uC/OS-II Part 1:
Getting Started with uC/OS-II

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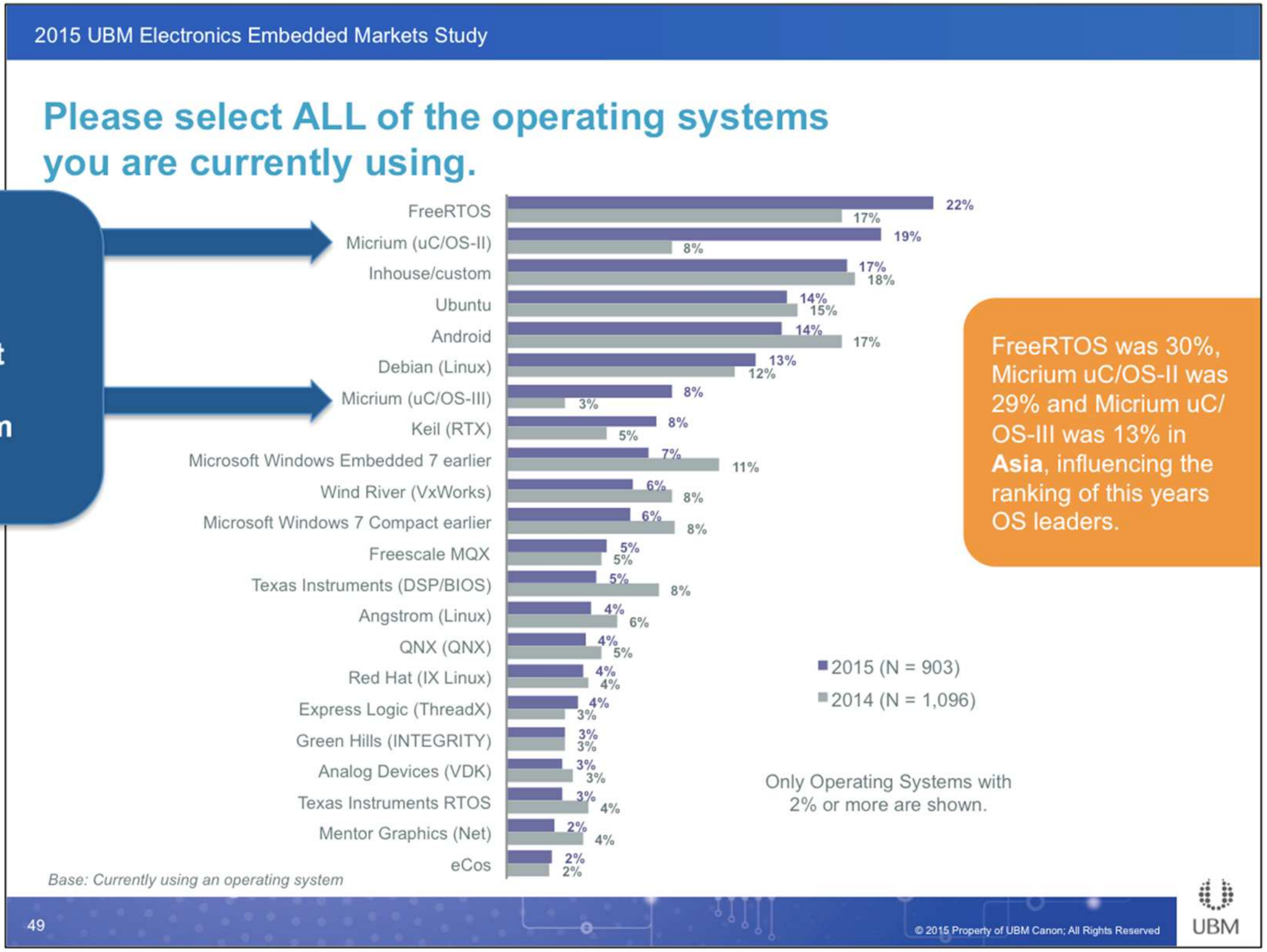
uC/OS-2

- A tiny open-source real-time kernel
  - Memory footprint is about 20k for a fully functional kernel
  - Supporting preemptive priority-driven real-time scheduling
  - Supporting many platforms: x86, 68x, ARM, MIPS…

Micrium®
Embedded Software

The Most Widely Used Operating System in the World!



2015 UBM Electronics Embedded Markets Study

Please select ALL of the operating systems you are currently using.

	2015 (N = 903)	2014 (N = 1,096)
FreeRTOS	22%	17%
Micrium (uC/OS-II)	19%	8%
Inhouse/custom	17%	18%
Ubuntu	14%	15%
Android	14%	17%
Debian (Linux)	13%	12%
Micrium (uC/OS-III)	8%	3%
Keil (RTX)	8%	5%
Microsoft Windows Embedded 7 earlier	7%	11%
Wind River (VxWorks)	6%	8%
Microsoft Windows 7 Compact earlier	6%	8%
Freescale MQX	5%	5%
Texas Instruments (DSP/BIOS)	5%	8%
Angstrom (Linux)	4%	6%
QNX (QNX)	4%	5%
Red Hat (IX Linux)	4%	4%
Express Logic (ThreadX)	4%	3%
Green Hills (INTEGRITY)	3%	3%
Analog Devices (VDK)	3%	3%
Texas Instruments RTOS	3%	4%
Mentor Graphics (Net)	2%	4%
eCos	2%	2%

Only Operating Systems with 2% or more are shown.

Base: Currently using an operating system

Micrium's uC/OS RTOS is used by 27%, making Micrium the most widely used Operating System in the World!

FreeRTOS was 30%, Micrium uC/OS-II was 29% and Micrium uC/OS-III was 13% in **Asia**, influencing the ranking of this years OS leaders.

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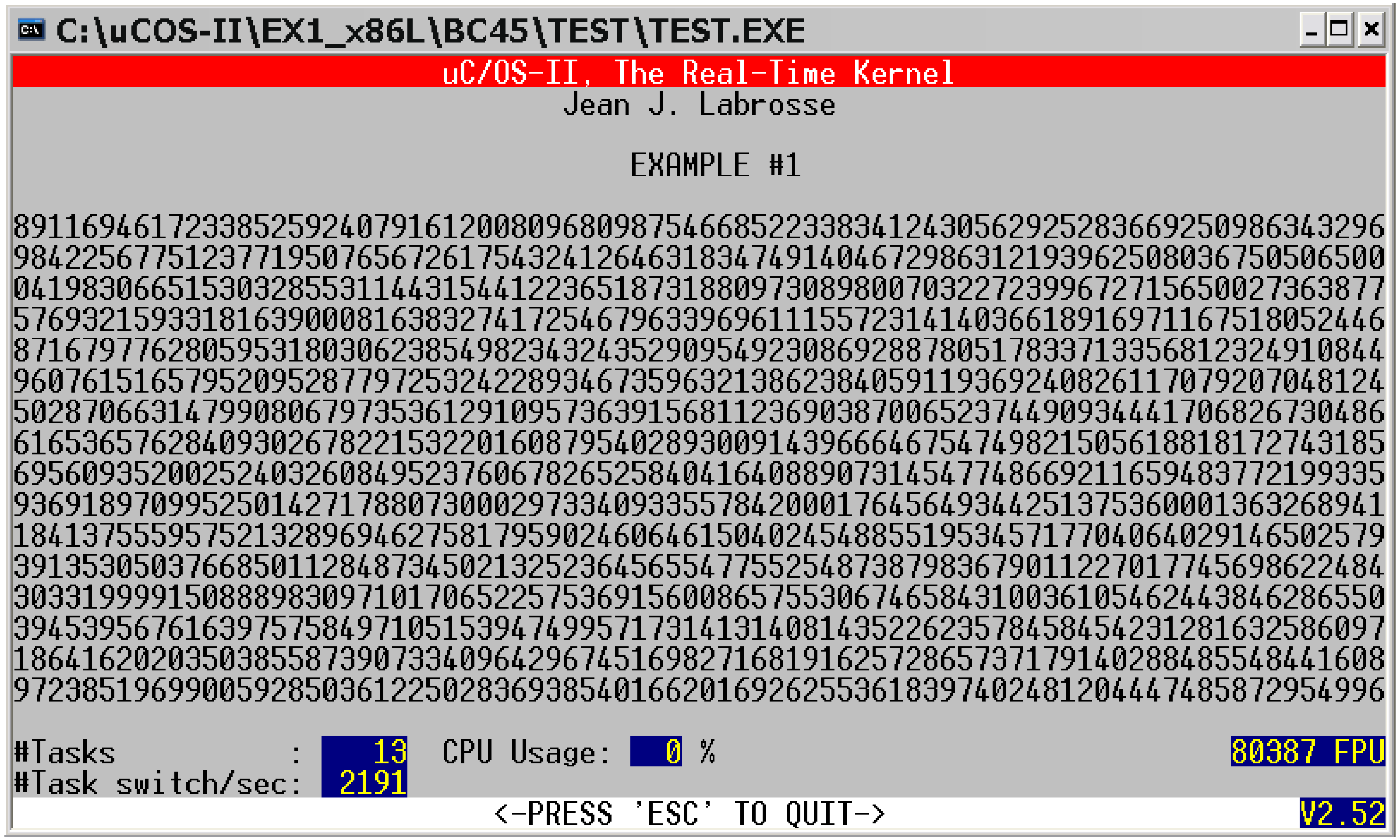
UBM

https://www.micrium.com/ubm2015/#foobox-1/0/ubm_os_in_use.png

Getting started with uC/OS-2!

- See what a uC/OS-2 program looks like
- Learn how to write a skeleton program for uC/OS-2
  - How to initialize uC/OS-2?
  - How to create tasks?
  - How to use inter-task communication mechanism?
  - How to hook on system event?

Example 1



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

                                    EXAMPLE #1

89116946172338525924079161200809680987546685223383412430562925283669250986343296
98422567751237719507656726175432412646318347491404672986312193962508036750506500
04198306651530328553114431544122365187318809730898007032272399672715650027363877
57693215933181639000816383274172546796339696111557231414036618916971167518052446
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
```

Example 1

- Files needed:
  - The main program (test.c)
  - The configuration for uC/OS-2(os_cfg.h)
  - The big include file (includes.h)
  - The kernel source

- Tools needed:
  - Borland C++ compiler (V3.1+)
  - DOSBox (x86 real mode + DOS/BIOS emulator)
  - Windows (tested) or MacOS (not tested)

Example 1

- Install software
  - Install DOSBox
  - Put borland C files in <dir>\bc45
  - Put uc/OS-II files in <dir>\software
- Run DOSBox and do the following in DOSBox
  - mount c <dir>
  - cd c:\SOFTWARE\uCOS-II\EX1_x86L\BC45\test
  - maketest.bat
  - test.exe

Example 1

- Before we start…
  - Source tree structure
  - Makefile

Example 1

- 13 tasks run concurrently
  - 2 internal tasks:
    - The idle task and the statistic task
  - 11 user tasks:
    - 1 startup task
    - 10 worker tasks randomly print numbers on the screen

- Focus: System initialization and task creation

Example 1

```
#include "includes.h"

/*
**********************************************************************************************************
*                                                CONSTANTS
**********************************************************************************************************
*/

#define  TASK_STK_SIZE                 512       /* Size of each task's stacks (# of WORDs)            */
#define  N_TASKS                        10       /* Number of identical tasks                          */

/*
**********************************************************************************************************
*                                                VARIABLES
**********************************************************************************************************
*/

OS_STK        TaskStk[N_TASKS][TASK_STK_SIZE];        /* Tasks stacks                                  */
OS_STK        TaskStartStk[TASK_STK_SIZE];
char          TaskData[N_TASKS];                      /* Parameters to pass to each task               */
OS_EVENT     *RandomSem;
```

A semaphore (to be explained later)

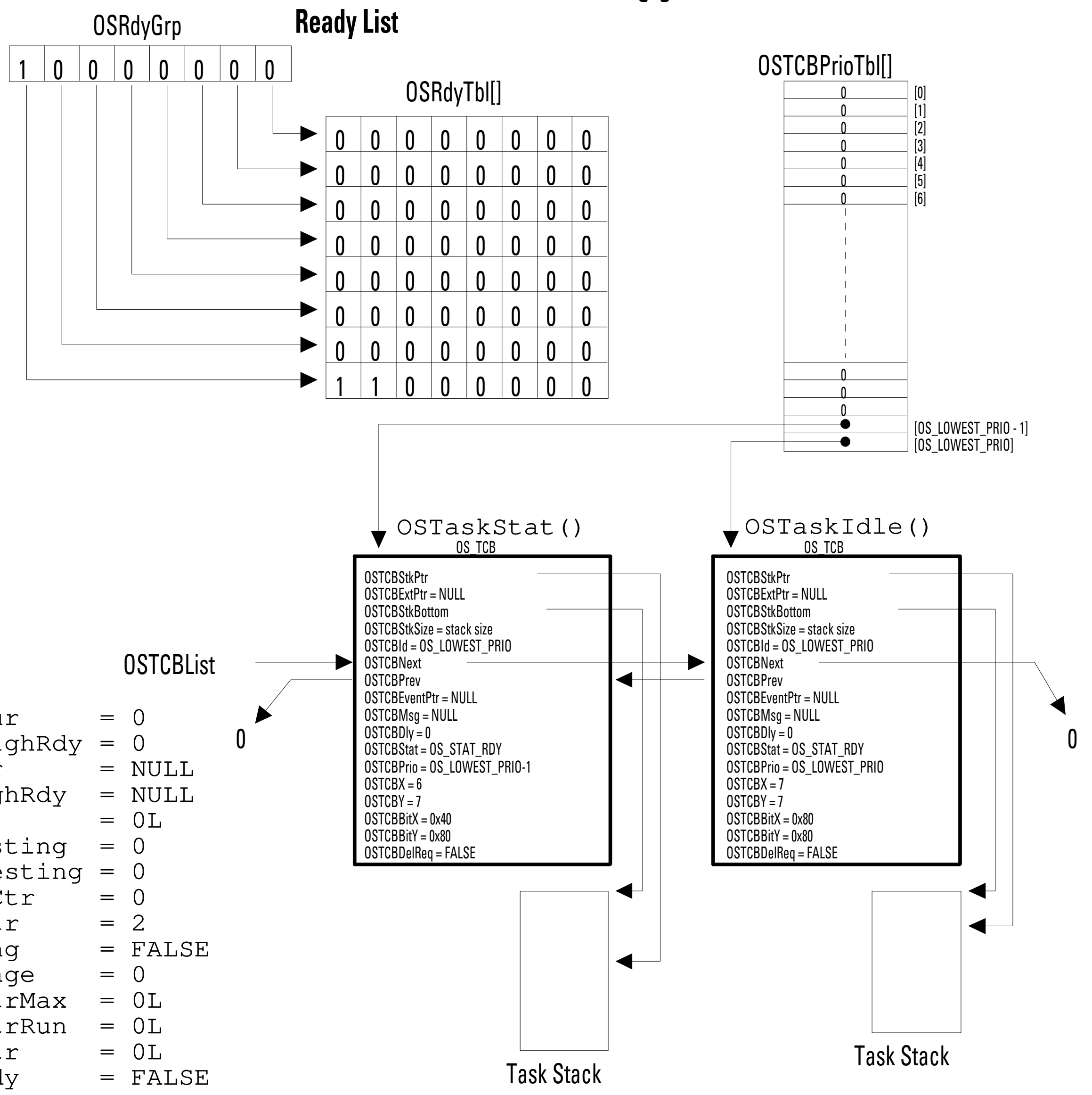
Main()

```
void main (void)
{
    PC_DispClrScr(DISP_FGND_WHITE + DISP_BGND_BLACK);          (1)
    OSInit();                                                   (2)
    PC_DOSSaveReturn();                                         (3)
    PC_VectSet(uCOS, OSCtxSw);                                  (4)
    RandomSem = OSSemCreate(1);                                 (5)
    OSTaskCreate(TaskStart,                                     (6)
                 (void *)0,
                 (void *)&TaskStartStk[TASK_STK_SIZE-1],
                 0);
    OSStart();                                                  (7)
}
```

Main()

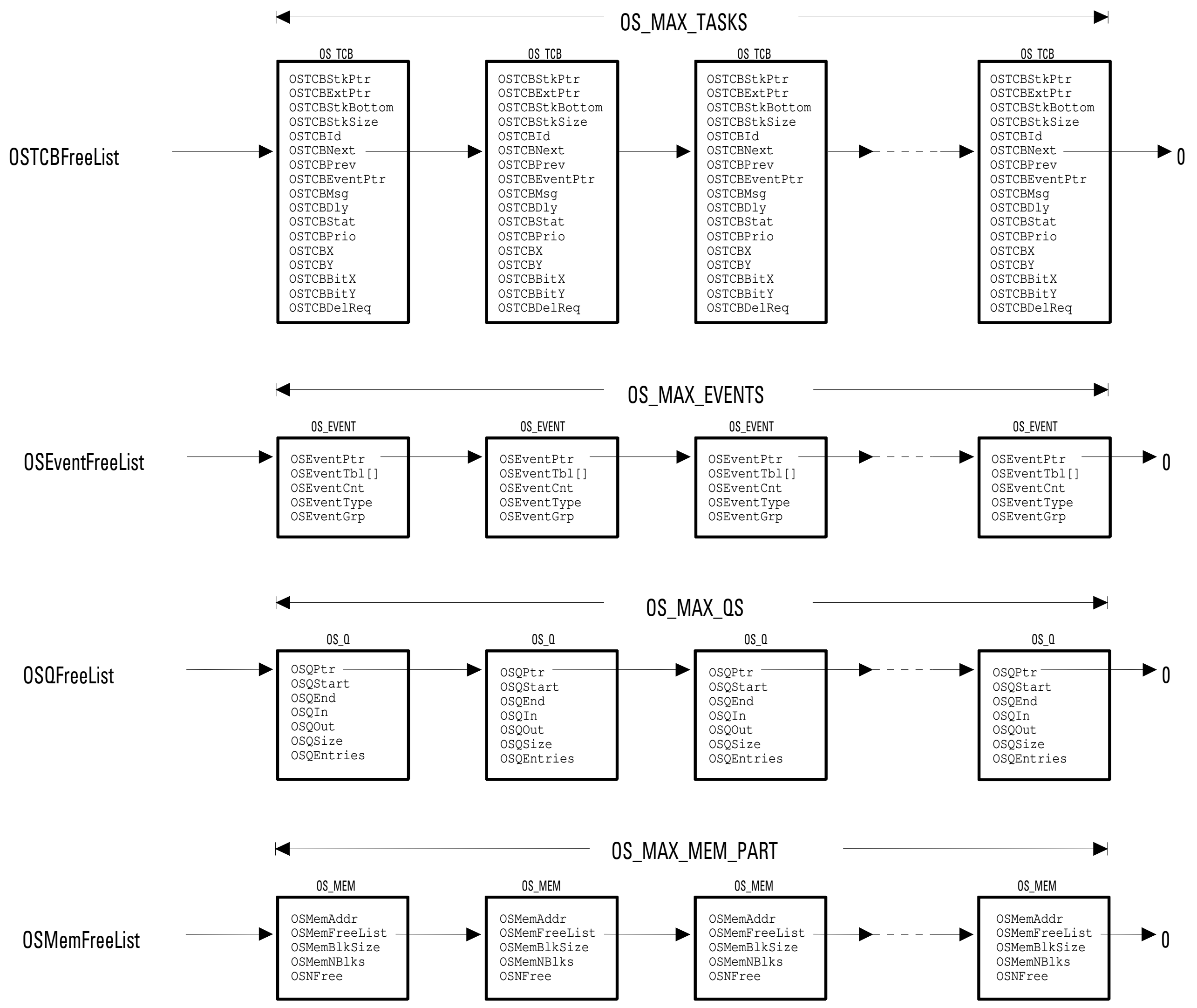
- OSinit():
  - Init internal structures of uC/OS-2
    - Task ready list
    - Priority table
    - Task control blocks (TCB)
    - Free pool
  - Create housekeeping tasks
    - The idle task
    - The statistics task

OSinit()



