Digital Manufacturing and Performance Testing for Application Specific Electronic Packaging (ASEP)

iMAPS New England 43rd Symposium & Expo

May 03, 2016

Introduction

Why do material choices and tight controls matter?

Because we need to move beyond fascinating toys (much less fascinating now) and move to real products.

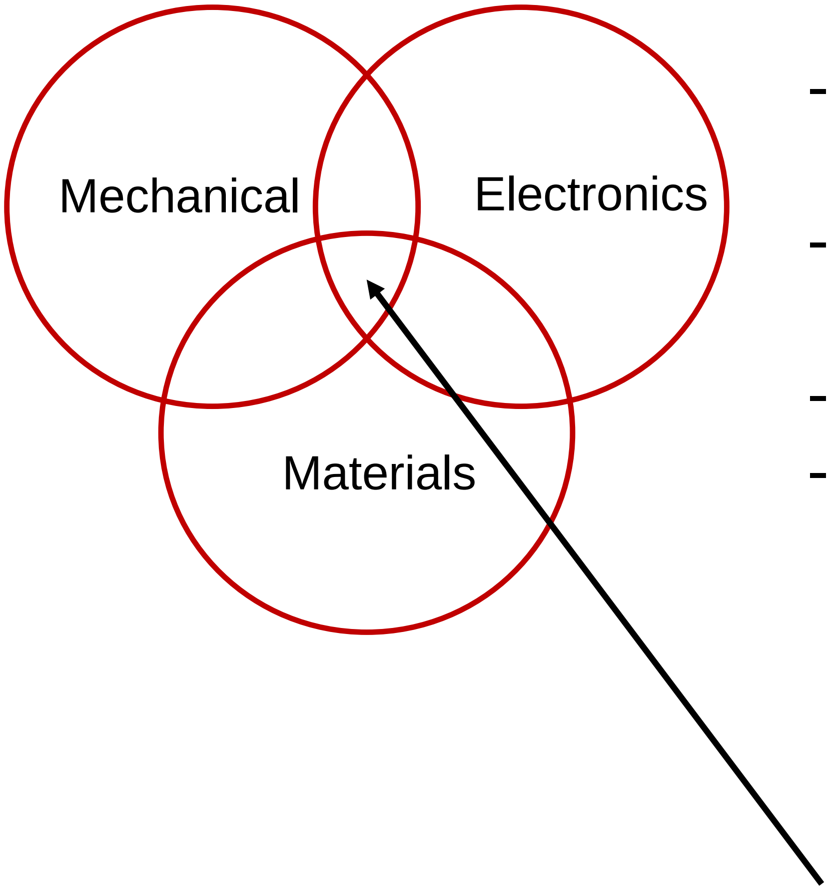
http://3dprint.com/24522/ge-pennsylvania-printing-3d/

Move from real products that are really hard to make, but one single material and one single function…. to multi-material, multi-function.

http://www.neoglobeconsulting.com/blog/2014/5/31/whats-next-five-innovations-of-future-smartphones

Introduction

Structure + Electronics = Structural Defects



- Direct Digital Manufacturing (DDM) => Do we need it?
- Printed Circuit Structures (PCS) => What is it?
- What needs to be done next?
- Conclude

Printed Circuit Structures ⇔ Structural Electronics

Direct Digital Manufacturing

Devices => SmartPump™ also know as micro-dispensing with pico-liter control, nFD™ also known as Fused Filament Fabrication with 12.5 micron features, nMill™ for precision milling and polishing and nPnP™ for pick and place. Diverse material placement for diverse material properties

Slim profiles to allow all devices to set next to each other for tool swapping.

SmartPump™

nFD
™

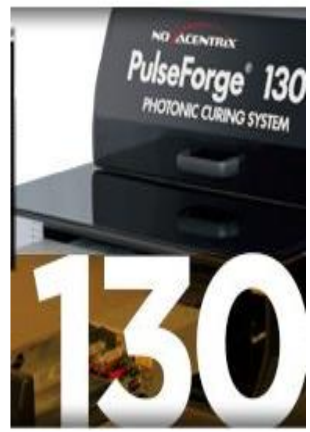
nMill
™

nPnP™

Direct Digital Manufacturing

In Situ Processing => Heaters for the base plate or the pumps, photonic curing utilizing the Novacentrix PulseForge™, UV curing using arrays of UV diodes and diverse lasers for heating, curing, sintering, melting, cutting and surface treatment. These are standard processes in conventional

Heater Controller



PulseForge ™

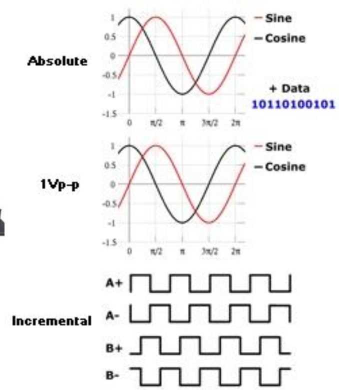
UV Cure

Lasers

All of these are options that fit on existing tool plates, thus combining all processes on a single platform.

Direct Digital Manufacturing

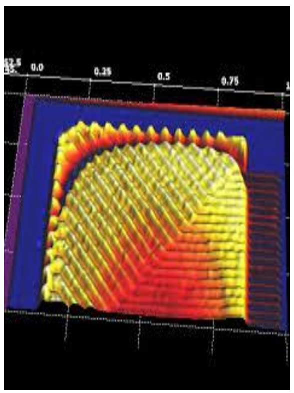
In Situ Feedback => Precision in motion control using linear motors, but also utilizing encoder feedback for precise location of each device, Z height sensing and line scanning using precision Keyence sensors, Cognex vision for quantitative optical feedback and temperature



Encoder Feedback

Z Height Sensing Scanning

Vision



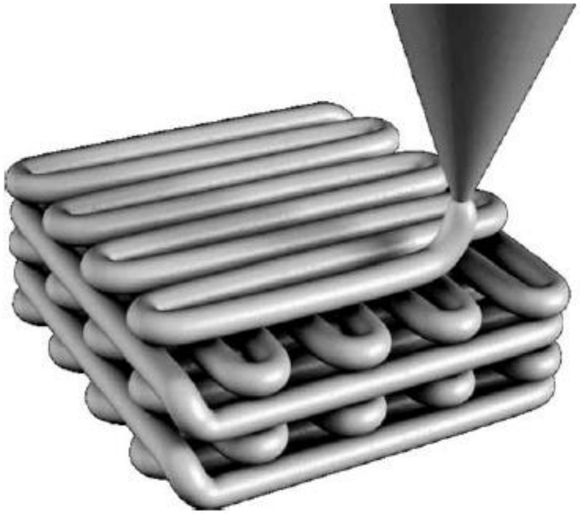
Temperature Feedback

All of these are options that fit on existing tool plates, thus combining all processes on a single platform.

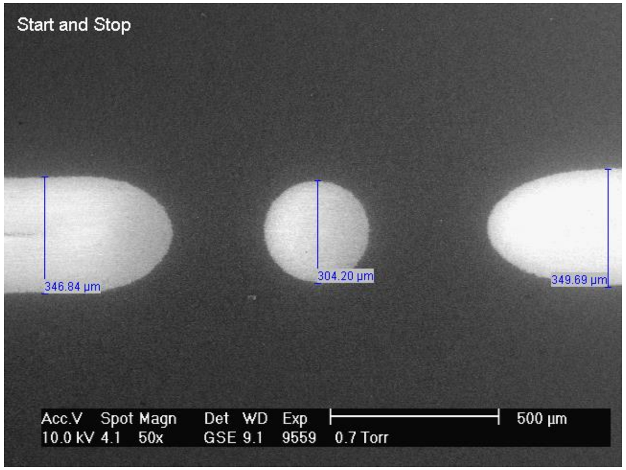
Sciperio
A Science Revolution

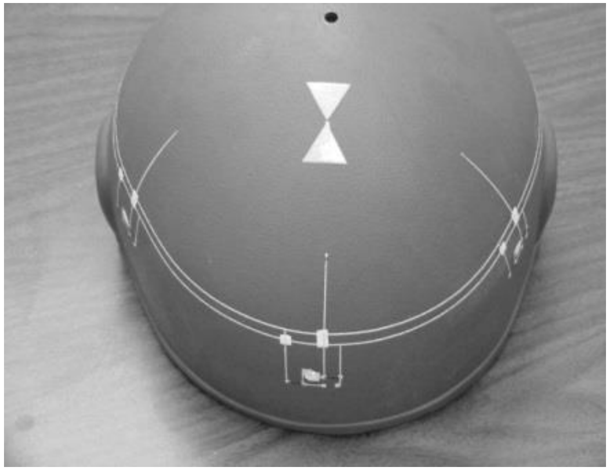
Dispensing Material Control

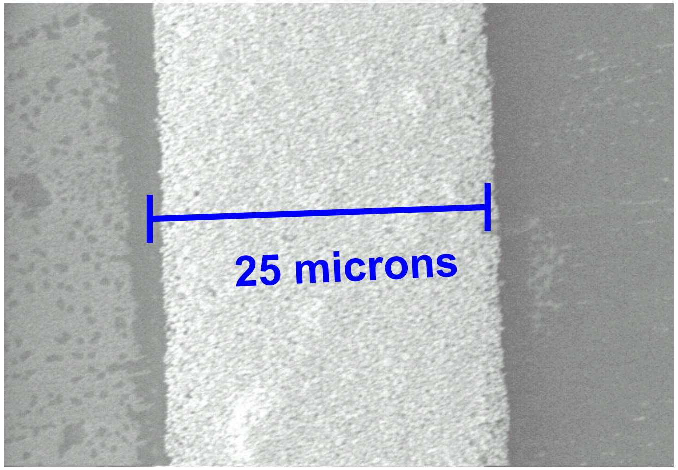
Controlling: 1) Line Width, 2) Start/Stop, 3) Volume, 4) Juxtaposition in XYZ, and 5) Texture



Adjusting the "knobs" of valve opening, pressure, speed, gap and z movement, it is possible to control 3D prints.

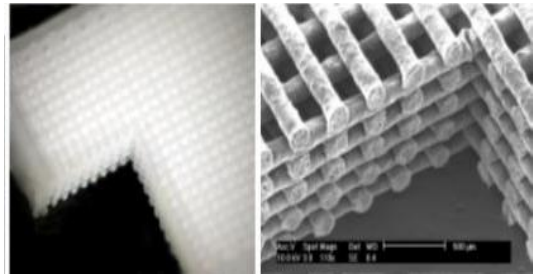






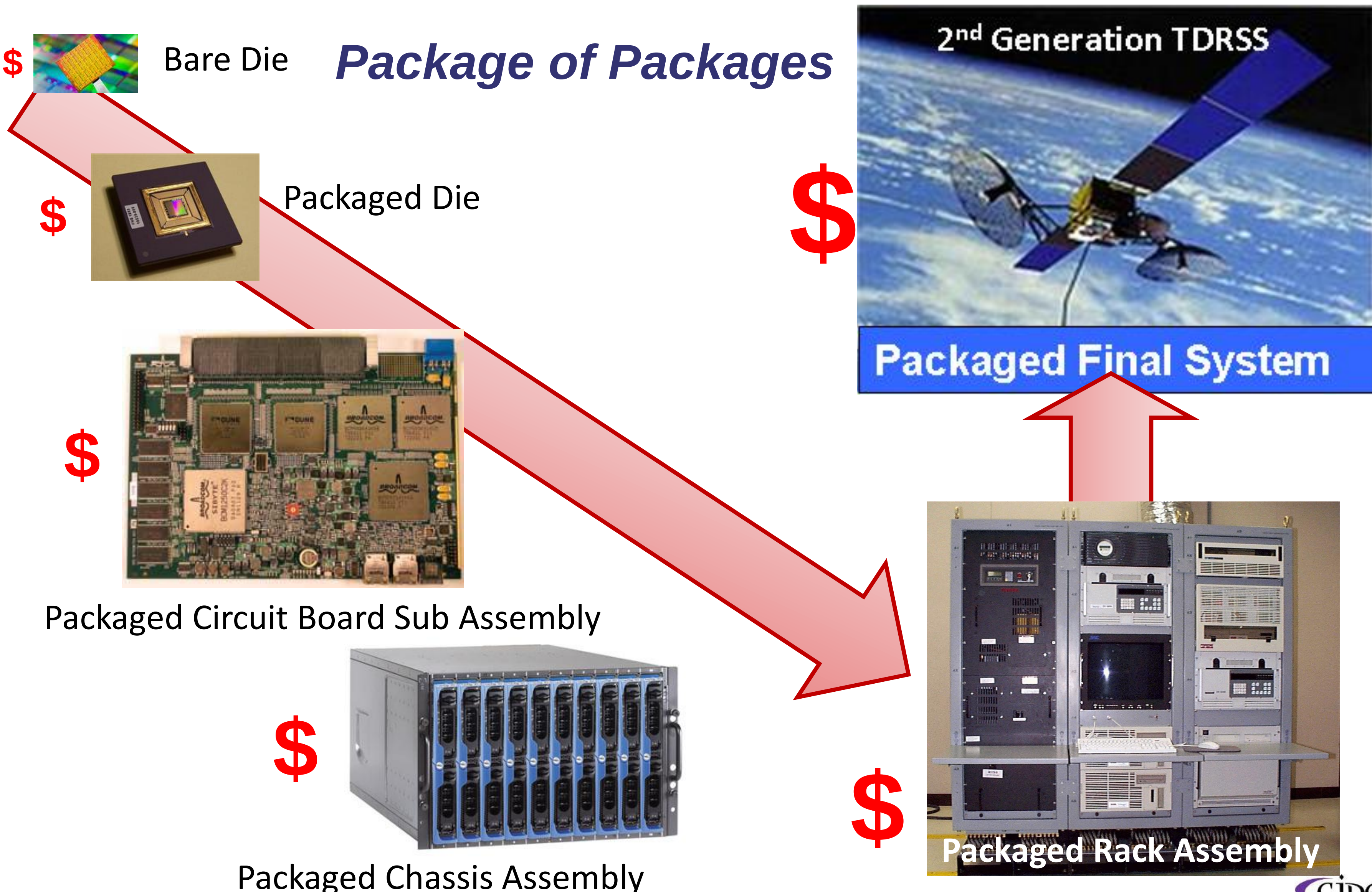
Printing in 3D with Thermoplastics and More

- Thermoplastic materials (ABS, ULTEM™…) have been utilized in products for many years. 3D printing of those materials is not new. Advances in 3D software, temperature controls and motion control have enabled 3D printing.
- Thermoset materials are also in numerous products. Polymer (epoxy) can be loaded with a number of materials and including carbon fiber and then printed in a through nozzle system at room temperature; no clean room required.
- Not all polymers are well suited for 3D printing. Using thixotropic polymers with very high viscosities (greater than 100,000 cP), structures can be built by layering of material; “any” 3D shape.
- Strength of a polymer can be increased by mixing milled carbon fibers or carbon nanotubes into it; both demonstrate strength increases. Continuous carbon fiber is now part of this.
- Compatible printing with other materials to provide true composite builds and including metals.



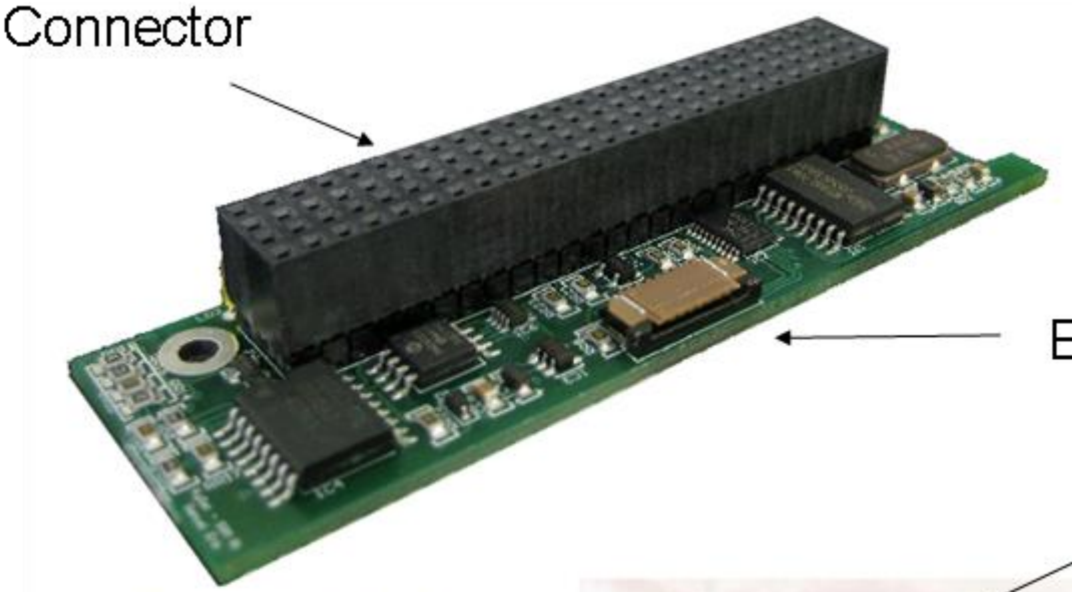
Application Specific Electronic Packaging (ASEP)

A Hierarchy of System Packaging



Sciperio
A Science Revolution

Electronic Packaging



System Support Module

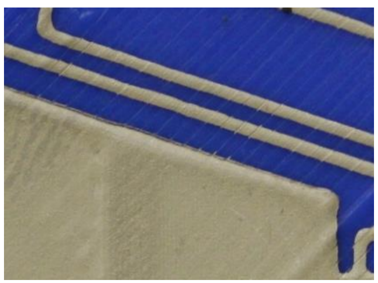
Power System module

3D Electronic Packaging

Revolutionary Art

Most Significant Advantage:
One system with multiple pumps for multiple results.

