Uninterruptable Power Supply

Did you ever wish you could have a backup AC power supply in case of a power failure? Or did you ever wish you could take one or more of your home appliances with you on family outings? Well, this easy-to-build power inverter can help you do both!

DAVE SWEENEY

A POWER INVERTER IS USEFUL GADGET that can lend some degree of portability to otherwise home-bound electronics devices. Its function is to convert a low DC-voltage to a usable AC level. The power inverter we'll describe here will let you generate alternating current that will allow you to power a small television, personal computer, strobe light, or other AC-operated device without being tied down to an AC outlet.

While the project was originally designed so that AC devices could be operated in a car (from the 12-volt system), it has another important use: it can serve as part of an uninterruptable (backup) AC supply. If you suffer from some short-term power outages, it could be particularly valuable. Your burgular alarm could still operate during a blackout, and your clock would still keep time.

We won't go into detail on particular applications of the uninterruptable power supply. But we will mention that you have several options for making the unit "kick in" automatically when the power company cannot deliver. The easiest way, as shown in Fig. 1, is to use a 117-volt relay to switch between the standard AC line or the 117 volts from the inverter. One possible disadvantage there is that the relay might not be fast enough in some applications. For example, only a very slight disruption in power can overwrite your computer's memory with garbage. Only experimentation will let you know for sure. A solid-state relay, which typically has a faster switching time than a mechanical relay, might be your best bet. In either case, you'll want to make sure that you have a fully charged battery to supply power to your inverter. A trickle charger would be a valuable addition to the circuit.

Provided the inverter's power capacity is not exceeded, you can power most any AC-operated device indoors or outdoors, and during power failures. Be cautioned however, that the output of this inverter is closer to a squarewave than a sinewave. Even though the high-frequency components of the squarewave output are filtered, some devices will not operate properly with such an input and others may even be damaged!

In a motor vehicle (which is where this unit was designed to be used), the inverter produces 117-volt AC from your auto's 12-volt DC battery. So you can use the unit to add to the fun of an outdoor party, or even to power an electric razor while you wait in line at the drive-in bank!

Voltage isn't everything

Besides generating the correct AC voltage, an inverter must provide the correct frequency. Many devices, especially those with transformers or motors, require 60 Hz. If the frequency varies as the load changes, or when the DC input fluctuates, the performance of the device may be reduced, or the equipment might be damaged.

Low-power, inexpensive inverters typically rely on a special winding of the transformer for oscillation. Since most inverters are little more than an oscillator with specially wound transformers, the unit's output frequency is determined by transformer's inductance. Therefore, loading the transformer changes its effec-

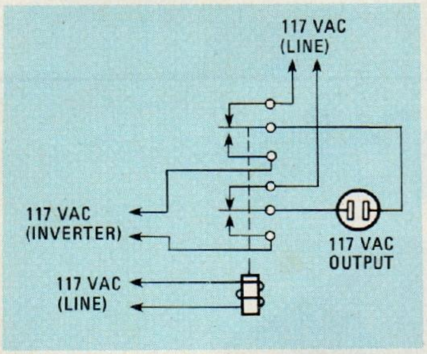

FIG. 1—A SIMPLE RELAY SETUP will let you use the inverter as a backup power supply.

tive inductance, and results in an output-frequency that varies with load requirements.

The inverter power supply that we'll describe here overcomes that deficiency by using a 555 oscillator to control the output frequency. Isolated from the power output, the oscillator maintains a 60-Hz output frequency regardless of the load. And if that isn't enough, it has a low parts-count and the parts used are easy to find.

For example, the transformer is an inexpensive, general-purpose 25.2-volt center-tapped, 2-amp unit with a single high-voltage winding.

Circuit description

Figure 2 shows a schematic of the power supply inverter. MOSFET transistors, Q3 and Q4, form a flip-flop whose output is used to turn power transistors Q1 and Q2 on and off alternately. When Q1 is on, current flows in half the low-voltage winding; when Q1 is off, Q2 is on and current flows in the other half of the low-voltage winding.

