Data Device Corporation

Considerations for 3-D Multi-Chip Modules for High Rel Applications

Joseph Castaldo, Product Line Director, Custom Microelectronics Solutions

CMSE

DDC
Connectivity Power Control

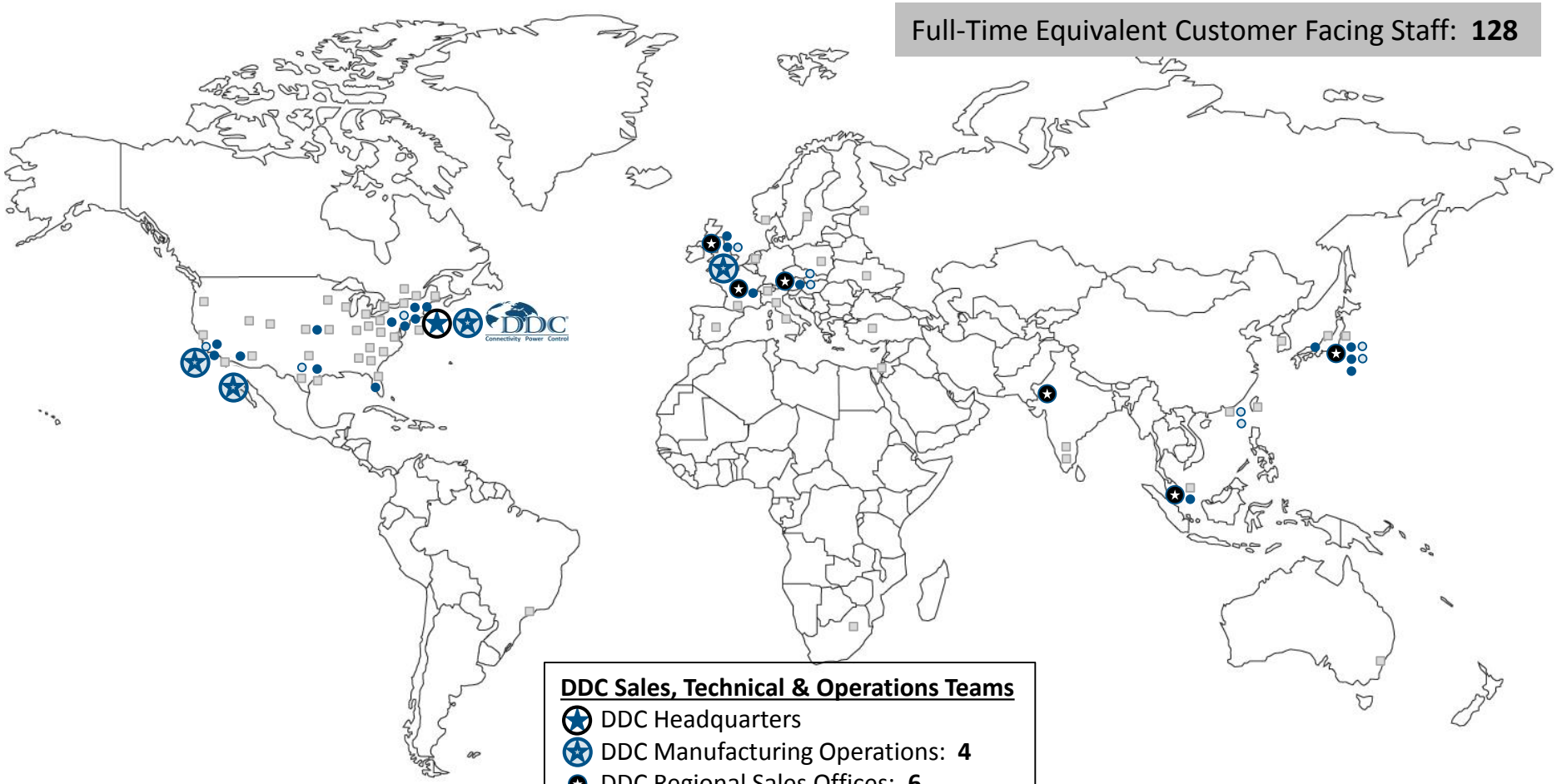
Data Device Corporation

Your Solution Provider for... Connectivity, Power and Control

- **Headquarters** – *Bohemia, NY, USA*
  - Established 1964
  - Manufacturing Operations – NY, San Diego, UK & Mexico (>200,000 sq-ft)
  - 700 Employees Worldwide
- **Local Support… Worldwide**
  - Direct Sales Offices – USA, UK, Germany, France, India, Japan, Singapore
  - Local Representatives – Sales & Technical Support in 36 Countries

DDC Worldwide Sales Channel

Full-Time Equivalent Customer Facing Staff: **128**

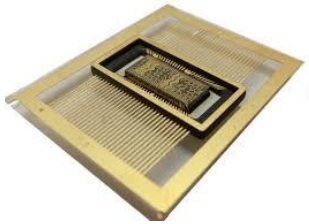


DDC Sales, Technical & Operations Teams

- DDC Headquarters
- DDC Manufacturing Operations: **4**
- DDC Regional Sales Offices: **6**
- Direct Sales: **24** (15, 9)
- FAE's: **14** (7, 7)
- Sales Rep Offices: **55** (31, 24)

Examples of 3D MCMs

DDC is a leading producer of 3D MCMs for High Reliability Applications, having successfully delivered thousands of units to Mil and Space Platforms.

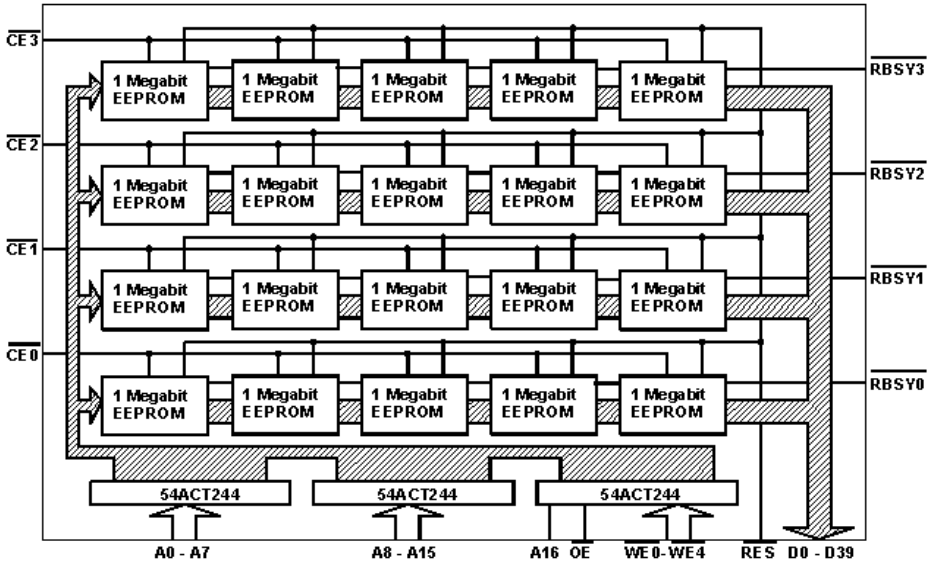


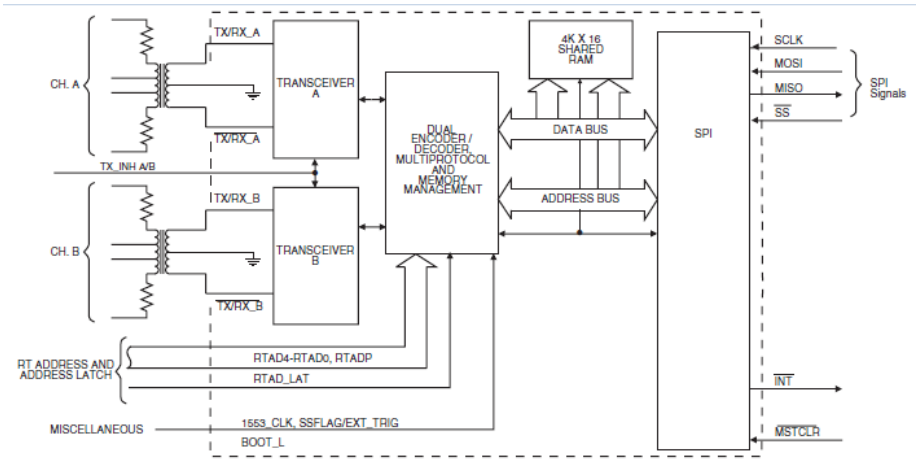
79C2040B 20 Megabit, EEPROM MCM

34.8mm (1.37”) x 22.4mm (0.88”) x 10.1mm (0.40”)

Nano-ACE™ MIL-STD-1553 Remote Terminal/Monitor

7.1mm (0.28”) x 7.1mm (0.28”) x 1.0mm (0.40”)





Material Compatibility

MATERIAL	Thermal Conductivity (κ) W/cm-°K	MATERIAL	Thermal Conductivity (κ) W/cm-°K
METALS		**INSULATORS**	
Silver	4.3	Diamond	20.0
Copper	4.0	AlN (Low O_2 impurity)	2.30
Gold	2.97	Silicon Carbide (SiC)	2.2
Copper Tungsten	2.48	Beryllia (BeO) (2.8 g/cc)	2.1
Aluminum	2.3	Beryllia (BeO) (1.8 g/cc)	0.6
Molybdenum	1.4	Alumina (Al_2O_3) (3.8 g/cc)	0.3
Brass	1.1	Alumina (Al_2O_3) (3.5 g/cc)	0.2
Nickel	0.92	Alumina (96%)	0.20
Solder (SnPb)	0.57	Alumina (92%)	0.18
Steel	0.5	Glass Ceramic	0.05
Lead	0.4	Thermal Greases	0.011
Stainless Steel	0.29	Silicon Dioxide (SiO_2)	0.01
Kovar	0.16	High-κ Molding Plastic	0.02
Silver Filled Epoxy	0.008	Low-κ Molding Plastic	0.005
SEMICONDUCTORS		Polyimide-Glass	0.0035
Silicon	1.5	RTV	0.0031
Germanium	0.7	Epoxy Glass (PC Board)	0.003
Gallium Arsenide	0.5	BCB	0.002
LIQUIDS		FR4	0.002
Water	0.006	Polyimide	0.002
Liquid Nitrogen (at 77°K)	0.001	Asbestos	0.001
Liquid Helium (at 2°K)	0.0001	Teflon™	0.001
Freon 113	0.0073	Glass Wool	0.0001
GASES			
Hydrogen	0.001		
Helium	0.001		
Oxygen	0.0002		
Air	0.0002		

Source: ICE, "Roadmaps of Packaging Technology" 15810A

Figure 6-14. Thermal Conductivities of Various Materials (At Room Temperature Unless Noted Otherwise)

DESCRIPTION	MATERIAL	THICKNESS (cm)	κ (W/cm•°K)	THERMAL RESISTANCE (°C/W)
Chip	Silicon	0.075	1.5	0.05
Die Attach	Silver-Filled Epoxy Solder Epoxy	0.0025 0.005 0.0025	0.008 0.51 0.002	0.313 0.0098 1.25
Ceramic Package	Alumina Copper Tungsten Aluminum Nitride	0.08 0.08 0.08	0.2 2.48 2.3	0.4 0.032 0.035
Interconnect	FR4 Board Polyimide	0.25 0.005	0.002 0.002	125.0 2.5
Heat Spreader	Copper Aluminum	0.63 0.63	4.0 2.3	0.158 0.274

Source: ICE, "Roadmaps of Packaging Technology" 15811A

Figure 6-11. Selected Junction-to-Case Thermal Resistances

Element	Thermal Resistance (°C/W)	Temperature Drop (°C)
Silicon Die	0.05	1
Silver-filled Epoxy	0.3	6
Ceramic Base	0.4	8
Total Junction-to-Case	0.75	15

Source: ICE, "Roadmaps of Packaging Technology" 16453

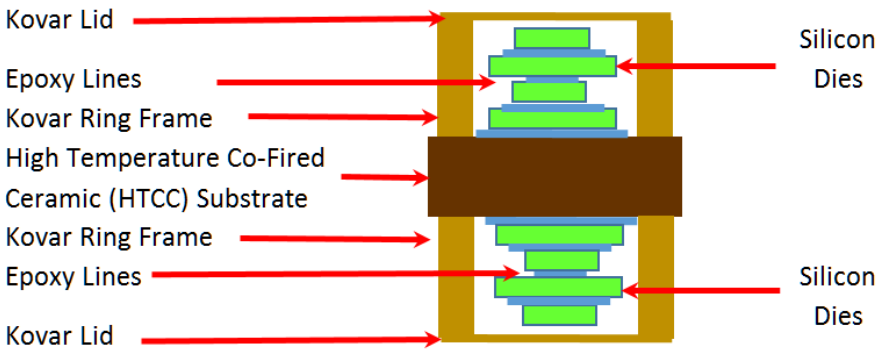
2. Layer Contributions to Thermal Resistance and Temperature Drop for 20 Watts

Widely used Materials

Material	Thermal Conductivity W/cm·K
Gold	2.97
Molybdenum	1.40
Solder (SnPb)	0.57
Kovar	0.16
AlN (Low O_2 impurity)	2.30
Beryllia (BeO) (2.8 g/cc)	2.1
Alumina (Al_2O_3) (3.5 g/cc)	0.2
Glass Ceramic	0.05
FR4	0.002
Polyimide	0.002

Material Considerations

- **20 Megabit, EEPROM MCM**
  - **Dual Cavity, Dual Stack, Cantilevered Construction**
  - **Die and Materials are carefully selected for CTE compatibility**
  - **TRL 9 achieved on multiple Space Missions**



Artistic Representation

- **Goal: Minimize CTE delta with consideration of design factors:**
  - Operating & Storage Range
  - The greater the range the more CTE mismatch is a concern
  - Critical material properties such as electrical and thermal conductivity of the materials
  - How will the materials and form factor impact the stress on the connection?
  - Does the supplier's computer analysis support the selected materials and proposed construction?

