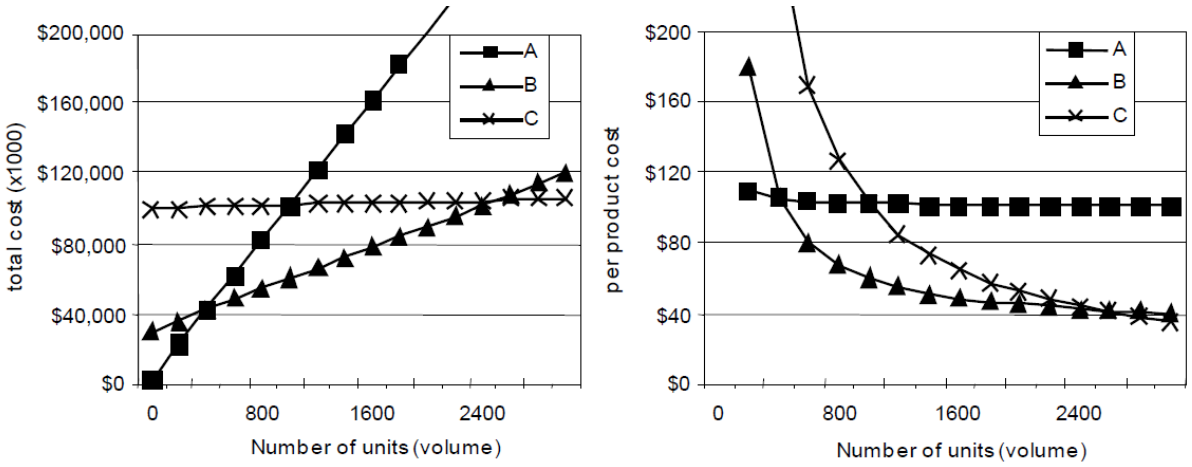
Embedded Operating System Midterm, Chang Gung University, Autumn 2022

Name: Student ID:

1. (12%) Please define the (a) Non-Recurring Engineering (NRE) Cost and (b) the Unit Cost of a system of products. (c) In the following figures, which technology has the highest NRE cost? (d) In the following figures, which technology has the highest unit cost? Please provide the reason to support your answer.

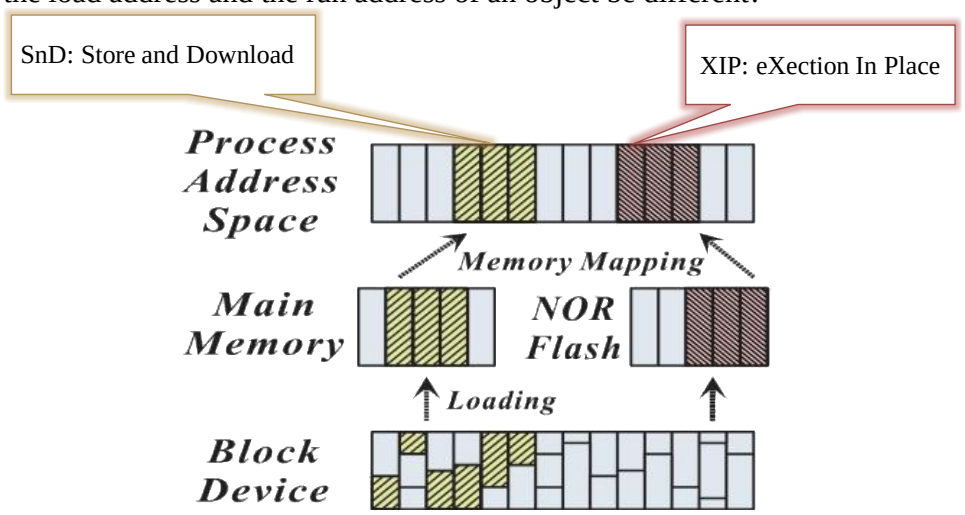


Answer: (a) Unit Cost: the monetary cost of manufacturing each copy of the system
(b) NRE Cost: the one-time monetary cost of designing the system
(c) Technology C
(d) Technology A

2. (8%) Context switching is an overhead of task scheduling. Thus, whenever we have a new task scheduling algorithm, we would like to analyze the number of context switching. Stack Discipline is a very useful rule for analyzing the context switching overhead of a task scheduling algorithm. Please provide the definition of Stack Discipline.

