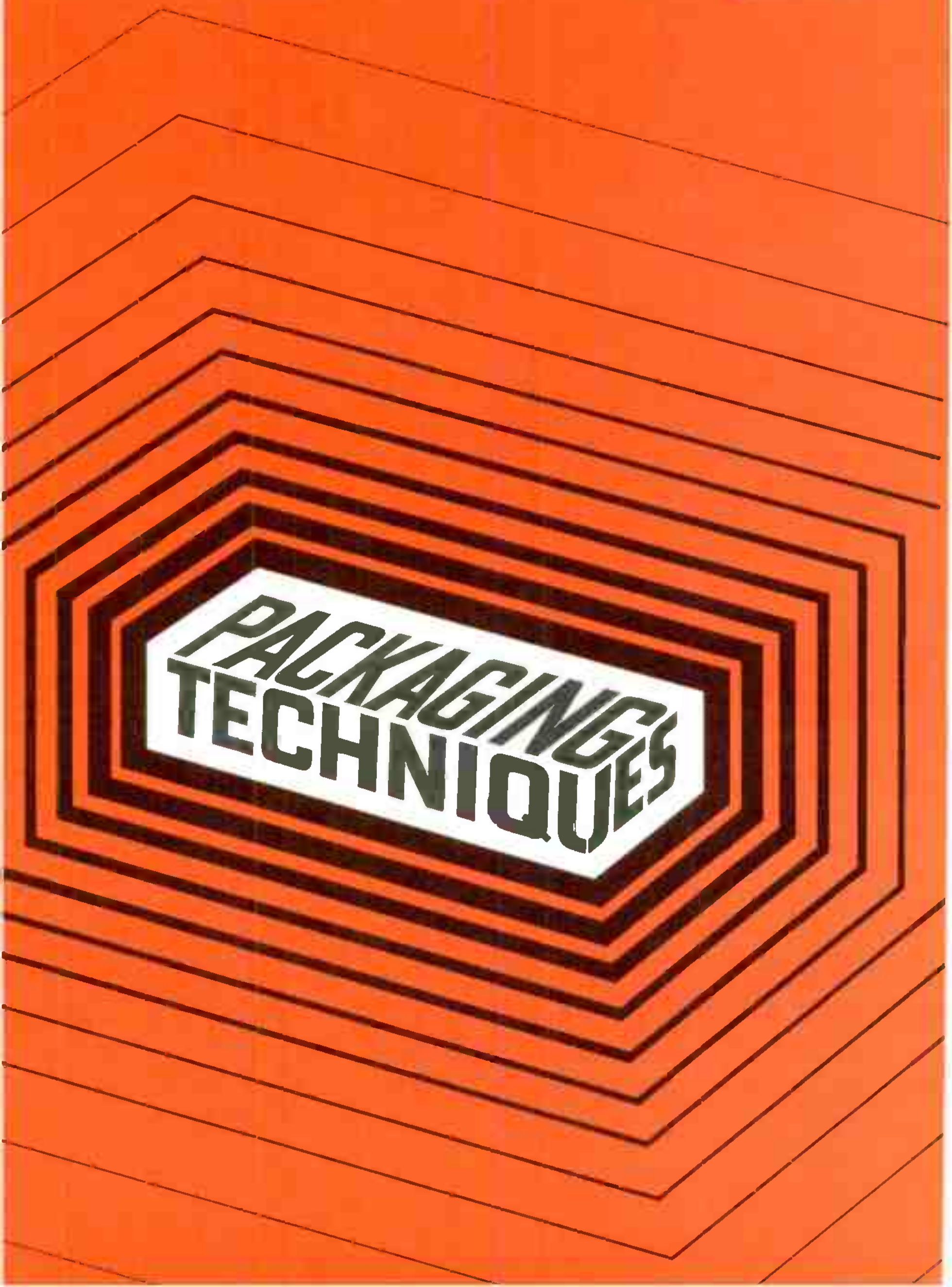
GTE LENKURT

DEMODULATOR

MARCH 1973



PACKAGING TECHNIQUES

Circuits are getting smaller, more complex, and more dense. At the same time, repair is becoming more difficult and unit replacement is becoming the simplest alternative to circuit repair.

