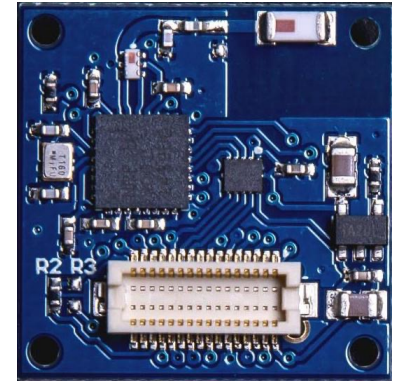
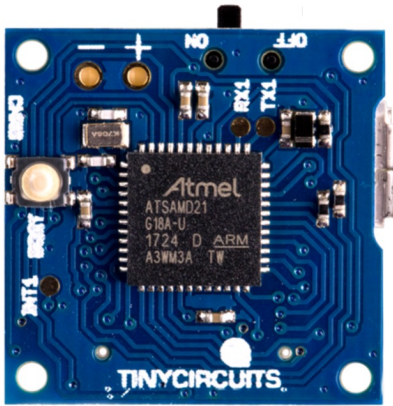


CSE190 Fall 2023

Lecture 5

Time



Wireless Embedded Systems

Aaron Schulman

What time is the Apple Watch tracking?

How often | Granularity

Clock (all the time | sec)

Alarm (all the time | sec)

Stopwatch (when open | msec)

Sync (all the time | sec)

UI (when open | msec)

Buzzer (when buzzing | msec)

WiFi (when communicating | usec)



Why do we need timers?

- In general, why do we need timers?
 - What time is it now?
 - How much time has elapsed since I last checked?
 - Let me know when this much time passes.
 - When did this external input occur?

What peripherals do we use to track time?

(all the time | sec) - [Alarm, Sync]

32-bit Real time clock (RTC) peripheral with interrupts

(when open/buzzing | msec) - [Stopwatch, UI, Buzzer]

Processor's *timer* peripheral with interrupts

(when communicating | usec) - [WiFi]

WiFi chip's internal timer peripheral with interrupts

What peripherals do we use to track time?

(all the time | sec) - [Alarm, Sync]

32-bit Real time clock (RTC) peripheral with interrupts

The term is used to avoid confusion with ordinary hardware clocks which are only signals that govern digital electronics, and do not count time in human units.

(when open/buzzing | msec) - [Stopwatch, UI, Buzzer]

Processor's *timer* peripheral with interrupts

(when communicating | usec) - [WiFi]

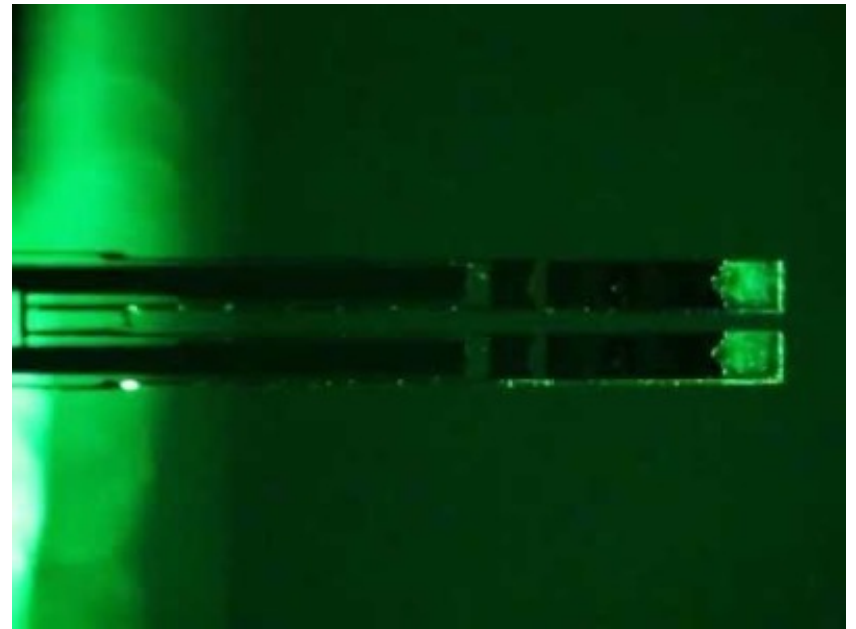
WiFi chip's internal timer peripheral with interrupts

Why do we need timers?

In the first project, what do we need timers for?

