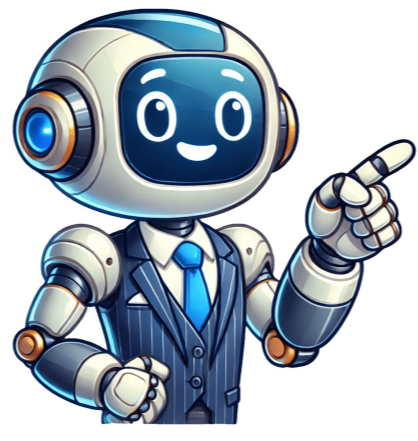


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Individual/batch boards, single/multi-layer, we use the latest component testing technologies to fault find a vast array of circuit board/PCBs to be configured with Printed electronics,"PC Board" redirects here. For the mainboard of personal computers, see Motherboard."Panelization" redirects here. For the page layout strategy, see N-up.Printed circuit board of a DVD playerPart of a 1984 Sinclair ZX Spectrum computer board, a printed circuit board, showing the conductive traces, through-hole paths to the other surface, and some electronic components mounted using through-hole mounting[1] Printed circuit board (PCB), also called printed wiring board (PWB), is a laminated sandwich structure of conductive and insulating layers, each with a pattern of traces, planes and other features (similar to wires on a flat surface) etched from one or more sheet layers of copper laminated onto or between sheet layers of a non-conductive substrate.[1] PCBs are used to connect or "wire" components to one another in an electronic circuit. Electrical components may be fixed to conductive pads on the outer layers, generally by soldering, which both electrically connects and mechanically fastens the components to the board. Another manufacturing process adds vias, metal-lined drilled holes that enable electrical interconnections between conductive layers, to boards with more than a single side.Printed circuit boards are used in nearly all electronic products today. Alternatives to PCBs include wire wrap and point-to-point construction, both once popular but now rarely used. PCBs require additional design effort to lay out the circuit, but manufacturing and assembly can be automated. Electronic design automation software is available to do much of the work of layout. Mass-producing circuits with PCBs is cheaper and faster than with other wiring methods, as components are mounted and wired in one operation. Large numbers of PCBs can be fabricated at the same time, and they can be made in one or more PCBs can also be made manually in small quantities, but PCBs are the most common.

Multi-layer PCBs provide much higher component density, because circuit traces on the inner layers would otherwise take up surface space between components. The rise in popularity of multilayer PCBs with more than two, and especially with more than four, copper planes was concurrent with the adoption of surface-mount technology. However, multilayer PCBs make repair, analysis, and field modification of circuits much more difficult and usually impractical.The world market for bare PCBs exceeded US\$60.2 billion in 2014,[13] and was estimated at \$80.33 billion in 2024, forecast to be \$96.57 billion for 2029, growing at a 4.87% per annum.[4]Before the development of printed circuit boards, electrical and electronic circuits were wired point-to-point on a chassis. Typically, the chassis was a sheet metal frame or pan, sometimes with a wooden bottom. Components were attached to the chassis, usually by insulators when the connecting point on the chassis was metal, and then their leads were connected directly or with jumper wires by soldering, or sometimes using crimp connectors, wire connector jugs on screw terminals, or other methods. Circuits were large, bulky, heavy, and relatively fragile (even discounting the breakable glass envelopes of the vacuum tubes that were often included in the circuits), and production was labor-intensive, so the products were expensive.Development of the methods used in modern printed circuit boards started early in the 20th century. In 1903, a German inventor, Albert Hanson, described flat foil conductors laminated to an insulating board, in multiple layers. Thomas Edison experimented with chemical methods of plating conductors onto linen paper in 1904. Arthur Berry in 1913 patented a print-and-etch method in the UK, and in the United States Max Schoop obtained a patent[5] to flame-spray metal onto a board through a patterned mask. Charles Ducas in 1925 patented a method of electroplating circuit patterns.[6]Predating the printed circuit invention, and similar in spirit, was John Sargrove's 19361947 Electronic Circuit Making Equipment (ECME) that sprayed metal onto a Bakelite plastic board. The ECME could produce three radio boards per minute.Proximity fuse Mark 53 production line 1944The Austrian engineer Paul Eisler invented the printed circuit as part of a radio set while working in the UK around 1936. In 1941 a multi-layer printed circuit was used in German magnetic influence naval mines.Around 1943 the United States began to use the technology on a large scale to make proximity fuzes for use in World War II.[6] Such fuzes required an electronic circuit that could withstand being fired from a gun, and could be produced in quantity. The Centralab Division of Globe Union submitted a proposal which met the requirements: a ceramic plate would be screenprinted with metallic paint for conductors and carbon material for resistors, with ceramic disc capacitors and submarine vacuum tubes soldered in place.