As circuits get smaller and more complex, field repair of circuits becomes more complicated; consequently, systems are being constructed in a modular fashion so that field replacement instead of repair can be used as a method to keep equipment operating. New packaging techniques are being developed that may reduce the cost of electronic circuits to the point where it may not be economical to do any repair at all – in the field or in the factory. The faulty boards will be recycled only to recover any precious materials.

In some cases double or triple redundancy may be built into systems to compensate for possible equipment failure. This can be a costly protection device but not when compared to the alternative of customer outage during maintenance and repair, or total disposal.

Microwave solid state devices have provided the impetus for miniaturization of microwave elements, particularly at low-power levels. in mixers, and in IF strips. Microstrip transmission lines are replacing traditional waveguide in microwave equipment, in many cases, to achieve a compact, integrated unit at lower cost and with greater reliability than equipment designed and composed entirely of discrete components (refer to the November 1972 GTE Lenkurt Demodulator).

Flexible Wiring and Circuits

Flat flexible cable has decided advantages over round cable where weight, size, and labor costs are critical. This is usually the case in military and aerospace applications, in consumer and computer products, and anywhere interconnection is a large task and reliability is critical. Areas of future application include the automotive and construction industries, appliance manufacturers, and automated tooling manufacturers.

There are two major types of flat cable – extruded-conductor cable and etched-conductor cable. Extruded-conductor cable can be bonded, where conventional insulated wires are joined side-by-side by fusing their insulation; laminated, where the conductors are laid between two sheets of insulation; and woven, where conductors with different insulations are woven together in a flat configuration. Figure 1 shows an application of extruded-conductor flat cable. Etched-conductor cable is a series of flat conductors formed on a common flexible substrate by the same process as printed circuits. In fact, if the conductors run in non-parallel patterns on the substrate, the etched wiring is known as a flexible printed circuit.

Flexible printed circuits offer many of the same weight, size, and labor advantages over rigid PCs that flexible

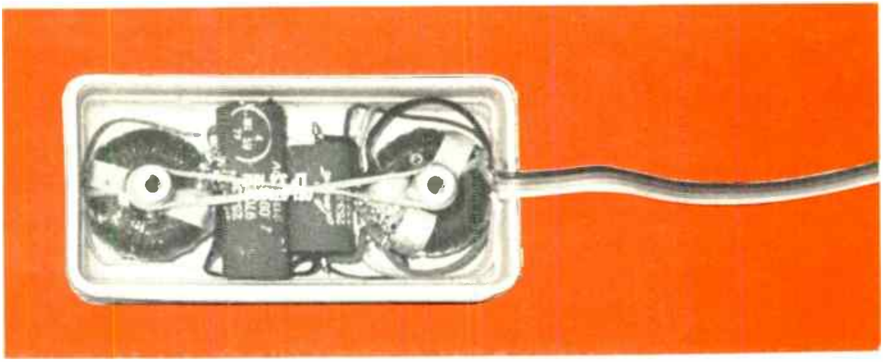


Figure 1. Flat, extruded cable is all that is exposed to the air in this potted filter.

flat cable offers over rigid cable harnesses. An important advantage is that flexible printed circuits can be tucked into tight spaces. As a rule, flexible circuits are presently used only where weight and space restrictions prevent the use of rigid PC boards.

When trying to determine the practicality of flexible circuits, there are three points to be considered. The first is cost. The total installed cost of the functioning circuit should be considered, not just the cost of the circuitry compared with wire. Second, the circuit function should be examined. An evaluation of the circuit's purpose and whether that purpose could be served as well by other wiring techniques must be considered. The last point is that of the actual wiring operation and the possible labor savings that would be gained by using flexible circuits. It may be less expensive to look at ways to eliminate cabling altogether rather than going to the initial expense of flexible circuits.

It's also important to consider the complexity of the proposed flexible circuit. The complexity must be weighed against the number of circuits required. If the total quantity is relatively small, the circuit must be very complex to be economically worthwhile. In larger quantities, however, simple as well as complex configurations will pay for themselves.

