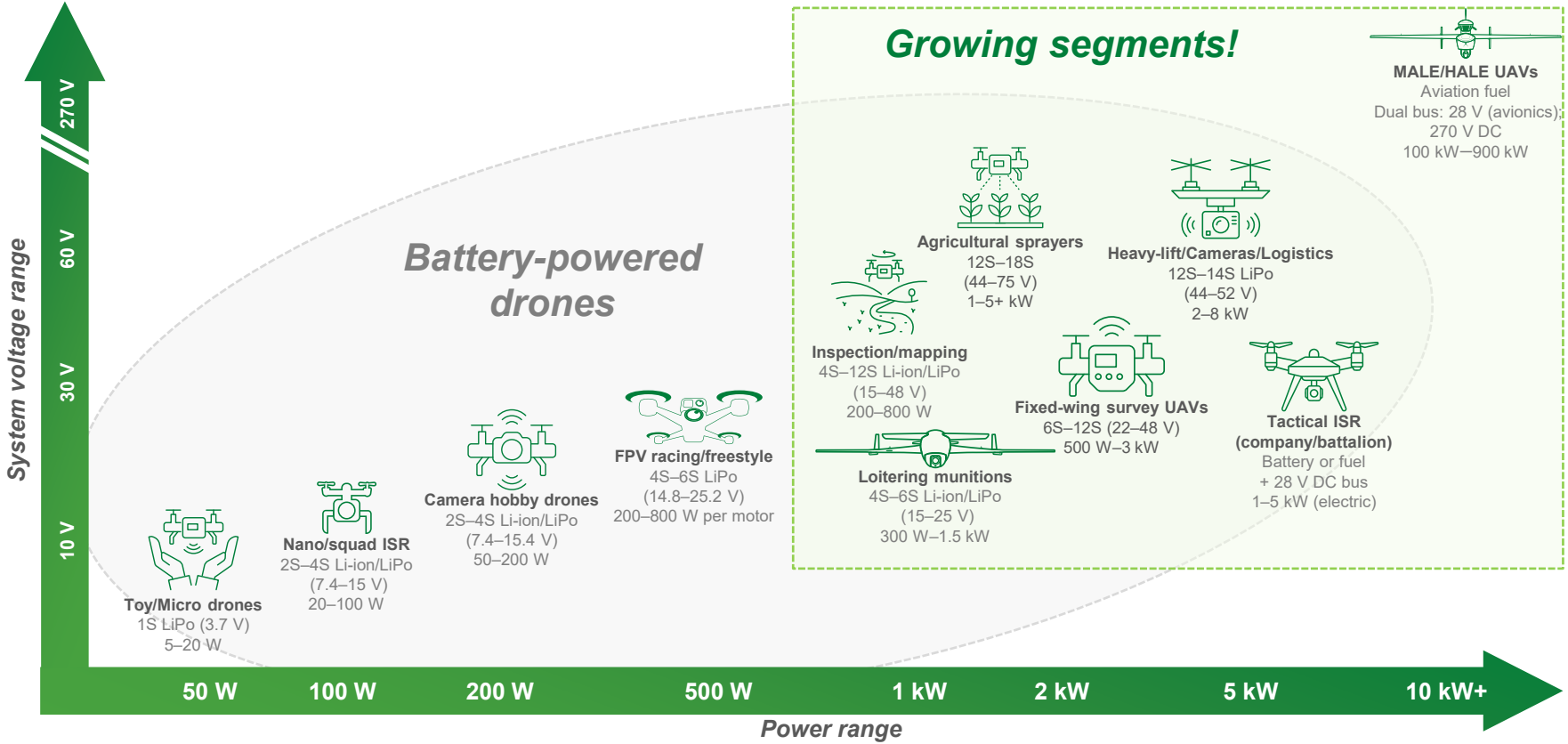
Military UAV, commercial, and consumer drone systems

Military UAV (Unmanned Aerial Vehicle)

Commercial/Industrial

Consumer

Drone & UAV market shift toward commercial & defense applications



Commercial drones & military UAVs represent the largest market opportunity

Global	Consumer	Military	Commercial	Others
				
$73B in 2024	**$4.1B** in 2022	**$41B** in 2024	**$30B** in 2024	**~$19B** in 2024
$164B by 2030	**$26B** by 2030	**~$67B** by 2030	**$55B** by 2030	**~$50B** by 2030
▲ **14.3% CAGR**	▲ **13.3% CAGR**	▲ **7.6% CAGR**	▲ **10.6% CAGR**	
		Growth drivers		
▪ Autonomy & AI improvements ▪ Sensor and camera advances ▪ Regulatory progress (BVLOS)	▪ Camera improvements ▪ Creator economy ▪ Lower cost & ease of use	▪ ISR & surveillance ▪ Loitering munitions ▪ Attritable/autonomous systems	▪ Agriculture ▪ Delivery & logistics pilots ▪ Infrastructure inspection ▪ Enterprise analytics/ROI	
		Key applications		
	▪ Photography/video ▪ FPV racing ▪ Recreational flying	▪ ISR ▪ Tactical strike ▪ Border surveillance	▪ Agriculture ▪ Delivery/logistics ▪ Inspection ▪ Public safety	▪ Government & low enforcement ▪ Drone services ▪ Software
Source: Global Market Report	*Source: Consumer Market Report*	***Focus subsegments for Littelfuse***		*Source: Global Market Report*
		Source: Military Market Report	*Source: Commercial Market Report*	

Drone & UAV system challenges & Littelfuse solutions

Electrical stress & power scaling

- High fault energy (I^2t) in >60 V and kW class systems
- Switching transients (dv/dt) from ESCs and DC-DC converters
- Load dump & unstable DC bus (hybrid/generator systems)

Comprehensive circuit protection

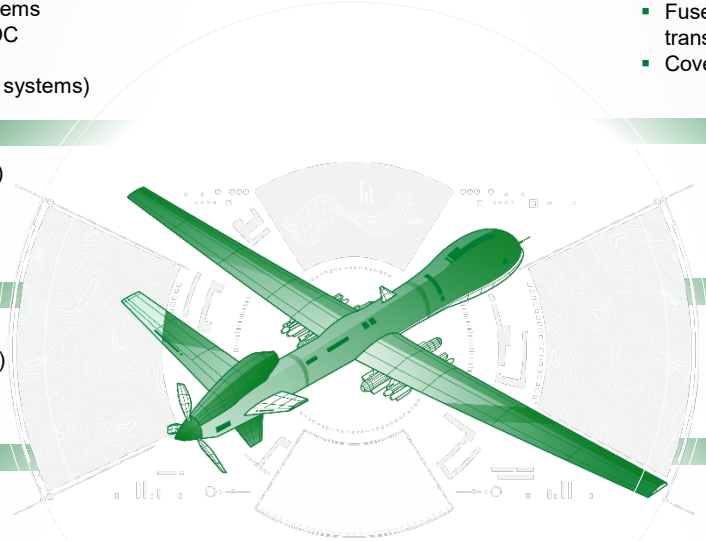
- Fuses, TVS, MOV, PPTC for fault, surge, and transient protection
- Coverage from low-voltage to high-energy HV systems

Interface & connection challenges

- Hot-plug events (USB-C, battery swap, payloads)
- Inrush current from bulk capacitance
- Connector wear, arcing, and resistance drift

Power path control & switching

- MOSFETs, SSRs, contactors for:
  - inrush control
  - battery disconnect/pre-charge
  - safe power switching



Thermal & reliability constraints

- High current density → thermal rise
- Continuous operation (industrial, agriculture, ISR)
- Risk of thermal runaway in Li-ion systems

Thermal & current monitoring

- NTC, Ttape™, CSR for:
  - temperature sensing
  - current measurement
  - battery safety optimization

Signal integrity & protection

- ESD (IEC 61000-4-2) on USB, RF, comm lines
- EMI coupling in compact, high-speed systems
- Sensitive BMS and control electronics

Interface & ESD protection

- ESD/TVS arrays for: USB-C, RF, CAN, communication lines
- Improves system robustness and reliability

