Experiment 4: Playing With Time

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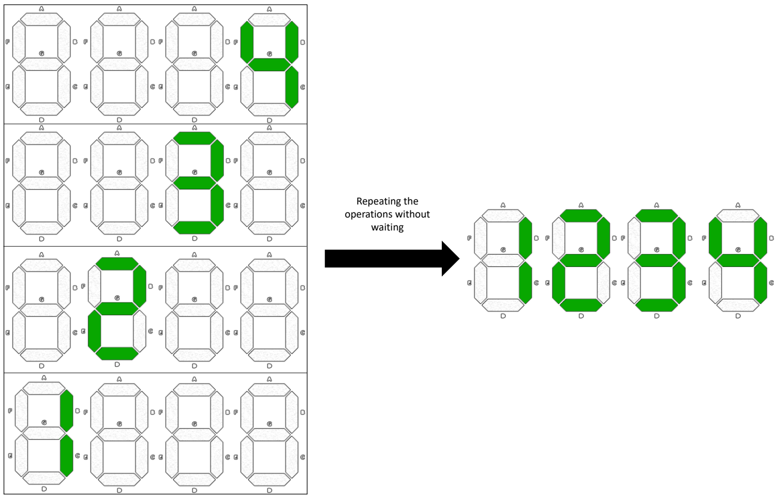
*M*ost people think time is like a river that flows swift and sure in one direction, but I have seen the face of time and I can tell you they are wrong. Time is an ocean in a storm. You may wonder who I am and why I say this; sit down and I will tell you a tale like none that you have ever heard!

Prince of Persia The Sand of Time, 2003 Video Game

1 Part 1 (30 pts) 4 digits on 7-seg

Recall the following part from the document for Experiment 2.

Enabling only one at a time, it is impossible to show a four digits number on the kit. *Or is it?* Luckily, human visual cortex is not very complex. If we enable each LED respectively, and do not do waiting operations between each LED, we can fool the mortals! An example showcase is shown in the Figure.



Use this trick to show a four digit number on the 7-segment displays. Define an array of four bytes in the data section to define the digits to show.

```
                    .data
digits              .byte 0, 1, 2, 3
```

2 Part 2: (70 pts) Chronometer Design

In this part, we will use timer interrupts to design a two digit chronometer counting down from 60. The idea is simple:

- Activate the timer interrupt so that it automatically sends an interrupt signal after each centisecond.
- In the timer interrupt subroutine, decrease the current value of seconds and centiseconds.
- If the value ”00” is reached, halt.

MSP430 family micro-controllers contain two 16-bit timers which could be utilized independently. Basic building blocks of the timers are as represented in Figure 1. We will use the Timer A.

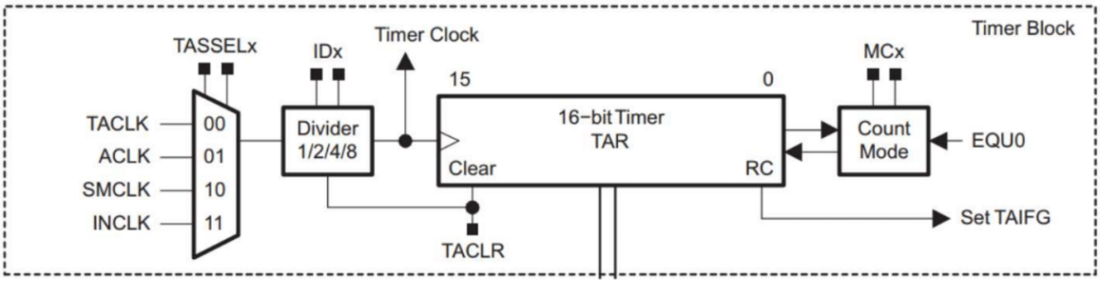


Figure 1: Timer Circuit

You can obtain more detailed information from the ”Timer-A” chapter of ”MSP430 User Guide”. Briefly, it is a 16-bit counter which has four modes: Stop, Up, Continues, UpAndDown. According to the values in mode control bits, we can select a mode. The details of the modes are given in Table 1. Here, the ”Up” mode is more suitable for us, since we could count from zero to a predefined value using the timer.

The timer also has two operation modes: Capture and Compare. The capture mode is useful to record time events. For example, in the code we can measure the passed

MCx bits	Mode	Description
00	Stop	The timer is halted.
01	Up	The timer repeatedly counts from zero to the value of TACCR0
10	Continuous	The timer repeatedly counts from zero to 0FFFFh.
11	Up/down	The timer repeatedly counts from zero up to the value of TACCR0 and back down to zero.

Table 1: The modes for Timer A and B.

time between some operations in this mode. Compare mode is more suitable for us. In the compare mode, when the value in the timer (TAR) reaches the value in TACCR0, an interrupt signal is send. The vector for this interrupt signal could be set using the following lines. We should also set the CAP bit of TACCTL0 to zero to use compare mode.

```
                .sect    ".int09"
                .short   TISR
```

Another decision to make is the source of the clock signal. For every up→down signal (It could also be changed too.), the value in TAR is incresed by one. In MSP430, we have four different signal sources which could be used as clock signal: TACLK, ACLK, SMCLK and INCLK. SMCLK is the most suitable one to use here. It is a square wave with with 1048576 Hz frequency. The clock source could be selected using TASSEL bits of TA0CTL.

To sum up, you should set TA0CTL, TA0CCR0 and TA0CCTL0 registers correctly to set the timer interrupt correctly.

Your code should start with the following lines.

```
        bis.b  #020h,  &P2IE
        and.b  #0DFh,  &P2SEL
        and.b  #0DFh,  &P2SEL2
        bis.b  #020h,  &P2IES
        clr  &P2IFG

        mov  xxx,  &TA0CTL
        mov  xxx,  &TA0CCR0
        mov  xxx,  &TA0CCTL0

        eint
```

You can use the following list to show digits on the 7-segment displays.

```
array .byte 00111111b, 00000110b, 01011011b, 01001111b, 01100110b ,01101101b,01111101b,00000111b,01111111b,01101111b
```