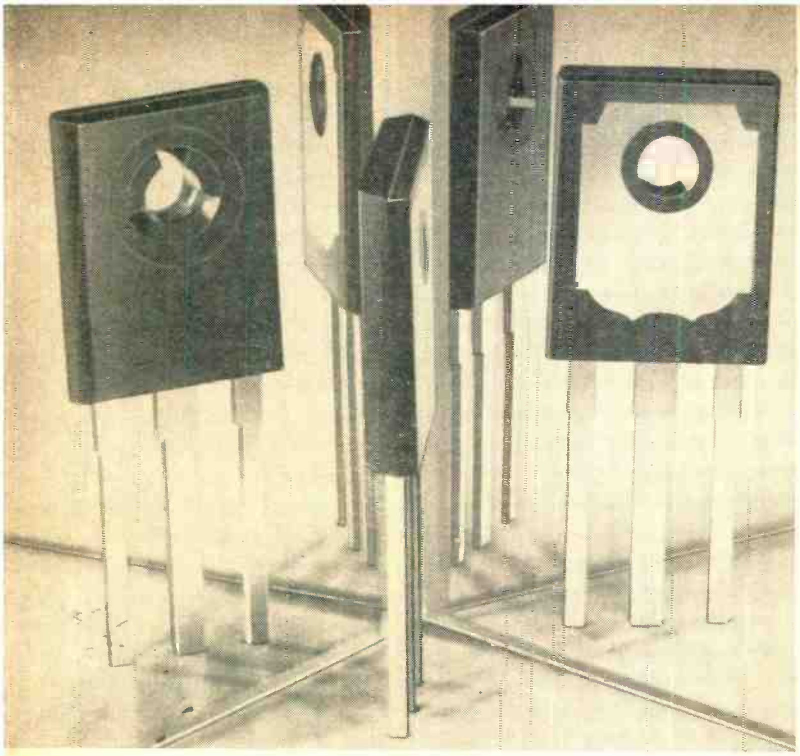


Mounting hole is in the center of these power transistors.

PLASTIC POWER TRANSISTORS Advantages and Applications

By DONALD E. LANCASTER

Greatly reduced circuit costs, simplified assembly, and superior circuit performance are promised by these new low-cost transistors.

PLASTIC-ENCASED transistors are now making a serious bid for the high-power semiconductor market, with significant benefits to the user in the form of greatly reduced circuit costs, simplified assembly, and superior circuit performance. Half a dozen major semiconductor manufacturers now make plastic power transistors with dissipations ranging from a few watts to over 80 watts per device, and performance from d.c. to 2000 MHz.

For instance, one plastic-packaged silicon power transistor can safely dissipate 20 watts, has a 300-volt breakdown, is useful to 10 MHz, and costs only about a dollar in single quantities. Let's take a closer look at these new devices and see what specific advantages they offer over older power transistors. Then, we'll look into some of the many possible applications for these new semiconductors.

Some of the leading manufacturers of plastic power transistors are listed in Table 1. Although each manufacturer's particular plastic package is unique, they have a number of things in common. The transistors are small—usually much smaller than an ordinary power transistor with an equivalent rating. They are usually planar devices that start with a flat collector tab which supports the entire semiconductor structure, integrally molded into a silicone plastic or epoxy case. Many of the transistors have a single-hole heat-sink mounting. Both *Texas Instruments* and *General Electric* use packages with a large collector tab out the top, while *Motorola's* approach is to put the mounting hole right through the middle of the plastic package, as shown in the photograph at the beginning of the article. Other packages, such as the *Bendix* and *RCA* designs, differ somewhat in shape and mounting. Some premium u.h.f. plastic transistors make use of very special packages designed for strip-line circuitry where lead inductance and capacitance must be held to an absolute minimum. Nearly all of the plastic power transistors are silicon.

Table 1. List of manufacturers who produce the new transistors.

