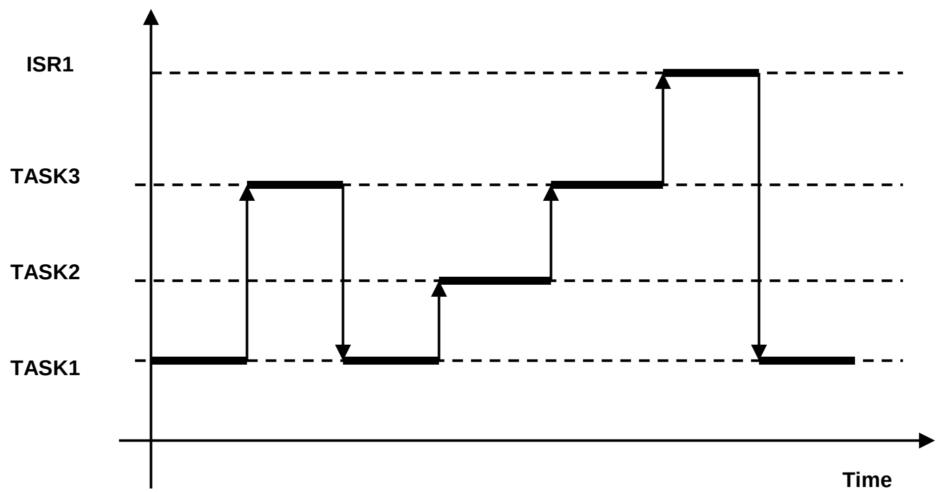
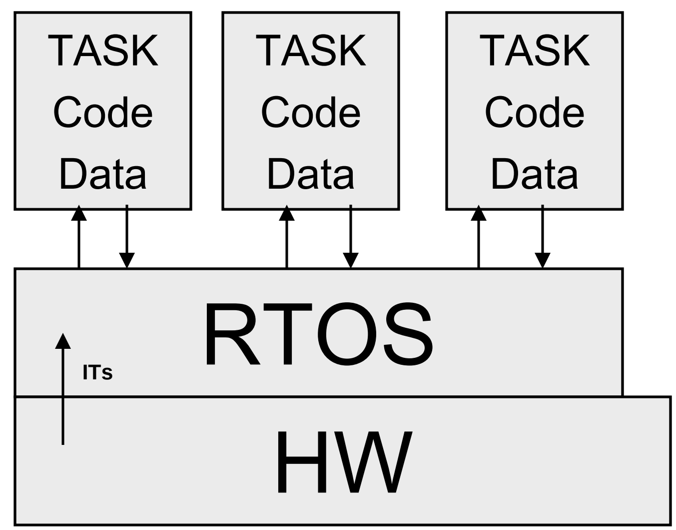
RTOS Basics

- Kernel: schedules tasks
- Tasks: concurrent activity with its own state (PC, registers,stack, etc.)



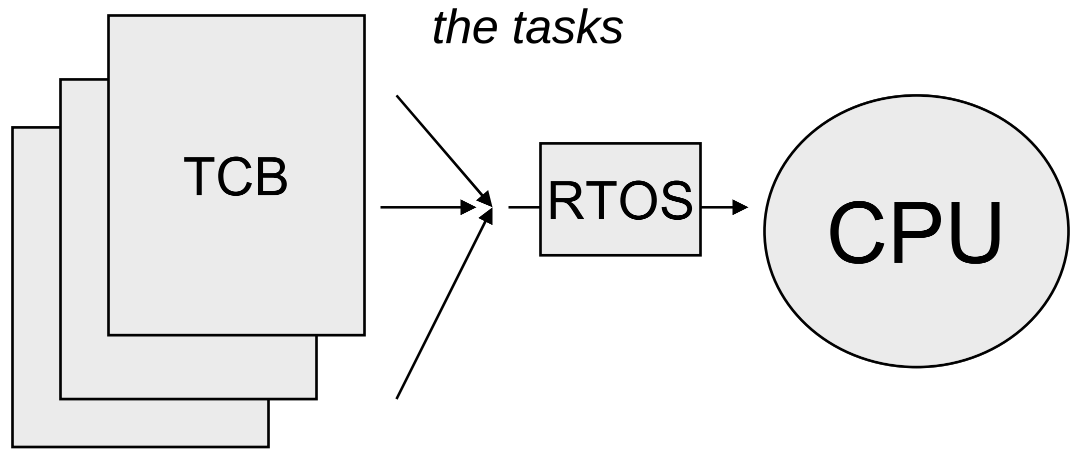


Tasks

- Tasks = Code + Data + State (context)
- Task State is stored in a Task Control Block (TCB) when the task is not running on the processor
- Typical TCB:

ID
Priority
Status
Registers
Saved PC
Saved SP

The RTOS effectively multiplexes the CPU among the tasks

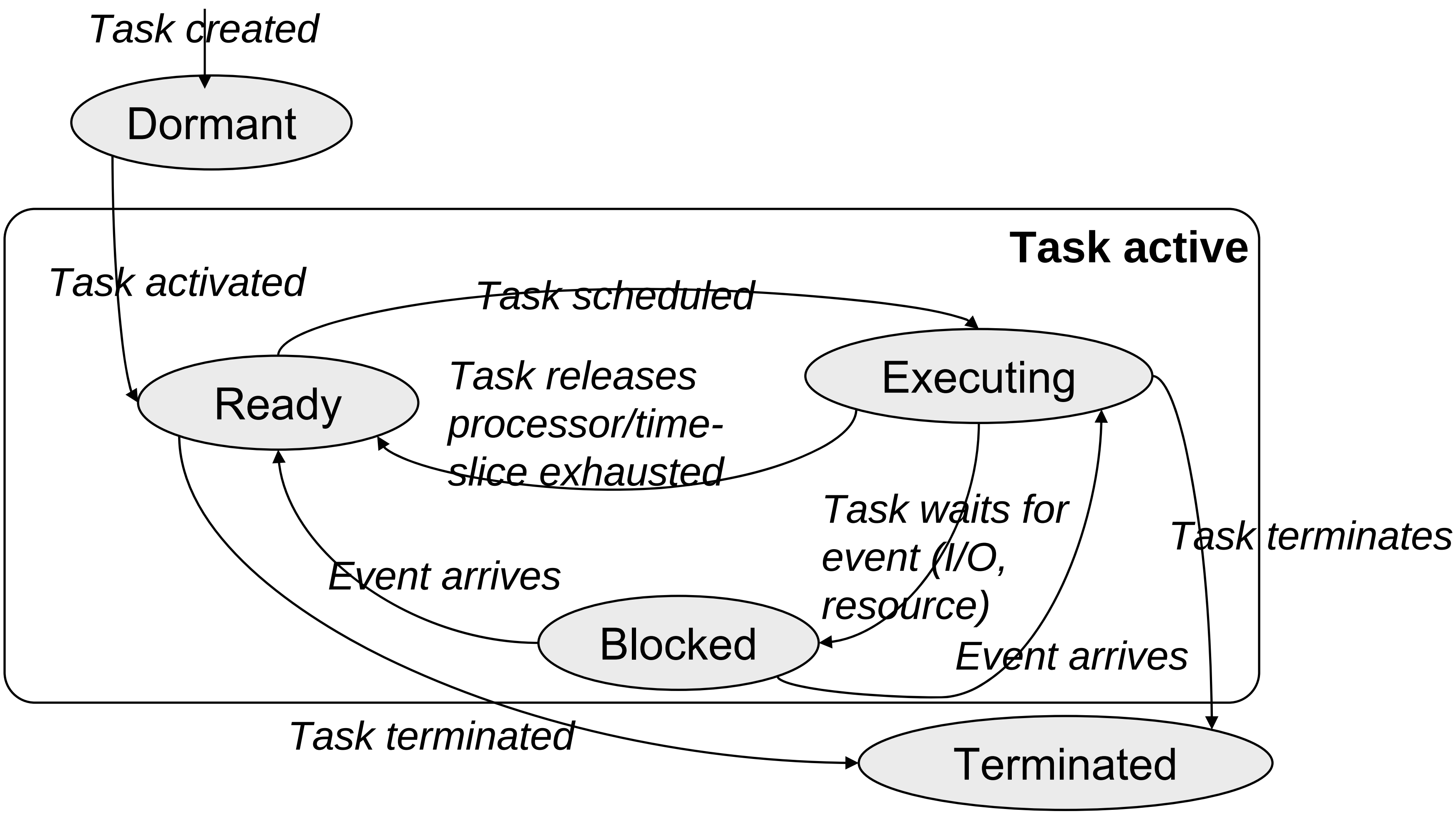


Task states

- **Executing**: running on the CPU
- **Ready**: could run but another one is using the CPU
- **Blocked**: waits for something (I/O, signal, resource, etc.)
- **Dormant**: created but not executing yet
- **Terminated**: no longer active

The RTOS implements a Finite State Machine for each task, and manages its transitions.

Task State Transitions



RTOS Scheduler

- Implements task state machine
- Switches between tasks
- Context switch algorithm:
  1. Save current context into current TCB
  2. Find new TCB
  3. Restore context from new TCB
  4. Continue
- Switch between EXECUTING -> READY:
  1. Task yields processor voluntarily: **NON-PREEMPTIVE**
  2. RTOS switches because of a higher-priority task/event: **PREEMPTIVE**

RTOS Tasks

- Run in the same memory space
- Can share data
  - » Data sharing problems as before!
  - » Cannot simply disable IT-s (this would stop the RTOS!)
- Can share code – Similar problems

```
void task1() { … vCountErr(9); … }
void task2() { … vCountErr(10); …}
static int cErrors;
void vCountError(int addErr) {
    cErrors += addErr;
}
```

Not an atomic operation

RTOS Tasks: Code sharing

- Reentrancy: A function is called *reentrant* if it can be entered simultaneously, by multiple tasks.
- Rules: A reentrant function
  - » May not use variables in a non-atomic way (unless local variables or private variables of the calling task)
  - » May not call other, non-reentrant functions
  - » May not use the HW in a non-atomic way

Process scheduling

- Goal: to satisfy timing requirements
- Pre-run-time (*static*) scheduling: determine precise task schedules at design-time.
  - » Ex: TTA
- Run-time (*dynamic*) scheduling: scheduling is done dynamically, by the RTOS, based on priorities.

