The Luminostat: Detection of Weak Luminescence and Modulation of Cell Density in a Benchtop Bioreactor

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This proposal seeks support for the development of the Luminostat, a device designed for the detection of weak bacterial luminescence signals and modulation of cell density in a bench top bioreactor. We will modify the Cosmic Watch DIY muon counting system, attaching it to a bioreactor as a low cost and highly sensitive luminescence monitor. We will then modify the Cosmic Watch microcontroller to control peristaltic pumps and validate the system through control of weak bacterial luminescence levels via dilution of the culture with growth media. The success of this project will benefit researchers in fields such as directed evolution, synthetic biology, and biotechnology, enabling them to achieve more accurate bioprocess optimization in a low-cost DIY framework.

I. PARTS

The sensing portion of this project is enabled by Silicon Photomultipliers (SiPMs). These sensors are composed of arrays of avalanche photodiodes and are touted as similar to classical photomultiplier tubes but with a lower cost, smaller size, and lower voltage requirements [1].

1. Cosmic Watch DIY muon sensor - Including Arduino Nano microcontroller [2]
2. eVOLVER bioreactor vial [3].
3. Light shielding box
4. Peristaltic pumps
5. MOSFETs to control 12V supply to peristaltic pumps (min-eVOLVER board has surface mount MOSFETS that will be jumpered to from unused Arduino Nano pins on the CosmicWatch)
6. 12V DC power supply

II. PLAN

- Week 1: Finalize parts and design.
- Week 2: Analyze Cosmic Watch Arduino code and test for noise.
- Week 3: Write preliminary Arduino code to actuate pumps and test with MOSFETs for power.
- Week 4: Initial testing of Luminostat sensing and pump activity.
- Week 5: Final testing and experimental design.

[1] M. M. Calabretta, A. Lopreside, L. Montali, M. Zangheri, L. Evangelisti, M. D'Elia, and E. Michelini, Portable light detectors for bioluminescence biosensing applications: A comprehensive review from the analytical chemist's perspective, Analytica Chimica Acta , 339583 (2022).
[2] S. N. Axani, J. M. Conrad, and C. Kirby, The desktop muon detector: A simple, physics-motivated machine-and electronics-shop project for university students, American Journal of Physics **85**, 948 (2017).
[3] B. G. Wong, C. P. Mancuso, S. Kiriakov, C. J. Bashor, and A. S. Khalil, Precise, automated control of conditions for high-throughput growth of yeast and bacteria with evolver, Nature biotechnology **36**, 614 (2018).

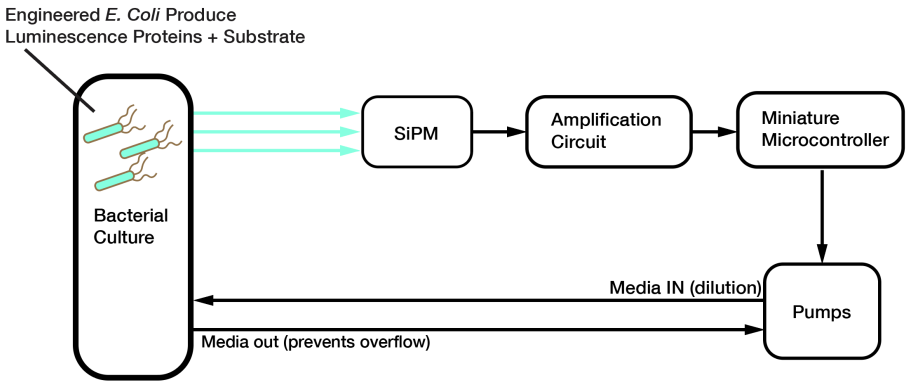

FIG. 1. Block diagram of the Luminostat. Sensing circuit (Silicon Photomultiplier, Amplification Circuit, and Miniature Microcontroller) are part of the CosmicWatch. All parts are sequestered inside of a dark box to block environmental light.

