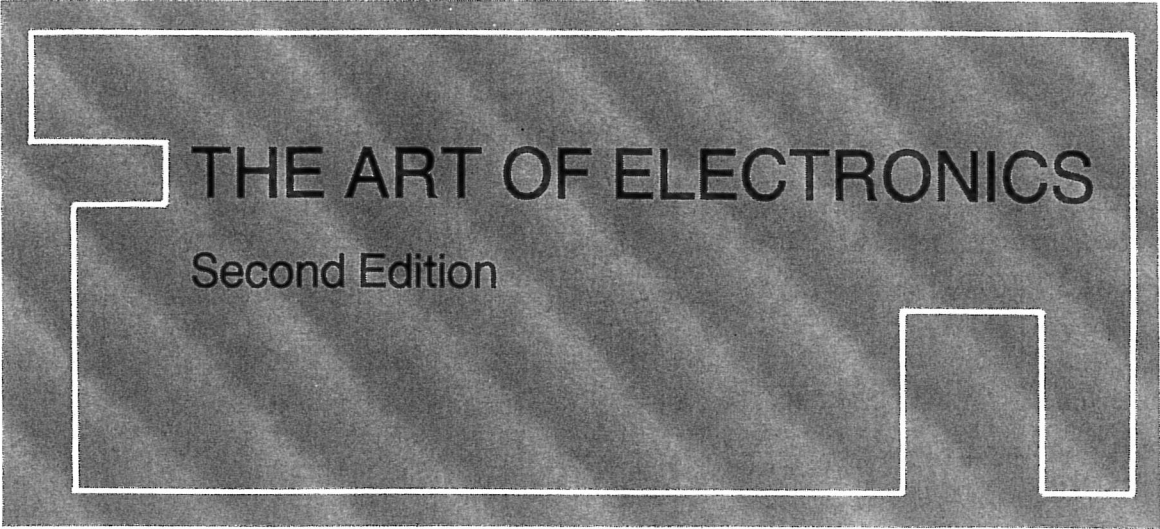


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THE
ART OF
ELECTRONICS

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THE ART OF ELECTRONICS

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ELECTRONIC CONSTRUCTION TECHNIQUES

CHAPTER

12

Between completing a circuit design and testing a finished product, you've got a number of decisions to make: Is the instrument going in a benchtop case, a "relay rack" enclosure, or perhaps some sort of modular "bin" chassis? Should the circuit itself be constructed with point-to-point wiring, on a "breadboard" card, with Wire-Wrap connections, or on a printed-circuit board? Are connections to the circuit board made with solder lugs, flat ribbon-cable connectors, or edge connectors? Should individual circuit cards be housed in a card "cage," plug into a motherboard, or what? Does it pay to design a printed-circuit motherboard or use hand-wired backplane connections? Which adjustments should be on the circuit board, and which on the front (or rear) panel? Decisions like these are important for the appearance, reliability, and serviceability of the finished product, not to mention cost and ease of construction and testing. In this chapter we will try to give some information and guidance on this important subject, one that tends to be overlooked in electronics courses where circuit

work is usually done on plug-in breadboarding gadgets. We will begin with the circuit construction itself, treating interconnections, controls, and enclosures last.

Because this chapter does not deal with circuit design, it could be skipped in an abbreviated reading.

PROTOTYPING METHODS

12.01 Breadboards

The unusual name "breadboard" seems to have arisen from the early practice of building radios on handsome slabs of varnished wood, with tubes, coils, condensers, etc., and the interconnecting wires all fastened to the topside of the board. Later, radios of greater refinement and elegance (to be used by stiff-skirted ladies in the parlor) were built with holes near each component so that the wiring would be hidden from view underneath the board. The practice of testing circuits by constructing trial versions on some sort of board or jig is still called breadboarding.

Wooden breadboards are no longer used (except in the kitchen). Instead, you can get handy plastic blocks with rows of holes spaced to accommodate ICs or other components and (usually) some extra rows for distributing the power-supply voltages. These breadboards are typified by those manufactured by AP and Global Specialties, and more elaborate breadboarding boxes are made by these companies and by E&L Instruments, among others. These are intended for *testing* circuits, not for constructing permanent (even semipermanent) versions.

12.02 PC prototyping boards

To construct one-of-a-kind circuits of some permanence, probably the best approach is to use a different kind of breadboard, one of the many printed-circuit (PC) prototyping cards available with predrilled pads for ICs and other components, but with no interconnections laid out on the board itself. Instead, each component pad is connected to two or three uncommitted pads nearby, and you wire the circuit by soldering lengths of insulated wire from pad to pad. There are usually some additional lines running around the board for power-supply distribution and ground. These boards, made by companies such as Douglas Electronics, Artronics, Vector, Triad, Radio Shack, and many others, usually include a card-edge connector – gold plated “fingers” of copper board material aligned at one end of the card for easy plug-in connection to a mating PC card-edge socket.

