EE230: Experiment 9
How Dark is Dark- an Application of PSD circuits

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March 25, 2018

1 Overview of the experiment

1.1 Aim of the experiment

The problem statement given to us is that how do we design a circuit that prompts us to change the cartridge of a printer, based on the decreasing contrast in between the paper colour(white) and the ink colour(black). In this experiment, we achieved the following :

1. Used the principle of Phase Sensitive Detection to solve this problem statement.

2. Analyze the robustness of this technique to interfering signals, realized using a white light LED.

1.2 Methods

In this experiment we used the principle that reflectance is different for black, grey and white colors, thus, we can expect the value of the photocurrent to vary with the colour of reflecting surface.The photocurrent also depends on the distance between the LED-photodiode pair and the reflecting surface and intensity of the light beam. In the presence of ambient light (Any light that is not generated by the LED we use is ambient light), both the reflected IR light and ambient light contribute to the photocurrent. We try to explore if

using PSD makes the measurement immune to ambient light.
In the first part of the experiment we build a trans-resistance amplifier circuit, followed by a PSD circuit in the next part as discussed in section 2.
Components used: IC:*LM324 CD4066B IC 311*, Photodiode: BPW46, LED: IR white,PVC Cylinder, different shades of grey, Capacitors: 1 μF, 1nF, Potentiometer: 10kΩ, Resistors.

2 Experimental Results

2.1 Part I: I-V converter/ amplifier circuits

The circuit diagram is given in figure 1, the circuit comprises of a trans-resistance amplifier in cascode configuration with a voltage amplifier.

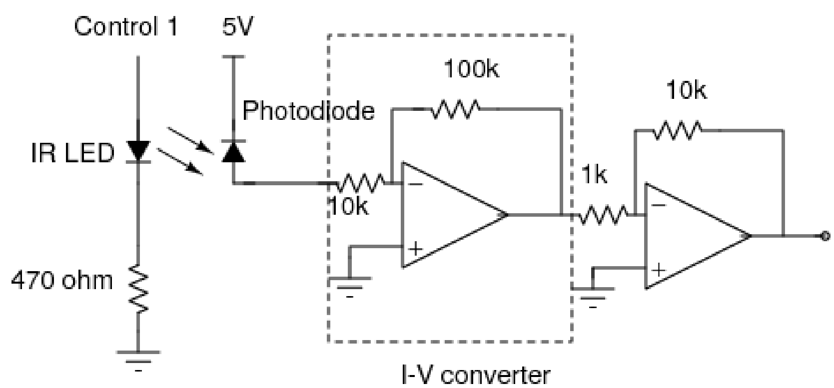

Figure 1: Circuit for part 1

To the circuit, we connect a variable DC input to the IR LED , varied from 0-5V in steps of 3. We observe the output of the amplifier in presence and absence of grey scale paper. Next we turn on the ambient light from white LED and then repeated the measurements. The readings are in the tables 1-3:

Voltage to IR LED(V)	V_g(V) (absence)	V_g(V) (presence in slot3)
0	1.04	0.24
2	1.12	0.33
3	1.33	0.41
5	1.71	0.82

Table 1: measurements for no noise

Voltage to IR LED(Volts)	V_g(V) (absence)	V_g(V) (presence in slot3)
0	1.52	0.31
2	1.64	0.42
3	1.75	0.51
5	1.93	0.94

Table 2: measurements for noise=2V

Voltage to IR LED(V)	V_g(V) (absence)	V_g(V) (presence in slot3)
0	1.62	0.42
2	1.73	0.51
3	1.91	0.65
5	2.32	1.04

Table 3: measurements for noise=4V

From the measurements made we can infer the following:

- The voltage in the presence of the black reflecting surface is smaller than the that obtained in the absence of a reflecting surface. This may be attributed to the high absorptivity of black surface, thereby absorbing most of the light falling on it.Hence, the photodiode produces relatively small current.
- On increasing the voltage of the IR LED, the intensity of the LED increases, thereby increasing V_g.
- The measurements may vary depending on the slots in which we place the refelcting surface.

2.2 Part II: USing the PSD circuit

The schematic of the the circuit after adding the PSD component used is given in figure 2.

