Universidad de Alcalá

ELECTRONICS DEPARTMENT

ADVANCED DIGITAL ELECTRONIC SYSTEMS

SOFTWARE DEVELOPMENT

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INTELLIGENT SYSTEMS

OUTLINE

- **INTRODUCTION**
- SOFTWARE DESIGN FLOW
  - LIBGEN
  - GNU TOOLCHAIN
  - LIBRARIES
- BOARD SUPPORT PACKAGE
  - STANDALONE BSP
  - DEVICE DRIVERS
- XPS SOFTWARE SETTINGS
  - SOFTWARE PLATFORM SETTINGS
  - COMPILER SETTINGS

SOFTWARE DEVELOPMENT FOR
DESKTOP COMPUTERS vs EMBEDDED SYSTEMS

DESKTOP COMPUTERS

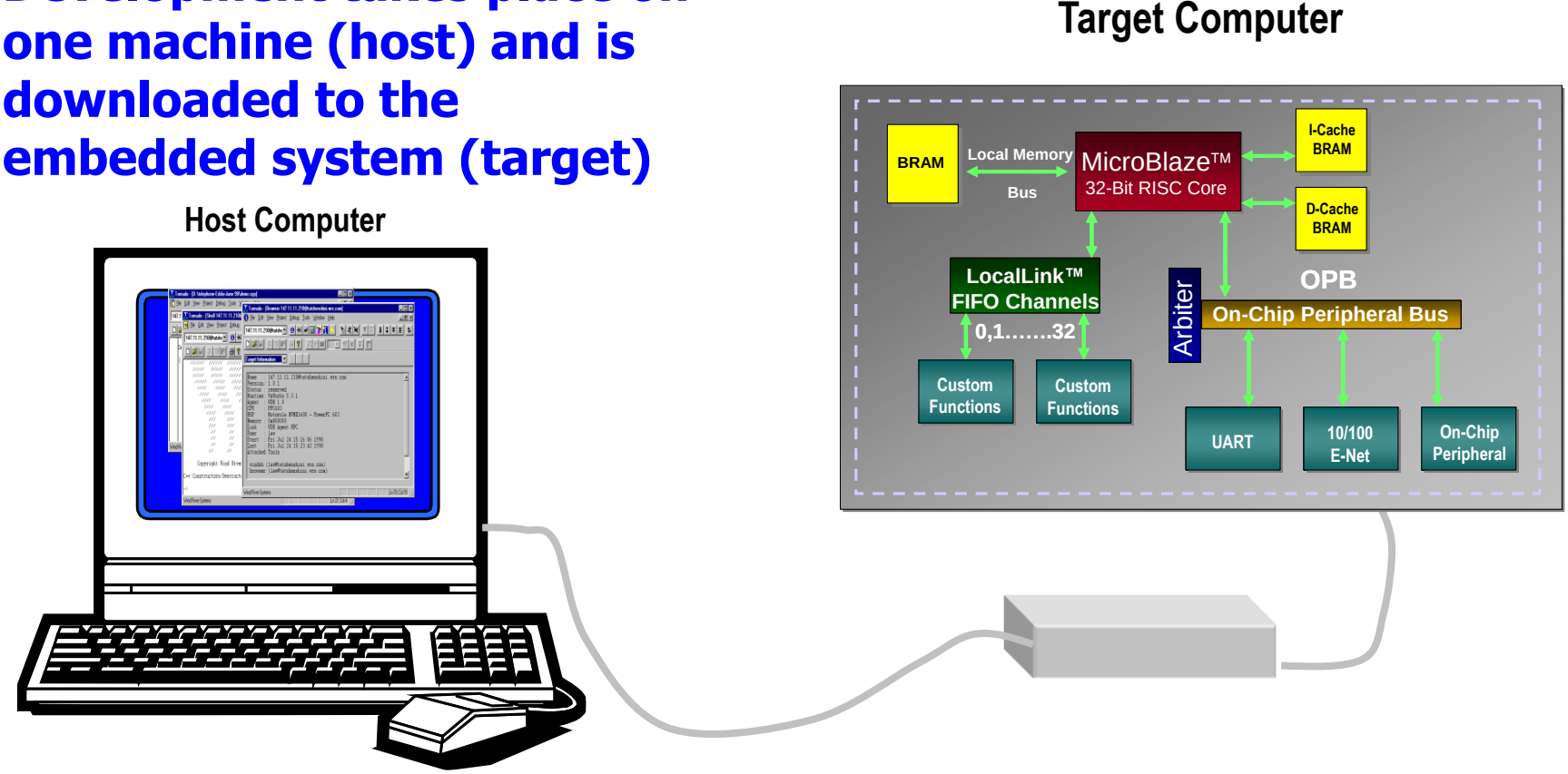
- Desktop development: written, debugged, and run on the same machine
- OS loads the program into the memory when the program has been requested to run
- Address resolution takes place at the time of loading by a program called the loader
  - The loader is included in the OS

EMBEDDED SYSTEMS

- The programmer glues into one executable file called ELF
  - Boot code, application code, RTOS, and ISRs
  - Address resolution takes place during the gluing stage
- The executable file is downloaded into the target system through different methods
  - Ethernet, serial, JTAG, BDM, ROM programmer

EMBEDDED vs DESKTOP

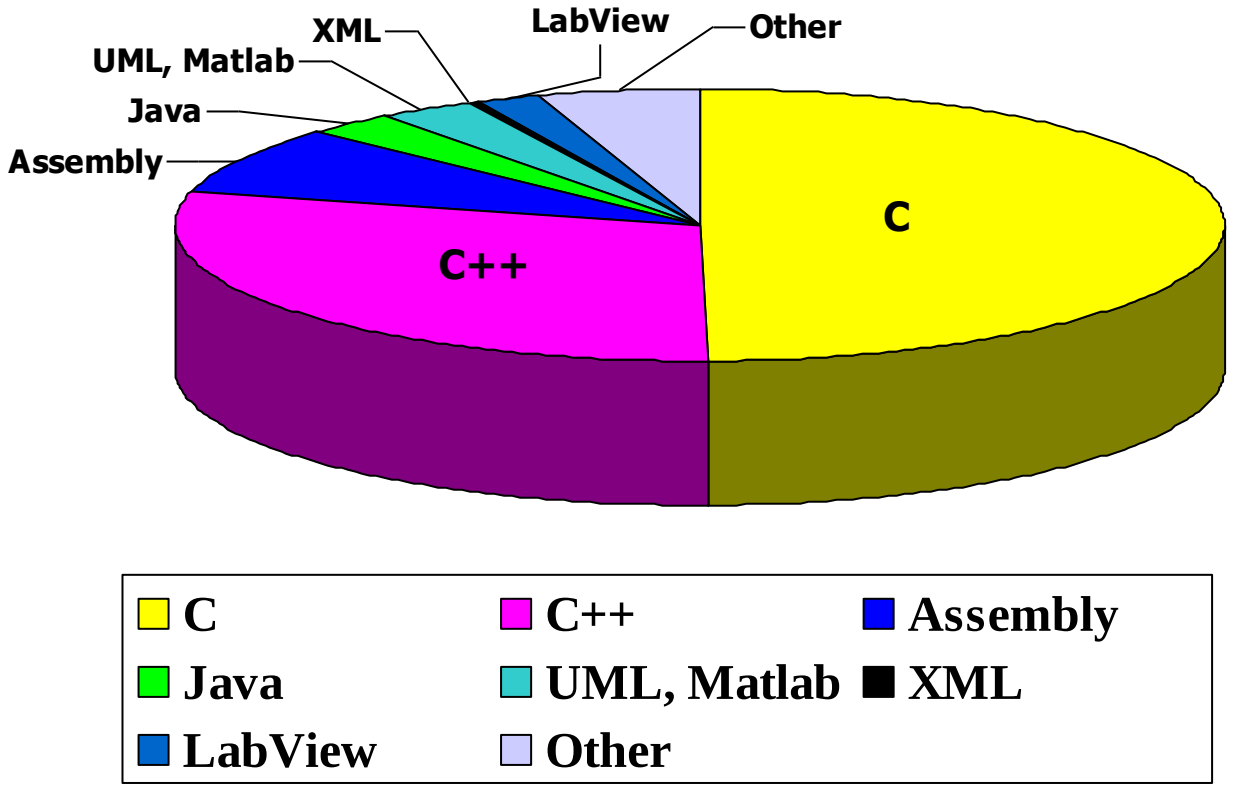
- **Development takes place on one machine (host) and is downloaded to the embedded system (target)**



A cross-compiler is run on the host

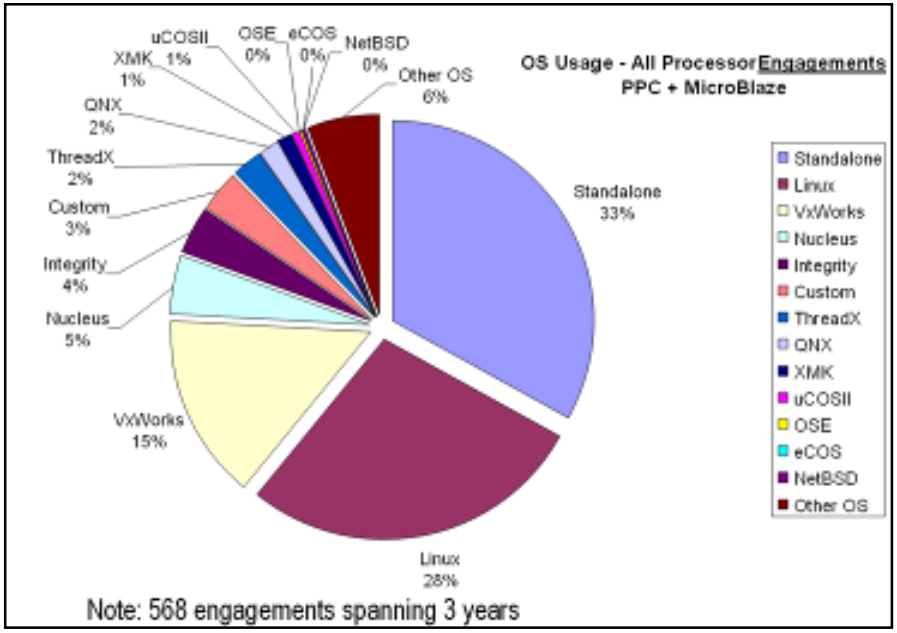
- Different set of problems
  - Unique hardware for every design
  - Reliability
  - Real-time response requirement (sometimes)
  - RTOS versus OS
  - Code compactness
  - High-level languages and assembly

PROGRAMING LANGUAGE USAGE



Source: 2006 Embedded Systems Design State of Embedded Market Survey

- Several alternatives
  - Standalone (No operating system)
  - Embedded Operating System (eOS)
    - General Purpose Operating Systems (GPOS)
    - Real Time Operating System (RTOS)



SOFTWARE PLATFORMS

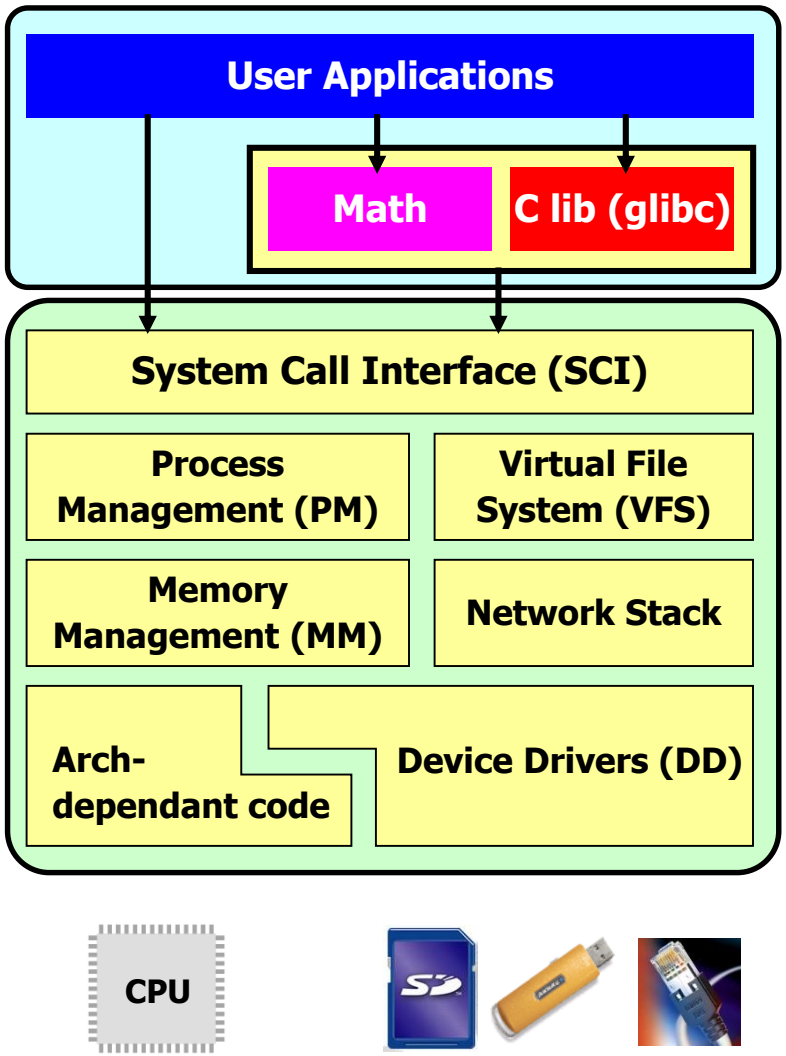
Embedded RTOS

- Multi-tasking
- Minimize latency
- Generally pre-emptive
  - VxWorks, ThreadX, etc.
- Hard and soft real time deadlines
  - execution deterministic
- Minimize CPU loading

Embedded OS

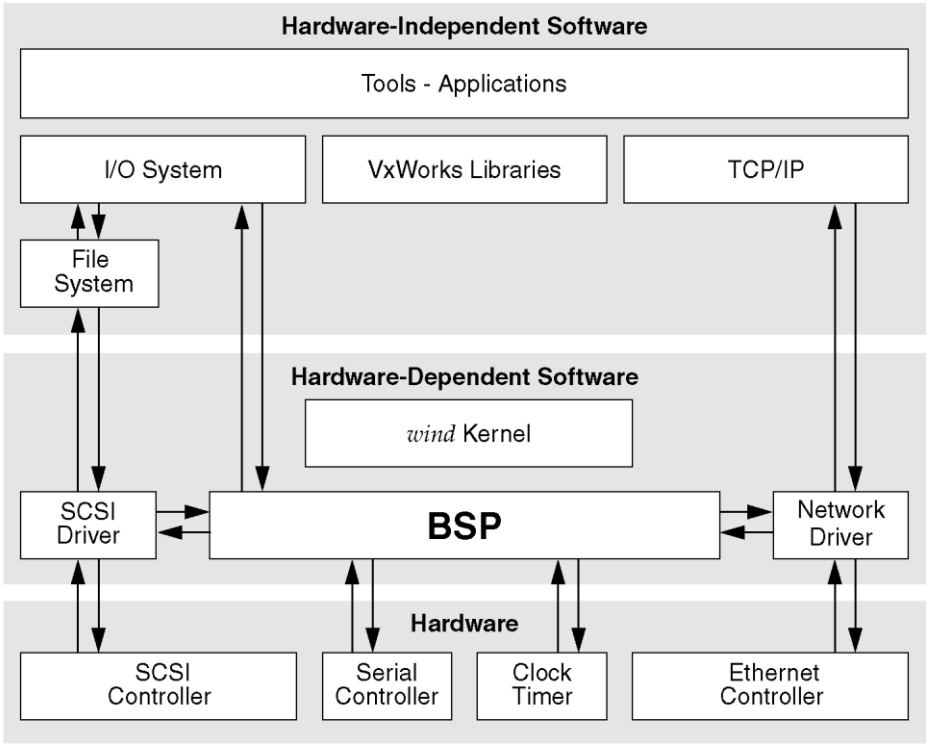
- Multi-tasking
- Maximize throughput
- Pre-emption not critical
  - Linux 2.4, Clinux
- Soft real time deadlines
  - execution less predictable
- Maximize CPU loading

GENERAL PURPOSE eOS: LINUX



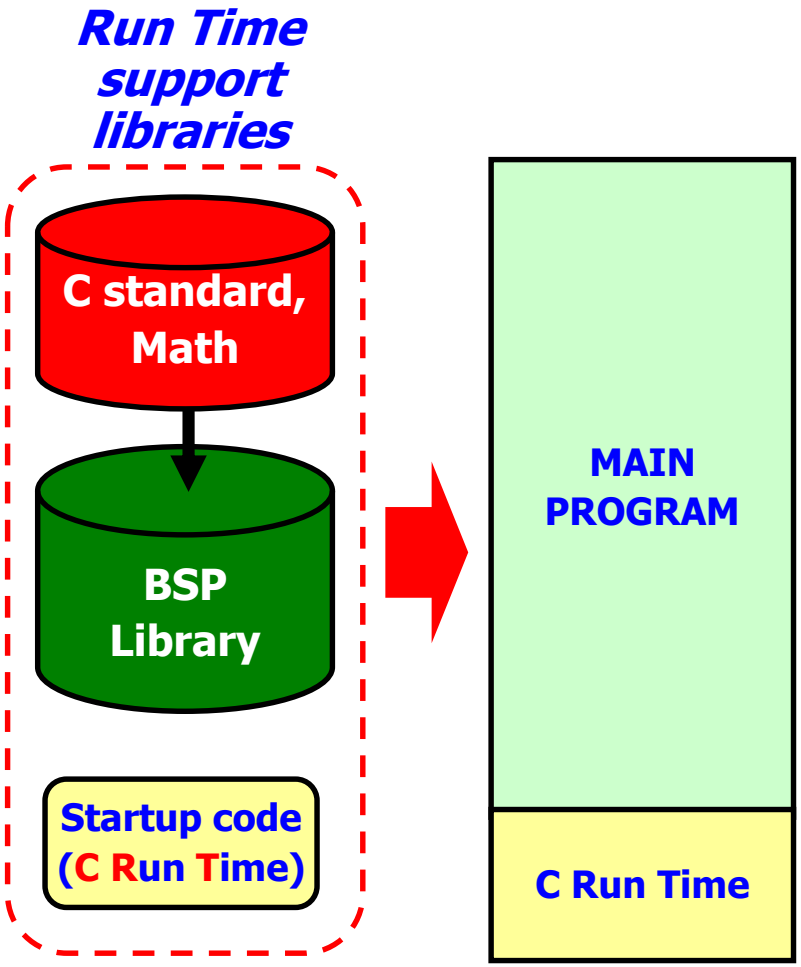
- Rich set of toolsets and utilities is available
- Multitasking
- Memory protection
- Portability

REAL TIME eOS: VxWorks



- Modular design
  - Scalability
- Microkernel provides minimal functionality
  - Process and memory management
- Other modules for the rest of the functionality
  - Client-server approach
- Hardware specific functionality in BSP libraries

STANDALONE PLATFORM



- Valid approach for very simple systems
  - Difficult to scale
  - One single task
- Monolithic structure
- Lightweight runtime support libraries

We will focus on this alternative

BOARD SUPPORT PACKAGES

- A Board Support Package (BSP) is the lowest layer of software modules used to access processor specific functions and custom hardware on the embedded system for a given target O/S
  - Virtualizes the platform hardware so that the different drivers can be ported easily on any hardware
  - Hides the board- and CPU-specific details from the rest of the OS
- The BSP has two components:
  - The microprocessor support
    - Interrupts, cache, endiannes
  - Board specific routines
    - Boot loader support
    - Memory map support
    - System timers
    - Interrupt controller support
    - Real-Time Clock (RTC)

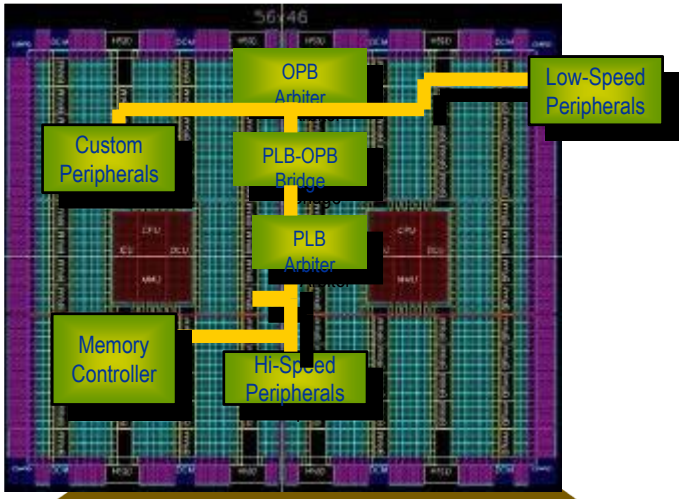
BOARD SUPPORT PACKAGES

Classical Embedded Platforms

- Fixed peripherals
- Fixed address maps
- Fixed BSP

Different

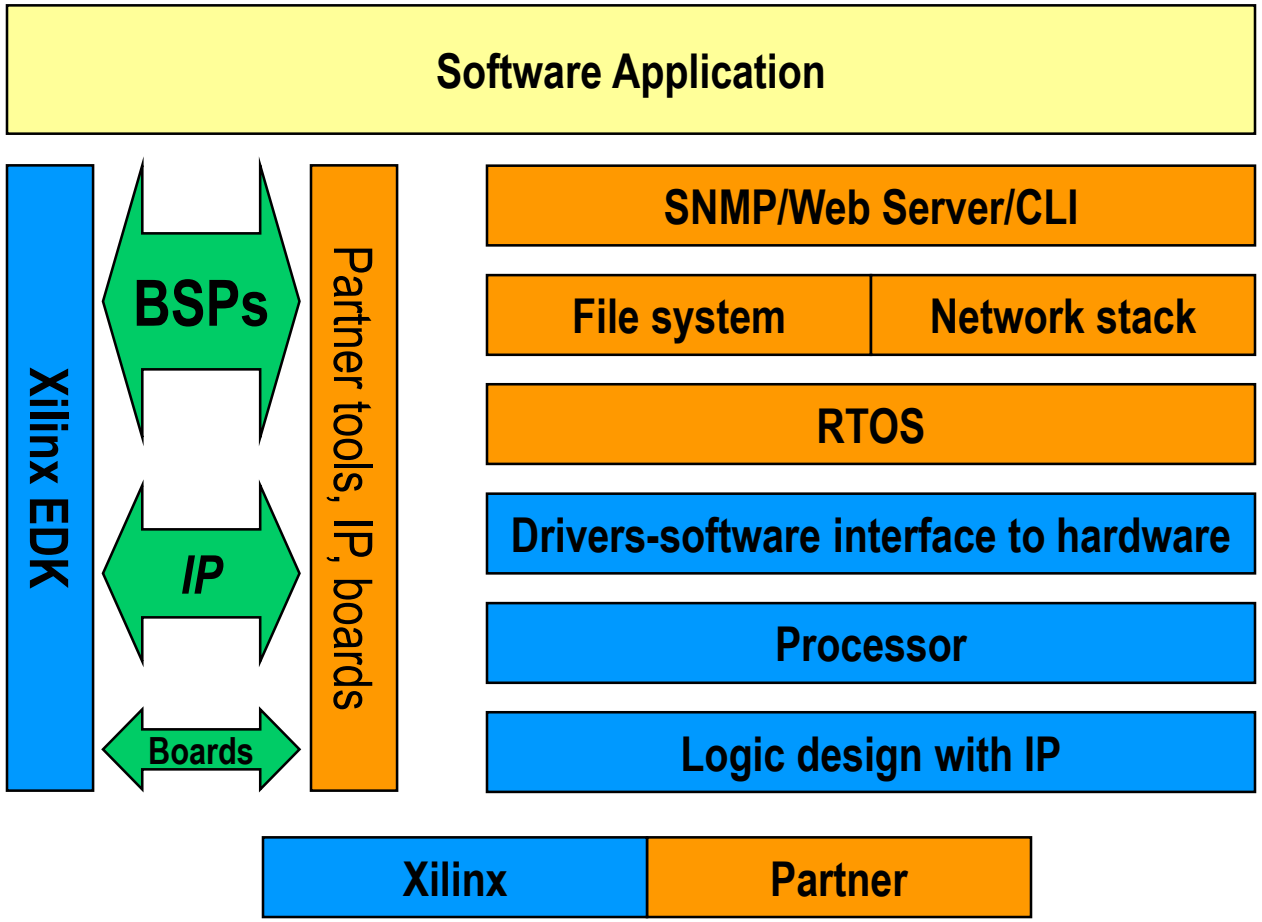
Platform FPGA



- Design dependent peripherals
- Each board is unique and custom
- Need efficient custom BSP creation

In an environment where hardware is defined in a programmable System-on-Chip (SoC), hardware changes can come about much more rapidly, making it difficult for the BSP to remain current with the revisions in hardware

BOARD SUPPORT PACKAGES



EDK provides a process called Automatic BSP Generation that tailors a BSP according to the current hardware configuration of the FPGA

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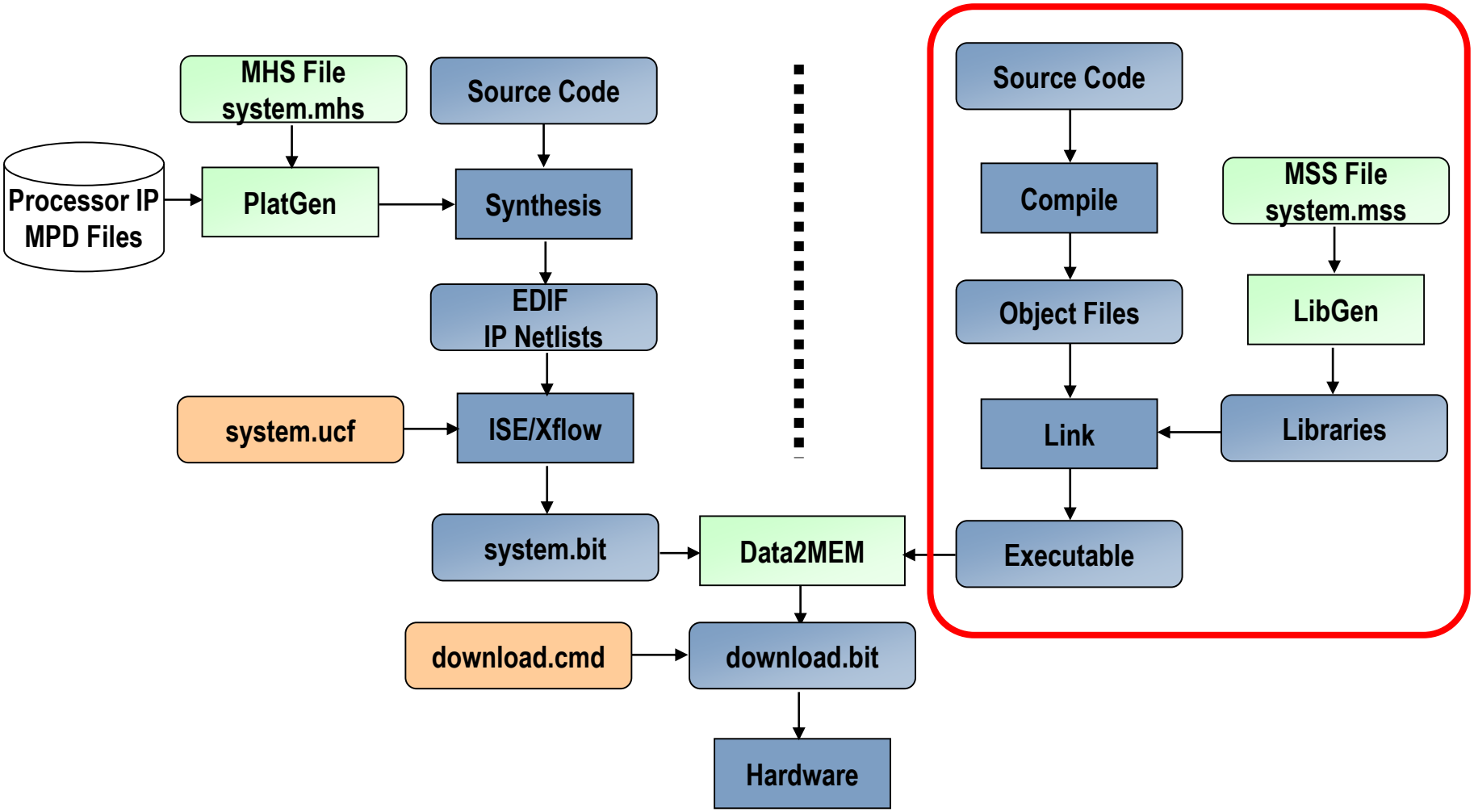
SW DESIGN FLOW



SW DESIGN ENVIRONMENT

- The Library Generator (LibGen) utility generates the necessary libraries and drivers for the embedded system
- LibGen takes an MSS (Microprocessor Software Specification) file created by the user as input. The MSS file defines:
  - the drivers associated with peripherals
  - standard input/output devices
  - interrupt handler routines
  - other related software features
- The MSS file is generated by XPS by using the software settings specified

LibGen configures libraries and device drivers

LibGen Generated Directories

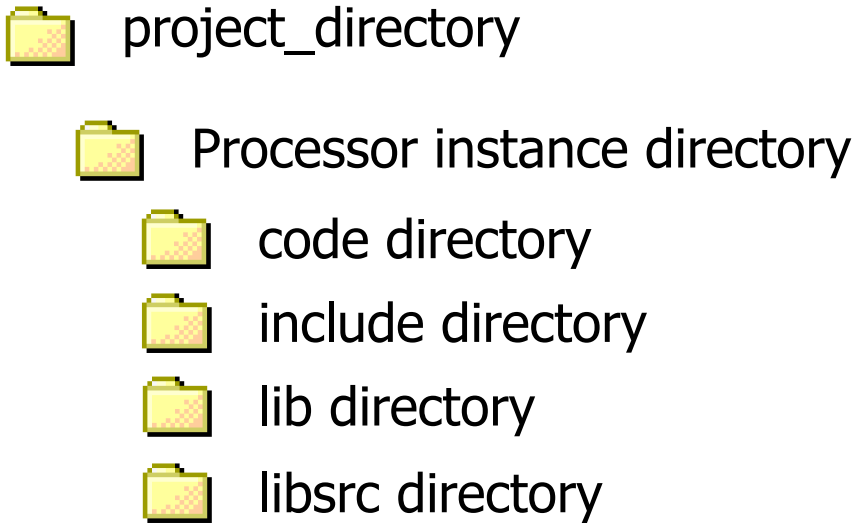
- project_directory
  - Processor instance directory
    - code directory
    - include directory
    - lib directory
    - libsrc directory

Note: The number of processor instance directories generated is related to the number of processor instances present in the system

- `code` directory
  - A repository for EDK executables
  - Creates `xmdstub.elf` for MB here
- include directory
  - C header files that are required by drivers
- `xparameters.h`
  - Defines base and high addresses of the peripherals in the system
  - Defines the peripheral IDs required by the drivers and user programs
  - Defines the function prototypes

Microblaze instance name in MHS file (e.g. microblaze_0)

LibGen Generated Directories



Note: The processor instance directories content is overwritten every time LibGen is run

- `libsrc` directory
  - Intermediate files and makefiles that compile the libraries and drivers
  - Peripheral-specific driver files that are copied from the EDK and user driver directories
- `lib` directory
  - System support libraries:
    - `libc.a`
    - `libm.a`
    - `libxil.a`

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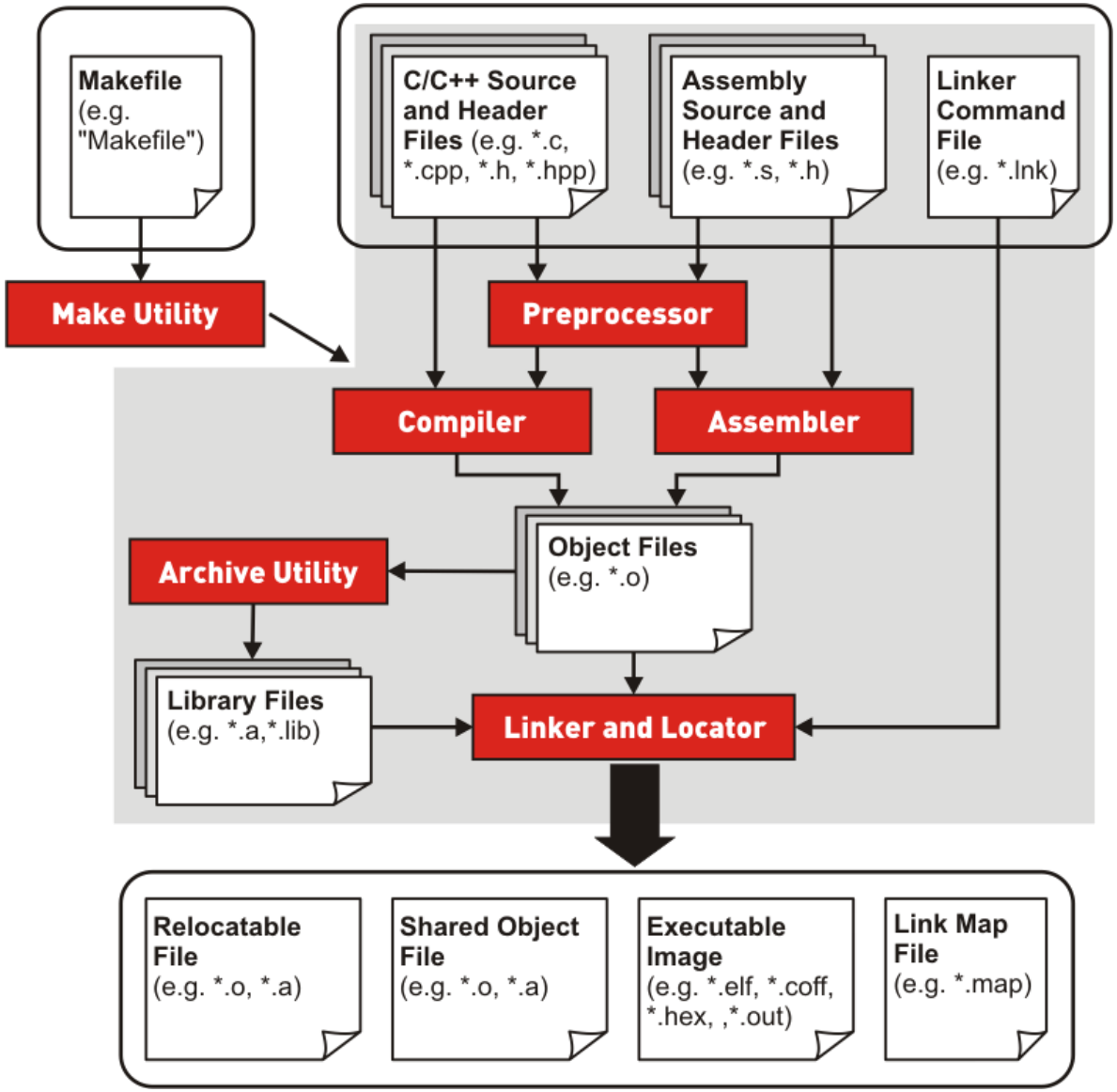
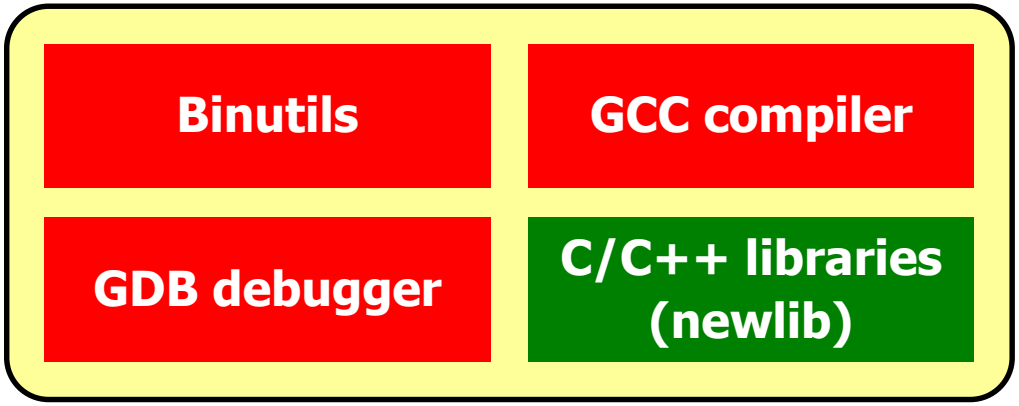
SOFTWARE TOOLCHAIN



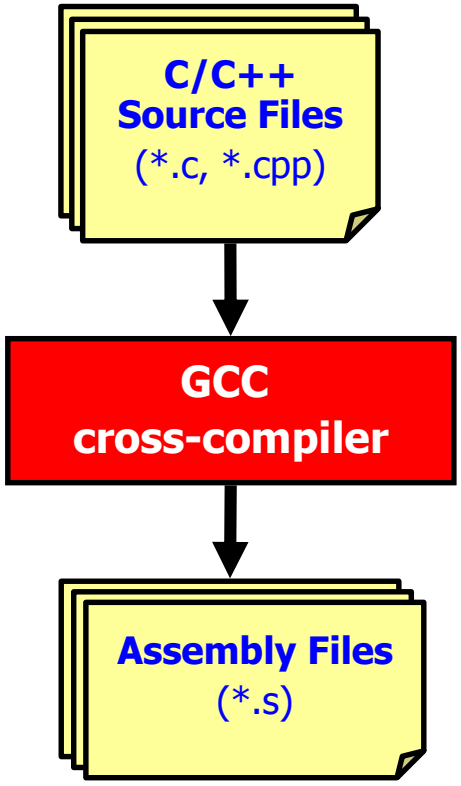
SOFTWARE TOOLCHAIN

- Microblaze uses the GNU toolchain as software development tools
  - mb-gcc: C/C++ Compiler
  - mb-as: Assembler
  - mb-ld: Linker
  - mb-ar: Archiver (Library management)
  - mb-objdump: Provides info about object files
  - mb-readelf: Provides info about elf (executable) files
  - etc.



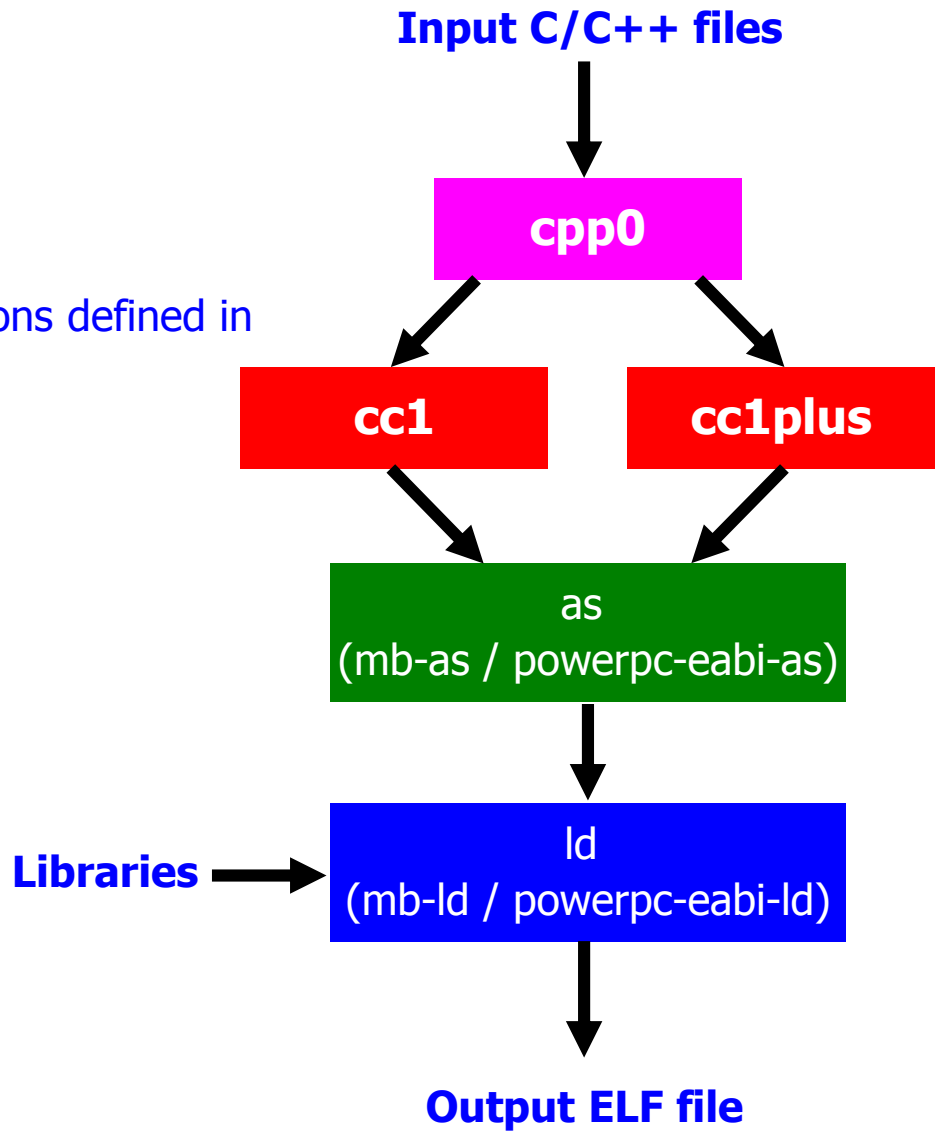
GNU COMPILER: GCC

- GCC translates C source code into assembly language
- GCC also functions as the user interface to the GNU assembler and to the GNU linker, calling the assembler and the linker with the appropriate parameters
- Supported cross-compilers:
  - PowerPC™ processor compiler
    - GNU GCC (powerpc-eabi-gcc)
    - Wind River Diab compiler (dcc)
  - MicroBlaze™ processor compiler
    - GNU GCC (mb-gcc)
- Command line only; uses the settings set through the GUI



GNU COMPILER: GCC

- Calls four different executables
  - Preprocessor (cpp0)
    - Analyzes and expands directives
    - Replaces all macros with definitions defined in the source and header files
  - Language specific c-compiler
    - cc1 C-programming language
    - cc1plus C++ language
  - Assembler
    - mb-as (MicroBlaze)
    - powerpc-eabi-as (PowerPC)
  - Linker and loader
    - mb-ld (MicroBlaze)
    - powerpc-eabi-ld (PowerPC)



MICROBLAZE SPECIFIC OPTIONS:

- Processor feature selection options:
  - -mcpu=vX.YY.Z
  - -mno-xl-soft-mul
  - -mxl-multiply-high
  - -mno-xl-multiply-high
  - -mxl-soft-mul
  - -mno-xl-soft-div
  - -mxl-soft-div
  - -mxl-barrel-shift
  - -mno-xl-barrel-shift
  - -mxl-pattern-compare
  - -mno-xl-pattern-compare
  - -mhard-float
  - -msoft-float

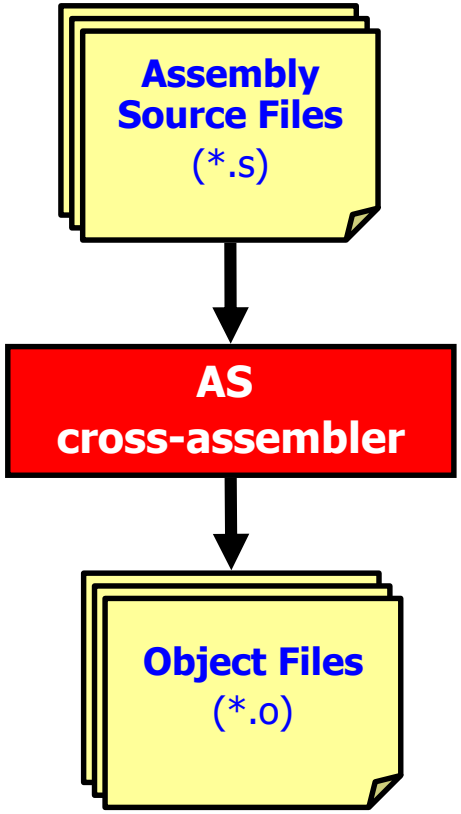
- General Program Options
  - -msmall-divides
  - -mxl-gp-opt
  - -mno-clearbss
  - -mxl-stack-check

- Application Execution Modes
  - -xl-mode-executable
  - -xl-mode-xmdstub
  - -xl-mode-bootstrap
  - -xl-mode-novectors

EDK automatically fixes the right options depending on MHS setting and compiler user dialogs

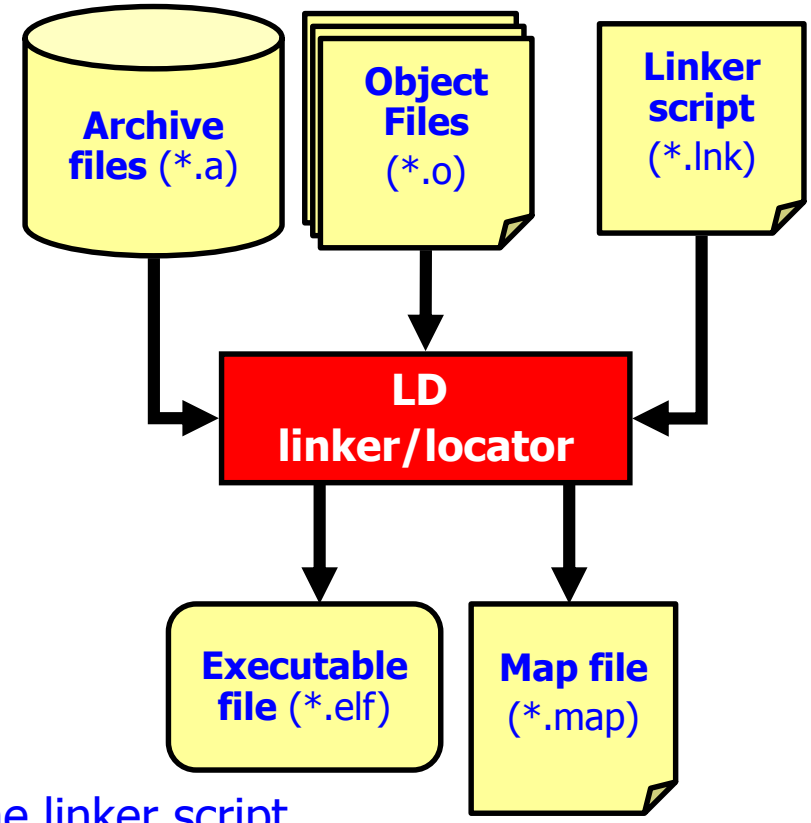
GNU ASSEMBLER: AS

- Input: Assembly language files
  - File extension: **.s**
- Output: Object code
  - File extension: **.o**
  - Contains
    - Assembled piece of code
    - Constant data
    - External references
    - Debugging information
- Typically, the compiler automatically calls the assembler
- It's possible to assemble a source file from gcc
  - Use `-Wa, xxx` to pass the xxx assembler option to mb-as from the gcc command line



GNU LINKER: LD

- Combines several object files and archive files, relocates their data and generates an executable file
- Inputs:
  - Several object files
  - Archived object files (library)
  - Linker script (mapfile)
- Output:
  - Executable image (.elf)
  - Mapping info file (.map)
- Command line options:
  - Have priority over those included in the linker script
  - Symbol definition: `-defsym symbol=expression`
- Use `-Wl,xxx` to set the xxx linker option from the GCC command line
  - `mb-gcc -Wl,defsym -Wl,_STACK_SIZE=0x800`



GNU BINARY UTILITIES: BINUTILS

- **Binutils** is a set of tools to generate and manipulate binaries for a given CPU architecture
  - as, the assembler, that generates binary code from assembler source code
  - ld, the linker
  - ar, ranlib, to generate .a archives, used for libraries
  - objdump, readelf, size, nm, strings, to inspect binaries.
  - Very useful analysis tools !
  - strip, to strip useless parts of binaries in order to reduce their size

GNU BINARY UTILITIES: BINUTILS

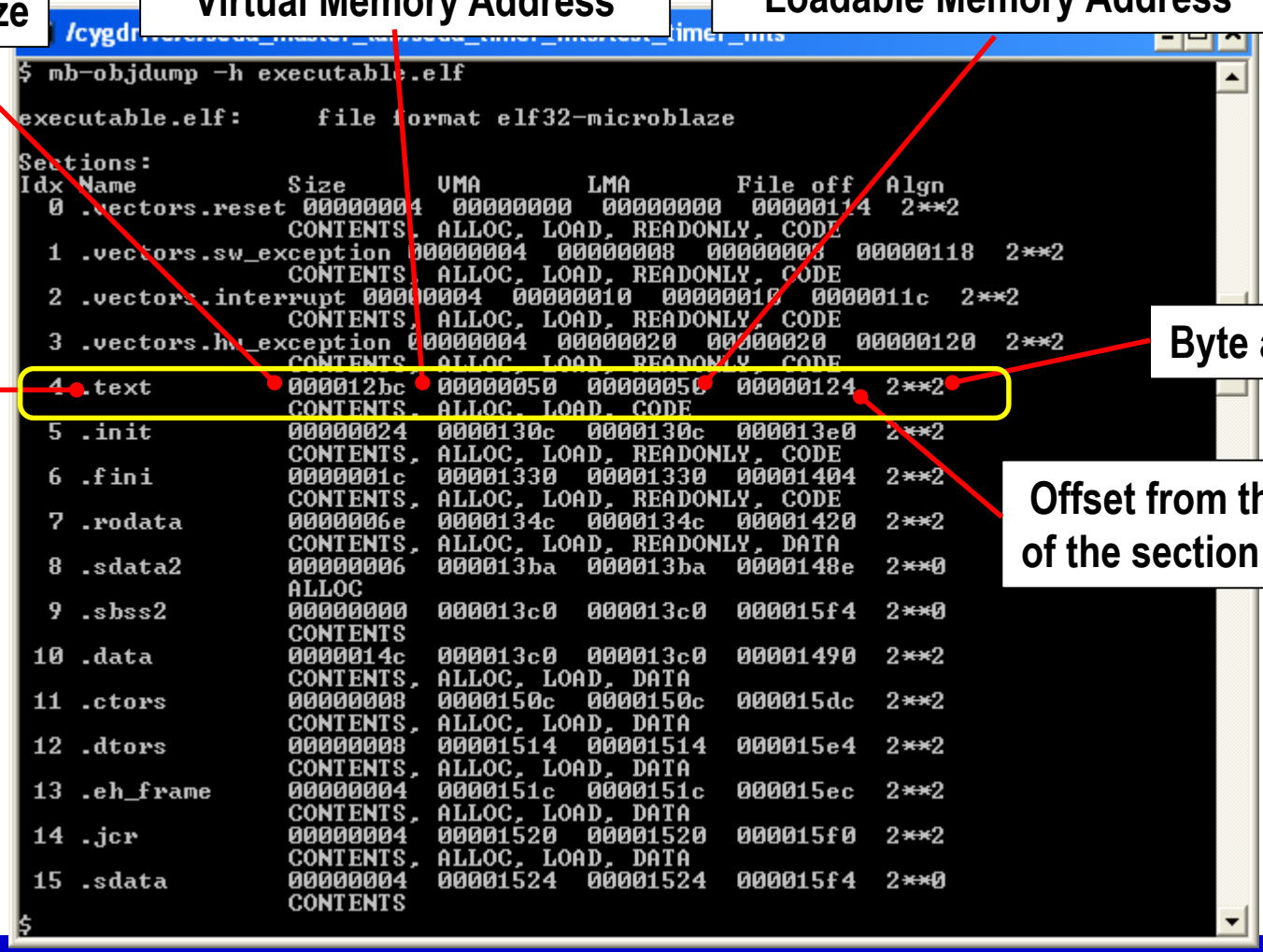
- AR Archiver
  - Library management
  - Create, modify, and extract object modules from libraries
  - Used in EDK to combine the object files of the Board Support Package (BSP) in a library
  - Used in EDK to extract object files from different libraries

- Object Dump
  - Display information from object files and executables
    - Header information, memory map
    - Data
    - Disassemble code
  - Two versions:
    - powerpc-eabi-objdump
    - mb-objdump

MICROBLAZE OBJECT DUMP

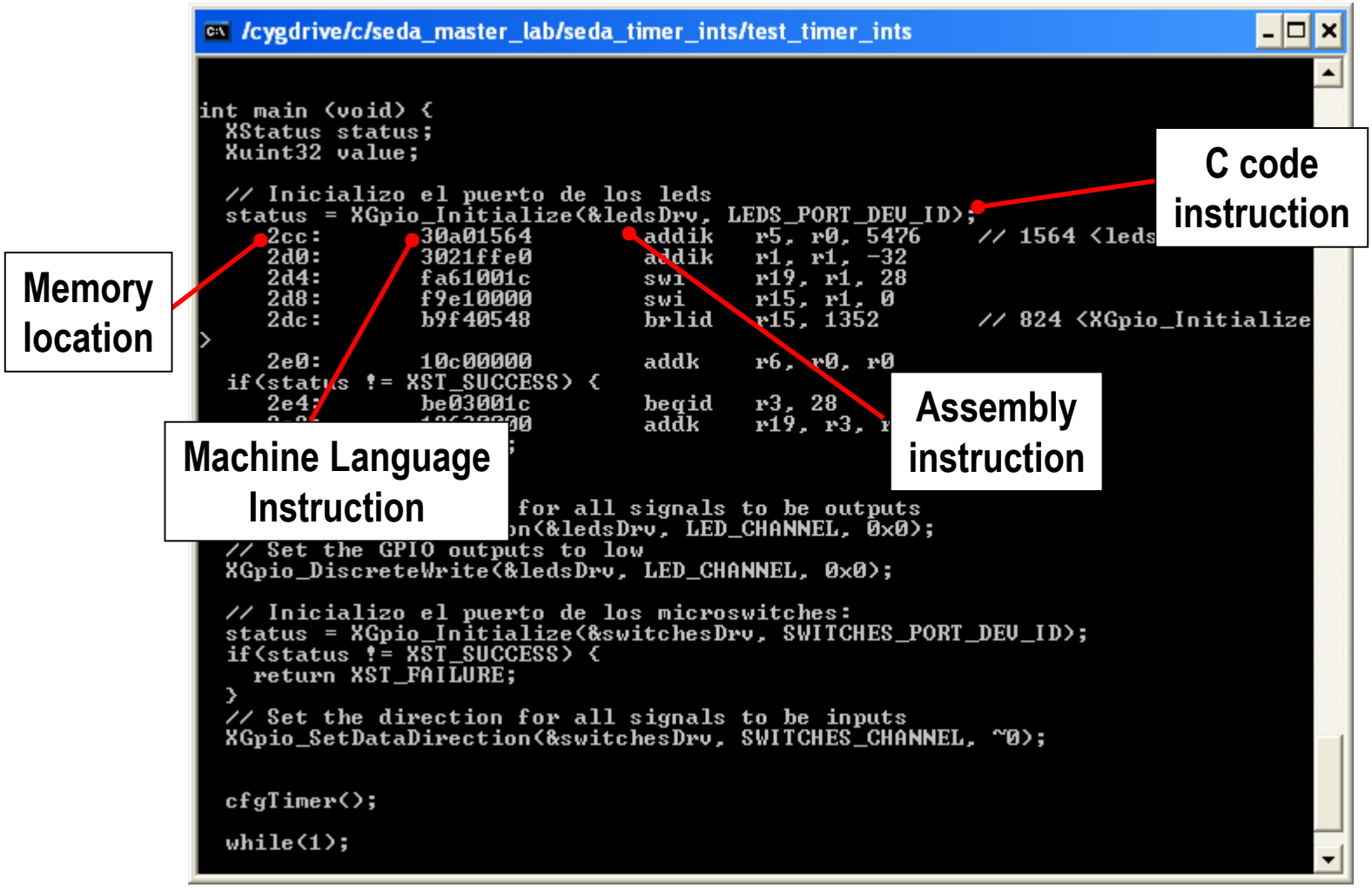
- Display summary information from the section headers:

```
mb-objdump -h executable.elf
```



- Dumping the source and assembly code:

```
mb-objdump -S executable.elf
```



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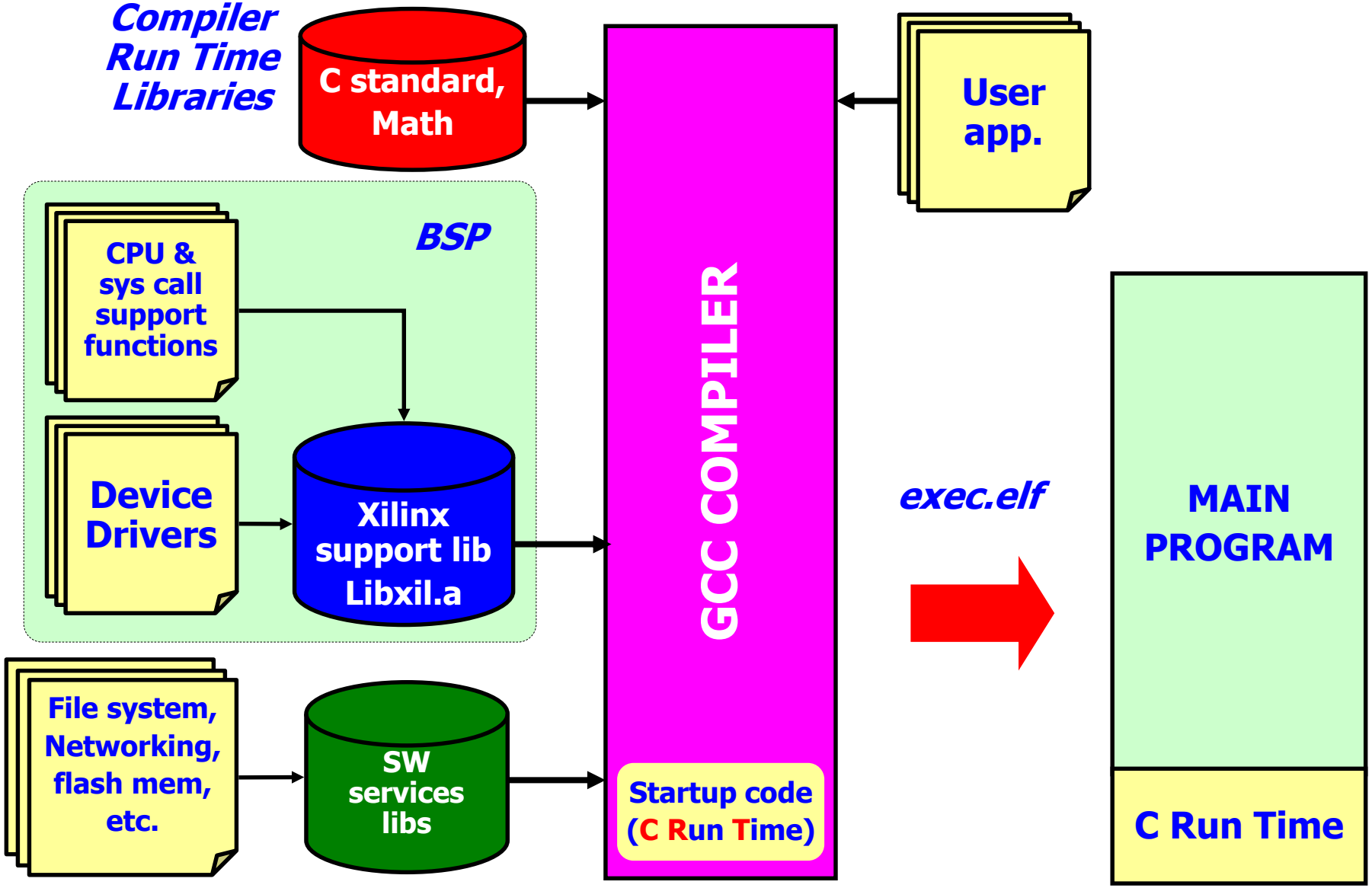
STANDALONE SW PLATFORM



COMPILER RUN-TIME LIBRARIES

- Desktop GCC compiler uses the GNU C library as the C standard library
  - Provides the system call interface that connects to the OS kernel
  - Shipped as a package that is made up of several modules: libc, libm
  - Full-featured but too large for embedded systems
  - More lightweight alternatives: uClibc, eglibc, dietlibc, and **newlib**

- Microblaze GCC uses **newlib** as run-time libraries for standalone and Xilinx Microkernel platforms
  - System services implemented by the Xilinx support library
  - Two files: libc, libm
  - EDK includes several precompiled variants for different CPU features
    - _bs Barrel shifter
    - _m HW multiplier
    - _p Patter comparator
    - _mh Extended HW multiplier
    - _fps Single precision
    - _fpd Double precision
  - LibGen copies the appropriated one to the project directory based on the used Microblaze HW configuration (MHS)

COMPILER RUN-TIME LIBRARIES

- Standard C language library (libc)
  - Contains standard C functions such us stdlib, stdio, string, etc.
  - Automatically linked with user code
    - No need to add the `-lc` option to the gcc command line
  - Limited functionality for dynamic memory allocation
  - I/O functions can result too heavy for embedded system
    - Consider to use simplified versions included in the Xilinx support library
- Math library (libm)
  - The math library is an improvement over the newlib math library
  - It must be explicitly linked with user code
    - Add the `-lm` option to the gcc commnad line

XILINX SUPPORT LIBRARY

- EDK includes a **libxil** precompiled basic version that provides:
  - OS-like support functionality for compiler libraries (sys call interface)
  - Default interrupt and exception handlers
  - Simplified I/O functions: xil_printf, print, putnum
  - Some low level support for GCC compiler (64 bits arithmetic)
- LibGen makes a local copy to the project directory and this copy is used to store platform BSP functions:
  - Microprocessor support: cache, interrupt and FSL management
  - Device drivers
- Automatically linked with user code
  - No need to add the `-lxil` option to gcc command line

XILINX SW SERVICES LIBRARIES

- Software service library package shipped as source code
  - LibXil MFS: Simple memory based file system
  - LibXil Flash: Access to parallel flash devices that conform to the Common Flash Interface (CFI)
  - LibXil Isf: Serial flash communication library
  - XilFATFS: File system support for System ACE CompactFlash or IBM microdrive devices
  - lwIP: open source TCP/IP stack to build network applications

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BOARD SUPPORT PACKAGES

- Currently EDK supports:
  - *Standalone BSP*: No OS is used and the user application accesses board or processor features directly
  - Wind River VxWorks (only for PPC)
  - Linux 2.4 & 2.6: (uCLinux for Microblaze without MMU)
  - Xilinx MicroKernel (XMK). It's a simple embedded processor Kernel that can be customized to a great degree for a given system

BSP

- Board Support Package (BSP):
  - Lowest layer of software modules used to access processor specific functions
    - Interrupt and Exception Handling
    - Instruction and Data Cache Handling
    - Fast Simplex Link interface macros
    - Program Profiling
  - Allows you to use IP peripheral-device drivers
    - GPIO, IIC controller, PCI controller, UART
  - Offers glue functionality to link code against standard libraries
    - Time, sleep
    - Files
    - Memory
  - Standalone BSP (no operating system)
    - Libgen generates `libxil.a` library

BSP: INTERRUPT MANAGEMENT FUNCTIONS

- Functions to enable, disable and register handlers (ISR)
  - Declared in **mb_interface.h**

```
void microblaze_enable_interrupts(void);
void microblaze_disable_interrupts(void);
void microblaze_enable_exceptions(void);
void microblaze_disable_exceptions(void);
void microblaze_register_handler(
         XInterruptHandler Handler,
         void *DataPtr);
void microblaze_register_exception_handler(
         Xuint8 ExceptionId,
         XExceptionHandler Handler,
         void *DataPtr);
```

BSP: CACHE MANAGEMENT FUNCTIONS

- Functions to enable, disable and update a single cache line or initialize a range of cache lines
  - Declared in **`mb_interface.h`**

```
void microblaze_enable_icache(void);
void microblaze_disable_icache(void);
void microblaze_enable_dcache(void);
void microblaze_disable_dcache(void);

void microblaze_update_icache(int tag, int inst, int lockValid);
void microblaze_init_icache_range(int cacheAddr, int cacheRange);
void microblaze_update_dcache(int tag, int inst, int lockValid);
void microblaze_init_dcache_range(int cacheAddr, int cacheRange);
```

BSP: FSL COMMUNITACION FUNCTIONS

- Blocking and not-blocking functions to send and receive write data through FSL channels
  - Defined as macros in **mb_interface.h**
  - Use in-line assembly

```
getfsl(val, id)    // Blocking Data Read and Write to FSL no. id
putfsl(val, id)
ngetfsl(val, id)   // Non-blocking Data Read and Write to FSL no. id
nputfsl(val, id)
cgetfsl(val, id)   // Blocking Control Read and Write to FSL no. id
cputfsl(val, id)
ncgetfsl(val, id) //Non-blocking Control Read and Write to FSL no. id
ncputfsl(val, id)
// Polling versions of FSL access macros.
// This makes the FSL access interruptible
getfsl_interruptible(val, id)
putfsl_interruptible(val, id)
cgetfsl_interruptible(val, id)
cputfsl_interruptible(val, id)
// FSL valid and error check macros.
fsl_isinvalid(result)
fsl_iserror(error)
```

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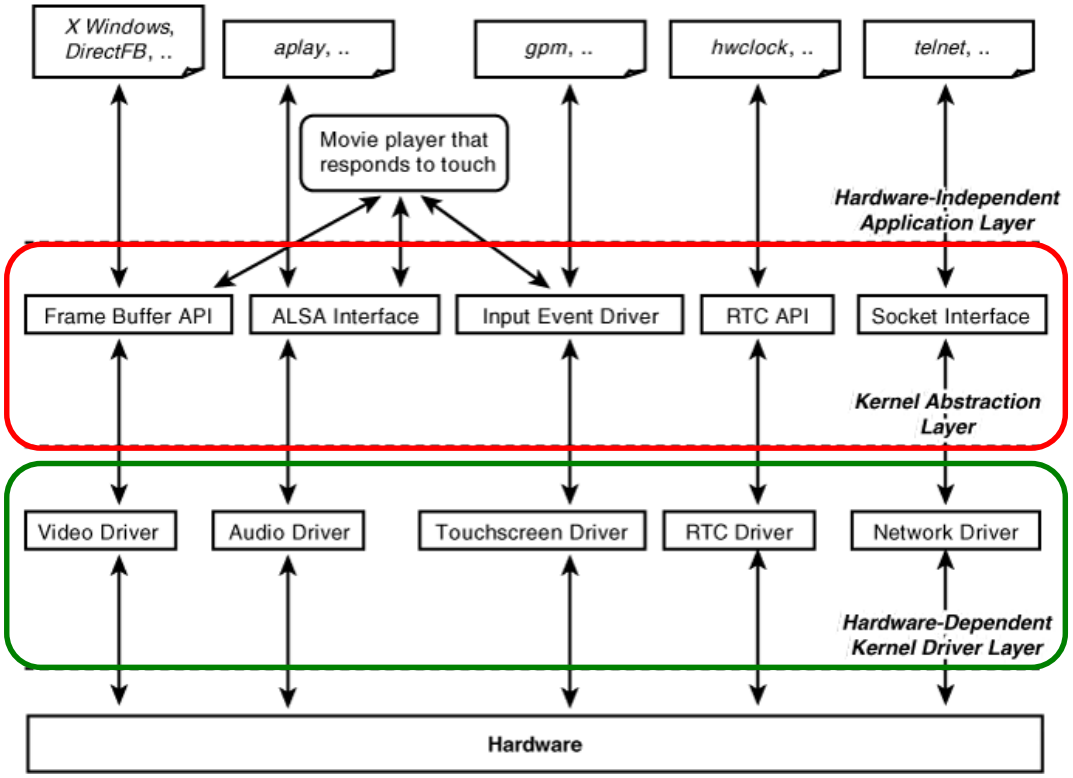
DEVICE DRIVERS

- A device driver is a SW module that directly interfaces with and controls a HW device
  - It manages access to HW by higher software layers (kernel, user apps)
- Every OS defines it own device driver model (or architecture)
  - Standard API to communicate from upper layers

VxWorks

µC/OS-II™
The Real-Time Kernel

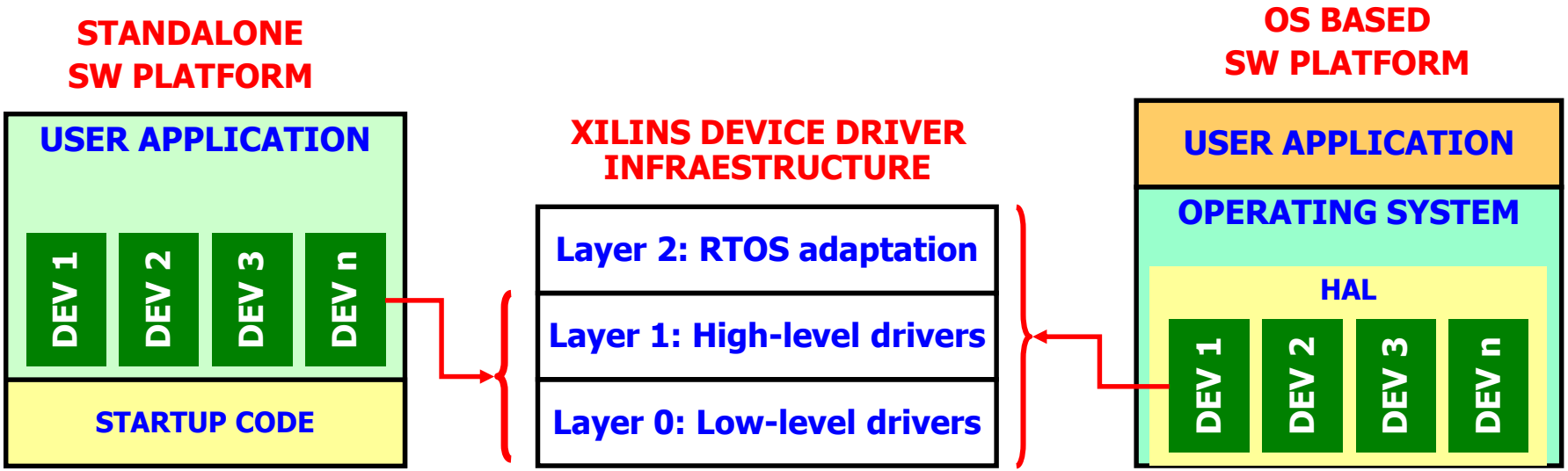


DEVICE DRIVERS

- The Xilinx device drivers are designed to meet the following objectives:
  - Provide maximum portability
    - The device drivers are provided as ANSI C source code
  - Support FPGA configurability
    - Supports multiple instances of the device without code duplication for each instance, while at the same time managing unique characteristics on a per-instance basis
  - Support simple and complex use cases
    - A layered device driver architecture provides both
      - Simple device drivers with minimal memory footprints
      - Full-featured device drivers with larger memory footprints
  - Ease of use and maintenance
    - Xilinx uses coding standards and provides well-documented source code for developers

DEVICE DRIVERS

- LibGen tool automatically generates drivers for devices included in the hardware platform
  - Designed to be portable across processor architectures and OS
  - Delivered as source code, allowing it to be built and optimized
  - C coded, limited use of assembly language
- Xilinx device driver infrastructure uses a multilayered approach
  - Layer 0: Low level drivers for simple use cases
  - Layer 1: High-level device drivers that are full-featured and portable across operating systems and processors
  - Layer 2: RTOS adaptation layer



DEVICE DRIVERS: LAYER 0

- Direct access to HW: Consists of very low level functions and macros
  - Designed to allow developer to create a small system
- Characteristics:
  - Small memory footprint, low function calling overhead
  - Include symbols (register offset, bit masks, etc.) and simple macros that give the user access to the HW registers
  - Little to no error checking is performed
  - Supports primary device features only
  - No support of device configuration parameters and device state
  - Supports multiple instances of a device
    - The API uses the device base address as identifier
  - Polled I/O only ➔ Blocking functions for simple use cases
  - Header files use '_l' suffix:
    - E.g. `xuartlite_l.h`

DEVICE DRIVERS: LAYER 1

- Provides high level functionality
- Implemented as macros and functions and designed to allow a developer to utilize all of the features of a device
- Characteristics
  - Abstract API that isolates the API from hardware device changes
  - Uses data structure to control the device configuration and/or status
  - Polled and interrupt driven I/O
  - Non-blocking function calls to aid complex applications
  - May have a large memory footprint
  - Typically, provides buffer interfaces for data transfers
    - as opposed to byte interfaces
  - Utilizes asynchronous callbacks for upward communication
  - Header files without '_' suffix
    - E.g. `xuartlite.h`

DEVICE DRIVERS: LAYER 2

- This layer adapts lower layers to the requirements of a given OS
  - Specific to every BSP
  - Every OS defines its device driver model
  - It converts a Layer 1 device driver to an interface that matches the requirements of the driver model for an RTOS
- Characteristics:
  - Communicates directly to the RTOS as well as the Layer 1 interface of the device driver
  - Not portable across operating systems
    - It contains references functions and identifiers specific to the RTOS
  - Can use memory management (i.e. malloc)
  - Can use RTOS services:
    - Threading, inter-task communication, etc.
  - Complexity depending on the RTOS interface and requirements for the device

DEVICE DRIVERS: EXAMPLE

Uartlite Level 1

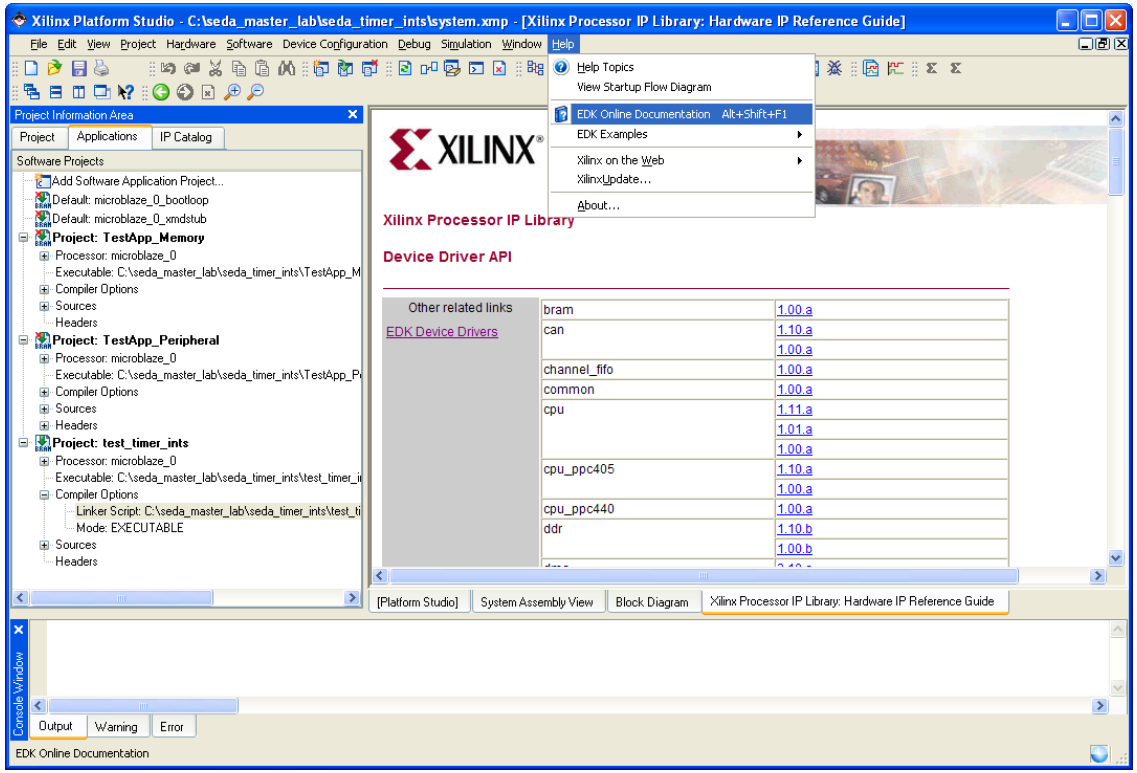
- XStatus XUartLite_Initialize (XUartLite *InstancePtr, Xuint16 DeviceId)
- void XUartLite_ResetFifos (XUartLite *InstancePtr)
- unsigned int XUartLite_Send (XUartLite *InstancePtr, Xuint8 *DataBufferPtr, unsigned int NumBytes)
- unsigned int XUartLite_Recv (XUartLite *InstancePtr, Xuint8 *DataBufferPtr, unsigned int NumBytes)
- Xboolean XUartLite_IsSending (XUartLite *InstancePtr)
- void XUartLite_GetStats (XUartLite *InstancePtr, XUartLite_Stats *StatsPtr)
- void XUartLite_ClearStats (XUartLite *InstancePtr)
- XStatus XUartLite_SelfTest (XUartLite *InstancePtr)
- void XUartLite_EnableInterrupt (XUartLite *InstancePtr)
- void XUartLite_DisableInterrupt (XUartLite *InstancePtr)
- void XUartLite_SetRecvHandler (XUartLite *InstancePtr, XUartLite_Handler FuncPtr, void *CallBackRef)
- void XUartLite_SetSendHandler (XUartLite *InstancePtr, XUartLite_Handler FuncPtr, void *CallBackRef)
- void XUartLite_InterruptHandler (XUartLite *InstancePtr)

Uartlite Level 0

- void XUartLite_SendByte (Xuint32 BaseAddress, Xuint8 Data)
- Xuint8 XUartLite_RecvByte (Xuint32 BaseAddress)

DEFINED API

- EDK provides a detailed description about the API for each device driver
  - HTML format generated with DOXIGEN
  - Available through EDK help
    - C:\EDA\Xilinx\10.1\EDK\doc\usenglish\xilinx_drivers_api_toc.htm
- EDK defines a standard API for level 1 drivers
  - Level 0 varies highly among different devices



LAYER 0 API

- Layer 0 is just a bundle of functions and macros that allow to access to the peripherals internal registers

```
void XGpio_mWriteReg(u32 BaseAddr, u32 RegOffset, u32 Data)
u32  XGpio_mReadReg(u32 BaseAddr, u32 RegOffset)
void XGpio_mSetDataDirection(u32 BaseAddr, unsigned Channel, u32 DirMask)
u32  XGpio_mGetDataReg(u32 BaseAddr, unsigned Channel)
void XGpio_mSetDataReg(u32 BaseAddr, unsigned Channel, u32 Data)
```

- It's necessary to know the base address in the memory map where every device instance is located
- Furthermore, IPs are highly parameterizable
  - It's necessary to know the configuration used by every device instance in order to properly control its operation
- System software also may need to know which interrupt vector the device is attached to
- LibGen tool automatically generates a file called '**`xparameter.h`**' containing all configuration info about the hardware platform

HW CONFIGURATION PARAMETERS

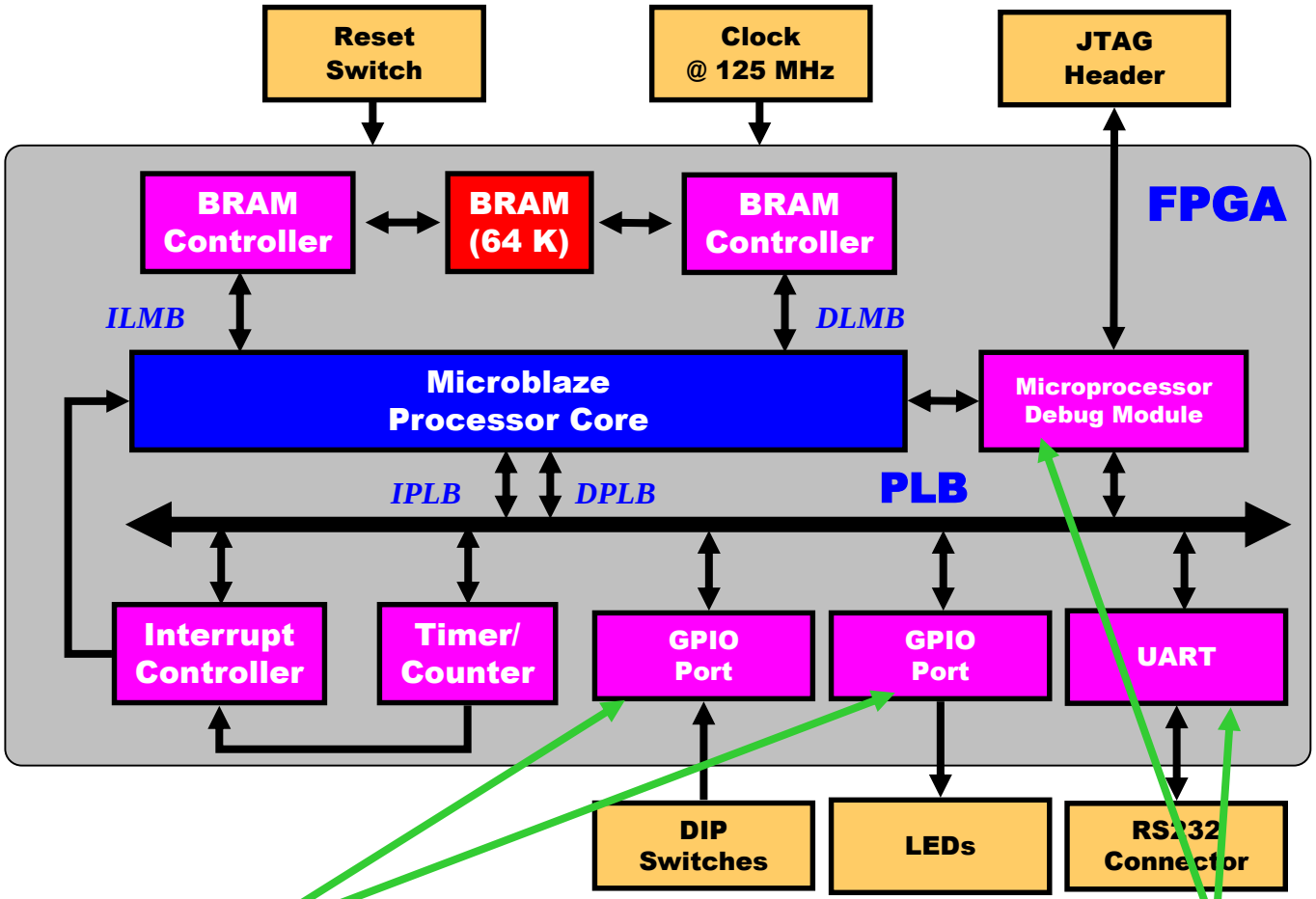
- 'xparameters.h' file contains symbols (#define) that provide info about the configuration used for every device and driver within the system
  - Used by BSP and device drivers to configure the system at runtime

- Configuration info for each device:

Common info

  - Number of device instances
  - Device ID for each instance (uint16)
    - used during initialization to perform the mapping of a device driver to a HW device
  - Base address for each device instance
  - Interrupt assignments for each device instance (if used)
  - *Other device specific info*

- For each device driver type:
  - XPAR_X<driver_name>_NUM_INSTANCES
- For each device instance:
  - XPAR_<driver_name>_<device_instance>_DEVICE_ID
  - XPAR_<driver_name>_<device_instance>_BASEADDR
  - XPAR_<driver_name>_<device_instance>_HIGHADDR
  - *XPAR_<intc_device_instance>_<interrupting_device_instance>_VEC_ID*



Two instances of the same device:
-Same driver (same code)
-One hander for each one

Two devices use the same driver:
- Driver 'uarlite' (same code)
- One handler for each one

HW CONFIGURATION PARAMETERS

MHS

```
BEGIN xps_uartlite
 PARAMETER INSTANCE = RS232_Uart_1
 PARAMETER HW_VER = 1.00.a
 PARAMETER C_BAUDRATE = 9600
 PARAMETER C_DATA_BITS = 8
 PARAMETER C_ODD_PARITY = 0
 PARAMETER C_USE_PARITY = 0
 PARAMETER C_SPLB_CLK_FREQ_HZ = 62500000
 PARAMETER C_BASEADDR = 0x84000000
 PARAMETER C_HIGHADDR = 0x8400ffff
 BUS_INTERFACE SPLB = mb_plb
 PORT RX = fpga_0_RS232_Uart_1_RX
 PORT TX = fpga_0_RS232_Uart_1_TX
 PORT Interrupt = uart_interrupt
END

BEGIN mdm
 PARAMETER INSTANCE = debug_module
 PARAMETER HW_VER = 1.00.b
 PARAMETER C_MB_DBG_PORTS = 1
 PARAMETER C_USE_UART = 1
 PARAMETER C_UART_WIDTH = 8
 PARAMETER C_BASEADDR = 0x84400000
 PARAMETER C_HIGHADDR = 0x8440ffff
 BUS_INTERFACE SPLB = mb_plb
 BUS_INTERFACE MBDEBUG_0 = microblaze_0_dbg
 PORT Debug_SYS_Rst = Debug_SYS_Rst
END
```

MSS

```
BEGIN DRIVER
 PARAMETER DRIVER_NAME = uartlite
 PARAMETER DRIVER_VER = 1.13.a
 PARAMETER HW_INSTANCE = RS232_Uart_1
END

BEGIN DRIVER
 PARAMETER DRIVER_NAME = uartlite
 PARAMETER DRIVER_VER = 1.13.a
 PARAMETER HW_INSTANCE = debug_module
END
```

xparameter.h

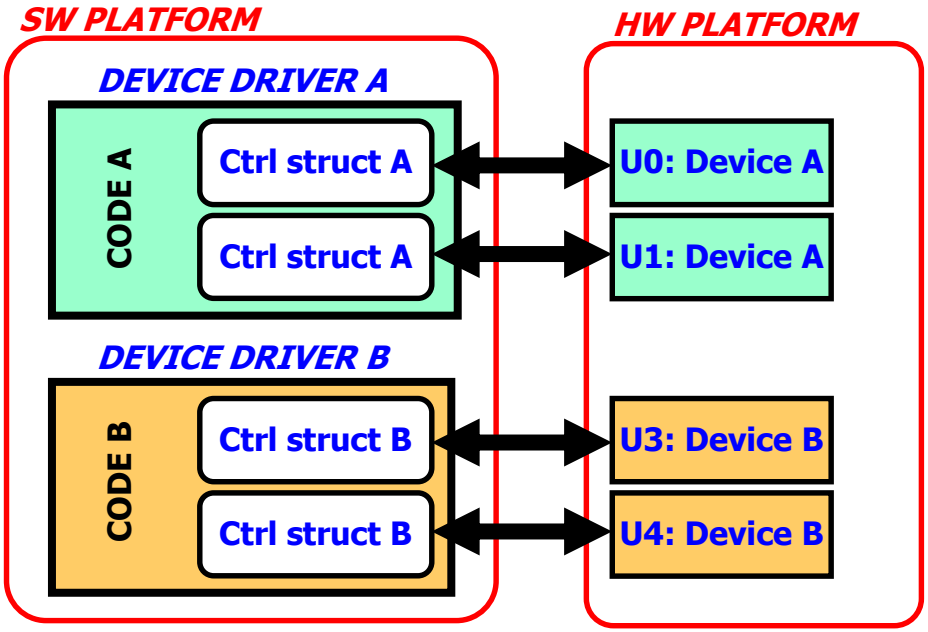
```
/* Definitions for driver UARTLITE */
#define XPAR_XUARTLITE_NUM_INSTANCES 2

/* Definitions for peripheral RS232_UART_1 */
#define XPAR_RS232_UART_1_BASEADDR 0x84000000
#define XPAR_RS232_UART_1_HIGHADDR 0x8400FFFF
#define XPAR_RS232_UART_1_DEVICE_ID 0
#define XPAR_RS232_UART_1_BAUDRATE 9600
#define XPAR_RS232_UART_1_USE_PARITY 0
#define XPAR_RS232_UART_1_ODD_PARITY 0
#define XPAR_RS232_UART_1_DATA_BITS 8

/* Definitions for peripheral DEBUG_MODULE */
#define XPAR_DEBUG_MODULE_BASEADDR 0x84400000
#define XPAR_DEBUG_MODULE_HIGHADDR 0x8440FFFF
#define XPAR_DEBUG_MODULE_DEVICE_ID 1
#define XPAR_DEBUG_MODULE_BAUDRATE 0
#define XPAR_DEBUG_MODULE_USE_PARITY 0
#define XPAR_DEBUG_MODULE_ODD_PARITY 0
#define XPAR_DEBUG_MODULE_DATA_BITS 0

/*****************************************

/* Canonical definitions for peripheral RS232_UART_1 */
#define XPAR_UARTLITE_0_DEVICE_ID XPAR_RS232_UART_1_DEVICE_ID
#define XPAR_UARTLITE_0_BASEADDR 0x84000000
#define XPAR_UARTLITE_0_HIGHADDR 0x8400FFFF
#define XPAR_UARTLITE_0_BAUDRATE 9600
#define XPAR_UARTLITE_0_USE_PARITY 0
#define XPAR_UARTLITE_0_ODD_PARITY 0
#define XPAR_UARTLITE_0_DATA_BITS 8
#define XPAR_UARTLITE_0_SIO_CHAN 0


/* Canonical definitions for peripheral DEBUG_MODULE */
#define XPAR_UARTLITE_1_DEVICE_ID XPAR_DEBUG_MODULE_DEVICE_ID
#define XPAR_UARTLITE_1_BASEADDR 0x84400000
#define XPAR_UARTLITE_1_HIGHADDR 0x8440FFFF
#define XPAR_UARTLITE_1_BAUDRATE 0
#define XPAR_UARTLITE_1_USE_PARITY 0
#define XPAR_UARTLITE_1_ODD_PARITY 0
#define XPAR_UARTLITE_1_DATA_BITS 0
#define XPAR_UARTLITE_1_SIO_CHAN -1
```

LAYER 0 API EXAMPLE


```
#include "xparameters.h"
#include "xgpio_l.h"
#include "xbasic_types.h"

#define LEDS_CHANNEL      1
#define SWITCHES_CHANNEL  1

int main(int argc, char *argv[]) {
  Xuint32 value;

  // set LEDS to OUT
  XGpio_mSetDataDirection(XPAR_LEDS_8BIT_BASEADDR, LEDS_CHANNEL, 0x00);
  // set SWITCHES to IN
  XGpio_mSetDataDirection(XPAR_DIP_SWITCHES_8BIT_BASEADDR,
    SWITCHES_CHANNEL, 0xFF);

  while(1) {
    value = XGpio_mGetDataReg(XPAR_DIP_SWITCHES_8BIT_BASEADDR,
              SWITCHES_CHANNEL);
    XGpio_mSetDataReg(XPAR_LEDS_8BIT_BASEADDR, LEDS_CHANNEL, value);
  }
  return 0;
}
```

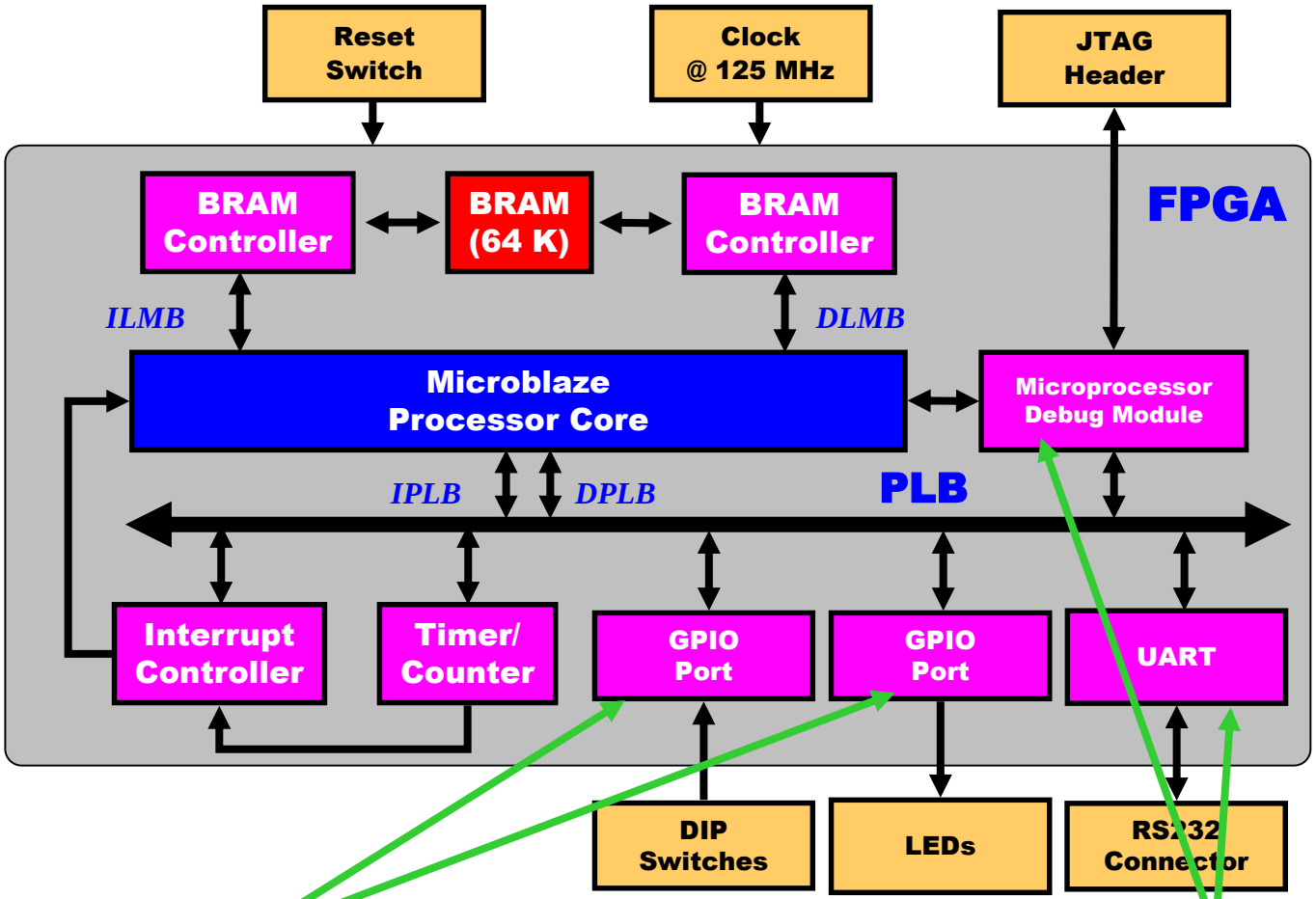
LAYER 1 STANDARD API

- For layer 1, each device instance is controlled by means of a data structure containing configuration and status info about this instance
  - Defined for each device driver
  - User must declare a variable of this type for each device instance
  - First parameter for API functions (OOP with C)
    - The pointer to the data structure serves as device driver reference
  - Deferred as *driver instance data* or *driver object*




```
typedef struct {
  XTmrCtrStats Stats;
  u32 BaseAddress;
  u32 IsReady;

  XTmrCtr_Handler Handler;
  void *CallBackRef;
} XTmrCtr;

...
void XTmrCtr_Start(
  XTmrCtr *InstancePtr,
  u8 TmrCtrNumber);
```

DEVICE AND DEVICE DRIVERS



Two instances of the same device:
- Same driver (same code)
- One hander for each one

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STANDARD API

- API common functions
  - Initialize: Initializes an instance of a device driver
    - Driver instance must be initialize before other API function can be called
  - Reset: resets the device driver and device with which it is associated
    - Allows to recover from exception conditions
  - SelfTest: performs a self-test on the device driver and its associated device
  - LookupConfig: retrieves a pointer to the configuration table for a device driver

- API optional functions
  - Start: Starts the device driver (device and interrupt enable)
  - Stop: Stops the device driver (device and interrupt disable)
  - GetStats: gets the statistics for the device and/or device driver
  - ClearStats: clears the statistics for the device and/or device driver
  - InterruptHandler: High level custom interrupt processing for each device
    - Interrupt acknowledge
    - User functionality provided through a callback function (hook)

LAYER 1 STANDARD API

- Before a device instance can be used its data structure must be properly initialized using the `Initialize()` function
  - It maps an instance driver with a given device
  - The user is responsible for allocating the driver handler passed as 1st parameter
  - The device instance is identified by the second parameter obtained from '**`x_parameter.h`**'

```
int XGpio_Initialize(XGpio *InstancePtr, u16 DeviceId)
```

- From that point, the driver instance is referred by its data structure address:

```
u32 XGpio_DiscreteRead(XGpio *InstancePtr, unsigned Channel)
```

HW CONFIGURATION PARAMETERS

- System software can need to obtain configuration info for each instance of a given driver at runtime
  - E.g. OS driver enumeration
- Each device driver (SW) uses a data structure to store info about the HW configuration applied to the associated device
  - Defined in `x<driver_name>.h` file
  - Contains most of the info included in `xparameters.h` file
  - It mustn't be confounded with the driver data structure (1st parameter used in Layer 1 functions)
  - Format:

```
typedef struct {
  u16 DeviceID;
  u32 BaseAddress;
  // Other device dependent data attributes
} X<driver_name>_Config;
```

- Moreover, an array of structures is defined with one element for each device instance in the system
  - Declared within `x<driver_name>_g.c`
  - The structure address for a given instance can be obtained by means of `x<driver_name>_LookupConfig()` function

LAYER 1 EXAMPLE


```
#include "xparameters.h"
#include "xtmrctr.h"


#define SYS_TIMER_DEV_ID      XPAR_XPS_TIMER_1_DEVICE_ID
XTmrCtr sysTimerDrv;  // The instance of the timer counter

int status;
Xuint32 options;

// Initialize the TmrCtr driver so that it's ready to use
status = XTmrCtr_Initialize(&sysTimerDrv, XPAR_XPS_TIMER_1_DEVICE_ID);
if(status != XST_SUCCESS) {
  return XST_FAILURE;
}
options =   XTC_DOWN_COUNT_OPTION   |
            XTC_INT_MODE_OPTION     |
            XTC_AUTO_RELOAD_OPTION;
XTmrCtr_SetOptions(&sysTimerDrv, TIMER_CNTR_0, options);
```

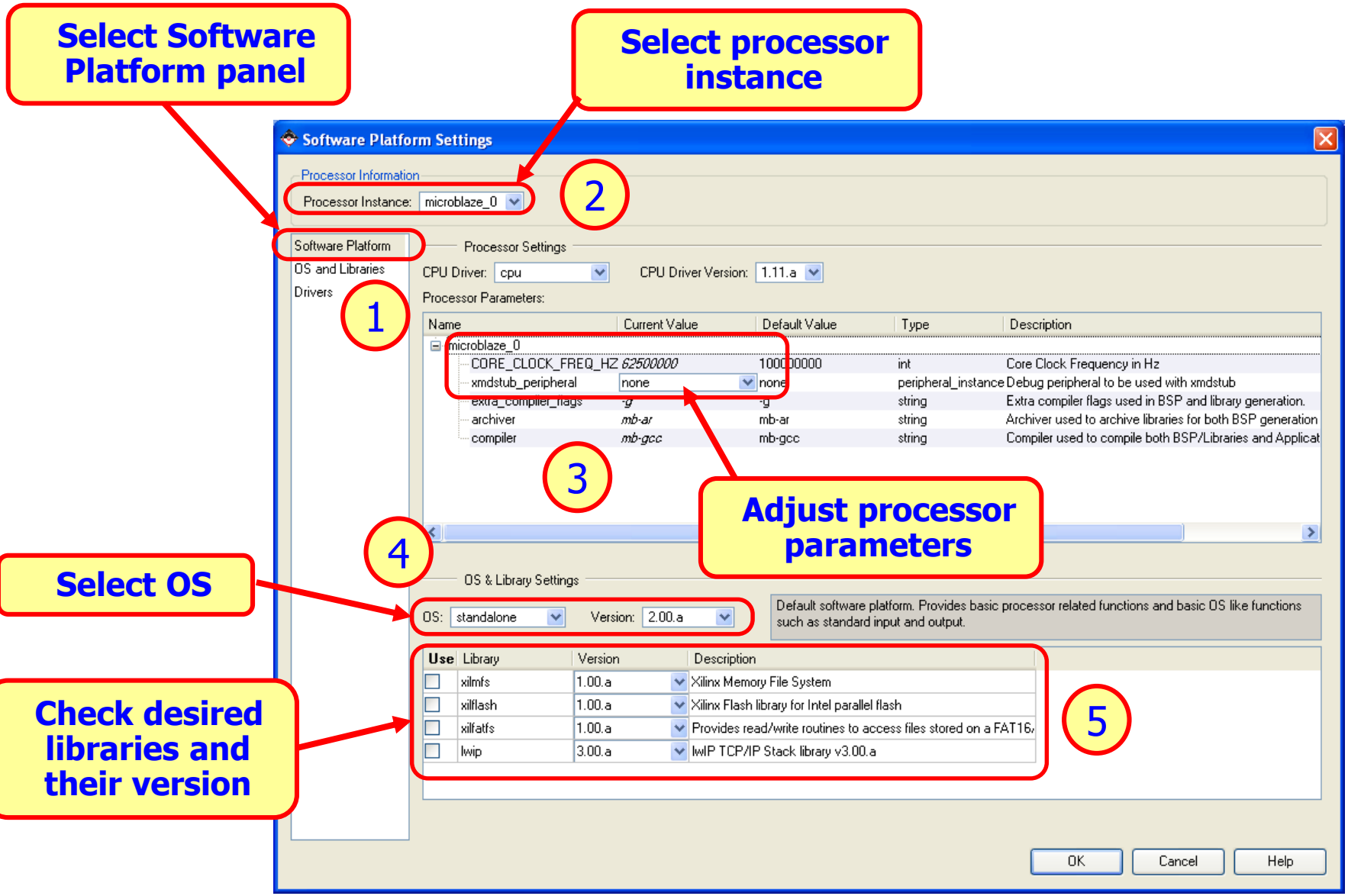
OUTLINE

- INTRODUCTION
- SOFTWARE DESIGN FLOW
  - LIBGEN
  - GNU TOOLCHAIN
  - LIBRARIES
- BOARD SUPPORT PACKAGE
  - STANDALONE BSP
  - DEVICE DRIVERS
- **XPS SOFTWARE SETTINGS**
  - SOFTWARE PLATFORM SETTINGS
  - COMPILER SETTINGS

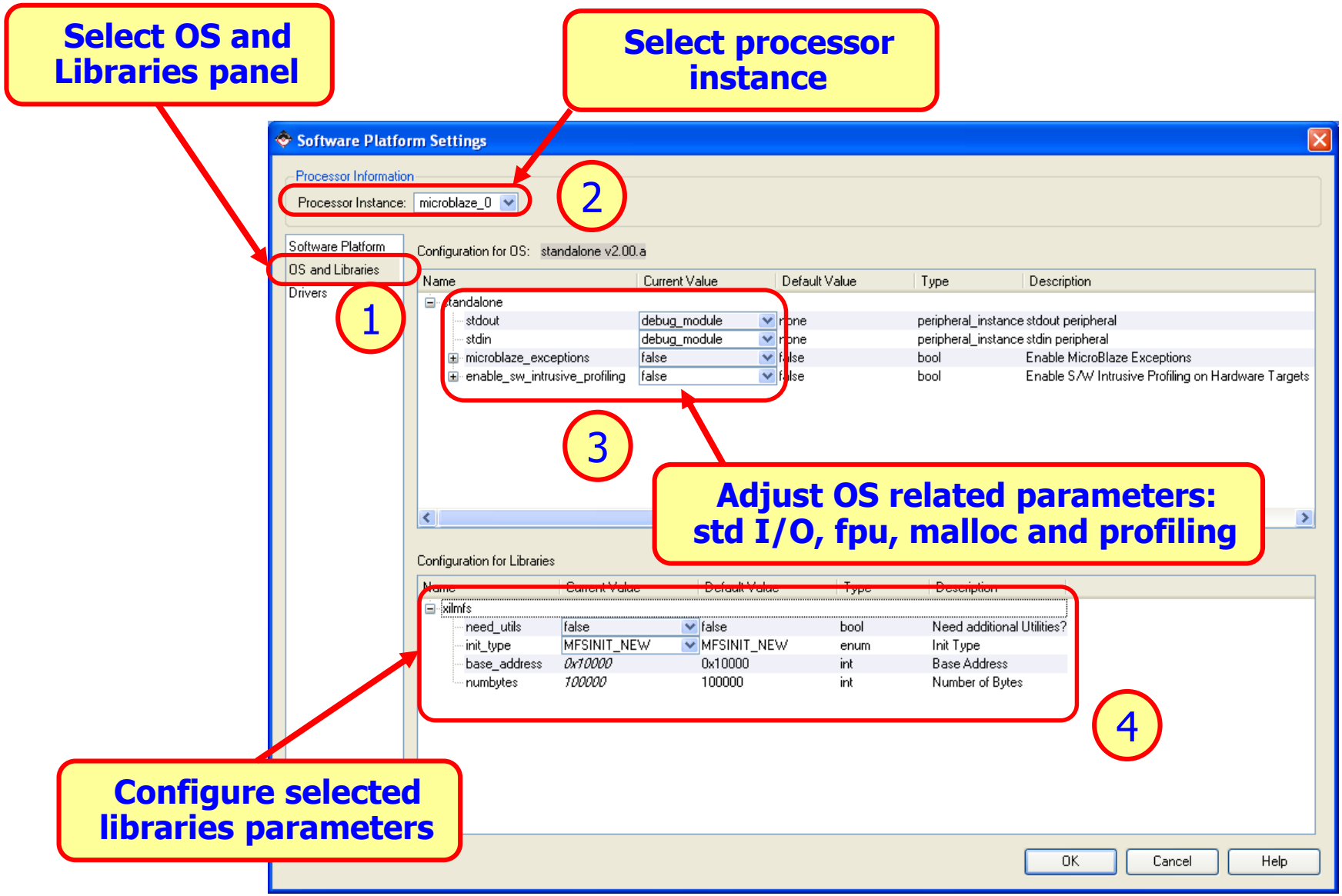
CODE GENERATION

- The following are the steps involved in generating software for EDK designs using XPS :
  1. Configure Software settings
  2. View and Set Project Options
  3. Create EDK Software libraries
  4. Open/Create your applications
  5. View and Set Applications' Options
  6. Build Applications
  7. Initialize bitstream with applications
  8. Download and execute application
  9. Download and debug applications by using XMD
- You can configure software settings for an EDK project
  - by using the XPS GUI 
  - by directly editing the MSS file.

SOFTWARE PLATFORM SETTINGS (I)

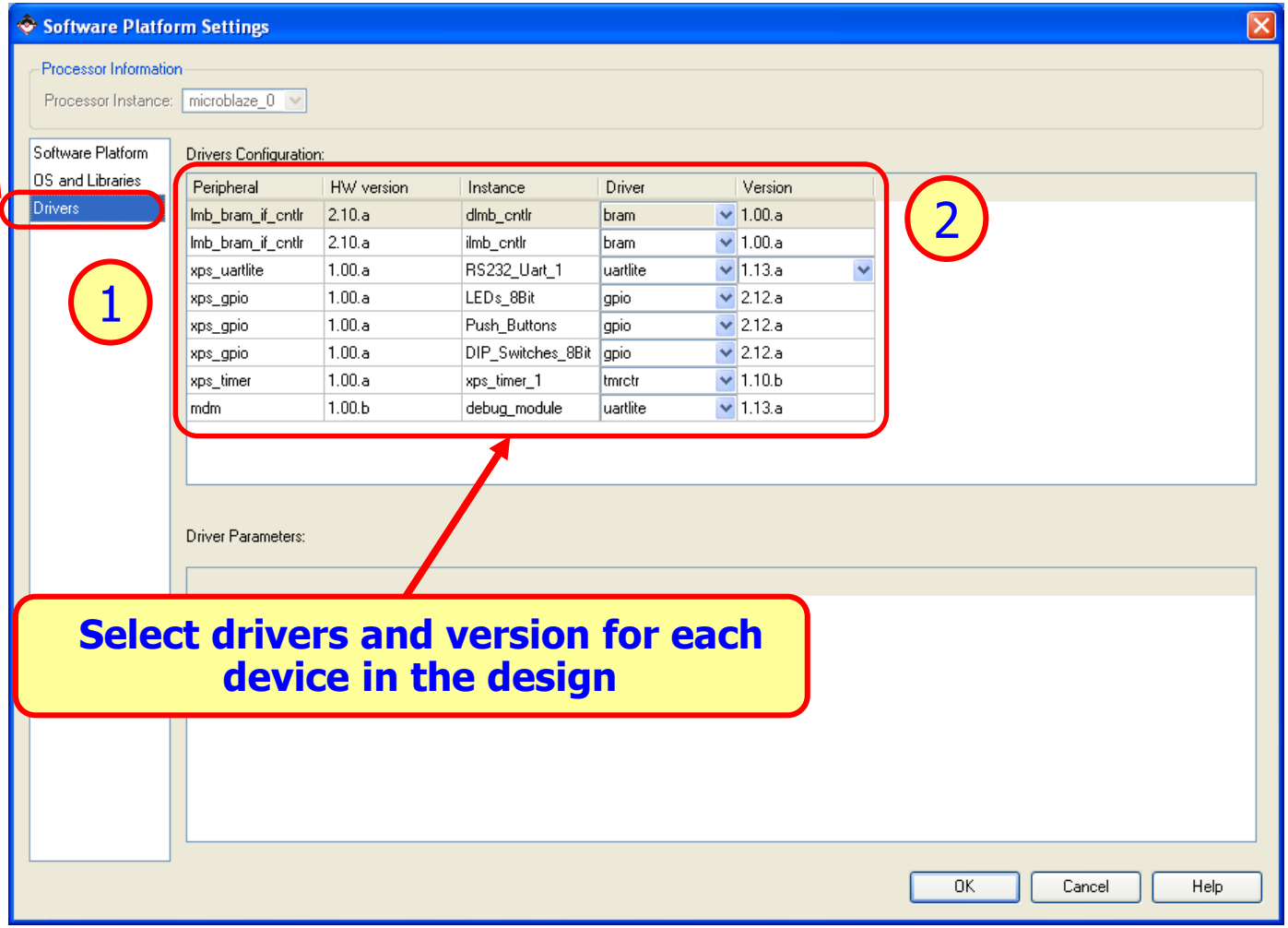


SOFTWARE PLATFORM SETTINGS (II)



SOFTWARE PLATFORM SETTINGS (III)

Select Drivers panel



Select drivers and version for each device in the design

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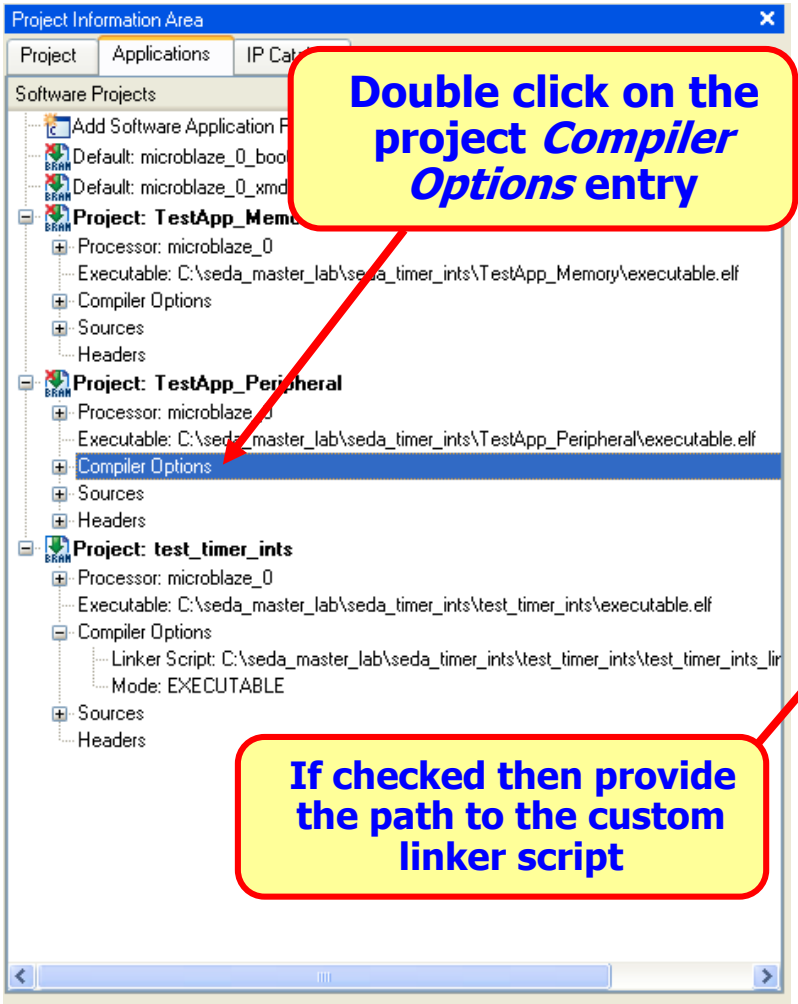
  - SOFTWARE PLATFORM SETTINGS
  - **COMPILER SETTINGS**

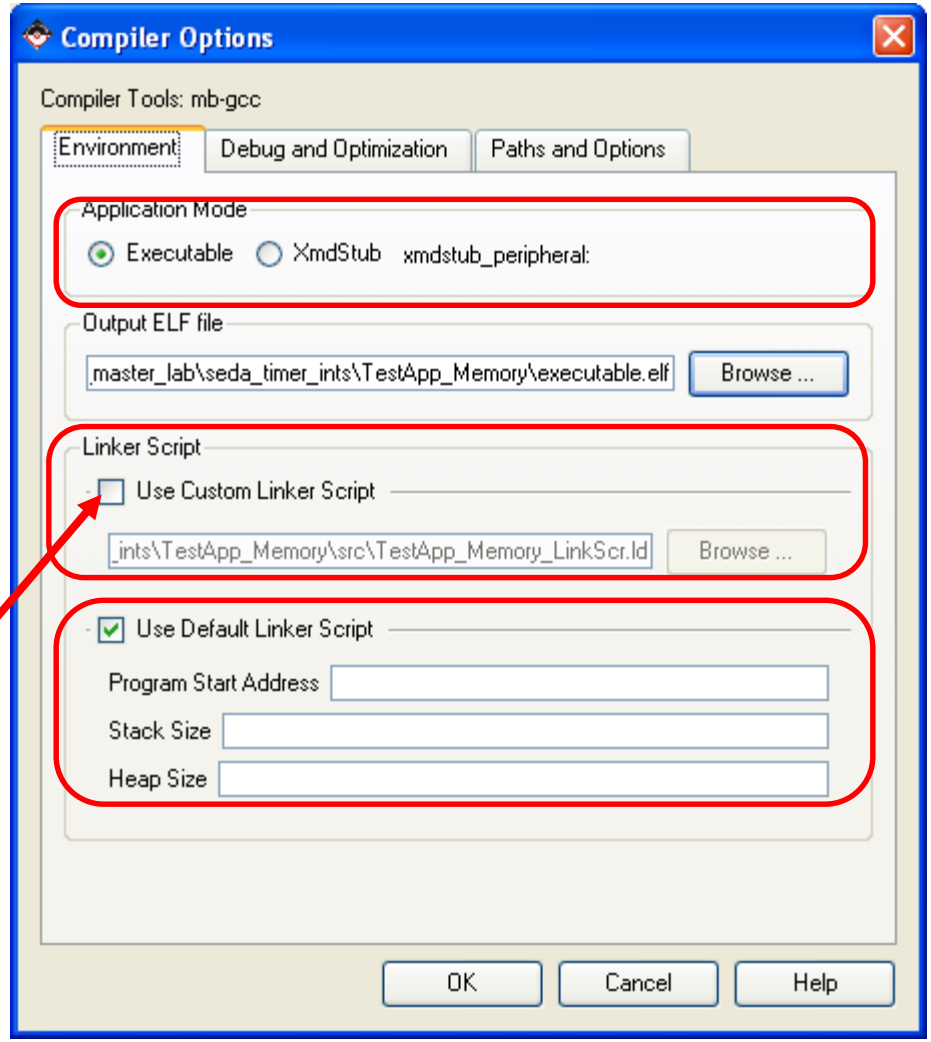
COMPILER SETTING (I)

ENVIRONMENT TAB



Double click on the project *Compiler Options* entry

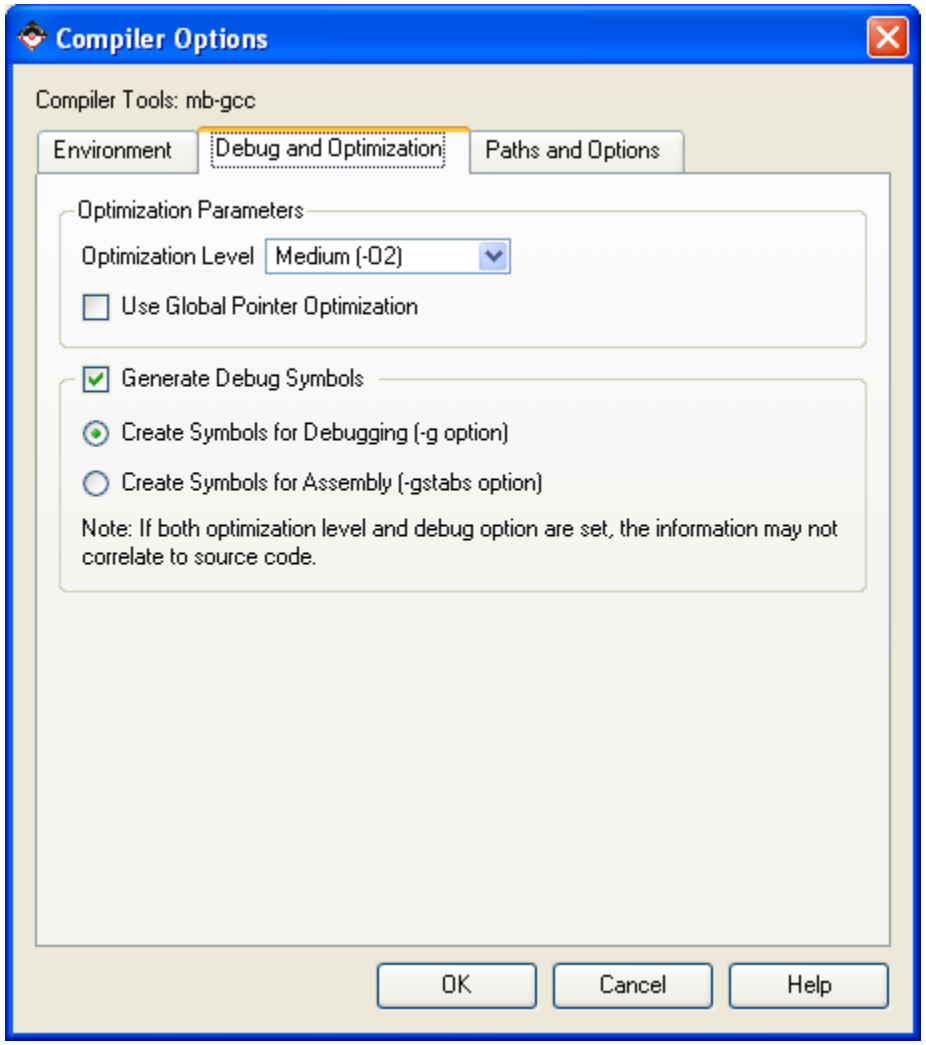
If checked then provide the path to the custom linker script



COMPILER SETTING (II)

DEBUG AND OPTIMIZATION TAB

- Optimization parameters:
  - Optimization level (0-3):
    - Level 0: No optimization, useful during debugging
    - Levels 1-3: Code reordering
- Use Global Pointer Optimization
  - Use of small data areas
    - Data size (8 bytes)
    - Registers: R2, R13
- Generate Debug Symbols
  - Include debugging information for GDB
    - C language: -g
    - Assembly: -gstabs



COMPILER SETTING (III)

PATH AND OPTIONS TAB

Search paths

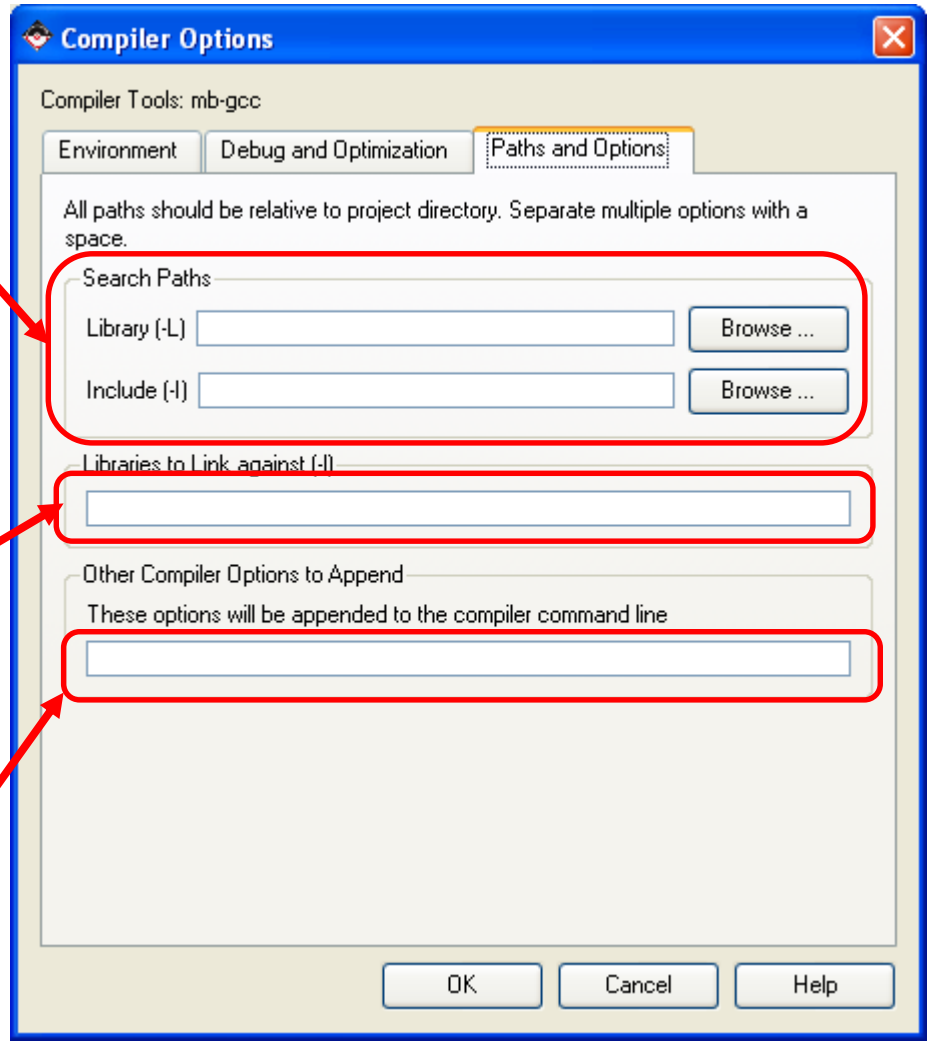
- Libraries. By default:
  - Project directory
  - MB_instance/lib directory
- Includes. By default:
  - Project directory
  - MB_instance/include directory

Additional libraries:

- User libraries

Other compiler options to append:

- E.g. Symbol definition for conditional compilations
  - -Dmy_def



END