



Section 3. Data Memory

HIGHLIGHTS

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Note: This family reference manual section is meant to serve as a complement to device data sheets. Depending on the device variant, this manual section may not apply to all dsPIC33F/PIC24H devices.

Please consult the note at the beginning of the “**Memory Organization**” chapter in the current device data sheet to check whether this document supports the device you are using.

Device data sheets and family reference manual sections are available for download from the Microchip Worldwide Web site at: <http://www.microchip.com>

3.1 INTRODUCTION

The dsPIC33F/PIC24H data width is 16 bits. All internal registers and data space memory are organized as 16 bits wide. The dsPIC33F/PIC24H features two data spaces. The data spaces can be accessed separately (for some Digital Signal Processing (DSP) instructions), or together as one 64-Kbyte linear address range (for microcontroller (MCU) instructions). The data spaces are accessed using two Address Generation Units (AGUs) and separate data paths.

Figure 3-1 is an example of a data space memory map. Data memory addresses between 0x0000 and 0x07FF are reserved for the device Special Function Registers (SFRs). The SFRs include control bits and status bits for the CPU and peripherals on the device.

The RAM begins at address 0x0800 and is split into two blocks, X and Y data space. For data writes, the X and Y data spaces are always accessed as a single, linear data space. For data reads, the X and Y memory spaces can be accessed independently or as a single, linear space. Data reads for MCU class instructions always access the X and Y data spaces as a single combined data space. Dual source operand DSP instructions, such as the `MAC` instruction, access the X and Y data spaces separately to support simultaneous reads for the two source operands.

MCU instructions can use any W register as an address pointer for a data read or write operation.

During data reads, the DSP class of instructions isolates the Y address space from the total data space. W10 and W11 are address pointers for reads from the Y data space. The remaining data space is referred to as X space, and could more accurately be described as “X minus Y” space. W8 and W9 are address pointers for data reads from the X data space in DSP class instructions.

Figure 3-2 illustrates how the data memory map functions for both MCU class and DSP class instructions. Note that the W register number and instruction type determine how address space is accessed for data reads. In particular, MCU instructions treat the X and Y memory as a single combined data space. The MCU instructions can use any W register as an address pointer for reads and writes. The DSP instructions that can simultaneously prefetch two data operands, split the data memory into two spaces. Specific W registers must be used for read address pointers in this case.

Some DSP instructions have the ability to store the accumulator that is not targeted by the instruction to data memory. This function is called “accumulator write back”. W13 must be used as an address pointer to the combined data memory space for accumulator write back operations.

For DSP class instructions, W8 and W9 should point to implemented X memory space for all memory reads. If W8 or W9 points to Y memory space, zeros are returned. If W8 or W9 points to an unimplemented memory address, an address error trap is generated.

For DSP class instructions, W10 and W11 should point to implemented Y memory space for all memory reads. If W10 or W11 points to implemented X memory space, zeros are returned. If W10 or W11 points to an unimplemented memory address, an address error trap is generated. Refer to **Section 6. “Interrupts”** (DS70184), for more details on address error traps.

Note: The data memory map and the partition between the X and Y data spaces is device specific. Refer to the specific dsPIC33F/PIC24H device data sheet for more details.

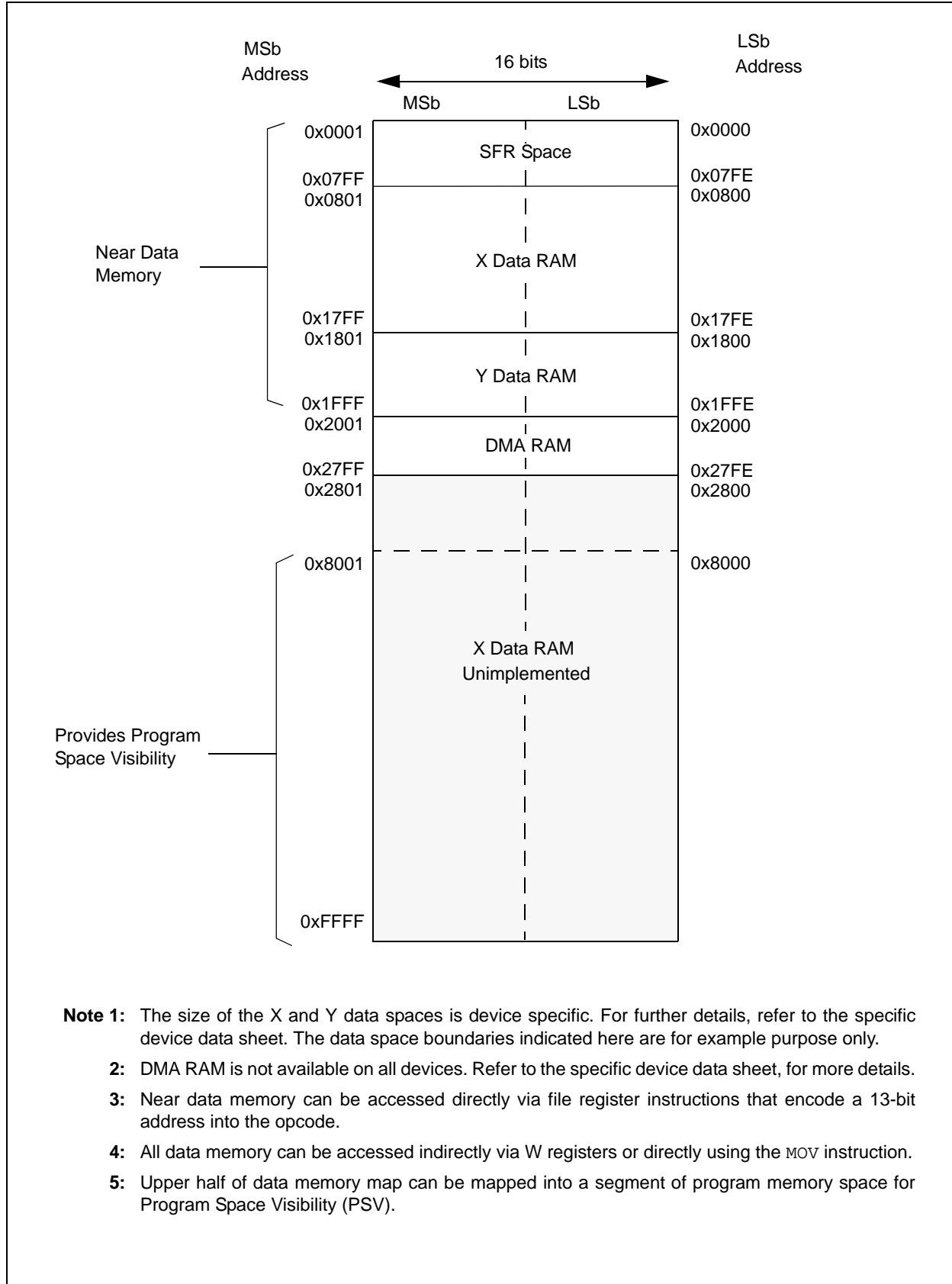
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In addition, some dsPIC33F/PIC24H devices contain DMA and dual-ported SRAM memory (DPSRAM). Both the CPU and DMA controller can write and read to/from addresses within the DPSRAM without interference, such as CPU stalls, resulting in maximized, real-time performance. Refer to **Section 22. “Direct Memory Access (DMA)”** (DS70182), for more details.

Note: The presence and size of DMA RAM is device specific. Refer to the specific dsPIC33F/PIC24H device data sheet for more details.

