WIND RIVER

# VxWorks®

## ARCHITECTURE SUPPLEMENT

6.2

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*VxWorks Architecture Supplement, 6.2*

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# Contents

# 1 Introduction



## 1.1 About This Document

This document provides information specific to VxWorks development on all supported VxWorks target architectures. The following topics are discussed for each architecture:

- **Interface Variations**

  Information on changes or additions made to particular VxWorks features in order to support an architecture or processor.

- **Architecture Considerations**

  Special features and limitations of the target architecture, including a figure showing the VxWorks memory layout for the architecture.

- **Migrating Your BSP**

  Architecture-specific information on how to migrate your BSP from an earlier version of VxWorks to VxWorks 6.x. (See the *VxWorks Migration Guide* for general migration information).

- **Reference Material**

  Sources for current development information on your target architecture.

In addition, this document includes an appendix that details architecture-specific information related to building VxWorks applications and libraries.

For general information on the Wind River Workbench development environment's cross-development tools, see the *Wind River Workbench User's Guide* or the *VxWorks Command-Line Tools User's Guide*. For more information on the VxWorks operating system, see the *VxWorks Kernel Programmer's Guide* or the *VxWorks Application Programmer's Guide*.

## 1.2 Supported Architectures

This document includes information for the following target architectures:

- ARM
- Intel XScale
- Intel Architecture (Pentium)
- MIPS
- PowerPC
- Renesas SuperH

**NOTE:** The product you have purchased may not include support for all architectures. For more information, refer to your release note.

# 2 ARM



## 2.1 Introduction

VxWorks for ARM provides the Wind River Workbench development tools and the VxWorks operating system for the Advanced RISC Machines (ARM) family of architectures. ARM is a compact core that operates at a low power level.

**NOTE:** This release of VxWorks for ARM supports the standard 32-bit instruction set only, in big-endian (ARM Architecture Version 5 processors only) and little-endian configurations. It does not support the 16-bit instruction set (the Thumb instruction set).

## 2.2 Supported Processors

VxWorks for ARM supports the following ARM architectures:

- ARM Architecture Version 5 CPUs running in ARM state, in big- or little-endian mode.
- ARM Architecture Version 6 CPUs running in ARM state, in little-endian mode.

The following processor cores are supported:

**ARM 926ej-s** ARM Architecture Version 5 core, big- or little-endian.
**ARM 1136jf-s** ARM Architecture Version 6 core, little-endian.

**NOTE:** VxWorks for ARM is built around ARM processor cores rather than specific ARM-based chips. This allows VxWorks to support hundreds of ARM derivatives. If your chip is based on any of the above listed processor cores, it is supported by this release.

## 2.3 Interface Variations

This section describes particular features and routines that are specific to ARM targets in one of the following ways:

- They are available only on ARM targets.
- They use parameters specific to ARM targets.
- They have special restrictions or characteristics on ARM targets.

For more complete documentation on these routines, see the individual reference entries.

### 2.3.1 Restrictions on cret( ) and tt( )

The **cret( )** and **tt( )** routines make assumptions about the standard prolog for routines. If routines are written in assembly language, or in another language that

generates a different prolog, the **cret( )** and **tt( )** routines may generate unexpected results.

The VxWorks kernel is built without a dedicated frame pointer. This is also the default build option for user application code. As such, **cret( )** and **tt( )** cannot provide backtrace information. To enable backtracing for user code using the GNU compiler, add **-fno-omit-frame-pointer** to the application's compiler command-line options. (Backtracing for user code cannot be enabled using the Wind River Compiler.)

**tt( )** does not report the parameters to C functions as it cannot determine these from the code generated by the compiler.

The **tt( )** routine cannot be used for backtracing kernel code.

⚠ **CAUTION:** The kernel is compiled without backtrace structures. For this reason, **tt( )** does not work within the kernel routines, and **cret( )** can sometimes work incorrectly. Breakpoints and single-stepping work, even if the code is compiled without backtrace structures.

### 2.3.2 cacheLib

The **cacheLock( )** and **cacheUnlock( )** routines always return **ERROR** (see *2.4.8 Caches*, p.12). Use of the cache and use of the MMU are closely linked on ARM processors. Consequently, if **cacheLib** is used, **vmLib** is also required. In addition, **cacheLib** and **vmLib** calls must be coordinated. For more information, see *2.4.9 Memory Management Unit (MMU)*, p.13.

The definition of the symbolic constant **_CACHE_ALIGN_SIZE** is not related to the defined CPU type (the latter now defines an architecture). Rather, it is related to the cache type of the specific CPU being used. Therefore, code (such as device drivers) for which it is necessary to know the cache line size should use the variable **cacheArchAlignSize** instead.

### 2.3.3 dbgLib

In order to maintain compatibility with hardware-assisted debuggers, VxWorks for ARM uses only software breakpoints. When you set a software breakpoint, VxWorks replaces an instruction with a known undefined instruction. VxWorks restores the original code when the breakpoint is removed; if memory is examined or disassembled, the original code is shown.

### 2.3.4 dbgArchLib

If you are using the target shell, the following additional architecture-specific routines are available:

**psrShow( )**
Displays the symbolic meaning of a specified processor status register (PSR) value on the standard output.

**cpsr( )**
Returns the contents of the current processor status register (CPSR) of the specified task.

### 2.3.5 intALib

**intLock( ) and intUnlock( )**
The routine **intLock( )** returns the I bit from the CPSR as the lock-out key for the interrupt level prior to the call to **intLock( )**. The routine **intUnlock( )** takes this value as a parameter. For ARM, these routines control the CPU interrupt mask directly. They do not manipulate the interrupt levels in the interrupt controller chip.

**intIFLock( ) and intIFUnLock( )**
The routine **intIFLock( )** returns the I and F bits from the CPSR as the lock-out key in an analogous fashion, and the routine **intIFUnlock( )** takes that value as a parameter. Like **intLock( )** and **intUnlock( )**, these routines control the CPU interrupt mask directly. The **intIFLock( )** routine is not a replacement for **intLock( )**; it should only be used by code (such as FIQ setup code) that requires that both the IRQ and the FIQ be disabled.

### 2.3.6 intArchLib

ARM processors generally have no on-chip interrupt controllers to handle the interrupts multiplexed on the IRQ pin. Control of interrupts is a BSP-specific matter. All of these routines are connected by function pointers to routines that must be provided in ARM BSPs by a standard interrupt controller driver. For general information on interrupt controller drivers, see Wind River *AppNote46*, *Standard Interrupt Controller Devices*. (VxWorks application notes are available on the Wind River Online Support Web site at **https://secure.windriver.com /windsurf/knowledgebase.html**.) For special requirements or limitations, see the appropriate interrupt controller device driver documents.

**intLibInit( )**
This routine initializes the interrupt architecture library. It is usually called from **sysHwInit2( )** in the BSP code.

```
STATUS intLibInit(nLevels, nVecs, mode)
```

The *mode* argument specifies whether interrupts are handled in preemptive mode (**INT_PREEMPT_MODEL**) or non-preemptive mode (**INT_NON_PREEMPT_MODEL**).

**intEnable( ) and intDisable( )**
The **intEnable( )** and **intDisable( )** routines affect the masking of interrupts in the BSP interrupt controller and do not affect the CPU interrupt mask.

**intVecSet( ) and intVecGet( )**
The **intVecSet( )** and **intVecGet( )** routines are not supported for ARM and are not present in this release.

**intVecShow( )**
The **intVecShow( )** routine is not supported for ARM and is not present in this release.

**intLockLevelSet( ) and intLockLevelGet( )**
The **intLockLevelSet( )** and **intLockLevelGet( )** routines are not supported for ARM. The routines are present in this release but are not functional.

**intVecBaseSet( ) and intVecBaseGet( )**
The **intVecBaseSet( )** and **intVecBaseGet( )** routines are not supported for ARM. The routines are present in this release but are not functional.

**intUninitVecSet( )**
You can use the **intUninitVecSet( )** routine to install a default interrupt handler for all uninitialized interrupt vectors. The routine is called with the vector number as the only argument.

### 2.3.7 vmLib

As mentioned for **cacheLib**, caching and virtual memory are linked on ARM processors. Use of **vmLib** requires that **cacheLib** be included as well, and that calls to the two libraries be coordinated. For more information, see *2.4.9 Memory Management Unit (MMU)*, p.13.

### 2.3.8 vxALib

**mmuReadId( )**
The **mmuReadId( )** routine is provided to return the processor ID on processors with MMUs that provide such an ID. This routine should not be called on CPUs that do not have this type of MMU, doing so causes an undefined instruction exception.

**vxTas( )**
The test-and-set primitive **vxTas( )** provides a C-callable interface to the ARM SWPB (swap byte) instruction.

### 2.3.9 vxLib

The **vxMemProbe( )** routine, which probes an address for a bus error, is supported by trapping data aborts. If your BSP hardware does not generate data aborts when illegal addresses are accessed, **vxMemProbe( )** does not return the expected results. The BSP can provide an alternative routine by inserting the address of the alternate routine in the global variable **_func_vxMemProbeHook**.

## 2.4 Architecture Considerations

This section describes characteristics of the ARM processor that you should keep in mind as you write a VxWorks application. The following topics are addressed:

- processor mode
- byte order
- ARM and Thumb state
- unaligned accesses
- interrupts and exceptions
- divide-by-zero handling
- floating-point support
- caches
- memory management unit (MMU)
- memory layout

For comprehensive documentation on the ARM architecture and on specific processors, see the *ARM Architecture Reference Manual* and the data sheets for your target processor.

### 2.4.1 Processor Mode

VxWorks for ARM executes mainly in 32-bit supervisor mode (SVC32). When exceptions occur that cause the CPU to enter other modes, the kernel generally switches to SVC32 mode for most of the processing. Tasks running within a real-time process (RTP) run in user mode.

**NOTE:** This release does not include support for the 26-bit processor modes, which are obsolete.

### 2.4.2 Byte Order

ARM CPUs include support for both little-endian and big-endian byte order. However, this release of VxWorks for ARM provides support for big-endian byte order on ARM Architecture Version 5 processors only. Little-endian byte order support is included for all supported processors.

### 2.4.3 ARM and Thumb State

VxWorks for ARM supports the 32-bit instruction set (ARM state) only. The 16-bit instruction set (Thumb state) is not supported.

### 2.4.4 Unaligned Accesses

On ARM CPUs, unaligned 32-bit accesses have well-defined behavior and can often be used to improve performance. Many of the routines in the VxWorks libraries use such accesses. For this reason, unaligned access faults should not be enabled (on those CPUs with MMUs that support this functionality).

### 2.4.5 Interrupts and Exceptions

When an ARM interrupt or exception occurs, the CPU switches to one of several exception modes, each of which has a number of dedicated registers. In order to make the handlers reentrant, the stub routines that VxWorks installs to trap interrupts and exceptions switch from exception mode to SVC (supervisor) mode for further processing. The handler cannot be reentered while executing in an exception because reentry destroys the link register. When an exception or base-level interrupt handler is installed by a call to VxWorks, the address of the handler is stored for use by the stub when the mode switching is complete. The handler returns to the stub routine to restore the processor state to what it was before the exception occurred. Exception handlers (excluding interrupt handlers) can modify the state to be restored by changing the contents of the register set that is passed to the handler.

ARM processors do not, in general, have on-chip interrupt controllers. All interrupts except FIQs are multiplexed on the IRQ pin (see *Fast Interrupt (FIQ)*, p.11). Therefore, routines must be provided within your BSP to enable and disable specific device interrupts, to install handlers for specific device interrupts, and to determine the cause of the interrupt and dispatch the correct handler when an interrupt occurs. These routines are installed by setting function pointers. (For examples, see the interrupt control modules in *installDir*/**vxworks-6.2/target/src/drv/intrCtl**.) A device driver then installs an interrupt handler by calling **intConnect( )**. For more information on interrupt controllers, see Wind River *AppNote46*, *Standard Interrupt Controller Devices*.

Exceptions other than interrupts are handled in a similar fashion: the exception stub switches to SVC mode and then calls any installed handler. Handlers are installed through calls to **excVecSet( ),** and the addresses of installed handlers can be read through calls to **excVecGet( )**.

#### Interrupt Stacks

VxWorks for ARM uses a separate interrupt stack in order to avoid having to make task interrupt stacks big enough to accommodate the needs of interrupt handlers. The ARM architecture has a dedicated stack pointer for its IRQ interrupt mode. However, because the low-level interrupt handling code must be reentrant, IRQ mode is only used on entry to, and exit from, the handler; an interrupt destroys the IRQ mode link register. The majority of interrupt handling code runs in SVC mode on a dedicated SVC-mode interrupt stack.

#### Fast Interrupt (FIQ)

Fast interrupt (FIQ) is not handled by VxWorks. BSPs can use FIQ as they wish, but VxWorks code should not be called from FIQ handlers. If this functionality is required, the preferred mechanism is to downgrade the FIQ to an IRQ by software access to appropriately-designed hardware which generates an IRQ. The IRQ handler can then make such VxWorks calls as are normally allowed from interrupt context.

### 2.4.6 Divide-by-Zero Handling

There is no native divide-by-zero exception on the ARM architecture. In keeping with this, neither the GNU compiler nor the Wind River Compiler toolchain synthesize a software interrupt for this event.

### 2.4.7 Floating-Point Support

VxWorks for ARM is built using the assumption that there is no hardware floating-point support present on the target. To perform floating-point arithmetic, VxWorks instead relies on highly tuned software modules. These modules are automatically linked into the VxWorks kernel and are available to any application that requires floating-point support.

The floating-point library used by VxWorks for ARM is licensed from ARM Ltd. For more information on the floating-point library, see **http://www.arm.com**.

#### Return Status

The floating-point math functions supplied with this release do not set errno. However, return status can be obtained by calling **__ieee_status( )**.

The **__ieee_status( )** prototype is as follows:

```
unsigned int __ieee_status (unsigned int mask, unsigned int flags);
```

For example:

```
d = pow( 0,0 );
status = __ieee_status(FE_IEEE_ALL_EXCEPT, 0);
printf( "pow( 0, 0 )=%g, __ieee_status=%#x\n", d, status );
```

### 2.4.8 Caches

ARM processor cores have a variety of cache configurations. This section discusses these configurations and their relation to the ARM memory management facilities. The following subsections augment the information in the *VxWorks Kernel Programmer's Guide: Memory Management*.

ARM-based CPUs have one of three cache types: no cache, unified instruction and data caches, or separate instruction and data caches. Caches are also available in a variety of sizes. An in-depth discussion regarding ARM caches is beyond the scope of this document. For more detailed information, see the ARM Ltd. Web site.

In addition to the collection of caches, ARM cores can also have one of three types of memory management schemes: no memory management, a memory protection unit (MPU), or a full page-table-based memory management unit (MMU). Detailed information regarding these memory management schemes can also be found on the ARM Web site.

**NOTE:** This release does not support the use of a memory protection unit (MPU).

Table 2-1 summarizes supported ARM cache and MMU configurations.

Table 2-1 **Supported ARM Cache and MMU Configurations**

| Core | Cache Type | Memory Management |
|---|---|---|
| ARM926e | 32 KB instruction cache<br>32 KB data cache/write buffer | Page-table-based MMU |
| ARM1136jf-s | Cache size ranges from 4 KB to 36 KB and is detected automatically during VxWorks initialization | Page-table-based MMU |

For all ARM caches, the cache capabilities must be used with the MMU to resolve cache coherency problems. When the MMU is enabled, the page descriptor for each page selects the cache mode, which can be cacheable or non-cacheable. This page descriptor is configured by filling in the **sysPhysMemDesc[ ]** structure defined in the BSP *installDir***/vxworks-6.2/target/config/***bspname***/sysLib.c** file.

For more information on cache coherency, see the **cacheLib** reference entry. For information on MMU support in VxWorks, see the *VxWorks Kernel Programmer's Guide: Memory Management*. For MMU information specific to the ARM family, see *2.4.9 Memory Management Unit (MMU)*, p.13.

Not all ARM caches support cache locking and unlocking. Therefore, VxWorks for ARM does not support locking and unlocking of ARM caches. The **cacheLock( )** and **cacheUnlock( )** routines have no effect on ARM targets and always return **ERROR**.

The effects of the **cacheClear( )** and **cacheInvalidate( )** routines depend on the CPU type and on which cache is specified.

#### ARM 926ej-s Cache

The ARM 926e has separate instruction and data caches. Both are enabled by default. The data cache, if enabled, must be set to copyback mode, as all writes from the cache are buffered. **USER_D_CACHE_MODE** must be set to **CACHE_COPYBACK** and not changed. The instruction cache is not coherent with stores to memory. **USER_I_CACHE_MODE** should be set to **CACHE_WRITETHROUGH** and not changed.

On the ARM 926e, it is not possible to invalidate one part of the cache without invalidating others so, with the data cache specified, the **cacheClear( )** routine pushes dirty data to memory and then invalidates the cache lines. For the **cacheInvalidate( )** routine, unless the **ENTIRE_CACHE** option is specified, the entire data cache is invalidated.

#### ARM 1136jf-s Cache

The ARM 1136jf-s has separate instruction and data caches. Both are enabled by default. The data cache can be set to copyback or write-through mode on a per-page basis. The instruction cache is not coherent with stores to memory. **USER_I_CACHE_MODE** should be set to **CACHE_WRITETHROUGH** and not changed.

### 2.4.9 Memory Management Unit (MMU)

On ARM CPUs, a specific configuration for each memory page can be set. The entire physical memory is described by **sysPhysMemDesc[ ]**, which is defined in *installDir***/vxworks-6.2/target/config/***bspname***/sysLib.c**. This data structure is made up of state flags for each page or group of pages. All of the page states defined in the *VxWorks Kernel Programmer's Guide: Memory Management* are available for virtual memory pages.

All memory management is performed on *small pages* that are 4 KB in size. The ARM concepts of *sections* or *large pages* are not used.

### Cache and Memory Management Interaction

The caching and memory management functions for ARM processors are both provided on-chip and are very closely interlinked. In general, caching functions on ARM require the MMU to be enabled. Consequently, if cache support is configured into VxWorks, MMU support is also included by default. On some CPUs, the instruction cache can be enabled (in the hardware) without enabling the MMU. This is not a recommended configuration.

Only certain combinations of MMU and cache-enabling are valid, and there are no hardware interlocks to enforce this. In particular, enabling the data cache without enabling the MMU can lead to undefined results. Consequently, if an attempt is made to enable the data cache by means of the **cacheEnable( )** routine before the MMU has been enabled, the data cache is not enabled immediately. Instead, flags are set internally so that if the MMU is enabled later, the data cache is enabled with it. Similarly, if the MMU is disabled, the data cache is also disabled until the MMU is reenabled.

Support is also included for CPUs that provide a special area in the address space to be read in order to flush the data cache. ARM BSPs must provide a virtual address (**sysCacheFlushReadArea**) for a readable, cached block of address space that is used for nothing else. If the BSP has an area of the address space that does not actually contain memory but is readable, it can set the pointer to point to that area. If it does not, it should allocate some RAM for this area. In either case, the area must be marked as readable and cacheable in the page tables.

The declaration can be included in the BSP *installDir*/**vxworks-6.2/target/config/**_bspname_/**sysLib.c** file. For example:

```
UINT32 sysCacheFlushReadArea[D_CACHE_SIZE/sizeof(UINT32)];
```

Alternatively, the declaration can appear in the BSP **romInit.s** and **sysALib.s** files. For example:

```
.globl  _sysCacheFlushReadArea
.equ    _sysCacheFlushReadArea, 0x50000000
```

A declaration in *installDir*/**vxworks-6.2/target/config/**_bspname_/**sysLib.c** of the following form cannot be used:

```
UINT32 * sysCacheFlushReadArea = (UINT32 *) 0x50000000;
```

This form cannot be used because it introduces another level of indirection, causing the wrong address to be used for the cache flush buffer.

Some systems cannot provide an environment where virtual and physical addresses are the same. This is particularly important for those areas containing page tables. To support these systems, the BSP must provide mapping functions to

convert between virtual and physical addresses: these mapping functions are provided as parameters to the routines **cache***type***LibInstall( )** and **mmu***type***LibInstall( )**. For more information, see *BSP Considerations for Cache and MMU*, p.15.

### BSP Considerations for Cache and MMU

When building a BSP, the instruction set is selected by choosing the architecture (that is, by defining **CPU** to be **ARMARCH***x*); the cache and MMU types are selected within the BSP by defining appropriate values for the macros **ARMMMU** and **ARMCACHE** and calling the appropriate routines (as shown in Table 2-2) to support the cache and MMU.

The values definable for MMU include the following:

**ARMMMU_NONE**
**ARMMMU_926E**
**ARMMMU_1136JF**

The values definable for cache include the following:

**ARMCACHE_NONE**
**ARMCACHE_926E**
**ARMCACHE_1136JF**

Defined types are in the header file *installDir***/vxworks-6.2/target/h/arch/arm/arm.h**. (Support for other caches and MMU types may be added from time to time.)

For example, to define the MMU type for an ARM 926e on the command line, specify the following option when you invoke the compiler:

```
-DARMMMU=ARMMMU_926E
```

To provide the same information in a header or source file, include the following line in the file:

```
#define ARMMMU ARMMMU_926E
```

Table 2-2 shows the MMU routines required for each processor type.

Table 2-2 **Cache and MMU Routines for Individual Processor Types**

| Processor | Cache Routine | MMU Routine |
|---|---|---|
| ARM 926e | **cacheArm926eLibInstall( )** | **mmuArm926eLibInstall( )** |
| ARM 1136jf | **cacheArm1136jfLibInstall( )** | **mmuArm1136jfLibInstall( )** |

Each of these routines takes two parameters: function pointers to routines to translate between virtual and physical addresses and vice-versa. If the default address map in the BSP is such that virtual and physical addresses are identical (this is normally the case), the parameters to this routine can be **NULL** pointers. If the virtual-to-physical address mapping is such that the virtual and physical addresses are not the same, but the mapping is as described in the **sysPhysMemDesc[ ]** structure, the routines **mmuPhysToVirt( )** and **mmuVirtToPhys( )** can be used. If the mapping is different, translation routines must be provided within the BSP. For further details, see the reference entries for these routines.

MMU and cache support installation routines must be called as early as possible in the BSP initialization (before **cacheLibInit( )** and **vmLibInit( )**). This can most easily be achieved by putting them in a **sysHwInit0( )** routine within **sysLib.c** and then defining macros in **config.h** as follows:

```
#define INCLUDE_SYS_HW_INIT_0
#define SYS_HW_INIT_0() sysHwInit0 ()
```

During certain cache and MMU operations (for example, cache flushing), interrupts must be disabled. You may want your BSP to have control over this procedure. The contents of the variable **cacheArchIntMask** determine which interrupts are disabled. This variable has the value **I_BIT | F_BIT**, indicating that both IRQs and FIQs are disabled during these operations. If a BSP requires that FIQs be left enabled, the contents of **cacheArchIntMask** should be changed to **I_BIT**. Use extreme caution when changing the contents of this variable from its default.

### 2.4.10 Memory Layout

The VxWorks memory layout (real or virtual, as appropriate) is the same for all ARM processors. Figure 2-1 shows memory layout, labeled as follows:

**Vectors**
Table of exception/interrupt vectors.

**FIQ Code**
Reserved for FIQ handling code.

**Shared Memory Anchor**
Anchor for the shared memory network and VxMP shared memory objects (if there is shared memory on the board).

**Exception Pointers**
Pointers to exception routines, which are used by the vectors.

**Boot Line**
ASCII string of boot parameters.

**Exception Message**
ASCII string of fatal exception message.

**Initial Stack**
Initial stack for **usrInit( )**, until **usrRoot( )** is allocated a stack.

**System Image**
VxWorks itself (three sections: text, data, and bss). The entry point for VxWorks is at the start of this region.

**WDB Memory Pool**
The size of this pool depends on the macro **WDB_POOL_SIZE**, which defaults to one-sixteenth of the system memory pool. The target server uses this space to support host-based tools. Modify **WDB_POOL_SIZE** under **INCLUDE_WDB**.

**System Memory Pool**
Size depends on size of the system image. The **sysMemTop( )** routine returns the end of the free memory pool.

All addresses shown in Figure 2-1 are relative to the start of memory for a particular target board. The start of memory (corresponding to 0x0 in the memory layout diagram) is defined as **LOCAL_MEM_LOCAL_ADRS** under **INCLUDE_MEMORY_CONFIG** for each target.

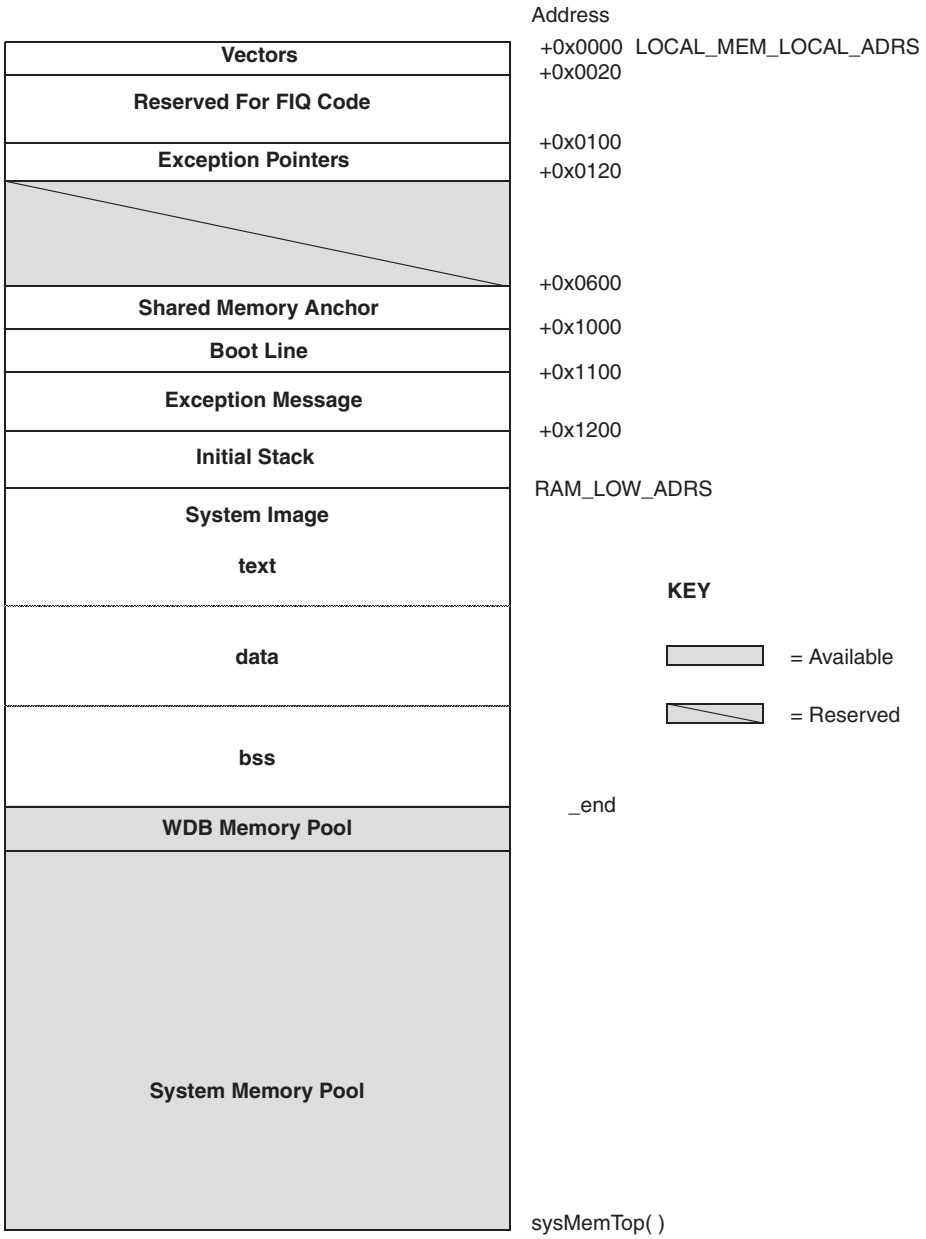
**NOTE:** The initial stack and system image addresses are configured within the BSP.

## 2.5 Migrating Your BSP

In order to convert a VxWorks BSP from an earlier VxWorks release to VxWorks 6.x, you must make certain architecture-independent changes. This includes making changes to custom BSPs designed to work with a VxWorks 5.5 release and not supported or distributed by Wind River.

This section includes changes and usage caveats specifically related to migrating ARM BSPs to VxWorks 6.x. For more information on migrating BSPs to this release, see the *VxWorks Migration Guide*.

Figure 2-1 **VxWorks System Memory Layout (ARM)**



### VxWorks 5.5 Compatibility

The memory layout shown in Figure 2-1 differs from that used for VxWorks 5.5. The position of the boot line and exception message have been moved to allow memory page zero protection (kernel hardening).

By default, all BSPs included with this release have the **T2_BOOTROM_COMPATIBILITY** option enabled in **config.h**. This retains compatibility with VxWorks 5.5 boot ROMs. In this configuration, the symbols are defined in **config.h** as follows:

```
#define SM_ANCHOR_OFFSET  0x600
#define BOOT_LINE_OFFSET  0x700
#define EXC_MSG_OFFSET    0x800
```

However, kernel hardening is not supported in this configuration. In order to enable kernel hardening, you must undefine **T2_BOOTROM_COMPATIBILITY** and use a VxWorks 6.x boot ROM.

If you create a Workbench project based on a VxWorks 5.5-compatible BSP (that is, a BSP that has **T2_BOOTROM_COMPATIBILITY** enabled) and you wish to remove the compatibility and enable kernel hardening, you must do *one* of the following:

- Update your BSP. Then, create a new project based on the modified BSP, and enable **INCLUDE_KERNEL_HARDENING**.

or:

- Undefine **T2_BOOTROM_COMPATIBILITY**. Enable **INCLUDE_KERNEL_HARDENING** and update the values of **SM_ANCHOR_OFFSET**, **BOOT_LINE_OFFSET**, and **EXC_MSG_OFFSET** to 0x1000, 0x1100, and 0x1200 respectively.

**NOTE:** VxWorks 5.5-compatible BSPs cannot support kernel hardening. **T2_BOOTROM_COMPATIBILITY** and **INCLUDE_KERNEL_HARDENING** are mutually exclusive. If both of these components are defined in your **config.h** file, Workbench issues a warning when you attempt to build your project.

## 2.6 Reference Material

Comprehensive information regarding ARM hardware behavior and programming is beyond the scope of this document. ARM Ltd. provides several hardware and programming manuals for the ARM processor on its Web site:

**http://www.arm.com/documentation/**

Wind River recommends that you consult the hardware documentation for your processor or processor family as necessary during BSP development.

### ARM Development Reference Documents

The information given in this section is current at the time of writing; should you decide to use these documents, you may wish to contact the manufacturer for the most current version.

- *Advanced RISC Machines, Architectural Reference Manual*, *Second Edition*, ARM DDI 0100 E, ISBN 0-201-73719-1.

**NOTE:** This document describes the architecture in general, including architectural standards for instruction bit fields. More specific information is found in the data sheets for individual processors, which conform to different architecture specification versions.

- *ARM System Architecture,* by Steve Furber. Addison-Wesley, 1996. ISBN 0-201-403352-8.
- *ARM Procedure Call Standard (APCS)*, a version of which is available on the Internet. Contact ARM for information on the latest version.

# 3 Intel XScale



## 3.1 Introduction

VxWorks for Intel XScale provides the Wind River Workbench development tools and the VxWorks operating system for the Intel XScale family of processors. The XScale microarchitecture features an ARM-compatible compact core that operates at a low power level. The core design supports both big- and little-endian configurations.

## 3.2 Supported Processors

VxWorks for Intel XScale supports XScale architecture CPUs running in ARM state, in either big- or little-endian mode (for example, IXDP425 and IXDP465 CPUs).

**NOTE:** VxWorks for Intel XScale provides support for the XScale architecture rather than for specific CPUs. If your chip is based on the XScale architecture, it should be supported by this release.

## 3.3 Interface Variations

This section describes particular features and routines that are specific to XScale targets in one of the following ways:

- They are available only on XScale targets.
- They use parameters specific to XScale targets.
- They have special restrictions or characteristics on XScale targets.

For more complete documentation on these routines, see the individual reference entries.

### 3.3.1 Restrictions on cret( ) and tt( )

The **cret( )** and **tt( )** routines make assumptions about the standard prolog for routines. If routines are written in assembly language, or in another language that generates a different prolog, the **cret( )** and **tt( )** routines may generate unexpected results.

The VxWorks kernel is built without a dedicated frame pointer. This is also the default build option for user application code. As such, **cret( )** and **tt( )** cannot provide backtrace information. To enable backtracing for user code using the GNU compiler, add **-fno-omit-frame-pointer** to the application's compiler command-line options. (Backtracing for user code cannot be enabled using the Wind River Compiler.)

**tt( )** does not report the parameters to C functions, as it cannot determine these from the code generated by the compiler.

The **tt( )** routine cannot be used for backtracing kernel code.

⚠ **CAUTION:** The kernel is compiled without backtrace structures. For this reason, **tt( )** does not work within the kernel routines, and **cret( )** can sometimes work incorrectly. Breakpoints and single-stepping should work, even if the code is compiled without backtrace structures.

### 3.3.2 cacheLib

The **cacheLock( )** and **cacheUnlock( )** routines always return **ERROR** (see *3.4.8 Caches*, p.29). Use of the cache and use of the MMU are closely linked on XScale processors. Consequently, if **cacheLib** is used, **vmLib** is also required. In addition, **cacheLib** and **vmLib** calls must be coordinated. For more information, see *3.4.9 Memory Management Unit (MMU)*, p.30.

The definition of the symbolic constant **_CACHE_ALIGN_SIZE** is not related to the defined CPU type (the latter now defines an architecture). Rather, it is related to the cache type of the specific CPU being used. Therefore, code (such as device drivers) in which it is necessary to know the cache line size should use the variable **cacheArchAlignSize** instead.

### 3.3.3 dbgLib

In order to maintain compatibility with hardware-assisted debuggers, VxWorks for Intel XScale uses only software breakpoints. When you set a software breakpoint, VxWorks replaces an instruction with a known undefined instruction. VxWorks restores the original code when the breakpoint is removed; if memory is examined or disassembled, the original code is shown.

### 3.3.4 dbgArchLib

If you are using the target shell, the following additional architecture-specific routines are available:

**psrShow( )**
Displays the symbolic meaning of a specified processor status register (PSR) value on the standard output.

**cpsr( )**
Returns the contents of the current processor status register (CPSR) of the specified task.

### 3.3.5 intALib

**intLock( ) and intUnlock( )**
The routine **intLock( )** returns the I bit from the CPSR as the lock-out key for the interrupt level prior to the call to **intLock( )**. The routine **intUnlock( )** takes this value as a parameter. For XScale processors, these routines control the CPU interrupt mask directly. They do not manipulate the interrupt levels in the interrupt controller chip.

**intIFLock( ) and intIFUnLock( )**
The routine **intIFLock( )** returns the I and F bits from the CPSR as the lock-out key in an analogous fashion, and the routine **intIFUnlock( )** takes that value as a parameter. Like **intLock( )** and **intUnlock( )**, these routines control the CPU interrupt mask directly. The **intIFLock( )** is not a replacement for **intLock( )**; it should only be used by code (such as FIQ setup code) that requires that both IRQ and FIQ be disabled.

### 3.3.6 intArchLib

XScale processors generally have no on-chip interrupt controllers to handle the interrupts multiplexed on the IRQ pin. Control of interrupts is a BSP-specific matter. All of these routines are connected by function pointers to routines that must be provided in the XScale BSPs by a standard interrupt controller driver. For general information on interrupt controller drivers, see Wind River *AppNote46*, *Standard Interrupt Controller Devices*. (VxWorks application notes are available on the Wind River Online Support Web site at **https://secure.windriver.com /windsurf/knowledgebase.html**.) For special requirements or limitations, see the appropriate interrupt controller device driver documents.

**intLibInit( )**
This routine initializes the interrupt architecture library. It is usually called from **sysHwInit2( )** in the BSP code.

```
STATUS intLibInit(nLevels, nVecs, mode)
```

The *mode* argument specifies whether interrupts are handled in preemptive mode (**INT_PREEMPT_MODEL**) or non-preemptive mode (**INT_NON_PREEMPT_MODEL**).

**intEnable( ) and intDisable( )**
The **intEnable( )** and **intDisable( )** routines affect the masking of interrupts in the BSP interrupt controller and do not affect the CPU interrupt mask.

**intVecSet( ) and intVecGet( )**
The **intVecSet( )** and **intVecGet( )** routines are not supported for XScale and are not present in this release.

**intVecShow( )**
The **intVecShow( )** routine is not supported for XScale and is not present in this release.

**intLockLevelSet( ) and intLockLevelGet( )**
The **intLockLevelSet( )** and **intLockLevelGet( )** routines are not supported for XScale. The routines are present in this release but are not functional.

**intVecBaseSet( ) and intVecBaseGet( )**
The **intVecBaseSet( )** and **intVecBaseGet( )** routines are not supported for XScale. The routines are present in this release but are not functional.

**intUninitVecSet( )**
You can use the **intUninitVecSet( )** routine to install a default interrupt handler for all uninitialized interrupt vectors. The routine is called with the vector number as the only argument.

### 3.3.7 vmLib

As mentioned for **cacheLib**, caching and virtual memory are linked on XScale processors. Use of **vmLib** requires that **cacheLib** be included as well, and that calls to the two libraries be coordinated. For more information, see *3.4.9 Memory Management Unit (MMU)*, p.30.

### 3.3.8 vxALib

**mmuReadId( )**
The **mmuReadId( )** routine is provided to return the processor ID on processors with MMUs that provide such an ID. This routine should not be called on CPUs that do not have this type of MMU, doing so causes an undefined instruction exception.

**vxTas( )**
The test-and-set primitive **vxTas( )** provides a C-callable interface to the ARM SWPB (swap byte) instruction.

### 3.3.9 vxLib

The **vxMemProbe( )** routine, which probes an address for a bus error, is supported by trapping data aborts. If your BSP hardware does not generate data aborts when illegal addresses are accessed, **vxMemProbe( )** does not return the expected results. The BSP can provide an alternative routine by inserting the address of the alternate routine in the global variable **_func_vxMemProbeHook**.

## 3.4 Architecture Considerations

This section describes characteristics of the XScale processor that you should keep in mind as you write a VxWorks application. The following topics are addressed:

- processor mode
- byte order
- ARM and Thumb state
- unaligned accesses
- interrupts and exceptions
- divide-by-zero handling
- floating-point support
- caches
- memory management unit (MMU)
- memory layout

For comprehensive documentation on the XScale architecture and on specific processors, see the *ARM Architecture Reference Manual* and the data sheets for the appropriate processors.

### 3.4.1 Processor Mode

VxWorks for Intel XScale executes mainly in 32-bit supervisor mode (SVC32). When exceptions occur that cause the CPU to enter other modes, the kernel generally switches to SVC32 mode for most of the processing. Tasks running within a real-time process (RTP) run in user mode.

**NOTE:** This release does not include support for the 26-bit processor modes, which are obsolete.

### 3.4.2 Byte Order

XScale CPUs include support for both little-endian and big-endian byte orders; libraries for both byte orders are included in this release.



### 3.4.3 ARM and Thumb State

VxWorks for Intel XScale supports 32-bit instructions (ARM state) only. The 16-bit instructions set (Thumb state) is not supported.

### 3.4.4 Unaligned Accesses

Unaligned accesses are not allowed on XScale CPUs and result in a data abort.

### 3.4.5 Interrupts and Exceptions

When an XScale interrupt or exception occurs, the CPU switches to one of several exception modes, each of which has a number of dedicated registers. In order to make the handlers reentrant, the stub routines that VxWorks installs to trap interrupts and exceptions switch from the exception mode to SVC (supervisor) mode for further processing. The handler cannot be reentered while executing in an exception because reentry destroys the link register. When an exception or base-level interrupt handler is installed by a call to VxWorks, the address of the handler is stored for use by the stub when the mode switching is complete. The handler returns to the stub routine to restore the processor state to what it was before the exception occurred. Exception handlers (excluding interrupt handlers) can modify the state to be restored by changing the contents of the register set that is passed to the handler.

XScale processors do not, in general, have on-chip interrupt controllers. All interrupts except FIQs are multiplexed on the IRQ pin (see *Fast Interrupt (FIQ)*, p.28). Therefore, routines must be provided within your BSP to enable and disable specific device interrupts, to install handlers for specific device interrupts, and to determine the cause of the interrupt and dispatch the correct handler when an interrupt occurs. These routines are installed by setting function pointers. (For examples, see the interrupt control modules in *installDir*/**vxworks-6.2/target/src/drv/intrCtl**.) A device driver then installs an interrupt handler by calling **intConnect( )**. For more information on interrupt controllers, see Wind River *AppNote46*, *Standard Interrupt Controller Devices*.

Exceptions other than interrupts are handled in a similar fashion: the exception stub switches to SVC mode and then calls any installed handler. Handlers are installed by calls to **excVecSet( )**, and the addresses of installed handlers can be read through calls to **excVecGet( )**.

#### Interrupt Stacks

VxWorks for Intel XScale uses a separate interrupt stack in order to avoid having to make task interrupt stacks big enough to accommodate the needs of interrupt handlers. The XScale architecture has a dedicated stack pointer for its IRQ interrupt mode. However, because the low-level interrupt handling code must be reentrant, IRQ mode is only used on entry to, and exit from, the handler; an interrupt destroys the IRQ mode link register. The majority of interrupt handling code runs in SVC mode on a dedicated SVC-mode interrupt stack.

#### Fast Interrupt (FIQ)

Fast interrupt (FIQ) is not handled by VxWorks. BSPs can use FIQ as they wish, but VxWorks code should not be called from FIQ handlers. If this functionality is required, the preferred mechanism is to downgrade the FIQ to an IRQ by software access to appropriately-designed hardware which generates an IRQ. The IRQ handler can then make such VxWorks calls as are normally allowed from interrupt context.

### 3.4.6 Divide-by-Zero Handling

There is no native divide-by-zero exception on the XScale architecture. In keeping with this, neither the GNU compiler nor the Wind River Compiler toolchain synthesize a software interrupt for this event.

### 3.4.7 Floating-Point Support

VxWorks for Intel XScale is built using the assumption that there is no hardware floating-point support present on the target. To perform floating-point arithmetic, VxWorks instead relies on highly tuned software modules. These modules are automatically linked into the VxWorks kernel and are available to any application that requires floating-point support.

The floating-point library used by VxWorks for Intel XScale is licensed from ARM Ltd. For more information on the floating-point library, see **http://www.arm.com**.



#### Return Status

The floating-point math functions supplied with this release do not set errno. However, return status can be obtained by calling **__ieee_status( )**.

The **__ieee_status( )** prototype is as follows:

```
unsigned int __ieee_status (unsigned int mask, unsigned int flags);
```

For example:

```
d = pow( 0,0 );
status = __ieee_status(FE_IEEE_ALL_EXCEPT, 0);
printf( "pow( 0, 0 )=%g, __ieee_status=%#x\n", d, status );
```

### 3.4.8 Caches

XScale processor cores have a variety of cache configurations. This section discusses these configurations and their relation to the XScale memory management facilities. The following subsections augment the information in the *VxWorks Kernel Programmer's Guide: Memory Management*.

XScale-based CPUs have separate instruction and data caches, as well as write buffers. Caches are also available in a variety of sizes and may include minicaches. An in-depth discussion regarding XScale caches is beyond the scope of this document. For more detailed information, see the Intel Web site.

In addition to the collection of caches, XScale cores also implement a full page-table-based memory management unit (MMU). Detailed information regarding the memory management scheme can also be found on the Intel Web site.

Table 3-1 summarizes some of the common XScale cache and MMU configurations.

Table 3-1 **Supported XScale Cache and MMU Configurations**

| Core | Cache Type | Memory Management |
|---|---|---|
| XScale | 32 KB instruction cache<br>32 KB data cache/write buffer<br>2 KB mini data cache | Page-table-based MMU |

For all XScale caches, the cache capabilities must be used with the MMU to resolve cache coherency problems. When the MMU is enabled, the page descriptor for each page selects the cache mode, which can be cacheable or non-cacheable. This page descriptor is configured by filling in the **sysPhysMemDesc[ ]** structure defined in the BSP *installDir*/**vxworks-6.2/target/config/***bspname*/**sysLib.c** file.

For more information on cache coherency, see the **cacheLib** reference entry. For information on MMU support in VxWorks, see the *VxWorks Kernel Programmer's Guide: Memory Management*. For MMU information specific to the XScale family, see *3.4.9 Memory Management Unit (MMU)*, p.30.

Not all XScale caches support cache locking and unlocking. Therefore, VxWorks for Intel XScale does not support locking and unlocking of XScale caches. The **cacheLock( )** and **cacheUnlock( )** routines have no effect on XScale targets and always return **ERROR**.

The effects of the **cacheClear( )** and **cacheInvalidate( )** routines depend on the CPU type and on which cache is specified.

All XScale processors contain an instruction cache and a data cache. By default, VxWorks uses both caches; that is, both are enabled. To disable the instruction cache, highlight the **USER_I_CACHE_ENABLE** macro in the **Params** tab under **INCLUDE_CACHE_ENABLE** and remove the value **TRUE**; to disable the data cache, highlight the **USER_D_CACHE_ENABLE** macro and remove **TRUE**.

It is not appropriate to think of the mode of the instruction cache. The instruction cache is a read cache that is not coherent with stores to memory. Therefore, code that writes to cacheable instruction locations must ensure instruction cache validity. Set the **USER_I_CACHE_MODE** parameter in the **Params** tab under **INCLUDE_CACHE_MODE** to **CACHE_WRITETHROUGH**, and do not change it.

With the data cache specified, the **cacheClear( )** routine first pushes dirty data to memory and then invalidates the cache lines, while the **cacheInvalidate( )** routine simply invalidates the lines (in which case, any dirty data contained in the lines is lost). With the instruction cache specified, both routines have the same result: they invalidate all of the instruction cache. Because the instruction cache is separate from the data cache, there can be no dirty entries in the instruction cache, so no dirty data can be lost.

### 3.4.9 Memory Management Unit (MMU)

On XScale CPUs, a specific configuration for each memory page can be set. The entire physical memory is described by **sysPhysMemDesc[ ]**, which is defined in *installDir*/**vxworks-6.2/target/config/***bspname*/**sysLib.c**. This data structure is made

up of state flags for each page or group of pages. All of the page states defined in the *VxWorks Kernel Programmer's Guide: Memory Management* are available for virtual memory pages. In addition, XScale-based processors support the **MMU_STATE_CACHEABLE_MINICACHE** (or **VM_STATE_CACHEABLE_MINICACHE)** flag, allowing page-level control of the CPU minicache.

All memory management is performed on *small pages* that are 4 KB in size. The ARM concepts of *sections* or *large pages* are not used.

### XScale Memory Management Extensions and VxWorks

The Intel XScale processor core introduces extensions to ARM Architecture Version 5. Among these extensions are the addition of the X bit and the P bit. This section describes VxWorks support for these extensions.

**NOTE:** This section supplements the documentation provided with the **vmBaseLib** and **vmLib** reference entries and in the *VxWorks Kernel Programmer's Guide: Memory Management*.

The Intel XScale processor extends the page attributes defined by the C and B bits in the page descriptors with an additional X bit. This bit allows four more attributes to be encoded when X=1. These new encodings include allocating data for the mini-data cache and the write-allocate cache.

If you are using the MMU, the cache modes are controlled by the cache mode values set in the **sysPhysMemDesc[ ]** table defined in *installDir***/vxworks-6.2 /target/config/***bspname***/sysLib.c** within the BSP directory.

The XScale processor retains the ARM definitions of the C and B encoding when X= 0, which differs from the behavior on the first generation Intel StrongARM processors. The memory attribute for the mini-data cache has been relocated and replaced with the write-through caching attribute.

When write-allocate is enabled, a store operation that misses the data cache (cacheable data only) generates a line fill. If disabled, a line fill only occurs when a load operation misses the data cache (cacheable data only).

Write-through caching causes all store operations to be written to memory, whether they are cacheable or not cacheable. This feature is useful for maintaining data cache coherency.

The type extension (TEX) field is present in several of the descriptor types. In the XScale processor, only the least significant bit (LSB) of this field is used; this is called the X bit.

A small page descriptor does not have a TEX field. For this type of descriptor, TEX is implicitly zero; that is, this descriptor operates as if the X bit has a zero value.

The X bit, when set, modifies the meaning of the C and B bits.

When examining these bits in a descriptor, the instruction cache only utilizes the C bit. If the C bit is clear, the instruction cache considers a code fetch from that memory to be non-cacheable, and does not fill a cache entry. If the C bit is set, fetches from the associated memory region are cached.

If the X bit for a descriptor is zero, the C and B bits operate as mandated by the ARM architecture. If the X bit for a descriptor is one, the C and B bits meaning is extended.

If the MMU is disabled, all data accesses are non-cacheable and non-bufferable. This is the same behavior as when the MMU is enabled, and a data access uses a descriptor with X, C, and B all set to zero.

The X, C, and B bits determine when the processor should place new data into the data cache. The cache places data into the cache in *lines* (also called *blocks*). Thus, the basis for making a decision about placing new data into the cache is called a *line allocation policy*.

If the line allocation policy is read-allocate, all load operations that miss the cache request a 32-byte cache line from external memory and allocate it into either the data cache or mini-data cache (this assumes the cache is enabled). Store operations that miss the cache do not cause a line to be allocated.

If a read/write-allocate is in effect, and if cache is enabled, load or store operations that miss the cache request a 32-byte cache line from external memory.

The other policy determined by the X, C, and B bits is the *write policy*. A write-through policy instructs the data cache to keep external memory coherent by performing stores to both external memory and the cache. A write-back policy only updates external memory when a line in the cache is cleaned or needs to be replaced with a new line. Generally, write-back provides higher performance because it generates less data traffic to external memory.

The write buffer is always enabled which means stores to external memory are buffered. The K bit in the auxiliary control register (CP15, register 1) is a global enable/disable for allowing coalescing in the write buffer. When this bit disables coalescing, no coalescing occurs regardless of the value of the page attributes. If

this bit enables coalescing, the page attributes X, C, and B are examined to see if coalescing is enabled for each region of memory.

All reads and writes to external memory occur in program order when coalescing is disabled in the write buffer. If coalescing is enabled in the write buffer, writes may occur out of program order to external memory. In this case, program correctness is maintained by comparing all store requests with all valid entries in the fill buffer.

The write buffer and fill buffer support a drain operation such that before the next instruction executes, all XScale processor data requests to external memory—including the write operations in the bus controller—are complete.

Writes to a region marked non-cacheable and non-bufferable (page attributes C, B, and X set to zero) cause execution to stall until the write completes.

If software is running in a privileged mode, it can explicitly drain all buffered writes.

Non-cache memory (X=0, C=0, and B=0) should only be used if required (as is often the case for I/O devices). Accessing non-cacheable memory is likely to cause the processor to stall frequently due to the long latency of memory reads.

VxWorks includes support for the X bit and there are now three new states supported in **vmLib.h** that allow you to set up buffers to use these extended states.

The following state flags have been added to **vmLib.h**:

| | |
|---|---|
| **MMU_STATE_CACHEABLE_MINICACHE** (**VM_STATE_CACHEABLE_MINICACHE**) | cache policy is determined by the MD field of the auxiliary control register |
| **VM_STATE_EX_CACHEABLE** | write-back, read/write allocate |
| **VM_STATE_EX_CACHEABLE_NOT** | |
| **VM_STATE_MASK_EX_CACHEABLE** | |
| **VM_STATE_EX_BUFFERABLE** | writes do not coalesce into buffers |
| **VM_STATE_EX_BUFFERABLE_NOT** | |
| **VM_STATE_MASK_EX_BUFFERABLE** | |

If **MMU_STATE_CACHEABLE_MINICACHE** (or **VM_STATE_CACHEABLE_MINICACHE**) is set, pages set to this state using **vmStateSet( )** result in those pages being cached in the minicache, and not in the main data cache.

Calling **cacheInvalidate(DATA_CACHE, ENTIRE_CACHE)** also invalidates the minicache, but in all other aspects, no support is provided for the minicache, and you are entirely responsible for ensuring cache coherency.

If **INCLUDE_MMU_BASIC** and **INCLUDE_SHOW_ROUTINES** are defined, you may use **vmContextShow( )** to display a virtual memory context on the standard output device. Extended bit states for **vmContextShow( )** are defined as:

**XC-** **VM_STATE_EX_CACHEABLE_NOT**

**XC+** **VM_STATE_EX_CACHEABLE**

**XB-** **VM_STATE_EX_BUFFERABLE_NOT**

**XB+** **VM_STATE_EX_BUFFERABLE**

For more information on the extended page table and X bit support, see the *Intel XScale Core Developer's Manual* (available from Intel).

### Setting the XScale P Bit in VxWorks

The XScale architecture introduces the P bit in the MMU first level page descriptors, allowing an *application specific standard product* (ASSP) to identify a new memory attribute. The bi-endian version of the IXP42*x* processor implements the P bit to control address and data byte swapping and requires support for the P bit in the first level descriptor and in the auxiliary control register (CP15, Rn 1, O2 1). The setting of the P bit in a first level descriptor enables address or data byte swapping on a per-section (1 MB) basis. As page table walks are performed with the MMU disabled, bit 1 in the auxiliary control register enables byte swapping for the page table walks.

Because VxWorks MMU support operates on a 4 KB page basis rather than on 1 MB regions, support for the P bit on a per region basis is best accomplished with a new interface that avoids excessive overhead during MMU initialization. An additional interface to the auxiliary control register is required as well.

The architecture-specific support code for the XScale MMU has been modified to support the P bit. A byte array of the size **NUM_L1_DESCS** (the number of first level descriptors) has been added. Each byte within the array represents the state of the P bit for the corresponding region; zero if the P bit is not to be set and one if it is. The default value is zero. For example:

```
#if (ARMMMU == ARMMMU_XSCALE)
/*
 * The array used to keep XSCALE mmu 'P' bit state for init purposes.
 */
```

```
LOCAL UCHAR mmuArmXSCALEPBit[NUM_L1_DESCS] =
    {
    0,
    };
#endif /* ARMMMU == ARMMMU_XSCALE */
```



Four subroutines have been implemented that enable the setting, clearing, and querying of the state of the P bit status on a per-region basis and within the CP15 auxiliary control register. All of the implemented region-specific subroutines have two behaviors, one if the MMU is not yet initialized by the current instance of VxWorks, and another if it is already initialized.

In the case where the MMU is not yet initialized, the subroutines operate on the appropriate bytes within the **mmuArmXSCALEPBit** array only. When the MMU is initialized, the P bit is set on a per-region basis as determined by the state of the **mmuArmXSCALEPBit** array.

When the MMU is initialized, the subroutines operate on the current first level descriptor, providing interrupt lockout, cache flushing, and TLB cache invalidates as necessary. Additionally, the **mmuArmXSCALEPBit** array mirrors the state of the P bit on a per-region basis.

- **mmuArmXSCALEPBitSet( )**

```
STATUS mmuArmXSCALEPBitSet      /* Set the P bit in a region
                                   or regions */
    (
    void *      virtAddr,       /* The beginning virtual address */
    UINT32      size            /* The size in bytes */
    )
```

The virtual address is converted into an index to a 1 MB region within 32 -bit virtual address space (rounded down).

The size is converted to the number of 1 MB regions to modify.

**NOTE:** A virtual address near the end of a 1 MB region and a size of less than or equal to 1 MB sets the P bit for the 1 MB region of the virtual address only.

If the MMU is not yet initialized, modify only the appropriate areas in the **mmuArmXSCALEPBit** array.

If the MMU is initialized:

a. Lockout IRQs and FIQs.

b. Write-enable the pages containing the first level descriptors.

c. Modify the selected first level descriptors, mirroring each region's state in the **mmuArmXSCALEPBit** array, and flush the data cache for each region's first level descriptor.

d. When all selected regions have been processed, flush and invalidate the TLB caches.

e. Write-protect the pages containing the first level descriptors.

f. Re-enable IRQs and FIQs.

**ERROR** is returned if **virtAddr** + **size** overflows the 32-bit virtual address space. Otherwise, **OK** is returned.

- **mmuPArmXSCALEBitClear( )**

```
STATUS mmuPArmXSCALEBitClear    /* Clear the P bit in a region(s) */
    (
    void *      virtAddr,       /* The beginning virtual address */
    UINT32      size            /* The size in bytes */
    )
```

The virtual address is converted into an index to a 1 MB region within 32-bit virtual address space (rounded down).

The size is converted to the number of 1 MB regions to modify.

**NOTE:** A virtual address near the end of a 1 MB region and a size of less than or equal to 1 MB clears the P bit for the 1 MB region of the virtual address only.

If the MMU is not yet initialized, modify only the appropriate bytes in the **mmuArmXSCALEPBit** array.

If the MMU is initialized

a. Lockout IRQs and FIQs.

b. Write-enable the pages containing the first level descriptors.

c. Modify the selected first level descriptors, mirroring each region's state in the **mmuArmXSCALEPBit** array, and flush the data cache for each regions first level descriptor.

d. When all selected regions have been processed, flush and invalidate the TLB caches.

e. Write-protect the pages containing the first level descriptors

f. Re-enable IRQs and FIQs.

**ERROR** is returned if **virtAddr** + **size** overflows 32-bit virtual address space. Otherwise, **OK** is returned.

- **mmuArmXSCALEPBitGet( )**

```
STATUS mmuArmXSCALEPBitGet
    (
    void *      virtAddr        /* The beginning virtual address */
    )
```

The virtual address is converted into an index to a 1 MB region within 32-bit virtual address space (rounded down).

If the MMU is not yet initialized, return the value of the selected byte in the **mmuArmXSCALEPBit** array.

If the MMU is initialized:

a. Return the state of the P bit in the selected first level descriptor.

```
STATUS mmuArmXSCALEAcrGet
    (
    void
    )
```

b. Return the contents of the CP15 Auxiliary Control Register, (CP15, 0, r0, c1, c0, 1).

```
void mmuArmXSCALEAcrSet
    (
    UINT32      acr     /@ value to load into ACR @/
)
```

c. Write the CP15 auxiliary control register with the contents of ACR.

#### Setting the P Bit in Virtual Memory Regions

There are two available methods to set the P bit in a region, or regions, of virtual memory. The first, and preferred method, is to modify the **sysHwInit0( )** routine within *installDir***/vxworks-6.2/target/config/***bspname***/sysLib.c** to call **mmuPBitSet( )** prior to the initialization of the MMU.

The second is to modify the state through calls to **mmuPBitSet( )** and **mmuPBitClear( )** during run-time. This method is less desirable due to the impact that disabling IRQs and FIQs may have on the application.

An example of the preferred method follows (from *installDir***/vxworks-6.2 /target/config/***bspname***/sysLib.c**).

```
#ifdef INCLUDE_MMU
    /* Install the appropriate MMU library and translation routines */
    mmuArmXSCALELibInstall (mmuPhysToVirt, mmuVirtToPhys);

#ifdef IXP425_ENABLE_P_BITS
```

```
    {
    int acrValue;

    /* Set all DRAM regions with P bit */
    mmuArmXSCALEPBitSet((void *)IXP425_SDRAM_BASE, LOCAL_MEM_SIZE);

#ifdef  INCLUDE_PCI

    /* Set PCI regions with P bit */
    mmuArmXSCALEPBitSet((void *)IXP425_PCI_BASE, IXP425_PCI_SP_SIZE);
    #endif

    /* Make table walks use P bit */
    acrValue = mmuArmXSCALEAcrGet();
    acrValue |= 0x2; /* Set the P bit in the ACR */
    mmuArmXSCALEAcrSet( acrValue );
    }

    #endif /* IXP425_ENABLE_P_BITS */

#endif /* INCLUDE_MMU */
```

### Cache and Memory Management Interaction

The caching and memory management functions on XScale processors are both provided on-chip and are very closely interlinked. In general, caching functions on XScale require the MMU to be enabled. Consequently, if cache support is configured into VxWorks, MMU support is also included by default. On some CPUs, the instruction cache can be enabled (in the hardware) without enabling the MMU; however, this is not a recommended configuration.

Only certain combinations of MMU and cache enabling are valid, and there are no hardware interlocks to enforce this. In particular, enabling the data cache without enabling the MMU can lead to undefined results. Consequently, if an attempt is made to enable the data cache by means of the **cacheEnable( )** routine before the MMU has been enabled, the data cache is not enabled immediately. Instead, flags are set internally so that if the MMU is enabled later, the data cache is enabled with it. Similarly, if the MMU is disabled, the data cache is also disabled, until the MMU is reenabled.

Support is provided for BSPs that include separate static RAM for the MMU translation tables. This support requires the ability to specify an alternate source of memory other than the system memory partition. The BSP should set a global function pointer, **_func_armPageSource**, to point to a routine that returns a memory partition identifier describing memory to be used as the source for translation table memory. If this function pointer is **NULL**, the system memory partition is used. The BSP must modify the function pointer before calling

**mmuLibInit( )**. The initial memory partition must be large enough for all requirements; it does not expand dynamically or overflow into the system memory partition if it fills.

Support is also included for CPUs that provide a special area in the address space to be read in order to flush the data cache. XScale BSPs must provide a virtual address (**sysCacheFlushReadArea**) of a readable, cached block of address space that is used for nothing else. If the BSP has an area of the address space that does not actually contain memory but is readable, it can set the pointer to point to that area. If it does not, it should allocate some RAM for this area. In either case, the area must be marked as readable and cacheable in the page tables.

The declaration can be included in the BSP *installDir***/vxworks-6.2/target /config/***bspname***/sysLib.c** file. For example:

```
UINT32 sysCacheFlushReadArea[D_CACHE_SIZE/sizeof(UINT32)];
```

Alternatively, the declaration can appear in the BSP **romInit.s** and **sysALib.s** files. For example:

```
.globl  _sysCacheFlushReadArea
.equ    _sysCacheFlushReadArea, 0x50000000
```

A declaration in *installDir***/vxworks-6.2/target/config/***bspname***/sysLib.c** of the following form cannot be used:

```
UINT32 * sysCacheFlushReadArea = (UINT32 *) 0x50000000;
```

This form cannot be used because it introduces another level of indirection, causing the wrong address to be used for the cache flush buffer.

Some systems cannot provide an environment where virtual and physical addresses are the same. This is particularly important for those areas containing page tables. To support these systems, the BSP must provide mapping functions to convert between virtual and physical addresses: these mapping functions are provided as parameters to the routines **cache***type***LibInstall( )** and **mmu***type***LibInstall( )**. For more information, see *BSP Considerations for Cache and MMU*, p.40.

All XScale BSPs using CPUs with a minicache must provide a similar virtual address (**sysMinicacheFlushReadArea**) of an area used to flush the minicache. It must be marked as cacheable within the minicache (that is, it must have the **MMU_STATE_CACHEABLE_MINICACHE** (or **VM_STATE_CACHEABLE_MINICACHE** state).

### BSP Considerations for Cache and MMU

When building a BSP, the instruction set is selected by choosing the architecture (that is, by defining **CPU** to be **XSCALE**); the cache and MMU types are selected within the BSP by defining appropriate values for the macros **ARMMMU** and **ARMCACHE** and calling the appropriate routines (as shown in Table 3-2) to support the cache and MMU. Setting the preprocessor variables **ARMMMU** and **ARMCACHE** ensures that support for the appropriate cache and MMU type is enabled.

The values definable for MMU include the following:

**ARMMMU_NONE**
**ARMMMU_XSCALE**

The values definable for cache include the following:

**ARMCACHE_NONE**
**ARMCACHE_XSCALE**

Defined types are in the header file *installDir*/**vxworks-6.2/target/h/arch/arm/arm.h**. (Support for other caches and MMU types may be added from time to time.)

For example, to define the MMU type for an XScale processor on the command line, specify the following option when you invoke the compiler:

```
-DARMMMU=ARMMMU_XSCALE
```

To provide the same information in a header or source file, include the following line in the file:

```
#define ARMMMU ARMMMU_XSCALE
```

Table 3-2 shows the cache and MMU routines required for XScale processors.

Table 3-2 **Cache and MMU Routines for Individual Processor Types**

| Processor | Cache Routine | MMU Routine |
|---|---|---|
| XScale | **cacheArmXScaleLibInstall( )** | **mmuArmXScaleLibInstall( )** |

Each of these routines take two parameters: function pointers to routines to translate between virtual and physical addresses and vice-versa. If the default address map in the BSP is such that virtual and physical addresses are identical (this is normally the case), the parameters to the routine can be **NULL** pointers. If the virtual-to-physical address mapping is such that the virtual and physical addresses are not the same, but the mapping is as described in the **sysPhysMemDesc[ ]** structure, the routines **mmuPhysToVirt( )** and

**mmuVirtToPhys( )** can be used. If the mapping is different, translation routines must be provided within the BSP. For further details, see the reference entries for the routines.

MMU and cache support installation routines must be called as early as possible in the BSP initialization (before **cacheLibInit( )** and **vmLibInit( )**). This can most easily be achieved by putting them in a **sysHwInit0( )** routine within **sysLib.c** and then defining the macros in **config.h** as follows:

```
#define INCLUDE_SYS_HW_INIT_0
#define SYS_HW_INIT_0() sysHwInit0 ()
```

During certain cache and MMU operations (for example, cache flushing), interrupts must be disabled. You may want your BSP to have control over this procedure. The contents of the variable **cacheArchIntMask** determine which interrupts are disabled. This variable has the value **I_BIT | F_BIT**, indicating that both IRQs and FIQs are disabled during these operations. If a BSP requires that FIQs be left enabled, the contents of **cacheArchIntMask** should be changed to **I_BIT**. Use extreme caution when changing the contents of this variable from its default.

### 3.4.10 Memory Layout

The VxWorks memory layout (real or virtual, as appropriate) is the same for all XScale processors. Figure 3-1 shows memory layout, labeled as follows:

**Vectors**
Table of exception/interrupt vectors.

**FIQ Code**
Reserved for FIQ handling code.

**Shared Memory Anchor**
Anchor for the shared memory network and VxMP shared memory objects (if there is shared memory on the board).

**Exception Pointers**
Pointers to exception routines, which are used by the vectors.

**Boot Line**
ASCII string of boot parameters.

**Exception Message**
ASCII string of fatal exception message.

**Initial Stack**
Initial stack for **usrInit( )**, until **usrRoot( )** is allocated a stack.

**System Image**
VxWorks itself (three sections: text, data, and bss). The entry point for VxWorks is at the start of this region.

**WDB Memory Pool**
The size of this pool depends on the macro **WDB_POOL_SIZE**, which defaults to one-sixteenth of the system memory pool. The target server uses this space to support host-based tools. Modify **WDB_POOL_SIZE** under **INCLUDE_WDB**.

**System Memory Pool**
Size depends on size of the system image. The **sysMemTop( )** routine returns the end of the free memory pool.

All addresses shown in Figure 3-1 are relative to the start of memory for a particular target board. The start of memory (corresponding to 0x0 in the memory layout diagram) is defined as **LOCAL_MEM_LOCAL_ADRS** under **INCLUDE_MEMORY_CONFIG** for each target.

**NOTE:** The initial stack and system image addresses are configured within the BSP.

## 3.5 Migrating Your BSP

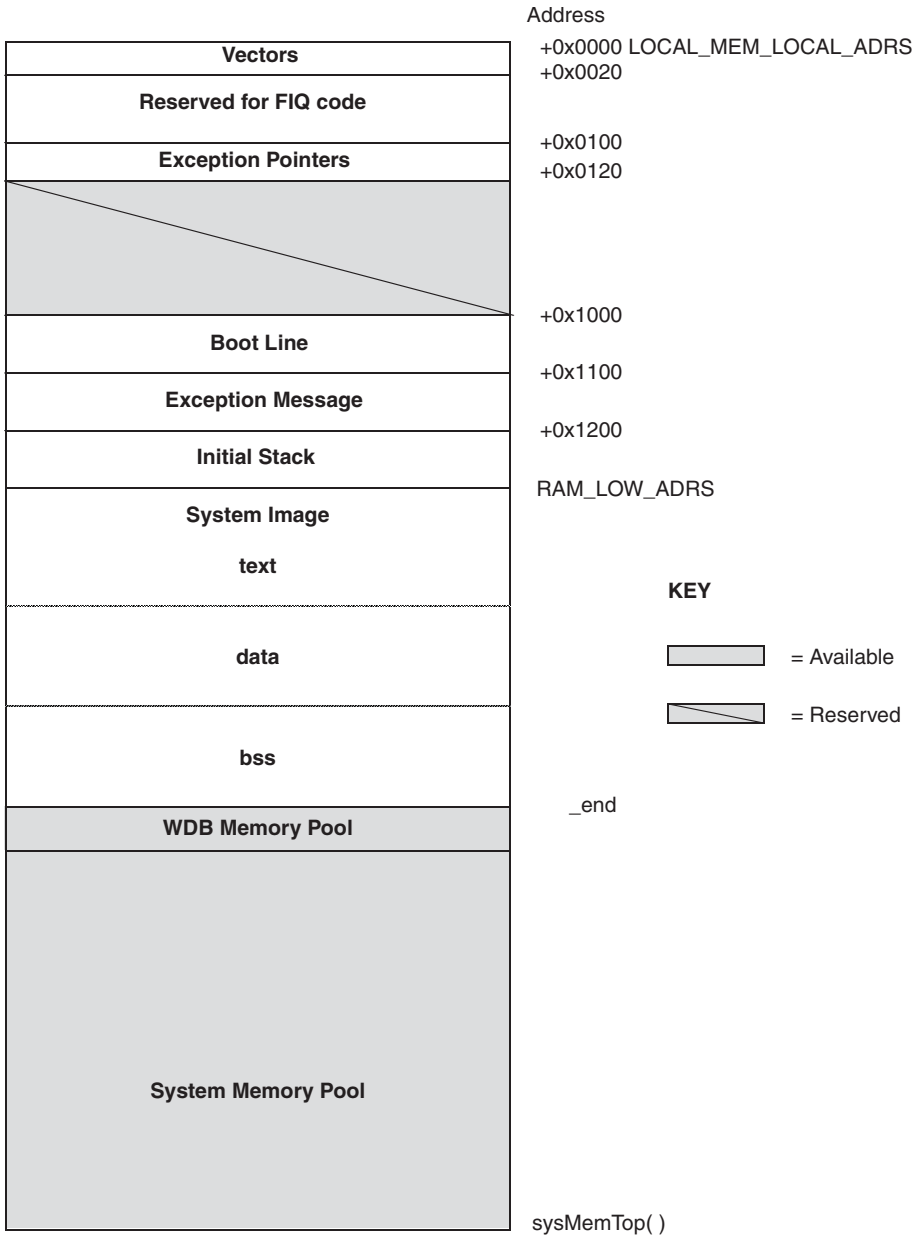
In order to convert a VxWorks BSP from an earlier VxWorks release to VxWorks 6.2, you must make certain architecture-independent changes. This includes making changes to custom BSPs designed to work with a VxWorks 5.5 release and not supported or distributed by Wind River.

This section includes changes and usage caveats specifically related to migrating Intel XScale BSPs to VxWorks 6.2. For more information on migrating BSPs to VxWorks 6.2, see the *VxWorks Migration Guide*.

### VxWorks 5.5 Compatibility

The memory layout shown in Figure 3-1 differs from that used for VxWorks 5.5. The position of the boot line and exception message have been moved to allow memory page zero protection (kernel hardening).

Figure 3-1 **VxWorks System Memory Layout (XScale)**



By default, all BSPs included with this release have the **T2_BOOTROM_COMPATIBILITY** option enabled in **config.h**. This retains compatibility with VxWorks 5.5 boot ROMs. In this configuration, the symbols are defined in **config.h** as follows:

```
#define SM_ANCHOR_OFFSET  0x600
#define BOOT_LINE_OFFSET  0x700
#define EXC_MSG_OFFSET    0x800
```

However, kernel hardening is not supported in this configuration. In order to enable kernel hardening, you must undefine **T2_BOOTROM_COMPATIBILITY** and use a VxWorks 6.x boot ROM.

If you create a Workbench project based on a VxWorks 5.5-compatible BSP (that is, a BSP that has **T2_BOOTROM_COMPATIBILITY** enabled) and you wish to remove the compatibility and enable kernel hardening, you must do *one* of the following:

- Update your BSP. Then, create a new project based on the modified BSP and enable **INCLUDE_KERNEL_HARDENING**.

or:

- Undefine **T2_BOOTROM_COMPATIBILITY**. Enable **INCLUDE_KERNEL_HARDENING** and update the values of **SM_ANCHOR_OFFSET**, **BOOT_LINE_OFFSET**, and **EXC_MSG_OFFSET** to 0x1000, 0x1100, and 0x1200 respectively.

**NOTE:** VxWorks 5.5-compatible BSPs cannot support kernel hardening. **T2_BOOTROM_COMPATIBILITY** and **INCLUDE_KERNEL_HARDENING** are mutually exclusive. If both of these components are defined in your **config.h** file, Workbench issues a warning when you attempt to build your project.

## 3.6 Reference Material

Comprehensive information regarding Intel XScale hardware behavior and programming is beyond the scope of this document. Intel provides several hardware and programming manuals for the Intel XScale processor on its Web site:

**http://www.intel.com/design/intelxscale**

Wind River recommends that you consult the hardware documentation for your processor or processor family as necessary during BSP development.

### ARM Development Reference Documents

The information given in this section is current at the time of writing; should you decide to use these documents, you may wish to contact the manufacturer for the most current version.

- *Advanced RISC Machines, Architectural Reference Manual, Second Edition*, ARM DDI 0100 E, ISBN 0-201-73719-1. This document describes the architecture in general, including architectural standards for instruction bit fields. More specific information is found in the data sheets for individual processors, which conform to different architecture specification versions.
- *ARM System Architecture*, by Steve Furber. Addison-Wesley, 1996. ISBN 0-201-403352-8.
- *ARM Procedure Call Standard (APCS)*, a version of which is available on the Internet. Contact ARM for information on the latest version.

# 4 Intel Architecture



## 4.1 Introduction

This chapter provides information specific to VxWorks development on Intel Architecture P5 (Pentium), P6 (PentiumPro, II, III), P7 (Pentium 4), and Pentium M family processor targets including their Celeron and Xeon series variants.

## 4.2 Supported Processors

This release supports Intel P5, P6, P7, and Pentium M family processors. This section provides information on the characteristics of each of these families,

including their major differences. For more information, refer to your target hardware documentation.

The P5 (Pentium) architecture is a third-generation 32-bit CPU. It has a 64-bit data bus and a 32-bit address bus, separate 8 KB L1 instruction and data caches, superscalar dispatch/execution units, branch prediction, two execution pipelines, and a write-back data cache protocol. Some P5 family processors also include support for MMX technology. This technology uses the single-instruction, multiple-data (SIMD) execution model to perform parallel computations on packed integer data contained in the 64-bit MMX registers.

P6 micro-architecture family processors include PentiumPro, Pentium II, Pentium III, Pentium M, and their variant Xeon/Celeron processors. P6 is a three-way superscalar architecture that executes up to three instructions per clock cycle. It has micro-data flow analysis, out-of-order execution, superior branch prediction, and speculative execution. Three instruction decode units work in parallel to decode object code into smaller operations called micro-ops. These micro-ops can be executed out-of-order by the five parallel execution units. The retirement unit retires completed micro-ops in their original program order, taking into account any branches. The P6 architecture has separate 8 KB L1 instruction and data caches and a 256 KB L2 unified cache. The data cache uses the MESI protocol to support a more efficient write-back mode. The cache consistency is maintained with the MESI protocol and the bus snooping mechanism. Pentium II adds MMX technology, new packaging, 16 KB L1 instruction and data caches, and a 256 KB (512 KB or 1 MB) L2 unified cache. Pentium III introduces the Streaming SIMD Extensions (SSE) that extend the SIMD model with a new set of 128-bit registers and the ability to perform SIMD operations on packed single-precision floating-point values. Pentium M processors utilize a new micro-architecture in order to provide high performance and low power consumption. These processors include cache and processor bus power management and large L1 and L2 caches.

The P7 (Pentium 4) processor is based on the NetBurst micro-architecture that allows processors to operate at significantly higher clock speeds and performance levels. It has a rapid execution engine, hyper pipelined technology, advanced dynamic execution, a new cache subsystem, Streaming SIMD Extensions 2 (SSE2), and a 400 MHz system bus.

The x86 architecture supports three operating modes: protected mode, real-address mode, and virtual-8086 mode. Protected mode is the native operating mode of the 32-bit processor. All instructions and architectural features are available in this mode for the highest performance and capability. Real-address mode provides the programming environment of the Intel 8086 processor. Virtual-8086 mode lets the processor execute 8086 software in a protected mode,

multitasking environment. VxWorks uses 32-bit protected mode. For more information, see the *VxWorks Kernel Programmer's Guide*.



## 4.3 Interface Variations

This section describes particular features and routines that are specific to Intel Architecture targets in any of the following ways:

- available only for Intel Architecture targets
- parameters specific to Intel Architecture targets
- special restrictions or characteristics on Intel Architecture targets

For complete documentation, see the reference entries for the libraries, routines, and tools discussed in the following sections.

### 4.3.1 Supported Routines in mathALib

For Intel Architecture targets, the following double-precision floating-point routines are supported:

| | | | | | |
|---|---|---|---|---|---|
| **acos( )** | **asin( )** | **atan( )** | **atan2( )** | **ceil( )** | **cos( )** |
| **cosh( )** | **exp( )** | **fabs( )** | **floor( )** | **fmod( )** | **infinity( )** |
| **irint( )** | **iround( )** | **log( )** | **log10( )** | **log2( )** | **pow( )** |
| **round( )** | **sin( )** | **sincos( )** | **sinh( )** | **sqrt( )** | **tan( )** |
| **tanh( )** | **trunc( )** | | | | |

The corresponding single-precision floating-point routines are not supported. In this release, hyperbolic cosine, sine, and tangent routines are supported. For more information, see the reference entry for **mathALib** and the individual reference entries for each routine.

### 4.3.2 Architecture-Specific Global Variables

The files **sysLib.c** and **sysALib.s** contain the global variables shown in Table 4-1.

Table 4-1 **Architecture-Specific Global Variables**

| Global Variable | Value | Description |
|---|---|---|
| **sysCsSuper** | 0x08 | Code selector for the supervisor mode task. |
| **sysCsExc** | 0x18 | Code selector for exceptions. |
| **sysCsInt** | 0x20 | Code selector for interrupts. |
| **sysIntIdtType** | 0x0000fe00 (default) = trap gate<br>0x0000ee00 = interrupt gate | This variable is used when VxWorks initializes the interrupt vector table. The choice of trap gate versus interrupt gate affects all interrupts (vectors 0x20 through 0xff). |
| **sysGdt[ ]** | 0xffff limit (default) | The global descriptor table begins with five entries. The first is a null descriptor. The second and third are for task-level routines. The fourth is for exceptions. The fifth is for interrupt-level routines. If kernel hardening is enabled, additional entries are added for task gate management of the OSM stack. |
| **sysProcessor** | 0 = i386<br>1 = i486<br>2 = P5/Pentium<br>4 = P6/PentiumPro, II, III, Pentium M<br>5 = P7/Pentium 4 | The processor type (set by the VxWorks **sysCpuProbe( )** routine). |
| **sysCoprocessor** | 0 = no coprocessor<br>1 = 387 coprocessor<br>2 = 487 coprocessor | The type of floating-point coprocessor (set by the VxWorks **fppProbe( )** routine). |
| **sysCpuId** | CPUID structure | Dynamically obtained processor identification and supported features (set by VxWorks **sysCpuProbe( )**). |

### 4.3.3 Architecture-Specific Routines

Table 4-2 provides information for a number of architecture-specific routines. Other architecture-specific routines are described throughout this section.



Table 4-2 **Architecture-Specific Routines**

| Routine | Function Header | Description |
|---|---|---|
| **fppArchSwitchHookEnable( )** | `STATUS fppArchSwitchHookEnable (BOOL enable)` | Enables or disables the architecture-specific FPU switch hook routine that detects illegal FPU/MMX usage. |
| **fppCtxShow( )** | `void fppCtxShow (FP_CONTEXT * f)` | Prints the contents of a task's floating-point register. |
| **fppRegListShow( )** | `void fppRegListShow (void)` | Prints a list of available registers. |
| **intStackEnable( )** | `STATUS intStackEnable (BOOL enable)` | Enables or disables the interrupt stack usage. **TRUE** to enable, **FALSE** to disable |
| **pentiumBts( )** | `STATUS pentiumBts (char * pFlag)` | Executes an atomic compare-and-exchange instruction to set a bit. (P5, P6, and P7) |
| **pentiumBtc( )** | `STATUS pentiumBtc (char * pFlag)` | Executes an atomic compare-and-exchange instruction to clear a bit. (P5, P6, and P7) |
| **pentiumMcaEnable( )** | `void pentiumMcaEnable (BOOL enable)` | Enables or disables the MCA (machine check architecture). (P5, P6, and P7) |
| **pentiumMcaShow( )** | `void pentiumMcaShow (void)` | Shows machine check global control registers and error reporting register banks. (P5, P6, and P7) |

Table 4-2 **Architecture-Specific Routines** (cont'd)

| Routine | Function Header | Description |
|---|---|---|
| **pentiumMsrGet( )** | `void pentiumMsrGet ( int address, long long int * pData )` | Gets the contents of the specified model specific register (MSR). (P5, P6, and P7) |
| **pentiumMsrInit( )** | `STATUS pentiumMsrInit (void)` | Initializes all MSRs. (P5, P6, and P7) |
| **pentiumMsrSet( )** | `void pentiumMsrSet ( int address, long long int * pData )` | Sets the value of the specified MSR. (P5, P6, and P7) |
| **pentiumMsrShow( )** | `void pentiumMsrShow (void)` | Shows all MSRs. (P5, P6, and P7) |
| **pentiumMtrrEnable( )** | `void pentiumMtrrEnable (void)` | Enables the memory type range register (MTRR). (P6 and P7) |
| **pentiumMtrrDisable( )** | `void pentiumMtrrDisable (void)` | Disables the MTRR. (P6 and P7) |
| **pentiumMtrrGet( )** | `void pentiumMtrrGet (MTRR * pMtrr)` | Gets MTRRs to the MTRR table specified by the pointer. (P6 and P7) |
| **pentiumMtrrSet( )** | `void pentiumMtrrSet (MTRR * pMtrr)` | Sets MTRRs from the MTRR table specified by the pointer. (P6 and P7) |
| **pentiumPmcStart( )** | `STATUS pentiumPmcStart ( int pmcEvtSel0; int pmcEvtSel1; )` | Starts PMC0 and PMC1. (P5 and P6) |
| **pentiumPmcStart0( )** | `STATUS pentiumPmcStart0 (int pmcEvtSel0)` | Starts PMC0 only. (P5) |
| **pentiumPmcStart1( )** | `STATUS pentiumPmcStart1 (int pmcEvtSel1)` | Starts PMC1 only. (P5) |
| **pentiumPmcStop( )** | `void pentiumPmcStop (void)` | Stops PMC0 and PMC1. (P5 and P6) |

Table 4-2 **Architecture-Specific Routines** (cont'd)

| Routine | Function Header | Description |
|---|---|---|
| **pentiumPmcStop0( )** | `void pentiumPmcStop0 (void)` | Stops PMC0 only. (P5) |
| **pentiumPmcStop1( )** | `void pentiumPmcStop1 (void)` | Stops PMC1 only. (P5 and P6) |
| **pentiumPmcGet( )** | `void pentiumPmcGet ( long long int * pPmc0; long long int * pPmc1; )` | Gets the contents of PMC0 and PMC1. (P5 and P6) |
| **pentiumPmcGet0( )** | `void pentiumPmcGet0 (long long int * pPmc0)` | Gets the contents of PMC0. (P5 and P6) |
| **pentiumPmcGet1( )** | `void pentiumPmcGet1 (long long int * pPmc1)` | Gets the contents of PMC1. (P5 and P6) |
| **pentiumPmcReset( )** | `void pentiumPmcReset (void)` | Resets PMC0 and PMC1. (P5 and P6) |
| **pentiumPmcReset0( )** | `void pentiumPmcReset0 (void)` | Resets PMC0. (P5 and P6) |
| **pentiumPmcReset1( )** | `void pentiumPmcReset1 (void)` | Resets PMC1. (P5 and P6) |
| **pentiumSerialize( )** | `void pentiumSerialize (void)` | Serializes by executing the CPUID instruction. (P5, P6, and P7) |
| **pentiumPmcShow( )** | `void pentiumPmcShow (BOOL zap)` | Shows PMC0 and PMC1, and resets them if the parameter **zap** is **TRUE**. (P5 and P6) |
| **pentiumTlbFlush( )** | `void pentiumTlbFlush (void)` | Flushes the translation lookaside buffers (TLBs). (P5, P6, and P7) |
| **pentiumTscReset( )** | `void pentiumTscReset (void)` | Resets the timestamp counter (TSC). (P5, P6, and P7) |
| **pentiumTscGet32( )** | `UINT32 pentiumTscGet32 (void)` | Gets the lower half of the 64-bit TSC. (P5, P6, and P7) |
| **pentiumTscGet64( )** | `void pentiumTscGet64 (long long int * pTsc)` | Gets the 64-bit TSC. (P5, P6, and P7) |

Table 4-2 **Architecture-Specific Routines** (cont'd)

| Routine | Function Header | Description |
|---|---|---|
| **sysCpuProbe( )** | `UINT sysCpuProbe (void)` | Gets information about the CPU with CPUID. |
| **sysInByte( )** | `UCHAR sysInByte (int port)` | Reads one byte from I/O. |
| **sysInWord( )** | `USHORT sysInWord (int port)` | Reads one word (two bytes) from I/O. |
| **sysInLong( )** | `ULONG sysInLong (int port)` | Reads one long word (four bytes) from I/O. |
| **sysOutByte( )** | `void sysOutByte (int port, char data)` | Writes one byte to I/O. |
| **sysOutWord( )** | `void sysOutWord (int port, short data)` | Writes one word (two bytes) to I/O. |
| **sysOutLong( )** | `void sysOutLong (int port, long data)` | Writes one long word (four bytes) to I/O. |
| **sysInWordString( )** | `void sysInWordString ( int port, short *address, int count )` | Reads a word string from I/O. |
| **sysInLongString( )** | `void sysInLongString ( int port, short *address, int count )` | Reads a long string from I/O. |
| **sysOutWordString( )** | `void sysOutWordString ( int port, short *address, int count )` | Writes a word string to I/O. |
| **sysOutLongString( )** | `void sysOutLongString ( int port, short *address, int count )` | Writes a long string to I/O. |

Table 4-2 **Architecture-Specific Routines** (cont'd)

| Routine | Function Header | Description |
|---|---|---|
| **sysDelay( )** | `void sysDelay (void)` | Allows enough recovery time for port accesses. |
| **sysIntDisablePIC( )** | `STATUS sysIntDisablePIC (int intLevel)` | Disables a programmable interrupt controller (PIC) interrupt level. |
| **sysIntEnablePIC( )** | `STATUS sysIntEnablePIC (int intLevel)` | Enables a PIC interrupt level. |
| **sysOSMTaskGateInit( )** | `STATUS sysOSMtaskGateInit (void)` | Initializes the OSM stack. |
| **vxCpuShow( )** | `void vxCpuShow (void)` | Shows CPU type, family, model, and supported features. |
| **vxCr[0234]Get( )** | `int vxCr[0234]Get (void)` | Gets respective control register content. |
| **vxCr[0234]Set( )** | `void vxCr[0234]Set (int value)` | Sets a value to the respective control register. |
| **vxDrGet( )** | `void vxDrGet ( int * pDr0, int * pDr1, int * pDr2, int * pDr3, int * pDr4, int * pDr5, int * pDr6, int * pDr7 )` | Gets debug register content. |
| **vxDrSet( )** | `void vxDrSet ( int dr0, int dr1, int dr2, int dr3, int dr4, int dr5, int dr6, int dr7 )` | Sets debug register values. |
| **vxDrShow( )** | `void vxDrShow (void)` | Shows the debug registers. |

Table 4-2 **Architecture-Specific Routines** (cont'd)

| Routine | Function Header | Description |
|---|---|---|
| **vxEflagsGet( )** | `int vxEflagsGet (void)` | Gets the EFLAGS register content. |
| **vxEflagsSet( )** | `void vxEflagsSet (int value)` | Sets the value of the EFLAGS register. |
| **vxPowerModeGet( )** | `UINT32 vxPowerModeGet (void)` | Gets the power management mode.<br>This API is deprecated, see *4.4.26 Power Management*, p.79. |
| **vxPowerModeSet( )** | `STATUS vxPowerModeSet (UINT32 mode)` | Sets the power management mode.<br>This API is deprecated, see *4.4.26 Power Management*, p.79. |
| **vxTssGet( )** | `int vxTssGet (void)` | Gets the task register content. |
| **vxTssSet( )** | `void vxTssSet (int value)` | Sets the task register value. This routine is deprecated and must not be used. |
| **vx[GIL]dtrGet( )** | `void vx[GIL]dtrGet (long long int * pValue)` | Gets the GDTR, IDTR, and LDTR register content, respectively. |
| **vxSseShow( )** | `void vxSseShow (int taskId)` | Prints the contents of a task's Streaming SIMD Extension (SSE) register context, if any, to the standard output device. |

#### Register Routines

The following routines read Intel Architecture register values, and require one parameter, the task ID:

**eax( )** **ebx( )** **ecx( )** **edx( )** **edi( )**
**esi( )** **ebp( )** **esp( )** **eflags( )**

### Breakpoints and the bh( ) Routine

VxWorks for Intel Architecture supports both software and hardware breakpoints. When you set a software breakpoint, VxWorks replaces an instruction with an **int 3** software interrupt instruction. VxWorks restores the original code when the breakpoint is removed. The instruction cache is purged each time VxWorks changes an instruction to a software break instruction.

A hardware breakpoint uses the processor's debug registers to set the breakpoint. The Pentium architectures have four breakpoint registers. If you are using the target shell, you can use the **bh( )** routine to set hardware breakpoints. The routine is declared as follows:

```
STATUS bh
    (
    INSTR        *addr,        /* where to set breakpoint, or       */
                               /* 0 = display all breakpoints       */
    int          type,         /* breakpoint type; see below        */
    int          task,         /* task to set breakpoint;           */
                               /* 0 = set all tasks                 */
    int          count,        /* number of passes before hit       */
    BOOL         quiet,        /* TRUE = don't print debug info     */
                               /* FALSE = print debug info          */
    )
```

The **bh( )** routine takes the following types in parameter *type*:

| | |
|---|---|
| **BRK_INST** | Instruction hardware breakpoint (0x00) |
| **BRK_DATAW1** | Data write 1-byte breakpoint (0x01) |
| **BRK_DATAW2** | Data write 2-byte breakpoint (0x05) |
| **BRK_DATAW4** | Data write 4-byte breakpoint (0x0d) |
| **BRK_DATARW1** | Data read-write 1-byte breakpoint (0x03) |
| **BRK_DATARW2** | Data read-write 2-byte breakpoint (0x07) |
| **BRK_DATARW4** | Data read-write 4-byte breakpoint (0x0f) |

A maximum number of hardware breakpoints can be set on the target system. This is a hardware limit and cannot be changed. For Intel Architecture targets, this limit is four hardware breakpoints. The address parameter of a hardware breakpoint command does not need to be 4-bytes aligned for data breakpoints on Intel Architecture. The address parameter is 1-byte aligned if width access is 1 byte, 2-bytes aligned if width access is 2 bytes, and 4-bytes aligned if width access is 4 bytes.

For more information, see the reference entry for **bh( )**.

#### Disassembler: l( )

If you are using the target shell, the VxWorks disassembler **l( )** routine does not support 16-bit code compiled for earlier generations of 80*x*86 processors. However, the disassembler does support 32-bit code for Intel Architecture processors.

#### Memory Probe: vxMemProbe( )

The **vxMemProbe( )** routine, which probes an address for a bus error, is supported on the Intel Architecture (Pentium) architectures by trapping both general protection faults and page faults.

#### Interrupt Lock Level: intLock( ) and intUnlock( )

The Intel Architecture (Pentium) architecture includes a single interrupt signal for external interrupts, and is able to enable and disable external interrupts to the CPU. The Intel Architecture (Pentium) architecture does not have an on-chip interrupt controller, and therefore does not have the capability of controlling the interrupt mask/lock level. The global variable **intLockMask** is set to 1 and is not used by **intLock( )**. The **intLock( )** routine simply disables the external interrupt, while the **intUnlock( )** routine restores the previous state of the signal (that is, enables it if it was previously enabled). Locking the individual external interrupt line or masking the interrupt level is done by a companion interrupt controller device driver such as the **i8259Intr.c** or **ioApicIntr.c**. These drivers are provided as source code in *installDir*/**vxworks-6.2/target/src/drv/intrCtl**.