```
OSPrioCur       = 0
OSPrioHighRdy   = 0
OSTCBCur        = NULL
OSTCBHighRdy    = NULL
OSTime          = 0L
OSIntNesting    = 0
OSLockNesting   = 0
OSCtxSwCtr      = 0
OSTaskCtr       = 2
OSRunning       = FALSE
OSCPUUsage      = 0
OSIdleCtrMax    = 0L
OSIdleCtrRun    = 0L
OSIdleCtr       = 0L
OSStatRdy       = FALSE
```

OSinit()



OS_MAX_TASKS
OS_TCB
OSTCBFreeList
OSTCBStkPtr
OSTCBExtPtr
OSTCBStkBottom
OSTCBStkSize
OSTCBId
OSTCBNext
OSTCBPrev
OSTCBEventPtr
OSTCBMsg
OSTCBDly
OSTCBStat
OSTCBPrio
OSTCBX
OSTCBY
OSTCBBitX
OSTCBBitY
OSTCBDelReq
0
OS_MAX_EVENTS
OS_EVENT
OSEventFreeList
OSEventPtr
OSEventTbl[]
OSEventCnt
OSEventType
OSEventGrp
0
OS_MAX_QS
OS_Q
OSQFreeList
OSQPtr
OSQStart
OSQEnd
OSQIn
OSQOut
OSQSize
OSQEntries
0
OS_MAX_MEM_PART
OS_MEM
OSMemFreeList
OSMemAddr
OSMemFreeList
OSMemBlkSize
OSMemNBlks
OSNFree
0

Main()

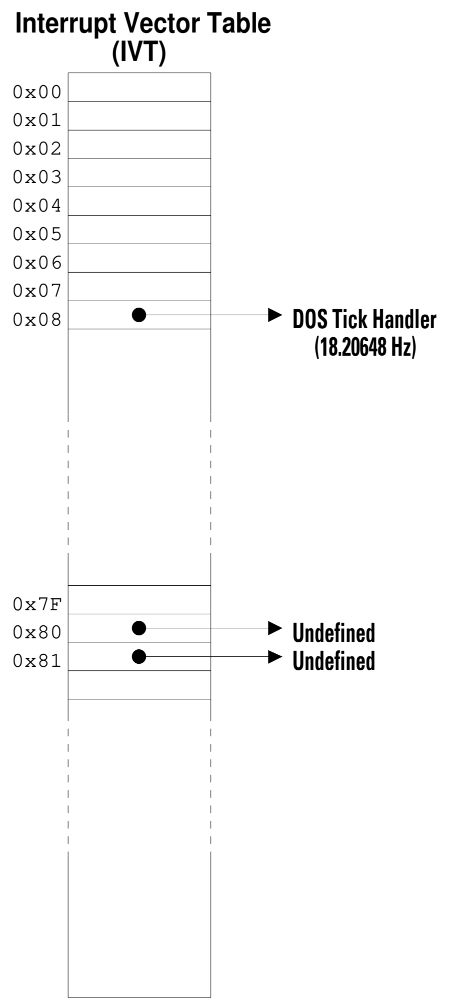
- PC_DOSSaveReturn()
  - Save the current status of DOS for the later restoration
    - Interrupt vectors and the RTC tick rate.
  - Set a global returning point using setjmp()
    - uC/OS-2 can come back here on OS termination
    - PC_DOSReturn()

PC_DOSSaveReturn()

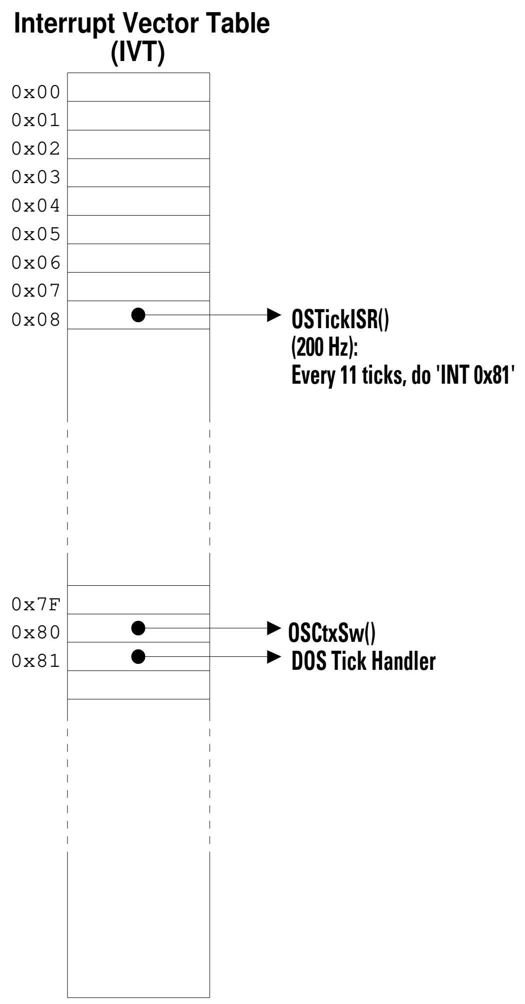
```
void PC_DOSSaveReturn (void)
{
    PC_ExitFlag  = FALSE;                                              (1)
    OSTickDOSCtr =     8;                                              (2)
    PC_TickISR   = PC_VectGet(VECT_TICK);                              (3)

    OS_ENTER_CRITICAL();
    PC_VectSet(VECT_DOS_CHAIN, PC_TickISR);                            (4)
    OS_EXIT_CRITICAL();

    setjmp(PC_JumpBuf);                                                (5)
    if (PC_ExitFlag == TRUE) {
        OS_ENTER_CRITICAL();
        PC_SetTickRate(18);                                            (6)
        PC_VectSet(VECT_TICK, PC_TickISR);                             (7)
        OS_EXIT_CRITICAL();
        PC_DispClrScr(DISP_FGND_WHITE + DISP_BGND_BLACK);              (8)
        exit(0);                                                       (9)
    }                                                                 *
}
```

(4): backup DOS tick ISR (entry point) to another interrupt vector. Later when we install a new tick ISR, the old DOS tick ISR can be called immediately after our new tick ISR.

Before (DOS only)



After (涽/OS-II installed)



Copied from part 5

Main()

- PC_VectSet(uCOS,OSCtxSw)
  - Install the context switch handler
    - Interrupt # 0x80 of 80x86 family
  - Context switches are handled during ISR!
    - Voluntary CXTSW via executing an INT instruction
    - Involuntary CXTSW during the return of a timer ISR

*

Main()

- OSSemCreate()
  - Create a semaphore for IPC
    - To protect non-reentrant codes and shared resources
  - The semaphore is initialized as a binary semaphore
    - For mutual exclusion
  - In this example, a semaphore is created to protect "random()" in the standard C library
    - random() hides a global variable
    - Linear Congruential Generator
    - $a_n=(a_{n-1}*p+q) \%m$

Main()

- OSTaskCreate()
  - Create tasks with the supplied arguments
  - Tasks become “ready” after being created

- Task
  - An active entity which does computation
  - **Priority, CPU registers, stack, text, housekeeping status**
  - uC/OS-2 allows maximum 62 tasks to be created

- uC/OS-2 picks up the highest-priority task for execution on rescheduling points
  - Clock ticks, interrupt return, and semaphore operations…
  - We shall see more in RTC ISR.

OSTaskCreate()

```
OSTaskCreate(
   TaskStart,
   (void *)0,
   &TaskStartStk[TASK_STK_SIZE - 1],
    0
   );
```

Entry point of the task (a pointer to function)

User-specified data

Top of Stack

Priority (0=hightest)

TaskStart()

Cxtsw begins as soon as the new tick ISR is installed. So install the tick ISR after OSStart() is called

```
void  TaskStart (void *pdata)
{
#if OS_CRITICAL_METHOD == 3                              /* Allocate storage for CPU status register */
    OS_CPU_SR  cpu_sr;
#endif
    char       s[100];
    INT16S     key;

    pdata = pdata;                                      ent compiler warning            */

    TaskStartDispInit();                                 /* Initialize the display          */

    OS_ENTER_CRITICAL();
    PC_VectSet(0x08, OSTickISR);                         /* Install uC/OS-II's clock tick ISR        */
    PC_SetTickRate(OS_TICKS_PER_SEC);                    /* Reprogram tick rate             */
    OS_EXIT_CRITICAL();

    OSStatInit();                                        /* Initialize uC/OS-II's statistics         */

    TaskStartCreateTasks();                              /* Create all the application tasks         */

    for (;;) {
        TaskStartDisp();                                /* Update the display              */


        if (PC_GetKey(&key) == TRUE) {                   /* See if key has been pressed             */
            if (key == 0x1B) {                           /* Yes, see if it's the ESCAPE key         */
                PC_DOSReturn();                          /* Return to DOS                   */
            }
        }

        OSCtxSwCtr = 0;                                  /* Clear context switch counter            */
        OSTimeDlyHMSM(0, 0, 1, 0);                       /* Wait one second                 */
    }
}
```

Install new Tick ISR and change the ticking rate from 18.2HZ too 200HZ

TaskStart()

- OS_ENTER(EXIT)_CRITICAL
  - Enable/disable maskable interrupts
  - A solution of critical section in uniprocessor systems
    - No preemption is possible until interrupt is re-enabled
    - Different from semaphores
  - Processor specific
    - CLI/STI (x86 real mode)
    - CPSID/CPSIE (ARM)

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 created task

Argument: character to print

Stack

Priority

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                             */
                                      /* Display the task number on the screen         */
        PC_DispChar(x, y + 5, *(char *)pdata, DISP_FGND_BLACK + DISP_BGND_LIGHT_GRAY);
        OSTimeDly(1);                 /* Delay 1 clock tick                            */
    }
}
```

Semaphore operations.

Semaphores

- OSSemPend() / OSSemPost()
- A semaphore consists of a wait list and an integer counter
- OSSemPend:
  – Counter--;
  – If the value of the semaphore <0, the task is blocked and moved to the wait list immediately
  – A time-out value can be specified
- OSSemPost:
  – Counter++;
  – If the value of the semaphore >= 0, a task in the wait list is removed from the wait list
  – Reschedule if needed

Main()

- OSStart()
  - Start multitasking of uC/OS-2 by “context switching” to the highest priority task
  - It never returns to main()
  - ucOS’s tick ISR should be installed after OSStart() is called, so it is called in the Startup task, which is the highest priority task upon calling OSStart()
  - uC/OS-2 is terminated if PC_DOSReturn() is called

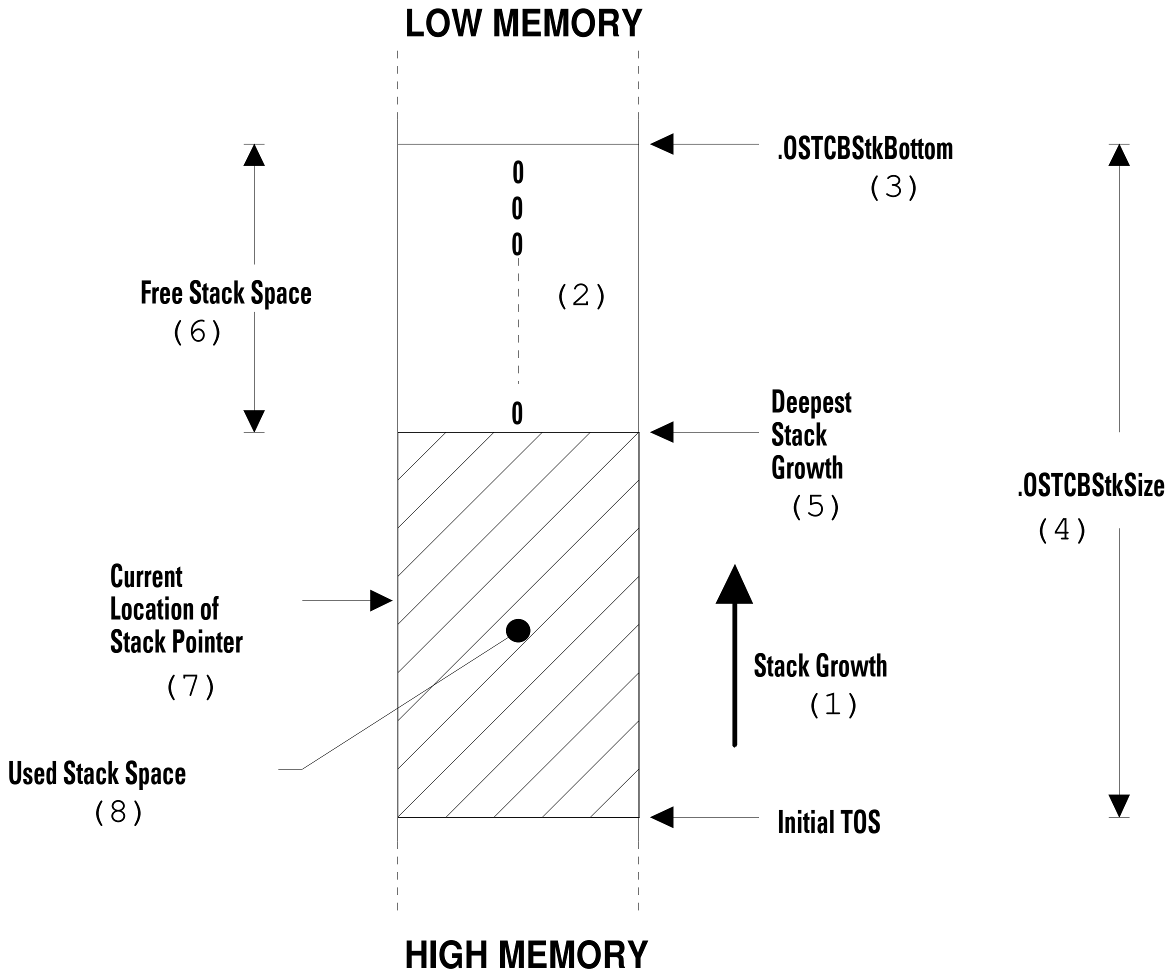
Summary: Example 1

- uC/OS-2 is initialized and started by calling OSInit() and OSStart(), respectively
- Before uC/OS-2 is started,
  - DOS status is saved by calling PC_DOSSaveReturn()
  - Context switch handler is installed by calling PC_VectSet()
  - User tasks must be created by OSTaskCreate()
- Shared resources must be protected by semaphores
  - OSSemPend(),OSSemPost()

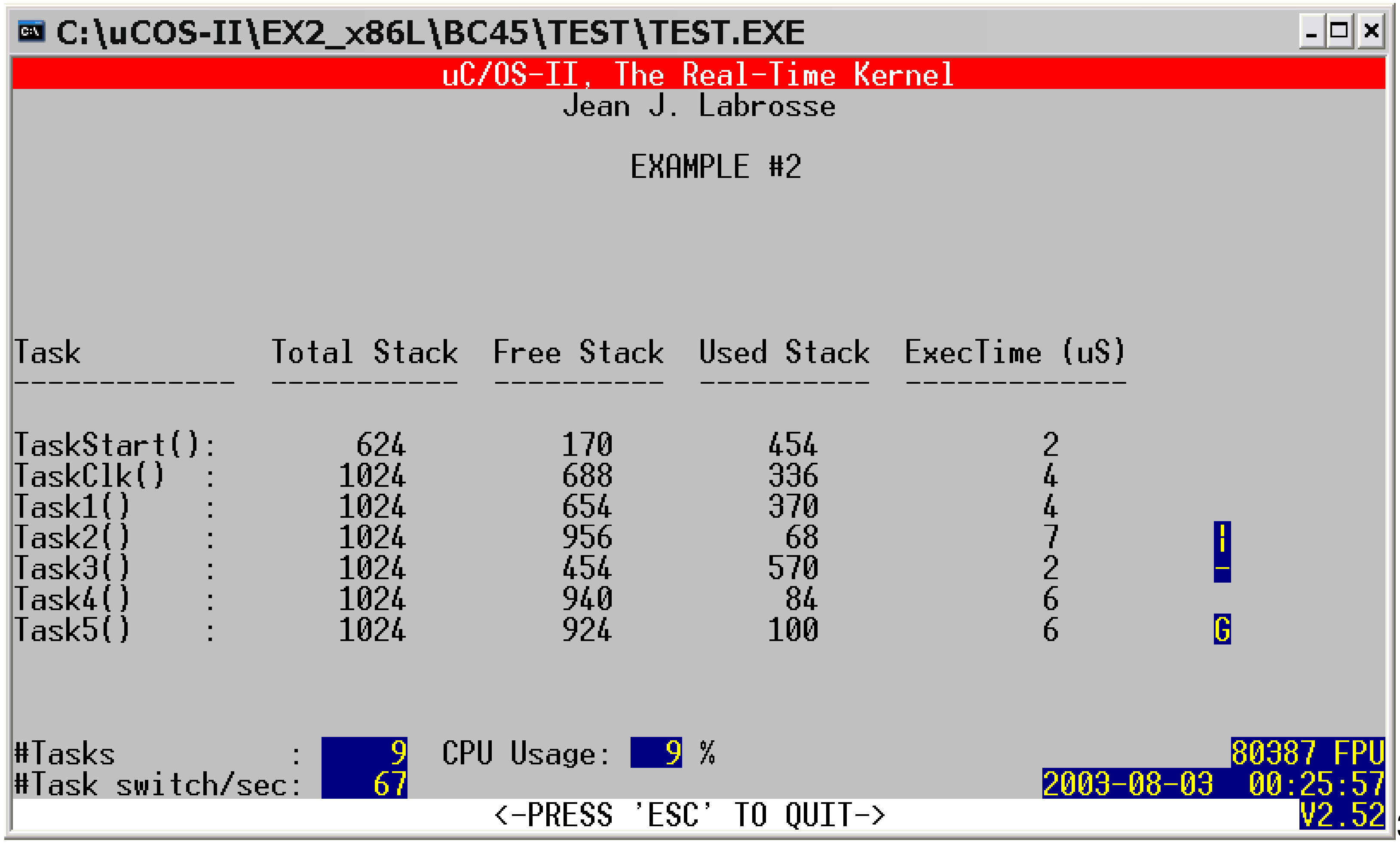
Example 2

- Example 2 focuses on:
  - More task creation options
  - **Stack usage** of each task
  - **Floating point** operations
  - IPC via **mailboxes**

Stack Usage of a Task



Example 2



```
                        uC/OS-II, The Real-Time Kernel
                              Jean J. Labrosse

                                 EXAMPLE #2




Task            Total Stack  Free Stack  Used Stack  ExecTime (uS)
--------------  -----------  ----------  ----------  -------------

TaskStart():        624         170         454             2
TaskClk()  :       1024         688         336             4
Task1()    :       1024         654         370             4
Task2()    :       1024         956          68             7         |
Task3()    :       1024         454         570             2         -
Task4()    :       1024         940          84             6
Task5()    :       1024         924         100             6         G


#Tasks          :      9  CPU Usage:   9 %                      80387 FPU
#Task switch/sec:     67                             2003-08-03  00:25:57
                      <-PRESS 'ESC' TO QUIT->                       V2.52
```

```
#define          TASK_STK_SIZE     512                /* Size of each task's stacks (# of WORDs)       */

#define          TASK_START_ID       0                /* Application tasks IDs                         */
#define          TASK_CLK_ID         1
#define          TASK_1_ID           2
#define          TASK_2_ID           3
#define          TASK_3_ID           4
#define          TASK_4_ID           5
#define          TASK_5_ID           6

#define          TASK_START_PRIO    10                /* Application tasks priorities                  */
#define          TASK_CLK_PRIO      11
#define          TASK_1_PRIO        12
#define          TASK_2_PRIO        13
#define          TASK_3_PRIO        14
#define          TASK_4_PRIO        15
#define          TASK_5_PRIO        16

OS_STK        TaskStartStk[TASK_STK_SIZE];            /* Startup    task stack                         */
OS_STK        TaskClkStk[TASK_STK_SIZE];              /* Clock      task stack                         */
OS_STK        Task1Stk[TASK_STK_SIZE];                /* Task #1    task stack                         */
OS_STK        Task2Stk[TASK_STK_SIZE];                /* Task #2    task stack                         */
OS_STK        Task3Stk[TASK_STK_SIZE];                /* Task #3    task stack                         */
OS_STK        Task4Stk[TASK_STK_SIZE];                /* Task #4    task stack                         */
OS_STK        Task5Stk[TASK_STK_SIZE];                /* Task #5    task stack                         */

OS_EVENT     *AckMbox;                                /* Message mailboxes for Tasks #4 and #5         */
OS_EVENT     *TxMbox;
```

2 Mailboxes

Main()

```
void main (void)
{
    OS_STK *ptos;
    OS_STK *pbos;
    INT32U  size;


    PC_DispClrScr(DISP_FGND_WHITE);                        /* Clear the screen                         */

    OSInit();                                              /* Initialize uC/OS-II                      */

    PC_DOSSaveReturn();                                    /* Save environment to return to DOS        */
    PC_VectSet(uCOS, OSCtxSw);                             /* Install uC/OS-II's context switch vector */

    PC_ElapsedInit();                                      /* Initialized elapsed time measurement     */

    ptos        = &TaskStartStk[TASK_STK_SIZE - 1];        /* TaskStart() will use Floating-Point      */
    pbos        = &TaskStartStk[0];
    size        = TASK_STK_SIZE;
    OSTaskStkInit_FPE_x86(&ptos, &pbos, &size);
    OSTaskCreateExt(TaskStart,
                   (void *)0,
                   ptos,
                   TASK_START_PRIO,
                   TASK_START_ID,
                   pbos,
                   size,
                   (void *)0,
                   OS_TASK_OPT_STK_CHK | OS_TASK_OPT_STK_CLR);

    OSStart();                                             /* Start multitasking                       */
}
```

TaskStart()

```
void  TaskStart (void *pdata)
{
#if OS_CRITICAL_METHOD == 3                              /* Allocate storage for CPU status register */
    OS_CPU_SR  cpu_sr;
#endif
    INT16S     key;


    pdata = pdata;                                       /* Prevent compiler warning               */

    TaskStartDispInit();                                 /* Setup the display                      */

    OS_ENTER_CRITICAL();                                 /* Install uC/OS-II's clock tick ISR      */
    PC_VectSet(0x08, OSTickISR);
    PC_SetTickRate(OS_TICKS_PER_SEC);                    /* Reprogram tick rate                    */
    OS_EXIT_CRITICAL();

    OSStatInit();                                        /* Initialize uC/OS-II's statistics       */

    AckMbox = OSMboxCreate((void *)0);                   /* Create 2 message mailboxes             */
    TxMbox  = OSMboxCreate((void *)0);

    TaskStartCreateTasks();                              /* Create all other tasks                 */

    for (;;) {
        TaskStartDisp();                                 /* Update the display                     */

        if (PC_GetKey(&key)) {                           /* See if key has been pressed            */
            if (key == 0x1B) {                           /* Yes, see if it's the ESCAPE key        */
                PC_DOSReturn();                          /* Yes, return to DOS                     */
            }
        }

        OSCtxSwCtr = 0;                                  /* Clear context switch counter           */
        OSTimeDly(OS_TICKS_PER_SEC);                     /* Wait one second                        */
    }
}
```

Create 2 mailboxes

The dummy loop wait for 'ESC'

Task1()

```
void  Task1 (void *pdata)
{
    INT8U       err;
    OS_STK_DATA data;                           /* Storage for task stack data                             */
    INT16U      time;                           /* Execution time (in uS)                                  */
    INT8U       i;
    char        s[80];


    pdata = pdata;
    for (;;) {
        for (i = 0; i < 7; i++) {
            PC_ElapsedStart();
            err  = OSTaskStkChk(TASK_START_PRIO + i, &data);
            time = PC_ElapsedStop();
            if (err == OS_NO_ERR) {
                sprintf(s, "%4ld        %4ld        %4ld        %6d",
                        data.OSFree + data.OSUsed,
                        data.OSFree,
                        data.OSUsed,
                        time);
                PC_DispStr(19, 12 + i, s, DISP_FGND_BLACK + DISP_BGND_LIGHT_GRAY);
            }
        }
        OSTimeDlyHMSM(0, 0, 0, 100);                       /* Delay for 100 mS                           */
    }
}
```

```
void  Task2 (void *data)
{
    data = data;
    for (;;) {
        PC_DispChar(70, 15, '|',  DISP_FGND_YELLOW + DISP_BGND_BLUE);
        OSTimeDly(10);
        PC_DispChar(70, 15, '/',  DISP_FGND_YELLOW + DISP_BGND_BLUE);
        OSTimeDly(10);
        PC_DispChar(70, 15, '-',  DISP_FGND_YELLOW + DISP_BGND_BLUE);
        OSTimeDly(10);
        PC_DispChar(70, 15, '\\', DISP_FGND_YELLOW + DISP_BGND_BLUE);
        OSTimeDly(10);
    }
}

void  Task3 (void *data)
{
    char    dummy[500];
    INT16U  i;


    data = data;
    for (i = 0; i < 499; i++) {        /* Use up the stack with 'junk'  */
        dummy[i] = '?';
    }
    for (;;) {
        PC_DispChar(70, 16, '|',  DISP_FGND_YELLOW + DISP_BGND_BLUE);
        OSTimeDly(20);
        PC_DispChar(70, 16, '\\', DISP_FGND_YELLOW + DISP_BGND_BLUE);
        OSTimeDly(20);
        PC_DispChar(70, 16, '-',  DISP_FGND_YELLOW + DISP_BGND_BLUE);
        OSTimeDly(20);
        PC_DispChar(70, 16, '/',  DISP_FGND_YELLOW + DISP_BGND_BLUE);
        OSTimeDly(20);
    }
}
```