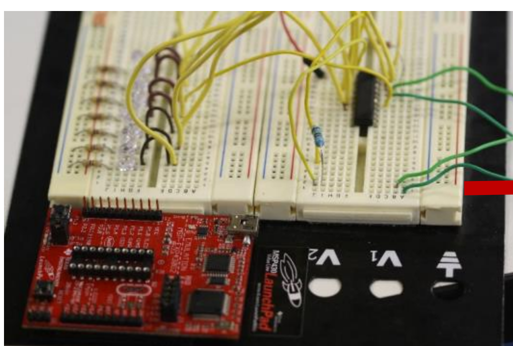
Printed Metal Conductors

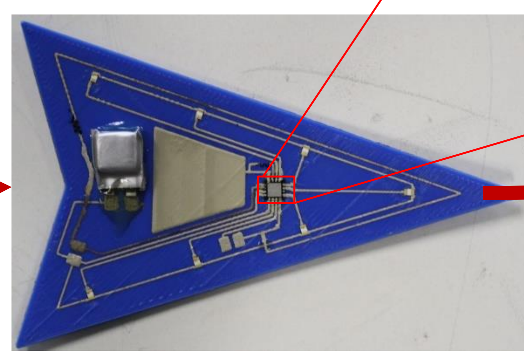


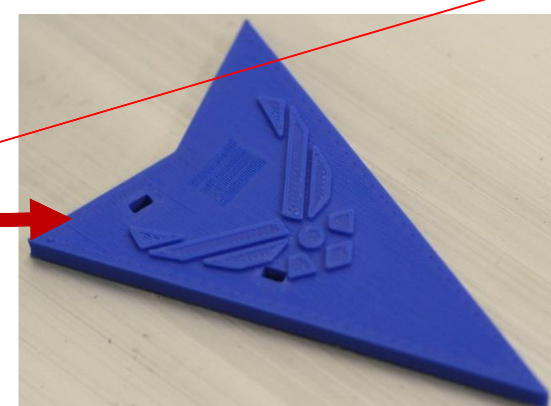
Printed

Plastic -

Pick and Place

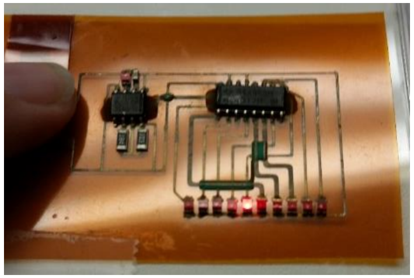






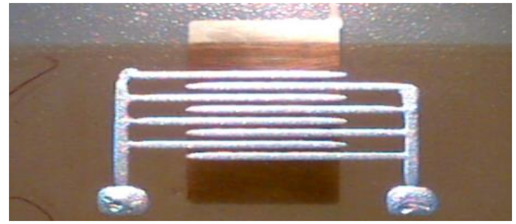
What is 3D Electronic Packaging

Printed Electronics =>

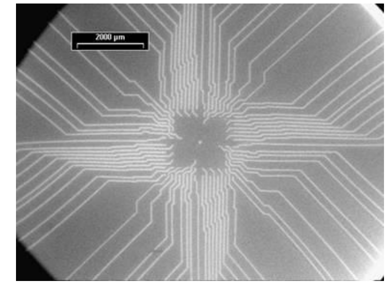


Flexible timing circuit

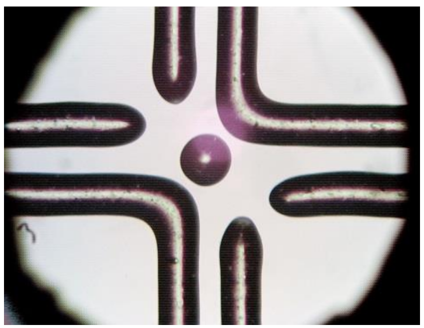
Passives



Polymer FETS



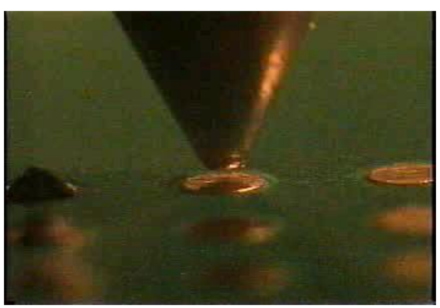
Breakout patterns



Adhesives

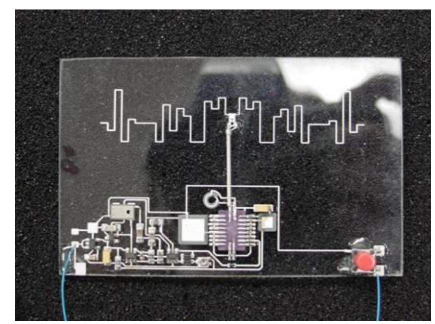
Borrowing from the Printed Electronics Industry….3D Printing is very similar. Both are layering approaches. Both use a variety of materials. Both are digital. Combining is a natural….what's not natural are the experts. The experts do not closely work together. They speak different languages.

Antennas



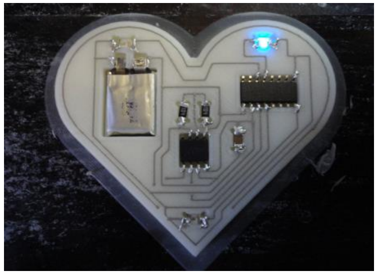
Solder and vias

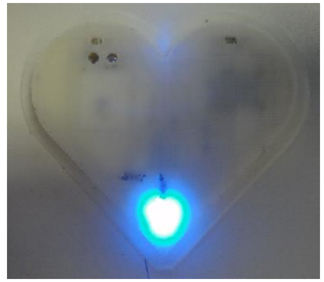
Electroluminesence



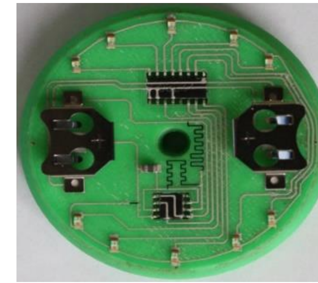
Working Devices

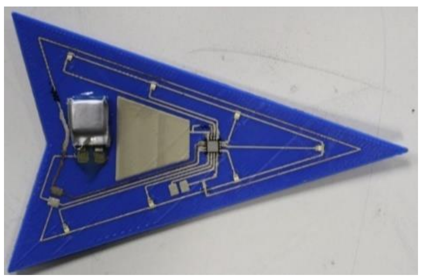
3D Printed Electronics =>


Timing circuit heart

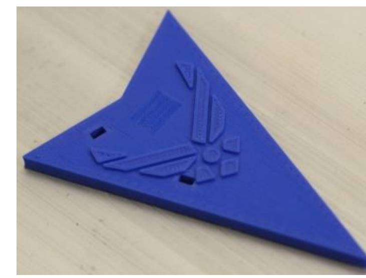

Timing circuit buried

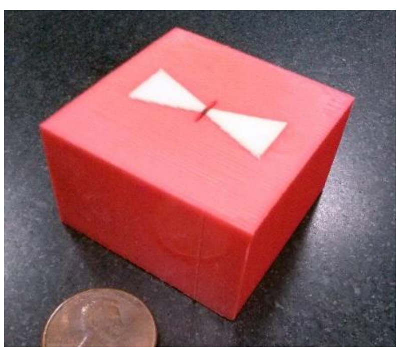

CAD timing circuit puck

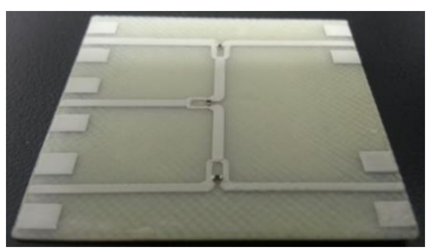

Timing circuit puck

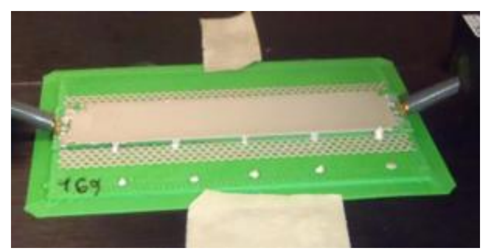

Micro-controller

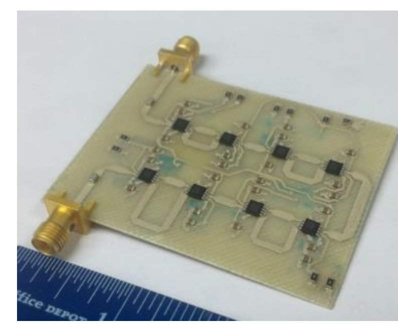
These devices are 3D printed or more completely described as fully digitally manufactured. Substrates for electronics are now structures. Structures for mechanical strength are now electrical substrates. It is critical to compete against State of the Art as a base foundation. This will lead to possibilities only Hollywood has.


