Design Description (DD)

W.I.D.M.O. Optical Payload Project

Version 2.1

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Contents

1 Scope and Purpose

The scope of this document is to provide a functional and detailed design description of the scientific optical payload **W.I.D.M.O.**, developed to analyze the spectral components of an incoming light beam. The system splits light into Infrared (IR) and Ultraviolet (UV) ranges, filters each path using motorized filter wheels, and detects radiation intensity.

2 Applicable and Reference Documents

Applicable Documents

- [**AD-01**] W.I.D.M.O. Electrical Interface Control Document (EICD)
- [**AD-02**] W.I.D.M.O. Mechanical Interface Control Document (MICD)
- [**AD-03**] W.I.D.M.O. Software Interface Control Document (SICD)

Reference Documents

- [**RD-01**] Maxon ECX Speed 16 L Data Sheet
- [**RD-02**] Maxon EPOS4 Compact 50/8 CAN Hardware Reference
- [**RD-03**] Waveshare UV Sensor / GenUV GUVA-S12SD Datasheet

3 Terms and Abbreviations

- **BLDC:** Brushless Direct Current (Motor)
- **CAN:** Controller Area Network
- **IR:** Infrared wavelength range ($> 760\,\text{nm}$)
- **UV:** Ultraviolet wavelength range ($< 370\,\text{nm}$)
- **OBC:** On-Board Computer
- **PCB:** Printed Circuit Board

4 Functional Design Description

4.1 General Description

The W.I.D.M.O. payload is an electro-optical instrument designed to perform spectral analysis. The core concept relies on splitting the incoming light beam into two distinct optical paths. Each path is equipped with an independent mechanism, a **Filter Wheel**, which allows the selection of different optical filters (e.g., bandpass, or shutter) before the light reaches the sensors.

4.2 Principle of Operation

The payload operation follows a linear sequence, illustrated by the mechanical layout shown in **Figure 1**:

1. **Beam Entry:** Collimated light enters the payload aperture.

2. **Spectral Splitting:** The beam hits the **Beam Splitter Unit** (Red Hot Mirror) positioned at a 45° angle.
    - **IR Path:** Infrared light is reflected 90° towards the IR Optical Bench.
    - **UV Path:** Ultraviolet and visible light passes through the mirror towards the UV Optical Bench.
3. **Filtration:** Each optical path contains a rotating filter wheel driven by a **Maxon ECX BLDC motor**. The On-Board Controller (OBC) commands the motor via the CAN bus to rotate the wheel to a specific angle, placing the desired filter in the optical axis.
4. **Detection:** The filtered light strikes the photodiode (UV or IR sensor). The sensor converts optical power into an analog voltage signal.
5. **Data Acquisition:** The Motherboard digitizes the signal and transmits telemetry data.

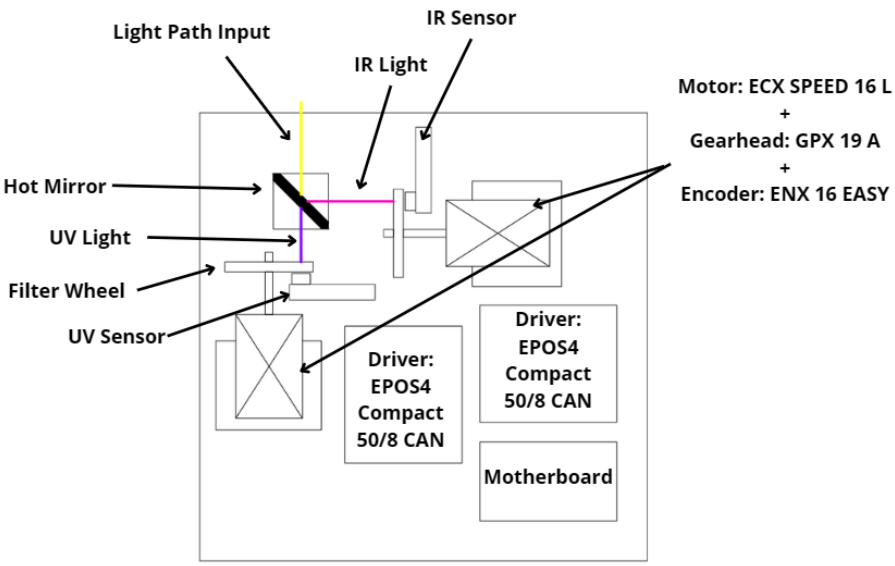

Figure 1: Mechanical configuration of the W.I.D.M.O. payload showing the Beam Splitter and two perpendicular Optical Benches.

5 Optical Design Description

5.1 Optics Architecture

The optical system is passive and relies on a single splitting element to minimize signal loss.

- **Beam Splitter (Hot Mirror):**
    - **Mounting:** Fixed at 45° incidence in a rigid aluminum block (visible in bottom-right of Figure 1).
    - **Specification:** Dielectric coating optimized to reflect IR ($760 - 1100$ nm) and transmit UV/VIS ($200 - 370$ nm).
- **Stray Light Control:** The optical cavity is physically shielded (black anodized enclosure) to prevent external ambient light from bypassing the filters and distorting the measurements.

6 Mechanical Design Description

6.1 Structure

The mechanism consists of two identical electromechanical assemblies, positioned perpendicularly:

1. **UV Path Assembly** (Aligned with the input axis).
2. **IR Path Assembly** (Aligned with the reflected axis).

Each assembly features a custom-designed **Filter Wheel** containing four apertures:

- **Position 1:** Open (100% Transmission) – For full intensity measurement.
- **Position 2:** Filtered (TBD) – For spectral analysis.
- **Position 3:** Filtered (TBD) – For spectral analysis.
- **Position 4:** Closed (Shutter) – For Dark Current calibration of the sensor.

6.2 Actuation & Drive Train

The rotation is achieved using a high-precision drive system selected for vacuum compatibility and torque density.

- **Motor: Maxon ECX Speed 16 L** (Brushless DC). Selected over standard DC motors to eliminate brush dust contamination on optical surfaces.
- **Gearbox: Maxon GPX 19** Planetary Gearhead (Ratio 590:1). This high ratio ensures the wheel holds its position without power (due to friction/cogging torque), optimizing the power budget.

6.3 Mounting and Alignment

The motors are mounted using flange brackets secured to the main baseplate (as seen in Figure 1). This rigid mounting ensures that the filter wheel apertures remain perfectly aligned with the detector active area, minimizing vignetting.

7 Electronic Design Description

The electronic subsystem controls the actuation and acquires scientific data. It is divided into two physical modules: the **Payload Motherboard** and the **External Driver**.

7.1 Payload Motherboard

The custom PCB (shown in Figure 2) serves as the central control unit.

- **MCU:** Raspberry Pi Pico 2 W handles logic, CAN communication, and ADC conversion.
- **Sensor Interface:** Dedicated JST connectors link to the optical sensors (Waveshare UV and Iduino IR modules).
- **Communication:** A CAN transceiver (MCP2515 + SN65HVD230) enables robust communication with the motor driver.

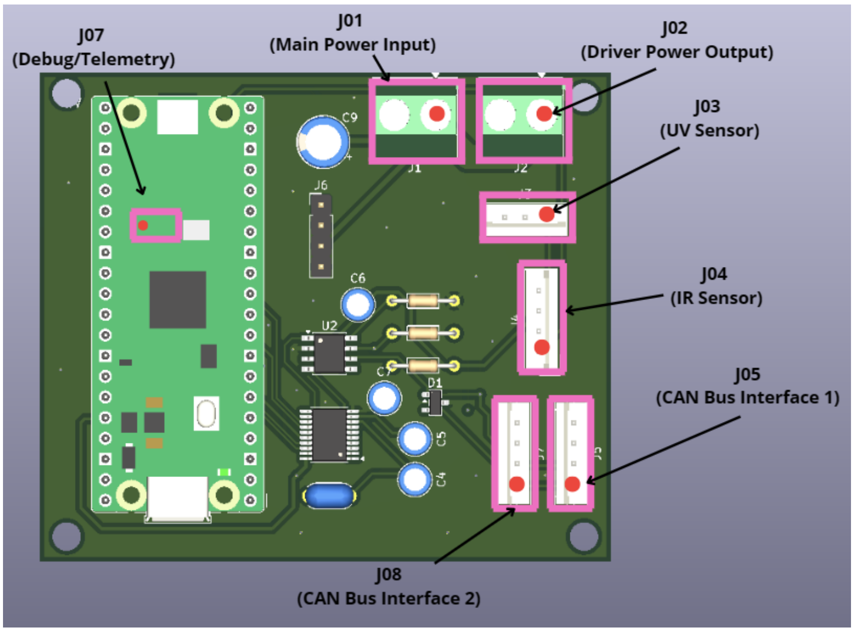

Figure 2: Payload Motherboard acting as the system controller.

7.2 Motor Control

The system utilizes a distributed control architecture.

- **Driver: Maxon EPOS4 Compact 50/8 CAN**. This unit handles the complex commutation of the BLDC motors and closes the PID position loop using encoder feedback.
- **Interface:** The Motherboard sends high-level "Profile Position" commands via CANopen, and the Driver executes the precise movement.

7.3 Power Budget

The payload operates on a 24V bus. The power consumption analysis (Table 1) is derived from the Maxon ECX Speed 16 L datasheet and component specifications.

Critical Design Note: The ECX Speed 16 L motor has a physical stall current of 115 A [RD-01]. To prevents power bus failure, the EPOS4 Driver Output Current Limit must be configured in software to a maximum of 1.5 A. The high-ratio gearbox (590:1) ensures sufficient torque is available even at this strictly limited current.

Table 1: Power Budget Analysis

Subsystem	**Component**	**State**	**Current @ 24V**	**Power**
Electronics	Motherboard	Active	0.02 A	0.5 W
Actuation	ECX 16 + EPOS4	Idle / Holding	0.08 A	2.0 W
Actuation	ECX 16 + EPOS4	Moving (Nominal)	0.45 A	10.8 W
Actuation	ECX 16 + EPOS4	Peak (Software Limit)	1.5 A	36.0 W
Total	System Average	Operational	0.5 A	12.0 W

Note: To minimize peak power, the control software ensures that only one filter wheel rotates at a time.

8 Software Design Description

The On-Board Software (OBSW) runs on the Raspberry Pi Pico 2 W, developed in C/C++ using the Pico SDK. It manages system orchestration, CANopen communication, and scientific data acquisition.

8.1 Software Architecture & Logic

The software utilizes a layered architecture comprising a **Hardware Abstraction Layer (HAL)** for peripheral access, **Middleware** for CAN/Sensor drivers, and an **Application Layer** for control logic. The system behavior is governed by a **Finite State Machine (FSM)** with defined states: **BOOT**, **IDLE**, **CONFIGURATION**, **MOTION**, **ACQUISITION**, and **SAFE**. This ensures deterministic transitions between low-power modes and active measurement cycles.

8.2 Control Mechanisms

- **Motor Control:** The system uses the **CANopen Profile Position Mode (PPM)** to execute precise filter wheel movements.
- **Current Limiting:** During initialization, the software strictly configures the EPOS4 driver output current limit to **1.5 A**. This software-imposed limit is critical to protect the power bus from the motor's high physical stall current.