Tulip Edge IO - Technical Datasheet

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Edge IO Overview

Edge IO is a compact, Wi-Fi-enabled edge device designed to simplify the collection and integration of operational data from machines, PLCs, sensors, and other equipment directly into the Tulip platform. With built-in support for 24V input/output, serial, and analog inputs, Edge IO provides manufacturers with a versatile, low-cost solution for driving digital transformation on the shop floor.

Edge IO runs the Tulip OS, based on Linux and maintained by Tulip. Users can program, read values, and connect equipment by configuring the hardware and building an application in Tulip. Further customization of the GPIO and analog interfaces (sampling interval, fourier transforms, and signal visualization) can all be accessed and configured with Node-RED.

Key features include:

- **GPIO & Serial Communication:** Seamlessly interface with external devices using general-purpose input/output and RS-232/RS-485 serial connections.
- **USB and Analog Input Support:** Connect a variety of peripherals and analog sensors for enhanced data acquisition.
- **Node-RED Integration:** Create advanced automations and control flows via an intuitive visual programming interface.
- **Over the Air Updates ("OTA"):** We release new firmware and Tulip OS images approximately every 3 months to address security and add features. These updates can be automatically applied or manually scheduled by users.
- **Tulip Light Kit Support:** Directly drive Tulip Light Kits for real-time visual

signaling with no additional hardware required.

Applications

- Smart workstation: Edge IO can connect to a variety of low voltage (5V) and industrial voltage (24V) systems. Control Andon light stacks and read simple digital inputs for other equipment.
- Industrial control: using Node-RED, connect Edge IO to multiple RS-485 devices or just connect the device to any RS-232 system.
- Industrial monitoring: connect your industrial 0-10V or 4-20mA sensors to Edge Io analog ports. Analyze the time series signals live in Node-RED and calculate the frequency components of the signal. Send these data easily back to Tulip using our Tulip Hardware Node-RED nodes
- Connect MQTT or other clients to Edge IO and use our Node-RED nodes to send these data as Tulip machine attributes or Tulip table data.

Software Applications and References

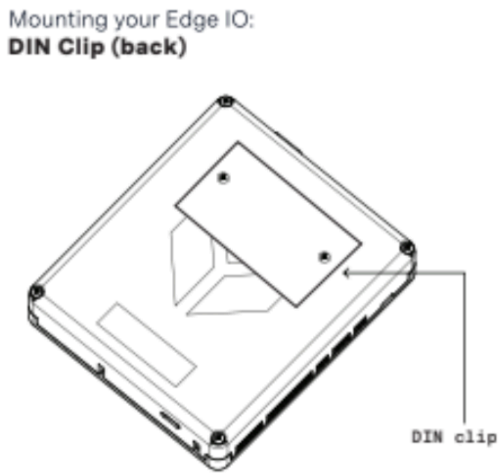
- Edge IO as a Machine Data Source
- Edge IO and FlowFuse
- Edge IO and MQTT Broker
- Edge IO and MQTT Bridge
- Edge IO and GPIO
- Edge IO and Node-RED
- Edge IO and Serial
- Edge IO and On-Prem Connector Host

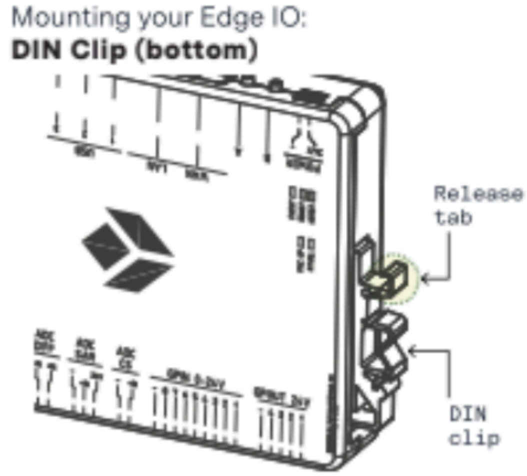
Physical Characteristics

- **Dimensions (W x H x D):** 150mm x 100mm x 40mm (5.91" x 3.94" x 1.57")
- **Weight:** 250g
- **Mounting:** DIN Rail Mountable (Integrated clip)

Mounting

The Edge IO supports vertical and horizontal DIN mounting options. The mounting hardware is included in the box.





