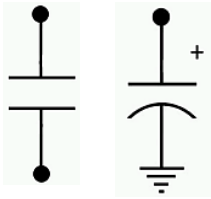
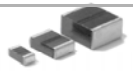
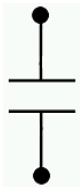
Voltage Coefficient of Capacitors
Comparison & Solutions

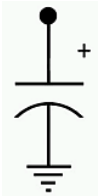


Capacitor Technology Comparison

Stable over VDC → **Unstable over VDC**

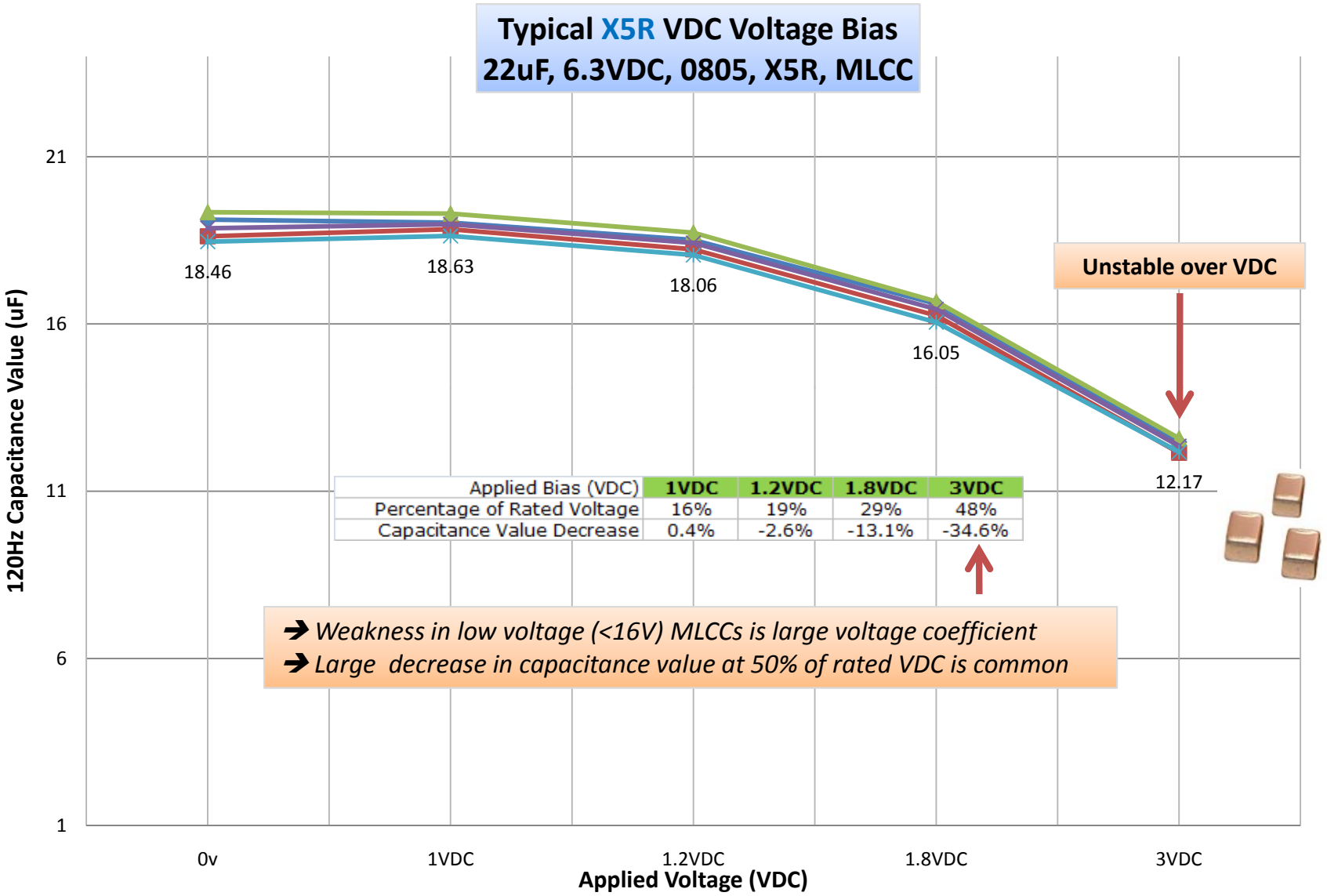
Capacitor Type	*Derating*		Advantage	Weakness
	Voltage	***Temp***	**Pros**	**Cons**
 **Ceramic**	None	None	☑ Non-Polarized ☑ Small Size ☑ Transient Resistant ☑ Low Cost	☒ Large Voltage Coefficient & Aging (X7R, X5R, Y5V) ☒ Limited cap range ☒ Short failure mode (*Typ*)
 **Film**	None	None	☑ Non-Polarized ☑ Transient Resistant ☑ **Stability: Voltage** & Temp	☒ Large Size ☒ Higher Cost ☒ Limited Soldering Heat
 **Aluminum Electrolytic***	None	None	☑ High Cap & High VDC ☑ Surge VDC Resistant ☑ Self Healing ☑ Open failure mode *(Typ)* ☑ Low Cost ☑ **Stability: Voltage**	☒ Polarized ☒ Limited Lifetime ☒ Large Size
 **Tantalum Electrolytic**	Yes	Yes	☑ Long Lifetime ☑ Small Sizes ☑ **Stability: Voltage** & Temp	☒ Polarized ☒ Low VDC ☒ Limited surge resistance ☒ Short failure mode (*Typ*)