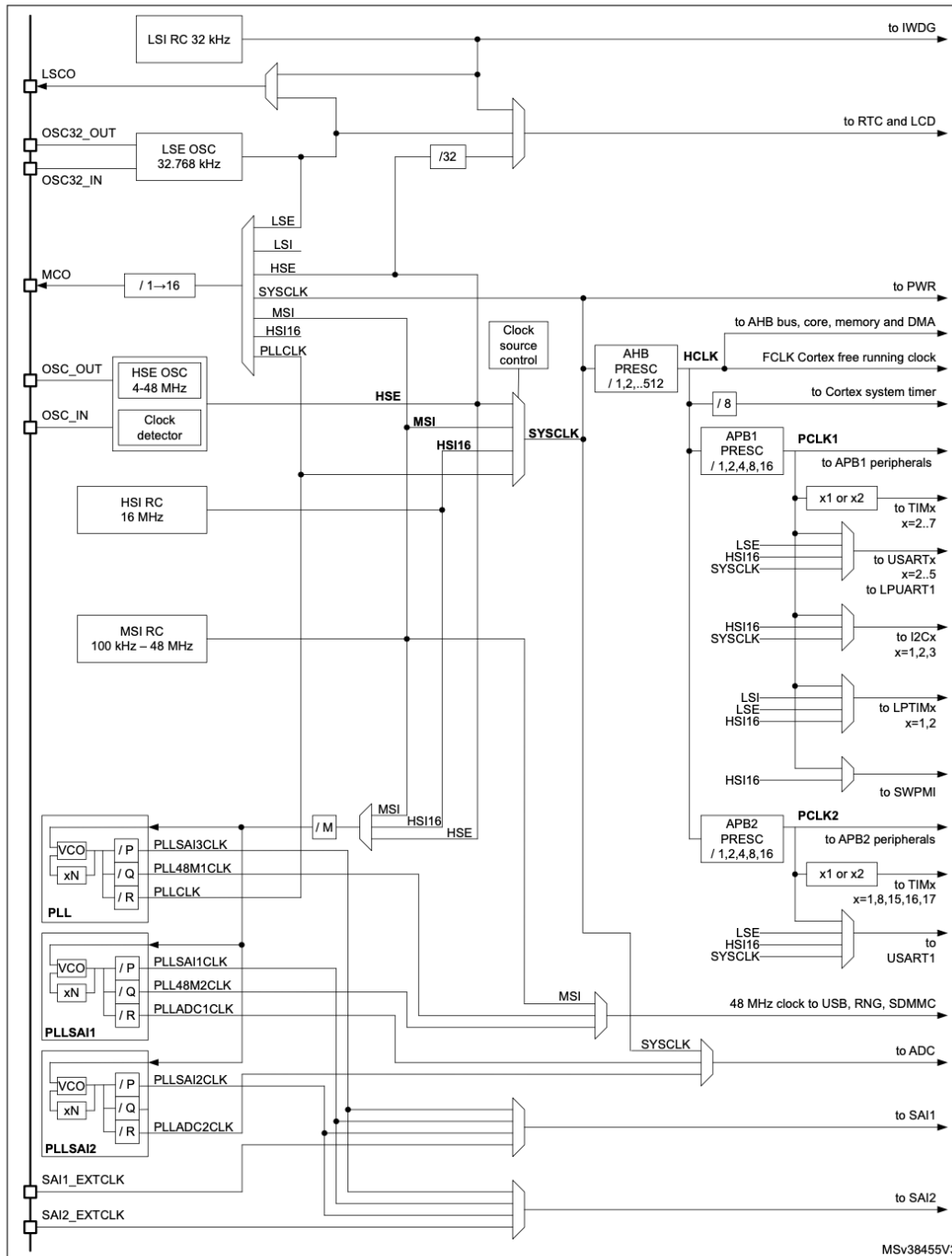
- Determining when to change LEDs
 - 20 Hz means change bits every 50 milliseconds
 - How to measure 50 ms?
 - Option 1: Use the timer hardware to let you know when 50 ms has passed.
 - Option 2: Count how many processor cycles it would take to equal 50 ms.