BENDIX SEMICONDUCTOR DIVISION South Street Holmdel, New Jersey 07733
GENERAL ELECTRIC SEMICONDUCTOR Electronics Park Syracuse, New York 13201
MOTOROLA SEMICONDUCTOR PRODUCTS Box 955 Phoenix, Arizona 85001
RCA ELECTRONIC COMPONENTS AND DEVICES 415 South 5th Street Harrison, New Jersey 07029
TEXAS INSTRUMENTS P.O. Box 5012 Dallas, Texas 75080
TRW SEMICONDUCTORS INC. 14520 Aviation Blvd. Lawndale, California 90260

Advantages

There are several major advantages in using plastic power transistors for new circuit designs. The prime one is unit cost. Except for the special u.h.f. types, these transistors cost only a dollar or so each in single quantities and well under 50 cents in production quantities. The low price is the result of several factors. The package costs less to make—there's no header, no welded seals, and much simpler lead bonding. Construction and testing are fully automatic. Yields are high. Production is geared to high-volume consumer and automotive electronics markets.

High performance is another major benefit. These transistors arrive at a time in silicon transistor technology when the device specifications far exceed the requirements of many of the circuits in which they would be used. For instance, consider a plastic power transistor used in an ordinary audio circuit. With a 10-MHz cut-off frequency, none of the transistor's high-frequency performance tradeoffs enter into the design. Being silicon, we can forget about leakage and, if we are using a 300-volt transistor in a 20-volt circuit,

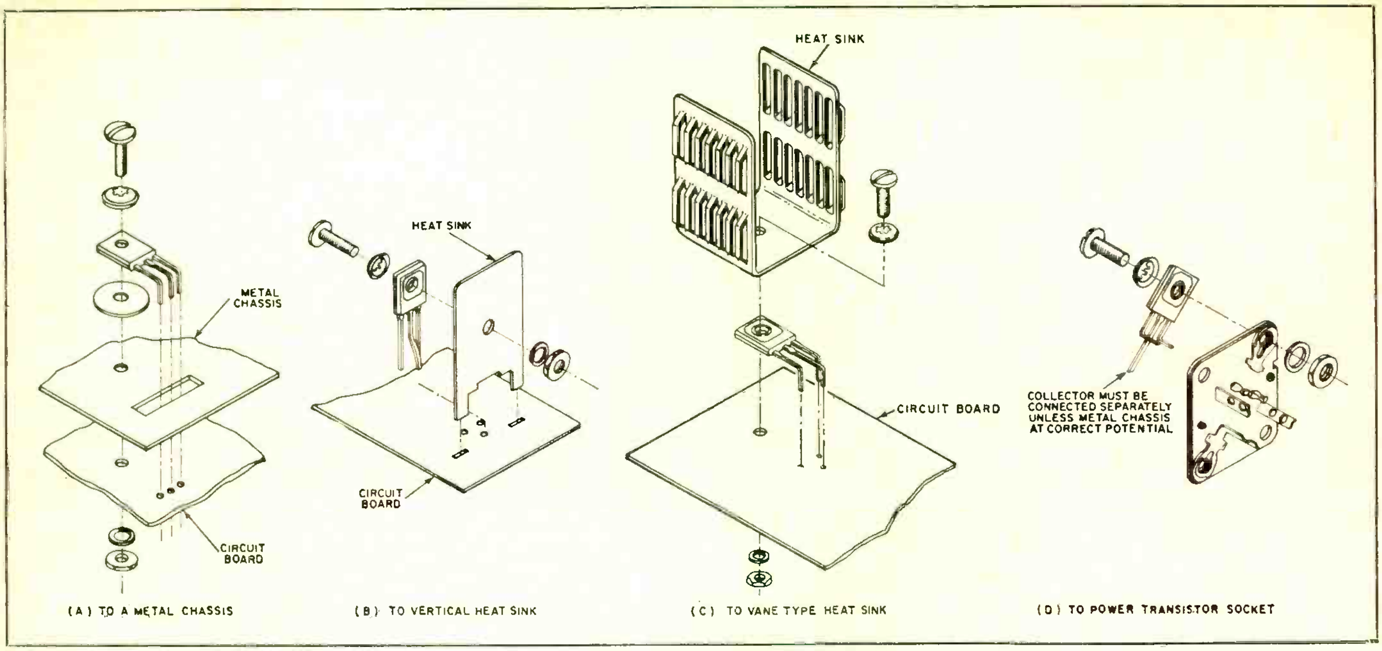


Fig. 1. Here are a number of suggested methods that can be employed to mount the plastic power transistors.

we can certainly forget about secondary breakdown. Thus, for many applications, the actual circuit design is much simpler and easier. This is especially true when updating older germanium circuits.

Another advantage is unique to a few special u.h.f. plastic power transistors. The plastic encapsulation allows a lead geometry more suited to u.h.f. stripline configuration. Wide, thin, low-impedance leads may now be used and circuit strays are more easily controlled.

Mounting Techniques

Another major advantage is easy mounting. You simply bolt, rivet, or sheet-metal screw the transistor to any suitable heat-sink material—no more precision hole patterns in expensive and awkward heat sinks. Where the device must be insulated, you use a single insulated washer instead of the multiple-part mounting kit normally required.

Motorola has several recommended mounting techniques for its transistors that clearly illustrate how easy to mount and how flexible any of the new transistors are. Some of these mounting techniques are shown in Fig. 1. If the dissipation is held to less than a watt or so, no heat-sinking is required and the transistor may be simply printed circuit-card mounted. Even bolting the collector junction to a wide foil area on the PC card will substantially improve the thermal properties. In Fig. 1A, the transistor is mounted directly to a metal chassis. A built-in insulated shoulder isolates the transistor from the mounting screw, while an access hole in the chassis lets the long leads contact a sub-chassis circuit board.

A vertical heat-sink mounting is diagrammed in Fig. 1B in which a large metal tab serves as a radiating fin. This vertical heat-sink mounting is limited to lower power levels. A one-screw, vane-type heat-sink mounting is shown in Fig. 1C. The transistors will also fit conventional power transistor sockets, as shown in Fig. 1D.

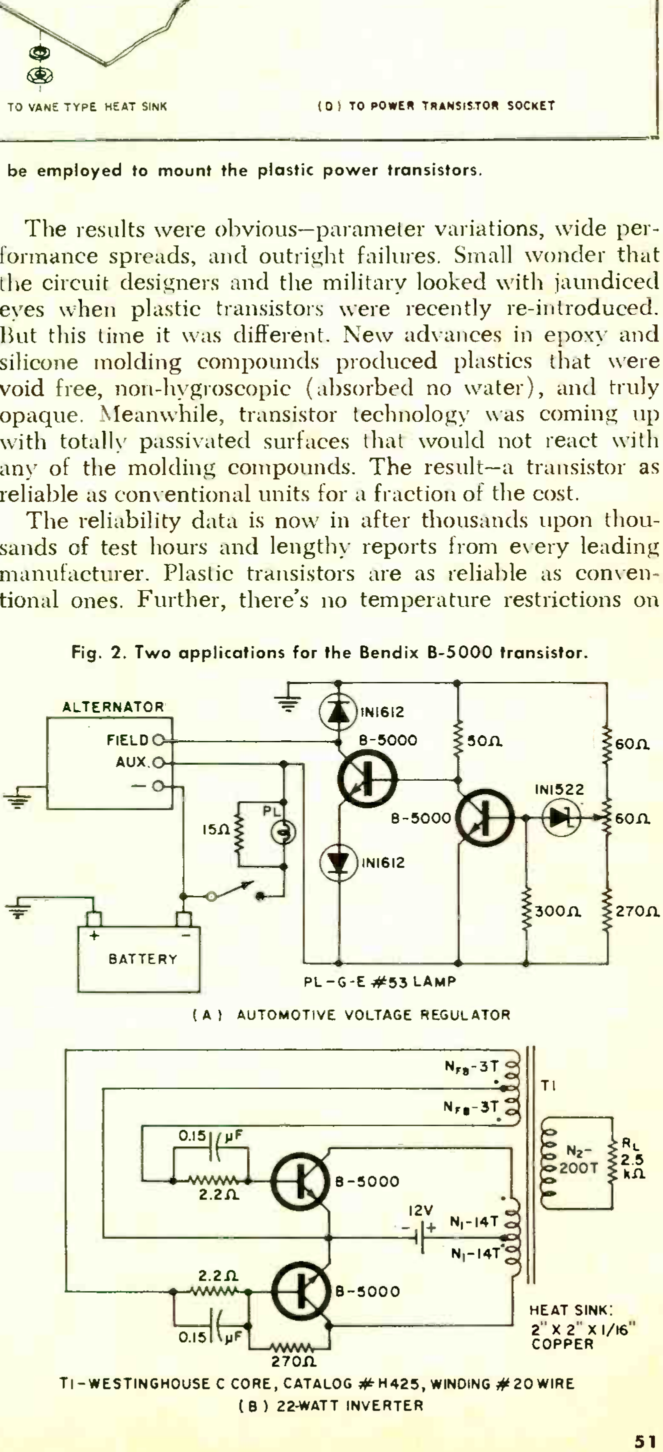
How Reliable?

