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ELECTRIC GUITAR AMPLIFIER Handbook

by Jack Darr

A complete explanation of electronic musical instrument amplifiers with service information for more than 20 commercial instruments.

Electric Guitar Amplifier Handbook

by JACK DARR

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ELECTRIC GUITAR AMPLIFIER HANDBOOK

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Preface

The guitar is a very popular musical instrument—not only in America, but also overseas. While you might think that this popularity started with the current "teenage idol" singers, it really goes back a long time before that. Folk singers and "Country & Western" musicians started to boom just before World War II, and they have been increasing steadily in number ever since. Dance bands used to use trumpets or saxophones, but now many are made up of nothing but stringed instruments—guitars, violins, banjos, and string basses.

The stringed instrument, by itself, does not have a high sound output. For use in places with a high noise level (dance halls, night clubs, or informal gatherings) help was needed, and electronics came to the rescue. Now a few men can create the same amount of sound that a big band once did.

With their increased sound power, electric guitars caught on in a hurry. Today there are uncounted numbers of these instruments in every city, town, and hamlet—almost as many as stereo record players! Someone has to keep them working, since they need regular servicing just as PA systems do. This can be a good source of income for the radio-TV technician. The amplifiers use standard parts, tubes, and circuits in the main. Regular radio and hi-fi test equipment will do the work; no special instruments are necessary.

In the past it has been very difficult to get service data or any other information on these instruments. This book is written to give you typical circuits, service methods, and testing techniques, plus all of the information available on commercial instruments.

JACK DARR

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SECTION I

How Guitar Amplifiers Work

1 *Amplifying the Signal*

Technically speaking, the title of this book should be "Servicing Electronically Amplified Musical Instruments" since electric guitars are not the only ones involved. Every instrument in the band can have its own pickup—violins, banjos, string basses, etc. However, there is no question that the guitar is the most popular of the group. Keep in mind that everything in this book can be applied to any of the instruments where electronic amplification has been used. So far, drums have been exempt, but anything can happen.

GENERAL DESCRIPTION

The first electric guitars used contact microphones. These small special microphones, when fastened to the body or shell of an instrument, pick up the actual sound vibrations and convert them into an electrical signal for amplification. They are like a phonograph pickup which changes mechanical vibration into electrical signals. One of the disadvantages is their poor sensitivity. If the amplifier is turned up high enough to get an adequate output, the whole body of the guitar acts as a microphone. When someone speaks toward the instrument or the player shifts it against his clothing, the sound can be heard everywhere. Also, when the sound from the speakers gets into the microphone, acoustic feedback occurs. A different method of picking up the music is obviously needed.

Since all guitars of this type use metal strings, a magnetic pickup has been developed. High impedance coils are wound on iron cores and placed under the strings at a point where the motion of the string is greatest—near the hole of the instrument. Movement of the metal string through the magnetic field of the coil induces a voltage in the coil; this is the electrical signal that is amplified. Much greater output is obtained by winding the coils on small, permanent magnet cores instead of the original soft iron types.

The first pickups used one large coil on a flat, rectangular form. The output of the pickup has been greatly increased by winding small individual coils, one for each string. Many turns of fine wire are used on these—the more wire, the more output voltage generated. As a result, all pickups have a fairly high impedance output. A volume control is usually mounted on the body of the guitar where the musician can reach it quickly. In more elaborate instruments a tone control is also placed here. Other volume and tone controls are located on the amplifier or are mounted in a special foot-pedal housing so the performer can change the volume without taking his hands off the strings.

The first electric guitars were standard instruments with electronic pickups added. Since the acoustic resonance of the guitar body isn't necessary if an electronic pickup is used, special, entirely electric guitars are now built (Fig. 1-1). The body is made of solid wood about 1.5 inches thick. The neck, frets, and proportions are the same as before, of course.

There are two basic types of guitar: the Spanish, which has raised frets on the neck, and the Hawaiian or steel guitar, which has no raised frets. They are played with the fingertips or a pick, by plucking one string at a time or by strumming chords. A steel bar is moved up and down the neck of the Hawaiian guitar to control the pitch, giving the music a characteristic glissando effect. Some special types of guitars have two full sets of strings, each with its own pickups and controls (Fig. 1-2). These are built in a rectangular box-shaped case mounted on four legs. The musician sits down to play these, just as he would to play a piano.

The more elaborate instruments have special effects, such as vibrato, tremolo, and echo. These will be discussed in detail in the following chapter. Tone controls of all kinds are used. Most are simple bass-cut or treble-cut types, but some use complex feedback circuits.

THE AMPLIFIER

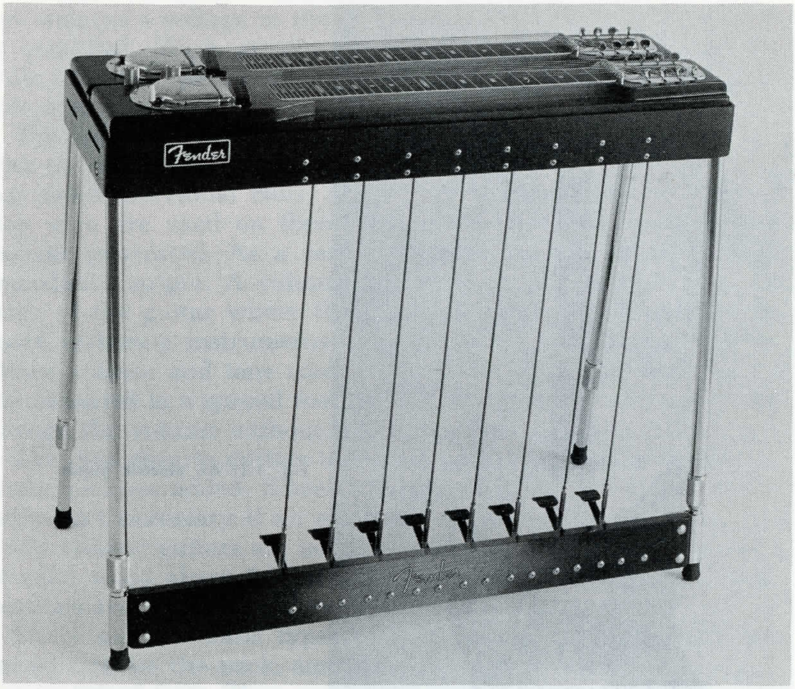
An electric guitar amplifier is the same as a public address (PA) system. It consists of a source of signal (the microphone or pickup), the amplifier (to build up the weak electrical signal to whatever power is needed), and the speakers. Fig. 1-3 shows a block diagram of such a system.

Courtesy Fender Electric Instrument Company

Fig. 1-1. An electric guitar.

The amplifiers used are all conventional, meaning that they are practically identical to those used in all kinds of sound equipment. In other words, these amplifiers are basically the same as those used in PA systems, hi-fi record-playing systems, and many others. This similarity makes things easier for the owner and the service technician, too. When they learn the basic circuits, they can apply what they have learned to all guitars. All amplifiers have the same basic divisions; the only difference is in the number of stages used and the total power output of the system.

What does the amplifier do? The signal, which is the electrical equivalent of the musical tone from the guitar, is fed to the input



Courtesy Fender Electric Instrument Company

Fig. 1-2. A pedal guitar.

of the amplifier through a shielded cable, to keep it from picking up hum and noise on the way. There it is amplified (raised to a much higher electrical level) to drive the speakers.

There are two kinds of stages in all amplifiers—transistor types and those with vacuum tubes. The first stages are all voltage amplifiers; they build up the signal voltage so that it is big enough to drive the power output stage to full output. The power-output stage—output for short—is always the last stage in an amplifier—just before the speakers.

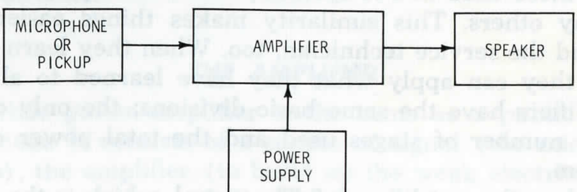


Fig. 1-3. Block diagram of typical guitar assembly.

Fig. 1-4 shows a block diagram of a typical amplifier. Since all amplifiers use a similar pattern, you should remember it. The only difference will be in the total number of stages and in the special effects added along the way. As you can see in the dotted boxes, tone controls of any kind—tremolo, vibrato, and echo effects—can be added to the signal before it goes to the power-

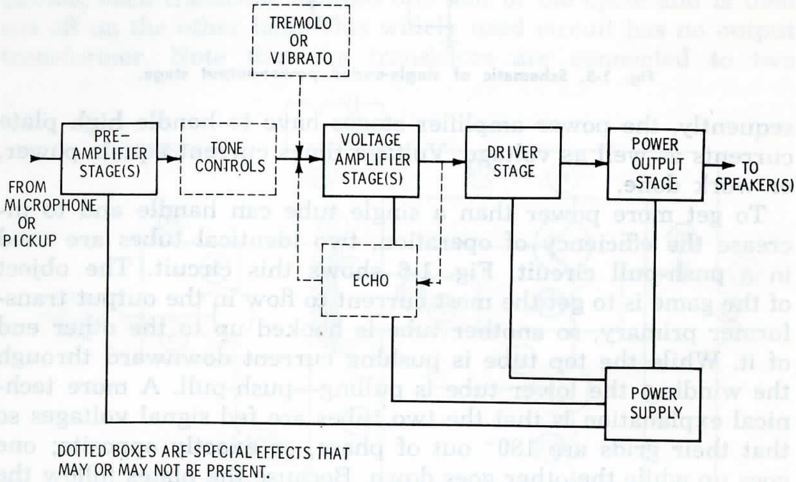


Fig. 1-4. Block diagram of typical guitar amplifier.

output stage and the speakers. These special effects are discussed in detail in the following pages, and instructions are given so you can add them to amplifiers that do not already have them.

THROUGH THE AMPLIFIER, A STEP AT A TIME

In order to see what each stage does, examine the amplifiers, a step at a time. Begin with the power output stage, just as an engineer would if he were designing the amplifier, since this is the stage that determines how much power output the amplifier is going to have.

Fig. 1-5 shows a typical single-ended output stage—the kind you will find in the smaller amplifiers. The tube used here can be a 6V6, 6L6, 6AQ5, 6BQ5, or any beam-power pentode type. In this circuit maximum power output is about 4 to 6 watts, depending on the tube type used and the voltage fed from the power supply.

These are called power amplifier stages, because they must do actual work—move the speaker cone to make the sound. Con-

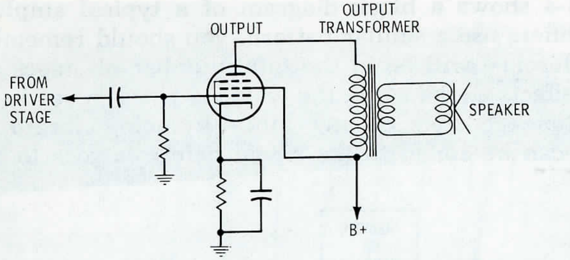


Fig. 1-5. Schematic of single-ended power-output stage.

sequently, the power amplifier stages have to handle high plate currents as well as voltage. Voltage times current equals power, or work done.

To get more power than a single tube can handle and to increase the efficiency of operation, two identical tubes are used in a push-pull circuit. Fig. 1-6 shows this circuit. The object of the game is to get the most current to flow in the output transformer primary, so another tube is hooked up to the other end of it. While the top tube is pushing current downward through the winding, the lower tube is pulling—push-pull. A more technical explanation is that the two tubes are fed signal voltages so that their grids are 180° out of phase, or exactly opposite; one goes up while the other goes down. Because the plates follow the grids, plate current rises in one tube and falls in the other at the same time.

There are several classes of push-pull circuits, depending on the bias voltages. There is no need to go into a full analysis of all of them in this book. You can look them up in an electronics text if you are interested.

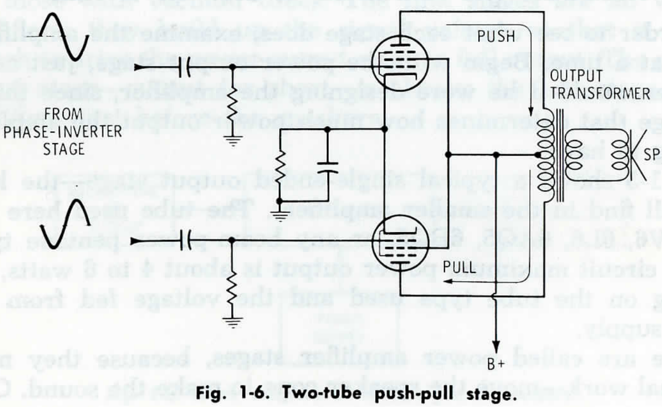


Fig. 1-6. Two-tube push-pull stage.

By using a push-pull output circuit, more than double the power output of one tube is obtained. This is due to the increased efficiency of the circuit and the fact that the plate current of both tubes flows through the same primary winding.

Fig. 1-7 shows the output circuit of a transistor amplifier. For maximum efficiency, almost all of these use a push-pull class-B circuit; each transistor handles one half of the cycle and is then cut off on the other half. This widely used circuit has no output transformer. Note that the transistors are connected to two

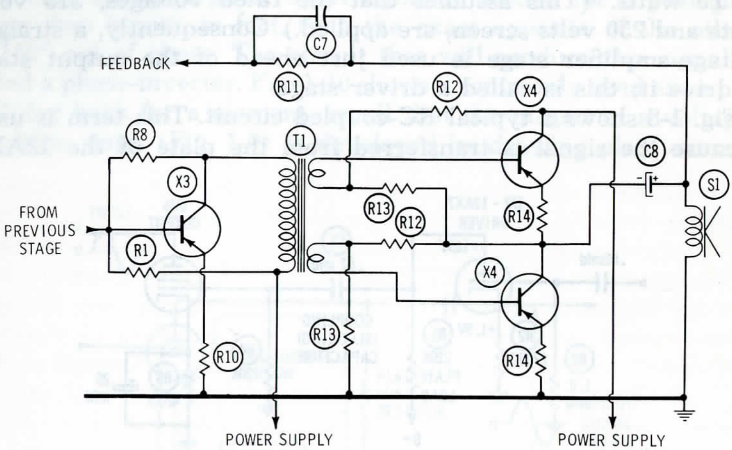


Fig. 1-7. Power-output stage of a transistor amplifier.

separate secondary windings on the driver transformer, and that the emitter of the top transistor is connected to the collector of the bottom one. The speaker voice coil is connected to this junction through a large electrolytic blocking capacitor that prevents any dc from flowing through the voice coil. Only the ac signal flows here. The dc is balanced; when one transistor is applying a positive voltage, the other is applying a negative voltage, and they normally balance out. If they do not, then there is something wrong in the circuit. Leakage in the blocking capacitor will also upset the operation by changing the d-c voltages present in the emitter-collector circuits.

The output stage alone determines the size of the power supply. It uses up something like 95% of the total electrical power of the entire amplifier. If a certain power output is desired, a power-output stage that will provide it will be needed, and also a power supply that will furnish enough voltage and current. Power supplies will be discussed in a section all their own, because they cause a large percentage of the troubles found in amplifiers. They do most of the work and they cause most of the difficulties.

THE DRIVER STAGE

A single-ended output stage needs a voltage-amplifier stage capable of delivering enough grid signal to the power stage to drive it to full output. For instance, a single 6V6 tube needs an input signal of about 25 volts peak-to-peak to give a full output of 5.5 watts. (This assumes that the rated voltages, 315 volts plate and 250 volts screen, are applied.) Consequently, a straight voltage-amplifier stage is used just ahead of the output stage to drive it; this is called a driver stage.

Fig. 1-8 shows a typical RC-coupled circuit. This term is used because the signal is transferred from the plate of the 12AX7

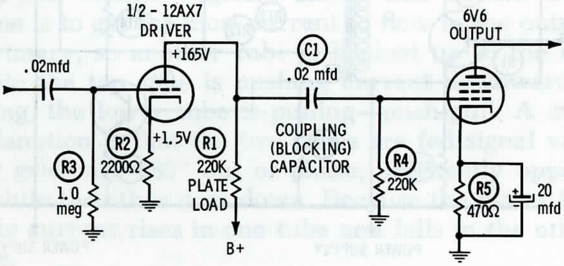


Fig. 1-8. Typical driver stage.

tube to the grid of the 6V6 through the .02-mfd coupling capacitor (C1), and the d-c returns needed are made through resistors (R1). The older amplifiers use audio transformers here. In later designs it has been found that RC coupling can do the job a lot cheaper with better fidelity. The capacitor is also called a blocking capacitor by some, because it blocks the high d-c plate voltage of the triode from the negative grid voltage of the 6V6. This component is a source of many amplifier problems.

Fig. 1-8 is a straight voltage-amplifier stage. A high-value (220,000 ohms) plate-load resistor, is used, so the stage will not draw a lot of plate current; it doesn't have to. What is required is the developing of a very large signal voltage across the plate load to feed the grid of the 6V6, which is a voltage-operated device.

The driver stage is designed to have the needed signal voltage (25 volts p-p in this case) at its output. A high-gain tube, proper circuit components, and correct supply voltages work together to supply the required amount of amplification. The actual amount needed depends on the number of voltage-amplifier stages used in front of the driver. For instance, if there is a 1-volt p-p signal on the 12AX7 grid, this stage will have to give a total voltage gain of 25 times—1 volt in and 25 volts out (both p-p). The actual figures used will vary a lot between different amplifiers, but the same principle will be used in all of them.

PUSH-PULL DRIVERS AND PHASE INVERTERS

A very special type of input signal is needed for a push-pull stage: two inputs, in fact, each the exact opposite of the other, or 180° out of phase. The circuit that will produce this signal is called a phase-inverter. Fig. 1-10 shows a commonly used example.

Going back for a moment, recall that the output of a voltage-amplifier stage (Fig. 1-9) is developed by drawing plate current

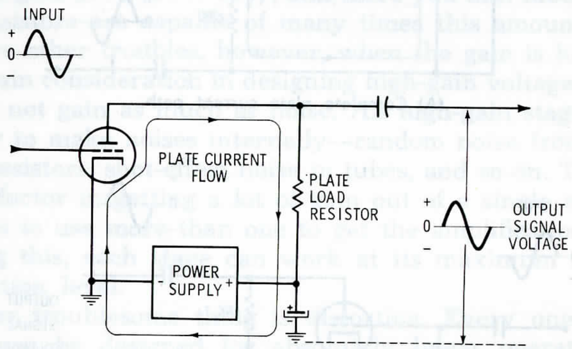
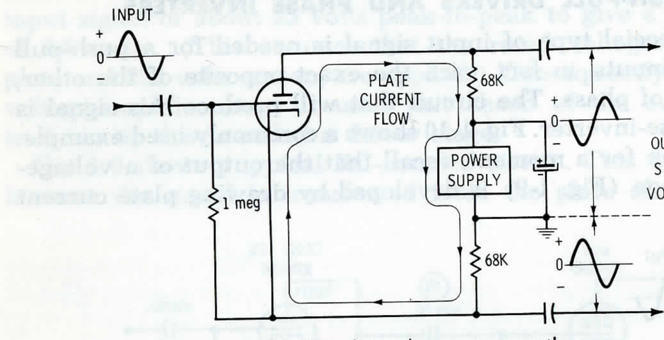


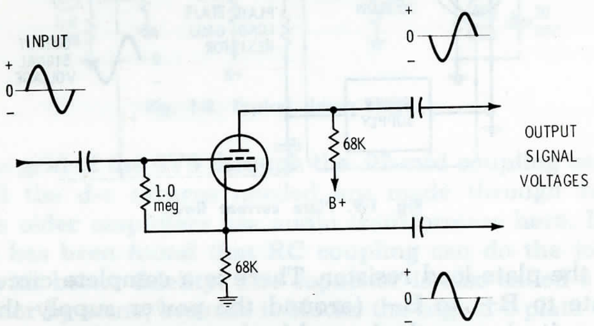
Fig. 1-9. Plate current flow.

through the plate-load resistor. There is a complete circuit here: tube plate to B+, to B− (around the power supply through a large capacitor), to cathode, and back again to plate. As you can see, the signal voltage shows up as a voltage drop across the plate load resistor. What is needed, however, are two signals, each the opposite of the other. These can be obtained by taking advantage of a characteristic of a vacuum tube—the voltages on the plate and the cathode are always 180° out of phase. One goes down when the other goes up, and vice versa.

To get two equal output signal voltages, split the load, putting half of it in the plate circuit and the other half in the cathode, as shown in Fig. 1-10. The similarity to Fig. 1-9 is more apparent in Fig. 1-10A, while the conventional method of drawing the circuit (with the power supply indicated but omitted) is shown in Fig. 1-10B. Since the same signal current flows through the whole circuit, a signal voltage will be developed across any resistor that this current flows through. The size or amplitude of this signal voltage depends on the size of the resistor. In the split-load circuit the two resistors are exactly the same size, so equal but out-of-phase signal voltages result across them. Notice that the plate voltage on the first half-cycle is going negative and the



(A) Complete plate current path.



(B) Conventional drawing.

Fig. 1-10. The split-load phase inverter.

cathode voltage is going positive. This is because the grid voltage is going positive on the same half-cycle. Check any textbook on vacuum-tube theory for a fuller explanation.

There are other phase-inverter circuits, but this is probably the most frequently used, because of its simplicity and ease of design. In most applications this circuit will simply invert phases, but if a high-gain tube is used, a little voltage gain can be developed—which is always good.

THE PREAMPLIFIER STAGES

The signal voltage at the input of the phase-inverter or driver stage can be fairly small. Although this varies with the requirements of the power-output stage, something like 1 volt p-p is normal. This voltage and the actual output voltage of the guitar pickup determines how many voltage-amplifier and preamplifier stages will be used in the rest of the amplifier.

For example, if the pickup has an output of 50 millivolts (50 mv or .050 volt), and if a signal voltage of 50 volts p-p is needed at the grid(s) of the output stage, a total voltage amplification of 1000 times is necessary. This sounds pretty high, but it is not; many amplifiers have voltage gains up to a million! It works very simply: if a stage has a gain of 10 and is followed by another just like it, the total is the product of the individual gains, or 100, from these two stages alone. Adding another stage with a gain of 10 will give 1000 (10×100), and there you are. Modern tubes and transistors are capable of many times this amount of gain. There are other troubles, however, when the gain is high.

The main consideration in designing high-gain voltage-amplifier stages is not gain as much as noise. All high-gain stages have a tendency to make noises internally—random noise from current flow in resistors, shot-effect noise in tubes, and so on. This is the limiting factor in getting a lot of gain out of a single stage. The answer is to use more than one to get the amplification needed. By doing this, each stage can work at its maximum noise-free amplification level.

Another troublesome thing is distortion. Every one of these stages must be designed for absolutely linear operation. This means that the signal in the output must be exactly the same shape as the signal in the input. If the stage changes the waveform in any way as the signal passes through, a very poor sound quality results due to distortion. This is the second major consideration.

There are several ways of avoiding distortion. As a matter of fact, you don't have to worry about it, as far as the original design is concerned. This work has all been done for you by the engineer who built the amplifier. In all but the very cheapest amplifiers, distortion and noise will be at a very low level when the instruments are new. What you have to do is put them back in the same condition! Although you don't have to design amplifiers, you do have to know how and why the circuits work so you can tell when they are working correctly.

Many of the better amplifiers use built-in correction circuits to hold the distortion down to a very low level. These are usually inverse feedback circuits. In them a part of the output of the amplifier is fed back into an earlier stage in such a way that it cancels out some of the distortion. While this does reduce the overall gain of an amplifier, it also improves the tone quality so much that the small loss of gain does not matter. The loss can be corrected by using another voltage-amplifier stage if necessary.

Feedback voltage must get back into the amplifier in the right phase so it will be degenerative—tending to stop oscillation. If the phase is wrong, it will be regenerative—tending to cause oscillation. When certain components are replaced, there is a possibility of wrong connections. If an output transformer is replaced, for example, the amplifier can oscillate if the phase of the feedback is reversed. Other causes of oscillation will be taken up later in the section on servicing.

Distortion is not always easy to detect and cure. The ear alone is seldom accurate enough to pinpoint the actual cause or type. It is necessary to use an oscilloscope and very accurately shaped test signals, in bad cases, to find and fix this kind of trouble.

2

Special Signal Circuits

The basic function of the guitar amplifier is to increase the sound of the instrument so it can be heard under many different conditions—from small practice rooms to large concert halls. Yet electronics offers many possibilities for adding variety to the basic guitar sound. The location of the pickup influences the signal; some guitars use as many as three in different positions for various effects. Tone control circuits in the amplifier itself can make the sound brilliant or mellow. Other special circuits—echo (reverberation) and tremolo—can be added by separate units or can be built into the amplifier.

THE PICKUPS: TYPES AND CONSTRUCTION

At the input of the amplifier is the pickup itself—the device that converts the motion of the guitar strings into electrical signals. The first type used was a contact microphone constructed as shown in Fig. 2-1. The correct technical term for any of these things would be "electromechanical transducer," but they are called pickups for convenience.

The contact mike is just a microphone element of any kind—crystal, dynamic, etc. Instead of having a diaphragm like the

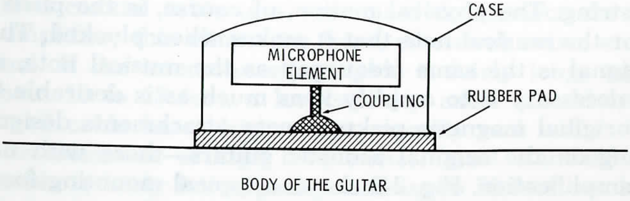


Fig. 2-1. Typical contact microphone.

voice-operated types, it has a coupling of some kind, so it can pick up only the vibration of the surface with which it is in contact (theoretically!). Actually, due to the high gain that is required, this kind of mike picks up many sounds very well—talking close by, the rubbing of clothing on the guitar, any jar that is given the instrument, and so on. Now the contact mike has been replaced almost entirely by the magnetic pickup. This responds only to a motion of the metal strings through the magnetic field of the pickup coil and has no microphonic effects at all.

Fig. 2-2 shows how this works. Only one coil is shown, although there is normally one for each string; they all work in the same

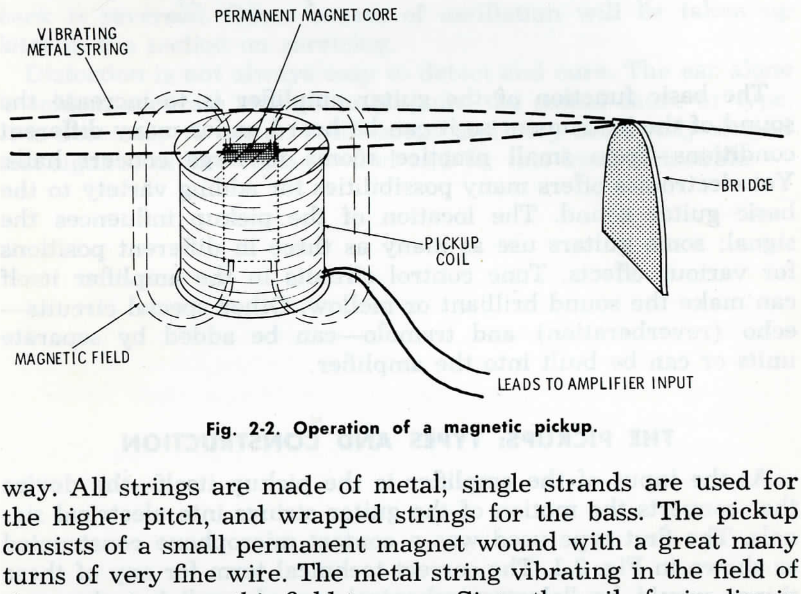


Fig. 2-2. Operation of a magnetic pickup.

way. All strings are made of metal; single strands are used for the higher pitch, and wrapped strings for the bass. The pickup consists of a small permanent magnet wound with a great many turns of very fine wire. The metal string vibrating in the field of the magnet causes this field to move. Since the coil of wire lies in the moving magnetic field, a small electric current is generated in the coil. This is the oldest principle in electronics: the moving conductor in a magnetic field.

This electrical signal will be a duplicate of the physical motion of the string. The physical motion, of course, is the pitch of the string or the musical note that it makes when plucked. The electrical signal is the same frequency as the musical note, and all that is necessary is to amplify it as much as is desirable.

The original magnetic pickups were attachments designed for mounting on the original acoustic guitars—those with no electronic amplification. Fig. 2-3 shows a typical mounting for one of these. A single, long, flat coil in a metal shielding case was used, and a clamp was provided to hold it tightly in place under the strings. Some models had volume controls in the same assembly.

In specially built electric guitars the pickup coils, volume and tone controls, etc. are installed in cutouts in the body of the instrument where they are covered with chromed metal plates or plastic covers. There are other controls and special effects used on the custom models, which are discussed later.

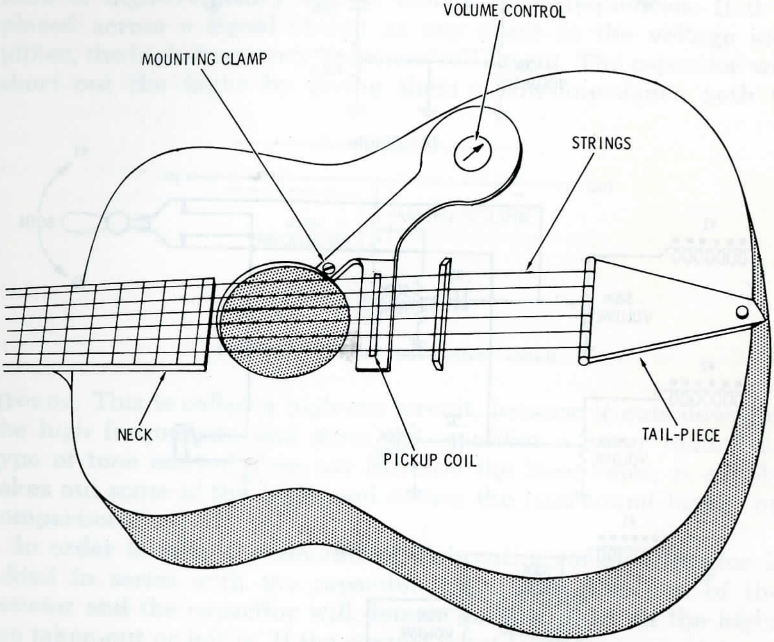


Fig. 2-3. Acoustic guitar with pickup-coil attachment.

All of the pickups use the same basic circuit shown in Fig. 2-4. If individual coils are used for each string, they are connected in series or parallel; the whole pickup unit is connected across a volume control of from 0.5 to 1.0 megohm or more. The simple high-cut tone control shown may be mounted on the guitar itself. A shielded coaxial cable is always used to connect the pickup to the amplifier; this eliminates hum, electrical noise, etc. from the signal. If the interconnecting cable is fairly long, say more than about 10 to 15 feet, a low-capacity cable should be used. Very small cable has a high shunt capacity and will cut down on the transmission of high frequencies. Most standard microphone cable is fairly low capacity, and up to 50 feet can be used without trouble.

Standard phone plugs and jacks are the type of connectors most commonly used. The connections on these must be kept clean and tight to get rid of any noise and hum. Full details on how to handle these plugs and make repairs to the mike cables will be given in the section on servicing.

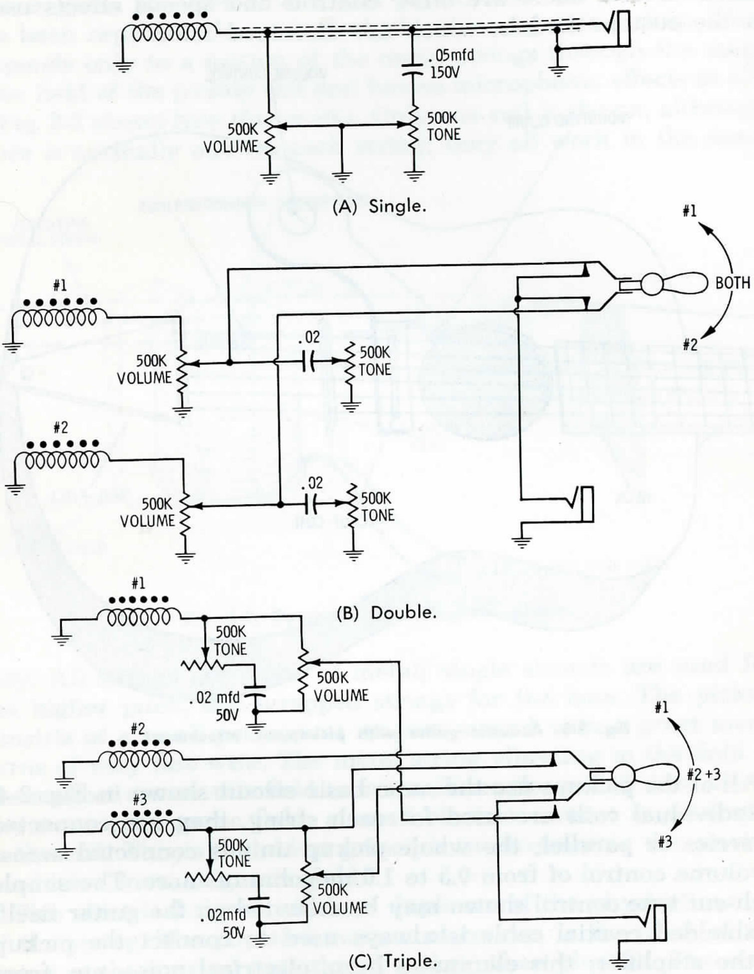


Fig. 2-4. Pickup circuits.

TONE CONTROLS

All except the very smallest amplifiers have some sort of tone-control circuit. These do not change the fundamental tone of the instrument—that is, the pitch or frequency of the string. However, they can change the characteristics of the amplifier by increasing or decreasing the amplification of high or low notes, depending on the control setting.

The simplest tone control is what is known as a high-cut type, as used in Fig. 2-4. Basically, it looks like Fig. 2-5. A capacitor has one valuable characteristic: it shows a much lower impedance to high-frequency signals than to low frequencies. If it is placed across a signal circuit at any point in the voltage amplifier, the high-frequency response will be cut. The capacitor will short out the highs by giving them a low-impedance path to

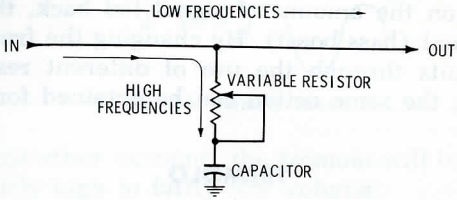


Fig. 2-5. High-cut tone-control circuit.

ground. This is called a high-cut circuit, because it cuts down on the high frequencies and gives the amplifier a lower tone. This type of tone control does not increase the bass tones; it simply takes out some of the highs and makes the bass sound bigger by comparison.

In order to vary the amount of high cut, a variable resistor is added in series with the capacitor (Fig. 2-5). The size of the resistor and the capacitor will determine how much of the highs are taken out or left in. If the control is set to its lowest resistance position, all of the capacitance is across the circuit, and the lowest tones will be prominent. If the variable resistor is set to the maximum resistance position, in effect the capacitor is taken out of the circuit, and the high tones are present, because the path to ground is now high resistance. After the tone control, the signal goes on to the next stage of the amplifier.

FEEDBACK TONE CONTROLS

In the more expensive instruments, a different type of tone control is used, involving what is called negative feedback. This either boosts or cuts the bass and treble frequencies. Since it is a pretty complicated circuit, the details of its design will not be discussed. However, it can be found in any good electronics textbook under bass boost and treble boost tone-control circuits.

A feedback tone control can increase the amount of bass frequencies in a tone (bass boost) or cut them; the same thing can be done with the treble frequencies. Neither of these actions will affect the other. The simple high-cut tone control, of course, affects all frequencies somewhat. The basis of operation is the use of selective feedback—a network of resistors and capacitors that feeds back a part of the output signal into the input. By changing the amount, and in some cases the phase, the input signal can either be built up or lowered at selected frequencies. Inverse feedback always lowers the gain of an amplifier but improves its fidelity. If a large amount of bass frequencies are fed back, for example, the gain of the amplifier for bass notes is reduced. By cutting down on the amount of signal fed back, the gain is returned to normal (bass boost). By changing the frequency of the feedback circuits through the use of different resistor and capacitor values, the same action can be obtained for treble tones.

TREMOLO

Tone controls have no effect on the action of the amplifier; they simply change its frequency response or volume a little. The special effects result in a whole new character to the sounds. There are three of these in common use: tremolo (a variation in volume level), vibrato (a variation in frequency or pitch), and echo or reverberation.

Tremolo is basically pretty simple. If the bias of an amplifier stage is raised or lowered, the volume changes. Almost any audible speed or frequency can be used to give a pleasing "vibration" effect to the musical tone. This causes the two effects to be confused; unless you have a very keen ear for musical notes, you can easily get tremolo and vibrato mixed up since they do sound a lot alike.

A tremolo effect can be created by varying the bias voltage on any amplifier stage at any desired frequency. The typical circuit will use frequencies from about 1 cycle per second up to 50 or 60 cycles. The average amplifier has a tremolo rate of about 10 to 15 cycles per second. Fig. 2-6 shows how this circuit works. Typical waveforms are included. Note that there are two controls shown. In most amplifiers these are marked STRENGTH and SPEED, meaning amplitude and frequency.

The heart of the tremolo circuit is a very low-frequency oscillator, the output of which can be varied in frequency (by the SPEED control) to give the rate of tremolo wanted. The STRENGTH (amplitude) control varies the voltage of the output. At its low end there will be a barely perceptible quaver in

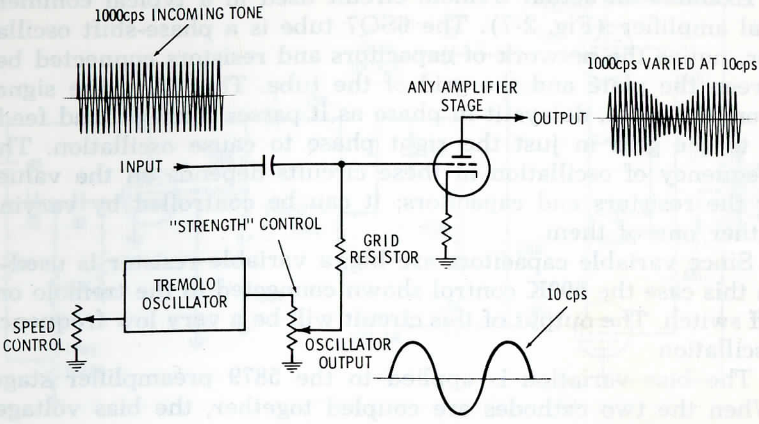


Fig. 2-6. Tremolo circuit.

the note; at the other extreme, the tremolo will consist of variations from fairly high to fairly low volume.

