# *Real-Time Systems Design*

Chapter 10

# *Lesson Objectives*

- Introduce some terms related to real-time system
- Describe the design process for real-time system

# *Real-time System*

- A real-time system is a software system whose correct functioning depends on the results produced and the time at which these results are produced.

- Example?

# Real-time System

- A "soft" real-time system is a system whose operation is degraded if results are not produced according to the specified timing requirements.

Example?


- A "hard" real-time system is a system whose operation is incorrect if results are not produced according to the timing specification.

Example?

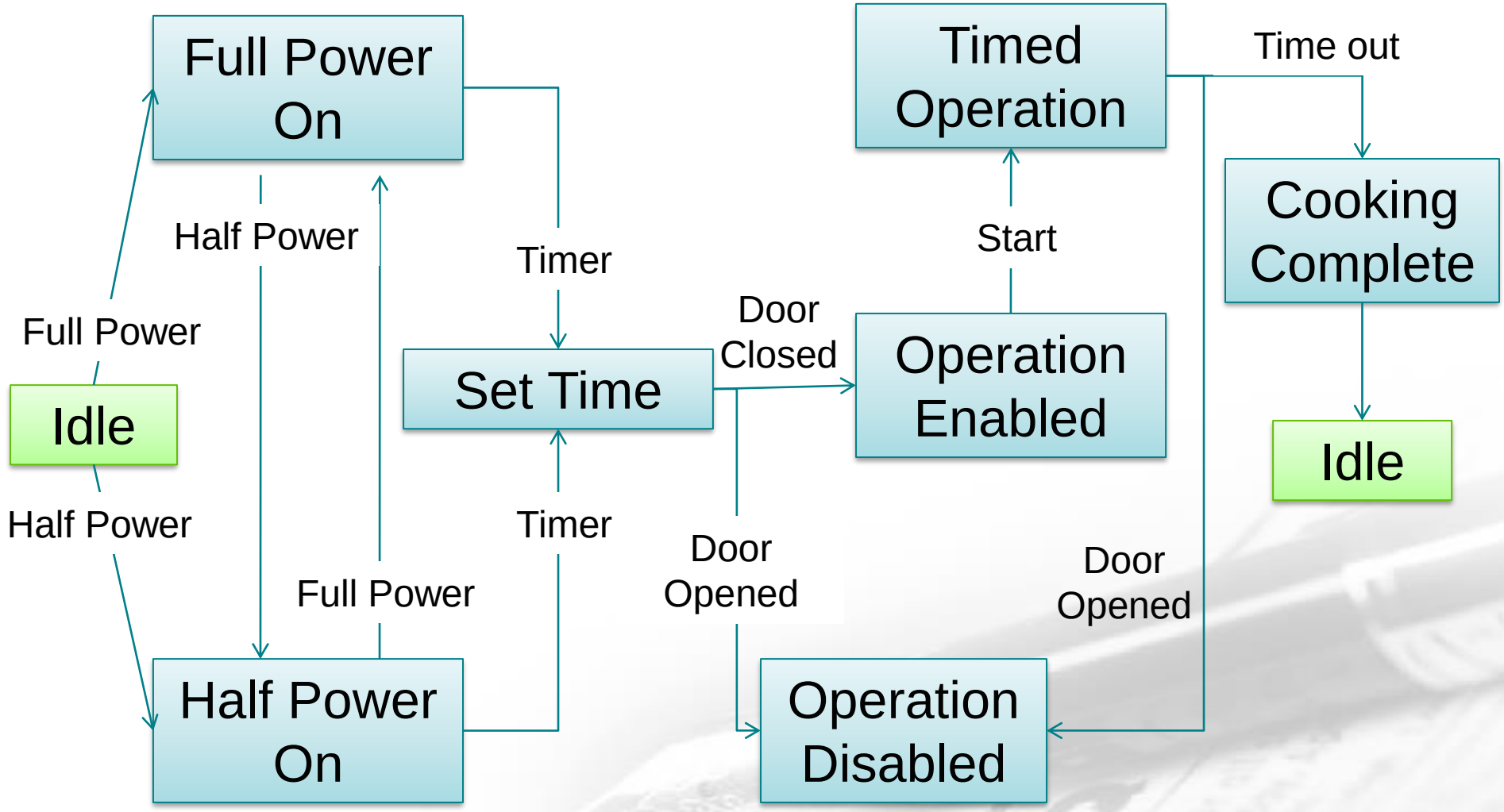
# Stimuli of Real-time System

- Real-time systems have to respond to events occurring at irregular intervals. These events (or stimuli) often cause the system to move to a different state.
- Thus, state machine modeling may be used as a way of describing a real-time system.

# Stimuli of Real-time System

- A state model of a system assumes that, at any time, the system is in one of a number of possible states.
- An example of state model of a simple microwave oven, extracted from the text book.

# Stimuli of Real Time System




**State Machine Model of a Microwave Oven**

# Stimulus/response System

- One way of looking at a real-time system is as a stimulus/response system.
- Stimuli fall into two classes: -

1) Periodic stimuli

– These occurs at predictable time intervals. E.g. the system will examine a sensor every 50ms & take action (respond) depending on the sensor value (stimulus).

