



# Operating System Practice

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# An Real-Time OS: $\mu$ C/OS-II Quick Overview

# Introduction of $\mu$ C/OS-II (1 / 2)

- ▶ The name is from micro-controller operating system, version 2
- ▶  $\mu$ C/OS-II is certified in an avionics product by FAA in July 2000 and is also used in the Mars Curiosity Rover
- ▶ It is a very small real-time kernel
  - Memory footprint is about 20KB for a fully functional kernel
  - Source code is about 5,500 lines, mostly in ANSI C
  - It's source is open but not free for commercial usages
- ▶ Preemptible priority-driven real-time scheduling
  - 64 priority levels (max 64 tasks)
  - 8 reserved for  $\mu$ C/OS-II
  - Each task is an infinite loop

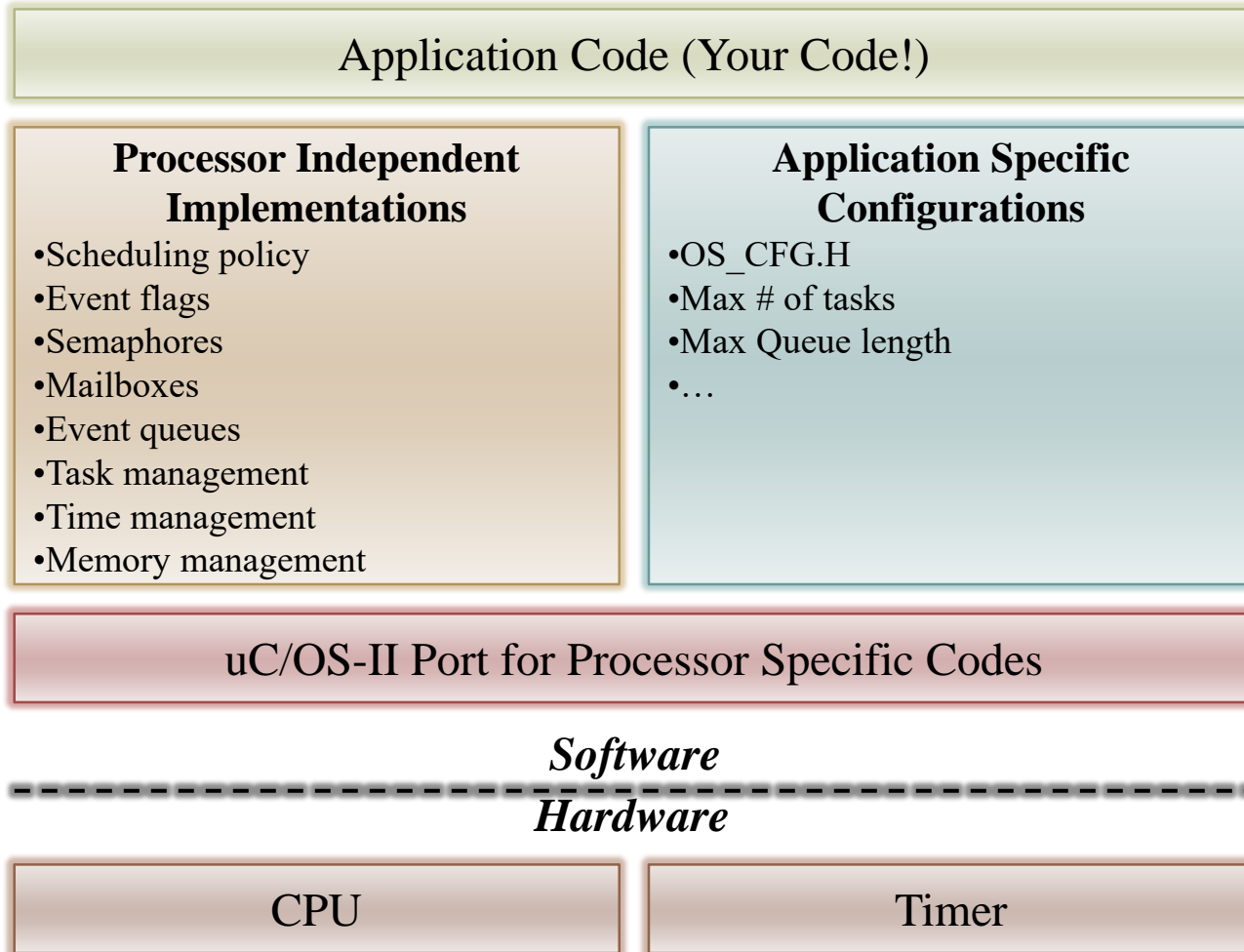


# Introduction of $\mu\text{C}/\text{OS-II}$ (2 / 2)

- ▶ Deterministic execution times for most  $\mu\text{C}/\text{OS-II}$  functions and services
- ▶ Nested interrupts could go up to 256 levels
- ▶ Supports of various 8-bit to 64-bit platforms: x86, ARM, MIPS, 8051, etc.
- ▶ Easy for development: Borland C++ compiler and DOS (optional)
