AMD
XILINX

Software Development and Debug

2021.2

Objectives

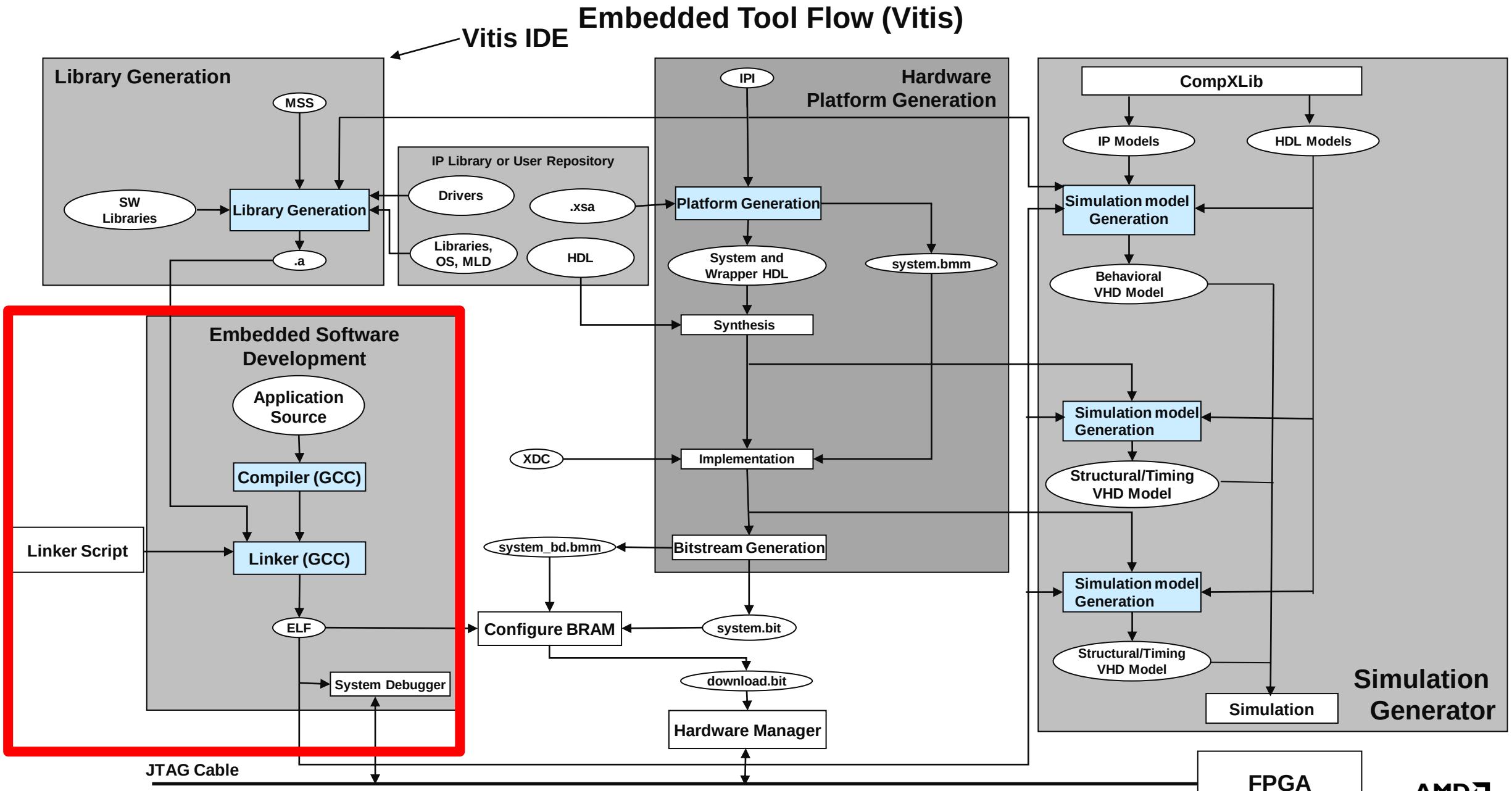
- **After completing this module, you will be able to:**
  - Identify the GNU tools functionality
  - State when address management is needed
  - Describe the object file sections
  - Describe what a linker script does
  - Describe Debug functionality and Eclipse Target Communications Framework

Outline

- GNU Development Tools: GCC, AS, LD, Binutils
- Address Management
- Software Settings
  - *Software Platform Settings*
  - *Compiler Settings*
  - *Linker Script*
- Software Debug in Vitis
- Summary

GNU Development Tools: GCC, AS, LD, Binutils

Embedded Tool Flow (Vitis)



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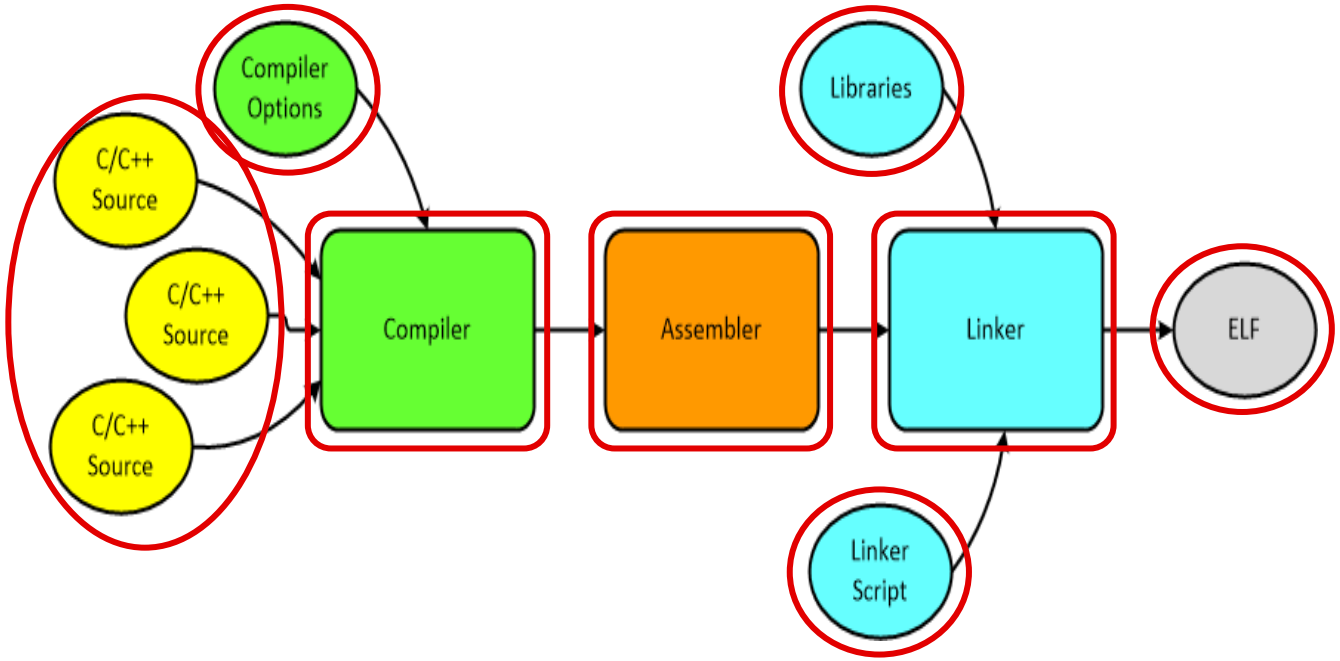
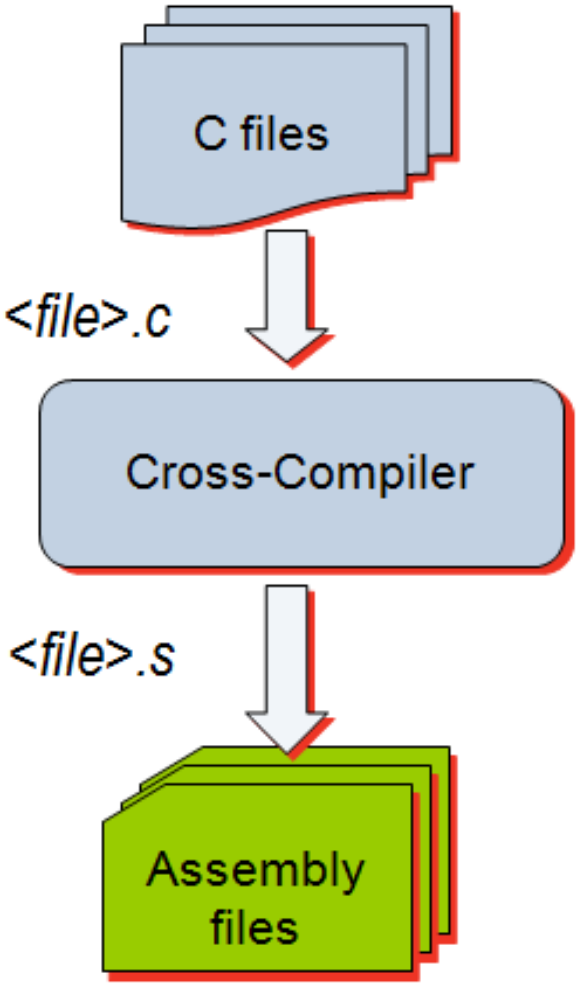
Controlling Compilation

- Eclipse development tool does not contain a toolchain
- Vitis IDE includes the GNU toolchain
- User can replace toolchain
- All toolchains have a well-defined path through the tools
- All toolchains require certain files for each stage



