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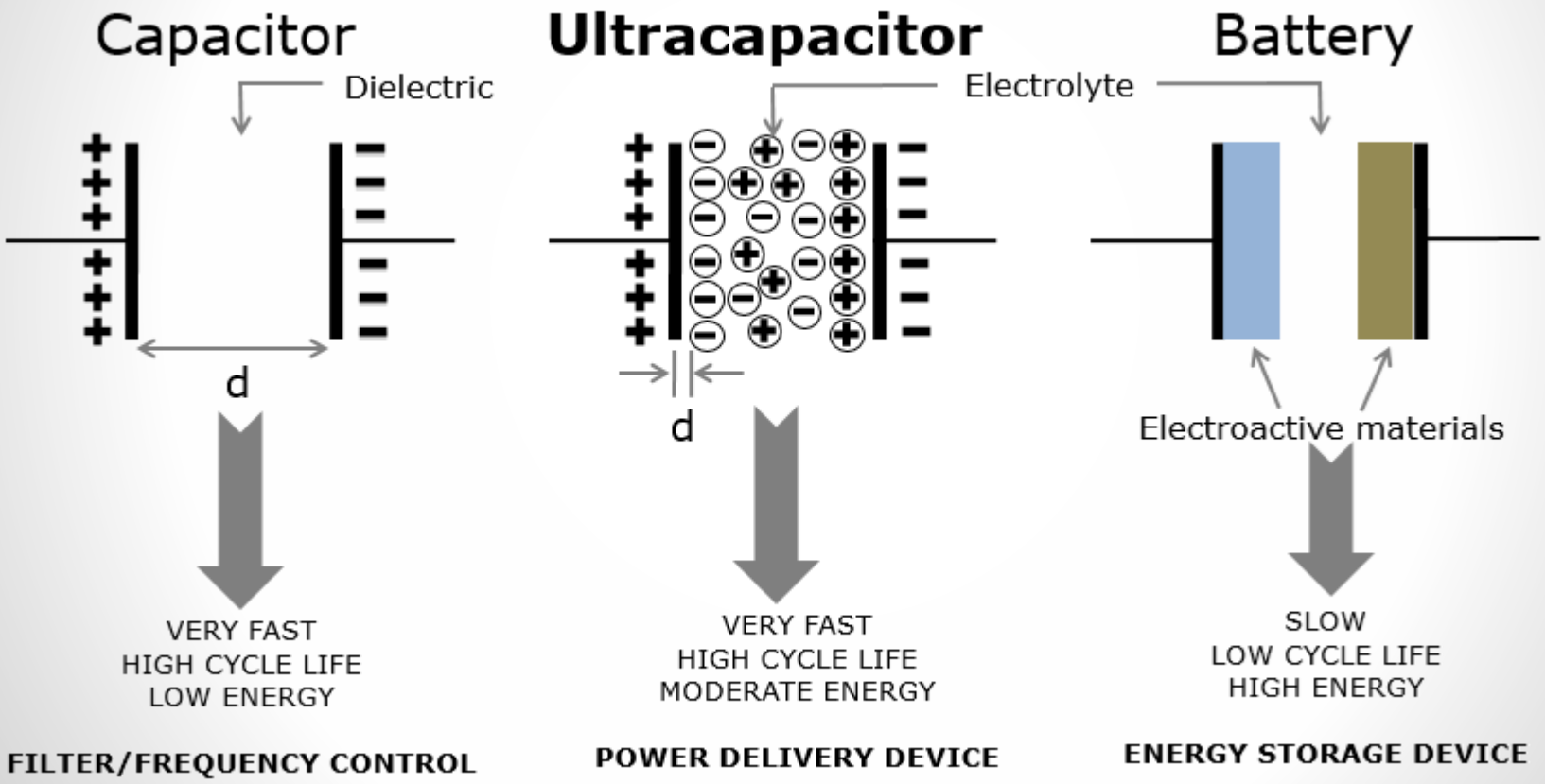
General Supercapacitor Presentation

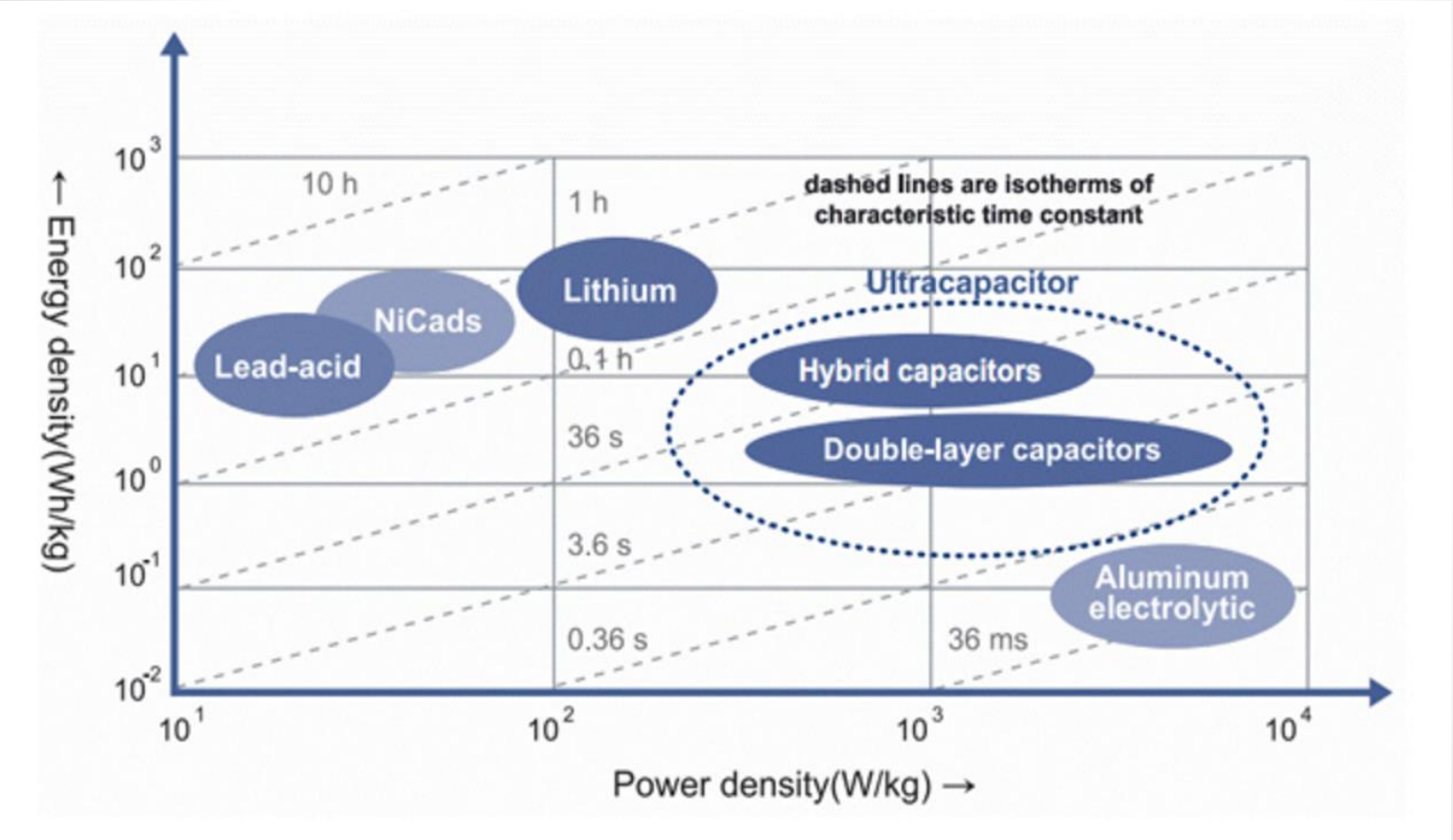
Supercapacitors – Rapid, Reliable, Safe Power

- Supercapacitor, Ultracapacitor, EDLC
- Power Delivery vs Energy Storage Device
- Store energy as electrostatic charge – NO chemical reaction
- Low sensitivity to number of charge/discharge cycles or discharge current
- Wide Operating Temperature -40^{o}C to 85^{o}C
- Lightweight

Technology Primer



Performance Characteristics Comparison



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Application Classifications

Dynamic

- Rapid change of current
- Rapid change of power in and out
- Rapid change of voltage
- Wide ambient temperature fluctuations over the application life
- High current/power loads
- High vibration environment
- Long cycle life requirement

