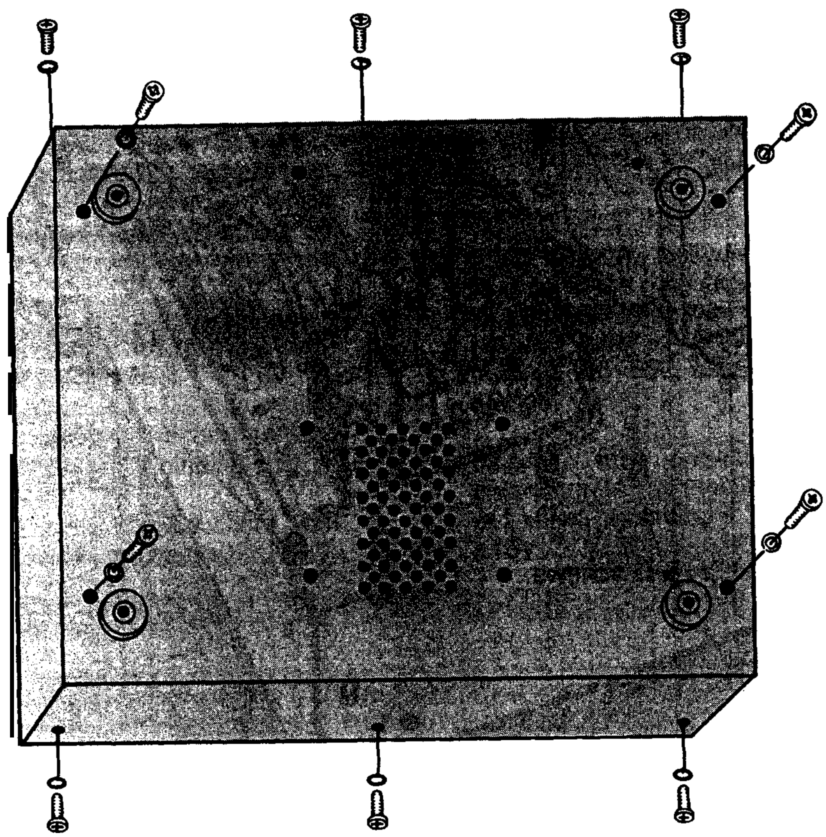


FIG. 98

Refer to Fig. 97 for the following steps.

___17. Place the cabinet bottom on your work surface as shown in Fig. 97.

___18. Make sure that all four brackets are lined up perpendicular with 'the cabinet top before proceeding.

___19. Hold the cabinet top so that it can be folded onto the cabinet bottom like a hinge. Carefully position all wires so that they will not be pinched between any metal or other parts when the cabinet top is assembled to the cabinet bottom.

___20. Gently lower the cabinet top onto the cabinet bottom. Observe the wires to be sure they are not pinched between any parts.

___21. Once the cabinet top is positioned firmly onto the cabinet bottom, hold the two cabinet halves tightly together while you turn the unit over. Continue to hold the cabinet tightly together.

Refer to Fig. 98 for the following steps.

___22, While holding the cabinet together, install four (4) 3 x 8mm screws with 3mm lockwashers into the four (4) holes in the bottom of the cabinet- DO NOT TIGHTEN THE SC -.

___23. Install three (3) 3 x 8mm screws with 3mm lockwashers into the three holes on the left side of the cabinet. DO NOT TIGHTEN THE SCREWS.

___24. Install three (3) 3 x 8mm screws with 3mm lockwashers into the three (3) holes on the left side of the cabinet. DO NOT TIGHTEN THE SCREWS.

___25. Tighten the screws installed in Step 22.

___26 Tighten the screws installed in Step 23.

___27 Tighten the screws installed in Step 24.

___28. This completes construction of your Graymark Model 808 Triple Power Supply/Bread board.

Purpose: To verify that the three power supplies work properly after cabinet assembly

Equipment: **VOM** or **DMM**
50 Ohm 5 Watt Resistor

____ 1. Connect one end of the **50** Ohm resistor to the **COM** terminal. Connect the other end to the + 5 VDC terminal.