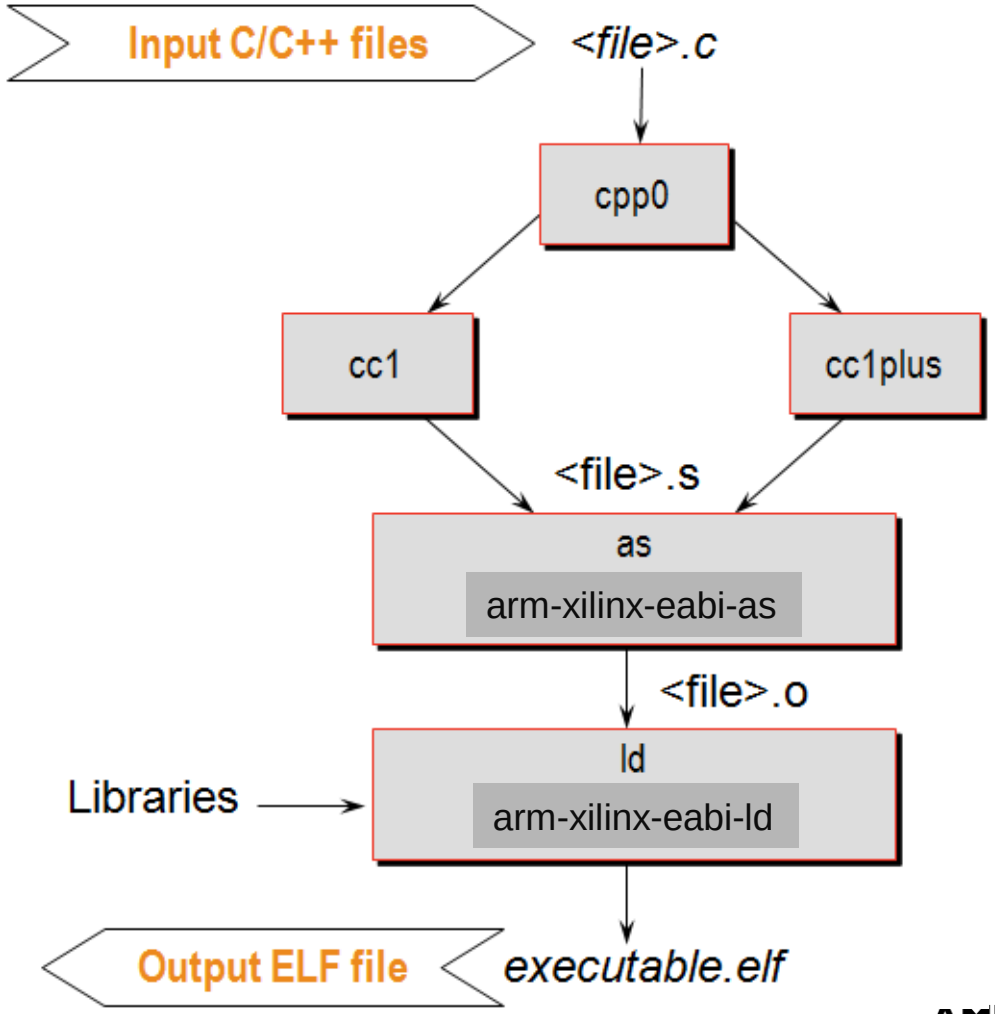
GNU Tools: GCC

- 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:
  - GNU GCC (arm-xilinx-eabi-gcc)
- Command line only; uses the settings set through the GUI



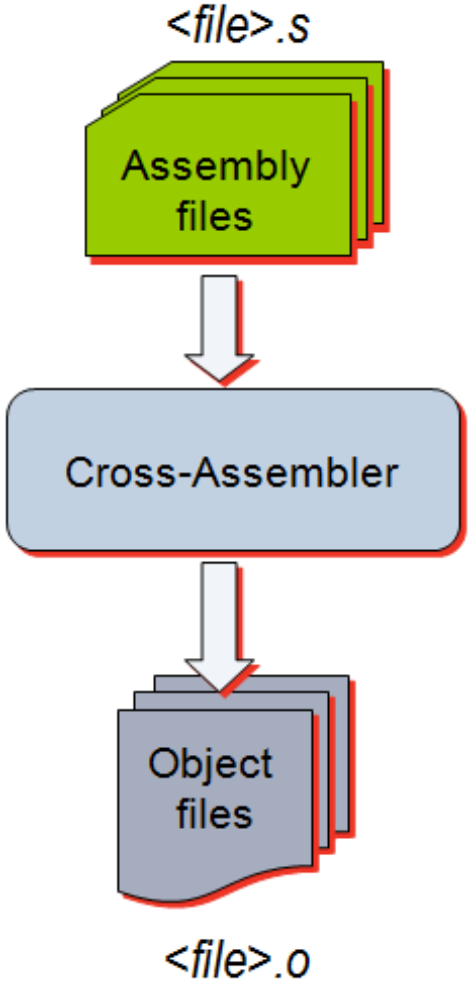
GNU Tools: GCC

- Calls four different executables
  - Preprocessor (cpp0)
    - Replaces all macros with definitions defined in the source and header files
  - Language specific c-compiler
    - cc1 C-programming language
    - cc1plus C++ language
  - Assembler
    - arm-xilinx-eabi-as
  - Linker
    - arm-xilinx-eabi-ld



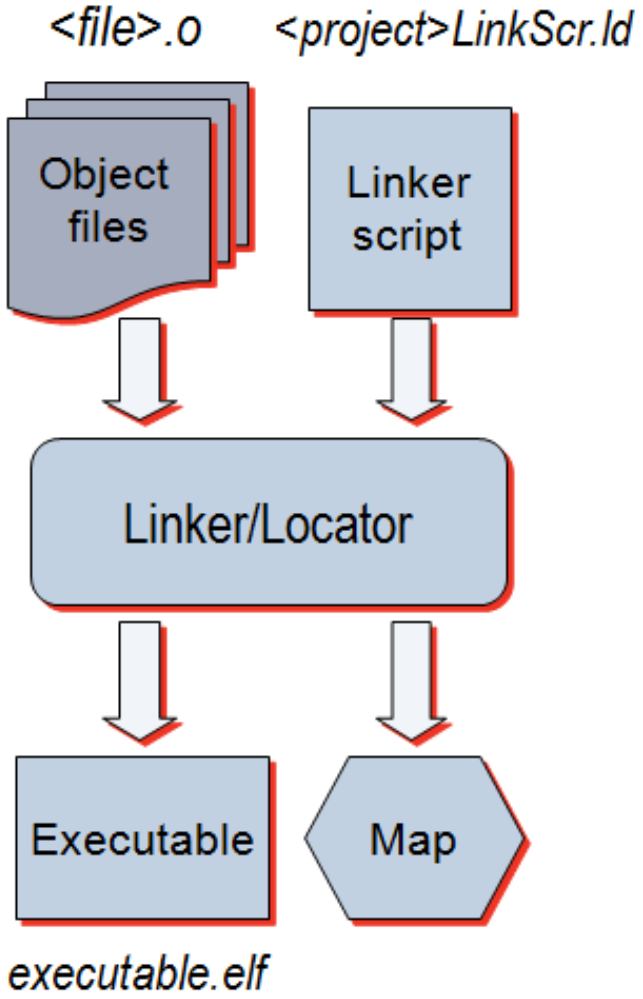
GNU Tools: AS

- 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
- Use the -Wa switch if the source files are assembly only and want to use the gcc



GNU Tools: LD

- Linker
- Inputs:
  - Several object files
  - Archived object files (library)
  - Linker script (mapfile)
- Output:
  - Executable image (.ELF)
  - Map file



Object File Sections

- What is an object file?
  - An object file is an assembled piece of code
    - Machine language:
      li r31,0 = 0x3BE0 0000
  - Constant data
  - There may be references to external objects that are defined elsewhere
  - This file may contain debugging information

Object File Sections

Sectional layout of an object or an executable file

.text	Text section
.rodata	Read-only data section
.sdata2	Small read-only data section (less than eight bytes)
.sbss2	Small read-only uninitialized data section
.data	Read-write data section
.sdata	Small read-write data section
.sbss	Small uninitialized data section
.bss	Uninitialized data section

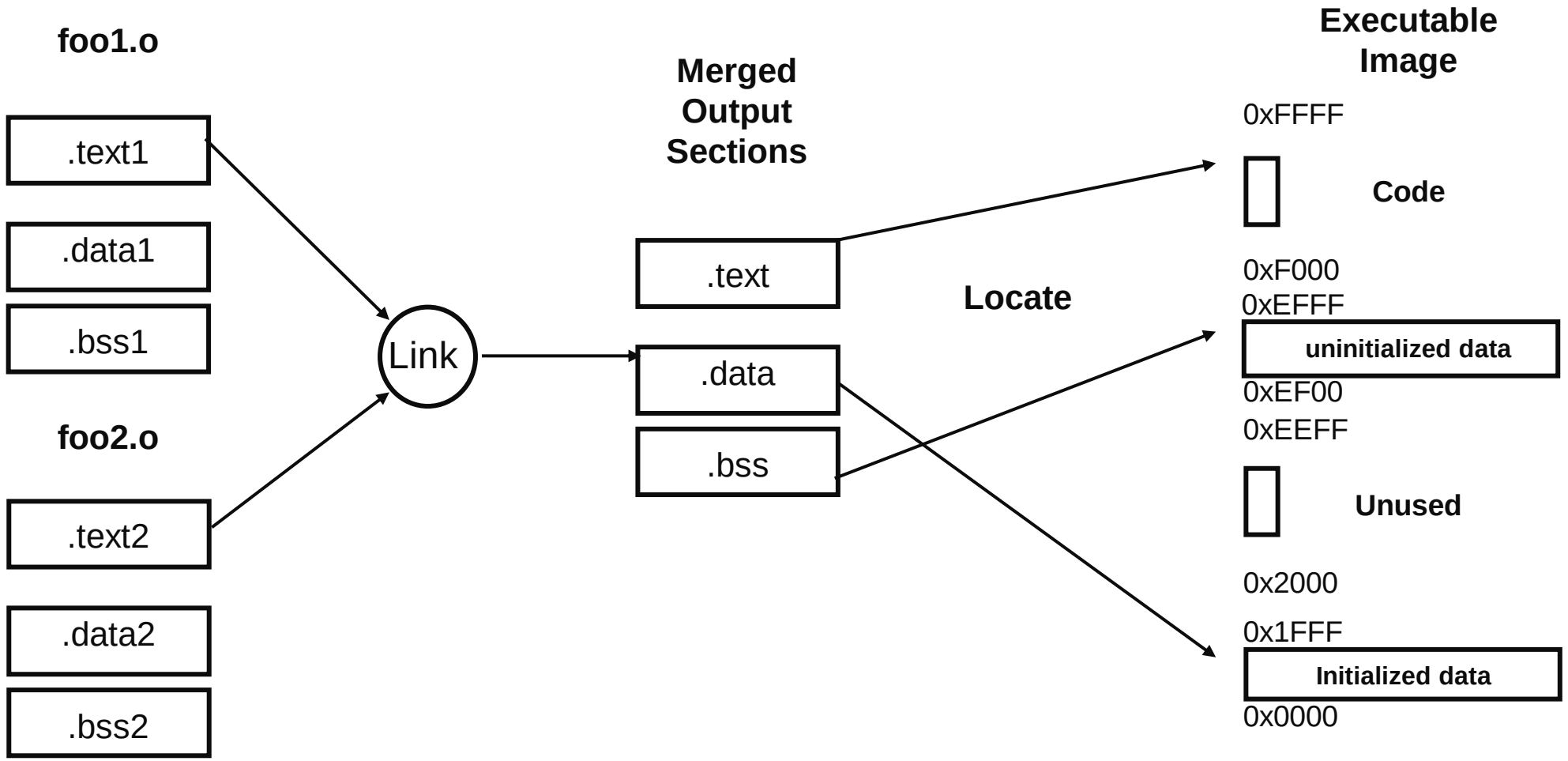
Sections Example

```
int ram_data[10] = {0,1,2,3,4,5,6,7,8,9};        /* DATA */

const int rom_data[10] = {9,8,7,6,5,4,3,2,1};    /* RODATA */

int I;   /* BSS */

main(){

...
I = I + 10;  /* TEXT */
...

}
```