Qual Testing – Hermetics

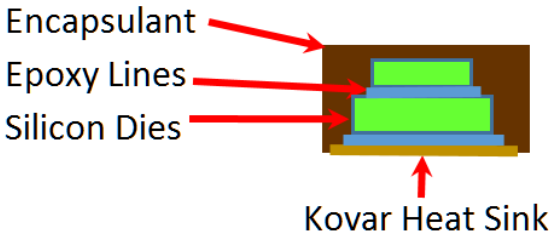
- **Follows MIL-PRF-38534, Class H or K**

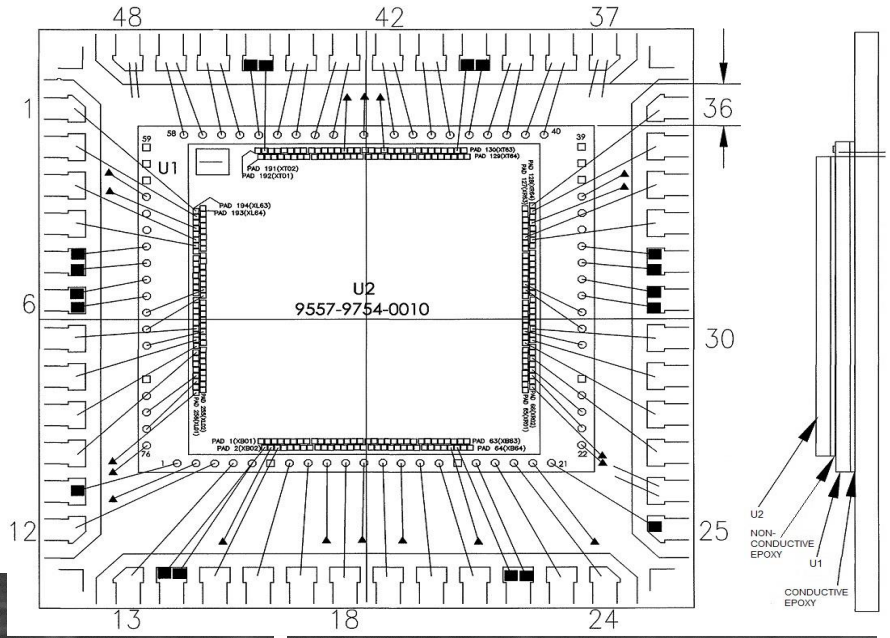
Subgroup	Test	MIL-STD-883 Test Method
1	Resistance to Soldering Heat	2036
1	External Visual	2009
1	Particle Impact Noise Detection	2020
1	Temperature Cycling	1010
1	Mechanical Shock	2002
1	Constant Acceleration	2001
1	Random Vibration	2026
1	Seal (Fine & Gross Leak)	1014
1	Particle Impact Noise Detection	2020
1	Visual Examination	1010
1	End-point Electrical	IAW ATP
2	1000 Hour Life Test	1005
3	Internal Gas Analysis	1018
4	Internal Visual	2017
4	Wire Bond Strength	2011
4	Element Shear	2019 or 2027

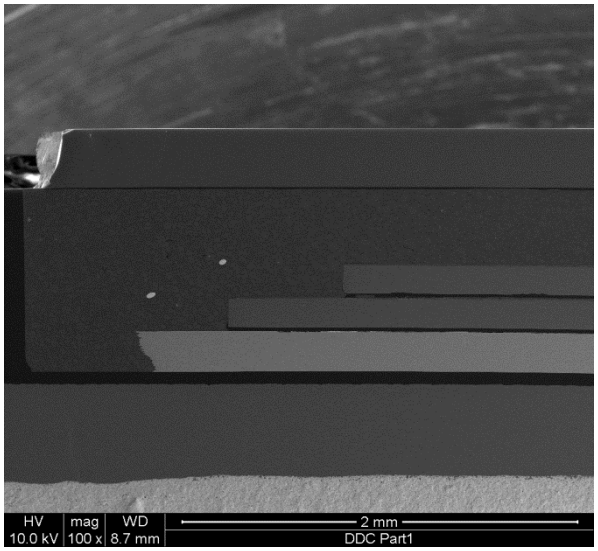
Material Compatibility

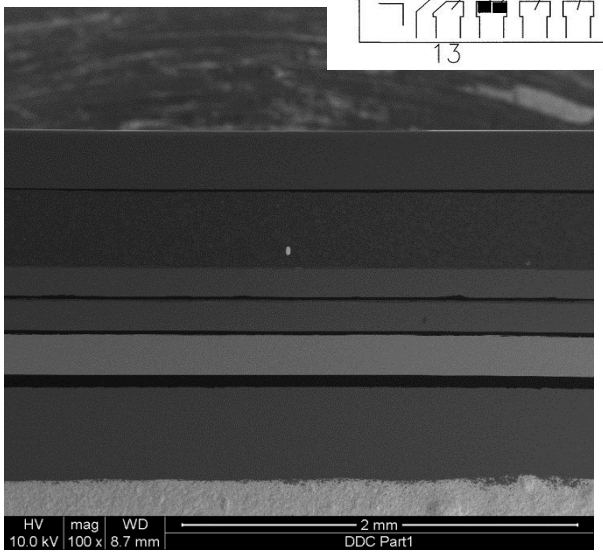
- **NANO Ace**

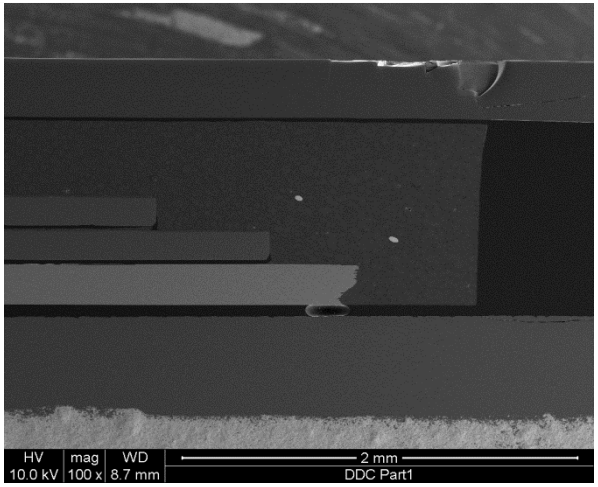
  - **Rugged Molded Construction**







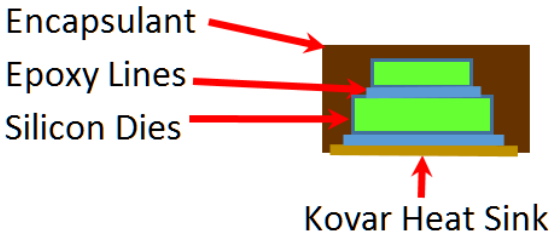


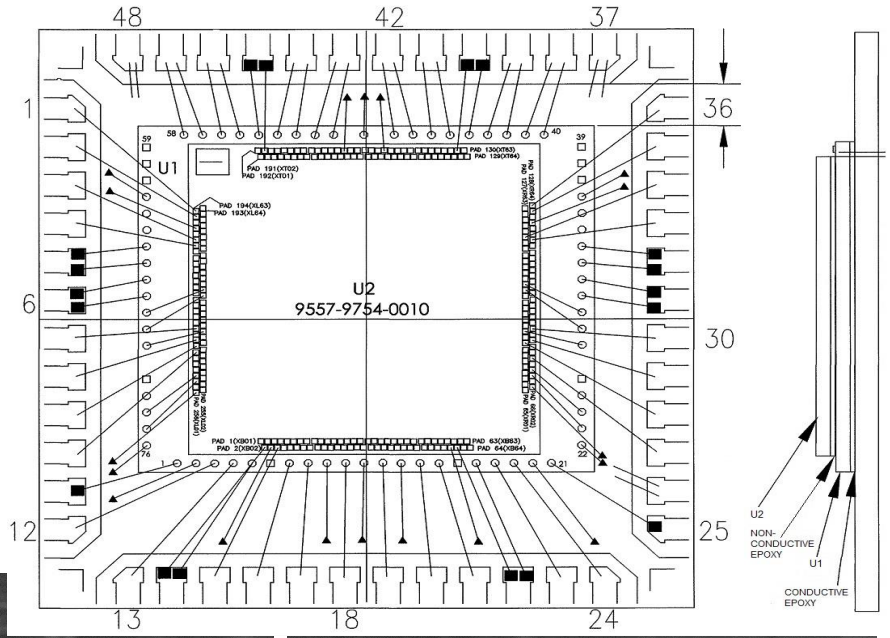


Material Compatibility

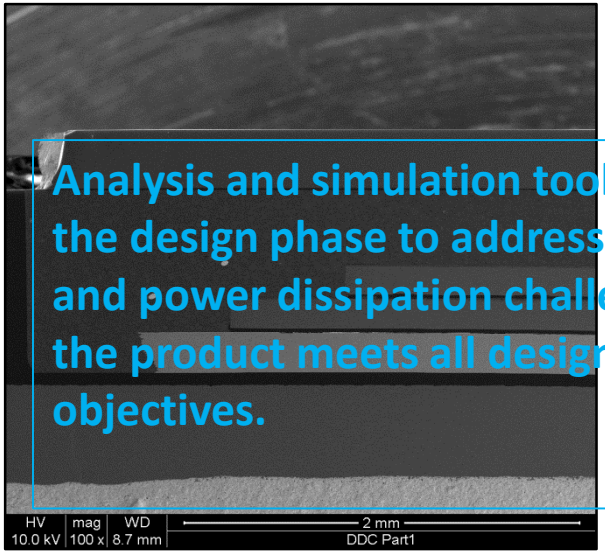
- **NANO Ace**

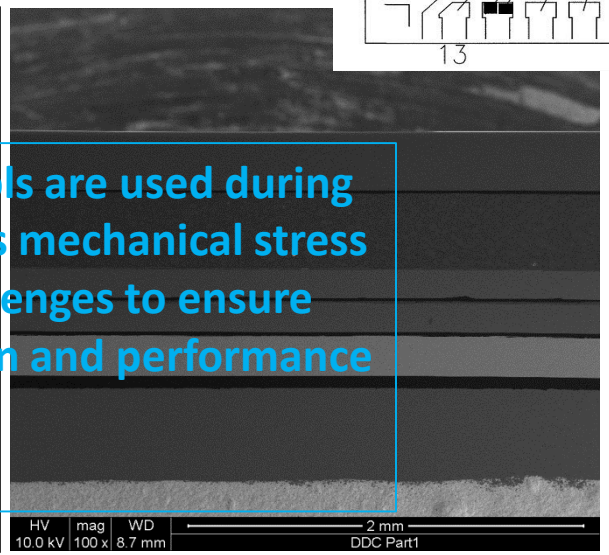
  - **Rugged Molded Construction**

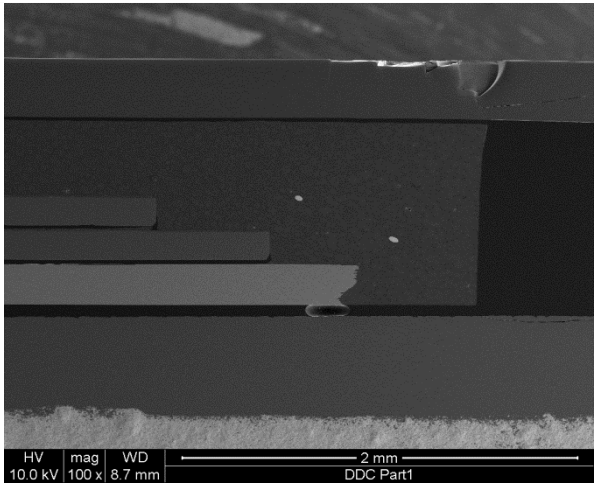




Analysis and simulation tools are used during the design phase to address mechanical stress and power dissipation challenges to ensure the product meets all design and performance objectives.







Material Compatibility *cont.*

- Materials with compatible Coefficients of Thermal Expansion (CTE) promotes long term reliability
- CTE of Materials
  - High Temperature Co-Fired Ceramic (HTCC), typical CTE 6.9 – 7.5 ppm/K
  - Does the selected material have the desirable Thermal Conductivity property? Thermal Conductivity (TC) for HTCC can range from 0.14 – 0.21W/cmK
  - The TC of an epoxy will be driven by the choice of filler.

Material	Conductivity (W / cmK)
Copper (Cu)	0.393
Gold (Au)	0.297
Silver (Ag)	0.418
Alumina (Al_2O_3)	0.030
Boron Nitride	0.600

- Silicon Semiconductors typically have a Thermal Conductivity of 1.5W/cmK
- Thermal Conductivity of (Al_2O_3) spacers between the die is 0.2W/cmK

Qualification Testing – Non-Hermetic Devices

- **Moisture/Reflow Sensitivity Classification Test IAW J-STD-020D.1***

Step	Test
1	Base line Acoustic Microscopy
2	Acceptance Test IAW Acceptance Test Procedure
3	External Visual
4	Bake Out
5	Humidity Soak
6	Reflow
7	Cool Devices
8	Reflow
9	Cool Devices
10	Reflow
11	Post - Reflow cool down
12	External Visual
13	Acceptance Test IAW Acceptance Test Procedure
14	Acoustic Microscopy

- **High Temp Storage Life Test**

Test	Conditions
Electrical Test	Over MIL Temp Range
High Temperature Storage	500 hours IAW JESD22-A-103
Visual Inspection	IAW IPC-A-610
Electrical Test	At Room Temperature within 96 Hours of exiting High Tempearture Storage