____ 2. Adjust the meter to read **+5** VDC.

____ 3. Connect the negative meter lead to the COM terminal.

____ 4. Connect the positive meter lead to the **+5** VDC terminal.

____ 5. Connect the 808 power plug to an electrical outlet and turn the power switch ON.

____ 6. The voltmeter should read between 4.7 and 5.3 Volts. If the voltage is correct, proceed to the next step. If it is not correct, **STOP,** turn power OFF and remove the power plug from the **outlet. Then,** check the resistor and meter connections. If all connections are correct, you may have pinched or broken a wire during the cabinet assembly.

____ 7. Turn the power switch OFF

____ 8. Adjust the DC Voltmeter to read + 15 VDC.

____ 9. Disconnect the resistor lead and the positive meter lead from the **+5** VDC terminal. Reconnect both to the 0 to + 15 VDC terminal.

____ 10. Turn the power switch ON.

____ 11. Monitor the voltage while turning the adjustment potentiometer using a small screwdriver. You should be able to adjust the supply between 0 and 15 Volts. If the voltage is correct, proceed to the next step. If it is not correct, STOP, turn power OFF and remove the power plug from the outlet. Then check the resistor and meter connections. If all connections are correct, you may have pinched or broken a wire during the cabinet assembly.

____ 12. Turn the power switch OFF

____ 13. Adjust the DC Voltmeter to read **-15** VDC.

____ 14. Disconnect the resistor lead from the 0 to + 15 VDC terminal. Reconnect it to the 0 to **-15** VDC terminal.

____ **15.** Disconnect both meter leads.

____ 16. Adjust the meter to read + 15 VDC.

____ 17. Connect the negative meter lead to the 0 to **-15 VDC** terminal.

____ 18. Connect the positive meter lead to the COM terminal.

____ 19. Turn the power switch ON.

____ 20. Monitor the voltage while turning the adjustment potentiometer. You should be able to adjust the supply between 0 and 15 Volts. You should be able to adjust the supply between 0 and 15 Volts. If the voltage is correct, proceed to the next step. if it is not correct, **STOP,** turn power OFF and remove the power plug from the outlet. Then check the resistor and meter wnnections. If all wnnections are **correct,** you may have pinched or broken a wire during the cabinet assembly.

____ 21. Turn the power switch OFF

____ 22. Disconnect the voltmeter and resistor from the Model 808.

____ 23. This completes the Final Test.

OPERATION

The Breadboard portion of your Model 808 is populated with 2,420 **holes. The** leads of **electronic** wmponents such as integrated circuits, transistors, resistors and capacitors, as well as wires, can be inserted into these holes By inserting electronic components and wires into the Breadboard, you can design and **construct** experimental (prototype) circuits. Before you can use the Breadboard, however, you must understand how the 2,420holes are interwnnected.

The Breadboard is comprised of eight sections, five bus strip sections and threecomponent sections, as shown in Fig 99. The bus strips are used to distribute or "bus" power and electronic signals to different areas of the Breadboard. The component sections are where the electronic components are mounted.

Various wire sizes can be accommodated by the Breadboard, as well as the following component leads:

SIP and DIP Integrated Circuits
1/8 to **1/2** Watt Resistors
Most Capacitors
Most Small Transistors

Bus **Strips**

Each of the five bus strips wntains four segments of 25 holes each. Each segment is identified by a blue or red stripe printed next to the segment.The 25 holes which are next to each stripe are connected together, so that a wire or component lead inserted into any of the 25 holes will be connected to any wire or wmponent which is inserted into any of the remaining 24 holes in that segment.

Component Sections

Each of the three component sections contains 128 segments of five holes each.The segments are horizontal rows, and each segment is identified by a number (1 to 64) printed next to the segment.The five holes in the row next to each number are wnnected together, so that a wireor component lead inserted into any of the five holes will be connected to any wire or wmponent which is inserted into any of the remaining four holes in that segment.

In each wmponent section, for reference only, the columns are identified by letters A, B, C, D **&** E, and **F,** G, H, **I &** J.

