Instituto Superior Técnico

Master's Degree in Information Systems and Computer Engineering

Software for Embedded Systems

3rd Lab work: Wired Communications between embedded systems

Goal

The goal of this work is the implementation and test of a wired communications link between two embedded controllers. Communications will be based on the I2C protocol.

Description

This work is based on the assembly of the previous lab work, but with one main difference

- Sensors will be connected to an Arduino controller;
- Actuators will be driven by another Arduino controller.

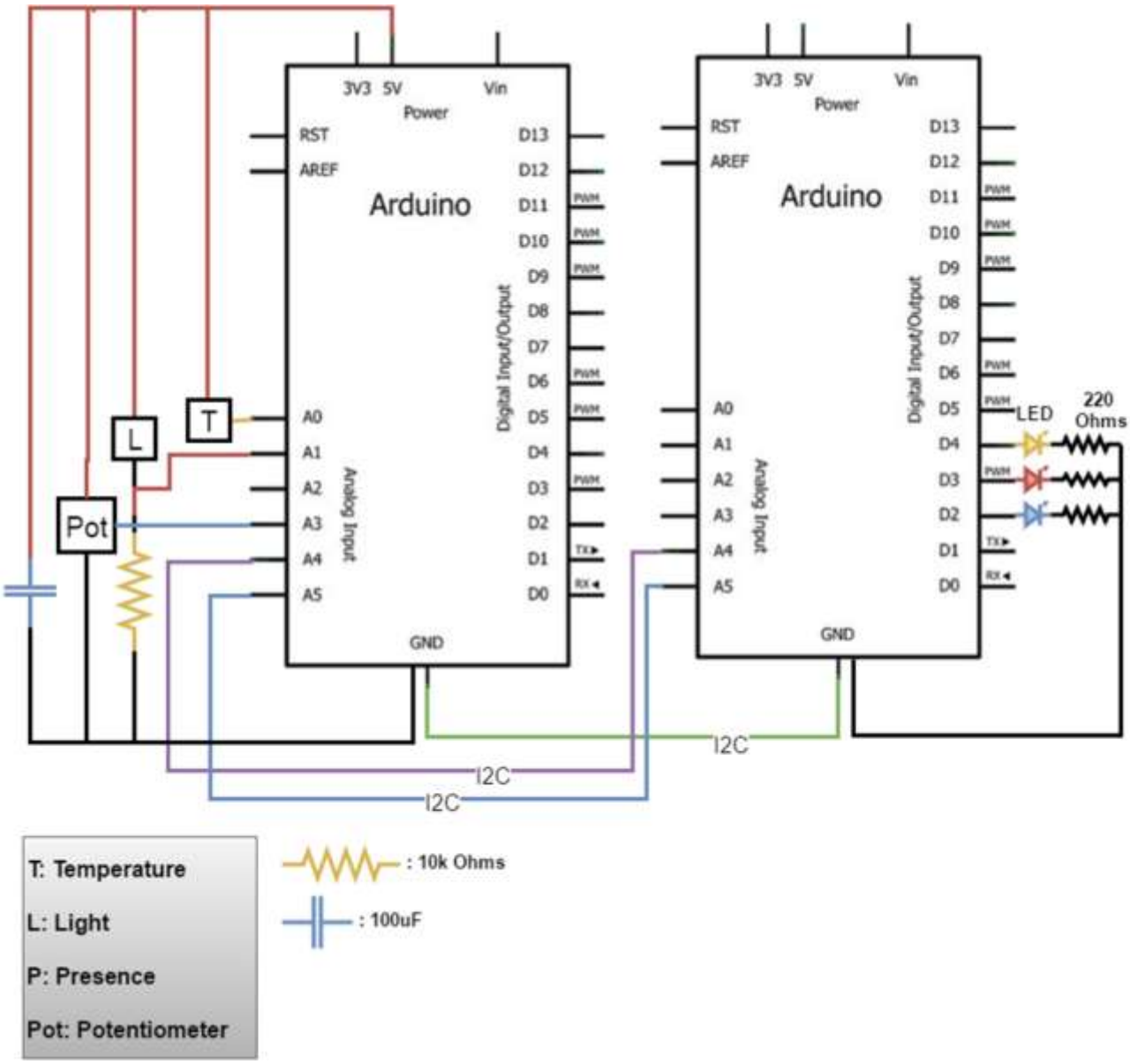
Therefore the overall functionality of this system is identical to that of the system implemented in the 2nd lab work:

"Build an embedded system (…) to simultaneously control 3 LEDs depending on the state of 3 different sensors – temperature, rotation angle (potentiometer) and light intensity.

- *The LED associated with the temperature sensor must be turned on when the temperature read is greater than 26 ^{o}C (to be eventually redefined at the laboratory).*
- *The LED controlled by the potentiometer must blink with a period of time varying continuously between 0.2 and 2 seconds, depending of the rotation applied to the potentiometer.*
- *The LED for the light intensity function must continuously change its own light intensity based on the light intensity sensed in the surrounding environment …"*

To implement the required functionality now it is necessary to interconnect two controllers through a wired communications link.

