Real-Time Concepts for Embedded Systems

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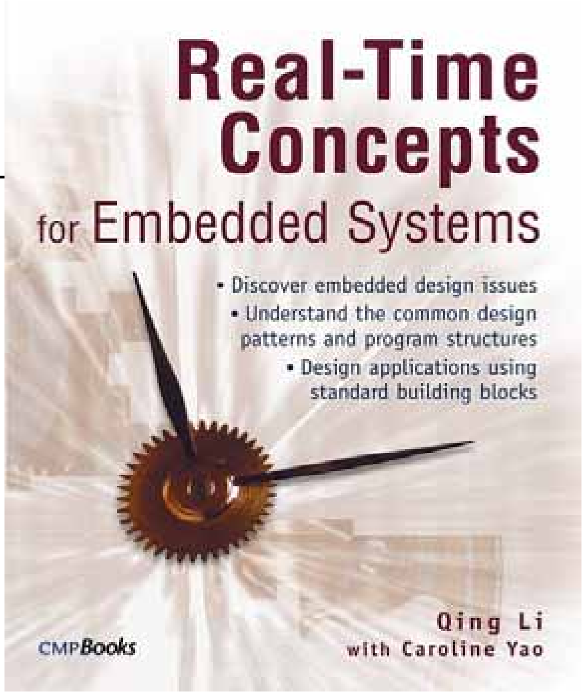
CMP*Books*



Chapter 12
I/O Subsystem

Outline

- 12.1 Introduction
- 12.2 Basic I/O Concepts
- 12.3 The I/O Subsystem

12.1 Introduction

- All embedded systems include some form of input and output (I/O) operations
- Examples of embedded systems built explicitly to deal with I/O devices:
  - Cell phone, pager, and a handheld MP3 player
- I/O operations are interpreted differently depending on the *viewpoint taken* and place different requirements on the level of understanding of the hardware details

Introduction (Cont.)

- From the perspective of a *system software developer*
  - I/O operations imply communicating with the device
  - Programming the device to initiate an I/O request
  - Performing actual data transfer between the device and the system
  - Notifying the requestor when the operation completes
  - Must understand
    - the physical properties (e.g. register definitions, access methods) of the device
    - locating the correct instance of the device
    - how the device is integrated with rest of the system
    - how to handle any errors that can occur during the I/O operations

Introduction (Cont.)

- From the perspective of the *RTOS*
  - Locating the right device for the I/O request
  - Locating the right device driver for the device
  - Issuing the request to the device driver
  - Ensure synchronized access to the device
  - Facilitate an abstraction that hides both the device characteristics and specifics from the application developers

Introduction (Cont.)

- From the perspective of an *application developer*
  - The goal is to find a simple, uniform, and elegant way to communicate with all types of devices present in the system
  - The application developer is most concerned with presenting the data to the end user in a useful way

Introduction (Cont.)

