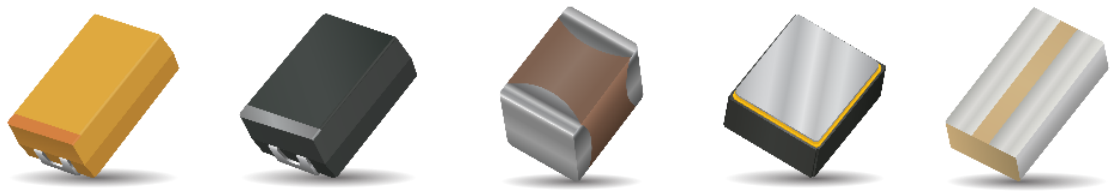
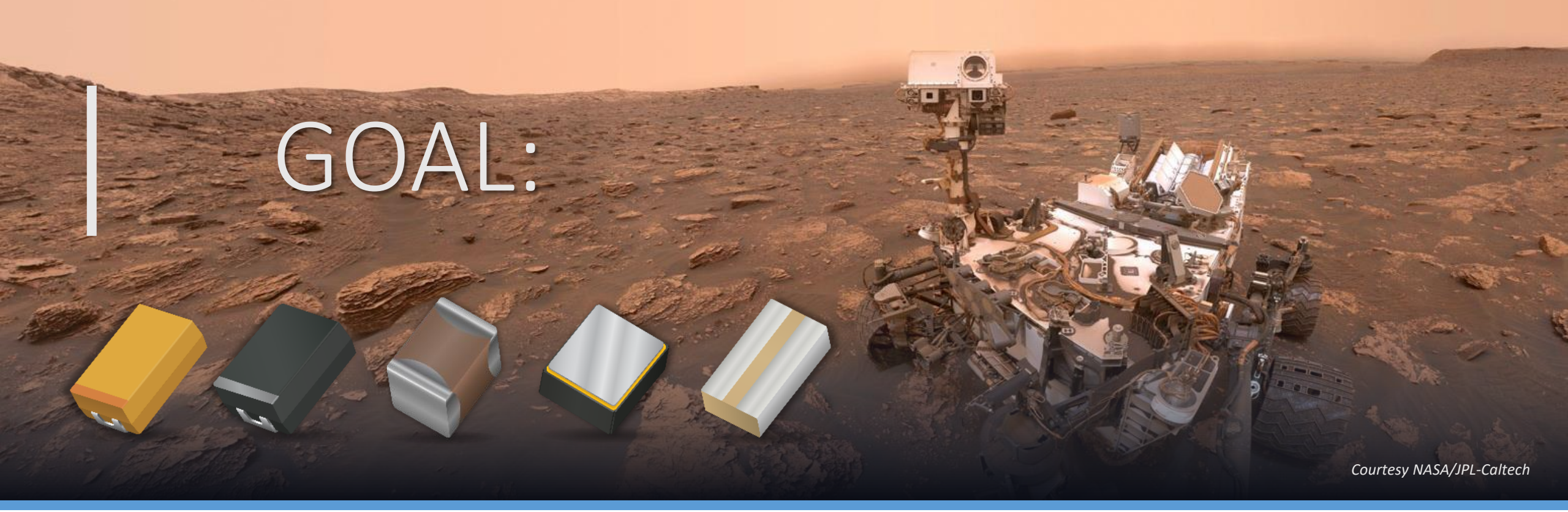
High level overview:
Specification Options & Grades Capacitors, Inductors, Resistors and Filters



CMSE 2021 Tutorial #2
April 19, 2021

Ron Demcko | Ron.Demcko@avx.com | 919-271-0047

GOAL:



Courtesy NASA/JPL-Caltech

- High-level overview of Mil, ESA, COTS & Auto Grade
- Key component specification are discussed relative to their intent & purpose

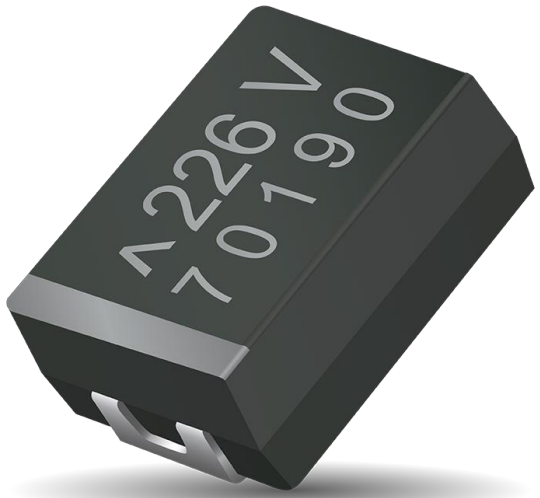
- Summary of significant differences between components by the different grades of specs
- Component technology, ranges and failure modes discussed
- Alternates grades are shown when possible

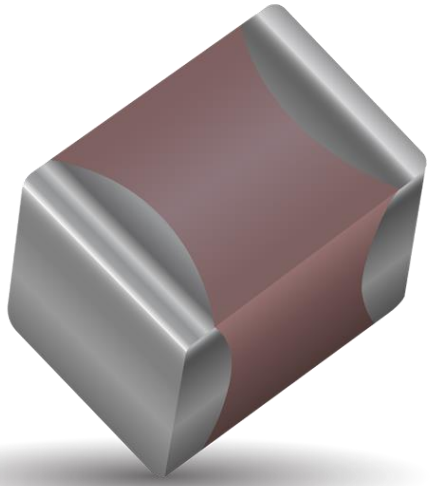
CAPACITOR CATEGORIES PER MIL-HDBK-198B

CERAMIC MIL-PRF-32535 *(New Addition)*	MIL-PRF-20	Temperature Compensating (ER and Non-ER)
	MIL-PRF-81	Variable (Non-ER)
	MIL-PRF-123	Temperature Stable and General Purpose (High Reliability)
	MIL-PRF-39014	General Purpose (ER and Non-ER)
	MIL-PRF-49464	Single Layer Chip
	MIL-PRF-49467	Multilayer High Voltage
	MIL-PRF-49470	Switch Mode Power Supply (High Reliability)
	MIL-PRF-55681	Chip (ER)
ELECTROLYTIC	MIL-PRF-39003	Solid Electrolyte Tantalum (ER)
	MIL-PRF-39006	Nonsolid Electrolyte Tantalum (ER)
	MIL-PRF-39018	Aluminum Oxide (ER)
	MIL-PRF-49137	Solid Electrolyte Tantalum (Non-ER)
	MIL-PRF-55365	Tantalum Chip (ER and Non-ER)
GLASS	MIL-PRF-14409	Variable Piston Type Tubular Trimmer (Non-ER)
	MIL-PRF-23269	(ER)
MICA	MIL-PRF-39001	(ER)
PAPER / PLASTIC	MIL-PRF-11693	Feed Through, Radio-Interference Reduction, DC (ER and Non-ER)
	MIL-PRF-19978	(ER)
	MIL-PRF-39022	DC/AC (ER)
	MIL-PRF-55514	DC or DC-AC (ER)
	MIL-PRF-83421	DC/AC, Hermetically Sealed (ER)

1.2 Purpose of handbook.
a. To provide the equipment designer with a selection of std capacitors for use in most DoD applications.

Why concentrate on **Ceramic** & **Tantalum** Capacitors?





- Most common capacitors used on PCBs
  MLCCs + Tantalums
- Ceramics - general purpose to HF decoupling
- Tantalum high efficiency bulk capacitors
- Major trends impacting & expanding both technologies

HF

&

Bulk Capacitors

Capacitors :
Federal Stock Class 5910

CERAMIC	MIL-PRF-20	Temperature Compensating (ER and Non-ER)
	MIL-PRF-81	Variable (Non-ER)
	MIL-PRF-123	Temperature Stable and General Purpose (High Reliability)
	MIL-PRF-39014	General Purpose (ER and Non-ER)
	MIL-PRF-49464	Single Layer Chip
	MIL-PRF-49467	Multilayer High Voltage
	MIL-PRF-49470	Switch Mode Power Supply (High Reliability)
	MIL-PRF-55681	Chip (ER)
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	MIL-PRF-39018	Aluminum Oxide (ER)
	MIL-PRF-49137	Solid Electrolyte Tantalum (Non-ER)
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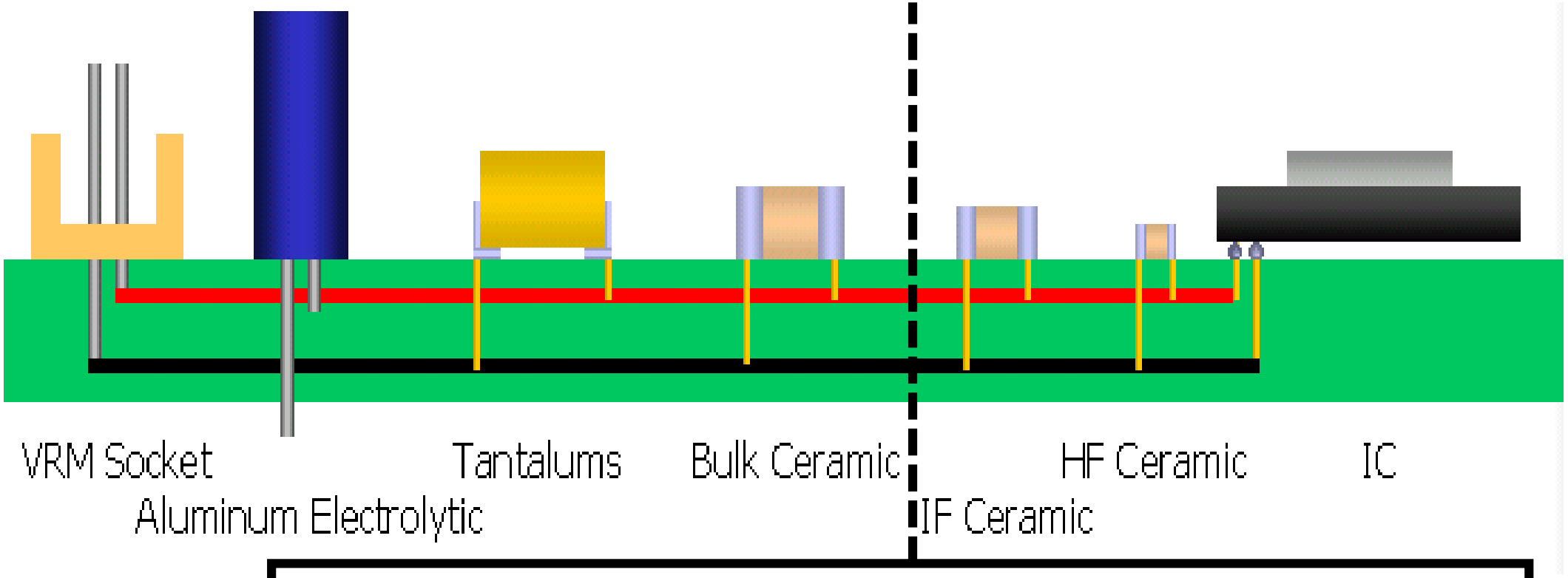
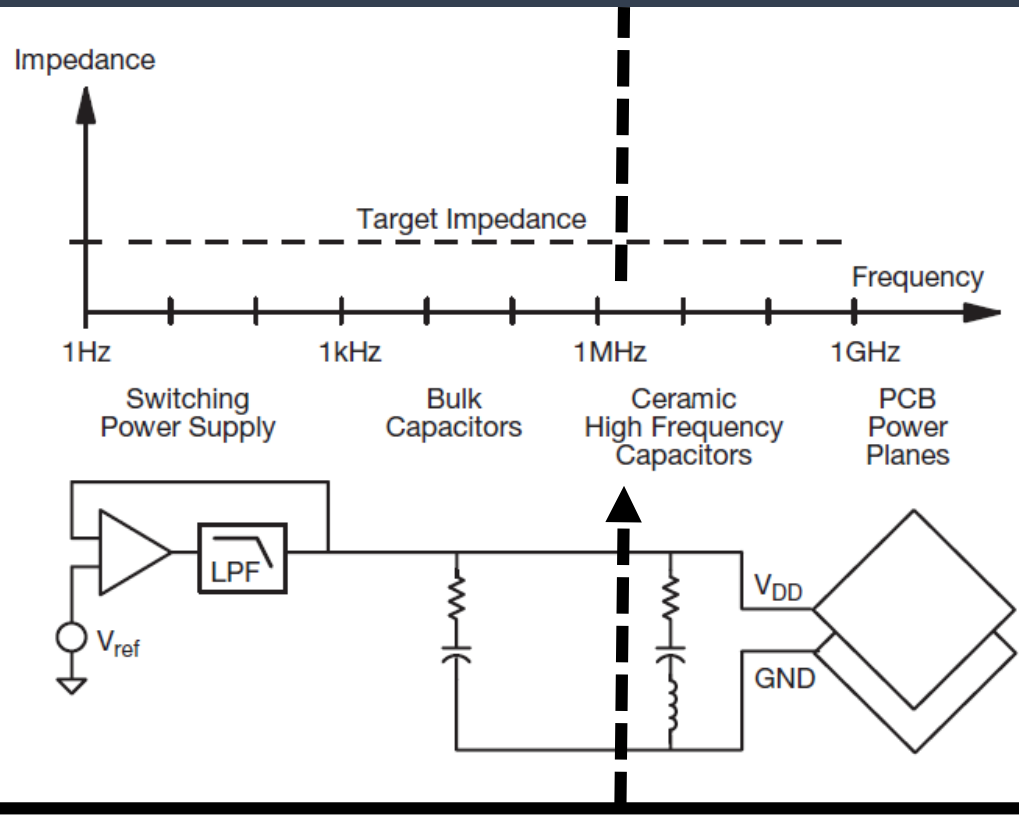
	MIL-PRF-19978	(ER)
	MIL-PRF-39022	DC/AC (ER)
	MIL-PRF-55514	DC or DC-AC (ER)
	MIL-PRF-83421	DC/AC, Hermetically Sealed (ER)

Example of Bulk & HF Capacitors : Power Distribution to FPGA

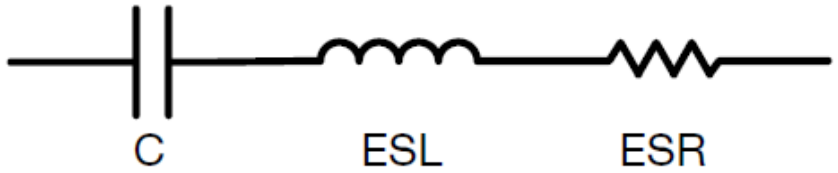


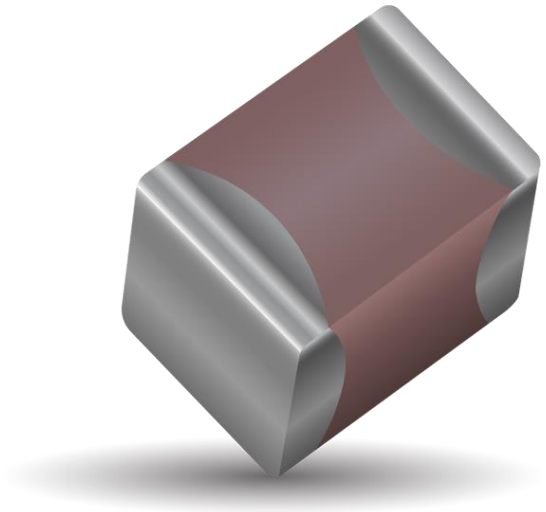
Example of Bulk & HF Capacitors : Power Distribution to FPGA

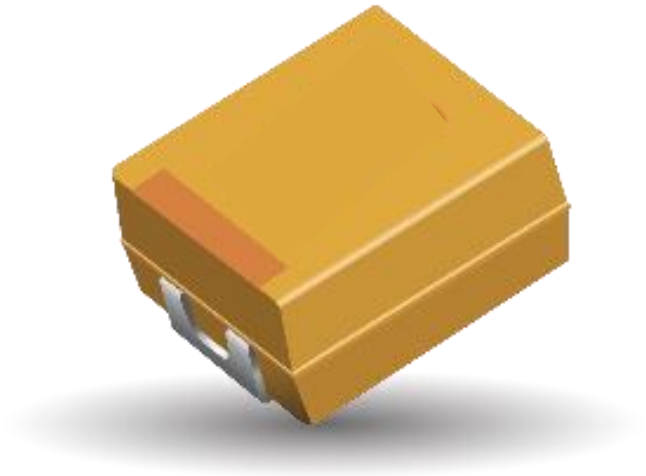


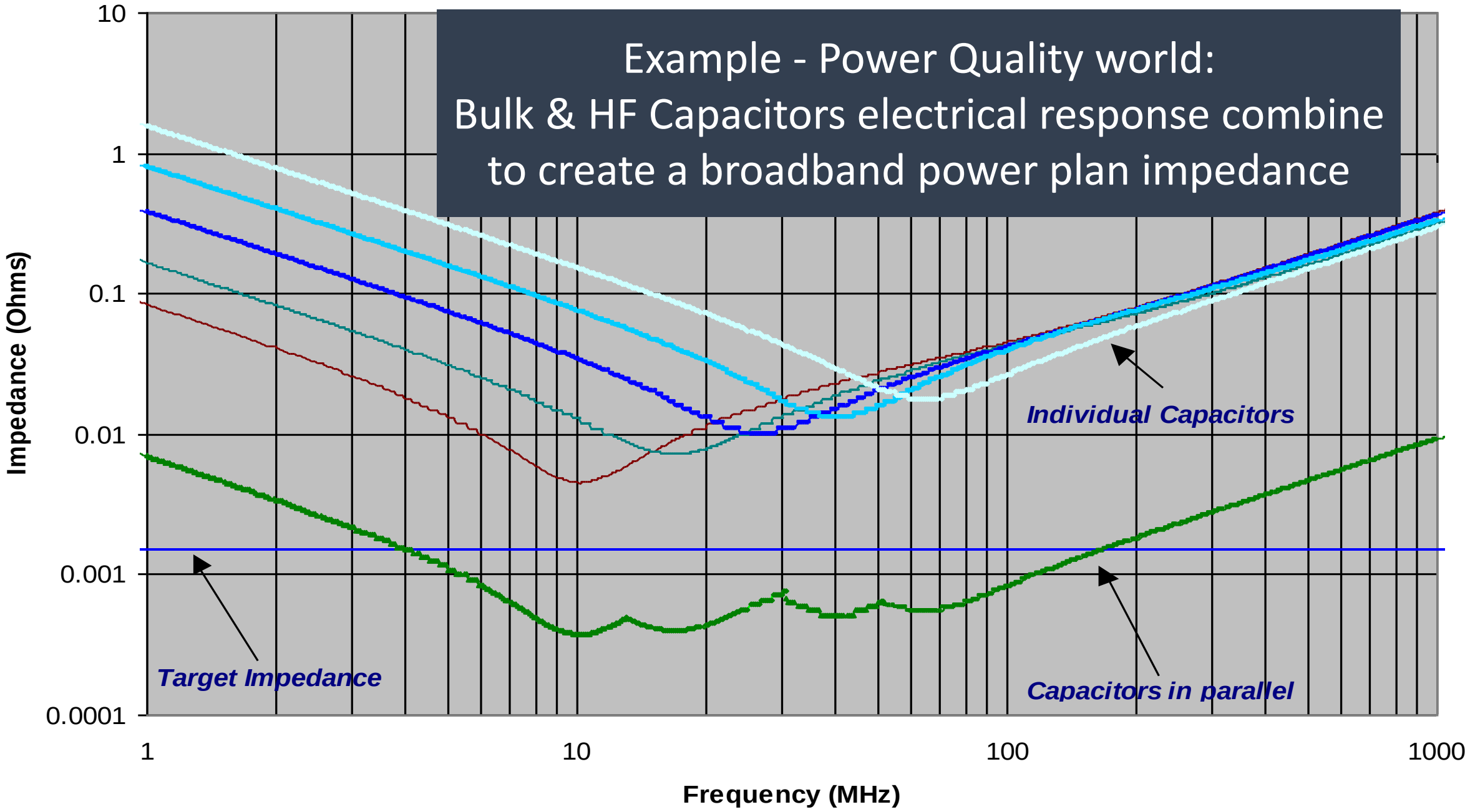
Bulk Capacitors HF Capacitors

Example - Power Quality world:
Bulk & HF Capacitors electrical response combine to create a broadband power plan impedance



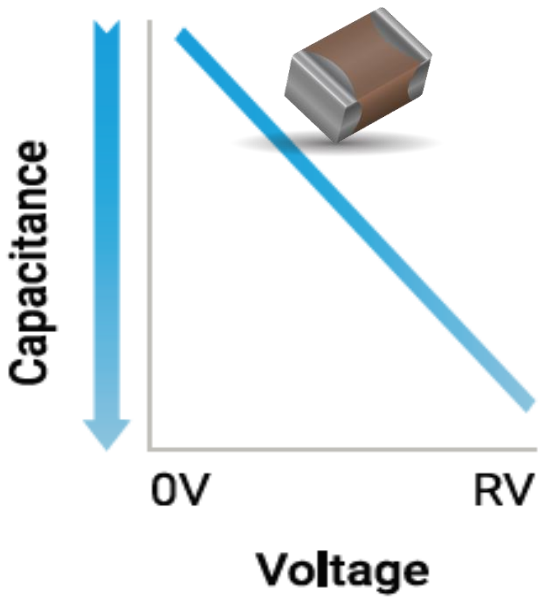




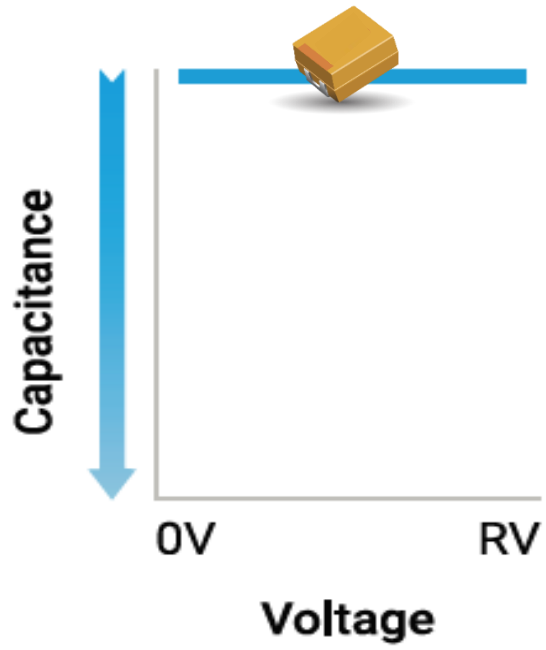

Example - Power Quality world:
Bulk & HF Capacitors electrical response combine to create a broadband power plan impedance
10
1
0.1
0.01
0.001
0.0001
Impedance (Ohms)
1
10
100
1000
Frequency (MHz)
Individual Capacitors
Target Impedance
Capacitors in parallel

MLCC & Tantalum Capacitor stability vs:
Applied voltage
Temperature

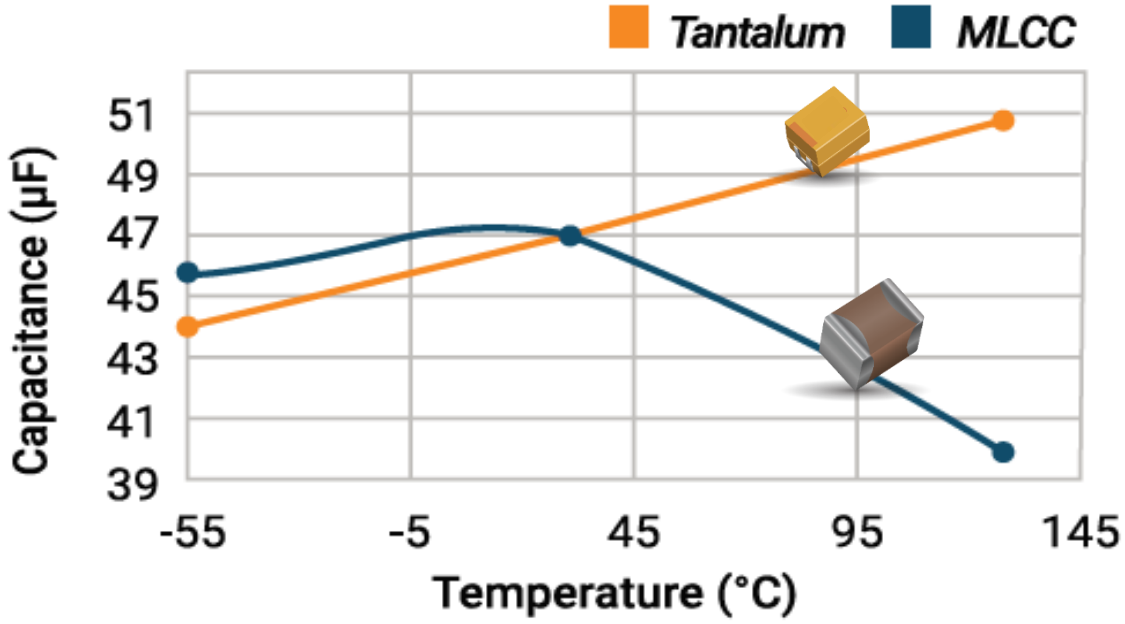
MLCC



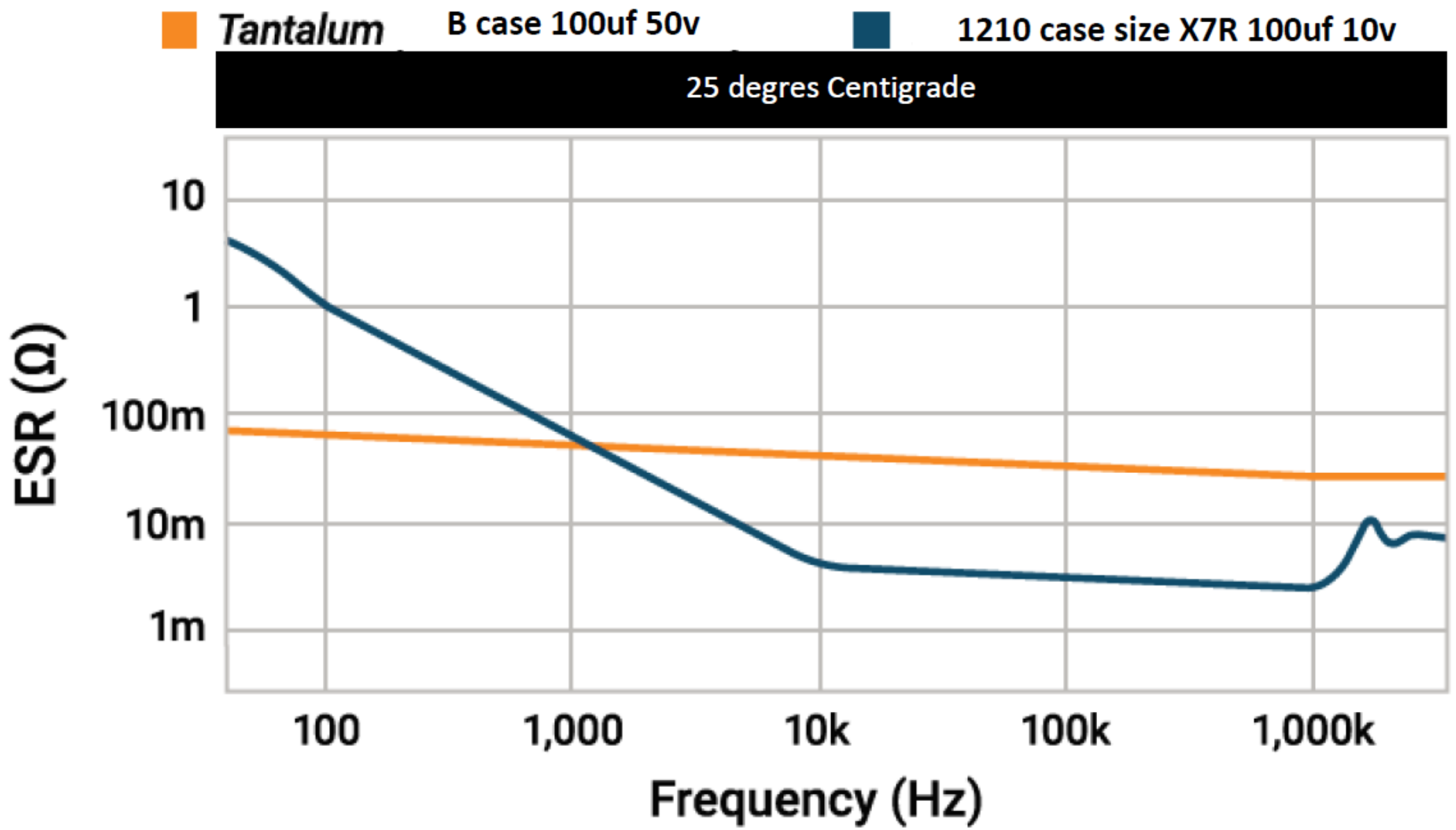
TA / NbO / POLYMER



TYPICAL 47µF / 10V CAPACITANCE VS. TEMPERATURE



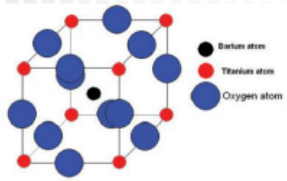
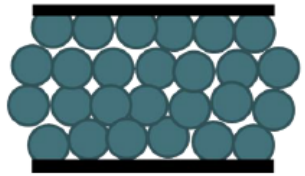
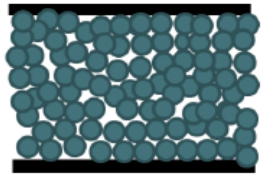
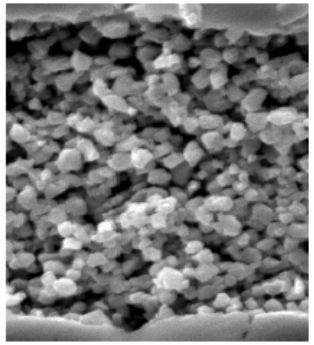
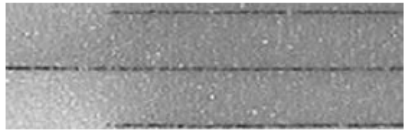
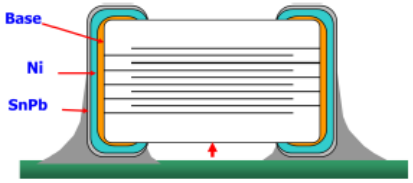
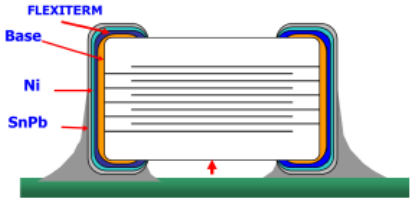
TYPICAL ESR – 1210 SIZE: *(Typical values only)*



IMPORTANT FLIGHT GRADE MLCC TRENDS: BME

WHY BME?

- Reduced Weight
- Reduced Size
- Expanded Values
- Reduced Inductance

	PME (Space)	BME
Internal Electrodes:	Pd/Ag	Ni
Dielectric	BaTiO3, K3500  	BaTiO3, K3500, reduced particle size:  
Dielectric Thickness: (50 V)	30 µm typical 	5 µm typical Automotive - 9µm Space grade 
Termination:	Ag base, Ni barrier, Sn or SnPb finish: 	Cu base, FLEXITERM®, Ni barrier, Sn or SnPb finish: 

Excerpt from:

Section A NASA 311-INST-001

Guidance From NASA

311-INST-001

PURPOSE

The purpose of this document is to establish a baseline criteria for the selection, screening and qualification of Electrical, Electronic, and Electromechanical (EEE) parts intended for use in GSFC space systems. This will assist project managers to develop effective EEE parts program requirements, based on mission reliability objectives and budget constraints, and will also assist the contractors and subcontractors in implementing those program requirements for specific projects.

311-INST-001
REVISION A

INSTRUCTIONS FOR EEE PARTS SELECTION, SCREENING, AND QUALIFICATION

AUGUST 1996

Prepared by:
The Parts Branch
Office of Flight Assurance
Goddard Space Flight Center

Excerpt from:

Section A NASA 311-INST-001

Capacitors included

Part Family	Capacitor Style and Type		Reference Specification	FAILURE RATE LEVEL REQUIRED 2/ Level 1	Level 2	Level 3
CERAMIC	CCR	Encapsulated	MIL-C-20	S 6/	R 6/	P
	CKR	Encapsulated, Feed-Thru	MIL-C-39014	3/ 6/	S 6/	R
	CKS	Encapsulated / Chip	MIL-C-123	X	X	X
	CDR	Chip	MIL-C-55681	S 6/	R 6/	P
	HVR	High Voltage	MIL-C-49467	S	R	P
	PC	Variable (Non-ER)	MIL-C-14409	3/	3/	X
	CV	Variable (Non-ER)	MIL-C-81	3/	3/	X
	CPC	Single Plate	MIL-C-49464	S	R	P
	SMPS	Stacked Chips	DESC 87106	3/	3/	3/
			SCD	4/	4/	4/
			Commercial	4/	4/	4/
TANTALUM	CSR	Solid	MIL-C-39003	C 5/	B	B
	CSS	Solid	MIL-C-39003	C	B	B
	CWR	Chip (Solid)	MIL-C-55365	C 5/	B	B
	CLR	Foil (Wet)	MIL-C-39006	R	P	P
			SCD	4/	4/	4/
			Commercial	4/	4/	4/
MICA	CMS	Fixed, High Reliability	MIL-C-87164	X	X	X
	CMR	Fixed, Established Reliability	MIL-C-39001	3/	3/	R
			SCD	4/	4/	4/
			Commercial	4/	4/	4/
PAPER OR PLASTIC FILM	CQR	Foil, Hermetically Sealed	MIL-C-19978	3/	3/	R
	CHR	Metallized, Hermetically Sealed, DC and AC	MIL-C-39022	3/	3/	R
	CHS	Supermetallized, Hermetically Sealed, DC	MIL-C-87217	X	X	X
	CRH	Metallized, Hermetically Sealed, DC, AC, or DC and AC	MIL-C-83421	S	R	R
			SCD	4/	4/	4/
			Commercial	4/	4/	4/
GLASS	CYR	Established Reliability	MIL-C-23269	S	R	P
			SCD	4/	4/	4/
			Commercial	4/	4/	4/

Excerpt from:

Section A NASA 311-INST-001

Capacitor Screening Requirements

Table 2 CAPACITOR SCREENING REQUIREMENTS (Page 1 of 3)

Inspection/Test	Test Methods, Conditions and Requirement 1/	Part Type/ Level																					
		Ceramic			Plastic			Tantalum			Glass			Mica			Variable			RFI Feed-Thru			Switch Mode Power Supply		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1. a. Visual and mechanical Examination. b. Electrical Measurements	Optional for all grades. Same as step 10 and step 5.																								
2. Thermal Shock	MIL-STD-202, Method 107, Condition B, -55°C to +125°C	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
3. Voltage Conditioning (Burn-In)	2 x Rated Voltage, 125°C, 160 hours 125°C, 96 hours 125°C, 48 hours	X												X						X			X		
			X												X						X			X	
				X												X						X			X
	140% rated voltage, 125°C, 48 hours				X	X	X										X	X							
	1.2 x rated AC voltage at maximum rated frequency 160 hours 96 hours 48 hours																			X					
																					X				
																						X			
	Rated voltage 85°C 48 hours							X	X	X															
	3 x rated voltage room temp., 48 hours										X	X													

Notes at end of Table 2

Excerpt from:

Section A NASA 311-INST-001

Capacitor Screening Requirements

Table 2 CAPACITOR SCREENING REQUIREMENTS (Page 2 of 3)

Inspection/Test	Test Methods, Conditions and Requirement 1/	Part Type/ Level																											
		Ceramic			Plastic			Tantalum			Glass			Mica			Variable			RFI Feed-Thru			Switch Mode Power Supply						
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3				
4. Surge Current	MIL-C-39003/10							X																					
5. High Impedance temp. and voltage ramp 2/	5 cycles, -55°C to 100°C in accordance with MIL-C-87217 4.7.4				X																								
6. Electrical measurements	As specified. 3/																												
Capacitance	MIL-STD-202, Method 305	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Dissipation Factor		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
DWV	MIL-STD-202, Method 301	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				
Insulation Resistance 1	MIL-STD-202, Method 302	X	X	X	X	X	X				X	X		X	X	X	X	X	X	X	X	X	X	X	X				
Insulation Resistance 2	Repeat at 125°C	X			X			X			X			X			X			X			X						
DC Leakage 1	MIL-STD-202, Method 301							X	X	X																			
DC Leakage 2	Repeat at 85°C							X																					
Equivalent Series Resistance Quality Factor Driving Torque Insertion Loss								X	X								X X	X X	X	X	X	X							
7. Percent Defective Allowable	5% 10% 20%	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X				

Notes at end of Table 2

Excerpt from:

Section A NASA 311-INST-001

Capacitor Screening Requirements

Table 2 CAPACITOR SCREENING REQUIREMENTS (Page 3 of 3)

Inspection/Test	Test Methods, Conditions and Requirement 1/	Part Type/ Level																					
		Ceramic			Plastic			Tantalum			Glass			Mica			Variable			RFI Feed-Thru			Switch Mode Power Supply		
		1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
8. Partial Discharge 4/	MIL-C-49467 Appendix B	X	X																						
9. Seal Test (Hermetic Types Only)	MIL-STD-202, Method 112																								
Gross Leak	Condition A or B				X	X		X	X											X	X				
Fine Leak	Condition C				X			X												X					
10. Radiographic Inspection	MSFC-STD-355C	X			X			X						X			X			X			X		
11. Visual and Mechanical Examination	Dimensions, Marking, Workmanship	X	X		X	X		X	X		X	X		X	X		X	X		X	X		X	X	
12. Humidity Steady State, Low Voltage 5/	MIL-STD-202, Method 103, Condition A and MIL-C-123, Pargraph 4.6.16.1	13(0) 5(0)																					5(0)	5(0)	

Notes:

1/ User should refer to the nearest equivalent military specification listed in Table 2A if required for better definition of testing requirements.

2/ Required only for metallized polycarbonate low energy, high impedance capacitors similar to those specified by MIL-C-87217.

3/ It is the responsibility of the user to define minimum and maximum values for each parameter (pass/fail criteria) and delta criteria, if applicable. These values should be based on the nearest equivalent military specification, manufacturer specifications, or the application, whichever is most stringent.

4/ Required only for high voltage capacitors similar to those specified by MIL-C-49467. This test requirement may affect capacitor design and should be performed by the manufacturer. If performed only by the user, it could result in a high probability of failure.

5/ Required only for capacitors with applied voltage of 10 volts or less. Parts shall be tested with zero failures allowed.

Excerpt from:

Section A NASA 311-INST-001

Capacitor Screening Requirements

Table 2A EQUIVALENT MILITARY SPECIFICATIONS

Ceramic MIL-C-123 MIL-C-39014 MIL-C-49467 Multilayer, High Voltage MIL-C-55681 Chip, Multiple Layer MIL-C-49464 Chip, Parallel Plate	**Glass** MIL-C-23269 **Mica** ~~MIL-C-39001~~ MIL-C-87164
Plastic (Paper Plastic) MIL-C-55514 Nonmetal MIL-C-83421 Metallized, Hermetic MIL-C-87217 Supermetallized, Low Energy High Impedance	**Filter** MIL-C-83439 EMI Suppression MIL-F-28861 **Variable** ~~MIL-C-14409 Piston, Tubular Trimmer~~
Tantalum MIL-C-39003 Solid Electrolyte MIL-C-39006 Nonsolid Electrolyte MIL-C-83500 Nonsolid Electrolyte MIL-C-55365 Chip	**Switch Mode Power Supply** DESC 87106

Excerpt from:

Section A NASA 311-INST-001

Ceramic Qualification Table Requirements

Table 3A CERAMIC CAPACITOR QUALIFICATION REQUIREMENTS 1/ 6/ (Page 1 of 3)

Inspection/Test 5/	Test Methods, Conditions and Requirements	Notes	Quantity (Accept Number) Level 1	Level 2	Level 3
Group 1 Screening to Table 2	Table 2	1/ 2/	100% X	100% X	100% X
Group 2 Voltage/Temperature Limits	Capacitance change over the range of temperatures and voltages specified shall not exceed limits of specification	2/	12(1) X	6(1) X	
Temperature Coefficient and Drift	Capacitance change over the range of temperatures specified shall not exceed limits of specification	2/	X	X	
Series Resonance (When required by application)	Refer to Electronics Industry Association EIA RS-483	2/	X	X	
Group 3 Terminal Strength	MIL-STD-202, Method 211 Condition A (all leaded devices) Condition C (radial leaded and DIP devices only) Condition D (axial leaded devices only)	2/, 4/	12(0) X	6(1) X	6(0)
Resistance to Solder Heat	MIL-STD-202, Method 210 Condition C (chips), Condition G (leaded) IR, ΔC and DF to specification	2/	X	X	

Notes at end of Table 3A

Excerpt from:

Section A NASA 311-INST-001

Ceramic Qualification Table Requirements

Table 3A CERAMIC CAPACITOR QUALIFICATION REQUIREMENTS 1/ 6/ (Page 2 of 3)

Inspection/Test 5/	Test Methods, Conditions and Requirements	Notes	Quantity (Accept Number) Level 1	Level 2	Level 3
Moisture Resistance	MIL-STD-202, Method 106 20 cycles (1st 10 cycles with Vrated applied) DWV, IR and ΔC to specification	2/	X	X (0)	
	MIL-STD-202, Method 103 Condition B, No bias DWV, IR and ΔC to specification				X
Group 4 Humidity, Steady State, Low Voltage (When required by application)	MIL-STD-202, Method 103 Vtest = 1.3 ± 0.25 Vdc IR, ΔC, and DF to specification	2/, 7/	12(0) X	6(0) X	
Group 5 Solderability	MIL-STD-202, Method 208	2/	5(0) X	3(0) X	
Destructive Physical Analysis	EIA RS-469	2/	X		
Group 6 Life (at elevated temp.)	MIL-STD-202, Method 108 Ttest = maximum operating temperature Vtest = 2 x Vrated Duration: Hours IR, ΔC, and DF to specification	8/ 2/	44(0) or 22(0) X 2000	44(1) or 22(1) X 1000	
Partial Discharge (AC Corona)	High Voltage Types (only) MIL-C-49467 Appendix B Corona Inception Voltage to specification	2/, 3/	X	X	

Notes at end of Table 3A

Excerpt from:

Section A NASA 311-INST-001

Ceramic Qualification Table Requirements - NOTES

Notes:

1/ Qualification shall consist of the tests specified in Table 3A in the order as shown. All parts submitted for qualification testing shall be subjected to screening tests. These sample units shall then be divided as shown in Table 3A for Groups 3 through 7 and subjected to the tests for their particular group. The user must subject an appropriate number of samples to screening tests to meet the PDA requirement and still have enough passing samples for Groups 3 through 7.

2/ It is the responsibility of the user to specify the appropriate test conditions and define the pass/fail criteria for each inspection. These values shall be based on the nearest equivalent military specification, the manufacturer's specification, or the application, whichever is most severe. Refer to Table 1 for the nearest equivalent military specification.

3/ This test is applicable to high voltage styles only.

4/ This test is not applicable to chip capacitors.

5/ Qualification tests which are performed to the nearest equivalent military specification, using grouping and sample sizes from the military specification, are acceptable if they satisfy the minimum requirements specified in Table 3A

6/ Generic 2 data is an acceptable basis for qualification for the indicated tests.

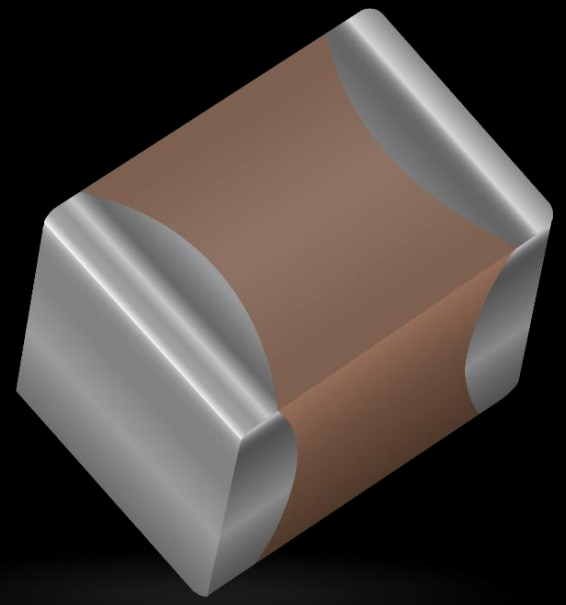
7/ Humidity steady state, low voltage test is applicable for parts being used in low voltage applications (< 10 Vdc).

8/ When qualifying a range of capacitance values and voltage ratings, quantities for the life test group shall be selected as follows:

If Qualifying:	Select:
Risk Level 1 and 2	
A single value and voltage rating	22 parts of the same value and voltage rating
A range of values in a single voltage rating	11 parts of the highest value and 11 parts of the lowest value in the range
A range of values in a range of voltage ratings	11 parts of the highest value and 11 parts of the lowest value in the highest voltage rating
	11 parts of the highest value and 11 parts of the lowest value in the lowest voltage rating
Risk Level 3	
A single value and voltage rating	10 parts of the same value and voltage rating
A range of values in a single voltage rating	5 parts of the highest value and 5 parts of the lowest value in the range
A range of values in a range of voltage ratings	5 parts of the highest value and 5 parts of the lowest value in the highest voltage rating
	5 parts of the highest value and 5 parts of the lowest value in the lowest voltage rating

MLCC Capacitors:

MIL-PRF-123
MIL-PRF-55681
MIL-PRF-32535



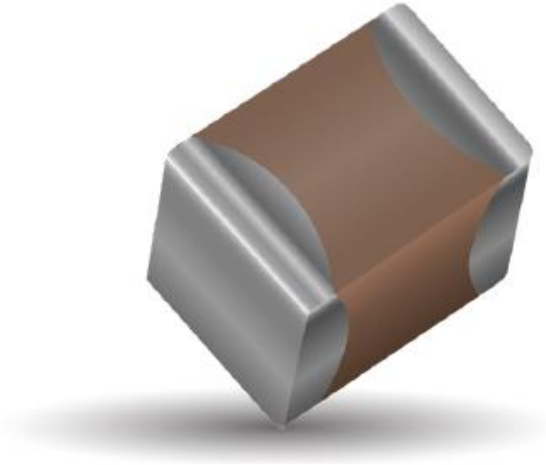
Parameter	MIL-PRF-123	MIL-PRF-55681	MIL-PRF-32535
Case Size Range			0201,0402,0603,0805,1206,1210, 1812,2220; 0306,0508 in qualification
Value Range			1pf to 22uf
Voltage Range			10v to 200v
Material & Design			
Material Systems	PME only	PME only	PME or BME
Design Modifications	>/= 0.8 Mil dielectric thickness	No requirement	No requirement
Termination options	Ag/Ni/Au; Pd/Ag; BME barrier with Sn/Pb finish	No 100% Sn	See table next slide
Testing & Inspection			
DPA	Sample per Mil-PRF-123 table	Not Required	Sample per EIA 469 + additional spec requirements
Non Destructive Test	Yes – 100%	Not Required	Yes- 100% CSAM x 2 Pre / Post term
Group A Thermal Shock	20 cycles per Mil-PRF-123	None	20 Cycles per Mil STD 202
Voltage Conditioning	168 hours min., 264 hours max; PDA <0.1% or 1 Part in the last 24 hours	100 hours	T Level 168 hr - 264 hr max; PDA <0.2% or 1 Part in last 48 hours ; M 100 hrs
	2% or 3% Overall PDA Depending on case size	8% overall PDA	T 5% , M 8% PDA
Hot IR (125c)	100% inspection	Sample	100% Inspection
Visual Inspection	100% inspection	Sample	100% Inspection
85c/85% RH	Group B every lot Low Voltage	Required every 6 months	Every Lot Sample test Rated Voltage
Group B Thermal Shock	100 Temp. Cycles Each lot	None	T level 100 cycles , M 5 cycles
Group B life	1000 hours each lot	Required every 6 months	1000hrs each lot

MIL-PRF-123	MIL-PRF-32535 (T level)	MIL-PRF-32535 (M level)
MIL-PRF-123 / In-Process	**Mil-PRF-32535 / In-Process (T level)**	**Mil-PRF-32535 / In-Process (M level)**
100% Nondestructive Internal Examination	100% Nondestructive Internal Examination	Not applicable
Pre-termination DPA (Sample)	Not applicable	Not applicable
100% Visual Examination	100% Visual Examination	Not applicable
Post-termination DPA (Sample)	Not applicable	Not applicable
MIL-PRF-123 / GROUP A	**Mil-PRF-32535 / GROUP A (T level)**	**Mil-PRF-32535 / GROUP A (M level)**
Thermal Shock (20 cycles)	Thermal Shock (20 Cycles), 100% CSAM (sizes ≥ 0805 only)	Not applicable
Voltage Conditioning (Burn-in) at 125ºC @ 168 hours (Accelerated conditions allowed) 3% PDA (BI & all post electrical)	Voltage Conditioning (Burn-in) at 125ºC @ 168 hours at 2X voltage (Accelerated conditions allowed) 5% PDA (BI & all post electrical)	Voltage Conditioning (Burn-in) at 125ºC @ 100 hours at 2X voltage (Accelerated conditions allowed) 8% PDA (BI & all post electrical)
100% Insulation Resistance at 125ºC	100% Insulation Resistance at 125ºC	Sample Insulation Resistance at 125ºC
100% Cap / DF / DWV / IR / Visual	100% Cap / DF / DWV / IR / Visual	100% Cap / DF / DWV / IR / Visual
Sample inspection for visual and mechanical characteristics	Sample inspection for visual and mechanical characteristics	Sample inspection for visual and mechanical characteristics
Final DPA (Sample)	Final DPA (Sample)	Not applicable
Not applicable	Solderability (term D, R, & Z), Bond Strength (wire) (term G & V), Shear stress (term M)	Solderability (term D, R, & Z), Bond Strength (wire) (term G & V), Shear stress (term M)
MIL-PRF-123 / GROUP B	**MIL-PRF-32535 / GROUP B (T level)**	**MIL-PRF-32535 / GROUP B (M level)**
Every Lot	***Every Lot***	***Periodic Inspection every 6 months***
Thermal Shock (100 cycles)	Thermal Shock (100 cycles)	Thermal Shock (5 cycles)
Life Test @ 1000 hours	Life Test @ 1000 hours	Life Test @ 1000 hours
Humidity, Steady-State, Low Voltage	Not applicable	Not applicable
Not applicable	Temperature Humidity bias (@ rated voltage)	Temperature Humidity bias (@ rated voltage)
Voltage-Temperature Limits	Voltage-Temperature Limits	Voltage-Temperature Limits
Moisture Resistance	Not applicable	Not applicable
Not applicable	Dielectric Voltage breakdown	Dielectric Voltage breakdown
Results are included with each shipment	Results are included with each shipment	Results are included with each shipment
MIL-PRF-123 / GROUP C	**Mil-PRF-32535 / GROUP C (T level)**	**Mil-PRF-3235 / GROUP C (M level)**
Periodic Inspection every 2 months	***Periodic Inspection every 3 months***	***Periodic Inspection every 3 months***

Capacitor: MIL-PRF-32535

MIL-PRF-32535

Capacitor, Chip, Fixed, Ceramic Dielectric (Temperature Stable and General Purpose), Extended Range, High Reliability and Standard Reliability, General Specification for



Specification Intent – To give designers a larger capacitance value product than those listed in MIL-PRF-123 and MIL-PRF-55681

Component Technology – MLCC Base Metal Electrode or Precious Metal Electrode

Component Range – 0201 to 2220, 1pf -18uf, 4v to 200v

Recent/Future Activity – Low inductance decoupling capacitor slash sheets – see next page

Special Features or concerns relative to other parts -
M level (standard reliability) and T level (high reliability)
T level capacitors are intended for space, missile, and other high reliability applications

A list of alternate parts – NOT EQUIVALENT PARTS
AEC Q200 MLCC
NASA
ESCC

MIL-PRF-32535

A list of alternate parts – NOTE NOT EQUIVALENT PARTS

Institution	Spec. name	Specification Details
NASA	S-311-P-838	Space-Level BME X7R MLCC
ESA / ESCC*	ESCC QPL 3009/04	0402 to 2220 SMT MLCC
Automotive Electronics Council	AEC Q200	Auto Grade MLCCs

Description	Commercial	Auto	ESCC - Space
Material	No restrictions, Frequent changes	Change Notice requires PCN	**No change allowed:** requalification / Re-audit
Chip Dimensions	No restrictions	Minimum thickness constraint	Minimum Thickness: **No change allowed –** requalification
Design	No restrictions, frequent changes	Major change requires PCN	**No change allowed:** requalification / Re-audit
Margins	>= 75um	>= 100um	>=170um
Cover Layers	>= 75um	>= 100um	>=112um
Dielectric Thickness	No restrictions, frequent changes	Major change requires PCN	**No change allowed:** requalification

Alternate part comparison – NOTE NOT EQUIVALENT PARTS

	Commercial	Automotive	Space
Mechanical	2mm board flex Smallest margins and cover layer	2mm board flex Superior material set Balanced dimensions for performance and cost	5mm board flex as standard Conservative design employs Largest margins /cover layers, and thick dielectric layers
Electrical	Highest CV range per case size High Voltage Coeff. factor VC Voltage breakdown closer to V_R	Consistent temperature and voltage characteristics Reasonable CV range	Lower CV Range Good ripple current handling Higher breakdown voltage Best VC performance
Reliability	No ratings. 1000 hr life test for small sample No PCN process	Ratings based on 1000 hr life test and generic data for a family of parts. PCN process	Ratings based on 4000 hr life test and Lot Group B test (100hrs) . No changes - Full Qualification

Alternate part comparison – NOTE NOT EQUIVALENT PARTS

Test	Commercial	Automotive	M32535 T-Level
Operating Temperature	-55°C to 125°C	-55°C to 125°C	-55°C to 125°C
Capacitance	Within specified limits	Within specified limits	Within specified limits
Dissipation Factor	≤ 10% (≥ 50 RV), ≤ 12.5% (< 50 RV)	≤ 10%(≥ 50 RV), ≤ 12.5%(< 50 RV)	≤ 3% (≥ 50V), ≤ 5% (16-25V), ≤ 7.5% (10V), ≤ 10% (4-6.3V)
Insulation Res. (+25°C)	100,000MΩ or 1000MΩ-µF	MIL-STD-202	MIL-STD-202
Hot IR (+125°C)			MIL-STD-202
Dielectric Withstanding V	250% of RV for 1-5 seconds	250% of RV	250-400% of RV for 5 +1 seconds
Board Flex	2mm deflection for 30 seconds	AEC-Q200-005, 60 seconds	2mm min. for 60 seconds
Solderability	≥ 95% coverage	J-STD-002	MIL-STD-202
Solder Heat Resist.	C ≤ +7.5%. DF, IR, DWV meets IL	J-STD-002	MIL-STD-202
Thermal Shock	C ≤ +7.5%. DF, IR, DWV meets IL, 5 cycl		MIL-STD-202, 100 cycles
Operational Life	C ≤ 12.5%, DF ≤ 2x IL, IR ≥ 0.3x IL, (1.5x or 2x RV) 1000 hrs	MIL-STD-202, 1000 hrs	MIL-STD-202, 4000 hrs, C ≤ 20%, DF ≤ IL, IR/Hot IR ≥ 0.3x IL
Temp. Humidity Bias	C ≤ 12.5%, DF ≤ 2x IL, IR ≥ 0.3x IL, (85/85) 1000 hrs	MIL-STD-202, (85/85) 1000 hrs	MIL-STD-202, (85/85) 1000 hrs
DPA		EIA-469	EIA-469
Visual Examination		MIL-STD-883	MIL-PRF-32535 Appendix B
Physical Dimension	Within specified limits	JESD22	MIL-PRF-32535 Appendix B

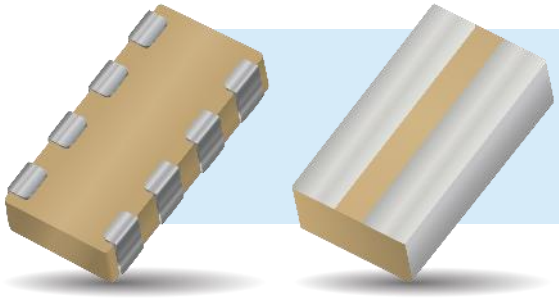
Alternate part comparison – NOTE NOT EQUIVALENT PARTS

Test	Commercial	Automotive	M32535 T-Level
Material			MIL-STD-790
Design			MIL-PRF-32535 Appendix B
Construction		MIL-STD-883	MIL-PRF-32535 Appendix B
Marking		MIL-STD-883	MIL-PRF-32535 Appendix B
Workmanship		MIL-STD-883	MIL-PRF-32535 Appendix B
Terminal Strength		MIL-STD-202 (leaded), AEC-Q200-006 (SMD)	MIL-STD-202
Mechanical Shock		MIL-STD-202	
Vibration		MIL-STD-202, 5g's, 20 minutes, 12 cycles, 10-2000 Hz	
ESD		AEC-Q200-200 or ISO/DIS 10605	
Beam Load Test		AEC-Q200-003	
Resistance to solder heat		MIL-STD-202	MIL-STD-202
Shear Stress		AEC-Q200-006	MIL-PRF-32535, 60 seconds
Csam			2 x 100% Acoustic Micro Inspection
Thermal Shock / Cycle			100% x 20 Cycles
Voltage Conditioning			100% 2x RV for 168-264 hrs @125°C
Hot IR			100% @ 125C
Dielectric Voltage Breakdown			6x Rated Voltage or 1,200Vdc, whichever is less

Alternate part comparison – NOTE NOT EQUIVALENT PARTS

Parameter	Automotive BME	Space BME	Specification System
Pre-Inspection	none	100% visual sort; 100% CSAM	Mil
Electrical Test	100% C/DF+ 100% Volt/IR	100% C/DF+ 100% Volt/IR	
Q.A.	Life (1.5 to 2x rated voltage) + THB sample	Life (2x rated voltage) + THB sample	
Visual Sort	100% 2 - 4 side	100% 6 sided	
Q.C.	Sample Test – Completed - ship	Sample Test	
Inspection		100% CSAM	NASA/MIL
Burn In		100% @2x Rated Voltage 100% hot IR @125c, 100% Cap/DF + 100% V/IR	ESA/NASA/MIL NASA/MIL
Visual Sort		100% 6 sided	
QC		Sample tests – parameter	
QA		Group A/B - LVT	NASA/MIL
Data Pack + C of C		Every lot	

MIL-PRF-32535



Recent/Future Activity:
Low inductance decoupling capacitor slash sheets qualification activity.

MIL-PRF-32535/9
Reverse geometry 0306 package

MIL–PRF-32535/10
Reverse geometry 0508 package

Specification Intent

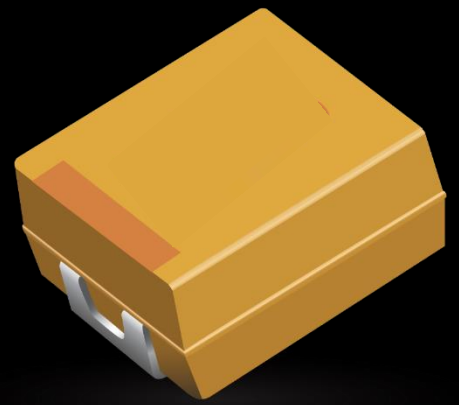
To offer designers a low inductance, high reliability MLCC.

Component Range & Special Features Or Concerns Relative To Other Parts

0306 32535/9		
Cap nf	**Voltage**	**Dielectric**
1 - 68	25	X7R
100	16	X7R

0508 32535/10		
Cap nf	**Voltage**	**Dielectric**
1-100	50	X7R
150 -220	16	X7R
470 -1000	10	X7R

Capacitor: MIL-PRF-55365



MIL-PRF-55365

CAPACITOR, FIXED, ELECTROLYTIC (TANTALUM), CHIP, ESTABLISHED RELIABILITY, NONESTABLISHED RELIABILITY, AND HIGH RELIABILITY, GENERAL SPECIFICATION FOR

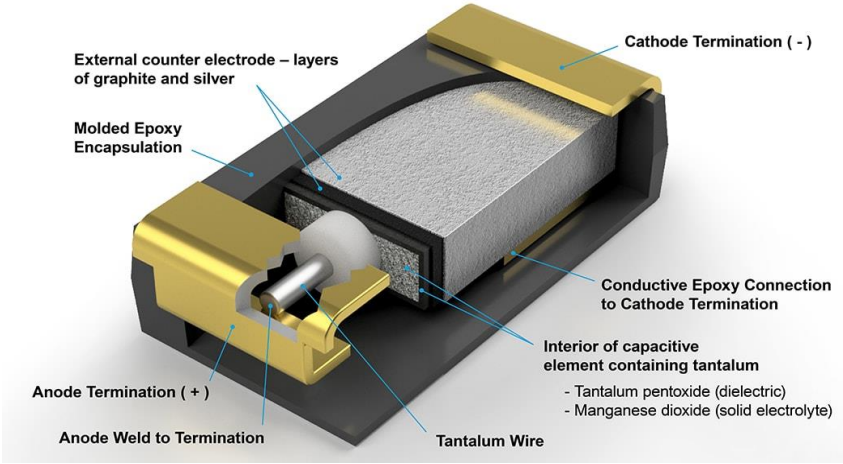
Specification Intent – To give designers bulk capacitance of non-ER, ER and high reliability tantalum dielectric capacitors, for use in thick & thin film hybrids or SMT applications of filter, bypass, coupling …..

Component Technology – Tantalum SMT – lead frame and non lead frame

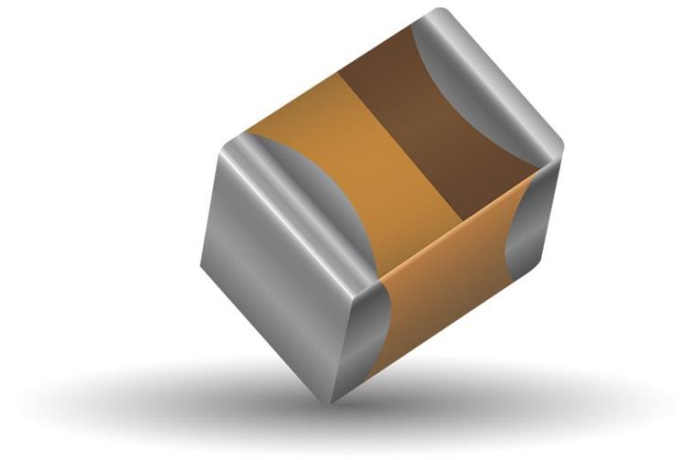
Component Range – CWR06, 09, 11, 15, 16, 19, 29

Recent/Future Activity – Addition of Tantalum Polymer Capacitors

Special Features or concerns relative to other parts -
Weibull and Exponential Failure rate grading
Optional Surge tests at various temperatures before or after reliability grading



A list of alternate parts – NOTE NOT EQUIVALENT PARTS
AEC Q200 Tantalum
COTS
ESCC Generic Specification 3012 –
CAPACITORS, LEADLESS SURFACE MOUNTED, TANTALUM, SOLID ELECTROLYTE, ENCLOSED ANODE CONNECTION



High Level Commercial / Auto/ Military Grade Material & Design Comparison

	Commercial / Automotive	Military
Powder Type	Leading Edge Small particle size, and high O2 content. Higher leakage	Conservative Larger particle size for thicker dielectric and lower O2 concentration
Formation Ratio (Dielectric Thickness)	2 times R.V. or less	3 to 4 times R.V.
Reliability Level	1%/1000 Hours, 60% confidence No individual lot characterization	0.1%/1000 Hours Minimum, 90% Confidence based on individual lot performance
DC Leakage	0.01CV Maximum	0.01 CV Maximum
Rating Design	Multiple Variations, no lot-to-lot control of design or Ta powder	Consistent and strictly controlled
Design Changes	No Change Notifications	PCNs to DLA for changes in design, raw materials, process, etc.
Intended Application	Consumer / Automotive	Military / Aerospace / Hi-Rel

High Level TESTING Comparison COTS- Plus to std Mil & Mil T Level

	COTS-Plus	MIL-PRF-55365 Standard CWR	MIL-PRF-55365 CWR "T" LEVEL
REFLOW CONDITIONING	YES	YES	YES
THERMAL SHOCK	YES	YES	YES
SURGE CURRENT C	ON REQUEST	ON REQUEST	YES
WEIBULL BURN-IN B / C / D	ON REQUEST	YES	C LEVEL MINIMUM
SURGE CURRENT A / B	ON REQUEST	ON REQUEST	NO
ELECTRICAL SCREENING	SPECIFICATION OR CUSTOM TEST LIMITS AVAILABLE	SPECIFICATION LIMITS	+3 SIGMA LIMITS (ESR and DCL)
REAL TIME MICROFOCUS X-RAY	NO	NO	100%
DPA – DESTRUCTIVE PHYSICAL ANALYSIS (SAMPLE)	NO	NO	YES
VISUAL AND MECHANICAL INSPECTION	YES (Sample)	YES (Sample)	YES (100% 20x)
TEMPERATURE STABILITY TEST (SAMPLE)	ON REQUEST	YES	YES
SOLDERABILITY (SAMPLE)	ON REQUEST	YES	YES
FUNCTION TEST (SAMPLE)	NO	NO	NO
SURGE VOLTAGE TEST (SAMPLE)	NO	NO	NO
HOT DC LEAKAGE TEST (SAMPLE)	NO	NO	NO
LIFE TESTING (SAMPLE)	NO	NO	YES, INCLUDED IN GROUP C
GROUP C (SAMPLE): MOUNTED THERMAL SHOCK RESISTANCE TO SOLDERING HEAT, MOISTURE RESISTANCE, 2000 HR. 125C LIFE, RESISTANCE TO SOLVENTS	NO	QUARTERLY PRODUCTION SAMPLE	YES ON EACH LOT, EXCEPT NO RESISTANCE TO SOLVENTS

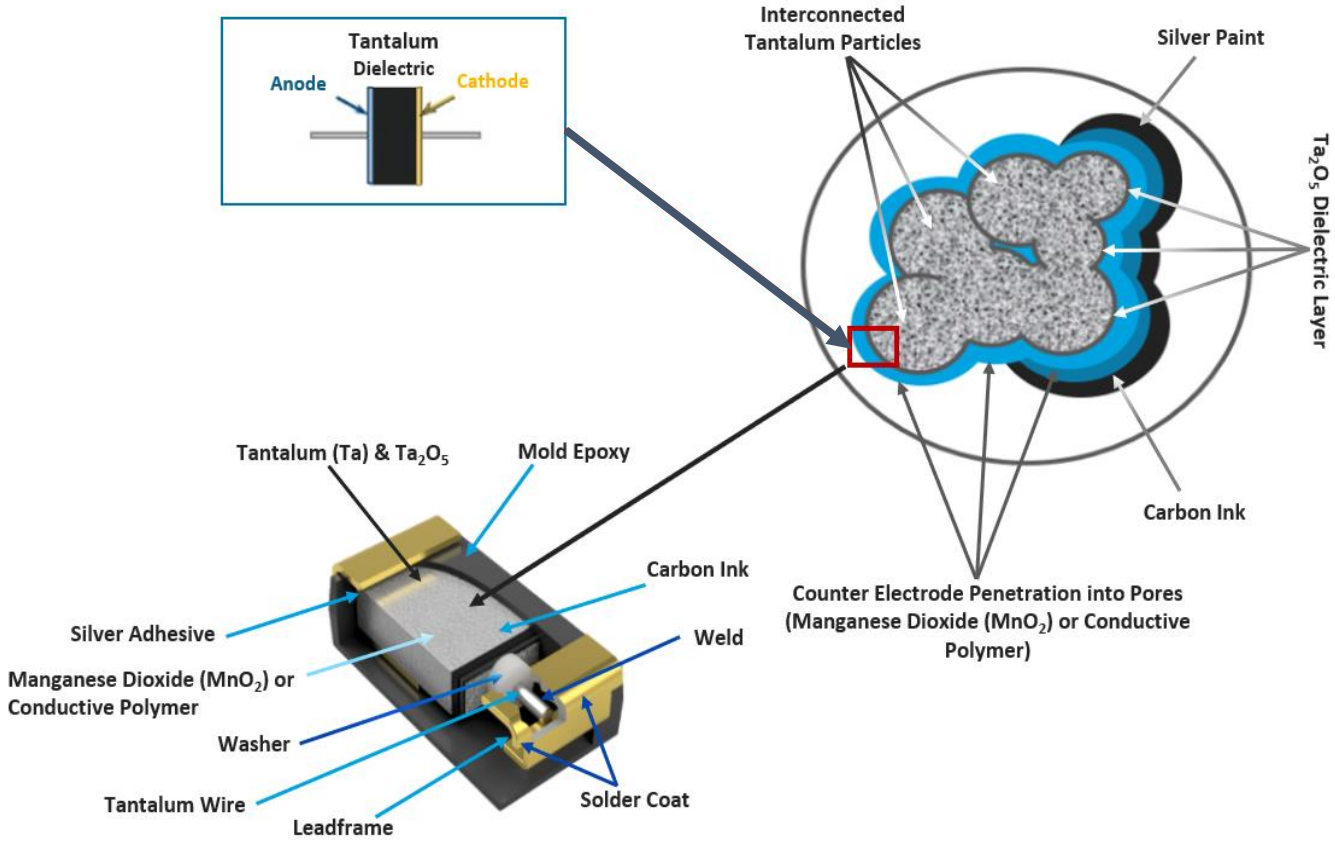
		Commercial / Industrial / Automotive			Avionic / MIL		MIL / Space Level
	Parameter / Test	Commercial Hi CV	Commercial / General Purpose	Professional / Automotive	COTSplus	MIL-PRF-55365 QPL	
						MIL Weibull B, C, D	MIL T Level
	Series:					CWR09 / 11/ / 15 / 19 /29	CWR09 / 11/ / 15 / 19 /29
Performance Specifications	Min Operating Temperature	-55°C	-55°C	-55°C	-55°C	-55°C	-55°C
	Max Operating Temperature	+40°C	+85°C	+85°C	+85°C	+85°C	+85°C
	Max Category Temperature	+125°C / derated 60%	+125°C / derated 33%	+125°C / derated 33%	+125°C / derated 33%	+125°C / derated 33%	+125°C / derated 33%
	Base Reliability (FR)	1% / 1000hrs / 60% conf	1% / 1000hrs / 60% conf	(0.5 - 1)% / 1000hrs / 60% conf	(0.01 - 0.1)% / 1000hrs / 90% conf	(0.001 - 0.1)% / 1000hrs / 90% conf	0.01% / 1000hrs / 90% conf
	Environmental (Humidity)	65°C / (90-95)% RH / 500hrs	65°C / (90-95)% RH / 500hrs	65°C / (90-95)% RH / 500hrs	65°C / (90-95)% RH / 500hrs	(10-65)°C / (90-95)% RH / 20 cycles	(10-65)°C / (90-95)% RH / 20 cycles
	Environmental (Biased Humidity)			85°C / (85)% RH / 1000hrs @ rated volts			
Preconditioning	100% Reflow	✓	✓	✓	✓	✓	✓
	100% Thermal Shock	✓	✓	✓	✓	✓	✓
	100% Voltage Aging	(2 - 4)hrs	(2 - 4)hrs	(2 - 4)hrs	Optional Weibull	Mandatory Weibull	Mandatory - Weibull - Grade C min
	100% Surge Current	(1 - 2) Cycles / 25°C	(1 - 2) Cycles / 25°C	(2 - 4) Cycles / 25°C	Optional A, B or C	Optional A, B or C	Mandatory - C Surge
	Simulated mounting (reflow)	✓	✓	✓			
	Surge Voltage						
100% Test	100% Electrical Testing (Cap, DF, ESR, Z, DCL)	To specification limits only	To specification limits only	Custom test limits available	Custom test limits available	To specification limits only	+ 3 sigma Limits
	100% Visual & Mechanical						✓
	100% X-Ray						✓
Lot Conformance	Simulated mounting, rework and Lot Conformance.						
	Solderability Test - 8hr Steam Age				Optional - 75% Coverage	Mandatory - 90% Coverage	Mandatory - 90% Coverage
	Hot DC Leakage						
	Visual & Mechanical				✓	✓	✓
	DPA - 1580 Destructive Physical Analysis						✓
	Temperature Stability				Optional	Mandatory	Mandatory

IMPORTANT Tantalum Polymer Ongoing Work: Potential exists for a 55365 'LIKE' TaPoly MIL-PRF

Why Tantalum and Polymer?

Reduced ESR | Increased Current | Lowered Inductance | 125v ratings **(GaN)**

	Lowest ESR Available Large Case Sizes (mΩ)	DC Leakage Catalog	DC Leakage Performance
MnO_2 Tantalum	65 – 500	0.01 CV	0.0025 CV
Multi-anode Tantalum	18 – 100	0.01 CV	0.0025 CV
Polymer	5 - 250	0.1 – 0.05 CV	0.05 CV



IMPORTANT Tantalum Polymer Ongoing Work: Potential exists for a 55365 'LIKE' TaPoly MIL-PRF

Why Tantalum Polymer? Efficient electrical performance with manageable and predictable risks

Feature / Performance	MnO_2 Tantalum	Polymer Tantalum
High Temperature Storage	No Concern	Potential for degradation of AC characteristics
Moisture Sensitivity Level	MSL 1 to MSL 3	MSL 3 - 5
Humidity Sensitivity Post Mounting	No Concern	Wear out accelerated by temperature and voltage
Anomalous Transients	No Concern	Occurs under dry conditions
Oxidation	No Concern	Wear out accelerated by temperature
ESR	Low ESR in standard Ultra-low ESR in multi-anode	Ultra-Low ESR Single digit mΩ in multi-anode
DCL Performance	Ultra-low	Medium to High DCL

IN PROGRESS – MIL TaPoly Capacitor Option

- Low ESR and Surge Robust.
- AEC-Q200 Mechanical Design.
  - 500h 85°C / 85%RH / Ur Capability.
- Individual Lot Reliability Assessment.

Technology Comparison

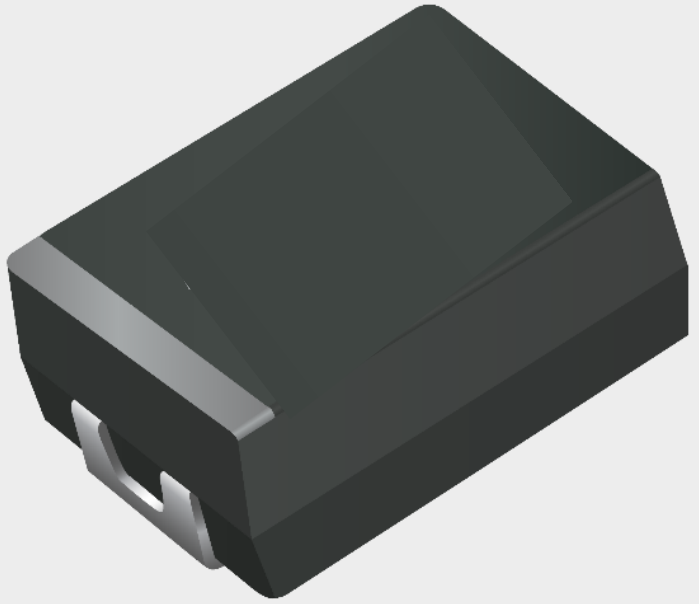
MnO_2 Tantalum:

- No known wear out mechanism.

- Provides infinite parametric lifetime.

Polymer Tantalum:

- Parametric change in Capacitance & ESR over time at high temperatures & voltages from cathode material oxidation.
- Parametric Lifetime can be calculated for a given application and accommodated for in initial design.



TaPoly Capacitor Emerging Flight Approvals

Hermetic and Non Hermetic case TaPoly Capacitors

Hermetic package – ceramic can
ESA approved

Technology Comparison

MnO_2 Tantalum:

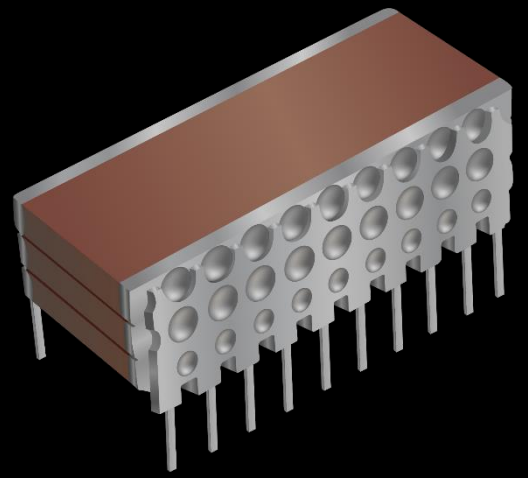
- **No known wear out mechanism**
- Provides infinite parametric lifetime

Hermetic SMD Polymer Tantalum example:

- Hermetic design eliminates oxidation effects to cathode and results in no parametric degradation over time.

Molded plastic case
ESA approved

Stacked MLCC Capacitor: MIL-PRF-49470



MIL-PRF-49470

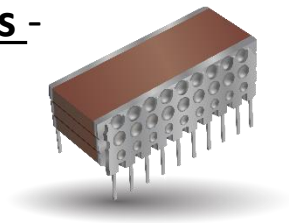
CAPACITOR, FIXED, CERAMIC DIELECTRIC, SWITCH MODE POWER SUPPLY (GENERAL PURPOSE AND TEMPERATURE STABLE), STANDARD RELIABILITY AND HIGH RELIABILITY, GENERAL SPECIFICATION FOR

Specification Intent – To give designers a larger capacitance value in high voltages with LOW ESR.

Component Technology – MLCC Precious Metal Electrode stacked vertically in lead frame. The SMPS capacitors are designed for high current, high-power and high-temperature applications. These capacitors have very low ESR (Equivalent Series Resistance) and ESL (Equivalent Series Inductance). MIL-PRF-49470 SMPS Series capacitors are primarily used in input/output filters of high-power and high-voltage power supplies as well as in bus filters and DC snubbers for high power inverters and other high-current applications.

Component Range – 56nf to 270 uf, 50v to 500v,

Special Features or concerns relative to other parts -
B level (standard reliability)
T level (high reliability)



A list of alternate parts – NOTE NOT EQUIVALENT PARTS
AEC Q200 Stacked MLCC (limited)
DSCC Drawings
COTS

Typical ESR Performance (mΩ)

	Aluminum Electrolytic 100µF/50V	Low ESR Solid Tantalum 100µF/10V	Solid Aluminum Electrolytic 100µF/16V	MLCC SMPS 100µF/50V	MLCC SMPS 4.7µF/50V
ESR @ 10KHz	300	72	29	3	66
ESR @ 50KHz	285	67	22	2	23
ESR @ 100KHz	280	62	20	2.5	15
ESR @ 500KHz	265	56	18	4	8
ESR @ 1MHz	265	56	17	7	7.5
ESR @ 5MHz	335	72	17	12.5	8
ESR @ 10MHz	560	91	22	20	14

Resistors

RESISTOR CATEGORIES PER MIL-HDBK-199DB

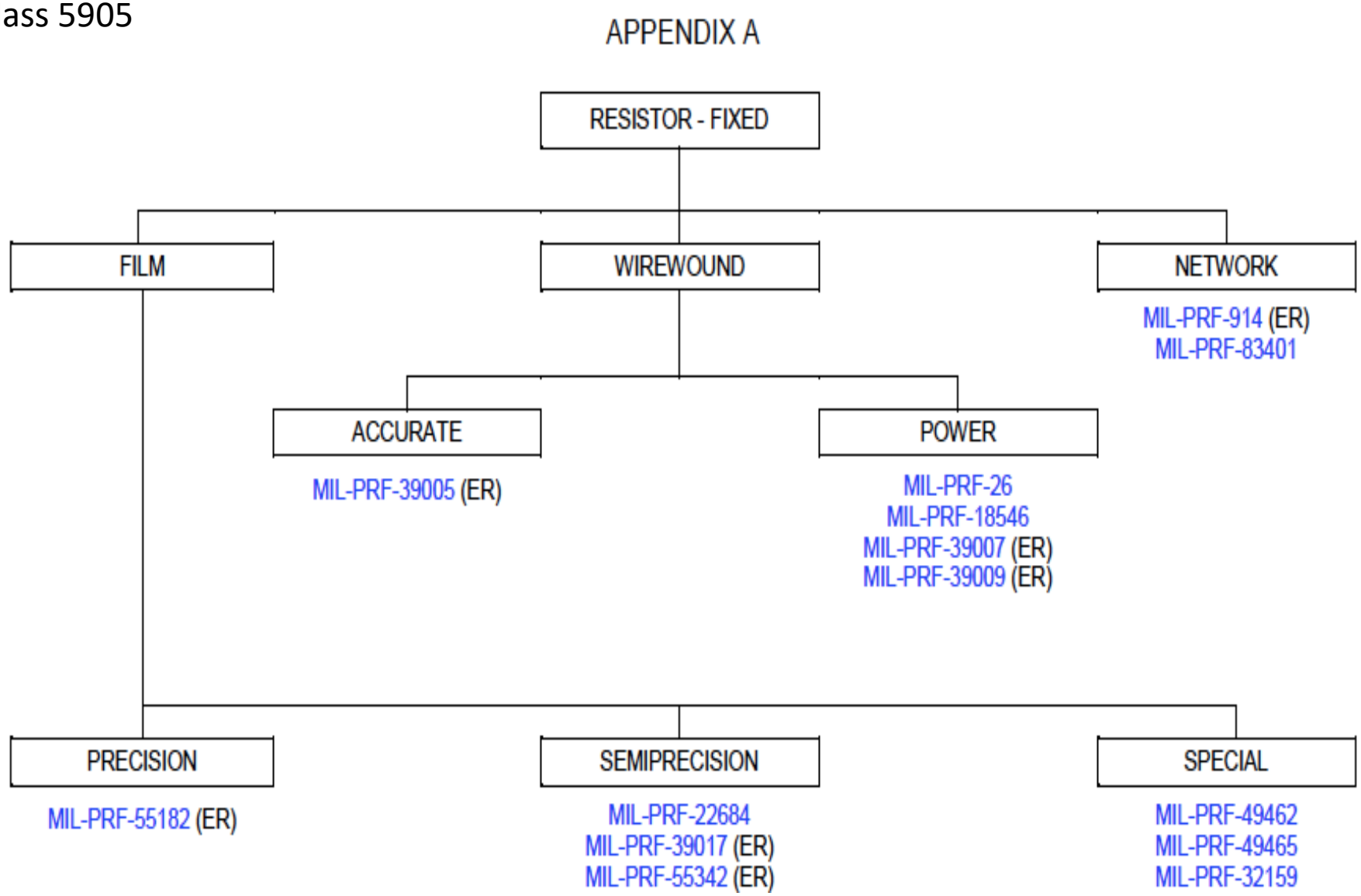
Fixed Film	MIL-PRF-22684	RL42..TX, Resistor, Fixed, Film, Insulated
	MIL-PRF-32159	RCZ, Resistor, Chip, Fixed, Film, Zero Ohm, Industrial, High Rel., Space Level
	MIL-PRF-39017	RLR, Resistor, Fixed, Film, Insulated, Non ER and ER
	MIL-PRF-49462	RHV, Resistor, Fixed, Film, High Voltage
	MIL-PRF-49465	RLV, Resistor, Fixed, Metal Element, Power Type, Very Low Resistance Value
	MIL-PRF-55182	RNC, RNN, or RNR, Resistor, Fixed, Film, Non ER, ER, Space Level
	MIL-PRF-55342	RM, Resistor, Chip, Fixed, Film, Non ER, ER, Space Level
Fixed WireWound	MIL-PRF-26	RW, Resistor, Fixed, Wirewound, Power Type
	MIL-PRF-18546	RE, Resistor, Fixed, Wirewound, Power Type, Chassis Mounted
	MIL-PRF-39005	RBR, Resistor, Fixed, Wirewound, Accurate, Non ER, ER
	MIL-PRF-39007	RWR, Resistor Fixed, Wirewound, Power Type, Non ER, ER, Space Level
	MIL-PRF-39009	RER, Resistor, Fixed, Wirewound, Power Type, Chassis Mounted, Non ER, ER
Fixed Film Networks	MIL-PRF-914	RNS, Resistor Network, Fixed, Film, Surface Mount, Non ER, ER
	MIL-PRF-83401	RZ, Resistor Network, Fixed Film, and C-R Networks, Ceramic Capacitor and Fixed Film Resistor
Variable Wire Wound	MIL-PRF-19	RA, Resistor, Variable, Wirewound, Low Operating Temperature
	MIL-PRF-22	RP, Resistor, Variable, Wirewound, Power Type
	MIL-PRF-12934	RR, Resistor, Variable, Wirewound, Precision
	MIL-PRF-27208	RT, Resistor, Variable, Wirewound, Nonprecision
	MIL-PRF-39002	RK, Resistor, Variable, Wirewound, Semi-Precision
	MIL-PRF-39015	RTR, Resistor, Variable, Wirewound, Lead Screw Actuated, Non ER, ER
Variable Non Wirewound Resistors	MIL-PRF-94	RV, Resistor, Variable Composition
	MIL-PRF-22097	RJ, Resistor, Variable, Nonwirewound, Adjustment Type
	MIL-PRF-39023	RQ, Resistor, Variable, Nonwirewound Precision
	MIL-PRF-39035	RJR, Resistor, Variable, Nonwirewound, Adjustment Type, Non ER, ER
Special Resistors	MIL-PRF-29	MF_, Resistor, Fixed, Meter Multiplier, External, High Voltage, Ferrule-Terminal Type
	MIL-PRF-23648	RTH, Resistor, Thermal (Thermistor) Insulated
	MIL-PRF-32192	NTC/PTC, Resistor Chip, Thermal
	MIL-PRF-83530	RVS, Resistor, Voltage Sensitive Resistor, Varistor, Metal-Oxide

1.2 Purpose of handbook.
a. To provide the equipment designer with a selection of std resistors for use in most DoD applications.

RESISTOR TUTORIAL

MIL HANDBOOK -199C

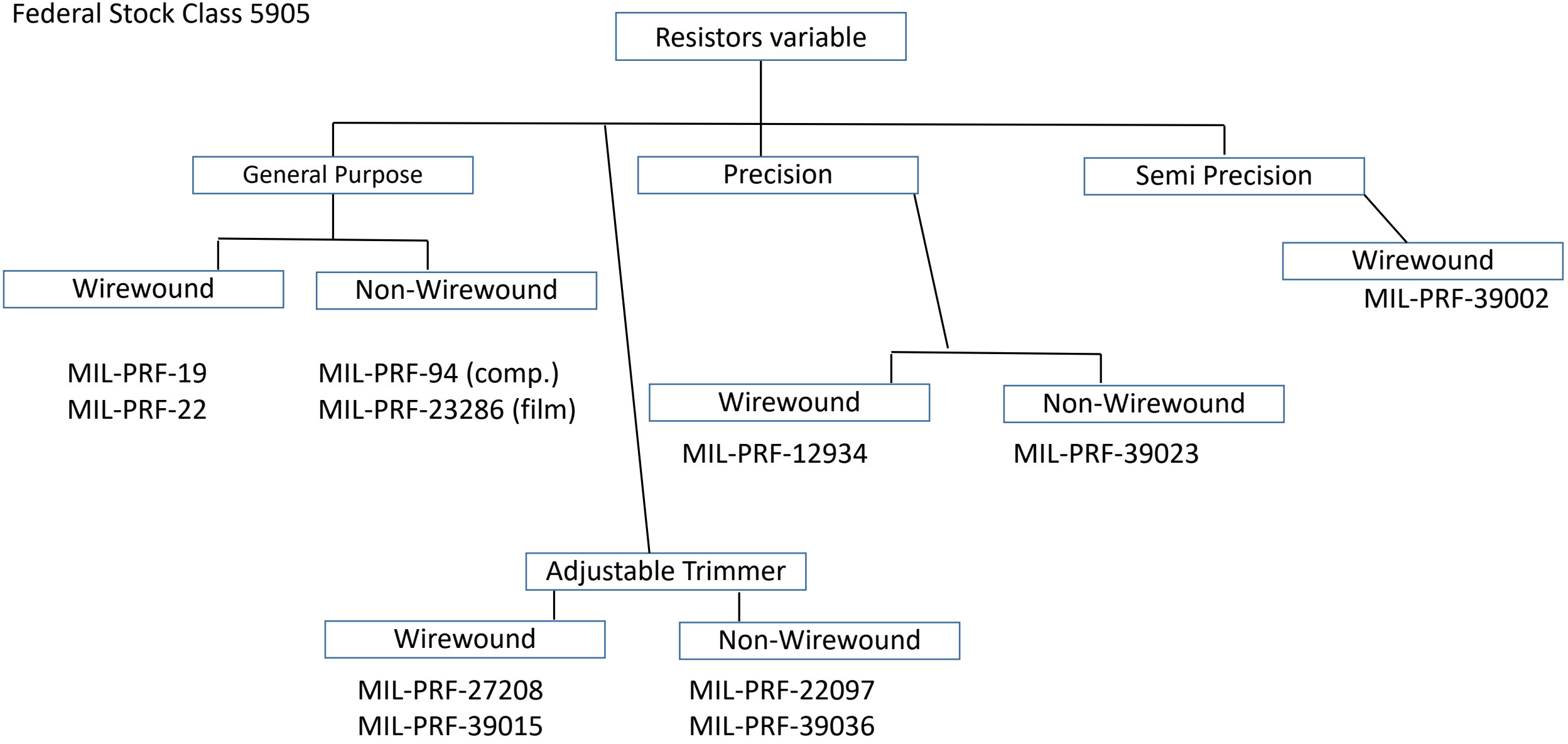
Federal Stock Class 5905



RESISTOR TUTORIAL

MIL HANDBOOK -199C

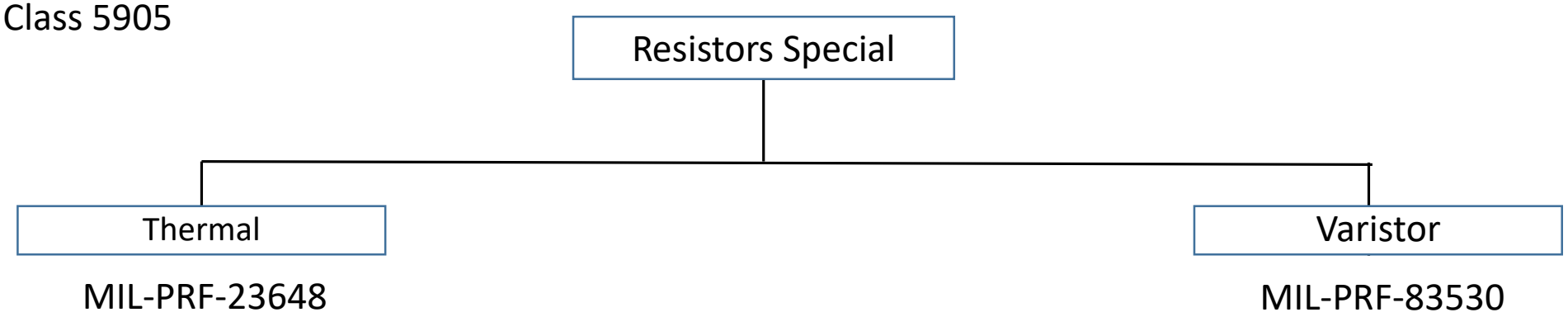
Federal Stock Class 5905



RESISTOR TUTORIAL

MIL HANDBOOK -199C

Federal Stock Class 5905



MIL-PRF-23648

MIL-PRF-83530

Excerpt: NASA Parts selector list Resistors

https://nepp.nasa.gov/npsl/Resistors/Res_type.htm

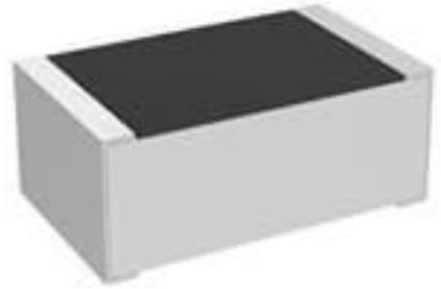
Film			Network	
MIL-PRF-39017	RLR		MIL-PRF-83401	RZ
MIL-PRF-55182	RNC/RNR			
MIL-PRF-55342	RM			
GSFC S-311-P-742	G311P742			
GSFC S-311-P-813	G311P813			
Wirewound			**High Voltage**	
MIL-PRF-39005	RBR	NO SOURCE AVAILABLE SINCE 2015	GSFC S-311-P-672	G311P672
MIL-PRF-39007	RWR		GSFC S-311-P-683	G311P683
MIL-PRF-39009	RER			
MIL-PRF-39015	RTR			

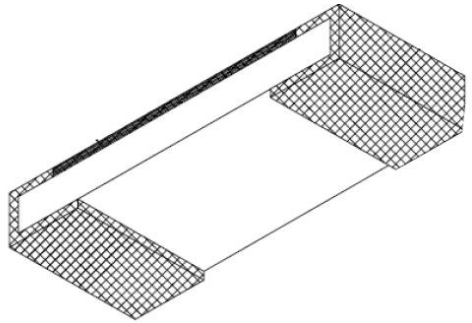
MIL PRF 55342

RESISTOR, CHIP, FIXED, FILM, NONESTABLISHED RELIABILITY, ESTABLISHED RELIABILITY, SPACE LEVEL, GENERAL SPECIFICATION FOR

MIL-PRF-55342

RESISTORS, CHIP, FIXED, FILM, NONESTABLISHED RELIABILITY, ESTABLISHED RELIABILITY, SPACE LEVEL, GENERAL SPECIFICATION FOR





Specification Intent – To give designers a highly stable resistor with a wide range of resistances and Failure rates from 1% to 0.001% per 1000 hours

Component Technology – Thin film technology

Component Range – 0402 to 2512, 1ohm to 22 Megohm, 15v to 200v

Special Features or concerns relative to other parts -

A list of alternate parts – NOT EQUIVALENT PARTS

AEC Q200

SCD

Medical Grade Devices

Guidance From NASA

311-INST-001

PURPOSE

The purpose of this document is to establish a baseline criteria for the selection, screening and qualification of Electrical, Electronic, and Electromechanical (EEE) parts intended for use in GSFC space systems. This will assist project managers to develop effective EEE parts program requirements, based on mission reliability objectives and budget constraints, and will also assist the contractors and subcontractors in implementing those program requirements for specific projects.

311-INST-001
REVISION A

INSTRUCTIONS FOR EEE PARTS SELECTION, SCREENING, AND QUALIFICATION

AUGUST 1996

Prepared by:
The Parts Branch
Office of Flight Assurance
Goddard Space Flight Center

Excerpt from:

Section L NASA 311-INST-001

Resistors included

Selection Priority	Resistor Style And Type		MIL/NASA/DESC Reference Specification	Failure Rate Level Required 2/		
				Level 1	Level 2	Level 3
Composition						
MIL Specification	RCR	Fixed, Established Reliability	MIL-R-39008	S	R, P	M
SCD				3/	3/	3/
Commercial				3/	3/	3/
Film/Foil						
MIL/NASA Specification	RFP	Fixed, Precision, Established Reliability	MIL-R-122	3/	B, F, J, N, R, V	A, E, I, M, Q, U
	RLR	Fixed, General Purpose, Established Reliability	MIL-R-39017	S	R, P	M
	RNX	Fixed, High Stability, Established Reliability	MIL-R-55182	S	R, P	M
	RM	Fixed, Chip, Established Reliability	MIL-R-55342	S	R, P	M
	RZ	Fixed, Network	MIL-R-83401	4/	4/	4/
	MOX	Fixed, High Voltage	S-311-P-683	5/	5/	5/
	HG	Fixed, High Voltage, Precision	S-311-P-672	5/	5/	5/
	TG	Fixed, High Voltage, Precision, Low TC	S-311-P-741	6/	6/	6/
	TK	Fixed, Precision, Low TC, Radial-Lead	S-311-P-742	5/	5/	5/
	TK	Fixed, Low TC, Precision, High Stability	S-311-P-794	6/	6/	6/
	VPR	Fixed, Foil, Precision, Power, Current Sensing	S-311-P-795	6/	6/	6/
	TK	Fixed, "Matched-Pair", Low TC, Precision	S-311-P-796	6/	6/	6/
	1285G	Potentiometer, Precision Trimming	S-311-P-798	6/	6/	6/
	RJR	Variable, Lead Screw, Established Reliability	MIL-R-39035	R	R, P	M
DESC		Fixed, Network, 20-Pin, Leadless Chip Carrier	87016	5/	5/	5/
SCD				3/	3/	3/
Commercial				3/	3/	3/
Wirewound						
MIL Specification	RBR	Fixed, Accurate, Established Reliability	MIL-R-39005	R	R, P	M
	RWR	Fixed, Power, Established Reliability	MIL-R-39007	S	R, P	M
	RER	Fixed, Power, Established Reliability	MIL-R-39009	R	R, P	M
	RTR	Variable, Lead Screw, Established Reliability	MIL-R-39015	R	R, P	M
SCD				3/	3/	3/
Commercial				3/	3/	3/

Excerpt from:

Section L NASA 311-INST-001

Resistor
Screening Requirements

Inspection/Test	Test Methods, Conditions and Requirements 1/	Notes	Part Type/Level								
			Composition			Film/Foil			Wirewound		
			1	2	3	1	2	3	1	2	3
Precap Visual Inspection	Networks: Particles, metallization (scratches, voids, adherence, bridging, alignment, corrosion, probe marks), laser trim faults, bonding pad defects, oxide defects Others: Not applicable	2/, 3/				X					
Visual Inspections	Materials, design, construction, marking, and workmanship	4/	X	X	X	X	X	X	X	X	X
Mechanical Inspections	Critical physical dimensions	5/	X	X		X	X		X	X	
Initial dc Resistance	MIL-STD-202, Method 303	6/, 7/, 8/	X	X	X	X	X	X	X	X	X
Thermal Shock	MIL-STD-202, Method 107 Level 1 - 25 cycles Level 2 - 10 cycles High temperature - max. rated operating Low temperature - min. rated operating	9/, 10/				X	X				
Conditioning or Overload	MIL-STD-202, Method 108 Specified rated wattage or voltage multiple Specified temperature Specified time If time ≤ 24 hours: continuous operation If time > 24 hours: 1.5 hours on, 0.5 hours off	9/, 10/ 11/, 12/				X	X		X	X	
Final dc Resistance	MIL-STD-202, Method 303 Resistance and ΔR to specification					X	X				
Hermetic Seal	Fine leak: MIL-STD-202, Method 112 Test Condition C 5.0 X 10^{-7} cc/sec. (networks) 1.0 X 10^{-8} cc/sec. (others) Gross Leak: MIL-STD-883, Method 1014 Condition D	13/				X	X				
Radiographic Inspection	MSFC-STD-355C	14/				X			X		
Percent Defective Allowable (PDA)	Level 1 - 5% Level 2 - 15%	15/	X	X		X	X		X	X	

Excerpt from:

Section l NASA 311-INST-001

Resistor
Screening Requirements

Notes:

1/ It is the responsibility of the user to define test conditions and pass/fail criteria for each inspection not specified herein. These values should be based o the nearest equivalent military specification, manufacturer specification, or the application, whichever is most severe.

2/ Examination shall be performed using binocular magnification of 50X to 100X.

3/ If solder is used for internal connections, it shall have a liquid point not less than +280°C.

4/ Small resistors, such as chip resistors, shall be examined using 30X to 60X magnification, but in case of conflict, 30X shall be the referee power.

5/ A minimum of 3 resistors shall be measured. In the event of a failure, the entire lo shall be screened for dimensions and rejects discarded.

6/ The test voltage must be specified in the SCD or by the manufacturer (commercial parts).

7/ For networks, unless otherwise specified, individual resistive elements shall be isolated (whenever possible) to minimize computation of pin-to-pin resistance values.

8/ Out of tolerance composition resistors shall be baked in accordance with the SCD or manufacturer's instructions and then remeasured. Resistors that remain out of tolerance after baking shall be considered failures.

9/ ΔR is optional after this inspection if ΔR is specified for thermal shock and conditioning combined.

10/ External visual examination required after testing to verify no evidence of mechanical damage.

11/ Not applicable to chip resistors.

12/ Unless otherwise specified, the manufacturer's maximum rated continuous dc working voltage should not be exeeded during conditioning as determi by $V = \sqrt{PR}$.

13/ Applicable only to hermetically sealed networks and resistors.

14/ Not applicable to composition, chip or network resistors.

15/ Incorrect, incomplete, or illegible marking shall be considered major defects. However, cosmetic marking defects shall not be counted for purposes o establishing the failure rate.