# Stimulus/response System

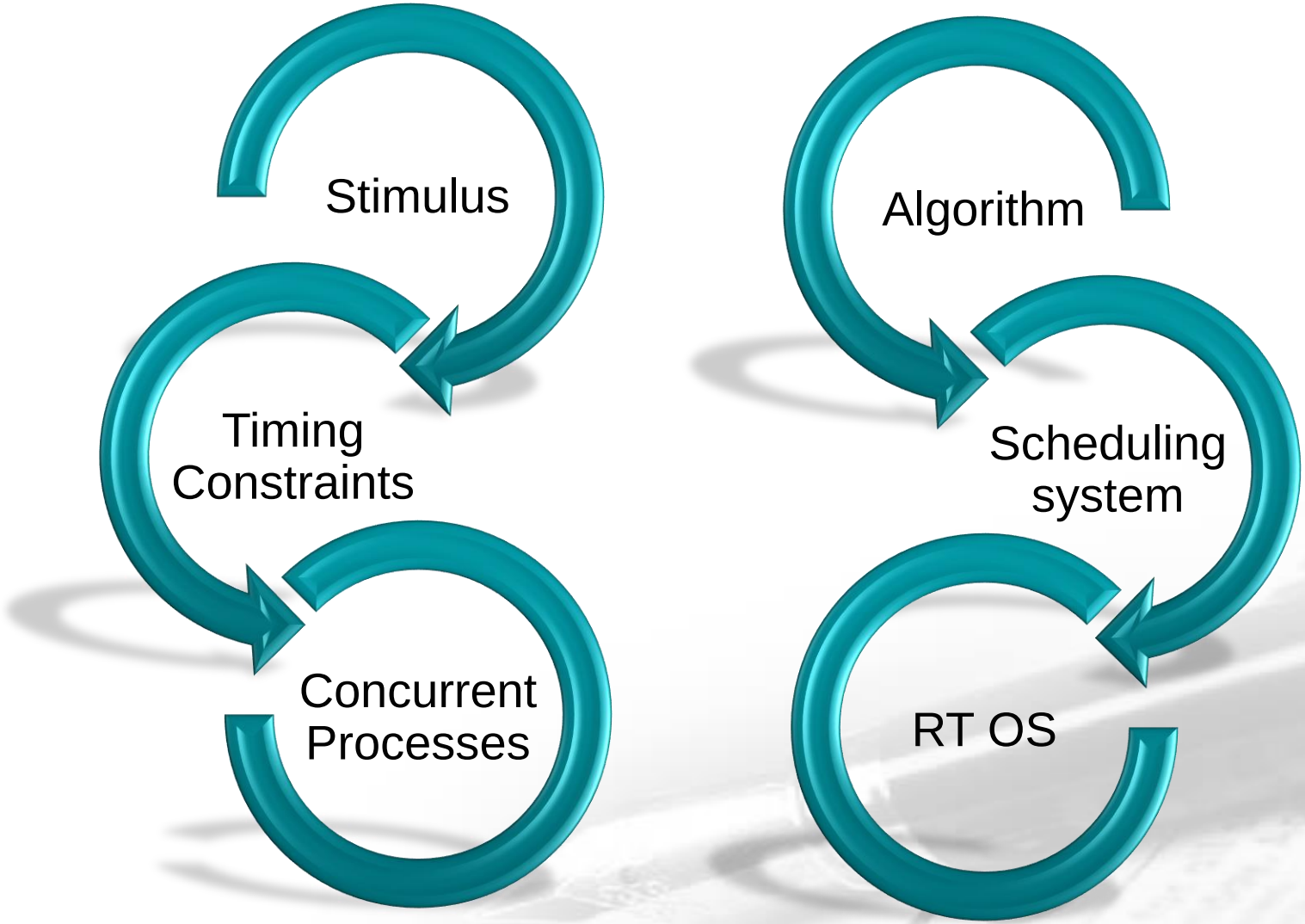
- Stimuli fall into two classes: -

  2) Aperiodic stimuli

  – These occurs irregularly (usually signaled using the computer's interrupt mechanism).

  - E.g. I/O interrupt in a comp system → indicating that an I/O transfer was complete & that data was available in a buffer.

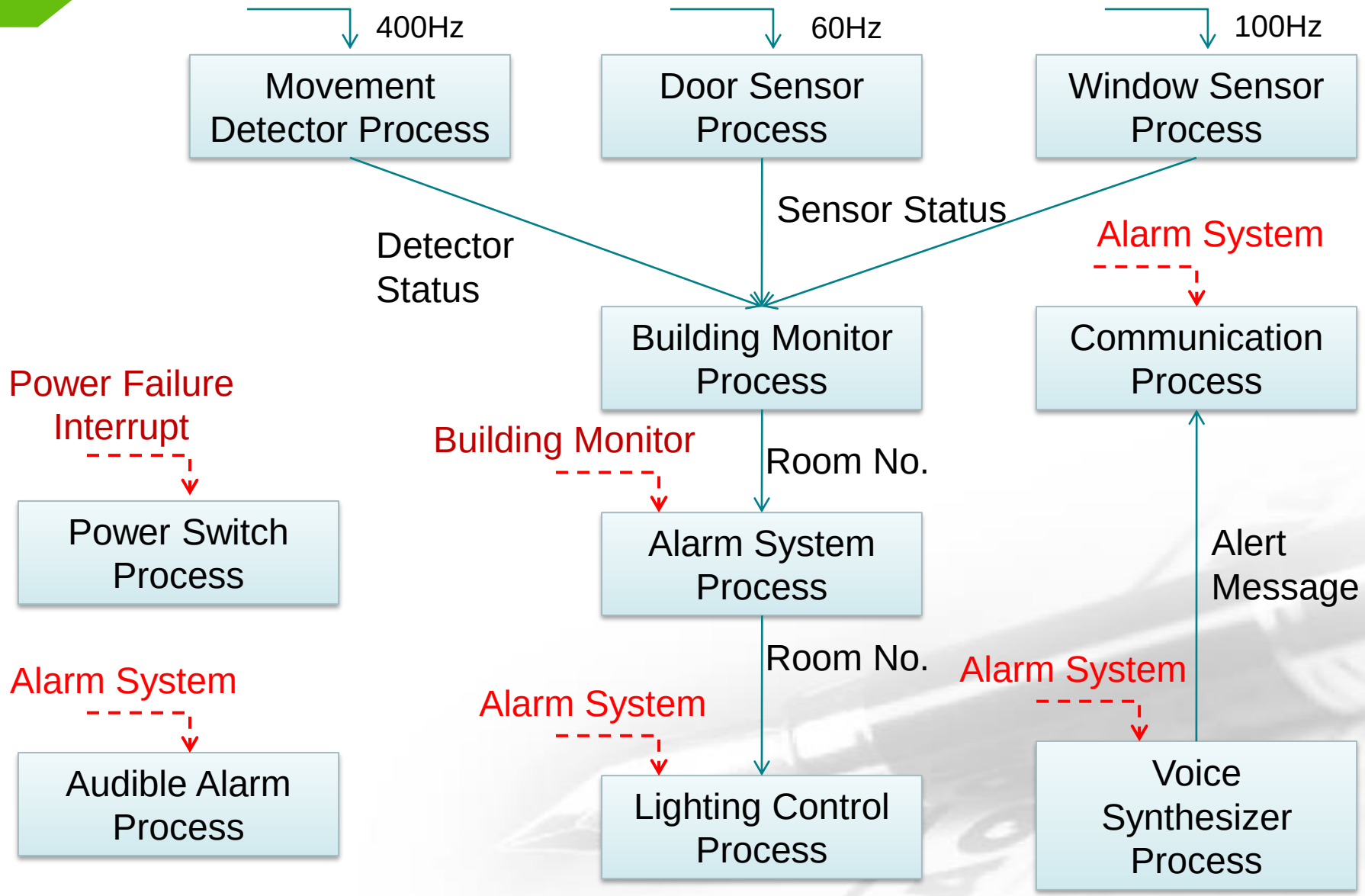
# Stages of RT System Design



# Stages of RT System Design

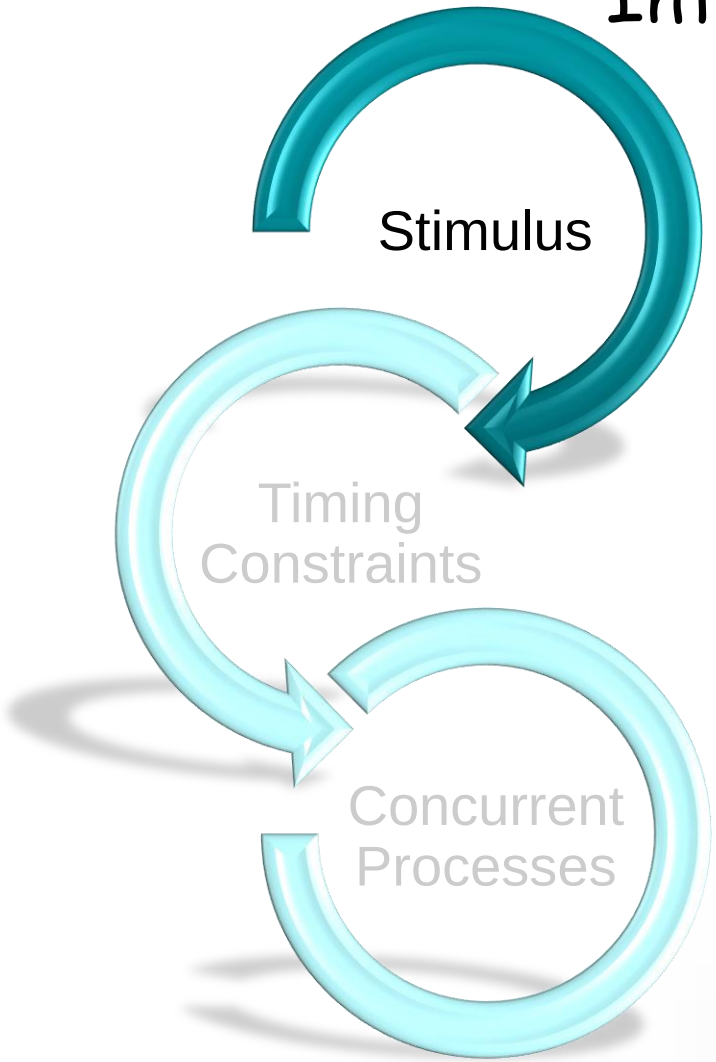
1. Identify the stimuli that the system must process and the associated responses
2. For each stimulus and associated response, identify the timing constraints which apply to both stimulus and response processing
3. Aggregate the stimulus and response processing into a number of concurrent processes.
4. For each stimulus and response, design algorithm to carry out the required computations
5. Design a scheduling system which will ensure that processes are started in time to meet their deadlines
6. Integrate the system under the control of a real-time operating system

# Stages of RT System Design



# Stages of RT System Design

## Intruder Alarm System




**Stimuli**

- Intruder alarm

(intruder alarm is triggered)

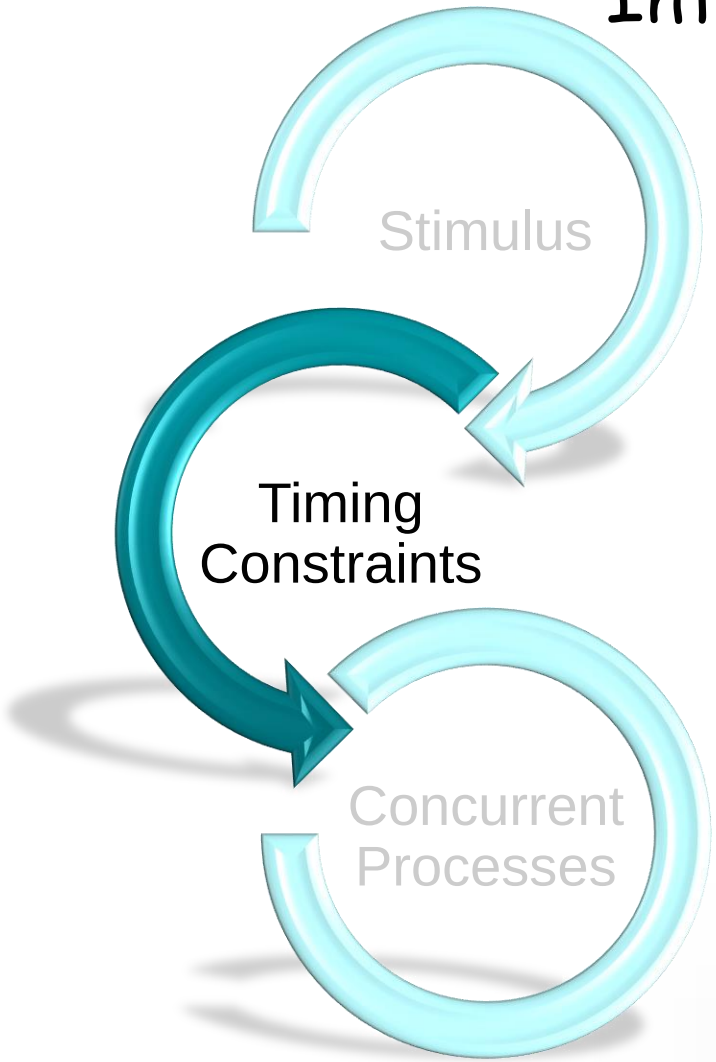
**Response**

- Compute room no.
- Call to police
- Initiate voice synthesizer
- Switch on audible alarm
- Switch on light

1. Identify the **stimuli** that the system must process and the **associated responses**

# Stages of RT System Design

## Intruder Alarm System



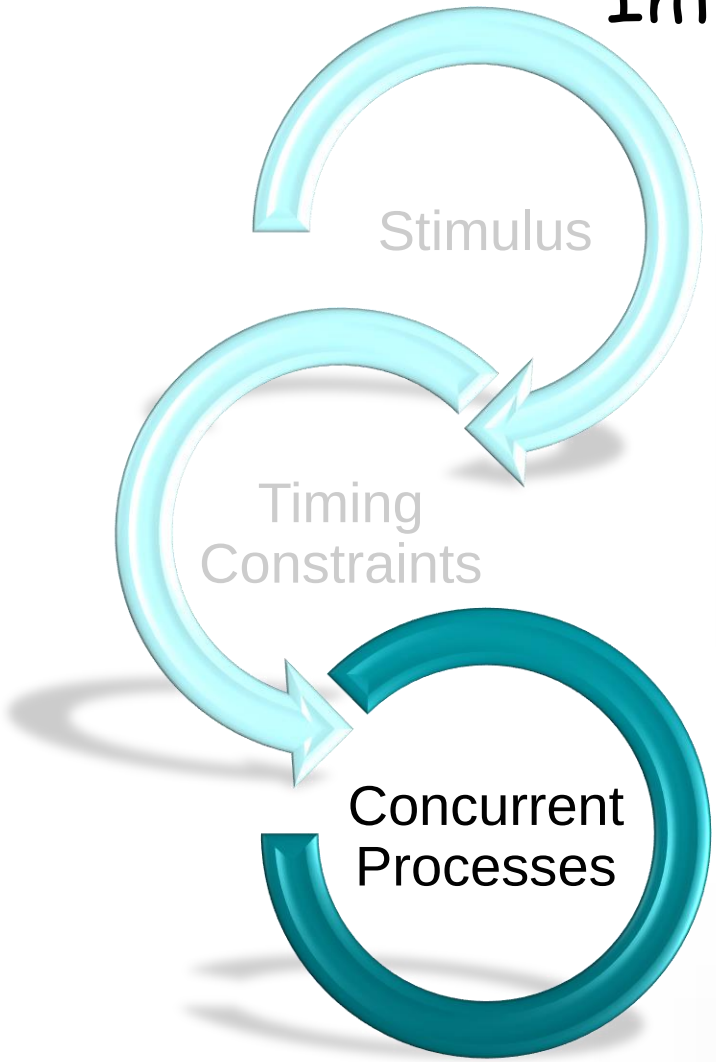

timing

Stimuli → Response

2. For each stimulus and associated response, identify the **timing constraints** which apply to both stimulus and response processing

# Stages of RT System Design

## Intruder Alarm System




Window Sensors → Windows Sensor Process

Door Sensors → Door Sensor Process

Motion Sensors → Motion Sensor Process

Concurrent processes

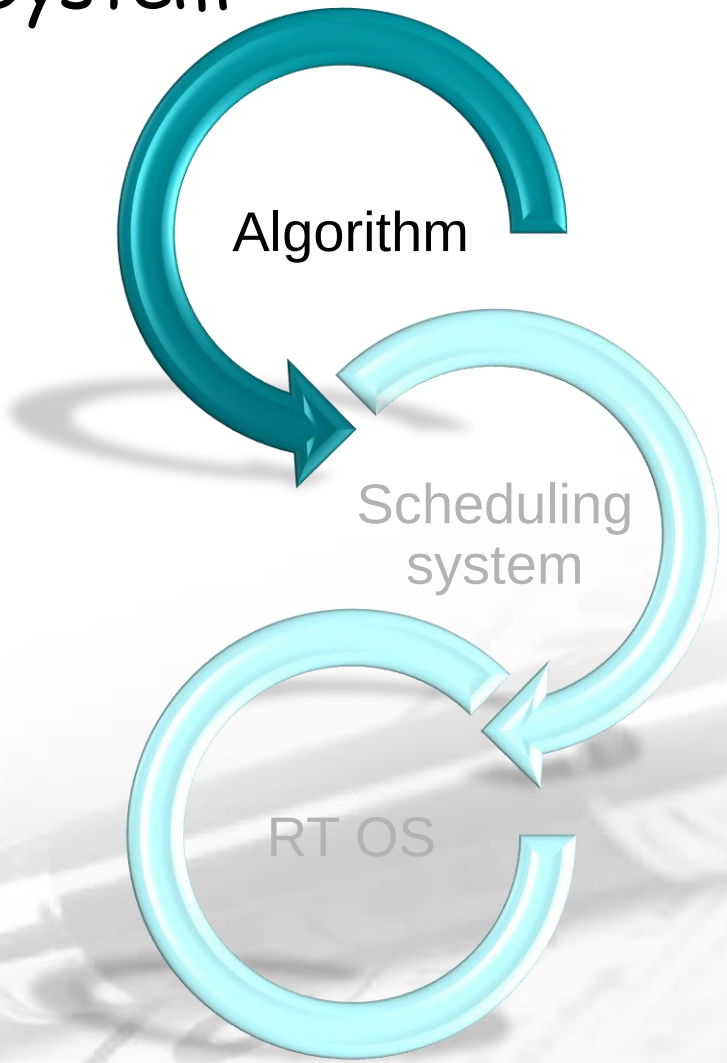
# Stages of RT System Design

## Intruder Alarm System

timing

Stimuli → Response

Computation algorithm



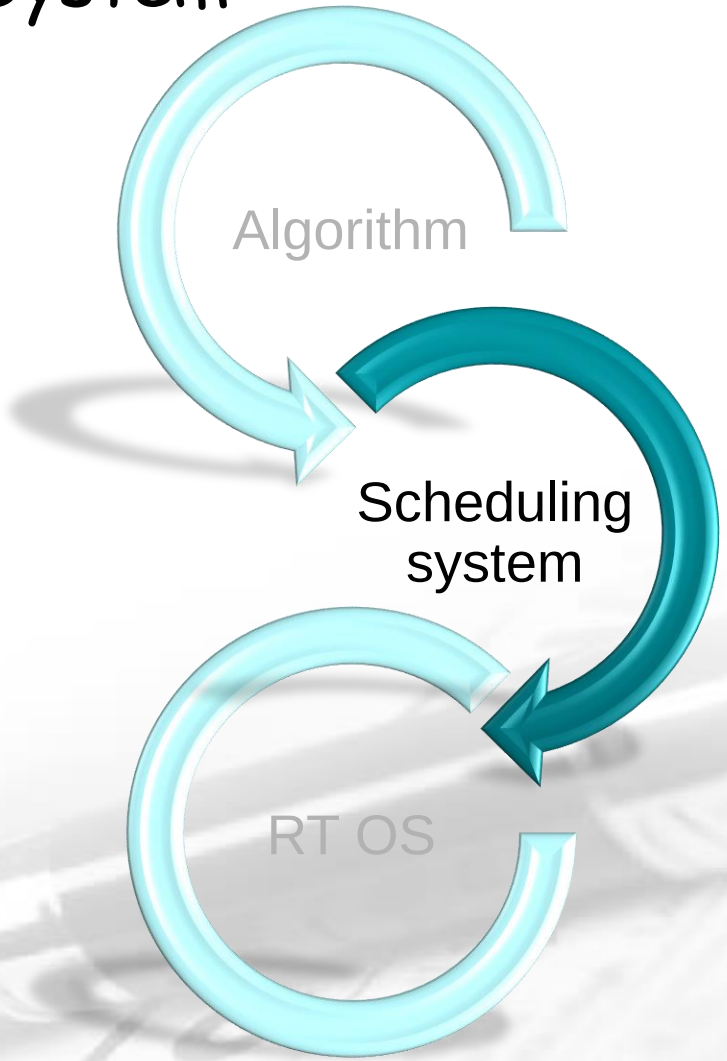

4. For each stimulus and response, design **algorithms** to carry out the required computations

# Stages of RT System Design

## Intruder Alarm System

timing
A set of stimuli → Responses
Computation algorithm

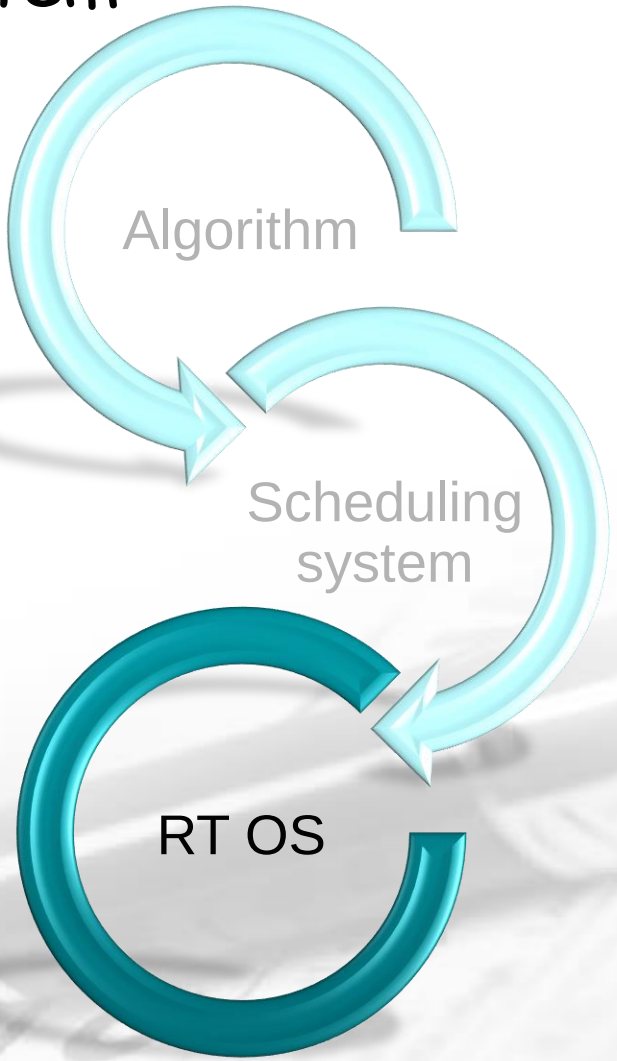
A set of concurrent processes
+
Scheduling system



# Stages of RT System Design

## Intruder Alarm System

*Manages processes & resources allocation such as processor & memory in RT system*



# Real Time System Design

- Real time system must respond to stimulus at different time. Its architecture must therefore be organized so the control is transferred to the appropriate handler for that stimulus as soon as it is received.