Buried micro-controller

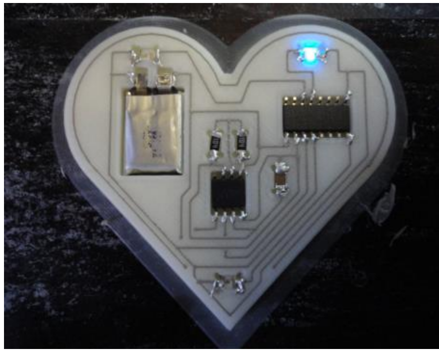

Antenna

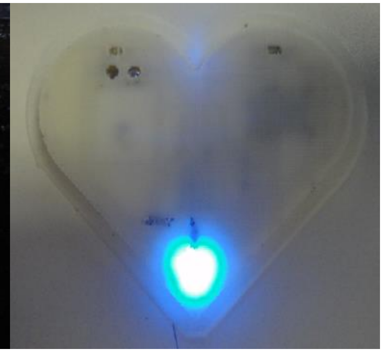

Mult-GHz Power Divider

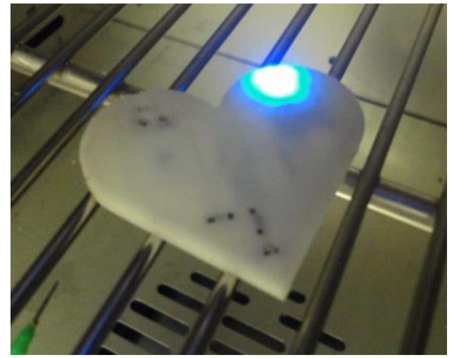

Stripline

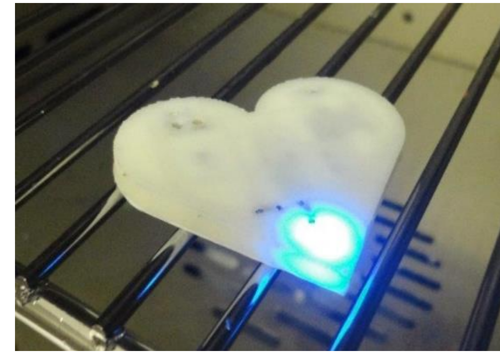

4 Bit Phase Shifter

Printed Circuit Structure Temperature Cycling



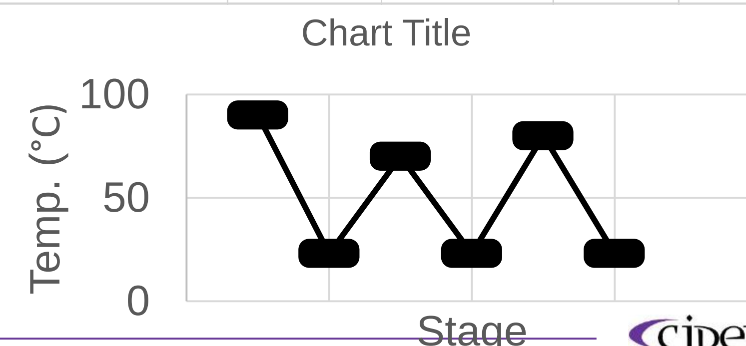




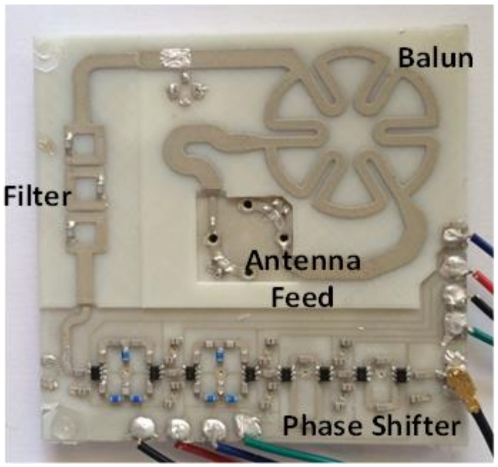


- Digital Patterning (Shape Agnostic)
- Multi-material (Multiple Properties)
- Print to Actives (nPnP)
- Single Tool (One tool, multiple processes)
- TLC (Graduate Students)
- Print and Play (Started Working during Printing)
- Nonstop Operation (Has been running more then 12 months nonstop)
- Temperature Cycling (Initial testing shows good results)

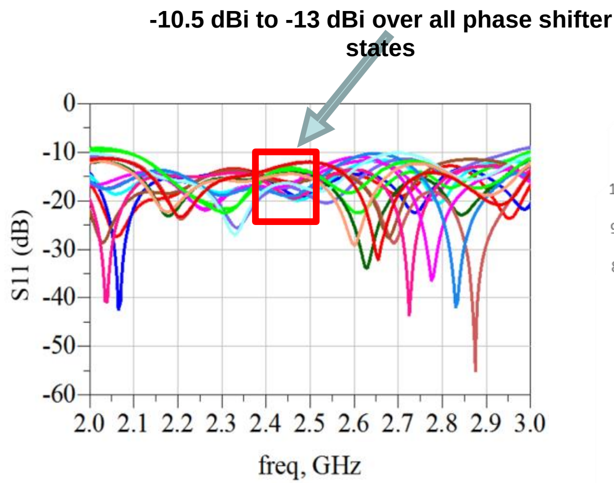
Action	Temp. (°C)	Baking (hrs)	Time	Status
Manufacture	90	4		Working
Oven post-print bake	90	2		Working
Standard Operation	23		130 days	Working
Thermal cycle	70	24		Working
Standard Operation	23		2 days	Working
Thermal cycle	80	8		Working
Standard Operation	23		50 days	Working
Present time	23			Working