*** - Aluminum Electrolytic includes liquid electrolyte, hybrid construction and solid polymer types**

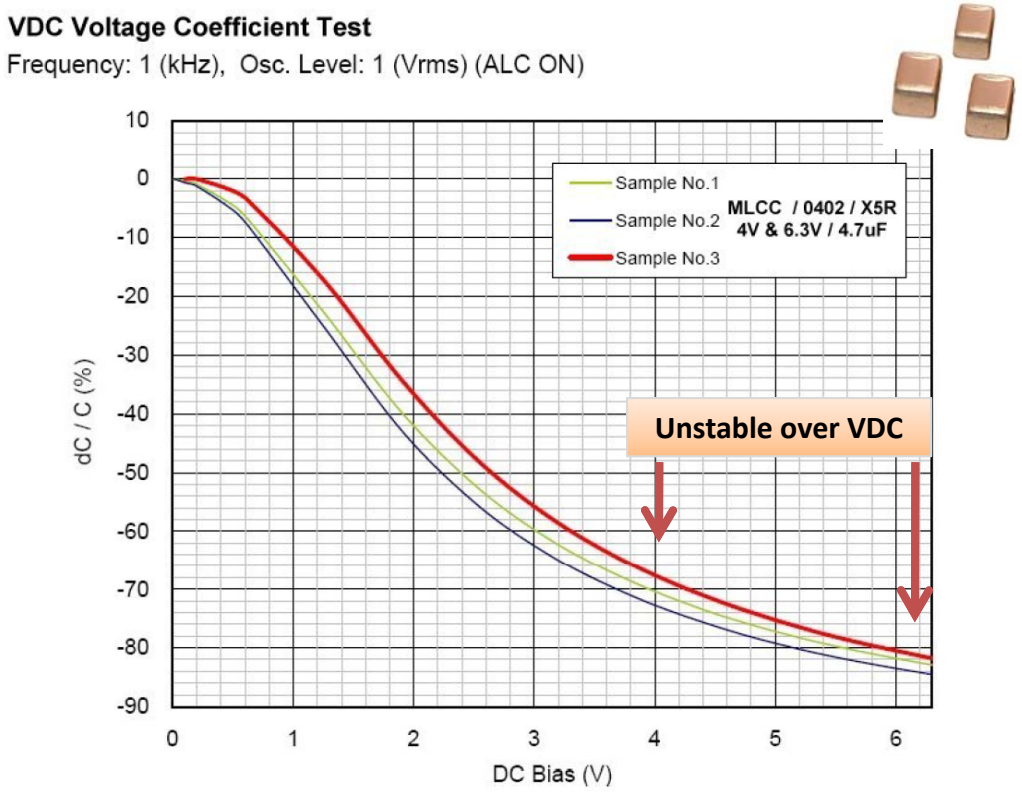
Voltage Coefficient - X5R MLCC



Applied Bias (VDC)	1VDC	1.2VDC	1.8VDC	3VDC
Percentage of Rated Voltage	16%	19%	29%	48%
Capacitance Value Decrease	0.4%	-2.6%	-13.1%	-34.6%

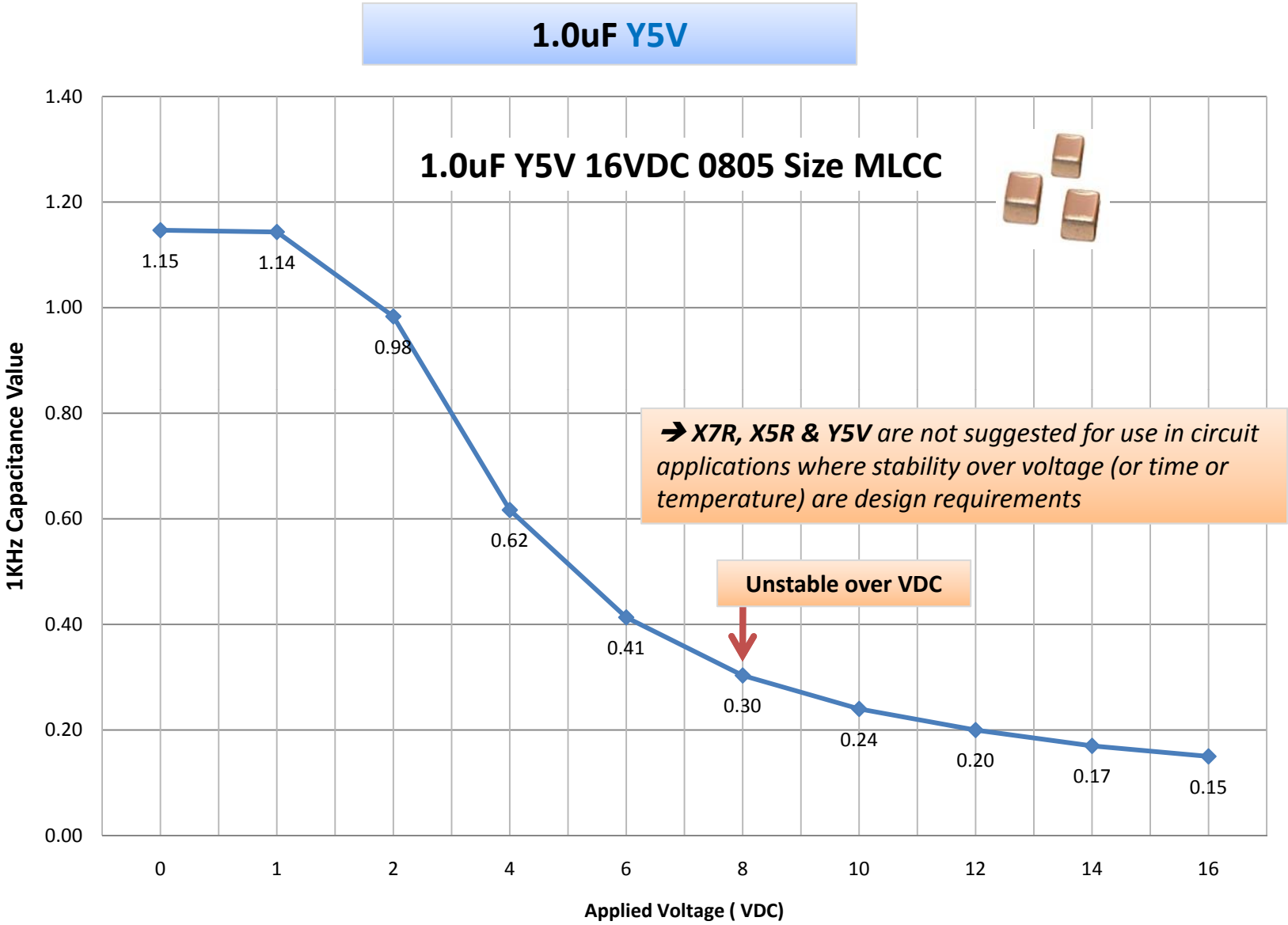
➔ *Weakness in low voltage (<16V) MLCCs is large voltage coefficient*
➔ *Large decrease in capacitance value at 50% of rated VDC is common*

4.7uF X5R 4V & 6.3V



➔ ***X5R*** *dielectric is most popular for high capacitance (>1 uF) MLCCs in small sizes*
➔ *4V and 6.3V ratings are common today*
➔ *Exhibit large capacitance value decrease under applied VDC …*
➔ *2VDC applied can result in 35~45% capacitance value decrease*

Voltage Coefficient - Y5V MLCC

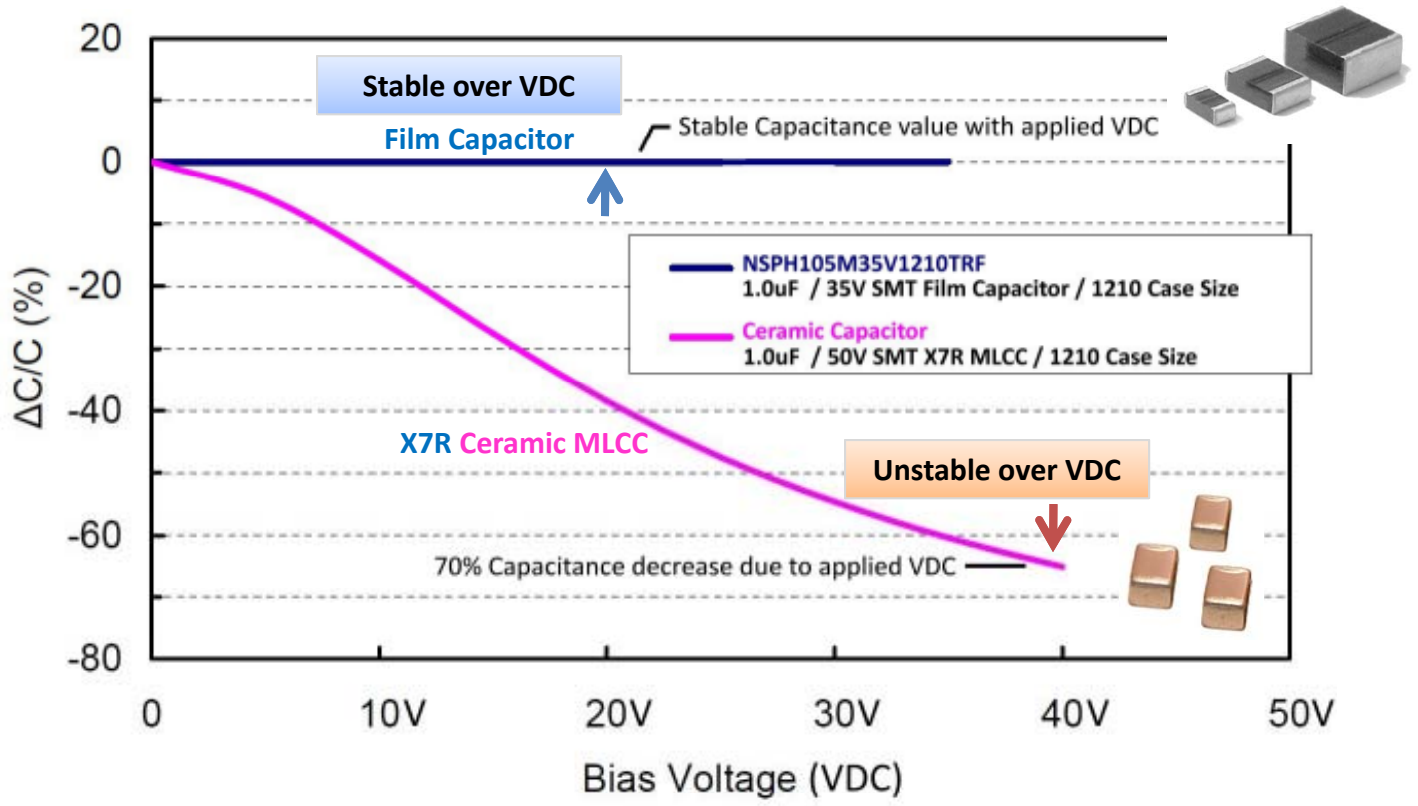


1.0uF Comparison

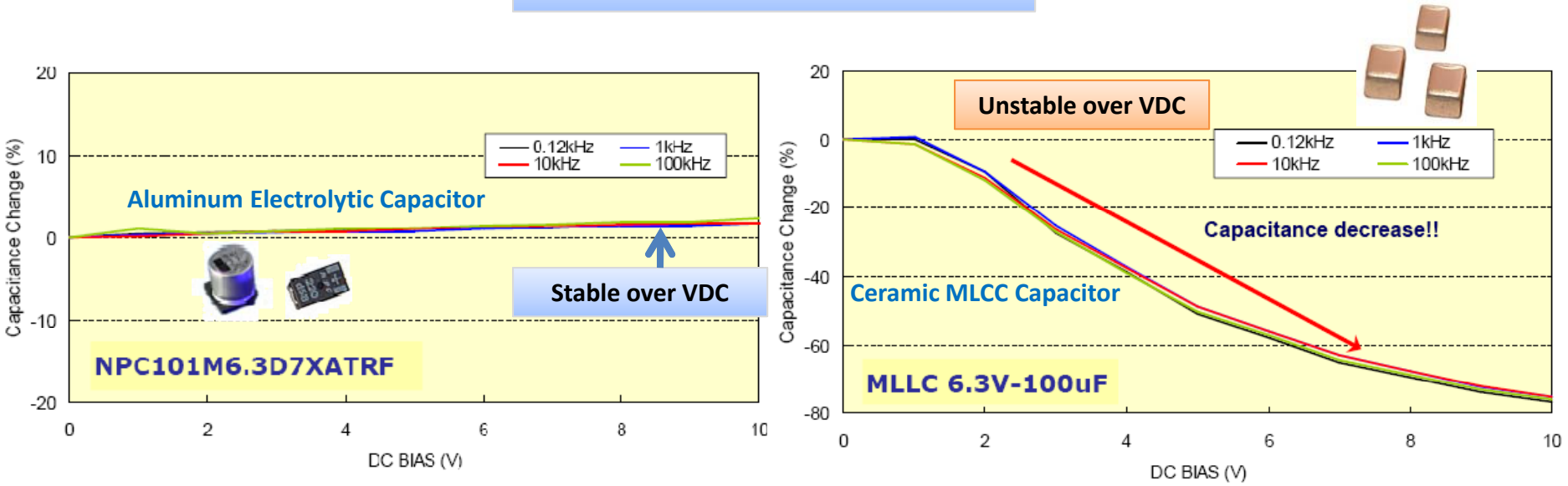
NSPH - High Capacitance SMT Film Chip Capacitors

SMT Film capacitors offer stability not possible from high capacitance MLCCs

NSPH stability advantage over high capacitance MLCCs capacitors