High Temperature Storage	500 hours IAW JESD22-A-103
Visual Inspection	IAW IPC-A-610
Electrical Test	Over MIL Temp Range within 96 hours of exiting High Temperature Storage

- **Low Temp Storage Life Test**

Test	Conditions
Electrical Test	Over MIL Temp Range
Low Temperature Storage	168 hours IAW JESD22-A119
Visual Inspection	IAW IPC-A-610
Electrical Test	Over MIL Temp Range within 96 Hours of exiting Low Tempearture Storage

*Quantity of cycles dependent on the Operating range of the device.

Qualification Testing – Non-Hermetic Devices *cont.*

- **Temperature Cycling of Un-mounted SMT Devices IAW JESD22-A104**

Step	Test
1	Acceptance Test IAW Acceptance Test Procedure
2	Temperature Cycle - 100 Cycles
3	External Visual
4	Acceptance Test IAW Acceptance Test Procedure
5	Temperature Cycle - 300 Cycles
6	External Visual
7	Acceptance Test IAW Acceptance Test Procedure
8	Temperature Cycle - 300 Cycles
9	External Visual
10	Acceptance Test IAW Acceptance Test Procedure over MIL Temp Range

- **1000 Hour Life Test @ 125°C**

Test	Conditions
Electrical Test	Over MIL Temp Range
Life Test	168 hours at 125°C
Visual Inspection	IAW IPC-A-610
Electrical Test	Over MIL Temp Range
Life Test	500 hours at 125°C
Visual Inspection	IAW IPC-A-610
Electrical Test	Over MIL Temp Range
Life Test	500 hours at 125°C
Visual Inspection	IAW IPC-A-610
Electrical Test	Over MIL Temp Range

Summary

- Material compatibility is an important consideration when designing high reliability 2.5 / 3D Multi-Chip Modules
- Qualification of the design applying as many applicable Test Methods of MIL-PRF-38534 and JEDEC Standards is highly advisable
- Consider the long term viability of your supplier versus the life of your program
- Suppliers who build 2.5 / 3D Multi-Chip Modules on a continuous basis are best qualified to successfully deliver such MCMs while improving the size, weight and power (SWaP) of your product

Contact Data

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  Email: castaldo@ddc-web.com

Please contact me if you have any questions regarding how the packaging technology presented herein can be applied to your project.