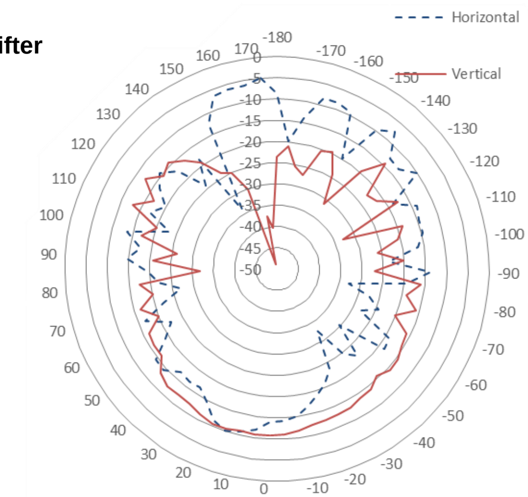
PAA Unit Cell Results



Printed and populated unit cell



Unit cell return loss at all phases

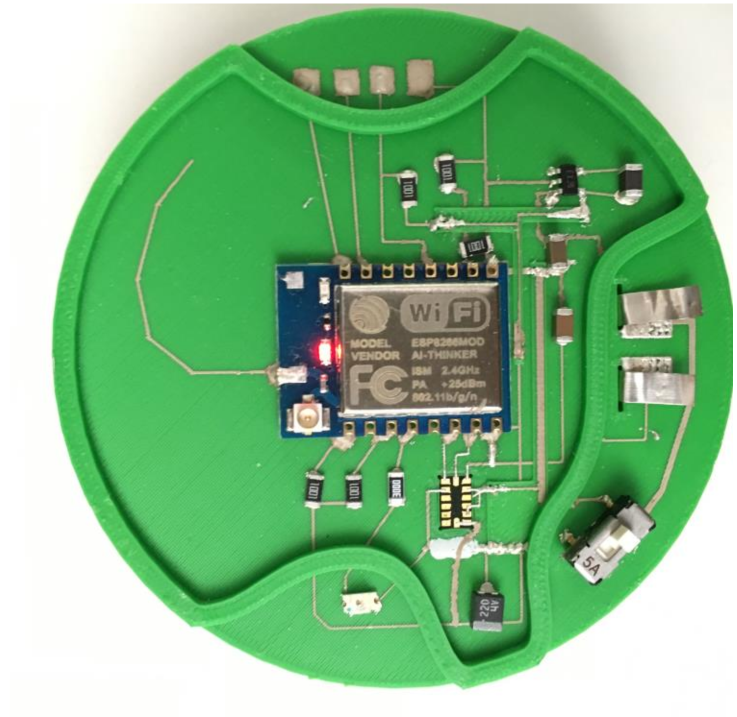


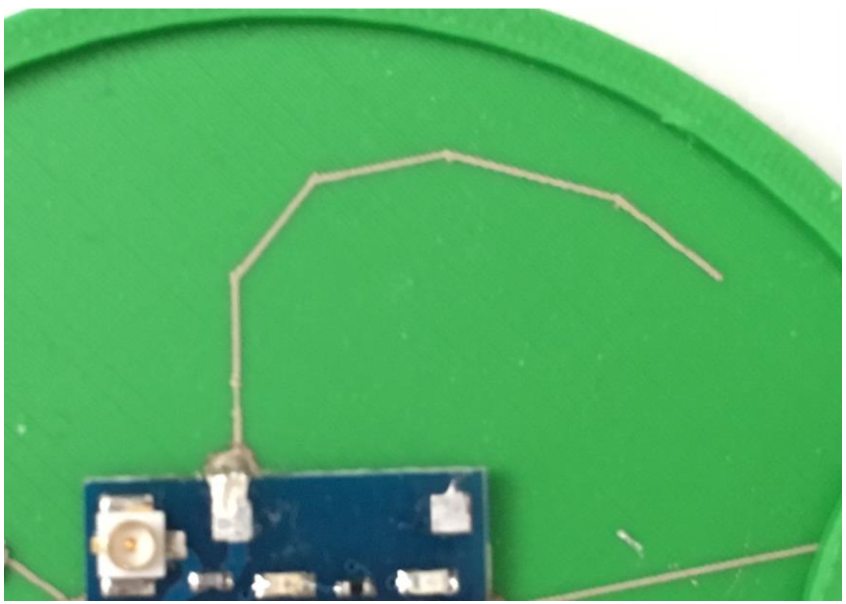
Antenna radiation pattern

Wireless Shock Sensor

Basic Design

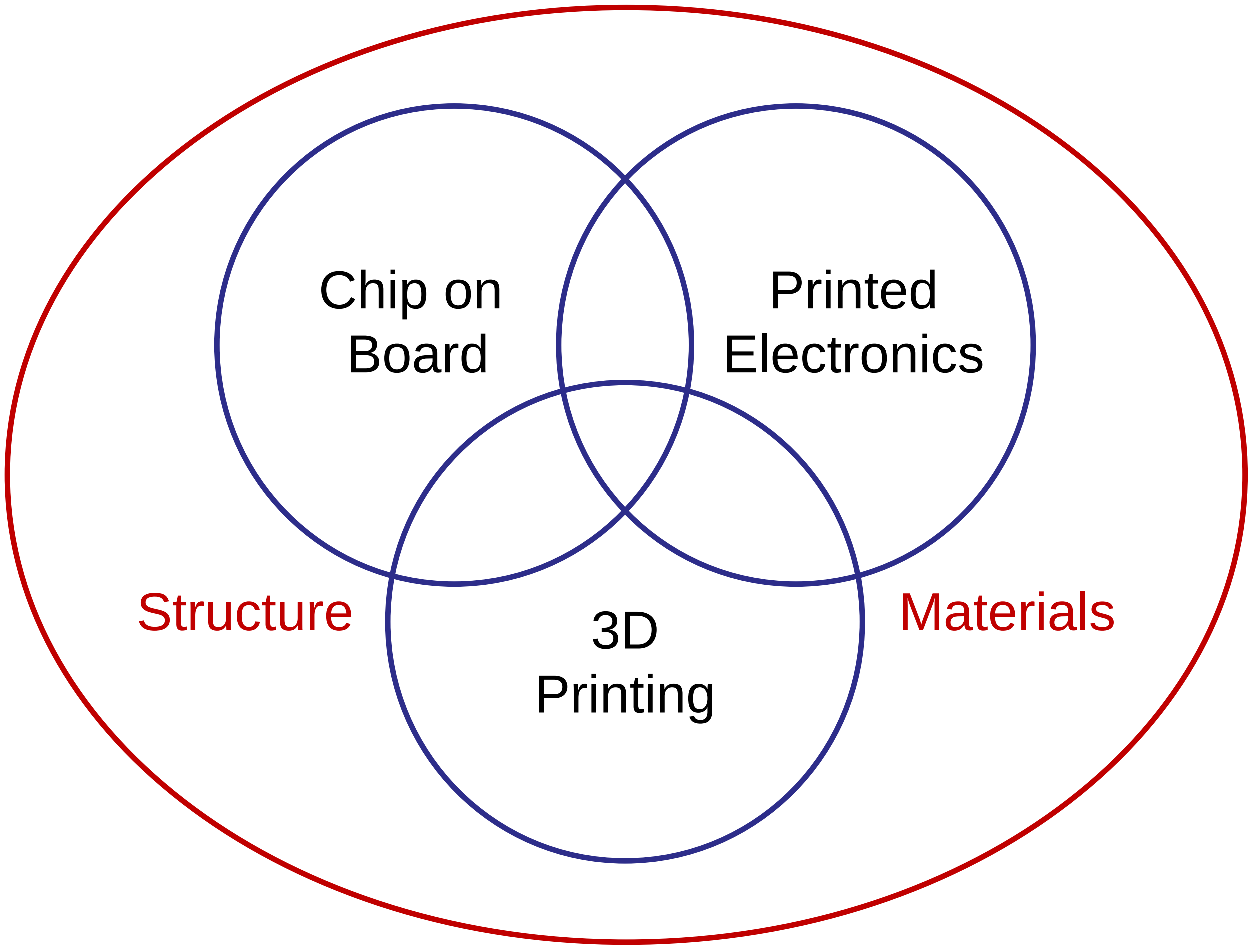
- Uses ESP8266 WiFi controller
- Powered by embedded 200 mAh Li-Po battery
- Printed antenna





The printed antenna is a simple curved monopole. Its range is about equal to the ceramic chip antenna it replaced.

Application Specific Electronic Packaging



Relevant Test standards

ASEP

IPC	JEDEC	ISO	ASTM	DOD
IPC-MC-790 (MCM)	JESD93 (Hybrid/MCM)	ISO/TC 261	F42	MIL-PRF-38534
* IPC/JPCA-2291		ISO 9000	F-1578 thru F3152	Mil-STD-883
				MIL-HDBK-217

MCM - Multichip Modules

JOINT - Additive Manufacturing

IPC/JPCA-2291:
- Printed Electronics

F-1578 thru F3152:
- Printed Electronics
- Membrane Switches

* Joint w/ Japan Electronics Packaging Circuits Association

IPC - Institute of Printed Circuits

IPC-SM-784
Guidelines for Chip-on-Board Technology Implementation

http://www.ipc.org/TOC/IPC-SM-784.pdf

COB has two major subsets:

- Chip-and-Wire technology where the integrated circuit die is first adhesively bonded to a printed wiring board and is then interconnected by wire bonding with either gold or aluminum wire; and
- Flip Chip technology where the integrated circuit die is plated with solder bumps at the interconnect points and soldered in an inverted fashion to the board, thus effecting both attachment and interconnection in one step. Flip chip bonding has also been done using a conductive organic-based adhesive (rather than solder) onto organic based printed boards

http://www.ipc.org/ContentPage.aspx?pageid=Printed-Electronics-Initiative

Military Standards

MIL-PRF-38534J
APPENDIX D

GENERIC PERFORMANCE VERIFICATIONS FOR NON-HERMETIC DEVICE TECHNOLOGIES

D.1 SCOPE

D.1.1 Scope. This appendix is intended to be used by manufacturers in developing their baseline flow of processes, screens, and Periodic Inspections / Qualified Manufacturers List (PI/QML) for non-hermetic devices. This appendix provides an acceptable standard which will be used to verify the performance requirements of compliant non-hermetic devices This appendix is a mandatory part of the specification. The information contained herein is intended for compliance. Manufacturers may demonstrate a test and inspection system that achieves at least the same level of quality as could be achieved by complying with this appendix. These standards may be used as is or as modified in accordance with 3.9.1. The test flow presented in this appendix may not be appropriate for all non-hermetic technologies. For these types of devices, this appendix should be used as a starting point in developing an appropriate test flow.

NOTE: Non-hermetic devices should be used with caution and in appropriate end item use environments. Refer to D.3.3 for non-hermetic requirements.