The output of the low-frequency oscillator might be called a slowly varying d-c voltage for simplicity. This is fed, through isolating resistors, into the bottom of the grid circuit of the de-

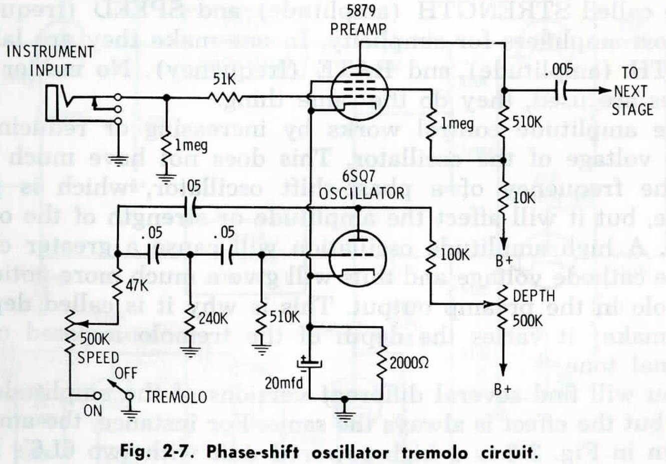


Fig. 2-7. Phase-shift oscillator tremolo circuit.

sired amplifier stage. There it affects the grid-bias voltage by adding and subtracting to the bias already present in normal operation. As a consequence, it changes the volume at the output of the stage. The tremolo effect, once added to the signal, goes on through all of the following amplifier stages.

Examine an actual tremolo circuit used in a typical commercial amplifier (Fig. 2-7). The 6SQ7 tube is a phase-shift oscillator; notice the network of capacitors and resistors connected between the plate and the grid of the tube. This takes the signal from the plate, delays it in phase as it passes through, and feeds it to the grid in just the right phase to cause oscillation. The frequency of oscillation in these circuits depends on the values of the resistors and capacitors; it can be controlled by varying either one of them.

Since variable capacitors are big, a variable resistor is used—in this case the 500K control shown connected to the tremolo on-off switch. The output of this circuit will be a very low frequency oscillation.

The bias variation is applied to the 5879 preamplifier stage. When the two cathodes are coupled together, the bias voltages on both stages vary simultaneously. This changes the gain and consequently the amplitude of the output of the preamp tube. Any instrument connected to the input of the 5879 preamp tube will have a tremolo in its output that can be varied by the setting of the tremolo controls.

There are two controls: frequency, the variable resistor in the oscillator circuit itself; and amplitude, the variable resistor in the B+ supply circuit to the oscillator plate. You will find these called STRENGTH (amplitude) and SPEED (frequency) in most amplifiers for simplicity. In one make they are labelled DEPTH (amplitude) and RATE (frequency). No matter what names are used, they do the same thing.

The amplitude control works by increasing or reducing the plate voltage of the oscillator. This does not have much effect on the frequency of a phase-shift oscillator, which is pretty stable, but it will affect the amplitude or strength of the oscillations. A high amplitude oscillation will cause a greater change in the cathode voltage and thus will give a much more noticeable tremolo in the preamp output. This is why it is called depth in one make: it varies the depth of the tremolo imposed on the original tone.

You will find several different versions of the amplitude control, but the effect is always the same. For instance, the amplifier shown in Fig. 2-8 is a high-powered unit with two 6L6's in the output, and feeds the tremolo bias directly to the output tubes. Here a 6AU6 tube is used as the tremolo oscillator (a phase-shift type), and the voltage variations are coupled into the grid return of the 6L6's through a 0.1-mfd coupling capacitor from the 6AU6 plate and the strength control. In this case the strength control is a divider across the tremolo oscillator output.

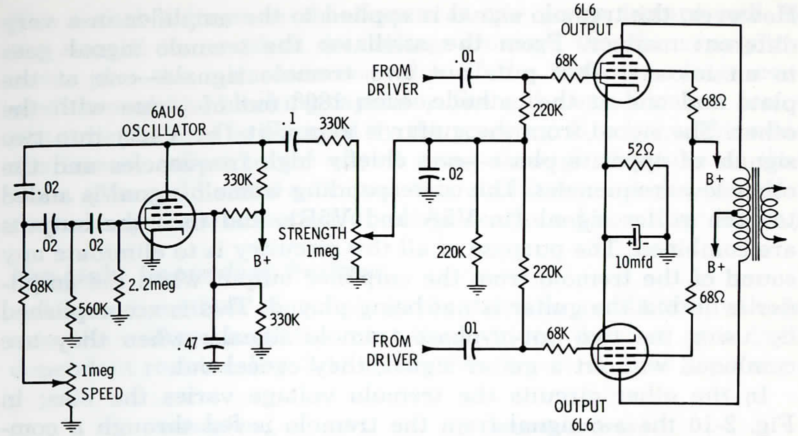


Fig. 2-8. Tremolo applied to grids of the output tubes.

The tremolo circuit in Fig. 2-9 is somewhat more involved than the previous ones. The phase-shift oscillator is like all the others although the actual controls are in a remote control assembly.

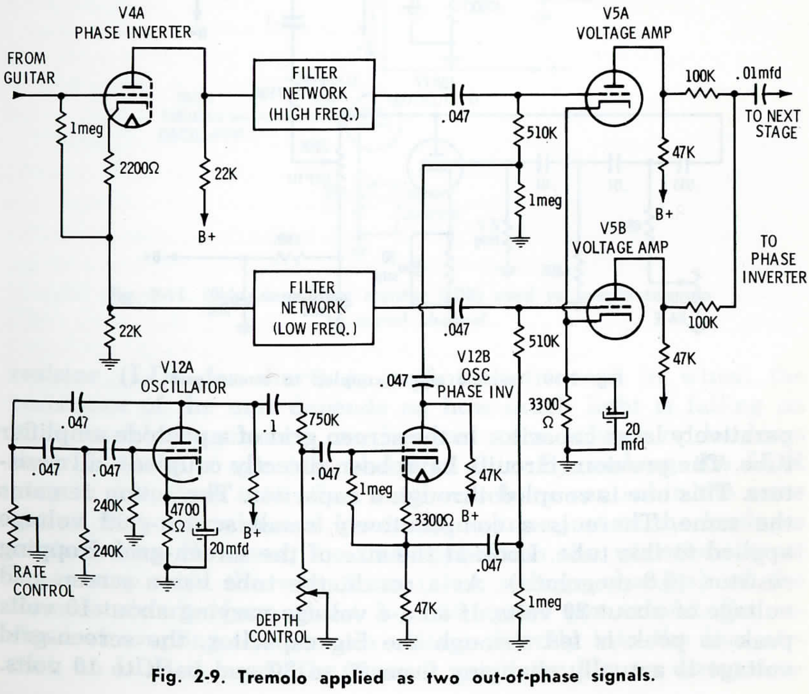


Fig. 2-9. Tremolo applied as two out-of-phase signals.

However, the tremolo signal is applied to the amplifier in a very different manner. From the oscillator the tremolo signal goes to an inverter that puts out two tremolo signals—one at the plate and one at the cathode, each 180° out of phase with the other. The signal from the guitar is also split (by V4A) into two signals of opposite phase—one chiefly high frequencies and the other low frequencies. The corresponding tremolo signal is added to each guitar signal (in V5A and V5B), and then the outputs are combined. The purpose of all this circuitry is to eliminate any sound of the tremolo from the amplifier output when the amplifier is on but the guitar is not being played. This is accomplished by using the two out-of-phase tremolo signals; when they are combined without a guitar signal, they cancel out.

In the other circuits the tremolo voltage varies the bias; in Fig. 2-10 the a-c signal from the tremolo is fed through a com-

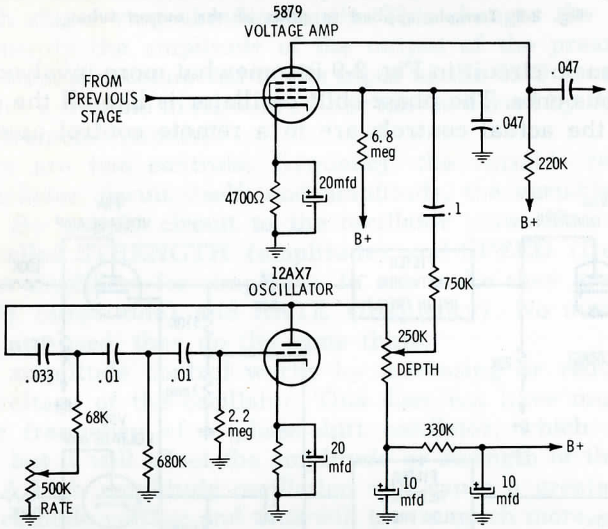


Fig. 2-10. Tremolo signal coupled to screen grid.

paratively large capacitor to the screen grid of a pentode amplifier tube. The previous circuits have been directly coupled—all resistors. This one is coupled through a capacitor. The action remains the same. There is a comparatively small screen-grid voltage applied to this tube. Look at the size of the screen-grid dropping resistor (6.8 megohms). As a result, the tube has a screen-grid voltage of about 20 volts. If an a-c voltage varying about 10 volts peak to peak is fed through the big capacitor, the screen-grid voltage is actually changing from 20 to 30 and back to 10 volts.

The actual voltage on the screen at any given instant will be the sum of the residual d-c voltage through the B+ supply resistor plus the instantaneous value of the tremolo voltage coupled through the blocking capacitor. Since the amplification factor of a tube can also be changed by the screen-grid voltage, this adds the tremolo effect to the signal going through the tube at that time. (Very old radio sets used this circuit for volume controls; they changed the screen-grid voltage on the r-f amplifier stages.)

The Light Dependent Resistor

A novel method of coupling the tremolo oscillation voltage into the voltage amplifier circuits involves the use of a light dependent resistor. Fig. 2-11 shows this circuit. A light dependent

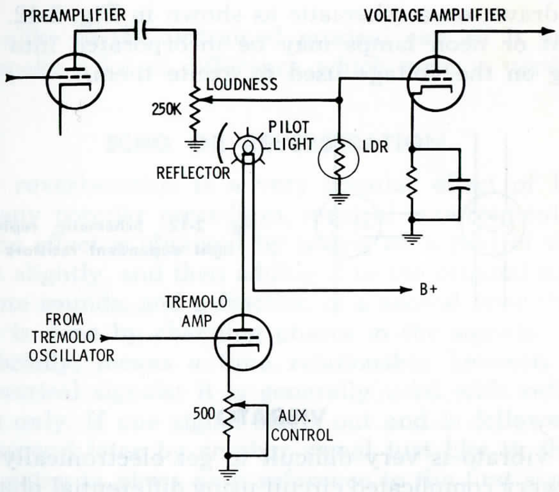


Fig. 2-11. Light dependent resistor (LDR) used to couple tremolo to signal channel.

resistor (LDR for short) is a photoelectric cell in which the resistance of the unit depends on how much light is falling on it. A variable resistance can be used as a volume or loudness control; there is one just ahead of this. By making the LDR vary in size, there is in effect another volume control in the same circuit that will raise and lower the volume just as the loudness control does. However, for this application the variations must be in step with the vibrations (slow voltage changes) of the tremolo circuit—from about 3 to 50 cycles per second. So, instead of coupling the tremolo voltage directly into the bias circuit, an LDR is used. The tremolo oscillator has no direct connection to the sound circuits; its plate circuit contains a small pilot light. As the signal changes, this light gets brighter and dimmer. The light is focused on the LDR, making its resistance change. This varies the volume in the signal channel, adding tremolo to the signal.

One reason for the use of the LDR is to isolate the tremolo oscillator from the signal circuits. Unless some precautions are taken, the low-frequency oscillation will go through the amplifier when the guitar is not being played and give an unpleasant sound in the output. With this system no oscillator signal is introduced into the guitar signal circuits; there is tremolo in the output only when there is a musical signal going through the amplifier.

Usually the LDR and the lamp are contained in a single unit which is drawn on a schematic as shown in Fig. 2-12. Either incandescent or neon lamps may be incorporated into the units, depending on the voltage used to excite them.

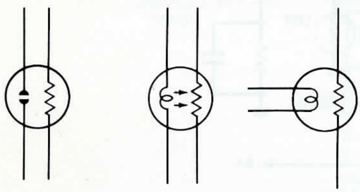


Fig. 2-12. Schematic representation of light dependent resistors and lamps.

VIBRATO

A true vibrato is very difficult to get electronically. It would involve a very complicated circuit using differential phase-shifting that would be very hard to make adjustable. Most manufacturers use a mechanical lever action on the tailpiece of the guitar; the player strikes a chord, then moves a long handle back and forth. This changes the tension on all strings at the same time, alternately raising and lowering the pitch of the chord. Fig. 2-13 shows two vibrato units, one functioning as a tailpiece only and the other combining an adjustable bridge with the tailpiece.

NOTE: You will find the two terms—tremolo and vibrato—used interchangeably, even in some of the catalogs. By a strict musical definition, they are not interchangeable. If the circuit varies the volume of the tone, it will be a tremolo no matter what is on the control knob. If the pitch of the tone varies, then it is a vibrato. Frankly, both effects sound

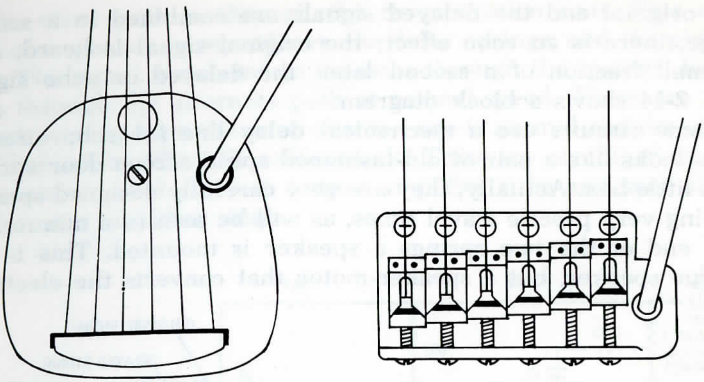


Fig. 2-13. Mechanical vibrato units.

exactly alike to the untrained musical ear, so it probably doesn't make a lot of difference which term is used.

ECHO OR REVERBERATION

Echo or reverberation is a very popular effect of late. It is used in many popular recordings, musical arrangements, and so on. An echo effect is obtained by taking off a part of the signal, delaying it slightly, and then adding it to the original signal. The original note sounds, and a fraction of a second later there is an echo. This is done by changing phases in the signals.

Phase, briefly, means a time relationship between any two similar electrical signals; it is generally used with reference to a-c signals only. If one signal starts out and is followed a fraction of a second later by another signal just like it, the second signal is lagging in phase with reference to the first signal. This, of course, is the same effect you get if you yell into a canyon. First you hear your own voice come back from a nearby cliff, and then, a wee bit later, it comes from a more distant cliff. It is the same thing: echoes.

If the echoes are so close together that the listener can't separate them, the sound is called reverberation. The only difference between echoes and reverberation is the length of time or amount of delay between the signals.

To get an echo effect electronically, only a part (approximately half) of the signal is taken off. The original goes on through the amplifier; the part that is taken off goes through a special circuit which causes it to lose time—it is delayed. The amount of delay is regulated by controls in the echo circuitry; also the amplitude or the strength of the delayed signal can be varied. When the original and the delayed signals are combined in a second stage, there is an echo effect; the original signal is heard, and, a small fraction of a second later, the delayed or echo signal. Fig. 2-14 shows a block diagram.

Some circuits use a mechanical delay line for echo circuits. This looks like a pair of old-fashioned spiral screen door springs in a little box. Actually, they are very carefully designed springs, having very precise travel times, as will be seen in a minute. On one end of the two springs a speaker is mounted. This is not a true speaker, but a speaker-motor that converts the electrical

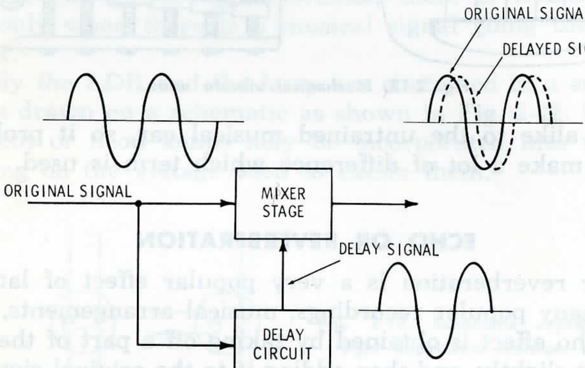


Fig. 2-14. Using signal delay to produce echoes.

signal into mechanical vibrations, just as a speaker does. This puts the sound signal onto the ends of the two springs. It travels the length of the two springs in very slightly different times due to the way the springs are wound. A typical time used by one major manufacturer is 29 milliseconds for one spring and 37 milliseconds for the other (1 millisecond equals .001 second). The delay effect is accomplished in the springs themselves. At the receiving end of the springs, there is a small microphone or its equivalent. It changes the mechanical vibrations that have traveled down the springs back into electrical vibrations (signal) which become the phase-shifted (delayed) signal.

The reverb circuit used in a commercial guitar amplifier is shown in Fig. 2-15. The signal comes in at the preamp grid; it is amplified, and fed to the "reverb-in" amplifier tube. From the plate circuit of this tube there are two paths for the signal to follow. One is through the resistor network above to the input of the next stage. Despite the size of these resistors, they will not cause a voltage loss of the signal because the current flow is very small in such circuits.

The other path is through the reverberation unit. This consists of a speaker or reproducer, the delay springs, and the pickup unit. The signal is delayed as it passes through the springs, but it goes through the alternate path at normal speed. There are two signals coming from the same source—one is normal and the other lags behind by 29 or 56 milliseconds. They are combined in the plate circuit of the reverb output amplifier tube and sent along to the next amplifier stage.

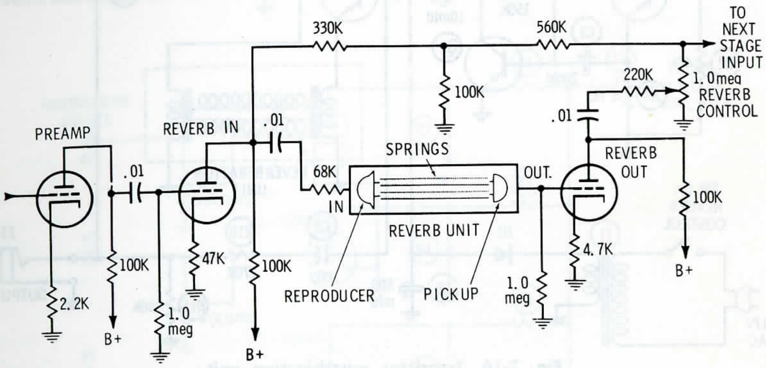


Fig. 2-15. Reverberation circuit.

The reverb control determines the proportion of delayed signal used. You can use just a little or a lot, depending on how deep you want the reverb effect. This, in effect, is a reverb volume control.

Transistor Units

Fig. 2-16 shows a reverberation unit with transistors. This unit is designed as an attachment instead of a part of the original amplifier. The basic action, of course, is the same. The signal comes in at the input jack to the base of Q1, which is an emitter-follower circuit in order to match the high impedance output of the amplifier. This is fed to the base of the second transistor, and coupled to a third transistor which drives the reverb springs. The pickup at the output end of the springs feeds its signal to the base of the output transistor, (a common emitter circuit) which in turn feeds the output jack.

The reverb control is a 10,000-ohm variable resistor across the pickup. A foot-switch can be used to cut the reverb effect in or out as desired. It does this by grounding the junction of two .005-mfd capacitors in series in the output circuit, eliminating the reverb signal.

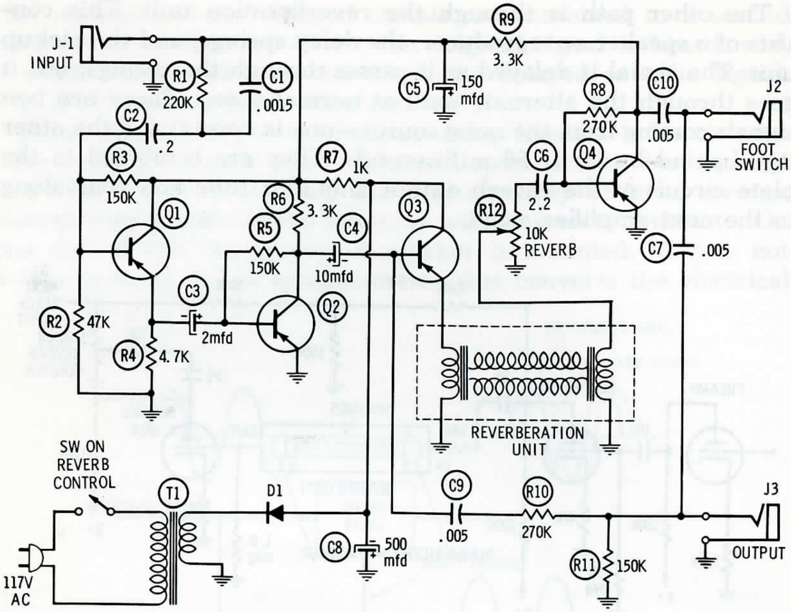


Fig. 2-16. Transistor reverberation unit.

MULTIPLE INPUT CONNECTIONS

One feature found in all but the smallest guitar amplifiers is multiple input connections. These are provided so that several instruments can be connected to the same amplifier at the same time. If two guitars (a lead and a rhythm), a bass, and a violin are plugged in together, for example, the whole band can use a single amplifier.

Some of the amplifiers have microphone inputs as well. These have slightly higher gain than the instrument inputs to compensate for the low output of microphones and to give ample volume for vocal choruses.

The main problem, of course, is not gain, but of mixing the various inputs. All of these must be controllable so that the volume of one instrument can be raised to take a solo passage, for example, while the rest stay below him. One volume control must not affect any of the rest. Instead of connecting them all together, it is necessary to isolate them by means of mixer stages. Correctly built, these give some gain too.

Fig. 2-17 shows a diagram of the most common mixer circuit, with four instrument inputs and a mike input. Each one has its own volume control; a master volume control to adjust the gain of all inputs at the same time is used later in the amplifier circuit.

Here (Fig. 2-17) the output of each instrument goes to the grid (input) of a triode tube. For economy, one of the popular twin-triodes (12AX7, 12AT7, etc.) is used. All of the grids are separate, but notice that all of the plates are tied together. They are connected in parallel, but with isolating resistors (R1, R3, R6, R7, and R9) in series with each plate circuit. These will not affect the gain, but they will help to keep one circuit from in-

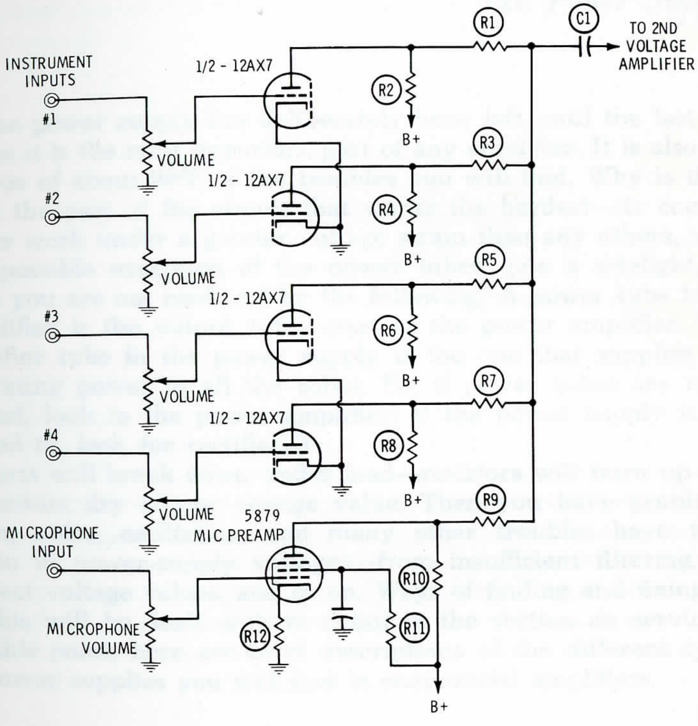


Fig. 2-17. Typical circuit for four-channel mixer.

terfering with another. You may find isolating series resistors used in the grid circuits, too.

Individual volume controls are used, ordinarily in the input of each stage, although they will work the same in the plate circuits.

The microphone input uses a pentode tube instead of the triode for higher gain. Because of the increased gain, noise becomes a problem again. So, the tube type shown (5879) is a non-microphonic pentode especially designed for use in such a stage as this. The output goes to the same common line; all of the signals are mixed here and are fed through coupling capacitor C1 into the next stage of the amplifier.

Twin-triodes are shown in Fig. 2-17. You will probably find triple triodes (Compactrons) in some amplifiers.

3

The Power Supply

The power supply has deliberately been left until the last because it is the most important part of any amplifier. It is also the source of about 90% of the troubles you will find. Why is this? It is the part of the circuit that works the hardest—its components work under a greater voltage strain than any others, with the possible exception of the power tubes. (As a sidelight, be sure you are not confused by the following. A power tube in an amplifier is the output tube—part of the power amplifier. The rectifier tube in the power supply is the one that supplies the operating power to all the tubes. So, if power tubes are mentioned, look in the power amplifier; if the power supply is referred to, look for rectifiers.)

Parts will break down under load—resistors will burn up and capacitors dry out or change value. Then you have problems. Hum, noise, oscillation, and many other troubles have their origin in power-supply voltages—from insufficient filtering, incorrect voltage values, and so on. Ways of finding and fixing all of this will be dealt with in detail in the section on servicing. At this point, here are brief descriptions of the different types of power supplies you will find in commercial amplifiers.

THE AC/DC POWER SUPPLY

The simplest is the ac/dc power supply, found only in very low-powered amplifiers with an output up to about 2 watts (audio). Fig. 3-1 shows a typical ac/dc power supply circuit using a vacuum-tube rectifier. Typical tubes used in this circuit have type numbers beginning with 35 (35W4, 35F5, etc.), indicating their filaments are designed to operate at approximately 35 volts. The a-c line (117 volts is standard) is connected directly to the plate of the rectifier tube, where it is rectified to pulsating dc by the tube, then filtered to a fairly smooth dc in the filter circuits. Resistor R2, capacitor C1, and capacitor C2 make up what is called a pi-type filter; its schematic resembles the Greek letter π. In the better circuits filter resistor R2 is replaced by a small iron-core choke. The choke gives much better filtering action, but the resistor is cheaper. Most of the actual filtering in this circuit is done by large electrolytic capacitors C1 and C2 that are usually 80 to 100 microfarads at 150 working volts.

In these circuits the tube heaters, or filaments, (either word is correct) are simply connected in series. This is possible because they all will have been designed for the same filament current. The total voltages must add up to the line voltage, 117 volts. In the circuit shown in Fig. 3-1, for example, the tubes

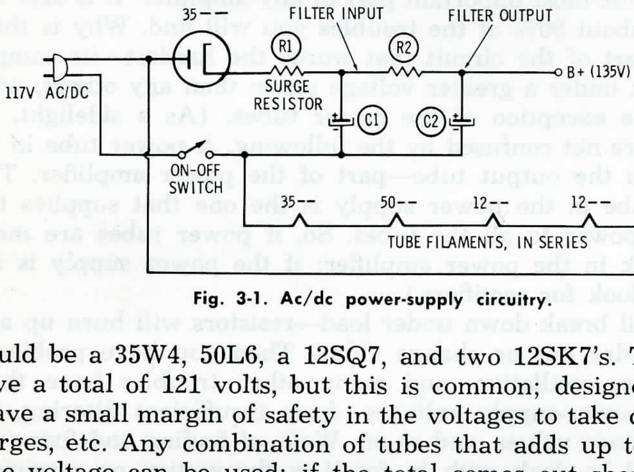


Fig. 3-1. Ac/dc power-supply circuitry.

could be a 35W4, 50L6, a 12SQ7, and two 12SK7's. This would give a total of 121 volts, but this is common; designers usually leave a small margin of safety in the voltages to take care of line surges, etc. Any combination of tubes that adds up to the right line voltage can be used; if the total comes out short, a series resistor is added to take up the extra voltage. These tubes are usually operated at about 5% below their rated voltage for longer life.

This type of power supply is called ac/dc, because it will work just as well on 117-volt dc as it will on the more common ac. Of course, the applied dc must be of proper polarity so it can flow through the rectifier to supply plate voltages (B+). Due to the fact that one side of the circuit is connected directly to the a-c line, there is always a shock hazard present when this circuit is used. If you do have one of these to work on, be very careful not to touch the chassis unless you are standing on a dry, well-insulated surface. Incidentally, a concrete floor is not an insulator—it is a well-grounded conductor.

You may have noticed that the output voltage seems to be higher than the input: 135 volts on the simple half-wave rectifier with 117-volt line input. This variation is due to the method of measurement used for the a-c voltages. See Fig. 3-2. D-c voltage is straight, but when measuring a-c voltages, one normally reads the rms value. In the operation of rectifier circuits, the filter capacitors are actually charged up to the peak value of the voltage. This is 1.414 times the rms voltage. The load on the B+ will pull this down slightly, but the output will still be higher than the numerical value (rms) of the input. This is normal, and it is just a trick of measurement and definitions.

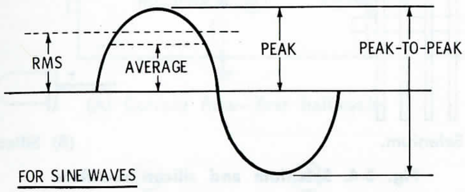


Fig. 3-2. Measuring alternating voltages.

DRY RECTIFIERS

In many sets today you will find a silicon or a selenium rectifier instead of a vacuum tube. These so-called dry rectifiers (semiconductor diodes) do not require any filament voltage, thus saving that much power. Also, their life is much longer than the vacuum-tube rectifiers that are prone to sudden failure if there is a short in the amplifier itself. Fig. 3-3 shows a typical power-supply circuit using a dry rectifier. Note that the d-c output is higher than for the comparable tube circuit since this rectifier is more efficient.

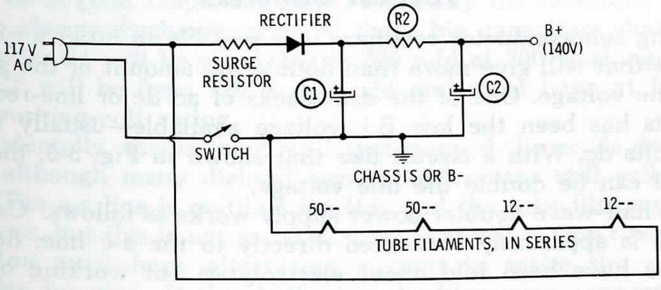
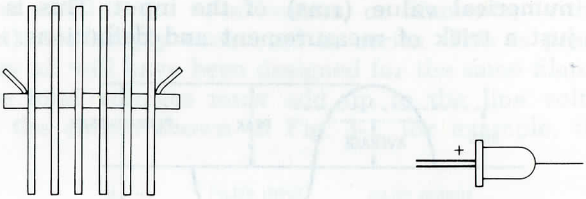


Fig. 3-3. Dry rectifier power supply.

The schematic symbol used is the same for both the older selenium rectifiers and the new silicon types. The triangle is the plate or anode of the rectifier, and the crossbar is the cathode. In this circuit the triangle (anode) is always connected to the source of a-c voltage, and the B+ comes from the crossbar (cathode). Fig. 3-4 shows the two rectifiers: the selenium types have the large cooling fins, while the silicon are much smaller and more compact. Silicon rectifiers are available in many different



(A) Selenium. (B) Silicon.

Fig. 3-4. Selenium and silicon rectifiers.

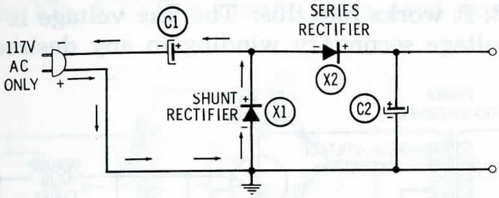
sizes and shapes other than the one shown. Voltage drop across the silicon types is much smaller than even the seleniums, and the former have almost replaced the latter in modern designs. Incidentally, you can use either one interchangeably, providing the current rating of the replacement rectifier is equal to or higher than that of the bad one you are replacing.

Note the little resistor shown in the schematics, between the rectifiers and the a-c line. This is small, usually 8 to 15 ohms and is used to hold down the first inrush of current; therefore it is called a surge resistor. Since the dry rectifiers do not have to warm up, they conduct full current as soon as the set is turned on. To keep this from damaging something, a small limiting resistor is included in the circuit.

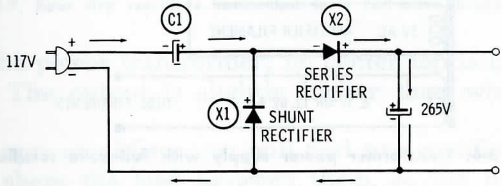
VOLTAGE DOUBLERS

Using semiconductor rectifiers it is possible to build a type of circuit that will give more than double the amount of the standard line voltage. One of the drawbacks of ac/dc or line-rectifier circuits has been the low B+ voltage available—usually about 135 volts dc. With a circuit like that shown in Fig. 3-5, the B+ output can be double the line voltage.

The half-wave doubler power supply works as follows: Capacitor C1 is apparently connected directly to the a-c line, despite all you have been told about electrolytics not working on ac. Actually, because of the circuits following it, the capacitor is not on the a-c line. On the first half-cycle of the supply voltage, current flows through shunt rectifier X1, because its plate (anode) is positive (Fig. 3-5A); this charges C1 to approximately the peak line voltage minus the drop across the rectifier. On the next half-cycle (Fig. 3-5B) the polarity is reversed, and series rectifier X2 carries the current. The line voltage is now in series with the charge on capacitor C1, so capacitor C2 charges to ap-



(A) Current flow—first half-cycle.



(B) Current flow—second half-cycle.

Fig. 3-5. Half-wave voltage-doubler circuit.

proximately the sum of these voltages. Allowing for losses in the circuit and the slight discharging of the capacitors, the output is about 265 volts dc. Effectively, the line voltage has been doubled and rectified at the same time.

The two electrolytic capacitors are the key to this doubling action; it is their charging and discharging that make the circuit work. This holds true in all voltage-doubling circuits. All parts must be in good shape, of course, especially the rectifiers, but it is the charge/discharge cycle of these big capacitors that does the trick. C1 will be about 150 to 200 mfd at 200 working volts, and C2 will be from 120 to 150 mfd and must have at least a 300 working-volt rating.

Incidentally, this is the circuit that stopped the ac/dc designation, although many diehard service technicians still call them that. The a-c line is rectified for B+, and the tube filaments are in series, but this is not an ac/dc circuit at all; it won't work on dc. You must have alternating current to make the voltage doubler function. If this half-wave doubler were connected to the wrong polarity of d-c voltage, components could be damaged. The correct name for this circuit, and all others like it, is transformerless.

TRANSFORMER POWER SUPPLIES

The power-supply circuit used in most guitar amplifiers is the full-wave rectifier with power transformer. Fig. 3-6 shows a typical circuit. It works like this: The line voltage is stepped up in the high-voltage secondary winding to any desired value. In

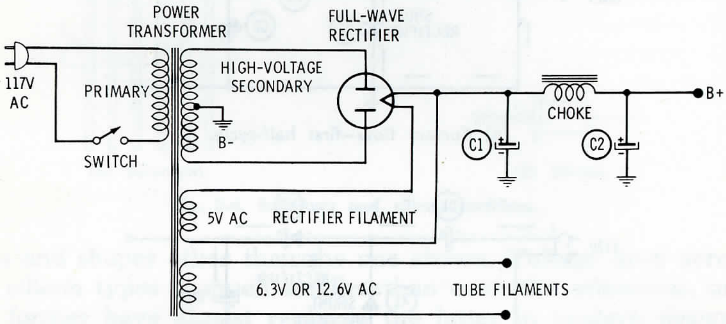


Fig. 3-6. Transformer power supply with full-wave rectifier.

the average medium-power amplifier this is about 350 volts ac, so the output is about 300 volts dc after taking off the filter and rectifier-tube voltage drops. The other tube filaments are all connected in parallel and supplied from a filament winding as shown.

The rectifier tube is a full-wave type. Both halves of the a-c wave are rectified as first one plate and then the other goes positive. This produces a small 120-cycle ripple in the rectifier output in addition to the d-c voltage. This ripple is just a little bit easier to filter out than the 60-cycle ripple that results in half-wave rectifiers, so you will find much smaller filter capacitors in this circuit compared to the transformerless types. Filters will run about 60 to 80 mfd instead of 125 to 150 or even 200 mfd in the brute-force filters needed for the others.

The center-tap of the HV winding is returned to the chassis, and this is used as B−. Filter chokes are generally used in place of resistors for better efficiency, and the d-c output is usually very smooth. Normal ripple at the filter output is less than 2.0 volts p-p, which can be considered as almost pure dc.

This type of power supply has several advantages. For one, the power transformer provides complete isolation from the a-c line, so there is no shock hazard. For another, the desired B+ voltage can be easily obtained by simply choosing a transformer with the desired step-up voltage ratio. Tube filaments are connected in parallel. If one burns out, it is easy to find since all the others remain lit. In series circuits, if one burns out, it opens the circuit and they all go out.

In some circuits you may find dry rectifiers used in place of the vacuum tube. These will sometimes be in a bridge arrangement as shown in Fig. 3-7. This circuit gives good rectification and

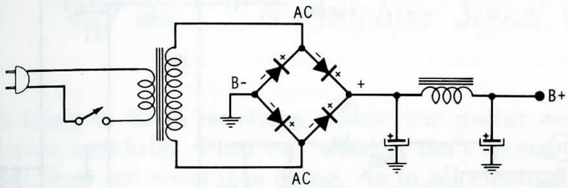


Fig. 3-7. Four dry rectifiers connected in a full-wave bridge circuit.

simplifies the power transformer; no center tap is needed on the secondary. The output is slightly higher than when a tube is used.

In the larger amplifiers you will find two rectifier tubes. This is done to share the load between them, so the tubes will last longer. In the very high-powered amplifiers, two rectifier tubes will be used on the very high voltage for the plates of the power output tubes (up to 600 volts dc), and another will be used to supply the B+ to all other stages.

Dry rectifiers are often used in straight full-wave circuits. Here you will find standard TV rectifiers connected in series to get a higher breakdown-voltage rating. If the voltage is high enough, they may even be connected three-in-series.

SPECIAL BIAS SUPPLY

A fixed-bias voltage is used for the power output stage in some of the larger amplifiers (Fig. 3-8). Follow the control grid circuits of the output tubes. They do not return to ground, as in the smaller units, but go through 1500-ohm swamper resistors (to damp out any tendency to ultrasonic oscillation) and 200K grid resistors to a special negative voltage supply. This is provided by a 50-volt tap on the high-voltage secondary of the power transformer (T1). The ac is rectified by diode D1 and filtered by the 5600-ohm series resistor, the 100-mfd electrolytic capacitor, and the 56K loading resistor across the output of the bias rectifier. Notice that the output voltage of this circuit is negative: it comes from the triangle side of the dry rectifier instead of from the bar side as in the normal B+ circuits. Bias voltage varies with the type of tubes used and their bias requirements; it is usually around −50 volts in most of the high power amplifier circuits. This fixed bias is necessary to get 5881's and similar power tubes up to their rated output.

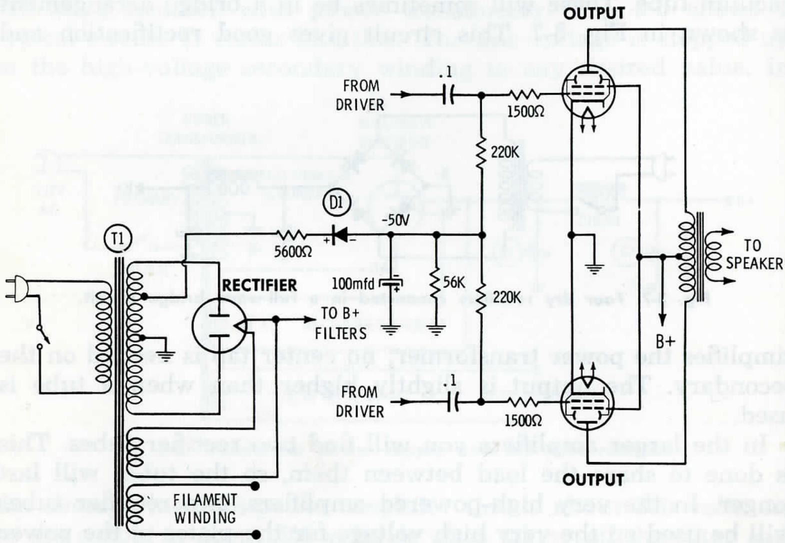


Fig. 3-8. Negative grid-bias voltage supply.

SUMMARY

There you have a complete rundown on all of the circuits used in guitar amplifiers. If you know how each one works and what it is supposed to do, then it will be a lot easier to find and fix any trouble that shows up. In the next chapter professional methods of locating and curing trouble will be explained. Diagnosis is half the battle. Anybody can fix an amplifier; it takes only the replacement of a leaky capacitor or a burned resistor and two solder joints. The trouble comes in finding the correct part to replace. This separates the men from the boys, electronically speaking.

SECTION II

Service Procedures and Techniques

4 *The Amplifier Signal Circuits*

The first thing to do in servicing an electric guitar amplifier is to look it over carefully. Find out what it isn't doing, and, just as important, find out what it is doing. As in all electronics work, the diagnosis is the hardest part. First, look for what is working; this will give you an idea as to what is not.

Troubles in amplifiers will fall into three classes; it will be dead, weak, or sound funny. This last class covers hum, oscillation, motorboating, and similar things; in other words, the amplifier is making the noises itself when it should not. The first thing to decide is in which class this trouble falls. Make the easiest possible test: turn the instrument on and listen to it.

A normal reaction in a functioning amplifier is a slight rushing sound in the speakers called "blow" (as if you were blowing very softly into a microphone). Some slight hum is also normal, especially if the input connections are open and the volume controls are turned up. All tubes should show a little light in the top, but none of them should get red hot or show any flashing between the elements. If you see the latter, turn off the amplifier immediately; there is a short somewhere in the power supply. Also, if you hear a loud hum, smell smoke, or see smoke coming from under the chassis, turn it off.

Take the easiest problem first: the completely dead amplifier. Nothing happens when you turn it on. This means that some part has completely broken down, and it is easy to find. Simply check out all circuits in the amplifier, beginning with the power supply. It doesn't take long to find a bad component with the proper tests. These tests are listed in later paragraphs.

First, look at the statistical order of failures in this kind of electronic equipment. The author's experience in actual repair operations indicates certain troubles are more likely than others. The experienced technician checks them in the order of frequency of occurrence, and he finds the trouble faster. Likelihood of failures come in this order:

1. Tubes
2. Power supply
3. Components—resistors, capacitors, and controls
4. Cables—plugs and wiring between the guitar and the amplifier
5. Transformers—output transformers, speakers, and power transformers

Remember this list, and use it; it will make the repair job a lot faster. If you find a completely dead amplifier, the first thing to look for is a bad tube. The second most likely source of failure is something in the B+ power supply, and so on in the order given.

In checking electric guitars, break the complete system down into three parts: the amplifier itself (including the speakers), the connecting cables, and the guitar (including the pickup and controls on it). Here is how to check it out. First, pull out all cables to the instruments and mikes. Turn the amplifier on, and listen for any signs of trouble. See if you can hear the normal blow or hum that means it is alive. If you do not, check at any one of the inputs. Turn its volume control all the way up, and touch the hot terminal of the jack. If the amplifier is working, you ought to hear a very loud buzz or honk noise in the speaker. There are two easy ways to make this test: One, plug in one of the cables, and touch the tip of the phone plug; this is always connected to the hot terminal on the jack. Two, make up a special test plug with the hot wire brought out to where you can touch it with a fingertip. Try this on an amplifier you know is working, and you will recognize the sound the next time you hear it.

If you hear a loud buzz, chances are the amplifier is OK, so go to the connecting cables. Plug them into the amplifier one at a time, and touch the center conductor of each cable. Again, the loud buzz says this section is functioning. Before going on, however, flex each of the cables near both connectors while touching the center conductor. Any static or break in the buzzing sound indicates there is a problem in the connector. Look over each one carefully for poorly soldered connections, broken wires, and strands of wire shorting across the connector. The section on servicing has procedures for repairing shielded cables.

When the connecting cables have been eliminated as the source of trouble, only the pickup remains. About all that can be done here is to substitute a new unit. If it is definitely established that the pickup is at fault, some effort can be made to repair it, and there are suggestions in the section on servicing as to how to proceed. Since these usually are sealed units, it is probably quickest to replace the pickup if replacements are readily available.

If you don't hear a loud buzz when you touch a hot input terminal, the amplifier is dead. Check to be sure that all volume controls are turned on in the channel you are testing. (In all servicing, you must watch out for the obvious; it is easy to overlook. For instance, if you are not careful, you may take the amplifier out of the case looking for a dead stage, and then find out that the master gain control had been turned off. Don't laugh—it has happened!)

If you can't get a sound through the amplifier from one input jack, try another one; try them all, in fact, before you pull the amplifier chassis out of the case. It may be that one channel is dead and the others are OK. If no sound is heard at all, pull the amplifier. More detailed testing will have to be performed.

Set the amplifier upside down on the bench, and make sure that the speaker is still connected. In high-powered amplifiers you can overload the output tubes and burn up a very expensive output transformer in about one minute if the amplifier is turned on without the right load (the speakers) connected. In some amplifiers you may have to rig up extension wires, but this is easy.

CHECKOUT PROCEDURES

Here is a step-by-step method of testing that will show you where the trouble is in the least possible time. This is based on actual field experience in repairing these amplifiers, so follow it as closely as you can.

1. Check the B+ voltage—most of the troubles will be found in the power supply.
2. Check the amplifier, stage by stage, for voltage on plates and screen grids. Use a d-c voltmeter for testing, set on a scale that is at least twice the maximum voltage you expect to find. For example, if there is about 250 to 300 volts of B+, then use a 500-volt scale to save damaging the meter.

When servicing, always start at the output—the speaker and output tubes—and work your way back toward the inputs. Why? Because this is the fastest way! No matter what you find in the early stages of the amplifier, you can't tell if the basic trouble is fixed unless the output tubes and speakers are working. So, start at the output. Check back through the circuit, fixing all troubles as you find them, and when you get to the input, the amplifier will be working.

When you make voltage measurements, watch the meter reading and listen also. When you touch the voltmeter prod to the plate of an amplifier tube, you will hear a small pop in the speaker if everything is working past that point. This pop won't be very loud when the plate of the power-output tube is touched, but it will be on the control grid. So, if you get the right voltage on the plate and screen, touch the grid with the prod. This should give you a louder pop, for you have gone through the circuitry of the tube, which amplifies the tiny disturbance you make when you touch the grid with the prod.

As you go toward the input, you will hear louder and louder pops. This is one of the oldest methods of troubleshooting known—it was worked out back in the early days of radio where they called it the circuit disturbance test. It is still just as good as it was then, since it works every time. As you go along, watch for the stage where there is no pop. That is where the trouble is!

Fig. 4-1 shows a partial schematic of a typical amplifier. The idea is to check the signal path by listening for pops as the volt-

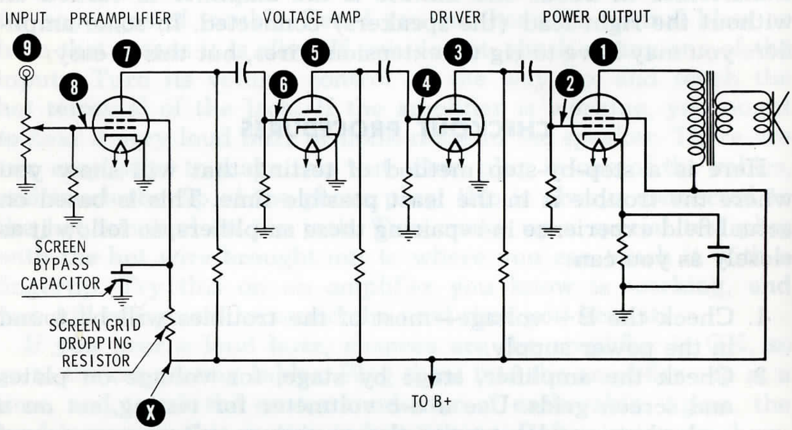


Fig. 4-1. Sequence of testing amplifiers.

ages are being checked. This path starts at the input and goes all the way through in a plain series circuit. Each time the signal passes through an amplifier stage, it gets louder (more amplification). Anything that breaks the chain will stop the signal right there. You can see the test method: Start at the output and work back toward the input. The numbers in Fig. 4-1 show the correct sequence. For this test it is assumed that the power supply has been checked and the right B+ voltage found at the filter output (X). If the output of the power supply is correct, the power supply itself must be OK, and the trouble must be somewhere in one of the amplifier circuits.

As an example, look at a typical case of trouble. Suppose you get good loud pops all the way up to and including test point #6. At point #7 you get a pretty weak pop, and hardly any at all on #8 (the control grid). This means that the trouble is somewhere in the preamp stage, and everything from there on is normal. The first step is replacing the tube—this is done simply because it is easiest and the problem could be a bad tube. If this doesn't help, leave the new tube in, at least until the trouble is found.

Next, measure the d-c voltages around the tube—plate and screen. Assume that the plate voltage is nearly OK, but there is no screen grid voltage at all. This means that there is one of two troubles: an open screen-grid dropping resistor, or a shorted screen bypass capacitor. Either one will give the same symptom. Now you start to eliminate. (All of this work is a straight process of elimination—just keep testing until you find the bad part, once the defective stage has been isolated.)

First, measure the supply voltage at point X (the supply end of the resistor) to be sure that it is there. When you look at the schematic, it would seem that the earliest checks of the power supply output would also check out this point. Remember, however, there are wires connecting the various common points in the chassis, so these wires have to be eliminated as possible points of failure, at least indirectly. Assuming the proper voltage is present at X, the fault must be in the screen grid dropping resistor or the screen bypass capacitor. Turn the set off, and take a resistance measurement with an ohmmeter from the screen-grid tube pin to ground. If the capacitor is shorted, there will be a zero reading here—a dead short. If the capacitor is good, you will get a reading of the resistance of the screen dropping resistor plus the resistance to ground through the power supply. A normal reading here is something like one to two megohms. In this kind of circuit the screen dropping resistor is usually 820K to 1.2 megohms.

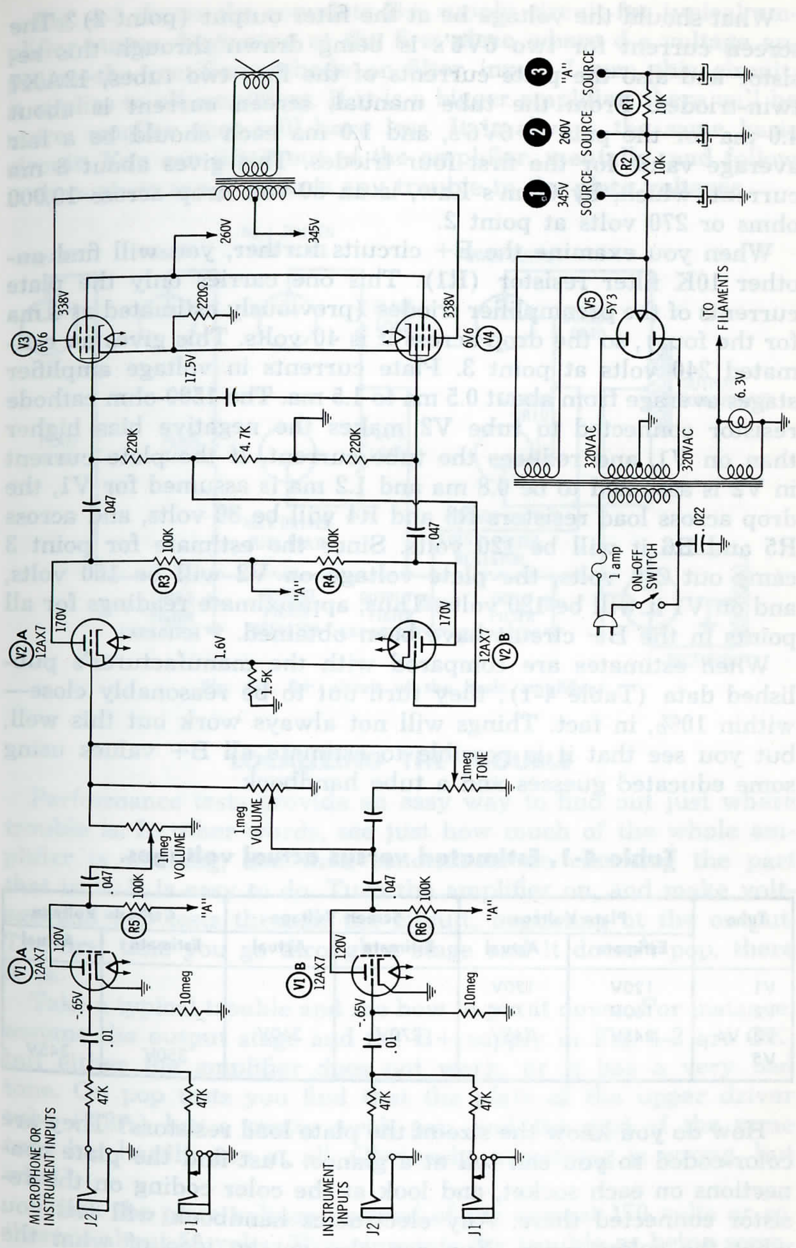
This resistor could be open, so you take your next measurement directly across the resistor itself; the reading should be the rated value. All resistors are color coded to tell what size they are supposed to be. The ohmmeter reading must agree within 10% of this. If this resistor reads completely open, there is the trouble! Replace it with another of the same size and wattage, and turn the set on. The screen grid voltage reading will be normal. The input will now pop as loud as it should, and the input jack will give a very loud buzz or honk when touched with a fingertip—if the resistor was the only source of trouble.

In the previous section you made a voltage analysis of the amplifier using information gained from the schematic diagram of the amplifier. However, at times schematics are hard to find. Now see what can be done if you must test an amplifier circuit without this information. Fortunately, most of the amplifiers are conventional and since they use the same basic circuits, you can use a model amplifier for comparison. It has been done for many years. Servicing is easier if you have the service data, of course, but you can still test an amplifier and find the trouble if you know what each stage is supposed to do and how it does it. That is the reason for so much detail in the first section. How can this information be used in checking an unknown amplifier?

Fig. 4-2 shows the schematic of a commercial amplifier. This one isn't actually unknown, but it will serve as an example. What should the normal voltages be? Incidentally, there is a very valuable feature in your favor when checking voltages in vacuum-tube amplifiers—tolerance. A tube voltage can be inside a certain range, and still be OK. For example, a tube plate voltage rated at 100 volts can measure from 90 to 110 volts and still operate without affecting the performance of that stage. This is a 10% tolerance; many voltages have 20% or even slightly more. The only voltage that is really critical is the grid bias.

When you start on the unknown amplifier, the first thing, as always, is the supply voltage. Check the B+ voltage, at the filter input (point 1 on the schematic). How much should it be? A very accurate idea can be arrived at by measuring the a-c voltage on the plates of the rectifier, and converting. With a normal load it can be assumed that the rectified voltage will be 10% to 20% above the rms voltage on the plates. In this one you will find about 320 volts rms on the plate, so an added 10% will give about 350 volts at the rectifier cathode for a guess.

In the circuit shown, a 10,000-ohm resistor (R2) is used as a filter choke, giving a fairly large voltage drop. The circuit indicates that the plates of the output tubes are connected directly to the rectifier output (filter input); their plate current will not flow through the filter resistor. This connection provides more voltage on the output tube plates; it also results in more hum. However, this hum is cancelled out in the push-pull output transformer, so this circuit is a practical arrangement to get a bit more plate voltage and consequently more output. Here the power-tube plate voltage will be very close to the voltage found on the rectifier cathode, or about 345 volts, since the only drop is in the output transformer.



Courtesy Gibson Electronics

Fig. 4-2. Schematic of Gibson Model GA-6.

What should the voltage be at the filter output (point 2)? The screen current for two 6V6's is being drawn through this resistor and also the plate currents of the first two tubes, 12AX7 twin-triodes. From the tube manual, screen current is about 4.0 ma for the pair of 6V6's, and 1.0 ma each should be a fair average value for the first four triodes. This gives about 8 ma current, which, by Ohm's Law, is an 80-volt drop across 10,000 ohms or 270 volts at point 2.

When you examine the B+ circuits further, you will find another 10K filter resistor (R1). This one carries only the plate currents of the preamplifier triodes (previously estimated at 4 ma for the four), so the drop across it is 40 volts. This gives an estimated 240 volts at point 3. Plate currents in voltage amplifier stages average from about 0.5 ma to 1.5 ma. The 1500-ohm cathode resistor connected to tube V2 makes the negative bias higher than on V1, and reduces the tube current. If the plate current in V2 is assumed to be 0.8 ma and 1.2 ma is assumed for V1, the drop across load resistors R3 and R4 will be 80 volts, and across R5 and R6 it will be 120 volts. Since the estimate for point 3 came out 240 volts, the plate voltage on V2 will be 160 volts, and on V1 it will be 120 volts. Thus, approximate readings for all points in the B+ circuit have been obtained.

When estimates are compared with the manufacturer's published data (Table 4-1), they turn out to be reasonably close—within 10%, in fact. Things will not always work out this well, but you see that it is possible to estimate all B+ values using some educated guesses and a tube handbook.

Table 4-1. Estimated versus actual voltages.

Tube	Plate Voltage		Screen Voltage		Cathode Voltage	
	Estimate	Actual	Estimate	Actual	Estimate	Actual
V1	120V	120V				
V2	160V	170V				
V3, V4	345V	345V	270V	260V		
V5					350V	345V

How do you know the size of the plate load resistors? They are color-coded so you can tell at a glance. Just find the plate connections on each socket, and look at the color coding on the resistor connected there. Any electronics handbook will tell you what the colors mean. You can also get an idea of what the normal plate voltage should be from the typical operating conditions table given for each tube in the tube manual.

Fig. 4-3 shows the complete B+ supply circuit for typical amplifier stages, beginning at the first place where d-c voltage appears—the rectifier cathode or filter input. Learn this circuit; it applies to all amplifiers. If it is a bigger amplifier, there will be more; smaller ones will have less. It is always the same basic circuit. You can lift it out of the amplifier, mentally, and follow it through to see if there is any trouble in the plate voltages.

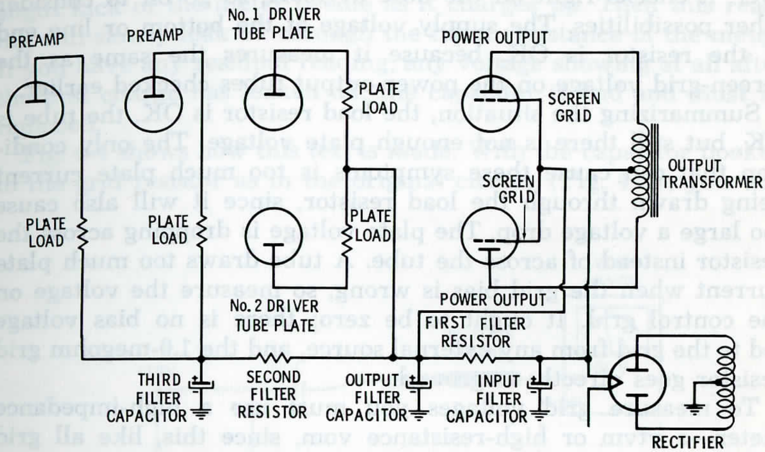


Fig. 4-3. B+ circuit of the basic amplifier.

LOCALIZING THE TROUBLE

Performance tests provide an easy way to find out just where trouble is. In other words, see just how much of the whole amplifier is working, and then concentrate on checking the part that isn't. It is easy to do. Turn the amplifier on, and make voltage and pop tests through the circuit, beginning at the output. The first time you go through a stage and it doesn't pop, there it is.

Take a typical trouble and see how to pin it down. For instance, assume the output stage and the B+ supply in Fig. 4-2 are OK, but either the amplifier does not work, or it has a very bad tone. On pop tests you find that the plate of the upper driver tube (V2A) has a pretty weak pop, and the grid of the same tube has hardly any at all. Obviously, something is wrong, but what?

Check the plate voltage; instead of the normal 170 volts or so, there is about 50 volts. This pinpoints the trouble as being somewhere in the driver stage. The first thing to check is the tube, so replace it—simply because this is the easiest thing to do, and experience has shown that tubes cause a lot of troubles. However, the results are the same, so the tube must have been OK.

To proceed, look at the B+ supply circuit in Fig. 4-2. Note that the plate voltage of this tube is fed through a 100K plate-load resistor (R3). Turn the amplifier off, and measure the resistance of this resistor. If it has opened up or increased in value, the symptoms would be exactly what have been described. However, it checks right on the nose at 100K, so go on to consider other possibilities. The supply voltage at the bottom or line end of the resistor is OK, because it measures the same as the screen-grid voltage on the power-output tubes checked earlier.

Summarizing the situation, the load resistor is OK, the tube is OK, but still there is not enough plate voltage. The only condition that can cause these symptoms is too much plate current being drawn through the load resistor, since it will also cause too large a voltage drop. The plate voltage is dropping across the resistor instead of across the tube. A tube draws too much plate current when the grid bias is wrong, so measure the voltage on the control grid. It ought to be zero; there is no bias voltage fed to the grid from any external source, and the 1.0-megohm grid resistor goes directly to ground.

To measure grid voltages you must use a high-impedance meter—a vtvm or high-resistance vom, since this, like all grid circuits, is very high impedance. A low-resistance meter will cause the voltage present to be incorrect, since the meter itself acts as a shunt.

Assume that there is about 5 volts positive on the grid. This is definitely wrong. No grid in this type of amplifier ever reads positive if it is in good shape. It will be either zero or slightly negative. A 5-volt positive bias on a grid will cause the tube to draw a very heavy plate current; thus, the plate voltage will drop very badly because of the excess drop across the plate-load resistor.

Where could this voltage come from? Only a one-megohm resistor and a coupling capacitor are connected to this grid. The resistor goes straight to ground, so this is not a very likely source of voltage; however, the coupling capacitor is connected to the plate of the preceding tube, and this tube has about 120 volts positive on its plate. This is a likely suspect.

In all cases a capacitor must be a completely open-circuit to d-c. The capacitor is used to transfer the a-c signal voltages from the plate (output) of one stage to the grid (input) of the one following; it must always block any d-c from getting through. (Although the correct name for these is coupling capacitors, you will find them called blocking capacitors in some cases.)

From the symptoms that have been assumed, it looks as if the capacitor must be leaking d-c onto the grid. To make sure, disconnect the grid end of the capacitor, and hook the dc-volts probe of a vtvm to the open end. Now turn the amplifier on to get a positive voltage on the connected end of the capacitor. If it is leaking, there will be a positive voltage reading through the capacitor. A normal capacitor with good insulation will give just a very slight kick of the meter needle as it charges up. Then this reading will slowly leak off through the input resistance of the meter. If you have any residual reading, any voltage showing at all after the first charge has leaked off, the capacitor is bad and must be replaced.

Fig. 4-4 shows how this test is made. With the capacitor hooked to the grid resistor as in the original circuit (Fig. 4-2), you will

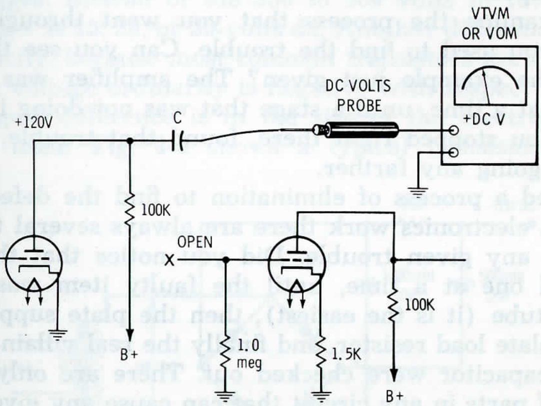


Fig. 4-4. Testing a coupling capacitor for leakage.

probably read 5 to 6 volts d-c. With the capacitor disconnected, you may read as high as 35 to 40 volts positive dc on it. The input resistance of the vtvm (11 megohms average) is much higher than the 1-megohm grid resistor. If you use a vtvm for this test, set it on a low d-c volts scale. If you use a vom, set it on a voltage scale that will carry the maximum voltage to be read. In this case it is the 120 volts on the preceding tube plate. You can't blow up a vtvm with a voltage overload, but you can damage a vom, so be careful. After the first charging kick, set the meter to a lower voltage scale. For the final test use the lowest scale available; even one volt positive through a coupling capacitor means it must be replaced.

You cannot make a leakage test with a common ohmmeter. The actual leakage through these capacitors is very small. If you could measure it, the resistance would go up to almost 100 megohms (far above the capacity of a service ohmmeter), but the capacitor will still leak enough to cause a lot of trouble. The voltage test is sure and fast, so use it.

Capacitor leakage is a very common trouble; that is why it is used as an example. It will cause loss of volume, a very bad distortion, and even damaged tubes if the leakage is bad enough. All of these problems result from the change in the grid bias voltage. The amplifier tubes are driven into a very nonlinear part of their operating range, and the tone suffers very severely as a result. In fact, after a little practice you will almost be able to identify the problem by listening to the amplifier. Leaky coupling capacitors give the tone a characteristic muffled sort of sound that is easy to spot.

Now examine the process that you went through and the methods you used to find the trouble. Can you see the orderly steps in the example just given? The amplifier was examined one stage at a time, until a stage that was not doing its job was located. You stopped right there, found that trouble, and fixed it, before going any farther.

You used a process of elimination to find the defective component. In electronics work there are always several things that can cause any given trouble. Did you notice that things were eliminated one at a time, until the faulty item was reached? First the tube (it is the easiest), then the plate supply voltage, next the plate load resistor, and finally the real villain, the leaky coupling capacitor were checked out. There are only a certain number of parts in any circuit that can cause any given trouble. Patiently eliminate them one at a time, and eventually you will find the right one. You may find it the first time; on the other hand, you may have to go all the way, as you did in the example. Just keep on until you find it. Later in this book there are more elaborate tests using complicated equipment. However, you will find that in this, as in all other electronics work, the majority of the troubles can be located and fixed with only very simple test equipment plus a good bit of plain old common sense. This is because a very large percentage of troubles are simple ones: a dead tube, a burned resistor, a leaky capacitor, and so on. Even the more complicated troubles will have very simple causes.

Always remember the process of elimination, and use it. If you know how each circuit works, you can quickly find the one that is not working, and start from there. There are some other tests later in this book that will help in the more difficult cases.

TRANSISTOR AMPLIFIERS

Up to this point, most of the discussion has been concentrated on vacuum-tube amplifiers. The first guitar amplifiers used tubes, and there are uncounted thousands of tube amplifiers still being built and in service. Lately, the transistor has been showing up in amplifiers. The transistor amplifier very seldom requires service: that is, in the internal circuits of the amplifier itself. There are no filaments, so heat to damage components is practically nonexistent; operating voltages are much lower, so the high-voltage shorts that plague tube circuits are practically never found. As in tube amplifiers, most of the troubles show up in the power supply.

Transistor power supplies differ slightly from tube types since the transistor amplifier usually needs only a single voltage to run all stages. Instead of the 350 to 500 volts in tube circuits, transistor B+ is 15, 20, or 30 volts dc. Another difference is noted in the polarity, because most common transistors are PNP's, and the supply voltage ordinarily is negative with respect to ground.

The biggest difference is in the size of the electrolytic filter capacitors used. Fig. 4-5 shows a typical transistor amplifier

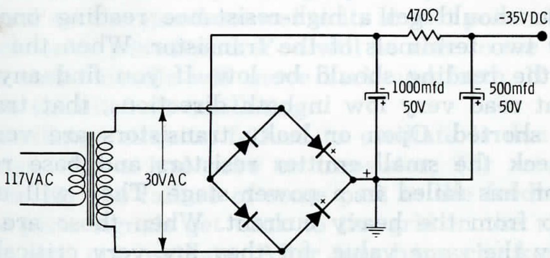


Fig. 4-5. Typical transistor amplifier power supply.

power supply. Note the capacitors: C1 is a 1000-mfd unit, and C2 is a 500-mfd; sizes up to 2000 or 2500 mfd are common. Why? The transistor is a current-operated device rather than a voltage device like the tube. This puts a greater demand on the regulation of the power supply. Intermittent heavy current drains on peaks of music must not cause a voltage drop in the power supply, since this would cause a very bad distortion. The very large capacitors act as reservoirs. They must have sufficient capacitance that they can discharge through the load circuit and hold the output voltage up on heavy peak currents. Voltage-regulated circuits with regulating transistors and Zener diodes are used in many amplifiers.

If you find trouble in a transistor amplifier, check the power supply first. If there is any doubt as to whether the trouble is actually in the power supply, try another one. Disconnect the original, and feed the same voltage, with the same polarity, to the amplifier; see if this cures the trouble. This is a positive test. Most troubles will be caused by weak or open filter capacitors. The best test in these cases is to disconnect the old unit and bridge one known to be good across the circuit. Low voltage capacitors have a tendency toward fairly high leakage, as compared to the higher voltage units. Resistance measurements are of little help, because of the extremely low impedance of the power supply; you will read a short everywhere.

Measurement of power supply output current with an ammeter is about as good a test as you can get on a transistor amplifier. The normal current will usually be given on the label or the schematic. If you should have a 2.4-ampere rating and the amplifier draws 5 amperes, then something is wrong. Probably in a case like this the problem is leakage in a bypass capacitor or a short in one of the output transistors.

Output transistors are the same as those used for power-output stages in auto radios; they can be checked in the same way. Take the transistor out (most plug in), and check it with an ohmmeter. You should get a high-resistance reading one way between any two terminals of the transistor. When the prods are reversed, the reading should be low. If you find any two terminals that read very low in both directions, that transistor is internally shorted. Open or leaky transistors are very seldom found. Check the small emitter resistors and base resistors if a transistor has failed in a power stage. They will usually be burned up from the heavy current. When those are replaced, use exactly the same value, for they are very critical. If a resistor calls for 3.6 ohms, don't put in a 4.0-ohm unit; use a 3.6-ohm resistor. Bias on transistors is usually measured in tenths of a volt, so you can see why these resistors must be exactly right.

Transistor amplifiers can be signal traced through from the output to the input in exactly the same way as vacuum-tube types. After the power supply is checked out, feed a small audio signal into all transistors, starting at the output. The signal is normally fed to the base, because most units use the grounded-emitter circuit. The base is then equivalent to the grid of a vacuum tube (input), the collector to the plate (output), and the emitter to the cathode. If you find a stage where the signal stops entirely, check it out. Measure voltages around that stage, check resistors, and check electrolytic capacitors. Don't replace the transistor until everything else has been thoroughly checked out. In field service the author has found very few actually defective transistors in the preamplifier and driver stages of amplifiers.

Vibrato, tremolo, and echo circuits work exactly like the corresponding tube circuits and can be checked in the same way—by testing input and output for signal with a voltmeter. In transistor circuits the bias voltage from a tremolo is probably applied to the base of one of the early amplifier stages.

Transistors are seldom microphonic because of their construction. Any trouble with microphonics probably involves the guitar pickup. Cables and other apparatus work in exactly the same way as they do on tube amplifiers.

TROUBLESHOOTING THE TREMOLO CIRCUITS

The first symptom of trouble in the tremolo circuit will be the absence of any tremolo effect in the tone. With the strength control wide open the tone will still be plain. This can be chased out just as you would any other trouble. The first thing to check is the tremolo oscillator tube. Replace it and see if this helps. If it does not, then see how far the tremolo signal is going.

You will not need a scope to trace such a low-frequency signal. Put your voltmeter on the plate or cathode of the tremolo oscillator tube, and set the speed control to its lowest point; this will be only a cycle or so per second. You will be able to see the oscillations—the meter needle will move back and forth. If it remains steady, the circuit isn't oscillating.

In all oscillator circuits, failure to oscillate is due to one of three things: (1) a bad tube or transistor, (2) wrong supply voltages, or (3) the failure of some part in the feedback loop—unless the plate signals get back to the grid in the right phase, the circuit will not oscillate. After you have checked the tube by substitution, check the plate voltage to make sure it is all right. If it is not, then find out why—open plate resistor, open depth or strength control, etc. If there is plate voltage but still no oscillation, check all of the capacitors in the feedback loop. If one of them is open, it will open the loop.

A leaky capacitor here will change the phase shift angle; the oscillator will work, but on the wrong frequency. So, if it is working much too fast or slow, check the capacitors in the feedback loop. Also check for any drift in the value of the resistors; they are equally important in making the thing work on the right frequency. Use the same servicing methods here that you did on the amplifier stages earlier; there are only a few parts in the circuit, and if the oscillator does not work, then some component must be defective.

If the oscillator is working as shown by the swinging of the meter needle, but there is no tremolo effect, signal trace the varying voltage. Start at the plate where the signal is OK, and follow it through the various parts until you find where it is being blocked. In the circuit of Fig. 2-10 the tremolo signal comes from the 12AX7 oscillator, through the 250K depth control, a 750K resistor, and a .1-mfd capacitor, and is applied to the screen grid of the 5879 second preamplifier stage.

You can follow the voltage swings up through the control and the 750K resistor, and even through the capacitor onto the screen grid itself, if they are very slow. Failure of any part in the circuit will show up right away. For example, if the .1-mfd capacitor gets leaky, it will change the screen grid voltage. There is about 90 volts on the plate of the tremolo oscillator and only 20 on the 5879; a leak in the capacitor would result in the screen grid voltage going above normal. Incidentally, if you get a peculiar action in this circuit—the tremolo is working but isn't working right, or you can't get enough depth or strength—check that 6.8 megohm resistor. If it has increased in value, it will reduce the screen grid voltage and upset the action of the tremolo. A key clue here will be the fact that without any tremolo being used, the amplification of that channel is very low, since there is no screen-grid voltage at all. It can even work very peculiarly—you may not be able to get any signal at all through that input unless the tremolo is turned on. Always suspect any big resistors you may find in these circuits. Many servicemen have a habit of thinking, "Oh well, 6.8 megohms. What if it does drift a little off value? It's so big that it won't make any difference!"

This is not so. Most of the very large resistors are critical, especially if they are used in a B+ voltage distribution circuit as this one is. When they do drift, they seem to want to increase in size most of the time. Many of these have been checked and found to be up to 10, 12, or even 20 megohms in value, when the color code stated plainly that they were supposed to be 3.3, 6.8 megohms, and so on. Don't ever overlook these resistors—that just might be the trouble.

VIBRATO

A true vibrato is very hard to get electronically, so all manufacturers use the mechanical type; a tailpiece on the guitar can be moved very slightly back and forth by a long lever. Troubles here are mechanical. Frankly, the author has encountered very little trouble in this assembly, but it is always possible. One of the bearings or suspension brackets can wear or become loose, and this would lead to some odd troubles when the vibrato lever was moved.

REVERBERATION CIRCUITS

Troubles in the reverberation units are typical—plenty of signal (volume), but no reverb effect at all. Check tubes, voltages, capacitors, and resistors, and follow the signals through the reverb unit just as you would through any other amplifier. Leaky coupling capacitors in tube units can cause a very odd distortion: the straight signal will not be distorted but the delayed signal will. Open electrolytics in transistor units can cause trouble; so can shorted transistors. Check base and emitter voltages very carefully on transistors to make sure that the bias is OK. Since this is only a few tenths of a volt, incorrect bias can be easily overlooked.

The reverberation unit springs must be left severely alone. Because of their construction, they can seldom be repaired successfully in the field. There are only two things that go wrong with these: failure of the transducer or failure of the pickup unit. In either case the defective unit must be replaced which involves taking the springs out and putting them back later. This inevitably causes them to get stretched, and their delay time changes very drastically. Since no service shop has the facilities for testing delay times in milliseconds, the best thing to do with a defective reverb unit is replace it with a new one. Some manufacturers have service facilities where the bad unit can be sent back for repairs.

Reverb units are easy to test so you can be sure that the unit is definitely defective. Simply feed a signal into the grid of the reverb input tube, and check to see if it is coming through the reverb unit and is getting to the grid of the reverb output tube. If the circuit is confusing, the direct path circuit can be broken by disconnecting a resistor. That way you know that any signal you get must be coming through the reverb unit itself. Broken wires are not uncommon, and these, of course, can be repaired; as long as the delay springs are not disturbed, you can do anything you have to.

5

The Power Supply

No amplifier can work unless the power supply is providing the correct voltages and currents. Be sure that it is OK—check it first in every service job. It is the part of the circuit that works the hardest, so it will have the most troubles.

Some typical circuits were discussed in Chapter 3. Almost all of the amplifiers now use the power transformer circuit. However, you will find the transformerless type occasionally, and it is simpler, so it is listed first.

THE TRANSFORMERLESS CIRCUIT

Fig. 5-1 shows the circuit of a typical transformerless power supply with the parts named. It is simple but effective. The rectifier converts ac into a pulsating dc by allowing only one half of the voltage to get through—those half-cycles which make the anode (plate) of the rectifier positive. These half-cycles of voltage charge the input filter capacitor up to the peak value of the a-c line voltage, which will be about 150 volts with a 117-volt line. This drops slightly because of the load current drawn by

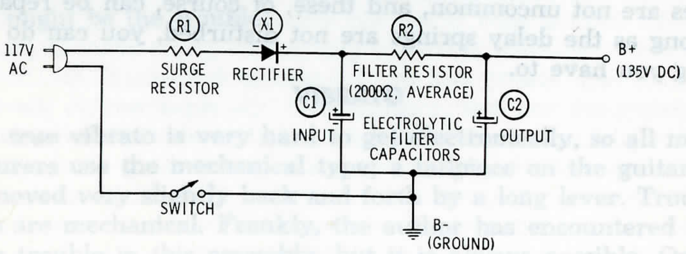


Fig. 5-1. Transformerless power supply.

the amplifier, and the usual d-c output voltage, under load, will be about +135 volts as shown.

What kind of troubles can develop in this circuit? One is capacitor failure. Electrolytic capacitors can dry out and become open. If the input capacitor opens, the voltage will drop very badly—to between 40 and 50 volts in most cases. The input filter capacitor acts as a reservoir; it holds a charge as the half-cycles of voltage are fed to it from the rectifier. If it will not hold a charge (if it is open), then the voltage has no place to be stored, and the output falls very badly. This filter is sometimes called a reservoir capacitor for this reason.

A quick test for an open input electrolytic is as follows: If you find a circuit with very low voltage at the rectifier, simply bridge another capacitor across the filter input to take the place of the one you suspect to be open. Hook a d-c voltmeter across the output. If the voltage jumps back up to normal when the new capacitor is shunted across the old, the original one is definitely bad; replace it.

If the output filter capacitor opens, you will notice very little difference in the output voltage, but there will be a noticeable increase in the hum. The main job of this capacitor is to take out the last of the a-c ripple and leave the B+ as fairly smooth dc. If it fails, you will hear a loud hum. The same test as before is used: bridge another capacitor across it. Listen to the hum. If the old one is bad, you will hear the hum drop to an almost imperceptible level. Again, replace it.

Most power supplies have dual filter capacitors; that is, both capacitors are in one can. If one fails, always replace both of them. The condition inside the can that caused one to fail will quickly cause the remaining one to go, too. Don't take chances--always replace the complete unit if any section of a multiple-unit capacitor fails. You will find as many as four in a single can in the larger amplifiers; change them all, for safety.

The rectifiers can fail, also. If selenium rectifiers—the ones with the large cooling fins—are used, they can get weak and develop too much voltage drop across the rectifier itself. This, of course, drops the B+ output voltage. You will naturally suspect the input filter capacitor, for this is a more common trouble; when bridging the old filter does not bring the voltage back up, check the rectifier.

You can bridge a selenium rectifier just as you did a filter capacitor: connect a new rectifier, being very careful to get the right polarity (+ to +, − to −), directly across the suspected one, checking the output voltage at the same time. If the new rectifier brings the voltage back up to normal, replace the old one.

If the much smaller silicon rectifiers are used, you will not find this kind of trouble. Silicons are made in various shapes, but have no cooling fins. You can always identify them by their very small size. They will never get weak and show low output voltage because of their construction. When they fail, they are like the little dog—they die all over. In other words, they short out completely.

A shorted rectifier lets the a-c line flow to the input electrolytic capacitor. Since an electrolytic is a very effective short circuit to ac, a large current will flow, and the surge resistor will blow. As a matter of fact, that is part of its job. These are specially-built wirewound resistors or chemical resistors, and they are designed to blow out just like fuses if there is a current overload. They are called fusible resistors. If a surge resistor does burn out, be sure to replace it with a resistor of the same value and type, for it is designed to give the power supply circuit exactly the right amount of protection against overloads.

You will find short circuits in the loads too. If a bypass capacitor or one of the power tubes shorts out, you may find a blown surge resistor. Always check carefully before replacing rectifiers and/or fusible resistors to find out what caused the fuse to blow. Make ohmmeter tests from the B+ point to B−, directly across the filter capacitors. If you get less than about 12,000 to 15,000 ohms, disconnect the B+ circuit from all loads and recheck. This amount of resistance is normal across one of these power-supply circuits; it is the leakage resistance of the very large electrolytic capacitors used. By reversing the ohmmeter prods, you will find that one way there is a much higher resistance; this is because you have hooked up the ohmmeter (with its built-in battery) with the right polarity, and the electrolytics will not show as much leakage current. The 12,000-ohm reading is a minimum; if you get less than this, disconnect parts, one at a time, until you find which one is causing the trouble.

If you get an amplifier where you cannot locate the trouble from the ohmmeter reading, disconnect the load, leaving the B+ supply all by itself, and turn on the amplifier. If you get the normal voltage reading, or quite a bit more (due to the lack of loading), the power supply is OK. The short is in some of the load circuits, and you have eliminated the power supply as a suspect. Use the process of elimination again to find the defective component.

Electrolytic filter capacitors used in transformerless power supplies are very large. You will find values like 80 to 100 mfd in the input, and 60 to 80 mfd or more in the output. These will have working voltages of 150 volts dc, and they will usually be in the same can. When you replace a filter, be sure to get as close to the original values as possible. However, filter capacitors are not too critical; you can change from the original values as long as you use larger ones. For example, 100 mfd is a good replacement for 80 mfd, but 60 mfd might allow some hum to creep in.

Watch out for output filter capacitors with a high power factor. This happens when the capacitor gets a little too old and starts to dry up, losing some of its capacitance. Since the filter capacitor also acts as a bypass capacitor for all other circuits in the amplifier, this can cause an increased hum level, and can even allow the amplifier to go into oscillation or motorboat (a slow "put-put-put" oscillation, sounding very much like an old motorboat).

In a few cases, to get a positive check on filters with a high power factor, you will have to disconnect the old capacitor entirely and substitute a new one across the terminals of the circuit. Sometimes the old capacitor develops a fairly low series resistance, and this can upset the tests. To make sure the old filter is bad, substitute a new one.

TRANSFORMER-POWERED CIRCUITS

Most of the larger electric guitar amplifiers use power transformers; this is done because much higher voltages can be obtained, and the always-present shock hazard in line-connected circuits is eliminated. Fig. 5-2 shows a typical power-transformer B+ supply with parts named.

Notice that the filter system is like the one used on the transformerless type, except a filter choke is used in place of the

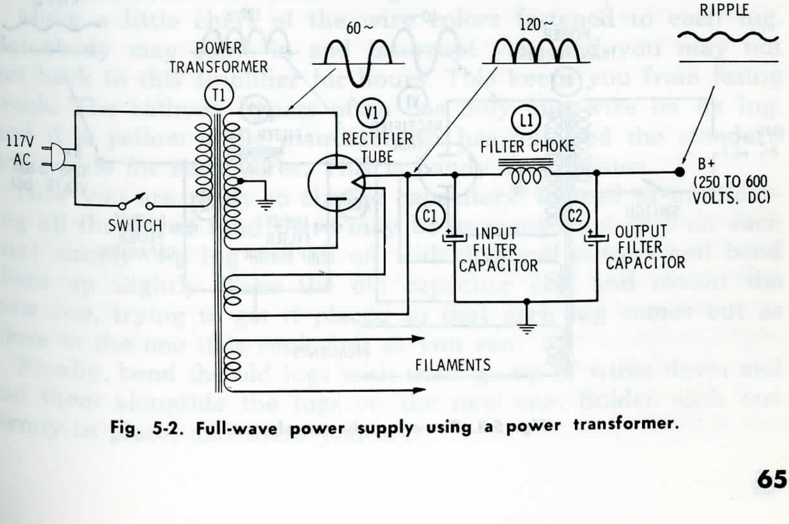


Fig. 5-2. Full-wave power supply using a power transformer.

resistor. The choke gives much better filtering action, and has far less voltage drop. The average d-c resistance of a filter choke is about 40 to 50 ohms instead of the 2000 ohms of a filter resistor.

When a choke is a part of the filter, smaller filter capacitors can be used without reducing the filtering action. You will find sizes like 20 to 30 microfarads in the input and 40 to 60 microfarads in the output. The schematic (Fig. 5-2) is for a full-wave rectifier; both halves of the incoming a-c voltage are used. There is no 60-cycle hum in this power supply. By folding up the other half of the a-c cycle, there results a basic 120-cycle hum or ripple component. Remember this: it is used in further troubleshooting tests. After a little practice you will be able to tell the difference between 120-cycle hum and 60-cycle since the latter is definitely lower pitched and smoother. Fig. 5-3 shows the folding up of the a-c voltage in the full-wave rectifier and the 120-cycle hum component (ripple) at the output.

B+ output voltages are much higher in transformer power supplies. You will find from 250 volts to 450 volts in common use, and in some of the very high powered amplifiers there is up to 600 volts d-c output at the filter. So, filter capacitors must have a much higher working voltage rating; in such circuits never use units with less than 450 working volts. Check the voltage shown on the schematic or measure it in the actual amplifier circuit, and use a capacitor that will stand it. A good rule is to use a capacitor with a working voltage at least 100 volts above the normal voltage.

Capacitor troubles are the same in transformer as in transformerless power supplies. An open input filter capacitor causes

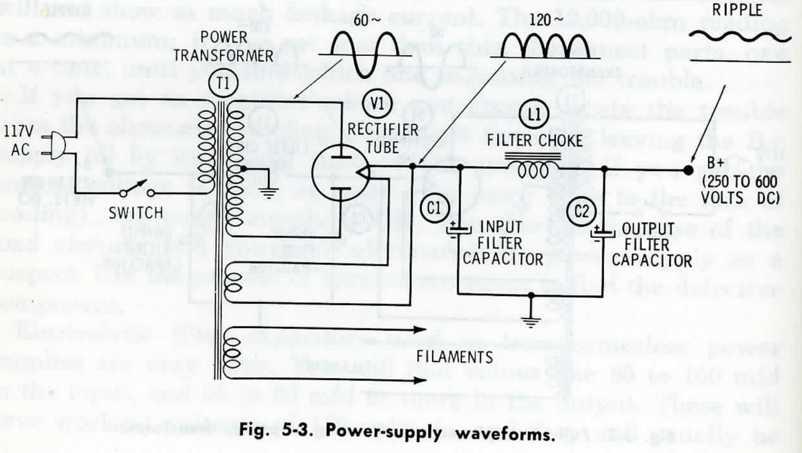


Fig. 5-3. Power-supply waveforms.

the B+ voltage to fall off a lot; in a full-wave circuit the drop is to about half the normal voltage. Test for it in the same way: Bridge a capacitor known to be good across the suspected unit, and see if the voltage comes back up to normal. Always replace the whole thing when one section of a multiple unit is bad.

Bad output filter capacitors will cause hum, oscillation, or both in the amplifier. Use the same check as before: Bridge with a good one and listen to the hum. Open input filters ordinarily do not cause as much increase in the hum level as open output filters. However, this is not always true, so check both input and output capacitors if you have too much hum.

REPLACING ELECTROLYTIC CAPACITORS

If you do find an open electrolytic capacitor, you will have to replace it. Many amplifiers use multiple units, having as many as four sections in a single can. There is a trick you can use on this to save time. Get a replacement capacitor as near to the same value as possible and with the same type of mounting. Leave the old unit in the circuit until you have done the following.

Check the position and especially the working voltage of each section of the new units. Many will have three high-voltage capacitors and one low-voltage unit (for cathode bypassing) in the same can. You do not want to hook up the 50-volt cathode bypass to a 400-volt circuit—the capacitor has a tendency to explode! Check to make sure just which ones are high-voltage types. All sections are coded by small punchouts in the fiber insulator on the lug end: triangle, square, half-moon, and plain. The values corresponding to each mark are stamped on the side of the can—the capacitor size and rated voltage.

Make a little chart of the wire colors fastened to each lug. Somebody may come in and interrupt you, and you may not get back to this amplifier for hours. This keeps you from losing track. The cathode bypass often has only one wire on its lug, and it is yellow if the manufacturer has followed the standard color code for such wires. This is handy as a locator.

Now you are ready to change capacitors. Instead of unsoldering all the wires (and there may be as many as 4 or 5 on each lug) simply clip lug and all off with diagonal cutters and bend them up slightly. Take the old capacitor out, and mount the new one, trying to get it placed so that each lug comes out as close to the one it is replacing as you can.

Finally, bend the old lugs with their group of wires down and lap them alongside the lugs on the new one. Solder each one firmly in place, and there you are.

SHORT CIRCUITS

Short circuits in the B+ supply network are a common trouble. Looking back at Fig. 4-3 you can see how the B+ voltage is fed to all tube plates and to screen grids (if they are used). There will be numerous bypass capacitors throughout this network; they are not shown in Fig. 4-3 to simplify the drawing. However, they are a source of a lot of the shorts, so they must be checked. Fig. 5-4 shows one bypass capacitor circuit. This might be the screen-grid bypass of a pentode driver tube, for instance.

What happens if the bypass capacitor suddenly develops a very low leakage resistance? Current flows through the capacitor

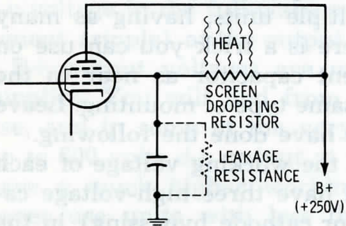


Fig. 5-4. Capacitor leakage overheats dropping resistor.

where none should flow at all, adding to the normal current through the dropping resistor. The resistor promptly gets very hot, giving a good clue to the nature of the trouble. Look for hot resistors—not just warm or even uncomfortably hot to the touch (some resistors normally run that hot). Look for the ones that are smoking. Resistors on which the color-coding paint is burning off are definitely overloaded. There are several tests that point directly to the trouble if you find a "hot one." First, turn the amplifier off, and check the resistance readings on both sides of the resistor. Normally, you will get a fairly low resistance on the B+ side of the resistor since you are reading through the leakage resistance of the electrolytic capacitors in the filter. However, going to the load side of the resistor (the screen grid), you ought to find the normal value of the screen dropping resistor, plus the first reading.

If you get approximately 25,000 ohms on the B+ side and about 5000 ohms on the load side, look out. Disconnect the capacitor, and take the second reading. Also check the resistance from ground to the open end of the capacitor itself; in fact, this is usually the first test made. If you get any resistance reading at all across the capacitor, it is bad. Replace it.

The axiom for troubleshooting in RC circuits is: Always check for a short on the load side (not the B+ side) of a hot resistor. This is a simple and obvious test, but it is surprising how many men will not make it correctly. You will find RC networks used all over the amplifiers, especially in B+ circuitry. Take the time to learn how to check them out correctly, and you will find many of the troubles very rapidly.

LOW B+ VOLTAGES

Sometimes you will find an amplifier that is very weak—not enough volume. This is a common trouble, so it deserves close study. The first thing to be suspected, as always, is the tubes. Replace the rectifier tube and the power output tubes, because these are the hardest working tubes and the most likely to be weak. If this does not help enough, replace the other tubes, one at a time. This will cure most weak amplifiers, since weakness is caused by tubes more often than by anything else.

Tubes are not the only cause, however. If tube replacement fails, check the B+ voltage; this is the next most common cause. Measure the B+ to see whether it is up to normal. If you do not have a schematic, check the a-c voltage on the rectifier tube plates (one plate to ground, not plate-to-plate) and add a correction factor of about 10 to 15%, which is the normal amount the rectified output voltage is above the rms a-c input. A plate-to-ground measurement of 320 volts ac should result in a rectifier cathode output of 350 volts to 370 volts dc with load connected. Likely power-supply troubles have been discussed previously.

If the B+ is up to normal (and it must be before you go any farther with this testing), start looking for something off in the rest of the circuits. Most likely suspects are plate load resistors that have increased in size in any of the voltage-amplifier circuits. If a 100K plate resistor rises to about 750,000 ohms, it cuts down on the plate voltage of that tube and the amplification. Check them against the color-coded value printed on each one.

A good quick check for off-value load resistors is the plate voltage. Make a fast run through the whole amplifier, looking to see if all plate voltages are about normal. After a little practice you will be able to do this very quickly since these are not critical (within about 10 to 15%). For instance, if you see a stage with a 100K plate resistor and you know that the supply voltage is about 175 to 200 volts, then you expect to have about 100 to 120 volts on the plate. If your voltmeter needle swings up to around 100 volts, don't even wait for it to stop; go on. This is not the one, most likely. What you are looking for is one with only about 35 to 50 volts, or no plate or screen-grid voltage at all.

Watch out for filter resistors, especially those secondary filters used to isolate preamplifier stages from the rest of the amplifier. Resistor R1 in the schematic of Fig. 4-2 is an example. If this increases in value, all plate voltages fed from the load end of this resistor will be low, and so will the gain and volume. Leakage in the electrolytic capacitors used to filter the load end of these resistors also causes low supply voltage. In this case the resistor will be very hot, giving a good clue to the source of trouble.

If the low volume complaint is also accompanied by some bad audio distortion and the tone is very mushy, look for a leaky coupling capacitor between two stages. In fact, most really good technicians make it a practice to check the grid voltages on all voltage-amplifier tubes. If you find even the slightest trace of positive voltage (even half of a volt), check that coupling capacitor; it is probably getting ready to break down. Always use replacement capacitors with ample voltage ratings. No coupling capacitor should ever have less than a 600 working-volt rating to get a low leakage characteristic. Some of the cheaper amplifiers will have 400-volt capacitors installed as they come from the factory; these ought to be replaced by the sturdier 600-volt types whenever possible for longer service life.

TESTING POWER TRANSFORMERS

Now and then you get an amplifier with the power transformer smoking or bleeding wax from the bottom. This means one thing definitely: The power transformer has been very badly overheated. However, it does not necessarily mean that it is burnt out.

There are two things that happen to power transformers that cause overheating: (1) an internal short in the windings, which is hopeless since it can't be repaired, and (2) an external short such as a shorted filter capacitor or rectifier tube that has overloaded the transformer and made it overheat. In the latter situation, it is still good unless it has gotten so hot that the insulation inside has broken down.

Here is how to find out. Take off all loads from the transformer: take out all of the tubes, and if the amplifier uses silicon or selenium rectifiers, disconnect these. With all external loads removed, a good transformer will draw practically no current at all. When disconnecting leads for testing, don't unsolder them; clip them off near the terminals, leaving a short piece of the original wire on the terminal so that you can tell the color code. If a new transformer is necessary, you can disconnect the rest of the lead and follow the color coding when installing the new unit. This makes the job faster.

If you have a wattmeter, plug the transformer into it, and apply power. If the transformer is OK, it will not draw enough current to give a reading. The only input current that flows in this condition is the iron loss; this is never more than about one or two watts in a well-designed transformer. However, if you see as much as 25 to 50 watts indicated and you are sure that all external loads have been removed, the transformer is internally shorted and must be replaced.

You can make up an emergency wattmeter that will give you the same answer; Fig. 5-5 shows how. It is not precise, but it will

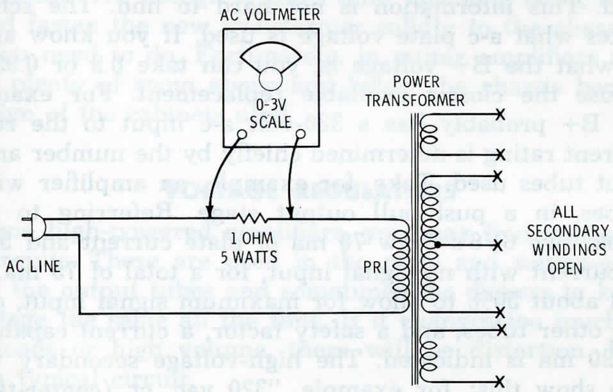


Fig. 5-5. Emergency wattmeter circuit.

tell you what you need to know. Hook a non-inductive 1-ohm resistor of about 5 watts in series with one side of the input a-c line to the primary. Put an a-c voltmeter across the resistor, and you can read the voltage drop, which is directly proportional to the a-c current through the resistor. Any appreciable current being drawn by the transformer will give you a reading. A 1-volt drop across a 1-ohm resistor means that 1 ampere of current is flowing; 1 ampere of current at roughly 100 volts (approximate line voltage) equals 100 watts of power being used by the transformer. Power is figured by multiplying current times voltage.

There is still a third way. Take off all loads and turn the amplifier on; let it sit on the bench for about 10 minutes. If the transformer gets hot, it is shorted internally. If it is badly shorted, you will know it right away; you will hear it hum inside, and smoke will start to come out very shortly.

Replacing Power Transformers

To make replacements faster after the old transformer has been definitely proven bad, leave it on the chassis until the new transformer is at hand, ready to install. If the old transformer uses non-standard color coding, trace the circuits (filament, plate, etc.) and make up a scratch-paper list of the colors and where each one goes. This is a great time saver.

If you cannot get a replacement transformer from the manufacturer that is an exact duplicate or if you do not have the time to wait, you can figure out what size is needed. This requires that three things be determined: the electrical ratings of the transformer, the physical size, and the shape and kind of mounting used. This information is not hard to find. The schematic designates what a-c plate voltage is used. If you know approximately what the B+ voltage is, you can take 0.9 or 0.95 times it and use the closest available replacement. For example, a 350-volt B+ probably has a 320-volt a-c input to the rectifier. The current rating is determined chiefly by the number and type of output tubes used. Take, for example, an amplifier with two 6V6 tubes, in a push-pull output stage. Referring to a tube handbook, two 6V6's draw 70 ma of plate current and 5 ma of screen current with no signal input, for a total of 75 ma. When you add about 50% to allow for maximum signal input, current through other tubes, and a safety factor, a current capability of about 120 ma is indicated. The high-voltage secondary will be rated to show this: for example, "320 vac, ct (center-tapped), at 120 ma" or "200 ma," or whatever is necessary. You can always use a higher current rating, since this is the maximum current that the transformer can supply. Do not go over the peak a-c voltage rating, however. If you do, there can be trouble; a higher than normal B+ voltage for the circuit will blow filter capacitors, bypass capacitors, and so on. Stick within about 10 volts of the original. If you must miss it, take one rated 10 volts lower rather than 10 volts higher.

Filaments are easy; just add up the filament currents of the tubes. Most amplifiers use all 6-volt tubes, or 12-volt tubes with the heaters connected for 6 volts. Get a transformer with a 6.3-volt winding at so many amperes. For instance, seven tubes drawing 0.3 ampere each add up to 2.10 amperes, so a transformer with a 6.3-volt winding rated at 3.0 amperes (safety factor) would be needed.

If one 5U4 rectifier tube is used, the transformer must have an additional filament winding "5.0 volts at 2.0 amperes." If two 5U4's are used, the voltage will be the same but the current must be doubled (to 4.0 amperes), and so on. If dry rectifiers are used, there will be no need for this filament winding on the power transformer.

If a bridge rectifier made up of silicon or selenium rectifiers is used, the high-voltage winding will not need the center tap used on full-wave tube rectifier circuits since the B–, or negative return, for the power supply is taken off at one terminal of the bridge. If the transformer you get has a center tap on this winding (probably a red/yellow wire), simply tape it up and forget it.

Get a transformer with the same physical size and mounting if you can; it makes mounting the new transformer a lot easier. However, if you cannot get the right mounting, other types are simple to convert, though it takes time. Get long bolts, brackets, etc., and fasten the new transformer solidly to the chassis; that is all you need to do. Fortunately, in guitar amplifiers there is usually plenty of room above and below the chassis because of the design of the cabinets used.

VOLTAGE REGULATORS

In some high-powered amplifiers, you may find voltage-regulator circuits. These are used in the plate and screen-grid circuits of the output tubes and sometimes the drivers to keep the B+ voltage the same all the time. If it changes too much under heavy loads or high volume, there will be distortion. Fig. 5-6 shows a typical circuit.

The basic principle of this is simple. The B+ supply is connected directly to the plates of the high-power output stage so that it is not regulated. Another tube (the voltage regulator) is connected in series with the screen grids of the power output tubes and other stages ahead of this point. A tube is chosen for this that is capable of carrying the total currents of all regulated stages. The B+ voltage supply goes to its plate, and the other tubes are all actually connected to its cathode.

This circuit puts the plate resistance of the voltage-regulator tube in series with the stages using the regulated B+ supply. The tube acts as an automatically variable resistor. If the supply voltage goes up, the plate resistance automatically increases to cause a greater voltage drop; the regulated output stays the same. If the voltage goes down, the opposite happens; the regulator tube reduces its plate resistance, taking less of the voltage.

How does this happen? Notice that the control grid of the 6V6 regulator is connected to a voltage divider of a 150K and a 100K resistor in series; the top of the divider is B+, the bottom, is ground. The grid always has two-fifths of the B+ as bias at all times. The bias voltage controls the amount of plate current drawn by the tube, and thus controls the tube plate resistance. If the B+ voltage rises (goes more positive), then the bias rises with it, and the tube draws more current, increasing its plate resistance, and vice versa.

Voltage-regulator circuits are not hard to service. Check the voltage input and output of the regulated stages; if it is within limits, the regulator is probably OK. If it is quite high or low, then check the regulator. Replace the tube first, and, if this does not help, turn the amplifier off and measure the resistance of the voltage-divider resistors. These are pretty critical since the ratio between the two determines the amount of bias and the action of the regulator tube. If one is replaced, the other should also be replaced at the same time. Use at least 10% tolerance resistors for this; 5% is even better.

To test these resistors for heat drift, hook an ohmmeter across each one, and heat it up by holding the tip of a hot soldering iron on the body of the resistor until it is good and hot. If the resistance changes more than a very few percentage points, replace it. They must never drift over 5%. Use high-quality resistors, and always use at least the same wattage rating as the original.

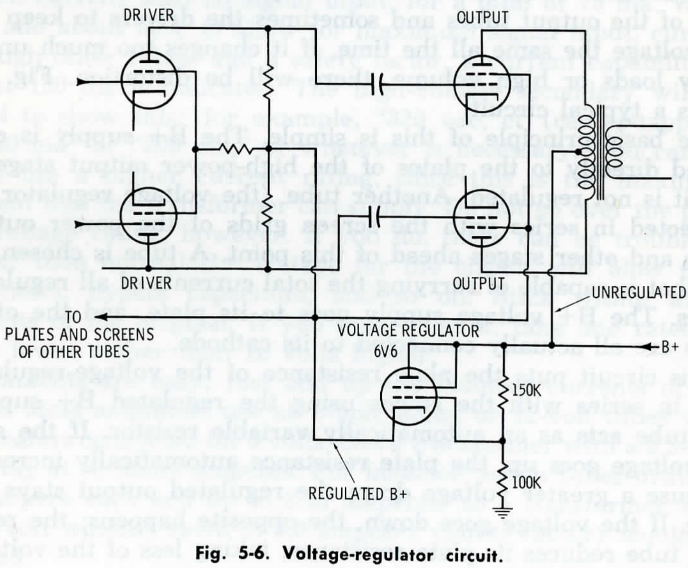


Fig. 5-6. Voltage-regulator circuit.

Voltage-Regulator Tubes

There are several tubes made especially for voltage regulation. Different regulated output voltages (75, 90, 150 volts, etc.) are available. They are gas-filled tubes—basically diodes. The circuit of Fig. 5-7 shows how they work. Until a certain value of positive voltage is applied to the plate, the tube does not conduct current at all. Once this value is exceeded, however, the tube fires and begins to conduct heavily. To use it for voltage regulation, a resistor is placed in series with the tube, connecting the plate to the full B+ voltage.

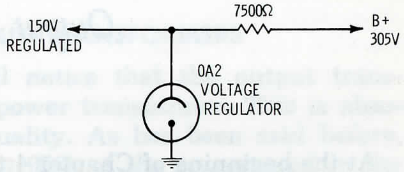


Fig. 5-7. Voltage-regulator tube circuits.

This circuit is used in several commercial amplifiers. When the voltage on the tube plate reaches the ionization value, the tube fires. This acts as a partial short across the circuit, and the tube draws current from B+ through the 7500-ohm resistor. This current is enough to cause a voltage drop across the resistor, so the regulated output drops to the rated value—150 volts with a type OA2 tube.

If the B+ voltage rises above normal, the OA2 conducts more current and a higher voltage drop appears across the 7500-ohm resistor. The output voltage stays at 150 volts. If the B+ voltage falls below normal, the OA2 tube conducts less current, and the voltage stays at 150 volts just as before. Voltage-regulator tubes will hold the voltage constant over a range of 5 to 30 ma of current through the tube itself, taking care of any normal variation in supply voltage.

If the voltage at the output of a VR tube circuit is not correct, replace the tube, and check the dropping resistor.

6

Output Transformers and Speakers

At the beginning of Chapter 4 there is a list of types of failures in guitar amplifiers arranged by the frequency of their occurrence. Way down the list—on the bottom, in fact—are speakers and output transformers. Defects in these components are not encountered every day in a servicing operation. Unless there is physical evidence of trouble here—an output transformer dripping wax or a badly-torn speaker cone—these parts are not normally tested directly. They become suspect only when the output stage is definitely working but there is absolutely no sound coming from the speaker.

TESTING FOR TROUBLE

In the preliminary checking of a defective amplifier the power output stage is used as a starting point. Previous chapters have described the normal "blow" and hum heard from the speaker of a properly operating amplifier. When this is not present, the power-output stage is examined for defects. Should checking reveal that this stage is functioning correctly, then attention is focused on the output transformer and the speaker as possible sources of trouble.

If a defective output transformer or a speaker is causing a dead amplifier, there will most likely be an open winding on one or the other. Speakers are quickly checked with an ohmmeter after one terminal is disconnected from the circuit. When the resistance of the voice coil is measured, listen for a click as the test probes are touched to the speaker terminals. If you hear it, you can be certain that the speaker is working.

While the speaker is disconnected, measure the resistance of the output transformer secondary. Shorted turns or even a shorted winding are almost impossible to spot with an ohmmeter, but a defect here is much more likely to be an open rather than a short. The primary of the output transformer has been checked out when voltage was measured on the plate of the output tube. As long as voltage is present here, the primary cannot be open.

So far, then, the tests in this section have been just to determine whether the components are good or bad. The speaker and output transformer can be the source of distortion; this is discussed in later paragraphs.

REPLACING OUTPUT TRANSFORMERS

In better amplifiers you will notice that the output transformer is almost as big as the power transformer. This is absolutely necessary to get good quality. As has been said before, the output stage dissipates about 95% of the power used in the whole amplifier. To be able to handle this kind of power without distortion, a big transformer with lots of iron is needed. This eliminates the core saturation that is responsible for distortion.

When an output transformer is replaced, check the schematic and the parts list. The type of tubes used and their operating voltages determine the wattage rating of the output transformer. For example, two 6V6's, with 250 volts on both plate and screen, are rated at 10 watts output. Two 6L6's, with 360 volts on the plates and 270 volts on screens, have an output of up to 45 watts. Check the tube manual to see what power you need.

To find a suitable replacement output transformer you must have other information besides the wattage rating. Its primary winding impedance must match the load resistance (sometimes called load impedance) of the output tubes used, and the secondary winding must match the voice-coil impedance of the speakers. The 6V6's mentioned have a plate-to-plate load impedance of 10,000 ohms. With these tubes and a 16-ohm speaker the rating would be "Push-pull plates, 10,000 ohms, to 16-ohm voice coil, 10 watts." Replacement transformers are available from many different manufacturers, all of whom publish very detailed catalogues with lists of output transformers of all sizes, shapes, and variety of ratings. Standard PA-type output transformers can be used; the only difference between them and the regular guitar-amplifier output transformers is in the number of extra taps on the secondary winding. They have provision for hooking up 4-, 8-, and 16-ohm speakers, a 500-ohm output, and so on. Simply use the leads you need and leave the rest open.

INVERSE FEEDBACK

Most of the larger amplifiers use inverse feedback in order to reduce distortion and give a better tone. The feedback voltage is often taken from one side of the output-transformer secondary winding at a speaker connection (Fig. 6-1 shows how this can be connected). The voltage that is fed back must be of the right polarity; it should produce degeneration instead of regeneration. (Regeneration causes oscillation, and degeneration stops it.)

If you replace an output transformer and turn the amplifier on, only to get a deafening howl, turn it off and change the polarity of the feedback voltage—move the feedback connection to the other end of the voice-coil winding. This reverses the polarity; opposite ends of a transformer winding are 180° out of phase with each other. In Fig. 6-1 note that a ground is shown on the end marked "B" of the voice-coil winding. To reverse the feedback connection, move the ground to A and the feedback to B. The voice coil, being nonpolarized, can be left where it is. Do not move just the feedback; this grounds out all inverse feedback, and the tone will suffer. You might notice a little increase in volume with the arrangement; inverse feedback cuts the gain but helps the tone quality.

As a final precaution, never turn on an amplifier for testing without some kind of load hooked to the output-transformer secondary. If you do, the impedance in the power-output stage will be so far off that you may burn out the output transformer in just a few seconds. The stage is set up to work with an 8-ohm or a 16-ohm load across the secondary so that the primary winding will have the proper loading.

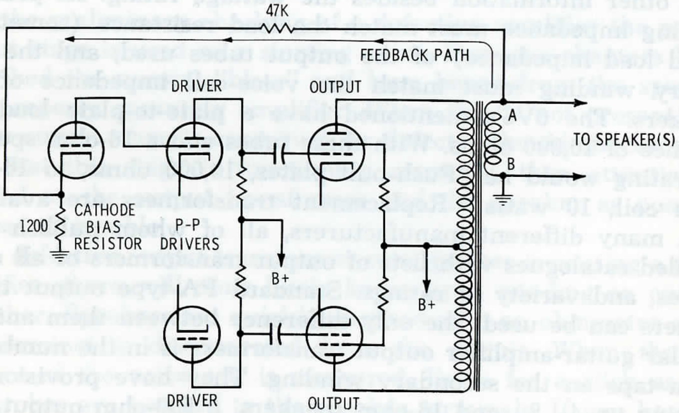


Fig. 6-1. Inverse-feedback connection on output-transformer secondary.

MEASURING OUTPUT POWER

Now and then you will have to test an amplifier to see if it is capable of delivering full power output. This test is also handy for finding out if an amplifier is really weak, or if the low volume comes from some other cause, such as a defective pickup.

The first step is to find out what the actual power output should be. Disregard any advertising claims, check the circuit, and turn to your tube handbook. If you find a pair of 6V6 tubes with about 250 volts on the plates and screens, the maximum power output is about 10 watts. Most amplifiers are honestly rated, but now and then you will find one that is puffed up. If you know how to obtain actual values, you will not waste time looking for power that was never there to start with.

What is needed is some kind of load on the amplifier so you can measure power. The speakers will not work; you can't stay in a room with 10 watts of true audio power. Use a dummy load that has the same resistance as the speakers used on the amplifier. (By the way, this figure is usually stamped on the loudspeaker somewhere.) So, use either an 8- or 16-ohm load resistor. To handle high powers, this must have a rating of at least 50 watts. Such resistors are available in army surplus electronics stores, etc. Many of these will be adjustable, so you can use any resistance needed.

To get the power output of an amplifier, hook up the load resistor and feed in a sine-wave signal from an audio signal generator or from an audio test record and a record player. Connect an a-c voltmeter across the load resistor, and turn the amplifier wide open. Take the voltage reading, and you can figure out the watts from the formula,

$$P = \frac{E^2}{R}$$

where,

P is the power in watts,
E is the a-c voltage across the load resistor in volts,
R is the resistance of the load resistor in ohms.

There is a quick and dirty check you can make for power output. Hook a regular incandescent lamp across the output, especially if the amplifier has a 500-ohm or a 70.7-volt tap on the output transformer. (This will be found mainly on PA amplifiers, however.) Now turn the amplifier on, feed a tone signal into it, and watch the lamp. If you can light a 15-watt lamp to pretty good brightness across the output of a 10-watt amplifier, it is probably putting out plenty of power. Match the wattage of the

Here advantage is taken of the basic characteristics of inductance and capacitance. A capacitor has a very high impedance at low frequencies that gets smaller as the frequency increases. The inductance has exactly the opposite effect: high impedance at high frequencies, very low at low frequencies. If components are hooked up as shown in Fig. 6-2A, the capacitor will let the lows go only to the woofer while feeding the highs through to the tweeter. In the series circuit (Fig. 6-2B) the high frequencies are bypassed around the woofer by the capacitor so that they appear across the inductance. Reverse the action for lows: the lows are bypassed across the tweeter by the inductance and blocked by the capacitor so that they have to go through the woofer.

Troubles in Speakers

All speakers are dynamic types. A voice coil, which is a hollow cylinder with a small coil wound on it, fits over a magnetic pole piece so the coil is suspended in a magnetic field (Fig. 6-3). The voice coil actually moves back and forth in a very narrow slot. If the cone warps or the voice coil touches the sides of the slot at any point, a distorted, harsh, scraping sound comes from the speaker.

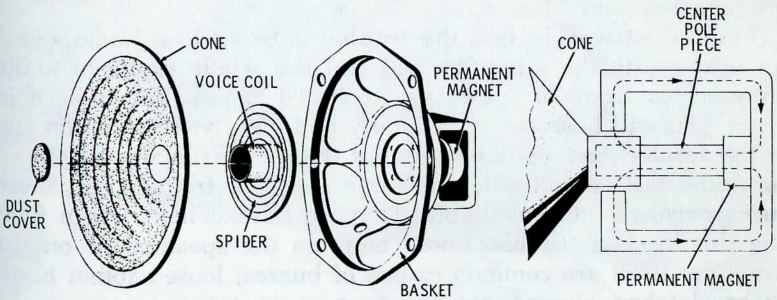


Fig. 6-3. Construction of a PM speaker.

To test for this, place your fingertips on both sides of the cone at once, and push straight in and out. Listen to the sound: you shouldn't hear anything at all if the voice coil is floating freely. If it is dragging, you will hear a scraping sound. Trouble is usually caused by dampness that warps the cone or voice-coil form. There is no cure for this: modern speakers can not be re-aligned, as the old ones could. However, you can always have the speaker reconed at far less than the cost of a whole new one. This is especially true in the case of the heavy-duty speakers in high-powered amplifiers. Magnets never wear out, so if you replace the cone and voice coil assembly, the speaker is as good as new. Usually radio parts houses do this kind of work.

Since speaker cones are basically paper, they deteriorate with age and then crack, especially under high volume. This can cause a crackling or buzzing sound on certain notes. If the crack is caught in time, it can be patched with cement. Don't use the so-called "speaker cement"—this dries out, turns hard, and usually breaks loose at one edge. After a while the speaker buzzes worse than it did before. The best cement the author has found for repairing speaker cones is rubber-to-metal cement. It stays flexible indefinitely and sticks very well. Never use scotch tape for patching cracks—it will dry up, come loose, and buzz horribly. If you must make emergency repairs to a speaker, use surgical adhesive tape; this has very sticky adhesive and is flexible.

FALSE SPEAKER TROUBLES

Now and then you will find an amplifier that will buzz when certain chords or notes are played on the guitar. This may sound like speaker trouble, and in some cases it is, but not always. The most common cause of this kind of trouble is something loose in the cabinet; this hits a harmonic resonance on certain frequencies, and buzzes.

The fastest way to find the trouble is to feed an audio signal generator into the amplifier and run the whole range of audio frequencies from 20 cycles up to 20,000 cycles. Somewhere in there you will hear the buzz loudly and clearly. If an audio signal generator isn't available, get out the record player and put on an audio test record with the same range of frequencies; there are several of these available. They do an excellent job in finding this kind of trouble. Loose bolts on the speakers or on the amplifier itself are common causes of buzzes; loose cabinet hardware—latches, clamps, etc.—may cause it, too.

7

Cables and Pickups

Not all servicing problems involve the amplifier chassis; there are occasions when parts mounted on the guitar need repair. Disassembly is usually fairly obvious; once the plastic or chromed cover plates are removed, all the electronic parts are exposed (Fig. 7-1). Be very careful in handling the guitar. Keep the

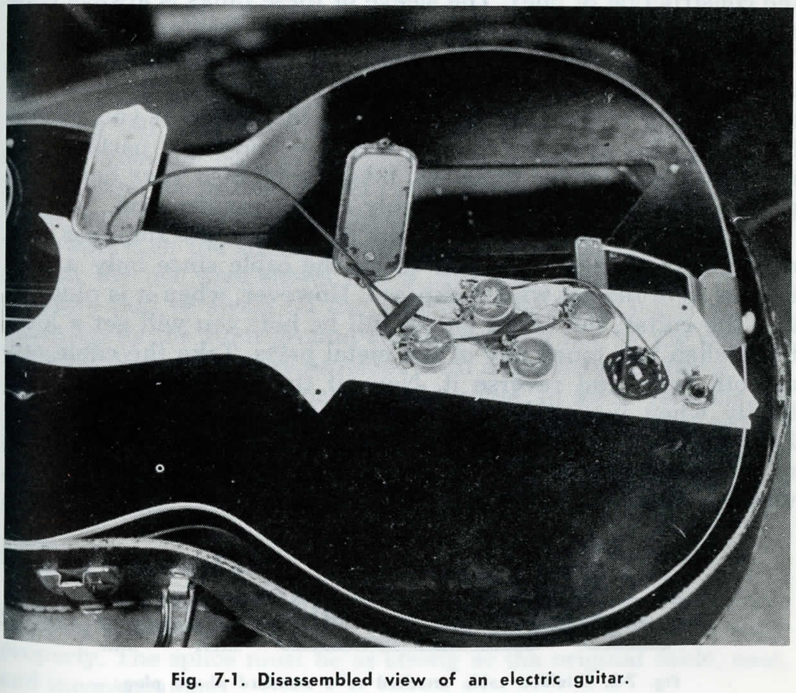


Fig. 7-1. Disassembled view of an electric guitar.

finish protected as you would the most expensive TV cabinets. You might try leaving the guitar in the case while you work on it.

