EE4800-03
Embedded Systems Design

Lessons 19 - 22

Real Time Operating Systems

Overview

- RTOS Concepts
- Data structures
- Dynamic memory allocation
- Task and Task Control Blocks
- RTOS tracking mechanisms
- RTOS scheduling algorithms
- RTOS issues

RTOS Concepts

- A parable - waitron
- What is RTOS?
  - Multiple events handled by a single processor
  - Events may occur simultaneously
  - Processor must handle multiple, often competing events
  - Wide range of RTOS systems
    - Simple polling through multiple interrupt driven systems

RTOS Concepts

- Each system activity designated as Task
- RTOS is a multitasking system where multiple tasks run concurrently
  - system shifts from task to task
  - must remember key registers of each task
    - called its context

RTOS Concepts

- RTOS subdivided into categories based on the criticality of meeting time constraints:
  - Hard Real Time System: failure to meet time constraints leads to system failure
  - Firm Real Time System: low occurrence of missing a deadline can be tolerated
  - Soft Real Time System: performance is degraded by failure to meet time constraints

RTOS Concepts

- RTOS responsible for all activities related to a task:
  - scheduling and dispatching
  - intertask communication
  - memory system management
  - input/output system management
  - timing
  - error management
  - message management

Dynamic Memory Allocation

- RTOS uses abstract data types such as record, linked list, and queue
- These data types normally use RAM dynamic memory allocation techniques
- Data structures are created (allocated) on the fly during program execution and destroyed when no longer needed
  - Requires large RAM memory

Dynamic Memory Allocation

- Memory allocation command   malloc( ) used in conjunction with size of ( )

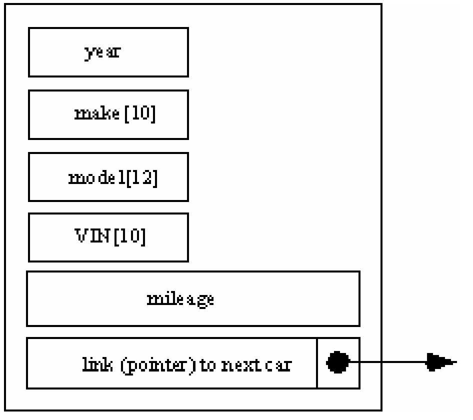
ptr = (variable_type *) malloc(sizeof (variable_type));

- Memory returned to system when no longer needed using free( ) command
- Heap is portion of memory used for dynamic memory allocation
- Must allocate separate RAM spaces for the Heap as well as the Stack

Data Structures - Record

- Record/Structure
  - Custom design a data type
  - Related information but of different data types

```
struct car
{
int  year;                  /*year of manufacture                 */
char make[10];              /*BWM, Hummer, Saturn                 */
char model[12];             /*coupe, convertible, SUV, pickup     */
char VIN[10];               /*combination of numbers, characters  */
float mileage;              /*odometer reading: 0 to 500,000+     */
struct car *next;           /*pointer to next car in list         */
};
                            /*typedef provides compiler an alternate */
typedef   struct car  ELEMENT;     /*for a variable type          */
typedef   ELEMENT  *car_temp_ptr;  /*defines pointer to car       */
```



Data Structures - Record

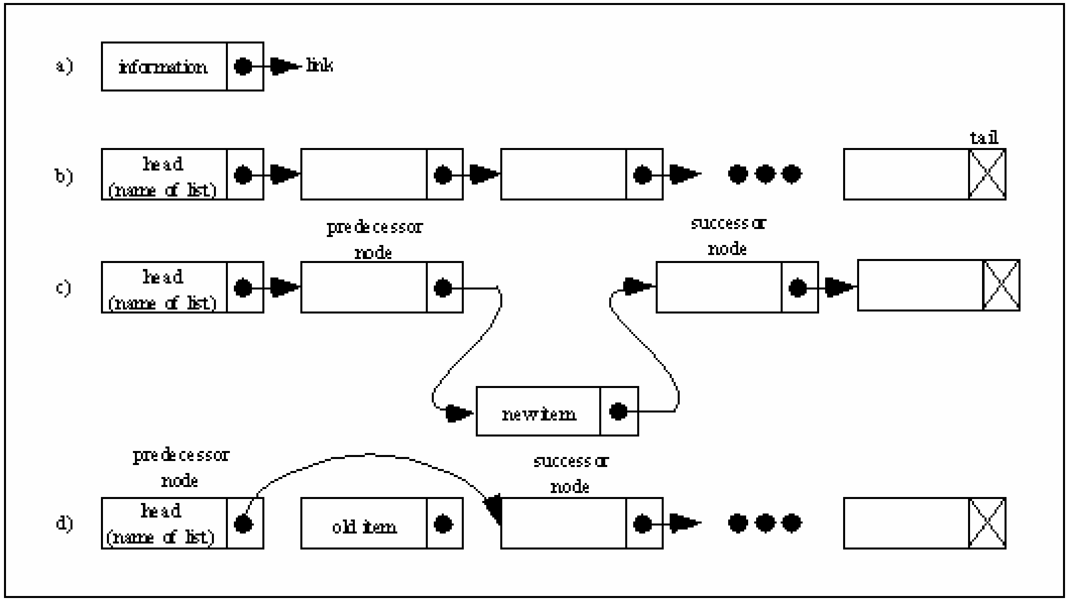
- To create (allocate) a record during program execution:

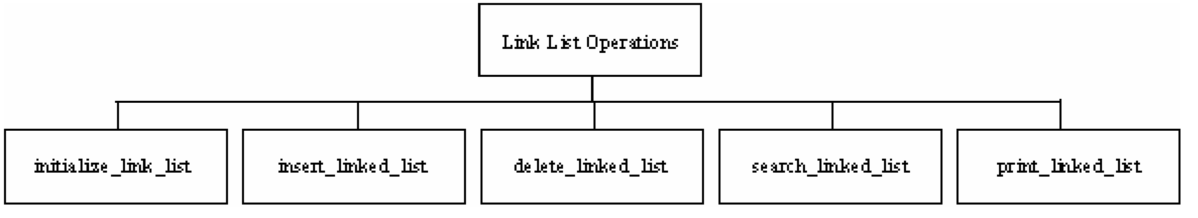
```
car_temp_ptr     new_car-entry;
new_car_entry = (car_temp_ptr) malloc(sizeof(ELEMENT));
```

Data Structures - Linked List

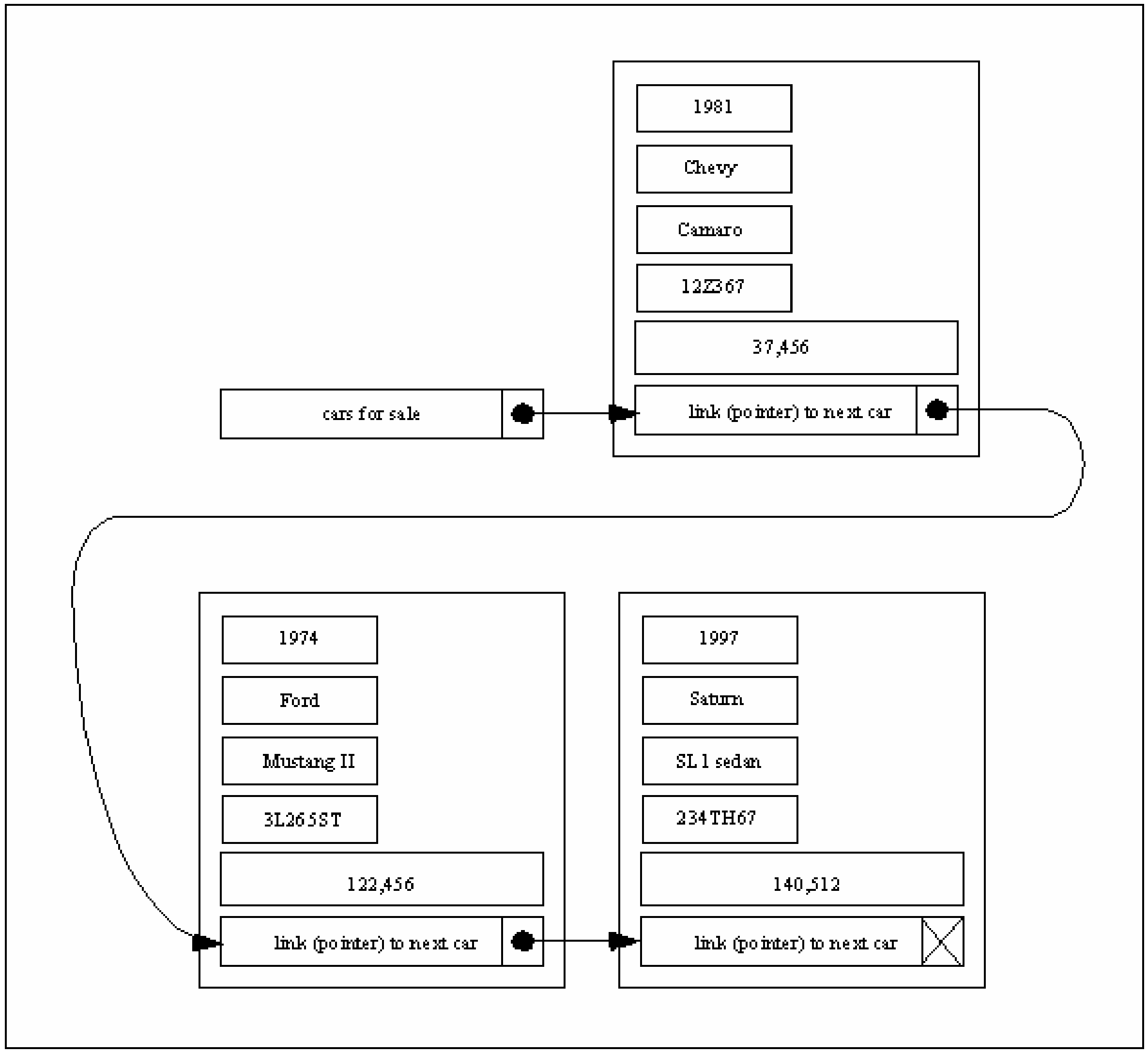
- Linked list consists of a node with two parts:
  - data portion: information about node
  - link field: pointer (address) to the next node in list
- Beginning of list called head
- End of list called tail
  - contains null character in link field

