TI Designs
IR Filter Analog Controller Reference Design

Description

The TIDA-01165 is an analog controller for infrared (IR) filters. This TI Design highlights the DRV8837C motor driver used to open and close an IR filter when the module is exposed to high-intensity sunlight. The simplified layout is suited to cost-conscious applications while also creating a solution that does not require firmware.

Resources

TIDA-01165	Design Folder
DRV8837C	Product Folder
TLV3202AIDGK	Product Folder
CSD13381F4	Product Folder
SN74LVC1G32DCKR	Product Folder

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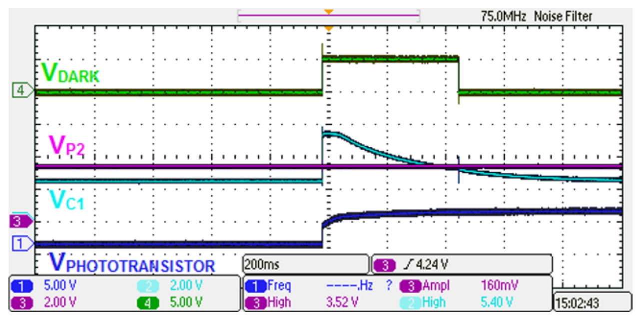
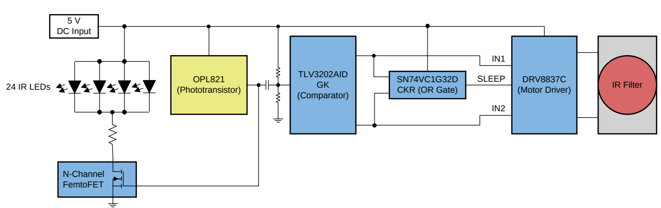
Features

- Low Component Count
- Simplified Layout
- Low-Power Sleep Controller
- Small Footprint Solution Size
- Fast Manufacturing

Applications

- Surveillance Cameras
- IP Cameras





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1 System Overview

1.1 System Description

This design includes several Texas Instruments logic devices as well as power and motor drive circuits. Keeping the signal conditioning for this design entirely analog creates a low-cost solution for both design and manufacturing. The following TI devices are highlighted in Table 1.

1.2 Key System Specifications

Table 1. Key System Specifications

PARAMETER	SPECIFICATIONS
Phototransistor wavelength	800 nm
IR LED bank radiant power	720 mW
IR LED wavelength	890 nm
Filter open time	440 ms
Filter close time	440 ms
Motor driver sleep current	1 mA
Motor driver active current	30 nA
Total LED bank current	1.2 A
Individual LED bank current	50 mA
Bias voltage V_Light	1.7 V
Bias voltage V_Dark	3.3 V

1.3 Block Diagram

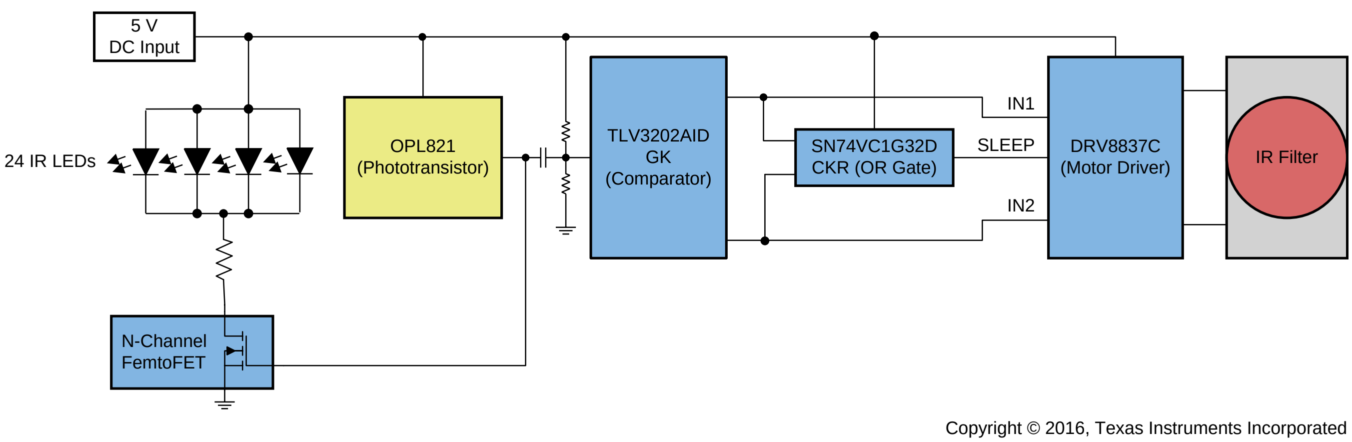

Figure 1. System Block Diagram

1.4 Highlighted Products

1.4.1 DRV8837C

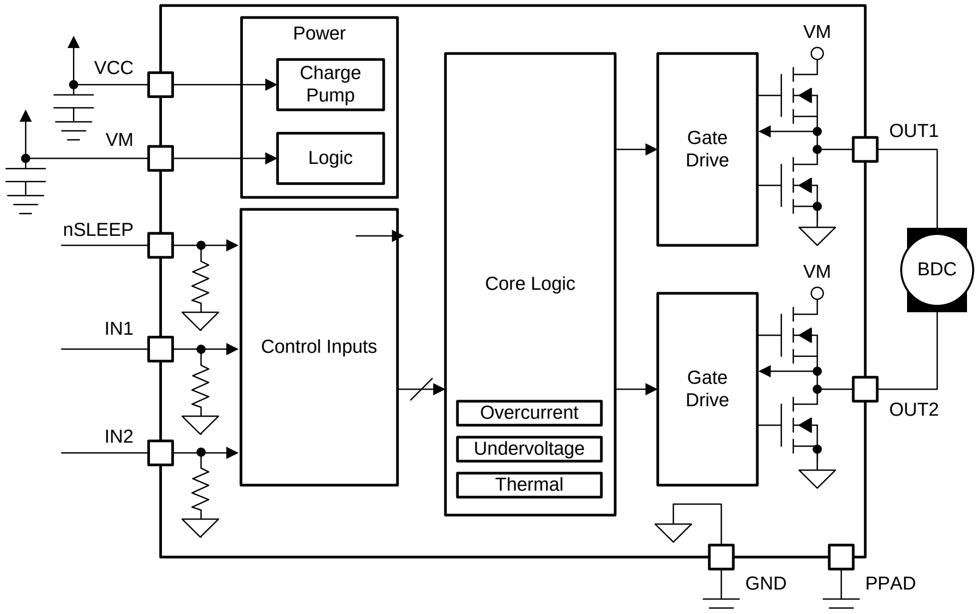

Figure 2. DRV8837C Functional Diagram

Figure 2 shows the functional diagram of the DRV8837C. The DRV8837C is a low-cost, integrated H-bridge motor driver used in this design to open and close the filter. The device has a simple IN1 and IN2 interface, which allows two logic signals to be fed to the driver to control current direction through the H bridge. This device also includes an nSLEEP pin that can be used to put the device into its low-power sleep mode. In this TI Design, nSLEEP puts the driver to sleep after a direction change pulse ends.

1.4.2 CSD13381F4

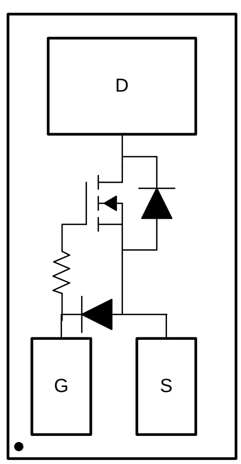

Figure 3. CSD13381F4 Functional Diagram

Figure 3 shows the functional diagram of the CSD13381F4. The CSD13381F4 is a small-package, N-Channel MOSFET used to switch the IR LEDs on and off based on the signal present on the IR sensor. This device is a good fit for this design because it is a small-package device perfect for a small layout like this IR filter.

1.4.3 TLV3202AIDGK

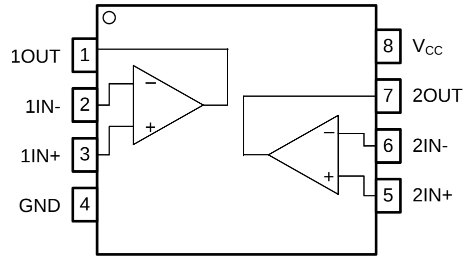

Figure 4. TLV3202AIDGK Functional Diagram

Figure 4 shows the functional diagram of the TLV3202AIDGK. The TLV3202AIDGK is a dual-comparator device used in the design to create the correct trigger signals based on rising or falling edge signals coming from the IR sensor populated on this board. This device is a small-package, low-voltage circuit that is well suited for this design because of its 5-V supply capability. This device also includes an internal pullup circuit, which eliminates an external resistor needed in the layout.

1.4.4 SN74LVC1G32DCKR

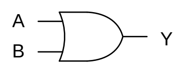

Figure 5. SN74LVC1G32DCKR Functional Diagram

Figure 5 shows the functional block diagram of the SN74LVC1G32DCKR. The SN74LVC1G32DCKR is a simple OR gate logic device used to pull up the nSLEEP pin on the DRV8837C whenever either of the comparator outputs go high. This device is a small footprint, low-cost logic device that allows the DRV8837C to be put into a low-power sleep state.

2 System Design Theory

2.1 Pulse Generator From Edge Transition

The output from the phototransistor is either 5 V or ground depending on the light intensity directly in front of the sensor. The edge transition from high to low or low to high generates a 400-ms pulse that is fed to the DRV8837C motor driver to open or close the IR filter in front of the cameras optical sensor. The method used to generate these pulses is outlined in Section 4.1.

2.2 High-to-Low Transition Logic

When the phototransistor transitions from high to low, a falling edge is sent to the input of C2, as shown in Figure 6. A passive differentiator is created using C2 and R10 with a fall time of approximately 438 ms. R9 and R10 create a voltage divider from the 5-V rail that biases pin 6 of U1B to 2.5 V. The passive differentiator creates a falling edge that is clipped at ground voltage through the U5 protection diode.

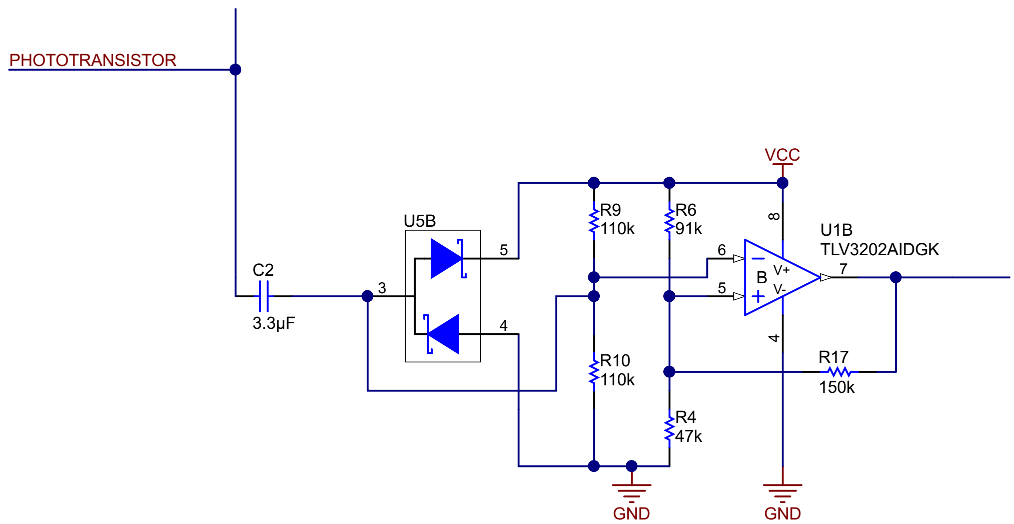

Figure 6. High to Low Transition Logic

After the initial falling edge, the passive differentiator voltage exponentially decays back to the steady-state offset of 2.5 V. During this decay time, the voltage is less than the voltage present on pin 5 of U1B, which causes the output of the device to be pulled up to 5 V. Once the output of U1B goes high, R17 is in parallel with R6 between the 5-V rail and pin 5 of the comparator. This combination increases the voltage on pin 5, which creates a hysteresis window for the comparator input.

Once the voltage measured across the passive differentiator rises above the voltage on pin 5, the output of U1B is pulled low, and the hysteresis window is reset to R17 in parallel with R4, which lowers the pin 5 voltage.

2.3 Low to High Transition Logic

When the phototransistor transitions from low to high, a falling edge is sent to the input of C1, as shown in Figure 7. A passive differentiator is created using C1 and R8 with a fall time of approximately 438 ms. R7 and R8 are used to create a voltage divider from the 5-V rail that biases pin 3 of U1A to 2.5V. The passive differentiator creates a rising edge that is clipped at 5 V through the U5 protection diode.

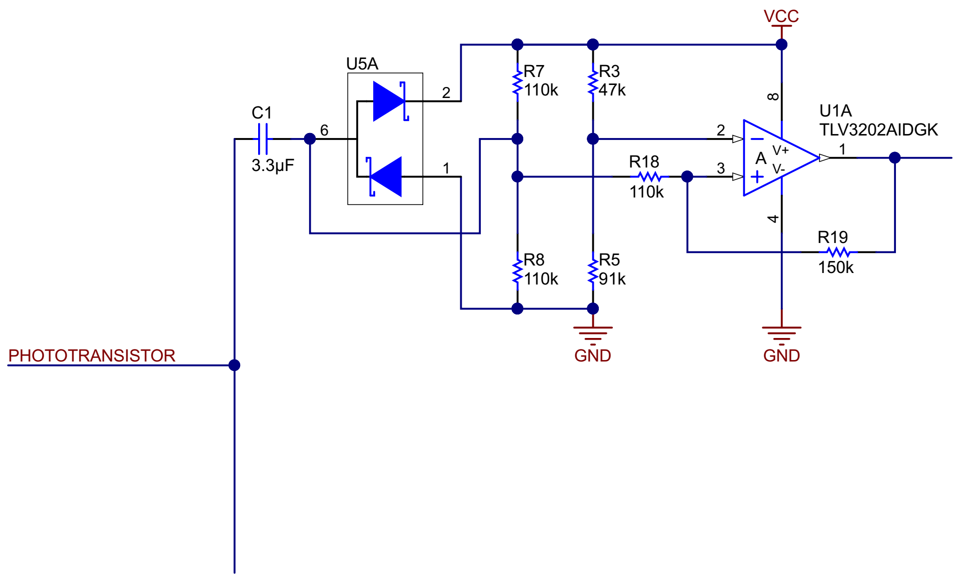

Figure 7. Low to High Transition Logic

After the initial rising edge, the passive differentiator voltage exponentially decays back to the steady-state offset of 2.5 V. During this decay time, the voltage is greater than the voltage present on pin 2 of U1A, which causes the output of the device to be pulled up to 5 V. Once the output of U1A goes high, R19 and R6 create a voltage divider between 5 V and the bias voltage. This combination increases the voltage on pin 3, which creates a hysteresis window for the comparator input.

Once the voltage measured across the passive differentiator falls below the voltage on pin 5, the output of U1B is pulled low, and the hysteresis window is reset to R19 and R16, referenced between the bias voltage and ground, which lowers the pin 3 voltage.

2.4 OR Gate Sleep Logic

Each of the comparator outputs are also tied to the input pins of an OR gate that controls the sleep pin on the DRV8837C, as shown in Figure 8. When either of the comparator outputs is pulled high, the output of the OR gate is also pulled high, which causes the DRV8837C to wake from its low-power sleep state and move the IR filter. Once the pulse ends and both comparator outputs are pulled low, the output of the OR gate is pulled low, and the DRV8837C goes back into its low-power sleep state.

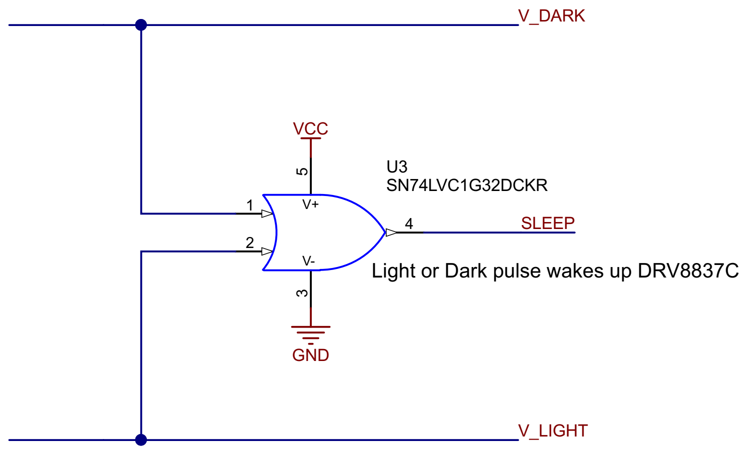

Figure 8. OR Gate Sleep Logic

2.5 Motor Driver Connections

The three control signals sent to the DRV8837C motor driver are VDARK, VLIGHT, and SLEEP, as shown in Figure 9. The VDARK and VLIGHT commands are sent to the two inputs on the DRV8837C, which control the direction of current flow through the H-bridge. The solenoid inside of the IR filter connects to the two output pins of the DRV8837C. If either IN1 or IN2 pins are pulled up to 5 V, the SLEEP pin is also pulled up to 5 V, which wakes up the driver to open or close the IR filter.