Adhesives

One way to bring down the cost of electronic equipment is to reduce manufacturing time. This can be done by reducing the number of parts that have to be assembled in production (this also increases reliability). Recent advances in the field of adhesives have had impressive results in both reducing time and decreasing the number of necessary parts. Areas that used to be dominated by mechanical means of fastening such as bolts, screws, and clamps are now being taken over by adhesives. Some applications of solder are also being replaced by the use of conducting adhesives. Adhesives are commonly used to attach components to printed circuit boards or substrates; for package sealing; to laminate coverings to equipment housings; to attach miniature light bulbs in telephone sets; and a multitude of other applications.

One of the most prevalent applications of adhesive in the electronics industry involves the attachment of semiconductor chips to ceramic substrates using conductive epoxy. Conductive epoxies perform just as well if not better than previous bonding techniques, and the bonds have proven reliable even in a constant environment of 250°C. Conductive epoxies are used for bonding components to circuit substrates, for bonding the substrates to the base of the package, and for sealing the lid on the package. In other areas, conductive epoxies are used to seal mechanical interfaces against electronic radiation, to seal RF connector leads, and to replace solder in potentiometer connections and on PC board assemblies. The most popular conductive adhesives are epoxy based because of their high adhesion, low shrinkage, good chemical resistance, and good electrical properties.

Non-conductive adhesives also play an important role in electronics packaging. Thermosetting materials such as epoxy and thermoplastics are widely used. Thermoplastics are so-called hot-melt adhesives. In the hot-melt process, hot adhesive is applied to the individual parts which need only to be held together until the adhesive resin cools to its natural solid state – which normally takes only a few seconds. The speed of assembly possible with hot-melt adhesives has led to their popularity. Hot-melt adhesives are available for joining practically any material.

Hot-melt adhesives have found almost instant success in the assembly of plastics, foam rubber, composite and fiber board, fabrics, fiberglass insulation, and similar "soft" materials. Now there is growing interest in bonding these soft materials to hard materials such as metal, ceramics, glass, molded plastics, and wood. Hot melts are also used as a "third hand," instead of expensive jigs and fixtures to hold components in place temporarily until traditional fasteners can be inserted and torqued down or spot welded in place. Figure 2 shows the application of hot-melt techniques.

Adhesive tapes are also popular as a "third hand" and they are commonly used to provide insulation in coil winding applications. Adhesives are also used in conjunction with traditional fasteners. For example, there are adhesive backed plastic clamps to retain wire harnesses, hoses, and tubing. The adhesive backing eliminates the need for panel holes, screws, or rivets.

About the only limitations placed on the use of adhesives is the imagination of the user. The secret of success in using adhesives is in the method of application – cheap, quick, and in the proper quantity.

Coatings

Coatings serve many functions; the two most important ones are to provide protection from environmental damage and to provide high electrical insulation between conductors, interconnections, components, and other electrical parts. Environmental conditions that coatings protect against are moisture, heat, salt spray, oxygen, radiation, microorganisms, chemicals, and solvents. Coatings also protect microelectronic assemblies from damage due to abrasion, handling, shock, and vibration. And, coatings provide electrical conductivity for RF interference and for ohmic contacts, and provide thermal insulation or thermal conductance. Coatings are a vital part of electronic assemblies, and the development of superior electrical coatings has made highly dense and intricate microelectronic assemblies and intricate windings possible. Figure 3 shows the use of protective coatings with hybrid circuitry.

