How Dark Is Dark

Wadhwani Electronics Lab

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Spring 2018

Acknowledgement

- You are the first users of this newly designed experiment.
- This experiment originated as a course project by Kaushal Patel and Dhruvin Shah under the guidance of course instructor Prof. Siddharth Tallur in the EE617 (Sensors in Instrumentation, Autumn 2017) course at IIT Bombay.
- We are also thankful to WEL lab staff for the assembly of experimental setup.

Motivation

We have studied the principle of phase sensitive detection in the previous lab. In this session, we will study one of its applications: to extract a small signal from large undesired background.

1. We often experience that the contrast between the paper colour (white) and printer ink (black) decreases after use, so much that sometimes the printed matter is just not readable.
2. How about designing a circuit which can prompt us that it is the time to change the cartridge of the printer?
3. In this experiment, we shall investigate how we use the principle of phase detection to solve this problem. You will also see how robust this technique is to interfering signals (realized with a white LED)

Background

1. We shall use a photodiode (BPW46) and an LED (GaAs IR LED - can you name a commonly used object that you use often, that has such an LED?)
2. The arrangement we design will be such that LED shines light on the target surface and the reflected light is detected by the photodiode. This detector generates e^-- h^+ pairs (photocurrent) when it absorbs the incident photons.
3. Since the reflectance is different for black, grey and white colors, we expect the photocurrent value to vary with the colour of reflecting surface. (It should be noted that reflectivity will not change with wavelength).
4. The photocurrent also depends on the distance between the LED-photodiode pair and the reflecting surface, intensity of the light beam.
5. If there is ambient light, both the reflected IR light and ambient light contribute to the photocurrent. Any light that is not generated by the LED we use is ambient light, and not of interest to us.
6. We shall see how to use PSD to make the measurement immune to ambient light.

An arrangement to change the reflecting surface and the distance.

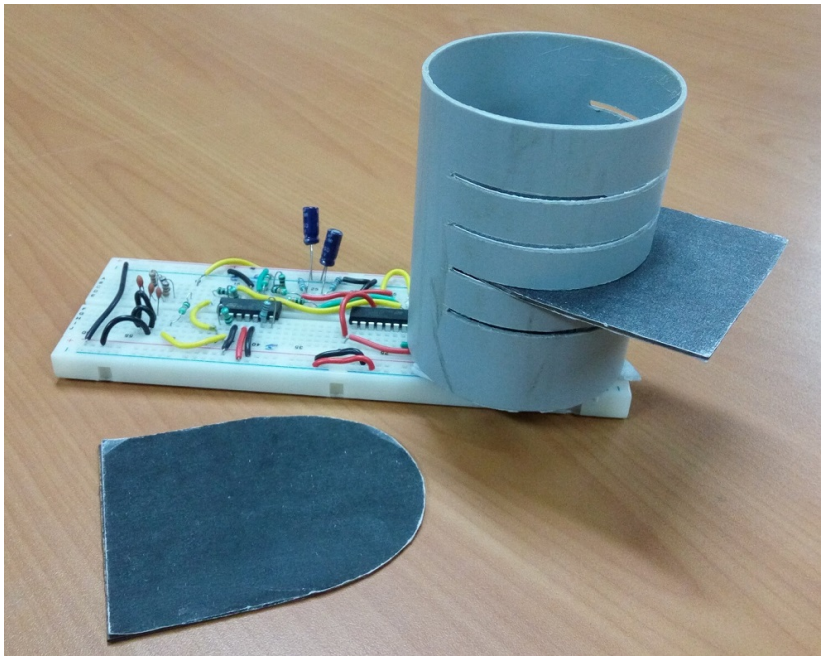


Figure: Assembly for the experiment

- Reflecting surface has two faces with different grey shades.
- There are four slots made on the PVC cylinder to insert the plate.
- The arrangement can be used to vary distance between the source and reflecting surface and grey shade (to vary the relative reflectance).

