



TIO-0808

Mixed Signal I/O Card with RS-485 Modbus RTU Interface

8 opto-isolated digital inputs, 6 digital outputs, integrated step/direction motion axis, isolated 0–10 V DAC, 0–10 V ADC and high-frequency PWM generator.

OPERATION MANUAL

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THIS MANUAL CONTAINS INFORMATION FOR INSTALLING AND OPERATING THE FOLLOWING PRODUCT: TIO-0808 MIXED SIGNAL I/O CARD WITH RS-485 MODBUS RTU INTERFACE.

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Tiny Controls Private Limited

Office B-17/A, Nishat Park, Kakrola, New Delhi – 110078

Works Khewat 863-Killa 103/8/2(1-18), Village Barhana, Tehsil Beri, District Jhajjar, Haryana – 124107

Sales & Support +91 99111 93212 | Office +91 99111 93210 | anil@tinycontrols.com | www.tinycontrols.com

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Revision History

Revision	Date	Timestamp	Sections affected	Summary of change
R1.0	April 2024	2024-04-24	All	Initial release for hardware v1.0 and firmware 2.00.
R2.0	September 2026	2026-09-26	All	Complete modernization to ADR-001 industrial family documentation standard (R13.0). Standardized Modbus register architecture for Firmware 3.00 with integrated step/direction motion engine. Added dedicated Quick Start (Chapter 4, Quick Start), standalone Technical Specifications (Chapter 5, Technical Specifications), and four standard engineering appendices (Appendices A–D).

Chapter 1 — Safety Information

Read this chapter before wiring, configuring or commanding the TIO-0808 card. It applies to every installation regardless of what the card interfaces or drives.

1.1 Warning Levels

Level	Meaning
DANGER	An imminently hazardous situation which, if not avoided, will result in death or serious injury.
WARNING	A potentially hazardous situation which, if not avoided, could result in death or serious injury.
CAUTION	A situation which, if not avoided, may result in minor injury or damage to equipment.
NOTE	Information needed for correct operation. No injury risk.

1.2 Electrical Safety

WARNING

Disconnect the main 24 V DC supply before plugging or unplugging terminal blocks, changing DIP switch settings, or modifying any bus wiring. Reversing 24 V DC power polarity causes permanent damage to the onboard protection network.

CAUTION

The 0–10 V analog output (DAC) requires an external isolated 10 V reference supply. Never connect the main 24 V DC supply rail to the DAC reference terminals; doing so destroys the DAC optocoupler and output operational amplifier.

CAUTION

Digital outputs OUT3 through OUT6 are open-collector transistor drivers. Always install an external flyback diode (such as a 1N4007) across any inductive load (solenoids, DC relay coils, brake coils). Omitting suppression diodes allows inductive kickback spikes to puncture the driver transistors.

1.3 Motion Safety

WARNING

Limit-seeking commands (Commands 5 and 6) lack automatic travel limits and built-in software timeouts. The pulse engine drives continuously until the designated input asserts. If the seek sensor is disconnected, damaged, or unpowered, the axis will travel indefinitely. The host controller must enforce a watchdog timeout and issue Command 0 (Stop) if travel limits are exceeded.

WARNING

Retrying motion commands without updating the sequence register (0x020B) risks double execution of relative moves. Always increment the sequence register before each motion command as documented in (section 11.2, Idempotent Command Execution via Sequence Register).

1.4 General Safety Rules

1. Always run RS-485 communication lines using shielded twisted-pair cabling (STP).
2. Terminate both physical ends of the RS-485 bus trunk with 120 Ω 0.25 W resistors.
3. Never exceed the maximum ratings of 250 VAC / 30 VDC at 5 A on relay outputs OUT1 and OUT2.
4. Clamp maximum sinking current on open-collector outputs OUT3–OUT6 to 500 mA per channel.
5. Power-cycle the card after changing any DIP switch position; switch states are read only at power-up.
6. Ensure common ground connectivity between the master controller and the card RS-485 ground reference.
7. Provide adequate enclosure ventilation to maintain ambient temperatures between -10°C and +70°C.
8. Incorporate an independent, hard-wired emergency stop circuit that disconnects actuator power directly.

Chapter 2 — Product Overview

The TIO-0808 is an industrial mixed-signal input/output expansion card with an onboard RS-485 interface communicating via the standard Modbus RTU protocol. It expands machine automation controllers by providing flexible digital I/O, an isolated analog output, a precision analog input, a high-frequency PWM generator, and a dedicated step/direction motion axis.

2.1 Key Features

- 8 opto-isolated digital inputs accepting 12–24 V DC industrial signals (active-high).
- 2 SPST Form A relay outputs with dry contacts rated for 250 VAC / 30 VDC at 5 A.
- 4 open-collector transistor outputs rated for 24 V DC at 500 mA sink current.
- Dedicated step/direction motion axis outputs (OUT7/OUT8) delivering up to 100,000 steps/s.
- 0–10 V isolated analog output (DAC) with 1% resolution for spindle or drive speed control.
- 0–10 V non-isolated analog input (ADC) reporting direct millivolt readings (0–10,000 mV).
- High-frequency PWM output generator with configurable frequency (100–10,000 Hz) and duty cycle.
- Standard Modbus RTU slave interface over 2-wire RS-485 with hardware address selection (17–24).
- Selectable communication baud rate (19,200 or 115,200 baud) via dedicated hardware switch.
- Non-volatile flash memory for storing commissioned motion acceleration, speed, and distance profiles.

2.2 Functional Architecture and Bus Sharing

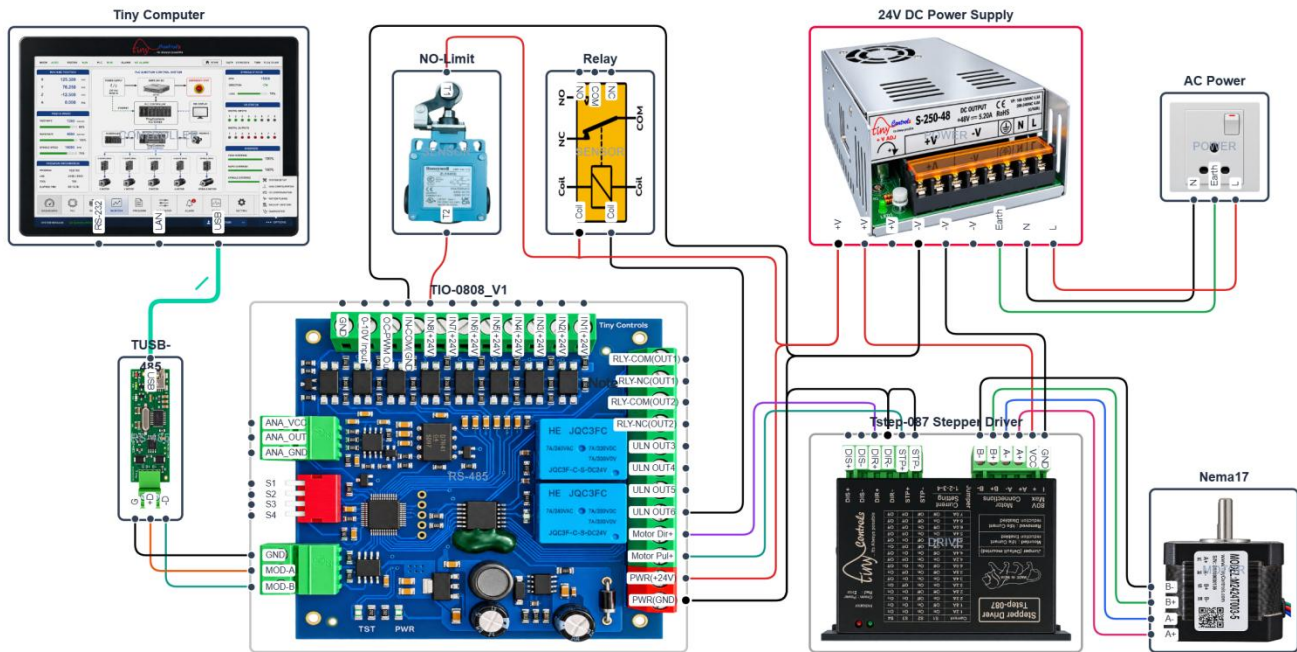
At Firmware 3.00, the TIO-0808 integrates the high-speed motion engine directly from the Tiny Controls Tstep-087 stepper drive family. The motion registers sit at the exact same Modbus addresses and share identical command syntax with Tstep-087 drives, allowing master software to control standalone stepper drives and expansion I/O motion channels with a single unified driver codebase.

To avoid communication collisions on shared industrial buses, the TIO-0808 hardware address range is constrained to 17 through 24 by DIP switches S1–S3. Tstep-087 drives occupy addresses 1 through 16. A single 2-wire RS-485 trunk can therefore host up to 16 stepper drives and 8 TIO-0808 expansion cards without address conflicts, as detailed in (Chapter 6, DIP Switch Configuration).