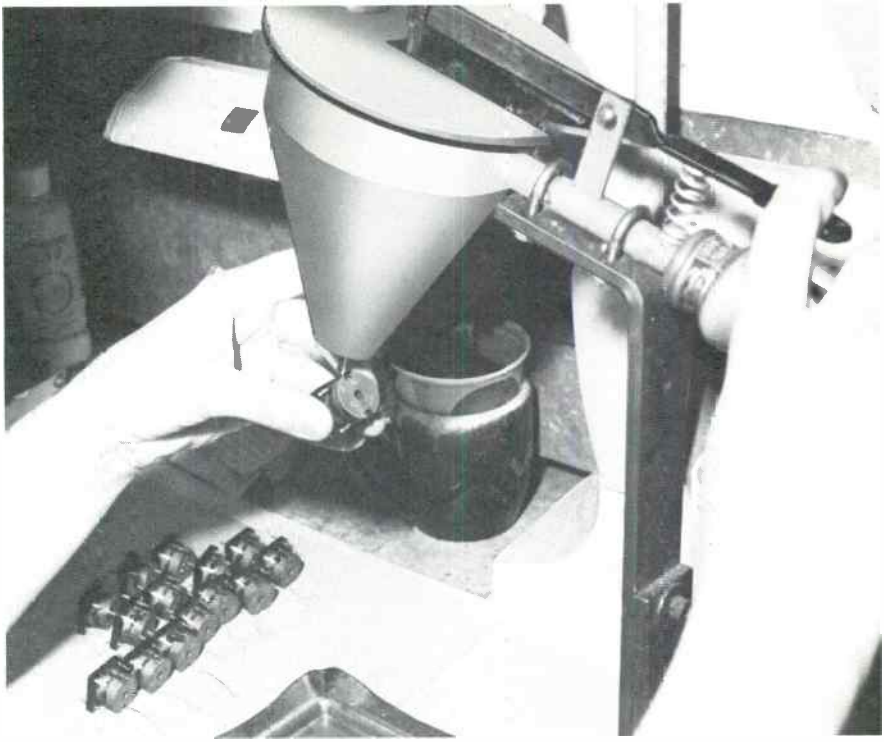


Figure 2. Hot wax is applied, using the hot-melt technique, to fix a toroidal coil to its housing.

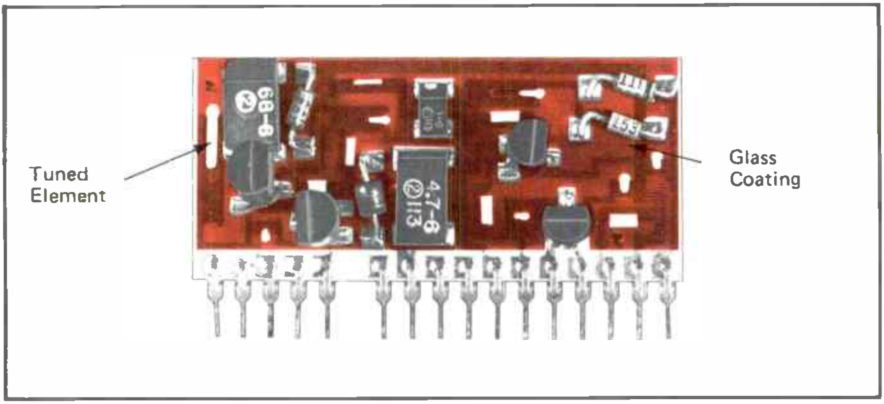


Figure 3. A coating of glass, with holes for attaching components, is screened on the surface of hybrids to protect them from moisture and to provide electrical insulation. The elements that make up the hybrid are tuned by using a laser trimmer to cut through both the protective coating and the circuit elements.

The most important function of coatings for printed circuits, and all electronic assemblies, is as moisture and gas barriers to prevent corrosion and breakdown of electrical insulation. All present coatings absorb water and are permeable to moisture and other gases to some extent and cannot be considered true hermetic seals. It is possible, however, to select plastic coatings which will reduce moisture penetration sufficiently to satisfy long-term storage and operational requirements.

Coatings protect metal surfaces from the corrosive effects of the surrounding environment. Applications in which there is excessive handling, rubbing, or contact with other objects require coatings with a high degree of abrasion resistance to insure corrosion resistance.

Millions of dollars of loss each year are attributed to the growth of microbes that trap moisture that causes metal and bimetal corrosion, mechanical and electrical deterioration of coatings or substrates, or an increase of surface roughness producing friction and drag. The resistance of coatings to attack by microbes is important for electronic hardware stored or operated in humid or tropical or semitropical environments. Moist soil is an ideal condition for microbe growth, since it is estimated that one cubic centimeter of soil contains as many as 50,000 fungi, 500 million bacteria, and 250 million plant or animal biotics. Synthetic coatings, such as epoxies, silicones, and polyurethanes help to reduce the destruction caused by microbes.

Material thickness and the distribution of this thickness over the object being coated is just as important as the type of coating used. On a circuit board, for example, coatings protect corners, edges, depressions, and protruding components. If the coating thickness varies, the protection will also vary. In comparisons between materials and application systems, coverability becomes an important consideration.

In order to encapsulate integrated circuits, it is necessary to use a coating material that is compatible with the chip. The coating material must be chemically and electrically neutral, and perhaps most importantly, the coating must have the same coefficient of thermal expansion as the chip, the bonding wires, the gold lead frame, and any other material that may be placed on top of this conformal coating. In some cases it is necessary to use a polymer coating first and then encapsulate the whole thing with an epoxy resin. While in other cases, the chip can be placed directly in a silicone package.

Heat Transfer and Cooling

Adequate cooling of electronic equipment has always been of prime concern to packaging engineers. For most applications, cooling is provided through simple natural convection. But, with the complexity and density of today's electronic equipment, higher heat transfer may be required and other cooling techniques may take the form of liquid heat exchangers, heat pipes, thermoelectric heat pumps, forced air, or transpiration panels.

Liquid heat exchangers provide one of the highest cooling rates of any heat removal system. Their use does involve penalties in size, weight, cost, and design complications, but in some applications these must be tolerated to acheive the corresponding high cooling rate necessary.

The concept of the heat pipe is simple and fascinating, but it has yet to find widespread use in the electronic equipment area. Heat pipes, however, remain a particularly useful device for removing heat in high density electronic circuits. The heat pipe is a closed, evacuated chamber whose inside walls are lined with a capillary structure, or wick, saturated with a volatile fluid. The operation of the heat pipe combines two familiar principles of physics – vapor heat transfer and capillary action. The working fluid within the heat pipe absorbs the latent heat of vaporization received at the evaporator section, transports it as a vapor through the pipe, and releases this energy at the condenser end where it is cooled to a liquid again.

Thermoelectric heat pumps are low-voltage, high-current devices used for spot cooling and temperature stabilization. The basic design consists of P- and N-type semiconductor elements joined to copper straps. When electron current flows in the P to N direction, the electrons absorb heat to move to the higher energy level – resulting in a cooling effect. The amount of heat absorbed is proportional to the flow of current. Reversing the polarity of the input results in a heating effect since the electrons now release energy to move from the higher energy N-type material to the lower energy P-type material. Thermoelectric heat pumps have been used to cool lasers, inertial guidance systems, crystals, and other electronic components. Although they have the advantage of no moving parts, they have the disadvantage of requiring relatively high-current, low-ripple power supplies. They also possess a low efficiency factor in the cooling mode. They have been used to best advantage for temperature stabilization.

Heat sinks combined with convection cooling are a popular, proven standard for cooling electronic equipment. Today, semiconductor cases often serve as the initial heat sink, the first of a series used to limit temperature buildup. The case, however, has only a small thermal capacity which means a comparatively massive heat sink must be intimately attached to the semiconductor body. As power demands increase, the space needed for convection cooling also increases until the designer is forced to seek other more efficient means of cooling.

One of these other methods is known as transpiration cooling. Here heat transfer is accomplished by forcing air through a metal matrix, which cools the matrix surface and its various attached components. This method is generally more effective than convection cooling since the matrix has an abundance of cooling surfaces and causes the low-velocity air stream to break into turbulent flow – which is more efficient in removing heat than non-turbulent flow. Figure 4 illustrates the principle of transpiration cooling.

Transpiration cooling has made it possible to have greater packaging density than was possible with conventional cooling systems for power rectifiers and regulator systems. A transpiration cooler is like an empty box with porous sides for mounting semiconductors and through which air is pumped. The porous transpiration zones are made of sintered metal of high thermal conductivity – copper or, to a lesser degree, bronze.

The semiconductors, mounted on the inside of the cooling matrix, are immersed directly in the denser air moving through the inside of the matrix. By removing any side of the box the semiconductors can be serviced. Five sides of the box are available for transistor mounting. The packaging engineer is not limited by

Figure 4. In transpiration cooling, the forced air stream becomes turbulent as it passes through the porous transpiration panels.

the usual geometry characteristic of systems cooled by extrusion-type heat sinks.

The heat transfer rate of the cooling material can be matched within limits of the heat load of the particular components by selection of the proper pore size of the matrix material. Mounting of parts is possible such that a thermal path of minimum length from the heat source to cooling air is effected. Transpiration cooling also minimizes induced temperature rise on adjacent components.

To the packaging engineer, transpiration cooling affords a versatility in shaping cooling surfaces together with substantial possibilities for increasing the density of his package. However, there is the added expense of putting in blowers for forced-air cooling and the increased need for reliability, since the engineer no longer has the degree of protection afforded by the mass of a heat sink. Transpiration panels are largely voids and generally thin (1/8 inch), and as a result have a small thermal capacity. The ability to cool is almost completely dependent upon the amount of air passage resulting through the matrix.

Lighting and Displays

Incandescent lights have almost entirely been replaced with LEDs (light emitting diodes) on the latest, smallest electronic equipment. Conventional incandescent lights are usually bulky and dissipate more heat than LEDs. Both of these qualities of incandescent lights make them incompatible with the trend toward miniaturization. LEDs, on the other hand, are small, require only a small amount of current and generate very little heat. LEDs can be arranged in patterns for displays and are easily used for small indicator lights on panels. For example, by

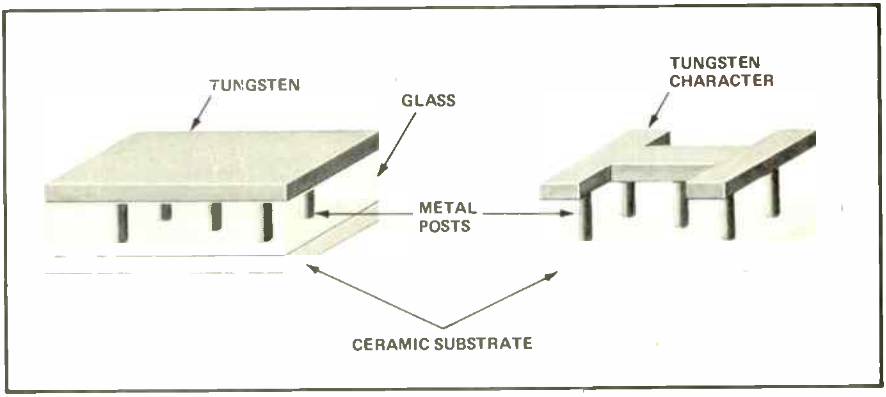


Figure 5. Incandescent lights can be mass produced by making a sandwich of ceramic, glass, and tungsten. The tungsten and glass are etched away, as in a printed circuit process, leaving a tungsten filament character.

reversing the polarity on an LED, it changes color from red to green; therefore, LEDs are ideal polarity checkers with built-in indicators.

The latest developments in lighting are in the field of incandescents – thin-film integrated incandescent displays that in some applications can outdo LEDs in cost, power dissipation, brightness, and character size. These new displays, which are still in the development stage, are fabricated with a thin-film, batch processing technique, and require only one mask – which is why they are potentially less expensive to manufacture than LEDs.

These new displays consist of a ceramic substrate covered with a thick layer of glass. Filament support posts are produced by making holes in the glass and filling them with metal. A thin layer of refractory material – such as tungsten – is then deposited on the glass. The filaments are formed by etching away the metal and glass, leaving only the filaments attached to the metal posts (see Figure 5). When completed, the device is sealed in a vacuum in a glass package.

These incandescent displays dissipate only 30 mW of power per segment – comparable with the dissipation of LEDs. By decreasing the filament width, it may be possible to reduce this to about 10 mW, or possibly even less.

These new incandescent lamps are as bright and efficient as LEDs, and like an incandescent light, various colors can be achieved by placing filters in front of the display. Another plus is that one-inch high characters can be inexpensively produced. Such large displays are not practical with LEDs since the semiconductor material is so expensive. Designing these displays is also simple. Tungsten filaments do not require current limiting resistors as LEDs do. This cuts the number of components needed and decreases power dissipation. Even though these incandescent displays generate heat, this isn't a major problem, since the ceramic substrates on which they are mounted can be maintained at 50°C.

But, this new device is still an incandescent lamp and susceptible to

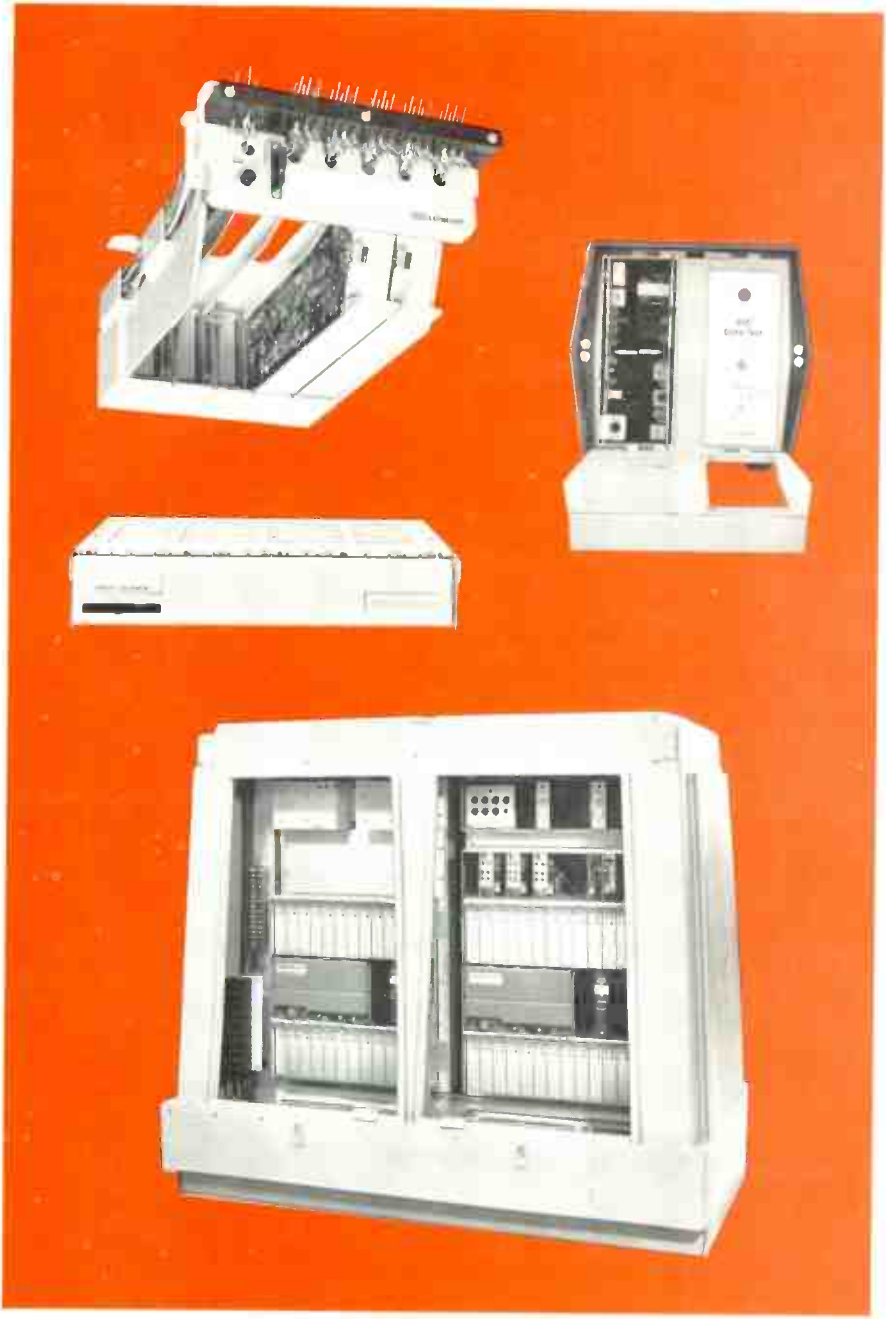


Figure 6. Plastics have been used to achieve functional, attractive, low-cost, weatherproof, and durable equipment packages.

the problems peculiar to these devices. The life expectancy is less than for LEDs, although final life testing has not been completed.

Applications for these new displays appear at first glance to include all those currently covered by LEDs plus some of those not now covered – such as those operating under high ambient light conditions and those requiring multi-colored or large displays.

Plastics

Plastics are finding their way into packaging areas in increasing numbers. Plastics are used to package components and they're used to cover or to completely enclose total systems. Plastics are being used for a variety of reasons. Among these are low cost, light weight, corrosion resistance, scratch resistance, and shapability.

As circuitry becomes more compact, it is necessary to reduce the weight of individual components. Because plastics are lighter in weight, they are now used where metal used to be commonplace.

The low cost aspect is a great aid toward the expendable age of electronics. Although the molds and tooling used for making plastic enclosures are relatively expensive, the material costs are low enough to quickly amortize the tooling costs.

In production, the fact that plastic pieces such as faceplates are not as easily scratched as metal ones also helps to keep the cost down, since the extra precautions and the careful masking used to prevent scratches in metal parts is no longer necessary. Markings that used to be painted or silk screened on face plates are now molded into the plastic piece, saving time and materials.

The use of plastics for packaging gives the designer added flexibility in designing package shapes. The square or rectangular box is being replaced with shapes that harmonize with the environment in which they will be used, and which take the best advantage of the space available. Figure 6 shows some of the new functional, aesthetic package shapes achieved through the use of plastics.

Total Package

Components are coated to form their own airtight packages, and then they are compactly packaged on circuit boards with adhesives. The completed boards are then often coated to protect them from their environment – physical and electrical. The circuit boards can be packaged together in tight places with flexible wiring. The whole package can be kept cool with the latest cooling technique. Tiny new lights fit into these dense packages. And, clean plastic covers can be used to improve the appearance of the package as well as to protect the equipment modules from the surrounding environment.

The total package is really a series of smaller packages. These small packages are becoming just as complex as the total package. It is these small packages that are quickly moving toward the expendable age, since they are generally sealed and not easily repaired in the field, or in the factory.

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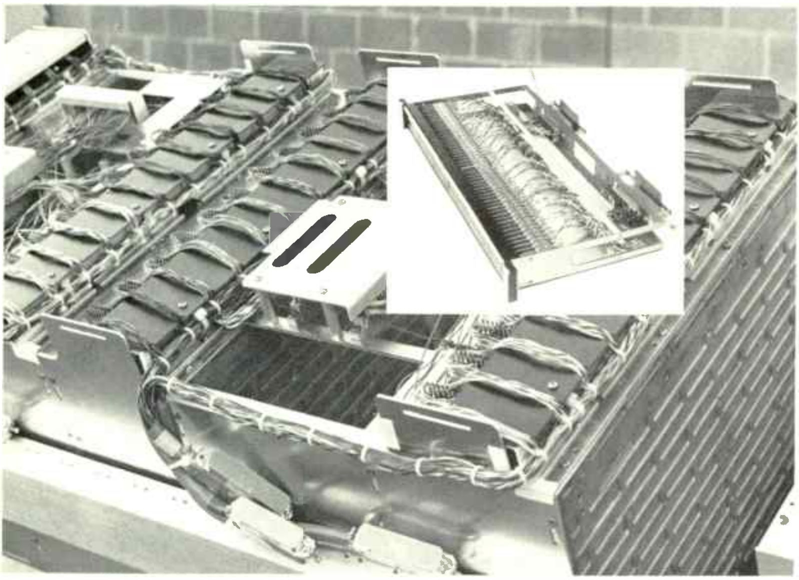

Cable Connections Simplified

A pair of ribbon-type plugs on the rear of each jack panel are used for drop connections from 24 channels. One plug serves the transmit circuits; the other, the receive circuits. Cable stubs in 25-foot increments up to 300 feet with prewired connectors mate with the plugs on the jack panel and complete the wiring to the office equipment. For more information write GTE Lenkurt, Department C134.

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