Data Structures - Linked List



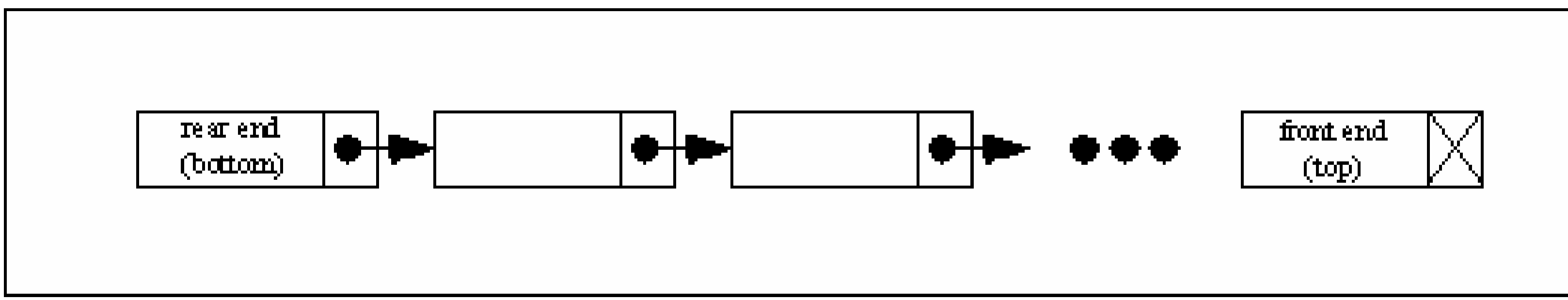


Data Structures - Linked List

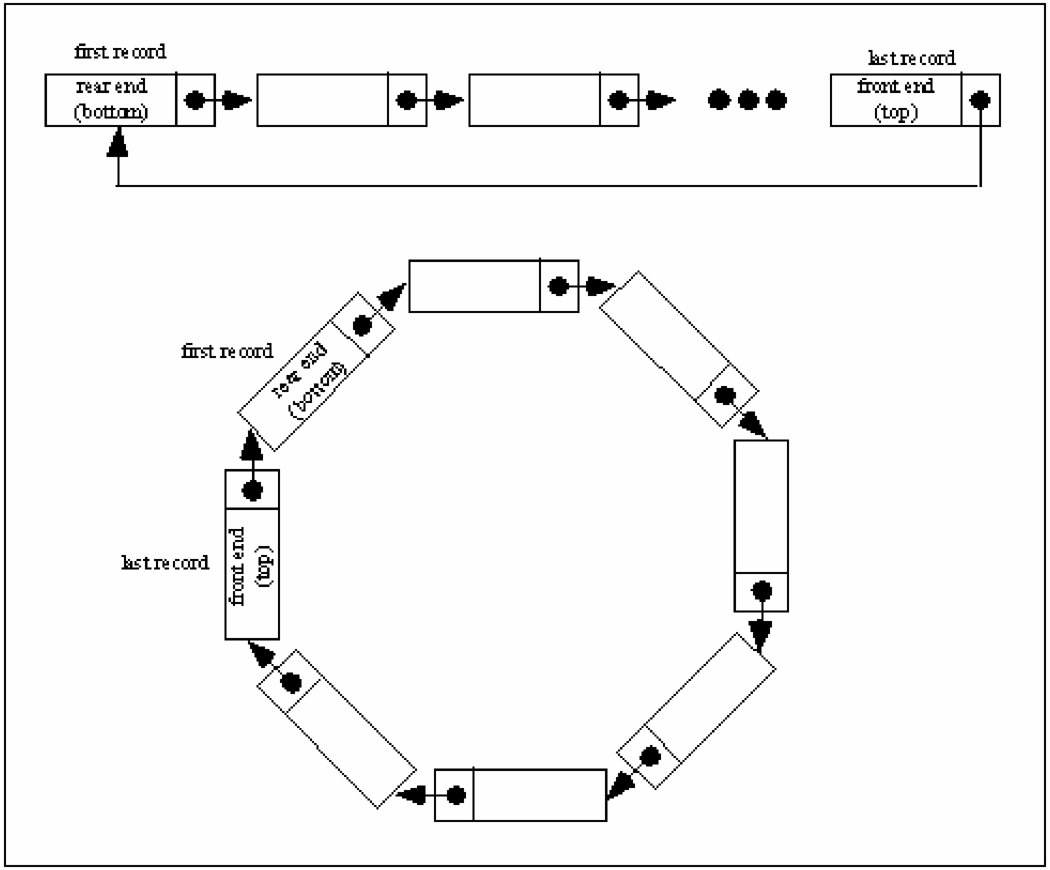


Data Structures - Queue

- Specially configured linked list
- First-in-first-out (FIFO) buffer
- Elements added to rear
- Elements extracted from front
- Queue length variable dependent upon system activity

