CS 5372
Specification and Design of Real-Time Systems

Lecture 5: Real Time Messages

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Outline

- Quiz (10 min)
- Groups Presentations (45)
- Lecture: RT Messages (45)
- Lab exercise – Messages and Pipes (60)
- Exam 1: Discussion

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Quiz

Message Based Communication

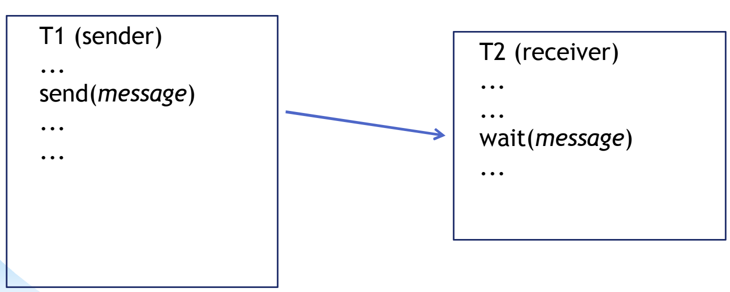
- The message-driven approach is used both for synchronization and communication
- It uses single construct ***message***
- Theoretical issues:
  - synchronization model
  - process naming method
  - message structure

Process Synchronization Models

- **Asynchronous** - the sender proceeds immediately regardless whether the message was received or not (no-wait)
- **Synchronous** - the sender proceeds only if the message has been received
- **Remote Invocation** - the sender proceeds only when a reply has been returned from receiver

Asynchronous Message Passing

- Task T1 sends the *message* and continues
- Task T2 waits for the *message*



Synchronous Message Passing

- synchronous message passing is implemented using asynchronous primitives (the sender waits for confirmation/acknowledgement)

  send(M)/wait(A) => synchr send(M)

  wait(M)/send(A) => synchr_wait(M)

T1 (sender)
…
send(*message*)
wait(acknowledgment)

…

T2 (receiver)
…
…
wait(*message*)
send(acknowledgment)
…

Remote Invocation

- Implemented with double “hand-shaking”
- T2, after receiving the *message*, constructs and sends *reply* (synchronously)
- T1 waits for the *reply* before proceeding

T1 (sender)
…
send(*message*)
Synchr_wait(reply)

…

T2 (receiver)
…
…
wait(*message*)
{construct reply}
Synchr_send(reply)
…

Issues and Message Structure

- Asynchronous model is most flexible as it can implement the other two
  - Potential problems:
    - large buffer size required for the messages not read
    - “out of date” syndrome
- Asynchronous communication can be implemented by a synchronous model using intermediary buffer
- Message Structure:
  - Any data object defined by language should be allowed to be sent as the message
  - Message passing may be difficult
    - when sender and receiver have data objects represented in different formats
    - when using pointers to the data
  - Unit of messages are bytes

Process Naming

- **Direction:**
  - **Direct** naming scheme - sender explicitly names the receiver:

    send <*msg*> **to** <*process_name*>
  - **Indirect** naming scheme - sender names intermediate entity (channel, mailbox, pipe, queue):

    send <*msg*> **to** <*mailbox*>

- **Symmetry:**
  - **Symmetric** naming scheme - sender and receiver name each other:

    send <*msg*> **to** <*process*/*mailbox*>

    wait <*msg*> **from** <*process*/*mailbox*>

  - **Asymmetric** naming scheme - receiver waits for message regardless what process sends it:

    wait <*msg*>

Message Queue

- To facilitate inter-task communication, kernels provide a message queue object and message queue management service
- A message queue is a buffer-like object through which tasks and ISRs send and receive messages to communicate and synchronize.
- It decouples tasks operation with respect to sending and receiving messages

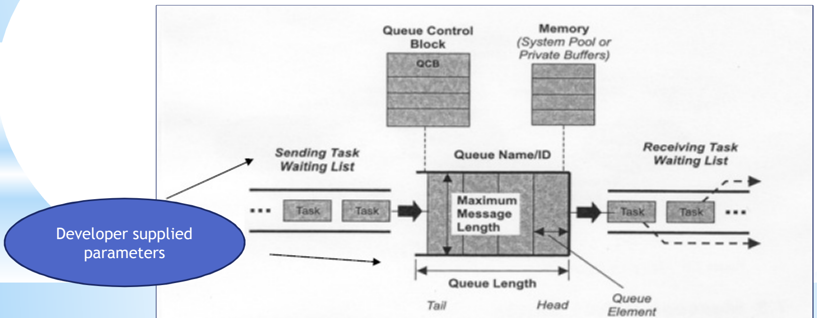


Figure 7.1 A message queue, its associated parameters, and supporting data structures.

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Message Queue States

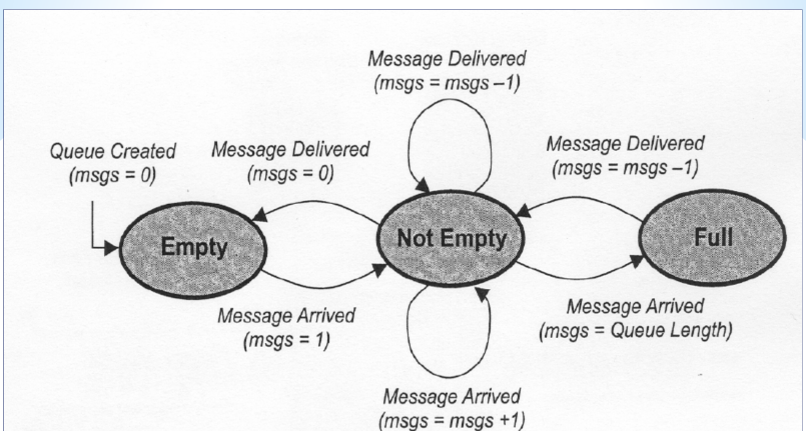

Figure 7.2 The state diagram for a message queue.

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Message Queue Content

- Messages can be sent by content or by pointer
- Normally message is copied twice (memory usage)

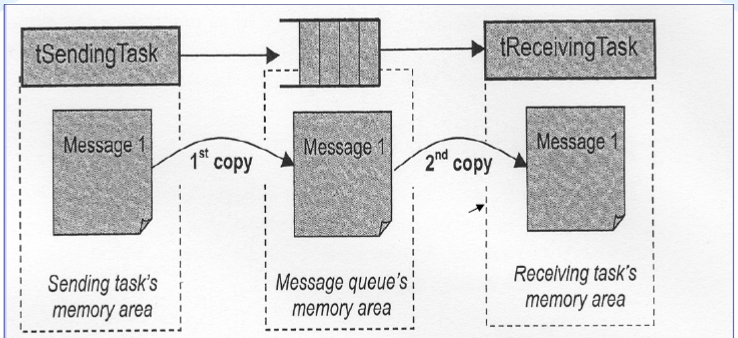

Figure 7.3 Message copying and memory use for sending and receiving messages.

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Message Queue storage

- **System Pools**
  - Message of all queues have common memory area
  - Usually saves on memory use
  - Message queue with large message can use most of the pool and leave little memory for others
- **Private Buffers**
  - Requires enough memory for full capacity of every message queue that will be created
  - Uses up more memory
  - Better reliability than memory pool

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Message Queue Operations

- Creating and deleting
  - Global objects
  - The queue to be used by a group of tasks or ISRs are decided in the design
  - Length of the queue, max size of the message, and wait order is assigned by the developer
  - Messages in the queue are lost when queue is deleted

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Message Queue Operations: Sending

- Kernel typically fills a message queue in FIFO or priority order
- With RTOS options, urgent messages will go straight to the head of the queue
- Many implementation allows ISRs to send message to queue. ISRs cannot block, if message queue is full, error might be returned
- Messages are sent to message queue in the following ways
  - Not block (ISR and task)
  - Block with a timeout (task only)
  - Block forever (task only)

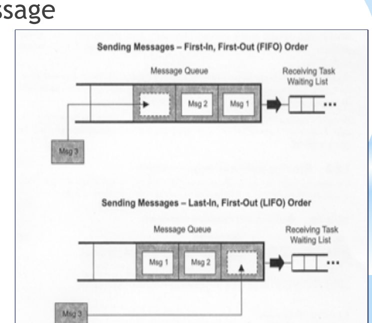

Figure 7.4 Sending messages in FIFO or LIFO order.

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Message Queue Operations: Receiving

- Messages are received from message queue in the following ways
  - Not block (ISR and task)
  - Block with timeout (task only)
  - Block forever (task only)

- Messages could be read from the queue in the following ways
  - Destructive (message gets removed after read).
  - Non-destructive (message does not get removed after read)

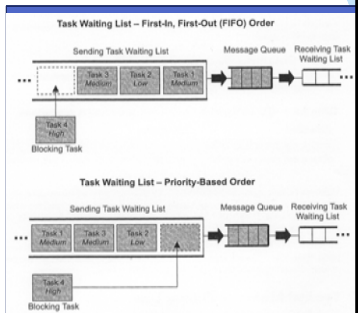

Figure 7.5 FIFO and priority-based task-waiting lists.

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Typical Message Queue Use

Figure 7.6 Non-interlocked, one-way data communication.

- Non-interlocked, one-way data communication
  - Simple, activities of sending task and receiving task is not synchronized, no acknowledgement required from receiving task, ISR use this type (should not block)

- Interlocked, one-way data communication
  - Sending task requires an acknowledgement from the receiving task
  - Reliable mechanism for task communication

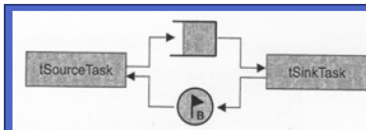

Figure 7.7 Interlocked, one-way data communication.

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Typical Message Queue Use

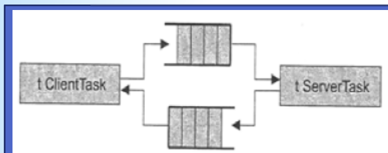

Figure 7.8 Interlocked, two-way data communication.

- Interlocked, two-way data communication
  - Full duplex or tightly coupled communication
  - Bi-directional communication (client-server)
  - Two message queues are required

- Broadcast communication
  - Send a copy of the same message to multiple tasks
  - One-to-many-tasks

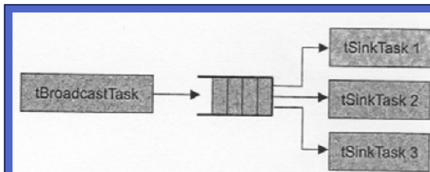

Figure 7.9 Broadcasting messages.

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VxWorks Message Queue (1)

- VxWorks message queues are the primary inter-task communication mechanism with a single CPU
- WxWorks message queues enable tasks to exchange information in a flexible, secure, formal, and efficient manner.
- Message queues allow a variable number of messages, each of variable length, to be queued
- RTOS provides routines for message queue control (defined in *msgQLib.h*):
  - (*http://www.vxdev.com/docs/vx55man/vxworks/ref/msgQLib.html*)
    - *msgQCreate(),*
    - *msgQDelete(),*
    - *msgQSend(),*
    - *msgQReceive()*
  - Options used include:
    - *MSG_Q_FIFO,*
    - *MSG_Q_PRIORITY,*
    - *NO_WAIT,*
    - *WAIT_FOREVER,*
    - *MSG_PRI_URGENT,*
    - *MSG_PRI_NORMAL,*
    - …
    - *etc.*

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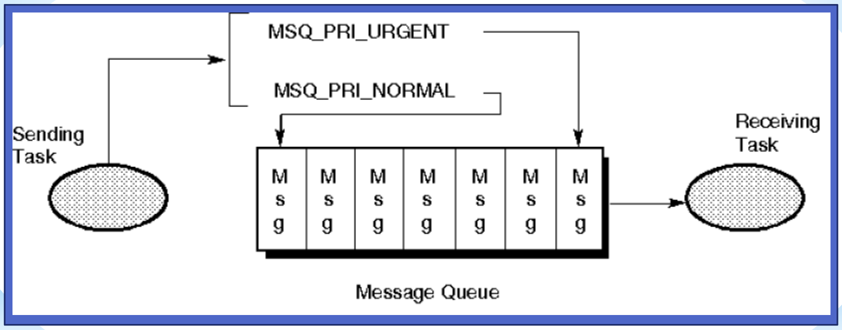
VxWorks Message Queue (2)

- Message is placed in the queue according to the priority



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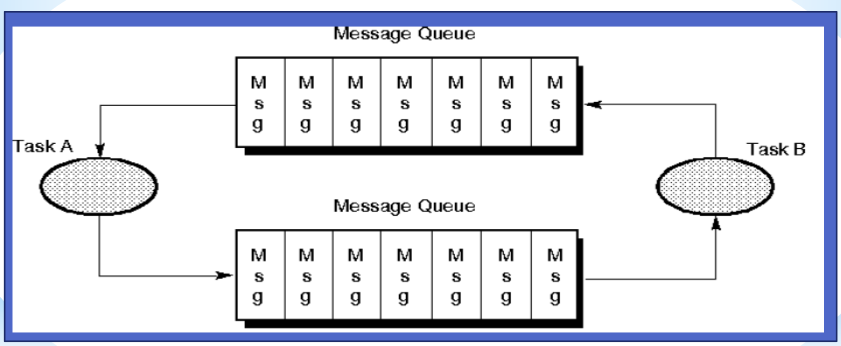
VxWorks Message Queue (3)

- Full-Duplex Communication



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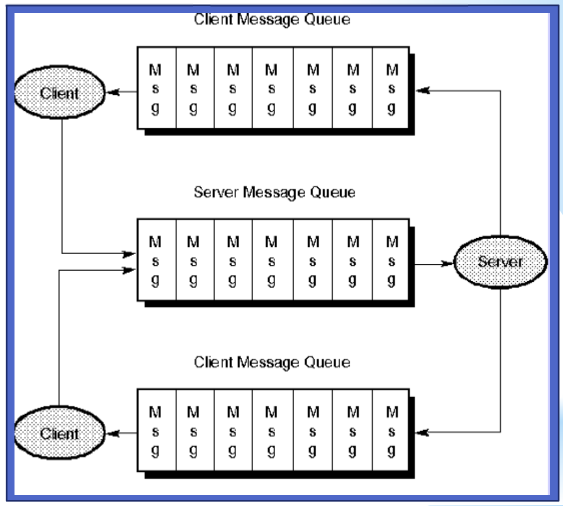
VxWorks Message Queue (4)

- Client-Server



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Example: experiment with VxWorks MQ
In Group

- create message queue (up to ten, length 100 bytes, priority):
  mQ = msgQCreate (10, 100, 1)
- create a string:
  str = "my message\n"
- write to the queue (NO_WAIT, MSG_PRI_NORMAL):
  msgQSend mQ, str, strlen(str)+1, 0, 0
- create an empty buffer:
  buffer = calloc(20, 1)
- read it back from the queue (No_WAIT):
  msgQReceive mQ, buffer, 20, 0
- check the results:
  printf buffer

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vxWorks Pipes

- Virtual I/O device managed in pipeDev
- Built on top of vxWorks message queues
- Standard I/O system interface (read/write)
- Similar to named pipes in UNIX (UNIX host)

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Creating a Pipe

- **STATUS pipeDevCreate (name, nMessages, nBytes)**
  - name   Name of pipe device. By convention use “pipe/yourName”
  - nMessages max number if messages in pipe
  - nBytes   max size of bytes in each message

- Returns OK if successful, ERROR otherwise

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Example Pipe Creation

```
-> pipeDevCreate ("/pipe/myPipe", 10, 100)
Value = 0 = 0x0

-> devs

drv      name
  0      /null
  1      /tyCo/0
  1      /tyCo/1
  4      columbia
  2      /pipe/myPipe
Value = 0 = 0x0
```

- devs() command displays available device list
- drv column indicates the number of driver managing the device

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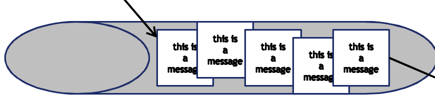
Reading/Writing to a Pipe

http://www.vxdev.com/docs/vx55man/vxworks/ref/pipeDrv.html

- To access an existing pipe, first open it with open()
- read(): pends if pipe is empty
- write(): pends if pipe is full
- close()

```
fd = open ("pipe/myPipe", O_RDWR, 0);
write (fd, msg, len)
```



```
read (fd, msg, len)
close (fd);
```

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Queues vs. Pipes

- Message Queues Adv:
  - Timeout capable
  - Message prioritization
  - Faster
  - show()
- Pipes Adv:
  - Use standard I/O interface (open(), close(), read(), write())
  - Can perform redirection via ioTaskStdSet()
  - Allows tasks to wait for data on a combination if several pipes, sockets, or serial devices
- Both maybe written to/from an ISR

Queues and Pipes in-class lab