MICROPHONE AND INSTRUMENT CABLES

One important feature of electric guitar systems is the use of shielded cable for all connections between the guitar, microphone, remote (foot) volume controls and the amplifier. This is absolutely necessary in order to keep these sensitive circuits from picking up hum and noise. You need to know how the cables are made and to find ways of repairing them if they give trouble.

Because they are flexible and because they get hard wear from being rolled up, stepped on, pulled, and jerked, cables often break. If the hot wire (center conductor) breaks, the instrument will simply go dead. If the ground (shield) is pulled loose, the amplifier will give a very loud hum when this cable is plugged in; that is the key clue to cable trouble. When hum troubles are being checked out, the first thing to do is pull all cables out of the input jacks to find out whether the hum is in the amplifier itself or in an ungrounded cable.

Most guitar amplifiers use standard phone plugs (Fig. 7-2 shows the construction of one). The sleeve of these plugs is always connected to ground and the tip to the hot wire (center conductor). This provides an easy way to check for a broken cable: plug it into an amplifier input, turn the volume up on that channel, and touch the tip of the plug that goes into the guitar. If you hear a loud buzz, the cable is OK. If you get a loud hum, particularly if the hum gets louder when you hold the cable in your hand, the ground connection is open, probably at the amplifier end.

If the cable ground is open at the guitar end, the amplifier will not hum too badly when you check the cable since only a half inch or so of the hot wire is exposed. However, when it is plugged into the guitar, the whole guitar will be hot: you will get a loud hum when you touch any of the metal parts. Take the cable out at both ends, and reverse it. Now, if the amplifier hums very loudly when you grab the cable, you have found the trouble. Hint: because of the flexing of the cables, you will find almost all cable troubles located in the six inches at either end. This is where it takes the sharpest bending in use.

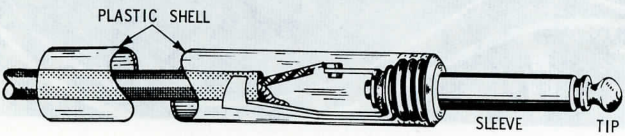


Fig. 7-2. Shielded cable attached to a standard phone plug.

Installing Phone Plugs

There is a right way and a wrong way to install a phone plug. Here is the right way. Prepare the wire by cutting off the insulation for about an inch and a half: ring the jacket with a very sharp knife, being careful not to cut through the braided shield. Now pull out a pigtail from the shield (Fig. 7-3A). The easiest way is to double the cable very sharply just at the end of the jacket, then work a pointed tool such as a soldering aid through the braid, parting the strands but not breaking any more than you can help (Fig. 7-3B). Work the inner insulator and wire out through this hole. Pull the braided shield left empty out into a pigtail. This will not unravel, and it will give you a sturdy ground connection (Fig. 7-3C).

Trim the insulation off the hot wire *very* carefully so as not to cut the very fine inner conductor. In most cables you will find a silk inner wrapping which is hard to get off. The easiest way is to burn it off with a match or cigarette lighter (Fig. 7-3D). Then scrape the inner conductor very delicately, twist the strands together, and tin them with a clean soldering iron (Fig. 7-3E).

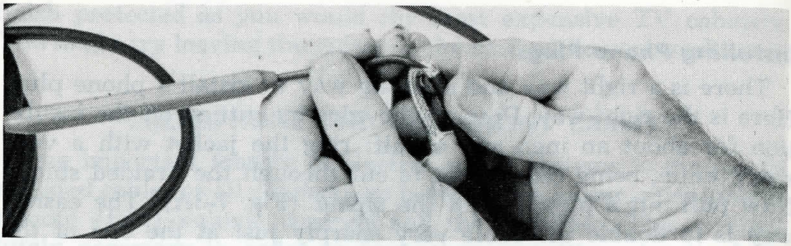
Next, put the shell of the plug on over the cable. Be sure that it is right end to. It's embarrassing to have to take the plug off just to reverse the shell—it's even more embarrassing to forget it completely, so watch it.

Solder the hot wire to the terminal going to the tip of the plug. You can tell which one this is; it will always be obviously insulated from the body of the plug. Also, it will be in the center. Next, fasten the ground pigtail to the sleeve terminal (Fig. 7-3F).

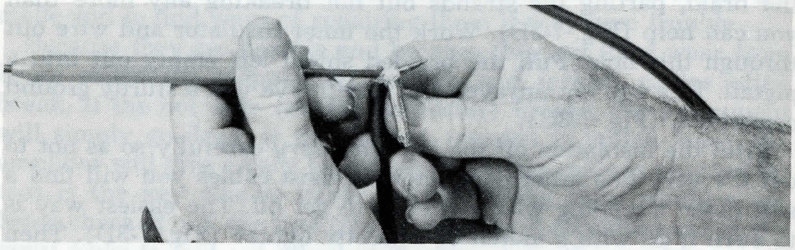
For long life the most important point in wiring a connector is to be sure that the strong ground pigtail is pulled tightly enough so that the hot wire shows just a little bit of bend. This means that any pull or strain on the plug and the solder joints will be taken up by the stout ground connection and not by the delicate hot wire. Some plugs are provided with a strain-relief clamp. This is fastened to the outer jacket of the cable. In some versions the jacket slips through a sleeve at the back of the plug and is held in place by being wrapped with strong linen thread. Other plugs can be wrapped with this thread if you want to make a good strong connection (Fig. 7-3G).

Splicing Coaxial Cables

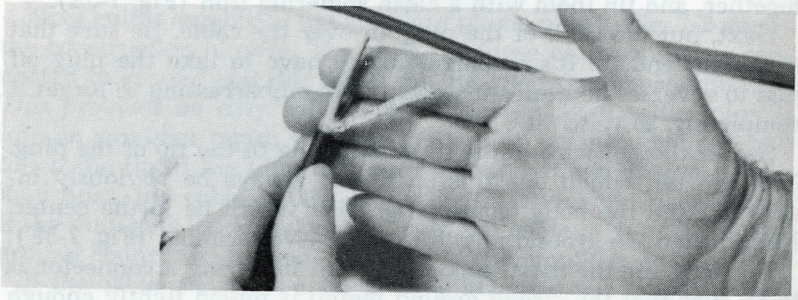
There is a right and wrong way to splice broken cables, too. Splicing must be done correctly every time if the cable is to work properly. The splice must be as strong as the original cable, neat, and inconspicuous.



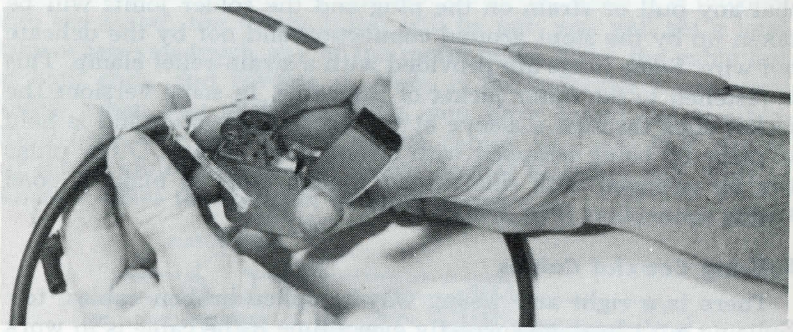
(A) Step 1.



(B) Step 2.

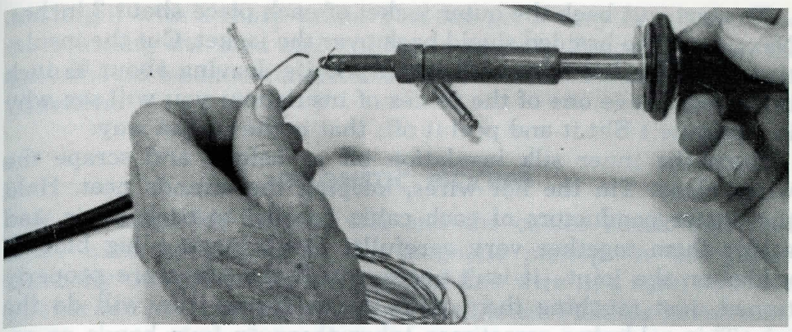


(C) Step 3.

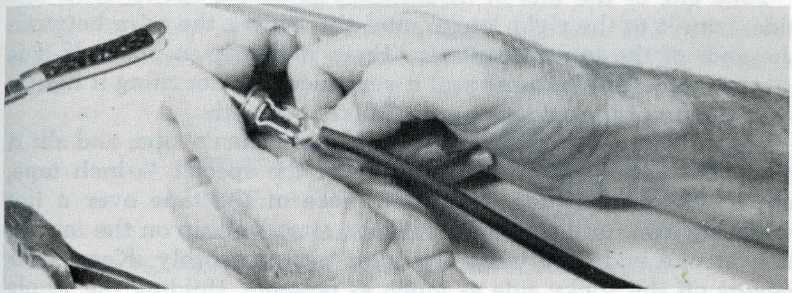


(D) Step 4.

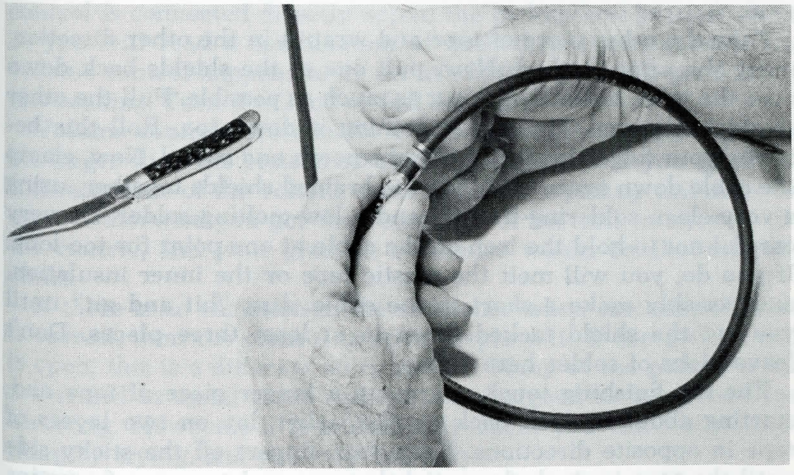
Fig. 7-3. Attaching shielded



(E) Step 5.



(F) Step. 6.



(G) Step 7.

cable to a phone plug.

To start, cut back the outer jacket of each piece about 2 inches. Next, push the braided shield back over the jacket. Cut the insulation off of the hot wire with a sharp knife, leaving about ½ inch insulated. (Save one of the pieces of insulation; you will see why in a minute.) Slit it and peel it off; that is the easiest way.

Burn the inner silk insulation off as before, and scrape the wires clean. Tin the hot wires, keeping the strands neat. Hold the center conductors of each cable parallel to each other, and solder them together very carefully. Don't leave a big blob of solder on the joint—it isn't necessary. If the wires are properly tinned, just touching them with the soldering iron will do the job. This soldering sometimes takes three or four hands or requires the use of some kind of clamp to hold things in place.

Take one of the bits of insulation you saved, slit it down one side, trim it to the right length, and slip it over the wire between the ends of the inner insulation. Press it tightly in place. If it is plastic, you can sometimes seal it very nicely by touching it lightly with the tip of the soldering iron. Make it smooth.

Take about a 5-inch piece of plastic electrician's tape, and slit it down the middle. If you have some of the special ¼-inch tape, use it without splitting. Hold one piece of the tape over a hot soldering iron until it gets limp. Then, start well up on the insulation at one end, and wrap the joint very smoothly. Keep your fingers off the sticky side as much as possible. Holding the whole thing over the soldering iron while doing the wrapping will help keep the tape soft and smooth. Make this neat; you will see why soon.

Take the other piece of tape and wrap it in the other direction, using the same method. Now, pull one of the shields back down over the joint, smoothing it out as much as possible. Pull the other shield back over this one, smoothing it down too. Roll this between your fingertips to get things smooth and round. Now, clamp the cable down again, and tack the braided shields together, using a very clean soldering-iron tip and a low-melting solder. Be very careful not to hold the iron on the cable at one point for too long. If you do, you will melt the plastic tape or the inner insulation, and possibly make a short in the cable. Just "hit and git" until you get the shield tacked down in at least three places. Don't leave blobs of solder here either.

For the finishing touch, warm up a longer piece of tape and, starting about an inch back on the jacket, lay on two layers of tape in opposite directions. Keep your fingers off the sticky side until the tape is stuck down tightly—grease from your fingertips will make the tape pull loose. The best way is to hold it by one end, pull it tight, and then trim off the piece where you have been holding it with a sharp knife. You can get a very neat joint here by warming the tape and pulling it smooth. Properly done, the joint should be almost undetectable even when viewed from short distances.

MAGNETIC PICKUPS

If the amplifier itself is OK and the cables check out, then there must be trouble in the magnetic pickup on the guitar. Basically this is nothing but a roll of fine wire in a case, so it can be checked for continuity with an ohmmeter. Pickups have resistances ranging from 500 or 600 ohms up to several thousand ohms, depending on the amount of wire used and its size. The smaller the wire is, the higher the resistance.

Fig. 7-4 shows the basic circuit of all pickups. The first check should be for continuity at the jack on the guitar. This can be

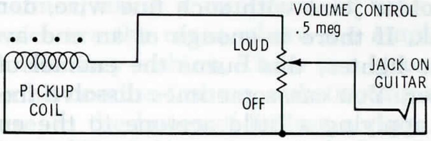


Fig. 7-4. Schematic of pickup coil and its volume control.

made more easily by plugging one of the cables into the jack and checking between tip and sleeve of the open plug. The volume control is connected directly across the pickup coil in most units, so you will read a combination of both their resistances. If the volume control happens to be set at off, then you will get a fairly low reading. Turn it to loud or full on.

Volume controls are usually a half-megohm or larger—quite a bit larger than the resistance of the pickup coil. If you read the full resistance of the volume control, then the pickup coil must be open. Otherwise you get the resistance of the coil in shunt with the control, and your greatest resistance would be about 10,000 ohms.

If there is no variation in the resistance when the control knob is turned, then the control is open. Replace it. If the pickup coil is open, this is a different story indeed. Many of the pickup units are sealed in metal cases and are not designed to be opened for servicing. However, if it is definitely open, you can't hurt anything by trying, and you may be lucky.

First, get into the case—this may not be so easy. Many have metal lids on the bottom, soldered in place. Pry or melt the solder loose, and take the lid off very carefully to expose the coil. Watch out that you don't pull the wires loose in taking the lid off if they happen to be stuck to it by varnish or insulating material.

You will be able to see where the wires come into the case from a shielded cable and join the coil; the shield will always be soldered to the case just inside the point of entry. Get a jeweler's loupe or a powerful magnifying glass, and check the very fine wires. In many cases the wires have been found to be broken just inside the case. If so, they can usually be picked up out of the winding, cleaned, and soldered back.

Pickups are always wound with very fine enamelled wire. Use a delicate touch in working with it; a sharp-pointed tool is handy. Find a small round wooden stick, and drive a sharp pin or needle into one end; this makes a good pick for working wires loose.

If you can find the two ends of the wires, check them for continuity; you can touch the broken end of a wire with the tip of a clean ohmmeter prod while holding the other prod on the case. Find out if the coil has continuity from this point to ground.

To make a solder joint with such fine wire, don't try to clean it—it will break. If there is enough of an end available, heat it with a cigarette lighter; this burns the enamel off and lets you get to the copper. You can sometimes dissolve the enamel off by very carefully applying a little acetone to the end of the wire, but don't let it drip into the coil itself. Lay the coil on one side if this is attempted.

If you can't clean the wires at all, hold them close together and start heating the ends with a soldering iron. This will require a very clean iron with a very fine, sharp tip. Touch the wires with the end of a piece of solder, using some of the low-melting-point fluxcore solder now available. The soldering flux and heat will eventually burn off the enamel and make the joint. Just a "wee touch" is enough. You won't have enough to twist; be satisfied with any kind of a lap joint. Recheck continuity. If this does the job, tuck the joint very carefully back inside the case, and paint it with some kind of insulating dope. Let this dry, put a very small piece of plastic tape over it (to keep it from shorting to the lower lid), and replace the lid. This will not have to be resoldered completely, just enough to keep it in place.

8

Customer Complaints

If a guitar amplifier is dead, the problem is relatively simple. Find the bad component and replace it. Procedures mentioned previously can be used so that the troubleshooting can be done in a logical manner, using a minimum of time. Probably more difficult to service are the cases where the amplifier is working, but not in a satisfactory fashion. There is a strong tendency here to proceed in a hit-or-miss fashion, substituting a tube here or a component there, in the hopes of finding a cure. Don't do it; the whole secret to speedy servicing is an orderly search for defective parts.

Often the owner gives valuable clues to the nature of the problem when he describes what is wrong. Listen carefully to him, and, if possible, verify what he says by listening to the amplifier while he is present. The player's ears are sensitive to the sound of an instrument in a way the serviceman can never be; even so, you can't do much to repair an instrument if you can't hear what is wrong.

Some of the common customer complaints are listed in the following sections along with suggestions for finding the source of the trouble.

DISTORTION

One of the worst problems in all audio amplifiers is distortion. This simply means that the amplifier isn't putting out what goes into it. An amplifier must never *change* the shape of the signal fed into it—it must only make the signal bigger. If the amplifier changes the wave shape of the note, there is distortion. If an amplifier tube operates on any but the linear part of its curve, troubles develop. Fig. 8-1 shows how this works; if the stage is properly biased, the output signal is exactly the same shape as the input. If bias is wrong, then the signal is changed—clipped or otherwise distorted. It is possible even to get a frequency-selective form of distortion; some notes are amplified clearly, others are distorted. (This is a simplification of what actually happens, but it's good enough to illustrate the problem; it can be fixed.)

You must work on the assumption that the guitar and amplifier were practically distortion free when new, and try to make them work as well as they did then. This means finding all of the parts that have drifted off tolerance and replacing them, replacing all

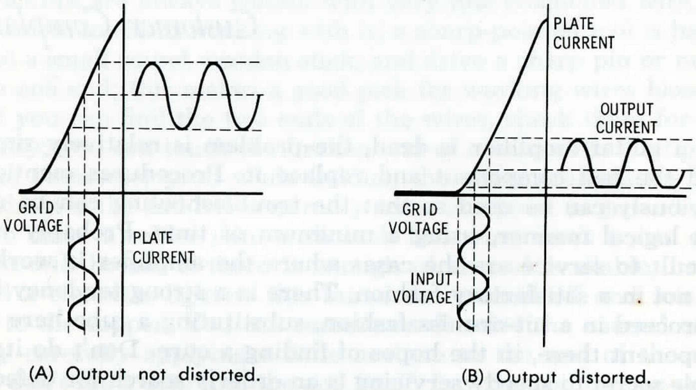


Fig. 8-1. Transfer curves showing signal amplification.

tubes that have weakened or developed grid emission, replacing all leaky capacitors, and so on. If you take a stage at a time, you can gradually get the amplifier back to normal.

Probably the most frequent cause of distortion is leaky coupling capacitors between stages. This has been covered previously, but don't overlook it.

Using an Oscilloscope to Find Distortion

About the only instrument that makes it easy to find distortion is the oscilloscope. The ear is pretty unreliable at this for obvious reasons. However, if a pure signal is fed to the input of a stage and something else comes out, then there is distortion in that stage. Fig. 8-2 shows how this works.

Here, a pure signal (W1) is fed to the input, and the same signal is undistorted at the output of the next two stages (W2 and W3). However, look at the output of stage 3 (W4). Something has happened here. This pinpoints the source of the distortion; something is very definitely wrong in the third stage. To find the cause of the trouble, start checking parts. First, replace the tube, because it is the easiest. Then, check the operating voltages, pay-

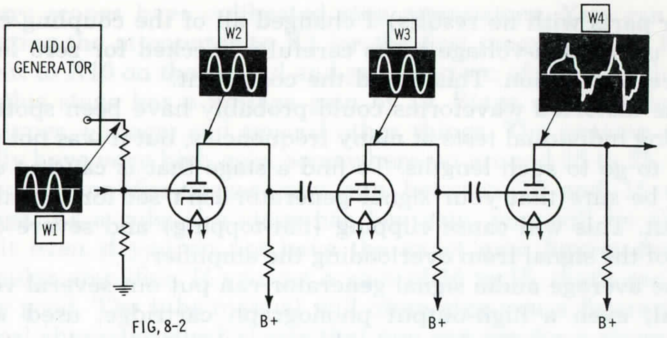


Fig. 8-2. Waveforms at critical points in an amplifier.

ing particular attention to the grid bias voltage. Most RC-coupled stages are very simple; there is actually nothing to them but three resistors, two capacitors, and the tube. If there is distortion in a stage, one of these parts must be bad.

As an example of how the scope can help, the author once found an amplifier where the complaint was simply "It sounds like . . ." Feeding in sine-wave signals didn't seem to show anything at all. However, when the guitar was hooked up to the amplifier and a few chords were played at high volume, the trouble was apparent. On the oscilloscope there was a pattern that looked like Fig. 8-3. (Because of the movement in this pattern, it couldn't be photographed, but this is an accurate reproduction.)

Several different frequencies were present at the same time: this caused a rapid movement of the scope pattern. However, by careful observation and juggling of the sweep controls, I finally spotted the trouble: there in the background were several waveforms that were very obviously clipped (flat topped). So, just for luck, (and as a starting point, for I had already replaced several

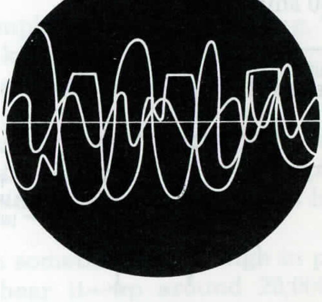


Fig. 8-3. Drawing of an actual scope pattern of a defective amplifier.

other parts with no results) I changed all of the coupling capacitors, using high-voltage types carefully checked for zero leakage before installation. This cured the complaint.

The distorted waveforms could probably have been spotted by making individual tests at many frequencies, but it was not necessary to go to such lengths. To find a stage that is causing distortion, be sure that your signal generator isn't set for too high an output. This will cause clipping (flat-topping) and severe distortion of the signal from overloading the amplifier.

The average audio signal generator can put out several volts of signal; even a high-output phonograph cartridge, used with a frequency test record, can do the same thing, so, make sure that you are not overloading the input. A voltage divider set up like that shown in Fig. 8-4 will help out. By using a pair of resistors, one 50K and one 950K, you can get a 50-millivolt output. This is a good average input from a guitar pickup and should not cause overloading. To make sure, test with the scope at the plate of the first stage—the preamplifier tube. If there is any clipping due to too much input signal, it will probably show up there. For the final test, plug in the guitar itself and have the owner play a few chords on it while you watch the scope screen. To get best results in this test, always use a low-capacitance probe on the scope input. This will give the lowest loading on the high-impedance circuits you are working with.

You can also make stage-by-stage gain checks with the scope when troubleshooting weak amplifiers. Feed in the signal at the input. Set the signal-generator output for a clean sine wave. Now, put the scope probe on the grid of the preamp tube. Set the vertical gain of the scope so that the signal takes up a certain number of squares on the graticule (the calibrated screen on the scope). It doesn't make any difference how many as long as you remember. The best way is to make the signal cover a small number of small squares—say 5. Now move the probe to the plate. If this stage has a gain of 10, your pattern will be 10 times as high —50 small squares.

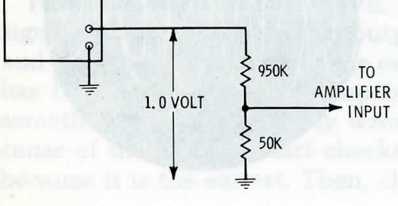


Fig. 8-4. Voltage divider to reduce generator output.

Many scopes have calibrated step attenuators. You can start by setting the attenuator to X1 for the first measurement. If you move it to X10 on the second and get a pattern of the same height, then this stage has a voltage gain of 10. Stage gain varies with tube types, voltage, and several other things. The preamp stages usually have very high gain, somewhere up around 15 to 25, while following amplifier stages may run between 10 and 15 as an average. As a rule, if a stage has low gain, you will be able to spot it even if you do not have the exact gain figures for that particular amplifier. If you get a gain of 10 to 15, that's probably pretty good. The tube manual will often give you a figure in the "typical characteristics" charts that you can use for a given tube.

Fig. 8-5 shows waveforms and stage gains for an imaginary amplifier. The signal always has the same shape, but the amplitude

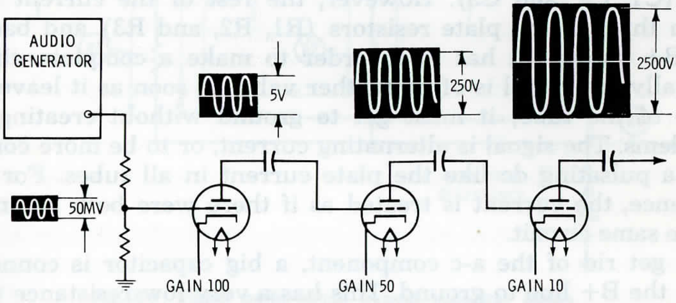


Fig. 8-5. Possible waveform values and stage gains.

(height) increases. Even small amplifiers can have amazingly large amounts of actual voltage gain. When you remember that some amplifiers begin with a signal of only about 0.050 volt and wind up with perhaps as much as 50 volts, you can see that an overall voltage amplification of 1,000 times is not unusual.

OSCILLATION, HUM, AND MOTORBOATING

Now and then you will find an amplifier that is oscillating. This means that the amplifier has some kind of internal feedback (the cause of all oscillation). There are several different kinds:

1. Low-frequency oscillation is usually accompanied by a fairly bad hum. It is called motorboating from the "plup-plup-plup" sound it makes, something like an old motorboat (not a high-speed outboard).
2. High-frequency oscillation can sometimes be so high in pitch that the human ear cannot hear it—up around 20,000 or

25,000 cycles. It is also called ultrasonic oscillation. You cannot hear the oscillation itself, but you can hear the effects. It will cause the amplifier to have a very bad distortion.

All oscillation is caused by a feedback. Amplifier circuits have many common connections such as the plate voltage supply circuit shown in Fig. 8-6. Only the plate circuit and grid circuit is shown, for that is all that is necessary. When there is a common plate supply circuit like this, it must be very well bypassed. A big electrolytic capacitor is put across the power supply, from the B+ line to chassis or ground.

What does this do? In the plate circuits of all amplifier tubes there is a signal current flowing. It is taken off at the plate and fed to the grid of the following stage through the coupling capacitors (C1, C2, and C3). However, the rest of the current flows down through the plate resistors (R1, R2, and R3) and back to the B+ supply; it has to in order to make a complete circuit. Actually the signal is of no further value as soon as it leaves the plate of the tube; it must get to ground without creating any problems. The signal is alternating current, or to be more correct, it is a pulsating dc like the plate current in all tubes. For convenience, the current is treated as if there were both ac and dc in the same circuit.

To get rid of the a-c component, a big capacitor is connected from the B+ line to ground. This has a very low resistance to ac, so the B+ is at a-c ground potential. There should never be any a-c components on B+ lines. You can see from Fig. 8-6 that the signal currents flow down the load resistors and then through the low resistance of the capacitor to ground where they are lost. What happens if the capacitor opens up or develops a very high resistance (high power factor)?

This is different. Instead of any easy path to ground, the signal now has a very high-resistance path to ground if any at all. As

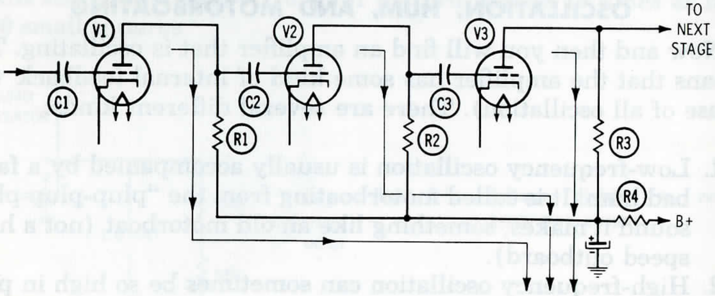


Fig. 8-6. Normal signal paths to ground.

you can see in Fig. 8-7, under these conditions the signal currents go everywhere. Instead of being dissipated harmlessly in the chassis, they can flow back up into other circuits. For example, the signal from tube V3 can get back into the plate circuit of tube V2, where it is promptly transferred through coupling capacitor C3 back to the grid of tube V3. The phase shifts in this feedback path are complicated, but it suffices to say that somewhere in there the signal manages to get back to a grid in exactly the right phase to cause in-phase regenerative feedback. The stage then goes into violent oscillation.

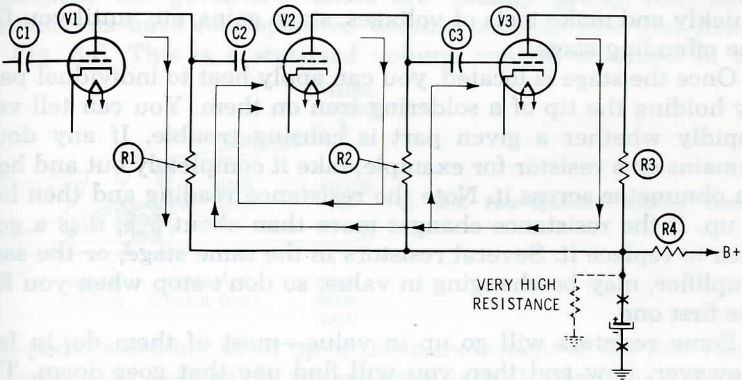


Fig. 8-7. Signal paths when bypass capacitor opens.

An open filter capacitor causes almost all oscillation. If you find an amplifier howling, blubbering, or making other odd noises, it is probably in oscillation. Take a good electrolytic capacitor and bridge all of the filter capacitors in the circuit; there is no other fast way to find out just which one is causing the trouble. When you bridge a good capacitor across the open unit, the feedback will stop or at least change in pitch quite a lot. In some cases there will be more than one capacitor open at the same time. A broken ground lead (inside the can) on a multiple-unit capacitor will open all the sections. Then, you may have to turn off the amplifier and disconnect the capacitors one at a time, checking each one for capacitance, to find the bad one. An alternative is to tack new capacitors across several of the suspected units with solder.

HEAT-SENSITIVE RESISTORS

A common trouble is the amplifier that "sounds all right when I first turn it on, but sounds awful after it works for a while," or "gets weak as it gets hot." This is some kind of a thermal trouble;

it is caused by some part in the amplifier getting hot and changing in value. The most common cause of this is bad resistors, although now and then a capacitor will do the same thing. A common symptom of this is the amplifier that won't work while in the cabinet, but when taken out on the bench for service, works for hours. This is because the amplifier chassis is better ventilated out in the open and stays cooler.

To find such troubles quickly, apply heat. One trick is to cover the amplifier chassis with a cardboard box, cutting off all ventilation (with it out of the regular cabinet, of course) and letting it run until the trouble shows up. Then take the box off very quickly and make tests of voltages, stage gains, etc. until you find the offending stage.

Once the stage is located, you can apply heat to individual parts by holding the tip of a soldering iron on them. You can tell very rapidly whether a given part is causing trouble. If any doubt remains on a resistor for example, take it completely out and hook an ohmmeter across it. Note the resistance reading and then heat it up. If the resistance changes more than about 5%, it is a good idea to replace it. Several resistors in the same stage, or the same amplifier, may be changing in value, so don't stop when you find the first one.

Some resistors will go up in value—most of them do, in fact. However, now and then you will find one that goes down. This makes no difference; if it changes in value at all, it is definitely bad and ought to be replaced.

Tubes will sometimes short out. When they do, a very heavy current is drawn through resistors in their circuits. This may overload and overheat resistors to such an extent that they will become thermals. Look for signs of overheating and charring, or a bad discoloration of the color-code paint. A good color to check is red; if the resistor has been overheated, the red stripe will turn a brownish-grey.

NOISY CONTROLS

Guitar amplifiers use standard carbon-element variable resistors for volume and tone controls. After a certain length of time, these controls get very noisy. If they are not worn too badly, they can be repaired by spraying contact cleaner into the body of the control. This washes away dirt and dust and cleans the sliding contact that is responsible for most of the noise. The standard test is to turn the amplifier on, turn the control rapidly up and down, and listen to the speaker. If the control is still noisy, you will hear it. In this case, replace it.

Worn controls must be replaced. The most common control used in these circuits is a standard audio taper of whatever resistance is needed. The 1-megohm control is often used, but you will find everything from 0.5 megohm to 2.5 megohms in use. These are not too critical; you can replace a 0.5 megohm with a 1 megohm if you have to, and there will not be a lot of difference in the performance. Exact duplicate replacements are best, of course.

FOOT-OPERATED CONTROLS

Because the guitarist's hands are usually pretty full, some instruments have foot-operated volume controls like that shown in Fig. 8-8. This is a standard volume control mounted in the

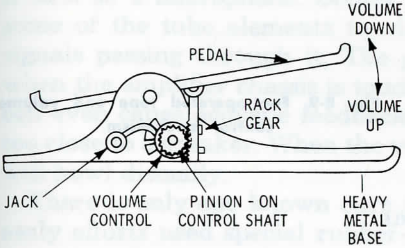


Fig. 8-8. Foot-operated volume control.

foot-pedal assembly so an up or down movement of the foot raises or lowers the volume. It is connected into the amplifier circuits through a shielded cable and plug. These are usually wired in such a manner that the panel volume control is disconnected automatically when the foot control is plugged in.

In some a rack and pinion gear arrangement is used to move the control. Others have a cable-drive arrangement that does the same thing by means of winding a cable around the volume-control shaft. Slack is taken up by a spring.

In a more elaborate version, straight up and down movement of the foot controls the volume while rocking the foot from side to side controls the tone. A typical unit is shown in Fig. 8-9. The same basic hookup is used here to get the control action; there is just more of it. In one other application of the foot control, a simple on-off switch operates the vibrato on amplifiers equipped with this feature. Tremolo and reverberation circuits are often fitted with foot-operated switches too.

RADIO-FREQUENCY INTERFERENCE IN GUITAR AMPLIFIERS

As in all other kinds of electronics work, you will find the odd and unusual cases that will drive you crazy! Here is one of them that the author encountered. A string band, using one very large and one medium-sized amplifier, got along fine until they made a radio broadcast from the station itself. In the studio all of the instruments sounded so very peculiar that they finally had to turn off the amplifiers. This, to their surprise, cured the troubles.

The problem was traced to radio-frequency (r-f) pickup in the input of the guitar amplifiers. Since studio and transmitter were in the same building, there was a very strong r-f field all around

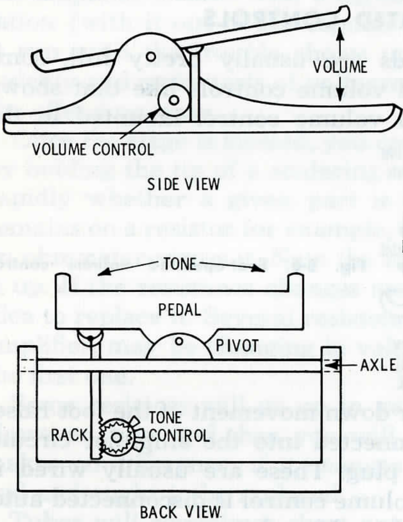


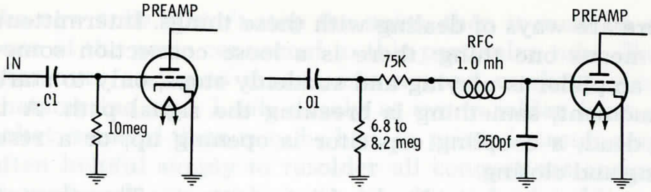
Fig. 8-9. Foot-operated tone and volume control mechanism.

them. The transmitter signal was being detected by the grids of the amplifier input stage. This generated a very high grid-leak bias (high negative voltage) and drove the input stages nearly to cutoff. Naturally, this caused a very severe distortion.

The cure was simple. Since the trouble was due to the presence of rf on the grids, a very small bypass capacitor was connected directly from grid to ground at each tube socket. Such a capacitor has a very low impedance at radio frequencies, so it makes a short circuit to ground for them. However, its impedance at audio frequencies is very high, so it doesn't affect the guitar tones. Fig. 8-10 shows how this is done. If the capacitor alone does not entirely clear up this kind of interference, the small r-f choke shown can be added in series with the grid.

MICROPHONICS

Microphonics is a word that needs more explanation. Previously it has been said that a contact mike can act as a microphone,



(A) Original circuit. (B) Modified circuit.

Fig. 8-10. Eliminating r-f interference.

picking up extraneous sounds in addition to string vibrations. Trouble very much like this can develop if one of the tubes in the front end (input stages) becomes microphonic—translation, it acts as a microphone. Sound vibrations in the air can cause some of the tube elements to vibrate; this affects the electrical signals passing through it. The general result is a loud BONG when the amplifier chassis is touched or jarred. In bad cases tubes can even cause acoustic feedback, just like putting a microphone too close to a speaker. When the volume is turned up, the amplifier will howl dismally.

There is only one known cure for this—replace the tube. Some early efforts used special rubber-mounted sockets and fiber tube covers to damp out the sound vibrations, but these were pretty unsuccessful. The best cure is the use of specially designed non-microphonic tube types, like the 5879 shown in the microphone input circuit of Fig. 2-17. These are built with all elements rigidly held in place so they cannot vibrate when sound waves strike them. This construction keeps the tubes from becoming microphonic.

Transistors are very seldom microphonic because of their construction. However, nothing is impossible in electronics, so you may find a microphonic transistor before you finish reading this book. If you do, the same remedy applies—replace it. Most silicon transistors are comparatively noise-free and so far have given absolutely no trouble with microphonics or other noise effects.

INTERMITTENT AMPLIFIERS

The most infuriating complaint on an amplifier, or on any kind of electronic gear is an intermittent—one that works beautifully and suddenly quits. Then, (in the standard intermittent) it starts working again just as if nothing had happened. Usually this happens just as soon as you get it out of the box and start looking for the cause of the trouble. You can hammer on it and do anything you want with it, and it plays on just like new.

There are ways of dealing with these things. Intermittent operation means one thing: there is a loose connection somewhere. If the amplifier is playing and suddenly stops, only to start again in a moment, something is breaking the signal path. A tube is going dead, a coupling capacitor is opening up, or a resistor is opening and closing.

There are two main kinds of intermittents. The physical type can be jarred to make it cut in and out. Something in there is mechanically loose—a bad solder joint, broken wire, an intermittent coupling capacitor, a dirty tube socket, etc. The electrical type can be hammered on with no effect; the amplifier simply cuts out when it gets ready to. The latter are the most annoying, of course.

If you find a physical intermittent, take the amplifier out of the cabinet, set it up on the bench, feed a continuous signal through it so that you can tell when it cuts out, and then tap every part in it. Right now you have no ideas at all as to where this thing is located; it could actually be caused by almost any part in the whole amplifier.

Here is another place to use the process of elimination. Start at the power output tube socket, and tap all of the parts in the signal path—coupling capacitors, resistors, tube sockets, tubes, etc. Use something like a pencil eraser or an insulated tool of any kind. If you get close to the cause of the trouble, you will notice that you hear a pop every time you hit a certain part. This is very apt to be the one you are hunting.

