Inter- Digitated Capacitors (IDC) for Space and Military Applications

John Marshall
john.marshall@avx.com
(+1) 44 28 703 40407

LOW INDUCTANCE MLCC CAPACITORS FOR HIGH SPEED MICRO- PROCESSOR CIRCUITS

Product Description

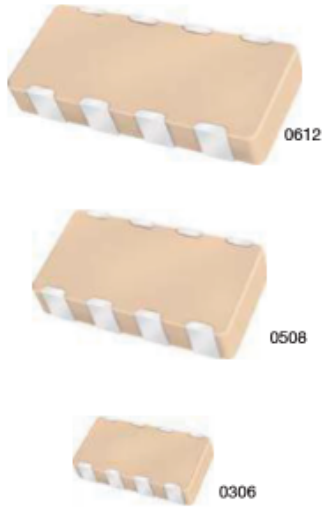
- ***Inter-Digitated Capacitors (IDC)*** provide semiconductor package and board level decoupling
- The ***ESL*** of the capacitor(s) determine response time of the Power Delivery Network
- ***Low ESL*** device delivers ***faster response time***
- Higher speed processors need this faster response achieved via multiple MLCC caps in parallel OR a single IDC
- IDC typical small sizes 0306 or 0508, 0612 larger
- Available with a max height of 0.95mm or the ***low profile version 0.55mm***
- Available in Sn/Pb finish for Space and military applications

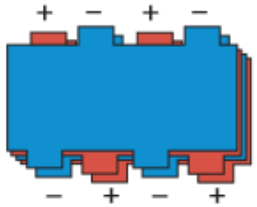
Product Application

- IDC components are used on semi-conductor products with power levels of 15 watts +
- Used on FPGA , VPU, CPU, GPU, ASIC and ASSP devices produced on 0.13um and 90, 65 and 45nm processes.
- Used on both ceramic and organic substrates
- Can be placed on the bottom side or the top side of the package substrate
- Used for board level decoupling of systems with speeds of greater than 300 Mhz

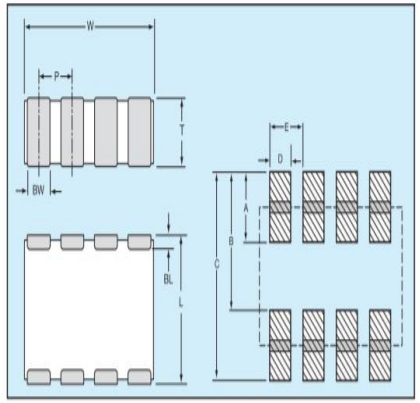
LOW INDUCTANCE MLCC CAPACITORS FOR HIGH SPEED MICRO-PROCESSOR CIRCUITS

Product Description





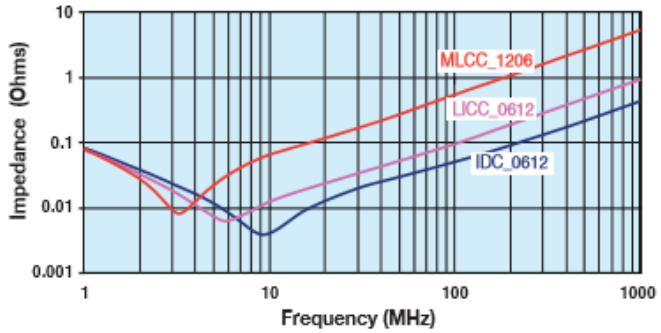
PHYSICAL DIMENSIONS AND PAD LAYOUT



Consult factory for additional requirements

= X7R
= X5R
= X7S

TYPICAL IMPEDANCE



PHYSICAL CHIP DIMENSIONSMILLIMETERS (INCHES)

SIZE	W	L	BW	BL	P
0306	1.60 ± 0.20 (0.063 ± 0.008)	0.82 ± 0.10 (0.032 ± 0.006	0.25 ± 0.10 (0.010 ± 0.004)	0.20 ± 0.10 (0.008 ± 0.004)	0.40 ± 0.05 (0.015 ± 0.002)
0508	2.03 ± 0.20 (0.080 ± 0.008)	1.27 ± 0.20 (0.050 ± 0.008)	0.30 ± 0.10 (0.012 ± 0.004)	0.25 ± 0.15 (0.010 ± 0.006)	0.50 ± 0.05 (0.020 ± 0.002)
0612	3.20 ± 0.20 (0.126 ± 0.008)	1.60 ± 0.20 (0.063 ± 0.008)	0.50 ± 0.10 (0.020 ± 0.004)	0.25 ± 0.15 (0.010 ± 0.006)	0.80 ± 0.10 (0.031 ± 0.004)