Transformer T1, which has a 117-volt primary and 25.2-volt secondary is used as a step-up, rather than a step-down, transformer. (A transformer transfers power in either direction—the terms *primary* and *secondary* are assigned rather arbitrarily.) Current in each half of the center-tapped winding flows in opposite directions (i.e., positive and negative). That alternating current (AC) in the center-tapped "secondary" winding induces AC in the high-voltage "primary" winding. That voltage step-up results from the operation of Q1 and Q2, which are turned on and off alternately.

As long as the power transistors (Q1 and Q2) alternate at 60 Hz, the output voltage will also be at 60 Hz. To maintain that operating frequency, the flip-flop (Q3 and Q4) switches the base currents of Q1 and Q2. The flip-flop is triggered by the output of the 555 oscillator, IC1. Since Q3 and Q4 conduct alternately, they are always inversely related to each other. And because they operate from the same trigger, they'll always generate a symmetrical AC squarewave.

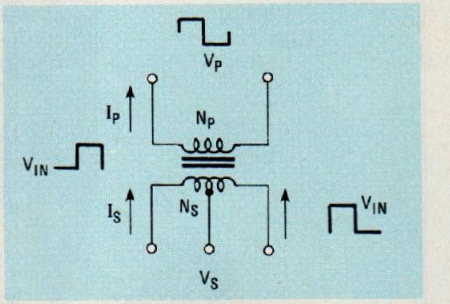

FIG. 3—WHEN A 60-Hz AC VOLTAGE is applied to a standard transformer, the relationships of the voltage (V), current (I) and windings (n) may be expressed as $V_P/V_S = I_S/I_P = N_P/N_S$.