Don't hammer on the whole chassis; this does no good at all. What you must do is tap or jar certain parts without moving the rest of the amplifier in an effort to pin down the trouble to a small area. If you jar the whole chassis naturally you are going to get a response. Take it easy, and hammer gently and selectively.

Dirty or old tube sockets are a common cause of physical intermittents. Put your finger on the top of each tube, and move it around in the socket. If you hear a popping or scratching noise, the tube pins and the socket contacts are dirty. Take the tube out, spray contact cleaner into the socket, and straighten out the pins. Put the tube back in. Push it up and down several times in the socket; this scrapes the corrosion off of tube-socket contacts. Now tap it again, and see if the noise has stopped. If it has not, substitute a new tube and try again. The original noise may have been inside the tube itself (a common trouble not too long ago, but not as common now, with improvements in the internal construction of vacuum tubes). Don't replace the tube first in this case; clean up first. You may put in a new tube with clean pins, and throw away a perfectly good tube with dirty pins.

If the new tube doesn't stop the noise, then it must be coming from one of the parts connected to this particular tube. Turn the amplifier over and give these parts a good working over with your hammering tool. Look closely at every solder joint around the socket; some of them may be bad. In printed-circuit amplifiers it is often helpful simply to resolder all connections around that socket; melt each one, apply just a tiny bit of fresh solder, and let it cool. In the early printed-circuit boards this kind of trouble was common, but here again material improvement has stopped a lot of it.

The most annoying type is the electrical intermittent. No amount of hammering will affect it; it just suddenly stops working when it gets good and ready! Of course if it stays out, it is easy to locate the trouble by signal-tracing—but it usually doesn't. Many will cut out, but will come on the moment a test probe is placed anywhere on the circuit.

There are ways of dealing with these, of course. One good way is to connect indicators of some kind to several points in the circuit. For example hook the scope to the grid of an output tube, a vtvm on "ac volts" to the plate of an amplifier tube, and a d-c voltmeter to some point along the B+ supply lines. Now, turn the unit on and wait until it cuts out. By checking the reading on each of the indicating instruments, you can get some idea of where the circuit is opening. In this example, if the scope shows that the signal disappeared from the grid of an output tube, but the a-c vtvm shows no change in its reading, then you have the defect pinned down to somewhere between those two points. Move the scope one stage closer to where the vtvm is connected, and try again. Eventually you will be able to close in on the thing and find out exactly which part is giving trouble.

Many intermittents are thermal—they show up after the amplifier has been turned on long enough to get thoroughly warmed up. In these cases some part expands physically due to heat and breaks the circuit. For example, a paper capacitor that has been installed with too much tension on the connecting leads will open with heat; when the amplifier expands, the end of the capacitor is pulled loose and it becomes open, stopping the signal.

To catch a thermal intermittent, put the amplifier on the bench and cover it up with a cardboard box, blanket, or anything that will hold the heat in. Let it get hot and cut out, and then you will be able to find the bad component easily. Try applying heat to suspected parts of any kind with the tip of a soldering iron; this will often cause intermittents to show up.

Some units operate in reverse; they won't work at all until they are thoroughly warmed up. Then they come on very suddenly, and refuse to cut out at all until they are cooled off again. There is a way to deal with this, too. You can get coolant fluid in spray cans at parts houses. This can be sprayed on suspected parts to cool them off, possibly making the trouble show up.

The easiest way, of course, is to cool the amplifier off, and check it by signal tracing while the part is defective. However, this can have its drawbacks. Many chassis will not cool off enough to cut out for a long time after they have started to work. One exasperated technician put an amplifier like this into his deep freeze and really cooled it off. He found the trouble very quickly, too, I might add.

SUMMARY

Servicing guitar amplifiers is not difficult if you use the right methods, and, above all, if you know how the circuits work. A logical method of eliminating first one possible cause and then the next will lead you to the real cause of trouble in the shortest possible time.

SECTION III

Commercial Instrument Amplifiers

9 *Low-Power Amplifiers*

Guitar amplifiers, like people, come in all different shapes and sizes. They start out with little ones, go through medium-sized ones, and wind up with big ones. Sometimes the same unit is sold under several different trade names. If you do not find the brand you are looking for, compare tube types with those used in the schematic shown in this section. There is apt to be a great similarity between amplifiers of approximately the same power. The following descriptions include small units suitable for home or practice use only. The audio power output (approximately 2 watts) is not sufficient for dances or concert hall use.

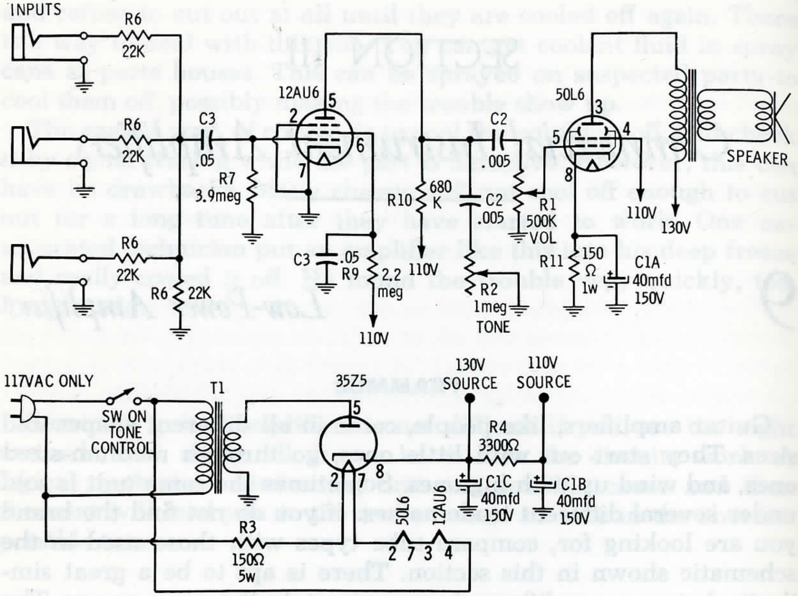
KAY MODEL 703

Fig. 9-1 shows a schematic of one of the small models. This is not an ac/dc circuit, despite the series filament tube circuit. Note the use of the isolation transformer in the B+ circuit for protection against electrical shock hazard. This circuit will work on ac only.

A voltage amplifier using a 12AU6 pentode feeds a 50L6 power output tube. A 35Z5 tube is the rectifier with a standard π-section filter circuit. Power output of this amplifier, and all others using the same tubes and circuit, is about 2.0 watts; this is all that can be obtained from a single 50L6 tube.

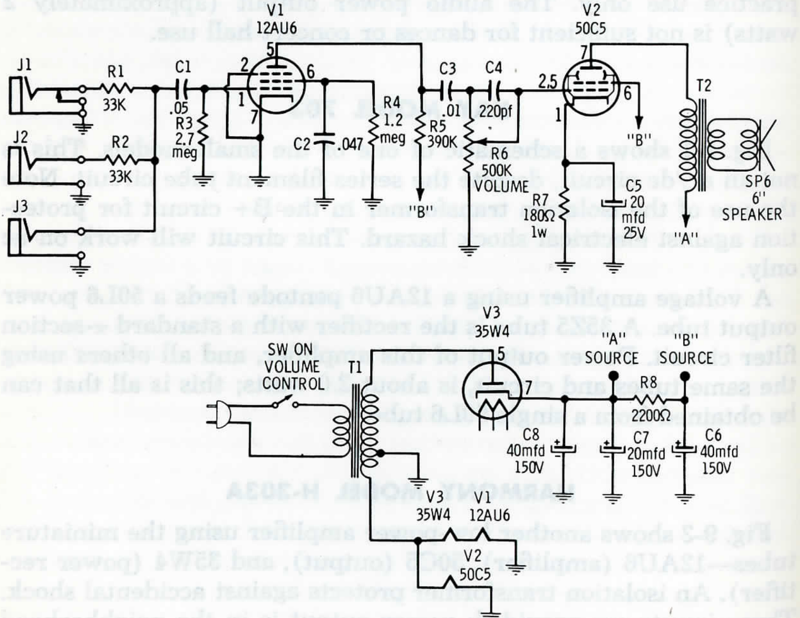
HARMONY MODEL H-303A

Fig. 9-2 shows another low-power amplifier using the miniature tubes—12AU6 (amplifier), 50C5 (output), and 35W4 (power rectifier). An isolation transformer protects against accidental shock. Three inputs are provided; power output is in the neighborhood of 2 watts.



Courtesy Kay Musical Instrument Co.

Fig. 9-1. Kay Model 703.

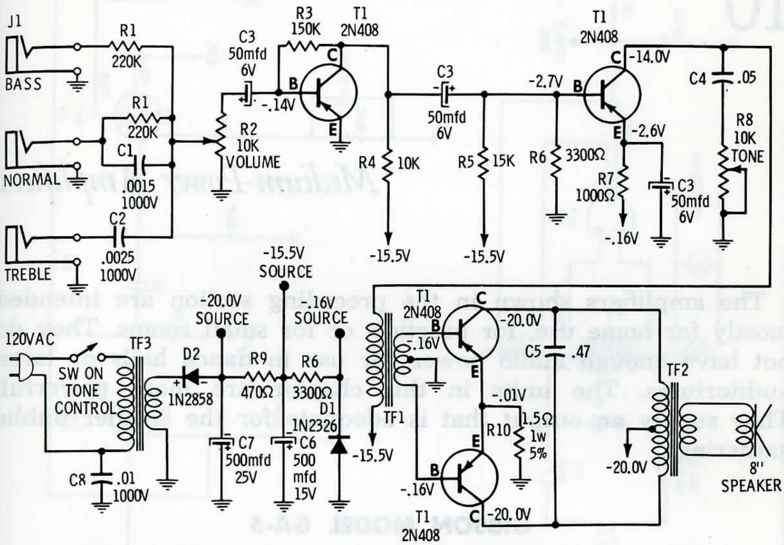


Courtesy The Harmony Company

Fig. 9-2. Harmony Model H-303A.

KAY MODEL 700

Fig. 9-3 shows the transistor equivalent of the tube amplifier of Fig. 9-1. Four transistors are used, giving a power output of



Courtesy Kay Musical Instrument Co.

Fig. 9-3. Kay Model 700.

about 2.0 watts. A 1N2858 silicon diode is the rectifier, and all transistors are 2N408's—germanium pnp audio transistors. The power supply delivers 20 volts with a current rating of about 100 ma. Filtering is standard: two 500-mfd electrolytic capacitors and a 470-ohm resistor in a π-section.

Notice the novel three-way input connection. These are used to give tone control. For more bass the instrument is plugged into the upper jack, for a flat response into the middle jack, and for greater treble into the lower one, where a series capacitor cuts down on the proportion of lows (bass). A standard high-cut tone control is also used in the output circuit of the driver transistor. The on-off switch is attached to this control.

10

Medium-Power Amplifiers

The amplifiers shown in the preceding section are intended mostly for home use, for practice, or for small rooms. They do not have enough audio power for use in dance halls or large auditoriums. The units in this chapter are more powerful. They supply an output that is adequate for the smaller public gatherings.

GIBSON MODEL GA-5

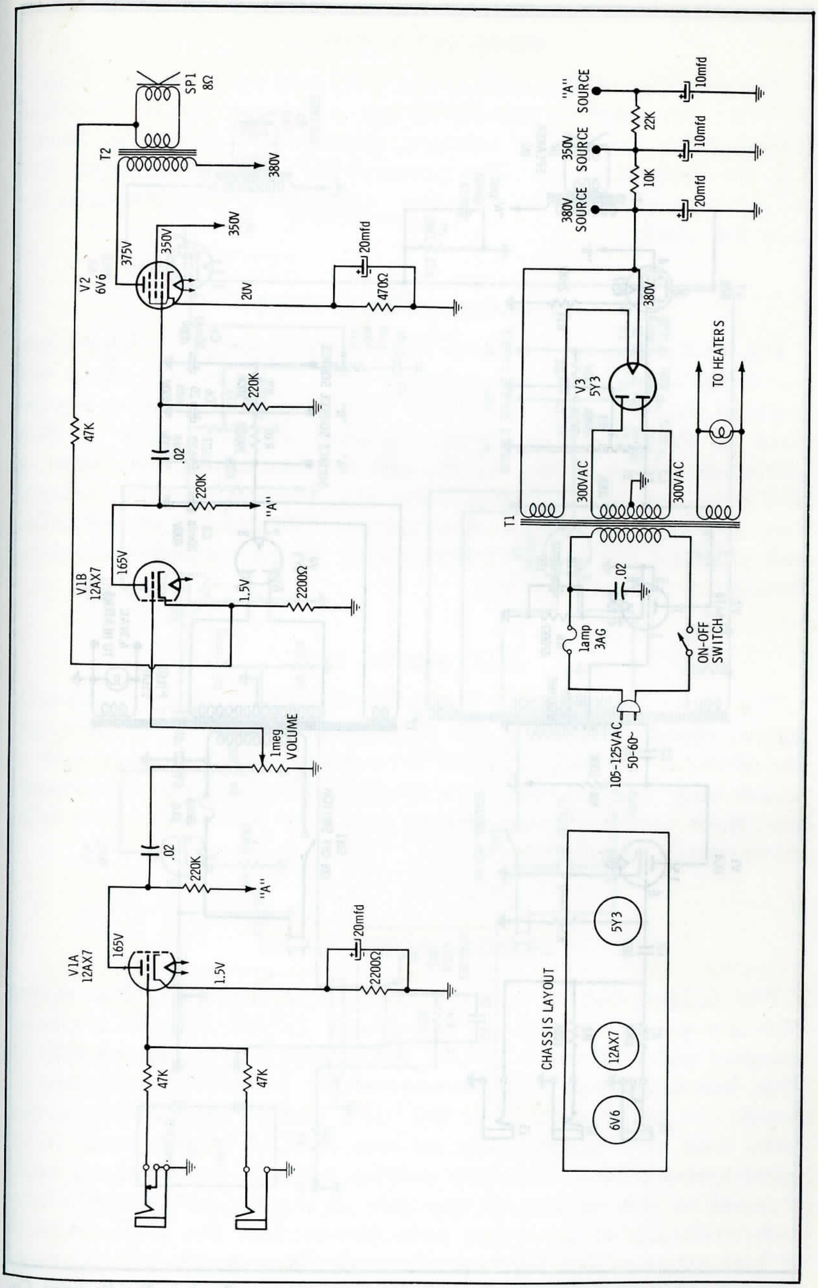
The amplifier shown in Fig. 10-1 has about 4 to 5 watts of power, using a single 6V6 tube in the power output stage. A twin-triode 12AX7 is used in the preamplifier and drive stages. Dual inputs allow the use of two guitars at the same time. They are identical, as you can see.

HARMONY MODEL H-304A

The amplifier of Fig. 10-2 is another 5-watt unit. This uses a 6C4 (preamplifier), a 6AT6 (voltage amplifier), and a single 6V6 (power output). Three inputs are provided.

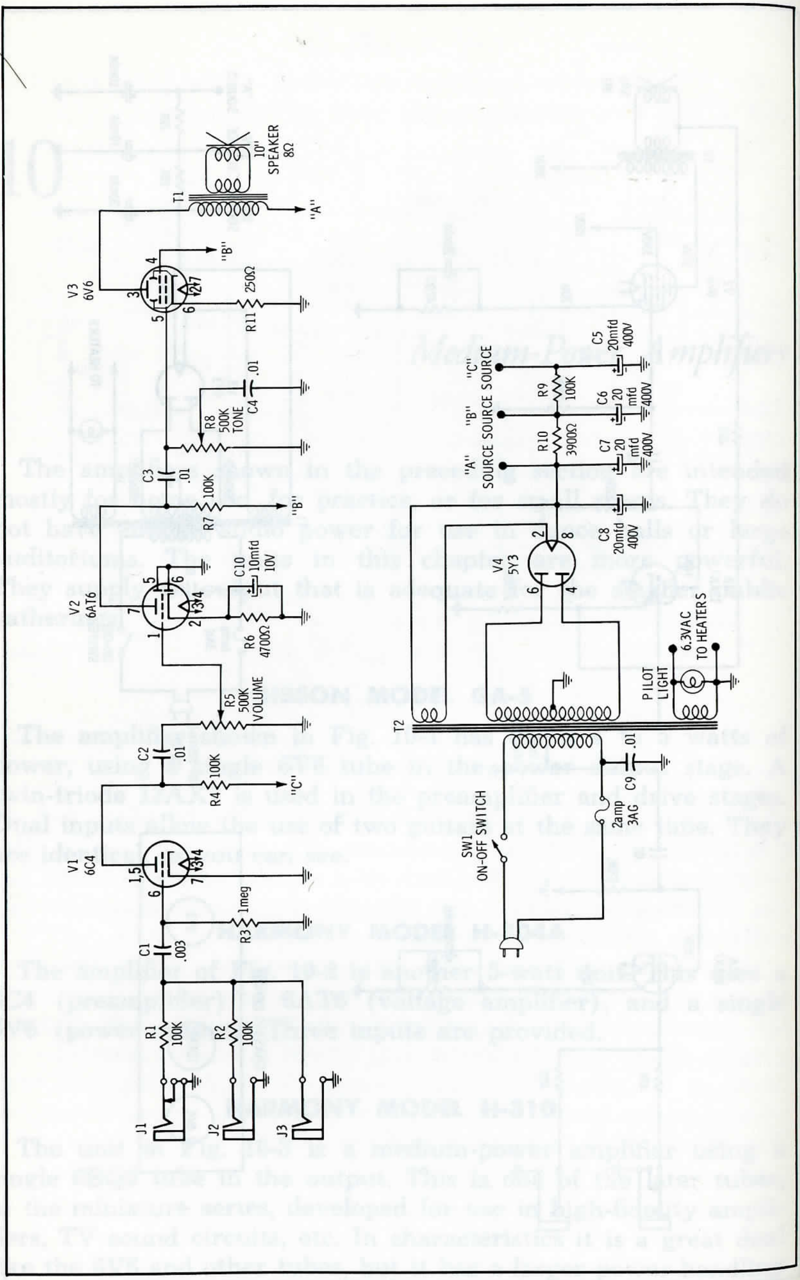
HARMONY MODEL H-310

The unit in Fig. 10-3 is a medium-power amplifier using a single 6BQ5 tube in the output. This is one of the later tubes, in the miniature series, developed for use in high-fidelity amplifiers, TV sound circuits, etc. In characteristics it is a great deal like the 6V6 and other tubes, but it has a larger power-handling ability. One 6BQ5 is capable of handling a power output of 5.7 watts. A Hammond "F" reverberation unit is included.



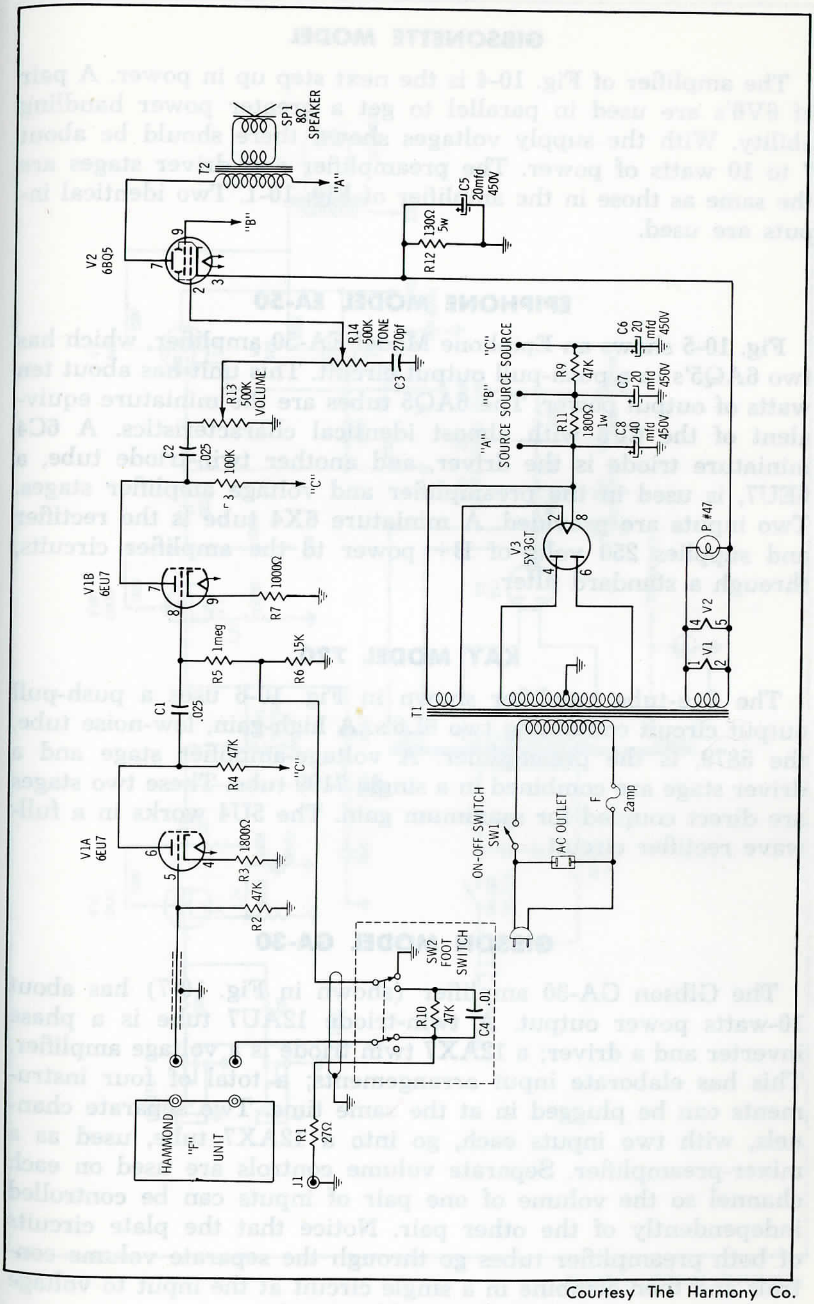
Courtesy Gibson Electronics

Fig. 10-1. Gibson Model GA-5.



Courtesy The Harmony Co.

Fig. 10-2. Harmony Model H-304A.



Courtesy The Harmony Co.

Fig. 10-3. Harmony Model H-310.

GIBSONETTE MODEL

The amplifier of Fig. 10-4 is the next step up in power. A pair of 6V6's are used in parallel to get a greater power handling ability. With the supply voltages shown there should be about 7 to 10 watts of power. The preamplifier and driver stages are the same as those in the amplifier of Fig. 10-1. Two identical inputs are used.

EPIPHONE MODEL EA-50

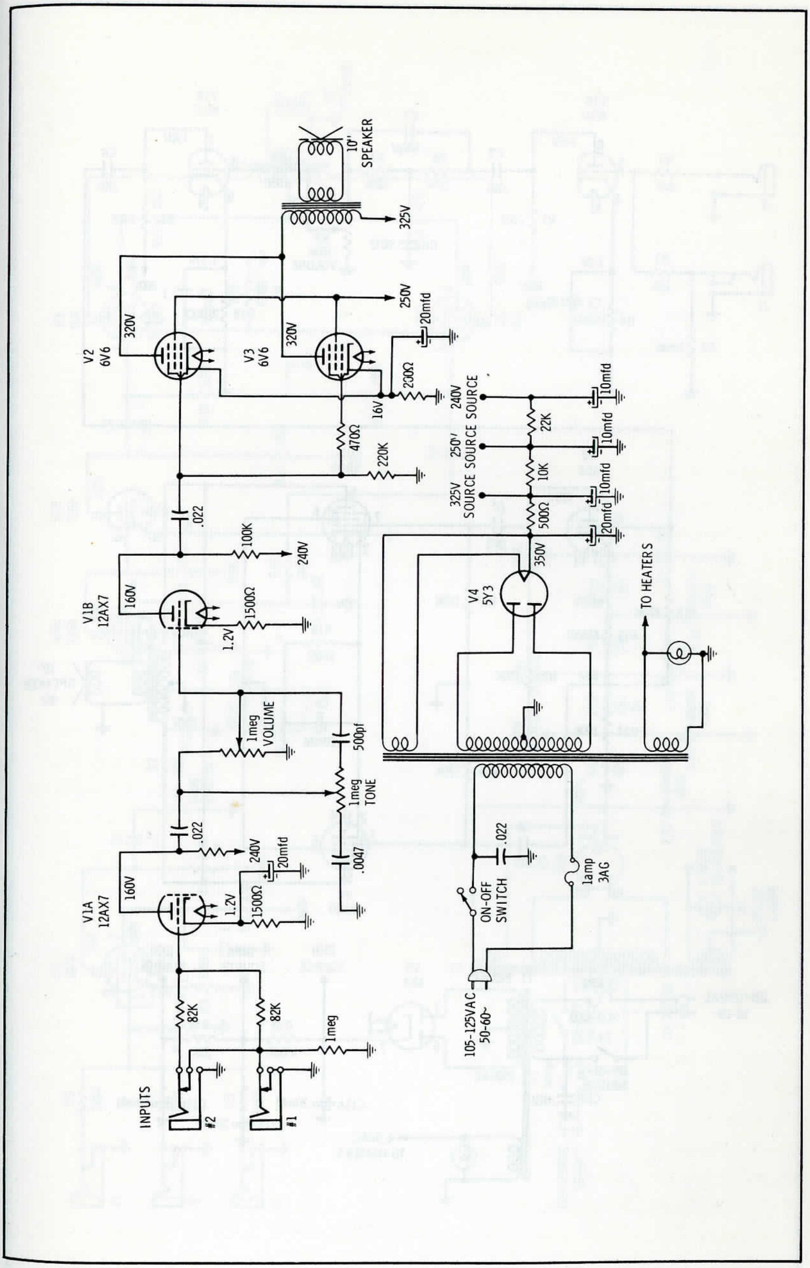
Fig. 10-5 shows an Epiphone Model EA-50 amplifier, which has two 6AQ5's in a push-pull output circuit. This unit has about ten watts of output power. The 6AQ5 tubes are the miniature equivalent of the 6V6 with almost identical characteristics. A 6C4 miniature triode is the driver, and another twin-triode tube, a 6EU7, is used in the preamplifier and voltage amplifier stages. Two inputs are provided. A miniature 6X4 tube is the rectifier and supplies 250 volts of B+ power to the amplifier circuits, through a standard filter.

KAY MODEL 720

The five-tube amplifier shown in Fig. 10-6 uses a push-pull output circuit containing two 6L6's. A high-gain, low-noise tube, the 5879, is the preamplifier. A voltage-amplifier stage and a driver stage are combined in a single 7199 tube. These two stages are direct coupled for maximum gain. The 5U4 works in a full-wave rectifier circuit.

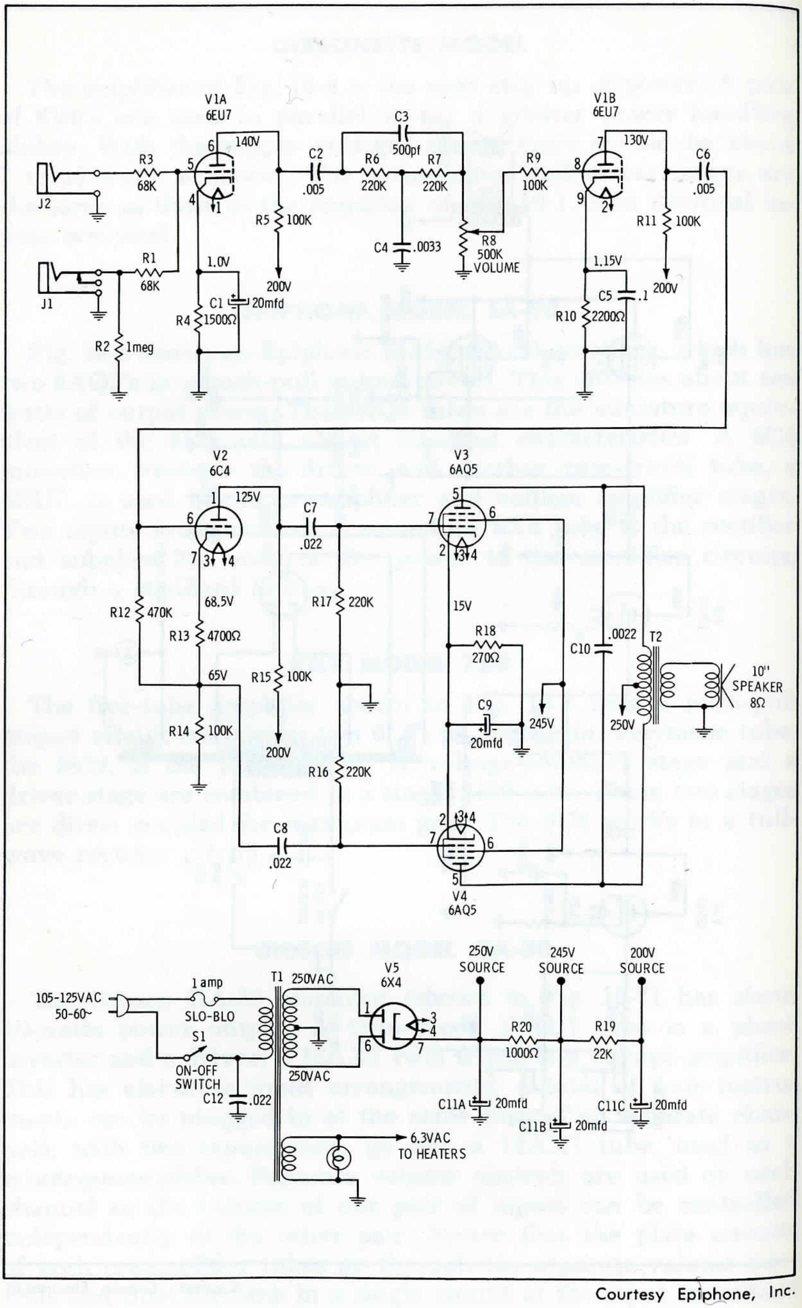
GIBSON MODEL GA-30

The Gibson GA-30 amplifier (shown in Fig. 10-7) has about 10-watts power output. A twin-triode 12AU7 tube is a phase inverter and a driver; a 12AX7 twin triode is a voltage amplifier. This has elaborate input arrangements; a total of four instruments can be plugged in at the same time. Two separate channels, with two inputs each, go into a 12AX7 tube, used as a mixer-preamplifier. Separate volume controls are used on each channel so the volume of one pair of inputs can be controlled independently of the other pair. Notice that the plate circuits of both preamplifier tubes go through the separate volume controls and then combine in a single circuit at the input to voltage amplifier stage V2A.



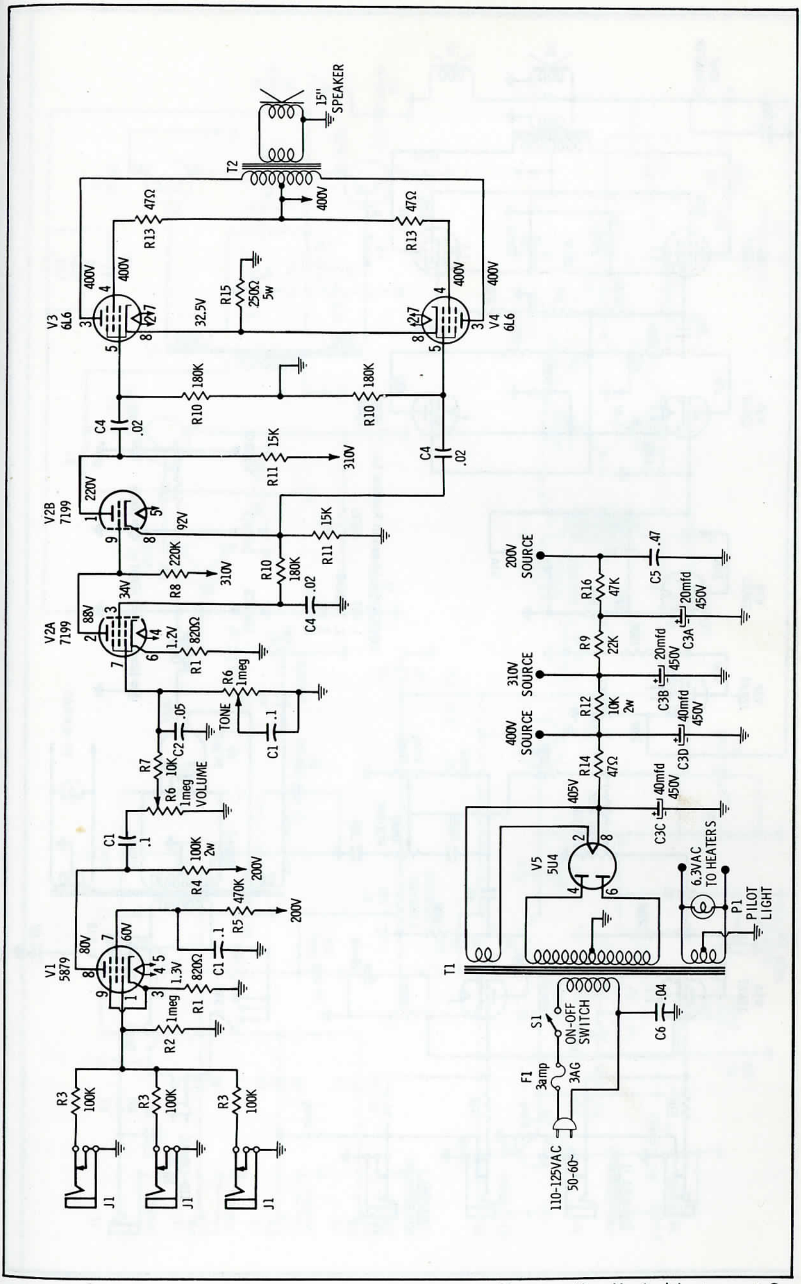
Courtesy Gibson Electronics

Fig. 10-4. Gibsonette Model.



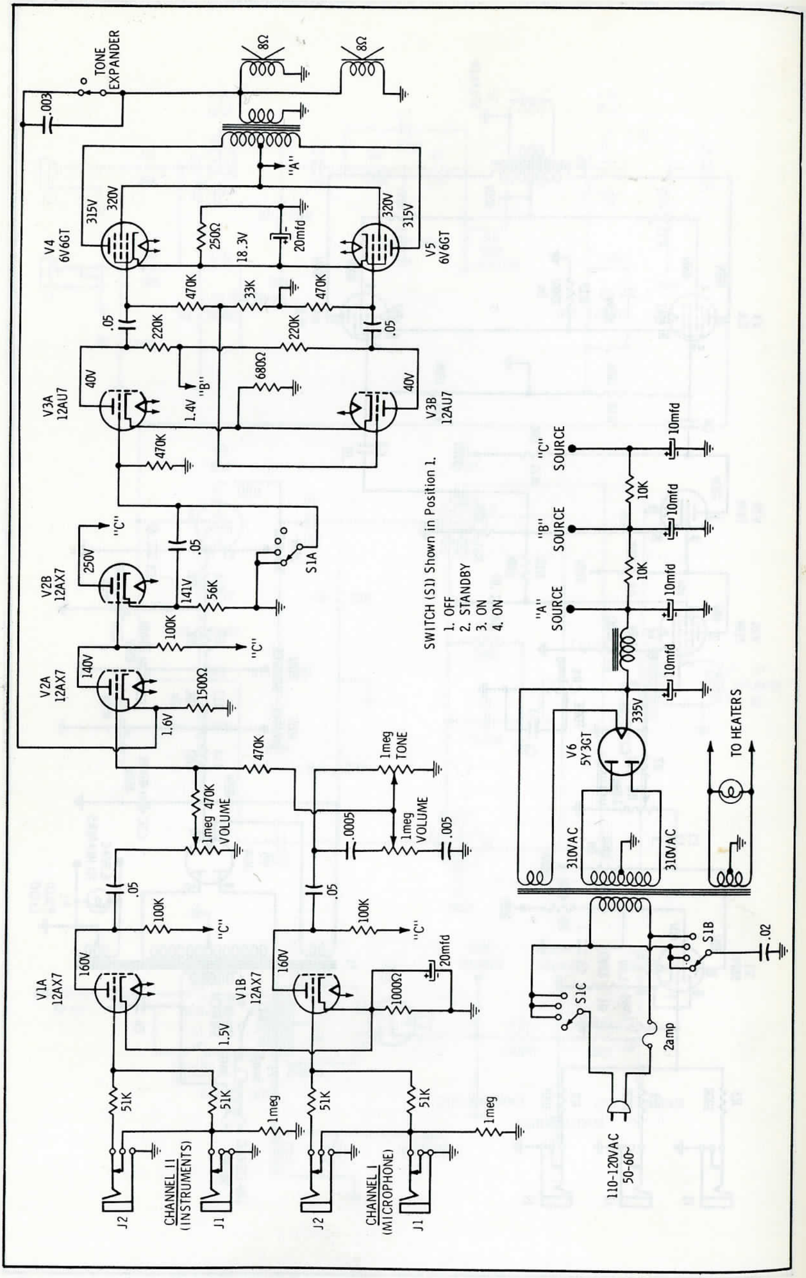
Courtesy Epiphone, Inc.

Fig. 10-5. Epiphone Model EA-50.



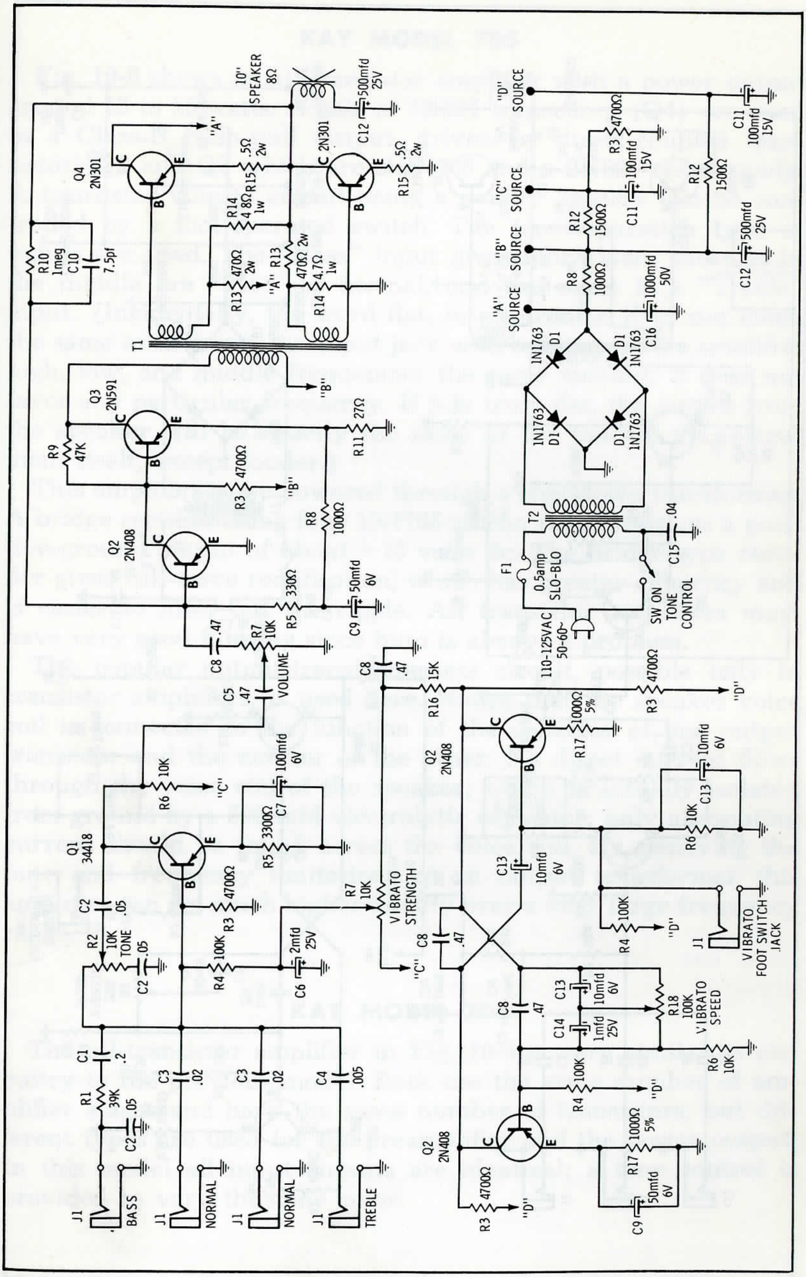
Courtesy Kay Musical Instrument Co.

