AVX®

A KYOCERA GROUP COMPANY

ACCELERATING
INNOVATION

Saving Board Space Using Low ESR Polymer Capacitors

ARROW

Targeting SMPS

(Switch-Mode Power Supplies)

Output Capacitors

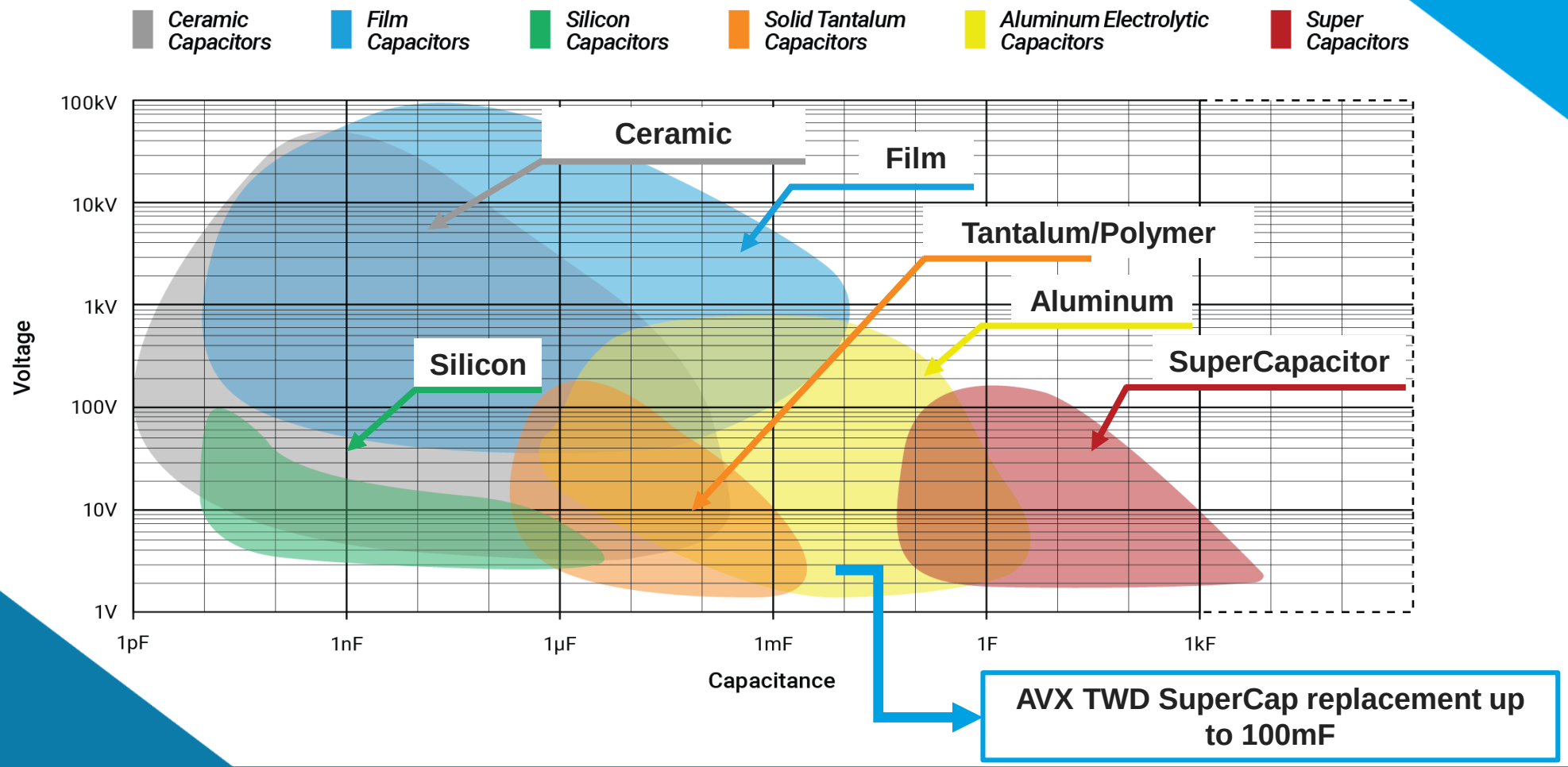
SMPS (*Specifically DC/DC Convertors*) are in most of today's electronic devices

Output capacitors of DC/DC Converters can act as energy carriers and can have a direct impact on functionality and filtering quality

Datasheets of semiconductor devices often don’t show the various available options for the given electrical requirements and the capacitor selection criteria

Capacitor Hi CV Technologies

Technology Overlap



ELECTROLYTIC CAPACITOR TYPES

TECHNOLOGIES

Wet Electrolytics

Solid Electrolytics

Electrolytic Capacitors

Tantalum Wet

- Large Cap in Large Case
- Long Life, High Reliability
- Harsh Environment
- High Energy Density

Al Wet / Al Solid / Hybrid

- Large Cap in Large Case
- Lowest Price
- Limited Lifetime

Ta Anode / MnO_2 Cathode

- Large Cap in Small Case
- Long Life, High Reliability
- Harsh Environment
- High Energy Density

NbO Anode / MnO_2 Cathode

- High Safety
- Very High Reliability

Ta Anode / Polymer Cathode

- Low ESR
- High Volumetric Efficiency
- Benign Failure Mode
- Wide Voltage Range

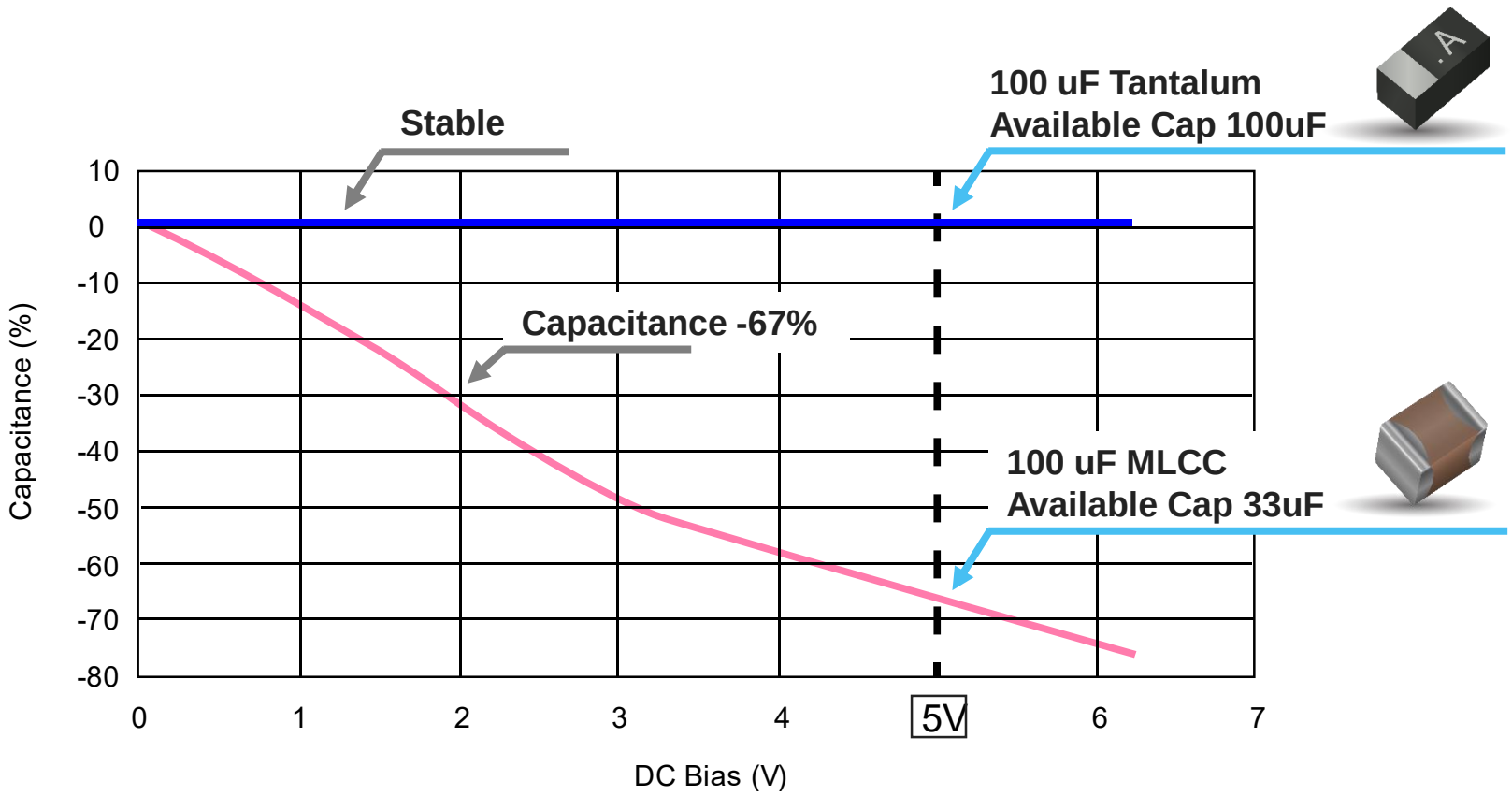
- Polar Components
- Consists of Anode, Cathode & Dielectric
- DC Operation

Electrolytic Comparison

PARAMETERS

Attribute	MnO_2	Polymer	OxiCap®
Benefits	• No noise • Highest CV/cc • High Reliability • -55°C - +230°C • Stable Cap V/T • Indefinite Lifetime • Mechanically Robust	• No Noise • Low ESR • High Voltage • Benign Failure • High Reliability • Stable Cap V/T • Surge Resistant • -55°C/+105/150°C • 10% or 20% Derating	• Fail Safe • Self-Healing • Highest Reliability • Indefinite Lifetime • Surge Resistant • 20% Derating • -55°C - +125°C • Stable Cap V/T • No Noise
Check	• < 50V Ratings • 50% Derating	• Moisture Sensitive	• ≤ 10V Ratings

DC Bias – Capacitance Change



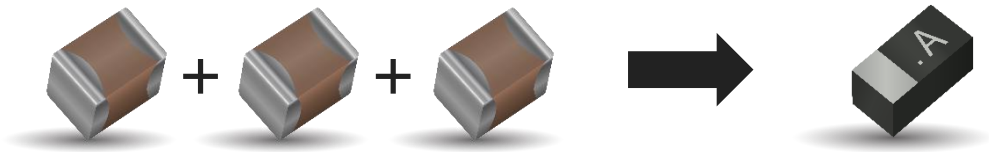
Tantalum

100 uF, 6.3V, 0805

MLCC

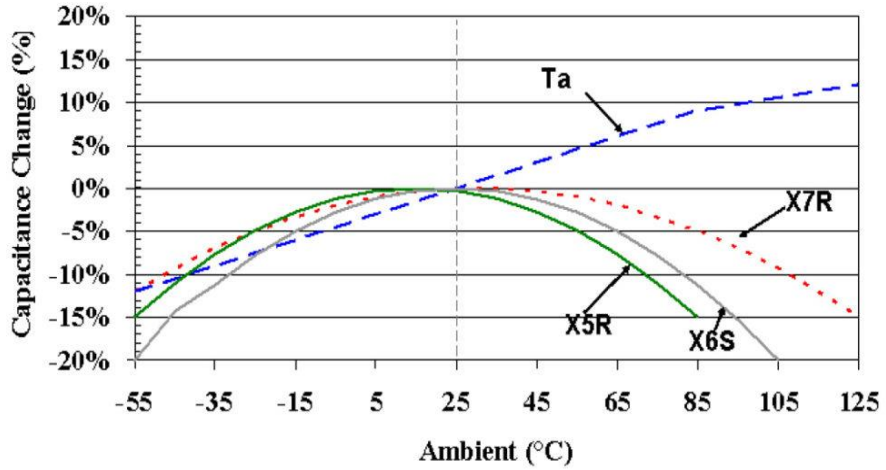
100 uF, 6.3V, 1206

Replace Several MLCCs with
One Ta/Polymer Capacitor



Key Features – Details I

Temperature Dependency



Tantalum/NbO/Polymer & MLCC

- Stable Capacitance with DC/AC Voltage BIAS & Temperature

Figure 3. Capacitance versus temperature behavior by different dielectric types. Chart Credit: Kemet

Capacitance vs. DC Voltage

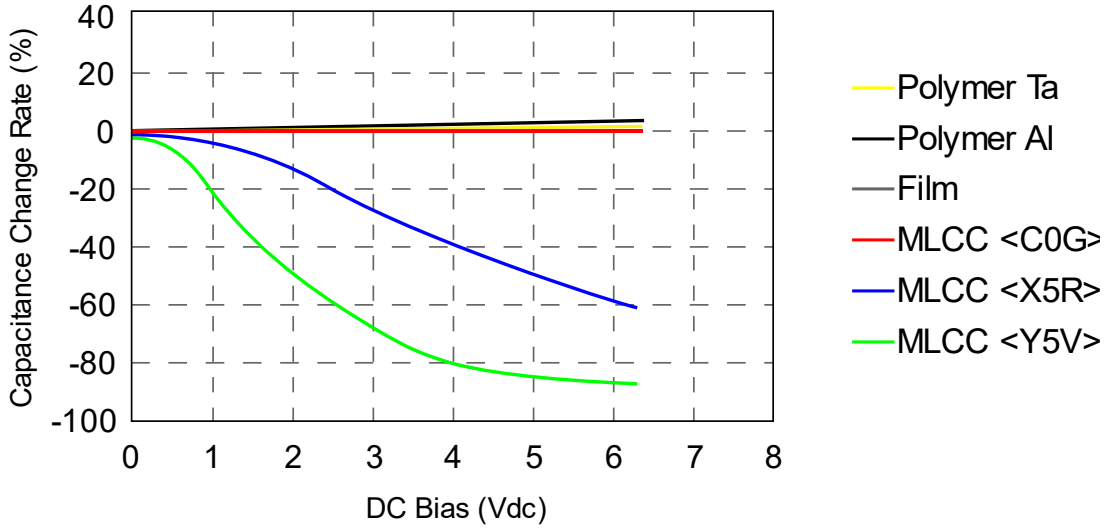


Figure 4. Cap versus DC Bias behavior by different dielectric types, Chart Credit: Murata

Figure 5. Cap versus AC voltage behavior by different dielectric types, Chart Credit: Murata

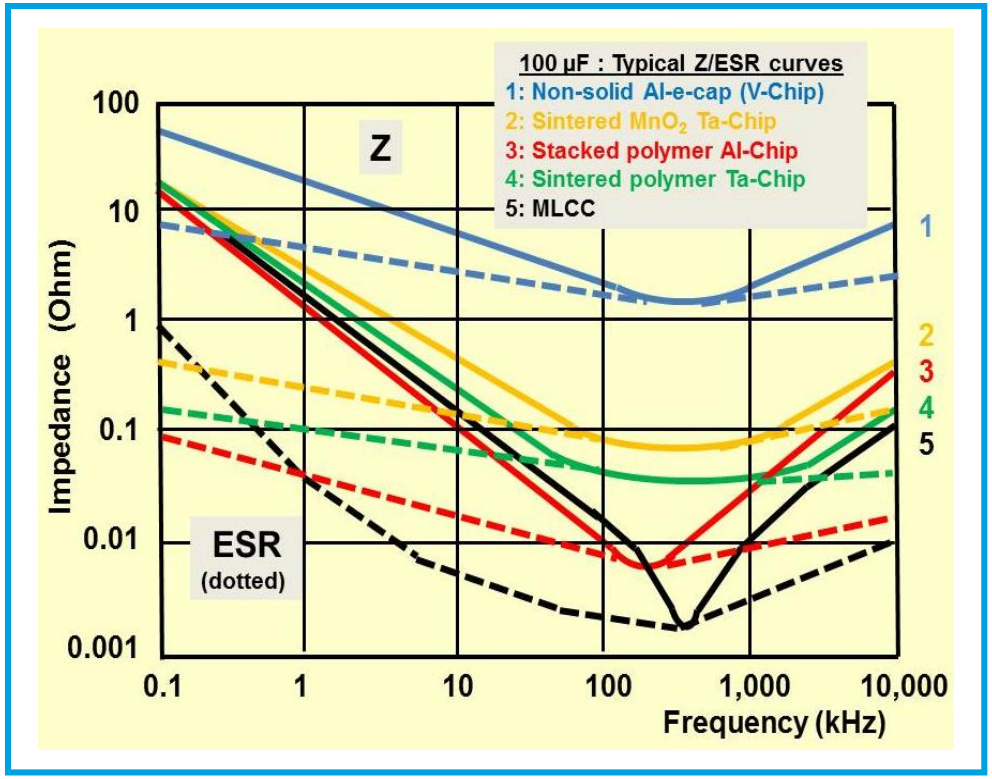
Key Features – Details II

Tantalum/NbO/Polymer & MLCC

Low ESR and High Ripple Load (at high “switching” frequency)

WATCH FOR WORKING FREQUENCY

MLCC’s ESR may be even higher than tantalum at low frequencies (sub 1kHz)



This is then reflected into the capacitors’ power dissipation and ripple current load capability.

Figure 6. ESR and IMP versus freq. behavior by different dielectric types, Chart Credit: Wikimedia

RIPPLE CURRENT

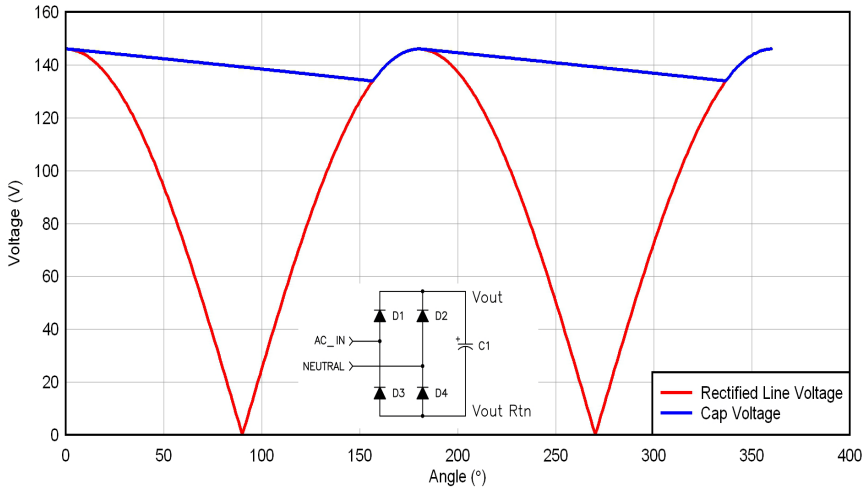


Fig 7. Capacitor smoothing function in a rectifier circuit.

Specific Comparison – 1210 Equivalent

	MLCC		Standard Ta Chip		Polymer Ta Chip		NbO Chip OxiCap®	
Attributes	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**
Max Capacitance 1210	100uF	10uF	150uF	100uF	220uF	47uF	47uF	47uF
Voltage Range 1210	4v - 500v	16v - 100v	4v - 50v	4v - 50v	2v - 125v	2v - 125v	4v - 10v	4v - 10v
Typical ESR 1210	2 - 15m Ohms	10 - 40m Ohms	300 - 800m Ohms	300 - 800m Ohms	30 - 200m Ohms	70 - 250m Ohms	300 - 600m Ohms	300 - 600m Ohms
Temperature Range	-55°C - +85°C	-55°C - +125 / +150°C	-55°C - +125°C	-55°C - +125 / +200°C	-55°C - +105 / +125°C	-55°C - +125°C	-55°C - +105°C	-55°C - +125°C
Base Reliability	N/A	N/A	1% / 1000 hrs	(0.05 - 1%) / 1000 hrs	1% / 1000 hrs	1% / 1000 hrs	0.02 - 0.05% / 1000 hrs	0.02 - 0.05% / 1000 hrs
Primary Failure Mode	Short	Short	Short	Short	Short	Short	Resistive	Resistive
Lifetime (10% Cap loss @ Tmax / Vmax)	Indefinite	Indefinite	Indefinite	Indefinite	10,000 hrs	10,000 hrs	Indefinite	Indefinite
Recommended Voltage Derating	20%	20%	50%	50%	20%	20%	20%	20%
Disadvantages	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**	**Commercial**	**AEC-Q200**
Voltage Coefficient	Cap Loss Vs V	Cap Loss Vs V						
Piezo Noise	@ Audio Frequencies	@ Audio Frequencies	N/A	N/A	N/A	N/A	N/A	N/A
Reverse Voltage			Not Allowed	Not Allowed	Not Allowed	Not Allowed	Not Allowed	Not Allowed
Mechanical Robustness	Caution	Caution	No Issues	No Issues	No Issues	No Issues	No Issues	No Issues

Which Capacitor Technology?

There are several different capacitor technologies available for the output capacitor area.

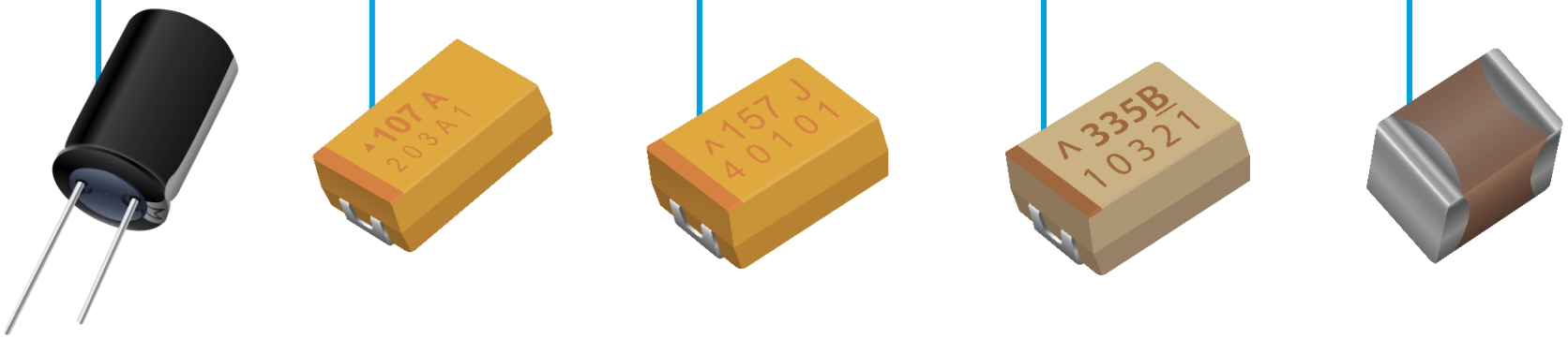
Standard Al-El (Wet)

Ta-MnO_2

Ta-Polymer

NbO-MnO_2

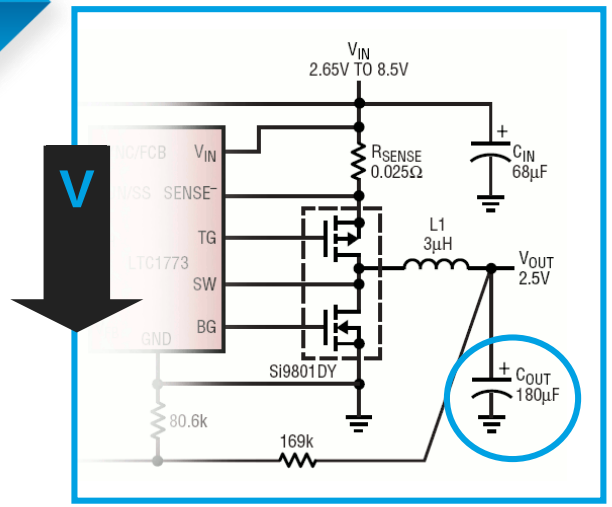
MLCC



Output Capacitor
SWITCHING DC/DC CONVERTER

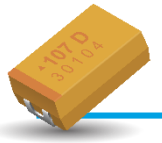
Output Capacitor Selection

- Load Character & Sink Current
- Storage Inductor Value
- Converter Switching Frequency
- Parallel Capacitors (for ESR & ripple demands)



Output Capacitor Choice

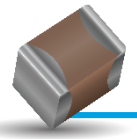
(Low ESR Required)



Tantalum - Low ESR
TPS Series

Tantalum – Conductive Polymer
TCJ Series

OxiCap® – Low ESR
NOS Series



MLCC – High Capacitance, Low Temperature Coefficient

Aluminum
Low ESR Capacitor

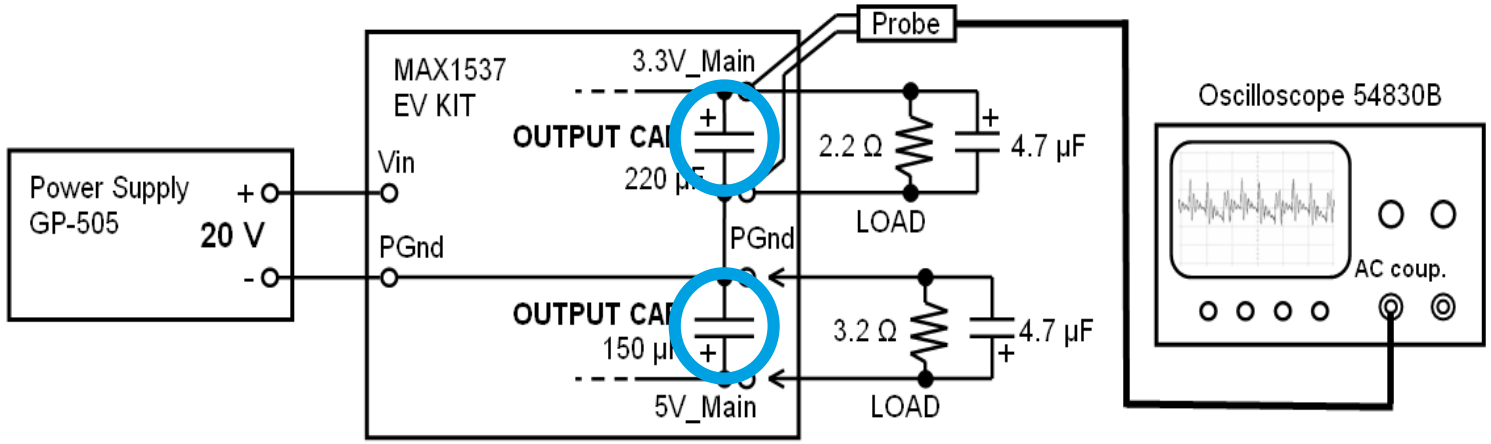
Capacitor Parameters

Summary Table of Output Capacitor Static Measurements

✓ Very Good	○ Good	– Neutral	✗ Not Good

Capacitor Technology	Level of the ESR at f_{sw} = 300 kHz	Capacitance Stability vs. Temperature	Capacitance Stability vs. DC Voltage Bias	ESR Stability vs. Temperature
Ta-Polymer	✓	○	○	✓
Ta-MnO_2 (Single)	○	✓	✓	○
NbO-MnO_2	○	○	○	○
Ta-MnO_2 (Multi)	✓	✓	✓	○
MLCC	✗	–	✗	○
Aluminium - Electrolytic	✗ too high	✗	✓	✗

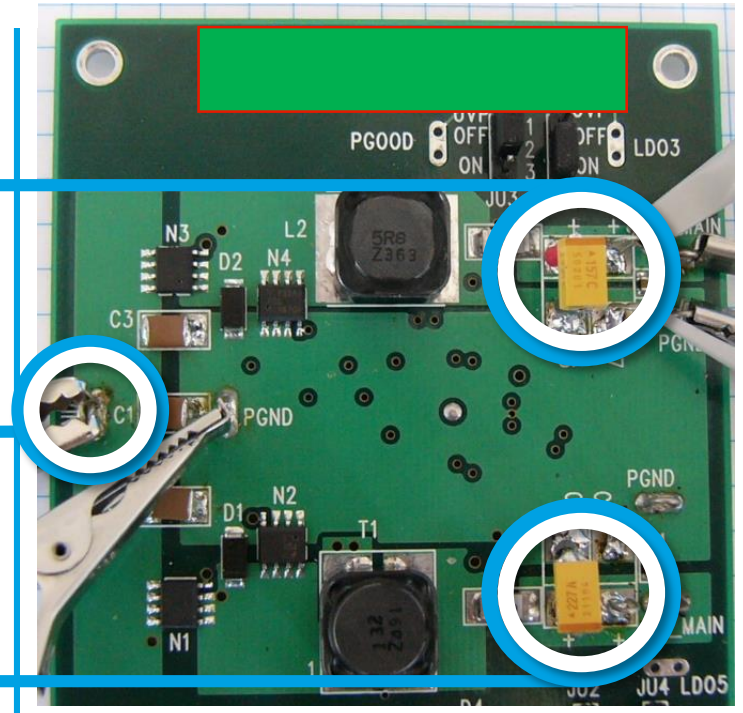
SMPS Measuring Appliance



3.3V Bus Output Capacitor

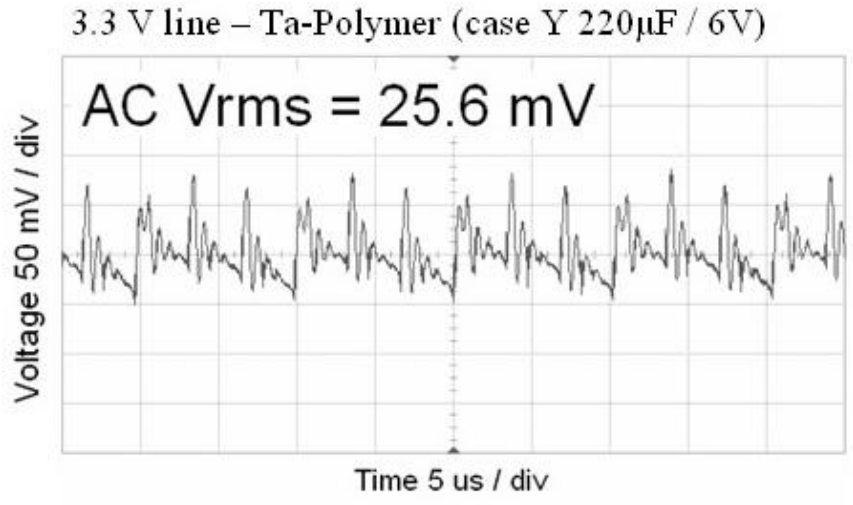
Power Input, Vin = 20V

5V Bus Output Capacitor

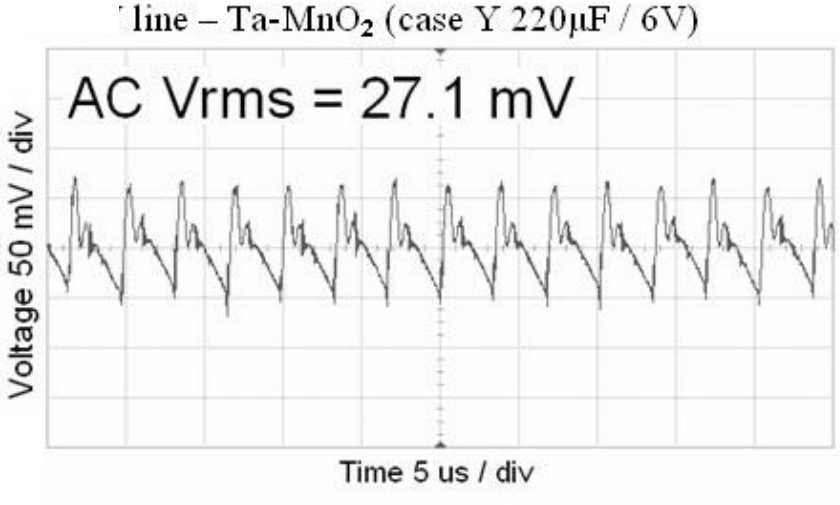


Output Ripple Voltage Waveform – 3.3V Bus

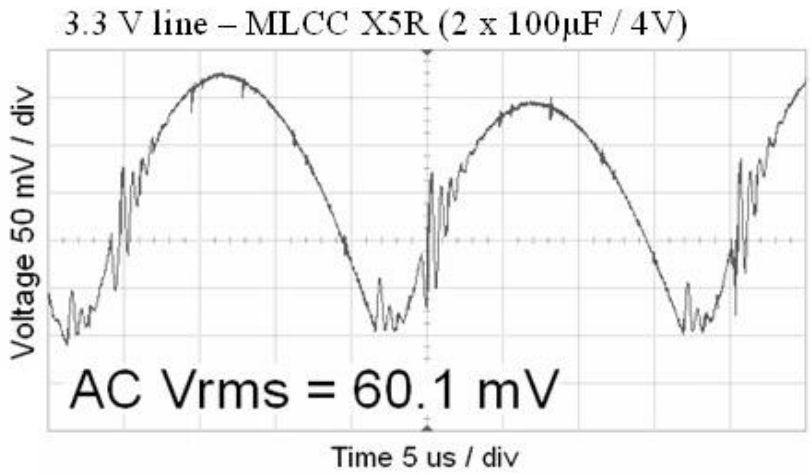
Tantalum - Polymer



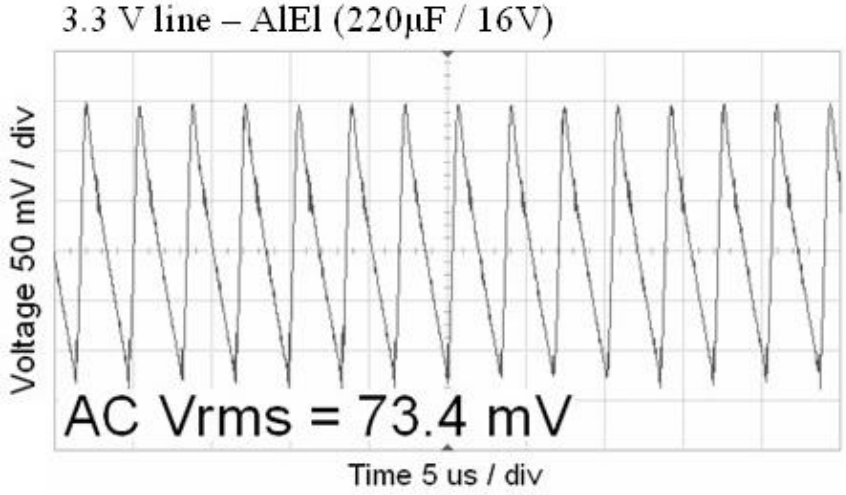
Tantalum – MnO_2



MLCC



Aluminum-Electrolytic



Summary Table of prev. slide test measurements

✓	○	–	✗
Very Good	Good	Neutral	Not Good

Capacitor Technology	AC Vrms at 25 °C	Vrms Stability vs. Temperature	Capacitance Stability vs. DC Voltage Bias
Ta-Polymer	✓	✓	✓
Ta-MnO_2 (Single)	○	○	○
NbO-MnO_2	–	–	○
Ta-MnO_2 (Multi)	✓	✓	–
MLCC	✗	✗	○
Aluminium - Electrolytic	✗	✗	✗

Al & HiCV MLCC Replacement

Al Electrolytic

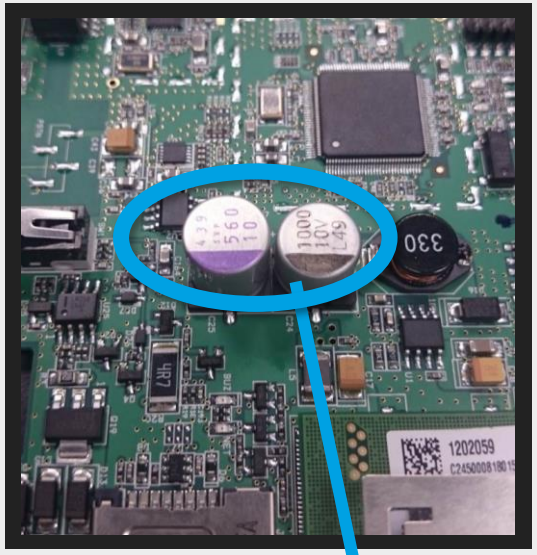
- Large Case Size
- Limited Lifetime
- Limited Lead-Free Assembly
- Limited Operation Temperature

Replace with HiCV SMD Polymer

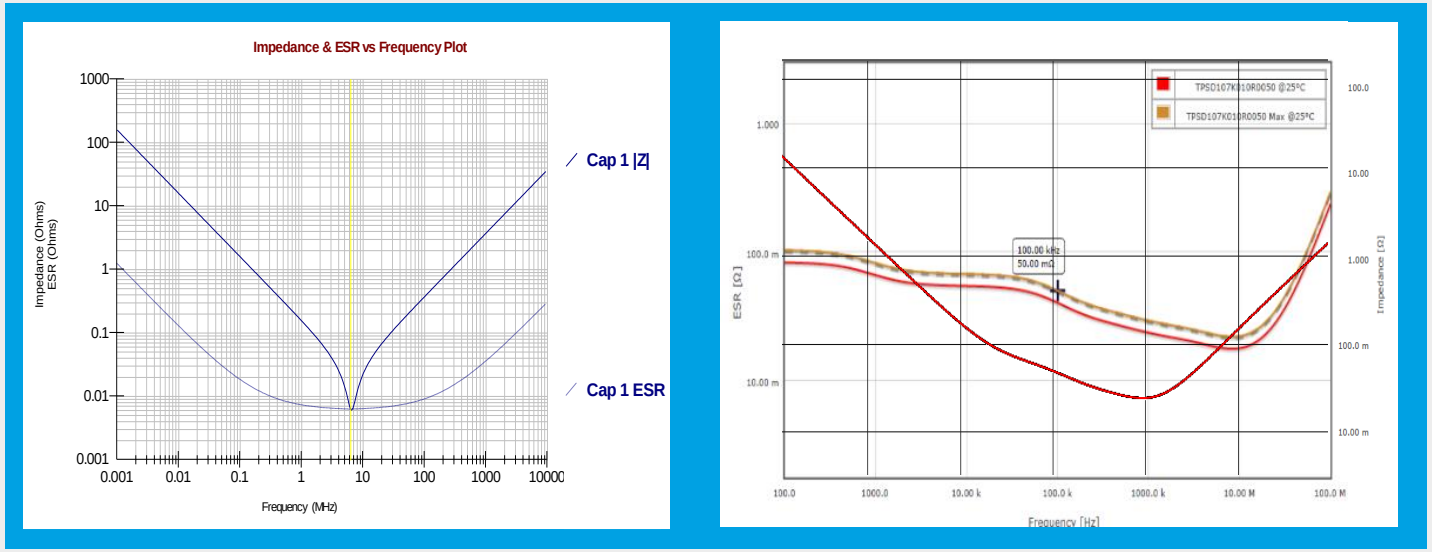
X5R MLCC

- Noise/Voltage Coefficient Limitation
- Limited Operation Temperature
- Very Low ESR

Replace with HiCV SMD Ta, Conductive Polymer, or X7R/Polymer Combination



Saving Board Space



Achieve target bulk capacitance, broadband, and low notch ESR.

Conclusion

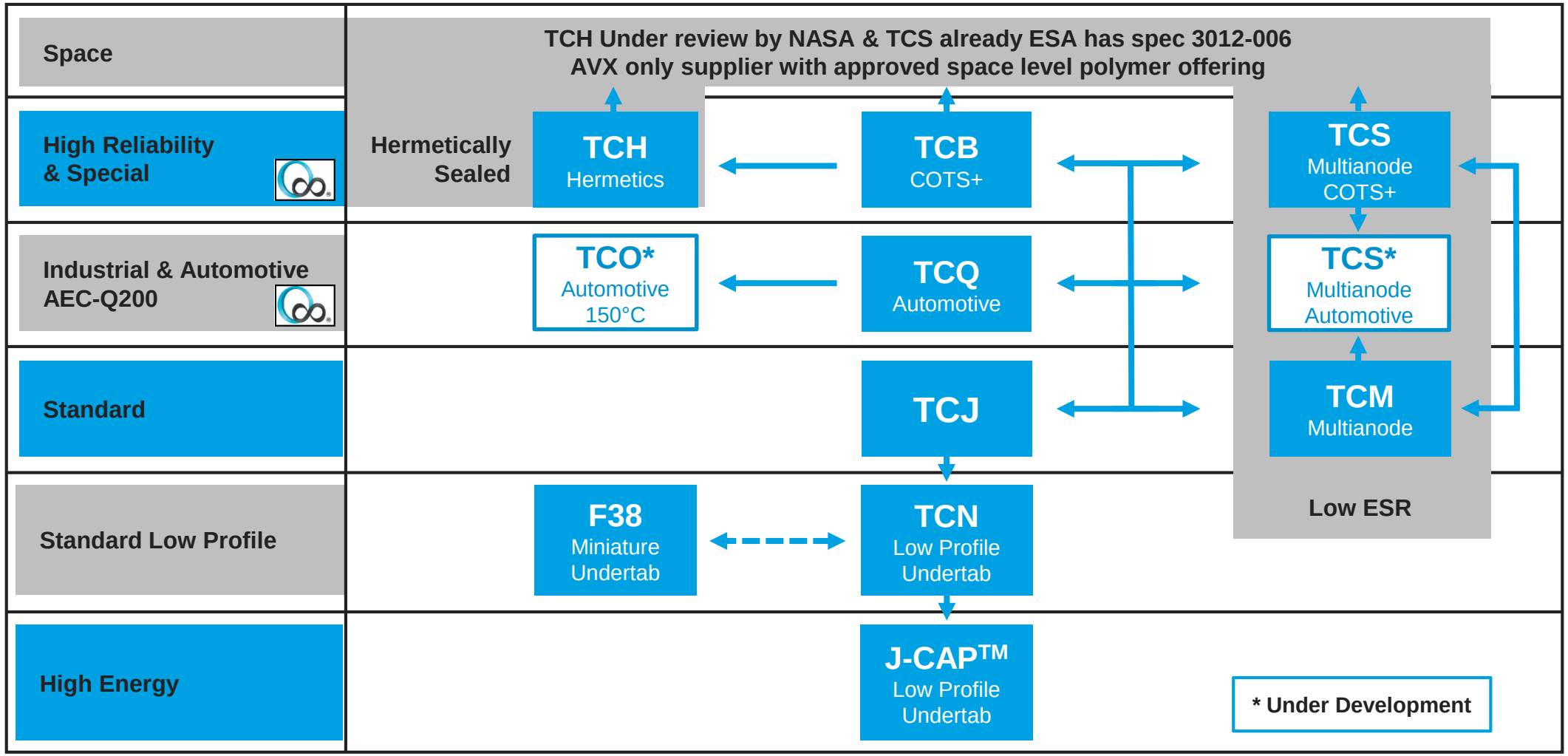
For optimal functionality, efficiency and circuit stability of SMPS; designers have to carefully select output capacitors considering:

- Capacitance stability
- ESR stability
- Temperature range (stability)

Different technologies exhibit different parameters and behavior

Polymer Series Line

SOLID ELECTROLYTIC CAPACITORS

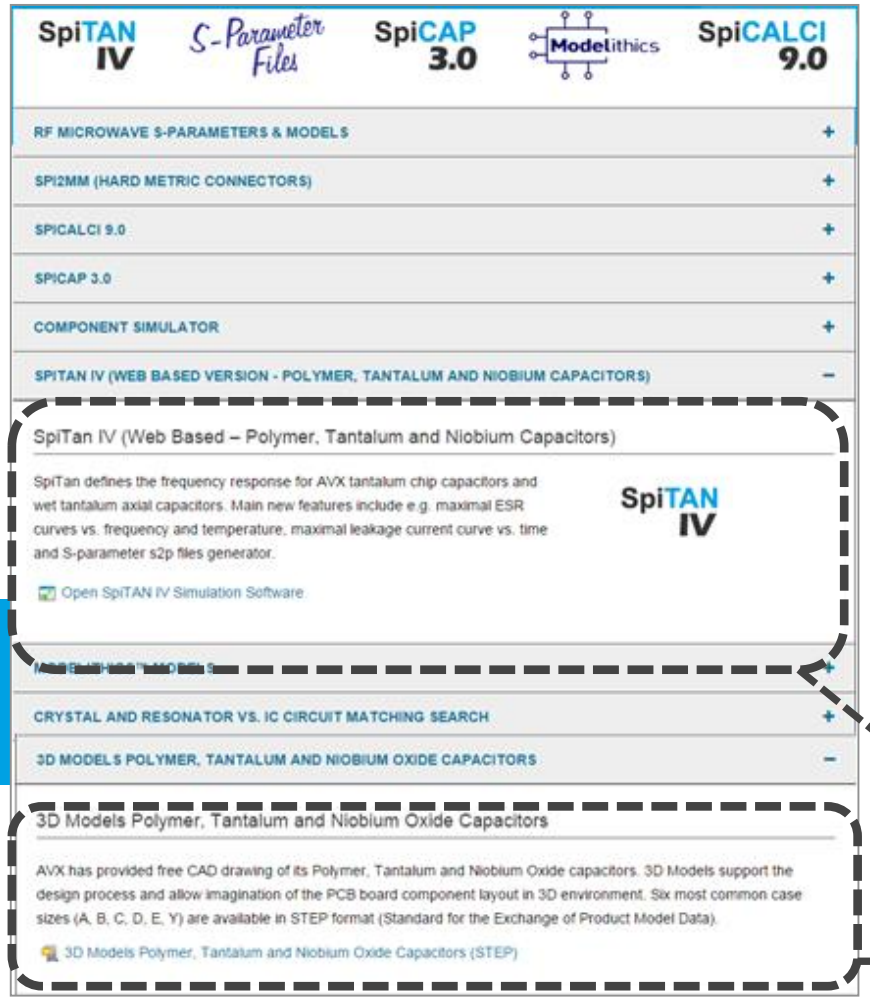


Summary

- Special attention should be paid to the feedback loop stability in the case of using MLCC with its very low ESR
- Conventional Al-El capacitors are not suitable due to very high ESR and potentially causing high output ripple voltage resulting in temperature instability
- Low ESR Tantalum-Polymer and Tantalum-MnO_2 capacitors have the best performance with a multi-anode construction when measured by AC Vrms and Vrms temperature stability, alternatively combined with MLCCs to cover filtration and smooth output single at above 1.5MHz frequency area
- MnO_2 Tantalum is the best solution for temperatures up to 200°C applications
- NbO OxiCap® and polymer is the best solution for temperatures up to 125°C/150°C applications

AVX Customer Support

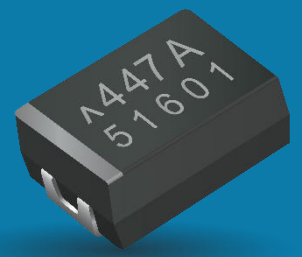
DESIGN TOOLS



Design Tools

- Spi TanIV – ESR, Frequency Leakage Current V's Time, S2P
- 3D Model – CAD Drawings STEP Format

More Information | AVX Polymers



Part Number Information

TCJ	A	226	M	004	R	0300	E
Type	**Case Size** See table above	**Capacitance Code** pF code: 1st two digits represent significant figures, 3rd digit represents multiplier (number of zeros to follow)	**Tolerance** M = ±20%	**Rated DC Voltage** 002 = 2.5Vdc, 004 = 4Vdc, 006 = 6.3Vdc, 010 = 10Vdc, 016 = 16Vdc, 020 = 20Vdc, 025 = 25Vdc, 035 = 35Vdc, 050 = 50Vdc, 063 = 63Vdc, 075 = 75Vdc, 100 = 100Vdc, 125 = 125Vdc	**Packaging** R = Pure Tin 7" Reel, S = Pure Tin 13" Reel	**ESR in mΩ**	**Additional Character** E = Black resin

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- Polymer Capacitors Landing Page
- Technical Guidelines
- Tantalum Niobium Catalog

THANK YOU.

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