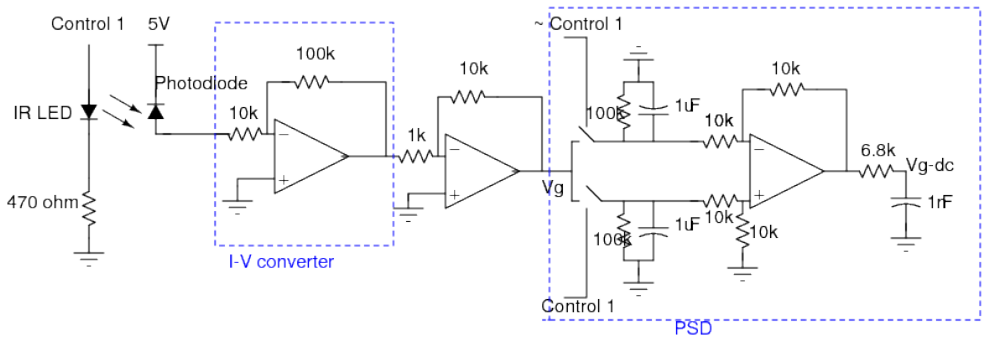

Figure 2: Circuit after adding PSD

We first vary the peak voltage to the IR LED from 2.5V to 5V and measure the values of V_g and V_{dc} using a DMM. The data is tabulated in table 4.

Voltage to IR LED(V)	V_g(V)	$V_{dc}(V)$
5	1.23	0.62
4	0.87	0.501
3.5	0.7	0.402
3	0.51	0.312
2.5	0.35	0.201

Table 4: V_g and V_{dc} at different peak voltage to IR LED

Next, we measure the values for V_g and V_{dc} using a DMM for different shades of grey and the results are tabulated in tables 5-7.

Shade of Grey	V_g(mV)	$V_{dc}(V)$
white	1.53	-1.12
grey1	0.98	-0.508
grey2	0.82	-0.461
grey3	0.72	-0.371
black	0.66	-0.334

Table 5: measurements at noise= 0V

Shade of Grey	V_g(mV)	$V_{dc}(V)$
white	1.52	1.12
grey1	0.96	0.512
grey2	0.8	0.462
grey3	0.69	0.371
black	0.65	0.333

Table 6: Voltage to the White LED = 2V

Shade of Grey	V_g(mV)	$V_{dc}(V)$
white	1.78	1.13
grey1	1.08	0.51
grey2	0.93	0.461
grey3	0.84	0.369
black	0.78	0.332

Table 7: Voltage to the White LED = 4V

Next we measure the value of V_{dc} for different ink shades placed in different slots, the readings are given in the following table:

Slot	lightest shade	Middle shade	Darkest Shade
s1	0.372	0.369	0.366
s1	0.481	0.466	0.449
s3	0.761	0.748	0.701
s4	1.514	1.321	1.25

Table 8: V_{dc} values for different slots and shades

The plots for the above data tables are given in figures 3-8.

