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ELEC 327 S15

Lab #2:
PWM, Low Power Modes and PCBs

Part 1: Different Clocks, Low Power Mode, and PWM

1) Using the DCO, what is the minimum frequency for a timer interrupt? What is the typical default frequency of the VLO? How do you turn on the VLO, and how do you change code from last week to run off the VLO instead of the DCO?

User guide 5.1, page 278, basic clock module+ introduction, DCO can be divided by 1, 2, 4, and 8. If we choose the lowest frequency of DCO, which is 0.06MHz, and divide by 8, we get 7500Hz. For timer interrupt, one cycle involves 65536 counts, so the timer frequency is 7500/65536 = **0.114Hz** counts. (data sheet 29)

Typical default frequency of the VLO is **12 kHz**. User guide 5.2.2, "Internal Very-Low-Power Low-Frequency oscillator(VLO)", page 281.

According to user guide 5.2.2, page 281, I need to set LFXT1Sx = 10 when XTS = 0. By looking at the processor header file, I figured out that I need to set the basic clock system control for LFX1. So first I erase the following two lines: BCSCTL1 = CALBC1_1MHZ, DCOCTL = CALDCO_1MHZ. The following line of code turns on VLO: BCSCTL1 = LFXT1S0.

2) What clock sources can drive the ACLK? In which low power modes is only ACLK active? If we only want to enable the VLO when not in an interrupt, what low power mode should we put the MSP430 into?

The ACLK is driven directly from a common **32 kHz** (32768 Hz, to be more precise) watch crystal (user guide 1.2, "Flexible Clock System", page 26). It can also be driven by **LFXT1CLK** or **VLOCLK**. (user guide 5.1, basic clock module+ introduction, page 278).

In low power mode 3 (**LPM3**) is only ACLK on, as can bee seen from figure 2-9 on page 42 of user guide. LPM2 is not the correct choice because in table 2-2 on page 42 of user guide, it says in LPM2, in addition to ACLK, DC generator remains enabled.

If we only want to enable VLO when not in an interrupt, we should put MSP430 in **LPM3**, since in this mode only ACLK is active, and we need only ACLK to enable VLO, by use VLO as source for ACLK.

3) What line of code should we add to the end of our main loop to do this? How can you change this one line to also enable interrupts?

We will need the following command: **_bis_SR_register(LPM3_bits)**. To modify this line to also enable interrupts, we need to type the following command: **_bis_SR_register(LPM3_bits + GIE)**.

4) What is the difference in supply current between LPM1 (when SMCLK is set to 1 MHz) and LPM3 (when ACLK is set to use the VLO)?

LPM1 supply current 56 µA, LPM3 in VLO mode supply current is 0.5 µA. The difference in supply current between these two modes are 56 - 0.5 = **55.5 µA**. (data sheet, page 23)

5) The timer counter register (TAR) is 16-bits. Assuming we use the VLO to drive the Timer module at 12kHz, and run the counter in up/overflow mode, where it increments to 0xFFFF then overflows to 0x0, at what frequency will the TAR overflow? If we want our PWM modulation to not appear to flicker, the minimum modulation frequency is about 100 - 200 Hz. Is this achievable if the TAR is configured to overflow?

possible answer: In order to overflow, the count must exceed 0xFFFF, since if in one clock cycle it counts more than 0xFFFF, TAR will overflow. 0xFFFF correspond to 65535 in decimal, so when count exceeds 65535, TAR will overflow. Frequency is 12,000 / 65535 = **0.183** Hz. (user guide 12.2.3, "timer mode control", page 366)

possible answer:
   a) **If overflow mode means up mode**, then: **yes**, we only need to set the TACCR0 register to a smaller value. In this way, when the clock reaches the number of counts, TAR will overflow, and back down to zero. In this case, we need to set TACCR0 to value in range 12000/200 ~ 12000/100, which is 60 ~ 120.
   b) **If overflow mode means continuous mode**, then: **No**. the clock that needs to run 100 ~ 200 65535 counts in one second, meaning that the clock speed needs to be at least 65535*100 = 6.6 MHz. However, if we use VLO which is only 12kHz at maximum, we cannot get the modulation frequency to at least 100 Hz.

