Embedded Systems Programming - PA8001

http://bit.ly/15mmqf7

Lecture 7

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For the Development of Organisations, Products and Quality of Life

Center for Research on Embedded Systems

School of Information Science, Computer and Electrical Engineering

Real Time?

In what ways can a program be related to time in the environment (the *real time*)?

Salvador Dali, The Persistence of Memory.

Real Time

An external process to . . .

- Sample: reading a clock,
- React: a handler for an interrupt clock, and
- Constraint: a deadlock to respect.

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Sampling the time

Requires a hardware clock (read as an external device)

Multitude of alternatives

- Units? Seconds? Milliseconds? CPU cycles?
- Since when? Program start? System boot? Jan 1, 1970?
- Real time? Time stops when: other threads are running? when CPU sleeps? Time that cannot be set and always increases?

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Timer/Counter1 on the AVR

What about the 16-bit counter (accessible through register TCNT1)?

Units
CPU clock (8Mhz) divided by a programmable prescaling value (1, 8, 64, 256, 1024).

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System reset, timer reset or timer overflow (whichever was last).

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Shows real time although can be stopped.

Aligning TCNT1 with calendar time: calculations and extra storage (for counting overflows).

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Timestamps

Relative timing: prevalent in reactive systems, reactions are relative to events

Example

Teacher left 15 min. after the start of the lecture.

In embedded programming, time-stamping an event: reading performed around the event detection.

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Time spans

The difference between two time-stamps: a time span independent of the nominal clock values (modulo clock resolution).

The meaning of time-stamp

- The time of some arbitrary program instruction?
- The beginning or end of a function call?
- The time of sending or receiving an asynchronous message?

Too much program dependent!

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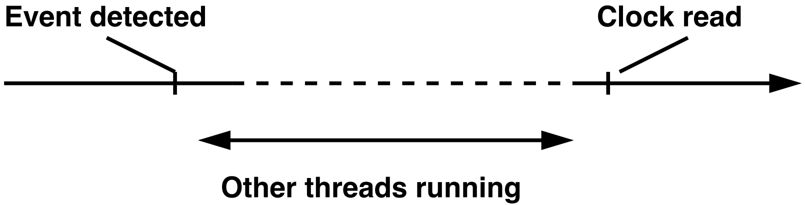
In a scheduled system

What looks like . . .

might very well be . . .



Close proximity is not the same as subsequent statements!

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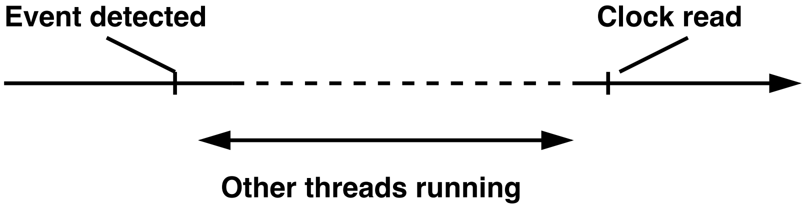

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Time-stamping events

Our goal: to time-stamp events that *drive* a system

Idea!

Read the clock in the interrupt handler detecting the event

- Disable other interrupts, hence no threads might interfere
- Tight predictable upper bound on the time-stamp error

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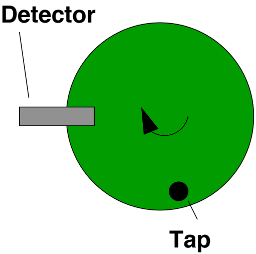
Calculate the speed

For a rotating wheel, measuring the time between two subsequent detections of a passing tap.

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typedef struct{
 Object super;
 int previous;
 Other *client;
} Speedo;
...
Speedo speedo;
int main(){
   INSTALL(&speedo, detect, SIG_XX);
   return TINYTIMBER(...)
}
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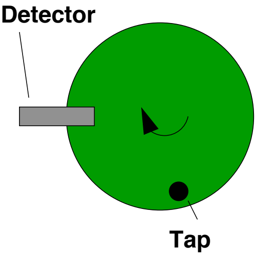


