Lab 8

Mechatronics
MENG483 Fall 2006

Light Intensity and Temperature Sensors

1 Objectives

The objective of this laboratory exercise is to familiarize students with light intensity and temperature sensing. Two types of sensors are employed in the experiments: optical transistors and integrated circuit temperature sensor. The sensor data is acquired via the MRK controller board and signal is processed using the on-board mathematics and the external software environments such as Matlab and Excel.

2 Theoretical background

2.1 Optical Transistors

A transistor is a device that allows a small current to control a larger current. In the optical transistor, small current is provided by the light impinging on the surface of the sensor. As more intense light is allowed to impinge on the transistor's surface, the current passing through the transistor will increase. In this laboratory exercise we use a PN 168 photo transistor. Typical light intensity (lux) vs. current output characteristics for this device are illustrated in Figure 1.

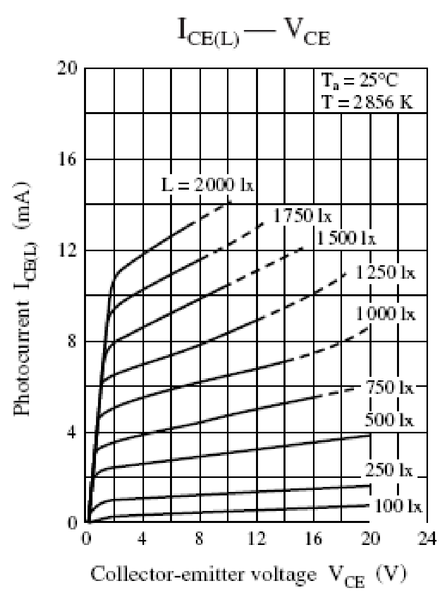


Figure 1 Photocurrent vs. C-E Voltage for PN168 phototransistor.

2.2 Integrated Circuit Temperature Sensors

The temperature measurements in this laboratory exercise are realized using the TMP36 integrated circuit sensor. The output voltage of this sensor is proportional to the temperature variation. Unlike thermisters and thermocouples, an integrated circuit temperature sensor may already include a signal conditioning circuit and therefore could have reduced requirements for the signal amplification. However, similar to thermisters and thermocouples, resistance of the integrated circuit temperature sensor varies with temperature. As temperature increases, the resistance decreases. An advantage of using integrated circuit temperature sensors is that the circuitry is isolated and not readily available to oxidation and contaminates. The TMP36 exhibits a linear voltage output vs. temperature dependence as shown in Figure 2. This integrated temperature sensor accepts a voltage source of 3V.

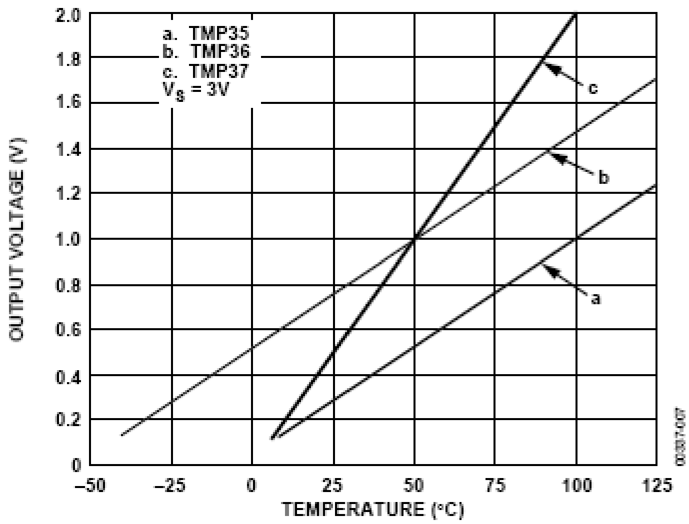


Figure 2 Output Voltage vs. Temperature characteristic of the TMP36 integrated circuit temperature sensor.

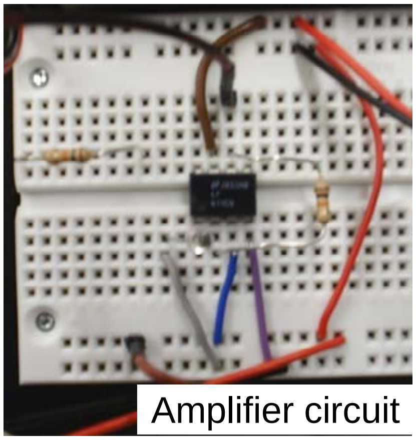


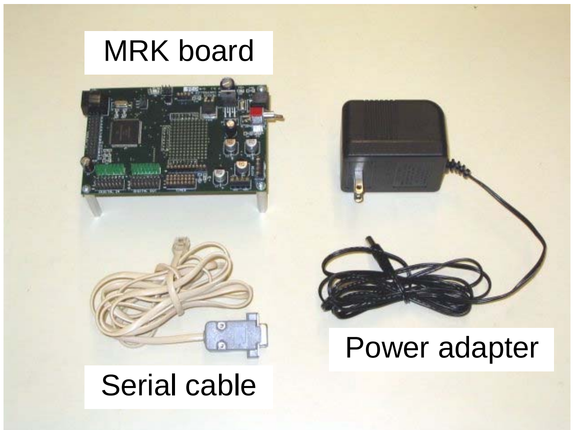
Figure 3 A practical reasization of the signal amplifier.

The TMP36 only draws ~60 micro amps from its power source and it has an accuracy of +/-0.8 ^{o}C over the temperature range of -25 to 125^{o}C. A typical TMP36/35 setup is presented below.

2.3 Op-amp signal conditioning

The PN168 optical transistor outputs an electric current proportional to the light intensity. In the laboratory applications, amplitude of this current is relatively low and therefore additional amplification is required. The amplification circuit designed to bring the signal amplitude within the range acceptable by the MRK board is shown in Figure 3. The circuit utilizes a LF411 op-amps such as the active element and an array of resistors and capacitors to enable amplification within the chosen range.

3 Equipment

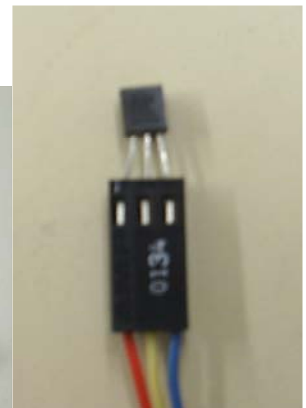


Volt-Ohmmeter (VOM)

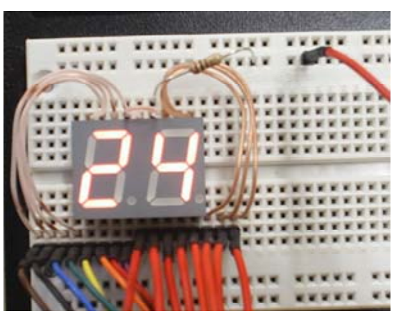
Hot plate

Light intensity sensor

Thermometer



Temperature sensor



Seven segment LED displays

Cooler

Plastic cover

- MRK Controller Board
- Serial communication cable
- Power adapter
- LED Display
- Pyrex Beaker
- Hotplate
- Cooler and Ice
- PN168 Optical Transistor
- TMP36 Thermistor
- Amplifier circuit for PN168
- Multimeter
- Sand
- Thermometer
- Plastic covers

4 Procedures

In this laboratory exercise you will use two devices to measure the sensor output: a multimeter and the MRK controller board. To verify correctness of the acquired digital data, compare the digital values with their analog counterparts displayed on the screen of the multimeter. Record your observation and include it in the lab report

The data acquisition procedure for both light intensity and temperature measurements utilizes a low sample rate program developed for the continuous data acquisition. An example of a C – code that enables this type of data collection is presented below.

```
#include "MRK.h"

char running = 0x00;

void sci_isr(void) {
        char c;
        c = fgetchar(SCI0);
        if (c == 's') running = ~running;
}

int main() {
        int channel;
        fprintf(SCI0,"Select channel (2-9): ");
        channel = fgetchar(SCI0)-'0';
        if (channel < 2 || channel > 9) channel = 2;
        analog_in(RESOLUTION, 10);
        setup_sci(SCI0,INTERRUPT,&sci_isr);

        fprintf(SCI0,"\n\rPress 's' to start and stop data transfer.\n\r");
        while (1) {
                if (running) {
                        fprintf(SCI0,"%R4u\n\r",analog_in(IN,channel));
                        delay (10);
                }
        }
}
```

4.1 Measurement of light condition in the room

Exercise #1: In this exercise you will be conducting relative measurements of the light intensity. Connect the PN168 sensor to the signal conditioning unit; make sure that the output lead of the signal conditioning circuit match exactly the location of the ANALOG_IN pin indicated in the data acquisition program. First you will need to determine an output voltage corresponding to the zero light intensity. For this purpose, cover sensor with a relatively thick cloth that does not allow light to penetrate through. Run the data acquisition program to obtain an average voltage correspondent to the “absolute darkness.” Record your results and compare them with the multimeter reading between the output lead of the signal amplifier and ground.

All groups will perform the next part of the exercise simultaneously. Therefore, we will start the experiment when everyone’s hardware and software setups are ready. If you finish your program well before the experiment, do not loose time and move on to the programming for the Exercise # 2.

In the second step, when everyone is ready, the TA will turn off all of the lab lights. Sunlight through the windows should be the only light in the room. Take a reading using your MRK data acquisition setup and record the average voltage value correspondent to this lighting condition. Compare this value to the results produced by the multimeter.

In the third step, when everyone is ready, the TA will turn on one of the two lights in the lab. You will need to record the analog and digital data and determine the average voltage value.

In the fourth step, when everyone is ready, the TA will turn on both lights in the lab. Please, record and process the analog and digital data to find an average voltage correspondent to the two lights lighting condition.

Table 1 Measurement of four different lighting conditions.

Light Source	Voltage Multimeter	Voltage MRK board
None		
Sun Through Windows		
+1 Set of Lights		
+2 Sets of Lights		

Useful expression for converting digital values into analog voltage are indicated below.

<u>Analog-to-digital conversion:</u>

digital_value = 255.2819 * analog_voltage – 123.4782

analog_voltage = 0.003917 * digital_value + 0.483694

These equations are based on the following data

analog_voltage	0.500	0.993	1.508	2.025	3.079	3.99	4.30
average digital_value	4.5	130	262	393	661	896	974.5

4.2 Temperature measurements

In the subsequent exercises, you will measure temperature using the TMP36 thermal sensor and thermometer. The same set up as in the light intensity experiments will be used for the data acquisition, excluding the signal conditioning circuit, i.e. the amplifier. You will need to connect the integrated circuit temperature sensor directly to the pins of the ANALOG_IN. Modify the sampling rate of your program to have reasonable number of point for the record length of approximately 5 minutes.

Table 2 Measurement of the temperature in the cooler.

Time (minutes)	Temperature Thermometer	Voltage MRK board
0		
1		
2		
3		
4		
5		

Exercise #2: Measure the “ambient” temperature in the laboratory using a conventional thermometer. Configure your data acquisition system to record the temperature data and perform the measurement using the TMP36 sensor. Your record length should be approximately 5 minutes. Did any significant changes in temperature occur during experiment? Compare results of the experiment with TMP36 characteristics presented in Figure 2.

Exercise #3: Place a layer of ice, approximately 2 inches thick inside the cooler. One cooler will be shared between two or three groups. Cover a layer of ice with a plastic sheet so that the thermal sensor is protected from the ice when placed in the cooler. Measure the temperature in a cooler using a thermometer and TMP36. You record length should be approximately 5 minutes. Did the sensor reading change during the time of experiment? Did the actual temperature change as indicated by the thermometer? Record your data in a Table 2. Calculate the response time of TMP36.

Table 3 Measurement of the temperature in the sand filled beaker subjected to the elevated temperatures.

Time (minutes)	Temperature Thermometer	Voltage MRK board
0		
1		
2		
3		
4		
5		

Exercise #4: In this exercise, you will use a heating plate to heat up a Pyrex beaker filled with sand. Preheat the beaker so that a relatively constant temperature of the sand is achieved. Place the TMP36 sensor approximately 1 inch inside the sand. CAUTION - HOT. Run the data acquisition program for approximately 5 minutes. Are there any differences between the thermometer's and digital data? What is the response time of the TMP36 sensor? Record results of the experiment in Table 3.

Exercise #5: Write a program for continuous acquisition of the temperature data. The program should output the measurement results: (a) in degrees Celsius on two 7-segment LED displays and (b) in degrees Fahrenheit on the computer screen. Use the following subroutine to control the 7-segment LED displays.

```
#include "MRK.h"

int main() {
      digital_in(OUTPUT,ALL);
      digital_out(OUTPUT,ALL);
      analog_in(RESOLUTION, 10);

      const char segments[] = {0x3f, 0x06, 0x5b, 0x4f, 0x66,
                               0x6d, 0x7d, 0x07, 0x7f, 0x67};

      int i, input, a, b;
      i = 0;
      while (1) {
            input = analog_in(IN,2);
            a=input/10; b=a;
            fprintf(SCI0,"%R4d = %R3d \r",input,b);
            if (a > 99) {        // too big, can't display
                  digital_in(OUT,ALL,0x40);
                  digital_out(OUT,ALL,0x40);
            }
            else {
                  digital_in(OUT,ALL,segments[a/10]);
                  digital_out(OUT,ALL,segments[a%10]);
            }
            delay(100);
      }
}
```

The following expressions can be used to calculate the actual temperature.

analog_voltage = 0.01 * tempC + 0.5 (approximate)

tempC = (0.003917 * digital_value + 0.483694 – 0.5) / 0.01

= 0.3917 * digital_value – 1.63

= (4 * digital_value – 16) / 10 (C code, integer math only)

tempF = 9/5 * tempC + 32 = 9/5 * (0.3917 * digital_value – 1.63) + 32

= 0.70506 * digital_value + 29.066

= (71 * digital_value) / 100 + 29 (C code, integer math only)

To test your program, place the TMP36 sensor 1 inch deep into the sand and start heating the plate. Your temperature reading should exhibit a constant temperature increase. Show your data acquisition and displaying process to TA.

5 Report and analysis requirements

5.1 Theory

Discuss how the optical transistor works.

Discuss how the integrated circuit temperature sensor works.

Discuss effect of the sample rate on both light intensity and temperature measurements.

5.2 Results and analysis

Answer all questions in previous sections of these laboratory instructions.

Present and discuss you results.

Are you analog light intensity data (multimeter) differ from the digital one (MRK board). Why?

Based on your measurement results recommend sample rates for the light intensity and temperature measurements.

Is there any difference between the thermometer's and MRK board's readings of the temperature in three experimental setups: ambient, lowered, and elevated temperatures?

How fast does the TMP36 sensor respond to the temperature deviations?

Why would one display temperature in degrees Celsius on two 7-segment LED displays but temperature in degrees Fahrenheit on the computer screen? Why not vice versa?

Last updated
October 18, 2006.