Installing programming tools on macOS machines V2.0
2/24/24
ECE-231 Spring 2024

This note provides instructions for downloading the VSCode editor and the AVR toolchain (compiler and other tools) onto a computer running macOS.

VS Code text editor. *Visual Studio Code (aka VS Code)* is a no-cost text editor owned by Microsoft. This is a popular editor among programmers because it has a number of features (eg, color coding, indentation, syntax, error checking, code folding, file management, etc..) that help to develop source code. Note that VS Code is not the same as another similarly-named Microsoft product, Visual Studio. Studio is a full blown Integrated Development Environment, while VS Code is simply a text editor that happens to have many features helpful for creating source code.

avr-gcc compiler. Use the *avr-gcc* compiler and assorted tools (aka, the tool-chain) on your macOS machine to compile source code into machine language understandable by AVR processors such as the ATmega328p and the ATtiny85. Access these tools by downloading the the AVR 8-bit GNU[1] Toolchain freely available from the Microchip web site. (Microchip is the company that manufactures the AVR ATmega328P mcu.)

homebrew. Homebrew is a software package manager for macOS. Once installed, homebrew helps with the installation of other software, handling dependencies, PATH variables, and other things that need to be set up for software to work correctly. Homebrew needs the macOS xcode command line tools in order to operate (*not the full xcode* system) and will install them during its own installation. Homebrew is similar to MacPorts and Fink, and if you already have one of these installed and know how to use it, feel free to use that instead.

avrdude (avr download/uploader) is the program used to flash compiled code to the ATmega328p MCU on the Arduino Uno development board.

make is a program that automates the multi-step process of compiling, linking,copying and flashing a program to a microcontroller. A version of make comes installed as part of macOS, but it needs the xcode command line tools to work, and those tools will be installed when you install homebrew.

macOS version. You should be using an up-to-date version of the mac OS, such as mac OS 12 Monterey, or 13 Ventura or 14 Sonoma.

[1] GNU is a recursive acronym for "GNU's Not Unix!" and refers to the GNU Operating System supported by the Free Software Foundation. (A gnu -- lowercase letters -- is a wildebeest, which is a type of antelope.) GNU is pronounced as one syllable with a hard g, like "grew" but "gnew". See https://www.gnu.org/gnu/gnu.html if interested.

There are many steps involved in downloading, installing, and setting up these programs on your mac. You will need to set some environment PATH variables on your machine and use the Terminal command line app throughout. You should carefully read thru these instructions, twice, before you begin to download anything.

A few words about the terminal and the PATH variable. In ECE-232 and ECE-304, we use the Terminal App extensively rather than the graphical user interface on macOS machines. Whenever we start a new coding project, we will create a new folder, or subdirectory, for that project and we will be working within that directory. In order for the binary executable files associated with VS Code, avr-gcc, avrdude, make, etc... to be able to run from different directories, we need to have the directory paths for these files included in the environmental PATH variable. More in this below...

PART 1. Install VS Code.

Goto https://code.visualstudio.com/docs/setup/mac
and follow the Installation instructions there to download and install VS Code to your Applications folder and install a shortcut link in your dock. Important: Be sure to follow the instructions for "Launching from the command line".

To test your installation, quit VS Code. Then open the Terminal App (found in /Applications/Utilities/Terminal.app) and type

```
% code .
```

(Note: In this document, I have highlighted in yellow whenever you have something to type on the command line in Terminal. The % symbol represents the prompt you will see on the command line. Don't type it. Also: don't forget the space followed by the period after code. When you hit return, VS Code should open.

Under the VS Code file menu, be sure that autosave is checked. If not, check it.

Add the Terminal to your dock, since we'll be using it frequently. Quit terminal and quit VS Code.

PART 2. Install the avr-gcc compiler from Microchip.

2.1 Google "microchip avr gcc compiler" or goto
https://www.microchip.com/en-us/tools-resources/develop/microchip-studio/gcc-compilers

2.2 Scroll down and download "AVR 8-bit Toolchain (OSX)" version 3.7.0

2.3 A compressed tar file will download, probably to your download folder, depending on your machine settings. Move this file into your Applications folder and double-click to open it.

2.4 You will now have a folder named "avr8-gnu-toolchain-osx-3.7.0.518-darwin.any.x86_64" that contains numerous subfolders. Rename this folder "avr" and delete the downloaded tar file since that is no longer needed.

2.5 You now need to adjust the environmental PATH variable on your system so that it can find the binary files in the avr toolchain. You need to do two things:

2.5.1 Create a simlink (symbolic link) to the avr toolchain: open terminal and type the following (again: % is the prompt. Don't type that.)

```
% cd /usr/local
% sudo ln -s /applications/avr avr
% cd $HOME
```

You will be asked to provide your computer login password after the sudo command.

2.5.2 Modify your shell startup file so that your PATH variable contains the above link to the avr binary files. Your laptop probably is set up for the "zsh" shell by default, so you will be editing or creating the .zshrc file or the .zprofile in your home directory. If your mac is using the "bash" shell, then you will be editing or creating the .bash_profile in your home directory. You can edit/create these files using VS Code. Type "code ." to open up all the files in your home directory and look for .zshrc or .zprofile (if you're using .zsh) or .bash_profile (if you're using the .bash shell). Either edit the appropriate file or create a new one if needed, adding the line:

```
export PATH=/usr/local/bin:/usr/local/avr/bin:$PATH
```

Quit VSCode, close Terminal then re-open it for this new setting to take effect.

Type

```
% which avr-gcc
```

and you should see something like

```
/usr/local/avr/bin/avr-gcc
```

Now type

```
% avr-gcc --version
```

and you should see something like

avr-gcc (GCC) 7.3.0

this means you have successfully installed the avr toolchain. So far, so good!

3. Install Homebrew.

goto https://brew.sh/

You will see a link under the words "Install Homebrew" that looks like this:

```
/bin/bash -c "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/install/HEAD/install.sh)"
```

Copy that link using the copy symbol shown, open Terminal, and past the entire link contents on the command line. Press return, and homebrew will install. You will be asked for your password, then asked to hit return. It will take some time, and it will install xcode command line tools along the way. Be patient. You may be asked to provide your computer login password a few times to give permission.

Important: when Homebrew finishes loading, you will see "Next steps: Run these two comands in your terminal to add Homebrew to your PATH". Carefully copy those two lines, one at a time, into your Terminal command line and hit return after pasting each line.

Quit, then reopen Terminal for these path changes to take effect.

4. Install avrdude. Once homebrew is installed, you can install avrdude simply by typing

```
% brew install avrdude
```

at the Terminal prompt. Homebrew will respond by fetching and downloading numerous files. When it finishes, check the avrdude installation by typing

```
% which avrdude
```

you should see

/usr/local/bin/avrdude (on a mac with intel processor) or
/opt/homebrew/bin/avrdude (on a mac with Apple silicon processor)

then just type

```
% avrdude
```

and you'll see a screen full of menu options. This means avrdude was installed correctly.

5. Test make. Type

```
% which make
```

you should see

```
/usr/bin/make
```

type

```
% make --version
```

you should see something like:

```
GNU Make 4.2.1 or Make 3.81
```

This means you're ready to proceed.

6. Build your first program.

If everything so far has been successful, you are now able to write a source code file in VS Code then compile it from the command line and download the machine code to the flash ROM of your AVR MCU. Create the classic “blink” project to test everything. The following instructions assume you are coding for an ATmega328p MCU on an Arduino Uno development (dev) board.

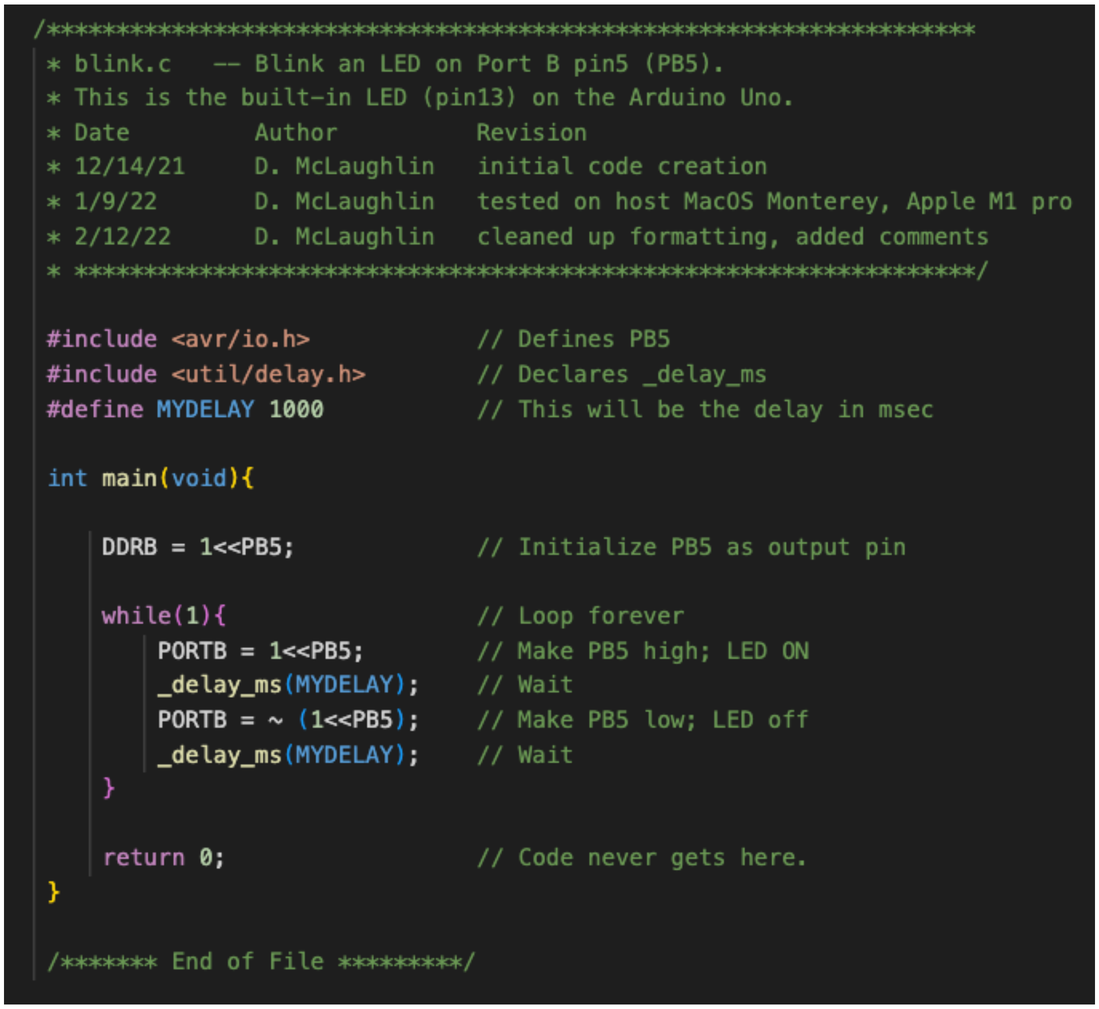
6.1 First, make a directory called “codingprojects” in your home directory. This is where you will be storing all your embedded coding projects. Next, move into this new directory. Then, create a new directory called “blink” for the project that you will now build. Move into that directory. Then open VS Code from that directory. You do all this with the following Terminal commands:

```
% mkdir codingprojects
% cd codingprojects
% mkdir blink
% cd blink
% code .
```

This will open up VS Code in the blink project folder. Create a source code file called “blink.c” by first hovering, then clicking on the + file box toward the top of the window.

6.2 Next, type in the source code shown or copy it from here:

https://github.com/ProfMcL/ECE231/blob/main/blink/blink.c



```c
/**********************************************************************
 * blink.c   -- Blink an LED on Port B pin5 (PB5).
 * This is the built-in LED (pin13) on the Arduino Uno.
 * Date         Author          Revision
 * 12/14/21     D. McLaughlin   initial code creation
 * 1/9/22       D. McLaughlin   tested on host MacOS Monterey, Apple M1 pro
 * 2/12/22      D. McLaughlin   cleaned up formatting, added comments
 * *******************************************************************/

#include <avr/io.h>             // Defines PB5
#include <util/delay.h>         // Declares _delay_ms
#define MYDELAY 1000            // This will be the delay in msec

int main(void){

    DDRB = 1<<PB5;              // Initialize PB5 as output pin

    while(1){                   // Loop forever
        PORTB = 1<<PB5;         // Make PB5 high; LED ON
        _delay_ms(MYDELAY);     // Wait
        PORTB = ~ (1<<PB5);     // Make PB5 low; LED off
        _delay_ms(MYDELAY);     // Wait
    }

    return 0;                   // Code never gets here.
}

/******* End of File *********/
```

6.3 Now, compile the code by typing:

```
% avr-gcc -Wall -Os -DF_CPU=16000000 -mmcu=atmega328p -o main.elf blink.c
```

If there are any errors, fix them and re-type the line above. Then type:

```
% avr-objcopy -j .text -j .data -O ihex main.elf main.hex
```

Then connect your Arduino Uno to your computer using the USB cable. Determine which USB port the Uno is connected to by typing:

```
% ls /dev/tty.*
```

You'll see something like

```
/dev/tty.usbmodem1101  (the numbers may be different)
```

Now flash the code to the ATmega328P mcu by typing

```
% avrdude -c Arduino -b 115200 -P /dev/tty.usbmodemXYZ  -p atmega328p -U
flash:w:main.hex:i
```

In place of XYZ type the number of your USB port identified in the previous step. You should now see the internal LED on the Arduino board blinking on and off at 1 second each.

6.4 Now modify the code by changing MYDELAY to 100.

Redo the commands avr-gcc, avr-objcopy, and avrdude and the LED should be blinking much faster. Note: you do not need to type in these commands. Position your cursar in the terminal prompt line and use the up and down arrows to scroll through previous commands.

6.5 You have undoubtedly noted that the three lines we're using to compile and flash are tedious to type. A makefile is a text file that contains a set of instructions for building code without needing to type in all the command line steps. Download the makefile from https://github.com/ProfMcL/ECE231/blob/main/blink/makefile and move that file to your blink project folder. (You should have version 2.0 of the makefile created by Prof. McLaughlin for this class). You will notice that this file is now listed along with blink.c and other files in the explorer panel of VS Code. Your laptop may have appended .txt or another extension to makefile during the download process. If so, right-click on makefile.txt and change its name to makefile without any extension.

6.6 Read through the makefile using VSCode and update the PORT variable to the correct USB port for your Arduino Uno. You can find this by typing ls /dev/tty.* from terminal.

6.7 Go back to blink.c and change MYDELAY to some other value, such as 3000, corresponding to 3 seconds.

From the terminal command line, type

```
% make
```

This will compile your code. Then type

```
% make flash
```

This will flash your code to your device.

6.8 Unplug your USB cable from your laptop and plug it into a wall outlet via a USB adapter if you have one.

Congratulations on your first embedded coding project!

Document History

Revised on	**Version**	**Author**	**Description**
2/13/23	1.0	D. McLaughlin	Initial document creation
2/15/23	1.1	D.McLaughlin	Corrected typo page 3 part 2.5.1
2/17/23	1.2	D. McLaughlin	added instruction 6.6 about changing USB port in makefile
4/24/24	2.0	D. McLaughlin	optimized for ECE-204 Spring 2024