HIGH TEMPERATURE RF MULTI-LAYER CERAMIC CAPACITORS (MLCC)

IMAPS NEW ENGLAND
45TH SYMPOSIUM & EXPO

BRIAN WARD
MAY 1, 2018

A WORLD OF SOLUTIONS™

AGENDA

- Applications
- Products
- Test results

APPLICATIONS FOR HIGH FREQUENCY MLCCS

- Broadband communication
- Satellite communication
- Base stations
- RRUs
- Medical instrumentation
- Medical devices
- Military radios
- Radars
- MRI coils and generators
- RF instruments
- RF power amplifiers
- Filter networks
- Timing circuits
- Automotive control
- Automotive communication

HOW CAN HIGH-TEMP CAPS IMPROVE?

GaN used in 5G development can have junction temperature >200°C

- Satellite communication
- Base stations
- RRUs
- Medical instrumentation
- Medical devices
- Military radios
- Radars

Ability to perform at 200°C speaks volumes to performance at lesser conditions

Drilling equipment runs >200°C and communicates data

- RF instruments
- RF power amplifiers
- Filter networks
- Timing circuits
- Automotive control
- Automotive communication

Automotive electronics continue to grow including circuits operating at high temperatures

125°C RF MLCCS OFFERING

	Capacitance Range (pF)		
Voltage	0402	0603	0805
25	0.1 to 82	0.1 to 470	0.1 to 1500
50	0.1 to 56	0.1 to 330	0.1 to 1000
100	0.1 to 27	0.1 to 150	0.1 to 680
200	0.1 to 27	0.1 to 100	0.1 to 390
250		0.1 to 100	0.1 to 330

Tolerance as tight as ± 0.05 pF for capacitance values ≤ 10 pF
Tolerance as tight as ± 1 % for capacitance values > 10 pF

	Capacitance Range (pF)			
Voltage	0505	1111	2525	3838
50	0.1 to 1000	0.2 to 5100	1 to 3000	1 to 12000
100	0.1 to 470	0.2 to 3300		
150	0.1 to 470	0.2 to 1600		
200	0.1 to 240			
250	0.1 to 68	0.2 to 1000		
300				
500		0.2 to 470	1 to 3000	1 to 7500
630			1 to 2400	1 to 5100
800		0.2 to 200	1 to 2000	
1000			1 to 1200	
1500		0.2 to 110	1 to 1200	1 to 750
2000			1 to 470	
2500			1 to 270	
3000			1 to 270	1 to 390
3600			1 to 100	
5000				1 to 180
7200				1 to 100

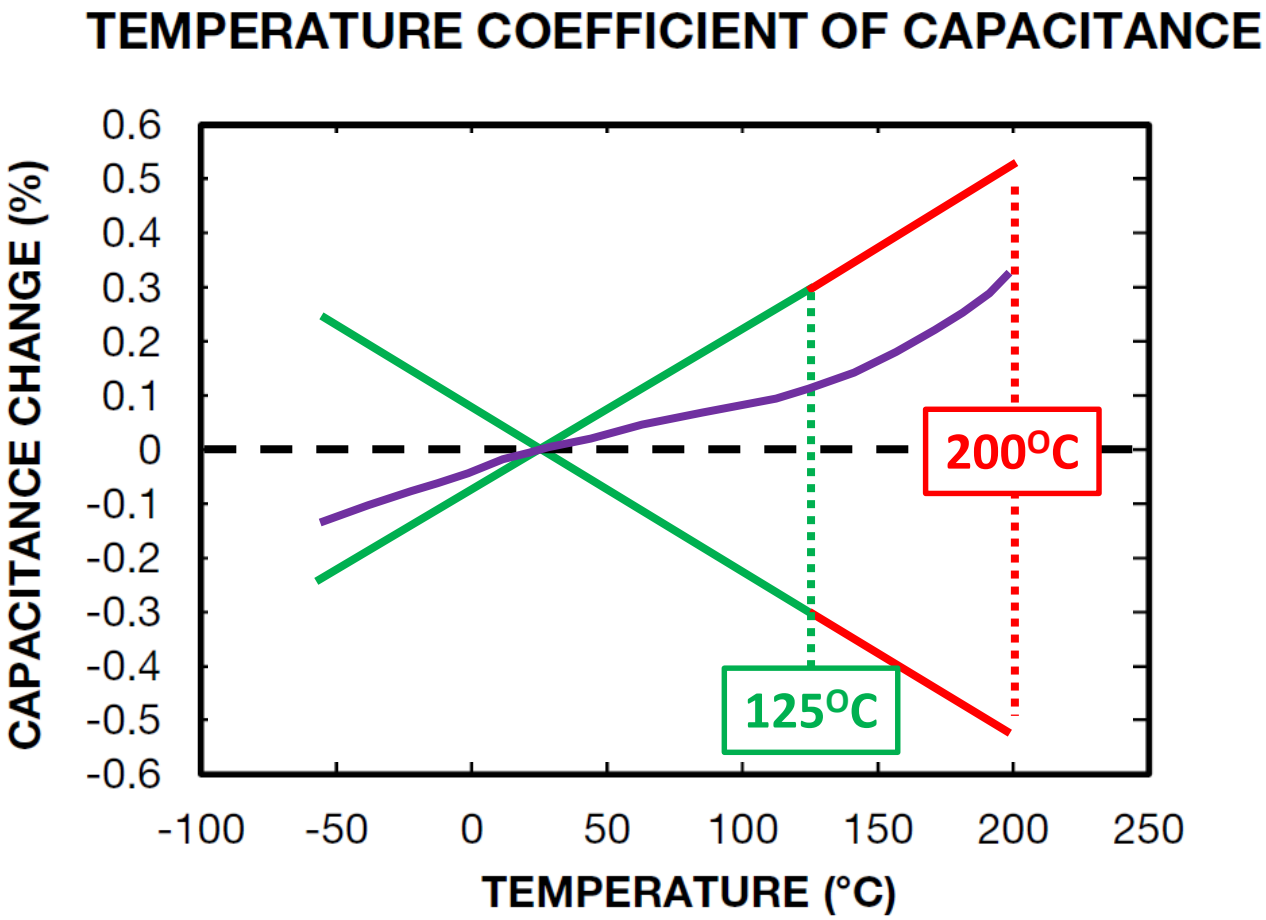
Tol. as tight as ±0.05 pF for cap. values ≤ 10 pF (0505 / 1111)
Tol. as tight as ±0.1 pF for cap. values ≤ 10 pF (2525 / 3838)
Tol. as tight as ±1 % for capacitance values > 10 pF

200°C RF MLCCS OFFERING

Voltage	Capacitance Range				
	0402	0505	0603	0805	1111
16	0.1 to 47	0.1 to 330	0.1 to 270	0.1 to 1000	0.1 to 3300
25	0.1 to 27		0.1 to 150	0.1 to 680	
50	0.1 to 15		0.1 to 100	0.1 to 510	
100	0.1 to 2.7	0.1 to 180	0.1 to 47	0.1 to 240	0.1 to 2000
150		0.1 to 130	0.1 to 8.2	0.1 to 75	0.1 to 1000
200		0.1 to 68			
250		0.1 to 47		0.1 to 62	0.1 to 510
300					
500					0.1 to 390