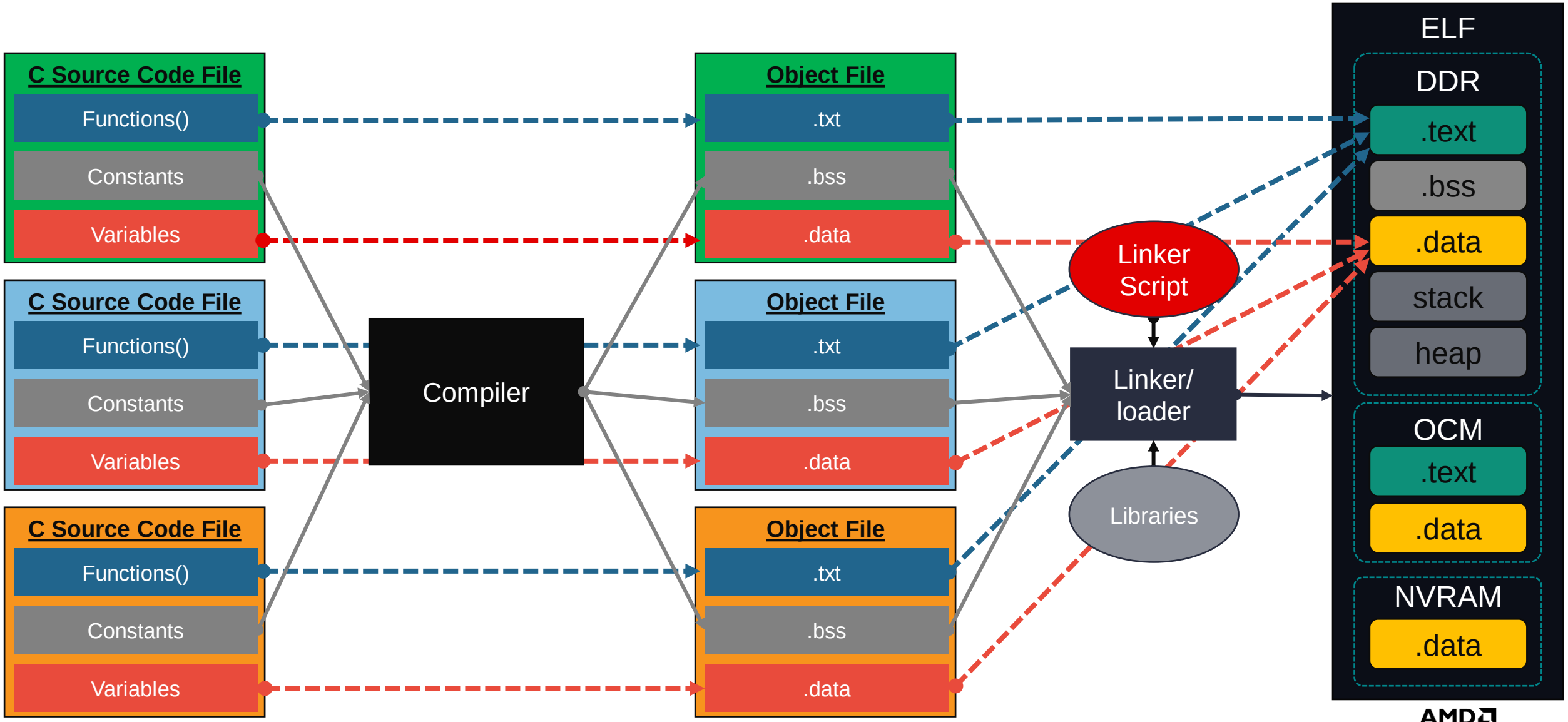
Linker Script

- **Linker script controls the linking process**
  - Map the code and data to a specified memory space
  - Set the entry point to the executable
  - Reserve space for the stack
- **Required if the design contains a discontinuous memory space**

Linker and Locator Flows



Linker and Locator Flows



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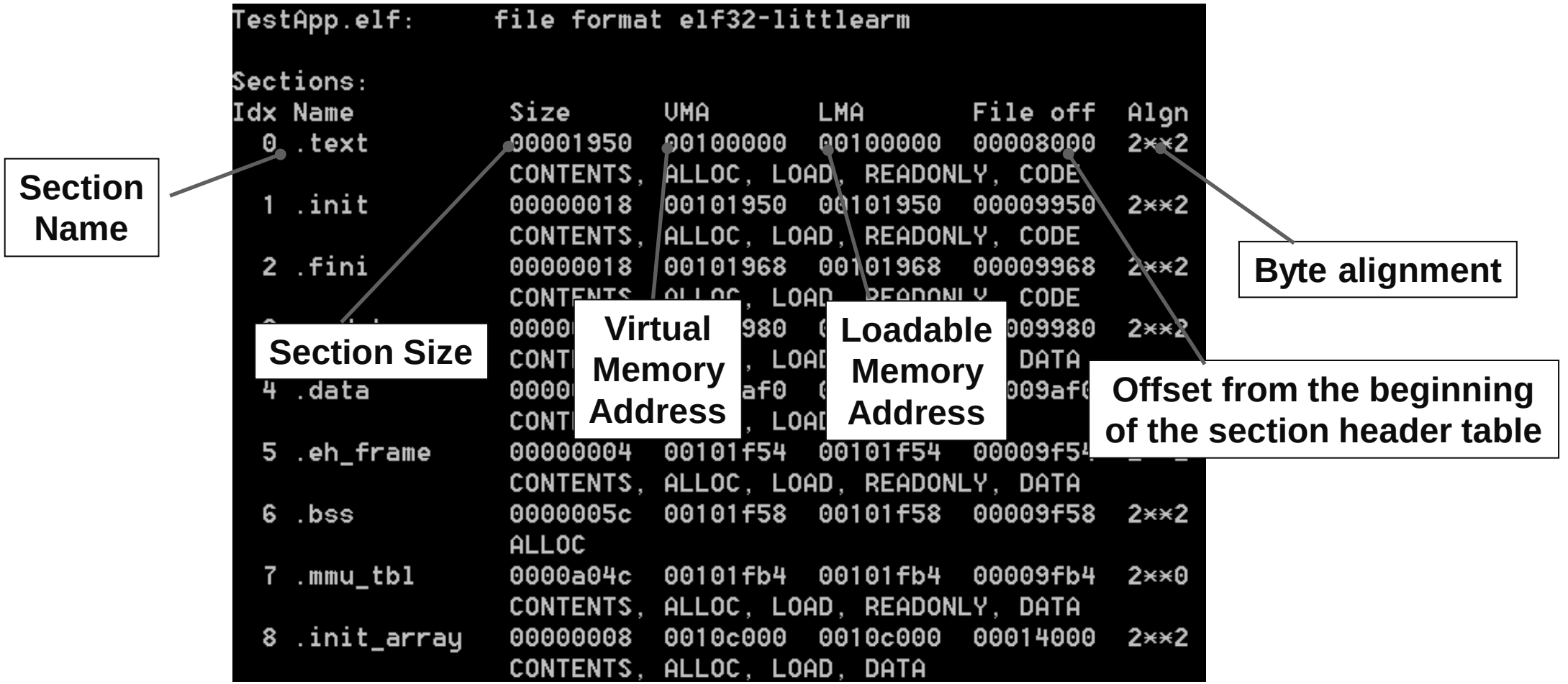
GNU Utilities

- AR Archiver
  - Create, modify, and extract from libraries
  - Used in Vitis to combine the object files of the Board Support Package (BSP) in a library
  - Used in Vitis to extract object files from different libraries
- Object Dump
  - Display information from object files and executables
    - Header information, memory map
    - Data
    - Disassemble code

Object Dump

Display summary information from the section headers

arm-xilinx-eabi-objdump –h executable.elf



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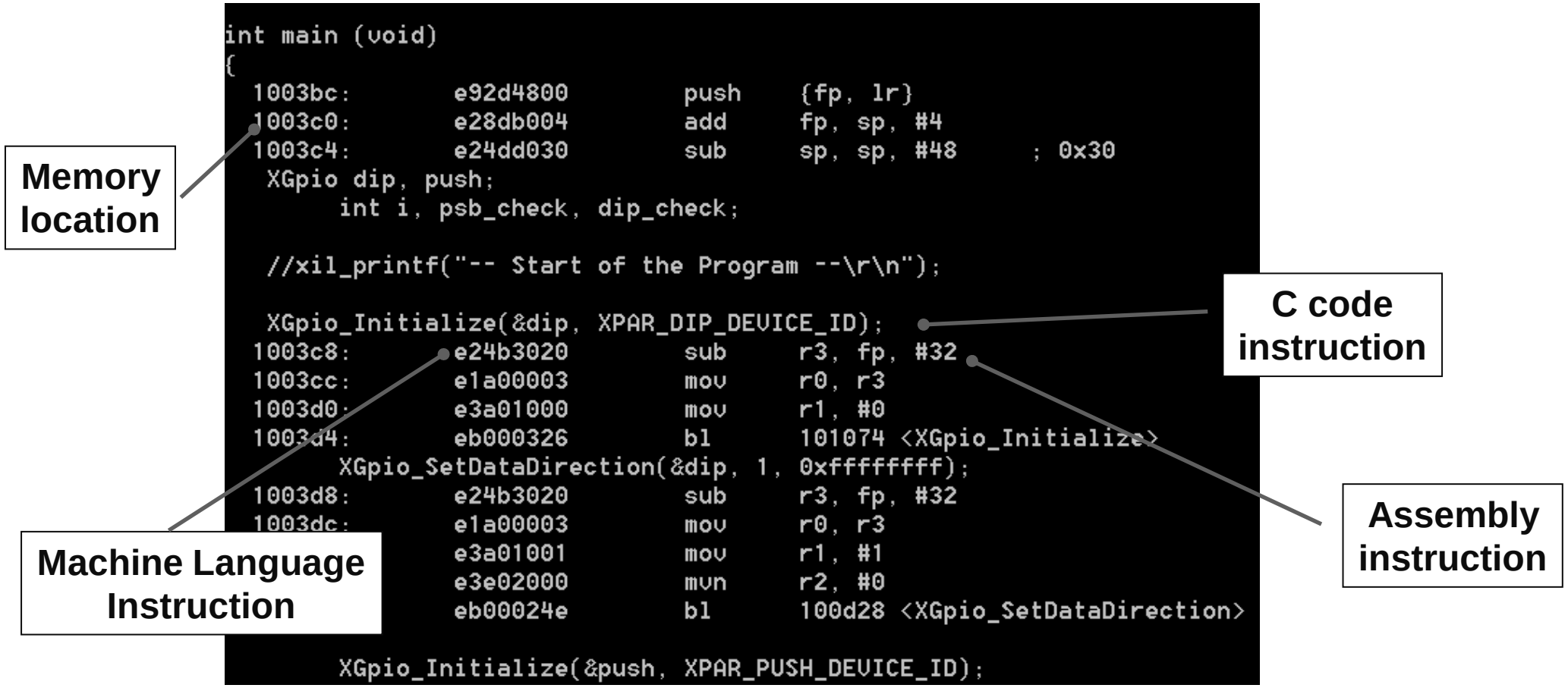
Object Dump