Operating Environment

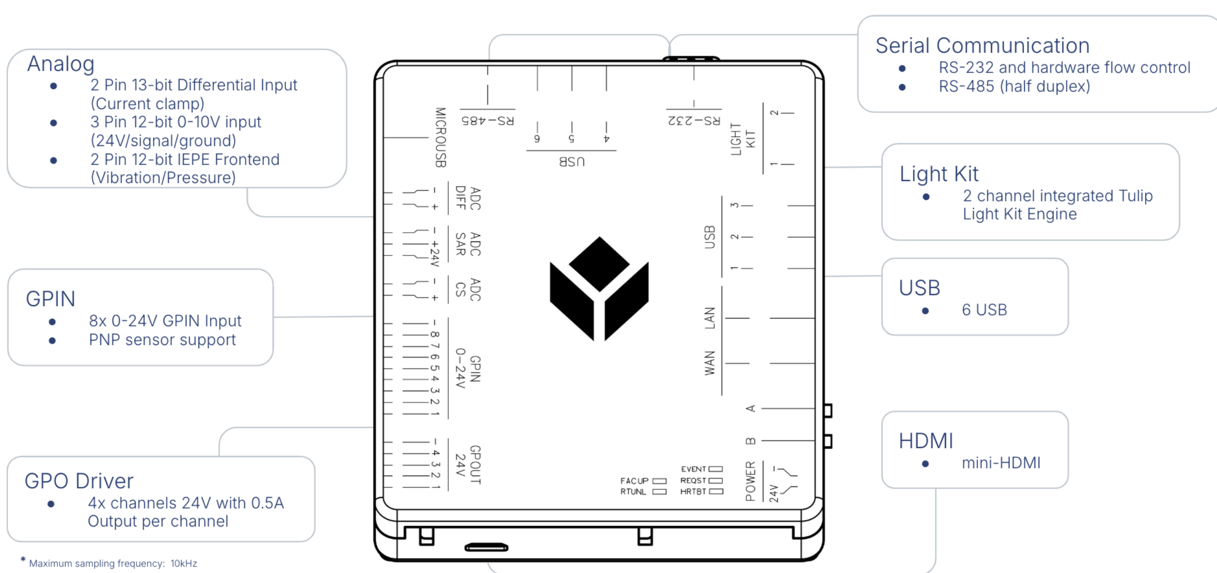
Commercial: 0 °C to 70 °C (32 to 158 °F). Consider additional ventilation (passive or forced air if the device is mounted inside an enclosure).

Certification and Conformance

Certification reports are available upon request.

- **RoHS:** Compliant
- **Certification:** FCC, CE, TELEC, CMIIT

Technical Specifications



* Maximum sampling frequency: 10kHz

* 4-20mA current sensors are supported (eg, use external resistor)

Processor

- ARMv8 4x A53 core (passive heatsink included)
- 8GB eMMC
- 2 GB DDR3 RAM

Power

- **Input Voltage:**
  - 24V DC (+/- 20%)
  - 24V 2 terminal, non-locking Phoenix Contact connector
- **Power Consumption:**
  - Typical: 5W
  - Maximum: 15W
- **Connector:**
  - 2-pin Phoenix Connector (Included)
- **Battery + RTC**

Networking

- 1x Gigabit Ethernet Phy (native) WAN
- 1x 10/100 Ethernet Phy LAN
- Dual Band 802.11 ac Wireless (supports concurrent AP/Station modes)
  - Wi-Fi: 802.11 b/g/n/ac (2.4GHz & 5GHz)
  - Chipset: 6222D-UUC (RTL8822CU)

Interfaces

- **USB:**
  - 6 x USB 2.0 Ports
  - 1 x 2 channel integrated Tulip Light Kit Engine
- **Serial:**
  - 1 x RS232 via DB9 Connector with RTS/CTS
  - 1 x RS485 via 3-pin Phoenix Connector (Included)
- **GPIN**
  - 8 x Digital Inputs (0-24V DC, Opto-isolated)
  - PNP sensor support
- **GPO Driver**
  - 4 x Digital Outputs (0-24V DC, Opto-isolated, Max 0.5A per channel)
- **Analog Input**
  - Nominal sampling: 10 ksps (user selectable in Node-RED)
  - 3 x Analog Inputs
    - ±3.3V 2 Pin 13-bit Differential Input