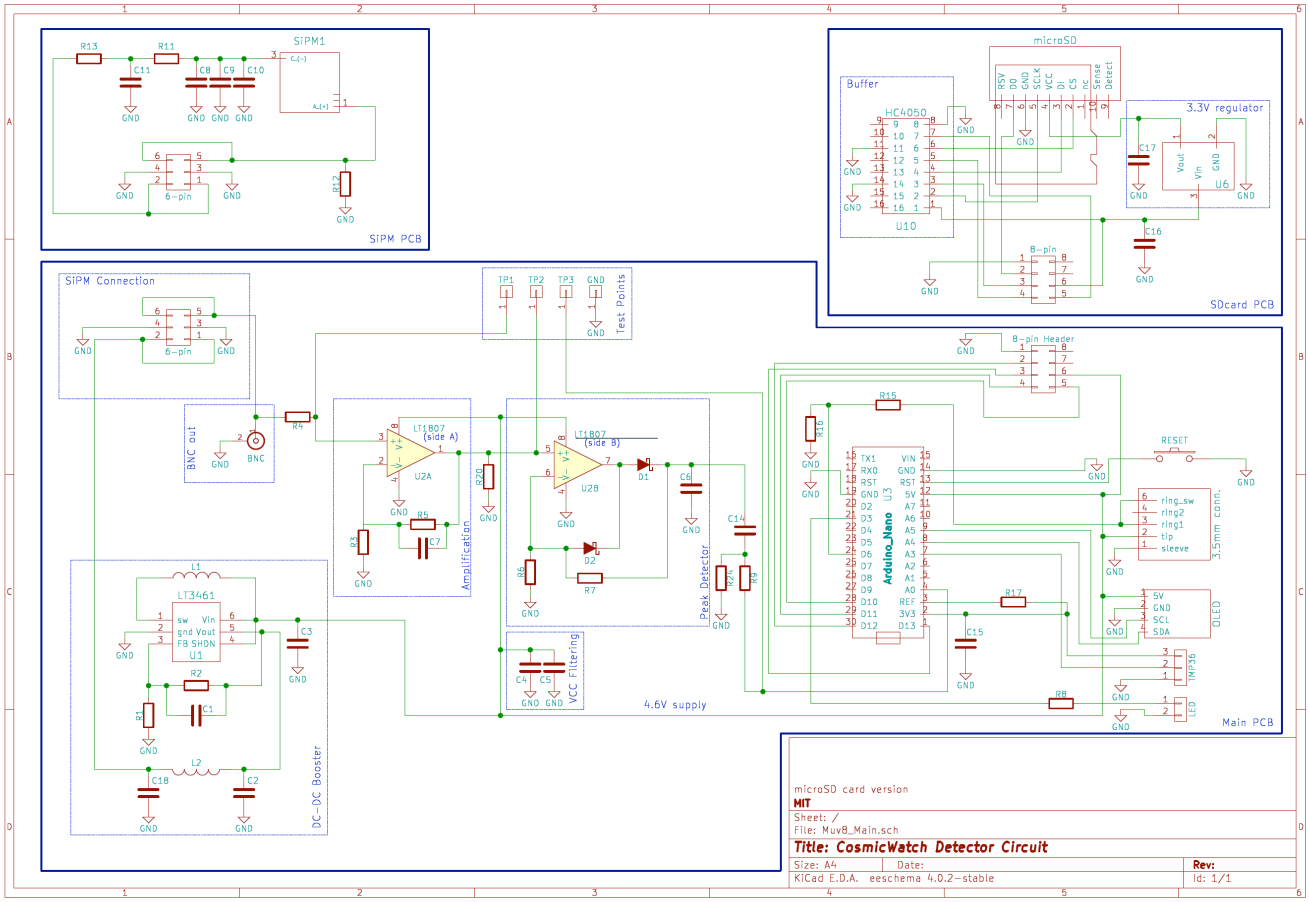

FIG. 2. Electronics schematic of the Cosmic Watch.

