

# Phototransistor based Feedback Array Circuit for Robot Navigation

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**Abstract** - The proposed feedback system is focused on path following hardware and surface colours that are useful in robotics and automation for navigation. Arrays which are built with IR or photodiodes don't work on materials like wood, shiny tapes, gypsum board etc. The observations from various robotics applications are that the arrays used for navigation consume more than one input port of micro-controller, which led our approach to include features of SPI communication. The obvious advantage of this system is the ability to connect more than one array on the same SPI port. In an application which uses three arrays, it normally takes three 8 bit ports, but in this implementation only one SPI port will be used.

The main objective of this paper is to highlight the use and need of a line following array capable of differentiating any background colours with white line and at different light conditions with manual adjustment.

**Key Words:** Photo transistor array, light sensor; photo transistor array ;line following array; robot sensing; SPI communication.

## 1. INTRODUCTION

Path following systems play a vital role in navigating robotic systems accurately. Previously photo-diodes were used in arrays which give inconsistent output and need calibration for every new surface. For a square or rectangular robot we needed more than an array, so to connect all arrays at a single 8-bit port of a micro-controller and to overcome the problems. I designed the system consisting of photo transistor light dependent sensors AN3005[1] and blue light. 4bit ADC LM339[2]. The outputs of both ICs are coalesced to 8-bit digital code and further transmitted through MCP3208[3] SPI conversion IC for communication with micro-controller[4][5]. Since SPI has the flexibility to connect to 128 slaves and select them serially, it becomes easy to select 4 arrays one after the other or simply, consequently in the algorithm of the path following[5].

### 1.1 Basic system description

The basic design flow of the system is as shown in the flowchart (fig 1).

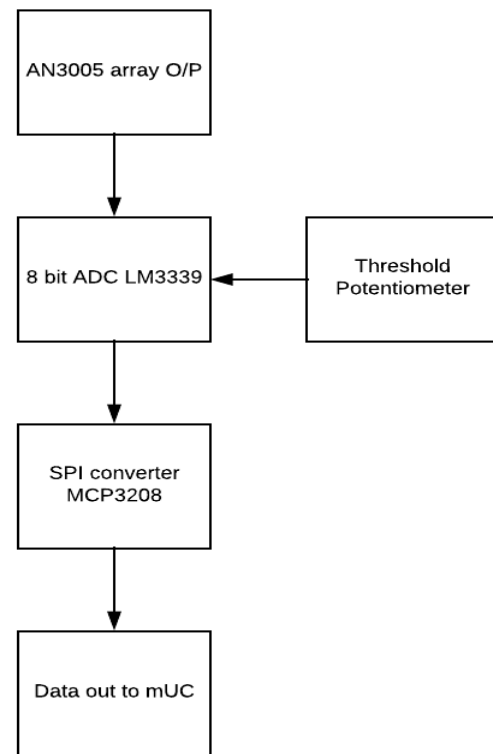


Fig.1. Block diagram.

The circuit for this logic is divided as:

- A) Row of 8 sensors with ADC.
- B) Transmission of 8-bit digital code.

Each sensor is a photo transistor biased with 10K resistor and output is driven at emitter end in common collector mode (shown in Fig.3). The common-collector amplifier (Fig.3) produces an output which transits from a low state to a high state when light is incident on a photo transistor. The output is read at the emitter terminal[1]. When the amount of light surpasses that level, the photo transistor becomes saturated and the output will not increase even as the light level increases. This mode is useful in applications where it is desired to detect two levels of inputs for comparison[1]. Operating in the switch mode means that the photo transistor will either be "off" (cut-off) or "on" (saturated) in response to the light[1].

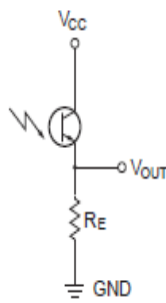


Fig. 2.[1]

This mode is useful when a digital output is required for colour detection.