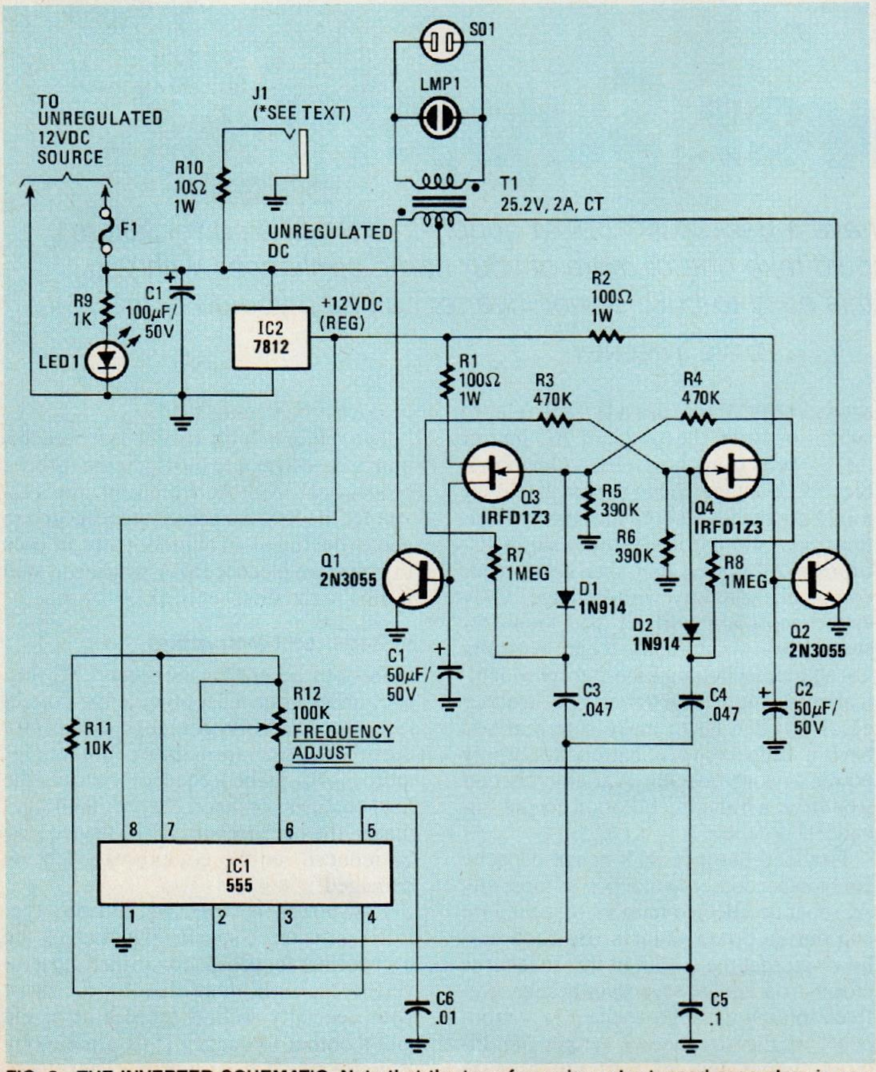

FIG. 2—THE INVERTER SCHEMATIC. Note that the transformer's center tapped secondary is connected as the input. So T1 is used as a step-up transformer.

Now let's turn to Fig. 3 for a discussion of the turns ratio and transfer characteristics of the transformer. When a 60-Hz AC voltage is applied to a standard transformer, the relationships of the input/output voltage (V), current (I), and the number of turns in the transformer windings (N) can be expressed as $V_P/V_S = I_S/I_P = N_P/N_S$. For the transformer specified, the turns ratio is 117/25.2; therefore, feeding 25.2-volts AC to the secondary of T1 (without allowing for inefficiencies) produces a 117-volt output.

Since transformer T1 is rated at 2-amperes maximum in the secondary winding, the transferable power is 25.2 (V) × 2 (A) or 50.4 watts. Because the turns ratio determines the output voltage, applying 12-volts AC to half the secondary also yields an output of 117 volts. However, the output power capacity will be cut in half.

To increase the capacity of the unit, connect two identical transformers in parallel, a similar effect to placing two batteries in parallel. Just be sure to connect like terminals together, so as not to cause a phase difference that could damage the transformers! The unit's power-handling capacity will then be then the sum of all parallel transformers.

The net result is while transformer T1 determines the step-up voltage level, the 555 oscillator determines the output frequency. Therefore, even if T1 is severely loaded, the oscillator and MOSFET's maintain a symmetrical 60-Hz AC signal for T1.

PARTS LIST

All resistors ¼, 5% unless otherwise noted.

R1, R2—100 ohms, 1 watt
R3, R4—470,000 ohms
R5, R6—390,000 ohms
R7, R8—1 megohm
R9—1000 ohms
R10—10 ohms, 1 watt
R11—10,000 ohms
R12—100,000 ohm potentiometer

Capacitors

C1, C2—50µF, 50 volts electrolytic
C3, C4—.047µF, ceramic disc
C5—.1µF, ceramic disc
C6—.01µF, ceramic disc
C7—100µF, 50 volts electrolytic

Semiconductors

IC1—555 oscillator
IC2—7812 12-volt regulator
Q1, Q2—2N3055 NPN power transistor
Q3, Q4—IRFD1Z3 N-channel FET
D1, D2—1N914
LED1—Standard red LED
LMP1—neon panel lamp
T1—25.2 volts, 2A center-tapped

Miscellaneous: Cabinet, perforated construction board, AC panel socket, miniature phono jack, 4A slow-blow fuse, cigarette lighter plug, etc.

