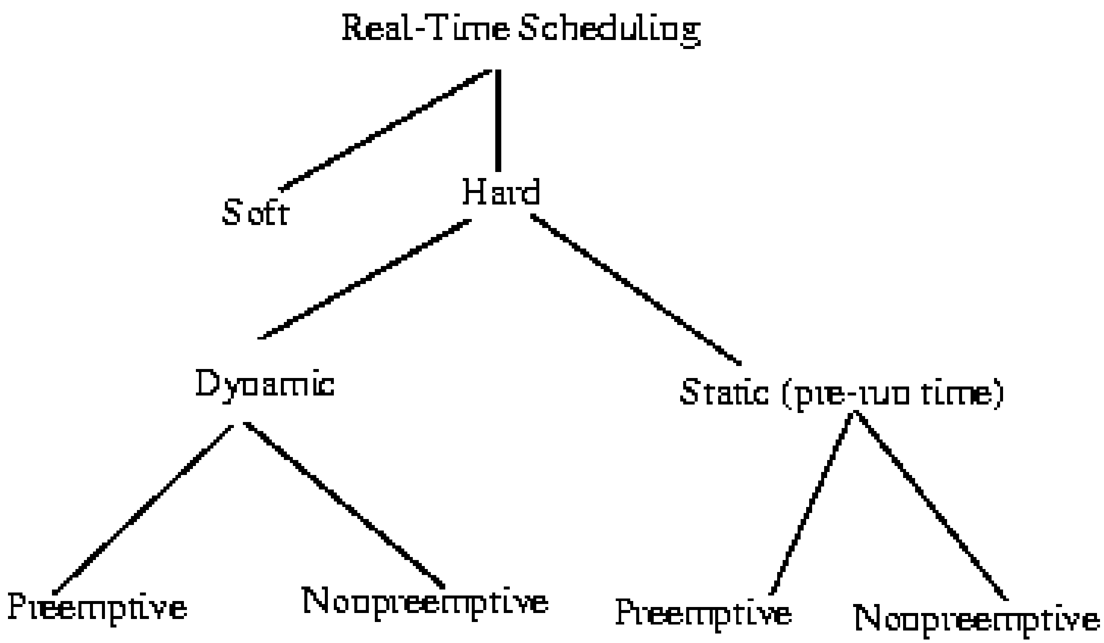
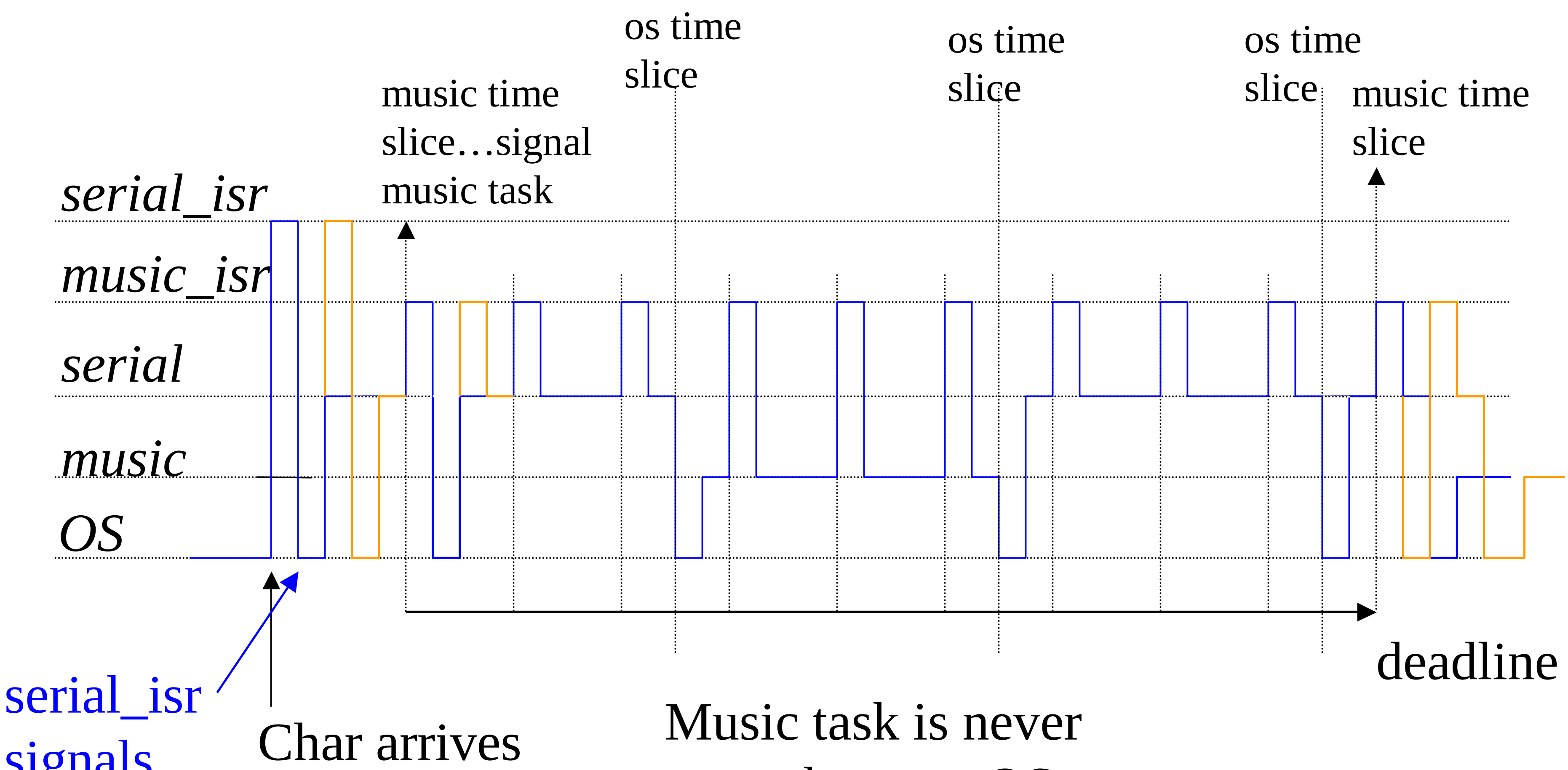
# Back to RTOS