By adjusting the potentiometer (Fig.4) as shown in the amplifier circuit one can set the mode of operation. The correct value for the resistor can be determined by *Active Mode* where  $V_{in} > R_L \times I_c$  [1]

The output voltage variation of each sensor depends on the wavelength of the light incident on it (Fig.3). The graph will show the slope of varying voltage with wavelength which was close to blue light (500nm). Since this test required more differential change in wavelength, blue light was the most effective.

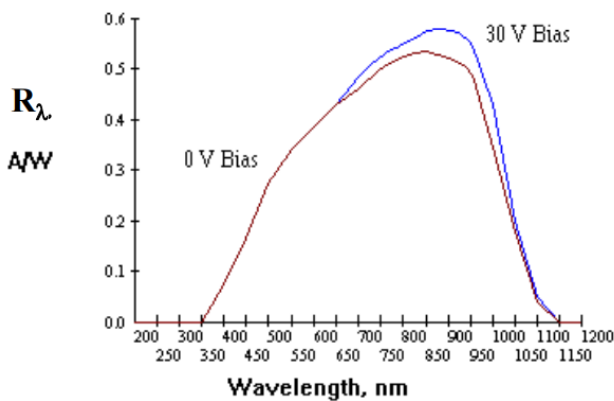


Fig. 3. Variation of wavelength [8].

As per tests in normal lighting conditions and results from the research of optical detectors [8], the high level output voltage in the switching mode should equal the supply voltage  $V_{in}$ . The low level output voltage in the switching mode should be less than 0.75-0.78 V.

With most micro-controller SPI ports, it is required to send groups of eight bits. It is also required that the micro-controller SPI port be configured to clock out data on the falling edge of the clock and latch data on the rising edge. Because communication with the MCP3008 devices may not need multiples of eight clocks, it will be necessary to

provide more clocks than are required [3][7]. The 10-bit operation of MCP3208 is used for this purpose (Fig 8).

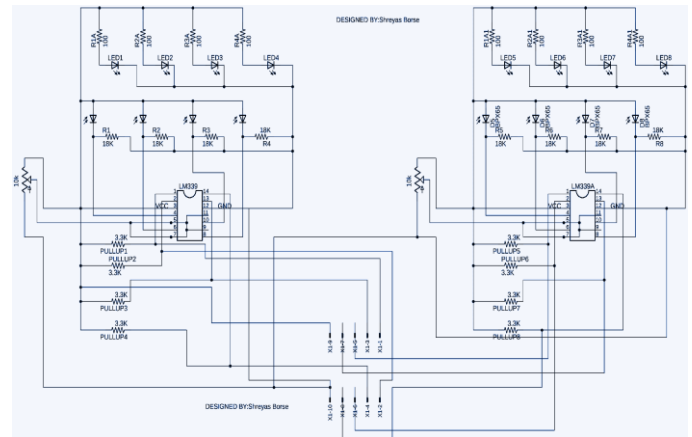


Fig 4 .Schematic of prototype.

### 1.2 Functioning with MCP3208

MCP3208 is a 2.7V 8-Channel, 10-Bit converter with SPI Serial Interface. This IC is the main component of the system for converting ADC output of an array to a block of 1 byte for transmission. It works on low power with 10-bit resolution [3][7].

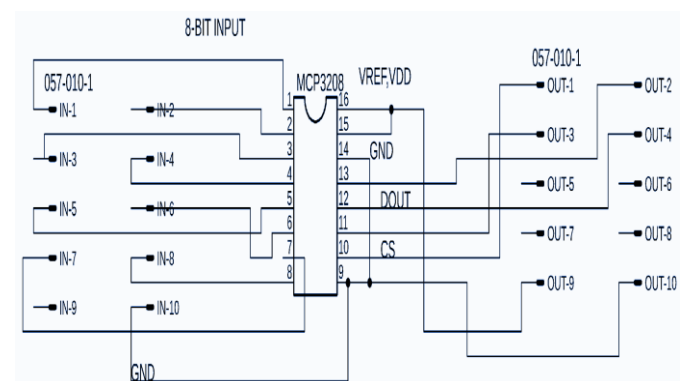


Fig 5. Connections of MCP3208.

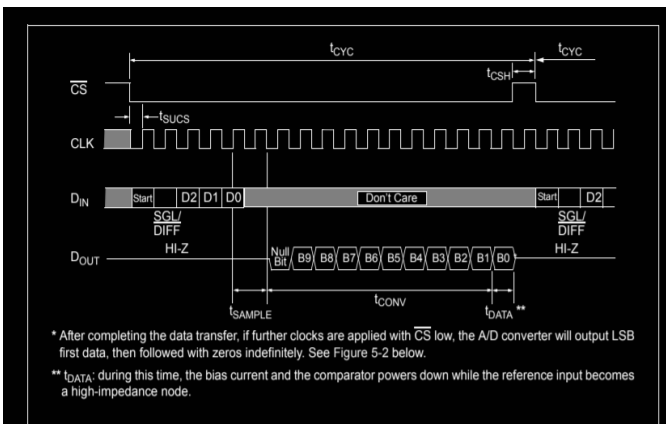


Fig 6.[3] Transmitted block from MCP3208.

The output code depends on the reference voltage i.e.  $V_{ref}$ . Code length =  $1024 * V_{in} / V_{ref}$  bits; As  $V_{ref} = V_{in} = 5V$  then code is equal 1byte [3] for a single array. This is interfaced with SPI port B on Atmega2560[4]. where PB0-SS Slave select; PB1-SCK; PB2 - MOSI; PB3- MISO.

The basic receiving SPI code is executed on a micro-controller and the received block is converted to an 8-bit data set for controlling motion parameters and indication.

While using multiple arrays, slave select is used to choose the address of each slave which allows data input of each slave. For example, If 4 slave arrays are interfaced, we have to take 2 digital pins to connect the different slave arrays. Values at both digital pins will decide slave selection and 4 byte data is received at the micro-controller end.

- 0 0 - 1<sup>st</sup> slave
- 0 1 - 2<sup>nd</sup> slave
- 1 0 - 3<sup>rd</sup> slave
- 1 1 - 4<sup>rd</sup> slave.

The advantage here is that the number of pins engaged will be the same and the microcontroller will be comparatively less loaded for direct computing of analog values.

## 2. EXPERIMENTAL RESULTS.

The complete assembly consisting of an array printed circuit board connected to MCP3208 followed by micro-controller was tested at different colored boards as shown (Fig 7).

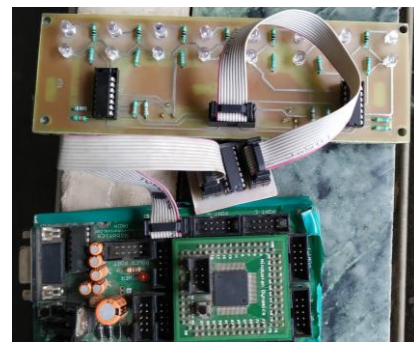


fig 7

The array was tested on an orange wooden board (Fig 9) with white grid line and potentiometer set manually according to the threshold value of the reflected colour wavelength at a height of 2cm from the wooden board. The reference voltage of 4 bit comparators and the output is shown on an 8 LED indicator.



Fig 8.

The red LED indicator subsequently shows the output of each sensor on white line. The Atmega2560 reads the received block and also it reflects back as output on the LED indicator.



Fig 9.

Here, sensor 6 and sensor 7 are on the white path, so we can see the output on the indicator (fig.10) 6<sup>th</sup> and 7<sup>th</sup> leds are low. And output of the sensor 8 (right most in fig 9.) is high even though it is away from the wooden board, this shows that all sensors are successfully meeting out the threshold.

### 3. CONCLUSION

This photo transistor array prototype was successfully tested and implemented on a four wheeled drive robot and can be used on any surface. Also we can use green light instead of blue but the threshold value is to be changed manually by the potentiometer. The circuit is cost effective and more reliable in external light source interference. SPI communication is a major advantage if we want more number of arrays at a given time with any micro-controller.

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