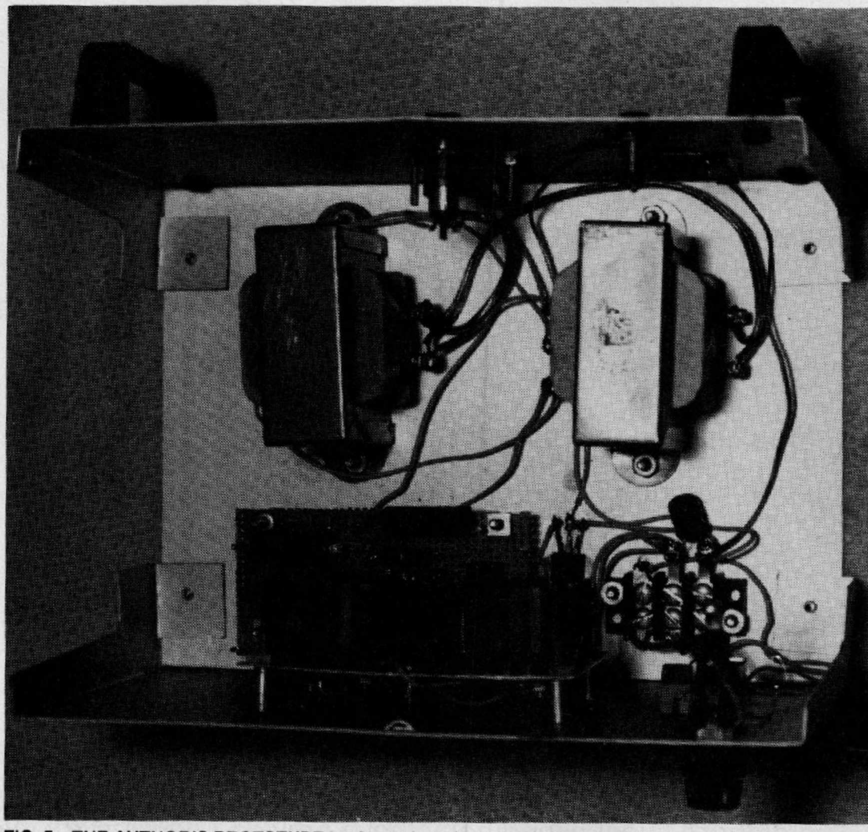

FIG. 5—THE AUTHOR'S PROTOTYPE is shown here installed in metal cabinet. Note that two transformers are used to increase power handling capabilities.

Circuit operation

Capacitor C5 and potentiometer R12 determine the frequency of the output signal at pin 3 of IC1, the 555 oscillator. The output signal is differentiated by C3 and C4 before it's input to the base of the two power transistors (Q1 and Q2) via diodes D1 and D2, respectively. The signal from IC1 is adjusted to 120 Hz. That's because the flip-flop formed by transistors Q3 and Q4 divides the frequency by 2.

When Q3 is on, the base of Q1 is connected via R1 to the regulated 12-volt supply. Then, when the flip-flop changes states, Q4 is turned on and the base of Q2 connected to the 12 volt supply through R2. The 100 mA base current allows Q1 and Q2 to alternately conduct through their respective halves the transformer's secondary winding.

FIG. 4—THE ABOVE TRACE SHOWS the 60-Hz output from the inverter. Note that although the output is closer to a squarewave than a sinewave, most of the high-frequency components have been removed.

To eliminate switching transients caused by the rapid switching of Q3 and Q4, capacitors C1 and C2 filter the inputs to the base of Q1 and Q2 respectively. Figure 4 shows the waveform that appears at the output (primary) of the transformer. Though the output is not a sinewave, it is close enough to operate all but the most critical equipment. But don't risk damage to your expensive equipment if you're not sure. As a rule of thumb, if your equipment can be damaged by transients, it's not a good candidate for this backup power supply.

Power for the unit comes from your automobile's 12-volt system, or—if you want to use the inverter for backup applications—from a storage battery. It is regulated by IC2 (a 7812 regulator). LED 1, connected across the 12-volt input, may be used to indicate whether power is being fed to the circuit. The neon pilot lamp, LMP 1, shows a presence or absence of output power. Jack J1 is included to provide a convenient 9-volt DC supply for a videogame, like the Atari *2600*.

Circuit construction

The method of construction is not critical, but if you're going to build the inverter as a portable unit, it's important to build it to withstand punishment. The author's prototype was built on perforated construction-board using point-to-point wiring, as shown in Fig. 5. Note that there are two transformers shown; as mentioned previously, two or more transformers may be paralleled to increase the unit's power handling capacity.

