Lab 5: System Timer (SysTick)
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Goals
1. Understand the clock tree of STM32L4 processor
2. Understand the basic concept of system timer
3. Gain knowledge of using SysTick to create a time delay function
4. Understand the basic procedure of interrupt handling
5. Understand the auto stacking and un-stacking of interrupt handling process

Pre-Lab Assignment
1. Read Chapter 11.4 System Timer
2. Complete the pre-assignment

In-Lab Demo
1. Use SysTick to generate an interrupt every 1*ms*. Implement a delay function to toggle a LED with a time interval of one second by calling *delay* (1000). Use an oscilloscope to measure the period of the LED pin signal. Calculate the accuracy of the processor clock.
2. Something cool. Note that controlling another LED is not accounted as something cool. The following gives a few examples.
    a. Use the delay function to accurately control the rotation speed of a stepper motor. If you make your motor runs 60 rounds per minute, your motor is a second clock.
    b. Display a second counter on the LCD.
    c. Calibrate the MSI or HSI clock if your clock has an error larger than 0.5%.
    d. Use HSE, instead of HSI or MSI, to drive the system timer
    e. Use the delay function to send out a Morse code of SOS (···– – –···) via the LED light.

Post-Lab Assignment
1. Complete the post-lab assignment report
2. Write your answers in the file *Readme.md* and submit to the gitlab server

Processor Clock
Four different clock sources can be used to drive the system clock (SYSCLK):
1. 16MHz HSI (high-speed internal) oscillator clock
2. 4-48MHz HSE (high-speed external) oscillator clock
3. PLL (phase-locked loop) clock that is clocked by HSI, HSE, and MSI.
4. MSI (multispeed internal) oscillator clock

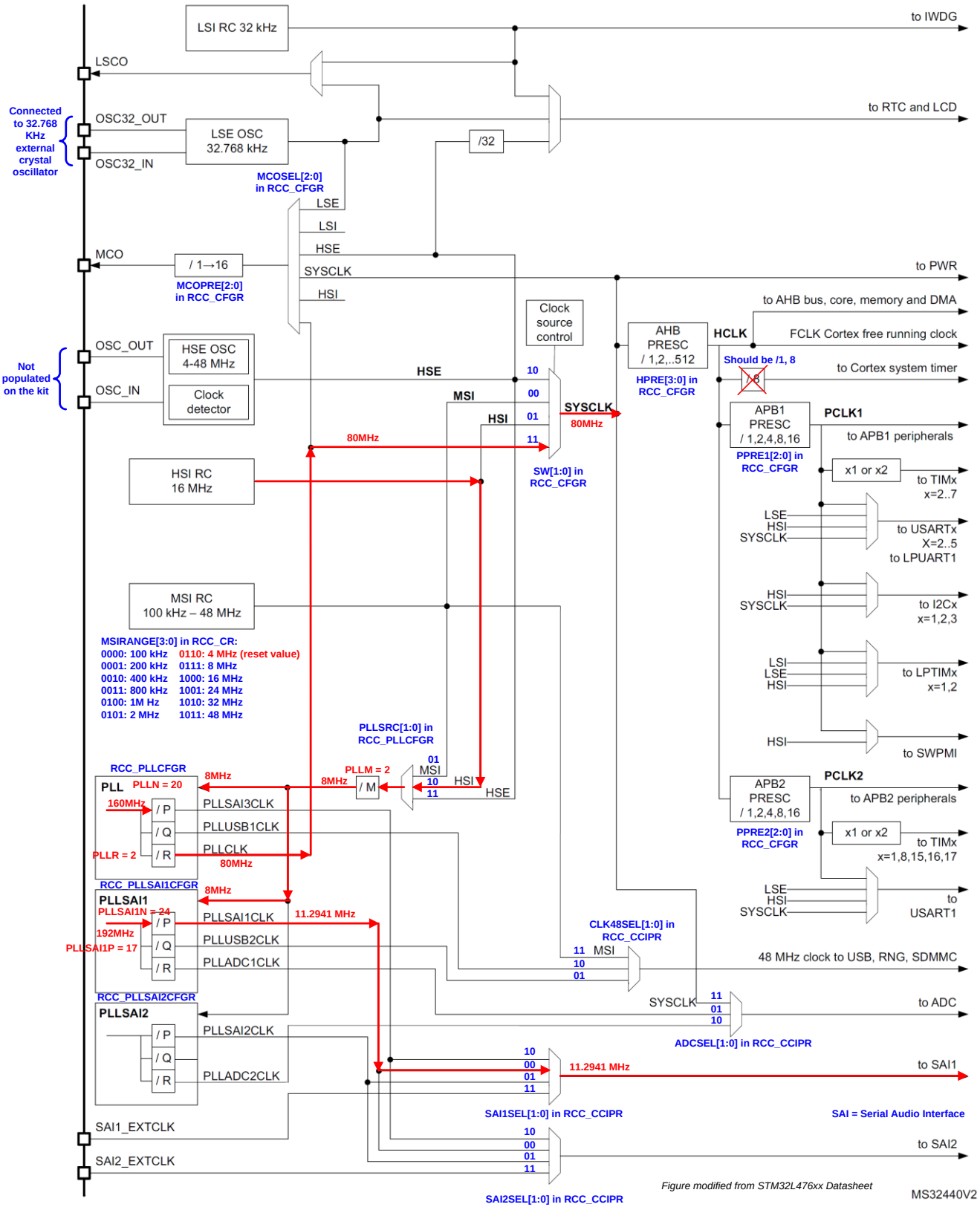

Diagram configuring SYSCLK as 80 MHz and SAI to 11.2941 MHz. (SAI is not used in this lab)

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Pre-Lab Report

Student Name: _____

In this lab, you generate a system ticker with a time period of 1*ms* second. When you call the *delay(1000)*, you will get a delay of one second. The CLKSOURCE of the SYS_CTRL register indicates the clock source for SysTick.

- If CLKSOURCE = 0, the external clock is used. The frequency of SysTick clock is the frequency of the AHB clock divided by 8.
- If CLKSOURCE = 1, the processor clock is used.

In this lab, you are required to configure the AHB clock frequency as 8 MHz by using MSI. In order to change the clock frequency, you need to

1. Select the MSI clock range by configurating MSIRANGE bits of RCC_CR (RCC Clock Control Register) or RCC_CSR (Control/status register). Check "STM32L4 Reference Manual" and find out what value should MSIRANGE bits should be.

   MSIRANGE = _____

   Note:
   - MSIRANGE can be modified when MSI is OFF (MSION=0) or when MSI is ready (MSIRDY=1). MSIRANGE must NOT be modified when MSI is ON and NOT ready (MSION=1 and MSIRDY=0)
   - The MSIRGSEL bit in RCC-CR selects which MSIRANGE is used.
     - If MSIRGSEL is 0, the MSIRANGE in **RCC_CSR** is used to select the MSI clock range. (This is the default)
     - If MSIRGSEL is 1, the MSIRANGE in **RCC_CR** is used.

2. Set **MSION** (MSI Clock Enable) and wait for **MSIRDY** (MSI Clock Ready Flag) of RCC_CR (Clock Control Register).

   - If CLKSOURCE = 0, what is the value of the SysTick Reload Value Register?

     SysTick_LOAD = _____

   - If CLKSOURCE = 1, what is the value of the SysTick Reload Value Register?

     SysTick_LOAD = _____

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Lab Demo

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In this lab, you are required to use the MSI 8MHz as the processor clock.

The frequency of internal clocks (RC oscillators) may vary from one chip to another due to the manufacturing process variations. In addition, the operating temperature has an impact on the accuracy of the RC oscillators. At 25 °C, the HSI and MSI oscillators have an accuracy of ±1.5% typically, but in the temperature range of -40 to 105 °C, the accuracy decreases.

Write a program to toggle a GPIO pin. Use an oscilloscope to measure the signal period of the GPIO pin.

```
while(1){
  delay(1000);       % delay 1 second
  toggle_red_led();
}
```

1. What is the time delay you measure on the oscilloscope in room temperature? What is the percentage of error?
2. What is the time delay you measure on the oscilloscope in outdoor temperature? What is the percentage of error?

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Post-Lab Assignment

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Write your answer to the following questions in ***Readme.md*** file and submit it to the gitlab server.

1. What is the time delay you have measured on the oscilloscope at indoor and outdoor temperature? What is their percentage of error?
2. Is it possible to use the SysTick timer to generate an interrupt once every 100 seconds if there is only a clock 8 MHz? If not, what solutions could we have? If yes, how to set up the SysTick_LOAD register?