#### IntArchLib: intVecSet2( ) and intVecGet2( )

The routines **intVecSet2( )** and **intVecGet2( )** replace **intVecSet( )** and **intVecGet( )**, respectively. (**intVecSet( )** and **intVecGet( )** are kept only for backward compatibility.) The routines **intVecSet2( )** and **intVecGet2( )** include two additional parameters: gate and selector. **intVecSet2( )** also includes task gate support. The gate is either **IDT_TRAP_GATE**, **IDT_INT_GATE**, or **IDT_TASK_GATE**; and the selector is either **sysCsExc** or **sysCsInt**.

#### pentiumLib, pentiumALib, and pentiumShow: pentiumXXX( )

Routines that manipulate the memory type range registers (MTRR), performance monitoring counter (PMC), timestamp counter (TSC), machine check architecture (MCA), and model specific registers (MSR) are included. The routines are listed in Table 4-2.

#### vxLib, vxALib, and vxShow: vxXXX( )

The routine **vxCpuShow( )** shows the CPU type, family, model, and supported features.

The routines **vxCr0Get( )**, **vxCr2Get( )**, **vxCr3Get( )**, and **vxCr4Get( )** get the current values from the respective control registers, while the routines **vxCr0Set( )**, **vxCr2Set( )**, **vxCr3Set( )**, and **vxCr4Set( )** assign values to the respective control registers.

The routines **vxEflagsGet( )** and **vxEflagsSet( )** respectively get and set the EFLAGS register.

The routines **vxDrGet( )** and **vxDrSet( )** respectively get and set the debug registers. **vxDrShow( )** shows the content of the debug registers. These routines are intended to be primitive and generate exceptions if they are not claimed by WDB or the debug library.

The routines **vxTssGet( )** and **vxTssSet( )** respectively get and set the task register.

The routines **vxGdtrGet( )**, **vxIdtrGet( )**, and **vxLdtrGet( )** get the current value of the respective system registers: GDTR, IDTR, and LDTR.

The routine **vxLdtrSet( )** sets the content of the local descriptor table.

The routines **vxPowerModeGet( )** and **vxPowerModeSet( )** respectively get and set the power management mode.

**NOTE:** The **vxPowerModeGet( )** and **vxPowerModeSet( )** routines are deprecated, see *4.4.26 Power Management*, p.79.

The **vxCsGet( )**, **vxDsGet( )**, and **vxSsGet( )** routines get the current value of the code segment, data segment, and stack segment, respectively.

#### taskSRSet( )

The routine **taskSRSet( )** sets its second parameter to the EFLAGS register of the specified task.

### 4.3.4 a.out/ELF-Specific Tools for Intel Architecture

The following tools are specific to the **a.out** format for x86 and Pentium processors, as well as the PC simulator that was used in earlier VxWorks releases. In the current release, the object module format has been changed to ELF. Therefore,

these tools are replaced with **objcopypentium** and no longer supported. For more information, see the reference entries for each tool.

**hexDec**
converts an **a.out**-format object file into a Motorola hex record.

**aoutToBinDec**
extracts text and data segments from an **a.out** file and writes them to standard output as a simple binary image.

**xsymDec**
extracts the symbol table from an **a.out** file.

## 4.4 Architecture Considerations

This section describes characteristics of the Intel Architecture that you should keep in mind as you write a VxWorks application:

- boot disks
- operating mode and byte order
- Celeron processors
- cache issues
- FPU, MMX, SSE, and SSE2 support
- segmentation
- paging with MMU
- ring level protection
- interrupts
- exceptions
- stack management
- context switching
- machine check architecture (MCA)
- registers
- counters
- advanced programmable interrupt controller (APIC)
- I/O mapped devices
- memory-mapped devices
- memory considerations for VME
- ISA/EISA bus
- PC104 bus

- PCI bus
- software floating-point emulation
- VxWorks memory layout

For more information on the Intel Architecture, consult the *Intel Architecture Software Developer's Manual*.



### 4.4.1 Boot Floppies

Information regarding the creation and use of a boot floppy for booting VxWorks on Intel Architecture targets is included in the BSP reference documentation (the BSP **target.ref** file).

### 4.4.2 Operating Mode and Byte Order

VxWorks for Intel Architecture runs in the 32-bit flat protected mode. If real-time processes (RTPs) are not enabled, no privilege protection is used, thus there are no call gates. The privilege level is always 0, which is the most privileged level (supervisor mode). If RTPs are enabled, both level 0 and level 3 (user mode) are used, with the RTP task(s) running at level 3. A call gate is established and used as a system call mechanism to allow RTP task(s) to communicate with the kernel.

The Intel Architecture byte order is little-endian, but network applications must convert some data to a standard network order, which is big-endian. In particular, in network applications, be sure to convert the port number to network byte order using **htons( )**.

### 4.4.3 Celeron Processors

If your target is a Celeron processor, you must determine what type of Celeron processor your are using in order to take advantage of certain features and optimizations. Celeron processors based on the Pentium II (such as the Celeron model 5) belong to the **pcPentium2** BSP which is optimized to take advantage of the Pentium II processor. Celeron processors based on the Pentium III (such as Celeron model 8) belong to the **pcPentium3** BSP which is optimized for the Pentium III. The Pentium III optimized toolchain supports Streaming SIMD Extensions (SSE). To detect whether a particular CPU supports SSE, in *Application Note AP-485*, Intel recommends using the CPUID instruction (**vxCpuShow( )** in VxWorks) rather than the CPU family or model, stating as follows:

- Do not assume that a given family or model has any specific feature. For example, do not assume that family value 5 (that is, a P5 family processor) implies a floating-point unit on-chip; use the feature flags to make this determination.
- Do not assume processors with higher family or model numbers have all the features of a processor with a lower family or model number. For example, a processor with a family value 6 (that is, a P6 family processor) may not necessarily have all the features of a processor with a family value of 5.

### 4.4.4 Pentium M Processors

In general, Pentium M is not considered a new family of processors. The family code in the CPU signature for a Pentium M processor is Intel Architecture P6. However, certain P7 features (such as SSE2) are also supported. Therefore, if your target is a Pentium M processor, you can use either the **pcPentium3** or **pcPentium4** BSP.

**NOTE:** BSPs released with this release of VxWorks for Intel Architecture support Pentium M processors with the Intel 855 chipset only. Additional BSP support may be added in the future, see the Wind River Online Support Web site for a complete list of supported devices.

In *Application Note AP-485*, Intel recommends using the CPUID instruction (**vxCpuShow( )** in VxWorks) to determine which features are supported by a given CPU instead of relying on the CPU family code or model number. The application note recommends the following:

- Do not assume that a given family or model includes a specific feature. For example, do not assume that a P5 family processor always includes a floating-point unit. You can use the feature flags to determine what features are available on your chip.
- Do not assume that processors with a higher family or model number include all of the features included in a processor with a lower family number. For example, a P6 family processor may not include all of the features available for a P5 family processor.

For more information on Pentium M processors, see the Intel Web site. For information on identifying your CPU and its features, see the Intel *Application Note AP-485*.

### 4.4.5 Caches

The CD and NW flags in CR0 control the overall caching of system memory. The PCD and PWT flags in CR3 control the caching of the page directory. The PCD and PWT flags in the page directory or page table entry control page-level caching. In **cacheLib**, the WBINVD instruction is used to flush the cache if the CLFLUSH instruction is not supported by the processor.



P5 (Pentium) family processors have separate L1 instruction and data on-chip caches. Each cache is 8 KB. The P5 family data cache supports both write-through and write-back update policies. The PWT flag in the page table entry controls the write-back policy for that page of memory.

P6 (PentiumPro, II, III) family processors include separate L1 instruction and data caches, and a unified internal L2 cache. The P6 processor MESI data cache protocol maintains consistency with internal L1 and L2 caches, caches of other processors, and with an external cache in both update policies. The operation of the MESI protocol is transparent to software.

P7 (Pentium 4) family processors include a trace cache that caches decoded instructions, as well as an L1 data cache and an L2 unified cache. The CLFLUSH instruction allows the selected cache line to be flushed from memory.

### 4.4.6 FPU, MMX, SSE, and SSE2 Support

The x87 math coprocessor and on-chip FPU are software compatible, and are supported by VxWorks using the **INCLUDE_HW_FP** configuration macro.

There are two types of floating-point contexts and a set of routines associated with each type. The first type is 108 bytes and is used for older FPUs (i80387, i80487, Pentium) and older MMX technology. The routines **fppSave( )**, **fppRestore( )**, **fppRegsToCtx( )**,and **fppCtxToRegs( )** are used to save and restore the context and to convert to or from **FPPREG_SET**. The second type is 512 bytes and is used for newer FPUs, newer MMX technology, and SSE technology (Pentium II, III, 4). The routines **fppXsave( )**, **fppXrestore( )**, **fppXregsToCtx( )**, and **fppXctxToRegs( )** are used to save and restore the context and to convert to or from **FPPREG_SET**. The type of floating-point context used is automatically detected by checking the CPUID information in **fppArchInit( )**. The routines **coprocTaskRegsSet( )** and **coprocTaskRegsGet( )** then access the appropriate floating-point context. The bit interrogated for the automatic detection is the “Fast Save and Restore” feature flag.

**NOTE:** The routines **fppTaskRegsSet( )** and **fppTaskRegsGet( )** are obsolete and should no longer be used. These routines are replaced by **coprocTaskRegsSet( )** and **coprocTaskRegsGet( )**, respectively.

Saving and restoring floating-point registers adds to the context switch time of a task. Therefore, floating-point registers are not saved and restored for every task. Only those tasks spawned with the task option **VX_FP_TASK** will have floating-point state, MMX technology state, and streaming SIMD state saved and restored. If a task executes any floating-point operations, MMX operations, or streaming SIMD operations, it must be spawned with **VX_FP_TASK**.

**NOTE:** The value of **VX_FP_TASK** changed from 0x0008 (VxWorks 5.5) to 0x01000000 (VxWorks 6.x). However, its meaning and usage remain unchanged.

Executing floating-point operations from a task spawned without the **VX_FP_TASK** option results in serious and difficult to find errors. To detect this type of illegal, unintentional, or accidental floating-point operation, a new API and a new mechanism have been added to this release. The mechanism involves enabling or disabling the FPU by toggling the TS flag in the CR0 register of the new task switch hook routine, **fppArchSwitchHook( )**, respecting the **VX_FP_TASK** option. If the **VX_FP_TASK** option is not set in the switching-in task, the FPU is disabled. Thus, the device-not-available exception is raised if the task attempts to execute any floating-point operations. This mechanism is disabled in the default VxWorks configuration. To enable the mechanism, call the enabler, **fppArchSwitchHookEnable( )**, with a parameter **TRUE** (1). The mechanism is disabled using the **FALSE** (0) parameter.

There are six FPU exceptions that can send an exception to the CPU. They are controlled by the exception mask bits of the control word register. VxWorks disables these exceptions in the default configuration. The exceptions are as follows:

- Precision
- Overflow
- Underflow
- Division by zero
- Denormalized operand
- Invalid operation

### 4.4.7 Mixing MMX and FPU Instructions

A task with the **VX_FP_TASK** option enabled saves and restores the FPU and MMX state when performing a context switch. Therefore, the application does not need to save or restore the FPU and MMX state if the FPU and MMX instructions are not mixed within the task. Because the MMX registers are aliased to the FPU registers, care must be taken to prevent the loss of data in the FPU and MMX registers, and to prevent incoherent or unexpected results, when making transitions between FPU instructions and MMX instructions. When mixing MMX and FPU instructions within a task, Intel recommends the following guidelines:



- Keep the code in separate modules, procedures, or routines.
- Do not rely on register contents across transitions between FPU and MMX code modules.
- When transitioning between MMX code and FPU code, save the MMX register state (if it will be needed in the future) and execute an EMMS instruction to empty the MMX state.
- When transitioning between FPU and MMX code, save the FPU state, if it will be needed in the future.

#### Mixing SSE/SSE2 and FPU/MMX Instructions

The XMM registers and the FPU/MMX registers represent separate execution environments. This has certain ramifications when executing SSE, SSE2, MMX and FPU instructions in the same task context:

- Those SSE and SSE2 instructions that operate only on the XMM registers (such as the packed and scalar floating-point instructions and the 128-bit SIMD integer instructions) can be executed without any restrictions in the same instruction stream with 64-bit SIMD integer or FPU instructions. For example, an application can perform the majority of its floating-point computations in the XMM registers using the packed and scalar floating-point instructions, and at the same time use the FPU to perform trigonometric and other transcendental computations. Likewise, an application can perform packed 64-bit and 128-bit SIMD integer operations simultaneously without restrictions.
- Those SSE and SSE2 instructions that operate on MMX registers (such as the CVTPS2PI, CVTTPS2PI, CVTPI2PS, CVTPD2PI, CVTTPD2PI, CVTPI2PD, MOVDQ2Q, MOVQ2DQ, PADDQ, and PSUBQ instructions) can also be executed in the same instruction stream as 64-bit SIMD integer or FPU instructions. However, these instructions are subject to the restrictions on the

simultaneous use of MMX and FPU instructions, as mentioned in the previous section.

### 4.4.8 Segmentation

In the default configuration—that is, error detection and reporting and RTPs disabled—three code segments and one data segment are defined in the global descriptor table (GDT). The GDT is defined as table **sysGdt[ ]** in **sysALib.s**, and is copied to the destination address at (**LOCAL_MEM_LOCAL_ADRS** + **GDT_BASE_OFFSET**). The defined code and data segments are:

- supervisor code/data segment with privilege level 0 (PL0)
- interrupt/exception code segment with privilege level 0 (PL0)

They are fully overlapped in the 4 GB, 32-bit address space (flat model). These segments are used when a task changes its execution mode during its lifetime.

When RTPs are enabled, an additional three segments, a call gate, and a TSS descriptor are added to the GDT. The three segments are level 3 (PL3) for use by user-mode RTP tasks. The segments include one data, one code, and one stack segment. The call gate and TSS descriptor are used by the system call mechanism to allow a mode switch to occur when a system call is made.

When error detection and reporting is enabled, the IDT gets a task gate entry for page fault management. The GDT gets two TSS entries (one for OSM save information and one for OSM restore information) and one task gate entry. An LDT entry is also established for context switching through TSS.

### 4.4.9 Paging with MMU

When paging is used, the linear address space is divided into fixed-size pages (4 KB in the default configuration). Entries in the page directory point to page tables and entries in the page table point to pages in physical memory. Bits 22 through 31 of the linear address space provide an offset to an entry in the page directory. Bits 12 through 21 of the linear address space provide an offset to an entry in the selected page table. Bits 0 through 11 provide an offset to a physical address in the page.

If **INCLUDE_MMU_BASIC** component is enabled, VxWorks enables the MMU with the **mmuPhysDesc[ ]** table which includes PCI memory mapping information. This is the default VxWorks configuration.

If you have other memory-mapped devices, and if **INCLUDE_MMU_BASIC** is included (the default), you may need to add your device address space into the MMU table by manually editing the MMU configuration structure **sysPhysMemDesc[ ]** in **sysLib.c**. For information on editing this structure, see the *VxWorks Kernel Programmer's Guide: Memory Management*. Do not overlap any existing MMU entries and be sure all entries are page aligned. Wind River recommends that you also maintain a 1:1 correlation between virtual and physical memory because VxWorks and all tasks use a common address space.

Attempts to access areas not mapped as valid in the MMU result in page faults.

#### P6 (PentiumPro, II, III, Pentium M) and P7 (Pentium 4) MMU

The enhanced MMU on P6 and P7 family processors supports two additional page attribute bits.

The global bit (G) indicates a global page when set. When a page is marked global, and the page global enable (PGE) bit in register CR4 is set, the page-table or page-directory entry for the page is not invalidated in the TLB when register CR3 is loaded. This bit is provided to prevent frequently used pages (such as pages that contain kernel or other operating system or executive code) from being flushed from the TLB.

The page-level write-through/write-back bit (PWT) controls the write-through or write- back caching policy of individual pages or page tables. When the PWT bit is set, write-through caching is enabled for the associated page or page table. When the bit is clear, write-back caching is enabled for the associated page and page table.

The following macros describe these attribute bits in the physical memory descriptor table **sysPhysMemDesc[ ]** in **sysLib.c**.

| | |
|---|---|
| **MMU_ATTR_CACHE_COPYBACK** (or **VM_STATE_WBACK**) | Use write-back cache policy for the page. |
| **MMU_ATTR_CACHE_OFF** (or **VM_STATE_CACHEABLE_NOT**) | Use write-through cache policy for the page. |
| **VM_STATE_GLOBAL** | Set page global bit. |
| **VM_STATE_GLOBAL_NOT** | Do not set page global bit. |

Support is provided for two page sizes, 4 KB and 4 MB. The linear address for 4 KB pages is divided into three sections. These sections are as follows:

| | |
|---|---|
| Page directory entry | bits 22 through 31 |
| Page table entry | bits 12 through 21 |
| Page offset | bits 0 through 11 |

The linear address for 4 MB pages is divided into two sections. These sections are as follows:

| | |
|---|---|
| Page directory entry | bits 22 through 31 |
| Page offset | bits 0 through 21 |

The page size is configured using **VM_PAGE_SIZE**. The default configuration is 4 KB pages. If you wish to reconfigure for 4 MB pages, you must change **VM_PAGE_SIZE** in **config.h**. (For more information, see the *VxWorks Kernel Programmer's Guide: Memory Management*.)

#### Global Descriptor Table (GDT)

The GDT is defined as the table **sysGdt[ ]** in **sysALib.s**. The table begins with five entries: a null entry, an entry for program code, an entry for program data, an entry for exceptions, and an entry for interrupts. If error detection and reporting is enabled, an additional entry is added for task gate management of the OSM stack as well as two TSS entries (one for OSM save information and one for OSM restore information). If RTPs are enabled, an entry is provided for level 3 (user-mode) support. The table is initially set to have an available memory range of 0x0-0xffffffff. For boards that support PCI, **INCLUDE_PCI** is defined in **config.h** and VxWorks does not alter the pre-set memory range. This memory range is available at run-time with the MMU configuration.

If **INCLUDE_PCI** is not defined (the default for boards that do not support PCI), VxWorks adjusts the GDT using the **sysMemTop( )** routine to check the actual memory size during system initialization and set the table to have an available memory range of 0x0-**sysMemTop( )**. This causes a general protection fault to be generated for any memory access outside the memory range 0x0-**sysMemTop( )**.

### 4.4.10 Ring Level Protection

The processor's segment protection mechanism recognizes four privilege levels numbered 0 to 3. The greater numbers have fewer privileges. VxWorks uses privilege level 0 (PL0) when executing kernel exceptions and interrupt code. Privilege level 3 (PL3) is used when executing RTP task code.

### 4.4.11 Interrupts

Interrupt service routines (ISRs) are executed in supervisor mode (PL0) with the task's supervisor stack or the dedicated interrupt stack.

The task supervisor stack is the default stack, and its use does not require the OS to perform any software intervention. Whereas, the dedicated interrupt stack does require software manipulation. That is, you can control the trade-off between performance and memory consumption by selecting the stack used with an ISR. If you want faster interrupt response time, use the task stack; if you want to save on memory consumption, use the dedicated interrupt stack. To use the dedicated interrupt stack, perform **intStackEnable(TRUE)** in the task level.



### Interrupt Handling

Exceptions and the NMI interrupt are assigned vectors in the range of 0 through 31. Unassigned vectors in this range are reserved for possible future use. The vectors in the range 32 to 255 are provided for maskable interrupts.

The Intel Architecture (Pentium) architecture enables or disables all maskable interrupts with the IF flag in the EFLAGS register. An external interrupt controller handles multi-level priority interrupts. The most popular interrupt controller is the Intel 8259 PIC (programmable interrupt controller) which is supported by VxWorks as an interrupt controller driver.

The Fully Nested Mode and the Special Fully Nested Mode are supported and configurable in the BSP. In the Special Fully Nested Mode, when an interrupt request from a slave PIC is in service, the slave is not locked out from the master's priority logic and further interrupt requests from higher-priority IRQs within the slave are recognized by the master and initiate interrupts to the processor.

The PIC (8259A) IRQ0 is hard-wired to the PIT (8253) channel 0 in a PC motherboard. IRQ0 is the highest priority in the 8259A interrupt controller. Thus, the system clock interrupt handler blocks all lower-level interrupts. This may cause a delay of the lower-level interrupts in some situations even though the system clock interrupt handler finishes its job without any delay. This is quite natural from the hardware point of view, but may not be ideal from the application software standpoint. The following modes are supplied to mitigate this situation by providing the corresponding configuration macros in the BSP. The three mutually exclusive modes are Early EOI Issue in IRQ0 ISR, Special Mask Mode in IRQ0 ISR, and Automatic EOI Mode. For more information, see your BSP documentation.

The **intLock( )** and **intUnlock( )** routines control the IF flag in the EFLAGS register. The **sysIntEnablePIC( )** and **sysIntDisablePIC( )** routines control a specified PIC interrupt level.

### Interrupt Descriptor Table

The interrupt descriptor table (IDT) occupies the address range from 0x0 to 0x800, starting from **LOCAL_MEM_LOCAL_ADRS** (also called the interrupt vector table, see Figure 4-1). Vector numbers 0x0 to 0x1f are handled by the default exception handler. Vector numbers 0x20 to 0xff are handled by the default interrupt handler.

The trap gate is used for exceptions (vector numbers 0x0 - 0x1f). The configurable global variable **sysIntIdtType**, which can be set to either trap gate or interrupt gate in the BSP, is used for interrupts (vector numbers 0x20 - 0xff). The difference between an interrupt gate and a trap gate is its effect on the IF flag: using an interrupt gate clears the IF flag, which prevents other interrupts from interfering with the current interrupt handler.

Each vector entry in the IDT contains the following information:

- offset (offset to the interrupt handler)
- selectors (**sysCsExc(0x0018)**, fourth descriptor (code) in GDT for exceptions; or **sysCsInt(0x0020)**, fifth descriptor (code) in GDT for interrupts)
- descriptor privilege level (3)
- descriptor present bit (1)

### OSM

The OSM stack is needed for handling and recovery of stack overflow/underflow conditions and is triggered immediately following a page fault (stack overflow/underflow conditions are seen as a page fault). Issues that exist when possible stack overflow/underflow occurs are passed to the OSM stack. A task gate is used for the page fault. This allows VxWorks to jump to the OSM task routine. The task routine then establishes an OSM task, reconfigures both OSM TSS entries and the segment descriptors to their proper states before the exception occurs, and then enters the **excStub** as if handling a standard page fault. By using a new “safe” stack, the OSM allows the user to attempt a recovery and to debug the issue that caused the stack problem.

### BOI and EOI

The interrupt handler calls **intEnt( )** and saves the volatile registers (eax, edx, and ecx). It then calls the ISR, which is usually written in C. Finally, the handler restores the saved registers and calls **intExit( )**.

The beginning-of-interrupt (BOI) and end-of-interrupt (EOI) routines are called before and after the ISR. The BOI routine ascertains whether or not the interrupt is stray; if it is stray, the BOI routine jumps to **intExit( )**. If the interrupt is not stray,

the BOI routine returns to the caller. The EOI routine issues an EOI signal to the interrupt controller, if necessary.

Some device drivers (depending on the manufacturer, the configuration, and so on) generate a stray interrupt on IRQ7 (which is used by the parallel driver), and on IRQ15. The global variable **sysStrayIntCount** is incremented each time such an interrupt occurs, and a dummy ISR is connected to handle these interrupts. For more information about **sysStrayIntCount**, see your BSP documentation.



#### Interrupt Mode

Three interrupt modes are supported. The PIC Mode is the default interrupt mode. This mode uses the popular i8259A interrupt controller. The Virtual Wire Mode uses local APIC and i8259A. The Symmetric I/O Mode uses local APIC and I/O APIC. For more information, see your BSP documentation and *4.4.18 Advanced Programmable Interrupt Controller (APIC)*, p.74.

### 4.4.12 Exceptions

Exception handlers are executed in supervisor mode (PL0) with the task supervisor stack. All exceptions are expected to use the exception stack.

Exceptions differ from interrupts, with regard to the operating system, because interrupts are executed at the interrupt level and exceptions are executed at the task level.

After saving all registers on the supervisor stack, the task prints out the exception messages and then suspends itself. Execution can be resumed with the information stored in the supervisor stack.

The processor generates an exception stack frame in one of two formats, depending on the exception type. The types are as follows:

(**EIP** + **CS** + **EFLAGS**) or (**ERROR** + **EIP** + **CS** + **EFLAGS**)

The CS (Code Selector) register is taken from the vector table entry. That entry is the **sysCsExc** global variable defined in the BSP.

### 4.4.13 Stack Management

The task stack is used for task-level execution. The **intEnt( )** and **intExit( )** routines are used to switch to and from the interrupt stack. The size of the interrupt stack is determined by the **ISR_STACK_SIZE** macro (the default value is 1000).

### 4.4.14 Context Switching

Context switching is handled in software by the VxWorks kernel. Hardware multitasking through task gates and TSS descriptors is not used for normal context switching. The switch is accomplished by building a dummy exception stack frame and then using the IRET instruction to make the contents of the stack frame the new processor state.

### 4.4.15 Machine Check Architecture (MCA)

The P5 (Pentium) family processor introduced a new exception called the machine check exception (interrupt -18). This exception is used to signal hardware-related errors, such as a parity error on a read cycle. The P6 (PentiumPro, II, III) and P7 (Pentium 4) family processors extend the type of errors that can be detected and allowed to generate a machine check exception. These architectures also provide a new machine check architecture that records information about the machine check errors and provides the basis for extended error logging capability.

MCA is enabled by default and its status registers are set to zero in **pentiumMcaEnable( )** in **sysHwInit( )**. These registers are accessed by **pentiumMsrSet( )** and **pentiumMsrGet( )**.

### 4.4.16 Registers

#### Memory Type Range Register (MTRR)

MTRRs are a feature of P6 (PentiumPro, II, III) and P7 (Pentium 4) family processors that allow the processor to optimize memory operations for different types of memory, such as RAM, ROM, frame buffer memory, and memory-mapped I/O. MTRRs configure an internal map of how physical address ranges are mapped to various types of memory. The processor uses this internal map to determine the cache ability of various physical memory locations and the optimal method of accessing memory locations.

For example, if a memory location is specified in an MTRR as write-through memory, the processor handles accesses to this location either by reading data from that location in lines and caching the read data or by mapping all writes to that location to the bus and updating the cache to maintain cache coherency. In mapping the physical address space with MTRRs, the processor recognizes five types of memory: uncacheable (UC), write-combining (WC), write-through (WT), write-protected (WP), and write-back (WB).

The MTRR table is defined as follows:

```
typedef struct mtrr_fix   /* MTRR - fixed range register */
{
char type[8];             /* address range: [0]=0-7 ... [7]=56-63 */
} MTRR_FIX;

typedef struct mtrr_var   /* MTRR - variable range register */
{
long long int base;       /* base register */
long long int mask;       /* mask register */
} MTRR_VAR;
typedef struct mtrr       /* MTRR */
{
int cap[2];               /* MTRR cap register */
int deftype[2];           /* MTRR defType register */
MTRR_FIX fix[11];         /* MTRR fixed range registers */
MTRR_VAR var[8];          /* MTRR variable range registers */
} MTRR;
```

#### Model-Specific Register (MSR)

The P5 (Pentium), P6 (PentiumPro, II, III), and P7 (Pentium 4) families of processors implement the concept of model specific registers (MSRs) to control hardware functions in the processor or to monitor processor activity. The new registers control the debug extensions, the performance counters, the machine-check exception capability, the machine check architecture, and the MTRRs. The MSRs can be read from and written to using the RDMSR and WRMSR instructions, respectively.

**NOTE:** Pentium M processors include their own set of MSRs. For more information, see the Model-Specific Registers appendix of the *Intel Architecture Software Developer's Manual*.

### 4.4.17 Counters

#### Performance Monitoring Counters (PMCs)

The P5 (Pentium) and P6 (PentiumPro, II, III) families of processors have two performance-monitoring counters for use in monitoring internal hardware operations. These counters are duration or event counters that can be programmed to count any of approximately 100 different types of events, such as the number of instructions decoded, number of interrupts received, or number of cache loads.

PMCs are initialized in **sysHwInit( )**.

#### Timestamp Counter (TSC)

The P5 (Pentium), P6 (PentiumPro, II, III), and P7 (Pentium 4) families of processors provide a 64-bit timestamp counter that is incremented every processor clock cycle. The counter is incremented even when the processor is halted by the HLT instruction or the external STPCLK# pin. The timestamp counter is set to 0 following a hardware reset of the processor. The RDTSC instruction reads the timestamp counter and is guaranteed to return a monotonically increasing unique value whenever executed, except for 64-bit counter wraparound. Intel guarantees, architecturally, that the timestamp counter frequency and configuration will be such that it will not wraparound within 10 years after being reset to 0. The period for counter wrap is several thousands of years in these processors.

### 4.4.18 Advanced Programmable Interrupt Controller (APIC)

#### Local APIC/xAPIC

The local APIC/xAPIC module is a driver for the local advanced programmable interrupt controller in the P6 (PentiumPro, II, III) and P7 (Pentium 4) families of processors. The local APIC/xAPIC is included in selected P6 and P7 processors. On P6 and P7 family processors, the presence or absence of an on-chip local APIC can be detected using the CPUID instruction. When the CPUID instruction is executed, bit 9 of the feature flags returned in the EDX register indicates the presence (set) or absence (clear) of an on-chip local APIC.

The local APIC performs two main functions for the processor:

- It processes local external interrupts that the processor receives at its interrupt pins as well as local internal interrupts generated by software.
- In multiple-processor systems, it communicates with an external I/O APIC chip. The external I/O APIC receives external interrupt events from the system as well as interprocessor interrupts from the processors on the system bus and distributes them to the processors on the system bus. The I/O APIC is part of Intel's system chip set.

The local APIC controls the dispatching of interrupts (to its associated processor) that it receives either locally or from the I/O APIC. It provides facilities for queuing, nesting, and masking interrupts. The local APIC handles the interrupt delivery protocol with its local processors as well as accesses to APIC registers. In addition, it manages interprocessor interrupts and remote APIC register reads. A timer on the local APIC allows local generation of interrupts, and local interrupt pins permit local reception of processor-specific interrupts.

The local APIC can be disabled and used in conjunction with a standard 8259A-style interrupt controller. Disabling the local APIC can be done in hardware for Pentium (P5) processors or in software for P6 and P7 family processors.

The local APIC in P7 (Pentium 4) processors (called the xAPIC) is an extension of the local APIC found in P6 family processors. The primary difference between the APIC architecture and xAPIC architecture is that with Pentium 4 processors, the local xAPICs and I/O xAPIC communicate with one another through the processor's system bus; whereas, with P6 family processors, communication between the local APICs and the I/O APIC is handled through a dedicated 3-wire APIC bus. Also, some of the architectural features of the local APIC have been extended and/or modified in the local xAPIC.

The base address of the local APIC and I/O APIC is taken from the MP configuration table (for more information, see *Intel MP Specification Version 1.4*) or the **IA32_APIC_BASE** MSR. If the local APIC driver is unable to find the addresses, it uses **LOAPIC_BASE** and **IOAPIC_BASE** as defined in the BSP. This driver contains three routines for use. The routines are:

- **loApicInit( )** initializes the local APIC for the interrupt mode chosen.
- **loApicShow( )** shows the local APIC registers.
- **loApicMpShow( )** shows the MP configuration table.

The MP specification defines three interrupt modes: virtual wire mode, symmetric I/O mode, and PIC mode. Local APIC is used in the virtual wire mode (define **VIRTUAL_WIRE_MODE** in the BSP) and the symmetric I/O mode (define **SYMMETRIC_IO_MODE** in the BSP). However, it is not used in PIC mode (the default interrupt mode) which uses the 8259A PIC.

In the virtual wire mode, interrupts are generated by the 8259A equivalent PICs, but delivered to the boot strap processor by the local APIC. The local APIC is programmed to act as a "virtual wire"; that is, it is logically indistinguishable from a hardware connection. This is a uniprocessor compatibility mode.

In symmetric I/O mode, the local and I/O APICs are fully functional, and interrupts are generated and delivered to the processors by the APICs. Any interrupt can be delivered to any processor. This is the only multiprocessor interrupt mode.

The local and I/O APICs support interrupts in the range of 32 to 255. Interrupt priority is implied by its vector, according to the following relationship: priority = vector / 16. Here the quotient is rounded down to the nearest integer value to determine the priority, with 1 being the lowest and 15 the highest. Because vectors 0 through 31 are reserved for exclusive use by the processor, the priority of user defined interrupts range from 2 to 15. A value of 15 in the interrupt class field of

the task priority register (TPR) masks off all interrupts that require interrupt service. A P6 family processor's local APIC includes an in-service entry and a holding entry for each priority level. To avoid losing interrupts, software should allocate no more than 2 interrupt vectors per priority. P7 (Pentium 4) family processors expand this support by allowing two interrupts per vector rather than per priority level.

#### I/O APIC/xAPIC

The I/O APIC/xAPIC module is a driver for the I/O advanced programmable interrupt controller for P6 (PentiumPro, II, III) and P7 (Pentium 4) family processors. The I/O APIC/xAPIC is included in some Intel system chip sets, such as ICH2. Software intervention may be required to enable the I/O APIC/xAPIC on some chip sets.

The 8259A interrupt controller is intended for use in uniprocessor systems; I/O APIC can be used in either uniprocessor or multiprocessor systems. The I/O APIC handles interrupts very differently than the 8259A. Briefly, these differences are:

- Method of Interrupt Transmission. The I/O APIC transmits interrupts through a 3-wire bus and interrupts are handled without the need for the processor to run an interrupt acknowledge cycle.
- Interrupt Priority. The priority of interrupts in the I/O APIC is independent of the interrupt number. For example, interrupt 10 can be given a higher priority than interrupt 3.
- More Interrupts. The I/O APIC supports a total of 24 interrupts.

The I/O APIC unit consists of a set of interrupt input signals, a 24-entry by 64-bit interrupt redirection table, programmable registers, and a message unit for sending and receiving APIC messages over the APIC bus or the front-side (system) bus. I/O devices inject interrupts into the system using one of the I/O APIC interrupt lines. The I/O APIC selects the corresponding entry in the redirection table and uses the information in that entry to format an interrupt request message. Each entry in the redirection table can be individually programmed to indicate edge/level sensitive interrupt signals, the interrupt vector and priority, the destination processor, and how the processor is selected (statically and dynamically). The information in the table is used to transmit a message to other APIC units (via the APIC bus or the front-side (system) bus).

I/O APIC is used in the symmetric I/O mode (define **SYMMETRIC_IO_MODE** in the BSP). The base address of the I/O APIC is determined in **loApicInit( )** and stored in the global variables **ioApicBase** and **ioApicData**. The **ioApicInit( )** routine initializes the I/O APIC with information stored in **ioApicRed0_15** and

**ioApicRed16_23**. **ioApicRed0_15** is the default lower 32-bit value of the redirection table entries for IRQ 0 to IRQ 15 which are edge triggered positive high, **ioApicRed16_23** is the default value for IRQ 16 to IRQ 23 which are level triggered positive low. The **ioApicRedSet( )** and **ioApicRedGet( )** routines are used to access the redirection table. The **ioApicEnable( )** routine enables the I/O APIC or xAPIC. The **ioApicIrqSet( )** routine sets the specific IRQ to be delivered to the specific local APIC. The **ioApicShow( )** routine shows the I/O APIC registers. This implementation does not support a multiple I/O APIC configuration.

### Local APIC Timer

The local APIC timer library contains routines for the timer in the Intel local APIC/xAPIC in P6 (PentiumPro, II, III) and P7 (Pentium 4) family processors.

The local APIC contains a 32-bit programmable timer for use by the local processor. This timer is configured through the timer register in the local vector table. The time base is derived from the processor's bus clock, divided by a value specified in the divide configuration register. After reset, the timer is initialized to zero. The timer supports one-shot and periodic modes. The timer can be configured to interrupt the local processor with an arbitrary vector.

The library gets the system clock from the local APIC timer and auxiliary clock from either RTC or PIT channel 0 (define **PIT0_FOR_AUX** in the BSP). The macro **APIC_TIMER_CLOCK_HZ** must also be defined to indicate the clock frequency of the local APIC timer. The parameters **SYS_CLK_RATE_MIN**, **SYS_CLK_RATE_MAX**, **AUX_CLK_RATE_MIN**, and **AUX_CLK_RATE_MAX** must be defined to provide parameter checking for the **sysClkRateSet( )** and **sysAuxClkRateSet( )** routines.

The timer driver uses the processor's on-chip TSC (timestamp counter) for the timestamp driver. The TSC is a 64-bit timestamp counter that is incremented every processor clock cycle. The counter is incremented even when the processor is halted by the HLT instruction or the external STPCLK# pin. The timestamp counter is set to 0 following a hardware reset of the processor. The RDTSC instruction reads the timestamp counter and is guaranteed to return a monotonically increasing unique value whenever executed, except for 64-bit counter wraparound. Intel guarantees, architecturally, that the timestamp counter frequency and configuration will be such that it will not wraparound within 10 years after being reset to 0. The period for counter wrap is several thousands of years in P6 (PentiumPro, II, III) and P7 (Pentium 4) family processors.

### 4.4.19 I/O Mapped Devices

For I/O mapped devices, use the following routines from *installDir*/**vxworks-6.2/target/config/***bspName*/**sysALib.s**:

| | |
|---|---|
| **sysInByte( )** | Input one byte from I/O space. |
| **sysOutByte( )** | Output one byte to I/O space. |
| **sysInWord( )** | Input one word from I/O space. |
| **sysOutWord( )** | Output one word to I/O space. |
| **sysInLong( )** | Input one long word from I/O space. |
| **sysOutLong( )** | Output one long word to I/O space. |
| **sysInWordString( )** | Input a word string from I/O space. |
| **sysOutWordString( )** | Output a word string to I/O space. |
| **sysInLongString( )** | Input a long string from I/O space. |
| **sysOutLongString( )** | Output a long string to I/O space. |

### 4.4.20 Memory-Mapped Devices

For memory-mapped devices, there are two kinds of memory protection provided by VxWorks: paging with the memory management unit (MMU) and segmentation with the global descriptor table. Because VxWorks operates at the highest processor privilege level, no “protection rings” exist.

Intel Architecture processors allow you to configure memory space into valid and invalid areas, even under supervisor mode. Thus, you receive a page fault only if the processor attempts to access addresses mapped as invalid, or addresses that have not been mapped. Conversely, if the processor attempts to access a nonexistent address space that has been mapped as valid, no page fault occurs.

### 4.4.21 Memory Considerations for VME

The global descriptors for Intel Architecture targets are configured for a flat 4 GB memory space.

If you are running VxWorks for Intel Architecture on a VME board, be aware that addressing nonexistent memory or peripherals does not generate a bus error or fault.

### 4.4.22 ISA/EISA Bus

The optional PC-compatible hardware cards supported in this release (the Ethernet adapter cards and the Blunk Microsystems ROM card) use the ISA/EISA bus architecture.



### 4.4.23 PC104 Bus

The PC104 bus is supported and tested with the NE2000-compatible Ethernet card (4I29: Mesa Electronics). The Ampro Ethernet card (Ethernet-II) is also supported.

### 4.4.24 PCI Bus

The PCI bus is supported and tested with the Intel EtherExpress PRO100B Ethernet card (Intel 8255[789]). Several routines to access PCI configuration space are supported. Functions addressed here include:

- Locate the device by **deviceID** and **vendorID**.
- Locate the device by **classCode**.
- Generate the special cycle.
- Access its configuration registers.

For more information, see the reference entry for **pciConfigLib**.

### 4.4.25 Software Floating-Point Emulation

The software floating-point library is supported for Intel Architecture (Pentium) architectures that do not have on-chip FPUs; select **INCLUDE_SW_FP** for inclusion in the project facility VxWorks view to include the library in your system image. This library emulates each floating point instruction by using the exception "Device Not Available." For other floating-point support information, see *4.3.1 Supported Routines in mathALib*, p.49.

### 4.4.26 Power Management

CPU power management for the Intel Architecture is no longer an architecture-specific function. As such, kernel applications using the

**vxPowerModeGet( )** and **vxPowerModeSet( )** routines must migrate to the API provided by the light power manager. (For more information, see the reference entry for **cpuPwrLightMgr**.)

To perform this migration, do the following:

- Replace calls to **vxPowerModeSet(VX_POWER_MODE_DISABLE)** with **cpuPwrMgrEnable(FALSE)**.
- Replace calls to **vxPowerModeSet(VX_POWER_MODE_AUTOHALT)** with **cpuPwrMgrEnable(TRUE)**.
- Replace calls to **vxPowerModeGet( )** with **cpuPwrMgrIsEnabled( )**.

**NOTE:** The return types for the **vxPowerModeGet( )** and **cpuPwrMgrIsEnabled( )** routines are not the same.

For the **cpuPwrLightMgr** API to be present in a VxWorks image, the VxWorks kernel must be configured with the **INCLUDE_CPU_LIGHT_PWR_MGR** component. This component is included by default so the API is present unless the component is explicitly removed.

For more information on available power management facilities, see the *VxWorks Kernel Programmer's Guide*.

### 4.4.27 VxWorks Memory Layout

Two memory layouts for Intel Architecture (Pentium) architectures are described in this section. The figures contain the following labels:

**Interrupt Vector Table (IDT)**
Table of exception/interrupt vectors (IDT).

**Global Descriptor Table (GDT)**
Anchor for the shared memory network (if there is shared memory on the board).

**Boot Line**
ASCII string of boot parameters.

**Exception Message**
ASCII string of the fatal exception message.

**FD DMA Area**
Diskette (floppy device) direct memory access area.

**Initial Stack**
Initial stack for **usrInit( )**, until **usrRoot( )** gets allocated stack.

**System Image**
Entry point for VxWorks.

**WDB Memory Pool**
Size depends on the macro **WDB_POOL_SIZE** which defaults to one-sixteenth of the system memory pool. This space is used by the target server to support host-based tools. Modify **WDB_POOL_SIZE** under **INCLUDE_WDB**.

**Interrupt Stack**
Size is defined by **ISR_STACK_SIZE** under **INCLUDE_KERNEL**. Location depends on system image size.

**System Memory Pool**
size depends on size of system image and interrupt stack. The end of the free memory pool for this board is returned by **sysMemTop( )**.

Figure 4-1 shows a lower memory option.

Figure 4-2 illustrates the typical upper memory configuration.

All addresses shown in Figure 4-2 are relative to the start of memory for a particular target board. The start of memory (corresponding to 0x0 in the memory-layout diagram) is defined as **LOCAL_MEM_LOCAL_ADRS** under **INCLUDE_MEMORY_CONFIG** for each target.

In general, the boot image is placed in lower memory and the VxWorks image is placed in upper memory, leaving a gap between lower and upper memory. Some BSPs have additional configurations which must fit within their hardware constraints. For details, see the reference entry for each BSP.

