**Embedded Systems with ARM Cortex-M Microcontrollers in Assembly Language and C**

# Chapter 18
# Real-time Clock (RTC)

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# Real-Time Clock (RTC)

- RTC is a digital clock that provides calendar time and date.
- Typical requirements:
  - Low power consumption
  - Separately powered by a battery
  - Accurate
  - Run independently from the processor core

# UNIX Epoch Time

- Definition: number of seconds that have elapsed since 00:00:00 UTC, Thursday, 1 January 1970
- Example:
  - Converting 2:07:39am, April 21, 2014 (UTC) to Unix Epoch number

UNIX Epoch Number

$$= 16181 \text{ days} \times \frac{\text{seconds}}{\text{day}} + 2 \text{ hours} \times \frac{\text{seconds}}{\text{hour}} + 7 \text{ minutes} \times \frac{\text{seconds}}{\text{minutes}} + 39$$

$$= 16181 \times 86400 + 2 \times 3600 + 7 \times 60 + 39$$
$$= 1398046059$$
$$= 0x53547D6B$$

*Note a day has 86400 seconds* ($24 \times 60 \times 60 = 86400$)

# UNIX Epoch Time

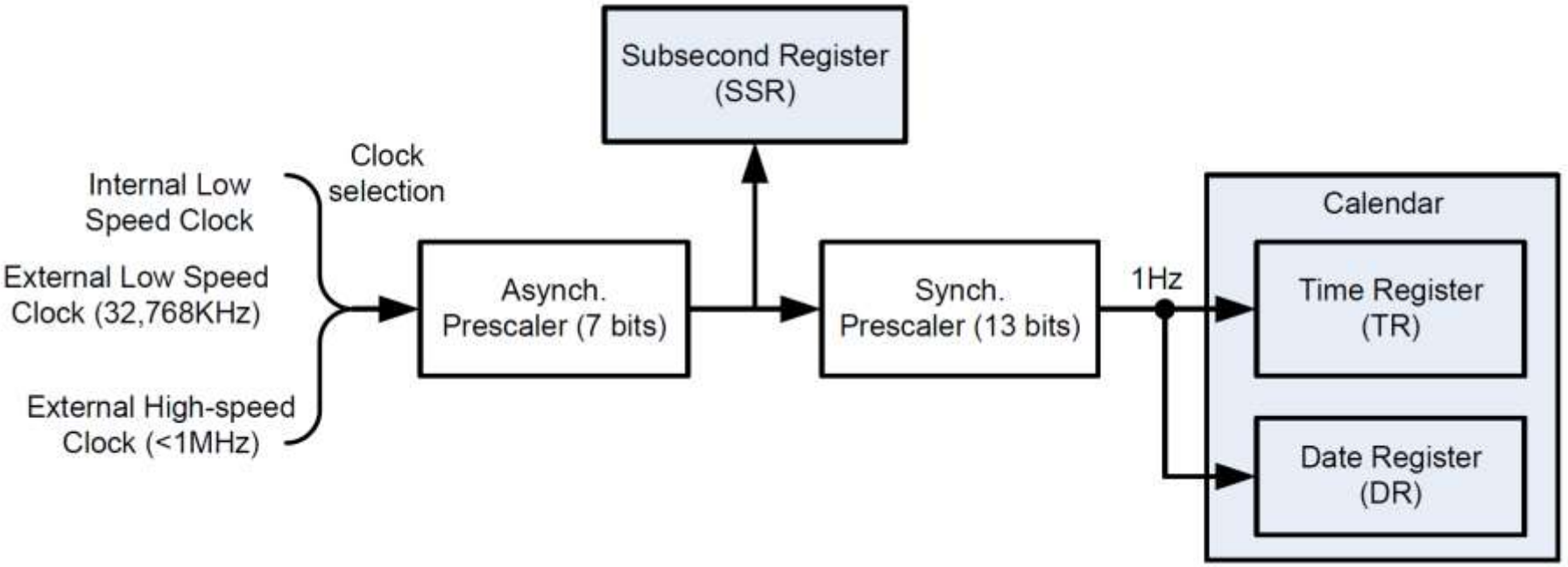
- Use a signed 32-bit integer to hold the UNIX Epoch Time
  - Covers a time span of 136 years.
  - Minimum representable time is `1901-12-13`
  - Maximum representable time is `2038-01-19`

- Year 2038 Problem (also called Unix Millennium Bug)
  - The second after 03:14:07 UTC 2038-01-19 is an overflow (which became 1901-12-13).
  - Use a signed 64-bit integer to fix the problem
  - A challenge in embedded systems

# Crystal Inaccuracy: PPM

- Parts Per Million (PPM) = $10^{-6}$
- Crystal Inaccuracy
  - 1 PPM $\longrightarrow \pm 1.1$ seconds per year
  - A typical watch crystal has 20 PPM
    - Error per day: $86400 \text{ seconds} \times 20 \times 10^{-6} = 1.728 \text{ seconds/day}$
    - Error per month: $30 \text{ days} \times 1.728 \text{ seconds/day} = 51 \text{ seconds/month}$
- STM32 RTC
  - At 25°C, HSI and MSI have an accuracy of 100 ppm (not accurate enough for RTC)
  - Need to use a Low Speed External (LSE) crystal, typically 32.768 kHz ($2^{15}$ Hz)

# Frequency Setting




$$f_{1Hz} = \frac{f_{RTC}}{(Asynch\_Prescaler + 1) \times (Synch\_Prescaler + 1)}$$

# Frequency Setting

If $f_{RTC}$ is 32.768 kHz, *i*.e. $2^{15}$ Hz, then $Asynch\_Prescaler$ is $2^7$-1, *i*.e. 127, and $Synch\_Prescaler$ is set as $2^8$-1, *i*.e. 255, in many applications, as shown below.

$$
\begin{aligned}
f &= \frac{f_{RTC}}{(Asynch\_Prescaler + 1) \times (Synch\_Prescaler + 1)} \\
&= \frac{2^{15}}{(127 + 1) \times (255 + 1)} \\
&= \frac{2^{15}}{2^7 \times 2^8} \\
&= 1Hz
\end{aligned}
$$