PAD LAYOUT DIMENSIONS

SIZE	A	B	C	D	E
0306	0.38 (0.015)	0.89 (0.035)	1.27 (0.050)	0.20 (0.008)	0.40 (0.015)
0508	0.64 (0.025)	1.27 (0.050)	1.91 (0.075)	0.28 (0.011)	0.50 (0.020)
0612	0.89 (0.035)	1.65 (0.065)	2.54 (0.010)	0.45 (0.018)	0.80 (0.031)

Product History

- Developed for high speed “chip set“ commercial applications
- In use for around 10 years++ with semi-conductor products
- Qualified for Space flight by end user in 2012
- Parts tested and approved were 0508 size 2.2uF and 0.68uF plus the smaller size 0306 1uF
- Qualification based on a modified version of the MIL-PRF-123/MIL-PRF-55681 specification
- Parts are low voltage 4, 6V typical for core dense IC Voltages applications <=1.2v
- Designs use dielectric thickness range 2 to 4um

Product Hi Rel Screening Process 2012-2020

100% Voltage Conditioning
No Capability

- **Group A test : 100%**
  - CSAM
  - Thermal Cycle x 20
  - Electrical test includes Cp/Df/DWV/IR
  - Visual Inspection + sample DPA
- **Group B test : Sample**
  - Thermal Shock per Mil 123
  - Life test per Mil 123 @ 1.5 rated Voltage
  - Humidity tests per Mil 123 @ 1.3V
  - Moisture Resistance per Mil 123 @1V

Process and Material Development

Process and Material Development Direction

Execute & Deliver

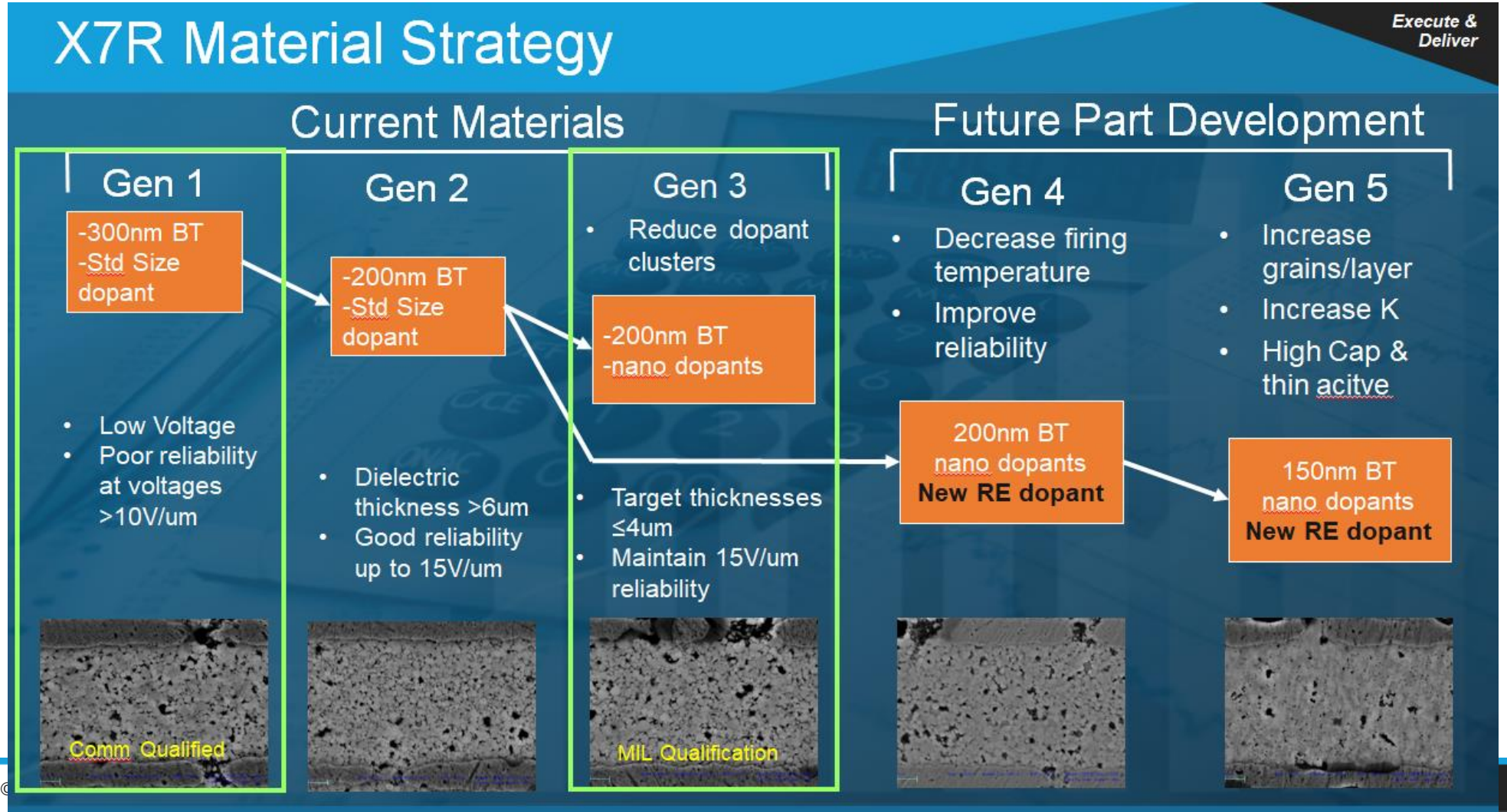
Higher V/um – Higher Reliability, Increased Voltage Ratings = New Business

DEVELOPMENT: Continue to increase volts/um through equipment, process and material improvements.

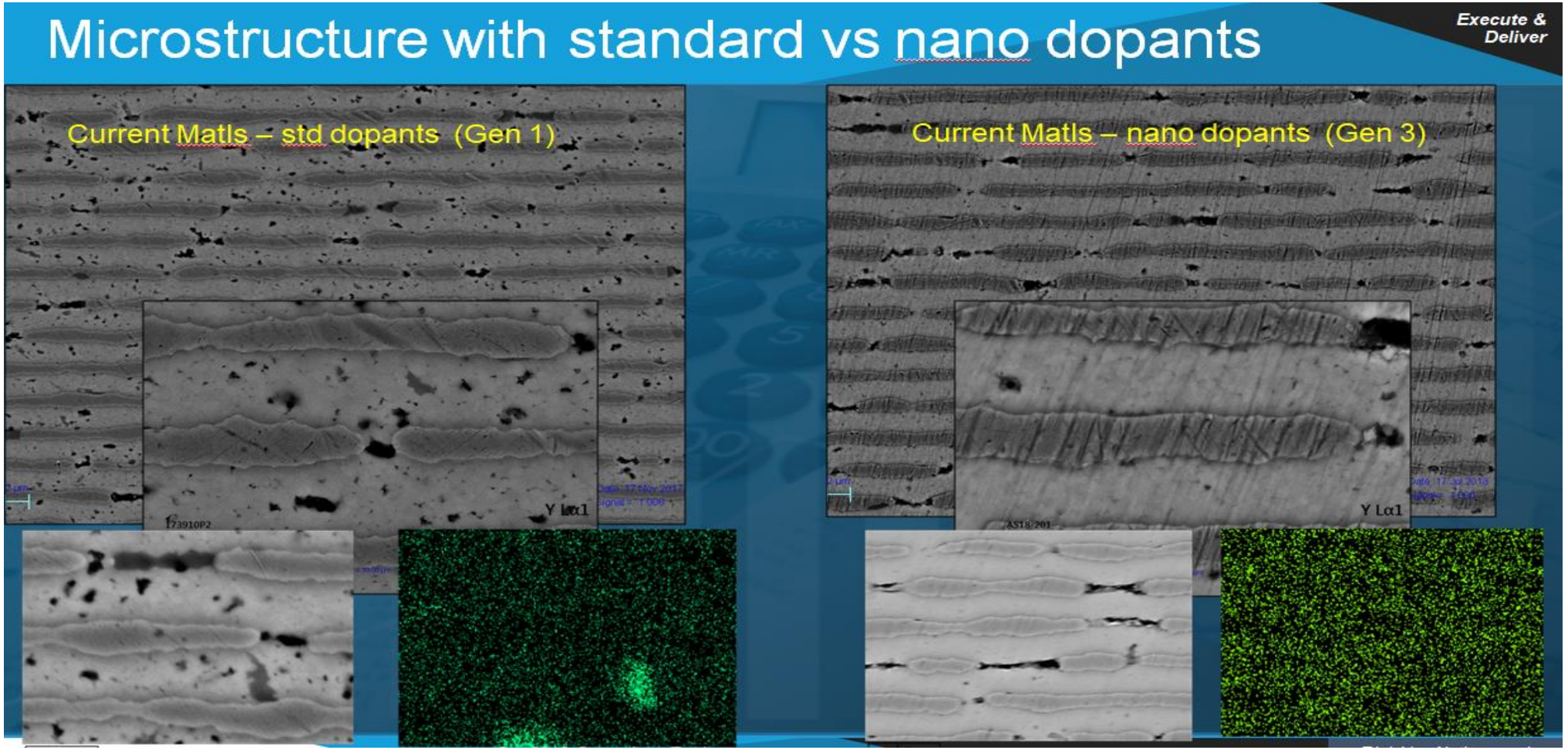
Current Capability for CMAP (Wet Process) and TTP (Thin Tape Process) | Development

LOW INDUCTANCE MLCC CAPACITORS FOR HIGH SPEED MICRO-PROCESSOR CIRCUITS

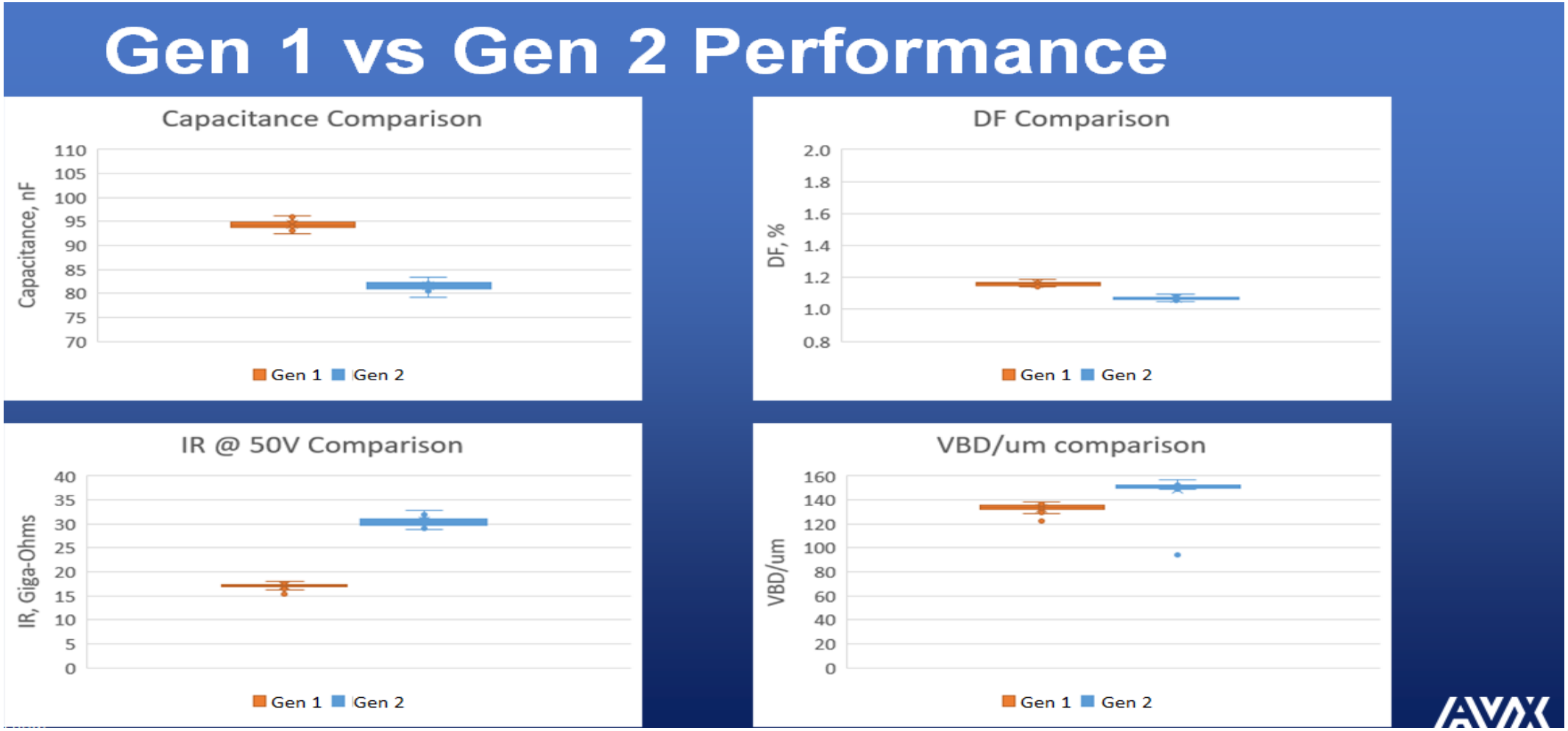
Material Development 2018 – 2020 →21/22



Product Microstructure



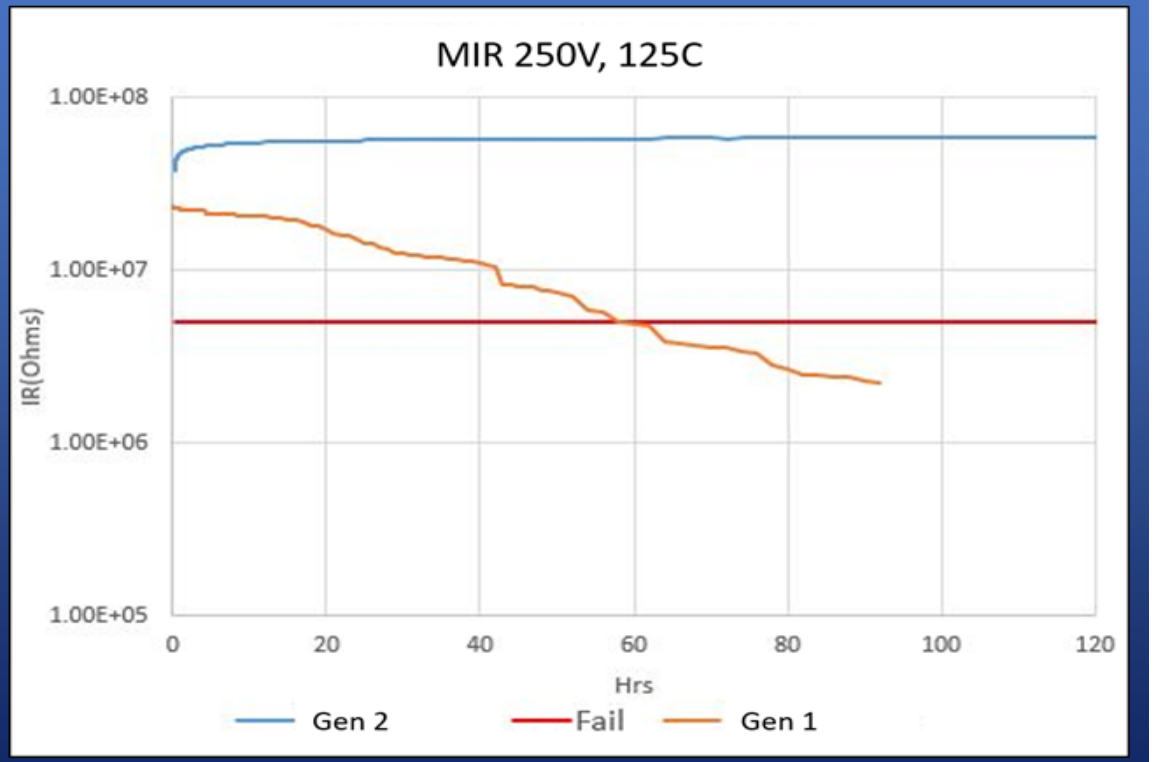
Material Generation Type Comparison



Material Generation Type Comparison