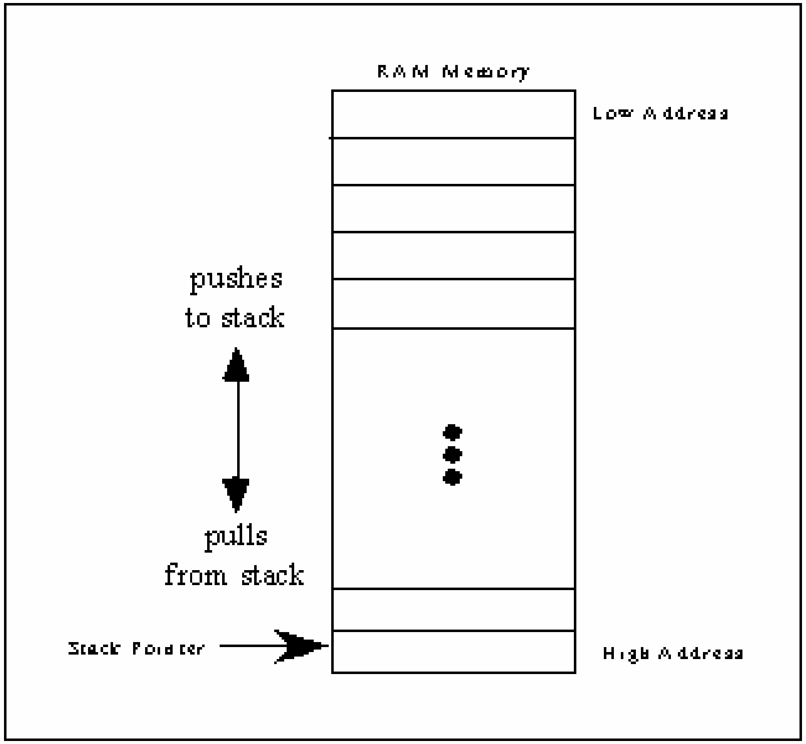


Data Structures - Circular Queue

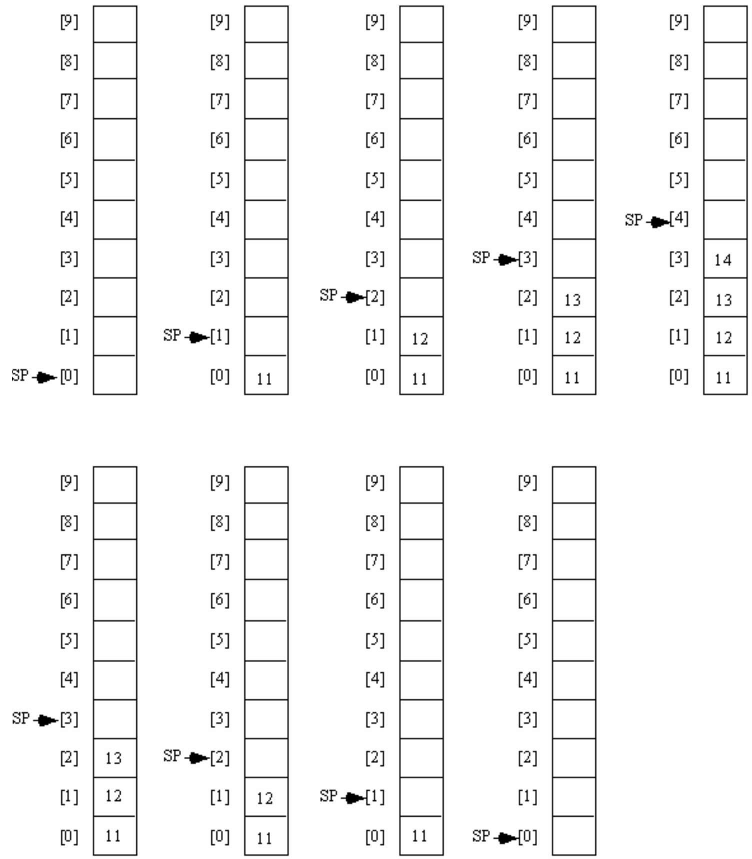


Data Structures - The Stack

- Last-in-first-out (LIFO) data structure
- RTOS requires multiple stacks - one for each task
- Stack operations
  - initialize
  - push
  - pull
  - stack_empty
  - stack_full
  - print_stack