Scheduling techniques

- Round-robin scheduling:
  - » Each task is assigned a fixed time quantum (slice).
  - » Fixed-rate timer generates a periodic IT. Rate is equal to the slice
  - » Task runs until completion or slice expiration
  - » If task does not complete, it is placed at the end of a queue of executable ("ready") tasks.

  \- Fair scheduling

  \- All tasks have the same priority

Scheduling techniques

- Cyclic executive:
  - » A frame (f) is long enough s.t. every task can start and complete within the frame – No preemption within the frame.
  - » Scheduler makes scheduling decisions only at the beginning of each frame.
    - – Cond #1: *f >= max(e(i))* : “Frame is long enough”.
    - – Cond #2: *floor(p(i)/f) – p(i)/f = 0*: “Hyperperiod has integer number of frames”
    - – Cond #3: *2*f – gcd(p(i),f) < D(i)* : “There is at least one frame between the release time and deadline of each task.”

Scheduling techniques

- Fixed priority – Rate Monotonic Scheduling

  Given a set of periodic tasks and a preemptive priority scheduling, then assigning priorities s.t. tasks with the shorter periods have higher priorities (rate-monotonic), yields a feasible scheduling algorithm. (RM Rule).

Utilization: u(i) = e(i)/p(i)

A set of N periodic,independent tasks is RM-schedulable [Liu73] if

$$\boxed{U = \sum_{i=1}^{N} u(i) \leq N * (2^{1/N} - 1)}$$

Note: If N -> infinity lim () = ln2 ~ 0.69.

Scheduling techniques

- Dynamic priority – Earliest Deadline First Scheduling: *The ready task with the earliest deadline has the highest priority.*
- EDF Bound theorem:

  A set of N tasks, each of whose relative deadline equals to its period, can be feasibly scheduled by EDF if and only if

  $$\boxed{\sum_{i=1}^{N} (e(i)/p(i)) \leq 1}$$

  EDF is optimal for a single processor (with preemption allowed)