PIC16F91X/946

PIC16F91X/946 Memory Programming Specification

This document includes the programming specifications for the following devices:

- PIC16F913
- PIC16F914
- PIC16F946
- PIC16F916
- PIC16F917

1.0 PROGRAMMING THE PIC16F91X/946 DEVICES

The PIC16F91X/946 devices are programmed using a serial method. The Serial mode will allow the PIC16F91X/946 to be programmed while in the user's system. This allows for increased design flexibility. This programming specification applies to the PIC16F91X/946 devices in all packages.

1.1 Hardware Requirements

PIC16F91X/946 devices require one power supply for VDD and one for VPP (see **Section 6.0 "Program/Verify Mode Electrical Characteristics"** for more details).

1.2 Program/Verify Mode

The Program/Verify mode for the PIC16F91X/946 devices allow programming of user program memory, data memory, user ID locations and the Configuration Word.

Programming and verification can take place in any memory region, independent of the remaining regions. This allows independent programming of program and data memory regions.

TABLE 1-1: PIN DESCRIPTIONS IN PROGRAM/VERIFY MODE: PIC16F91X/946

Pin Name	During Programming		
	Function	Pin Type	Pin Description
RB6	ICSPCLK	I	Clock Input – Schmitt Trigger Input
RB7	ICSPDAT	I/O	Data Input/Output – Schmitt Trigger Input
$\overline{MCLR}$	Program/Verify mode	P(1)	Program Mode Select
VDD	VDD	P	Power Supply
VSS	VSS	P	Ground
AVDD(2)	AVDD	P	Analog Power Supply
AVSS(2)	AVSS	P	Analog Ground

Legend: I = Input, O = Output, P = Power

Note 1: In the PIC16F91X/946, the programming high voltage is internally generated. To activate the Program/Verify mode, high voltage needs to be applied to $\overline{MCLR}$ input. Since the $\overline{MCLR}$ is used for a level source, $\overline{MCLR}$ does not draw any significant current.

2: AVDD AND AVSS pins are only available on PIC16F946.

FIGURE 1-1: PIC16F913/916 28-PIN PDIP (300 MIL), SOIC, SSOP

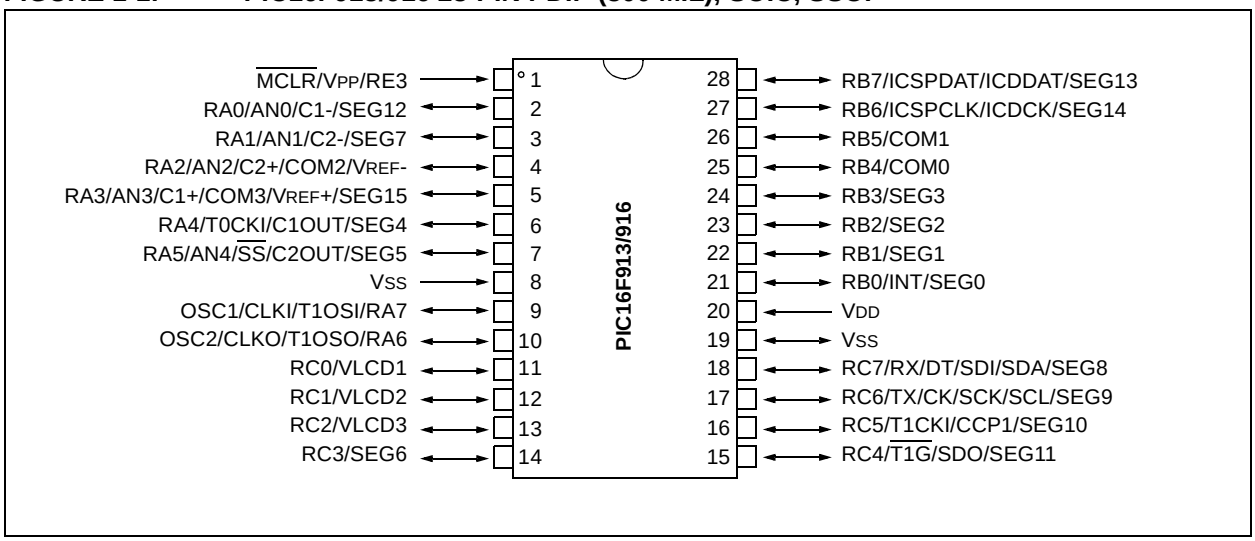


FIGURE 1-2: PIC16F913/916 28-PIN QFN

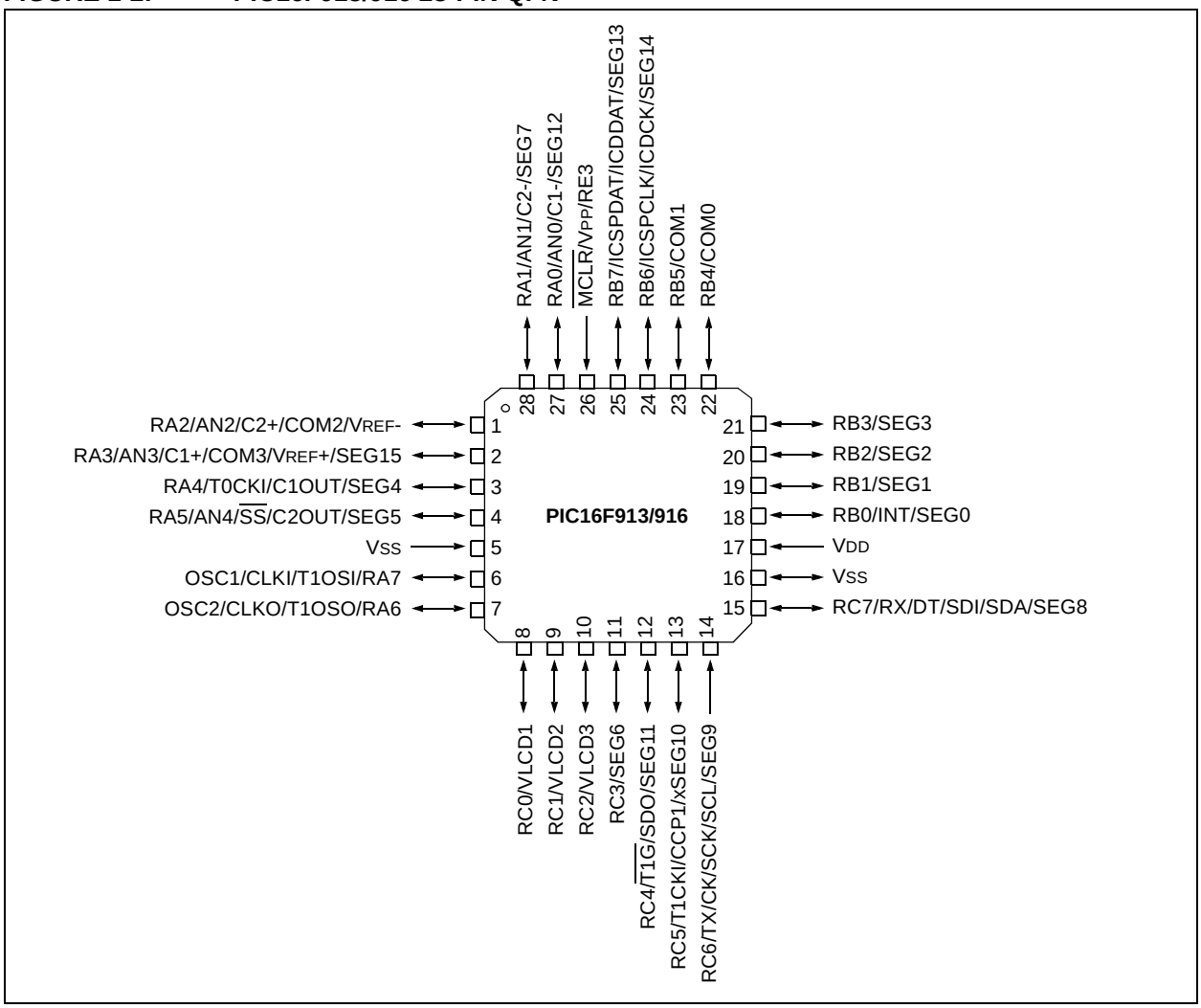


FIGURE 1-3: PIC16F914/917 44-PIN DIAGRAM TQFP, QFN

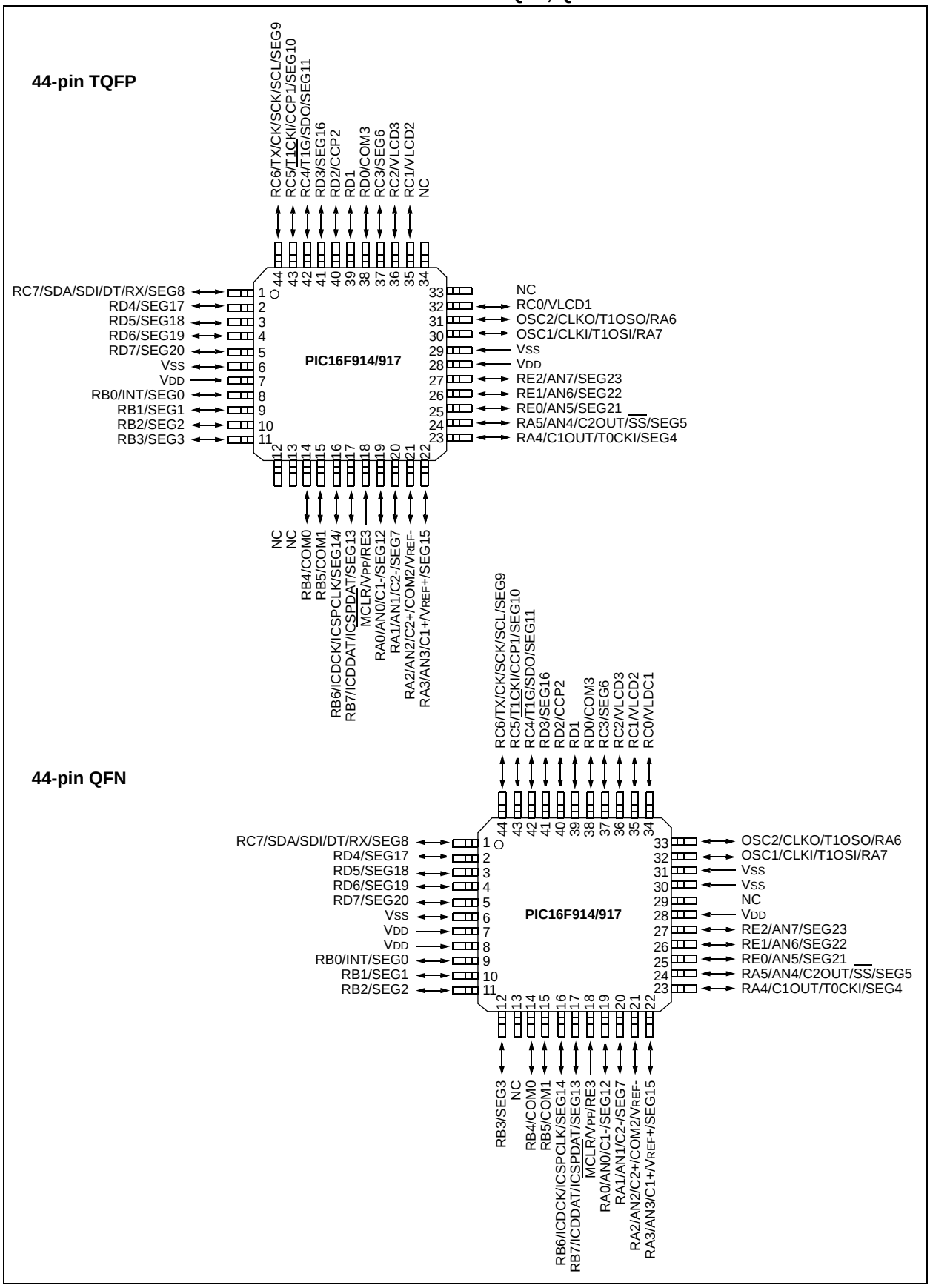


FIGURE 1-4: PIC16F914/917 40-PIN PDIP (600 MIL)

