The Sparse Synchronous Model

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COMPUTER SCIENCE AT
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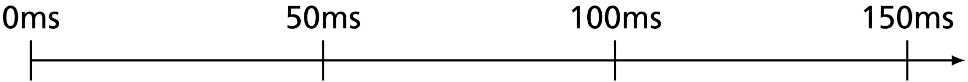
Synchron 2020, November 26, 2020

See also Edwards and Hui, FDL 2020

Time modeled arithmetically



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Program execution a series of
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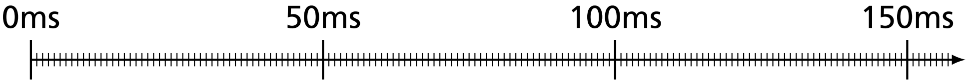

Time modeled arithmetically

Quantized; quantum
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Infinitely fast processor model:
Program execution a series of
zero-time instants
(hence “synchronous”)

Nothing happens in
most instants (hence “sparse”)

```
main(led : Ref (Sched Int)) =
  loop
    50 ms later led <— 1
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    50 ms later led <— 0
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```
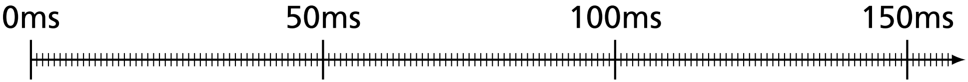

led is a pass-by-reference integer that can be scheduled

Infinite loop

Schedule a future update

Wait for a write on a variable



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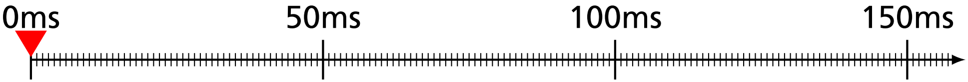

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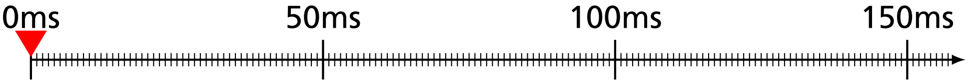

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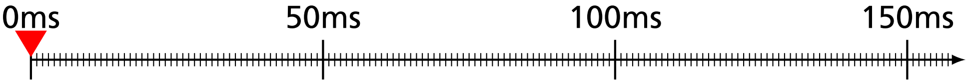

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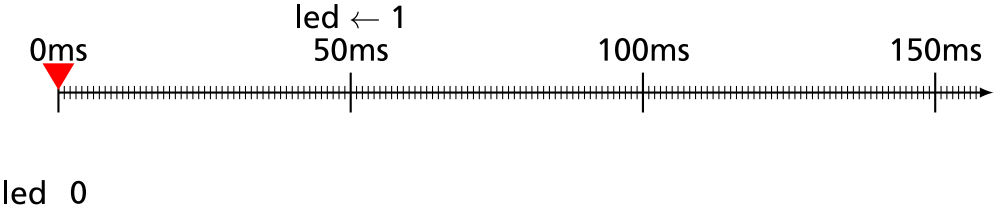

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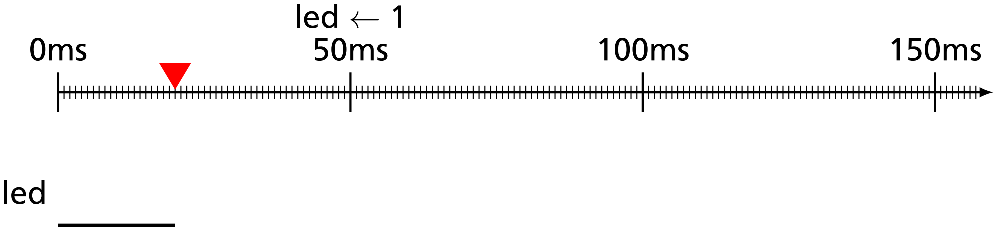

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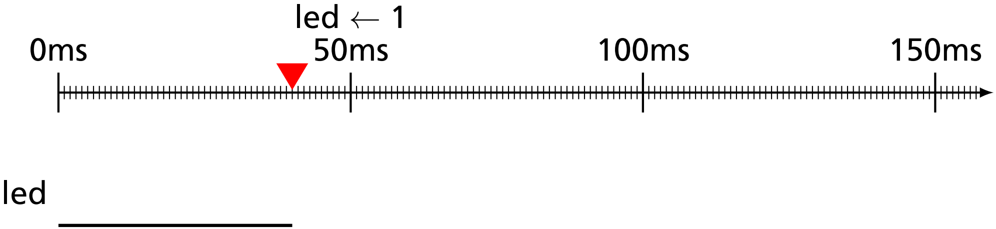

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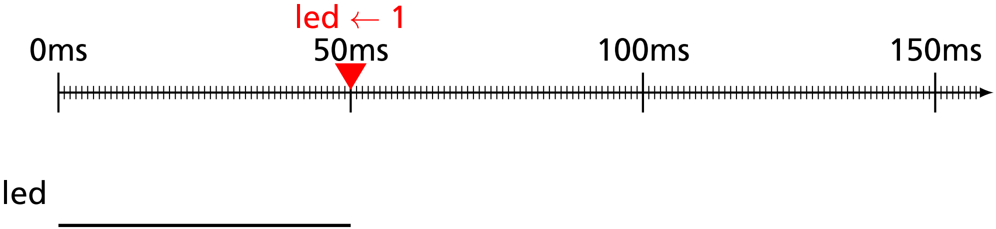