Some of the earliest transistors ever built used plastic encapsulation with a variety of unsatisfactory results. The plastics were often clear, which made the transistor light-sensitive should the thin paint overcoat be inadvertently scraped off. The plastics used soaked up water. Worse yet, they had air bubbles and voids that would react with the then-unpassivated transistor surfaces.

The results were obvious—parameter variations, wide performance spreads, and outright failures. Small wonder that the circuit designers and the military looked with jaundiced eyes when plastic transistors were recently re-introduced. But this time it was different. New advances in epoxy and silicone molding compounds produced plastics that were void free, non-hygroscopic (absorbed no water), and truly opaque. Meanwhile, transistor technology was coming up with totally passivated surfaces that would not react with any of the molding compounds. The result—a transistor as reliable as conventional units for a fraction of the cost.

The reliability data is now in after thousands upon thousands of test hours and lengthy reports from every leading manufacturer. Plastic transistors are as reliable as conventional ones. Further, there's no temperature restrictions on

Fig. 2. Two applications for the Bendix B-5000 transistor.



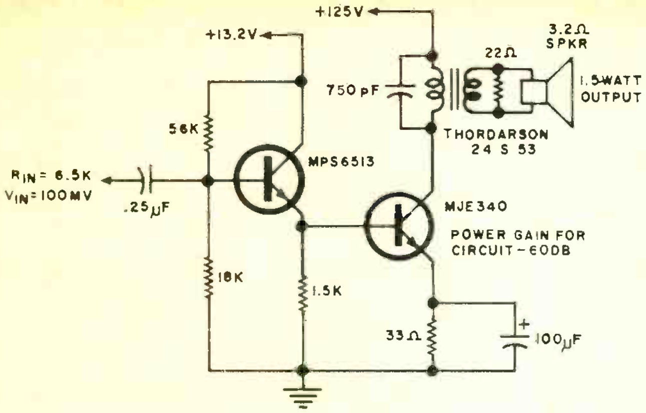


Fig. 3. Line-operated audio amplifier uses $1 transistor.

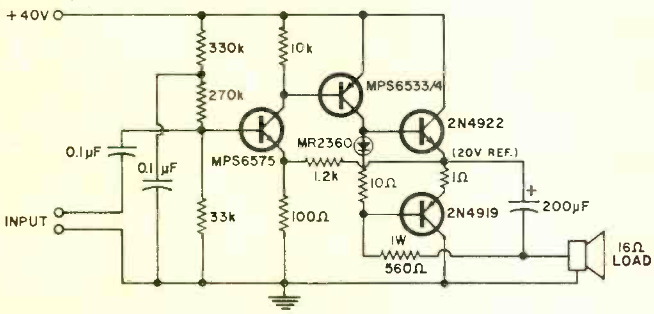


Fig. 4. Complementary symmetry 10-watt audio amplifier.

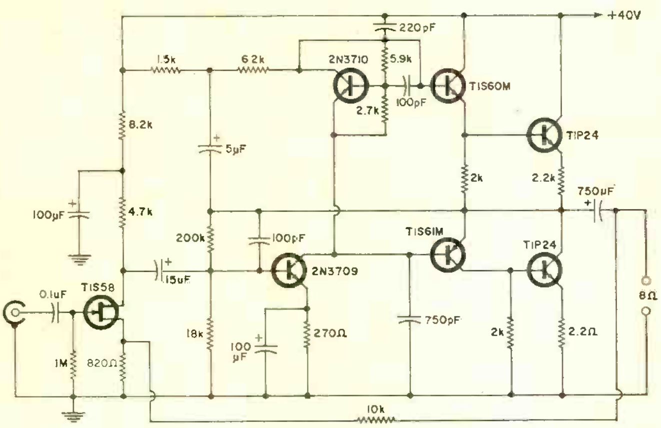


Fig. 5. Circuit of 15-watt quasi-complementary audio amplifier.

these newer devices. Most manufacturers guarantee operation over a −65°C to +150°C operating range.

Many times equipment reliability will be improved by a switch to the plastic devices, due to the simplified mounting and the fewer parts required.