The power-inverter circuit should be housed in a metal cabinet, and power transistors Q1 and Q2 should be heat sinked. To avoid damage from vibration, the components should be secured to the driver board with an epoxy adhesive.

The FREQUENCY-ADJUST potentiometer, R12, should be set prior to connecting the collectors of Q1 and Q2 to the transformer. Set the frequency at pin 3 of the IC1 to 120 Hz; then using a scope, monitor the base of both Q1 and Q2 to verify that a 60-Hz signal is present. Once the signal is established, the Q1 and Q2 collectors may be connected to the transformer.

Potentiometer R12 may be mounted on the panel to allow frequency adjustments from outside the inverter. To test the unit out, plug it into the cigarette-lighter socket in the vehicle. Both pilot lights should come on. If not, go back and check your work. If all is well, the unit is ready for use.

Safety procedures

Caution: Keep in mind that the inverter, whether being tested or used, has the same output-voltage level as that of an ordinary household power-outlet and is just as dangerous. Exercise the same caution that you would in dealing with household line voltage. **R-E**

UNINTERRUPTABLE

POWER SUPPLY

Power failures? Don't worry! This UPS will keep your computer running when the powerline fails.

DUANE M. PERKINS

AN UNINTERRUPTABLE POWER SUPply, usually called a UPS, is one that continues to supply power when the powerline fails, and it does so without even a momentary interruption. The switchover is made so quickly that a computer connected to the UPS wouldn't even know that the powerline had failed.

A UPS's backup power is supplied by a storage battery that switches in only during during a power outage. Naturally, a backup battery isn't going to provide a full day's operation, but it will power the computer for a few minutes; certainly long enough to save whatever data is in the computer, and if necessary, allow enough time to close down in an orderly, non-destructive manner.

Sinewave output

The UPS described here can supply 40 watts continuously at 115 volts with a frequency of 60 Hz. The output is essentially a sinewave that looks to the load like standard household power. A built-in power supply functions as a battery charger. While the UPS can be used for many different purposes, it was designed specifically to power a small personal computer and a critical peripheral, such as a disk drive, so that a power failure will not result in loss of data or interruption of the program that is running at the moment. What constitutes "a small personal computer?" Something like the Radio Shack Color Computer, or a Commodore VIC-20 or C64, although the C64 when used in conjunction with a disk drive draws about 45 watts. The 40-watt UPS will not carry an IBM PC or XT or a clone, which normally run upwards of 60 watts—the actual power depending on the number and type of floppy and hard-disk drives, expansion boards, and the internal modem.

Another advantage in using our UPS is that it supplies "clean" power: defects such as noise, surges, or low voltage on the powerline will not affect the computer's operation.

The load

Before undertaking construction, be sure that the planned load will not exceed the capacity of the UPS. Current ratings for computer peripherals are maximums that may occur only momentarily when a motor starts. The author operates a Radio Shack Color Computer 2 and a disk drive even though the combined current rating is .53 amperes. The momentary overloads do not adversely affect operation. If the load can operate satisfactorily when a 25-ohm, 10-watt resistor is connected in series with one of the leads from the powerline, then it should operate from the UPS.

The power supply

The power supply is unique in that it draws energy from an external 12-volt storage battery as well as from the AC power line because the battery is required for circuit operation. As shown in Fig. 1, when CHARGE-OFF-OPERATE switch S1 is set to either the CHARGE or OPERATE position, relay RY2 is energized and its contacts supply AC power to the primaries of power transformers T1 and T2. The current from the secondaries is rectified by diodes D1, D2, D3, and D4. Chokes L1 and L2 limit the charging current to the battery and also block most of the ripple. The choke coils are available in Radio Shack's *270-030* automotive filter kit. The 220-µF capacitors that come in the kits can be used for C6 and C7. Diode D5 provides "crowbar" overload protection; its job is to protect the other components by causing fuse F1 to blow out if the battery is inadvertently connected with its polarity reversed.