Static

- Steady operation vs time
- Majority of time spent in charged state
- Low charge current, long charge duration
- DC life critical
- Self discharge critical

Supercapacitor Applications

Supercapacitor Functions

- **Main power**
  Provides primary power for high reliability applications
- **Back-up power**
  Provides short term back-up power
- **Pulse power**
  Supplies peak power to the load while drawing low power from the source

Main Power
Secondary Battery
Primary Battery
Solar Cell
RF Energy Harvester

Application

User Benefits

- Reduce size and weight of required power source
- Improves run-time and battery life
- Protects against accidental power loss or fluctuations/interruptions
- Unlimited discharge cycles
- Efficiency: >95%
- Safety

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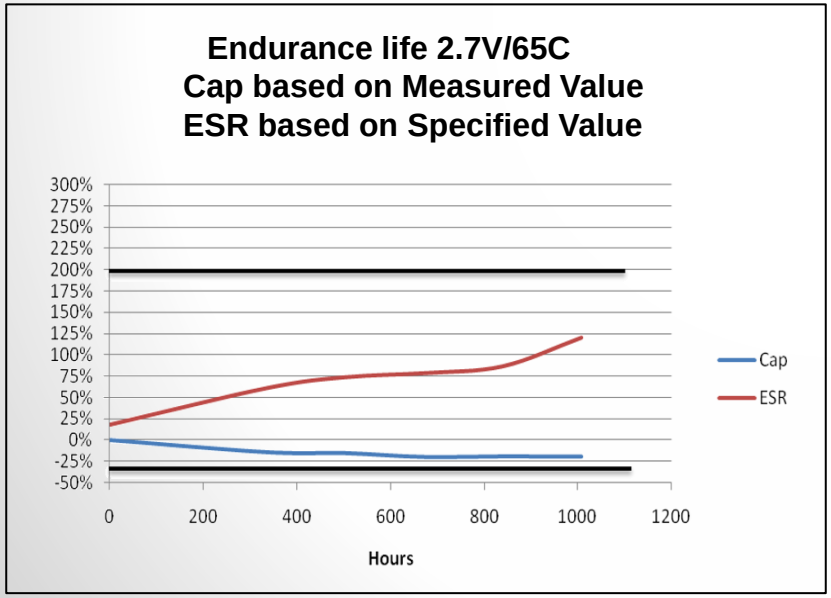
End of Life & Failure Modes

- In general supercapacitors do not have a hard end of life failure like batteries
- End of Life (EOL)
  - 30% drop in capacitance
  - Doubling of internal resistance (ESR)

Failure under typical use condition



Failure under Abuse Conditions

- Over Voltage
  - Loss of capacitance
  - Increase of ESR
  - Bulging
  - Possible venting
- Over Temperature
  - Loss of capacitance
  - Increase in ESR
  - Bulging
  - Possible venting
- Mechanical Stress
  - Deformation
  - Fractured leads
  - Increase in ESR

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CDE Supercapacitor Product Offering

Series	Description	Cap Range	Rated Voltage	Temp Range	Construction
DGH	85c Low ESR Supercapacitor	1F-600F	**2.7v**	-40C to +85c	Cylindrical
DGH	85c Low ESR Supercapacitor	0.5F-5.0F	**5.5v**	-40C to +85c	Module
DSF	85c Low ESR Supercapacitor	3F-600F	**3v**	-40C to +85c	Cylindrical
DSF	85c Low ESR Supercapacitor	1.5F-5F	**6v**	-40C to +85c	Module
VMF	LiC Hybrid Supercapacitor	10F-220F	**3.8v**	-15C to +85C	Cylindrical
VPF	LiC Hybrid Supercapacitor	40F-220F	**3.8v**	-25C to +70C	Cylindrical
EDC	70c Coin Cell Supercapacitor	.047F-1.5F	**5.5v**	-25c to +70c	Coin
EDS	85c Coin Cell Supercapacitor	.047F-1.5F	**5.5v**	-25c to +85c	Coin

*CDE offers a broad range of cells values and module packages readily available through our distribution partners

Supercapacitor Comparison Chart

SUPERCAPACITORS						
Type	**EDLC**		**LIC Hybrid**		**Coincell**	
Series	**DGH**	**DSF**	**VMF**	**VPF**	**EDC**	**EDS**
Description	• Very Fast Charge/Discharge • High Power Density • Low ESR	• High Voltage 3.0 Vdc • Higher Energy Density than 2.7 V (+24%)	• High Voltage 3.8V • High Energy Density • High Temp. +85 °C	• High Voltage 3.8 V • High Energy Density • Low Temp. -25 °C	• Long Life • High Operating Temp. 70 °C	• Long Life • Higher Operating Temp. 85 °C
Capacitance Range (Tolerance)	0.5F to 600F (-10% +30%)	1.2 to 600F (-10% +30%)	10F to 220F (±20%)	40F to 220F (±20%)	0.047F to 1.5F (-20% +80%)	0.047F to 1.5F (-20% +80%)
WVdc	2.7 Vdc (1F to 600F) 5.5 Vdc (0.5F to 5F)	3 Vdc (3F to 600F) 6 Vdc (1.5F to 5F)	2.2 Vdc - 3.8 Vdc (Vmin - Vmax)	2.2 Vdc - 3.8 Vdc (Vmin - Vmax)	5.5 Vdc (0.047F to 1.5F) 6.3 Vdc (0.1F to 1F)	3.6 Vdc (0.047F to 1.5F) 5.5 Vdc (0.1F - 1F)
Temp. Range	-40 °C to +85 °C (2.3 Vdc @ +85 °C)	-40 °C to +85 °C (2.5 Vdc @ +85 °C)	-15 °C to +70 °C (3.5 Vdc @ +85 °C)	-25 °C to +70 °C	-25 °C to +70 °C	-25 °C to +85 °C
ESR	3mΩ - 200mΩ (2.7 Vdc, AC 1kHz) 80mΩ - 400mΩ (5.5 Vdc, AC 1kHz)	3mΩ - 80mΩ (3 Vdc, AC 1kHz) 100mΩ - 180mΩ (6 Vdc, AC 1kHz)	60mΩ - 250mΩ (AC 1kHz)	60mΩ - 250mΩ (AC 1kHz)	30Ω - 120Ω (AC 1kHz)	30Ω - 120Ω (AC 1kHz)
Case Size	ø 6mm - 35mm (2.7 Vdc) 15mm - 26mm (5.5 Vdc)	ø 6mm - 35mm (3 Vdc) 15mm - 21mm (6 Vdc)	ø 8mm - 18mm	ø 8mm - 18mm	ø 11.5mm & 19mm (V Type) ø 11.5mm & 19mm (H Type) ø 13.5mm - 21.5mm (C Type)	ø 11.5mm & 19mm (V Type) ø 11.5mm & 19mm (H Type) ø 13.5mm - 21.5mm (C Type)
Life Time	• 1,500 h with Vr @ 65 °C • 10 years @ ambient Temp. • 500,000+ cycles	• 1,500 h with Vr @ 65 °C • 10 years @ ambient Temp. • 500,000+ cycles	• 1,000 h with Vr @ 70 °C • 10 Years • 500,000+ cycles	• 1,000 h with Vr @ 60 °C • 10 Years • 250,000+ cycles	• 1,000 h with Vr @ 70 °C	• 1,000 h with Vr @ 85 °C
Lead Configurations	Radial - 1F to 70F 2 Pin Snap In - 100F to 350F 4 Pin Snap In - 400F to 600F Dual Pack (5.5 Vdc) - 1F to 5F	Radial - 1.2F to 110F 2 Pin Snap In - 100F to 200F 4 Pin Snap In - 350F to 600F Dual Pack (6 Vdc) - 1.5F to 5F	Radial	Radial	V Type (Vertical) H Type (Horizontal) C Type (Radial)	V Type (Vertical) H Type (Horizontal) C Type (Radial)
Applications	Industrial IoT – Green Energy/Wind/Solar – Small EV – Power backup – Pulse Power – Energy Harvesting – LED Displays – Mechanical Actuators – UPS Systems – Asset Tracking – AGV		Solar/Wind Energy Storage – Pulse Power – Energy Harvesting – UPS Systems – Smart Meters – Mechanical Actuator – LED Displays – AGV		CPU Memory Backup – Solar Battery Backup & Energy Storage – RTC - Battery Backup – Smart Meters – Industrial Controls – Telematics	

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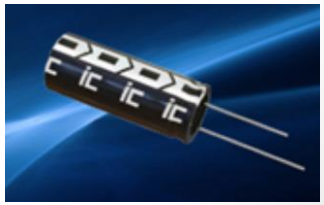
New VMF/VPF Series – Hybrid Capacitor

- VMF/VPF combines the long life (calendar and cycle life) characteristics of the ultracapacitor with the high energy density of the Li-Ion battery
- Volumetric efficiency in small can size with low resistance -> 10F to 220F
- Broad operating temperature range -25^{o}C～85^{o}C
- Safety - Low Self discharge, no thermal runaway – open failure with use of safety vent
- No shipping restrictions
- RoHS compliant
- UL Recognized



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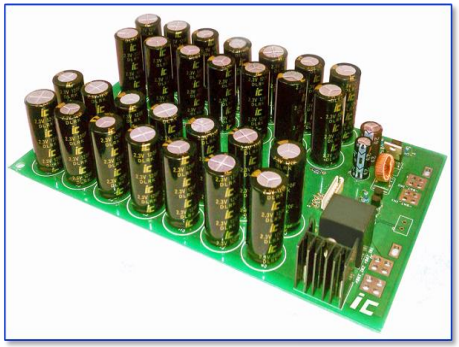
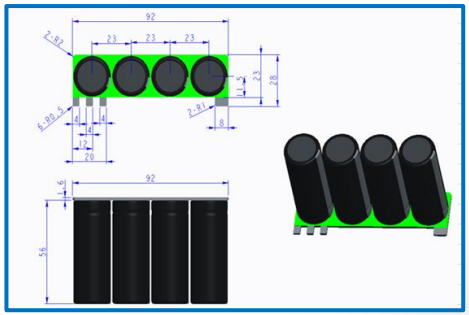
Technology Comparison

	Supercapacitor (DGH, DSF, EDC, EDS)	Hybrid LIC Supercapacitor (VMF, VPF)	Lithium-Ion Battery
Energy density	Low	Medium	Very high
Power density	High	Medium	Medium
Rapid charge/discharge	Seconds	Minutes	Hours (requires charge control)
Internal resistance	Low	Medium	High
Low temperature performance	Good	Limited	Poor
High temperature performance	Good (up to 85℃)	Good (up to 85℃)	Poor (up to 55℃)
Self discharge rate	Medium	Low	Low
Maintenance	Maintenance free	Maintenance free	Maintenance/Replacement
Lifetime (float/cycling)	Long	Long	Relatively short
Safety and flammability	High Safety, no thermal runaway	High Safety, no thermal runaway	Safety Issues (Self heating/flammability)
Application	Very high power (Lower energy)	High power (Medium energy)	Medium power (High energy)

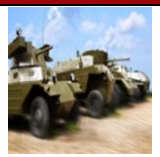
Optimizing the Custom Solution Process

- Custom PCBA layouts
- Quick turn in-house design capabilities
- Higher-level circuit integration
- Solid Works 3-D modeling
- Comprehensive radial cell offering in various voltage platforms
- Passive, active, or custom voltage balancing
- Custom packaging, including shrink sleeves, metal enclosures, conformal coating for outdoor applications, and open frames for easy system integration





Supercapacitor Markets and Applications

Market		Applications	Product Type
Military/Aerospace		Autonomous Weapons	DGH, DSF, VMF, VPF, Modules
		Guidance/Control Systems	10F-3000F
		Security	
		UPS	
		Drones	
		Vehicle Fire Suppression System	
Industrial		Actuator/Electric Valve Control	DGH, DSF, Modules
		AGV	100F-3000F
		Material Handling	
		Video Surveillance/Security	
Handheld		Barcode Scanner/Reader	DGH, DSF, VMF, VPF, Modules
		Medical	1F-100F
		Mobile Computers	
		RFID	
Smart Grid		AMR	DGH, DSF, VMF, VPF, Modules
		Data Collector	3F-400F
		Data Management	
		Powerline Networking	
		Smart City/Lighting	
		5G Connected Devices	
Data Storage		Server	DGH, DSF, VMF, VPF, Modules
		NVDIMM	1F-400F
		SSD	
		UPS	
Automotive (after market)		OBD2	DGH, DSF, VMF, VPF, Modules
		DVR/Car Recorder	1F-100F
		Tbox	
		CDR	
		GPS	
		Tracking	
		Security	

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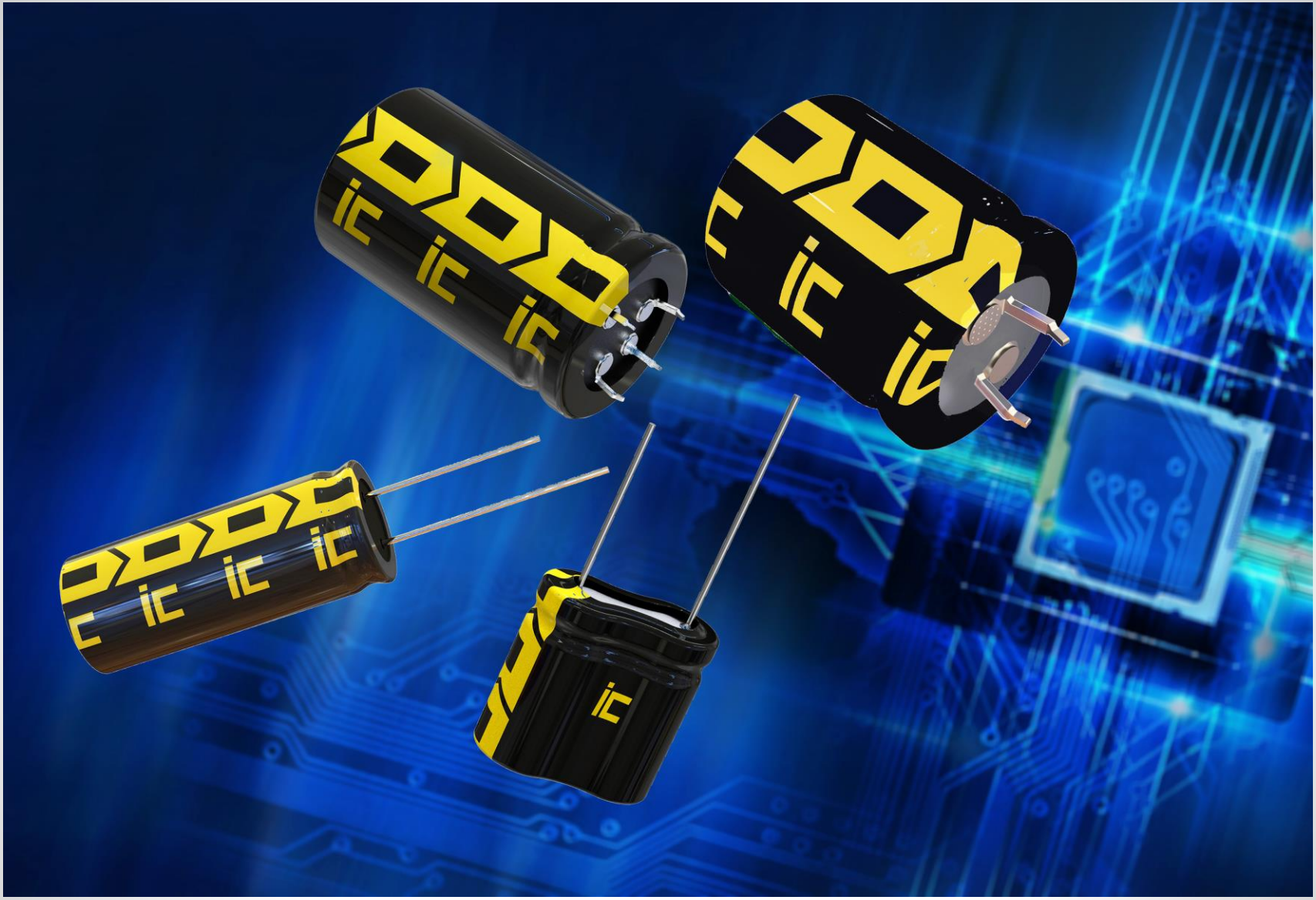

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