Smart Blind Controller
SLG47115

This app note implements a Smart Blind Controller. It describes the implemented logic, HVPAK SLG47115 implementation and the obtained results of two controller variants, designed for different types of shutter sensors. This application note comes complete with design files which can be found in the References section.

Contents

1. References

For related documents and software, please visit:

https://www.renesas.com/eu/en/products/programmable-mixed-signal-asic-ip-products/greenpak-programmable-mixed-signal-products/hvpak

Download our free GreenPAK Designer software [1] to open the .gp files [2] and view the proposed circuit design. Use the GreenPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Find out more in a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the GreenPAK IC.

[1] GreenPAK Designer Software, Software Download and User Guide
[2] AN-CM-346 Smart Blind Controller.gp, GreenPAK Design File
[3] GreenPAK Development Tools, GreenPAK Development Tools Webpage
[4] GreenPAK Application Notes, GreenPAK Application Notes Webpage

2. Introduction

Smart homes nowadays are one of the most important markets for electronic devices. Users, and public in general, are searching new ways for home automation which enable them to implement unattended tasks and, also, to increment home security. Therefore, the so-called “smart homes" are now an interesting and growing global phenomenon.

A smart home can be defined as a living environment where advanced intelligent technologies manipulate traditional domestic things and respond according to the requirements of the home residents. These technologies are designed to control lights, control HVAC (heating, ventilation, and air conditioning), to lock and unlock doors, turn on/off the coffee maker and so many other applications. In a few words, smart home appliances are devices designed to make life easier.

In the last few years, increase in climate change has become one of the main concerns for people and governments. Energy consumption, and in particular the burning of fossil fuels, is the main source of human-induced greenhouse gas emissions. Several studies show that residential energy use has a considerable impact on energy use. In the US, 20% of total emissions are due to residential energy use. In Europe, where according to the European Environment Agency energy generation is responsible for 40% of emissions, 26% of this total is accounted for by industry and 25% by households.

Therefore, reducing domestic energy consumption has become one of the main objectives of societies all over the world. There are two different techniques that can be used at home to reduce the fossil-based energy consumption and its associated cost: generate electricity at home or control and reduce the usage of electric devices.

The first way is the best in terms of carbon footprint and sustainable life. However, planning for a home renewable energy system is a process that includes analyzing the existing electricity usage, looking at local codes and requirements and understanding technology options. Although there are many government plans in different countries that subsidized the development of energy generation at home, this is a long-term and expensive process which cannot be afforded by most households.

The other way is the most popular and the easier one. There are various ways to reduce energy consumption, but they typically focus on three main aspects: lighting, heating, or cooling systems, and home appliances. It can be estimated that lighting accounts for around 15% of an average home's electricity use. This is the main reason why several smart devices are designed to remotely control lamps, automate outdoor lighting, etc.

In this application note, a smart blind controller is implemented. It is designed to control the indoor lighting level by opening or closing blinds to regulate the outdoor light that enters the room. This implementation has two variants. One of them is based on external mechanical switches that limit the movement of the blind. The other one controls the movement of the blind by measuring the motor current. To implement this, a HVPAK SLG47115 is used, resulting in a controller that only requires passive components. The IC's HV capabilities allow the system to power the DC motor directly because it supports up to 26.4 V and 1.5 A at the HV GPIOs, so a very-small sized smart controller is obtained.

3. Motion Sensors alternatives

As a smart controller, the system has to detect when the blind is fully up or fully down, in order to prevent damaging the blind system and the dc motors used for rolling up or down the blinds.

The first alternative proposed for this system is to use mechanical switches placed in the rolling system, so they are activated when the blind has reached its limits. This first system has the advantage of being the simplest not only because it is mechanical but also because it simplifies the digital logic in the implementation. However, as this smart controller is intended to be installed by end users, it can be a challenge to install it on existing blinds at home.

The second alternative is to use the characteristics of typical DC motors to detect when the blind reached its limits. This option is designed on the basis that when the blind is, for example, fully up, any movement in the same direction (that is, try to go up) will generate an additional effort for the motor, which will have to increase its torque.

Any motor can be described by two primary values: its speed, measured in rpm, and its torque, measured in kg.m. By multiplying both the torque and speed, the power delivered by the motor is obtained. It can be concluded that if two motors are compared, one with twice the speed and half the torque than the other, they have the same power output.

A DC motor has a maximum speed, which can be obtained when no force, or torque, is applied and a maximum torque obtained when the motor is completely stopped. Those maximum values are usually called the free-running speed and the stall torque. As it can be expected, DC current is highly related with the torque of the motor. This is shown on the next expression, where torque and current relationship is shown.

$$\boldsymbol{Torque} = \boldsymbol{k_T} * (\boldsymbol{I} - \boldsymbol{I_{free}})$$

When no force is applied, the DC current is minimum, and it is called the free-running current. In the same way, the current is maximum when the motor is applying the stall current. Both currents (the free-running current and the stall current) are the two other parameters that describes a DC motor. The stall current is usually much higher than the free-running current as shown Figure 1.

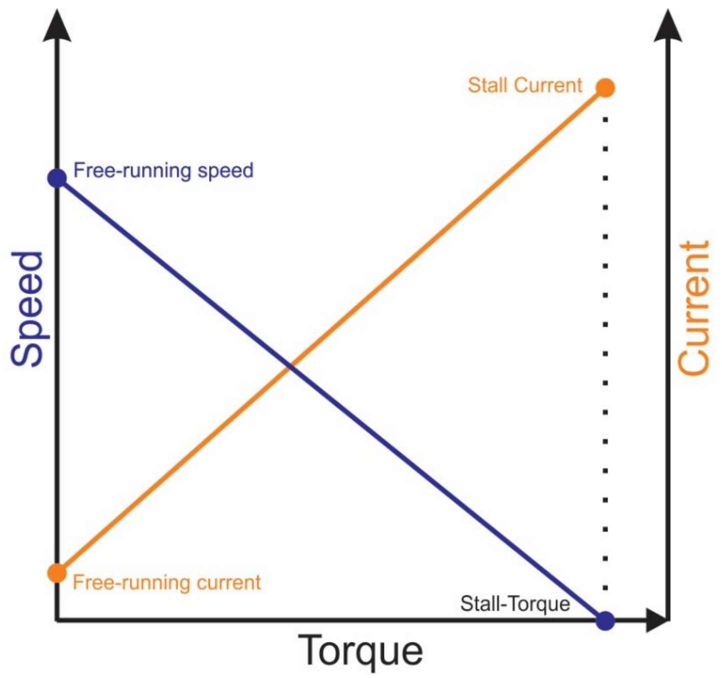


Figure 1. Current and Speed vs. Torque in DC motors.