Dumping the source and assembly code

arm-xilinx-eabi-objdump –S executable.elf



Address Management

Address Management

- Embedded processor design requires you to manage the following:
  - Address map for the peripherals
  - Location of the application code in the memory space
    - Block RAM
    - External memory (Flash, DDR3, SRAM)
- Memory requirements for your programs are based on the following:
  - The amount of memory required for storing the instructions
  - The amount of memory required for storing the data associated with the program

Standard ARM Programming Model

- Processing system and programmable logic look the same
  - AMBA® and AXI interfaces
  - Memory-mapped I/O
  - Register access
- Consistency for PS and PL = ease of use
- Memory map usage: total of 4 GB
  - 1 GB: DDR RAM
  - 2 GB: dedicated to PL peripherals
  - 1 GB: PS peripherals, OCM, external flash

Start Address	Size	Description
0x0000_0000	1GB	External DDR RAM
0x4000_0000	2GB	Custom Peripherals (Programmable Logic including PCIe)
0xE000_0000	256MB	PS I/O Peripherals
0xF800_0000	32MB	Fixed Internal Peripherals (Timers, Watchdog, DMA, Interconnect)
0xFC00_0000	64MB	Flash Memory
0xFFFC_0000	256KB	On-Chip Memory

Programmer's View of Programmable Logic

- Programmable logic (PL) memory map
  - 2 GB total space
    - 1 GB for each AXI master: GP0, and GP1
  - Accessible from any processing system (PS) master
    - Either Cortex-A9 CPU
    - PS DMA engine
    - PS peripheral DMA engine
      - Ethernet
      - USB
      - SD/SDIO

Custom Peripheral

Start Address	Description
0x4000_0000	Accelerator #1 (Video Scaler)
0x6000_0000	Accelerator #2 (Video Object Identification)
0x8000_0000	Peripheral #1 (Display Controller)

Code Snippet

```
int main() {

int *data = 0x1000_0000;
int *accel1 = 0x4000_0000;

// Pure SW processing
Process_data_sw(data);

// HW Accelerator-based processing
Send_data_to_accel(data, accel1);
process_data_hw(accel1);
Recv_data_from_accel(data, accel1);
}
```

Software Settings

Minimal Required Services

- C language standard services
  - C language construct services
  - *stdin* and *stdout*
  - Math library
  - *malloc*
- Processor support requires these services
  - Interrupt
  - Cache
  - Language environment support

Operating Systems

- Operating systems are a collection of software routines that comprise a unified and standard set of system services
- The Standalone domain is used when no operating system is desired
  - Provides a minimal amount of processor and library services as previously illustrated
  - Can be considered a minimal, non-standard operating system
  - Installed as a software platform
- Variety of third-party operating systems are available
  - Linux – many flavors
  - RTOS – real-time operating system; also has many flavors; Free RTOS (an option for the Cortex™-A9 processor)
  - XilKernel – provided by Xilinx; small and simple; only for MicroBlaze
- Operating system domains are added and become part of the Vitis Platform

What an Operating System Provides?

- Operating system services
  - GUI support
  - TCP/IP services**
  - Task management
  - Resource management**
  - Familiar programming services and tasks
  - Easy connection to already written applications
  - Ability to reload and change applications
  - Full file system services**

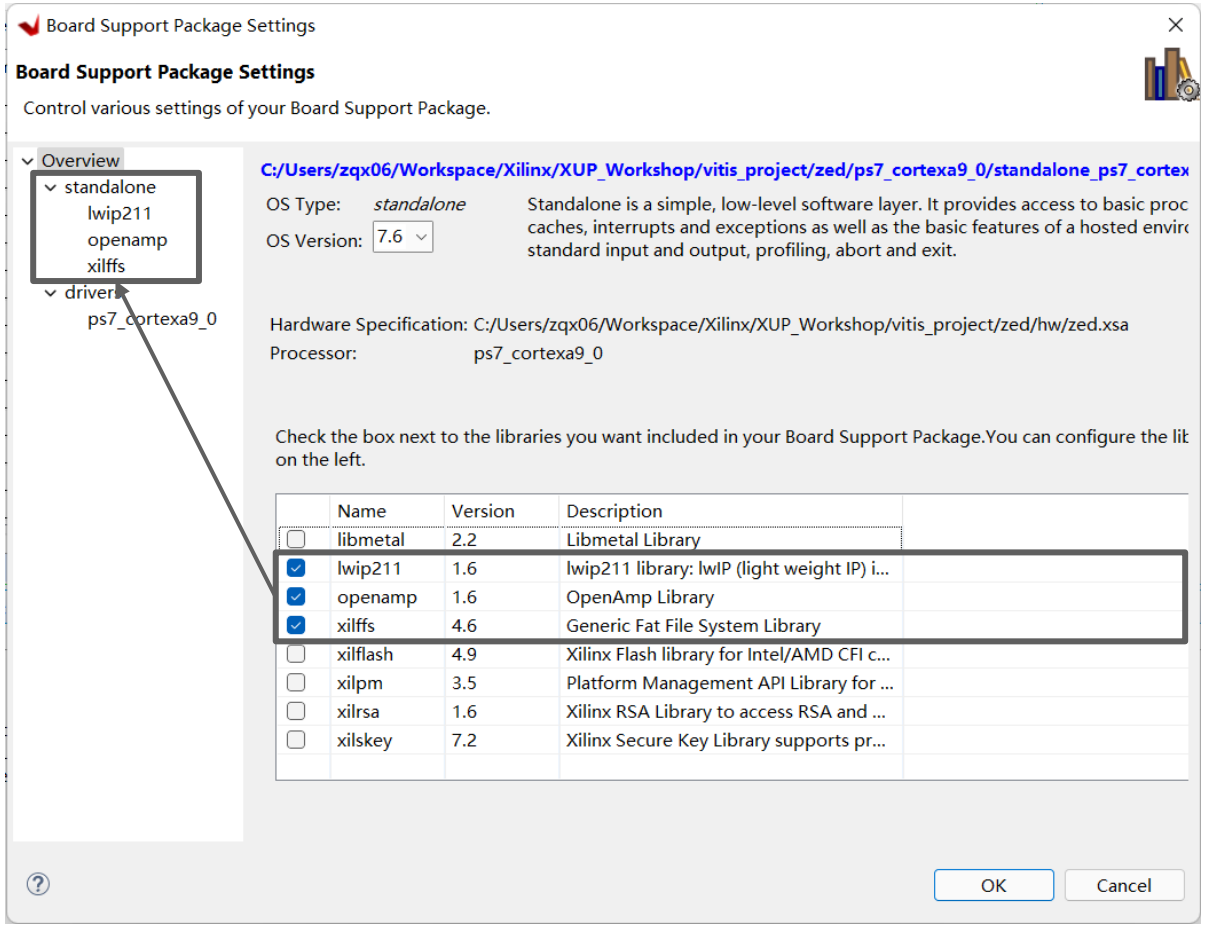
** Also available as additions to the Standalone domain

Do I Need an Operating System?

- **The Standalone domain includes the previously discussed items**
- **Design considerations for systems using the Standalone domain**
  - All services needed are included in the platform
  - The application is static—it never changes
  - The application fits in block RAM (MicroBlaze™ processor), OCM RAM (Zynq™ AP SoC), or DDR memory
  - The application is single-task based
  - Interrupts may or may not be used

Accessing Software Platform Properties

- Double click the platform.spr in the Project Explorer view
- Click on Modify BSP Settings
- Sets all of the software BSP related options in the design
- Has multiple forms selection
  - Overview
  - Standalone
  - Drivers
  - CPU
- As individual Standalone services are selected a configurable menu selection item will appear