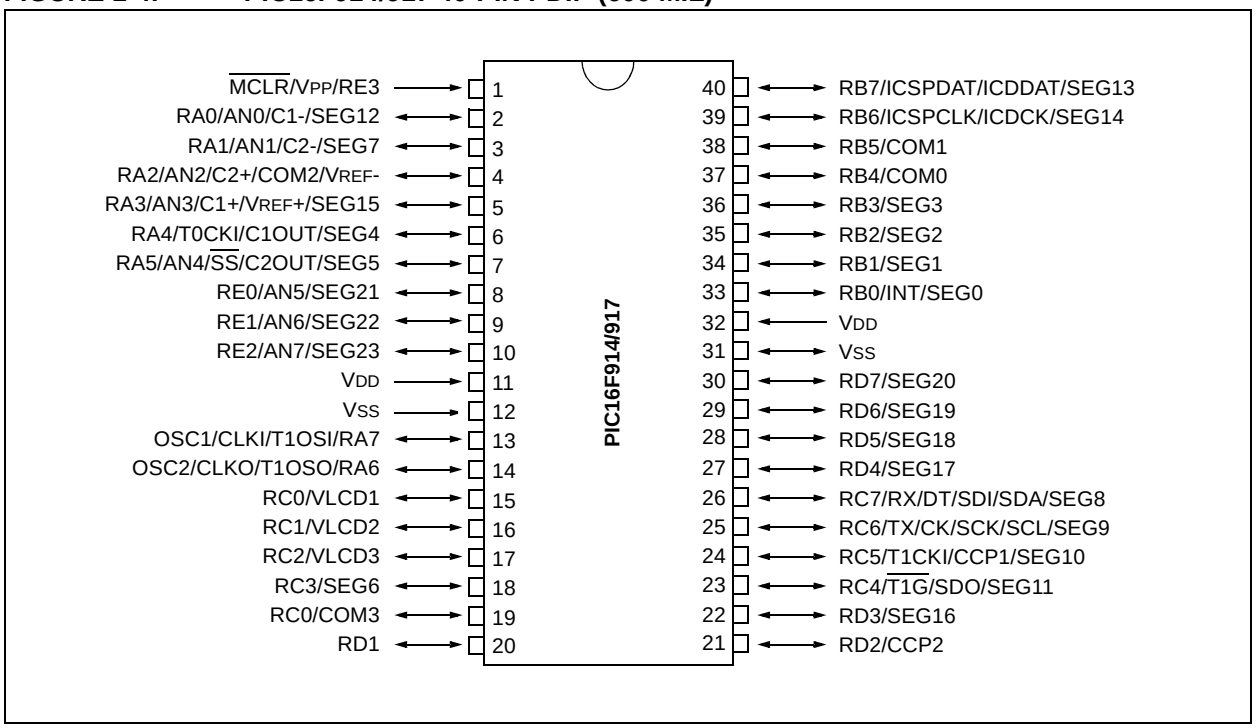
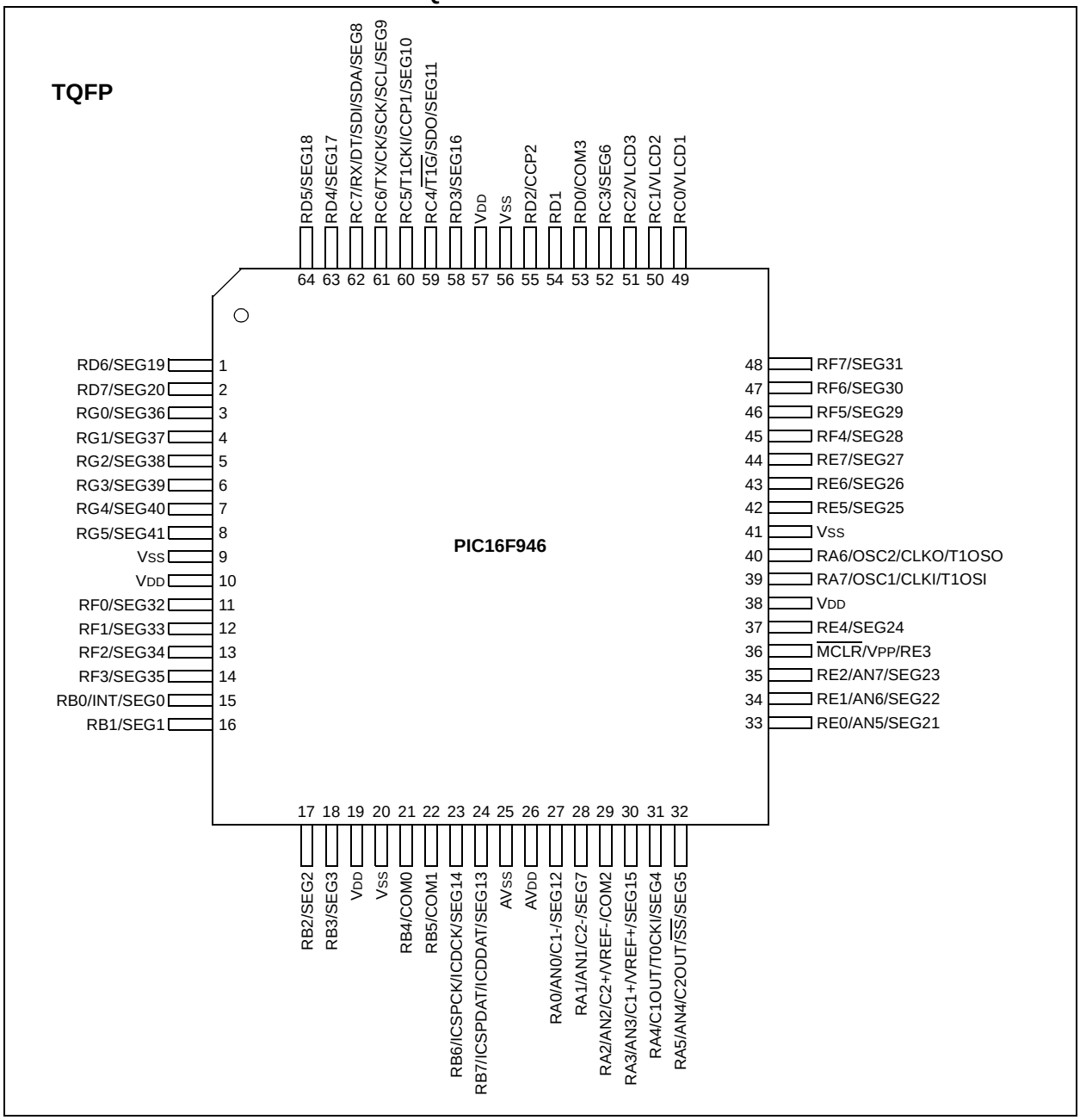


FIGURE 1-5: PIC16F946 64-PIN TQFP



2.0 MEMORY DESCRIPTION

2.1 Program Memory Map

The user memory space extends from 0x0000-0x0FFF for PIC16F913/914 and from 0x0000-0x1FFF for PIC16F916/917/946. In Program/Verify mode, the program memory space extends from 0x0000 to 0x3FFF, with the first half being user program memory and the second half (0x2000-0x3FFF) being configuration memory. The PC will increment from 0x0000 to 0x1FFF (or 0x0FFF) and wrap to 0x0000, 0x2000 to 0x3FFF and wrap-around to 0x2000 (not to 0x0000). Once in configuration memory, the highest bit of the PC stays a '1', thus always pointing to the configuration memory. The only way to point to user program memory is to reset the part and re-enter Program/Verify mode as described in **Section 3.0 "Program/Verify Mode"**.

For the PIC16F91X/946 devices, the configuration memory space, 0x2000-0x2009, are physically implemented. However, only locations 0x2000-0x2003 and 0x2007-0x2009 are available. Other locations are reserved.

2.2 User ID Locations

A user may store identification information (user ID) in four designated locations. The user ID locations are mapped in 0x2000-0x2003. It is recommended that the user use only the seven Least Significant bits (LSb) of each user ID location. The user ID locations read out normally, even after code protection is enabled. It is recommended that ID locations are written as 'xx xxxx xbbb bbbb' where 'bbb bbbb' is user ID information.

The 14 bits may be programmed, but only the 7 LSbs are displayed by MPLAB® IDE. The xxxx's are "don't care" bits and are not read by MPLAB® IDE.

2.3 Calibration Word

For the PIC16F91X/946 devices, the 8 MHz internal oscillator (INTOSC), the Power-on Reset (POR), and the Brown-out Reset (BOR) modules are factory calibrated and stored in the Calibration Word 1 (0x2008). The Low-Voltage Detect (LVD) module is factory calibrated and stored in the Calibration Word 2 (0x2009). See the applicable device data sheet for more information.

The Calibration Word locations are written at the time of manufacturing and are not erased when a Bulk Erase is performed. See **Section 3.1.6.10 "Bulk Erase Program Memory"** for more information on the various erase sequences. However, it is possible to inadvertently write to these locations. The device may not function properly or may operate outside of specifications if the Calibration Word locations do not contain the correct value. Therefore, it is recommended that the Calibration Words be read prior to any programming procedure and verified after programming is complete. See Figure 3-22 for a flowchart of the recommended verification procedure.

The device should not be used if the verification of the Calibration Word values fail after the device is programmed. The 0x3FFF value is a special case, it is a valid calibration value but, it is also the erased state of the register.

Note:	The device should not be used if verification of the Calibration Word locations fails. This information should be reported to the user through the user interface of the device programmer.

