Automation of LED Grow Light Control

At A Glance: The integration of an external digital controller for Light Emitting Diode (LED) grow lights can increase the accuracy of light level control, enable supplemental lighting, recreate daylight cycles, and add the capability for remote monitoring and control.

Custom controller adding supplemental LED light to hydroponically grown lettuce.

Introduction

Indoor agriculture provides several advantages to traditional agriculture, including the reduction of pest damage and use of pesticides, space efficiency, removal of the reliance on weather, and increased crop yield. In operations that employ grow lights for complete or supplemental lighting, the ability to optimize control is critical to ensure proper light intensity and minimize power consumption. Many LED grow light fixtures are not sold with automated or digital controls for intensity and timing – or these features are only included on more expensive models and within a proprietary ecosystem. This document compares the performance of LED fixtures with built-in manual controls, as well as to a custom device that allows automation of intensity and timing controls.

Typical Features of Manual Control

The light intensity in most LED fixtures is controlled with a hand-turned dial. Other relevant features include the ability to completely turn off the light fixture and the acceptance of an external control signal. The external connection allows for the daisy chaining of multiple fixtures, typically up to four units, which allow the dial in a single fixture to control the intensity of all fixtures in the chain. In this study, three grow lights were tested, and details of the stock configuration for these units are shown in Table 1.

Dial Performance

The manual dial either has continuous control through the entire range of motion or is limited to a fixed number of positions at which to set the intensity. The fixed-position dials provide consistent and repeatable control of light intensity, as the intensity will be the same at each setting even after switching back and forth. All light intensity measurements were made with an Apogee SQ610 ePAR sensor (Apogee Instruments, Logan, UT)], which measures light at wavelengths between 400-750 nm, which encompasses the range used by plants for photosynthesis.

On the Viparspectra P1000 (Viparspectra, Richmond, CA), the rotary switch limits the grow light to five light intensities (Figure 1), which differ by 92-117 umol/m^2/d between adjacent dial settings. This dial does not provide the ability to precisely set the intensity for plants and would limit the ability to adequately control the Daily Light Integral (DLI), or total amount of light that plants receive each day. The smallest possible

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Table 1. Light-intensity control features of full-spectrum LED grow lights.

Parameter	Spider Farmer SF1000	Viparspectra PAR100	Viparspectra P1000
Dial	Continuous	Continuous	5 Settings
Manual Shut Off	Yes	Yes	No
Built-in External Control	Yes	No	Yes

increment achieved with this dial is 6.7 mol/m^2/d, which is usually larger than the optimum range of most plants. Note that the light intensities described throughout this document are included for illustration purposes only. The ePAR sensor was placed approximately 18 inches directly below the light; the intensity would change if the sensor was moved to another location within the grow area or the light was raised.

Alternatively, the continuous dials on the Viparspectra P1000 and Spider Farmer SF1000 (Spider Farmer, Alhambra, CA) adjust the light intensity from the minimum to maximum by carefully turning the dial. Although continuous dials provide more resolution, there are two issues that can affect consistent control. First, the user's ability to adjust the dial to the exact location during each instance the light is turned on may not be very precise. Additionally, if the dial is prone to backlash, the light intensity will not change immediately after a change in rotational direction. Therefore, it is possible that even when the dial points to the exact same position on the face, the brightness will not be the same.

For the two light fixtures with continuous dials, only the SF1000 exhibited backlash, which can be physically felt when turning the knob and has a magnitude of approximately 5% of the full scale, according to the printed text and markings on the knob plate. This resulted in 4.4 W of difference in measured power consumption when making fine adjustments back and forth. This can be mitigated somewhat by turning the dial completely to the maximum or minimum settings prior to approaching the desired setting. This technique was applied during a short trial (n=20) of carefully adjusting the dial to the 40% setting, which is in the middle of the range of the knob. It was observed that the power consumption deviation can be lowered to 2.6 W when turning to 40% intensity from a lower setting instead of from a higher setting. Over the course of a year, backlash in the knob could result in additional electricity expenses of $6-$10 per light. The observed light intensity differed by 11 umol/m^2/s on average, with a maximum of 18 umol/m^2/s.

External Control

The SF1000 and P1000 have connectors for external control so that LED fixtures can be daisy chained together and controlled by one dial (Figure 2). The PAR100 does not have this ability in the stock configuration, however, the dial can be disconnected from its LED driver or power supply so the driver can receive a control signal. The most common types of control signals found on LED drivers are a 0-10 VDC (Voltage Direct Current) and an electrical resistance, which is what the built-in rotary switches and potentiometers provide. The label plate on any LED driver should indicate the type of control signal that it will accept.

Figure 2. External control receptacles on the Viparspectra P1000 (left) and Spider Farmer SF1000 fixtures (right).

