| **VIDEO P6-2-2b\_PWM Version 2** | | |
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| Cell | **Visuals** | **Audio** |
| 1 |  | Welcome back to Cypress Academy, PSoC 6 101. In the last video I showed you how to use a PWM to control the brightness of an LED … in this video let's put the PWM to work controlling my robot's servo motors.  We will add the PWM functions to our BLE-controlled robotic arm project, “MainController”. |
| 2 |  | The servo motor in my robotic arm requires a train of pulses with a frequency of 50Hz – which is a period of 20ms - and the pulse width needs to be between one and two milliseconds. At one millisecond it’s turned all the way to the left and at two milliseconds, it’s all the way to the right. At one and a half milliseconds, it is right in the middle. |
| 3 |  | So, to make all the math work, we’ll choose a 4MHz clock and pre-divide it by 4 which means that each tick of the PWM clock will be 1uS. Then we'll set the period to 20,000 so that we can go from 0 to 20,000uS which is also 20ms. For a 1ms wide pulse - also known as a 1000 microsecond wide pulse – I'll need a compare value of 1000. This also means that 1% will be 10 PWM clock ticks. Now I can set the compare value with software between 1,000 and 2,000 to give us full range control on the motors. |
| 4 | SCREEN CAPTURE:  P6-2-2b\_PWM\_capture1.trec | I’ll start by dragging and dropping one PWM from the catalog on to the schematic. Let’s setup the period and compare to 20,000 and 1,000 respectively, turn on the divide by 4 pre-divider, and click okay.  We want to control two motors to start, so let’s copy that component and paste a second one into our design. It will be named PWM\_2 and that’s convenient since PWM\_1 will control motor 1 and PWM\_2 will control motor 2. The copy paste function is also nice in that all of the settings from PWM\_1 were also copied over to PWM\_2 saving us some time.  Now let’s add two digital output pins to our design…I like the copy-paste function, so I’ll pull in one and rename it “M\_1” for motor 1. A quick copy/paste and I now have “M\_2” as well.  Let’s connect those pins to the PWM output line on the components.  Next, we need a clock. I’ll drag and drop a clock in and set it to 4MHz. Then wire it to both PWMs.  One of the most forgotten steps in a design is to assign the pins, so let’s do that now before we forget. Go to the pins settings and we’ll set M\_1 to P0[2] and M\_2 to P5[5] which matches up to the H-bridge pins on the Arduino shield I’m using.  Let’s generate the application and start working on some firmware. |
| 5 | SCREEN CAPTURE:  P6-2-2b\_PWM\_capture2.trec | Create and edit the file pwmTask.h. Add the #prama once, and the includes for FreeRTOS and Semaphores. Next, I will create two enumerated types, one for motors called motors\_t and one for position called motor\_pos\_t. These enums will be used in the structure called PWM\_Message\_t that the other tasks will use to communicate with our PWM controller.  All right, let's define the structure to send messages to the PWM. This structure will allow me to tell the PWM task, that we’ll create next, what motor we want to change, whether we want a relative or absolute change, and a percent change we want to make. I’ll call this structure “PWM\_Message\_t”.  Finally, I will define the function prototypes for the motor task and a helper function called getMotorPercent that the other tasks can use to find out the current state of the motors. |
| 6 | SCREEN CAPTURE:  P6-2-2b\_PWM\_capture3.trec | After the pwmTask.h header file is built, we can go ahead and update the main\_cm4.c file. Four things need to happen:   1. Add the include for the pwmTask.h 2. Create a variable for the pwmQueue 3. Initialize the pwmQueue 4. Start the PWM Task |
| 7 |  | When you have different tasks communicating with each other via an RTOS queue, there is always a question of where you define and initialize the queue. I like the main function to “own” these and then tell the other files about it in a global.h. |
| 8 | SCREEN CAPTURE:  P6-2-2b\_PWM\_capture4.trec | So, create a global.h, add the guards, put in includes for FreeRTOS and semaphores, and define the extern for the pwmQueue. Now other files can get access to the queue just by including global.h. |
| 9 | SCREEN CAPTURE:  P6-2-2b\_PWM\_capture5.trec | Now create and edit the file pwmTask.c. |
| 10 |  | The only purpose of this whole pwmTask is to take a message from the other tasks in the form of percent … meaning a number between 0 and 100 and then turn the percent into a pulse width between 1ms and 2ms. And finally turn the pulse width into a compare value which can be written into the PWM compare value register so that you get output pulses of the correct frequency and width. |
| 11 | TEXT ON SCREEN:  Percent <-> Pulse Width  PWM Compare <-> Pulse Width  Percent <-> PWM Compare | I am going to want 3 pairs of functions:  percent to pulse width and pulse width to percent  PWM compare value to pulse width and pulse width to PWM compare value  and finally, percent to compare value and compare value to percent. |
| 12 | GRAPHIC:  Use Graphic1 from below. | So, how do I do that? Well… the math is simple. Look at this graph. On the X-axis I have pulse width in micro seconds and on the Y-axis I have percent. When you have a pulse width of 1000 us you should have a percent of 0…here is the first point of the line. Then when you have a pulse width of 2000us you will have 100%, that is the next point on the line. |
| 13 | TEXT ON SCREEN:  y = mx + b  pct = [100/(2000-1000)] \* pw – 100 | From algebra one we remember y=mx + b… OK, so the formula that turns pulse widths into percent is percent = slope times the pulse width minus 100 percent. The slope of the line is rise over run, or 100 percent minus 0 percent over 2000 microseconds minus 1000 microseconds. |
| 14 | TEXT ON SCREEN:  pw = (pct + 100) \* (2000-1000)/100  pw = (pct \* 10) + 1000 | And that can be rearranged to get percent into pulse width like this:  Pulse width = percent plus 100 times the slope which is 2000us minus 1000us divided by 100 minus 0.  Or, simplifying further, pulse width = percent times 10 plus 1000us. |
| 15 | SCREEN CAPTURE:  P6-2-2b\_PWM\_capture6.trec | So, let's start this thing by creating the helper functions. First define the ranges of pulses… MIN\_US and MAX\_US. Then define the PWM parameters PWM clock, and PWM divider. These could be read from the schematic… but I wanted to make this simpler to understand so I am hard coding them. Next derive the number of PWM ticks per microsecond.  Now I can build the helper functions.  Percent to pulse just takes a percent and turns it into a pulse width with the formula I derived earlier… then pulse to percent does the inverse.  Then two helper functions to turn compare values into pulse widths and pulse widths into compare values. These two functions use the settings on our schematic to figure this out.  And finally, two functions to turn compare values into percent and percent into compare values. |
| 16 |  | Now in my program I can use these help functions to set the PWMs using percent or find out what percent is currently set by reading the compare value of the PWMs. |
| 17 | SCREEN CAPTURE:  P6-2-2b\_PWM\_capture7.trec | The next function I build will be used by other tasks to look at the current state of the PWM in percent. I'll call the function get motor percent. The getMotorPercent function takes as input either M1 or M2, then it looks at the PWM and figures out what the compare value is for that PWM, uses the helper function compare to percent, and then returns the current percent value. |
| 18 | SCREEN CAPTURE:  P6-2-2b\_PWM\_capture8.trec | Now I’ll create the PWMTask. When the task starts I’ll start the two PWMs using the start API command; then in an infinite loop I’ll wait to receive an RTOS command from the queue. When I get a command from the queue, I’ll figure out what the hardware and counter numbers are so I can use the appropriate macros.  Then what I’ll do is, if the message coming in wants to make a relative change in percent, I’ll get the current compare value, convert it to percent, and make the change. If the message calls for an absolute value change, I’ll make the change. Then I’ll update the compare value of the appropriate PWM.  That’s it for the PWM Task. |
| 19 | SCREEN CAPTURE:  P6-2-2b\_PWM\_capture9.trec | Now, I need a way to test this, so I’m going to add it to the UART command set we defined earlier. In the UARTTask.c I need to add includes for global.h and pwmTask.h. And down in the UART Task I’m going to use the commands “o” and “p” to change the relative percent value of motor one by negative 10% and positive 10%, respectively. And I’ll use commands “k” and “l” to do the same for motor 2. So, in the case statement for the command ‘p’, I’ll set the message to one, to control motor one, absolute percent to minus one since we’re doing a relative change, and relative percent change to 10. Then queue the message and break. Now I’ll do the same for the other commands.  In order to make the debugging easier I am going to add a command to printout the current status of the motors. So, add to the case statement a case for ‘s’ that printfs the getMotor percent for M1 and M2.  Are we done? No! We can’t forget to add the messages to the help command, “?”. So, I’ll do that real quick. |
| 20 |  | And that’s it…that’s the beauty of an RTOS. Simplifying complex designs. |
| 21 | SCREEN CAPTURE:  P6-2-2b\_PWM\_capture10.trec | Let’s build, program and test… |
| 22 |  | Now we have a functioning UART-controlled robotic arm…but we’re not done yet, this is supposed to be a BLE-controlled robotic arm. So, we have a little more work still to go. In the next video, I will walk you through setting up an I2C control interface. |
| 23 | TEXT ON SCREEN:  Cypress Developer Community  community.cypress.com  VIDEO:  Show video of ARH email and twitter windows. | You can post your comments and questions in our PSoC 6 community or as always you are welcome to email me at alan\_hawse@cypress.com or tweet me at @askioexpert with your comments, suggestions, criticisms and questions. |

**Graphic1**

