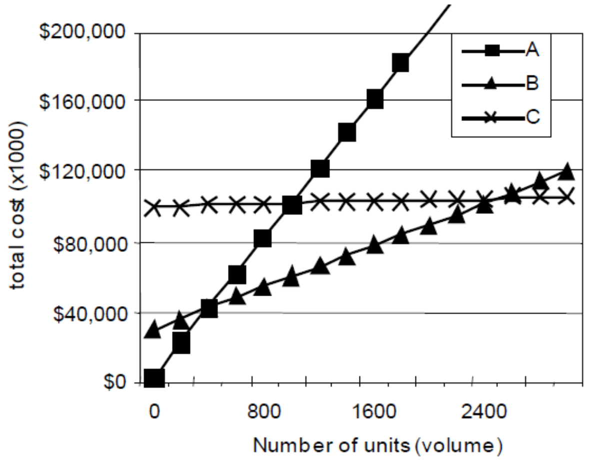
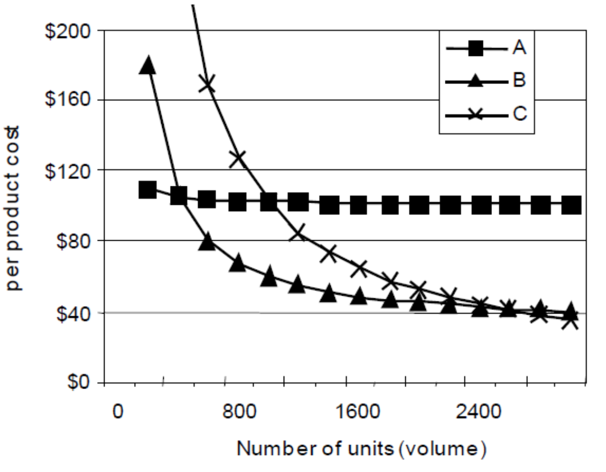
Embedded Operating System Midterm, Chang Gung University, Autumn 2023

Name: Student ID:

1. (10%) Please define the (a) (2%) Non-Recurring Engineering (NRE) Cost and (b) (2%) the Unit Cost for providing the final products. (c) (2%) In the following figures, which technology has the highest unit cost? (d) (4%) If we have a short-term project to provide less than 400 copies of a product, which technology should be better for the product development? Please provide the reason for the answer of question d.





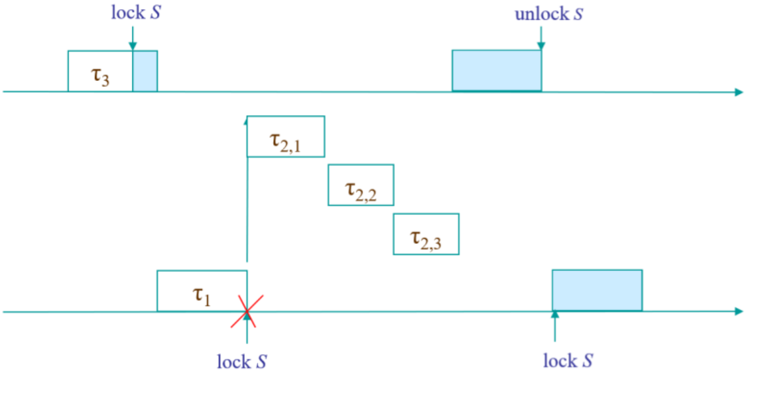
Answer: (a) Unit Cost: the monetary cost of manufacturing each copy of the system
(b) NRE Cost: the one-time monetary cost of designing the system
(c) Technology C
(d) Technology A. According to the figures, when the number of units is less than 400, Technology A has the lowest per product cost.

2. (10%) We have to download an executable image onto an embedded system before we run the executable image. During this process, we can use a scatter file to specify the load address and run address of each section in the executable image. Please define the (a) load address and (b) run address.

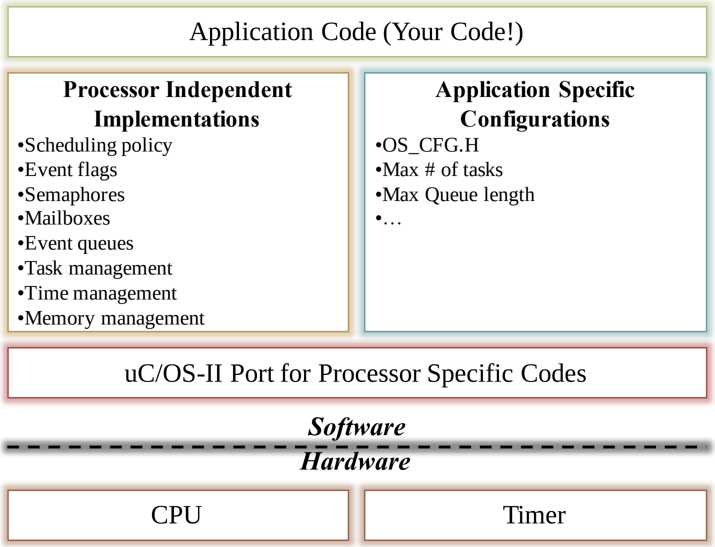
Answer: (a) Load address: the address in ROM or non-volatile storage for downloading the sections
(b) Run address: the location where the section is at the time of execution

3. (10%) (a) Please define Priority Inversion. (b) Please provide an example to illustrate Priority Inversion.

Answer: (a) A high-priority task is (indirectly) preempted by a low-priority task.
(b) When τ_1 is blocked by τ_3, and τ_3 is then preempted by middle priority tasks, there are priority inversions.



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.

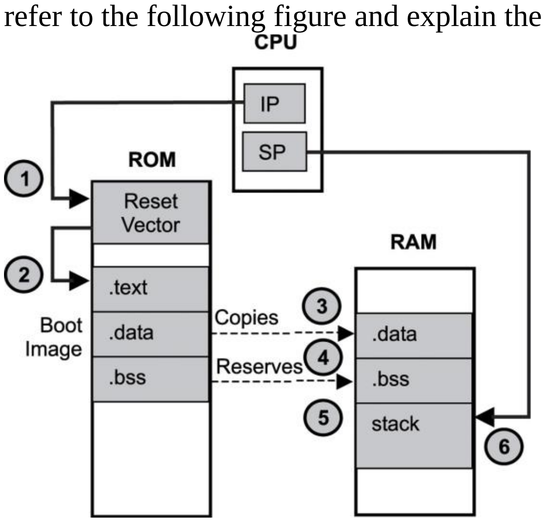
5. (10%) Please provide the definitions of (a) Dynamic Voltage and Frequency Scaling (DVFS) and (b) Dynamic Power Management (DPM).

Answer: (a) Scale down the voltage and/or frequency to reduce the processor power consumption.
(b) Change to an energy-efficient state to reduce the power consumption of peripheral devices.

6. (10%) 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 running an image on ROM directly and using data on RAM. Please refer to the following figure and explain the Steps 1 to 6.



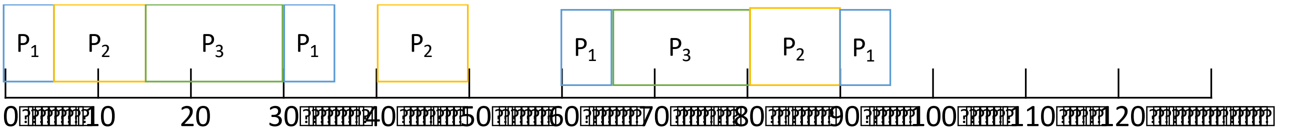
Answer:

1. The CPU's IP register is hardwired to execute the first instruction in memory, i.e., the reset vector
2. The reset vector jump 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

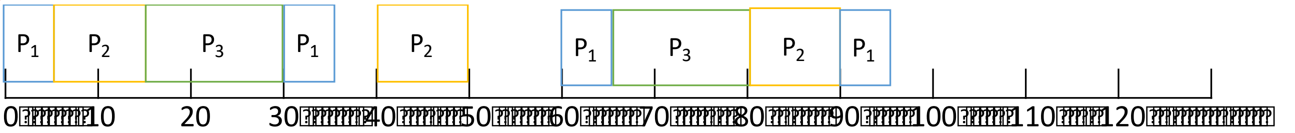
8. (12%) For three periodic tasks P_1, P_2 and P_3. P_1 has its period 30 and execution time 5. P_2 has its period 40 and execution time 10. P_3 has its period 60 and execution time 15. Please draw the scheduling results of (a) the Earliest Deadline First scheduling and (b) the Rate Monotonic Scheduling from time 0 to time 120.

Answer:

(a) EDF



(b) RM



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_3 for 5 ms.
- Task t_3 will lock semaphore S_2 for 9 ms and lock semaphore S_1 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_2

Blocking Time: t_1: 8 ms, t_2: 10 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: