

Side-by-Side Comparisons of EEStor and Commercial Capacitors

EEStor Provides Longer Lasting, More Cost-Effective Solutions

Less Material

Since capacitors contain little to no empty space, the volume of the final part is directly related to the volume of material needed to construct it.

Capacitor - voltage, size	40V, 33 μ F	450V, 10 μ F	450V, 470 μ F
Kemet Volume	1.57 cm ³	5.83 cm ³	-
United Chemi-Con Volume	-	-	43.3 cm ³
EEStor Volume	0.874 cm ³	0.811cm ³	38 cm ³
% larger than EEStor	80%	618%	14%

EEStor's capacitor are thus more cost effective per farad to manufacture. When this low cost to manufacture is added to the additional longer expected lifetime of the EEStor licensed solution, the cost per farad per year shows a significant advantage for the EEStor technology.

EEStor CMBT-glass dielectric vs. Kemet 40 volt 33 μ Farad

The projected volume calculation for a 40 volt, 33 micro-farad MLCC, built from EEStor's CMBT-glass dielectric, is calculated based on its performance [as reported in Phase 8 Intertek report](#). and found that the Kemet capacitor volume, at 1.57 cm³, would be 80% larger than that of EEStor's CMBT-glass capacitor.

A Kemet 40 volt, 33 micro-farad aluminum electrolytic capacitor is contained in a cylinder with a diameter of 10 mm and a length of 20 mm. The cylinder volume is thus: $\pi \times 5^2 \times 20 = 1570 \text{ mm}^3$ or 1.57 cm³ (https://www.mouser.com/datasheet/2/212/KEM_A4011_PEG124-1104316.pdf)

The projected volume calculation for a 40 volt, 33 micro-farad MLCC, built from EESstor's CMBT-glass dielectric, is calculated based on the performance of Sample 344-2B [as reported in Phase 8 Intertek report](#). The k of 644 is that measured at the lowest field of 9.2 volt per micron.

Package Lengh =	10.20	mm
Package Width =	10.20	mm
Package Height =	8.40	mm
Dielectric Thickness =	10.00	μm
Conductor Thickness =	5.00	μm
k =	644	
Dielectric Resistivity =	8.32E+10	Ω-m
Voltage =	40.00	V
Field =	4.00	V/μm
One Layer Area =	1.0404	cm ² /layer
Number of Layers =	560	layers
Total Area of Layers =	582.624	cm ²
Part Volume =	0.8739	cm ³
One Layer Capacitance =	59.30	nF/layer
Total Capacitance =	33,206.1	nF
Total Resistance =	1.43E+07	Ω
Leakage Current =	2,801.08	nA
Time Constant =	474	sec

The resulting MLCC capacitor would have a volume of 0.874 cm³. The Kemet capacitor volume, at 1.57 cm³ would therefore be 80% larger than that of EESstor's CMBT-glass capacitor.

EESstor CMBT-glass dielectric to Kemet 450v 10 μFarad

The projected volume calculation for a 450 volt, 10 micro-farad MLCC, built from EESstor's CMBT-glass dielectric, is calculated based on its performance [as reported in Phase 8 Intertek report](#). Results of the comparison found that the Kemet 450 volt 10 micro-farad would have a volume of 5.83 cm³ making it 618% larger than the 0.8115 cm³ EESstor CMBT-glass capacitor.

A Kemit 450 volt, 10 micro-farad aluminum electrolytic capacitor is contained in a cylinder with a diameter of 16 mm and a length of 29 mm. The cylinder volume is thus: $\pi \times 8^2 \times 29 = 5830 \text{ mm}^3$ or 5.83 cm^3

(https://www.mouser.com/datasheet/2/212/KEM_A4011_PEG124-1104316.pdf)

The projected volume calculation for a 450 volt, 10 micro-farad MLCC, built from EESStor's CMBT-glass dielectric, is calculated based on the performance of Sample 344-2B [as reported in Phase 8 Intertek report](#). The k of 254 is interpolated from the k of 245 at a field of 46.9 volt per micron and k of 282 at a field 39.1 volt per micron.

Package Lengh =	10.20	mm
Package Width =	10.20	mm
Package Height =	7.80	mm
Dielectric Thickness =	10.00	μm
Conductor Thickness =	8.00	μm
k =	254	
Dielectric Resistivity =	8.32E+10	$\Omega\text{-m}$
Voltage =	450.00	V
Field =	45.00	V/ μm
One Layer Area =	1.0404	cm^2/layer
Number of Layers =	433	layers
Total Area of Layers =	450.4932	cm^2
Part Volume =	0.8115	cm^3
One Layer Capacitance =	23.39	nF/layer
Total Capacitance =	10,126.6	nF
Total Resistance =	1.85E+07	Ω
Leakage Current =	24,365.62	nA
Time Constant =	187	sec

The resulting MLCC capacitor would have a volume of 0.8115 cm^3 . The Kemet capacitor volume, at 5.83 cm^3 would therefore be 618% larger than that of EESStor's CMBT-glass capacitor.

EESStor CMBT-glass dielectric to United Chemi-Con 450v 470 μFarad

The projected volume calculation for a 450 volt, 470 micro-farad MLCC, built from EESStor's CMBT-glass dielectric, is calculated based on its performance [as reported in Phase 8 Intertek report](#). Results of the comparison found that the United Chemi-Con 470 micro-farad, 450V capacitor would have a volume of 43.3 cm^3 making it 13% larger than

the 38.02 cm³ EESstor CMBT-glass capacitor. However, the life-time and performance advantage of the EESstor ceramic dielectric allows a licensee to price it with much increased profitability.

A United Chemi-Con EKMQ451VSN471MA45S 470 micro-farad, 450 volt capacitor, with a diameter of 35 mm and length of 45 mm, for a volume of: $\pi \times 17.5^2 \times 45 = 43,295 \text{ mm}^3$ or 43.3 cm³. (<https://www.digikey.com/product-detail/en/united-chemi-con/EKMQ451VSN471MA45S/565-3031-ND/758243>)

The projected volume calculation for a 450 volt, 470 micro-farad MLCC, built from EESstor's CMBT-glass dielectric, is calculated based on the performance of Sample 344-2B [as reported in Phase 8 Intertek report](#). The k of 254 is interpolated from the k of 282 at a field of 39.1 volt per micron, and 245 at field of 46.9 volt per micron.

Package Lengh =	20.30 mm
Package Width =	15.30 mm
Package Height =	15.30 mm
Dielectric Thickness =	10.00 μm
Conductor Thickness =	8.00 μm
k =	254
Dielectric Resistivity =	8.32E+10 Ω-m
Voltage =	450.00 V
Field =	45.00 V/μm
One Layer Area =	3.1059 cm ² /layer
Number of Layers =	850 layers
Total Area of Layers =	2640.015 cm ²
Part Volume =	4.7520 cm ³
One Layer Capacitance =	69.82 nF/layer
Total Capacitance =	59,344.9 nF
Total Resistance =	3.15E+06 Ω
Leakage Current =	142,789.27 nA
Time Constant =	187 sec

$470,000 \text{ nF} / 59,344.9 \text{ nF} = 7.9$. So, 8 MLCCs of the above specification would be needed for 470 micro-farad. $8 \times 4.752 \text{ cm}^3 = 38.016 \text{ cm}^3$, $8 \times 59,344.9 \text{ nF} = 474.8 \text{ micro-farad}$.

In this case the commercial capacitor is 43.3 cm³ and the EESstor capacitor is 38.016 cm³, so EESstor is marginally smaller per farad especially considering the unknown portion of the volume attributed to packaging. However, the life-time and performance advantage of the EESstor

ceramic dielectric confer its licensee a pricing and thus profitability advantage that make EESstor's dielectric disruptive across the entire Aluminum Electrolytic market.

About EESstor

EESstor is in the business of developing and licensing high energy density dielectric material, with the specific purpose of a) allowing its licensees to price disrupt growing portions of the \$20 billion commodity capacitor industry, with the performance attributes that have already been disclosed; and b) by improving its material into a competitive and then disruptive \$250+ billion energy storage market contender; with all further material improvements accentuating the price disruption.