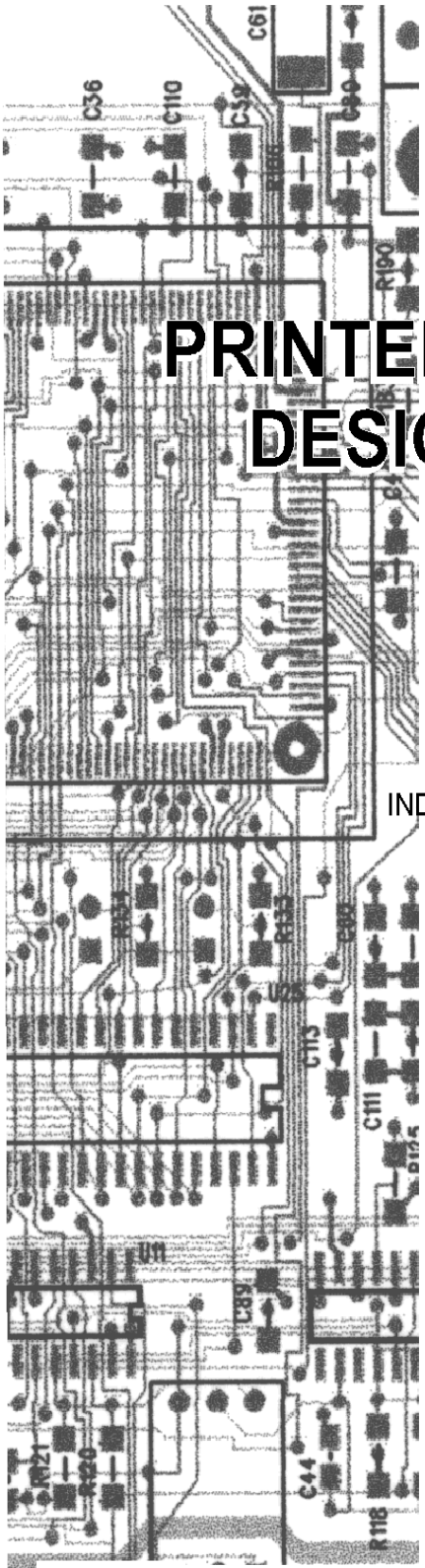


PRINTED CIRCUIT BOARD DESIGN GUIDELINES

CUTLER-HAMMER
INDUSTRIAL CONTROLS DIVISION
WATERTOWN, WI

Cutler-Hammer

EATON

Cutler-Hammer

EATON

Preface

The PCB Design Guidelines are intended to provide a foundation for conveying Design for Manufacturing information to all of those that may influence the design of the product. The guidelines are not meant to replace the concurrent engineering interaction that is essential for optimum design results and product life cycle costs. Design trade-off analyses performed in conjunction with the design guidelines must also consider the manufacturing strategies and business direction of producing all products.

This document will continue to change as capabilities, technology, and processes improve and as product and manufacturing strategies evolve. Your involvement and feedback is fundamental for the continuous improvement of this document. If you have any questions or suggestions regarding the PCB Design Guidelines structure, its content, or its distribution, please contact one of the following Watertown representatives or your specific manufacturing engineering contact for assistance. They will help you or direct you to the appropriate individual.

Document Owner

Daryl Feryance Phone: 920-262-6127 Adnet 450-6127

email: feryade@ch.etn.com

What's new with revision 1.04

- **Section 3 has been updated with electronic requirements for Unicam CAM software.**
- **Section 2.3 panel drawing with ICT tooling hole keep out dimension. Break-away drawing clarified with additional dimensions.**

What's new with revision 1.03

- Section 2.3 Panelization has be updated with additional panel sizes. Also dimensions and notes have added to the panel drawing for clarity.
- Section 2.1.3 Standard SMT Parts, wave solder land patterns were corrected from previous errors for both chip resistors and chip capacitors (pages 12 & 14). Please update your CAD library accordingly.
- Please note that IPC land patterns are for reference use only, and do not represent the most recent process capability of the industry.

What's new with revision 1.02

- Section 2.3 Panelization page 46 has been changed. We added several more panel sizes to choose from. Also the dimensioning reference is now the right hand edge of the panel.

What's new with revision 1.01

- The stencil opening aperture requirement has been deleted. All stencil artwork should be size on size.
- An error was corrected in section 2.2.1.7 for radial components maximum height is now 0.847"
- Clinched lead to trace and via spacing was added to the DIP, Axial, and Radial sections.
- The panel specification was expanded to include a 13.5" long panel.
- Section 3.3 now includes an MS Excel format for electronic B.O.M.

1. Manufacturing Strategy

1.1 Assembly Strategy

1.1.1 Industry Trends

- Mixed technology will be predominant for the next 5 years and beyond.
- New component technology will continue to expand manufacturing requirements.

1.1.2 Long Range Plans

- Extensive conveyorization of material flow
- Bar code material tracking system
- Real time quality data collection and reporting
- Dynamic smart scheduling for maximum equipment and personnel utilization.

1.2 Test Strategy

1.2.1 Test Plan/Sequence

The basic test sequence employed at the Watertown facility is as follows:

- In-circuit test
- Functional test - board level
- Burn-in / Environmental Stress Test
- Functional test - final

1.3 New Product Industrialization

Most products follow a traditional development process from the early concept stage to the final release for sale. There are many industrialization elements that need to be addressed throughout the entire process via ***the use of concurrent engineering to maximize manufacturability and reliability while simultaneously shortening the time-to-market.*** See **Figure 1** for a representation of the development process and associated industrialization elements.

Concurrent engineering is the practice of getting people involved from multi-functional areas in order to make optimum trade-off analyses in the areas of functionality, cost, manufacturability, reliability, time-to-market, testability, parts procurability, appearance, and marketability.

One of the methods used to assess the manufacturability of a product is the manufacturability review conducted by the manufacturing site. Manufacturability reviews should be conducted early in the design process and should not be slotted at just the end of the design process.

Concept and Feasibility Phase		Manufacturing Site Input (Assembly, Test, Process, Materials	
Design Phase	Initial Paper Design and Breadboard	1	DEVELOP PLAN AND TIMELINE FROM DESIGN TO SHIP
		2	Make Project Team Assignments
		3	Estimate Production Quantities
		4	Mfg. Input for Ass'y, Test, Processes and Materials and Incorporate Design
	Layout and Prototype Stage	5	Develop Prototype Plan (timing, material, tooling, build locations, etc.)
		6	Provide Quotation for Prototype Builds
		7	Perform Production Capacity Analysis (floor space, equip., manpower, skills)
		8	Develop Funding Plans for New Tooling/Equipment processes
		9	Formulate Manufacturing Plan for Production
		10	Develop Test Plan and Preliminary Test Specification
		11	Identify and Order Long Lead Purchased Items for Production (and
		12	Build Prototypes
		13	Conduct Manufacturability Review (Assembly, Test, Processes, Materials)
		14	Provide Quotations for Production Tooling
		15	Provide Cost Estimate for Production Units
		16	Identify and Order Long Lead Tooling for Production
		17	Identify Shipping Packaging Requirements
		18	Develop Warranty/Repair Policy
		19	Define Product Manuals that Are Included in Shipments
		20	Purchase Orders Received and Invoiced for Prototypes
	Eng Production	21	Provide Engineering Release to WTN Production Letter
		22	Release Documentation (Assy dwgs, B/M's, Purchased Part Drawings, S/W,
		23	Issue Purchase Orders and/or Generate Firm Forecast
		24	Issue Purchase Orders to WTN for Production Ass'y & Test Tooling and other
Industri-alization Phase	Release into WTN System	25	Release All New Parts and Documents in WTN (into Mfg/Pro and Distribution)
		26	Create Routing (Mfg. Flow and Direct Labor Hrs.)
		27	Issue Tool Orders on Mfg/Pro
		28	Enter Forecast/Orders on Mfg/Pro
		29	Develop Production Build Plan/Schedule
	Prepare For Production	30	Prepare Facilities (layout, utilities, maintenance)
		31	Add Manpower and Train New Manpower
		32	Prepare Process Specifications and Work Instructions
		33	Receive and Checkout New Tooling and Capital Equipment
		34	Order and Receive Purchased Materials
		35	Perform Assessments on New Supplier (Purchasing)
		36	Develop Test Software
		37	Issue Work Orders to Production Floor
	1st Production Lot Build	38	Conduct 1st Production Audit
		39	Debug Tooling/Fixturing/Software
		40	Provide Operator Assembly Training and Technician Training
		41	Modify/Create Work Instructions and Process Specifications
		42	Formulate 1st Production Yields
		43	Acquire Engineering Acceptance of 1st Production Units
		44	Identify Documentation Errors and Changes
		45	Provide Manufacturability Feedback to Engineering
		46	Invoice Customer Purchase Orders for All Tooling and NRE
Enhancement and Maintenance Phase		47	Implement Yield Improvement Thru Process Changes or design Changes
		48	Assess Field Returns and establish Corrective Actions
		49	Maintain Documentation to Reflect Latest Requirement and Design Changes

Figure 1 - Product Industrialization Guide

1.3.1 Manufacturability Review Elements

In reviewing a design for manufacturability, the review categories listed below may be analyzed for acceptability. The design information used to perform a manufacturability review may include drawings, schematics, test specifications, bills of material, prototypes, sketches, or marked-up documentation. However, the review thoroughness is limited by the availability of sample units and accurate/complete documentation. Typically designs are reviewed by establishing a manufacturing process flow and then analyzing each process relative to the product.

- ☐ **Assembly Drawings**
- ☐ **Bills of Material**
- ☐ **Schematics**
- ☐ **Purchased Part Drawings**
- ☐ **Test Specification Drawings**
- ☐ **Bare PCB Drawings/Artwork**
- ☐ **Special Workmanship Standards**
- ☐ **List of parts on tape and reel**

- ☐ **Surface Mount Pads and Orientation**
- ☐ **Axial Part Pads and Spacing**
- ☐ **Radial Part Pads and Spacing**
- ☐ **DIP Parts Pads and Spacing**
- ☐ **Manual Inserted Parts**
- ☐ **Wiring and Cables**
- ☐ **Plastic Molded Parts**
- ☐ **Cleaning**
- ☐ **Fiducials**
- ☐ **PWB material and soldermask**
- ☐ **Stiffeners and tooling**
- ☐ **Tooling Holes**
- ☐ **Connectors/Terminals**
- ☐ **Special Parts Forming**
- ☐ **ax. lead length 0.085”**
- ☐ **Via size and Spacing**
- ☐ **Programmed Parts**
- ☐ **Labeling/Serialization**
- ☐ **Panelization**
- ☐ **Manufacturing Flow**
- ☐ **No Post Wave Assembly**

- ☐ **Node Access (Test Points)**
- ☐ **Incircuit Test Compatibility**
- ☐ **Functional Test Compatibility**
- ☐ **Burn-in Test Compatibility**
- ☐ **Hypot Test Requirements**
- ☐ **ESS Test Requirements**

- ☐ **Conformal Coating**
- ☐ **Potting**
- ☐ **Adhesives**

- ☐ **Shipping/Packing Requirements**
- ☐ **Product Manuals**
- ☐ **Regulatory Agency Requirements**

- ☐ **Long Lead Purchased Parts**
- ☐ **Purchased Part Commonality**
- ☐ **High Cost Purchased Parts**

Figure 2 - Design Review Checklist

The above only represents some broad categories that are reviewed. For more specifics on how designs are reviewed for manufacturability, contact the manufacturing site manufacturing engineer.

1.3.2 Equipment Capability Overview Stencil Printing

- 2- DEK 265 Stencil Printers
- Panasonic SP-LL Stencil Printer

1.3.3 SMT Placement

Chip Shooters
- Panasonic MV2C
- Panasonic MV150
- Panasonic MK

Placement Machines
- Panasonic MPA3
- Panasonic MPA80
- Panasonic MPA

1.3.4 Reflow

Reflow Ovens
- 2- Conceptronic HVN155
- Conceptronic HVNIO2

1.3.5 DIP Insertion

- 2- Universal Instruments 6662A

1.3.6 Axial Insertion

- 2- Universal Instruments 6241B

1.3.7 Radial Insertion

- Universal Instruments 6663A

1.3.8 Contact Systems

Guided Manual Assembly

1.3.9 Component preparation/lead forming

1.3.10 Wave Solder

Wave Soldering Systems
- Sensbey LG400-DV
  2- Electrovert EconoPak equipped with ATT spray fluxers.

1.3.11 Cleaning

Aqueous Wash Systems

1.3.12 Board Transfer System

1.3.13 In-Circuit Test

- 6 - Teradyne
- 3 Schlumberger

1.3.14 Functional Test

- 8 - General purpose

1.3.15 Burn-In & Environmental

- Thermal cycling Chamber

1.3.16 Coating and Potting

Conformal Coating

- 5 - Nordson Select-Coat Conformal Coat Robots
  3 - Conveyorized ovens

Potting

- 1 - Ashby-Cross 2500 Series Automatic Meter and Dispense System

1.3.17 Plastic Molding

1.3.18 Wire/Cable/Terminal Processing

1.4 Workmanship Standards

1.4.1 Overview

- IPC-A-610 Rev. B workmanship standards.
- Leads may extend up to .098” from the surface of the board. Shorter lead lengths add manual labor cost to the product.

2. PCB Design

2.1 Land Patterns

2.1.1 General Considerations

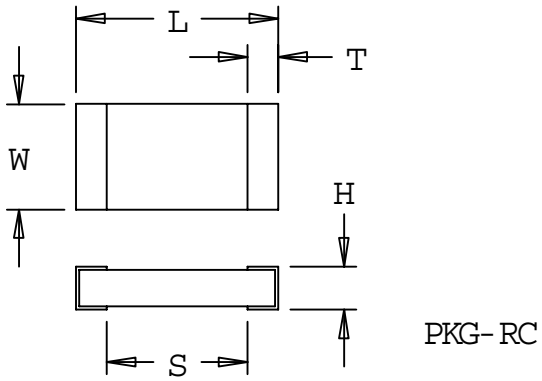
Item	Rules	Remarks
Silkscreen	• Silkscreen artwork should use at least .010 wide lines. .012 wide is preferable. • Preferred text height for clear legibility is .080 min. The minimum legible text height is .040 high. • Silkscreen image should clear solderable surfaces, including vias, by .020.	• Silkscreen ink on pads will cause a significant level of soldering defects.
Soldermask	• Liquid photo-imageable soldermask requires openings of .008 min. larger than the pad for board fabrication. • Screened-on soldermask materials, such as SR-1010, require .020 min. larger than the pads.	• Keep conductors out of soldermask openings.
Stencil	• Stencil opening in general should be the same as the copper pattern.	

2.1.2 Via Sizes (does not apply to test points)

Board Density	Hole Size (Dia.)	Annular Ring (Dia.)	Remarks
Very High	Smaller than .014	0.010” Nominal	• Higher cost • May fill in hot air level
High	.014 to .017	0.010” Nominal	• Cost premium • May fill in hot air level
Normal	.018 or larger	0.010” Nominal	• No cost premium
Low	.038	0.010” Nominal	• Lower Cost

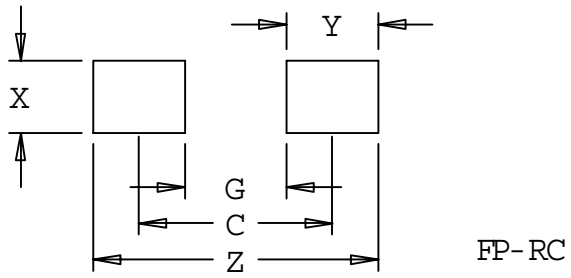
2.1.3 Standard SMT Parts

PART TYPE: CHIP RESISTOR PACKAGE DRAWING



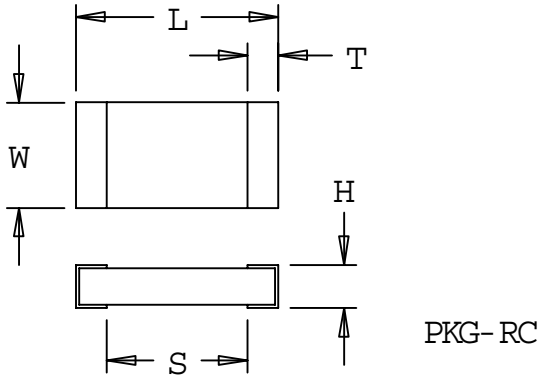
Part Dimensions Max./Min. (inches)					
Case	**L**	**S**	**W**	**H**	**T**
RC0402 (max.)	.043	.028	.024	.016	.012
RC0402 (min.)	.039	.016	.019		.004
RC0603 (max.)	.067	.044	.037	.024	.016
RC0603 (min.)	.059	.028	.028		.006
RC0805 (max.)	.085	.052	.055	.026	.026
RC0805 (min.)	.073	.022	.043		.006
RC1206 (max.)	.132	.091	.069	.028	.030
RC1206 (min.)	.120	.061	.057		.010
RC1210 (max.)	.132	.091	.104	.028	.030
RC1210 (min.)	.120	.061	.092		.010
RC2010 (max.)	.203	.154	.104	.028	.033
RC2010 (min.)	.191	.124	.093		.014
RC2512 (max.)	.254	.206	.132	.028	.033
RC2512 (min.)	.242	.175	.120		.014

PART TYPE: CHIP RESISTOR LAND PATTERN



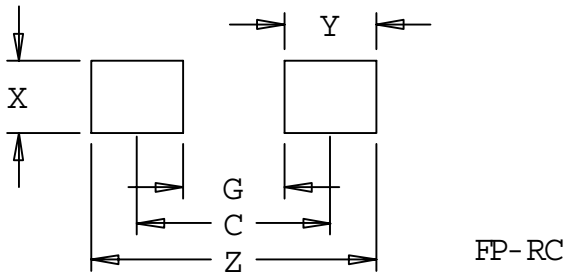
Land Pattern (inches)							
Case	**Side**	**Z**	**G**	**X**	**Y ref.**	**C ref.**	**Remarks**
RC0402	R	.083	.020	.028	.031	.051	DO NOT USE
RC0402	W						DO NOT USE
RC0603	R	.106	.028	.043	.039	.067	
RC0603	W	.115	.025	.025	.045	.070	DO NOT USE
RC0805	R	.150	.032	.038	.059	.091	
RC0805	W	.150	.035	.035	.0575	.0925	
RC1206	R	.196	.070	.050	.063	.133	
RC1206	W	.200	.080	.040	.060	.140	
RC1210	R	.196	.070	.074	.063	.133	
RC1210	W	.200	.080	.065	.060	.140	
RC2010	R	.240	.106	.098	.067	.173	
RC2010	W	.270	.106	.070	.082	.188	
RC2512	R	.287	.154	.122	.067	.220	
RC2512	W	.310	.154	.122	.078	.232	

PART TYPE: CHIP CAPACITOR PACKAGE DRAWING



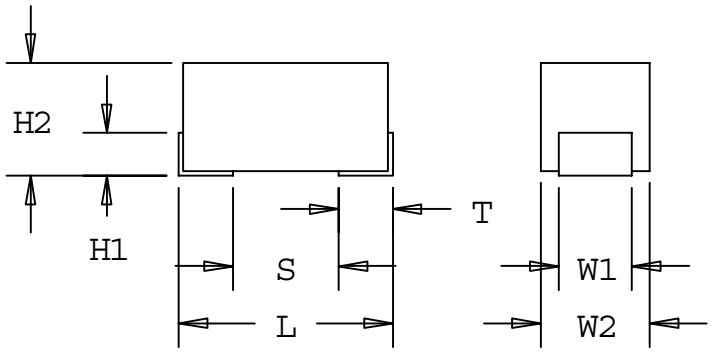
Part Dimensions Max./Min. (inches)					
Case	**L**	**S**	**W**	**H**	**T**
CC0402 (max.)	.043	.026	.024	.024	.012
CC0402 (min.)	.035	.012	.016		.004
CC0504 (max.)	.052	.028	.050	.040	.015
CC0504 (min.)	.040	.010	.030		.005
CC0603 (max.)	.069	.038	.037	.033	.020
CC0603 (min.)	.057	.018	.026		.008
CC0805 (max.)	.087	.044	.057	.043	.030
CC0805 (min.)	.071	.012	.041		.010
CC1206 (max.)	.134	.091	.071	.053	.030
CC1206 (min.)	.118	.059	.055		.010
CC1210 (max.)	.134	.091	.106	.053	.030
CC1210 (min.)	.118	.059	.091		.010
CC1812 (max.)	.189	.136	.134	.053	.037
CC1812 (min.)	.165	.091	.118		.010
CC1825 (max.)	.189	.136	.268	.043	.037
CC1825 (min.)	.165	.091	.236		.010

PART TYPE: CHIP CAPACITOR LAND PATTERN



Land Pattern (inches)							
Case	**Side**	**Z**	**G**	**X**	**Y ref.**	**C ref.**	**Remarks**
CC0402	R	.083	.020	.028	.031	.051	DO NOT USE
CC0402	W						DO NOT USE
CC0504	R	.091	.020	.043	.035	.055	DO NOT USE
CC0504	W						DO NOT USE
CC0603	R	.106	.028	.043	.039	.067	
CC0603	W	.135	.025	.025	.055	0.08	DO NOT USE
CC0805	R	.150	.032	.038	.059	.091	
CC0805	W	.175	.040	.035	.0675	.1075	
CC1206	R	.196	.070	.050	.063	.133	
CC1206	W	.240	.060	.040	.090	.150	
CC1210	R	.212	.070	.074	.071	.141	
CC1210	W	.240	.080	.065	.080	.160	
CC1812	R	.268	.126	.094	.071	.197	
CC1812	W						NOT RECOMMENDED
CC1825	R	.220	.083	.170	.075	.153	Changed 5/19/99
CC1825	W						NOT RECOMMENDED

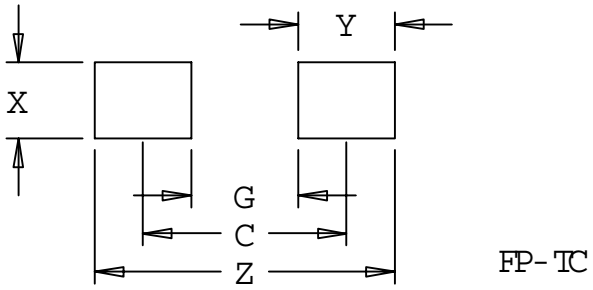
TANTALUM CHIP CAPACITOR PACKAGE DRAWING



PKG-TC

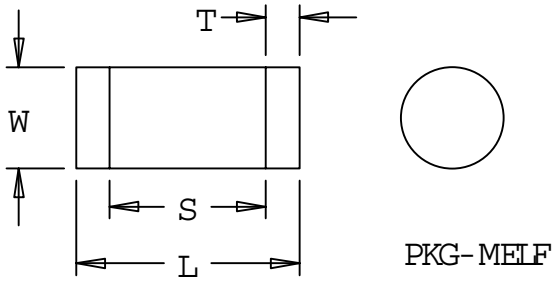
Part Dimensions Max./Min. (inches)							
Case	**L**	**S**	**W1**	**W2**	**H1**	**H2**	**T**
TC3216 (max.)	.134	.069	.048	.071	.028		.043
TC3216 (min.)	.118	.031	.046	.055		.071	.020
TC3528 (max.)	.146	.080	.087	.118	.028		.043
TC3528 (min.)	.130	.043	.086	.102		.083	.020
TC6032 (max.)	.248	.139	.087	.138	.039		.063
TC6032 (min.)	.224	.098	.086	.114		.110	.039
TC7343 (max.)	.299	.191	.095	.181	.039		.063
TC7343 (min.)	.276	.150	.094	.157		.122	.039

TANTALUM CHIP CAPACITOR LAND PATTERN



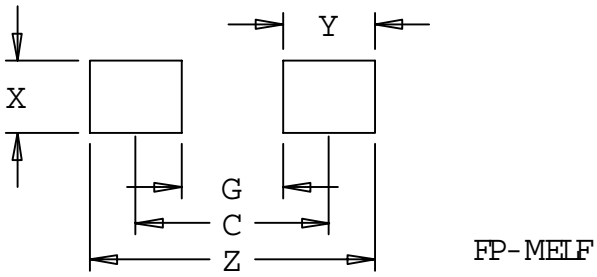
Land Pattern (inches)							
Case	**Side**	**Z**	**G**	**X**	**Y ref.**	**C ref.**	**Remarks**
TC3216	R	.190	.032	.056	.079	.111	
TC3216	W	.276	.032	.056	.122	.154	
TC3528	R	.206	.048	.094	.079	.127	
TC3528	W	.311	.048	.094	.132	.180	
TC6032	R	.314	.126	.094	.094	.220	
TC6032	W	.469	.126	.094	.171	.297	
TC7343	R	.354	.166	.102	.094	.260	
TC7343	W	.543	.166	.102	.189	.355	

MELF



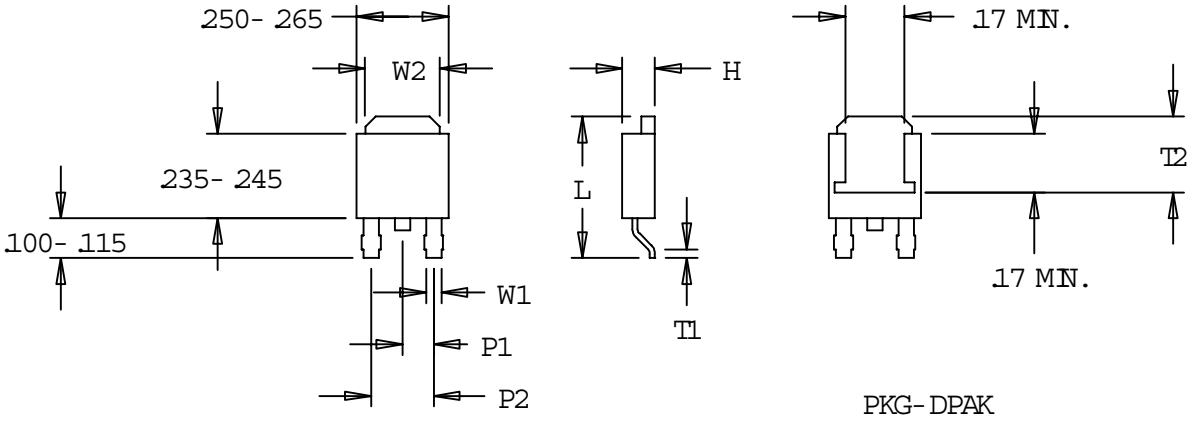
Part Dimensions Max./Min. (inches)				
Case	**L**	**S**	**W**	**T**
SOD-80/MLL34 (max.)	.146	.104	.067	.022
SOD-80/MLL34 (min.)	.130	.087	.063	.016
SOD-87/MLL41 (max.)	.205	.167	.100	.020
SOD-87/MLL41 (min.)	.189	.150	.096	.014
0805 (max.)	.083	.057	.057	.015
0805 (min.)	.075	.046	.053	.009
1206 (max.)	.134	.091	.073	.022
1206 (min.)	.118	.073	.069	.017
1406 (max.)	.146	.103	.065	.022
1406 (min.)	.130	.085	.061	.017
2309 (max.)	.240	.189	.098	.026
2309 (min.)	.224	.172	.094	.021

MELF

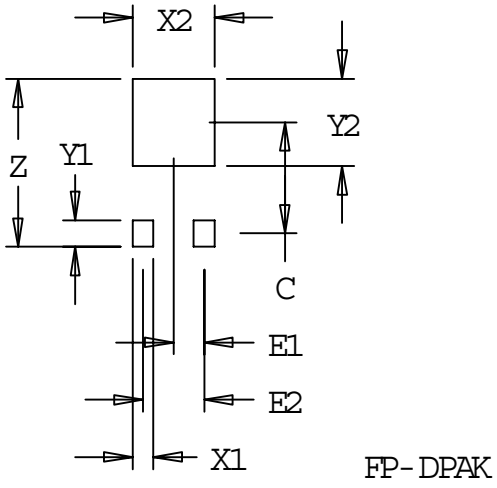


Land Pattern (inches)							
Case	**Side**	**Z**	**G**	**X**	**C ref.**	**Y ref.**	**Remarks**
SOD-80/MLL34	R	.185	.083	.067	.134	.051	DO NOT USE
SOD-80/MLL34	W	.185	.083	.067	.134	.051	DO NOT USE
SOD-87/MLL41	R	.240	.138	.098	.189	.051	DO NOT USE
SOD-87/MLL41	W	.240	.138	.098	.189	.051	DO NOT USE
0805	R	.122	.035	.059	.079	.043	DO NOT USE
0805	W	.122	.035	.059	.079	.043	DO NOT USE
1206	R	.169	.067	.075	.118	.051	DO NOT USE
1206	W	.169	.067	.075	.118	.051	DO NOT USE
1406	R	.185	.083	.067	.134	.051	DO NOT USE
1406	W	.185	.083	.067	.134	.051	DO NOT USE
2309	R	.272	.169	.098	.220	.051	DO NOT USE
2309	W	.272	.169	.098	.220	.051	DO NOT USE

TO-252 (DPAK)

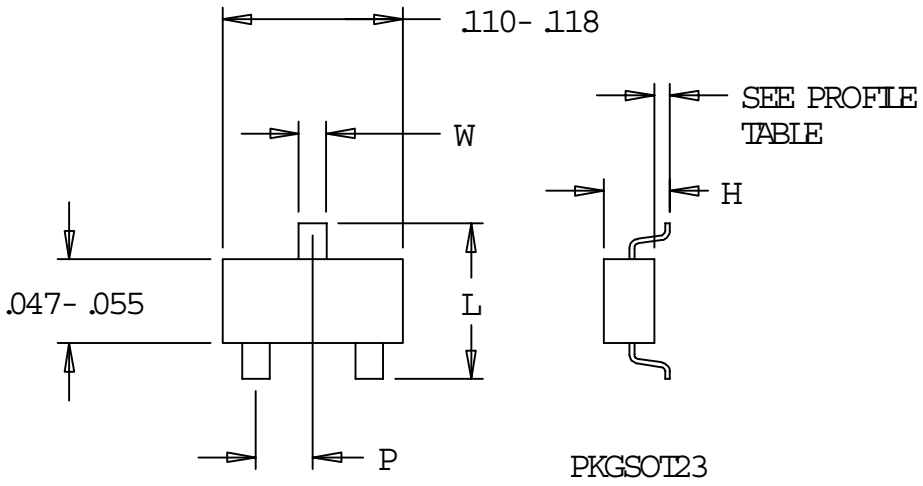


Package Dimensions Max./Min. (inches)								
Case	**L**	**W1**	**W2**	**T1**	**T2**	**P1 basic**	**P2 basic**	**H**
TO-252 (max.)	.410	.045	.215	.031	.209	.090	.180	.094
TO-252 (min.)	.370	.030	.205	.020	.185			



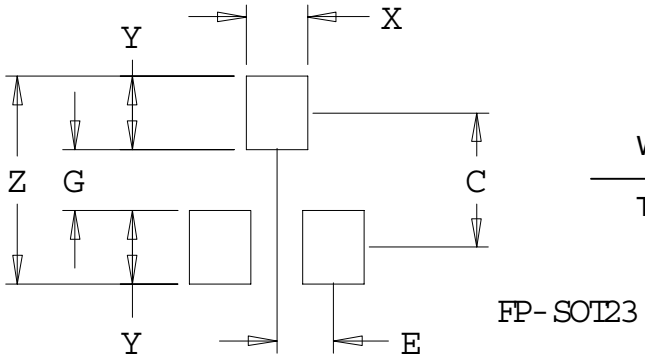
Land Pattern (inches)										
Case	**Side**	**Z**	**Y1**	**Y2**	**X1**	**X2**	**E1 basic**	**E2 basic**	**C ref.**	**Remarks**
TO-252	R	.453	.118	.265	.063	.265	.090	.180	.262	
TO-252	W									DO NOT USE

SOT-23



Profile	Dimension (inches)	TO 236 Des	Remark
Low	.0004-.004	AB	
Medium	.003-.005	-	
High	.004-.010	AA	Reflow Only

Part Dimensions Max./Min. (inches)				
CASE	**L**	**W**	**H**	**P nom.**
SOT-23 (min.)	**.096**	.016	.043	.037
SOT-23 (max.)	.091	.014		

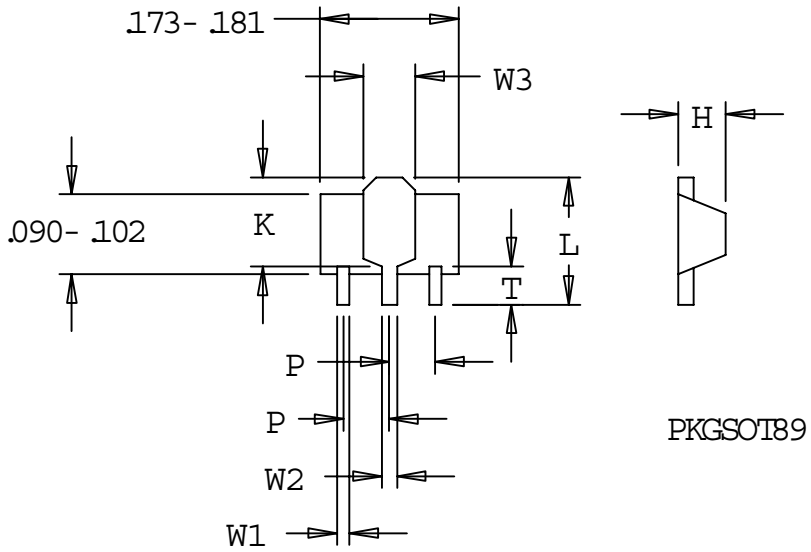


Wave Solder

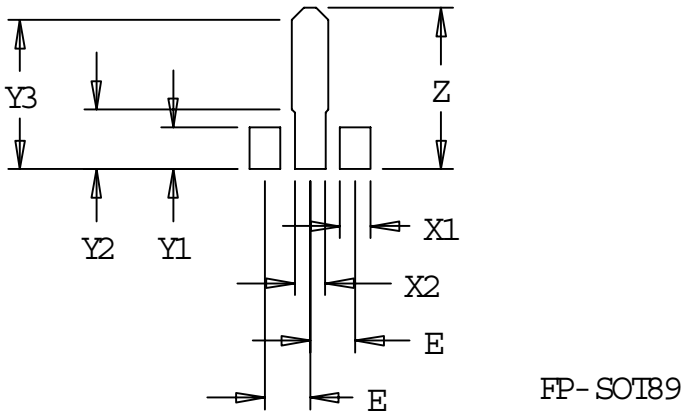
Travel Direction

Land Pattern (inches)								
CASE	**SIDE**	**Z**	**G**	**X**	**Y ref.**	**C ref.**	**E ref.**	**Remarks**
SOT-23	R	.136	.040	.040	.048	.088	.040	
SOT-23	W	.195	.055	.040	.070	.110	.040	Low - Medium Profile only

SOT-89

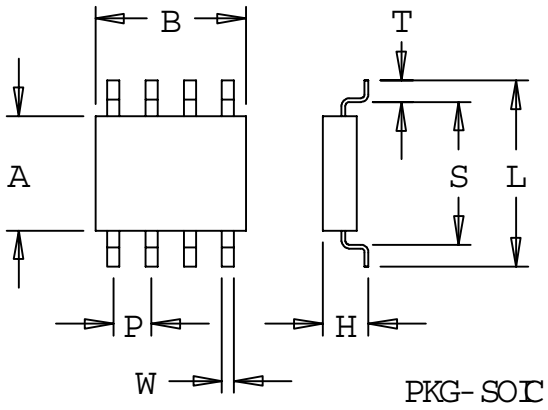


Package Dimensions Max./Min. (inches)								
Case	**L**	**T**	**W1**	**W2**	**W3**	**K**	**H**	**P basic**
SOT-89 (max.)	.167	.047	.019	.022	.072	.112	.063	.059
SOT-89 (min.)	.155	.035	.014	.017	.064	.102		



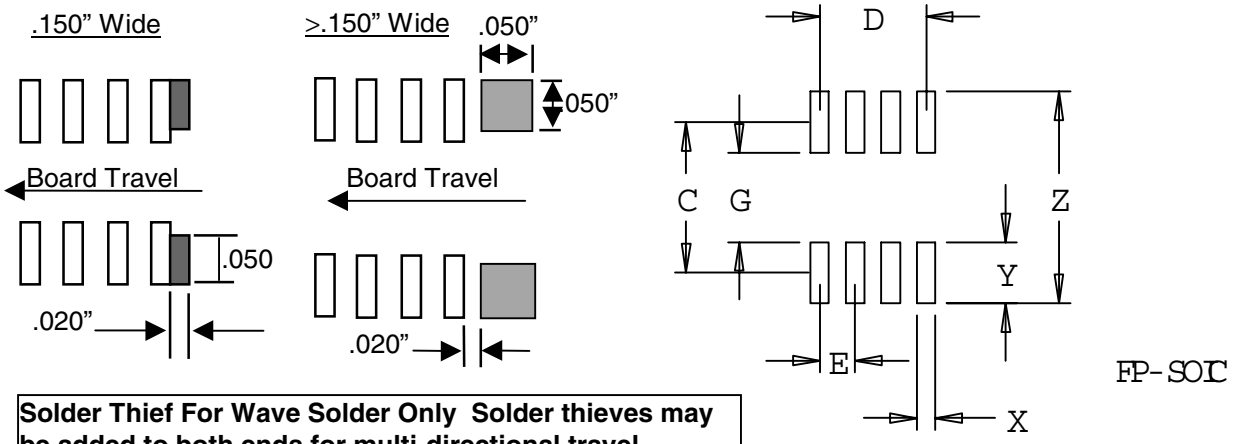
Land Pattern (inches)										
Case	**Side**	**Z**	**Y1**	**X1**	**X2**	**X3**	**Y2 ref.**	**Y3 ref.**	**E basic**	**Remarks**
SOT-89	R	.212	.055	.040	.040	.048	.070	.196	.059	
SOT-89	W									DO NOT USE

GULL WING SOIC



IPC Package Dimensions Max./Min. (inches)								
Case	**L**	**S**	**W**	**T**	**A**	**B**	**H**	**P basic**
SO8 (max.)	.244	.179	.020	.050	.157	.197	.069	.050
SO8 (min.)	.228	.128	.013	.016	.150	.189	.053	
SO8W (max.)	.419	.348	.020	.050	.299	.215	.104	.050
SO8W (min.)	.394	.294	.013	.016	.291	.199	.093	
SO14 (max.)	.244	.179	.020	.050	.157	.344	.069	.050
SO14 (min.)	.228	.128	.013	.016	.150	.337	.053	
SO14W (max.)	.419	.348	.020	.050	.299	.362	.104	.050
SO14W (min.)	.394	.294	.013	.016	.291	.346	.093	
SO16 (max.)	.244	.179	.020	.050	.157	.394	.069	.050
SO16 (min.)	.228	.128	.013	.016	.150	.386	.053	
SO16W (max.)	.419	.348	.020	.050	.299	.413	.104	.050
SO16W (min.)	.394	.294	.013	.016	.291	.398	.093	
SO20W (max.)	.419	.348	.020	.050	.299	.512	.104	.050
SO20W (min.)	.394	.294	.013	.016	.291	.496	.093	
SO24W (max.)	.419	.355	.020	.041	.299	.624	.104	.050
SO24W (min.)	.405	.323	.014	.021	.291	.612	.092	
SO24X (max.)	.479	.415	.020	.041	.355	.624	.104	.050
SO24X (min.)	.465	.383	.014	.021	.345	.612	.092	
SO28W (max.)	.419	.355	.020	.041	.299	.724	.104	.050
SO28W (min.)	.405	.323	.014	.021	.291	.712	.092	
SO28X (max.)	.479	.415	.020	.041	.355	.724	.104	.050
SO28X (min.)	.465	.383	.014	.021	.345	.712	.092	
SO32W (max.)	.419	.355	.020	.041	.299	.824	.104	.050
SO32W (min.)	.405	.323	.014	.021	.291	.812	.092	
SO32X (max.)	.479	.415	.020	.041	.355	.824	.104	.050
SO32X (min.)	.465	.383	.014	.021	.345	.812	.092	
SO36W (max.)	.419	.355	.020	.041	.299	.924	.104	.050
SO36W (min.)	.405	.323	.014	.021	.291	.912	.092	
SO36X (max.)	.479	.415	.020	.041	.355	.924	.104	.050
SO36X (min.)	.465	.383	.014	.021	.345	.912	.092	

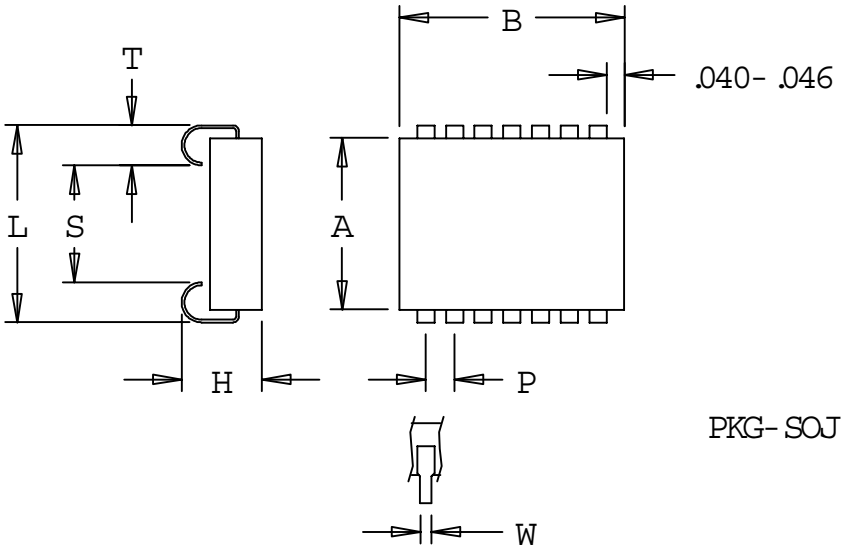
GULL WING SOIC



Solder Thief For Wave Solder Only Solder thieves may be added to both ends for multi-directional travel.

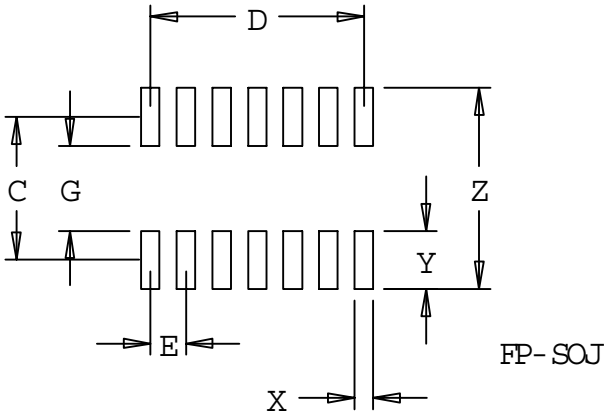
Land Pattern (inches)									
Case	**Side**	**Z**	**G**	**X**	**Y ref.**	**C ref.**	**D ref.**	**E ref.**	**Remarks**
SO8	R	.275	.115	.026	.080	.195	.150	.050	
SO8	W	.300	.150	.022	.075	.225	.150	.050	USE THIEF
SO8W	R	.460	.300	.026	.080	.380	.150	.050	
SO8W	W	.500	.285	.022	.107	.392	.450	.050	USE THIEF
SO14	R	.275	.115	.026	.080	.195	.300	.050	
SO14	W	.300	.150	.022	.075	.225	.300	.050	USE THIEF
SO14W	R	.445	.285	.026	.080	.365	.300	.050	
SO14W	W	.500	.285	.022	.107	.392	.300	.050	USE THIEF
SO16	R	.275	.115	.026	.080	.195	.350	.050	
SO16	W	.300	.150	.022	.075	.225	.350	.050	USE THIEF
SO16W	R	.445	.285	.026	.080	.365	.350	.050	
SO16W	W	.500	.285	.022	.107	.392	.350	.050	USE THIEF
SO20W	R	.445	.285	.026	.080	.365	.450	.050	
SO20W	W	.500	.285	.022	.107	.392	.450	.050	USE THIEF
SO24W	R	.445	.285	.026	.080	.365	.550	.050	
SO24W	W	.500	.285	.022	.107	.392	.550	.050	USE THIEF
SO24X	R	.520	.360	.026	.080	.440	.550	.050	
SO24X	W	.550	.360	.022	.095	.455	.550	.050	USE THIEF
SO28W	R	.460	.300	.026	.080	.380	.650	.050	
SO28W	W	.500	.285	.022	.107	.392	.650	.050	USE THIEF
SO28X	R	.520	.360	.026	.080	.440	.650	.050	
SO28X	W	.550	.360	.022	.095	.455	.650	.050	USE THIEF
SO32W	R	.460	.300	.026	.080	.380	.750	.050	
SO32W	W								NOT RECOMMENDED
SO32X	R	.520	.360	.026	.080	.440	.750	.050	
SO32X	W								NOT RECOMMENDED
SO36W	R	.460	.300	.026	.080	.380	.850	.050	
SO36W	W								NOT RECOMMENDED
SO36X	R	.520	.360	.026	.080	.440	.850	.050	
SO36X	W								NOR RECOMMENDED

J-LEADED SOIC



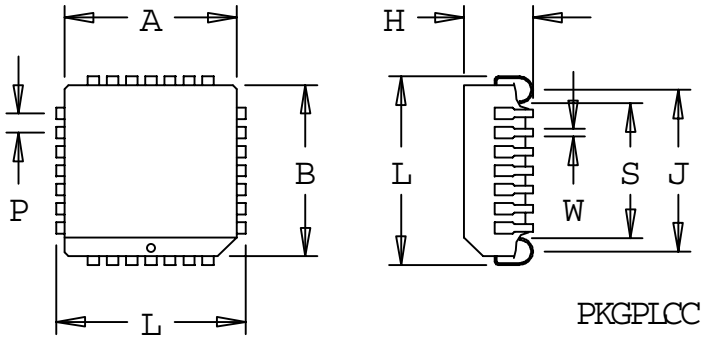
Part Dimensions Max./Min. (inches)								
Case	**L**	**S**	**W**	**T**	**B**	**H max**	**P basic**	**A (ref)**
SOJ 14/300	.330/.345	.172/.199	.015/.020	.063/.079	.380/.392	.148	.050	.300
SOJ 16/300	.330/.345	.172/.199	.015/.020	.063/.079	.430/.442	.148	.050	.300
SOJ 18/300	.330/.345	.172/.199	.015/.020	.063/.079	.480/.492	.148	.050	.300
SOJ 20/300	.330/.345	.172/.199	.015/.020	.063/.079	.530/.542	.148	.050	.300
SOJ 22/300	.330/.345	.172/.199	.015/.020	.063/.079	.580/.592	.148	.050	.300
SOJ 24/300	.330/.345	.172/.199	.015/.020	.063/.079	.630/.642	.148	.050	.300
SOJ 26/300	.330/.345	.172/.199	.015/.020	.063/.079	.680/.692	.148	.050	.300
SOJ 28/300	.330/.345	.172/.199	.015/.020	.063/.079	.730/.742	.148	.050	.300
SOJ 14/350	.380/.395	.222/.339	.015/.020	.063/.079	.380/.392	.148	.050	.350
SOJ 16/350	.380/.395	.222/.339	.015/.020	.063/.079	.430/.442	.148	.050	.350
SOJ 18/350	.380/.395	.222/.339	.015/.020	.063/.079	.480/.492	.148	.050	.350
SOJ 20/350	.380/.395	.222/.339	.015/.020	.063/.079	.530/.542	.148	.050	.350
SOJ 22/350	.380/.395	.222/.339	.015/.020	.063/.079	.580/.592	.148	.050	.350
SOJ 24/350	.380/.395	.222/.339	.015/.020	.063/.079	.630/.642	.148	.050	.350
SOJ 26/350	.380/.395	.222/.339	.015/.020	.063/.079	.680/.692	.148	.050	.350
SOJ 28/350	.380/.395	.222/.339	.015/.020	.063/.079	.730/.742	.148	.050	.350

J-LEADED SOIC



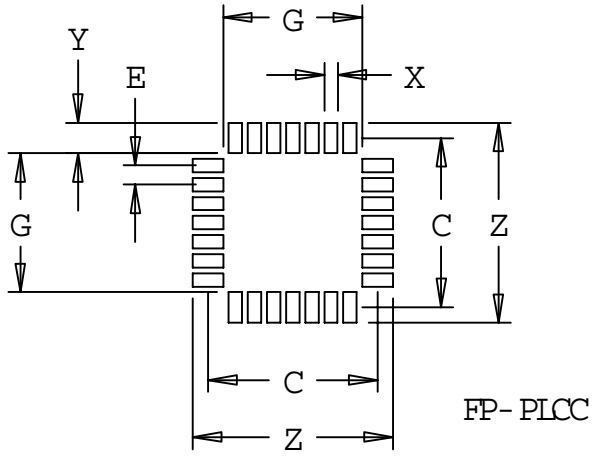
Land Pattern (inches)									
Case	Side	Z	G	X	Y ref.	C ref.	D basic	E basic	Remarks
SOJ 14/300	R	.350	.190	.026	.080	.270	.300	.050	
SOJ 16/300	R	.350	.190	.026	.080	.270	.350	.050	
SOJ 18/300	R	.350	.190	.026	.080	.270	.400	.050	
SOJ 20/300	R	.350	.190	.026	.080	.270	.450	.050	
SOJ 22/300	R	.350	.190	.026	.080	.270	.500	.050	
SOJ 24/300	R	.350	.190	.026	.080	.270	.550	.050	
SOJ 26/300	R	.350	.190	.026	.080	.270	.600	.050	
SOJ 28/300	R	.350	.190	.026	.080	.270	.650	.050	
SOJ 14/350	R	.400	.240	.026	.080	.320	.300	.050	
SOJ 16/350	R	.400	.240	.026	.080	.320	.350	.050	
SOJ 18/350	R	.400	.240	.026	.080	.320	.400	.050	
SOJ 20/350	R	.400	.240	.026	.080	.320	.450	.050	
SOJ 22/350	R	.400	.240	.026	.080	.320	.500	.050	
SOJ 24/350	R	.400	.240	.026	.080	.320	.550	.050	
SOJ 26/350	R	.400	.240	.026	.080	.320	.600	.050	
SOJ 28/350	R	.400	.240	.026	.080	.320	.650	.050	

J-LEADED PLCC (SQUARE)



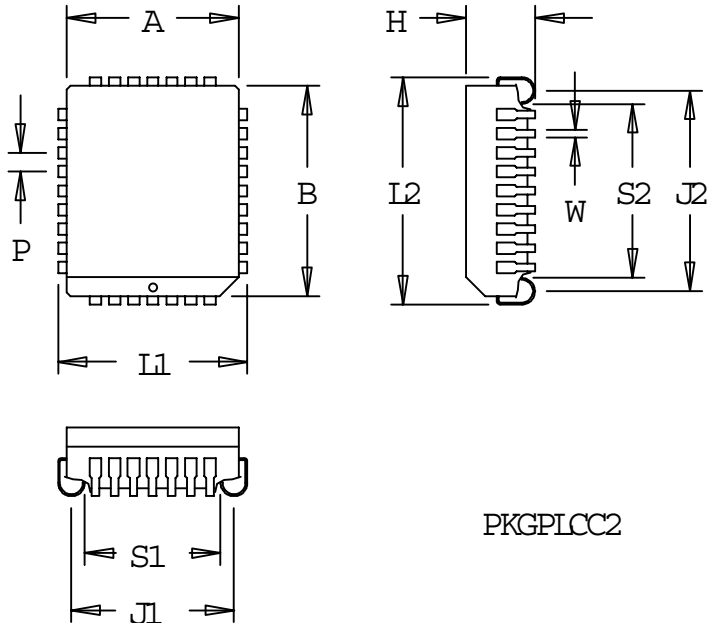
Part Dimensions Max./Min. (inches)									
Case	**L**	**S**	**W**	**T**	**A**	**B**	**J ref.**	**H**	**P**
PLCC 20	.385/.395	.228/.257	.013/.021	.059/.079	.350/.356	.350/.356	.310	.180	.050
PLCC 28	.485/.495	.328/.357	.013/.021	.059/.079	.450/.456	.450/.456	.410	.180	.050
PLCC 44	.685/.695	.528/.557	.013/.021	.059/.079	.650/.656	.650/.656	.610	.180	.050
PLCC 52	.785/.795	.628/.657	.013/.021	.059/.079	.750/.756	.750/.756	.710	.200	.050
PLCC 68	.985/.995	.828/.857	.013/.021	.059/.079	.950/.958	.950/.958	.910	.200	.050
PLCC 84	1.185/1.195	1.028/1.057	.013/.021	.059/.079	1.150/1.157	1.150/1.157	1.110	.200	.050
PLCC 100	1.385/1.395	1.228/1.257	.013/.021	.059/.079	1.350/1.358	1.350/1.358	1.310	.200	.050
PLCC 124	1.685/1.695	1.528/1.557	.013/.021	.059/.079	1.650/1.658	1.650/1.658	1.610	.200	.050

J-LEADED PLCC (SQUARE)



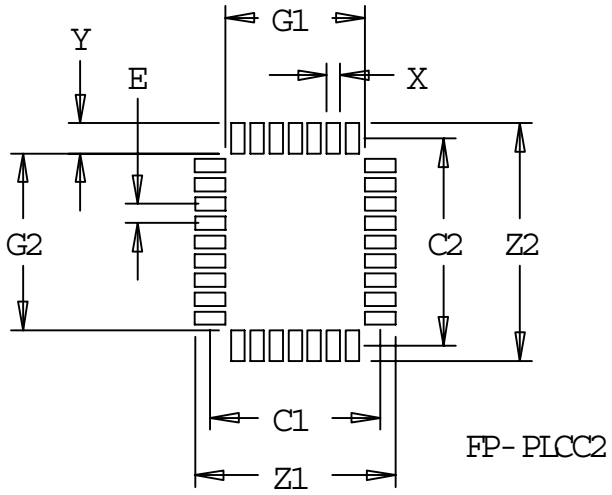
Land Pattern (inches)									
Case	**Side**	**Z**	**G**	**X**	**Y ref.**	**C ref.**	**D ref.**	**E ref.**	**Remarks**
PLCC 20	R	.424	.264	.026	.080	.364	.2	.050	
PLCC 28	R	.524	.364	.026	.080	.464	.3	.050	
PLCC 44	R	.724	.564	.026	.080	.664	.5	.050	
PLCC 52	R	.824	.664	.026	.080	.764	.6	.050	
PLCC 68	R	1.024	.864	.026	.080	.964	.8	.050	
PLCC 84	R	1.224	1.064	.026	.080	1.164	1.0	.050	
PLCC 100	R	1.424	1.264	.026	.080	1.364	1.2	.050	
PLCC 124	R	1.724	1.564	.026	.080	1.664	1.5	.050	

J-LEADED PLCC (RECTANGULAR)



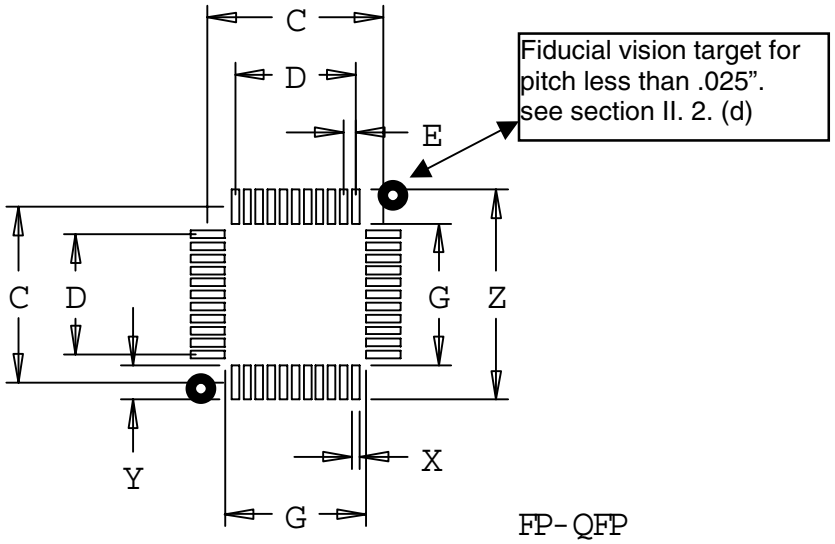
Part Dimensions Max./Min. (inches)												
Case	L1	S1	L2	S2	W	T	A	B	J1 ref.	J2 ref.	H	P
PLCC 18	.317/.327	.159/.189	.458/.467	.300/.329	.013/.021	.059/.079	.288	.428	.244	.384	.141	.050
PLCC 18L	.320/.335	.163/.194	.520/.535	.363/.394	.013/.021	.059/.079	.293	.493	.244	.443	.141	.050
PLCC 22	.320/.335	.163/.194	.520/.535	.363/.394	.013/.021	.059/.079	.293	.493	.244	.443	.141	.050
PLCC 28	.385/.395	.228/.257	.585/.595	.428/.457	.013/.021	.059/.079	.353	.553	.311	.510	.141	.050
PLCC 32	.485/.495	.328/.357	.585/.595	.428/.457	.013/.021	.059/.079	.453	.553	.409	.510	.141	.050

J-LEADED PLCC (RECTANGULAR)



Land Pattern (inches)													
Case	Side	Z1	G1	Z2	G2	X	Y ref.	C1 ref.	C2 ref.	D1 ref.	D2 ref.	E ref.	Remarks
PLCC 18	R	.356	.196	.496	.336	.026	.080	.276	.416	.150	.200	.050	
PLCC 18L	R	.364	.204	.564	.404	.026	.080	.284	.484	.150	.200	.050	
PLCC 22	R	.364	.204	.564	.404	.026	.080	.284	.484	.150	.300	.050	
PLCC 28	R	.424	.264	.624	.464	.026	.080	.344	.544	.200	.400	.050	
PLCC 32	R	.524	.364	.624	.464	.026	.080	.444	.544	.300	.400	.050	

QUAD FLAT PACK (General Guideline)



Pitch E mm (in)	Land	Remarks
.5 mm (.0197")	.080" x .012"	Center of foot
0.650 mm (.0256")	.080" x .015"	Center of foot
0.787 mm (.031")	.080" x .020"	Center of foot
1.0 mm (.039")	.080" x .025"	Center of foot

2.1.4 Fine Pitch SMT Parts

Use land patterns in guidelines first, use IPC land patterns second, and manufacturer's recommendation third. Contact Manufacturing Engineering for help if none of the above are successful.

2.1.5 Rules for New SMT Packages

Use land patterns in guidelines first, if not there use IPC land pattern, if not there use manufacturer's recommendation, or call Manufacturing Engineering for help.

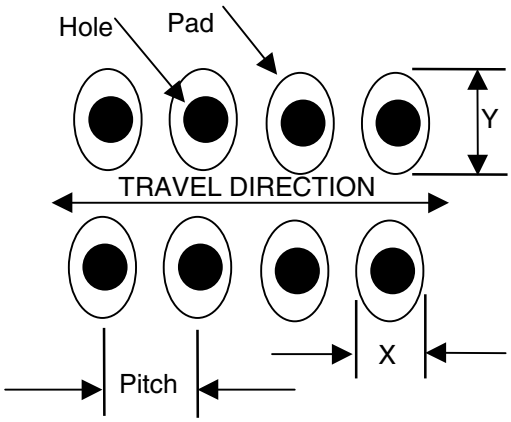
2.1.6 Through Hole Parts

Nominal Finished Hole = Maximum lead diameter + .017"

Nominal Pad (Multilayer) = Nominal finished hole + .022"

Nominal Pad (Single Sided) - Nominal finished hole + .030”

Double Sided / Multilayer Boards				Single Sided Boards			
Comp. Type	Lead Size Max. Dia./Diag.	Hole Size +/- .004”	Recommended Pad Size	Comp. Type	Lead Size Max. Dia./Diag.	Hole Size +/- .003”	Recommended Pad Size
All	.021	.038	.060	All	.021	.038	.065
IC’s only	-	.038	.060	-	-	.038	.060
All	.028	.045	.067	All	.028	.045	.075
All	.035	.052	.075	All	.035	.052	.085
All	.042	.059	.085	All	.042	.059	.090
All	.049	.066	.095	All	.049	.066	.100
All	.059	.076	.100	All	.059	.076	.110
All	.073	.087	.110	All	.073	.087	.120
All	.087	.101	.135	All	.087	.101	.140
All	.101	.115	.140	All	.101	.115	.150
All	.115	.129	.170	All	.115	.129	.180
All	.129	.143	.190	All	.129	.143	.200
All	.143	.157	.210	All	.143	.157	.220



ARRAY LEADED DEVICES ≤ 0.100” Pitch

Pad Diameter X = (.6)(Component Lead Pitch)

Pad Diameter Y = Nominal Finished Hole + .016

Minimum X = Plated Hole Diameter

Pad break - out allowable in X dimension only; Trace connections must be on the Y dimension.

If X < Y use oval pad as defined

If X > Y use round pad of diameter Y

2.2 Design Rules

Note: For those situations not covered in this document, please refer to IPC standards.

2.2.1 Placement Rules

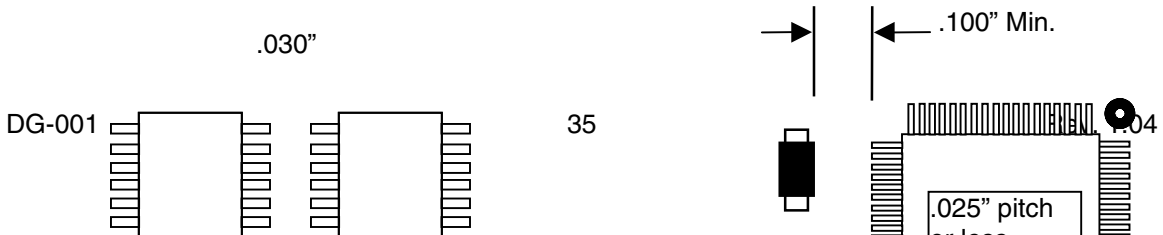
Item	Rules	Remarks
Antipads	• If hole < .060 add .035 -.040 to Diam. • If hole >.060 add .060 to Diameter.	• See sec. 0
Board outline	Parts must not be placed nearer than .125 to the board edge for ICT gasketing.	• See secs. 0, 0
DIP	• Must provide .010 plus maximum body lengths for end to end spacing. Must provide .400 min. spacing from lead center to board edge for parts placed parallel to board tooling.	• See secs. 0, 0, 0
Axial, auto-inserted	• Maximum component diameter: .420 minus 2 times board thickness. • Lead spacing: .300 min./.850 max. Center to center distance should be minimum of .170 over maximum body length (prefer .200 over). • Lead diameter - .015 to .032 dia. • Board thickness: .062 • Orientation: Rotations of 0, 90, 180, 270 allowable. Prefer components in line, not staggered.	• See secs. 0, 0, 0
Axial, manually inserted, Contact inserted	• Orientation: Rotations of 0, 90, 180, 270 allowable. Prefer components in line, not staggered. Staggered parts are acceptable with staggered part's lead to nearest part's lead a minimum of .100.	• See sec. 0
Radial	• TO-92 transistor leads must be in-line. • All leads must be on .100" centers. • .1", .2",.3" auto insertable lead centers. • 0°, 90°, 180°, 270° part orientation only • Unclinched SIP leads require an additional .004" added to the hole size. Unclinched leads are not guided in by the tooling.	• See sec. II.B.1.f.
Fiducial Marks	• Two fiducial vision points should be provided on PCB (or panel) for artwork registration.	• See secs. 0, 2.3.1.1
Ground plane on outer layers	• Ground planes on outer layers of board should be crosshatched to reduce board warpage.	See sec. 0

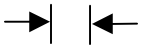
Item	Rules	Remarks
Hand soldered parts	Adjacent component body clearance from hand soldered lead must be equal to the adjacent component height. This is needed for solder iron access.	• See sec. 0
Orientation	It is preferred that all IC pin 1's and polarized parts (i.e. diodes, tantalum caps) be oriented in the same direction, for ease of assembly and to reduce errors.	
Plane layers	• Must use thermal relief's on all pins connected to inner planes • Antipads for pins not connected to plane layers should be .035 - .040 larger dia. than hole diameter for holes smaller than .060 diameter.	• See secs. 0, 0.
SMT 0402, 0504	• Should not be used on wave solder side of board, because adhesive squeezes onto pads causing soldering problems • Should not be used on reflow side of board due to placement machine limitations. New equipment required	See sec. 0
SMT 1812, 1825, 2010, 2512 or larger	• Should not be used on wave solder side of board, because of susceptibility to cracking in wave solder • Should not be used in applications with a high degree of temperature cycling over the life of the product; these devices are subject to thermal cycling fatigue under these conditions. • Parts should be oriented so as to minimize the stress on solder joints due to board flexing.	See sec. 0
SMT, fine pitchX	• Parts should be placed a minimum of .100 from fine pitch devices having land patterns with pad widths of less than .016, other.	•

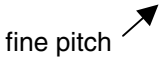
Item	Rules	Remarks
SMT resistors/caps	• SMT components placed on solder side of board under auto-inserted axial components must be spaced a minimum of .125 from lead. For manually placed components this distance is .150 min. No SMT components mounted on wave solder side under DIP packages.	•
SMT SOT-23	Prefer not to use on wave solder side, because of solderability problems and adhesive bonding problems (due to height variations). • SOT-23 place on wave solder side must be spaced a minimum of .125” from leads	See sec. 0
Terminals	• Must allow for insertion head tooling. Contact Manufacturing Engineering for specific applications.	
Test points	• Must provide one access point on solder side of board for each node of circuit and each unused IC pin. • Test points should be .050 min. from any component under .200 tall, and .100 from any component over .200 tall. • Test point spacing preferably .100, the minimum spacing is .050. The .050 spacing requires the use of smaller more fragile probes, which are more expensive and less durable. • Test probe pads to be .045 diameter min. • Test probe pads should be separated from surface mount pads. • Test points may be leaded components, vias, or surface pads. Preference order is 1) Leaded components 2) Vias 3) Surface pads.	• See sec. 0
Thermal reliefs for plane layers	• Thermal reliefs must be used on pins connected to plane layers of multilayer boards.	• See sec. 0

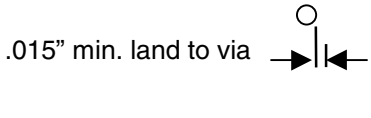
Item	Rules	Remarks
Thermal relief for SMT pads	• Traces wider than .010" should not be connected directly to SMT pads. To provide thermal relief, connect several .010 wide traces between the wide trace and the pad. The minimum distance should be .025"	• See sec. 0
Tooling holes	• Preferably, .125 dia. non-plated holes should be provided for tooling holes. .093 dia. are acceptable. If non-plated mounting holes are present in board, these holes may also be used. • For ICT an area of .350 dia. around tooling holes should be free of components and test points.	• Required for ICT gasketing
Trace width/spacing	• Trace width - .010 min. preferred, .008 min. acceptable • Spacing pad to pad - .010 min. preferred, .008 min. acceptable • Spacing trace to trace - .010 min. preferred, .008 min. acceptable Spacing trace to pad - .010 preferred, .008 min. acceptable	• Board fab cost premium for smaller trace widths and spaces • Vulnerable to solder bridging with smaller spacings • See sec. 0, 0
Vias	• No vias are allowed under parts with metal bodies. Solder wicking through via holes can short to part body, cause damage to insulation covering metal bodied part, or allow processing chemicals to be trapped inside insulation material.	See sec. 0
Vision targets (for components)	All layers should be free of traces .180 diameter around component vision targets.	See sec. 0
Wave soldered parts	• Typically .025 spacing between pads, parts, and leads exposed to wave is sufficient to avoid solder bridging. • Manufacturer's soldering specifications for a part should be reviewed before placing parts on wave solder side of board.	See sec. 0, 0, 0, 0

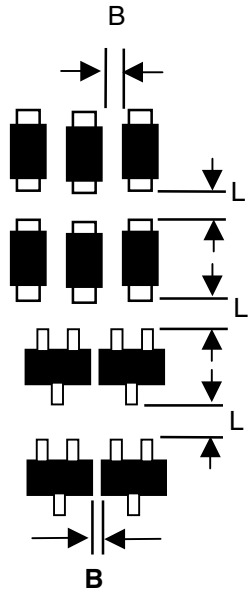
2.2.1.1 Top Side SMT Reflow





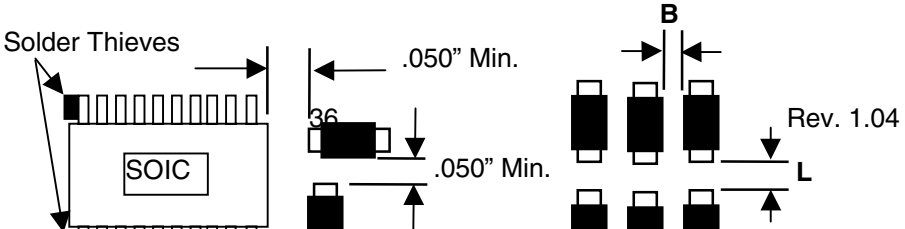






Package Type	Minimum Land Spacing		Minimum Body Spacing	
	L Minimum	L High Reliability	B Minimum	B High Reliability
0603	.030	.050	.030	.050
0805	.030	.050	.030	.050
1206	.030	.050	.030	.050
1210	.030	.050	.030	.050
SOT-23	.030	.050	.030	.050
Tantalum	.030	.050	.030	.050
Fine Pitch	.100	.100	.100	.100
SOIC	.030	.050	.030	.050

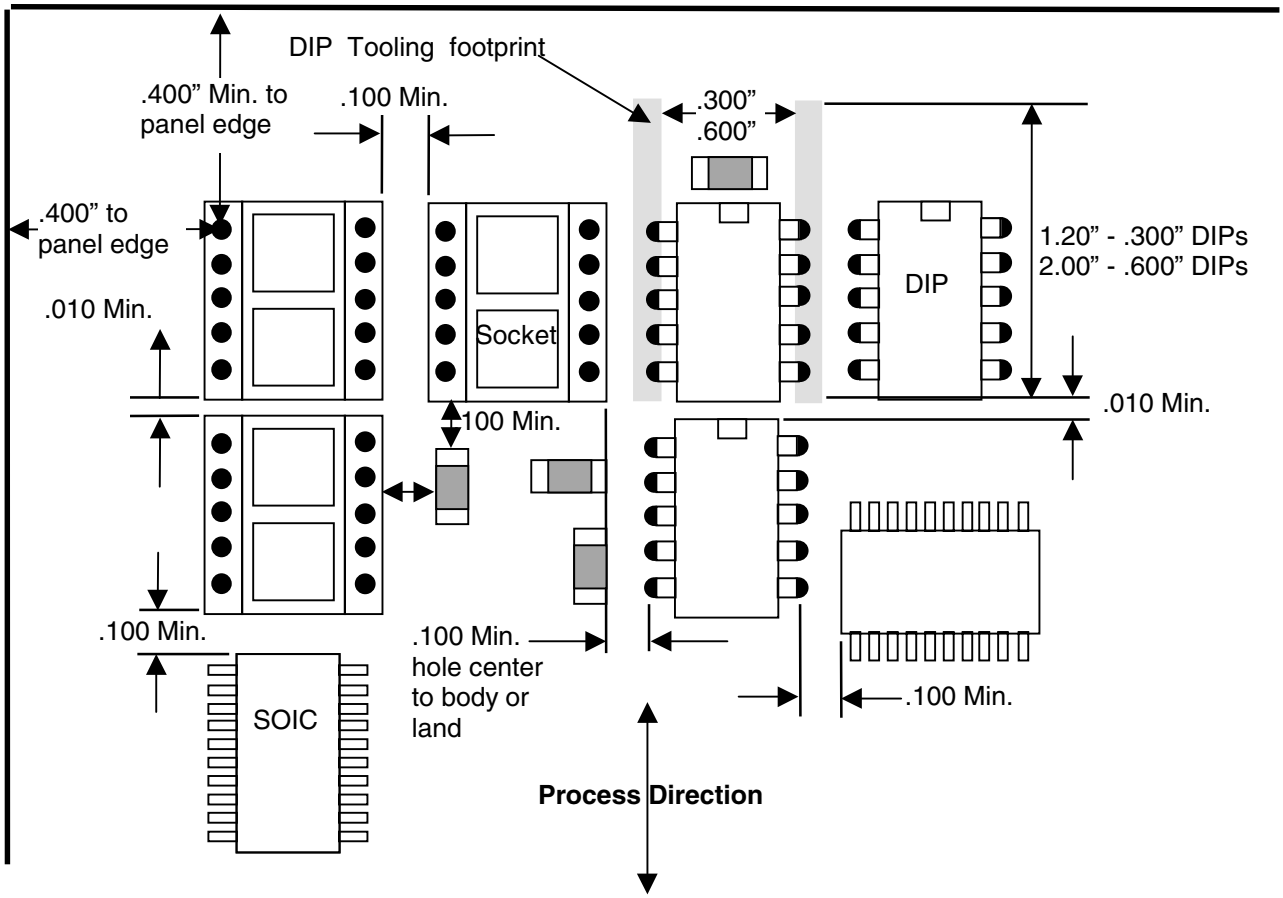
2.2.1.2 Bottom side SMT Wave Solder



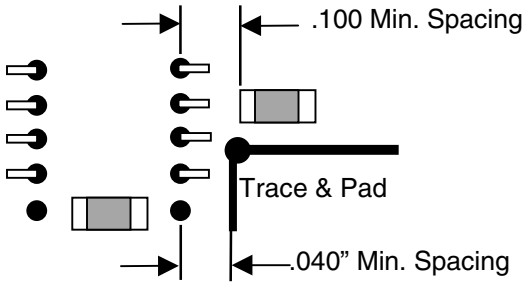
Panel Travel Direction

Package Type	Land Spacing		Body Spacing	
	L Minimum	L High Reliability	B Minimum	B High Reliability
0603	.035	.050	.025	.050
0805	.035	.050	.025	.050
1206	.035	.050	.025	.050
1210	.040	.050	.025	.050
SOT-23	.040	.060	.025	.050
Tantalum	.050	.100	.050	.100
SOIC	.100	.150	.100	.150
Via	.025	.035		

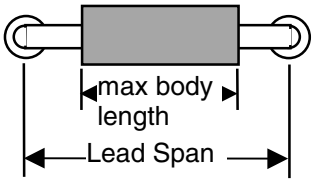
2.2.1.3 DIP Auto-Insertion Top Side Spacing



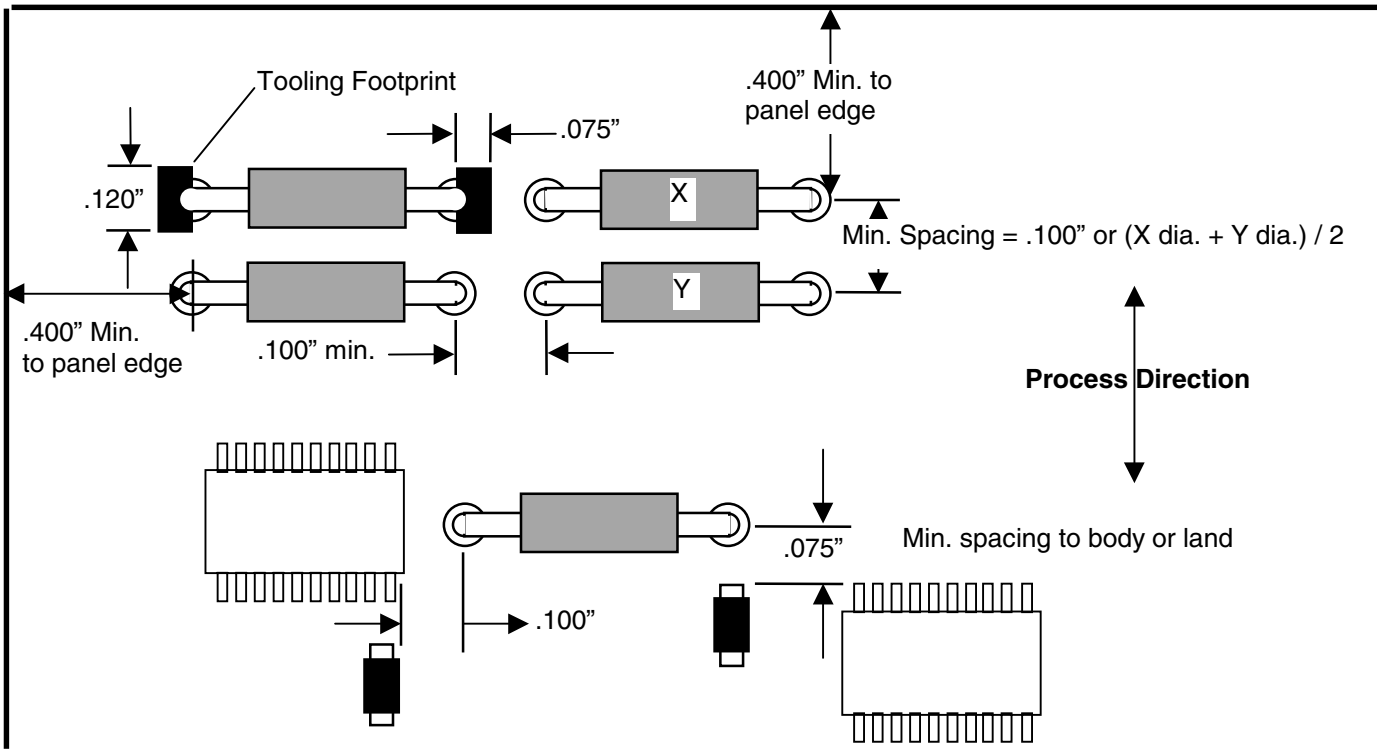
2.2.1.4 DIP Auto-Insertion Bottom Side Clinch Spacing



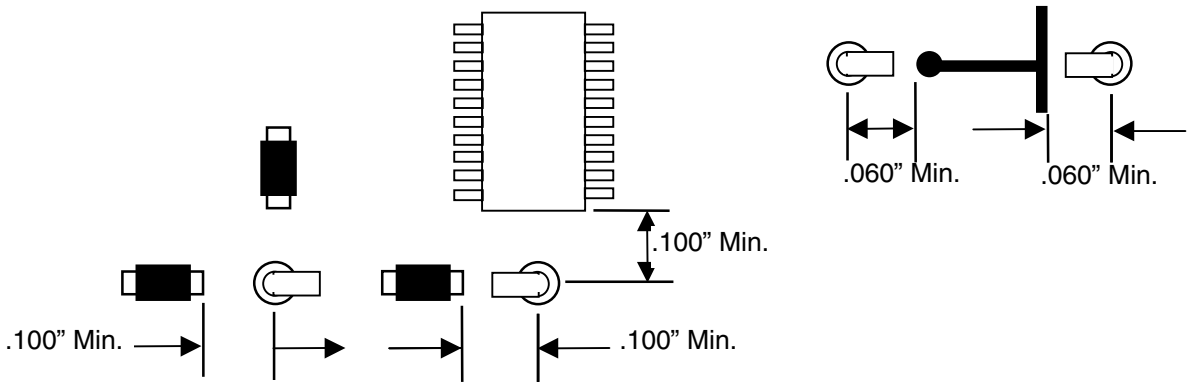
2.2.1.5 Axial Auto-Insertion Top Side Assembly



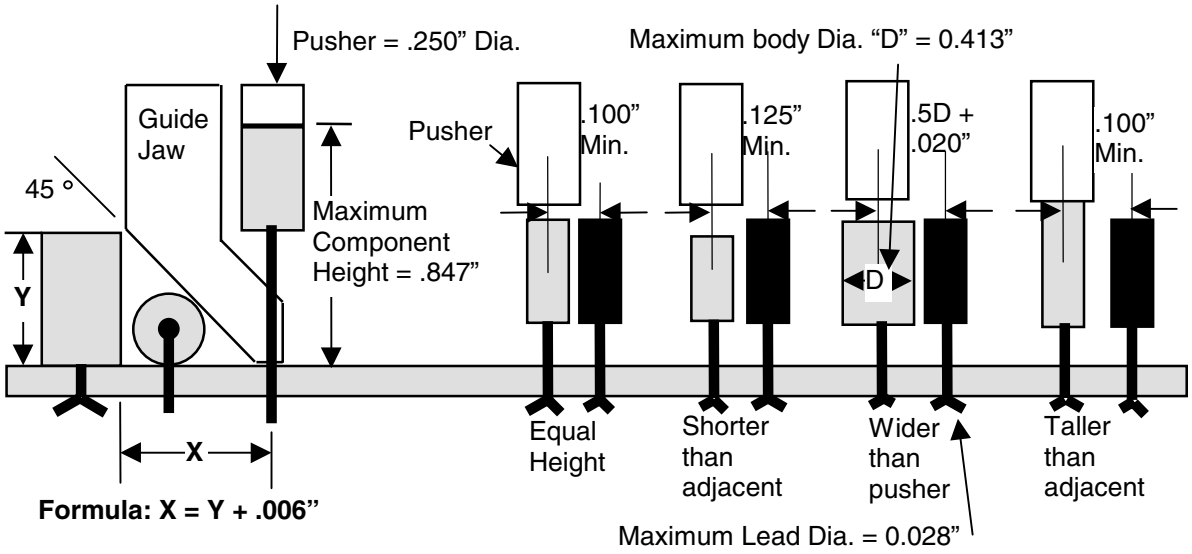
Lead Span (min.) = max body length + .160” + lead diameter
Axial Inserter Lead Span Range : .300” - .850”
Lead Diameter Range : .015” - .032”
Maximum Body Diameter = .420” - Board Thickness



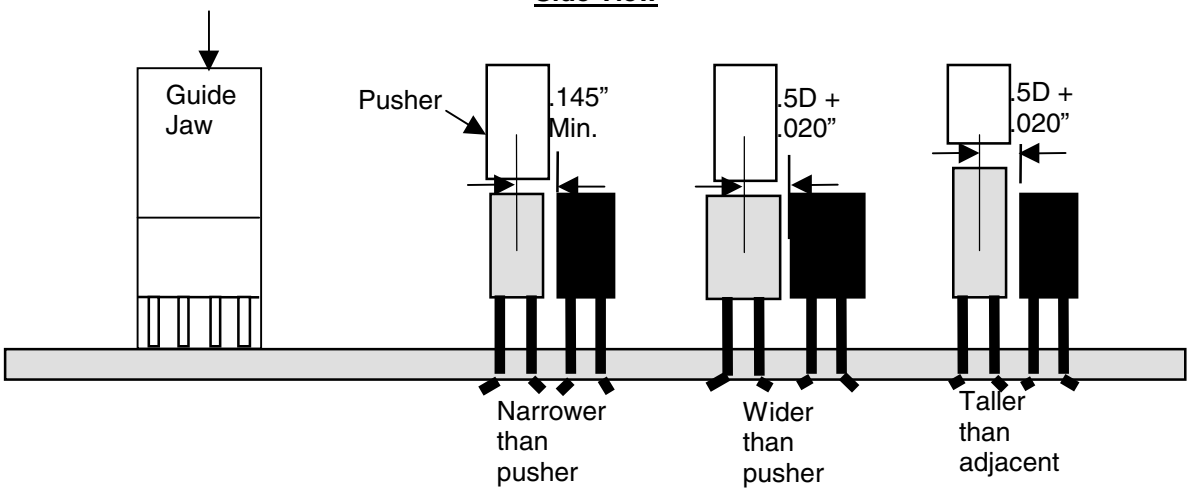
2.2.1.6 Axial Auto-Insertion Bottom Side Clinch Spacing



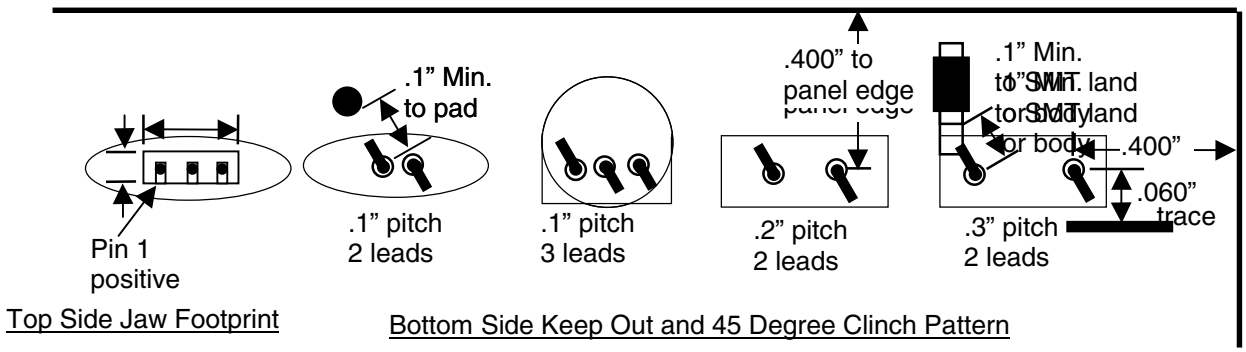
2.2.1.7 Radial Top Side Auto-Insertion Assembly



Side View



Front View

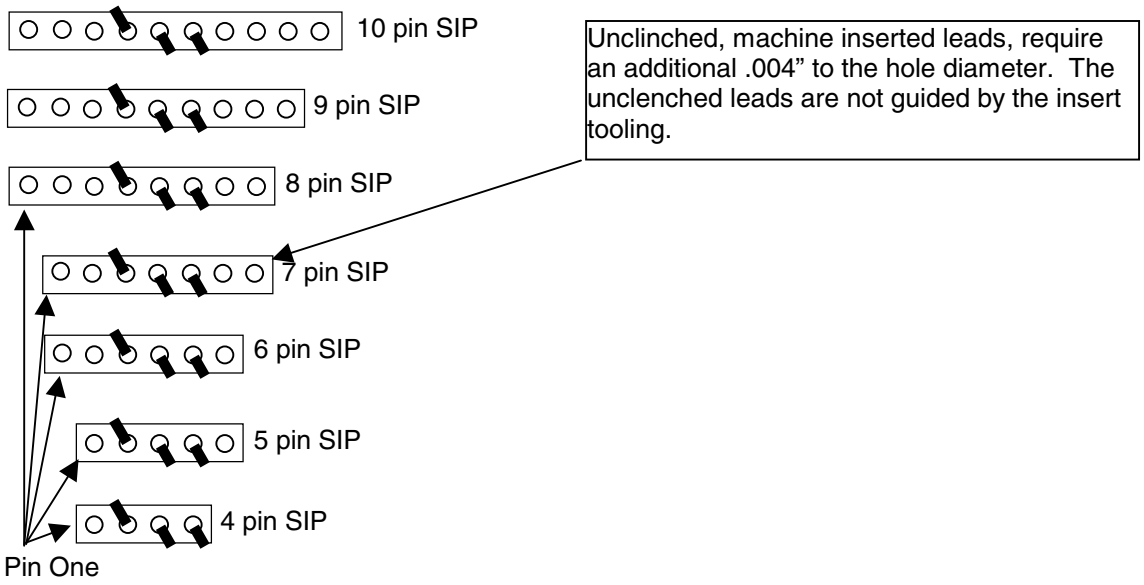


Top Side Jaw Footprint

Bottom Side Keep Out and 45 Degree Clinch Pattern

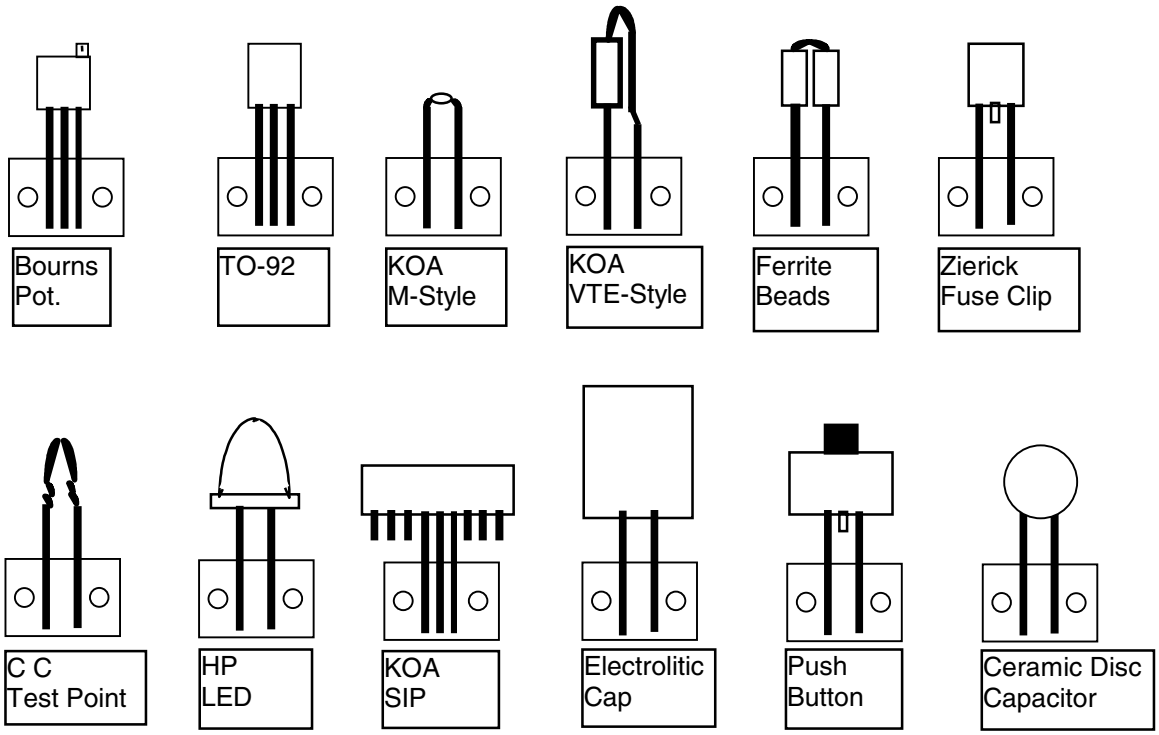
Top View

Radial SIP resistor networks



Top View

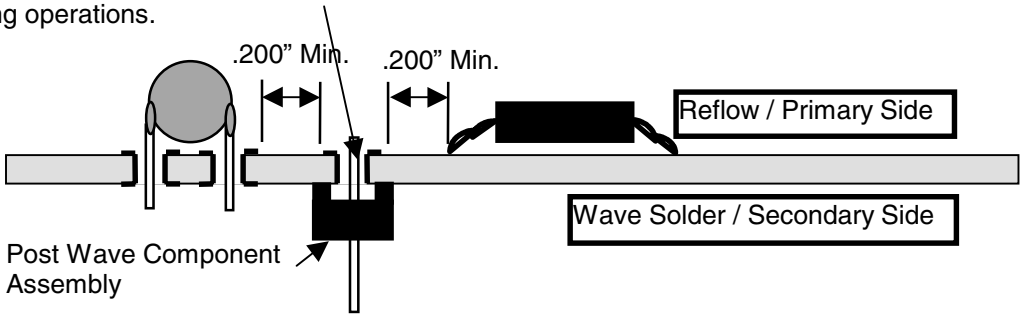
Radial component type examples
All radial components must be packaged on tape and reel or tape and ammo pack.
Maximum lead diameter = 0.028”
Maximum body diameter = 0.413”



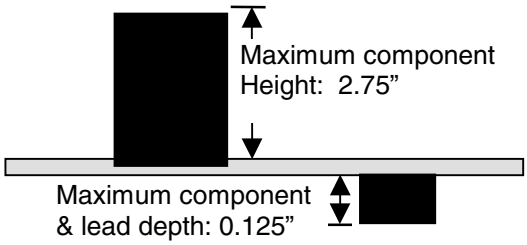
2.2.1.8 Post Wave Solder Manually Manually Inserted Components

Leaded parts mounted on wave solder side

Maintain a 0.200” minimum clearance between the pad and the next adjacent pad or land. This is needed for soldering operations.

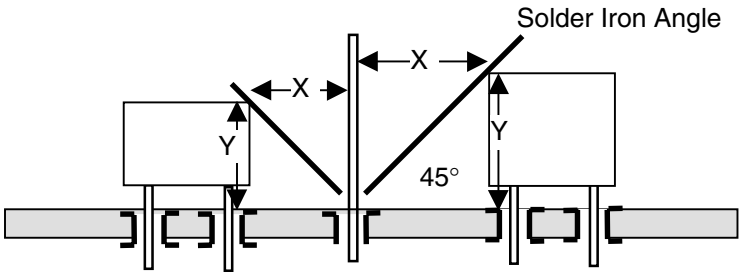


2.2.1.9 Process Clearances Through Wave Solder



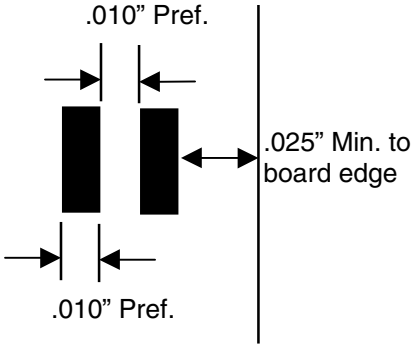
2.2.1.10 Height Rules for Hand Soldering

Lead center to adjacent component : X = Y

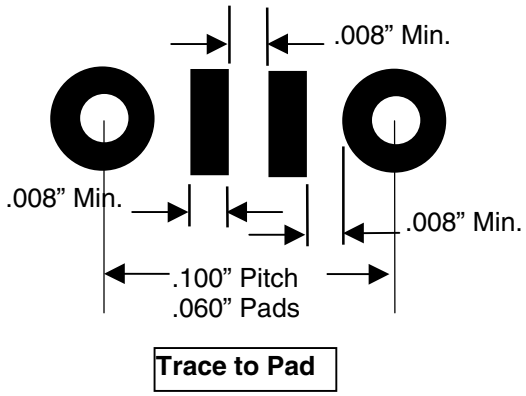


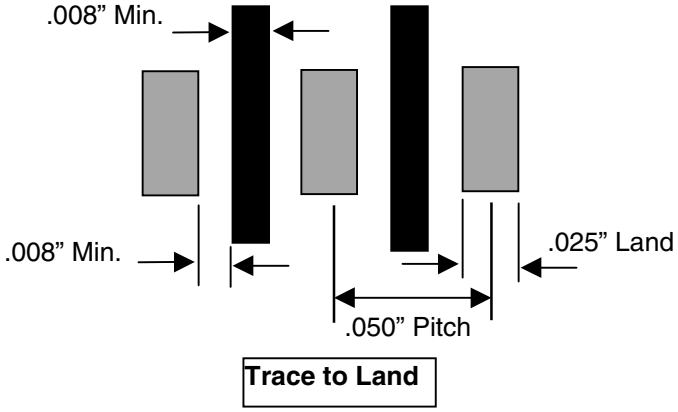
2.2.2 Board Routing

2.2.2.1 Trace to Trace Spacing

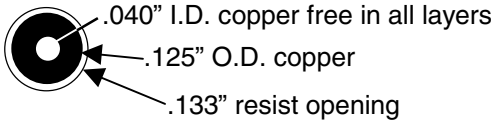


2.2.2.2 Trace to Pad/Land Spacing

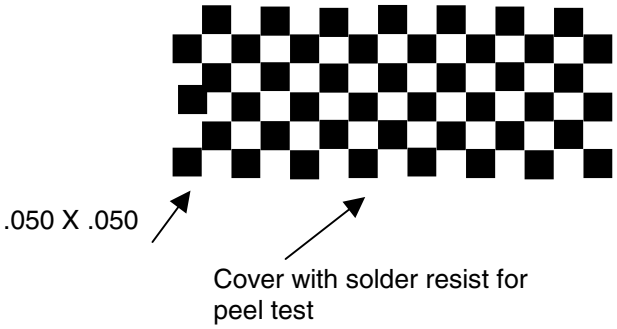


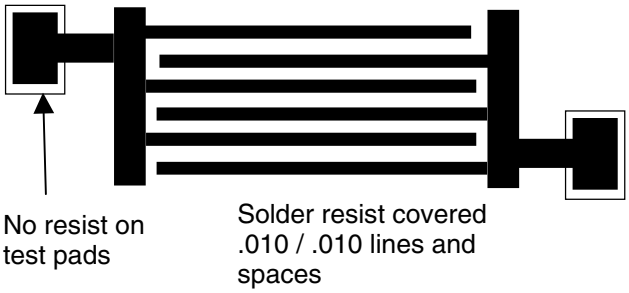


2.2.2.3 Vision Targets



2.2.2.4 IPC Standard Patterns





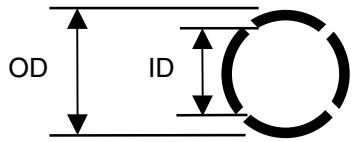
2.2.3 Multilayer Boards

2.2.3.1 Border on Plane Layers

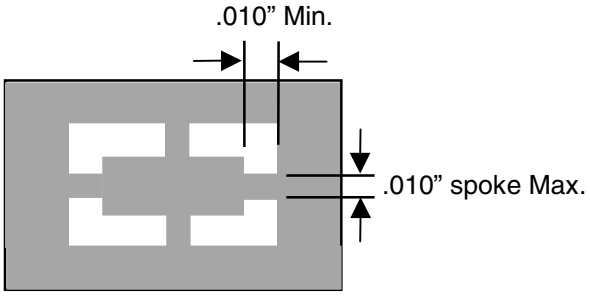
Maintain .050” minimum, .075” recommended copper clearance from the edge of the board

2.2.3.2 Thermal Reliefs for SMT and IMT

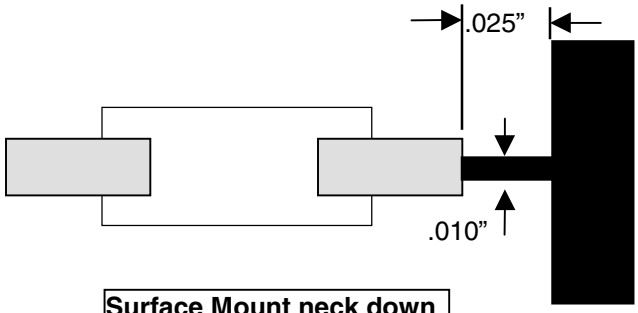
Use a thermal relief pattern for every layer of ground or voltage plane connection.



ID	OD	Spoke
.030	.050	.008
.038	.058	.010
.043	.063	.010
.048	.068	.010
.058	.078	.012
.068	.088	.012
.078	.098	.015
.088	.108	.015
.098	.118	.015
.118	.138	.020
.148	.168	.020
.208	.228	.020
.278	.298	.020



Surface Mount Land Thermal Relief
for outer layer copper plane only



Surface Mount neck down traces to lands

2.2.4 Ground Plane on Outer Layers
Use cross hatch method to reduce thermal load.

2.2.5 Board Identification

2.2.5.1 UL Mark
Provide clear area for PCB manufacturer to put UL mark.

2.2.5.2 Board Part Number
Put board number and revision in copper on the bottom side.
Make room for assembly number label on top side.

2.2.5.3 *Artwork Number and Revision*

2.3 Panelization

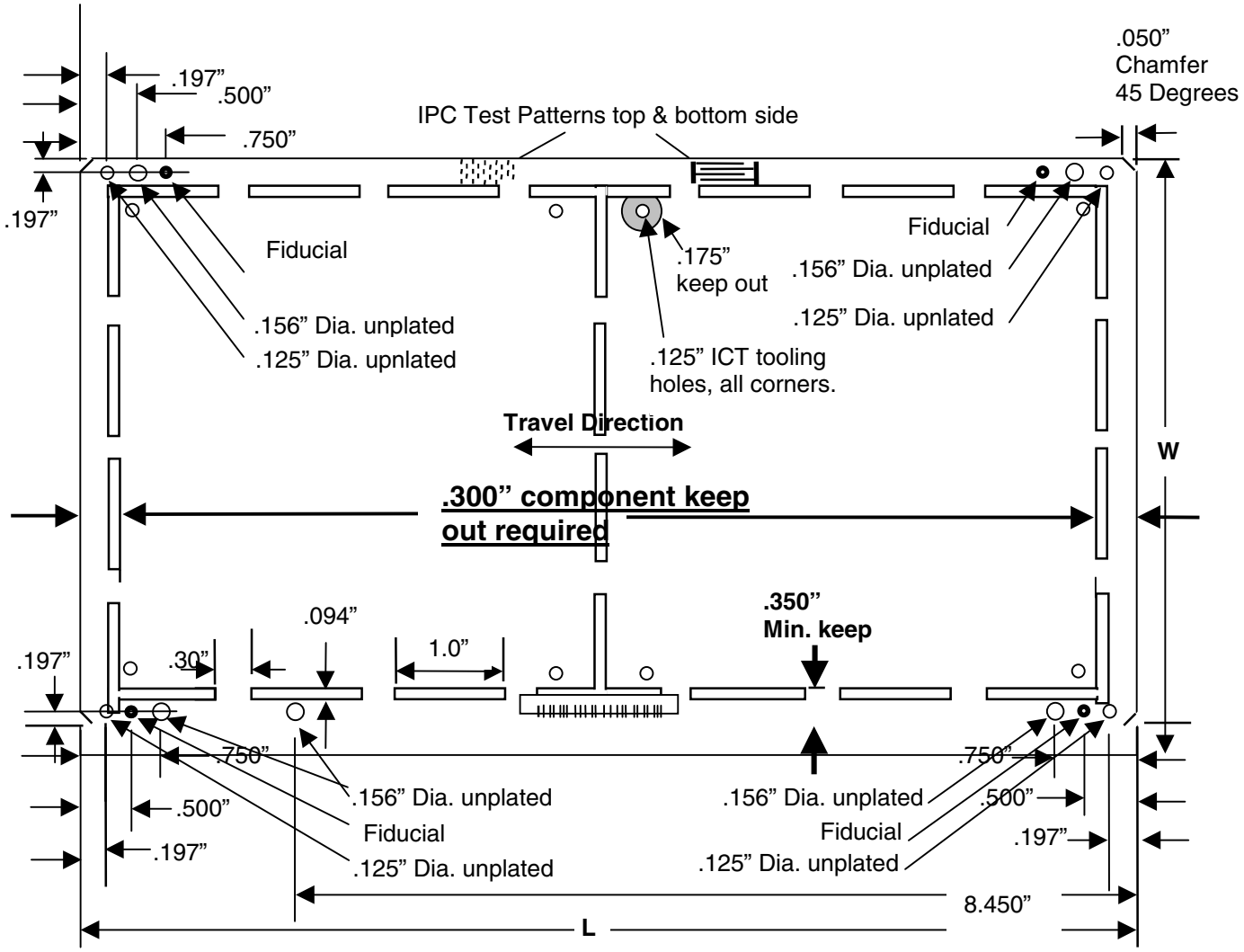
2.3.1 Panel and Board Requirements

All circuit boards require panelization acording to the following specifications.

2.3.1.1 Panel Design

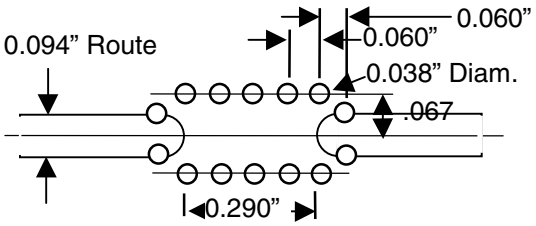
Standard Panel Sizes:

- W = 8" , L = 11", Thickness = .062" (preferred for all production lines)
- W = 8" , L = 13.5", T = .062" (preferred for all production lines)
- W = 7.5", L = 10.4", T = .062" (alternate for PCB-2)
- W = 7.5", L = 9.2, T = .062" (alternate for PCB-2)
- W = 6.0", L = 11.2", T = .062" (alternate for PCB-2)
- W= 5.5", L = 11.2", T = .062" (alternate for PCB-3)

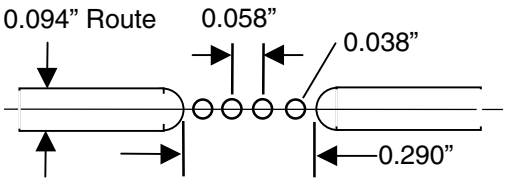


2.3.1.2 Depanelization Approaches

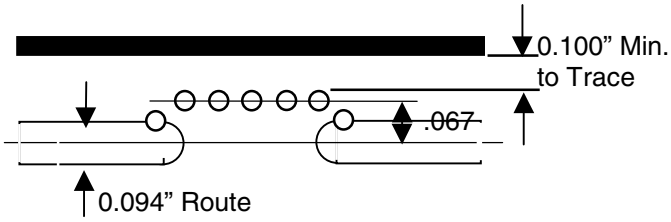
2.3.1.2.1 Break-Away Tab Design



Board to Board Indentation Breakaway

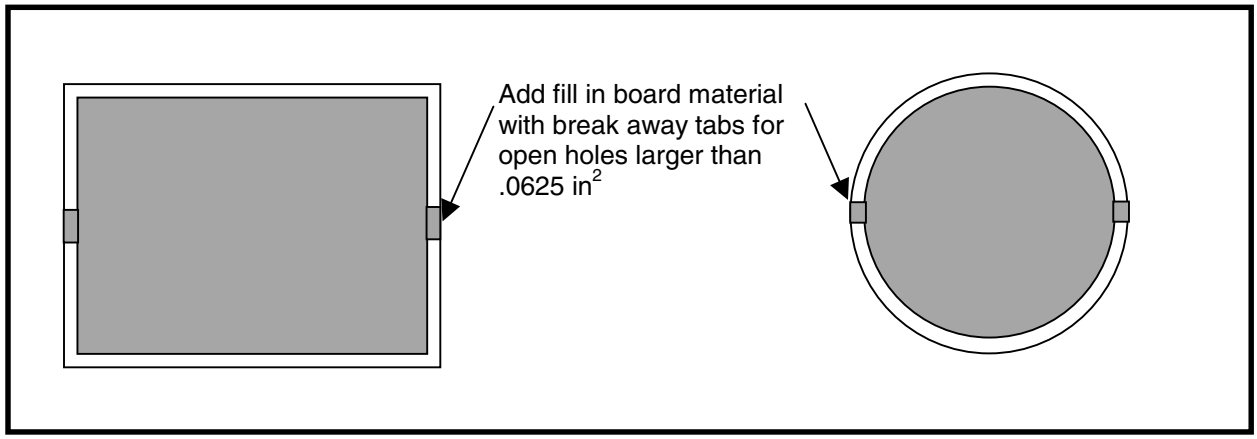


Non-Indented Breakaway

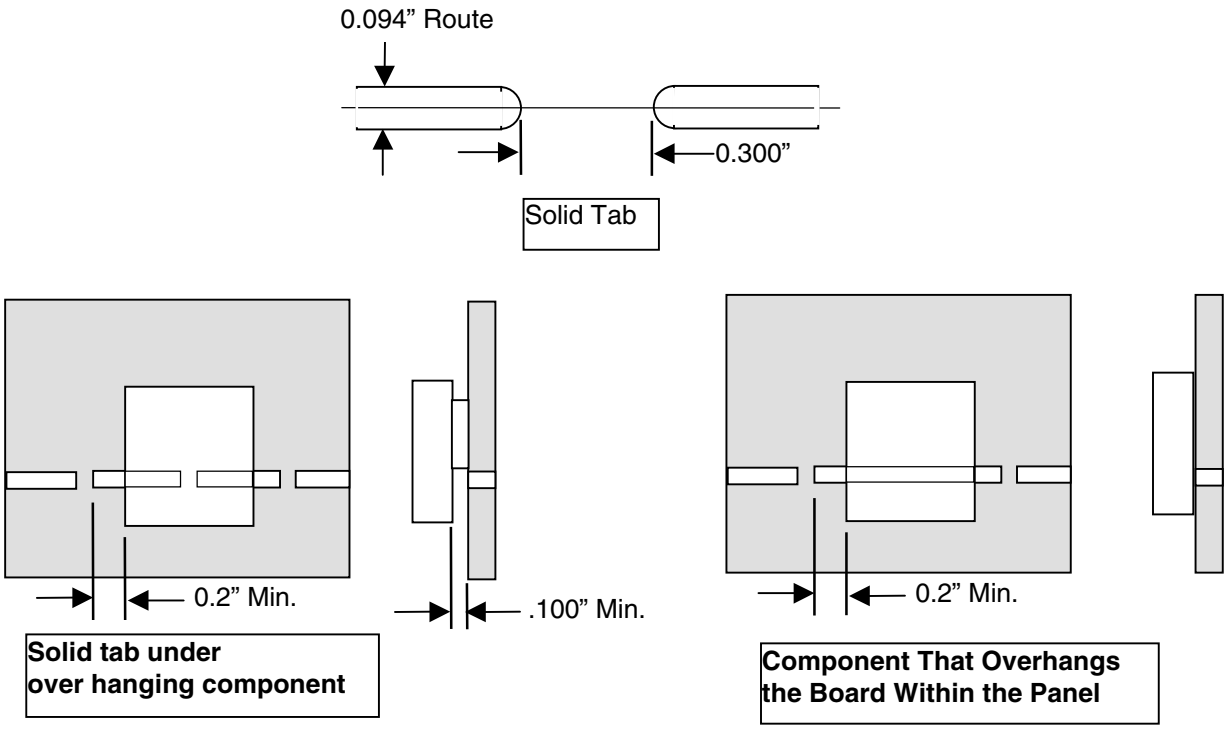


Board to Panel Indentation Breakaway

.000" = +/- .005"
.00" = +/- .010"



2.3.1.2.2 Routed Panel



2.3.1.2.3 Scored Panel

Do not use scoring as depanelization method due to score depth variability.

2.4 Design for Testing

2.4.1 Test Plans and Test Specifications

For any new product a production test plan should be developed early in the project by the project team such that the packaging design facilitates the accomplishment of the test plan. The test plan is simply a sequence of test events which when implemented combine to assure a high level of test comprehensives as related to the product test specification. The Test plan should be total in nature and therefore show test events at both Watertown and any subsequent final product assembly locations. If the total test plan can be developed early, then duplication of efforts and investments can be minimized and test results correlation problems between facilities eliminated.

After the test plan is finalized, then the product design engineer (with inputs from the plant test engineers) should prepare a test specification for each level of testing as related to the test plan.

These test specifications may be combined into one document, but must be officially released from engineering and remain under engineering document control procedure.

Functional test specifications should be designed to test the product to its parametric design limits. Input levels should be specified at worst case input drive levels and the same for output loads, etc. The intent is to prove that the product will "play" with the total mating population. These parametric test specifications tie directly to the published product functional specifications. It is not the intent of a production functional test to prove all interactions of the product firmware. Rather to use this firmware, along with the product communication I/O to detect input actuation and enable output actuation.

The functional test specification should also be designed in a manner such that the product is essentially compartmentalized to aid in design-proof testing and product troubleshooting whenever possible. Also many times it will be necessary for the product software to have built in routines, etc., to facilitate complete and efficient product testing.

The Watertown test engineers and the product development team need to work closely together early on to accomplish early test plans and means to accomplish them.

2.4.2 Test Sequence

The test sequence at Watertown is as follows:

- In- Circuit Test
- Panel Functional Test
- Burn-In Test
- Final Assembly Functional Test

2.4.3 Testability Design Guidelines

2.4.3.1 *In-Circuit Testing*

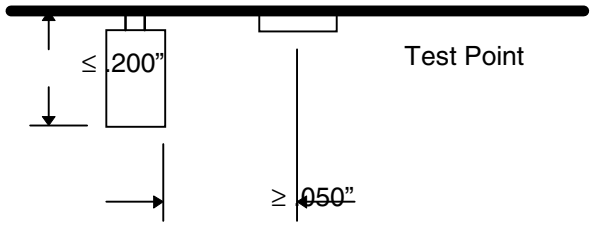
In establishing test points on the PCB solder side, three major areas need to be considered in the decision making process: 1) the test points themselves, 2) vias, and 3) pad-to-pad spacing.

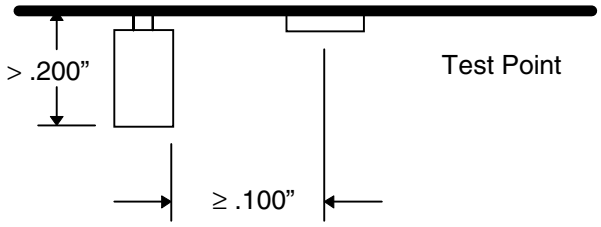
2.4.3.2 Mechanical Considerations

- Test points

A test point on the solder side is recommended for every node and unused IC pin. A test point can be a through-hole lead, test pad, or via.
The solder side test points (either a through-hole lead, via, or test pad) must meet the following criteria

- Test point centers shall be ≥ 0.050" from the edge of a solder side component that is ≤ 0.200" tall.
- Test point centers shall be ≥ 0.100" from the edge of a solder side component that > 0.200" tall.





- Test point centers shall be ≥ 0.050" from the center of another through-hole lead.

The above criteria is based on probe pin limitations. The smallest spacings mentioned above require the use of small fragile SMT probe pins, and consequently, larger spacings are preferred in order to utilize more durable probe pins. Through-hole leads are preferred as test points over vias and test pads as long as they meet the criteria above.

All other nodes not accessible with through-hole leads should have a test point (either a via or test pad) on the solder side. The center-to-center spacing from test point to test point shall be ≥ 0.050". Again, this 0.050" restriction is based on probe pin limitations.

The test points selected (either vias or test pads) shall have a pad diameter ≥ 0.045". If a via is selected as a potential test point, the minimum hole size is 0.020" in order that they can be reliably plated by the PCB supplier and have the holes fill with solder during wave solder.

- Vias

For vias not used as potential test points, the via holes should be tented. The hole size restriction is derived from the PCB suppliers' ability to consistently tent the vias and cost premiums for small holes, and it is desirable for vias to be consistently tented for fixture vacuum and conformal coating seepage concerns.

- Other

- Pad-to-Pad Spacings: 0.040" (Unmasked vias, smt pads, through-hole pads, test pads, or traces)
- Test locations should be distributed as evenly as possible over the board
- Tooling/guide holes must be located in opposite corners of the board.
- There must be an area .175" R from center of tooling hole free of component and test points.
- Provide a sealing edge for vacuum pull down of the board .100" wide when possible.
- In cases where PCB's are manufactured in panels and broken out, tooling/guide holes should be supplied both in the mother panels and in each individual board.

2.4.3.3 Electrical Considerations

- Provide a test point for all electrical nodes. This includes unused IC pins.

- Do not tie IC control lines and resets directly to ground or Vcc. The preferred method is to use pull-up or pull-down resistors. This allows the In-Circuit tester to control these lines as needed during IC testing.

- Oscillators should be buffered with a logic circuit that will allow the In-Circuit tester to disable the clock signal as needed during IC testing.

2.4.4 Functional Testing

No special requirements beyond those for in-circuit testing.

2.5 Coating

2.5.1 Product Design Considerations

- Conformal coating is an extra cost operation.
- Boards not in standard panel size will require additional tooling.
- Humiseal Coatings offered:
  - 1B31, 1B73LOC, 1A33, 1A33LOC.
- Coating material must be part of the Bill of Material.
- A coating map must be included with the drawing package. This must include thickness and no coat areas.
- Coat areas should be kept square or rectangular (90° corners).
- Tall components shield short ones from the coating material.
- Do not place components needing coating within 0.125" of no coat areas.
- No coat area must be a minimum of 0.25" X 0.25"
- Do not coat unsealed parts such as relays, connectors, ect.
- Tooling holes should be of a standard size and located in all four corners.

- Parts that require coating should not be placed closer than .125” from tooling holes. This is needed to prevent obstructed tooling holes.
- Parts should be at least .125” from panel edge from oven conveyor clearance
- Test points and no coat areas should be a minimum of .250” by .250” square.
- Parts or points that require coating should not be placed closer than .250” from parts that are taller than .5”.
- Parts or points that require coating should not be placed closer than .125” from parts or points that are “no coat areas”.
- Avoid placing components that require coating in an inaccessible place or placed closer than .250” from parts that are taller than .5”.

Potting

2.6.1 System Capabilities:

- Material is delivered to product via a static-mixer dispense tube. The potting material opening on this tube is approximately 3/16”. Thus material is delivered in a 3/16” stream.
- Material viscosity is 750 cps @ 25°C
- Dispense rate is variable. The range of variation is 16cc/second. The slower dispense rates are preferred to prevent bubbling of the material.
- Dispense amount precision is $\pm$ 1cc.

Curing is currently performed at either 66°C [150°F] or 120°C [248°F].

Product Design Considerations:

- Dispense Opening: A minimum of 1/2” opening is recommended as a fill point.
- Air Pockets: If air pockets cannot by tolerated, the design needs to allow the escape of air as the potting is dispensed into the product (i.e. large horizontal surfaces or inverted pockets tend to trap air and make processing difficult.)
- Cure: The cure temperature stated under system capabilities are preferred, however other temperatures are an option. See the UR-190 data sheet for recommended cure schedules.
- Fill Quantities: Tight tolerances ($\pm$ 1cc) fill quantities are possible, however it is recommended that these be avoided.
  Seal: The viscosity of UR-190 decreases when introduced to heat for curing, thus the enclosure needs to have appropriate sealing.

3. Documentation

3.1 Design Documentation Set

The preparation of clear and complete design documentation is vital for the successful transition from design engineering to the all of the production facility functional groups including purchasing, manufacturing, production control, process engineering, test engineering, etc**. For any document, the writer should focus on who will be using the document and what actions or decisions the users will be making based on the document.** Eaton, Cutler-Hammer, Watertown has the following CAD packages: Anvil, AutoCAD Lt., ECAM, PADS, PADS Logic, Pantheon, UniCam, and View Logic. Any drawings or files available in these formats, along with PDF (Adobe), HPGL (Plotter File), Postscript, and Gerber File formats, are required (electronically).

A complete documentation package must include:

Assembly Drawings
Bills of Materials
Test Specifications (as required)
PCB Data / Files
Packaging Specifications
Programmed Part Drawings / Files (as required)
Schematics
PCB Panel Fabrication Drawings
Special Workmanship Standards
Purchased Part Drawings
Engineering Change Notices

An additional resource of the documentation requirements for manufacturing may be found in industry standard ANSI/IPC-D-326 (or latest revision) titled "Information Requirements for Manufacturing Printed Circuit Board Assemblies".

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3.2 Assembly Drawings

Drawings available in the file formats listed in Section 3.1 (Design Documentation Set) must be sent electronically. The assembly drawings for all assembly levels of the product should only contain information necessary to meet design requirements or specifications. Each part on the drawing must be traceable to its corresponding bill of material (i.e. via reference designators, item numbers, etc.). The drawing should accurately identify the proper orientation of electronic and mechanical parts. There may be notes which specify requirements that are not governed by or are more restrictive than the applicable workmanship standards. Other items to consider when developing assembly drawings are as follows:

- **component height** - Specify the maximum and minimum heights where appropriate when the height of a component may fluctuate upon assembly and the height is critical to next higher level assemblies.
- **lead protrusion height** - Specify lead protrusion minimum and maximum heights when the control of the heights cannot be relinquished to general workmanship standards.
- **component perpendicularity** - Specify the perpendicularity of components when the control of the element cannot be relinquished to general workmanship standards.
- **switch settings** - Specify switch settings when specific product switch settings are required upon shipment.
- **torques** - Specify minimum and maximum torque requirements when the control of the torques cannot be relinquished to general workmanship standards.
- **unfilled plated holes** - Specify the plated holes that are to be free of solder for use at the next higher level assemblies or for use by the customer.
- **wire/cable positioning** - Specify the exact positioning, routing, and length of wires or cables when critical.
- **adhesives** - Specify adhesives as generically as possible by using terms such as "or equivalent". Specify acceptability criteria/diagram when application of the adhesive is critical or when the application of the adhesive cannot be relinquished to general workmanship standards.
- **conformal coating/map** - Show or describe areas of conformal coat coverage. Specify dimensions of coverage acceptability when critical. (Remember to use squares/rectangles in reflecting no-coat areas).
- **marking/labeling** - Specify marking/labeling requirements as generic as possible to allow for manufacturing flexibility. Specify positioning and content to the minimum requirements.
- **order sequence of multi-level parts (hardware)** - Specify or show stacking order/position of hardware components.
- **rework grid for product returns** - For products susceptible to numerous changes, it is desirable to have a grid displaying the disposition/repair of each revision of the returned product.

Any specific assembly work instructions, unless they are a design requirement or are uniquely critical, should not be included on assembly drawings.

Revision notes should be specific and meaningful as space allows.

If there are multiple configurations of assembly, the differences between configurations should be distinguished by 1) showing a separate view for each configuration, or 2) detailing which parts differ between configurations.

If there is only one configuration and there are component locations that are not populated, these component locations should be identified as such on the drawing and bill of materials.

3.3 Bills of Material

The checked and corrected bill of materials (B/M) must be in a Microsoft Excel, Microsoft Access, Plain Text, or equivalent format using the following columns:

- Watertown Part Number / Quantity / Description / Reference Designators
- Customer Part Number / Manufacturer Part Number / Manufacturer / Quantity / Description / Reference Designators

Each item on the bill of material should be traceable to the applicable assembly drawing via item numbers or reference designators along with quantity, part number, and part description. The bill of materials should also reflect other required specification documents that apply to that assembly level such as test specifications, schematics, firmware, special process specifications, coatings, etc.

Revision notes should be specific and meaningful as space allows.

3.4 Purchased Part Drawings

Drawings available in the file formats listed in Section 3.1 (Design Documentation Set) must be sent electronically. Purchased part drawings or specifications should only contain the minimum requirements for procurement and inspection purposes. Any other information presented on the drawing should be denoted as for engineering use only.

For "off-the-shelf" components, specify the part by manufacturer and manufacturer's part number. List all acceptable sources known. For industry standard parts and where any source is acceptable, list the standard part number and note that any source is acceptable. Contact the manufacturing site for preferred parts.

For "custom" components, specify the minimum requirements along with approved sources. If any source is acceptable, note as such, but also identify some potential suppliers as this will assist the buyer in the initial procurements.

Revision notes should be specific and meaningful as space allows.

3.5 Schematic Drawings

The schematic drawing should identify each component by its reference designator as it relates to the assembly drawing and bill of materials. The value, wattage, voltage, and generic part number of each component would assist the users as well.

The schematic drawing should identify all point to point connections. All pins (including unused pins) should be identified along with all test points and external connection points. Showing signal names is also beneficial in that it allows users to troubleshoot product and understand the operation of the product.

If the schematic drawing consists of more than one page, it is desirable to link the signal connectivity between pages.

If there are multiple configurations of an assembly, the differences between configurations should be distinguished on the schematic by 1) showing a separate view for each configuration, or 2) detailing which parts differ between configurations.

If there is only one configuration and there are component locations that are not populated, these component locations should be identified as such on the schematic.

3.6 PCB Panel Fabrication Drawings

A PCB fabrication drawing is a mechanical and dimensional representation of the PWB. It details board dimensions, hole sizes, plated vs. non-plated holes, layers, tolerances, engineering notes, materials, testing, applied specifications, and IAW (in accordance with) regulations.

The fabrication drawing should show the panelized PCB as it is going to be received by the buying facility.

The table format similar to the one shown in the fabrication drawing example may be used to show some requirements and the differences between designs. Many requirements can also be specified by referencing a global specification. Watertown drawing 9073A35 (appended in this section) is an example of a general printed circuit board specification. Consult with Watertown for the latest revision of this documentation and controlled distribution. If any requirements are not defined by or are more restrictive than any referenced specifications, the fabrication drawing should detail this information. In all, the fabrication drawing and referenced specifications should address the following items:

Standards - The standard(s) for which the PWB is to be built. Typically, PCB's are manufactured to meet IPC-A-600 and IPC-RB-276.

Inside Corners Maximum Radius - Determined by how/where the PCB is mounted and the outline of the board.

Minimum Track Width and Space - This is used for determining the complexity of the design for both the buyer and the manufacturer.

Performance Class - The performance class is determined by the end use of the product, and in turn, will determine how the PCB supplier manufactures the PCB. In general, the higher the class, the more expensive and complex the PCB. Most PCB's fall into Class 2. The following is an explanation of each class:

CLASS 1 GENERAL ELECTRONIC PRODUCTS
Includes consumer products, some computers and computer peripherals, as well as general military hardware suitable for applications where cosmetic imperfections are not important and the major requirement is the function of the completed printed circuit board.

CLASS 2 DEDICATED SERVICE ELECTRONIC PRODUCTS
Includes communications equipment, sophisticated business machines, instruments and military equipment where high performance and extended life is required and for which uninterrupted service is desired but not critical. Certain cosmetic imperfections are allowed.

CLASS 3 HIGH RELIABILITY ELECTRONIC PRODUCTS
Includes the equipment for commercial and military products where continued performance or performance on demand is critical. Equipment downtime cannot be tolerated and must function when required such as in life support items or flight control systems. Printed boards in this class are suitable for applications where high levels of assurance are required and service is essential.

Base Material - The base material is specified along with any specifications that must be met. FR-4 glass fiber/epoxy resin is a NEMA grade laminate that is a standard base material for PCB's. GFN per MIL-S-13949/4D is per a military standard and is equivalent to a specific grade of NEMA FR-4.

Thickness - The finished thickness and tolerance of the base material (.062" +/- .007" is typical).

Copper Thickness (Weight) - The weight of copper per square foot that is needed for the inner and outer layers (1 oz. is typical). Specify finished copper weight.

Silkscreen - The color (white is typical) of the silkscreen and the degree to which silkscreen is allowed to be removed in order to avoid pads and plated through holes.

Layers - The number of conductor layers that applies to the design (i.e. single-sided, two layer, four layer, etc.). For multi-layer boards, the layer stackup should be detailed.

Solder Coating - SMOBC (Solder Mask Over Bare Copper) is typical. SMOBC actually refers to the finished product where the PCB will have the solder mask coating applied to the bare copper and then the PCB will have a tin-lead coating applied to the remaining exposed copper areas.

Board Markings - The requirements and board location for the manufacturers' trademark, date code, and UL marking.

Testing - Testing to be performed at the PCB supplier.

Note that if the drawing is sent to Watertown in an electronic file format, the preferred format is AutoCAD(Release 12).

3.7 PCB Data/Files

Along with the PCB fabrication drawing, an electronic data file is needed. Separate the PCB files from any other drawing files. The following information should be included where applicable:

Zip File	PCB Artwork Files	Description	Reference
Zip File #1 PkZip Compatible File Compression Software	Gerber Files • Component Side Copper Layer • Inner Copper Layers • Solder Side Copper Layer • Component Side Legend • Component Side Solder Mask • Solder Side Legend • Solder side Solder Mask • Pre-Route Lines Detail • Solder Paste Stencil Layer(s)	Gerber Photoplotter Language	*See Note 1 *See Note 1 *See Note 1 *See Note 1 *See Note 1 *See Note 1 *See Note 1 *See Note 1 *See Note 1 & Note 2
	Common Aperture List	ASCII Aperture List	
	Drill File	NC Drill File	
	Drill Report (Drill Sizes for Setup of Drill Operation)	ASCII Drill Report	
	Fabrication Drawings (Electronic, e.g. *.DWG, *.PLP, Gerber, Adobe.PDF)	File Types from Section 3.1	
	Netlist (From Schematic Capture Program)	ASCII Circuit Connection List	
	Readme File	List of files contained with a reference to PWB/Panel P/N and revision along with a description of each file	
Zip File #2 PkZip Compatible File Compression Software	Assembly Drawings	AutoCAD, Anvil, *.PLT or *.HPGL	
	Schematic	PADS Logic, View Logic	
	UNICAM ASCII CAD File	ASCII Format Dump	*See Note 3
	PADS, Pantheon	Binary CAD File	
	Parts Placement	ASCII Pick and Place File	*See Note 4
	Readme File	List of files contained with a reference to PWB/Panel P/N and revision along with a description of each file	

* Note 1: RS-274-X format preferred. RS-274-D is acceptable.
* Note 2: Solder Paste Stencil Layer information should:

- Clearly define panel corners and outline.
- Clearly define global panel fiducials.
- Be step-and-repeated if boards are panelized.
- Be "size-on-size" with corresponding metal

layer. If not size-on-size, identify to what extent the stencil layer is reduced.

*Note 3: Instructions for generating UniCam ASCII files can be found at HTTP://www.unicam.com/

*Note 4: X-Y positions should be centroids for SMT parts and Pin 1 for through-hole parts. The Eaton part numbers should also be listed for each part (if UniCam ASCII CAD file is unavailable).

Files should be panelized (where applicable) per the design guidelines prior to being sent to the manufacturing facility. Watertown does offer panelization services - please contact a manufacturing engineering representative if desired.

Compressed (zipped) files must be compatible with PKZIP 2.02, or the corresponding decompressing software must be included with compressed files.

3.8 Programmed Part Drawings/Files

Components requiring programming as part of the manufacturing process should be documented such that the configuration of the software can be easily identified, implemented, and controlled throughout the life cycle of the product.

It is preferred to handle firmware as a manufactured assembly with its own unique part number assigned. This manufactured firmware assembly would then have a bill of materials which at least consisted of the blank device part number. For implementation purposes, it is also preferred that subsequent revisions of the firmware be assigned new manufactured part numbers.

Firmware transfers from the design group to the manufacturing floor can be accomplished through the use of hardware (component) masters or electronic data files. When using the electronic data file transfer method, it is desirable to include file transfer parameters as part of the documentation package. Watertown presently uses Data I/O programming equipment. File translation formats should be Data I/O compatible. It is desirable that firmware master files be created from a previously programmed and verified accurate device. This methods embeds parameters such as offsets and fillstrings into the file. Compiled files or files derived directly from the software development platform are acceptable.

The following diagram portrays some of the information, such as blank part number, sumcheck, and labeling requirements, that should be part of the firmware documentation package.

For more information on the handling of firmware by the manufacturing site, please contact your Watertown representative and/or request a copy of the following Watertown procedure and form.

QS-0415	Product Master Software Release Procedure
F-QS-0415	Product Firmware Information Request Form

Bill of Materials		
1	EATON RAW PART NUMBER	Description - AM27C256JC 150N=ns
1		Label .312" x .500"
1	XXXXXXXX.HEX	Software Data File
1	FIRMWARE NUMBER	Firmware # if different from programmed #

File Transfer SumCheck: 00287A9

Program SumCheck: 00287A9

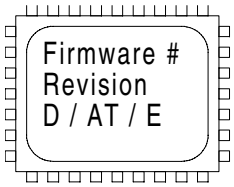
Set programmer to blow and program security fuse to 1

Translation Format: Motorola Exorciser Data I/O Code 81

Block fill all unused locations with 00

Data Offset Information

Byte Swap Information



CAD DIRECT	T:\FIRMWARE	DWG. NO.	FIRMWARE#
SUBTITLE	Control Pannel Prom Firmware	SHEET NO.	1 of 1

3.9 Test Plans and Test Specifications

For any new product, a production test plan should be developed early in the project such that the design facilitates the accomplishment of the test plan. The test plan should be jointly developed by the design team and manufacturing site. The test plan is simply a sequence of test events, which when implemented, combine to assure a high level of test comprehensives as related to the product test specification. The test plan should be total in nature, and therefore, it should show test events at both Watertown and any subsequent product assembly facilities where tests are going to be performed on the product. If the total test plan can be developed early in the design cycle, then the duplication of efforts and investments can be minimized and the problems with test correlation between facilities can be eliminated.

After the test plan is finalized, the product design engineer (with inputs from the manufacturing test engineers) should prepare a test specification detailing each level of testing as related to the test plan.
Test specifications must be officially released from the design engineering group and remain under engineering document control.

Functional test specifications should be designed to test the product to its parametric design limits. Input levels should be specified at worst case input drive levels and the same for output loads, etc. The intent is to prove that the product will “play” with the total mating population. These parametric test specifications tie directly to the published

product functional specifications. It is the intent of a production functional test to prove all interactions of the product firmware. The firmware along with the product communication I/O will be used to detect input actuation and to enable output actuation.

The functional test specification should also be designed in a manner such that the product is essentially “compartmentalized” to aid in design-proof testing and product troubleshooting whenever possible. Many times it may be necessary for the product software to have built-in routines, etc. to facilitate complete and efficient product testing. For any new product, a production test plan should be developed early in the project such that the design facilitates the accomplishment of the test plan. The test plan should be jointly developed by the design team and manufacturing site. The test plan is simply a sequence of test events, which when implemented, combine to assure a high level of test comprehensives as related to the product test specification. The test plan should be total in nature, and therefore, it should show test events at both Watertown and any subsequent product assembly facilities where tests are going to be performed on the product. If the total test plan can be developed early in the design cycle, then the duplication of efforts and investments can be minimized and the problems with test correlation between facilities can be eliminated.

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3.10 Packaging Specifications

Final assembled products being shipped to the end customer should have packaging requirements defined. This includes any boxes, manuals, inserts, foam, labeling, etc. that are required to be shipped with each product. The manufacturing engineer at the shipping site should be contacted to assist in determining proper packaging methods as well as to recommend already existing materials and methods.

3.11 Special Workmanship Standards

Any non-Watertown or non-industry workmanship standards referenced in any of the product documentation should be included as part of the documentation package for

Watertown. Please confer with your Watertown representatives prior to specifying any special or unique workmanship standards.

3.12 Engineering Change Orders

1) To implement a customers' engineering change notice, updated drawings and parts lists are needed. If just the change notice is received and immediate action is not required, the manufacturing engineer at the manufacturing facility would hold the change notice until updated documentation is received.

2) If a customers' engineering change notice requires immediate action, the change notice must identify the corresponding change in revision number. Also, there must be only one change notice per change in revision number, OR all of the change notices that will be implemented with the change in revision number must be identified. The manufacturing engineer will then implement the changes based on the information contained in the change notice(s). Any subsequent change notices written require further increases in the revision number. When updated drawings and parts list are received they will be released into the document control system.

3) Updated drawings and parts lists must reflect all, and only those, changes shown in the corresponding change notices.

In all cases above, the "engineering change" to be implemented shall show the change to all affected documents and provide a clear disposition to other functional areas (manufacturing, purchasing, production control, test, warehouse, etc.). The changes to all affected documents shall be grouped in order to deliver a complete change notice to those functional areas affected.

4. INDEX

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