A diagram of the circuit to be assembled is presented in the figure.



References

1. https://www.arduino.cc/en/Reference/digitalWrite
2. https://www.arduino.cc/en/Reference/AnalogRead
3. https://www.arduino.cc/en/Reference/Serial
4. https://www.arduino.cc/en/Tutorial/Calibration
5. https://www.arduino.cc/en/Tutorial/PWM
6. https://www.arduino.cc/en/Reference/Delay
7. https://www.arduino.cc/en/Reference/Wire

Recommendations

In order to fulfill your work with security and not damaging the hardware involved, remember to carry out the recommendations below. As you are working fill the boxes to be certain that you fulfill all security measures.

Always work with the circuits disconnect from its power sources.	
Call the teacher, or responsible for the laboratory, before you connect the circuits to its power sources.	
Make sure the circuit is well connected (resistors, capacitors, etc.) to prevent a short circuit, or damage to the hardware.	

This work shall be implemented in two lab sessions. In the lab will be available some additional Arduino UNO boards for development and test of the communications channel. Outside the lab, groups shall cooperate to time-share their Arduino kits to develop inter-controller communications. However each group must develop its own work.

To ease the connection of each controller to its specific interface circuits – sensors on one controller, actuators on the other controller – follow the guidelines for breadboard layout presented and check any issues at the beginning of the first lab session with the teacher.

The only signals (lines) common to both controllers are the two I2C lines and GND.

To interconnect both controllers, avoiding electrical hazards and noise, consider the following requirements:

- supply power (VCC) to each Arduino through its own USB cable;
- do not connect in any other way the VCCs of the two Arduino boards; VCCs **must not be directly interconnected**;
- connect both USB cables to the same computer running the IDE;
- connect the grounds (GND = 0 V) of the two Arduino boards (the single green connection on the diagram).

To simplify the test of the system with two controllers, but with both electric interface circuits sharing the same prototyping breadboard, consider the following guidelines:

- mount each interface on a separate half of the breadboard – sensors on one side, actuators on the other side;
- each half of the breadboard must have its own power supply – VCC and GND lines
    - GND lines shall be interconnected through the GND line of the I2C bus;
    - VCC lines must not be interconnected.

Inter-Integrated Circuit (I2C) Communications

To put the system to work it is necessary to implement the communication link connecting the two controllers. For this we will use I2C communications.

I2C is a serial communications bus implemented with two bidirectional lines – Serial Data Line (SDA), and Serial Clock Line (SCL) – and the GND reference. I2C works in a Master-Slave protocol where one or more Slaves can be connected to one Master on the same bus. There are no fault tolerance or recovery mechanisms included in the protocol. If necessary they must be provided at the application level. There is available an Arduino Library to handle at the application level communications over an I2C bus (see Reference 7 about the Wire library).

To start communications between controllers both Arduinos must start the Wire communication:

```
void setup() {
      Wire.begin(8);
}
```

`Wire.begin` only receives an argument if the board is a Slave. Masters do not need this address.

Subsequent communication transfers may be performed as Master-Writer:

```
void loop() {
      // Master writes for a Slave to read
      Wire.beginTransmission(8);
                              // Transmission to port 8 of the I2C bus
      Wire.write("value:");
                        // Wire.write(string) reads every char as a byte
      Wire.write(80); // Wire.write(int) reads int as byte
      Wire.endTransmission();
      ...
}
```

On the Slave side, when some message is detected, the I2C port triggers an interrupt. The Wire Library uses the `onReceive` function to associate a callback function to the interrupt:

```
void setup() {
      …
      Wire.onReceive(callbackFunction);
}

void loop() {
      …
}
```

Corresponding to the previous example – on the Master side – the following function – on the Server side – will consume and print the string and will print the integer separately afterwards.

```
void callbackFunction(int i) {
      while (1 < Wire.available()) {
            // make sure there is something to read
            char c = Wire.read(); // read the next byte as a char
            Serial.print(c);      // print the char
      }
      int x = Wire.read();       // read the next byte as an int
      Serial.println(x);         // print the int in a new line
}
```

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Group:		
Student 1:		
Student 2:		

Results

Fill the following fields or provide the corresponding printed listings.

1. Describe the changes in the program developed in lab 2 (Sensing the Real World) to port it to the new configuration with two controllers.
    a. Describe any changes in the design pattern (such as changing tasks in the round-robin loop).

    b. Describe other implementation issues changed (implementation of tasks).

2. Controller #1 program – I2C master:

```
void setup() {




}

void loop() {









}
```

3. Controller #2 program – I2C slave:

```
void setup() {




}

void loop() {

}
```

4. Evaluate the performance of the I2C bus in your system (data rate, latency).