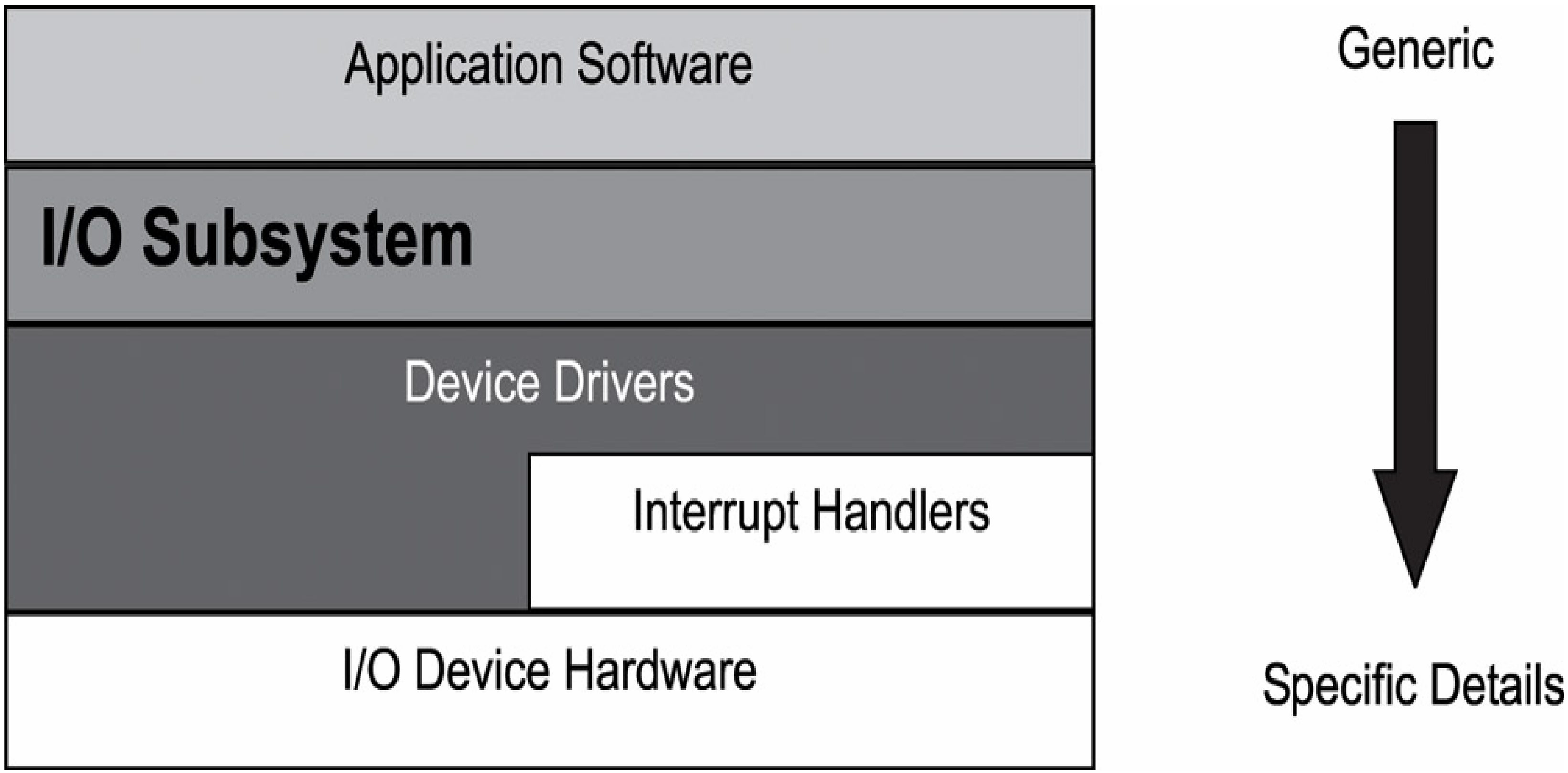
- This chapter focuses on
  - basic hardware I/O concepts,
  - the structure of the I/O subsystem, and
  - a specific implementation of an I/O subsystem

12.2 Basic I/O Concepts

- The combination of *I/O devices*, *device drivers*, and the *I/O subsystem* comprises the overall I/O system in an embedded environment

- The purpose of the I/O subsystem
  - To hide the device-specific information from the kernel as well as from the application developer
  - To provide a uniform access method to the peripheral I/O devices of the system