Custom Controller

A custom controller was developed to add automation, wireless capability, and finer control of light intensity. The device is USB powered and also provides timer capabilities. Notable components of the device (Figure 3)

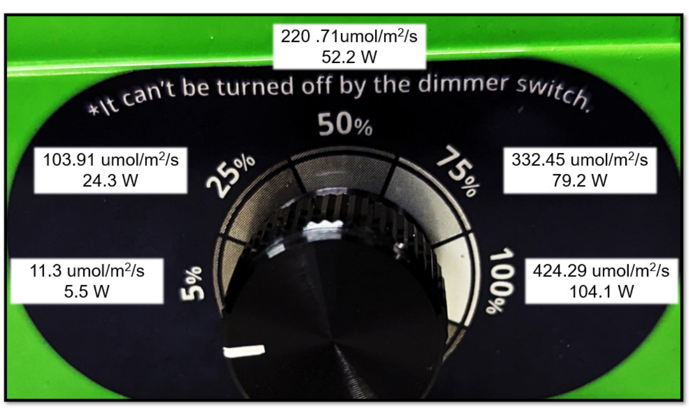

Figure 1. Fixed position rotary switch dial on Viparspectra P1000 with light intensity and power consumption

Table 2. Component costs for custom controller.

Component	Cost
Adafruit[1] ESP32 Feather TFT S2 Reverse	$25
Adafruit[1] Digital to Analog Converter	$8
Real Time Clock w/ CR1220 battery	$7
5V - 12 V Converter	$2
3.3V - 10 V amplifier Components LM358N Resistors 2kΩ (x2)	$2
Breadboard	$2
3D printed case	$2
Wires	$2
Screws	$1
Total	$51

include a microcontroller with built-in LCD screen and physical buttons, a 3D-printed case with mounting brackets, a real-time clock, and converters/amplifiers to create the 10 VDC control signal. The light intensity can be set as a percentage of the full strength or to automatically bring the intensity up to a level measured by an external sensor, such as the Apogee SQ 610 or a previously developed low-cost Photosynthetically Active Radiation (PAR) sensor (Kurasaki et al., 2023). Expandability to control up to four groups of light fixtures at different intensities and timings can be accomplished at an additional cost of $2 for a second LM358 amplifier (or equivalent) and extra resistors, bringing the cost of adding automated control per each group to $13.25. Not included in the cost, as detailed in Table 1, are connectors or receptacles to connect the control wires from the controller to each light, which can be of the type used in each operation. [1]*Adafruit, New York, NY*

When using the automated controller with an external light sensor, the device controlled the PAR100 to exactly the desired intensity setting and within 4 umol/m2/s with the SF1000 and P1000 fixtures. The relationships between the controller signal, light level, and power

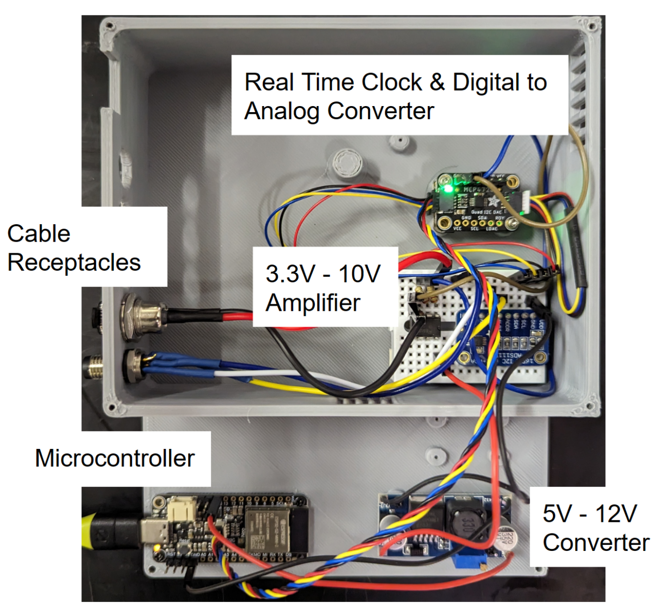

Figure 3. Controller components.

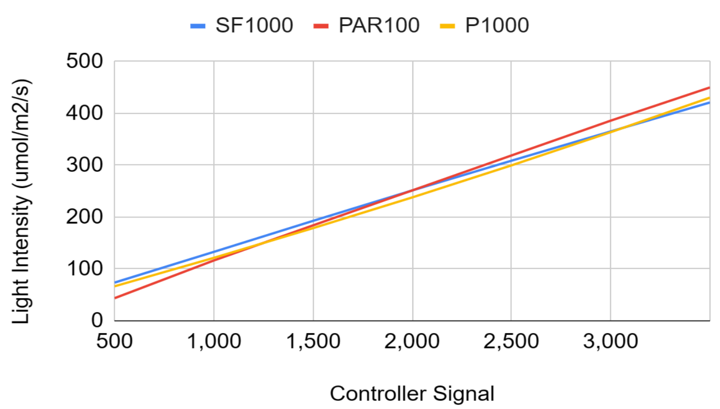

Figure 4. Proportional light intensity control with custom controller.

consumption were proportional or linear (Figure 4), which indicates that each finite increase in the control signal voltage will increase the light intensity by a predictable amount. Recall that the stock dial on the P1000 limited the fixture to 5 light settings, however, the addition of this device adds continuous control to the P1000. This controller is also able to completely turn off the PAR100 fixture, but will only bring the SF1000 and P1000 fixtures down to approximately the minimum brightness. This limitation can be addressed by pairing this controller with a mechanical timer.

