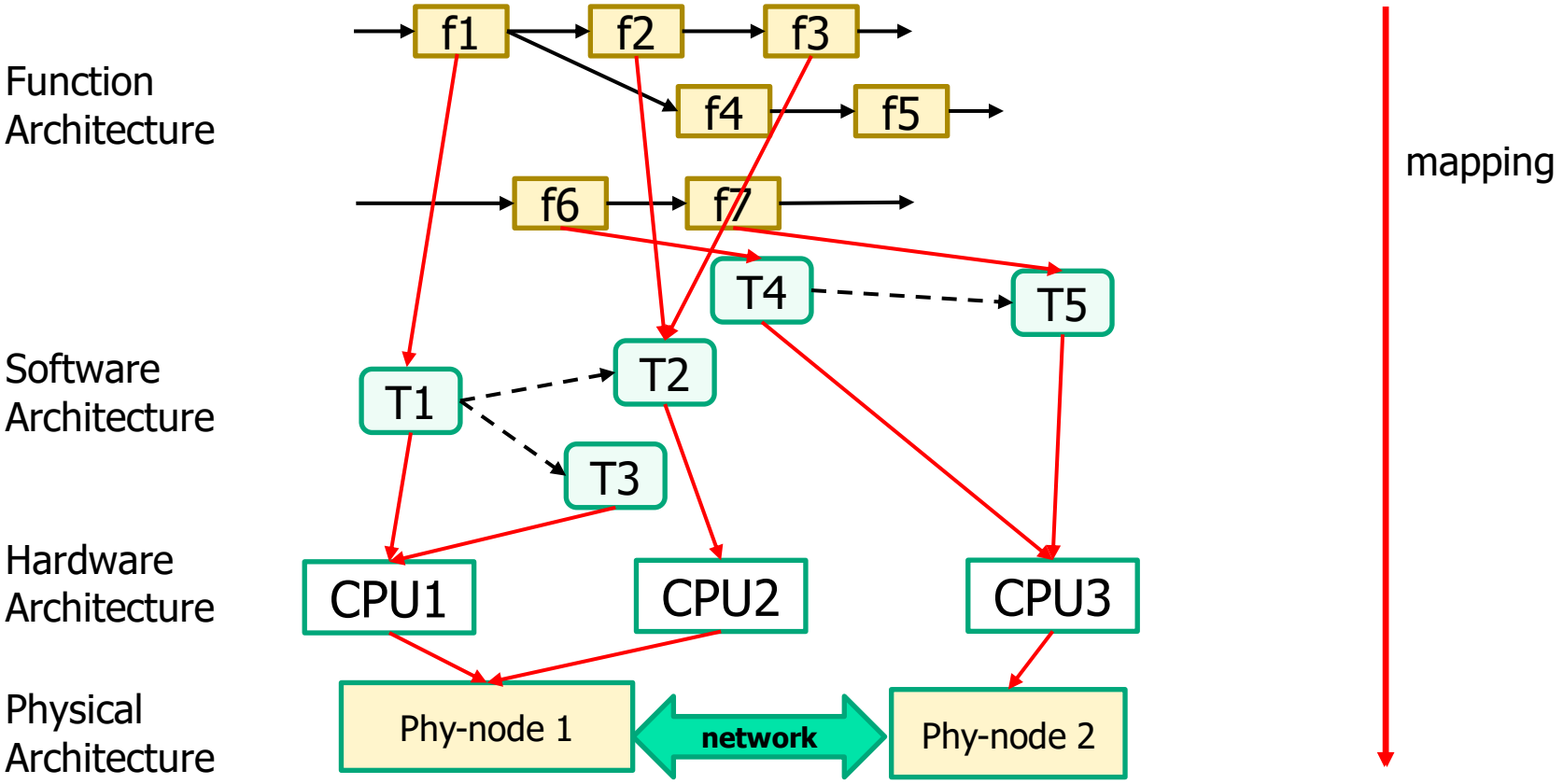
Real Time Programming with Ada (1)

Design of Real-Time Systems
(the Autosar approach in automotive industry)



Real time programming

- It is mostly about "Concurrent programming"
- We also need to handle Timing Constraints on concurrent executions of tasks

However, remember:

- "concurrency" is a way of structuring computer programs e.g. "concurrent modules": func 1, func 2 …
- "concurrency" may be implemented on "uniprocessor platforms" using a scheduler: task 1, task 2 …
- "concurrency" may be implemented on "multiprocessor platforms": CPU 1, CPU 2 …
- "concurrency" may be implemented on "distributed platforms": Phy-Node 1, Phy-Node 2 …

This is the classic approach: cyclic execution

- Program your tasks in any sequential language

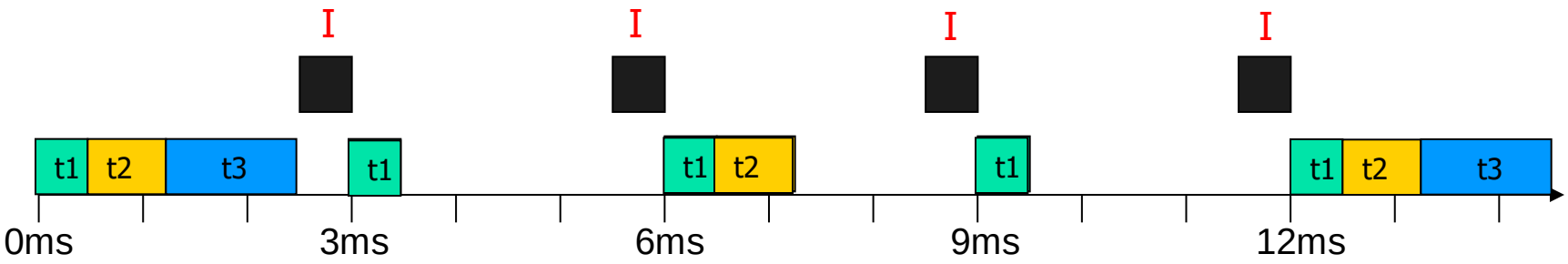
```
loop
  run task 1
  run task 2
  run task 3
end loop
```

Efficient code, deterministic, predictable,
But (1) difficult to make it right, (2) difficult to reuse existing design
(3) extremely difficult for constructing large systems

Cyclic Execution

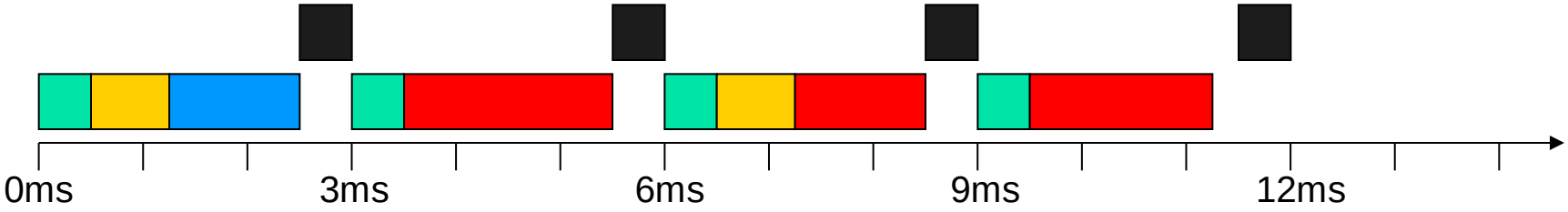
Task	Period (rate)	Execution time
t1	3ms (333Hz)	0.5ms
t2	6ms (166Hz)	0.75ms
t3	12ms (83Hz)	1.25ms

If there is an interrupt handling task: I with 0.5ms execution time every 3ms, we have to insert this …



Adding new functionality … … ?

- Every 12ms, 5.25ms is still free
- add t4 with period: 12ms & execution time: 5ms
- t4 has to be artificially partitioned



Effect of new task at code level

```
void do_task_t4(void)
{
        /* Task functionality */
}
```

```
void do_task_t4_1(void)
{
        /* first bit */
        state_var_1 = x;
        state_var_2 = y;
        ...
}
```

```
void do_task_t4_2(void)
{
        x = state_var_1;
        ...
        /* second bit */
        state_var_3 = a;
        state_var_4 = b;
        ...
}
```

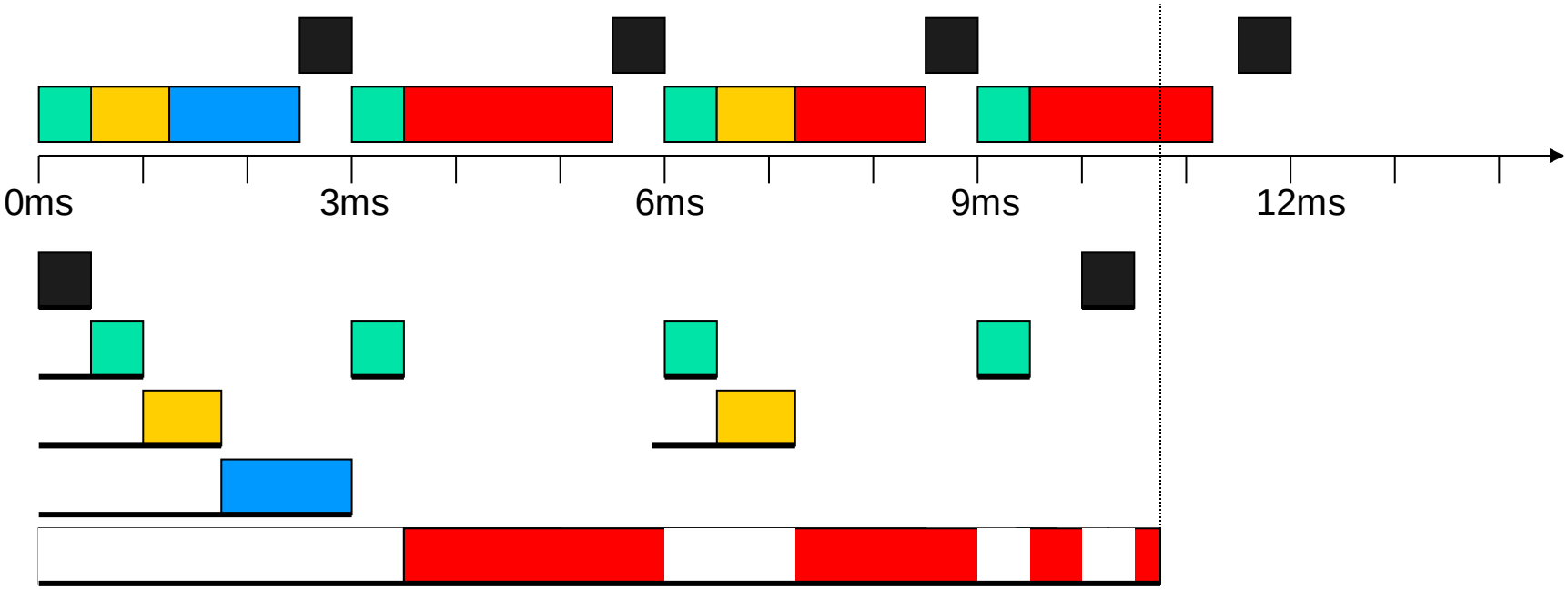
```
void do_task_t4_3(void)
{
        c = state_var_4;
        ...
        /* third bit */
}
```

```
int state_var_1;
int state_var_2;
int state_var_3;
int state_var_4;

void main(void)
{
        do_init();
        while(1) {

                do_task_t1();
                do_task_t2();
                do_task_t3();
                busy_wait();
                do_task_t1();          /* 3ms */
                do_task_t4_1();
                busy_wait();
                do_task_t1();          /* 6ms */
                do_task_t2();
                do_task_t4_2();
                busy_wait();

                do_task_t1();          /* 9ms */
                do_task_t4_3();
                busy_wait();

        }
}
```

This is ”ad hoc”, but it is often used in industry

- This is not feasible for large software systems, say a few hundreds of control tasks
- This was why “Multitasking” came into the picture

Cyclic Execution vs. Multitasking



Ada95

- It is strongly typed OO language, looks like Pascal
- Originally designed by the US DoD as a language for large safety critical systems i.e. Military systems
  - Ada83
  - Ada95 + RT annex + Distributed Systems Annex
  - Ada 2005 (allows scheduling policies e.g. RR, EDF, dynamic priorities for protected types …)

The basic structures in Ada

- A large part in common with other languages
  - Procedures
  - Functions
  - Basic types: integers, characters, ...
  - Control statements: if, for, ..., case analysis
- Any thing new?
  - Abstract data type
    - Package (objects)
    - (protected package)
  - Concurrency
    - Tasking/Task declaration
  - Communication/synchronization
    - Rendezvous
    - Protected package/shared data type
  - Real Time facilities
    - Two pre-defined packages

Typical structure of programs

Program Foo(...)

Declaration 1 ←----- to introduce identities/variables
and define data structures

Declaration 2 ←----- to define ”operations” : procedures, functions
and/or tasks (concurrent operations)
to manopulate the data structures

Main program
(Program body) ←------ a sequence of statements or ”operations” to
compute the result (output)

Control-statements: If, case, for, while and assignment: x := exp

```
if TEMP < 15 then
      some smart code;
else
 do something else..;
end if;

case TAL is
      when <2 =>
            PUT_LINE(”one or two”);
      when >4 =>
            PUT_LINE(”greater than 4);
end case;

for I in 1..12 loop
      PUT(”in the loop”);
end loop;


While B loop  ... end loop
```

Declarations and statements

- Before each block, you have to declare (define) the variables used, just like any sequential program

```
procedure PM (A : in  INTEGER;
                  B:  in out  INTEGER;
                    C : out     INTEGER) is
begin
     B := B+A;
     C := B + A;
end PM;
```

Types (like in Pascal or any other fancy languages)

```
type LINE_NUMBER is range 1 .. 72
type WEEKDAY is (Monday, Tuesday, Wednesday);
type serie is array (1..10) of FLOAT;

type CAR is
    record
        REG_NUMBER     : STRING(1 .. 6);
        MODEL          : STRING(1 .. 20);
    end record;
```

Concurrent and Real-Time Programming with Ada

- Abstract data types
  - Package
  - (protected data package)
- Concurrency: tasking
  - task declaration
- Communication/synchronization
  - Rendezvous
  - protected package/shared data type
- Real time facilities:
  - Delay ”time period” and Delay until ”next-time point”
  - Real-time scheduling/”Fixed-priority scheduling”

Package --- Class/Object

”Package”: abstract data type in Ada

- package definition ---- specification
- package body ---- implementation

Package definition -- Specificaiton

- Objects declared in specification is visible externally.

```
package MY_PACKAGE is
-- declare/define data structures
    Type myobject is record
       Name: string
       Personalnr: integer
    End myobject
-- declare/define all public operations
    procedure myfirst_operation;
    procedure mysecond_operation;
    function mythird_operation (name: string) return myobject;
end MY_PACKAGE;
```

Package body -- Implementation

- Implements package specification

```
(you probably want to use some other packages here e.g.. )
with TEXT_IO;
use TEXT_IO;

 package body MY_PACKAGE is
                procedure myfirst_operation is
                begin
                                myfirst_operation code here;
                end;
                function MAX (X,Y :INTEGER) return INTEGER is
                begin
                   … …
                end;
                procedure mysecond_operation is
                begin
                                PUT_LINE("Hello Im Ada Who are U");
                                GET();
                end;
                function mythird_operation (name: string) return myobject is
                                                begin
                                        … …
                                                end;

end MY_PACKAGE;
```

Protected data type

```
protected Buffer is
        procedure read(x: out integer)
        procedure write(x: in integer)
        private
           v: integer := 0  /* initial value */

protected body Buffer is
        procedure read(x: out integer) is
           begin x:=v end
        procedure write(x: in integer) is
           begin  v:= x end
```

(note that you can solve similar problems with semaphores)

Concurrent and Real-Time Programming with Ada

- Abstract data types
  - package
  - (protected package)
- Concurrency: tasking
  - Task declaration
- Communication/synchronization
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Tasking

Ada tasking: concurrent programming

- Ada provides at the language level light-weight tasks. These often refered to as threads in some other languages. The basic form is:

```
task T is                                  <-------- specification
--- operations/entry (or simply: task T)
end T;

task body T is                             <--------- implementation/body
begin
---- processing----
end T;
```

Example: the sequential case

```
procedure shopping is
begin
buy-meat;
buy-salad;
buy-wine;
end
```

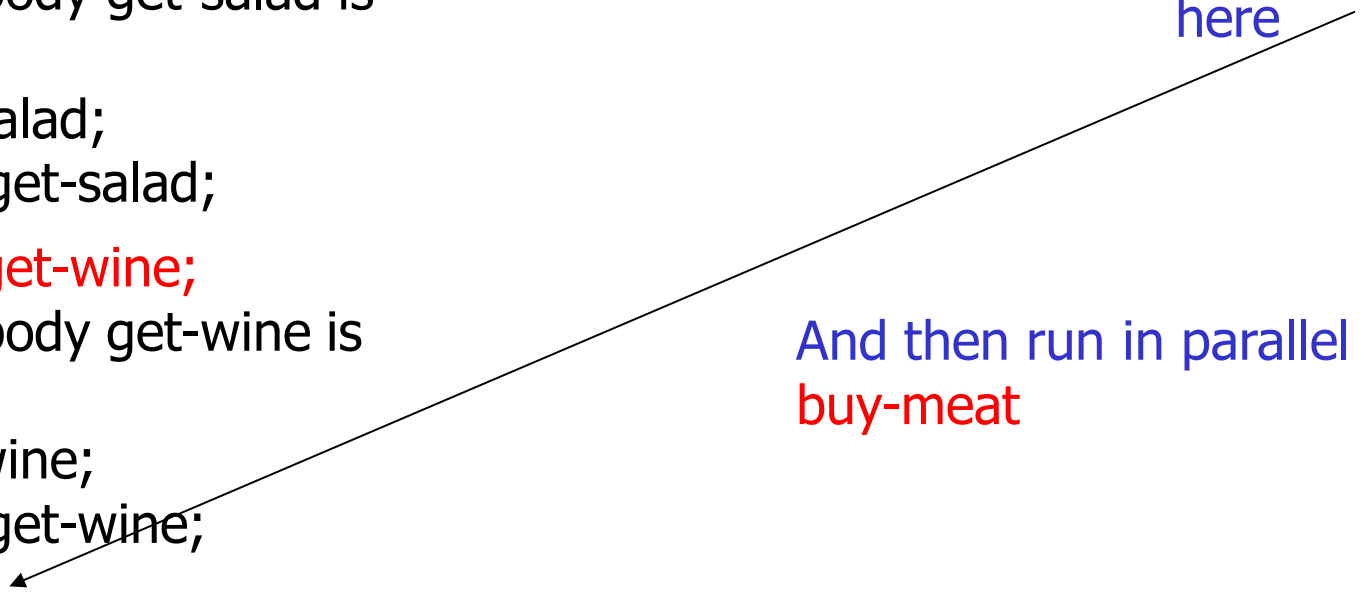
Assume pre-defined procedures:
buy-meat
buy-salad
buy-wine

The concurrent version

```
procedure shopping is

task get-salad;
task body get-salad is
begin
buy-salad;
end  get-salad;
task get-wine;
task body get-wine is
begin
buy-wine;
end  get-wine;
begin
buy-meat;
end
```

buy-salad and buy-wine will be activated concurrently here

And then run in parallel with buy-meat



Creating Tasks

- Tasks may be declared at any program level
- Created implicitly upon entry to the scope of their declaration.
- Possible to declare task types to start several task instances of the same task type

example

```
procedure Example1 is
    task type A_Type;
    task B;
    A,C : A_Type;

    task body A_Type is
        --local declarations for task A and C
    begin
        --sequence of statements for task A and C
    end A_Type;

    task body B is
        --local declarations for task B
    begin
        --sequence of statements for task B
    end B;

begin
    --task A,C and B start their executions before the first statement of this procedure.
end Example1;
```

Task scheduling

- Allow priorities to be assigned to tasks in task definition
- Allow task dispatching policy to be set (Default: highest priority first)

```
task Controller is
      pragma Priority(10)
end Controller
```

Task termination: a task will terminate if:

- It completes execution of its body
- It executes a terminate alternative of a select statement
- It is aborted:
  - abort_statement ::= abort task_name {, task_name};

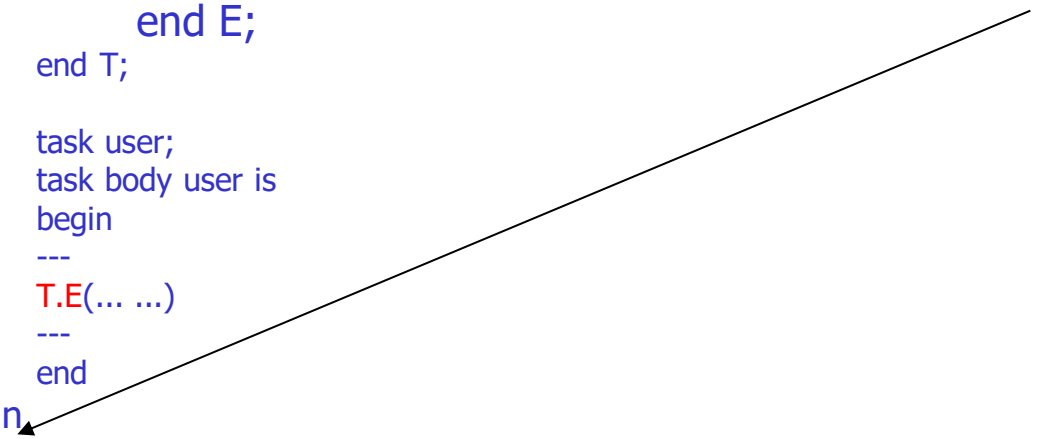
Communication/Synchronization

Task communication/synchronization

- Message passing using ”rendezvous”
  - entry and accept
- Shared variables
  - protected objects/variables

Rendezvous

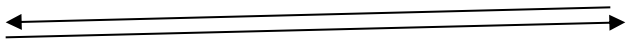
```
procedure foo

        task T is
         entry E(...in/out parameter...);
        end;

        task body T is
                begin
                        -------
                         accept E(... ...) do
                        ------- sequence of statements
                end E;
         end T;

         task user;
         task body user is
         begin
         ---
         T.E(... ...)
         ---
         end
begin
...
end
```



T and user will be started concurrently

Rendezvous

```
task body A is
begin
...
B.Call;
...
end A
```



```
task body B is
begin
...
accept Call do
....
end Call
...
end A
```

This is implemented with Entry queues (the compiler takes care of this!)

- Each entry has a queue for tasks waiting to be accepted
  - a request to the entry is inserted in the queue
  - the first task in the queue will be ”accepted” first (like the queue for a semaphore)
- By default, the queuing policy is FIFO
  - it can be different queuing policies

Potential deadlocks

- Task A: …. B.b; accept a …
- Task B: …. A.a; accept b …

An Example: Buffer

```
task buffer is
entry put(X: in integer)
entry get(x: out integer)
end;

task body buffer is
  v: integer;
 begin
 loop accept put(x: in integer) do v:= x end put;
        accpet get(x: out integer) do x:= v end get;
 end loop;
 end buffer;
```

---

buffer.put(...) ←---------- other tasks (users)!!

Buffer.get(...)

An Example, the Semaphore

- The Idea of a (binary) semaphore
- Two operations, p and v
  - p grabs semaphore or waits if not available
  - v releases the semaphore

Program Semaphore using Task & RV. Synch.

The specification

- task type Semaphore is
  entry p;
  entry v;
  end Semaphore;

The implementation

- task body Semaphore is
  begin
  loop
  accept p;
  accept v;
  end loop;
  end Semaphore;

Use a semaphore to protect critical sections

- Lock : Semaphore;
  Lock.P;
  Code for Critical Section
  Lock.V;

Choice: Select statement

```
task Server is
      entry S1(...);
      entry S2(...);
end Server;

task body Server is
      ...
begin
      loop
            --prepare for service
            select
               when <boolean expression> =>
                  accept S1(...) do
                        --code for this service
                  end S1;
            or
                  accept S2(...) do
                        --code for this service
                  end S2;
            or
                 terminate;
            end select;
      --do any house keeping
      end loop;
end Server;
```

Real-Time Facilities (next lecture)