ENGINE

Teaching online electronics, microcontrollers and programming in Higher Education

Output 2: Online Course for Microcontrollers: syllabus, open educational resources

Practice leaflet: Module_2-5 Keypad 4x4

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Erasmus+

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Declaration

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Executive summary

In this Module we will use PIC18F4550 with a Keypad 4x4.

Chapter 1: **Overview**

Table 1. Overview

Title / short summary	**5. Keypad 4x4**
Expected learning outcomes	• The student will be able to connect a keypad 4x4 on the PIC18F4550 • The student will be able to modify the keypad driver for CCS C Compiler • The student will be able to read ASCII characters from a keypad 4x4 • The student will be able to design a simple calculator with a keypad 4x4 and a LCD 16x2 • The student will be able to load and animate a microcontroller program in the Proteus Design Suite
Keywords	Keypad 4x4, matrix, rows, columns
Duration	The duration of the module_2-5 is 3 hours • Presentation of the module_2-5 by the teacher, 30 minutes • 1st activity, keypad 4x4 and LEDs, 30 minutes • 2nd activity, keypad 4x4 and LCD 16x2, 45 minutes • 3rd activity, simple calculator, 75 minutes
Involved	**The teacher:** Presents the slides associated with the module_2-5 and answers question

	The students: Draw circuits in Proteus Schematic, write programs in C language, load programs to a microcontroller and run the simulation using the Proteus Design Suite
Assignment	At the end of the Module_2-5 will be given: • Open Project
Educational tools and equipment	• **Material:** PC • **Software:** CCS C compiler, Proteus Design Suite
Prerequisites / pre-existing knowledge	• The student must be familiarized with the Proteus Design Suite (link1) • The student must be completed Module_2-1, Module_2-2, Module_2-3 and Module_2-4
Educational content	• CCS C Compiler manual (C Compiler Reference Manual) • MICROCHIP, PIC18F2455/2550/4455/4550 Data Sheet • Module_2-5 slides • Module_2-5 Evaluation leaflet • Module_2-5 Open project leaflet • Module_2-5 Programs, Schematic Proteus (Compressed folder)
Tips	***Tip1.*** *The #define row0 PIN_ etc statements in keypad.h should be checked and possibly modified.* ***Tip2.*** *The #define LCD_DB4 PIN_B4 etc statements in flex_lcd.c should be checked and possibly modified.*

Chapter 2: **Activities**

2.1 Activity 1. Keypad 4x4 and LEDs

The purpose of this activity is for microcontroller to read an ASCII character from a keypad 4x4, and display its code in 8 LEDs.

Table 2. ASCII code for digits

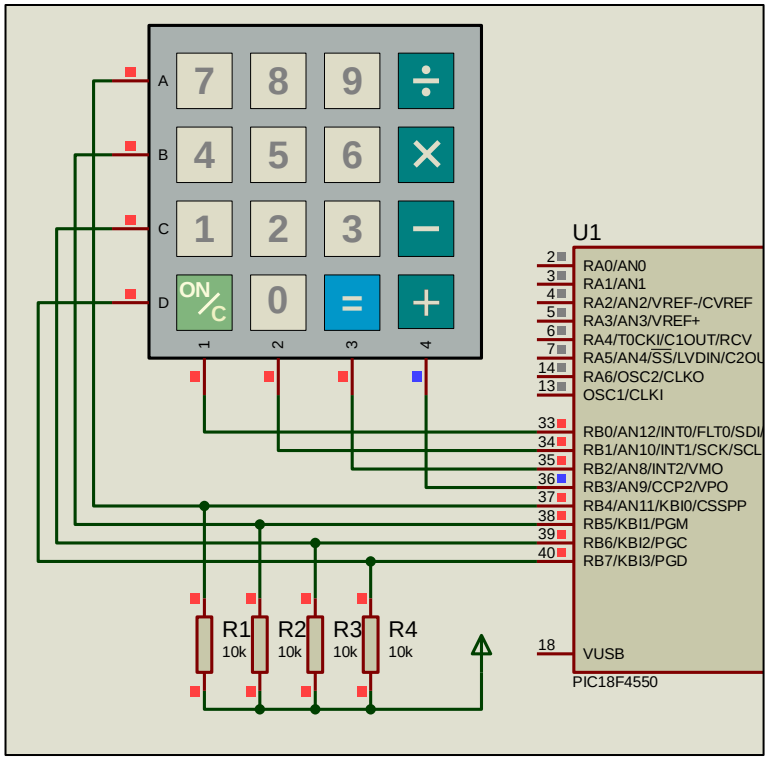
Digit	ASCII code (hex)	ASCII code (binary)
0	0x30	0011 0000
1	0x31	0011 0001
2	0x32	0011 0010
3	0x33	0011 0011
4	0x34	0011 0100
5	0x35	0011 0101
6	0x36	0011 0110
7	0x37	0011 0111
8	0x38	0011 1000
9	0x39	0011 1001

Table 3. ASCII code for characters

Character	ASCII code (hex)	ASCII code (binary)
/	0x2F	0010 1111
X	0x58	0101 1000
-	0x2D	0010 1101
+	0x2B	0010 1011
=	0x3D	0011 1101
C	0x43	0100 0011

Table 4. Activity 1

Activity 1st (30 minutes)	**Step 1.** The circuit is drawn in the Proteus Design Suite. **Step 2.** The program in C language is written. **Step 3.** The program is compiled with the use of CCS C compiler to the microcontroller machine code.