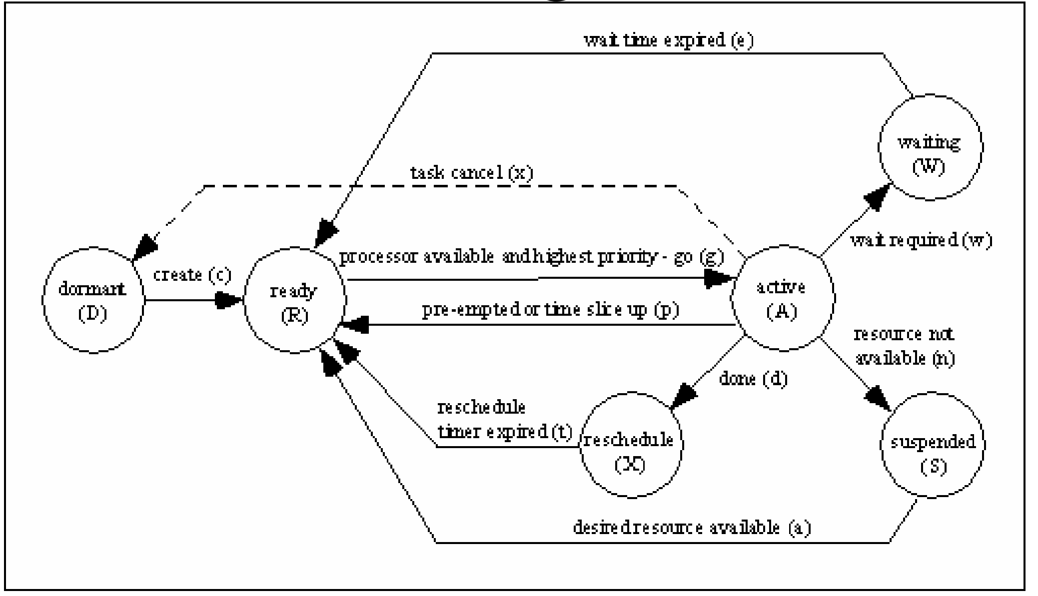
Data Structures - The Stack



Task and Task Control Blocks

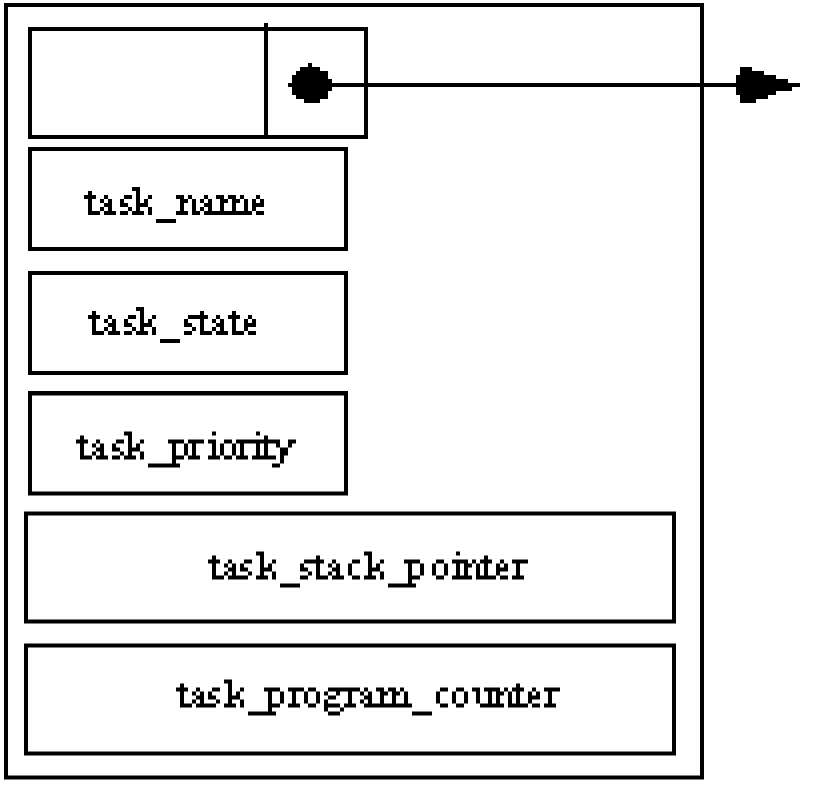
- In RTOS program consists of independent, asynchronous, and interacting tasks
- All tasks are competing for precious processing time
- Task: independent, asynchronous activities
  - small independent program that completes a specific activity
  - Must have capability to store task context