Figure 4-1 **VxWorks System Memory Layout (x86 Lower Memory)**

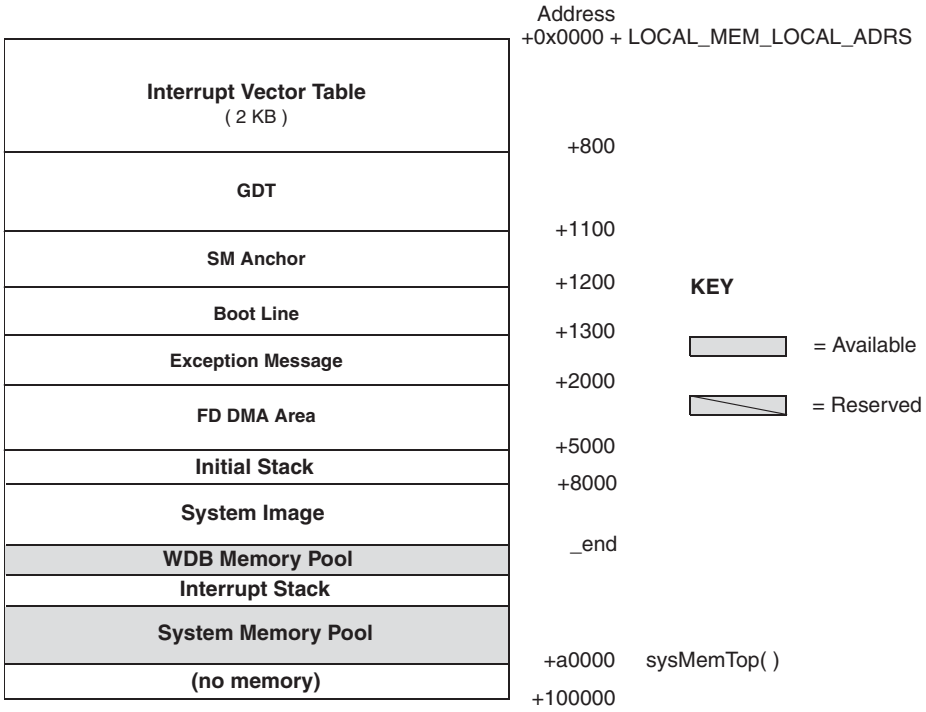
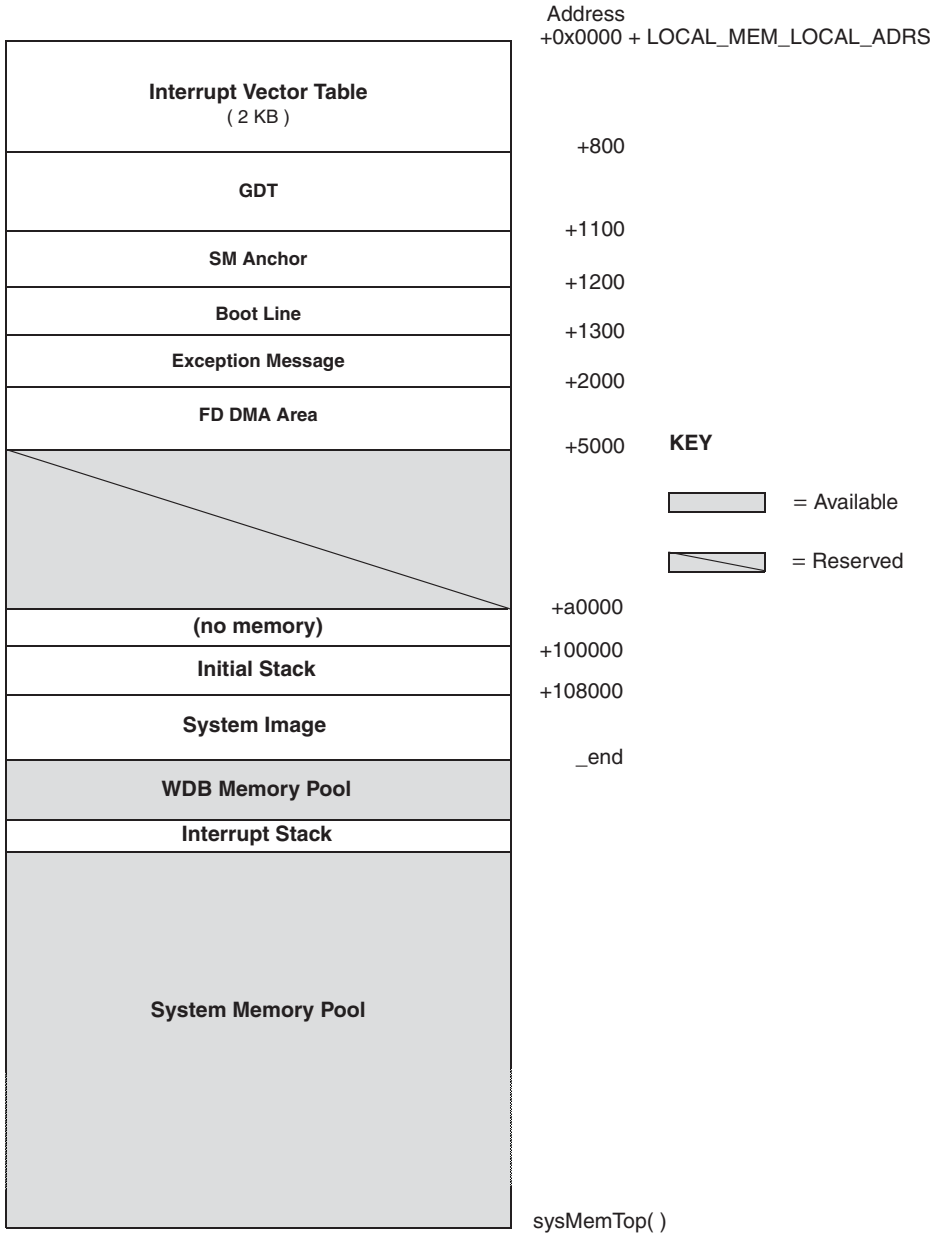


Figure 4-2 **VxWorks System Memory Layout (x86 Upper Memory)**



## 4.5 Reference Material

Comprehensive information regarding Intel Architecture hardware behavior and programming is beyond the scope of this document. Intel Corporation provides several hardware and programming manuals for the Intel Architecture processor families on its Web site:

**http://developer.intel.com/**

Wind River recommends that you consult the hardware documentation for your processor or processor family as necessary during BSP development.

# 5 MIPS



## 5.1 Introduction

This chapter provides information specific to VxWorks development on MIPS processors.

## 5.2 Supported Processors

VxWorks supports a number of MIPS microprocessors, which can be categorized by the libraries that support them.

**MIPS32sf**
This category includes both big- and little-endian versions of the library. The 32-bit R4000-style processors are represented here.

**MIPS64**
This category includes both big- and little-endian versions of the library. The 64-bit R4000 and later processors are represented here.

The VxWorks 6.2 libraries support a wide range of MIPS CPUs, including MIPS32 and MIPS64 implementations. Because of the wide range of MIPS processors available, it is beyond the scope of this document to provide a complete listing of supported CPUs. However, Table 5-1 provides information for a representative group of CPUs supported by VxWorks.

**NOTE:** Table 5-1 is accurate at the time of this writing. However, support for additional CPUs and libraries may be added at any time. For a complete and updated list of supported MIPS devices, libraries, and BSPs, see the Wind River Online Support Web site.

When reviewing the information in the table, you should note that the cache support for a particular processor is *independent* of the library.

Each MIPS ISA level contains a superset of the instructions in the preceding level. Normally, this means that processors implementing ISA III (for example, **MIPS64**) are supported by both the ISA II **MIPS32** libraries and the ISA III **MIPS64** libraries. However, processors implementing the ISA II (for example, **MIPS32**) are only supported by the ISA II **MIPS32** libraries.

Table 5-1 **Summary of Supported MIPS Devices and Libraries**

| CPU | CPU Variant | ISA Level | Library |
|---|---|---|---|
| **Broadcom Devices** | | | |
| bcm1250 | **_bcm125x** | MIPS64 | **MIPS64***xxx* |
| bcm1250e | **_bcm125x** | MIPS64 | **MIPS64***xxx* |
| **MIPS Technologies, Inc. Devices** | | | |
| 4kc | **_mti4kx** | MIPS32 | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le** |
| 4kec | **_mti4kx** | MIPS32 | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le** |

Table 5-1 **Summary of Supported MIPS Devices and Libraries** (cont'd)

| CPU | CPU Variant | ISA Level | Library |
|---|---|---|---|
| 5kc | **_mti5kx** | MIPS32 [a] | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le** |
| 5kf | **_mti5kx** | MIPS64 | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le**<br>**MIPS64***xxx*<br>**MIPS64***xxx***le** |
| 24kc | **_mti24kx** | MIPS32[b] | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le** |
| 24kec | **_mti24kx** | MIPS32 | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le** |
| **NEC Devices** | | | |
| vr5500 | **_vr55xx** | IV | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le**<br>**MIPS64***xxx*<br>**MIPS64***xxx***le** |
| **PMC Sierra Devices** | | | |
| rm9000 | **_rm9xxx** | MIPS64 | **MIPS64***xxx* |
| **Toshiba Corporation Devices** | | | |
| tx4938 | **_tx49xx** | MIPS32 | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le** |
| tx4938 | **_tx49xx** | MIPS64 | **MIPS64***xxx*<br>**MIPS64***xxx***le** |

a. The 5kc is a MIPS64 device with an optional floating-point unit. However, because VxWorks does not provide MIPS64 support for software floating-point operations, it is listed as a MIPS32 device.

b. Toolchain support for the Revision 2 instruction set implemented in 4kec and 24kc processors is not available at this time. However, in the **_mti24kx** variant kernel libraries, the use of a series of **nop** or **ssnop** instructions used to handle hazards has been replaced by the **ehb** instruction by using a **.word 0x000000c0** directive.

**NOTE:** The library support examples provided in Table 5-1 represent both Wind River Compiler- and GNU-compiled libraries. For example, **MIPS32sf***xxx* represents both **MIPS32sfdiab** (the Wind River Compiler-compiled library) and **MIPS32sfgnu** (the GNU-compiled library). You should substitute the appropriate option (**diab** or **gnu**) based on your chosen compiler.

Keep in mind that MIPS CPUs are organized by CPU variant. This allows the VxWorks kernel to take advantage of the specific architecture characteristics of one variant without negatively impacting another variant. As shown in Table 5-1, this organization leads to certain library-to-CPU variant mappings. For example, the **MIPS32sf***xxx*, **MIPS32sf***xxx***le**, **MIPS64***xxx*, and **MIPS64***xxx***le** libraries are supplied for all CPUs with the **_mti5kx** variant. However, the 5kc processor, a member of the **_mti5kx** variant family, is only supported in **MIPS32** mode. Also, available libraries are sometimes subject to individual processor and board limitations. For example, although both big- and little-endian libraries are provided for the **_bcm125x** CPU variant, only the big-endian bcm1250 BSP is provided.

## 5.3 Interface Variations

This section describes particular routines and tools that are specific to MIPS targets in any of the following ways:

- available only on MIPS targets
- parameters specific to MIPS targets
- special restrictions or characteristics on MIPS targets

For complete documentation, see the reference entries for the libraries, subroutines, and tools discussed in the following sections.

## 5.3.1 dbgArchLib

### tt( ) Routine

In VxWorks for MIPS, the **tt( )** routine does not currently display parameter information. A more complete stack trace, including function call parameter information, may be available through the use of a host-based debugger.



### Hardware Breakpoints and the bh( ) Routine

Support for the **bh( )** debugger command is provided for those MIPS processor cores that are MIPS32 and MIPS64 compliant in VxWorks 6.2 and newer releases. The MIPS32/MIPS64 specification provides a mechanism to support up to eight hardware breakpoints (also referred to as *watchpoints*). Currently, only the following MIPS32/MIPS64 compliant processor cores are supported:

- Malta4kc (1 hardware breakpoint available)
- Malta5kx (1 hardware breakpoint available)
- Malta20kc (1 hardware breakpoint available)
- Malta24kx (4 hardware breakpoints available; 2 for instruction access and 2 for data access)

#### Known issues with Hardware Breakpoints

Watchpoint exceptions can be configured to occur on data read, data write, or instruction execution. Which mode the watchpoint is configured for is determined by bits 2..0 of the WatchLo register.

| | |
|---|---|
| Bit 0 | Data write |
| Bit 1 | Data read |
| Bit 2 | Instruction execution |

**NOTE:** This leaves only bits 31..3 implemented for specifying the address (**Vaddr**) in the WatchLo register(s) for the breakpoint. This arrangement only allows watchpoints to be set on doubleword boundaries. This means that because bits 2..0 are ignored, executing an instruction at either 0xc0010000 or 0xc0010004 results in a watchpoint exception. While the instruction not designated as the watchpoint is not processed beyond the exception handling, operational speed may be reduced.

Watchpoints set on instructions that reside in branch delay slots are not available as valid watchpoint addresses. However, nothing prevents you from setting these

addresses as a watchpoint. An indication of this type of set up error is that the watchpoint address is never hit.

### 5.3.2 intArchLib

In VxWorks for MIPS, the routines **intLevelSet( )** and **intVecBaseSet( )** have no effect. For a discussion of the MIPS interrupt architecture, see *5.4.7 Interrupts*, p.99.

### 5.3.3 taskArchLib

The routine **taskSRInit( )** is specific to the MIPS architecture. This routine allows you to change the default status register with which a task is spawned. For more information, see *5.4.7 Interrupts*, p.99.

### 5.3.4 Memory Management Unit (MMU)

This section describes the memory management unit implementation for MIPS processors.

VxWorks for MIPS includes support for memory management. You can build your BSP with or without memory management, depending upon the BSP configuration.

- To include memory management support in a VxWorks Image Project, add the component **INCLUDE_MAPPED_KERNEL** to your project.
- To include memory management support in a BSP-built kernel, execute **make MAPPED=yes** in the BSP directory. Do not define **INCLUDE_MAPPED_KERNEL** in **config.h**. This definition is intended to be added by **Makefile**, not by **config.h**.

In unmapped VxWorks images:

- The kernel resides in **kseg0** and **kseg1** because these address ranges do not utilize the MMU.
- RTPs reside in the kernel heap, which is allocated in **kseg0**. RTPs run in the kernel protection state.

When memory management is enabled, the address map of VxWorks is changed:

- The kernel resides in **kseg2**.
- RTPs reside in **kuseg** (the lower 2 GB of the 32-bit virtual address space).

#### Kernel Text Segment Static Mapping

When the VxWorks kernel includes memory management, the kernel reserves a portion of the hardware translation lookaside buffer (TLB) registers to create a persistent memory map for the kernel text segment. This persistent memory map eliminates any address translation overhead for instruction references within the kernel text segment. BSPs provided by Wind River initialize the TLB registers appropriately for mapped operation. Pre-VxWorks 6.0 BSPs that make use of the MMU (for example, for accessing memory and peripheral devices at addresses beyond the top of the 32-bit address space) need to be modified to avoid conflicting with the new memory management design of this VxWorks release.

#### Data Segment Alignment

When the VxWorks kernel includes memory management, static TLB entries are used to provide the address mapping for the kernel text segment. During the build process, mapped kernels are linked with the load address of the data segment aligned to a multiple of an MMU page boundary. This has two effects:

- It minimizes the number of TLB entries needed to statically map the kernel text.
- It allows write protection to be applied to the kernel text section independent of the kernel data, which must remain read/write.

For all practical purposes, the physical memory between the end of the kernel text section and the beginning of the kernel data is unallocated and unusable. However, because the padding is done in the linker, the kernel is not increased in size by the padding amount.

### 5.3.5 Caches

For most MIPS devices, the caching characteristics of memory in **kseg0** are determined at startup time by the **K0** field of the CONFIG register, and should not be changed once set. For this reason, the VxWorks **cacheEnable( )** and **cacheDisable( )** routines are not implemented for MIPS and return **ERROR**.

For mapped kernels, cache characteristics can be controlled on a page-by-page basis through the use of the standard VM library API calls.

### 5.3.6 AIM Model for Caches

The Architecture-Independent Model (AIM) for cache provides an abstraction layer to interface with the underlying architecture-dependent cache code. This allows uniform access to the hardware cache features that are usually CPU core specific. AIM for cache is for VxWorks internal use and does not change the VxWorks API for application development. For more information, see the reference entry for **cacheLib**.

Not all CPU families in which MIPS BSPs are provided utilize AIM for cache. Currently, only the following CPU variants are supported by AIM for cache:

**_mti4kx**
**_mti5kx**
**_mti24kx**
**_vr55xx**

Support for other variants will be added in a future release.

### 5.3.7 Cache Locking

Cache locking is implemented as part of MIPS AIM for cache support. For more information, see the reference entry for the cache locking routine.

### 5.3.8 Building MIPS Kernels

As described in *5.4 Architecture Considerations*, p.95, VxWorks for MIPS kernels can be configured with or without MMU support. MIPS kernels that are compiled with MMU support are referred to as *mapped* kernels, kernels without MMU support are considered *unmapped*. This section describes the new procedures and considerations for selecting the desired kernel mode.

#### Default (Unmapped) Build Configuration

Consistent with earlier VxWorks releases, pre-built kernels provided in your VxWorks for MIPS installation are configured for unmapped operation. Creating a VxWorks Image Project using the Wind River Workbench results in an unmapped kernel configuration. As with earlier releases, operation of the default kernel is limited to accessing memory in the unmapped memory regions **kseg0** (0x80000000-0x9fffffff) and **kseg1** (0xa0000000-0xbfffffff).

### Mapped Build Configuration

Although unmapped kernels can be configured with support for real-time processes (RTPs), they do not have access to some of the more advanced protection features in this VxWorks release, such as memory write protection, inter-task memory protection, exception vector write protection, user-supervisor address space protection, and stack overflow protection. If you require these protection features, you must use a mapped kernel.

There are several changes to the build process required to create a mapped kernel. Provisions are made in Wind River-supplied BSPs to easily make these changes, but BSPs that are not derived from those on this VxWorks distribution must take the following items into account:.

- Building a mapped kernel in a Wind River-supplied BSP directory involves adding the **MAPPED=yes** option to the **make** command. For example, if you previously used the **make vxWorks** command to build an unmapped kernel, you must now use the **make MAPPED=yes vxWorks** command to build a mapped kernel.
- To build a mapped VxWorks Image Project (kernel) in Workbench, you must build a VxWorks Image Project with the **INCLUDE_MAPPED_KERNEL** component (found under **Hardware > Memory > MMU** in the kernel configuration tool).

For more information on building VxWorks Image Projects, see the *Wind River Workbench User's Guide* or the *VxWorks Command-Line Tools User's Guide*.

### Mapped Kernel Build Details

In order to support a mapped kernel, the Wind River-supplied MIPS BSPs for this VxWorks release have been updated in the following ways:

- Changes have been made to the BSP makefiles (**Makefile**) to assign appropriate values to the variables **LOCAL_MEM_LOCAL_ADRS**, **RAM_LOW_ADRS**, and **RAM_HIGH_ADRS** based on whether **MAPPED=yes** is specified. These addresses are **kseg0** for unmapped kernels and **kseg2** for mapped kernels.
- The BSP makefiles (**Makefile**) have been changed to add an **EXTRA_DEFINE** for **INCLUDE_MAPPED_KERNEL** when building mapped kernels.

**NOTE:** Do not define (**#define**) **INCLUDE_MAPPED_KERNEL** in **config.h**. This could result in an incorrect linkage address, and could prevent the makefile from correctly selecting between mapped and unmapped kernels.

- The BSP makefiles (**Makefile**) have been modified to set an appropriate **DATA_SEG_ALIGN** value. This value is not critical for unmapped kernels, but must be an even power of two (for example, 1, 4, 16, and so forth) multiple of the default virtual memory (VM) library page size of 8 KB.
- The BSP makefiles (**Makefile**) have been modified to define **ADJUST_VMA=1** to arrange to post-process the kernel load image. This allows the boot ROM to load a mapped kernel.
- The BSP **config.h** files have been modified to include logic to correctly set the **INCLUDE_MMU_BASIC** component and **SW_MMU_ENABLE** parameter dependent upon whether **INCLUDE_MAPPED_KERNEL** or **INCLUDE_RTP** are defined. If **INCLUDE_RTP** is added to **config.h**, it must be done before this logic. Also, the **LOCAL_MEM_LOCAL_ADRS**, **RAM_LOW_ADRS**, and **RAM_HIGH_ADRS** definitions in **config.h** have been removed. For BSP builds, these values are provided in **Makefile** and the definitions are passed to the compiler on the command line. For project builds, these values are determined by the presence or absence of the **INCLUDE_MAPPED_KERNEL** component.
- A new structure known as **sysPhysMemDesc[ ]** and a global variable **sysPhysMemDescNumEnt** have been added to **sysLib.c**. These variables describe the physical and virtual addresses and size of the system RAM to the VM library. This structure is only included if **INCLUDE_MAPPED_KERNEL** is defined.
- New startup code has been added to **sysALib.s** to provide initialization of the MMU to create static entries in the MMU that allow loading the kernel into mapped memory space. This avoids the overhead of running the TLB refill handler when accessing kernel code.

#### Mapped Kernel BSP Build Precautions

The addition of mapped kernels results in certain build product combinations in the BSP directories that should be avoided. For example, **INCLUDE_MAPPED_KERNEL** should not be defined if the kernel is linked in **kseg0**. (Kernels built from the Workbench are immune to these effects, as long as the BSP directory is not modified, the kernel is configured as unmapped, and **INCLUDE_RTP** is not defined in **config.h**.)

To avoid many of these interactions, Wind River recommends that you create one BSP directory in which boot ROMs and unmapped kernels are built, and a separate BSP directory in which mapped kernels are built.

#### Other Recommendations

- Avoid building the **bootrom.hex** image in a directory where a mapped kernel was previously built. The boot ROM will appear to compile correctly, but will contain unused data and code, and may not work. The safest method for building a **bootrom** image is to use:

  ```
  make clean bootrom.hex
  ```

  However, the **clean** is not necessary if you are certain that a mapped kernel was never built in the BSP directory.

- Conversely, avoid building a mapped kernel in a BSP directory in which a boot ROM was built. In this case, the link step will fail with undefined symbols for **sysPhysMemDesc[ ]** and **sysPhysMemDescNumEnt**. If you inadvertently encounter this situation, clean the BSP directory with **make clean** and try again with **make MAPPED=yes** or **make MAPPED=yes vxWorks**.

- Use caution if you need to modify the logic in **config.h** that determines the definitions of **INCLUDE_MMU_BASIC** and **SW_MMU_ENABLE**. Specifically, all combinations of these variables produce unmapped kernels (which must be linked at appropriate addresses) *except* if **INCLUDE_MMU_BASIC** is defined and **SW_MMU_ENABLE** is set to **FALSE**. In this case, you build a kernel that expects to be mapped but, because the linkage address is determined in **Makefile** (which is configured to build an unmapped kernel), the kernel will not boot.

- If you switch between mapped and unmapped kernels in the same BSP directory, always run **make clean** before attempting to build the new kernel.

- Do not attempt to build a mapped boot ROM (for example, **make MAPPED=yes bootrom.hex**).

## 5.4 Architecture Considerations

This section describes characteristics of the MIPS architecture that you should keep in mind as you write a VxWorks application. The following topics are addressed:

- memory ordering
- debugger
- gp-rel addressing

- reserved registers
- signal support
- floating-point support
- interrupts
- memory management unit (MMU)
- AIM model for MMU
- virtual memory mapping
- memory layout
- 64-bit support
- hardware breakpoints

### 5.4.1 Byte Order

Most MIPS RISC processors are capable of big-endian or little-endian memory ordering. The **MIPS32sfgnule**, **MIPS32sfdiable**, **MIPS64diable**, and **MIPS64gnule** are supported little-endian libraries. All other libraries are big-endian.

### 5.4.2 Debugging and tt( )

On all MIPS targets, the **tt( )** routine displays a stack trace. However, this routine does not currently display function parameter information. It is not possible to reliably report parameter information on architectures (such as MIPS) that pass some or all function parameters in registers (as opposed to placing them on the run-time stack). A more complete stack trace, including function parameter information, is obtained by using the host-based debugger available with VxWorks.

### 5.4.3 gp-rel Addressing

User code should not change the GP register, which is used in the implementation of shared libraries. This is accomplished through the use of the **-G 0** command line option for the GNU compiler, or appropriate use of the **-t** selection for the Wind River Compiler.

### 5.4.4 Reserved Registers

Following standard MIPS usage, the k0, k1, and GP registers should be considered reserved. This is also required to implement shared libraries. The values for these registers should not be changed, nor should they be assumed to contain any particular repeatable value at any point in the execution of user-supplied code.



### 5.4.5 Signal Support

VxWorks provides software signal support for all architectures. However, the manner in which MIPS maps its own exceptions onto the software signals is architecture-dependent. Table 5-2 shows this mapping.

Table 5-2 **Mapping of MIPS Exceptions onto Software Signals**

| MIPS Exception Name | MIPS Exception Description | Software Signal |
|---|---|---|
| **IV_TLBMOD_VEC** | Translation Lookaside Buffer Modification | **SIGBUS** |
| **IV_TLBL_VEC** | Translation Lookaside Buffer Load | **SIGBUS** |
| **IV_TLBS_VEC** | Translation Lookaside Buffer Store | **SIGBUS** |
| **IV_ADEL_VEC** | Address Load | **SIGBUS** |
| **IV_ADES_VEC** | Address Store | **SIGBUS** |
| **IV_IBUS_VEC** | Instruction Bus Error | **SIGSEGV** |
| **IV_DBUS_VEC** | Data Bus Error | **SIGSEGV** |
| **IV_SYSCALL_VEC** | System Call | **SIGTRAP** |
| **IV_BP_VEC** | Breakpoint | **SIGTRAP** |
| **IV_RESVDINST_VEC** | Reserved Instruction | **SIGILL** |
| **IV_CPU_VEC** | Coprocessor Unusable | **SIGILL** |
| **IV_FPA_UNIMP_VEC** | Unimplemented Instruction | **SIGFPE** |
| **IV_FPA_INV_VEC** | Invalid Operation | **SIGFPE** |
| **IV_FPA_DIV0_VEC** | Divide-by-zero | **SIGFPE** |

Table 5-2 **Mapping of MIPS Exceptions onto Software Signals** (cont'd)

| MIPS Exception Name | MIPS Exception Description | Software Signal |
|---|---|---|
| **IV_FPA_OVF_VEC** | Overflow | **SIGFPE** |
| **IV_FPA_UFL_VEC** | Underflow | **SIGFPE** |
| **IV_FPA_PREC_VEC** | Inexact | **SIGFPE** |

### 5.4.6 Floating-Point Support

VxWorks supports the same set of **math** routines for all MIPS targets using either hardware facilities or software emulation. The following double-precision routines are supported for MIPS architectures:

| | | | | | | |
|---|---|---|---|---|---|---|
| **acos( )** | **asin( )** | **atan( )** | **atan2( )** | **ceil( )** | **cos( )** | **cosh( )** |
| **exp( )** | **fabs( )** | **floor( )** | **fmod( )** | **log10( )** | **log( )** | **pow( )** |
| **sin( )** | **sinh( )** | **sqrt( )** | **tan( )** | **tanh( )** | **trunc( )** | |

Few 32-bit MIPS processors supported by the **MIPS32sf** libraries have a hardware floating-point unit. As a result, floating-point hardware for these processors is not supported by VxWorks. However, VxWorks provides software emulation support for the **math** routines listed above. These **math** routines are provided using the VxWorks **math** libraries.

On 64-bit MIPS III and above microprocessors, a hardware floating-point unit is often available. On these devices, there is an option of either emulating thirty-two single-precision (32-bit) floating-point registers, or using the thirty-two double-precision (64-bit) floating-point registers. Note that VxWorks hardware floating-point support is available only for processors that include both a complete double-precision floating-point hardware implementation and the ISA III instruction set. Table 5-3 shows the available MIPS libraries and the level of floating-point support provided by each for all possible MIPS CPU types. Note that access to the 32-bit, single-precision, floating-point registers is not supported by any VxWorks library. CPUs with this type of floating-point unit must use the software floating-point emulation provided in the MIPS32 libraries.

Table 5-3 **MIPS Library Compatibility Matrix**

| Floating-Point Hardware | 32-bit Core and/or ISA II or ISA III | 64-bit Core and ISA III |
|---|---|---|
| None or Single-Precision | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le** | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le** |
| Double-Precision | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le** [a] | **MIPS32sf***xxx*<br>**MIPS32sf***xxx***le**<br>**MIPS64***xxx*<br>**MIPS64***xxx***le** [a] |

a. **MIPS32sf***xxx* and **MIPS32sf***xxx***le** libraries do not utilize the floating-point coprocessor.



To utilize MIPS floating-point support in VxWorks, you must spawn a floating-point task with the **VX_FP_TASK** option set. Spawning a task with this option sets the coprocessor usable bit (CU1) in the MIPS SR register on MIPS64 processors. For floating-point tasks, all registers are saved and restored on context switches. Thus, you do not need to be concerned about storing and restoring floating-point registers on a per-task basis. If you are developing floating-point tasks, you need to determine which of the five floating point exceptions are significant. (For more information, refer to IEEE 754 and your processor documentation.) These exceptions can be enabled on a per-task basis by changing the floating-point status and control register. However, you must provide the routine that manipulates the register.

### 5.4.7 Interrupts

#### MIPS Interrupts

The MIPS architecture has inputs for six external hardware interrupts and two software interrupts. In cases where the number of hardware interrupts is insufficient, board manufacturers can multiplex several interrupts on one or more interrupt lines.

The MIPS CPU treats exceptions and interrupts in the same way; that is, it branches to a common vector and provides status and cause registers that let the system software determine the CPU state. The CPU does not generate an IACK cycle. This function must be implemented in software or in board-level hardware. (For example, the VMEbus IACK cycle is a board-level hardware function.) VxWorks

for MIPS has implemented an interrupt and exception stack for all tasks, including both user and kernel tasks.

Because the MIPS CPU does not provide an IACK cycle, the interrupt handler must acknowledge (or clear) the interrupt condition. If the interrupt handler does not acknowledge the interrupt, VxWorks hangs while repeatedly trying to process the interrupt condition. The unacknowledged interrupts can fill the work queue and cause a **workQPanic( )** event.

VxWorks for MIPS uses a 256-entry table of vectors. Exception or interrupt handlers can be attached to any given vector with the **intConnect( )** and **intVecSet( )** routines. Note that for interrupt sources whose lines are shared on a PCI bus, the **pciIntConnect( )** routine should be used to attach the handler. The files *installDir*/**vxworks-6.2/target/h/arch/mips/ivMips.h** and *bspname*.**h** list the vectors used by VxWorks.

VxWorks for MIPS follows the same stack conventions as all other VxWorks 6.x architectures. There is a single interrupt stack, per-task exception stacks, and per-task execution stacks.

### Interrupt Support Routines

Because the MIPS architecture does not use interrupt levels, the **intLevelSet( )** routine is not implemented. The six external interrupts and two software interrupts can be masked or enabled by manipulating eight bits in the status register with **intDisable( )** and **intEnable( )**. Be careful to pass correct arguments to these routines because the MIPS status register controls much more than interrupt generation.

For interrupt control, the **intLock( )** and **intUnlock( )** routines are recommended. The **intLock( )** routine prevents interrupts from occurring while the current task is running. However, if some action is taken that causes another task to run (such as a call to **semTake( )** or **taskDelay( )**), the **intLock( )** routine is not honored while the other task is running. For more information, see the reference entry for **intLock( )**.

To change the default status register with which all tasks are spawned, use the **taskSRInit( )** routine. The **taskSRInit( )** routine is provided in case the BSP must mask any interrupts from all tasks. This is useful for systems that do not connect each interrupt line to an appropriate signal or that connect the lines to unwanted signals. Such lines can cause spurious interrupts. Masking these interrupts can prevent this from occurring. When using this routine, call it before **kernelInit( )** in **sysHwInit( )**.

The **intConnect( )** and **intVecSet( )** routines handle attaching interrupt handlers to any given vector. Any vectors not currently defined in **ivMips.h** are available for use. Vector numbers should be defined in the board-specific **include** file. The **intVecBaseSet( )** routine has no meaning on MIPS processors; calling it has no effect.

The data structure **intPrioTable**, found in **sysLib.c**, is a board-dependent array that aids in the processing of the eight MIPS interrupt sources. Each entry in the array consists of a structure composed of four fields: the interrupt ID, the vector number, the mask field, and the demultiplex field. A typical structure definition and table are as follows:

```
typedef struct
    {
    ULONG intCause;           /* CAUSE IP bit of int source  */
    ULONG bsrTableOffset;     /* index into BSR table        */
    ULONG intMask;            /* interrupt mask              */
    ULONG demux;              /* demultiplex argument        */
    } PRIO_TABLE;

PRIO_TABLE intPrioTable[] =
    {
    {CAUSE_SW1,(ULONG) IV_SWTRAP0_VEC, 0x0100, 0},   /* sw trap 0 */
    {CAUSE_SW2,(ULONG) IV_SWTRAP1_VEC, 0x0200, 0},   /* sw trap 1 */
    {CAUSE_IP3,(ULONG) sysVmeDeMux, 0x0400,
    IV_VME_BASE_VEC},                                /* VME muxed */
    {CAUSE_IP4,(ULONG) sysIoDeMux, 0x0800,
    IV_IO_BASE_VEC},                                 /* IO muxed  */
    {CAUSE_IP5,(ULONG) IV_TIMER0_VEC, 0x1000, 0},    /* timer 0   */
    {CAUSE_IP6,(ULONG) sysFpaDeMux, 0x2000,
    IV_FPA_BASE_VEC},                                /* FPA muxed */
    {CAUSE_IP7,(ULONG) IV_TIMER1_VEC, 0x4000, 0},    /* timer 1   */
    {CAUSE_IP8,(ULONG) IV_BUS_ERROR_VEC, 0x8000, 0}  /* bus error */
    };
```

When an interrupt is received, the handler maps the highest-priority pending line to its corresponding table entry. It does so in three steps. First, the demultiplex field is read. If the field is zero, field two is taken as the vector number for the BSR table. Otherwise, field two is interpreted as a demultiplex function and called with field four passed as its parameter. When multiple sources share an interrupt line, the job of the demultiplex function is to calculate a desired vector number and pass it back to the handler. Next, the mask field is read, and interrupts not currently pending and not masked are re-enabled. Finally, the handler uses the vector number as an index into the BSR table and calls the interrupt service routine previously installed by the user with **intConnect( )** or **intVecSet( )**.

Because tying interrupting sources to the processor's interrupt lines is board-dependent and sometimes arbitrary, VxWorks allows the BSP author to set the prioritization of interrupt lines. The pointer **sysHashOrder** points to a lookup

table that the interrupt handler uses to perform the actual mapping of pending interrupt lines to a corresponding table entry in **intPrioTable**. The operation of the lookup table is simple; that is, the IP field of the cause register is used as an index into the lookup table to obtain a value that is then used as an index into **intPrioTable**.

#### Acknowledging the Interrupt Condition

Because MIPS processors do not provide an IACK cycle, it is the job of the user-attached interrupt handler to acknowledge (or clear) the interrupt condition. The **sysAutoAck( )** routine must be provided as a default handler for any possible interrupt condition. If a spurious interrupt occurs, it is the job of **sysAutoAck( )** to acknowledge the interrupt condition. If an interrupt condition is not acknowledged, VxWorks tries continuously to process the interrupt condition, resulting in a **workQPanic( )** event. If this occurs, a warm reset will fail to auto-boot the target because the VxWorks environment variables have been corrupted by an interrupt stack that has overflowed. A cold start will copy the variables back into memory.

#### Interrupt Inversion

When a single interrupt is pending in the cause register, the kernel masks out that interrupt's bit before dispatching it to the interrupt handler. The kernel performs this mask operation using the contents of the cause register in combination with field three of the table **intPrioTable**. Interrupts not masked and not currently pending are re-enabled. Often, the field three value only explicitly masks its own interrupt. As a result, any subsequent interrupt, even if it is of a lower priority, can interrupt the interrupt service routine (ISR). This is known as interrupt inversion.

To prevent interrupt inversion, modify the interrupt masks listed in **intPrioTable.** The new values should mask not only the interrupt in question, but all lower-priority interrupts as well. For example, the interrupt mask for the highest-priority interrupt is 0xff00. Similarly, the next-highest priority interrupt mask is 0x7f00. These values explicitly mask the interrupt and all lower-priority interrupts.

Keep in mind that the value of the appropriate interrupt mask is also dependent upon whether the least significant bit (LSB) or the most significant bit (MSB) of the

mask is the highest priority. If the LSB is the highest priority, the masks are as shown in Table 5-4:

Table 5-4 **Interrupt Mask Values When LSB Is Highest Priority**

| Priority of the interrupt being serviced | Mask value required to prevent an equal- or lower-priority interrupt from being acknowledged |
|---|---|
| 0 (software, highest) | 0xff00 |
| 1 | 0xfe00 |
| 2 | 0xfc00 |
| 3 | 0xf800 |
| 4 | 0xf000 |
| 5 | 0xe000 |
| 6 | 0xc000 |
| 7 (lowest) | 0x8000 |

If the MSB is the highest priority, the masks are as shown in Table 5-5:

Table 5-5 **Interrupt Mask Values When MSB Is Highest Priority**

| Priority of the interrupt being serviced | Mask value required to prevent an equal- or lower-priority interrupt from being acknowledged |
|---|---|
| 0 (software, lowest) | 0x0100 |
| 1 | 0x0300 |
| 2 | 0x0700 |
| 3 | 0x0f00 |
| 4 | 0x1f00 |
| 5 | 0x3f00 |
| 6 | 0x7f00 |
| 7 (highest) | 0xff00 |

Note that due to the processor's mapping of bits 1 and 0 to software interrupts, most MIPS BSPs select the MSB as the highest priority. This causes hardware interrupts to take precedence over software interrupts.

### VMEbus Interrupt Handling

The VMEbus has seven interrupt levels. On most MIPS VME boards, these interrupts are bound to a single interrupt line. This requires software to sense the VMEbus interrupt and demultiplex the interrupt condition to a single pending interrupt level. This can be performed using **intPrioTable**.

It is possible to bind to VMEbus interrupts without vectored interrupts enabled, as long as the VMEbus interrupt condition is acknowledged with **sysBusIntAck( )**. In this case, there is no longer a direct correlation with the vector number returned during the VMEbus IACK cycle. The vector number used to attach the interrupt handler corresponds to one of the seven VMEbus interrupt levels as defined in *bspname***.h**. Mapping the seven VMEbus interrupts to a single MIPS interrupt is board-dependent.

Vectored interrupts do not change the handling of any interrupt condition except VMEbus interrupts. All of the necessary interrupt-acknowledgement routines are provided in either **sysLib.c** or **sysALib.s**.

### Extended Interrupts on the RM9000

In the original MIPS architecture, provision is made for eight interrupt sources: six hardware interrupts and two software interrupts. For most MIPS targets, this is sufficient. With the advent of more complex embedded systems, six hardware interrupts may not suffice. One common solution is to multiplex multiple interrupt sources onto a single interrupt pin. This approach requires two levels of processing to handle each interrupt. First, it must be determined that the interrupt came from the multiplexed interrupt input. Second, the multiplexed input that caused the interrupt must be determined.

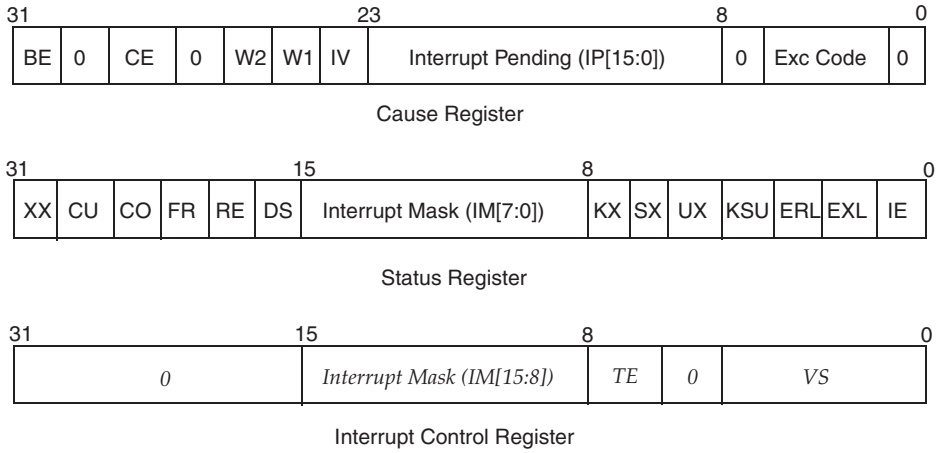
The PMC Sierra RM9000 family of processors provides an alternative solution. These processors make provisions for four additional hardware interrupt inputs. This allows additional expansion without requiring multiple interrupts to be multiplexed on a single input.

PMC Sierra implemented this change in a manner consistent with the original design of the status and cause registers. Specifically, the Interrupt Pending (IP) field of the cause register was extended from 8 to 16 bits, as shown in Figure 5-1. Six of these bits are now defined; the remaining two are reserved for future use. This expansion of the IP field was possible because the added bits were not previously defined.

However, the status register did not have extra bits available for the needed additional interrupt mask fields. Therefore, the mask bits had to be placed in a new register, the interrupt control register (Coprocessor 0, Set 1, Register 20), shown in Figure 5-1. This field is considered to be an extension of the Interrupt Mask (IM) field, and mask bits for interrupts 15:8 are placed in bits 15:8 of the interrupt control register.



Figure 5-1 **RM9000 Register Formats**




While four additional hardware interrupts have been added, *six* bits of the extensions to the IP and IM fields have been used. Bits 11:8 of these fields correspond to the newly added hardware interrupt inputs. Bit 12 is used to control the Timer interrupt source that was multiplexed with Interrupt input 5 in the original design. For backward compatibility, the Timer interrupt may still be placed on Interrupt 5, but setting the TE bit (bit 7) of the interrupt control register frees Interrupt 5 for use solely as a hardware input, and moves the Timer interrupt to Interrupt 12. The second additional interrupt input is used in conjunction with the Performance Counters implemented in the RM9000 family. This has been placed on Interrupt 13.

The additional hardware interrupts on the RM9000 family add to the **intPrioTable** that is used by the exception and interrupt handling routines in **excLib** to call a user-attached interrupt handler. A typical extended interrupt table is as follows:

```
PRIO_TABLE intPrioTable[] =
{
    {CAUSE_SW1,(ULONG) IV_SWTRAP0_VEC,  0x000100, 0},   /* sw trap 0      */
    {CAUSE_SW2,(ULONG) IV_SWTRAP1_VEC,  0x000200, 0},   /* sw trap 1      */
    {CAUSE_IP3,(ULONG) IV_IORQ0_VEC,    0x000400, 0},   /* Reserved       */
```

```
    {CAUSE_IP4,(ULONG) IV_IORQ1_VEC,     0x000800, 0},   /* Uart           */
    {CAUSE_IP5,(ULONG) IV_IORQ2_VEC,     0x001000, 0},   /* Expansion Conn */
    {CAUSE_IP6,(ULONG) IV_IORQ3_VEC,     0x002000, 0},   /* Expansion Conn */
    {CAUSE_IP7,(ULONG) IV_IORQ4_VEC,     0x004000, 0},   /* Expansion Conn */
    {CAUSE_IP8,(ULONG) IV_TIMER_VEC,     0x008000, 0},   /* Timer          */
    {CAUSE_IP9,(ULONG) IV_IORQ6_VEC,     0x010000, 0},   /* Expansion Conn */
    {CAUSE_IP10,(ULONG)IV_IORQ7_VEC,     0x020000, 0},   /* Expansion Conn */
    {CAUSE_IP11,(ULONG)IV_IORQ8_VEC,     0x040000, 0},   /* Expansion Conn */
    {CAUSE_IP12,(ULONG)IV_IORQ9_VEC,     0x080000, 0},   /* Expansion Conn */
    {CAUSE_IP13,(ULONG)IV_IORQ10_VEC,    0x100000, 0},   /* Alternate Tmr  */
    {CAUSE_IP14,(ULONG)IV_IORQ11_VEC,    0x200000, 0},   /* Perf Counter   */
    {CAUSE_IP15,(ULONG)IV_IORQ12_VEC,    0x400000, 0},   /* Reserved       */
    {CAUSE_IP16,(ULONG)IV_IORQ13_VEC,    0x800000, 0},   /* Reserved       */
};
```

Corresponding to the expansion of **intPrioTable** for extended interrupts, the **sysHashOrder** table lookup also required modification. Due to memory considerations, the size of the lookup table was not increased from 256 (2^8) to 16384 entries (2^14). Instead, the lookup table pointed to by **sysHashOrder** is left at 256 entries, and the cause register pending bits are checked in two separate iterations. The first iteration uses the interrupt sources corresponding to IP[7:0]. If none of those sources is active, a second lookup is performed using the interrupt sources corresponding to IP[15:8]. The value from the lookup table in the second iteration is automatically increased by 8 to place the proper offset into **intPrioTable**. As a result of this design decision, interrupt sources in the status register IM[7:0] are always given higher priority than those sources in the interrupt control register IM[15:8].

For more details on register formats on the RM9000, see the PMC Sierra *RM9000x2 Integrated Multiprocessor Data Sheet*.

### 5.4.8 Memory Management Unit (MMU)

MIPS processors include a minimal memory management unit commonly referred to as the translation lookaside buffer (TLB). This release of VxWorks supports the TLB in mapped kernels. MIPS processors provide three different modes of operation: user mode, kernel mode, and supervisor mode. The VxWorks kernel runs in kernel mode. RTPs run in user mode for mapped kernels and in kernel mode for unmapped kernels. *Supervisor mode*, as described in MIPS documentation, is not used. However, some Wind River documentation refers to *supervisor mode*. In this context, the reader should substitute the MIPS-equivalent term, *kernel mode*.

### 5.4.9 AIM Model for MMU

The Architecture-Independent Model (AIM) for MMU provides an abstraction layer to interface with the underlying architecture-dependent MMU code. This allows uniform access to the hardware-dictated MMU model that is typically CPU core specific. AIM for MMU is for VxWorks internal use. However, the new model adds support for a new routine, **vmPageLock( )** to the VxWorks **vmLib** API. For more information on this routine, see the reference entry for **vmPageLock( )**. All MIPS architecture variants supported in this release implement the AIM for MMU and the new routine.



**vmPageLock( )** requires the use of static MMU entries. To ensure minimal resource usage, this routine requires alignment of the lock regions. This routine provides a mechanism for reducing page misses and should boost performance when used correctly.

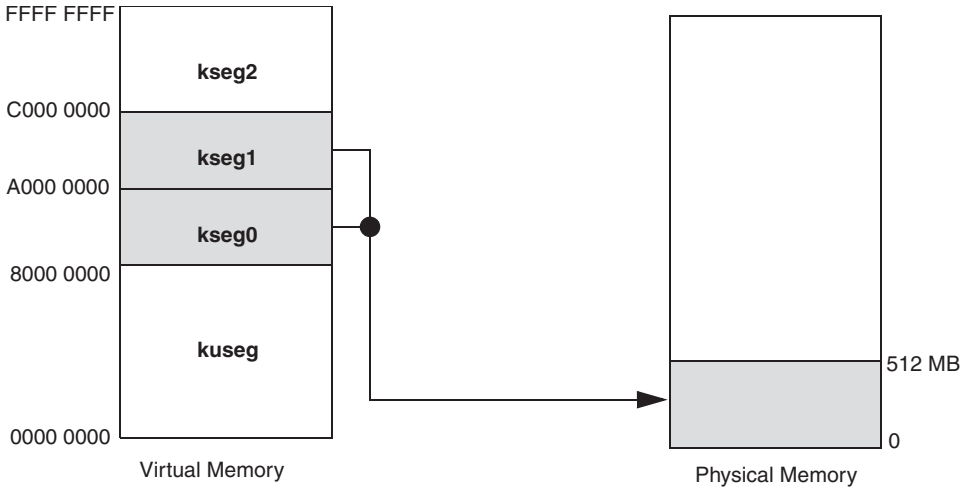
Page locking of a text section will fail if the alignment and size of the text section is such that the number of resources available is not sufficient to satisfy the required number of MMU resources. If the BSP uses too many resources, it may not be possible to enable this feature. Because not all MIPS processors have the same number of resources, page locking requests that succeed on one processor may fail on another.

The MIPS architecture uses a basic page size of 4 KB. However, because each MMU resource controls a pair of 4 KB pages, the minimum (and default) page size for MIPS is 8 KB, so that the two 4 KB pages can be controlled together.

### 5.4.10 Virtual Memory Mapping

The MIPS memory map is arranged in segments that have pre-determined modes of operation. Unlike some processors that can set specific virtual memory addresses to any mode of operation, MIPS processors pre-assign certain ranges of virtual memory addresses to kernel mode or user mode.

Figure 5-2 **MIPS Memory Map - Unmapped Kernel**




As indicated in Figure 5-2, VxWorks operation is limited to kernel mode in the two unmapped memory segments, **kseg0** and **kseg1**. A physical addressing range of 512 MB is available. The on-chip translation lookaside buffer (TLB) is not supported in this mode therefore access to **kuseg** and **kseg2** is not available.

To summarize the **kseg0** and **kseg1** segments:

**kseg0**
When the most significant three bits of the virtual address are 100, the $2^{29}$–byte (512 MB) kernel physical space, labeled **kseg0**, is the virtual address space selected. The physical address selected is defined by subtracting 0x8000.0000 from the virtual address. The cache mode for these accesses is determined by the K0 field of the configuration register, which is initialized in the BSP **romInit( )** routine.

**kseg1**
When the most significant three bits of the virtual address are 101, the $2^{29}$–byte (512 MB) kernel physical space, labeled **kseg1**, is the virtual address space selected. The physical address selected is defined by subtracting 0xA000.0000 from the virtual address. Caches are always disabled for accesses to these addresses; physical memory or memory-mapped I/O device registers are accessed directly.

Figure 5-3 **MIPS Memory Map - Mapped Kernel**

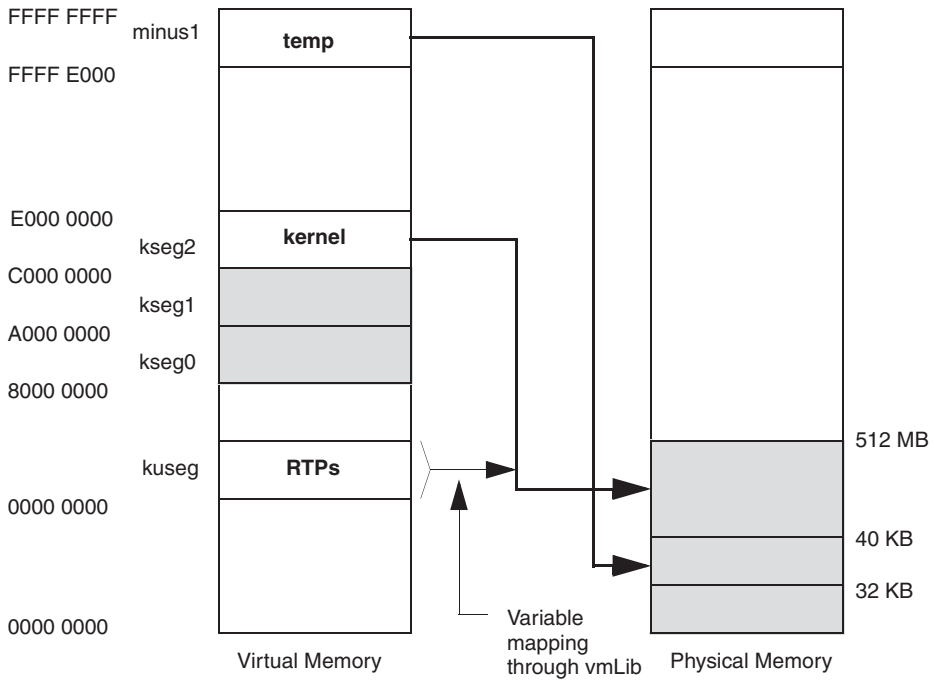



Figure 5-3 illustrates the memory map used for mapped kernels. In mapped mode, kernel text and data are located in **kseg2**, while RTPs operate in **kuseg**. A region at the top of the 32-bit address space is used for temporary storage of working variables during exception processing. The descriptions of the additional segments **kseg2**, **kuseg**, and **minus1** are as follows:

**kuseg**

When the most significant three bits of the virtual address are 000, the $2^{31}$–byte user virtual space, labeled **kuseg**, is selected. Access to **kuseg** addresses requires a TLB entry to map that virtual address to a physical address. The specifics of the translation between virtual and physical addresses are dynamic and managed by the virtual memory (VM) library. Cache characteristics and write protection are controlled (through the VM library) by control bits in the TLB entry, and may be selected on a page-by-page basis.

**kseg2**

When the most significant three bits of the virtual address are 110, the $2^{29}$–byte kernel virtual space, labeled **kseg2**, is selected. Access to **kseg2** addresses

requires a TLB entry to map those virtual addresses to corresponding physical addresses. There is a fixed relationship between virtual addresses in the kernel text section and corresponding physical addresses: subtracting 0xc0000000 from the virtual address results in the physical address. This relationship may not be depended upon for other addresses in **kseg2**.

**minus1**
The region marked **minus1** in the mapped kernel memory map is a statically mapped virtual region used for temporary storage of variables that are used during exception and interrupt handling.

### 5.4.11 Memory Layout

#### Unmapped Kernels

The memory layout of an unmapped MIPS kernel occupies memory in segments **kseg0** and **kseg1**. The value **LOCAL_MEM_LOCAL_ADRS**, defined in the BSP **config.h** file, indicates the start of memory for the system. For single core BSPs, this value is 0x80000000, the virtual starting address of **kseg0**. In multi-core BSPs, this value is normally adjusted for each subsequent core, depending upon the system requirements.

The boot ROM is responsible for setting up the system and loading the VxWorks kernel into memory. The memory layout is set up by the boot ROM in a three-step process, as shown in Figure 5-4. First, the initial boot loading routines located at **ROM_TEXT_ADRS** are executed. These routines copy data from **ROM_TEXT_ADRS** to **RAM_LOW_ADRS** and uncompress the data, if necessary. Once in RAM, the boot process continues by loading the VxWorks kernel. The constants **RAM_LOW_ADRS**, **RAM_HI_ADRS**, and **ROM_TEXT_ADRS** are located in the BSP **config.h** and **Makefile** files. **LOCAL_MEM_SIZE** and **LOCAL_MEM_LOCAL_ADRS** are located in **config.h**.

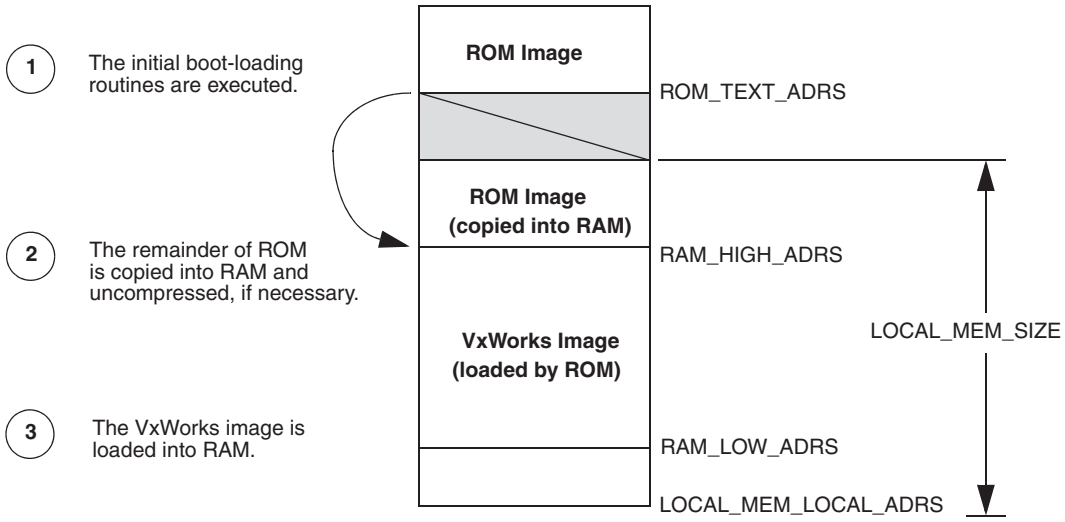
#### Mapped Kernels

The memory layout of a mapped MIPS kernel occupies memory in **kseg2** for the kernel text and data sections, **kseg0** and **kseg1** for vectors and DMA device buffers, **kuseg** for RTPs, and **minus1** for variable storage while entering and exiting exception handling code. For single core BSPs, the value of **LOCAL_MEM_LOCAL_ADRS** is typically defined as 0xC0000000 (the virtual starting address of **kseg2**) for mapped kernels. In multi-core BSPs, **LOCAL_MEM_LOCAL_ADRS** is normally adjusted for each subsequent core, depending upon the system requirements.

Because the MMU is not yet set up when the boot ROM runs, the mapped kernel is loaded into **kseg0**, just as it is for unmapped kernels. However, the **kseg0** address is an alias of the **kseg2** address at which the kernel is linked. When the boot ROM loads the mapped kernel and transfers to its entry point, the mapped kernel sets up the MMU so that the kernel text and data can be accessed at their mapped addresses in **kseg2**. Then, the boot process continues by running from **kseg2**.

It should be noted that alternate values are required for **LOCAL_MEM_LOCAL_ADRS**, **RAM_LOW_ADRS**, and **RAM_HIGH_ADRS** for mapped kernels. The mapped kernel build mechanism takes these differences into account.

Figure 5-4 **MIPS Memory Layout Process**




**NOTE:** The values for **LOCAL_MEM_LOCAL_ADRS**, **RAM_LOW_ADRS**, and **RAM_HIGH_ADRS** shown in Figure 5-4 correspond to the boot ROM (or unmapped kernel) values, which are always located in unmapped memory. Different values for these variables are used when linking a mapped kernel.

The details of the VxWorks image are shown in Figure 5-5. The figure contains the following labels:

**Exception Vectors**
Table of exception and interrupt vectors. It is located at the base of kseg0, 0x80000000 for both mapped and unmapped kernels.

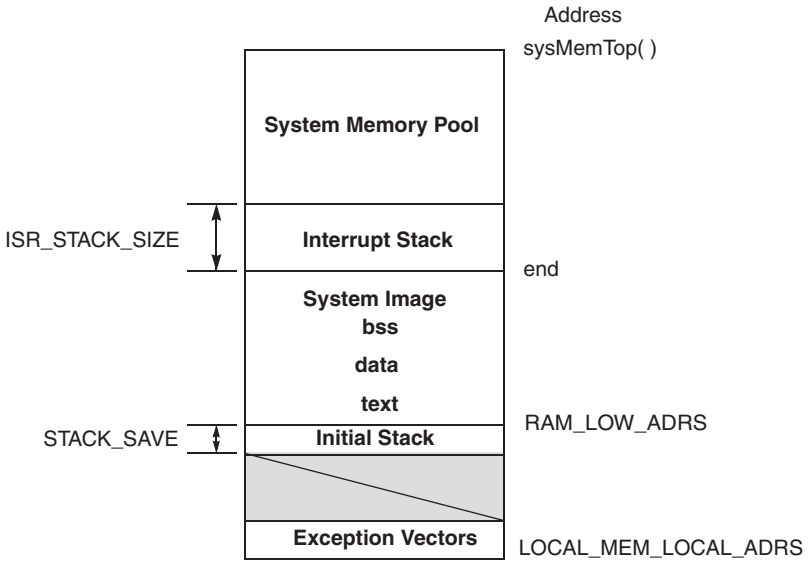
**Initial Stack**
Initial stack set up by **romInit( )** and used by **usrInit( )** until **usrRoot( )** has allocated the stack. Its size is determined by **STACK_SAVE**.

**System Image**
The VxWorks image entry point. The VxWorks image consists of three segments: **.text**, **.data**, and **.bss**.

**Interrupt Stack**
The stack used by interrupt service routines. Its size is determined by **ISR_STACK_SIZE**. It is placed at the end of the VxWorks image, before the kernel heap.

**System Memory Pool**
The memory allocated for system use. The size of the memory pool is dependent on the size of the system image and interrupt stack. The end of the system memory pool is determined by **sysMemTop( )**.

Figure 5-5 **VxWorks Image in MIPS Memory Layout**



### 5.4.12 64-Bit Support

VxWorks provides real-time applications with access to a 64-bit data type. This allows applications to perform 64-bit calculations for enhanced performance.

The **long long** data type is available for both MIPS32 and MIPS64. However, in MIPS32, two 32-bit registers are paired to represent a 64-bit value. In MIPS64, such a value is a true 64-bit value represented by a 64-bit register. For better performance in your MIPS64 applications, use the **long long** data type when representing 64-bit values.

Support for 64-bit virtual addresses is not provided by VxWorks. That is, all pointer data types are 32-bits in length.



## 5.5 Reference Material

Comprehensive information regarding MIPS hardware behavior and programming is beyond the scope of this document. MIPS Technologies, Inc. provides several hardware and programming manuals for the MIPS processor on its Web site:

**http://www.mips.com/**

Wind River recommends that you consult the hardware documentation for your processor or processor family as necessary during BSP development.

#### MIPS Architecture References

The information given in this section is current at the time of writing; should you decide to use these documents, you may wish to contact the manufacturer or publisher for the most current version.

*See MIPS Run*. Sweetman, Dominic. Morgan Kaufmann Publishers, Inc., San Francisco, CA. 1999.

# 6 PowerPC



## 6.1 Introduction

This chapter provides information specific to VxWorks development on supported PowerPC processors.

## 6.2 Supported Processors

Table 6-1 shows the processor core types supported by this VxWorks for PowerPC release.

Table 6-1 **Supported PowerPC Processor Core Types**

| VxWorks PowerPC CPU Family | Description |
|---|---|
| PPC403 | Includes PowerPC 403 processor cores.<br>Note that PowerPC 403 is an obsolete core and is not recommended for use in new development. The core is still supported for legacy reasons. |
| PPC405 | Includes PowerPC 405 processor cores. |
| PPC440 | Includes PowerPC 440 processor cores. |
| PPC603 | Includes PowerPC 603, MPC82XX, and MPC83XX processor cores. |
| PPC604 | Includes MPC7XX and MPC74XX processor cores as well as PowerPC 604, 750CX, 750FX, and 750GX cores. |
| PPC85XX | MPC85XX |
| PPC860 | Includes MPC860 processor cores. |
| PPC32 | Includes PowerPC 970 and PowerPC 440EP processor cores.<br>Note that PowerPC 970 support is limited to 32-bit mode. |

**NOTE:** Support for additional processor core types may be added periodically. See the Wind River Online Support Web site for the latest information.

## 6.3 Interface Variations

This section describes particular functions and tools that are specific to PowerPC targets in any of the following ways:

- available only for PowerPC targets
- parameters specific to PowerPC targets
- special restrictions or characteristics on PowerPC targets

For complete documentation, see the reference entries for the libraries, routines, and tools discussed in the following sections.



### 6.3.1 Stack Frame Alignment

The stack frame alignment for all PowerPC CPU families is now 16 bytes. In earlier versions of VxWorks (prior to 6.0), only PowerPC 604 (including the MPC74XX family) and MPC85XX had 16-byte stack alignment. Other CPU families had 8-byte stack alignment by default. Therefore, for these CPU families, objects compiled for earlier versions of VxWorks must be recompiled for this VxWorks release.

**NOTE:** In general, Wind River recommends that you recompile your code and that you do not reuse objects compiled for a different environment, including an older version of VxWorks.

### 6.3.2 Small Data Area

Both the GNU compiler and the Wind River Compiler support small data area (SDA). However, this release of VxWorks for PowerPC does not support the small data area feature for kernel code. Therefore, for the GNU compiler, the **-msdata** compiler flag must not be used. In addition, Wind River recommends that you use the **-G0** option on the command line as well. The default configuration for the Wind River Compiler selects the no SDA setup, which has the equivalent effect of specifying the optional flags of **-Xsmall-data=0** and **-Xsmall-const=0**.

### 6.3.3 HI and HIADJ Macros

The **HI** and **HIADJ** macros are used in PowerPC assembly code to facilitate the loading of immediate operands larger than 16 bits. The macro **HI(***x***)** is the simple high-order 16 bits of the value *x*. The macro **HIADJ(***x***)** is the high-order 16 bits adjusted by the MSB (most significant bit) of the low-order 16 bits of value *x*. That is, if the MSB is set, **HIADJ(***x***)** truncates the lower 16 bits and adjusts the resulting value by adding 1 to the upper 16 bits.

The macro **HIADJ(***x***)** must be used whenever the low-order 16 bits are used in an instruction that interprets them as a signed quantity (for instance, **addi** or **lwz**). If the low-order bits are used in an instruction that interprets them as an unsigned quantity (for instance, **ori**), the proper macro **HI**, not **HIADJ**, should be used.

For example, **addi** uses a *signed* quantity, so **HIADJ** is the proper macro:

```
lis   rx, HIADJ(VALUE)
addi  rx, rx, LO(VALUE)
```

However, **ori** uses an *unsigned* quantity, so **HI** is the proper macro:

```
lis   rx, HI(VALUE)
ori   rx, rx, LO(VALUE)
```

### 6.3.4 Memory Management Unit (MMU)

This section describes the memory management unit (MMU) implementation for PowerPC processors and how its use varies from the standard VxWorks implementation.

#### Instruction and Data MMU

The PowerPC MMU introduces a distinction between instruction and data MMU and allows them to be separately enabled or disabled. Two parameters, **USER_I_MMU_ENABLE** and **USER_D_MMU_ENABLE**, are provided in the **Params** tab of the **Properties** window under **SELECT_MMU**. The default settings of these parameters are specified by the BSP. Wind River-supplied BSPs for PowerPC 405 and PowerPC 440 processors specify **USER_I_MMU_ENABLE** as **FALSE** because this setting provides performance benefits in images that do not support RTPs (see *PowerPC 405 Performance*, p.124 and *PowerPC 440 Performance*, p.126).
Wind River-supplied BSPs for other PowerPC processor types specify both **USER_I_MMU_ENABLE** and **USER_D_MMU_ENABLE** as **TRUE**.

**NOTE:** When configuring a VxWorks image for use with real-time processes (RTPs), both the instruction and the data MMU must be enabled.

### MMU Translation Model



The VxWorks PowerPC implementations share a common programming model for mapping 4 KB memory pages. The physical memory address space is described by the data structure **sysPhysMemDesc[ ]**, defined in **sysLib.c**. This data structure is made up of configuration constants for each page or group of pages. All of the configuration constants defined in the *VxWorks Kernel Programmer's Guide* are available for PowerPC virtual memory pages.

Use of the **MMU_ATTR_CACHE_DEFAULT** (or **VM_STATE_CACHEABLE)** constant sets the cache to copy-back mode.

In addition to **MMU_ATTR_CACHE_DEFAULT**, the following additional constants are supported:

- **MMU_ATTR_CACHE_WRITETHRU** (or **VM_STATE_CACHEABLE_WRITETHROUGH**)
- **MMU_ATTR_CACHE_OFF** (or **VM_STATE_CACHEABLE_NOT**)
- **MMU_ATTR_SUP_RWX** (or **VM_STATE_WRITEABLE**)
- **MMU_ATTR_PROT_SUP_READ** | **MMU_ATTR_PROT_SUP_EXE** (or **VM_STATE_WRITEABLE_NOT**)
- **MMU_ATTR_CACHE_COHERENCY** (or **VM_STATE_MEM_COHERENCY**)
- **MMU_ATTR_CACHE_GUARDED** (or **VM_STATE_GUARDED**)

**NOTE:** In VxWorks 5.5, memory protection attributes are set using various **VM_STATE**_*xxx* macros. These macros (as listed above) are still supported for this release. However, these macros may be removed in a future release. Wind River recommends that you use the **MMU_ATTR**_*xxx* macros for new development and that you update any existing BSP to use the new macros whenever possible. For more information on the **VM_STATE**_*xxx* macros, see the *VxWorks Migration Guide*.

**NOTE:** Memory coherency page state is only supported for PowerPC 603, PowerPC 604, MPC85XX, and PowerPC 970. On PowerPC 970 processors, the memory coherency attribute is not supported; PowerPC 970 always enforces memory coherency, whether the attribute is set or not.

The first constant sets the page descriptor cache mode field in cacheable write-through mode. Cache coherency and guarded modes are controlled by the

other constants. There is no default configuration, because each memory region may have specific requirements; see individual BSPs for examples.

For more information regarding cache modes, see *PowerPC Microprocessor Family: The Programming Environments.*

For more information on memory page states, state flags, and state masks, see the *VxWorks Kernel Programmer's Guide*: *Memory Management*.

### PowerPC 60x Memory Mapping

The PowerPC 603 (including MPC82XX and MPC83XX) and PowerPC 604 (including MPC7XX, MPC74XX, PowerPC 750CX, 750FX, and 750GX; collectively, the PowerPC 604 family) MMU supports two models for memory mapping. The first, the block address translation (BAT) model, allows mapping of a memory block ranging in size from 128 KB to 256 MB (or larger, depending on the CPU) into a BAT register. The second, the segment model, gives the ability to map the memory in pages of 4 KB. VxWorks for PowerPC supports both memory models.

#### PowerPC 603/604 Block Address Translation Model

The block address translation (BAT) model takes precedence over the segment model. However, the BAT model is not supported by the VxWorks **vmLib** or cache libraries. Therefore, routines provided by those libraries are not effective, and no errors are reported, in memory spaces mapped by BAT registers. Typically, in VxWorks, the BATs are only used to map large external regions, or PROM/flash, where fine grain control is unnecessary; this has the advantage of reducing the size of the page table entry (PTE) table used by the segment model.

All PowerPC 603 and PowerPC 604 family members include eight BATs: four instruction BATS (IBAT) and four data BATs (DBAT). The BAT registers are always active, and must be initialized during boot. Typically, **romInit( )** initializes all (active) BATs to zero so that they perform no translation. No further work is required if the BATs are not used for any address translation.

Motorola MPC7X5, MPC74X5, MPC8349, MPC8272, and MPC8280 CPUs have an additional four IBAT and four DBAT registers. These extra BATs can be enabled or disabled (**HID0** or **HID1**, depending on the CPU); they are disabled by hardware reset. Configuring these additional BATs for VxWorks is optional.

The IBM PowerPC 750FX also adds four IBAT and four DBAT registers, but these are always enabled. In this case, the additional BATs must be configured.

The data structure **sysBatDesc[ ]**, defined in **sysLib.c**, handles the BAT register configuration. All of the configuration constants used to fill **sysBatDesc[ ]** are defined in *installDir*/**vxworks-6.2/target/h/arch/ppc/mmu603Lib.h** for both the PowerPC 603 and the PowerPC 604. Providing the correct entries in **sysBatDesc[ ]** is sufficient to configure the basic four BATs; no additional software configuration is required. For information on configuring all eight BAT registers, see the following section. If **sysBatDesc[ ]** is not defined by the BSP, the BATs are left alone after being configured by **romInit( )**.



#### Enabling Additional BATs

If the extra BATs are to be used, the following steps must be performed in the BSP:

1. Extend the **sysBatDesc[ ]** array to provide initialization values for the additional BATs.
2. Select or write a BAT initialization routine. Initialization routines for the MPC7X5, MPC74X5, and PowerPC 750FX are provided with this release.
3. Connect the initialization routine to the function pointer provided by the kernel, so that the BATs are initialized at the proper time during MMU initialization.

The **sysBatDesc[ ]** array essentially doubles in size, and the order of the entries is fixed. The initial 16 entries are identical in meaning to the original array, so may remain unchanged. For example (from the **sp745x** BSP):

```
UINT32 sysBatDesc [2 * (_MMU_NUM_IBAT + _MMU_NUM_DBAT +
            _MMU_NUM_EXTRA_IBAT + _MMU_NUM_EXTRA_DBAT)] =
{
    /* I BAT 0 */
    ((ROM_BASE_ADRS & _MMU_UBAT_BEPI_MASK) | _MMU_UBAT_BL_1M |
    _MMU_UBAT_VS | _MMU_UBAT_VP),
    ((ROM_BASE_ADRS & _MMU_LBAT_BRPN_MASK) | _MMU_LBAT_PP_RW |
    _MMU_LBAT_CACHE_INHIBIT),

    0,0,    /* I BAT 1 */
    0,0,    /* I BAT 2 */
    0,0,    /* I BAT 3 */
    /* D BAT 0 */
    ((ROM_BASE_ADRS & _MMU_UBAT_BEPI_MASK) | _MMU_UBAT_BL_1M |
    _MMU_UBAT_VS | _MMU_UBAT_VP),
    ((ROM_BASE_ADRS & _MMU_LBAT_BRPN_MASK) | _MMU_LBAT_PP_RW |
    _MMU_LBAT_CACHE_INHIBIT),

    0,0,    /* D BAT 1 */
    0,0,    /* D BAT 2 */
    0,0,    /* D BAT 3 */
```

```
/*
* These entries are for the the I/D BATs (4-7) on the MPC7455/755.
* They should be defined in the following order.
* IBAT4U,IBAT4L,IBAT5U,IBAT5L,IBAT6U,IBAT6L,IBAT7U,IBAT7L,
* DBAT4U,DBAT4L,DBAT5U,DBAT5L,DBAT6U,DBAT6L,DBAT7U,DBAT7L,
*/
0,0,    /* I BAT 4 */
0,0,    /* I BAT 5 */
0,0,    /* I BAT 6 */
0,0,    /* I BAT 7 */
0,0,    /* D BAT 4 */
0,0,    /* D BAT 5 */
0,0,    /* D BAT 6 */
0,0     /* D BAT 7 */
};
```

The BAT initialization routine is declared as follows:

```
(void) myBatInitFunc (int * &sysBatDesc[0])
```

This routine reads **sysBatDesc[ ]**, initializes the BAT registers, and performs any other required setup; for example, configure **HID0** for MPC74X5. For additional BAT register numbers and configuration information, see the CPU-specific reference manual. The following example routines initialize the MPC7X5:

```
/*
* mmuPpcBatInitMPC74x5 initializes the standard 4 (0-3)  I/D BATs &
* the additional 4 (4-7) I/D BATs present on the MPC74[45]5.
*/

IMPORT void mmuPpcBatInitMPC74x5 (UINT32 *pSysBatDesc);
```

Finally, the BAT initialization routine must be connected to the MMU initialization hook, **_pSysBatInitFunc**, which is **NULL** by default:

```
IMPORT FUNCPTR _pSysBatInitFunc;

_pSysBatInitFunc = mmuPpcBatInitMPC7x5;
```

The assignment to **_pSysBatInitFunc** may be made conditional upon the value of the processor version register (PVR), to allow the same kernel to run on different CPUs.

#### PowerPC 603/604 Segment Model

The segment model allows memory to be mapped in 4 KB pages. All mapping attributes are defined in the individual page descriptors (write-through/copy-back, cache-inhibited, memory coherent, guarded, execute, and write permissions).

The application programmer interface for the PowerPC 603/604 memory mapping unit is the same as that described previously for the MMU translation model (see *MMU Translation Model*, p.119).

For PowerPC 604, the page table size depends on the total memory to be mapped. The larger the memory to be mapped, the bigger the page table. The VxWorks implementation of the segment model follows the recommendations given in *PowerPC Microprocessor Family: The Programming Environments*. The total size of the memory to be mapped is computed during MMU library initialization, allowing dynamic determination of the page table size. Table 6-2 shows the correspondence between the total amount of memory to map and the page table size for PowerPC 604 processors.



Table 6-2 **Page Table Size (PowerPC 604 only)**

| Total Memory to Map | Page Table Size |
|---|---|
| 8 MB or less | 64 KB |
| 16 MB | 128 KB |
| 32 MB | 256 KB |
| 64 MB | 512 KB |
| 128 MB | 1 MB |
| 256 MB | 2 MB |
| 512 MB | 4 MB |
| 1 GB | 8 MB |
| 2 GB | 16 MB |
| 4 GB | 32 MB |

### PowerPC 405 Memory Mapping

The PowerPC 405 memory mapping model allows memory to be mapped in 4 KB pages. The translation table is organized into two levels. The top level consists of an array of 1,024 Level 1 (L1) table descriptors; each of these descriptors can point to an array of 1,024 Level 2 (L2) table descriptors. All mapping attributes are defined in L2 descriptors (write-through/copy-back, cache-inhibited, guarded, execute, and write permissions).

The translation table size depends on the total memory to be mapped. The larger the memory to be mapped, the bigger the table.

**NOTE:** VxWorks allocates page-aligned descriptor arrays from the heap at virtual memory initialization time. This results in a small amount of initial memory fragmentation.

The application programmer interface for the PowerPC 405 memory mapping unit is the same as that described previously for the MMU translation model (see *MMU Translation Model*, p.119).

### PowerPC 405 Performance

For optimal performance, the number of translation lookaside buffer (TLB) entries for data access should be maximized. To eliminate instruction MMU contention for TLB entries, leave **USER_I_MMU_ENABLE** undefined except in cases where the system will be running RTPs. Because a virtual address is always the same as the real address in a system that is not running RTPs, enabling the instruction MMU provides no additional functionality but can result in a performance impact.

**NOTE:** **USER_I_MMU_ENABLE** must be defined for systems that require RTP support.

### PowerPC 440 Memory Mapping

The PowerPC 440 core provides a 36-bit physical address space and a 32-bit program (virtual) address space. The mapping is accomplished with translation lookaside buffers (TLBs), which are managed by software.

The PowerPC 440 is an implementation of the Book E processor specification. The MMU is always active and all program addresses are translated by the TLBs. The $MSR_{IS}$ and $MSR_{DS}$ bits are used to extend the virtual address space so that TLB lookups can happen from two different address spaces for either instruction or data references. This easily allows for a static map to be used for boot and basic operation when $MSR_{(IS,DS)} = (0,0)$ (VxWorks regards this as MMU “disabled”), and enables dynamic 4 KB page mapping (MMU “enabled”) when $MSR_{IS} = 1$ or $MSR_{DS} = 1$.

### Boot Sequencing

After a processor reset, the board support package sets up a temporary static memory model. The following steps are included in the BSP **romInit.s** module:

1. The processor receives a reset exception.
2. The processor hardware maps a single 4 KB page of memory at the top of the 32-bit program address space and branches to the reset vector (located in the last word of the program address space).
3. The reset vector contains a branch instruction to **resetEntry( )** (located within the last 4 KB of the program address space).
4. The **resetEntry( )** routine initializes the TLB entries to map the entire program address space to physical address space devices and memory, using large size (256 MB) translation blocks. Unused TLBs are marked as invalid. The $MSR_{IS}$ and $MSR_{DS}$ fields are set to zero, and execution continues with an **rti** to the **romInit( )** routine.



### Run-Time Support

The VxWorks kernel provides support for the PowerPC 440 memory management unit (MMU). To include this support, configure **INCLUDE_MMU_BASIC**.

VxWorks supports two cooperating models for memory mapping. The first, the *static model*, allows mapping of memory blocks ranging from 1 KB to 256 MB in size by dedicating an individual processor TLB entry to each block. The second, the *dynamic model*, provides the ability to map physical memory in 4 KB pages using the remaining available TLB entries in a round-robin fashion.

#### PowerPC 440 Static Model

The data structure **sysStaticTlbDesc[ ]**, defined in **sysLib.c**, describes the static TLB entry configuration. The number of static mappings is variable, depending on the size of the table, but should be kept to a minimum to allow the remaining TLB entries on the chip to be used for the dynamic model.

The static TLB entry registers are set by the initialization software in the MMU library.

Entry descriptions in **sysStaticTlbDesc[ ]** that set the **_MMU_TLB_TS_0** attribute are used when VxWorks has the MMU "disabled" (that is, $MSR_{(IS,DS)} = (0,0)$). Note that the VxWorks virtual memory library cannot represent physical addresses larger than the lowest 4 GB, and several of the PowerPC 440GP devices are located at higher physical addresses. To provide access to these devices when VxWorks has

the MMU "enabled" (that is, $MSR_{IS}$ = 1 or $MSR_{DS}$ = 1), some entry descriptions in **sysStaticTlbDesc[ ]** set attribute **_MMU_TLB_TS_1**.

All of the configuration constants used to fill **sysStaticTlbDesc[ ]** are defined in *installDir***/vxworks-6.2/target/h/arch/ppc/mmu440Lib.h**.

#### PowerPC 440 Dynamic Model

The PowerPC 440 dynamic mapping model allows memory to be mapped in 4 KB pages. The translation table is organized into two levels: the top level consists of an array of 1,024 Level 1 (L1) table descriptors; each of these descriptors can point to an array of 1,024 Level 2 (L2) table descriptors. All mapping attributes are defined in L2 descriptors (write-through/copy-back, cache-inhibited, guarded, execute, and write permissions).

The translation table size depends on the total memory to be mapped. The larger the memory to be mapped, the bigger the table.

**NOTE:** VxWorks allocates page-aligned descriptor arrays from the heap at virtual memory initialization time. This results in a small amount of initial memory fragmentation.

The application programmer interface for the PowerPC 440 dynamic model is identical to the MMU translation model described previously (see *MMU Translation Model*, p.119).

### PowerPC 440 Performance

For optimal performance, the number of TLB entries for data access should be maximized as follows:

1. Minimize the number of static entries defined in **sysStaticTlbDesc[ ]**.
2. Leave **USER_I_MMU_ENABLE** undefined, eliminating instruction MMU contention for dynamic TLB entries, except in cases where the system will be running RTPs. (Because a virtual address is always the same as the real address in a system that is not running RTPs, enabling the instruction MMU provides no additional functionality but can result in a performance impact.)

**NOTE:** **USER_I_MMU_ENABLE** must be defined for systems that require RTP support.

### MPC85XX Memory Mapping

The MPC85XX CPU uses 32-bit virtual and physical addressing similar to the PowerPC 60x processors.

The MPC85XX is an implementation of the Book E processor specification. The MMU is always active and all addresses are translated by a TLB0 (dynamic, fixed-4 KB size TLB) or a TLB1 (static, variable-size TLB) entry. This easily allows for a static map to be used for boot and basic operations when $MSR_{(IS,DS)} = (0,0)$ (VxWorks regards this as MMU "disabled"), and enables dynamic 4 KB page mapping when $MSR_{IS} = 1$ or $MSR_{DS} = 1$ (MMU "enabled").



### Boot Sequencing

After a processor reset, the board support package sets up a temporary static memory model. The following steps are included in the BSP **romInit.s** module:

1. The processor receives a reset exception.
2. The processor hardware maps a single 4 KB page of memory at the top of the 32-bit program address space and branches to the reset vector (located in the last word of the program address space).
3. The reset vector contains a branch instruction to **resetEntry( )** (located in the last 4 KB of the program address space).
4. The **resetEntry( )** routine initializes the TLB entries to map the entire program address space to physical address space devices and memory, using large size (256 MB) translation blocks. The internally mapped registers are mapped with a static TLB here also and the base address is changed to 0xFE000000.

### Run-Time Support

The VxWorks kernel provides support for the MPC85XX memory management unit (MMU). To include this support, configure **INCLUDE_MMU_BASIC**.

VxWorks supports two cooperating models for memory mapping. The first, the *static model*, allows mapping of memory blocks ranging from 1 KB to 256 MB in size by dedicating an individual processor TLB entry to each block. The second, the *dynamic model*, provides the ability to map physical memory in 4 KB pages using the remaining available TLB entries in a round-robin fashion.

#### MPC85XX Static Model

The data structure **sysStaticTlbDesc[ ]**, defined in **sysLib.c**, describes the static TLB entry configuration. The number of static mappings is variable, depending on

the size of the table, but should be kept to a minimum to allow the remaining TLB entries on the chip to be used for the dynamic model.

The static TLB entry registers are set by the initialization software in the MMU library.

Entry descriptions in **sysStaticTlbDesc[ ]** that set the **_MMU_TLB_TS_0** attribute are used when VxWorks has the MMU "disabled" (that is, $MSR_{(IS,DS)} = (0,0)$). All of the configuration constants used to fill **sysStaticTlbDesc[ ]** are defined in *installDir*/**vxworks-6.2/target/h/arch/ppc/mmuE500Lib.h**.

#### MPC85XX Dynamic Model

The MPC85XX dynamic mapping model allows memory to be mapped in 4 KB pages. The translation table is organized into two levels. The top level consists of an array of 1,024 Level 1 (L1) table descriptors; each of these descriptors can point to an array of 1,024 Level 2 (L2) table descriptors. All mapping attributes are defined in L2 descriptors (write-through/copy-back, cache-inhibited, guarded, execute, and write permissions).

The translation table size depends on the total memory to be mapped. The larger the memory to be mapped, the bigger the table.

**NOTE:** VxWorks allocates page-aligned descriptor arrays from the heap at virtual memory initialization time. This results in a small amount of initial memory fragmentation.

The application programmer interface for the MPC85XX dynamic model is identical to the MMU translation model described previously (see *MMU Translation Model*, p.119).

### MPC8XX Memory Mapping

The MPC8XX memory mapping model allows you to map memory in 4 KB pages; requests for larger page sizes are mapped into an appropriate number of 4 KB pages. The translation table is organized into two levels. The top level consists of an array of 1,024 Level 1 (L1) table descriptors; each of these descriptors can point to an array of 1,024 Level 2 (L2) table descriptors. Three mapping attributes are defined in the L1 descriptors (copy-back, write-through, and guarded cache modes), the others (cache off and all access permission attributes) are defined in the L2 descriptors. This affects granularity. For example, if one 4 KB page is mapped in copy-back mode, all pages within the corresponding 4 MB block (1,024 x 4 KB pages) are mapped in copy-back mode, except for any pages having cache

off defined. That is, the cache mode setting of a single page can affect the cache mode setting of all mapped pages in the block.

The application programmer interface for the MPC8XX memory mapping unit is described previously for the MMU translation model (see *MMU Translation Model*, p.119). MPC8XX processors that implement hardware memory coherency typically do not support the use of the **MMU_ATTR_CACHE_COHERENCY** (or **VM_STATE_MEM_COHERENCY**) attribute; the state **MMU_ATTR_CACHE_OFF** (or **VM_STATE_CACHEABLE_NOT**) identifies a page as memory-coherent.



#### RTP Limitation

The MPC8XX memory management unit (MMU) supports 16 unique address space identifiers (ASIDs). Therefore, only 15 real-time processes (RTPs) are supported as one ASID is reserved for kernel use.

### 6.3.5 Coprocessor Abstraction

Coprocessor abstraction decouples the core OS from the CPU-family-specific implementation of coprocessor features. Each architecture maps their coprocessors by logical number into the abstraction layer provided by the core OS. For PowerPC processors, the coprocessors are listed in Table 6-3.

Table 6-3 **PowerPC Coprocessors**

| Coprocessor Number | Name | Task Option Flag |
|---|---|---|
| 1 | Floating-Point | **VX_FP_TASK** |
| 2 | AltiVec | **VX_ALTIVEC_TASK** |
| 3 | SPE | **VX_SPE_TASK** |

### 6.3.6 vxLib

**vxTas( )**

The **vxTas( )** routine provides a C-callable interface to a test-and-set instruction, and it is assumed to be equivalent to **sysBusTas( )** in **sysLib**. Due to hardware limitations, VxWorks for certain PowerPC processors requires the operand of **vxTas( )** to be a cached address. Currently, this restriction applies to the MPC7450 family and the PowerPC 970.

### 6.3.7 AltiVec and PowerPC 970 Support

**NOTE:** The AltiVec features and requirements described in this section also apply to the IBM PowerPC 970 processor family which includes similar functionality. All documentation in this section applies to both AltiVec-enabled MPC74XX processors and similarly enabled PowerPC 970 processors unless otherwise noted.

AltiVec is a vector coprocessor and PowerPC instruction set extension introduced on the MPC74XX family of processors. (The IBM PowerPC 970 processors include similar functionality and are treated as AltiVec-enabled processors by VxWorks.) VxWorks treats AltiVec as an extension to the PowerPC 604 core; that is, a PowerPC 604 binary image can, in certain situations, run without modification on any AltiVec part, but the image does not provide access to, or control of, the AltiVec unit itself. This section describes the VxWorks implementation of AltiVec support, including:

- VxWorks run-time support for AltiVec
- Enabling AltiVec support
- C language extensions for vector types and formatted I/O
- Compiling modules that use the AltiVec unit
- Debugging extensions for AltiVec
- Workbench tool support; WTX and WDB extensions for AltiVec
- Known problems with C++ mixed linking of AltiVec and non-AltiVec modules

#### VxWorks Run-Time Support for AltiVec

The following features are supported for the AltiVec unit by the VxWorks kernel.

- Run-time detection of the AltiVec unit is possible using the **altivecProbe( )** routine. This routine is used internally by VxWorks to prevent attempts to enable AltiVec for a CPU that lacks such a unit. This allows a single build of a VxWorks kernel to run on boards that support both AltiVec and non-AltiVec parts, for example, the mv5100 family of boards can be configured with either an MPC750/755 or an MPC7400/7410 CPU.
- Tasks that use the AltiVec unit must be spawned with the **VX_ALTIVEC_TASK** option flag set.
- Tasks created without the **VX_ALTIVEC_TASK** option that use AltiVec instructions incur an AltiVec Unavailable Exception error, and the task is suspended.

- Tasks cannot be spawned with vector parameters. Only integer-sized parameters can be passed to **taskSpawn( )**.
- The MPC74XX processor's AltiVec registers are saved and restored as part of the task context. The VxWorks kernel saves and restores all 32 AltiVec registers when switching between AltiVec contexts. The value of the VRSAVE register is preserved, but not used, by the context switch code.
- The **altivecTaskRegsShow( )** routine displays values of AltiVec registers in the shell.
- The **altivecSave( )** and **altivecRestore( )** routines save and restore AltiVec register contents from memory. These routines can be called from interrupt handlers. Before calling these routines, the programmer must ensure that memory has been allocated to store the values, and that the memory is aligned on a 16-byte boundary.



The AltiVec-specific routines shown in Table 6-4 have been added to VxWorks.

Table 6-4 **AltiVec-Specific Routines**

| Routine | Command Syntax | Description |
|---|---|---|
| **altivecInit( )** | | Initializes AltiVec coprocessor support. |
| **altivecTaskRegsShow( )** | [*task*] | Prints the contents of the AltiVec registers of a task. |
| **altivecTaskRegsSet( )** | [*task*, ALTIVECREG_SET *] | Sets the AltiVec registers of a task. |
| **altivecTaskRegsGet( )** | [*task*, ALTIVECREG_SET *] | Gets the AltiVec registers from a task TCB. |
| **altivecProbe( )** | | Probes for the presence of an AltiVec unit. |
| **altivecSave( )** | [ALTIVEC_CONTEXT *] | Saves vector registers to memory. |
| **altivecRestore( )** | [ALTIVEC_CONTEXT *] | Restores vector registers from memory. |

Table 6-4 **AltiVec-Specific Routines** (cont'd)

| Routine | Command Syntax | Description |
|---|---|---|
| **vec_malloc( )** | `size_t` | Returns a 16-byte aligned pointer for an object of a given size. |
| **vec_calloc( )** | `size_t` *nObj*`, size_t` *size* | Returns a 16-byte aligned pointer for an array of *nObj* objects each of size *size*, initialized to 0. |
| **vec_realloc( )** | `void *p, size_t` *nbytes* | Increases the size of a 16-byte aligned buffer to *nbytes*. |
| **vec_free( )** | `void *p` | Deallocates the memory area pointed to by **p**. |

**NOTE:** Memory allocation in VxWorks for PowerPC 604 is always 16-byte aligned; **vec_malloc( )**, **vec_calloc( )**, and **vec_realloc( )** are aliases for **alloc( )**.

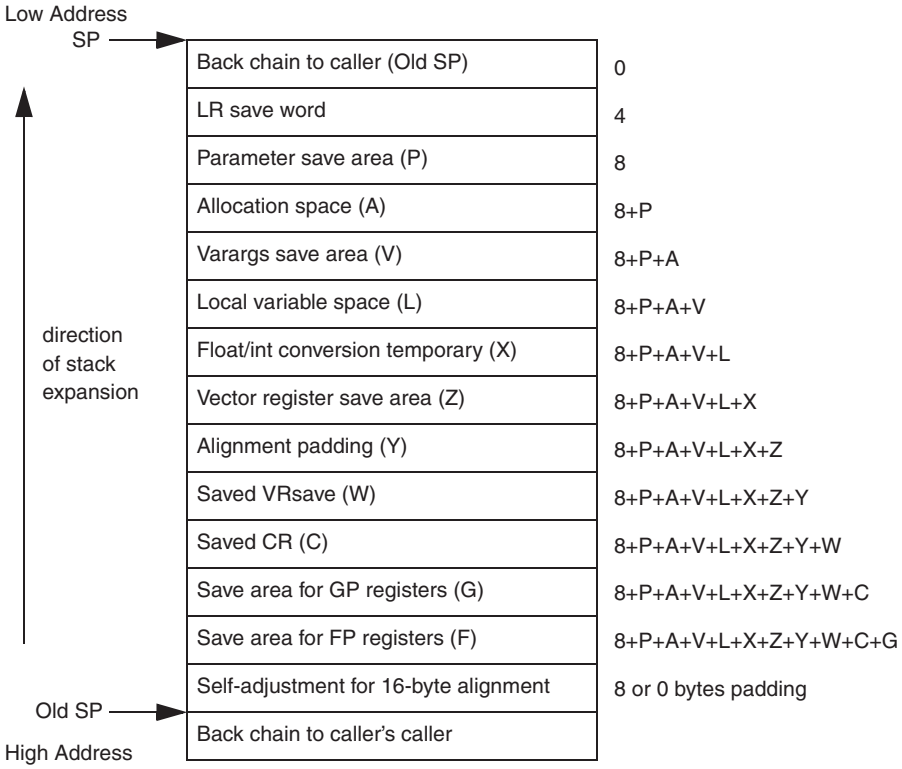
### Layout of the AltiVec EABI Stack Frame

The stack frame for routines using the AltiVec registers adds the following areas to the standard EABI frame:

- vector register save area (32 * 128 bytes)
- alignment padding (always zero bytes because the frame is always 16-byte aligned)
- saved VRSAVE register (4 bytes)

The stack frame layout for routines using the AltiVec registers is shown in Figure 6-1. Non-AltiVec stack frames are unchanged from prior VxWorks releases.

Figure 6-1 **Stack Frame Layout for Routines That Use AltiVec Registers**



### C Language Extensions for Vector Types

The AltiVec specification adds a new family of **vector** data types to the C language. **vector** types are 128 bits long, and are used to manipulate values in AltiVec registers. Under control of a compiler option, **vector** is now a keyword in the C and C++ languages. The AltiVec programming model introduces five new keywords as simple type-specifiers: **vector**, **__vector**, **pixel**, **__pixel**, and **bool**.

⚠ **CAUTION:** **vector** is used as both a C++ class name and a C variable name in the VxWorks header files and some BSP source files, and conflicts with the **vector** keyword. Where possible, use **__vector** rather than **vector** in VxWorks code as a precaution.

### Formatted Input and Output of Vector Types

The *AltiVec Technology Programming Interface Manual* also specifies vector conversions for formatted I/O. VxWorks supports the new formatted input and output of **vector** data types using the **printf( )** and **scanf( )** class routines shown in Table 6-5.

Table 6-5 **Vector Format Conversion Specifications**

| Character | Argument Type; Converted To |
|---|---|
| **%vc** | **vector unsigned char** |
| **%vd** | **vector signed int** |
| **%vhd** | **vector signed short** |
| **%vf** | **vector float** |
| **%vu** | **vector unsigned int** |
| **%vs** | null-terminated character string |

For a comprehensive discussion on the new format specifications, see the *AltiVec Technology Programming Interface Manual*. The following example program illustrates the input and output of sample **vector** values as well as several formatting variations.

```
void testFormattedIO()
    {
    __vector unsigned char s;
    __vector signed int I;
    __vector signed short SI;

    __vector __pixel P;

    __vector float F;

    s = (__vector unsigned char)
        ('0','1','2','3','4','5','6','7','8','9','A','B','C','D','E','F');

    I  = (__vector signed int) (99, 88, -34, 0);
    SI = (__vector signed short) (1, 2, -1, -2, 0, 3, 4, 5);
    P  = (__vector __pixel) (50, 51, 52, 53, 54, 55, 56, 57);
    F  = (__vector float) (-3.1415926, 3.1415926, 9.8, 0.000);

    printf("s = (%vc), (%,vc)\n\n", s, s);
    printf("I = (%,vd), (%,2vld), (%,_3lvi)\n\n", I, I, I);
    printf("I = (%,#vd), (%,vlx), (%,_lvX), (%vo)\n\n", I, I, I, I);
    printf("I = (%,#vd), (%,#vlp), (%,_lvp), (%#vo)\n\n", I, I, I, I);
    printf("SI = (%_vhd), (%:hvd), (%;vhi)\n\n", SI, SI, SI);
    printf("VECTOR STRING: (%vs)\n\n", "GOOD !!");
    printf("VECTOR PIXEL (%+:5hvi)\n\n", P);

    printf("VECTOR FLOAT *e5.6*: (%,5.6ve)\n", F);
    printf("VECTOR FLOAT *E5.6*: (%:5.6vE)\n", F);
    printf("VECTOR FLOAT *g5.6*: (%;5.6vg)\n", F);
    printf("VECTOR FLOAT *G5.6*: (%5.6vG)\n", F);
    printf("VECTOR FLOAT *f.7* : (%_.7vf)\n", F);
    printf("VECTOR FLOAT *e*   : (%ve)\n", F);
    }
```

This program generates the following output:

```
-> testFormattedIO
s = (0123456789ABCDEF), (0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F)

I = (99,88,-34,0), (99,88,-34, 0), ( 99_ 88_-34_  0)

I = (99,88,-34,0), (63,58,fffffde,0), (63_58_FFFFFFDE_0), (143 130 37777777736 0)

I = (99,88,-34,0), (0x63,0x58,0xfffffde,0x0), (0x63_0x58_0xfffffde_0x0),
(0143 0130 037777777736 0)

SI = (1_2_-1_-2_0_3_4_5), (1:2:-1:-2:0:3:4:5), (1;2;-1;-2;0;3;4;5)

VECTOR STRING: (GOOD !!)

VECTOR PIXEL (  +50:  +51:  +52:  +53:  +54:  +55:  +56:  +57)

VECTOR FLOAT *e5.6*: (-3.141593e+00,3.141593e+00,9.800000e+00,0.000000e+00)
VECTOR FLOAT *E5.6*: (-3.141593E+00:3.141593E+00:9.800000E+00:0.000000E+00)
VECTOR FLOAT *g5.6*: (-3.14159;3.14159;  9.8;    0)
VECTOR FLOAT *G5.6*: (-3.14159 3.14159   9.8     0)
```

```
VECTOR FLOAT *f.7* : (-3.1415925_3.1415925_9.8000002_0.0000000)
VECTOR FLOAT *e*   : (-3.141593e+00 3.141593e+00 9.800000e+00 0.000000e+00)
value = 76 = 0x4c = 'L'
->
```

### Compiling Modules with the Wind River Compiler to Use the AltiVec Unit

Modules that use the AltiVec registers and instructions must be compiled with the Wind River Compiler option: **-tPPC7400FV:vxworks62** (or **-tPPC970FV:vxworks62** for PowerPC 970). Use of this flag always enables the AltiVec keywords **__vector**, **__pixel**, and **__bool**.

The Wind River Compiler also enables the AltiVec keywords **vector**, **pixel**, **bool** (and **vec_step**) by default if the **-tPPC7400FV** (or **-tPPC970FV** for PowerPC 970) option is used. However, each keyword can be individually enabled or disabled with the Wind River Compiler (**dcc**) option **-Xkeywords=***mask*, where *mask* is a logical **OR** of the values in Table 6-6.

Table 6-6 **Wind River Compiler -Xkeywords Mask**

| Mask | Keyword Enabled |
|---|---|
| 0x01 | **extended** |
| 0x02 | **pascal** |
| 0x04 | **inline** |
| 0x08 | **packed** |
| 0x10 | **interrupt** |
| 0x20 | **vector** |
| 0x40 | **pixel** |
| 0x80 | **bool** |
| 0x100 | **vec_step** |

**NOTE:** Many non-AltiVec-specific keywords are also controlled by **-Xkeywords**.

For example, the following command-line sequence enables **bool** and **vec_step**, but disables **vector** and **pixel** (and also all of the non-AltiVec keywords in Table 6-6). For more information, see your release notes.

```
% dcc -tPPC7400FV:vxworks62 -Xkeywords=0x180-DCPU=PPC604
-DTOOL_FAMILY=diab -DTOOL=diab -c fioTest.c
```

⚠ **CAUTION:** **vector** is used as both a C++ class name and a C variable in the VxWorks header and source files, and conflicts with the **vector** keyword.



The version of the Wind River Compiler included with this VxWorks release is fully compliant with the Motorola AltiVec EABI document.

### Compiling Modules with GNU to Use the AltiVec Unit

Modules that use the AltiVec registers and instructions must be compiled with the **-Wa** and **-maltivec** flags (or **-mcpu=power4 -Wa** and **-mppc64bridge** for PowerPC 970). These flags enable the following five keywords as a new family of types: **bool**, **vector**, **__vector**, **pixel**, and **__pixel**.

⚠ **CAUTION:** **vector** is used as both a C++ class name and a C variable in the VxWorks header and source files, and conflicts with the **vector** keyword enabled by the **-maltivec** option.

The version of the GNU compiler included with this VxWorks release is fully compliant with the Motorola AltiVec EABI specification.

⚠ **CAUTION:** Examples of commonly used AltiVec-enabled routines are the **printf( )** and **scanf( )** family of routines. Applications calling these routines with more than eight integer-class or more than eight floating-point arguments may behave unpredictably.

### Extensions to the WTX Protocol for AltiVec Support

The presence and state of the AltiVec unit must also be communicated to the Workbench host tools, such as the debugger. The following WTX API routines are available for AltiVec support.

Table 6-7 **WTX API Routines for AltiVec Support**

| Routine | Command Syntax | Description |
|---|---|---|
| **wtxTargetHasAltivecGet( )** | **hWtx** | Returns **TRUE** if the target has an AltiVec unit. |

### C++ Exception Handling and AltiVec Support

Throwing C++ exceptions between modules compiled with different compiler flags may result in unexpected behavior. C++ exceptions save register state. Modules compiled with AltiVec support (using **-maltivec**) save all non-volatile AltiVec registers, but modules compiled without AltiVec support do not save any AltiVec registers. If a C++ exception is thrown from an AltiVec-enabled module, caught by a non-AltiVec enabled handler, and then thrown from there to an AltiVec-enabled handler that alters the AltiVec registers, it is possible to corrupt the saved AltiVec state. In particular, the non-volatile vector registers (v20 through v31) may be corrupted.

The following example illustrates the above scenario. It consists of a program composed of two files, **file1.cpp** and **file2.cpp**. Because **file2** is compiled with the **-maltivec** option, it is considered AltiVec code. **file1** is compiled without the **-maltivec** option, so it is considered non-AltiVec code.

The example takes program flow across the two modules. It is also contrived to make intelligent guesses about the compiler register allocation strategy. The output is incorrect when one of the files is compiled without the **-maltivec** option.

#### Listing For file1.cpp

```
extern "C" int printf (const char *fmp, ...);
extern void bar ();

void foo ()
    {
    try
        {
        bar ();
        }
    catch (...)
        {
        }
    }
```

### Listing For file2.cpp

```
extern "C" int printf (const char *fmp, ...);
extern void foo ();

typedef __vector signed long T;

void bar ()
    {
    // use a non-volatile vector register
    asm ( "vsplitisw 24,0" );        // v24 <- (0,0,0,0)
    }

void Start ()
    {
    // use a non-volatile vector register v24
    T local = (__vector signed long) (-1, -1, -1, -1);

    asm ( "vsplitisw 24,15" );        // v24 <- (15, 15, 15, 15)

    foo ();

    // continue using the non-volatile vector registers
    asm ( "addi 9, 31, 32" );        // local <- v24
    asm ( "stvx 24, 0, 9" );

    printf ("Finally, local = (%vld)\n", local);
    }
```

### Reproduce the Problem

To produce a partially linked object **file2.o**, compile the two files with the following commands:

```
% ccppc -mcpu=604 -c file1.cpp
% ccppc -mcpu=604 -nostdlib -maltivec -r file1.o file2.cpp
```

Download **file2.o** to a target, and execute the **Start** routine.

```
-> Start
Finally, local = (0,0,0,0)
->
```

Routine **foo** in **file1.cpp** is non-AltiVec code. Therefore, the **try...catch** block in **foo** does *not* save and restore the AltiVec context. Within the **try...catch** block, the call to **bar** alters the value of vector register v24. Because **file1.cpp** does not save AltiVec context, the value 0 in **v24** assigned by **bar** remains unchanged when the program flow returns to **Start**. The original value 15, assigned before the call to **bar**, is now corrupted. Hence, the incorrect output, **local = (0,0,0,0)**.

#### Correct the Behavior

Compile both files with the **-maltivec** option:

```
% ccppc -mcpu=604 -nostdlib -maltivec -r file1.cpp file2.cpp -o file2.o
```

Download **file2.o** to a target and execute the **Start** routine.

```
-> Start
Finally, local = (15,15,15,15)
->
```

Because both modules now have AltiVec code (compiled with the **-maltivec** option), the **try...catch** block in **foo** now saves and restores the AltiVec context. The value 15 originally assigned in **Start** is faithfully restored by **foo** when it returns.

### 6.3.8 Signal Processing Engine Support

The signal processing engine (SPE) is a SIMD processing unit with a PowerPC instruction set extension introduced on the MPC85XX family of processors. This section describes the VxWorks implementation of SPE support including:

- VxWorks run-time support for SPE
- the SPE EABI stack frame
- C language extensions for vector types and formatted I/O
- compiling modules that use the SPE unit
- Workbench tool support; WTX and WDB extensions for SPE

#### VxWorks Run-Time Support for the Signal Processing Engine

The following features are supported for the SPE unit by the VxWorks kernel.

- The SPE unit initialization **speInit( )** is performed by the **usrSpeInit( )** routine in *installDir***/vxworks-6.2/target/src/config/usrSpe.c**. Typically, this is called by the **usrRoot( )** routine if **INCLUDE_SPE** is defined.
- Run-time detection of the SPE unit is possible using the **speProbe( )** routine. This routine is used internally by VxWorks to prevent attempts to enable SPE for a CPU that lacks such a unit.
- Tasks that use the SPE unit must be spawned with the **VX_SPE_TASK** option flag set.
- Tasks created without the **VX_SPE_TASK** option that use SPE instructions incur an SPE Unavailable Exception error, and the task is suspended.

- Tasks cannot be spawned with vector parameters. Only integer-sized parameters can be passed to **taskSpawn( )**.
- The MPC85XX processor's upper 32 bits in the general purpose registers are saved and restored as part of the task context. The VxWorks kernel saves and restores all 32 SPE register extensions when switching between SPE contexts. The SPEFSCR and the accumulator are also saved in the context switch.
- The **speTaskRegsShow( )** routine displays values of all 64 bits of the general purpose registers in the shell.
- The **speSave( )** and **speRestore( )** routines save and restore the upper 32 bits of the general purpose register contents from memory. These routines can be called from interrupt handlers. Before calling these routines, you must ensure that memory is allocated to store the values, and that the memory is aligned on a 32-bit boundary.



Table 6-8 **SPE-Specific Routines**

| Routine | Command Syntax | Description |
|---|---|---|
| **speInit( )** | | Initializes SPE APU support. |
| **speTaskRegsShow( )** | [*task*] | Prints the contents of the SPE registers of a task. |
| **speTaskRegsSet( )** | [*task*, SPEREG_SET *] | Sets the SPE registers of a task. |
| **aspeTaskRegsGet( )** | [*task*, SPEREG_SET *] | Gets the SPE registers from a task TCB. |
| **speProbe( )** | | Probes for the presence of an SPE unit. |
| **speSave( )** | [SPE_CONTEXT *] | Saves upper GPR registers to memory. |
| **speRestore( )** | [SPE_CONTEXT *] | Restores registers from memory. |

### Layout of the SPE EABI Stack Frame

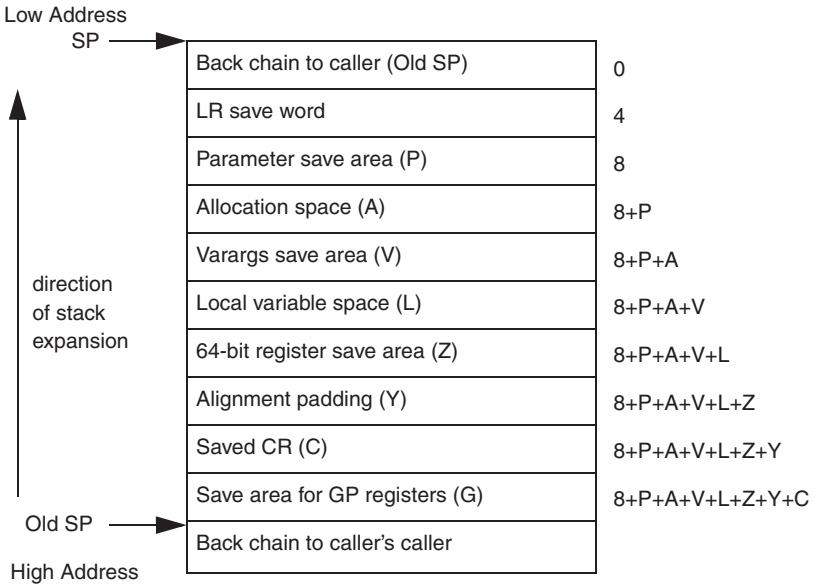
The stack frame for routines using the whole of the 64-bit general purpose registers adds the following areas to the standard EABI frame:

- 64-bit register save area (32 * 64 bytes)

- alignment padding (always zero bytes because the frame is always 8-byte aligned)

The stack frame layout for routines using the upper 32 bits of the general purpose registers is shown in Figure 6-2. Non-SPE stack frames are unchanged from prior VxWorks releases.

Figure 6-2 **Stack Frame Layout for Routines That Use SPE Registers**




### Alignment Constraints for SPE Stack Frames

The required alignment for the SPE EABI specification is 16 bytes. Therefore, it is compatible to call routines compiled for SPE from certain other PowerPC EABI-compliant code that assumes an 8-byte alignment for the stack boundary. However, the converse does not hold true and undefined results can occur.

### C Language Extension for Vector Types

The SPE specification adds a new family of vector data types to the C language. These data types are 64-bit entities which have other data types embedded in them. The new entities are: **__ev64_u16__**, **__ev64_s16__**, **__ev64_u32__**, **__ev64_s32__**, **__ev64_u64__**, **__ev64_s64__**, and **__ev64_fs__**. The type **__ev604_opaque__** represents any of the above types.

### Formatted Input and Output of Vector Types

The *SPE Programming Interface Manual* also specifies vector conversions for formatted I/O. VxWorks supports the new formatted input and output of **vector** data types using the **printf( )** and **scanf( )** class routines shown in Table 6-9.

Table 6-9 **Vector Format Conversion Specifications**

| Format String | Required Argument Type |
|---|---|
| **%hr** | signed 16-bit fixed point |
| **%r** | signed 32-bit fixed point |
| **%lr** | signed 64-bit fixed point |
| **%hR** | unsigned 16-bit fixed point |
| **%R** | unsigned 32-bit fixed point |
| **%lR** | unsigned 64-bit fixed point |

For a comprehensive discussion on the new format specifications, see the *SPE Programming Interface Manual*.

### Compiling Modules with the Wind River Compiler to Use the SPE Unit

Modules that use the SPE registers and instructions must be compiled with the Wind River Compiler option: **-tPPCE500FS:vxworks62**.

```
% dcc -tPPCE500FS:vxworks62 -DCPU=PPC85XX -DTOOL_FAMILY=diab -DTOOL=diab
-c fioTest.c
```

The version of the Wind River Compiler included with this VxWorks release is fully compliant with the Motorola SPE EABI document.

### Compiling Modules with the GNU Compiler to Use the SPE Unit

Modules that use the SPE registers and instructions must be compiled with the GNU compiler option: **-mcpu=8540**.

```
% ccppc -mcpu=8540 -fno-builtin -Wall -DCPU=PPC85XX -DTOOL_FAMILY=gnu
-DTOOL=gnu -c fioTest.c
```

The version of the GNU compiler included with this VxWorks release is fully compliant with the Motorola SPE EABI specification.

#### Extensions to the WTX Protocol for SPE Support

The presence and state of the SPE unit must also be communicated to the Workbench host tools, such as the debugger. The following WTX API routines are available for SPE support.

Table 6-10 **WTX API Routines for SPE Support**

| Routine | Command Syntax | Description |
|---|---|---|
| **wtxTargetHasSpeGet( )** | **hWtx** | Returns **TRUE** if the target has an SPE unit. |

## 6.4 Architecture Considerations

This section describes characteristics of the PowerPC architecture that you should be aware of as you write a VxWorks application. The following topics are addressed:

- divide-by-zero handling
- SPE exceptions under likely overflow/underflow conditions
- SPE unavailable exception in relation to task options
- 26-bit addressing and extended-call exception vector support
- byte order
- hardware breakpoint access types
- PowerPC register usage
- cache information
- AIM model for caches
- AIM model for MMU
- floating-point support
- VxMP support for MPC boards
- exceptions and interrupts
- memory layout
- power management
- build mechanism
- real-time processes (RTPs)

For more information on the PowerPC architectures, see the corresponding microprocessor user's manual from Freescale, Inc. or IBM.

### 6.4.1 Divide-by-Zero Handling

Integer division by zero produces undefined results. Exception generation and handling are not provided by the compiler or run-time.

Floating-point exceptions are disabled by default during task initialization, causing zero-divide conditions to be ignored. On processors with hardware floating point (for example, PowerPC 603 or PowerPC 604), individual tasks may modify their machine state register (MSR) and the floating-point status and control register (FPSCR) in order to generate exceptions. Likewise, for the MPC85XX, the SPEFSCR and MSR must be modified to generate exceptions. On processors without hardware floating point (for example, PowerPC 405 or MPC860), neither the software floating-point library nor the compiler provide support for simulating a floating-point exception.



### 6.4.2 SPE Exceptions Under Likely Overflow/Underflow Conditions

The signal processing engine (SPE) unit on the MPC85XX processors provides floating-point support for scalar or vector quantities. Some of these instructions generate an exception (if SPEFSCR is set accordingly) and return a pre-determined value if an overflow or underflow is *likely*, even though the actual result does not cause an overflow or underflow. The action needed to handle such a condition is application dependent. Thus, the user must set SPEFSCR accordingly and handle the erroneous result. The instructions that exhibit this behavior include: **efsadd**, **efssub**, **efsmul**, **efsdiv**, **evfsadd**, **evfssub**, **evfsmul**, and **evfsdiv**.

### 6.4.3 SPE Unavailable Exception in Relation to Task Options

The SPE on the MPC85XX processors does not implement the standard PowerPC floating-point feature. The SPE implements its own floating-point instruction set. While the hardware supports only single-precision floating-point computation, there are two kinds of floating-point instructions:

- Scalar floating-point, uses lower 32 bits of a GPR ONLY.
- Vector floating-point, uses all 64 bits of a GPR.

**VX_FP_TASK** corresponds to the scalar floating-point, while **VX_SPE_TASK** corresponds to the vector floating-point. The difference between spawning a task with **VX_FP_TASK** and **VX_SPE_TASK** is that the task that is spawned with **VX_SPE_TASK** will save and restore the upper 32 bits in the GPRs during context switch, by means of task hooks.

Because both kinds of floating-point instructions require the use of the SPE coprocessor, the $MSR_{SPE}$ bit is enabled when either options is specified for the task. The following are some of the behaviors that result from this semantic:

- Tasks spawned with **VX_FP_TASK** but without **VX_SPE_TASK** do not save and restore the upper 32 bits of GPRs upon context switch.
- Tasks spawned with either **VX_FP_TASK** or **VX_SPE_TASK** are not able to generate the *SPE unavailable* exception when executing any SPE vector instructions.
- Tasks that use both scalar and vector floating-point instructions can only be spawned with **VX_SPE_TASK**. However, as a good programming practice, you should regard scalar floating-point as associated with **VX_FP_TASK**.

Programmatically, VxWorks makes no distinction between a task spawned with **VX_SPE_TASK**, and a task spawned with both **VX_SPE_TASK** and **VX_FP_TASK**. However, any debugging information will show the corresponding options as specified during task creation.

### 6.4.4 26-bit Address Offset Branching

VxWorks uses **bl** or **bla** instructions by default for both exception/interrupt handling, and for dynamically downloaded module relocations. By using **bl** or **bla**, the PowerPC architecture is only capable of branching within the limits imposed by a signed 26-bit offset. This limits the available branch range to +/- 32 MB.

#### Branching Across Large Address Ranges

Branches across larger address ranges must be made to an absolute 32-bit address with the help of the LR or CTR register. Each absolute 32-bit jump is accomplished with a sequence of at least three instructions (more, if the register state must be preserved). This is rarely needed and is expensive in terms of execution speed and code size. Such large branches are typically seen only in very large downloaded modules and very large (greater than 32 MB) system images.

One way of getting around this restriction for downloadable applications is to use the **-mlongcall** compiler option in the GNU compiler. However, this option may introduce an unacceptable amount of performance penalty and extra code size for some applications. It is for this reason that the VxWorks kernel is not compiled using **-mlongcall**.

Another way to get around this limitation is to increase the size of the WDB memory pool for host tools. By default, the WDB pool size is set to one-sixteenth of the amount of free memory. Memory allocations for host-based tools (such as the shell) are done out of the WDB pool first, and then out of the general system memory pool. Requests larger than the available amount of WDB pool memory are done directly out of the system memory pool. If an application is anticipated to be located outside of the WDB pool—thus potentially crossing the 32 MB threshold—the size of the WDB memory pool can be increased to ensure the application fits into the required space.



To change the size of the WDB memory pool, redefine the macro **WDB_POOL_SIZE** in your BSP **config.h** file. This macro is defined in *installDir*/**vxworks-6.2/target/config/all/configAll.h** as follows:

```
#define WDB_POOL_SIZE       ((sysMemTop() - FREE_RAM_ADRS)/16)
```

Redefining **WDB_POOL_SIZE** in your BSP local **config.h** file alters the macro for that BSP only.

#### Branching Across Large Address Ranges Using the Wind River Compiler

The Wind River Compiler handles far branching in a different way than the GNU compiler. The linker automatically inserts branch islands in the code for far addresses known at link time. Thus, this slower branch approach is used only when necessary.

#### Extended-Call Exception Vector Support

VxWorks for PowerPC adds support for extended-call (32-bit addressable) exception vectors.

When exceptions and interrupts occur, PowerPC processors transfer control to a predetermined address, the exception vector, depending on the exception type. After saving volatile task state, the handler routine installed for that exception vector is called. This call is made using **bl** or **bla** instructions that, as described previously, require the handler routine to be located within the 32 MB of the vector table or within the first 32 MB of memory. Most systems are able to satisfy this 32 MB constraint. However, if a given handler routine were to be located outside of the addressable areas, the target address would be unreachable in some previous VxWorks releases.

This release provides support for extended-call exception vectors, which can call handler routines located anywhere in the 4 GB address space. Extended-call exception vectors make calls to a 32-bit address in the link register (LR) using the **blrl** instructions. Extra work is required for an extended-call exception vector to

load a 32-bit address into the LR, and make a call to it. Therefore, using extended-call exception vectors incurs an additional eleven instruction overhead in increased interrupt latency. It is therefore not advisable to use this feature unless absolutely necessary.

This release still maintains the earlier style 26-bit call vectors as the default. Using a single **bl/bla** instruction is much more efficient than the multiple-instruction sequence described previously. It is expected that most targets will continue to use the original relative branch (default) style exception handling.

A new global boolean, **excExtendedVectors**, has been added, that allows users to enable extended-call exception vectors. By default, **excExtendedVectors** is set to **FALSE**. When set to **TRUE**, extended-call vectors are enabled. **excExtendedVectors** must be set to **TRUE** *before* the exception vectors are initialized in the VxWorks boot sequence (that is, before the call to **excVecInit( )**). Setting **excExtendedVectors** after **excVecInit( )** does *not* achieve the desired result, and results in unpredictable system behavior. Selection of extended-call exception vectors is done on a per-BSP basis in order to minimize the impact on those BSPs that do not require this feature.

#### Enabling Extended-Call Exception Vectors for Command-Line BSP Builds

Because **excExtendedVectors** must be set to **TRUE** before the call to **excVecInit( )**, users must define the preprocessor define **INCLUDE_SYS_HW_INIT_0**, and also supply a **sysHwInit0( )** routine that sets **excExtendedVectors** to **TRUE**.

The following example is taken from the **ads860** BSP.

Add the following code to **config.h**:

```
#ifdef INCLUDE_SYS_HW_INIT_0

    /*
     * Perform any BSP-specific initialisation that must be done before
     * cacheLibInit() is called and/or BSS is cleared.
     */

#ifndef _ASMLANGUAGE
IMPORT BOOL excExtendedVectors;
extern void sysHwInit0();
#endif /*_ASMLANGUAGE */


#define SYS_HW_INIT_0 sysHwInit0
#endif /* INCLUDE_SYS_HW_INIT_0 */
```

Now, add the following code to **sysLib.c**:

```
#ifdef INCLUDE_SYS_HW_INIT_0

/*************************************************************************
* sysHwInit0 - Used here to enable extended exception vector support.
*
* RETURNS: None.
*/

void sysHwInit0 ()
    {
    excExtendedVectors = TRUE;/* enable extended-call exc. vectors */
    }
#endif /*INCLUDE_SYS_HW_INIT_0 */
```



#### Enabling Extended-Call Exception Vectors for Project Builds

The **INCLUDE_EXC_EXTENDED_VECTORS** component must be enabled for your project. This component sets **excExtendedVectors** to **TRUE** before **excVecInit( )** is called during the boot sequence. **INCLUDE_EXC_EXTENDED_VECTORS** is found in the kernel folder.

### 6.4.5 Byte Order

The byte order used by VxWorks for the PowerPC family is big-endian.

### 6.4.6 Hardware Breakpoints

Not all target architectures support hardware breakpoints, and those that do, accept different values for the access type passed to the **bh( )** routine. The PowerPC family supports hardware breakpoints, however, the access type of hardware breakpoints allowed depends upon the specific processor.

For each processor family, the number of hardware breakpoints (a hardware limitation), address alignment constraints, and access types are detailed in the following tables. Both instruction and data access must be 4- byte aligned unless otherwise noted.

For more information, see the reference entry for **bh( )**.

#### PowerPC 405

PowerPC 405 targets have two data breakpoints and two instruction breakpoints.

Address data parameters are 1-byte aligned if width access is 1 byte, 2-bytes aligned if width access is 2 bytes, 4-bytes aligned if width access is 4 bytes, and cache-line-size aligned if access is a data cache line (32 bytes on PowerPC 405). Instruction accesses are always 4-byte aligned.

PowerPC 405 processors allow the following access types for hardware breakpoints. The byte width means break on all accesses between (**addr**) and (**addr** + *x*):

Table 6-11 **PowerPC 405 Access Types**

| Access Type | Breakpoint Type |
|---|---|
| 0 | Instruction. |
| 1 | Data write byte (one byte width). |
| 2 | Data read byte (one byte width). |
| 3 | Data read/write byte (one byte width). |
| 4 | Data write half-word (two bytes width). |
| 5 | Data read half-word (two bytes width). |
| 6 | Data read/write half-word (two bytes width). |
| 7 | Data write word (four bytes width). |
| 8 | Data read word (four bytes width). |
| 9 | Data read/write word (four bytes width). |
| 0xa | Data write cache line (32 bytes width). |
| 0xb | Data read cache line (32 bytes width). |
| 0xc | Data read/write cache line (32 bytes width). |

### PowerPC 603

The PowerPC 603 processor has a single instruction breakpoint, and no data breakpoints. The PowerPC 603 allows the following access types for hardware breakpoints:

Table 6-12 **PowerPC 603 Access Types**

| Access Type | Breakpoint Type |
|---|---|
| 0 | Instruction. |

**NOTE:** PowerPC 603 **_83xx** and **_g2le** variants include two instruction and two data access breakpoints.



#### PowerPC 604 (including MPC7XX and MPC74XX), PowerPC 440, MPC8XX, and MPC85XX

The PowerPC 604, MPC75X, and MPC74XX CPUs have one data and one instruction breakpoint. Data and instruction access must be 4-byte aligned

The MPC8XX and PowerPC 440 have 4 instruction and 2 data breakpoints. Data access is 1-byte aligned on MPC8XX and PowerPC 440 CPUs.

The MPC85XX has 2 instruction and 2 data breakpoints. Data access is 1-byte aligned.

All of these processors allow the following access types for hardware breakpoints:

Table 6-13 **PowerPC 604, PowerPC 440, MPC8XX, and MPC85XX Access Types**

| Access Type | Breakpoint Type |
|---|---|
| 0 | Instruction. |
| 1 | Data read/write. |
| 2 | Data read. |
| 3 | Data write. |

#### PowerPC 970

VxWorks for PowerPC does not include support for hardware breakpoints on PowerPC 970 processors.

### 6.4.7 PowerPC Register Usage

The PowerPC conventions regarding register usage, stack frame formats, parameter passing between routines, and other factors involving code inter-operability, are defined by the Application Binary Interface (ABI) and the

Embedded Application Binary Interface (EABI) protocols. The VxWorks implementation for PowerPC follows these protocols. Table 6-14 shows PowerPC register usage in VxWorks (note that only CPUs with hardware floating-point support have fpr0-31).

Table 6-14 **PowerPC Registers**

| Register Name | Usage |
|---|---|
| gpr0 | Volatile register that may be modified during routine linkage. |
| gpr1 | Stack frame pointer, always valid. |
| gpr2 | Small data area, small **const** pointer register (**_SDA2_BASE_**). VxWorks does not support SDA. |
| gpr3 | Volatile register used for parameter passing and return values. |
| gpr4-gpr10 | Volatile registers used for parameter passing. |
| gpr11-gpr12 | Volatile registers that may be modified during routine linkage. |
| gpr13 | Small data area pointer register (**_SDA_BASE_**). (VxWorks does not support SDA.) |
| gpr14-gpr30 | Non-volatile registers used for local variables. |
| gpr31 | Used for local variables or environment pointers. |
| sprg4-sprg7 | Book E and PowerPC 4xx special purpose registers; used by VxWorks. |
| usprg0 | Book E special purpose register; not used by VxWorks. |
| fpr0 | Volatile floating-point register. |
| fpr1 | Volatile floating-point register used for parameter passing and return values. |
| fpr2-fpr8 | Volatile floating-point registers used for parameter and results passing. |
| fpr9-fpr13 | Volatile floating-point registers. |
| fpr14-fpr31 | Non-volatile floating-point registers used for local variables. |

### 6.4.8 Caches

The following subsections augment the information in the *VxWorks Kernel Programmer's Guide*.

Most PowerPC processors contain an instruction cache and a data cache. In the default configuration, VxWorks enables both caches, if present. To disable the instruction cache, highlight the **USER_I_CACHE_ENABLE** macro in the **Params** tab under **INCLUDE_CACHE_ENABLE** and remove the **TRUE**; to disable the data cache, highlight the **USER_D_CACHE_ENABLE** macro and remove the **TRUE.**



For most boards, the cache capabilities must be used with the MMU to resolve cache coherency problems. The page descriptor for each page selects the cache mode. This page descriptor is configured by filling the data structure **sysPhysMemDesc[ ]** defined in **sysLib.c**. (For more information about cache coherency, see the reference entry for **cacheLib**. For information about the MMU and VxWorks virtual memory, see the *VxWorks Kernel Programmer's Guide: Memory Management*. For MMU information specific to the PowerPC family, see *6.3.4 Memory Management Unit (MMU)*, p.118.)

The state of both data and instruction caches is controlled by the WIMG[1] information saved either in the BAT (block address translation) registers or in the segment descriptors. Because a default cache state cannot be supplied, each cache can be enabled separately after the corresponding MMU is turned on. For more information on these cache control bits, see *PowerPC Microprocessor Family: The Programming Environments*, published jointly by Motorola and IBM.

On PowerPC processors, cache flush at a specific address is usually performed by the **dcbst** instruction. Flushing of the entire cache usually involves loading from main memory over an address range. The starting address of the address range to load from is determined by the value stored in the variable **cachePpcReadOrigin**. The default value of **cachePpcReadOrigin** is 0x10000; this value can be changed in the BSP.

During initialization of the MMU library (before cache is enabled for the first time), **cachePpcReadOrigin** is set to a suitably aligned address within the first cacheable entry of **sysPhysMemDesc[ ]** that is of a sufficient size to accommodate the flush mechanism requirements. The required size is processor-dependent: 4 MB for PPC970, one and a half times the size of the cache for other processors. If the MMU

1. W: the **WRITETHROUGH** or **COPYBACK** attribute.
I: the cache-inhibited attribute.
M: the memory coherency required attribute.
G: the guarded memory attribute.

is not configured, or if such a block of memory cannot be found, the default value of **cachePpcReadOrigin** is used. If your BSP overrides the default value of **cachePpcReadOrigin**, the overridden value is used in place of the default value.

**cachePpcReadOrigin** needs to point to cacheable memory in order for the load to properly displace modified entries in the cache that is flushed. A cacheable block of at least one an a half times the size of the cache is required due to the nature of the pseudo LRU (Least Recently Used) algorithm used by several processors. If this scheme does not work for a your target system for any reason, you must override **cachePpcReadOrigin** in **sysHwInit( )** in the BSP.

#### PowerPC 405

PowerPC 405 targets, when not using the MMU, control the W, I, and G attributes using special purpose registers (SPRs). (Because it does not provide any hardware support for memory coherency, this processor always considers the M attribute to be off.)

See the processor user's manual for detailed descriptions of the data cache cacheability register (DCCR), data cache write-through register (DCWR), instruction cache cacheability register (ICCR), and storage guarded register (SGR).

#### PowerPC 440

The Book E specification and the PowerPC 440 core implementation do not provide a means to set a global cache enable/disable state, nor do they permit independently enabling or disabling the instruction and data caches.

In the default configuration, VxWorks enables both caches. If you disable one cache, you must disable the other. To disable both caches, highlight the **USER_I_CACHE_ENABLE** and **USER_D_CACHE_ENABLE** macros in the **Params** tab under **INCLUDE_CACHE_ENABLE** and remove the **TRUE**.

The state of both data and instruction caches is controlled by the WIMG information saved either in the static TLB entry registers or in the dynamic memory mapping descriptors. Because a default cache state cannot be supplied, both caches are enabled after the corresponding MMU is turned on.

If an application requires a different cache mode for instruction versus data access on the same region of memory, **#undef USER_I_MMU_ENABLE**, **#define USER_D_MMU_ENABLE**, use **sysStaticTlbDesc[ ]** to set up the instruction access mode, and **sysPhysMemDesc[ ]** to set up the data access mode.

The VxWorks cache library interface has changed for the following two calls:

```
STATUS cacheEnable(CACHE_TYPE cache);
STATUS cacheDisable(CACHE_TYPE cache);
```

The *cache* argument is ignored and the instruction and data caches are both enabled or disabled together. If called before the MMU library is initialized, **cacheEnable( )** returns **OK** and signals the MMU library to activate the cache after it has completed initialization. If the MMU library is active (that is, $MSR_{DS} = 1$), **cacheEnable( )** returns **ERROR**.

#### PowerPC 603 and 604

On PowerPC 603 and 604 processors, cache is disabled when the MMU is disabled. For more information on the PowerPC 6xx MMU implementation, see *PowerPC 60x Memory Mapping*, p.120.



#### PowerPC 970

Because of the cache and MMU properties of PowerPC 970 targets, any memory region that can potentially contain segment register tables (that is, any space which may be part of the kernel heap when a task is created) must not be configured as cache-inhibited in **sysPhysMemDesc[ ]**.

In addition, PowerPC 970 targets ignore the W and M attribute settings. The M attribute is considered to always be set and the W attribute is set based on the cache level. For more information, see the PowerPC 970 reference documentation.

### 6.4.9 AIM Model for Caches

The architecture-independent model (AIM) for cache provides an abstraction layer to interface with the underlying architecture-dependent cache code. This allows uniform access to the hardware cache features that are typically CPU core specific. AIM for cache is for VxWorks internal use and does not change the VxWorks API for application development. For more information on the cache API, see the reference entry for **cacheLib**.

On PowerPC processors, the following CPU families use the AIM for cache:

- PowerPC 440
- PowerPC 603 (for the MPC82XX family)
- PowerPC 604 (including the MPC74XX family)
- MPC8XX
- MPC85XX
- PowerPC 970

These CPU families now implement the **cacheClear( )** VxWorks API routines. Prior to VxWorks 6.0, PowerPC processors did not populate the **cacheClear( )** routine

and **cacheClear( )** was equivalent to a no-op. The PowerPC 405 family continues to operate this way.

### 6.4.10 AIM Model for MMU

The architecture-independent model (AIM) for MMU provides an abstraction layer to interface with the underlying architecture-dependent MMU code. This allows uniform access to the hardware-dictated MMU model that is usually CPU core specific. AIM for MMU is for VxWorks internal use. However, this new model adds support for two new routines, **vmPageLock( )** and **vmPageOptimize( )**, to the VxWorks **vmLib** API. For more information, see the reference entries for these routines. The PowerPC CPU families that implement AIM for MMU (and support for the new routines) are:

- PowerPC 405: **vmPageLock( )** and **vmPageOptimize( )**
- PowerPC 440: **vmPageLock( )** and **vmPageOptimize( )**
- MPC85XX: **vmPageLock( )** only

The **vmPageLock( )** routine requires the use of static TLB entries. This routine also requires alignment of the lock regions to ensure minimal resource usage in general. The **vmPageOptimize( )** routine requires variable page size support in the dynamic TLB entries. Both routines provide a mechanism for reducing TLB misses and should boost system performance when used correctly.

The configuration components for AIM for MMU are as follows:

```
#define INCLUDE_AIM_MMU_CONFIG

#ifdef INCLUDE_AIM_MMU_CONFIG
#define INCLUDE_AIM_MMU_MEM_POOL_CONFIG /* Configure the memory pool
                                           allocation for page tables */
#define INCLUDE_AIM_MMU_PT_PROTECTION   /* Page Table protection */
#endif

#ifdef INCLUDE_AIM_MMU_MEM_POOL_CONFIG
#define AIM_MMU_INIT_PT_NUM 0x40        /* Number of pages pre allocate for
                                           page table */
#define AIM_MMU_INIT_PT_INCR 0x20       /* Number of pages increment alloc
                                           for page table if previous
                                           allocation is exhausted */

#define AIM_MMU_INIT_RT_NUM 0x10        /* Number of pages pre allocate for
                                           region table */
#define AIM_MMU_INIT_RT_INCR 0x10       /* Number of pages increment alloc
                                           for region table if previous
                                           allocation is exhausted */
#endif
```

```
#define INCLUDE_MMU_OPTIMIZE

#ifdef INCLUDE_MMU_OPTIMIZE
#define INCLUDE_LOCK_TEXT_SECTION       /* Calls vmPageLock with kernel text
                                           start address and and size of
                                           text section */
#define INCLUDE_PAGE_SIZE_OPTIMIZATION  /* Calls vmPageOptimize to optimize
                                           all of mapped virtual kernel
                                           address space */
#endif
```

Page locking of the text section will fail if the alignment of text and the number of resources available are not sufficient. For PowerPC 405 and PowerPC 440 processors, the resource is pulled from the general TLB pool which has 64 entries. The allowance set aside by the architecture for locking is 5 static pages (this may change). For MPC85XX processors, the resource is pulled from the TLB1 entries (also known as CAM entries). There are 16 TLB1 entries available. If the BSP uses too many entries, it may not be possible to enable this feature.



### 6.4.11 Floating-Point Support

#### PowerPC 405, 440 (soft-float), and MPC860

The PowerPC 405, 440 (soft-float), and MPC860 processors do not support hardware floating-point instructions. However, VxWorks provides a floating-point library that emulates these mathematical routines. All ANSI floating-point routines have been optimized using libraries from U. S. Software.

| | | | |
|---|---|---|---|
| **acos( )** | **asin( )** | **atan( )** | **atan2( )** |
| **ciel( )** | **cos( )** | **cosh( )** | **exp( )** |
| **fabs( )** | **floor( )** | **fmod( )** | **log( )** |
| **log10( )** | **pow( )** | **sin( )** | **sinh( )** |
| **sqrt( )** | **tan( )** | **tanh( )** | |

In addition, the following single-precision routines are also available:

| | | | |
|---|---|---|---|
| **acosf( )** | **asinf( )** | **atanf( )** | **atan2f( )** |
| **cielf( )** | **cosf( )** | **expf( )** | **fabsf( )** |
| **floorf( )** | **fmodf( )** | **logf( )** | **log10f( )** |
| **powf( )** | **sinf( )** | **sinhf( )** | **sqrtf( )** |
| **tanf( )** | **tanhf( )** | | |

The following floating-point routines are not available on PowerPC 405, 440 (soft-float), and MPC860 processors:

| | | | |
|---|---|---|---|
| **cbrt( )** | **infinity( )** | **irint( )** | **iround( )** |
| **log2( )** | **round( )** | **sincos( )** | **trunc( )** |
| **cbrtf( )** | **infinityf( )** | **irintf( )** | **iroundf( )** |
| **log2f( )** | **roundf( )** | **sincosf( )** | **truncf( )** |

#### MPC85XX

MPC85XX processors support single-precision hardware floating-point instructions. The default compilation rules for **CPU=PPC85XX** targets use the option **-tPPCE500FS:vxworks62** when using **TOOL=diab**. The **S** in **E500FS** indicates that only software instructions are used, but the following options are available:

**N** no floating point

**S** software floating point only

**G** both **float** and **double** data types are allowed, but actual operands and results are single-precision only using hardware floating-point instructions

**F** both **float** and **double** data types are allowed, single-precision uses hardware floating-point, double-precision uses software integer instructions

For a list of available math routines, see your compiler documentation.

When using the GNU compiler (**TOOL=gnu**), VxWorks provides a floating-point library that emulates the following mathematical routines. All ANSI floating-point routines have been optimized using libraries from U.S. Software.

| | | | |
|---|---|---|---|
| **acos( )** | **asin( )** | **atan( )** | **atan2( )** |
| **ciel( )** | **cos( )** | **cosh( )** | **exp( )** |
| **fabs( )** | **floor( )** | **fmod( )** | **log( )** |
| **log10( )** | **pow( )** | **sin( )** | **sinh( )** |
| **sqrt( )** | **tan( )** | **tanh( )** | |

The following single-precision routines are also available:

| | | | |
|---|---|---|---|
| **acosf( )** | **asinf( )** | **atanf( )** | **atan2f( )** |
| **cielf( )** | **cosf( )** | **expf( )** | **fabsf( )** |
| **floorf( )** | **fmodf( )** | **logf( )** | **log10f( )** |
| **powf( )** | **sinf( )** | **sinhf( )** | **sqrtf( )** |
| **tanf( )** | **tanhf( )** | | |

The following floating-point routines are not available on MPC85XX processors:

| | | | |
|---|---|---|---|
| **cbrt( )** | **infinity( )** | **irint( )** | **iround( )** |
| **log2( )** | **round( )** | **sincos( )** | **trunc( )** |
| **cbrtf( )** | **infinityf( )** | **irintf( )** | **iroundf( )** |
| **log2f( )** | **roundf( )** | **sincosf( )** | **truncf( )** |

#### PowerPC 440 (hard-float), 60x, and 970



The following floating-point routines are available for PowerPC 440 (hard-float), 60x, and 970 processors:

| | | | |
|---|---|---|---|
| **acos( )** | **asin( )** | **atan( )** | **atan2( )** |
| **ciel( )** | **cos( )** | **cosh( )** | **exp( )** |
| **fabs( )** | **floor( )** | **fmod( )** | **log( )** |
| **log10( )** | **pow( )** | **sin( )** | **sinh( )** |
| **sqrt( )** | **tan( )** | **tanh( )** | |

The following subset of the ANSI routines is optimized using libraries from Motorola:

| | | | |
|---|---|---|---|
| **acos( )** | **asin( )** | **atan( )** | **atan2( )** |
| **cos( )** | **exp( )** | **log( )** | **log10( )** |
| **pow( )** | **sin( )** | **sqrt( )** | |

The following floating-point routines are not available on PowerPC 440 (hard-float), 60x, and 970 processors:

| | | | |
|---|---|---|---|
| **cbrt( )** | **infinity( )** | **irint( )** | **iround( )** |
| **log2( )** | **round( )** | **sincos( )** | **trunc( )** |

No single-precision routines are available for these processors.

Handling of floating-point exceptions is supported for PowerPC 440 (hard-float), 60x, and 970 processors. By default, the floating-point exceptions are disabled.

To change the default setting for a task spawned with the **VX_FP_TASK** option, modify the values of the machine state register (MSR) and the floating-point status and control register (FPSCR) at the beginning of the task code.

- The MSR **FE0** and **FE1** bits select the floating-point exception mode.
- The FPSCR **VE**, **OE**, **UE**, **ZE**, **XE**, **NI**, and **RN** bits enable or disable the corresponding floating-point exceptions and rounding mode. (See **archPpc.h** for the macro **PPC_FPSCR_VE** and so forth.)

You can access register values using the routines **vxMsrGet( )**, **vxMsrSet( )**, **vxFpscrGet( )**, and **vxFpscrSet( )**.

### 6.4.12 VxMP Support for Motorola PowerPC Boards

VxMP is an optional VxWorks component that provides shared-memory objects dedicated to high-speed synchronization and communication between tasks running on separate CPUs. For complete documentation of the optional component VxMP, see the *VxWorks Kernel Programmer's Guide: Shared Memory Objects: VxMP*.

Normally, boards that make use of VxMP must support hardware test-and-set (*TAS*: atomic read-modify-write cycle). Motorola PowerPC boards do not provide atomic (indivisible) TAS as a hardware function. VxMP for PowerPC provides special software routines that allow the Motorola boards to make use of VxMP.

#### Boards Affected

The current release of VxMP provides a software implementation of a hardware TAS for PowerPC-based VME boards manufactured by Motorola. No other PowerPC boards are affected.

**NOTE:** Some PowerPC board manufacturers, for example Cetia, claim to equip their boards with hardware support for true atomic operations over the VME bus. Such boards do not need the special software written for the Motorola boards.

#### Implementation

The VxMP product for Motorola PowerPC boards has special software routines that compensate for the lack of atomic TAS operations in the PowerPC and the lack of atomic instruction propagation to and from these boards. This software consists of the routines **sysBusTas( )** and **sysBusTasClear( )**.

The software implementation uses ownership of the VMEbus as a semaphore; in other words, no TAS operation can be performed by a task until that task owns the VME bus. When the TAS operation completes, the VME bus is released. This method is similar to the special read-modify-write cycle on the VME bus in which the bus is owned implicitly by the task issuing a TAS instruction. (This is the hardware implementation employed, for example, with a 68K processor.) However, the software implementation comes at a price. Execution is slower because, unlike true atomic instructions, **sysBusTas( )** and **sysBusTasClear( )** require many clock cycles to complete.

#### Configuring VMEbus TAS

To invoke the VMEbus TAS, set **SM_TAS_TYPE** to **SM_TAS_HARD** on the **Params** tab of the project facility under **INCLUDE_SM_OBJ**.

#### Restrictions for Multi-Board Configurations

Systems using multiple VME boards where at least one board is a Motorola PowerPC board must have a Motorola PowerPC board set with a processor ID equal to 0 (the board whose memory is allocated and shared). This is because a TAS operation on local memory by, for example, a 68K processor does not involve VME bus ownership and is, therefore, not atomic as seen from a Motorola PowerPC board.

This restriction does not apply to systems that have globally shared memory boards that are used for shared memory operations. In this case, specifying **SM_OFF_BOARD** as **TRUE** on the **Params** tab of the properties window for the processor with ID of 0 and setting the associated parameters enables you to assign processor IDs in any configuration.



### 6.4.13 Exceptions and Interrupts

#### PowerPC 405, 440, and MPC85XX

PowerPC 405, 440, and MPC85XX processors support two classes of exceptions and interrupts: *normal* and *critical*. The PowerPC 440GX and 440EP processors, also referred to as revision x5 of the PowerPC 440, have an additional class called *machine check interrupt*. This release correctly attaches default handlers to the corresponding vectors. **excVecSet( )**, which internally recognizes whether the vector being modified is normal or critical, can be used with either class of vector and is the preferred method for connecting alternative handlers.

The routines **excCrtConnect( )** and **excIntCrtConnect( )** are available in addition to the basic routines **excConnect( )** and **excIntConnect( )**:

```
STATUS excCrtConnect (VOIDFUNCPTR *vectr, VOIDFUNCPTR routine);
STATUS excIntCrtConnect (VOIDFUNCPTR *vectr, VOIDFUNCPTR routine);
```

The **excCrtConnect( )** routine connects a C routine to a critical exception vector, in a manner analogous to **excConnect( )**. The **excIntCrtConnect( )** routine performs a similar function for an interrupt (also see *excVecGet( ) and excVecSet( )*, p.164).

The **excIntConnectTimer( )** routine, required for PowerPC 405 targets, is not needed for the PowerPC 440 targets.

In the case of the machine check interrupt class, the VxWorks machine check exception handler is customized by macros in the BSP **config.h** file. The following macros can be defined to enable their respective features:

**INCLUDE_440X5_DCACHE_RECOVERY**
This macro makes data cache parity errors recoverable. Selecting this option also selects **INCLUDE_440X5_PARITY_RECOVERY**, and sets **USER_D_CACHE_MODE** to **CACHE_WRITETHROUGH**.

**INCLUDE_440X5_TLB_RECOVERY**
This macro makes TLB parity errors recoverable. Selecting this option also selects **INCLUDE_440X5_PARITY_RECOVERY** and **INCLUDE_MMU_BASIC**. The **INCLUDE_MMU_BASIC** component is required because TLB recovery requires setup performed by MMU library initialization. However, you can to undefine (**#undef**) both **USER_D_MMU_ENABLE** and **USER_I_MMU_ENABLE** if you do not want the functionality provided by the MMU library.

**INCLUDE_440X5_PARITY_RECOVERY**
This macro sets the PRE bit in CCR0. This macro is required by the 440x5 hardware if either data cache or TLB recovery is enabled. Selecting this option also selects **INCLUDE_EXC_HANDLING**.

**INCLUDE_440X5_TLB_RECOVERY_MAX**
This macro dedicates a TLB entry to the machine check handler, and a separate TLB entry to the remaining interrupt/exception vectors, in order to maximize the ability to recover from TLB parity errors. Selecting this option also selects **INCLUDE_440X5_TLB_RECOVERY**.

**INCLUDE_440X5_MCH_LOGGER**
This macro causes the machine check handler to log recovered events which are otherwise handled transparently by the OS and the application.

### MPC85XX

MPC85XX processors support three classes of exceptions and interrupts: normal, critical, and machine check. Besides the standard **excConnect( )** and **excIntConnect( )** routines, **excCrtConnect( )** and **excIntCrtConnect( )** are available for the critical exception class, and **excMchkConnect( )** is available for the machine check exception class (see *excVecGet( ) and excVecSet( )*, p.164). The routine prototypes are the same for all connect routines.

The exception vector base address defined in the interrupt vector prefix register (IVPR) is set to 0x0. The current release does not support a different base address.

The interrupt vector offset registers (IVORs) are set as follows:

Table 6-15 **Interrupt Vector Offset Register Settings for MPC85XX**

| IVOR | Interrupt Type | Offset |
|---|---|---|
| IVOR0 | Critical input | 0x100 |
| IVOR1 | Machine check[a] | 0x200 |
| IVOR2 | Data storage | 0x300 |
| IVOR3 | Instruction storage | 0x400 |
| IVOR4 | External input | 0x500 |
| IVOR5 | Alignment | 0x600 |
| IVOR6 | Program | 0x700 |
| IVOR7 | Floating-point unavailable (not supported on MPC85XX) | 0x800 |
| IVOR8 | System call | 0x900 |
| IVOR9 | Auxiliary processor unavailable (not supported on MPC85XX) | 0xa00 |
| IVOR10 | Decrementer | 0xb00 |
| IVOR11 | Fixed-interval timer interrupt | 0xc00 |
| IVOR12 | Watchdog timer interrupt | 0xd00 |
| IVOR13 | Data TLB error | 0xe00 |
| IVOR14 | Instruction TLB error | 0xf00 |
| IVOR15 | Debug | 0x1000 |
| IVOR32 | SPE APU unavailable | 0x1100 |
| IVOR33 | SPE floating-point data exception | 0x1200 |
| IVOR34 | SPE floating-point round exception | 0x1300 |
| IVOR35 | Performance monitor | 0x1400 |

a. If cache parity recovery is enabled in the BSP **config.h** file, IVOR1 will be modified to address 0x1500, where the parity recovery code resides. Exception processing will fall back to address 0x200 after examining the MCSR if the machine check is not caused by parity error.

### excVecGet( ) and excVecSet( )

In a standard VxWorks image, **excVecInit( )** and **excInit( )** install the default exception and interrupt handlers, along with the stub for the entry and exit code, by calling the connect routines described previously. Application code can change the default handler to an alternate handler by calling **excVecSet( )**. **excVecSet( )** does not copy the stub for the entry and exit code, and thus, the exception type (normal, critical, or machine check) need not be specified. The default exception type for the vector of interest is used. If the application code changes the location of a vector (for example, using IVOR which is not recommended), the connect routines are still needed to install the stub as well as the handler. **excVecSet( )** is used to install an alternate handler, and **excVecGet( )** returns the address of the installed handler given a vector:

```
void excVecSet (FUNCPTR *vectr, FUNCPTR function);
FUNCPTR excVecGet (FUNCPTR *vectr);
```

### Relocated Vectors

On some PowerPC processors, certain exception vectors are located very close to each other. In order to fit the prologue instructions that prepare the values needed for **excEnt( )** and **intEnt( )**, it becomes necessary to move these vectors to a different address. Thus, such vectors are relocated. Table 6-16 lists the relocated vectors. All standard VxWorks API routines correctly use the relocated addresses when the original address is supplied. Examples of these routines include **excVecSet( )**, **excVecGet( )**, and **excIntConnectTimer( )**.

Table 6-16 **Relocated Exception Vectors for PowerPC Processors**

| Name | Interrupt Type | Affected Processors | From | To |
|---|---|---|---|---|
| **PIT** | Periodic interval timer | PowerPC 405, PowerPC 405F | 0x1000 | 0x1080 |
| **FIT** | Fast interval timer | | 0x1010 | 0x1300 |

Table 6-16 **Relocated Exception Vectors for PowerPC Processors** (cont'd)

| Name | Interrupt Type | Affected Processors | From | To |
|---|---|---|---|---|
| **PERF_MON** | Performance monitor | PowerPC 604 (PowerPC 604, MPC7XX, MPC74XX, and PowerPC 970) | 0xf00 | 0xf80 |



Note that the relocated vectors and addresses are not user changeable. If you relocate other vectors, or change a relocated vector's address, VxWorks does not convert to the new address properly.

### 6.4.14 Memory Layout

The VxWorks memory layout is the same for all PowerPC processors. Figure 6-3 shows the memory layout with the following labels:

**Interrupt Vector Table**
Table of exception/interrupt vectors.

**SM Anchor**
Anchor for the shared memory network and VxMP shared memory objects (if there is shared memory on the board).

**Boot Line**
ASCII string of boot parameters.

**Exception Message**
ASCII string of the fatal exception message.

**Initial Stack**
Initial stack for **usrInit( )**, until **usrRoot( )** is allocated a stack.

**System Image**
The VxWorks system image itself (three sections: text, data, and bss). The entry point for VxWorks is at the start of this region, which is BSP dependent (see the BSP-specific documentation).

**Host Memory Pool**
Memory allocated by host tools. The size depends on the macro **WDB_POOL_SIZE**. Modify **WDB_POOL_SIZE** under **INCLUDE_WDB**.

**Interrupt Stack**
Size is defined by **ISR_STACK_SIZE** under **INCLUDE_KERNEL**. Location depends on the system image size.

**System Memory Pool**
Size depends on the size of the system image. The **sysMemTop( )** routine returns the address of the end of the free memory pool.

**Error Detection and Reporting Preserved Memory**
Size is defined in **PM_RESERVED_MEM**. This memory is used when **INCLUDE_EDR_PM** is defined.

All addresses shown in Figure 6-3 are relative to the start of memory for a particular target board. The start of memory (corresponding to 0x0 in the memory-layout diagram) is defined as **LOCAL_MEM_LOCAL_ADRS** under **INCLUDE_MEMORY_CONFIG** for each target.

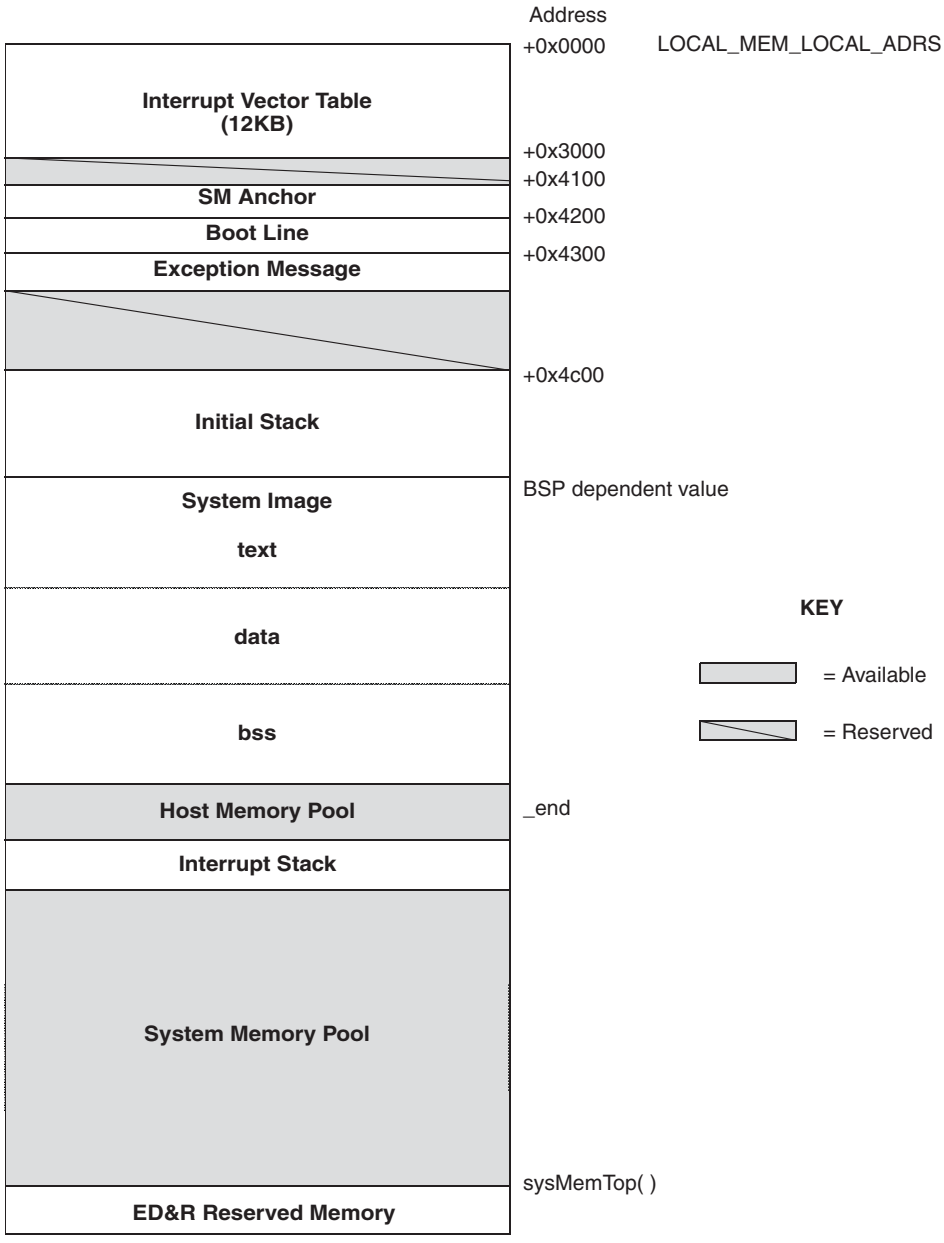
**NOTE:** The PowerPC architecture supports the placement of the exception vector table (EVT) in high memory (0xfff00000) by setting the IP bit in the MSR; PowerPC 4xx supports arbitrary placement of the EVT through the EVPR/IVPR (exception vector prefix register/interrupt vector prefix register). However, VxWorks does not support this placement.

### 6.4.15 Power Management

The PowerPC DEC timer is generally used as the system tick timer in VxWorks applications. Although this timer works well in that role, it has a weakness that makes it unsuitable for long power management timekeeping: the timer has a tendency to drift unless the interrupt service routine takes special care to correct for under-run. This sort of processing adds overhead to the interrupt service routine; but under normal circumstances this only occurs at a system tick. Long power management requires that the system time be advanced with each interrupt. In this case, the extra processing required by the DEC timer is undesirable. In order to make use of the long sleep mode, an alternate timer device must be available for use as the system clock. The **m8260** timer has been adapted for use in the MPC8260 BSPs. To determine if this feature is supported for your target board, see your BSP reference documentation.

It is not possible to disable the DEC timer interrupt without disabling all peripheral interrupts. In addition, it is not possible to change the timer frequency of the timer. Therefore, the DEC timer is used as the timestamp timer in the long

Figure 6-3 **VxWorks System Memory Layout (PowerPC)**



power management configuration. If a timestamp component is not included in your VxWorks image, the DEC interrupt is ignored.

**NOTE:** VxWorks 5.5 provided short power management support for all PowerPC cores. This behavior is retained if the power management component is not included.

### 6.4.16 Build Mechanism

The general build mechanism for VxWorks uses **make** along with the macros **CPU** and **TOOL** to determine how to build for a specific target processor. Prior to VxWorks 6.0, each CPU family needed to link with its own set of library archives. The updated build mechanism eliminates much of the redundancy associated with the old build method by building most of the files for a generic 32-bit PowerPC UISA. This allows the same set of library archives to be used by different CPU families.

There are two general sets of VxWorks library archives for PowerPC. One set is for processors with hardware floating-point support (defined by the PowerPC floating-point model, excluding any core or chip specific floating-point model). The other set is for processors that lack hardware floating-point support and require what is commonly known as software floating-point support. The **TOOL** macro is used to differentiate between these two modes of floating-point (FP) support. This macro now takes the following values:

| | |
|---|---|
| **diab** | Wind River Compiler with hardware FP support |
| **sfdiab** | Wind River Compiler with software FP support |
| **gnu** | GNU compiler with hardware FP support |
| **sfgnu** | GNU compiler with software FP support |

The directory organization of the library archives in *installDir***/vxworks-6.2/target/lib/ppc/PPC32** reflects the new build mechanism. There are now two sets of library archives, one for hard-float and one for soft-float. These libraries reside in the **common** and **sfcommon** directories, respectively. These two common directories contain files that can be compiled for the generic 32-bit PowerPC UISA model and contain no processor-specific instructions. (The term **common** refers to the compiler, in the sense that these directories are used by both the Wind River Compiler and the GNU compiler as opposed to those directories that specify the compiler that their library archives are linked with as part of the directory name).

Under *installDir*/**vxworks-6.2/target/lib/ppc/PPC32**, some directories have names with the CPU variant attached, such as **_ppc440_x5**, **_ppc604**, or **_ppc85XX**. These directories contain library archives that must be compiled for a specific CPU variant because they may contain processor-core-specific instructions. For example, if a BSP uses the PowerPC 405 processor, it can be built with **TOOL=sfdiab** which links it with the library archives in **sfcommon**, **sfcommon_ppc405**, and **sfdiab**. Likewise, a BSP that uses a MPC74XX processor can be built with **TOOL=gnu** which links it with the library archives in **common**, **common_ppc604**, and **gnu**.



The value for the macro **CPU** is set to the CPU family in the BSP makefile. This remains unchanged from prior releases. However, outside of the BSP, the macro **CPU** takes on a new value when compiling for the generic 32-bit PowerPC UISA. This new value is **PPC32**. This value is used when building in *installDir*/**vxworks-6.2/target/src** (kernel) or **/target/usr** (RTP).

Table 6-17 lists the **CPU** and **TOOL** combinations for building RTP applications. (**CPU** and **TOOL** combinations for building kernel applications are listed in Table A-1.)

Table 6-17 **CPU and TOOL Values When Building For an RTP**

| CPU | TOOL |
|---|---|
| **PPC32** (hardware FP) | **diab**<br>**gnu** |
| **PPC32** (software FP) | **sfdiab**<br>**sfgnu** |

## 6.5 Reference Material

Comprehensive information regarding PowerPC hardware behavior and programming is beyond the scope of this document. IBM and Freescale Semiconductor, Inc. provide several hardware and programming manuals for the PowerPC processor on their Web sites:

**http://www.ibm.com/**

**http://www.freescale.com/**

Wind River recommends that you consult the hardware documentation for your processor or processor family as necessary during BSP development.

### PowerPC Architecture References

The references provided in this section are current at the time of writing; should you decide to use these documents, you may wish to contact the manufacturer for the most current version.

- *The PowerPC Architecture: A Specification for a New Family of RISC Processors*, Morgan-Kaufmann, 1994, ISBN 1-55860-316-6.
- *Programming Environments Manual for 32-bit Implementations of the PowerPC Architecture*, Order #MPCFPE32B/AD, 1/1997.

# 7 Renesas SuperH



## 7.1 Introduction

This chapter provides information specific to VxWorks development on Renesas SuperH targets.

## 7.2 Supported Processors

This release of VxWorks for Renesas SuperH supports the SH-4 family of processors only.

## 7.3 Interface Variations

This section describes particular routines and tools that are specific to SuperH targets in any of the following ways:

- available only on SuperH targets
- parameters specific to SuperH targets
- special restrictions on, or characteristics of SuperH targets

For complete documentation, see the reference entries for the libraries, subroutines, and tools discussed in the following sections.

### 7.3.1 dbgArchLib

#### Register Routines

The SuperH version of **dbgArchLib** provides the following architecture specific routines:

**r0( )-r15( )**
Returns a task's register value.

**sr( )**
Returns a task's Status Register value.

**gbr( )**
Returns a task's Global Base Register value.

**vbr( )**
Returns a task's Vector Base Register value.

**mach( ), macl( )**
Returns a task's MACH, MACL register value.

**pr( )**
Returns a task's Procedure Register value.

**NOTE:** The Global Base Register and Vector Base Register are system-wide global registers. Therefore, these registers are not included in the task context. The **gbr( )** and **vbr( )** routines return the register value only when the task is suspended or stopped by an exception handler. Otherwise, the routines return the initial value of 0.

### Stack Trace and the tt( ) Routine

The **tt( )** routine does not display the parameters of the subroutine call. For a complete stack trace, use Wind River Workbench.

### Software Breakpoints

VxWorks for Renesas SuperH supports both software and hardware breakpoints. When you set a software breakpoint with the **b( )** command, VxWorks replaces an instruction with a **trapa** instruction. VxWorks restores the original instruction when the breakpoint is removed.



If you set a breakpoint just after a delayed branch instruction, the **b( )** command returns the following warning message:

```
-> l 0x6001376,2
6001376  b1a0               bsr     +832         (==> 0x060016ba)
6001378   0606                  (mov.l   r0,@(r0,r6))
-> b 0x6001378
WARNING: address 0x6001378 might be a branch delay slot
value = 0 = 0x0
->
```

In addition, you may see an illegal instruction exception when the breakpoint is hit. However, the **b( )** command does not prevent setting a breakpoint in a branch delay slot because code just after a constant data may also match the pattern of a delayed branch instruction.

### Hardware Breakpoints and the bh( ) Routine

The SuperH architecture provides flexible hardware breakpoint support for instruction and data access through the User Break Controller (UBC module). The supported combinations and the number of channels (one to four) vary, depending on the SuperH processor type. For more details, consult the appropriate SuperH hardware manual.

Hardware breakpoints can be set from the target or host shell using the **bh( )** routine. For the target shell, the **INCLUDE_DEBUG** definition is required in order to include **dbgLib**. For more information, see the reference entry for the **bh( )** routine. For SuperH, the access type qualifier of the **bh( )** routine represents a bitmap combination. The combinations are defined in Table 7-1.

Table 7-1 **SuperH Bitmap Combinations**

| Bits | Value | Breakpoint Type |
|---|---|---|
| 0-1 | 00 | Instruction fetch and data access |
| | 01 | Instruction fetch only |
| | 10 | Data access only |
| 2-3 | 00 | Read and write cycle |
| | 01 | Read cycle only |
| | 10 | Write cycle only |
| 4-5 | 00 | Operand size byte, word, and long (any) |
| | 01 | Operand size byte only |
| | 10 | Operand size word |
| | 11 | Operand size long |
| 6-7 | 00 | CPU access only |
| | 01 | DMAC access only |
| | 10 | CPU and DMAC access |
| 8-9 | 00 | IBUS (regular memory access) |
| | 01 | XBUS (DSP XRAM only) |
| | 10 | YBUS (DSP YRAM only) |

**NOTE:** Bit 0 represents the least significant bit (LSB).

Table 7-2 provides some useful access value examples.

Table 7-2 **Access Value Examples**

| Access Value | Breakpoint Type |
|---|---|
| 0x0000 | Instruction fetch, CPU data read and write of any size. |
| 0x0001 | Instruction fetch only. |

Table 7-2 **Access Value Examples** (cont'd)

| Access Value | Breakpoint Type |
|---|---|
| 0x0032 | CPU long read and write. |
| 0x0026 | CPU word read only. |

### BSP Requirements for Hardware Breakpoints



The architecture-specific debug library uses a UBC abstraction layer in order to cope with differences in the various SuperH processors. To support this, the BSP must set up the UBC structure accordingly in a BSP-specific initialization routine. This routine must be registered as **_func_wdbUbcInit**. The initialization routine should set the UBC structure members as follows:

**chanCnt**
Number of UBC channels (0-4).

**brcrSize**
UBC identification. The supported values are:

**BRCR_NONE** - no UBC support
**BRCR_0_1** - no BRCR, 1 channel (SH7050, SH7000)
**BRCR_16_1** - 16-bit BRCR, 1 channel (SH7055, SH7604)
**BRCR_16_2** - 16-bit BRCR, 2 channels (SH7750, SH7709)
**BRCR_32_2** - 32-bit BRCR, 2 channels (SH7729, SH7709A)
**BRCR_32_4** - 32-bit BRCR, 4 channels (SH7615)
**CCMFR_32_2** - 32-bit CCMFR, 2 channels (SH7770)

**brcrInit**
BRCR value (or CCMFR value for SH-4A architectures) to initialize.

**pBRCR**
Address of the BRCR register (or CCMFR register for SH-4A architectures).

**base**[*i*]
Channel base addresses. Up to four channels are supported.

For example, in **sysHwInit( )**, add the following:

```
#if defined(INCLUDE_WDB) || defined (INCLUDE_DEBUG)
    _func_wdbUbcInit = sysUbcInit;
#endif
```

The following function, **sysUbcInit( )**, is an example for SH7750-based BSPs. SH7750 has a 16-bit BRCR register and two user break channels. For examples using other CPU types, see the appropriate Wind River-provided BSP.

```
/*******************************************************************
*
* sysUbcInit - Initialize the UBC structure
*
* This routine is called when setting the first hardware breakpoint to
* initialize the User Break Controller structure and identify the UBC.
*
*/


void sysUbcInit
    (
    UBC * pUbc
    )
    {
    pUbc->brcrSize = BRCR_16_2;
    pUbc->brcrInit = 0;
    pUbc->pBRCR = (UINT32) UBC_BRCR;
    pUbc->base[0] = (UINT32) UBC_BARA;
    pUbc->base[1] = (UINT32) UBC_BARB;
    }
```

### 7.3.2 **excArchLib**

#### Support for Bus Errors

SH7750 processors detect various types of access alignment errors as address error exceptions, but do not support access timeout errors to non-existent memory.

The exception handling library provides a way to detect this type of bus error in a board-dependent manner. To implement the bus timeout detection, the target board must be able to detect the timeout and interrupt the CPU. This interrupt should be non-maskable and edge-triggered.

- Specify a bus error interrupt vector number to **excBErrVecInit(***vecnum***)** in your BSP code.
- Set the interrupt-acknowledge routine to a function pointer **_func_excBErrIntAck**.

#### Support for Zero-Divide Errors (Target Shell)

The exception handling library uses a CPU-specific trap number (see **ivSh.h**) to detect divide-by-zero errors. For example, the target shell responds to a zero-divide condition with:

```
-> 1/0
Zero Divide
TRA Register: 0x00000004 (TRAPA #1)
Program Counter: 0x0c008a2a
Status Register: 0x40001001
shell restarted.
->
```



Other tasks handle the zero-divide trap as any other exception; the task is suspended unless the trap is caught either as a signal (SIGFPE) or by installing a user handler with **intVecSet( )**.

For application code, this implementation requires support from the compiler used to build the code. The GNU compiler includes support for this type of exception. However, the Wind River Compiler does not include this support. Therefore, application code built with the Wind River Compiler does not generate an exception for a divide-by-zero operation.

### 7.3.3 intArchLib

#### intConnect( ) Parameters

The **intConnect( )** routine takes the following parameters: the interrupt vector address, the handler function, and an integer parameter to the handler function.

The **intConnect( )** routine can be extended by setting **_func_intConnectHook** to the new routine, for example **sysIntConnect( ).** This routine can be implemented for a BSP that has an off-chip interrupt controller (for example, VME).

#### intLevelSet( ) Parameters

The **intLevelSet( )** routine takes an argument from 0 to 15.

#### intLock( ) Return Values

The **intLock( )** routine returns the old status register value.

#### intEnable( ) and intDisable( ) Parameters

The **intEnable( )** and **intDisable( )** routines can invoke BSP-supplied routines when they are set to the **_func_intEnableRtn** and **_func_intDisableRtn** global pointers, respectively. These routines take one integer parameter. If the function pointers are not set (**NULL**), the **intEnable( )** and **intDisable( )** routines do nothing and return **ERROR** when called. The following points must be considered when implementing these routines:

- An interrupt level, in general, can be shared by two or more interrupt sources. In order to implement **intEnable( )** and **intDisable( )**, the BSP must restrict each level to a single interrupt source; otherwise, the value passed to these routines cannot be used to identify the source.
- The interrupt controller's priority registers (IPRA-IPRx) are different for each SuperH CPU variant. Consult the appropriate SuperH hardware manual for the bit definitions of these registers.

### 7.3.4 mathLib

VxWorks for Renesas SuperH supports the following double-precision math routines:

**acos( ) asin( ) atan( ) atan2( ) ceil( ) cos( ) cosh( )**
**exp( ) fabs( ) floor( ) fmod( ) frexp( ) ldexp( ) log( )**
**log10( ) modf( ) pow( ) sin( ) sinh( ) sqrt( ) tan( )**
**tanh( )**

The following single-precision math routines are supported:

**acosf( ) asinf( ) atanf( ) atan2f( ) ceilf( ) cosf( ) coshf( )**
**expf( ) fabsf( ) floorf( ) fmodf( ) frexpf( ) ldexpf( ) logf( )**
**log10f( ) modff( ) powf( ) sinf( ) sinhf( ) sqrtf( ) tanf( )**
**tanhf( )**

### 7.3.5 vxLib

**vxTas( )**
The **vxTas( )** routine provides a C-callable interface to a test-and-set instruction, and it is assumed to be equivalent to **sysBusTas( )** in **sysLib**. The SuperH version of **vxTas( )** simply executes the **tas.b** instruction, but the test-and-set (atomic read-modify-write) operation may require an external bus locking mechanism on some hardware. In this case, wrap **vxTas( )** with the bus locking and unlocking code in **sysBusTas( )**.

**vxMemProbe( )**
The **vxMemProbe( )** routine probes a specified address by capturing a bus error. The SuperH version of the **vxMemProbe( )** routine captures the address error (defined by the CPU), MMU exceptions (defined by the CPU), and the bus-timeout error (optional, defined by the BSP). If a function pointer **_func_vxMemProbeHook** is set by the BSP, the **vxMemProbe( )** routine calls the hook routine instead of its default probing code.



### 7.3.6 SuperH-Specific Tool Options

This section includes information on supported compiler, linker, and assembler options for both the Wind River GNU Compiler (**gnu**) and the Wind River Compiler (**diab**).

#### GNU Compiler (ccsh) Options

VxWorks for Renesas SuperH supports the following SuperH-specific GNU compiler (**ccsh**) options:

| | |
|---|---|
| **-m4** | SH-4 instruction set. |
| **-ml** | Little-endian. |
| **-mb** | Big-endian (default option). |
| **-mbigtable** | Use long jump tables. |
| **-mdalign** | Align doubles on 64-bit boundaries. |
| **-mno-ieee** | No IEEE handling of floating point NaNs. |
| **-mieee** | IEEE handling of FP NaNs (default option). |
| **-misize** | Dump out instruction size information. |
| **-mrelax** | Generate pseudo-ops needed by the assembler and linker to do function call relaxing. |
| **-mspace** | Generate smaller code rather than faster code. |

### GNU Assembler Options

VxWorks for Renesas SuperH supports the following SuperH-specific GNU assembler (**assh**) options:

| | |
|---|---|
| **-little** | Generate little-endian code. |
| **-relax** | Alter jump instructions for long displacements. |
| **-small** | Align sections to 4-byte boundaries instead of 16-byte boundaries. |

### GNU Linker Options

VxWorks for Renesas SuperH supports the following SuperH-specific GNU linker (**ldsh**) options:

| | |
|---|---|
| **-EB** | Enable SuperH ELF big-endian emulation (default). |
| **-EL** | Enable SuperH ELF little-endian emulation. |

### Wind River Compiler Options

There are no SuperH-specific Wind River Compiler compiler (**dcc**) options. The following SuperH target definitions are supported with the **-t** compiler option:

| | |
|---|---|
| **-tSH4EH:vxworks62** | Big-endian SH-4 targets with hardware floating point. |
| **-tSH4LH:vxworks62** | Little-endian SH-4 targets with hardware floating point. |
| **-tSH4EH:rtp** | Big-endian SH-4 RTPs with hardware floating point. |
| **-tSH4LH:rtp** | Little-endian SH-4 RTPs with hardware floating point. |

### Wind River Compiler Assembler Options

The target definitions listed in the previous section, also apply to the assembler. The following Wind River Compiler assembler option is useful when building GNU-compatible modules:

**-Xalign-power2** The **.align** directive specifies power-of-two alignment.

#### Wind River Compiler Linker Options

There are no SuperH-specific Wind River Compiler linker options. The target definitions listed in *Wind River Compiler Options*, p.180 apply to the linker as well.

## 7.4 Architecture Considerations



This section describes characteristics of the Renesas SuperH architecture that you should keep in mind as you write a VxWorks application. The following topics are addressed:

- operating mode, privilege protection
- byte order
- register usage
- banked registers
- exceptions and interrupts
- memory management unit
- maximum number of RTPs
- null pointer dereference detection
- caches
- floating-point support
- power management
- signal support
- SH7751 on-chip PCI window mapping
- VxWorks virtual memory mapping
- memory map

### 7.4.1 Operating Mode, Privilege Protection

VxWorks runs in privileged mode on SuperH processors. RTPs (real-time processes) run in user mode. RTPs issue a **trapa** number 32 instruction when jumping to a VxWorks system call and switch to privileged mode to access resources that are protected in user mode. For more information on RTPs, see the *VxWorks Application Programmer's Guide*.

### 7.4.2 Byte Order

For SH-4 processor families, both big- and little-endian byte orders are supported. Pre-built VxWorks libraries are provided for both endian byte orders and the included makefiles can be used to build applications with either byte order. For big-endian byte order, set the make variable **TOOL** to **gnu** or **diab**. For little-endian byte order, set the make variable to **gnule** or **diable**.

Those SuperH BSPs that support both big- and little-endian byte order are delivered as two copies: one copy for little-endian support and another copy for big-endian support. The little-endian version is appended with **_le**. The BSPs differ in the makefile only.

Wind River Workbench host tools (such as GDB and the Wind River System Viewer) automatically detect the byte order of the target system. Additionally, the byte order for GDB can be forced using the **set endian** command.

### 7.4.3 Register Usage

Register usage for SuperH processors is as follows:

| | |
|---|---|
| **r0** | return value |
| **r1...r3** | scratch registers |
| **r4...r7** | function parameters |
| **r8...r13** | call saved registers |
| **r14** | frame pointer (call saved) |
| **r15** | stack pointer |
| **pr** | subroutine return address |
| **fpul** | FP to integer communication register |
| **dr0 (fr0)** | FP return value |
| **dr2 (fr1...fr3)** | FP scratch registers |
| **dr4..dr10 (fr4..fr11)** | FP parameters |
| **dr12,dr14 (fr12...fr15)** | call saved FP registers |
| **xd0..xd14 (xf0...xf15)** | not used by the compiler |

### 7.4.4 Banked Registers

In the privileged mode of SuperH processors, two sets of general registers r0 - r7 are available. One set is called BANK0, and another set is called BANK1. The register bank (RB) bit in the status register (SR) defines which banked register set is accessed as r0 - r7. While RB = 1, BANK1 registers (r0_bank1 - r7_bank1) are

accessed as r0 - r7. While RB = 0, BANK0 registers (r0_bank0 - r7_bank0) are accessed as r0 - r7. When an exception or interrupt happens, VxWorks for Renesas SuperH automatically sets the RB bit to 1.

VxWorks for Renesas SuperH sets the RB bit as follows:

RB = 0
system initialization (**romInit - kernelInit**)

RB = 0
multi tasking (after **usrRoot**)

RB = 1
TLB mis-hit exception handling

RB = 1
common processes for exception/interrupt handling

RB = 0
individual exception/interrupt handling

Generally, all VxWorks tasks run with BANK0 registers. There are some common processes for exception and interrupt handling which run with BANK1, but those processes switch back to BANK0 before dispatching to an individual handler. The switching is done by applying a new SR value from **intPrioTable[ ]** in the BSP. One exception is translation lookaside buffer (TLB) mis-hit exception handling which runs with BANK1 to the end.



### 7.4.5 Exceptions and Interrupts

The SuperH architecture (SH-4) defines four branch addresses for exceptional events, as shown in Table 7-3.

Table 7-3 **SuperH Branch Addresses**

| Event | Branch Address | Cause Register |
|---|---|---|
| Reset, Power-on | 0xa0000000 | EXPEVT |
| Exception, Trap | VBR + 0x100 | EXPEVT/TRA |
| TLB mis-hit (MMU) | VBR + 0x400 | EXPEVT |
| Interrupt | VBR + 0x600 | INTEVT |

To support the standard vectored interrupt handling scheme on SuperH, VxWorks defines a virtual vector table which starts at (VBR + 0x800). This vector table size is (4-bytes x 256-entries), and the entry offset is defined as follows:

exception/interrupt
    (EXPEVT/INTEVT register value) / 8

trap
    (TRA register value)

Specify the entry offset as the first argument (*vector*) of **intConnect** (*vector*, *routine*, *parameter*).

VxWorks for Renesas SuperH uses the **trapa** instruction to implement system calls, software breakpoints, and to detect an integer zero-divide.

### Multiple Interrupts

The status register of SuperH has 4 bits of interrupt masking field; thus it supports 15-levels of prioritized interrupts. Control of masking field is fully left to software.

To support the prioritized interrupt handling system on SuperH, VxWorks defines a table of status register values in the BSP. This table is called **intPrioTable[ ]**, and is located in **sysALib**.

When a SuperH CPU accepts an interrupt request, it first blocks any succeeding exception or interrupt by setting the block bit (BL) to 1 in the status register (SR), the processor then branches to (VBR + 0x600).

The common interrupt dispatch code is loaded at (VBR + 0x600), and the processor instructs the following: (1) save critical registers on interrupt stack, (2) update SR with a value in **intPrioTable[ ]**, (3) branch to an individual interrupt handler. Here, step (2) typically unblocks higher-priority interrupts, thus multiple interrupts can be processed. Also, the SR is not updated if the corresponding **intPrioTable[ ]** entry is null.

As a specification of the on-chip interrupt controller (INTC), the processor may branch to (VBR + 0x600) with a **NULL** value in the INTEVT register. This could happen if the interrupt status or control flags of the on-chip peripheral modules are modified while the BL bit of the SR is 0. To safely ignore this spurious interrupt, the common interrupt dispatch code checks the INTEVT register value and immediately calls the RTE (return from exception) instruction if the value is **NULL**.

#### Interrupt Stack

For VxWorks on all Renesas SuperH architectures, an interrupt stack allows all interrupt processing to be performed on a separate stack. The interrupt stack is implemented in software because the SuperH family does not support such a stack in hardware. The interrupt stack size is defined by the **ISR_STACK_SIZE** macro in the **configAll.h** file. The default size of the interrupt stack is 1000 bytes. The interrupt stack is initialized by calling **kernelInit( )**.

For SuperH, the common interrupt dispatch code pushes some critical registers on the interrupt stack while the BL bit of SR is 1. As a specification, SuperH immediately reboots if any exception occurs while the BL bit is 1. Note that if the MMU is enabled, any access to logical address space may lead to a TLB mis-hit exception. In other words, no logical address space access is allowed while the BL bit is 1 if the MMU is enabled. Therefore, the interrupt stack must be located on a fixed physical address space (P1/P2) if the MMU is enabled. Interrupt stack underflow/overflow guard pages are not available on SuperH architectures due to the location of the stack in the P1/P2 area (which is MMU unmappable). The SuperH version of **kernelInit( )** internally calls **intVecBaseGet( )** and uses the upper three bits of its returned address as the base address of the interrupt stack, so that you can specify your choice of P1/P2 to **intVecBaseSet( )** in **usrInit( )**, typically through a redefined macro **VEC_BASE_ADRS** in your BSP.



### 7.4.6 Memory Management Unit (MMU)

The current version of the MMU library for SuperH processors supports a default page size of 4 KB. 64 KB and 1 MB pages are supported for static MMU entries only (for more information, see the reference entry for **vmPageLock( )** and *7.4.13 SH7751 On-Chip PCI Window Mapping*, p.193). The default page size **VM_PAGE_SIZE** is defined as 0x1000 (4 KB) in *installDir*/**vxworks-6.2/target/config/all/configAll.h**.

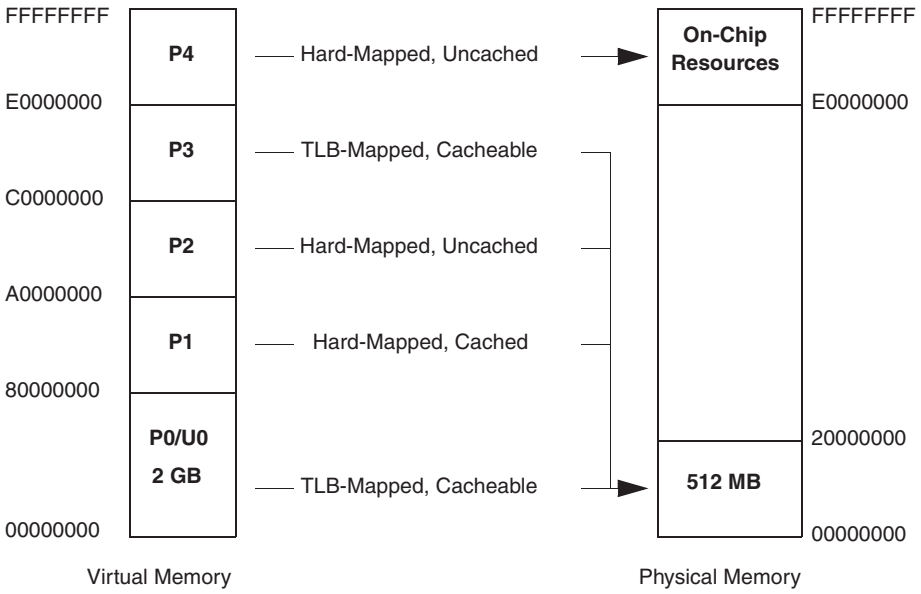
By default, VxWorks and user applications are linked to the P0 area (2 GB logical address space, copyback/write-through cacheable). The ROM initialization code is also linked to P0, but the code is executed from the P2 area (0.5 GB fixed physical address space, non-cacheable) at the beginning of the ROM initialization routine, **romInit( )**, when the board is powered on or reset.

SH-4 processors include a memory management unit (MMU) commonly referred to as the translation lookaside buffer (TLB). The TLB holds the most recently used virtual-to-physical address mappings in the form of TLB entries. The SH-4 TLB is two-layered; instruction-TLB (ITLB) for program text, and unified-TLB (UTLB) for

program text/data/bss. The ITLB has four full-associative entries, and the UTLB has 64 full-associative entries. In a sense, the ITLB caches some UTLB entries and the UTLB caches some page table entries on the physical memory. If an SH-4 processor accesses a virtual address that is not mapped on the UTLB, a TLB mis-hit exception immediately takes place and control is transferred to the VxWorks TLB mis-hit exception handler placed at the pre-determined vector address (VBR + 0x400). The TLB mis-hit handler walks through the translation table on physical memory, and loads the missing virtual-to-physical address mapping to the TLBs, if any exist. If the handler fails to find a valid page table entry for the accessed virtual address, a TLB Miss/Invalid exception event is reported in the VxWorks shell.

The SH-4 memory map is depicted in Figure 7-1. Note that the SH-4 memory map is arranged into segments that have pre-determined modes of operation. Unlike some processors that can set specific virtual addresses to any mode of operation, SH-4 pre-assigns certain ranges of virtual addresses as accessible in privileged mode or user mode.

Figure 7-1 **SH-4 Processor Memory Map**




In Figure 7-1, there are five memory segments: P0/U0, P1, P2, P3, and P4. The lowest 2 GB segment is accessible in either privileged or user mode; it is called P0

in privileged mode, and U0 in user mode. The other segments are accessible only in privileged mode—that is, in the VxWorks supervisor mode.

The five SH-4 memory segments are also pre-designated as either TLB-mapped or hard-mapped, as shown in Figure 7-1. Ranges of addresses designated as TLB-mapped, P3 and P0/U0, use the TLB to determine the physical mappings for the virtual addresses. Ranges of addresses specified as hard-mapped, P1 and P2, do not use the TLB. Instead, SH-4 directly maps the virtual address starting at physical address 0x0. Likewise, P4 is directly mapped to various on-chip resources.

To summarize each of the segments:



P0/U0
: When the most significant bit of the virtual address is 0, the 2 GB user space labeled P0/U0 is the virtual address space selected. All references to P0/U0 are mapped through the TLB while the MMU is enabled. This memory segment can be marked either as cacheable or uncacheable on a page-by-page basis.

P1
: When the most significant three bits of the virtual address are 100, the 512 MB kernel space labeled P1 is the virtual address space selected. References to P1 are not mapped through the TLB; the physical address selected is defined by subtracting 0x80000000 from the virtual address. The cache mode for these accesses is determined by the copyback (CB) bit of the cache control register (CCR) mapped in P4, and the CB bit is set if the **CACHE_COPYBACK_P1** option is specified in the **USER_D_CACHE_MODE** parameter of the BSP's **config.h** file.

P2
: When the most significant three bits of the virtual address are 101, the 512 MB kernel space labeled P2 is the virtual address space selected. References to P2 are not mapped through the TLB; the physical address selected is defined by subtracting 0xA0000000 from the virtual address. Caches are always disabled for accesses to these addresses; physical memory or memory-mapped I/O device registers are accessed directly.

P3
: When the most significant three bits of the virtual address are 110, the 512 MB kernel space labeled P3 is the virtual address space selected. All references to P3 are mapped through the TLB while the MMU is enabled. This memory segment can be marked either as cacheable or uncacheable on a page-by-page basis.