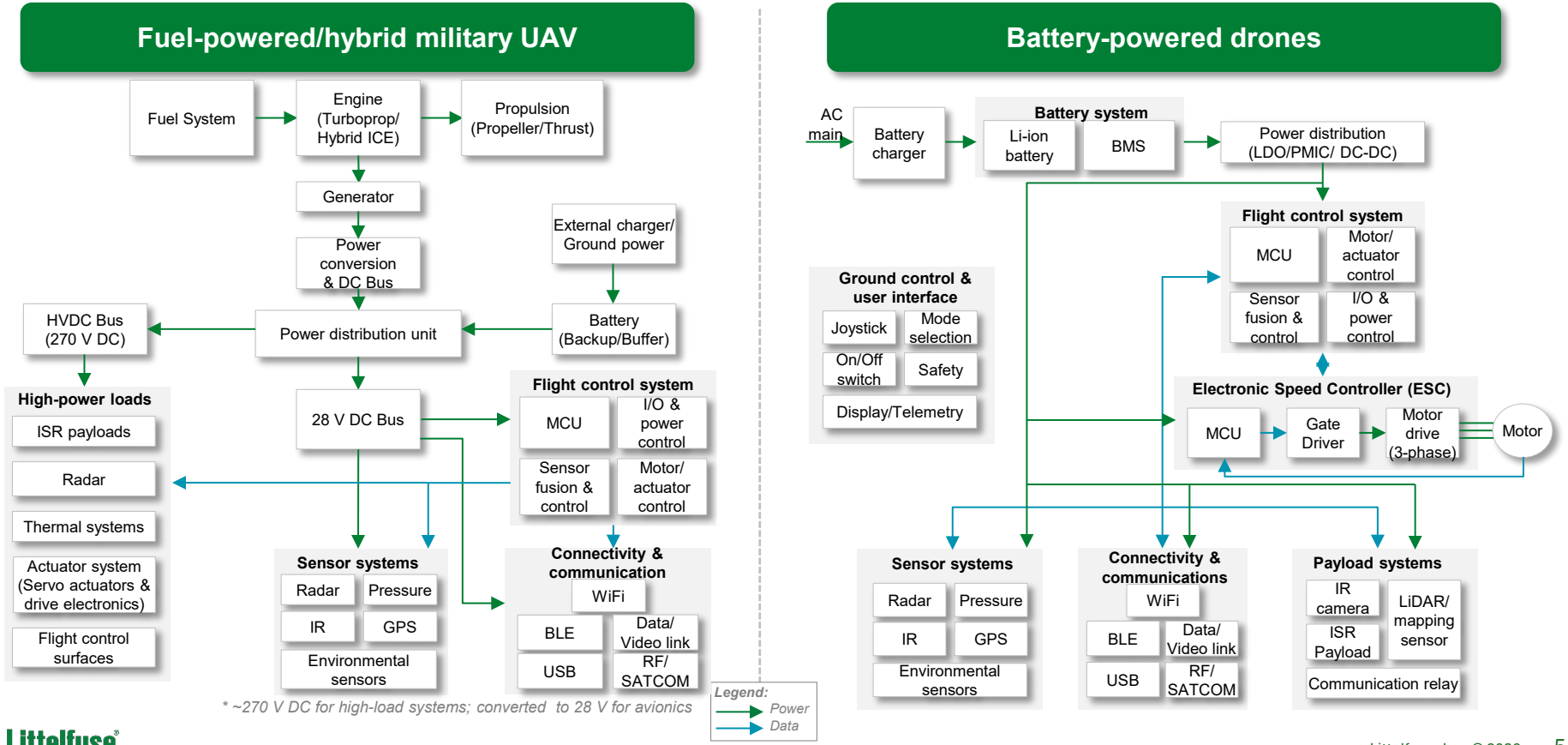
Harsh & mission-critical environments

- Wide voltage range (12 V → 75 V → 270 V bus)
- Shock, vibration, moisture, temperature extremes
- Failure = mission loss (ISR/defense)

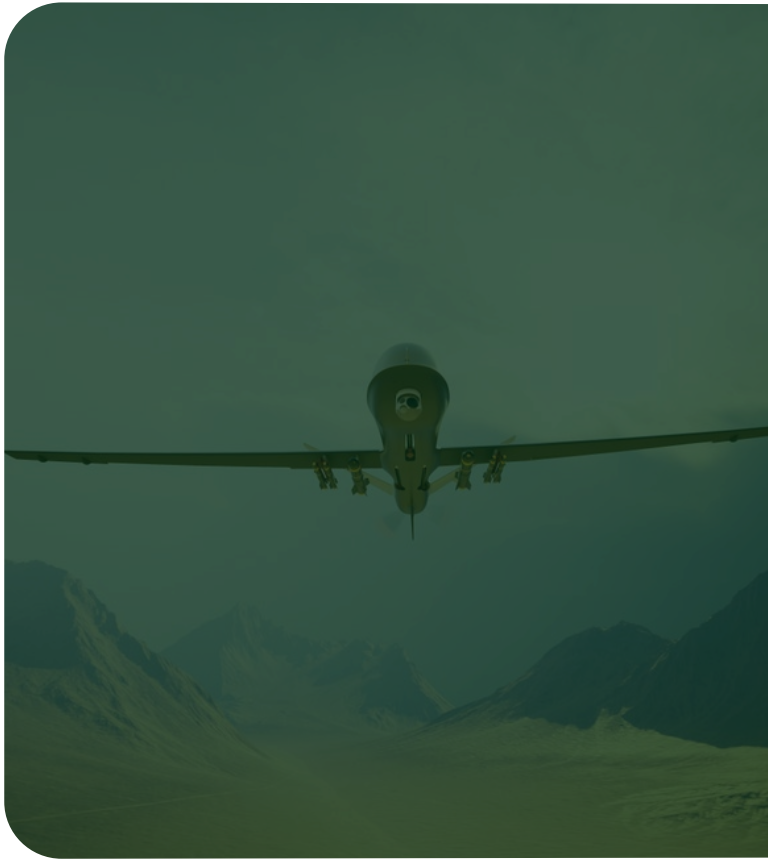
High-reliability & harsh environment solutions

- Automotive & MIL-grade capable components
- DO-160 compliance
- Designed for: hybrid UAVs, high-power systems, and defense applications

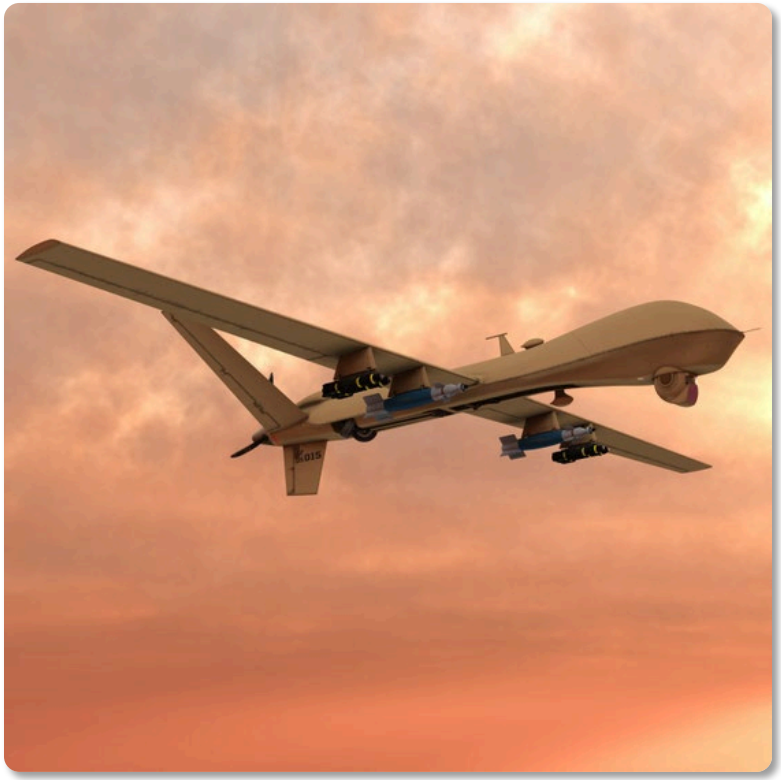
High-level drone and UAV system architecture (fuel/hybrid vs. battery-powered)



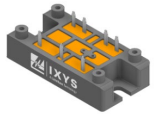
Fuel-powered/ hybrid military UAV systems



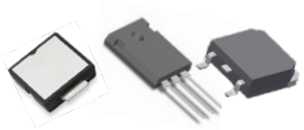
Littelfuse solutions for fuel-powered/hybrid military UAV system



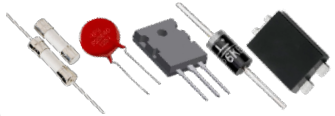
1 Power conversion & DC Bus
Rectifier Diode



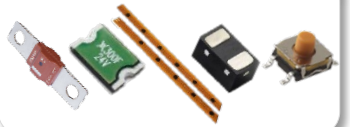
2 Power distribution
TVS Diode, Power Diode, MOSFET



3 Charger/Ground power
Fuse, MOV, MOSFET, TVS Diode, Shottkey Diode

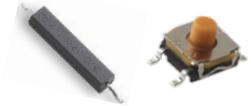


4 Battery backup
Fuse, PPTC, TTape™, TVS Diode Array, Switch



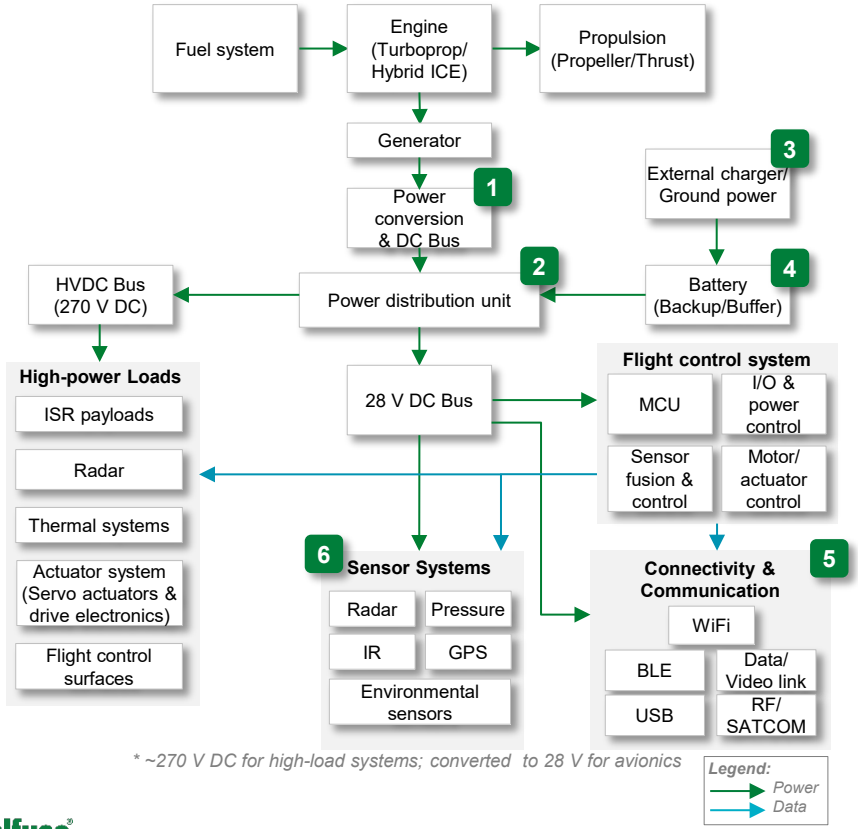
5 Connectivity & communications
TVS Diode, Diode Array, Polymer ESD