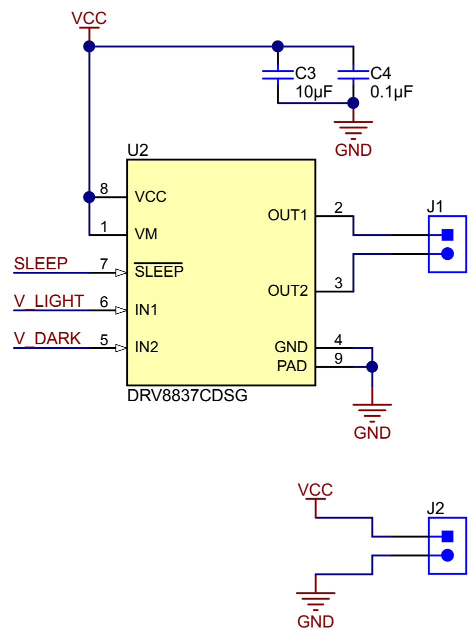

Figure 9. DRV8837C Motor Driver

2.6 Phototransistor and FemtoFET

The output of the phototransistor is tied to the gate of Q2 and each of the passive differentiators outlined in Section 2.2 and Section 2.3. When the output of the phototransistor is pulled logic high, Q2 turns on and allows current to flow from each of the IR LED banks to ground. When the phototransistor output is pulled low in a bright light environment, the gate of Q2 is pulled low, and the MOSFET turns off stopping current from flowing through each of the IR LED banks.

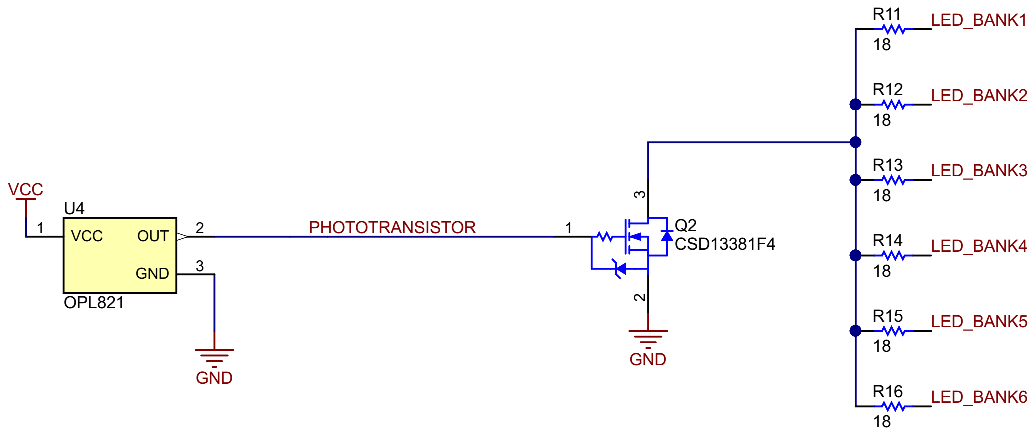

Figure 10. Phototransistor and FemtoFET

2.7 IR Filter

In order to properly filter IR light during operation in direct sunlight conditions, security cameras and other outdoor optical sensor applications require a filter be placed between the focal lens and optical sensor. This filter is shown mounted to the PCB in Figure 11.

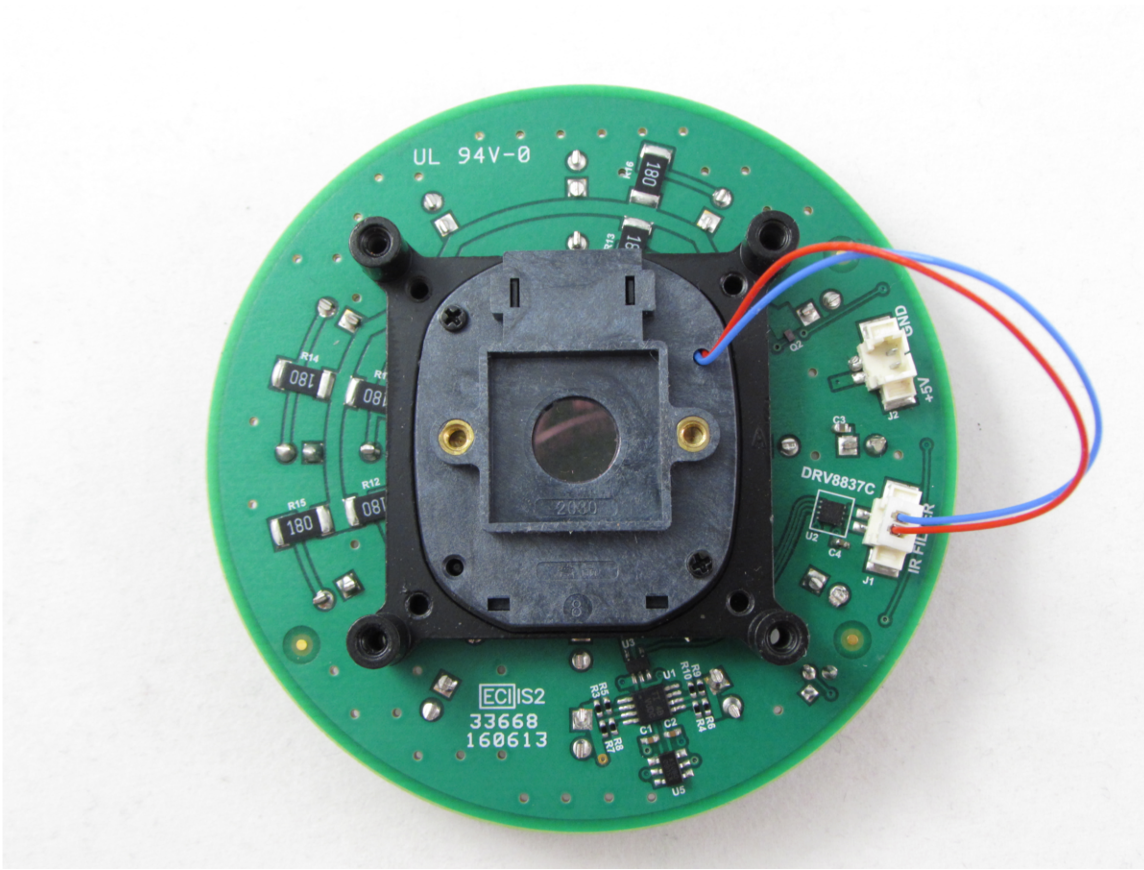

Figure 11. IR Filter Mounted to Backside of PCB

The IR filter module used for this reference design operates using a solenoid with a plastic arm connected to both a clear lens and an IR filter lens, as shown in Figure 12.

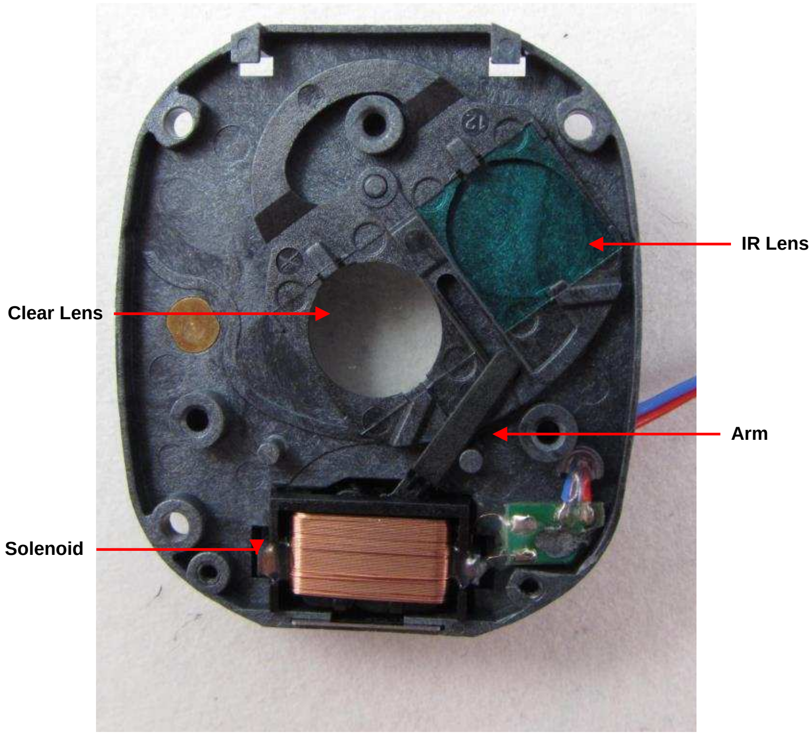

Figure 12. IR Filter Lens and Solenoid

When the solenoid is energized, the arm pulls one of the two lenses across the image port depending on the direction of current. Once the solenoid arm passes the middle point of its travel range, the spring inside the solenoid assembly keeps it in either the left or right position.

Once the solenoid has shifted the lens in either direction, the solenoid no longer needs to be energized because the tension in the spring will hold the lens in place. Using the mechanical tension in the spring, the DRV8837C motor driver no longer needs to be conducting current and can be put in a low-power sleep state where the H-bridge is disabled, and no current flows through the solenoid.

3 Getting Started Hardware

3.1 5-V Supply

This design is intended to run on a 5-V rail and will require 1.3 A when all LEDs are active. A device capable of supplying this amount of power should be connected to J2.

3.2 Mounting IR Module

The reference design PCB can be mounted to the IR filter module by lining up the four drill holes in the PCB with the four mounting points on the IR filter module, as shown in Figure 13. The round bezel of the filter module can be placed inside of the circular cutout in the center of the reference design PCB. Once mounted, the filter module bezel should sit flush with the top side of the PCB.

