

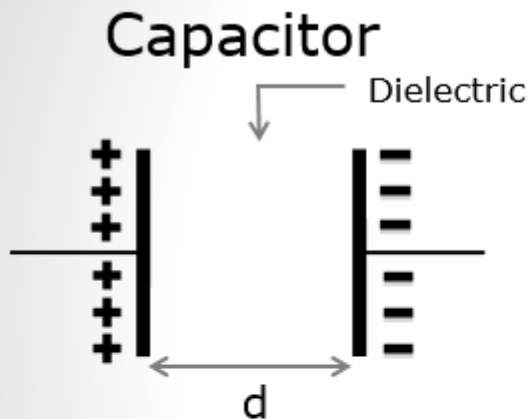


General Supercapacitor Presentation

Supercapacitors – Rapid, Reliable, Safe Power

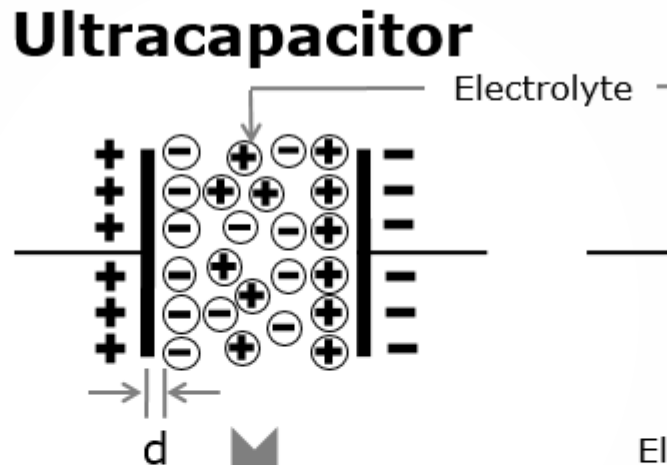
- Supercapacitor, Ultracapacitor, EDLC
- Power Delivery vs Energy Storage Device
- Store energy as electrostatic charge – NO chemical reaction
- Low sensitivity to number of charge/discharge cycles or discharge current
- Wide Operating Temperature -40°C to 85°C
- Lightweight

Technology Primer



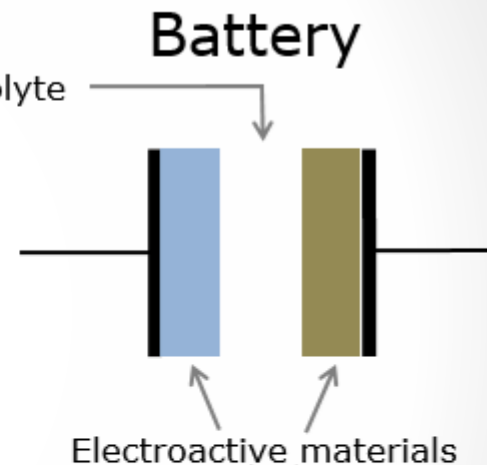
VERY FAST
HIGH CYCLE LIFE
LOW ENERGY

FILTER/FREQUENCY CONTROL



VERY FAST
HIGH CYCLE LIFE
MODERATE ENERGY

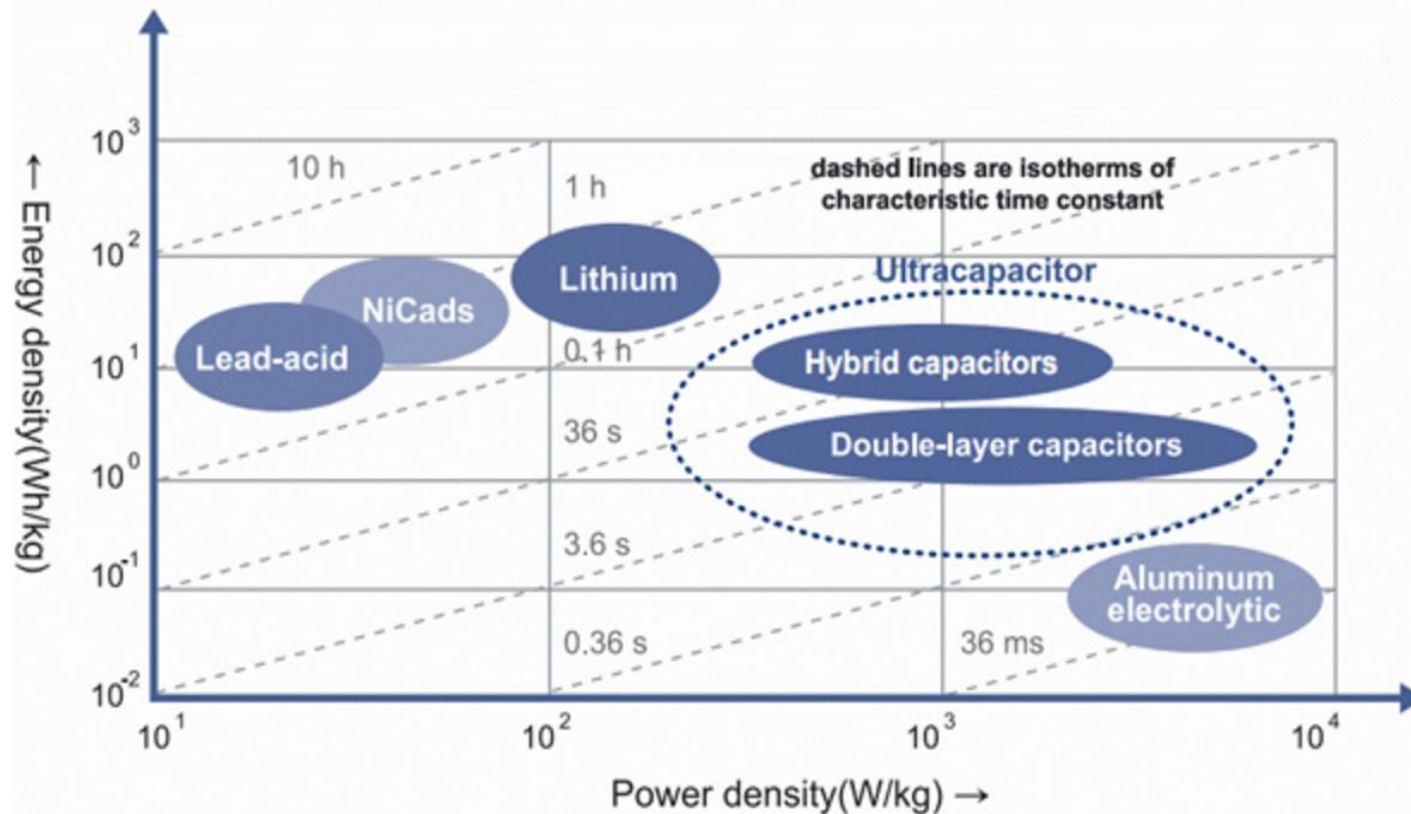
POWER DELIVERY DEVICE



SLOW
LOW CYCLE LIFE
HIGH ENERGY

ENERGY STORAGE DEVICE

Performance Characteristics Comparison



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

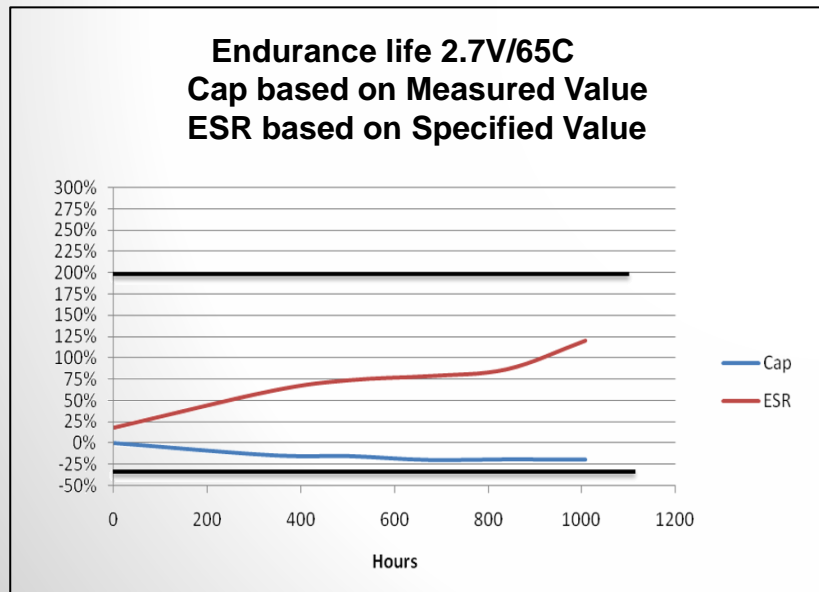
User Benefits

- 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

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

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	<ul style="list-style-type: none"> • Very Fast Charge/Discharge • High Power Density • Low ESR 	<ul style="list-style-type: none"> • High Voltage 3.0 Vdc • Higher Energy Density than 2.7 V (+24%) 	<ul style="list-style-type: none"> • High Voltage 3.8V • High Energy Density • High Temp. +85 °C 	<ul style="list-style-type: none"> • High Voltage 3.8 V • High Energy Density • Low Temp. -25 °C 	<ul style="list-style-type: none"> • Long Life • High Operating Temp. 70 °C 	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • 1,500 h with Vr @ 65 °C • 10 years @ ambient Temp. • 500,000+ cycles 	<ul style="list-style-type: none"> • 1,500 h with Vr @ 65 °C • 10 years @ ambient Temp. • 500,000+ cycles 	<ul style="list-style-type: none"> • 1,000 h with Vr @ 70 °C • 10 Years • 500,000+ cycles 	<ul style="list-style-type: none"> • 1,000 h with Vr @ 60 °C • 10 Years • 250,000+ cycles 	<ul style="list-style-type: none"> • 1,000 h with Vr @ 70 °C 	<ul style="list-style-type: none"> • 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	

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 $-25^{\circ}\text{C} \sim 85^{\circ}\text{C}$
- Safety - Low Self discharge, no thermal runaway – open failure with use of safety vent
- No shipping restrictions
- RoHS compliant
- UL Recognized

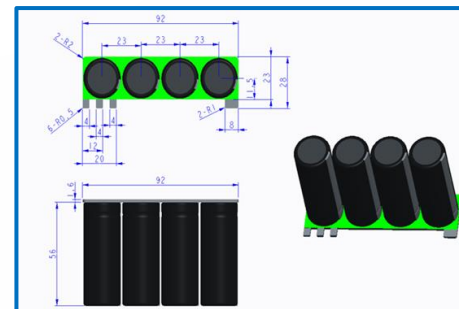
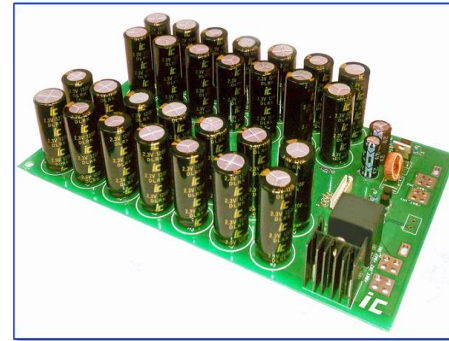


Technology Comparison

	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°C)	Good (up to 85°C)	Poor (up to 55°C)
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	

