PASSIVE COMPONENTS

Keys to Enabling Advanced Future System Designs

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OUTLINE

Current State
Where Are We At Today

How Did We Get Here
Drivers

Examples
Where Capacitors Enable Performance

Where Are We Going & What Does The Future Hold

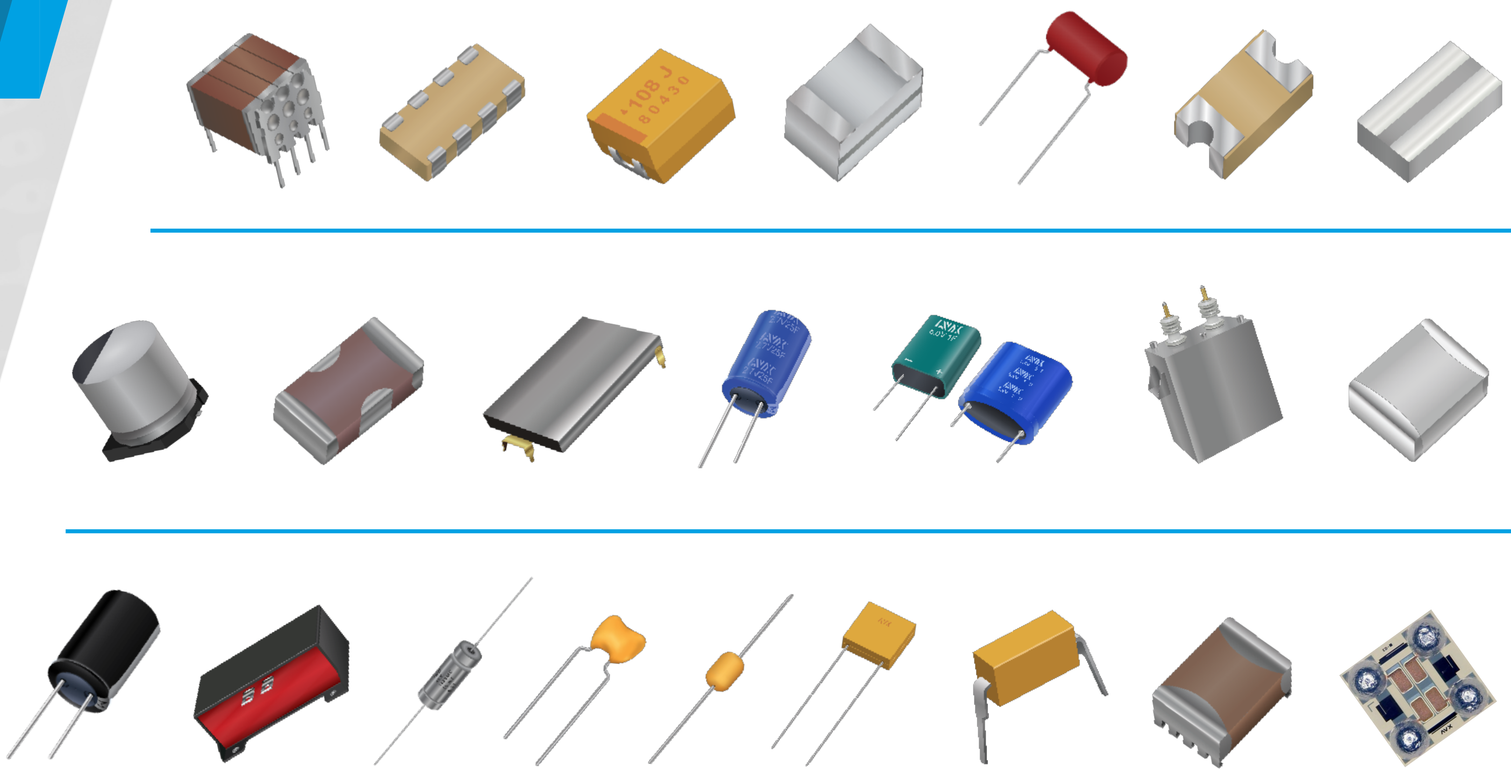
ADVANCEMENT OF CAPACITOR TECHNOLOGY

Then vs Now

State of the Art Technology Then

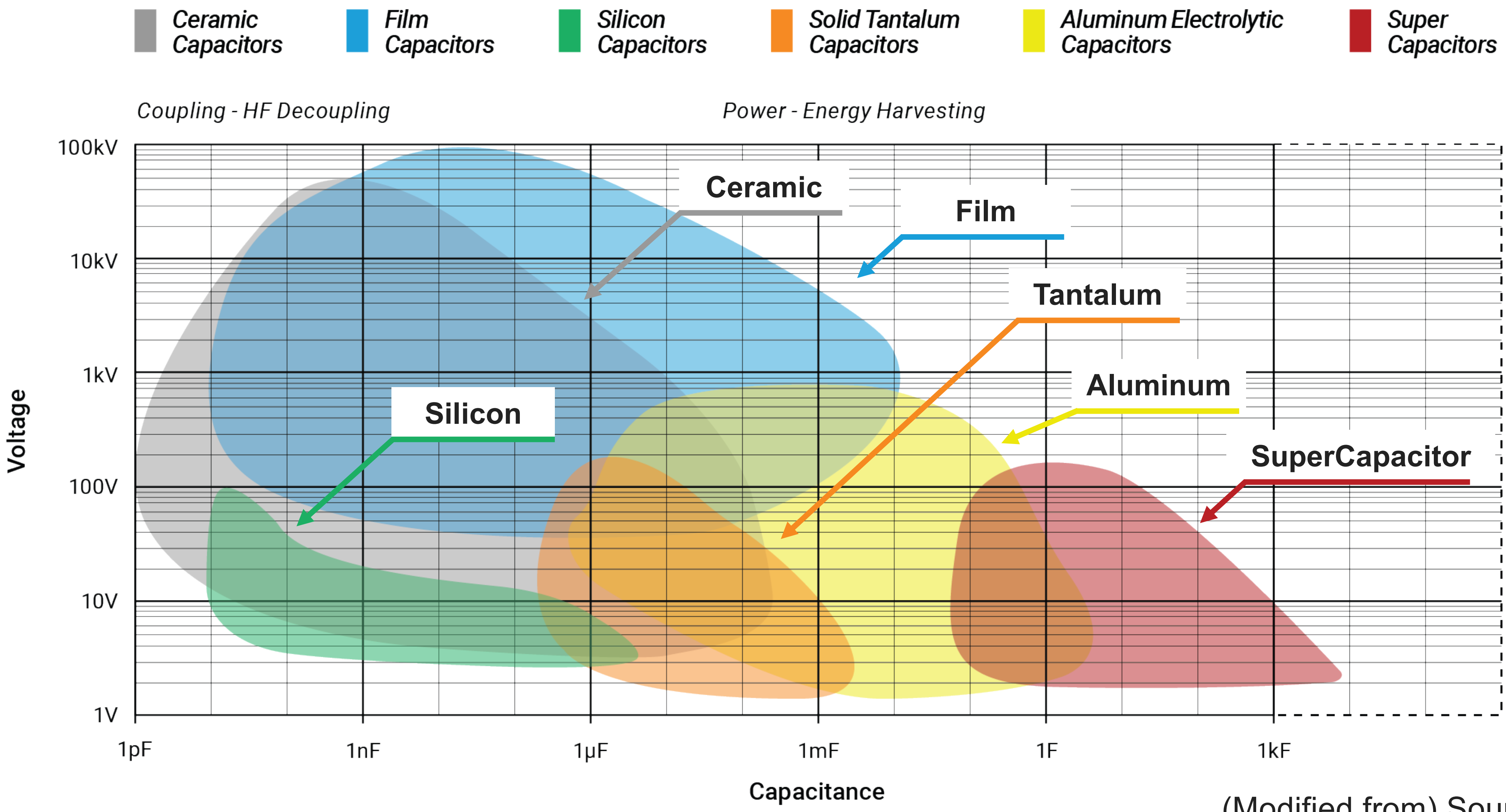
Leyden Jar
Source: ETHW.org

In 1746, the Leyden Jar was considered to be the very first capacitor. It was the first device capable of storing an electric charge.



State of the Art Technology Now

WHERE ARE CAPACITORS TODAY

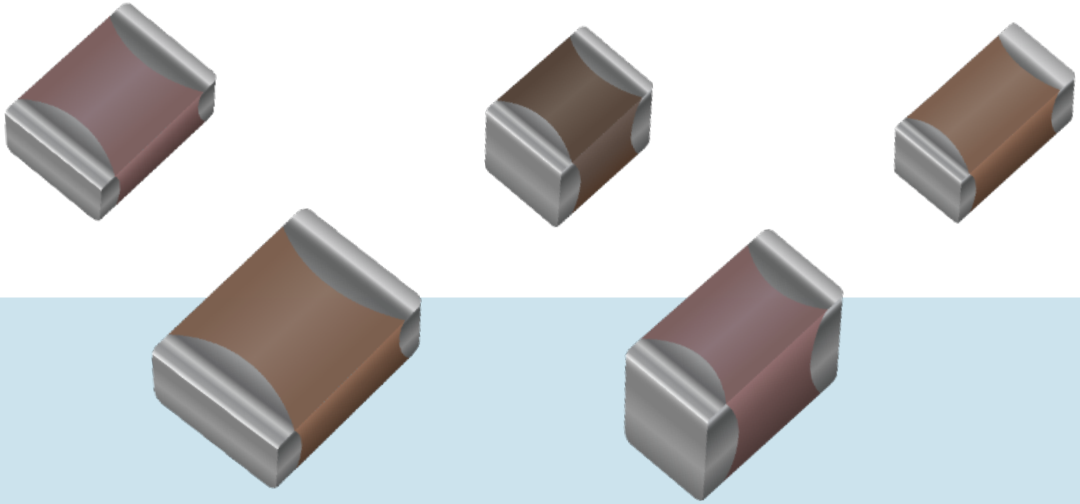


(Modified from) Source: EPCI

2019

WHERE WE ARE TODAY

Just experienced shortages and market conditions unlike anything we have seen before



Source: [The Wall Street Journal]