FIGURE 2-1: PIC16F913/914 PROGRAM MEMORY MAPPING

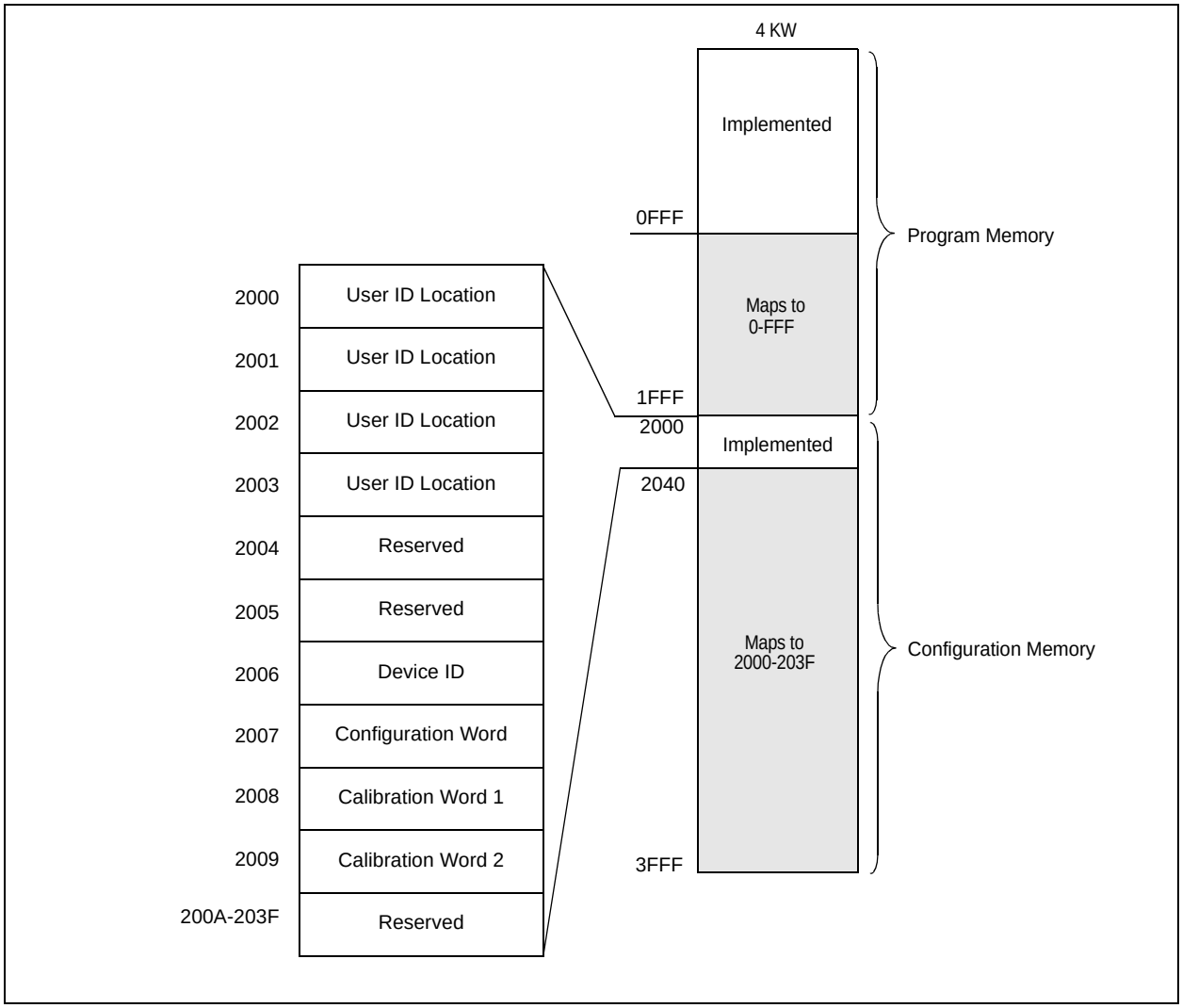


FIGURE 2-2: PIC16F916/917/946 PROGRAM MEMORY MAPPING

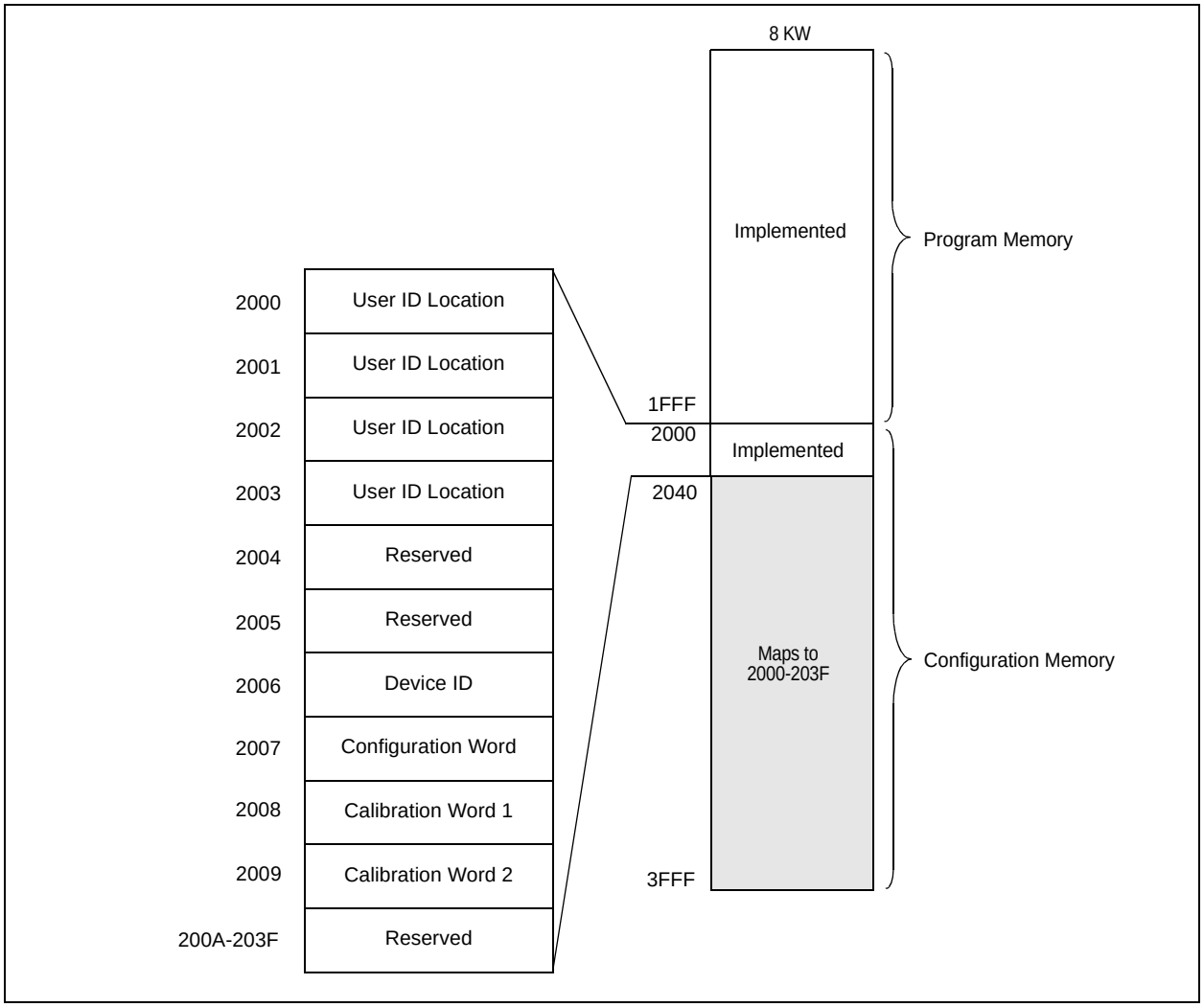
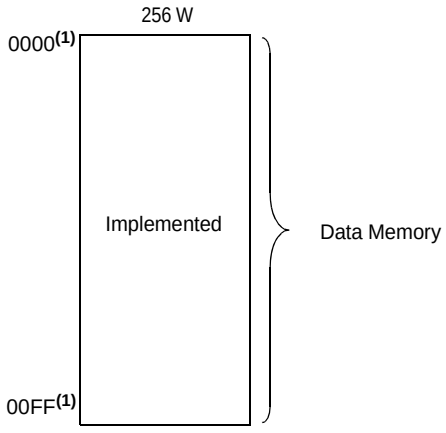


FIGURE 2-3: PIC16F91X/946 DATA MEMORY MAPPING



Note 1: When writing assembly code, data memory is addressed using 0x2100-0x21FF. See **Section 5.3.2 "Embedding Data Memory Contents In Hex File"** for more details.

3.0 PROGRAM/VERIFY MODE

Two methods are available to enter Program/Verify mode. The "VPP-first" is entered by holding ICSPDAT and ICSPCLK low while raising MCLR pin from VIL to VIHH (high voltage), then applying VDD and data. This method can be used for any Configuration Word selection and **must** be used if the INTOSC and internal MCLR options are selected (FOSC<2:0> = 100 or 101 and MCLRE = 0). The VPP-first entry prevents the device from executing code prior to entering Program/Verify mode. See the timing diagram in Figure 3-1.

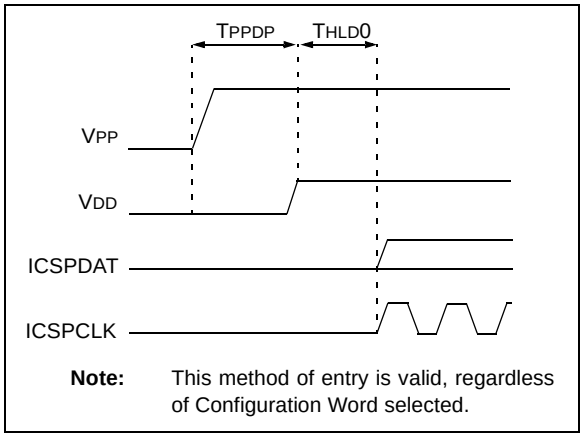
The second entry method, "VDD-first", is entered by applying VDD, holding ICSPDAT and ICSPCLK low, then raising MCLR pin from VIL to VIHH (high voltage), followed by data. This technique is useful when programming the device when VDD is already applied, for it is not necessary to disconnect VDD to enter Program/Verify mode. See the timing diagram in Figure 3-2.

Once in this mode, the program memory, data memory, and configuration memory can be accessed and programmed in serial fashion. ICSPDAT and ICSPCLK are Schmitt Trigger inputs in this mode. RB6 is tri-state, regardless of fuse setting.

The sequence that enters the device into the Programming/Verify mode places all other logic into the Reset state (the MCLR pin was initially at VIL). Therefore, all I/Os are in the Reset state (high-impedance inputs) and the Program Counter (PC) is cleared.

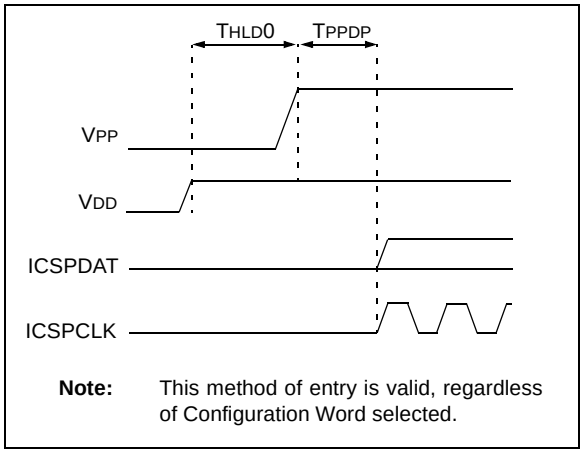
To prevent a device configured with INTOSC and internal MCLR from executing after exiting Program/Verify mode; VDD needs to power-down before VPP. See Figure 3-3 for the timing.

FIGURE 3-1: VPP-FIRST PROGRAM/ VERIFY MODE ENTRY



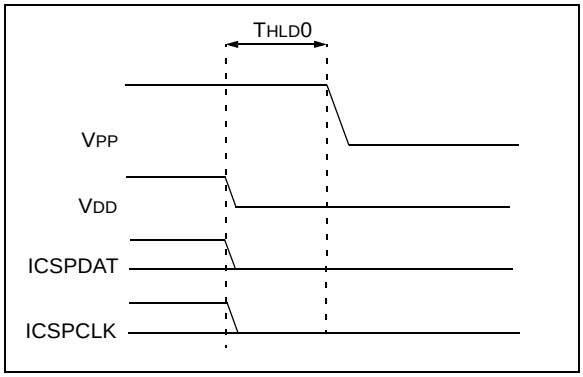
Note: This method of entry is valid, regardless of Configuration Word selected.

FIGURE 3-2: VDD-FIRST PROGRAM/ VERIFY MODE ENTRY



Note: This method of entry is valid, regardless of Configuration Word selected.

FIGURE 3-3: PROGRAM/VERIFY MODE EXIT



3.1 Program/Erase Algorithms

The PIC16F91X/946 program memory may be written in three ways. The PIC16F913/914 uses one-word and four-word writes. The PIC16F916/917/946 uses one-word, four-word and eight-word writes. The four-word or eight-word algorithm is used to program the program memory only. The one-word algorithm can write any available memory location (i.e., program memory, configuration memory and data memory).

After writing the array, the PC may be reset and read back to verify the write. It is not possible to verify immediately following the write because the PC can only increment, not decrement.

A device Reset will clear the PC and set the address to '0'. The Increment Address command will increment the PC. The Load Configuration command will set the PC to 0x2000. The available commands are shown in Table 3-1.

3.1.1 EIGHT-WORD PROGRAMMING

Only the program memory on PIC16F916/917/946 can be written using this algorithm. Data and configuration memory (>0x2000) must use the one-word programming algorithm (**Section 3.1.3 "One-Word Programming"**).

This algorithm writes eight sequential addresses in program memory. The eight addresses must point to an eight-word block with addresses modulo 8 of 0, 1, 2, 3, 4, 5, 6 and 7. For example, programming address 8 through 15 can be programmed together. Programming addresses 2 through 9 will create an unexpected result.

The sequence for programming eight words of program memory at a time is as follows:

1. Load a word at the current program memory address using Load Data For Program Memory command.
2. Issue a Increment Address command.
3. Load a word at the current program memory address using Load Data For Program Memory command.
4. Repeat Step 2 and Step 3 six times.
5. Issue a Begin Programming command either internally or externally timed.
6. Wait TPROG1 (internally timed) or TPROG2 (externally timed).
7. Issue a End Programming command if externally timed.
8. Issue a Increment Address command.
9. Repeat this sequence as required to write program memory.

See Figure 3-18 for more information.

3.1.2 FOUR-WORD PROGRAMMING

Four-word programming can be used on all devices in the PIC16F91X/946 family. Only the program memory can be written using this algorithm. Data and configuration memory (>0x2000) must use the one-word programming algorithm (**Section 3.1.3 "One-Word Programming"**).

This algorithm writes four sequential addresses in program memory. The four addresses must point to a four-word block with addresses modulo 4 of 0, 1, 2 and 3. For example, programming address 4 through 7 can be programmed together. Programming addresses 2 through 5 will create an unexpected result.

The sequence for programming four words of program memory at a time is as follows:

1. Load a word at the current program memory address using Load Data For Program Memory command.
2. Issue a Increment Address command.
3. Load a word at the current program memory address using Load Data For Program Memory command.
4. Repeat Step 2 and Step 3 two times.
5. Issue a Begin Programming command either internally or externally timed.
6. Wait TPROG1 (internally timed) or TPROG2 (externally timed).
7. Issue a End Programming command if externally timed.
8. Issue a Increment Address command.
9. Repeat this sequence as required to write program memory.

See Figure 3-17 for more information.

3.1.3 ONE-WORD PROGRAMMING

The program memory may also be written one word at a time to allow compatibility with other 8-pin and 14-pin Flash PIC® devices. Configuration memory (>0x2000) and data memory must be written one word (or byte) at a time.

Note:	The write latches must be reset after programming the user ID (0x2000-0x2003) or Configuration Word (0x2007). See **Section 3.1.4 "Resetting Write Latches"**.

The sequence for programming one word of program memory at a time is as follows:

1. Load a word at the current program memory address using Load Data For Program Memory command.
2. Issue a Begin Programming command either internally or externally timed.
3. Wait TPROG1 (internally timed) or TPROG2 (externally timed).
4. Issue a End Programming command if externally timed.
5. Issue a Increment Address command.
6. Repeat this sequence as required to write program, data or configuration memory.

See Figure 3-16 for more information.

3.1.4 RESETTING WRITE LATCHES

The user ID (0x2000-0x2003) and Configuration Word (0x2007) are mapped into the configuration memory, but do not physically reside in it. As a result, the write latches are not reset when programming these locations and must be reset by the programmer. This can be done in two ways, either loading all the latches with '1's or by exiting Program/Verify mode. There are four latches on the PIC16F913/914 and eight latches on the PIC16F916/917/946.

The sequence for manually resetting the write latches is as follows:

1. Load a word using Load Data For Program Memory or Load Data For Configuration Memory command with a data word of all '1's.
2. Issue a Increment Address command.
3. Repeat this sequence three times on PIC16F913/914 and seven times on PIC16F916/917/946 to reset all write latches.

3.1.5 ERASE ALGORITHMS

The PIC16F91X/946 will erase different memory locations depending on the Program Counter (PC), $\overline{CP}$ and $\overline{CPD}$ values, and which erase command is executed. The following sequences can be used to erase noted memory locations. In each sequence, the data memory will be erased if the $\overline{CPD}$ bit in the Configuration Word is programmed (clear).

To erase the program memory and Configuration Word (0x2007), the following sequence must be performed. Note the Calibration Words (0x2008-0x2009) and user ID (0x2000-0x2003) **will not** be erased.

1. Do a Bulk Erase Program Memory command.
2. Wait TERA to complete erase.

To erase the user ID (0x2000-0x2003), Configuration Word (0x2007) and program memory, use the following sequence. Note that the Calibration Words (0x2008-0x2009) **will not** be erased.

1. Perform Load Configuration with dummy data to point the Program Counter (PC) to 0x2000.
2. Perform a Bulk Erase Program Memory command.
3. Wait TERA to complete erase.

To erase the data memory, use the following sequence:

1. Perform a Bulk Erase Data Memory command.
2. Wait TERA to complete erase.

3.1.6 SERIAL PROGRAM/VERIFY OPERATION

The ICSPCLK pin is used as a clock input and the ICSPDAT pin is used for entering command bits and data input/output during serial operation. To input a command, ICSPCLK is cycled six times. Each command bit is latched on the falling edge of the clock with the LSb of the command being input first. The data input onto the ICSPDAT pin is required to have a minimum setup and hold time (see Table 6-1), with respect to the falling edge of the clock. Commands that have data associated with them (Read and Load) are specified to have a minimum delay of TDLY1 between the command and the data. After this delay, the clock pin is cycled 16 times with the first cycle being a Start bit and the last cycle being a Stop bit.

During a read operation, the LSb will be transmitted onto the ICSPDAT pin on the rising edge of the second cycle. For a load operation, the LSb will be latched on the falling edge of the second cycle. A minimum TDLY1 delay is also specified between consecutive commands, except for the End Programming command, which requires a TDIS.

All commands and data words are transmitted LSb first. Data is transmitted on the rising edge and latched on the falling edge of the ICSPCLK. To allow for decoding of commands and reversal of data pin configuration, a time separation of at least TDLY1 is required between a command and a data word.

The commands that are available are described in Table 3-1.

TABLE 3-1: COMMAND MAPPING FOR PIC16F91X/946

Command	Mapping (MSb … LSb)						Data
Load Configuration	x	x	0	0	0	0	0, data (14), 0
Load Data For Program Memory	x	x	0	0	1	0	0, data (14), 0
Load Data For Data Memory	x	x	0	0	1	1	0, data (8), zero (6), 0
Read Data From Program Memory	x	x	0	1	0	0	0, data (14), 0
Read Data From Data Memory	x	x	0	1	0	1	0, data (8), zero (6), 0
Increment Address	x	x	0	1	1	0	
Begin Programming	x	0	1	0	0	0	Internally Timed
Begin Programming	x	1	1	0	0	0	Externally Timed
End Programming	x	0	1	0	1	0	
Bulk Erase Program Memory	x	x	1	0	0	1	Internally Timed
Bulk Erase Data Memory	x	x	1	0	1	1	Internally Timed
Row Erase Program Memory	x	1	0	0	0	1	Internally Timed

3.1.6.1 Load Configuration

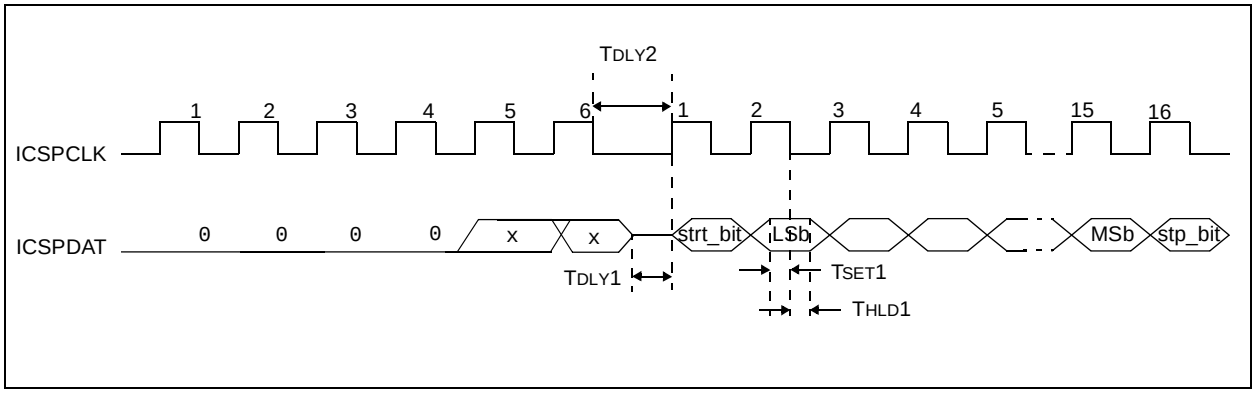
The Load Configuration command is used to access the Configuration Word (0x2007) and user ID (0x2000-0x2003). This command sets the Program Counter (PC) to address 0x2000 and loads the data latches with one word of data.

After receiving a Load Configuration command, the Configuration Word is accessed by performing an Increment Address command seven times, to point the PC to the Configuration Word. It can then be programmed with the loaded data using a Begin Programming command either internally or externally timed.

After the 6-bit command is input, the ICSPCLK pin is cycled an additional 16 times for the Start bit, 14 bits of data and a Stop bit. See Figure 3-4 for more details.

After the configuration memory is entered, the only way to get back to the program memory is to exit the Program/Verify mode by taking MCLR low (V_{IL}).

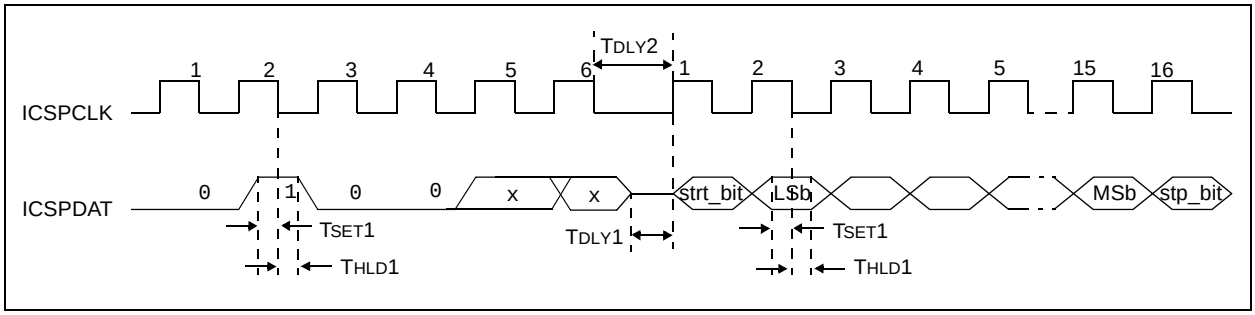
FIGURE 3-4: LOAD CONFIGURATION COMMAND



3.1.6.2 Load Data For Program Memory

After receiving this command, the chip will load in a 14-bit “data word” when 16 cycles are applied, as described previously. A timing diagram for the Load Data For Program Memory command is shown in Figure 3-5.

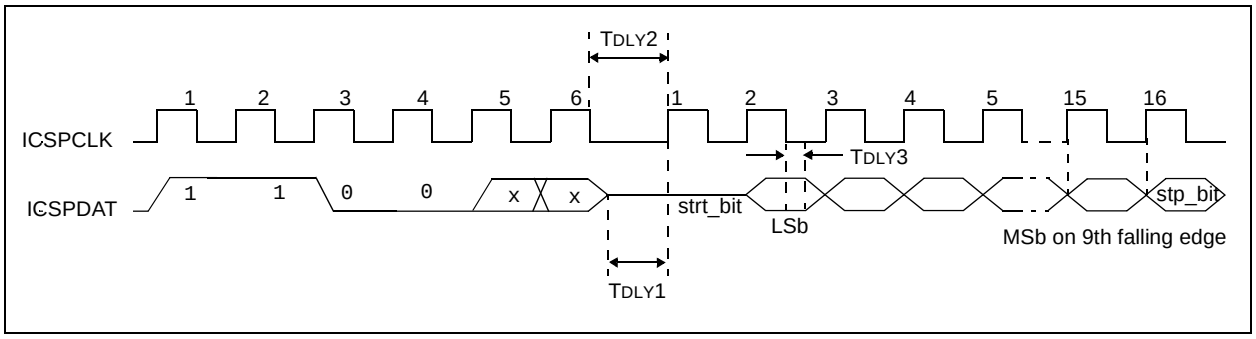
FIGURE 3-5: LOAD DATA FOR PROGRAM MEMORY COMMAND



3.1.6.3 Load Data For Data Memory

After receiving this command, the chip will load in a 14-bit “data word” when 16 cycles are applied. However, the data memory is only 8-bits wide and thus, only the first 8 bits of data after the Start bit will be programmed into the data memory. It is still necessary to cycle the clock the full 16 cycles in order to allow the internal circuitry to reset properly. The data memory contains 256 bytes.