Excerpt from:

Section L NASA 311-INST-001

Resistor Qualification Table Requirements

Table 3 FIXED RESISTOR QUALIFICATION REQUIREMENTS 1/ (Page 1 of 6)

Inspection/Test	Test Methods, Conditions and Requirements 2/	Notes	Quantity (Accept Number)								
			Composition			Film/Foil			Wirewound		
			1	2	3	1	2	3	1	2	
Group 1 Screening to Table 2	Table 2	3/	100%	100%	100%	100%	100%	100%	100%	100%	10
Group 2			3(0)	3(0)		3(0)	3(0)		3(0)	3(0)	
Solderability	MIL-STD-202, Method 208	4/	X	X		X	X		X	X	
Resistance to Solvents	MIL-STD-202, Method 215	5/, 6/				X	X		X	X	
Group 3		7/	10(0)	6(0)	3(0)	10(0)	6(0)	3(0)	10(0)	6(0)	3(
Thermal Shock	MIL-STD-202, Method 107	5/									
	Level 1 - 25 cycles		X						X		
	Level 2 - 10 cycles			X						X	
	Level 3 - 5 cycles				X			X			X
	High temperature - max. rated operating Low temperature - min. rated operating ΔR to specification										
Resistance Temperature Characteristic	MIL-STD-202, Method 304 Specified test temperature sequence Specified reference temperature PPM to specification	5/	X	X		X	X		X	X	
Low Temperature Storage	-65°C no load dwell for 24±4 hours +25°C ambient no load dwell for 2-8 hours ΔR to specification	5/	X			X			X		
Low Temperature Operation	-65°C no load dwell for 1 hour Full rated voltage for 45 minutes 25°C ambient no load dwell for 24±4 hours ΔR to specification	5/	X			X			X		

Excerpt from:

Section L NASA 311-INST-001

Resistor Qualification Table Requirements

Table 3 FIXED RESISTOR QUALIFICATION REQUIREMENTS 1/ (Page 2 of 6)

Inspection/Test	Test Methods, Conditions and Requirements 2/	Notes	Quantity (Accept Number)								
			Composition			Film/Foil			Wirewound		
			1	2	3	1	2	3	1	2	3
Group 3 (continued)											
Short-time Overload	Specified voltage (wattage) multiple Specified temperature Specified time ΔR to specification	5/	X	X		X	X		X	X	X
Terminal Strength	MIL-STD-202, Method 211 Conditions A and C Applied force to specification ΔR to specification	5/, 6/	X	X		X	X		X	X	
Hermetic Seal	Fine leak: MIL-STD-202, Method 112 Test Condition C 5.0 X 10^{-7} cc/sec.(networks) 1.0 X 10^{-8} cc/sec.(others) Gross Leak: MIL-STD-883, Method 1014 Condition D	8/				X X	X X	X X			
Group 4		7/	9(0)	6(0)		9(0)	6(0)		9(0)	6(0)	
Dielectric Withstanding Voltage	MIL-STD-202, Method 301 Between leads and conductive material surrounding body Specified test voltage ΔR to specification	5/	X	X		X	X		X	X	
Insulation Resistance	MIL-STD-202, Method 302 Between leads and conductive material surrounding body Resistance (minimum) to specification		X	X		X	X		X	X	

Excerpt from:

Section L NASA 311-INST-001

Resistor Qualification Table Requirements

Table 3 FIXED RESISTOR QUALIFICATION REQUIREMENTS 1/ (Page 3 of 6)

Inspection/Test	Test Methods, Conditions and Requirements 2/	Notes	Quantity (Accept Number)								
			Composition			Film/Foil			Wirewound		
			1	2	3	1	2	3	1	2	3
Group 4 (continued)											
Resistance to Soldering Heat	MIL-STD-202, Method 210 Test Condition C ΔR to specification	5/	X	X		X	X				
Moisture Resistance	MIL-STD-202, Method 106 DC resistance to specification DWV to specification IR to specification	5/				X	X		X	X	
Terminal Strength	MIL-STD-202, Method 211 Conditions A and D Applied force to specification ΔR to specification	5/	X	X		X	X		X	X	
Hermetic seal	Same as Group 3	8/				X	X				
Group 5		7/	9(0)	6(0)		9(0)	6(0)		9(0)	6(0)	
Shock	MIL-STD-202, Method 213 Specified number and direction of applied shocks Specified test condition (g's, pulse time, waveform) ΔR to specification	5/, 6/	X	X		X	X		X	X	
Vibration, High Frequency	MIL-STD-202, Method 204 Specified test condition (amplitude, frequency range, sweep time and duration) ΔR to specification	5/, 6/	X	X		X	X		X	X	
Hermetic Seal	Same as Group 3	8/				X	X				

Excerpt from:

Section L NASA 311-INST-001

Resistor Qualification Table Requirements

Table 3 FIXED RESISTOR QUALIFICATION REQUIREMENTS 1/ (Page 4 of 6)

Inspection/Test	Test Methods, Conditions and Requirements 2/	Notes	Quantity (Accept Number)								
			Composition			Film/Foil			Wirewound		
			1	2	3	1	2	3	1	2	
Group 6		7/	12(0)	9(0)		12(0)	9(0)		12(0)	9(0)	
Life	MIL-STD-202, Method 108 Specified test temperature Specified operating conditions ΔR to specification	5/									
	Level 1 - 2000 hours		X			X			X		
	Level 2 - 1000 hours			X			X			X	
Group 7A		7/, 9/				10(0)	5(0)				
Resistance to Bonding	Specified mounting method 4-12 hours stabilization at 25±5°C ΔR to specification	5/				X	X				
Moisture Resistance	MIL-STD-202, Method 106 DC resistance to specification DWV to specification IR to specification	5/				X	X				
Group 7B		9/				10(0)	5(0)				
Adhesion	Specified mounting method Specified force, angle, and duration	5/				X	X				
Group 8			5(0)	5(0)		5(0)	5(0)				
Voltage Coefficient	MIL-STD-202. Method 309 Specified continuous working voltage Specified resistance range Voltage coefficient to specification	10/	X	X		X	X				

Excerpt from:

Section L NASA 311-INST-001

Resistor Qualification Table Requirements

Table 3 FIXED RESISTOR QUALIFICATION REQUIREMENTS 1/ (Page 5 of 6)

Inspection/Test	Test Methods, Conditions and Requirements 2/	Notes	Quantity (Accept Number)								
			Composition			Film/Foil			Wirewound		
			1	2	3	1	2	3	1	2	3
Group 9						5(0)	5(0)		5(0)	5(0)	
High Temperature Exposure	Specified Temperature Specified no load dwell time ΔR to specification DWV to specification IR to specification	5/				X	X		X	X	
Group 10											
Thermal Outgassing	ASTM E595 TML = 1.0% maximum CVCM = 0.10% maximum	11/	X	X	X	X	X	X	X	X	X

Notes:

1/ The qualification samples shall be subdivided as specified in the table for Groups 3 through 10 inclusive. Group 2 inspections can be performed on unscreened samples or on samples that have completed one of the other qualification test groups.

2/ It is the responsibility of the user to define test conditions and pass/fail criteria for each inspection not specified herein. These values should be base the nearest equivalent military specification, manufacturer specification, or the application, whichever is most severe.

3/ These minimum samples sizes are required for qualification:

	Composition	Film	Wirewound
Level 1-	45	50	45
Level 2-	32	37	32
Level 3-	3	3	3

An additional 20 chip resistor qualification samples are required for Level 1 and an additional 10 are required for Level 2.

4/ Not applicable for weldable, bondable chip resistors or any type of resistor with "weldable only" leads.

5/ External visual examination required after testing to verify no evidence of mechanical damage.

6/ Not applicable to chip resistors.

Excerpt from:

Section L NASA 311-INST-001

Resistor Qualification Table Requirements

Table 3 FIXED RESISTOR QUALIFICATION REQUIREMENTS 1/ (Page 6 of 6)

Notes (continued):

7/ To qualify a range of resistance values, equally subdivide the group samples into highest, critical, and lowest resistance values. If the desired resista range does not span the critical value, equally divide the samples into highest and lowest values except as follows: the extra resistor for odd sample shall be of highest value if the resistance range is below the critical value, or of lowest value if the resistance range is above the critical value. For sir resistance value qualification, the sample size shall be as specified for each applicable test group.

8/ Applicable only to hermetically sealed networks and high stability film resistors.

9/ Applicable only to chip resistors.

10/ Applicable to resistors ≥1000 ohms.

11/ Materials listed in Revision 3 of NASA Reference Publication 1124 that meet TML and CVCM limits are acceptable for use without further testing.

Films Surface Mount

Established Reliability Thick Film Military Chip Resistors

MIL-PRF-55342, TYPE RM
RCWPM-Series

- Available for MIL Sheets /01 through /13
- Verified Failure Rate
  – *C, M, P, R, S, T Failure Rate Levels Available*
- Available in either Characteristic K (100 ppm) or M (300 ppm)
- Termination Style
  – *Standard Pre-Tinned Nickel Barrier Wraparound (style B)*

Established Reliability Thin Film Military Chip Resistors

MIL-PRF-55342, TYPE RM
E/H-Series

- Available for MIL Sheets /01 through /12
- Verified Failure Rate
  – *C, M, P, R Failure Rate Levels Available*
- Available in Characteristics E (25 ppm), H (50 ppm), K (100 ppm) or M (300 ppm)
- Termination Style
  – *Standard Pre-Tinned Nickel Barrier Wraparound (style B)*

FIXED RESISTOR TECHNOLOGIES

- **Thick Film**

  Specially built surface mount film resistor that carries high power for the part size. For thick film resistors, the ruthenium oxide "film" is applied using traditional screen-printing technology.

- **Thin Film**

  A type of surface mount film resistor with a relatively thin resistive element, measured in millionths of an inch. Thin film resistors are made by sputtering (also known as vacuum deposition) a resistive material, such as Nichrome or Tantalum Nitride, onto the surface of the resistor.

- **Metal Film or Foil**

  A type of cylindrical resistors made by depositing a resistive element made of a thin conducting film of a metal or metal alloy, such as Nichrome, onto a cylindrical ceramic or glass core. The resistance is controlled by cutting a helical groove through the conducting film.

  Bulk Metal Foil

  A type of resistor made from photo fabricating a homogeneous metal in a specific pattern onto a ceramic substrate. The unique combination of materials and construction results in a product with unmatched performance characteristics and high reliability.

- **Carbon Film**

  A general class description for resistors made by depositing a carbon film on the surface of a center core insulator.

FIXED RESISTOR TECHNOLOGIES

WIREWOUND RESISTORS

A type of resistor made from winding a metal wire, such as Nichrome, on an insulating form, such as a ceramic, plastic, or fiberglass core.

POWER METAL STRIP® RESISTORS

A type of resistor constructed using a solid metal alloy, such as Nichrome or Manganese-Copper, as the resistive element, which is then welded to copper terminals. Used in current sense and shunt applications.

COMPOSITION RESISTORS

- **Carbon Composition**

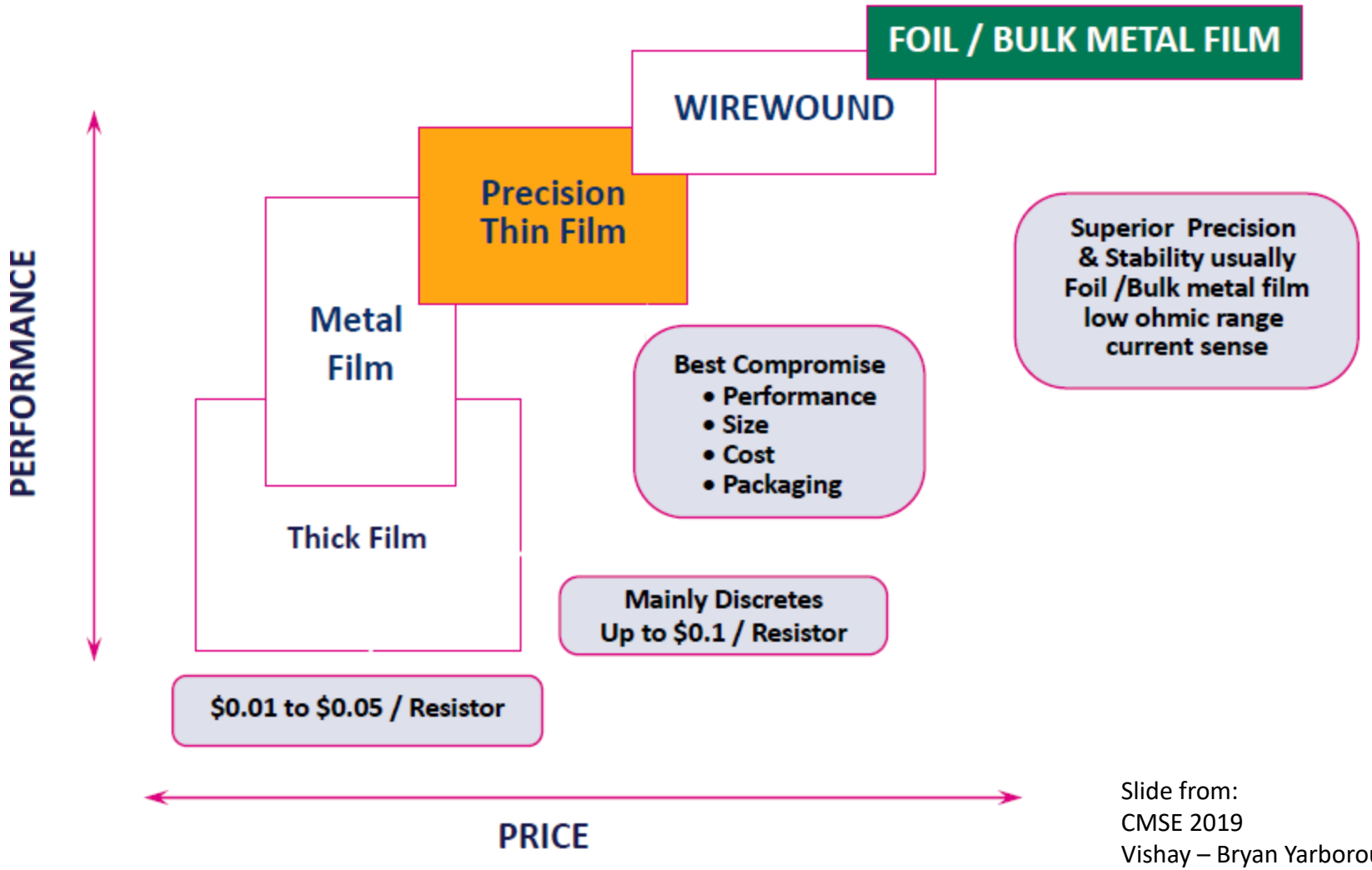
  A general class description for resistors consisting of a carbon mixture resistive core and a molded outer insulating core.

- **Ceramic Composition (Cermet)**

  A type of resistors that consists of a clay, alumina, and carbon mixture that has been blended and pressurized into a resistive core and then covered with a molded outer insulating core.

Resistor Properties

Comparison of Technology, Performance, & Price



Slide from:
CMSE 2019
Vishay – Bryan Yarborough
Resistor Overview – Technologies, Materials, Construction

Resistor Properties

Comparison Matrix

Technology	Thick Film	Thin Film	Wirewound	Metal Strip
Low Values	Good	Poor	Excellent	Excellent
High Values	Excellent	Good	Poor	Poor
Tolerance	Fair	Excellent	Good	Excellent
TCR	Fair	Excellent	Good	Good
Power Rating	Good	Good	Excellent	Good
Voltage Rating	Excellent	Good	Fair	Poor
Stability	Good	Excellent	Good	Good
Overload	Fair	Good	Good	Good
Pulse	Poor	Fair	Excellent	Good
High Temperature	Good	Excellent	Excellent	Excellent

- Thick Film is best suited to high voltage and high values
- Thin Film is best suited to precision and stability
- Wirewound for pulse and power applications
- Metal Strip low resistance values

Slide from:
CMSE 2019
Vishay – Bryan Yarborough
Resistor Overview – Technologies, Materials, Construction

SURFACE MOUNT RESISTORS

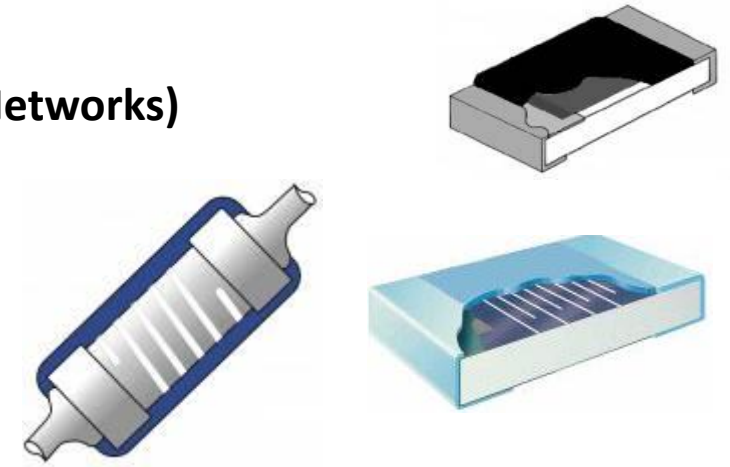
Technology by Resistor value & performance

	THICK FILM	THIN FILM	WIREWOUND	POWER METAL STRIP	BULK METAL FOIL
Resistance	.1 to 50 Gig	10 to 1 Meg	.1 to 100k	.001 to 1	.01 to 150k
Typical Tolerance	1% to 5%	0.10%	1%	1%	0.05%
Typical T.C.	100ppm/C to 200ppm/C	25ppm/C	20ppm/C	75ppm/C	15ppm/C
Strengths	_General Purpose _Wide Resistance Range _High Frequency	_Instrumentation _Stability _High Frequency	_Power Ratings _Harsh Environment	_Current Sensing _Ultra Low Values	_Precision, Current Sensing _Precision Voltage Division

Slide from:
Leon Hamiter CMSE

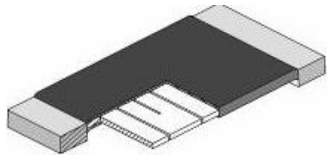
FIXED RESISTOR TECHNOLOGIES

- **FILM (Surface Mount / Leaded)**
  - **THICK FILM (Chip Resistors / Chip Arrays / Networks)**
  - **THIN FILM (Chip Resistors / Chip Arrays)**
  - **METAL FILM (Leaded / MELF *)**
  - **METAL OXIDE (Leaded thru hole)**
  - **CARBON FILM (Leaded thru hole)**

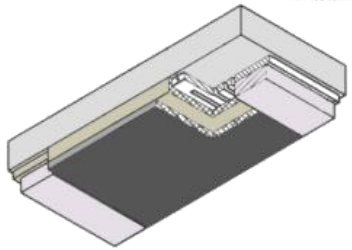


- **WIREWOUND (Surface Mount / Leaded)**

- **BULK METAL FOIL (Surface Mount / Leaded)**



- **POWER METAL STRIP® (Surface Mount)**



- **COMPOSITION (Leaded)**
  - **CARBON COMPOSITION**
  - **CERAMIC COMPOSITION**

Slide from:
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* **MELF =** *metal electrode leadless face attachment*

FILM THROUGH-HOLE

Metal Film Military Resistors

MIL-R-10509, TYPE RN,
MIL-PRF-22684, TYPE RL
CMF-Series

- Available in MIL Sheet sizes 50, 55, 60, 65 & 70 for RN style, and sizes 07 & 20 for RL style
- Full Material and Process Traceability
- Values range from 0.1 ohm to 22.1 Megohm (far beyond Military Spec Value limits)

Established Reliability Metal Film Military Resistors

MIL-PRF-39017, TYPE RLR
ERL-Series

- Available in MIL Sheet sizes 05, 07, 20 & 32
- Verified Failure Rates
  - *S Failure Rate Standard for most sizes*
  - *M, P, R Failure Rate Levels also Available*
- Full Material and Process Traceability
- DSCC Drawing (Non-QPL) Available on multiple sizes to Extended Resistance Ranges

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FILM THROUGH-HOLE

Established Reliability Metal Film Military Resistors

MIL-PRF-55182, TYPE RNC/RNR

ERC-Series

- Available in MIL Sheet sizes 50, 55, 60, 65 & 70
- Charactersistics J, H & K (Non-Hermetically-Sealed)
- Verified Failure Rates
  - *S Failure Rate Standard for most sizes*
  - *M, P, R Failure Rate Levels also Available*
- Full Material and Process Traceability

Established Reliability Metal Film Military Resistors

MIL-PRF-55182, TYPE RNR/RNN

HDN-Series

- Available in MIL Sheet sizes 55, 57, 60, 65, 70 & 75
- Charactersistics C & E (Hermetically-Sealed)
- Verified Failure Rates
  - *S Failure Rate Standard for most sizes*
  - *M, P, R Failure Rate Levels also Available*
- Full Material and Process Traceability