P4

When the most significant three bits of the virtual address are 111, the 512 MB kernel space labeled P4 is the virtual address space selected. References to P4 are not mapped through the TLB; this space is mapped to various on-chip resources. Caches are always disabled for accesses to these addresses; on-chip registers or PCI bus windows are accessed directly.

While the memory segments P1 and P2 are both hard-mapped kernel segments, both segments map to the same physical memory in the lowest 512 MB of memory. As a result, to virtually reference a variable or code in P1 is to virtually reference the same in P2. However, because P2 is not cacheable, virtually referencing a variable or code in P2 results in an uncached reference. Note that the SH-4 MMU manages a 29-bit physical address. In other words, the SH-4 MMU translates a 32-bit virtual address into a 29-bit physical address. Also note that virtual addresses referenced in hard-mapped space do not cause a TLB mis-hit exception at any time. These points are important to the implementation of the software side of the MMU.

The current version of the MMU library for SuperH does not support SH-4A 32-bit address extended mode (4 GB physical address memory space). VxWorks runs in SH-4 29-bit emulation mode on SH-4A processors.

### SH-4-Specific MMU Attributes

SH-4 processors support certain special MMU attributes (**MMU_ATTR_SPL_0** through **MMU_ATTR_SPL_3**) which allow you to set the PTEA (Page Table Entry Assistant) register during an MMU TLB mishandling and then load the value to the UTLB data array 2. The special attributes can be used to set the PTEA register as follows:

| | |
|---|---|
| **MMU_ATTR_SPL_0** | Enables setting of the SA[0] bit on the PTEA register |
| **MMU_ATTR_SPL_1** | Enables setting of the SA[1] bit on the PTEA register |
| **MMU_ATTR_SPL_2** | Enables setting of the SA[2] bit on the PTEA register |
| **MMU_ATTR_SPL_3** | Enables setting of the TC bit on the PTEA register |

**NOTE:** The above register settings are required for PCMCIA use. However, due to the PTEA register value read/write operation during the TLB mishandle, exception handling becomes much slower when the special attributes are implemented. For this reason, Wind River does not recommend using the special attributes unless they are required for PCMCIA support.

#### AIM Model for MMU

The Architecture-Independent Model (AIM) for MMU provides an abstraction layer to interface with the underlying architecture-dependent MMU code. This allows uniform access to the hardware-dictated MMU model that is typically CPU core specific. AIM for MMU is for VxWorks internal use. However, the new model adds support for a new routine, **vmPageLock( )** to the VxWorks **vmLib** API. For more information on this routine, see the reference entry for **vmPageLock( )**.

**vmPageLock( )** requires the use of static MMU entries. To ensure minimal resource usage, this routine requires alignment of the lock regions. This routine provides a mechanism for reducing page misses and should boost performance when used correctly.



Page locking of a text section will fail if the alignment and size of the text section is such that the number of resources available is not sufficient to satisfy the required number of MMU resources. If the BSP uses too many resources when the "Lock program text into TLBs" (**INCLUDE_LOCK_TEXT_SECTION**) option is defined, it may not be possible to enable this feature. SH-4 reference BSPs *do not* enable the **INCLUDE_LOCK_TEXT_SECTION** option by default.

The maximum number of MMU entries that can be used for static memory pages is seventy-five percent of 64, or the CPU-supported UTLB entry number, which is 48.

### 7.4.7 Maximum Number of RTPs

The maximum number of real-time processes available in a given system is limited for the SH-4 processor family due to the implementation of virtual context support. The maximum number of RTPs available in a system is 255.

**NOTE:** The SH-4 ASID (address space identification) provides 256 virtual contexts. However, one virtual context is always assigned to the system page.

### 7.4.8 Null Pointer Dereference Detection

In order to implement null pointer dereference detection for the SH-4 processor family, you must leave the virtual address zero unmapped. Alternatively, you can add an entry start from 0x0 using the **MMU_ATTR_VALID_NOT** (or **VM_STATE_VALID_NOT**) parameter. **MMU_ATTR_VALID_NOT** is configured by **sysPhysMemDesc[ ]** which is declared in the **sysLib.c** file in your BSP.

**NOTE:** The **VM_STATE**_*xxx* macros (listed above) are used in VxWorks 5.5 releases and are still supported for this release. However, these macros may be removed in the future. Wind River recommends that you use the **MMU_ATTR**_*xxx* macros for new development and that you update any existing BSP to use the new macros whenever possible. For more information on the **VM_STATE**_*xxx* macros, see the *VxWorks Migration Guide*.

### 7.4.9 Caches

The SuperH cache implementation differs from processor to processor; refer to your processor hardware manual for details. The SuperH target libraries include support for the following processor types, as shown in Table 7-4. The SuperH cache libraries for this release do not use the processor abstraction layer method (referred to as cache AIM) used for certain other processors as of VxWorks 6.0. Instead, the libraries are directly linked to the upper layer of the cache library as in earlier VxWorks releases.

Table 7-4 **Cache Libraries and Supported Processors**

| Cache Library | Supported Processors |
|---|---|
| **cacheSh7750Lib** | SH7750, SH7750R, SH7751, SH7751R, SH7760, SH7770 |

The BSP must assign **sysCacheLibInit** to the cache library initialization routine. For example:

```
FUNCPTR sysCacheLibInit = (FUNCPTR)  cacheSh7750LibInit;
```

### 7.4.10 Floating-Point Support

SH-4 processors have an on-chip floating-point unit. The **mathHardInit( )** routine does the necessary initialization for this library, and is automatically called from **usrRoot( )** in **usrConfig.c** if the **INCLUDE_HW_FP** option is defined. Tasks that perform floating-point arithmetic must be spawned with the **VX_FP_TASK** option.

Floating-point exceptions are disabled by default. This can be changed temporarily on a per-task basis by setting the FPSCR register (using **fpscrSet( )**). Note that the compiler automatically generates code to change the FPSCR value in order to switch from double- to single-precision arithmetic and back. The two values are stored in two 32-bit globals pointed to by **__fpscr_values**.

The FPSCR register can also be set globally with the help of the global **fpscrInitValue** variable (declare this variable as **extern UINT32**). This value must be set early at startup. It is used to initialize **__fpscr_values** and each floating-point task's initial FPSCR value.

The default **fpscrInitValue** variable sets the rounding mode to the *Round to Nearest* policy and enables denormalized numbers. The SH7750 processor requires software support for handling denormalized numbers in the form of an exception handler. This handler is provided with the VxWorks target library. If your application does not require support for denormalized numbers you may change the FPSCR setting accordingly. Disabling denormalized numbers causes the FPU to treat them as zero. For more information, see the *SH7750 Hardware Manual*.



The floating-point context includes the extended floating-point registers. To save and restore the extended floating-point registers at context switches, tasks performing floating-point instructions should be spawned with the **VX_FP_TASK** option. Interrupt handlers using floating-point operations must explicitly call **fppSave( )** and **fppRestore( )**. These two functions are also used to save and restore the extended floating-point registers.

There are no special compiler flags required for enabling hardware or software floating-point. Provided you use the appropriate target CPU option, both the GNU compiler and the Wind River Compiler default to hardware floating-point for SH-4 processors. For more information, see *7.3.6 SuperH-Specific Tool Options*, p.179.

### 7.4.11 Power Management

SuperH processors provide a simple power management mechanism that allows them to enter a low power mode during idle periods. To enable processor power management, the BSP must configure the **vxPowerModeRegs[ ]** structure. Power management registers differ considerably from processor to processor, even within the same processor family. The **vxPowerModeRegs[ ]** structure allows the architecture support library to abstract these differences.

For SuperH processors that have two power management (standby) control registers, initialize the structure in **sysHwInit( )** as follows:

```
vxPowerModeRegs.pSTBCR1 = STBCR;
vxPowerModeRegs.pSTBCR2 = STBCR2;
vxPowerModeRegs.pSTBCR3 = NULL;
```

For SuperH processors that have three power management (standby) control registers, initialize the structure in **sysHwInit( )** as follows:

```
vxPowerModeRegs.pSTBCR1 = STBCR;
vxPowerModeRegs.pSTBCR2 = STBCR2;
vxPowerModeRegs.pSTBCR3 = STBCR3;
```

The **vxPowerModeSet( )** routine can be used to set the power mode. The supported parameter values for this routine are:

| | |
|---|---|
| **VX_POWER_MODE_DISABLE** | disable power management |
| **VX_POWER_MODE_SLEEP** | sleep mode |
| **VX_POWER_MODE_DEEP_SLEEP** | deep sleep mode |
| **VX_POWER_MODE_USER** | user-specified mode |

The user-specified mode (**VX_POWER_MODE_USER**) allows you to set the standby registers to user-specified values (up to three registers). For example:

```
vxPowerModeSet (VX_POWER_MODE_USER | sbr1<<8 | sbr2<<16 | sbr3<<24);
```

The **DEFAULT_POWER_MGT_MODE** configuration parameter can be used to set the boot-up power management mode.

**NOTE:** Before working with power management, always consult the SuperH processor hardware manual for your chip for information on supported power modes and restrictions and requirements for RAM refresh, timers, and other on-chip devices. Note that some power modes require the SDRAM to be switched to self-refresh mode. Because SDRAM cannot be read while in self-refresh mode, the kernel cannot be run from SDRAM.

**NOTE:** This power management implementation does not support the SH-4A processor family.

### 7.4.12 Signal Support

VxWorks provides software signal support for all architectures. However, the manner in which SH-4 processors map their own exceptions to software signals is architecture-dependent. Table 7 shows this mapping for SH-4 processors:

Table 7-5 **Exception-to-Software-Signal Mapping for SH-4 Processors**

| SH-4 Exception Name | Software Signal |
|---|---|
| **INUM_TLB_READ_MISS** | SIGSEGV |
| **INUM_TLB_WRITE_MISS** | SIGSEGV |

Table 7-5 **Exception-to-Software-Signal Mapping for SH-4 Processors** (cont'd)

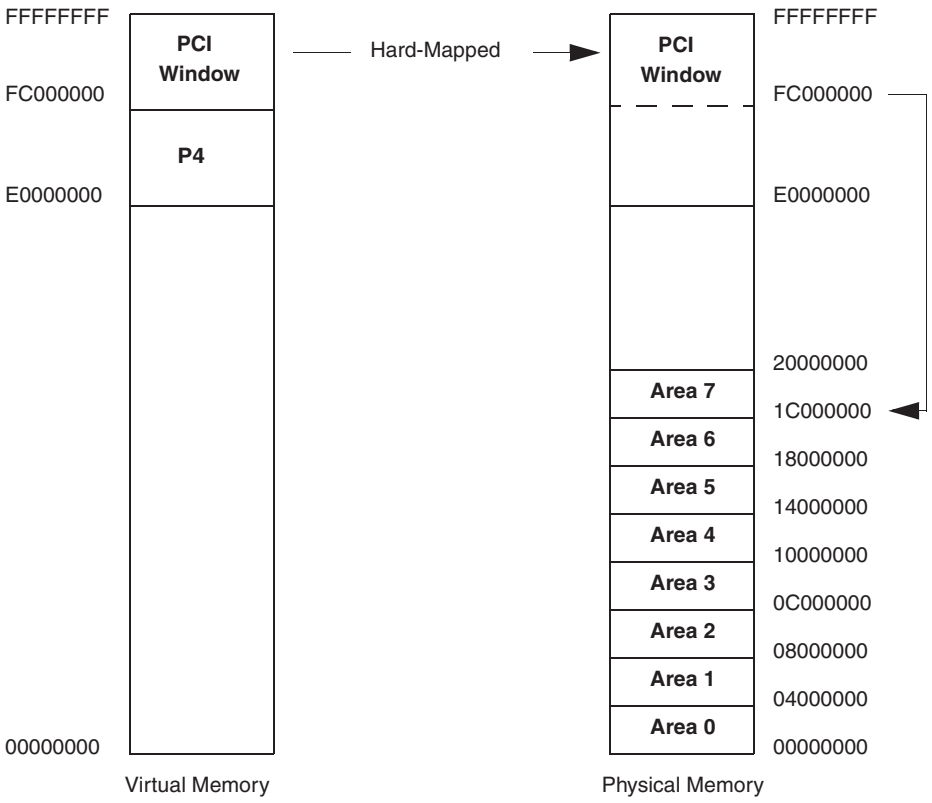
| SH-4 Exception Name | Software Signal |
|---|---|
| **INUM_TLB_WRITE_INITIAL_MISS** | SIGSEGV |
| **INUM_TLB_READ_PROTECTED** | SIGSEGV |
| **INUM_TLB_WRITE_PROTECTED** | SIGSEGV |
| **INUM_READ_ADDRESS_ERROR** | SIGSEGV |
| **INUM_WRITE_ADDRESS_ERROR** | SIGSEGV |
| **INUM_FPU_EXCEPTION** | SIGFPE |
| **INUM_ILLEGAL_INST_GENERAL** | SIGILL |
| **INUM_ILLEGAL_INST_SLOT** | SIGILL |
| **INUM_TRAP_1** | SIGFPE |



### 7.4.13 SH7751 On-Chip PCI Window Mapping

Some SH-4 processors (SH7751 and SH7751R) have an on-chip PCI bus controller, and the PCI windows are memory-mapped to the highest 64 MB address range in the P4 segment (FC000000 - FFFFFFFF). This type of memory mapping is not manageable in the page-oriented manner that is used by the VxWorks page manager library, **pgMgrLib**. This could be a problem for PCI devices that require memory-mapped PCI space (for example, a frame buffer on a graphics card). As mentioned previously, the SH-4 MMU handles a 29-bit physical address. This 29-bit address space is designated as external memory space and is divided into eight 64 MB areas (**Area0** - **Area7**). The first seven areas (**Area0** - **Area6**) are used to connect various types of memory. The last segment (**Area7**) is reserved. However, if the MMU is enabled, **Area7** becomes a shadow of the highest 64 MB address range in the P4 segment. Therefore, a PCI frame buffer is TLB-mappable from **Area7**. Figure 7-2 illustrates this memory mapping.

Figure 7-2 **SH7751 On-Chip PCI Window Memory Mapping**



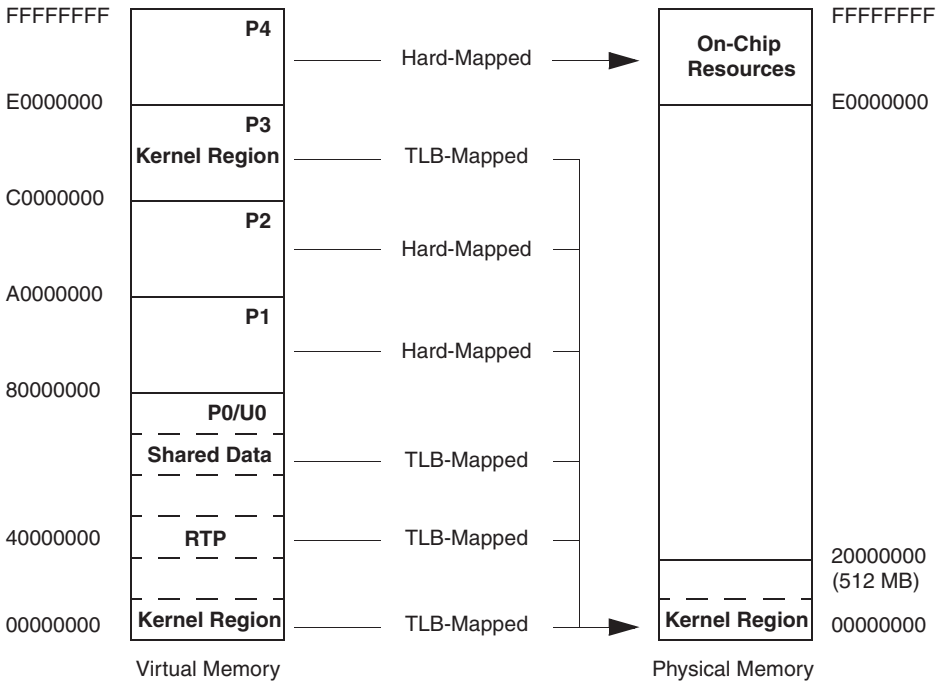

## 7.4.14 VxWorks Virtual Memory Mapping

The virtual to physical mapping for VxWorks is shown in Figure 7-3. The segments P1 and P2 are hard-mapped to the lowest 512 MB of memory. A small portion of P0, the VxWorks kernel, is also TLB-mapped here. The remainder is mapped to physical memory through the TLB.

Two address spaces, kernel and RTP, are also shown in Figure 7-3. This space is the standard VxWorks address space used by the SH-4 processor to differentiate between kernel code and RTP code. Note that the kernel domain is located in P0 (or P3, depending on your BSP configuration), while RTPs are located in U0. Also note that RTP address space is overlapped at virtual address 40000000. One virtual page, the system page, is also shown in Figure 7-3. Shared data is mapped to the

beginning of the kernel's data segment, and is used to export specific global variables to the RTPs.

Figure 7-3 **SH-4 Virtual-to-Physical Memory Map**




The TLB-mapping model allows you to map memory in 4 KB pages. The translation table is organized into three levels: the top level consists of an array of 256 level 0 (L0) context table descriptors; in turn, each of the level 0 descriptors can point to an array of 1024 level 1 (L1) table descriptors; and each of the level 1 descriptors can point to an array of 1024 level 2 (L2) table descriptors. Each L2 table entry is actually a page table entry value to be applied to the PTEL register by the TLB mis-hit exception handler; each L2 table entry describes memory attributes in a 4 KB page. Each L2 table describes a 4 MB (1024 entries x 4 KB) virtual space, and each L1 table describes a 4 GB (1024 entries x 4 MB) virtual space. This 4 GB virtual space is called a virtual context, and is selected by an 8-bit address space ID (ASID) in the PTEH register. Therefore, the L0 context table has 256 entries which are indexed by ASID.

VxWorks runs in one of two modes, user or supervisor. Furthermore, addresses can be specified as read-only, write-only, or read/write. Memory attributes determine the addresses' accessibility: that is, whether the address is accessible by the user or supervisor, and whether it is in read/write or read-only mode. Table 7-6 summarizes the valid MMU attribute combinations for the SH-4 processor family. Note that the P3 segment can only be assigned supervisor access, and that the P0/U0 segment can be assigned supervisor or user access. Also note that in the P0/U0 segment, user mode cannot have read/write attributes enabled unless they are enabled in supervisor mode as well. This means that an address in P0/U0 cannot have a read and write attribute in user mode with a read-only attribute in supervisor mode.

Table 7-6 **Valid MMU Attribute Combinations for SH-4 Processors**

| | | Supervisor Mode | | User Mode | |
|---|---|---|---|---|---|
| **Segment** | **Virtual Address Range** | **Read** | **Write** | **Read** | **Write** |
| P4 | E0000000 - FFFFFFFF | X | X | n/a | n/a |
| P3 | C0000000 - DFFFFFFF | X | | n/a | n/a |
| | | X | X | n/a | n/a |
| P2 and P1 | 80000000 - BFFFFFFF | X | X | n/a | n/a |
| P0/U0 | 00000000 - 7FFFFFFF | X | | | |
| | | X | X | | |
| | | X | | X | |
| | | X | X | X | X |

## 7.4.15 Memory Layout

The memory layout of the Renesas SuperH is shown in Figure 7-4. The figure contains the following labels:

**Part of Kernel Text and Data**
Part of Kernel code which needs to be located in P1 space.

**Exception Handling Stub**
Stub to handle exception vectoring.

**TLB Mis-hit Handler**
Handler for translation lookaside buffer (TLB) mis-hit.

**Interrupt Handling Stub**
Stub to handle interrupt priority control and vectoring.

**Interrupt Vector Table**
Table of exception/interrupt vectors.

**Interrupt Priority Table**
Copied image of **intPrioTable[ ]**.

**SM Anchor**
Anchor for the shared memory network.

**Boot Line**
ASCII string of boot parameters.

**Exception Message**
ASCII string of the fatal exception message.

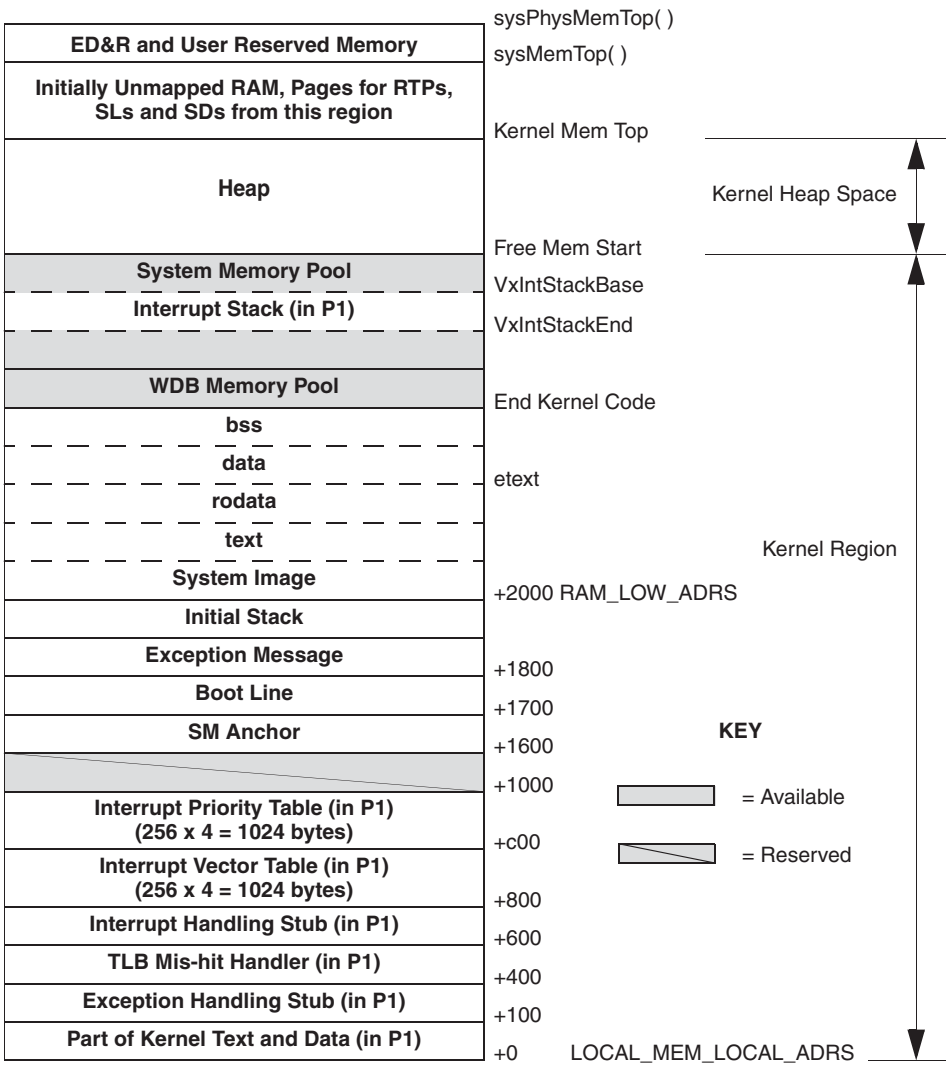
**Initial Stack**
Initial stack for **usrInit( )**, until **usrRoot( )** is allocated a stack.

**System Image**
VxWorks itself (four sections: text, rodata, data, and bss). The entry point for VxWorks (**sysInit( )**) is at the start of this region.

**Interrupt Stack**
Stack for the interrupt handlers. Size is defined in **configAll.h**. Location depends on system image size.

**System Memory Pool**
Heap for the kernel.

Figure 7-4 **VxWorks Memory Layout for the SH-4 System Module (P0 or P3)**



**NOTE:** Some SuperH BSPs set **LOCAL_MEM_SIZE** to a value that is smaller than the actual physical memory. This is done to reduce boot-up time for the default boot ROM shipped with the BSP or because of variations in physical memory size on different hardware revisions. If this is the case for your BSP, you can increase **LOCAL_MEM_SIZE** up to the physical memory size. This will result in an increase in the system memory pool size. (If your BSP supports **LOCAL_MEM_AUTOSIZE**, the physical memory size is calculated by the BSP automatically.) For more information, see your BSP **config.h** or **target.ref** file.



All addresses shown in Figure 7-4 are relative to the start of memory for a particular target board. The start of memory (corresponding to +0 in the memory-layout diagram) is defined as **LOCAL_MEM_LOCAL_ADRS** in **config.h** for each target.

## 7.5 Migrating Your BSP

In order to convert a VxWorks BSP from an earlier release to VxWorks 6.2, you must make certain architecture-independent changes. This includes making changes to custom BSPs designed to work with a VxWorks 5.5 release and not supported or distributed by Wind River.

This section includes changes and usage caveats specifically related to migrating SuperH BSPs to VxWorks 6.2. For more information on migrating BSPs to VxWorks 6.2, see the *VxWorks Migration Guide*.

### 7.5.1 Memory Protection

The SH-4 reference BSPs provided by Wind River disable the MMU by default. If you require memory protection for your board, you must enable the MMU by including the **INCLUDE_MMU_BASIC** component in the BSP **config.h** file.

## 7.6 Reference Material

Comprehensive information regarding SuperH hardware behavior and programming is beyond the scope of this document. Renesas Technology Corporation provides several hardware and programming manuals for the SuperH processor on its Web site:

**http://www.renesas.com/**

Wind River recommends that you consult the hardware documentation for your processor or processor family as necessary during BSP development.

# A Building Applications



## A.1 Introduction

Wind River recommends that you use Workbench or the **vxprj** command-line utility whenever possible to build your VxWorks image or application. Workbench and **vxprj** are correctly pre-configured to build most types of projects. However, this appendix provides architecture-specific information that you may need to build certain types of VxWorks applications and libraries, specifically in situations where you must invoke the **make** command directly.

For more information on building applications and libraries, see the *Wind River Workbench for VxWorks User's Guide* or the *VxWorks Command-Line Tools User's Guide: Building Kernel and Application Projects*.

## A.2 Defining the CPU and TOOL Make Variables

There are several make variables used to control the VxWorks build system, including the **CPU** and **TOOL** variables. The **CPU** variable is used to describe the the target instruction-set architecture. The **TOOL** variable specifies the compiler and toolkit used (Wind River Compiler or Wind River GNU Compiler) and can also be used to specify the endianess or floating-point support as necessary.

These options can be specified when invoking the make command directly. For example:

```
% make CPU=MIPS32 TOOL=sfgnule
```

This command compiles for a 32-bit MIPS target using the GNU compiler, with software floating-point support and little-endian byte order.

Table A-1 shows the supported values for **CPU** and **TOOL**. When referencing this table, note the following:

- Not every combination of target processor family, toolkit, floating-point mode, and endianess is supported.
- The CPU value used by the VxWorks build system does not necessarily correspond to the exact microprocessor model.
- The information in the table may not be up to date. For information regarding current processor support, see your product release notes or the Online Support Web site.

**NOTE:** Modules built with either **gnu** or **diab** can be linked together in any combination, except for modules that require C++ support. Cross-linking of C++ modules is not supported in this release. For more information, see your product migration guide.

Table A-1 **Values for the CPU and TOOL Make Variables**

| CPU Value | TOOL Value | Processor Class | Floating Point | Endian |
|---|---|---|---|---|
| **ARMARCH5** | **diab** | ARM Architecture Version 5 CPUs (running in ARM state) | | little |
| | **gnu** | | | little |

Table A-1 **Values for the CPU and TOOL Make Variables** (cont'd)

| CPU Value | TOOL Value | Processor Class | Floating Point | Endian |
|---|---|---|---|---|
| **ARMARCH6** | **diab** | ARM Architecture Version 6 CPUs (running in ARM state) | | little |
| | **gnu** | | | little |
| **PENTIUM** | **diab** | Pentium | | little |
| | **gnu** | | | little |
| **PENTIUM2** | **diab** | Pentium Pro, Pentium II | | little |
| | **gnu** | | | little |
| **PENTIUM3** | **diab** | Pentium III, Pentium M | | little |
| | **gnu** | | | little |
| **PENTIUM4** | **diab** | Pentium 4, Pentium M | | little |
| | **gnu** | | | little |
| **XSCALE** | **gnu** | XScale Architecture CPUs (running in ARM state) | | little |
| | **diab** | | | little |
| | **gnube** | | | big |
| | **diabbe** | | | big |
| **MIPS32** | **sfgnu** | 32-bit MIPS | Software | big |
| | **sfdiab** | 32-bit MIPS | Software | big |
| | **sfgnule** | 32-bit MIPS | Software | little |
| | **sfdiable** | 32-bit MIPS | Software | little |

Table A-1 **Values for the CPU and TOOL Make Variables** (cont'd)

| CPU Value | TOOL Value | Processor Class | Floating Point | Endian |
|---|---|---|---|---|
| **MIPS64** | **gnu** | 64-bit MIPS | Hardware | big |
| | **diab** | 64-bit MIPS | Hardware | big |
| | **gnule** | 64-bit MIPS | Hardware | little |
| | **diable** | 64-bit MIPS | Hardware | little |
| **PPC405** | **sfdiab** | PowerPC 405GP, 405GPr | Software | big |
| | **sfgnu** | PowerPC 405GP, 405GPr | Software | big |
| **PPC440** | **sfdiab** | PowerPC 440GP | Software | big |
| | **sfgnu** | PowerPC 440GP | Software | big |
| | **diab** | PowerPC 440GX | Hardware | big |
| | **gnu** | PowerPC 440GX | Hardware | big |
| **PPC603** | **diab** | PowerPC 603, MPC824X, MPC825X, MPC826X, MPC8349, MPC8272, MPC8280 | | big |
| | **gnu** | PowerPC 603, MPC824X, MPC825X, MPC826X, MPC8349, MPC8272, MPC8280 | | big |
| **PPC604** | **diab** | PowerPC 604, 604e, MPC745, PowerPC 750, 750CX, 750CXe, MPC755, MPC7400, MPC7410 | | big |
| | **gnu** | PowerPC 604, 604e, MPC745, PowerPC 750, 750CX, 750CXe, MPC755, MPC7400, MPC7410 | | big |

Table A-1 **Values for the CPU and TOOL Make Variables** (cont'd)

| CPU Value | TOOL Value | Processor Class | Floating Point | Endian |
|---|---|---|---|---|
| **PPC604** (AltiVec[a]) | **diab** | MPC7445, MPC7450, MPC7455 | | big |
| | **gnu** | MPC7445, MPC7450, MPC7455 | | big |
| **PPC860** | **sfdiab** | MPC821, MPC823, MPC823e, MPC850, MPC850SAR, MPC855, MPC855T, MPC860 | | big |
| | **sfgnu** | MPC821, MPC823, MPC823e, MPC850, MPC850SAR, MPC855, MPC855T, MPC860 | | big |
| **PPC85XX** | **sfdiab** | MPC8540, MPC8560 | | big |
| | **sfgnu** | MPC8540, MPC8560 | | big |
| **PPC32** | **diab** | PowerPC 440EP, 970 | | big |
| | **gnu** | PowerPC 440EP, 970 | | big |
| **SH7750** (kernel applications only) | **gnu** | SH-4 | hardware | big |
| | **gnule** | SH-4 | hardware | little |
| | **diab** | SH-4 | hardware | big |
| | **diable** | SH-4 | hardware | little |
| **SH32** (RTPs only) | **gnu** | SH-4 | hardware | big |
| | **gnule** | SH-4 | hardware | little |
| | **diab** | SH-4 | hardware | big |
| | **diable** | SH-4 | hardware | little |

a. Motorola PowerPC MPC74XX CPUs are treated as a variation of the PowerPC 604 CPU type. AltiVec support in the MPC74XX processors is in addition to the existing PowerPC 604 functionality. Modules that make use of AltiVec instructions must be compiled with certain compiler-specific options, but can be linked with modules that do not use the AltiVec compile options. See *6.3.7 AltiVec and PowerPC 970 Support*, p.130, for details

### Special Considerations for PowerPC Processors

#### CPU_VARIANT

On PowerPC processors, specifying **CPU** and **TOOL** is usually sufficient to build a module using the pre-defined rules, with the following exceptions:

- Processors that are based on the x5 version of the PowerPC 440 core (such as PowerPC 440GX or 440EP) require support for the recoverable machine check mechanism even if none of the mechanism's optional capabilities are enabled. In order to select the proper version of architecture support code, BSPs for these processors must specify either **CPU=PPC440 CPU_VARIANT=_x5** or **CPU=PPC32 CPU_VARIANT=_ppc440_x5**.
- The MPC744X and MPC745X processors require execution of additional synchronization operations when accessing certain hardware registers. To select the version of the architecture support code that contains these additional instructions, BSPs for the MPC744X and MPC745X processors must specify **CPU=PPC604 CPU_VARIANT=_745x** or **CPU=PPC32 CPU_VARIANT=_ppc604_745x**. This specification is not needed for the MPC7400 or MPC7410, and must not be used for processors that do not implement the AltiVec instruction set.
- Freescale Semiconductor, Inc. processors based on the G2_LE core, such as the MPC827X and the MPC828X, vary from the traditional G2 core that belongs to the PPC603 family in VxWorks. The G2_LE core provides additional BAT registers in the MMU, includes additional SPRG registers, and incorporates the critical interrupt class of exception. To select the proper architecture support code, the BSP must specify either **CPU=PPC603 CPU=VARIANT=_g2le** or **CPU=PPC32 CPU_VARIANT=_ppc603_g2le**.
- Like the G2_LE core, the e300 core also provides additional BAT registers and the critical interrupt class of exception. The e300 core is synonymous with the Freescale PowerQUICC Pro processor family (processors such as the MPC834X and MPC836X belong to this family). BSPs for this family must specify either **CPU=PPC603 CPU_VARIANT=_83xx** or

**CPU=PPC32 CPU_VARIANT=_ppc603_83xx** to select the proper architecture support code.

#### Backward Compatibility

In order to maintain backwards compatibility with earlier VxWorks releases, specifying the values for **TOOL** (**gnu** or **diab**) will continue to work as it did in prior releases. The **TOOL** value will be converted to **sfdiab** or **sfgnu** as necessary based on the specified **CPU** value.

For example, specifying **CPU=PPC440** with any **TOOL** option (**TOOL=diab**, **TOOL=sfdiab**, **TOOL=gnu**, or **TOOL=sfgnu**) will build for software floating point. (You may also specify software floating point using **CPU=PPC32 CPU_VARIANT=_ppc440 TOOL=sfdiab** or **sfgnu**.)

If you want to build for hardware floating point, use **CPU=PPC32**, **CPU_VARIANT=_ppc440** or **_ppc440_x5** (for PowerPC 440EP), and **TOOL=diab** or **gnu**.



## A.3 Make Variables to Support Additional Compiler Options

In addition to **CPU** and **TOOL**, some architectures utilize the **ADDED_C++FLAGS** or the **ADDED_CFLAGS** make variables to set additional compiler options. The following sections describe how these variables are used for certain architectures.

### A.3.1 Compiling Downloadable Kernel Modules

Certain architectures require special compiler options when compiling downloadable kernel modules. These options can be passed to the compiler using the **ADDED_C++FLAGS** or the **ADDED_CFLAGS** make variables from the command line or by adding the appropriate flags to the **CC_ARCH_SPEC** macro using Workbench. The following sections describe the requirements for the affected architectures.

### ARM and Intel XScale

On ARM and Intel XScale targets, the **-Xcode-absolute-far** flag (Wind River Compiler (**diab**)) and the **-mlong-calls** flag (GNU compiler) may be required to compile VxWorks downloadable kernel modules. These flags are required if the board you are working with has more memory than can be accessed using relative branches. The flags are not automatically passed to the build command and if the flags are not added explicitly, the loader may issue a relocation overflow error (this happens using both the GNU compiler and the Wind River Compiler).

A macro is already defined for this purpose in the respective compiler definition (**defs**) files and can be included by modifying the compiler settings in your project or specifying the appropriate option on the command line when building your module. For example:

```
% make TOOL=tool CPU=cpu ADDED_CFLAGS=$(LONGCALL)
ADDED_C++FLAGS=$(LONGCALL)
```

### MIPS

The MIPS Application Binary Interface (ABI) normally uses the **jal** instruction to call functions not accessed through a pointer. Thus, the function call:

```
func( );
```

would cause the compiler to generate the assembly code:

```
jal    func
```

However, the bit encoding of the **jal** instruction contains only a 26-bit field to select the word address of the entry point of the routine. Because MIPS instructions are all word aligned, it is not necessary to specify the byte address; this implies that a 28-bit byte address can be inferred from a 26-bit word address, because the lower 2 bits of the byte address are always 0. The target address of a function call is assumed to have the same pattern in the top 4 bits as the **jal** instruction which references it.

The result of this limitation is that special consideration is required to reference functions outside the current 512 MB address segment. For unmapped kernels, this is rarely an issue because all code typically resides in the 512 MB **KSEG0** segment.

However, mapped kernels running in systems with large amounts of memory may require special precautions to deal with function call accesses not in the current 512 MB memory segment.

Two solutions are possible: Either the routine can be accessed through a pointer instead of directly, or the compiler can be instructed to modify the routine calling convention to load the 32-bit address of the routine into a register and then use the **jalr** instruction instead of **jal**.

The first approach requires changing the function call example presented above to look something like the following:

```
{
VOIDFUNCPTR pFunc = func;
...
(*pFunc)();
...
}
```



The second solution requires adding an option to the compiler command line. For the Wind River Compiler (**diab**), the **-Xcode-absolute-far** option is used, and for the GNU compiler (**gnu**), the option is **-mlong-calls**. To specify these command-line options, modify the compiler settings in your project or specify the appropriate option on the command line when building the module. For example:

For the Wind River Compiler, use:

```
% make TOOL=diab CPU=cpu ADDED_CFLAGS="-Xcode-absolute-far"
ADDED_C++FLAGS="-Xcode-absolute-far"
```

For the GNU compiler, use:

```
% make TOOL=gnu CPU=cpu ADDED_CFLAGS="-mlong-calls"
ADDED_C++FLAGS="-mlong-calls"
```

Either of the above solutions causes the compiler to generate similar code for calling the routine:

```
lui     $24,%hi(func)
addui   $24,$24,%lo(func)
jalr    $24
```

**NOTE:** Code compiled with the **-Xcode-absolute-far** or **-mlong-calls** command-line option does not require the use of special libraries or linker considerations.

### PowerPC

On PowerPC targets having more than 32 MB of memory, the **-Xcode-absolute-far** flag (Wind River Compiler (**diab**)) or the **-mlongcall** flag (GNU compiler) may be required when compiling VxWorks downloadable kernel modules. The flags are not automatically passed to the build command and, if the flags are not added

explicitly, the loader may issue a relocation overflow error (this happens using both GNU and the Wind River Compiler (**diab**)).

To specify these flags, modify the compiler settings in your project or specify the appropriate option on the command line when building the module. For example:

For the Wind River Compiler, use:

```
% make TOOL=diab CPU=cpu ADDED_CFLAGS="-Xcode-absolute-far"
ADDED_C++FLAGS="-Xcode-absolute-far"
```

For the GNU Compiler, use:

```
% make TOOL=gnu CPU=cpu ADDED_CFLAGS="-mlongcall" ADDED_C++FLAGS="-mlongcall"
```

For more information on relative branching, see *6.4.4 26-bit Address Offset Branching*, p.146.

### A.3.2 Compiling Modules for RTP Applications on PowerPC

The pre-defined options used to compile modules for an RTP (real-time process) application on a PowerPC target should suffice in most cases. RTPs are compiled for the generic 32-bit PowerPC UISA EABI using the **CPU=PPC32** macro setting. Two general options are available using the **TOOL** macro to select the floating-point mode. When you specify **TOOL=diab**, hardware floating-point is selected. When you specify **TOOL=sfdiab**, software floating-point is selected. A similar distinction is made between **TOOL=gnu** and **TOOL=sfgnu**.

**NOTE:** RTPs built with **TOOL=sfdiab** or **sfgnu** will run correctly on any PowerPC processor, including those that provide hardware floating point support. However, RTPs built with soft float options (**sfdiab** or **sfgnu**) will not be able to use the processor hard float capability.

When extra options are required (for example, when you must compile for AltiVec or SPE support), the extra options can be specified using the **ADDED_CFLAGS** macro in the BSP makefile. For example, enable AltiVec support in the Wind River Compiler (**diab**) by appending the following line to the end of **Makefile** for an RTP application:

```
ADDED_CFLAGS += -tPPC7400FV:vxworks62
```

**NOTE:** The make rules to build RTPs are in **rules.rtp** and compiler-specific options come from the make fragments in *installDir*/**target/usr/tool/gnu** or **diab**. If the RTP source is built with a makefile that includes **rules.rtp**, simply specifying the appropriate **CPU** and **TOOL** options will build the RTP using the specified compiler. Note that **CPU** is always defined as **PPC32** for RTPs regardless of the target processor type.



## A.4 Additional Compiler Options and Considerations

This section discusses additional special compiler options and requirements for certain target architectures.

### A.4.1 Intel Architecture

In some cases, special compiler options and considerations are required when compiling applications for the Intel Architecture. The following sections discuss these instances.

#### GNU Assembler Compatibility

The **-Xemul-gnu-bug** option is included in the Wind River Compiler to emulate a known behavior in the GNU assembler's encoding of **fdivp**, **fdivrp**, **fsubp**, and **fsubrp** instructions. The **-Xemul-gnu-bug** option should only be used when assembly code produced by, or written for use with, the GNU toolchain is assembled using the Wind River Compiler toolchain assembler.

If the Wind River assembler is invoked using the compiler driver (**dcc**), the **-Xemul-gnu-bug** option should be preceded by **-Wa** so that it is passed to the assembler. The appropriate makefiles for the Wind River Compiler (**diab**) toolchain (*installDir*/**vxworks-6.2/target/h/tool/$TOOL/make.$CPU$TOOL** and *installDir*/**vxworks-6.2/target/usr/tool/$TOOL/make.$CPU$TOOL**) include this option.

#### Compiling Modules for Debugging

To compile C and C++ modules for debugging, you must use the **-g** compiler flag to generate debug information. An example command line for the GNU compiler is as follows:

```
% ccpentium -mcpu=pentium -IinstallDir/vxworks-6.2/target/h -fno-builtin \
-DCPU=PENTIUM -c -g test.cpp
```

In this example, *installDir* is the location of your VxWorks tree and **-DCPU** specifies the CPU type. An equivalent example for the Wind River Compiler is as follows:

```
% dcc -tPENTIUMLH:vxworks62 -IinstallDir/vxworks-6.2/target/h \
-DCPU=PENTIUM -c -g test.cpp
```

**NOTE:** Debugging code compiled with optimization is likely to produce unexpected behavior, such as breakpoints that are never hit or an inability to set breakpoints at some locations. This is because the compiler may re-order instructions, expand loops, replace routines with in-line code, and perform other code modifications during optimization, making it difficult to correlate a given source line to a particular point in the object code. You are advised to be aware of these possibilities when attempting to debug optimized code. Alternatively, you may choose to debug applications without using compiler optimization. To compile without optimization using the GNU compiler, you must compile without a **-O** option or use the **-O0** option. To compile without optimization using the Wind River Compiler, you must compile without the **-XO** option or use the **-Xno-optimized-debug** option.

### A.4.2 MIPS

In some cases, special compiler options and considerations are required when compiling applications for MIPS. The following sections discuss these instances.

#### Small Data Model Support

Small data model is not currently supported by VxWorks for MIPS.

When using the GNU compiler, Wind River recommends using the **-mno-branch-likely** switch. This switch suppresses the branch-likely version of the branch instructions. The **-G 0** switch is required. This switch prevents short data references from being generated by the GNU compiler.

#### -mips2 Compiler Option

Processors supported with the **MIPS32sfgnu** and **MIPS32sfgnule CPU** and **TOOL** combinations use the R4000-compatible **cache** and **eret** instructions which are not supported when using the **-mips2** GNU compiler option. This incompatibility does not generally cause a problem because these instructions are typically found only in assembly-language kernel library code, not in user-provided code such as BSPs. If your code needs to use these instructions, you should choose one of the following recommended options:

- Assemble the file with the Wind River Compiler (**diab**) toolchain, which supports these instructions in **-tMIPS2***xx***:vxworks62** (32-bit, soft float) modes.
- Temporarily alter your ISA selection with the **.set** option as follows:

```
.set    mips3
eret
.set    mips0
```

- Substitute a **.word** assembler directive in place of the required instruction:

```
#       eret   /* not supported by GNU compiler */
        .word  0x42000018
```

Wind River does not support modifying the GNU compiler option from **-mips2** to **-mips3**. This may generate instructions that are not supported on all MIPS processors, and will cause linkage problems with kernel libraries that are compiled with the **-mips2** option.

### A.4.3 PowerPC

In some cases, special compiler options and considerations are required when compiling applications for PowerPC. The following sections discuss these instances.

#### Signal Processing Engine (SPE) for MPC85XX

MPC85XX CPUs have a Signal Processing Engine (SPE). The compiler option **-tPPCE500FG:vxworks62** or **-tPPCE500FF:vxworks62** should be used for the Wind River Compiler (**diab**) to generate SPE instructions. For the GNU compiler, SPE instruction generation is already enabled by the **-mcpu=8540** option. Refer to your compiler documentation for more information.

### Compiling Modules for Debugging

To compile C and C++ modules for debugging, you must use the **-g** flag to generate debug information. An example command line for the GNU compiler is as follows:

```
% ccppc -mcpu=603 -IinstallDir/vxworks-6.2/target/h -fno-builtin \
-DCPU=PPC603 -c -g test.cpp
```

In this example, *installDir* is the location of your VxWorks tree and **-DCPU** specifies the CPU type. An equivalent example for the Wind River Compiler is as follows:

```
% dcc -tPPC603FH:vxwork55 -IinstallDir/vxworks-6.2/target/h \
-DCPU=PPC603 -c -g test.cpp
```

**NOTE:** Debugging code compiled with optimization is likely to produce unexpected behavior, such as breakpoints that are never hit or an inability to set breakpoints at some locations. This occurs because the compiler may re-order instructions, expand loops, replace routines with in-line code, and perform other code modifications during optimization, making it difficult to correlate a given source line to a particular point in the object code. You are advised to be aware of these possibilities when attempting to debug optimized code. Alternatively, you can choose to debug applications without using compiler optimization. To compile without optimization using the GNU compiler (**gnu**), compile your code without a **-O** option or use the **-O0** option. To compile without optimization using the Wind River Compiler, compile your code without the **-XO** option or use the **-Xno-optimized-debug** option.

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