I/O Subsystem and The Layered Model

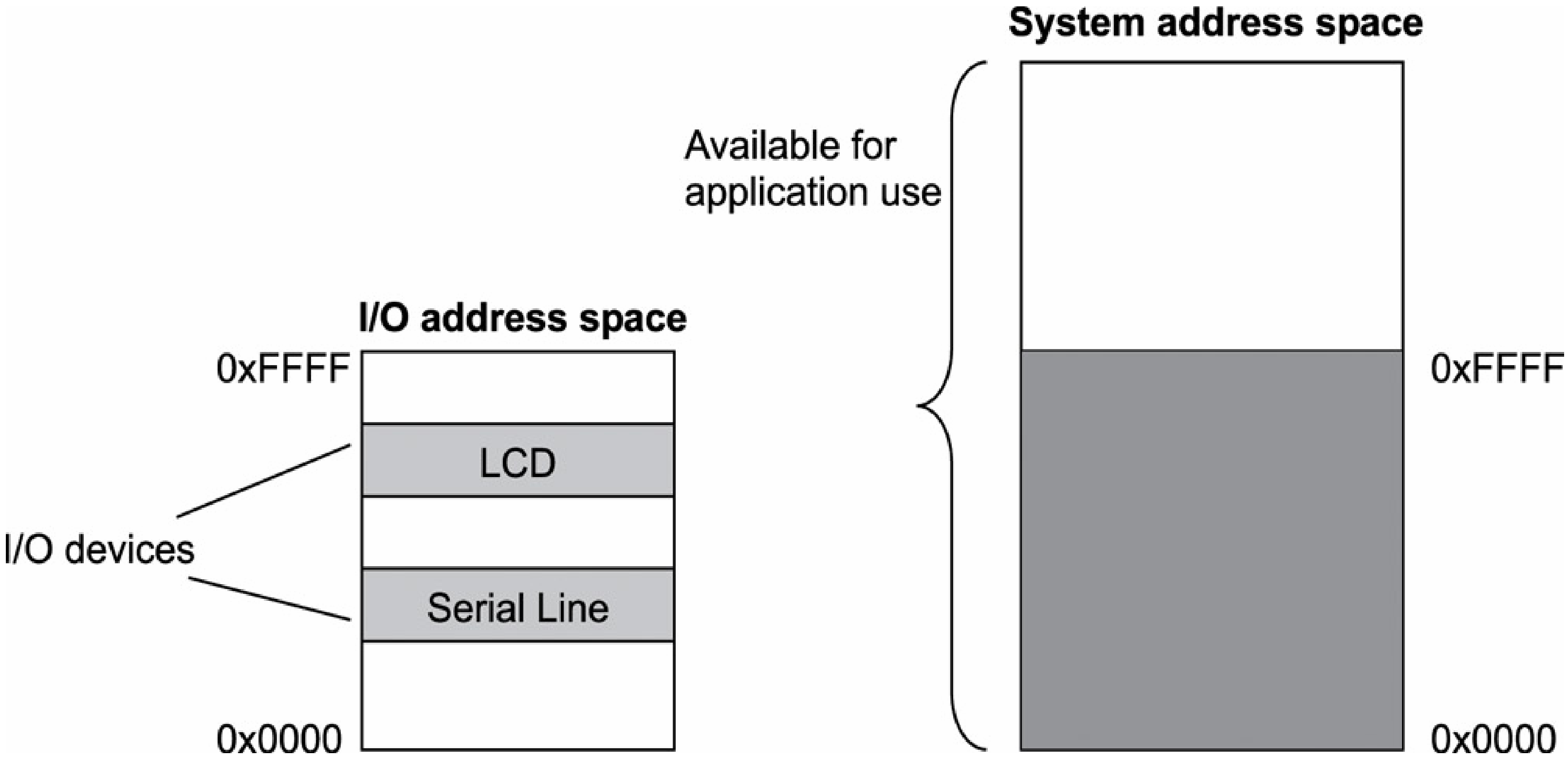


12.2.1 Port-Mapped vs. Memory-Mapped I/O and DMA

- All I/O devices must be initialized through *device control registers* which located on the *CPU board* or in the *devices themselves*
- During operation, the device registers are accessed again and are programmed to process data transfer requests
- To access these devices, it is necessary for the developer to determine if the device is *port mapped* or *memory mapped*

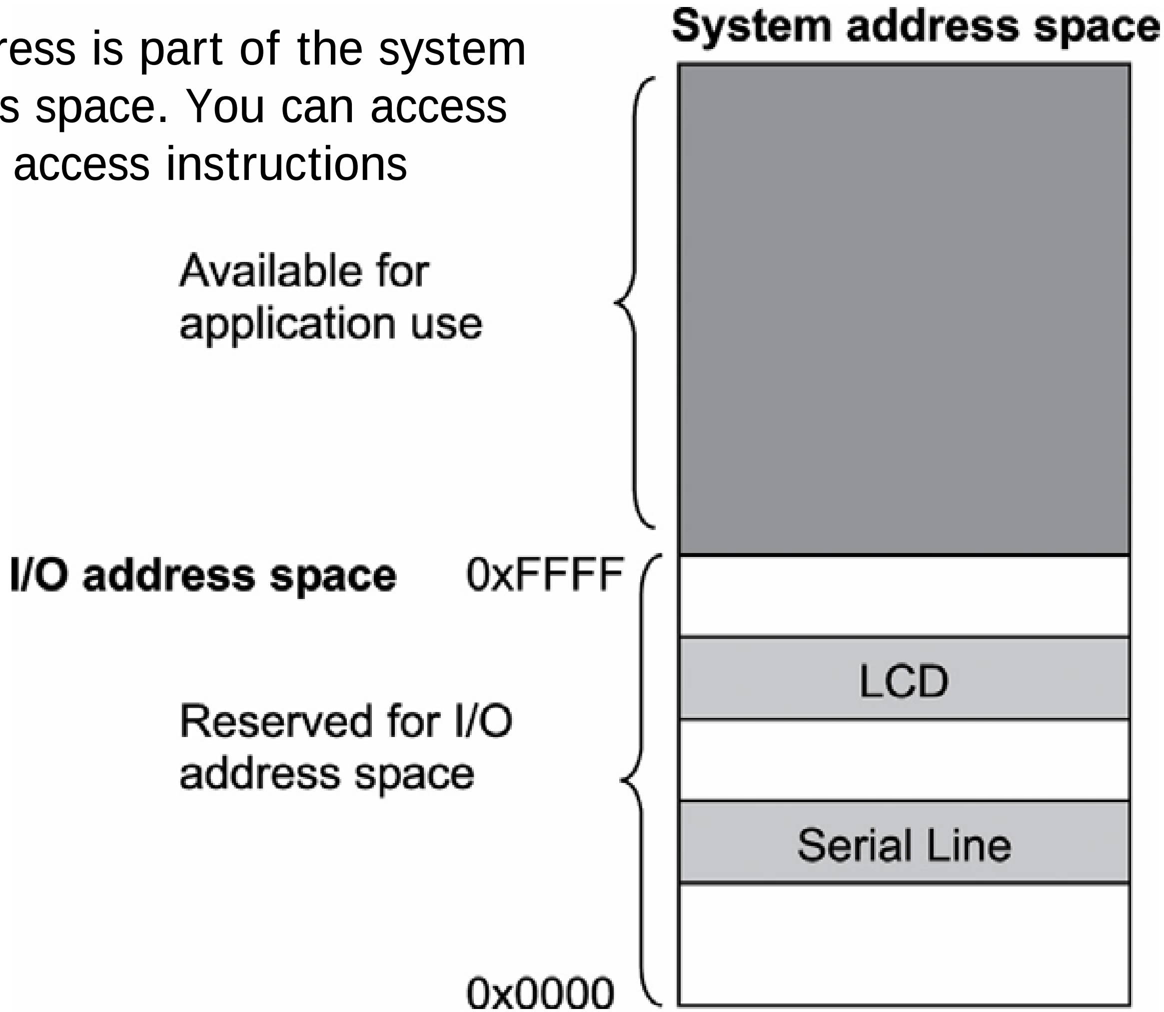
Port-Mapped I/O

The *I/O device address space* is ***separate*** from the *system memory address space*, special processor instructions, such as the **IN** and **OUT** instructions offered



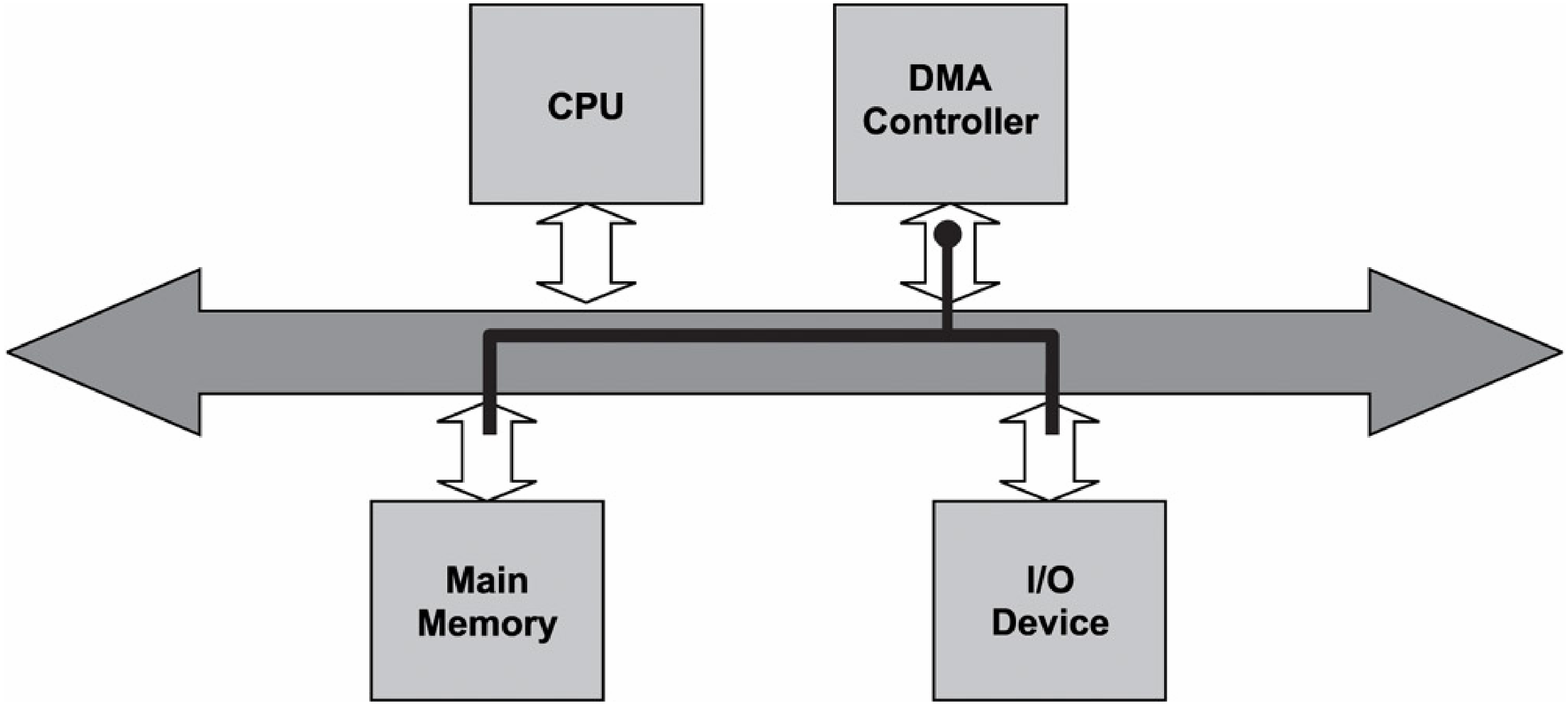
Memory-Mapped I/O

The device address is part of the system memory address space. You can access by any memory access instructions



DMA I/O

Direct memory access (DMA) chips or controllers allow the device to access the memory directly without involving the processor



12.2.2 Character-Mode vs. Block-Mode Devices

- Character-mode devices
  - Allow for *unstructured data transfers*
  - Data transfers typically take place in serial fashion (one byte at a time)
  - Simple devices (e.g. serial interface, keypad)
  - The driver *buffers* the data in cases where the transfer rate from system to the device is faster than what the device can handle

Character-Mode vs. Block-Mode Devices

- Block-mode devices
  - Transfer data one block at time (1,024 bytes per data transfer)
  - The underlying hardware imposes the block size
  - Some structure must be imposed on the data or transfer protocol enforced

12.3 The I/O Subsystem

- Each I/O device driver can provide a driver-specific set of *I/O application programming interfaces* to the applications
  - However, each application must be aware of the nature of the underlying I/O device
- Thus, embedded systems often include an *I/O subsystem* to reduce this implementation-dependence

The I/O Subsystem (Cont.)

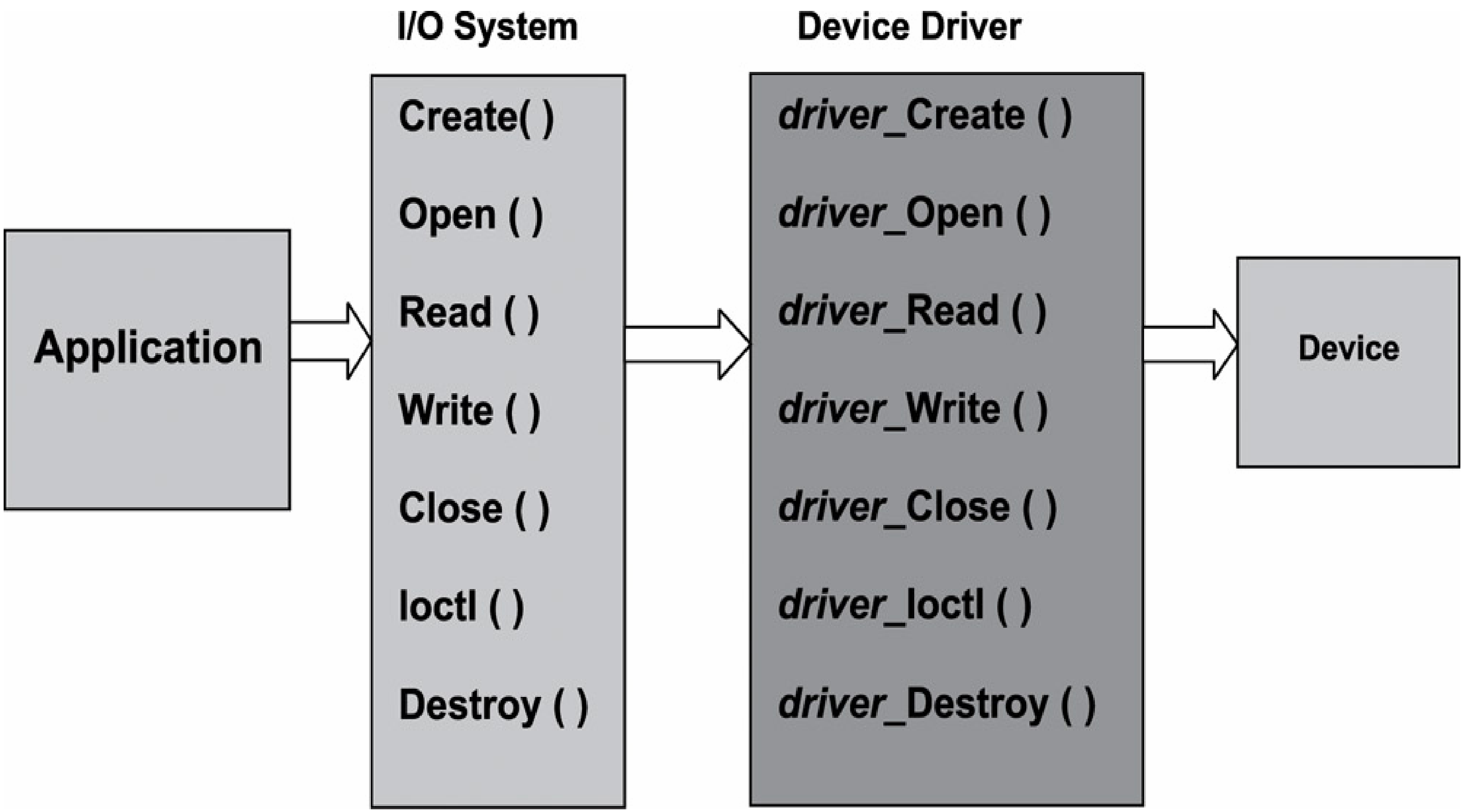
- I/O subsystem defines *a standard set of functions* for I/O operations
  - To hide device peculiarities from applications

- All I/O device drivers conform to and support this function set
  - To provide uniform I/O to applications across a wide spectrum of I/O devices of varying types

I/O Functions

Function	Description
Create	Creates a virtual instance of an I/O device
Destroy	Deletes a virtual instance of an I/O device
Open	Prepares an I/O device for use.
Close	Communicates to the device that its services are no longer required, which typically initiates device-specific cleanup operations.
Read	Reads data from an I/O device
Write	Writes data into an I/O device
Ioctl	Issues control commands to the I/O device (I/O control)

I/O Function Mapping



C Structure Defining the Uniform I/O API Set

```
typedef struct
{
    int (*Create)( );
    int (*Open) ( );
    int (*Read)( );
    int (*Write) ( );
    int (*Close) ( );
    int (*Ioctl) ( );
    int (*Destroy) ( );
} UNIFORM_IO_DRV;
```

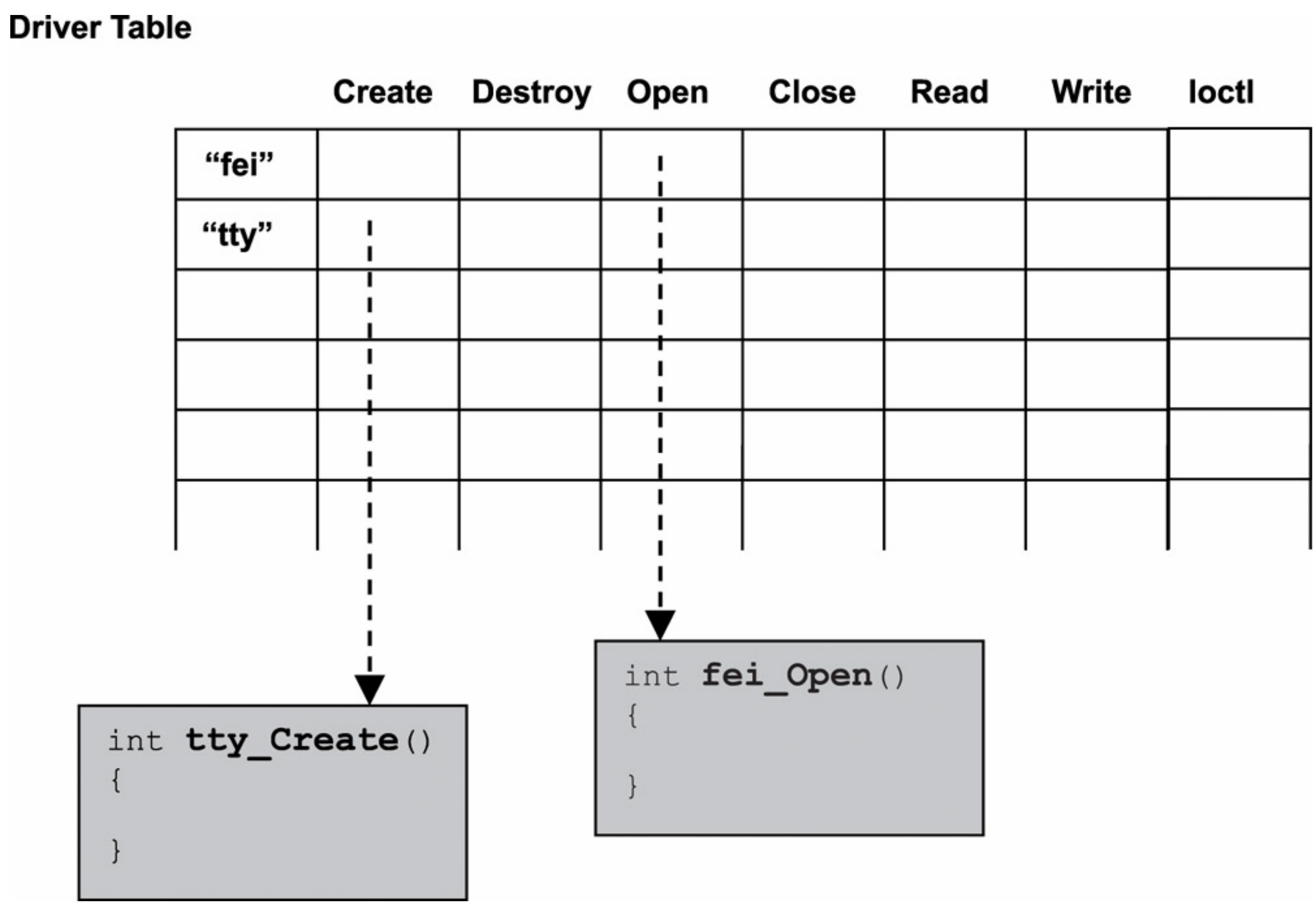
Mapping *Uniform I/O API* to *Specific Driver Functions*

```
UNIFORM_IO_DRV ttyIOdrv;
ttyIOdrv.Create = tty_Create;
ttyIOdrv.Open = tty_Open;
ttyIOdrv.Read = tty_Read;
ttyIOdrv.Write = tty_Write;
ttyIOdrv.Close = tty_Close;
ttyIOdrv.Ioctl = tty_Ioctl;
ttyIOdrv.Destroy = tty_Destroy;
```

Driver Table

- An I/O subsystem usually maintains a uniform I/O *driver table*
  - Associate *uniform I/O calls* with *driver-specific I/O routines*
  - A new driver can be installed to or removed from this driver table

Uniform I/O Driver Table



Associating Devices with Device Drivers

- The create() function is used to create a virtual instance of a device
- The I/O subsystem tracks these virtual instances using the device table
- Each entry in the device table holds *generic information*, as well as *instance-specific information*

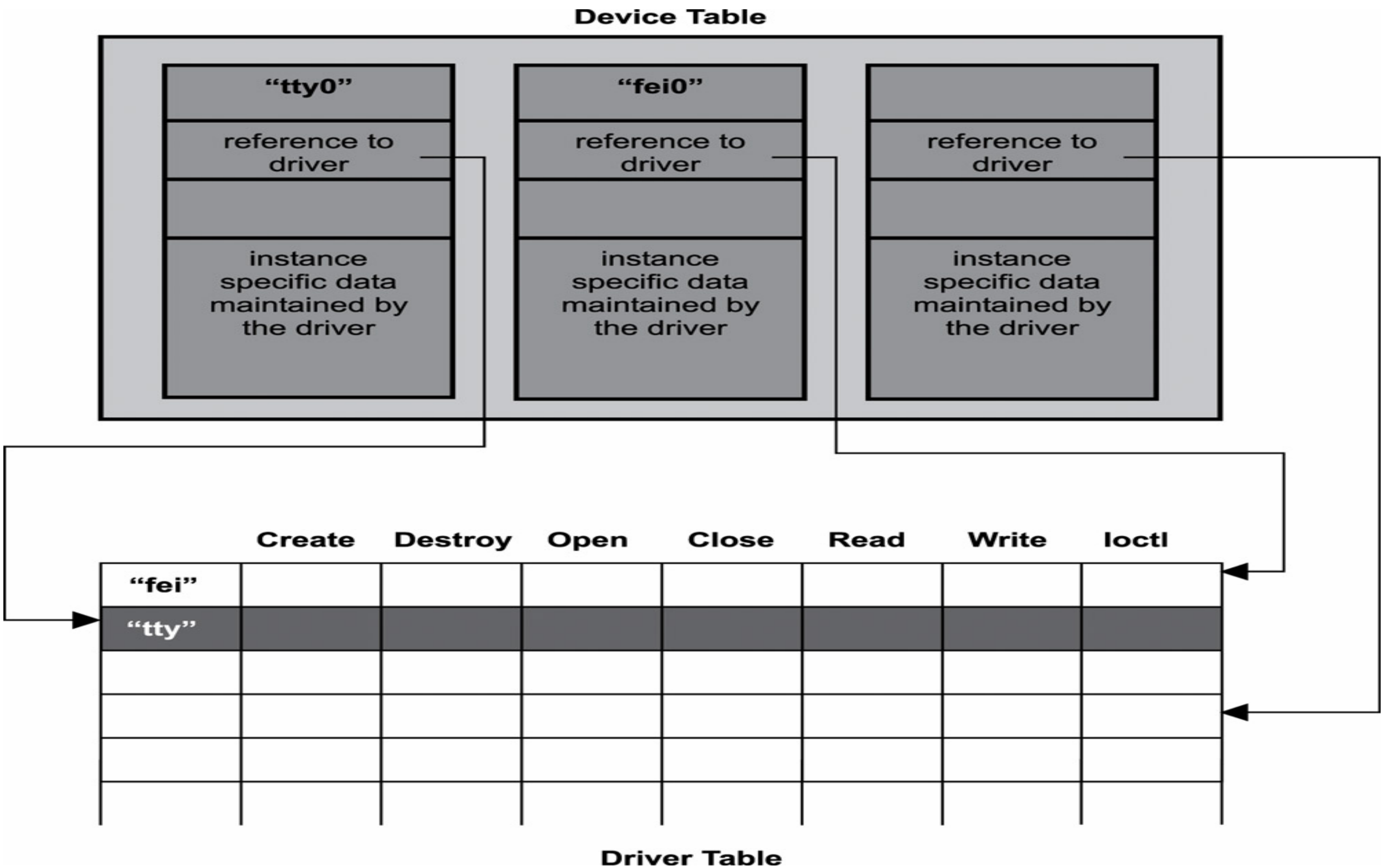
Associating Devices with Device Drivers (Cont.)

- The generic part can include the *unique name of the device instance* and *a reference to the device driver*
  - A device instance name is constructed using the *generic device name* and the *instance number*
  - For example, the device named **tty0** implies that
    - This I/O device is a serial terminal device
    - The first instance created in the system

Associating Devices with Device Drivers (Cont.)

- The driver-dependent part is a block of memory
  - Hold instance-specific data.
  - The content of this information is dependent on the driver implementation.
  - The driver is the only entity that accesses and interprets this data.
- A reference to the newly created device entry is returned to the caller of the create function.
  - Subsequent calls to the open and destroy functions use this reference.

Associating Devices with Drivers



Points to Remember

- Interfaces between a device and the main processor occur in two ways: *port mapped* and *memory mapped*
- DMA controllers allows data transfer bypassing the main processor
- I/O subsystems must be flexible enough to handle a wide range of I/O devices.
- Uniform I/O hides device peculiarities from applications.

Points to Remember (Cont.)

- The I/O subsystem maintains a *driver table* that associates *uniform I/O calls* with *driver-specific I/O routines*.
- The I/O subsystem maintains a *device table* and forms an association between this table and the driver table