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int detect(Speedo *self, int sig){
   int timestamp = TCNT1;
   ASYNC(self -> client,
        newSpeed,
        PERIMETER/DIFF(timestamp,self->previous));
   self->previous=timestamp;
}
```

DIFF will have ot take care of timer overflows!

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Real-time events to react to

So far: how to sample the real-time clock to know about time

Now: how to take action after a certain amount of time

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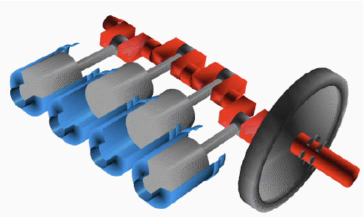

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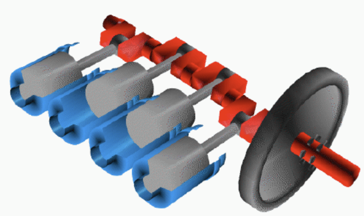

How to postpone program execution until certain time

Reacting to real time events

Very poor man's solution

Consume a fixed amount of CPU cycles in a (silly) loop

```
int i;
for(i=0;i<N;i++);  // wait
do_future_action();
```

Problems

1. Determine N by testing!
2. N will be highly platform dependent!
3. A lot of CPU cycles will simply be wasted!

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Configure a timer/counter with a known clock speed, and busy-wait for a suitable time increment

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unsigned int i = TCNT1+N;
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The standard solution

Use the OS to *fake* busy-waiting

```
delay(N);   // wait (blocking OS call)
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- No platform dependency!
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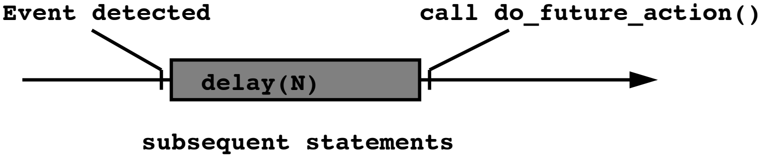

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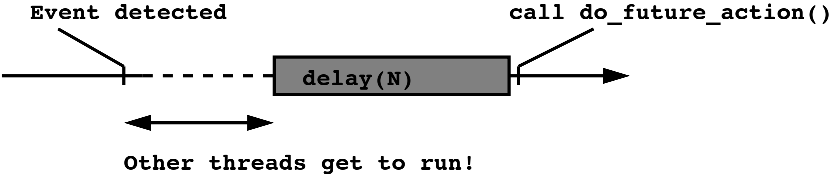

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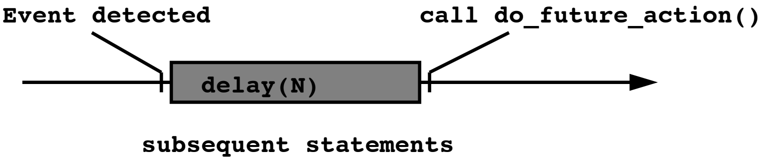

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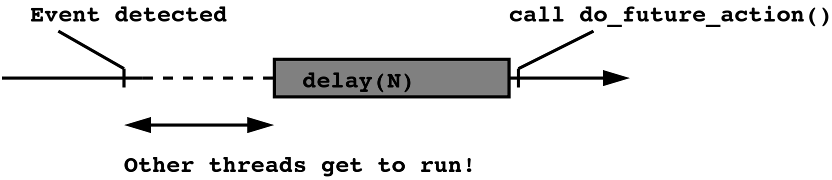

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Relative delays

The problem: relative time without fixed references:

- The constructed real-time event will occur at after `N` units from *now*.
- What is *now*?!

Other common OS services share this problem: `sleep`, `usleep` and `nanosleep`.

We are not going to use OS services in the course.

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Yet another problem

Threads and interleaving make it worse

Example

Consider a task running a CPU-heavy function `do_work()` every 100 millisecods. The naive implementation sing `delay()`:

```
while(1){
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  delay(100);
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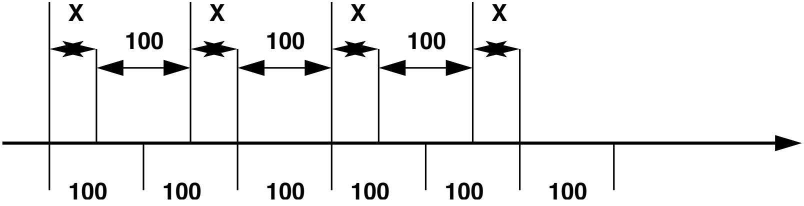

`X` is the time take to `do_work`

Each turn takes at least 100+`X` milliseconds.

A drift of `X` milliseconds will accumulate every turn!

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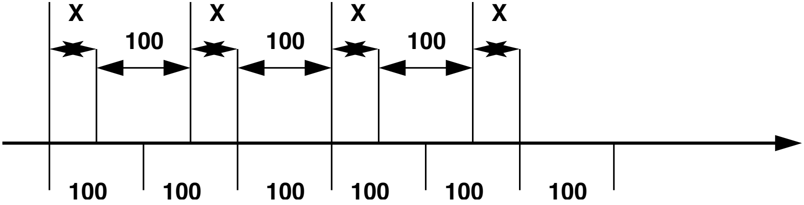

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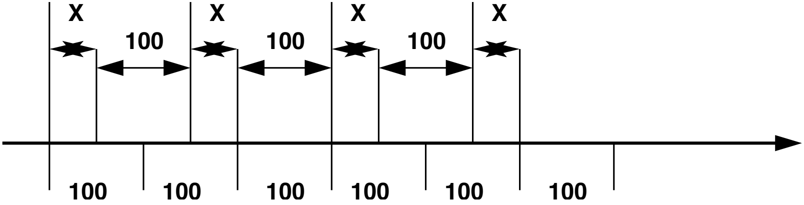

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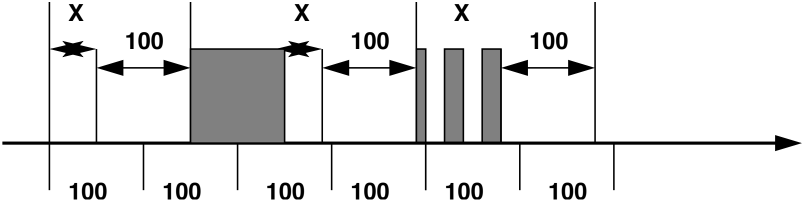

With threads and interleaving, the bad scenario gets worse!

Even with a known X, delay time is not predictable.

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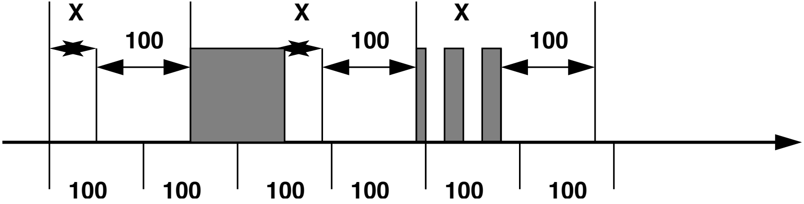

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A stable reference

What we need is a stable time reference to use as a basis whenever we specify a relative time (instead of now).

Baselines

We introduce the baseline of a message to mean the earliest time a message is allowed to start.

Time stamps of interrupts!

The baseline of an event is its time-stamp:

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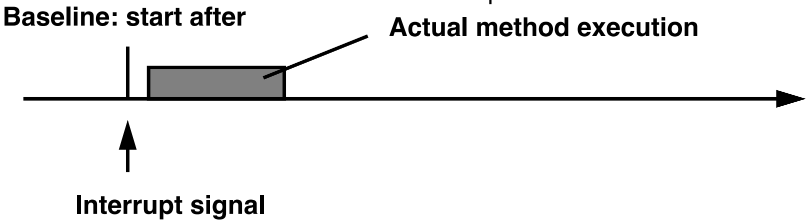
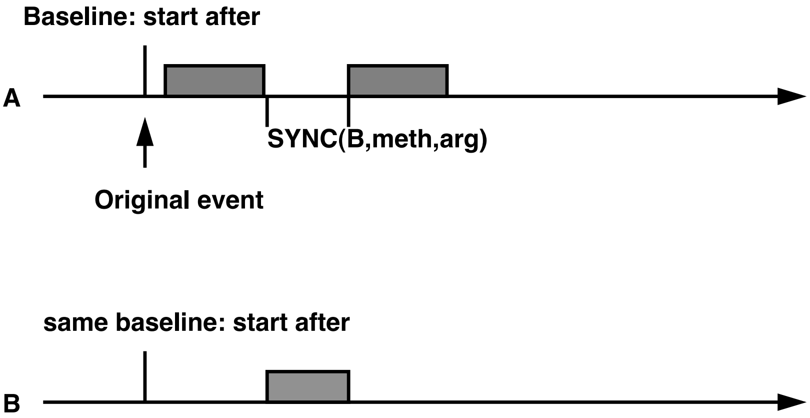


A stable reference

SYNC

Calling methods with `SYNC` doesn't change the baseline (the call inherits the baseline)



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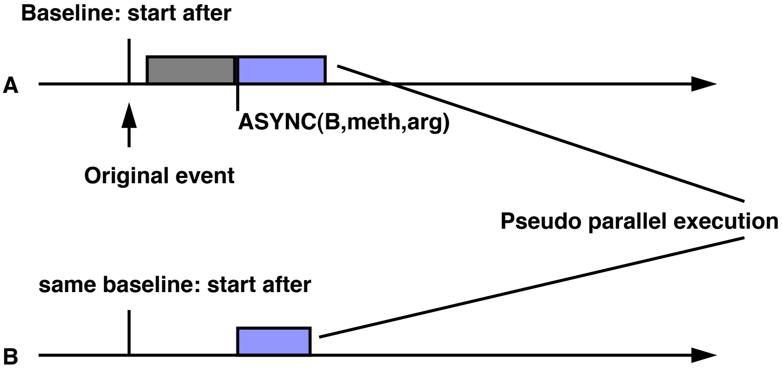
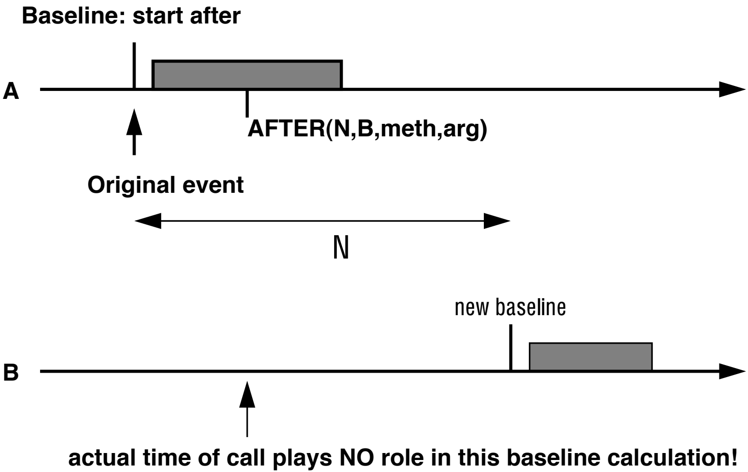
ASYNC

By default `ASYNC` method calls will inherit the baseline



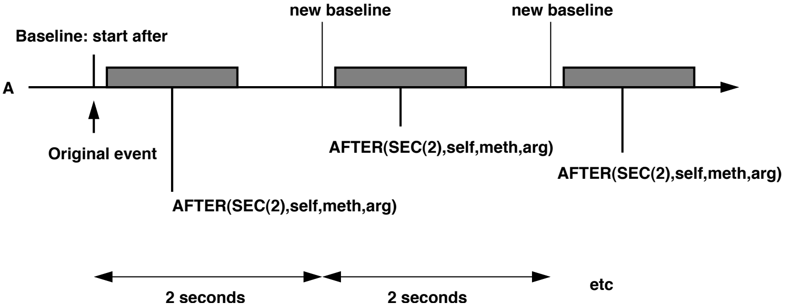
A stable reference

For `ASYNC` we may also consider adding a baseline offset `N`!



Periodic tasks

To create a cyclic reaction, simply call **self** with the same method and a new baseline:



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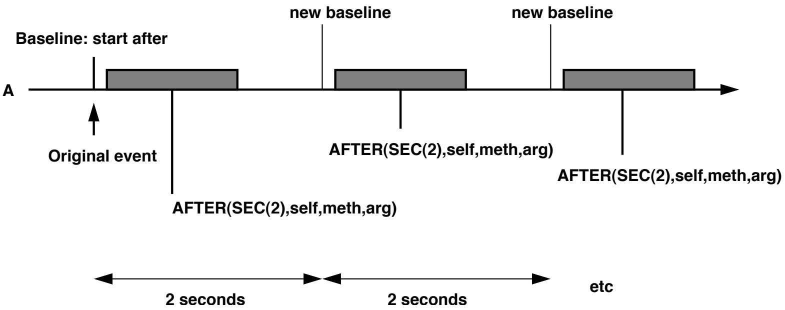

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Implementing AFTER

1. Let the baseline be stored in every message (as part of the `Msg` structure)
2. `AFTER` is the same as `ASYNC`, but
   - New baseline is `MAX(now, offset+current->baseline)`
   - If `baseline > now` , put message in a timerQ instead of readyQ
   - Set up a timer to generate an interrupt after earliest baseline
   - At each timer interrupt, move first timerQ message to readyQ and configure a new timer interrupt

In fact `ASYNC` can now be defined as

```
#define ASYNC(to,meth,arg) AFTER(0,to,meth,arg)
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   - If `baseline > now` , put message in a timerQ instead of readyQ
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   - At each timer interrupt, move first timerQ message to readyQ and configure a new timer interrupt

In fact `ASYNC` can now be defined as

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Implementing AFTER

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Bonus Questions

What are the issues with time in a distributed system? Find out what Lamport Clocks are and explain them (in your own words) in a few lines.
(Please send your answers by email before 13:00 today.)