Accelerated Test Methods

HAST

The **highly accelerated stress test** (HAST) method was invented by Nihal Sinnadurai while working as a Research Engineer at British Telecommunications Research Laboratories in 1968 in order to perform highly accelerated reliability testing of electronics components that are likely to encounter humid environments during normal (ambient) operation. The method uses the principle of a non-saturating autoclave designed and engineered with no moving parts, to deliver close temperature (<1°C) and humidity (<2%RH) control and a high reliability of the stress equipment. Nihal Sinnadurai and his team carried out many millions of device hours of reliability stress testing in HAST chambers, and arrived at a clear correlation with a humidity exponent as the stress accelerating agent.

https://en.wikipedia.org/wiki/Highly_accelerated_stress_test

Accelerated Test Methods

HALT

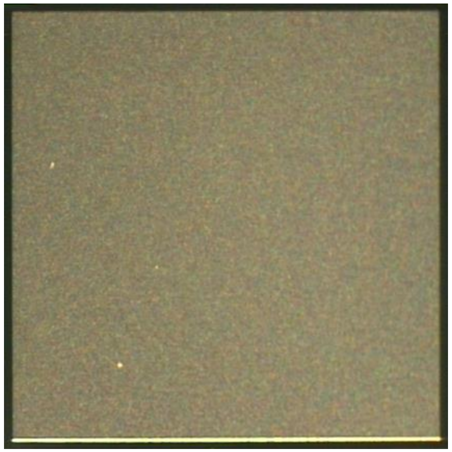
A **highly accelerated life test** (**HALT**), is a stress testing methodology for accelerating product reliability. HALT testing is currently in use by most major manufacturing organizations to improve product reliability in a variety of industries, including electronics, computer, medical and military.

HALT can be effectively used multiple times over a product's life time. During product development, it can find design weakness when changes are much less costly to make. By finding weaknesses and making changes early, HALT can lower product development costs and compress time to market. When HALT is used at the time a product is being introduced into the market, it can expose problems caused by new manufacturing processes. When used after a product has been introduced into the market, HALT can be used to audit product reliability caused by changes in components, manufacturing processes or suppliers etc.

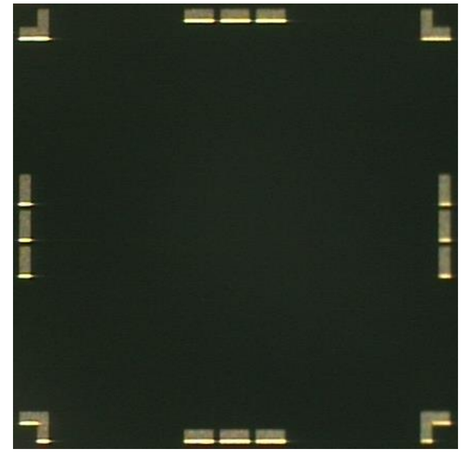
https://en.wikipedia.org/wiki/Highly_accelerated_life_test

Silicon Test Die

Die Attach Test Die

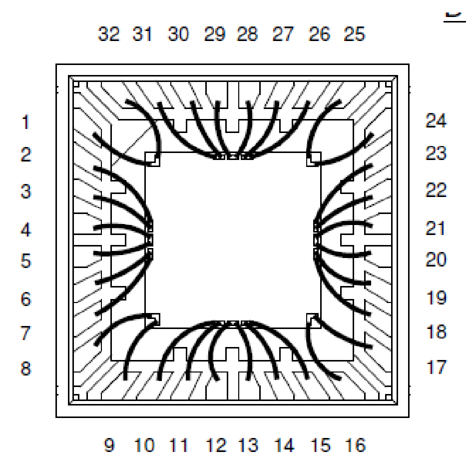


"Wire Bond" Test Die



Silicon Dummy Test Die
Size: 2.5mm x 2.5mm
Metallization;

Die Attach Pad – Au
Wire Bond Pad – Au



QFN32W.5-DCW25322
32L - 5X5mm

32 I/O Fan Out

Mechanical Shock

MS883 Test Method 2002.5 Mechanical Shock – Condition F

Test condition	g level (peak)	Duration of pulse (ms)
A	500	1.0
B	1,500	0.5
C	3,000	0.3
D	5,000	0.3
E	10,000	0.2
F	20,000	0.2
G	30,000	0.12

CAUTIION: If this test is performed using a potting compound type test fixture (e.g., waterglass/sodium silicate) the facility performing the test shall assure that this procedure/material does not mask fine/gross leakers.

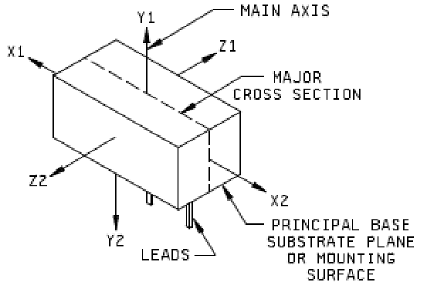


FIGURE 1a. Orientation of microelectronic device to direction of applied force.

Orientations X1, X2, Y2, Y1, Z1, and Z2

Vibration

METHOD 2005.2
VIBRATION FATIGUE

1. PURPOSE. The purpose of this test is to determine the effect on the device of vibration in the frequency range specified.

2. APPARATUS. Apparatus for this test shall include equipment capable of providing the sustained vibration within the specified levels and the necessary optical and electrical equipment to conduct post-test measurements.

3. PROCEDURE. The device shall be rigidly fastened on the vibration platform and the leads or cables adequately secured. The device shall be vibrated with a constant amplitude simple harmonic motion having a peak acceleration corresponding to the specified test condition. For test condition A, constant amplitude harmonic motion in the range of 60 ±20 Hz having an amplitude of 0.06 inch double amplitude (total excursion) shall be acceptable as an alternative to the specified peak acceleration. The vibration shall be applied for 32 ±8 hours minimum, in each of the orientations X, Y, and Z for a total of 96 hours, minimum. When specified, devices with an internal cavity containing parts or elements subject to possible movement or breakage during vibration shall be further examined by radiographic examination in accordance with method 2012 or by delidding or opening and internal visual examination at 30X magnification to reveal damage or dislocation. Where this test is performed as part of a group or subgroup of tests, the post-test measurements or inspections need not be performed specifically at the conclusion of this test, but may be performed once at the conclusion of the group or subgroup.

Test condition	Peak acceleration, g
A	20
B	50
C	70

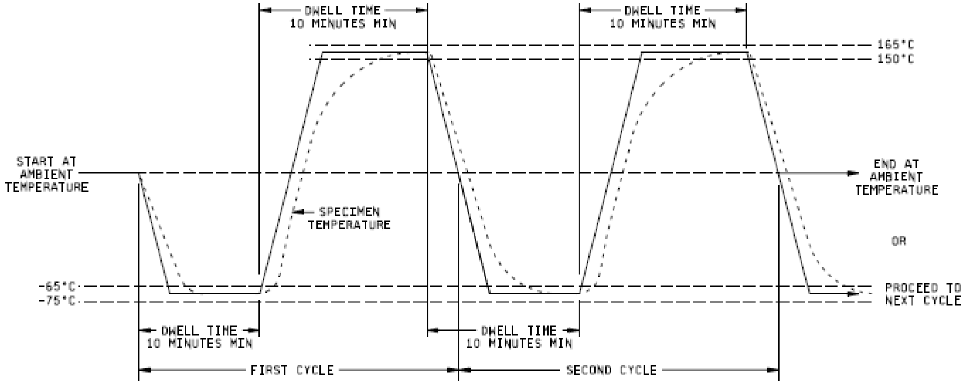
Temperature Cycling

MS883 Test Method 1010.8 Temperature Cycling – Condition A

TABLE I. Temperature-cycling test conditions.