Say we want to use Timer A1 for our PWM signal. Which pins is register 1 of Timer A1 capable of sending a PWM signal to? What should PxSEL, PxSEL2, and PxDIR be for these pins?

Pin P2.1 P2.2 are A1 capable of sending PWM signals to.

For P2.1: PxSEL = 1, PxSEL2 = 0.

For P2.2: PxSEL = 1, PxSEL2 = 0.

PxDIR should be set to 1, so that the pin is served as output. (data sheet page 51)

7) In up mode, the timer will continuously count up to the value in TACCR0, resetting to 0 every time it reaches it. If we want our output (using TACCR1) to be initially on for some fraction of each cycle and then turn off, what mode should we put the capture compare block in? How do we actually set it to this mode?

We should put the capture compare block in **output mode 6**: toggle/set. From table 12.2 and figure 12-12 in user guide page 372, it is clear that when in this mode, the output is initially high, then low, then repeat the previous pattern in the subsequent clock cycles. Note that if we put the capture compare block in **output mode 7**: reset/set, we can achieve the same desired effect. In this mode, the output is initially high, then low (turned off), then repeat. Therefore, I believe that putting the capture compare block in both modes can achieve the effect the question asks.

How to set to mode: the output modes are defined by the OUTMODx bits in table 12.2 in user guide page 372. **To set to mode 6**, we need to set **OUTMODx to 110**. **To set to mode 7**, we need to set **OUTMODx to 111**.

8) To drive an RGB LED, you in general need 3 output pins. In general, what is the maximum number of PWM signals that can be generated by the Timer A1 module? What if the module is configured in up mode?

Assume all the questions involve only Timer1_A3.

The maximum number of PWM signals that can be generated by the Timer A1 is 2, since each capture/compare block contains a output unit, and there are maximum 2 capture/compare blocks. Therefore, there are **max 2 distinct output (PWM) signals**.

If configured in up mode, the answer is the same: **max 2 distinct output (PWM) signals**.

9) If you had to generate 4 different PWM signals (i.e. using both Timer A1 and Timer A0) what is a valid set of 4 output pins?

Using Timer A, there is no way to generate 4 different PWM signals. We can generate at most 3 PWM signals using Timer A, no more. We could use Timer B to generate up to 7 output signals, but not with Timer A.

There is, therefore, no valid set of 4 output pins. There is, however, a valid set of 3 output pins. Possible set of pins is: {P1.6, P2.2, P2.4}

10) If you were to set CCR0 to be 500, why does the LED flicker and not dim?

Because CCR0 controls the period of PWM signal. When CCR0 is set to 500, and when Timer A is sourced from ACLK which 12 kHz, the LED frequency is 12000/500 = 24Hz, which is **1/24 second period**. This is a **relatively long period**; **human eyes can detect such long period**. Therefore, the LED appears to flicker, not dim.

11) What do you measure for each case, and why are they different? If you were using a 250mAh join cell battery to power this circuit, how long could it run in each mode?

With low power mode on, the current is **66.7** micro amps. It can last 250*1000/66.7 = **3748 hours**.

Without low power mode on, the current is **333.3** micro amps. It can last 250*1000/333.3 = **750 hours**.

The difference is that in low power mode, only ACLK is turned on, and all the modules that consumes a lot of power are not on. Therefore, in low power mode, the current is a lot less than that when not in low power mode.

Part 2: Design a Mood Ring

12) Refer to the RGB LED's data sheet - assuming your MSP430 is running at 3.6V, what values of resistance should you use for each channel of the LED to limit the driving current in each channel to 6 mA?

Red channel voltage range: 1.8 - 2.1 V. The smallest resistance you should use: (3.6-1.8)/0.006 = **300** ohms.

Green channel voltage range: 3.0 - 3.2 V. The smallest resistance you should use: (3.6-3)/0.006 = **100** ohms.

Blue channel voltage range: 3.0 - 3.2 V. The smallest resistance you should use: (3.6-3)/0/0.006 = **100** ohm.