



Section 5. Flash Programming

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 PIC32 devices.

Please consult the note at the beginning of the “**Flash Program Memory**” 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>

5.1 INTRODUCTION

This section describes techniques for programming the Flash memory. PIC32 devices contain internal Flash memory for executing user code. There are three methods by which the user can program this memory:

- Run-Time Self-Programming (RTSP) – Performed by the user’s software
- In-Circuit Serial Programming™ (ICSP™) – Performed using a serial data connection to the device, which allows much faster programming than RTSP
- Enhanced Joint Test Action Group Programming (EJTAG) – Performed by an EJTAG-capable programmer, using the EJTAG port of the device

RTSP techniques are described in this chapter. The ICSP and EJTAG methods are described in the “*PIC32 Flash Programming Specification*” (DS60001145), which is available for download from the Microchip web site (www.microchip.com).

5.2 CONTROL REGISTERS

Flash program and erase operations are controlled using the following Nonvolatile Memory (NVM) Control registers:

- **NVMCON: NVM Programming Control Register**
- **NVMKEY: NVM Programming Unlock Register**
- **NVMADDR: NVM Flash Address Register**
- **NVMDATA or NVMDATA0/1: NVM Flash Program Data Register^(1,2)**
- **NVMSRCADDR: NVM Source Data Address Register**

Table 5-1 provides a brief summary of all of the Flash programming related registers. Corresponding registers appear after the summary, followed by a detailed description.

Table 5-1: Flash Controller SFR Summary

Name	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
NVMCON ⁽¹⁾	31:24	—	—	—	—	—	—	—
	23:16	—	—	—	—	—	—	—
	15:8	WR	WREN	WRERR	LVDERR	LVDSTAT	NVMPIDL ⁽⁴⁾	—
	7:0	—	—	—	—	NVMOP<3:0>		
NVMKEY	31:24	NVMKEY<31:24>						
	23:16	NVMKEY<23:16>						
	15:8	NVMKEY<15:8>						
	7:0	NVMKEY<7:0>						
NVMADDR ⁽¹⁾	31:24	NVMADDR<31:24>						
	23:16	NVMADDR<23:16>						
	15:8	NVMADDR<15:8>						
	7:0	NVMADDR<7:0>						
NVMDATA ⁽²⁾	31:24	NVMDATA<31:24>						
	23:16	NVMDATA<23:16>						
	15:8	NVMDATA<15:8>						
	7:0	NVMDATA<7:0>						
NVMDATA0 ⁽³⁾	31:24	NVMDATA0<31:24>						
	23:16	NVMDATA0<23:16>						
	15:8	NVMDATA0<15:8>						
	7:0	NVMDATA0<7:0>						
NVMDATA1 ⁽³⁾	31:24	NVMDATA1<31:24>						
	23:16	NVMDATA1<23:16>						
	15:8	NVMDATA1<15:8>						
	7:0	NVMDATA1<7:0>						
NVMSRCADDR	31:24	NVMSRCADDR<31:24>						
	23:16	NVMSRCADDR<23:16>						
	15:8	NVMSRCADDR<15:8>						
	7:0	NVMSRCADDR<7:0>						

Legend: — = unimplemented, read as '0'.

Note 1: This register has an associated Clear, Set and Invert register at an offset of 0x4, 0x8 and 0xC bytes, respectively. These registers have the same name with CLR, SET or INV appended to the end of the register name (e.g., NVMCONCLR). Writing a '1' to any bit position in these registers will clear, set or invert valid bits in the associated register. Reads from these registers should be ignored.

2: Implemented only in PIC32 devices that implement word programming, but not double-word programming.

3: Implemented only in PIC32 devices that implement double-word programming.

4: Implemented in select devices only; refer to the specific device data sheet for details.

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5.2.1 NVMCON Register

The NVMCON register is the control register for Flash program/erase operations. This register selects whether an erase or program operation can be performed and is used to start the program or erase cycle. The lower byte of NVMCON configures the type of NVM operation that will be performed. The register is shown in [Register 5-1](#).