Fig. 10-6. Kay Model 720.



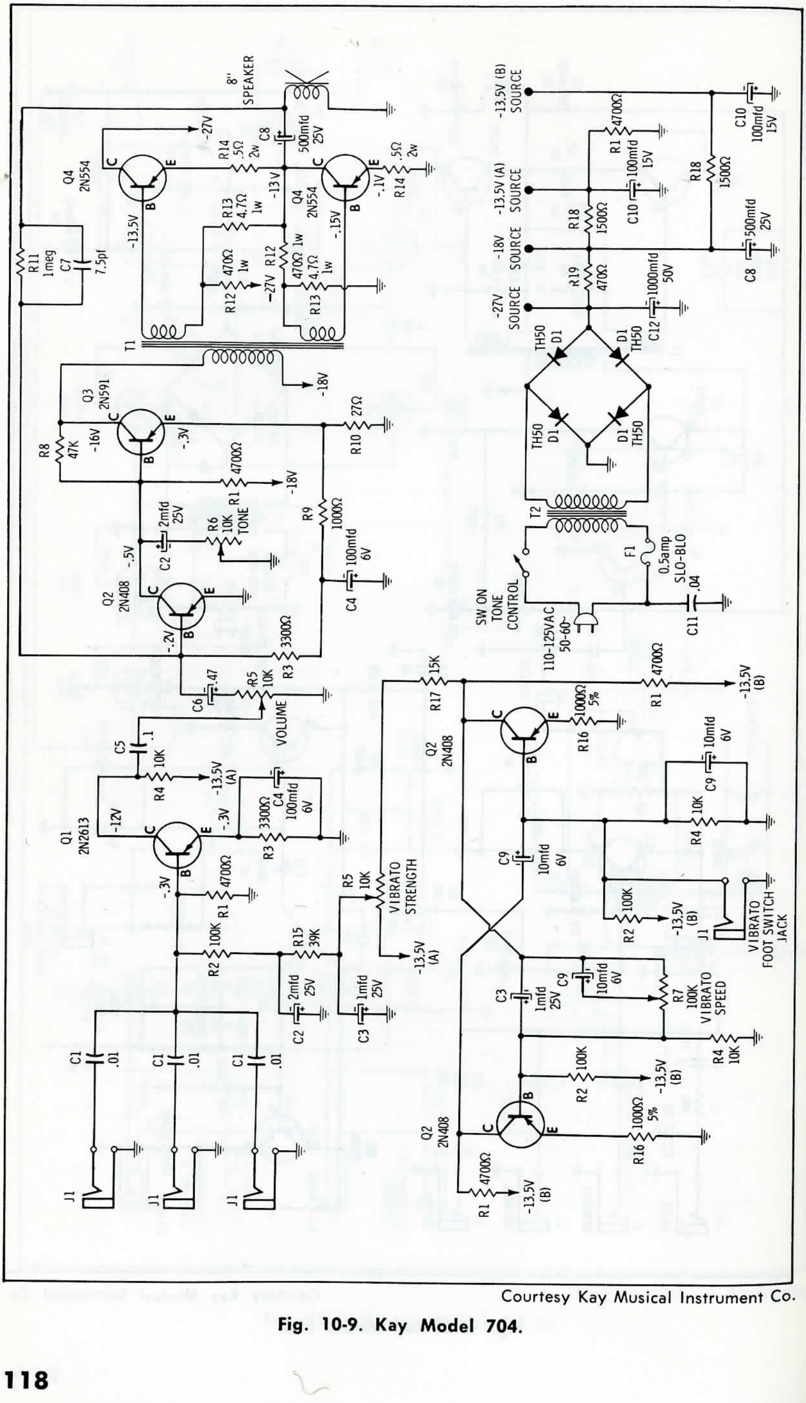
Courtesy Gibson Electronics

Fig. 10-7. Gibson Model GA-30.



Courtesy Kay Musical Instrument Co.

Fig. 10-8. Kay Model 705.



Courtesy Kay Musical Instrument Co.

Fig. 10-9. Kay Model 704.

KAY MODEL 705

Fig. 10-8 shows an all-transistor amplifier with a power output around 13 to 15 watts. A pair of 2N301 transistors (Q4) are used in a Class-B push-pull output, driven by direct-coupled transistors Q2 and Q3 which are a 2N408 and a 2N591 respectively. A transistor vibrato circuit using a pair of 2N408's can be controlled by a foot-operated switch. The tone-separation type of inputs are used. The "Bass" input gives more lows, the two in the middle are "Flat" or normal, and the other is a "Treble" input. (Incidentally, the word flat, in electronics, does not mean the same as in music. An input jack with a flat response amplifies high, low, and middle frequencies the same amount; it does not favor any particular frequency. If it is truly flat, the output from the speaker will be exactly the same as the tone of the instrument itself, except louder.)

This amplifier is a-c powered through a step-down transformer. A bridge rectifier using four 1N1763 silicon rectifiers gives a positive-ground output of about −15 volts dc. The bridge-type rectifier gives full-wave rectification, which has greater efficiency and is easier to filter out the ripple. All transistor amplifiers must have very good filtering since hum is always a problem.

The popular output-transformerless circuit, possible only in transistor amplifiers, is used here. Notice that the speaker voice coil is connected to the junction of the collector of one output transistor and the emitter of the other. No direct current flows through the voice coil of the speaker, which is actually isolated from ground by a 500-mfd electrolytic capacitor; only alternating current should be found across the voice coil. By removing the tone and frequency limitations of an output transformer this amplifier can get much higher fidelity over a very large frequency range.

KAY MODEL 704

The all-transistor amplifier in Fig. 10-9 is very similar in circuitry to the previous model. Both use the same number of amplifier stages and have the same number of transistors, but different types are used for the preamplifier and the power output. In this model all input circuits are identical; a tone control is provided to vary the tone color.

11

High-Power Amplifiers

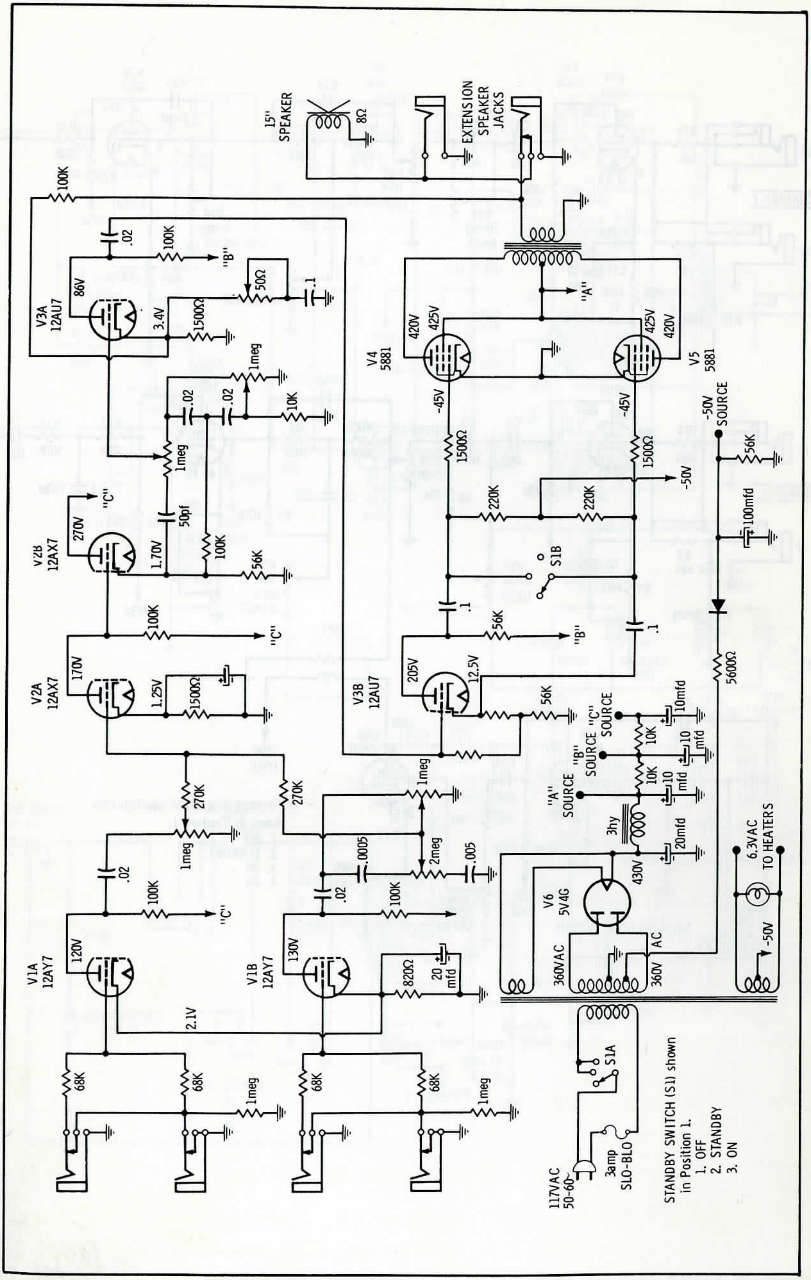
Amplifiers with a rated output of over 30 watts are considered high powered. They are normally used for more than a single instrument or for voice (microphone) and instrument combinations. Speaker systems are often desirable both to handle the wide frequency range and to take full advantage of the available power. Few speakers are designed to handle much more than 25 watts by themselves.

GIBSON MODEL GA-77

Fig. 11-1 shows a high-power tube-type amplifier, the Gibson Model GA-77. This uses a pair of special tubes in the output stage, the 5881's. With 425 volts on the plates and screen grids this circuit can have an output of up to 40 or 45 watts of audio power. A heavy-duty rectifier tube is used, a 5V4G, which is needed to supply approximately 200 ma of plate current. Voltage amplifiers, drivers, and preamplifiers are about the same as those used in the medium-power amplifiers. Four inputs are provided, and a microphone can be used with any of them. This amplifier has higher voltage gain in the preamplifier and voltage amplifier stages than the smaller units in order to drive the 5881's to full power output. Note the special negative bias supply used for the output tubes.

GIBSON "TITAN MEDALIST" MODEL

Fig. 11-2 shows another high-power circuit, four 6L6G tubes in parallel push-pull. Two tubes are tied together and used to carry greater power in each half of the push-pull circuit than a single tube could handle. Total output here is a full 50 watts of



Courtesy Gibson Electronics

Fig. 11-1. Gibson Model GA-77.

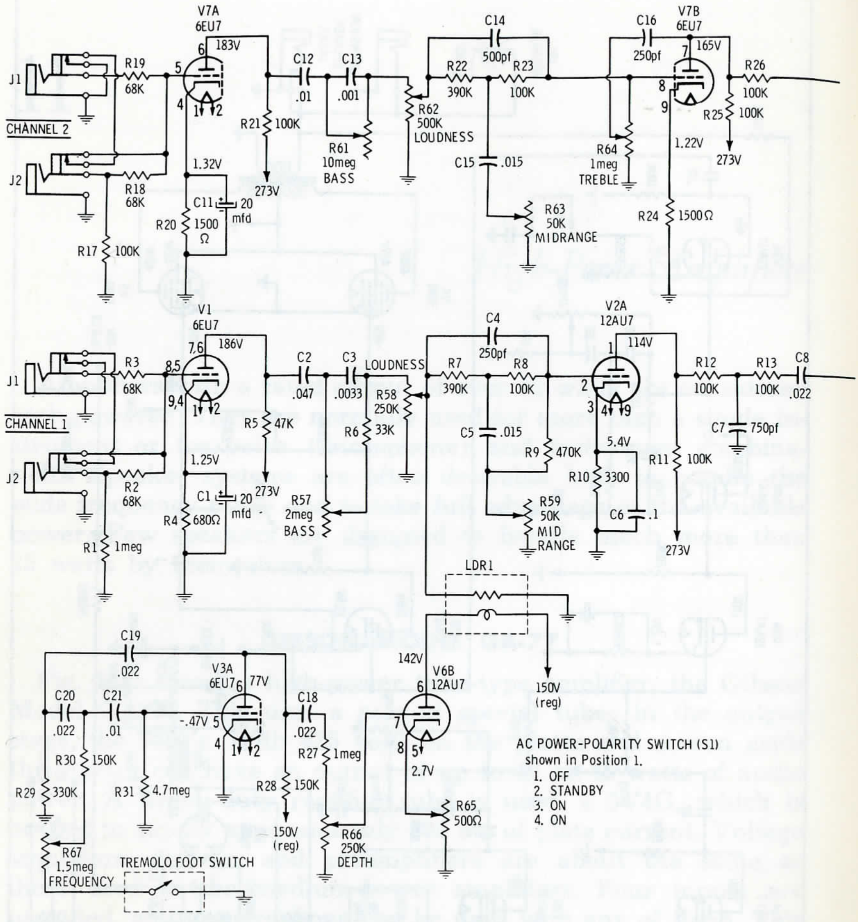
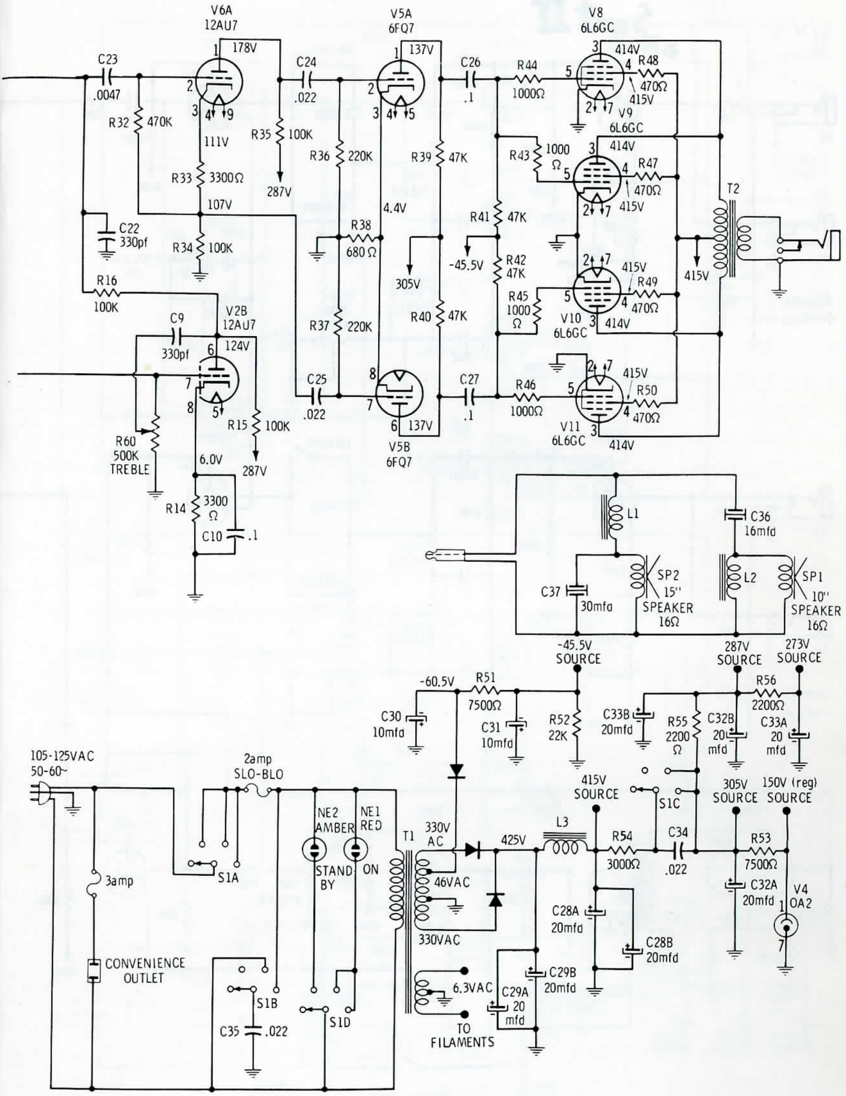


Fig. 11-2. Gibson "Titan



Courtesy Gibson Electronics

Medalist" Model.

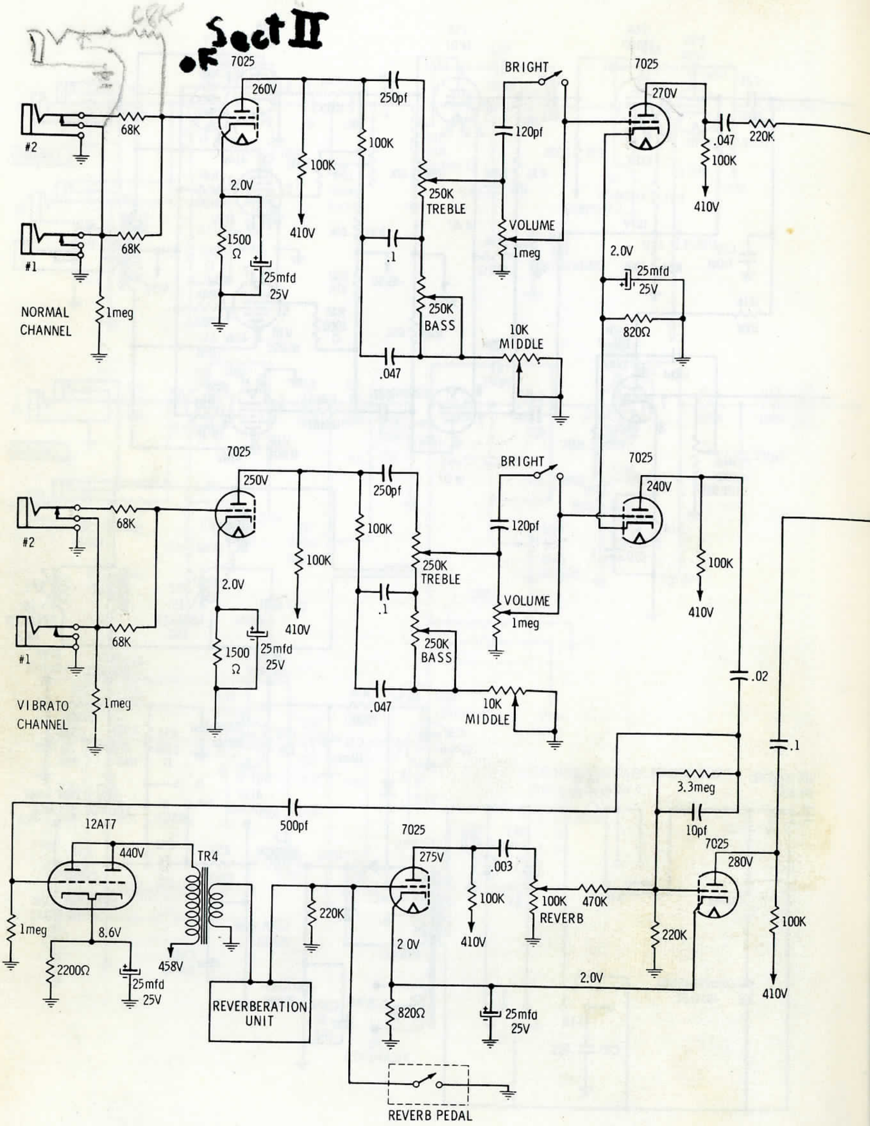
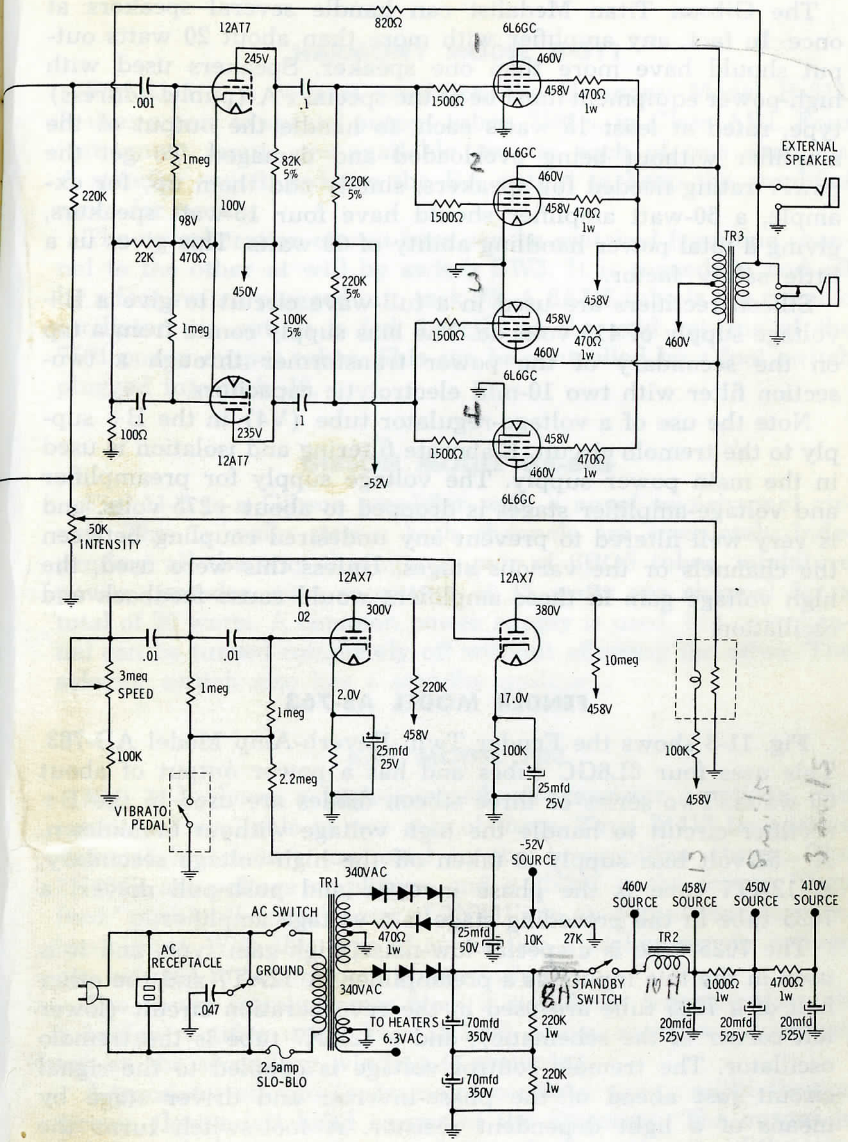


Fig. 11-3. Fender



Courtesy Fender Electric Instrument Company

Model AB-763.

audio. A special negative bias supply of −45 volts is used for the 6L6 tubes.

The Gibson Titan Medalist can handle several speakers at once. In fact, any amplifier with more than about 20 watts output should have more than one speaker. Speakers used with high-power equipment must be of the special PA (public-address) type, rated at least 15 watts each, to handle the output of the amplifier without being overloaded and damaged. To get the power rating needed for speakers, simply add them up; for example, a 50-watt amplifier should have four 15-watt speakers, giving a total power handling ability of 60 watts. This gives us a little safety factor.

Silicon rectifiers are used in a full-wave circuit to give a B+ voltage supply of 415 volts dc. The bias supply comes from a tap on the secondary of the power transformer through a two-section filter with two 10-mfd electrolytic capacitors.

Note the use of a voltage-regulator tube (V4) in the B+ supply to the tremolo circuit. Elaborate filtering and isolation is used in the main power supply. The voltage supply for preamplifier and voltage-amplifier stages is dropped to about +275 volts, and is very well filtered to prevent any undesired coupling between the channels or the various stages. Unless this were used, the high voltage gain in these amplifiers would cause feedback and oscillation.

FENDER MODEL AB-763

Fig. 11-3 shows the Fender Twin Reverb-Amp Model AB-763. This uses four 6L6GC tubes and has a power output of about 60 watts. Two series of three silicon diodes are used in the B+ rectifier circuit to handle the high voltage without breakdown. A −52-volt bias supply is taken off the high-voltage secondary. A 12AT7 tube is the phase inverter and push-pull driver; a 7025 tube in the preceding stage is a voltage amplifier.

The 7025 tube is a special low-noise, high-gain type, and it is used in the two inputs as a preamplifier. A 12AT7 and the other half of a 7025 tube are used in the reverberation circuit (lower left corner of the schematic), and a 12AX7 tube is the tremolo oscillator. The tremolo control voltage is coupled to the signal circuit just ahead of the phase-inverter and driver stage by means of a light dependent resistor. A foot-switch turns the tremolo on or off as desired.

Fig. 11-4 shows a parts layout of the Fender AB-763 amplifier. Note how the resistors, capacitors, and other components are mounted on the central insulating board to make them easier to get at for service. All controls are mounted along one apron of the chassis, and tube sockets are in a row on the back.

HARMONY MODEL H-311

Fig. 11-5 is a 30-watt amplifier, the Harmony Model H-311. It uses a pair of special output tubes, 7591's, in Class AB1. Four instrument inputs are available, two in each of two channels. A standby switch reduces the B+ output to keep the amplifier quiet for tuning.

The reverberation circuit here can be switched from one channel to the other at will by switch SW3. It is turned on and off by a foot switch plugged into jack J5. A 6AU6 tube is the tremolo oscillator; its output is fed directly to the grid returns of the 7591 power-output tubes. This can be controlled by a foot switch plugged into jack J6.

GIBSON MODEL GA-88S

Fig. 11-6 is a Gibson amplifier with a novel two-channel circuit. This is really stereo; both channels are completely independent all the way through. A pair of 6BQ5 tubes, miniature power pentodes, give an output of 15 watts per channel for a total of 30 watts. A common power supply is used, but one channel can be turned completely off without affecting the other. The selector switch also has a standby position.

KAY MODEL 707

Fig. 11-7 shows a high-powered, all-transistor amplifier. Six inputs are available in two sets of three. Type 34418 transistors (special low noise) are used in the preamplifier stages. The 2N408's are voltage amplifiers, and a 2N301 is the driver. They feed "push-pull-series" pairs of 2N301's in an output-transformerless circuit. With this type of connection a higher supply voltage can be used to obtain more power output.

The power supply comes from a step-down transformer with a bridge rectifier using four 1N1763 silicon rectifiers. A center tap on the secondary winding is grounded.

A transistor vibrato (or tremolo) oscillator uses a multivibrator circuit (lower left hand corner of the diagram). The output is fed through the strength controls into the base circuits of the preamplifier transistors. Changing the base bias voltage on a transistor is the same as changing the grid bias on a vacuum tube, so the vibrato effect is added to the signal. Individual foot switch

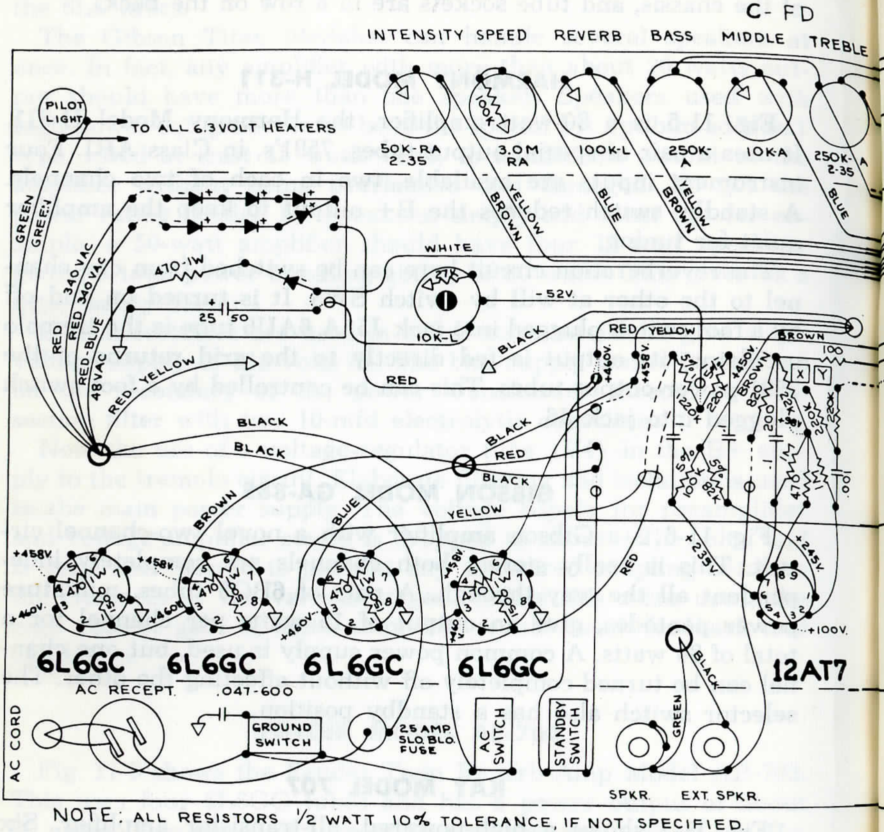
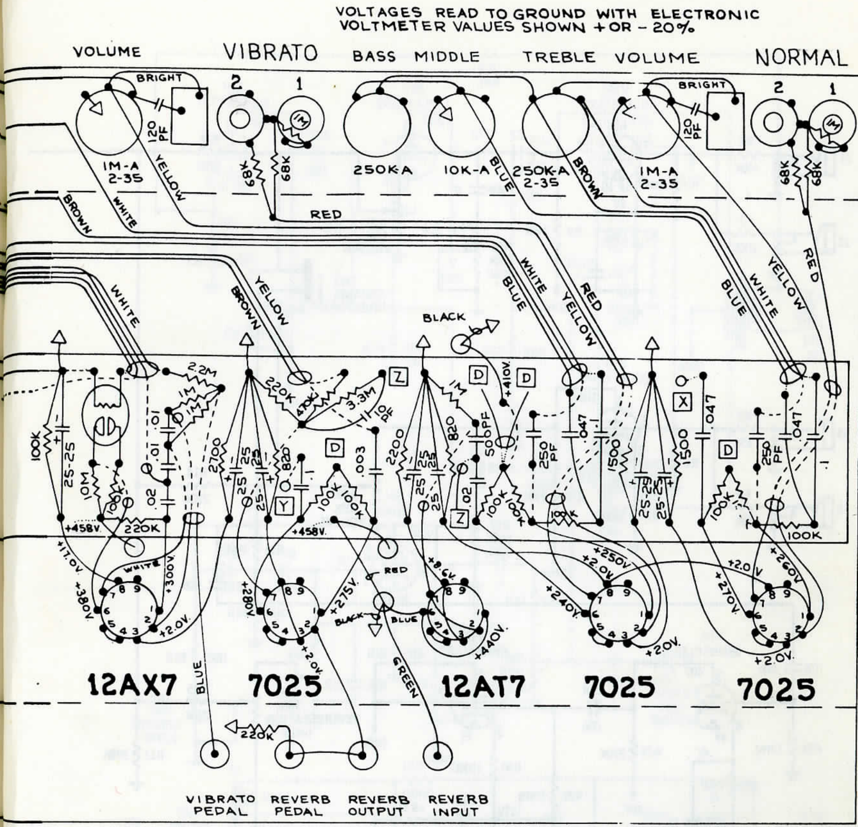


Fig. 11-4. Parts layout of

controls allow the vibrato to be used on either channel, or on both at the same time.

GIBSON "MERCURY MEDALIST" MODEL

In high-fidelity amplifying systems a single speaker is seldom used. A large speaker for the bass notes (woofer) and a smaller speaker for the treble or highs (tweeter) are coupled by special components to form a speaker system. This same principle is used in many of the more powerful guitar amplifiers, such as the Gibson Mercury Medalist model shown in Fig. 11-8. Notice that two speakers are shown, a 15-inch woofer and a 10-inch tweeter. The coils and capacitors connected across the speakers



NOTE: ALL CAPACITORS AT LEAST 400 VOLT RATING IF NOT SPECIFIED.

Courtesy Fender Electric Instrument Company

Fender AB-763 amplifier.

form what is known as a crossover network; these parts separate the bass notes from the treble, and feed them to the correct speaker. This process is entirely automatic. The amplifier itself has a two-channel preamplifier, with two inputs for each channel. Different tone combinations can be set up on either channel without affecting the other one. Each one has a full set of controls—bass, treble, and volume. Vibrato can be added to the Channel I inputs by depressing a foot pedal.

HARMONY MODEL H-322

Fig. 11-9 shows a special unit, called a bass amplifier, that is used in bands for the bass only. Since the bass notes in this type

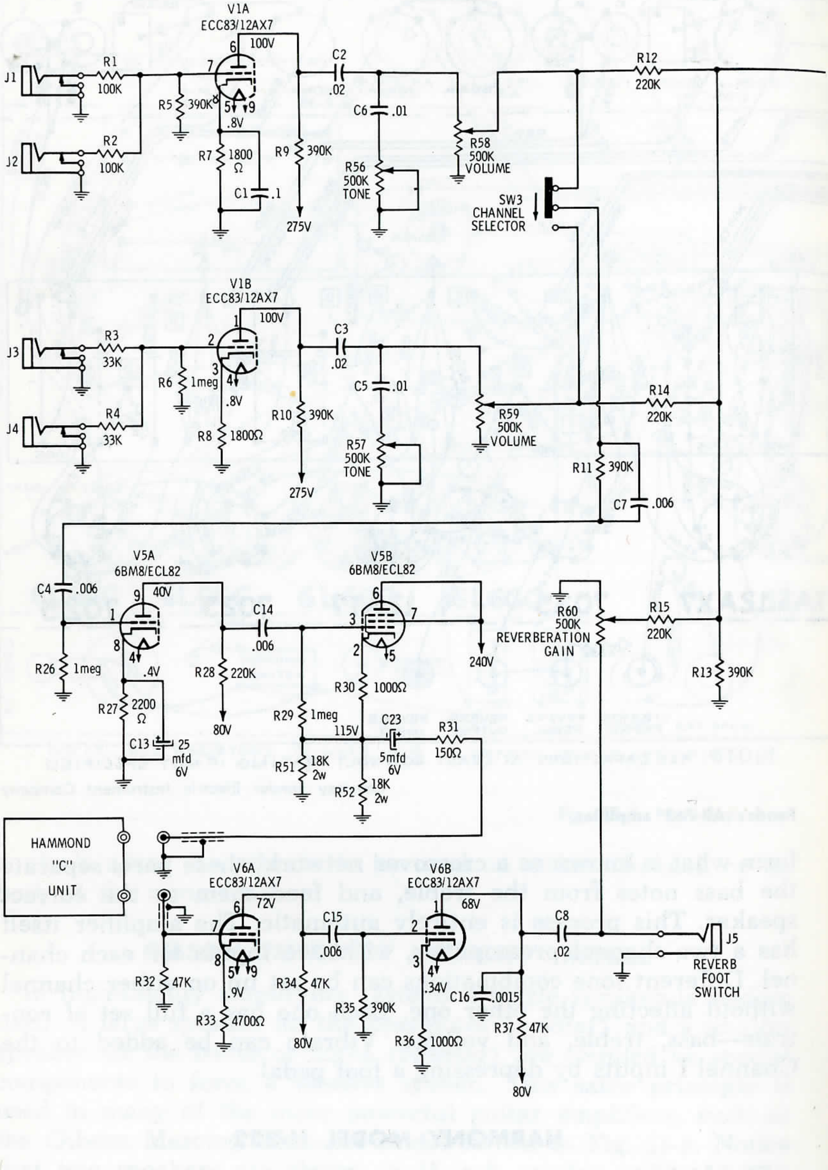
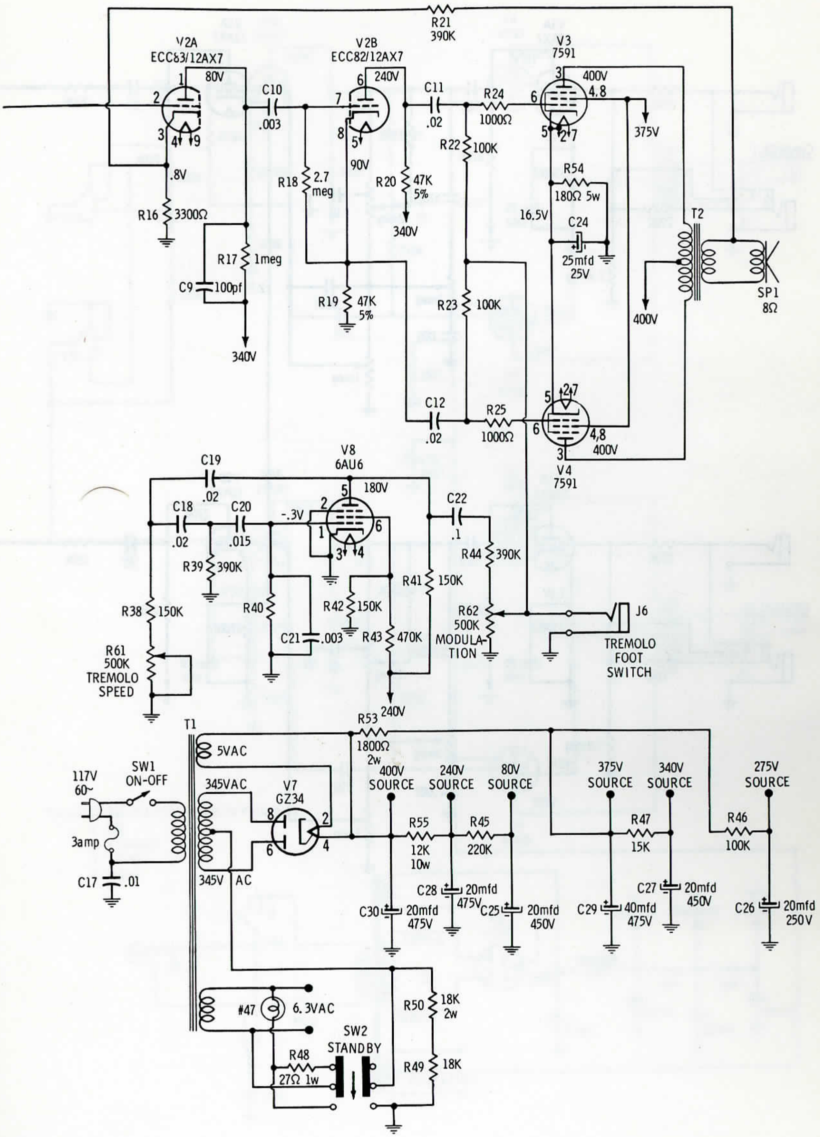


Fig. 11-5. Harmony



Courtesy The Harmony Co.

Model H-311.