[7] The technique proved viable, and the resulting patent on the process, which was classified by the U.S. Army, was assigned to Globe Union. It was not until 1984 that the Institute of Electrical and Electronics Engineers (IEEE) awarded Harry W. Rubinstein its Cleo Brunetti Award for early key contributions to the development of printed components and conductors on a common insulating substrate. Rubinstein was honored in 1984 by his alma mater, the University of Wisconsin-Madison, for his innovations in the technology of printed electronic circuits and the fabrication of capacitors.[8][9] This invention also represents a step in the development of integrated circuit technology, as not only wiring but also passive components were fabricated on the ceramic substrate.In 1948, the US released the invention for commercial use. Printed circuits did not become commonplace in consumer electronics until the mid-1950s, after the Auto-Semby process was developed by the United States Army. At around the same time in the UK work along similar lines was carried out by Geoffrey Dummer, then at the RDDE, Motorola was an early leader in bringing the process into consumer electronics, announcing in August 1952 the adoption of "plated circuits" in home radios after six years of research and a \$1M investment.[10] Motorola soon began using its trademarked term for the process, PLAcir, in its consumer radio advertisements.[11] Hallicrafters released its first "foto-etch" printed circuit board, a ckt radio, on November 1, 1952.[12]Even as circuit boards became the point-to-point chassis construction method remained in common use in industry (such as TV and hi-fi sets) into at least the late 1960s. Printed circuit boards were introduced to reduce the size, weight, and cost of parts of a circuitry. In 1960, a small consumer radio receiver might be built with all its circuitry on one circuit board, but a TV set would probably contain one or more circuit boards.Originally, every electronic component had wire leads, and a PCB had holes drilled for each wire of each component. The component leads were then inserted through the holes and soldered to the copper PCB traces. This method of assembly is called through-hole construction. In 1949, Moe Abramson and Stanislaus F. Danko of the United States Army Signal Corps developed the Auto-Semby process in which component leads were inserted into a copper foil interconnection pattern and dip soldered. The patent they obtained in 1956 was assigned to the U.S. Army.[13] With the development of board lamination and etching techniques, this concept evolved into the standard printed circuit board fabrication process in use today. Soldering could be done automatically by passing the board over a ripple, or wave, of molten solder in a wave-soldering machine. However, the wires and holes are inefficient since drilling holes is expensive and consumes drill bits and the protruding wires are cut off and discarded.Since the 1980s, surface mount parts have increasingly replaced through-hole components, enabling smaller boards and lower production costs, but making repairs more challenging.In the 1990s the use of multilayer surface boards became more frequent. As a result, size was further minimized and both flexible and rigid PCBs were incorporated in different devices. In 1995 PCB manufacturers began using microvia technology to produce High-Density Interconnect (HDI) PCBs.[14]Recent advances in 3D printing have meant that there are several new techniques in PCB creation. 3D printed electronics (3DPE) can be utilized to print items layered and built subsequently. Items can be printed with a liquid ink that contains electronic functionalities.HDI (microvia interconnect) technology allows for a denser design on the PCB and thus potentially smaller PCBs with more components and components in a given area. As a result, HDI technology has become a popular choice for high-end consumer electronics, such as smartphones, due to its ability to reduce the size and weight of the board while maintaining reliability and performance. HDI technology for HDI technology are computer and mobile phone components as well as medical equipment and military communication equipment. A 4-layer HDI microvia PCB is equivalent in quality to an 8-layer through-hole PCB, so HDI technology can reduce costs. HDI PCBs are often made using build-up film such as ajinomoto build-up film, which is also used in the production of flip chip packages.[15][16] Some PCBs have optical waveguides, similar to optical fibers built on the PCB.[17]An example of hand-drawn etched traces on a PCBAs basic PCB consists of a flat sheet of insulating material and a layer of copper foil, laminated to the substrate. Chemical etching divides the copper into separate conducting lines called tracks or circuit traces, pads for connections, vias to pass connections between layers of copper, and features such as solid conductive areas for electromagnetic shielding or other purposes. The tracks function as wires fixed in place, and are insulated from each other by air and the board substrate material. The surface of a PCB may have a coating that protects the copper from corrosion and reduces the chances of solder shorts between traces or undesired electrical contact with stray bare wires. For its function in helping to prevent solder shorts, the coating is called solder resist or solder mask.The pattern to be etched into each copper layer of a PCB is called the "artwork". The etching is usually done using photoresist which is coated onto the PCB, then exposed to light projected in the pattern of the artwork. The resist material protects the copper from dissolution into the etching solution. The etched board is then cleaned. A PCB design can be mass-produced in a way similar to the way photographs can be mass-produced using photographic film negatives. The etching process is similar to that used in photolithography. Another substrate material called paper impregnated with phenolic resin is often used. When a PCB has components installed, it is less accurately called a printed wiring board (PWB) or a wiring board.[18] However, the term "printed wiring board" has fallen into disuse. PCB populated with electronic components is called a printed circuit assembly (PCA), resist material coated paper impregnated with phenolic resin is called a printed circuit board assembly or PCB assembly (PCBA). In informal usage, the term "printed circuit board" is commonly used to refer to "printed circuit assembly" with components. The IEC preferred term for an assembled board is circuit card assembly (CCA).[19] and for an assembled backplane it is backplane assembly. "Card" is another widely used informal term for a "printed circuit assembly". For example, expansion card.A PCB may be printed with a legend identifying the components, test points, or identifying text. Originally, silkscreen printing was used for this purpose, but today other, finer quality printing methods are usually used. Normally the legend does not affect the function of a PCBA.A printed circuit board can have multiple layers of copper which almost always are arranged in pairs. The number of layers and the interconnection designed between them (vias, PTHs) provide a general estimate of the board complexity. Using more layers allow for more routing options and better control of signal integrity, but are also time-consuming and costly to manufacture. Likewise, selection of the vias for the board also allow fine tuning of the board size, escaping of signals off complex ICs, routing, and long term reliability, but are tightly coupled with production complexity and cost.One of the simplest boards to produce is the two-layer board. It has copper on both sides that are referred to as external layers; multi layer boards sandwich additional internal layers of copper and insulation. After two-layer PCBs, the next step is to the four-layer. The four layer board adds significantly more routing options in the internal layers as compared to the two layer board, and often some portion of the internal layers are used as ground plane or power plane, to achieve better signal integrity, higher signaling frequencies, lower EMI, and better power supply decoupling.In multi-layer boards, the layers of material are laminated together. The copper on the top and bottom layers is called the copper cladding. The copper on the internal layers is called prepreg. Only the copper on the top and bottom layers is protected by the adjacent substrate layers.Through-hole plated resistors:Through-hole devices mounted on the circuit board of a mid-1980s Commodore 64 home computerA box of drill bits used for making holes in printed circuit boards. While tungsten-bit drills are very hard, they eventually wear out or break. Drilling is a considerable part of the cost of a through-hole printed circuit board.Surface mount components, including resistors, transistors and an integrated circuitA PCB in a computer mouse: the component side (left) and the printed side (right)Through hole components are mounted by their wire leads passing through the board and soldered to traces on the other side. "Surface mount" components are attached by their leads to copper traces on the same side of the board. A board may use both methods for mounting components. PCBs with only through-hole mounted components are now uncommon. Surface mounting is used for transistors, diodes, IC chips, resistors, and capacitors. Through-hole mounting may be used for some large components such as electrolytic capacitors and connectors.The first PCBs used through-hole technology, mounting electronic components by lead inserted through holes on one side of the board and soldered onto copper traces on the other side. Boards may be single-sided, with an unplated component side, or more compact double-sided boards, with components soldered on both sides. Horizontal installation of through-hole parts with two axial leads (such as resistors, capacitors, and diodes) is done by bending the leads 90 degrees in the same direction, inserting the part in the board (often bending leads located on the back of the board in opposite directions to improve the part's mechanical strength), soldering the leads, and trimming off the ends. Leads may be soldered either manually or by a wave soldering machine.[20]Surface-mount technology emerged in the 1960s, gained momentum in the early 1980s, and became widely used by the mid-1990s. Components were mechanically redesigned to have small metal tabs or leads instead of wire leads. This allowed for smaller components and more components per board. Surface mount technology also allowed for more compact boards and higher component density. Surface mount components can be about one-quarter to one-tenth of the size and weight of through-hole components and passive components much cheaper. However, prices of semiconductor surface mount devices (SMDs) are determined more by the chip itself than the package, with little price advantage over larger packages, and some wire-wired components, such as 1N4148 small-signal switch diodes, are actually significantly cheaper than SMD equivalents.Each trace consists of a flat, narrow part of the copper foil that remains after etching. Its resistance, determined by its width, thickness, and length, must be sufficiently low for the current the conductor will carry. Power and ground traces may need to be wider than signal traces. In a multi-layer board one entire layer may be mostly solid copper to act as a ground plane for shielding and power return. For microwave circuits, transmission lines can be laid out in a planar form such as stripline or microstrip with carefully controlled dimensions to assure a consistent impedance. In radio-frequency and fast switching circuits the inductance and capacitance of the printed circuit board conductors become significant circuit elements, usually undesired; conversely, they can be used as a deliberate part of the circuit design, as in distributed-element filters, antennae, and fuses, obviating the need for additional discrete components. High density interconnects (HDI) PCBs have tracks or vias with a width or diameter of under 152 micrometers.[21]Laminates are manufactured by curing layers of cloth or paper with thermoset resin under pressure and heat to form an integral final piece of uniform thickness. They can be up to 4 by 8 feet (1.2 by 2.4m) in width and length. Varying cloth weaves (threads per inch or cm), cloth thickness, and resin percentage are used to achieve the desired final thickness and mechanical strength. The cloth or fiber material is cut to the desired size and shape, and the resin is applied to the cloth or fiber material. The cloth or fiber material is then pressed into the resin. The resin is then cured to form the laminate. The laminate is fire retardant, the dielectric constant (εr), the loss tangent (tan δ), the tensile strength, the shear strength, the glass transition temperature (Tg), and the Z-axis expansion coefficient (how much the thickness changes with temperature). There are quite a few different dielectrics that can be chosen to provide different insulating values depending on the requirements of the circuit. Some of these dielectrics are polytetrafluoroethylene (Teflon), FR-4, FR-1, CEM-1 or CEM-3. Well known pre-preg materials used in the PCB industry are FR-2 (phenolic cotton paper), FR-3 (cotton paper and epoxy), FR-4 (woven glass and epoxy), FR-5 (woven glass and epoxy), FR-6 (matte glass and polyester), G-10 (woven glass and epoxy), CEM-1 (cotton paper and epoxy), CEM-2 (cotton paper and epoxy), CEM-3 (non-woven glass and epoxy), CEM-4 (woven glass and epoxy), CEM-5 (woven glass and polyester). Thermal expansion is an important consideration especially with ball grid array (BGA) and naked die technologies, and glass fiber offers the best dimensional stability.FR-4 is by far the most common material used today. The board stock with unetched copper on it is called "copper-clad laminate". With decreasing size of board features and increasing frequencies, small non-homogeneities like uneven distribution of fiberglass or other filler, thickness variations, and bubbles in the resin matrix, and the associated local variations in the dielectric constant, are gaining importance.The circuit-board substrates are usually dielectric composite materials. The composites contain a matrix (usually an epoxy resin) and a reinforcement (usually a woven, sometimes non-woven, glass fibers, sometimes even carbon), and in some cases a filler is added to the resin (e.g. ceramics; titanate ceramics can be used to increase the dielectric constant).The reinforcement type defines two major classes of materials: woven and non-woven. Woven reinforcements are cheaper, but the high dielectric constant of glass may not be favorable for many higher-frequency applications. The spatially non-uniformity of woven fibers can cause local variations in the dielectric constant, which can be a problem for high-frequency applications. Non-woven reinforcements are more expensive, but they are more uniform. The dielectric constant of glass is not as favorable for many higher-frequency applications. The spatially non-uniformity of woven fibers can cause local variations in the dielectric constant, which can be a problem for high-frequency applications. Non-woven reinforcements are more expensive, but they are more uniform. The dielectric constant of glass is not as favorable for many higher-frequency applications. The spatially non-uniformity of woven fibers can cause local variations in the dielectric constant, which can be a problem for high-frequency applications. Non-woven reinforcements are more expensive, but they are more uniform. The dielectric constant of glass is not as favorable for many higher-frequency applications. 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