6 Sensor systems
Reed Sensor, Switch



Fuel-powered/hybrid military UAV system architecture and Littelfuse solutions mapping

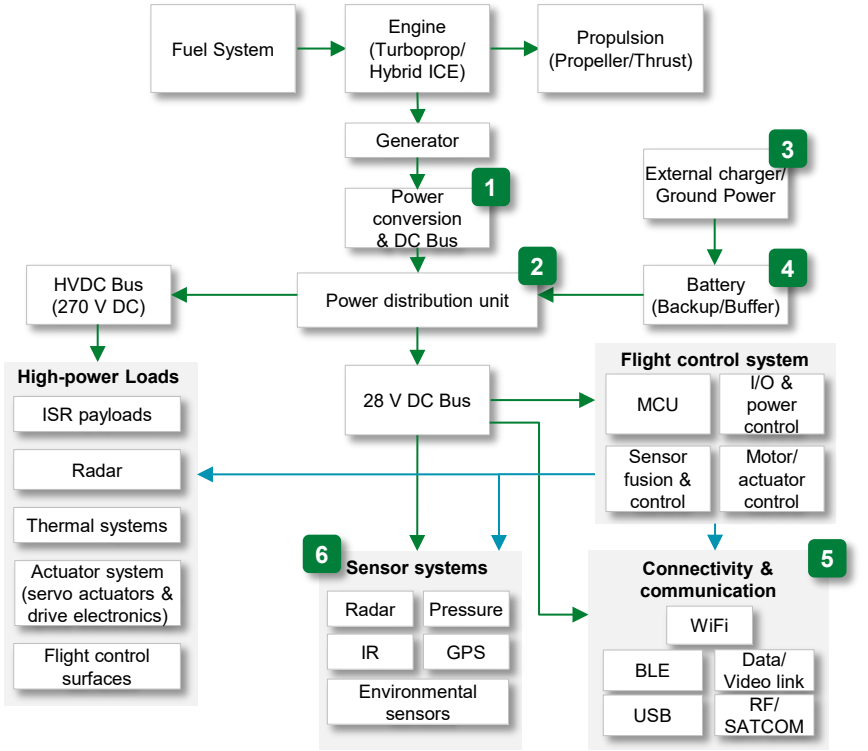
Click on the product series in the table below for more info



	Technology	Function in application	Product series	AEC-Q/ MIL-grade
1	Rectifier Diode	Converts AC line voltage to DC	AC Bridges, Diode Modules, Rectifier	
2	TVS Diode	Clamps fast switching spikes from DC–DC converters	15KPA, 30KPA	TP8.0SMDJ SMD15KPA/HR (DO-160 Compliant), SMD30KPA/HR (DO-160 Compliant)
	Power Diode	Rectification	Power Diode	
	MOSFET	Semiconductor switch	Si MOSFET	Automotive qualified
3	Fuse	Input protection/overcurrent protection	216, 215, 314	MIL-PRF-23419 Fuses (592/593/594)
	MOV	Surge suppression (AC input/charger front-end)	LA, CIII, TMOV, Xtreme	AUMOV, SM10 DSCC Qualified Parts List (QPL), TX Hi-Rel
	MOSFET	Semiconductor switch	Si MOSFET	Automotive qualified
	TVS Diode	DC output transient/ surge protection	P6KE, P6SMB, SMBJ	TPSMB/TPSMC SMBJ-HR (DO-160 Compliant), SMDJ-HR (DO-160 Compliant)
	Power Diode	Rectification	Power Diode	

Fuel-powered/Hybrid Military UAV System Architecture and Littelfuse Solutions Mapping

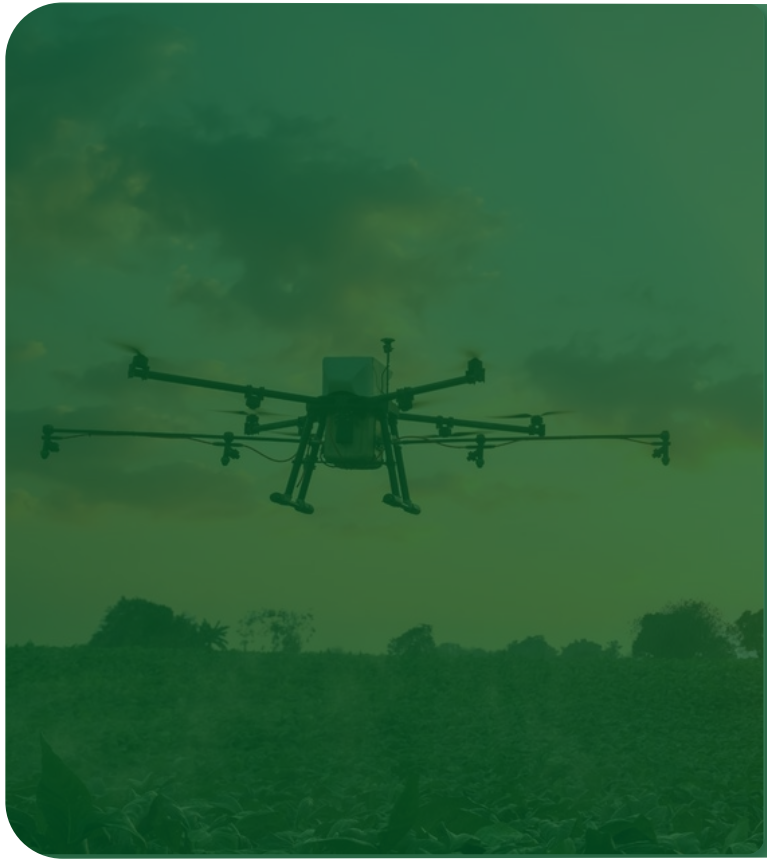
Click on the product series in the table below for more info



* ~270 V DC for high-load systems; converted to 28 V for avionics

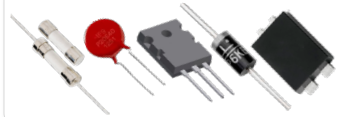
	Technology	Function in application	Product series	AEC-Q/ MIL-grade
4	Fuse	Main pack fault isolation (high-energy short protection)	MIDI 70V, MAXI 58V, 871, 881	263 PICO® Fuses, MICRO™ 262/268/269
	Fuse/PPTC	Branch circuit overcurrent protection	438A, 437A/1812L	438A, 437A/1812L
	TTape™	Temperature monitoring	TTP	
	MOSFET	Battery disconnect/power path control (pre-charge support)	200V X4-Class	
	TVS Diode	DC bus surge and switching transient protection	TPSMD, TP5.0SMDJ, TPSMB-L	SMBLCE-HR/HRA, SMCLCE-HR/HRA (DO-160 Compliant)
	CSR	Pack charge/discharge current monitoring (BMS feedback)	WSTM-A, SSA	SSA
	C&K® Switch	User control, service disconnect, and safety interlock	ZMS, LCS, KSC, ZMV, ATS	8020, PBA, KSC, KSJ
5	TVS Diode Array	ESD protection for BLE, WiFI, USB, etc	SP3213-01UTG, SP1006-01UTG	AQ24COM-02, AQ1003
	Polymer ESD		PGB10402, PGB10603	AXGD
	TVS Diode	Transient protection	SMDJ	SMDLCE-HR/HRA (DO-160 Compliant)
6	Reed Sensor	Position sensing (payload/ actuator/safety)	59170	
	C&K® Switch	Various functions	KSC	

Commercial & Tactical UAV

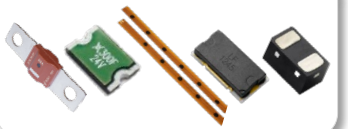


Littelfuse solutions for commercial drone & tactical UAV systems

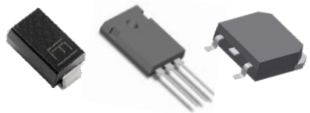
1 Battery charger
Fuse, MOV, MOSFET, TVS Diode, Shottkey Diode



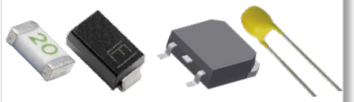
2 Li-Ion battery protection
Fuse, PPTC, TTape™, Battery Protector, TVS Diode Array



3 Power distribution
TVS Diode, Power Diode, MOSFET

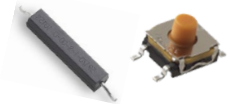


4 Electronic speed controller
Fuse, TVS Diode, MOSFET, NTC



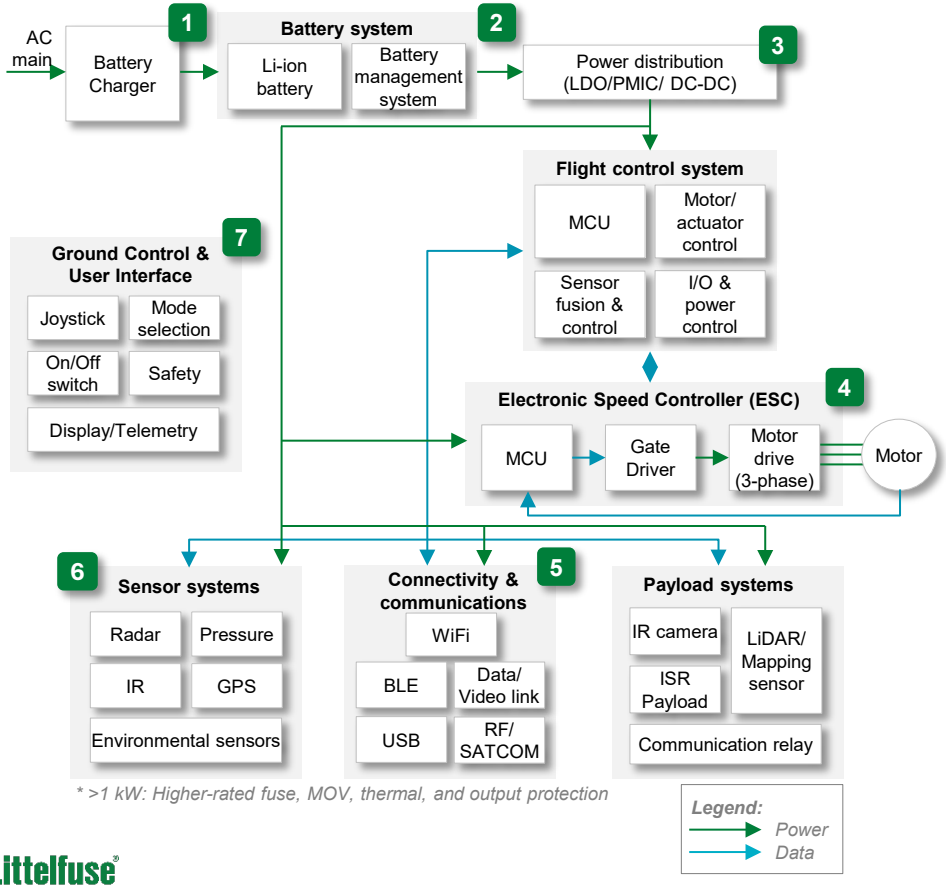
5 Connectivity & communications
TVS Diode, Diode Array, Polymer ESD

6 Sensor system
Reed Sensor, Switch



Commercial drone and UAV system architecture and Littelfuse solutions mapping

Click on the product series in the table below for more info

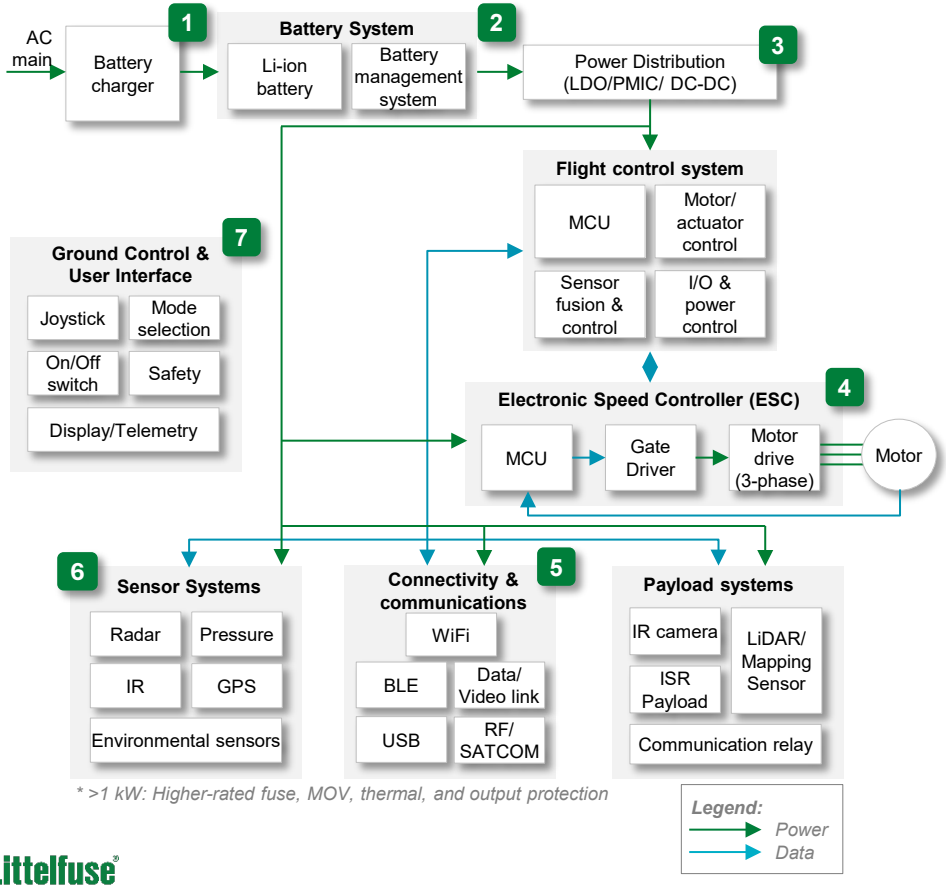


* >1 kW: Higher-rated fuse, MOV, thermal, and output protection

	Technology	Function in application	Product series	AEC-Q
1	**Dedicated Li-ion battery chargers (Commercial & Military UAVs) (15–60 V, 150 W–1 kW (typical); 48–100 V, 1–5+ kW (high power)***			
	Fuse	Input protection/ overcurrent protection	216, 215, 314	
	MOV	Surge suppression (AC input/charger front-end)	LA, CIII, TMOV, Xtreme	AUMOV
	MOSFET	Semiconductor switch	Si MOSFET	Automotive qualified
	TVS Diode	DC output transient/ surge protection	P6KE, P6SMB, SMBJ	TPSMB/TPSMC
	Power Diode	Rectification	Power Diode	
2	**Battery protection>60 V (Commercial & Military Drones)**			
	Fuse	Main pack fault isolation (high-energy short protection)	MIDI 70V, MAXI 58V	871 881
	Fuse/PPTC	Branch circuit overcurrent protection	438A, 437A/1812L	438A, 437A
	TTape™	Temperature monitoring	TTP	
	MOSFET	Battery disconnect/power path control (pre-charge support)	200V X4-Class	
	TVS Diode	DC bus surge and switching transient protection	TPSMD, TP5.0SMDJ, TPSMB-L	TPSMD, TP5.0SMDJ, TPSMB-L
	CSR	Pack charge/discharge current monitoring (BMS feedback)	WSTM-A	SSA
	C&K® Switch	User control, service disconnect, and safety interlock	ZMS, LCS, KSC, ZMV, ATS	

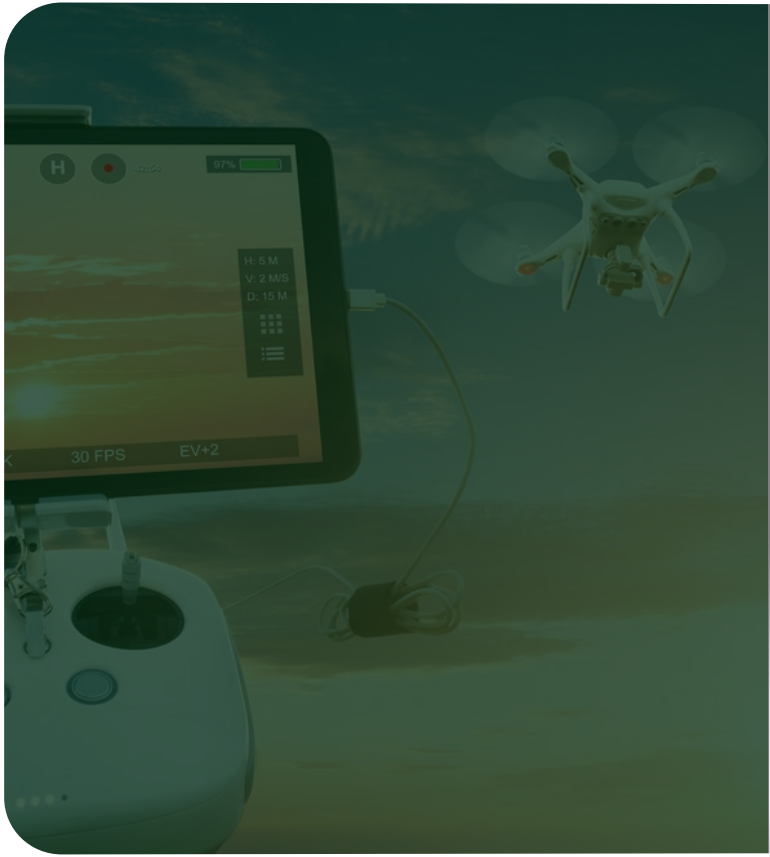
Commercial drone and UAV system architecture and Littelfuse solutions mapping

Click on the product series in the table below for more info



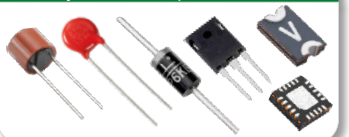
	Technology	Function in application	Product series	AEC-Q
3	TVS Diode	Clamps fast switching spikes from DC–DC converters	SMAJ, SMBJ, 5KP	TPSMB
	Power Diode	Rectification	Power Diode	
	MOSFET	Semiconductor switch	Si MOSFET	Automotive qualified
4	TVS Diode	Motor drive transient/ EMI protection	SMAJ, SMBJ, 5KP	TPSMB
	NTC	Thermal monitoring	RB	
5	TVS Diode Array	ESD protection for BLE, WiFI, USB, etc.	SP3213-01UTG, SP1006-01UTG	AQ24COM-02, AQ1003
	Polymer ESD		PGB10402, PGB10603	AXGD
6	Reed Sensor	Position sensing (payload/actuator/safety)	59170	
	C&K® Switch	Various function	KSC	
7	Ground Control and User Interface			

Consumer drones



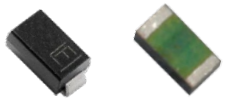
Littelfuse solutions for consumer drone systems

1 USB-C charging
Fuse, MOV, TVS Diode, Schottky Diode, Temp. Indicator, eFuse

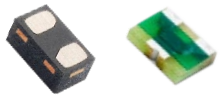


2 Battery system (Main/Buffer)
Fuse, PPTC, MHP, Battery Protector, CSR, TVS Diode

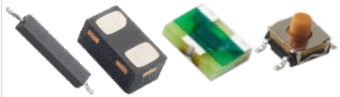
3 Electronic speed controller
TVS Diode, NTC



4 Connectivity & communications
TVS Diode Array, Polymer ESD

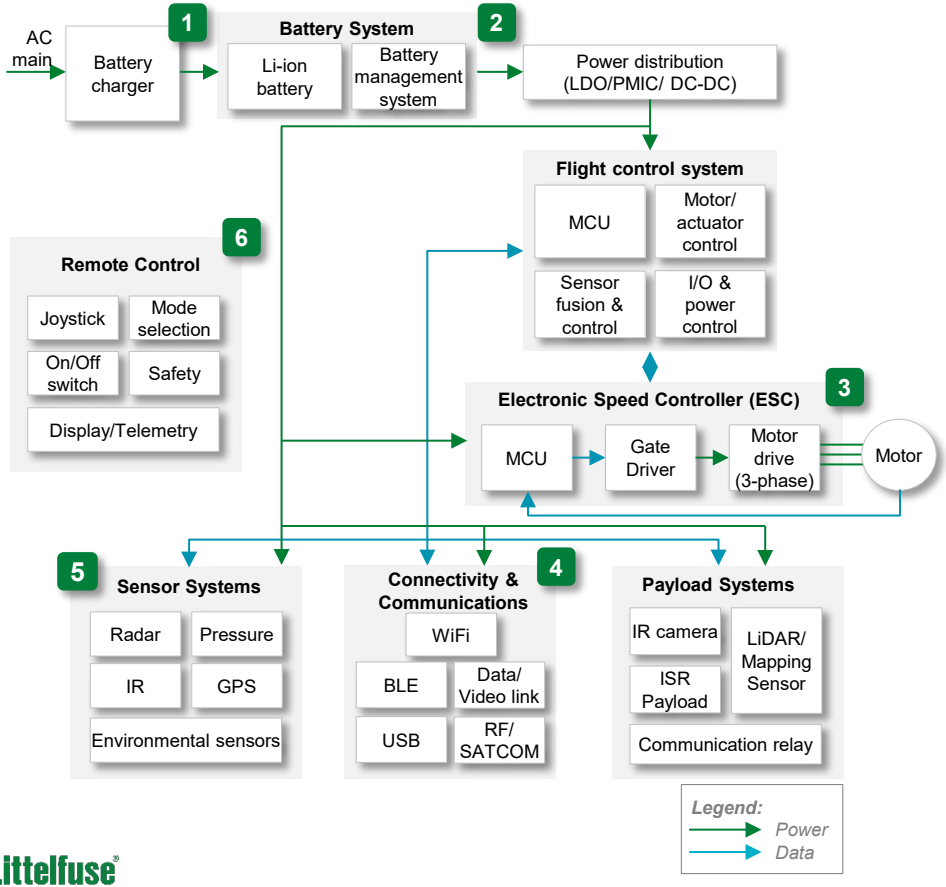


5 Payload systems
Reed Sensor, TVS Diode Array, Polymer ESD, Switch



Consumer drone architecture and Littelfuse solutions mapping

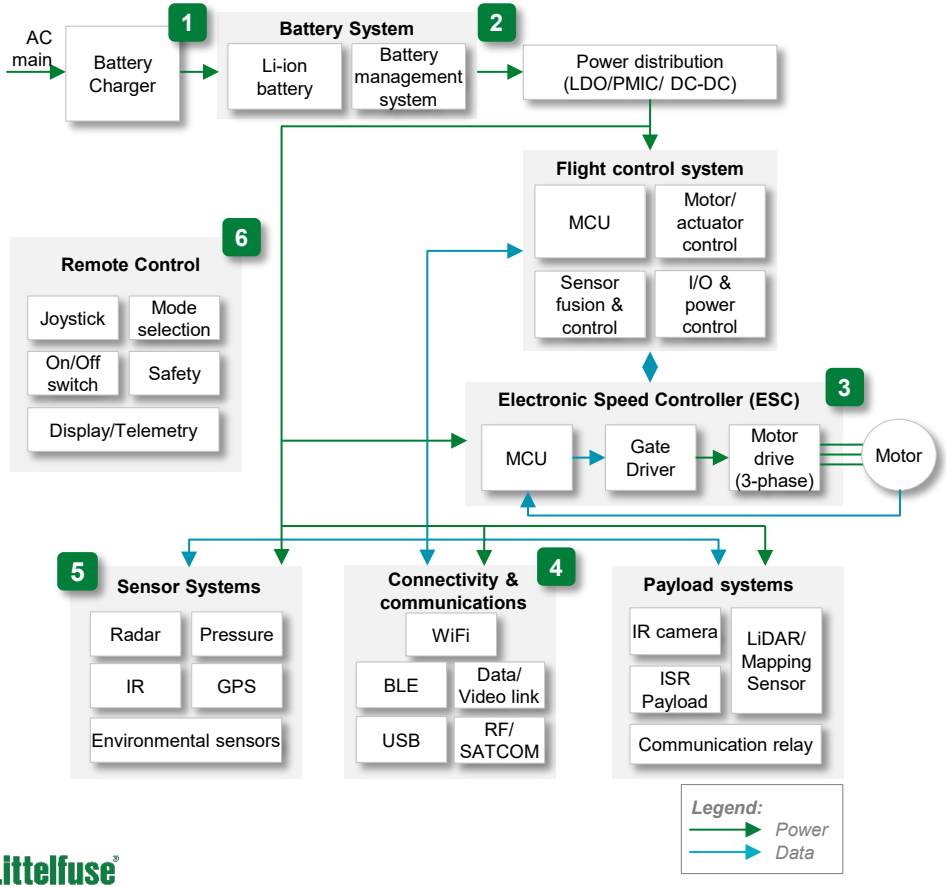
Click on the product series in the table below for more info



	Technology	Function in application	Product series	MIL-grade
1	**USB-C for consumer drones (5–48 V, up to 240 W (typical 100–140 W))**			
	Fuse	Protects power stage from overcurrent	218, 373, 443E	Not Applicable
	MOV	Protects against voltage transients and lightning	LA, M3	
	TVS Diode	Secondary protection against voltage transients	P6KE, P6SMB, 8.0SMDJ, 1.5SMB, SMF4L	
	Bridge Diode	AC rectification (50/60 Hz)	Dxx15L	
	Schottky Diode	Output rectification/reverse blocking	MBR, DST	
	Temperature Indicator	Protects USB-C plugs and receptacle from overheating	SETP0805-100-CC	
	Protection IC (eFuse)	Protects USB-C and USB-C PD from overcurrent and overvoltage	LS Series	
2	**Battery protection for <60 V (Consumer Drones)**			
	PolySwitch® Resettable Device /Battery Mini-Breaker	Resettable overcurrent and overtemperature protection	LSP, MHP-TAT18	Not Applicable
	Fuse ***OR*** Battery Protector	Secondary pack protection/ fail-safe overcurrent protection	881, 688 ***OR*** ITV	
	Fuse/ PolySwitch® Resettable Device	Branch or accessory line protection	458 ***OR*** 0805L	
	CSR	Current sensing for charge/ discharge & BMS control	L4CL	
	TVS Diode	Voltage transient protection	SMF, SMF4L	

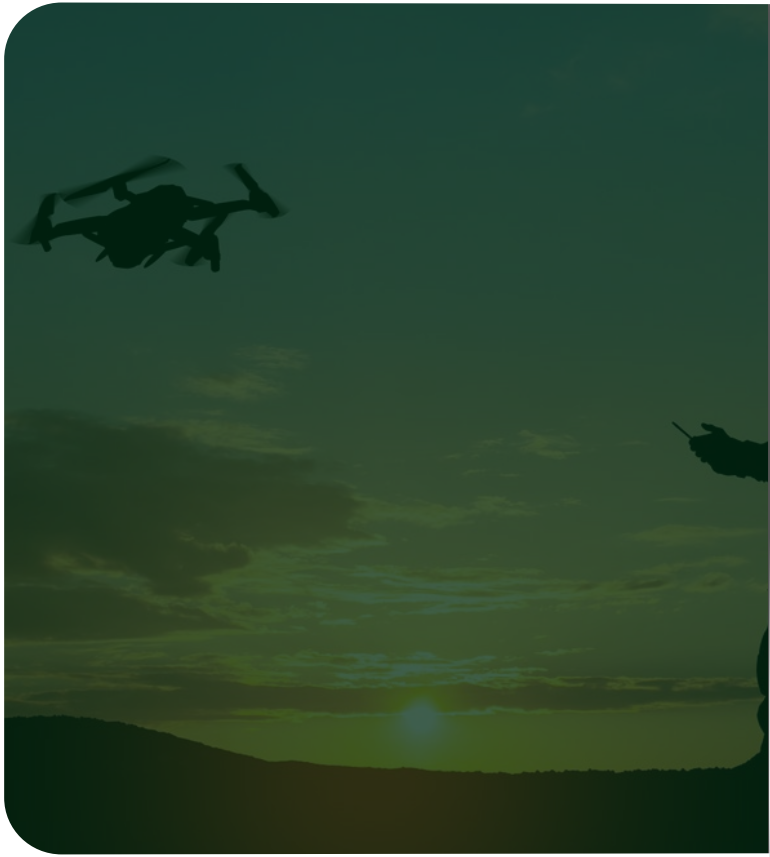
Consumer drone architecture and Littelfuse solutions mapping

Click on the product series in the table below for more info

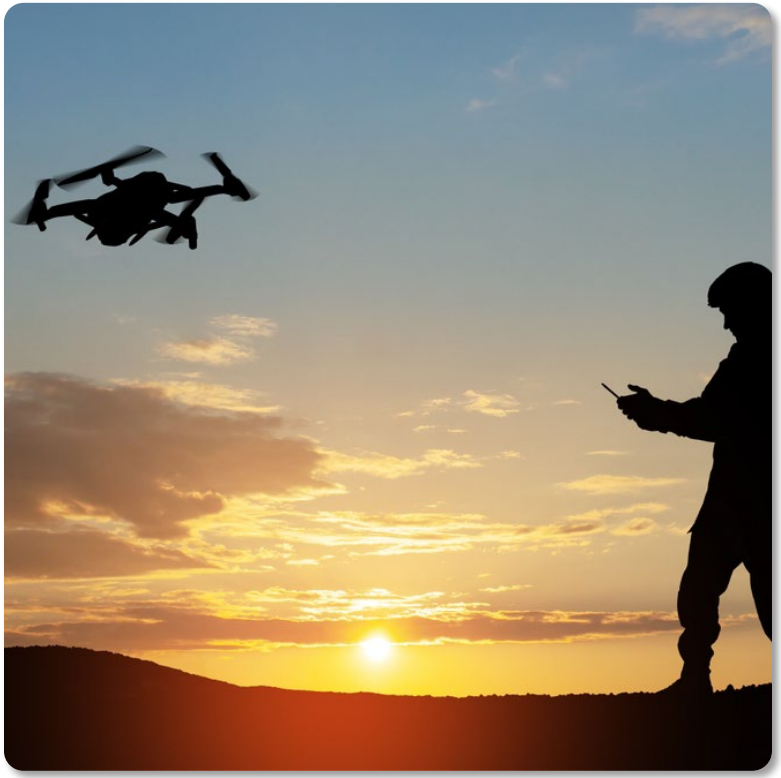


	Technology	Function in application	Product series	MIL-grade
3	TVS Diode	Motor drive transient/EMI protection	SMAJ, SMBJ, 5KP	SMBLC/ SMCLE-HR/HRA
	NTC	Thermal monitoring	RB	
4	TVS Diode Array	ESD protection for BLE, WiFi, USB, etc	SP3213-01UTG, SP1006-01UTG	
	Polymer ESD		PGB10402, PGB10603	
5	Reed Sensor	Position sensing (payload/ actuator/safety)	59170	
	TVS Diode Array/ Polymer ESD	ESD protection	SP3213-01UTG, SP1006-01UTG/ PGB10402, PGB10603	
	C&K® Switch	Reset/On-Off	KSC	
6	Remote Control			

Remote control



Remote control and Littelfuse solutions



1 USB
Digital Temp Indicator, PPTC, TVS Diode Array, eFuse

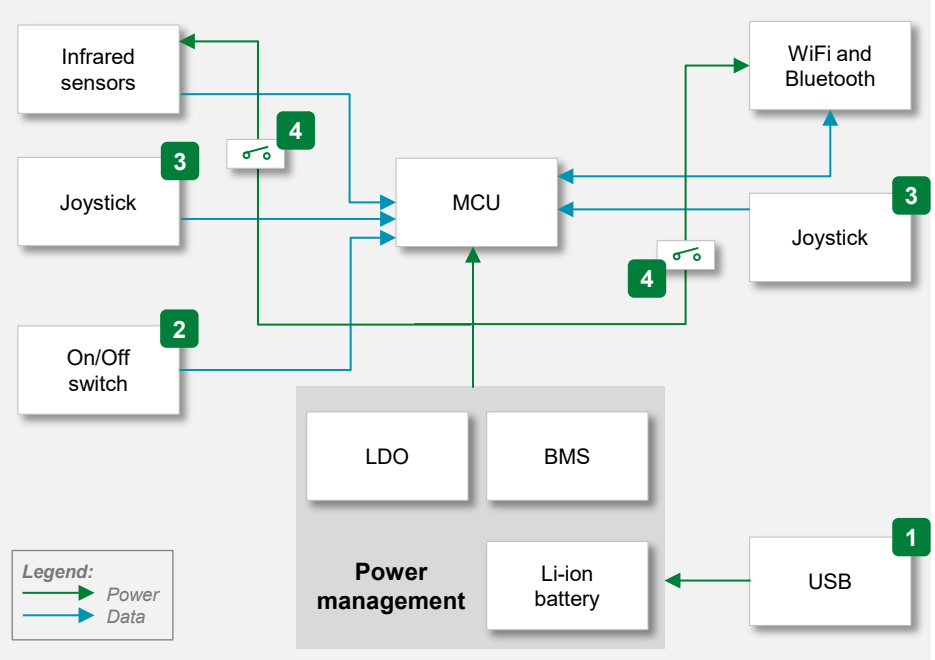
2 On/Off switch
Tactile Switch

3 Joystick
Navigation Switch

4 Load switching
Load Switch IC

Drone and UAV ground control system block diagram & solutions mapping

Click on the product series in the table below for more info



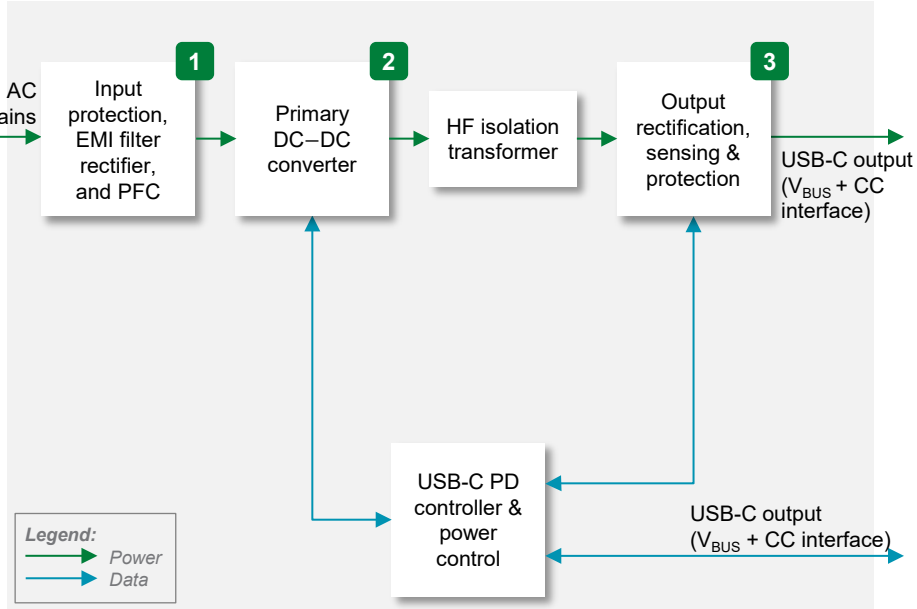
	Technology	Function in application	Product series	MIL-grade
1	Digital Temperature Indicator (USB-C)	Connector temperature monitoring/thermal protection	setP™	
	Protection IC (eFuse) (USB-C)	Overcurrent, overvoltage and short-circuit protection for USB input	LS0505EVD22, LS0504EVT233, LS0504EDD12	
	TVS Diode Array	ESD protection for USB data lines (high-speed interface)	SPHV-C, SC1205-01ETG, SP1021, SP3021	
2	C&K® Switch	Power on/off, mode selection, user interface input	KMT0, KSC7, KMR4, PTS645	KSC/KSJ (Tactile)
3	C&K® Switch	Joystick input/directional control for UAV operation	THB001P	MIL-DTL-83731F (Toggle), 8020, PBA (Pushbutton)
4	Load Switch IC	Power distribution control, subsystem on/off switching, battery load management	LQ0502, LQ0504	

Drone subsystems

USB-C PD charger

Appropriate for toy, camera hobby, and selected small smart-battery drones

Click on the product series in the table below for more info

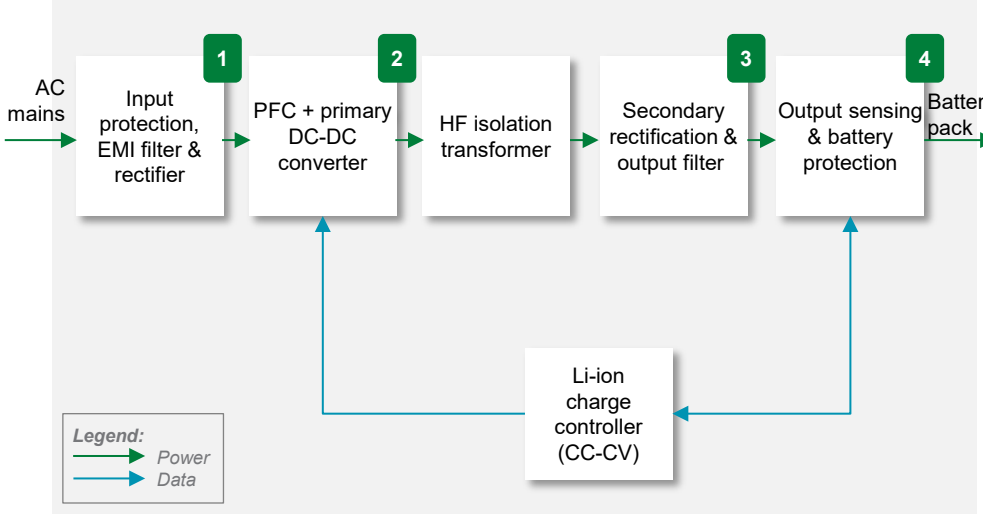


	Technology	Function in application	Product series
1	Fuse	AC input overcurrent protection and fault isolation	218, 373, 443E
	MOV	AC mains surge/lightning transient suppression	LA, M3
2	Optocoupler	Feedback isolation between primary and secondary control	CPC1301
	TVS Diode	Primary-side switching transient suppression	P6KE, P6SMB, 8.0SMDJ, 1.5SMB, SMF4L
	Bridge Diode	AC rectification (50/60 Hz)	Dxx15L
3	Schottky Diode	Secondary rectification and reverse current blocking	MBR, DST
	Temperature Indicator	USB-C connector thermal monitoring/overheating protection	SETP0805-100-CC
	Protection IC (eFuse)	VBUS overcurrent, overvoltage, and short-circuit protection	LS Series
	TVS Diode Array	ESD protection for USB-C CC and high-speed data lines	SPHV-C, SC1205-01ETG, SP1021, SP3021

Dedicated Li-ion battery charger (<1 kW)

Appropriate for FPV, enterprise, industrial, and ISR drones

Click on the product series in the table below for more info



	Technology	Function in application	Product series	MIL-grade
1	Fuse	AC input overcurrent and fault protection	5X20mm Fuse, TR3, TR5	MIL-PRF-23419 Fuses (592/593/594)
	MOV	AC line surge protection	LA, CIII, TMOV	DSCC Qualified Parts List (QPL), TX Hi-Rel
2	MOSFET	Primary power switching in PFC/DC-DC stage	Si MOSFET	
	Power Diode	Rectification	Power Diode	
	TVS Diode	Primary-side transient suppression	P6KE, P6SMB	SMBJ-HR/HRA, SMDJ-HR/HRA
3	Power Diode	Rectification	Power Diode	
4	TVS Diode	Battery-side output transient protection	SMBJ	

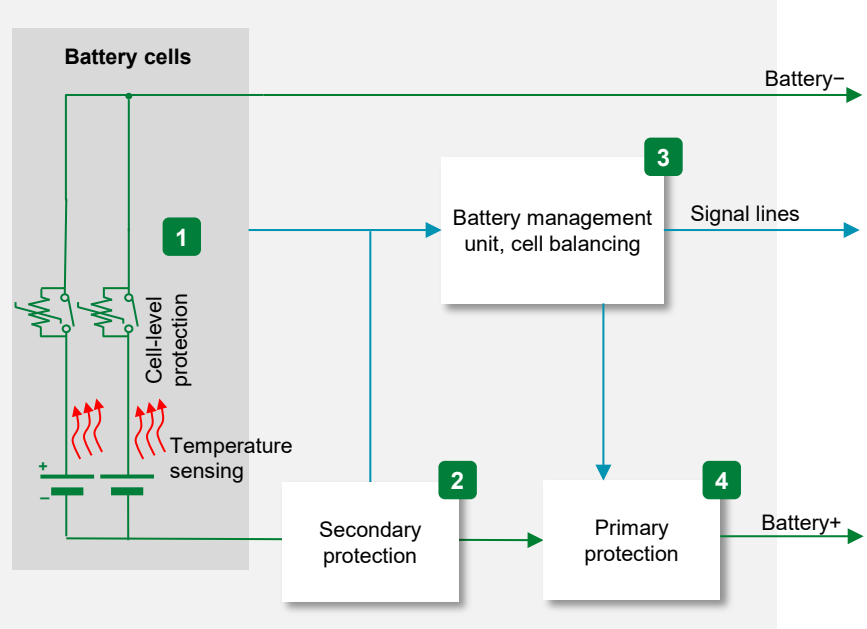
Battery swap, high-power charging, and hybrid UAV systems

System Type	Typical drone types	What changes	Key electrical risks	Littelfuse focus
Battery swap systems	Agriculture drones, delivery UAVs, ISR field systems	Frequent pack insertion/removal	Hot-plug, inrush current, connector wear, arcing	TVS at interface, fuse coordination, MOSFET/ relay disconnect, current sensing, pack detection
High-power charging (>1 kW)	Agriculture, heavy-lift, industrial inspection	Higher voltage/ current charging	Thermal stress, high fault energy, cable/connector heating	High interrupt fuse, high-energy MOV, power MOSFET, high-power TVS, thermal monitoring
Hybrid/Fuel (MALE/HALE)	Long-endurance ISR, military UAVs	Engine + generator + battery buffer	Load dump, unstable DC bus, high-energy transients	Robust TVS, HV fuse, power switching, isolation, MIL-grade components

Battery pack system architecture: <60 V

Appropriate for most drones (Camera, FPV, inspection mapping, small ISR)

Click on the product series in the table below for more info



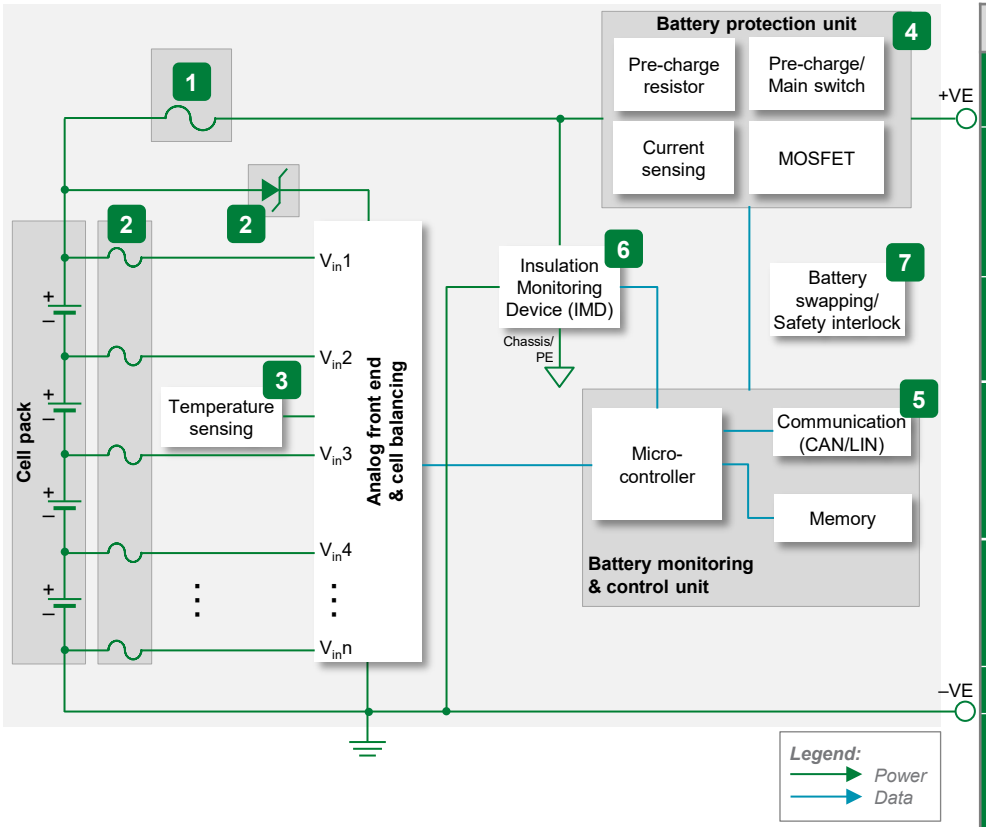
- ***Secondary protection:*** *Protects cells if the primary safety circuit fails.*
- ***Primary protection:*** *Handles all the basic safety functions: overvoltage, undervoltage, overcurrent, under-temperature, and overtemperature.*

	Technology	Function in application	Product series
1	NTC	Cell temperature sensing for BMS monitoring and protection	KC
	PolySwitch® Resettable Device ***OR*** Battery Mini-Breaker	Resettable overcurrent and overtemperature protection at cell/pack level	LSP ***OR*** MHP-TAT18
2	Fuse ***OR*** Battery Protector	Secondary protection (fail-safe cutoff during fault conditions)	881, 688 ***OR*** ITV
3	Fuse ***OR*** PolySwitch® Resettable Device	BMS protection	458 ***OR*** 0805L
	Current Sensing Resistor	Charge/discharge current measurement for BMS control	L4CL
4	TVS Diode	Clamp voltage transients on battery output/DC bus	SMF, SMF4L

Battery pack system architecture: >60 V

Appropriate for large industrial drones such as agriculture, heavy lift, large ISR, etc.

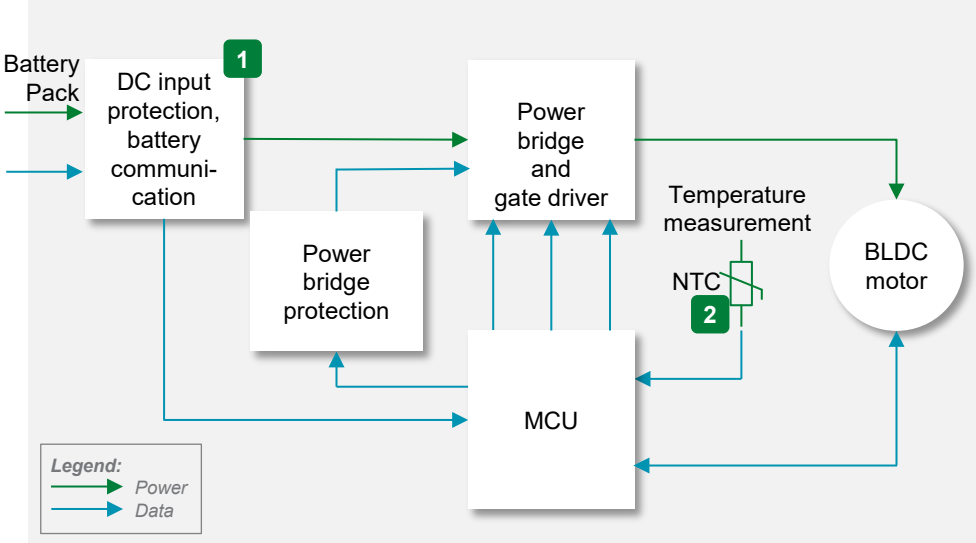
Click on the product series in the table below for more info



	Technology	Function in application	Product series
1	Fuse	Clears hard shorts; protects pack, wiring, and controller	MIDI 70V, MAXI 58V, 871, 881
2	Fuse **OR** PolySwitch® Resettable Device	Protects the balancing circuit/ AFE	438A, 437A
			1812L
	TVS Diode	Cell monitor IC sense line input overvoltage protection	TPSMB-L
3	NTC		Leaded, Surface Mount
	TTape™ Platform	Manages battery lifetime and helps identify hazardous temperature levels	TTP
4	MOSFET	Battery protection (hybrid/solid-state)	200V X4-Class
	TVS Diode	Protects against voltage spikes and transients	TPSMD, TP5.0SMDJ, SZ5KASMC
	Current Sensing Resistor	Measures pack charge/ discharge current	WSTM-A, SSA
5	TVS Diode Array	Protects sensitive electronic ICs from ESD, EFT, and voltage spikes	AQ24COM-02, AQ24COM-01
	PolySwitch® Resettable Device	Resettable overcurrent protection	nanoASMD
6	Solid State Relay	Monitors isolation	LAA110, LCA701, CPC1009N
7	Reed Switch	Provides the control signal for the battery pack	MDSR-10
	C&K® Switch	Enables battery detection switching/anti-tamper protection	ZMS, ZMSM, LCS, KSC, ZMV, ZMW, ATS

BLDC motor protection architecture

Click on the product series in the table below for more info



	Technology	Function in application	product Series
1	Fuse	Protects the battery and downstream controller from damage due to inrush current, motor shorting, or external shorts at contacts	501
	TVS Diode	Protect battery pack from voltage transients	SMAJ, SMBJ, 5KP
2	NTC	Temperature sensing to prevent motor damage due to overheating	RB

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Littelfuse

Application Note:
Designing Reliable Drones using Proper Circuit Protection

Are you safe with Drones in the sky?

Designing Reliable Drones using Proper Circuit Protection

A drone filming a Pamplona-style "running of the bulls" at Virginia Motorsports Park suddenly dips into the crowd below, injuring spectators... a 15kg. camera drone drops out of the sky during a ski race in Italy, narrowly missing Austrian Marcel Hirscher before smashing into the slope behind him... a rogue drone smashes through a fifth-story office window in Cape Town, South Africa, striking unsuspecting race car driver David Perel in the head... a drone narrowly misses colliding with an Airbus A320 as it takes off from London's Heathrow airport... a drone hits the Seattle Great Wheel - believed to be the largest Ferris wheel of its kind on the West Coast, standing 175 feet tall - near downtown Seattle's waterfront, crashing into a nearby pier and prompting a police response.

Introduction/Overview

No doubt "pilot losing control" is behind many drone incidents and crashes. **But what's behind that "loss of control?"** After all, even small recreational drones depend on a host of subsystems – GPS, receiver antennae, WiFi I/O ports and electronic speed controllers – to stay in the air. Lose one and that UAV becomes a UFO pretty quickly.

The number of consumer, professional, and commercial drones, sometimes called unmanned aircraft systems (UASs) or unmanned aerial vehicles (UAVs), sold annually has risen rapidly over the last few years. Future sales growth looks even more rapid, with the Federal Aviation Administration predicting that sales will grow from roughly 2.5 million this year to 7 million by 2020, with 4.3 million being sold to hobbyists and 2.7 million units being sold for professional and commercial applications. Non-military drones are available at a wide range of price points, anywhere from toys that cost less than $100 to sophisticated commercial drones for use in fields like aerial photography, public safety services, agriculture, and wildlife management that can cost thousands (**Figure 1**).

Figure 1: Drones are available with a wide range of functionality at a variety of price points, but all share a number of common circuit protection requirements.

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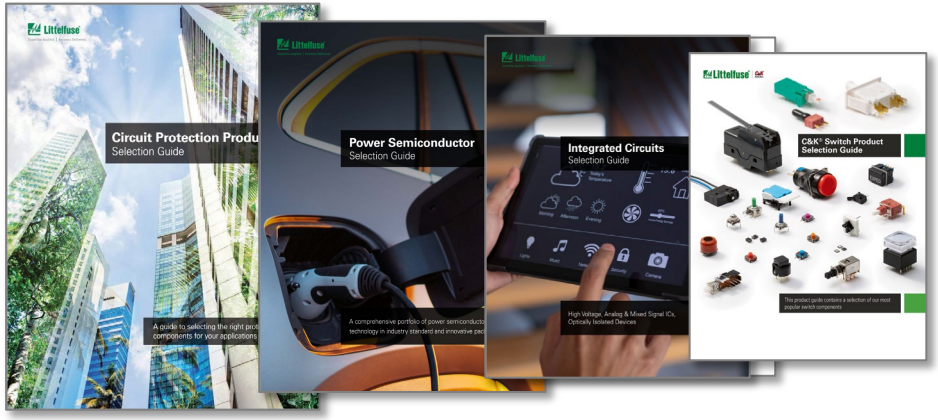
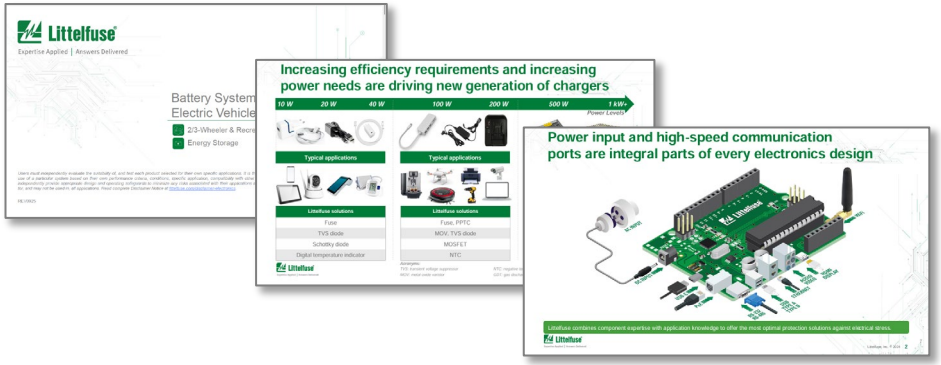
Drone Application Note



eCatalogs



Application Spotlights

Local resources supporting our global customers

Partner for tomorrow’s electronic systems

Broad product portfolio

We are an industrial technology manufacturing company empowering a sustainable, connected, safer world.

Testing capabilities

We help customers get products to market faster, and we offer certification testing to global regulatory standards.

Application expertise

Our engineers partner directly with customers to help accelerate product design and to meet their unique needs.

Compliance and regulatory

We help customers in the design process to account for requirements set by global regulatory authorities.

Global customer service

Our global customer service team is with you to anticipate your needs and ensure a seamless experience.

Global manufacturing

Our high-volume manufacturing is committed to the highest quality standards.

Littelfuse®

Expertise Applied | Answers Delivered

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