**Design of an Open-Source and Flexible Low-Cost Data Acquisition Device**

**Requirements**

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# Revision History

The version number is incremented by 0.1 each time an edit is made to the document.

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| --- | --- | --- |
| **Version** | **Date** | **Change Description** |
| 1.0 | 2022-09-13 | Initial version. |
| 1.1 | 2022-09-19 | Update high speed definition for Requirement 4.3.1 |
| 1.2 | 2022-10-26 | Update requirements for adjustable gain for Requirement 4.3.4. |
| 1.3 | 2023-03-25 | Update number of high-speed single-ended channels in Requirement 4.1. |

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# Nomenclature

Requirements and general statements of intent are distinguished by the following:

* Mandatory requirements are denoted with “**shall”.**
* Strongly recommended requirements are denoted with “**should**”.
* Optional requirements or statements of intent are denoted with “**may**” or “**will”**.

These conventions align with those used by the Design, Test, & Evaluation Guide from the Spaceport America Cup competition documents.

This document also uses the abbreviations in Table 1.

Table 1: Abbreviations

|  |  |
| --- | --- |
| **Abbreviation** | **Expansion** |
| ADC | Analog-to-Digital Converter |
| CAN | Controller Area Network |
| DAQ | Data Acquisition |
| I2C | Inter-Integrated Circuit |
| IO | Input/Output |
| SPI | Serial Peripheral Interface |
| UART | Universal Asynchronous Receiver-Transmitter |
| USB | Universal Serial Bus |

# Hardware Requirements

## Digital and Analog Channels

The data acquisition (DAQ) device **shall** provide:

1. At least 24 digital input/output (IO) channels.
2. At least 4 high speed differential analog inputs.
3. At least 20 low speed single-ended analog inputs.
4. At least 4 high speed single-ended analog inputs.

The test site currently uses 10 digital channels for relay control for the hybrid engine. In the future, for a bi-propellant liquid engine, the test site will require at least 16 digital channels. To add some margin for expandability and contingency, 24 digital channels was chosen.

Although most analog sensors used for instrumentation at the test site have differential outputs, the team currently uses a dedicated sensor board to condition the signals before digitization by the LabJack T7 DAQ device. This approach provides greater flexibility as there are both current-output and voltage-output sensors that are often swapped, depending on the test being conducted. Therefore, to keep the DAQ device flexible, a total of 4 differential inputs and 24 single-ended analog inputs was chosen.

Depending on the microcontroller chosen and board space requirements, more channels may be implemented to increase the capability of the DAQ device.

## Input Protections

The device **shall** protect all inputs to the following ratings:

1. Digital inputs **shall** be protected against input voltages up to +/- 27 V.
2. Analog inputs **shall** be protected against input voltages up to +/- 15 V.

As this device is intended to be flexible, it is not unlikely that signals which exceed the typical 3.3 V or 5 V input ratings of microcontrollers will be accidentally connected to the device. These protections will ensure that the device is not damaged by these accidental connections.

## Analog Inputs

### Minimum Sampling Rates

For analog inputs:

* Low speed channels **shall** have a minimum of 50 Hz sampling rate
* High speed channels **shall** be able to accurately sample signals with frequency content up to 20 kHz

At the test site, most signals are adequately sampled with 50 Hz. For a few select sensors that can give insight into combustion stability and performance, higher sampling rates are required, hence the 10 kHz minimum high speed sampling rate requirement.

### Common-Mode Voltage Range

The common-mode input voltage range of all analog inputs **shall** be at least +/- 10 V.

### ADC Resolution

All analog inputs **shall** be measured by ADCs that have at least 16-bit resolution.

### Adjustable Gain

The device **shall** be able to apply adjustable gain to the analog inputs. The adjustable gain **shall** be 1 V/V, 10 V/V, 50 V/V, and 100 V/V.

The adjustable gain **shall** be implemented in hardware but controlled through software.

## Board Temperature Sensor

The device **shall** be able to measure the temperature of the printed circuit board (PCB) of the device. The measurement accuracy **shall** be within +/- 3 °C.

Please note that the internal temperature sensor on some microcontrollers does not satisfy this requirement because microcontrollers may generate significant heat.

## Operating Temperature Range

The device **shall** have a rated operational temperature range of -40 °C to 85 °C.

## Standalone Operation

### Battery Power Input

To enable standalone operation without computer control, the device **shall** have a connector to accept battery power.

The battery power input voltage ratings will be determined later in the design phase (open-ended for now).

### SD Card

The device **shall** have a microSD card slot to save data to a microSD card. This is intended to enable the device to be programmed to run without interfacing to a computer.

## Computer Interface

The DAQ device will be used with a computer to display live values of inputs and outputs at the test site. As such, the device **shall** interface with a computer via USB or Ethernet\*.

\*: For the scope of the Honours Thesis project, Ethernet capability **shall** be present but may not necessarily be usable.

## Add-Ons and Expansion

As DAQ requirements vary significantly between projects, the device **shall** be designed to facilitate integration of custom add-on boards, like Arduino shields and Raspberry Pi HATs.

### Power

The device **shall** provide access to 5 V power and ground (GND) for add-ons.

### Digital IO

The device **shall** provide access to at least 8 digital IO pins that are unique to the add-ons.

Please note that this requirement does not mean that each add-on must have 8 unique digital IO ports assigned to it; rather, all add-ons would share the 8 digital IO pins.

### Analog Inputs

The device **shall** provide access to at least 8 analog inputs that are unique to the add-ons, like Requirement 4.8.1.

### Peripheral Expansion Ports

To enable easy integration of additional features, the device **shall** provide access to the following hardware peripheral ports:

1. SPI (serial peripheral interface).
2. CAN (controller area network).
3. I2C (inter-integrated circuit).
4. UART (universal asynchronous receiver-transmitter).

Please note the emphasis on “hardware peripheral ports”. While bit banging could likely provide SPI, I2C, and UART interfaces, bit banging will probably reduce the logging speed significantly.