Survey of software architectures: function-queue-scheduling architecture and real time OS

Reference: Simon chapter 5

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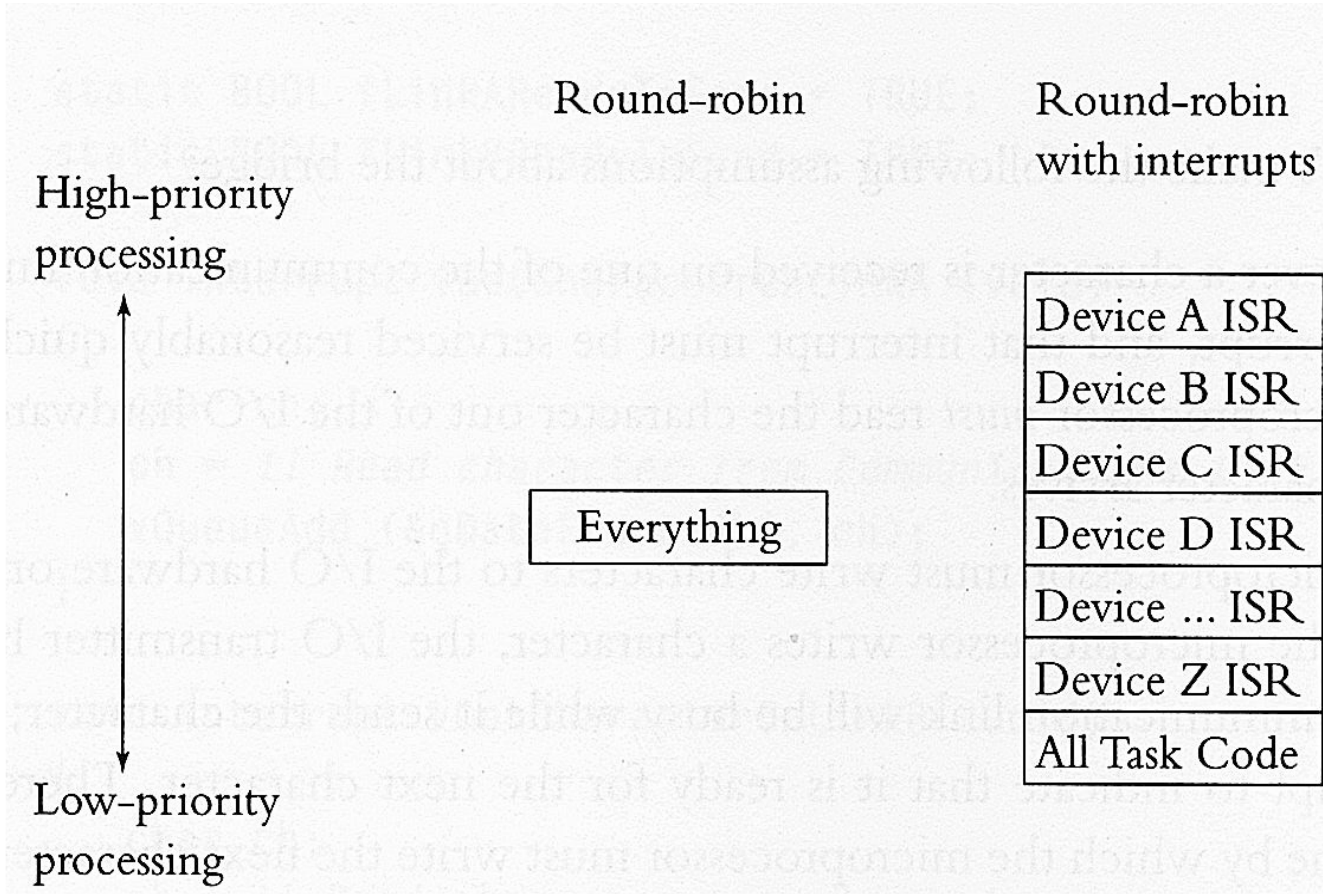
Last class: round robin with interrupts and without interrupts



Function-Queue-Scheduling Architecture

Function-Queue-Scheduling Architecture

- In this architecture, the interrupt routines add function pointers to a queue of function pointers for the main function to call.
- What makes this architecture worthwhile is that no rule says the main task code has to call the functions in the order that the interrupt occurred.
- It can call them based on any priority scheme of your choosing.
- Any task code functions that need quicker response can be executed earlier.
- All you need is some coding in the routines that queue up the function pointers.

Function Queue Schedule

```
!! Queue of function pointers;
void interrupt vHandleDeviceA (void)
{
  !! Take care of I/O Device A
  !! Put  function_A on queue of function pointers
}
void  interrupt vHandleDeviceB  (void)
{
  !! Take care of I/O Device B
  !! Put function_B on queue of function pointers
}

void function_A  (void) {
  !!  Handle actions required by device A
}

void function_B  (void)  {
  !! Handle actions required by device B
}

void main(void)
{
  while (TRUE)
  {
    while  (!!Queue of function pointers  is empty)
      !!  Call  first  function on queue
  } //end of while (TRUE)
} //end of void main()
```

- Every time there is an interrupt quickly collect all appropriate data

- ...And state that the appropriate data-handling function needs to be executed soon.

- This is done put putting a function pointer into a queue.

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Function Queue Schedule

```
!! Queue of function pointers;
void interrupt vHandleDeviceA (void)
{
  !! Take care of I/O Device A
  !! Put  function_A on queue of function pointers
}
void  interrupt vHandleDeviceB  (void)
{
  !! Take care of I/O Device B
  !! Put function_B on queue of function pointers
}

void function_A  (void) {
  !!  Handle actions required by device A
}

void function_B  (void)  {
  !! Handle actions required by device B
}

void main(void)
{
  while (TRUE)
  {
    while  (!!Queue of function pointers  is empty)
      !!  Call  first  function on queue
  } //end of while (TRUE)
} //end of void main()
```

- The main routine just reads pointers from the queue and calls the functions.

Function Queue Schedule

```
!! Queue of function pointers;
void interrupt vHandleDeviceA (void)
{
  !! Take care of I/O Device A
  !! Put  function_A on queue of function pointers
}
void  interrupt vHandleDeviceB  (void)
{
  !! Take care of I/O Device B
  !! Put function_B on queue of function pointers
}

void function_A  (void) {
  !!  Handle actions required by device A
}

void function_B  (void)  {
  !! Handle actions required by device B
}

void main(void)
{
  while (TRUE)
  {
    while  (!!Queue of function pointers  is empty)
      !!  Call  first  function on queue
  } //end of while (TRUE)
} //end of void main()
```

•If interrupt for device B was triggered first, then this function ought to be executed first.

Example

```
!! Queue of function pointers;
void interrupt vHandleDeviceA (void)
{
  !! Take care of I/O Device A
  !! Put  function_A on queue of function pointers
}
void  interrupt vHandleDeviceB  (void)
{
  !! Take care of I/O Device B
  !! Put function_B on queue of function pointers
}

void function_A  (void) {
  !!  Handle actions required by device A
}

void function_B  (void)  {
  !! Handle actions required by device B
}

void main(void)
{
  while (TRUE)
  {
    while  (!!Queue of function pointers  is empty)
      !!  Call  first  function on queue
  } //end of while (TRUE)
} //end of void main()
```

- While the code is here, Device A interrupts, then Device B interrupts.
- FunctionA and FunctionB are placed in the queue
- While code executes functionA, another interrupt occurs, for DeviceA.
- The code will finish functionA, then will do functionB and finally function A.

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Priorities

```
!! Queue of function pointers;
void interrupt vHandleDeviceA (void)
{
  !! Take care of I/O Device A
  !! Put  function_A on queue of function pointers
}
void  interrupt vHandleDeviceB  (void)
{
  !! Take care of I/O Device B
  !! Put function_B on queue of function pointers
}

void function_A  (void) {
  !!  Handle actions required by device A
}

void function_B  (void)  {
  !! Handle actions required by device B
}

void main(void)
{
  while (TRUE)
  {
    while  (!!Queue of function pointers  is empty)
      !!  Call  first  function on queue
  } //end of while (TRUE)
} //end of void main()
```

- You can call functions based on any priority scheme that suits your purposes.

- Any task code functions that need quicker response can be executed earlier.

- This looks like a good homework problem :)

Big advantage!

```
!! Queue of function pointers;
void interrupt vHandleDeviceA (void)
{
  !! Take care of I/O Device A
  !! Put  function_A on queue of function pointers
}
void  interrupt vHandleDeviceB  (void)
{
  !! Take care of I/O Device B
  !! Put function_B on queue of function pointers
}

void function_A  (void) {
  !!  Handle actions required by device A
}

void function_B  (void)  {
  !! Handle actions required by device B
}

void main(void)
{
  while (TRUE)
  {
    while  (!!Queue of function pointers  is empty)
      !!  Call  first  function on queue
  } //end of while (TRUE)
} //end of void main()
```

- Since the interrupt routines take very little time...

- You can have a lot of interrupts happening all at once and you will execute the same function sequentially multiple times!

Issues with function-queue-scheduling architectures

- In this architecture the worst wait for the highest-priority task code function is the length of the longest of the task code functions.

- This worst case happens if the longest task code function has just started when the interrupt for the highest-priority device occ

▸ This is because, the function that is being currently processed needs to finish first and only after this is done, the highest priority function in the queue can be executed.

- The et wor

- If one of the lower-priority task code functions is quite long, it will affect the response for the higher-priority functions.

Issues with function-queue-scheduling architectures

- In this architecture the worst wait for the highest-priority task code function is the length of the longest of the task code functions.

- This worst case happens if the longest task code function has just started when the interrupt for the highest-priority device occurs.

- The response for lower-priority task code functions may get w

- If ng, it w

▸ That's right... Since interrupts now only add functions to the queue (and don't execute them immediately), you need to wait until the current function that is being executed to end.

Issues with function-queue-scheduling architectures

- In this architecture the worst wait for the highest-priority task c le f

▸ Yes. If an higher priority interrupt keeps happening, then that particular function will always be the first in the queue to be processed.

- n has just started when the interrupt for the highest-priority device occurs.

- The response for lower-priority task code functions may get worse.

- If one of the lower-priority task code functions is quite long, it will affect the response for the higher-priority functions.

Issues with function-queue-scheduling architectures

- In this architecture the worst wait for the highest-priority task code function is the length of the longest of the task code functions.
- T ... has ju ... vice oc

▸Yes. If an lower priority function is (eventually) executed, and if its really slow... then the higher priority functions will have to wait until the slower function is done.

- The response for lower-priority task code functions may get worse.
- If one of the lower-priority task code functions is quite long, it will affect the response for the higher-priority functions.

Queues vs round robin

- Of course there are some trade-offs.
- In queues higher priority functions have better response, however lower priority functions will suffer.
- In round robin architectures, all functions will eventually be processed.
- With queues, there is an off change that all low priority functions will never be processed, if high priority interrupts keep happening.

Real-time operating system architecture

Real time architectures

```
void interrupt vHandleDeviceA  (void){
   !! Take care of I/O Device A
   !! Set signal X
}
void interrupt vHandleDeviceB  (void){
   !! Take care of I/O Device B
   !! Set signal  Y
}

void Task1 (void){
  while (TRUE){
      !! Wait  for Signal X
      !! Handle data to/from I/O Device A
    }
}
void Task2  (void){
  while  (TRUE){
      !! Wait for Signal  Y
      !! Handle data to/from I/O Device B
    }
}
```

- Today is just a brief introduction to real time architectures.
- We will be spending most of the next couple of weeks discussing this type of architecture in detail.
- Interrupt routines take care of the urgent operations.
- They then “signal” that there is work to be done in the task code.