There are several standard connector configurations, a very common one being 22 connections on each side of the card, with 0.156 inch spacing (spacings of 0.125 and 0.1 inch are also common). A connector to mate with such a card is called a 44-pin “dual-readout” PC card-edge connector. Prototyping cards are available in various sizes, accommodating from 12 to 36 or more IC packages, with some larger

computer-compatible cards available that will accept 100 or more ICs and will plug directly into small-computer mainframes. Some of these boards are single-sided, and others are double-sided with plated-through holes, a subject we will discuss shortly in connection with custom PC design. Figure 12.1 shows a small PC prototyping card (Douglas Electronics 11-DE-3) plugged into a 44-pin dual-readout socket that includes card-supporting guides (Elco 6022).

Another form of breadboard that has enjoyed considerable popularity is the so-called perfboard, a thin sheet of laminated insulating material manufactured with regularly spaced holes ($3/16$ inch is a common spacing) designed to accept little metal pins. To wire up a circuit, you shove in dozens of the little pins wherever you want, then stick in the components. You then solder wires from pin to pin to complete the circuit. Perfboard works OK, but it is awkward to use with the tight spacings of IC packages (0.1 inch between pins). Figure 12.2 shows an example.

12.03 Wire-Wrap panels

A variation on the PC breadboard is the Wire-Wrap (a registered trademark of Gardner-Denver) panel, a circuit card festooned with IC sockets (or pads), with a pin 0.3 to 0.6 inch long protruding from each socket connection (Fig. 12.3). These pins are square in cross section, typically 0.025 inch on a side, and made of a hard metal with sharp corners, plated with gold or tin. Instead of soldering to the pin, you wrap an inch of bare wire tightly around it, using an electric wire-wrapping tool (there's an inexpensive variation known euphemistically as a “hand-operated Wire-Wrap tool”). Wire-wrapping is very fast. You just stick the stripped end of the wire into the Wire-Wrap tool, put the tool over the Wire-Wrap pin, and zip, you're done. The standard wire used for this purpose is

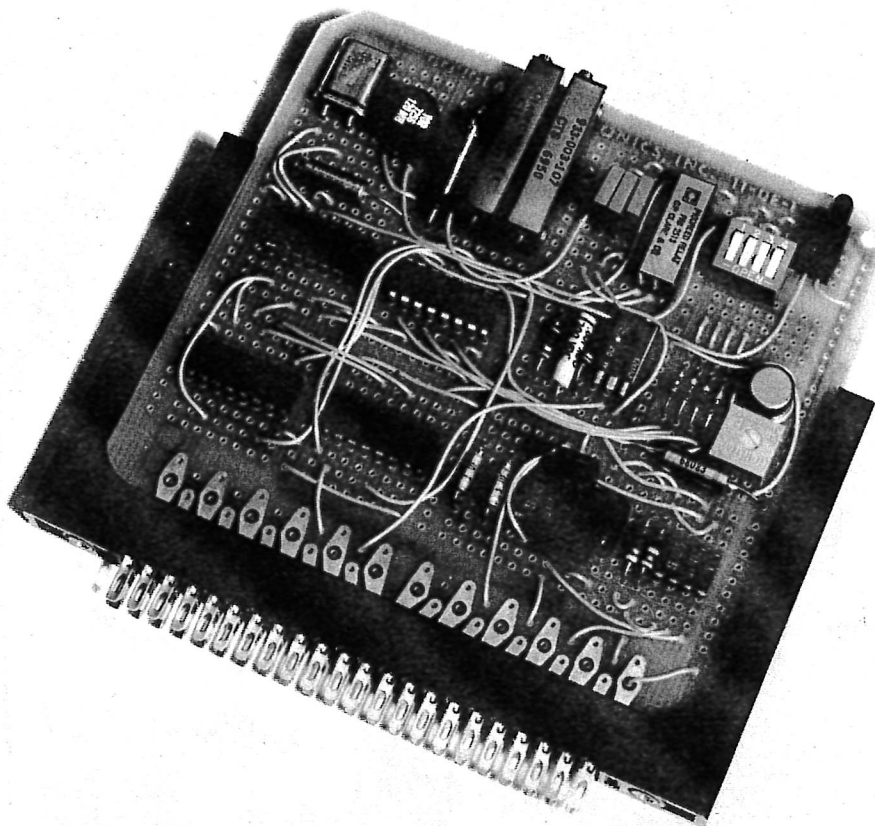


Figure 12.1. A "solder breadboard" prototyping card is useful for wiring up small circuits, especially those involving both discrete parts and ICs. This particular specimen will accommodate 12 dual in-line (DIP) packages, and it includes common lines for ground and power supply voltages. An "edge-connector" foil pattern is standard, so the card can be plugged into a card cage or supporting connector, as shown. This particular circuit uses a variety of components, including single-turn and multiturn trimmers, inductors, a crystal, a DIP switch, a miniature relay, and a logic-state indicator, in addition to both transistor and IC circuitry.

silver-plated copper wire of 26 or 30 gauge, with Kynar insulation. There are special tools available for stripping the insulation from the thin wire without nicking it. The wire is stretched tightly around the sharp corners during the wrapping process, forming a few dozen gas-tight cold welds. As a result, wire-wrapped connections are as reliable as well-soldered connections, and it is extremely easy to do them rapidly. For logic circuits, where you have few discrete components, wire-wrapping is probably the best technique for constructing one or two custom circuits of reasonable complexity.

Because Wire-Wrap panels are laid out primarily for IC packages, the technique is less convenient for linear circuits with many resistors, capacitors, etc., and the soldered prototype breadboard technique described earlier will usually be better.

It is possible to use discrete components with a Wire-Wrap panel. You just mount them on little "headers" that plug into IC sockets, then do the wire-wrapping as usual from the socket pins. Some Wire-Wrap panels have extra solderable pads (rather than IC sockets) available for discrete components. A very nice kind

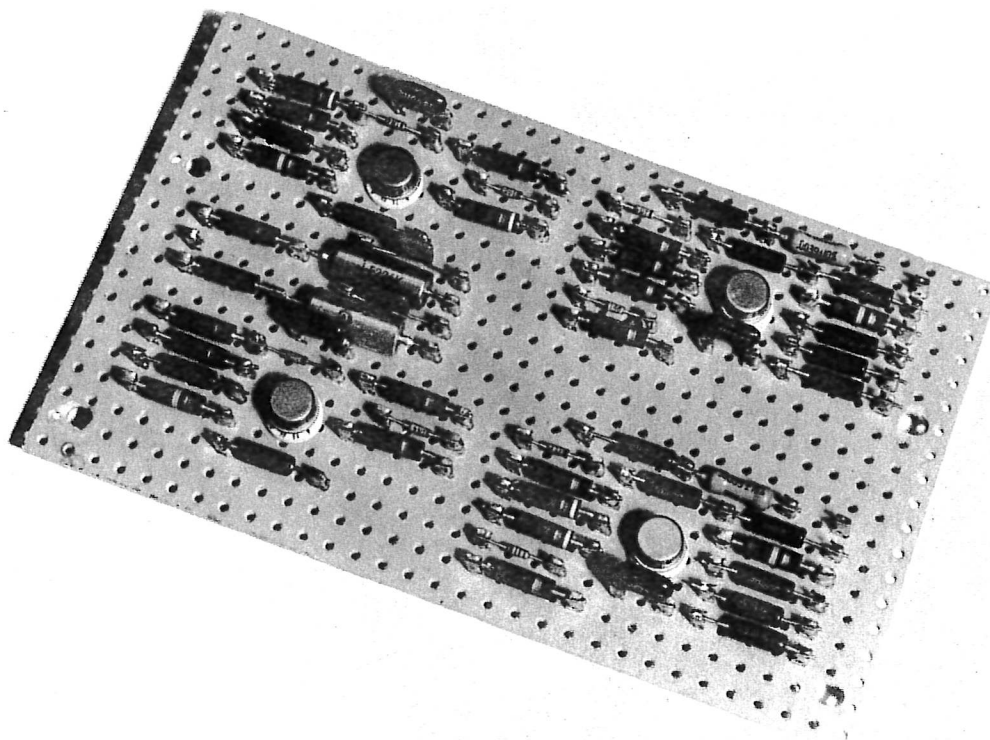


Figure 12.2. "Perfboard" can be handy for prototype circuits constructed with discrete components, although it is not particularly good for ICs. The terminals are press-fit into the holes (or flared with a special tool) and wired underneath.

of Wire-Wrap board is available with the pins on the *component* side of the board (the usual procedure is to have the pins stick out the other side). Although this type of board is less dense (fewer ICs per square inch), it is easier to use with discrete components, since you can see them while wrapping, and it allows closer spacing between adjacent circuit boards, since both components and Wire-Wrap pins take space on the same side. This kind of board without sockets is actually quite convenient for construction of linear or digital circuits. Figure 12.4 shows an example. In Figure 12.5 we have compared a prototype circuit built on a Wire-Wrap panel with the final printed-circuit version used in production. Printed circuits are much easier to produce in quantity; they are superior electrically and less cluttered than Wire-Wrap panels. We will talk about PC cards next.

PRINTED CIRCUITS

12.04 PC board fabrication

The best method of constructing any electronic circuit in quantity is to use a printed circuit, a stable insulating sheet of material with thin plated copper lines bonded to the sheet forming the circuit paths. Although early printed circuits were associated with poor reliability (Remember the advertisements stressing the superior quality that only handcrafted television sets without printed circuits could provide?), the process of manufacturing board material and producing finished boards has been perfected to the point that printed-circuit boards now have very few problems. In fact, PC boards offer the most reliable fabrication technique. They are routinely used in computers, spacecraft, and military electronics where high reliability is essential.