Term Project: Temperature-Initiated Object Detection

# Introduction:

This term project, as part of the Introduction to Microprocessors and Microcontrollers course, focuses on designing and implementing a Temperature-Initiated Object Detection System using the TM4C123G microcontroller. The system integrates multiple sensors and peripheral modules to perform a multi-functional task that combines temperature monitoring and object detection. Specifically, the system operates in deep sleep mode to conserve energy while continuously monitoring ambient temperature through an LM35 analog sensor. Upon detecting a temperature rise beyond a user-defined threshold, the system awakens and utilizes a high-precision BMP280 digital sensor for confirmation. If the elevated temperature is verified, the system initiates object detection using an HC-SR04 ultrasonic sensor mounted on a stepper motor, scanning a range of -90 to 90 degrees. The detected information, including object distance and angle, is presented on a Nokia 5110 LCD display, while auditory and visual alerts are provided through a speaker and RGB LEDs. This project aims to demonstrate the effective integration of various hardware components and software modules to accomplish a complex task, reinforcing the foundational concepts learned throughout the course.

# Heat Sensing in Deep Sleep Mode:

An essential component of the system's operation is its ability to monitor temperature changes efficiently while conserving power. To achieve this, the TM4C123G microcontroller utilizes its deep sleep mode in conjunction with the LM35 analog temperature sensor. The analog comparator peripheral is employed to continuously compare the sensor output against a threshold voltage set by a multiturn trimpot. When the sensor detects a temperature rise above this threshold, the analog comparator triggers an interrupt to wake the system. This mechanism ensures low power consumption while maintaining responsiveness to critical environmental changes.

We’ve used COMP1 as analog comparator. LM35 which is connected to C4 is V+, The voltage divided by the trimpot connected to C5 which is V-. When “V+ > V-“ satisfied, system wakes up and continues to other operations.

## LM35 and Analog Temperature Threshold:

Even though Analog Comparator handles the comparing temperature with threshold, We need to print that values to the LCD screen. In order to obtain these values, we employed to Analog-to-Digital-Converter modules which are ADC0 and ADC1. ADC0 is responsible for the temperature of LM35. ADC0 uses Sample Sequencer 3, and returns the average of 16 measurements from B4 pin which is also connected to output of LM35. ADC1 executes same operations for B5 pin.

## Deep Sleep Screen:

System enters Deep Sleep Mode via ASM command “WFI” at the begging of the program, and after “K12” is pushed. The program updates LCD screen one last time before entering the deep sleep mode, that shows analog and digital temperature thresholds. Until LM35 detects higher temperature than threshold, program keeps its state.

## Power LED:

A power led is employed for visual feedback about Deep Sleep mode. When the program in Deep Sleep, the power LED is off, and when the program wakes up, i.e. LM35 detects higher temperature than threshold, the power LED lights up. The power LED is driven by MOSFET switching, which draw current from MOSFET’s drain, if MOSFET’s gate is high. MOSFET’s gate terminal is connected to A4 pin which is set by the COMP1\_Handler, while its source terminal is connected to an external DC supply.

# Heat Sensing with BMP280

After waking from deep sleep mode, the system performs a more precise temperature measurement using the BMP280 digital sensor through the I2C protocol. To ensure measurement accuracy, the system averages 128 consecutive readings from the BMP280 sensor. If the averaged temperature exceeds the predefined threshold, the system activates the speaker to emit a square wave sound for two seconds, serving as an audible alert. This immediate feedback mechanism informs users of significant temperature changes and transitions the system into the object detection phase.

## Speaker:

A speaker is employed to give audible feedback. The speaker is driven by MOSFET switching similar to the power LED. Timer1A is employed to generate PWM signals to drive the spiker. The frequency depends on the temperature measured by BMP280. As the temperature is higher, the frequency of PWM is increased. The speaker plays the pre-adjusted sound for two seconds, then program goes to object detection phase.

# Object Detection:

Once the system confirms an elevated temperature using the BMP280 sensor, it transitions to the object detection phase. This process involves scanning the environment using the HC-SR04 ultrasonic distance sensor mounted on a stepper motor. The motor rotates the sensor across a 180 degree range, enabling comprehensive area coverage. Distance measurements are collected at each 32 steps, allowing the system to detect nearby objects within a maximum range of 1 meter. The angle and distance of the nearest detected objects are displayed on the Nokia 5110 LCD, providing real-time feedback to the user. The user could also view the 180 degree distance graph on the LCD Screen by pushing “K15”. Additionally, the system uses onboard RGB LEDs to visually indicate object proximity, enhancing user awareness through color-coded signals. This seamless integration of sensor data acquisition and motor control showcases the microcontroller's capability to manage complex tasks efficiently.

## Step Motor:

A 5V DC step motor is employed to rotate the distance censor in a 180 degree range. After the speaker plays, the first measurement is taken, then motor starts to rotate. We implemented the system as after 32 full-step, another measurement is taken. After last measurement, motor returns its starting point. E0-3 pins are used to drive the steps of motor, while it is supplied by an external DC Supply. The motor goes to next step after 10ms while in measurement phase. In returning phase, steps are given with 5ms intervals.

## Distance Censor:

A HC-SR04 ultrasonic distance censor is employed to measure the 180 degre and 1m field. The censor is mounted on the shaft of step motor. Trigger pin of censor is connected to F0 pin of the board. F0 generates a triggering pulse with the help of Timer0A. Timer0 is set to 16 bit split timer, periodic, count down modes and prescaled by “15” in order to get 1µs unit time. Timer0A generates 2000µs high pulse with following 8000µs low period via F0 pin in order to trigger the censor. Another timer, Timer2A is employed to capture the echo of the censor. Timer2 is set to 16 bit split timer, capture edge time, count up mode. It capture both edges via F4 pin. Program takes 33 measurments and push them into a float array. The censor supplied by an external DC supply.

## On Board LED:

The MCU has an on board RGB LED controlled by F1-3 pins. F1 controls the red light, F2 controls the blue light, and F3 controls the green light. Activity of this lights depends on the minimum distance measured. If the minimum distance is lower than 50.0 cm, LED lights red. If it is between 50.0 and 75.0 LED lights blue. If it is between 75.0 and 100.0 LED lights green. Finally, if there is no measurment less than 100.0, the LED is off.

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