A portion of the Breadboard is shown in Fig. 104 to illustrate

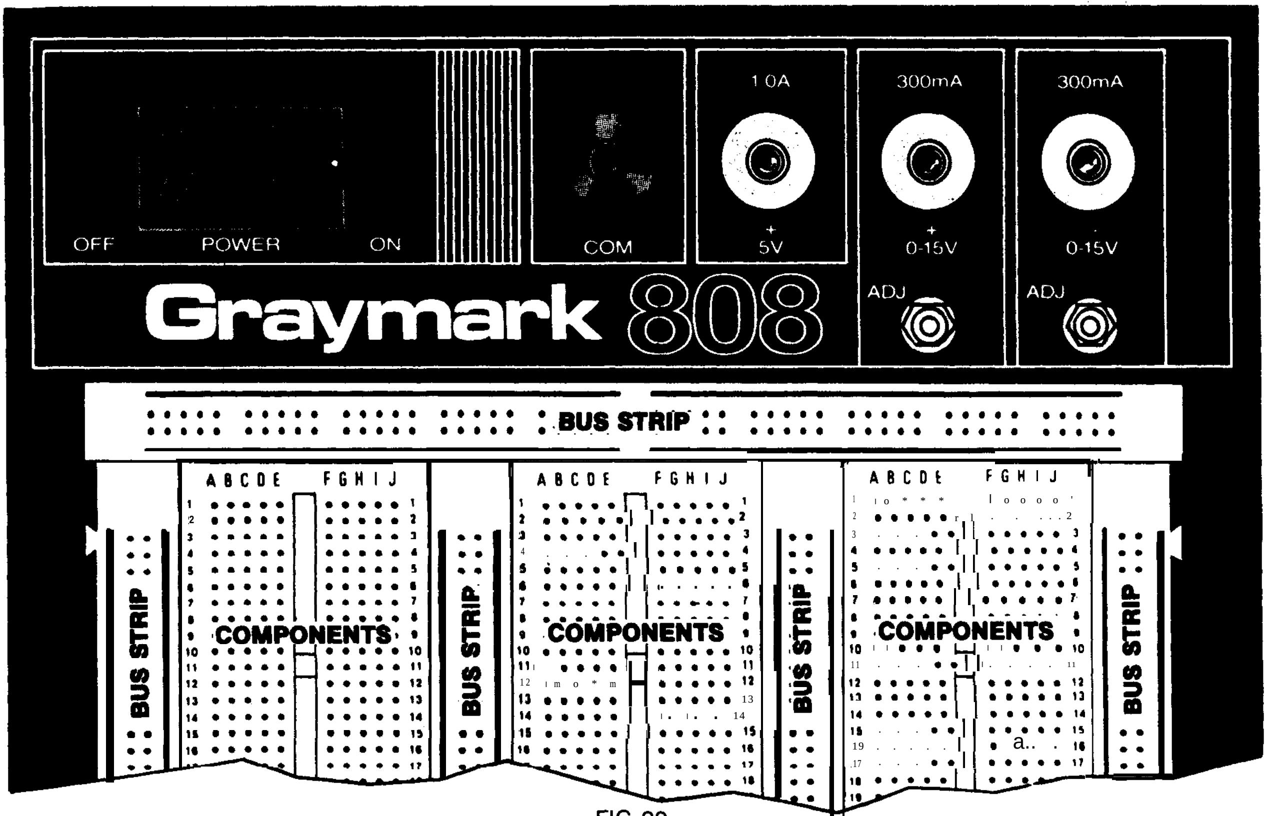


FIG. 99

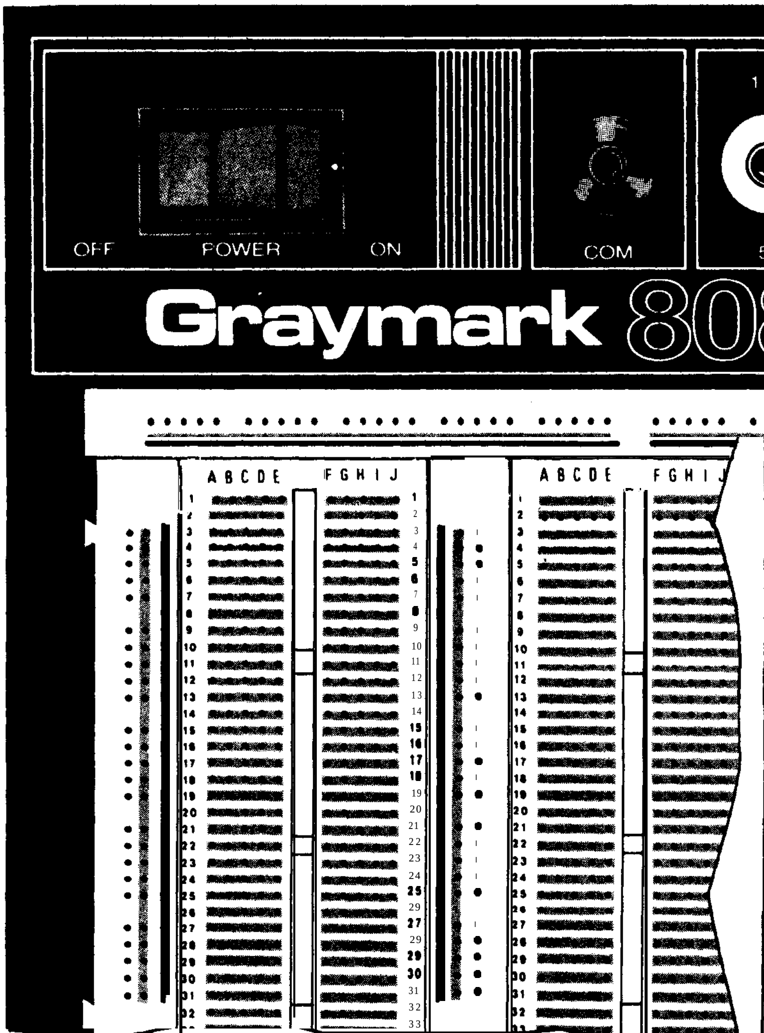


FIG. 100

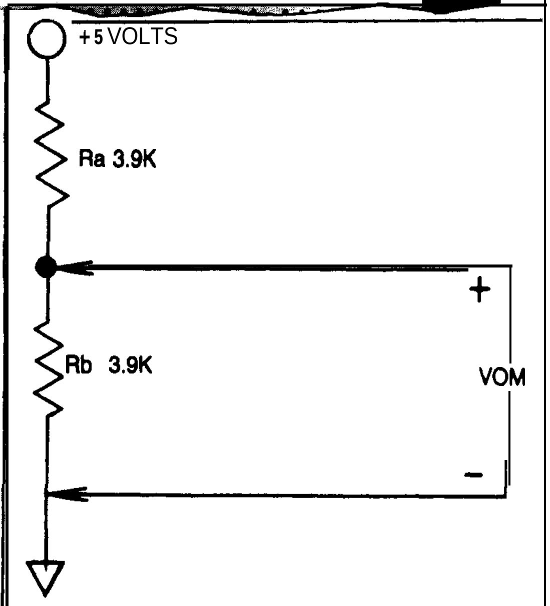


FIG. 101

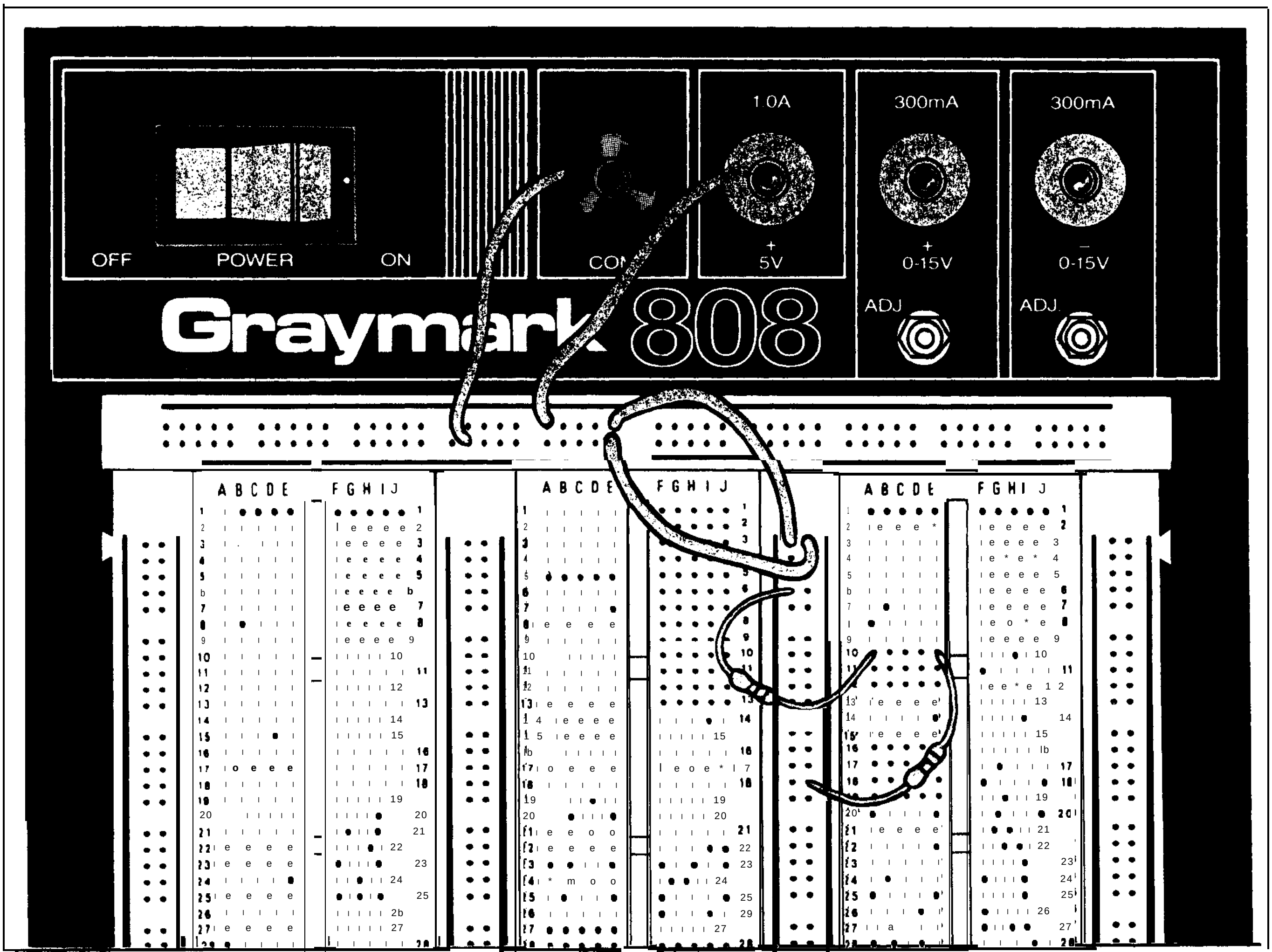


FIG. 102

the interconnections in both the bus strip and the component sections.

Sample Circuit

Equipment: VOM or DMM
Two 3.9 kOhm Resistors

To demonstrate how the Breadboard can be used to construct circuits, you can build the voltage divider circuit shown in Fig. 101.

Refer to Fig. 102 for the following steps.