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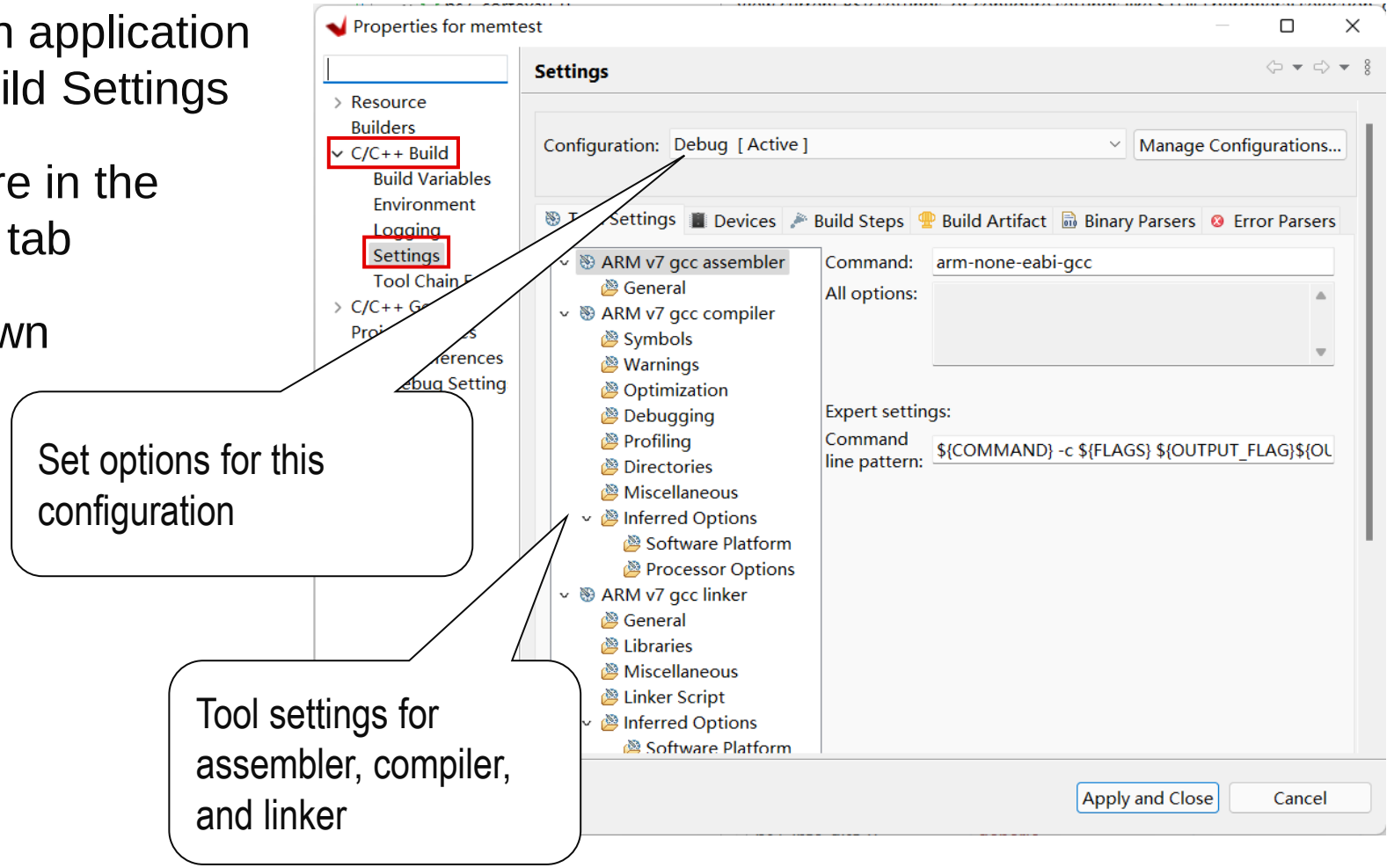
C/C++ Build Settings

- Right-click the top level of an application project and select C/C++ Build Settings
- Most-accessed properties are in the C/C++ Build panel **Settings** tab
- Each configuration has its own properties



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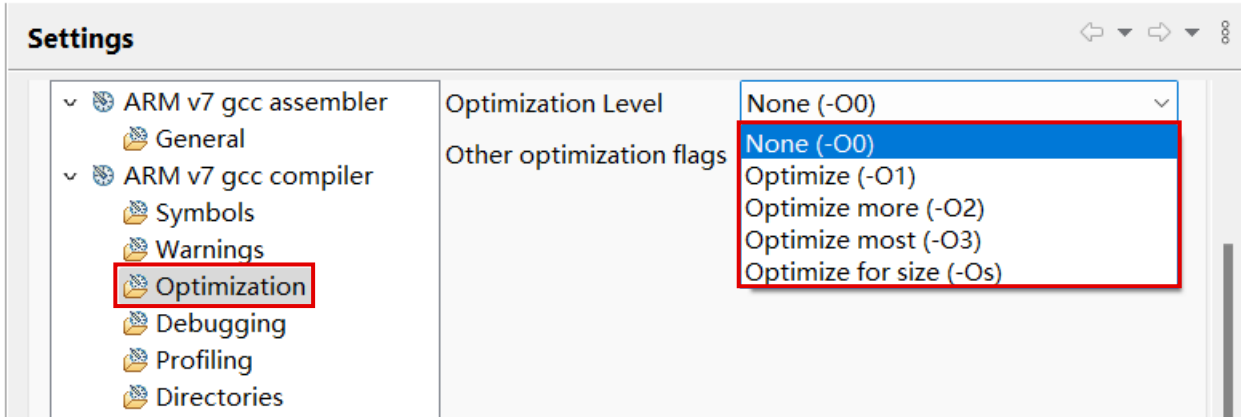
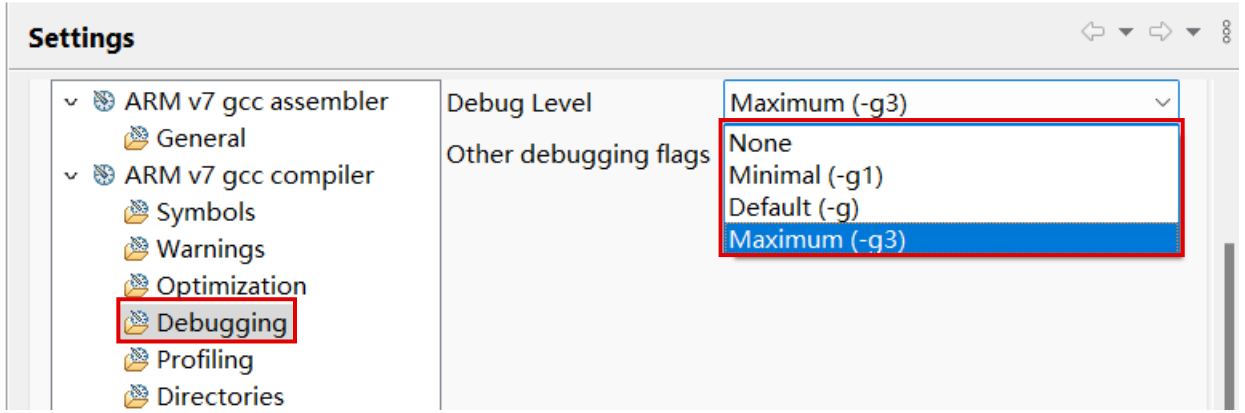
Debug/Optimization Properties

- Compiler optimization level
  - None
  - Low
  - Medium
  - High
  - Size Optimized
- Enable debug symbols in executable
  - Necessary for debugging
  - Set optimization level to none if possible



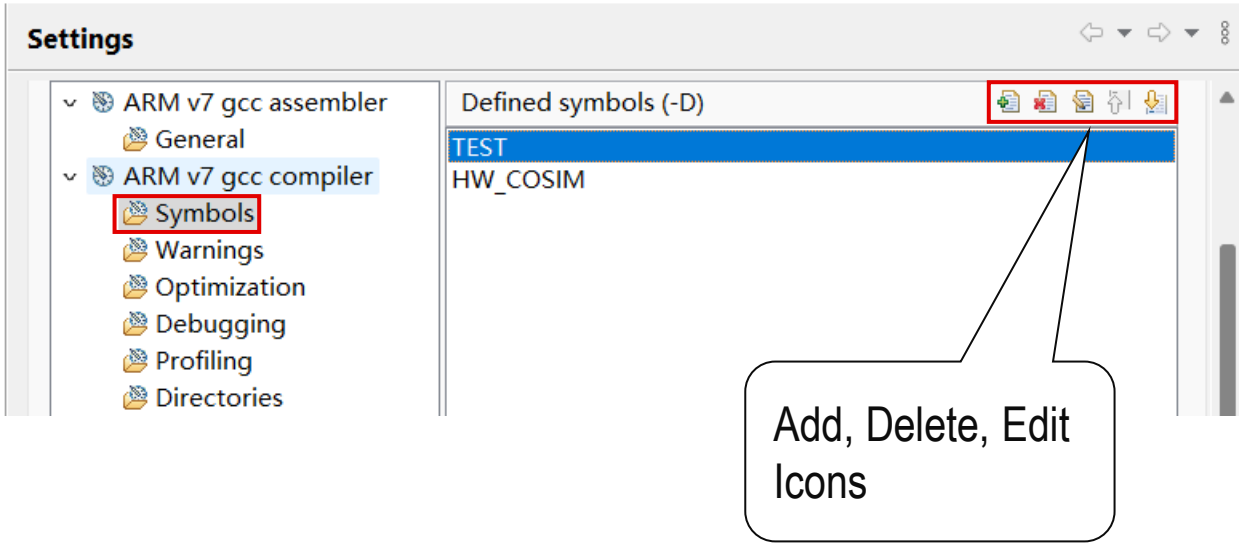


Miscellaneous Compiler Properties

- Define symbols for conditional compiling
  - Add
  - Delete
  - Edit
- References C source

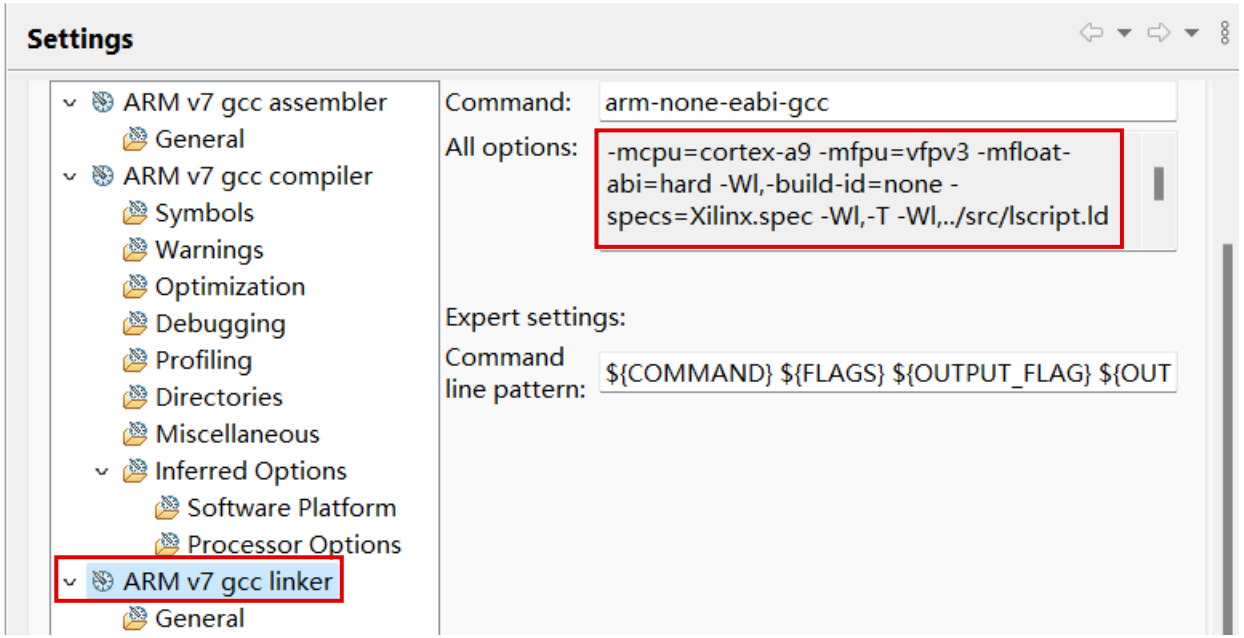
```
#ifdef symbol
conditional statements
#endif
```

- Passed to compiler as *–D* option
- Other compiler options are available



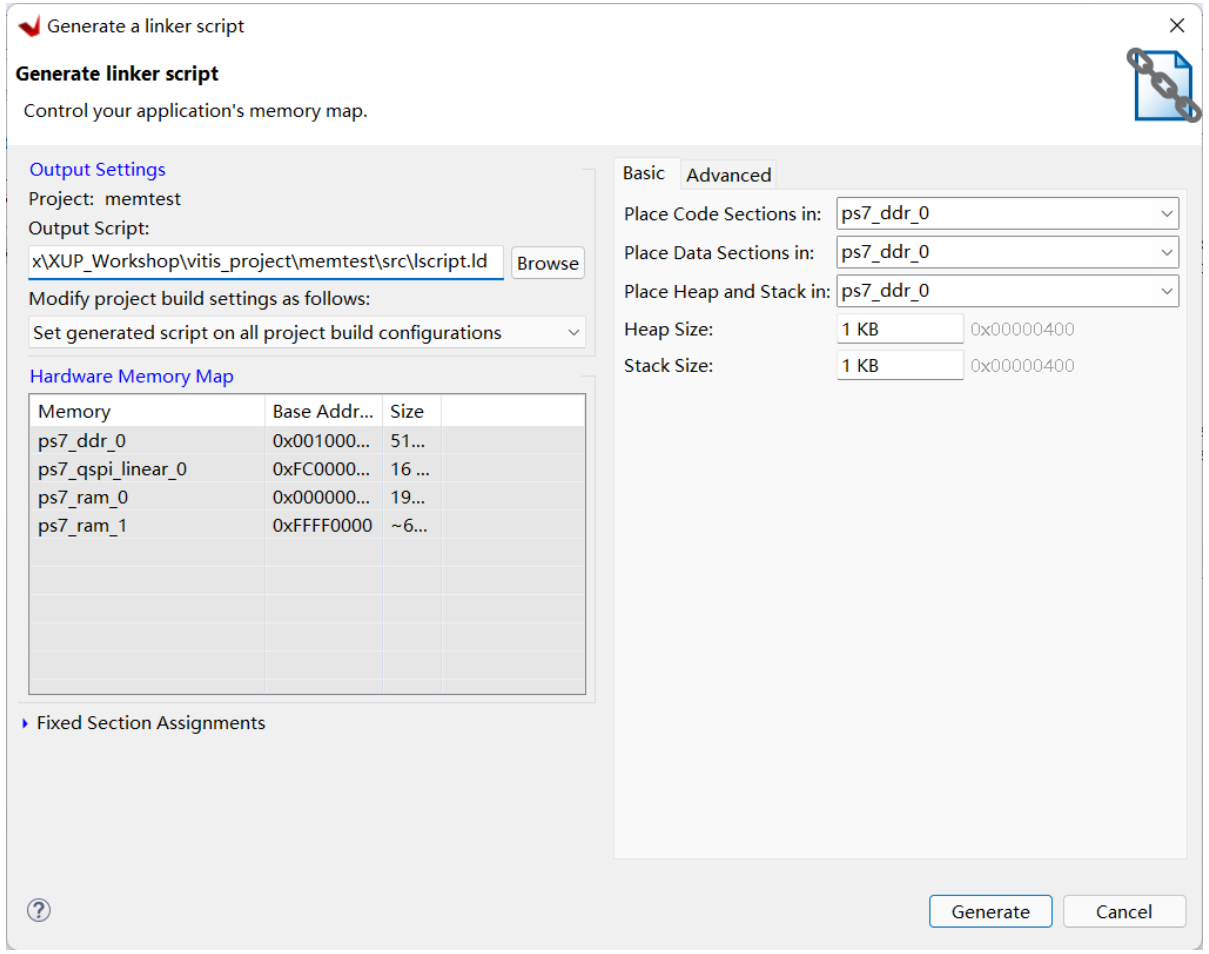
Linker Properties

- The Root panel displays properties for the selected configuration
- Shown are the linker options for the Debug configuration
- Default settings are fine for simple applications



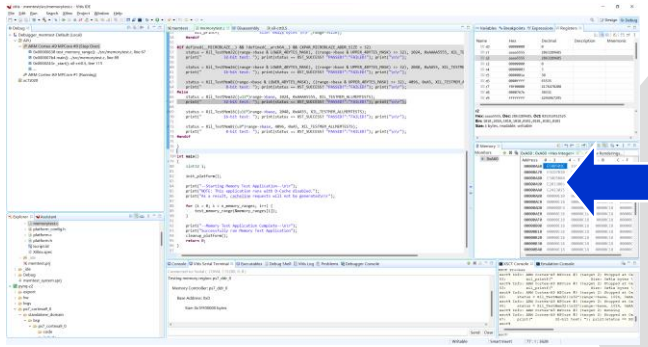
Linker Script Generator GUI

- Table-based GUI allows you to define the memory space for code and data sections
- Launch from **Xilinx > Generate Linker Script**, or from the Explorer view, **right-click on project > Generate Linker Script**
- The tool will create a new linker script (the old script is backed up)

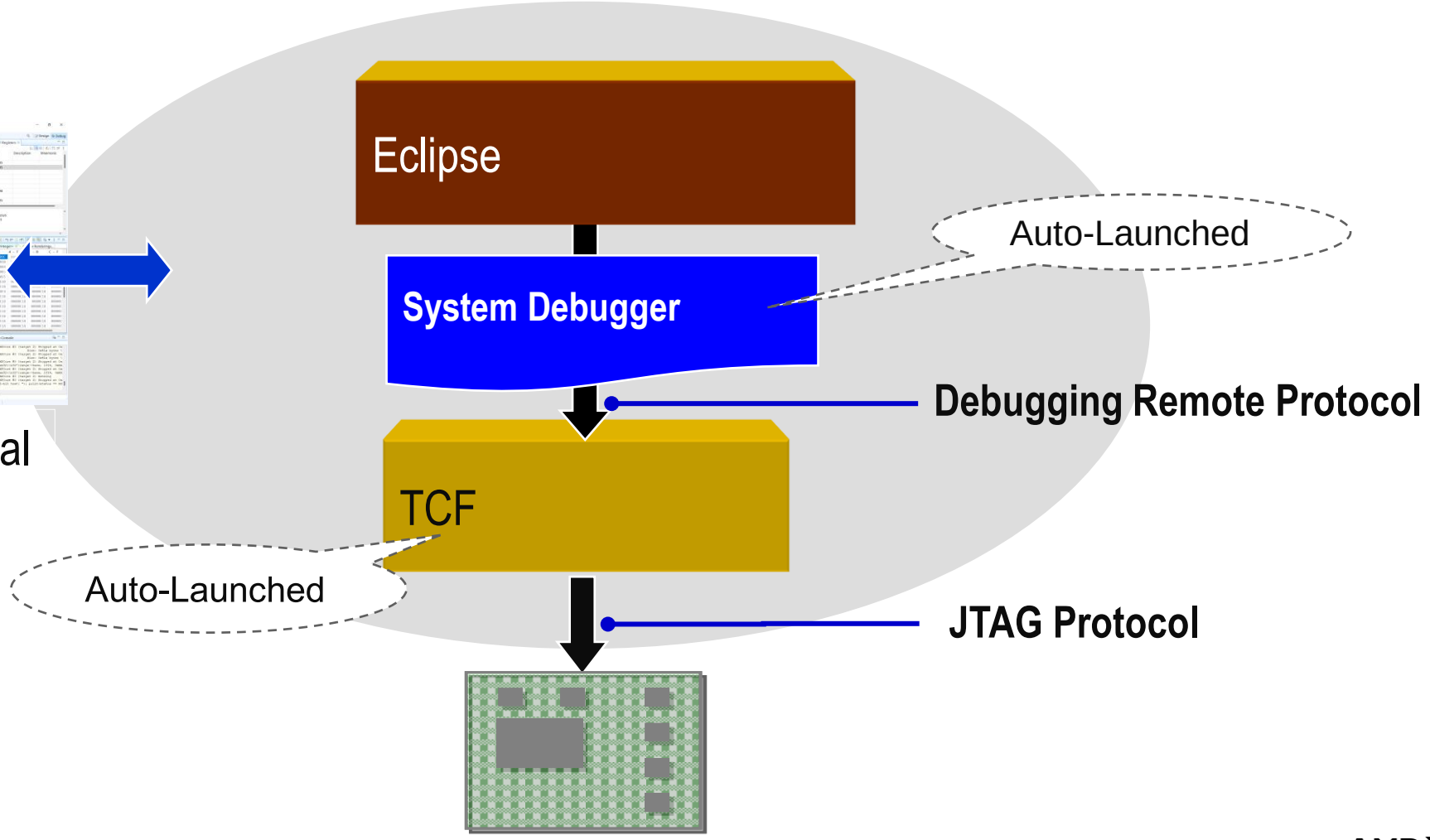


Software Debug in Vitis

Debugging Using Vitis IDE (TCF)



Xilinx Custom Graphical Debug Interface



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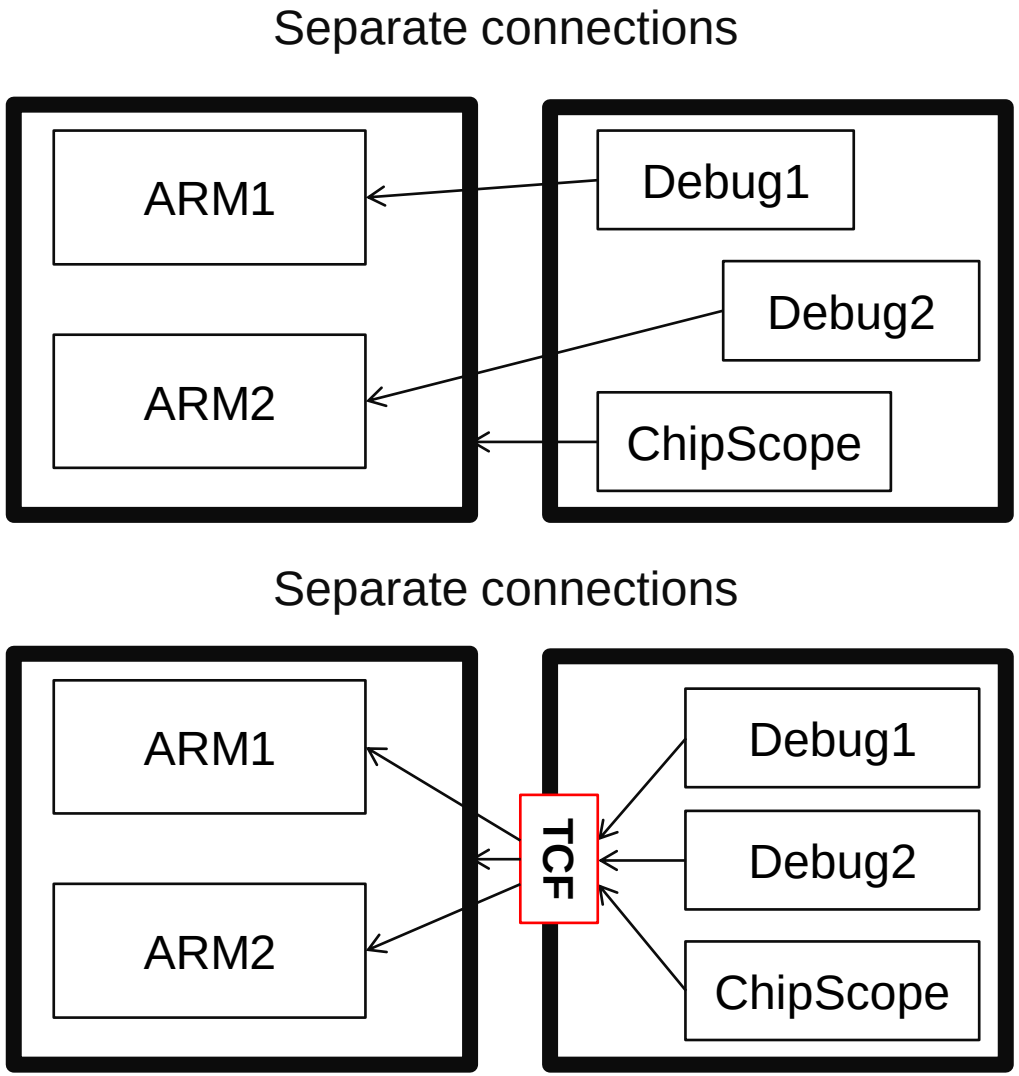
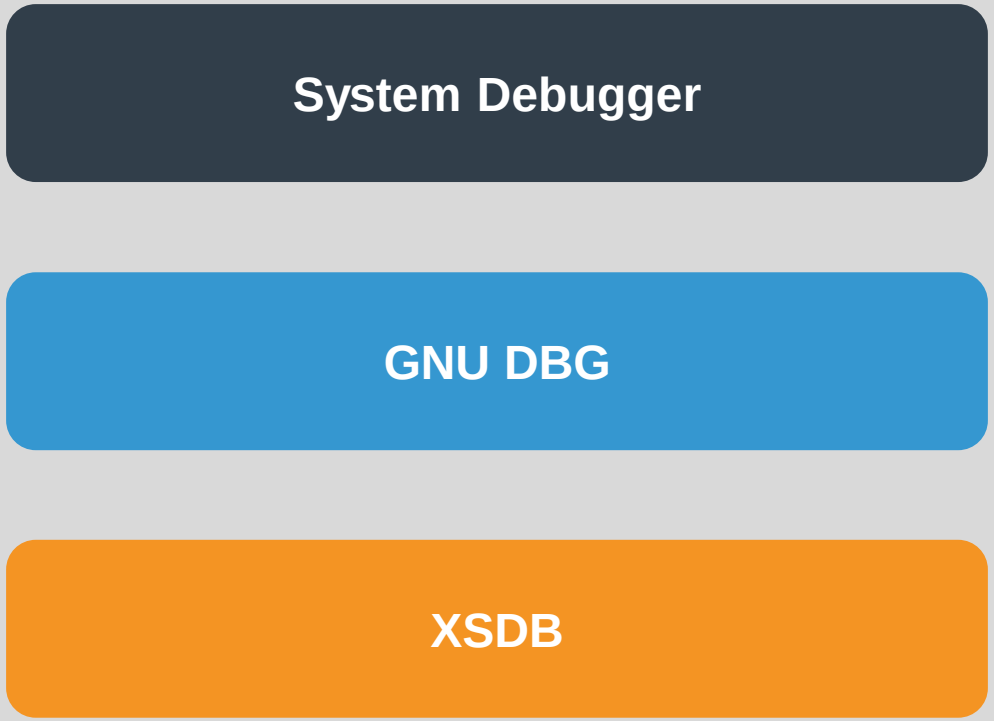
Eclipse Target Communication Framework

- Open, extensible network protocol
- Allows services to transparently plug in
- All communication links can share the same protocol
- Transport-agnostic channel abstraction
  - (No specific transport layer. E.g. TCP/IP, Serial Line, SSH tunnel)

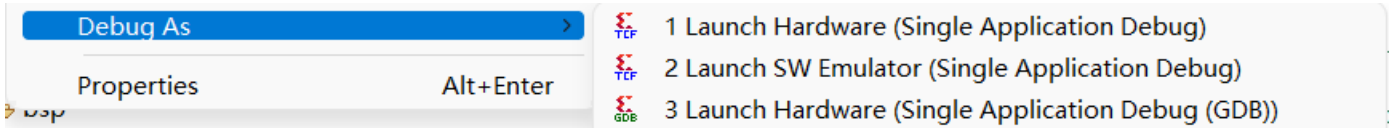


Software Debugging Support



System Debugger

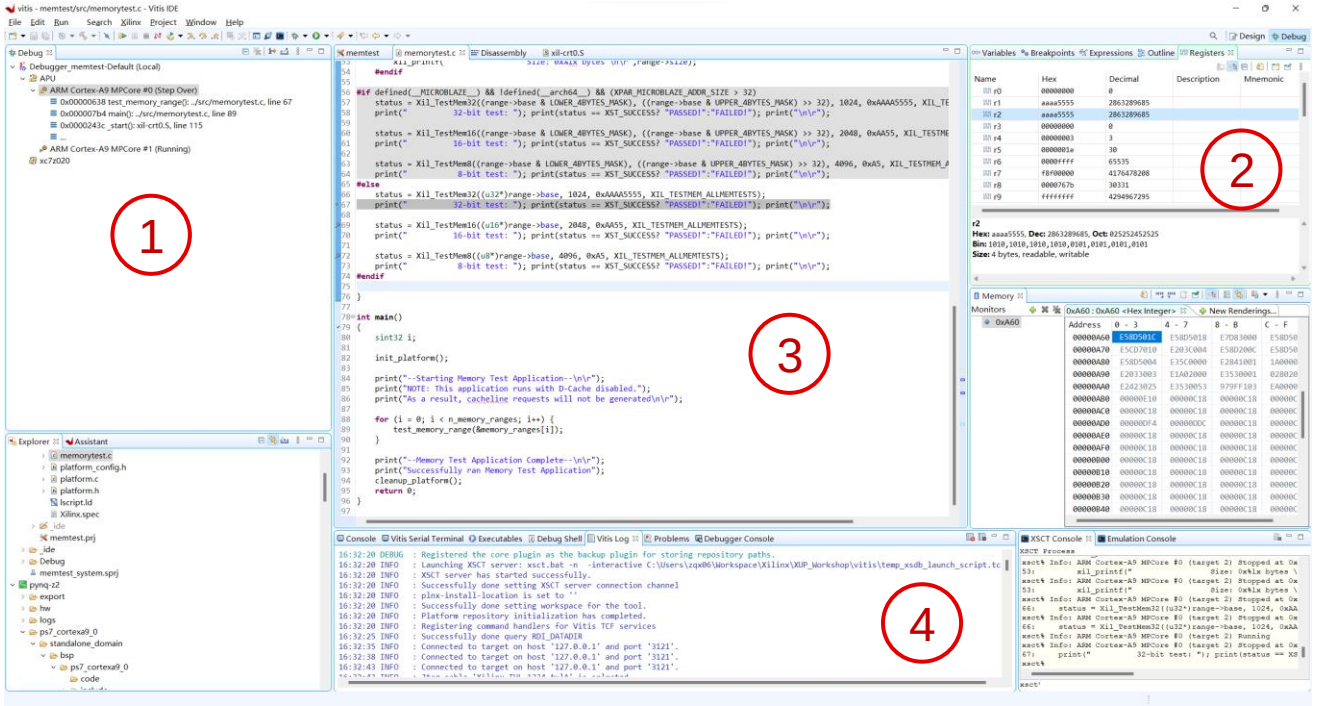
- Eclipse Target Communication Framework
  - Extensible network protocol for communicating with embedded systems
- Single Configuration per target
  - (Not per tool like gdb)



- Homogenous, and heterogeneous, SMP and AMP support
- Neon Support
- True multicore debug through a single JTAG
- Faster than GDB/XSDB

Vitis Debug Perspective

1. Stack frame for target threads
2. Outline, Variables, breakpoints, and registers views
   a. Disassembly view can be added using
   Window > Show View > Disassembly
3. C/C++ editor
4. Console, Vitis Log, and Memory views