FIGURE 3-6: LOAD DATA FOR DATA MEMORY COMMAND

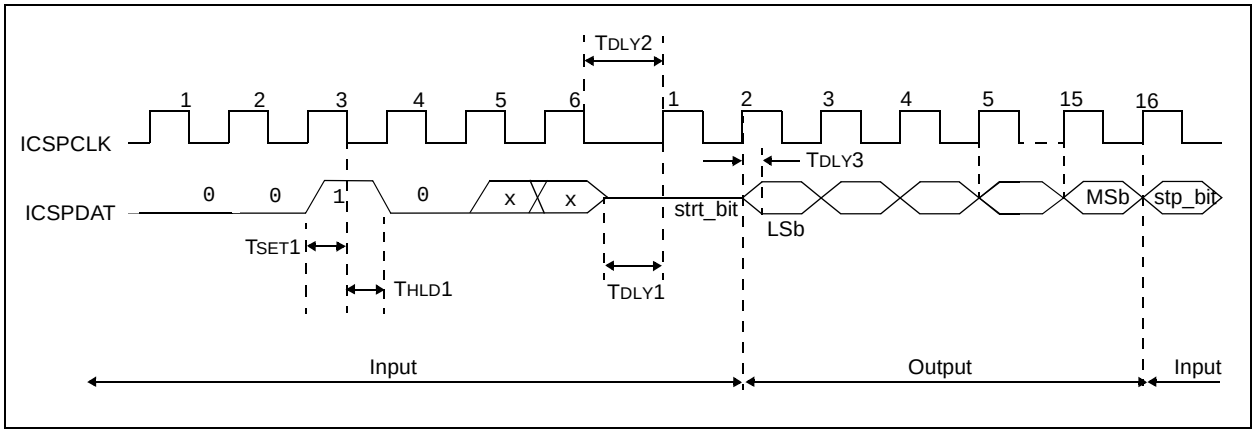


3.1.6.4 Read Data From Program Memory

After receiving this command, the chip will transmit data bits out of the program memory (user or configuration) currently accessed, starting with the second rising edge of the clock input. The data pin will go into Output mode on the second rising clock edge, and it will revert to Input mode (high-impedance) after the 16th rising edge.

If the program memory is code-protected ($\overline{CP}$ = 0), the data is read as zeros.

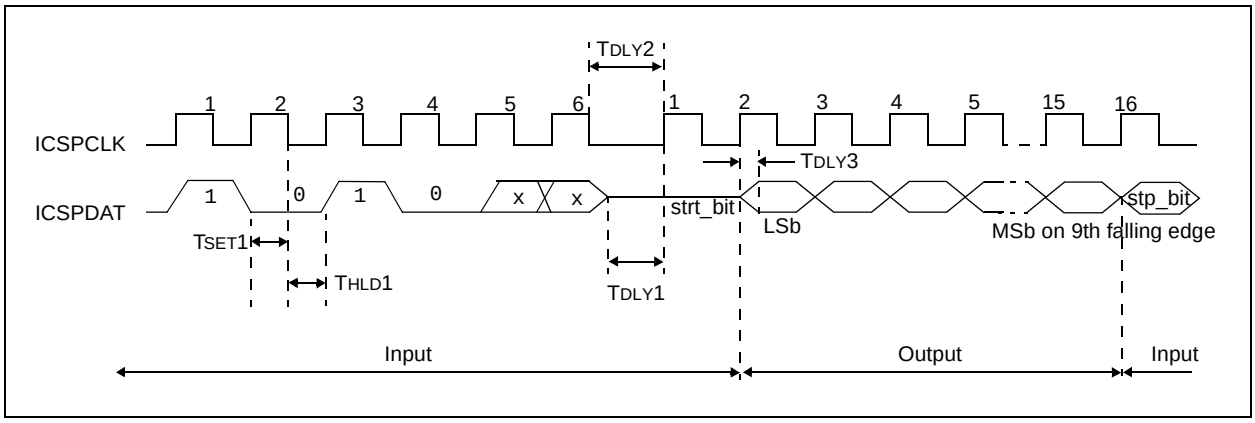
FIGURE 3-7: READ DATA FROM PROGRAM MEMORY COMMAND



3.1.6.5 Read Data From Data Memory

After receiving this command, the chip will transmit data bits out of the data memory, starting with the second rising edge of the clock input. The ICSPDAT pin will go into Output mode on the second rising edge and it will revert to Input mode (high-impedance) after the 16th rising edge. As previously stated, the data memory is 8-bits wide, and therefore, only the first 8 bits that are output are actual data. If the data memory is code-protected, the data is read as all zeros. A timing diagram of this command is shown in Figure 3-8.

FIGURE 3-8: READ DATA FROM PROGRAM MEMORY COMMAND

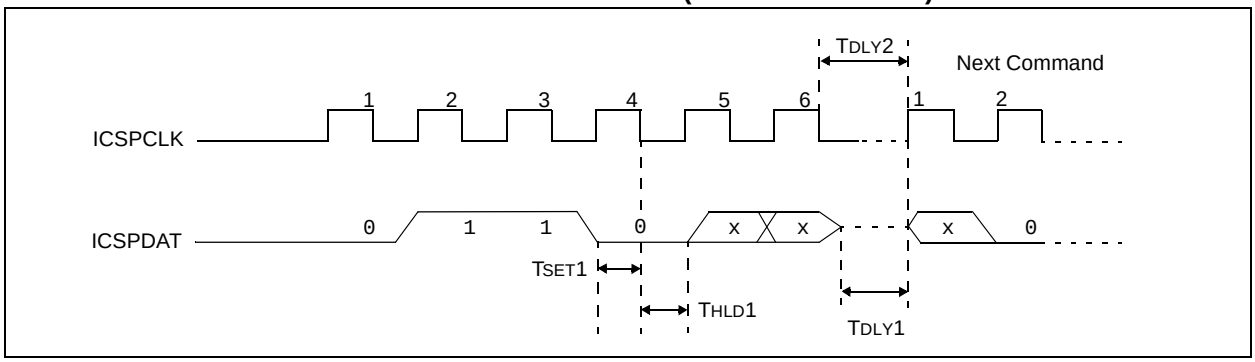


3.1.6.6 Increment Address

The PC is incremented when this command is received. A timing diagram of this command is shown in Figure 3-9.

It is not possible to decrement the address counter. To reset this counter, the user should exit and re-enter Program/Verify mode.

FIGURE 3-9: INCREMENT ADDRESS COMMAND (PROGRAM/VERIFY)

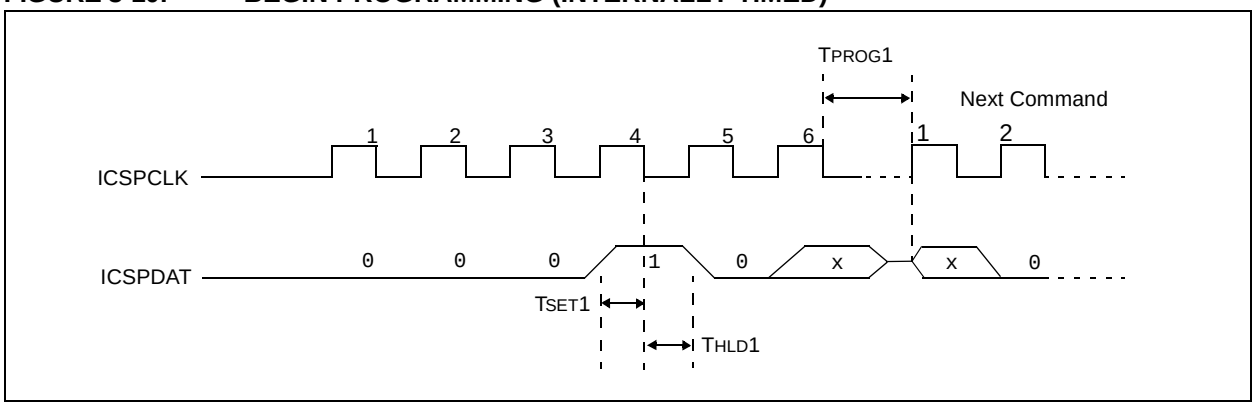


3.1.6.7 Begin Programming (Internally Timed)

A Load command must be given before every Begin Programming command. Programming of the appropriate memory (user program memory, configuration memory or data memory) will begin after this command is received and decoded. An internal timing mechanism executes a write. The user must allow for program cycle time for programming to complete. No End Programming command is required.

The addressed location is not erased before programming. However, the address location is erased if Data Memory is being programmed.

FIGURE 3-10: BEGIN PROGRAMMING (INTERNALLY TIMED)

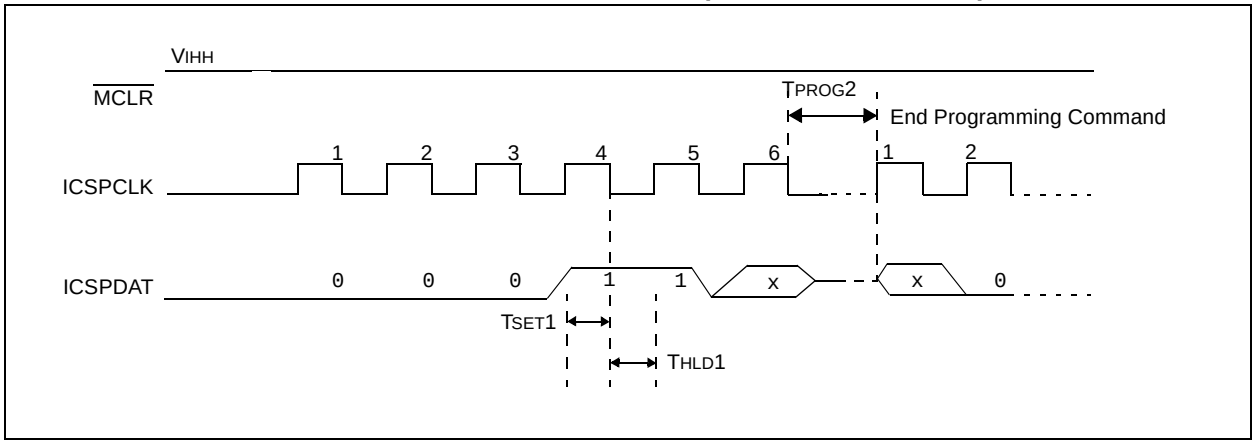


3.1.6.8 Begin Programming (Externally Timed)

A Load command must be given before every Begin Programming command**.** Programming of the appropriate memory (program memory, configuration or data memory) will begin after this command is received and decoded. Programming requires (TPROG2) time and is terminated using an End Programming command.

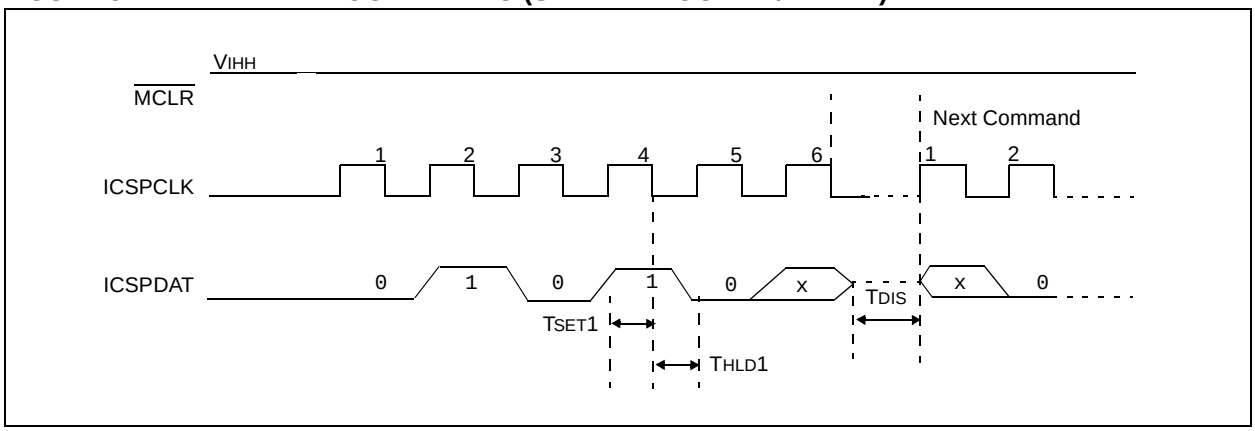
The addressed location is not erased before programming.