As it can be concluded from the Figure 1, DC motor current is an indirect way to measure the torque of the motor.

As stated before, when the blind reaches its maximum or minimum position, it will not continue to go up or down even when if the motor tries to wind or unwind it. In this situation, the torque of the motor will increase because the blind is trying to maintain its position, so the motor must make a greater effort. By applying the relationship between torque and current, the DC current can be sensed to detect when the motor has increased its torque. If the torque is greater than the expected value, it can be interpreted as the rolling limit of the blind, so the system cannot go further in that direction.

Considering the SLG47115 characteristics, the motor can be controlled and supplied with the HV pins, and the driven current can be measured with the current sense and comparator. By using these features, the blind limits can be detected by comparing the current driven from the pins with a threshold level that indicates that torque has increased over the expected level.

4. Smart Blind Controller design diagram and schematic

The Smart Blind Controller described and implemented in this app note is based in the block diagram shown in Figure 2.

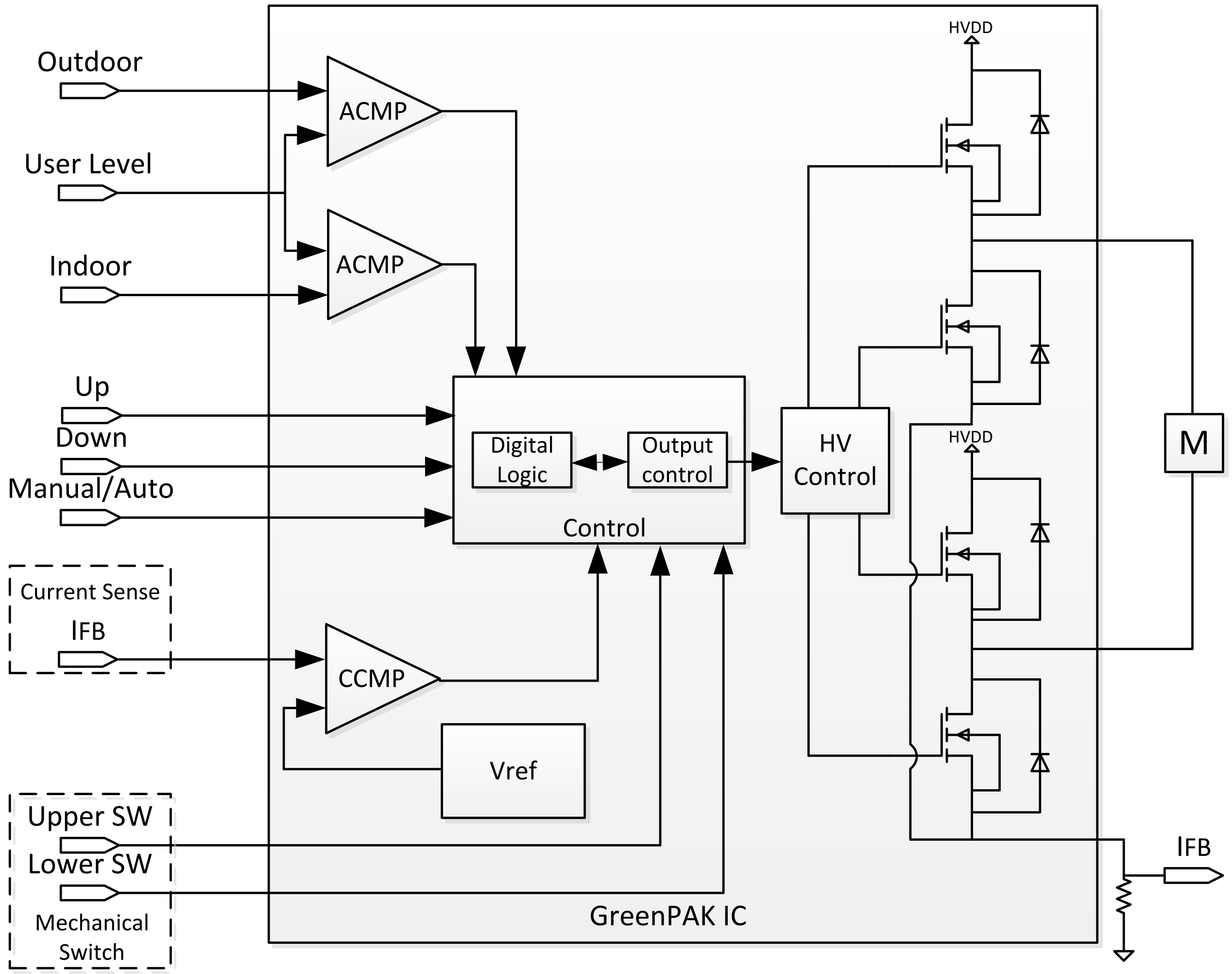


Figure 2. Smart Blind Controller block diagram.

A single DC motor is used to roll up or down the blind. To control it, the internal HV GPIOs of the SLG47115 are configured as full bridge. These pins, as the current drivers for the smart blind process, switch the polarity output to the motor so it can turn clockwise or counter-clockwise.

The pins are managed with the internal HV Out control module of the GreenPAK IC, which is controlled by the internal logic based on the light sensors and blind position. The voltage reference corresponding to the desired light level is determined by the user externally with a potentiometer connected to the corresponding reference input. The light sensors are based on light dependent resistors (LDRs) connected to a resistive divider network.

The motion limit sensors feedback is obtained in different way depending on the implementation alternative. When mechanical switches are used, their outputs, with the corresponding internal pull-down resistors, are connected directly to the digital circuit inside the IC. Alternatively, when the current limit sensor is used as stated before, the internal analog comparator and current sense module is used. The current reference for this sensor is generated internally with the internal programmable voltage references.

All the logic related to light regulation can be disabled if the end user changes the mode between automatic and manual. When in manual, the blind can be rolled up or down with the corresponding buttons that enable the HV control output only if the motion limit sensors allow it, but regardless of the interior or exterior light levels.

The diagram shown in Figure 2 is represented, considering the required external components for both alternatives presented in this app note, in the schematic circuit shown in Figure 3.