Op-amp IC1 is connected as an inverting voltage comparator whose reference potential can be varied through the range of 11 to 14 volts by potentiometer R3. When the battery voltage drops below the reference, opto-coupler IC2 is triggered, which energizes relay RY1. Current flowing through RY1's contacts will charge the battery if the load is light. When the UPS is operating at or near its full capacity, an external battery charger is required to supply enough current to keep the battery from being discharged. A 10-

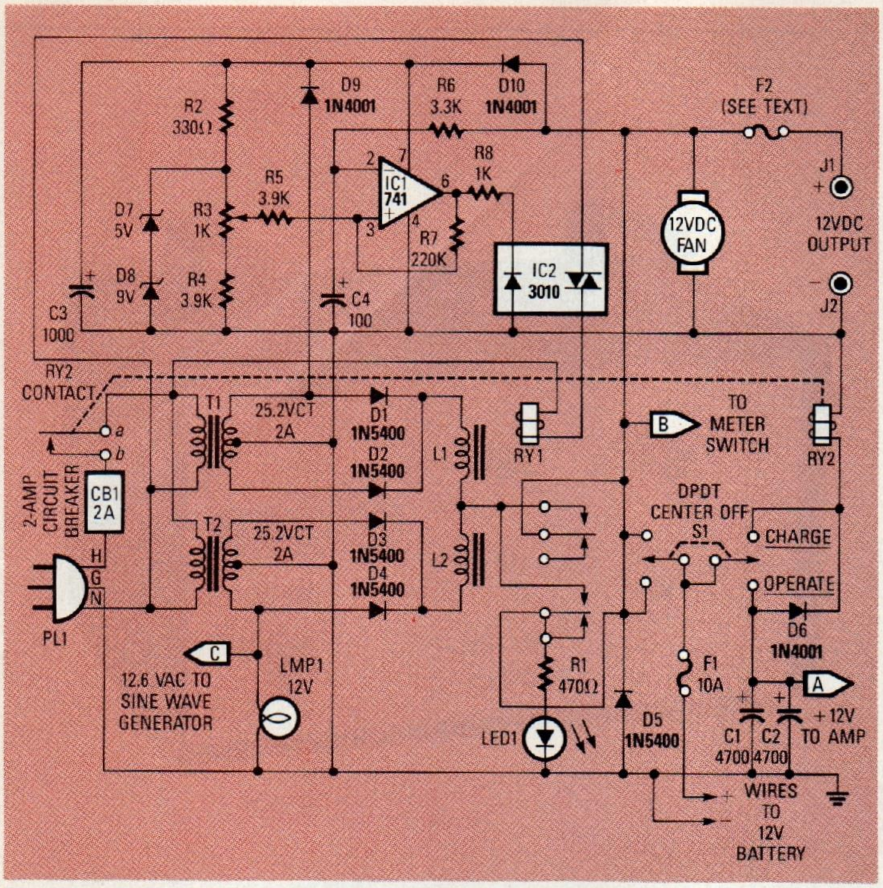

FIG. 1—WHEN THE UPS IS NOT OPERATING, or operating under a light load, this power supply also is used to charge the 12-volt battery. When the UPS is under a heavy load, however, an external 10-amp charger is needed to keep a full charge on the batteries. To prevent overcharging the battery, that charger must be turned off whenever the UPS is not operating.

ampere charger is recommended. Since most battery chargers do not have a filter, a Radio Shack *270-051* 10-amp. filter should be connected between the charger and the battery to reduce ripple. So as not to overcharge the battery, the charger should be turned on only when the UPS is operated under full load.

The 12-volt DC output at jacks J1 and J2 can be used to power a small lamp and possibly a small 12-volt TV receiver for use as an emergency monitor. Fuse F2 should be smaller than 10 amps so that the main fuse, F1, will not blow if the 12-volt output is accidentally shorted.