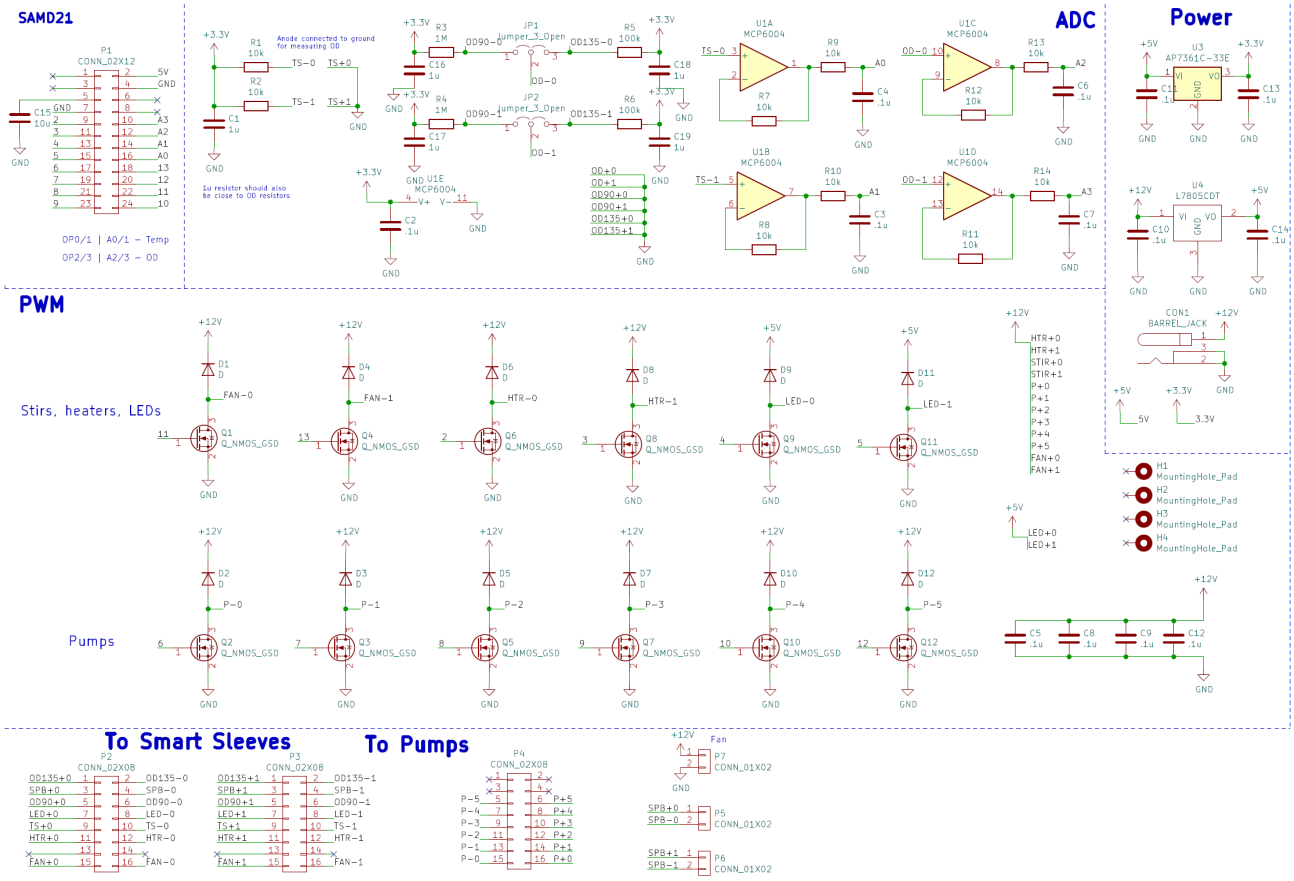

FIG. 3. Electronics schematic of the min-eVOLVER board. The original min-eVOLVER Arduino is removed. Jumpers have been soldered from the CosmicWatch to pins on the min-eVOLVER to shuttle a 12V DC power supply through MOSFETs that control the pumps.