        - (ADC: MCP3301, Differential Amp: MCP6D11)
      - 0-10V 12-bit input
        - (ADC: MCP3201, Amp: OPA350)
      - 2 Pin 12-bit IEPE Frontend (Vibration/Pressure) (ADC: MCP3201, Amp: OPA350)
- **HDMI**
  - mini-HDMI

Software & Management

- **Operating System:** TulipOS (Yocto)
- **Operating System Updates:** Yes, Tulip provides "OTA" updates.   (Network based controlled in Tulip Platform)
- **Configuration:** Via Tulip Device Portal and Cloud Platform
- **Edge Capabilities:** Runs Tulip Edge features, Node-RED
- **Warranty Information:** 1 year warranty - https://tulip.co/legal/shipping-returns/.
- **Ordering Information:** Edge IO - https://tulip.co/products/buy-edge-io/.

Recommended Sensors and Applications

Application Notes

Detailed application notes are available upon request. An example application note covering the single-ended input stage (0-10V inputs) is included in this datasheet.

Differential Input

- Hall Effect, MFG: Flex-Core, P/N: CTH-025, Type 4-20mA (4-wire isolated)
- Split-Core Current Clamp, MFG: CR Magnetics, P/N: CR3111-3000

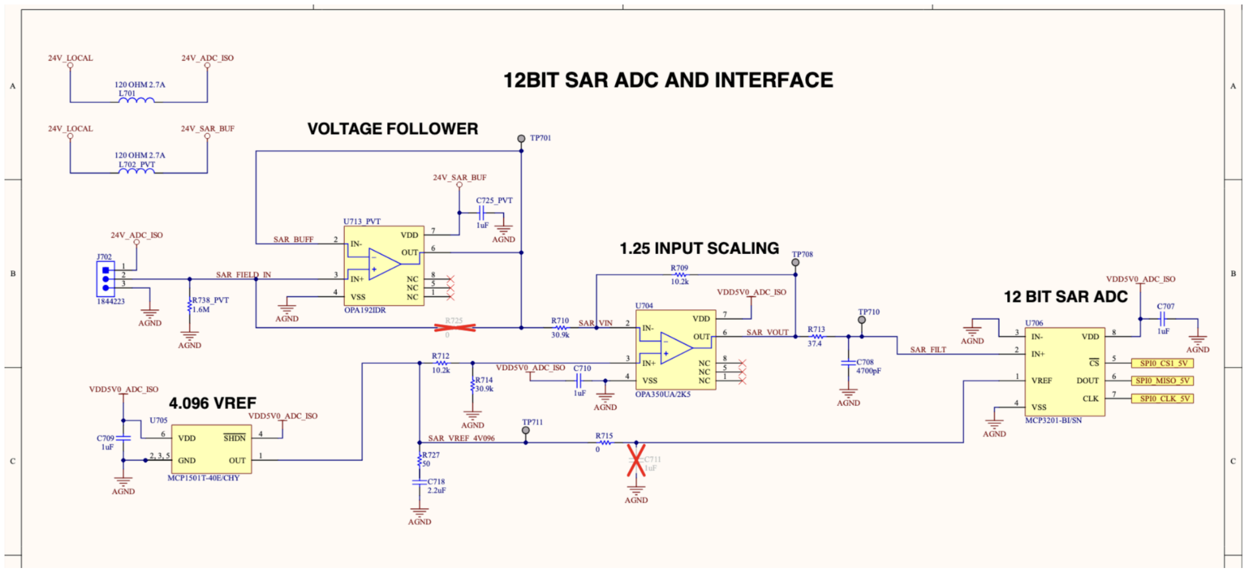
Single-Ended Input

- Split-Core Current Clamp, MFG: Flex-Core, P/N: H921, Type 4-20mA (2-wire)
- Split-Core Current Clamp, MFG: Flex-Core, P/N: H923, Type 0-10V (3-wire)
- Pressure Transmitter, MFG: Automation Direct, P/N: PTD25-10 series, Type 0-10V (3-Wire)

Two-Wire IEPE Input

- IEPE Accelerometer, MFG: PCB Piezotronics, P/N: 603C01

Application Note 1: User Guide for the 12-Bit SAR ADC Input Stage



1. Overview

This document provides guidance for users connecting signal sources to the `SAR_FIELD_IN` input of the 12-Bit SAR ADC and Interface circuit. This stage is designed to accept a single-ended analog voltage, buffer it, scale it, and convert it into a 12-bit digital value. This note focuses on an intended input voltage range of 0V to 10V. A 24V reference (`24V_ADC_ISO`) is provided for power sensors connected to the device.

The sampling frequency (maximum 10 ksps) is configurable in software [ref here]. Consider additional low frequency anti aliasing filters (eg, with approximately 5 kHz of bandwidth) when connecting sensors to this input.

Circuit Components Referenced:

- **Input Connector:** J702 (`SAR_FIELD_IN` on pin 3, `AGND` on pin 2)
- **Input Buffer:** U713_PVT (OPA192IDR) - Voltage Follower
- **Scaling Amplifier:** U704 (OPA350UA/2K5)
- **Voltage Reference:** U705 (MCP1501T-40E/CHY) - Outputting `SAR_VREF_4V096` = 4.096V
- **ADC:** U706 (MCP3201-BI/SN) - 12-bit resolution

2. Input Characteristics

- **Input Voltage Range (Full Capability):** The analog front-end (U713 buffer + U704 scaler) is designed to process SAR_FIELD_IN voltages from **0V to approximately 12.41V** before the scaling stage output (SAR_VOUT) saturates.

- **Intended User Input Voltage Range:** This application note focuses on an input of **0V to 10V**.
- **Input Type:** Single-ended (voltage measured with respect to AGND on J702, Pin 2).
- **Input Impedance:** The input SAR_FIELD_IN is connected to the non-inverting input of the OPA192IDR (U713) voltage follower. A 1.6MΩ pulldown resistor (R738_PVT) is present from SAR_FIELD_IN to AGND.
  - The OPA192 has a very high intrinsic input impedance (GΩ range).
  - Therefore, the **DC input impedance seen by the sensor connected to** (dominated by R738_PVT). This high input impedance minimizes loading on most voltage sources.

3. ADC Scaling and Measurement (for 0V to 10V Intended Input)

The U704 scaling stage and ADC U706 work together as follows:

- **Transfer Function of U704 Stage:**
  SAR_VOUT ≈ 4.096V - (R709/R710) * SAR_VIN
  SAR_VOUT ≈ 4.096V - (10.2kΩ / 30.9kΩ) * SAR_VIN
  SAR_VOUT ≈ 4.096V - 0.330097 * SAR_VIN
  (Since SAR_FIELD_IN is buffered by U713 and connected via R725=0Ω, SAR_VIN = SAR_FIELD_IN).
- **ADC (U706) Operation:**
  - Input to ADC: SAR_FILT (which is SAR_VOUT after a low-pass filter R713/C708).
  - ADC Reference: SAR_VREF_4V096 = 4.096V.
  - ADC Output: 0 to 4095 counts.
- **Expected ADC Output for Intended 0-10V Input:**
  - **When**
    SAR_VOUT ≈ 4.096V - 0.330097 * 0V = 4.096V
    ADC Input (SAR_FILT) ≈ 4.096V
    Expected ADC Count = (4.096V / 4.096V) * 4095 = **4095 counts** (Full Scale Positive)
  - **When**
    SAR_VOUT ≈ 4.096V - 0.330097 * 10V = 4.096V - 3.30097V ≈ 0.79503V
    ADC Input (SAR_FILT) ≈ 0.79503V
    Expected ADC Count = (0.79503V / 4.096V) * 4095 ≈ **795 counts**
- **Inverting Relationship:** Note that as SAR_FIELD_IN increases, the ADC count *decreases*. Your software will need to account for this.
- **Sensitivity (mV/bit) for the 0-10V Intended Range:**
  - Input Voltage Span at SAR_FIELD_IN: 10V (from 0V to 10V).

- Corresponding ADC Count Span: 4095 - 795 = 3300 counts.
- `mV/bit = (Input Voltage Span / ADC Count Span) * 1000 mV/V`
- `mV/bit = (10V / 3300 counts) * 1000 mV/V ≈ **3.0303 mV/bit**`
  This means each 1-count change in the ADC output corresponds to an approximate 3.03 mV change at the `SAR_FIELD_IN` input, over this 0-10V range.

- **Converting ADC Counts back to**
  `SAR_FIELD_IN (Volts) ≈ (4095 - ADC_Count) * (10V / 3300 counts)`
  `SAR_FIELD_IN (Volts) ≈ (4095 - ADC_Count) * 0.0030303`

4. Performance Characteristics

- **Bandwidth:**
  - **Analog Front-End Bandwidth:** The primary analog bandwidth limitation before the ADC is the RC filter (R713 = 37.4Ω, C708 = 4700pF), which has a -3dB cutoff frequency of approximately **905 kHz**. The op-amps U713 (OPA192, GBWP ~10MHz) and U704 (OPA350, GBWP ~38MHz) have much higher bandwidths in their respective configurations and do not limit this.
  - **Effective Signal Bandwidth (Anti-Aliasing):** The ADC (MCP3201) has a maximum sampling rate of around 123 ksps. To avoid aliasing, the input signal frequencies should be kept below half the sampling rate (Nyquist frequency, ~61.5 kHz). The ~905 kHz RC filter provides some anti-aliasing, but it is not a steep filter. For optimal performance with signals containing frequencies above ~60 kHz, a more aggressive anti-aliasing filter closer to the Nyquist frequency might be considered externally. For DC or low-frequency signals (<< 60 kHz), this is less of a concern.
- **Effective Resolution (ENOB):**
  - **Nominal ADC Resolution:** 12 bits.
  - **ADC Standalone ENOB:** The MCP3201 ADC itself typically has an ENOB of around 11.4 bits due to its internal noise and non-linearities.
  - **System ENOB:** Noise from the analog front-end components (voltage reference U705, op-amps U713 and U704, and resistors) will further reduce the overall system ENOB. The dominant noise contributor from the front-end is typically the voltage reference U705 noise, as it's amplified by the U704 stage.
  - Based on detailed noise calculations the overall system ENOB is approximately 11 bits.

5. User Considerations and Precautions

- **Grounding:** Ensure your signal source's ground reference is solidly connected to `AGND` (J702, Pin 3) to avoid ground loop issues and ensure accurate measurements.

- **Input Voltage Limits:**
    - While the circuit can measure up to ~12.41V at `SAR_FIELD_IN`, if your application assumes a 0-10V range, be aware that inputs above 10V will result in ADC counts below 795, eventually reaching 0 around 12.41V.
    - Do not apply voltages to `SAR_FIELD_IN` that exceed the absolute maximum ratings of the OPA192IDR (U713), which are typically slightly beyond its power supply rails (e.g., -0.5V to `24V_SAR_BUF` + 0.5V). Refer to the OPA192 datasheet. `24V_SAR_BUF` appears to be the VDD for U713.
- **Noise:** For optimal performance, especially with low-level signals or in noisy environments, consider using shielded cables for the input signal, with the shield connected to AGND at the J702 connector.
- **J702 Pin 1:** Be cautious with Pin 1 of J702 (`24V_ADC_ISO`). Ensure your sensor wiring does not accidentally contact this pin.

6. Disclaimer

This application note provides general guidance based on the provided schematic and typical component characteristics. Users are responsible for verifying that their specific sensor and connection scheme meet all electrical requirements for proper operation and to prevent damage. Always consult the datasheets for the components used. Actual performance may vary due to component tolerances, PCB layout, and environmental factors.

Change Log

Feb 23, 2023	EIO Manual ver0.1 • Original document shared with Tulip employee • Image legends updated • Test Tables created - easier legibility	
May 8, 2025	EIO Manual ver1.0 • Diagram added • Certificates added • Use Cases Added • Application Notes Added	

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