100uF Comparison



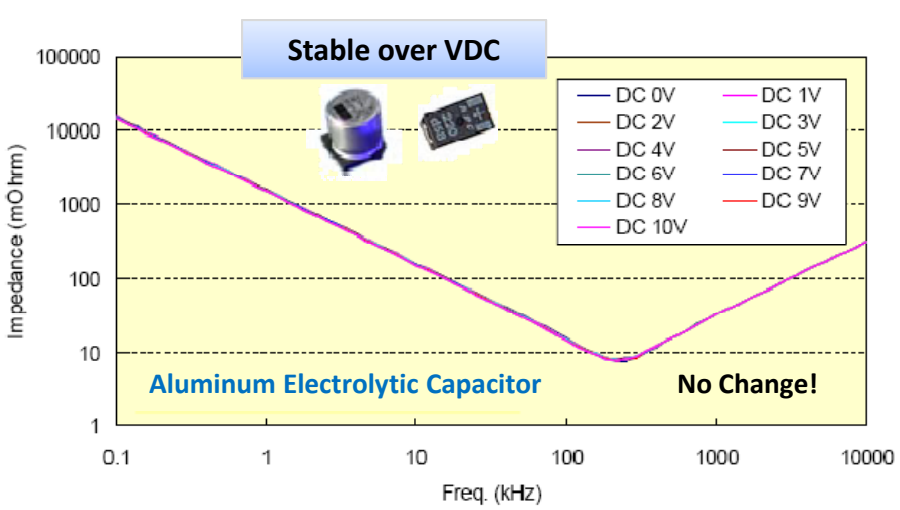
- Class II & III (*X7R, X5R & Y5V*) MLCCs exhibit large voltage coefficient
- The graphs above show typical change in capacitance of Aluminum Electrolytic (*left*) and Ceramic MLCC (*right*) with VDC from 0 ~ 10VDC applied
- Bias greater than 1VDC results in decrease in capacitance value on the MLCC. *(Your 100uF will NOT be 100uF at its rated working voltage)*
- Aluminum Electrolytic Capacitors *(NPC series shown)* exhibits minimal change in capacitance value with rated voltage applied