		Test condition temperature (°C)					
Step	Minutes	A	B	C	D	E	F
1 Cold	≥10	-55 +0 -10	-55 +0 -10	-65 +0 -10	-65 +0 -10	-65 +0 -10	-65 +0 -10
2 Hot	≥10	85 +10 -0	125 +15 -0	150 +15 -0	200 +15 -0	300 +15 -0	175 +15 -0

NOTE: Steps 1 and 2 may be interchanged. The load temperature may exceed the + or - zero (0) tolerance during the recovery time. Other tolerances shall not be exceeded.



10 Minute Dwell at extremes

ESD Testing – Package Level

Performance Work Statement (SOW)

??

MS883 Test Method 3015.9 ELECTROSTATIC DISCHARGE SENSITIVITY CLASSIFICATION

1. PURPOSE. This method establishes the procedure for classifying microcircuits according to their susceptibility to
damage or degradation by exposure to electrostatic discharge (ESD). This classification is used to specify appropriate
packaging and handling requirements in accordance with MIL-PRF-38535, and to provide classification data to meet the
requirements of MIL-STD-1686.

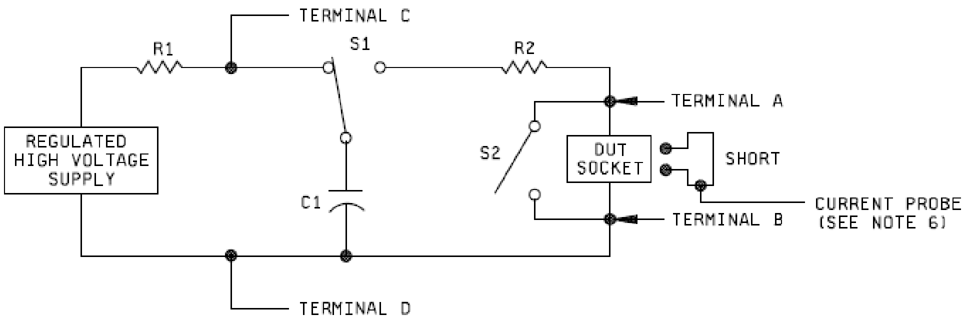
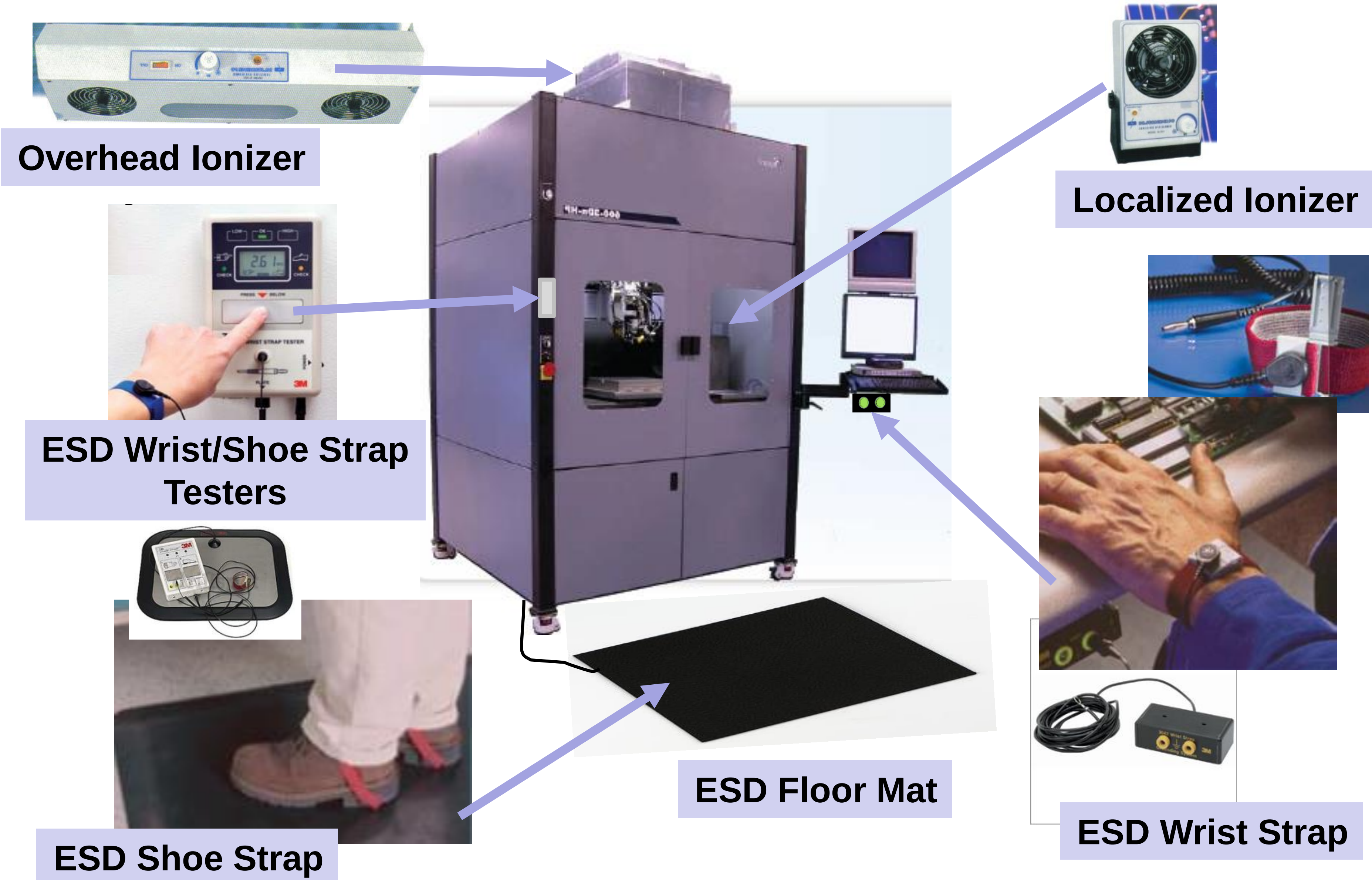


TABLE III. Device ESD failure threshold classification.

Class 0	< 250 volts
Class 1A	250 volts to 499 volts
Class 1B	500 volts to 999 volts
Class 1C	1,000 volts to 1,999 volts
Class 2	2,000 volts to 3,999 volts
Class 3A	4,000 volts to 7,999 volts
Class 3B	≥ 8,000 volts

Classification Threshold

Integrated Work-cell ESD Control & Monitoring System



State of the Art & What's Next =>

- FR4 – complex and very mature
- Ceramic (LTCC) – complex and very mature
- Multichip modules – complex and very mature
- Flexible electronics – building complexity and maturity
- Printed electronics – pushing to compete, and gaining ground
- 3D printed electronics – infancy
  - Demonstrations
  - Limited testing
  - DC to RF is very different

Hybrid approach – Print what you can, place what you can't… "get by with a little help from my friends."

Mindset of 2.5D will not change if we cannot truly demonstrate 3D effectively, accurately and with significant speed.

RF needs a focus….wireless is not going away.