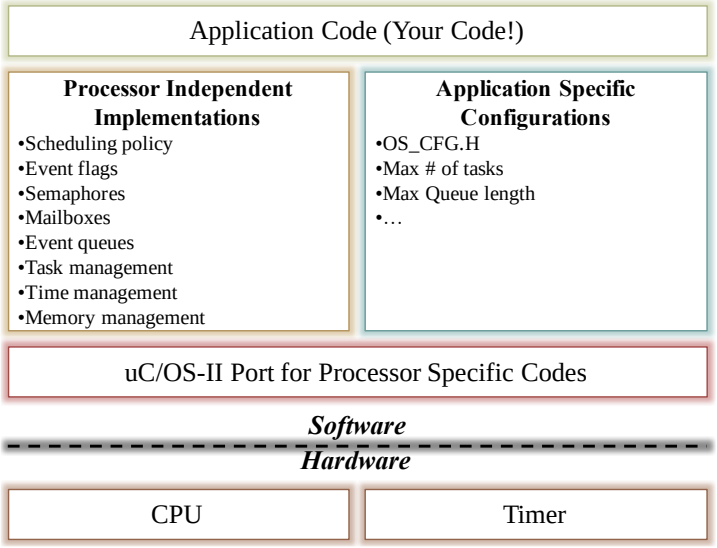
Answer: If process A preempts process B, process A must complete before process B can resume.

3. (12%) For program execution, please define (a) Store and Download (SnD) and (b) eXection In Place (XIP). You can refer to the following figure to answer questions a and b. For each object in an embedded system, we can specify the load address for its address in ROM and the run address for its execution. (c) When can we use the same address for the load address and the run address of an object? (d) When should the load address and the run address of an object be different?



Answer: (a) SnD: It is to store the results in the storage before power-off and to download binary and data before running programs.
(b) XIP: It is to directly run programs on non-volatile and byte-addressable memory.
(c) If the object is read-only and will be used only once (or few times), we can keep it in ROM.
(d) If the object is not read-only and might be accessed many times, we should load it into DRAM to write some data and to improve the performance.

4. (8%) The following figure shows the structure of µC/OS-II. If now we want to launch a new application on a running system with µC/OS-II, please explain the process for running the new application on µC/OS-II.

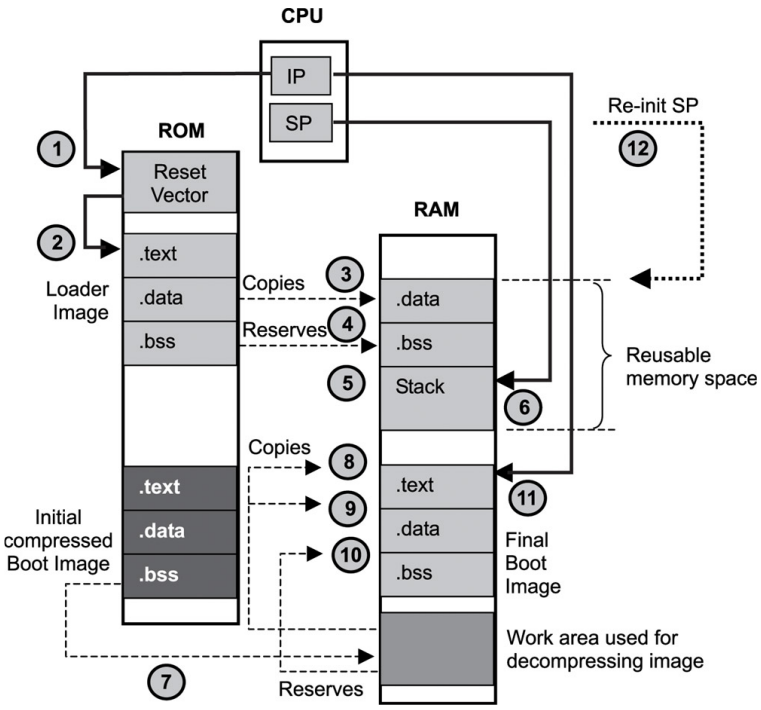


Answer: We have to compile the whole package including the OS and application source files, shutdown the system, install the whole image, and reboot the system.

