LAB #7: PWM WAVEFORM GENERATION

INTRODUCTION

There are many devices that can be controlled by periodically pulsing one or more of their control signals. For example, stepper motors rotate some fixed amount for each pulse applied to their inputs. The intensity of a light or the speed of a D.C. motor can be controlled with pulse-width modulated (PWM) digital waveforms, with the light/motor effectively controlled by the average voltage of the signal. A PWM waveform is a periodic signal comprising pulses of variable duration (width). For a constant period, variations in the pulse width can create different desired effects.

The purpose of this lab is to generate a PWM signal waveform, with keypad-selectable pulse widths. This will be used in the next lab as a control signal to drive a D.C. motor at one of several keypad-selectable speeds.

PWM SIGNAL CHARACTERISTICS

Figure 1 illustrates three PWM signals, and the two key parameters of a PWM signal. Each waveform is characterized by two parameters:

$$T = T_1 + T_2 \qquad (1)$$

and

$$\text{duty cycle} = T_1/T \qquad (2)$$

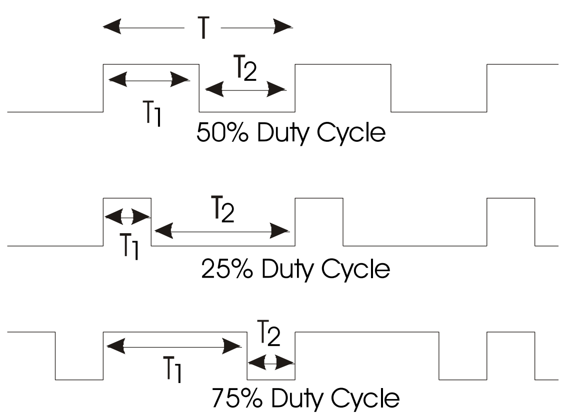

Figure 1. Pulse-width modulated (PWM waveforms)

Here, T is the *period* of the waveform, with the signal high for time T_1 and low for time T_2. The *duty cycle* of the waveform is defined as the high time divided by the period: $T_1/(T_1 + T_2) = T_1/T$. The three waveforms in Figure 1 have duty cycles of 50%, 25%, and 75%, as indicated.

The term "pulse-width modulation" refers to the alteration (modulation) of the high time, T_1, while maintaining a constant period, T. In the next lab, we will drive a D.C. motor with an amplified PWM signal, varying its duty cycle to control the speed of the motor. The rationale for using pulse width modulation will be motivated at that time by examining the amplifier efficiency.

PWM SIGNAL GENERATION

In this lab, PWM signals are to be generated by two different methods. One is to utilize the special PWM module available in the HCS12. The second is to utilize the "output compare" operating mode of the HCS12 main timer module utilized in the previous lab.

Overviews of these two modules are given in the class presentation slides, posted on the class web page, plus ELEC 2220 course slides on timers, also posted on the class web page

HARDWARE AND SOFTWARE DESIGN

Using both methods described above, you are to implement a keypad-selectable, variable duty cycle PWM waveform generator. The keypad is to be used to select one of ten duty cycle values for the PWM waveform: 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10% and 0% (i.e. stopped). The selected duty cycle should be displayed on the 4 LEDs. When waveform generation is stopped, the signal is to be in the <u>low</u> state. *(HINT – Consider storing counter register values for the 9 non-zero duty cycles in an array, with the number corresponding to the pressed keypad button used as an index into that array.)*

Two C programs, one for each method, must be written to produce the variable duty cycle PWM signal. For this lab, the period T should be 1 msec. Hence, the resulting PWM signal is said to have a "1 kHz switching frequency."

LABORATORY EXPERIMENTS

1. Verify that your hardware is operating properly by using test programs from previous labs, or some other brief program that exercises the hardware.

2. Download and run your first PWM waveform generation program, using the HCS12 PWM module, displaying the generated waveform on the oscilloscope. Demonstrate to the lab instructor that you can use the keypad to select the nine duty cycles and the stop condition. Also show that the stop condition leaves the signal in the low state.

3. Measure and record the duty cycle for each of the ten keypad buttons (0-9), and plot the measured values on a graph (vs. button number) to ensure a linear increase in duty cycle with keypad selection.

4. Repeat steps 2 and 3 for the second PWM waveform generation program, utilizing the HCS12 timer module output compare function.

5. Do not hesitate to use the logic analyzer to trace the flow of your program. For example, if the program does not appear to be responding to certain keypad entries, capture I/O port information to determine the sequence of instructions executed, the values read from the keypad, etc.

DELIVERABLES

Midterm reports are to be submitted ***by all students*** by 3:00 p.m. Friday. Each student must submit a self-authored report; these reports are not team projects. Midterm reports should include the following.

1. Describe the problem to be solved, e.g. design a stopwatch. Then describe the *engineering* problem, e.g. design an accurate timer and display its value. Describe the desired performance specifications.
2. Summarize the engineered solution. Include circuit diagrams and software descriptions as appropriate.
3. Describe experiments used to collect data about the design.
4. Present the data.
5. Present objective conclusions BASED ON DATA. For example, compare desired performance to actual performance.

POSSIBLE INFORMATION FOR FUTURE LABORATORY REPORTS

1. Briefly describe the circuit (but not "wire by wire") and the test programs (include a circuit diagram and C program source listings).

2. Discuss your results. For each program, include a table and graphical plot of measured duty cycles, and at least one image of the oscilloscope or logic analyzer screen that shows the generated PWM signal.

3. After comparing the two PWM signal generation methods, select one for use in future labs, and briefly discuss the reasons for this selection.