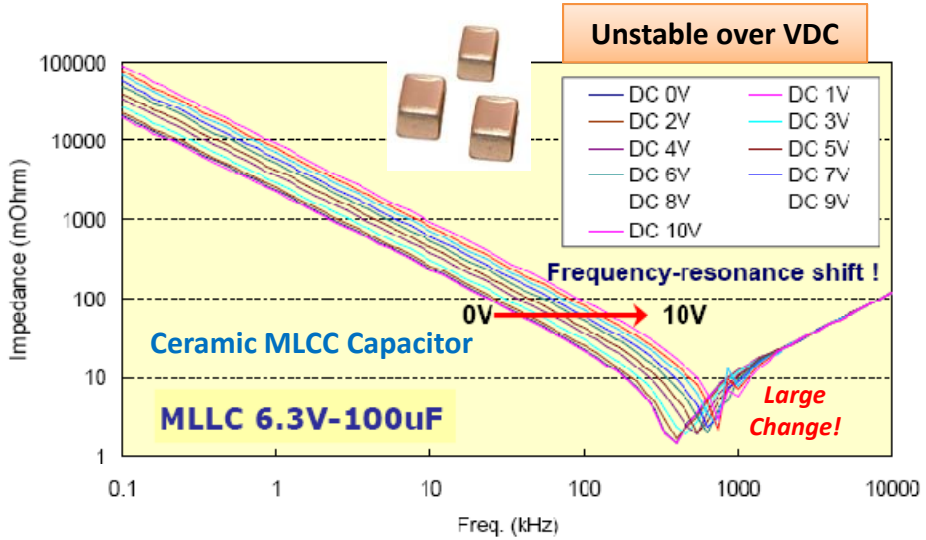
➔ *Electrolytic capacitors are non-ferroelectric with a very low dielectric constant. Their capacitance is derived from a very high surface area and nanometer thick dielectric layers.* ***Their capacitance is not a function of applied voltage.***

- Design Solutions For DC Bias In Multilayer Ceramic Capacitors (August 2010 Electronic Engineering Times)

Impedance (Z) Shift Due to Voltage Coefficient Comparison

100uF Comparison





- MLCCs have lower impedance (Z) over Frequency (*See graph at Right*)
- But MLCC impedance (Z) is **unstable** over VDC bias
- With 10VDC bias applied impedance MLCC exhibits up to 500KHz frequency shift
- Impedance (Z) of Aluminum Electrolytic Capacitor is very stable (*See graph at Left*)
- Aluminum Electrolytic Capacitor NO CHANGE in impedance characteristics, versus DC Voltage

Capacitance Voltage Range Comparison - SMT Capacitors (1uF ~ 2200uF / 2.5VDC ~ 100VDC)

Voltage	*Capacitance* 1.0uF	2.2uF	3.3uF	4.7uF	10uF	22uF	33uF	47uF	100uF	150uF	220uF	330uF	470uF	1000uF	2200uF
100VDC	C A	C A	C A	C A	A	A	A	A	A	A	A	A			
80VDC	↑	↑	A	A	A	A	A	A	A	A		A	A		
63VDC	A	A	A	A	A	A	A	A	A	A	A	A			
50VDC	T C A	T C A	T C A	T C A	C A	A	A	A	A	A	A	A	A	A	
35VDC	T C A	T C A	T A	T C A	T C A	T A	A	A	A	A	A	A	A	A	A
25VDC	T C	T C	T C A	T C A	T C A	T C A	T A	A	A	A	A	A	A	A	A
16VDC	T C	T C S	T C	A C T S	T C A	T C A	T A	T C A	T A	T A	A	A	A	A	A
12.5VDC	↑	↑	↑	S	S	S	↑	↑	↑	↑	↑	↑	↑	↑	↑
10VDC	T C	T C	T C	T C	T C A	T C A	T A	T C A	T C A	T A	T A	T A	A	A	A
8VDC	↑	↑	↑	↑	↑	S	S	S	S	S	↑	↑	↑	↑	↑
6.3VDC	T C	T C	T C	T C	A C T S	A C T S	T A S	A C T S	A C T S	T A S	T A S	T A	T A	A	A
4VDC	C	T C	T	T	T C	T A	T A	A C T S	T A S	T A S	T A S	T A S	T A	A	↑
2.5VDC	↑	↑	↑	T	T	T	T	T	T S	T S	T S	T S	T S	T	↑

