DarcyJProjects **Hardware Ver:** v1.194

STM32G4 Embedded Industrial Controller

Features

- **Core:** STM32G431 Cortex-M4 MCU @ 170MHz
- **Power:** 12V-28V DC (Rev. Polarity, OCP, TVS)
- **Isolation & Protection:** 1 kV Galvanic Isolation, ESD Protection up to 30 kV
- **Field I/O (All Isolated):** 4x Analog Inputs (12-bit, 4-20mA/0-5V), 2x Analog Outputs (12-bit, 4-20mA/0-5V), 4x Digital Inputs (24V), 2x Digital Outputs (24V), 2x Relays (10A / 30VDC, ELV 50VAC), Isolated I^2C Header.
- **On-Board HMI:** 0.96" OLED Display, 4x Tactile Buttons, 5x Status LEDs, 6x Hardware Mode Switches (Analog Current/Voltage Mode Configuration).
- **Memory:** 4KB EEPROM with CRC (Stores Configuration & Automation Rules)
- **Connectivity:** Isolated RS485 (MODBUS RTU Master/Slave); USB-C (DFU Flashing & Serial Debug)
- **Reliability:** 4-Layer PCB with Isolation Barrier, PPTC Fuses, TVS Protection.
- **Control:** Web Panel with custom "No-Code" automation engine; Full MODBUS RTU support for SCADA integration.

Example Demonstration Use Cases

- **Industrial Sensor Node:** Aggregation of voltage or 4-20mA process signals (pressure, flow, level) to MODBUS RTU.
- **Distributed I/O Expansion:** Cost-effective relay control and status monitoring for existing SCADA networks.
- **Hybrid Edge Controller:** Autonomous control of downstream MODBUS slaves (e.g., VFDs, remote sensors) while simultaneously reporting status to an upstream SCADA system.
- **Embedded Logic Prototyping:** Development platform for custom control loops and automation logic using the STM32G4.

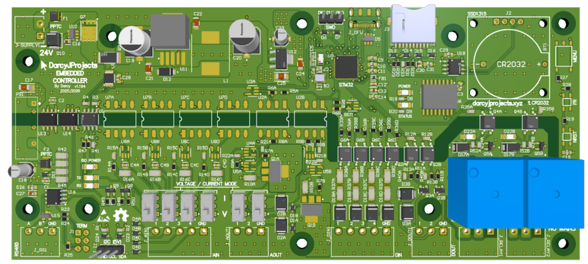

Figure 1: Board Top View

General Description

The **DJP-G431-EIC** is an educational embedded controller inspired by industrial I/O and PLC-style design practices. Built around the high-performance STM32G4 series, it features a high-efficiency 24V buck converter and **full galvanic isolation** on all field interfaces, ensuring system stability in noisy environments.

Unique to this controller is a **Hybrid Master-Slave** configuration handled by a custom **DMA-driven MODBUS RTU stack**. This allows the board to autonomously control downstream devices while simultaneously reporting to an upstream SCADA system or Web Panel. An on-board OLED display with burn-in protection provides local feedback on system status and configuration.

For logic control, the board natively supports a custom **Rule-Based Automation Engine**. This system is fully programmable over MODBUS using the Node.js Web Panel or manually with the vendor-defined functions, allowing for remote "No-Code" logic configuration without the need to reflash firmware.

System Architecture

The internal architecture of the DJP-G431-EIC is divided into two galvanically isolated domains: the **Logic Domain** (MCU, Main Power Supply, etc.) and the **Field Domain** (Field I/O, RS485, etc.).

The following block diagram illustrates the power distribution path, isolation barriers, and internal peripheral connections. A physical separation width is maintained along the isolation barrier on the PCB utilising different electrical isolation methods (capacitive, optical, etc.), depending on the signal.

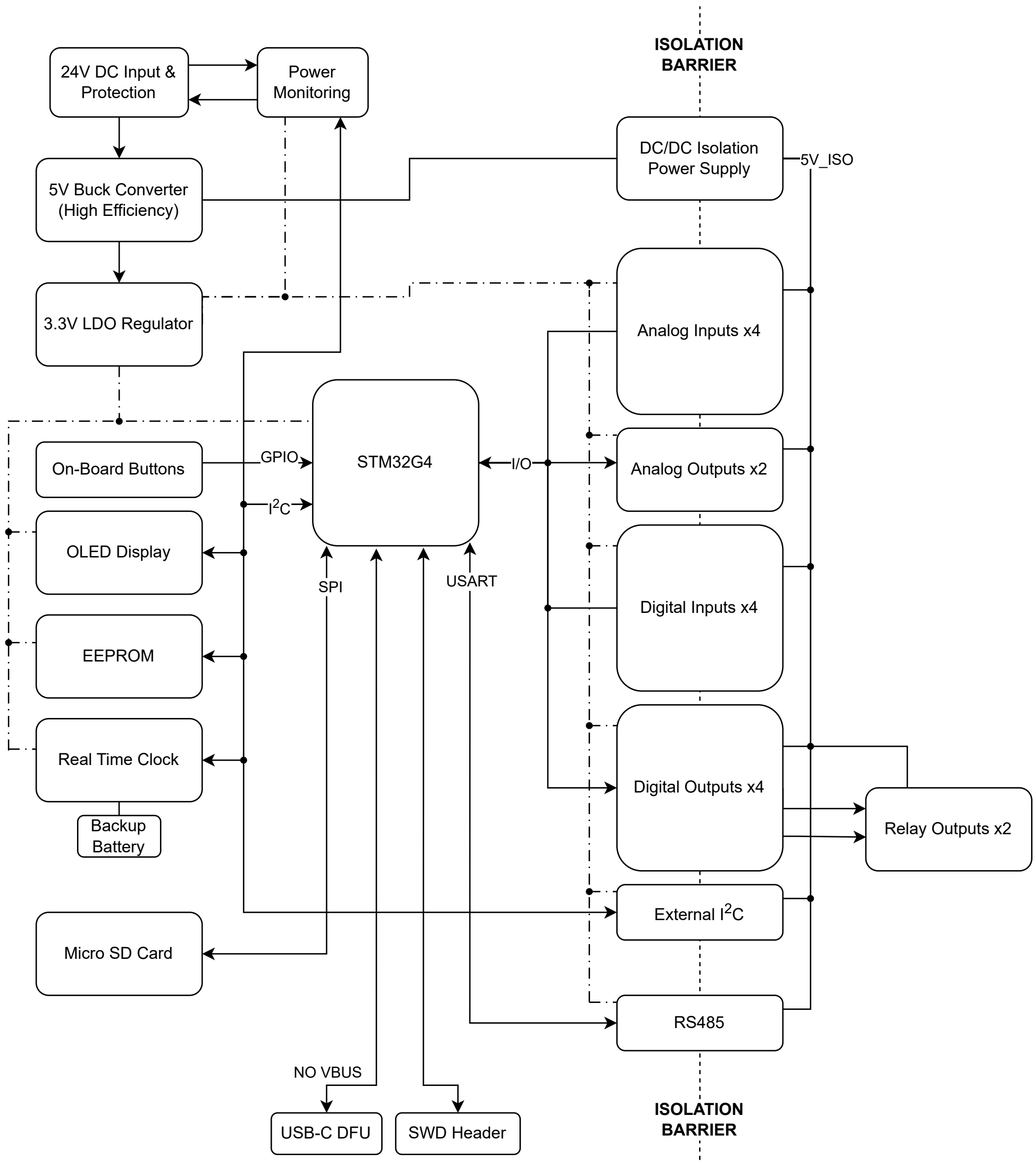

Figure 2: System Block Diagram showing Power Architecture and Galvanic Isolation.

Electrical Specifications

Conditions: $V_{IN} = 24V$, $T_A = 25°C$ unless otherwise noted.

Table 1: Isolation & Protection Characteristics

Parameter	Symbol	Value	Conditions
Galvanic Isolation			
System Isolation	V_{ISO_SYS}	**1000 VDC**	**Limited by DC/DC Power Supply**
Data Channel Rating	V_{ISO_DAT}	3750 Vrms	Component Rating (Isolators Only)
Isolation Capacitance	C_{ISO}	∼40 pF	Barrier Capacitance (Typical)
ESD Protection			
General I/O & Power	V_{ESD_GEN}	±30 kV	**IEC 61000-4-2** (Air & Contact)
(Includes: Power In, Digital I/O, Analog I/O, SD Card, SWD)			
Comm. Interfaces	V_{ESD_COM}	±15 kV	**IEC 61000-4-2** (Air)
		±8 kV	**IEC 61000-4-2** (Contact)
(Includes: RS485, USB DFU)			
I2C Expansion	V_{ESD_I2C}	±4 kV	**HBM** (ISO1540 Native Rating)
EFT Immunity			
Power & Field I/O	V_{EFT}	4 kV	**IEC 61000-4-4** (Level 4)

Table 2: Over-Current Protection (PPTC Resettable Fuses)

Protected Rail	Hold (I_{HOLD})	Trip (I_{TRIP})	Max V	Notes
Main Power Input (V_{IN})	2 A	∼2x the hold	30 V	Protects entire board
5V_ISO	750 mA	∼2x the hold	6 V	Protects B0505S isolated DC/DC

Note: Fuses are self-resetting. To reset a tripped fuse, remove the fault and cycle power for > 10 seconds.

Table 3: DC Characteristics

Parameter	Symbol	Min.	Typ.	Max.	Unit	Comments
Power Supply						
Supply Voltage	V_{IN}	12	24	28	V	Operating Range
Supply Current	I_{IN}	-	90	150	mA	Idle vs. Relays Active @ V_{IN}=24 V
Digital Inputs						
Input Voltage High	V_{IH}	1.5	24	28	V	Logic "1" Threshold
Input Voltage Low	V_{IL}	0	0	1.3	V	Logic "0" Threshold
Input Current	I_{DIN}	-	11.4	14.9	mA	@ 24V (Typ) / 28V (Max)
Digital Outputs						
Cont. Sink Current	I_{DOUT}	-	-	500	mA	**Sinking** Per Channel
Output Voltage Drop	V_{DROP}	-	10	16	mV	@ 500mA Load
Digital Outputs (Relays)						
Switching Voltage (DC)	V_{SW}	-	24	30	V	DC Voltage
Switching Voltage (AC)	V_{SW}	-	24	50	VAC	AC Voltage
Switching Current	I_{SW}	-	-	10	A	Max Resistive Load
Contact Resistance	R_{CONT}	-	-	100	mΩ	Initial value
Analog Inputs (12-Bit)						
Input Impedance (V)	$R_{IN(V)}$	-	49	-	kΩ	0-5V Mode
Input Impedance (I)	$R_{IN(I)}$	-	10	-	Ω	4-20mA Mode
Analog Outputs (12-Bit)						
Output Voltage	V_{OUT}	0	-	5	V	0-5V Mode – **Sourcing** (Active)
Max Loop Voltage[3]	V_{LOOP}	12	24	30	V	4-20mA Mode – Ext. Loop Supply
Max Loop Resistance	R_{LOOP}	300	900	1075	Ω	@ 12V / 24V / 30V Loop Voltage
RS485 Interface						
Bus Voltage Range[2]	V_{BUS}	-7	-	12	V	Common Mode Range (A/B)
Input Impedance	R_{IN}	12	-	-	kΩ	1 Unit Load (Max 32 Nodes)
External I^2C Expansion Header						
Field Signal Voltages[2]	V_{SDA2}, V_{SCL2}	0	-	5.0	V	Field Signal Voltages
Pull-Up Resistance	R_{PU}	4.4	4.7	5.0	kΩ	On-Board I^2C Field Pull-ups

[1] **Note:** The exact 4mA and 20mA setpoints are determined by firmware calibration values. Improper configuration may result in output currents deviating from these nominal targets (e.g. $<$ 4mA or $>$ 20mA).
[2] Relative to 5V_ISO_GND (the GND pin in the field header or connector).
[3] **Important:** The maximum loop voltage drops significantly as the ambient temperature rises. See Absolute Maximum Ratings.