	Step 4. The machine code is loaded to the microcontroller. **Step 5.** The animation is activated. **Step 6.** Modifications and discussion.
Step 1 (10 minutes)	Draw the circuit of the picture in the Proteus Design Suite.  *Figure 1 (a). Keypad and LEDs*

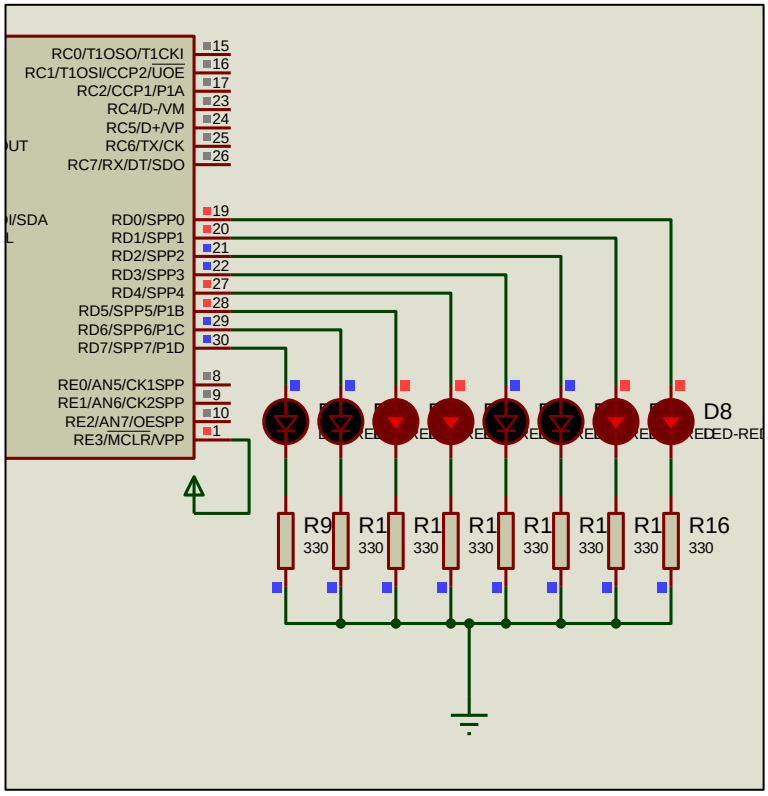


Figure 1 (b). Keypad and LEDs

Step 2
(5 minutes)

Write in CCS C Compiler the program in C language

```
#include <main.h> // the file main.h with the
                  // initial settings is included.
                  // This file must be placed in
the same
                  // folder with the project.
                  // Also the 18F4550.h file must
exist
                  // in the same folder with the
project

#include <keypad.h>    // The h file of the keypad
driver
                        // should be in the same
folder where we will save our program.
                        // The #define row0 PIN_B4
etc statements in keypad.h
                        // should be checked and
possibly modified.
                        //     These     statements
determine the pins of the microcontroller
                        // that are connected to the
keypad 4x4.

#byte PORTB =0xF81
```

```
                        // We attribute to the memory
position 0xF81 the name PORTB.
                        // This means that we define
a 8 bit variable whose value
                        //  will  be  stored  to  the
memory position F81h.
                        // The memory position F81h
is the PORTD data register.

#byte PORTD=0xF83     // F83h is the position or
PORTD data register
                        // at the data memory of the
microcontroller
                        //   SFR   Special   Function
Register

//initialization routine
void init(void);

// ********* main program ***********************
void main(){
   char k;       //variable for storing the ASCII
code of the key pressed
   init();      //initialization routine
   kbd_init();   //initialization routine for the
keypad 4x4

   while(TRUE){
      k=kbd_getc(); //Keypad reading.
                    //If  a  key  is  pressed,  the
variable k gets the ASCII code of the key.
                    //If  no  key  is  pressed,  the
function kbd_getc() returns the value 0.
      If(k!=0){     //If a key is pressed
         PORTD=k;    //The ASCII code of the key
pressed is transferred to PORTD
      }
   }
}

//initialization routine
void init (void){
   set_tris_d(0x00);  //PORTD is defined as output
   PORTD=0x00;          //PORTD takes the initial
value of 0x00
}
```

Step 3 (4 minutes)	Compile the program in C in order to create the program in the microcontroller machine code (hex file).

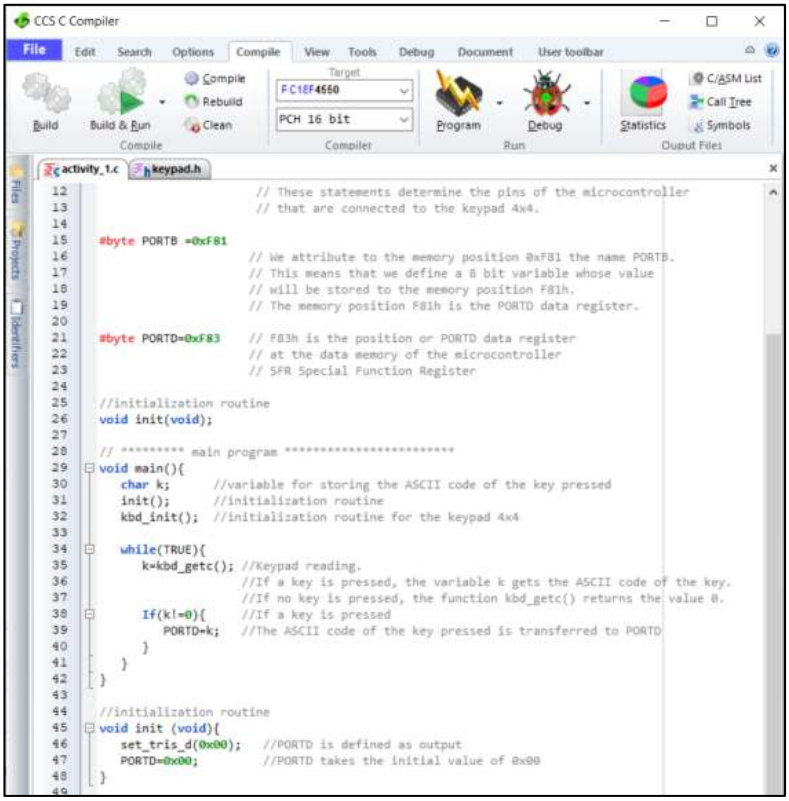


Figure 2. CCS C Compiler, translation to machine code (hex file)