- ▶ However,  $\mu\text{C}/\text{OS-II}$  still lacks of the following features:
  - Resource synchronization protocol
  - Soft-real-time support



# The $\mu$ C/OS-II File Structure



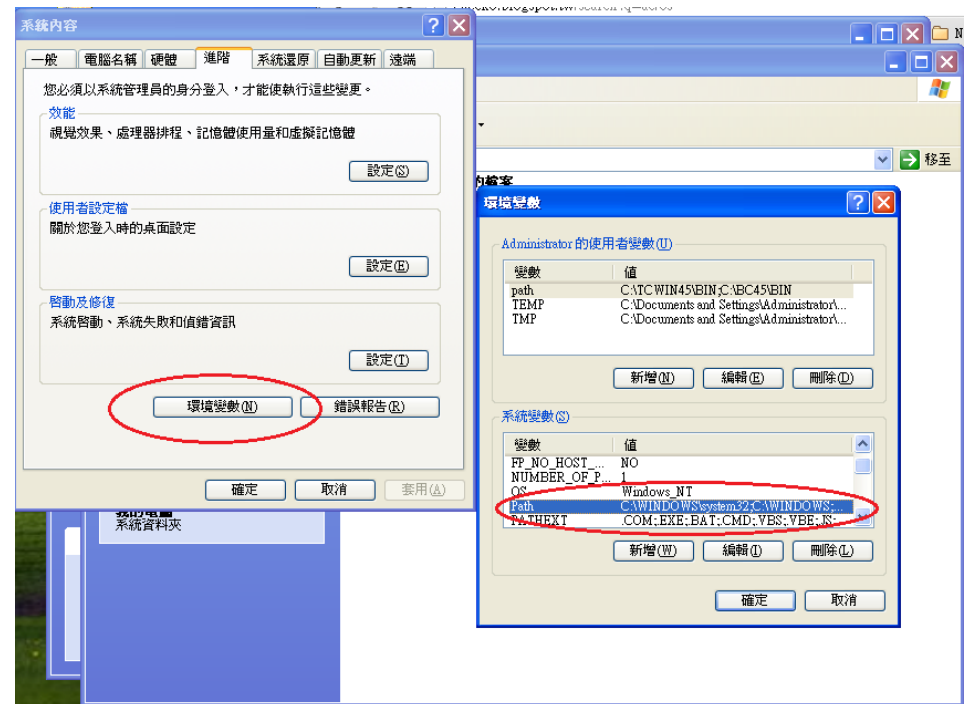
# Requirements of $\mu$ C/OS-II Emulator

- ▶ Operating System
  - Windows XP 32bits
  - Use virtual machine to install the OS
  - Install “Guest Additions” for Virtualbox
- ▶ Tools
  - Borland C++ compiler (V4.5)
    - BC45 is the compiler
  - Turbo Assembler
    - The assembler is in tasm
  - The source code and the emulation environment of  $\mu$ C/OS-II
    - SOFTWARE is the package
- ▶ Full Package
  - Download it from the course website with password: csie2020
  - [https://www.csie.cgu.edu.tw/~chewei/files/ucOSII\\_ProjectPackage.zip](https://www.csie.cgu.edu.tw/~chewei/files/ucOSII_ProjectPackage.zip)
  - <https://www.csie.cgu.edu.tw/~chewei/files/Files.zip>



# Borland C++ Compiler

- ▶ Download Borland C++ and install it on your windows XP environment
  - Double click the “INSTALL.EXE”
- ▶ Add “;C:\BC45\BIN” to your system Path