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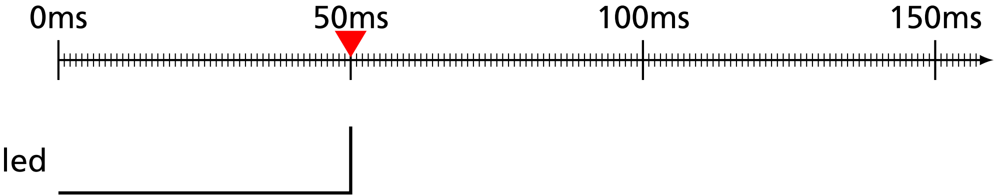

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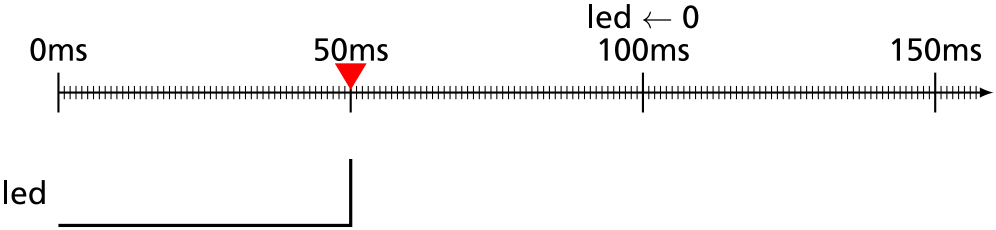

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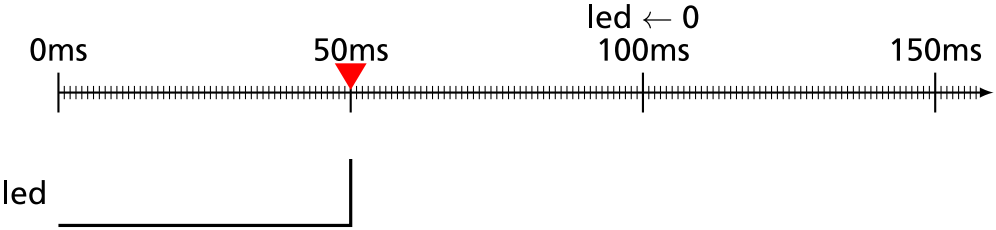

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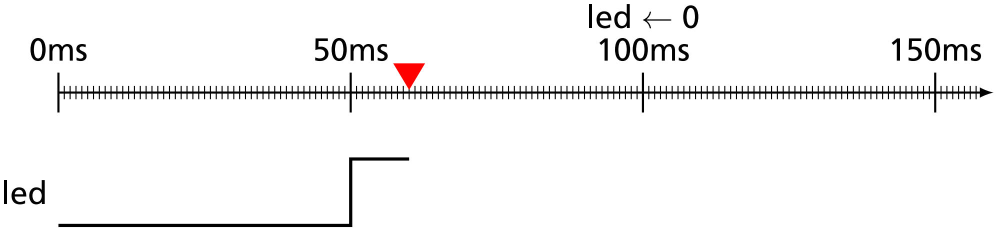

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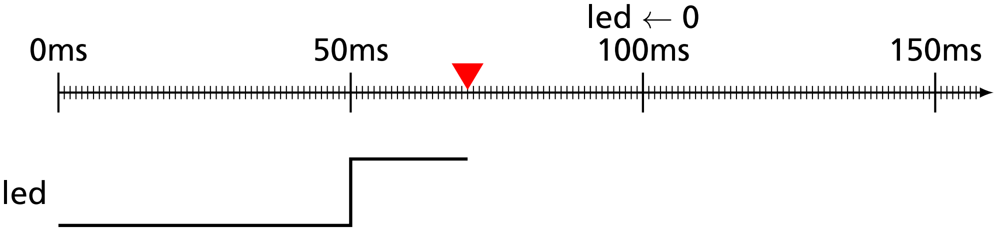

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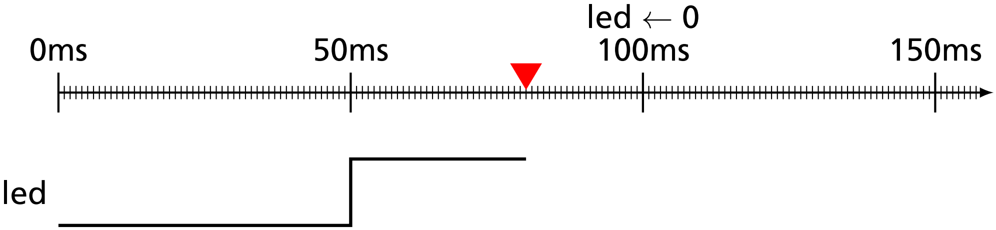

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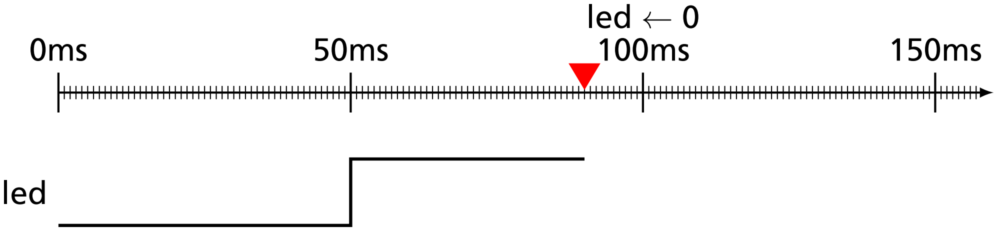

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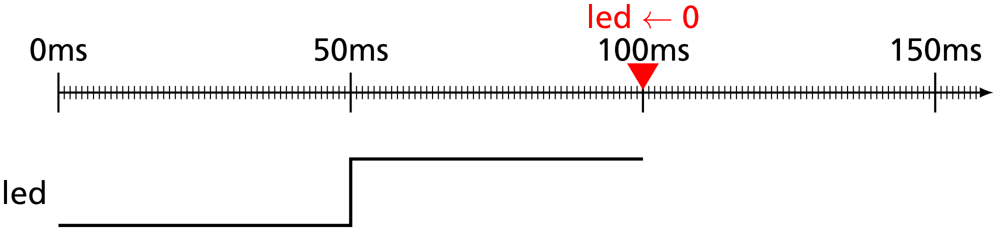

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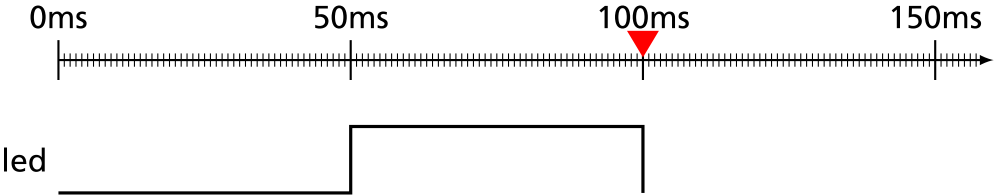

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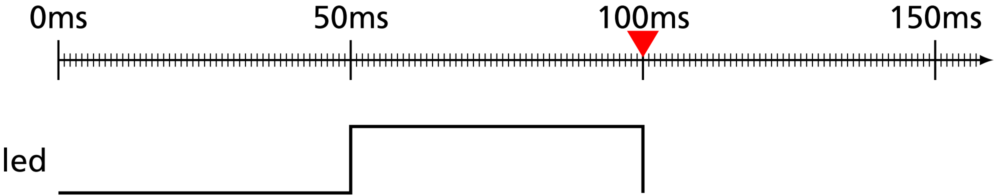