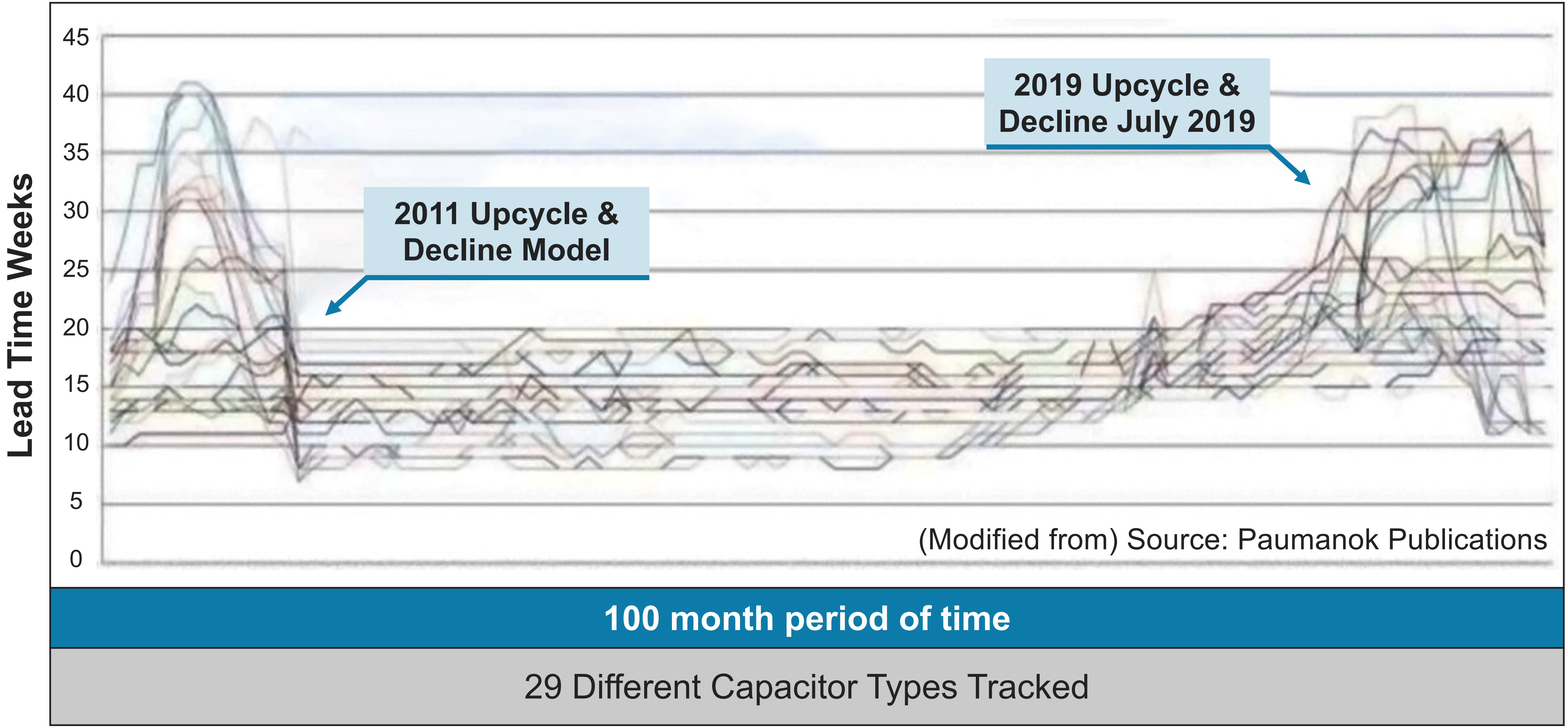
BUSINESS

Parts Shortages Crimp U.S. Factories

As suppliers struggle to meet demand, Caterpillar fights to fill orders and Oshkosh idles crane output

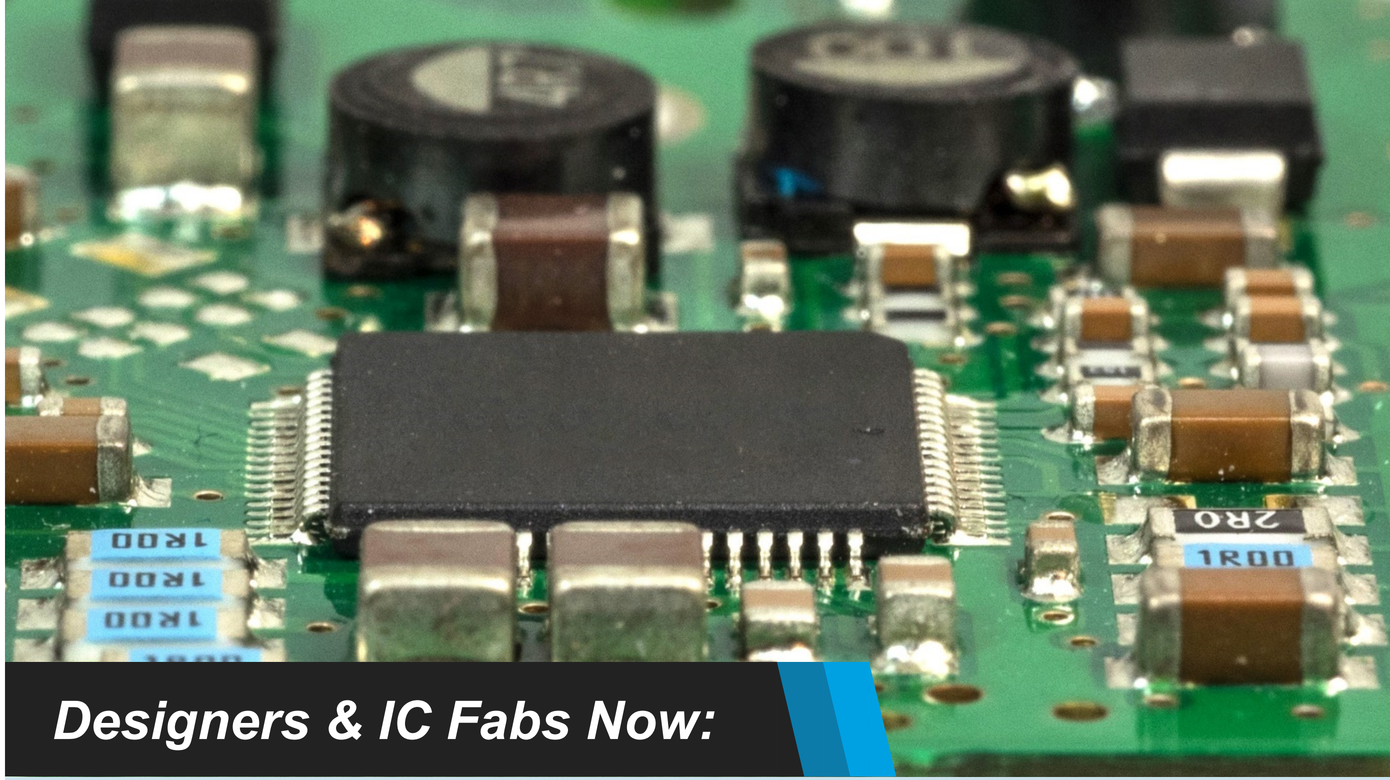
PHOTO: MIKE BLAKE/REUTERS

CYCLIC NATURE OF CAPACITOR SHORTAGES



SUPPLY SHORTAGE IMPACTS:

*Design Engineers were driven to align usage with parts readily available – **compromises made***



Designers & IC Fabs Now:

1. Exploring Design Changes to Reduce Component Count
2. Increased Collaboration in New IC Types Causing Accelerated Innovation / Rate of Change

DRIVERS -

MASSIVE NEW MARKETS AND APPLICATION NEED

The next 10 years will be nothing like anything we have seem

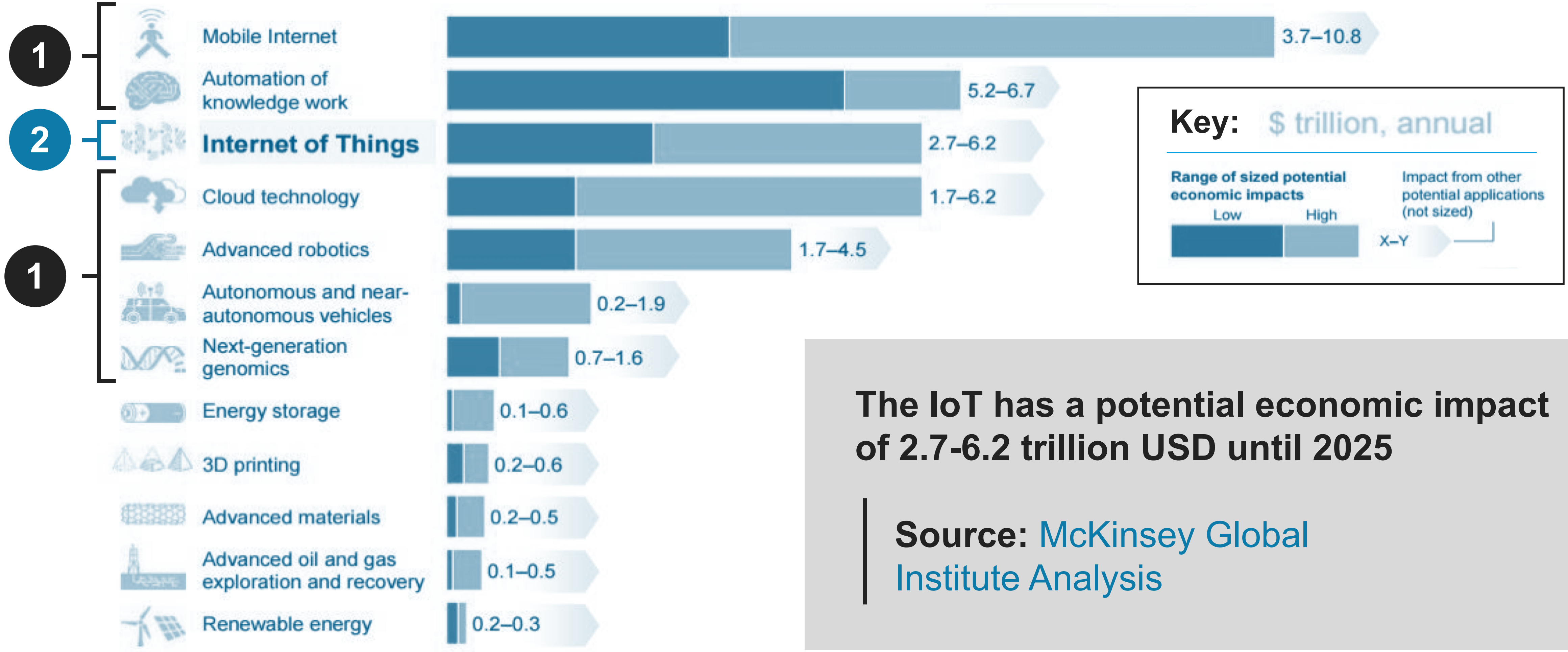
Rapid Emergence Of Whole New Markets, Systems & Applications:

- Virtual Reality / Augmented Reality
- EVs
- Autonomous Vehicles
- 5G
- IoT Cloud

- Smartphones/ PDA
- Charging – Wireless Low Power & Wired High Power
- Medical Electronics
- Advanced Robotics

MULTIPLE KEY GROWTH AREAS

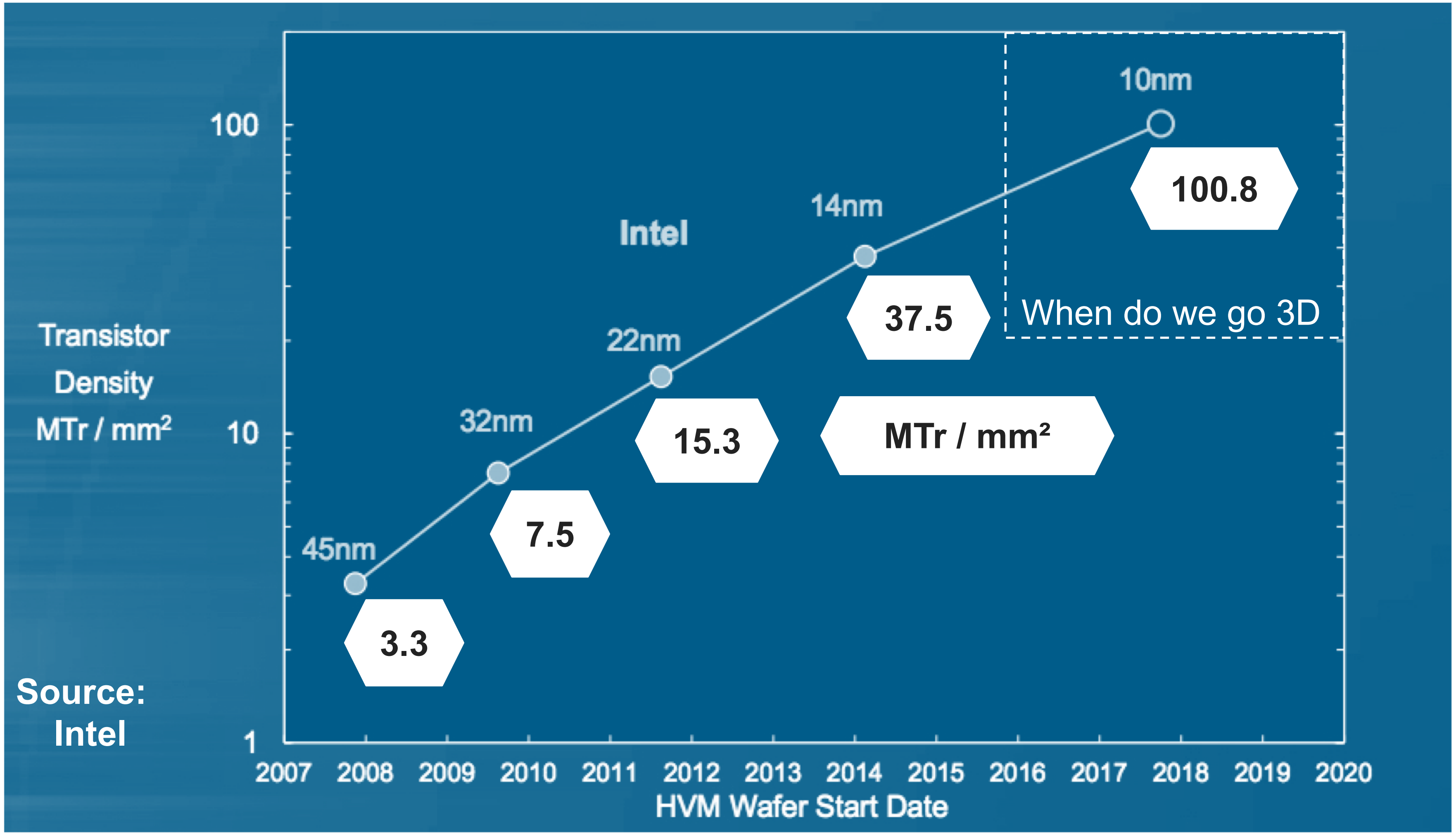
LETS DIVE INTO 2 ‘SECTORS’

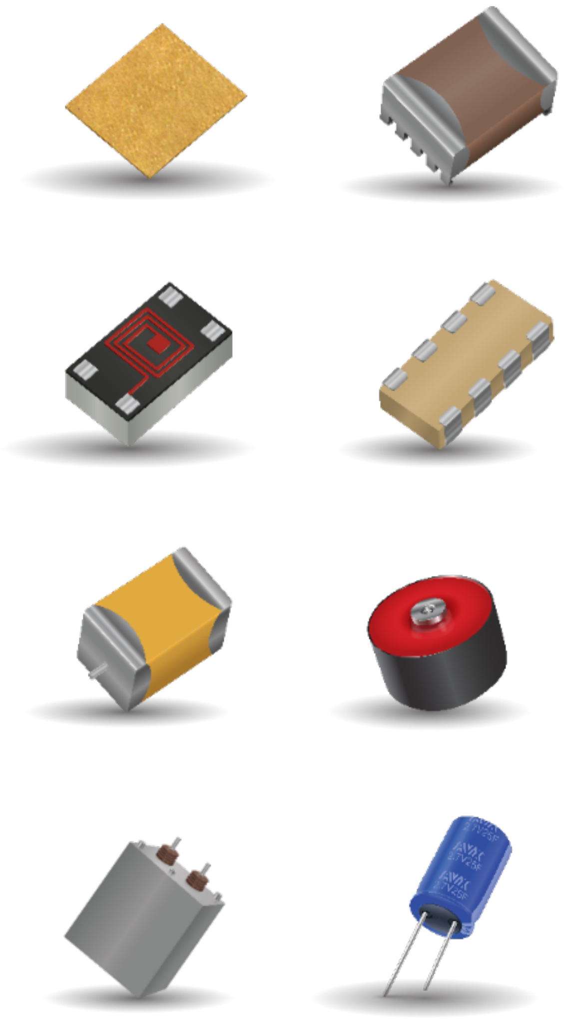


The IoT has a potential economic impact of 2.7-6.2 trillion USD until 2025

Source: McKinsey Global Institute Analysis

EXAMPLE - WHERE CAPACITORS ENABLE PERFORMANCE: ADVANCED SEMICONDUCTORS

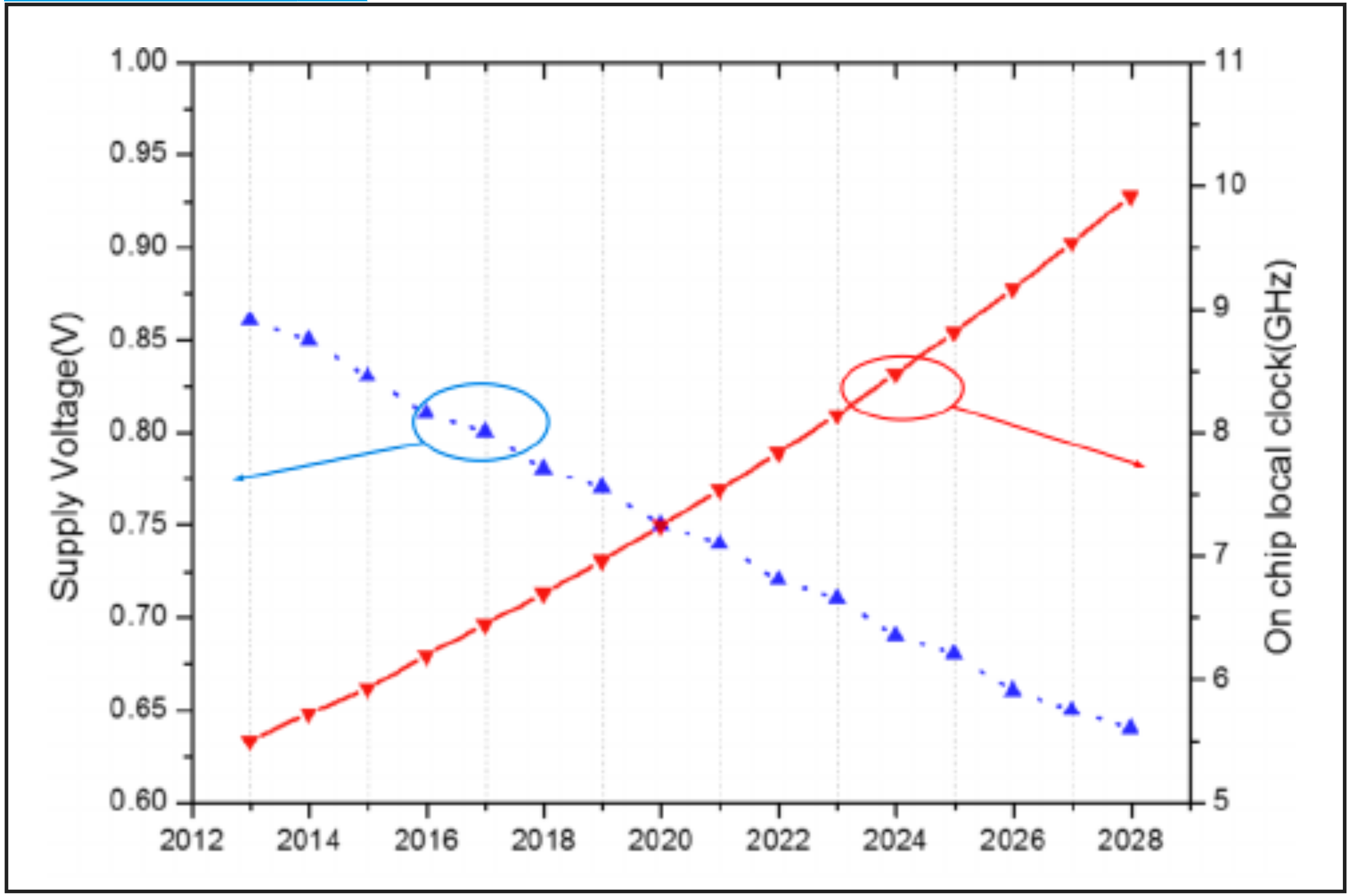




DIE SCALING HAS DROPPED IC SUPPLY VOLTAGE

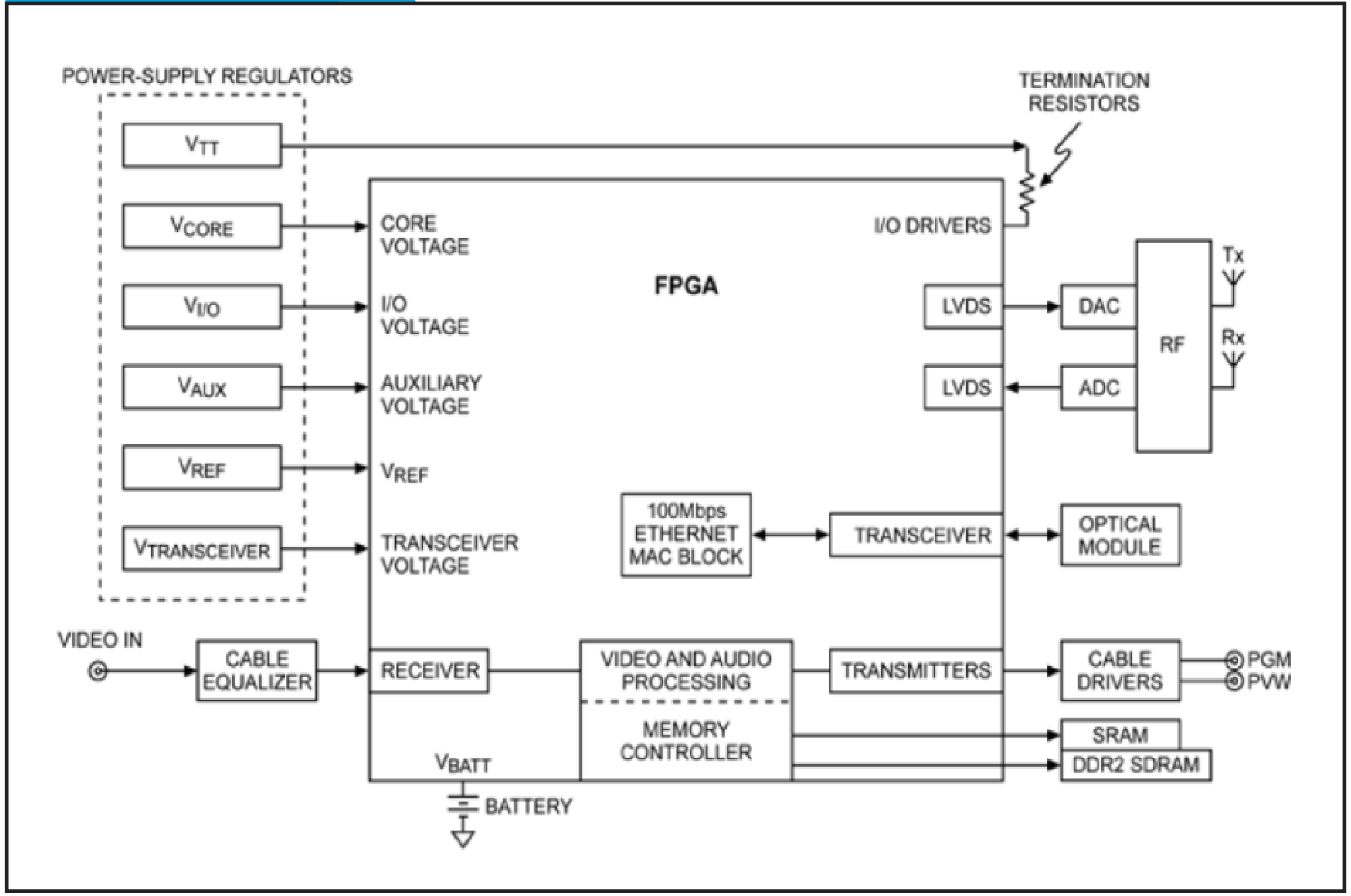
- *Capacitors job decoupling more critical*
- *Clock & data speeds making Di/Dt drawn larger*

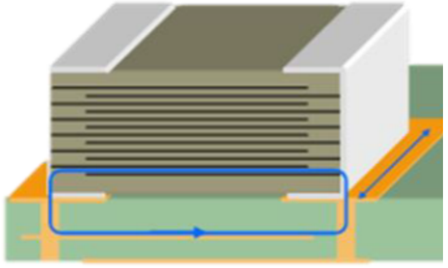
Source: ITRS



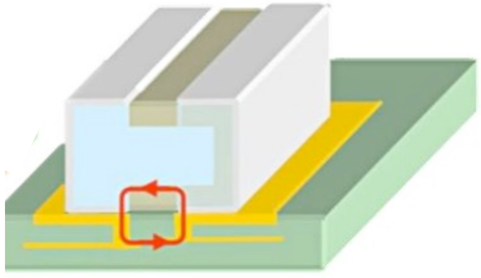
TYPICAL FPGA 6 OR MORE DIFFERENT VOLTAGES

Source: Maxim





0805 MLCC
ESL ~ 600pH



0508 LGA
ESL ~ 27pH

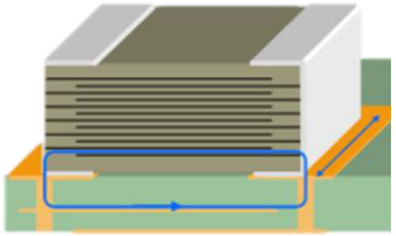
TYPICAL FPGA 6 OR MORE DIFFERENT VOLTAGES

Source: Maxim

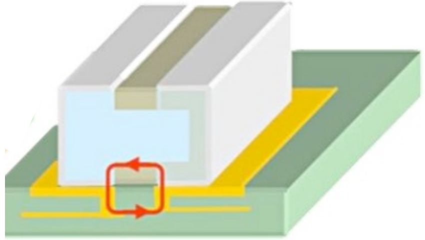
Table 1. Xilinx Virtex-7 Power-Supply Requirements

Power Rail	Nominal Voltage (V)	Tolerance	Description
V_{CCINT}	1.0*	±3%*	Voltage supply for the internal core logic
V_{CCAUX}	1.8	±5%	Voltage supply for auxiliary logic
V_{CCO}	1.2 to 3.3	1.11V to 3.45V**	Voltage supply for I/O banks
MGTAVCC	1.0	±3%	Voltage supply for GTX transceiver
MGTAVTT	1.2	±30mV	Voltage supply for GTX transceiver termination circuits

*The lowest-speed "-1L" version of the Virtex-7 has a 0.9V core voltage with a ±30mV tolerance.
**The specification for 3.3V HR I/O banks is 3.45V (max). The specification for 1.8V HR I/O banks is 1.89V (max).



0805 MLCC
ESL ~ 600pH



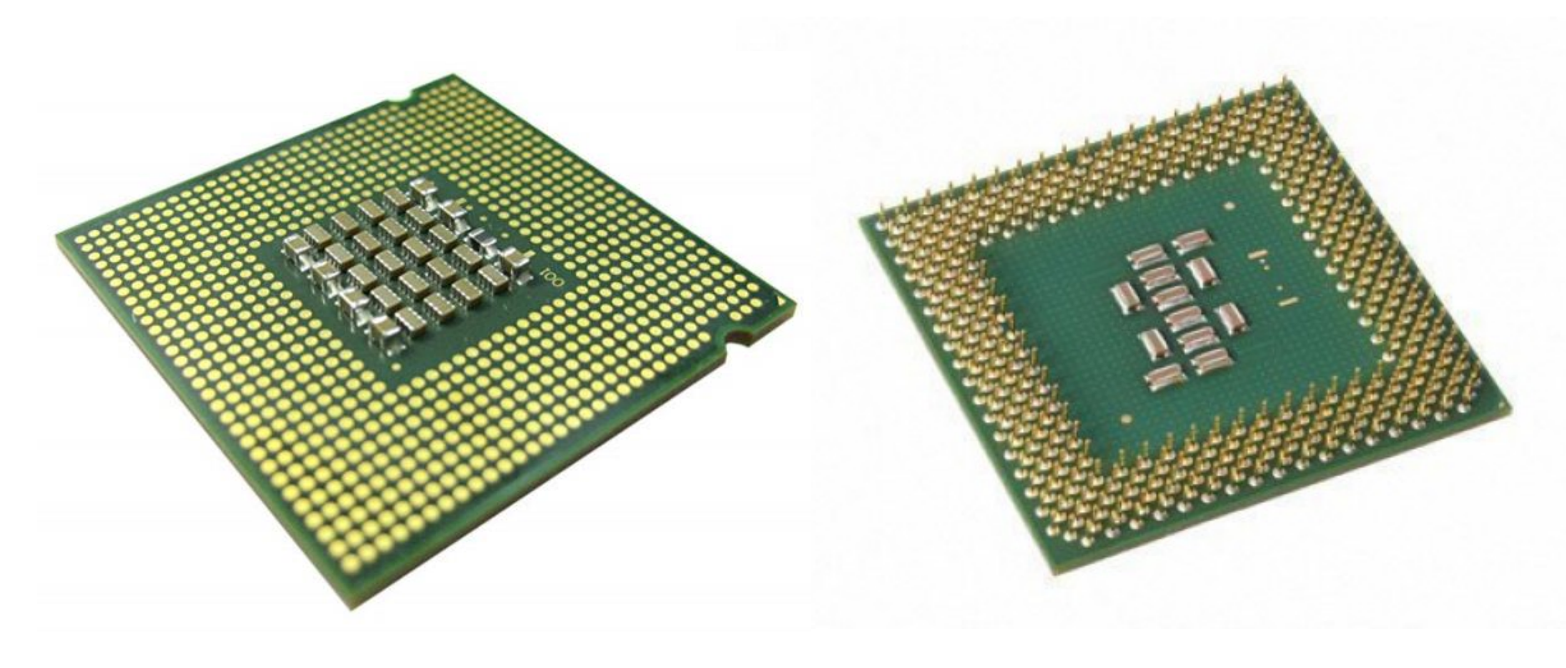
0508 MLCC
ESL ~ 45pH

TODAYS SOLUTION

LOW INDUCTANCE MLCCS OR SMALL CASE MLCCS IN LOW INDUCTANCE CONFIGURATION

- 0402 Caps Inside 0.8 mm Pitch BGA
- 0201 Caps Placed 90° Rotated Allows For More Caps Underneath The BGA Area

Source: **Maxim**



Source: **Intel**

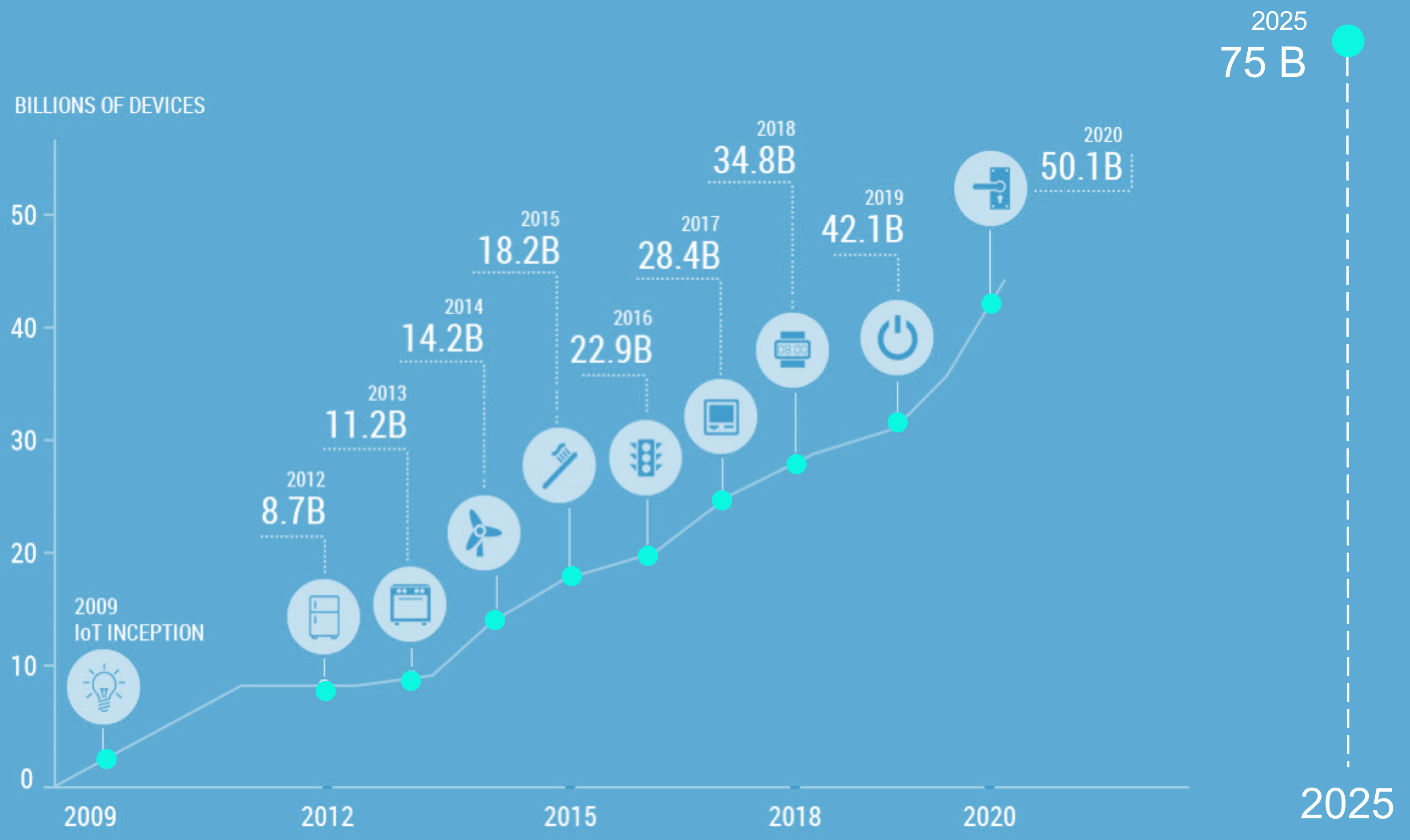
EXAMPLE - WHERE CAPACITORS ENABLE PERFORMANCE: IoT

2

GROWTH OF THE IoT

Key:

- Per Statista 37 billion 2019, 75 Billion 2025
- Per Ericsson 18 billion 2019



The Number of Connected Devices will Exceed 75 Billion by 2025

Source: CISCO

IoT WILL DRIVE PASSIVE COMPONENT VOLUMES

IoT WILL DRIVE ENERGY HARVESTING METHODS, CIRCUITS & MODULES

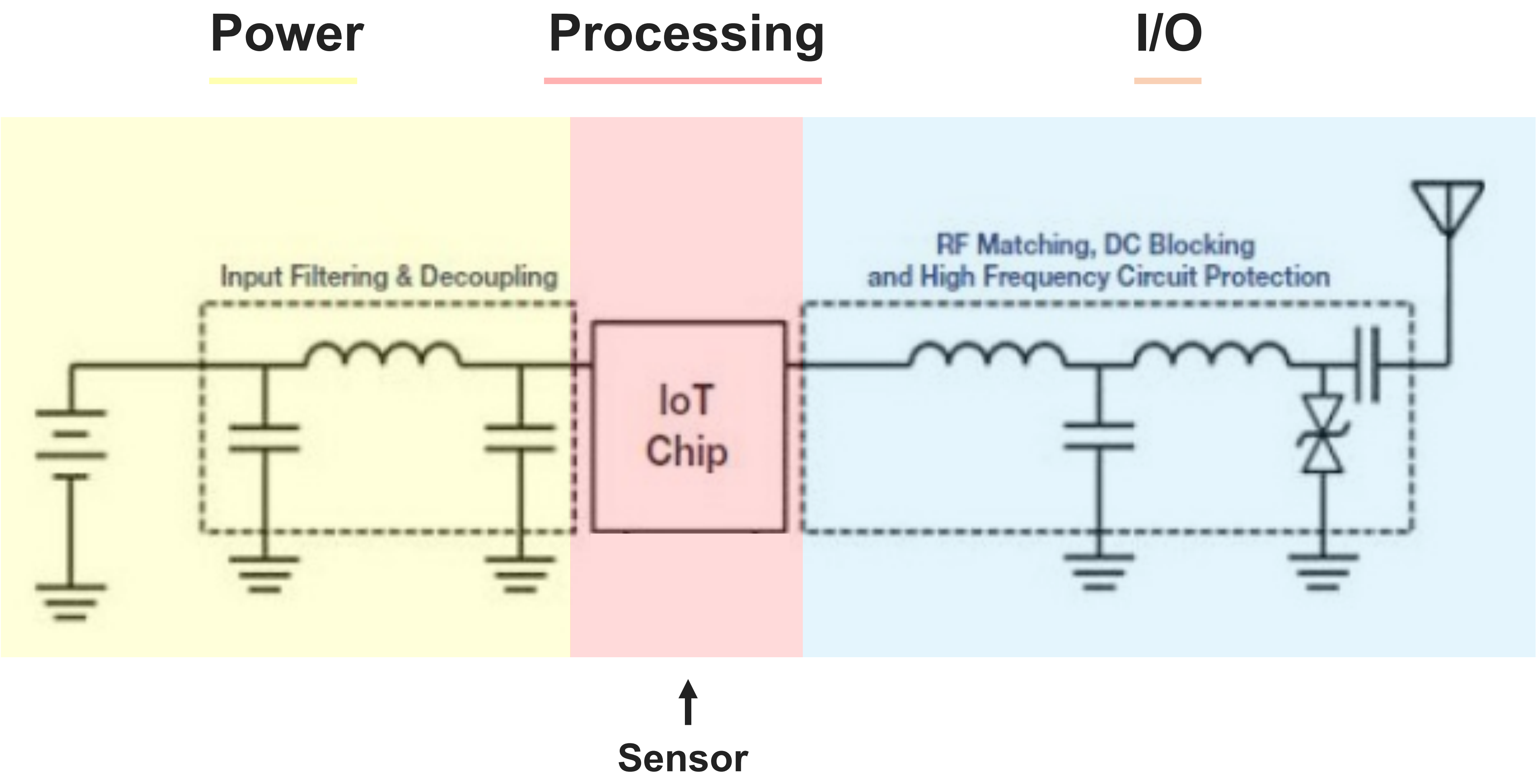
Hard to replace the battery here.