Procedure I

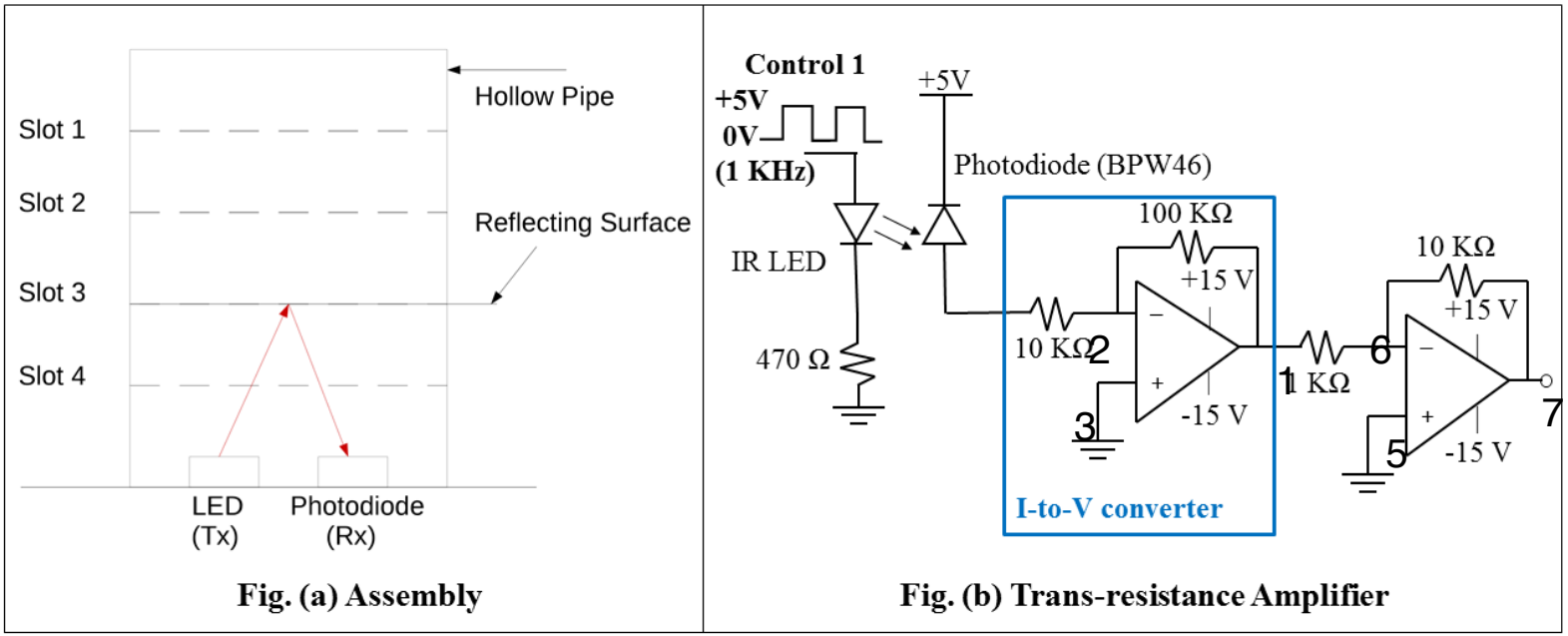


Fig. (a) Assembly

Fig. (b) Trans-resistance Amplifier

1 Place the components (LED and photodiode) a centimeter apart at the bottom of PVC cylinder and facing upward such that beam follows the path as shown in figure (a).

Procedure II

2 As shown in fig.(b), connect an IR LED in series with 470 *ohm* resistor. The photodiode is reverse biased and connected to an I-to-V converter. The output of the I-to-V converter is connected to an inverting amplifier. Provide ± 15 V supply to OPAMP (LM324).

3 Connect a dc input to IR-LED and vary it from 0 to 5V in three steps. Observe the output of amplifier on DMM in presence and absence of a specific grey scale paper sample for a specific slot.

4 Turn on a bias light - (a white light LED with a series resistor to a variable supply) close to LED-photodiode arrangement. This light acts as an ambient noise to the actual IR-LED light signal.