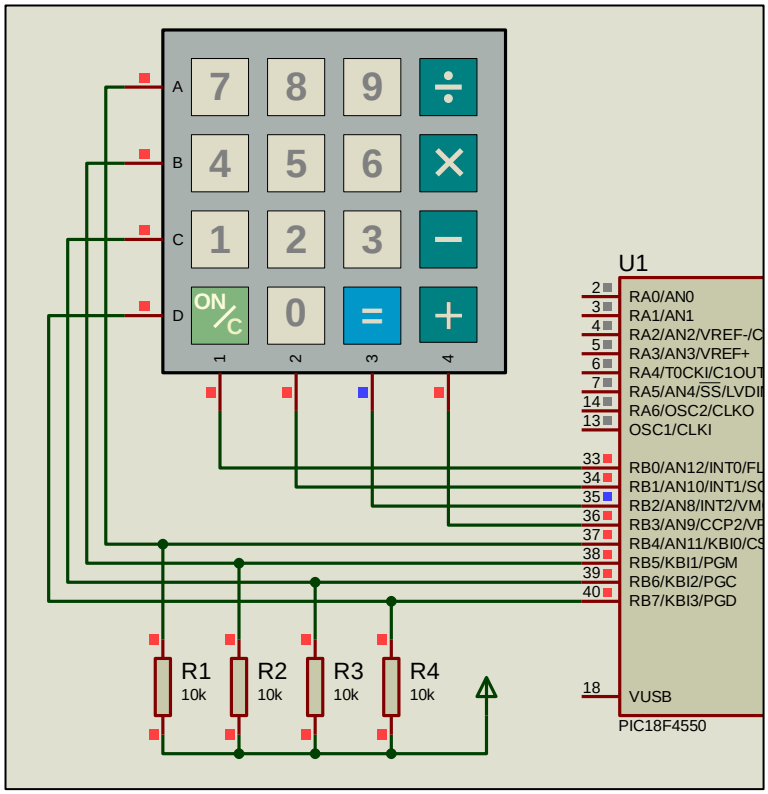
Step 4 (1 minutes)	Load to the microcontroller the hex file (program in machine code) that was created from the CCS C Compiler.
Step 5 (5 minute)	Run the simulation and check the correct operation of the circuit.
Step 6 (5 minutes)	Suggested modifications and discussion: • modify the code so that PORTD does not display the ASCII code but the numeric value of the key ***Tip**. Notice the values of the first 4 bits of the ASCII codes of digits 0, 1, 2,… 9.*

2.2 Activity 2. Keypad 4x4 and LCD 16x2

The purpose of this activity is for microcontroller to read an ASCII character from a keypad 4x4, and display it in a LCD 16x2.

- If ‘C’ key is pressed, then the screen clears.

Table 5. Activity 2

Activity 2nd (45 minutes)	**Step 1.** The circuit is drawn in the Proteus Design Suite. **Step 2.** The program in C language is written. **Step 3.** The program is compiled with the use of CCS C compiler to the microcontroller machine code. The machine code is loaded to the flash memory of the microcontroller. **Step 4.** The animation is activated. **Step 5.** Modifications and discussion.
Step 1 (15 minutes)	Draw the circuit of the picture at the Proteus Design Suite.  *Figure 3 (a). Keypad 4x4 and LCD 16x2*

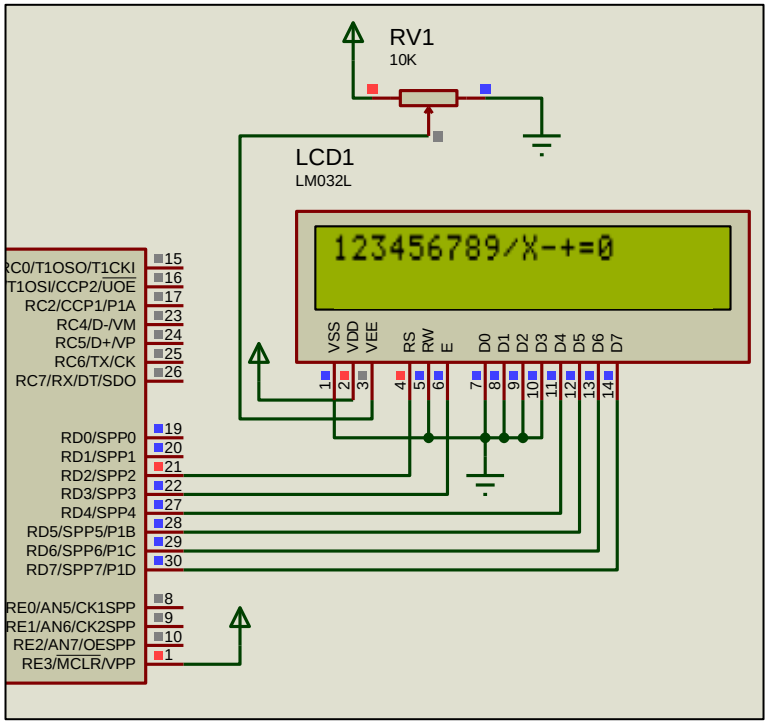


Figure 3 (b). Keypad 4x4 and LCD 16x2

Step 2
(15 minutes)