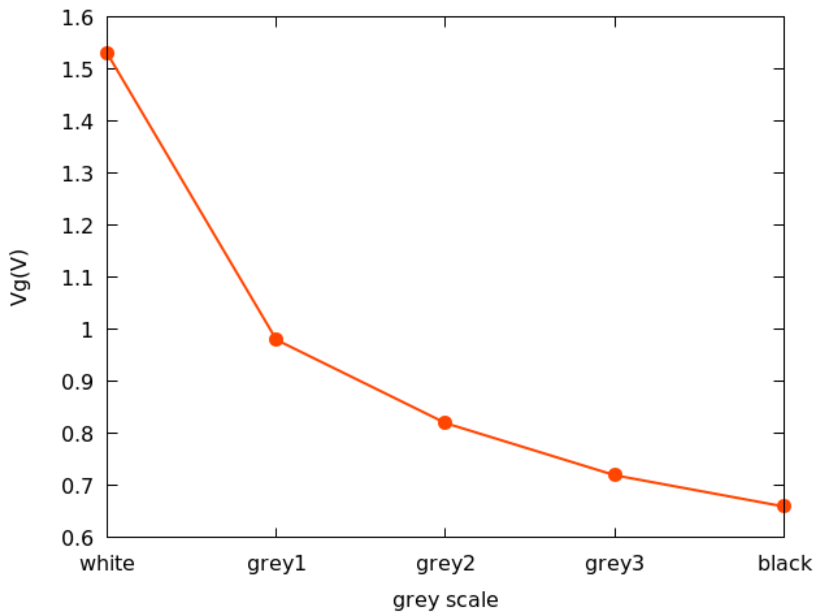

Figure 3: V_g for various shades at noise=0V

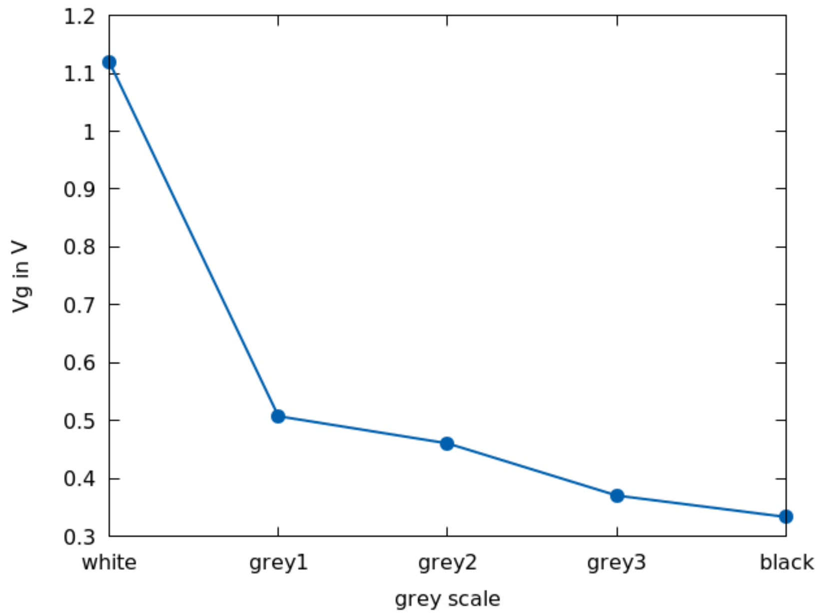

Figure 4: V_{dc} for various shades at noise=0V

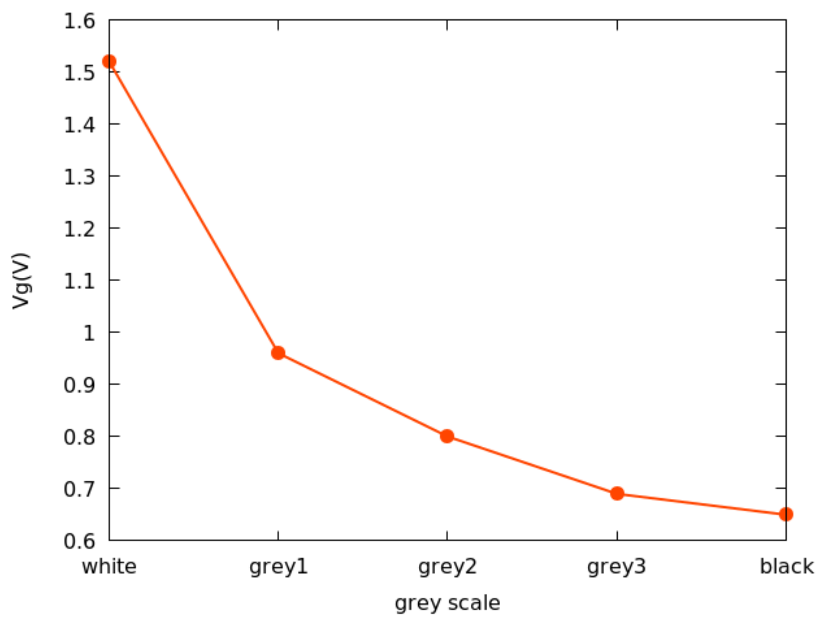

Figure 5: V_g for various shades at noise=2V

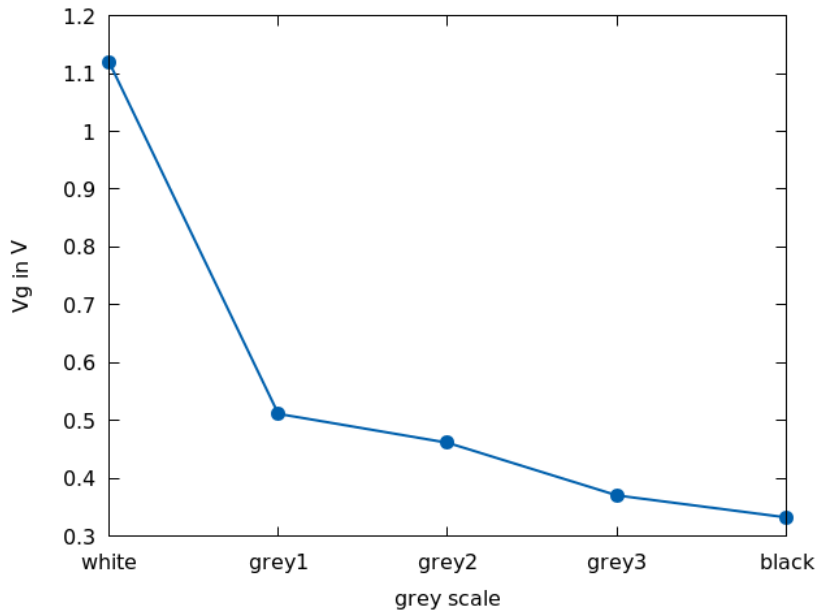

Figure 6: V_{dc} for various shades at noise=2V

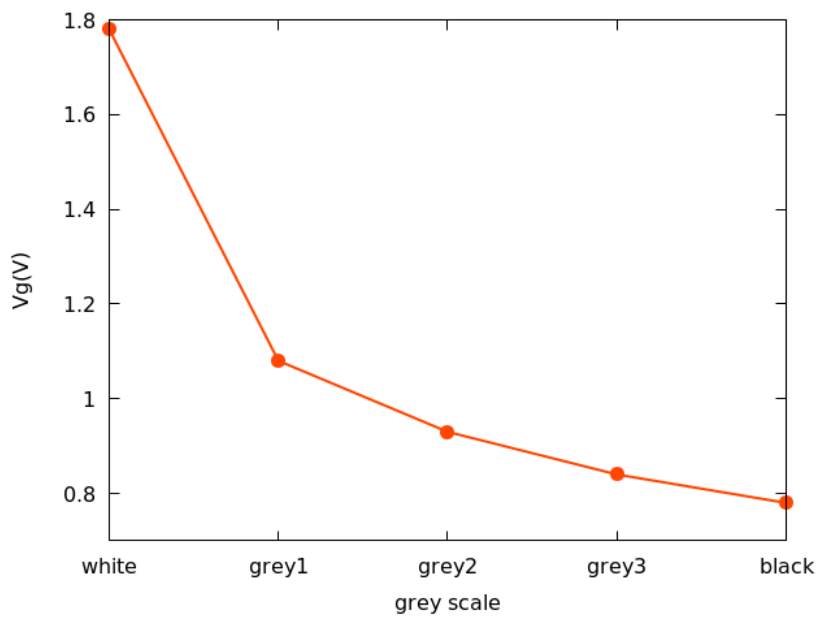

Figure 7: V_g for various shades at noise=4V

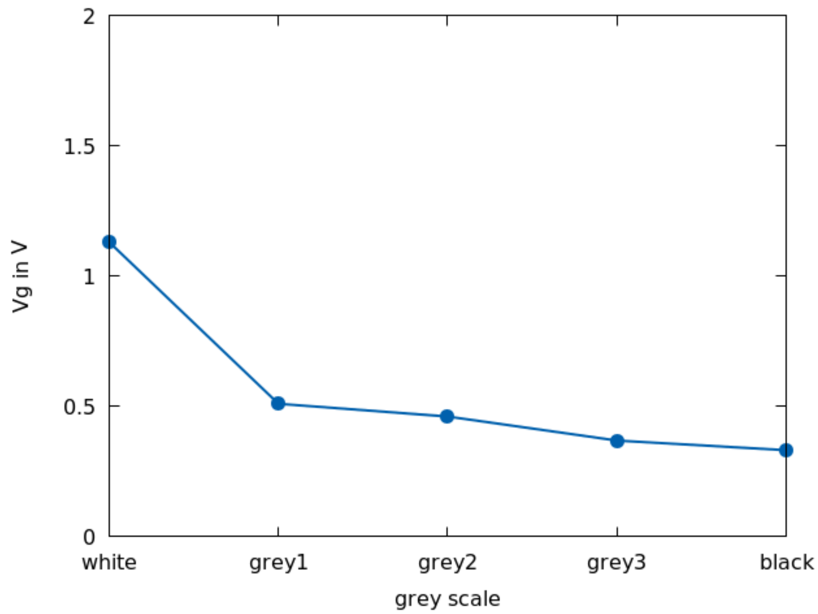

Figure 8: V_{dc} for various shades at noise=4V

From the observed data we infer that the magnitude of V_{dc} follows similar pattern as that of V_g.However V_{dc} is a more reliable measure of the darkness of ink as its value does not change significantly with ambient light(here white light). This was achieved because of using a PSD circuit.

2.3 Working of the PSD circuit

When the control 1 is high, the output V_g (including the noise) is obtained at the amplification stage. This is stored in the capacitor C1(bottom). However, when the control 1 is low, the output of the amplification stage V_g comprises only of the noise component.This is stored in capacitor C2(top).The resistance of 100kΩ help to increase the time constant as compared to the switching time so the capacitors hold the voltage.
Using a subtractor circuit we obtain the desired output which is then passed through the low pass filter. The 1nF capacitor forms a part of the filtering circuit and acts as a low-pass filter(eliminating the noise due to the ambient light)