Register 5-1: NVMCON: NVM Programming Control Register

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	—	—	—	—	—	—	—	—
23:16	U-0	U-0	U-0	U-0	U-0	U-0	U-0	U-0
	—	—	—	—	—	—	—	—
15:8	R/W-0, HC	R/W-0	R-0, HS	R-0, HS	R-0, HS, HC	R-0, HS	U-0	U-0
	WR	WREN ⁽¹⁾	WRERR ⁽²⁾	LVDERR ⁽²⁾	LVDSTAT ⁽²⁾	NVMPIDL ^(2,3)	—	—
7:0	U-0	U-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
	—	—	—	—	NVMOP<3:0>			

Legend:	HS = Hardware Settable bit	HC = Hardware Clearable bit
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 31-16 **Unimplemented:** Read as '0'

bit 15 **WR:** Write Control bit

This bit is writable when WREN = 1 and the unlock sequence is followed.

1 = Initiates a Flash operation; hardware clears this bit when the operation completes

0 = Flash operation is complete or inactive

bit 14 **WREN:** Write Enable bit⁽¹⁾

1 = Enables writes to the WR bit and enables the Low-Voltage Detect (LVD) circuit

0 = Disables writes to the WR bit and disables the LVD circuit

bit 13 **WRERR:** Write Error bit⁽²⁾

This bit is read-only and is automatically set by hardware.

1 = Program or erase sequence did not complete successfully

0 = Program or erase sequence completed normally

bit 12 **LVDERR:** Low-Voltage Detect Error bit (LVD circuit must be enabled)⁽²⁾

This bit is read-only and is automatically set by hardware.

1 = Low-voltage event detected (possible data corruption if WRERR is set)

0 = Voltage level is acceptable for programming

bit 11 **LVDSTAT:** Low-Voltage Detect Status bit (LVD circuit must be enabled)⁽²⁾

This bit is read-only and is automatically set and cleared by hardware.

1 = Low-voltage event is active

0 = Low-voltage event is NOT active

bit 10 **NVMPIDL:** NVM Array Power-Down in Idle Enable bit^(2,3)

1 = Power is removed from Flash memory when the device enters Idle mode

0 = Power is maintained to Flash memory during Idle mode

bit 9-4 **Unimplemented:** Read as '0'

Note 1: This bit is reset by a device Reset.

2: This bit is cleared by setting NVMOP<3:0> = 0000 and initiating a Flash operation (i.e., WR).

3: Implemented in select devices only; refer to the specific device data sheet for details.

4: Operations are only valid if the page or address selected by NVMADDR is not write-protected.

Register 5-1: NVMCON: NVM Programming Control Register (Continued)

bit 3-0 **NVMOP<3:0>**: NVM Operation bits

These bits are writable when WREN = 0.

1111 = Reserved

-
-
-

0111 = Reserved

0110 = No operation

0101 = Program Flash Memory (PFM) Erase Operation: Erases PFM if all pages are not write-protected

0100 = Page Erase Operation: Erases page selected by NVMADDR⁽⁴⁾

0011 = Row Program Operation: Programs row selected by NVMADDR⁽⁴⁾

0010 = Double-Word Program Operation: Programs word selected by NVMADDR^(3,4)

0001 = Word Program Operation: Programs word selected by NVMADDR^(3,4)

0000 = No operation

Note 1: This bit is reset by a device Reset.

2: This bit is cleared by setting NVMOP<3:0> = 0000 and initiating a Flash operation (i.e., WR).

3: Implemented in select devices only; refer to the specific device data sheet for details.

4: Operations are only valid if the page or address selected by NVMADDR is not write-protected.

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5.2.2 NVMKEY Register

NVMKEY is a write-only register that is used to prevent accidental writes/erasures of Flash or EEPROM memory. To start a programming or an erase sequence, the following steps must be taken in the exact order shown:

1. Write 0xAA996655 to NVMKEY.
2. Write 0x556699AA to NVMKEY.

After this sequence, only the next transaction on the peripheral bus is allowed to write to the NVMCON register. In most cases, the user will simply need to set the WR bit in the NVMCON register to start the program or erase cycle. Interrupts should be disabled during the unlock sequence.

Register 5-2: NVMKEY: NVM Programming Unlock Register

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	W-0	W-0	W-0	W-0	W-0	W-0	W-0	W-0
NVMKEY<31:24>								
23:16	W-0	W-0	W-0	W-0	W-0	W-0	W-0	W-0
NVMKEY<23:16>								
15:8	W-0	W-0	W-0	W-0	W-0	W-0	W-0	W-0
NVMKEY<15:8>								
7:0	W-0	W-0	W-0	W-0	W-0	W-0	W-0	W-0
NVMKEY<7:0>								

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 31-0 **NVMKEY<31:0>**: NVM Unlock Register bits
 These bits are write-only and read as '0' on any read.

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5.2.3 NVMADDR Register

The NVM Address register selects the row for Flash memory writes, the address location for word writes and the page address for Flash memory erase operations.

Note: The NVM Address register must be loaded with the physical address of the Flash memory and *not* the virtual address.

Register 5-3: NVMADDR: NVM Flash Address Register

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMADDR<31:24>								
23:16	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMADDR<23:16>								
15:8	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMADDR<15:8>								
7:0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMADDR<7:0>								

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 31-0 **NVMADDR<31:0>**: NVM Flash Address bits
 Bulk/Chip/PFM Erase: Address is ignored.
 Page Erase: Address identifies the page to erase.
 Row Program: Address identifies the row to program.
 Word Program: Address identifies the word to program.

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5.2.4 NVMDATA Registers

The NVM Data registers hold the data to be programmed during Flash word program operations. Devices that implement only word and row programming implement a single register, NVMDATA.

Devices that implement double-word programming implement two registers, named NVMDATA0 and NVMDATA1. In these devices, NVMDATA0 is used for the lower word of the data to be written in double-word operations.

Register 5-4: NVMDATA or NVMDATA0/1: NVM Flash Program Data Register^(1,2)

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMDATA<31:24> or NVMDATA0/1<31:24>								
23:16	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMDATA<23:16> or NVMDATA0/1<23:16>								
15:8	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMDATA<15:8> or NVMDATA0/1<15:8>								
7:0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMDATA<7:0> or NVMDATA0/1<7:0>								

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 31-0 **NVMDATA<31:0>**: NVM Flash Programming Data bits
NVMDATA0<31:0>: NVM Flash Programming Data bits (lower word, select devices only)
NVMDATA1<31:0>: NVM Flash Programming Data bits (upper word, select devices only)

- Note 1:** The name and number of registers implemented is device-specific. Refer to the device data sheet for more information.
- 2:** This register is reset only on a Power-on Reset (POR).

5.2.5 NVMSRCADDR Register

The NVM Source Data Address register selects the source data buffer address in SRAM for performing row programming operations.

Note: The address must be word-aligned.

Register 5-5: NVMSRCADDR: NVM Source Data Address Register

Bit Range	Bit 31/23/15/7	Bit 30/22/14/6	Bit 29/21/13/5	Bit 28/20/12/4	Bit 27/19/11/3	Bit 26/18/10/2	Bit 25/17/9/1	Bit 24/16/8/0
31:24	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMSRCADDR<31:24>								
23:16	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMSRCADDR<23:16>								
15:8	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMSRCADDR<15:8>								
7:0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
NVMSRCADDR<7:0>								

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 31-0 **NVMSRCADDR<31:0>**: NVM Source Data Address bits

The system physical address of the data to be programmed into the Flash when the NVMOP<3:0> bits (NVMCON<3:0>) are set to perform row programming.

5.3 RUN-TIME SELF-PROGRAMMING (RTSP) OPERATION

Run-Time Self-Programming (RTSP) allows the user code to modify Flash program memory contents. The device Flash memory is divided into two logical Flash partitions: the Program Flash Memory (PFM) and the Boot Flash Memory (BFM). The last page in Boot Flash Memory contains the debug page, which is reserved for use by the debugger tool while debugging.

The program Flash array for the PIC32 device is built up of a series of rows to form a page. Refer to the “**Flash Program Memory**” chapter of the specific device data sheet to determine the row and page sizes. For example, a row may contain 128 32-bit instruction words or 512 bytes. A group of 8 rows compose a page; which, therefore, contains $8 \times 512 = 4096$ bytes or 1024 instruction words. A page of Flash is the smallest unit of memory that can be erased at a single time. The program Flash array can be programmed in several ways:

- Word Programming, with 1 instruction word at a time (most devices)
- Double-Word Programming, with 2 instruction words at a time (select devices only)
- Row Programming, with 64 or 128 instruction words at a time

Performing an RTSP operation while executing (fetching) instructions from Program Flash Memory causes the CPU to stall (wait) until the programming operation is finished. The CPU will not execute any instruction, or respond to interrupts, during this time. If any interrupts occur during the programming cycle, they remain pending until the cycle completes.

If performing an RTSP operation while executing (fetching) instructions from RAM memory, the CPU can continue to execute instructions and respond to interrupts during the programming operation. Any executable code scheduled to execute during the RTSP operation must be placed in RAM memory; this includes the relevant interrupt vector and the Interrupt Service Routine (ISR) instructions.

<p>Note: A minimum VDD requirement for Flash erase and write operations is required. Refer to the “Electrical Characteristics” chapter in the specific device data sheet for more information.</p>
--

5.4 LOCK-OUT FEATURE

5.4.1 NVM WREN

A number of mechanisms exists within the device to ensure that inadvertent writes to program Flash do not occur. The WREN bit (NVMCON<14>) should be zero unless the software intends to write to the program Flash. When WREN = 1, the Flash Write Control bit, WR (NVMCON<15>), is writable and the Flash LVD circuit is enabled.

5.4.2 NVMKEY

In addition to the write protection provided by the WREN bit, an unlock sequence needs to be performed before the WR bit (NVMCON<15>) can be set. If the WR bit is not set on the next peripheral bus transaction (read or write), WR is locked and the unlock sequence must be restarted.

5.4.3 Unlock Sequence

To unlock Flash operations, perform Steps 4 through 8 in order. If the sequence is not followed, WR is not set.

1. Suspend or disable all initiators that can access the peripheral bus and interrupt the unlock sequence (e.g., DMA and interrupts).
2. Set the WREN bit (NVMCON<14>) to allow writes to WR and set the NVMOP<3:0> bits (NVMCON<3:0>) to the desired operation with a single store instruction.
3. Wait for LVD to start-up.
4. Load 0xAA996655 to CPU Register X.
5. Load 0x556699AA to CPU Register Y.
6. Load 0x00008000 to CPU Register Z.
7. Store CPU Register X to NVMKEY.
8. Store CPU Register Y to NVMKEY.
9. Store CPU Register Z to NVMCONSET.
10. Wait for the WR bit (NVMCON<15>) to be cleared.
11. Clear the WREN bit (NVMCON<14>).
12. Check the WRERR (NVMCON<13>) and LVDERR (NVMCON<12>) bits to ensure that the program/erase sequence completed successfully.

When the WR bit is set, the program/erase sequence starts and the CPU is unable to execute from Flash memory for the duration of the sequence.

Example 5-1: Unlock Example

```
unsigned int  NVMUnlock (unsigned int nvmop)
{
    unsigned int  status;

    // Suspend or Disable all Interrupts
    asm          volatile ("di %0" : "=r" (status));

    // Enable Flash Write/Erase Operations and Select
    // Flash operation to perform
    NVMCON = nvmop;

    // Write Keys
    NVMKEY = 0xAA996655;
    NVMKEY = 0x556699AA;

    // Start the operation using the Set Register
    NVMCONSET = 0x8000;

    // Wait for operation to complete
    while (NVMCON & 0x8000);

    // Restore Interrupts
    if (status & 0x00000001)
        asm      volatile ("ei");
    else
        asm      volatile ("di");

    // Disable NVM write enable
    NVMCONCLR = 0x0004000;

    // Return WRERR and LVDERR Error Status Bits
    return (NVMCON & 0x3000);
}
```

5.5 WORD PROGRAMMING SEQUENCE

The smallest block of data that can be programmed in a single operation is one 32-bit word. The data to be programmed must be written to the NVMDATA register and the address of the word must be loaded into the NVMADDR register before the programming sequence is initiated. The instruction word at the location pointed to by the NVMADDR register is then programmed.

A program sequence comprises the following steps:

1. Write 32-bit data to be programmed to the NVMDATA register.
2. Load the NVMADDR register with the address to be programmed.
3. Run the unlock sequence using the word program command (see [Section 5.4.3 “Unlock Sequence”](#)).

The program sequence completes and the WR bit (NVMCON<15>) is cleared by hardware.

Example 5-2: Word Program Example

```
unsigned int NVMWriteWord (void* address, unsigned int data)
{
    unsigned int res;

    // Load data into NVMDATA register
    NVMDATA = data;
    // Load address to program into NVMADDR register
    NVMADDR = (unsigned int) address;
    // Unlock and Write Word
    res = NVMUnlock (0x4001);
    // Return Result
    return res;
}
```

5.6 DOUBLE-WORD PROGRAMMING SEQUENCE

Double-word programming follows essentially the same sequence as word programming, except that the data is written to two NVMDATA registers. In this scenario, the lower word of data is written to NVMDATA0 and the upper word to NVMDATA1.

A program sequence comprises the following steps:

1. Write 64-bit data to be programmed to the NVMDATA0 and NVMDATA1 registers.
2. Load the NVMADDR register with the address to be programmed.
3. Run the unlock sequence using the word program command (see [Section 5.4.3 “Unlock Sequence”](#)).

The program sequence completes and the WR bit (NVMCON<15>) is cleared by hardware.

Example 5-3: Word Program Example

```
unsigned int NVMWriteWord (void* address, unsigned int data)
{
    unsigned int res;

    // Load data into NVMDATA register
    NVMDATA0 = data_l;
    NVMDATA1 = data_h;
    // Load address to program into NVMADDR register
    NVMADDR = (unsigned int) address;
    // Unlock and Write Word
    res = NVMUnlock (0x4010);
    // Return Result
    return res;
}
```

5.7 ROW PROGRAMMING SEQUENCE

The largest block of data that can be programmed is 1 row, which is equal to 512 bytes of data (refer to the “**Flash Program Memory**” chapter in the specific device data sheet to determine the row size). The row of data must first be loaded into a buffer in SRAM. The NVMADDR register then points to the Flash address where the Flash controller will start programming the row of data.

Note: The Flash controller ignores the sub-row address bits and always starts programming at the beginning of a row.

A row program sequence comprises the following steps:

1. Write the entire row of data to be programmed into system SRAM. The source address must be word-aligned.
2. Set the NVMADDR register with the start address of the Flash row to be programmed.
3. Set the NVMSRCADDR register with the physical source address from Step 1.
4. Run the unlock sequence using the row program command (see [Section 5.4.3 “Unlock Sequence”](#)).
5. The program sequence completes and the WR bit (NVMCON<15>) is cleared by hardware.

Example 5-4: Row Program Example

```
unsigned int NVMWriteRow (void* address, void* data)
{
    unsigned int res;

    // Set NVMADDR to Start Address of row to program
    NVMADDR = (unsigned int) address;
    // Set NVMSRCADDR to the SRAM data buffer Address
    NVMSRCADDR = (unsigned int) data;
    // Unlock and Write Row
    res = NVMUnlock(0x4003);
    // Return Result
    return res;
}
```

5.8 PAGE ERASE SEQUENCE

A page erase performs an erase of a single page of either PFM or BFM. Refer to the specific device data sheet for the page size. The page to be erased is selected using the NVMADDR register.

Note: The lower bits of the address are ignored in page selection.

A page of Flash can only be erased if its associated write protection page is not enabled.

- All BFM pages are affected by the Boot Write Protection Configuration bit
- PFM pages are affected by the Program Flash Write Protection Configuration bits

If in Mission mode, the application must not be executing from the erased page.

A page erase sequence comprises the following steps:

1. Set the NVMADDR register with the address of the page to be erased.
2. Run the unlock sequence using the desired erase command (see [Section 5.4.3 “Unlock Sequence”](#)).
3. The erase sequence completes and the WR bit (NVMCON<15>) is cleared by hardware.

Example 5-5: Page Erase Example

```
unsigned int NVMErasePage(void* address)
{
    unsigned int res;

    // Set NVMADDR to the Start Address of page to erase
    NVMADDR = (unsigned int) address;
    // Unlock and Erase Page
    res = NVMUnlock(0x4004);
    // Return Result
    return res;
}
```

5.9 PROGRAM FLASH MEMORY ERASE SEQUENCE

It is possible to erase the entire PFM area. This mode leaves the boot Flash intact and is intended to be used by a field-upgradeable device.

The program Flash can be erased if all pages in the program Flash are not write-protected.

Note: The application must *not* be executing from the PFM address range.

A PFM erase sequence comprises the following steps:

1. Run the unlock sequence using the Program Flash Memory erase command (see [Section 5.4.3 “Unlock Sequence”](#)).
2. The erase sequence completes and the WR bit (NVMCON<15>) is cleared by hardware.

Example 5-6: Program Flash Erase Example

```
unsigned int NVMErasePFM(void)
{
    unsigned int res;

    // Unlock and Erase Program Flash
    res = NVMUnlock(0x4005);
    // Return Result
    return res;
}
```

5.10 OPERATION IN POWER-SAVING AND DEBUG MODES

5.10.1 Operation in Sleep Mode

When a PIC32 device enters Sleep mode, the system clock is disabled. The Flash controller does not function in Sleep mode. If entry into Sleep mode occurs while an NVM operation is in progress, the device will not go into Sleep mode until the NVM operation is complete.

5.10.2 Operation in Idle Mode

Idle mode has no effect on the Flash controller module when a programming operation is active. The CPU continues to be stalled until the programming operation completes.

In select PIC32 devices, users have the option to control the Idle mode behavior of the program memory, which also permits incremental power savings. The NVMPIDL bit (NVMCON<10>) determines Flash power control when the device enters Idle mode. When NVMPIDL is '1', power is removed from Flash program memory. When NVMPIDL is '0', the Flash program memory remains powered in Idle mode.

5.10.3 Operation in Debug Mode

The Flash controller does not provide debug freeze capability, and therefore, has no effect on the Flash controller module when a programming operation is active. The CPU continues to be stalled until the programming operation completes. Interrupting the normal programming sequence could cause the device to latch up. The only exception to this is the NVMKEY unlock sequence, which is suspended when in Debug mode, allowing the user to single step through the unlock sequence.

5.11 EFFECTS OF VARIOUS RESETS

5.11.1 Device Reset

Only the NVMCON bits for WREN and LVDSTAT are reset on a device Reset. All other SFR bits are only reset by a POR; however, the state of the NVMKEY register is reset by a device Reset.

5.11.2 Power-on Reset

All Flash Controller registers are forced to their Reset states upon a POR.

5.11.3 Watchdog Timer Reset

All Flash Controller registers are unchanged upon a Watchdog Timer Reset.

5.12 INTERRUPTS

The Flash controller can generate an interrupt reflecting the events that occur during the programming operations. The following interrupts can be generated:

- Flash Control Event Interrupt Flag (FCEIF)

The interrupt flag must be cleared in software. The Flash controller is enabled as a source of interrupt via the following bit:

- Flash Controller Event Interrupt Enable (FCEIE)

The Interrupt Priority Level (IPL) bits and interrupt subpriority level bits must also be configured:

- FCEIP<2:0>
- FCEIS<1:0>

Refer to **Section 8. “Interrupts”** (DS60001108) in the *“PIC32 Family Reference Manual”* for details.

5.12.1 Interrupt Configuration

The Flash controller module has a dedicated interrupt flag bit, FCEIF, and a corresponding interrupt enable/mask bit, FCEIE.

These two bits determine the source of an interrupt and enable or disable an individual interrupt source. All the interrupt sources for a specific Flash controller module share one interrupt vector.

In addition, the FCEIF bit will be set without regard to the state of the corresponding enable bit and the FCEIF bit can be polled by software if desired.

The FCEIE bit is used to define the behavior of the Vector Interrupt Controller (VIC) when a corresponding FCEIF bit is set. When the corresponding FCEIE bit is clear, the VIC module does not generate a CPU interrupt for the event. If the FCEIE bit is set, the VIC module will generate an interrupt to the CPU when the corresponding FCEIF bit is set (subject to the priority and subpriority as outlined in the following paragraphs).

It is the responsibility of the user's software routine that services a particular interrupt to clear the appropriate interrupt flag bit before the service routine is complete.

The priority of the Flash controller module can be set independently with the FCEIP<2:0> bits. This priority defines the priority group to which the interrupt source is assigned. The priority groups range from a value of 7 (the highest priority) to a value of 0, which does not generate an interrupt. An interrupt being serviced is preempted by an interrupt in a higher priority group.

The subpriority bits allow setting the priority of a interrupt source within a priority group. The values of the subpriority bits, FCEIS<1:0>, range from 3 (the highest priority) to 0 (the lowest priority). An interrupt with the same priority group, but having a higher subpriority value does not preempt a lower subpriority interrupt that is in progress.

The priority group and subpriority bits allow more than one interrupt source to share the same priority and subpriority. If simultaneous interrupts occur in this configuration, the natural order of the interrupt sources within a priority/subpriority group pair determine the interrupt generated. The natural priority is based on the vector numbers of the interrupt sources. The lower the vector number, the higher the natural priority of the interrupt. Any interrupts that are overridden by natural order generate their respective interrupts based on priority, subpriority and natural order, after the interrupt flag for the current interrupt is cleared.

After an enabled interrupt is generated, the CPU jumps to the vector assigned to that interrupt. The vector number for the interrupt is the same as the natural order number. Then, the CPU begins executing code at the vector address. The user's code at this vector address should perform any application-specific operations, clear the FCEIF interrupt flag and then exit.

For more information on interrupts and the vector address table details, refer to **Section 8. “Interrupts”** (DS60001108) in the *“PIC32 Family Reference Manual”* and the **“Interrupt Controller”** chapter of the specific device data sheet.

5.13 RELATED APPLICATION NOTES

This section lists application notes that are related to this section of the manual. These application notes may not be written specifically for the PIC32 device family, but the concepts are pertinent and could be used with modification and possible limitations. The current application notes related to Flash Programming include the following:

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

Note: Please visit the Microchip web site (www.microchip.com) for additional application notes and code examples for the PIC32 family of devices.

5.14 REVISION HISTORY

Revision A (September 2007)

This is the initial released version of this document.

Revision B (October 2007)

Updated document to remove Confidential status.

Revision C (April 2008)

Revised status to Preliminary; revised U-0 to r-x.

Revision D (June 2008)

Revised Register 5-1, bit 14 NVMWREN. Added footnote 1 to Registers 5-12 through 5-14. Added note to Section 5.3. Revised Section 5.4.1. Revised Example 5-1. Changed Reserved bits from "Maintain as" to "Write".

Revision E (December 2010)

This revision includes the following updates:

- Minor updates to the text and formatting have been incorporated throughout the document
- Added Notes 1, 2 and 3, which describe the Clear, Set and Invert registers to the following:
 - [Table 5-1](#): Flash Controller SFR Summary
 - [Register 5-1](#): NVMCON: NVM Programming Control Register^(1,2,3)
 - [Register 5-3](#): NVMADDR: NVM Flash Address Register^(1,2,3)
- Removed all Clear, Set and Invert register descriptions
- Removed all Interrupt register references
- The following NVMCON register bit names were changed throughout the document:
 - NVMWR was renamed to WR
 - NVMWREN was renamed to WREN
 - NVMERR was renamed to WRERR
- Updated the third paragraph and added a new (fourth) paragraph to [Section 5.3 "Run-Time Self-Programming \(RTSP\) Operation"](#)
- Updated the unlock Flash operations sequence by adding a new Step 3 (see [Section 5.4.3 "Unlock Sequence"](#))
- Updated the code in the Unlock Example (see [Example 5-1](#))
- Removed Table 5-3

Revision F (July 2012)

This revision includes the following updates:

- Updated Note 1 and removed Notes 2 and 3 from the Flash Controller SFR Register Summary (see [Table 5-1](#))
- Updated the NVMCON register (see [Register 5-1](#))
- Removed Notes 1, 2 and 3 from NVMADDR (see [Register 5-3](#))
- Updated the second paragraph of [Section 5.3 "Run-Time Self-Programming \(RTSP\) Operation"](#)
- Updated the first paragraph of [Section 5.7 "Row Programming Sequence"](#)
- Updated the first paragraph of [Section 5.8 "Page Erase Sequence"](#)
- Minor updates to the text and formatting have been incorporated throughout the document

Revision G (March 2016)

Added double-word programming:

- Added the NVMPIDL bit and supporting footnotes to NVMCON<10>; also defines a combinatorial for double-word programming (and supporting footnotes) to NVMCON<3:0>.
- Added NVMDATA0 and 1 registers to [Table 5-1](#).
- Updated [Section 5.2.4 “NVMDATA Registers”](#) to add descriptions for NVMDATA0 and 1 registers.
- Updated [Section 5.3 “Run-Time Self-Programming \(RTSP\) Operation”](#) to add a description for double-word programming.
- Added [Section 5.6 “Double-Word Programming Sequence”](#); all subsequent sections are renumbered accordingly.
- Amended [Section 5.10.2 “Operation in Idle Mode”](#) to include a description of the NVMPIDL bit's functionality.
- Other minor typographic corrections throughout the document.

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ISBN: 978-1-5224-0424-8



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