FARADFLEX

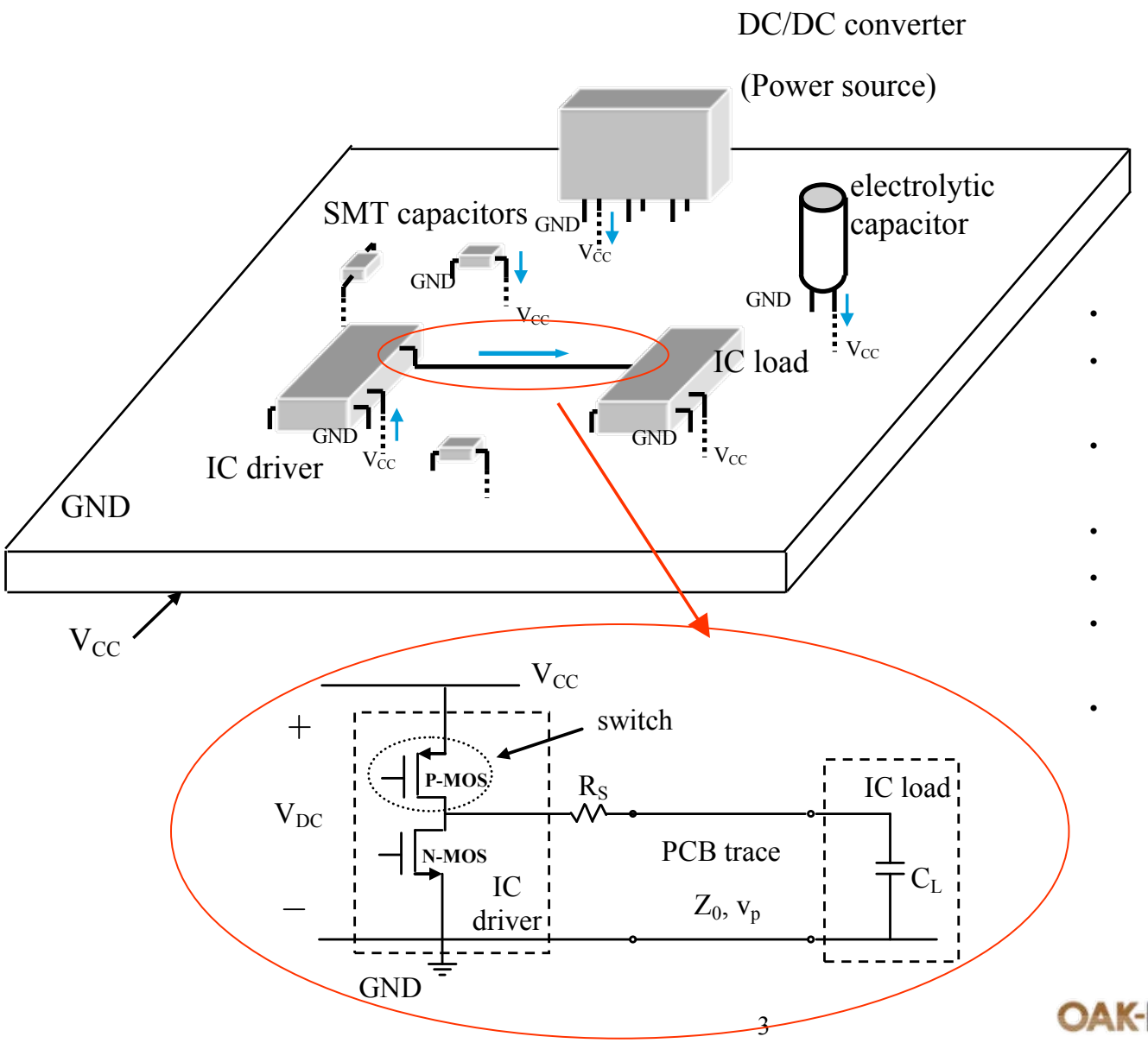
Improve Power Delivery and Reduce Noise with Embedded Capacitance

OAK-MITSUI TECHNOLOGIES
MITSUI KINZOKU CORPORATE GROUP

FARADFLEX®

- Typical PDN
- Why consider it
- Types of Embedded Capacitance
- Space
- Target Impedance/ Low Inductance
- Materials
- In a PCB
- Electrical Performance
- Case Studies

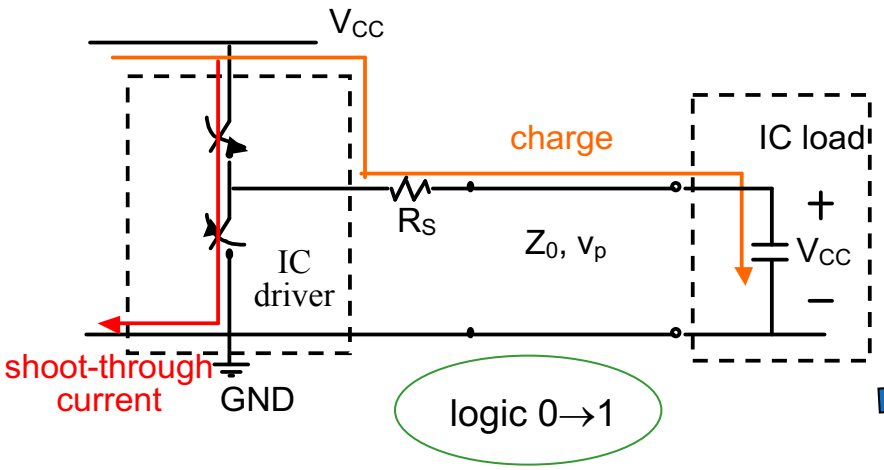
PDN in a Multi-Layer PCB

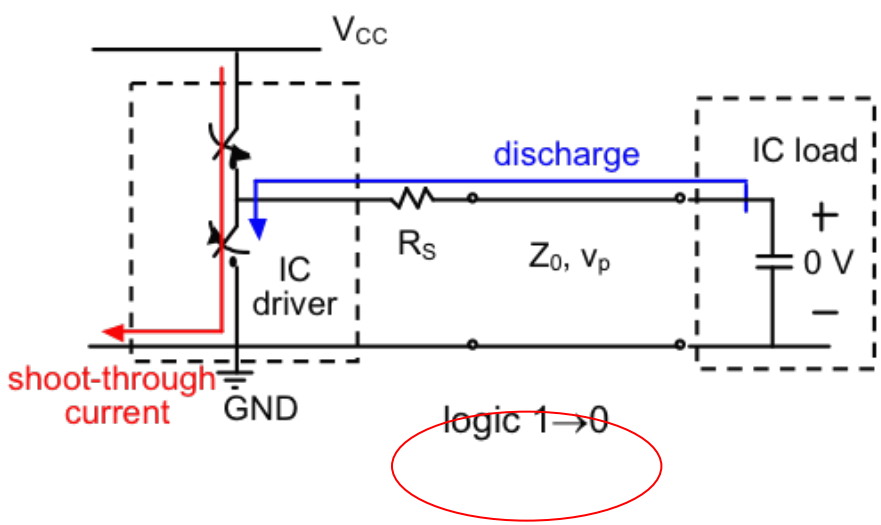


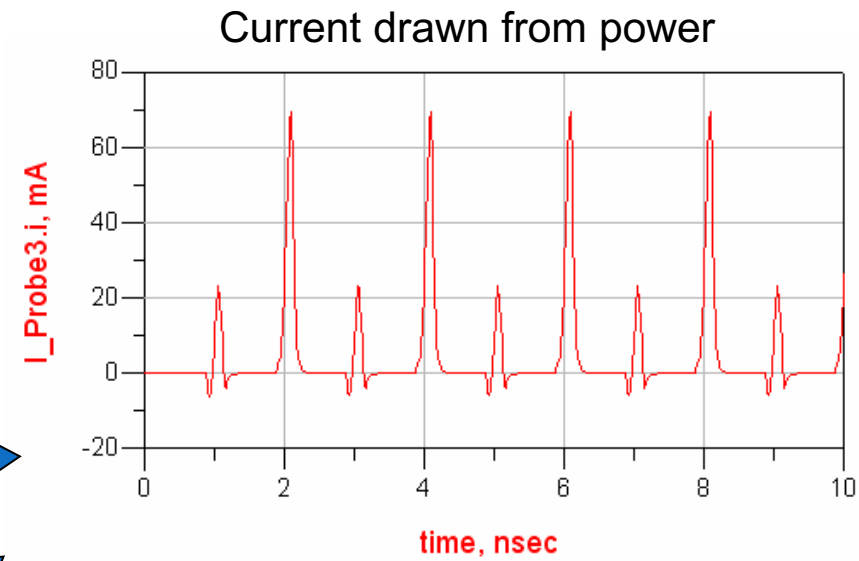
- Capacitor interconnects;
- Individual capacitor values and packaging forms;
- Number of capacitors needed;
- Capacitor placement;
- PCB stack-up;
- Power/ground plane pair geometry;
- Segmentation and isolation

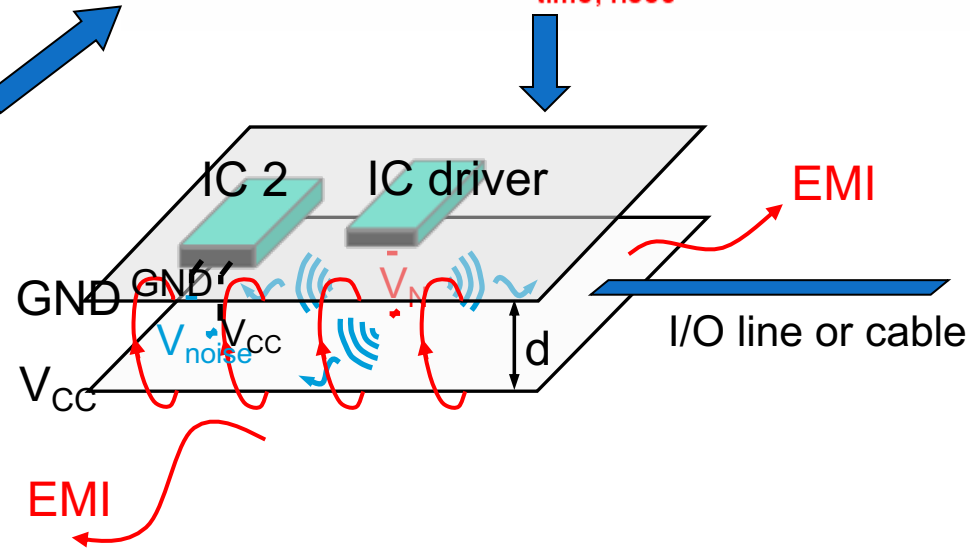
Courtesy of Dr. Jun Fan, MST

Device Switching And Noise Current







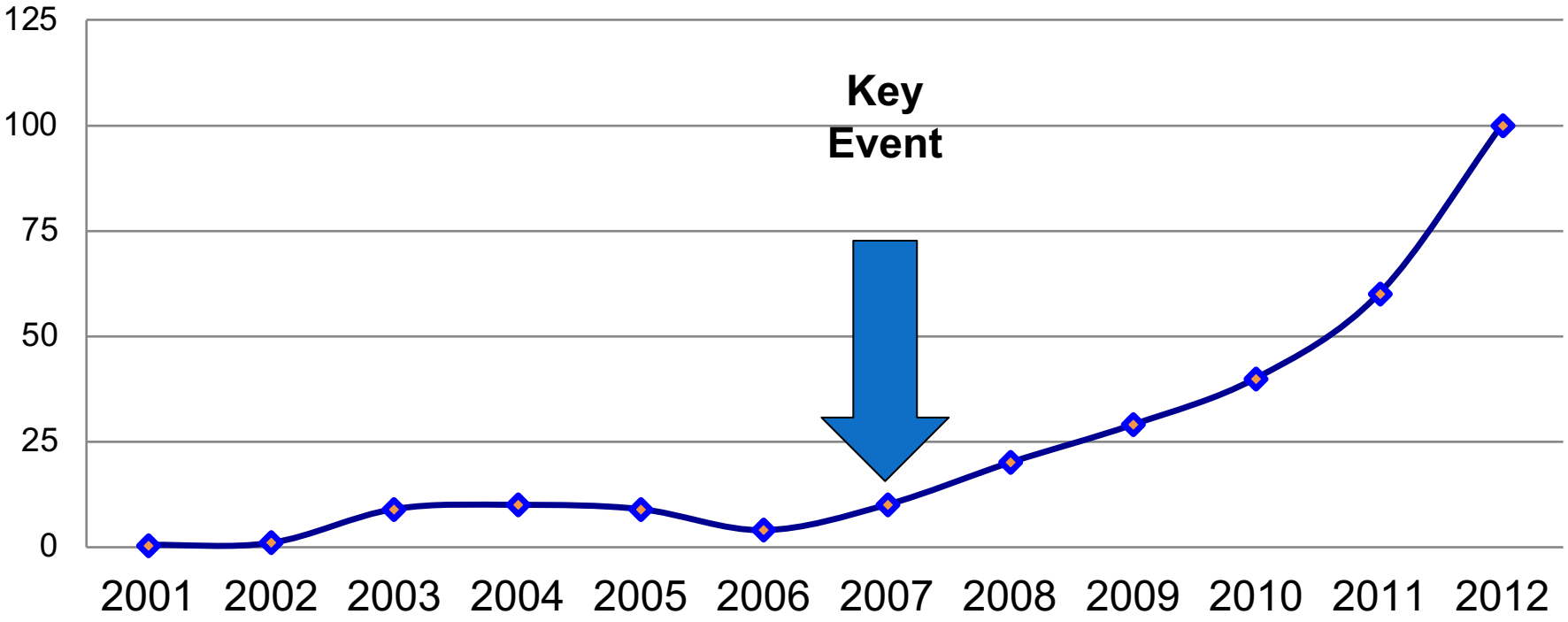


J. L Knighten, B. Archambeault, J. Fan, et. al., "PDN Design Strategies: IV. Sources of PDN Noise," *IEEE EMC Society Newsletter*, Winter 2007, Issue No. 212, pp. 66-76.

Why Embedded Capacitance and Thin Dielectrics?

- Better PDN
  (Power Delivery Network)
- Lower profile
- More design space
- Low inductance
- Low impedance
- Reduced noise
- Thickness reduction
- Can remove most 0.1μf and 0.01 μf decoupling capacitors
- Weight reduction
- Higher reliability
- In some designs better thermal transfer

Background / Motivation



Ultra-Thin Laminate Market Growth

2014 IPC Survey

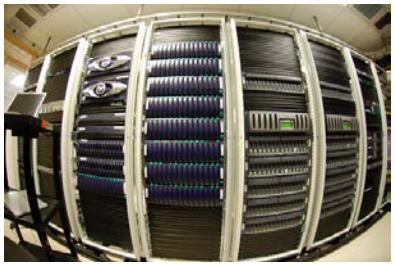
1. Of the companies in the survey 30% of their PCB's are using Embedded Capacitance

2. In 2015 and beyond the expectation are that this will more than double

FaradFlex® Applications

Routers

Servers
(Cloud computing)



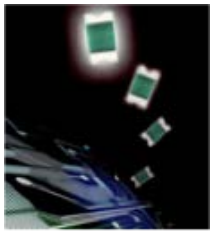
SSD storage

Super computers

Military

Aerospace

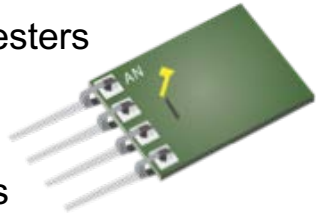
Drones



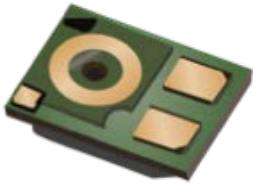
Organic Capacitor chip
Diplexers, RF Filters

Medical

IC testers



Modules



MEMS Microphones
(Size 2.5mmx3.5mm)

Automotive

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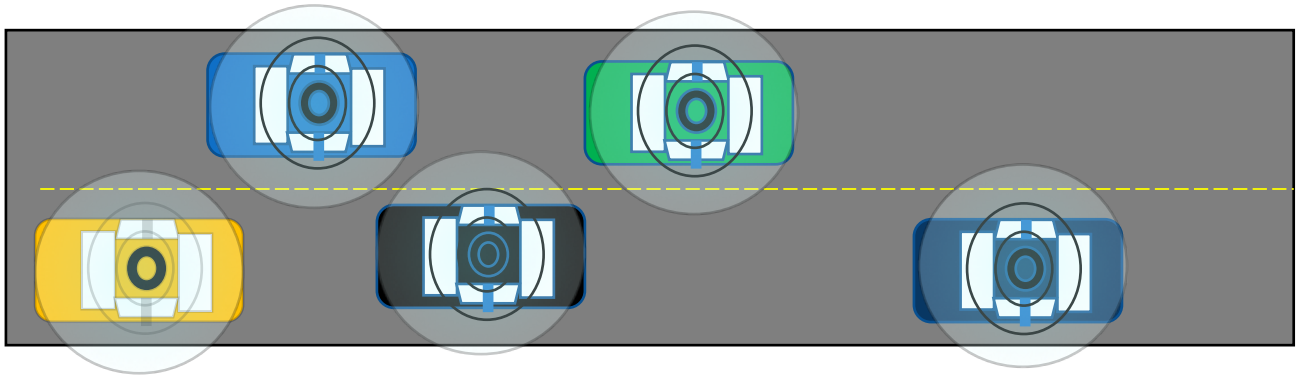
Automotive Applications

Vehicle to Infrastructure Network and Vehicle-to-Vehicle



Vehicle communication with each other and surrounding infrastructure traffic information like accidents, traffic jams, incoming emergency vehicles, and weather information, among other things

- **Electronic Toll Collection**
- **Cooperative Adaptive Cruise Control**
- **Intersection Collision Avoidance**
- **Approaching Emergency Vehicle Warning**
- **Automatic Vehicle Safety Inspection**
- **Transit or Emergency Vehicle Signal Priority**
- **Electronic Parking Payments**
- **Commercial Vehicle Clearance**
- **In-Vehicle Display of Road Signs and Billboards**
- **Traffic Data Collection**
- **Rail Intersection Warning**

Automotive Applications

Sensors and Controls for **Intelligent Operating**

LIDAR

Radar

Thermal

Ultrasonic

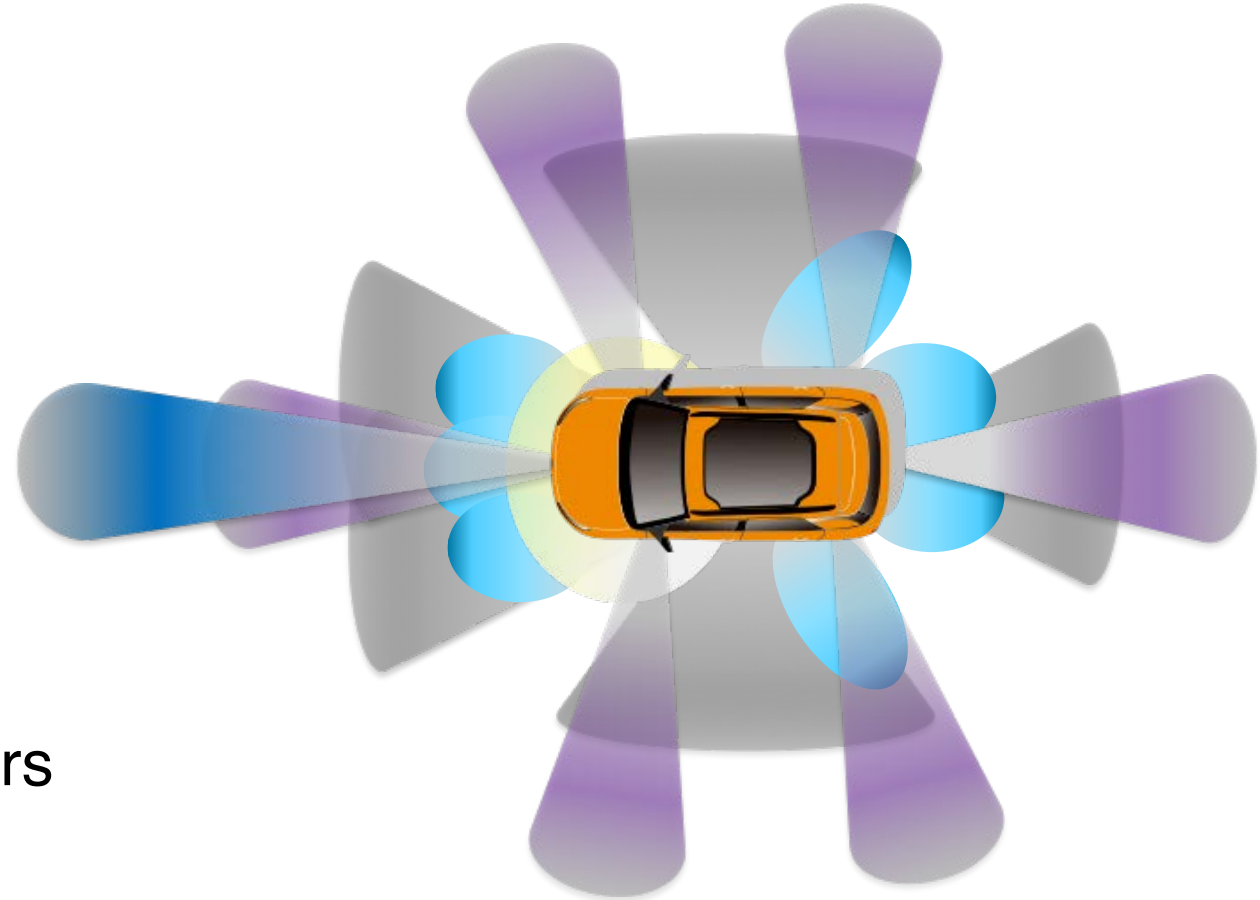
Sonar

Camera

Air Bag Sensors

GPS

Night Vision



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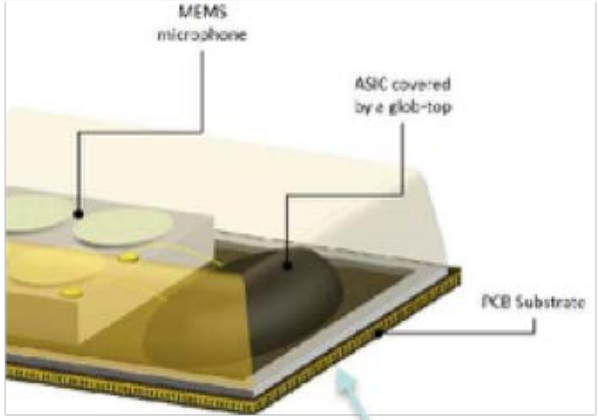
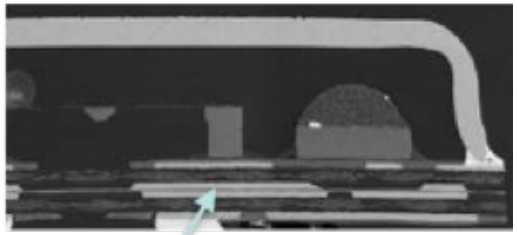
Microphone Substrates