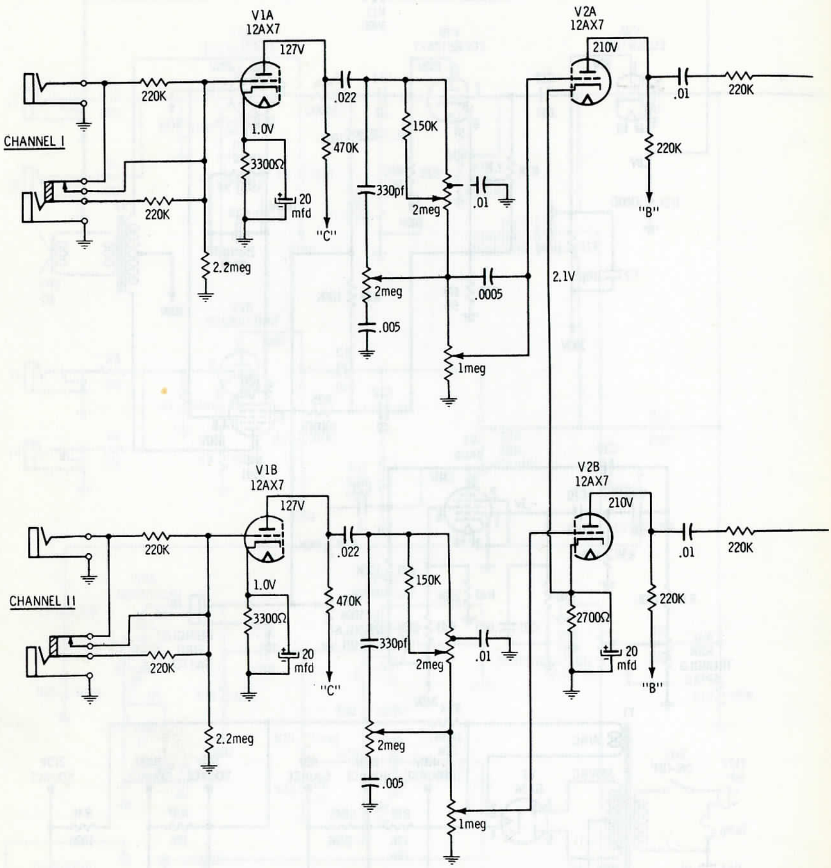
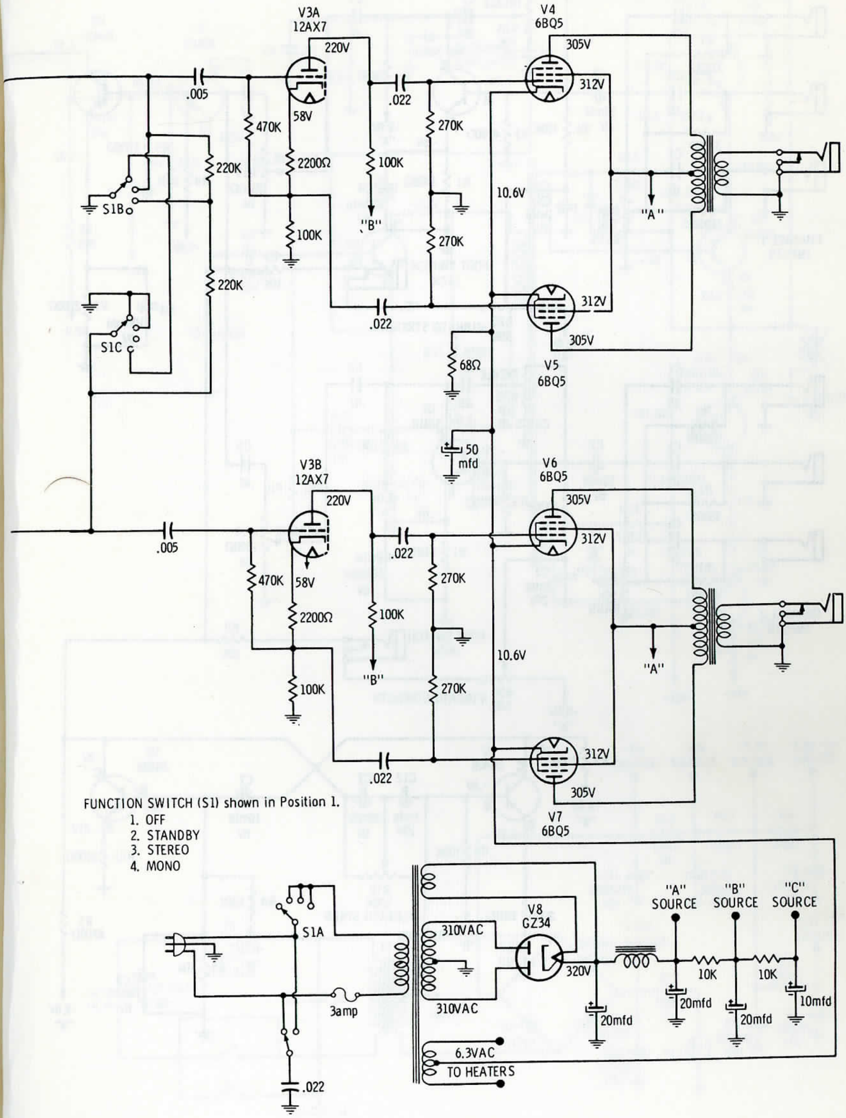
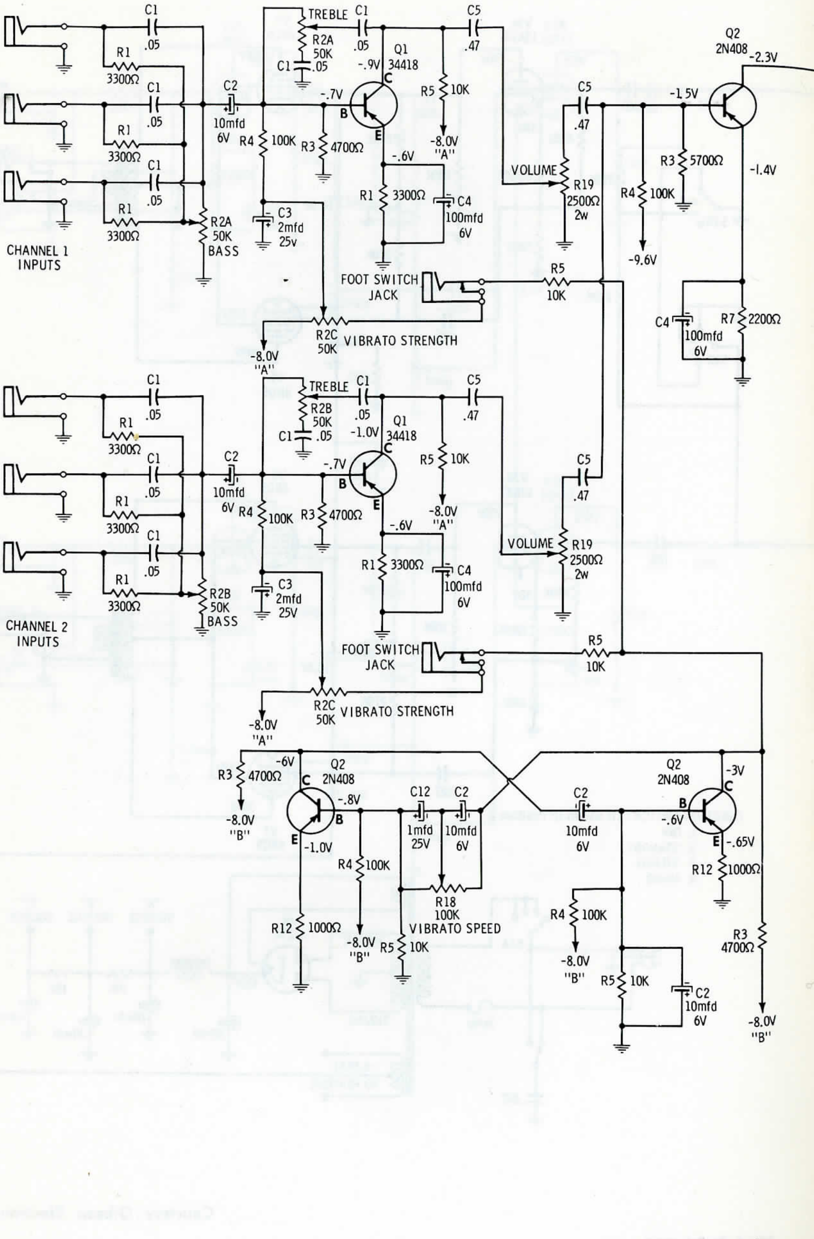


Fig. 11-6. Gibson



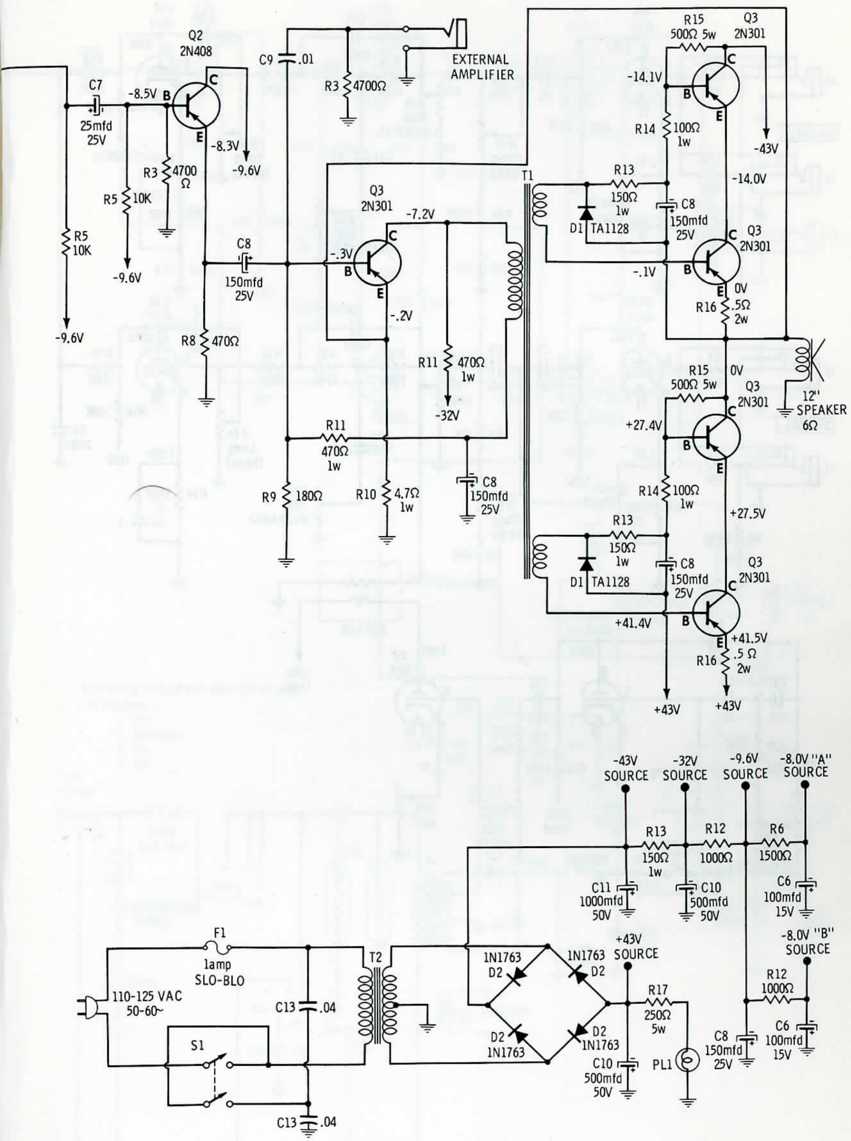
Courtesy Gibson Electronics

Model GA-88S.



CHANNEL 1 INPUTS
CHANNEL 2 INPUTS
C1 .05
R1 3300Ω
C2 10mfd 6V
R4 100K
R3 4700Ω
TREBLE
R2A 50K
R2B 50K
R2A 50K BASS
R2B 50K BASS
Q1 34418
R5 10K
C5 .47
-8.0V "A"
R1 3300Ω
C4 100mfd 6V
C3 2mfd 25v
FOOT SWITCH JACK
R2C 50K VIBRATO STRENGTH
VOLUME
R19 2500Ω 2w
Q2 2N408
R3 5700Ω
R4 100K
-9.6V
R7 2200Ω
C4 100mfd 6V
R3 4700Ω
-8.0V "B"
C12 1mfd 25V
C2 10mfd 6V
R18 100K VIBRATO SPEED
R12 1000Ω
R5 10K

Fig. 11-7. Kay



Courtesy Kay Musical Instrument Co.

Model 707.

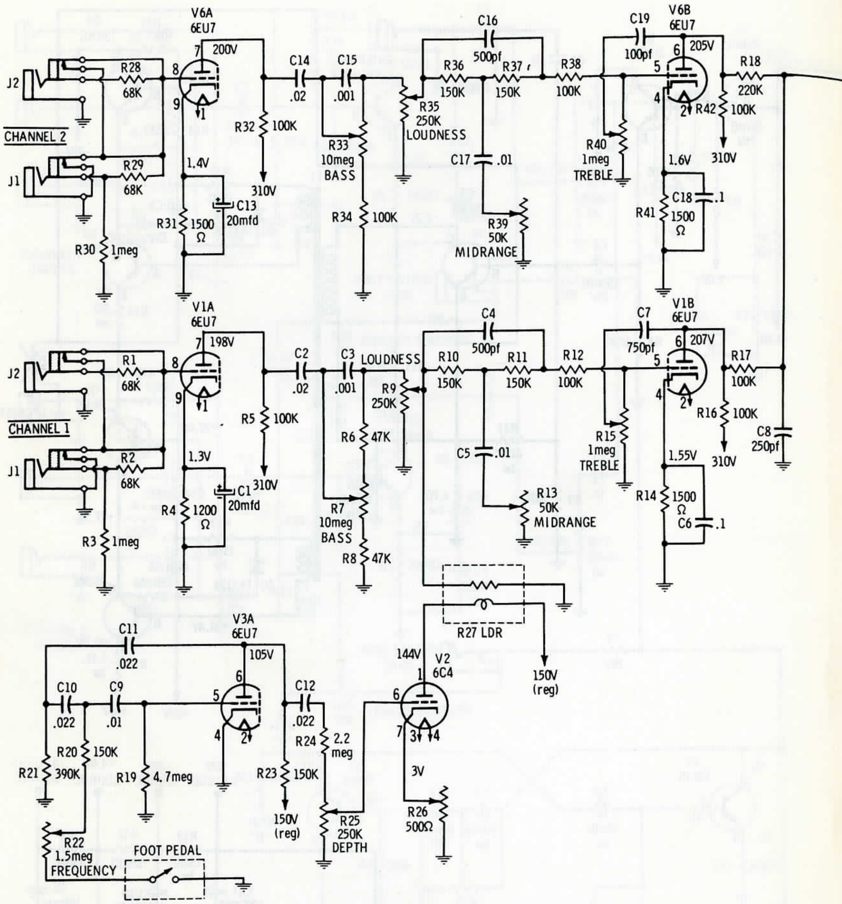
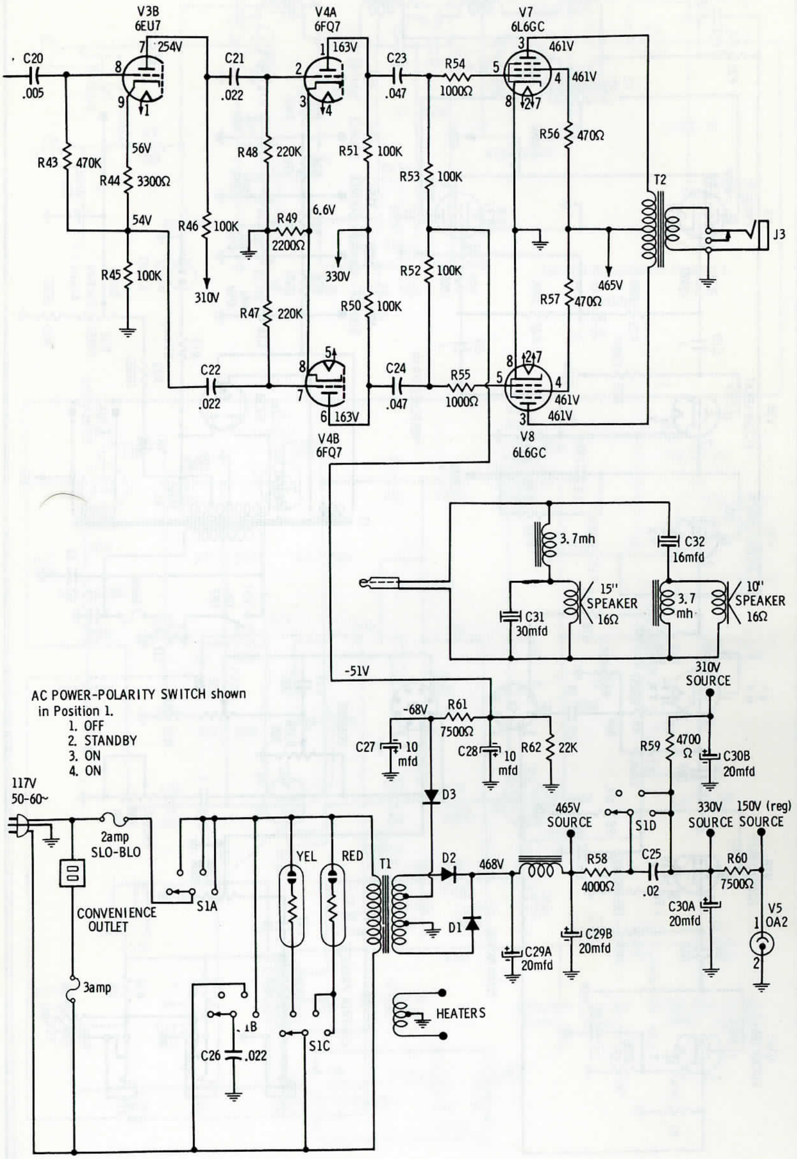
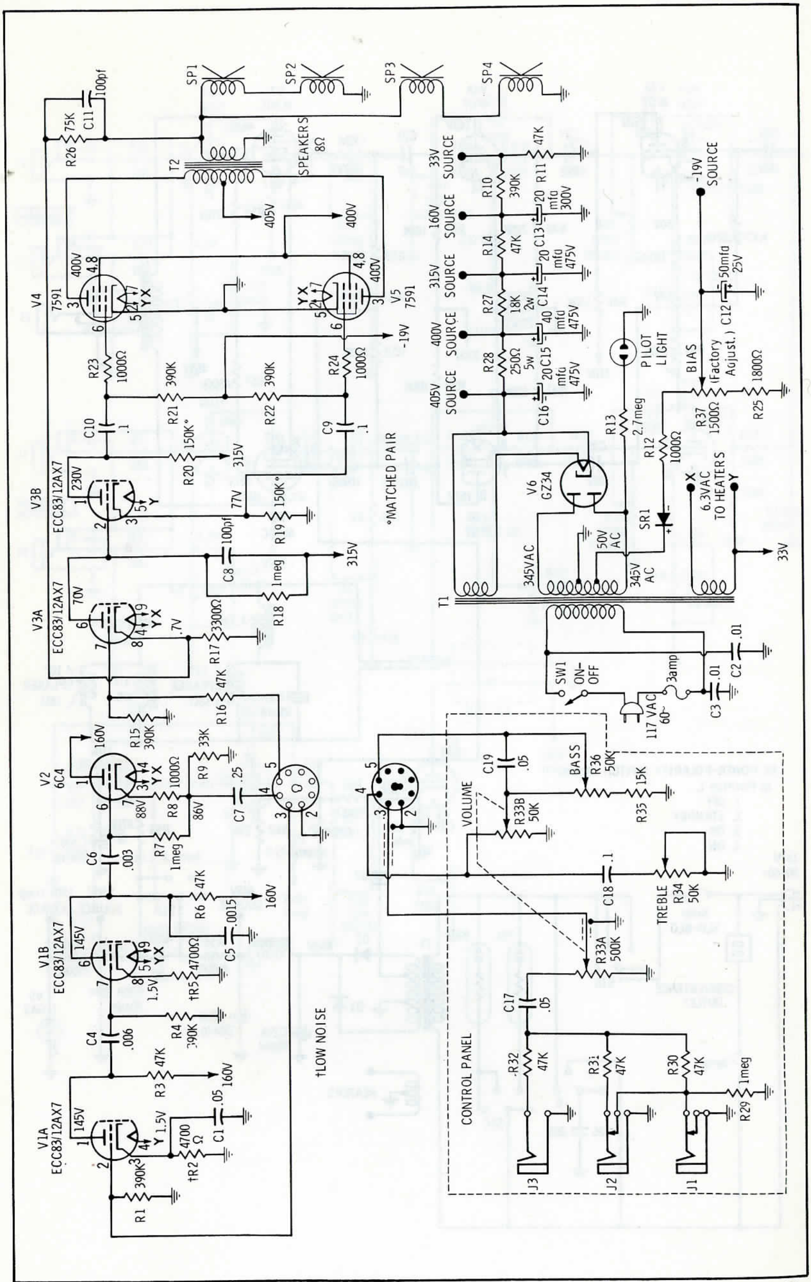


Fig. 11-8. Gibson "Mercury



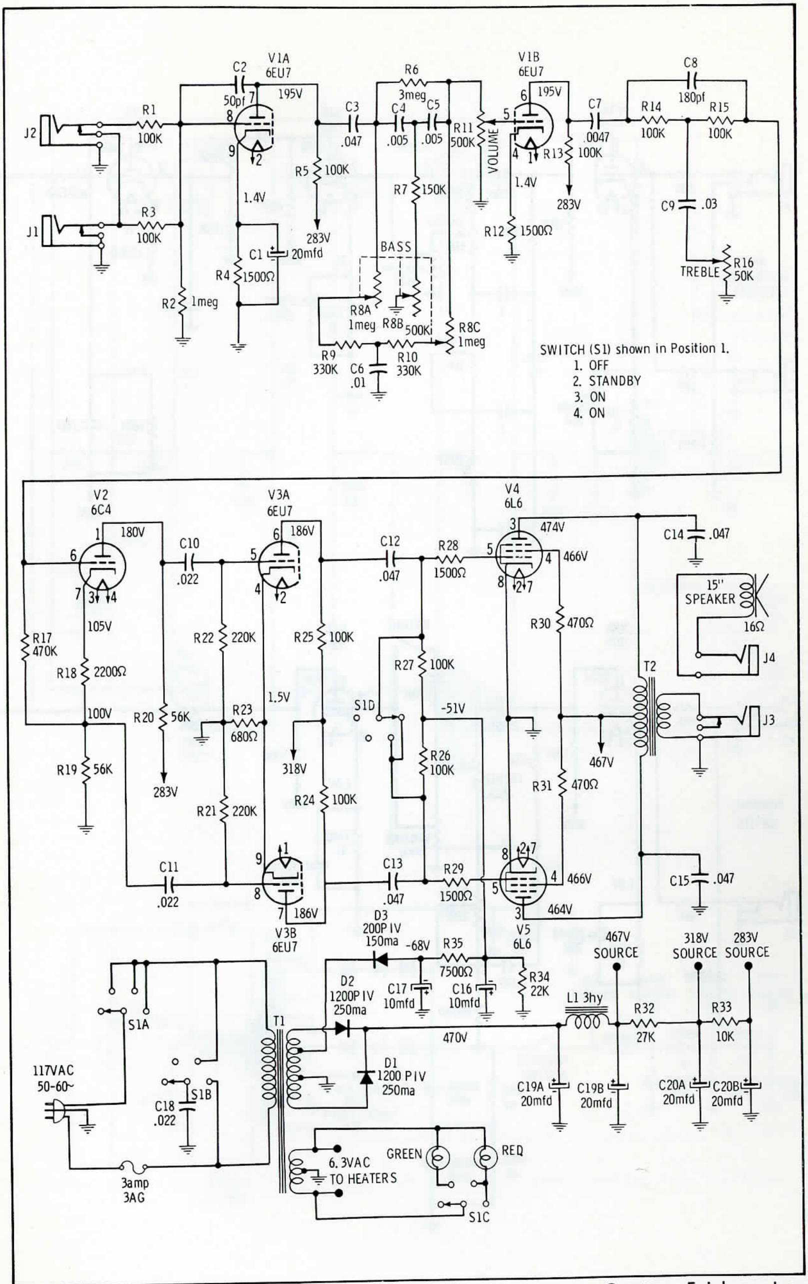
Courtesy Gibson Electronics

Medalist" Model.



Courtesy The Harmony Co.

Fig. 11-9. Harmony Model H-322.



Courtesy Epiphone Inc.

Fig. 11-10. Epiphone Model EA-72.

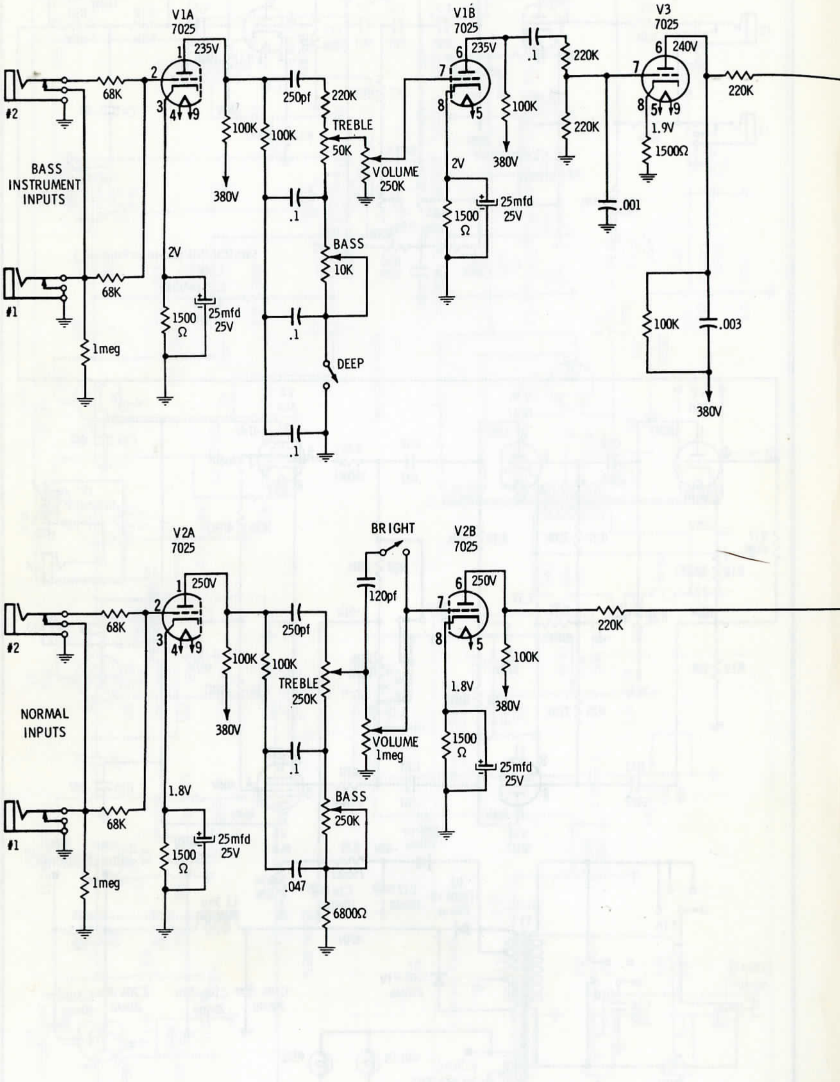
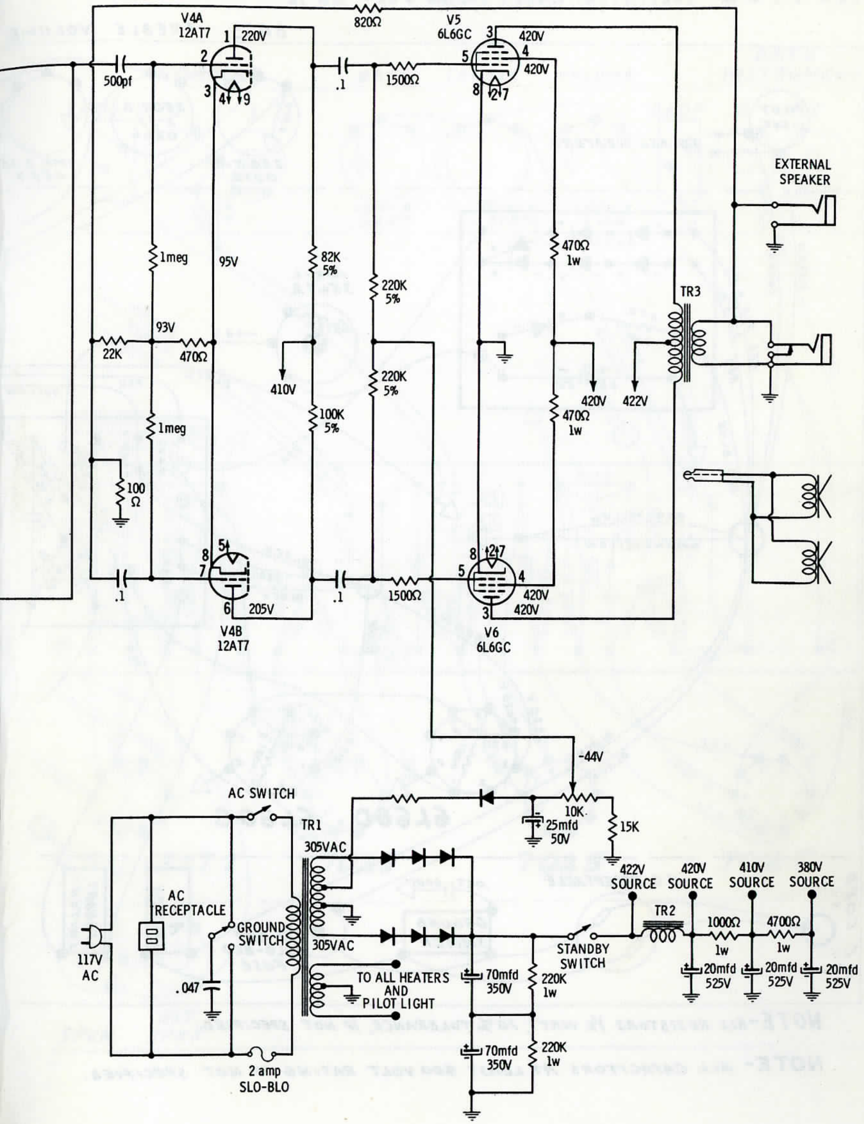


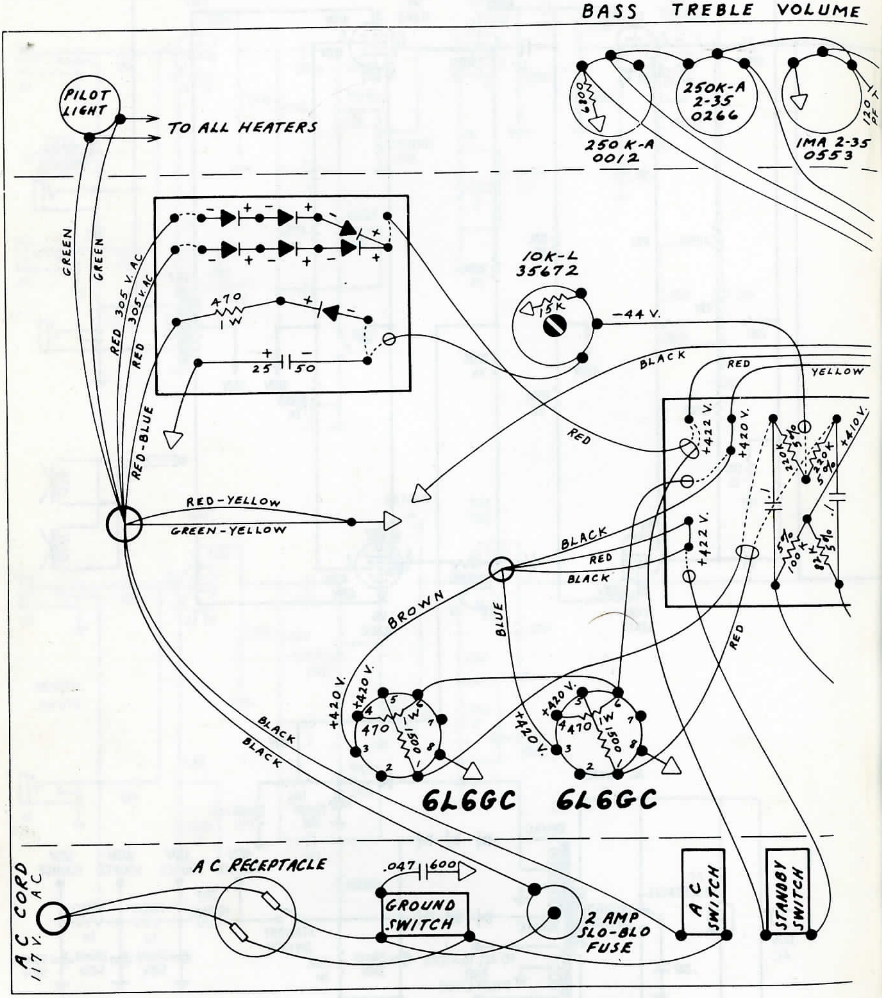
Fig. 11-11. Fender



Courtesy Fender Electric Instrument Co.

Model AA-864.

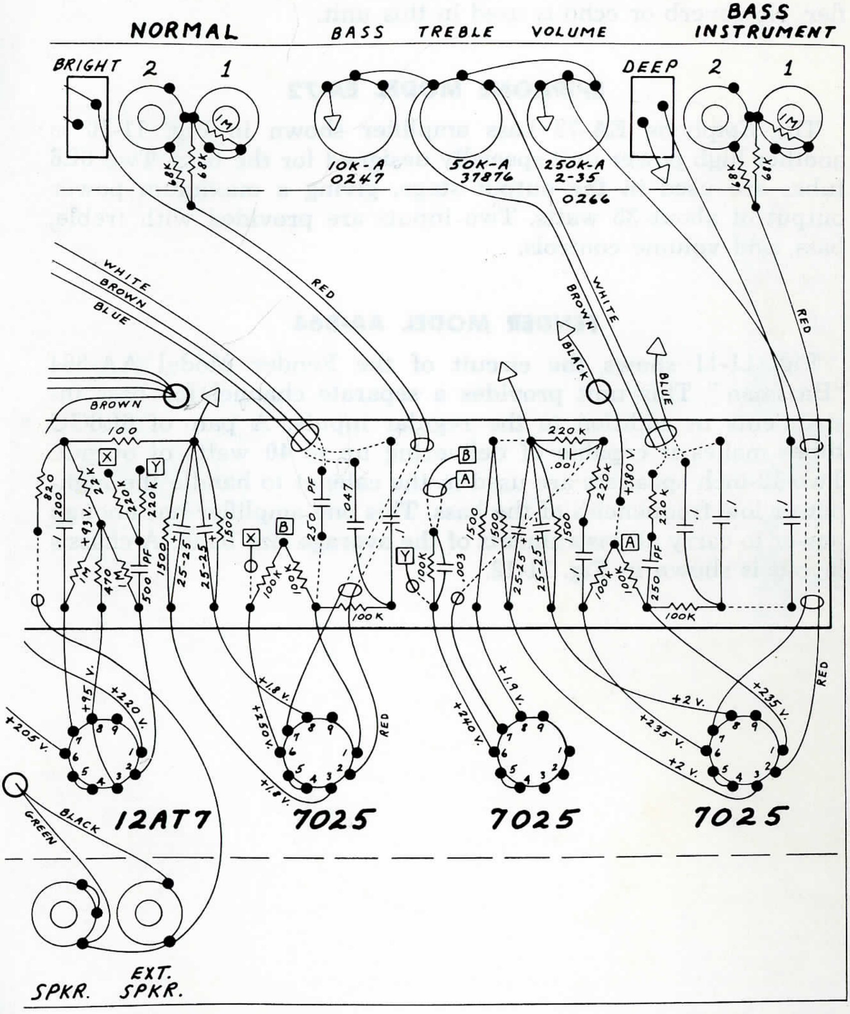
NOTICE VOLTAGES READ TO GROUND WITH ELECTRONIC VOLTMETER. VALUES SHOWN + OR − 20%



NOTE– ALL RESISTORS ½ WATT, 10% TOLERANCE, IF NOT SPECIFIED.

NOTE– ALL CAPACITORS AT LEAST 400 VOLT RATING IF NOT SPECIFIED.

Fig. 11-12. Parts layout of



Courtesy Fender Electric Instrument Co.

Fender Model AA-864.

of music are the ones that carry the beat, they need power; this amplifier is in the 40- to 50-watt range. Special power output tubes, 7591's, are used.

Three inputs are provided, so it is possible to feed other instruments in addition to the string bass through the same amplifier. No reverb or echo is used in this unit.

EPIPHONE MODEL EA-72

The Epiphone EA-72 bass amplifier shown in Fig. 11-10 is another high power unit specially designed for the bass. Two 6L6 tubes are used in the output stage, giving a maximum power output of about 35 watts. Two inputs are provided with treble, bass, and volume controls.

FENDER MODEL AA-864

Fig. 11-11 shows the circuit of the Fender Model AA-864 "Bassman." This unit provides a separate channel for bass instruments in addition to the regular inputs. A pair of 6L6GC tubes makes it capable of delivering up to 40 watts of output. Two 12-inch speakers are used in the cabinet to handle the high-power low frequencies of the bass. This one amplifier has enough power to carry all instruments of the average size band. A chassis layout is shown in Fig. 11-12.

ELECTRIC GUITAR AMPLIFIER HANDBOOK

by Jack Darr

The electric guitar is a natural product of today's electronics explosion. All stringed instruments by themselves have a rather limited volume, but modern amplifiers can give each a voice with almost unlimited power.

Radio and TV servicemen hesitate to work on musical instruments for several reasons. Musicians look on their instruments with great affection, and technicians are overawed by electronics that can arouse such personal feelings. Also, the ultimate test of a guitar amplifier is the musical sound, which servicemen feel unqualified to judge from an aesthetic point of view. In addition, information needed to repair electric guitars is not easily available, or it must be obtained through different channels from those normally used by TV servicemen.

Electric Guitar Amplifier Handbook is written to dispel any qualms the serviceman may have about entering a strange field. While explaining in detail the exact functioning of all parts of the guitar, the author relates them to familiar electronic circuitry. Musical complaints of guitar players are translated into the common language of electronics—faulty components, grid bias, voltages, and waveforms. Finally, the lack of service information is eliminated for the technician, since this book contains a large number of schematics and drawings of commercial instruments. Typical circuits are included for use where specific information is not available. All of this is presented in a readable style by an author who, as an electronics technician, knows all the problems.

Musicians with a limited electronics background, but with a curiosity about the electronics of their instrument, will find that explanations in this boo[illegible]mprehend. Technicians will receive all the information the[illegible] enter an interesting and profitable servicing field.

ABOUT THE AUTHOR

Jack Darr began working with radios in 1927, and he has devoted his life to understanding and practicing new skills in electronics servicing. A member of the IEEE, Jack is service editor for *Radio-Electronics* magazine. He has written numerous books and articles. His other SAMS books include: *Two-Way Mobile Radio Maintenance, How to Repair Small Appliances,* and *Servicing Garage-Door Openers.*

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