DUILIO F4 - Hardware Deep Manual

This manual is intended for makers, hardware developers, and system integrators working with DUILIO F4.
It provides a consolidated reference for the board hardware, power distribution, pinout, and safety considerations.
The content focuses on technical characteristics and interface constraints and does not replace basic technical competence.

Board overview

Top side

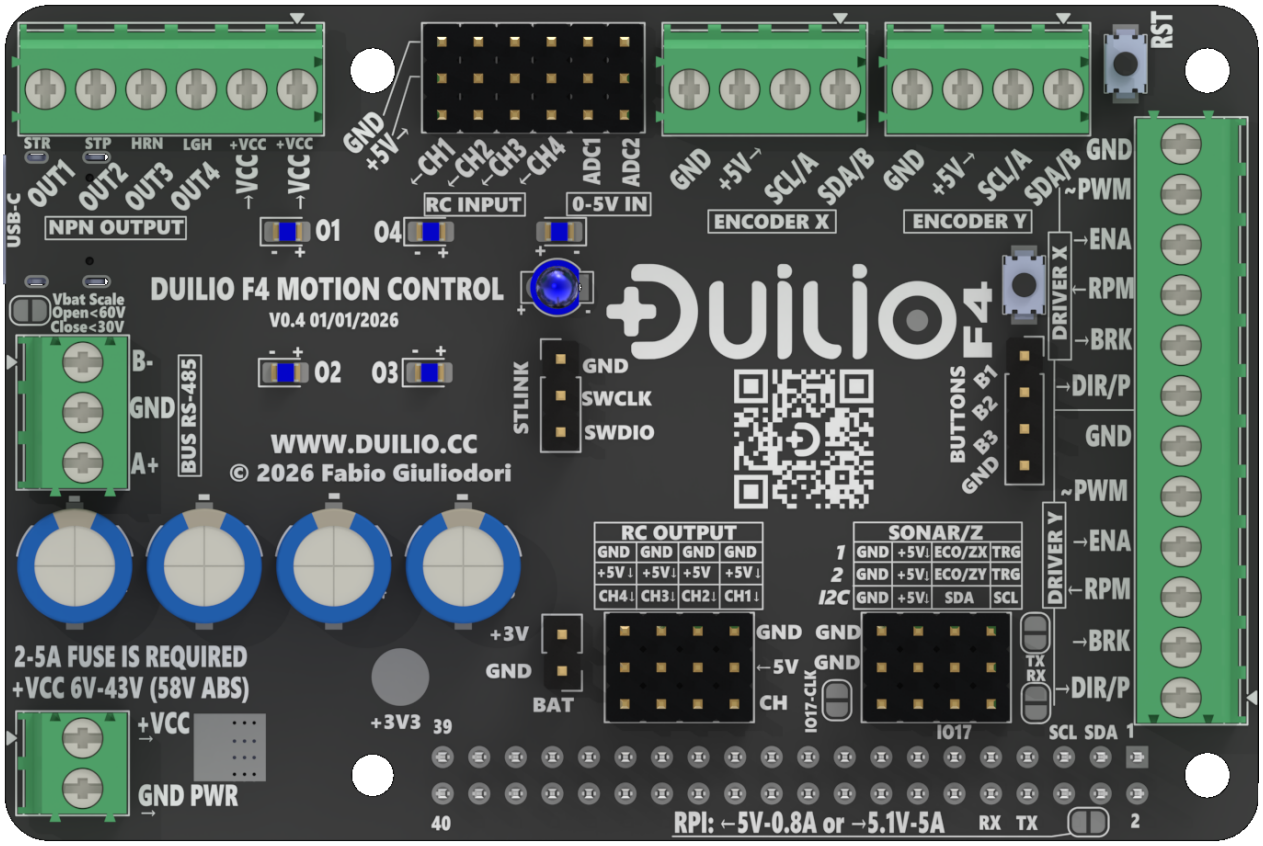


Figure 1: DUILIO F4 – Top view

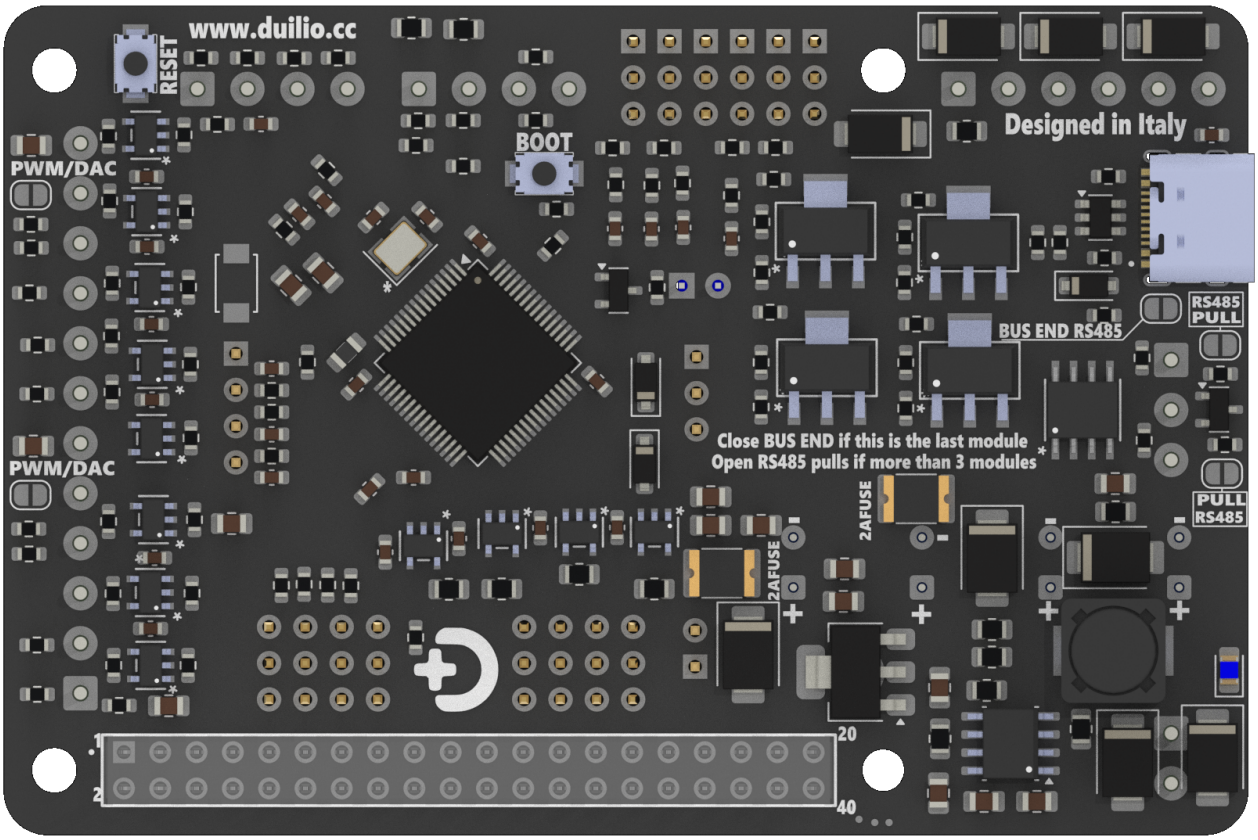


Figure 2: DUILIO F4 – Bottom view

Bottom side

1. Introduction

1.1 What is DUILIO F4

DUILIO F4 is a modular motion control board based on STM32, designed to act as the central interface between control logic and external motor drivers. It supports multiple control sources, including RC receivers, USB, and Raspberry Pi. The board separates 5 V and 3.3 V logic domains to accommodate mixed-voltage peripherals and improve system integration.

1.2 Intended use

DUILIO F4 is intended for technical development and integration in: - Prototyping and validation benches. - Embedded systems requiring deterministic motor control interfaces. - Robotics and motion control platforms.

1.3 What DUILIO F4 is not

DUILIO F4 is not a high-power motor driver and must be paired with appropriate external power stages. It is not a consumer plug-and-play product and is not designed for general-purpose end users. It is also not designed or certified for safety-critical environments that require functional safety compliance.

1.4 Typical system architectures

Typical system architectures include: - STM32 standalone: the onboard MCU manages I/O and motor interfaces without external hosts. - STM32 + Raspberry Pi: a Raspberry Pi provides high-level control while STM32 handles real-time motion tasks. - RC + external drivers: RC input commands external motor drivers through DUILIO F4 interfaces.

2. Features & Specifications

2.1 Electrical specifications

Table 2-1 - Electrical specifications

Parameter	Value	Notes
Main supply input (VIN range)	6-43 V DC	Primary supply input for board and power distribution; use a regulated DC source.
Logic voltage levels	Separate 5 V and 3.3 V domains	Use peripherals compatible with the respective logic domain.

Parameter	Value	Notes
Power distribution concept	Central VIN distribution with local regulation for logic rails	Provide external protection and current limiting as appropriate.
External power dependency	Depends on connected loads and external drivers	Output power availability is defined by the external supply and driver stages.

2.2 Environmental specifications

Table 2-2 - Environmental specifications

Parameter	Value	Notes
Operating environment	Typical indoor / sheltered use	Avoid direct heat sources and uncontrolled outdoor exposure.
Humidity	Non-condensing	Avoid condensation and conductive contamination.

2.3 Mechanical specifications

Table 2-3 - Mechanical specifications

Parameter	Value	Notes
PCB board type	Rigid PCB	Intended for fixed mounting inside an enclosure.
Mounting holes concept	Mounting holes for standoffs	Use insulating hardware where required.
External connectors accessibility	Edge-accessible connectors	Keep cable bend radius compatible with connector orientation.

3. Safety Precautions

3.1 Safety symbols

Table 3-1 - Safety symbols and meaning

Symbol	Meaning
Warning	Indicates a hazardous situation that could cause serious injury or equipment damage.
Caution	Indicates a hazardous situation that could cause minor injury or damage.
Note	Highlights important information or constraints.
Electrical hazard	Indicates risk of electric shock, overheating, or damage due to power.

3.2 Device scope and limitations

DUILIO F4 is a control board, not a power driver and not a safety-rated device. Motor power never flows through DUILIO F4; external drivers and the mechanical system must handle emergency stops and safety interlocks. Integration must assume that power stages and safety functions are implemented outside the board.

> NOTE: Power distribution and current limits (system-level) - Individual pin current ratings are maximum limits, not guarantees. - The sum of all output currents depends on the active power source. - When powered from VIN: total available 5 V current approx. 3 A continuous, 5 A peak (shared). - When powered ONLY from USB or Raspberry Pi GPIO: total available 5 V current < 0.8 A. - Exceeding the total budget may cause voltage drop, reset, or thermal shutdown.

3.3 Electrical vs functional safety

Electrical safety concerns correct voltage, current, and insulation to avoid damage or shock. Functional safety concerns predictable system behavior under faults, including stopping motion safely. DUILIO F4 addresses electrical interface constraints only; functional safety must be provided by external drivers and system-level design.

3.4 Back-powering risks

Applying power simultaneously through VIN, USB, and GPIO sources can create unintended back-power paths. This can energize interfaces in an uncontrolled manner and may damage the host USB port or connected single-board computers. Avoid simultaneous power paths unless the system includes explicit isolation and power sequencing. Back-powering from a Raspberry Pi through the GPIO interface can also energize the board when VIN is off.

3.5 Motor and motion hazards

Motor systems can start unexpectedly due to firmware bugs, signal noise, or configuration errors. Perform initial tests on a bench with the mechanical load removed or

decoupled, and secure the system to prevent motion. Disconnect motors or actuators during firmware debugging or interface validation.

3.6 Commissioning safety checklist

- Verify the supply type, polarity, and intended VIN usage before connecting power.
- Inspect the board and wiring for shorts, loose strands, or foreign objects.
- Confirm external power stages or drivers are correctly wired before enabling outputs.
- Keep motors or mechanical loads disconnected during the first power-up.
- Ensure only one power source is active unless isolation is present.
- Confirm an accessible power cutoff or emergency stop is available.
- Secure the board with standoffs and provide cable strain relief.
- Use a current-limited supply for initial validation.

4. Power System

4.1 Power domains overview

DUILIO F4 is a **control board**. It has **no power stages** on-board and is intended to drive **external motor drivers** only.

- **Logic power (5 V domain):** board electronics, communications, logic I/O.
- **Servo power (5 V rail):** RC/servo output headers.
- **Motor power:** always external. **Motor power never flows through DUILIO F4.**

DUILIO F4 can be supplied from a wide input **VIN (6 V to 43 V)** which is regulated to 5 V for logic and auxiliary rails. VIN is for the **control electronics and low-power outputs only**. It is **not** a motor supply. Input transient protection is provided on VIN, but requires an external fuse for correct operation.

WARNING: Do not route motor power through DUILIO F4.

> NOTE: Power distribution and current limits (system-level) - Individual pin current ratings are maximum limits, not guarantees. - The sum of all output currents depends on the active power source. - When powered from VIN: total available 5 V current approx. 3 A continuous, 5 A peak (shared). - When powered ONLY from USB or Raspberry Pi GPIO: total available 5 V current is typically < 0.8 A and depends on the actual current capability of the USB source or Raspberry Pi supply.
>
> - Exceeding the total budget may cause voltage drop, reset, or thermal shutdown.

4.2 Power scenarios

DUILIO F4 supports three practical power scenarios. The total 5 V current budget is defined by the system-level limits above.

- **VIN-powered system:** VIN feeds the onboard regulation, providing 5 V rails for logic and auxiliary outputs. Use this for full system operation with external drivers.
- **USB-only logic power:** USB powers logic for bench setup and firmware work. This is limited to low current loads and should not feed external peripherals.
- **Raspberry Pi stack power:** 5 V is supplied through the Raspberry Pi header when the link is closed. Use only for compact Pi-based systems with low 5 V load.

WARNING: Use one 5 V source at a time and avoid multiple active 5 V inputs to prevent back-powering.

4.3 Logic power inputs

Logic power can be sourced from the following 5 V inputs. **Use ONE source at a time.**

- **USB 5 V**
  - Use for: bench setup, firmware work, quick checks.
  - Limitations: USB current is limited; not suitable for servos or external 5 V loads.
  - WARNING: Do not combine USB power with any other 5 V source (risk of back-feeding a host).
- **External regulated 5 V**
  - Use for: installations with a dedicated 5 V regulator / BEC.
  - Requirements: regulated 5 V within tolerance, sized for board + intended 5 V peripherals.
  - Safety: keep wiring short, use proper gauge, and avoid noisy/long 5 V runs.
- **Raspberry Pi 5 V (HAT / header)**
  - Use for: compact Pi-based systems where the Pi provides the only 5 V source.
  - Limitations: do not use Pi 5 V to power servos or external loads.
  - WARNING: Incorrect jumper settings or simultaneous USB power can back-power the Pi or the USB host.

WARNING: One 5 V source, one direction of power flow.

4.4 Raspberry Pi power path

DUILIO F4 can power a Raspberry Pi from its 5 V rail (up to **5.1 V / 5 A**). This path is **disabled by default**: the Raspberry Pi 5 V link is an **open solder jumper**.

When the Pi 5 V link is closed, the DUILIO 5 V rail is connected to the Raspberry Pi 5 V pins. This connection is **bidirectional** by nature, therefore the system must be designed with a single intended power direction.

WARNING: BACK-POWER RISK - If the Pi link is closed and USB power is applied to either board, back-powering can occur. - Incorrect configuration can create unsafe current paths and can damage: - DUILIO F4 - Raspberry Pi - USB host / PC

4.5 Servo power output

DUILIO F4 provides a dedicated 5 V servo power rail for the RC/servo output headers.

- The servo rail is separated from logic power.
- Current protection is provided by a **PTC resettable fuse** (RC/servo output current limited to approximately **2 A**).
- Protection diodes help prevent unsafe reverse current paths when an external 5 V source is present.

Use this rail only for **small RC servos and receivers** within the current limit and total 5 V power budget.

WARNING: Do NOT use the servo rail to power high-current loads or motors. WARNING: A PTC fuse is not a power supply. It only limits fault current and may trip under load peaks.

4.6 Backup battery

An optional **3 V backup battery** can be connected to preserve position memory and avoid re-homing. It is **not** a primary power source and does **not** power the main 5 V rail.

- With the battery installed: position memory is retained when main power is removed.
- Without the battery: the board operates normally but loses that memory on power-off.

WARNING: Observe polarity and use only the specified **3 V** battery. Reverse polarity or higher voltage can damage the board.

4.7 Grounding strategy

DUILIO F4 requires a **common ground (GND)** with external devices such as motor drivers, sensors, and a Raspberry Pi.

Without a shared ground, control signals have no valid reference and the system will malfunction.

Typical grounding mistakes: - Connecting only signal wires without GND. - Using isolated supplies without bonding grounds where required. - Relying on chassis/earth ground instead of signal ground.

WARNING: Always connect GND between DUILIO F4 and each external driver.

4.8 Power-related jumpers

Power-related jumpers are **solder links** that configure 5 V routing. The main user-facing power jumper is the **Raspberry Pi 5 V link**, which is **open by default** to avoid back-powering.

Close the link only when a single power direction is intentionally chosen for the system.

WARNING: Do not change solder jumpers while the board is powered. This can create short circuits or unsafe power paths.

Advanced jumper configurations are covered in Chapter 10.

DUILIO F4 integrates on-board protection elements intended to improve robustness against wiring errors and transient events. These protections are **not a replacement for proper external power design**.

4.9 Power input protection and current limiting

Input transient protection (TVS diode)

The main VIN input is protected by a **TVS diode connected in parallel** to the supply rails. This device clamps high-voltage transients and protects the board against short overvoltage events and supply spikes.

To operate correctly, the TVS diode **requires an external fuse** installed upstream of the board power input. Without an upstream fuse, the TVS may be forced to dissipate excessive energy during a fault condition.

Recommended external protection: - One fuse in series with VIN - Typical rating: **2 A to 5 A**, depending on supply capability and application - Fast or automotive-type fuse recommended

The external fuse ensures that, in the event of sustained overvoltage or reverse-energy conditions, the fault is safely cleared.

5 V rail protection (PTC fuses)

The regulated 5 V rails are protected by **two independent resettable PTC fuses**. These devices limit current during overload or short-circuit conditions and automatically recover once the fault is removed.

PTC protection is applied to: - The 5 V rail feeding RC servos and external peripherals - The internal 5 V logic distribution

Each rail is protected by a **PTC fuse with a nominal hold current of approximately 2 A**. PTC fuses are intended to **limit fault current**, not to regulate power.

Under sustained overload or high peak current, the voltage may drop and the PTC may trip temporarily until the fault is removed and the device cools down.

Raspberry Pi power jumper and PTC bypass

When the Raspberry Pi 5 V solder jumper is **left open**, the 5 V rail supplying the Pi is protected by the PTC fuse.

When the solder jumper is **closed**, the PTC fuse is **bypassed** in order to provide the maximum available current to the Raspberry Pi. This configuration is intended for applications requiring high peak current (e.g. Raspberry Pi 4 / 5 under load).

Important considerations when the jumper is closed: - Current limiting relies entirely on the external power source and upstream protection - Adequate supply capability and wiring are mandatory - An external fuse on VIN is strongly recommended

Improper configuration or insufficient upstream protection can lead to excessive current flow and thermal stress.

5. Board Overview

This chapter provides a visual orientation of the main functional areas on the DUILIO F4 PCB.

5.1 Top-side functional blocks

The top side contains the primary user-accessible connectors and most of the high-level functional blocks. When holding the board with the silkscreen readable, the top side highlights the motor control output area, RC input/output headers, and the main communication connectors.

Central area. The control core and surrounding passive components form the logic section. This area is distinct from the edge connectors and keeps short trace runs for signal integrity.

Connector edge. Along the board edge, the external connector groups are organized by function: motor control outputs, RC I/O, general I/O, and communications. These grouped blocks allow quick visual identification when wiring.

USB and service area. The USB connector and service access points are placed near the edge for easy access when the board is installed in an enclosure.

5.2 Bottom-side functional blocks

The bottom side carries supporting circuitry, power conditioning components, and secondary headers. These elements are intended to limit fault propagation and improve robustness, not to replace external system-level protections.

Power regulation zone. The input conversion and filtering components are concentrated in one area to keep power routing short and reduce noise.

Secondary headers and test access. Secondary connectors and test pads are distributed along the edges, aligned with the corresponding top-side connector groups.

5.3 Logic vs external power separation

The board is laid out to keep logic power and external motor power clearly separated. The logic domain is concentrated around the control core and low-level connectors, while the external power interfaces are routed to the connector edge and power-conditioning area.

This separation reduces coupling from high-current paths and simplifies inspection. When holding the board, the separation is visible as a physical gap between the logic section and the external power section.

5.4 Safety-related hardware features

Protection components are grouped near the power entry and the external-facing connectors. This includes current protection on low-power rails and protection elements on exposed interfaces.

Status indication and service access points are placed on the top side for visibility during bring-up and diagnostics. These features allow quick confirmation of board state without probing internal circuitry.

5.5 Mechanical drawing and dimensions

The following drawing provides the overall board dimensions and mounting references. It is intended for mechanical integration, enclosure design, and panel mounting.

This section lists all external connectors of the DUILIO F4. Pin numbering follows the board silkscreen. Signal direction and electrical limits are reported in the “Notes” column. The electrical limits indicated per pin are subject to total current constraints of the board power system.

NOTE: Power distribution and current limits (system-level) - Individual pin current ratings are maximum limits, not guarantees. - The sum of all output currents depends on the active power source. - When powered from VIN: total available 5 V current approx. 3 A continuous, 5 A peak (shared). - When powered ONLY from USB or Raspberry Pi GPIO: total available 5 V current < 0.8 A. - Exceeding the total budget may cause voltage drop, reset, or thermal shutdown.

Connector J1 - Main supply input

Pin number	Pin name (silkscreen)	Function	Notes
1	GND_PWR	Power ground (logic / signal reference)	0 V reference, connect to system ground
2	+VCC	Main supply input (+VIN)	Input, main power supply (VIN range 6-43V)