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Debug GUI

- Run-time control

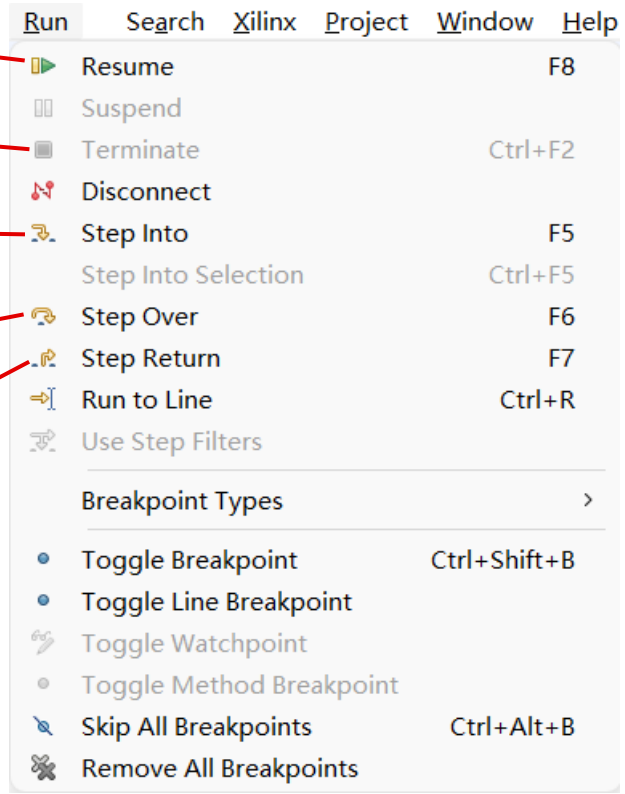
Continue to next breakpoint

Stop debug session

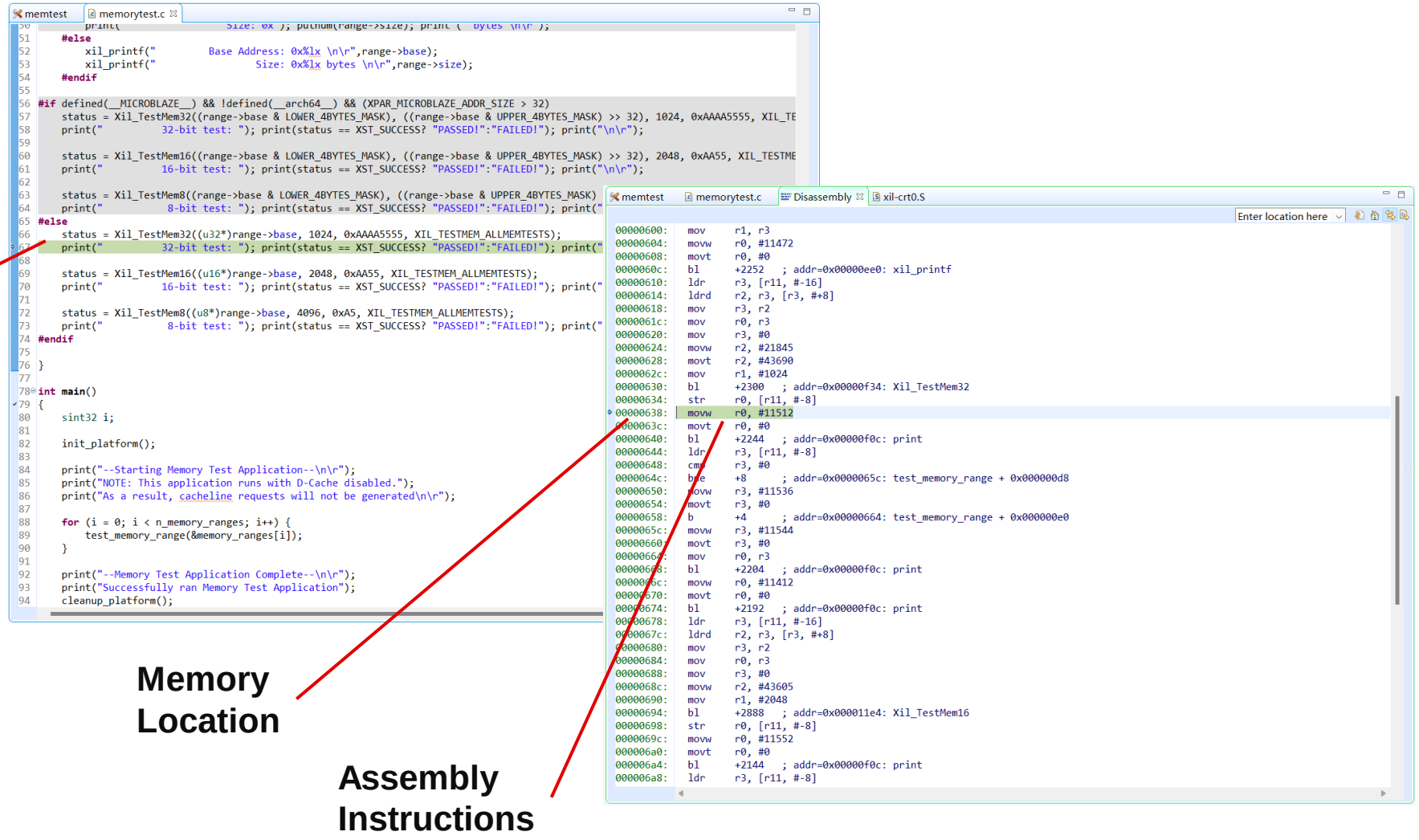
Step by source lines
(steps into functions)

Next source line
(steps over functions)

Step return from function



Debug



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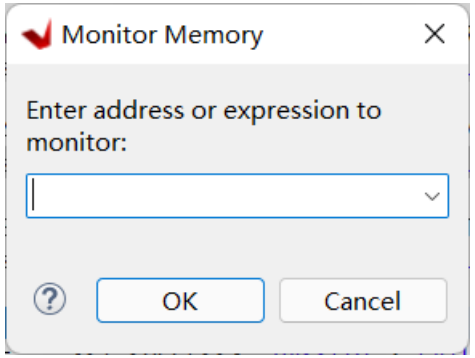
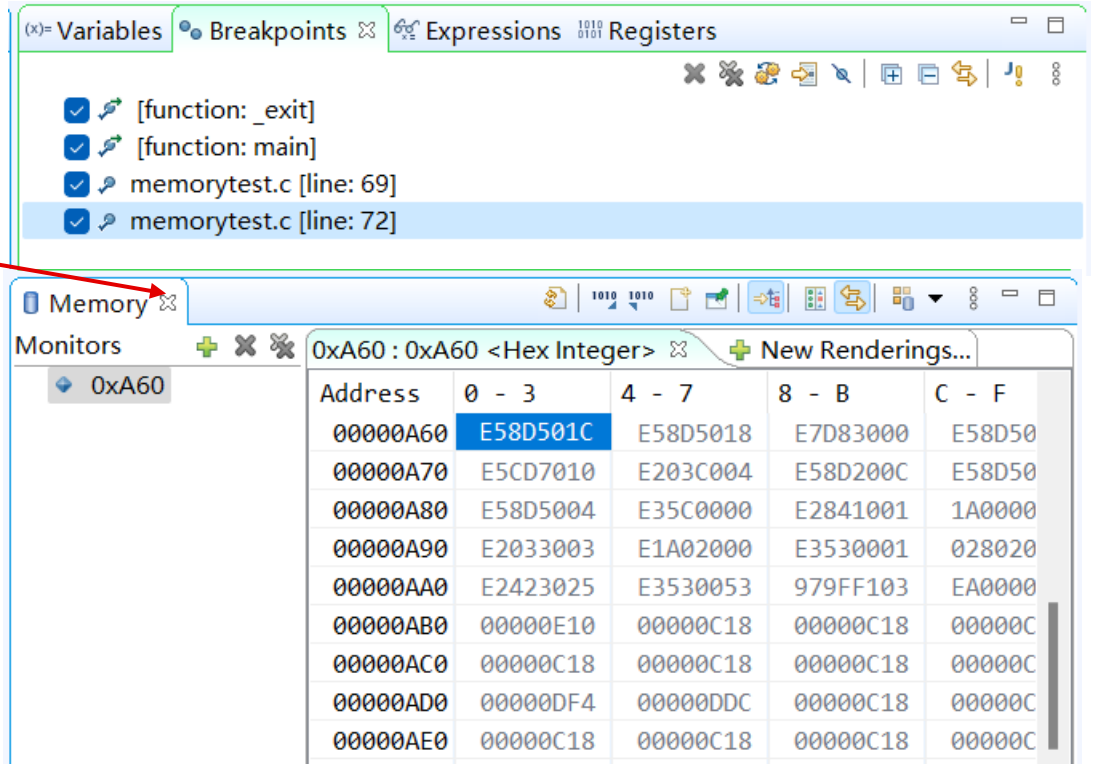
Debug Functionality

- Breakpoints can be enabled or disabled
- To change any memory value, click a memory field

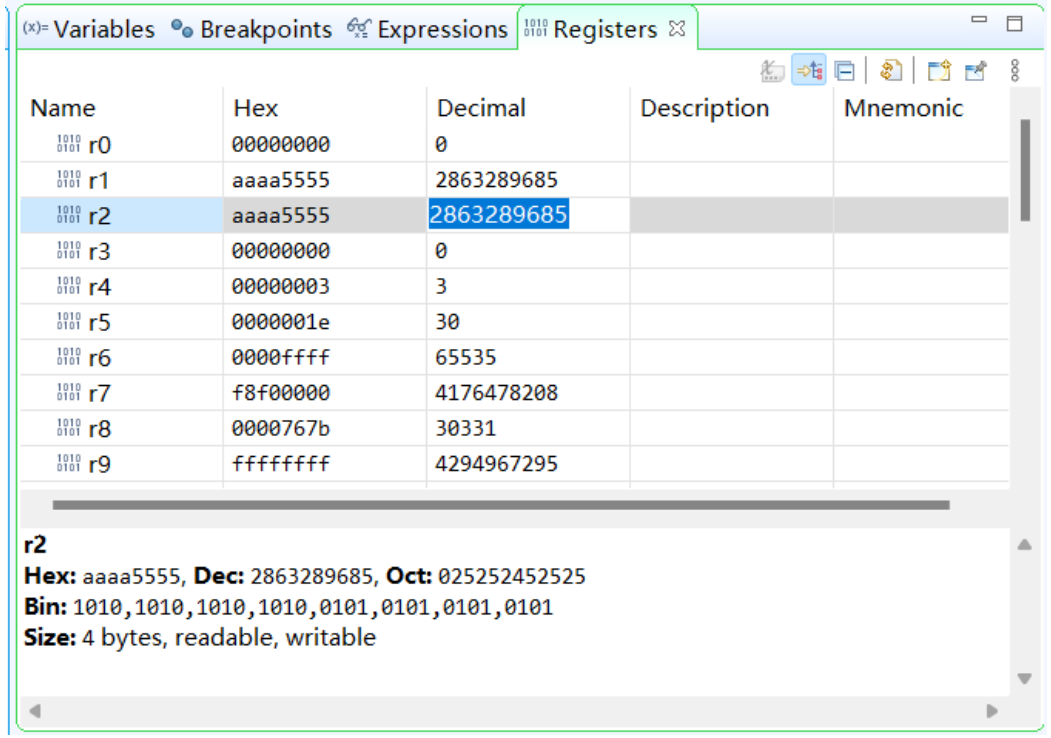
Add a memory monitor





Debug Functionality

- Yellow represents registers that have changed (useful when following assembly code)
- To change any value, click to edit



Summary

Summary

- Standalone APIs and Drivers
  - Different level of drivers
- Debugging is an integral part of embedded systems development
- System Debugger/TCF
  - Multicore Debug, shared connection
- Vitis provides environment, perspective, and underlying tools to enable seamless software debugging

Thank You

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