# Gray Scale Detection using IR Sensor

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***Abstract*—This project mainly focuses on determining end of life of printer cartridge.Two different IR sensor based circuits have been used to detect different gray scales.In order to make the system insensitive to ambient light (noise), concept of phase sensitive detection has been used.Concepts of Scientific methods i.e. repeatability and reproducibility of measurements have also been used with 3 different samples over the span of 14 days.**

***Index Terms*—IR Sensor, Phase Sensitive Detection, Repeatability, Reproducibility.**

## I. Introduction

To check whether the printer cartridge needs an ink refill or not, one has to manually check the clarity of the printed text on a paper.It is not possible every time to intervene manually to check such things in fully automated environment i.e. electronic voting machine.As the ink of the printer reduces,it will print the paper with lower gray level.So one can decide whether the text on a paper is readable or not based on the gray level of text.IR sensor has been used to detect different gray scales.

IR sensor which comprises of IR LED and Photo-receiver, provides different responses for different gray level.Since photo-receiver is sensitive to ambient light sources, operating distance etc., one has to make sure of all these parameters while measuring the results.

Two different circuits have been analyzed to detect gray scale i.e. 1) Using Integrated IR Transceiver Pair and 2) Using IR LED and Photo-diode separately.

## II. Circuits Explored

### A. Using Integrated IR Transceiver Pair

*1) TCRT5000 Transceiver Pair:* TCRT5000 integrated IR sensor has been used as detection device, which can transmit light and measure light reflected from object as well. TCRT5000 is reflective optical sensor with transistor output.It includes day light blocking filter within the integrated package, so it becomes very easy to use as no complex circuitry required for filtering unwanted day light signal. Depending on the amount of light falling on photo transistor, collector current varies accordingly. This current is converted to voltage and fed to preceding circuit. White color reflects light and black color absorbs light completely. Therefore very less current flows through transistor in case of black color and more current in case of white color.

As shown in Fig.1, both IR LED and photo transistor are inclined towards each other. When object is absent, no reflection being detected through photo transistor. When object is present, reflection from object falls on photo transistor and current will start flowing.

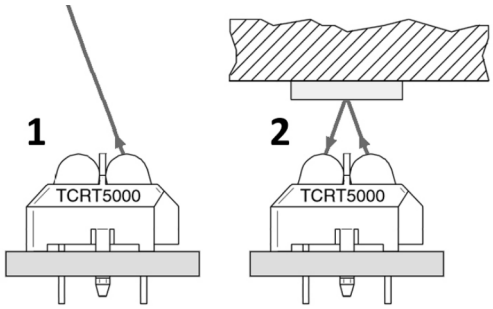
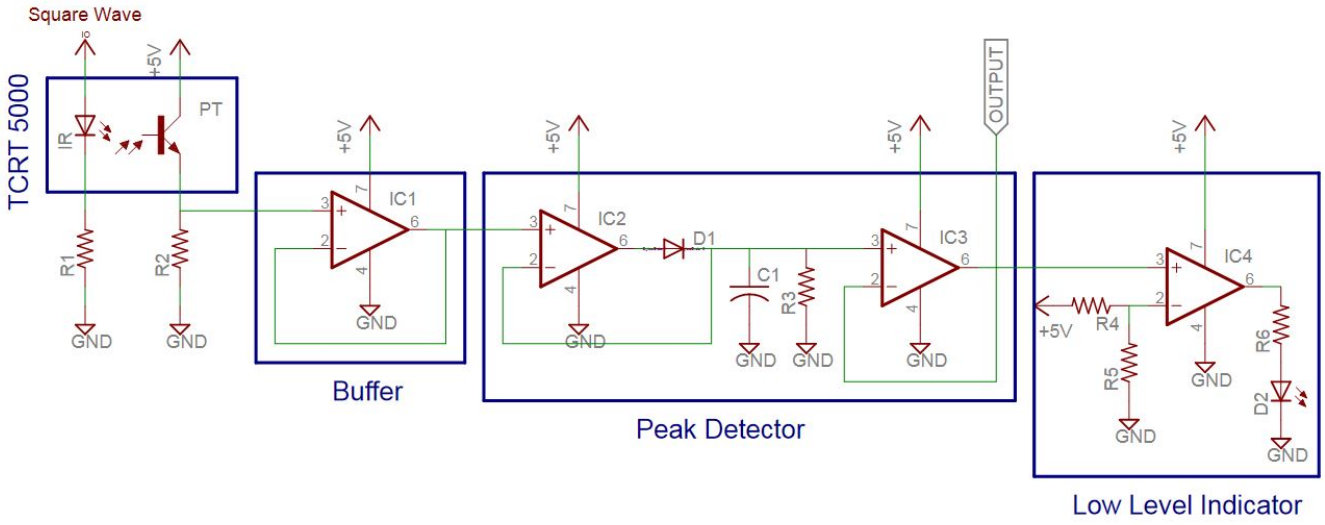