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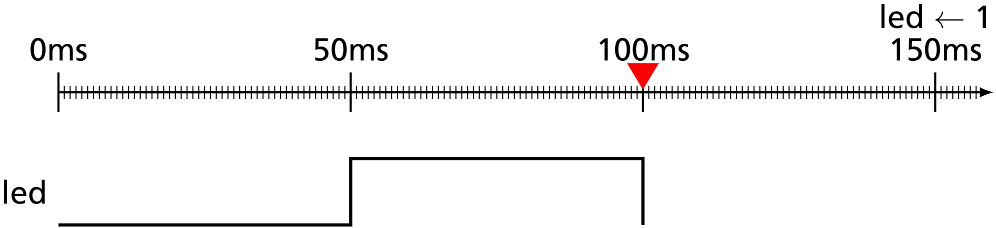

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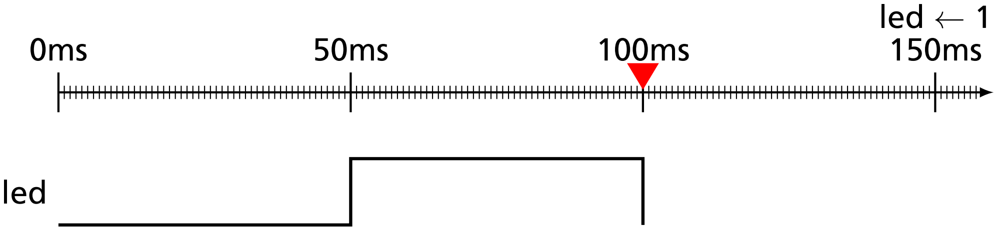

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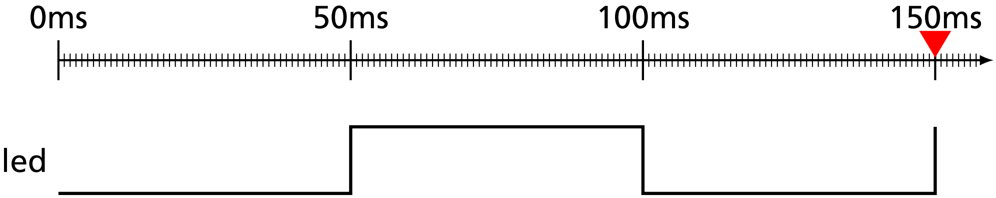

Missing Deadlines Doesn't Affect Period

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main(led : Ref (Sched Int)) =
  loop
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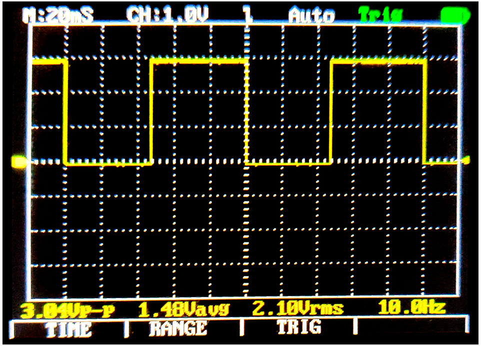

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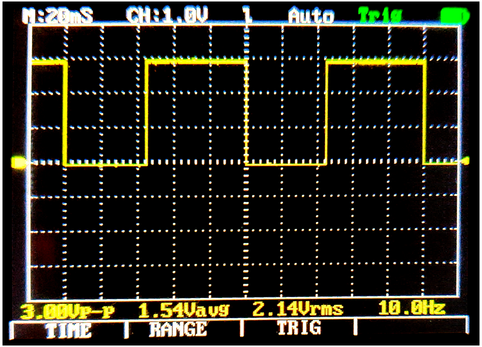
```
main(led : Ref (Sched Int)) =
  loop
    fib 19 r
    50 ms later led <— 1
    wait led
    50 ms later led <— 0
    wait led
```



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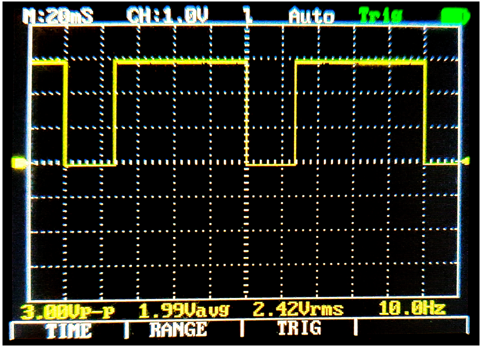

Recursive subroutines

```
toggle(led : Ref (Sched Int)) =
  led <- 1 - led
```

Pure events like "void" or "unit"

```
toggle(led : Ref (Sched Int)) =
  led <− 1 − led

slow(led : Ref (Sched Int)) =
  let e1 = Occur : Sched Event
```

Function call

```
toggle(led : Ref (Sched Int)) =
  led <− 1 − led

slow(led : Ref (Sched Int)) =
  let e1 = Occur : Sched Event
  loop
    toggle led
```

"Occur": only value of a pure event

```
toggle(led : Ref (Sched Int)) =
  led <– 1 – led

slow(led : Ref (Sched Int)) =
  let e1 = Occur : Sched Event
  loop
    toggle led
    30 ms later e1 <– Occur
    wait e1
```

Concurrent function calls

```
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  led <– 1 – led

slow(led : Ref (Sched Int)) =
  let e1 = Occur : Sched Event
  loop
    toggle led
    30 ms later e1 <– Occur
    wait e1

fast(led : Ref (Sched Int)) =
  let e2 = Occur : Sched Event
  loop
    toggle led
    20 ms later e2 <– Occur
    wait e2

main(led : Ref (Sched Int)) =
  par slow led
      fast led
```

Concurrent Routines Execute in Syntactic Order for Determinism

```
main()
  let a = 1 : Int
  par foo a
      bar a
```

Concurrent Routines Execute in Syntactic Order for Determinism

```
foo(a : Ref Int) =          main()
  a <- a + 2                  let a = 1 : Int
                              par foo a
bar(a : Ref Int) =                bar a
  a <- a * 4
```

Concurrent Routines Execute in Syntactic Order for Determinism

foo(a : Ref Int) =
  a <− a + 2

bar(a : Ref Int) =
  a <− a ∗ 4

main()
  let a = 1 : Int
  par foo a
      bar a
  *// foo runs first: a = 12 = (1 + 2) * 4*

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  par bar a
      foo a
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foo(a : Ref Int) =
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```
main()
  let a = 1 : Int
  par foo a
      bar a
  // foo runs first: a = 12 = (1 + 2) * 4
  par bar a
      foo a
  // bar runs first: a = 50 = (12 * 4) + 2
```

SSM vs. Esterel

[Berry and Gonthier, SCP 1992]

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Deterministic	Yes	Yes

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Runtime	Dynamic Event Queues	Statically Scheduled

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Topology	Dynamic, recursive	Static

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Within instants	Totally-ordered	Discrete-Event
Topology	Dynamic, recursive	Static
Implementation	Single-threaded	Distributed

[Zou Ph.D 2011] See also Lee, Lohstroh et al. *Linga Franca*

Compared to Dynamic Ticks

Haxlenden, Bourke, Girault, FDL 2017

Dynamic ticks uses repeated “min” to decide “how long to wait”

SSM uses an event (priority) queue to decide this

Dynamic Ticks uses the richer, but harder-to-compile Esterel semantics

Compared to Boussinot’s Work

Boussinot’s schedule-based-on-syntactic-order inspired the SSM policy

Boussinot: Round-robin cooperative scheduler; SSM: totally-ordered-within-an-instant

Less concern for real-time behavior; more an operational replacement for Esterel-style semantics https://github.com/sedwards-lab/peng