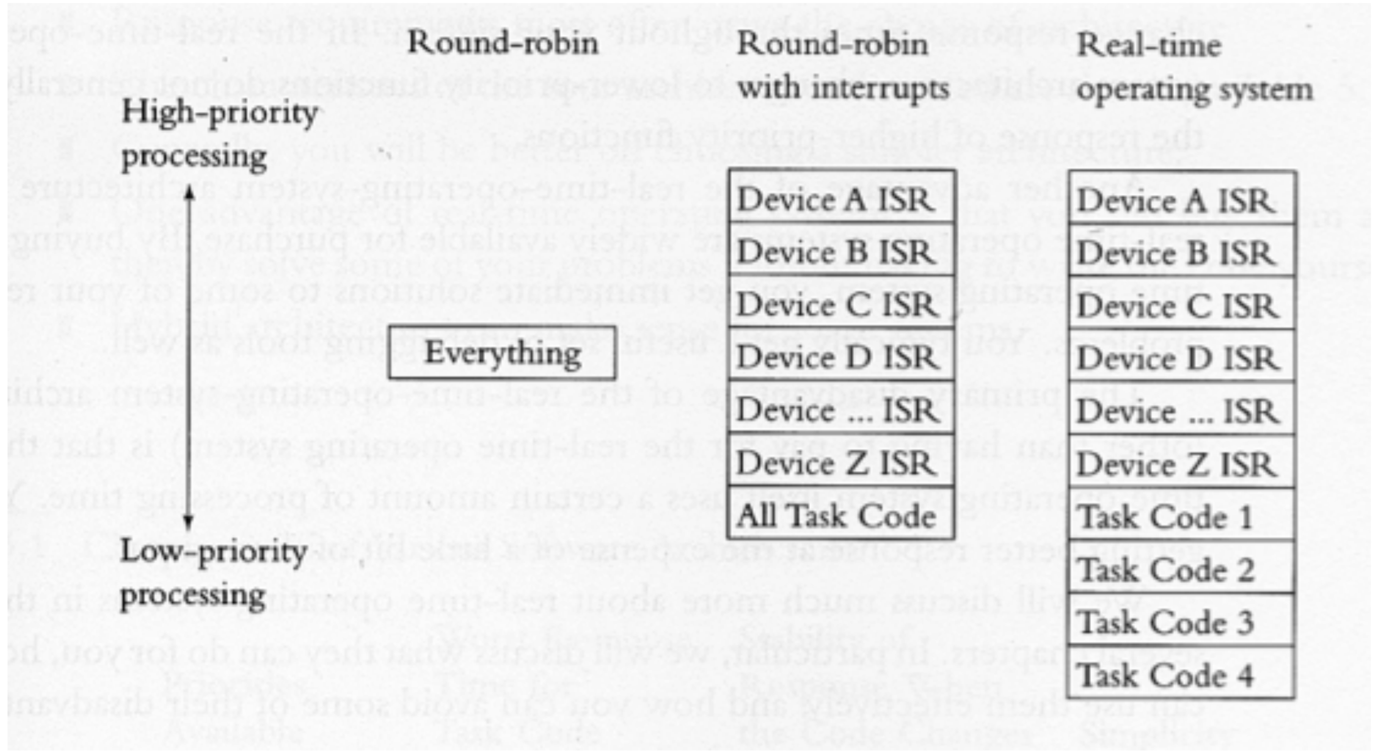
Basics of RTOS architectures

```
void interrupt vHandleDeviceA  (void){
   !! Take care of I/O Device A
   !! Set signal X
}
void interrupt vHandleDeviceB  (void){
   !! Take care of I/O Device B
   !! Set signal  Y
}

void Task1 (void){
  while (TRUE){
      !! Wait  for Signal X
      !! Handle data to/from I/O Device A
    }
}
void Task2  (void){
  while  (TRUE){
      !! Wait for Signal  Y
      !! Handle data to/from I/O Device B
    }
}
```

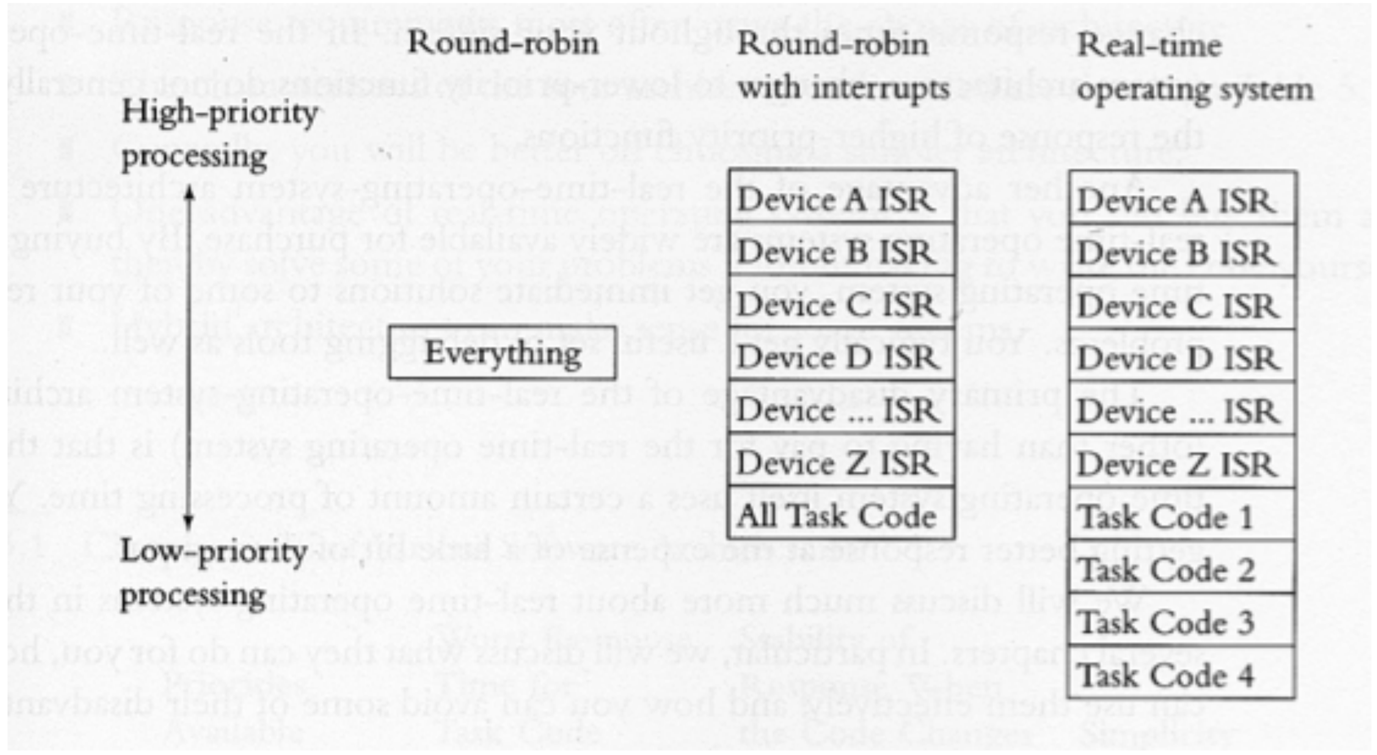
- The necessary signaling between the interrupt routines and the task code is handled by the real time operating system (RTOS).
- The RTOS code is not outlined in the code.
- We do **NOT** need shared variables for this.
- No loop in the code decides what to do next. The RTOS also decides what tasks run next.

