

Basically, this type of capacitor consists of a sintered porous anode of tantalum powder housed in a silver or silver-plated container. The porous anode is made by pressing a high-purity tantalum powder into a cylindrical body and sintering in vacuum at about 2000° C.

Tantalum Electrolytics With Porous Anode and Solid Electrolyte

The so-called "solid" tantalum capacitor originally developed by Bell Telephone Laboratories developed from the porous-anode type with liquid electrolyte by replacing the liquid with a semiconductor. This overcame the problem of sealing common to all other types of electrolytic capacitors. Since there is no liquid electrolyte, it is possible to use a conventional hermetic seal.

CERAMIC CAPACITORS

Ceramic capacitors are defined in classes based on their distinct and inherent electrical properties.

Class I

Class I capacitors are stable temperature-compensating capacitors that have essentially linear characteristics with properties independent of frequency over the normal range. Materials are usually magnesium titanate for positive temperature coefficient of capacitance and calcium titanate for negative temperature coefficient of capacitance. Combinations of these and other materials produce a dielectric constant of 5 to 150 and temperature coefficient of capacitance of +150 to -4700 ppm/°C with tolerances of ± 15 ppm/°C.

Low-K ceramics are suitable for resonant-circuit or filter applications, particularly where temperature compensation is a requirement. Disc and tubular types are the best forms for this purpose. Stability of capacitance is good, being next to that of mica and polystyrene capacitors.

Class II

Class II includes ceramic dielectrics suitable for fixed capacitors used for bypass, coupling, and decoupling. This class is usually divided into two subgroups for which the temperature characteristics define the characteristics.

- (A) Embody stable K values of 250 to 2400 over a temperature range of -55° C to +125° C with maximum capacitance change 15% from a 25° C ambient.
- (B) Embody combinations of materials, including titanates, with K values of 3000 to 12 000 made by keeping the Curie point near room ambient.

The high-K materials are the ferroelectrics.

Because of their crystal structure, they sometimes have very high values of internal polarization, giving very high effective dielectric constants. In this way, these materials are comparable with ferromagnetic materials. Above the Curie temperature, a change of domain structure occurs that results in a change of electrical characteristics. This region is known as the paraelectric region. In common with the ferromagnetic materials, a hysteresis effect is apparent, and this makes the capacitance voltage-dependent.

The ferroelectrics are based on barium titanate, which has a peak dielectric constant of 6000 at the Curie point of 120° C. Additions of barium stannate, barium zirconate, or magnesium titanate reduce this dielectric constant but make it more uniform over the temperature range. Thus a family of materials can be obtained with a Curie point at about room temperature and with the dielectric constant falling off on either side. The magnitude of this change increases with increasing dielectric constant. These materials exhibit a decrease of capacitance with time and, as a result of the hysteresis effect, with increasing voltage.

Inductance in the leads and element causes parallel resonance in the megahertz region. Care is necessary in their application above about 50 megahertz for tubular styles and about 500 megahertz for disc types.

Class III

Class III includes reduced barium titanate in which a reoxidized layer or diffusion zone is the effective dielectric. Also included are internal grain boundary layer strontium titanate capacitors in which an internal insulating layer surrounds each grain. These capacitors are suitable for use in low-voltage circuits for coupling and bypass where low insulation resistance and voltage coefficient can be tolerated.

Color Code

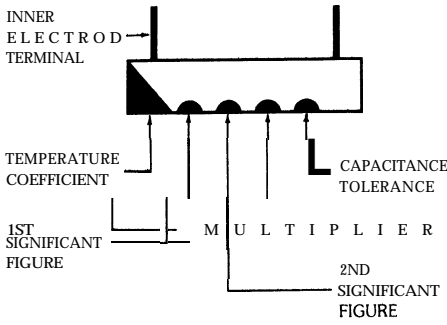
The significance of the various colored dots for EIA Standard RS-198-B (ANSI C83.4-1972) fixed ceramic dielectric capacitors is explained by Figs. 16 and 17 and may be interpreted from Table 17.