5. (8%) Please define (a) “Soft” real-time systems and (b) “Hard” real-time systems.
Answer: (a) Soft real-time systems: We want to meet the deadline constraint so as to guarantee the quality of applications, but deadline missing is not fatal, e.g., multimedia applications.
(b) Hard real-time systems: If the deadline is missed, critical data are permanently lost or people might get hurt. Thus, it does not allow any deadline missing, e.g., nuclear power plant controllers and anti-lock brake systems.

6. (8%) To develop software on embedded systems, we usually need the cross-platform development environment consisting of some cross compiler, linker, and source-level debugger. (a) What is the cross compiler? (b) Why do we need it?
Answer: (a) A cross compiler is a compiler which can run on the host system, such as a PC, and can produce the binary which can run on the target embedded system.
(b) Some embedded systems do not have enough computing power, memory and/or system software to support the compiler. Thus, cross compiling is needed to build the embedded software.

7. (12%) Let’s have an example for an image transferred from ROM and running on RAM. Steps 1 to 6 are provided as follows. Please complete Step 7 to 12.



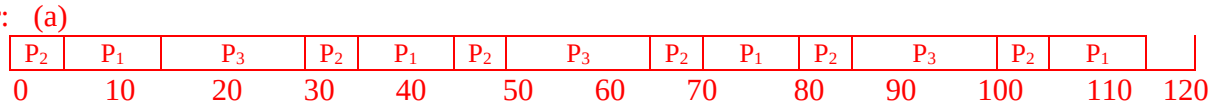
1. The CPU's IP register is hardwired to execute the first instruction in memory, i.e., the reset vector
2. The reset vector jumps to the first instruction of the .text section of boot image
3. The .data section is copied to RAM
4. Reserve space if RAM for the .bss section
5. Reserve stack space in RAM
6. Set SP register to the beginning of the newly created stack

Answer:

7. Copy the Compressed application image from ROM to RAM in a work area
8. Decompress and initialize the application image for instructions
9. Decompress and initialize the application image for global data
10. Decompress and initialize the application image for .bss section
11. The loader transfers control to the image using a processor-specific jump instruction
12. Recycle the memory area occupied by the loader and the work area and reinitialize the SP to point to the memory area occupied by the loader to use it as the stack space

8. (12%) For three periodic tasks P_1, P_2 and P_3. P_1 has its period 30 and execution time 10. P_2 has its period 20 and execution time 5. P_3 has its period 40 and execution time 15. Please draw the scheduling results of (a) the Earliest Deadline First scheduling and (b) the Rate Monotonic Scheduling from time 0 to time 120. If there is any deadline missing, please point it out and stop the scheduling when it has the deadline missing.

Answer: (a)



(b)

Task P_3 misses its deadline at time 40.

9. (12%) Consider 4 tasks, t_1, t_2, t_3, and t_4 which have priorities x_1, x_2, x_3, and x_4, respectively, and assume $x_1>x_2>x_3>x_4$ (x_1 is the highest priority). After we profile the programs of the 4 tasks, we have the following information:

- Task t_1 will lock semaphore S_1 for 3 ms.
- Task t_2 will lock semaphore S_2 for 4 ms and lock semaphore S_1 for 5 ms.
- Task t_3 will lock semaphore S_2 for 9 ms and lock semaphore S_3 for 7 ms.
- Task t_4 will lock semaphore S_1 for 8 ms and lock semaphore S_3 for 10 ms.

Please derive the priority ceiling of each semaphore. If the Priority Ceiling Protocol (PCP) is used to manage the semaphore locking, please derive the worst-case blocking time of each task.

Answer: Priority Ceiling: S_1: x_1, S_2: x_2, S_3: x_3
Blocking Time: t_1: 8 ms, t_2: 9 ms, t_3: 10 ms, t_4: 0ms

10. (12%) A sporadic server has a replenishment period 5 and the maximum execution budget 2. Let the sporadic server have the budget 2 at time 0. Assume that events arrive at 1, 3, 6, 9, 11, and each event consumes the execution time 1. Please draw a diagram to show the changing of the execution budget from time 0 to time 20.

Answer: