CALIFORNIA STATE POLYTECHNIC UNIVERSITY, POMONA
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ECE 3301L **Microcontroller Lab** **Felix Pinai**
Spring 2024 - Session 1

LAB 12: Fan Speed measurement with Speed control through PWM

The goal of this lab is to control the speed of a fan using PWM (Pulse Width Modulation) by varying an input voltage. Beside the speed control feature, this lab will also measure the speed that the fan is rotating by capturing the number of tach pulses from the fan. The result will be displayed on the TFT panel.

Before we start the lab, we need to make some declarations first. Take a look at the provided schematics and determine what port connections are the following signals tied to:

1) FAN_EN
2) FAN_PWM
3) FAN_MODE
4) TFT_D/C#

The first two signals are new for this lab while the last one (TFT_D/C#) was moved from the previous lab. Add the port definitions for the first two signals in the provided 'Fan_Support.h' file (make sure to put this file in the Header folder).Make the appropriate change to adjust the new definition for the
In addition, copy lab #11 to create lab #12 as usual and place the following lines:

#include Fan_Support.h

at the beginning on the newly lab12.c file.

Part A) Fixed time-based measurements using a timer

We will be using the fan that I have provided in the kit along with a wall plug +12V power supply. The fan has four wires:

1) Black wire: Ground pin to be connected to the power supply's ground pin and also to the system's ground.
2) Yellow wire: +12V pin to be connected to the power supply's +12V.
3) Green wire: Tach signal providing a pulse when the fan makes ½ the revolution.
4) Blue wire: PWM wire to control the speed of the fan.

Make all the connections shown on the schematics related to the fan. **Make sure than the +12V wire does not get connected to the VCC (+5V) of your breadboard**. Any short between that

+12V signal to the VCC can damage your computer since the VCC is provided by your computer!

To measure the speed of a fan, we just need to count the number of pulses generated on the Tach signal (green wire). When a fan makes a full revolution, a total of two (2) pulses will be generated. We now use a counter to count the number of pulses within a fixed period of time. Let us use the timer T1 as a counter. To setup it up as a timer, use the datasheet of the PIC18F4620:

http://ww1.microchip.com/downloads/en/devicedoc/39626e.pdf

and go to chapter 12 starting on page 137 and look at the register T3CON. Set the following:

Bit 7: RD16 – We don't need 16-bit operations
Bits 6,3: Ignore these two bits
Bit 5-4: No prescaler used (1:1)
Bit 2: Synchronize to external clock
Bit 1: External clock is from T13CKI
Bit 0: Disable Timer 3 first

Derive the correct value for T3CON. Initialize T3CON in the main initialization routine.

We need to write next a routine called int get_RPM() to measure and to return the RPM (revolution per minute) of the fan. We know that RPM = 60 * RPS where RPS is revolution per second. To get RPS, we can count the number of pulses from the Tach signal per second and since there are 2 tach pulses per revolution, then RPS will be half the amount of pulses counted in one second.

```
int get_RPM()
{
        int RPS = TMR3L / 2;            // read the count. Since there are 2 pulses per rev
                                        // then RPS = count /2
        TMR3L = 0;                      // clear out the count
        return (RPS * 60);              // return RPM = 60 * RPS
}
```

Put this routine in the provided 'Fan_Support.c'.

Next, take the program used on lab 11 and add the line: rpm = get_RPM(); when a new second has been detected. Here is a typical code:

```
  FAN_EN = 1;
  FAN_PWM = 1;
  char duty_cycle = 100;
  while (1)
  {
    DS3231_Read_Time();
```

```
    if(tempSecond != second)
    {
      tempSecond = second;
      DS1621_tempC = DS1621_Read_Temp();
      DS1621_tempF = (DS1621_tempC * 9 / 5) + 32;
      rpm = get_RPM();
      printf ("%02x:%02x:%02x %02x/%02x/%02x",hour,minute,second,month,day,year);
      printf (" Temp = %d C = %d F ", DS1621_tempC, DS1621_tempF);
      printf ("RPM = %d  dc = %d\r\n", rpm, duty_cycle);
    }
  }
```

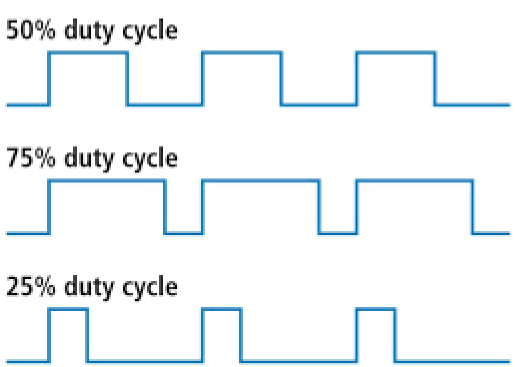
When the program runs successfully, the fan should run at full speed and the RPM should be about 3600 rpm.

