Lab 3 - Microcontroller

Introduction

You will program, assemble and test a microcontroller-based electronic combination lock. The device must operate according to the specifications given below. You will be supplied with parts that you will use to build the system on a prototyping board in the lab. You will write the control program in C and program the microcontroller using a device programmer. You will demonstrate your device to the TA and hand in the programmed device and a program listing.

Specifications

Inputs and Outputs

The electronic lock has four slide switches and one pushbutton switch as inputs and four LEDs as outputs. The inputs are used to enter the digits of the lock's "combination" in binary. The LEDs display the digits (in binary) as you enter them and will show all 1's when the proper combination has been entered to show that the lock is open.

Microcontroller Behaviour

When your microcontroller is reset your program (the `main()` function) will begin to execute. Your program should start by turning off all the LEDs to help you verify that all the outputs are properly connected.

Each time the pushbutton is pressed and released the microcontroller should read the value entered on the switches and display it on the LEDs. The binary value of each digit is displayed on the 4 LEDs connected to Port 1 bit 7 on pin 19 (MS bit) through Port 1 bit 4 on pin 16 (LS bit) (see below).

The lock should open when the correct sequence of three digits has been entered. These three digits should be the first three digits of *your* student number. If an error is made in entering any of the digits the lock should start looking for the first digit again (i.e. the correct digits have to be entered in order and without any errors). Once the last digit has been entered the microcontroller should turn on all the LEDs to indicate that the lock has been opened. The next button push should close the door again and the lock will start waiting for the three digits to be entered again.

Components

You will be supplied with a microcontroller, crystal and a capacitor. All components must be handed in to the TA in the lab when you finish your lab (do not put them in the assignment box).

Microcontroller

You will use an ATMEL 89C1051. You may want to look at the data sheets for the microcontroller which are available in PDF format from `http://www.atmel.com/atmel/acrobat/doc0366.pdf`. The first three pages are probably all you'll want to look at.

The microcontroller has two 8-bit parallel I/O ports, called P1 and P3. In the descriptions below the notation P*n*.*m* refers to bit *m* of the 8-bit parallel port *n*. *n* can be 1 or 3 (P1 or P3) and *m* is 0 to 7.

Other Parts

You will also be supplied with an 11.059 MHz crystal that must be connected between pins 4 and 5 (XTAL2 and XTAL1 respectively). The crystal determines the CPU's clock frequency. You will be supplied with a capacitor that must be connected between pins 1 and 20 to reset the microcontroller when power is first applied.

Wire and wire cutters/strippers will be available in the lab. Use these to connect the microcontroller to the power and ground outputs, the LEDs and the switches. Use reasonably short wires and keep your wiring neat.

Circuit Description

You should connect the switch and LEDs to the pins indicated below.

You will wire up your interface circuit on a "DigiDesigner" prototyping unit. The unit includes a 5V power supply, a solderless breadboard, 4 LED displays, 4 slide switches and two pushbutton switches mounted in a box.

The breadboard (the rectangular white plastic block) is used to connect the various components to your chip. The chip should be plugged in horizontally over the wide horizontal channel running down the middle of the board. Each pin of the chip is connected to the other five sockets in each column.

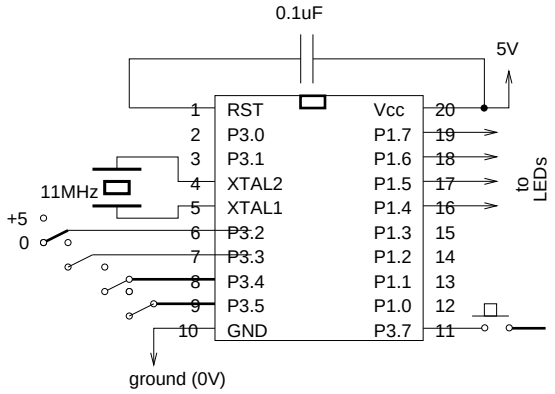
WARNINGS

Turn off the power when setting up or making changes to your circuit. Double check your connections before turning on the power (ask the TA if you are unsure of anything).

Semiconductor devices can be damaged by static electricity. The damage is invisible and is cumulative. Ideally you would work on a bench with grounding straps and anti-static surfaces. Since this equipment is not available you should take common-sense precautions such as touching a grounded piece of equipment before handling the chip and avoiding touching the pins.

Assembling the Circuit

A schematic of the circuit is given below:



- Plug the chip into the breadboard.
- Connect pin 10 to the ground (0V) power supply output.
- Connect pin 20 to the +5 volt power supply output.
- Connect the crystal to Pins 4 and 5.
- Connect the 0.1 μF capacitor from pin 20 to pin 1.
- Connect pins 19 through 16 to the LEDs.
- Connect the slide switch outputs to pins 6 through 9 (note that the order of the pins is LS to MS bit of P3).
- Connect an active-high pushbutton output to pin 11.
- Make sure the chip is properly connected to both +5 V and ground rails. Reverse biasing the chip or it's inputs will destroy the chip. Double check your connections before applying power.

Compiling your Code

You will use a free (demonstration version) of a C cross-compiler for the 8051 that runs under MS-DOS.

The compiler has been installed in the PCs in the lab.

If you want to run the compiler on another PC you can download the file `51demo.exe` from the course Web page. Copy it to any convenient directory on a DOS machine and execute it to unpack the demo compiler. You will need about 2 Megabytes of free disk space.

Type the command `bin\hpd51` (or just `hpd51` if using the lab computers) to start the interactive editor/compiler environment. There is no command-line version.

Define A Project

You should start by defining a project so that you do not have to re-enter the compiler options each time you start the compiler.

From the main menu select the menu item "New Project" from the "Make" project. You will be presented with a series of dialog boxes:

- Project Name

  Enter a project name, for example `lab4`.

- Processor and Memory Model

  select:

  - Generic 8051
  - Small memory model

- Output File Format

  select:

  - Intel HEX

- ROM and RAM Addresses

  Set all RAM and ROM addresses and sizes to zero (0).

- Compiler Optimizations

  select:

  - Full Optimization (press 'F')
  - Global Optimization level: 1

- Source Files

  Add the name of your C file to the list, for example, `lab4.c`.

- select DONE (press Esc)

Edit/Compile/Link

Enter your source code in the edit window. You may want to start with the sample code given below. Select the "Make" item from the "Make" menu or press F5. Correct any errors, and re-run the make command as necessary. Make sure the code does not take up more than 1k Bytes and the internal RAM (IRAM) does not take more than 64 bytes.

The object code will be written to a file in "Intel Hex" format. This is one of several formats that are commonly used to transfer data to device programmers.

Copy the resulting hex file (e.g. `lab4.hex`) to a floppy and use it to program the microcontroller as described below.

Programming the Microcontroller

This microcontroller has 1k byte of internal (EEPROM) program memory and 64 bytes of (RAM) data memory.

You will use the device programmer attached to one of the PCs in the lab. Please use this computer only for programming the devices.

The programmer has ZIF (zero insertion force) socket. Flip the lever to open the contacts, insert the chip into the programmer and flip the lever back to hold the device in the socket. Be careful to follow the chip alignment diagram drawn beside the socket (the bottom of the chip should be aligned with the bottom of the socket).

Type `ACCESS` to run the device programmer software.

The device programmer software is menu-driven. Select the following options:

Device	MPU/MCU
MFR	Atmel
Type	AT89C1051 (or AT89C2051)

This will start a second program that is specific to the 8051 microcontrollers. First select option 2 "Load Hex". Enter the name of your file (e.g. `lab4.hex`). Select the options for Intel hex format and to set unused bytes to FF. Then select option "A" to automatically erase, blank check, program and verify. Select the option to not program any lock bits.

It will take a few seconds for the device to be programmed. You may remove the device when the LED on the programmer goes on.

Submitting The Lab

Once your device is working properly print a program listing and demonstrate its operation to the TA. Make sure the lock only opens for *your* personal code.

Hand in the programmed microcontroller and crystal along with a listing of your C code to the TA in the lab when you are done. Do *not* put the components in the assignment box. You must return all the parts to get a mark for the assignment.

Sample Code

The following code continuously copies bits P3.2 through P3.5 to P1.4 through P1.7:

```
#include <8051.h>

void main (void)
{
  int n ;

  while ( 1 ) {
    n = P3 ;
    P1 = n << 2 ;
  }

}
```

You need to include the `8051.h` file to define constants like `P3`. Of course, your program should include comments, define symbolic constants and include an algorithm to implement the lock. You may want to define functions to do things like waiting for a button push.