____ 1. Connect one end of a wire to the COM terminal. Insert the other end of the wire into the hole in the upper bus strip as shown.

____ 2. Insert one end of a wire into the hole in the upper bus strip as shown. Insert the other end into the hole in the vertical bus strip as shown.

____ 3. Insert one end of a 3.9 kOhm resistor into the hole in the vertical bus strip as shown. Insert the other end in hole **A10** in the center component section.

____ 4. Insert one end of another 3.9 kOhm resistor into hole E10. Insert the other end into the hole in the vertical bus strip as shown.

____ 5. Insert one end of a wire into the hole in the vertical bus strip as shown. Insert the other end into the hole in the upper bus strip as shown.

____ 6. Insert one end of a wire into the upper bus strip **as** shown. Connect the other end to the +5V terminal.

____ **7.** Adjust the meter to read 10 VDC.

____ 8. Connect the positive (+) meter lead to the resistor lead which is in hole E10. Connect the negative (-) meter lead to the COM terminal.

____ 9 Plug the Model 808 into a 110 VAC outlet and turn the Power ON.

____ 10 Read the meter. It should read approximately **2.5 VDC,** showing that the voltage divider circuit is performing as expected. Since the circuit is operating as expected, you know that the circuit which you built on the Breadboard is connected in accordance with the schematic in Fig. 101.