# Turbo Assembler

- ▶ Download Turbo assembler and unzip the file
- ▶ Copy “\tasm\BIN\TASM.EXE” to your “C:\BC45\BIN”
  - Include the missing assembler which is going to be used during we compile the source code of  $\mu$ C/OS-II





# Compile $\mu$ C/OS-II Example Code

- ▶ Download the source code and emulator  $\mu$ C/OS-II
  - It is recommended to put the source code package “SOFTWARE” directly in C:\
- ▶ Test the first example
  - Execute C:\SOFTWARE\uCOS-II\EX1\_x86L\BC45\TEST\TEST.EXE
  - Press ECS to leave
- ▶ Rename or remove the executable file
  - Rename TEST.EXE
- ▶ Compile the  $\mu$ C/OS-II and the source code of the first example
  - Run C:\SOFTWARE\uCOS-II\EX1\_x86L\BC45\TEST\MAKETEST.BAT
  - A new “TEST.EXE” will be created if we compile it successfully

# OSTimeDly() and OSTimeDlyHMSM()

- ▶ Study the two function by yourself and use them for the homework implementation
- ▶ Requirements
  1. Print out “This is OPS homework!”
  2. Delay for 5 seconds
  3. Print out YOUR STUDENT ID
  4. Delay for 2 seconds
  5. Print out 1 2 3 4 5 6 7 8 9 10 one by one, call delay for 1 second after the printing of each number
  6. Clean all numbers printed in Step 5, and call delay for 5 seconds
  7. Goto Step 5



# Common Mistakes

- ▶ Did you directly put the package “SOFTWARE” in C:\ ?
- ▶ Have you copied the correct file “TASM.EXE” to your “C:\BC45\BIN” directory?
- ▶ Did you set the Path correctly?
  - See the picture in Page 7
  - There is no space



# Reading Exercise

- ▶ Read the e-book of  $\mu$ C/OS-II
  - Try to read and understand the first chapter
- ▶ Read the source code to understand the application
  - The application source code is in C:\SOFTWARE\uCOS-II\EX1\_x86L\BC45\SOURCE
- ▶ Browse the source code of  $\mu$ C/OS-II
  - The source code of  $\mu$ C/OS-II is in C:\SOFTWARE\uCOS-II\SOURCE



# Report

- ▶ Each student should write a report
- ▶ Upload it to our E-learning system
- ▶ Only **two** A4 pages
- ▶ 內文 **12 pt** font
- ▶ Deadline is **23:00 2022/05/08**
- ▶ File name: **OSP-Homework-StudentID**
- ▶ File type: **PDF**



# Grading Rules

- ▶ You have to demonstrate your homework to TAs
- ▶ Grading
  - Reports 30%  $\pm$  10
  - Demo 40%  $\pm$  10
  - Answer questions 10%
- ▶ No late submission will be accepted



# An Example on $\mu$ C/OS-II: Multitasking

```
C:\uCOS-II\EX1_x86L\BC45\TEST\TEST.EXE
uC/OS-II, The Real-Time Kernel
Jean J. Labrosse

EXAMPLE #1

89116946172338525924079161200809680987546685223383412430562925283669250986343296
98422567751237719507656726175432412646318347491404672986312193962508036750506500
04198306651530328553114431544122365187318809730898007032272399672715650027363877
5769321593318163900081638327417254679639696111557231414036618916971167518052446
87167977628059531803062385498234324352909549230869288780517833713356812324910844
96076151657952095287797253242289346735963213862384059119369240826117079207048124
50287066314799080679735361291095736391568112369038700652374490934441706826730486
61653657628409302678221532201608795402893009143966646754749821505618818172743185
69560935200252403260849523760678265258404164088907314547748669211659483772199335
93691897099525014271788073000297334093355784200017645649344251375360001363268941
18413755595752132896946275817959024606461504024548855195345717704064029146502579
39135305037668501128487345021325236456554775525487387983679011227017745698622484
30331999915088898309710170652257536915600865755306746584310036105462443846286550
39453956761639757584971051539474995717314131408143522623578458454231281632586097
18641620203503855873907334096429674516982716819162572865737179140288485548441608
97238519699005928503612250283693854016620169262553618397402481204447485872954996

#Tasks      : 13      CPU Usage: 0 %      80387 FPU
#Task switch/sec: 2191

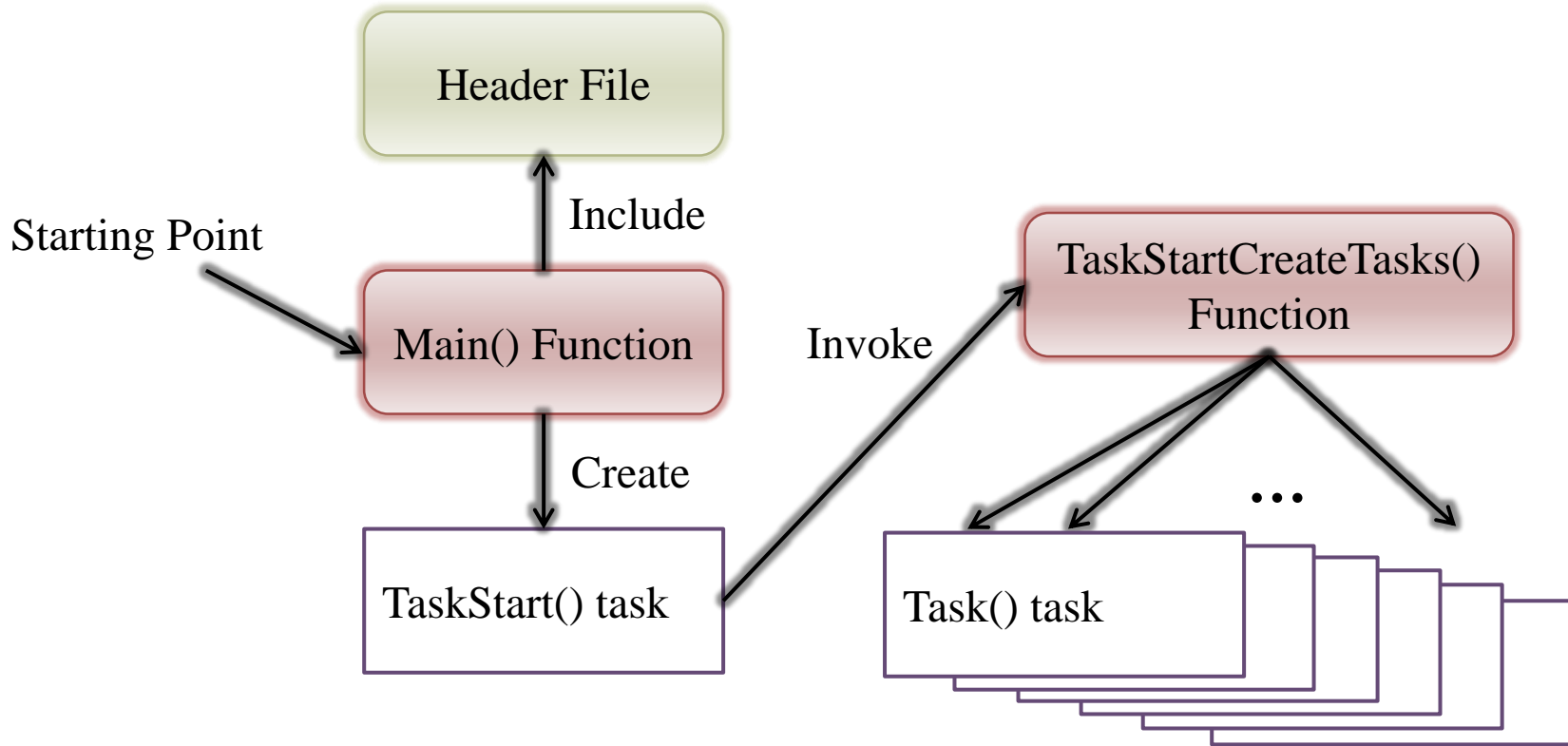
<-PRESS 'ESC' TO QUIT->      V2.52
```

- ▶ Three system tasks
- ▶ Ten application tasks randomly prints its number





# Multitasking: Workflow



# Multitasking: TEST.C

(\SOFTWARE\uCOS-II\EX1\_x86L\BC45\SOURCE\TEST.C)

```
#include "includes.h"
```

```
/*
```

```
*****
```

```
CONSTANTS
```

```
*****
```

```
*/
```

```
#define TASK_STK_SIZE 512
```

```
#define N_TASKS 10
```

```
/*
```

```
*****
```

```
VARIABLES
```

```
*****
```

```
*/
```

```
OS_STK TaskStk[N_TASKS][TASK_STK_SIZE];
```

```
OS_STK TaskStartStk[TASK_STK_SIZE];
```

```
char TaskData[N_TASKS];
```

```
OS_EVENT *RandomSem;
```



# Multitasking: Main()

```
void main (void)
{
    PC_DispcClrScr(DISP_FGND_WHITE + ISP_BGND_BLACK);
    OSInit();
    PC_DOSSaveReturn();
    PC_VectSet(uCOS, OSCtxSw);
    RandomSem = OSSemCreate(1);
    OSTaskCreate( TaskStart,
                 (void *)0,
                 (void *)&TaskStartStk[TASK_STK_SIZE-1],
                 0);
    OSStart();
}
```

Entry point of the task  
(a pointer to a function)

User-specified data

Top of stack

Priority (0=highest)

# Multitasking: TaskStart()

```
void TaskStart (void *pdata)
```

```
{
```

```
    /*skip the details of setting*/
```

```
    OSStatInit();
```

```
    TaskStartCreateTasks();
```

```
    for (;;)
    {
```

```
        {
```

```
            if (PC_GetKey(&key) == TRUE)
```

```
            {
```

```
                if (key == 0x1B) { PC_DOSReturn(); }
```

```
            }
```

```
            OSTimeDlyHMSM(0, 0, 1, 0);
```

```
        }
```

```
    }
```

Call the function to create the other tasks

See if the ESCAPE key has been pressed

Wait one second



# Multitasking: TaskStartCreateTasks()

```
static void TaskStartCreateTasks (void)
```

```
{
```

```
    INT8U i;
```

```
    for (i = 0; i < N_TASKS; i++)
```

```
    {
```

```
        TaskData[i] = '0' + i;
```

```
        OSTaskCreate(
```

```
            Task,
```

```
            (void *)&TaskData[i],
```

```
            &TaskStk[i][TASK_STK_SIZE - 1],
```

```
            i + 1 );
```

```
    }
```

```
}
```

Entry point of the task  
(a pointer to function)

Argument:  
character to print

Top of stack

Priority

# Multitasking: Task()

```
void Task (void *pdata)
{
    INT8U x;
    INT8U y;
    INT8U err;
    for (;;)
    {
        OSSemPend(RandomSem, 0, &err);
        /* Acquire semaphore to perform random numbers */
        x = random(80);
        /* Find X position where task number will appear */
        y = random(16);
        /* Find Y position where task number will appear */
        OSSemPost(RandomSem);
        /* Release semaphore */
        PC_Dispatch(x, y + 5, *(char *)pdata, DISP_FGND_BLACK +DISP_BGND_LIGHT_GRAY);
        /* Display the task number on the screen */
        OSTimeDly(1);
        /* Delay 1 clock tick */
    }
}
```

Print & delay

Randomly pick up the position to print its data



# OSinit()

(\SOFTWARE\uCOS-II\SOURCE\OS\_CORE.C)

- ▶ Initialize the internal structures of  $\mu$ C/OS-II and **MUST** be called before any services
- ▶ Internal structures of  $\mu$ C/OS-2
  - Task ready list
  - Priority table
  - Task control blocks (TCB)
  - Free pool
- ▶ Create housekeeping tasks
  - The idle task
  - The statistics task





# PC\_DOSSaveReturn()

(\SOFTWARE\BLOCKS\PC\BC45\PC.C)

- ▶ Save the current status of DOS for the future restoration
  - Interrupt vectors and the RTC tick rate
- ▶ Set a global returning point by calling setjump()
  - $\mu$ C/OS-II can come back here when it terminates.
  - PC\_DOSReturn()



# PC\_VectSet(uCOS,OSCtxSw)

(\SOFTWARE\BLOCKS\PC\BC45\PC.C)

- ▶ Install the context switch handler
- ▶ Interrupt 0x08 (timer) under 80x86 family
  - Invoked by INT instruction



# OSStart()

(SOFTWARE\uCOS-II\EX1\_x86L\BC45\SOURCE\CORE.C)

- ▶ Start multitasking of  $\mu$ C/OS-II
- ▶ It never returns to main()
- ▶  $\mu$ C/OS-II is terminated if PC\_DOSReturn() is called