Absolute Maximum Ratings

Table 4: Stress Ratings

Parameter	Symbol	Min.	Max.	Unit	Comments
Power					
Input Voltage	V_{IN_MAX}	7	30	V	Continuous (Limited by Input PPTC & TVS)
Max Total Current	I_{IN_MAX}	-	2	A	Limited by Input PPTC
Digital I/O					
DIN Voltage	V_{DIN_MAX}	-	30	V	Continuous (Thermal Limit of Series Resistors)
DOUT Sink Current	I_{DOUT_MAX}	-	3	A	Continuous (Per Channel) @ $T_A = 85°C$
Relay Voltage	$V_{SW\_MAX(DC)}$	-	30	V	Max DC Contact Switching Voltage
Relay Voltage	$V_{SW\_MAX(AC)}$	-	50	VAC	Max AC Contact Switching Voltage
Relay Current	I_{REL_MAX}	-	10	A	Resistive Load
Analog I/O					
AIN Voltage (V-Mode)	$V_{AIN\_MAX(V)}$	-	**5.5**	V	**Risk of Damage!** (Do not connect 24V) — Continuous (Limited by Input TVS)
AIN Current (I-Mode)	$I_{AIN\_MAX(I)}$	-	140	mA	Max Loop Current (Shunt Resistor Limit)
AOUT Voltage (V-Mode)	$V_{AOUT\_MAX(V)}$	-	**5.3**	V	**Risk of Damage!** (Do not connect 24V) — Max External Voltage applied to pin
AOUT Voltage (I-Mode)	$V_{AOUT\_MAX(I)}$	-	26	V	Max External Loop Voltage (Open Collector) @ $T_A = 85°C$
Communication Interfaces					
RS485 Bus Voltage In	$V_{485\_IN\_ABS}$	-8	+12.5	V	Max voltage on A/B pins before damage
RS485 Bus Voltage Out	$V_{485\_OUT\_ABS}$	-8	+12.5	V	Max voltage from driver to A/B pins
I2C Pin Voltage	V_{I2C_ABS}	-0.5	5.5	V	Max voltages on SDA/SCL

MODBUS Register Map

Table 5: Complete Register Map

Addr	Name	Type	Access	Description
Discrete Inputs (Digital Inputs)				
0	DIN_1	Bool	R	Digital Input Channel 1
1	DIN_2	Bool	R	Digital Input Channel 2
2	DIN_3	Bool	R	Digital Input Channel 3
3	DIN_4	Bool	R	Digital Input Channel 4
Coils (Digital Outputs & Relays)				
0	DOUT_1	Bool	R/W	Digital Output 1
1	DOUT_2	Bool	R/W	Digital Output 2
2	RELAY_1	Bool	R/W	Relay Output 1
3	RELAY_2	Bool	R/W	Relay Output 2
Input Registers (Analog Inputs)				
0	AIN_1	uint16	R	Analog Input 1 Raw Value
1	AIN_2	uint16	R	Analog Input 2 Raw Value
2	AIN_3	uint16	R	Analog Input 3 Raw Value
3	AIN_4	uint16	R	Analog Input 4 Raw Value
Holding Registers (Analog Outputs)				
0	AOUT_1	uint16	R/W	Analog Output 1 Setpoint (0-65535)
1	AOUT_2	uint16	R/W	Analog Output 2 Setpoint (0-65535)

Access Key: R = Read Only, R/W = Read/Write.
Function Codes: Discrete (0x02), Coils (0x01/0x05/0x15), Inputs (0x04), Holding (0x03/0x06/0x16).

Virtual Registers

Virtual Registers can be created dynamically to serve as intermediate variables within the automation logic (e.g., linking rules where the 2-condition limit per rule is exceeded).

- **Addressing:** Virtual registers are automatically mapped starting at the address *after* the last physical channel.
- *Example:* If the last physical coil is Address 3, the first Virtual Coil will be **Address 4**.

Since Virtual Registers are defined with specific Modbus data types, they can be fully accessed (Read/Write) using standard Modbus function codes.

External Expansion (I^2C)

The isolated 5V I^2C header allows external peripherals to be mapped to MODBUS registers. On-board field side 5V_ISO pull-up resistors (4.7 kΩ) are installed on SCL and SDA so only 5 V-tolerant I^2C devices should be connected directly. Lower-voltage devices may require an external level shifter, such as a PCA9306.

Note: *Unlike the Rule Engine, adding new I^2C devices requires custom read/write drivers and a* ***firmware update****. Reference implementations for common sensors can be found in the project source code.*

Vendor Defined Function Codes

These proprietary function codes provide access to specialized device capabilities, including the internal logic engine and virtual register management, that are not covered by standard MODBUS definitions. **Range:** 0x65–0x73 (Firmware Defined)

Code	Name	Description
0x65	ADD_RULE	Defines a new automation rule
0x66	GET_RULE_COUNT	Returns the number of automation rules
0x67	GET_RULE	Returns the requested automation rule configuration
0x68	DELETE_RULE	Deletes the requested automation rule
0x69	ADD_VIRTUAL_REG	Defines a new virtual register
0x6A	READ_VIRTUAL_REG	Returns the value of the requested virtual register
0x6B	WRITE_VIRTUAL_REG	Write the specified value to the requested virtual register
0x6C	GET_VIRTUAL_REG_COUNT	Returns the number of virtual registers
0x6D	CLEAR_VIRTUAL_REG	Deletes all virtual registers. Warning: Do not execute if there are **any** rules that reference **any** virtual registers.
0x6E	SET_RTC	Sets the RTC date and time
0x6F	SET_HOLDING_REG_MODE	Sets the requested holding register to the specified mode (current/voltage)
0x70	SET_INPUT_REG_MODE	Sets the requested input register to the specified mode (current/voltage)
0x71	GET_REG_MODE	Returns the mode (current/voltage) of the requested register (holding/input)
0x72	SET_EMERGENCY_STOP	Sets the E-STOP button configuration
0x73	FACTORY_RESET	Performs a factory reset, resetting the on-board EEPROM to default values

Note: These function codes are firmware-specific and should not be considered MODBUS-standard or interoperable with other devices.

User Interface

Button Functions

The board features 4 tactile buttons for menu interaction, system recovery, and boot control.

Button	Function	Description
MENU	Navigation	Short Press: Next Menu Screen
NRST	System Reset	Short Press: Hardware Reset (Reboots MCU)
BOOT0 + NRST	DFU Mode	Hold BOOT0 and short press NRST to enter DFU mode. OLED should indicate that DFU mode has been entered.
FR + NRST	Factory Reset	Hold FR and short press NRST to restore default configuration options on the EEPROM. Further button press instructions will be provided on the OLED.
MENU + NRST	Skip Boot Animations	Hold MENU and short press NRST to skip boot animations when starting. Useful for quick tests during firmware development.

LED Indicators

Name	Color	Indication
PWR	Green	3.3V Logic Domain Power Active
STATUS	Red	General Status Indicator
ISO_PWR	Green	5V Isolated Field Domain Power Active
RX/TX	Blue	Modbus RS485 Data Traffic
REL1 / REL2	Red	Relay Coil Energized (Output Active)

RS485 Bus Configuration

The isolated RS485 interface features a 6-pin jumper header (JP_RS485) to enable line termination and failsafe biasing. These should be configured based on the device's position in the network.

Jumper Map (Top View)

1 (A)	**2** (PULL_UP)
3 (B)	**4** (PULL_DOWN)
5 (A)	**6** (TERM. TO B)

Bridge adjacent pins to enable.

Configuration Settings:

- **Bias High (Pins 1-2):** Pulls Line A to 5V_ISO. *Keeps bus logic "1" during idle.*
- **Bias Low (Pins 3-4):** Pulls Line B to 5V_ISO_GND. *Keeps bus logic "0" during idle.*
- **Termination (Pins 5-6):** Connects a 120Ω resistor across lines A and B. *Enable only if this device is at the physical end of the bus cable.*

Note: *Failsafe biasing (Pins 1-4) is recommended to prevent noise interpretation when the bus is idle, but ensure only ONE device on the bus provides biasing (usually the Master).*

Software Ecosystem

The DJP-G431-EIC is supported by a comprehensive software suite:

- **Web Configuration Panel:** A Node.js-based dashboard connecting via the USB-Serial bridge. Allows for real-time monitoring of all registers, hardware configuration, and "No-Code" logic automation; all over MODBUS RTU.
- **Automation Engine:** Custom logic engine supporting drop-down based "If-This-Then-That" rules, executed locally on the STM32, programmed over MODBUS vendor functions. A single rule can include up to two conditions, with virtual registers provided as memory to link several rules (>2) together.

Mechanical & Installation

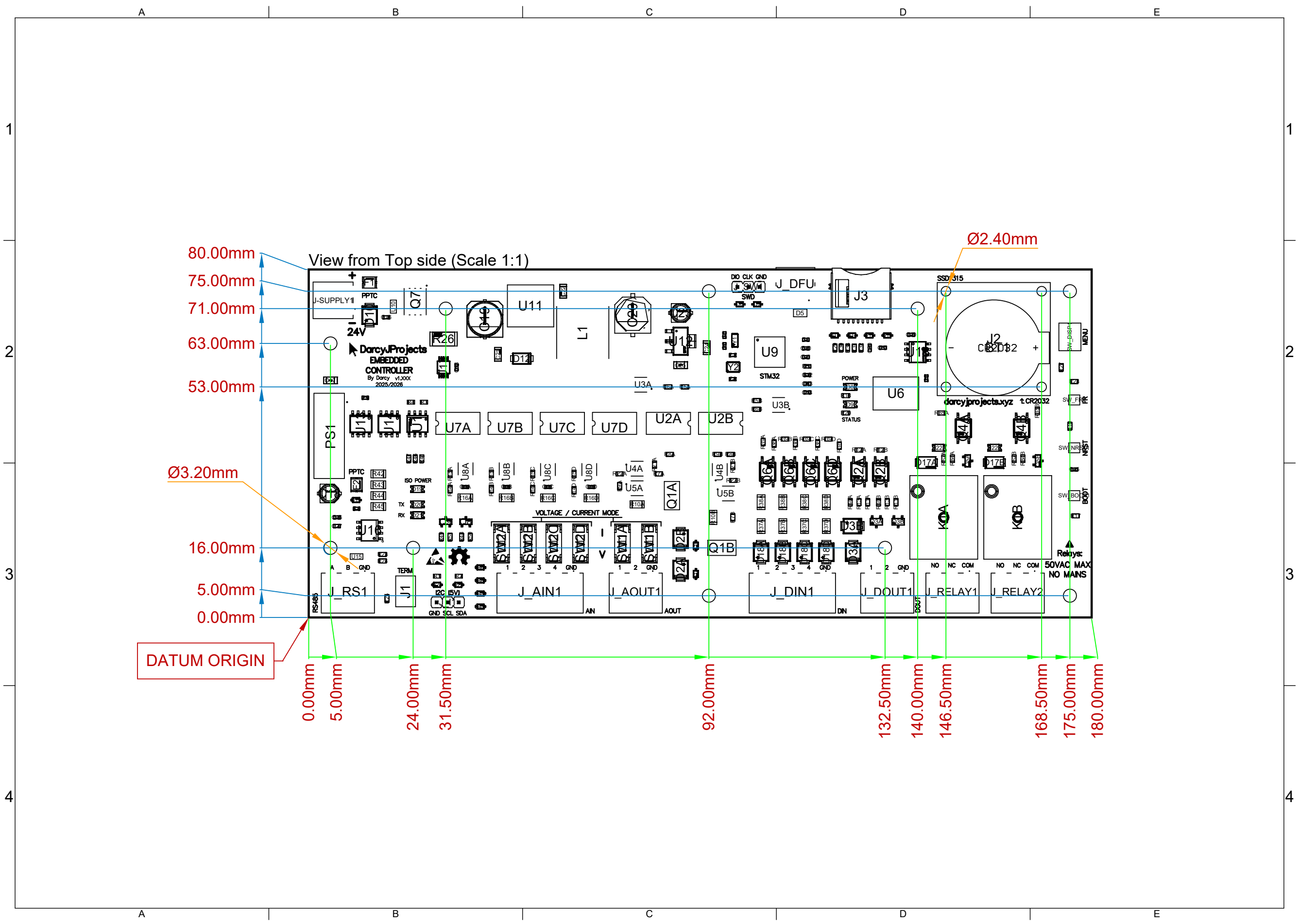

Figure 3: Mechanical Dimensions (Units: mm).

Safety Disclaimer

This hardware is a personal engineering project created solely for educational purposes, experimentation, and skill development.

Although it uses industrial-style design techniques, it has **not** been tested, approved, certified, or validated against industrial, safety, EMC, electrical, environmental, functional safety, or regulatory standards, including IEC, UL, CE, RCM, or any similar certification scheme.

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