Chapter 3 — Installation and Wiring

This chapter details mechanical mounting, terminal connections, and wiring rules for the TIO-0808 card. Follow industrial panel wiring practices, including physical separation of low-voltage signal lines from high-voltage AC motor power conductors.

Figure 3.1 — TIO-0808 Board Wiring Diagram



3.1 Board Layout and Terminals

The card is housed on a compact PCB designed for panel sub-plate or DIN rail mounting. Pluggable screw terminal blocks along the board edges provide secure, service-friendly wiring connections for field power, I/O signals, analog loops, and communication lines.

3.2 Power Supply

The card operates from an external 24 V DC power supply ($\pm 10\%$). Quiescent current consumption is below 100 mA with all digital outputs inactive. When sizing the 24 V DC power source, account for external loads connected to open-collector outputs OUT3–OUT6 (up to 2.0 A total if all four outputs sink their maximum rated 500 mA).

NOTE

The card does not generate field power for inputs or loads. Field sensors and open-collector loads must be powered from the external 24 V DC supply system.

3.3 Digital Inputs (IN1–IN8)

The card provides eight opto-isolated digital inputs (IN1 through IN8). The inputs accept 12 V to 24 V DC industrial signals and draw approximately 5 mA per channel at 24 V DC. Inputs use active-high logic referenced to a common negative return terminal (IN_GND). Connect standard PNP sourcing

sensors or dry contact switches between the 24 V DC supply positive rail and the designated input terminal.

Inputs IN1 and IN2 double as hardware limit/seek inputs for the onboard motion engine, as described in (Chapter 9, Motion Commands).

3.4 Digital Outputs (OUT1–OUT6)

The card provides six general-purpose digital output channels, split between electromechanical relays and solid-state open-collector transistors:

1. OUT1 and OUT2 (Relays): SPST Form A normally-open dry contacts. Rated for switching up to 250 VAC or 30 VDC at 5 A resistive load. Ideal for pilot lamps, AC contactor coils, and power isolation interlocks.
2. OUT3 through OUT6 (Transistors): NPN open-collector drivers sinking up to 500 mA at 24 V DC. External loads must be connected between the positive supply rail (+24V) and the output terminal. An external flyback diode must be installed across inductive coils.

3.5 Step/Direction Axis Outputs (OUT7, OUT8)

Terminals OUT7 and OUT8 are exclusively reserved for the onboard pulse engine and cannot be driven as general-purpose digital outputs:

- OUT7: Direction output signal (5 V differential/TTL logic). Sets the motion travel direction.
- OUT8: Step pulse output signal (5 V differential/TTL logic). Emits high-speed pulse trains up to 100,000 steps/s with a minimum pulse width of 5.0 μ s.

WARNING

Writing to bit 6 (OUT7) or bit 7 (OUT8) in output register 0x0405 returns Modbus exception code 03. The motion axis must be commanded strictly through the motion registers documented in (Chapter 9, Motion Commands).

3.6 Analog Output — DAC (0–10 V Isolated)

The analog output provides an isolated 0 to 10 V DC signal with 1% resolution for commanding variable-frequency drives (VFDs), proportional valves, or power controllers. The DAC circuit is galvanically isolated from the card logic and requires an external isolated 10 V DC reference power supply connected to terminals 10V_IN and 10V_GND.

CAUTION

Connecting the main 24 V DC supply to the 10V_IN terminal will destroy the isolated DAC circuitry. Use only a regulated 10 V DC reference supply.

3.7 Analog Input — ADC (0–10 V Non-Isolated)

The analog input accepts a single-ended 0 to 10 V DC voltage referenced to the card common ground (GND). Input impedance is 100 k Ω . An onboard 10-bit analog-to-digital converter reports the input voltage in millivolts (0 to 10,000 mV) in Modbus register 0x0502. The analog input can also serve as a live speed potentiometer reference when potentiometer mode is enabled (section 9.4, Potentiometer Mode Operation).

3.8 PWM Output (Non-Isolated)

The PWM output terminal provides a non-isolated open-collector switching signal with software-configurable frequency from 100 Hz to 10,000 Hz and duty cycle resolution of 0.1% (1 to 999 per mille). The PWM output can be utilized for heating element control, DC motor speed governing, or LED intensity dimming.

3.9 RS-485 Serial Interface

The RS-485 communication port provides 2-wire half-duplex differential signalling over terminals A and B, accompanied by a shield/ground terminal (GND). Adhere to the following bus installation rules:

- Use shielded twisted-pair (STP) cable with characteristic impedance of 120 Ω (e.g. Belden 9841).
- Daisy-chain all devices along a single trunk line; avoid star configurations or long stubs.
- Install 120 Ω 0.25 W termination resistors across terminals A and B at the two extreme ends of the trunk.
- Connect the cable shield continuously across the bus and earth it at a single point near the master.

Chapter 4 — Quick Start

Follow this eight-step commissioning procedure to bring the TIO-0808 online and verify hardware communication with a host controller or USB-RS485 commissioning adapter.

1. **Set the card address:** Configure DIP switches S1, S2, and S3. With all three switches OFF, the card selects default Modbus address 17 (section 6.1, Address Selection).
2. **Select the baud rate:** Set DIP switch S4. Set S4 to OFF for 19,200 baud, or turn S4 ON for 115,200 baud (section 6.2, Baud Rate Selection).
3. **Connect RS-485 bus wiring:** Wire lines A and B to the master RS-485 transceiver, and connect the cable shield to the card ground reference.
4. **Apply 24 V DC power:** Connect regulated 24 V DC power to terminals +24V and GND. Confirm the green power LED illuminates and the status LED pulses steadily.
5. **Query device identity:** Send a Modbus function code 0x03 request to read four holding registers starting at address 0x0000.
6. **Verify identity response:** Confirm the card replies with Product ID 0x0808, Firmware 0x0300, unit address 17, and capability word 0x001F.
7. **Test digital output switching:** Write value 0x003F to register 0x0405 via function code 0x06. Verify relays OUT1–OUT2 click and transistors OUT3–OUT6 turn on.
8. **Read digital input status:** Poll register 0x0500 via function code 0x03 and verify that applying 24 V DC to inputs IN1–IN8 reflects in bits 0 through 7.

The verified hex byte exchange for Step 5 and Step 6 at address 17 is shown below:

```
-> 11 03 00 00 00 04 46 99          read identity block from unit address 17
<- 11 03 08 08 08 03 00 00 11 00 1F 58 8F
    [ 0808 ] [ 0300 ] [ 0011 ] [ 001F ]
    product  firmware  address  capabilities
```

WARNING

The Modbus register map shifted significantly at Firmware 3.00 to accommodate the integrated step/direction motion engine. Card control registers (DAC, PWM, digital outputs) moved from 0x0200 to 0x0400. Card status registers (inputs, ADC, temperature) moved from 0x0300 to 0x0500. A legacy master written for Firmware 2.00 that polls 0x0300 for inputs will now read the low word of the current motion speed. Read register 0x0001 first: 0x0300 or higher confirms Firmware 3.00 architecture.

NOTE

If the card fails to respond during initial bring-up, check three common failure modes: (1) Baud rate mismatch — ensure master serial port matches switch S4 (19,200 or 115,200 baud); (2) RS-485 line inversion — swap wires A and B; (3) Address offset — verify the master addresses slave 17 rather than default slave address 1.

Chapter 5 — Technical Specifications

This chapter specifies the absolute electrical ratings, motion performance limits, and environmental operating parameters for the TIO-0808 expansion card.

DIGITAL INPUTS 8 Opto-Isolated	OUTPUT CHANNELS 2 Relay + 4 OC	PULSE ENGINE 100 kHz Step/Dir	SERIAL BUS RS-485 Modbus RTU
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Table 5.1 lists the comprehensive engineering specifications and operating boundaries of the TIO-0808 card.

Parameter	Specification	Conditions / Remarks
Operating Supply Voltage	24 V DC ($\pm 10\%$)	Regulated industrial DC power supply
Quiescent Current	< 100 mA	At 24 V DC, all output channels inactive
Digital Inputs (IN1–IN8)	8 channels, opto-isolated	12–24 V DC, 5 mA sinking, active-high
Relay Outputs (OUT1, OUT2)	2 channels, SPST Form A	250 VAC / 30 VDC, 5 A max resistive load
Transistor Outputs (OUT3–OUT6)	4 channels, open-collector	24 V DC max, 500 mA sink max per channel
Motion Step Pulse Output (OUT8)	Up to 100,000 steps/s	5 V differential/TTL logic, min pulse 5.0 μ s
Motion Direction Output (OUT7)	5 V differential/TTL logic	Direction setup time > 10.0 μ s
Acceleration Range	1 to 1,000,000 steps/s ²	Staged in registers 0x0200–0x0201
Speed Range (Start & Cruise)	1 to 100,000 steps/s	Staged in registers 0x0202–0x0205
Move Distance Range	0 to 2,147,483,647 steps	Staged in registers 0x0206–0x0207
Position Counter	-2,147,483,648 to +2,147,483,647	Signed 32-bit two's complement accumulator
Analog Output (DAC)	0–10 V DC isolated	Requires external 10 V reference, 1% resolution
Analog Input (ADC)	0–10 V DC non-isolated	100 k Ω impedance, 1 mV resolution (0–10,000 mV)
PWM Output Frequency	100 Hz to 10,000 Hz	Open-collector, 100 Hz resolution steps
PWM Output Duty Cycle	1 to 999 per mille	0.1% resolution (0.1% to 99.9% duty cycle)
Serial Interface	RS-485 2-wire differential	8N1 framing, max frame length 64 bytes
Communication Baud	19,200 or 115,200 baud	Hardware selectable via DIP switch S4

Parameter	Specification	Conditions / Remarks
Rates		
Modbus Slave Addresses	17 to 24 (factory default 17)	Hardware selectable via DIP switches S1–S3
Operating Ambient Temperature	-10°C to +70°C	Relative humidity < 90% non-condensing
Storage Temperature	-25°C to +85°C	Clean, non-corrosive industrial atmosphere
Dimensions and Mounting	145 mm × 90 mm × 25 mm	Panel screw mount or DIN rail carrier mount

5.1 Operating and Environmental Exclusions

Operating the card under conditions outside the specified envelopes compromises system reliability and voids product warranty. The following operating practices are strictly excluded:

- Connecting AC mains power or voltages exceeding 28 V DC to the 24 V DC main power terminals.
- Operating inductive loads on open-collector outputs OUT3–OUT6 without external flyback suppression.
- Switching loads exceeding 5 A continuous current or 250 VAC on relay outputs OUT1 and OUT2.
- Applying external voltages exceeding 10.5 V DC to the isolated DAC reference input terminals.
- Operating the card in atmospheres containing conductive dust, corrosive chemical fumes, or condensing moisture.

Chapter 6 — DIP Switch Configuration

The card features a 4-position DIP switch module (S1 through S4) to configure the Modbus slave address and communication baud rate. Switch states are evaluated by the onboard microcontroller strictly once during power-up boot initialization.

6.1 Address Selection (S1, S2, S3)

Switches S1 (AD0), S2 (AD1), and S3 (AD2) determine the unit slave address within the dedicated range 17 through 24 according to the following mathematical weighting:

$$\text{Address} = 17 + (4 \cdot S3 + 2 \cdot S2 + 1 \cdot S1)$$

Table 6.1 lists the switch combinations for all eight selectable unit addresses.

Modbus Address	S3 (AD2)	S2 (AD1)	S1 (AD0)	Binary Weight	Factory Default
17	OFF	OFF	OFF	0 (000b)	Default Setting
18	OFF	OFF	ON	1 (001b)	
19	OFF	ON	OFF	2 (010b)	
20	OFF	ON	ON	3 (011b)	
21	ON	OFF	OFF	4 (100b)	
22	ON	OFF	ON	5 (101b)	
23	ON	ON	OFF	6 (110b)	
24	ON	ON	ON	7 (111b)	

6.2 Baud Rate Selection (S4)

DIP switch S4 selects the serial communication baud rate on the RS-485 bus.

Switch S4 Position	Communication Baud Rate	Character Transmission Time	Notes
OFF	19,200 baud	0.52 ms / character	Factory default setting
ON	115,200 baud	0.087 ms / character	High-throughput setting

NOTE

DIP switch inputs are sampled only during power-on reset. Modifying switch positions while the card is powered produces no immediate change. Always power-cycle the card after altering switch positions.

6.3 Bus Address Coexistence with Tstep-087 Drives

The TIO-0808 address space (17–24) is intentionally distinct from the address space allocated to Tiny Controls Tstep-087 stepper drives (1–16). This non-overlapping allocation guarantees that mixed

installations sharing a single RS-485 bus trunk suffer zero address collisions. A master controller can identify the device type directly from the target address.

Chapter 7 — Modbus RTU Protocol Fundamentals

The TIO-0808 implements the industry-standard Modbus RTU slave protocol over a 2-wire RS-485 differential physical link. This chapter defines framing rules, CRC checksum generation, supported function codes, and register serialization conventions.

7.1 Serial Transmission Mode

The serial framing format is fixed to standard 8N1 across all baud rates:

- 8 Data Bits, No Parity, 1 Stop Bit (8N1).
- Baud rate: 19,200 or 115,200 baud (selected by switch S4).
- Inter-character silence: must not exceed 1.5 character transmission times.
- Frame delimiter: minimum 3.5 character times of continuous bus silence before and after each frame.

7.2 Message Framing and Timing Limits

Every Modbus transaction consists of an address byte, a function code byte, a data payload, and a 16-bit cyclic redundancy check (CRC):

```
[ Unit Address (1B) ][ Function Code (1B) ][ Data Payload (0-60B) ][ CRC Low (1B) ][ CRC High (1B) ]
```

Key transmission timing constraints:

- Send entire frames in a single atomic operating system write call. Pausing during frame transmission causes the receiver to detect an end-of-frame timeout, splitting the packet and failing CRC validation.
- Maximum frame length is 64 bytes. Frames exceeding 64 bytes are discarded silently.
- Broadcast address 0 is executed by all cards on the bus but is never answered with a response frame.

7.3 CRC-16/MODBUS Computation

The frame checksum is computed using the standard CRC-16/MODBUS algorithm with generator polynomial 0xA001 (bit-reversed representation of 0x8005) and an initial seed of 0xFFFF. The CRC covers all bytes from the unit address through the final data byte.

WARNING

The CRC-16 is transmitted low byte first on the physical wire. All other multi-byte fields in Modbus RTU (register addresses, register counts, and 16-bit data words) are transmitted big-endian (high byte first). Transposing CRC byte order is the most frequent cause of master communication timeouts.

The C reference implementation below demonstrates standard CRC calculation and wire byte packing:

```
uint16_t crc16_modbus(const uint8_t *buffer, uint16_t length)
{
    uint16_t crc = 0xFFFF;
    for (uint16_t i = 0; i < length; i++) {
        crc ^= buffer[i];
        for (uint8_t bit = 0; bit < 8; bit++) {
```

```

        if (crc & 0x0001) crc = (crc >> 1) ^ 0xA001;
        else
            crc = crc >> 1;
    }
    return crc;
}

// Appending CRC to transmission buffer of length n:
uint16_t crc = crc16_modbus(frame, n);
frame[n] = (uint8_t)(crc & 0xFF); // CRC low byte first
frame[n + 1] = (uint8_t)((crc >> 8) & 0xFF); // CRC high byte second

```

Verification test vector: Calculating CRC-16 over the 9 ASCII bytes "123456789" produces hex value 0x4B37 (wire bytes 37 4B).

7.4 Supported Function Codes

The card supports four standard Modbus public function codes, listed in Table 7.1.

Function Code	Function Name	Transaction Register Limit	Description
0x03	Read Holding Registers	Up to 8 registers (16 bytes)	Reads configuration, control, and motion registers
0x04	Read Input Registers	Up to 8 registers (16 bytes)	Operates identically to function code 0x03
0x06	Write Single Register	Exactly 1 register (2 bytes)	Writes a single control, parameter, or command register
0x10	Write Multiple Registers	Up to 4 registers (8 bytes)	Writes up to two 32-bit motion parameters atomically

All other function codes, including Read Device Identification (0x2B/0x0E), are unsupported and return Modbus exception code 01 (Illegal Function).

7.5 32-Bit Register Representation

All motion parameters and real-time status values (acceleration, speeds, distance, position) are 32-bit integers. Each 32-bit value occupies two consecutive 16-bit Modbus registers, aligned on even register boundaries and serialized big-endian (high word first):

```
int32_t value = ((int32_t)register[n] << 16) | (uint16_t)register[n + 1];
```

Position (registers 0x0302–0x0303) is a signed two's complement 32-bit value. All other motion parameters are unsigned. The 4-register limit on function code 0x10 allows exactly two 32-bit motion values (e.g. cruise speed and travel distance) to be staged in a single atomic transaction.

Chapter 8 — Register Map

The TIO-0808 register space is partitioned into five distinct functional blocks: Identity, Motion Parameters, Motion Status, Card Control, and Card Status.

8.1 Identity Registers (0x0000–0x0003, Read Only)

The identity block provides read-only hardware, firmware, and capability metadata.

Register	Field Name	Typical Value	Description
0x0000	Product Identifier	0x0808	Identifies the TIO-0808 mixed-signal I/O card
0x0001	Firmware Version	0x0300	0x0300 represents Firmware Revision 3.00
0x0002	Unit Modbus Address	17–24	Live address configured by DIP switches S1–S3
0x0003	Hardware Capabilities	0x001F	Hardware feature bitmask (see Table 8.2)

Table 8.2 defines the capability bitmask reported in register 0x0003.

Bit Position	Hex Mask	Feature Flag	Functional Meaning
Bit 0	0x0001	DAC Present	Onboard 0–10 V isolated analog output is present
Bit 1	0x0002	PWM Present	High-frequency PWM output generator is present
Bit 2	0x0004	ADC Present	Onboard 0–10 V analog input converter is present
Bit 3	0x0008	Digital I/O Present	8 digital inputs and 6 digital outputs are present
Bit 4	0x0010	Motion Engine Present	Step/direction pulse generation engine is present

8.2 Motion Parameters (0x0200–0x020B, Read/Write)

Registers 0x0200 through 0x020B stage parameters for the motion engine. Writing to these registers stages the value into RAM; parameters take physical effect only when a command is written to command register 0x020A.

Registers	Parameter Name	Data Type	Engineering Units	Valid Range
0x0200–0x0201	Acceleration	Unsigned 32-bit	steps/s ²	1 to 1,000,000
0x0202–	Start Speed	Unsigned 32-bit	steps/s	1 to 100,000

Registers	Parameter Name	Data Type	Engineering Units	Valid Range
0x0203				
0x0204– 0x0205	Cruise Speed	Unsigned 32-bit	steps/s	1 to 100,000
0x0206– 0x0207	Move Distance	Unsigned 32-bit	steps	0 to 2,147,483,647
0x0208– 0x0209	Dwell Time	Unsigned 32-bit	ms	Not implemented in firmware
0x020A	Command Register	Unsigned 16-bit	—	Dispatches motion (Chapter 9, Motion Commands)
0x020B	Command Sequence	Unsigned 16-bit	—	Idempotency tag (section 11.2, Idempotent Command Execution via Sequence Register)

NOTE

Dwell registers 0x0208–0x0209 accept data and read back correctly, but are not acted upon by the motion profile generator. A host controller requiring dwell pauses between motion profiles must time delays internally.

8.3 Motion Status (0x0300–0x0305, Read Only)

Registers 0x0300 through 0x0305 report live motion engine telemetry. A single function code 0x03 read with quantity 6 fetches the complete axis state in one transaction.

Registers	Telemetry Field	Data Type	Engineering Units	Description
0x0300– 0x0301	Current Speed	Unsigned 32-bit	steps/s	Instantaneous pulse generator velocity
0x0302– 0x0303	Axis Position	Signed 32-bit	steps	Cumulative step accumulator counter
0x0304	Axis State Word	Unsigned 16-bit	Bitmask	Real-time motion status flags (Table 8.5)
0x0305	Seek Input States	Unsigned 16-bit	Bitmask	Bit 0 = IN1, Bit 1 = IN2 (debounced)

Table 8.5 details the bit definitions of the Axis State Word (register 0x0304).

Bit Position	Hex Mask	Status Flag Name	Description
Bit 0	0x0001	Moving	Set to 1 while the step pulse generator is actively emitting pulses
Bit 1	0x0002	Direction CW	1 = Clockwise / positive travel; 0 = Counter-clockwise / negative
Bit 2	0x0004	Dwell Active	Always 0 (dwell timing not implemented in firmware)
Bit 3	0x0008	Potentiometer Mode	Set to 1 when analog input is actively scaling cruise speed
Bit 4	0x0010	Driver Fault	Always 0 on TIO-0808 (no external driver fault input pin)

8.4 Card Control Registers (0x0400–0x0406, Read/Write)

Registers 0x0400 through 0x0406 govern analog outputs, PWM generation, status LED brightness, and digital outputs OUT1–OUT6.

Register	Control Field Name	Valid Range	Engineering Units	Default	Description
0x0400	DAC Output Level	0 to 100	%	0	Isolated analog voltage (0–10 V DC)
0x0401	DAC Enable	0 or 1	Boolean	0	0 = Output disabled (0 V); 1 = Enabled
0x0402	PWM Frequency	100 to 10,000	Hz	1,000	Switching frequency of PWM output
0x0403	PWM Duty Cycle	1 to 999	per mille	500	0.1% resolution (e.g. 500 = 50.0%)
0x0404	PWM Enable	0 or 1	Boolean	0	0 = PWM off (high-Z); 1 = PWM active
0x0405	Digital Output Port	0 to 63	Bitmask	0	Bit n controls OUT(n+1), OUT1–OUT6 only
0x0406	Status LED Brightness	0 to 100	%	50	Onboard green status LED duty cycle

WARNING

The digital output port register 0x0405 accepts values strictly from 0 to 63 (6 bits). Bits 6 and 7 correspond to motion terminals OUT7 (Direction) and OUT8 (Step). Writing any value with bit 6 or bit 7 set (such as 0xFF) is rejected with Modbus exception code 03. General digital output control is strictly restricted to channels OUT1–OUT6.

8.5 Card Status Registers (0x0500–0x0503, Read Only)

Registers 0x0500 through 0x0503 report live field input signals, output readbacks, analog measurements, and microcontroller internal temperature.

Register	Status Field Name	Data Range	Engineering Units	Description
0x0500	Digital Input Port	0 to 255	Bitmask	Bit n represents physical terminal IN(n+1)
0x0501	Digital Output Readback	0 to 63	Bitmask	Bit n reports driven state of OUT(n+1)
0x0502	Analog Input (ADC)	0 to 10,000	mV	Direct millivolt measurement of 0–10 V input
0x0503	Microcontroller Temp.	-40 to +125	°C	Internal silicon junction temperature

8.6 Unmapped Register Holes

Register spans 0x0004–0x01FF, 0x020C–0x02FF, 0x0306–0x03FF, 0x0407–0x04FF, and 0x0504 upward are unmapped address holes. Attempting to read from or write to any unmapped register returns Modbus exception code 02 (Illegal Data Address). The card never returns dummy zero data for non-existent registers.

Chapter 9 — Motion Commands

Motion operations are initiated by writing a command integer to register 0x020A via Modbus function code 0x06. The command numbers and profile staging logic match the Tiny Controls Tstep-087 stepper drive architecture.

Table 9.1 lists all supported motion commands and their operating rules.

Command	Action / Profile	Parameters Utilized	Operational Behavior
0	Stop Motion	Acceleration	Ramps axis down to zero velocity at configured acceleration
1	Move Clockwise	Distance, Speeds, Accel	Executes trapezoidal move of specified steps in CW direction
2	Move Counter-Clockwise	Distance, Speeds, Accel	Executes trapezoidal move of specified steps in CCW direction
3	Run Clockwise Continuous	Speeds, Accel	Ramps to cruise speed and runs indefinitely until stopped
4	Run CCW Continuous	Speeds, Accel	Ramps to cruise speed in CCW direction until stopped
5	Seek Input 1	Speeds, Accel	Runs CW until digital input IN1 asserts; ramps to stop
6	Seek Input 2	Speeds, Accel	Runs CCW until digital input IN2 asserts; ramps to stop
7	Reset Position Counter	—	Sets position accumulator (0x0302–0x0303) to zero
8	Save Parameters to Flash	Motion parameters	Stores accel, start/cruise speeds, and distance into flash
13	Enable Potentiometer Mode	Cruise speed	Analogue input scales cruise speed in real time
14	Disable Potentiometer Mode	—	Disengages analogue input speed scaling
20	Apply Staged Cruise Speed	0x0204–0x0205	Updates cruise speed of currently running continuous move

NOTE

Commands 17 (Driver Enable), 18 (Driver Disable), and 19 (Clear Driver Fault) exist on Tstep-087 drives but are not supported on the TIO-0808 because the card has no stepper driver enable line or fault input. Sending command 17, 18, or 19 returns Modbus exception code 03.

9.1 Motion Execution and Completion Polling

A motion profile begins executing immediately when a valid command is acknowledged. To monitor motion progress, the master polls registers 0x0300–0x0305 (quantity 6) and inspects bit 0 (Moving) of

the State Word (0x0304). Bit 0 remains 1 throughout acceleration, cruising, and deceleration, clearing to 0 precisely when the final step pulse is emitted. A polling interval of 50 ms to 100 ms provides responsive host coordination without bus saturation.

9.2 Real-Time Cruise Speed Modification (Command 20)

During a continuous run (Command 3 or 4), the master can modify axis speed dynamically without stopping motion: stage the new target speed into registers 0x0204–0x0205 and write value 20 to command register 0x020A. The velocity profile ramps smoothly toward the new cruise speed at the configured acceleration rate. Command 20 is rejected with exception 03 if potentiometer mode is currently enabled.

9.3 Dynamic Direction Reversal

Writing Command 3 while running counter-clockwise, or Command 4 while running clockwise, executes a controlled reversal. The pulse generator decelerates to start speed, pauses at zero velocity, reverses the direction output line (OUT7), and accelerates to cruise speed in the opposite direction. Position tracking remains completely continuous throughout. Reversing during a finite distance move (Commands 1 or 2) is rejected with exception 03.

9.4 Potentiometer Mode Operation (Commands 13 and 14)

When potentiometer mode is activated via Command 13, the 0–10 V analog input voltage linearly scales the cruise speed staged in registers 0x0204–0x0205. The staged cruise speed acts as the 100% full-scale ceiling. An operator turning an external potentiometer can adjust speed from 1 step/s up to the full configured cruise speed. Transitions follow the configured acceleration ramp.

WARNING

Reducing the potentiometer voltage to 0 V slows the axis to 1 step/s but does not halt pulse emission. The axis state word bit 0 remains 1. Halting motion requires issuing Command 0 (Stop). Disabling potentiometer mode via Command 14 leaves the axis operating at whatever speed the potentiometer last demanded until Command 20 or a new motion profile is issued.

9.5 Limit-Seeking Logic and Safety Precautions

Commands 5 and 6 initiate homing or limit seeking. The axis accelerates to cruise speed and runs continuously until the designated input (IN1 for Command 5, IN2 for Command 6) transitions high. Upon detection, the pulse engine decelerates to a stop at the configured acceleration rate. Position continues accumulating through deceleration.

WARNING

Seek commands have no travel limits or timeout safeguards. If a limit switch fails to actuate, the axis will run indefinitely. Master control software must enforce an independent travel distance or time budget, transmitting Command 0 if the seek does not complete within the expected window.

9.6 Non-Volatile Parameter Storage (Command 8)

Command 8 burns the current staged values of acceleration, start speed, cruise speed, and move distance into onboard non-volatile flash memory. At power-up, the card restores these commissioned settings automatically. Dwell and I/O states are not stored in flash.

WARNING

Command 8 is refused with exception code 03 if the motion axis is actively moving. Flash erase and write operations stall the microcontroller for approximately 35 ms, which would corrupt high-speed pulse timing. Always confirm bit 0 of the state word is 0 before issuing Command 8.

Chapter 10 — Exceptions

When a master request cannot be executed, the card responds with a standard Modbus exception packet. The returned function code equals the request function code OR'd with 0x80, followed by a 1-byte exception code and a 16-bit CRC.

Table 10.1 defines the three exception codes returned by the TIO-0808.

Exception Code	Exception Name	Trigger Conditions on TIO-0808
01	Illegal Function	Request contains any function code other than 0x03, 0x04, 0x06, or 0x10.
02	Illegal Data Address	Requested register address falls in an unmapped hole, or a multi-register request extends across an unmapped boundary.
03	Illegal Data Value	Quantity is zero or exceeds limits (8 for read, 4 for write); payload byte count mismatches quantity; register value exceeds range; unsupported command sent to 0x020A; or save command sent while axis is moving.

10.1 Atomic Write Rejection

If a multi-register write (function code 0x10) touches any invalid register or contains any out-of-range value, the card rejects the entire request with an exception. No registers within the range are modified. This all-or-nothing validation guarantees that 32-bit motion parameters are never left partially updated.

10.2 Slave Silence Conditions

The card remains completely silent (no response, no exception) under four conditions:

- The packet is addressed to another slave unit address.
- The frame CRC checksum fails. Answering a corrupted frame risks communicating with the wrong slave.
- The request is transmitted to broadcast address 0. Broadcasts are executed but never acknowledged.
- The received frame violates framing rules (e.g. invalid length or exceeding 64 bytes).

Chapter 11 — Reliable Communication

This chapter provides implementation recommendations for host drivers to guarantee robust Modbus RTU communications in electrically noisy industrial environments.

11.1 Master Timing Recommendations

Host drivers should implement the communication parameters listed in Table 11.1.

Parameter	Recommended Setting	Engineering Rationale
Response Timeout	100 ms	Normal round trip is ~5 ms at 115,200 baud; 100 ms accommodates flash saves (~35 ms) with comfortable margin.
Retry Limit	2 retries	Discards transient noise bursts before escalating to system fault.
Inter-Frame Delay	≥ 5.0 ms	Guarantees the card detects 3.5 character times of bus silence between consecutive master transactions.
Frame Transmission	Atomic write call	Prevents OS scheduling gaps from splitting Modbus frames.

11.2 Idempotent Command Execution via Sequence Register

Retrying I/O writes is naturally safe: writing the same output bit pattern or DAC level multiple times produces the identical physical state. Motion commands, however, are not inherently idempotent: resending an incremental move command because an acknowledgement was lost in transit will drive the axis twice the desired distance.

Register 0x020B resolves this ambiguity by providing an execution sequence tracking mechanism. Host masters commanding motion should follow this two-step sequence:

1. Write a unique sequence integer N to register 0x020B via function code 0x06.
2. Write the motion command to register 0x020A via function code 0x06.

When the card receives a command at 0x020A, it compares the current value in 0x020B against the sequence number of the previously executed command. If the sequence matches an already-executed command, the card acknowledges the write immediately but does not re-trigger the pulse engine. Reading register 0x020B returns the sequence number of the last executed command, allowing a master recovering from a timeout to determine whether its command took effect before re-transmitting.

11.3 Wrong Baud Rate Tolerance

The card receiver flushes internal error flags automatically on every poll pass. If a master scans the bus at an incorrect baud rate, the resulting framing and noise errors are discarded without locking up the UART. Once the master switches to the correct baud rate, the card answers subsequent valid frames immediately.

11.4 Bus Performance and Polling Budgets

Measured transaction turnaround times over a USB-RS485 interface at 115,200 baud:

- Read 4 registers (function 0x03): 5.03 ms typical round trip.
- Write single register (function 0x06): 4.60 ms typical round trip.
- Write multiple registers (function 0x10, 4 registers): 5.10 ms typical round trip.

Because fixed protocol overhead dominates transaction time, batch multiple register reads into single requests. Polling a card faster than once every 50 ms provides negligible control benefit and unnecessarily saturates the serial bus.

NOTE

When using USB-to-RS485 adapters based on FTDI chips, reduce the driver Latency Timer setting from the default 16 ms to 1 ms in Windows Device Manager. The default 16 ms delay dominates every communication cycle.

Chapter 12 — Worked Examples

The following 13 examples show byte-for-byte hex packet traces captured from a physical TIO-0808 card at unit address 17 (0x11) running Firmware 3.00. Host drivers reproducing these request frames byte-for-byte confirm exact CRC and framing compliance.

12.1 Read Identity Block

Query four identity registers starting at 0x0000 via function code 0x03:

```
-> 11 03 00 00 00 04 46 99
<- 11 03 08 08 08 03 00 00 11 00 1F 58 8F
```

Payload: Product ID = 0x0808, Firmware = 0x0300 (v3.00), Unit Address = 17 (0x0011), Capabilities = 0x001F (all five subsystem blocks present).

12.2 Read Motion Parameter Block

Query eight motion parameter registers starting at 0x0200:

```
-> 11 03 02 00 00 08 47 24
<- 11 03 10 00 00 07 D0 00 00 00 C8 00 00 03 20 00 00 06 40 AD AD
```

Payload: Accel = 2,000 steps/s² (0x000007D0), Start Speed = 200 steps/s (0x000000C8), Cruise Speed = 800 steps/s (0x00000320), Distance = 1,600 steps (0x00000640).

12.3 Multi-Register Write: Stage Cruise Speed and Distance

Write four registers starting at 0x0204 using function code 0x10 to stage Cruise Speed = 800 steps/s and Distance = 1,600 steps:

```
-> 11 10 02 04 00 04 08 00 03 20 00 00 06 40 D3 5F
<- 11 10 02 04 00 04 83 23
```

The card echoes the starting address and register quantity, acknowledging the staged parameters.

12.4 Read Back Staged Motion Parameters

Verify the staged values in registers 0x0204–0x0207 via function code 0x03:

```
-> 11 03 02 04 00 04 06 E0
<- 11 03 08 00 00 03 20 00 00 06 40 42 B3
```

12.5 Command Motion with Sequence Number

Stage sequence number 77 (0x004D) in 0x020B, then dispatch Command 1 (Move Clockwise) at 0x020A:

```
-> 11 06 02 0B 00 4D 3B 15      write sequence 77
<- 11 06 02 0B 00 4D 3B 15
-> 11 06 02 0A 00 01 6B 20      dispatch Command 1 (Move CW)
<- 11 06 02 0A 00 01 6B 20
```

12.6 Poll Motion Axis to Completion

Poll six motion status registers starting at 0x0300 after the move completes:

```
-> 11 03 03 00 00 06 C7 1C
<- 11 03 0C 00 00 00 00 00 00 06 40 00 02 00 00 23 15
```

Payload: Current Speed = 0, Position = 1,600 steps (0x00000640), State Word = 0x0002 (Moving bit 0 cleared, Direction CW bit 1 set), Seek Inputs = 0x0000.