An important opportunity within IoT is **Energy Harvesting.**

IoT Allows:

24/7 remote monitoring of anything

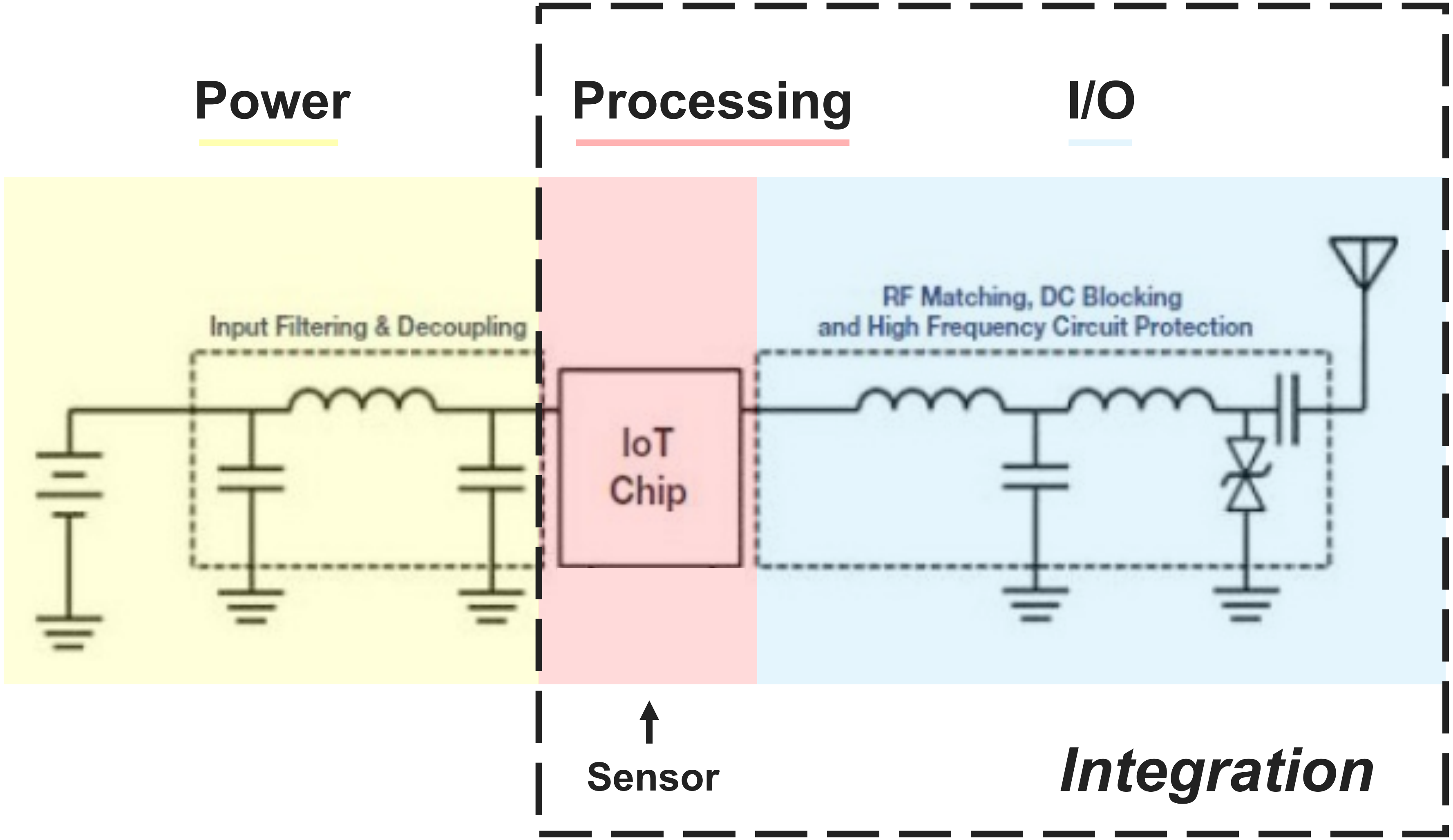
SIMPLIFIED IoT STAMP PROFILE



COST PRESSURES WILL DRIVE INTEGRATION

Power: *Energy Harvesting*

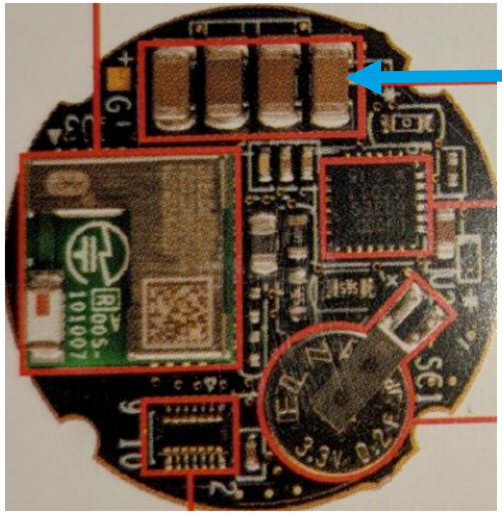
- Low Leakage, Hi Value Cap
- Hybrid Battery
- OR Battery Design



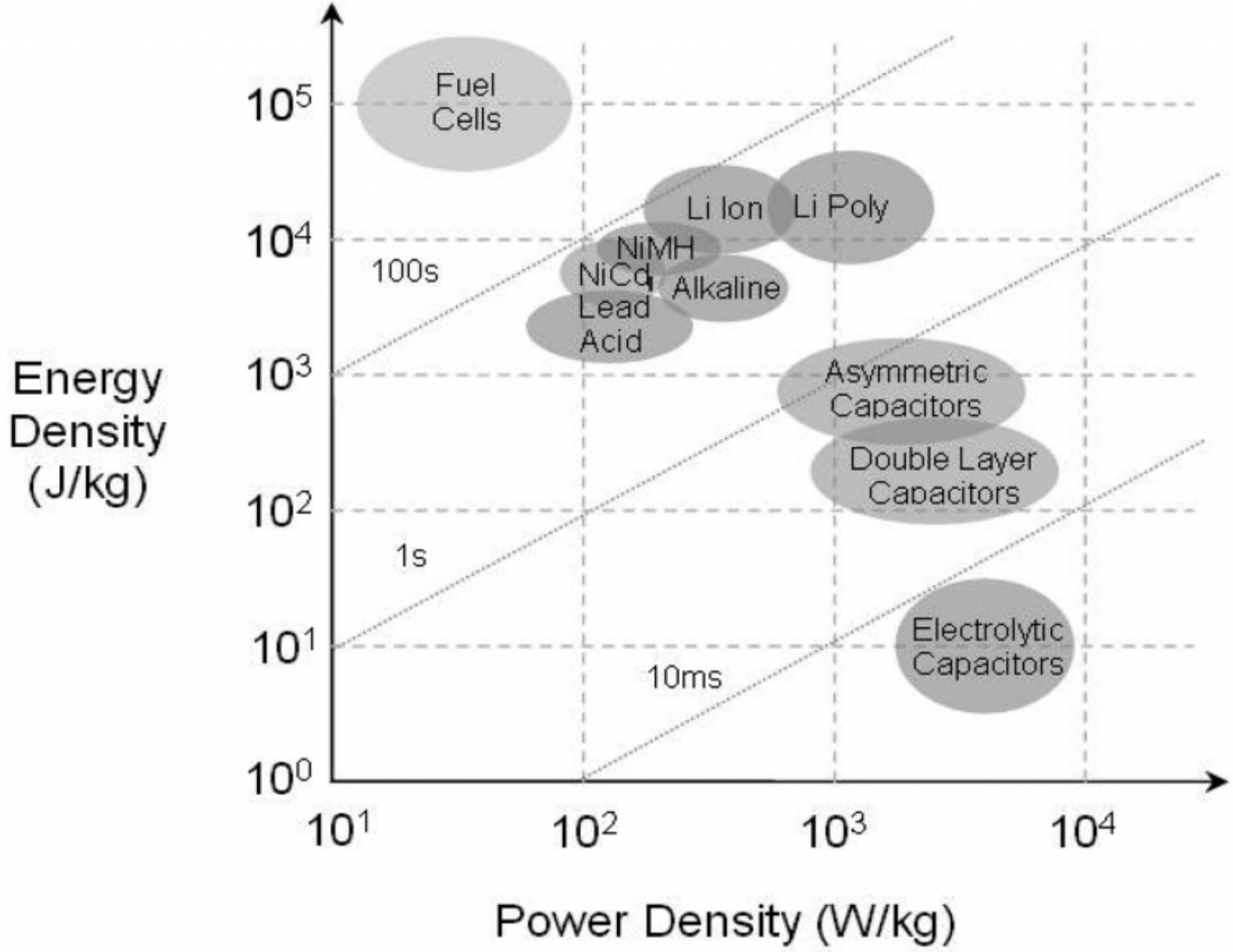
WILL COST PRESSURES DRIVE INTEGRATION

Power Of the Future:

- Small, Light, Cheap
- High Performance
- High Life Cycles
- Reliable
- Billions Made



What's Next?



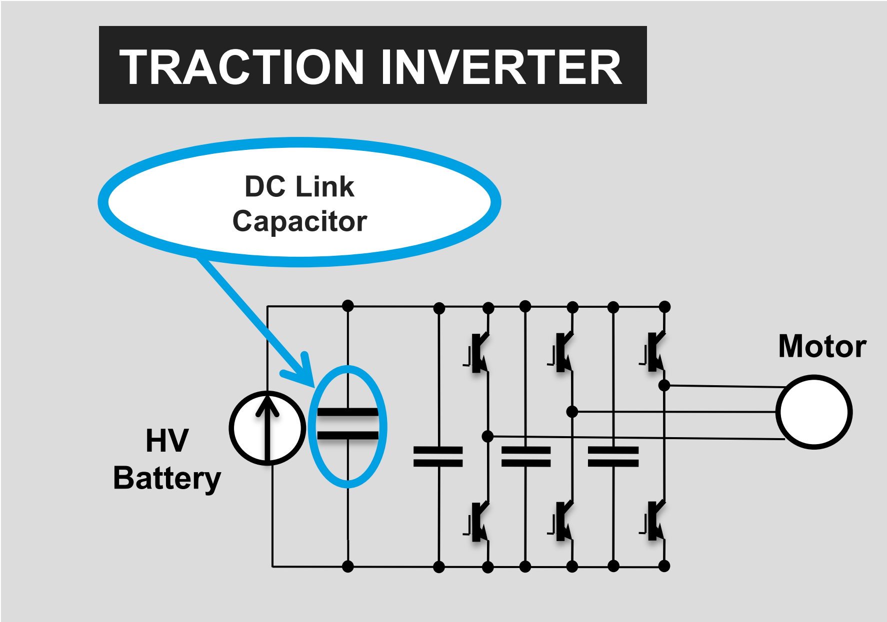
APPLICATION #3 CAPACITORS

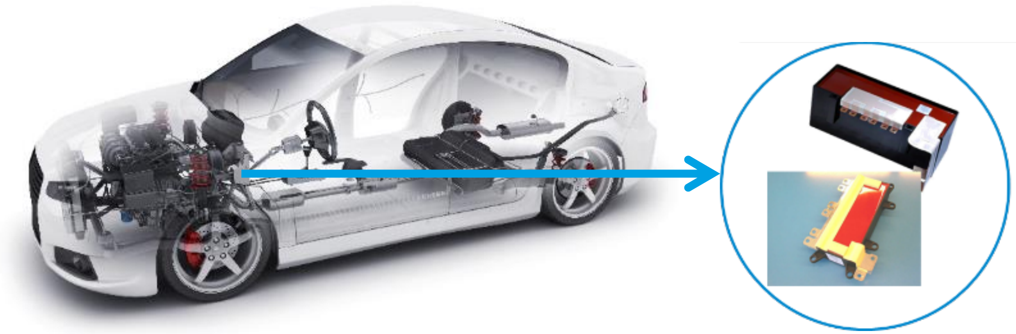
ELECTRIC VEHICLES

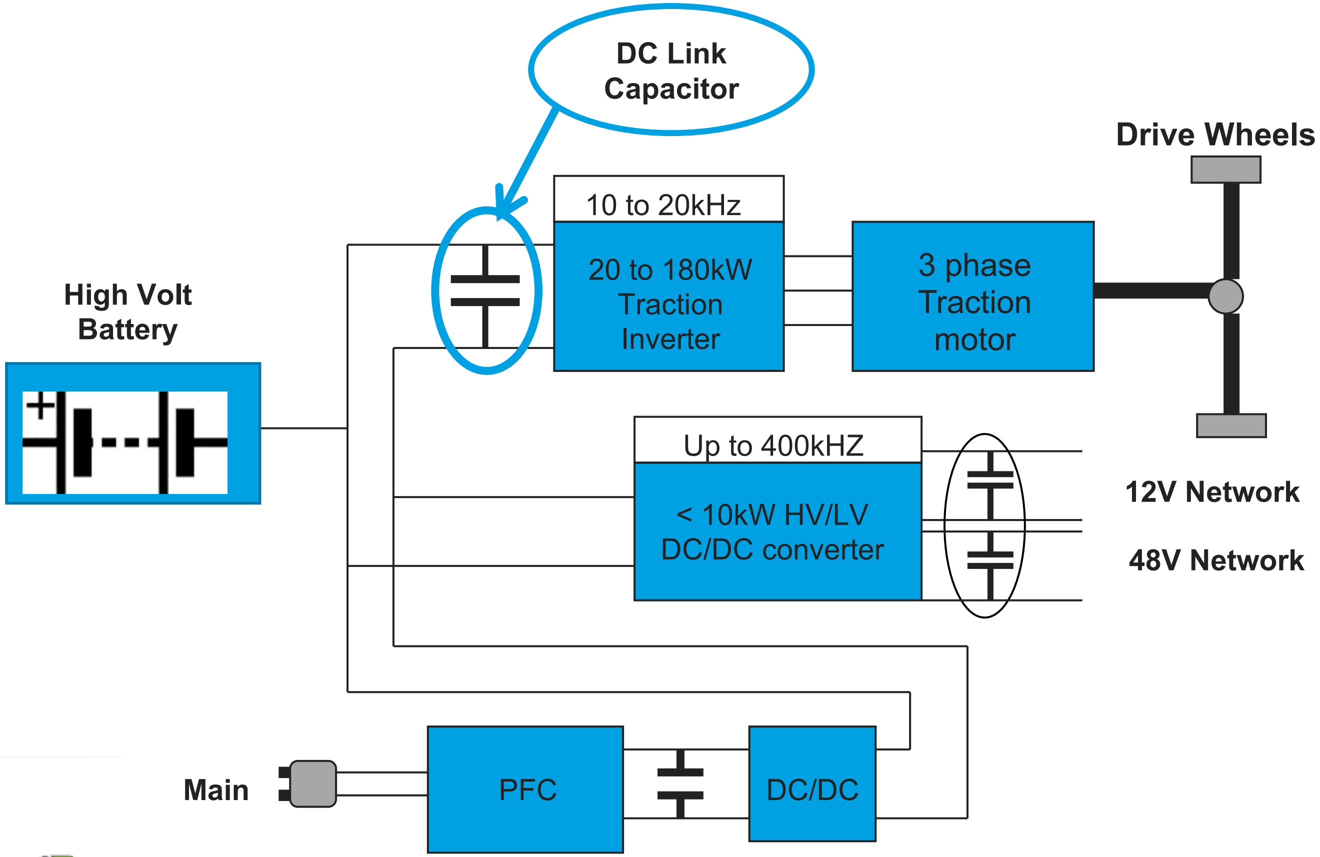
- EV Capacitor content massive - >10,000 capacitors
- Ranges from RF to Power Caps
- High Temp 150c/175c to decoupling & AC coupling on ADAS Drive – (critical for safety)
- Wireless charge circuitry

- Plug in charger & DC drive filtering
- DC Link Caps
- EMI Filter Caps
- Safety Caps

HEV/EV TRACTION CHAIN



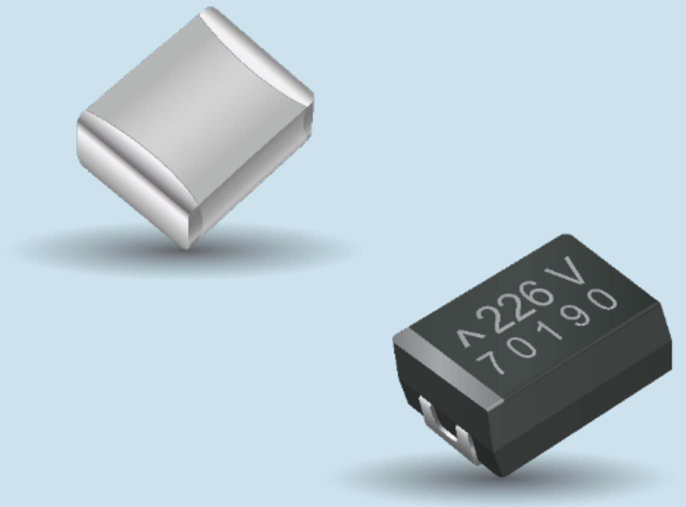




EV POWER CAP OPTIONS & TRADE OFFS

Application Needs:

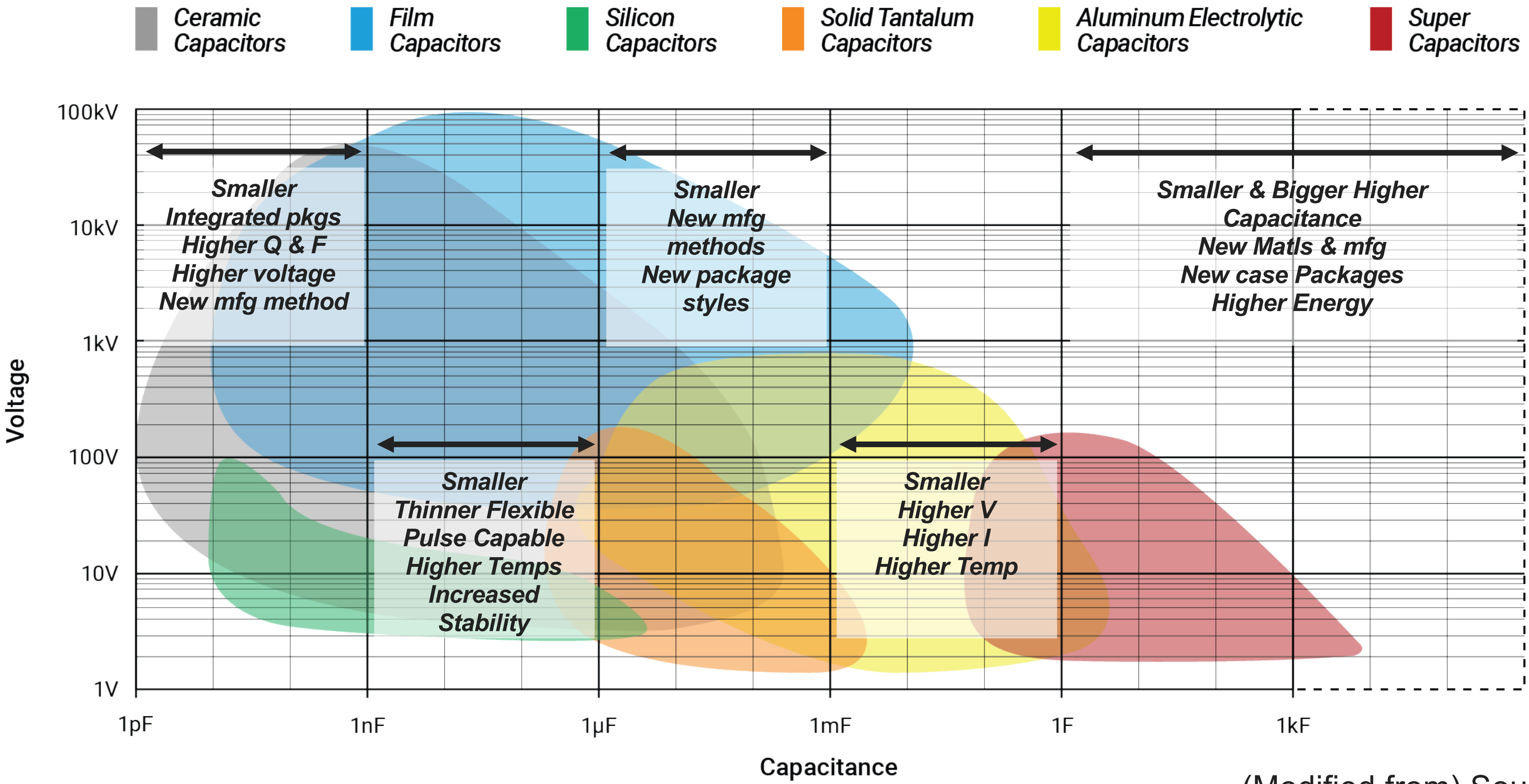
More Cap, Higher Voltages, Smaller & Lighter Packages That Work At Hotter Temperatures



PARAMETER	FILM CAPACITOR	ELECROLYTIC CAPACITOR
Cost	High	Low
Size	Potentially smaller	Mixed volumetric efficiency
Surge Voltage Capability	2x rated voltage	1.2x rated voltage
Revere Voltage Capable	Yes	No
RMS Current	</= 1 A rms/ uF	</=0.025A rms/uF
MTBF	>/= 10 million hours	1 Million hours
Life Time	> / = 100,000 hours	>/= 40,000 hours
Storage	> 10 years	1 year
Environmentally friendly	Yes	No
End of life	Soft – failure loss of cap	Explosion Risk

WHERE ARE WE GOING & WHAT DOES THE FUTURE HOLD ?

FUTURE TRENDS BY GROUP



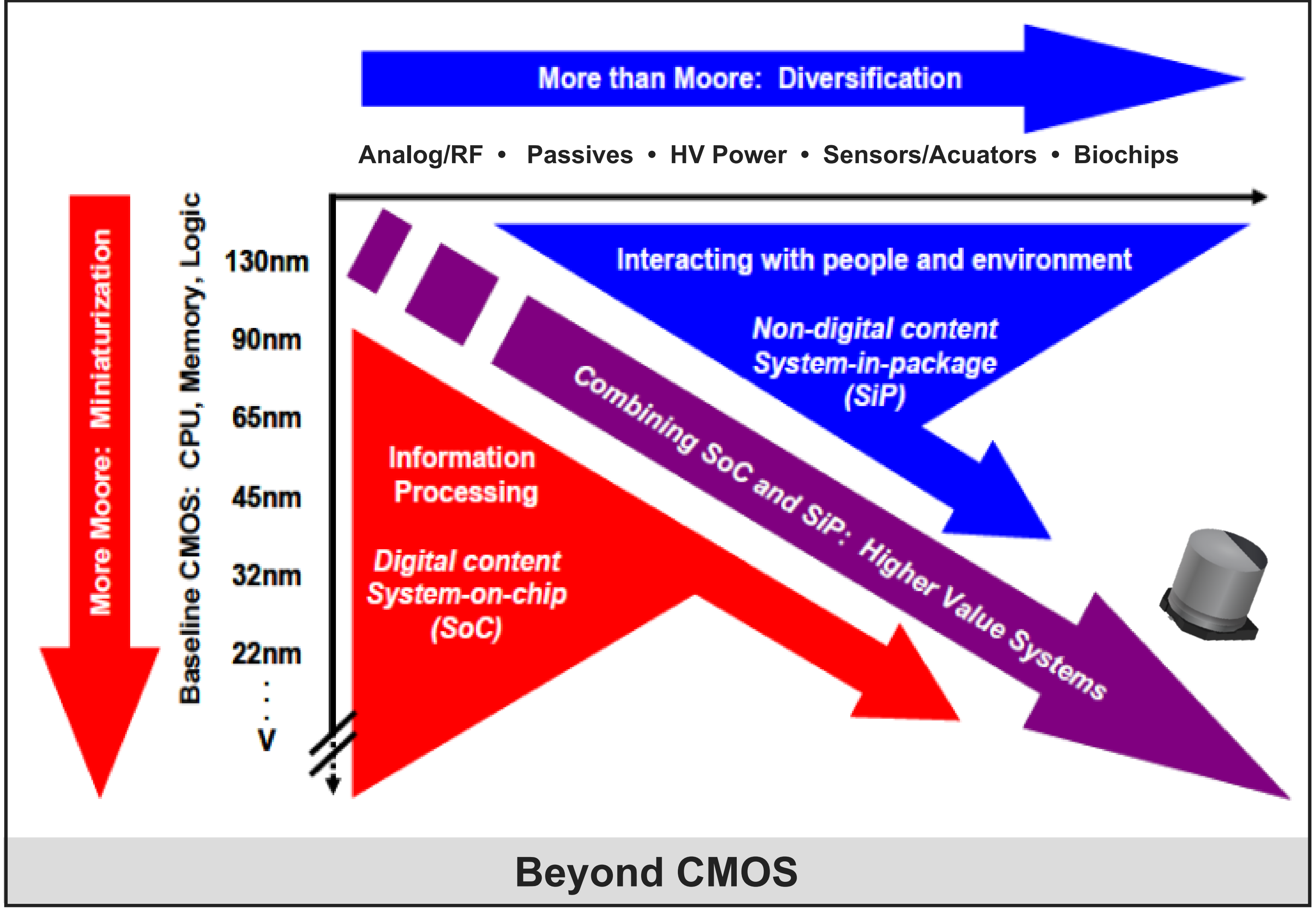
(Modified from) Source: EPCI

WHERE ARE WE GOING & WHAT DOES THE FUTURE HOLD ?

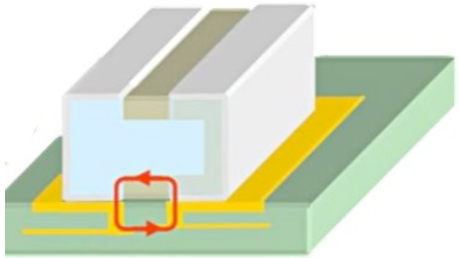
PARAMETER	CAPACITOR TYPE			
	SMALL SIGNAL	RF	POWER	BULK GENERAL PURPOSE
Cap Value	↓↑	↓↑	↑	↑
Rated Voltage	↓↑	↑	↑	↓↑
Size	↓ →	↓ →	↓	↓
Temperature Stability	↓↑	↑	→	↑ →
DC Bias Stability Need	↑	↑	→	↑
Temperature Range	↑ →	↑ →	↑	↑
Frequency	↑	↑	↑	↑ →
Loss Characteristics	↓	↓	↓	↓

AS ICs EVOLVE INTO SOCS & SIPS POWER QUALITY NEEDS INCREASE

Source: ITRS

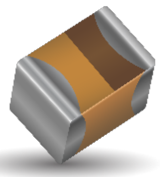


Decoupling:

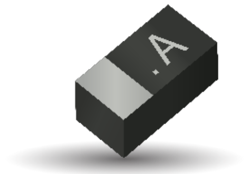


0508 LGA
ESL ~ 27pH

Bulk Filtering:

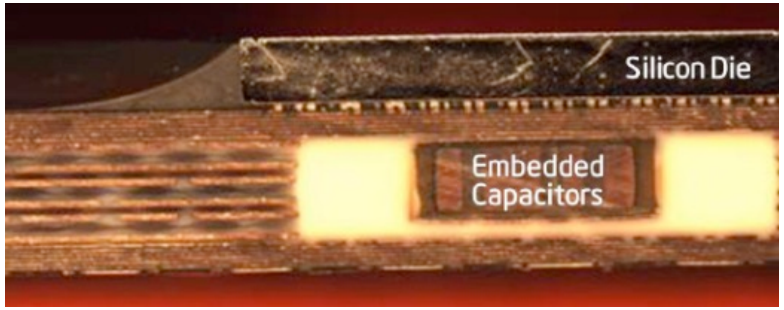


0402
ESL ~ 1.1nH

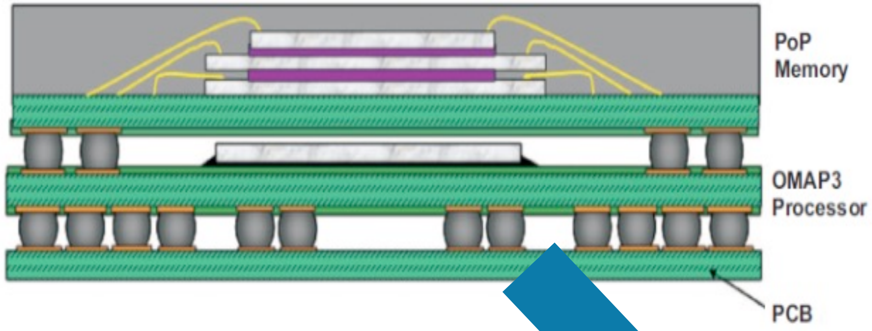


0402
ESL ~ 1.1nH

Source: Intel



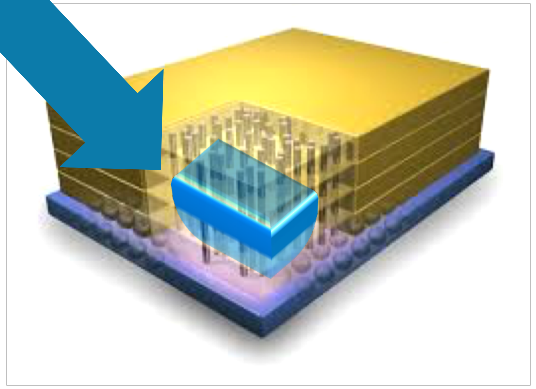
Source: TI



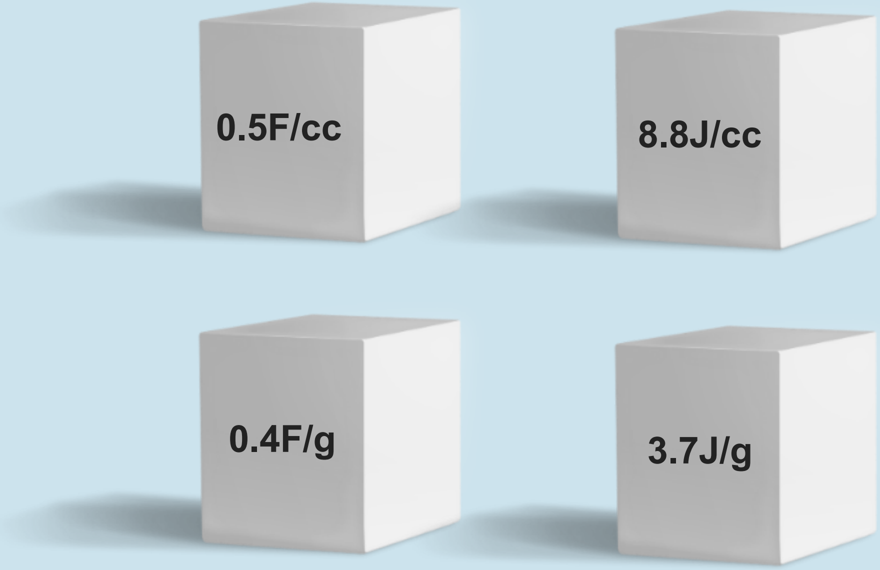
ONE POSSIBLE EVOLUTION

Source: IBM NIST

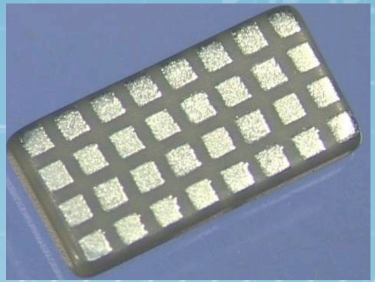
Novel Designs



WHAT IF THIS IS THE CAPACITOR ?



Summary:



THE FUTURE HAS UNIMAGINABLE UPSIDES

Shortages Drive Design Innovation

Need for efficient caps is growing

Capacitor evolution driven by:

1) **IC Demands**
2) **New Applications**
3) **Emerging Active/Passive Packages**

THANK YOU.

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