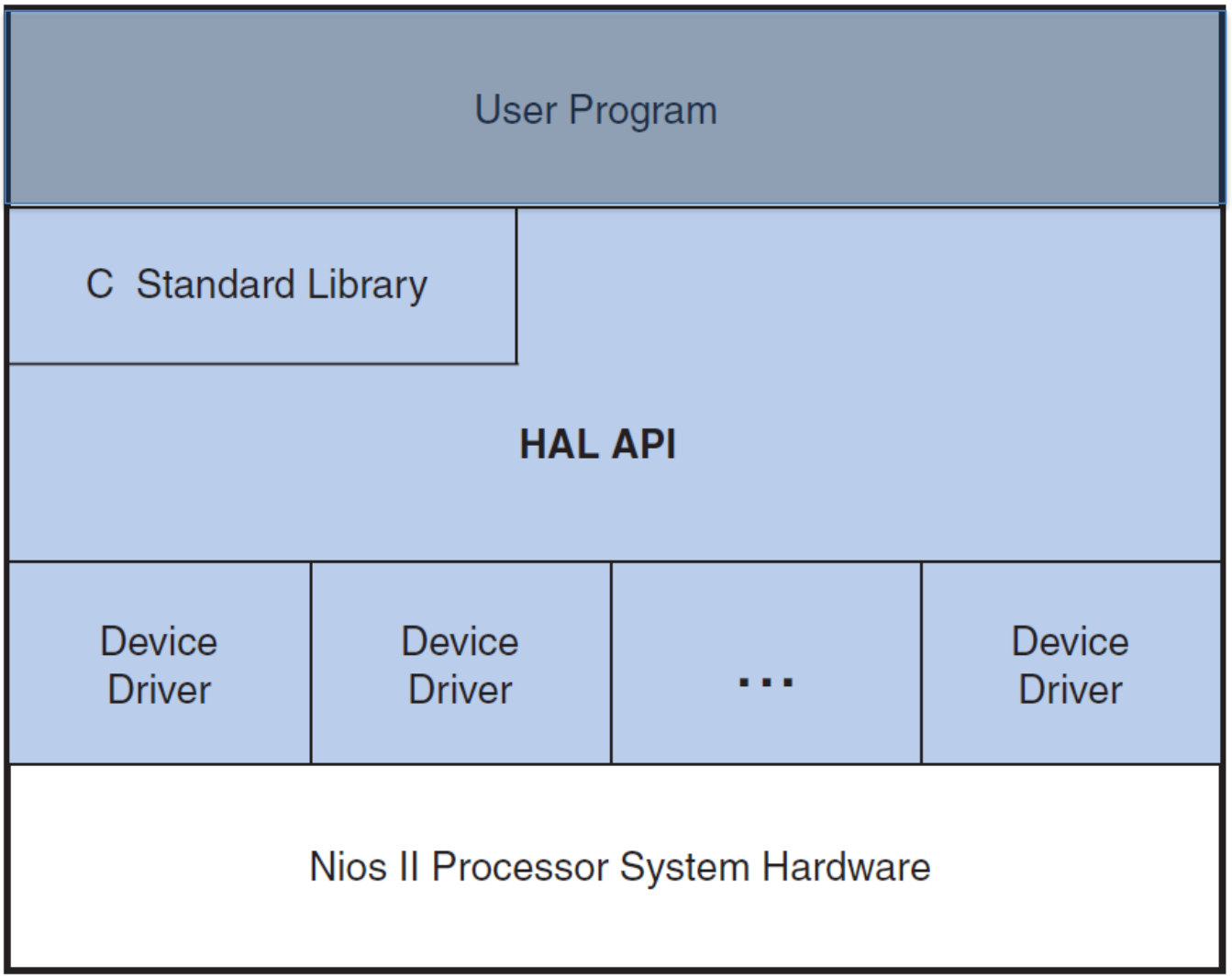
SISTEMI EMBEDDED
AA 2012/2013

SOPC Nios II
Hardware Abstraction Layer

Layered software



Hardware Abstraction Layer (1)

- Isolates User Program from hardware implementation
- Uses the services provided by the Device Driver Layer to create a standard interface (API: Application Programming Interface) towards the User Program
- Automatically generated by the Board Support Package (BSP) from specific hardware configuration contained in the SOPC information file (.sopcinfo)
- Integrated w/ Standard C Library
  - Peripherals can share the same API (eg. printf(), fopen(), fwrite(), …)

Hardware Abstraction Layer (2)

- Pros:
  - Speed-up software development
  - Code reusability
  - Tolerance to hardware changes during software developing
- Cons:
  - Less optimized code
    - Larger memory footprint
    - Slower performances

Hardware Abstraction Layer (3)

- **HAL additional services:**
  - System Initialization
    - Performs initialization tasks for the processor and the runtime environment before *main*()
  - Device Initialization
    - Instantiates and initializes each device in the system before *main*()

Generic Device Models

- **Character-mode devices:** Hardware peripherals that send and/or receive characters serially, such as a UART
- **Timer devices:** Hardware peripherals that count clock ticks and can generate periodic interrupt requests
- **File subsystems:** A mechanism for accessing files stored in physical device(s)
- **Ethernet devices:** Devices that provide access to an Ethernet connection for a networking stack such as the Altera-provided NicheStack® TCP/IP Stack - Nios II Edition
- **Direct memory access (DMA) devices:** Peripherals that perform bulk data transactions from a data source to a destination
- **Flash memory devices:** Nonvolatile memory devices that use a special programming protocol to store data

Benefits of a Device Model

- **HAL defines a set of functions to initialize and access each class of device**
- Application use a **standard API** independent of the device driver implementation (e.g. printf(), fopen(),... for character-mode devices and file subsystems)
- Device driver provides a set of driver functions according to the device class that are used by the standard API to manipulate the peripheral of the specific class

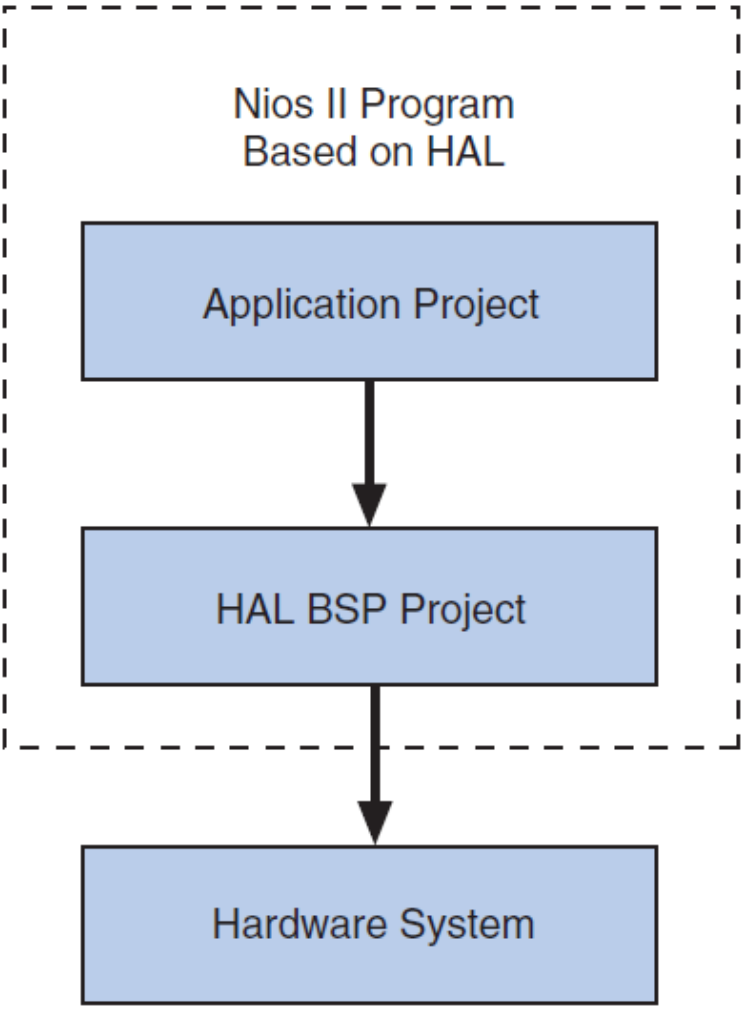
Peripherals supported by HAL (1)

- **Character mode devices:**
  - UART core
  - JTAG UART core
  - LCD 16207 display controller
- **Timer devices:**
  - Timer core
- **File subsystems:**
  - Altera host based file system
  - Altera read-only zip file system
- **Ethernet devices:**
  - Triple Speed Ethernet MegaCore® function
  - LAN91C111 Ethernet MAC/PHY Controller
- **DMA devices:**
  - DMA controller core
  - Scatter-gather DMA controller core
- **Flash memory devices:**
  - Common flash interface compliant flash chips
  - Altera's erasable programmable configurable serial (EPCS) serial configuration device controller

Peripherals supported by HAL (2)

- All peripherals (both from Altera and third party vendors) must provide a header file that defines the peripheral's low-level interface to hardware
- Some peripherals might not provide device drivers. If drivers are not available, use only the definitions provided in the header files to access the hardware. Do not use unnamed constants, such as hard-coded addresses, to access a peripheral
- Some peripherals provide dedicated functions that are not based on the HAL generic device models. For example, Altera provides a general-purpose parallel I/O (PIO) core for use with the Nios II processor system. The PIO peripheral does not fit in any class of generic device models provided by the HAL, and so it provides a header file and a few dedicated functions only

Structure of a project w/ HAL (1)



Also known as: Your program, or user project
Defined by: **.c**, **.h**, **.S**, **.s** files
Created by: You

Defined by: Nios II BSP settings
Created by: Nios II IDE or Nios II command line tools

Also known as: Nios II processor system, or the hardware
Defined by: **.sopcinfo** file
Created by: System integration tool (Qsys or SOPC Builder)

Structure of a project w/ HAL (2)

- Two projects:
  - User application project
  - BSP project
- The executable image (.elf) is the result of building both projects
- The BSP project incorporates the HAL and device drivers relevant to the specific hardware system defined by .sopcinfo file
- The BSP can be update when hardware system changes

System description file (1)

- **system.h** contains all information related to the hardware system
  - The hardware configuration of the peripheral
  - The base address
  - Interrupt request (IRQ) information (if any)
  - A symbolic name for the peripheral
- Generated automatically from .sopcinfo file and HAL BSP properties

System description file (2)

- Extracts from **system.h** related to the DE2 Basic Computer

```
/*
 * Pushbuttons configuration
 *
 */

#define ALT_MODULE_CLASS_Pushbuttons altera_up_avalon_parallel_port
#define PUSHBUTTONS_BASE 0x10000050
#define PUSHBUTTONS_IRQ 1
#define PUSHBUTTONS_IRQ_INTERRUPT_CONTROLLER_ID 0
#define PUSHBUTTONS_NAME "/dev/Pushbuttons"
#define PUSHBUTTONS_SPAN 16
#define PUSHBUTTONS_TYPE "altera_up_avalon_parallel_port"
```

System description file (3)

```
/*
 * Interval_timer configuration
 *
 */

#define ALT_MODULE_CLASS_Interval_timer altera_avalon_timer
#define INTERVAL_TIMER_ALWAYS_RUN 0
#define INTERVAL_TIMER_BASE 0x10002000
#define INTERVAL_TIMER_COUNTER_SIZE 32
#define INTERVAL_TIMER_FIXED_PERIOD 0
#define INTERVAL_TIMER_FREQ 50000000u
#define INTERVAL_TIMER_IRQ 0
#define INTERVAL_TIMER_IRQ_INTERRUPT_CONTROLLER_ID 0
#define INTERVAL_TIMER_LOAD_VALUE 6249999ull
#define INTERVAL_TIMER_MULT 0.0010
#define INTERVAL_TIMER_NAME "/dev/Interval_timer"
#define INTERVAL_TIMER_PERIOD 125.0
#define INTERVAL_TIMER_PERIOD_UNITS "ms"
#define INTERVAL_TIMER_RESET_OUTPUT 0
#define INTERVAL_TIMER_SNAPSHOT 1
#define INTERVAL_TIMER_SPAN 32
#define INTERVAL_TIMER_TICKS_PER_SEC 8u
#define INTERVAL_TIMER_TIMEOUT_PULSE_OUTPUT 0
#define INTERVAL_TIMER_TYPE "altera_avalon_timer"
```