12.7 Query Command Sequence Register

Confirm the last executed command sequence number by reading register 0x020B:

```
-> 11 03 02 0B 00 01 F6 E0
<- 11 03 02 00 4D B9 B2          sequence 77 confirmed executed
```

12.8 Read Card Status Block (Inputs, Analogue, Temperature)

Read four card status registers starting at 0x0500 in one batched transaction:

```
-> 11 03 05 00 00 04 46 55
<- 11 03 08 00 00 00 00 00 00 00 20 C0 CF
```

Payload: Inputs = 0x0000 (all inactive), Outputs = 0x0000, ADC = 0 mV, MCU Temp = 32°C (0x0020).

12.9 Control Digital Outputs and Range Validation Rejection

Energise all six output channels (OUT1–OUT6) by writing 0x003F to register 0x0405:

```
-> 11 06 04 05 00 3F DA 7B      write 0x003F (bits 0-5 on)
<- 11 06 04 05 00 3F DA 7B      acknowledged
```

Attempting to write 0x00FF (requesting eight outputs) is rejected because OUT7 and OUT8 belong to the motion engine:

```
-> 11 06 04 05 00 FF DA 2B      write 0x00FF (illegal bits 6 & 7)
<- 11 86 03 03 A4              exception 03 (Illegal Data Value)
```

12.10 Adjust Status LED Brightness

Set onboard status LED brightness to 42% by writing 42 (0x002A) to register 0x0406:

```
-> 11 06 04 06 00 2A EB B4
<- 11 06 04 06 00 2A EB B4
```

12.11 Potentiometer Mode Configuration and Collision Prevention

Engage potentiometer mode via Command 13, verify rejection of Command 20, and disengage via Command 14:

```
-> 11 06 02 0A 00 0D 6B 25      dispatch Command 13 (Enable Pot Mode)
<- 11 06 02 0A 00 0D 6B 25      pot mode active
-> 11 06 02 0A 00 14 AA EF      dispatch Command 20 while pot mode active
<- 11 86 03 03 A4              exception 03 (rejected: pot owns speed)
-> 11 06 02 0A 00 0E 2B 24      dispatch Command 14 (Disable Pot Mode)
<- 11 06 02 0A 00 0E 2B 24      pot mode disengaged
```

12.12 Non-Volatile Motion Parameter Save to Flash

Stage motion settings across two write transactions and commit to flash using Command 8:

```
-> 11 10 02 00 00 04 08 00 00 10 E1 00 00 00 DE 9F EA accel 4321, start 222
<- 11 10 02 00 00 04 C2 E2
-> 11 10 02 04 00 04 08 00 00 0D 05 00 01 56 66 73 AC cruise 3333, dist 87654
<- 11 10 02 04 00 04 83 23
-> 11 06 02 0A 00 08 AB 26 dispatch Command 8 (Save Flash)
<- 11 06 02 0A 00 08 AB 26 acknowledged (~35 ms)
```

Issuing Command 8 while the axis is actively running returns exception 03:

```
-> 11 06 02 0A 00 03 EA E1 dispatch Command 3 (Run CW)
<- 11 06 02 0A 00 03 EA E1
-> 11 06 02 0A 00 08 AB 26 dispatch Command 8 while moving
<- 11 86 03 03 A4 exception 03 (rejected: stop axis first)
```

12.13 Unsupported Commands and Exception Responses

Common exception generation patterns:

```
// Command 17 (Driver Enable) not supported on this card:
-> 11 06 02 0A 00 11 6A EC
<- 11 86 03 03 A4 code 03 (Illegal Data Value)

// Reading unmapped register hole 0x9999:
-> 11 03 99 99 00 01 78 29
<- 11 83 02 C1 34 code 02 (Illegal Data Address)

// Requesting 9 registers (exceeding read limit of 8):
-> 11 03 00 00 00 09 87 5C
<- 11 83 03 00 F4 code 03 (Illegal Data Value)

// Unsupported function code 0x2B (Device Identification):
-> 11 2B 0E 01 00 00 74 74
<- 11 AB 01 9F 35 code 01 (Illegal Function)
```

Chapter 13 — Not Supported

To avoid invalid assumptions during system architecture and master driver development, the following operations and protocol features are explicitly unsupported by the TIO-0808:

- Modbus function codes other than 0x03, 0x04, 0x06, and 0x10.
- Read Device Identification (0x2B / 0x0E). Use identity registers 0x0000–0x0003 instead.
- Transactions requesting reads over 8 registers or writes over 4 registers.
- Serial frames exceeding 64 bytes total length.
- Response generation for broadcast requests addressed to unit 0.
- Software modification of slave address or baud rate over the bus; both are switch-only.
- Using terminals OUT7 and OUT8 as general-purpose digital outputs.
- Saving non-motion parameters (DAC level, PWM settings, I/O states, or potentiometer mode) into flash.
- Executing flash parameter saves (Command 8) while the motion axis is moving.
- Onboard execution of dwell delays; registers 0x0208–0x0209 store values but do not pause motion.
- Commands 17, 18, and 19 (stepper driver enable, disable, and fault clearing).
- Selectable byte or word ordering for 32-bit motion values; serialization is strictly big-endian.

Chapter 14 — Troubleshooting

Table 14.1 provides a systematic diagnostic guide for resolving hardware, communication, and motion faults on the TIO-0808 expansion card.

Fault Symptom	Probable Root Cause	Corrective Diagnostic Action
Power LED off; card entirely unresponsive	24 V DC power absent or reversed polarity	Verify 24 V DC supply across +24V and GND terminals with a multimeter. Confirm power supply polarity.
Status LED pulses, but card does not respond to Modbus queries	Baud rate mismatch, incorrect slave address, or inverted A/B lines	Confirm switch S4 matches master baud rate (19,200 or 115,200). Verify slave address (17–24). Swap wires A and B.
Card returns Modbus exception code 01	Master issued unsupported function code	Restrict master commands to function codes 0x03, 0x04, 0x06, or 0x10. Replace 0x2B queries with register 0x0000 reads.
Card returns Modbus exception code 02	Master queried an unmapped register hole	Review (Chapter 8, Register Map). Ensure register addresses fall within valid mapped blocks.
Card returns Modbus exception code 03	Register value out of range, read limit > 8, or write limit > 4	Ensure reads request ≤ 8 registers and writes request ≤ 4 registers. Check that output register 0x0405 ≤ 63 .
Stepper motor does not rotate when commanded	Motion parameters not staged or start speed exceeds motor torque	Verify non-zero values for acceleration, speed, and distance. Check wiring to drive Step/Dir inputs from OUT7/OUT8.
Motor stalls or vibrates during acceleration	Acceleration rate set too high or start speed too aggressive	Lower acceleration in registers 0x0200–0x0201 (try 1,000 steps/s ²). Reduce start speed in 0x0202–0x0203 (try 100 steps/s).
Homing seek (Command 5 or 6) continues past sensor	Seek input not wired, not powered, or wrong sensor logic	Poll register 0x0305 while manually actuating sensor. Verify input voltage reaches ≥ 12 V DC when active.
Relay outputs OUT1/OUT2 do not switch	Output register bit not set or coil power fault	Write 0x0003 to register 0x0405 and listen for relay clicks. Verify continuity across dry contact terminals.
Isolated DAC output remains at 0 V	External 10 V reference supply missing or DAC disabled	Verify external 10 V DC across 10V_IN and 10V_GND. Confirm register 0x0401 is written to 1 and 0x0400 > 0.

Chapter 15 — Warranty and Support

This chapter defines the warranty coverage, service return procedures, and technical support facilities for the TIO-0808 mixed-signal I/O card.

15.1 Warranty Coverage

Tiny Controls Private Limited warrants the TIO-0808 hardware against defects in materials and workmanship for a period of 12 months from the date of invoice. Under this warranty, Tiny Controls will, at its discretion, repair or replace any product proven defective under normal industrial use and proper operating conditions.

15.2 Warranty Exclusions

The standard warranty does not cover damage resulting from:

- Connection of incorrect supply voltages, reversed power polarity, or excessive voltage spikes.
- Operating open-collector outputs OUT3–OUT6 into inductive loads without external flyback suppression.
- Overloading relay contacts beyond 250 VAC / 30 VDC at 5 A.
- Applying external voltages exceeding 10.5 V DC to the isolated DAC reference input.
- Exposure to liquids, corrosive chemical fumes, conductive dust, or ambient temperatures outside -10°C to +70°C.
- Unauthorized physical repair, component replacement, or PCB modifications.