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WIREWOUND / METAL ELEMENT LEADED

Fixed Wirewound Military Resistors

MIL-PRF-26, TYPE RW

RS, NS-Series

G, GN-Series

- Available in either Standard (RS & G) or Non-Inductive (NS & GN) Winding
- 9 Sizes (1 W to 11 W)

Established Reliability Fixed Wirewound Military Resistors

MIL-PRF-39007, TYPE RWR

ESS, ESW, ESN-Series EGS, EGW, EGN-Series

- 100 % Power Stabilization and Screening Test
- Available in either Standard (ESS, ESW, EGS & EGW) or Non-Inductive (ESN & EGN) Winding
- 8 sizes (1 W to 10 W)
- S Failure Rate Available

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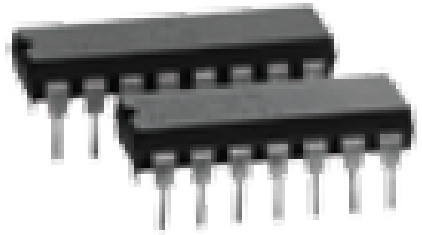
NETWORKS

Thick Film Military Networks



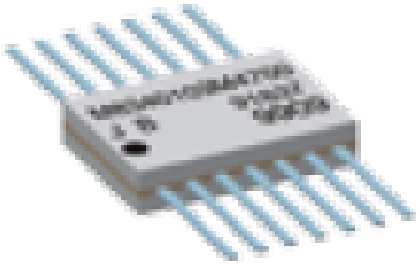
MIL-PRF-83401, TYPE RZ

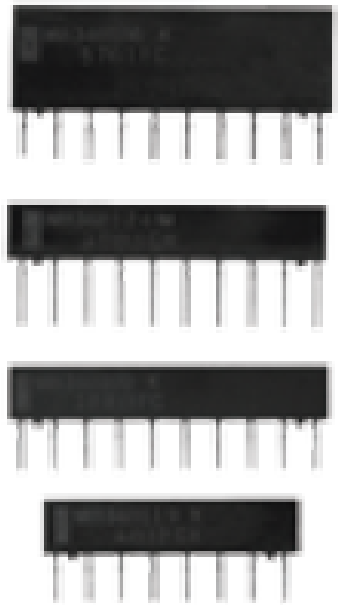
MSM-Series, Slash Sheets 04 - 09, 18, 19 & 24

MDM-Series, Slash Sheets 01 - 02

DFM-Series, Slash Sheets 03

- Thick Film Element in a Rugged Molded Case Construction
- Available in Isolated, Bussed, and Dual Terminator Schematics
- Hot Solder Dipped Leads





Slide from:
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Metal Element Through – Hole

Fixed Metal Element Military Resistors

MIL-R-49465, TYPE RLV,
LVR-Series
SPR-1005-Series

- Extremely Low Resistance Values
- Ideal for Current Sensing Applications

Slide from:
Leon Hamiter CMSE

Wire-wound / Metal Element Leaded

Fixed Wirewound Military Resistors

MIL-PRF-26, TYPE RW

RS, NS-Series

G, GN-Series

- Available in either Standard (RS & G) or Non-Inductive (NS & GN) Winding
- 9 Sizes (1 W to 11 W)

Established Reliability Fixed Wirewound Military Resistors

MIL-PRF-39007, TYPE RWR

ESS, ESW, ESN-Series EGS, EGW, EGN-Series

- 100 % Power Stabilization and Screening Test
- Available in either Standard (ESS, ESW, EGS & EGW) or Non-Inductive (ESN & EGN) Winding
- 8 sizes (1 W to 10 W)
- S Failure Rate Available

Slide from:
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Wire-wound Chassis Mount

Wirewound Chassis Mount Military Resistors

MIL-PRF-18546, TYPE RE,
RH, NH-Series

- Aluminum Housed Standard (RH) or Non-Inductive (NH) Winding/Molded Construction gives complete Environmental Protection
- Mounts on Chassis for High Stability at Conventional Power Ratings
- 6 Sizes (5 W to 120 W)

Established Reliability Wirewound Chassis Mount Military Resistors

MIL-PRF-39009, TYPE RER
ERH, ENH-Series

- Aluminum Housed Standard (ERH) or Non-Inductive (ENH) Winding/Molded Construction gives complete Environmental Protection
- Mounts on Chassis for High Stability at Conventional Power Ratings
- Utilize Heat Sink Effect
- 4 Sizes (5 W to 30 W)
- R Failure Rate

Slide from:
Leon Hamiter CMSE

Common causes of failure by Resistor type

Thick film resistor failures mostly occur due to external factors. The most common failure causes are:

- Mechanical stress.
- Environmental – metal migration.
- Thermal issues.
- Constant overload and Power Surge.
- ESD, typically causes latent failures after overstress

Composition resistor normally fails open when overheated or over stressed due to shock or vibration. Excessive humidity may **cause** an increase in resistance beyond the tolerance limit.

Bulk metal foil resistor has excellent precision and stability properties of all resistor types. The foil is made of an alloy of usually Nichrome with additives, mounted on a ceramic carrier with high heat conductivity.

- The few failure causes have been related to termination attachments, laser trimming and metal migration.
- This resistor has the greatest thermal stability and long term reliability of most.

Resistors

- **Military Qualified (QPL)** – products that are built to military test and performance specifications and to establish reliability ratings.

- **DLA listed** – specifications for commercial products that prescribes testing, packaging, and other requirements for military products. No Established Reliability as in QPL products.

- **Space: ESA** (European Space Agency) **& EEE-INST002** (NASA) – similar to Military Qualified products such as M55342 T-level reliability though they are not directly interchangeable.

- **AEC Q200** (Automotive Electronics Council) – a defined set of tests that assess the robustness, reliability, and suitability of resistors for automotive applications; http://www.aecouncil.com/

- **Source Controlled Drawing** (Medical, Military, Aerospace)– customer specified test conditions and criteria that uses a catalog product to up-screen based on a specified set of tests that benchmarks the performance and provides a measure of established reliability.

- **UL Recognized** resistors are typically not UL Recognized because are used in circuits to perform protective features, but are not the safety critical feature. The exception is fusible resistors.

- **CECC** (European Committee for Electro technical Standardization) - developed to harmonize system for electronic components of assessed quality to facilitate international trade by harmonizing specifications and quality assessment procedures for electronic components.

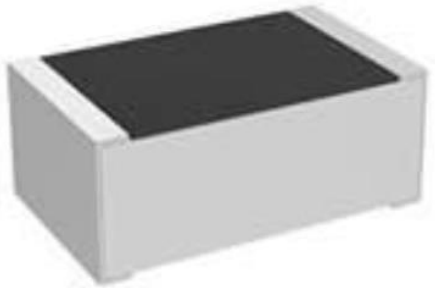
Inductors

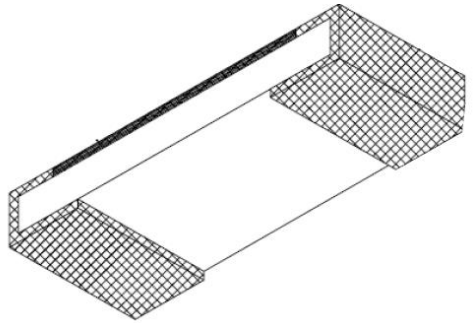
INDUCTOR CATEGORIES
MIL-HDBK-454B
GUIDELINE 14

MIL PRF 39010E	COIL, RADIO FREQUENCY, FIXED, MOLDED, ESTABLISHED RELIABILITY AND NONESTABLISHED RELIABILITY, GENERAL SPECIFICATION FOR
MIL PRF 15305	COILS, ELECTRICAL, FIXED AND VARIABLE, RADIO FREQUENCY GENERAL SPECIFICATION FOR
MIL PRF 27G	TRANSFORMERS AND INDUCTORS (AUDIO, POWER, AND HIGH-POWER PULSE), GENERAL SPECIFICATION FOR
MIL PRF 21038	PERFORMANCE SPECIFICATION TRANSFORMERS, PULSE, LOW POWER GENERAL SPECIFICATION FOR
MIL PRF 83446	PERFORMANCE SPECIFICATION COILS, RADIO-FREQUENCY, CHIP, FIXED OR VARIABLE, GENERAL SPECIFICATION FOR

Federal Stock Class 5950 Inductors

MIL-HDBK-454B
GUIDELINE 14
TRANSFORMERS, INDUCTORS, AND COILS





Specification Intent – This guideline establishes criteria for the selection and application of transformers, inductors, and coils.

Applicable documents -The documents listed below (on the following page) are not necessarily all of the documents referenced herein, but are those needed to understand the information provided by this handbook.

MIL-PRF-27	MIL-PRF-15305	MIL-PRF-21038
MIL-PRF-39010	MIL-PRF-83446	MIL-T-55631
MIL-T-83721	MIL-STD-981	

Excerpt: NASA Parts selector list Inductors

https://nepp.nasa.gov/npsl/Coils/coil_type.htm

Military Specification	Description
MIL-PRF-39010	Coil, Fixed, Radio Frequency, Molded, Established Reliability
MIL-PRF-83446	Coil, Fixed or Variable, Radio Frequency

Guidance From NASA

311-INST-001
Section J
Magnetics

PURPOSE

The purpose of this document is to establish a baseline criteria for the selection, screening and qualification of Electrical, Electronic, and Electromechanical (EEE) parts intended for use in GSFC space systems. This will assist project managers to develop effective EEE parts program requirements, based on mission reliability objectives and budget constraints, and will also assist the contractors and subcontractors in implementing those program requirements for specific projects.

311-INST-001
REVISION A

INSTRUCTIONS FOR EEE PARTS SELECTION, SCREENING, AND QUALIFICATION

AUGUST 1996

Prepared by:
The Parts Branch
Office of Flight Assurance
Goddard Space Flight Center

Excerpt from:

Section J NASA 311-INST-001

Magnetics

TABLE 1 MAGNETIC PART REQUIREMENTS 1/ 2/

Selection Priority	Procurement Military Specification	Level 1	Level 2	Level 3
INDUCTORS/COILS				
RF Fixed Coils	MIL-C-39010	R, P 3/	R, P	(P)
RF Fixed and Variable Coils	MIL-C-15305	4/	5/	X
RF Fixed and Variable Chip Coils	MIL-C-83446	4/	X	X
Inductors, Power, Audio, Charging, and Saturable	MIL-T-27 6/		X	X
SCD		4/	4/	4/
Commercial			4/	4/
Transformers				
RF Fixed and Variable	MIL-T-55631	4/	X	X
Lower Power Pulse	MIL-T-21038	4/	X	X
Transformers Power, Audio, Charging, and Saturable	MIL-T-27 6/	X	X	X
SCD		4/	4/	4/
Commercial			4/	4/

Excerpt from:

Section J NASA 311-INST-001

Magnetics

TABLE 1A MAGNETIC PART FAMILIES AND GROUPS

Group Part Types	Family	Applicable Military Specification
GROUP 1		
Power Transformers	03	MIL-T-27
Power Inductors	04	MIL-T-27
Audio Transformers	21	MIL-T-27
Audio Inductors	20	MIL-T-27
High Power Pulse Transformers	36	MIL-T-27
Charging Inductors	37	MIL-T-27
Saturable Transformers	40	MIL-T-27
Saturable Inductors	41	MIL-T-27
RF Fixed and Variable Transformers	11, 12	MIL-T-55631
Low Power Pulse Transformers	31	MIL-T-21038
GROUP 2		
RF Fixed and Variable Coils	13, 14	MIL-C-15305
GROUP 3		
RF Fixed and Variable Chip Coils	50, 51	MIL-C-83446

Excerpt from:

Section J NASA 311-INST-001

Magnetic
Screening Requirements

Table 2 MAGNETIC PART SCREENING REQUIREMENTS (Page 1 of 3)

Inspection/Test	Part Types	Test Methods and Conditions 1/	Part Type								
			Group 1 Level			Group 2 Level			Group 3 Level		
			1	2	3	1	2	3	1	2	3
External Visual and Dimensional Inspection	All	As specified in the detailed drawing. As a minimum shall include, material, physical dimensions and configuration, weight, marking and workmanship. 2/	X	X	X	X	X	X	X	X	X
Electrical Characteristics											
Insulation Resistance		MIL-STD-202, Method 302. Devices rated at 28 Vdc or less, measure insulation at 100 Vdc. Devices rated at 100 Vdc or more, measure at 2.5X the rated voltage or 500 Vdc whichever is less. Test duration 2 minutes ± 30 seconds. Insulation resistance 1000 Mohms minimum.	X	X	X	X	X	X	X	X	X
DC Winding Resistance	All	Use Kelvin bridge or equivalent for resistances less than one ohm. Pre and Post thermal shock delta R limit sheall be less than 3 percent.	X	X	X	X	X	X	X	X	X
Winding Inductance		Measure at voltage, frequency, and test current as specified in the device detail drawing. The pre and post thermal shock delta L limit shall be less than 3 percent.	X	X	X	X	X	X	X	X	X

Excerpt from:

Section J NASA 311-INST-001

Magnetic
Screening Requirements

Table 2 MAGNETICS SCREENING REQUIREMENTS (Page 2 of 3)

Inspection/Test	Part Types	Test Methods and Conditions 1/	Part Type								
			Group 1 Level			Group 2 Level			Group 3 Level		
			1	2	3	1	2	3	1	2	3
Turns Ratio or Voltage Ratio		Apply 1 Vrms at a specified frequency to each set of primary windings, monitor voltage across each secondary winding. The ratio not to exceed the specified limit. Use Wayne Kerr or equivalent instrument.	X	X	X						
Polarity		With the respective terminals excited at reference frequency, the instantaneous voltage measured at the output leads shall be in-phase with the input or as specified.	X	X	X						
Thermal Shock 25 Cycles 10 Cycles 5 Cycles	All	MIL-STD-202, Method 107 Continually monitor during final cycle to verify no intermittent conditions. 3/	X	X	X	X	X	X	X	X	X
Vibration	All	MIL-STD-202, Method 204. Test Condition as specified in the detail drawing.	X			X					
Burn-In No Load Power Power with Max Rated Load	Inductors/Coils Transformers <0.8 watts Output Transformers ≥ 0.8 watts output	MIL-STD-981, App. B, Paragraph 30.1.2 for Group 1 30.3.2 for Group 2 30.5.2 for Group 3 96 hours at max. temperature 4/	 X X X	 X X X		 X	 X		 X	 X	

Excerpt from:

Section J NASA 311-INST-001

Magnetic
Screening Requirements

Table 2 MAGNETICS SCREENING REQUIREMENTS (Page 3 of 3)

Inspection/Test	Part Types	Test Methods and Conditions 1/	Part Type								
			Group 1 Level			Group 2 Level			Group 3 Level		
			1	2	3	1	2	3	1	2	3
Seal	If Applicable	MIL-T-27 Paragraph 4.8.7	X	X							
D W V	All	MIL-STD-202, Methods 301 and 105 5/	X	X	X	X	X	X	X	X	X
Q	All	As Specified				X	X		X	X	
Induced Voltage	Transformers with greater than 25 volts per winding	MIL-T-27 Paragraph 4.8.9. 2 times rated voltage 6/	X	X	X						
Self Resonant Frequency	All	As Specified 7/				X	X		X	X	
Electrical Characteristics	All	As Specified	X	X	X	X	X	X	X	X	X
Radiographic	All	MIL-STD-981 Appendix C	X			X			X		
Visual	All	As Specified	X	X	X	X	X	X	X	X	X
Group "B"	All	MIL-STD-981 Tables IV, V, VI, and VII	X			X			X		

Notes:

1/ Unless otherwise specified, all inspection measurements and test shall be conducted at a temperature of +25°C (+5°C), a pressure of no less than one standard atmosphere and a relative humidity of between 30 and 70 percent.

2/ Perform inspection using a microscope with a 10X minimum magnification.

3/ For Level 1 parts with magnet wire less than 30 AWG, measure DC resistance before and after each cycle.

4/ For power burn-in, apply rated input current and voltage at minimum rated frequency and at maximum rated load.

5/ Dielectric withstanding voltage shall be measured at sea level and at high altitude. Test voltage and conditions shall be specified.

6/ For saturating core, applied voltage shall be 2 times rated peak to peak voltage at 2 times rated frequency. For pulse transformers, the applied voltage shall be as specified in Table XIII of MIL-T-27.

7/ Use instrument such as McGraw-Edison Model 159LF or equivalent.

Excerpt from:

Section J NASA 311-INST-001

Magnetic
Qualification Requirements

Table 3 MAGNETIC PART QUALIFICATION REQUIREMENTS (Page 1 of 6)

Inspection/ Test 1/	Test Methods and Conditions	Test Quantity (Accept Number)								
		Group 1 Level			Group 2 Level			Group 3 Level		
		1	2	3	1	2	3	1	2	3
Subgroup I 2/		All (0)	All (0)	All (0)	All (0)	All (0)	All (0)	All (0)	All (0)	All (0)
Thermal Shock Screening	MIL-STD-202, Method 107	X	X	X	X	X	X	X	X	X
Winding Continuity	Use any suitable means to check the continuity of all windings	X	X	X	X			X	X	X
Dielectric Withstanding Voltage At atmospheric pressure At reduced pressure	 MIL-STD-202, Method 301. Leakage current shall be as specified in the detailed part drawing. MIL-STD-202, Method 105. Leakage current shall be as specified in the detailed part drawing.	X	X		X	X		X	X	
Insulation Resistance	MIL-STD-202, Method 302. Devices rated at 28 Vdc or less, measure insulation at 100 Vdc. Devices rated at 100 Vdc or more, measure at 2.5X the rated voltage or 500 Vdc whichever is less. Test duration 2 minutes ±30 seconds. Insulation resistance 1000 Mohms minimum.	X	X		X	X		X	X	
Winding Inductance	Measure inductance at voltage, frequency, and current as specified in the device detail drawing.	X	X		X	X		X	X	
Q	The test shall be performed by using any suitable equipment such as the HP260A, HP4342A, HP250B, HP4192A, HP4194A Rx meter or equivalent. Suitable means shall be used to calibrate the frequency of the instrument to within ±0.1 percent of the applicable test frequency specified in the respective MIL-STD's.				X	X		X	X	

Excerpt from:

Section J NASA 311-INST-001

Magnetic
Qualification Requirements

Table 3 MAGNETIC PART QUALIFICATION REQUIREMENTS (Page 2 of 6)

Inspection/ Test 1/	Test Methods and Conditions	Test Quantity (Accept Number)								
		Group 1 Level			Group 2 Level			Group 3 Level		
		1	2	3	1	2	3	1	2	3
Self Resonant Frequency	Use MIL-C-15305, Paragraph 4.8.8.3 or MIL-C-83446, Paragraph 4.6.7.3 as applicable.				X	X		X	X	
D C Winding Resistance	Use Kelvin bridge or equivalent for resistances less than 1ohm.	X	X		X	X		X	X	
Visual and Mechanical Examination (external)	As specified in the detailed drawing. As a minimum shall include, materials, physical dimensions and configuration, weight, marking, and workmanship.	X	X	X	X	X	X	X	X	X
Subgroup II		6 (0)	4 (0)	4 (1)	6 (0)	4 (0)	4 (1)	6 (0)	4 (0)	4 (1)
Operating Torque (when Applicable)	In accordance with MIL-C-15305, paragraph 4.8.7 or MIL-C-83446, paragraph 4.6.8.				X	X		X	X	
Temperature Rise	For Group 1, in accordance with paragraph 4.8.12 of MIL-T-27 For Group 2, in accordance with paragraph 4.8.9 of MIL-C-15305 For Group 3, in accordance with paragraph 4.6.12 of MIL-C-83446	X	X		X	X		X	X	
Overload	Perform test in accordance with: MIL-T-27-paragraph 4.8.20, MIL-C-83446-paragraph 4.6.13, MIL-C-15305-paragraph 4.8.10, or MIL-T-21038-paragraph 4.7.21 as applicable.	X	X		X	X		X	X	
Resistance to Soldering Heat	Perform in accordance with: MIL-T-27-paragraph 4.8.5, MIL-T-21038-paragraph 4.7.5, or MIL-T-55631-paragraph 4.7.13.	X			X					

Excerpt from:

Section J NASA 311-INST-001

Magnetic
Qualification Requirements

Table 3 MAGNETIC PART QUALIFICATION REQUIREMENTS (Page 3 of 6)