FIGURE 3-11: BEGIN PROGRAMMING COMMAND (EXTERNALLY TIMED)



3.1.6.9 End Programming

FIGURE 3-12: END PROGRAMMING (SERIAL PROGRAM/VERIFY)

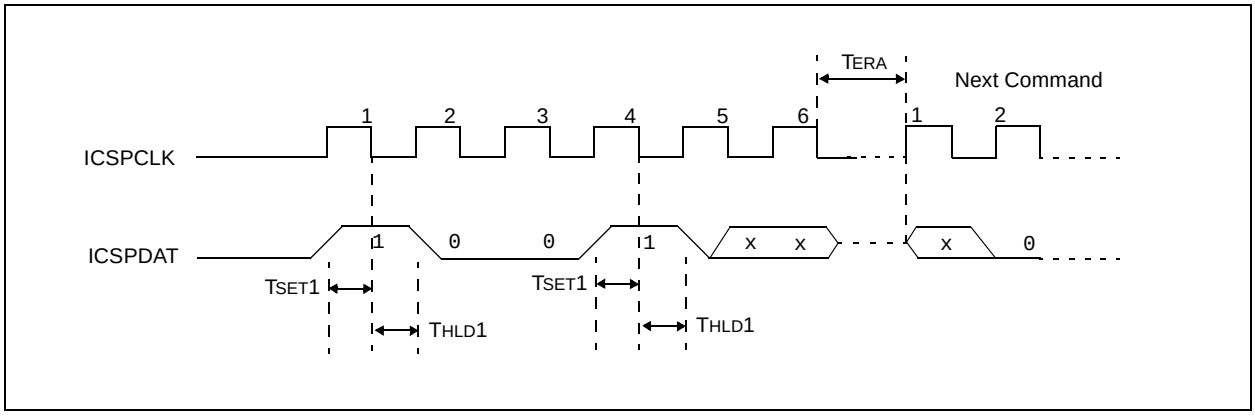


3.1.6.10 Bulk Erase Program Memory

After this command is performed, the entire program memory and Configuration Word (0x2007) is erased. Data memory will also be erased if the $\overline{CPD}$ bit in the Configuration Word is programmed (clear). See **Section 3.1.5 "Erase Algorithms"** for erase sequences.

Note:	All Bulk Erase operations must take place between 4.5V and 5.5V VDD.

FIGURE 3-13: BULK ERASE PROGRAM MEMORY COMMAND



3.1.6.11 Bulk Erase Data Memory

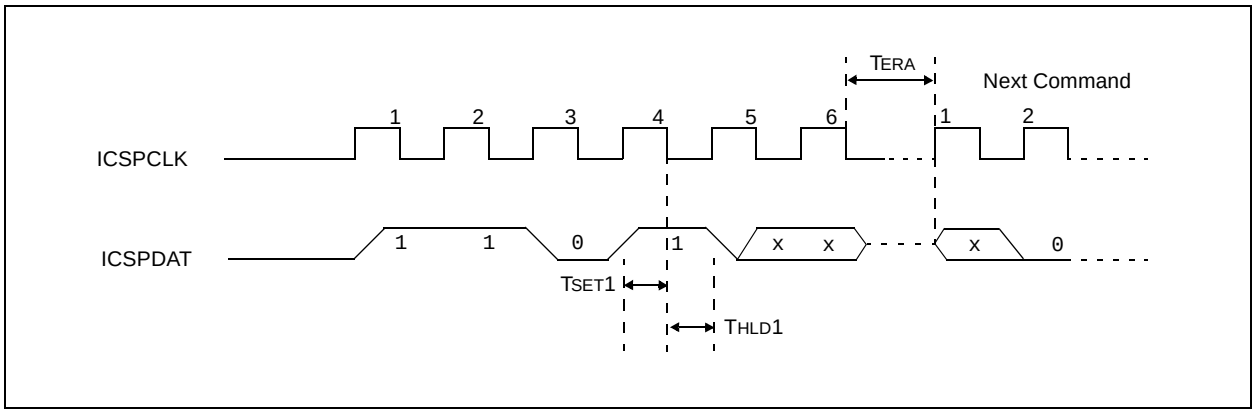
To perform an erase of the data memory, the following sequence must be performed:

1. Perform a Bulk Erase Data Memory command.
2. Wait TERA to complete Bulk Erase.

Data memory won't erase if code-protected ($\overline{CPD}$ = 0).

Note 1:	All Bulk Erase operations must take place between 4.5V and 5.5V VDD.

FIGURE 3-14: BULK ERASE DATA MEMORY COMMAND



3.1.6.12 Row Erase Program Memory

This command erases the 16-word row of program memory pointed to by PC<11:4>. If the program memory array is protected ($\overline{CP}$ = 0) or the PC points to configuration memory (>0x2000), the command is ignored.

To perform a Row Erase Program Memory, the following sequence must be performed:

1. Execute a Row Erase Program Memory command.
2. Wait TERA to complete a row erase.

FIGURE 3-15: ROW ERASE PROGRAM MEMORY COMMAND

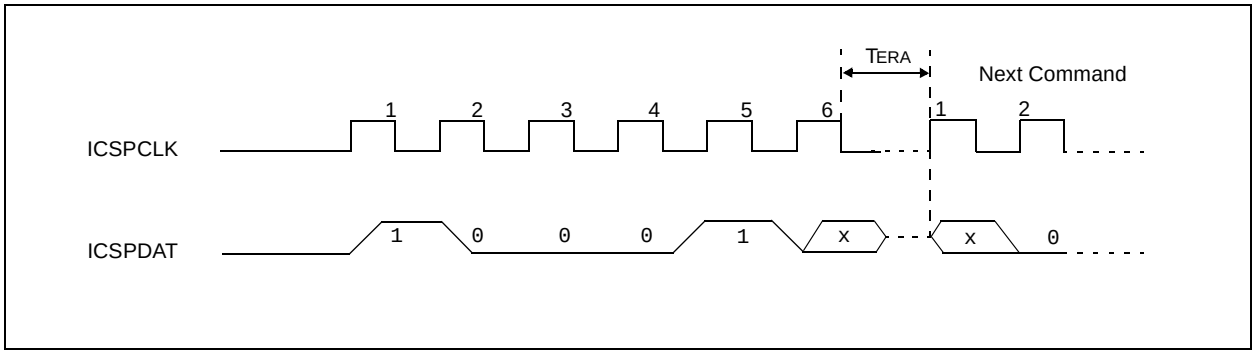
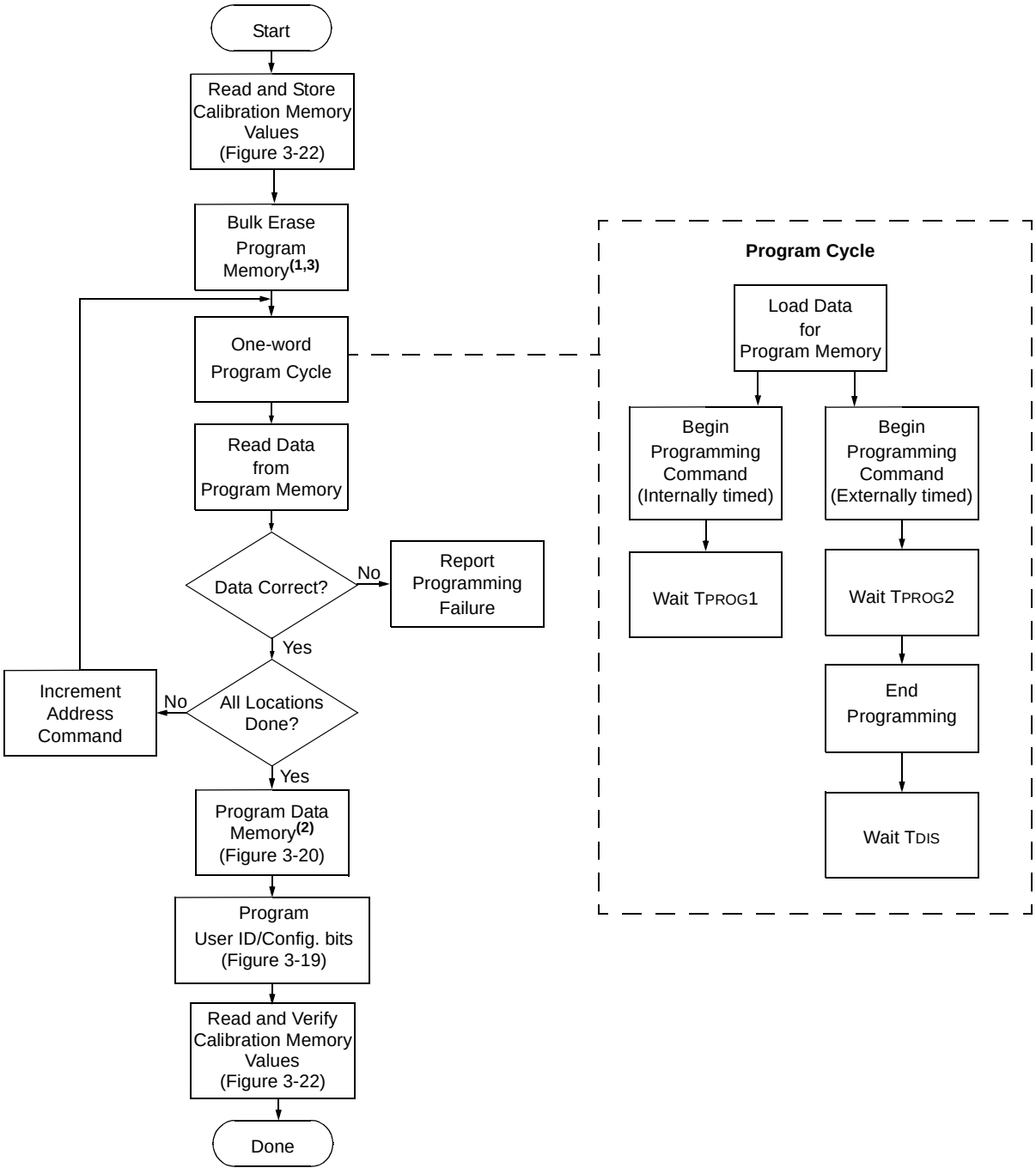


FIGURE 3-16: ONE-WORD PROGRAMMING FLOWCHART

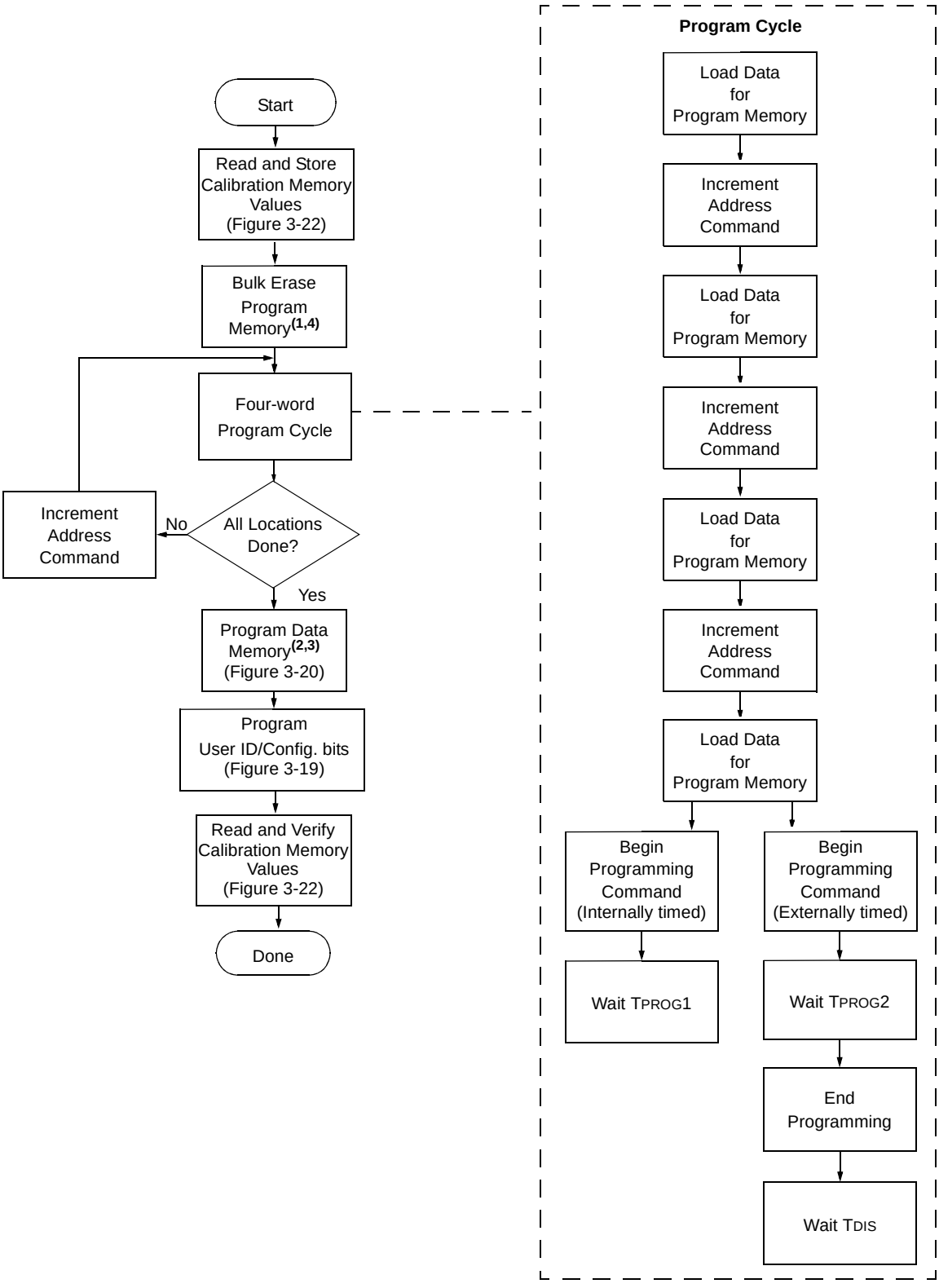


Note 1: This step is optional if device has already been erased or has not been previously programmed.