Write in CCS Compiler the program in C language

```
#include <main.h> // the file main.h with the
                  // initial settings is included.
                  // This file must be placed in
the same
                  // folder with the project.
                  // Also the 18F4550.h file must
exist
                  // in the same folder with the
project

#include <flex_lcd.h> // The h file of the lcd
driver
                      // should be in the same
folder where we will save our program.
                      // The #define LCD_DB4
PIN_B4 etc statements in flex_lcd.c
                      // should be checked and
possibly modified.
                      //     These     statements
determine the pins of the microcontroller
                      // that are connected to LCD
16x2.

#include <keypad.h>   // The h file of the keypad
driver
                      // should be in the same
folder where we will save our program.
```

```
                        // The #define row0 PIN_B4
etc statements in keypad.h
                        // should be checked and
possibly modified.
                        //     These     statements
determine the pins of the microcontroller
                        // that are connected to the
keypad 4x4.

#byte PORTB =0xF81
                       // We attribute to the memory
position 0xF81 the name PORTB.
                       // This means that we define
a 8 bit variable whose value
                       //  will  be  stored  to  the
memory position F81h.
                       // The memory position F81h
is the PORTD data register.

#byte PORTD=0xF83     // F83h is the position or
PORTD data register
                       // at the data memory of the
microcontroller
                       //   SFR   Special   Function
Register

//initialization routine
void init(void);

// ********* main program ************************
void main(){
   char k;       //variable for storing the ASCII
code of the key pressed
   init();      //initialization routine
   kbd_init();   //initialization routine for the
keypad 4x4
   lcd_init();   //initialization routine for the
LCD 16x2
   while(TRUE){
      k=kbd_getc();    //keypad reading

      //If a key is pressed (k! = 0) and if the
key pressed is not 'C',
      //the character will appear on the LCD
      if (k!=0 && k!='C'){
         printf(lcd_putc,"%c",k);
      }

      //If  'C'  key  is  pressedm  then  the  screen
clears
      else if(k=='C'){
         printf(lcd_putc,"\f");
      }
   }
}

// initialization routine
void init(void){
   set_tris_d(0x00);       //PORTD  is  defined  as
output
}
```

Step 3 (5 minutes)	Use the CCS C Compiler to translate the programm from C language to the microcontroller machine code. Load to the microcontroller the hex file (machine code) that was created from the CCS Compiler.
Step 4 (5 minutes)	Run the simulation and check the correct operation of the circuit.
Step 5 (5 minutes)	Suggested modifications and discussion: • what do we need to change in the circuit and in the code so that the keypad 4x4 is connected to PORTC?

2.3 Activity 3. Simple calculator

This activity uses a 4x4 keypad and a LCD 16x2, with the aim of making the PIC18F4550 a simple calculator that can perform 4 basic operations between 2 single-digit numbers.

The PIC18F4550:

- reads the first number
- reads which mathematical operation will be performed (+, -, X, /)
- reads the second number
- displays the result on the LCD
- waits for 'C' to be pressed to start the process from the beginning

Table 6. Activity 3

Activity 3rd (75 minutes)	**Step 1.** The circuit is drawn at the Proteus Design Suite. **Step 2.** The program in C language is written. **Step 3.** The program is compiled with the use of CCS C compiler to the microcontroller machine code (the hex.file is created). The program in machine code is loaded to the microcontroller. **Step 4.** The animation is activated. **Step 5.** Modification and discussion.

Step 1
(15 minutes)

Draw the circuit of the picture in the Proteus Design Suite.