Controlling a Task



- Dormant - task has no need for computer time
- Ready - task is ready to go active, waiting processor time
- Active - task is executing associated activities
- Waiting - task put on temporary hold to allow lower priority task chance to execute
- Suspended - task is waiting for resource
- Resceduled - task is complete, need not be repeated right away

Task Control Block (TCB)



- Task uses TCB to remember its context
- RTOS updates TCB when task is switched

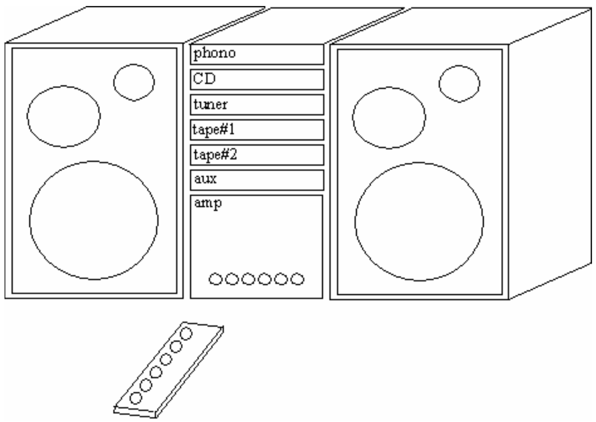
Multitasking System Components - RTOS Tracking Mechanisms

- Task Control Block (TCB)
  - track individual task status
- Device Control Block (DCB)
  - tracks status of system associated devices
- Dispatcher/Scheduler
  - primary function is to determine which task executes next

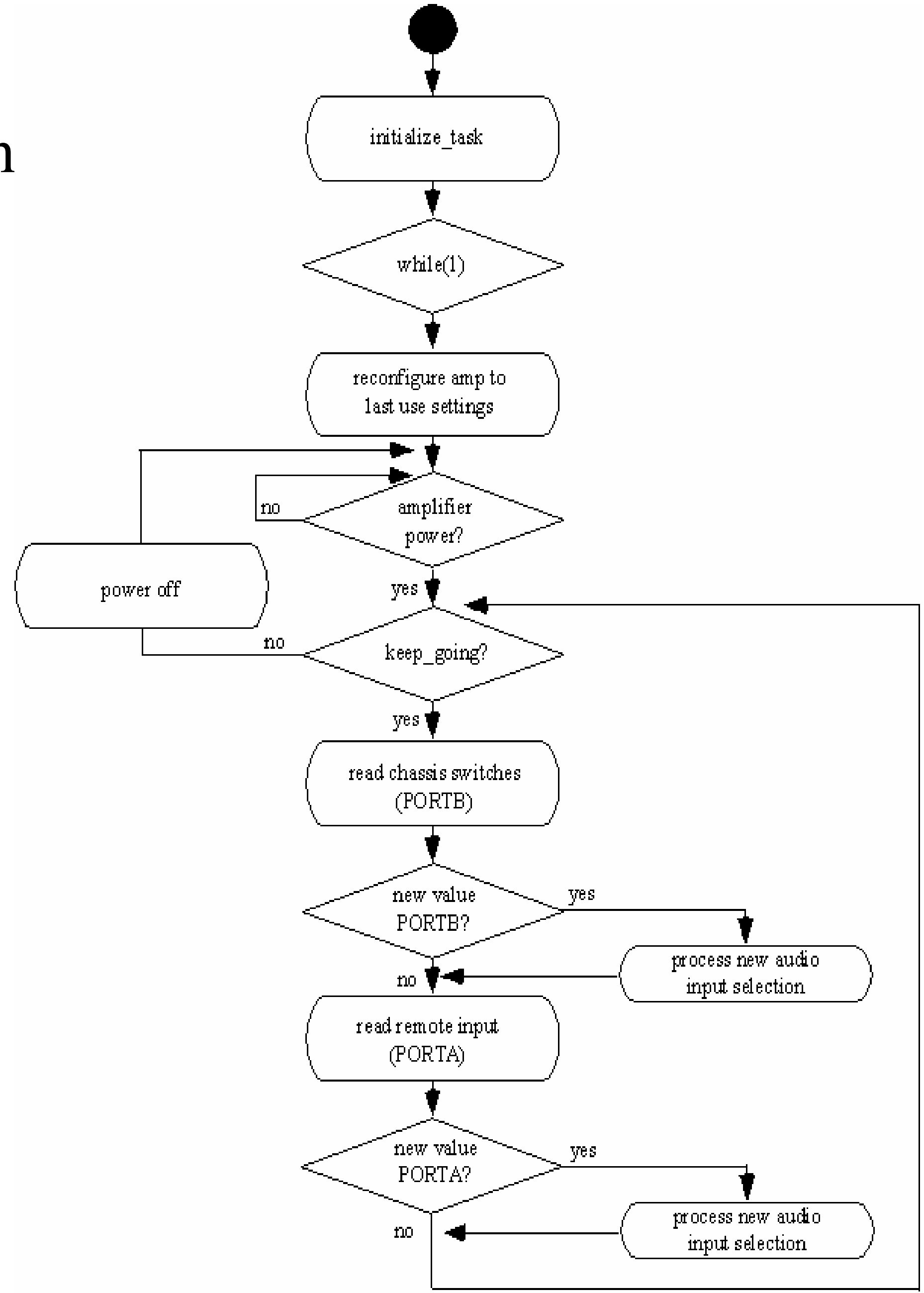
RTOS Scheduling Algorithms
Polled Loop System

- Sequentially determines is specific task requires processor time
- When task associated actions are complete, operating system continues polling for tasks requiring operating time
- Simple, easy to write and debug
- Can not handle burst of events, multiple tasks occurring simultaneously

RTOS Scheduling Algorithm
Polled Loop System

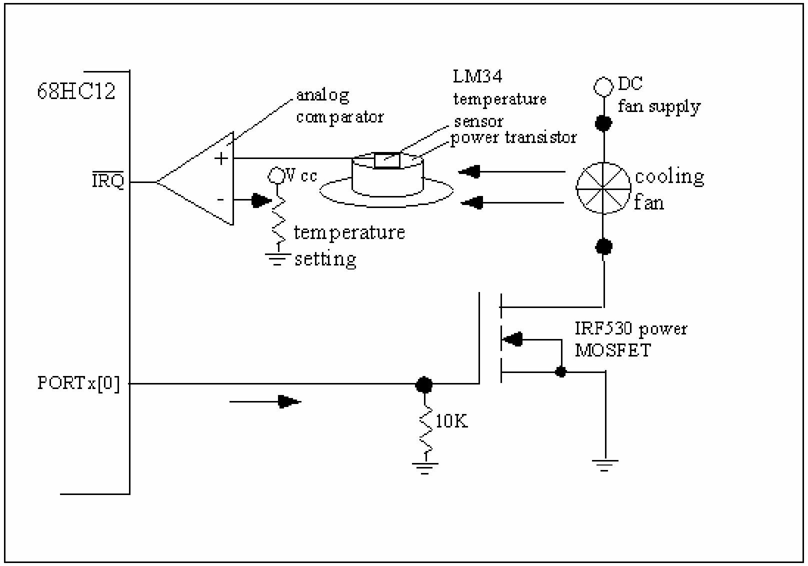


- System sequentially polls remote and front panel for switch activation
- Completes selected task



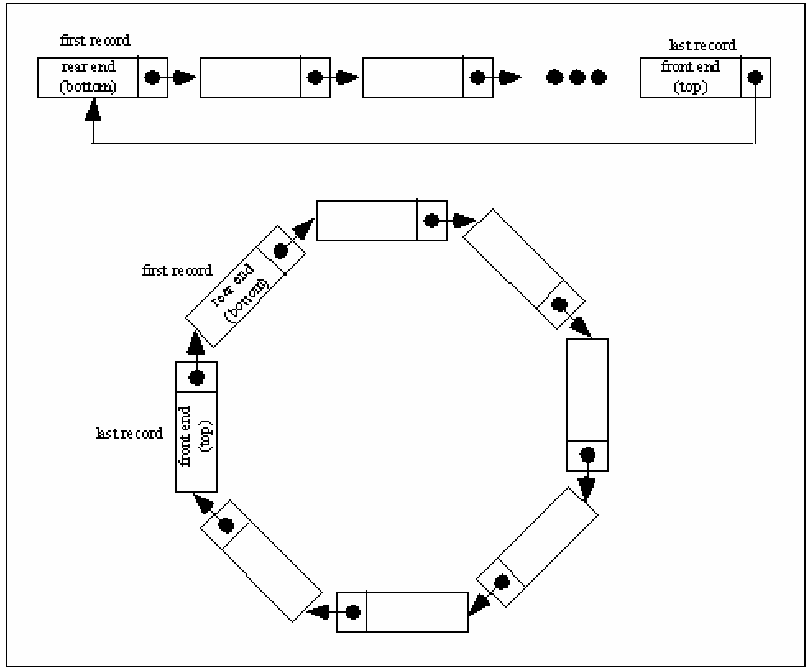
RTOS Scheduling Algorithms
Polled Loop System w/interrupts

- Polling system good fit; however, several time sensitive critical tasks exists
- Example: transistor amplifier overheat
  - employ interrupts



RTOS Scheduling Algorithms
Round-robin System

- Sequences from task to task
- Tasks may run to completion or time-slicing techniques may be used
  - Time-slicing: each task has fixed amount of processor time allocated
- Used for equal priority tasks
- Example: missile patch



RTOS Scheduling Algorithms
Hybrid Systems

- Round-robin scheduling equipped with interrupts
  - Background: round-robin scheduler
  - Foreground: higher priority interrupts
- Example: missile patch with flooded launch tube, fire, etc.

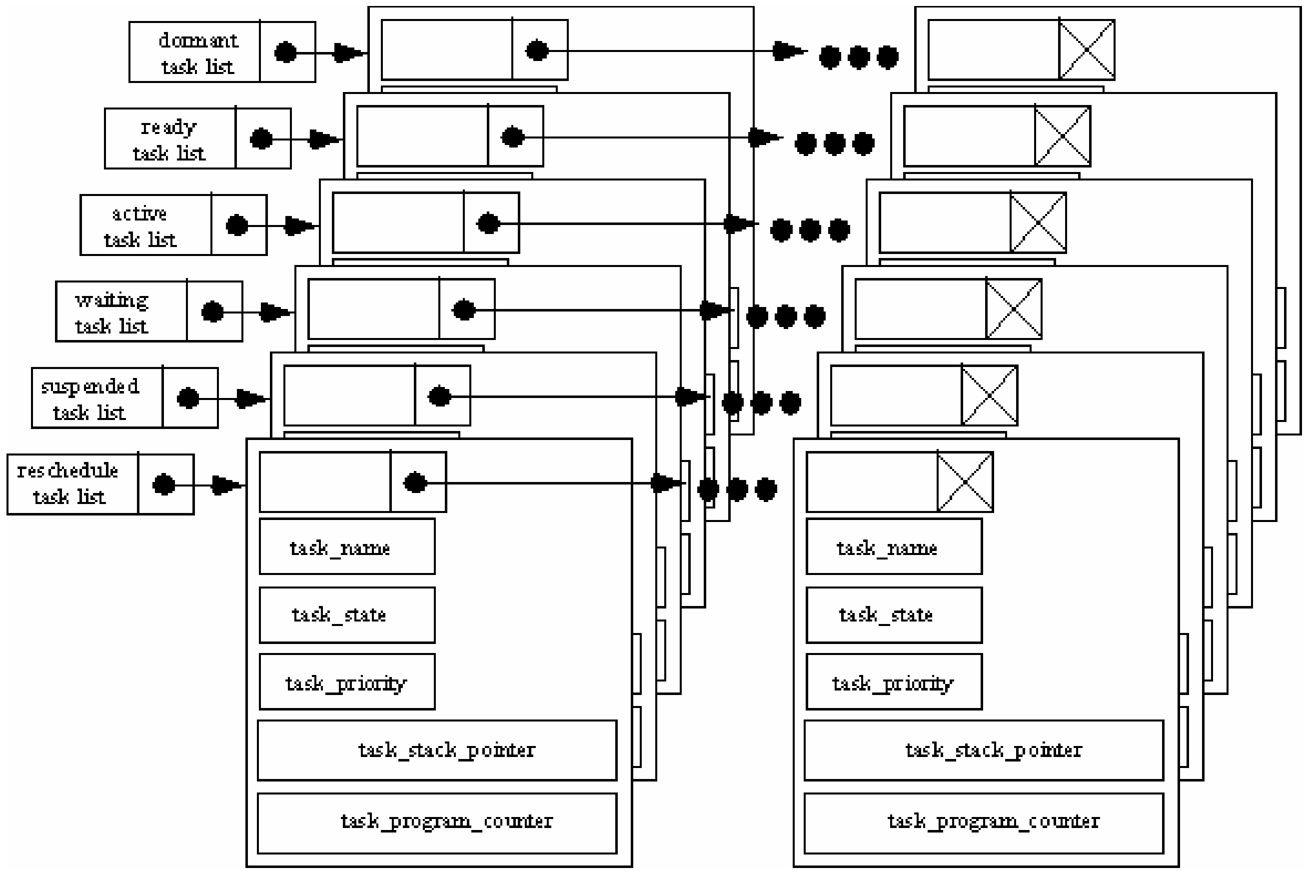
RTOS Scheduling Algorithms
Interrupt Driven System

- Main program consists of system initialization activities
- System then placed in continuous loop to wait for interrupt driven events
- System prioritizes multiple interrupts and handles highest priority tasks first
- Example: Wall-following Robot

RTOS Scheduling Algorithms
Cooperative Multitasking

- Highest priority ready task executes for some amount of time
- Task then relinquishes control back to operating system at convenient break point
  – TCB updated when control relinguished
- Task re-enters ready state
- System then determines next task for execution
- Implemented with series of linked lists

RTOS Scheduling Algorithms
Cooperative Multitasking



RTOS Scheduling Algorithms
Pre-emptive Priority Multitasking

- Operating system determines when a task should relinquish control
  - Examines linked lists of ready tasks and chooses task with highest priority to place in active state

RTOS Issues

- Concurrency: prevent two tasks from using the same critical resource simultaneously
- Reentrancy: a function is said to be reentrant if it always works correctly and preserves data even if interrupted and restarted
- Communication: intertask communication
  - employ global variables or mailbox techniques
- Safety, verification, fail-safe operation