2: This step is optional if the data memory does not require updates.

3: If the device is code-protected or must be completely erased, then Bulk Erase device per Figure 3-21.

FIGURE 3-17: FOUR-WORD PROGRAMMING FLOWCHART



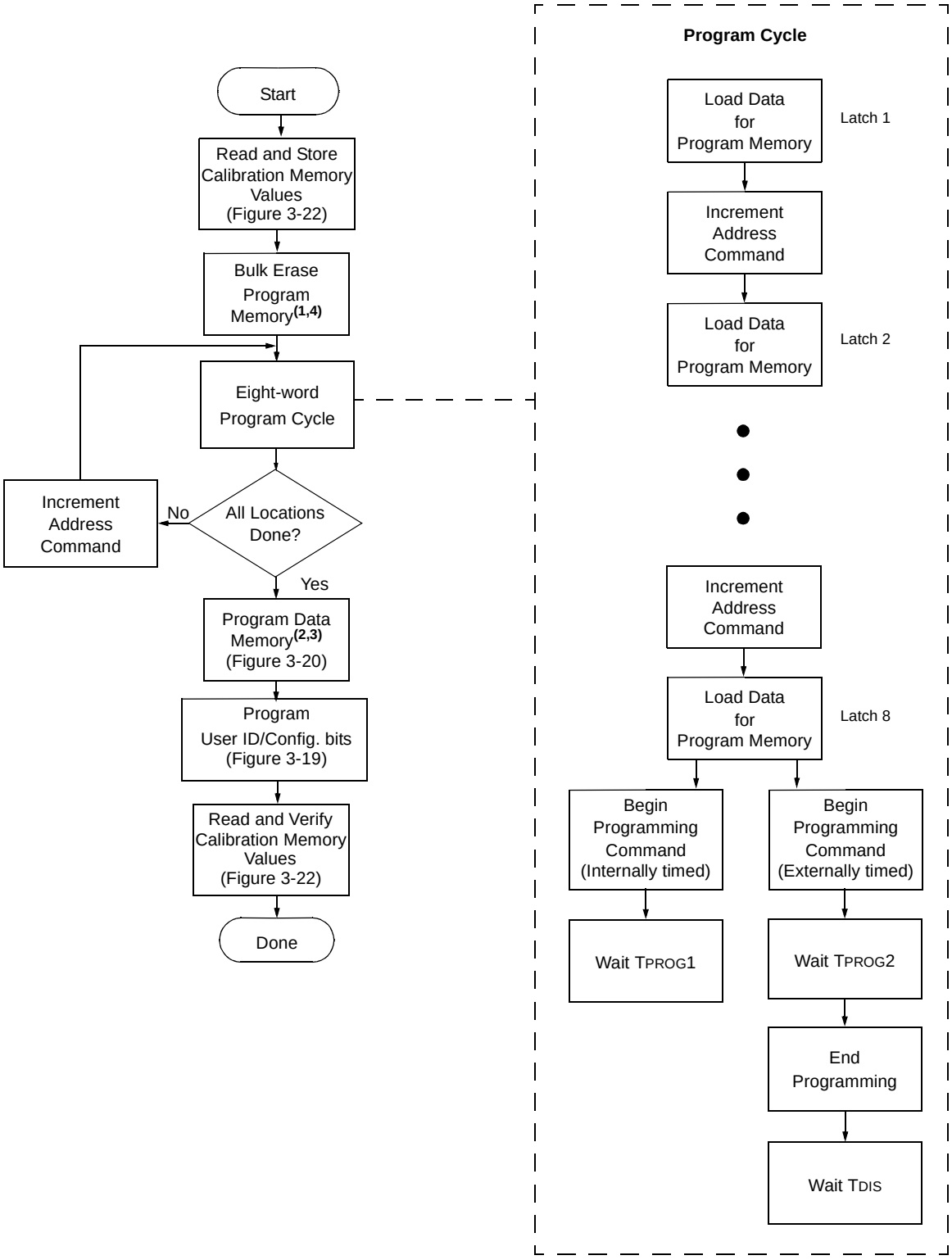
Note 1: This step is optional if device is erased or not previously programmed.

2: Verification in Four-word mode is accomplished after programming by reading back the entire memory.

3: This step is optional if the data memory does not require updates.

4: If the device is code-protected or must be completely erased, then Bulk Erase device per Figure 3-21.

FIGURE 3-18: EIGHT-WORD PROGRAMMING FLOWCHART



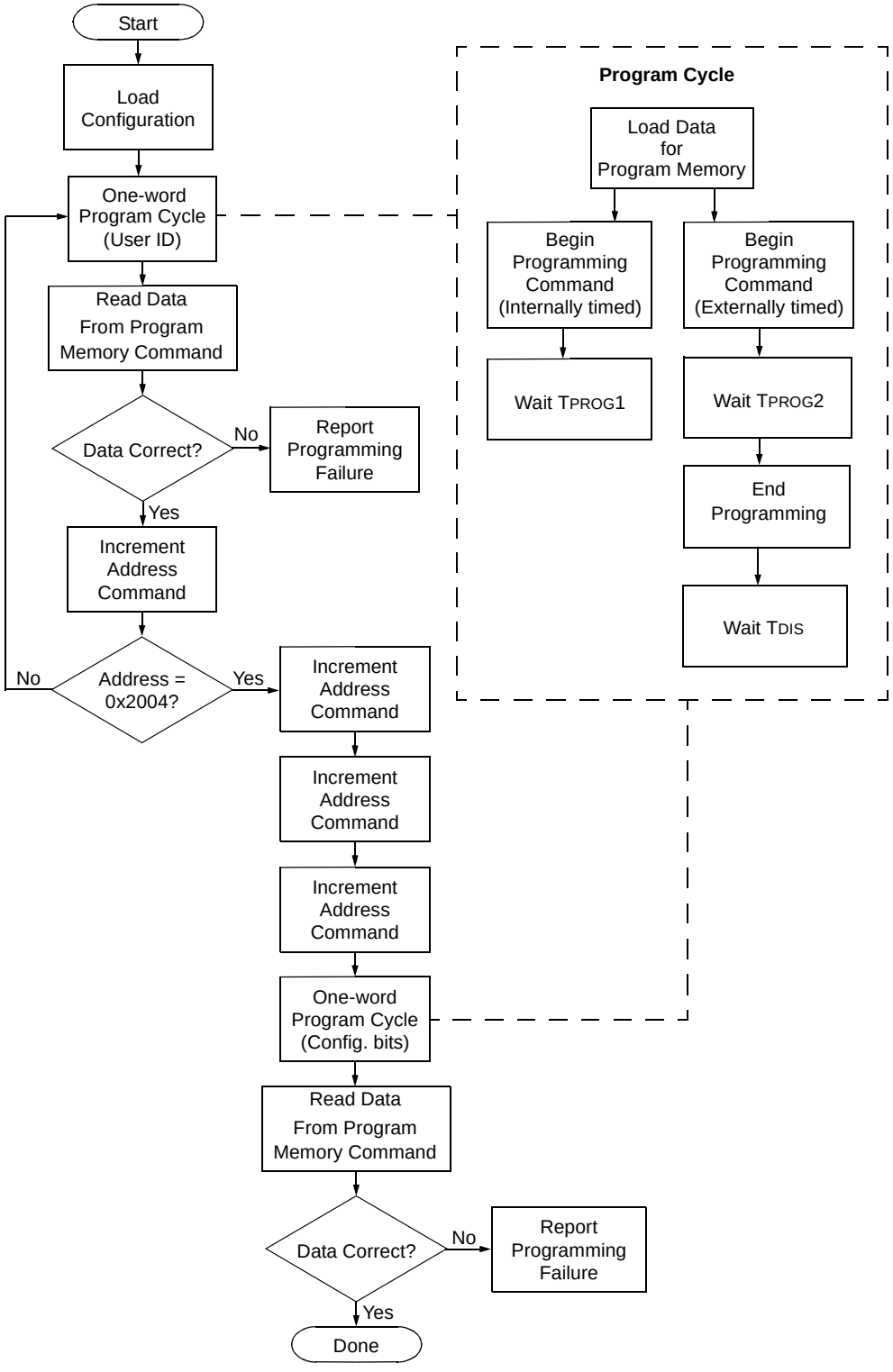
Note 1: This step is optional if device is erased or not previously programmed.

2: Verification in Eight-word mode is accomplished after programming by reading back the entire memory.

3: This step is optional if the data memory does not require updates.

4: If the device is code-protected or must be completely erased, then Bulk Erase device per Figure 3-21.

FIGURE 3-19: PROGRAM FLOWCHART – PIC16F91X/946 CONFIGURATION MEMORY



Note: Ensure that a device Bulk Erase has been performed or that the device is blank prior to programming the configuration memory.

