FALL 2025 EEL4742 – *Embedded Systems* - Quiz 6 Solution - Time: 30 Minutes

1. (10 points) Assume that TA0CCTL1.OUT is initially set to 1, and PWM output is enabled. The timer registers are externally configured such that `TA0CCR0` = 22000 and `TA0CCR1` = 12000.

   (a) To generate a PWM signal with a 45% duty cycle, which OUTMOD setting and which timer mode (up, up/down, or continuous) should be selected?

   (b) what configuration change(s) could be made to achieve a 50% duty cycle?
   (NOTE: `TA0CCR0` and `TA0CCR1` are externally given.)

   Answer: (part a) Given that `TA0CCR0 = 22000` and `TA0CCR1 = 12000`, the duty cycle in up mode with `OUTMOD = 3` (Set/Reset) is:

   $$D = \frac{\text{CCR0} - \text{CCR1}}{\text{CCR0}} = \frac{22000 - 12000}{22000} = \frac{10000}{22000} \approx 45.5\%.$$

   Thus, to obtain a 45% duty cycle:

Timer mode: Up mode	OUTMOD: 3 (Set/Reset)

   (part b) Since `TA0CCR0` and `TA0CCR1` are (externally) given and cannot be changed, the duty cycle cannot be adjusted to 50% using Set/Reset or Reset/Set modes (which depend on the ratio `CCR1`/`CCR0`). To achieve a 50% duty cycle without altering the CCR registers, is the use of Toggle option:

Timer mode: Up or Up/Down mode	OUTMOD: 4 (Toggle)

   In Up mode with Toggle output, the output toggles once the timer reaches `CCR0`. It resets counting and the output toggles again once the timer reaches `CCR0`. In Up/Down mode with Toggle output, the output toggles once on the upward count and once on the downward count when `TAR = CCR0`, producing equal high and low times independent of the specific CCR values.

2. (5 points) **Bonus** Let's assume a system uses an external interrupt to detect a push-button press. When the button is pressed, the system turns on an LED and starts a 5-second timer. If the button is pressed again while the timer is still counting, the timer is reset to 5 seconds starting from the new press.

   Due to switch bouncing, each physical button press generates a burst of 8 false interrupts spread uniformly over the first 4 milliseconds after the initial press.

   Now, let's assume two presses happens, one at $t = 0$ and one at $t = 3.5$.

   (a) How many times total will the 5-second timer be restarted from these two presses?

   (b) At what exact time (in seconds from the first press) will the LED finally turn off?

   Answer: (part a) Each physical button press generates:

   $$1 \text{ real interrupt} + 8 \text{ bounce interrupts} = 9 \text{ interrupts}.$$

   With two physical presses:

   $$\text{Total restarts} = 9 + 9 = \boxed{18}.$$

   (part b) After the first press at $t = 0$, the bounce interrupts occur over the next 4 ms, so the *last* interrupt happens at:

   $$t = 0.004\,\text{s}.$$

   Thus the timer is set to expire at:

   $$t_{\text{expiry, after first press}} = 0.004 + 5 = 5.004\,\text{s}.$$

   A second press occurs at $t = 3.5$ s with its bounce events lasting until:

   $$t = 3.504\,\text{s}.$$

   The *final* interrupt restart occurs at $t = 3.504$, so the LED will turn off at:

   $$t_{\text{final off}} = 3.504 + 5 = \boxed{8.504\,\text{s}}.$$