High Capacitance Multilayer Ceramic Chip Capacitors

Murata Manufacturing Co., Ltd.

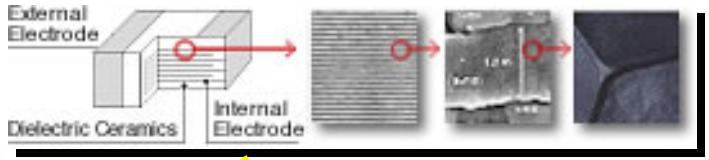
INTRODUCTION

Over 750 Billion pieces of MLCC capacitors are expected be shipped in 2005. From their humble beginnings in the early 1970s, the Multi Layer Ceramic Capacitors now comprise about 85% of the worldwide shipments of capacitors (quantity). Although every kind of capacitor has its merits, MLCCs offer the greatest flexibility and choice in terms of performance and product breadth. By choosing different combinations of dielectrics and electrode systems, one can manufacture MLCCs in different sizes and capacitance ranging from sub pico-Farads to a hundred micro-Farads; low to very high voltage for applications ranging from de-coupling, coupling, bypassing, smoothing, timing, high frequency and filtering, using essentially the same production process. MLCC offer capacitors with very low impedance/ESR and/or low ESLs; a flexibility that is highly appreciated by the design engineers.

Since the topic of today's seminar is capacitors with capacitances between 1 and 330 uF, I shall limit my discussion to those. Murata defines MLCC with capacitances greater than or equal to 1 uF as high capacitance MLCC (a.k.a. Hi-Caps). Hi-Caps are one of the crown jewels of the MLCC line-up and have helped to change the landscape of the capacitor world. The next slide depicts the four cornerstones of technology, which are needed to manufacture high performance and high reliability Hi-Caps.

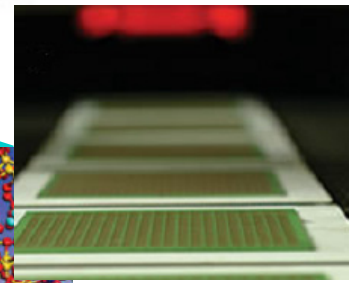
Hi-CAP Technology

Materials Technology



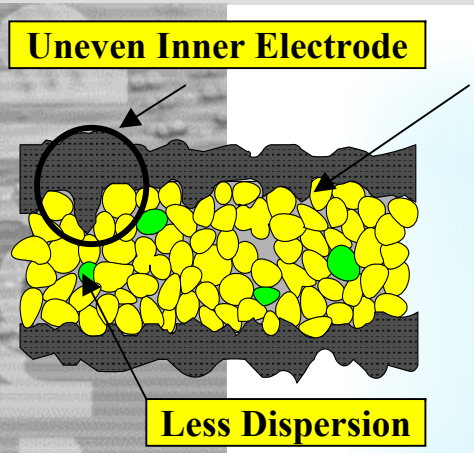
Thin Film Processing Technology

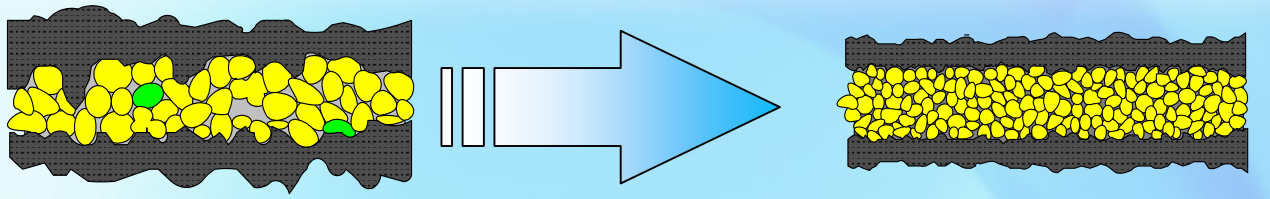
Production Technology



Base Metal Technology

Hi- Reliability Thin Film Multi-layer Technology





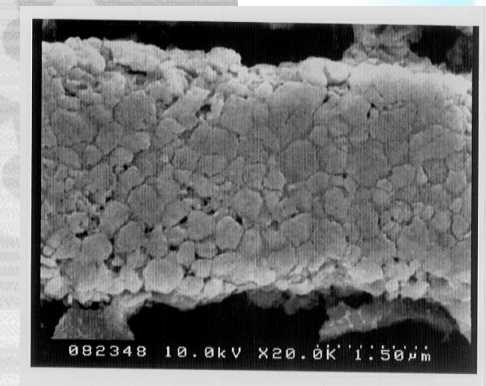
Low BDV

Bias Co-efficiency

Less Reliability

Innovation

Thin Film Technology



By Fine Ceramic Powder

High Dispersion

↓

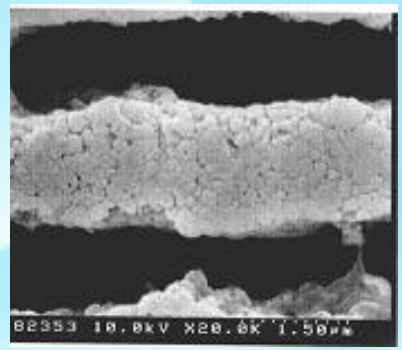
Uniform Ceramic Grain
high Density

By Fine Ni Powder

High Dispersion

↓

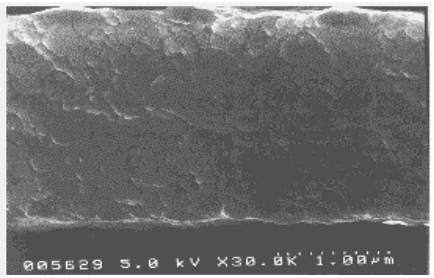
Thin Film With High Density Grain
Flatness Improvement



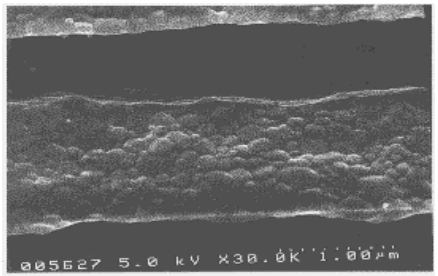
MLCC Layer Thickness

The latest technology

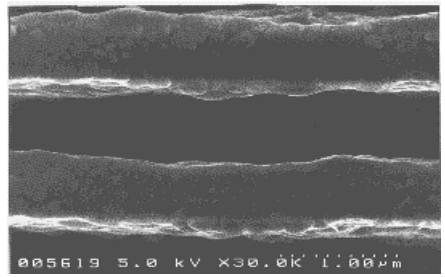
Next generation technology



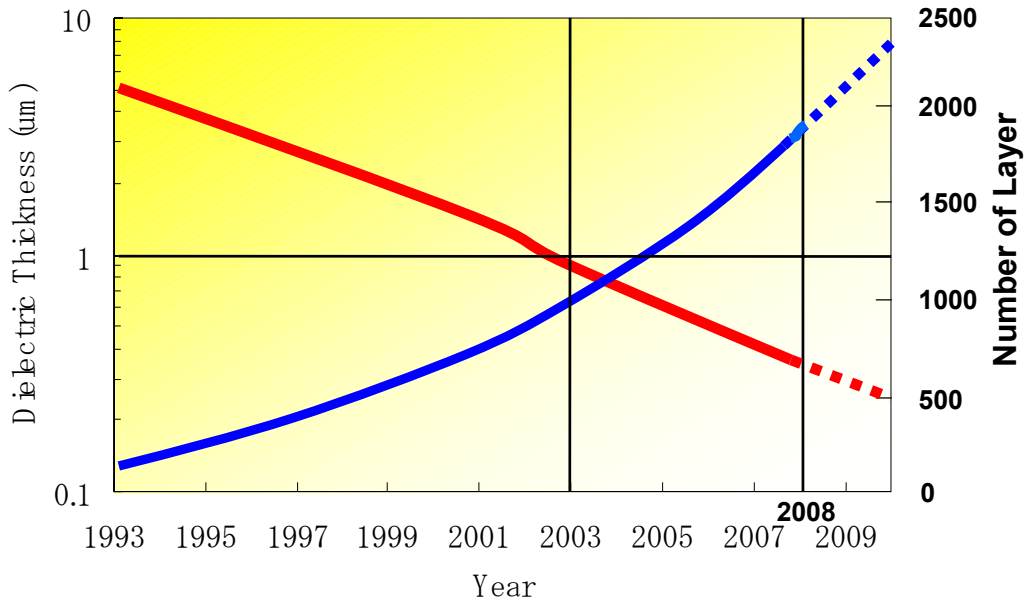
2000 2um



2003 1um

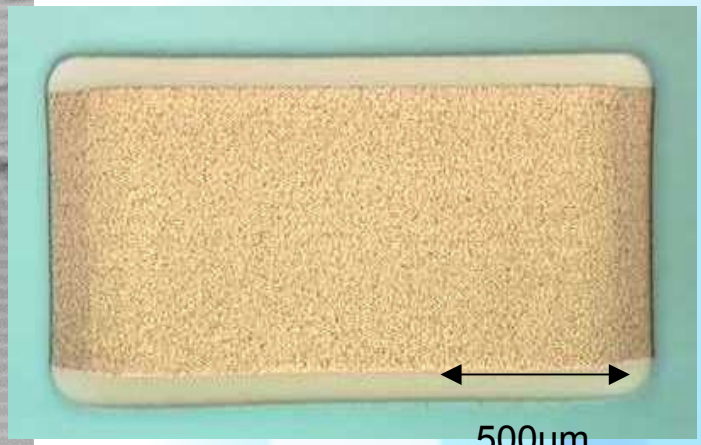
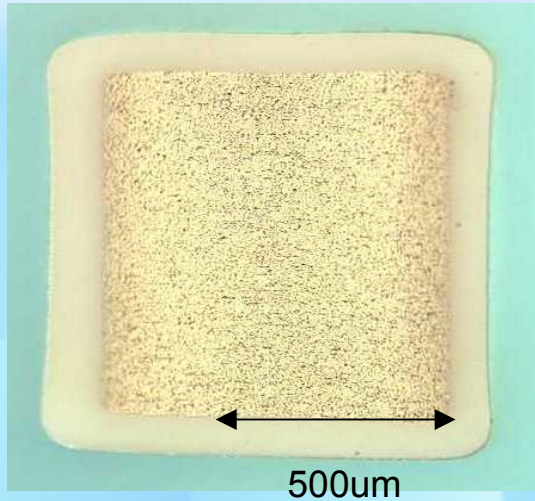


2007/2008 0.5um

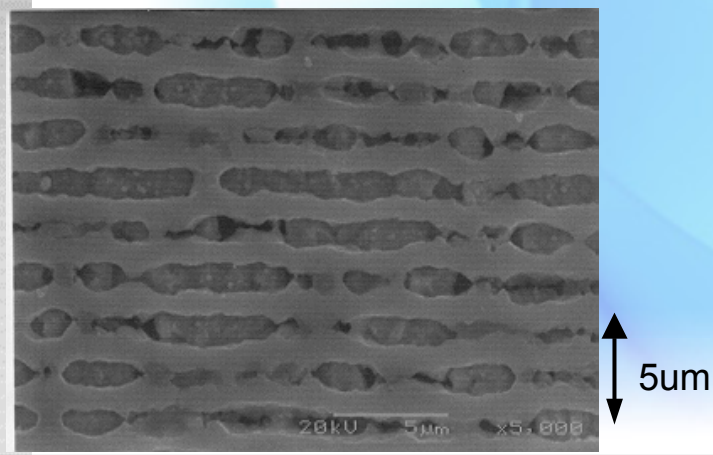


Murata's technology will achieve 0.5um dielectric thickness in 2007-2008.

Example of a Hi-Cap Part: 0603 / X5R / 10uF / 4V

LT-Cross Section	WT-Cross Section
	

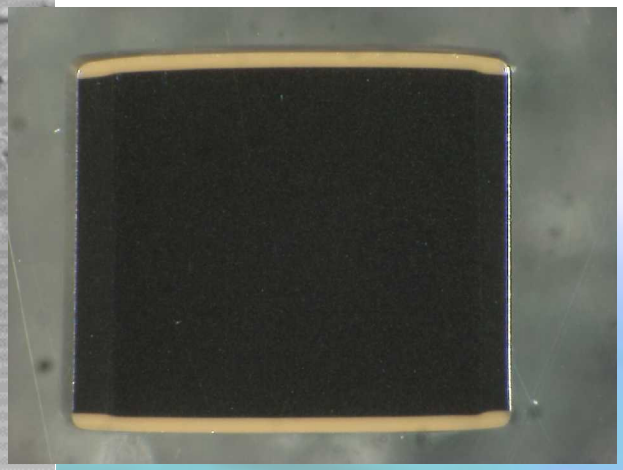
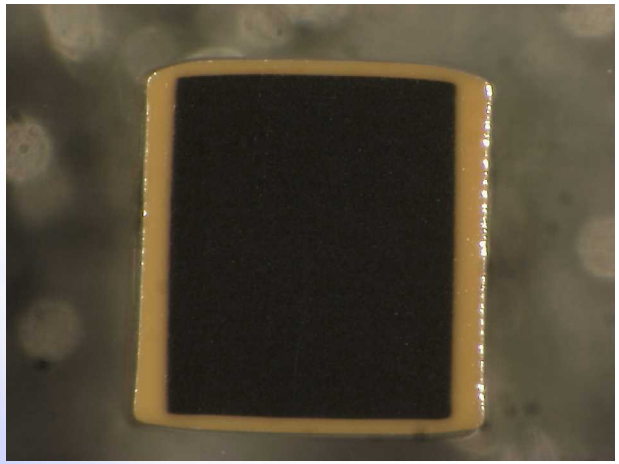
SEM Photo



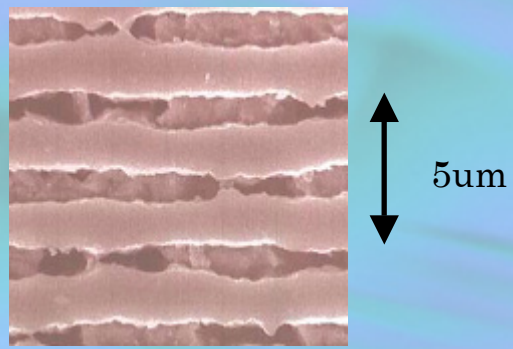
Dielectric layer 1.0um

Number of Electrode 330

Example of a Hi-Cap Part: 1210 / X5R / 100uF / 6.3V

LT-Cross Section	WT-Cross Section
	

SEM Photo



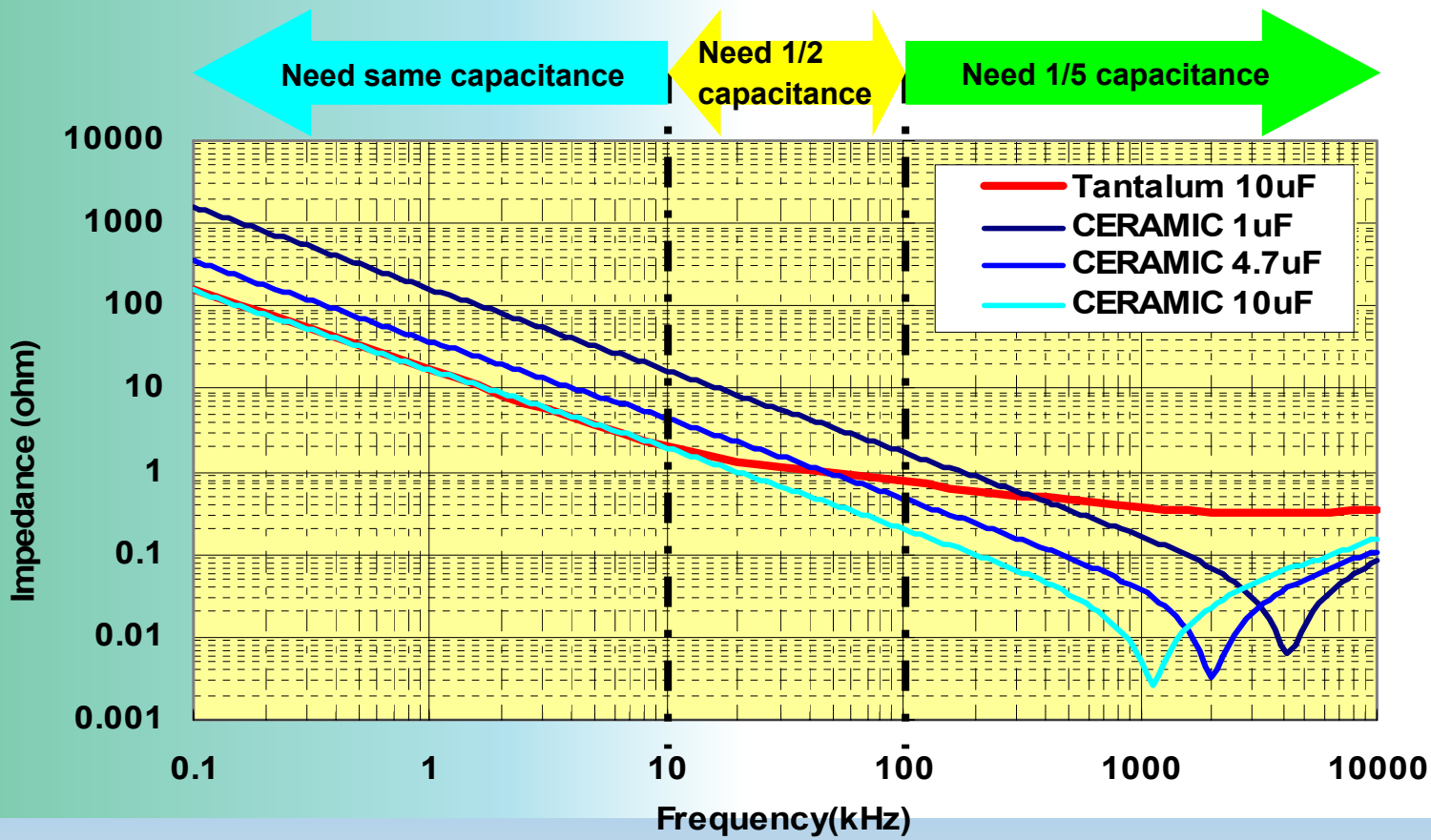
Dielectric layer 1.6um

Number of Electrode 865

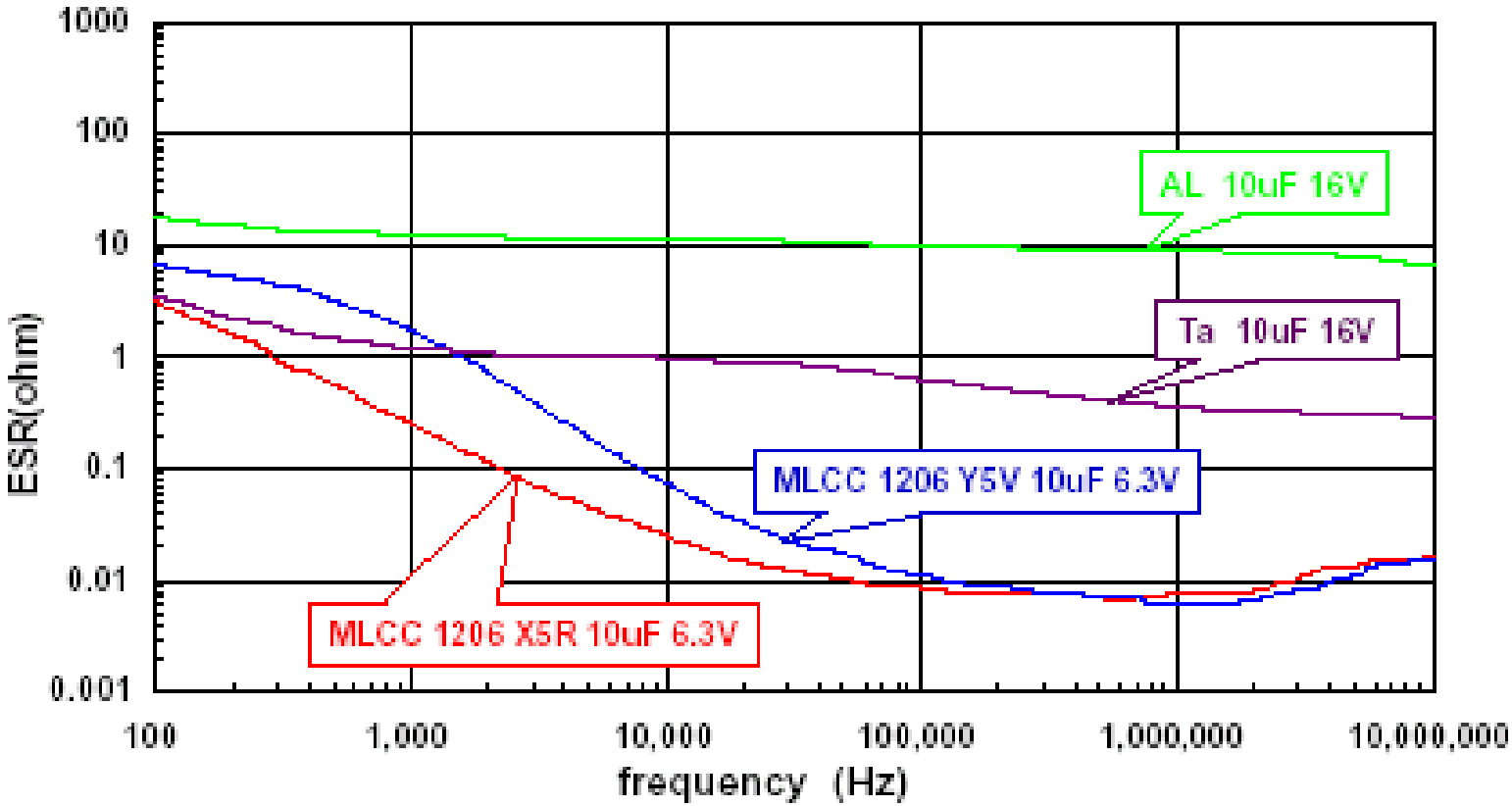
Electrical Performance Features

Impedance Curve of MLCC (vs Ta)

1. It is Important that capacitor's impedance is lower at ripple noise frequency.
2. MLCC can replace Tantalum capacitor with less capacitance at high frequency.



ESR vs Frequency



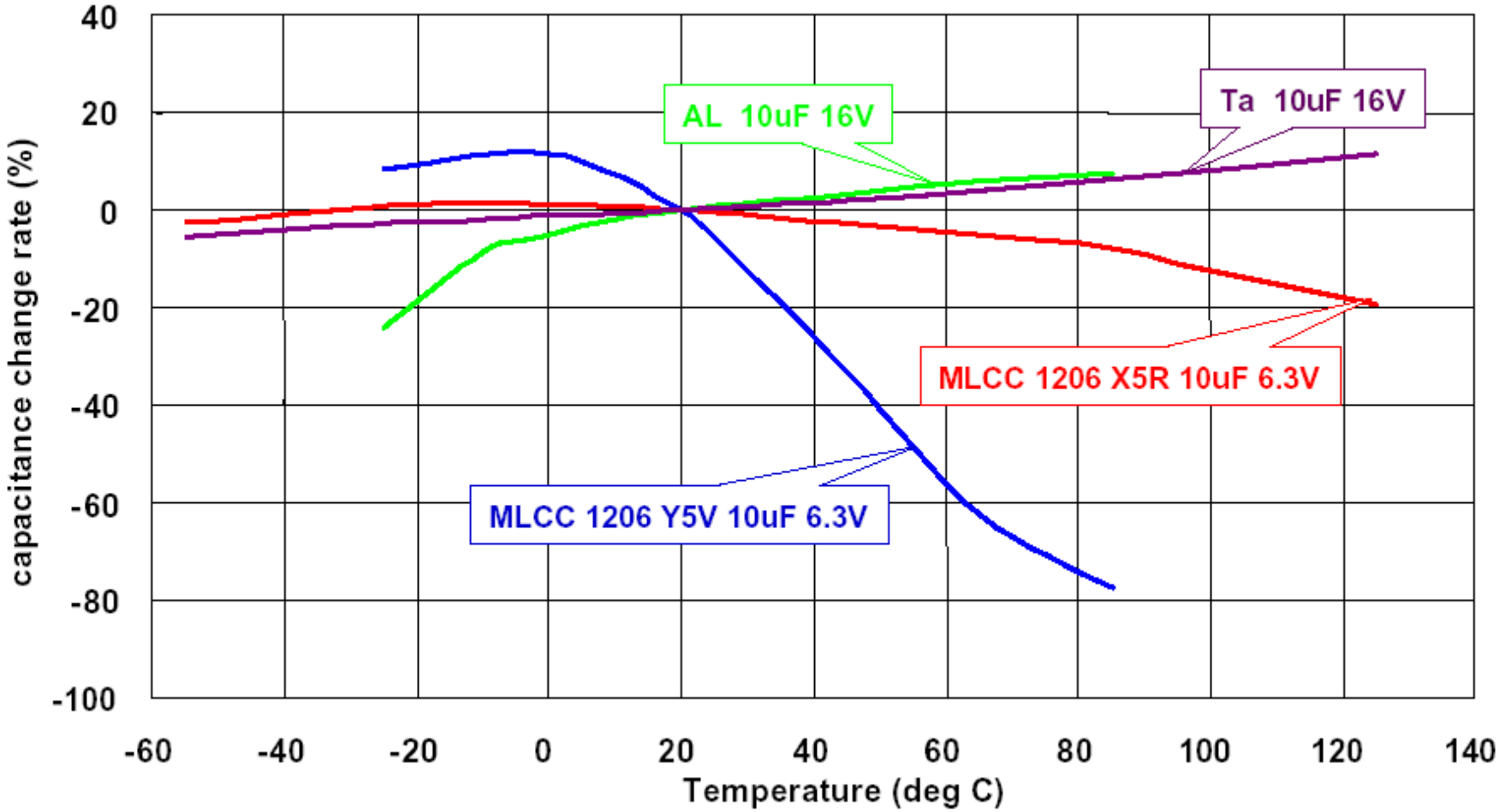
Self Heating of Capacitor ☞ $W = I_{ripple}^{*}(ESR)^2$ (1.2)

W : Consumption electricity

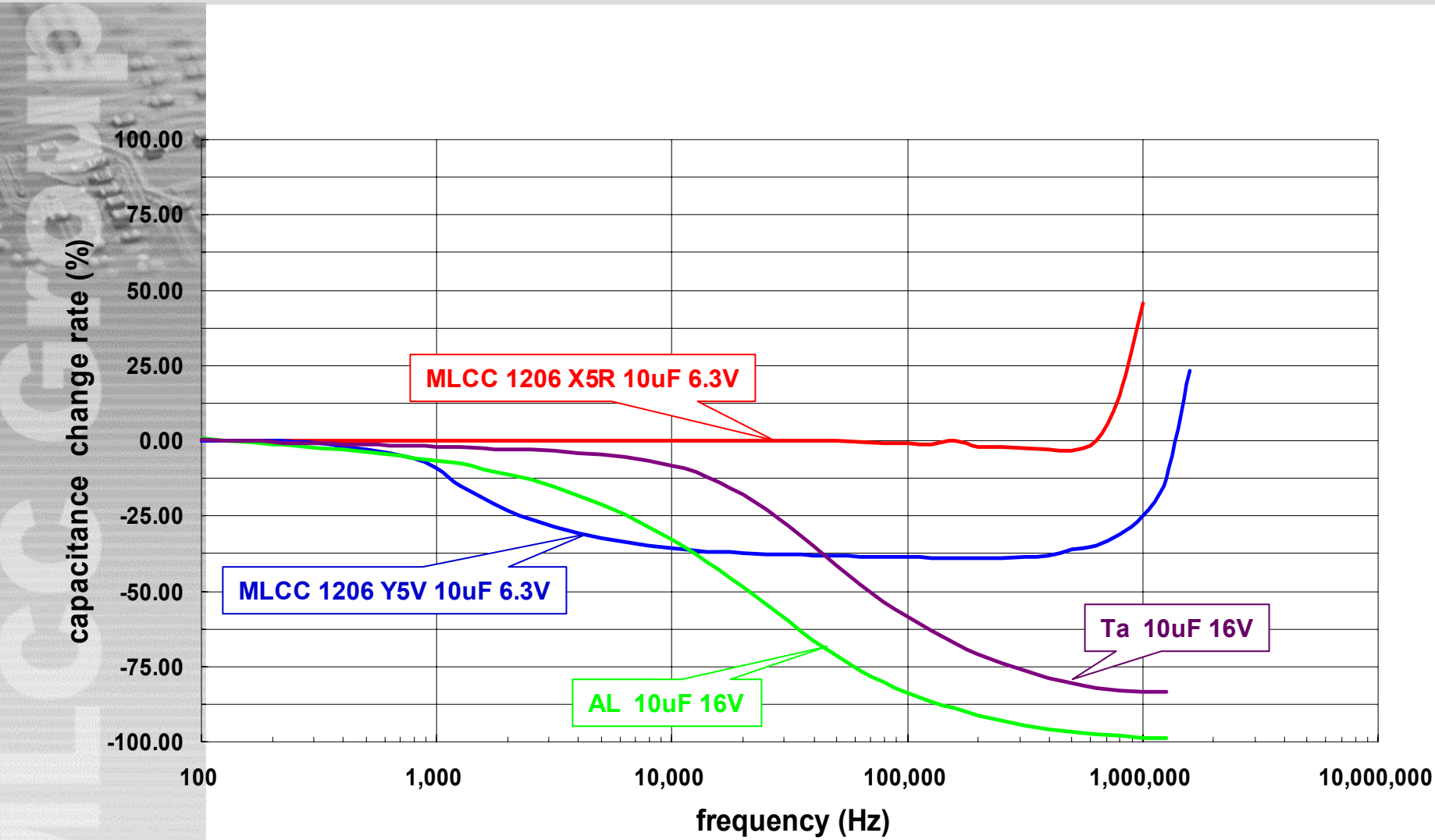
I_{ripple}: Ripple Current

MLCC's lower ESR at high frequency yields low self-heating characteristics due to ripple current.

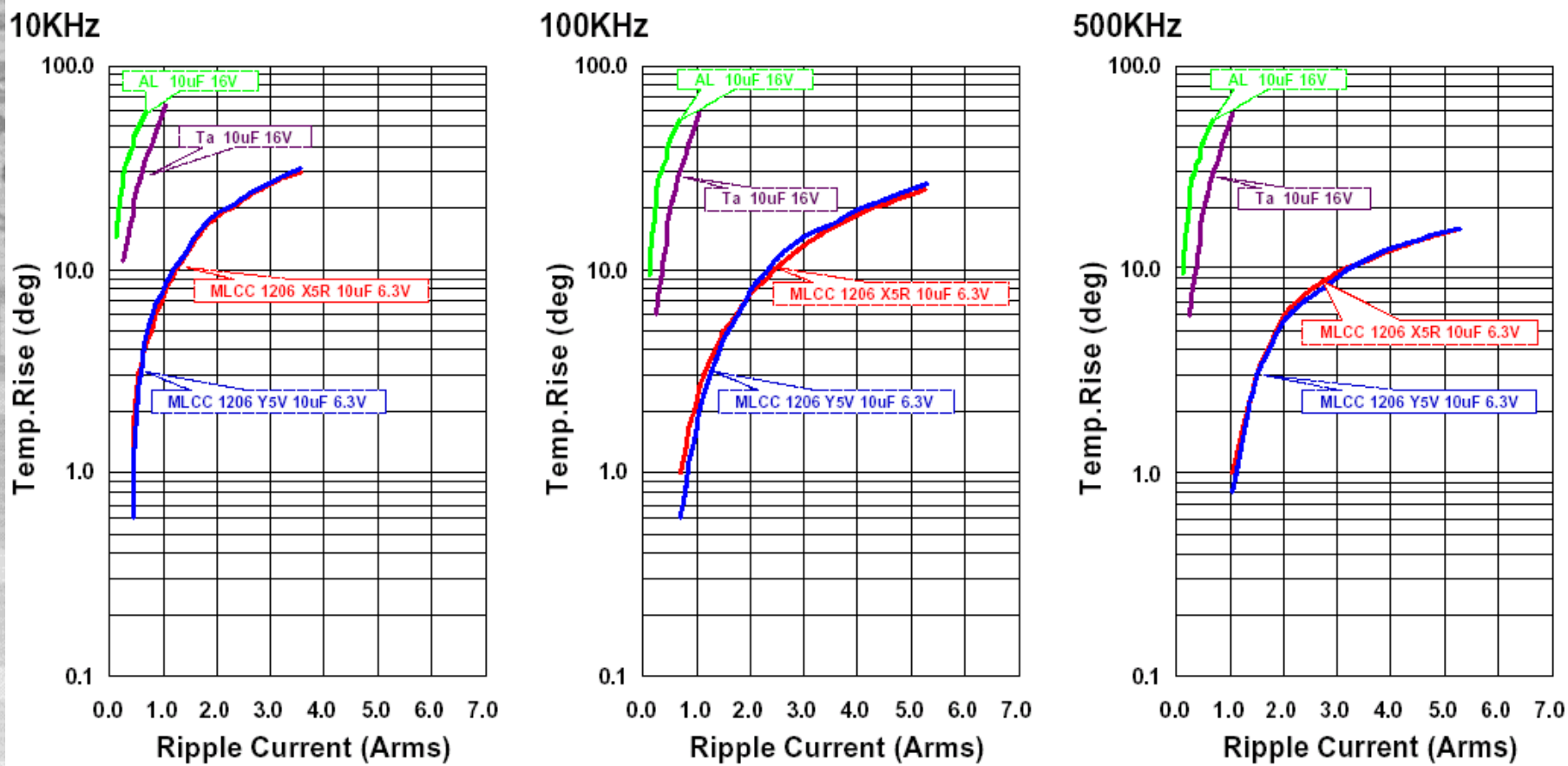
Capacitance vs Temperature



Capacitance vs Frequency



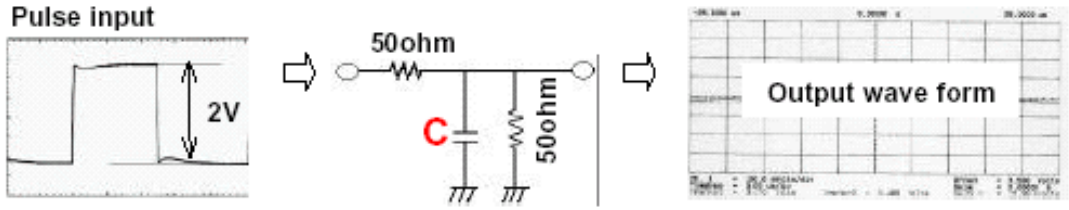
Self-Heating due to Ripple Current

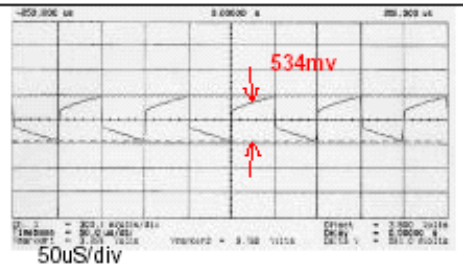
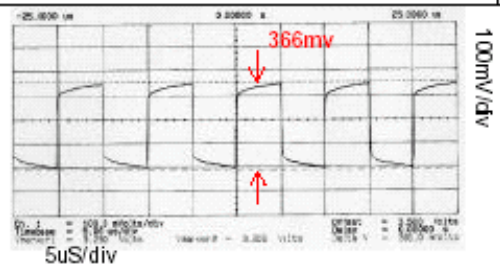
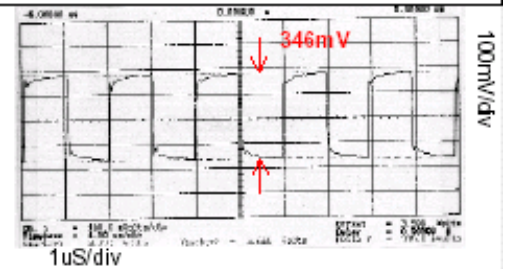
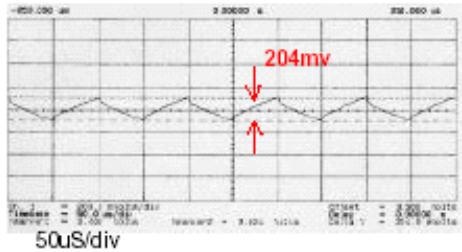
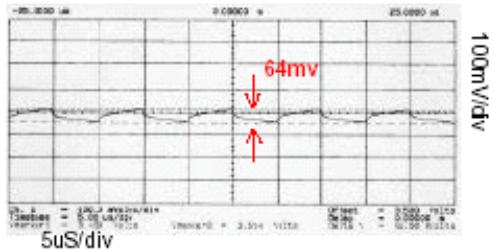
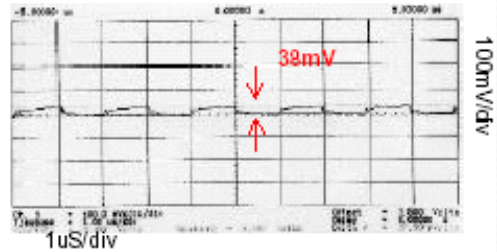
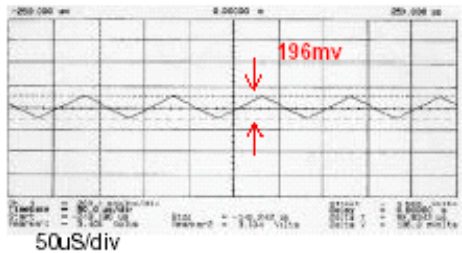
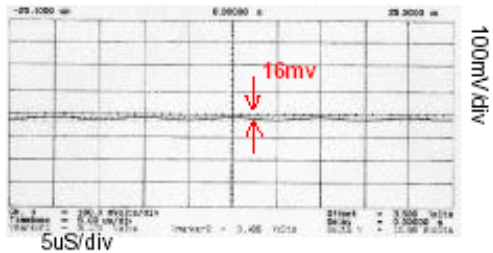
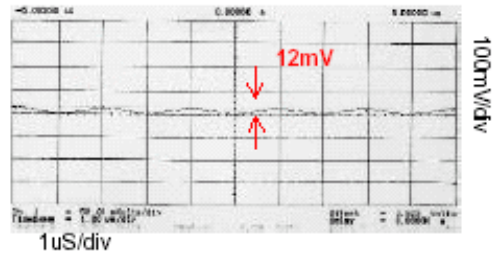


Self-Heating due to Ripple Current is small for MLCC's as compared to TA or AL.

Noise Absorption Characteristics of Hi-Caps

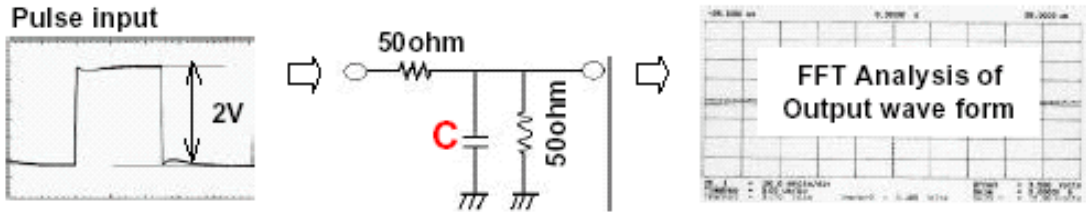
Low-Pass Filter Characteristic



Freq of input	10KHz	100KHz	500KHz
AL 10uF	 		
Ta 10uF	 		
MLCC 10uF	 		

Noise Absorption Characteristics of Hi-Caps

Low-Pass Filter Characteristic

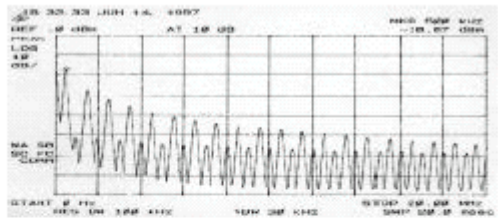
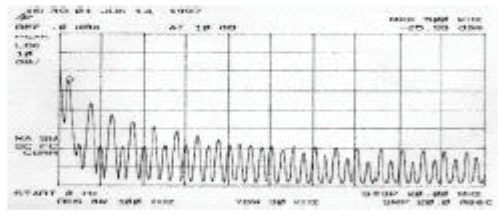
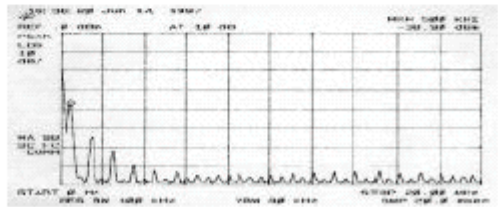


<Ripple voltage of output>

(mV)

Frequency of input pulse	10KHz	100KHz	500KHz
AL	534	336	346
Ta	204	64	38
MLCC	196	16	12

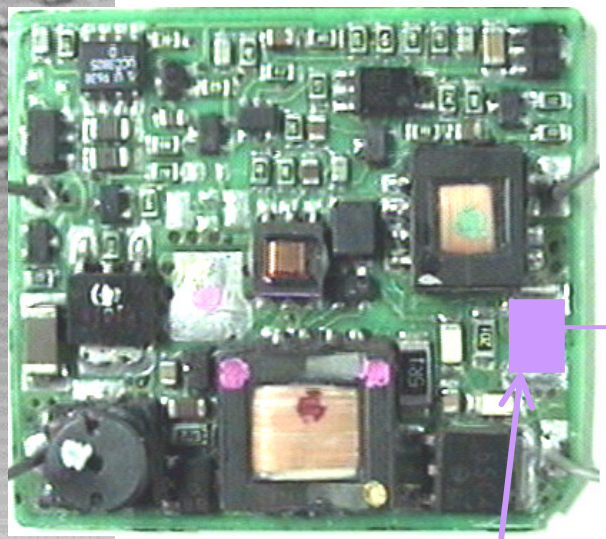
MLCC has excellent high frequency noise absorption performance compared with Ta/AL capacitor.

Freq of input	500 KHz
 AL 10uF	 Log10 dB 0 to 20MHz
 Ta 10uF	 Log10 dB 0 to 20MHz
 MLCC 10uF	 Log10 dB 0 to 20MHz

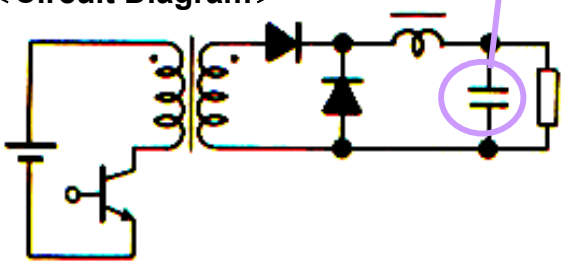
Comparing Output Filter Operation: Hi-Cap vs Tantalum

Non resonance type

forward method DC - DC converter.



＜Circuit Diagram＞



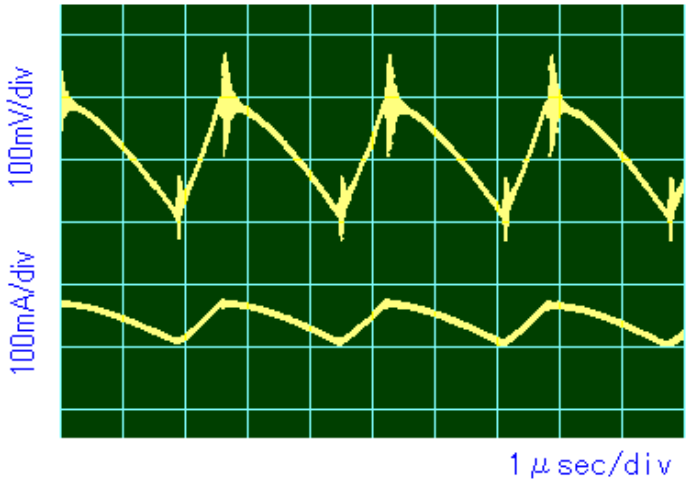
＜Spec＞

Input : 12VDC

Output : 5V / 2A (10W)

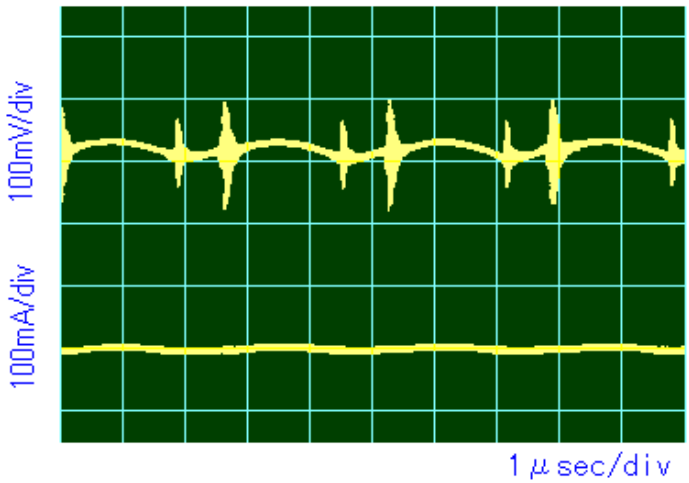
Smoothing Capacitor:

TA 22uF



Smoothing Capacitor:

MLC 22uF



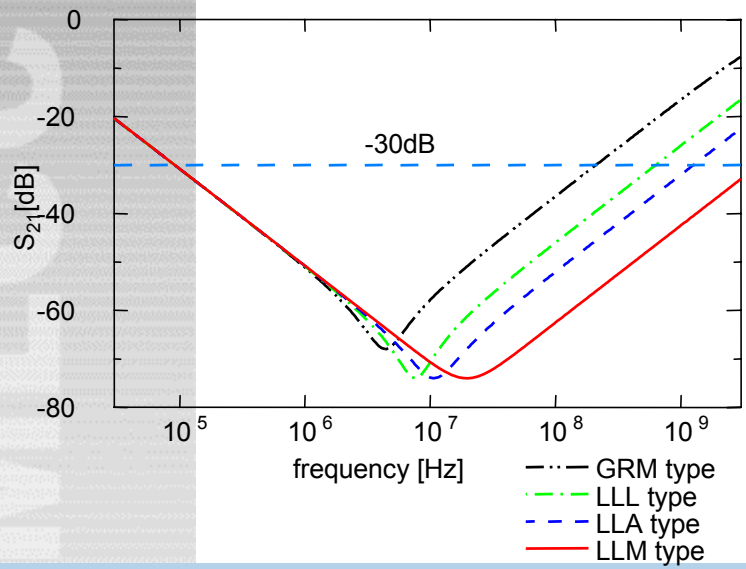
Comparing MLCC and TA , MLCC can reduce ripple noise by 1/3 in Forward method DC - DC converter.

Performance Advantage of a Low ESL MLCC Hi-Cap (LL series)

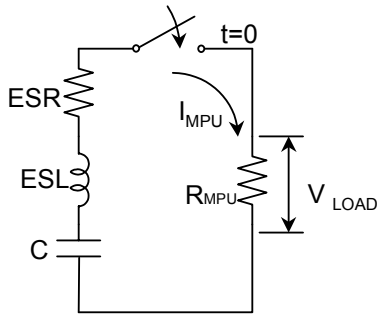
ESL and ESR

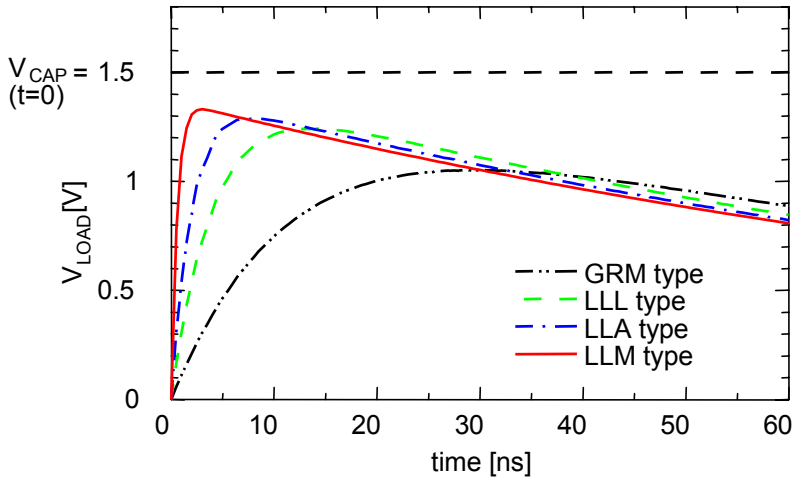
P/N	ESL	ESR
LLM315R70J225MA11 (LLM1206-22X7R225M6.3)	45pH	5mOHM
LLA319R70G225MA01 (LLA1206X7R225M4)	100pH	5mOHM
LLL31MR71A225MA01 (LL0612X7R225M10)	200pH	5mOHM
GRM31MR71C225KC11 (GRM42-6X7R225K16)	800pH	10mOHM

Insertion Loss



Responsiveness of power supply





Performance Comparison of MLCC vs TA and AL Caps (a summary)

Operating Characteristic		MLCC		TA	AL
High Freq.	Capacitance-vs-Frequency	Stable		Changes	
	Impedance-vs-Frequency	Low Impedance		High Impedance	
Reliability	Break Down Voltage	High		Low	
	Life	Long		Average	Short
	Self-Heating Due to Ripple Current	Low		High	
Other	Noise Absorption	Excellent		Poor	Very poor
	Polarity	No polarity concern		Must be positioned in correct orientation	
	Size	Small		Small to Medium	Large
	Capacitance-vs-Temperature	X7R / X5R	Stable	Stable	Stable
		Y5V	Significantly Changes		
	Capacitance-vs-DC Voltage	X7R / X5R	Changes	Stable	Stable
		Y5V	Significantly Changes		

Product Line-Up and Future Direction

Different Dielectrics Available for Hi-Caps

Dielectric Name	Specifications			Features
	Min Temp	Max Temp	Cap Change @	
X5R	-55 ℃	85 ℃	±15%	Highest capacitance available with good temperature stability; best value for performance
X6S	-55 ℃	105 ℃	±22%	Recommended for applications running close to 85℃.
X6T	-55 ℃	105 ℃	+22% to -33%	Recommended for applications running close to 85℃ and where greater capacitance variation is tolerable.
X7S	-55 ℃	125 ℃	±22%	Recommended for applications where high temperature is more critical than capacitance variation
X7R	-55 ℃	125 ℃	±15%	Recommended for applications where both temperature and capacitance variation is important
X8R	-55 ℃	150 ℃	±15%	Recommended for applications where temperatures exceed 120-125℃; however, the capacitance range is limited
Y5V	-30 ℃	85 ℃	+22% to -82%	Highest capacitance in a given case size, but not stable in terms of capacitance vs temperature

@: allowable change of capacitance within temperature range

The actual choice of dielectric depends upon factors like operating temperature range, allowable capacitance change, voltage rating, reliability & case size

A Bird's Eye View of Murata's MLCC Hi-Caps Offering

Capacitance Scale	1 uF	10 uF	100 uF
Standard Products			
GRM15 (0402)	X5R		
GRM18 (0603)	X7R/S		
GRM21 (0805)			
GRM31 (1206)			
GRM32 (1210)			
Capacitor Arrays			
GNM1M (0504)			
GNM21 (0805)			
GNM31 (1206)			
Low Inductance			
LLL18 (0306)			
LLL21 (0508)			
LLL31 (0612)			
LLA18 (0306)			
LLA21 (0508)			
LLA31 (0612)			

Volumetric Capacitance has increased 8 fold in past 6 years

FUTURE DIRECTION

- Increasing maximum Capacitance in smaller case sizes (0402/4.7uF; 0603/22uF; 0805/100uF).
- Increasing Voltage Rating of current Hi-Cap parts (expanding offerings up to 50V)
- Improving AC and DC characteristics
- Increasing absolute capacitance (expanding offering up to 220 uF and beyond)
- Cost reduction due to design changes

The above would be achieved via a combination of thin film technology, higher dielectric constant materials and improved reliability of dielectrics.

ENDING REMARKS

- Murata is dedicated to providing its customers with Hi-Cap products using its cutting edge technology. As mentioned in an earlier slide, once the fundamental technologies are available, Hi-Caps product roadmap is a function of market needs. For example, the technology to manufacture a 220 uF or a 330 uF Hi-cap exists even today. However, the availability of those products in production volumes would depend upon the market demand. *As of today, MLCC Hi-Caps up to 100uF can replace tantalums or electrolytic caps (up to 470 uF) in most applications*. Therefore Murata is currently focusing on increasing capacitance in smaller case sizes.
- However, Murata believes that the superior performance of MLCC Hi-Caps would require further increase in capacitance, but at lower rated voltages (2.2 V and below), as many applications move to lower operating voltages.
- Murata firmly believes that continuous innovation will allow MLCC Hi-Caps to expand their horizons even further and thereby offering the design community ever increasing flexibility.