

# 7-Segment LED Stopwatch Using Low-Memory MSP430™ MCUs

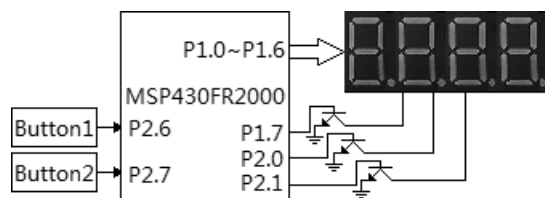


## Introduction

Segment LED displays provide information to users in a wide variety of applications from simple timers to smart meters and more. This application uses three 7-segment LEDs to display the time of a stopwatch. The demonstration uses the [MSP430FR2000](#) microcontroller (MCU) to implement the stopwatch, because it is inexpensive and the code size less than 512 bytes. To get started, [download project files and a code example](#) demonstrating this functionality.

## Implementation

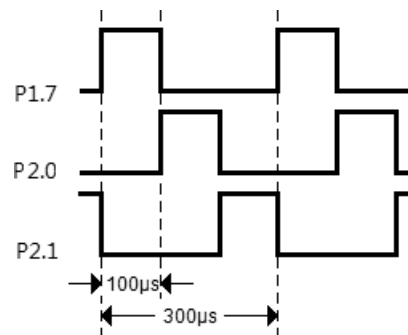
This application uses a 4-digit 7-segment LED to display the stopwatch time. The MCU measures the time using the real-time clock (RTC) peripheral and utilizes general-purpose output pins to drive the LEDs so that it displays the time. There are two buttons to control the time. One is to start and stop the stopwatch, and the other is to reset the timer. The LEDs and the buttons are connected to the MSP430FR2000 using digital I/O pins. [Figure 1](#) shows the stopwatch block diagram.



**Figure 1. Stopwatch Block Diagram**

P1.0 to P1.6 control the number displayed by setting the voltage high to light the LEDs. P1.7, P2.0, and P2.1 select which digit is shown by setting the voltage high to make sure the right segments light up. In this design, the current that is required by the LEDs is too large for the MSP430FR2000 MCU. Therefore, P1.7, P2.0, and P2.1 drive external transistors to supply the current.

[Figure 2](#) shows the outputs of P1.7, P2.0, and P2.1. To avoid visible flickering, the frequency of refresh timing should be greater than 10 Hz. In this application, the refresh frequency is approximately 3.3 kHz.



**Figure 2. Refresh Timing Diagram**

First the desired digit is selected using P1.7, P2.0, and P2.1, then the number to be shown is controlled by P1.0 to P1.6. After that, change to a different LED to display the number and repeat these steps. This design can show from 0.1 second up to 99.9 seconds. The unit can be rescaled from 1 second to 999 seconds based on the application.

P2.6 determines the start and stop function of the stopwatch and detects the rising edge to trigger the start or stop interrupt. The timer is stopped by default. Pressing the P2.6 button for the first time starts the timer, and pressing the button a second time stops the timer.

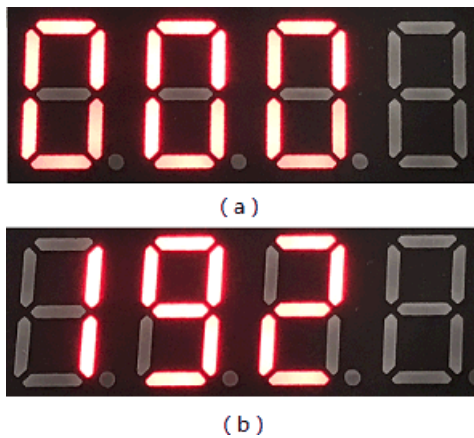
P2.7 is used to control the restart function of the stopwatch and detects the rising edge to trigger the restart interrupt. If the restart interrupt is triggered, the timer resets to zero and stops counting immediately.

Software or hardware methods can be used to avoid the debounce on the push buttons. In this application, a low-frequency hardware filter is used to avoid the issue.

This application uses the built-in RTC function of the MSP430FR2000 MCU to calculate the time. The RTC is sourced from the auxiliary clock (ACLK) source by the reference oscillator (REFO, 32.768 kHz). This allows a 0.1-second interrupt by dividing the ACLK by 64 and then setting the RTC count as 51 (see [Equation 1](#)).

$$0.1 \text{ s} \approx (64 / 32768) \times 51 \quad (1)$$

[Figure 3](#) shows the LED display of the stopwatch. [Figure 3\(a\)](#) shows the initial state of the stopwatch, and [Figure 3\(b\)](#) shows the operation of the stopwatch.



**Figure 3. LED Display**

### Performance

Using the MSP430FR2000 MCU has certain limitations due to number of GPIO pins. The RTC Counter module in the device uses the REFO instead of an external crystal as the clock resource. The absolute calibrated tolerance of the REFO based on the datasheet is  $-3.5\%$  to  $+3.5\%$  when the temperature changes from  $-40^{\circ}\text{C}$  to  $85^{\circ}\text{C}$  and the supply voltage changes from 1.8 V to 3.6 V. Therefore, the tolerance of this stopwatch is  $\pm 35 \mu\text{s/s}$ . If a better accuracy is

required, an external crystal can be used to supply the clock for the system. If more GPIO pins or more memory are needed to support additional digits or other functionality, other MSP430™ MCUs can be used.

The design can be easily modified to create a countdown timer by changing the RTC interrupt function to the countdown mode.

### Device Recommendations

The device used in this example is part of the MSP430 Value Line Sensing portfolio of low-cost MCUs, designed for sensing and measurement applications. This example can be used with the devices shown in [Table 1](#) with minimal code changes. For more information on the entire Value Line Sensing MCU portfolio, visit [www.ti.com/MSP430ValueLine](http://www.ti.com/MSP430ValueLine).

**Table 1. Device Recommendations**

Part Number	Key Features
MSP430FR2000	0.5KB FRAM, 0.5KB RAM, eComp
MSP430FR2100	1KB FRAM, 0.5KB RAM, 10-bit ADC, eComp
MSP430FR2110	2KB FRAM, 1KB RAM, 10-bit ADC, eComp
MSP430FR2111	3.75KB FRAM, 1KB RAM, 10-bit ADC, eComp

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