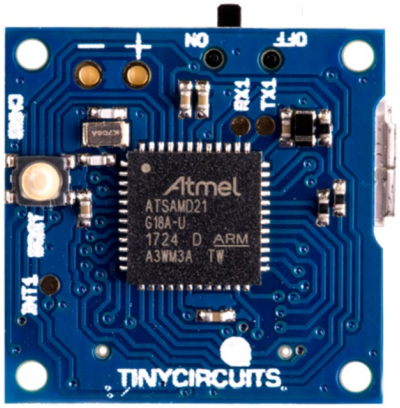
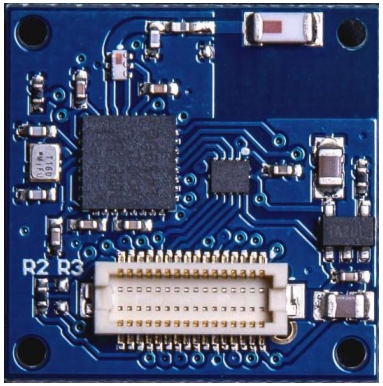
CSE190 Fall 2022



Lecture 6

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]

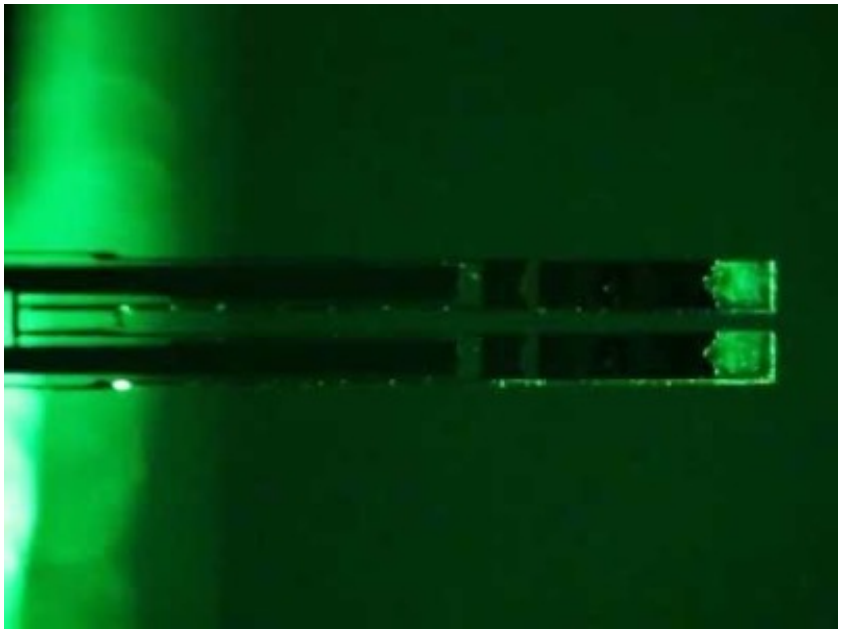
WiFi chip's internal timer peripheral with interrupts

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"

Why do we need timers?

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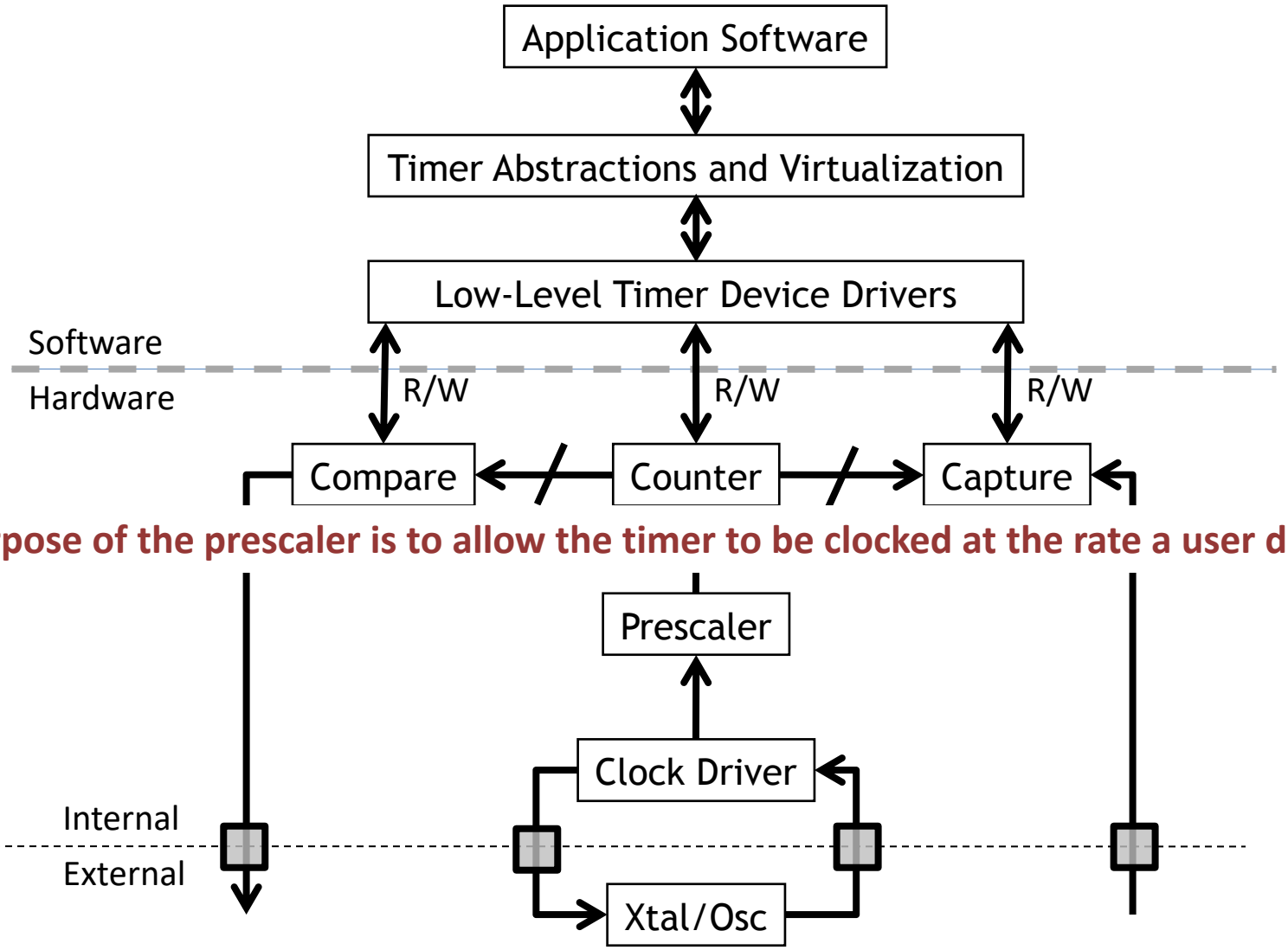
The internal structure of a timer peripheral



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

Figure adapted from Prabal Dutta's EE373 slides

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

Frequency (Hz) = Cycles / Second

1 / Frequency (Hz) = Seconds / 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?

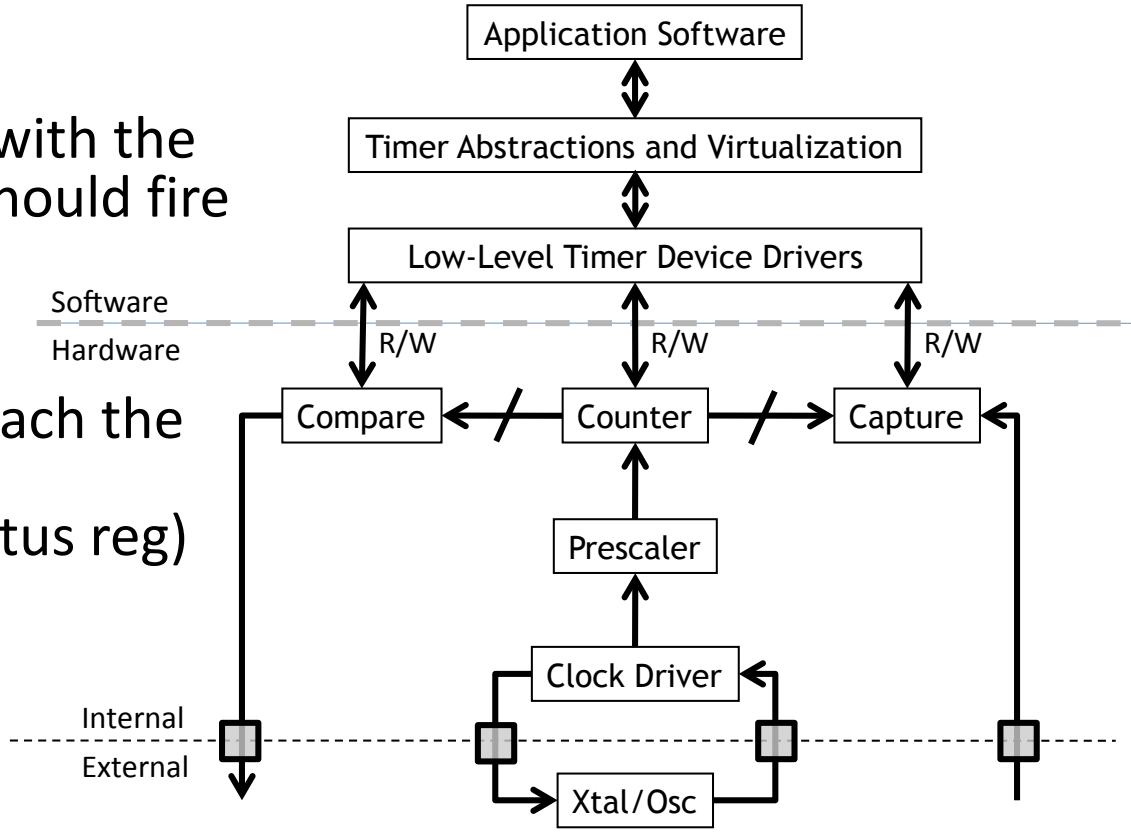
For timers, there will often be a tradeoff between resolution (high resolution requires a high clock rate) and range (high clock rates cause the timer to overflow more quickly).

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

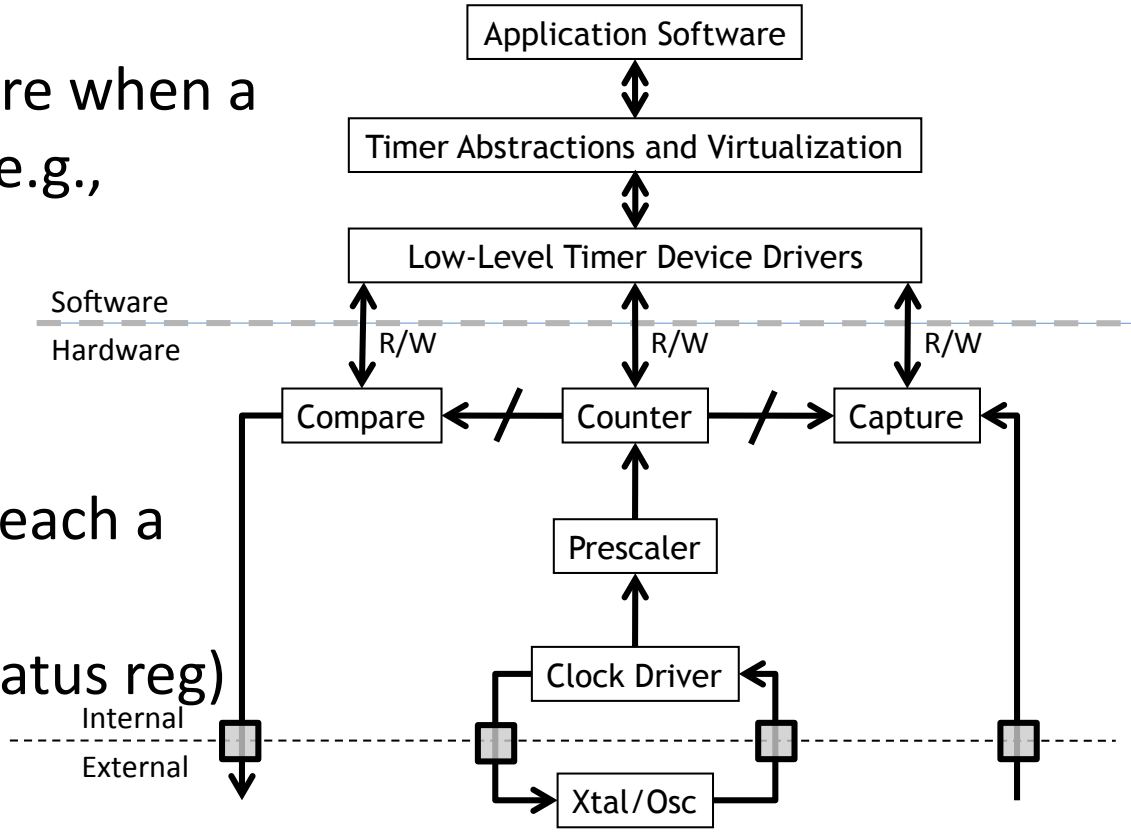
How does a firmware developer use the compare register?

1. Stop the timer
2. Set the compare register with the number of ticks when it should fire
3. Reset the counter
4. Start the timer
5. Wait for the counter to reach the compare
   (via interrupt or check status reg)



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)



The internal structure of a Real Time Clock (RTC)

Note: RTCs have their own oscillator.

Why is it 32,768 kHz?

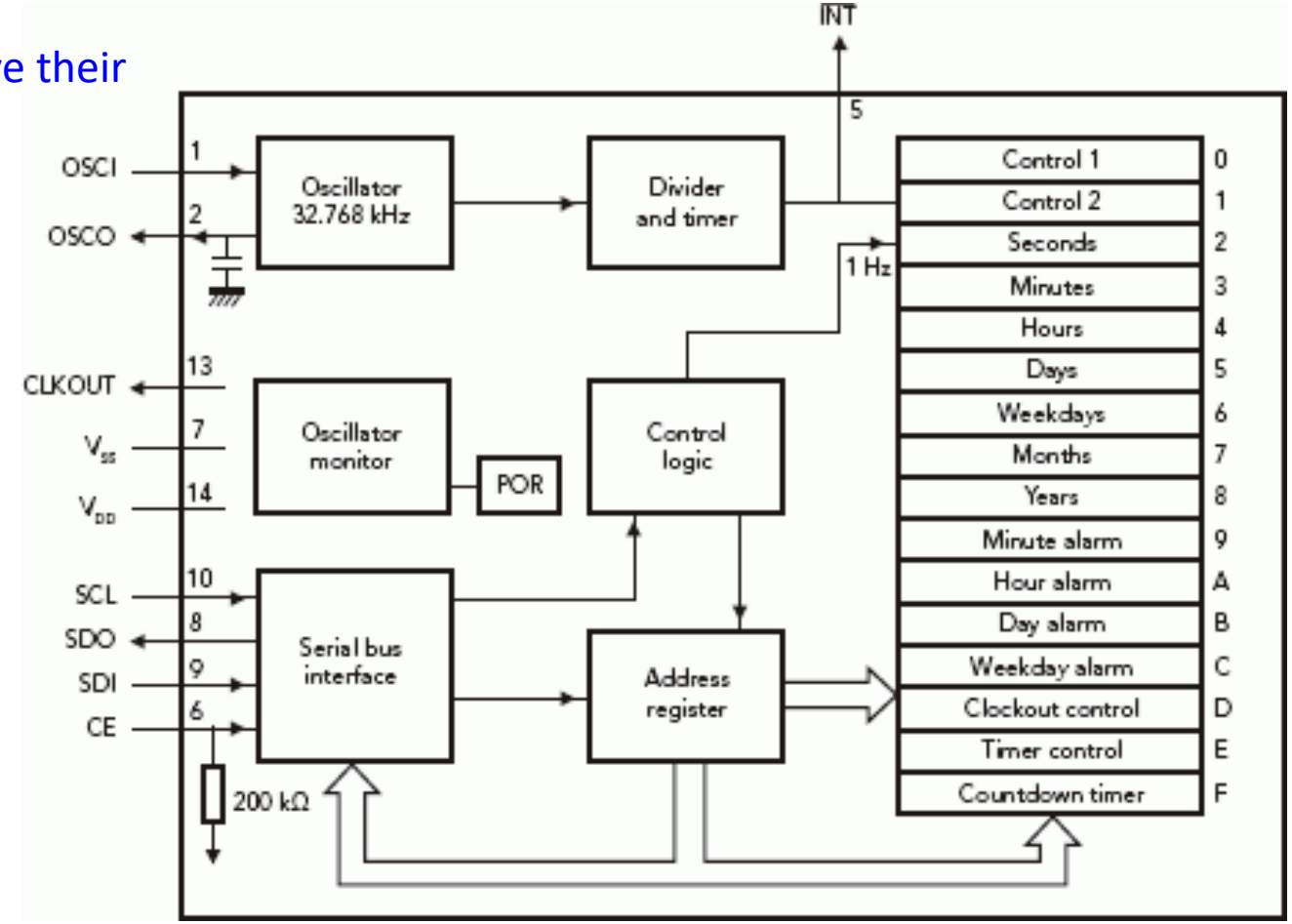


Figure adapted from Prabal Dutta's EE373 slides

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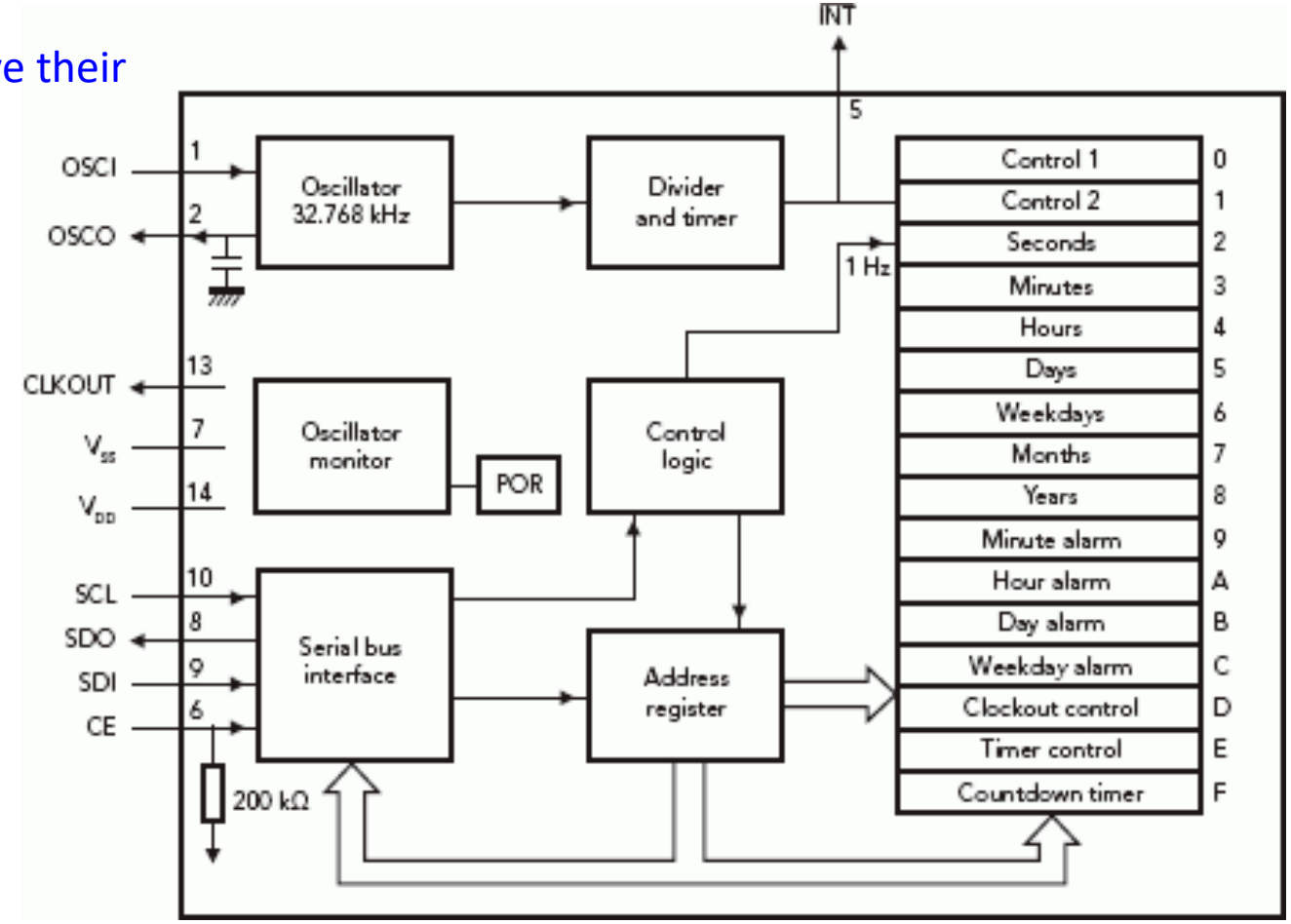

The reason the 32,768 Hz resonator has become so common is due to a compromise between the large physical size of low frequency crystals and the large current drain of high frequency crystals.

Figure adapted from Prabal Dutta's EE373 slides