Inspection/ Test 1/	Test Methods and Conditions	Test Quantity (Accept Number)								
		Group 1 Level			Group 2 Level			Group 3 Level		
		1	2	3	1	2	3	1	2	3
Terminal Strength	Finished devices with solid wire terminals shall be capable of passing the terminal twist test in accordance with MIL-STD-202, Method 211, Test Condition D, without causing discontinuity in the winding. When the bending of the terminal leads, as specified in MIL-STD-202, is impractical, the device shall be held stationary. The lead shall be clamped in a hand chuck and the chuck rotated as required. During the twist test, the winding shall be monitored for open circuit of 100 microseconds or longer duration.	X	X		X	X				
Induced Voltage 3/	MIL-T-27, Paragraph 4.8.9, 2X rated voltage. 4/ MIL-T-21038, Paragraph 4.7.9, 2X rated voltage. MIL-T-55631, Paragraph 4.7.4.	X	X	X						
Vibration	Perform test in accordance with: MIL-T-202, Method 204, specify the test condition, MIL-C-15305 - paragraph 4.8.15, MIL-T-21038 - paragraph 4.7.16 and MIL-T-55631 - paragraph 4.7.15.	X	X	X	X	X	X			
Shock	For MIL-T-27, MIL-T-21038 and MIL-T-55631 part types test in accordance with MIL-STD-202, Method 213, pulse as specified (Hor I). For MIL-C-15305, Paragraph 4.8.16, Test Condition I.	X	X	X						

Excerpt from:

Section J NASA 311-INST-001

Magnetic
Qualification Requirements

Table 3 MAGNETIC PART QUALIFICATION REQUIREMENTS (Page 4 of 6)

Inspection/ Test 1/	Test Methods and Conditions	Test Quantity (Accept Number)								
		Group 1 Level			Group 2 Level			Group 3 Level		
		1	2	3	1	2	3	1	2	3
Dielectric Withstanding Voltage At reduced pressure	MIL-STD-202, Method 105. Leakage current shall be as specified in the detailed part drawing.	X	X		X	X		X	X	
Insulation Resistance	MIL-STD-202, Method 302. Devices rated at 28 Vdc or less, measure insulation at 100 Vdc. Devices rated at 100 Vdc or more, measure at 2.5X the rated voltage or 500 Vdc whichever is less. Test duration 2 minutes ±30 seconds. Insulation resistance 1000 Mohms minimum.	X	X	X	X	X	X	X	X	X
Electrical Characteristics DC Winding resistance Winding inductance	Use Kelvin bridge or equivalent for resistances less than 1 ohms. Measure inductance at voltage, frequency, and current as specified in the device detail drawing.	X	X	X	X	X	X	X	X	X
Visual and Mechanical Examination (external)	As specified in the detailed drawing. As a minimum shall include, materials, physical dimensions and configuration, weight, marking, and workmanship.	X	X	X	X	X	X	X	X	X

Excerpt from:

Section J NASA 311-INST-001

Magnetic
Qualification Requirements

Table 3 MAGNETIC PART QUALIFICATION REQUIREMENTS (Page 5 of 6)

Inspection/ Test 1/	Test Methods and Conditions	Test Quantity (Accept Number								
		Group 1 Level			Group 2 Level			Group 3 Level		
		1	2	3	1	2	3	1	2	3
Subgroup III		6 (0)	4 (0)		6 (0)	4 (0)		6 (0)	4 (0)	
Life	Transformers shall be subjected to five (5) life cycles a week for a minimum of twelve (12) weeks i.e., a total of 2016 hours. Four (4) of these cycles shall consist of a twenty (20) hour period during which the transformers are operated at a temperature of 85 degrees Celsius with electrical conditions as specified in the detail drawing or specification and a four (4) hour period of operation at room ambient temperature without excitation. The fifth (5) cycle of the week shall be a sixty-eight (68) hour period at a temperature of 85 degrees Celsius and a four (4) hour period of excitation at room ambient temperature. An electrical test circuit shall be devised so that an open circuit or short circuit during this life cycle test shall be detected and the time of failure recorded. Upon completion of the life test, transformers shall be tested for insulation resistance and dielectric withstanding voltage (at reduced voltage). Sample also shall be examined for physical and electrical damage. The procuring activity shall be notified within 48 hours of any failures.	X	X		X	X		X	X	

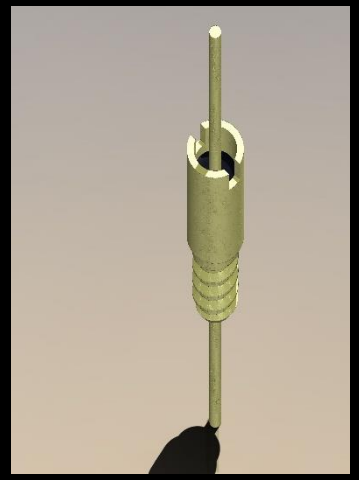
Excerpt from:

Section J NASA 311-INST-001

Magnetic
Qualification Requirements

Table 3 MAGNETIC PART QUALIFICATION REQUIREMENTS (Page 6 of 6)

Inspection/ Test 1/	Test Methods and Conditions	Test Quantity (Accept Number)								
		Group 1 Level			Group 2 Level			Group 3 Level		
		1	2	3	1	2	3	1	2	3
Life (continued)	Catastrophic failures (electrical failures, physical damage) shall be subjected to failure analysis to determine the cause of failure. For MIL-C-83446 types the test shall be conducted in accordance with paragraph 4.6.9 and MIL-STD-202, Method 108. For MIL-C-15305 types the test shall be performed in accordance with paragraph 4.8.13 MIL-STD-202, Method 108	X	X		X	X		X	X	
Electrical Characteristics DC Winding resistance Winding inductance	Use Kelvin bridge or equivalent for resistances less than 1 ohms Measure inductance at voltage, frequency, and current as specified in the device detail drawing.	X	X	X	X	X	X	X	X	X
Visual and Mechanical Examination (external)	As specified in the detailed drawing. As a minimum shall include, materials, physical dimensions and configuration, weight, marking, and workmanship.	X	X	X	X	X	X	X	X	X
Visual and Mech. Examination (internal) 2 units for Group 1, 2, and 3	MIL-STD-981, Appendix C	X	X		X	X		X	X	



Filters MIL-PRF-28861

FILTERS CATEGORIES
NO MIL-HDBK

MIL PRF 28861	FILTERS AND CAPACITORS, RADIO FREQUENCY / ELECTROMAGNETIC INTERFERENCE SUPPRESSION
MIL PRF 15733	FILTERS AND CAPACITORS, RADIO FREQUENCY INTERFERENCE

Federal Stock Class 5915 Filters

Excerpt: NASA Parts selector list Filters

https://nepp.nasa.gov/npsl/Filters/filter_type1.htm

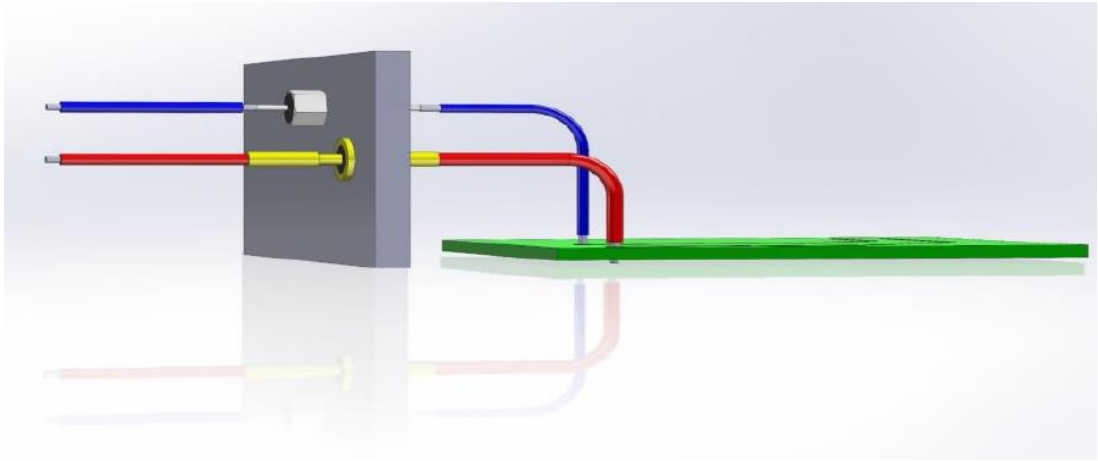
FILTERS, EMI/RFI

The following Filter specifications are available for selection:

Military Specification	Generic Designator	Description
MIL-PRF-28861	FSXX	Filter, Radio Frequency/Electromagnetic Interference Suppression

MIL PRF 28861

Filters and Capacitors, Radio Frequency / Electromagnetic Interference Suppression, GENERAL SPECIFICATION FOR



Guidance From NASA

311-INST-001
Section F
Filters

PURPOSE

The purpose of this document is to establish a baseline criteria for the selection, screening and qualification of Electrical, Electronic, and Electromechanical (EEE) parts intended for use in GSFC space systems. This will assist project managers to develop effective EEE parts program requirements, based on mission reliability objectives and budget constraints, and will also assist the contractors and subcontractors in implementing those program requirements for specific projects.

311-INST-001
REVISION A

INSTRUCTIONS FOR EEE PARTS SELECTION, SCREENING, AND QUALIFICATION

AUGUST 1996

Prepared by:
The Parts Branch
Office of Flight Assurance
Goddard Space Flight Center

Excerpt from:

Section F NASA 311-INST-001

Filters

Table 1 FILTER REQUIREMENTS 1/

Selection Priority	Use As Is	Screen to Requirements in Table 2	Qualify to Requirements in Table 3
Level 1			
MIL-F-28861, Class S	X		
MIL-F-28861, Class B 2/	X		
SCD		X	X
Level 2			
MIL-F-28861, Class B	X		
MIL-F-28861, Class S	X		
MIL-F-15733		X	
SCD		X	X
Commercial		X	X
Level 3			
MIL-F-28861, Class B	X		
MIL-F-28861, Class S	X		
MIL-F-15733	X		
Commercial		X	

Excerpt from:

Screening Requirements

Section F NASA 311-INST-001

Filters

Table 2 SCREENING REQUIREMENTS FOR FILTERS

Inspection/Test	Test Methods Conditions, and Requirements Reference MIL-F-28861	Level 1	Level 2			Level 3
		SCD	SCD	MIL-F-15733	Commercial	Commercial
1) Visual Inspection	Elements and subassemblies in accordance with paragraph 4.6.1.2	X	X			
2) External Visual	Dimensions, marking, workmanship	X	X		X	X
3) Thermal Shock	MIL-STD- 202, Method 107 Condition A except step 3 shall be 125°C	X 1/	X	X	X	
4) Voltage Conditioning (Burn-In) Duration (Hours)	MIL-STD-202, Method 108, 125°±3°C. 2 x rated voltage for dc rated. 1.2 x rated ac voltage at max. rated frequency for ac, ac/dc rated	X 2/ 240	X 160	X 96	X 160	X 48
5) Insulation Resistance or DC Leakage Current	MIL-STD-202, Method 302, rated dc voltage applied for 2 minutes max., charging current of 50 mA max.	X 3/	X 3/	X	X	X
6) Capacitance to ground	MIL-STD-202, Method 305, 1.0±.2V RMS. 1 Mhz ±100khz for capacitors ≤100pF. 1khz ±100Hz for Capacitors ≥100pF	X	X	X	X	X
7) Dissipation factor	Frequency and voltage specified in 6) above. Accuracy shall be ± 2 percent.	X	X	X	X	
8) Insertion Loss	MIL-STD-220 and paragraph 4.6.5	X	X4/	X4/	X 4/	
9) Voltage Drop	ac and dc. Paragraph 4.6.6	X	X	X		
10) Radiographic Inspection	MIL-STD-202, Method 209 and paragraph 4.6.8	X				
11) Seal Test (Hermetic types only) Gross Leak Fine Leak	MIL-STD-202, Method 112 Condition A or B Condition C	 X X	 X		 X	

Excerpt from:

Qualification Requirements

Section F NASA 311-INST-001

Filters

Table 3 QUALIFICATION TEST REQUIREMENTS FOR FILTERS

Inspection Test	Test Methods and Procedures MIL-F-28861 Paragraph	Quantity (Accept number)		
		Level 1	Level 2	Level 3
		SCD	SCD or Commercial	
Group 1		4(0)	4(0)	
Resistance to Solvents	3.21, 4.6.15	X	X	
Resistance to Soldering Heat	3.25, 4.6.20	X	X	
Solderability	3.31, 4.6.25	X	X	NOT
Thermal Strength	3.29, 4.6.23	X	X	
Group 2		5(0)	5(0) OR 10(1)	
Shock (specified pulse)	3.28, 4.6.22	X(1500G'S)	X(100G'S)	REQUIRED
Vibration (high frequency)	3.22, 4.6.16	X	X	
Random Vibration	3.23, 4.6.17	X	X	
Moisture Resistance 2/	3.30, 4.6.24	X	X	
Seal (when applicable)	3.15, 4.6.9	X	X	
Destructive Physical Analysis	3.27, 4.6.21	X		
Group 3		22(0)	10(0)	
Life	3.32, 4.6.26	X	X	

MIL-PRF-28861

FILTERS AND CAPACITORS, RADIO FREQUENCY/ELECTROMAGNETIC INTERFERENCE SUPPRESSION, GENERAL SPECIFICATION FOR

Specification Intent – To give designers options for EMI filtering on bulk head entry pins of electronic systems and sub systems

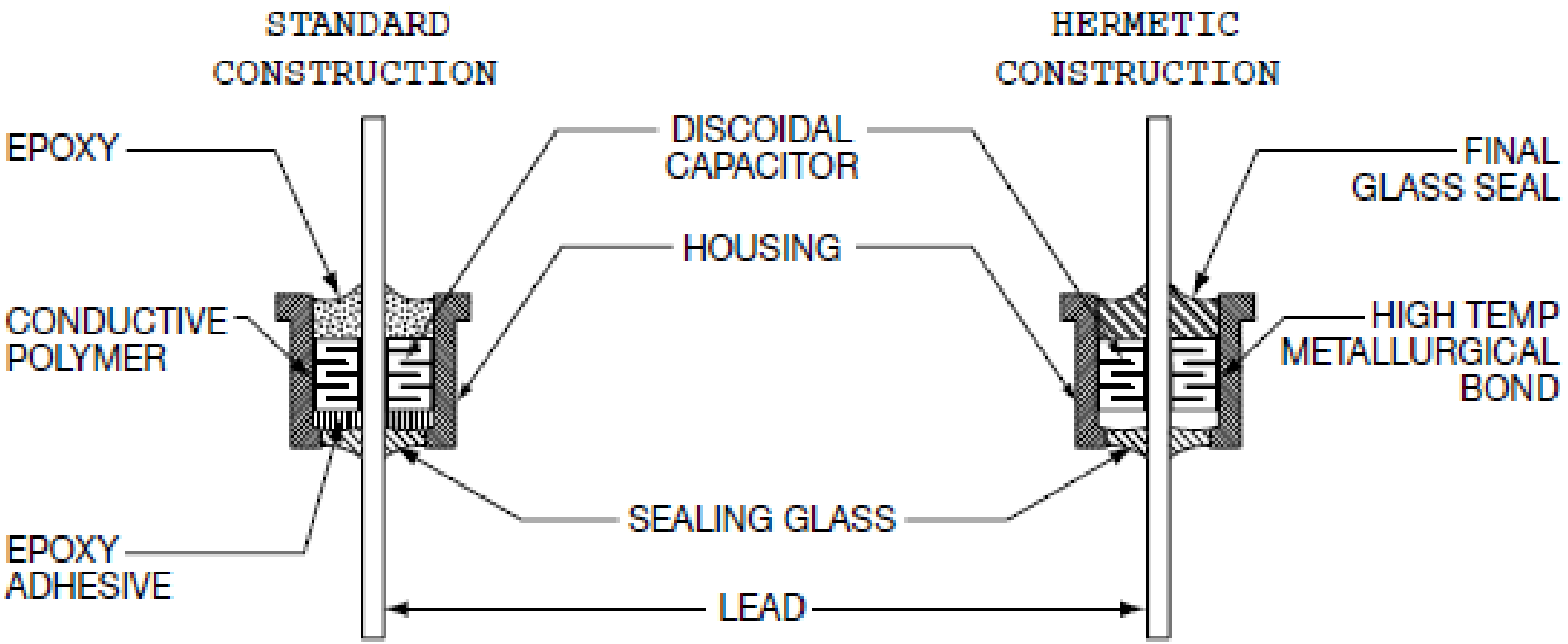
Component Technology – Discoidal capacitor and inductor elements sealed in a hermetic walled end Package, bolt in or solder in

Component Range – L, C, T, *pi* configuration, 50v to 400v, 10 pf to 1.2uf

Special Features or concerns relative to other parts -
Bolt in, Solder in configuration

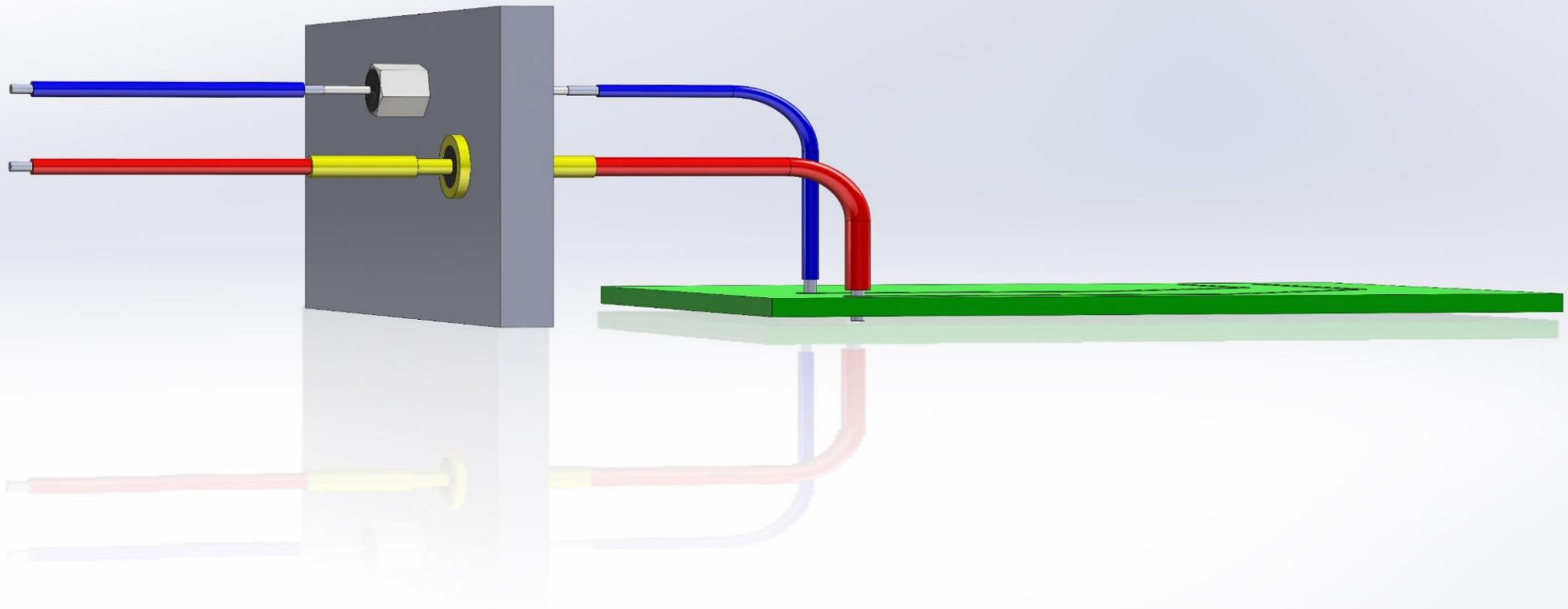
A list of alternate parts – NOTE NOT EQUIVALENT PARTS
SMT EMI Filters AEC Q200 qualified – NOT bolt in/press fit or solder in
Tubular FeedThrus = NOT auto grade
COTS

Commercial product vs. MIL-PRF-28861



Bolt in / Solder in Filter Use and Failure characteristics

Break in hermitic seal due to installation torque, cross thread, wrong thread, excessive heat, tooling



Summary:

- High-level overview of Mil, ESA, COTS & Auto Grade
- Key component specification are discussed relative to their intent & purpose

- Summary of significant differences between components by the different grades of specs
- Component technology, ranges and failure modes discussed
- Alternates grades are shown when possible