

**ECE471: Embedded Systems – Homework 3**  
Linux Assembly and Code Density

**Due: Thursday, 24 September 2015, 9:30AM EDT**

1. Use your Raspberry-Pi to work on this project.
  - Download the code from:  
`http://web.eece.maine.edu/~vweaver/classes/ece471_2015f/ece471_hw3_code.tar.gz` and copy it to the Raspberry-Pi.
  - Uncompress/unpack it with the command `tar -xzvf ece471_hw3_code.tar.gz`
  - Change into the `ece471_hw3_code` directory `cd ece471_hw3_code`
2. **Modify the `exit_asm.s` file to return the value 4. (1 point total)**
  - (a) Modify `exit_asm.s` where it tells you to add code
  - (b) Be sure to comment your code!
  - (c) Run `make` to generate an updated version
  - (d) To test, run `./exit_asm` followed by `echo $?` which will show you the last program's exit status.
  - (e) Some reminders about Linux GNU assembler (`as`) syntax:
    - `.equ IDENTIFIER, value` sets a macro replacement, like
    - `#define IDENTIFIER value` would in C
    - You can use `@` to specify a comment, like `//` in C
    - You prefix a constant value with `#`
    - (to move the number 5 into a register you would do `mov r0, #5`)
  - (f) Reminders about the Linux ARM EABI:
    - Arguments go in `r0` to `r6`
    - System Call Number goes in `r7`
    - Use `swi 0x0` to trigger a system call.
3. **Modify `hello_world.s` (3 points total)**
  - (a) Describe how the provided decimal printing routine `print_number` works. Put the answer in the README file.
  - (b) Modify the `print_string` routine so it works. You'll need to add code so that it counts the number of characters in the string pointed to by `r1`, stopping at the first NUL (0) byte. Then store this count in `r2`. (I'm not grading on density, but it is possible to do this with 5 instructions. Bonus if anyone can manage to do it in 4.)
  - (c) After the above is done, after running `make` then running `./hello_world` should print `0: ECE471 is cool`
  - (d) Now modify the code to loop from 0 to 15 printing the message with the first number changing from 0 to 15. (Much like the C example in HW#2). If your running code gets stuck in infinite loop, Control-C can break out of it.

**4. Convert the `print_string` routine to 16-bit THUMB code. (2 points total)**

- (a) Copy your working code to `hello_world.thumb.s`  
`cp hello_world.s hello_world.thumb.s`
- (b) Modify the `print_string` routine to be THUMB code  
First uncomment the `@.thumb` line to be `.thumb`
- (c) You can then try running `make`
- (d) If you get errors you will need to change things so that routine is only using 16-bit thumb instructions. Remember, no fancy addressing, no accessing registers above `r7`, no conditional execution.
- (e) Don't forget that you need to use `blx` when jumping to THUMB code otherwise your program will crash.

**5. Something cool: (1 point total)**

Copy your code to `hello_world.extra.s` and do one of the following.

```
cp hello_world.s hello_world.extra.s
```

- Easy: Make the counts backwards from 15 to 0
- Moderate: Print the count in hexadecimal
- Hard: Print lines in colors like `HW#2`
- Very hard: `read` a number from STDIN and print the message that many times.

**6. Questions to Answer: (2 points total)**

Put the answer to these in the README.

- (a) Compare the size of the ARM32 `hello_world` executable and the THUMB `hello_world.thumb` executable. You can get filesize with `ls -l` (that's a lowercase L) You will want to run the `strip` command on the executables first (i.e. `strip hello_world`) or your results might be unexpected.
- (b) Compare the size to that of the C executable you made for `HW#2`.
- (c) Which language might you use in space constrained system? Why?
- (d) Which piece of code was easier/faster to write, the C or assembly one?

**7. Linux Command Line Exploration (1 point total)**

Try out the `cal` program. This prints a calendar, by default the current month. You can also `cal 2015` or `cal 12 2015`. Beware not to do `cal 15` as that will give you year 15, not 2015.

- (a) Run `cal 9 1752` Is there a bug here? Can you explain what is happening?

**8. Submitting your work.**

- Run `make submit` which will create `hw3_submit.tar.gz` containing the various files. You can verify the contents with `tar -tzvf hw3_submit.tar.gz`
- e-mail the `hw3_submit.tar.gz` file to me by the homework deadline. Be sure to send the proper file!