HAL API (1)

- Unix-style functions
  - Facilitate portability of existing programs to Nios II
- HAL API can be further encapsulated by the C standard library
  - E.g. HAL API functions are used by the C standard library defined in **stdio.h** to perform underlying device access
  - Programmer can use both the C standard library or the HAL API functions

HAL API (2)

- Most commonly-used HAL API functions:

int **open**(const char* pathname, int flags, mode_t mode)	Opens a file or device and returns a file descriptor
int **close**(int fd)	Closes the file descriptor fd
int **read**(int fd, void *ptr, size_t len)	Reads a block of data from a file or device
int **write**(int fd, const void *ptr, size_t len)	Writes a block of data to a file or device
off_t **lseek**(int fd, off_t ptr, int whence)	Moves the read/write pointer associated with the file descriptor fd
int **fstat**(int fd, struct stat *st)	Obtains information about the capabilities of an open file descriptor
int **ioctl**(int fd, int req, void* arg)	Allows application code to manipulate the I/O capabilities of a device driver in driver-specific ways

Example (1)

- Using character-mode devices
  - A character-mode device (e.g. JTAG-UART) can be attached to stdin, stdout, stderr streams (BSP property)
    - printf() is available to access stdout!

```
#include <stdio.h>
int main ()
{
printf ("Hello world!");
return 0;
}
```

Example (2)

- Writing characters to the UART device “/dev/uart1”

```
#include <stdio.h>
#include <string.h>
int main (void) {
char* msg = "hello world";
FILE* fp;
fp = fopen ("/dev/uart1", "w");
if (fp!=NULL) {
   fprintf(fp, "%s",msg);
   fclose (fp);
   }
return 0;
}
```

Null device

- **/dev/null**
- Included by all HAL-based systems
- It is not connected to any hardware (virtual device)
- Writing to **/dev/null** has no effect and all data are discarded
- Used for safe I/O redirection during system startup and to sink unwanted data

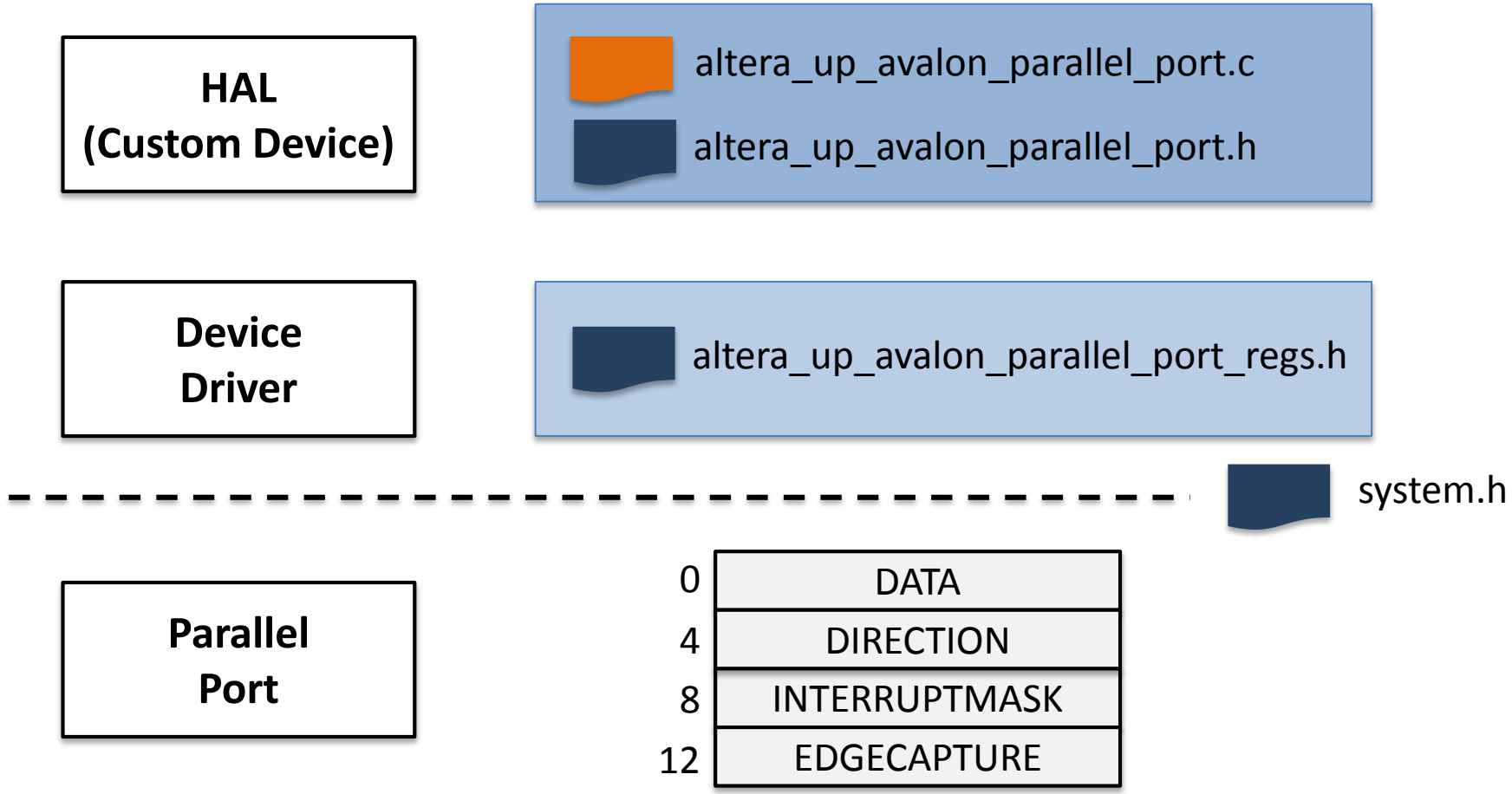
Device implementation

- **alt_dev.h**

```
typedef struct alt_dev_s alt_dev;


struct alt_dev_s {
  alt_llist    llist;     /* for internal use */
  const char*  name;
  int (*open)  (alt_fd* fd, const char* name, int flags, int mode);
  int (*close) (alt_fd* fd);
  int (*read)  (alt_fd* fd, char* ptr, int len);
  int (*write) (alt_fd* fd, const char* ptr, int len);
  int (*lseek) (alt_fd* fd, int ptr, int dir);
  int (*fstat) (alt_fd* fd, struct stat* buf);
  int (*ioctl) (alt_fd* fd, int req, void* arg);
};
```

Parallel Port HAL structure



Parallel Port Device Driver

- **altera_up_avalon_parallel_port_regs.h**

```
#ifndef __ALTERA_UP_AVALON_PARALLEL_PORT_REGS_H__
#define __ALTERA_UP_AVALON_PARALLEL_PORT_REGS_H__

#include <io.h>

// Data Register
#define ALT_UP_PARALLEL_PORT_DATA                              0
#define IOADDR_ALT_UP_PARALLEL_PORT_DATA(base)                      \
        __IO_CALC_ADDRESS_NATIVE(base, ALT_UP_PARALLEL_PORT_DATA)
#define IORD_ALT_UP_PARALLEL_PORT_DATA(base)                        \
        IORD(base, ALT_UP_PARALLEL_PORT_DATA)
#define IOWR_ALT_UP_PARALLEL_PORT_DATA(base, data)                  \
        IOWR(base, ALT_UP_PARALLEL_PORT_DATA, data)

/* ... */

#endif /* __ALTERA_UP_AVALON_PARALLEL_PORT_REGS_H__ */
```

Parallel Port HAL

- **altera_up_avalon_parallel_port.h**
  - Declares/Defines functions/MACROS to manage the device by the user application: open device, read and write data, …
  - Defines ancillary structure and MACROS to be used by the HAL runtime environment for device initialization
- **altera_up_avalon_parallel_port.c**
  - Defines:

    alt_up_parallel_port_dev*alt_up_parallel_port_open_dev(const char* name);

HAL runtime environment

- alt_sys_init.c
  - Allocates the device structures for the peripherals present in the hardware system
  - Initializes all the device
- The device structures are managed by a **list**

References

- Altera “Nios II Software Developer’s Handbook,” ***n2sw_nii5v2.pdf***
  - Section II. (Chapters 5, 6, 7) Hardware Abstraction Layer,
  - Chapter 14. HAL API Reference