Generation 2 Performance Increase

- MIR performance benchmarked at 250V
- Std Life Test voltage for 0306 IDC = 3.3V/um
- For benchmarking dielectric
  - Gen 1 tested at 24 V/um
  - Gen 2 tested at 33 V/um



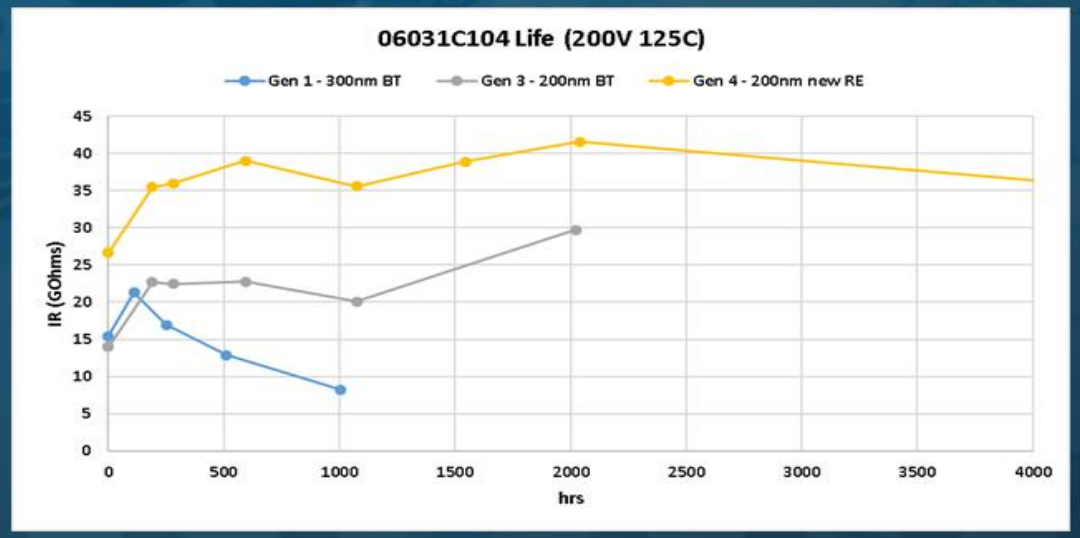
Ceramic Slurry evaluations for Reliability Performance