15.3 Return Material Authorization (RMA)

Before returning any unit for warranty evaluation or factory service, customers must contact Tiny Controls technical support to obtain a Return Material Authorization (RMA) number. Ship returned equipment in static-protective packaging, freight prepaid, clearly referencing the RMA number on all exterior shipping paperwork.

15.4 Technical Support and Company Facilities

Direct all technical inquiries, application assistance requests, and service dispatches to Tiny Controls engineering support using the facilities listed in Table 15.1.

Facility / Channel	Contact Information & Physical Address
Registered Office	Tiny Controls Private Limited B-17/A, Nishat Park, Kakrola, New Delhi – 110078, India
Manufacturing Works	Tiny Controls Private Limited (Works) Khewat 863-Killa 103/8/2(1-18), Village Barhana, Tehsil Beri, District Jhajjar, Haryana – 124107, India
Sales & Technical Support	Telephone: +91 99111 93212 Office: +91 99111 93210
Email Support	Technical & Sales: anil@tinycontrols.com
Official Website	Portal: www.tinycontrols.com

Appendix A — Connection Diagram

This appendix presents the complete field wiring and interconnection diagram for the TIO-0808 mixed-signal I/O card, detailing pin assignments across all terminal blocks.

Figure A.1 — TIO-0808 Complete Wiring and Interconnection Diagram

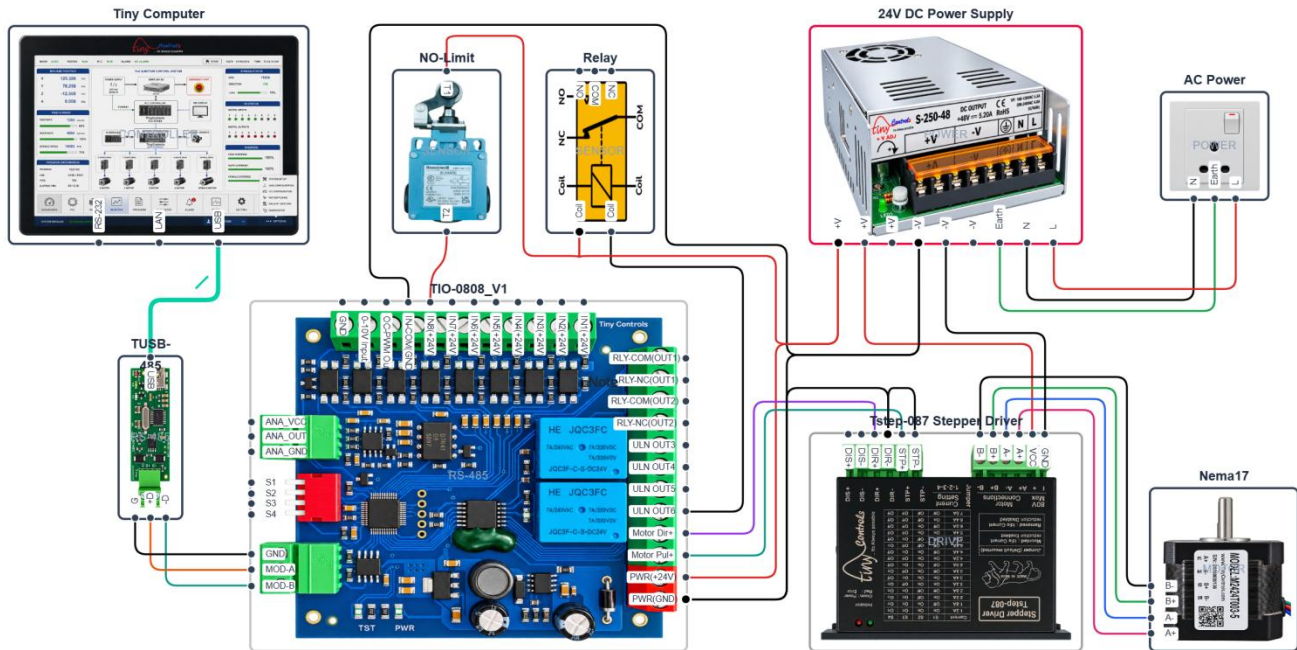


Table A.1 provides the terminal pinout legend corresponding to Figure A.1.

Terminal Block	Terminal Label	Signal Classification	Functional Connection Description
Power Supply	+24V	DC Power Input	Main +24 V DC power supply positive rail ($\pm 10\%$)
Power Supply	GND	DC Power Ground	Main 24 V DC power supply negative return / logic ground
Digital Inputs	IN1 – IN8	Opto-Isolated Input	8 digital input channels (12–24 V DC active-high sinking)
Digital Inputs	IN_GND	Input Common Return	Common ground reference for optocoupler inputs IN1–IN8
Relay Outputs	OUT1_A / OUT1_B	SPST Dry Contact	Relay 1 normally-open contact pair (250 VAC / 30 VDC, 5 A)
Relay Outputs	OUT2_A / OUT2_B	SPST Dry Contact	Relay 2 normally-open contact pair (250 VAC / 30 VDC, 5 A)
Transistor Outputs	OUT3 – OUT6	Open-Collector Sink	4 NPN open-collector outputs (24 V DC, 500 mA sink max)
Motion Outputs	OUT7 (DIR)	5 V Differential/TTL	Motion engine direction output line to

Terminal Block	Terminal Label	Signal Classification	Functional Connection Description
			external drive
Motion Outputs	OUT8 (STEP)	5 V Differential/TTL	Motion engine high-speed step pulse output (100 kHz max)
Analog Output	10V_IN	Isolated Reference In	External +10 V DC regulated reference supply input for DAC
Analog Output	10V_GND	Isolated Ground In	Isolated negative return for external 10 V reference supply
Analog Output	DAC_OUT	Isolated Analog Out	0 to 10 V DC proportional speed command output voltage
Analog Input	ADC_IN	Analog Input (0–10V)	0 to 10 V DC single-ended analog voltage input channel
Analog Input	ADC_GND	Analog Ground	Common ground reference for analog input ADC_IN
PWM Output	PWM_OUT	Open-Collector Sink	High-frequency PWM driver output terminal (100–10,000 Hz)
Serial Port	RS485_A	Differential Data (+)	Modbus RTU RS-485 non-inverting communication line A
Serial Port	RS485_B	Differential Data (-)	Modbus RTU RS-485 inverting communication line B
Serial Port	RS485_GND	Shield / Bus Ground	Cable shield drainage and common reference ground

Appendix B — Integrator Technical Specifications

This appendix details timing budgets, physical transceiver parameters, and electrical characteristics required by machine system integrators and firmware engineers.

Subsystem / Interface	Engineering Characteristic	Design Value / Limit	Integrator Design Remarks
RS-485 Transceiver	Differential Driver Output	≥ 1.5 V into 54 Ω load	Complies with ANSI TIA/EIA-485-A
RS-485 Transceiver	Receiver Sensitivity	± 200 mV threshold	1/8 unit load (up to 256 transceivers on bus)
RS-485 Bus Timing	Turnaround Latency	1.2 ms typical	Time between RX end-of-frame and TX preamble
RS-485 Bus Timing	Inter-Frame Silence Guard	≥ 3.5 character times	3.65 ms at 19,200 baud; 0.35 ms at 115,200 baud
Pulse Output (OUT8)	Maximum Pulse Frequency	100,000 steps/s (100 kHz)	Structural limit of 100 kHz timer interrupt
Pulse Output (OUT8)	Minimum Step Pulse Width	5.0 μ s	Guarantees optocoupler saturation on motor drives
Direction Output (OUT7)	Direction Setup Time	≥ 10.0 μ s	Direction line settles before first step pulse
Pulse Jitter	Period Jitter Accuracy	< 0.1% period variation	Deterministic hardware timer ISR execution
Digital Inputs (IN1–IN8)	Optocoupler Isolation	2,500 Vrms (1 minute)	Galvanic isolation from card digital logic
Digital Inputs (IN1–IN8)	Filter Debounce Time	2.5 ms debounce window	Prevents mechanical contact bounce triggering
Relay Outputs (OUT1–2)	Contact Resistance	< 100 m Ω initial	AgSnO2 alloy industrial relay contacts
Relay Outputs (OUT1–2)	Mechanical Service Life	10,000,000 operations	At zero electrical load
Relay Outputs (OUT1–2)	Electrical Service Life	100,000 operations	At rated 5 A 250 VAC resistive load
Open-Collector Drivers	Output Leakage Current	< 10 μ A (off state)	At 24 V DC collector voltage
Open-Collector Drivers	Saturation Voltage Vce(sat)	< 0.8 V DC at 500 mA	Internal power dissipation < 400 mW
Isolated DAC Output	Linearity Error	$\pm 0.5\%$ Full Scale Range	Over 1% to 99% configured output span
Isolated DAC	Settling Time	< 25 ms to 99% target	Filter step response for 0 to

Subsystem / Interface	Engineering Characteristic	Design Value / Limit	Integrator Design Remarks
Output			10 V transition
Analog Input (ADC)	Sampling Resolution	10-bit successive approx.	Converts 0–10 V span to 0–10,000 mV
Analog Input (ADC)	Measurement Accuracy	±1.0% FSR	Calibrated against onboard precision reference
PWM Output	Frequency Resolution	100 Hz steps	PWM counter clocked from 1 MHz hardware timer

Appendix C — Complete Register Map Tree

This appendix compiles the complete register memory map of the TIO-0808 (Firmware 3.00), providing address ranges, data types, access privileges, and factory reset defaults.

