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Guidelines for Phototool Generation and Measurement Techniques

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Guidelines for Phototool Generation and Measurement Techniques

Developed by the Artwork Generation Subcommittee of IPC



Users of this standard are encouraged to participate in the development of future revisions.

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Acknowledgment

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Guidelines for Phototool Generation and Measurement Techniques

1.0 INTRODUCTION

1.1 Scope and Purpose This publication defines guidelines for the design and production of phototools used in the production of printed boards, including general considerations and detailed descriptions of the major methods used. The purpose of this publication is to illustrate generally accepted techniques presently in use. (The procedures described are not to be construed as standards since the state-of-the-art is constantly changing and may vary beyond the scope of this publication.)

1.2 General Considerations All artwork elements will be viewed as generated from the primary side for both double sided and multilayer boards. Artwork elements are as right-reading positives except for plane layers generated by automated methods which may be right-reading negatives. (See section 3 for related terms.)

Basic artwork elements

Artwork may contain parts from the following list:

1. Multilayer internal conductor layers
2. Primary side
3. Secondary side
4. Legend symbolization
5. Solder mask artwork
6. Coupon
7. Drill alignment holes (multilayer boards only)
8. Process considerations (plating, bars, etc.)

1.2.1 Artwork Identification If revision letters of the circuit legend and/or solder mask artwork of the board are maintained independently, these revision letters change only when that particular element of the artwork is changed. When intermediate patterns are combined to form one layer, only one sheet will contain the revision letter for that layer. Revision of each layer, marking, or solder mask should be reflected in a revision control block on the master drawing.

Artwork in a multiple sheet master drawing should be assigned the same basic number as the master drawing. Place this number on each sheet of the artwork, along with the layer number and its revision letter or dash numbers. Layer one corresponds to the primary side of the board.

1.3 Classifications These guidelines recognize that the printed boards will be subject to classifications by intended end item use. Toward this end, three general classes have

been established to reflect progressive increases in sophistication, functional performance requirements, and testing inspection frequency. It should also be recognized that there may be an overlap of equipment between classes. The user has the responsibility to determine the class into which the product belongs. The three classes are defined below:

Class 1 – Consumer Products

Includes TV sets, toys, entertainment electronics, and noncritical consumer or industrial control devices. Boards in this class are suitable for applications where cosmetic imperfections are not of importance, and the major requirement is function of the completed circuit.

Class 2 – General Industry

Includes computers, communication equipment, sophisticated business machines, instruments, and certain noncritical military applications. Boards in this class are suitable for high performance commercial and industrial products in which extended life is required, but for which uninterrupted service is not critical. Certain cosmetic imperfections are allowable.

Class 3 – High Reliability

Includes those equipments where continued performance is critical, equipment downtime cannot be tolerated, or the equipment is a life support item. Boards of this class are suitable for applications where high levels of assurance are required, and uninterrupted service is essential.

The performance of the printed board products may be tested to any one of the three classes. The use of one class for a specific attribute does not mean that all other attributes must meet that same class. Selection should be based on minimum need; however, cross-over between classes requires complete definition of test requirements in the procurement document.

Note: Unless otherwise specified, military electronic equipment shall be Class 3.

1.4 Dimensions And Tolerances Dimensions are expressed in millimeters. Inches, shown in brackets [], are not direct conversions in order to provide usable numbers. Users are cautioned to employ a single system, and not intermix metric and inch-based equivalents. Reference information is shown in parentheses ().

2.0 DOCUMENTATION

2.1 Applicable Documents

2.1.1 IPC

IPC-D-275 Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies

IPC-D-325 End Product Documentation for Printed Boards

IPC-D-350 End Product Description in Numeric Form

IPC-D-390 Guidelines for Design and Artwork Generation on Computer Automated Equipment

IPC-S-804 Solderability Test Methods for Printed Wiring Boards

IPC-SM-840 Qualification & Performance of Permanent Polymer (solder mask) Coatings

2.1.2 American Astronomical Society (AAS) Photo Bulletin, 1973, No. 1

“Pre-exposure Cleaning of Astronomical Plates”

“Processing & Storage of Photographic Plates”

2.1.3 ANSI Publications

ANSI IT9.1 American National Standard for Imaging Media (Film)—Silver-Gelatin Type—Specifications for Stability

ANSI IT9.2 American National Standard for Imaging Media—Photographic Processed Films, Plates, and Papers—Filing Enclosures and Storage Containers

ANSI IT9.5 American National Standard for Imaging Media (Film)—Ammonia-Processed Diazo Films—Specifications for Stability

ANSI PH1.32 Method for Determining Dimensional Change Characteristics of Photographic Films and Papers

ANSI PH1.43 Practice for Storage of Processed Safety Photographic Film

ANSI PH1.45 Practice for Storage of Processed Photographic Plates

ANSI PH4.8 Methylene Blue Method for Measuring Thio-sulfate and Silver Densitometric Method for Measuring Residual Chemicals in Films, Plates, and Papers

ANSI Y14.5 Dimensioning and Tolerancing

2.1.4 Military Standards

MIL-STD-202 Test Methods for Electronic and Electrical Components Parts

MIL-STD-454 Standard General Requirements for Electronic Equipment

MIL-STD-883 Test Methods and Procedures for Microelectronics

MIL-STD-275 Printed Wiring for Electronic Equipment

MIL-P-55110 Military Specification Printed-Wiring Boards, General Specification For

MIL-C-45662 Calibration System Requirements

2.2 Reference Documents

2.2.1 IPC

IPC-T-50 Terms & definitions

IPC-SC-60 Post Solder Solvent Cleaning Handbook

IPC-AC-62 Post Solder Aqueous Cleaning Handbook

IPC-D-249 Design Standard for Flexible 1 & 2 Sided Printed Boards

IPC-FC-250A Standard for Single & Double Sided Flexible Wiring

IPC-D-300 Dimensions & Tolerances for Single & Double Sided Printed Boards

IPC-D-319 Design Standard for Rigid One & Two Sided Printed Boards

IPC-A-600 Acceptability of Printed Boards

IPC-A-610 Acceptability of Printed Board Assemblies

IPC-R-700 Modification & Repair for Printed Boards & Assemblies

IPC-CM-770 Guidelines for Printed Board Component Mounting

IPC-D-949 Design Standard for Rigid Multilayer Printed Boards

3.0 TERMS & DEFINITIONS

The definition of terms shall be in accordance with IPC-T-50 and the following. (For convenience, appropriate definitions from IPC-T-50 are contained herein; they are indicated with an asterisk.)

Actinic radiation Light energy that reacts with the photosensitive coatings to produce an image.

Alignment The accuracy of locating an existing image on a phototool with respect to an existing image on a substrate.

Alignment mark A stylized pattern selectively positioned on a phototool to assist in aligning.

Angstrom Unit of measurement used to define the wave length of radiant energy; one angstrom is equivalent to 10^{-1} nanometer (10^{-10} meter).

Artwork An accurately scaled pattern consisting of an image on the surface of a stable support (usually a single image), which is used to produce the artwork master or production master (see Figure 3-1).

Note: The proper description of the artwork must include the required specification for tone and orientation; these specifications impact subsequent photo-processing operations and/or usability (see Figure 3-2 and 3-3).

Artwork master An accurately scaled (usually 1:1) pattern, usually a single image, which is used to produce the production master.

Background The non-functional area of a phototool. The background area is usually much greater than the functional pattern area.

Back lighting Viewing or photographing an object by placing it between a light source and the eye or recording medium.

Base material (Phototool) The substrate onto which a pattern is delineated or onto which a photosensitive strippable or scrubbable material is applied for use in producing a functional pattern.

Border area The region on a phototool external to the area of the printed board outline.

Border data Patterns which appear in the border area; these patterns may include tooling hole bulls-eyes, identification, test patterns, and registration marks.

Bulls-eye Stylized patterns located in the phototool border area to assist in alignment and/or registration.

Characteristic curve (H & D curve) A curve of optical density of a photographic product verses the logarithm of the exposure, used to characterize the response of the material to exposure and development (see Figure 3-4).

Compensated artwork A process which modifies the original artwork by increasing or decreasing to meet the processing requirements based on the chemistry and equipment used by individual manufacturers.

Composite A photographic contacting technique in which two separate pieces of artwork are aligned or registered and imaged on to a third piece of film.

Contact printing A technique for making a reproduction in which the sensitized material is exposed after placing it in intimate contact with the original.

Coordinatograph An x and y coordinate plotting and measuring machine, consisting of a fixed or rotating table and a movable head on precision tracks that is capable of precisely locating a point on a line or surface. Coordinatographs are commonly used with cut-and-strip or scribe-coat materials to generate artwork.

Cosine Law A law of illumination which states that the radiant flux in a given direction from a given small area of a perfectly diffusing surface varies as the cosine of the angle of emission.

Corner mark (Crop mark)* The mark at the corners of a printed board artwork, the inside edges of which usually locate the borders and establish the contour of the board.

Crosshatching* Breaking large conductive areas through the use of a pattern of voids in the conductive material.

Cut-and-Strip A method of producing artwork by cutting the pattern and stripping away the unwanted areas of a two layer material. Although the terms "Cut-and-strip" and "cut-and-peel" are synonymous, "Cut-and-strip" is preferred.

Definition The clarity of detail in an optically produced image. Definition is affected by a combination of resolution and contrast.

Defect An undesirable blemish in the functional pattern or background, commonly called a fleck, void, pinhole, spur, notch, etc.

Density (D) The log (1/T) where T is the transmittance of a photographic image. Also defined as the log (opacity).

Densitometer An instrument used to measure the amount of light absorbed by a film sample.

Develop To subject a photosensitive material to a chemical treatment designed to produce a usable image in material previously modified by radiation.

Diazo A non-silver, room light handling, UV sensitive material coated on a polyester substrate. After contact printing and ammonia development, the material yields a mirror image of duplicate tone with high actinic density and useful visual transparency.

Digitizing* Any method of reducing feature locations on a flat plane to digital x-y coordinates.

Emulsion side The side of a photographic substrate on which the photographic layer is applied.

Etch factor The ratio of the depth of etch (conductor thickness) to the amount of lateral etch (undercut).

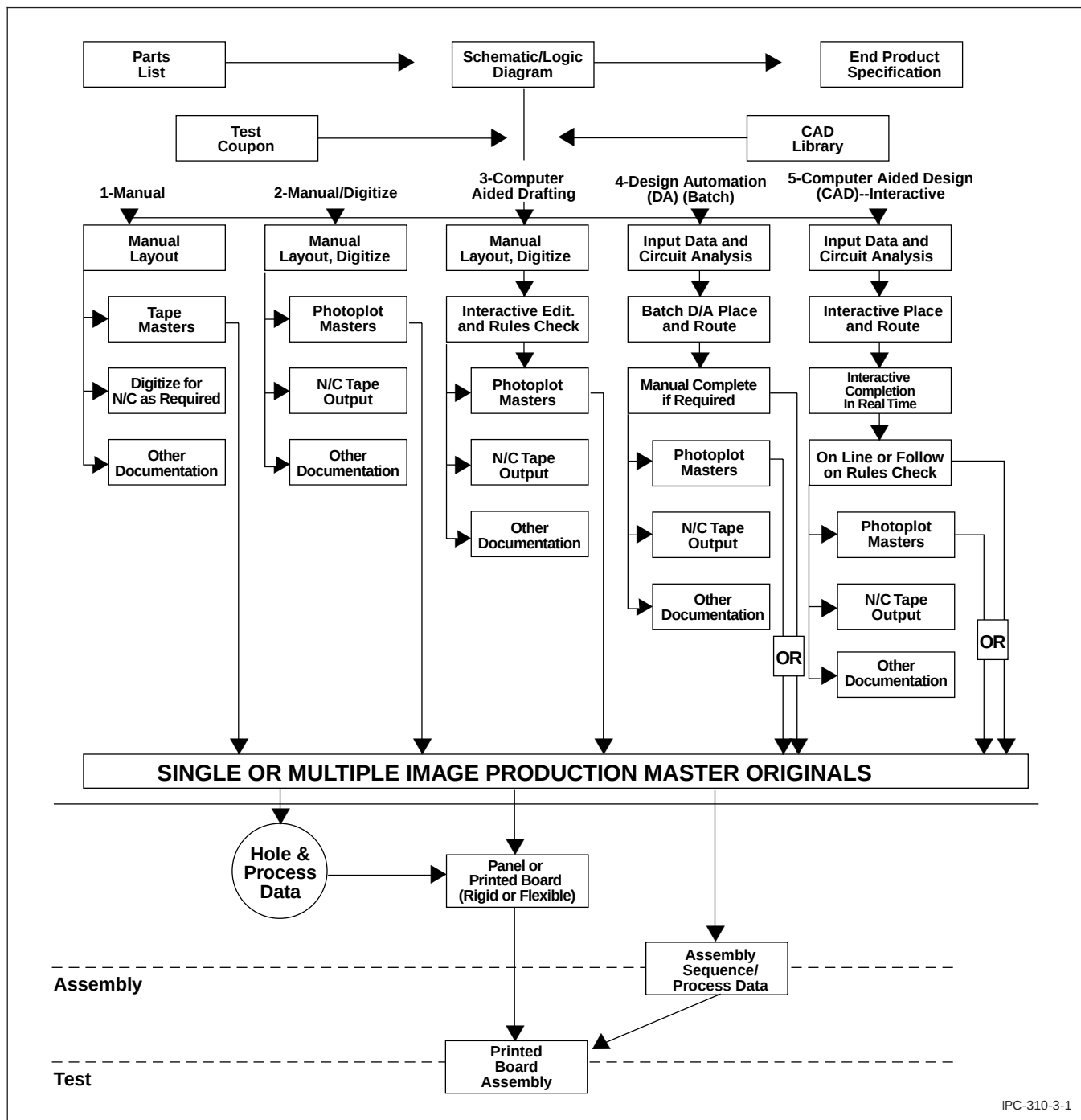


Figure 3-1 Simplified flow chart of printed board design/fabrication sequence

Exposure (E) Exposure is the total quantity of light received by a light sensitive layer, expressed as the product of illuminance x time.

Fiducial Optical targets used as reference points to accurately align and position a board.

File-master Any of the photo-tooling which may be retained for recreating or regenerating a production master. Typically, either the artwork master or working master function as file- masters. The file-master must include required specifications for tone and orientation; these speci-

fications impact subsequent photo-processing operations and/or usability.

Fleck A defect in the clear background of a phototool with a black pattern or within the clear pattern of a phototool with a black background.

Foot-candle A unit of illumination equal to a luminous flux density of one (1) lumen per square foot.

Functional pattern The image on a phototool which delineates the desired wiring configuration and layout.

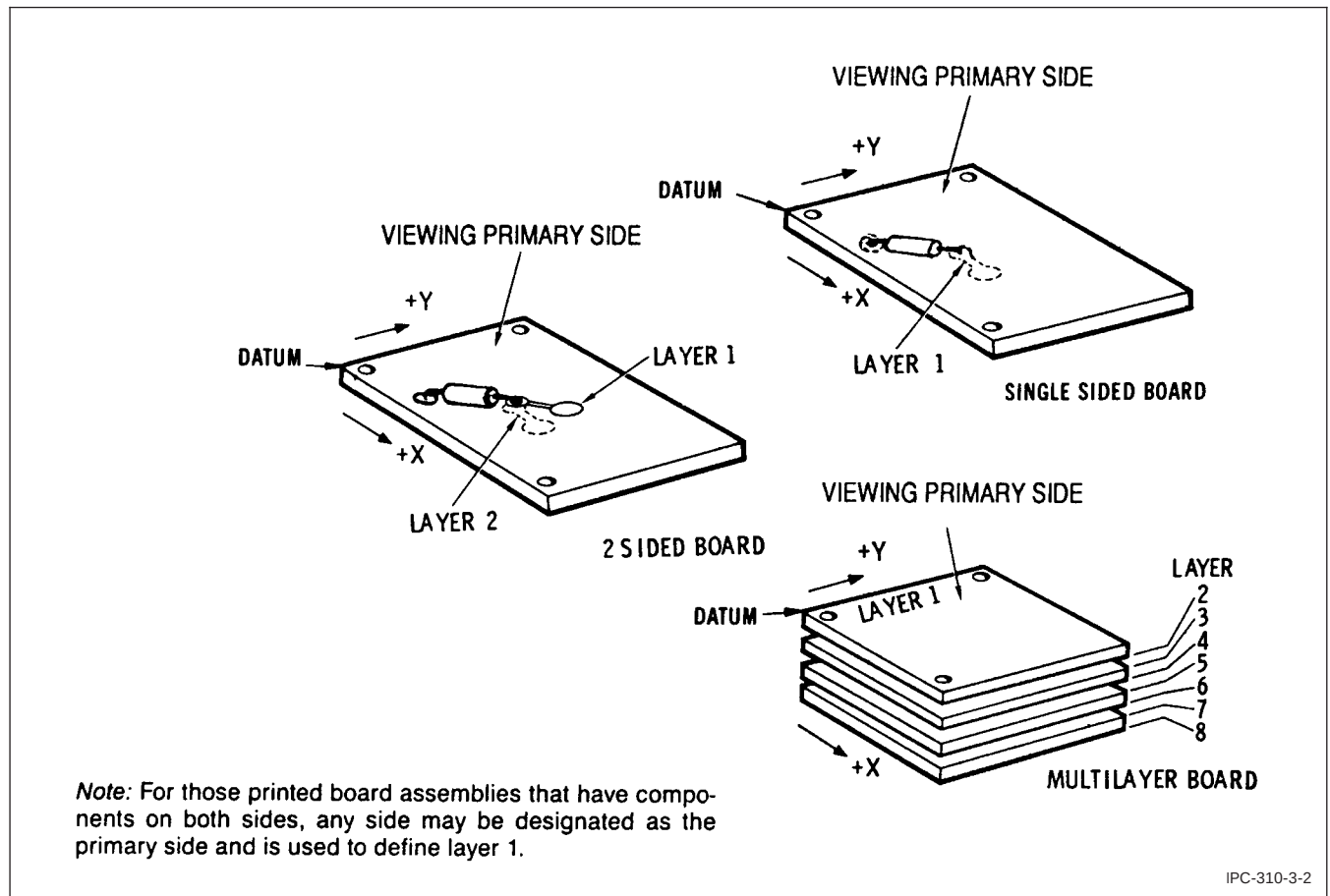


Figure 3-2 Printed wiring viewing (ANSI/IPC-D-350)

Grid Orthogonal network of 2 sets of parallel equidistant lines used for locating points on a board.

Illuminance (or Illumination) Luminous flux striking a surface. In English units, one lumen of flux falling on one square foot of area is defined as an illumination of one foot-candle. In metric units, one lumen illuminating one square meter is the definition of one lux. Therefore, 10.76 lux = 1 foot-candle.

Image A representation of the functional pattern on a substrate:

- (a) drafting—as part of a master drawing or layout;
- (b) optical—as projected on a screen;
- (c) photographic—as in a photo-mask or in the emulsion on a film or plate;
- (d) photo-resist—as occurs in an exposed and developed coating on a substrate.

Infrared Electromagnetic radiation in the invisible part of the electromagnetic spectrum, covering the wavelength range from approximately 700 to 10^6 nanometers.

Intermediate phototools Photographic films, other than plotter films, which are used to prepare the final working phototool or production master (e.g., step-and-repeat).

Inverse Square Law A law of illumination which states that the illumination of a surface due to a point source is proportional to the intensity of the source and inversely proportional to the square of the distance from the source to the surface.

Joule The total amount of energy incident on a given area, also referred to as a watt-second of energy.

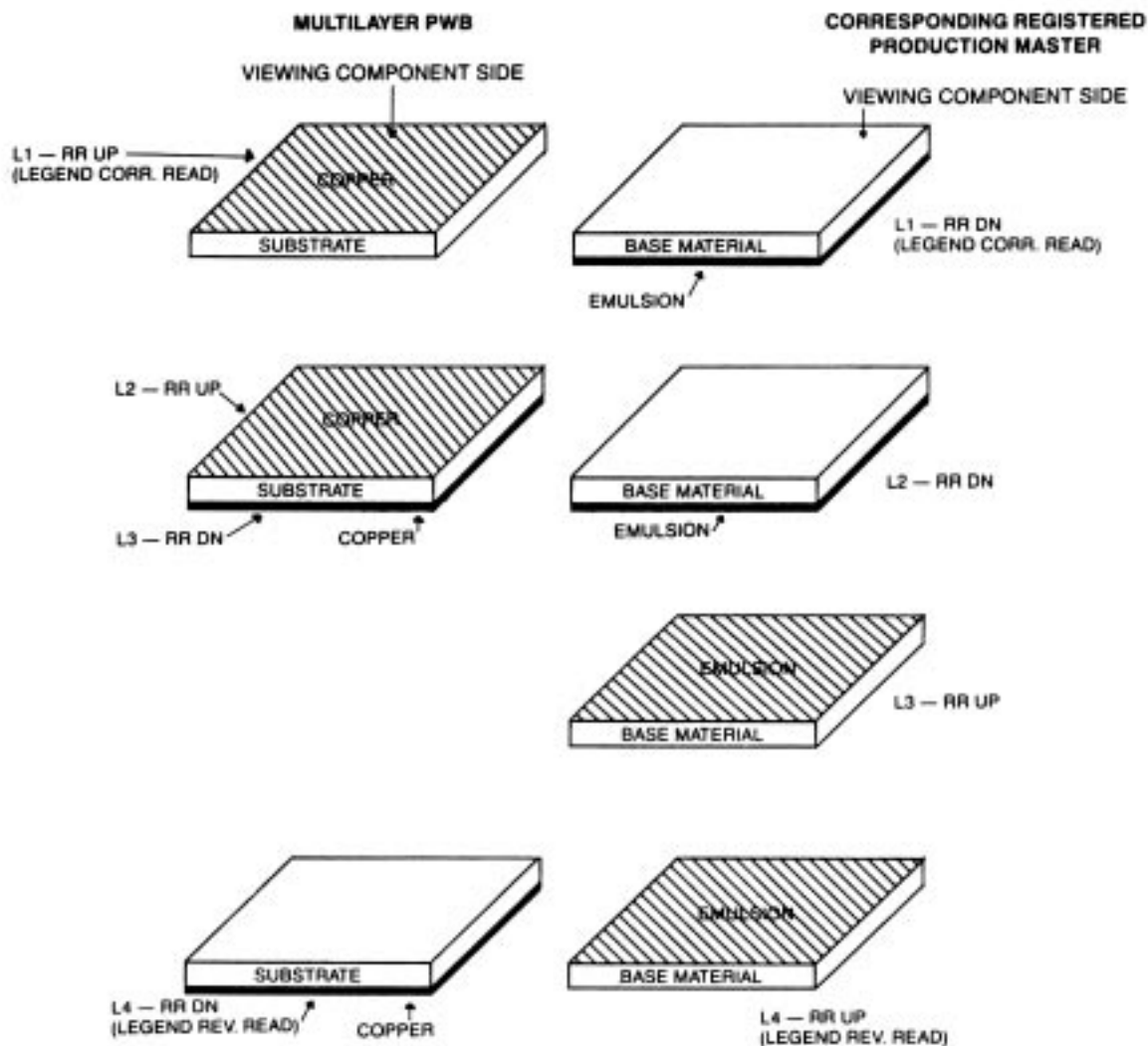
Land (Also referred to as *pad*) A portion of a conductive pattern usually, but not exclusively, used for the connection or attachment, or both, of components.

Lateral reversal A mirror image of the geometric orientation of a pattern.

Legend A format of letters and numbers or symbols and patterns on the printed board. Primarily used to identify component locations and orientation for convenience in assembly and replacement operations. (Also see Marking.)

Light Electromagnetic energy usually defined as visible radiation, covering the wavelength range 400 to 700 nanometers (nm). May also include the near ultraviolet, from 300 to 400 nm.

Luminance (or Brightness) A measure of flux reflected or emitted from a surface. It has English units of foot-lamberts and metric units of candelas per square meter.



Notes:

1. A precise definition of image tone and orientation necessitates that the orientation of the pattern and the legend be separately identified. For example:
 Layer 1 = Pos RR DN (Legend Corr. Read)
 or
 Layer 2 = Pos RR UP (Legend Rev. Read)
 (There is no such thing as wrong reading.)
2. By definition, all layer patterns are viewed from the same direction. (This view defines RR for the pattern appearance of all layers; this is not the same as viewing the final board copper head on.)
3. Legend is usually correct reading when viewing the copper; therefore, on occasion alphanumeric must be reversed reading when the pattern is right reading by definition.
4. Production master emulsion must be presented against the board copper in the stack up. Therefore, production master emulsion orientation is opposite to individual copper layer orientation, i.e., if copper is RR UP by definition, corresponding production master must be RR DN.
5. When specifying artwork tone and orientation, remember the board layup and the purpose of the artwork, i.e., file copy, artwork master, or production master, etc.
6. In manual designs the artwork is usually prepared at an enlarged scale with tapes and other drafting aids. The artwork master is produced from the artwork by photographic reduction.
7. In semi-automated designs, there may be no artwork by definition. Typically, an enlarged color-code printed wiring layout on a gridded format is prepared for subsequent digitizing and photoplotting. This procedure may yield intermediate phototools which can be photographically processed into an artwork master or it may directly yield an artwork master, working master, or production master.
8. In fully automated systems, there is usually no artwork or printed wiring layout prepared. A computerized procedure from a form of the electrical schematic by total computerization or a combination of computer and interactive design procedures. This procedure may yield intermediate phototools or the artwork master, working master, or production master directly.

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Figure 3-3 Exploded view of printed wiring layer orientation vs. registered production master orientation with legend correct reading in copper on layers 1 and 4

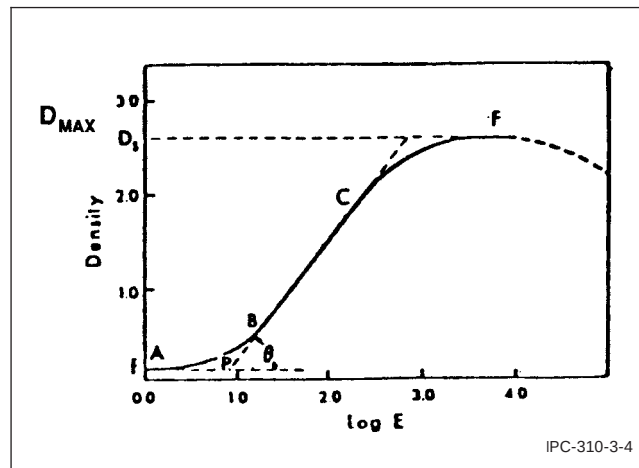


Figure 3-4 A typical curve of density vs. log exposure (H and D curve); AB, toe; BC, straight-line portion; CF, shoulder; P, the inertia point; f, the fog density; D_{MAX} , maximum density $\tau = \tan \theta$.

Luminous energy A measure of flux flow rate, usually in units of lumen-seconds.

Luminous flux A measure of flow of visible light energy past any given point in space, defined as the amount of flux generated by a source of one candela into a solid angle of one steradian.

Marking A method of identifying printed boards with part number, revision letter, manufacturer's code, etc. (See also Legend.)

Master drawing A document that shows the dimensional limits or grid locations applicable to any or all parts of a printed board (rigid or flexible), including the arrangement of conductive and nonconductive patterns or elements, size, type, and location of holes, and any other information necessary to describe the product to be fabricated.

Mirrored pattern A description of a printed board layer pattern orientation which denotes a transposition from right reading. Used in a panel drawing of composite circuit layer patterns to communicate the orientations of the patterns relative to each other and to the view which defines right reading (see Figure 3-5).

Note: Phototooling emulsion for the right reading pattern is by definition the same as for the mirrored pattern. That is, both are either emulsion up or both emulsion down.

Molecular dye imaging materials An alternative term used to describe diazo film material.

Nanometer (NM) 10^{-9} meters, a unit commonly used to measure the wavelength of light.

Negative (N) An artwork, artwork master or production master in which the intended conductive pattern is transparent to light and the areas to be free from conductive materials are opaque.

Negative acting resist A resist which is polymerized (hardened) by light and which, after exposure and development remains on the surface of a laminate in those areas which were under the transparent parts of a production master.

Notch A void; an undesirable indentation in an edge of a photographic pattern; e.g., a clear indentation in a black pattern; a black indentation in a clear pattern.

Opacity $1/T$ where T is transmittance.

Orientation The manner in which the functional pattern is to be viewed. Proper orientation requires a definition of "right reading"; orientation for the various phototooling elements is described as either "right reading up" or "right reading down".

Orthochromatic A photographic emulsion spectrally sensitive to the violet, blue, and green portions of the spectrum (see Figure 3-6).

Panchromatic A photographic emulsion sensitive to all portions of the visible spectrum (see Figure 3-6).

Panel drawing A document that shows the relationship of multiple circuit patterns with related manufacturing patterns and artifacts related to the production of the panel (see Figure 3-7).

Panel layout See Panel drawing

Pattern The configuration of conductive and nonconductive materials on a panel or printed board. (Pattern denotes also the circuit configuration on related tools, drawings, and masters).

Pattern area The area of a designed configuration which includes the pattern and background. The bounds of the pattern area can be defined by a physical outline or by an imaginary outline formed by enclosing the pattern in a box. For example, the area within the corner marks of a printed wiring interconnection pattern.

Perpendicularity The degree to which the angle between the X-X and Y-Y axes approaches a right angle (90°).

Photographic fog Any unwanted plus density on negative working photographic products (or a loss of density on positive working products) that appears on a piece of exposed and processed glass, film, or paper, but is not the result of image exposure.

Photographic layer A light sensitive coating capable of being exposed and processed to yield a visible image.

Photographic operations A term generically applied to all procedures and techniques used to prepare phototools, including photoplotting, contact printing, step & repeating, camera reduction or magnification, registration, touch-up, and image modification.

Photographic plate A photographic layer on "soda-lime-silica" sheet glass.



Documents

Document Sharing Hub

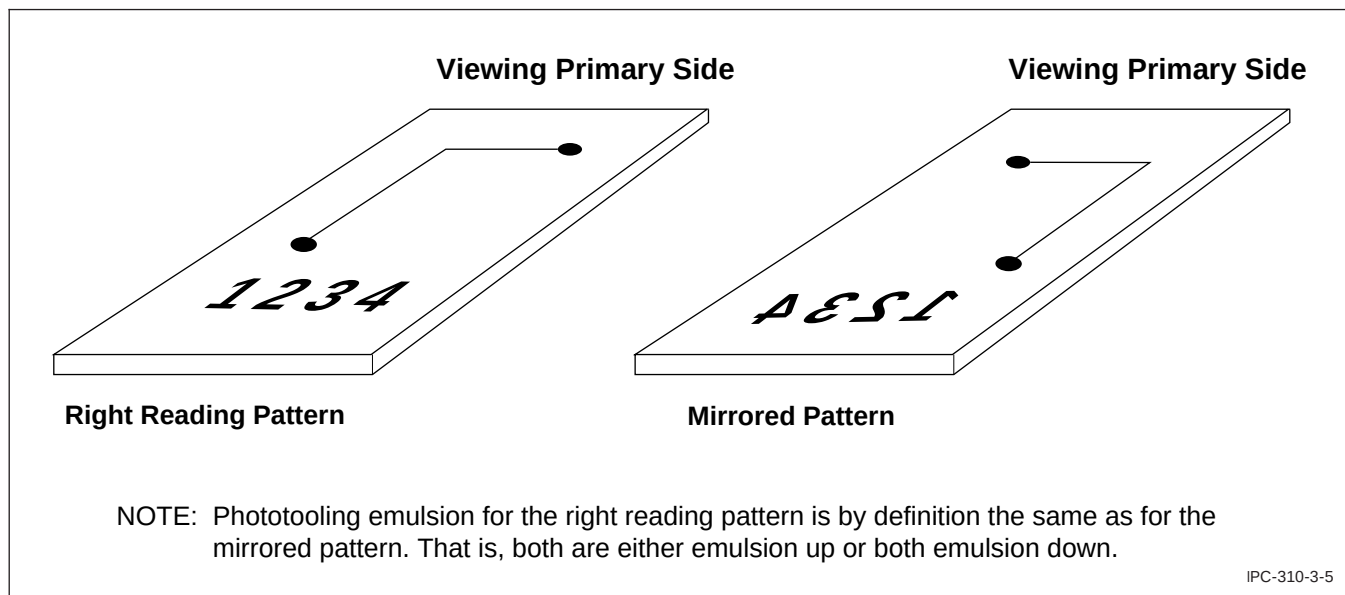


Figure 3-5 Example of mirrored pattern

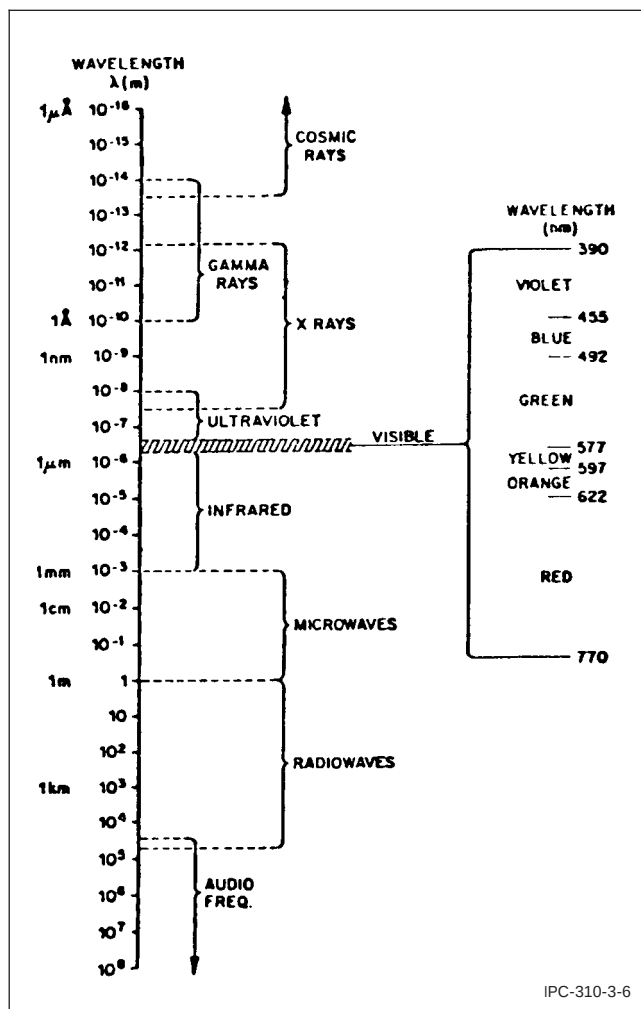


Figure 3-6 The visible part of the frequency spectrum

Photographic reduction dimension Dimension (e.g., the distance between lines or between two specified points) on the artwork master to indicate to the photographer the

extent to which the artwork master is to be photographically reduced. (The value of the dimension refers to the 1:1 scale and must be specified.)

Photometry The measurement of visible light intensity and energy as it affects the human eye.

Photoplotting Photographic process whereby an image is generated by the exposure of a controlled light beam directly onto a light sensitive material (usually emulsion).

Photoresist A material which, when properly applied to any of a variety of substrates, becomes sensitive to portions of the electromagnetic spectrum and when properly exposed and developed, masks portions of the substrate with a high degree of integrity.

Photoresist, Negative See Negative-acting resist

Photoresist, Positive See Positive-acting resist

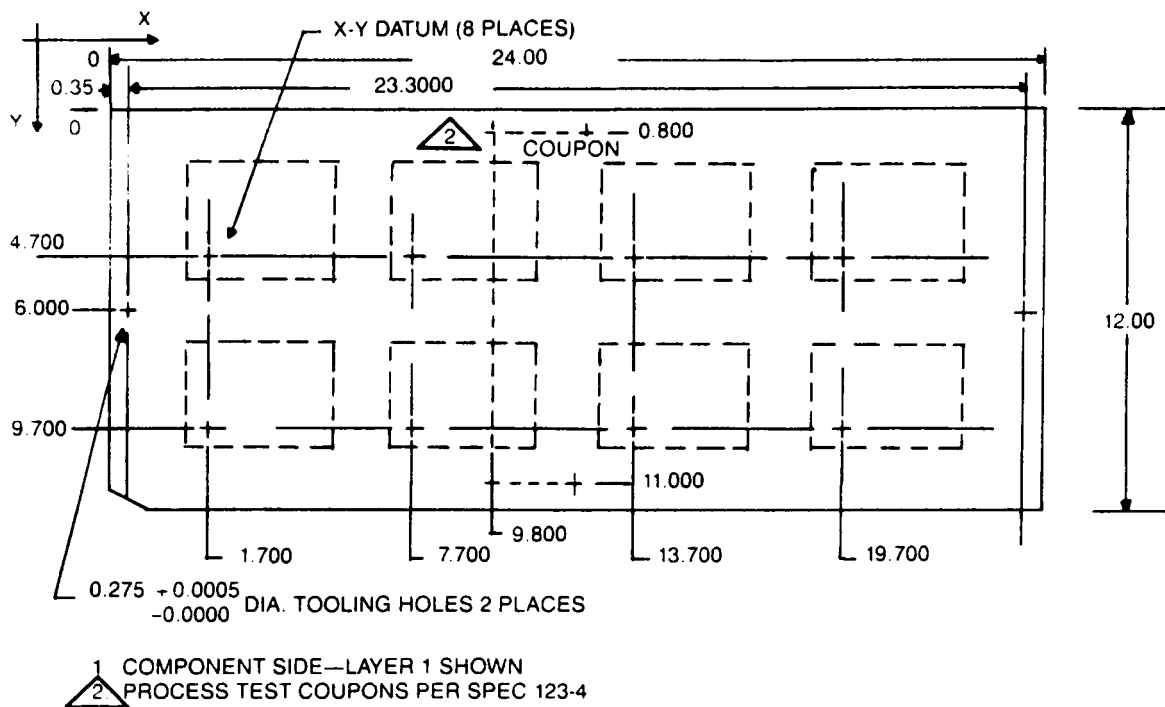
Phototool A general term applicable to any of the specifically defined photographic products. The artwork, artwork master, working master, and production master are each phototools. (See Phototooling.)

Phototooling A term generically applied to the entire group of photographic products used to produce printed circuitry.

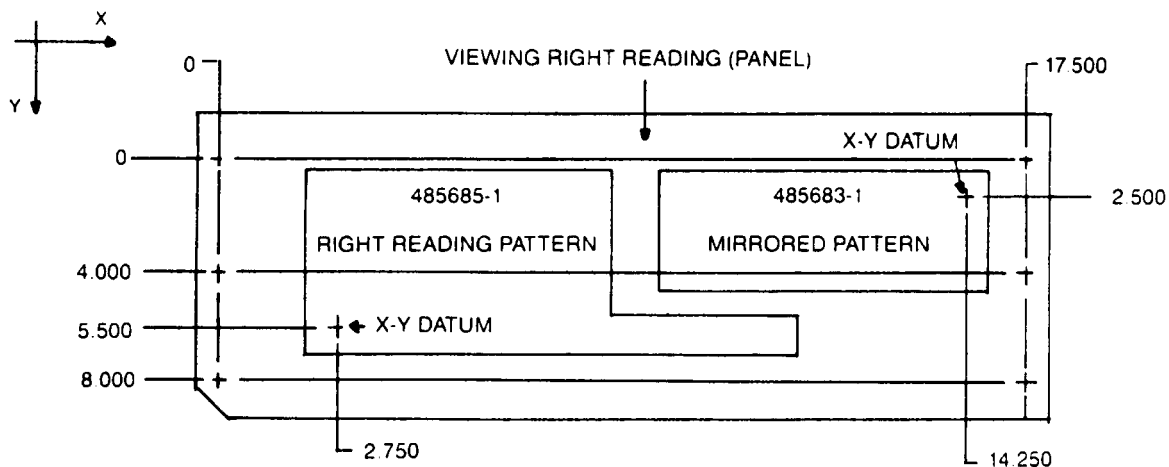
Phototooling aids Photographic products used to assist in inspection as overlays and not normally used for transferring imagery to photoresist.

Pinhole (Phototool) A small clear area completely within a black image area.

Plating bar The temporary conductive path interconnecting areas of a printed board to be electroplated, usually located on the panel outside of the borders of the artwork.



a) MULTIPLE CIRCUIT PATTERNS (ALL IDENTICAL LAYER/BOARD PATTERNS)



b) MULTIPLE CIRCUIT PATTERNS (DIFFERENT BOARD/LAYER PATTERNS)

NOTE: X-Y Datum for each of the individual circuit patterns shown on panel drawing (or panel layout) is identical to the datum for the individual printed board pattern delineated on master drawing.

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Figure 3-7 Examples of panel drawings

Plating thief A pattern added to a printed wiring design configuration or to the border area of a production master layout to assist in accomplishing uniformity of plating in the board manufacturing process.

Positive (P) An artwork, artwork master or production

master in which the intended conductive pattern is opaque to light; and areas intended to be free from conductive material are transparent.

Positive-acting resist A resist which is decomposed (softened) by light and which, after exposure, is removed by a solvent.

is removed from those areas which were under the transparent parts of a production master.

Production master A 1:1 scale pattern which is used to produce one or more printed boards (rigid or flexible) within the accuracy specified on the master drawing. Note: The proper description of the production master must include the required specification for tone and orientation; these specifications impact usability or subsequent transfer of the patterns to the photoresist coated substrate.

Radiance A measure of the power output of a point source; the amount of power per unit area per solid area defined by the unit watt/square meter-steradian.

Radiant energy The amount of watts reaching a given point accumulated over a given time interval, referred to as joules (watt-sec.).

Radiant flux The amount of power incident on a given surface expressed in watts.

Radiant intensity (power of source) The amount of power from a point source generated through a solid angle, measured in units of watts/steradian.

Radiometry The measurement of radiation in the optical spectrum which includes ultraviolet, visible, and infrared light.

Reciprocity failure Deviation from the reciprocity law. Typically, this deviation occurs at either low intensities for long exposure times or high intensities for short exposure times.

Reciprocity law A general law for photochemical reactions which states that the mass of photoproduct from such a reaction is determined simply by the total exposure involved, i.e., by the product of intensity and time, and is independent of the relative values of the two factors.

Reduction marks A set of stylized patterns in the border area of an artwork between which the "photographic reduction dimension" is defined.

Reduction mark A symbol used as a reference point to maintain registration.

Registered production master A production master which incorporates physical registration features. (See Registration.)

Registration The degree of conformity of the position of a pattern, or a portion thereof, with its intended position or with that of any other conductor layer of a board.

Note: The process of incorporating physical features (holes, pins, bushings, targets, etc.) in the production master in dimensional association with the photographic image(s) for the purpose of satisfying the required dimensional relationship to the panel tooling datum for multiple layer manufacturing operations.

Resist Coating material used to mask or protect selected areas of a panel from one or more subsequent processing steps. (See Photoresist.)

Resolution, Usable The smallest image and separation which can be produced and subsequently processed in a given emulsion or thickness of a photoresist coating.

Resolving power The ability of a photographic system to maintain, in a developed image, the separate identify of parallel lines and spaces when their relative displacement is small.

Reversal development A process used with certain photographic emulsions for reversing the tone of an image from that which is accomplished with conventional developing. This process is carried out by developing the exposed silver halide, subsequently bleaching out the developed silver, and then developing the remaining silver halide after an overall second exposure.

Right reading

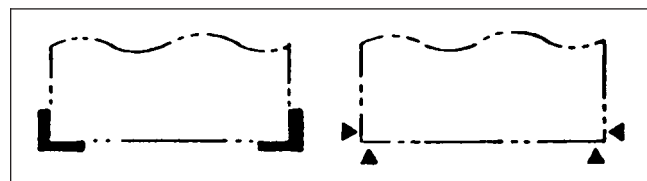
- A phototool definition of pattern orientation in which the geometric view of all layer patterns of a printed board are viewed through the primary side of the board which is designated layer 1 (see Figures 3-2 and 3-3).
- For manufacturing considerations, printed board layer patterns with opposite orientations can be included into the same phototool design (see Figure 3-5). The drawing which defines this composite design establishes the right reading orientation for phototools prepared in accord with it. (See Panel drawing.)

Right reading down An orientation of a phototool in which the printed board layer pattern is viewed right reading and the emulsion surface of the photo-tool is away from the view (see Figure 3-3).

Right reading up An orientation of a phototool in which the printed board layer pattern is viewed right reading and the emulsion surface of the photo-tool is toward the viewer (see Figure 3-3).

Rotational error The error that occurs when functional patterns are misaligned by some angle with respect to the X and Y axes during step-and-repeat.

Routing marks An artwork feature used for determining board periphery; and may be presented by angles or other marks as shown below:



Run-out The sum of cumulative-pitch error when measured across a number of functional patterns on a step & repeated phototool.

Scribe-coat A material composed of a stable base such as glass or film with an opaque coating.

Scribing To produce artwork by scraping the opaque coating from the scribe coat material with a blade-like cutting tool with the blade edge parallel to and resting on the plane of the base material.

Solarization A decrease in density with increased exposure.

Spur An undesirable projection from a photographic pattern, i.e., a clear projection from a clear pattern; a black projection from a black pattern.

Step-and-Repeat A method by which successive exposures of a single image are made to produce a multiple image production master.

Substrate A structure which underlies and supports or forms a base for something else, as a material on which a photoresist coating is applied.

Test Coupon A portion of the quality conformance test circuitry used for a specific acceptance test or group of related tests.

Test pattern A pattern used for inspection or testing purposes.

Tone The description used to identify phototool features as being opaque or clear, expressed as positive or negative.

Tooling See Phototooling.

Tooling pins (holes) Pins placed on a glass phototool to enable the plate to be positioned accurately from the manufacturing process. Similarly, holes punched in film artwork to enable the film to be positioned accurately for manufacturing. (See Registration.)

Touch up A process for identifying and eliminating defects in phototools. Magnifiers, light tables, microscopes, knives, brushes, and ink are typically used in performing touch up.

Transmittance The ratio of the amount of light transmitted through a sample to the quantity of light incident upon it.

Trim lines Lines which define the borders of a printed board. (See Corner mark.)

Ultraviolet Electromagnetic energy in the invisible part of the frequency spectrum between 100–390 nanometers.

Void (Phototool) A defect; an undesirable blemish within the photographic pattern, i.e., a black defect in a clear pattern (flecks and notches); a clear defect in a black pattern (pinholes and spurs).

Working master A 1:1 scale pattern which is used to reproduce the production master. Typically, the pattern of the working master is a complete representation of the pro-

duction master pattern but with opposite geometric orientation and tone dependent on the photosensitive materials to be utilized. The proper description of the working master must include the required specification for tone and orientation; these specifications impact usability in subsequent photo-processing operations (see Figure 3–3).

Wrong reading Transposition from right reading.

X Axis The horizontal or left-to-right direction in a two-dimensional system of coordinates. X-X signifies one direction followed in a step-and-repeat method.

Xenon One of the rare gases used to fill gas discharge lamps. It has high luminous efficiency and is rich in ultraviolet.

Y Axis The vertical direction, perpendicular to the X axis, in a two-dimensional system of coordinates. Y-Y signifies one direction followed in a step-and-repeat method.

4.0 GENERAL MANUFACTURING CONSIDERATIONS

In general, fabrication techniques have several areas of concern. Whether related to simple or complex types of packaging and interconnect structures, the detail fabrication techniques are similar. Table 4–1 shows some areas of fabrication concern.

In addition, most processes follow steps similar to those shown in Table 4–2.

These steps are detailed further in Figures 4–1 through 4–5 for typical double sided, multilayer, multilayer flex, multilayer rigid flex, and non-organic circuit boards.

4.1 Manufacturing Considerations This subsection acquaints artwork generation personnel with manufacturing areas which directly effect the conductive pattern on a completed printed board. The tolerances cited are not exact, but simply estimates intended to illustrate the board fabrication cycle, and show why the board fabricator should be consulted prior to artwork generation. If this is impossible because many fabricators will be used, then artwork should be prepared to evaluate worst-case considerations.

4.1.1 Etch-resist Considerations Etch-resist considerations are the corner-stone to optimum line definition. Since photoresist applications give more accurate reproductions, photo methods produce more accurate images than screening methods. In general, screen resist methods may produce conductor images that are 0.075 mm [0.003 in] different from the corresponding production master image due to screening ink viscosity, whereas photographic methods approximate the production master to within 0.025 mm [0.001 in].

4.1.2 Etchant Considerations Many etchants are available, ranging from proprietary to off-the-shelf.

Table 4-1 Areas of Concern

	Single Sided	Double Sided	Multilayer	Flex	Rigid-Flex	Impedance Control
Registration	—	X	X	X	X	X
Front-to-back	—	—	X	X	X	X
Layer-to-layer	—	—	—	X	—	X
Clearance hole	—	—	—	—	—	—
Plated-through-holes	—	X	X	—	X	X
Material instability	None	None	Limited	Significant	Significant	X
Tooling	Simple	Simple	Complex	Complex	Complex	Complex
Artwork control	None	Routine	Difficult	Routine	Special Handling & Storage	Special Handling & Storage
Routing	Routine	Routine	Complex	Special Tool	Precision	Precision
Drill bit control	—	—	—	—	X	X
Handling fixtures	—	—	—	—	Required	Required
Drilling	Routine	Routine	Complex	Routine	Critical	Critical
Tear susceptibility	—	—	—	X	X	X
Inspector training	Routine	Routine	Routine	Routine	Special Requirements	Special Requirements
Special controls for warp and twist	—	—	X	—	X	X

Table 4-2

	Single Sided Board	Double Sided Board (PTH)	Multilayer Board	Flex Harness	Rigid Flex
Print			X	X	X
Etch			X	X	X
Drill Cover Layers				X	
Laminate			X	X	X
Drill	X	X	X	X	X
Plasma Etch			X		X
Panel Plate		X	X		X
Print	X	X	X		X
Pattern Plate	X	X	X		X
Etch	X	X	X		X
Route	X	X	X	X	X

Determining the exact impact that etching has on the final conductor configuration requires complete knowledge of the type of etchant, specific etching equipment, type of base metal, type of over-plate and strength of the etching solution. This detail on etching parameters is not usually available to artwork generation personnel; nonetheless artwork on the design conductor width must include compensation for etching.

The production master artwork must allow for etching characteristics. This allowance is known as etch factor. Etch factor is the ratio of the depth of etch (conductor thickness) to amount of lateral etch (undercut). (See Figure 4-6.) It is calculated for one side of the conductor path only. The reference point for measuring the horizontal etch is from the edge of the resist (defined by the production master) to the solid metal.

An etch factor of 1:1 is usually considered practical. Higher factors may have to be specified in some applications.

4.1.3 Conductor Profile Consideration Different resists and different metal clad thicknesses can cause considerable variation in etch configurations. Growth may be or may not be present dependent on the thickness of resist coatings which could totally channel all plating.

The conductor width on the finished printed board may be either wider or narrower than the Design Conductor Width (DCW) on the production master. An increase in the conductor width is usually caused by plating material build up following the non-metallic resist application.

An increase in conductor width is termed “outgrowth.” A decrease in conductor width, usually caused by underplating,

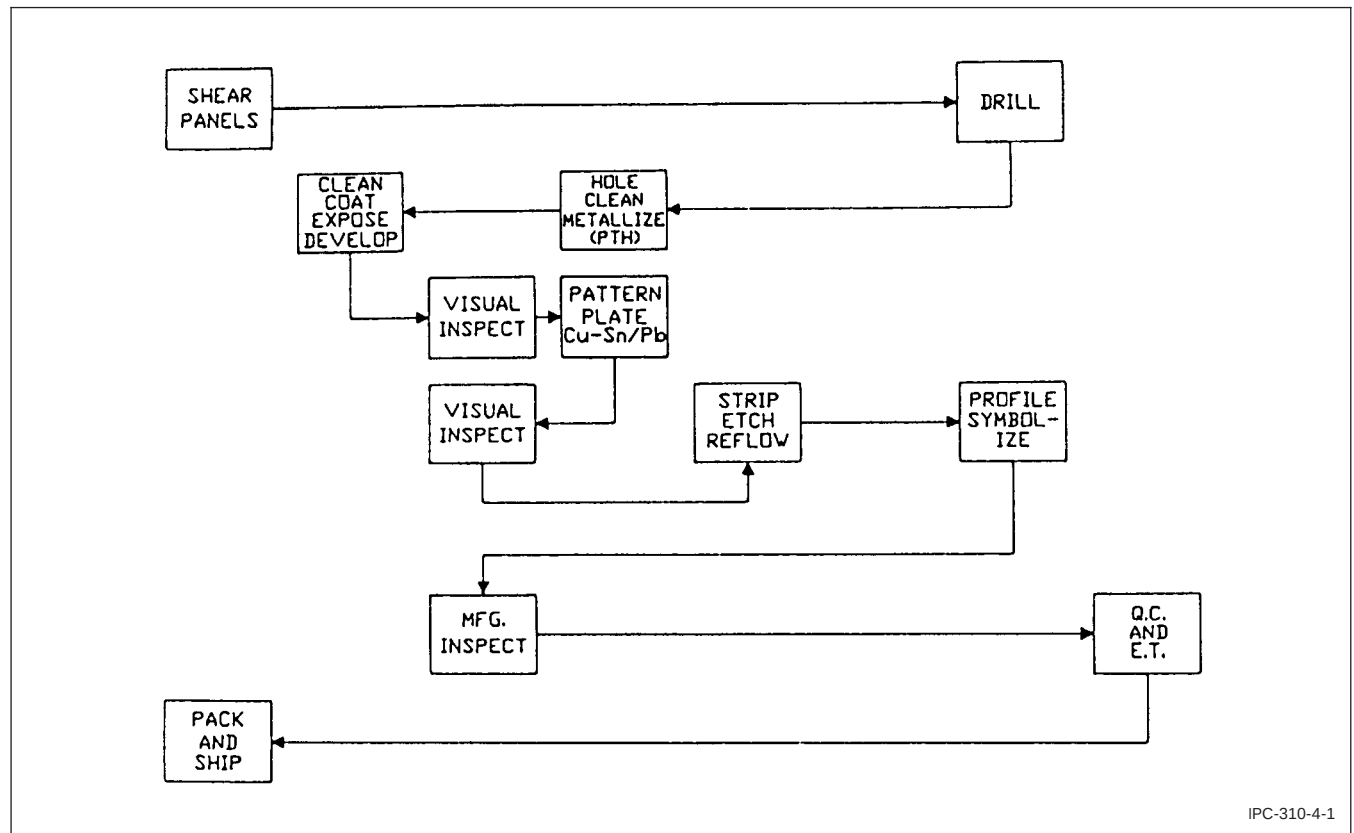


Figure 4-1 Double sided process flow chart (typical)

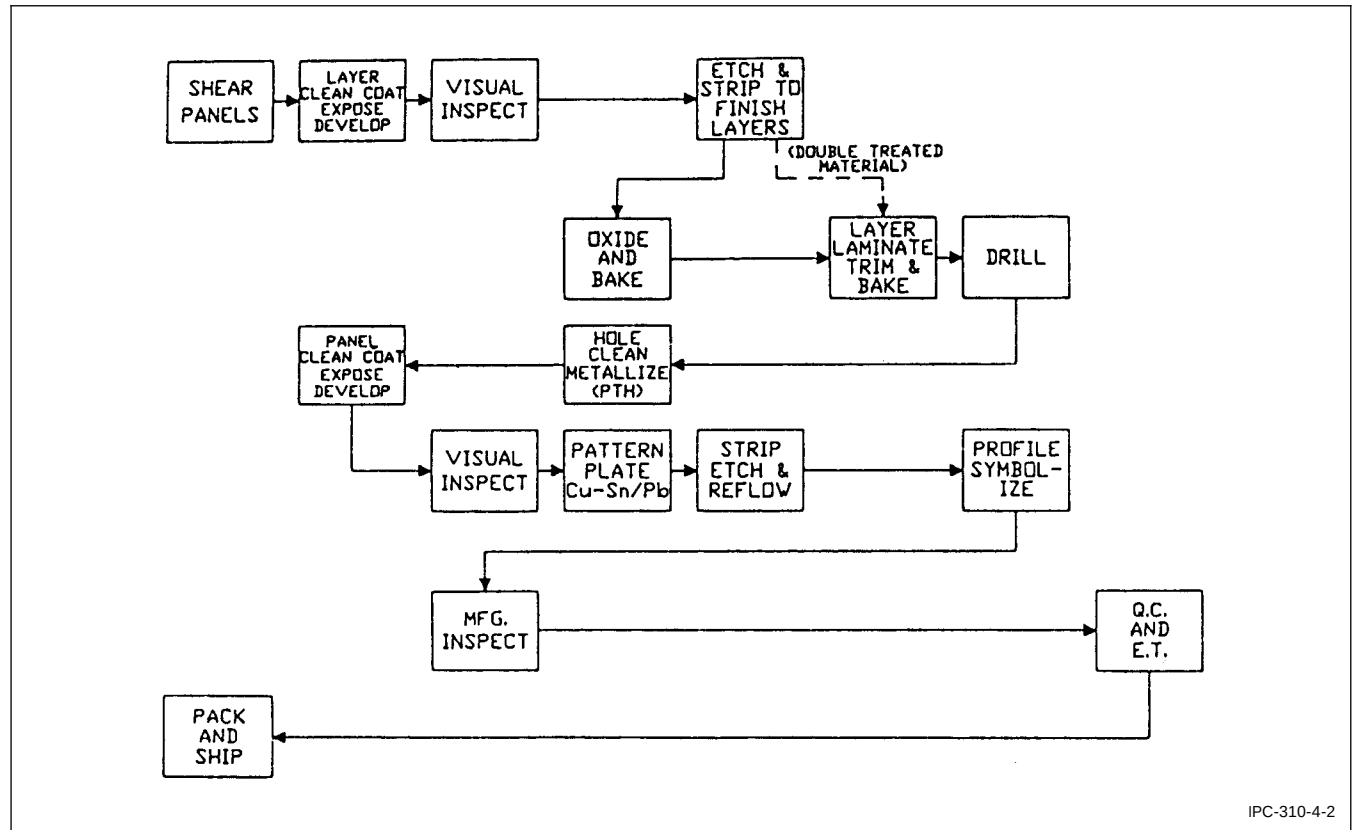


Figure 4-2 Multilayer rigid process flow chart (typical)

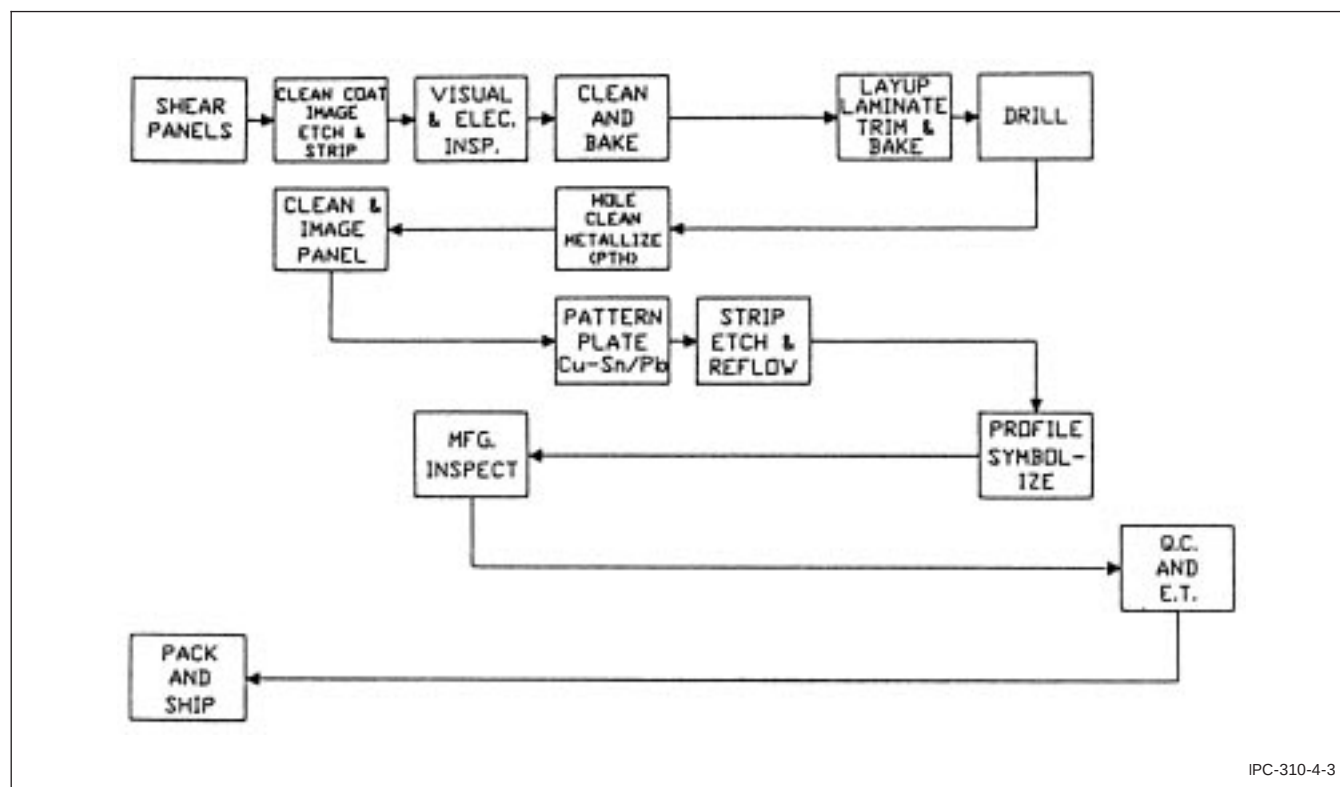


Figure 4-3 Multilayer flex process flow chart (typical)

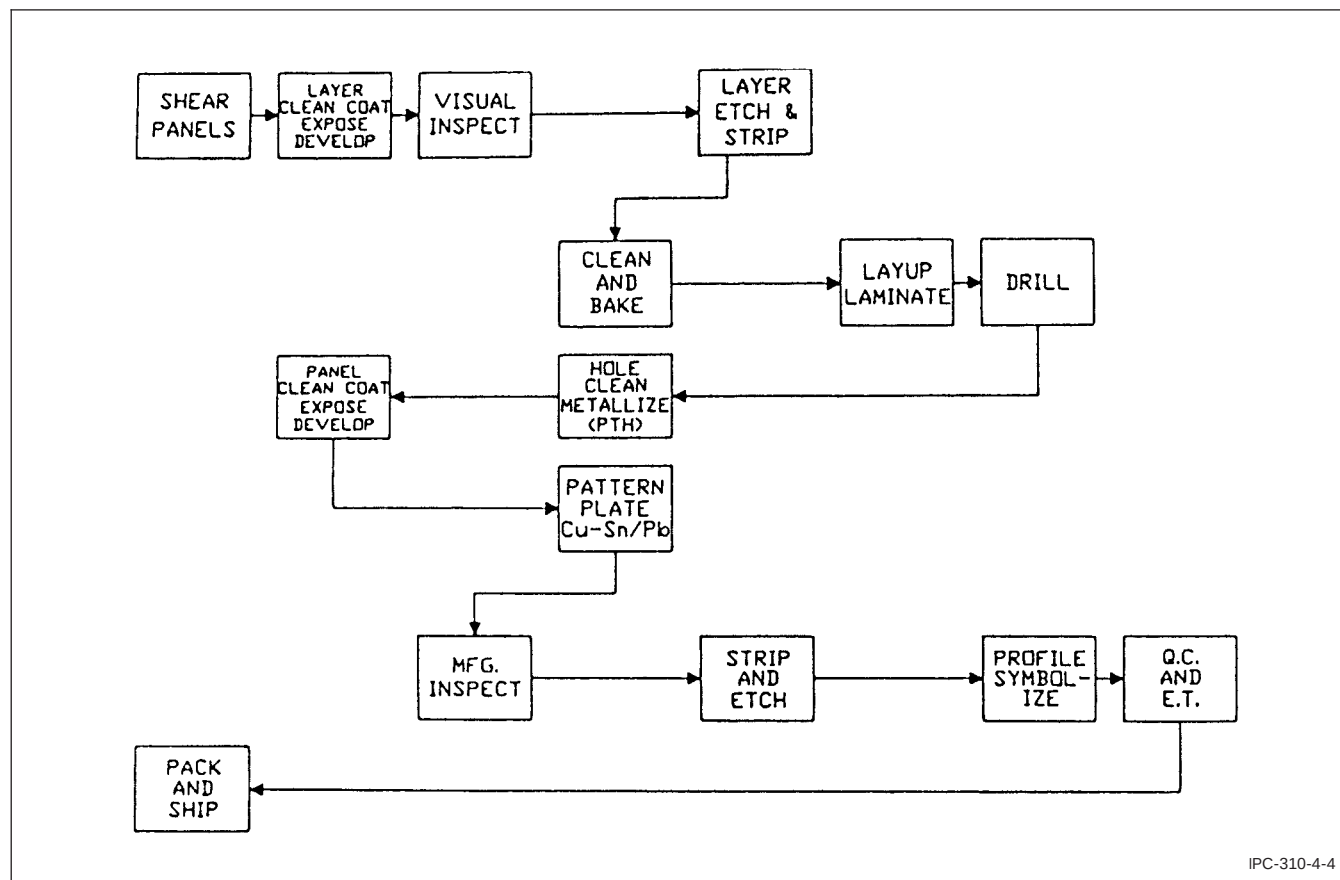


Figure 4-4 Multilayer rigid-flex process flow chart (typical)

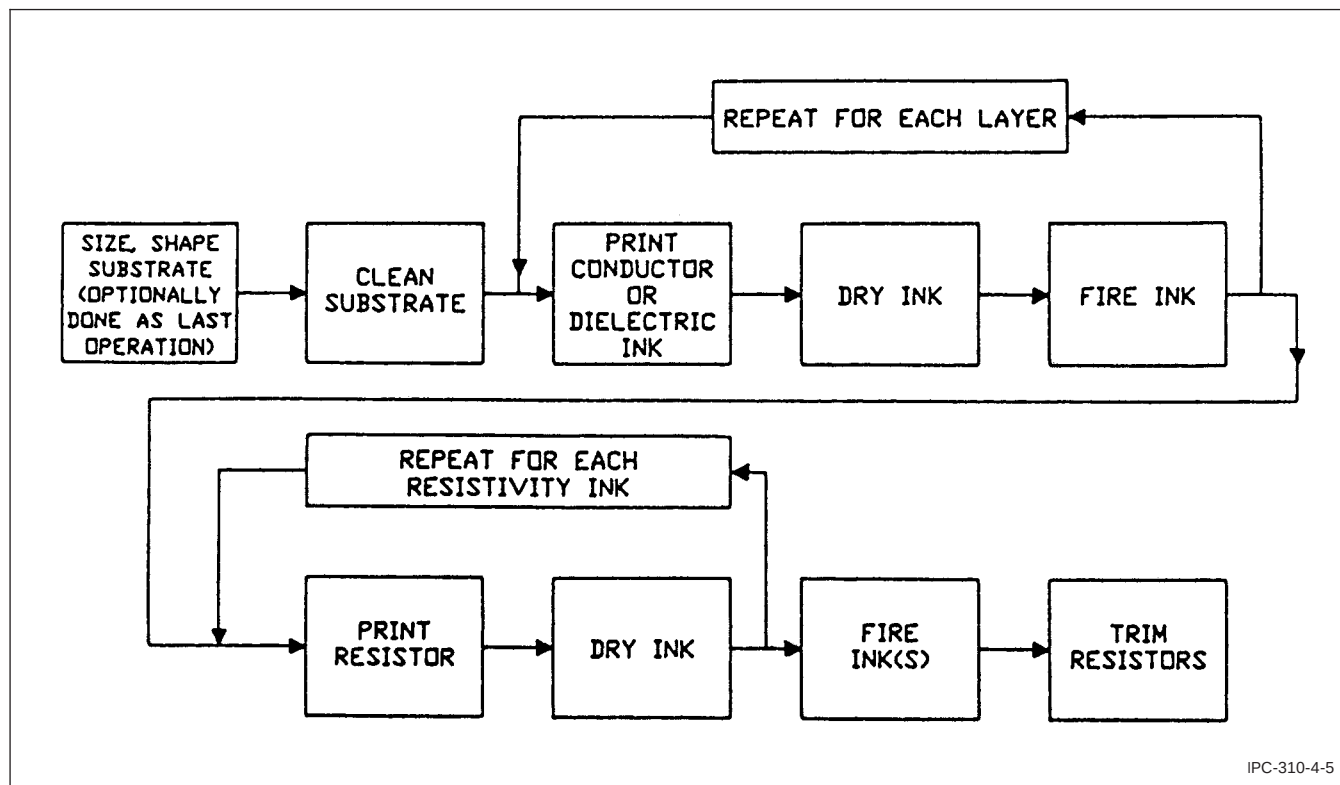


Figure 4-5 Non-organic process flow chart (typical)

process, is termed “undercut.” The sum of the outgrowth and undercut is termed “overhang” (see Figure 4-6). Table 4-3 provides typical values which should be considered in the preparation of artwork to compensate for these conductor configuration variations. The values provided are average and may vary from manufacturer to manufacturer since many processing steps impact the final conductor profile.

Production master artwork compensation can be incorporated prior to the imaging process which allows the artwork to be modified in order to offset the etch factor during the manufacturing process.

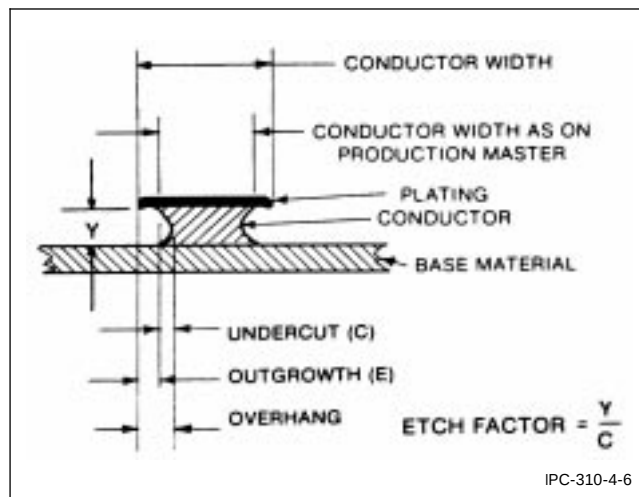


Figure 4-6 Etch factor in terms of outgrowth, undercut and overhang

4.1.4 Metallic Resist Metallic resists include plated metal which is resistant to the etchant being used. Avoid using a metal which is not compatible with the etchant (e.g., tin-lead as an etch resist with ferric chloride as the etchant). Resist or plating thickness also plays an important role since insufficient plating could result in excessive porosity, while too much plating will result in plating outgrowth. Plating outgrowth, which eventually becomes overhang, actually inhibits etching along edges.

Outgrowth is related to the nonmetallic resist thickness. Outgrowth occurs when plating thickness exceeds resist thickness.

4.1.5 Nonmetallic Resist Two types of non-metallic resist are photoresist (positive and negative) and screen. Photoresist is divided into two types, liquid and dry. The applied resist will vary in thickness for each type. Photoresist will be 2.5 µm to 12.5 µm [0.0001 in. to 0.0005 in.] thick for liquid and 12.5 µm to 62.5 µm [0.0005 in. to 0.0025 in.] for dry. Screen resist will usually be 25 µm to 75 µm [0.001 in. to 0.003 in.] depending on the screening methods, although thinner coating is achievable if desired. Processing variables for photoresist which affect the end product are application methods, exposure time and technique, developing time, and cleaning techniques. For screening resist, the mesh size and ink viscosity affect the end product board.

4.2 Plating Considerations In the fabrication of printed boards with plated-through holes, the process involves the

Table 4-3 Typical Values to be Added or Subtracted from the Desired Nominal Conductor Width in Order to Arrive at the Nominal Width on the Production Master

Description	1/2 Oz. Copper						1 Oz. Copper						2 Oz. Copper					
	Panel			Pattern			Panel			Pattern			Panel			Pattern		
	Screen	Liquid Photo	Dry Film Photo	Screen	Liquid Photo	Dry Film Photo	Screen	Liquid Photo	Dry Film Photo	Screen	Liquid Photo	Dry Film Photo	Screen	Liquid Photo	Dry Film Photo	Screen	Liquid Photo	Dry Film Photo
Subtractive Method																		
Simple Etch	+25 µm [+0.0010]	+25 µm [+0.0010]	+25 µm [+0.0010]	—	—	—	+ 38 µm [+0.0015]	+38 µm [+0.0015]	+38 µm [+0.0015]	—	—	—	+63 µm [+0.0025]	+63 µm [+0.0025]	+63 µm [+0.0025]	—	—	—
Bare Copper (PTH)	+38 µm [+0.0015]	+38 µm [+0.0015]	+50 µm [+0.0020]	-25 µm [-0.0010]	-25 µm [-0.0010]	+25 µm [+0.0010]	+50 µm [+0.0020]	+50 µm [+0.0020]	+63 µm [+0.0025]	0	0	+50 µm [+0.0020]	+76 µm [+0.0030]	+76 µm [+0.0030]	+89 µm [+0.0035]	+38 µm [+0.0015]	+38 µm [+0.0015]	+89 µm [+0.0035]
Tin-Lead (PTH)	+38 µm [+0.0015]	+38 µm [+0.0015]	+50 µm [+0.0020]	-25 µm [-0.0010]	-25 µm [-0.0010]	+25 µm [+0.0010]	+50 µm [+0.0020]	+50 µm [+0.0020]	+63 µm [+0.0025]	0	0	+50 µm [+0.0020]	+76 µm [+0.0030]	+76 µm [+0.0030]	+89 µm [+0.0035]	+38 µm [+0.0015]	+38 µm [+0.0015]	+89 µm [+0.0035]
Gold-Nickel (PTH)	+38 µm [+0.0015]	+38 µm [+0.0015]	+50 µm [+0.0020]	-25 µm [-0.0010]	-25 µm [-0.0010]	+25 µm [+0.0010]	+50 µm [+0.0020]	+50 µm [+0.0020]	+63 µm [+0.0025]	0	0	+50 µm [+0.0020]	+76 µm [+0.0030]	+76 µm [+0.0030]	+89 µm [+0.0035]	+38 µm [+0.0015]	+38 µm [+0.0015]	+89 µm [+0.0035]
FOR DEPOSITED COPPER THICKNESS EQUIVALENTS																		
Additive Method																		
Electroless Copper No-Etch	—	—	—	-50 µm [-0.0020]	-25 µm [-0.0010]	-0 µm [-0.0000]	—	—	—	-76 µm [-0.0030]	-50 µm [-0.0020]	-0 µm [-0.0000]	—	—		-101 µm [-0.0040]	-76 µm [-0.0030]	-0 µm [-0.0000]
Semi Additive Method																		
Copper—No Overplate	—	—	—	-50 µm [-0.0020]	-25 µm [-0.0010]	-0 µm [-0.0000]	—	—	—	-76 µm [-0.0030]	-50 µm [-0.0020]	-0 µm [-0.0000]	—	—		-101 µm [-0.0040]	-76 µm [-0.0030]	-0 µm [-0.0000]
Tin-Lead Overplate	—	—	—	-76 µm [-0.0030]	-50 µm [-0.0020]	-25 µm [-0.0010]	—	—	—	-101 µm [-0.0040]	-76 µm [-0.0030]	-25 µm [-0.0010]	—	—		-127 µm [-0.0050]	-101 µm [-0.0040]	-25 µm [-0.0010]

- = Not Applicable

choice of two methods for plating metal in the holes and on the conductors: pattern plating or panel plating. Each plating process requires allowances be made in the artwork to obtain specified land and conductor widths on the finished board. See Figure 4–7 for a plating diagram.

4.2.1 Pattern Plating In the pattern plating process, surface plating is deposited in the conductive pattern only. The usual process is to plate copper to the required thickness in the holes and then over-plate with an etch-resistant metal. The conductors' widths usually widen slightly after plating. If tin-lead reflow is specified the conductor will narrow slightly after reflow. Undercut will be minimized since the etchant must remove only the original laminate copper, not the built-up (plated) conductive areas.

4.2.2 Panel Plating In panel plating, metal is placed onto the entire surface of a panel while depositing the required copper thickness in the holes. An etch resist is then applied to achieve the conductive pattern. Due to the greater thickness of metal to be removed, a greater reduction or undercut of conductor widths usually results.

4.3 Conductor to Process Relationships The amount of undercut or outgrowth can be determined by comparison to the Design Conductor Width. Figures 4–8, 4–9, 4–10, and 4–11 show various conditions for conductor characteristics where:

A = The Minimum Conductor Width (MCW)

B = The Design Conductor Width (DCW) or what appears on the production master.

D = The overall conductor width.

4.4 Solder Mask Artwork Solder mask artwork provides a permanent polymer coating over selected areas of the board. This technique eliminates solder bridging during wave solder operations. Solder masks are applied primarily to boards having high-volume production requirements or to boards having close conductor spacing due to design density. Solder masks may also be used for other applications such as “select plating.” Solder mask is not intended to replace conformal coatings. (Refer to IPC-SM-840.)

4.4.1 Design Constraints The reliability of solder mask operations depends not only on manufacturing techniques but design constraints of the board. The masking process is most effective where large copper areas (planes) are not present, where adequate clearance is maintained between conductor and land areas, and where features to be masked do not have an over-plating of tin-lead. Where reflowed tin-lead is required, such boards should be reflowed before masking.

4.4.2 Artwork Requirements Artwork may be negative- or positive-tone. It will be prepared for each side to be

coated and will be viewed from the primary side of the board. Identify such artwork from the side to be coated. This artwork will be part of the master pattern artwork package. When more than one side of the board is to be coated, each artwork should specify the applicable side.

Solder mask artwork shall contain external indexing and registration patterns that match those on the master pattern artwork (see Figure 5–1, 5–2, and 5–3).

Soldermask clearance areas will normally be “lands only” in configuration. This allows conductors on the board to be covered.

5.0 GENERAL DESIGN CONSIDERATIONS

This section emphasizes the importance of “coordinated tooling” and provides guidance to phototool designers, PWB engineers, manufacturing process personnel, and printed board users in understanding and selecting a compatible phototool implementation process. The registered production master is a “manufacturing tool” in the truest sense. The quality and accuracy of the end product printed board can be no better than the quality and accuracy of the registered production master, which has a direct impact on the manufacturing yields, and therefore, the cost of the delivered product.

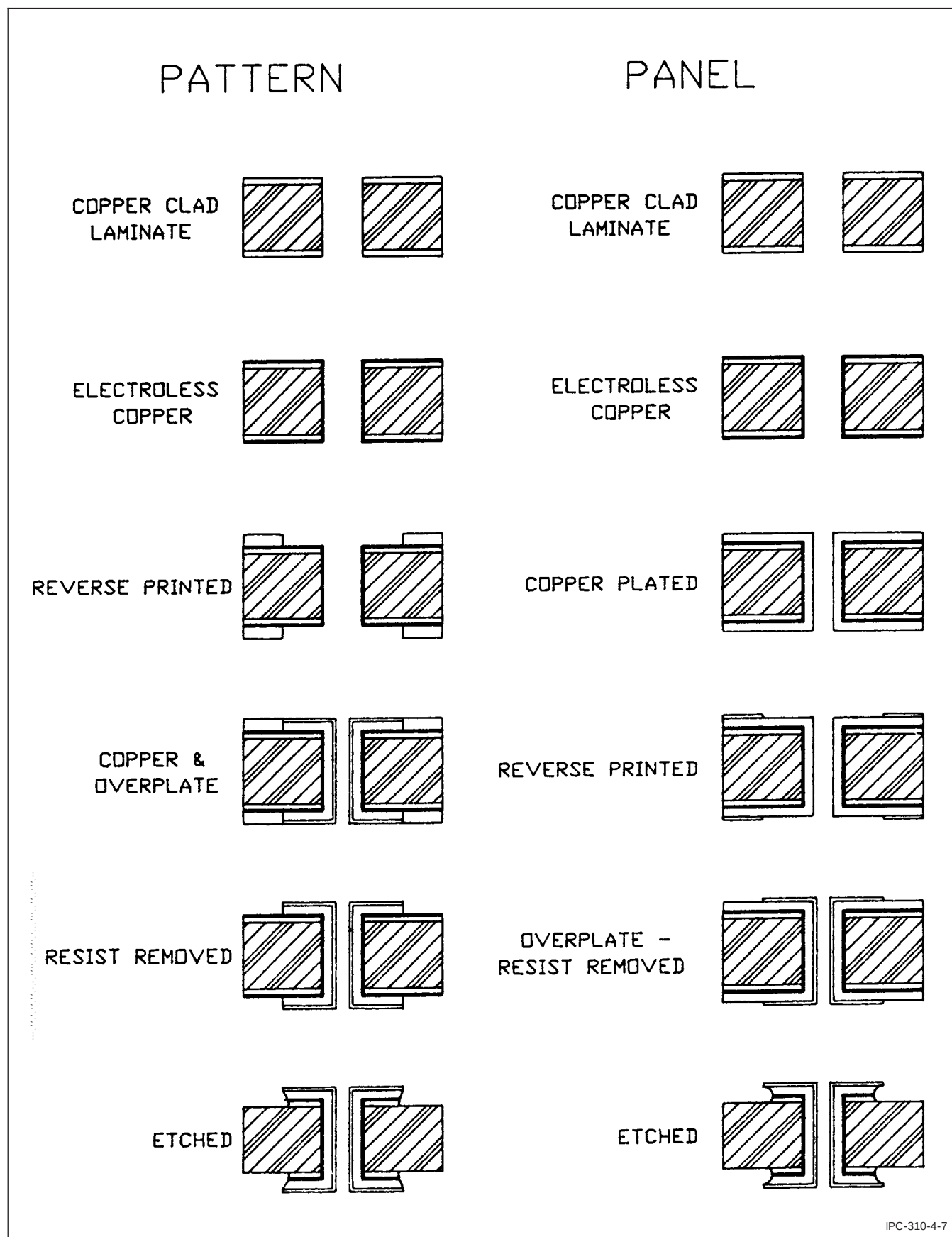
A summary of design trends indicates that electronic equipment will require the following:

- More layers of circuitry
- Larger plug-in multilayer printed wiring boards
- Larger backplane boards
- Greater functional/wiring densities
- Decreasing line widths
- Decreasing spaces
- 3-D Circuitry
- Increased controlled impedance needs
- More applications

These trends highlight the need for increased awareness of the phototooling implementation process and its end item: the registered production master, a manufacturing tool whose quality affects the achievable quality of the printed wiring end product itself.

Although the preparer of artwork often has only limited knowledge of the printed wiring board end product process, design trends dictate the need for coordinated tooling and an increased awareness of the entire phototooling implementation process. The process effects inherent in the selected phototooling implementation procedure must be considered to insure effective manufacturing tooling results.

The following are considerations common to all phototooling implementation approaches:



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Figure 4-7 Plating process diagram