Test Part 06031C104 used for Ceramic Slip type Evaluation on Reliability

Execute & Deliver

- Different generations of slip were tested on **Life (200V @ 125C)**
- All parts are 06031C104 with same design
- All parts were run for 1000hrs.
  - The best parts were submitted for 2000 and 4000 hour testing
- All slips are based on the same base composition

  - **300nm BT & dopants – Gen 1**
  - **200nm BT & nano dopants – Gen 3**
  - **200nm BT & nano dopants new RE – Gen 4**



LOW INDUCTANCE MLCC CAPACITORS
FOR HIGH SPEED MICRO-PROCESSOR CIRCUITS

IDC Product Qualification Plan Hi Rel

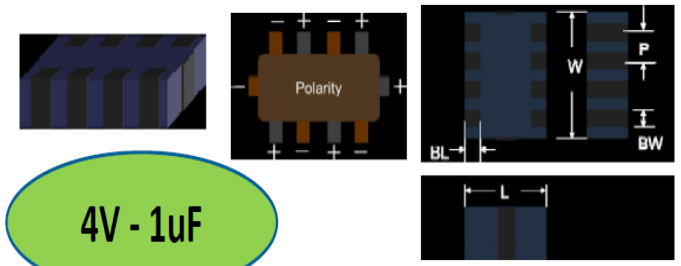
0306 — **X7S**

PERFORMANCE SPECIFICATION SHEET

CAPACITORS, CHIP, MULTIPLE LAYER, FIXED, CERAMIC DIELECTRIC (GENERAL PURPOSE), STANDARD RELIABILITY AND HIGH RELIABILITY, STYLE IDC 0306 (Interdigitated Capacitor)

This specification sheet is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the product described herein shall consist of this specification sheet and MIL-PRF-32535.



4V - 1uF

TABLE I. Style IDC 0306 capacitor characteristics.

Part or Identifying Number (PIN) 1/	Capacitance (pF)	Capacitance tolerance	VTL/TC	Rated voltage (Vdc)	Electrode Material
M3253511E3-104---	100,000	M	X7S	4	B
M3253511E3-224---	220,000	M	X7S	4	B
M3253511E3-334---	330,000	M	X7S	4	B
M3253511E3-474---	470,000	M	X7S	4	B
M3253511E3-105---	1,000,000	M	X7S	4	B

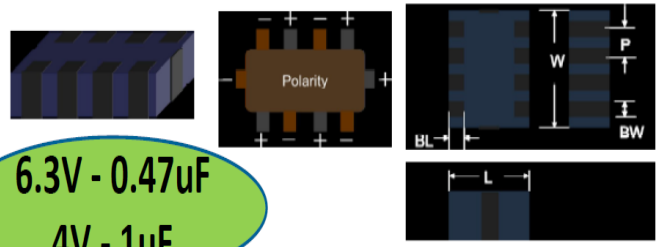
0508 — **X7R**

PERFORMANCE SPECIFICATION SHEET

CAPACITORS, CHIP, MULTIPLE LAYER, FIXED, CERAMIC DIELECTRIC (GENERAL PURPOSE), STANDARD RELIABILITY AND HIGH RELIABILITY, STYLE IDC 0508 (Interdigitated Capacitor)

This specification sheet is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the product described herein shall consist of this specification sheet and MIL-PRF-32535.



6.3V - 0.47uF
4V - 1uF

Part or Identifying Number (PIN) 1/	Capacitance (pF)	Capacitance tolerance	VTL/TC	Rated voltage (Vdc)	Electrode Material
M3253513E2-104---	100,000	M	X7R	6.3	B
M3253513E2-224---	220,000	M	X7R	6.3	B
M3253513E2-334---	330,000	M	X7R	6.3	B
M3253513E2-474---	470,000	M	X7R	4	B
M3253513E2-684---	680,000	M	X7R	4	B
M3253513E2-105---	1,000,000	M	X7R	4	B