Address	Register Name	Type / Size	Range / Units	Access	Default	Functional Summary
0x0000	Product Identifier	Uint16 (1 reg)	0x0808	RO	0x0808	Hard-coded product identification code
0x0001	Firmware Revision	Uint16 (1 reg)	0x0300	RO	0x0300	Firmware 3.00 indicator
0x0002	Unit Modbus Address	Uint16 (1 reg)	17 to 24	RO	17	Live address selected by DIP switches S1–S3
0x0003	Hardware Capabilities	Uint16 (1 reg)	0x001F	RO	0x001F	Subsystem presence bitmask (DAC, PWM, ADC, I/O, Axis)
0x0004–0x01FF	Reserved Space	—	—	—	—	Unmapped address hole (returns exception 02)
0x0200–0x0201	Acceleration	Uint32 (2 regs)	1–1,000,000 steps/s ²	RW	2,000	Motion profile acceleration rate
0x0202–0x0203	Start Speed	Uint32 (2 regs)	1–100,000 steps/s	RW	200	Motion profile initial and terminal speed
0x0204–0x0205	Cruise Speed	Uint32 (2 regs)	1–100,000 steps/s	RW	800	Motion profile cruise velocity target
0x0206–0x0207	Move Distance	Uint32 (2 regs)	0–2,147,483,647 steps	RW	1,600	Incremental move distance in pulses
0x0208–0x0209	Dwell Delay	Uint32 (2 regs)	ms	RW	0	Not implemented in firmware; stored only
0x020A	Command Register	Uint16 (1 reg)	0 to 20	RW	0	Writing dispatches motion operations
0x020B	Command Sequence	Uint16 (1 reg)	0 to 65,535	RW	0	Idempotency tag preventing double move execution
0x020C–	Reserved	—	—	—	—	Unmapped

Address	Register Name	Type / Size	Range / Units	Access	Default	Functional Summary
0x02FF	Space					address hole (returns exception 02)
0x0300–0x0301	Current Speed	Uint32 (2 regs)	0–100,000 steps/s	RO	0	Instantaneous step generator pulse velocity
0x0302–0x0303	Axis Position	Int32 (2 regs)	Signed 32-bit steps	RO	0	Signed cumulative axis position counter
0x0304	Axis State Word	Uint16 (1 reg)	Bitmask	RO	0	Motion status (Bit 0: Moving, Bit 1: CW, Bit 3: Pot)
0x0305	Seek Input States	Uint16 (1 reg)	Bitmask	RO	0	Debounced seek inputs (Bit 0 = IN1, Bit 1 = IN2)
0x0306–0x03FF	Reserved Space	—	—	—	—	Unmapped address hole (returns exception 02)
0x0400	DAC Output Level	Uint16 (1 reg)	0 to 100 %	RW	0	Isolated 0–10 V analog output percentage
0x0401	DAC Enable	Uint16 (1 reg)	0 or 1	RW	0	0 = Analog output disabled (0 V); 1 = Enabled
0x0402	PWM Frequency	Uint16 (1 reg)	100 to 10,000 Hz	RW	1,000	Switching frequency for PWM generator
0x0403	PWM Duty Cycle	Uint16 (1 reg)	1 to 999 per mille	RW	500	PWM duty cycle in tenths of a percent
0x0404	PWM Enable	Uint16 (1 reg)	0 or 1	RW	0	0 = PWM output disabled; 1 = Enabled
0x0405	Output Port (OUT1–6)	Uint16 (1 reg)	0 to 63 (6 bits)	RW	0	Bit n energises OUT(n+1); bits 6–7 reserved
0x0406	Status LED Level	Uint16 (1 reg)	0 to 100 %	RW	50	Onboard green status LED brightness
0x0407–	Reserved	—	—	—	—	Unmapped

Address	Register Name	Type / Size	Range / Units	Access	Default	Functional Summary
0x04FF	Space					address hole (returns exception 02)
0x0500	Input Port (IN1–8)	Uint16 (1 reg)	0 to 255 (8 bits)	RO	—	Bit n reports physical logic state of IN(n+1)
0x0501	Output Port Readback	Uint16 (1 reg)	0 to 63 (6 bits)	RO	0	Readback of actively driven output channels
0x0502	Analog Input (ADC)	Uint16 (1 reg)	0 to 10,000 mV	RO	0	Direct millivolt measurement on ADC_IN pin
0x0503	CPU Temperature	Int16 (1 reg)	-40 to +125 °C	RO	—	Silicon internal junction temperature
0x0504–0xFFFF	Reserved Space	—	—	—	—	Unmapped address hole (returns exception 02)

Appendix D — Quick Reference Card

This appendix consolidates high-frequency configuration tables, common Modbus RTU packet sequences, and critical integration rules onto a rapid field reference cheat-sheet.

D.1 DIP Switch Address and Baud Matrix

Address is configured by switches S1–S3; baud rate is selected by switch S4.

Address	S3 (AD2)	S2 (AD1)	S1 (AD0)	S4 Switch Position	Configured Baud Rate
17 (Default)	OFF	OFF	OFF	S4 = OFF (Default)	19,200 baud (8N1)
18	OFF	OFF	ON	S4 = ON	115,200 baud (8N1)
19	OFF	ON	OFF	—	Note: Switch states are sampled strictly once during power-up initialization.
20	OFF	ON	ON	—	
21	ON	OFF	OFF	—	Always power-cycle the card after
22	ON	OFF	ON	—	modifying any switch positions.
23	ON	ON	OFF	—	
24	ON	ON	ON	—	

D.2 Core Modbus RTU Packet Sequences (Unit 17)

Common command packets at factory address 17 (0x11):

```
// 1. Read Device Identity (Registers 0x0000-0x0003):
-> 11 03 00 00 00 04 46 99
<- 11 03 08 08 08 03 00 00 11 00 1F 58 8F

// 2. Poll Digital Inputs, Outputs, ADC, and Temp (Registers 0x0500-0x0503):
-> 11 03 05 00 00 04 46 55
<- 11 03 08 [IN] [OUT] [ADC_HI] [ADC_LO] [TEMP] [CRC_LO] [CRC_HI]

// 3. Energise Digital Outputs OUT1-OUT6 (Register 0x0405 = 0x003F):
-> 11 06 04 05 00 3F DA 7B
<- 11 06 04 05 00 3F DA 7B

// 4. Command Move Clockwise with Sequence Tag (Seq = 77, Cmd = 1):
-> 11 06 02 0B 00 4D 3B 15      write sequence 77
<- 11 06 02 0B 00 4D 3B 15
-> 11 06 02 0A 00 01 6B 20      dispatch Move CW
<- 11 06 02 0A 00 01 6B 20

// 5. Poll Motion Telemetry (Registers 0x0300-0x0305, Quantity 6):
-> 11 03 03 00 00 06 C7 1C
```

```
<- 11 03 0C [SPD_32] [POS_32] [STATE_16] [SEEK_16] [CRC_LO] [CRC_HI]

// 6. Stop Motion Immediately (Register 0x020A = 0):
-> 11 06 02 0A 00 00 AB 20
<- 11 06 02 0A 00 00 AB 20
```

D.3 Three Things That Bite

Integrators frequently encounter the following three architectural nuances:

- Outputs OUT7 and OUT8 cannot be driven as general outputs: Terminals OUT7 and OUT8 are hard-wired to the pulse generation engine (Direction and Step). Writing to bits 6 or 7 in register 0x0405 returns Modbus exception code 03. Motion must be commanded through motion registers (Chapter 9, Motion Commands).
- Register map shifted at Firmware 3.00: Card control registers moved from 0x0200 to 0x0400, and status registers moved from 0x0300 to 0x0500. Legacy software querying 0x0300 will read motion speed instead of inputs. Read register 0x0001 (0x0300) first to verify firmware version.
- Seek commands have no timeout: Commands 5 and 6 run indefinitely until their physical input asserts. Master software must enforce an independent travel distance watchdog or communication timeout and issue Command 0 if the seek boundary is exceeded.

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