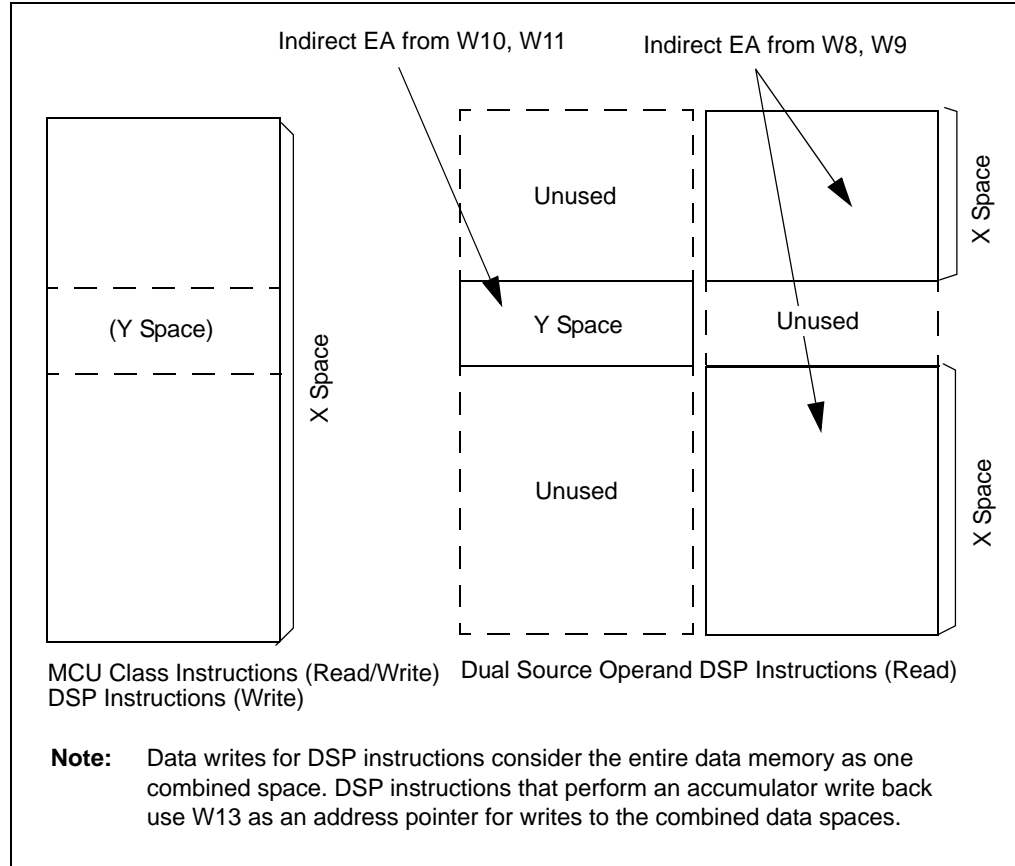
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Figure 3-1: Example Data Memory Map



- Note 1:** The size of the X and Y data spaces is device specific. For further details, refer to the specific device data sheet. The data space boundaries indicated here are for example purpose only.
- 2:** DMA RAM is not available on all devices. Refer to the specific device data sheet, for more details.
- 3:** Near data memory can be accessed directly via file register instructions that encode a 13-bit address into the opcode.
- 4:** All data memory can be accessed indirectly via W registers or directly using the MOV instruction.
- 5:** Upper half of data memory map can be mapped into a segment of program memory space for Program Space Visibility (PSV).

Figure 3-2: Data Spaces for MCU and DSP Instructions



3.1.1 Near Data Memory

An 8-Kbyte address space, referred to as near data memory, is reserved in the data memory space between 0x0000 and 0x1FFF. Near data memory is directly addressable through a 13-bit absolute address field within all file register instructions.

The memory regions included in the near data region depend on the amount of data memory implemented for each dsPIC33F/PIC24H device variant. At a minimum, the near data region includes all the SFRs and some of the X data memory. For devices that have smaller amounts of data memory, the near data region can include all of X memory space and possibly some or all of Y memory space. Refer to Figure 3-1, for more details.

Note: The entire 64K data space can be addressed directly using the MOV instruction. Refer to the “16-bit MCU and DSC Programmer’s Reference Manual” (DS70157), for more details.

3.2 CONTROL REGISTERS

This section outlines the specific functions of each register.

- **MODCON: Modulo and Bit-Reversed Addressing Control Register(1)**
 - Enables or disables the modulo addressing for X AGU and Y AGU
 - Selects register for Bit-Reversed addressing
 - Selects register for Modulo addressing
- **XMODSRT: X AGU Modulo Addressing Start Register**
 - Selects Modulo addressing start address for X RAGU and X WAGU
- **XMODEND: X AGU Modulo Addressing End Register**
 - Selects Modulo addressing end address for X RAGU and X WAGU
- **YMODSRT: Y AGU Modulo Addressing Start Register**
 - Selects Modulo addressing start address bits for YGAU
- **YMODEND: Y AGU Modulo Addressing End Register**
 - Selects Modulo addressing end address bits for YGAU
- **XBREV: X Write AGU Bit-Reversal Addressing Control Register**
 - Enables or disables Bit-Reversed addressing for X AGU
 - Selects buffer for X AGU Bit-Reversed modifier

3.3 CONTROL REGISTER DESCRIPTIONS

The registers described in this section control modulo and bit-reversed addressing.

Register 3-1: MODCON: Modulo and Bit-Reversed Addressing Control Register⁽¹⁾

| | | | | | | | |
|----------|--------|-------|-------|----------|-------|-------|-------|
| R/W-0 | R/W-0 | U-0 | U-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
| XMODEN | YMODEN | — | — | BWM<3:0> | | | |
| bit 15 | | | | | | | bit 8 |
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
| YWM<3:0> | | | | XWM<3:0> | | | |
| bit 7 | | | | | | | bit 0 |

Legend:

| | | |
|-------------------|------------------|--|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' |
| -n = Value at POR | '1' = Bit is set | '0' = Bit is cleared x = Bit is unknown |

- bit 15 **XMODEN:** X RAGU and X WAGU Modulo Addressing Enable bit
1 = X AGU modulo addressing enabled
0 = X AGU modulo addressing disabled
- bit 14 **YMODEN:** Y AGU Modulo Addressing Enable bit
1 = Y AGU modulo addressing enabled
0 = Y AGU modulo addressing disabled
- bit 13-12 **Unimplemented:** Read as '0'
- bit 11-8 **BWM<3:0>:** X WAGU Register Select for Bit-Reversed Addressing bits
1111 = Bit-reversed addressing disabled
1110 = W14 selected for bit-reversed addressing
1101 = W13 selected for bit-reversed addressing
•
•
•
0000 = W0 selected for bit-reversed addressing
- bit 7-4 **YWM<3:0>:** Y AGU W Register Select for Modulo Addressing bits
1111 = Modulo addressing disabled
1010 = W10 selected for modulo addressing
1011 = W11 selected for modulo addressing
All other settings of the YWM<3:0> control bits are reserved and should not be used.
- bit 3-0 **XWM<3:0>:** X RAGU and X WAGU W Register Select for Modulo Addressing bits
1111 = Modulo addressing disabled
1110 = W14 selected for modulo addressing
•
•
•
0000 = W0 selected for modulo addressing

Note 1: A write to the MODCON register should not be followed by an instruction that performs an indirect read operation using a W register. Unexpected results may occur. Some instructions perform an implicit indirect read. These are: POP, RETURN, RETFIE, RETLW and ULNK.

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Register 3-2: XMODSRT: X AGU Modulo Addressing Start Register

| | | | | | | | |
|----------|-------|-------|-------|-------|-------|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
| XS<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| | | | | | | | |
|---------|-------|-------|-------|-------|-------|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R-0 |
| XS<7:1> | | | | | | | 0 |
| bit 7 | | | | | | | bit 0 |

Legend:

R = Readable bit W = Writable bit U = Unimplemented bit, read as '0'
 -n = Value at POR '1' = Bit is set '0' = Bit is cleared x = Bit is unknown

bit 15-1 **XS<15:1>**: X RAGU and X WAGU Modulo Addressing Start Address bits
 bit 0 **Unimplemented**: Read as '0'

Register 3-3: XMODEND: X AGU Modulo Addressing End Register

| | | | | | | | |
|----------|-------|-------|-------|-------|-------|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
| XE<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| | | | | | | | |
|---------|-------|-------|-------|-------|-------|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R-1 |
| XE<7:1> | | | | | | | 1 |
| bit 7 | | | | | | | bit 0 |

Legend:

R = Readable bit W = Writable bit U = Unimplemented bit, read as '0'
 -n = Value at POR '1' = Bit is set '0' = Bit is cleared x = Bit is unknown

bit 15-1 **XE<15:1>**: X RAGU and X WAGU Modulo Addressing End Address bits
 bit 0 **Unimplemented**: Read as '1'

Register 3-4: YMODSRT: Y AGU Modulo Addressing Start Register

| | | | | | | | |
|----------|-------|-------|-------|-------|-------|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
| YS<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| | | | | | | | |
|---------|-------|-------|-------|-------|-------|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R-0 |
| YS<7:1> | | | | | | | 0 |
| bit 7 | | | | | | | bit 0 |

Legend:

R = Readable bit W = Writable bit U = Unimplemented bit, read as '0'
 -n = Value at POR '1' = Bit is set '0' = Bit is cleared x = Bit is unknown

bit 15-1 **YS<15:1>**: Y AGU Modulo Addressing Start Address bits
 bit 0 **Unimplemented**: Read as '0'

Register 3-5: YMODEND: Y AGU Modulo Addressing End Register

| | | | | | | | |
|----------|-------|-------|-------|-------|-------|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
| YE<15:8> | | | | | | | |
| bit 15 | | | | | | | bit 8 |

| | | | | | | | |
|---------|-------|-------|-------|-------|-------|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R-1 |
| YE<7:1> | | | | | | | 1 |
| bit 7 | | | | | | | bit 0 |

Legend:

R = Readable bit W = Writable bit U = Unimplemented bit, read as '0'
 -n = Value at POR '1' = Bit is set '0' = Bit is cleared x = Bit is unknown

bit 15-1 **YE<15:1>**: Y AGU Modulo Addressing End Address bits
 bit 0 **Unimplemented**: Read as '1'

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Register 3-6: XBREV: X Write AGU Bit-Reversal Addressing Control Register

| | | | | | | | |
|--------|----------|-------|-------|-------|-------|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
| BREN | XB<14:8> | | | | | | |
| bit 15 | | | | | | | bit 8 |

| | | | | | | | |
|---------|-------|-------|-------|-------|-------|-------|-------|
| R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 | R/W-0 |
| XB<7:0> | | | | | | | |
| bit 7 | | | | | | | bit 0 |

Legend:

| | | |
|-------------------|------------------|------------------------------------|
| R = Readable bit | W = Writable bit | U = Unimplemented bit, read as '0' |
| -n = Value at POR | '1' = Bit is set | '0' = Bit is cleared |
| | | x = Bit is unknown |

bit 15 **BREN:** Bit-Reversed Addressing (X AGU) Enable bit
 1 = Bit-reversed addressing enabled
 0 = Bit-reversed addressing disabled

bit 14-0 **XB<14:0>:** X AGU Bit-Reversed Modifier bits
 0x4000 = 32768 word buffer
 0x2000 = 16384 word buffer
 0x1000 = 8192 word buffer
 0x0800 = 4096 word buffer
 0x0400 = 2048 word buffer
 0x0200 = 1024 word buffer
 0x0100 = 512 word buffer
 0x0080 = 256 word buffer
 0x0040 = 128 word buffer
 0x0020 = 64 word buffer
 0x0010 = 32 word buffer
 0x0008 = 16 word buffer
 0x0004 = 8 word buffer
 0x0002 = 4 word buffer
 0x0001 = 2 word buffer

3.4 DATA SPACE ADDRESS GENERATOR UNITS (AGUs)

The dsPIC33F/PIC24H contains an X AGU and a Y AGU for generating data memory addresses. Both X and Y AGUs can generate any Effective Address (EA) within a 64-Kbyte range. However, EAs outside the physical memory provided (i.e., return all zeros for data reads and data writes to those locations), have no effect. Refer to **Section 6. “Interrupts”** (DS70184), for more details on address error traps.

3.4.1 X Address Generator Unit

The X AGU is used by all instructions and supports all Addressing modes. The X AGU consists of a read AGU (X RAGU) and a write AGU (X WAGU), which operate independently on separate read and write buses during different phases of the instruction cycle. The X read data bus is the return data path for all instructions that view data space as combined X and Y address space. It is also the X address space data path for the dual operand read instructions (DSP instruction class). The X write data bus is the only write path to the combined X and Y data space for all instructions.

The X RAGU starts its effective address calculation during the prior instruction cycle, using information derived from the just prefetched instruction. The X RAGU EA is presented to the address bus at the beginning of the instruction cycle.

The X WAGU starts its effective address calculation at the beginning of the instruction cycle. The EA is presented to the address bus during the write phase of the instruction.

Both the X RAGU and the X WAGU support modulo addressing. Bit-reversed addressing is supported by the X WAGU only.

3.4.2 Y Address Generator Unit

The Y data memory space has one AGU that supports data reads from the Y data memory space. The Y memory bus is not used for data writes. The function of the Y AGU and Y memory bus is to support concurrent data reads for DSP class instructions.

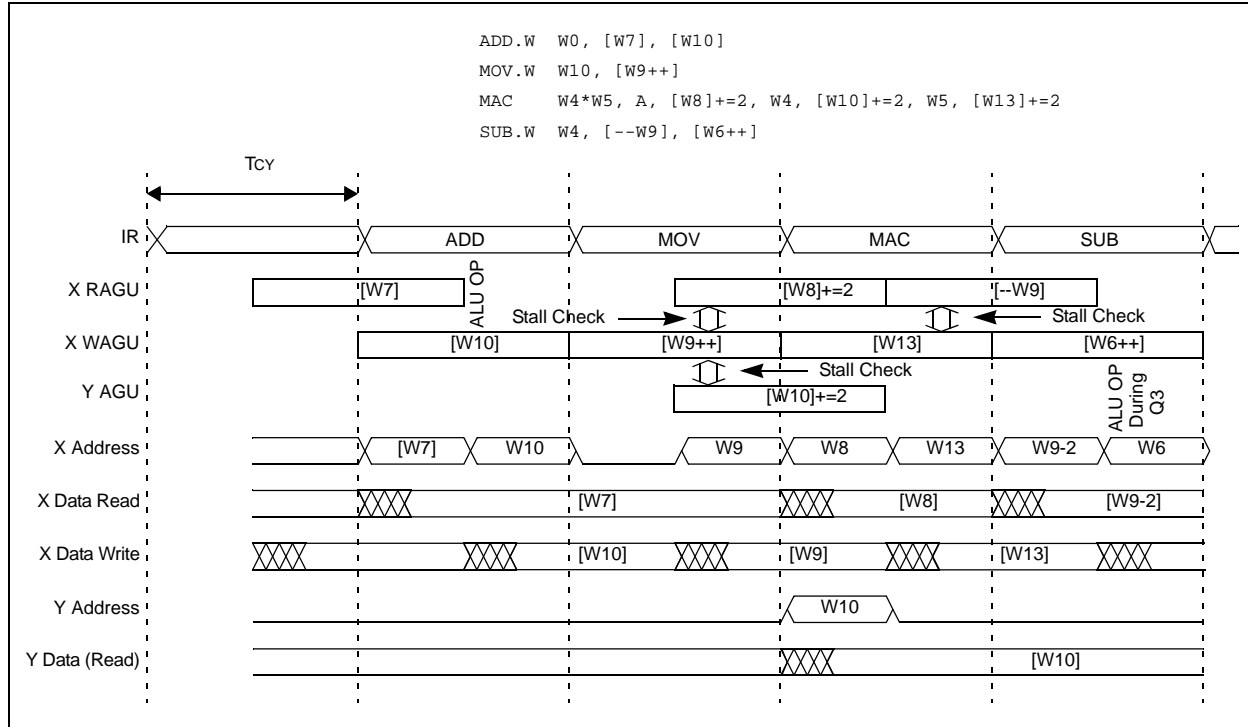
The Y AGU timing is identical to that of the X RAGU, in that its effective address calculation starts prior to the instruction cycle, using information derived from the prefetched instruction. The EA is presented to the address bus at the beginning of the instruction cycle.