The schematics is showing the channel 0 of the logic analyzer connected the tach pulse. Capture the waveform of this signal. Measure the period of this signal and calculate its frequency. Compare it to the rpm obtained on the TeraTerm.

Part B) Fan Speed control

Part B1)

To control the speed of the fan, we are going to use the signal 'FAM_PWM'. This signal uses the principle of duty cycle to increase or decrease the speed. A signal with a duty cycle has a pulse that is set high for a fixed amount of time with respect to the entire period of the signal. Here are some examples:



The concept of PWM allows the use of duty cycle to vary the speed. A PWM with 50% duty cycle will force the fan to run a half-speed. If PWM is set to 1 (100 % duty cycle), the fan will run at full speed. On the other hand, if PWM is set to 0, then the fan will rotate at its lowest speed.

The provided fan can take a PWM pulse with a frequency range from 18Khz to 30 Khz. Let assume that we are going to use 25 Khz as the frequency.

Next, let us use the following link:

http://www.micro-examples.com/public/microex-navig/doc/097-pwm-calculator.html

Enter the value of 8 Mhz for the PIC's operating frequency.

Next, enter 25000 for frequency of the PWM_pulse. This is the frequency required by the fan when PWM is used. By varying the value in duty cycle box from 0 to 99, you should see the value of the registers needed to be modified – PR2, T2CON, CCP1CON and CCPR1L – being changed accordingly.

I have compiled a routine that will change those registers based on a specified value of the duty cycle:

```
void do_update_pwm(char duty_cycle)
{
        float dc_f;
        int dc_I;
        PR2 = 0b00000100 ;                      // set the frequency for 25 Khz
        T2CON = 0b00000111 ;                    //
        dc_f = ( 4.0 * duty_cycle / 20.0) ;     // calculate factor of duty cycle versus a 25 Khz
                                                // signal
        dc_I = (int) dc_f;                      // get the integer part
         if (dc_I > duty_cycle) dc_I++;         // round up function
         CCP1CON = ((dc_I & 0x03) << 4) | 0b00001100;
         CCPR1L = (dc_I) >> 2;
}
```

Place this routine in the 'Fan_Support.c' file.

Next, go back to the code provided on part A) above. At the place of the line 'char duty_cycle = 100' replace it with the following lines:

```
        char duty_cycle = 50;
        do_update_pwm(duty_cycle) ;
```

Compile the program and notice the value of the RPM on Teraterm. It should be half the value because we are reducing the speed by half.

If that works, change the different value of 'duty_cycle' by modifying the value and rerun the program. Observe on TeraTerm that the fan runs faster or slower if 'duty_cycle' is increased or decreased.

Capture the waveform of the PWM signal using channel 1 of the logic analyzer. Observe and calculate the duty of the signal and compare it to the duty cycle selected on the program.

Part B2)

When the above task works successfully, then implement two new functions to control the outputs of the two RGB LEDs D1 and D2:

LED D1: void Set_DC_RGB(char duty_cycle)
LED D2: void Set_RPM_RGB(int rpm)

Here are the requirements for the routine Set_DC_RGB(char duty_cycle):

a) If duty cycle >= 0 and < 9, color is none
b) If duty cycle >=10 and < 19, color is RED
c) If duty cycle >=20 and < 29, color is GREEN
d) If duty cycle >= 30 and < 39, color is YELLOW
e) If duty cycle >= 40 and < 49, color is BLUE
f) If duty cycle >= 50 and < 59, color is PURPLE
g) If duty cycle >= 60 and < 69, color is CYAN
h) If duty cycle >= 70, color is WHITE

Here are the requirements for the routine Set_RPM_RGB(int rpm):

a) If rpm = 0, no color to be displayed
b) If rpm > 0 and < 500, color is RED
c) If rpm >= 500 and < 1000, color is GREEN
d) If rpm >= 1000 and < 1500, color is YELLOW
e) If rpm >= 1500 and < 2000, color is BLUE
f) If rpm >= 2000 and < 2500, color is PURPLE
g) If rpm >= 2500 and < 3000, color is CYAN
h) If rpm >= 3000, color is WHITE

Here are the requirements for the routine Set_TEMP_RGB(signed char TempC):

a) If TempC <16, RGB will be off
b) If TempC >= 16 and < 18, color is RED
c) If TempC >= 18 and < 20, color is GREEN
d) If TempC >= 20 and < 22, color is YELLOW
e) If TempC >= 22 and < 24, color is BLUE
f) If TempC >= 24 and < 26, color is PURPLE
g) If TempC >= 26 and < 28, color is CYAN

h) If TempC >= 28, color is WHITE

Write those routines without using a multiple IF or case statements. The implementation of each routine should be done as short as possible. Look at the sequence of numbers and derive a formula that should simply generate the proper output based on a given input.

Place those three functions in the 'Fan_Support.c'file.

Do call those three functions after the call to measure the rpm (rpm = get_RPM() in the main program.

Part C) Fan Operational Control using remote control

In the previous lab, a key was used to preload the time with a fixed set of values. This lab requires that the button 'EQ' (button number 8) should be used to perform that function.

Now we are going to use the remote control that we have developed on lab 11 to control the operations of the fan. Three buttons on the remote will be used:

- Button '-' or button number 6
- Button '+' or button number 7
- Button 'Play/Pause' or button number 5

Based on the code on lab 11, add more code to to check the variable 'found' to do the following:

- If found is 'Play/Pause' call the function Toggle_Fan()
- If found is '-' call the function Decrease_Speed()
- If found is '+' call the function Increase_Speed()

Next, we will need to implement those three functions to be placed in the Fan_Support.c file.

- Toggle_Fan():
  - If the variable 'Fan' is 1, call function Turn_On_Fan();
  - Else call function Turn_Off_Fan()

  Write up the code for both Turn_On_Fan() and Turn_Off_Fan() to be also placed in the Fan_Support.c file

  - Turn_On_Fan():
    - Set the variable Fan to be 1
    - Call function do_update_pwm(duty_cycle) to set the proper speed
    - Turn on the fan by setting the signal FAN_EN to 1.

  - Turn_Off_Fan():

        - Set the variable Fan to be 0
        - Turn off the fan using FAN_EN

- Increase_Speed():

    - Check if duty_cycle is at 100
        - If 100, then generate two beep codes using Do_Beep() function and then reprogram the pwm duty cycle. The duty cycle should remain at 100.
        - If not, then increase duty_cycle by 5 and reprogram the pwm duty cycle

- Decrease_Speed():

    - Check if duty_cycle is at 0
        - If 0, then generate two beep codes using Do_Beep() function and reprogram the duty cycle. The duty cycle must remain at 0.
        - If not, then decrease duty_cycle by 5 and change the pwm duty cycle

Note: The function Do_Beep() is simply the sequence of Activate_Beep, Wait_One_Sec(), Deactivate_Beep(). **When done, a call to re-initialize the pwm need to be performed because the Activate_Beep() function will destroy the original pwm.**

Run the program and use the remote control to turn on/off the fan and to increase/decrease the speed**. Make sure to have the program starts with the fan in the off state (FAN_EN = 0) and the duty_cycle set at 50.**

Part D) Fan Operational Control using temperature

Now, we are going to have a mode that will vary the speed of the fan based on the actual temperature. Assuming that the fan will run at the duty cycle of 50% when the temperature is in the range of 24 degrees C to 26 degrees C. The duty cycle will be bumped up by a value of 10 when the range is between 26 to 28 degrees C. The duty cycle will be reduced by a value of 10 when the temperature goes down. Here is the table of values for the duty cycles versus temperatures:

Temperature	Duty Cycle
<16	0
>16 && <=18	10
>18 && <=20	20
>20 && <=22	30
>22 && <=24	40
>24 && <=26	50

>26 && <=28	60
>28 && <=30	70
>30 && <=32	80
>32 && <=34	90
>34	100

Use the remote control button ‘CH’ to activate this mode. The LED ‘FAN_MODE’ will be turned on when this mode is activated and turned off when the mode is deactivated. This mode is defaulted to off when the operation is started