Dionysus   
Power Distribution Board

Functional Requirements  
[XX/XX/XXXX]

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# Overview

*The overview section should include a brief description of the project and functionality so that someone outside of the project team would be able to understand the project. The section should include a list of commonly used acronyms and abbreviations, a list of system components and their purpose, and inputs and outputs as discussed on the I/O list deliverable.*

## Description

The Dionysus project will be a self-sufficient NFT hydroponic garden capable of growing small vegetables and herbs. The controller for Dionysus will be an Arduino Due microcontroller embedded in the power distribution motherboard.

The purpose is to create a control board that can handle the inputs and outputs necessary to operate a Dionysus system. Today’s microcontrollers and single board computers are not capable of driving all the components required. Additional hardware and circuitry are required.

Rather than a larger collection of harnessing, piggyback boards, and modifications, a single power distribution board will be created to handle the necessary inputs, outputs, and communications.

## Scope

|  |  |
| --- | --- |
| **In Scope** | **Out of Scope** |
| Self-contained computer power | Raspberry Pi Model 4 and Compute Module compatibility |
| GPIO for IO expansion | Voltage and current feedback measurements on input/outputs |
| Raspberry Pi or Arduino based microcontroller | True grow light drivers |
| E-stop circuitry |  |
| Ability to add an optional nutrient control system |  |

## Acronyms and Abbreviations

|  |  |  |
| --- | --- | --- |
| **Acronym** | **Meaning** | **Notes** |
| NCS | Nutrient Control System | XXXXXXXXXXX |
| LED | Light-emitting Diode | XXXXXXXXXXX |
| TWI | Two-Wire Interface | Also known as I2C |
| TWD | Two-Wire Data | Also known as SDA |
| TWCK | Two-Wire Clock | Also known as SCL |
| CAN | Controller Area Network |  |
| USART | Universal Asynchronous Receive/Transmit |  |
| SPI | Serial Peripheral Interface |  |
| STB | Short to Battery |  |
| STG | Short to Ground |  |

# System Components

|  |  |  |
| --- | --- | --- |
| **Abbreviation** | **Meaning** | **Notes** |
| XXXXX | XXXXXXXXX | XXXXXXXXXXXXXX |

# Board Controller

The system controller will be an Arduino Due powered by a 32-bit ARM Cortex-M3 processor. The board contains 54 digital input/output pins, 12 analog inputs, and 2 digital-to-analog pins. For communication, it has 4 UART busses, 2 TWI, and a single SPI header. Refer to [Arduino’s official website](https://store-usa.arduino.cc/products/arduino-due?selectedStore=us) for more information.

The Due board will be installed as a piggy back board using stacking header pins. This does require an Arduino Due without headers to be purchased and have stacked headers added. Power will be provided to the power input pin through these headers.

The Due board operates at 3.3V. Therefore, all logical inputs and outputs will be restricted to 3.3V, and communications are restricted to 3.3V logic levels.

Board Specifications

Microcontroller: AT91SAM3X8E

Operating Voltage: 3.3 VDC

Input Voltage: 6-16 VDC (7-12 VDC recommended)

Digital I/O Pins: 54

Analog Input Pins: 12

Analog Output Pins: 2

I/O Output Current Total: 130 mA

3.3V Power Pin Current: 800 mA

5V Power Pin Current: 800 mA

Flash Memory: 512 KB

SRAM: 96KB

Clock Speed: 84 Mhz

# Inputs

|  |  |
| --- | --- |
| **Name** | **Description** |
| Ambient Temperature | Ambient temperature of environment |
| Ambient Light | Ambient light available to plants |
| Emergency Stop Feedback | Emergency stop feedback to control system |
| NCS Flow Rate | Volumetric flow rate going through nutrient control system |
| NCS Temperature In | Input temperature to nutrient control system |
| Chemical 1 Level Minimum | Chemical 1 tank almost empty. Signals operator to refill tank. |
| Chemical 2 Level Minimum | Chemical 2 tank almost empty. Signals operator to refill tank. |
| Chemical 3 Level Minimum | Chemical 3 tank almost empty. Signals operator to refill tank. |
| Chemical 4 Level Minimum | Chemical 4 tank almost empty. Signals operator to refill tank. |
| Chemical 5 Level Minimum | Chemical 5 tank almost empty. Signals operator to refill tank. |
| Chemical 1 Pump Feedback | Chemical 1 peristaltic pump dispensing active |
| Chemical 2 Pump Feedback | Chemical 2 peristaltic pump dispensing active |
| Chemical 3 Pump Feedback | Chemical 3 peristaltic pump dispensing active |
| Chemical 4 Pump Feedback | Chemical 4 peristaltic pump dispensing active |
| Chemical 5 Pump Feedback | Chemical 5 peristaltic pump dispensing active |
| Reservoir pH | Reservoir pH level measured in nutrient control system |
| Reservoir Flow Rate | Volumetric flow rate out of reservoir |
| Reservoir Temperature In | Input temperature to reservoir |
| Reservoir Temperature Out | Output temperature of reservoir |
| Reservoir TDS | Reservoir total dissolved solids measured in nutrient control system |
| Reservoir Level Minimum | Reservoir water level almost empty |
|  |  |
|  |  |

## 

## Input Processing

*The input processing section should include a description of the input processing requirements of the system. This should cover details about Debounce, Anti Tie-down, Overrides, dead banding, and other project specific input processing options.*

# Outputs

|  |  |  |
| --- | --- | --- |
| **Name** | **Abbreviation** | **Description** |
| LED Channel 1 | LEDCh1 | 3-wire RGB LED channel 1 |
| LED Channel 2 | LEDCh2 | 3-wire RGB LED channel 2 |
| LED Channel 3 | LEDCh3 | 3-wire RGB LED channel 3 |
| LED Channel 4 | LEDCh4 | 3-wire RGB LED channel 4 |
| LED Channel 5 | LEDCh5 | 3-wire RGB LED channel 5 |
| LED Channel 6 | LEDCh6 | 3-wire RGB LED channel 6 |
| LED Channel 7 | LEDCh7 | 3-wire RGB LED channel 7 |
| LED Channel 8 | LEDCh8 | 3-wire RGB LED channel 8 |
| NCS Pump Activation | NCSPmpAct | Nutrient control system water pump activation |
| Reservoir Heater Activation | RsvrHeaterAct | Reservoir heater activation |
| Reservoir Pump Activation | RsvrPmpAct | Reservoir water pump activation |
| Chemical 1 Pump | Chem1Pmp | Chemical 1 peristaltic dispensing control |
| Chemical 2 Pump | Chem2Pmp | Chemical 2 peristaltic dispensing control |
| Chemical 3 Pump | Chem3Pmp | Chemical 3 peristaltic dispensing control |
| Chemical 4 Pump | Chem4Pmp | Chemical 4 peristaltic dispensing control |
| Chemical 5 Pump | Chem5Pmp | Chemical 5 peristaltic dispensing control |
|  |  |  |
|  |  |  |
|  |  |  |

## Output Processing

*This section should be used if there are outputs to be processed by the control system.*

High Current Load FET

Flyback Protection

# Power Management Controller

The Arduino Due board requires 7 VDC to 12 VDC. The water pump(s) and reservoir heater activation use a FET to provide medium to high power to AC relays. Flyback protection should be used. The chemical peristaltic pumps and grow lights operate between 12 and 24 volts.

Power regulation is required for the board. Power management will consist of voltage regulation for the board’s controller, sensors, and other low power accessories. Four high side drivers will be used to power larger loads, such as peristaltic pumps, grow lights, and water pump relay coil activation.

The board must have an input voltage of 12 to 24 volts DC. Circuit protections must be used to protect the board from reverse polarity, overvoltage, and overcurrent.

The board must output voltages at 3.3 VDC, 9 VDC, and input voltage ranges. Each power source shall be protected by circuit protection devices. Fuses should be used for each device powered and located as close to the source as possible.

[need to specify what devices are powered by which bus]

[insert the power management calculation tables here]

[Specify the current limits for each power rail]

# Subsystems

## Two-Wire Interface Bus Isolator

The Atlas Scientific EZO boards require voltage isolation if multiple boards are used on the same two-wire bus. Each EZO board will have a voltage and communication isolator circuit. It uses a two-wire interface digital isolator along with an isolated DC-DC converter.

The isolated busses require termination resistors.

## GPIO

10 digital input/outputs and 5 analog inputs are available as general purpose input/outputs. These are available to the end user for additional sensors and system input/outputs.

Digital input/outputs should be protected against short to battery and short to ground

Overvoltage protection, overcurrent protection, back EMF protection, current limiting, basic filtering, external clipping diodes

## Pulse Width Modulation Controller

The grow lights used will be 3-wire RGB LED lights requiring brightness and color control. An RGB PWM LED driver will be used to drive at least 2 channels of grow lights. Additional channels may be add if space and circuitry constraints allow. Red and blue will be the main colors used.

PWM control will be used to control the brightness of the LEDs. This simulates the rising and setting of the sun.

Optional feature would be a way to create sectors of addressable LEDs. This would allow for simulating the sun moving east to west in the sky.

## Real-time Clock

This optional feature would be nice to have for data logging and future product improvements.

## Temperature Sensor

For the first design iteration, digital 1-wire temperature sensors, Maxim DS18B20, are acceptable. They require no additional hardware or circuitry to integrate. The digital communication bus must be scanned on start up to search for all available sensors.

5 temperature sensor channels are available.

There is no requirement for PCBA temperature sensors. The circuit board should have at least 1 temperature sensor installed for board diagnostics and ambient redundancy.

## CAN Bus

The microcontroller has CAN bus communication available. A CAN bus transceiver will be implemented into the PDB. CAN high and low will be externally available to the end user for additional functionality.

CAN high, low, 12 volt power, and 12 volt ground will be available in a four pin terminal block.

The CAN bus has selectable termination using a selector switch.

## EZO Board

The motherboard will allow for at least 4 Atlas Scientific EZO sensor boards. They use 2-three pin headers in a daughterboard configuration. Any EZO board must be compatible in any of the four spots.

A BNC or three pin terminal block will be used to connect the EZO sensor to the power distribution board.

## Peristaltic Pump

The Atlas Scientific peristaltic pumps will be used. These require 12 to 24 volt power for the motor and 3.3 to 5 volt power for the control section. Motor power is supplied through a two pin terminal block on the PDB and pump. The control section uses a Molex connection.

The circuit board must accommodate at least 5 peristaltic pumps.

## Water Pump

The PDB must be able to drive 2 AC relays. These will activate the reservoir and nutrient control system pumps. Each pump output will have its own two position terminal block, a positive and negative.

## Water Heater

The PDB must be able to drive an AC relay that provides power to the reservoir heater.

## Air Pump

The PDB must be able to drive an AC relay that provides power to the reservoir air pump.

# Operating Mode

*This section should define conditional operating modes of the system for expected use.*

Start-up/Initialization

Normal Operation

Fault Detection

# Failure Modes

*A failure mode is a mode that the system may enter into automatically upon a system fault. The most common system faults occur at an input or an output. This section should list potential input/output/communication faults and system responses.*

PMC failure

Sensor failure

Failure Mode 3

# Communications

*This section should describe the modes of communication used on the project, examples including CAN, Radio, Ethernet, Multiplex, etc.*

The circuit board will be a flexible design for the end user. Some or all of the inputs, outputs, and sensors may be used. Internal communication must be flexible. A two-wire interface bus will be used for internal board communication. The EC, pH, flow meter, and peristaltic pumps specified for this project are TWI and UART compatible. UART is simpler in its design but does not allow for the flexibility that a TWI bus has.

All communication busses will have selectable termination resistors at various points to allow the end user to select where the bus is terminated.

An external connector will be provided for TWI communication to an external board should once be added.

TWI-1

Topology

Message IDs

TWI-2

UART

CAN

Topology

Message IDs

1-Wire

Topology

Message IDs

# Limiting and Interlock

*This section should describe the components/devices/functionality which will limit functionality or provide interlock signals for the device. This section should describe what components allow for expected functional use.*

## Emergency Stop Device Interlock

The emergency stop device interlock consists of two circuits: a hardwired loop and feedback signal.

The feedback signal provides confirmation to the control system to prevent false errors.

The hardwired loop runs through various connectors to prevent power from being delivered to various components.

# Calibrations

*This section should list the expected calibrated inputs to the system.*

pH Sensor

EC Sensor

Peristaltic Pump

# Diagnostics

*This section should list the planned diagnostic/health information that is intended.*

## LED Indication

LED indication will be provided for all major functions of the board.

|  |  |
| --- | --- |
| Indication Color | Function |
| Green | Device functioning properly |
| Yellow | Device functionality limited, but not crucial to operation |
| Red | Device error occurred. Functionality is disabled. |
| Blue |  |
| Orange/Amber |  |

|  |  |
| --- | --- |
| Indication Pattern | Function |
| Solid |  |
| Flashing |  |
| Flashing |  |

|  |  |  |  |
| --- | --- | --- | --- |
| Component | Component Signal | Color |  |
| Input Voltage | - | Green |  |
| 3.3V Regulator | Regulator output | Green |  |
| 5.0V Regulator | Regulator output | Green |  |
| High Side Drivers | Driver output | Green |  |
| Chemical Pumps | Pump interrupt | Green |  |
| NCS Pump | Pump FET activation | Green |  |
| Reservoir Pump | Pump FET activation | Green |  |
| Reservoir Heater | Heater FET activation | Green |  |
| TWI Busses | Data FET | Green |  |
| UART Bus | Data FET | Green |  |
| CAN Bus | Data FET | Green |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

# External Connect

Header pins are available for all communication busses.

Programming Port

# Telematics

Telematics

This board does not contain any ability to transmit data.

# Data Logging

Data Logging

This board does not contain any ability to log data.

# Applicable Standards

*This section should list the standard requirements for the project, as well as the expected use of standardized information, such as EPS, Library Blocks, IEEE, SAE, etc.*

EPS, Library Blocks, IEEE, SAE, ANSI

# Appendix

# Figures

# Tables

# Revision History

|  |  |  |
| --- | --- | --- |
| **Revision History** | | |
| When: | Who: | What: |
| XX/XX/XXXX | XXXXXXX | XXXXXXXXXXXXXXXXXXXXXXXXX |
|  |  |  |
|  |  |  |