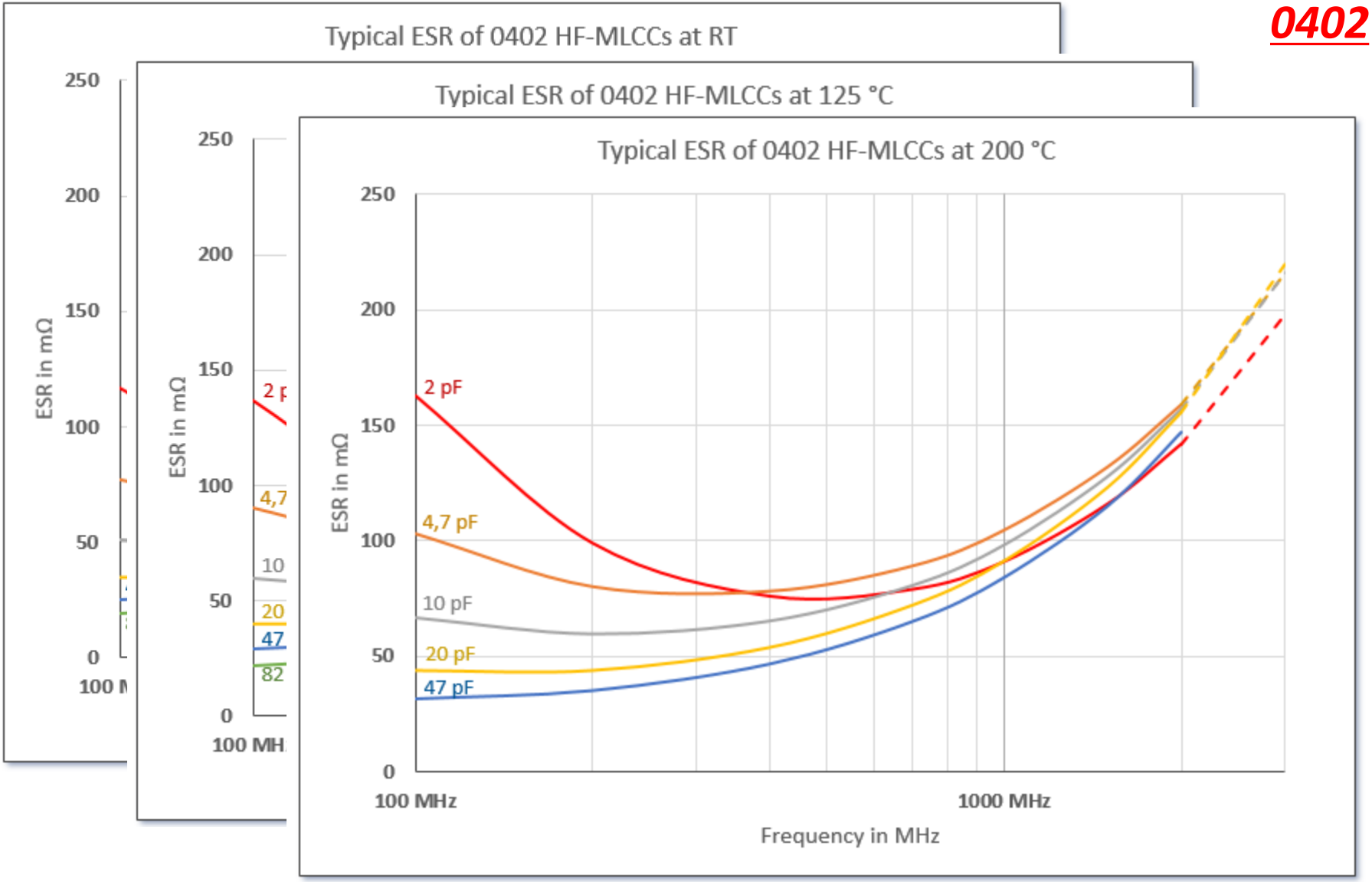
For cap. values ≤ 10 pF, tolerance as tight as ±0.05 pF
For cap. values > 10 pF, tolerance as tight as ±1%

HIGH TEMPERATURE TCC PERFORMANCE



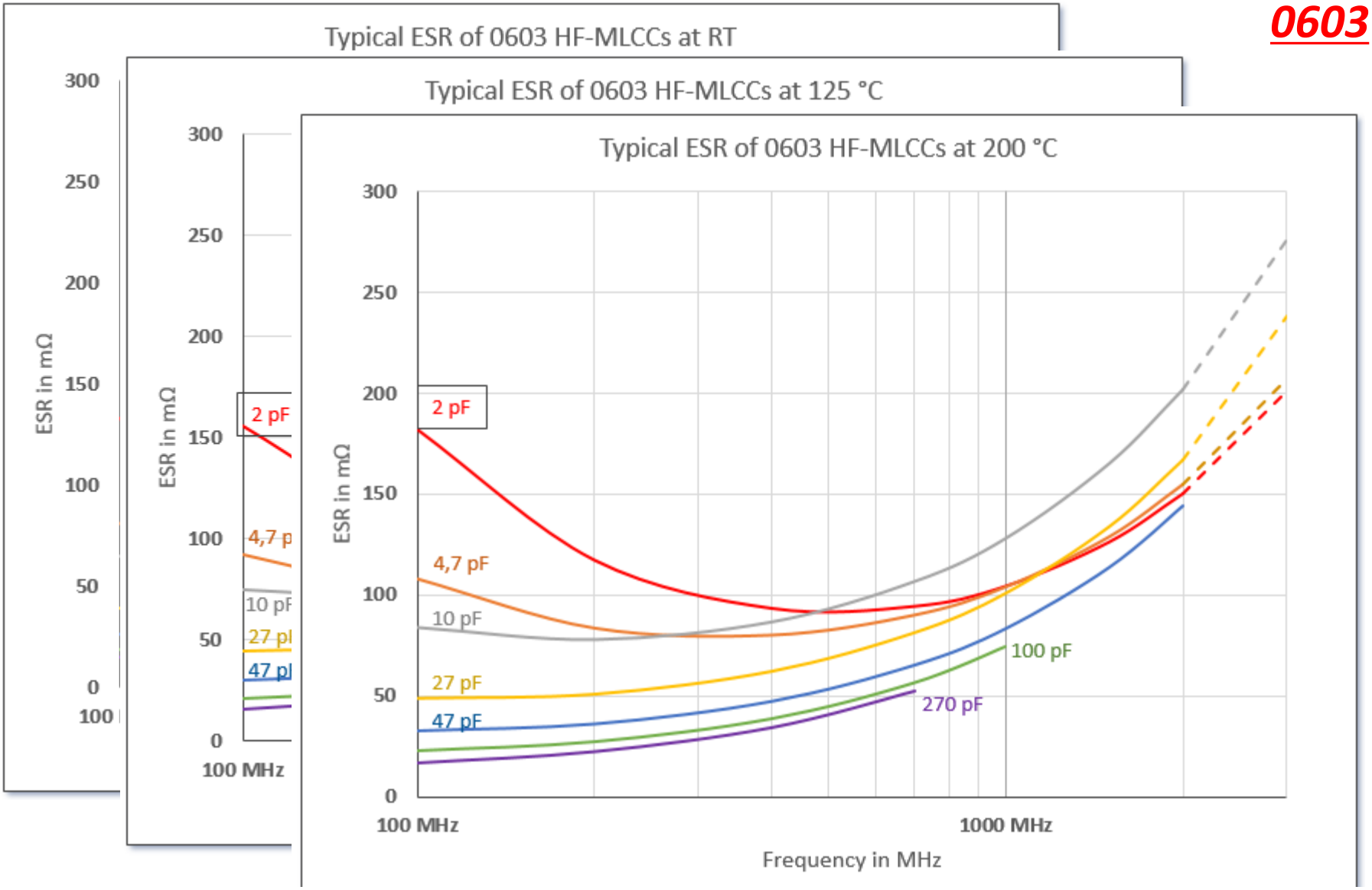
HIGH TEMPERATURE ESR PERFORMANCE

0402



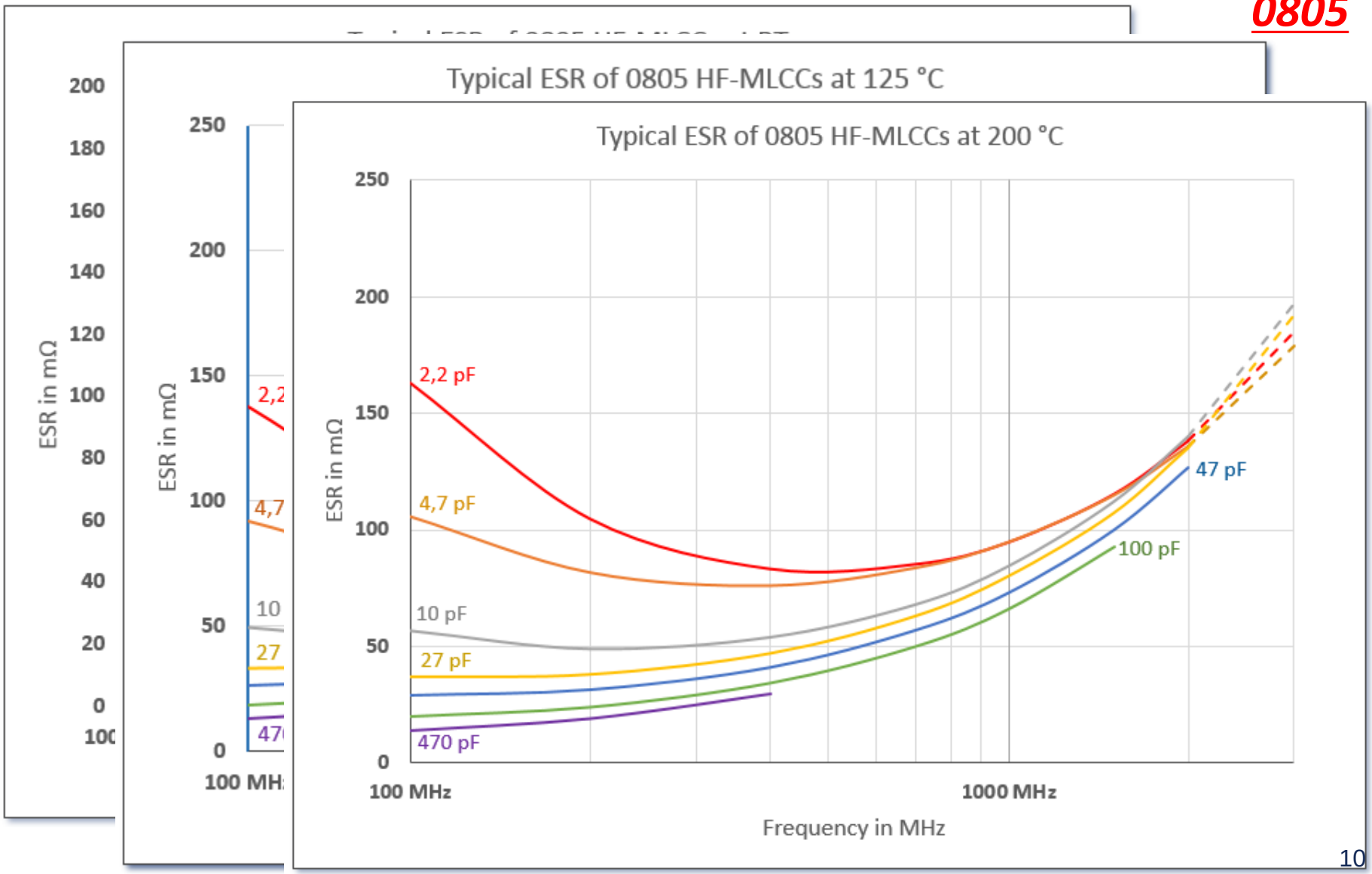
HIGH TEMPERATURE ESR PERFORMANCE

0603

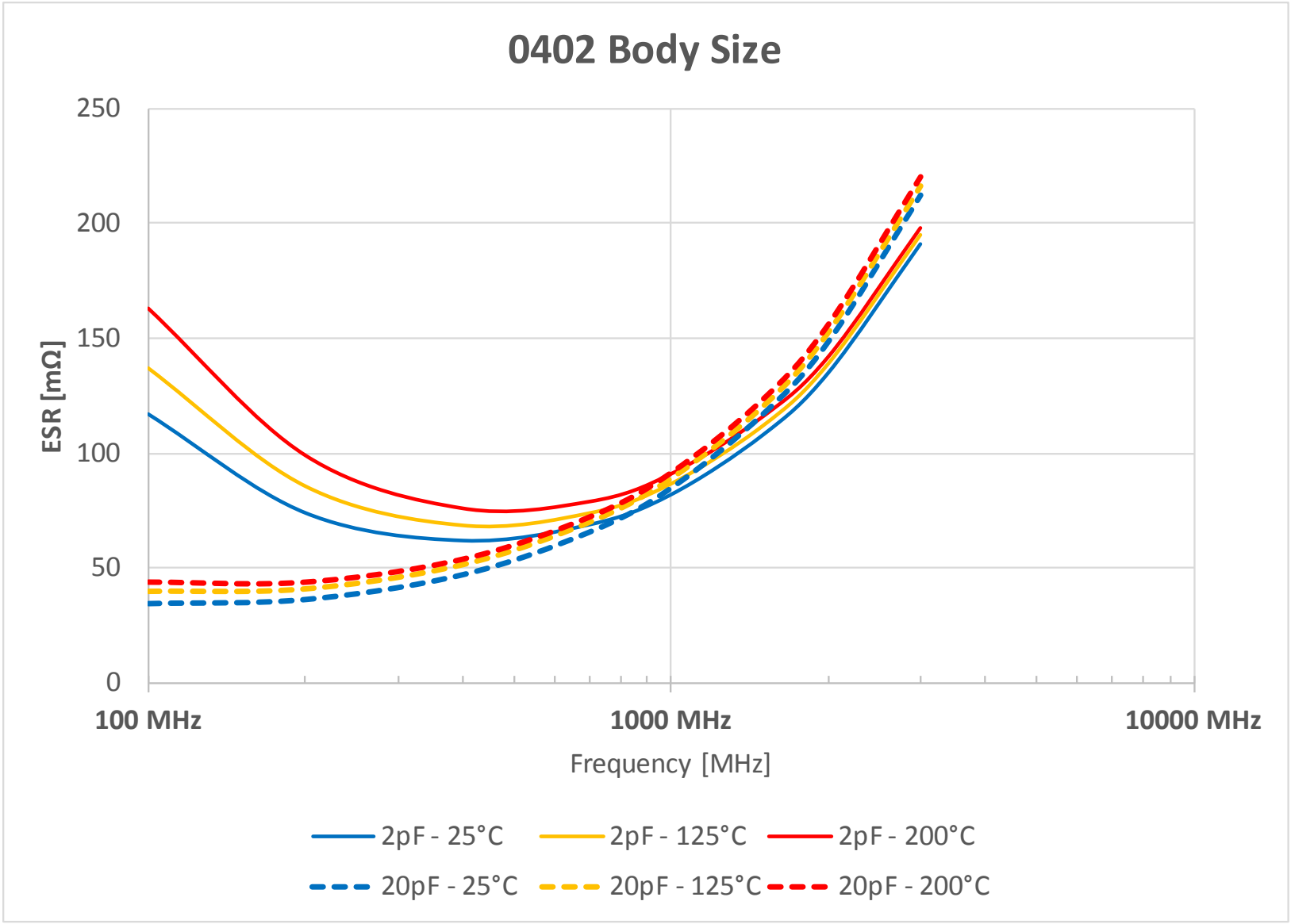


HIGH TEMPERATURE ESR PERFORMANCE

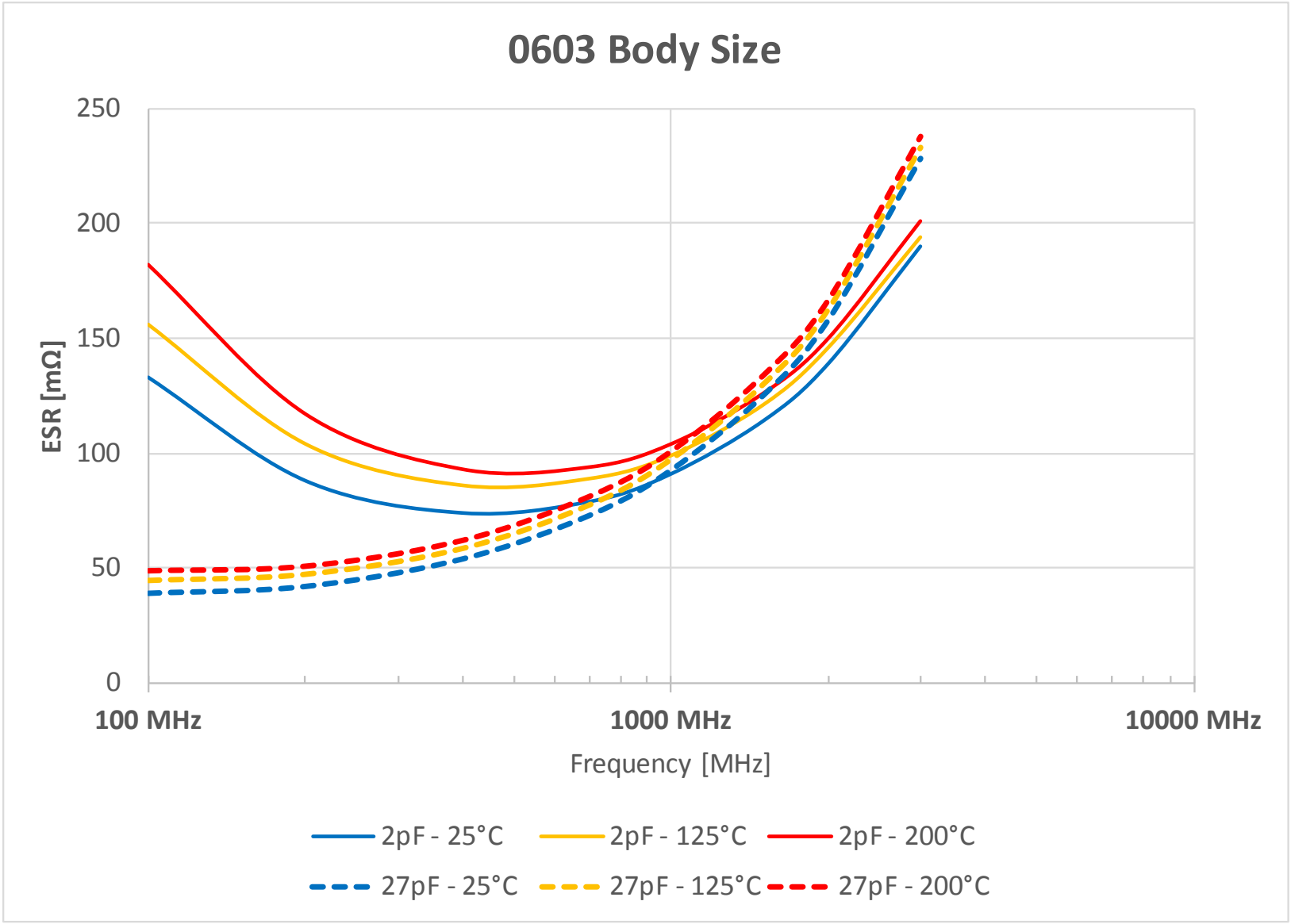
0805



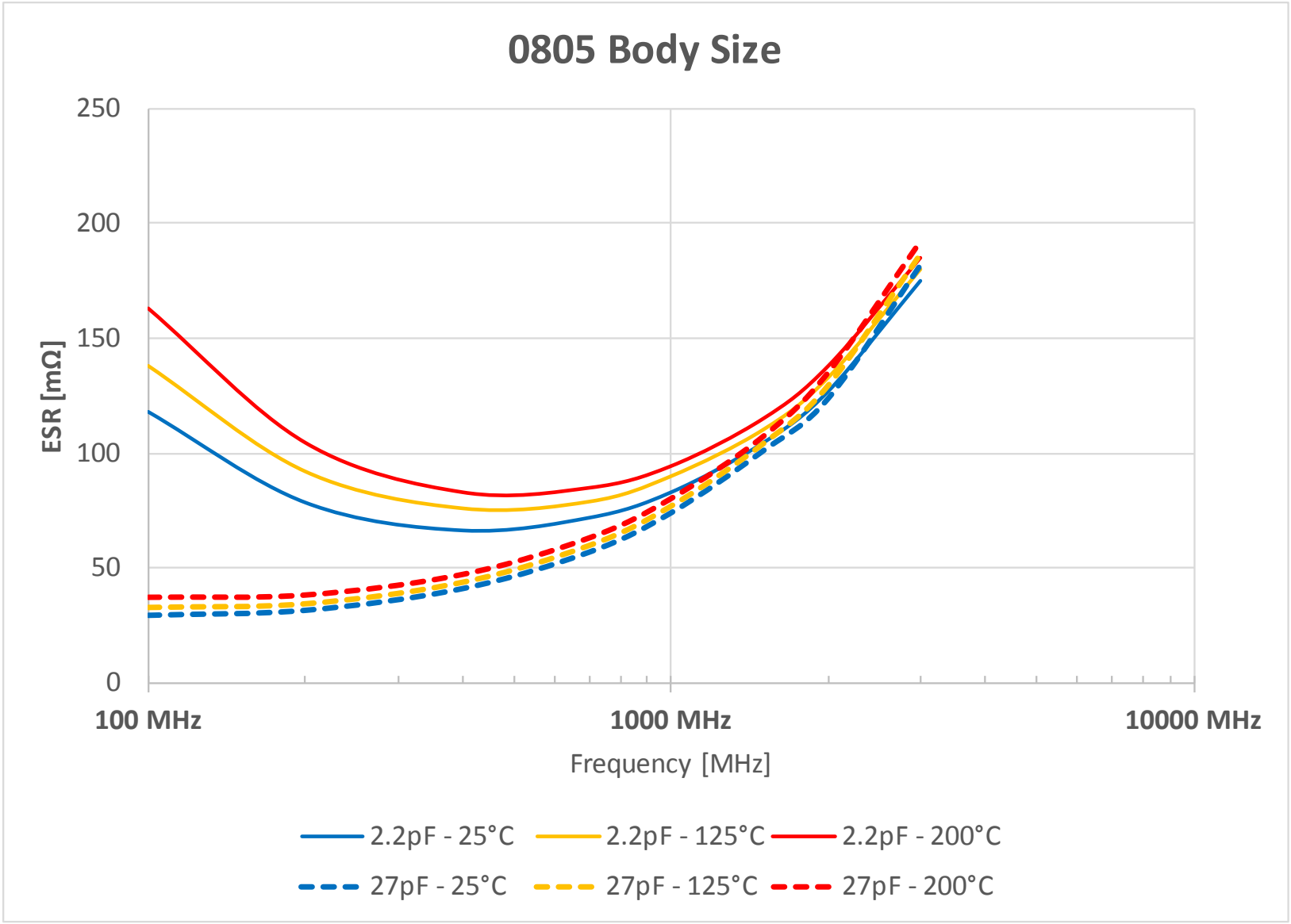
HIGH TEMPERATURE ESR PERFORMANCE



HIGH TEMPERATURE ESR PERFORMANCE

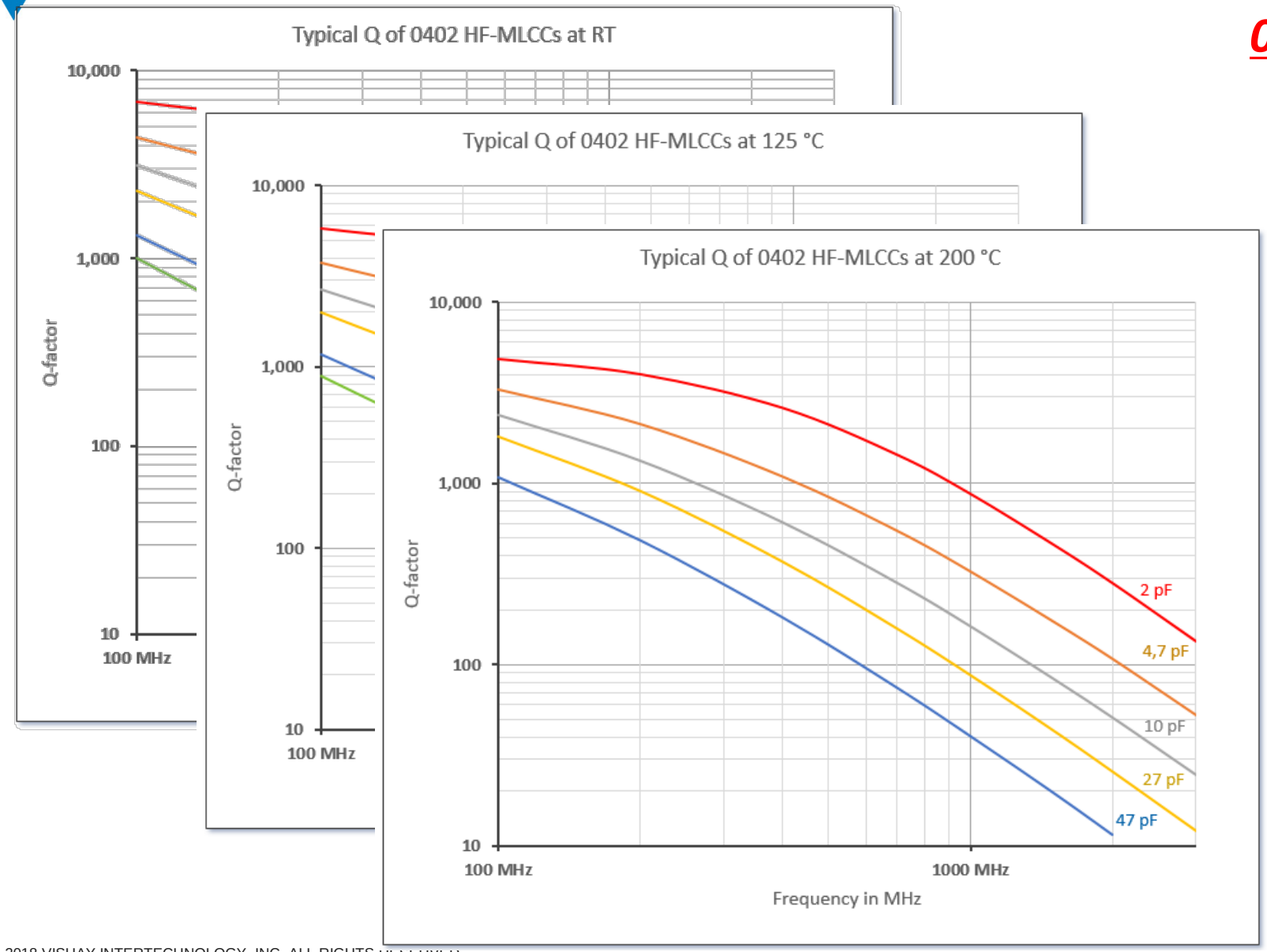


HIGH TEMPERATURE ESR PERFORMANCE



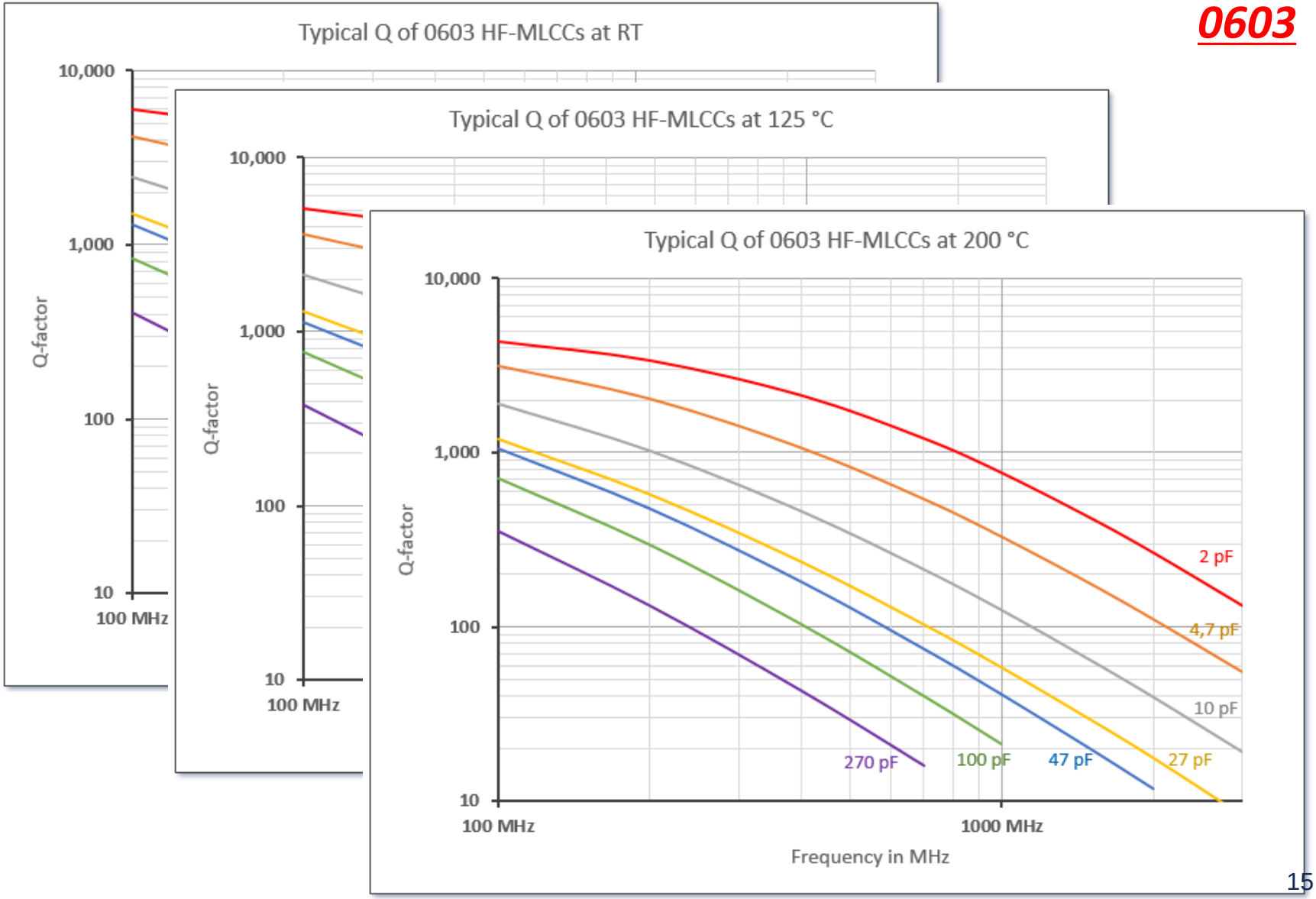
HIGH TEMPERATURE Q PERFORMANCE

0402



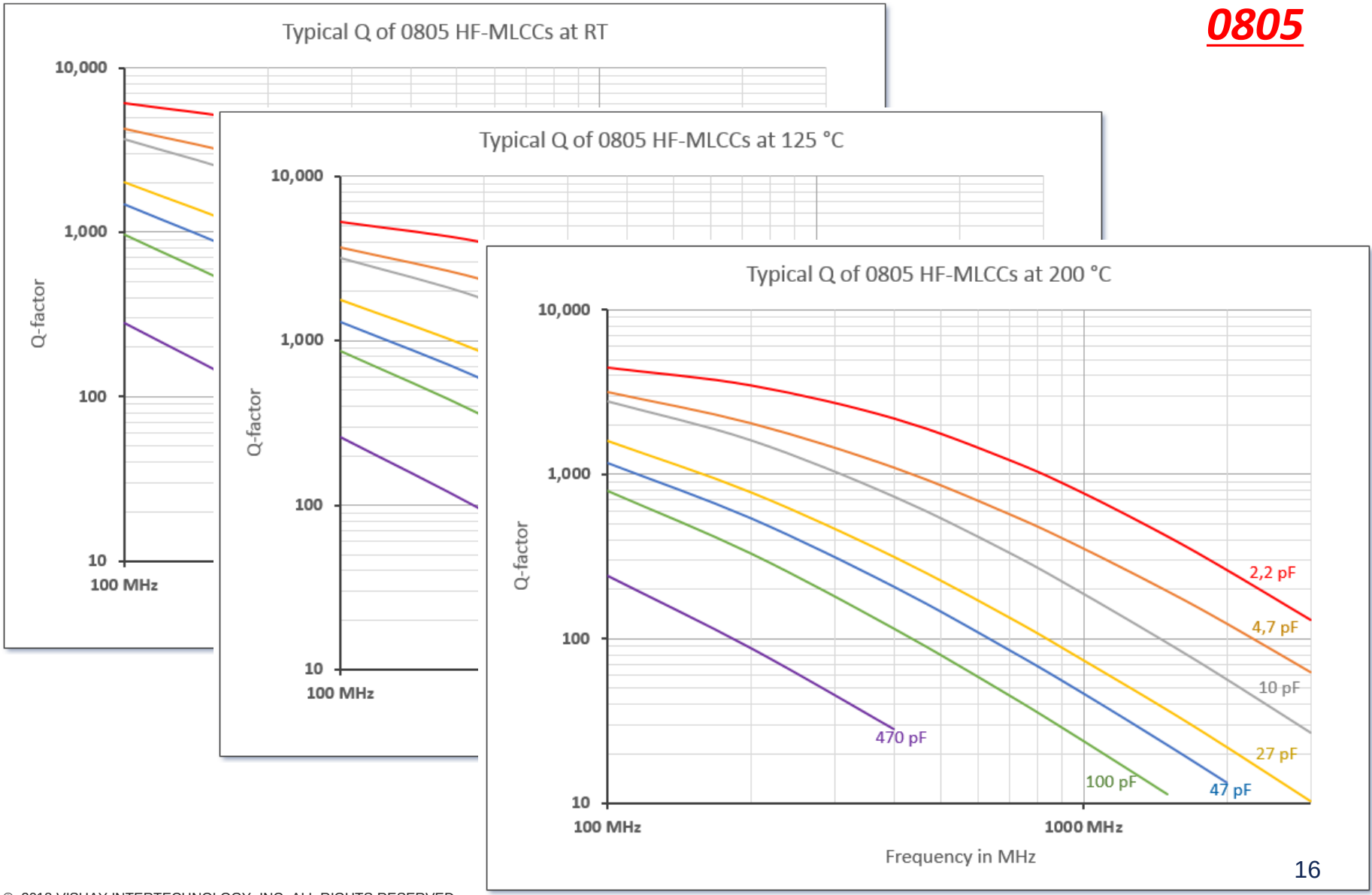
HIGH TEMPERATURE Q PERFORMANCE

0603



HIGH TEMPERATURE Q PERFORMANCE

0805



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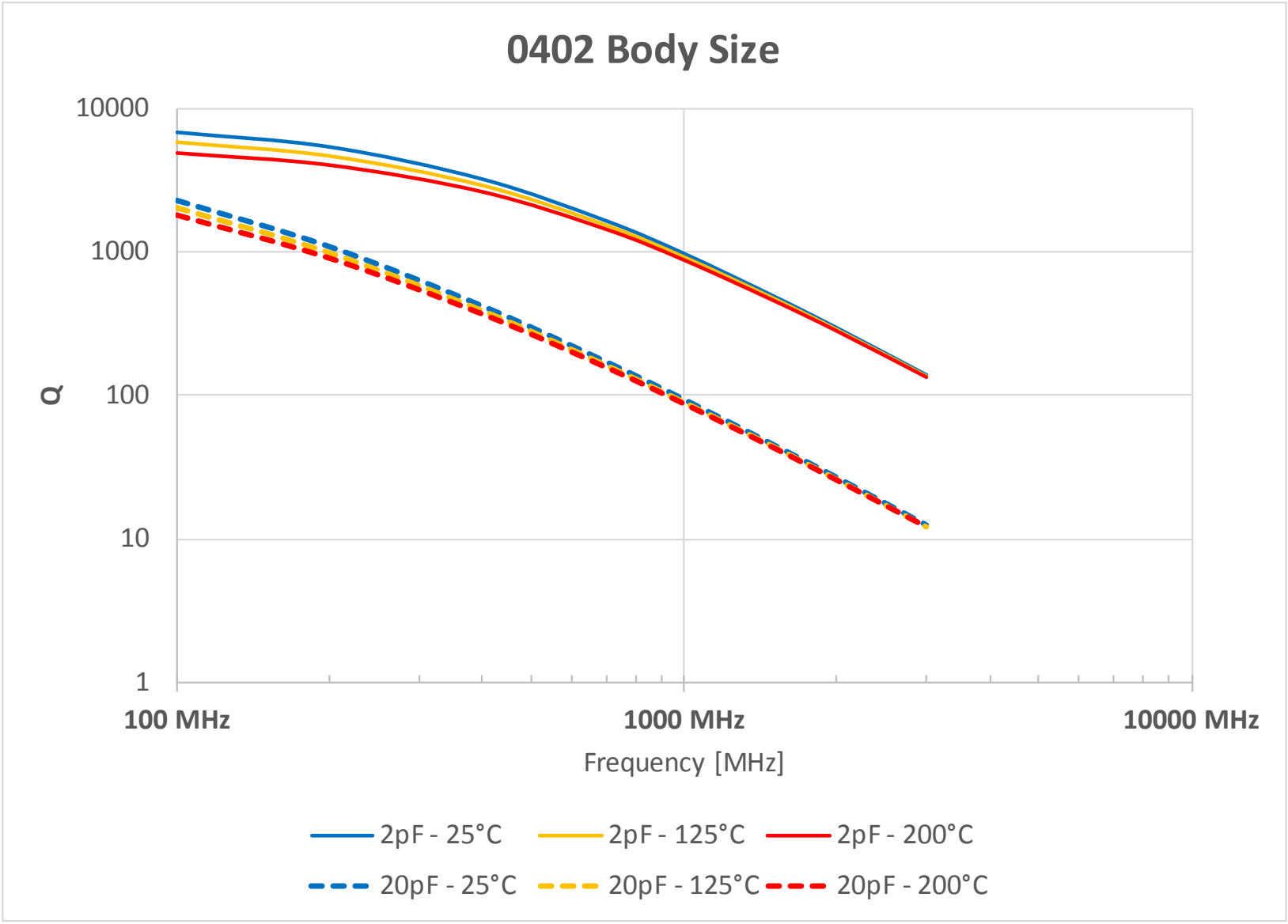

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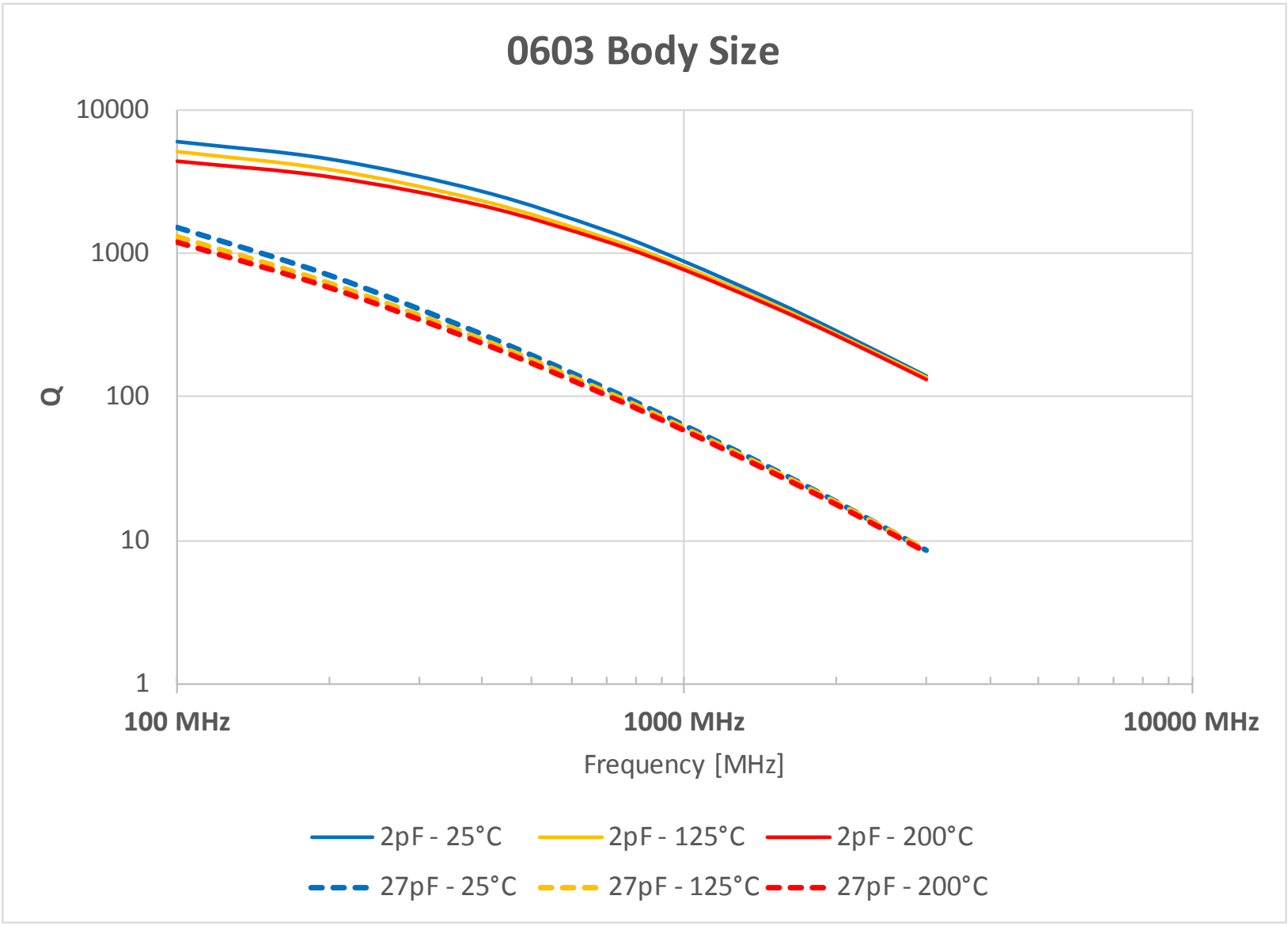
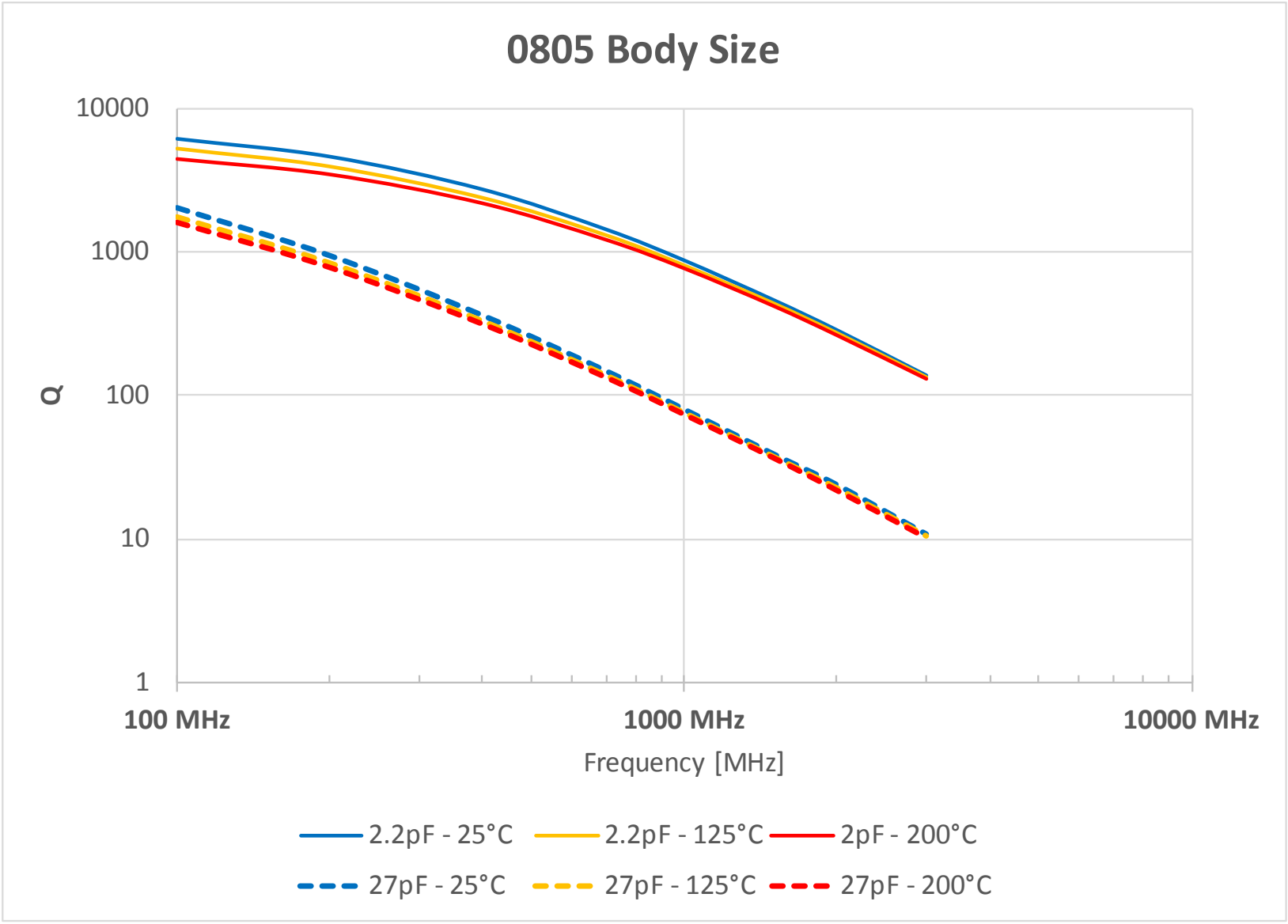


HIGH TEMPERATURE Q PERFORMANCE



HIGH TEMPERATURE RELIABILITY

Group QP-64			OVERVIEW OF QUALIFICATION RESULTS					
			-1-	-2-	-3-	-4-	-5-	-6-
200°C rated Quad-RF (series A- and B-case)		Part Number	0505D331KXA	0505D181KXB	0505D470JXP	1111D222KXA	1111D471FXD	1111D181KXE
		Lot Number	60425300	60425310	33842363	60425280	33697233	33753063
		Voltage rating	50 V	100 V	250 V	50 V	300 V	500 V
		Dielectric	C-173	C-173	C-173	C-173	C-173	C-173
Item	Qualification Tests	Test ID Number	Q-714	Q-715	Q-700	Q-716	Q-699	Q-698
	Pre-electrical tests							
1	Electrical Characterization Cap / DF / IR / DWV at 25 °C							
2	Electrical Characterization Cap / DF / IR / DWV at 200 °C							
3	TCC (-55 to +200°C)							
4	ESR (UHF), ohms							
5	ESR (RF), ohms							
6	Physical dimensions							
7	Visual Examination							
8	DPA							
9	Solderability							
10	Solderability Pb-free							
11	Resistance to soldering heat							
12	Moisture resistance (unpowered)							
13	Biased humidity RV (85°C/85RH, 1000H)							
14	Biased humidity LV (85°C/85RH, 240H)							
15	Thermal shock and Immersion 100 cycles -55/+200°C							
16	Terminal Strength							
17	Board Flex							
18	Beam Load Test							
19	Operational life 200 °C / 1000H / RV							
		Status:	Pass	Pass	Pass	Pass	Pass	Pass

Qualification plan is based on AEC-Q200 requirements

HIGH TEMPERATURE RELIABILITY

- Qualification is performed at
  - Extended temperatures
  - Extended voltage
  - Long period of time
- What does that give?

Qualification results + *Large sample size* = *Performance prediction at application conditions*

- So, parts qualified to 200°C used at lower temperatures and voltages provide highly reliable performance

HIGH TEMPERATURE RELIABILITY

- Two main factors influence reliability:
  - Temperature: The time to failure decreases with increasing temperature
  - Voltage: The time to failure is dependent on the applied electrical field
- When combined, these two factors can be calculate the relative acceleration factors (and therefore the relative reliabilities).
- The formula is:

$$F_{Acc} = \left(\frac{U_2}{U_1}\right)^3 * 2^{\left(\frac{T_2 - T_1}{10}\right)}$$

HIGH TEMP RELIABILITY AT LESSER CONDITIONS

- 0603 100V HT cap operating in the engine compartment of a vehicle
  - 150^{O}C and 14V
  - FIT: 2.06x10^{-7}
  - MTBF: >500K years
- 0805 250V HT cap operating in a circuit utilizing GaN for 5G:
  - 220^{O}C and 20V
  - FIT: 6.35x10^{-6}
  - MTBF: >>1M years
- 0402 16V cap in an implanted pacemaker
  - 37^{O}C and 3V
  - FIT: 2.53x10^{-10}
  - MTBF: >1B years

SUMMARY

- Higher power demands are creating higher operating temperature environments
- Key capacitor and high frequency parameters need to remain constant at the higher operating temperatures
  - As the applied frequency increases, differences in ESR and Q become smaller
- The capacitors built to operate at high temperatures can also give improved reliability at less demanding conditions

Thank you!