***Which control model is suitable for real-time system?***

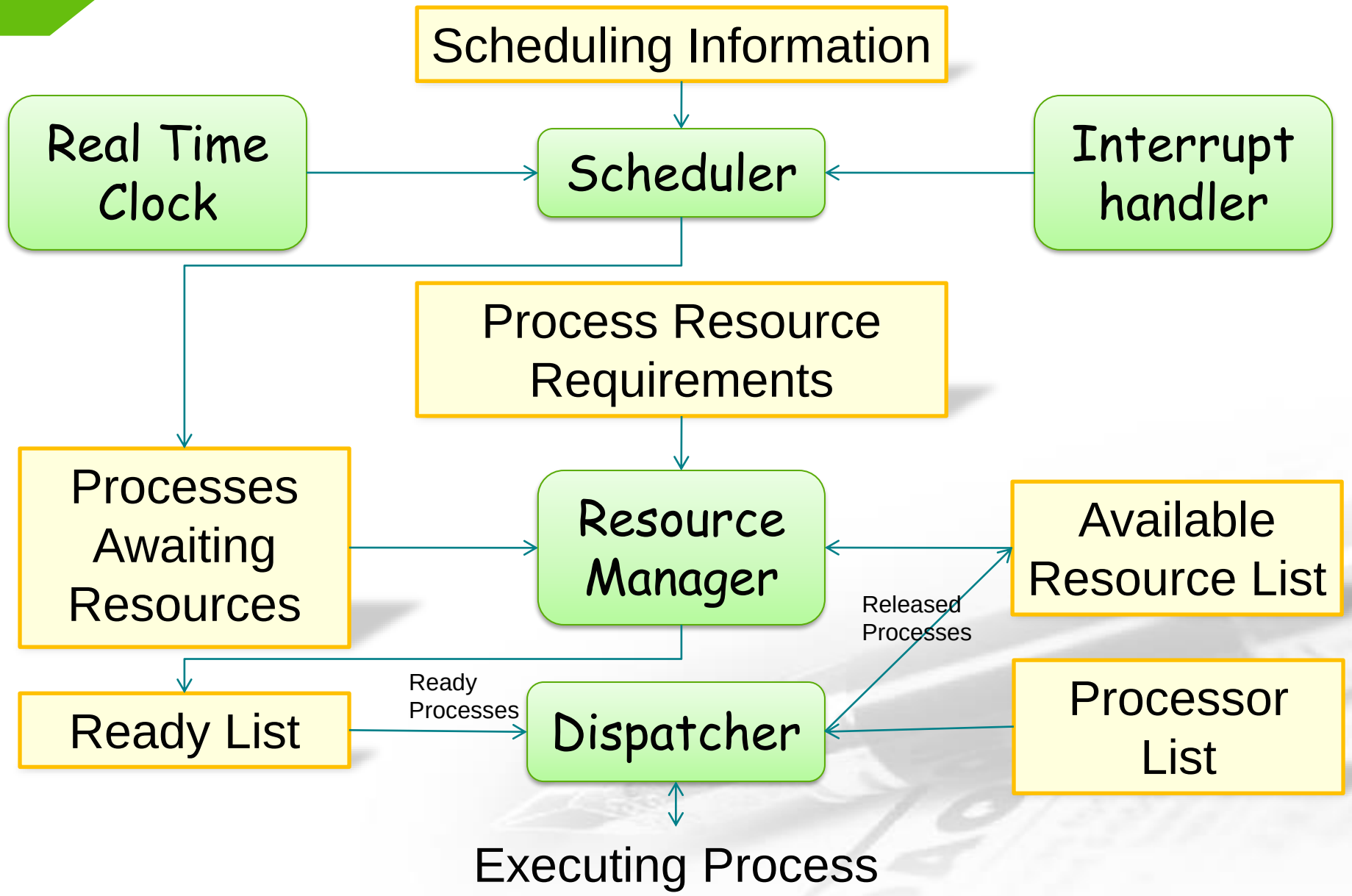
# *Real-time Operating System (RTOS)*

- A RTOS is analogous to an operating system in a general-purpose computer.
- It manages processes and resource allocation in a real-time system.
- *E.g.: It starts and stops appropriate processes so that stimuli can be handled, and allocates memory and processor resources.*

# Components of RTOS

- Real-time clock – provides info to schedule processes periodically
- Interrupt handler – manages aperiodic request for service
- Scheduler – examine the processes which can be executed & choosing one of these for execution
- Resource manager
- Dispatcher
- Diagram of RTOS

# Real Time Operating System



# *Priority Level of Stimulus*

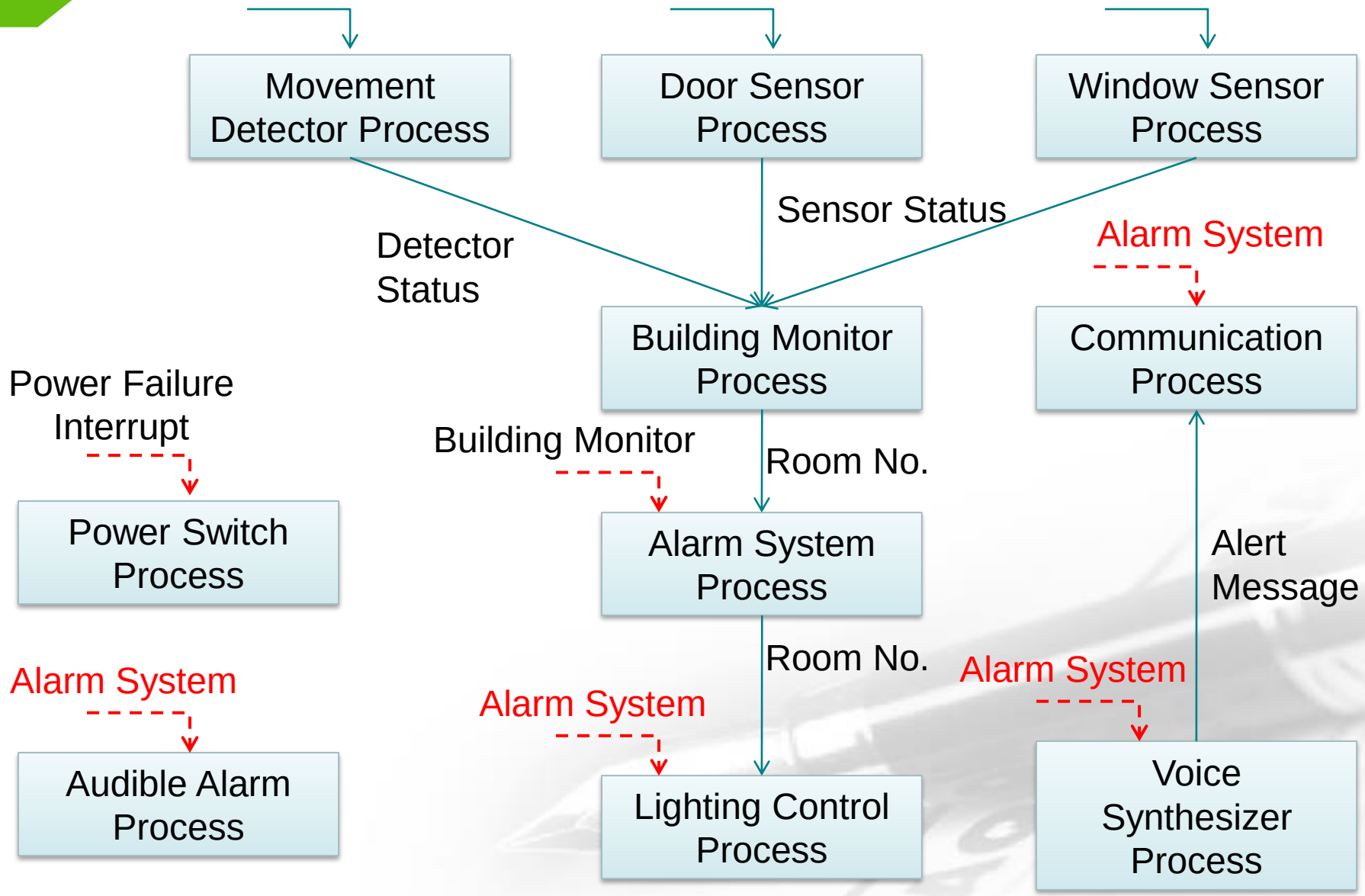
- Interrupt level – highest priority level. It is allocated to processes which need a very fast response.
- Clock level – allocated to periodic processes.

# Monitoring and control systems

- Monitoring and control systems are periodically poll a set of sensors, which capture information from the system's environment. They take actions, depending on the sensor readings, by issuing command to actuators.

- Let’s discuss the an example of this system Intruder alarm system (diagram) from the textbook

# Monitoring & Control Systems



# Monitoring & Control Systems

## Real-time system design process with example

- There are several stages in the design process for real-time embedded software (alarm system with door sensors, window sensors and motion detector)

# Monitoring & Control Systems

Real-time system design process with example

1. Identify the **stimuli** that the system must process and the **associated responses**

**Stimuli → Response**

Example:
Stimuli (Intruder Alarm) → Response (computer room no., call to police, initiate voice synthesizer, switch on audible alarm, switch on light)

Stimuli (power failure) → Response (switch to backup power)

# Monitoring & Control Systems

Real-time system design process with example

2. For each stimulus and associated response, identify the **timing constraints** which apply to both stimulus and response processing

timing

**Stimuli → Response**

# Monitoring & Control Systems

## Real-time system design process with example

| Stimulus/response | Timing requirement |
|---|---|
| Power fail interrupt | The switch to backup power must be complete within a deadline of 50 ms |
| Door alarm | Each door alarm should be polled twice per second |
| Window alarm | Each window alarm should be polled twice per second |
| Motion sensor | Each motion sensor should be polled once per second |
| Audible alarm | The audible alarm should be switched on within 0.5 second |
| Lights switch | The lights should be switched on within 0.5 second of an alarm being raised by sensor |
| Communications | The call to the police should be started within 2 seconds of an alarm being raised by a sensor |
| Voice synthesizer | A synthesized message should be available within 4 seconds of an alarm being raised by a sensor |

# Monitoring & Control Systems

Real-time system design process with example

3. Aggregate the stimulus and response processing into a number of **concurrent processes**

timing
A set of Stimuli → Response } A set of concurrent processes

Example:
Window Sensors → Window Sensors Process
Door Sensors → Door Sensors Process
Motion Sensors → Motion Sensors Process

# Monitoring & Control Systems

Real-time system design process with example

4. For each stimulus and response, **design algorithms** to carry out the required computations

timing

A set of Stimuli → Response

Computation
Algorithm

# Monitoring & Control Systems

Real-time system design process with example

5. Design a **scheduling system** which will ensure that processes are started in time to meet their deadlines

timing
A set of Stimuli → Response } A set of concurrent processes + Scheduling System
Computation Algorithm

# Monitoring & Control Systems

Real-time system design process with example

5. Design a **scheduling system** which will ensure that processes are started in time to meet their deadlines

| Time (second) | Action |
|---|---|
| Every 0.5 sc | Poll door sensor<br>Poll window sensor |
| Every 1 sc | Poll motion sensor |

# Monitoring & Control Systems

Real-time system design process with example

6. Integrate the system under the control of a real-time operating system (manages processes and resources allocation such as processor & memory in real-time system)