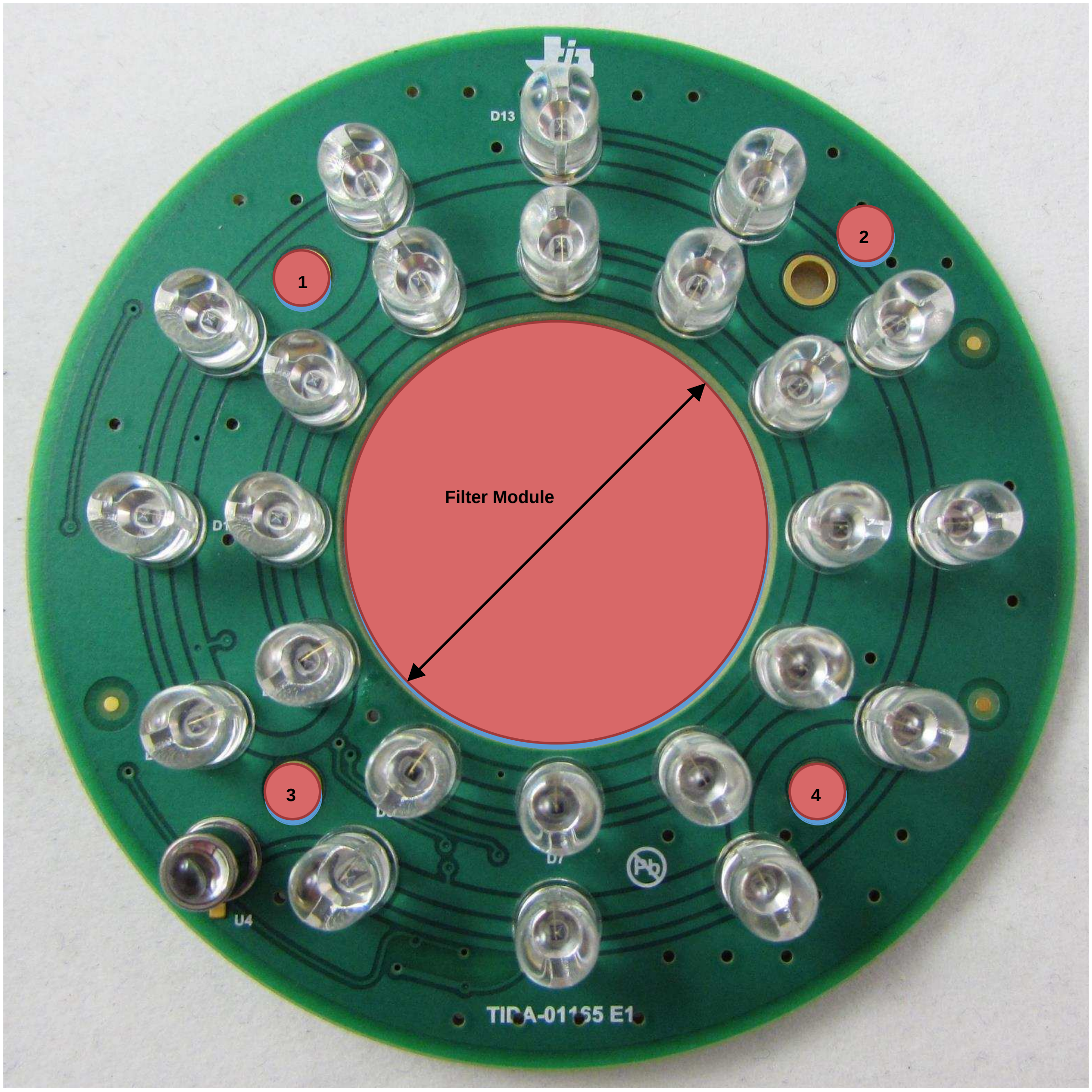

Figure 13. IR Filter Module Mounted to Front Side of PCB

4 Testing and Results

4.1 Comparator Pulse Generator

The phototransistor selected in this design is a binary device that outputs either a high or low signal dependent on the light intensity directly above the sensor case. The output of the phototransistor is then filtered through an analog differentiator and sent to two independent comparator circuits to generate an open or close pulse that is sent to the DRV8837C motor driver in the system. Overview of pulse generator is shown in Figure 14.

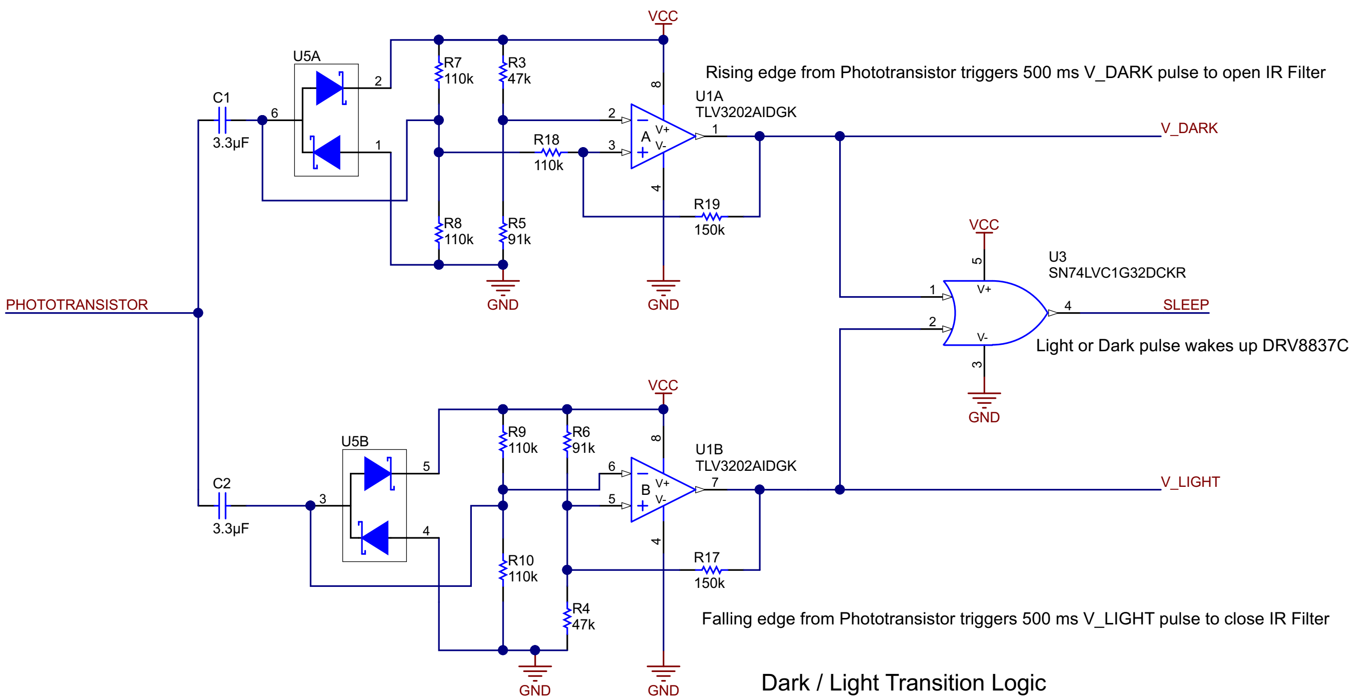

Figure 14. Comparator Pulse Generator

When the sensor triggers going from a light to dark environment, the phototransistor output will rise from low to high. Figure 14 shows the comparator circuit for this analysis. The voltage across the passive differentiator is labeled as V_{C1} in Figure 15. When V_{C1} rises above the static V_{P2} voltage, the output of the comparator (V_{DARK}) pulls to the 5-V rail until the V_{C1} voltage drops below the static V_{P2} value. The pulse generation for a low-to-high transition on the phototransistor is shown in Figure 15.

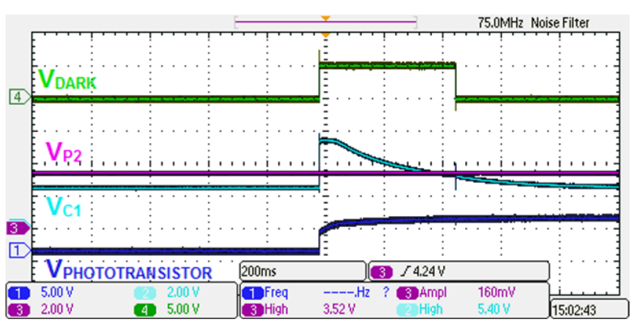

Figure 15. Open IR Filter Pulse Train

When the sensor triggers going from a dark to light environment, the phototransistor output will rise from high to low. Figure 14 shows the comparator circuit for this analysis. The voltage across the passive differentiator is labeled as V_{C2} in Figure 16. When V_{C2} falls below the static V_{P5} voltage, the output of the comparator (V_{LIGHT}) is pulled to the 5-V rail until the V_{C2} voltage rises above the static V_{P5} value. Figure 16 shows the pulse generation for a high-to-low transition on the phototransistor.

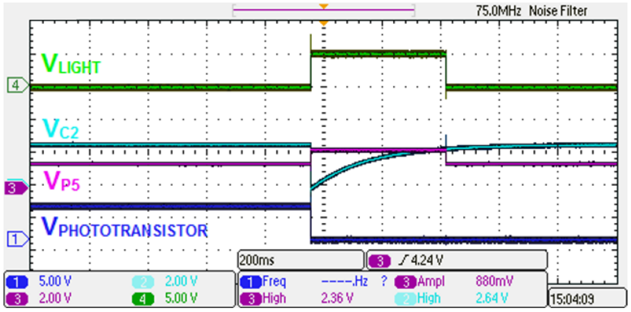

Figure 16. Close IR Filter Pulse Train

Both outputs from each comparator circuit are fed into the two inputs of the DRV8837C motor driver. These signals are also connected to a low-cost OR gate that generates a signal on the SLEEP pin of the DRV8837C. When neither output is high, the motor driver is put into its low-power sleep state. If either pin is pulled high by the comparator circuit, the OR gate sends a logic-high signal of equal time to the SLEEP pin for the motor driver to wake up and open or close the IR filter. Figure 17 shows the pulse train generated by both comparator outputs and the OR gate.

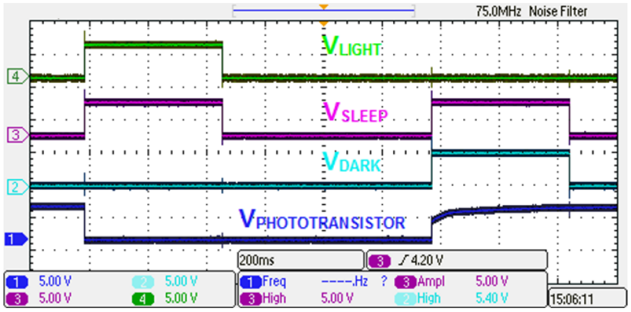

Figure 17. OR Gate Sleep Signal

4.2 IR LED Intensity

When the phototransistor detects a low-light environment, the output pulls up to 5 V. This signal is tied to the gate of an N-Channel FemtoFET, which begins conducting current from the 24 IR LEDs common anodes to ground. Figure 18 shows an image of the IR LEDs illuminated in a dark environment. The IR LEDs emit light at a wavelength of 890 nm, which the human eye perceives as a dim red glow. Figure 18 and Figure 19 were captured using an optical sensor that represents this wavelength of light as a purple-white color.

Figure 18. IR LED Illuminated Ring

Figure 19 shows an example of the light intensity from the LED ring. The two thumb tacks shown on the small block are approximately 6 inches away from the optical sensor and LED ring.

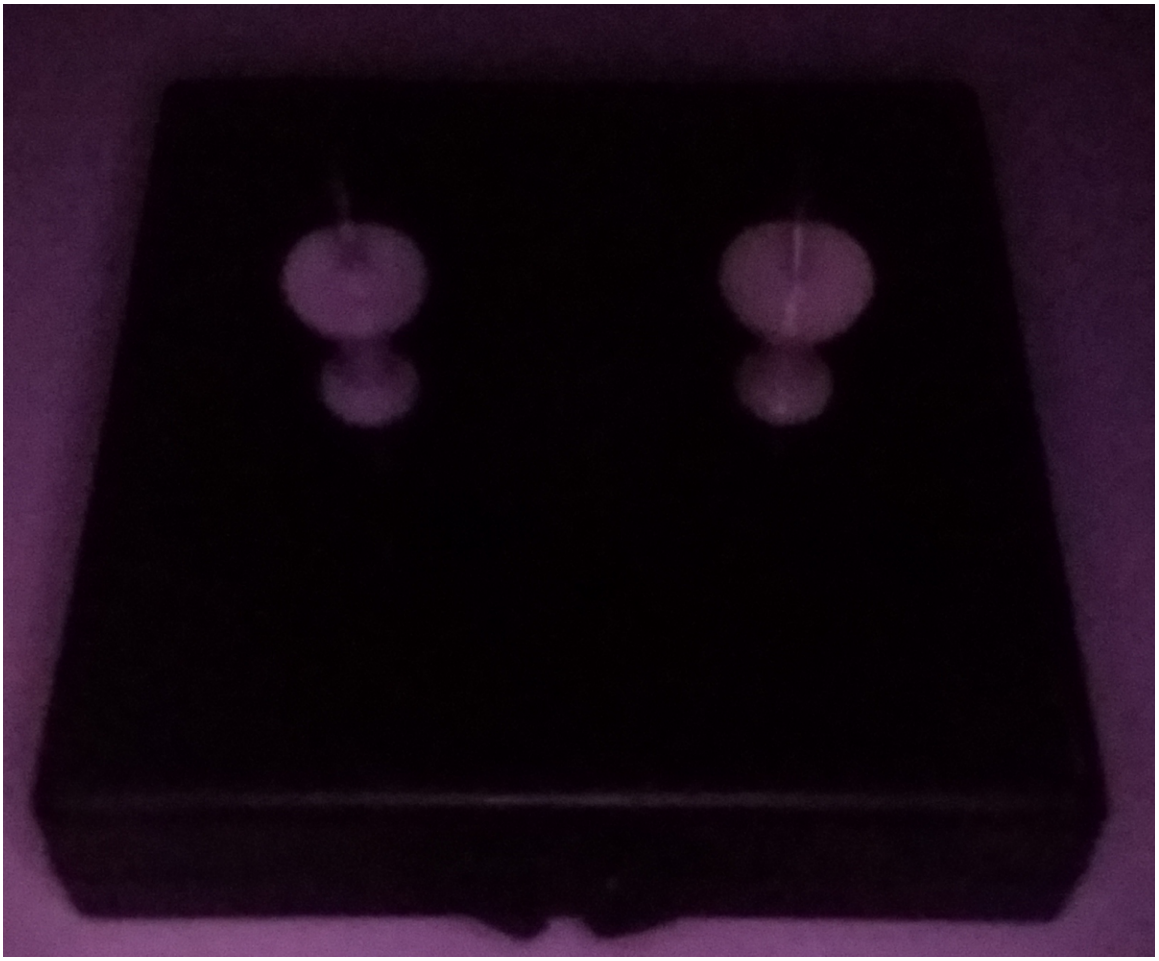

Figure 19. IR LED Illuminated Two-Tone Image

4.3 DRV8837C Bidirectional Control

By using the DRV8837C for this design, the direction of current through the IR filter coil can be controlled using the smallest possible form factor. A discrete solution would require four different MOSFETs in the design as well as the required control circuitry to switch the MOSFETs on and off. Figure 20 shows an example of the bidirectional current control using the DRV8837C.

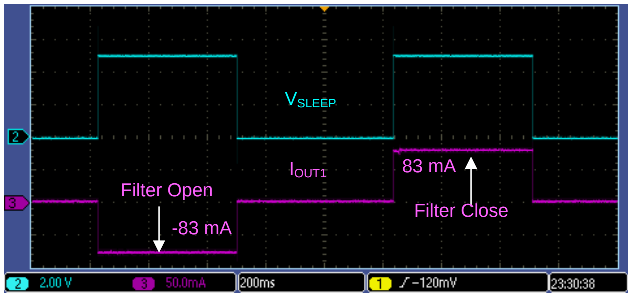

Figure 20. Bidirectional Current Measurements

The bidirectional current shown in Figure 20 shows the DRV8837C applying 83 mA in two different directions in relation to the IR filter coil. This application causes the IR filter to open and shut depending on the direction of current through the coil. Figure 20 also shows the V_{SLEEP} voltage rising, which causes the device to wake up from its low-power sleep mode.

4.4 DRV8837C Sleep Current

When the device is not opening or closing the IR filter, the device can be put into a low-power sleep mode where the driver will turn off the internal H-bridge into a high-impedance state and turn off all unnecessary logic. Figure 21 shows an example of the difference in sleep current and coil current consumption.

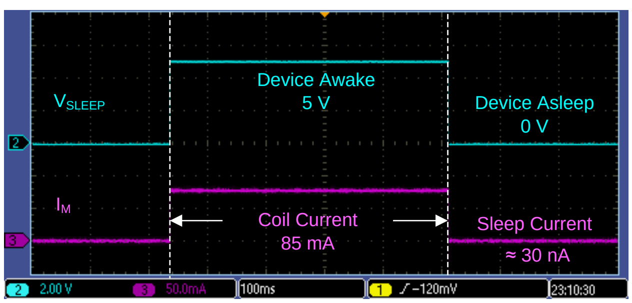

Figure 21. Sleep Current Operation

When the voltage on the DRV8837C's nSLEEP pin is low, the device will stay in a low-power sleep state and no current drives through the IR filter coil. In this design, the nSLEEP pin on the DRV8837C is tied to the output of an OR gate connected to both input pins on the DRV8837C. When either input pin is pulled high, the DRV8837C comes out of its low power sleep state and responds to the logic state on either of its input pins. Figure 21 shows this operation by the 85 mA of current flowing through the coil while the device outputs are on and then the resulting 30 nA of current while the device is in its low-power sleep state.

5 Design Files

5.1 Schematics

To download the schematics, see the design files at TIDA-01165.

5.2 Bill of Materials

To download the bill of materials (BOM), see the design files at TIDA-01165.

5.3 Altium Project

To download the Altium project files, see the design files at TIDA-01165.

5.4 Gerber Files

To download the Gerber files, see the design files at TIDA-01165.

5.5 Assembly Drawings

To download the assembly drawings, see the design files at TIDA-01165.

6 Related Documentation

1. Texas Instruments, *Comparator with Hysteresis Reference Design*, TI Design Guide (TIDU020)

6.1 Trademarks

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7 About the Author

PHIL BEARD is an Applications Engineer at Texas Instruments, where he is responsible for developing reference design solutions for automotive and industrial motor drives. Phil brings to this role his experience in analog circuit theory and power stage hardware design. Phil earned his Bachelors of Science in Electrical Engineering (BSEE) from Michigan State University in East Lansing, MI.

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