Fig. 1: (1) No object close to sensor (2) When object comes closer, IR light reflected to photo transistor

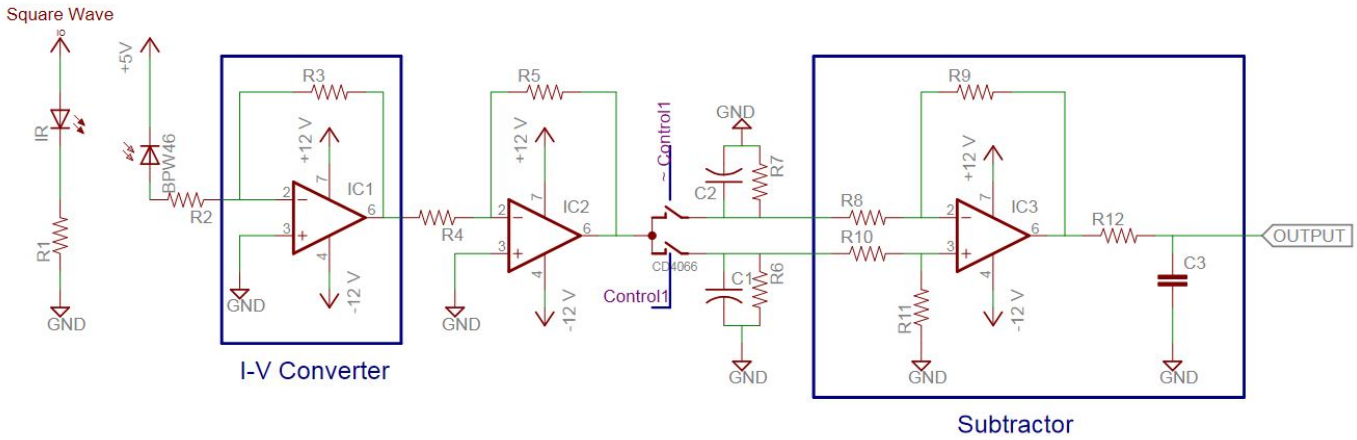
IR LED has been excited by $1kHz, 3V Squarewave$ signal and resistor $R2$ converts photo transistor current into voltage as shown in Fig.2a. Buffer has been used to provide high input impedance to TCRT5000 sensor circuitry.

*2) Peak Detector:* Peak detector circuit has been used to convert input $AC$ voltage signal into $DC$ level as final output of system. Excitation of $1kHz, 3V$ has been used for IR LED. During on cycle, photo transistor gives desired output caused by IR light and during off cycle(in the absence of IR light) it does not give any output. So, during off cycle, output has been held at previous state by capacitor $C1$ as shown in Fig.2a. Operational amplifier based peak detector circuit has been used to avoid forward voltage drop of diode during on state.

*3) Low Level Indicator:* Red LED has been used as a warning indicator. When printer cartridge level goes below certain level, printing on paper becomes very light and it is not easily readable. At that time red LED glows as a warning. It indicates that cartridge needs to be replaced now. By feeding this signal to controller, automation can be introduced in system and printing will automatically be stopped by controller itself. Different threshold level(Gray levels) can be detected by varying threshold voltage at inverting pin of operational amplifier using resistors $R4$ and $R5$ as shown in Fig.2a.




(a) Using TCRT5000 integrated transceiver




(b) Using IR LED and Photo-diode(BPW46)

Fig. 2: Various Circuit Implementation

### *B. Using IR LED and Photo Diode*

*1) IR LED and BPW46 Photo-diode:* In this implementation, IR LED and photo-diode have been used separately as shown in Fig.2b. IR LED has been excited by $1kHz, 5V Squarewave$ signal. Photo-diode BPW46 is sensitive to all lights(IR as well as any visible light). Some special kind of circuit is required to avoid unwanted signals coming from various light sources. Phase Sensitive Detection(PSD) concept has been used to recover data signal buried under noise.

BPW46 is silicon PIN photo-diode. It operates in reverse biased condition. It converts light into current. Generated current is proportional to falling amount of light.

*2) I-V Converter:* For converting photo-diode current into voltage, operational amplifier based I-V converter circuit has been used as shown in Fig.2b. An amplifier has been used for further amplification of signal.

*3) Phase Sensitive Detection:* IR LED has been excited by $1kHz, 5V Squarewave$ signal. During $ON$ cycle, desired output as well as noise due to external light sources has been obtained at the output of amplification stage. During $OFF$ cycle, IR LED remains off, so only noise(unwanted) signal of external light sources has been obtained at the output of amplification stage.

By using PSD circuit, unwanted noise can be removed. Special switching circuit is required for the same. For switching, $CD4066$ integrated chip has been used. $CD4066$ is CMOS bilateral switch, which connects input and output ports when control signal is high and disconnects them when control signal is low.

Output signal of amplification stage has been given to two switches. Two control signals of switches are same in ampli-

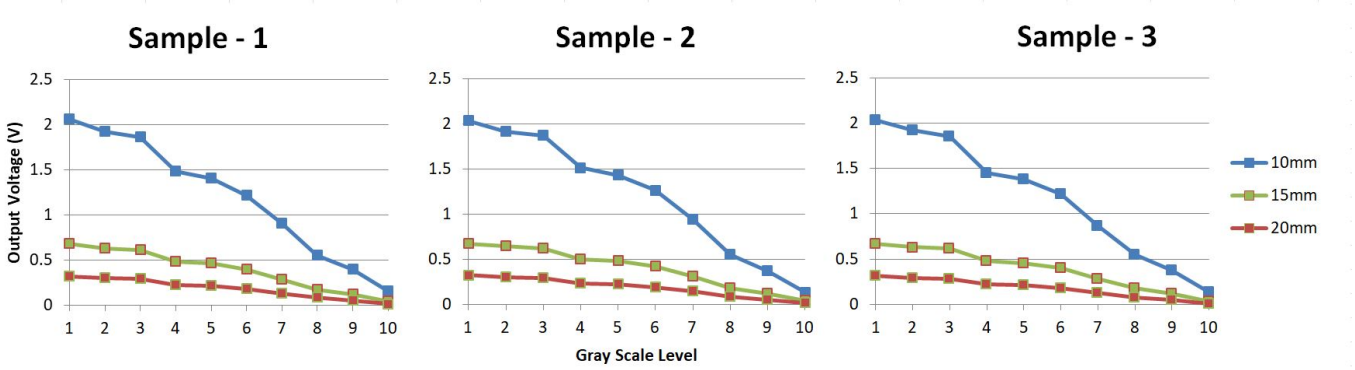



Fig. 3: Gray scale response of 3 samples with different operating distance

tude and out of phase by $180°$. One control signal(Control1) is of same frequency and in phase with excitation signal applied to IR LED and another control signal($\sim$Control1) is out of phase by $180°$ as shown Fig.2b. When control1 is high, desired signal along with noise is passed through switch and stored in capacitor $C1$. When control1 is low, only noise signal is passed through switch and stored in capacitor $C2$. Both capacitors hold charge during $OFF$ cycle of control signals.

*4) Subtractor:* Capacitor $C1$ has desired signal along with noise and $C2$ has only noise. Subtractor circuit has been used to obtain only desired signal from these two capacitor voltages as shown in Fig.2b. Noise has been cancelled at the output of subtractor circuit and desired signal has been recovered. Low-pass filter of cut-off frequency $2.341kHz$ has been implemented at output of subtractor to remove high frequency noise. Output of this low pass filter is final $DC$ output of system. Further decision making circuit can be used as mentioned in previous section.

## III. Experiments Performed and Results

As described above, two different circuits have been analyzed and experimented.

### A. Using Integrated IR Transceiver Pair

As TCRT5000 already has an inbuilt day-light blocking filter, the effect of ambient light is almost negligible. Since different gray levels were accurately distinguishable,results considering following parameters have been characterized.

- Operating Distance,
- Repeatability,
- Reproducibility

*1) Operating Distance:* Distance between photo transistor and measuring object decides the output.So by varying this operating distance, change in amount of reflection changes collector current of the photo transistor. Fig.3 shows response of the photo transistor for different gray scales and varying operating distance of $10mm, 15mm$ and $20mm$. As we move the object $20mm$ away from photo-transistor, the output reduces to around $20\%$ of w.r.t output we have got with operating distance of $10mm$.

*2) Repeatability:* Repeatability is the variation in measurement taken by the same observer with same setup and conditions over certain period of time.If the variation observed is smaller than the acceptance value then the measurement is said to be repeatable.

In order to check repeatability of the system, measurements have been taken for 3 different samples over 14 days with same instruments and observer. Fig.4 shows the repeatability curve of the voltage difference between $gray2$ and $gray3$ levels, where $gray1$ represents white and $gray10$ represents black color. While taking measurements, it has been observed that text with gray3 level is quite readable while text with gray2 is very difficult to read.So the transition of gray scale from 3 to 2 has been considered as threshold. If sensor detects gray scale lower than gray3, it indicates low level by glowing red LED in this case.

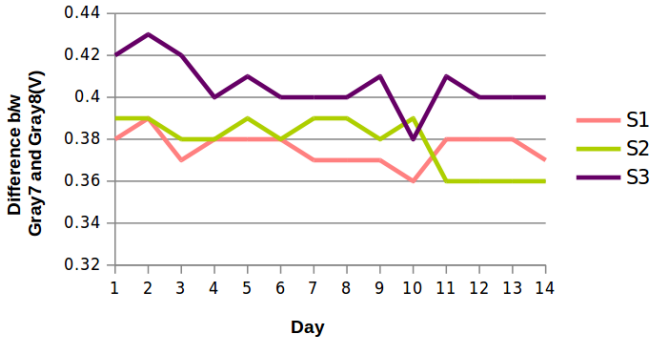



Fig. 4: Repeatability with readings of around 14 days

*3) Reproducibility:* Reproducibility is the variation in measurement taken with different samples at different time. Concept behind this is that the system should reproduce similar results/conculsions for different input samples. In order to check reproducibility of the system, measurements have been taken for 3 different samples at different time over 14 days. Fig.5 shows reproducibility curve of all the three samples.


Fig. 5: Reproducibility with three different samples

### B. *Using IR LED and Photo Diode*

Since the earlier circuit ( using TCRT5000 ) has an inbuilt day light blocking filter, effect of ambient light sources was not observed. This circuit has been built and examined mainly to observe the effect of ambient light so that in general the system can be insensitive of ambient noise.


Fig. 6: System Response with Phase sensitive detection

To examine the effect of noise, the measurements were taken in absence any additional noise at first. Next the measurements were taken with white LED excited with 5V DC and 7V DC voltage consecutively as an ambient light. This white LED has been placed next to photo didoe in order to introduce maximum noise.Fig.6 shows the response of different gray scales for three different cases mentioned above.

## IV. Conclusion

While experimenting with $1^{st}$ circuit, sufficient range of voltage difference between $gray2$ and $gray3$ levels has been obtained. Repeatability and Reproducibility as a part of scientific method have been tested and verified. While experimenting with $2^{nd}$ circuit, noise introduced due to additional white LED was successfully suppressed from desired output with 40-50mV ripple. Since the voltage difference between $gray2$ and $gray3$ levels is around 600mV, ripple of 40-50mV is almost negligible for the application of gray scale detection.

## V. Contributions and Acknowledgements

Contribution of Kaushal Patel & Dhruvin Shah:

- TCRT 5000 sensor characterization
- Circuit Design
- Testing and characterization
- PSD analysis
- Result Analysis
- Report and presentation

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