# WCET & Scheduling

- WCET analysis
- Rate monotonic and Earliest Deadline First scheduling
- Sufficient schedulability condition
- Problems demonstrated during exercise: WCET exam problem March 12 (2008), 45, 55, others not in compendium





(a) Assume that a procedure **Main** is used as part of a real-time program and that the procedure, when called, is allowed to take at most 100 *µs to execute.*

Derive WCET for procedure **Main** by using Shaw's method and check whether the procedure's deadline with be met or not.

Assume that each assignment statement, return statement and comparison operation costs 1 *µs to* execute. A function call costs 1 *µs plus WCET for the function in question. Each addition and* subtraction operation costs 2 *µs. Each multiplication operation costs 5 µs. All other language* constructs can be assumed to take 0 *µs to execute.*

```
procedure Main is
  A : Natural := 3;
  F : Natural := 0;
function Calculate (Z : in Natural) return Natural is
  R : Natural := 0;
  begin
    if Z = 0 then
       R := 1;
    else if Z = 1 then
       R := 1;
    else
       R := Calculate(Z-1)*Z;
  end;
  return R;
end Calculate;
begin
   F := Calculate(A);
end;
```





```
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  A : Natural := 3;
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function Calculate (Z : in Natural) return Natural is
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    if Z = 0 then
       R := 1;
    else if Z = 1 then
       R := 1;
    else
       R := Calculate(Z-1)*Z;
  end;
  return R;
end Calculate;

begin
   F := Calculate(A);
end;
```

We will solve it in white board





*(b)* Now assume that the data types for variables A, F, Z, R, and F, and the return type of function Calculate, are changed to Float.

Since floating point operations require more advanced hardware and algorithms to implement than integer operations, the cost for executing the arithmetic perations will now increase.

If each floating point addition and subtraction operation costs 5 *µs, decide the largest allowed cost* for the floating point multiplication operation while not exceeding the deadline (100 *µs) of the* procedure.

```
procedure Main is
  A : Natural := 3;
  F : Natural := 0;
function Calculate (Z : in Natural) return
    Natural is
  R : Natural := 0;
  begin
    if Z = 0 then
       R := 1;
    else if Z = 1 then
       R := 1;
    else
       R := Calculate(Z-1)*Z;
  end;
  return R;
end Calculate;
begin
   F := Calculate(A);
end;
```

## Assignment 45

Show that, if or if possibly not, the task set is schedulable using RM scheduling.

| Task | Period *T* [ms] | Deadline *D* [ms] | Execution time *C* [ms] |
|---|---|---|---|
| A | 7 | 7 | 1 |
| B | 14 | 14 | 1 |
| C | 18 | 18 | 4 |





## Solution 45

- Check the Sufficient condition for RM schedulability
  - We solve it in whiteboard





## Assignment (not in exercise compendium)

Show that, if or if possibly not, the task set is schedulable.

| Task | Period *T* [ms] | Deadline *D* [ms] | Execution time *C* [ms] |
|---|---|---|---|
| A | 7 | 5 | 1 |
| B | 14 | 10 | 1 |
| C | 18 | 18 | 4 |





## Problem (not from exercise compendium)

The following task set should be scheduled due to *earliest deadline first* (EDF).

| Task | *T* [ms] | *D* [ms] | *C* [ms] |
|---|---|---|---|
| A | 3 | 3 | 1 |
| B | 4 | 4 | 1 |
| C | 5 | 5 | 2 |

a) Calculate processor utilization factor.
d) Determine if the task set can be scheduled using EDF?

## Problem B (not in compendium)

The following task set should be scheduled due to *earliest deadline first* (EDF).

| Task | *T* [ms] | *D* [ms] | *C* [ms] |
|---|---|---|---|
| A | 3 | 3 | 2 |
| B | 4 | 4 | 1 |
| C | 5 | 5 | 2 |

a) Calculate processor utilization factor.
d) Determine if the task set can be scheduled using EDF?





## Assignment 55

The following task set should be scheduled due to *earliest deadline first* (EDF).

| Task | *T* [ms] | *D* [ms] | *C* [ms] |
|---|---|---|---|
| A | 3 | 2 | 1 |
| B | 4 | 2 | 1 |
| C | 5 | 4 | 2 |

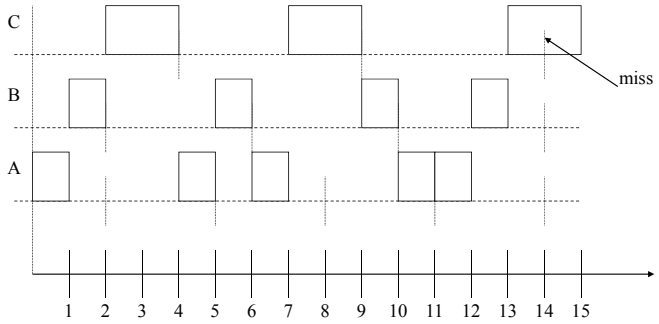
a) Calculate processor utilization factor.
b) Draw a timing diagram showing the possible scenarios for execution order. ("simulation").





## Assignment 55 (cont)

- (a) U=59/60. But we can not give any scheduling guarantee. Why?








## HARMONIC PERIODS

What is the difference between RM and EDF scheduling when the periods are harmonic and $T_i=D_i$?

(Harmonic means that $T_i=T_j * k$ for all $T_j \leq T_i$ and for some positive integer k)

What schedulability test should we use for RM scheduling of task set with harmonic periods and $T_i=D_i$ for all tasks? What is the utilization bound?