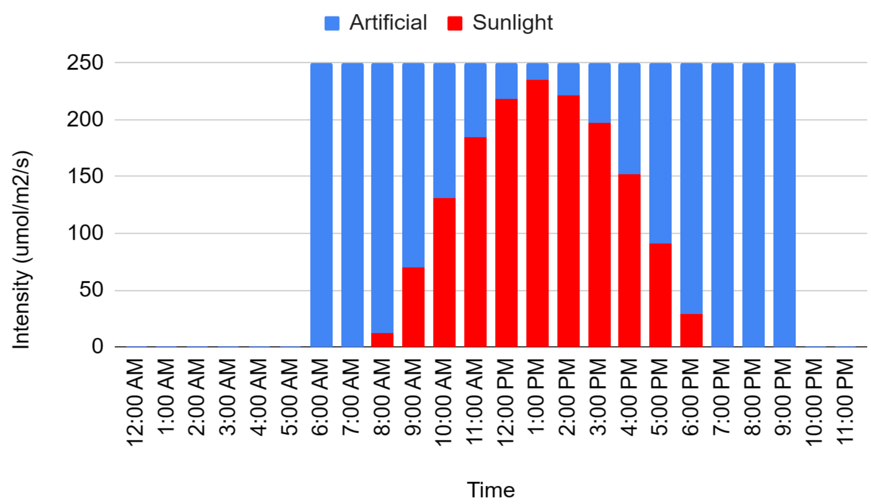

Figure 5. Scenario in which artificial light supplements natural light provided by the sun.

Summary

The custom controller described in this publication is a low-cost option for automated control of the light intensity and timing of LED grow lights. The device improves accuracy, and the intensity can be varied over the course of the day to supplement sunlight, recreate a daylight cycle indoors, or satisfy the changing requirements of the plant as it grows. With Wi-Fi access, the controller can also be integrated into an Internet of Things (IOT) network to provide capabilities, such as the inclusion of additional sensors, controls, and data analysis.

Resources

3D-printed files, including cases and mounts, and programming code for the light controller are available for download on Github.

Timed and Feedback Control

A typical daily light cycle of indoor growing operations is accomplished by turning the lights on at a constant intensity for a fixed portion of the day. An example cycle is 16 hours of constant illumination and 8 hours of darkness. However, there are other strategies for intensity control that can be employed with this controller, such as varying the intensity to recreate the sunlight patterns at any time of year and location, supplementing sunlight with artificial light to maintain required light exposure (Figure 5), and tuning the intensity at each growth stage to match the requirements of the plant. The timed response is accomplished using a real-time clock component, which maintains the current time even when the device is powered off. The real-time clock component can be eliminated if the controller is connected to a Wi-Fi network, through which it can check the time online.

Power Consumption

The use of an external timer in tandem can lower power consumption further as the power supplies on PAR100 and SF1000 LED fixtures consume electricity, 0.6 W and 1.1 W respectively, even when no light is produced. Whereas, light from the P1000 cannot be completely shut off. Annually, this would cost approximately $0.76 to $1.27 per fixture, with an 8-hour daily darkness period. The controller can be paired with a mechanical timer (Figure 6), which costs approximately $12 and always consumes 0.5 W of electricity, which would cost $2 annually. However, since multiple light fixtures can be controlled by each mechanical timer, this option can be more economical over time. Figure 6. Defiant 26378 mechanical timer (Jasco Products Company, Oklahoma City, OK).

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Disclaimer

Names of products and companies are given to illustrate the materials and resources used by the authors to develop the device described in this publication, as well as for the convenience of readers. Mention of these product and company names should not be considered a recommendation in preference to other products and companies that may also be suitable. Furthermore, the results obtained with the apparatus described may not be achieved under all conditions. Persons who follow the procedures suggested in this publication should be prepared to modify them to reflect different components and infrastructure that may be in use.

Cost estimates for electricity are based on an average of Hawaiian Electric Company's estimated rates per kilowatt hour for residential and commercial rates at the time of submission ($0.40/kwh).

References

Kurasaki, R., Byrd, M., and Kobayashi K. (2022). Low-Cost Light Sensors for Indoor Agriculture. College of Tropical Agriculture and Human Resources. Extension Publications. http://www.ctahr.hawaii.edu/oc/freepubs/pdf/FST-68.pdf

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