Connector J2 - RS485 interface

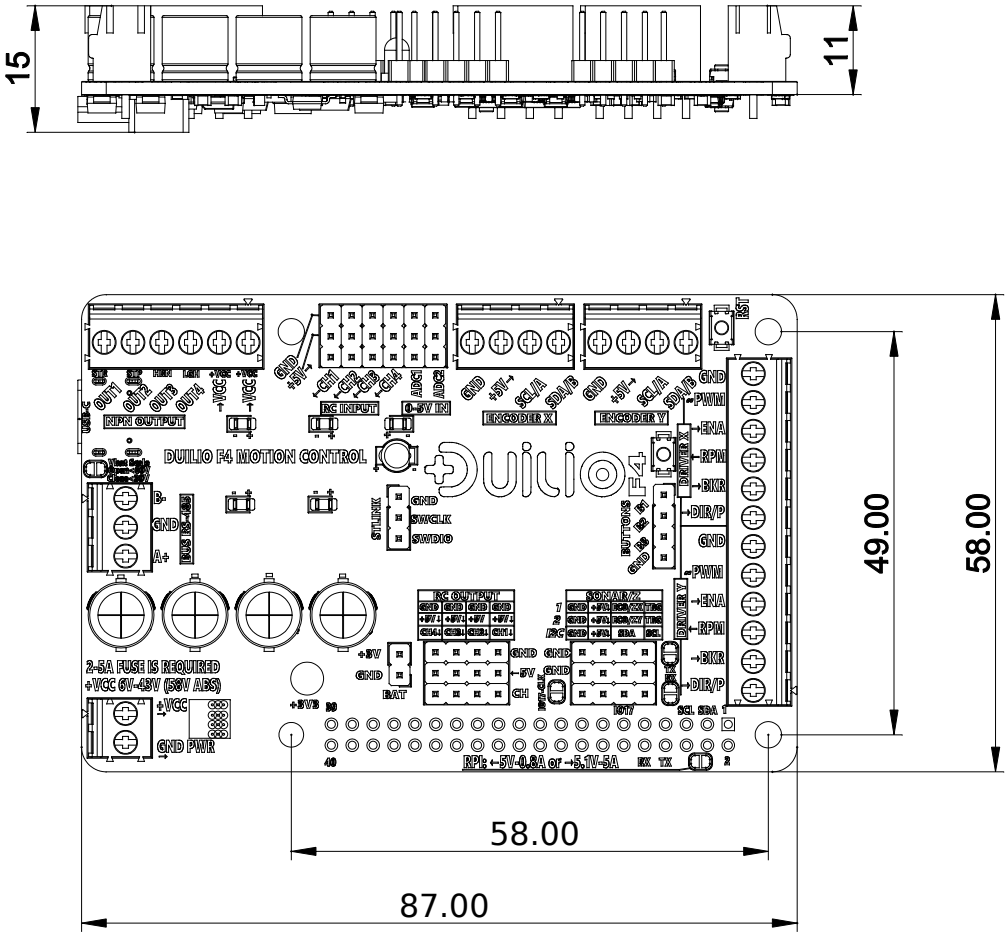


Figure 3: DUILIO F4 mechanical drawing

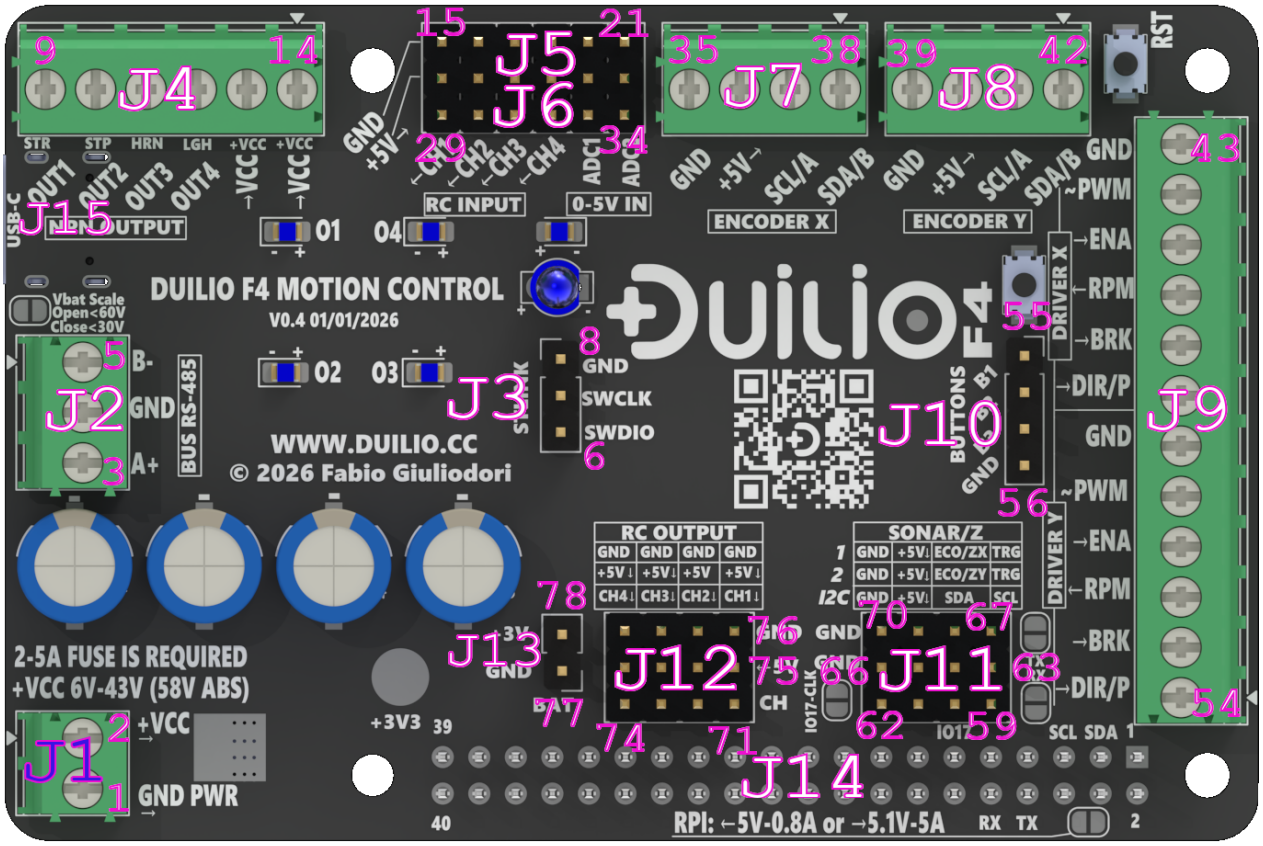


Figure 4: DUILIO F4 – Connector and pinout reference

Pin number	Pin name (silkscreen)	Function	Notes
3	A+	RS485 differential line A	Differential bus signal, do not apply external voltage
4	GND	Signal ground	0 V reference
5	B-	RS485 differential line B	Differential bus signal, do not apply external voltage

Connector J3 - SWD programming

Pin number	Pin name (silkscreen)	Function	Notes
6	SWDIO	SWD programming data	Programming/debug signal, 3.3 V logic
7	SWCLK	SWD programming clock	Programming/debug signal, 3.3 V logic
8	GND	Signal ground	0 V reference

Connector J4 - Low-side digital outputs (OUT1-OUT4)

Pin number	Pin name (silkscreen)	Function	Notes
9	OUT1	Low-side digital output 1 (NPN)	Output, open-collector NPN, 2 A continuous (5 A peak, non-continuous)
10	OUT2	Low-side digital output 2 (NPN)	Output, open-collector NPN, 2 A continuous (5 A peak, non-continuous)
11	OUT3	Low-side digital output 3 (NPN)	Output, open-collector NPN, 2 A continuous (5 A peak, non-continuous)
12	OUT4	Low-side digital output 4 (NPN)	Output, open-collector NPN, 2 A continuous (5 A peak, non-continuous)

Pin number	Pin name (silkscreen)	Function	Notes
13	+VCC	Main supply input (+VIN)	Power rail, VIN linked (same as +VCC main input)
14	+VCC	Main supply input (+VIN)	Power rail, VIN linked (same as +VCC main input)

Connector J5 - 5 V and GND distribution

Pin number	Pin name (silkscreen)	Function	Notes
15	GND	Signal ground	0 V reference
16	GND	Signal ground	0 V reference
17	GND	Signal ground	0 V reference
18	GND	Signal ground	0 V reference
19	GND	Signal ground	0 V reference
20	GND	Signal ground	0 V reference
21	+5V	5 V regulated output	Output, regulated 5 V, 0,5A
24	+5V	5 V regulated output	Output, regulated 5 V, 0,5A
25	+5V	5 V regulated output	Output, regulated 5 V, 0,5A
26	+5V	5 V regulated output	Output, regulated 5 V, 0,5A
27	+5V	5 V regulated output	Output, regulated 5 V, 0,5A
28	+5V	5 V regulated output	Output, regulated 5 V, 0,5A

Connector J6 - RC inputs and analog inputs

Pin number	Pin name (silkscreen)	Function	Notes
29	CH1_IN	RC channel 1 input (PWM)	Input, 5 V PWM signal, RC compatible (1-2 ms)
30	CH2_IN	RC channel 2 input (PWM)	Input, 5 V PWM signal, RC compatible (1-2 ms)
31	CH3_IN	RC channel 3 input (PWM)	Input, 5 V PWM signal, RC compatible (1-2 ms)

Pin number	Pin name (silkscreen)	Function	Notes
32	CH4_IN	RC channel 4 input (PWM)	Input, 5 V PWM signal, RC compatible (1-2 ms)
33	ADC1	Analog input 1 (0-5 V)	Input, analog 0-5 V only, do not exceed 5 V
34	ADC2	Analog input 2 (0-5 V)	Input, analog 0-5 V only, do not exceed 5 V

Connector J7 - I2C bus X

Pin number	Pin name (silkscreen)	Function	Notes
35	GND	Signal ground	0 V reference
36	+5V	5 V regulated output	Output, regulated 5 V, total current shared 0,5A
37	SCL_X	I2C bus X - clock	Bidirectional, I2C clock, pulled-up to 5 V (5 V logic bus)
38	SDA_X	I2C bus X - data	Bidirectional, I2C data, pulled-up to 5 V (5 V logic bus)

Connector J8 - I2C bus Y

Pin number	Pin name (silkscreen)	Function	Notes
39	GND	Signal ground	0 V reference
40	+5V	5 V regulated output	Output, regulated 5 V, total current shared 0,5A
41	SCL_Y	I2C bus Y - clock	Bidirectional, I2C clock, pulled-up to 5 V (5 V logic bus)
42	SDA_Y	I2C bus Y - data	Bidirectional, I2C data, pulled-up to 5 V (5 V logic bus)

Connector J9 - Motor driver interface (control signals)

Pin number	Pin name (silkscreen)	Function	Notes
43	GND	Signal ground	0 V reference
44	PWM_X	Motor X PWM output	Output, 5 V logic PWM signal to motor driver
45	ENA_X	Motor X enable output	Output, 5 V logic enable signal
46	RPM_X	Motor X speed feedback (RPM)	Input, digital speed feedback, max 5 V
47	BRK_X	Motor X brake output	Output, 5 V logic brake signal
48	DIR/PWM_X	Motor X direction or dual-PWM output	Output, 5 V logic, direction or dual-PWM mode
49	GND	Signal ground	0 V reference
50	PWM_Y	Motor Y PWM output	Output, 5 V logic PWM signal to motor driver
51	ENA_Y	Motor Y enable output	Output, 5 V logic enable signal
52	RPM_Y	Motor Y speed feedback (RPM)	Input, digital speed feedback, max 5 V
53	BRK_Y	Motor Y brake output	Output, 5 V logic brake signal
54	DIR/PWM_Y	Motor Y direction or dual-PWM output	Output, 5 V logic, direction or dual-PWM mode

Connector J10 - User buttons

Pin number	Pin name (silkscreen)	Function	Notes
55	B1	User button input 1	Input, active-low 5 V tolerant
56	B2	User button input 2	Input, active-low 5 V tolerant
57	B3	User button input 3	Input, active-low 5 V tolerant
58	GND	Signal ground	0 V reference

Connector J11 - Raspberry Pi and ultrasonic sensors

Pin number	Pin name (silkscreen)	Function	Notes
59	SCL_PI	I2C bus Raspberry Pi - clock	Bidirectional, I2C clock to Raspberry Pi header (3.3 V bus)
60	SDA_PI	I2C bus Raspberry Pi - data	Bidirectional, I2C data to Raspberry Pi header (3.3 V bus)
61	5V	5 V output (Raspberry Pi / peripherals)	Output, regulated 5 V 0,5A
62	GND	Signal ground	0 V reference
63	TRG_Y	Ultrasonic sensor Y - trigger	Output, digital trigger, 5 V logic
64	ECO/ZY	Ultrasonic sensor Y - echo (or ZY input)	Input, echo signal, max 5 V
65	5V	5 V output	Output, regulated 5 V 0,5A
66	GND	Signal ground	0 V reference
67	TRG_X	Ultrasonic sensor X - trigger	Output, digital trigger, 5 V logic
68	ECO/ZX	Ultrasonic sensor X - echo (or ZX input)	Input, echo signal, max 5 V
69	5V	5 V output	Output, regulated 5 V, total current shared 0.5 A
70	GND	Signal ground	0 V reference

Connector J12 - RC PWM outputs

Pin number	Pin name (silkscreen)	Function	Notes
71	CH4_OUT	RC output channel 4 (PWM)	Output, 5 V PWM signal, RC compatible
72	CH3_OUT	RC output channel 3 (PWM)	Output, 5 V PWM signal, RC compatible
73	CH2_OUT	RC output channel 2 (PWM)	Output, 5 V PWM signal, RC compatible

Pin number	Pin name (silkscreen)	Function	Notes
74	CH1_OUT	RC output channel 1 (PWM)	Output, 5 V PWM signal, RC compatible
75	5V	5 V output (RC / peripherals)	Output, regulated 5 V for RC / peripherals 2A PTC FUSE
76	GND	Signal ground	0 V reference

Connector J13 - Backup battery

Pin number	Pin name (silkscreen)	Function	Notes
77	BAT+	Battery 3V for data save	External 3 V RTC backup battery only, do not connect to 5 V
78	GND	Signal ground	0 V reference

Connector J14 - Raspberry Pi power and UART

Pin number	Pin name (silkscreen)	Function	Notes
79	GND	Signal ground	0 V reference
80	5.1V	5.1 V regulated output (Raspberry Pi supply)	Output, regulated 5.1 V, 3 A continuous (5 A peak), dedicated Raspberry Pi supply
81	TX-GPIO14	UART TX (GPIO14)	Output, UART TX, 3.3 V logic
82	RX-GPIO15	UART RX (GPIO15)	Input, UART RX, 3.3 V logic
83	GPIO17	General purpose digital I/O	Bidirectional, GPIO, 3.3 V logic (not 5 V)

Connector J15 - USB data and power

Pin number	Pin name (silkscreen)	Function	Notes
84	USB	USB data / power connection	USB data and power, USB data and power, onboard diode prevents external back-powering

7. Function and Usage

This chapter describes expected system-level behavior of DUILIO F4 when powered and connected, focusing on safe integration.

> NOTE: Power distribution and current limits (system-level) - Individual pin current ratings are maximum limits, not guarantees. - The sum of all output currents depends on the active power source. - When powered from VIN: total available 5 V current approx. 3 A continuous, 5 A peak (shared). - When powered ONLY from USB or Raspberry Pi GPIO: total available 5 V current < 0.8 A. - Exceeding the total budget may cause voltage drop, reset, or thermal shutdown.

7.1 Control signal logic

DUILIO F4 generates control signals for external motor drivers. It does not supply motor power and does not act as a power stage. Electrical characteristics for control signals are specified in Chapter 6.

Motion control is implemented through PWM-based command signals. PWM encodes a requested speed or torque level as a duty cycle, while a separate direction line indicates the intended motion direction. Some drivers use combined DIR/PWM signaling; DUILIO F4 provides both PWM and direction-capable signals to support common interfaces.

At system level, these signals are intended to be treated as low-power logic commands. PWM, DIR, ENABLE, and BRAKE are logic-level signals only. The external driver is responsible for converting them into motor power. They must never be interpreted as power or safety-rated signals.

7.2 Enable, brake and safety behavior

ENABLE and BRAKE signals control whether a driver is permitted to move or is forced into a stop condition. ENABLE must be asserted for motion; BRAKE requests a forced stop or hold, depending on the driver.

The expected default is a safe state: outputs remain inactive until a valid control condition is established. This reduces unintended motion at power-up and after resets.

Explicit enabling is required before motion so the integrator can enforce system interlocks and startup checks. This ensures that motion only occurs after external conditions are verified safe.

7.3 Control source priority

DUILIO F4 can accept multiple control sources such as USB, RC inputs, and external host interfaces. Only one control source must be used for commanding motion at any time.

At system level, control selection is deterministic and predictable. If multiple sources are present, the system uses a defined priority so control does not oscillate between sources.

This behavior allows a clear hierarchy, for example manual RC takeover or an external host override, depending on the integration strategy.

7.4 Startup and shutdown behavior

At power-up, the board remains in a non-driving state while logic power stabilizes. Control outputs should be considered inactive until an explicit enable condition is met.

A controlled startup sequence consists of: stable logic power, valid control source, and explicit enabling. This sequence reduces unintended motion and ensures the external driver receives coherent command signals.

On shutdown or power loss, outputs return to a safe state. External drivers should be expected to stop or enter their own safe mode when control signals disappear. WARNING: Do not rely on DUILIO F4 to maintain motion during power loss; external systems must handle safe stopping. System-level safety must be ensured by the external driver and mechanical design.

7.5 Fault and safe states

Loss of control signal should result in a safe state where motion commands are removed and drivers are disabled or braked, depending on the system configuration.

Loss of power results in all outputs dropping to inactive levels. External devices must be designed to fail safe in this condition.

Invalid or missing inputs should be treated as unsafe, and the system should prevent motion until inputs are valid again. This supports predictable behavior in noisy or unstable environments.

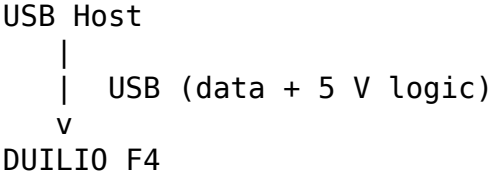
8. Connection Diagrams

This chapter shows simplified, example-level wiring diagrams to illustrate safe integration. All diagrams are example only.

8.1 Minimal bench setup

Figure 8-1 - Minimal bench setup (example only) Control signals only - motor power is external.

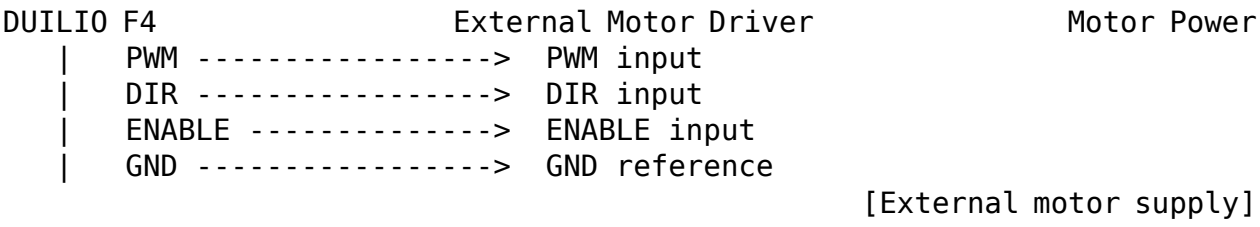
Use this setup for first checks and USB communication. No motors and no external driver power are connected.



8.2 Typical motor driver connection

Figure 8-2 - Typical motor driver connection (example only) Control signals only - motor power is external.

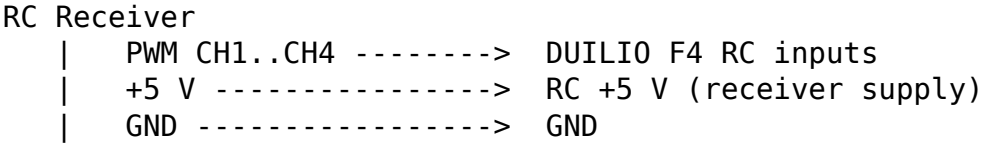
DUILIO F4 provides control signals to an external motor driver. Motor power is supplied externally and does not pass through DUILIO F4.



8.3 RC control setup

Figure 8-3 - RC control setup (example only) Control signals only - motor power is external.

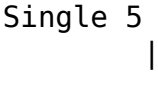
RC receiver outputs connect to the RC inputs with a shared 5 V and GND reference. WARNING: RC +5 V is not a power input for the board.



8.4 Raspberry Pi integration

Figure 8-4 - Raspberry Pi integration (example only) Control signals only - motor power is external.

Use a single 5 V power source for the stack or wired setup. Communication can be USB or serial. WARNING: Avoid back-powering by ensuring only one 5 V source is active.



```
        +----> Raspberry Pi 5 V
        |
        +----> DUILIO F4 5 V (if configured)

Communication:
Raspberry Pi  <---- USB or Serial ---->  DUILIO F4
```

8.5 Common wiring mistakes

Figure 8-5 - Common wiring mistakes (example only) Control signals only - motor power is external.

These examples highlight frequent errors that cause malfunction or damage. WARNING: Each case can create unsafe current paths or undefined signal references.

```
1) Missing GND
DUILIO F4  ---- PWM/DIR ---->  Driver
           (no ground reference)

2) Motor power through DUILIO F4
Motor supply ---> DUILIO F4 ---> Motor/Driver

3) Multiple 5 V sources
USB 5 V  +  External 5 V  +  Pi 5 V (simultaneous)

4) Reversed servo/RC polarity
GND and +5 V swapped on RC/servo connector
```

9. Communication Interfaces

This chapter describes the hardware communication interfaces available on DUILIO F4. Protocol details are intentionally excluded.

9.1 RS485 interface overview

RS485 provides a robust differential interface intended for multi-drop communication between multiple DUILIO F4 boards and a host system. At hardware level, the bus supports multiple nodes sharing a single pair, with each node connected in parallel. Differential signaling improves noise immunity in electrically noisy environments. No protocol definition is provided in this chapter.

9.2 RS485 hardware integration guidelines

Use a twisted pair for the RS485 differential lines to maintain signal integrity. A common ground between all connected devices is required to keep the differential reference within valid limits. RS485 lines are differential signals only; do not apply external voltage. Termination and biasing depend on the system topology.

Termination and biasing are required at the system level. Apply them according to network topology and cable length, without relying on default assumptions. Typical wiring mistakes include missing ground reference, star wiring with long stubs, and inconsistent termination.

9.3 I2C interface overview

DUILIO F4 provides I2C connectors for external sensors and peripherals. The interface is intended for short-distance, board-level communication with compatible devices. I2C signals are logic-level and require compatible voltage levels on connected devices.

9.4 I2C hardware integration guidelines

I2C is a shared bus; all devices connect in parallel and share the same clock and data lines. Pull-up resistors are required on the bus; ensure they exist in the system and avoid duplicating excessive pull-ups. Keep cable lengths short and avoid routing near high-current wiring to reduce noise and signal distortion. A shared ground reference between DUILIO F4 and I2C devices is mandatory.

9.5 Protocol status

This manual covers the hardware interface only. Protocol details, addressing, and timing are defined in firmware documentation and integration notes.

10. Advanced Hardware Configuration

This chapter describes non-default hardware configuration options intended for experienced integrators. Incorrect changes can cause malfunction or damage.

10.1 Power-related jumpers

Power routing jumpers configure how 5 V is distributed between DUILIO F4 and external systems. These are discussed in Chapter 4 and are open by default to avoid unsafe power paths.

Modify these jumpers only when a single, well-defined power direction is required for the system. Do not change jumpers while powered or during normal operation. WARNING: Incorrect power jumper settings can cause back-feeding or damage to the board or the host.

10.2 Communication-related options

RS485 configuration uses solder jumpers to control termination and line biasing. Default settings are suitable for small networks; larger networks may require adjustment to avoid bus loading. WARNING: Changes should be made only when the network topology is fully defined.

I2C hardware options are limited to external bus wiring and pull-up placement. Ensure only the required pull-ups are present in the system.

Additional RS485/I2C hardware options are defined by the specific system topology and external wiring choices.

10.3 Service and recovery configuration

BOOT configuration and SWD access are provided for service, recovery, and manufacturing use. These interfaces are intended for maintenance and should remain in their default state during normal operation.

Use BOOT configuration only for recovery or factory programming. Use SWD access for debugging and production testing. WARNING: Misuse of service interfaces can prevent normal startup or interrupt system operation.

11. Debug & Service

This chapter describes the hardware service features available for troubleshooting and recovery.

11.1 Status LEDs

DUILIO F4 includes status LEDs for basic visual indication. These LEDs are used to signal power presence, activity, or general status depending on firmware behavior. Exact blink patterns are firmware-defined and may vary between profiles.

11.2 SWD debug interface

An SWD debug interface is provided for development, recovery, and manufacturing test. It allows low-level access for programming and diagnostics when used with appropriate tools. WARNING: SWD access is not intended for normal system operation and can interfere with real-time behavior.

11.3 Test points

Test points are exposed for measurement and diagnostic access during service. They are intended for use with proper probing tools in controlled conditions. WARNING: Avoid shorting adjacent test points or probing during operation without appropriate fixtures.

12. Appendices

This chapter is reserved for supplementary reference material.

The following appendices may be added in future revisions of this manual: - Complete signal tables - Simplified reference diagrams - Hardware revision notes - Manufacturing and service notes

At the time of this release, no appendices are required for safe system integration.

Contents