- Scheduling
  - Deadline
  - Laxity
  - Rate Monotonic
- Shared Code in Multiprocessing
- Share Resources: Deadlock avoidance
- Process Synchronizati and Communication
- Memory Management

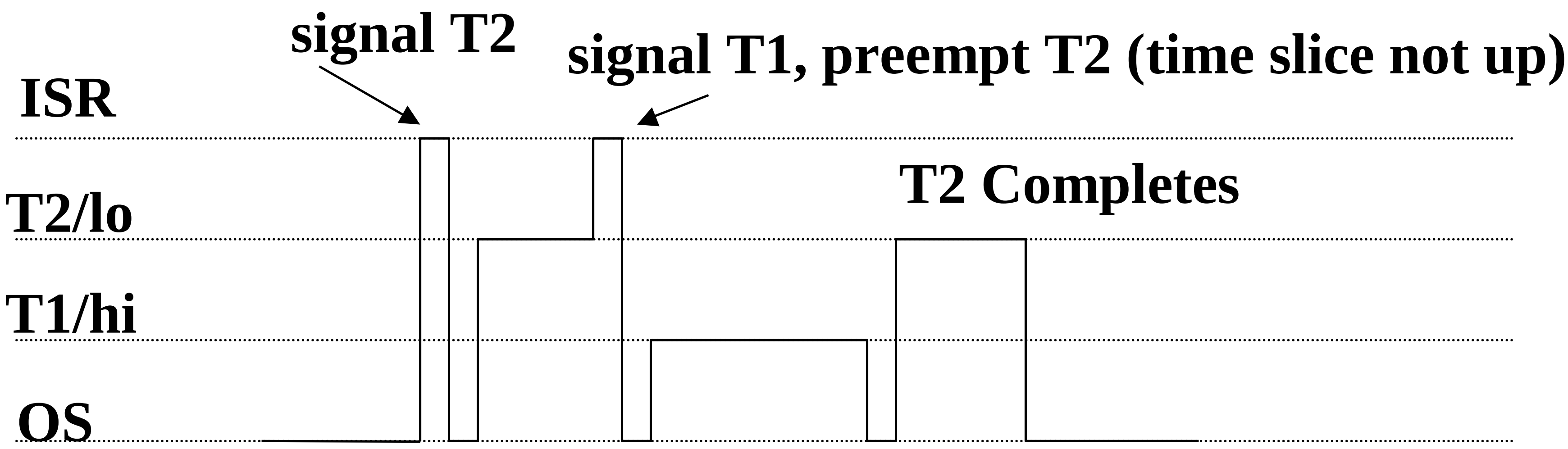


# Dynamic Non-preemptive Scheduling




Music task is never
more than one OS
time slice away

# Dynamic Preemptive Scheduling




Pre-emptive: hi priority tasks preempt low priority task.

Advantage: Lower latency, faster response for high priority tasks.

Disadvantage: Potential to starve a low priority task

Tiny: no priority, round robin only. No starvation.

<u>Priority Inversion:</u> when T2 disables interrupts

Priority Function: any suggestions?