What is measuring the time? Oscillators (generally, crystal oscillators)

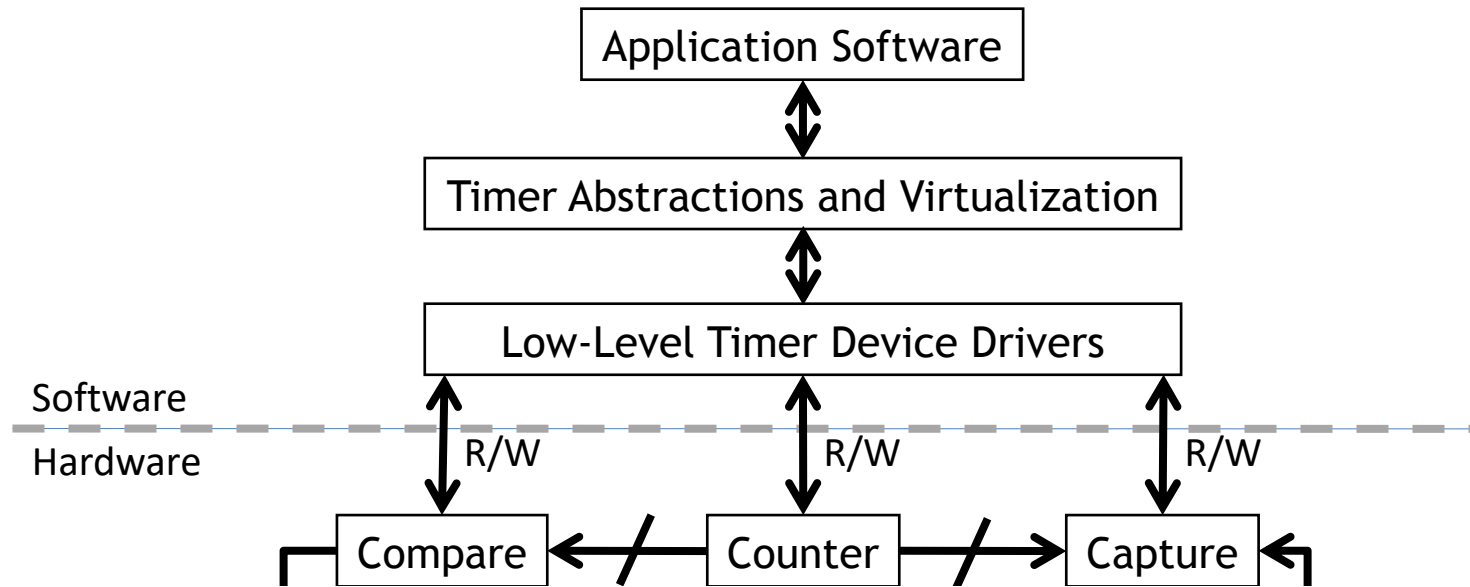


[Video: Crystal oscillators "go to war"](#)

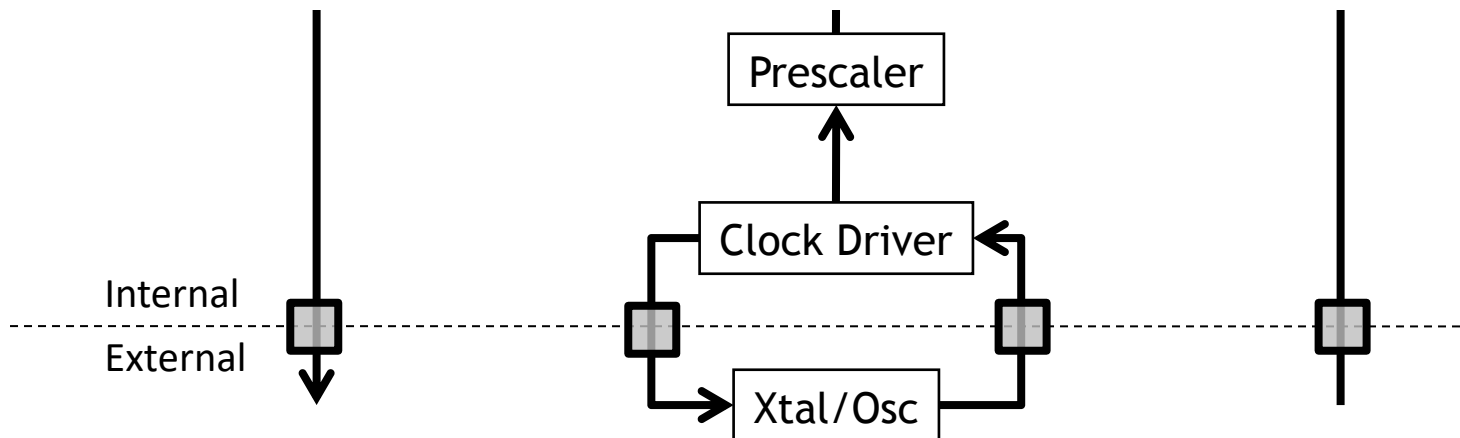
Figure 15. Clock tree (for STM32L47x/L48x devices)



Timer: A peripheral for tracking time



The purpose of the prescaler is to allow the timer to be clocked at the rate a user desires.



Frequency depends on the attached oscillator device

Timers, why do we need them?

In the first project, what do we need timers for?

- Determining when to change LEDs
 - 20 Hz means change LED bits every 50 milliseconds
 - How to measure 50 ms?
 - Option 1: Use the timer hardware to let you know when 50 ms has passed.
 - Option 2: Count how many processor cycles it would take to equal 50 ms.

How does the number in the counter register correspond to wall clock time?

$$\text{Frequency (Hz)} = \text{Cycles} / \text{Second}$$

$$1 / \text{Frequency (Hz)} = \text{Seconds} / \text{Cycle}$$

↓
The counter is incremented once per cycle.

You read 100 from the counter register which is clocked by a 1 MHz oscillator.
How much time has passed since the counter was reset?

How should we choose the OSC frequency?

For timers, there will often be a tradeoff between resolution (high resolution requires a high clock rate) and range (high clock rates cause the timer to overflow more quickly).

1MHz OSC: resolution = $1 / 1e6$ second = 1us

10MHz OSC: resolution = $1/10e6$ second = 0.1us

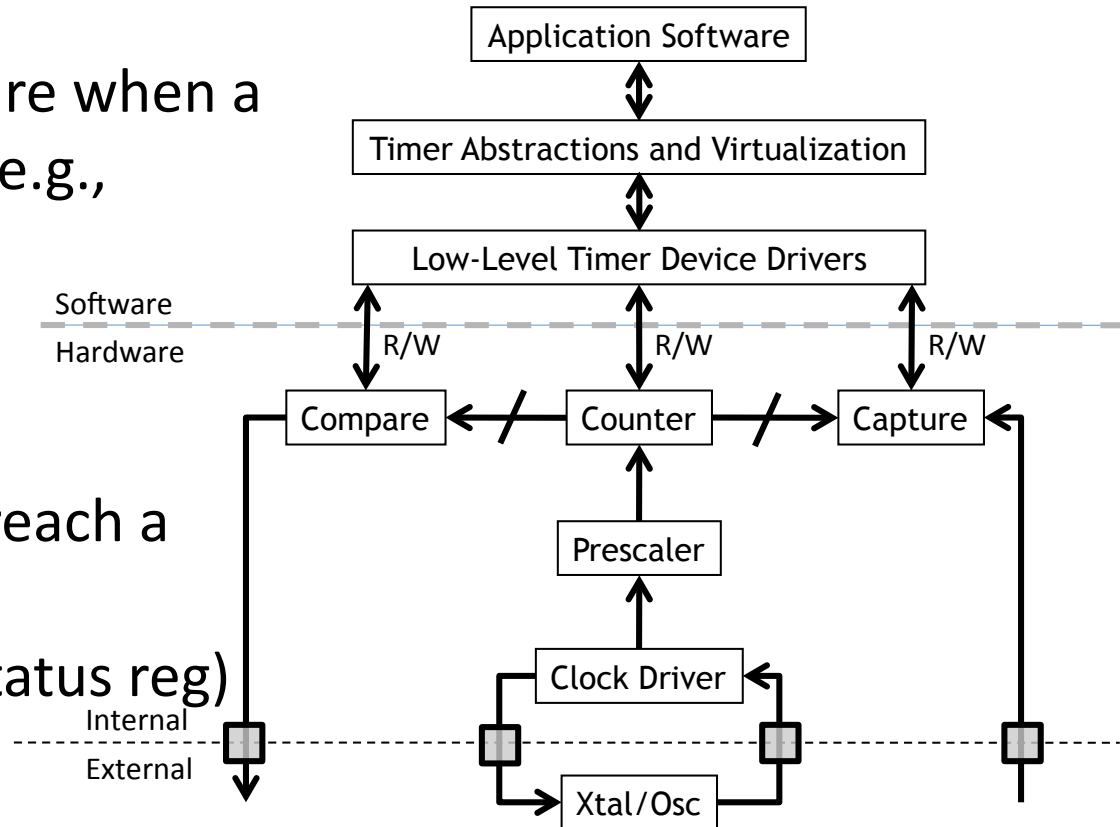
16-bits timer:

1MHz OSC: max range = $1 / 1e6 * 2^{16}$ = 65.536ms

10MHz OSC: max range = $1/10e6 * 2^{16}$ = 6.5536ms

How does a firmware developer use the capture register?

1. Stop the timer
2. Setup the timer to capture when a particular event occurs (e.g., change of GPIO pin)
3. Reset the counter
4. Start the timer
5. Wait for the counter to reach a capture event (via interrupt or check status reg)

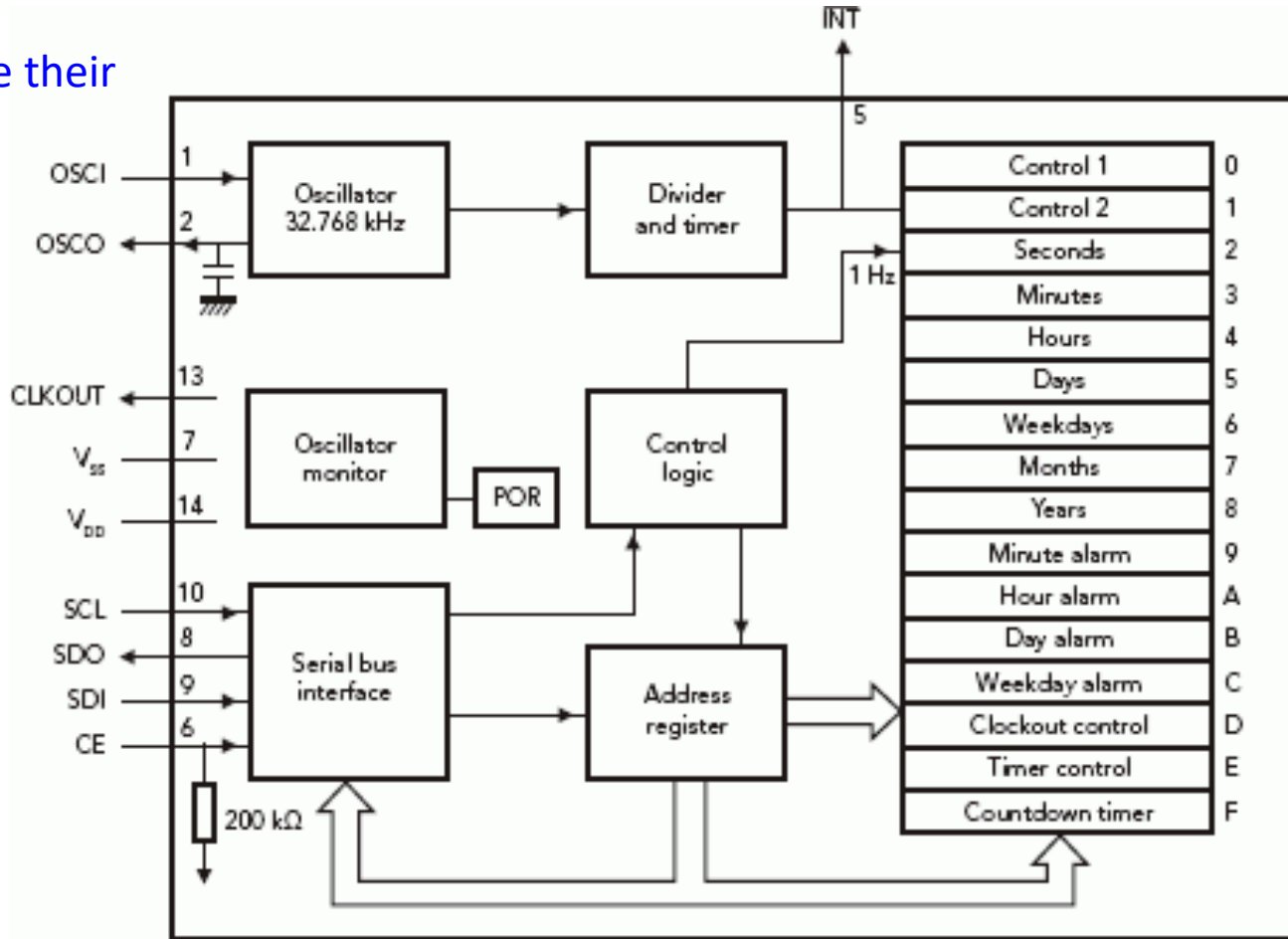


A timer for keeping track of wall-clock time

Real Time Clock (RTC)

Note: RTCs have their own oscillator.

Why is it 32,768 kHz?



The reason the 32,768 Hz resonator has become so common is due to a compromise between the large physical size of low frequency crystals and the large current drain of high frequency crystals.