Back-up Slides

- **The following slides provide additional background information to the reader about Data Device Corporation**

Markets/Solutions

		Markets			
		Defense	Civil Aviation	Space	Industrial
Solutions	Connectivity (Data Bus Solutions)	Market Leader in MIL-STD-1553 Components & Boards	ARINC 429 Boards & Components, ARINC 629 Plastic Optical Converter LRU	Class H & K MIL-STD-1553 Hybrid Microcircuits. Radiation Tolerant Transformers, Couplers, Memories, and Single Board Computers	High Temperature MIL-STD-1553 Components
	Power Control (Solid State Power Controllers; Power Supplies; Magnetics)	Largest Installed Base of SSPCs in Industry, Market Leader in Power Supplies	Flight Certified SSPCs, Leader in IFE&C Power Supplies	NASA-qualified Radiation Tolerant Magnetic Solutions	High Temperature Magnetics and Power Supplies for Sub-Sea and Harsh Environments
	Motion Control (Motor Controllers & Drives; Synchro/Resolver Conversion)	High Reliability Motor Controllers, Market Leader in Synchro/Resolver Conversion	High Reliability Motor Controllers, Incumbent RDC Design-ins	Radiation Tolerant Motor Controllers, RDCs and Reference Oscillators	Transportation, Factory Automation, High Temperature Position and Motor Control Solutions

DDC's Field Proven Technology is on Virtually Every Military & Aerospace Platform

Expanding Our Capabilities

	Rationale	Business Model	Investment
National Hybrid Incorporated	Expands leadership position in MIL-STD-1553 products & technology	1553 products offered as part of DDC's overall Data Bus Component Portfolio	**July 8, 2013** 1 resource *API Technologies* Carve-out (Windber, PA)
Beta Transformer Mexico, S. de R.L. de C.V.	Extends DDC's transformer manufacturing capabilities in low-cost geography	High-volume toroidal-wound transformer production capabilities in DLA certified facility	**March 17, 2014** ~90 resources Acquisition of *Tecnicas y Servicios Internacionale* (Ensenada, Mexico)
Pascall / XCEL Power Systems	Expands power solutions capabilities in aerospace, defense and industrial markets	Broad design and manufacturing capabilities for power supplies, RF Oscillators and OXCO's	**June 30, 2015** ~130 resources *Emrise Electronics Ltd.* Carve-out (Isle of Wight, UK)
Maxwell Technologies Microelectronics Division	Expands DDC's radiation tolerant IP and product capabilities for Space, Nuclear and Medical markets	Rad-Tolerant Memories, MCUs, Semiconductors, Packaging and Single Board Computers as part of DDC's overall product portfolio	**April 22, 2016** ~38 resources *Maxwell Technologies* Carve-out (San Diego, CA)

Product Overview

CONNECTIVITY
Data Bus Solutions & Systems

POWER CONTROL
Solid State Power Controllers;
Power Supplies & Magnetics

MOTION CONTROL
Motor Controllers &
Synchro/Resolver Conversion

Data Networking Component Solutions

Core competency with an extremely broad portfolio of military and space grade deterministic networking solutions components:
- MIL-STD-1553
- ARINC 429
- Rad-Hard MCU's and Memories
- Rad-Tolerant IC's

Data Networking Board & System Solutions

Rugged, configurable and scalable low power computing platforms and boards (including Rad-Tolerant) supporting a wide variety of networking protocols (1553, Ethernet, ARINC 429, Fiber Channel, CANbus, etc.).

Power Supplies

Rugged and highly reliable power supplies for harsh military, civil aerospace and industrial applications. Stand-alone and VME card-based AC input, DC input and DC-DC converters from 10W to 5KW.

Smart Power Control

High density power multiplexing & management Units with support to 600A+ and 32+ channels. 28V DC, 115V AC Solid-State Power Controller boards, modules, and rugged enclosed power distribution units. Flight certified & custom solutions.

Transformer & Magnetics

Transformers, inverters, couplers, pulse & power magnetics, 1Gb Ethernet magnetics, 1394b Firewire magnetics, cable assemblies.

Motor Drives & Controllers

DSP-based, flexible motor drive and controller solutions with speed, torque and position control, with power level support to 250A+ & 600V+. Analog drive solutions with support to 10A, 500V+.

Motion Feedback

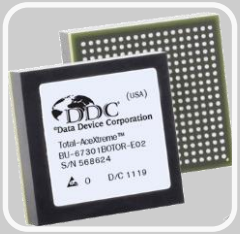
Broad portfolio of DDC-developed high-precision and high accuracy resolver-to-digital converter and LVDT to digital converter ASICs, hybrid modules, board-level and system-level solutions.