____ 11. Turn the Power OFF and unplug the Model 808.

____ 12. Remove the meter and all wires and resistors from the Breadboard.

NOTE: Due to the nature of the design, when the Positive and Negative Variable Voltage control pots (R8 and R10) are set to the **full** counter-clockwise position (for minimum output), the output voltage level can go past zero and produce an output in the opposite polarity. Levels upwards of one to two hundred millivolts (0.1 - 0.2 Volts) of reversed polarity are possible, and can adversely affect some semiconductor devices, Make sure that you have the two Variable Voltage Outputs set to the desired level before connecting them to the breadboarded circuit, and do not randomly adjust the control pots during operating.

SERVICING

If your Graymark project does not operate correctly, the following steps will help you to isolate the problem. There are three basic steps to follow when servicing any electronic device.

I. Isolate the defective section.
II. Isolate the defective component or connection.
III. Repair or replace the defective component or connection.

Check off each step as you proceed.

____ 1. Check ALL solder connections. Poorly soldered connections should be reheated to form good joints. Refer to the HOW TO SOLDER sectionfor examples of good and poor solder connections.

____ 2. Check the placement of ALL components. Make sure that the (-) leads of electrolytic capacitors are going into the PCB holes marked (-). Be certain that you have installed the proper capacitors in the right locations. It is easy to get confused by the numbers on capacitors. Check that all resistors have been installed in their proper locations. Resistor values can be determined by the RESISTOR COLOR CODE section.

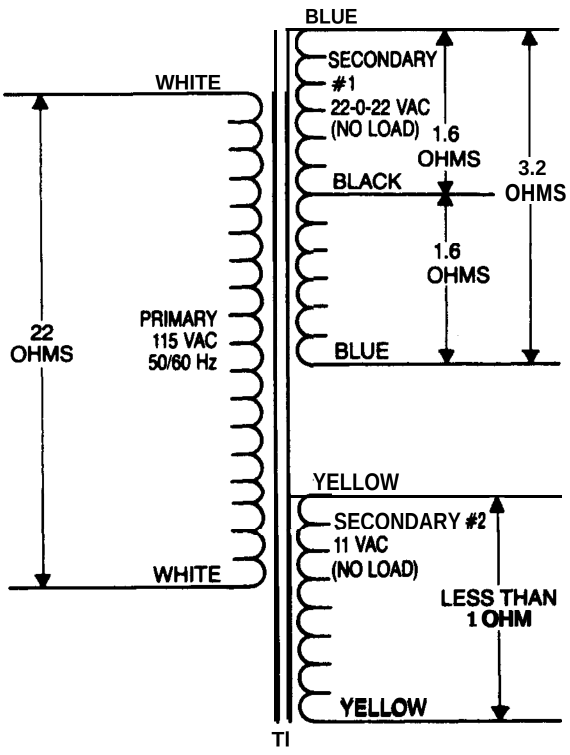
____ 3. Be sure that each IC has been installed in the proper location. Ul and U2 look similar, except for their part numbers. Each IC must be in the correct location.

____ 4. If the above procedures fail to locate the problem, performing the experiences located throughout the manual will be helpful in locating the problem, especially if you built the Power Supply using Mode II. These experiences demonstrate how the various sections of your Power Supply operate. If you find results that differ greatly from those described, youwill know where to look for trouble in your Power Supply.

TEST POINT DESCRIPTIONS

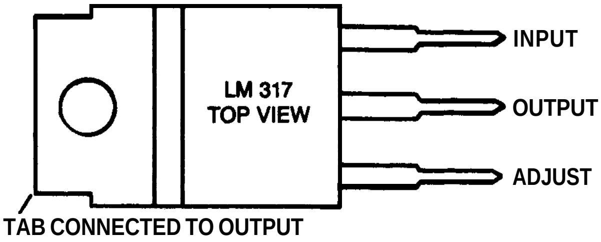
TP#	DESCRIPTION
1	Transformer Secondary #1 Start (Blue)
2	Transformer Secondary #1 Center Tap (Black) and COM (Ground)
3	Transformer Secondary #1 Finish (Blue)
4	Transformer Secondary #2 Start (Yellow)
5	Transformer Secondary #2 Finish (Yellow)
6	-22 Volts, Unregulated
7	COM (Ground)
8	+ 22 Volts, Unregulated
9	+ 11 Volts, Unregulated
10	Positive Regulator Input Terminal
11	Overcurrent Protection Transistor Base(Q3)
12	Negative Voltage Regulator Input Terminal
13	Positive Voltage Regulator Adjust Terminal
14	Minus 1.4 Volt Voltage Control Bias
15	Negative Voltage Regulator Input Terminal
16	Positive 1.4 Volt Voltage Control Bias
17	0 to + 15 Volt Output, Regulated
18	0 to -15 Volt Output, Regulated
19	+5 Volt Output, Regulated

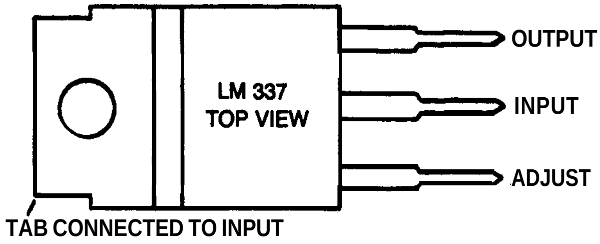
TRANSFORMER RESISTANCES

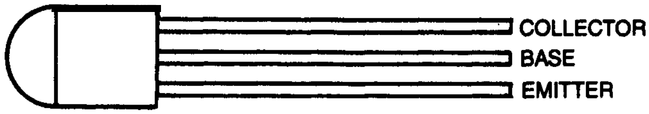


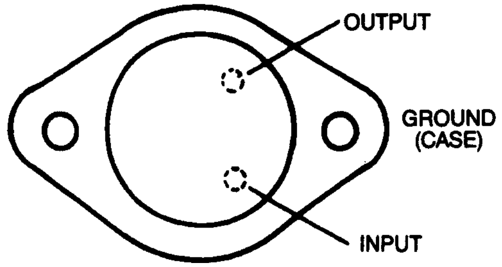
POWER TRANSFORMER SPECIFICATIONS

REGULATOR & TRANSISTOR PINOUTS









LM 309 TOP VIEW

RESISTOR COLOR CODE

Your kit contains precision resistors which may use two types of color code: a four band code and a five band code.

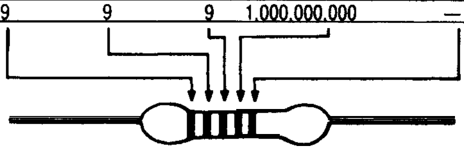
FIVE BAND COLOR CODE

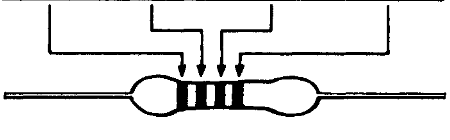
- First color (color nearest the end of the resistor) represents the first figure in the resistor value.
- Second color represents the second figure in the resistor value.
- Third color represents the third figure in the resistor value.
- Fourth color represents the multiplier of the first three figures.
- Fifth color represents the resistor tolerance.

FOUR BAND COLOR COOE

- First color (color nearest the end of the resistor) represents the first figure in the resistor value.
- Second color represents the second figure in the resistor value.
- Third color represents the multiplier of the first two figures.
- Fourth color represents the resistor tolerance.

1st COLOR	2nd COLOR	3rd COLOR	4th COLOR	5th COLOR		1st COLOR	2nd COLOR	3rd COLOR	4th COLOR
FIRST FIGURE	SECOND FIGURE	THIRD FIGURE	MULTIPLIER	TOLERANCE	BAND COLOR	FIRST FIGURE	SECOND FIGURE	MULTIPLIER	TOLERANCE
—	—	—	.01	—	SILVER	—	—	.01	10%
—	—	—	.1	—	GOLD	—	—	.1	5%
0	0	0	1	—	BLACK	0	0	1	—
1	1	1	10	1%	BROWN	1	1	10	1%
2	2	2	100	—	RED	2	2	100	—
3	3	3	1,000	—	ORANGE	3	3	1,000	—
4	4	4	10,000	—	YELLOW	4	4	10,000	—
5	5	5	100,000	—	GREEN	5	5	100,000	—
6	6	6	1,000,000	—	BLUE	6	6	1,000,000	—
7	7	7	10,000,000	—	VIOLET	7	7	10,000,000	—
8	8	8	100,000,000	—	GRAY	8	8	100,000,000	—
9	9	9	1,000,000,000	—	WHITE	9	9	1,000,000,000	—





EXAMPLES

BROWN	GRAY	YELLOW	SILVER	BROWN
1	8	4	.01	1%

equals 1.84 ohms

BROWN	GREEN	GREEN	BROWN
1	5	100,000	1%

equals 1,500,000 ohms or 1.5M

LEARNING EXPERIENCE AND SKILL DEVELOPMENT REVIEW

This project has afforded you the opportunity of expanding your knowledge of electronic& and electronic devices through experiments and related technical information.

You will probably be surprised at the number of skills you have learned, and the amount of knowledge you have acquired from building this project. The theory and skills which were covered are:

THEORY

- Transformers
- **Half-Wave** Rectification
- **Full-Wave** Center-Tap Rectification
- **Full-Wave** Bridge Rectification
- **Full-Wave** Bridge With Center-Tap Rectification
- Capacitive Filters
- Unregulated Power Supplies
- Fixed Voltage Regulators
- Variable Voltage Regulators
- Overcurrent Protection

SKILLS

- Electronic Component Identification
- Schematic Symbol Identification
- Reading Schematic Diagrams
- Reading Block Diagrams
- Reading Resistor Color Code
- Test Equipment Use
- Soldering
- Hand Tool Use

SPECIFICATIONS

POWER SOURCE:	**110 VAC**
POWER **OUTPUT:**	**+5** VDC, **1 Amp**
	0 to +15 VDC, 300 mA
	0 to -15 VDC, 300 mA
INTEGRATED CIRCUITS:	**3**
TRANSISTORS:	**4**
DIODES:	**12**

HOW TO ORDER REPLACEMENT PARTS

If you require a part, follow the instructions below. **Replacement** parts will be shipped subject to the warranty terms. Do not return the original component unless requested. The Factory Warranty does not cover components **damaged** through carelessness or incorrect assembly. Mail your request for replacement parts to Graymark.

Enclose the following:

1. Your name and mailing address.
2. Date kit was purchased.
3. Part number and description **(as** shown on Parts List)
4. If the part is not covered by warranty, you must also:
   - A. Show replacement price from Parts List.
   - B. Add $1**.00** for postage **&** handling.
   - C. If you are a **California** resident, add **Sales Tax** on **total** purchase price.
   - D. Enclose a money order or check for the full amount. Sorry, COD not accepted.

REPAIR POLICY

If your **Graymark** project does not operate properly, and you have completed the steps outlined in SERVICING, you may return the project to **Graymark** for inspection and repair.

____ 1. Carefully pack the completed project so it **will** not be damaged in shipment.

____ 2. Enclose a letter explaining the problem. Include your name, address and phone number.

____ 3. Allow 4 weeks for repair and return.

____ 4. Send your kit to:

GRAYMARK INTERNATIONAL, INC.
690 So. B Street
Tustin, CA 92680
Telephone: 714-544-1414

FACTORY WARRANTY

Graymark international, inc. warrants that each project was complete and ready to assemble at the time of shipment. All shortage claims must be made within 10 days from receipt of goods representing each project. Graymark warrants that, for a period of ninety (90) days from date of purchase, all merchandise is free of defects andworkmanship, under normal conditions of use and service. The obligation of Graymark under this warranty is limited to repair or replacement of those parts upon verification that they are defective in this manner. Graymark's obligation does not include labor required to service or repair any project.

This warranty is completely void and Graymark will not repair, replace, or service any project or parts thereof on which acid core solder, paste flux, or corrosive solders have been used in assembling the project. Any modification of the project will void the warranty.

This warranty is extended solely to the original buyer and only to the extent above expressed. No dealer or agent is authorized to make any other or additional guarantee or warranty. In no event shall Graymark be liable for any anticipated profits, consequential damage, loss of time, or other losses incurred by the buyer in connection with the purchase, assembly, or use of the project or components thereof.

GRAYMARK

OTHER GRAYMARK KITS

There are many other Graymark electronic projects you will enjoy building. Send your name and address to:

GRAYMARK, BOX **2015, TUSTIN, CA 92681**

for your personal copy of Graymark's latest catalog which includes:

ROBOTS
RADIOS
TOOLS
STROBE LIGHT
ELECTRONIC ACCESSORIES
VOM
POWER SUPPLIES

An extensive selection of low-cost KOMPONENT KITS is also described in the catalog.