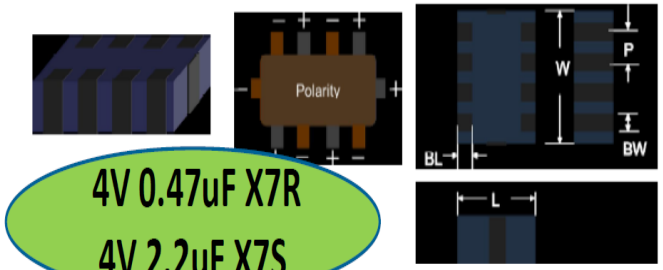
0508 - Thin — **X7R & X7S**

PERFORMANCE SPECIFICATION SHEET

CAPACITORS, CHIP, MULTIPLE LAYER, FIXED, CERAMIC DIELECTRIC (GENERAL PURPOSE), STANDARD RELIABILITY AND HIGH RELIABILITY, STYLE IDC Thin 0508 (Interdigitated Capacitor)

This specification sheet is approved for use by all Departments and Agencies of the Department of Defense.

The requirements for acquiring the product described herein shall consist of this specification sheet and MIL-PRF-32535.

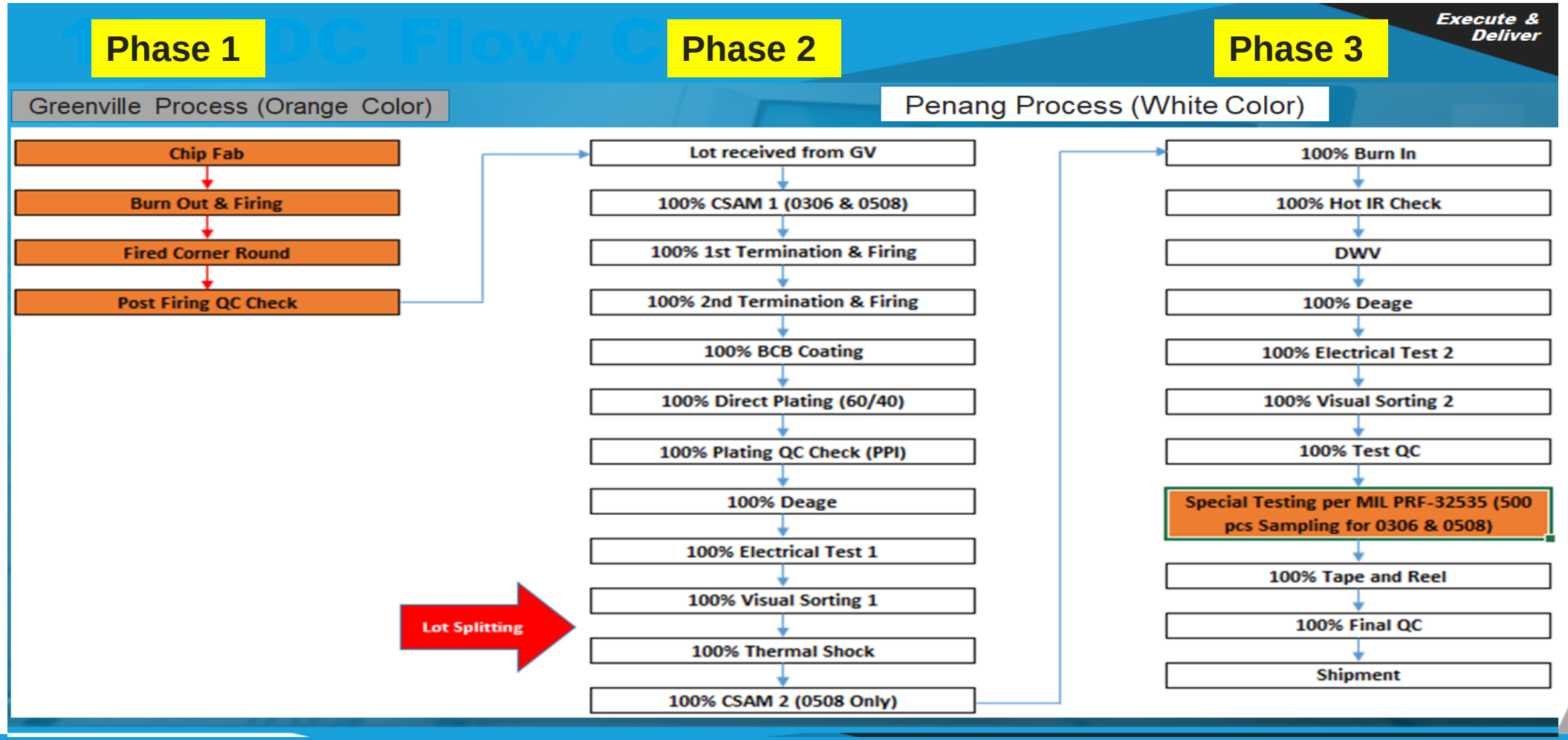


4V 0.47uF X7R
4V 2.2uF X7S

TABLE I. Style IDC Thin 0508 capacitor characteristics.

