UCDAVIS

Alpha Report Group India

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Abstract

A digital camera is based on a grid of photo-diodes that generate electrical **current** in response to incident light. This signal can be amplified, converted to a **voltage**, and processed through an analog-to-digital converter (ADC) to create digital data. The array can be read sequentially by using a multiplexer, which is regulated by a button on the PSoC micro-controller. The ADC data is sent to a computer over serial communication. This information is then converted and displayed as a gray-scale image on a computer, with each photo-diode corresponding to a single pixel. Each pixel is shown as a shade of gray based on the brightness of the light that was captured by its accompanying photo-diode. .

Project Description

The project aims to design and develop a digital camera that uses photo-diodes as an image sensor. Photo-diodes are light-sensitive devices that convert light into electrical signals, making them an ideal choice for capturing images in digital cameras. Trans-impedance amplifiers are used to convert the **current** generated by the photo-diodes into voltages that can be converted by the ADC. This project will demonstrate how an array of photo-diodes can be used to gather information from the light on the array, and display this as an image on a computer.

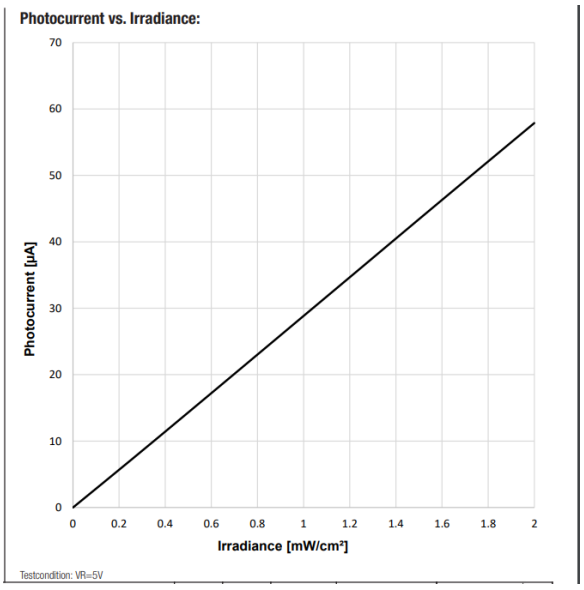

Figure 1: Photocurrent vs Irradiance

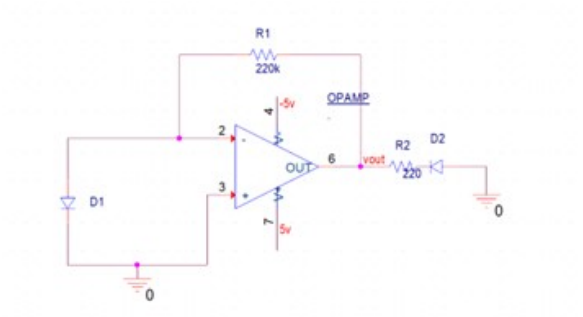

Figure 2: Trans-impedance Amplifier Circuit

Sensors

Photodiode (D1 in Figure 1) is connected so that the cathode is connected to the negative input and the anode is connected to the positive input of the OpAmp. When light is detected by the diode, it generates a small **current**. The amount of **current** produced by the photodiode is linear with the intensity of the incident light. This **current** is amplified and converted into **voltage** by the transimpedance amplifier (Figure 1). The sensitivity of the photodiode can be adjusted by changing the feedback resistor value (R1 in Figure 1). This **voltage** can be read by an ADC and converted into a digital number, which can be transformed into a shade of gray in a grayscale image.

System Design

The image sensor, a photo-diode, is the most crucial component of a digital camera, responsible for capturing the light and converting it into an electrical signal. A multiplexer is used to select and route signals from different sensors to the PSoC micro-controller board. The multiplexer allows for a reduced number of wired connections and greater control over the system. Instead of requiring connections from each photo-diode to its own ACD, the multiplexer allows all four photo-diodes to be read sequentially by a single ADC channel. The ADC converts the output **voltage** from the amplifier into a 12 bit digital signal read by the PSoC. MATLAB is used to convert this signal into 8 bit data so it can be displayed as a gray-scale image. The Op Amps (TL072IP) have high power consumption. Sinc, each photo-diode uses its own amplifier each circuit consumes approximately 20mW of power. This is manageable for a prototype due to the minimalist nature of a 2x2 pixel array. The power consumption will scale with the number of pixels in the array, which could result in an unreasonably high power consumption for larger arrays. An 8x8 array of pixels would draw approximately 1.3W which is excessive for a design that is ultimately intended to be a small handheld device powered by a single battery.

Firmware

The PSoC instructs the hardware how to function. Using pin 9.4, we enabled the multiplexer with active low signal. The channels of the multiplexer are addressed using pins 9.0 though 9.3. When the built in button on the PSoC is pressed, the multiplexer channels are addressed in sequence and the **voltage** data of the photo diode circuits are each read by the ADC. The ADC module has a 12 bit resolution. Pin 10.0 is set up to be the positive input and pin 10.1 to ground. The 12-bit output of the ADC is a signed binary number, which means it can convert both positive and negative voltages into digital numbers. Because the photo-diode circuits produce only positive voltages, the most significant bit of this signal (bit 12) is not used. Currently, all ADC results are transferred to a computer through serial communication via the UART module on the PSoC board. The data can be viewed through a serial terminal such as PuTTY. A built in function is also used to convert the ADC value into a **voltage** reading which is displayed for troubleshooting purposes.

Software or Mobile App

Using MATLAB a program will read the ADC values from a text file and convert them into a 2x2 gray-scale image. By default, MATLAB images have an 8-bit color scale. This program therefore converts the 12-bit ADC value into an 8-bit number by discarding the signed bit (bit 12) and the three least significant bits (bit 0, 1, and 2). The signed bit can be ignored because the photo-diode circuits produce only positive values, while the three least significant bits will be sensitive to noise and are therefore less important for constructing the overall image. Currently, ADC data is transferred from the PuTTY terminal to a text file manually. Future iterations of this software are intended to read the COM port directly and automatically import the data into MATLAB.

Project Budget

The total bill of materials for this project was $163.15. Our team of five members worked approximately 10 hours a week and were hired for $47/hr, which is approximately the average hourly salary for an entry-level electrical engineer in California. This total comes out to $2,350 for each week of work. The total with part is $2,513.15 at the **current** milestone.

Conclusion

The **current** design of our gray-scale image processing device receives input from the light sources around it and relates it into a gray-scale image. For the next steps, our team will work toward lowering the overall power consumption of the circuit, determine the best method for sending serial data automatically into MATLAB, and better utilize the multiplexer to simplify our design. The alpha prototype functions as expected and the key concept of the design allows for a four bit image to be generated based on the light received by the photo-diode array.

References

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