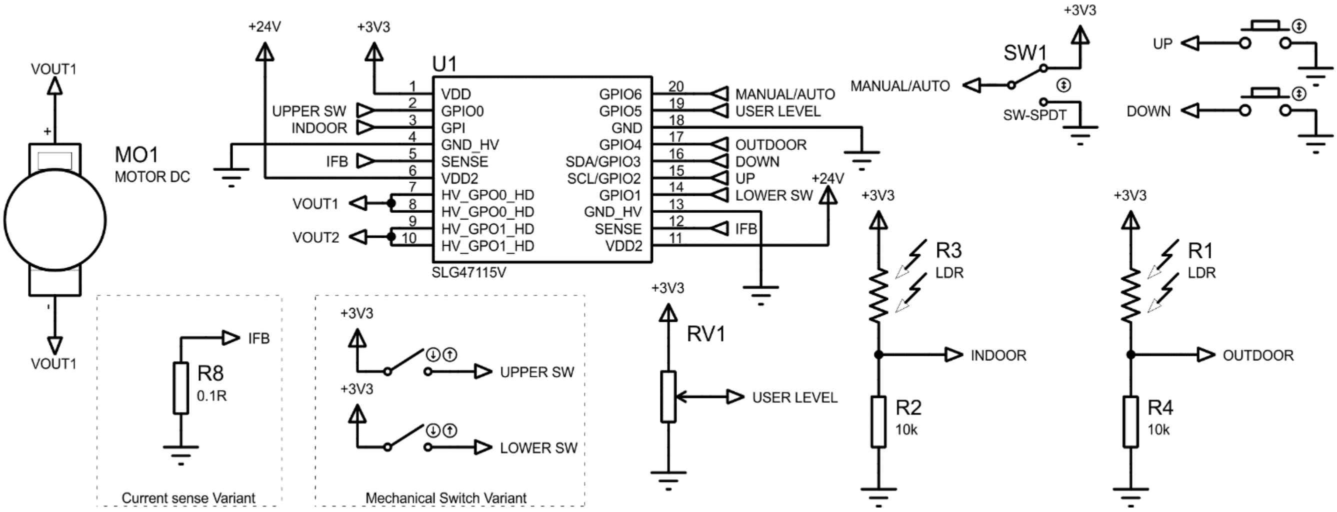


Figure 3. Smart Blind Controller schematic circuit.

5. Implementation and Configuration of Smart Blind Controller.

The implementation of the Smart Blind controller is based on a SLG47115V HVPAK. This programmable mixed-signal IC contains internal Analog Comparators, Current sensors, and High-Voltage Integrated H-Bridge /dual Half-Bridge functionality that can be used for driving the DC motor with the corresponding voltage levels required for moving the blind in the corresponding direction to increase or decrease the light intensity inside the room.

The automatic mode of the controller is implemented by using the internal logic and analog comparators with external reference, as it can be seen in Figure 4.

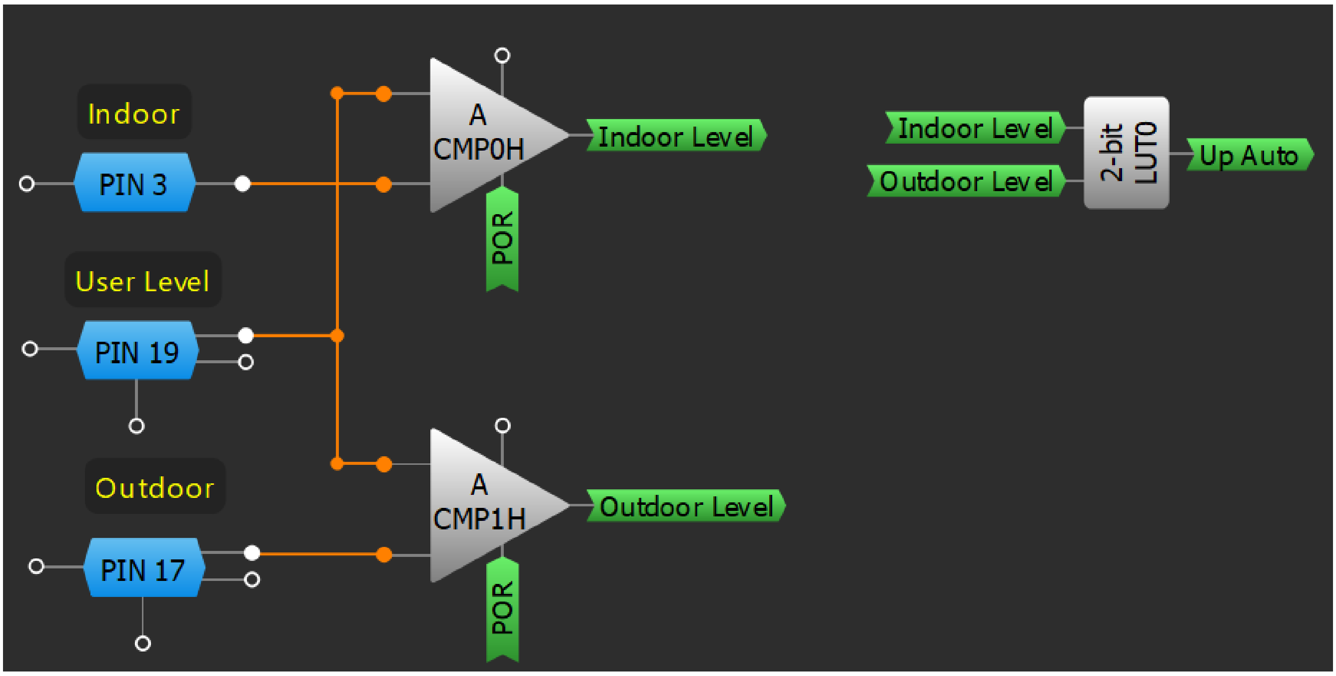


Figure 4. Automatic mode controller.

The external light sensors, placed at the window looking outside and inside the room respectively, are connected to the analog comparators ACMP0H and ACMP1H and compared with the reference level defined by the user with a potentiometer. The ACMP0H controls the inside light level while the ACMP1H controls the outside level. Both levels, with the corresponding logic implemented with 2-bit LUT0, determine when the blind must be rolled up or down. The configuration of both analog comparators sharing the same external voltage reference and the look up table can be seen in Figure 5, Figure 6, Figure 7.

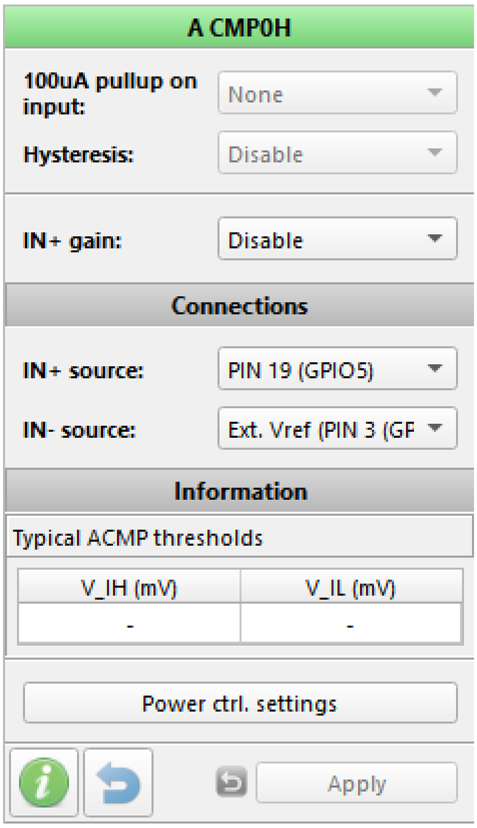


Figure 5: A CMP0H Configuration

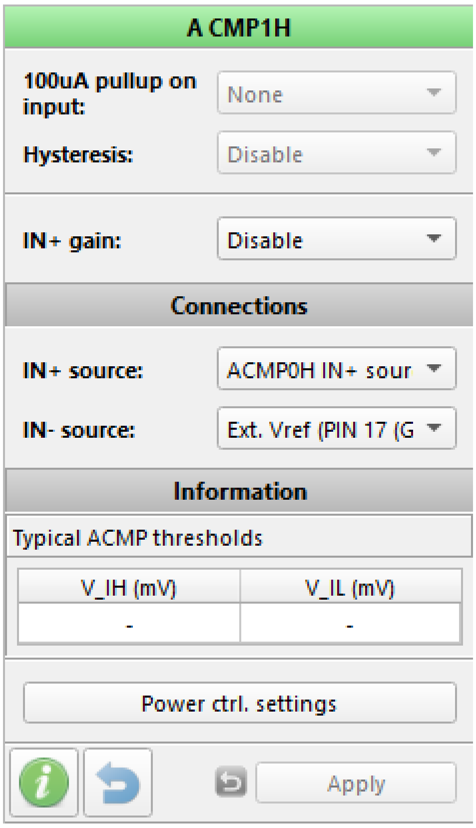


Figure 6: A CMP1H Configuration

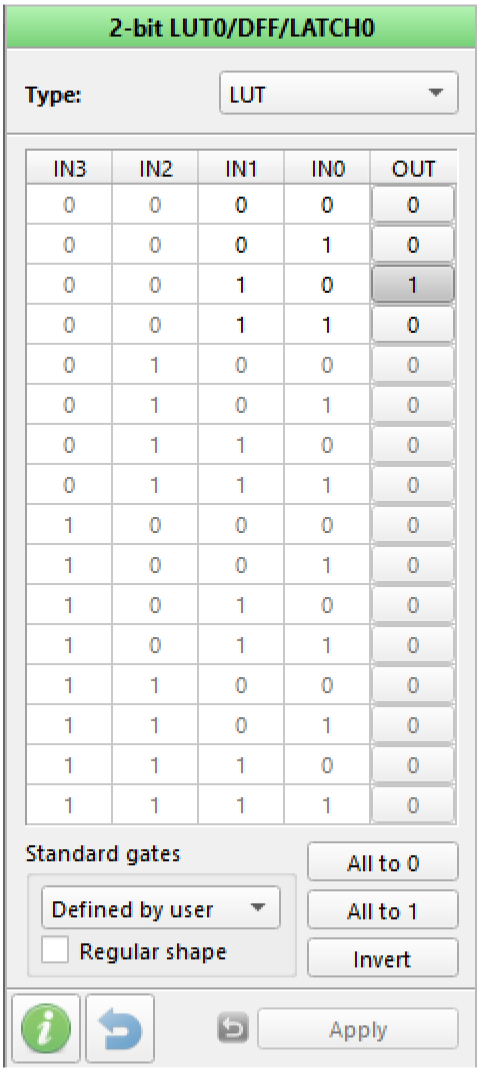
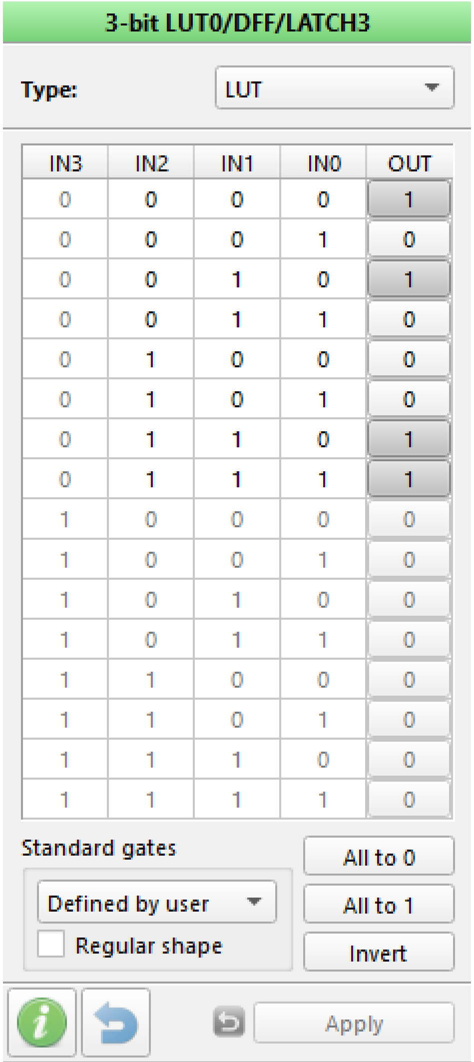


Figure 7: 2-bit LUT0 Configuration

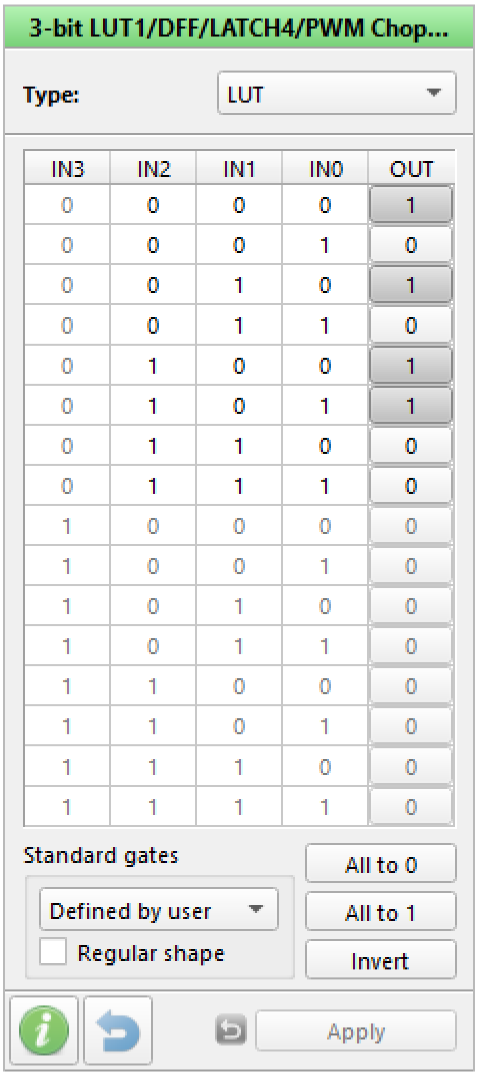
It can be analyzed from Figure 7 that 2-bit LUT0 is configured to roll up the blind when it is necessary only. That is, the blind will roll up if the indoor light level is lower than the desired one and if the available outdoor light is enough (outdoor light level higher than the configured level). In the same way, the system will roll down the blind if the interior light level is higher than the desired one regardless of the outdoor level. In other words, the control will try to reduce the indoor light by rolling down the blind even though the light is obtained from artificial sources such as lamps. So, the roll down signal is the inverse of the ACMP0H, and it will be considered for the configuration of the next LUTs.

As described in the previous section, the manual control disables the automatic mode, and the blind is controlled by the corresponding user switches. To do so, 3-bit LUT0 and 3-bit LUT1 are configured to select the control source. If in automatic mode, 3-bit LUT0 and 3-bit LUT1 select the up and down controls obtained from 2-bit LUT0 and ACMP0H. If in manual mode, up and down signals obtained from pins 15 and 16 are used to control the blind movement. The configuration of 3-bit LUT0 and 3-bit LUT1 are shown in Figure 8 and Figure 9.



IN3	IN2	IN1	IN0	OUT
0	0	0	0	1
0	0	0	1	0
0	0	1	0	1
0	0	1	1	0
0	1	0	0	0
0	1	0	1	0
0	1	1	0	1
0	1	1	1	1
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	0
1	1	0	1	0
1	1	1	0	0
1	1	1	1	0

Figure 8: 3-bit LUT0 Configuration



IN3	IN2	IN1	IN0	OUT
0	0	0	0	1
0	0	0	1	0
0	0	1	0	1
0	0	1	1	0
0	1	0	0	1
0	1	0	1	1
0	1	1	0	0
0	1	1	1	0
1	0	0	0	0
1	0	0	1	0
1	0	1	0	0
1	0	1	1	0
1	1	0	0	0
1	1	0	1	0
1	1	1	0	0
1	1	1	1	0

Figure 9: 3-but LUT1 Configuration

The output signals of those look up tables are, finally, the control signals which determine if the blind should be rolled up or down due to the corresponding control mode. However, up to this point the limits of the blind were not considered. To limit the movement, or mask the control signals, the two alternative methods are implemented.

In Figure 10, the control system based on mechanical switches is shown. The mechanical switches are connected to PINS 2 and 14, configured as digital inputs. The obtained signals are used in 2-bit LUT2 and 2-bit LUT3 to determine the output signals connected to the HV out control module. If the up or down switches input are at high level, the corresponding up or down control signals are applied to the output control. If one of the switches is low, the blind cannot move further in that direction, the control signal is disabled so the motor cannot move in that way

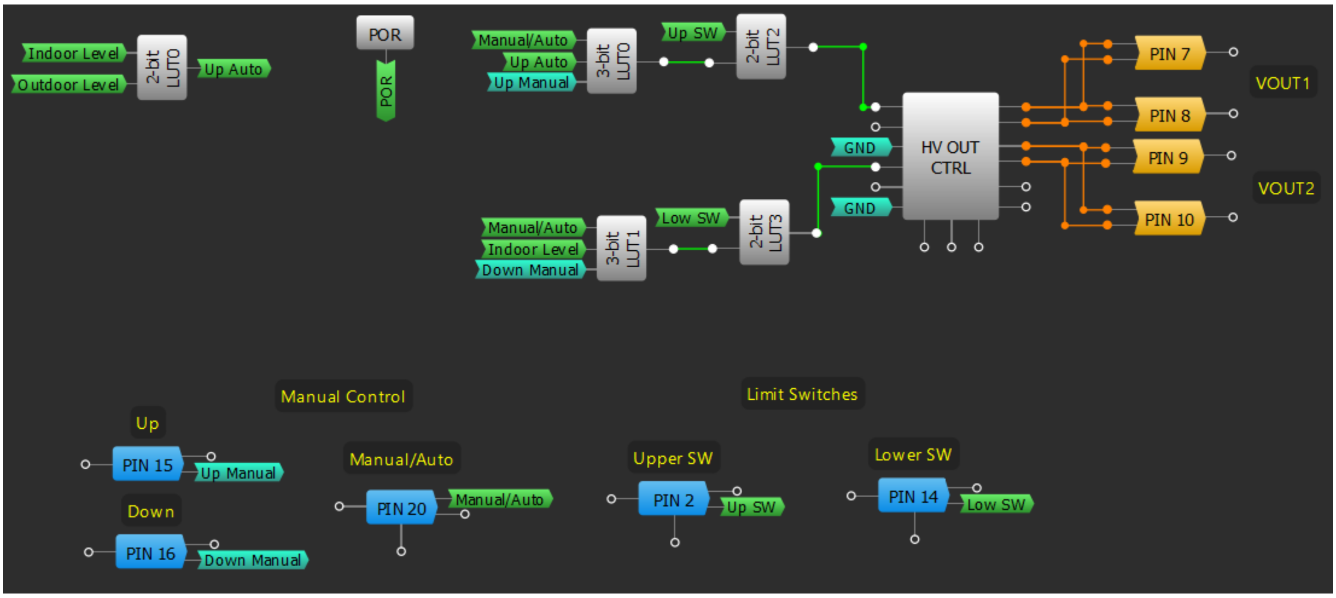


Figure 10: Mechanical switches output control alternative

In Figure 11, the control system based on current sense can be seen. The output current is sensed with the external shunt and the integrated sensor of the HV output port, and it is measured with the current sense comparator. If current (or the corresponding voltage) is greater than the configured threshold obtained from the programmable voltage reference, the overcurrent condition is triggered. The obtained signal is used in 2-bit LUT2 and 2-bit LUT3 to determine the output signals connected to the HV out control module. If the signal is low (no overcurrent), the corresponding up or down control signals are applied to the output control. If overcurrent occurs, the blind cannot move further in that direction, the control signal is disabled so the motor cannot move in that way