Task4 and Task5

```
void  Task4 (void *data)
{
    char   txmsg;
    INT8U  err;


    data  = data;
    txmsg = 'A';
    for (;;) {
        OSMboxPost(TxMbox, (void *)&txmsg);      /* Send message to Task #5                          */
        OSMboxPend(AckMbox, 0, &err);            /* Wait for acknowledgement from Task #5            */
        txmsg++;                                 /* Next message to send                             */
        if (txmsg == 'Z') {
            txmsg = 'A';                         /* Start new series of messages                     */
        }
    }
}

void  Task5 (void *data)
{
    char  *rxmsg;
    INT8U  err;


    data = data;
    for (;;) {
        rxmsg = (char *)OSMboxPend(TxMbox, 0, &err);                  /* Wait for message from Task #4 */
        PC_DispChar(70, 18, *rxmsg, DISP_FGND_YELLOW + DISP_BGND_BLUE);
        OSTimeDlyHMSM(0, 0, 1, 0);                                    /* Wait 1 second                 */
        OSMboxPost(AckMbox, (void *)1);                               /* Acknowledge reception of msg  */
    }
}
```

MailBox

- A mailbox is a data exchange between tasks
  - A mailbox consists of a data pointer and a wait-list
- OSMboxPend():
  - The message in the mailbox is retrieved
  - If the mailbox is empty, the task is immediately blocked and moved to the wait-list
  - A time-out value can be specified
- OSMboxPost():
  - A message is deposited in the mailbox
  - If there is already a message in the mailbox, an error is returned (not overwritten)
  - If tasks waiting for a message from the mailbox, the task with the highest priority is removed from the wait-list and scheduled to run

OSTaskStkInit_FPE_x86()

- OSTaskStkInit_FPE_x86(&ptos, &pbos, &size)
- Passing the original top address, bottom address, and size of the stack
- On return, the arguments are modified and some stack space are reserved for floating point library
  - For context switches

OSCreateTaskExt()

-
  ```
  OSTaskCreateExt(
  TaskStart,
  (void *)0,
  ptos,
  TASK_START_PRIO,
  TASK_START_ID,
  pbos,
  size,
  (void *)0,
  OS_TASK_OPT_STK_CHK | OS_TASK_OPT_STK_CLR
  );
  ```

OSTaskStkCheck()

- Check for stack overflow
  - Criteria
    - bos < (tos – stack length)
  - Who uses stacks?
    - Local variables,
    - arguments for procedure calls,
    - and temporary storage for ISR's
  - When stacks are checked?
    - When a task is created
    - When OSTaskStkCheck() is called
    - No automatic stack checking

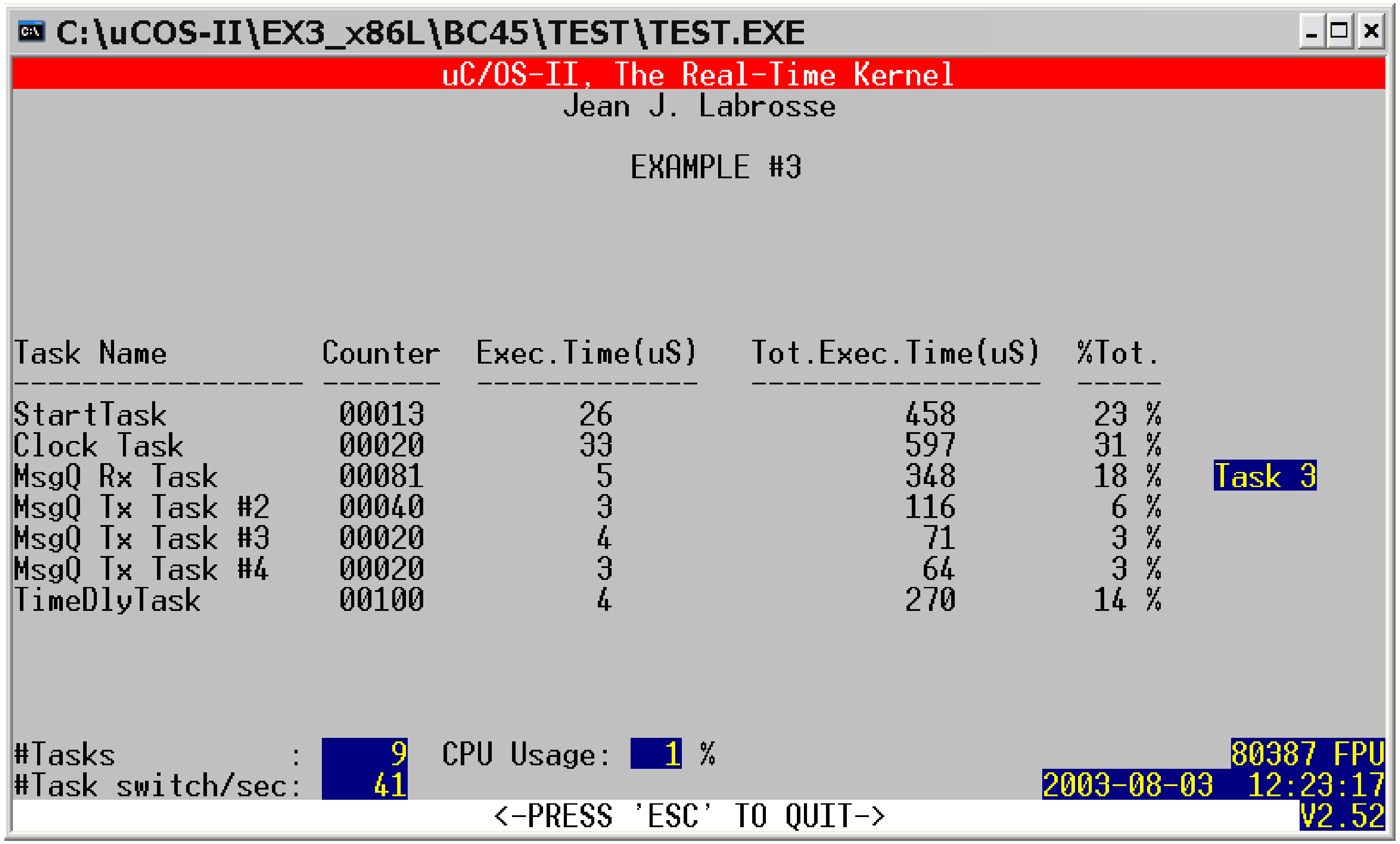
Summary: Example2

- Local variable, function calls, and ISR's will utilize the stack space of user tasks
  - ISR will use the stack of the task being interrupted
- If floating-point operations are needed, some stack space should be reserved
- Mailbox can be used to synchronize among tasks

Example 3

- Using message queues to pass user-defined data structures among tasks
- Demonstrating how to use OS hooks to monitor interested system events

Example 3



```
C:\uCOS-II\EX3_x86L\BC45\TEST\TEST.EXE
                         uC/OS-II, The Real-Time Kernel
                               Jean J. Labrosse

                                  EXAMPLE #3




Task Name          Counter  Exec.Time(uS)   Tot.Exec.Time(uS)  %Tot.
-----------------  -------  -------------   -----------------  -----
StartTask           00013         26                458         23 %
Clock Task          00020         33                597         31 %
MsgQ Rx Task        00081          5                348         18 %    Task 3
MsgQ Tx Task #2     00040          3                116          6 %
MsgQ Tx Task #3     00020          4                 71          3 %
MsgQ Tx Task #4     00020          3                 64          3 %
TimeDlyTask         00100          4                270         14 %



#Tasks          :       9  CPU Usage:   1 %                       80387 FPU
#Task switch/sec:      41                              2003-08-03  12:23:17
                      <-PRESS 'ESC' TO QUIT->                          V2.52
```

```
•    #define          TASK_STK_SIZE     512                /* Size of each task's stacks (# of WORDs)         */

•    #define          TASK_START_ID       0                /* Application tasks                               */
•    #define          TASK_CLK_ID         1
•    #define          TASK_1_ID           2
•    #define          TASK_2_ID           3
•    #define          TASK_3_ID           4
•    #define          TASK_4_ID           5
•    #define          TASK_5_ID           6

•    #define          TASK_START_PRIO    10                /* Application tasks priorities                    */
•    #define          TASK_CLK_PRIO      11
•    #define          TASK_1_PRIO        12
•    #define          TASK_2_PRIO        13
•    #define          TASK_3_PRIO        14
•    #define          TASK_4_PRIO        15
•    #define          TASK_5_PRIO        16

•    #define          MSG_QUEUE_SIZE     20                /* Size of message queue used in example           */

•    typedef struct {
•        char    TaskName[30];
•        INT16U  TaskCtr;
•        INT16U  TaskExecTime;
•        INT32U  TaskTotExecTime;
•    } TASK_USER_DATA;


•    OS_STK          TaskStartStk[TASK_STK_SIZE];          /* Startup    task stack                           */
•    OS_STK          TaskClkStk[TASK_STK_SIZE];            /* Clock      task stack                           */
•    OS_STK          Task1Stk[TASK_STK_SIZE];              /* Task #1    task stack                           */
•    OS_STK          Task2Stk[TASK_STK_SIZE];              /* Task #2    task stack                           */
•    OS_STK          Task3Stk[TASK_STK_SIZE];              /* Task #3    task stack                           */
•    OS_STK          Task4Stk[TASK_STK_SIZE];              /* Task #4    task stack                           */
•    OS_STK          Task5Stk[TASK_STK_SIZE];              /* Task #5    task stack                           */

•    TASK_USER_DATA  TaskUserData[7];

•    OS_EVENT       *MsgQueue;                             /* Message queue pointer                           */
•    void           *MsgQueueTbl[20];                      /* Storage for messages                            */
```

User-defined data structure to pass to tasks

Message queue and an array of messages

```
•   void  Task1 (void *pdata)
•   {
•      char  *msg;
•      INT8U  err;


•      pdata = pdata;
•      for (;;) {
•         msg = (char *)OSQPend(MsgQueue, 0, &err);
•         PC_DispStr(70, 13, msg, DISP_FGND_YELLOW + DISP_BGND_BLUE);
•         OSTimeDlyHMSM(0, 0, 0, 100);
•      }
•   }


•   void  Task2 (void *pdata)
•   {
•      char  msg[20];


•      pdata = pdata;
•      strcpy(&msg[0], "Task 2");
•      for (;;) {
•         OSQPost(MsgQueue, (void *)&msg[0]);
•         OSTimeDlyHMSM(0, 0, 0, 500);
•      }
•   }
```

Task 2, 3, 4 are functionally identical.

Message Queues

- A message queue= an array of elements + a wait-list
  - Different from a mailbox, many messages are queued in a message queue in a FIFO fashion
  - As same as mailboxes, there can be multiple tasks pend/post to a message queue
- **OSQPost**():
  - Appending a message to the queue
  - The highest-priority pending task (in the wait-list) receives the message and is scheduled to run, if any
  - If queue is full, return without being blocked
- **OSQPend**():
  - Remove a message from the queue
  - If no message can be retrieved, the task is moved to the wait-list and becomes blocked

Hooks

- A hook (callback) is cascaded after its corresponding system event
  - For example, OSTaskSwHook () is called every time when context switch occurs
  - User program could do something when the interested events occur
- The hooks are specified in compile time in uC/OS-2
  - Write your code in the body of predefined hooks
  - Registration/deregistration are not available

User Customizable Hooks

- void OSInitHookBegin (void)
- void OSInitHookEnd (void)
- void OSTaskCreateHook (OS_TCB *ptcb)
- void OSTaskDelHook (OS_TCB *ptcb)
- void OSTaskIdleHook (void)
- void OSTaskStatHook (void)
- void OSTaskSwHook (void)
- void OSTCBInitHook (OS_TCB *ptcb)
- void OSTimeTickHook (void)

```
void  OSTaskStatHook (void)
{
    char    s[80];
    INT8U   i;
    INT32U  total;
    INT8U   pct;


    total = 0L;                                          /* Totalize TOT. EXEC. TIME for each task */
    for (i = 0; i < 7; i++) {
        total += TaskUserData[i].TaskTotExecTime;
        DispTaskStat(i);                                 /* Display task data                      */
    }
    if (total > 0) {
        for (i = 0; i < 7; i++) {                        /* Derive percentage of each task         */
            pct = 100 * TaskUserData[i].TaskTotExecTime / total;
            sprintf(s, "%3d %%", pct);
            PC_DispStr(62, i + 11, s, DISP_FGND_BLACK + DISP_BGND_LIGHT_GRAY);
        }
    }
    if (total > 1000000000L) {                           /* Reset total time counters at 1 billion */
        for (i = 0; i < 7; i++) {
            TaskUserData[i].TaskTotExecTime = 0L;
        }
    }
}

void  OSTaskSwHook (void)
{
    INT16U           time;
    TASK_USER_DATA  *puser;


    time  = PC_ElapsedStop();                    /* This task is done                                  */
    PC_ElapsedStart();                           /* Start for next task                                */
    puser = OSTCBCur->OSTCBExtPtr;               /* Point to used data                                 */
    if (puser != (TASK_USER_DATA *)0) {
        puser->TaskCtr++;                        /* Increment task counter                             */
        puser->TaskExecTime     = time;          /* Update the task's execution time                   */
        puser->TaskTotExecTime += time;          /* Update the task's total execution time             */
    }
}
```

Summary: Example 3

- Synchronizing tasks with message queues
  - Multiple message can be held in the queue
  - Multiple tasks can pend/post to a message queues
- Hooking interested system events via customizable hooks
  - Write your code in the body of predefined hooks

Summary: Getting Started with uC/OS-2

- Do you understand
  - how to write a dummy uC/OS-2 program?
  - how the control flows among procedures?
  - how tasks are created?
  - how tasks are synchronized by semaphore, mailbox, and message queues?
  - how the space of stacks are allocated?
  - how to hook on system events?