The Y AGU supports Modulo Addressing and Post-Modification Addressing modes for the DSP class of instructions that use it.

Note: The Y AGU does not support data writes. All data writes occur via the X WAGU to the combined X and Y data spaces. The Y AGU is only used during data reads for dual source operand DSP instructions.

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Figure 3-3: Data Space Access Timing



3.4.3 Address Generator Units and DSP Class Instructions

The Y AGU and Y memory data path are used in concert with the X RAGU by the DSP class of instructions to provide two concurrent data read paths. For example, the MAC instruction can simultaneously prefetch two operands to use in the next multiplication. Refer to Figure 3-3.

The DSP class of instructions dedicates two W register pointers, W8 and W9, to always operate through the X RAGU and address X data space independently from Y data space, plus two W register pointers, W10 and W11, to always operate through the Y AGU and address Y data space independently from X data space. Any data write performed by a DSP class instruction takes place in the combined X and Y data space, and the write occurs across the X-bus. Consequently, the write can be to any address irrespective of where the EA is directed.

The Y AGU only supports Post-Modification Addressing modes associated with the DSP class of instructions. Refer to the "16-bit MCU and DSC Programmer's Reference Manual" (DS70157), for more details on the Addressing modes. The Y AGU also supports modulo addressing for automated circular buffers. All other MCU class instructions can access the Y data address space through the X AGU when it is regarded as part of the composite linear space.

3.4.4 Data Alignment

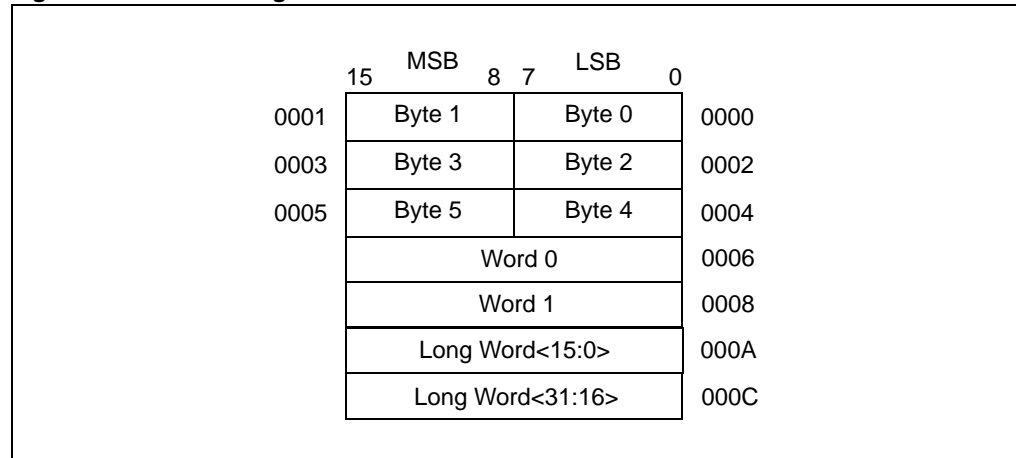
The Instruction Set Architecture (ISA) supports both word and byte operations for all MCU instructions that access data through the X memory AGU. The LSb of a 16-bit data address is ignored for word operations. Word data is aligned in the little-endian format with the Least Significant Byte (LSB) at the even address (LSb = 0) and the Most Significant Byte (MSB) at the odd address (LSb = 1). Refer Figure 3-4 for data alignment.

For byte operations, the LSB of the data address selects the byte that is accessed. The addressed byte is placed on the lower 8 bits of the internal data bus.

All EA calculations are automatically adjusted depending on whether a byte or a word access is performed. For example, an address is incremented by 2 for a word operation that post-increments the address pointer.

Note: All word accesses must be aligned to an even address (LSb = 0). Misaligned word data fetches are not supported, so care must be taken when mixing byte and word operations or translating code from an existing 8-bit PIC[®] MCU. If a misaligned word read or write is attempted, an address error trap occurs. A misaligned read operation completes, but a misaligned write will not take place. The trap is then taken, allowing the system to examine the machine state prior to execution of the address Fault.

Figure 3-4: Data Alignment



3.5 MODULO ADDRESSING

Modulo or Circular addressing provides an automated means to support circular data buffers using hardware. The objective is to remove the need for software to perform data address boundary checks when executing tightly looped code as is typical in many DSP algorithms.

Any W register, except W15, can be selected as the pointer to the modulo buffer. The modulo hardware performs boundary checks on the address held in the selected W register, and automatically adjusts the pointer value at the buffer boundaries, when required.

dsPIC33F/PIC24H modulo addressing can operate in either data space or program space (since the data pointer mechanism is essentially the same for both). One circular buffer can be supported in each of the X (which also provides the pointers into Program space) and Y data spaces.

The modulo data buffer length can be any size up to 32K words. The modulo buffer logic supports buffers using word or byte-sized data. However, the modulo logic only performs address boundary checks at word address boundaries, so the length of a byte modulo buffer must be even. In addition, byte-sized modulo buffers cannot be implemented using the Y AGU, because byte access is not supported via the Y memory data bus.

3.5.1 Modulo Start and End Address Selection

Four address registers are available for specifying the modulo buffer start and end addresses:

- **XMODSRT: X AGU Modulo Addressing Start Register**
- **XMODEND: X AGU Modulo Addressing End Register**
- **YMODSRT: Y AGU Modulo Addressing Start Register**
- **YMODEND: Y AGU Modulo Addressing End Register**

The start address for a modulo buffer must be located at an even byte address boundary. The LSB of the XMODSRT and YMODSRT registers is fixed at '0' to ensure the correct modulo start address. The end address for a modulo buffer must be located at an odd byte address boundary. The LSB of the XMODEND and YMODEND registers is fixed to '1' to ensure the correct modulo end address.

The start and end address selected for each modulo buffer have certain restrictions, depending on whether an incrementing or decrementing buffer is implemented. For an incrementing buffer, a W register pointer is incremented through the buffer address range. When the end address of the incrementing buffer is reached, the W register pointer is reset to point to the start of the buffer. For a decrementing buffer, a W register pointer is decremented through the buffer address range. When the start address of a decrementing buffer is reached, the W register pointer is reset to point to the end of the buffer.

| |
|--|
| <p>Note: The user must decide whether an incrementing or decrementing modulo buffer is required for the application. Certain address restrictions depend on whether an incrementing or decrementing modulo buffer is to be implemented.</p> |
|--|

3.5.1.1 MODULO START ADDRESS

The data buffer start address is arbitrary, but must be at a 'zero' power of two boundary for incrementing modulo buffers. The modulo start address can be any value for decrementing modulo buffers and is calculated using the chosen buffer end address and buffer length.

For example, if the buffer length for an incrementing buffer is chosen to be 50 words (100 bytes), the buffer start byte address must contain seven Least Significant zeros. Valid start addresses may therefore be, 0xNN00 and 0xNN80, where 'N' is any hexadecimal value.

3.5.1.2 MODULO END ADDRESS

The data buffer end address is arbitrary, but must be at 1's boundary for decrementing buffers. The modulo end address can be any value for an incrementing buffer and is calculated using the chosen buffer start address and buffer length.

For example, if the buffer size (modulo value) is chosen to be 50 words (100 bytes), the buffer end byte address for decrementing modulo buffer must contain seven Least Significant 1's. Valid end addresses can therefore be, 0xNNFF and 0xNN7F, where 'N' is any hexadecimal value.

Note: If the required modulo buffer length is a "power-of-2" modulo start and end addresses can be selected that satisfy the requirements for incrementing and decrementing buffers.

3.5.1.3 MODULO ADDRESS CALCULATION

The end address for an incrementing modulo buffer must be calculated from the chosen start address and the chosen buffer length in bytes. Equation 3-1 shows how the code can be used to calculate the end address.

Equation 3-1: Modulo End Address for Incrementing Buffer

$$\text{End Address} = \text{Start Address} + \text{Buffer Length} - 1$$

Equation 3-2 shows how the start address for a decrementing modulo buffer is calculated from the chosen end address and the buffer length.

Equation 3-2: Modulo Start Address for Decrementing Buffer

$$\text{Start Address} = \text{End Address} - \text{Buffer Length} + 1$$

3.5.1.4 DATA DEPENDENCIES ASSOCIATED WITH MODULO ADDRESSING SFRs

A write operation to the Modulo and Bit-Reversed Addressing Control Register (MODCON), should not be immediately followed by an indirect read operation using any W register. Example 3-1 shows the code segment.

Note 1: Using a POP instruction to pop the contents of the top-of-stack (TOS) location into the MODCON register, also constitutes a write to the MODCON register. The instruction immediately following a write to the MODCON register cannot be any instruction performing an indirect read operation.

2: Some instructions perform an indirect read operation, implicitly. These are: POP RETURN, RETFIE, RETLW and ULNK.

Example 3-1: Incorrect MODCON Initialization

```
MOV #0x8FF4, w0    ;Initialize MODCON
MOV w0, MODCON
MOV [w1], w2      ;Incorrect EA generated here
```

To work around this problem of initialization, use any addressing mode other than indirect reads in the instruction that immediately follows the initialization of the MODCON register. Example 3-2 shows a simple work around to the problem can be achieved by adding a NOP instruction after initializing the MODCON register.

Example 3-2: Correct MODCON Initialization

```
MOV #0x8FF4, w0    ;Initialize MODCON
MOV w0, MODCON
NOP                ;See Note below
MOV [w1], w2      ;Correct EA generated here
```

Note: Alternatively, execute other instructions that do not perform indirect read operations, using the W register designated for modulo buffer access.

An additional condition exists for indirect read operations performed immediately after writing to the modulo address SFRs:

- XMODSRT
- XMODEND
- YMODSRT
- YMODEND

If modulo addressing is already enabled in the MODCON register, then a write to the X (or Y) modulo address SFRs should not be immediately followed by an indirect read, using the W register designated for modulo buffer access from X-data space (or Y-data space). The code segment in Example 3-3 shows how initializing the modulo SFRs associated with the X-data space could lead to unexpected results. A similar example can be made for initialization in Y-data space.

Example 3-3: Incorrect Modulo Addressing Setup

```
MOV #0x8FF4,w0      ;Modulo addressing enabled
MOV w0, MODCON     ;in X-data space using w4
                   ;for buffer access

MOV #0x1200,w4     ;XMODSRT is initialized
MOV w4, XMODSRT

MOV #0x12FF,w0    ;XMODEND is initialized
MOV w0, XMODEND
MOV [w4++], w5    ;Incorrect EA generated
```

To work around this issue, insert a NOP, or perform any operation other than an indirect read that uses the W register designated for modulo buffer access, after initializing the modulo address SFRs, as shown in Example 3-4. Another alternative is to enable modulo addressing in the MODCON register after initializing the modulo start and end address SFRs.

Example 3-4: Correct Modulo Addressing Setup

```
MOV #0x8FF4,w0      ;Modulo addressing enabled
MOV w0, MODCON     ;in X-data space using w4
                   ;for buffer access

MOV #0x1200,w4     ;XMODSRT is initialized
MOV w4, XMODSRT

MOV #0x12FF,w0    ;XMODEND is initialized
MOV w0, XMODEND
NOP                ;See Note below
MOV [w4++], w5    ;Correct EA generated here
```

Note: Alternatively, execute other instructions that do not perform indirect read operations, using the W register designated for modulo buffer access.

3.5.2 W Address Register Selection

The X address space pointer W register to which modulo addressing is to be applied, is stored in the XWM bits (MODCON<3:0>) of the MODCON register. The XMODSRT, XMODEND and XWM register selections are shared between the X RAGU and X WAGU. Modulo addressing is enabled for X data space when the XWM bit is set to any value other than 15, and the XMODEN bit (MODCON<15>) is set. W15 cannot be used as the pointer for modulo addressing because it is the dedicated software stack pointer.

The Y address space pointer W register to which modulo addressing is applied, is stored in the YWM bits (MODCON<7:4>) in the MODCON register. Modulo addressing is enabled for Y data space when the YWM bit is set to any value other than 15 and the YMODEN bit (MODCON<14>) is set.

Note: A write to the MODCON register should not be followed by an instruction that performs an indirect read operation using a W register. Unexpected results may occur. Some instructions perform an implicit indirect read. These are: POP, RETURN, RETFIE, RETLW and ULNK.

3.5.3 Modulo Addressing Applicability

Modulo addressing can be applied to the EA calculation associated with the selected W register. It is important to realize that the address boundary tests look for addresses equal to, or greater than, the upper address boundary for incrementing buffers and equal to, or less than, the lower address boundary for decrementing buffers. Address changes can, therefore, jump over boundaries and still be adjusted correctly. The automatic adjustment of the W register pointer by the modulo hardware is unidirectional. That is, the W register pointer may not be adjusted correctly by the modulo hardware when the W register pointer for an incrementing buffer is decremented and vice versa. The exception to this rule is when the buffer length is an even power of 2, and the start and end addresses can be selected to meet the boundary requirements for both incrementing and decrementing modulo buffers.

A new EA can exceed the modulo buffer boundary by up to the length of the buffer and still be successfully corrected. This is important to remember when the Register Indexed ($[Wb + Wn]$) and Literal Offset ($[Wn + lit10]$) Addressing modes are used. In addition, the Register Indexed and Literal Offset Addressing modes do not change the value held in the W register. Only the indirect with Pre- and Post-modification Addressing modes ($[Wn++]$, $[Wn--]$, $[++Wn]$, $[--Wn]$) modify the W register address value.

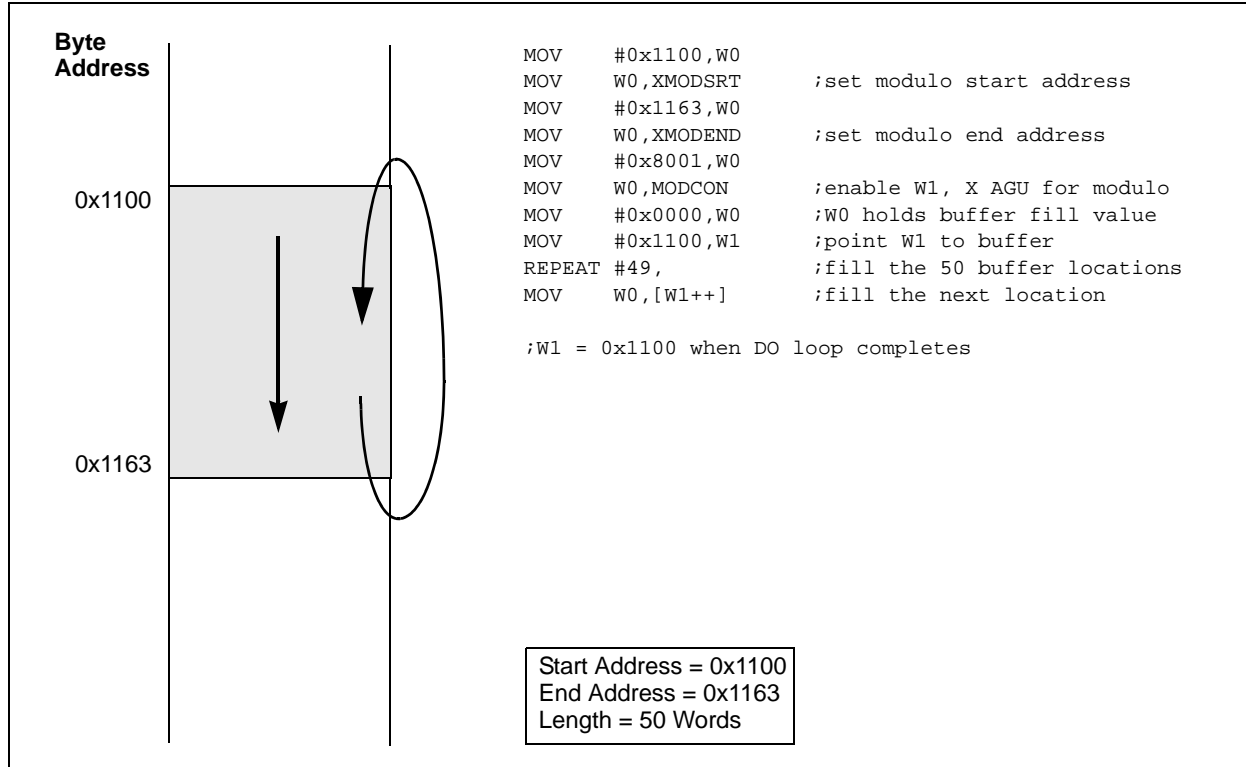
3.5.4 Modulo Addressing Initialization for Incrementing Modulo Buffer

The following steps describe the setup procedure for an incrementing circular buffer, using either the X AGU or the Y AGU:

1. Determine the buffer length in 16-bit data words. Multiply this value by 2 to get the length of the buffer in bytes.
2. Select a buffer starting address that is located at a binary 0's boundary based on the desired length of the buffer. Note that the buffer length in words must be multiplied by 2 to obtain the byte address range. For example, a buffer with a length of 100 words (200 bytes) could use 0xXX00 as the starting address.
3. Calculate the buffer end address using the buffer length chosen in Step 1 and the buffer start address chosen in Step 2. The buffer end address is calculated using Equation 3-1.
4. Load the XMODSRT or YMODSRT register with the buffer start address chosen in Step 2.
5. Load the XMODEND or YMODEND register with the buffer end address calculated in Step 3.
6. Write to the XWM bits (MODCON<3:0>) or YWM bits (MODCON<7:4>) to select the W register that will be used to access the circular buffer.
7. Set the XMODEN bit (MODCON<15>) or YMODEN bit (MODCON<14>) to enable the circular buffer.
8. Load the selected W register with address that points to the buffer.

The W register address is adjusted automatically at the end of the buffer when an indirect access with pre/post-increment is performed, as illustrated in Figure 3-5.

Figure 3-5: Incrementing Buffer Modulo Addressing Operation Example



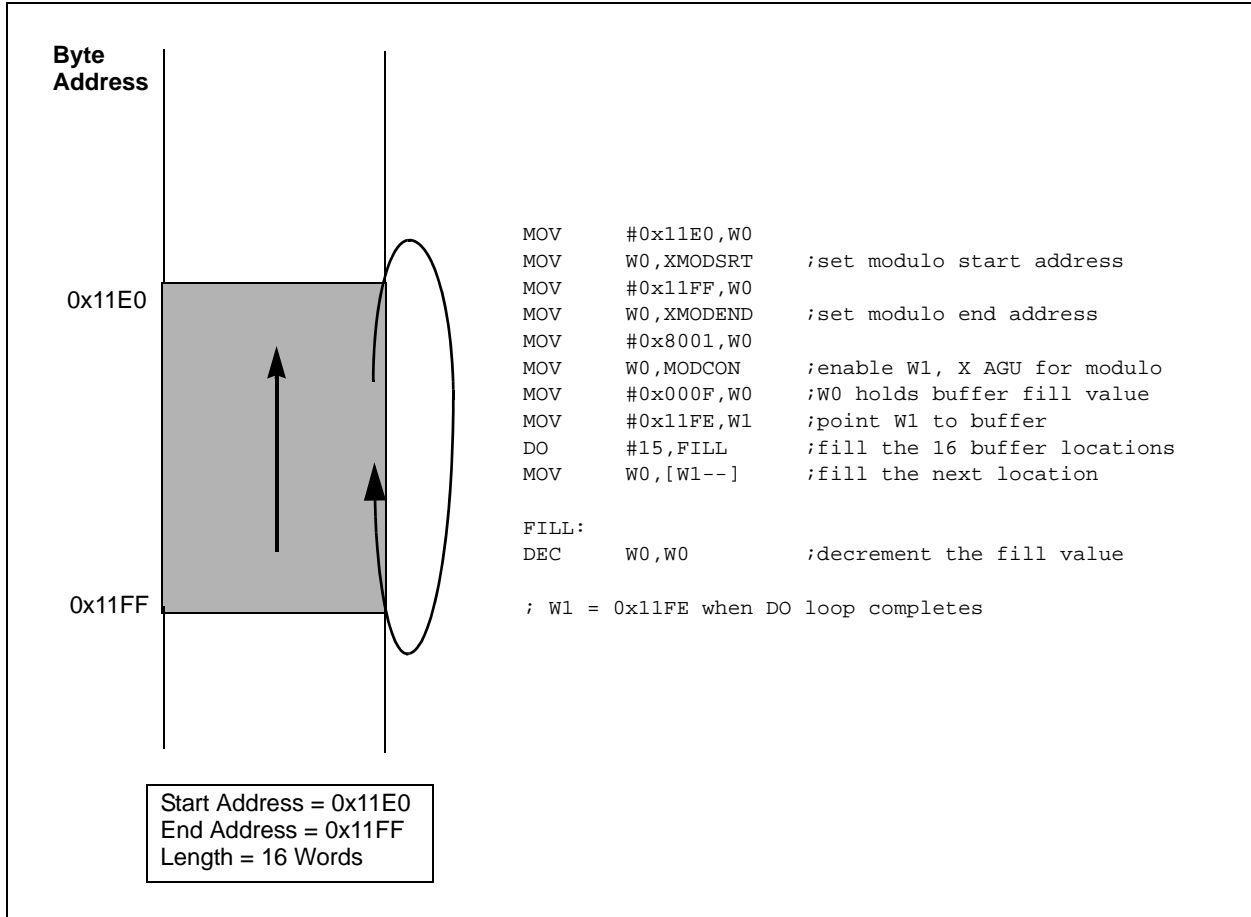
3.5.5 Modulo Addressing Initialization for Decrementing Modulo Buffer

The following steps describe the setup procedure for a decrementing circular buffer, using either the X AGU or YAGU:

1. Determine the buffer length in 16-bit data words. Multiply this value by 2 to get the length of the buffer in bytes.
2. Select a buffer end address that is located at a binary 1's boundary, based on the desired length of the buffer. Remember that the buffer length in words must be multiplied by 2 to obtain the byte address range. For example, a buffer with a length of 128 words (256 bytes) could use 0xFF as the end address.
3. Calculate the buffer start address using the buffer length selected in Step 1 and the end address selected in Step 2. The buffer start address is calculated using Equation 3-2.
4. Load the XMODSRT or YMODSRT register with the buffer start address selected in Step 3.
5. Load the XMODEND or YMODEND register with the buffer end address selected in Step 2.
6. Write to the XWM bits (MODCON<3:0>) or YWM bits (MODCON<7:4>) to select the W register that will access the circular buffer.
7. Set the XMODEN bit (MODCON<15>) or YMODEN bit (MODCON<14>) to enable the circular buffer.
8. Load the selected W register with the address that points to the buffer.

The W register address is adjusted automatically at the end of the buffer when an indirect access with pre/post-decrement is performed, as shown in Figure 3-6.