Icon	Type	Format	Component Image
T	Tantalum Electrolytic	SMT Flat Chip	
C	Ceramic Chip - MLCC	SMT Flat Chip	
A	Aluminum Electrolytic	SMT V-Chip	
S	Solid Aluminum Electrolytic	SMT Flat Chip	

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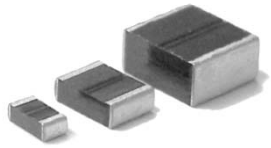
SMT Ceramic MLCC Capacitors; **TCs** & Case Sizes

NSPH is newly released
High Capacitance SMT Film Chip Capacitors



Please review to assure NSPH meets **circuit voltage** and **current requirements** of circuit

Voltage Rating (VDC)											
100V	X7R 1210, 1812, 1825, 2220, 2225	X7R 1210, 1812, 1825, 2220, 2225	X7R 1210, 1812, 2220, 2225	X7R 2220 & 2225	X7R 2220 & 2225						
50V	X7R 0805, 1206, 1210 1812, 1825, 2220	X7R 1210, 1812, 1825, 2220	X7R 1210, 1812, 1825, 2220	X7R 1812, 1825, 2220	X7R 1812, 1825, 2220	X7R 2220	X7R 2220				
35V				NSPH 1812	X7R 1210		NSPH 2220	← Advantage NSPH			
			X5R 1210	↑ Advantage NSPH		↓ Advantage NSPH	X5R 1210				
25V	X7R 0805, 1206, 1210 1812, 2225	X7R 2225	X7R 1206, 1210, 2225	X7R 1206 & 1210	X7R 1206	NSPH 2220	X7R 1210 & 1812	↓ Advantage NSPH			
	X5R 0603 & 0805		X5R 0805 & 1206	X5R 1206	X5R 1206 & 1210	NSPH 1812	X5R 1206 & 1210	NSPH 2220	↓ Advantage NSPH		
16V	X7R 0603, 0805, 1206 1210, 1812			X7R 1206	X7R 0805, 1206, 1210	↓ Advantage NSPH	X7R 1206 & 1210	NSPH 2220	NSPH 2220		
	X5R 0402, 0603, 0805	X5R 1206	X5R 0603, 0805, 1206	X5R 1206	X5R 0805, 1206, 1210	NSPH 1812	X5R 0805, 1206, 1210		X5R 1206 & 1210		
10V	X7R 0603, 0805, 1206 1210, 1812			X7R 1206	X7R 0805, 1206, 1210		X7R 1206 & 1210				
	X5R 0402, 0603, 0805		X5R 0402, 0603, 0805, 1206	X5R 0805 & 1206	X5R 0603,0805 , 1206, 1210		X5R 0805, 1206, 1210		X5R 1206 & 1210		
6.3V				X7R 0805	X7R 0805		X7R 1206				
	X5R 0402, 0603, 0805		X5R 0402	X5R 0603, 0805, 1206	X5R 0402, 0603,0805 , 1206, 1210	X5R 1206	X5R 0805, 1206, 1210		X5R 0603, 0805, 1206	X5R 1206 & 1210	X5R 1210
4V							X5R 0603			X5R 1206	
	1.0uF	1.5uF	2.2uF	3.3uF	4.7uF	6.8uF	10uF	15uF	22uF	47uF	100uF
	Capacitance Value										

Summary:

➔ Class II & II (X7R, X5R & Y5V) MLCCs will exhibit large voltage coefficient (capacitance value decreased with applied VDC)

➔ Impedance characteristics shift over VDC is common with high capacitance MLCCs

➔ For stability over VDC, look to electrolytic (aluminum or tantalum) or film capacitors

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