Temperature Coefficient

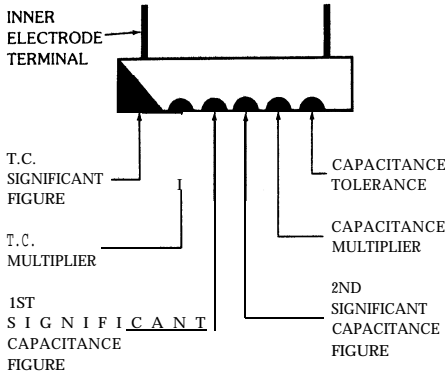
Standard temperature coefficients of capacitance expressed in parts per million per degree Celsius are: +150, +100, +33.0, -33, -75, -150, -220, -330, -470, 750, -1500, -2200, -3300, and -4700.

PAPER FOIL-TYPE CAPACITORS

In general, paper capacitors have been largely replaced by plastic film capacitors in both foil and



(A) Five-dot system.



(B) Six-dot system.

Fig. 16. Color coding of EIA Class-I ceramic dielectric capacitors. See Table 17 for color code. Tubular style shown to illustrate identification of inner electrode. For disc or plate styles, color code will read from left to right as observed with lead wires downward.

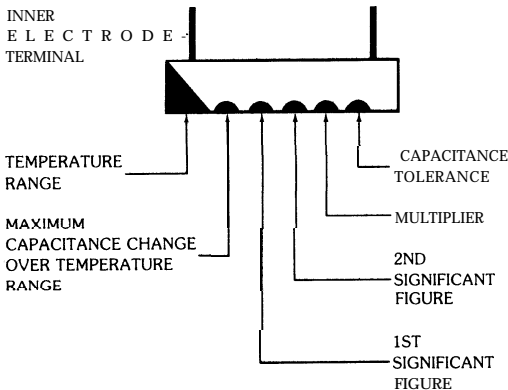


Fig. 17. Color coding of EIA Class-II ceramic dielectric capacitors. See Table 17 for color code. Tubular style shown to illustrate identification of inner electrode. For disc or plate styles, color code will read from left to right as observed with lead wires downward.

metallized constructions and in most dc electronic circuits. Impregnated paper capacitors for ac power applications are also being replaced with plastic-film capacitors with both impregnated and dry constructions.

Construction usually consists of multiple layers of paper as the dielectric interleaved with aluminum or tin alloy foil electrodes. Termination is either tabs inserted during winding or leads welded to extended foils.

Paper capacitors are impregnated with stabilized waxes or oils. Most chlorinated materials, such as chlorinated diphenyls, have been banned by the EPA as impregnants. The impregnant usually has a dielectric constant of about 6 and is used for size reduction and improvement in corona start and to reduce internal discharge in ac power applications.

Included among dc applications are coupling, decoupling, bypass, smoothing filters, power-separating filters, energy-storage capacitors, etc. Included among ac applications are motor start, fluorescent lighting, interference suppression, power-factor correction, power-line coupling, distribution capacitors for high-voltage switching gear, capacitor voltage dividers for ac measurement, etc.

MICA CAPACITORS

Mica capacitors fall within the classification of low loss and good capacitance stability. Mica is one of the earliest dielectric materials used and has an unrivaled combination of physical and electrical characteristics. It is of mineral origin and, because of its monoclinic structure, can be readily split into thin plates. It has a dielectric constant of about 6 (largely independent of frequency) together with a very low loss.

Construction

Mica capacitor constructions of the eyelet, molded, bonded, and button styles have been largely replaced by precision polystyrene, polypropylene, and polyester plastic film capacitors and by ceramic capacitors. The main surviving style is the dipped epoxy-coated radial-leaded capacitor using a clamp-type silvered mica stack with tin electrodes.

Applications

Their low temperature coefficient of capacitance and good stability with temperature and frequency, make mica capacitors a good choice for critical precision circuitry such as filter applications.

Type Designation

A comprehensive numbering system, the type designation, is used to identify mica capacitors. Type designations are of the form shown in Fig. 18.

TABLE 17. COLOR CODE FOR CERAMIC DIELECTRIC CAPACITORS, CLASSES I AND II*

Color	Digit	Multiplier	Class I					Class II		
			Capacitance Tolerance		Temperature Coefficient ppm/ °C (5-Dot System)	Temperature Coefficient Significant Figure (6-Dot System)	Temperature Coefficient Multiplier (6-Dot System)	Capacitance Tolerance (%)	Temperature Range (°C)	Maximum Capacitance Change Over Temperature Range (%)
			10 pF or less (pF)	Over 10 pF (%)						
Black	0	1	±2.0	±20	0	0.0	-1	±20	—	±2.2
Brown	1	10	±0.1	±1	-33	—	-10	—	+10 to +85	±3.3
Red	2	100	—	±2	-75	1.0	-100	—	-55 to +125	±4.7
Orange	3	1000	—	±3	-150	1.5	-1000	—	+10 to +65	±7.5
Yellow	4	10000	—	—	-220	2.2	-10000	GMV	—	±10
Green	5	—	±0.5	±5	-330	3.3	+1	±5	—	±15
Blue	6	—	—	—	-470	4.7	+10	—	—	±22
Violet	7	—	—	—	-750	7.5	+100	—	—	+22, -33
Gray	8	0.01	±0.25	—	+150 to -1500	(-1000 to 5200 ppm/ With Black Multiplier)	+1000	+80, -20	—	+22, -56
White	9	0.1	±1.0	±10	+100 to -750	—	+10000	±10	—	+22, -82
Silver	—	—	—	—	—	—	—	—	-30 to +85	±1.5
Gold	—	—	—	—	—	—	—	—	-55 to +85	±1

* EIA Standard RS-198-B (ANSI C83.4-1972). This standard classifies ceramic dielectric, fixed capacitors as follows:

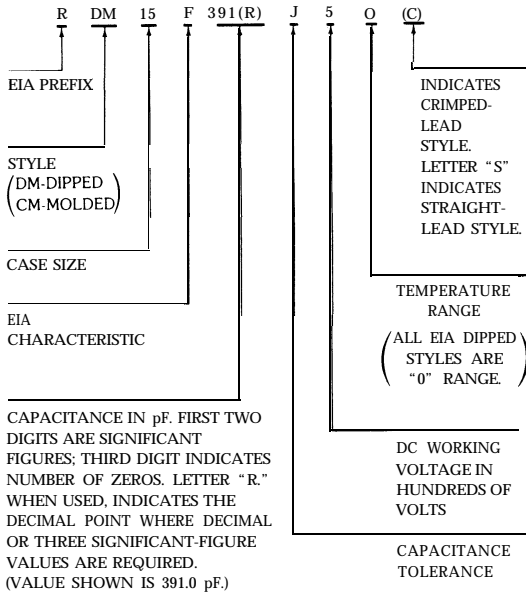
Class I -Temperature compensating ceramics suited for resonant circuit or other applications where high Q and stability of capacitance characteristics are required.

Class II -Ceramics suited for bypass and coupling applications, or for frequency discriminating circuits where high Q and stability of capacitance characteristics are not of major importance.

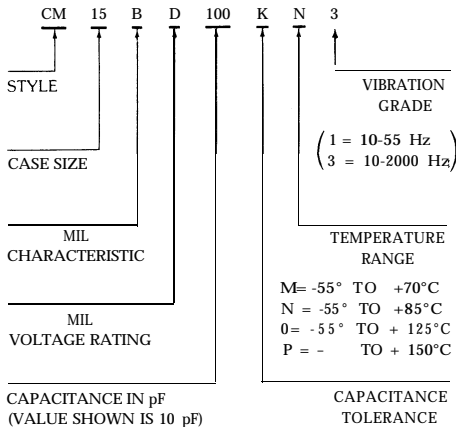
Class III-Low-voltage ceramics specifically suited for transistorized or other electronic circuits for bypass, coupling, or frequency determination where dielectric losses, high insulation resistance, and capacitance stability are not of major importance.

Note: Where size permits, EIA Class-III ceramics are typographically marked as follows:

- (1) Capacitance value in microfarads. (2) Rated voltage. (3) Manufacturer's mark or EIA source code.
- (4) Capacitance value tolerance or appropriate code letter; either ±20% (Code M) or +80, -20% (Code S)
- (5) Temperature stability code (see the EIA or ANSI Standard).



(A) EIA.



(B) MIL.

Fig. 18. Type designation for mica-dielectric capacitors.

MIL specifications now require type designation marking. Color coding is now used only for EIA standard capacitors.

Component Designation-Fixed mica-dielectric capacitors are identified by the symbol CM. For EIA, a prefix letter R is always included, and dipped types are identified by the symbol DM.

Case Designation-The case designation is a two-digit symbol that identifies a particular case size and shape.

Characteristic-The EIA or MIL characteristic

is indicated by a single letter in accordance with Table 18.

TABLE 18. FIXED-MICA-CAPACITOR REQUIREMENTS BY EIA AND MIL CHARACTERISTIC

EIA or MIL Characteristic	Maximum Capacitance Drift	Maximum Range of Temperature Coefficient (ppm/°C)
B	Not Specified	Not Specified
C	$\pm(0.5\% + 0.1 \text{ pF})$	± 200
D	$\pm(0.3\% + 0.1 \text{ pF})$	± 100
E	$\pm(0.1\% + 0.1 \text{ pF})$	- 20 to +100
F	$\pm(0.05\% + 0.1 \text{ pF})$	0 to +70

Capacitance Value-The nominal capacitance value in picofarads is indicated by a three-digit number. The first two digits are the first two digits of the capacitance value in picofarads. The final digit specifies the number of zeros that follow the first two digits. For EIA, if more than two significant figures are required, an additional digit is used, and the letter "R" is inserted to designate the decimal position.

Capacitance Tolerance-The symmetrical capacitance tolerance in percent is designated by a letter as shown in Table 1.

Voltage Rating-MIL voltage ratings are designated by a single letter as follows. A = 100, B = 250, C = 300, D = 500, E = 600, F = 1000, G = 1200, H = 1500, J = 2000, K = 2500, L = 3000, M = 4000, N = 5000, P = 6000, Q = 8000, R = 10000, S = 12000, T = 15000, U = 20000, V = 25 000, W = 30000, and X = 35 000 volts. EIA dc working voltage is a number designating hundreds of volts.

Temperature Range-MIL specifications provide for four temperature ranges, all of which have a lower limit of - 55°C; the upper limits are M = -i-70, N = +85, 0 = +125, and P = +150°C. The EIA uses only N and 0, which are identical to the MIL standard.

Vibration Grade-The MIL vibration grade is a number, 1 corresponding to vibration from 10 to 55 hertz at for 4.5 hours and 3 corresponding to 10 to 2000 hertz at 20g for 12 hours.

Capacitance

Capacitance is measured at 1 megahertz for capacitors of 1000 picofarads or smaller. Larger capacitors are measured at 1 kilohertz.

Temperature Coefficient

Measurements to determine the temperature coefficient of capacitance and the capacitance drift are based on one cycle over the following temperature values (all in degrees Celsius): +25, -55, -40, -10, +25, +45, +65, +70, +85, +125, +150, +25. Measurements at i-85, +125, and i-150 are not made if these values are not within the applicable temperature range of the capacitor.

Dissipation Factor

The EIA and MIL specifications require that for molded and dipped capacitors the dissipation factor not exceed the values shown in Fig. 19. For

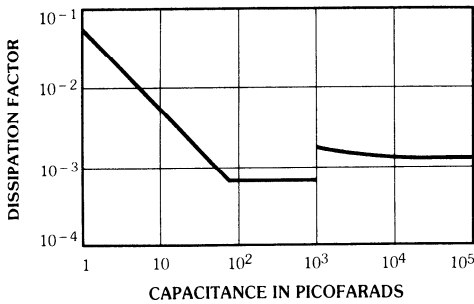


Fig. 19. EIA and MIL maximum dissipation factor at 1 megahertz for capacitance of 1000 picofarads or less and at 1 kilohertz for capacitance greater than 1000 picofarads.

potted and "cast epoxy capacitors, the dissipation factor shall not exceed 0.35 percent from 1 to 1000 picofarads and 0.15 percent above 1000 picofarads.

High-Potential or Withstanding-Voltage Test

Molded or dipped mica capacitors are subjected to a test potential of twice their direct-current voltage rating.

Humidity and Thermal-Shock Tests

EIA Standard RS-153-B capacitors must withstand 5 cycles of -55, +25, i-85, or i-125 (as applicable), and +25 degrees Celsius thermal shock followed by a humidity test of 10 cycles (each of 24 hours) given for EIA Standard RS-186-D in Fig. 1. Units must pass a withstanding-voltage test. Capacitance may not change by more than 1.0 percent or 1.0 picofarad, whichever is greater. Insulation resistance must meet or exceed 30 percent of the initial requirements at 25°C (50 000 megohms for capacitances of 20 000 picofarads or less; 1000 ohm-farads for larger capacitances).

MIL Specification MIL-C-SD capacitors must withstand 5 cycles of -55; i-25; i-85, i-125, or

+150 (as applicable); and +25 degrees Celsius thermal shock followed by a humidity test of 10 cycles (each of 24 hours) given for MIL-STD-202E in Fig. 1. Units must pass a withstanding-voltage test. Capacitance may not change by more than $\pm(0.2 \text{ percent} + 0.5 \text{ picofarad})$. Insulation resistance must meet or exceed 30 percent of the initial requirements at 25°C (100 000 megohms for 10000 picofarads or less; 1000 megohm-microfarads for larger capacitances).

Life

Capacitors are given accelerated life tests at 85 degrees Celsius with 150 percent of rated voltage applied for 2000 hours for MIL specification or 250 hours for EIA standard. If capacitors are rated above +85°C, the test will be at their maximum rated temperature.

PRINTED CIRCUITS

A printed circuit is a conductive circuit pattern on one or both sides of an insulating substrate. Multi-layer boards with tens of levels of circuitry are manufactured with conducting thru-holes to interconnect the circuitry levels. The conductive pattern can be formed by any of several techniques after which component lead holes are drilled or punched in the substrate and components are installed and soldered in place. Printed-circuit construction is ideal for assembly of circuits that employ miniature solid-state components. Its advantages over conventional chassis and point-to-point wiring include:

(A) Considerable space savings over conventional construction methods is usually a result.

(B) A complex circuit may be modularized by using several small printed circuits instead of a single larger one. Modularization simplifies troubleshooting, circuit modification, and mechanical assembly in an enclosure.

(C) Soldering of component leads may be accomplished in an orderly sequence by hand or by dip or wave soldering.

(D) A more uniform product is produced because wiring errors are eliminated and because distributed capacitances are constant from one production unit to another.

(E) The printed-circuit method of construction lends itself to automatic assembly and testing.

(F) Using appropriate base metals, flexible cables or flexible circuits can be built.

(G) By using several layers of circuits (in proper registry) in a sandwich construction, with the conductors separated by insulating layers, relatively complex wiring can be provided.

Printed-Circuit Base Materials

Rigid printed-circuit base materials are available in thicknesses varying from $1/64$ to $1/2$ inch. The

important properties of the usual materials are given in Table 19. For special applications, other rigid or flexible materials are available as follows:

- (A) Glass-cloth Teflon (polytetrafluoroethylene, PTFE) laminate.
- (B) Kel-F (polymonochlorotrifluoroethylene) laminate
- (C) Silicone rubber (flexible)
- (D) Glass-mat-polyester-resin laminate.
- (E) Teflon film.
- (F) Ceramic.

The most widely used base material is NEMA-XXXXP paper-base phenolic.

Conductor Materials

Copper is used almost exclusively as the conductor material, although silver, brass, and aluminum also have been used. The common thicknesses of foil are 0.0014 inch (1 oz/ft²) and 0.0028 inch (2 oz/ft²). The current-carrying capacity of a copper conductor may be determined from Fig. 20.

Manufacturing Processes

The most widely used production methods are:

(A) Etching process, wherein the desired circuit is printed on the metal-clad laminate by photographic, silk-screen, photo-offset, or other means, using an ink or lacquer resistant to the etching bath. The board is then placed in an etching bath that removes all of the unprotected metal (ferric chloride is a commonly used mordant for copper-clad laminates). After the etching is completed, the ink or lacquer is removed to leave the conducting pattern exposed.

(B) Plating process, wherein the designed circuit pattern is printed on the unclad base material using an electrically conductive ink, and, by electroplating, the conductor is built up to the desired thickness. This method lends itself to plating through punched holes in the board for making connections from one side to the other.

(C) Other processes, including metal spraying and die stamping.

Circuit-Board Finishes

Conductor protective finishes are required on the circuit pattern to improve shelf-storage life of the circuit boards and to facilitate soldering. Some of the most widely used finishes are:

(A) Hot-solder coating (done by dip-soldering in a solder bath) is a low-cost method and gives good results where coating thickness is not critical.

(B) Silver plating used as a soldering aid but is subject to tarnishing and has a limited shelf life.

(C) Hot-rolled or plated solder coat gives good solderability and uniform coating thickness.

(D) Other finishes for special purposes are gold plate, for corrosion resistance and solderability, and electroplated rhodium over nickel, for wear resistance. Insulating coatings such as acrylic, polystyrene, epoxy, or silicone resin are sometimes applied to circuit boards to improve circuit performance under high humidity or to improve the anchorage of parts to the board. Conformal coatings are relatively thick and tend to smooth the irregular contour of the mounted items; they add less mass than encapsulation. A protective organic coating (unless excessively thick) will not improve the electrical properties of an insulating base material during long exposure to high humidity. On two-sided circuit boards, where the possibility of components shorting out the circuit patterns exists, a thin sheet of insulating material is sometimes laminated over the circuit before the parts are inserted.

Design Considerations

Before a printed-circuit layout is made, the circuit must be breadboarded and tested under the anticipated final operating conditions. This procedure will permit operating deficiencies and quirks to be detected and corrected before the time-consuming process of producing the circuit board is begun. It is important to note that certain circuits may operate differently on a printed-circuit board than on a breadboard, and appropriate corrective steps may be necessary. For example, inductive coupling between foil patterns may cause unwanted oscillation in high-frequency or amplifier circuits.

All features (terminal areas, contacts, board boundaries, holes, etc.) should be arranged to be centered at the intersections of a 0.100-, 0.050-, or 0.025inch rectangular grid, with preference in the order stated. Many components are available with leads spaced to match the standard grids. Devices with circular lead configurations and a few other multilead devices are exceptions that require special attention and dimensioning. Following this grid-layout principle simplifies drafting and subsequent machine operations in board manufacture and assembly.

Drilled holes must be employed if the stated requirements for punched holes cannot be met, or if the material is not of a punching grade. Drilling is less detrimental to the laminate surrounding the hole; punching may cause crazing or separation of the laminate layers.

The diameter of punched holes in circuit boards should not be less than $\frac{2}{3}$ the thickness of the base material.

The distance between punched holes or between holes and the edge of the material should not be less than the material thickness.

TABLE 19. PROPERTIES OF TYPICAL PRINTED-CIRCUIT DIELECTRIC BASE MATERIALS

Material	Comparable MIL Type	Punchability	Mechanical Strength	Moisture Resistance	Insulation	Arc Resistance	Abrasive Action on Tools	Max Temperature (°C)*
NEMA type XXXP paper-base phenolic	—	Good	Good	Good	Good	Poor	No	105
NEMA type XXXPC paper-base phenolic	—	Very good	Good	Very good	Good	Poor	No	105
NEMA type FR-2 paper-base phenolic, flame resistant	—	Very good	Good	Very good	Good	Poor	No	105
NEMA type FR-3 paper-base epoxy, flame resistant	PX	Very good	Very good	Very good	Very good	Good	No	105
NEMA type FR-4 glass-fabric-base epoxy, general purpose, flame resistant	GF	Fair	Excellent	Excellent	Excellent	Very good	Yes	130 (125)
NEMA type FR-5 glass-fabric-base epoxy, temperature and flame resistant	GH	Fair	Excellent	Excellent	Excellent	Very good	Yes	155 (150)
NEMA type G-10 glass-fabric-base epoxy, general purpose	GE	Fair	Excellent	Excellent	Excellent	Very good	Yes	130 (125)
NEMA type G-11 glass-fabric-base epoxy, temperature resistant	GB	Poor	Excellent	Excellent	Excellent	Very good	Yes	155 (150)
Glass-fabric-base polytetrafluoroethylene	GT	—	Good	Excellent	Excellent	Excellent	—	(150)
Glass-fabric-base fluorinated ethylene propylene	FEP	—	Good	Excellent	Excellent	Excellent	—	(150)

*MIL-STD-275C rating shown in parentheses if different from industry rating.

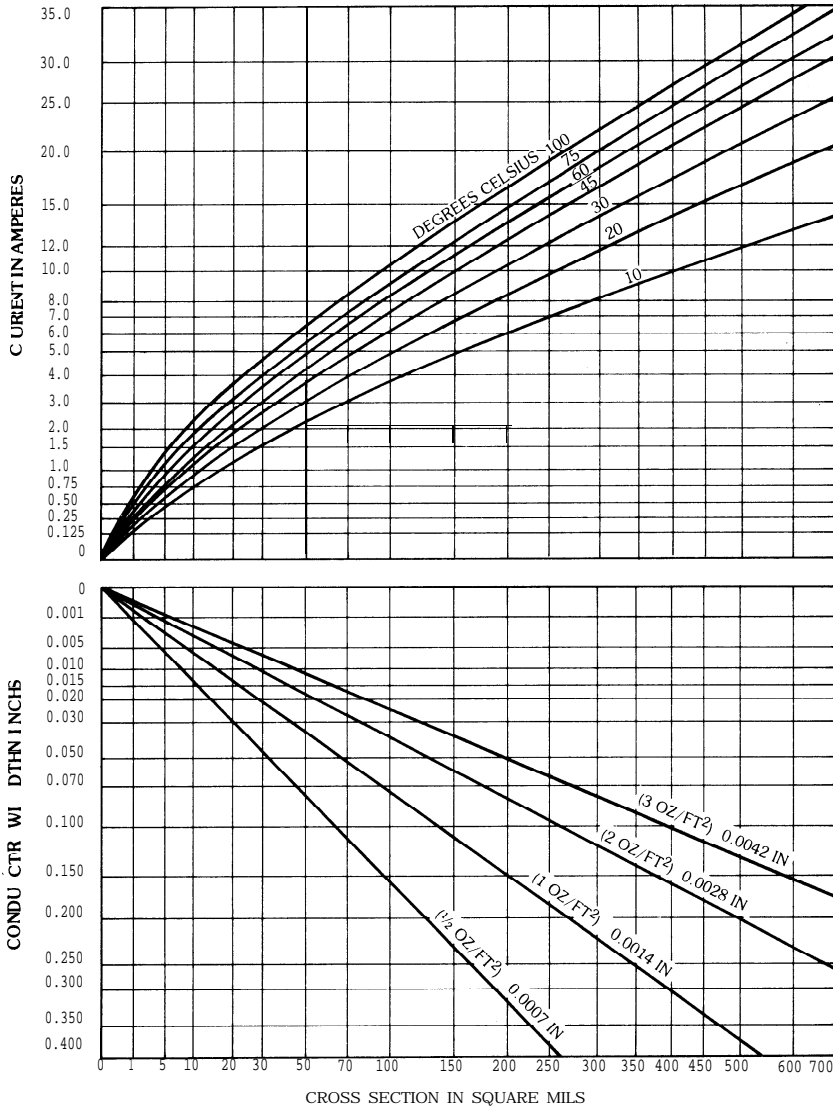


Fig. 20. Current-carrying capacity and sizes of etched copper conductors for various temperature rises above ambient, From MIL-STD-275C, 9 January 1970.

Punched-hole tolerance should not be less than ± 0.005 inch on the diameters.

Hole sizes should not exceed by more than 0.020 inch the diameter of the wire to be inserted in the hole. With smaller holes, hand insertion of the wire is difficult. Machine insertion requires the larger allowance. Clinching of the lead is desirable if the clearance is larger.

Tolerances with respect to the true-grid location for terminal area centers and for locating edges of boards or other locating features (datums) should not exceed on the board: 0.014 inch diameter for conductor widths and spacings above 0.031 inch; 0.010 inch diameter for conductor widths and spacings 0.010 to 0.031 inch, inclusive. Tolerances on

other dimensions (except conductor widths and spacings) may be larger. Closer tolerances may be needed if machine insertion is required.

Terminal area diameters should be at least (A) 0.020 inch larger than the diameter of the flange or projection of the flange on eyelets or standoff terminals, or the diameter of a plated-through hole, and (B) 0.040 inch larger than the diameter of an unsupported hole. Since the terminal area should be unbroken around the finished hole, the diameter should be further increased over the above minimum to allow for the permitted hole-position tolerance.

Conductor widths should be adequate for the current carried. See Fig. 20. For a given conductor-

width and copper-thickness intersection, proceed vertically to the allowable temperature-rise line and then horizontally to the left to determine the permissible current. An additional 15% derating is recommended for board thicknesses of 1/32 inch or less, or for conductors thicker than 0.004 inch (3 oz). The normal ambient temperature surrounding the board plus the allowable temperature rise should not exceed the maximum safe operating temperature of the laminate. For ordinary work, copper conductor widths of 0.060 inch are convenient; with high-grade technique (extra cost), conductor widths as small as 0.010 inch can be readily produced.

Conductor spacing requirements are governed by the applied voltage, the maximum altitude, the conductor protective coating used, and the power-source size. The guide in Table 20 is suggested.

1. Hand application of opaque, permanent black ink
2. Pressure-sensitive tape
3. Hand-cut stencil made from self-adhesive opaque film
4. Preformed self-adhesive layout patterns

Artwork should be prepared to a scale that is two to five times oversize. Photographic reduction to final negative size should be possible, however, in one step.

Avoid the use of sharp corners when laying out the circuit. See Fig. 21.

The centers of holes to be manually drilled or punched in the circuit board should be indicated by a circle of 1/32-inch diameter (final size after reduction). See Fig. 22. This feature is not needed on each board if templates or numerically controlled

TABLE 20. CONDUCTOR SPACINGS*

Voltage Between Conductors	Minimum Spacing Between Conductors (Inches)		
	Uncoated Boards		Conformal Coated Boards
	Sea Level to 10000 Ft	Over 10000 Ft	All Altitudes
0-30	0.025	0.025	0.010
0-50	0.025	0.025	—
0-150	0.025	—	—
31-50	0.025	0.025	0.015
51-100	0.025	0.060	0.020
101-170	—	0.125	0.030
101-300	—	—	0.030
151-300	0.050	—	0.030
171-250	0.050	0.250	0.030
251-500	—	0.500	—
301-500	0.100	0.500	0.060
Above 500	0.0002 per volt	0.001 per volt	0.00012 per volt

*From MIL-STD-275C

Preparation of Artwork

In preparing the master artwork for printed circuits, careful workmanship and accuracy are important. When circuits are reproduced by photographic means, much retouching time is saved if care is taken with the original artwork.

Artwork should be prepared on a dimensionally stable material. Tracing paper and bristol board are now outmoded, and specially treated (toothed) polyethylene terephthalate (Mylar, Cronar) base drafting films are used for most printed-circuit layouts. The layout pattern may be produced by one of the following methods:

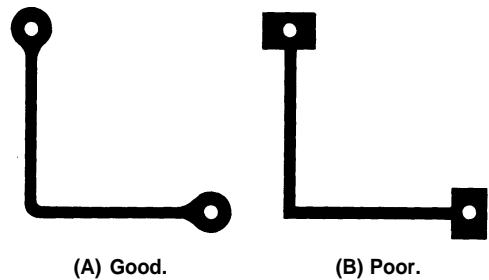


Fig. 21. Design of bends for printed-circuit conductors.



Fig. 22. Indication for hole.

machine tools are used for hole preparation; however, it is still a convenience for checking drawings, master artwork, and photographic negatives.

When drawing the second side of a printed-circuit board, corresponding centers should be taken directly from the back of the drawing of the first side.

In addition to the illustration of the circuit pattern, the trim line, registration marks, and two scale dimensions at right angles should be shown. Nomenclature, reference designations, operating instructions, and other information may also be added.

Assembly

All components should be inserted on one side of the board if practicable. In the case of boards with the circuit on one side only, the parts should be inserted on the side opposite the circuit. This allows all connections to be soldered simultaneously by dip-soldering.

Dip-soldering consists of applying a flux, usually a rosin-alcohol mixture, to the circuit pattern and then placing the board in contact with molten solder. Slight agitation of the board will ensure good fillets around the wire leads. In good present technique, the circuit board with its components assembled (on one side only) has its conductor pattern passed through the crest of a "wave" of molten solder; all junctions are soldered as the

board progresses through the wave. The flux, board temperature, solder temperature, and immersion time are interrelated and must be adjusted for best results. Long exposure to hot solder is detrimental to the insulating material and to the adhesive that joins the copper foil to the insulation. For hand dipping, a 5-second dip in a 60/40 tin-lead solder bath maintained at a temperature of 450 degrees Fahrenheit will give satisfactory results.

After solder-dipping, the residual flux should be removed by a suitable solvent. Be sure the solvent is compatible with the materials used in the component parts mounted on the board; solvents frequently dissolve cements or plastics and marking inks, or cause severe stress cracking of plastics.

To secure the advantages of machine assembly:

(A) Components should be of similar size and shape, or separate inserting heads will be required for each different shape of item.

(B) Components of the same size and shape must be mounted using the same terminal lead spacing at all points.

(C) Different values of a part, or even different parts of similar shape and sizes (if axial-lead style) may be specially sequenced in a lead-taped package for insertion by one programmed insertion head.

(D) A few oddly sized or shaped components may be economically inserted by hand after the machine insertion work is completed.

Reference

An excellent reference on microelectronic printed-circuit techniques is Scarlett, J.A. *Printed Circuit Boards for Microelectronics*. New York: Van Nostrand Reinhold Co., 1970.