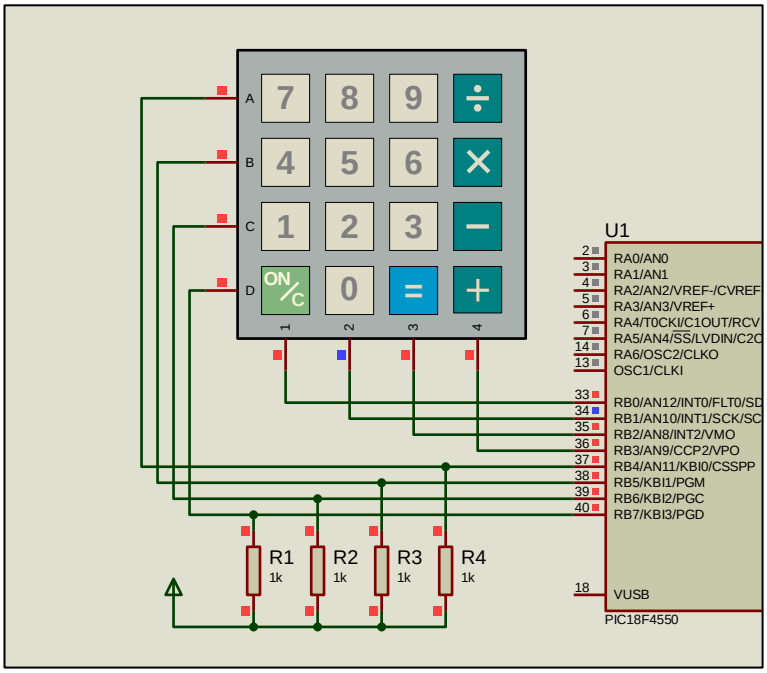


Figure 4 (a). Keypad 4x4 and LCD 16x2

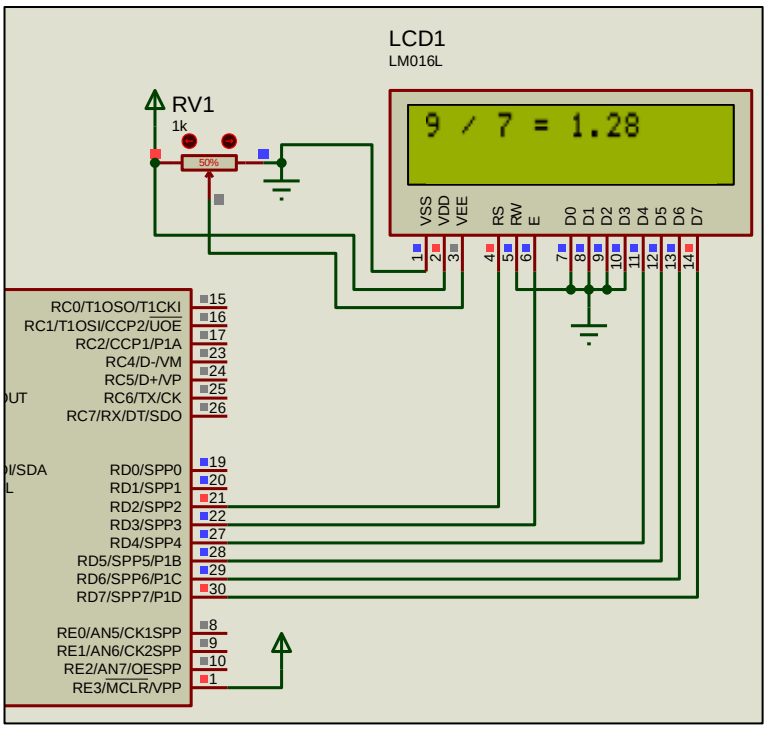


Figure 4 (b). Keypad 4x4 and LCD 16x2

Step 2 (35 minutes)	Write in CCS C Compiler the program in C language

```
#include <main.h> // the file main.h with the
                  // initial settings is included.
                  // This file must be placed in
the same
                  // folder with the project.
                  // Also the 18F4550.h file must
exist
                  // in the same folder with the
project

#include <flex_lcd.h> // The h file of the lcd
driver
                      // should be in the same
folder where we will save our program.
                      //  The  #define  LCD_DB4
PIN_B4 etc statements in flex_lcd.c
                      //  should be checked and
possibly modified.
                      //     These     statements
determine the pins of the microcontroller
                      // that are connected to LCD
16x2.

#include <keypad.h>   // The h file of the keypad
driver
                      // should be in the same
folder where we will save our program.
                      // The #define row0 PIN_B4
etc statements in keypad.h
                      //  should be checked and
possibly modified.
                      //     These     statements
determine the pins of the microcontroller
                      // that are connected to the
keypad 4x4.

#byte PORTB =0xF81
                     // We attribute to the memory
position 0xF81 the name PORTB.
                     // This means that we define
a 8 bit variable whose value
                     //  will  be  stored  to  the
memory position F81h.
                     // The memory position F81h
is the PORTD data register.

#byte PORTD=0xF83     // F83h is the position or
PORTD data register
                     // at the data memory of the
microcontroller
                     //   SFR   Special   Function
Register

char key;            //variable to save keypad's
characters
int num1=10;      //variable for the first number
int num2=10;      //variable for the second number
```

```
char operation;   //variable for the operation
float result;     //variable for the result
boolean flag=0;    //flag raised when the divider
is 0

//this function converts keypad's character to
integer
int convert_to_number(char c);

// ********* main program ***********************
void main() {
   set_tris_d(0x00);       //PORTD is defined as
output - LCD 16x2
   kbd_init();            //initialization routine
for the keypad 4x4
   lcd_init();            //initialization routine
for the LCD 16x2
   lcd_putc("\f");      //clear the screen

   while(TRUE){
      //read the first number
      do{
         //wait until a key is pressed
         key=kbd_getc();
         if(key!=0){
            //call the "convert_to_number"
            num1=convert_to_number(key);
         }
      }
      while(num1>9);
      //print the first number
      printf(lcd_putc,"%d",num1);

      //read the operation
      do{
         //wait until a key is pressed
         operation=kbd_getc();
      }
      while(operation!='X'  &&  operation!='/'  &&
operation!='+' && operation!='-');

      //print the operation
      if(operation=='+'){
         printf(lcd_putc," + ");
      }
      else if(operation=='-'){
        printf(lcd_putc," - ");
      }
      if(operation=='X'){
         printf(lcd_putc," * ");
      }
      else if(operation=='/'){
         printf(lcd_putc," / ");
      }

      //read the second number
      do{
         //wait until a key is pressed
         key=kbd_getc();
         if(key!=0){
            //call the "convert_to_number"
            num2=convert_to_number(key);
```

```
            }
         }
         while(num2>9);
         //print the second number
         printf(lcd_putc,"%d = ",num2);

         //calculate the result
         if(operation=='+'){
             result=num1+num2;
          }
         else if(operation=='-'){
            if(num1>num2){
               result=num1-num2;
            }
            else{
               result=num2-num1;
               printf(lcd_putc,"-");
            }
         }
         else if(operation=='X'){
           result=num1*num2;
         }
         else if(operation=='/'){
            if(num2==0){
               flag=1;
            }
            else{
               result=(float)(num1)/num2;
            }
         }

         if(flag==1){ //divider = 0
            flag=0;
            printf(lcd_putc,"\nUndefined");
         }
         else{
            //print the result
            printf(lcd_putc,"%f",result);
         }

         //wait until the "C" is pressed
         do{
            key=kbd_getc();
         }
         while(key!='C');

         //clear the LCD
         lcd_putc("\f");
         num1=num2=10;
      }
   }

   //this function converts keypad's character to
   integer
   int convert_to_number(char c){
     if(c=='0'){
       return 0;
     }
     else if(c=='1'){
       return 1;
     }
     else if(c=='2'){
```

	`` return 2; } else if(c=='3'){ return 3; } else if(c=='4'){ return 4; } else if(c=='5'){ return 5; } else if(c=='6'){ return 6; } else if(c=='7'){ return 7; } else if(c=='8'){ return 8; } else if(c=='9'){ return 9; } else if(c=='/'){ return 10; } else if(c=='X'){ return 11; } else if(c=='-'){ return 12; } else if(c=='+'){ return 13; } else if(c=='='){ return 14; } else if(c=='C'){ return 15; } else{ return 16; } } ```
Step 3 (5 minutes)	Compile the program in order to create the hex.file (program in machine code). Load the program (hex.file) to the microcontroller.
Step 4 (10 minutes)	Run the simulation and check the correct operation of the circuit.
Step 5 (10 minutes)	Suggested modifications and discussion:

	• can other operations be added, such as power, or square root? ***Tip***. *#include <math.h>, pow(), sqrt()*

Chapter 3: **Recapitulation**

- ☞ The schematic of the circuits was drawn with Proteus Design Suite
- ☞ A keypad 4x4 (and a LCD 16x2) were used to implement applications such as a simple calculator.
- ☞ The programs in C was written in CCS C compiler.
- ☞ The programs in C was compiled to the microcontroller machine code (hex file).
- ☞ The machine code was “loaded” to the microcontroller and the animation was activated.

References

CCS C Compiler Manual. Ccsinfo.com. (2021). Retrieved from https://www.ccsinfo.com/downloads/ccs_c_manual.pdf.

PIC18F2455/2550/4455/4550 Data Sheet. Ww1.microchip.com. (2006). Retrieved from https://ww1.microchip.com/downloads/en/devicedoc/39632c.pdf.

Proteus Tutorial : Getting Started with Proteus PCB Design (Version 8.6). Youtube.com. (2017). Retrieved from https://www.youtube.com/watch?v=GYAHwYUUs34.

Simple LED Circuits. Electronics Hub. (2017). Retrieved from https://www.electronicshub.org/simple-led-circuits/.

Appendix. Figures with high resolution

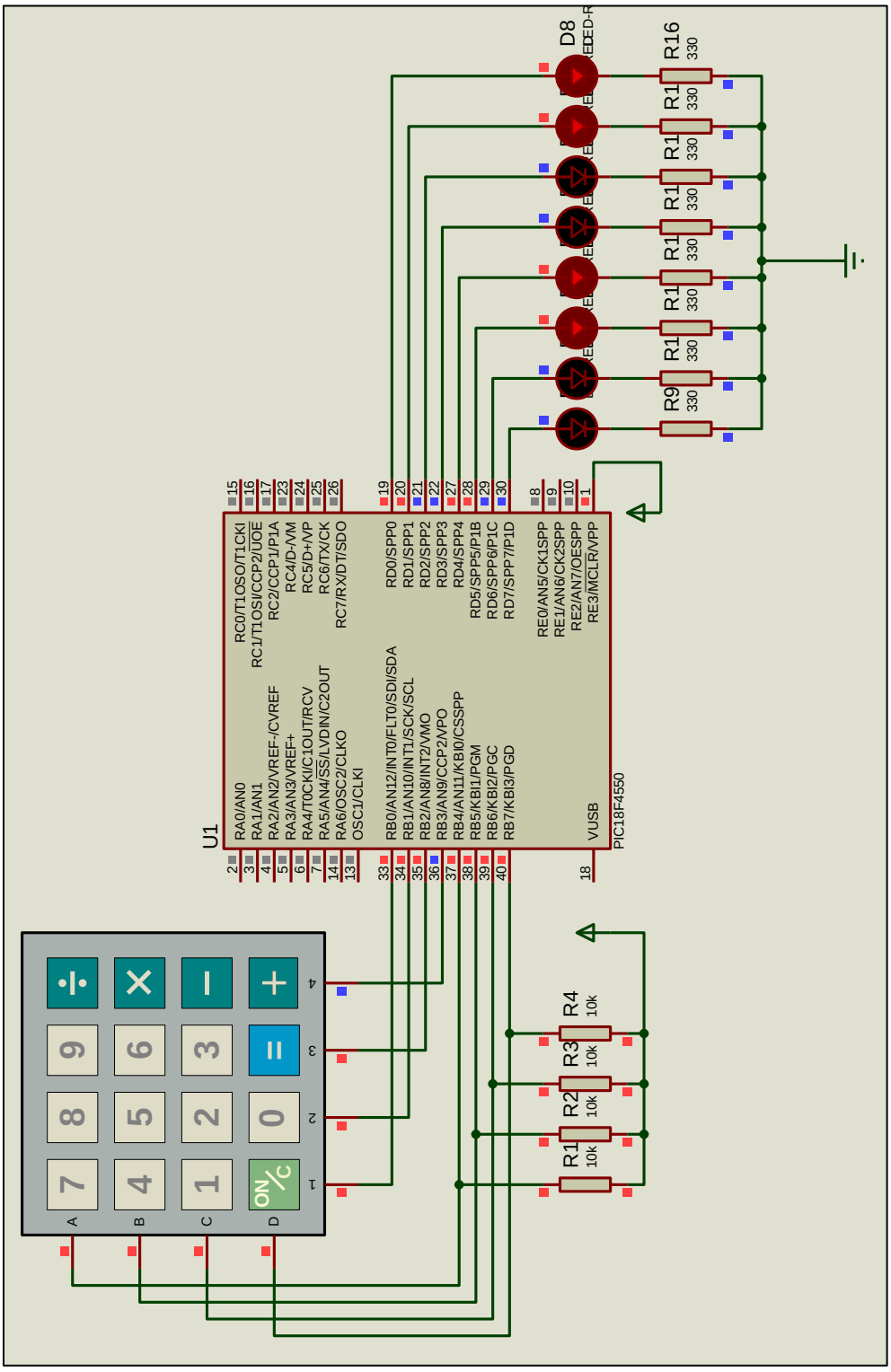


Figure 1. Keypad and LEDs

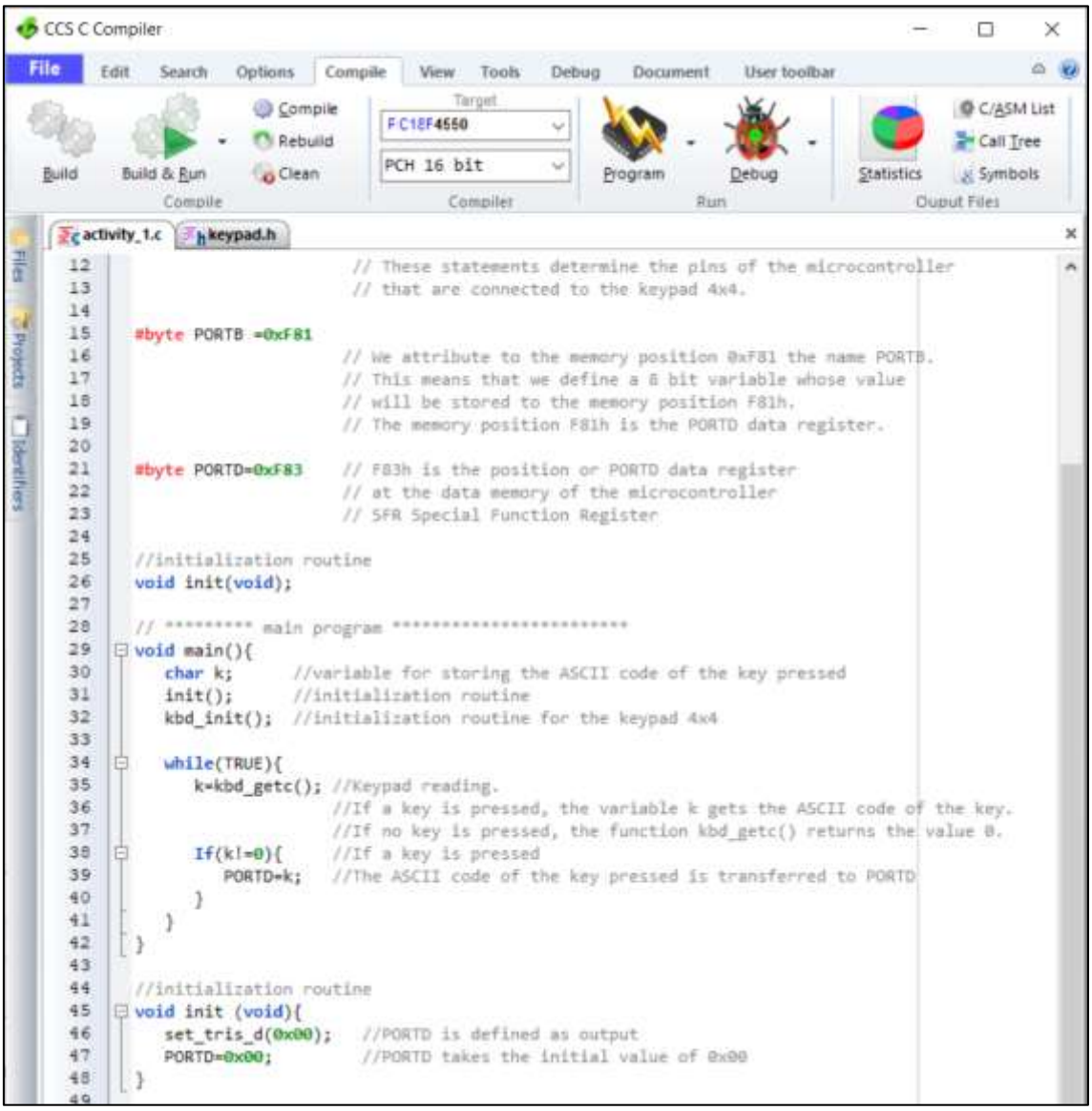


Figure 2. CCS C Compiler, translation to machine code (hex file)

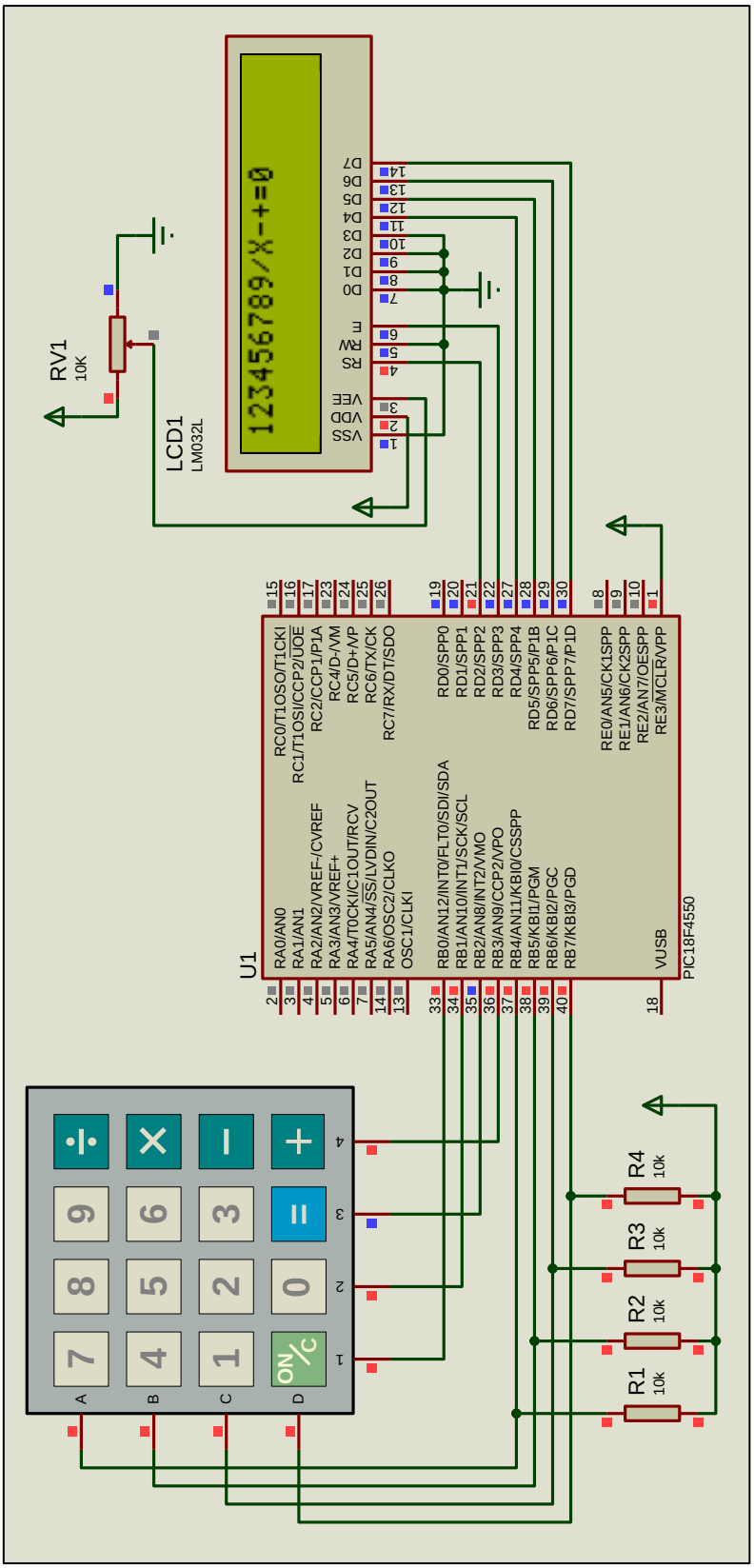


Figure 3. Keypad 4x4 and LCD 16x2

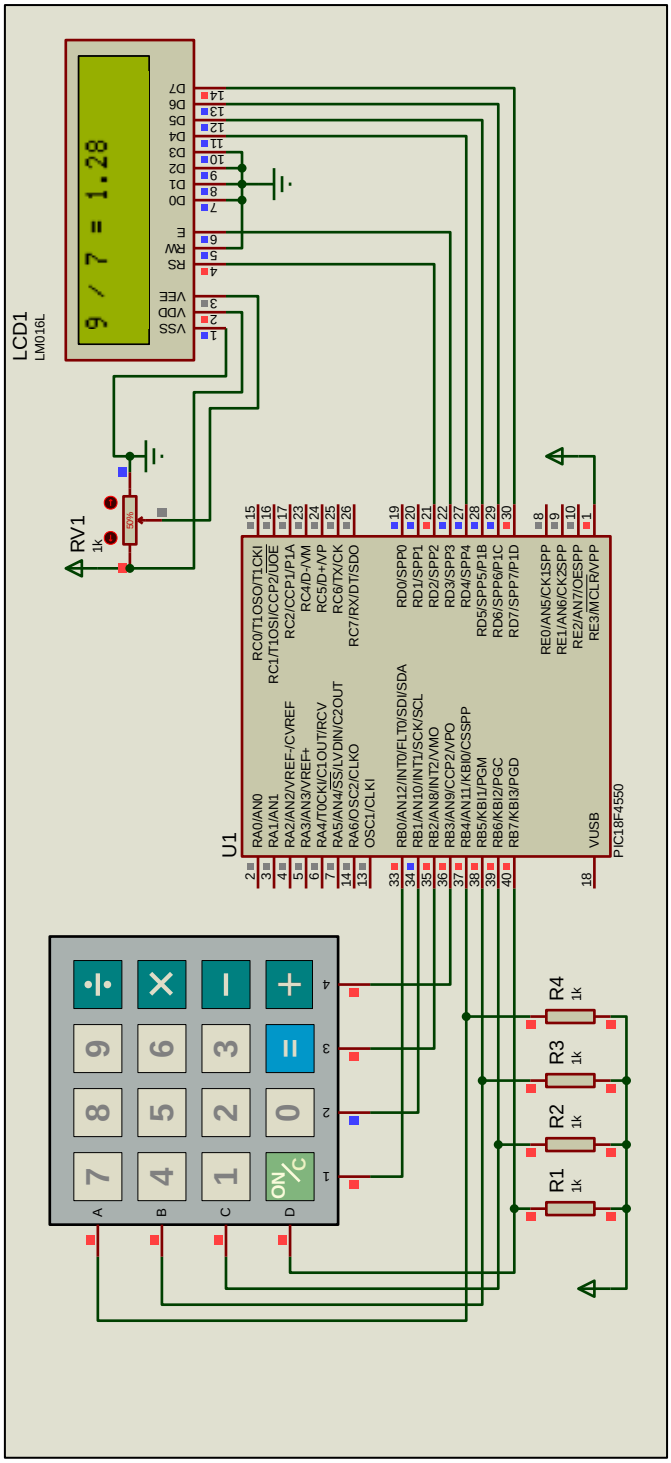


Figure 4. Simple calculator