Figure 3-6: Decrementing Buffer Modulo Addressing Operation Example



3.6 BIT-REVERSED ADDRESSING

3.6.1 Introduction to Bit-Reversed Addressing

Bit-reversed addressing simplifies data reordering for radix-2 FFT algorithms. It is supported through the X WAGU only. Figure 3-7 illustrates how bit-reversed addressing is accomplished by effectively creating a mirror image of an address pointer by swapping the bit locations around the center point of the binary value. Table 3-1 is an example bit-reversed sequence for a 4-bit address field.

Figure 3-7: Bit-Reversed Address Example

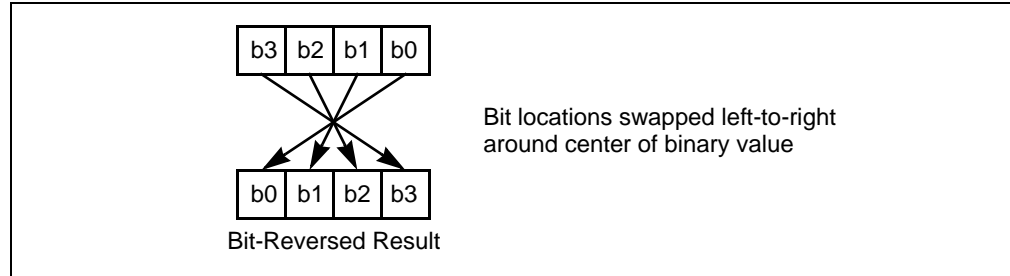


Table 3-1: Bit-Reversed Address Sequence (16-Entry)

| Normal Address | | | | | Bit-Reversed Address | | | | |
|----------------|----|----|----|---------|----------------------|----|----|----|---------|
| A3 | A2 | A1 | A0 | Decimal | A3 | A2 | A1 | A0 | Decimal |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 8 |
| 0 | 0 | 1 | 0 | 2 | 0 | 1 | 0 | 0 | 4 |
| 0 | 0 | 1 | 1 | 3 | 1 | 1 | 0 | 0 | 12 |
| 0 | 1 | 0 | 0 | 4 | 0 | 0 | 1 | 0 | 2 |
| 0 | 1 | 0 | 1 | 5 | 1 | 0 | 1 | 0 | 10 |
| 0 | 1 | 1 | 0 | 6 | 0 | 1 | 1 | 0 | 6 |
| 0 | 1 | 1 | 1 | 7 | 1 | 1 | 1 | 0 | 14 |
| 1 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 1 | 1 |
| 1 | 0 | 0 | 1 | 9 | 1 | 0 | 0 | 1 | 9 |
| 1 | 0 | 1 | 0 | 10 | 0 | 1 | 0 | 1 | 5 |
| 1 | 0 | 1 | 1 | 11 | 1 | 1 | 0 | 1 | 13 |
| 1 | 1 | 0 | 0 | 12 | 0 | 0 | 1 | 1 | 3 |
| 1 | 1 | 0 | 1 | 13 | 1 | 0 | 1 | 1 | 11 |
| 1 | 1 | 1 | 0 | 14 | 0 | 1 | 1 | 1 | 7 |
| 1 | 1 | 1 | 1 | 15 | 1 | 1 | 1 | 1 | 15 |

3.6.2 Bit-Reversed Addressing Operation

Bit-reversed addressing is supported only by the X WAGU and is controlled by the MODCON and X Write AGU Bit-Reversal Addressing Control (XBREV) special function registers. Bit-reversed addressing is invoked as follows:

1. Bit-reversed addressing is assigned to one of the W registers using the BWM (MODCON<11:8>) control bits.
2. Bit-reversed addressing is enabled by setting the BREN (XBREV<15>) control bit.
3. The X AGU bit-reverse modifier is set via the XB (XBREV<14:0>) control bits.

When enabled, the bit-reversed addressing hardware generates bit-reversed addresses, only when the register indirect with pre/post-increment Addressing modes are used ($[W_n++]$, $[++W_n]$). Furthermore, bit-reverse addresses are only generated for Word mode instructions. It will not function for all other addressing modes or Byte mode instructions (normal addresses are generated).

Note: A write to the MODCON register should not be followed by an instruction that performs an indirect read operation using a W register. Unexpected results may occur. Some instructions perform an implicit indirect read. These are: POP, RETURN, RETFIE, RETLW and ULNK.

3.6.2.1 MODULO ADDRESSING AND BIT-REVERSED ADDRESSING

Modulo addressing and bit-reversed addressing can be enabled simultaneously using the same W register, but bit-reversed addressing operation always take precedence for data writes when enabled. As an example, the following setup conditions would assign the same W register to modulo and bit-reversed addressing:

- X modulo addressing is enabled (XMODEN = 1)
- Bit-reverse addressing is enabled (BREN = 1)
- W1 assigned to modulo addressing (XWM<3:0> = 0001)
- W1 assigned to bit-reversed addressing (BWM<3:0> = 0001)

For data reads that use W1 as the pointer, modulo address boundary checking occurs. For data writes using W1 as the destination pointer, the bit-reverse hardware corrects W1 for data reordering.

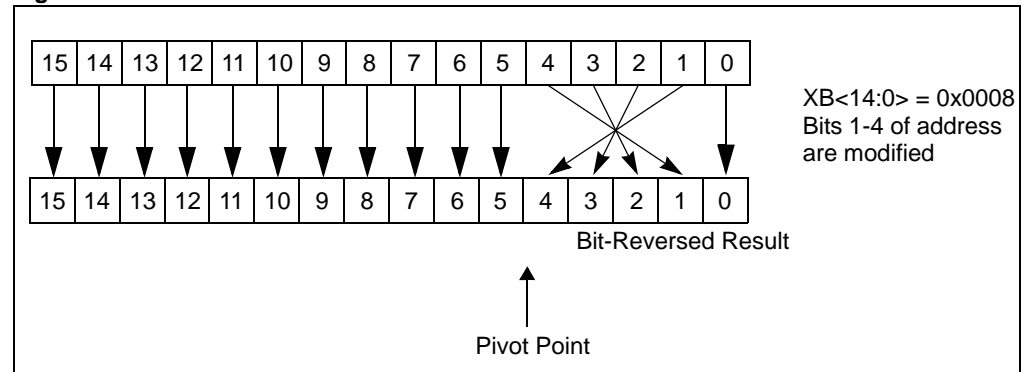
3.6.2.2 DATA DEPENDENCIES ASSOCIATED WITH XBREV

If bit-reversed addressing has already been enabled by setting the BREN bit (XBREV<15>), a write to the XBREV register should not be followed by an indirect read operation using the W register, designated as the bit-reversed address pointer.

When $\text{XB}\langle 14:0 \rangle = 0x0008$, the bit-reversed buffer size is 16 words. Bits 1-4 of the W register are subject to bit-reversed address correction; however, bits 5-15 (outside the pivot point) are not modified by the bit-reverse hardware. Bit 0 is not modified because the bit-reverse hardware operates only on word addresses.

The XB modifier controls the pivot point for the bit-reverse address modification. Bits outside of the pivot point are not subject to bit-reversed address corrections.

Figure 3-8: Bit-Reversed Address Modification for 16-Word Buffer



3.6.4 Bit-Reversed Addressing Code Example

The code shown in Example 3-6 reads a series of 16 data words and writes the data to a new location in bit-reversed order. W0 is the read address pointer and W1 is the write address pointer subject to bit-reverse modification.

Example 3-6: Bit-Reversed Addressing Code Example

```

; Set XB for 16-word buffer, enable bit reverse addressing
MOV    #0x8008,W0
MOV    W0,XBREV
; Setup MODCON to use W1 for bit reverse addressing
MOV    #0x01FF,W0
MOV    W0,MODCON
; W0 points to input data buffer
MOV    #Input_Buf,W0
; W1 points to bit reversed data
MOV    #Bit_Rev_Buf,W1
; Re-order the data from Input_Buf into Bit_Rev_Buf
REPEAT #15
MOV    [W0++],[W1++]
    
```

3.7 DMA RAM

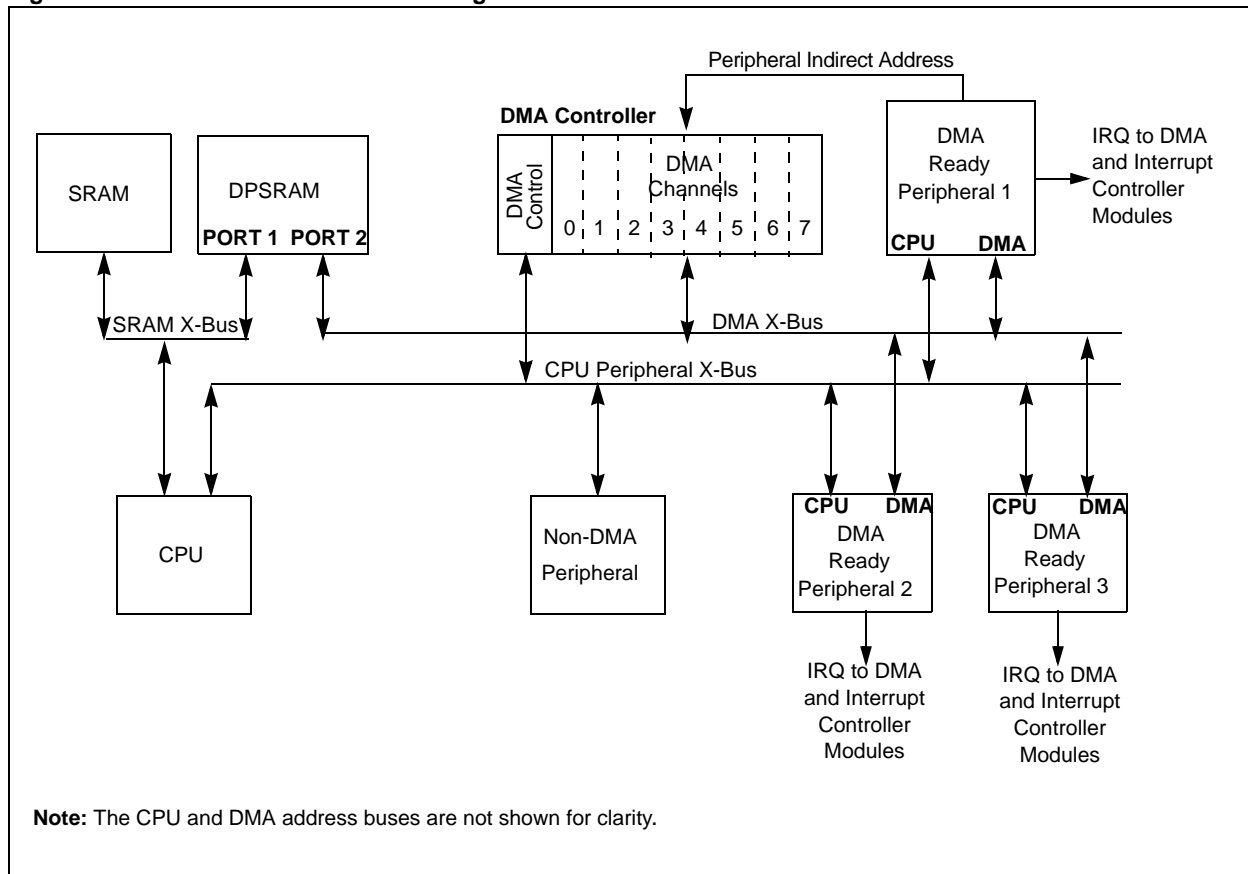
Some dsPIC33F/PIC24H devices contain DMA and dual-ported SRAM memory (DPSRAM). Both the CPU and DMA controller can write and read to/from addresses within the DPSRAM without interference, such as CPU stalls, resulting in maximized, real-time performance.

Note: The presence and size of DMA RAM is device specific. Refer to the specific dsPIC33F/PIC24H device data sheet for more details.

Figure 3-9 illustrates a block diagram that demonstrates how the DMA integrates into the dsPIC33F/PIC24H internal architecture. The CPU communicates with conventional SRAM across the X-bus. In addition, the CPU communicates with the peripherals across a separate Peripheral X-bus, which also resides within X data space.

The DMA channels communicate with Port 2 of the DPSRAM and the DMA port of each of the DMA-ready peripherals across a dedicated DMA bus. Refer to **Section 22. “Direct Memory Access (DMA)”** (DS70182), for more details.

Figure 3-9: DMA Controller Block Diagram



3.8 REGISTER MAP

Table 3-3 maps the bit functions for the Data Memory control registers.

Table 3-3: Data Memory Register Map

| File Name | Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | All Resets |
|-----------|----------|----------|--------|--------|----------|--------|-------|-------|----------|-------|-------|-------|----------|-------|-------|-------|------------|
| MODCON | XMODEN | YMODEN | — | — | BWM<3:0> | | | | YWM<3:0> | | | | XWM<3:0> | | | | 0000 |
| XMODSRT | XS<15:1> | | | | | | | | | | | | | | | 0 | xxxx |
| XMODEND | XE<15:1> | | | | | | | | | | | | | | | 1 | xxxx |
| YMODSRT | YS<15:1> | | | | | | | | | | | | | | | 0 | xxxx |
| YMODEND | YE<15:1> | | | | | | | | | | | | | | | 1 | xxxx |
| XBREV | BREN | XB<14:0> | | | | | | | | | | | | | | xxxx | |

Legend: x = unknown value on Reset, — = unimplemented, read as '0'. Reset values are shown in hexadecimal.

3.9 RELATED APPLICATION NOTES

This section lists application notes related to this section of the manual. These application notes may not be written specifically for the dsPIC33F/PIC24H device family, but the concepts are pertinent and could be used with modification and possible limitations. The current application notes related to the Data Memory module are:

| Title | Application Note # |
|--|--------------------|
| No related application notes at this time. | N/A |

Note: For additional Application Notes and code examples for the dsPIC33F/PIC24H device family, visit the Microchip web site (www.microchip.com).

3.10 REVISION HISTORY

Revision A (March 2007)

This is the initial released version of this document.

Revision B (April 2007)

Minor updates throughout the document.

Revision C (January 2010)

This revision includes the following updates:

- Renamed the Family Reference Manual name from dsPIC33F to dsPIC33F/PIC24H.
- All references to dsPIC33F in the document are updated to dsPIC33F/PIC24H.

- Figures:

- In Figure 3-3, the following line of code:

```
MAC W4*W5, A, W4, [W8]+=2, W5, [W10]+=2, [W13]+=2
```

was changed to:

```
MAC W4*W5, A, [W8]+=2, W4, [W10]+=2, W5, [W13]+=2
```

- In Figure 3-5, the following lines of code:

```
DO #49, FILL          ;fill the 50 buffer locations
FILL:
MOV    W0,[W1++]     ;fill the next location
```

were changed to:

```
REPEAT #49,          ;fill the 50 buffer locations
MOV    W0,[W1++]     ;fill the next location
```

- Notes:

- In the shaded note in 3.1.1 “Near Data Memory”, dsPIC30F/33F was changed to 16-bit MCU and DSC
- In the shaded note in 3.5.1.2 “Modulo End Address”, the term “even power of 2” was changed to “power-of-2”

- Sections:

- Added the Control Registers section (see 3.2 “Control Registers”)
- Rearranged the Registers section as 3.3 “Control Register Descriptions”
- Added the Register Map section (see 3.8 “Register Map”)

- dsPIC30F/33F was changed to 16-bit MCU and DSC in 3.4.3 “Address Generator Units and DSP Class Instructions”

- Additional minor corrections such as language and formatting updates are incorporated throughout the document

NOTES: