ADDITIVELY MANUFACTURED ELECTRONICS (AME)

Design Rules for Multi-metal Layered 2D Circuits

Introduction

This document describes the rules required for the successful design of Additively Manufactured Electronics (AME) circuits that are produced by the DragonFly LDM system.

AME circuits are based on the digital processing of acrylate polymer (dielectric) and silver nano-particle (conductive) inks, which are the materials that make functional electronics. The information in this document allows AME circuit designers and developers to attain the best performance by understanding the capabilities of this digital technology, which is governed by pixel size and micron layer build up methodology. Hence it is different from PCB manufacturing based on layering, patterning, drilling and compression of typically FR4 and copper sheets.

Performance is subject to the customer following not only these design rules, but also all the required preventive maintenance for the DragonFly LDM printer as defined in the system's user manuals.

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1. Mechanical & Physical Structure Rules for Conductors in 2D Planes

Maximum AME dimensions	160 x 160 x 3 mm (x, y, z)	
Overall AME thickness	0.7 – 3.0 mm, tolerance of less than ± 5%	
Signal / plane layer thickness*	Min: 17 um, 6 um steps up to 101 um.	
Prepreg between signal layers / signal to plane layer	Min: 25um ± 5% , 6um steps. Max: full job 3mm	
Prepreg between plane to plane**	Pad release and air-gap PTH	Prepreg
	275 um	200 um
	350 um	200 um
	400 um	150 um
	500 um	125 um
	600 um	125 um
	700 um	100 um

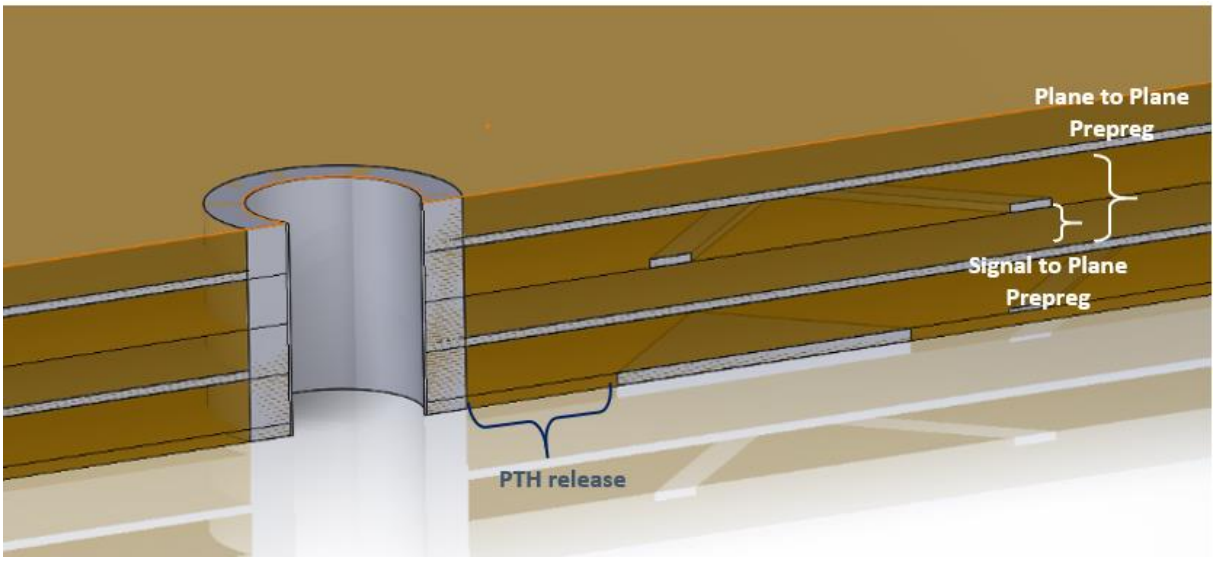

Figure 1. Drawing showing the relationship between signal to plane prepreg, plane to plane prepreg, and PTH release to plane.

Note: The lines between dielectric layers that do not exist in the buildup, are shown here for illustration purposes only.

Solder mask thickness (automatically generated, same dielectric as the rest of the AME device)	50 um		
Edge spacing	0.5 mm (Edge plating is optional) ***		
Annotations	Printed with conductive ink as part of the solder mask layer. If the annotation falls within 180 um from a trace, the Switch software automatically deletes the annotation.		
Number of signal layers (2D AME)	Stackup options related to 3mm total thickness:		
	Signal layer thickness	17 um	57 layers
	Signal layer thickness	35 um	42 layers
	Signal layer thickness	70 um	21 layers
Roughness on top surface****	<2 um		
Roughness on bottom surface	<0.25 um		
Bow tolerance	<0.75%		

* Signal layer is a layer of traces without polygon planes around vias and PTH in 1mm radius. Plane layer is only a conductive polygons layer. In Switch software, both the plane and the signal are tagged as a signal.

** Signal layers with signal-plane and signal-signal rules can be placed between two plane layers.

*** Edge connectors can be used, however each conductor trace that is not connected to the edge connector, must be have at least 0.5 mm spacing from the edge.

**** Per model with an area of more than 0.87mm x 0.66mm.

2. Trace Rules in the 2D Signal Layer

AME is digitally printed and has pixelization effects. All features apart from the thickness – Z axis have discrete steps of 36um squares. All other steps are converted to this scale. The DragonFly printer uses internal axis definitions relevant to its print method. The substrate moves in the Print Axis direction, the vertical is known as the Group Axis and the Z axis remains the Z Axis.

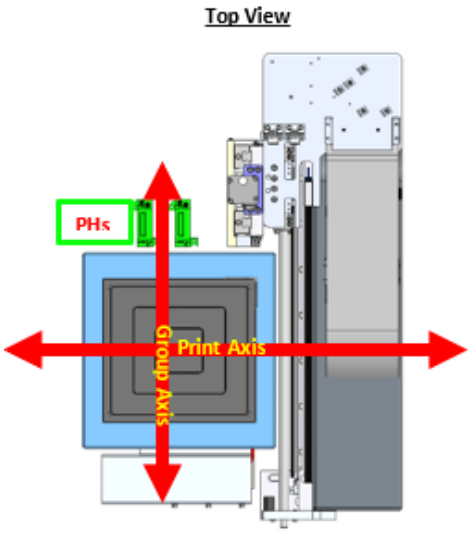

Figure 2. DragonFly Print Axes

Minimum recommended trace width	Direction	Trace thickness (um) (z axis) *
Trace width 110 (um)	Group	<70
	Print	<70
	Diagonal	<70
Minimum recommended electrical clearance / space between traces/planes	Direction	Trace thickness (um) (z axis) *
Electrical clearance 110(um)	Group	17
	Print	17
	Diagonal	17
Electrical clearance 144 (um)	Group	<35
	Print	<35
	Diagonal	<35
Electrical clearance 216 (um)	Group	<70
	Print	<70
	Diagonal	<70
*Tested trace thickness. Steps of 6 um is optional.		

3. Plated / Non-plated TH and VIAS

Through Hole (TH) diameter	Min 400 um ± 36 um
Plated TH diameter	Min 400 um ± 36 um Pad surrounding TH ≥ (TH diameter + 200 um)
VIA (filled) diameter	Min 200 micron ± 36 um Pad surrounding via ≥ (via diameter + 200 um) `
Minimum plating ring width	144 um

4. Design Spec: Main Materials

For more information, refer to the Nano Dimension Ink Users Guide.

Conductivity (silver nano particles)*	$3.15 \times 10^6 - 2.52 \times 10^7$ [σ (S/m) at 20 °C] Printing and sintering conditions dependent***							
Dielectric Constant (Dk) (1092 ink)*	200MHz	500MHz	1GHz	2GHz	5GHz	10GHz	15GHz	20GHz
Acrylate based polymer	2.80	2.81	2.81	2.80	2.78	2.76	2.75	2.78
Tangential loss (Df) (1092 ink)*	200MHz	500MHz	1GHz	2GHz	5GHz	10GHz	15GHz	20GHz
Acrylate based polymer	0.000	0.004	0.006	0.011	0.012	0.013	0.013	0.012
Dielectric breakdown voltage (thickness 0.6 mm)	40.3KV, tested based on IPC-TM-650 2.5.6							

* Due to the nature of the additive manufacturing process, variation on the conductivity is a result of the position of the ground vs signal planes and proximity to the printing chuck. By Q3 2020, the company will release a software feature that minimizes this variation.

** These numbers are measurement technique dependent. They are provided as a reference to start the AME design. For an optimum number it is recommended that customers requiring precise Dk and Df numbers, perform measurements with the equipment they use inhouse.

*** Bulk silver conductivity = 6.30×107 σ (S/m) at 20 °C.

5. Soldering and Population Process

Component placement	Manual or pick and place. Stencil compatible (customer standard mechanical fixture).
Iron soldering temperature	220°C – 235°C (Refer to the Manual Soldering guide).
Blower soldering	165°C - 175°C (Refer to the Manual Soldering guide).

6. Software Compatibility

2D PCB Input files	Gerber x274 design files and Excellon drill files.

Appendix A. Definitions and Acronyms

AME	Additively Manufactured Electronic
DF	DragonFly
LDM	Lights-out Digital Manufacturing
LMS	Learning Management System
ND	Nano-Dimension
PH	Printer Head
PTH	Plated Through Hole
TH	Through Hole

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