DDC Product Overview

CONNECTIVITY
Data Bus Solutions & Systems

POWER CONTROL
Power Supplies, SSPC's & Magnetics

MOTION CONTROL
Motor Controllers and RDC's



Data Networking Components

Data Networking Board and System Solutions

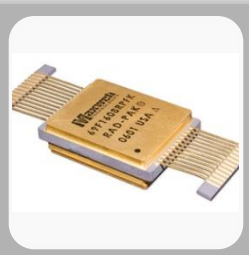
Power Supplies

Smart Power Control

Transformer & Magnetics

Motor Drive & Control

Motion Feedback



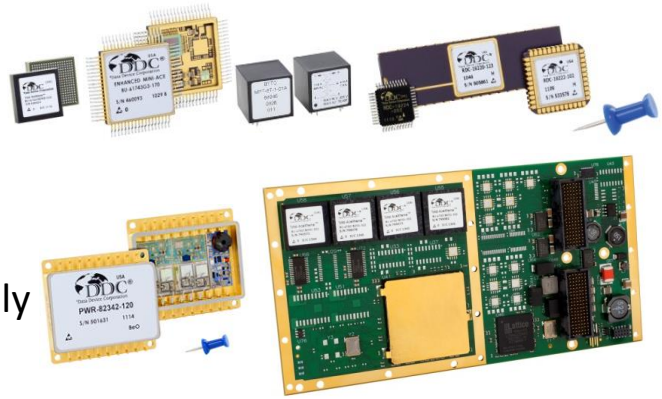
Rad-Tolerant Memories, MCU's and Semiconductor Solutions

Rad-Tolerant Single Board Computer Solutions

DDC's organic growth and acquisitions are transforming the company's capability to serve and enable our customers to be more competitive across a range of product segments.

Design & Manufacturing Leader

- **Product Capabilities**
  - ASIC Design and Fabless IC Manufacturing
    - Tier 1 Supply Chain for foundry, assembly and final test
  - Metal & Ceramic Hybrid Design and Manufacturing
  - Combined Flip Chip and Wire Bonded MCM
  - Surface-Mount and Through-Hole PCB Design and Assembly
  - Transformer, Magnetics Design and Manufacturing
  - DO-178 Software development, DO-254 Hardware development



- **Engineering / Mechanical Capabilities**
  - Analog and Digital Design
  - FPGA and ASIC Design
  - Power Hybrid Design and Manufacturing
  - Multi-Chip Module Design and Manufacturing
  - Printed Circuit Board Design and Manufacturing
  - Test and Evaluation
  - Mechanical & Process Engineering
  - Design Validation, Verification and Qualification
  - Ruggedization and Thermal Management




DDC… The Depended Source

- **Life Cycle**
  - Uninterrupted Product Availability
  - Backwards Hardware and Software Compatibility
  - Configuration control & Lifecycle Management
- **Advanced Components**
  - Custom ASICs (Analog, Digital, Mixed Signal)
  - Plastic Encapsulated Multi-Chip Modules
  - MIL-PRF-38534 Hybrid Manufacturing
- **World Class Board and Box Level Assemblies**
  - Surface-Mount and Through-Hole Board Assembly
  - IPC-A-610 Class 3
- **Products Qualified for…**
  - EMI, Vibration, Shock, Humidity, Extended Operating Temperatures

Distinguished with top industry certifications for our design and manufacturing processes utilizing our clean room manufacturing and state-of-the-art production equipment.

Qualified Partner & Source

- **Certifications & Reliability**
  - ISO-9001:2008 Quality Certified
  - ISO-14001:2004 Environmental Management System *(San Diego, CA)*
  - Aerospace Quality Certified *(Bohemia, NY and San Diego, CA)*
    - AS9100 Rev. C Certified (N. America)
    - EN9100 Compliant (Europe)
    - JIS Q9100 Compliant (Japan)
  - Hybrid Microcircuit & MCM Manufacturing Certified
    - MIL-PRF-38534; Class D, G, H, and K Hybrid Screening *(Bohemia, NY)*
    - MIL-PRF-38535; Class Q, V *(San Diego, CA)*

DATA DEVICE CORPORATION REGISTERED TO: ISO 9001:2008, AS9100C:2009-0 EN9100:2009, JIS Q9100:2009 FILE NO. 10001296 ASH09

Customer Focused

- **Best In Class On-time Delivery & Quality Recognition**
  - **Raytheon**
    - 3 Star Supplier Excellence
  - **Lockheed Martin**
    - Platinum Level Preferred Supplier
  - **General Atomics**
    - Supplier Excellence
  - **L-3 Communication Systems-West**
    - Platinum Award for Exceptional Supplier Quality & Delivery Performance
  - **Honeywell Sensor and Guidance**
    - Supplier Excellence
  - **BAE Gold Supplier Award**
  - **MBDA SC21 Bronze Award**

Data Device Corporation