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FACTORS IN DESIGNING PRINTED CIRCUITS FOR SPACE

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CONTENTS

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INTRODUCTION

This printed circuit design guide is intended to serve as a quick and ready reference for engineers, technical personnel and interested designers. It is divided into four main parts as follows:

Part I consists of a general specification sheet, which delineates the principal requirements that must be considered; for example, electrical power, space environmental factors and electrostatic shielding.

Part II covers the design parameters in more detail, especially component selection, conductor widths, spacing and electronic layout considerations.

Part III is intended as a step-by-step guide to enable the designer to produce a quality space flight printed circuit board.

Part IV is a bibliography of reference matter and standards.

I. PRINTED CIRCUIT GENERAL SPECIFICATIONS

1. The design of printed circuits requires clear definition of specific environments and requirements. A general specification sheet should contain the following information:

PRINTED CIRCUIT GENERAL SPECIFICATION

a. Voltage _____ DC, AC peak volts _____

b. Current __________

c. Wattage __________

d. Frequency __________

e. Ambient temperature + __________ °C - __________ °C

f. Laminate material MIL-P-13949C - Type __________

g. Laminate thickness 1/16 ☐ , 3/32 ☐ , 1/8 ☐

h. Size of board ______________________________

i. Mounting dim. if special ______________________

j. Altitude under 10,000 ft ☐, coated ☐ , uncoated

k. Altitude over 10,000 ft ☐, coated ☐ , uncoated

l. Potted ☐ , encapsulation ☐

m. Printed circuit one side ☐

n. Printed circuit two sides ☐

o. Eyelets - ☐

p. Plated thru hole std.

q. Plated thru hole minify

r. Shielded leads yes ☐ , no ☐

s. Heat sensitive components ______________________

t. Heat radiating components ______________________

u. Conductor width ______________________________

v. Minimum conductor spacing, (0.031 or 0.062 preferred)

w. Terminal or pad size __________________________

x. Circuit pattern ______________________________ X size

y. Plating (1 oz) Copper _____, (2 oz) Copper _____

z. Overplating - Silver ______________ =Good slow speed switch contact surface

- Tin-lead ______________ =Excellent soldering aid

- Nickle Gold ______________ =Good soldering non-corrosive, good low contact resistance, non-wiping contact surface

- Nickle Rhodium ______________ =Hard, noncorrosive, wear resistant wiping contact surface, good for intermittent and continuous operation

II. DESIGN FACTORS

From the schematic diagram the designer is required to make a hardware layout and subsequently the master artwork. The master artwork in addition to the dimensional machinery data will be used to manufacture the printed circuit board. The design factors are as follows:

A. Environmental Requirements

(1) Shock
(2) Vibration
(3) Acceleration
(4) Temperature
(5) Altitude
(6) Humidity
(7) Atmosphere
(8) Radiation
(9) Service life
(10) Fungus conditions

B. Component Selection

1. Components shall be selected to comply with the following design and reliability parameters:

   a. Marshall Space Flight Center, preferred parts, electrical (MSFC - PPD-600)
   b. Military Established Reliability Specifications
      (1) Mil-R-55182A resistors
      (2) Mil-39001 series for capacitors, resistors, relays
      (3) Mil-R-38100A, reliability Mil-R-38101, resistors, Mil-C-38102, capacitors, Mil-S-38103 semiconductors
   c. Jet Propulsion Laboratory (JPL - ZPP - 2061 - PPL)
      (1) Table 1 (High - reliability)
      (2) Table 2 (Spacecraft)
   d. Goddard Space Flight Center (GSFC - PPL)
   e. ANA Bulletin 400, Electronic Equipment

2. The following parameters shall be considered in component selection:

   a. Electrical and tolerance requirements of circuit design
   b. Minimum heat generation and heat dissapation problems
   c. Adaptability to printed circuit board mounting
   d. Reliability consistent with the service life or life expectancy of the equipment
   e. Component derating
   f. Component area requirement

C. General Electronic Layout Considerations

1. Time and effort spent on the layout can minimize assembly problems and save weight and space. The experience and ingenuity of the designer are important assets in arriving at an acceptable layout with minimum time and effort. Components shall first be located on a grid, then the wiring connections shall be made keeping connecting lines as short as possible. There shall be a minimum of crossovers--depending on size and complexity of circuit. Several arrangements of components are usually required before arriving at the optimum layout.

2. Conductor width, pattern, and spacing

   a. Prescribed space considerations are as follows:
      (1) Minimal amount and physical shape of space alloted electronic assemblies within the equipment
      (2) Weight allowed for electronic assembly
      (3) Cooling available within the equipment
      (4) Methods of interconnecting of electronic assemblies
      (5) Structure necessary to support electronic assembly
      (6) Density of components allowable and necessary within assembly
      (7) Access and maintenance requirements
   b. Conductor widths shall be chosen with respect to current carrying capacity, military specification requirements, space limitation and manufacturing process limitations. Allowable nicks and pinholes may reduce conductor cross sections locally as much as 20 percent. The conductor dimensions shall provide sufficient conductivity so that the maximum operating temperature of the base material will not be exceeded during peak current demand.
   c. Conductor pattern thickness, width, and size of land area should be based on current temperature rise. (See graph in Mil-STD-275). Preferred circuit conductors are 0.062 inch minimum. Subminiature assemblies, however, may be designed with a nominal minimum conductor of 0.031 inch where design so dictates. The absolute minimum specification width is 0.015 inch on a fabricated board, but allowance must be made for art work variation to processing. Therefore, to assure 0.015 inch minimum on the fabricated board, the art work shall be made at least 0.025 inch.

d. Factors affecting conductor spacing are voltage breakdown, distributed capacitance, space limitations, and manufacturing process limitations. Voltage breakdown spacing shall conform to MIL-STD-275. Spacing requirements vary with base material, altitude, humidity, and type of coating. The effect of component leads as well as the board characteristics shall be considered when computing capacitance effects.

e. Conductor factor spacing should be determined according to MIL-STD-275. Below 10,000 feet use data for area level. Above 10,000 feet increase spacing between conductors according to chart MIL-STD-275.

f. On standard sized circuit boards, the minimum spacing between conductors shall be 0.031 inch with preferred minimum of 0.062 whenever possible. For subminiature applications where it is impossible to maintain the 0.031 inch minimum spacing, 0.015 inch spacing may be used.

g. Hole-to-hole and hole-to-edge spacing shall be at least one board thickness or the diameter of the smaller hole. No circuit line or component shall be closer than 0.100 inch to the edge of the board.

III. CIRCUIT LAYOUT

A. Design Steps

1. Step one

Make schematic diagram with component designating letters according to MIL-STD-16C.

2. Step two

Place component templates on a piece of cardboard as closely as possible to determine the minimum area of circuit possible. Consider the leads of all components. Do not bend leads closer than 1/8 inch from the component body.

3. Step three

Make a rough diagram of the circuit with the components arranged in their relative positions. For ease of working, layouts should be two or four times actual size, whichever is more desirable.

4. Step four

Determine the best shape for the printed board from a mechanical viewpoint before making the final decision.

5. Step five

Determine if a one-sided pattern or a two-sided pattern will be needed. For ease of fabrication and lower cost, the one-sided pattern method of wiring is preferred.

6. Step six

Master drawings shall conform to MSFC-STD-154, MIL-STD-275, or ABMA-STD-428. All dimensioning of the printed circuit holes shall be by use of a modular grid system. The basic modular unit of length shall be 0.100, 0.050, or 0.025 inch. All holes shall be located within 0.007-inch radius of true grid intersections.

7. Step seven

Make a preliminary layout, followed by a final layout, drawn 4:1 or 2:1 scale on a dimensionally stable drawing material such as matte surface polyester drawing film that is preprinted with standard 0.100 or 0.050 inch grid spacing.

8. Step eight

Make a printed wiring board master artwork drawing, on film preprinted with the same standard grid spacing in nonphotographic blue ink, using black sensitive tape made specifically for this purpose. The scale shall be 2:1 or 4:1 for normal circuit boards and 8:1 for subminiature circuit boards.

9. Step nine

Make a drilling drawing from the master transparency to assure greater accuracy in transferring the details and to eliminate repetitious drafting work.

B. Tolerances

The cumulative effect of conductor widths and conductor spacing requires a normal tolerance of ± 0.015 inch for boards which have plating and ± 0.010 inch for boards without plating.

If a closer tolerance is required on a critical part of the circuitry, it shall be specified on the drawing by a minimum dimension in the local area rather than by reducing the tolerance on the entire circuit line or space. For miniature printed circuit boards where space is very critical, a tolerance on line widths and space can be specified when necessary at ± 0.010 inch for boards with plating and ± 0.005 inch for boards without plating.

Tolerances should be as liberal as possible. Recommended minimum tolerances are as follows:

a. Hole diameter: ± 0.003 inch
b. Hole locations: ± 0.003 to ± 0.015 inch depending upon type of laminate
c. Overall dimensions: ± 0.010 inch

Registry of holes to pattern ± 0.005 inch for glass-base laminates and ± 0.020 inch for paper-base laminates.

Component holes shall have a lead clearance diameter of at least 0.015 inch and not more than 0.050 inch greater than the maximum allowable component lead diameter to be inserted. Pad size for solder connection of wire lead shall be 0.100 inch greater in diameter than the required lead access hole. Where eyelets or terminals are used the pad shall extend 0.015 inch (minimum beyond the projecting edge of the eyelet or terminal).

BIBLIOGRAPHY

The documents listed below are applicable to printed circuit design and fabrication:

Specification	Title
MIL-STD-275	Printed wiring for electronic equipment
MSFC-STD-154	Printed circuit design and construction
ABMA-STD-428	Printed circuit design and construction
MIL-P-55110	Printed wiring boards, General Specifications
MIL-STD-429	Printed circuit terms and definitions
MIL-STD-8C	Dimensioning and Tolerancing
MSFC-SPEC-119	Connectors, receptacles, printed wiring board, general purpose, edge type
MSFC-PROC-274	Procedure for terminal installation
MSFC-PROC-158	Soldering of electrical connections (High Reliability)
NASA-NPC-200-4	Quality requirements for hand soldering of electrical connections
MIL-STD-440	Soldering techniques for standard solder type terminals
MSFC-PROC-257	Procedure for conformal coating (epoxy)
MSFC-SPEC-222	Resin systems electrical and environmental insulation, epoxy
MSFC-PROC-293	Coating conformal procedure (polyurethane)
MSFC-SPEC-393	Coating conformal materials (polyurethane)
MSFC-SPEC-202	Compound, potting and molding, elastomeric
MSFC-SPEC-377	Plastic sheet, laminated, copper clad
MIL-P-13949	Plastic sheet, laminated, copper clad
MIL-P-18177C	Plastic sheet, laminated, thermosetting, glass fiber base, epoxy resin
MIL-E-5272	General spec. for environmental testing, for flight application
MIL-STD-810	Environmental test methods for aerospace and ground equipment