CSE3442 Embedded Systems I
Programmable Colorimeter
Spring 2019 Project

1 Overview

The goal of this project is to build a device capable of measuring, learning, and recognizing the color of a target over the visible portion of the light spectrum. The device can communicate over a serial communication link to a PC or similar controller.

Most parts for the project, except the PCB, will be provided in 126ERB.

2 Hardware

The project will consist of a single board containing a socket for the M4F board, drivers and an RGB LED that is used to illuminate the target, and a TEPT5600 ambient light sensor and conditioning circuitry that will be used to measure the relative intensity of the reflected light.

The system measures color by measuring the intensity of the reflected light from the target when each of three illuminators (red ~630nm, green ~525nm, and blue ~465nm) are on.

A complete circuit will be given in class.

3 Suggested Parts List

Part	Quantity
EK-TM4C123GXL (rs-232 receiver/driver)	1
TEPT5600 (light sensor)	1
WP154A4SUREQBFZGC (RGB LED)	1
0.192” ID / 0.3125” OD / 0.5” L aluminum spacers	2
2N3906 PNP transistor	4
220ohm resistor (led current limiter)	3
1kohm resistor (sensor PNP collector sink)	1
10k resistor (sensor PNP base pull-up, LED base)	4
4.7k resistor (LED PNP base pull-up)	3
0.1uF capacitor (integrator)	1
10x2 100mil pitch unshrouded header	2
Wire (22-24 AWG solid wire, 3 colors) red for 3.3V or 5V, black for ground, another color for the other signals	1
PC board (3x5 size recommended)	1
Solder, iron, needle-nose pliers, diagonal cutters, safety glasses	1 each

4 Software

The software must support the following functionality:

4.1 Configuration

The virtual COM port connected to UART0 will deliver these instructions:

Calibration Functions	
calibrate	Instructs the hardware to calibrate the white color balance and displays the duty cycle information when complete
color N	Stores the current color as color reference N (N = 0..31)
erase N	Erases color reference N (N = 0..31)
Sampling Functions	
periodic T	Configures the hardware to send an RGB triplet in 8-bit calibrated format every 0.1 x T seconds, where T = 0..255 or off
delta D	Configures the hardware to send an RGB triplet when the RMS average of the RGB triplet vs the long-term average (IIR filtered, alpha = 0.9) changes by more than D, where D = 0..255 or off
match E	Configures the hardware to send an RGB triplet when the Euclidean distance (error) between a sample and one of the color reference (R,G,B) is less than E, where E = 0..255 or off
trigger	Configures the hardware to send an RGB triplet immediately
button	Configures the hardware to send an RGB triplet when the PB is pressed
User Interface Functions	
led off	Disable the green status LED
led on	Enables the green status LED
led sample	Blinks the green status LED for each sample taken
test	Drives up the LED from a DC of 0 to 255 on red, green, and blue LEDs separately and outputs the uncalibrated 12-bit light intensity in tabular form

4.2 Calibration

The goal is to scale each of red, green, and blue intensities to an 12-bit scale, based on calibration with a white reference target. There are many ways to perform this calibration, but the suggested calibration procedure is to determine the highest duty cycle for each of the illuminators to cause a half-scale ADC input with the white reference target, which make over-range detection easier. This also allows for a wider range of supply voltage differences, LED output levels, and ambient light sensor responses.

Calibration information is automatically saved and is recalled upon power-up from EEPROM.
Color references are also saved in the EEPROM for color matching.

4.3 Color Measurement and Reporting

The system will read the sensor and send RGB triplet data in text format to PC. The measurement can be triggered periodically, manually (trigger command or pb press), color change, or match with a reference color. If a sensor is over-range, 4095 will be reported instead of the 0-4095 value for the particular color.

Since the object being sensed could be in motion, the signal must be sampled at a sufficiently high rate and filtered to avoid aliasing and other measurement errors.

5 Deadlines

The hardware will be built in Labs 5 and 6.

Each team will send the current state of software by e-mail to the instructor on the following dates: 3/26, 4/9, 4/23. The file name should be *student1_student2*.c where *student1* and optionally *student2* are replaced with the student name(s) on the team. Since the project is small, all code should be contained in this single file.

The complete project is due at the time and date in the syllabus, with an oral defense, electronic and paper copy of your code, written report (containing theory of operation and software printout), and demonstration of hardware and software (including compilation on site). You may work in teams of one or two members. All members of the team shall participate equally and be prepared to answer any question about the project to avoid a deduction in points. Each member of the team will be graded independently, although only one report, hardware, and software submission is needed.

6 Safety Issues

While far beyond the scope of this document, it is important to use tools safely. Safety goggles are a good idea, since you can cause yourself great injury if a wire that is being cut flies toward you. Another good reason for safety goggles is that if unsoldering wires under some strain, the solder can be fling toward you. Soldering entails some care to prevent burning yourself or a burning down a building if you forget to turn it off. If you choose to use solder containing lead, then care should be taken to dispose of lead properly (don't cool off the iron in a drinking fountain, etc.). OSHA also recommends washing your hands after using solder to prevent the build-up of heavy metals. These are a few helpful suggestions and are a very incomplete listing. Please read and understand all safety labels and exercise caution.

Please utilize the supervised lab resources in Rm 126ERB when working on the project for your safety. You may only use the resources in Rm 126 ERB when the GTA or other CSE staff is present.

Have fun!