# Scheduling Algorithms (Priority Functions)

- Egalatarian: Round Robin

  Problem: We my have unused compute resources even though we don't meet some deadliines … it can be non optimal.

  Example: system with music task and n non-critical tasks.

  - if deadline < time_tick * n + music_task then we have a chance to miss the deadline.
  - If music is higher priority than worst case is: time_tick + music_task

- Theory: for a system with N periodic tasks. The system is schedulable if:

  $\Sigma Ci/Pi <= 1$ where Ci is seconds or computation per event i and Pi is period of event I where Ci/Pi is the fraction of time spent dealing with I

  - Let Ci = .5 and Pi = 2   Ci/Pi = .25 (1/4 of the time)

  **Rate monotonic scheduling: Priority $\alpha$ Frequency**

  At run time: Highest priority task always preempts lowest priority task.

  Proven to be optimal by Liu and Layland.

  Real systems rarely fit this model perfectly

# Other Scheduling Algorithms (Priority Functions)

- Earliest Deadline First
  - Keep list of runnable processes sorted by deadline
  - Algorithm always runs the first item on the list
- Least Laxity
  - Like earliest deadline first, but considers the expected run time of the task. Priority = Deadline – RunTime. Sort the list according to this criteria
  - Run the first item on the list
- Static Priority
  - Various combinations
    - Static priority with least laxity as the tie breaker
- Engineering Challenge
  - worst case analysis to satisfy yourself that your system will always meet your deadline given the scheduling policy

# Reentrant functions…sharing code not data

- Are there shared functions that we would like to have?
  - deq? enq? next (same for head or tail)?
  - C Library Routines!!
- Can task switching clobber local variables (parameters and automatics)?
  - What happens when this function is interrupted by the OS?

```
unsigned char next(unsigned char current, unsigned char size)  {
        if (current+1 == size) return 0;
        else return (current+1);
}
```

**it depends on where the parameters, automatics, and spill values are stored… this one is probably okay!**

**3 places for parameters**

**a. Registers**

**b. fixed locations**

**c. stack…but not the hardware stack!**

# Implementation Example: Reentrant, Encapsulated Queue

```
typedef struct qstruct {
        unsigned char head;
        unsigned char tail;
        unsigned char *array;
        unsigned char size;
} fifo;
```

**Shared functions are okay if we disallow task switch during calls. why? re-entrant stack not protected by Tiny OS. What about C-libraries (subroutine calls?)**

**is this okay for timing if we don't use it in Tone Gen ISR (overhead)?**

```
fifo Q;
unsigned char array[QSIZE];
void producer(void) _task_ 0 {
        unsigned char i;
        bit fail;
        initq(&Q, array, QSIZE);
        os_create_task(1);
        while (1) {
                do { disable();
                     fail = enq(&Q,i);
                     enable();
                }  while (fail);
                i++; // simulated data
        }
void consumer(void) _task_ 1 {
        bit fail;
        unsigned char i;
        while (1) {
            os_wait();
            disable();
             fail = deq(&Q,&i);
             enable();
             if (fail)…else use(I);
        }
}
```

## Examples of Reentrant functions

```
int sum(tree) {
        if (!tree) return 0;
        return sum(tree->left) + sum(tree->right) + tree->val;
}
```

reason for reentrancy: re-use code

The key to reentrancy: relative addressing

Other examples of reentrancy:

two tasks share a function, ISR and task share a function

# Reentrancy in Keil C51

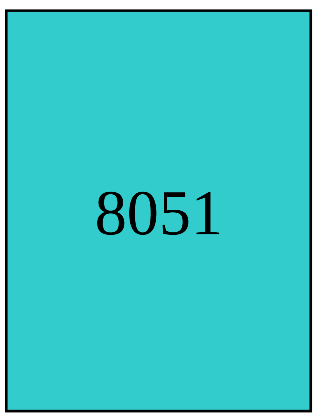
- In C51, most parameter passing is done through registers (up to three parameters). Then fixed memory locations are used. Register method is reentrant, the other isn't.
- Local (automatic) variables and temporary values in functions are also mapped to fixed memory locations (w/ overlaying)…definitely not reentrant.
- How can we solve this: declare functions to be reentrant as in:

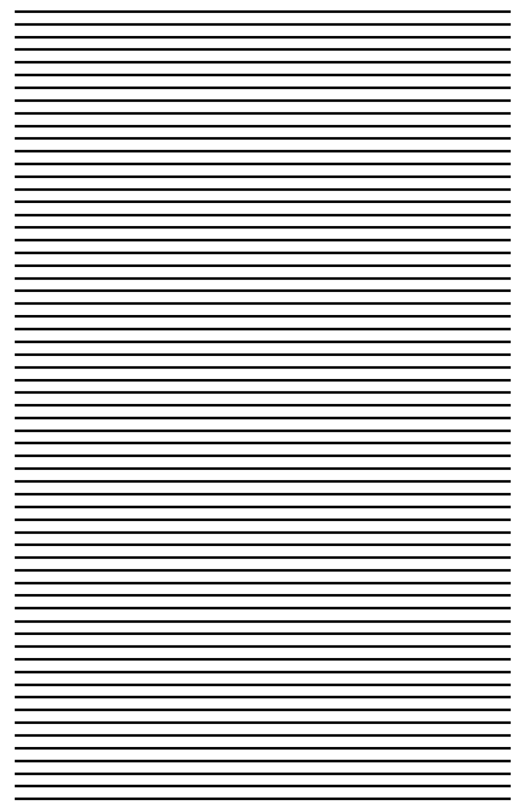
```
unsigned char next(unsigned char current, unsigned char size) reentrant {
    if (current+1 == size) return 0;
    else return (current+1);
}
```

- BUT…the stack used for reentrant functions is NOT the same as the hardware stack used for return address, and ISR/TASK context switching. There is a separate "reentrant" stack used for that, which is not protected by the TINY OS. It's a different region of memory, and a fixed memory location is used for the reentrant stack pointer. So this works for FULL and for recursion (no OS).
- Conclusion…you can have shared functions in TINY if you:
  - convince yourself that all parameters are passed through registers
  - convince yourself are no local variables that use fixed memory locations (compiler can allocate those to registers too)
  - be sure not not change HW settings non-atomically
  - or… you disable context switching in shared functions by disabling T0 interrupts
    - Think of shared functions as critical sections. Consider impact on interrupt latency?

## Sharing Resources

- What would be an example of a shared resource in a simple 8051-like application (other than RAM variables)
  - What if you have 64 control lines to manage, with no memory mapped I/O?



can Tiny OS help with this?

can memory mapped I/O help with this?

## How about these?

- Is this reentrant? … note: **we don't care about order**
  **void setLatch(addr, data) {port1 = data, port2 = addr, E = 1, E = 0}**

| **Thread 1 (x,y)** | **Thread 2 (a,b)** |
|---|---|
| Port1 = x | |
| | Port1 = a |
| | Port2 = b |
| Port2 = y | |

- How can we get atomicity here?
- Deadlock scenario:
  thread-1 requests and gets port1
  thread-2 requests and gets port2 then requests port1
  thread-1 requests port2
- Can TinyOS help with this?

# Deadlock

- Preemptable v. Nonpreemtable Resources
  - CPU – preemptable
  - Memory – Preemtable
  - Incoming packet processing on a network interface – non preemptable
  - Control of an external device like a disk drive, printer, display
- Deadlock: two threads each have a partial set of non-preemptable resources needed to complete their tasks and are waiting for the resources held by the other.
- Preconditions for Deadlock to occur
  - Mutual exclusion: each resource is either currently assigned to exactly one thread or is available
  - Hold and wait: A process currently holding resources granted earlier can request a new resource without giving up the other
  - Non-preemtive: Only the holder a resource can give it up
  - Circular Wait: see above

## Solutions to Deadlock

- Forggedaboutit
  - Statistical likelihood say once if fifty years. Statistical likelhood of a disk crash is once in 10…so worry about the disk. Also consider the consequences of its occurance!
- Detection and Recovery
  - Look for cycles in the request chain, then break the chain if it happens
  - Make sure that in any chain, there is always a thread that can tolerate being killed!
- Prevention
  - Prevent at least one of the four preconditions from occurring!
    - Mutual exclusion: spool I/O so that thread can continue
    - Hold and wait: Request at resources at once.
    - Circular wait: order resources numerically and allow a process to wait only on resources numerically higher than all that it currently holds.

## Safety – flip side of deadlock

- No two threads access a non-sharable resource at the same time (critical section protection)
- Access to a resource
  - Request Resource
  - Use Resource
  - Release Resource
- Safety is guaranteed if Request Resource is atomic. Just disable interrupts! But we don't want user tasks to do that.
  - Causes reduced predictability of system performance (latency).
  - A user thread could crash with interrupts disabled
- How to protect a critical section without disabling interrupts

# Coming Up

- A little more on OS
  - Real Time Scheduling Algorithms
  - Synchronization: Semaphores and Deadlock avoidance
  - Interprocess Communication
  - Concept of shared resources: Devices and Drivers
- Future
  - Linux and the Cerfboards
  - Networking
  - Product Safety
  - Java/Object Oriented Programming for Embedded Systems
- Design Meeting (Product Ideas…)