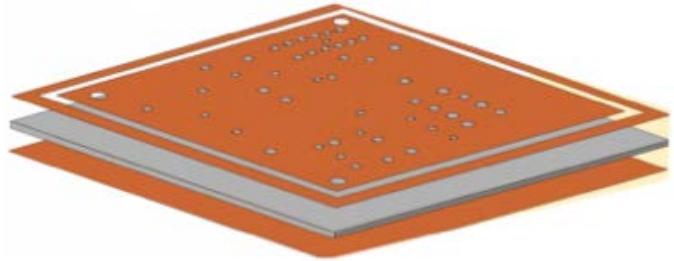


PCB Substrate using FaradFlex ultra-thin embedded capacitance material.

courtesy of Yole

Types of Embedded Capacitance

Planar Layers in PCB



Use this in an existing stack up of layers in the PCB

Pros
- Easy
- Addresses many issues with PCB design and power delivery
- Same or lower cost
- More reliable

Cons
- Limited capacitance currently available

Discrete in PCB cavity

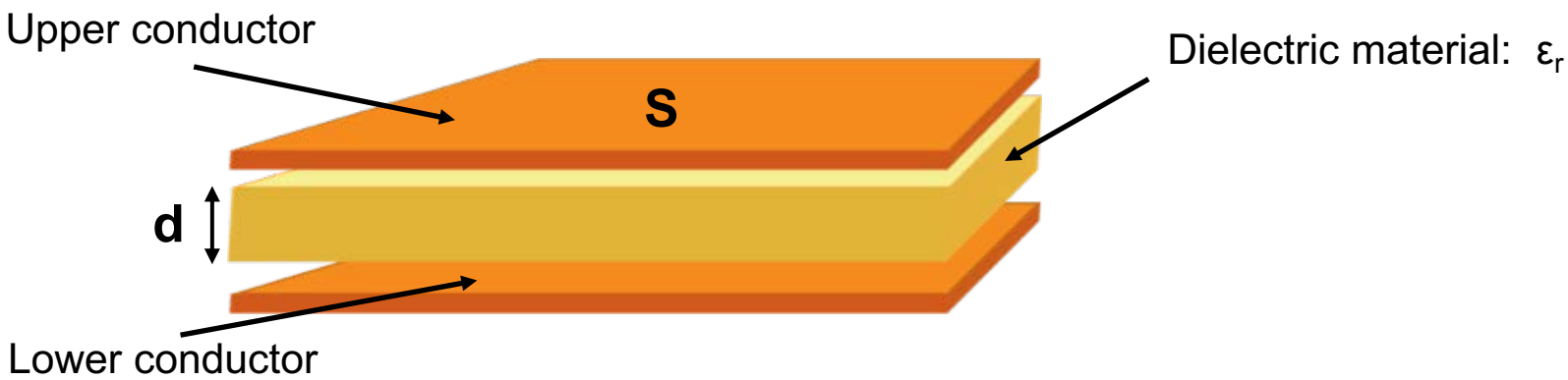
Leave a cavity open in the PCB and then place the capacitor and solder in place and then fill the cavity

Pros
- Full values of capacitance available

Cons
- Manufacturing and design difficulty
- Costly
- Less reliable

What is a Planar Capacitor?

Conductive plane pair with dielectric separation



$$C = \frac{K * D_k * S}{d}$$

C = Capacitance (Farads)

S = Area of plates

D_k = Dielectric constant of material between plates

K = Constant

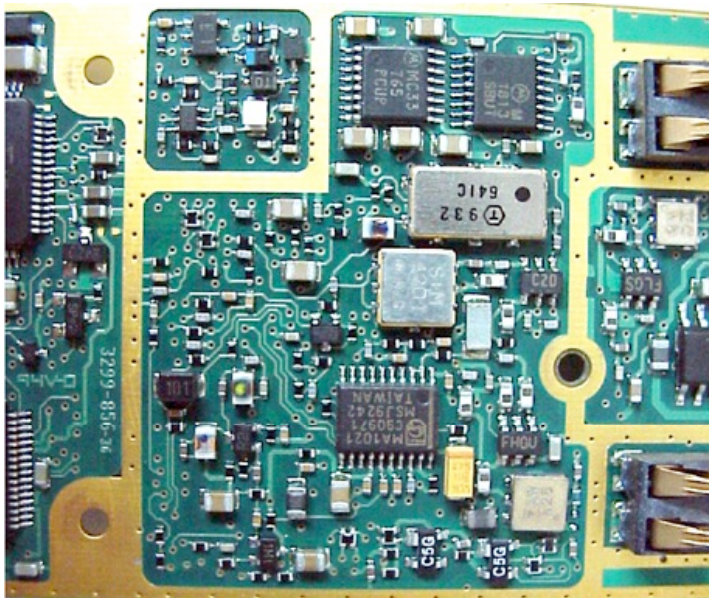
d = Thickness between plates

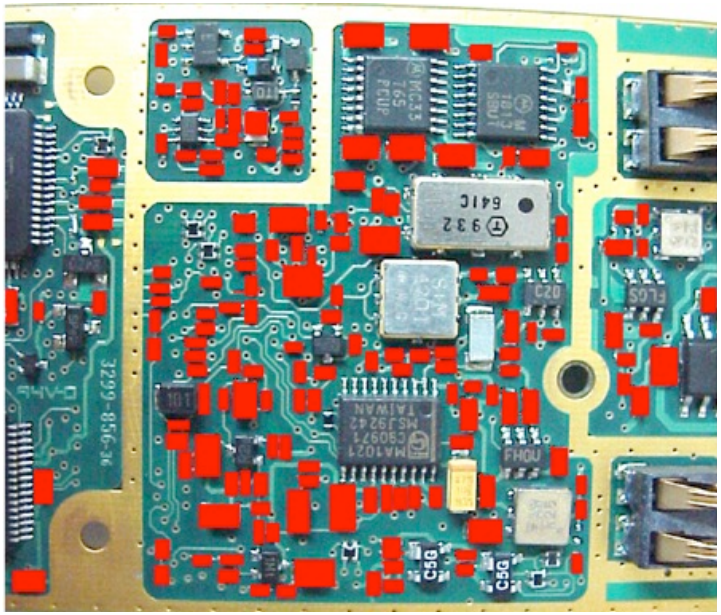
Current planar ultra-thin material sets:

1. Polymer film and resin combination (**Dupont and Oak-Mitsui**)
2. Unsupported resin filled with high Dk or other types of particles (**3M and Oak-Mitsui**)

Running Out of PCB Real Estate

Component density is reaching its limit





Passive components

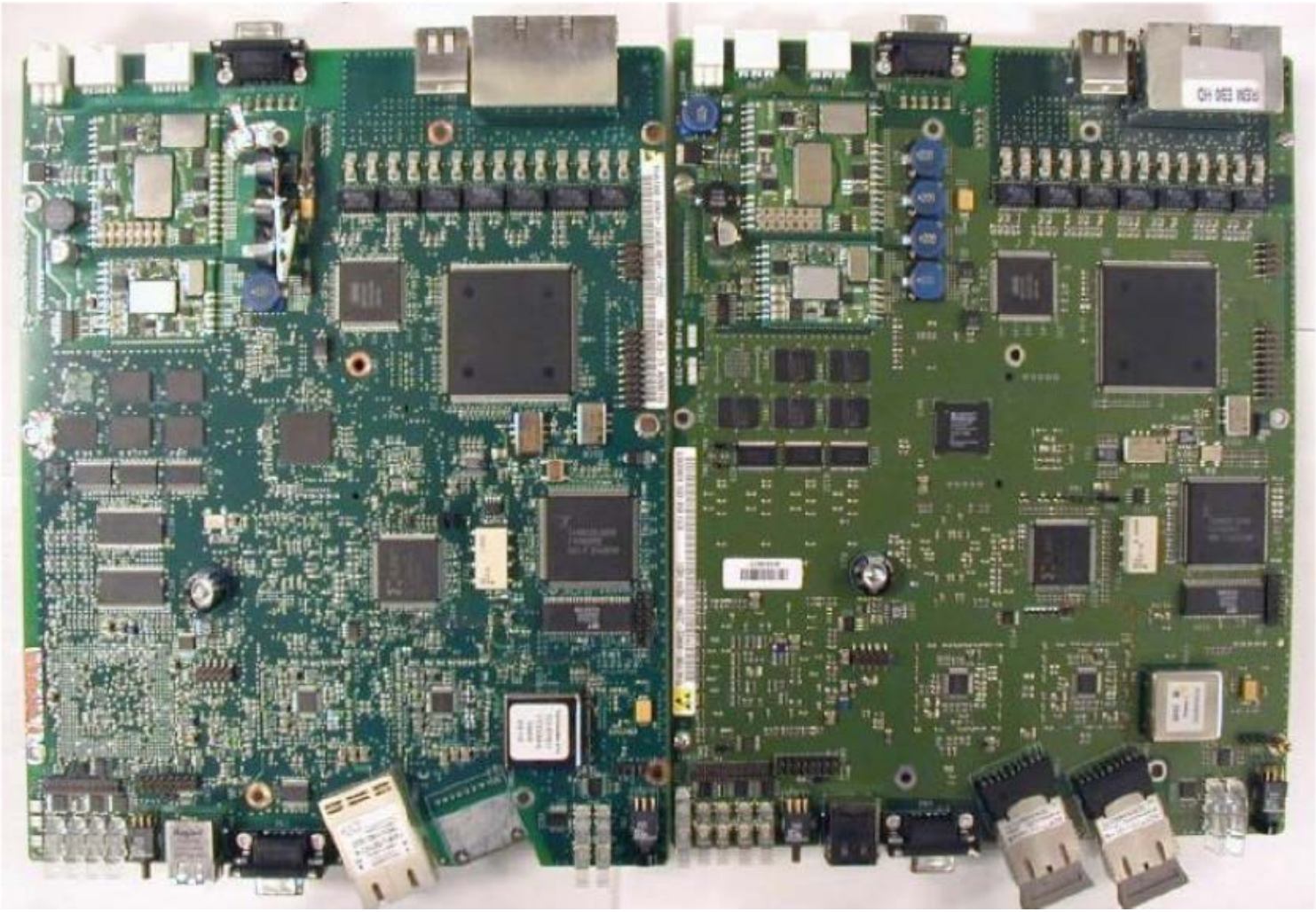
High capacitance and capacitance uniformity are key

Source: Richard Ulrich University of Arkansas

8 Layer HDI Design

With Decoupling Caps

Without Decoupling Caps



With shared planar embedded capacitance

Courtesy of Gary Ferrari, FTG

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14 Layer Design

With Decoupling Caps **Without** Decoupling Caps

With shared planar embedded capacitance

Courtesy of Gary Ferrari, FTG

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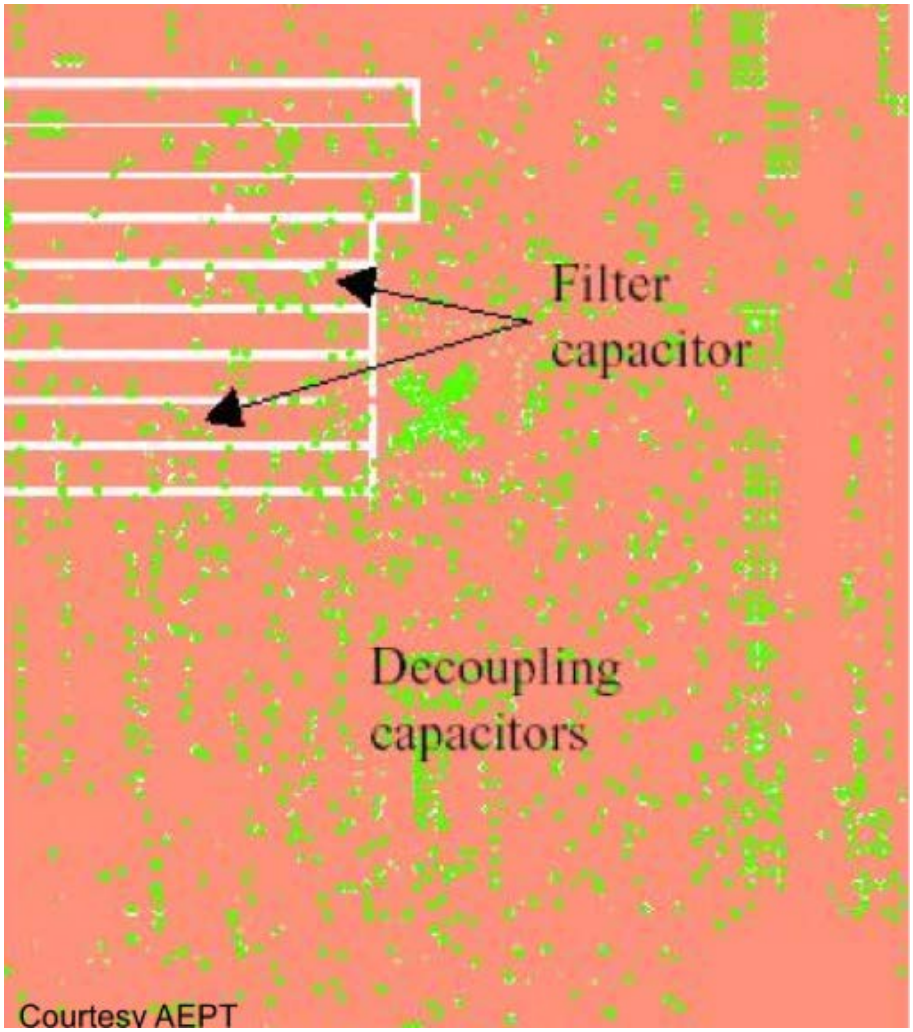
Discrete Capacitors on a Distributed Capacitor Plane



Courtesy of Gary Ferrari, FTG

Two Approaches to Embedded Capacitance

Solution

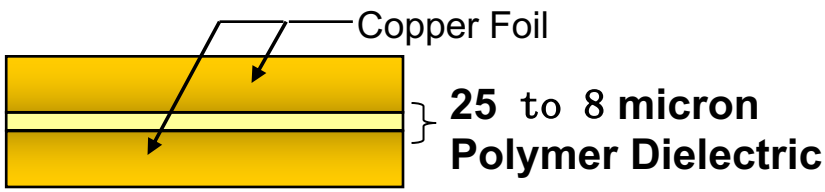
High speed computing boards

Servers, Routers, Switches, computers

Power distribution improvement

Uitra-Thin substrate

for use as embedded capacitor



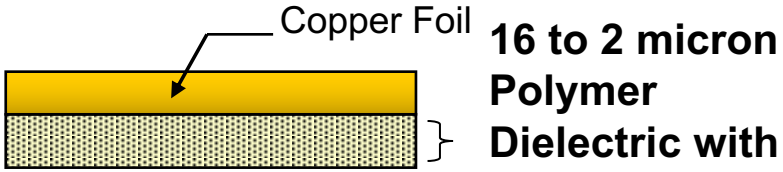
Module boards

Microphones, Cell phones, sensors, filters, tablets, controls

Miniaturization / HDI

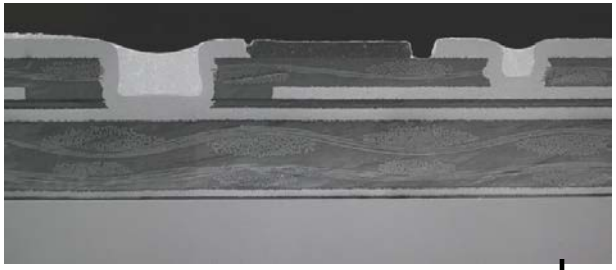
Hi-Dk RCF

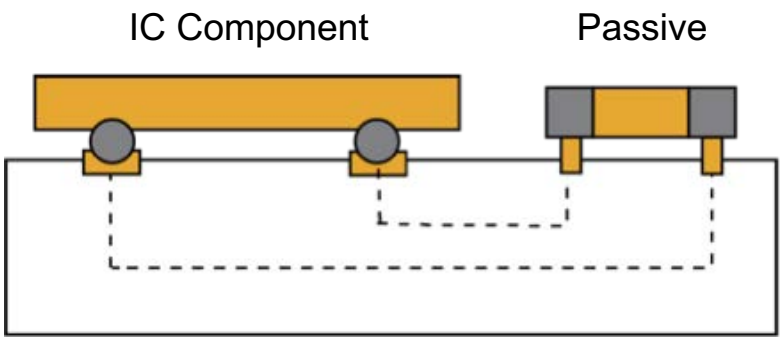
for used as embedded capacitor



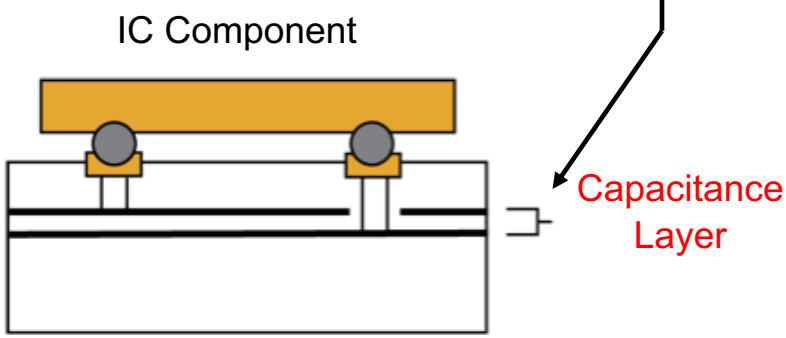
FaradFlex® for Enhanced Performance

FaradFlex® greatly reduces power buss noise and eliminates the need for many decoupling capacitors





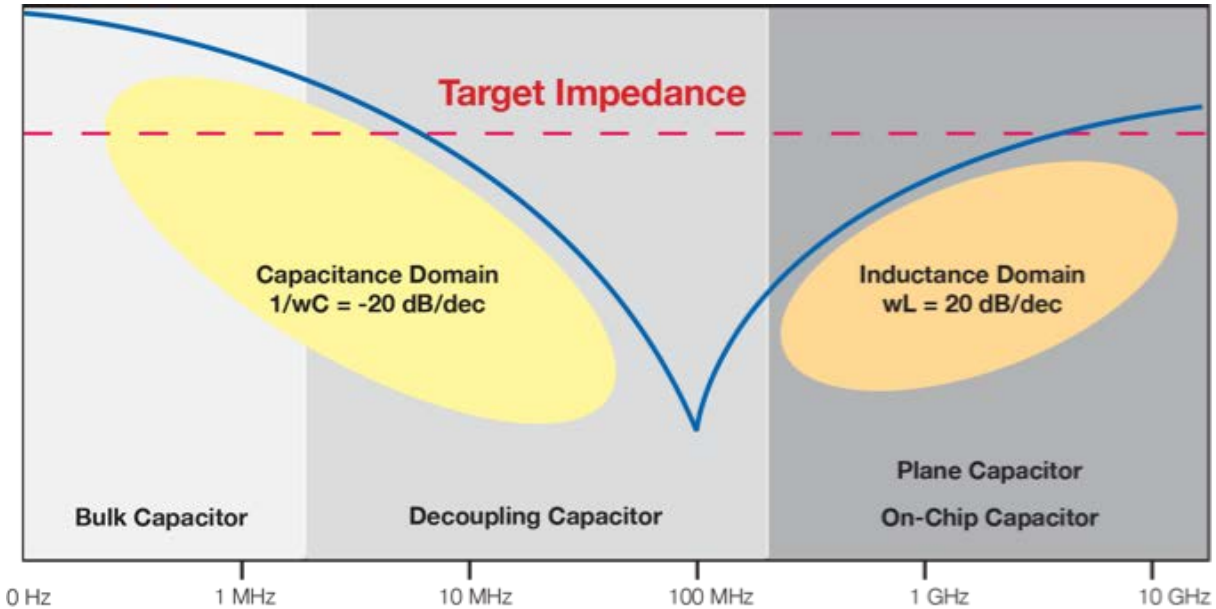
High Inductance



Low Inductance

FaradFlex® Compared to Traditional Material

- ***FaradFlex***® is ½ to 1/6 the thickness compared to the typical "thinnest" laminate using glass cloth reinforcement
- ***FaradFlex***® increases thermal transfer from the PCB due to the ultra thin power-ground substrate.
- Dielectric withstanding voltage is typically 10 times better with ***FaradFlex***® than the traditional FR-4 laminates and similar materials.



