# Rochester Institute of Technology
# SWEN 563/CMPE 663/EEEE 663

## Project 2 – Servo Control

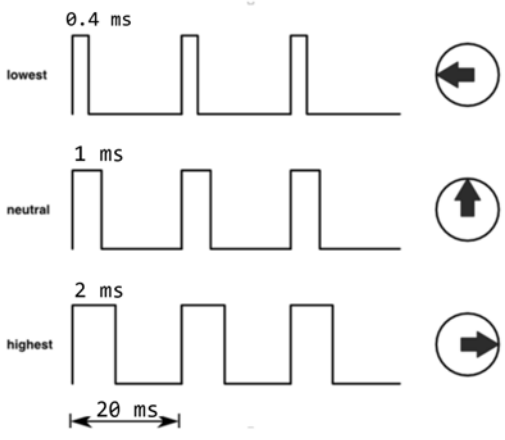
**Overview:**

Design and implement a STM32 Discovery board program exhibiting multitasking characteristics in simultaneously controlling a pair of servo motors using a custom interpreted control language. The system will be responsive to simultaneous independent, externally provided commands. The servo positions are controlled with pulse-width modulation (PWM). This first portion of the project utilizes the STM32 Discovery board. Each servo will be controlled by its own recipe of commands in the custom interpreted control language.

**Servo and PWM Overview:**

The servos can be positioned to any of six positions (0, 1, 2, 3, 4, 5) approximately evenly spaced along the servos' potential 160 degree arc. Position 0 is at the extreme clockwise position, and Position 5 is at the extreme counterclockwise position.


Typical Futaba position control servos require a PWM control signal with a 20 millisecond period. The duty cycle of this PWM signal controls the servo through its range of positions. The typical duty cycle ranges from 2% to over 10% for full range of positions. Pulse widths from 0.4 milliseconds to 2.0 milliseconds are a typical range.



**Connecting the Futaba Servo:**

These servos require 5 volts with sufficient current to move the motor. Use the 5 volt power adapter in the kit. Be sure to connect all grounds!

On the servo the black line is the ground, the red line is the +5 volts, and the white line is the PWM input line. Connect this PWM line to your selected GPIO output pin on the STM32.

**Mandatory Demo of PWM Signal:**

Before you will be allowed to connect to a servo motor you MUST demonstrate that your code produces a valid PWM signal. You will demonstrate this using an oscilloscope. If you fail to do this step and burn out a servo motor you are responsible for its replacement cost.

**Command Language:**

As memory space on microcontrollers is often at a premium, each of the recipe commands are encoded into one byte. These recipes are typically implemented as an array of byte values.

A master timer generates interrupts every 100 milliseconds, serving as the time basis the wait commands below. Since we are running on in a bare metal environment you do not have to use a timer interrupt. You can simply wait at the bottom of your control loop for the remainder of the 100 milliseconds.

**Design Recommendation:**

Create a non-blocking infinite loop that executes one loop every 100 milliseconds. This loop checks for a keyboard input and accumulates command lines, processes state changes for servo 1 (if any), processes state changes for servo 2 (if any), and then waits the remainder of the 100 milliseconds.

This is a simple type of scheduling algorithm that ensures that all tasks are completed within the required amount of time.

**Command Format:**

| command opcode | command parameter |
|---|---|
| 3 bits wide | 5 bits wide |

**Recipe Commands:**

| Mnemonic | Opcode | Parameter | Range | Comments |
|---|---|---|---|---|
| MOV | 001 | The target position number | 0..5 | An out of range parameter value produces an error. * |
| WAIT | 010 | The number of 1/10 seconds to delay before attempting to execute next recipe command | 0..31 | The actual delay will be 1/10 second more than the parameter value.. ** |
| LOOP | 100 | The number of additional times to execute the following recipe block | 0..31 | A parameter value of “n” will execute the block once but will repeat it “n” more times. *** |
| END_LOOP | 101 | Not applicable | | Marks the end of a recipe loop block. |
| RECIPE_END | 000 | Not applicable | | |

(Other opcodes such as 011, 110 and 111 are illegal, and if encountered at run time, transition the task into an error state.)

*An out-of-range parameter causes the task to enter an error state. The error state inhibits the operation of the “Continue” override command (see below), but all other overrides remain functional.

** The parsing of a “wait” command (as all other commands) takes a full system clock cycle (e.g. 1/10 second) to execute. Thus a wait + 0 skips 1/10 of a second before execution of the next command, a wait+1 would takes 2/10 seconds, etc.

*** Nested loops are not permissible and places the task in an error state

See recipe_ideas.c for some example code.

**Status:**

Use the red and green LEDs as described below to indicate the status.

Display these status indications for just the first servo:

- Recipe Running (only green on)
- Recipe Paused (all off)
- Recipe Command Error (red on)
- Recipe Nested Loop Error (red and green both on)

**User Commands:**

The User commands are entered via the system console keyboard. Each set of overrides are entered as a pair of characters followed by a <CR>. The first character represents the command for the first servo, the second for the second servo. Each character entered will be echoed to the console screen as entered. The <CR> will initiate the "simultaneous" execution of the overrides by each motor and generate a <LF> followed by the override prompt character ">" on the beginning of the next line.

Note that if either "X" or "x" is entered before the <CR>, the entire override command is cancelled and the ">" override prompt character is written on the beginning of a new line on the system console. See below for an example.

User Command Details:

| Command | Mnemonic | Comments |
|---|---|---|
| Pause Recipe execution | P or p | Not operative after recipe end or error |
| Continue Recipe execution | C or c | Not operative after recipe end or error |
| Move 1 position to the right if possible | R or r | Not operative if recipe isn't paused or at extreme right position |
| Move 1 position to the left if possible | L or l | Not operative if recipe isn't paused or at extreme left position |
| No-op no new override entered for selected servo | N or n | |
| Begin or Restart the recipe | B or b | Starts the recipe's execution immediately |

Example override commands:

- Pc <CR> Pause the recipe on Servo 1 and continue (resume) the recipe on Servo 2.
- Rn <CR> Move Servo 1 to the right one position (if possible), no op of Server 2.
- Bb <CR> Restart Servo 1's recipe and Servo 2's recipes.

As servo motors take time to reach a new position, the programs will need to introduce a delay in fetching and executing the next recipe command after a "mov" command. The delay will need to be adjusted depending upon how far the new position is from the current position. A starting estimate of the necessary added delays to reach a new position is approximately 200 milliseconds per position.

For safety, your program's execution should begin with tasks in the paused state. The startup sequence should include appropriate initialization of the task values.

Include a robust pair of demo recipes (a different one for each servo to demonstrate multitasking.)

The following test recipe snippets must be included in your demo:

```
MOV+0       ; There must NOT be intervening instructions in this group to allow
MOV+5       ; verification of default time delay.
MOV+0
MOV+3
LOOP+0      ;Test the default loop behavior.
MOV+1
MOV+4
END_LOOP
MOV+0
MOV+2
WAIT+0
MOV+3       ; Move to an adjacent position to verify
WAIT+0.
MOV+2
MOV+3       ; Measure the timing precision of the 9.3 second delay with an external
WAIT+31     ; timer.
WAIT+31
WAIT+31
MOV+4
```

Additional test recipes:

- Include a recipe to verify the moves to all possible positions.
- Include a recipe to end normally (i.e. with an "RECIPE_END" command, followed and by a MOV command to a position different from the previous MOV destination. This allows verification of the CONTINUE override.
- Include a recipe with a deliberate error near the end of a task's demo recipe, then follow the erroneous command with a MOV command to a new position.

**Graduate Student extensions:**

There are three unused recipe "opcodes" in the command descriptions above. Design one additional command and use one of the unused opcodes. Your report must document its operation, the limiting factors and parameters, etc. Add a new user command if appropriate. The new opcode must be included in the demo recipes to clearly demonstrate this new command's capabilities and limitations.

NOTE – Graduate students are responsible for all undergraduate components as well as this graduate student extension work.

**Due Date:**

Please refer to the course schedule for the due date. An in-class demo will be required. Please submit your source code and your report (in either PDF or Word compatible format) to the corresponding myCourses drop box.

**Grading Criteria:**

- Program Operation and Demo – 50%
  - Hardware setup is orderly and well organized – 10%
  - Demo sheet functions all completed – 30%
  - Demo operates without faults or restarts – 10%
- Program Design --- 15%
  - Proper initialization
  - Correct use of functions (no copy/paste/edit slightly)
  - Separation of hardware related code from pure software (e.g. the results reporting code)
- Source Code Structure and Readability – 10%
  - Appropriate use of white space – 2%
  - Consistent and good indentation – 2%
  - Appropriate comments at the function and paragraph levels (such as a for loop) – 2%
  - Following C style guide (good names, etc.)
- Report Content – 25%
  - Report is at least 2 pages (not counting pictures, cover page, diagrams) – 5%
  - Demonstrates team understands the problem, solution, and technology (hardware and software) – 10%
  - Report contains all required sections per the report guidelines – 10%