The amplifier

As shown in Fig. 2, the AC output of the UPS is supplied by a transformer-coupled Class-B amplifier. The four pairs of Darlington-connected transistors (Q4–Q8, Q5–Q9, Q6–Q10 and Q7–Q11) function as emitter-followers to supply voltage to the primaries of power transformers T5 and T6, which are standard power transformers connected in reverse—the secondary windings serve as the primaries and vice versa.

Capacitor C8 filters any high-frequency components that result from

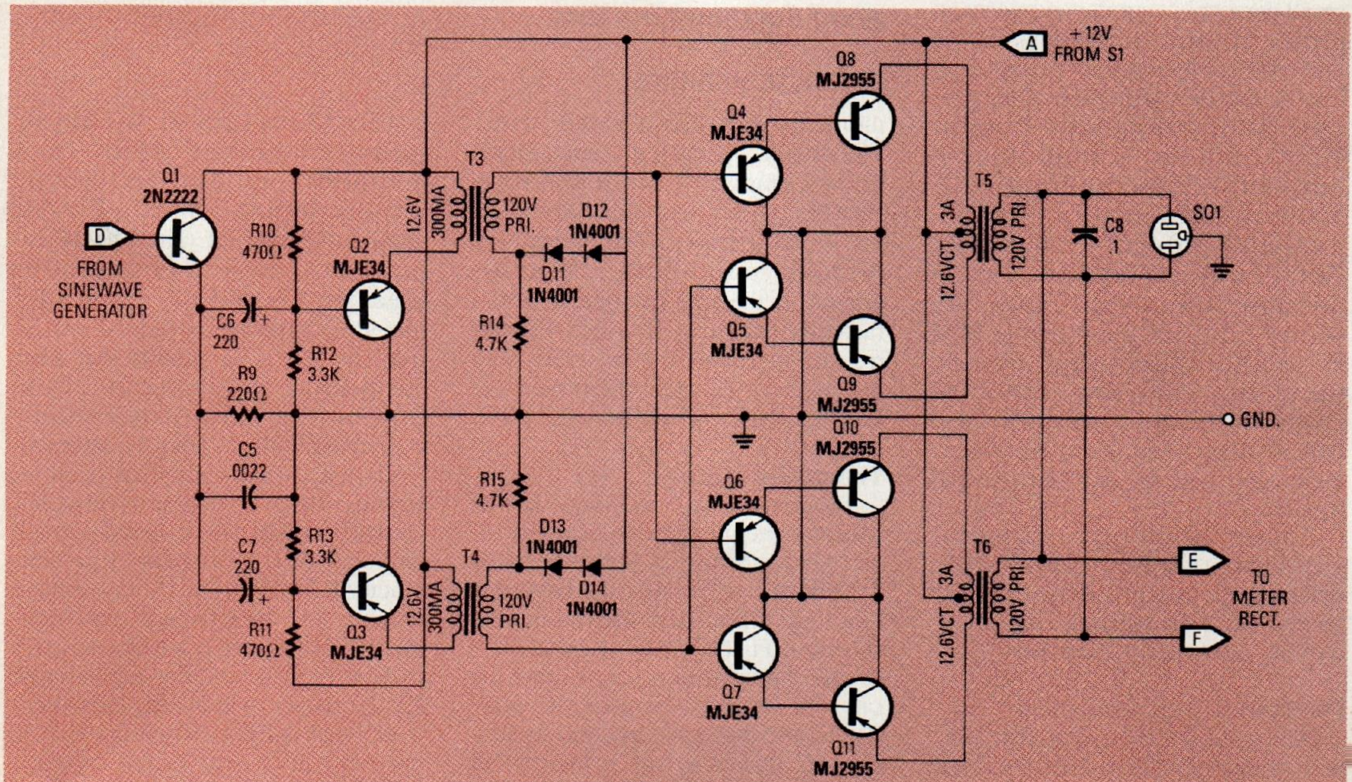

FIG. 2—THE AMPLIFIER STEPS UP the 60-Hz signal from the sinewave generator to nominally 120 volts. To ensure a clean output, C8 is included to remove any high-frequency components caused by crossover distortion or clipping from the output. It also prevents high-frequency self oscillation.