Embedded Systems Programming - PA8001

http://bit.ly/15mmqf7

Lecture 6

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Encoding state layout

TinyTimber: a micro-kernel for embedded systems programming

In MyClass.h

#include "TinyTimber.h"

typedef struct{
    Object super;
    int x;
    char y;
} MyClass;

#define initMyClass(z) \
    { initObject ,0,z}

1. .... refer to the object

2. ....

3. ....

Using it

#include "MyClass.h"
MyClass a = initMyClass(13);

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Comparing with Java

```
class MyClass{
    int x;
    char y;
    MyClass(int z){
        x=0;
        y=z;
    }
}
```

Objects are statically
allocated (unlike Java)

Constructors:
preprocessor macros!

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MyClass a = new MyClass(13);
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...
int myMethod( MyClass *self , int q);
```

In `MyClass.c`

```
int myMethod( MyClass *self , int q){
    self -> x  =  self -> y  + q;
}
```

In Java

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class MyClass{
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Encoding function calls

In Java

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...
MyClass a = new MyClass(13);
a.myMethod(44);
```

In our C programs

```
...
MyClass a = initMyClass(13);
myMethod( &a ,44);
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Today's order of business: synchronous and asynchronous messages

Encoding function calls

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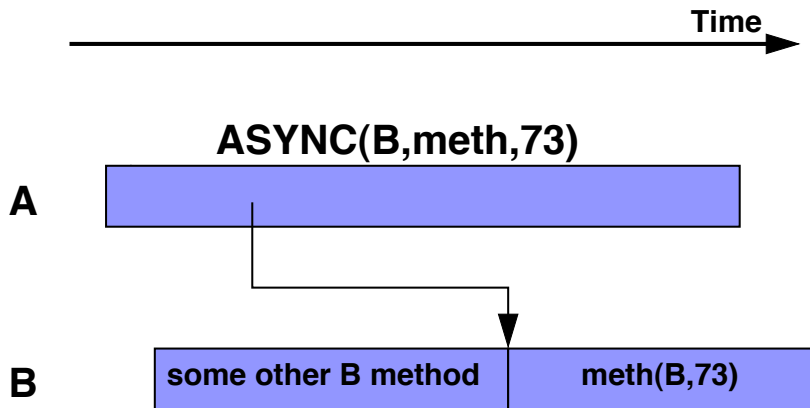Today's order of business: synchronous and asynchronous messages

Asynchronous calls

Time

ASYNC(B,meth,73)

A

B (resting) meth(B,73)
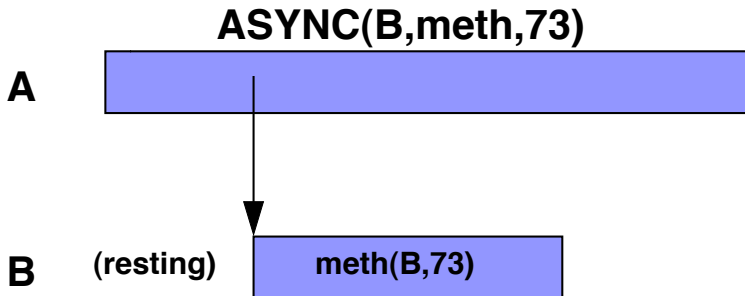
(Pseudo-) parallel
execution!

Asynchronous calls
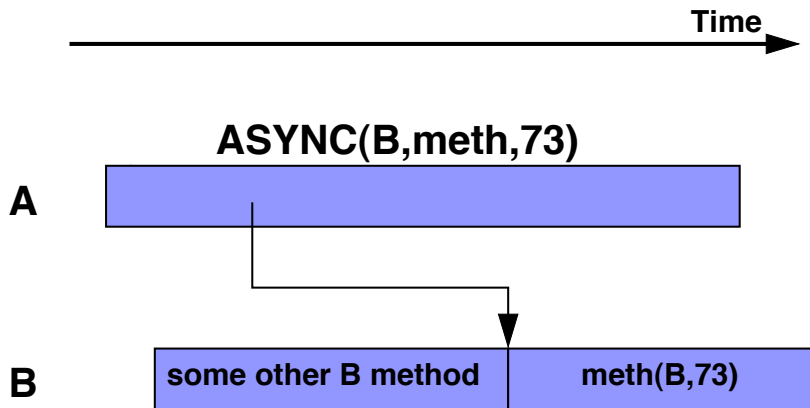
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(Pseudo-) parallel execution between A and B.

Strictly sequential execution between B's methods!

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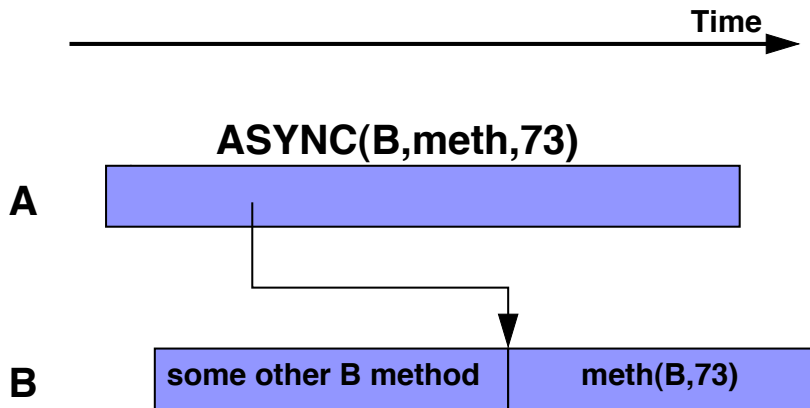# Asynchronous calls
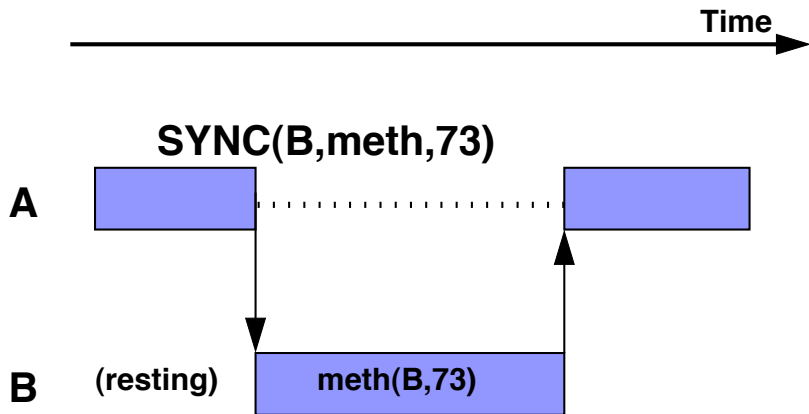
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Synchronous calls

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SYNC(B,meth,73)

A

B (resting)   meth(B,73)

Strictly sequential
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Synchronous calls
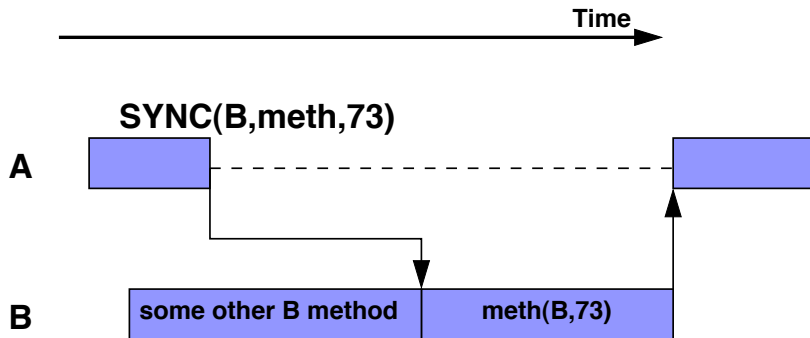
Synchronous calls

Time

SYNC(B,meth,73)

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(Pseudo-) parallel execution
between A and B's other method.

Strictly sequential execution
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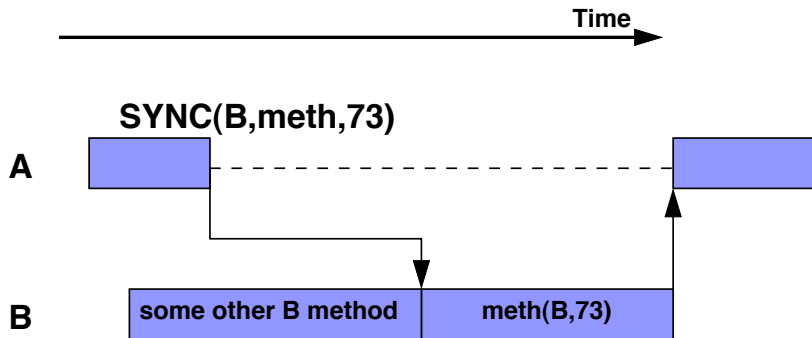between A and the method called
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Synchronous calls

(Pseudo-) parallel execution between A and B's other method.

Strictly sequential execution between B's methods and between A and the method called synchronously.

Observations

- Serialization of object methods: mutual exclusion

- Synchronous call: mutex-protected function call.

- Asynchronous calls: synchronous calls in concurrent threads

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Implementing SYNC

In `TinyTimber.c`

```c
int sync(Object *to, Meth meth, int arg){
   int result;
   lock(&to->mutex);
   result = meth(to,arg);
   unlock(&to->mutex);
   return result;
}
```

Every object has to have its own mutex and we need a way to
force every instance to have type Object!

Implementing SYNC

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Implementing SYNC

In `TinyTimber.h`

```
typedef struct{
   mutex mutex;
} Object;

typedef int (*Meth)(Object*,int);

#define SYNC(obj,meth,arg) = \
   sync((Object*)obj,(Meth)meth, arg)
```

Implementing ASYNC

In `TinyTimber.c`

```c
void async(Object* to, Method meth, int arg){
  Msg msg       = dequeue(&freeQ);
  msg->function = meth;
  msg->arg      = arg;
  msg->to       = to;

  if(setjmp(msg->context)!=0){
      sync(current->to,current->function,current->arg);
      enqueue(current,&freeQ);
      dispatch(dequeue(&readyQ));
  }

  STACKPTR(msg->context)=&msg->stack;
  enqueue(msg,&readyQ);
}
```

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```

Implementing ASYNC

In `TinyTimber.h`

```
#define ASYNC(obj,meth,arg) = \
  async((Object *)obj, (Meth)meth, arg)
```

Summary

- Threads are replaced by asynchronous messages
- Old operation spawn superceeded by async
- Old oprations lock and unlock are only used inside sync
- The new kernel interface:

  void async(Object *to, Meth meth, int arg)
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  typedefs for Object and Meth
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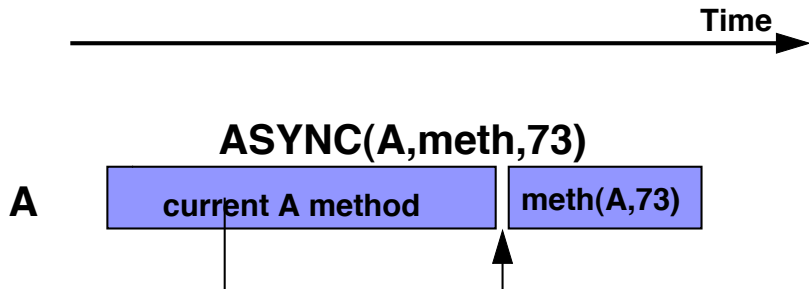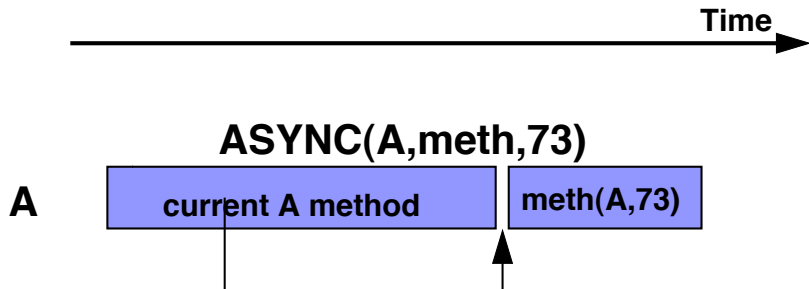
ASYNC to self?

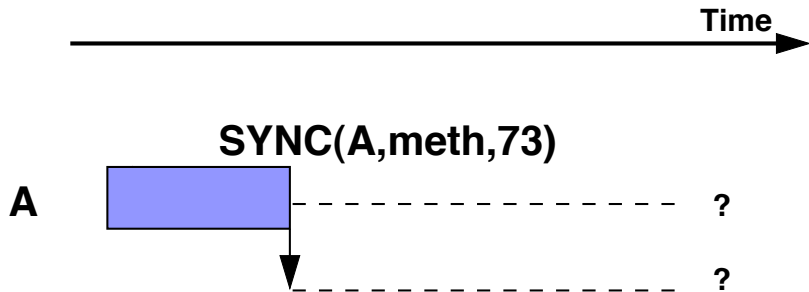**Time**

ASYNC(A,meth,73)

A   current A method   meth(A,73)

Strictly sequential
execution!

ASYNC to self?

Strictly sequential
execution!

SYNC to self?

SYNC to self?

Time

SYNC(A,meth,73)

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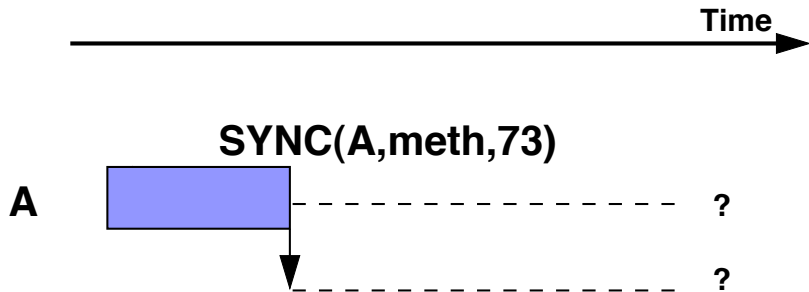
DEADLOCK!

Deadlock

Deadlock arises when requesting new exclusive access to something you already have. In general, a chain of tasks may be involved:
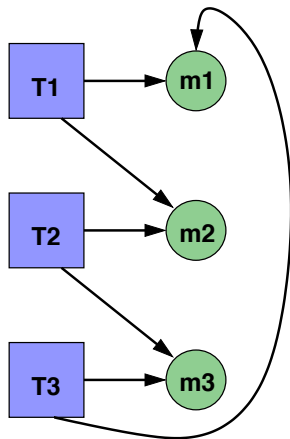
T1 holds **m1**
T1 wants **m2**

T2 holds **m2**
T2 wants **m3**

T3 holds **m3**
T3 wants **m1**

Deadlock

A system in deadlock will remain stuck, unless a thread chooses to back off from its current claim . . .

Deadlock in the real world

Deadlock via SYNC

A cycle of possible simultaneus calls to SYNC

Deadlock via SYNC

Sufficient deadlock protection: insert at least one ASYNC.

Programming idiom

1. Classes
All objects must *inherit* `Object`:

```
typedef struct{
  Object super;
  // extra fields
} MyClass;
```

2. Objects
Object instantiation is done declaratively on the top level (static object structure):

```
ClassA a = initClassA(ival);
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Whenever a method call goes to another object, either SYNC or ASYNC must be used.

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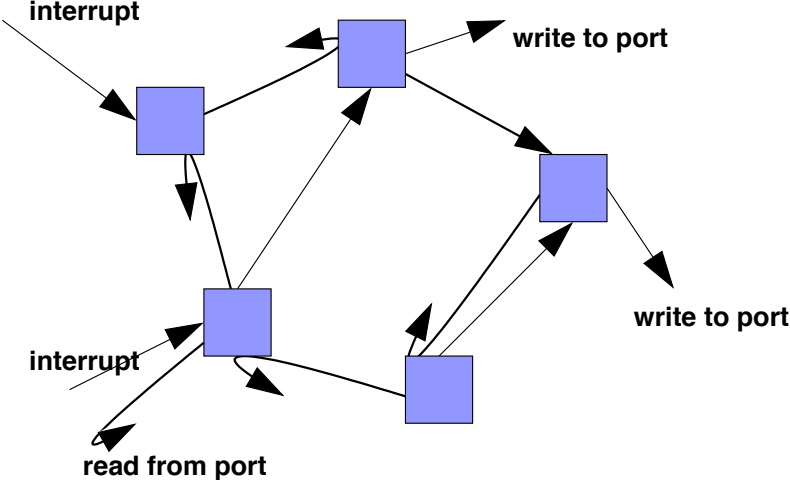
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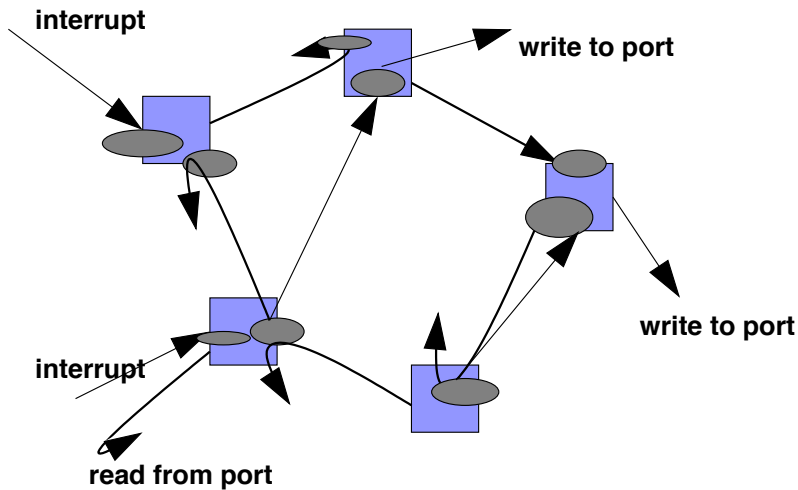
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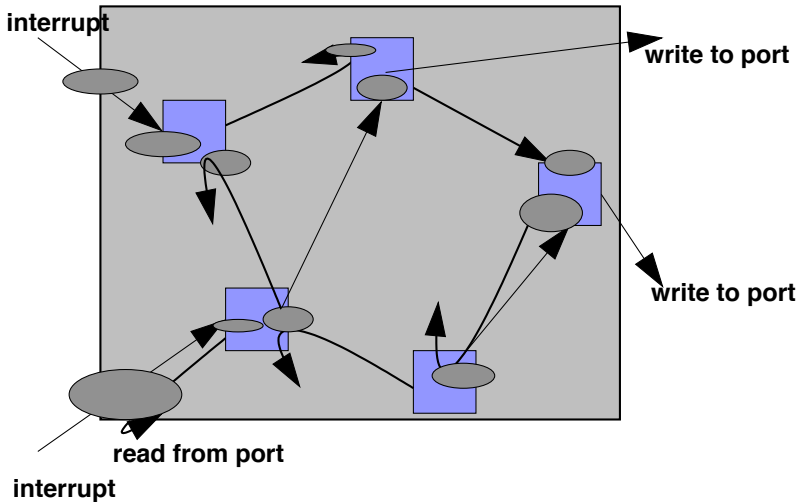All methods must take arguments `self` and an int!

Connecting the external world

Making the methods explicit

The top-level object

Notice the interrupt handlers.

The top-level object

The microprocessor itself!

- It is just like any other reactive object!
  - it is implicitly *instantiated* when power is turned on
  - its *state* is all global variables, of which many will be reactive objects in their own right
  - its *methods* are the installed interrupt handlers
  - its *self* is only conceptual (there is no concrete pointer . . .)
- The top-level object methods are scheduled by the CPU hardware, not by the TinyTimber kernel!

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Connecting interrupts

Incoming method calls from the hardware environment correspond to interrupt signals received by the microprocessor. Apart from this special link to the outside world, interrupt handlers are ordinary methods accepting the same type of parameters as methods invoked with SYNC and ASYNC.

To install method `meth` on object `obj` as an interrupt handler for interrupt source IRQ_X, one writes

```
INSTALL(&obj, meth, IRQ_X);
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Connecting interrupts

To install method `meth` on object `obj` as an interrupt handler for interrupt source `IRQ_X`, one writes

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INSTALL(&obj, meth, IRQ_X);
```

This call, which preferably should be performed during system startup, causes `meth` to be subsequently invoked with `&obj` and `IRQ_X` as arguments whenever the interrupt identified by `IRQ_X` occurs.

The symbol `IRQ_X` is here used as a placeholder only; the exact set of available interrupt sources is captured in a platform-dependent enumeration type `Vector` defined in the TinyTimber interface.

Example

Counter (counter.h)

```
#include "TinyTimber.h"
typedef struct{
  Object super;
  int val;
} Counter;
#define initCounter(n) {initObject(),n}
```

Counter (counter.c)

```
int inc(Counter *self, int arg){
   self->val = self->val + arg;
}
int reset(Counter *self, int arg){
   self->val = arg;
}
```

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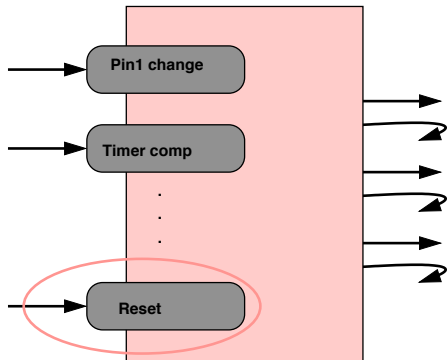
Example client

In `main.c`

```
Counter counter = initCounter(0);
INSTALL(&counter, inc, IRQ_PCINT1);
```

Reset

When system starts up, a reset signal is generated by the hardware. There will be an interrupt routine like any other one ...
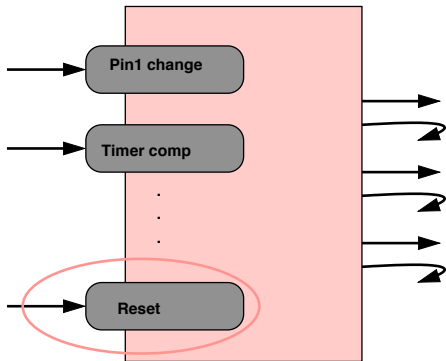

Complication

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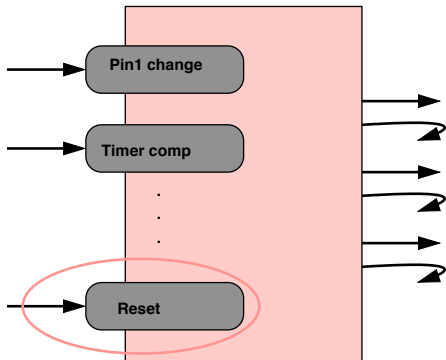

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main()

The **main()** function in C is an abstraction of the reset handler . . .

. . . just as a program is an abstraction of the notion of *running a computer until it stops*

In *traditional programs* **main()** does indeed return, which can be understood as a request to the OS to *turn off the power* to the virtual computer that was set up to run the program!

In a *reactive system* we do not want power to be turned off at all, but we also do not want to let **main()** compute forever just to keep it from returning . . . a reactive system *rests* when it is not reacting

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The idle task

Solution

Let main() finish by literally *putting the CPU to sleep* until the next interrupt! (Most architectures have a special machine instruction that does so!)

We want main() to finish by calling this instruction:

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main in a tinytimber program

This is achieved by invoking the non-terminating primitive
TINYTIMBER as the last main statement:

```
int main() {
   INSTALL(&obj1, meth1, IRQ_1);
   INSTALL(&obj2, meth2, IRQ_2);
   return TINYTIMBER(&obj3, meth3, val);
}
```

The scheduler

In TinyTimber:

```
int tinytimber(Object *obj, Method m, int arg) {
    DISABLE();
    initialize();
    ENABLE();
    if (m != NULL)
        m(obj, arg);
    DISABLE();
    idle();
    return 0;
}
```

Sanity rules

In a system of reactive objects

- Methods only access variables that belong to `self`.
- Global variables that are not objects, are considered local to the top-level object.
- method calls between objects that are wrapped within a `SYNC` or `ASYNC` shield.

Properly upheld, these rules guarantee a system that is

- free from deadlock (provided the absence of cyclic `SYNC`)
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