Part or Identifying Number (PIN) 1/	Capacitance (pF)	Capacitance tolerance	VTL/TC	Rated voltage (Vdc)	Electrode Material
M3253512E2-334---	330,000	M	X7R	4	B
M3253512E2-474---	470,000	M	X7R	4	B
M3253512E3-684---	680,000	M	X7S	4	B
M3253512E3-105---	1,000,000	M	X7S	4	B
M3253512E3-225---	2,200,000	M	X7S	4	B

Mil 32535 IDC Product Process Flow 2020 -21



Manufacturing Processes IDC Fabrication (Phase1)

1980s – 2020 PME only

Screener / Stacker
Dry Tape Process
Dielectric thickness 33um+
NO IDC Manufacture

1995 – 2020 PME /BME

CMAP Wet Process
Dielectric thickness 5um+
IDC 0612 and 0508 BME
Manufacture low to medium values

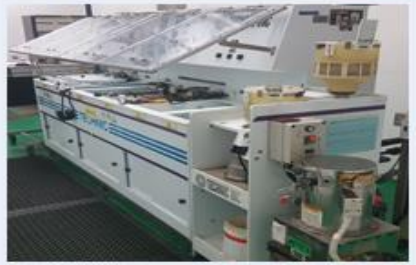
2000 – 2020 BME only

TTP Dry Tape Process
Dielectric Thickness 1um+
IDC 0508 and 0306 BME
Manufacture max caps

M32535 IDC Process Flow (Phase 2)

10T Process

Execute & Deliver

Process	Photo	Description
(1) CSAM		Screening for detecting internal defects (void delamination crack) in ceramic capacitor
(2) Termination		Add conductive paste to form electrode connection for the units
(3) Termination Firing		Add conductive paste to form electrode connection for the units
(4) Coating		Coating process is designed to apply a layer of coating on product to protect the chemical flow into to any pores on the ceramic body during chemical plating
(5) Plating		Process for plating nickel and 60/40 SnPb at the both end of chip termination
(6) Electrical Test		Tested the unit which have failure in Flash Voltage Insulator Resistance Capacitance and Dissipation factor

M32535 IDC Process Flow (Phase 3)

10T Process

Execute & Deliver

Process	Photo	Description
(7) Sorting		Screening for detecting cosmetic defects
(8) Thermal Shock		Reliability test to expose capacitor in alternating extreme high and low temperature
(9) Burn In		Accelerating test to screen out infant mortality capacitor

Process	Photo	Description
(10) Hot IR		To measure capacitor insulation resistance (IR) at elevated temperature
(11) Tape and Reel		Packaging process

LOW INDUCTANCE MLCC CAPACITORS
HIGH SPEED MICRO-PROCESSOR CIRCUITS 10T IDC QUALIFICATION PLAN

Process Step	0306 10T	0508 10T
Front End Fab	Complete	Complete
CSAM 1	Complete	Complete
Back End Fab	Complete	Complete
Thermal Shock	Complete	Complete
CSAM 2	N/A	Complete
Voltage Conditioning (Burn In)	Q2	Q2
Hot IR / DWV	Q2	Q2
Electrical Test 2	Q2	Q2
Visual Sort 2 / QC	Q2	Q2
QC Sample to GRV	Q2	Q2
Thermal Shock	Q2	Q2
4000hr Testing	Dec 2021	Dec 2021

Notes:

1. Materials and Processes fine tuned for enhanced V/um capability
2. Product at Penang Manufacture and test .
3. IDC Military Standard qualification date forecast through 2022 .
4. IDC Mil. Std. DLA audit date delayed due to Covid travel .

LOW INDUCTANCE MLCC CAPACITORS FOR HIGH SPEED MICRO-PROCESSOR CIRCUITS

Conclusions :

- **IDC - Low Inductance device *qualification underway* for Mil 32535 specification .**
- **Product focus *10T 0306 1uF & 0508 2.2uF***
  - Samples at Penang Manufacturing pre- reliability testing
  - Tests to start Q2 2021
  - DLA Audit date to Penang facility to be finalised COVID ?
- **Materials and Process Optimisation**
  - Ceramic formulation modified for improved v/um capability
  - Tooling available for 10T termination and electrical testing
  - Testing systems now available for 100% Burn-In and Hot IR
  - 100% CSAM Pre + Post termination

THANK YOU.