Some Types and Applications

The *Bendix* B-5000 was one of the first plastic power transistors introduced. This one costs about a dollar each in single quantities and is rated to 25 watts and 35 volts, with a maximum allowable collector current of 3 amperes. It measures ¼″ in diameter by ⅛″ high, and is aimed primarily at the automotive electronics market.

Fig. 2. shows two typical applications. In Fig. 2A, two of the B-5000 transistors are used as an alternator voltage regulator, while Fig. 2B shows a 22-watt power inverter used to convert a 12-volt storage-battery power into any desired higher voltage, determined by the turns ratio of *T*1. An output rectifier and filter are also required.

Several manufacturers have introduced low-cost, high-voltage transistors designed for the audio-output stages of a.c.-d.c. equipment and as general replacements for the 50L6 and 50C5 vacuum tubes. Typical devices are the *G-E* 2N4054, the *Texas Instruments* TIP-27, and *Motorola* MJE340.

The MJE340 is the 300-volt, 20-watt, 10-MHz, one-dollar transistor previously mentioned. One typical application is the a.c.-d.c. 1.5-watt line-operated audio amplifier in Fig. 3. Here the MJE340 is powered directly from the rectified power line, while the driver stage and the rest of the circuit is driven from a low-current, 12-volt supply obtained by a resistive divider or an extra winding on the phonograph motor.

This type of high-voltage transistor is most useful for low-current regulated power supplies, relay drivers, and other circuits where a transistor must withstand the full rectified line voltage. "On-off" or switching-mode operation allows the control of up to 55 watts of 117-volt, full-wave rectified power. Another application area is in sweep output stages for electrostatic CRT's and scopes.

A dozen or so plastic power transistors have dissipation ratings ranging from 10 to over 80 watts and thus are ideal for hi-fi and other amplifier designs in the 10- to 50-watt output power class. While many units are available, one typical unit is the *Texas Instruments* TIP-24, a 70-volt, 2-ampere, $1.50 device with a typical gain of 65 and a 10-MHz cut-off frequency. Maximum allowable dissipation is 10 watts.

Two approaches to hi-fi amplifier design are the complementary and the quasi-complementary amplifier. Neither requires a driver or output transformer. The complementary type of circuit requires a matched pair of *p-n-p* and *n-p-n* output transistors, while the quasi-complementary circuit is a bit more complicated, but requires only *n-p-n* output transistors. Figs. 4 and 5 show one circuit of each type. Fig. 4 diagrams a complementary 10-watt audio amplifier using a matched *p-n-p-/n-p-n* pair of *Motorola* transistors. In Fig. 5, a 15-watt quasi-complementary design using two TIP-24's in the output stage is shown. This particular circuit also makes use of an FET as a high-input-impedance preamplifier.

Either circuit provides hi-fi performance to currently accepted standards. They can be used in pairs for stereo.

Higher Power and U.H.F. Transistors

Higher power audio amplifiers and higher current voltage regulators are possible with a new family of *RCA* plastic power transistors. These dissipate 83 watts when used with suitable heat sinks. The 2N5037 is one representative unit, rated at 70 volts and up to 8 amperes of collector current. The frequency response of these larger transistors is somewhat poorer than the 10-36 watt types, typically 1 MHz or so.

We can finish off our plastic power transistor survey by looking at the benefits plastic packaging has brought to the u.h.f. power field. Today's u.h.f. transistors are by no means low in cost, but they do provide superior performance in high-power, high-frequency circuits. This is principally due to the flat, low-inductance, stripline connections possible with the new package, and a lead arrangement better suited to high-frequency circuit designs.

The input impedance of any power transistor in the u.h.f. region is, at best, an ohm or two; any series reactance at all and the entire circuit is badly mismatched and can deliver neither gain nor power. This is why minimum lead inductance and circuit capacitance are required.

The *RCA* 2N5017 produces 23 watts of output power at 400 MHz and as much as 12 watts at 700 MHz, with power gains of 5 or so throughout the u.h.f. range. As a self-excited oscillator, 5 watts of output r.f. may be obtained easily at 600 MHz.

Farther up the frequency spectrum, we come to the *TRW* 2N4976, a u.h.f. stripline plastic power transistor that will provide 1 watt of output and 5 dB of power gain at 2000 MHz. ▲