

Exercise 11: Microcontroller Periphery

Note: This exercise is completely optional and tries to communicate a basic understanding of microcontroller periphery for participants interested in this topic.

Overview

Embedded systems are tightly integrated pieces of hardware and software. Until now, we had a close look at the software part of an embedded system. This last session will try to complement the knowledge gained so far on the software side with information about the typical environment of a microcontroller, namely the electrical circuit it is built into.

Although the title of this lab course is “microcontroller programming”, some of you might want to design their own embedded systems and hence at least some basic knowledge about electronic circuits may be of advantage.

Since this topic is not in the focus of the lab course, the remaining exercises have been designed in the following manner: All information necessary to complete the exercises is available on a website. The exercises to complete are listed on this sheet.

For completing the exercises, each group receives a breadboard, a jumper kit and set of electronic components. Please be careful with the electronic components, because it is quite easy to destroy them. Because of reasons of safety and some technical reasons, the main power supply (12V) for your circuit is shared between the different groups. This also means that if one group has a short circuit on their board, the other teams will suffer from immediate power loss. Hence please double-check your circuit before attaching the power supply.

Here are the data for accessing the website with the online content:

- Navigate to: <https://wiki.tobiaskaechele.de/>
- Click on “anmelden” in the upper right corner of the website.
- User name: (only available to lab course participants)
- Password: (only available to lab course participants)

Introduction

Figure 1 shows the electric components as they are arranged in the box you receive along with this exercise. This figure will tell you which component serves which purpose and where to put components back after use.

Exercise 11.1

Open the main page of the Wiki. First read the chapters “Breadboard”, “Laws of Electrical Engineering” and “Circuit Simulator Applet” in section “Basics”. Then answer the following questions:

- a) Use table 1 to calculate the resistances of the resistors with the following color codes:
 - green – blue – brown – golden
 - orange – orange – orange – golden
 - brown – black – yellow – golden
- b) Use table 1 to calculate the color code for the following resistor values: 15 k Ω , 470 Ω , 10 k Ω (tolerance $\pm 10\%$ each)

Controller ATmega168 with socket, Voltage Converter MAX232			
Transistor BC547A, Crystal 8 MHz			
4× Diode 1N4001; Resistors (1/4 W): 3× 220 Ω, 1× 560 Ω, 2× 4.7 kΩ, 3× 10 kΩ, 1× 15 kΩ		5× Electrolytic Capacitor 1 μF, 1× 100 μF, 1× 470 μF	
4× Film Capacitor 100 nF	2× Push-button; 1× Poti 10 kΩ	1× Volt. Regulator; 1× SUB-D Jack	3× LED; 1× IR; 1× TF

Figure 1: Arrangement of components in the box

Color	Ring 1 1 st Digit	Ring 2 2 nd Digit	Ring 3 Multiplier	Ring 4 Tolerance
black	0	0	· 1 Ω	-
brown	1	1	· 10 Ω	-
red	2	2	· 100 Ω	2%
orange	3	3	· 1 kΩ	-
yellow	4	4	· 10 kΩ	-
green	5	5	· 100 kΩ	-
blue	6	6	· 1 MΩ	-
violet	7	7	-	-
gray	8	8	-	-
white	9	9	-	-
silver	-	-	· 0.01 Ω	5%
golden	-	-	· 0.1 Ω	10%

Table 1: Table for calculation of resistance values

Power Supply Assembly

Exercise 11.2

Follow the instructions in the "Voltage Regulation Assembly" chapter to build the supply circuit and answer the following questions:

- The supply voltage circuit uses electrolytic capacitors with high capacity and film capacitors with small capacity in parallel. One could assume that the capacitance just sums up and hence the film capacitors do not have a large effect. Can you imagine why it is still important to use both types of capacitors?
- The used voltage regulator has a metal shield that can be used to fix it with a screw. Why might this be necessary in certain circuits?

- c) The assembly of the operation indicator consists of an LED and a multiplier resistor (*German*: Vorwiderstand). The used LED needs a supply voltage of about 2.1 V. Since the voltage provided by the voltage regulator is 5 V, the voltage difference must be dropped at the resistor. How is the proposed resistance of $220\ \Omega$ calculated if we assume that the current through the LED is less than 15 mA?
- d) When a multiplier resistor causes a certain voltage drop and hence limits the current, why are we not using a multiplier resistor for the whole circuit instead of a voltage regulator (given the input voltage is also constant)?

Integration of the Microcontroller

Exercise 11.3

Follow the instructions in the “Microcontroller Assembly” chapter to add the microcontroller to your circuit.

- a) Can you imagine why the Reset pin of a microcontroller is usually inverted?
- b) If you continuously press the Reset push-button, a certain current will flow from ground over the push-button and the resistor R2 to the power supply. How large is this current? Could holding the push-button for a longer time be a problem?

LED Connection

Exercise 11.4

Follow the instructions in the “LED Assembly” chapter to add an LED to your circuit.

To program the microcontroller, remove it from the circuit, put it into the respective socket on STK500 and put it back after programming. This is cumbersome, but can only be avoided through in-system programming, which will be introduced later.

Make sure that the microcontroller works at the correct frequency by adding a `_delay_ms()` into the code and toggling the LED. If you remove the crystal, the microcontroller should stall.

Push-Button Integration

Exercise 11.5

Follow the instructions in the “Push-button Assembly” chapter to add a push-button to the circuit.

- a) Which purpose serves the resistor R5?
- b) Write a simple program that shows the interaction of push-button and LED.

UART Assembly

Exercise 11.6

Follow the instructions in the “UART Assembly” chapter to integrate a serial interface into your circuit.

- a) What is the MAX232 component used for? Which voltage levels are present at the four relevant pins of that IC (T1IN, T1OUT, R1OUT, R1IN)?
- b) What are the four electrolytic capacitors C7, C8, C9 and C10 used for?

Light Barrier Assembly

Exercise 11.7

Follow the instructions in the “Light Barrier Assembly” chapter to add a simple *infrared* light barrier with adjustable threshold to your circuit. Use your ADC or analog comparator program to measure the voltage levels on the potentiometer and the photo transistor.

- a) Which voltage is present at the collector pin of the photo transistor when the light barrier is blocked? Which voltage is present when it is not blocked?
- b) What is the operating range of the light barrier? Perform a few experiments (but do *not* use a smaller multiplier resistor than the one suggested).

More Ideas for Your own Projects

These projects could be realized using the knowledge you have obtained in this course:

- Light-barrier based alarm system with storage of time of alarm triggering: DCF77, LC display, (PWM modulated) infrared light barrier, custom microcontroller circuit
- Simple timer for control of electronic devices: possibly DCF77, LC display, setup using push-buttons, transistor driver circuit and relay for load switching (in any case, let a professional do the high voltage stuff!)
- Simple air conditioner: temperature sensor with simple heater and ventilator (with transistor driver circuit and/or relay, in any case let a professional do the high voltage stuff!)
- Distributed temperature sensing: connection of multiple “sensor nodes” (Modbus or SPI slaves) to a central data logger (Modbus or SPI master), export to PC

The following applications are possible with a little bit of additional work:

- Integration of other communication protocols (e.g., I²C).
- Simple MIDI-like music player using PWM generation, a transistor driver circuit and speaker.
- Recording and playback of audio using a microphone, the ADC and an external DAC circuit connected over SPI.
- “Weather station” with data logging for temperature, humidity, air pressure, internal or external logging (maybe even to an SD card interface connected over SPI).
- Thermometer with radio transmission

Good luck with your own projects!