5 Now repeat the step 3 for two noise voltages. What difference do you see? Note down the observation.

Procedure III

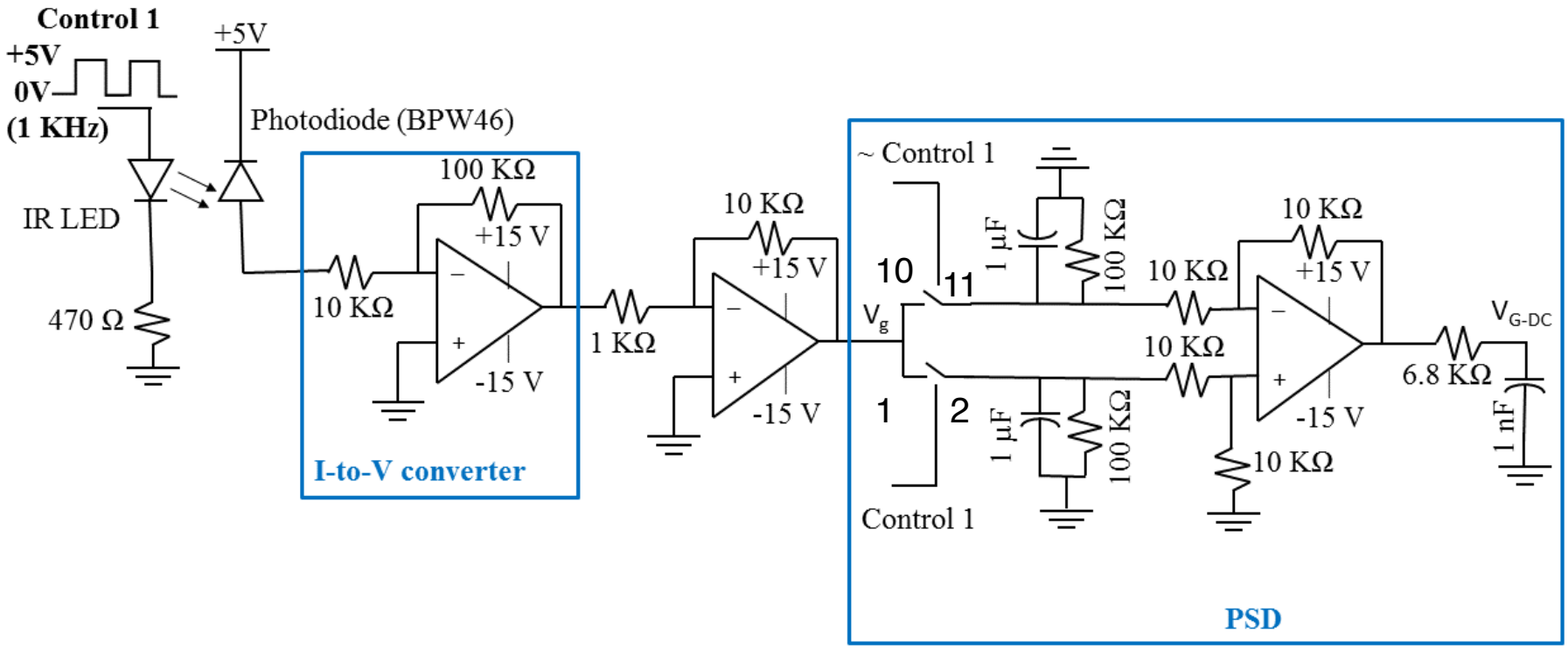
6 Get the signals viz., Control 1 and ¬Control 1 at the output of AFG both as 0 to 5Vp, 1KHz sqaure waves but 180 *degree* out of phase. Enabling 'Align phase' option on AFG makes sure precise phase alignment among two output channels.

7 Now we use CD4066B which is a CMOS Quad bilateral switch IC. Provide +5V supply to CD4066B. Check the IC by testing swicthes separately by giving constant DC input and control 1 as control signal or vice-varsa and check the output.

8 Connect the circuit labelled as PSD as shown in figure below. PSD block comprises a sample-and-hold followed by a subtractor followed by a low pass filter. State the use of 100 Kohm resistor.

9 Connect the signal Control 1 to IR-LED. Use signals control1 and ¬Control1 for switches as shown in fig below.

Procedure IV



Text

Procedure V

10 With a DMM, measure the RMS voltage of the signal (V_g) at the output of amplifier and the DC voltage after the low pass filter (V_{dc}).

11 Reduce the peak voltage to the IR-LED. Take measurements of V_g and V_{dc} at 5V, 4V, 3.5 V, 3V, and 2.5 V. This is to see what is the smallest signal that you can reliably measure.

12 Now use different shades of grey and measure the RMS signal V_g for each of the grey surface and V_{dc} at the output of the low pass filter. Make sure that the grey shade for the measurement faces the LED.

13 Observe that as the grey level gets closer to white (less black) it will not be possible to read the writing on the paper.

14 Observe on DSO the waveforms of Vg along with the voltages at capacitor nodes separately for different noise voltages (i.e. for different brightness levels of white LEDs). Comment on the job of two of the capacitors.

15 We can even connect a comparator IC 311 and set the desired reference voltage corresponding to an acceptable grey level. The output of PSD forms the other input of the comparator. Connect a buzzer at the output for audio indication.

Observations

I. Effect of changing the intensity of LED light

Vpulse	Vg	Vdc
5V		
4V		
3.5V		
3V		
2.5V		

Observations

II. Effect of noise with and without PSD for slot-3

Grey Scale	Vg (Without PSD)			Vdc (With PSD)		
	Noise= 0V	Noise= 2V	Noise = 4V	Noise= 0V	Noise= 2V	Noise = 4V
White						
Grey-1						
Grey-2						
Grey-3						
Black						

Plot the graph of Vg vs Grey scale and Vdc vs Grey scale in order to observe the significance of PSD.

Observations

III. Printer Cartridge gradually running out of ink

Slots	Vdc (With PSD)		
	Sample-1	Sample-2	Sample-3
S1			
S2			
S3			
S4			

Note Down your conclusions for all the observations made above.