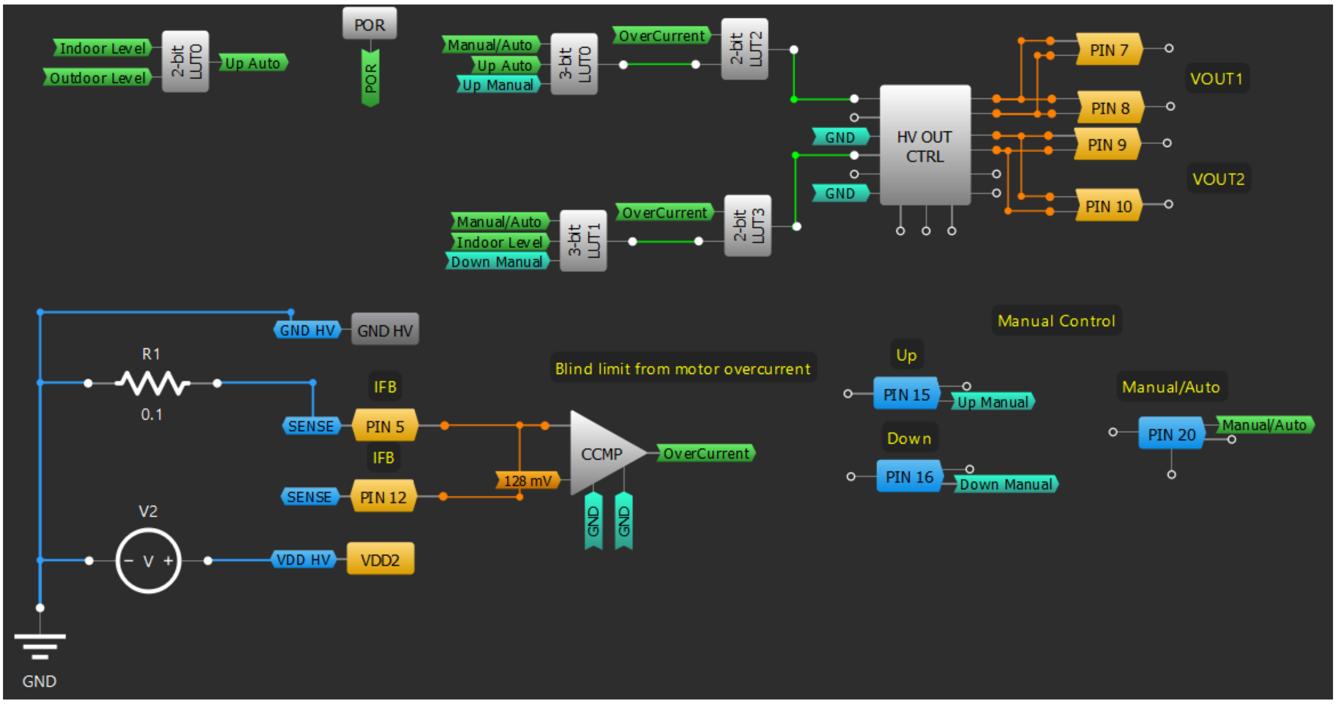


Figure 11: Current senses output control alternative

The configuration of 2-bt LUT2, 2-bit LUT3 and the current sensor can be seen in Figure 12, Figure 13, and Figure 14.

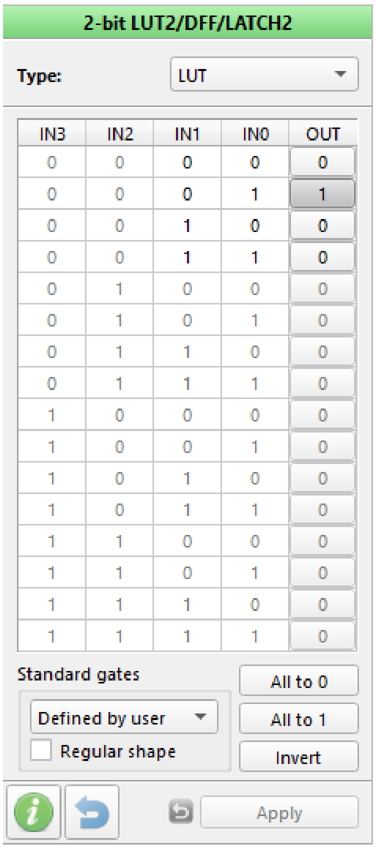


Figure 12: 2-bit LUT2 Configuration

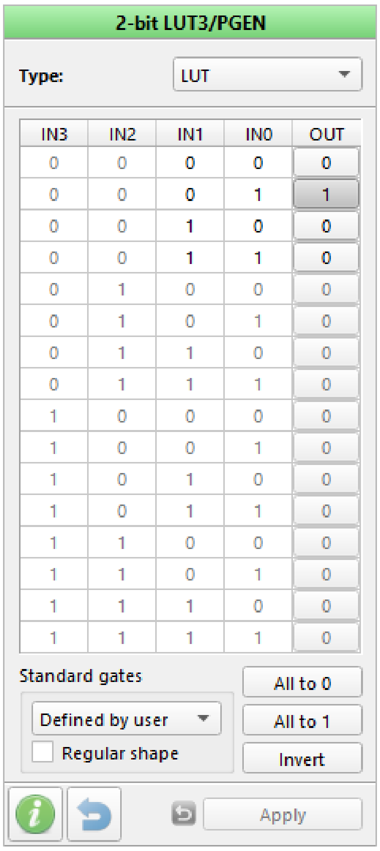


Figure 13: 2-bit LUT3 Configuration

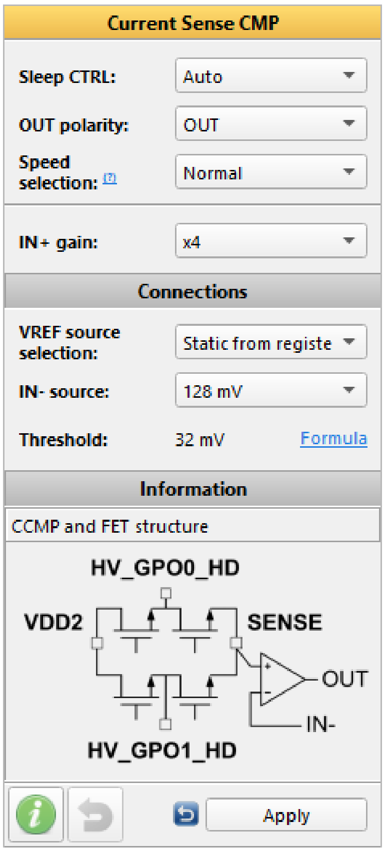


Figure 14: Current Sense CMP Configuration

As mentioned in previous sections, the motor is supplied and control by the HV GPIOs of the HVPAK configured as full bridge. This configuration is required to obtain the desired voltage with a high current output with the capability of changing polarity to generate clockwise and counterclockwise movement.

The HV GPIO ports connections, and its configurations, are shown in Figure 15 and Figure 16.

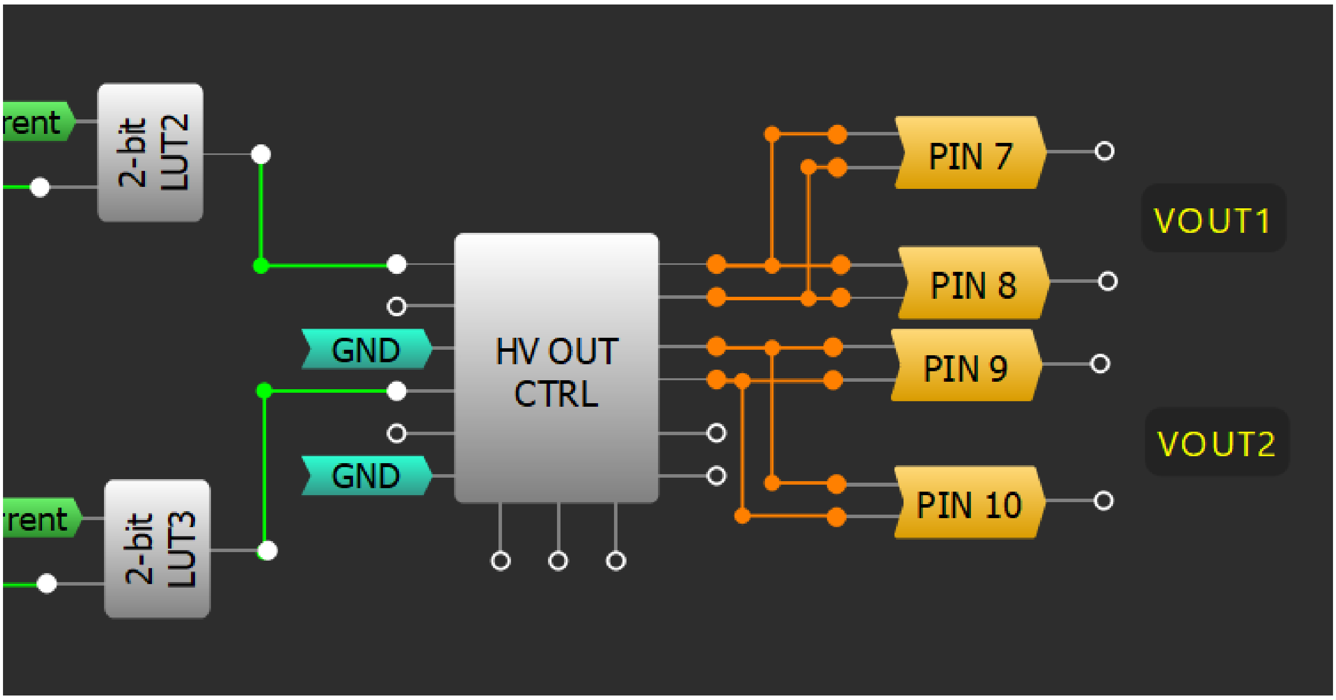


Figure 15: HV OUT connection.

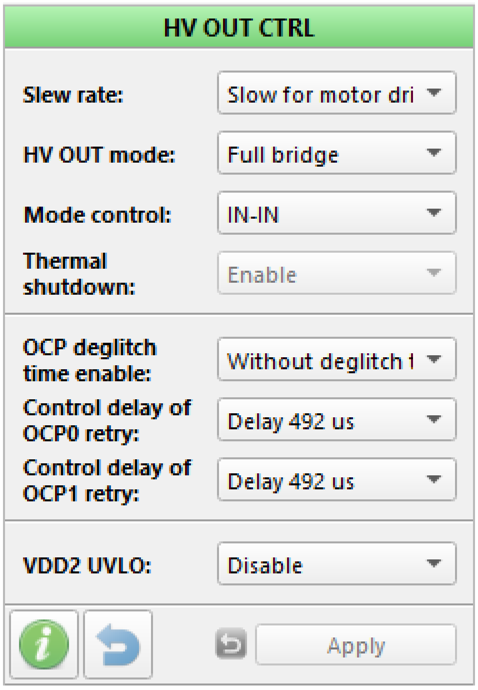


Figure 16: HV OUT Configuration

The entire Smart Blind controller implementation diagram, considering both alternatives, are shown in Figure 17 and Figure 18.

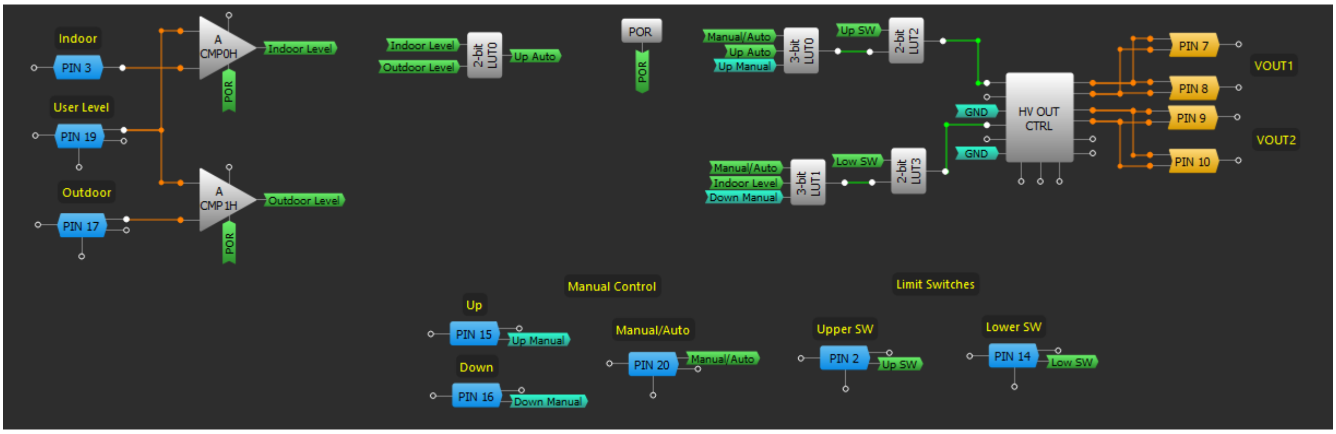


Figure 17. Smart Blind Controller with mechanical switches implementation

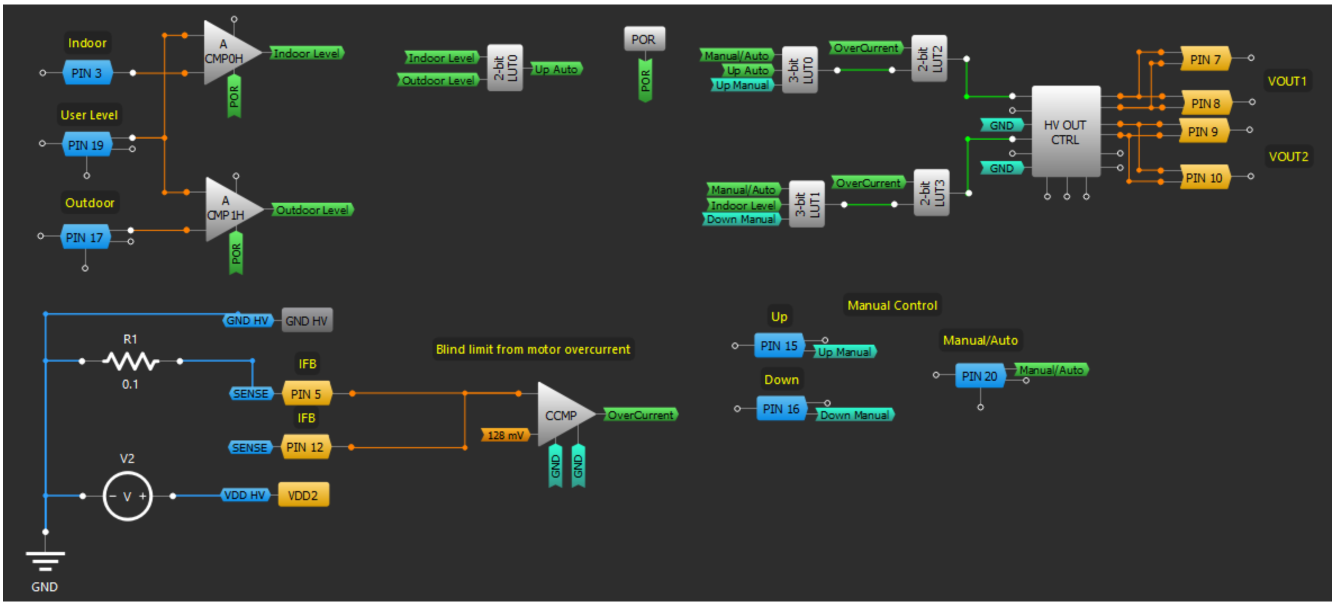


Figure 18. Smart Blind Controller with current sense implementation

6. Conclusion

To test the implementation, the entire system was assembled and tested in a workbench by simulating different operating conditions. The blind was set to limiting positions, and the system was set with different light conditions to simulate the system and hence obtain satisfactory results as it is shown in the video. The entire system can be seen in Figure 19.

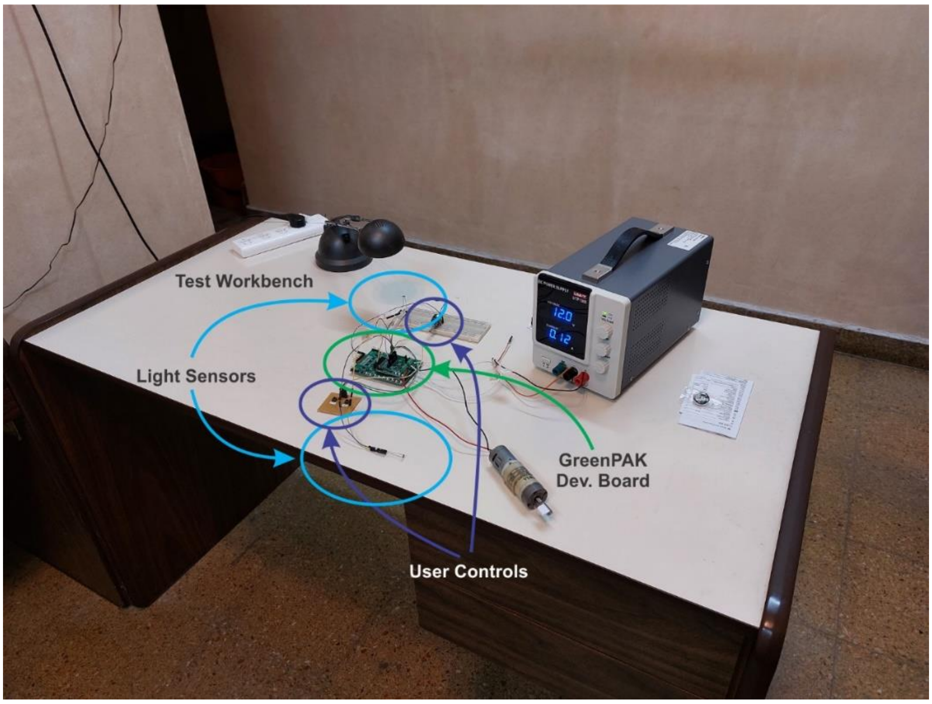


Figure 19. System Implementation

Measurements and signals were logged to analyze the different condition operations including the overcurrent triggering condition, as it is shown in Figure 20.

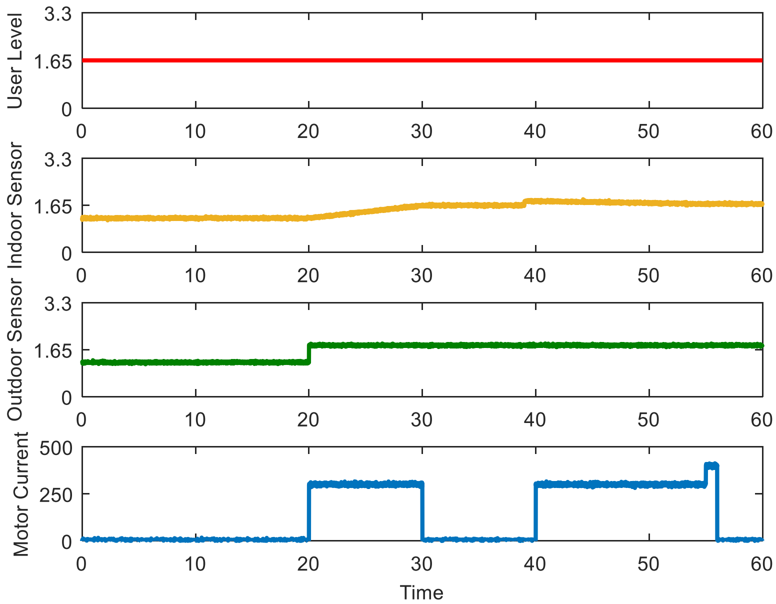


Figure 20. Workbench measurements

In this application note we implemented a Smart Blind Controller in two variants. Smart devices or adapters are nowadays one of the most important markets for electronic devices due to the fast evolution of communications, digital control, and embedded technologies.

There are several methods of implementing smart devices. In this application note, an SLG47115V is used as the main device, due to the high-voltage control capability and the analog and digital resources that are available. The two variants show how different analog features of the IC can be applied and how DC motors can be controlled by measuring its current consumption.

The size of the entire measurement system is smaller than many other implementations and outlines where HVPAK can be used and replace other commercial devices.

7. Revision History

Revision	Date	Description
1.00	Sep 26, 2022	Initial release.

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