Basics of RTOS architectures



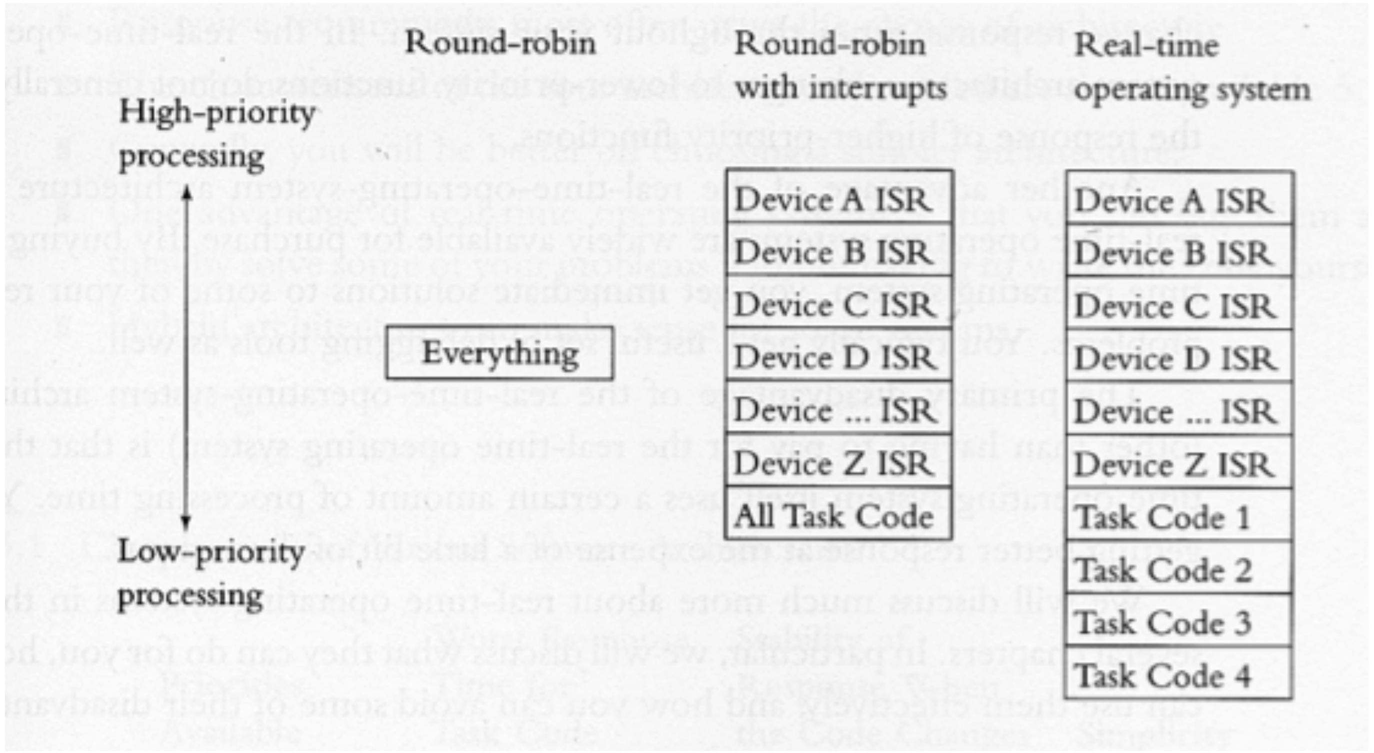
- The RTOS can suspend one task subroutine in the middle of processing in order to run another.
- If Task1 is the highest priority task, then when the vHandleDeviceA interrupt occurs, this task will be done immediately.
- The worst-case wait scenario for Task1 is then zero (plus the interrupt handling times).

Side effect #1 of RTOS architectures: stable response



- The system response is very stable, even when we change the code.
- In round robin architectures and queues, the response time depends on the various task code subroutines (even the lowest priority ones).
- In RTOS architectures, changing the low priority functions, does not affect high-priority functions.

Side effect #2 of RTOS architectures: widely available for purchase



- RTOS are so important and useful that there are several companies that specialize in selling the operating system for each architecture.
- ChibiOS/RT, FreeRTOS, MicroC/OS, Salvo
- Some are even compatible with the Atmel ATmega chips!
- For example, visit the <u>FreeRTOS website</u>.

Disadvantages of RTOS architectures

```
void interrupt vHandleDeviceA  (void){
   !! Take care of I/O Device A
   !! Set signal X
}
void interrupt vHandleDeviceB  (void){
   !! Take care of I/O Device B
   !! Set signal  Y
}

void Task1 (void){
  while (TRUE){
      !! Wait  for Signal X
      !! Handle data to/from I/O Device A
    }
}
void Task2  (void){
  while  (TRUE){
      !! Wait for Signal  Y
      !! Handle data to/from I/O Device B
    }
}
```

- The RTOS itself uses a certain amount of processing time.
- The RTOS requires storage space... and in embedded systems space is very sparse.

Summary of software architectures

Which architecture should you use?

- Select the simplest architecture that will meet your response requirements.
- If your system has response requirements that might necessitate using a real-time operating system, then use a real-time operating system.
- If it makes sense, you can even create hybrids architectures (e.g. round-robin with scheduling working side by side a RTOS).

	Priorities available	Worst time response for task code	Stability of response when code changes	Simplicity
Round-robin	None.	Sum of all task code.	Poor.	Very simple.
Round-robin with interrupts	Interrupt routines in priority order, then all task code with the same priority.	Total of execution time for all task code (plus execution time for interrupt routines).	Good for interrupt routines. Poor for task code.	Must deal with shared data problems between interrupt routines and task code.
Function queue-scheduling	Interrupt routines in priority order, then all task code in priority order.	Execution time for the longest function (plus execution time for interrupt routines).	Relatively good.	Must deal with shared data and must write function queue code.
Real time operating system	Interrupt routines in priority order, then all task code in priority order.	Zero (plus execution time for interrupt routines).	Very good.	Most complex (although much of the complexity is in the operating system itself).