ECE471: Embedded Systems – Homework 5

i2c interface and LED Display

Due: Friday, 10 October 2025, 5:00pm EDT

1. Use your Raspberry Pi for this homework.
   In addition you will need one 4x7 segment LED display that was handed out in class (if you missed class, stop by my office to pick one up). Note: this display is on loan, and we will use it for two homework assignments and then you should return it by the end of the semester.

   More info on the display can be found here: `https://www.adafruit.com/products/880`

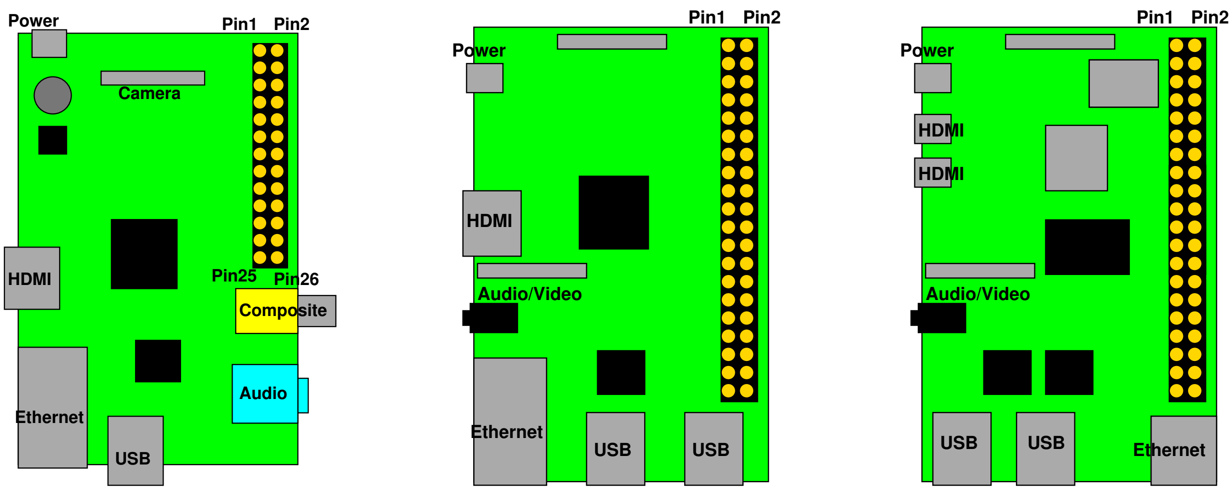


Figure 1: Location of header on Raspberry Pi Model 1B, 1B+/2/3, 4B

2. First you will need to hook up the LED display. You can use Figure 1 and Table 1 for guidance.

   (a) Hook the display to your pi on a breadboard:
   Connect `3.3V` on the Pi to + on the LED Display.
   Connect `GND` on the Pi to − on the LED Display.
   Connect `SDA` on the Pi to `D` on the LED Display.
   Connect `SCL` on the Pi to `C` on the LED Display.

   (b) Enable i2c support in Linux running on your pi.

   - With current Raspberry Pi OS the easiest way is to run `sudo raspi-config` select "Interface Options" then "I2C" then say yes to enable support.
   - You might have to reboot the pi for it to fully take effect.
   - You should be able to access i2c as a normal user (without sudo). If you get permission denied errors when trying to run the homework you can try running this command:
     `sudo addgroup username i2c`
     where username is your username.

Table 1: Raspberry Pi Header Pinout

3.3V	1	2	5V
GPIO2 (SDA)	3	4	5V
GPIO3 (SCL)	5	6	GND
GPIO4 (1-wire)	7	8	GPIO14 (UART_TXD)
GND	9	10	GPIO15 (UART_RXD)
GPIO17	11	12	GPIO18 (PCM_CLK)
GPIO27	13	14	GND
GPIO22	15	16	GPIO23
3.3V	17	18	GPIO24
GPIO10 (MOSI)	19	20	GND
GPIO9 (MISO)	21	22	GPIO25
GPIO11 (SCLK)	23	24	GPIO8 (CE0)
GND	25	26	GPIO7 (CE1)
ID_SD (EEPROM)	27	28	ID_SC (EEPROM)
GPIO5	29	30	GND
GPIO6	31	32	GPIO12
GPIO13	33	34	GND
GPIO19	35	36	GPIO16
GPIO26	37	38	GPIO20
GND	39	40	GPIO21

(c) Sanity check your i2c setup.

- If you have your pi on a network you can run
  `sudo apt-get install i2c-tools`
  to install the i2c-tools package. Then you can scan the bus to be sure you have things hooked up properly. If you can't install the package, skip the next step, as it's not really necessary (it's just a good way to verify you have things wired up correctly).
- Run `sudo i2cdetect -y -r 1` and if things are working you should see a "70" at address 70. This means Linux can see your device at address 0x70.

```
     0  1  2  3  4  5  6  7  8  9  a  b  c  d  e  f
00:          -- -- -- -- -- -- -- -- -- -- -- -- --
10: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
20: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
30: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
40: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
50: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
60: -- -- -- -- -- -- -- -- -- -- -- -- -- -- -- --
70: 70 -- -- -- -- -- -- --
```

3. **Documentation**

   The display is run by a ht16k33 chip. You can get the datasheet here:
   `https://www.adafruit.com/datasheets/ht16K33v110.pdf`

4. **Getting the Code**

   Download the template code from the ECE471 website:
   `https://web.eece.maine.edu/~vweaver/classes/ece471/ece471_hw5_code.tar.gz`

   Uncompress it with `tar -xzvf ece471_hw5_code.tar.gz`

5. **Light up the Entire Display** (3 points)

   Modify the provided `display_test.c` file. Running `make` should build your code. If you get clock skew errors, either set your clock to current time or else run `make clean` before running `make`.

   Comment your code! Fix all compiler warnings!

   Make sure you to check for errors and report them back to the user and exit if appropriate.

   Here are the steps needed to talk to the device:

   (a) Open the device using the `open()` function. This returns an integer file descriptor for the device, or -1 on error. The call will look something like

   `fd = open("/dev/i2c-1", O_RDWR);`

   where `O_RDWR` means open for reading and writing.

   (b) Set the device address. An IOCTL is used for this.

   `result=ioctl(fd, I2C_SLAVE, 0x70);`

   where `I2C_SLAVE` is a constant defined in the `linux/i2c-dev.h` header, `fd` is the file descriptor from earlier, and `0x70` is the device address from the data sheet. A negative value is returned on error.

   (c) Commands to the device are described starting on page 10 of the data sheet. Commands are an 8-bit value, with the command type in the top 4 bits and the data in the low 4 bits.

   (d) Send a command to activate the oscillator on the device by modifying the "System Setup Register". The high 4 command bits should be 0x2 and the low 4 bits should be 0x1. To generate this constant, shift the command left by 4-bits, then logical-or the low bits into the value. Write this 8-bit value to the device. The code will look something like this:

   ```
   unsigned char buffer[17];

   buffer[0]=(0x2<<4)|(0x1);
   result=write(fd, buffer, 1);
   ```

   This says we want to write 1 byte to the file desriptor `fd`, and the byte we want to write is found via `buffer` which points to the beginning of a 17-byte long char array declared earlier. The return value is how many bytes were successfully written.

   Feel free to use C pre-processor defines to make the constants for the commands and data easier to read.

(e) Next turn on the display, with blinking disabled. Do this via the "Display Setup Register"

(f) Next set the brightness. Set it to a value between 10 and 15 (your choice). Do this via the "Display Dimming Data Input". You will need to get the proper values from the data sheet.

(g) Finally write out the pattern you want on the display. For this simple test case we will write all 1s to make the display completely light up.

To do this, write the "Display Data Address Pointer" which for our case is 0, then followed by 16-bytes holding the two 8-bit values for each of the 8 rows. It is easiest to just write all 17 bytes at once.

```
unsigned char buffer[17];
int i;

buffer[0]=0x0;
for(i=0;i<16;i++) buffer[1+i]=0xff;
write(fd,buffer,17);
```

(h) Now close the file descriptor with `close(fd);` and exit the program. The display will keep displaying the last thing written to it.

6. **Display ECE 471** (3 points)

For this part of the homework, modify `display_final.c`. First copy your `display_test.c` file over as a starting point:

`cp display_test.c display_final.c`.

Then work on the `display_final.c` code.

The goal is to make the display show the following pattern:

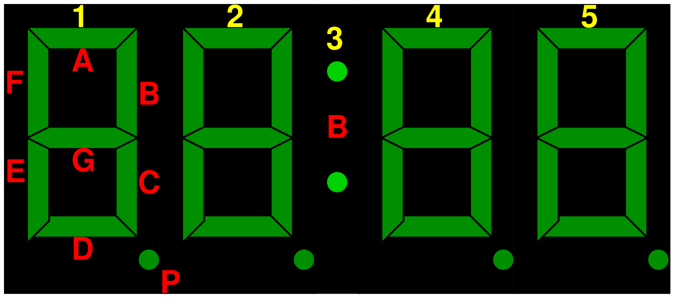
- `ECE`
  pause for 1 second
- `471`
  pause for 1 second
- Then loop back to the beginning to display ECE again, and repeat forever (you can stop it by pressing Control-C).

The display mapping for each LED segment is shown in Figure 2.

As an example, to display the letter 'E' in the far left column, you would do:

```
unsigned char buffer[17];

buffer[0]=0x00;  // offset pointer
buffer[1]=0x79;  // Column 1, Segments ADEFG
buffer[2]=0x00;  //  next 8 bits of column 1, not connected
buffer[3]=0x00;  // Column 2, empty
buffer[4]=0x00;  //  next 8 bits of column 2, not connected
...
write(fd,buffer,17);
```



byte 0 = 0x00 (display pointer offset)
byte 1 = (1P, 1G ,1F, 1E, 1D, 1C, 1B, 1A)
byte 2 = 0x00
byte 3 = (2P, 2G, 2F, 2E, 2D, 2C, 2B, 2A)
byte 4 = 0x00
byte 5 = (X, X, X, X, X, X, X, 3:, X)
byte 6 = 0x00
byte 7 = (4P, 4G, 4F, 4E, 4D, 4C, 4B, 4A)
byte 8 = 0x00
byte 9 = (5P, 5G, 5F, 5E, 5D, 5C, 5B, 5A)
byte10–byte16 = 0x00

Figure 2: LED Display Segment Mapping

The Linux/C function to pause (sleep) for a period of time is `usleep()`. The parameter is the amount of time to sleep in micro-seconds.

7. **Something Cool** (1 point)

   Copy your `display_final.c` code over to `display_cool.c` and modify it to do something extra.

   Some possible suggestions:

   - Record an i2c write transaction using an analog discovery board.
     See if you can interpret the SDA/SCL lines as bits are being sent. Some logic analyzers (possibly the analog discovery?) are smart enough to interpret i2c and can decode the transaction for you. Send an image of the plot along with your homework submission.
   - Display ECE 471 on the display but have it scroll left or right.
   - Make a little animation on the screen, bouncing ball, etc.
   - Display your name, or as much of your name as you can with 7-segment displays.
   - Display the time. (the `time()` and `localtime()` routines will be helpful here).

   Put into the README a note describing the something cool that you chose.

8. **Questions (2 points)**

   Answer the following in the README file: (note, we might not cover some of these topics in class until Monday)

   (a) Name one benefit of using an Operating System on an embedded system over programming bare-metal.

   (b) Name one downside of using an Operating System on an embedded system.

   (c) In the `i2cdetect` output in part 2c you can see that addresses 0-2 and 0x78-0x7f are not scanned. Why are these addresses skipped?

9. **Linux Fun (1 point)**

   (a) You can use the `wc` word-count program to count the lines, words, and bytes in a file.

   Use `wc -l display_final.c` (that's a lower-case L) to count the number of lines in your `display_final.c` file. Report how many lines it is.

   (b) You can use the `diff` command to compare two files and see the differences between them. Run `diff -u display_test.c display_final.c`

   You can use the pipe character `|` to "pipe" the output of one command into the input of another. Pipe the output of diff into wc and report how many lines are in the diff file:
   `diff -u display_test.c display_final.c | wc -l`

10. **Submitting your work**

   - Run `make submit` which will create a `hw5_submit.tar.gz` file containing `Makefile`, `README`, `display_test.c`, `display_final.c`, and `display_cool.c`
     You can verify the contents with `tar -tzvf hw5_submit.tar.gz`
   - e-mail the `hw5_submit.tar.gz` file to me by the homework deadline. Be sure to send the proper file!