FARADFLEX®

Power Distribution Network Simulations Resonance/Noise/EMI

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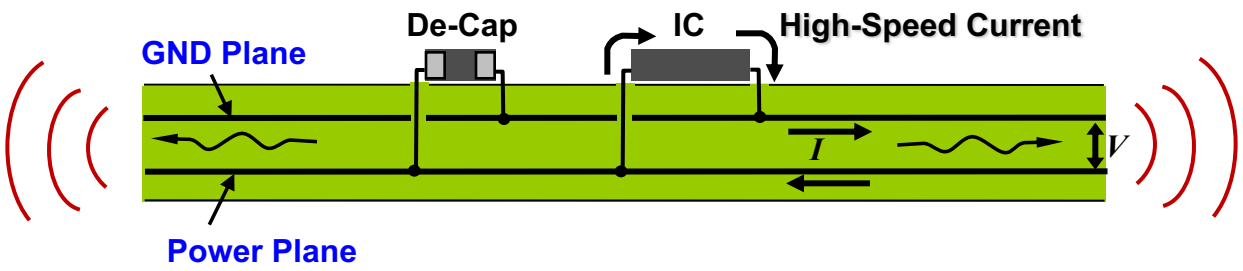
Why *FaradFlex*® Can Reduce EMI

1. Can minimize loop area $(E_r = 1.316 \times 10^{-14} \times I \times f^2 \times S/r)$
2. Can minimize power bus noise
3. Can minimize resonance
4. Can minimize propagation to the edge
   (Related to Transfer Impedance (S21))

E : Electric Field Strength
I : Normal Mode Current
f : Frequency
S : Loop Area
r : Distance



Standard Dk Products

Properties	Test Method	Standard Dk Products			
		MC24M	MC12M	MC8M	MC25L
Dielectric Thickness, µm	IPC or others	22	12	8	25
Cp @ 1 MHz, nF/in² (pF/cm²)	Nominal	1.2 (180)	1.9 (300)	3.1 (480)	1.0 (130)
Dk (Dielectric Constant) @ 1 MHz/ 1 GHz	IPC TM-650 2.5.5.2	4.4/ 3.5	4.4/ 3.5	4.4/ 3.5	3.9/ 3.8
Df (Loss Tangent) @1 MHz/ 1 GHz	IPC TM-650 2.5.5.2	0.015/ 0.016	0.015/ 0.020	0.016/ 0.021	*0.004/ 0.005
Peel Strength, lbs/ linear in.	IPC TM-650 2.5.5.2	8	8	5	8
Dielectric Strength, kV/ mil	IPC TM-650 2.4.9	>7	>7	>5	>7
Tensile Strength, MPa (kpsi)	ASTM D-882A	219 (31.8)	194 (28.2)	126 (18.3)	227 (32.9)
Elongation, %	ASTM D-882A	36.0	13.5	8.5	47.0
CTE, ppm/ °C, x-y (40-200 °C), TMA	TMA	24	23	32	30
Tg,°C	DMA	183	187	188	161
Dielectric Withstanding Voltage (Hi-Pot test)	IPC TM-650 2.5.7.2	PASS (500V)	PASS (500V)	PASS (500V)	PASS (500V)
Thermal Stress (20 Sec Float @288°C), Times	–	>10	>10	>10	>10
THB, 85°C/ 85% RH/ dc bias	1000 hr	PASS	PASS	PASS	PASS
Flammability/Temp Rating	UL	V0 130°C	V0 130°C	V0 130°C	V0 130°C
PWB Processing	–	Both sides	Both sides	Both sides	Both sides

Note: This chart provides typical values for FaradFlex products.
*Low loss material

High Dk Products

Properties	Test Method	High Dk Products				
		MC12TM	MC8TM	MC8T	MC25ST	MC25LD
Dielectric Thickness, µm	IPC or others	12	8	8	25	25
Cp @1 MHz, nF/in² (pF/cm²)	Nominal	**4.2 (650)**	**7.1 (1100)**	**22 (3400)**	**4.3 (660)**	**2.1(320)**
Dk (Dielectric Constant) @ 1 MHz/ 1 GHz	IPC TM-650 2.5.5.2	10.0/ 9.5	10.5/ 10.0	30.0/ 25.0	18.5/ 18.0	8.3/ 7.8
Df (Loss Tangent) @1 MHz/ 1 GHz	IPC TM-650 2.5.5.2	0.015/ 0.020	0.020/ 0.021	0.025/ 0.031	0.004/ 0.008	***0.0027/ 0.0032**
Peel Strength, lbs/ linear in.	IPC TM-650 2.5.5.2	5	5	4	4	4
Dielectric Strength, kV/mil	IPC TM-650 2.4.9	5	4	1	2	2
Tensile Strength, MPa (kpsi)	ASTM D-882A	153 (22.2)	127 (18.4)	NA	NA	NA
Elongation, %	ASTM D-882A	31.4	14	NA	NA	NA
CTE, ppm/°C, x-y (40-200 °C), TMA	TMA	28	22	17 (α1) 42 (α2)	32 (α1) 97 (α2)	55
Tg, °C	DMA	189	191	191	160	215
Dielectric Withstanding Voltage (Hi-Pot test)	IPC TM-650 2.5.7.2	PASS (500V)	PASS (250V)	PASS (100V)	PASS (100V)	PASS (100V)
Thermal Stress (20 Sec Float @288 °C), Times	-	>10	>10	>6	>10	>10
THB, 85 °C/85% RH/ dc bias	1000hr	PASS	PASS	PASS	PASS	PASS
Flammability/Temp Rating	UL	V0 130°C	V0 130°C	V0 130°C	V0 130°C	V0 130°C
PWB Processing	-	Both sides	Both sides	Sequential	Sequential	Sequential

Note: This chart provides typical values for FaradFlex products.
***Low loss material**

Solutions for Modules, Packages and RF

Properties	Unit							NEW MATERIALS				
		MC12LD	MC8TM	MC5TM	MC12ST	MC16T	MC8T	MC3TS	MC2TS	MC3TA	MC8TD 2 BC	MC2TA
Dielectric Thickness	µm	12	8	5	12	16	8	3	2	3	16	3
Capacitance @1 KHz	ηf/in²	**4.2**	**7**	**8.5**	**11**	**11**	**22**	**35**	**40**	**40**	**44**	**50**
Dk (Dielectric Constant) @1 KHz		7.4	10.5	9.5	25.1	30	24	18	18	22	24	22
Df (Loss Tangent) @1 KHz		**0.002**	0.020	0.023	0.005	0.030	0.020	0.020	0.020	0.030	0.030	TBD
Breakdown Voltage >than		150	1000	1000	180	500	250	150	50	100	250	50
Peel Strength	kN/m	0.6	0.8	0.6	0.8	0.8	0.6	0.6	0.6	0.6	0.6	0.6
Thermal Stress (@288°C x 20 Sec Float x 6 Times)		Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass	TBD	Pass	TBD
Tg (DMA0 *reference only	°C	170	191	191	170	191	191	191	191	TBD	191	TBD

Note: This chart provides typical values for ***FaradFlex®*** products.
***Low loss material**

Higher Dk/ Thinner/ Higher Capacitance

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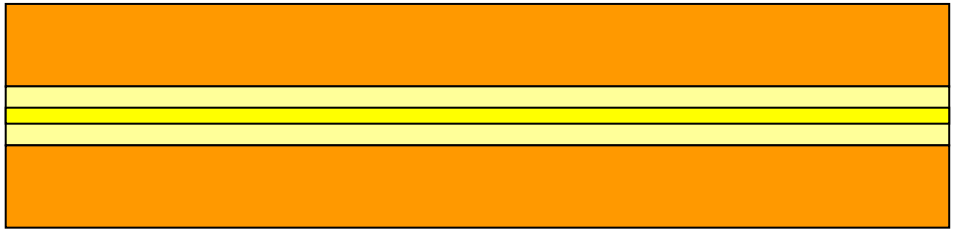
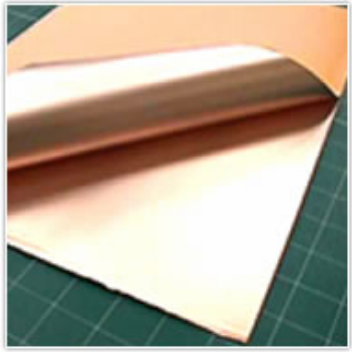
Embedded Capacitance Material (1)

First Type of Embedded Capacitance Laminate



Includes these products:

MC24M, MC12M, MC8M, MC25L



Laminate constructed with:

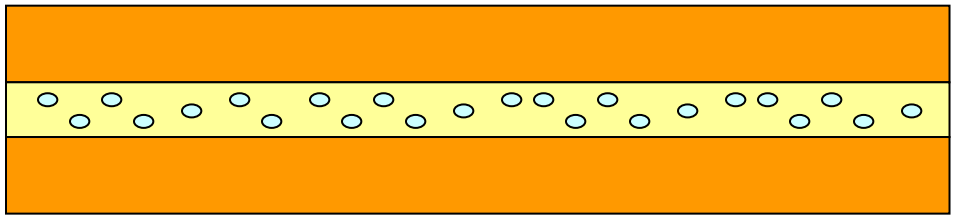
- **Copper**
- **Epoxy or other type resin bonded to a high performance polymer film**

Characteristics

- Most cost effective
- Longest in history
- Best processabilty
- Highest reliability

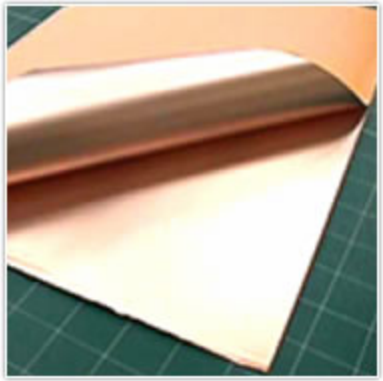
Embedded Capacitance Material (2)

Second Type of Embedded Capacitance Laminate



Includes these products:

MC16T, MC25ST, MC25LD



Laminate constructed with:

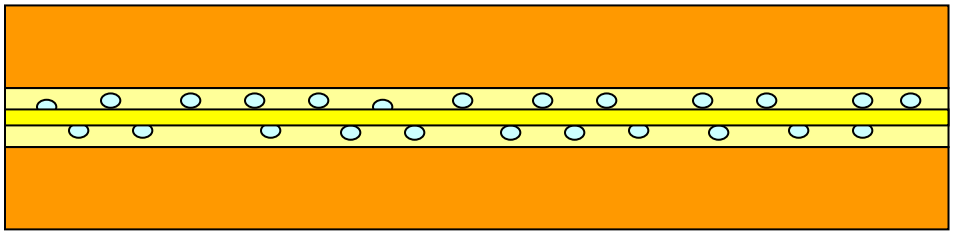
- **Copper**
- **Unsupported epoxy resin with barium titanate or other particles dispersed in the resin**

Characteristics

- Most costly laminate
- Highest Dk
- Lowest reliability
- Least processabilty
- Highest Capacitance

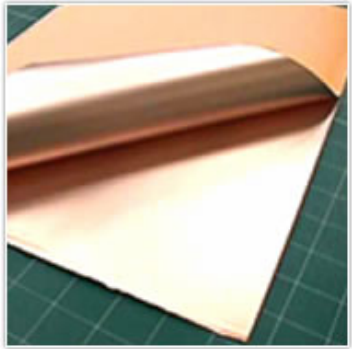
Embedded Capacitance Material (3)

Third Type of Embedded Capacitance Laminate



Includes these products:

MC12TM, MC8TM



Laminate constructed with:

- **Copper**
- **Supported epoxy resin and polymer film composite, barium titanate particles or other material dispersed**

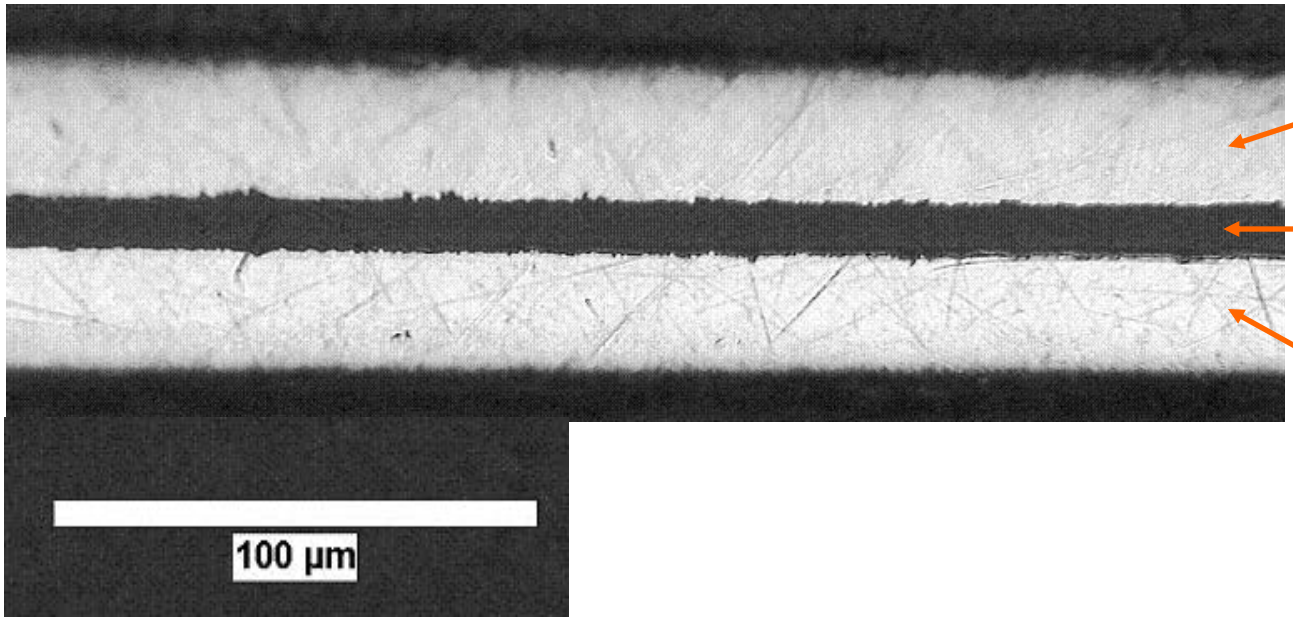
Characteristics

- Mid to more costly laminate
- Very High Dk
- High reliability
- High level of processabilty
- Very high capacitance
- High withstanding voltage

FaradFlex® Construction

Ultra-Thin substrate for use as power distribution layer

Construction of ultra-thin substrate



Copper foil

Dielectric layer using film 8 to 24 um

Copper foil

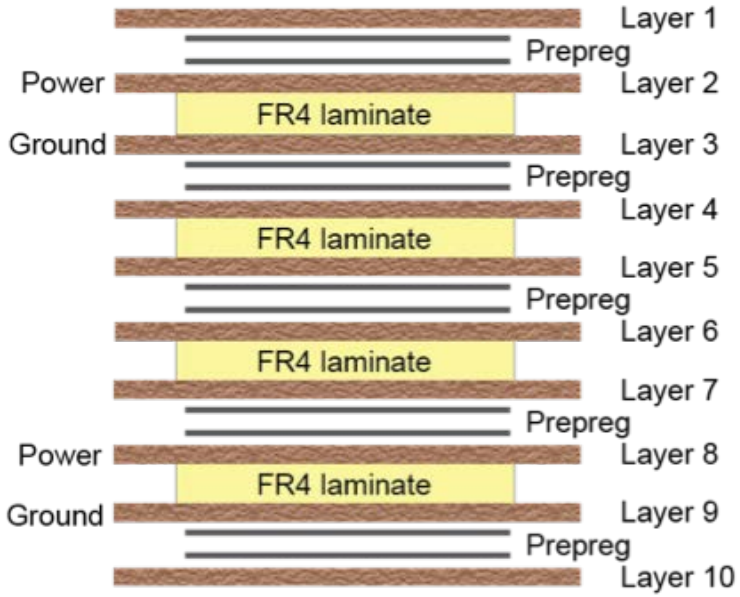
FARADFLEX®

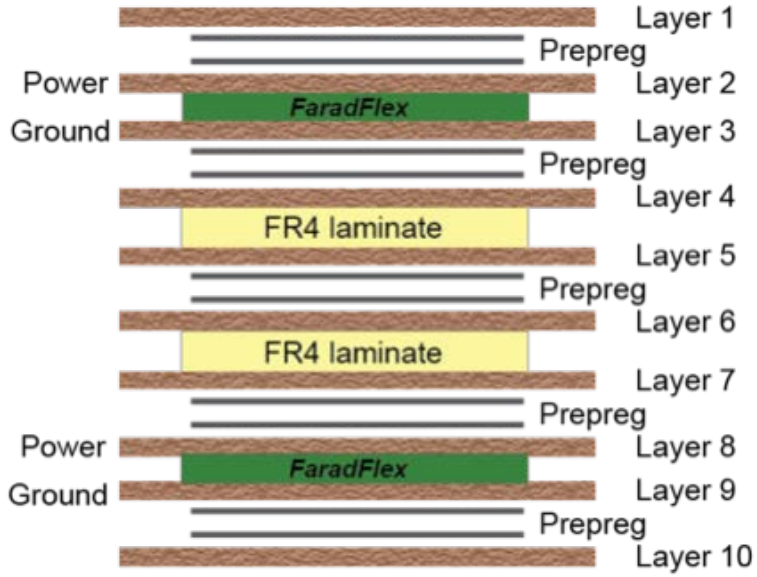
Typical PCB Design and Stack - Up

Stack-Up Example (1)

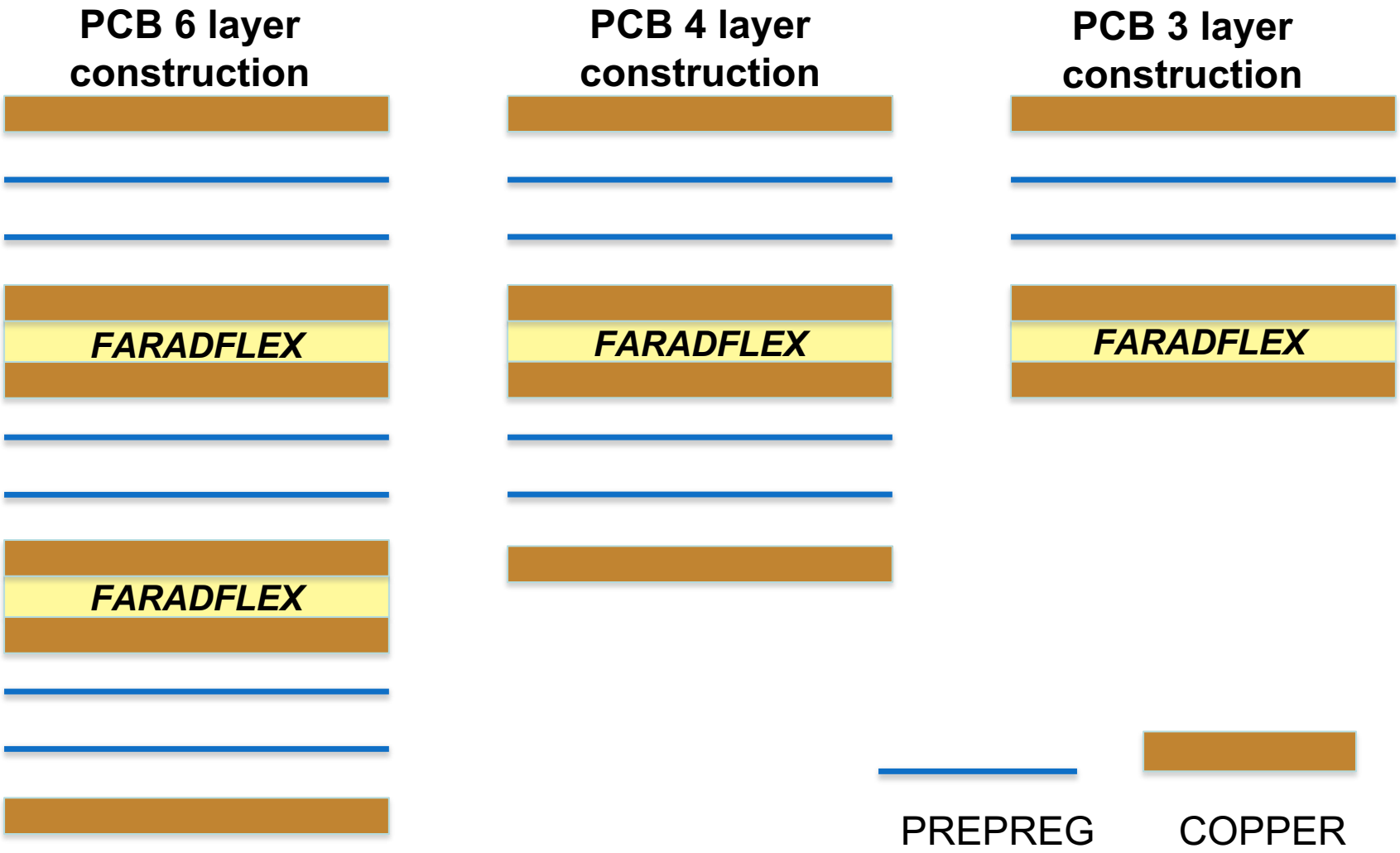
Replace existing power/ground layers with ***FaradFlex***®
for use as power distribution layer

10 layer stackup with 2 power-ground layers at
L2/L3 and **L8/L9** (using ***FaradFlex***® in the power-ground allows for embedded capacitance)





Stack-Up Example (2)

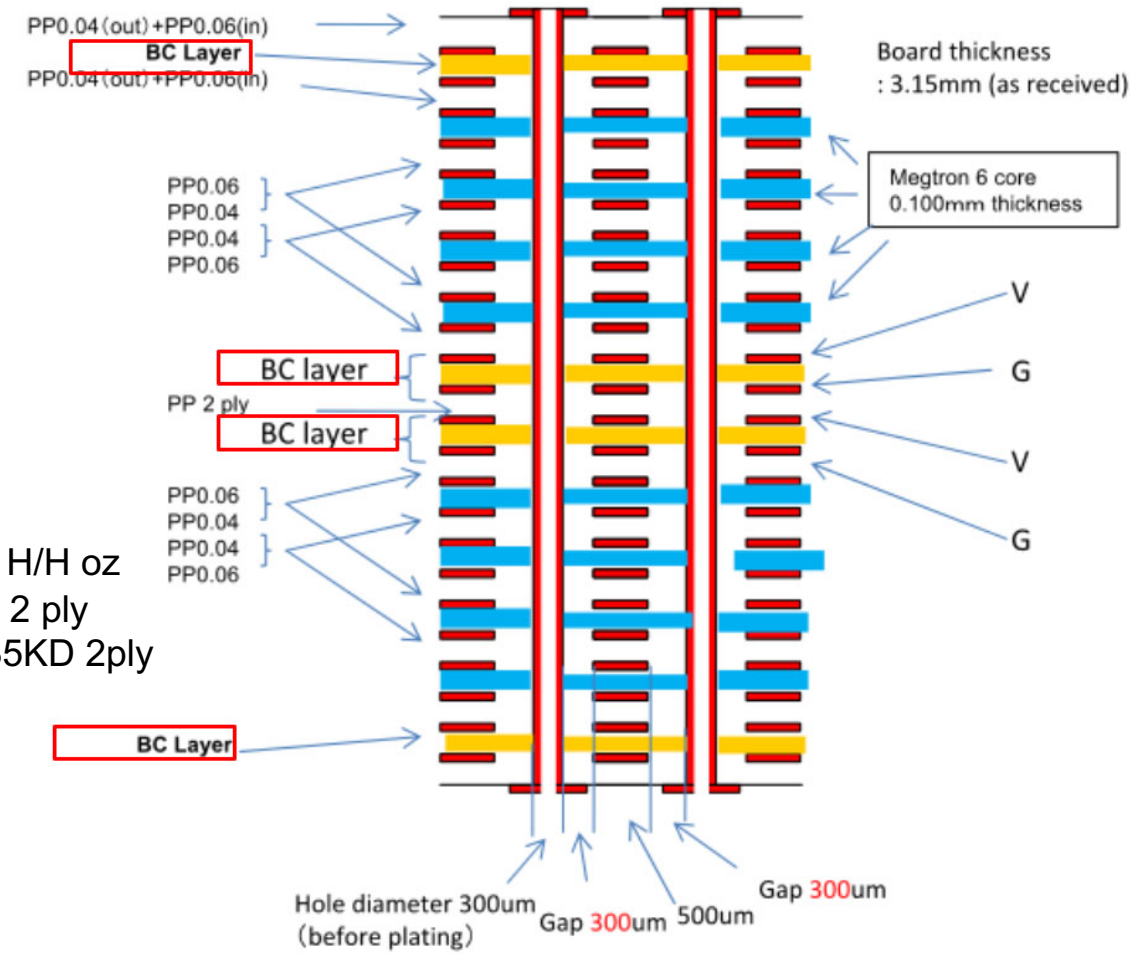


Stack-Up Example (3)

26 layer board was fabricated using MEGTRON6 and ***FaradFlex***

MC24M 2/2 in the center layers
MC24M1/1 in the outer 2 layers

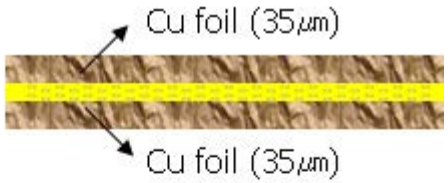
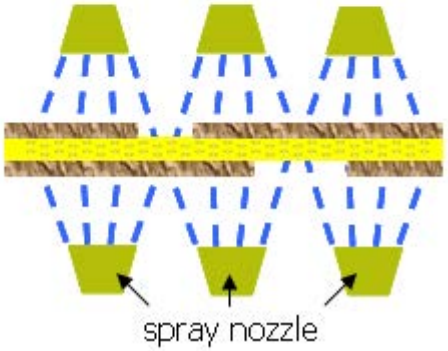
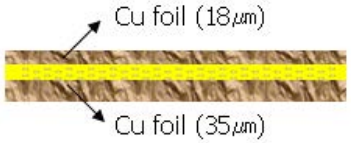
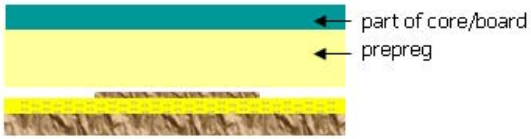
Core: MEGTRON6 1078 RTF x 2ply core H/H oz
Prepreg: MEGTRON6 1035KD + 1078KF 2 ply
Between center FF–FF, MEGTRON6 1035KD 2ply



FARADFLEX®

PCB Fabrication/Processing

Processing

Standard Etching for MC8TM	Sequential Etching for MC8T ,MC12ST, MC25LD, MC12LD
To etch both sides of the thin core material at the same time	To etch one side of the thin core material, laminate into a subpart, then etch the second side
Step 1  Step 2 ethcing on both side 	Step 1  Step 2 DES process on one side  Step 3 Laminate that side into a subpart  Step 4 Image and etch the second side 

FARADFLEX®

Reliability

Reliability Tests

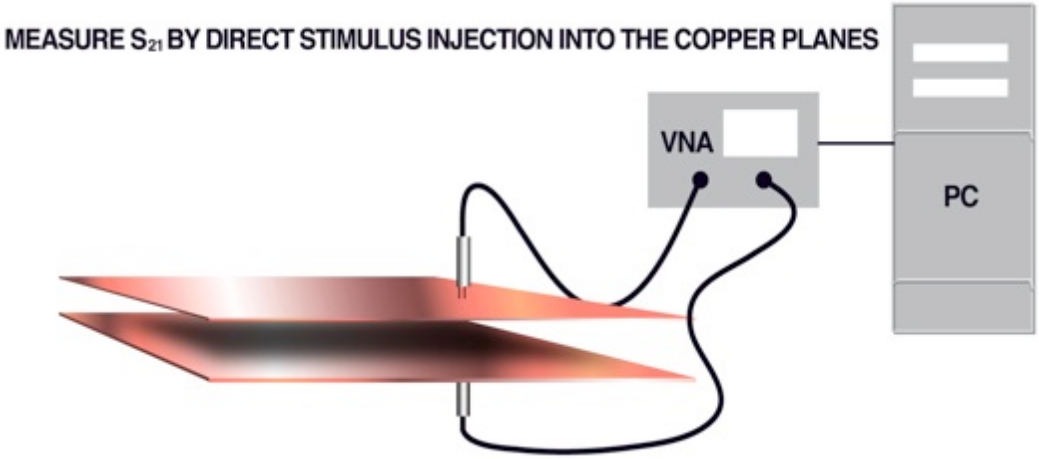
Description	
6x Through Hole Solder Shock	**PASS**
6x Blind Via Solder Shock	**PASS**
Dielectric Thickness per Cross Section within +/-10%	**PASS**
T-288(>20min)	**PASS**
IST Testing (500 cycles)	**PASS**
Core Level Hi-Pot Testing 100Cores(100V/sec; 500Vmax)	**PASS**
Finished Circuit Level Hi-Pot 50 circuits (100V/sec; 500Vmax)	**PASS**

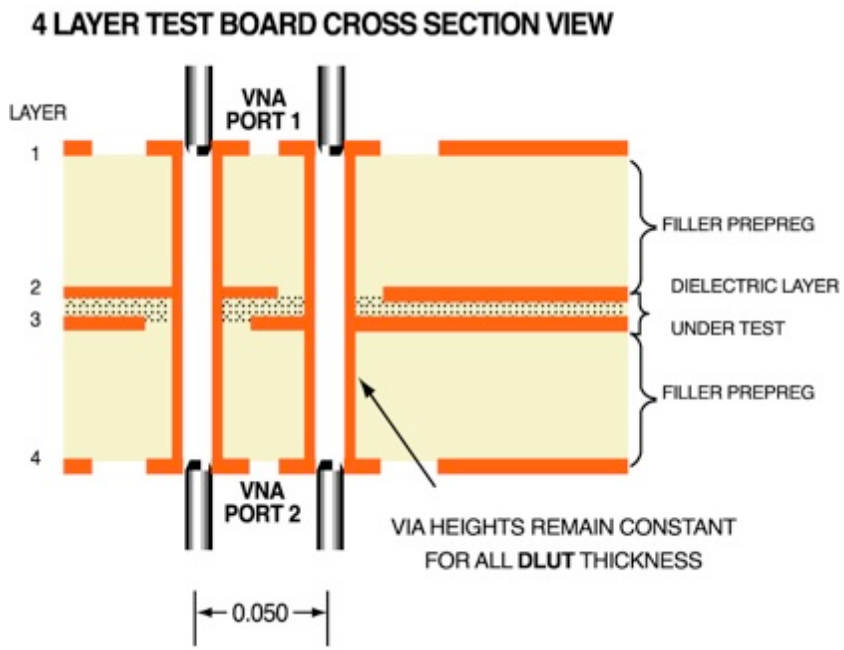
Courtesy of Sanmina-SCI

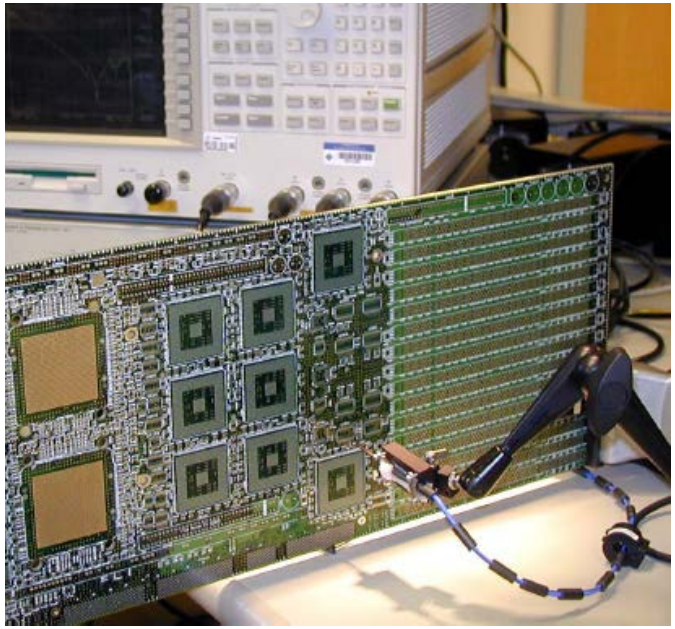
FARADFLEX®

Improved Impedance/Inductance

Bare Board Impedance Measurement



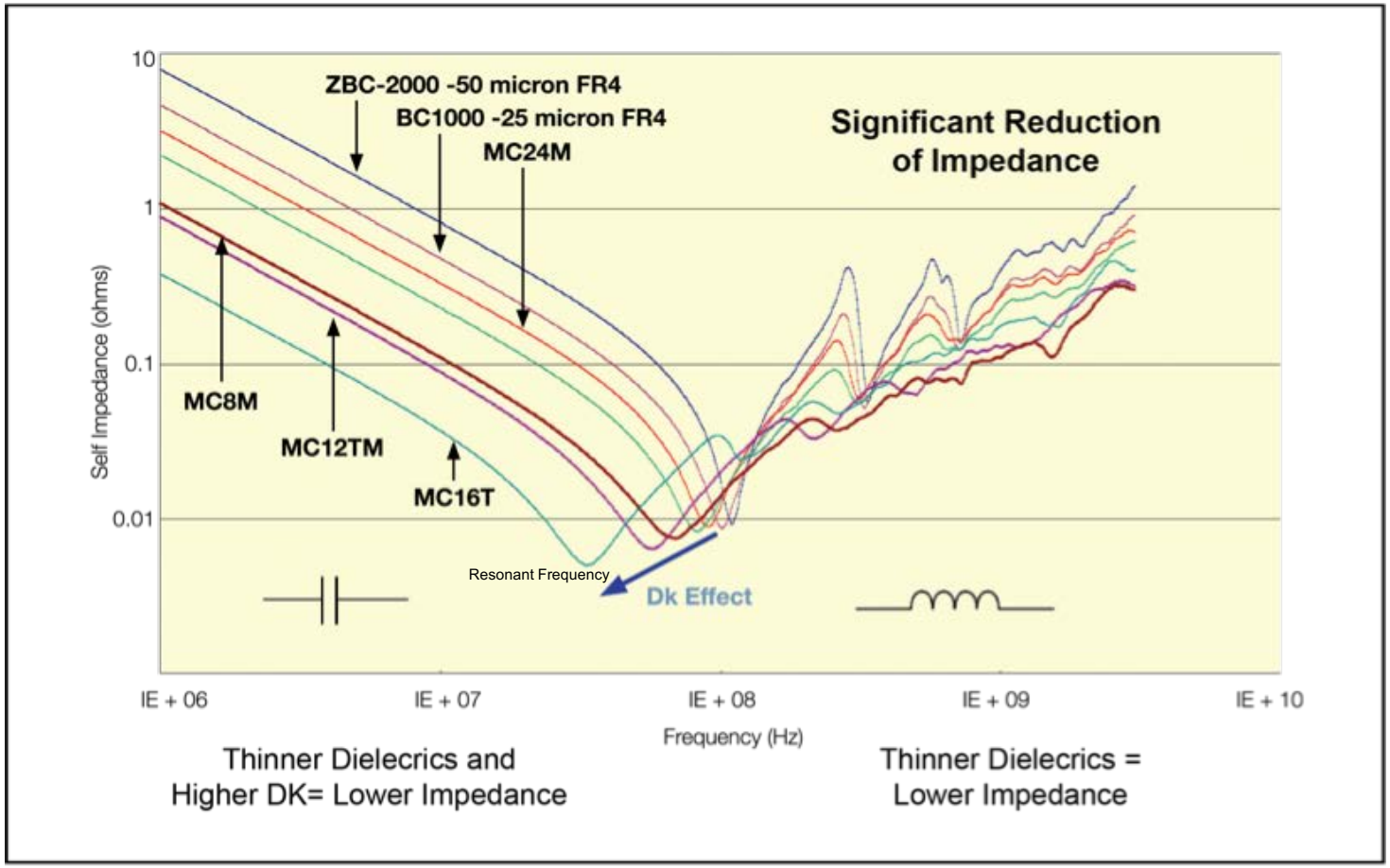




Courtesy of Oracle

PCB Electrical Performance

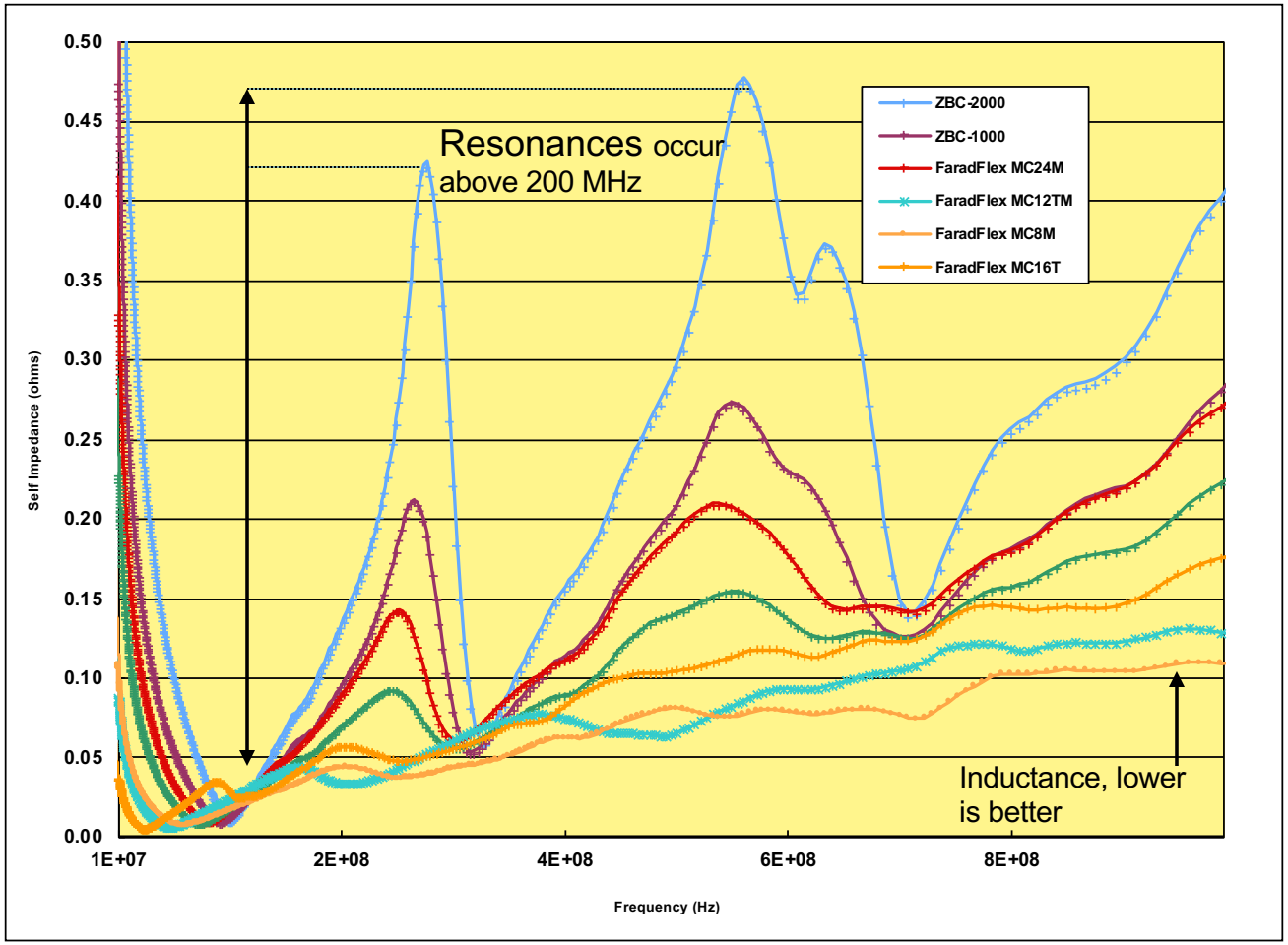
Discrete capacitors of 0.1μF have a resonance frequency of about 15 MHz
Discrete capacitors of 0.01μF have a resonance frequency of about 40 MHz.



Panel Size= 50 in^2
80% Retained Cu

Product	nF
ZBC2000	16
ZBC1000	32
MC24M	40
MC8M	124
MC12TM	180
MC16T	440

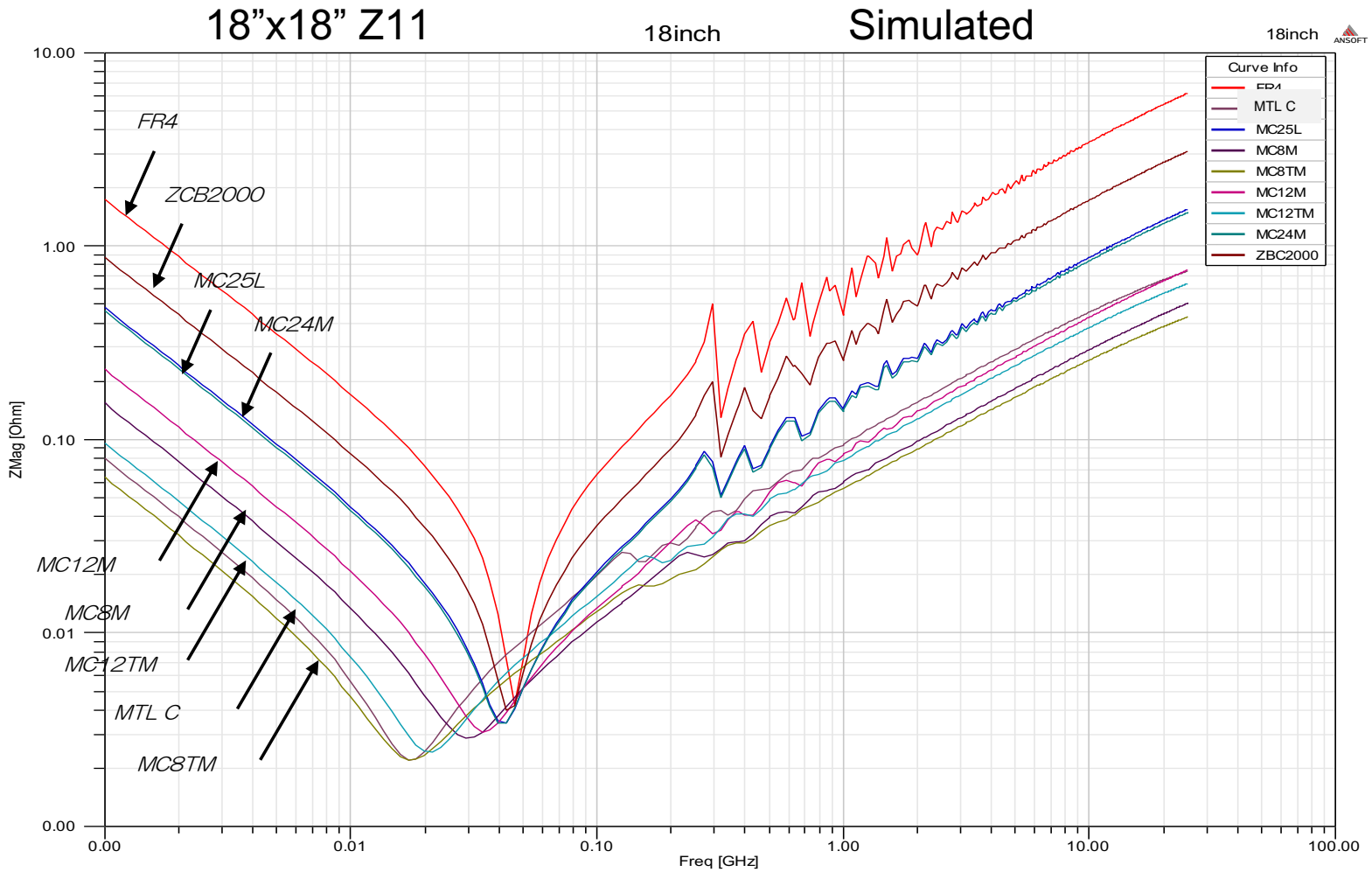
PCB Electrical Performance (Up to 1 GHz)



Panel Size= 50 in^2
80% Retained Cu

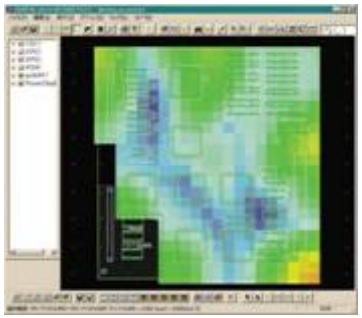
Product	nF
ZBC2000	16
ZBC1000	32
MC24M	40
MC8M	124
MC12TM	180
MC16T	440

PCB Electrical Performance (Up to 25 GHz)

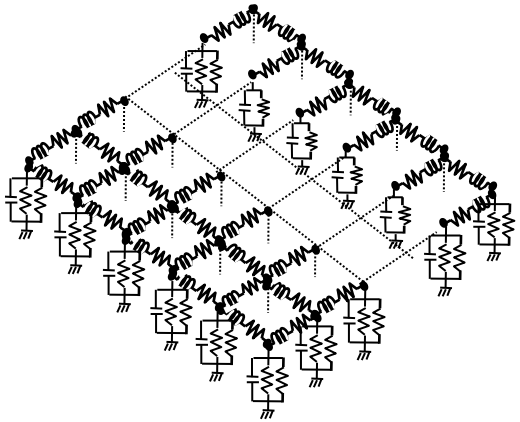


OAK-MITSUI TECHNOLOGIES
MITSUI KINZOKU CORPORATE GROUP

Power/Ground Plane Simulation



- Utilize EMIStream/PIStream
  - Developed by NEC
  - Based on PEEC method with Spice Simulation
- Input PCB Layout in Design File (xxx.dsn)
  - Output provided by standard PCB layout tools (Mentor Graphics, Cadence, Zuken, etc.)
- Select thickness, Dk and Cu thickness of P/G planes
- Select frequency range
- Can add/remove discrete decoupling capacitors



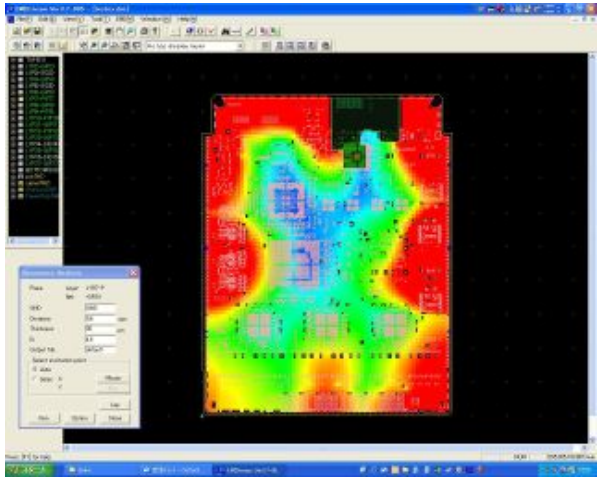
Partial Element Equivalent Circuit Model for Power/GND Plane Pair

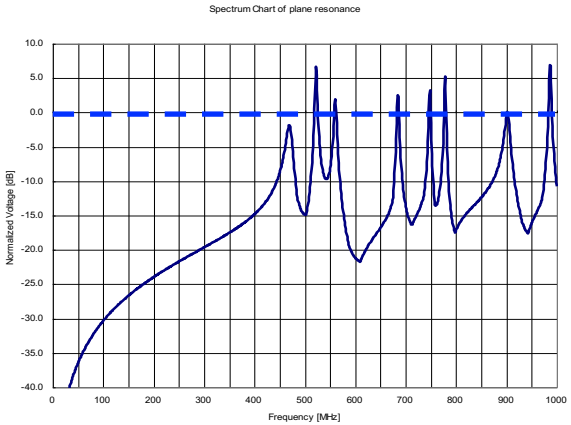
PI Simulation with EMIStream

Conditions : 18 Layer, Size (7.5” x 9.5”), 3.3V Plane,

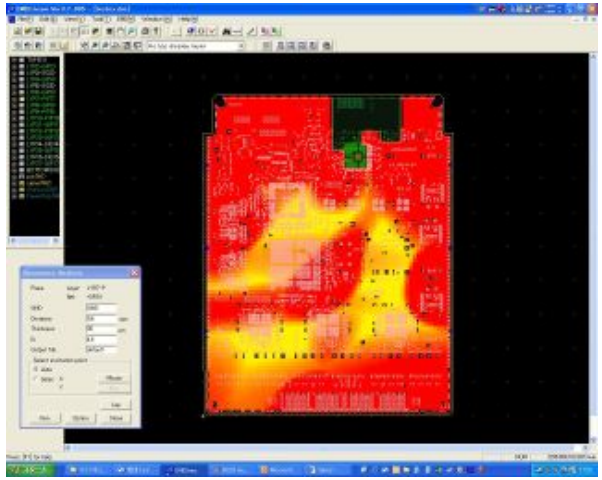
1 – 1000 MHz (1 MHz Step), 1 oz. Cu, Core 24 mil thickness

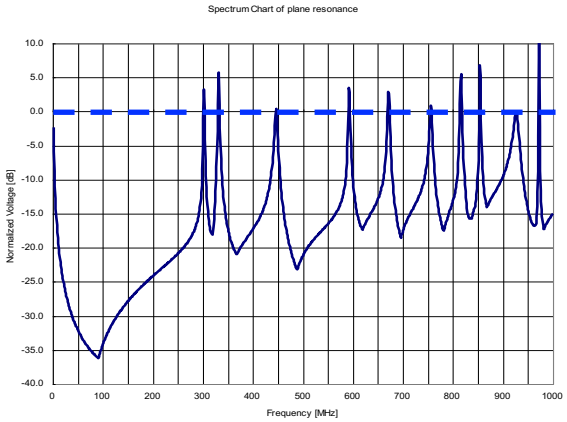
Normal Core (24 mil) with 580 De-Caps



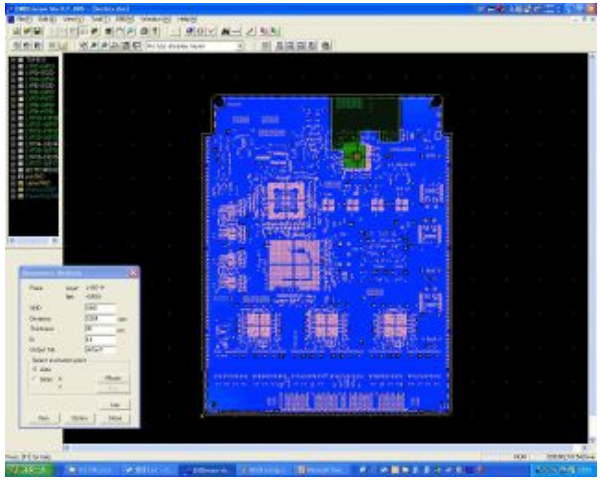


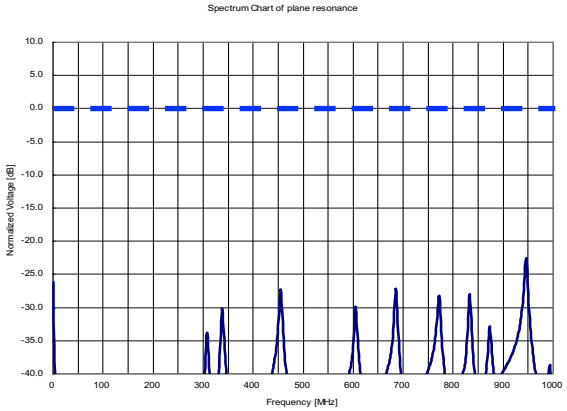
Normal Core (24 mil) without De-Caps





***FaradFlex*® (MC24M:1 mil) without De-Caps**

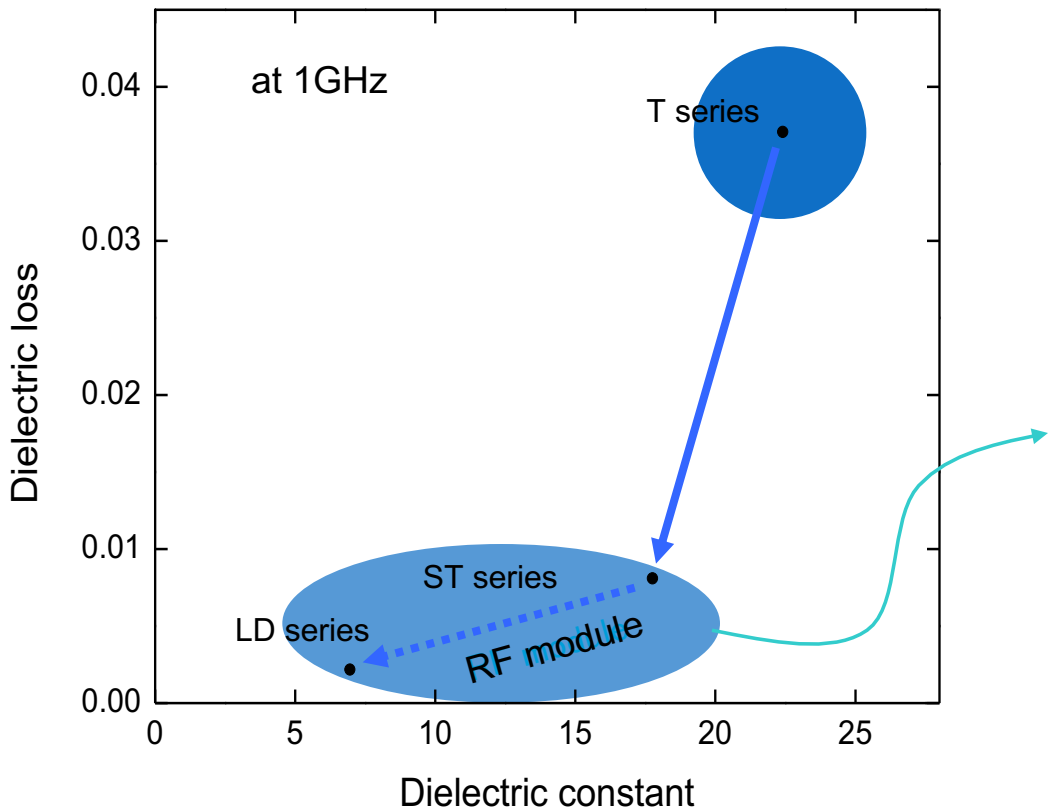




Courtesy of NEC & TOYOTech

For RF Applications

High DK and/ or Low Df



Main application:

→ WiMAX FEM
: LPF, BPF, Diplexer

→ WiFi RF module

Fig. 1. Low dielectric loss (DF) FaradFlex, “ST” & “LD” series for RF module

Dk & DF vs Frequency (1 GHz – 10 GHz)

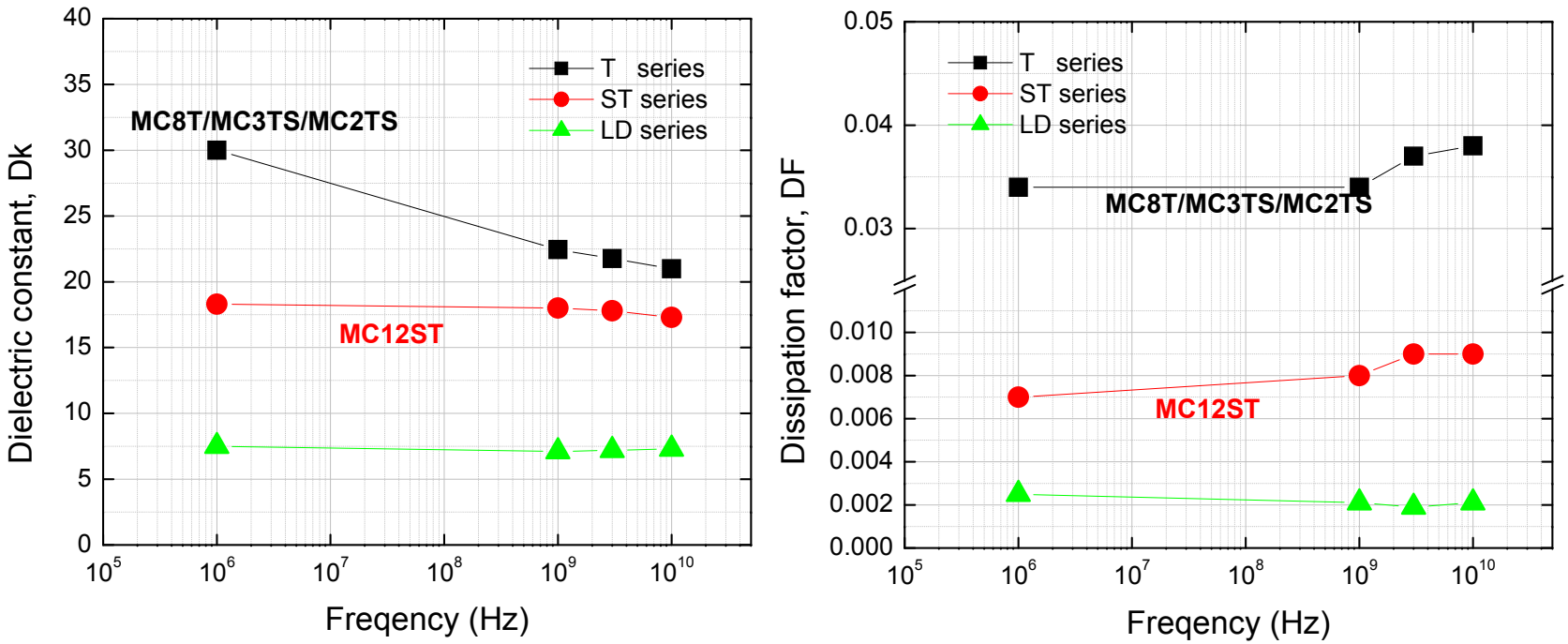


Fig. Dk and DF vs frequency at GHz of FaradFlex materials

FARADFLEX®

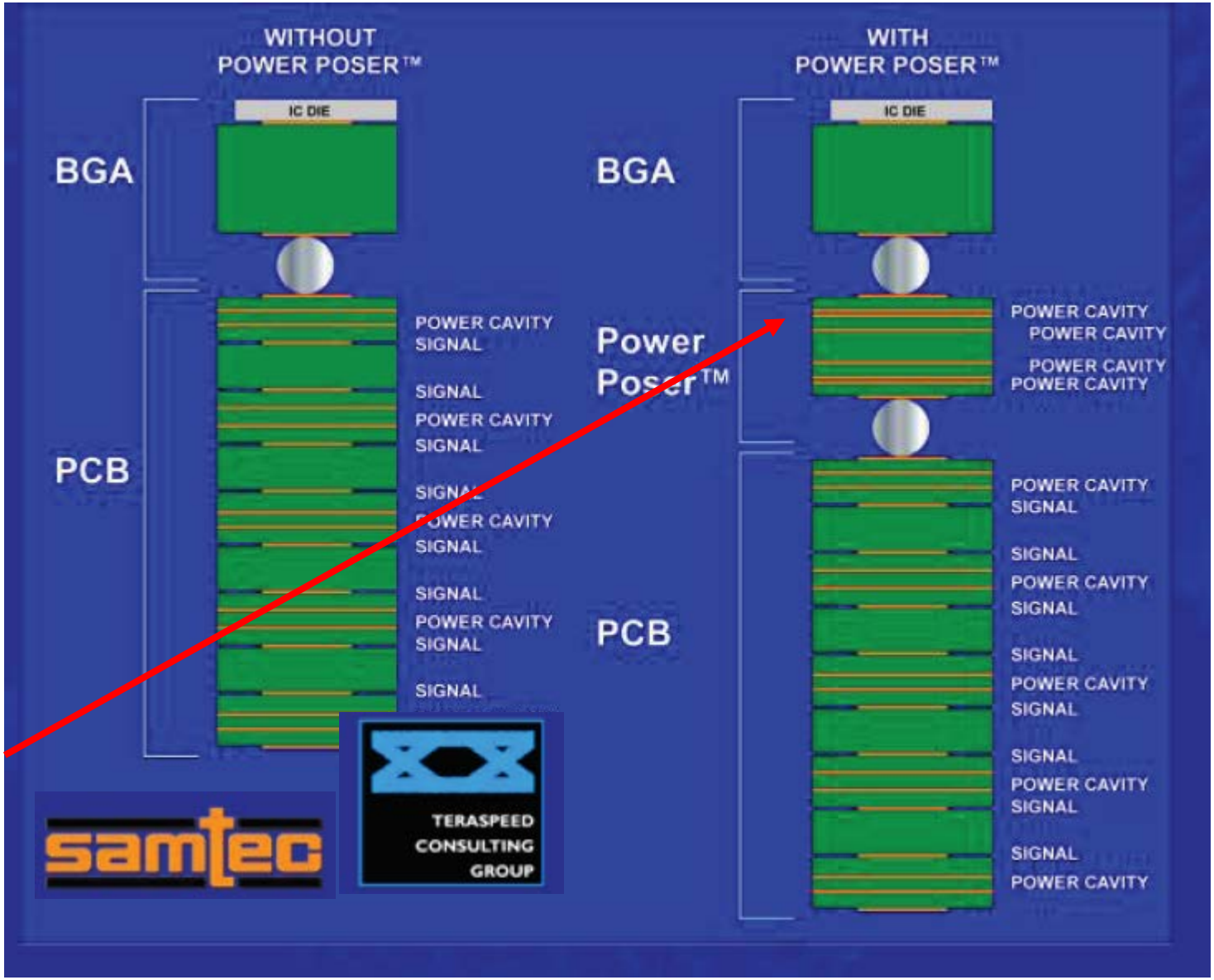
Electrical Benefits
Reduced Jitter/Improved “Eye”

Using
FaradFlex

MC24M

MC12TM

or MC8TM



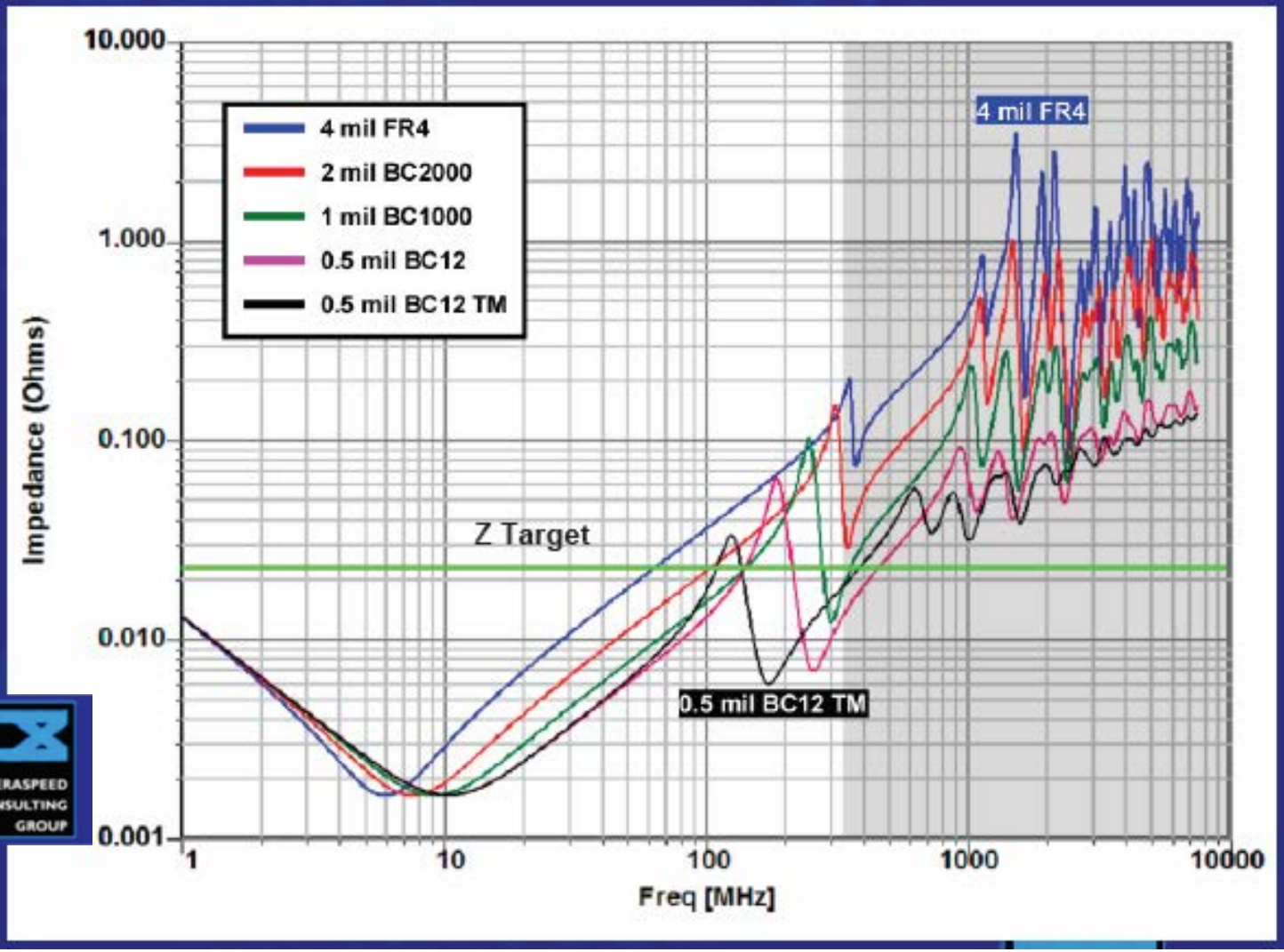
Courtesy of Samtec and Teraspeed

PDS Impedance Profile
0402 Capacitors with 4 mil Deep Planes
Various Plane Thicknesses on 6" x 6" PCB

Reduction in dielectric thickness decrease impedance, but also lowers resonance frequency.

Reduction in dielectric thickness increases magnitude of peaks.

Increase in material Er lowers resonance frequency.

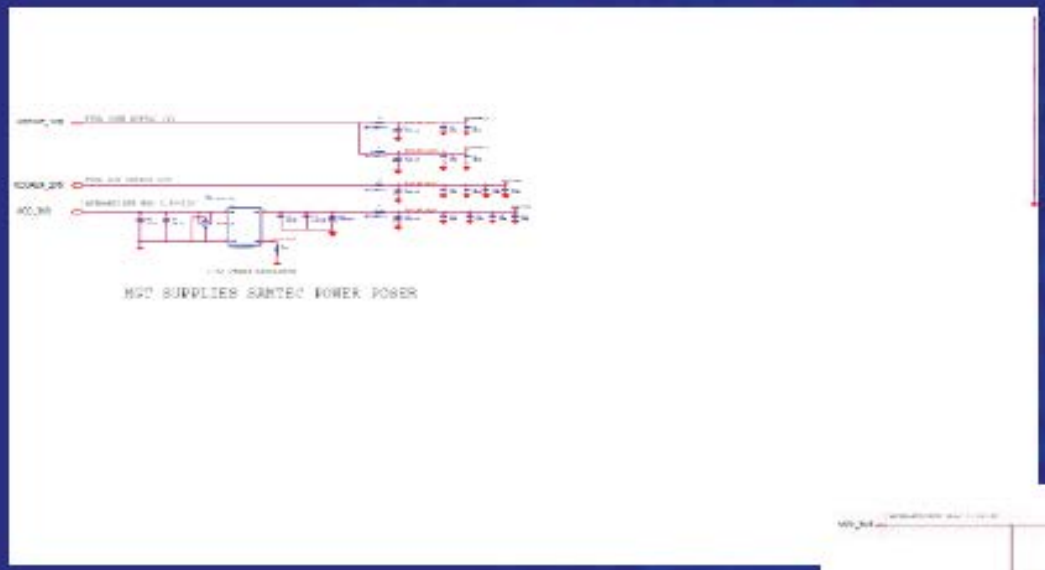


samtec

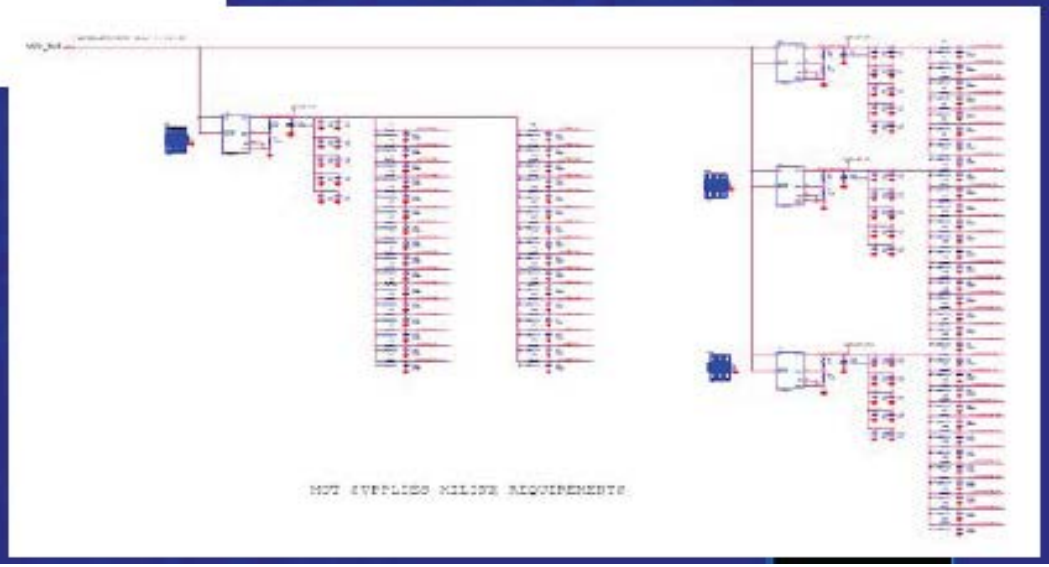
TERASPEED CONSULTING GROUP

Courtesy of Samtec and Teraspeed

SerDes Filtering Comparison



PowerPoser™ SerDes Filtering



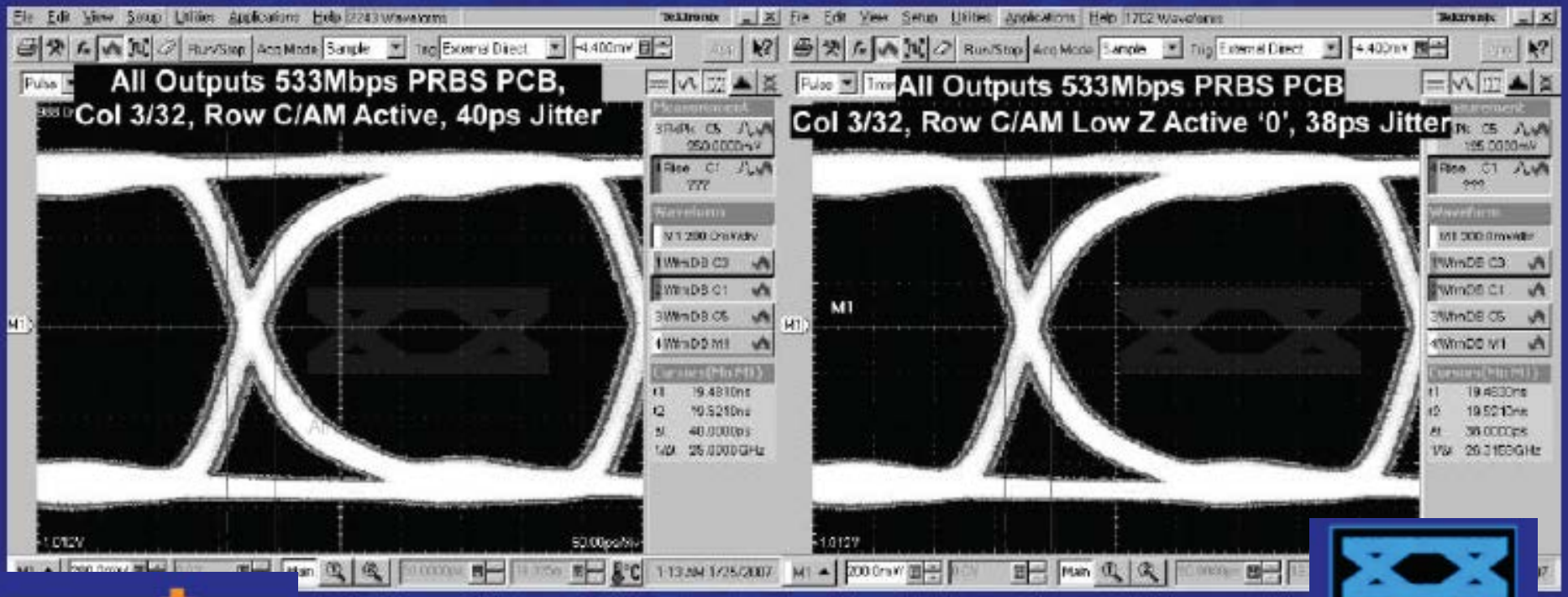
Xili iltering

TERASPEED CONSULTING GROUP

samtec

Courtesy of Samtec and Teraspeed

Xilinx Guidelines Board SerDes Best Performance @ 3.125 Gbps



samtec

Courtesy of Samtec and Teraspeed

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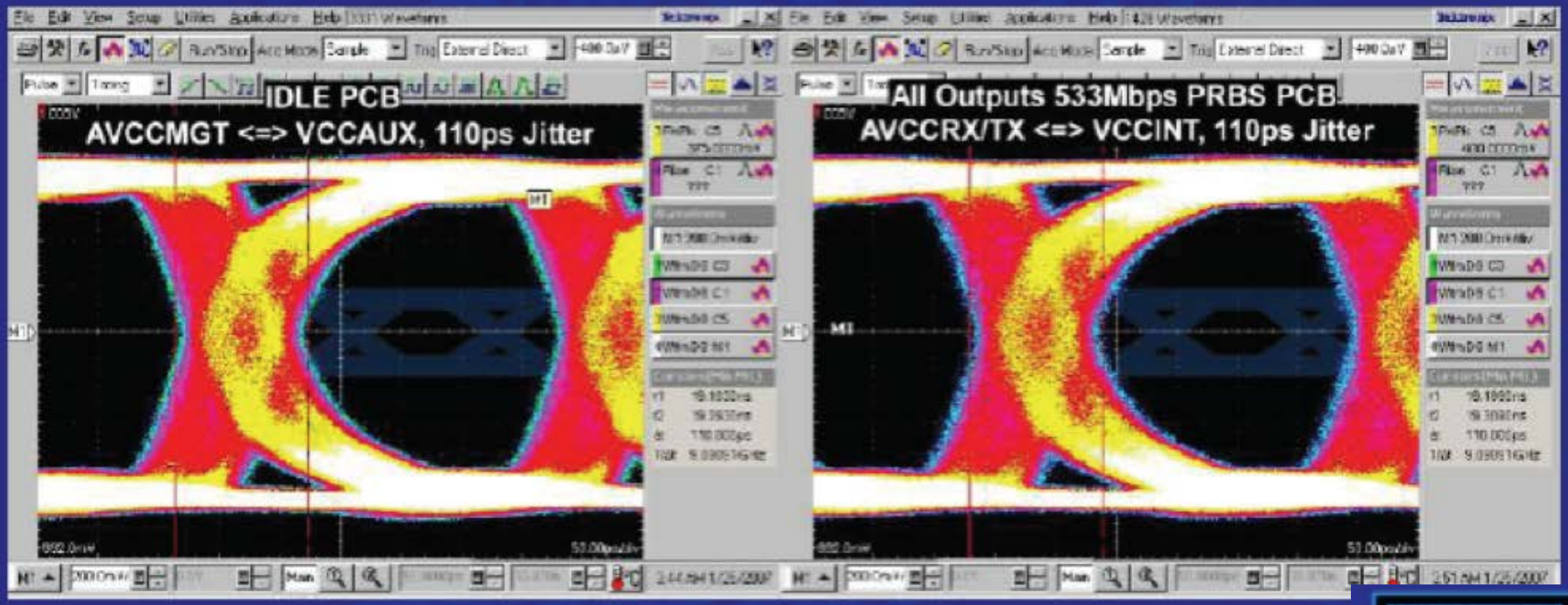
Design uses all Xilinx mandated linear power supplies and ferrite filter networks for MGT SerDes.

Xilinx Filter Network with SMPS Performance @ 3.125 Gbps



Courtesy of Samtec and Teraspeed

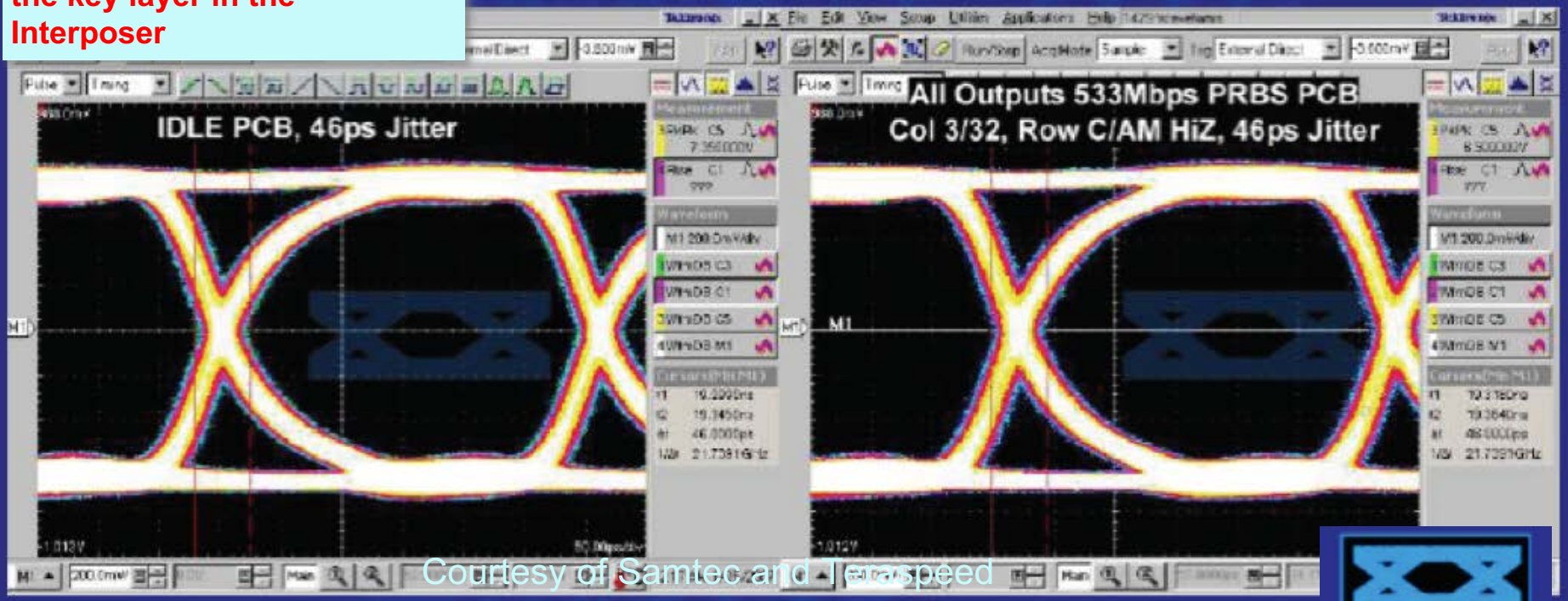
Without Power Poser

samtec

TERASPEED CONSULTING GROUP

PowerPoser™ DirectDrop™ Eval Board Measurements SerDes

Using *FaradFlex* MC12TM as the key layer in the Interposer



Courtesy of Samtec and Teraspeed

samtec

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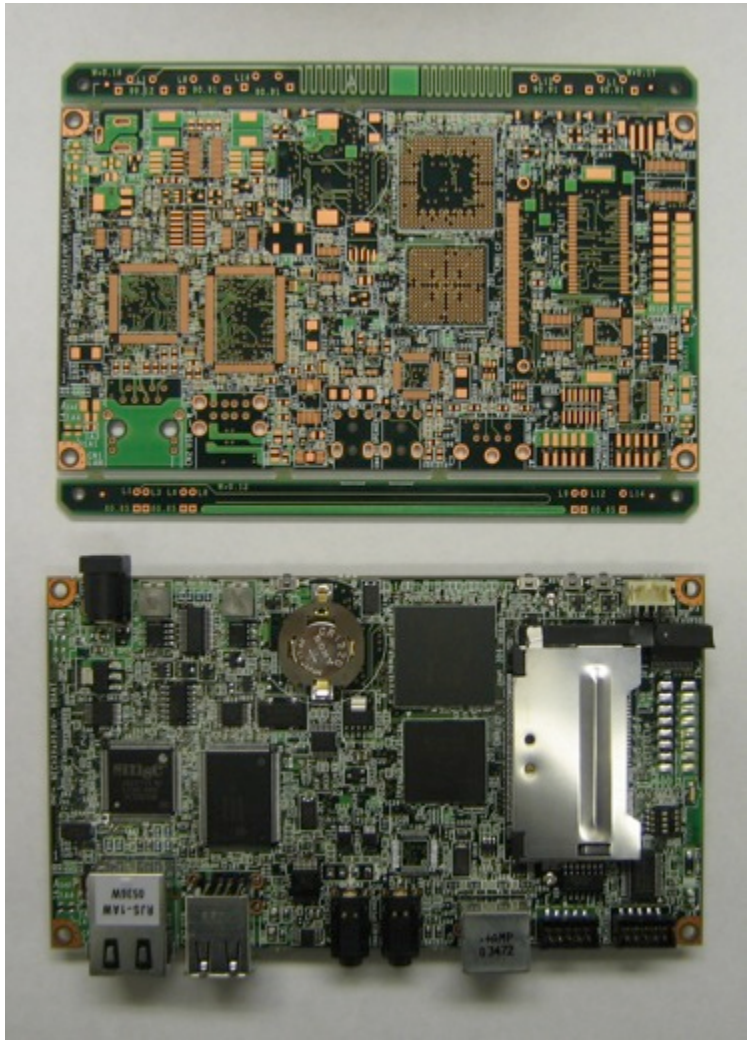
With Power Poser on Xilinx Worst Performance Layout

NEC Case Study

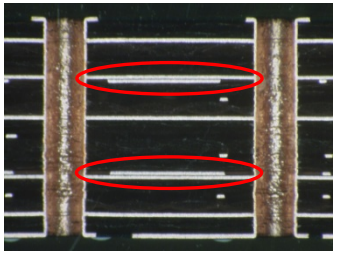
PCB Construction of Reference Board



(Courtesy of NEC System Technology, Inc.
& NEC Information Technology, Inc.)

No	Layer		Thickness[mm]	
		resist		
1	Signal		0.057	Include Plating
		prepreg	0.11	
2	Gnd(Plane)		0.032	
		core	0.15	
3	Signal		0.032	
		prepreg	0.17	
4	Gnd(Plane)		0.032	
		prepreg	0.14	
5	Vdd(Plane)		0.032	
		core	0.15	
6	Signal		0.032	
		prepreg	0.14	
7	Gnd(Plane)		0.032	
		core	0.15	
8	Signal		0.032	
		prepreg	0.14	
9	Signal		0.032	
		core	0.15	
10	Vdd(Plane)		0.032	
		prepreg	0.14	
11	Gnd(Plane)		0.032	
		prepreg	0.17	
12	Signal		0.032	
		core	0.15	
13	Gnd(Plane)		0.032	
		prepreg	0.11	
14	Signal		0.057	Include Plating
		resist		

MC24M
MC12M
MC12TM



MC24M
MC12M
MC12TM

Total thickness
2.368 mm
± 0.2 mm

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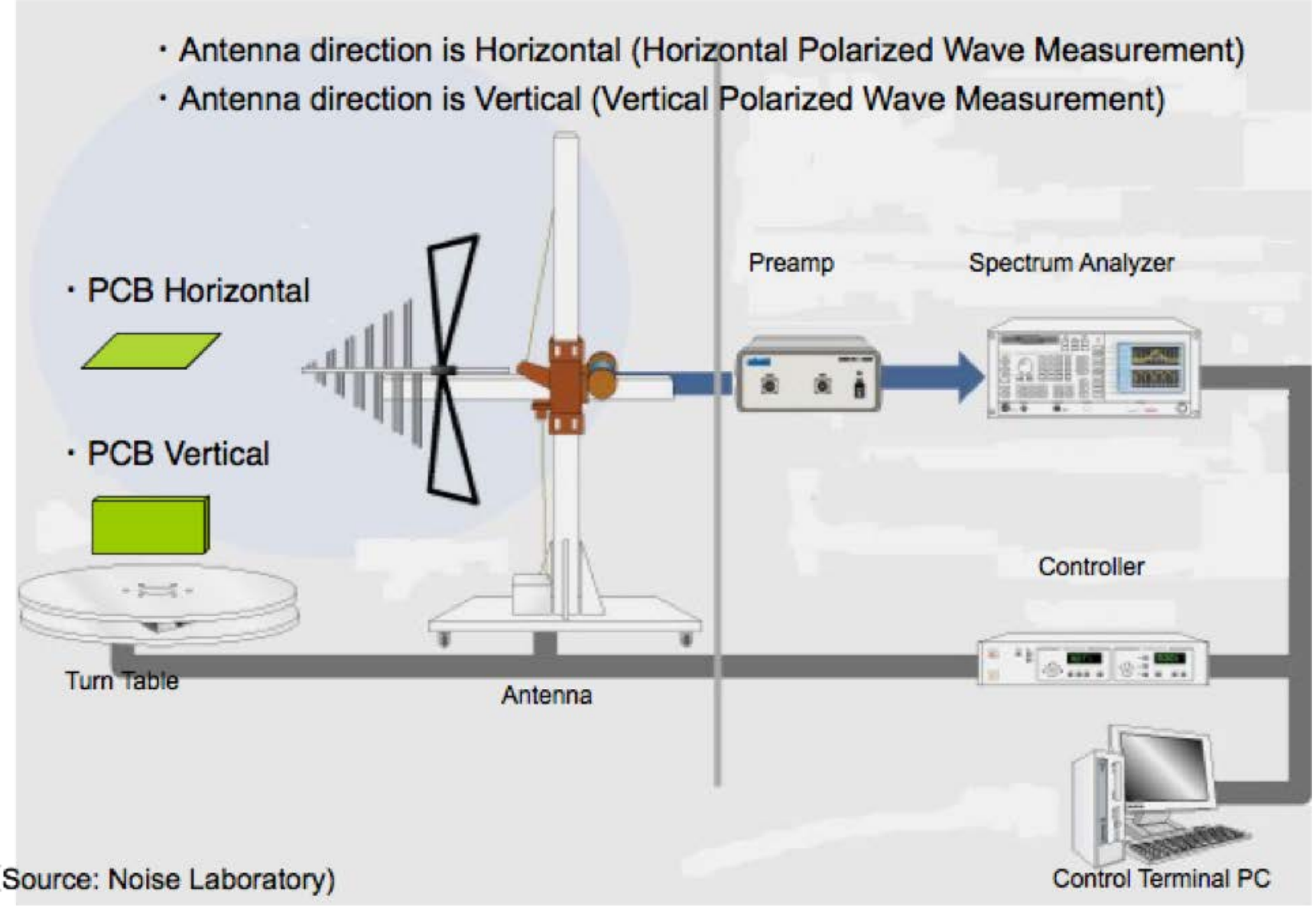
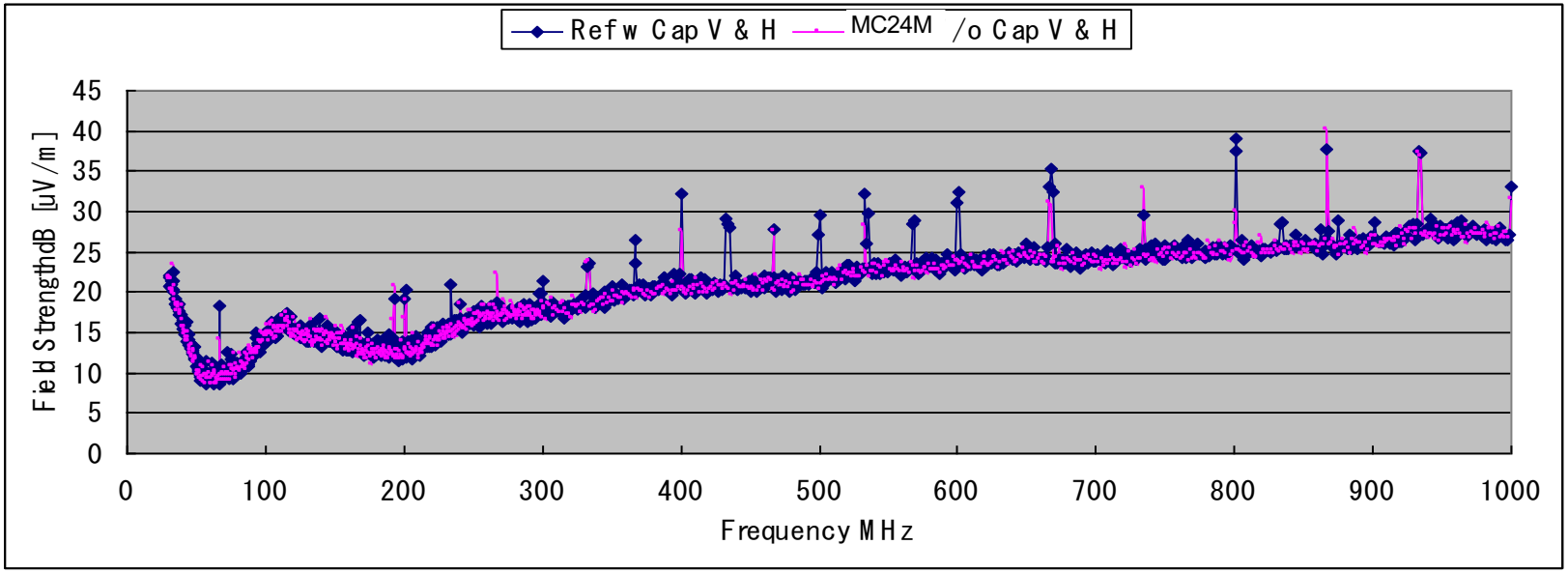
MITSUI KINZOKU CORPORATE GROUP

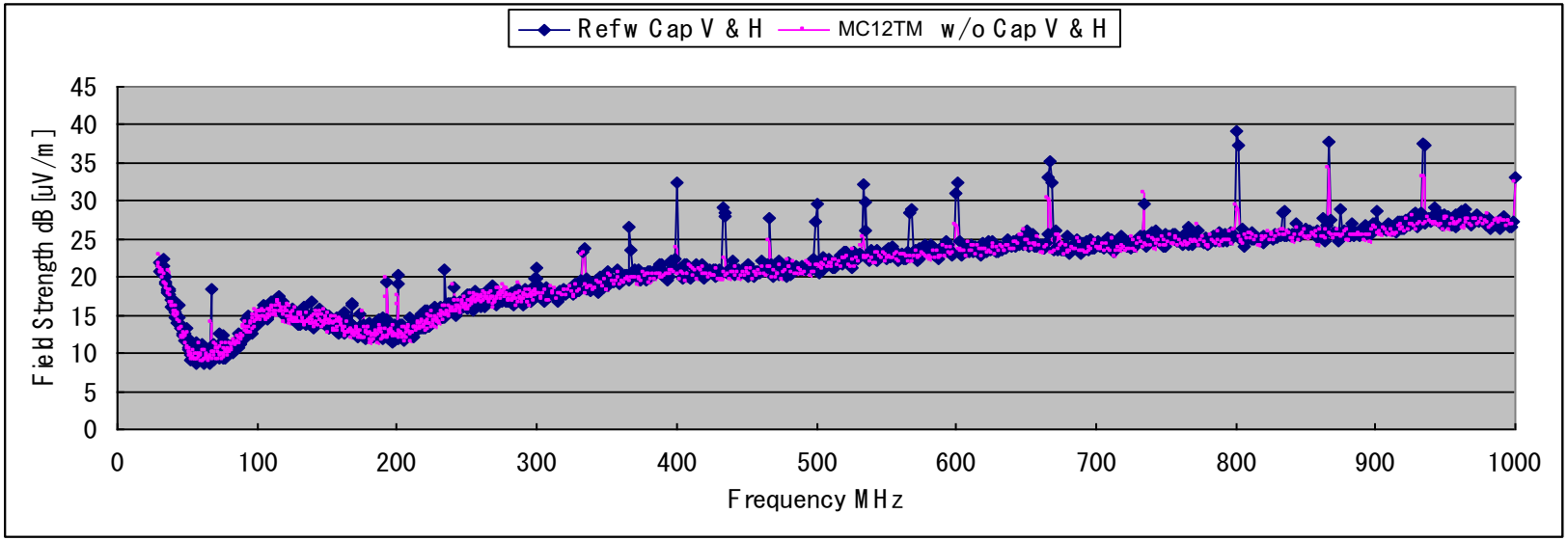
Distant Place Magnetic Field Measurement



(Source: Noise Laboratory)

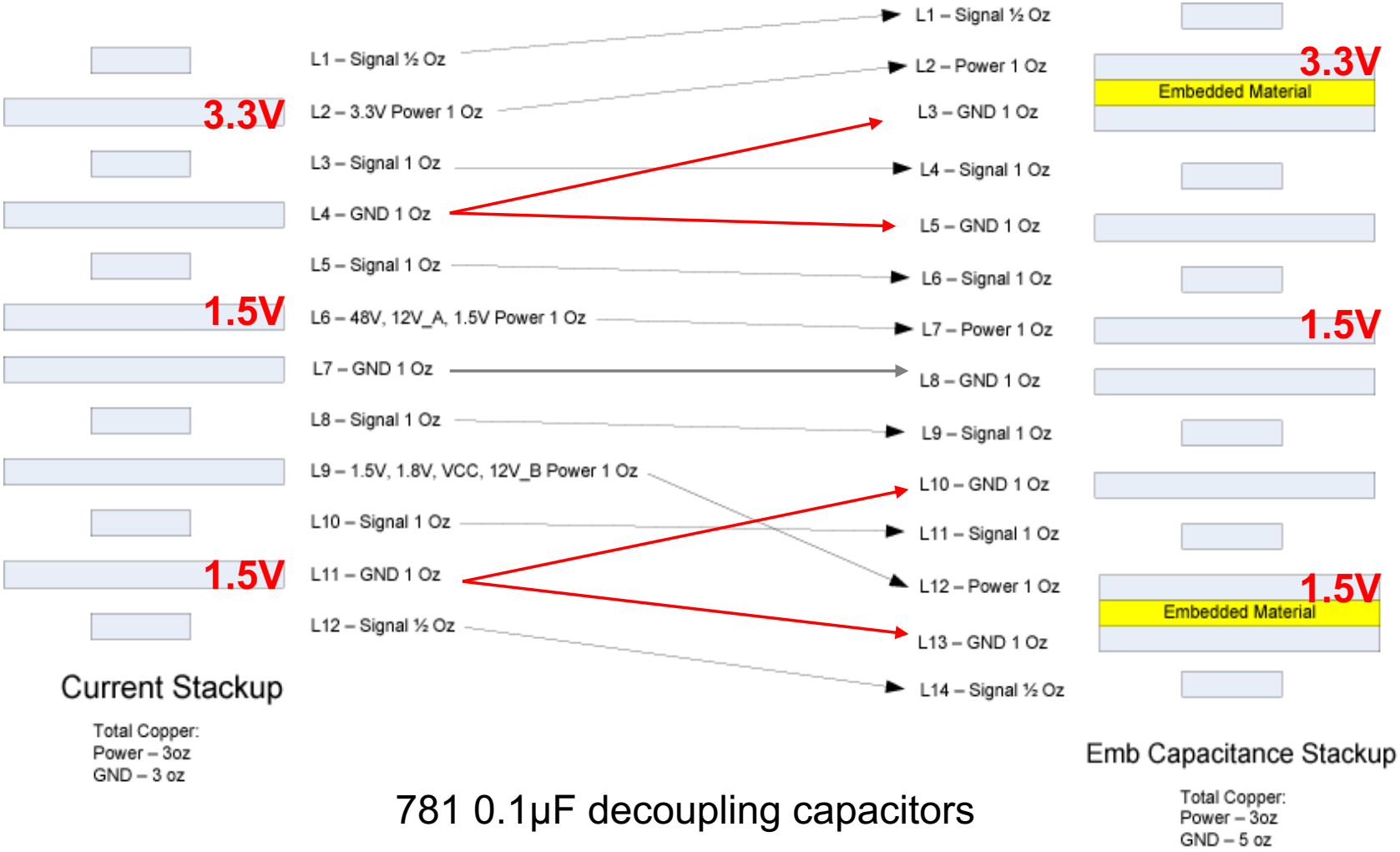
Comparison Between Reference Board with Caps and *FaradFlex*® without Caps





NCR-TERADATA Case Study

Board Stack-Up



Current Stackup

Total Copper:
Power – 3oz
GND – 3 oz

781 0.1µF decoupling capacitors

Emb Capacitance Stackup

Total Copper:
Power – 3oz
GND – 5 oz

Capacitance Measurement

Plane Pair	FR-4 (nF)	MC24M (nF)	MC12M (nF)	MC12TM (nF)
1.5V/GND	76.1 (75.8)	179.5 (179.0)	286.7 (266)	487 (478)
3.3V/GND	21.2 (21.2)	323.8 (321.3)	551 (541)	1148 (1082)

From LCR Meter

Extracted from VNA

Note: 1.5V plane is split resulting in smaller capacitor area

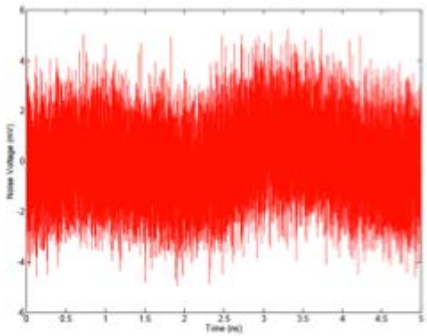
Replaces **78.1 µF** of capacitance on standard board
(781 capacitors of 0.1 µF)

(Courtesy of Univ. of Missouri at Rolla)

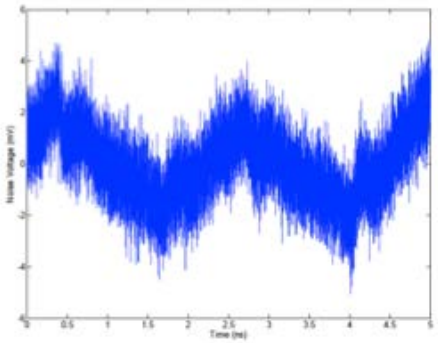
Time Domain Power Bus Noise Measurement

Measurement Equipment: Agilent Infiniium 54855A (Digital Sampling Oscilloscope)
Probe Point: Decoupling Capacitor Pad

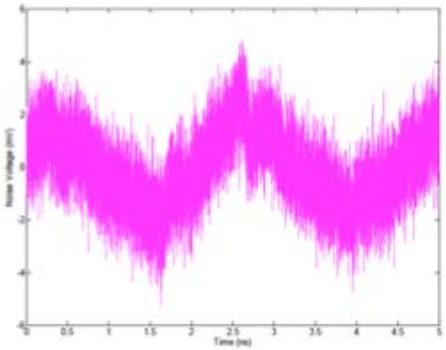
1.5V/GND (FR-4)



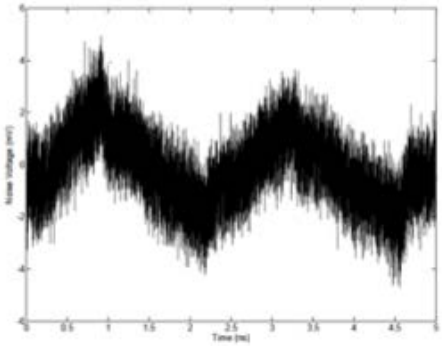
1.5V/GND (MC24M)



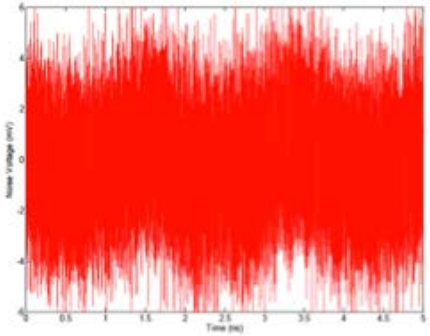
1.5V/GND (MC12M)



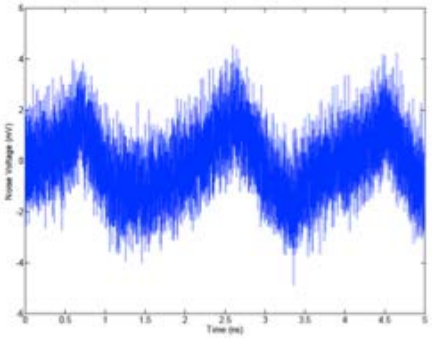
1.5V/GND (MC12TM)



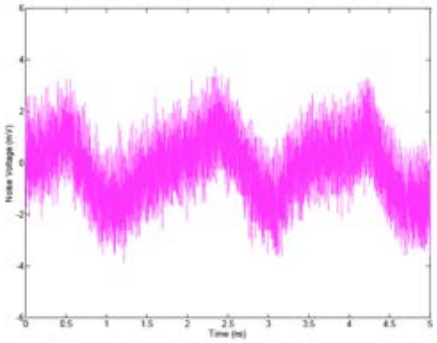
3.3V/GND (FR-4)



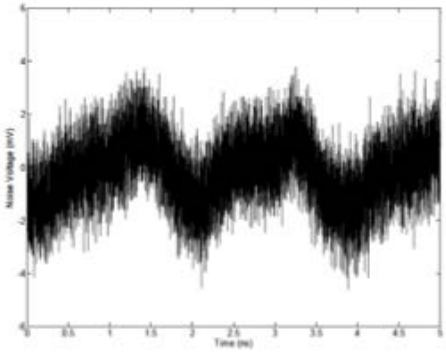
3.3V/GND (MC24M)



3.3V/GND (MC12M)



3.3V/GND (MC12TM)

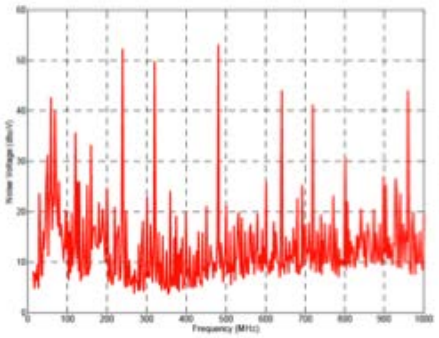


The embedded capacitance materials replaces 781 capacitors of 0.1 µF on the standard FR-4 board

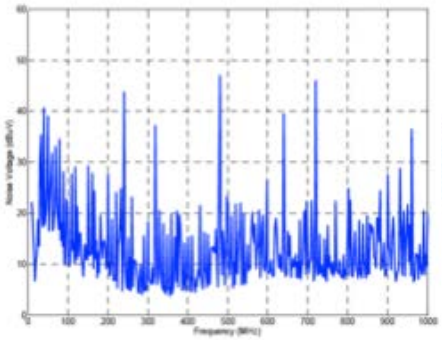
Frequency Domain Power Bus Noise Measurement

Measurement Equipment: Agilent E7404A EMC Analyzer (spectrum analyzer)
Probe Point: Decoupling Capacitor Pad
10 MHz to 1 GHz (10 KHz RBW)

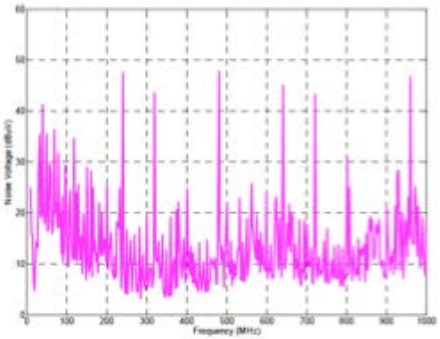
1.5V/GND (FR-4)



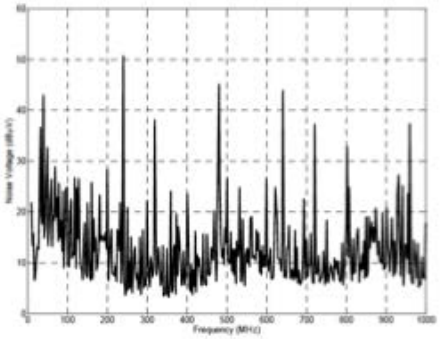
1.5V/GND (MC24M)



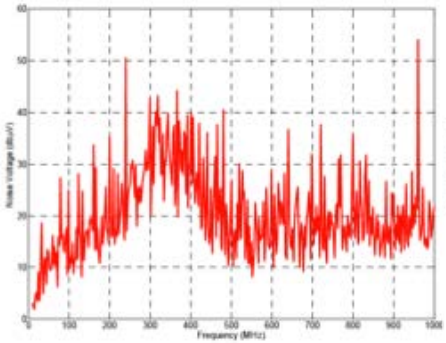
1.5V/GND (MC12M)



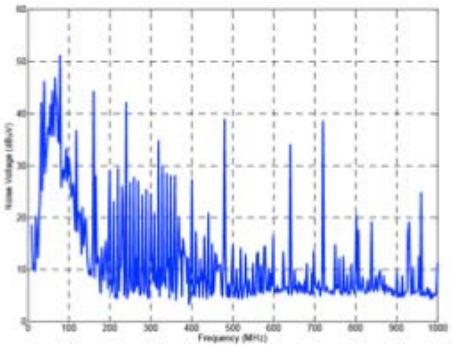
1.5V/GND (MC12TM)



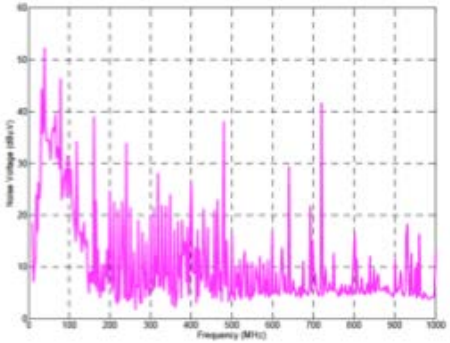
3.3V/GND (FR-4)



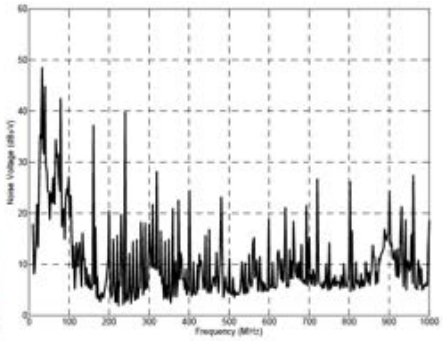
3.3V/GND (MC24M)



3.3V/GND (MC12M)



3.3V/GND (MC12TM)



The embedded capacitance materials replaces 781 capacitors of 0.1 µF on the standard FR-4 board

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FARADFLEX®

Harris Case Study

The Embedded Passive Journey

HARRIS

HARRIS CORPORATION
RF Communications Division

IPC/APEX – April 2, 2008

Authors:
Bill Devenish – Harris Corp., Mechanical Advanced Development (MAD)
Andrew Palczewski – Harris Corp., PCB Technologist

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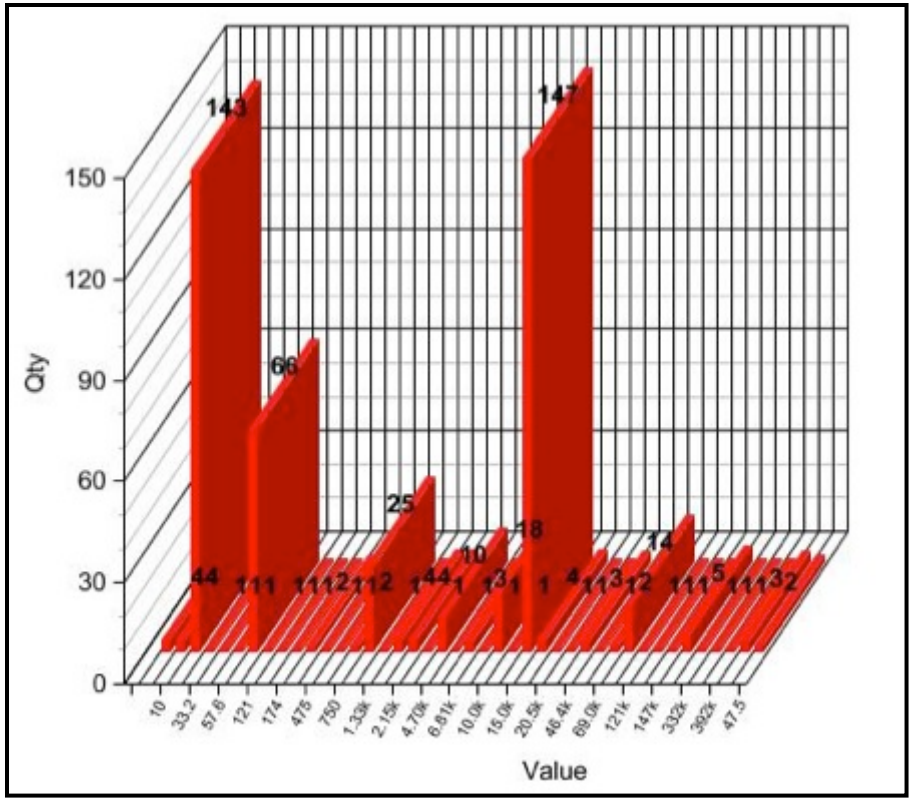
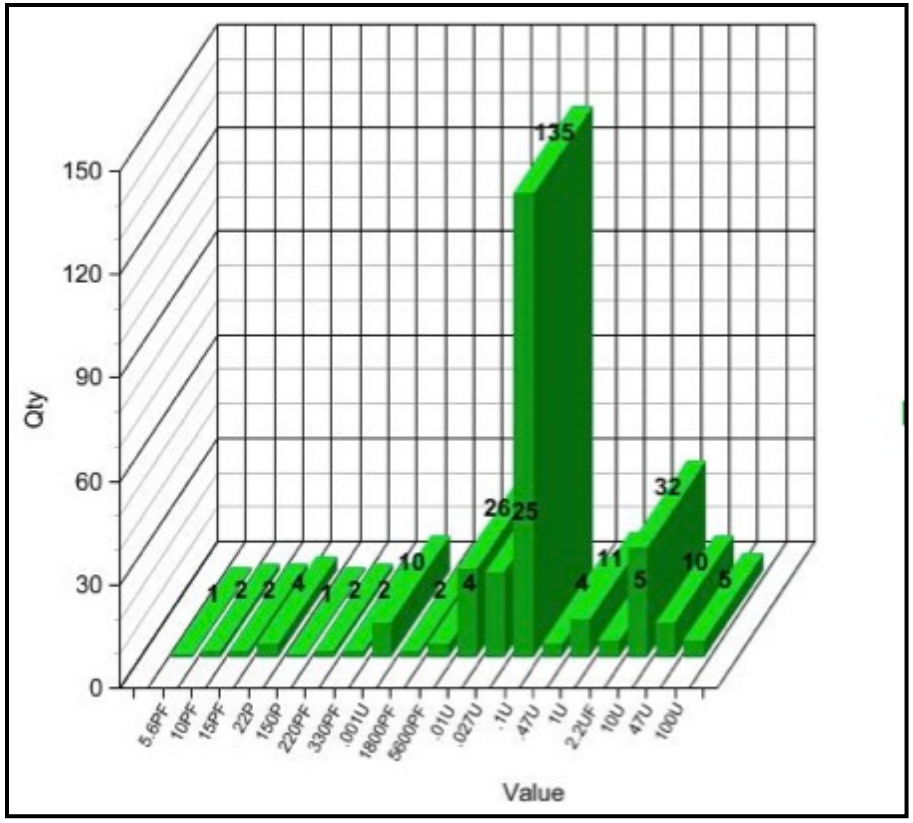
Passive Discrete Components

HARRIS

HARRIS CORPORATION
RF Communications Division





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Component Cost

COST SAVINGS		$37.88
-Part Cost		
	CAPACITORS	$1.19
	RESISTORS	$9.77
-Cost of Quality		
	Component	Body
	CAPACITORS	$4.04
		0603
		0402
	RESISTORS	$11.06
		0201
		0402
-Assembly Cost		$11.82
	Total Parts	591

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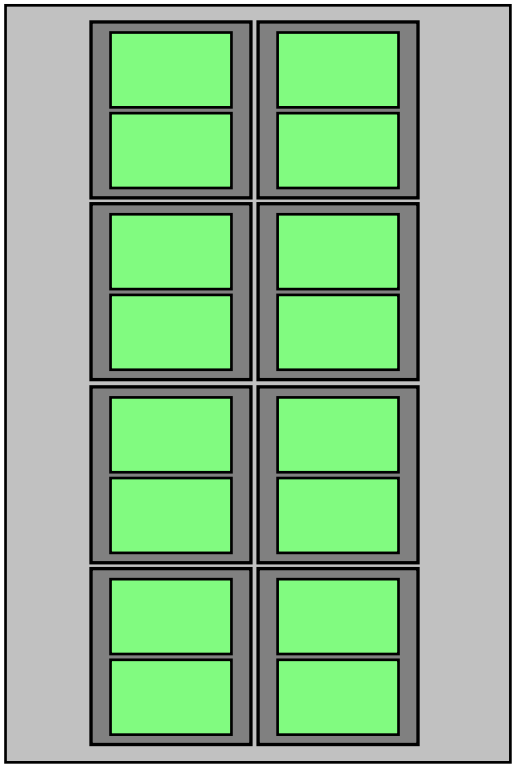
Reduce PCB Size

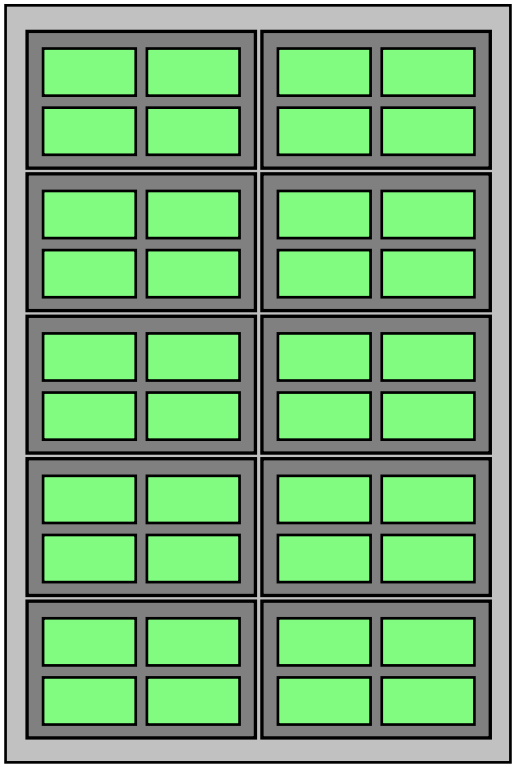
FaradFlex® embedded capacitance and embedded resistance shrinks PCB Size

Original panelization - 16 up



Size
Panel 18.0” x 24.0”
Array 5.6” x 5.524”
Part 4.54” x 2.15”
Panel Yield
8 Arrays of 2 Parts
16 Parts Total
57.3% Material Utilization
Matrix
On panel 2 x 4
Origin X3.35 YD.802
On Array 1 x 2
Spacing
On panel 0.1” x 0.1”
On Array 0.1” x 0.1”
Panel Borders
Left 3.35” Right 3.35”
Top 0.802” Bottom 0.802”
Array Borders
Left 0.53” Right 0.53”
Top 0.562” Bottom 0.562”

Revised panelization - 40 up



Size
Panel 18.0” x 24.0”
Array 8.0” x 4.42”
Part 3.4” x 1.61”
Panel Yield
10 Arrays of 4 Parts
40 Parts Total
81.9% Material Utilization
Matrix
On panel 2 x 5
Origin XD.95 YD.75
On Array 2 x 2
Spacing
On panel 0.1” x 0.1”
On Array 0.4” x 0.4”
Panel Borders
Left 0.95” Right 0.95”
Top 0.75” Bottom 0.75”
Array Borders
Left 0.4” Right 0.4”
Top 0.4” Bottom 0.4”

Cost Analysis

Conventional Board | Discrete Assembly | Embedded Board | Discrete Passives | Results

Analysis Results:

	Conventional	Embedded
Board Width (inches)	2.5	2.42
Board Length (inches)	4.0	3.87
Number Up	30	32
Number of Layers	12	10
Panelization Efficiency	0.69	0.69

Component Cost Difference	-11.11
Assembly Cost Difference	-19.41
Board Price Difference	4.52
System Total Cost Difference	-26.0

Positive values (red) indicate increases in cost when passives are embedded.

Negative values (green) indicate decreases in cost when passives are embedded.

Plot Results | Plot Histograms | Print Report

Courtesy of Harris Corp. and CALCE

Other *FaradFlex* Benefits

Lifetime Test Comparison

FaradFlex® Embedded Capacitors vs Surface Mount Discrete

150ºC 650V, Raw Data

Start Date:	8/12/14		
Start Time:	15:00		
Sample	Fail Date	Fail Time	Hours
MC24M-1			
MC24M-2			
MC24M-3			
MC24M-4			
MC24M-5			
MC24M-6			
MC24M-7			
MC24M-8			
MC24M-9			
MC24M-10			
MC24M-11			
MC24M-12			
MC24M-13			
MC24M-14			
MC24M-15			
MC24M-16			

PCBs using *FaradFlex*® for embedded capacitance

All the *FaradFlex*® embedded capacitors and test boards are still running with no failures

Typical Failure Mode of MLCC

under 150℃, 650V

There were no 50V chip caps included

PCBs using discrete surface mount capacitors

Sample	Fail Date	Fail Time	Hours
100V-1	11/8/14	8:00	2105.00
100V-2	10/24/14	13:00	1750.00
100V-3	11/5/14	18:00	2043.00
100V-4	10/4/14	13:30	1270.50
100V-5	11/13/14	10:25	2227.42
100V-6	10/8/14	1:30	1354.50
100V-7	9/23/14	4:30	997.50
100V-8	9/29/14	2:00	1139.00
100V-9	10/21/14	4:00	1669.00
100V-10	10/28/14	0:50	1833.83
100V-11	10/31/14	5:45	1910.75
100V-12	10/22/14	14:00	1703.00
100V-13	10/9/14	21:15	1398.25
100V-14	10/23/14	1:45	1714.75

All of the discrete surface mount capacitors test boards and all the capacitors have failed.

Lifetime Test Comparison

FaradFlex® Embedded Capacitors vs Surface Mount Discrete

The regression equations for the 1 mil embedded capacitance (MC24M) characteristic life and for the 100ppm failure rate, estimates at 150˚C for these failure rates can be calculated for any voltage below 800V on this material.

Characteristic life (hours) = 2.062672E+06(Voltage$^{-0.6891}$) Equation 1
Considering a long field history for 12V and below, the characteristic life for 12V at 150˚C as 372,191.5 hours which is approximately **42.5 years.** This is **over 10x longer Lifetime than PCB's with surface mount capacitors** at the same conditions.

100ppm failure rate (hours) = 1.404739E+06(Voltage$^{-0.6891}$) Equation 2
Similarly, the 100ppm estimated failure rate (Equation (2)) would not occur until 253,473 hours, which is approximately **28.9 years.**

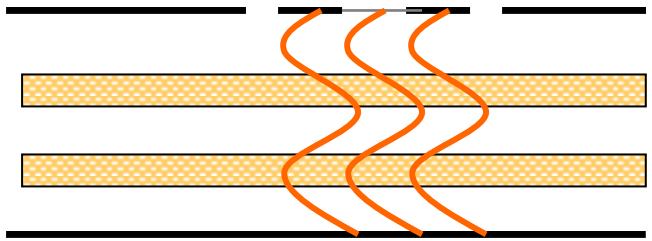
It would be **highly unusual** for the field environment **to exceed 130˚C** which is the UL rated MOT (Maximum Operating Temperature) **for most FR4** and similar printed circuit board materials. It becomes very clear why field failures would be highly unusual for the 1 mil embedded capacitance(MC24M) materials.

Performance: Thermal Stability

Embedded Capacitance Core

FaradFlex **1.5 to 3** times better heat transfer due to thinness

Standard Core



Thinner dielectric provides better heat transfer to copper

Capacitor Material vs. FR4

Enhanced when combined with Ohmega Material

Properties	NiP/Capacitor Core	NiP Core FR-4 (control)	Remarks and Conditions
Sheet Resistivities (ohm/square)	25	25	Nominal
Material Tolerance	+/-5%	+/-5 %	
Load Life Cycling Test Resistor Size: 0.500" X 0.050" Loaded: (Δ R%) @ 150mW Unloaded: (Δ R%)	 <0.9 after 3200 hrs.) <0.74 after 3200 hrs.)	<5	MIL-STD-202-108I Ambient Temp: 70C On Cycle: 1.5 hrs Off Cycle: 1.5 hrs Length Of Test: 10000 hrs
Current Noise Index in dB	<-23	<-15	MIL-STD-202-308 Voltage Applied: 5.6 Volts
Humidity Test (Δ R%)	0.5	0.5	MIL-STD-202-103A Temp: 40 °C Relative Humidity: 95% Time: 240 hrs
Characteristic (RTC) PPM/°C	-6.0	50	MIL-STD-202-304 Hot Cycle: 25°, 50°,75° 125°C Cold Cycle: 25°, 0°,-25°, -55°C
Thermal Shock (Δ R%)	0.2	-0.5	MIL-STD-202-107B No of Cycles: 25 Hot Cycle Temp: 125 °C Cold Cycle Temp: -65 °C
Solder Float (Δ R%) After 1 Cycle After 5 cycles	 -0.4 -0.6	0.5	MIL-STD-202-210D Temp: 260°C Immersion: 20 Second
Power Density (mW/mil ^{2}) derated at 50%	0.45	0.15	Step-up Power Test Resistor size 0.020" x 0.030"

Synergistic Effect !

3X better power density through resistor due to better heat conductivity of FaradFlex

Courtesy of Bruce Mahler of Ohmega

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Conclusion

- ***Embedded Capacitor*** **can improve system price/performance by**
  - Reducing discrete capacitors
  - Reducing PCB size
  - Increasing functionality
  - Improving Power Distribution
  - Improving Signal integrity
- ***Thinner Power Distribution Planes*** **are required for improved impedance performance at high frequency**
- **New substrates have demonstrated *excellent* electrical performance and physical properties.**
- **They are *compatible* with PCB processing; a truly "drop in" material.**
- **Materials are commercially available from many fabricators**
- **Substrates filled with ferroelectric particles have better performance, but result in higher cost PCBs**
- **GREEN and lead free solution**

FaradFlex® ADVANTAGES

- Broadest lineup of products
- Delivery is 1 week or less in US and Asia
- Local sales and technical support in US and Asia
- Highest quality material compared with competitive materials (no foreign material)
- Best panel size flexibility for PCB Designs
- Most copper weight options
- Lowest profile copper available used ONLY on *FaradFlex*®
- Reliability: All panels HIPOT tested by Oak-Mitsui prior to shipment

Contact Us

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Additional information available at
www.faradflex.com

How can FaradFlex® Optimize PDN and Reduce Noise?

Answer:

"Ask Bob"

FARADFLEX®

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