FIGURE 3-20: PROGRAM FLOWCHART – PIC16F91X/946 DATA MEMORY

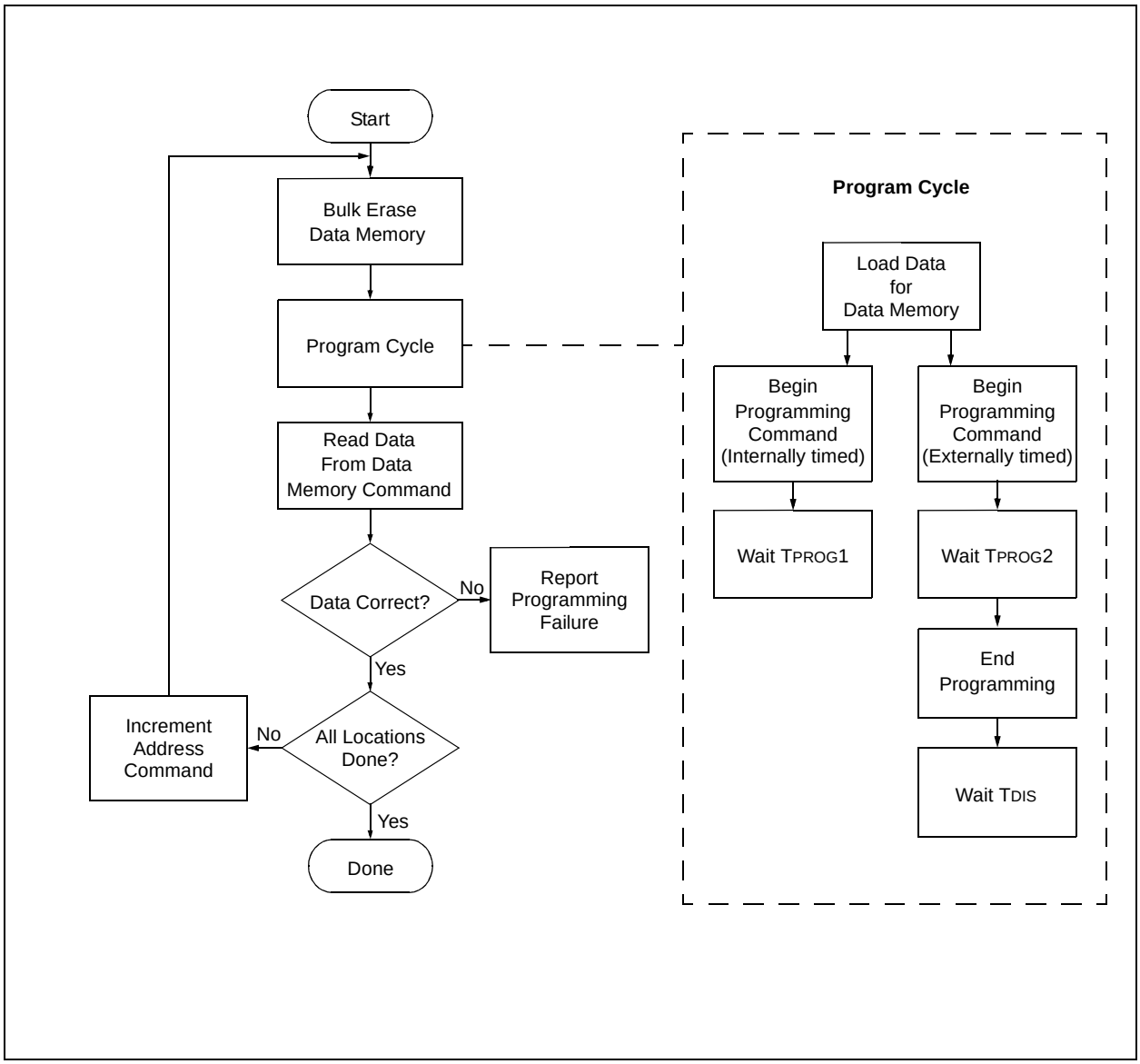


FIGURE 3-21: PROGRAM FLOWCHART – ERASE FLASH DEVICE

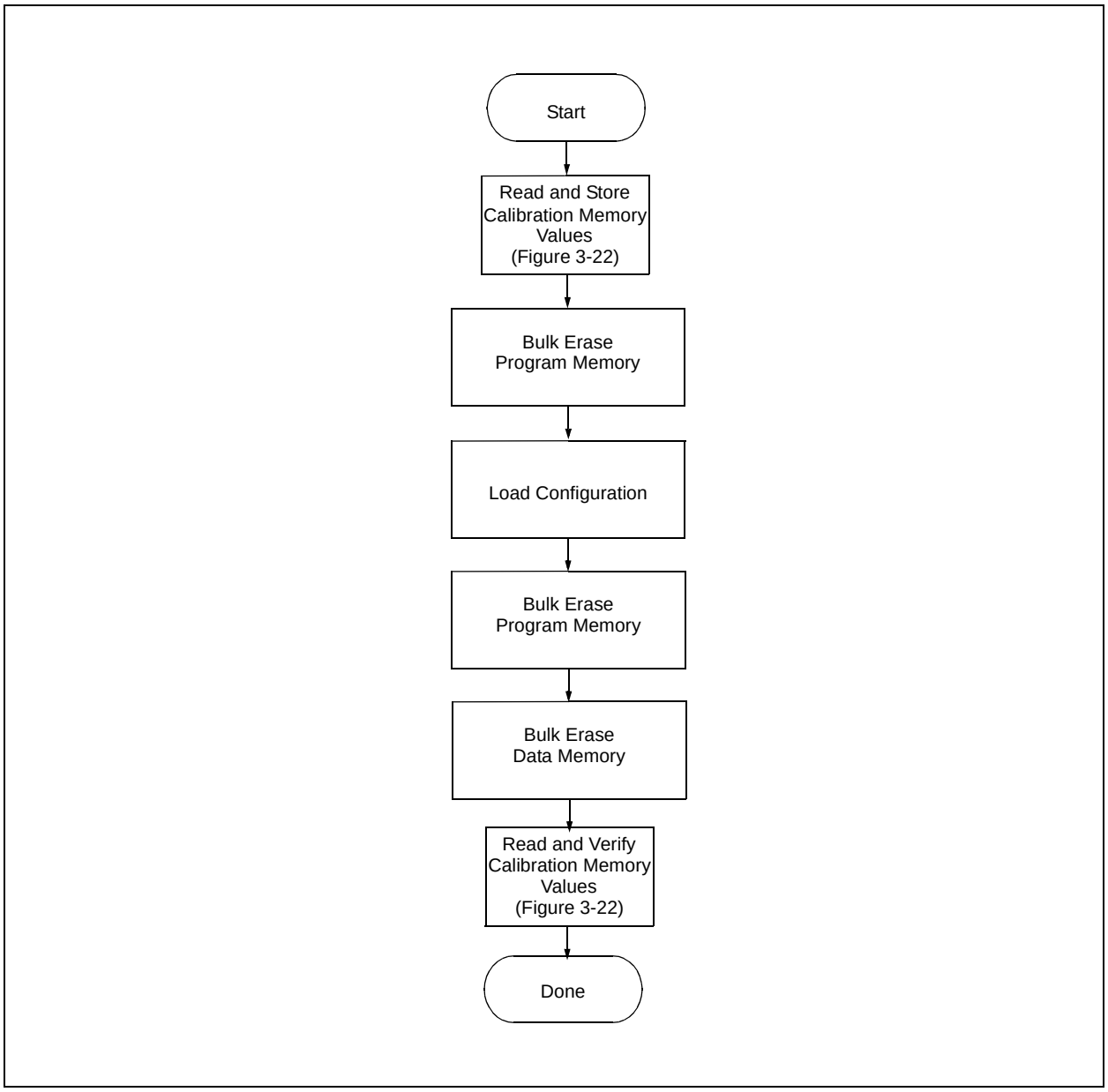
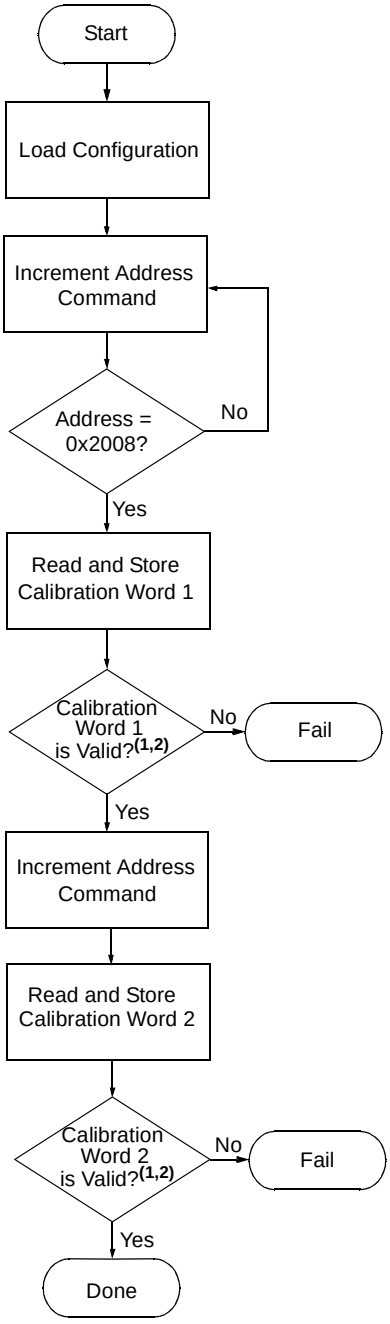


FIGURE 3-22: CALIBRATION WORD VERIFICATION FLOWCHART



Note 1: This step is not required for the Read and Store Calibration Memory Values procedure.

2: The device should not be used if verification of the Calibration Word locations fails. This information should be reported to the user through the user interface of the device programmer.

4.0 CONFIGURATION WORD

The PIC16F91X/946 has several Configuration bits. These bits can be programmed (reads '0') or left unchanged (reads '1'), to select various device configurations.

REGISTER 4-1: CONFIG: CONFIGURATION WORD (ADDRESS 2007h)

U-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1
—	$\overline{\text{DEBUG}}$	FCMEN	IESO	BOREN1	BOREN0	$\overline{\text{CPD}}$
bit 13						bit 7

R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1
$\overline{\text{CP}}$	MCLRE	$\overline{\text{PWRTE}}$	WDTE	FOSC2	FOSC1	FOSC0
bit 6						bit 0

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

bit 13 **Unimplemented:** Read as '1'

bit 12 **$\overline{\text{DEBUG}}$:** In-Circuit Debugger Mode bit
1 = In-Circuit Debugger disabled, RB6/ICSPCLK/ICDCK/SEG14 and RB7/ICSPDAT/ICDDAT/SEG13 are general purpose I/O pins
0 = In-Circuit Debugger enabled, RB6/ICSPCLK/ICDCK/SEG14 and RB7/ICSPDAT/ICDDAT/SEG13 are dedicated to the debugger

bit 11 **FCMEN:** Fail-Safe Clock Monitor Enabled bit
1 = Fail-Safe Clock Monitor is enabled
0 = Fail-Safe Clock Monitor is disabled

bit 10 **IESO:** Internal External Switchover bit
1 = Internal External Switchover mode is enabled
0 = Internal External Switchover mode is disabled

bit 9-8 **BOREN<1:0>:** Brown-out Reset Selection bits(1)
11 = BOR enabled
10 = BOR enabled during operation and disabled in Sleep
01 = BOR controlled by SBOREN bit (PCON<4>)
00 = BOR disabled

bit 7 **$\overline{\text{CPD}}$:** Data Code Protection bit(2)
1 = Data memory code protection is disabled
0 = Data memory code protection is enabled

bit 6 **$\overline{\text{CP}}$:** Code Protection bit(3)
1 = Program memory code protection is disabled
0 = Program memory code protection is enabled

bit 5 **MCLRE:** RB3/$\overline{\text{MCLR}}$/V_{PP} pin function select bit(4)
1 = RB3/$\overline{\text{MCLR}}$/V_{PP} pin function is MCLR
0 = RB3/$\overline{\text{MCLR}}$/V_{PP} pin function is digital input, $\overline{\text{MCLR}}$ internally tied to V_{DD}

bit 4 **$\overline{\text{PWRTE}}$:** Power-up Timer Enable bit
1 = PWRT disabled
0 = PWRT enabled

bit 3 **WDTE:** Watchdog Timer Enable bit
1 = WDT enabled
0 = WDT disabled and can be enabled by SWDTEN bit (WDTCON<0>)

bit 2-0 **FOSC<2:0>:** Oscillator Selection bits
111 = RC oscillator: CLKO function on RA6/OSC2/CLKO/T1OSO pin, RC on RA7/OSC1/CLKI/T1OSI
110 = RCIO oscillator: I/O function on RA6/OSC2/CLKO/T1OSO pin, RC on RA7/OSC1/CLKI/T1OSI
101 = INTOSC oscillator: CLKO function on RA6/OSC2/CLKO/T1OSO pin, I/O function on RA7/OSC1/CLKI/T1OSI
100 = INTOSCIO oscillator: I/O function on RA6/OSC2/CLKO/T1OSO pin, I/O function on RA7/OSC1/CLKI/T1OSI
011 = EC: I/O function on RA6/OSC2/CLKO/T1OSO pin, CLKI on RA7/OSC1/CLKI/T1OSI
010 = HS oscillator: High-speed crystal/resonator on RA6/OSC2/CLKO/T1OSO and RA7/OSC1/CLKI/T1OSI
001 = XT oscillator: Crystal/resonator on RA6/OSC2/CLKO/T1OSO and RA7/OSC1/CLKI/T1OSI
000 = LP oscillator: Low-power crystal on RA6/OSC2/CLKO/T1OSO and RA7/OSC1/CLKI/T1OSI

Note 1: Enabling Brown-out Reset does not automatically enable Power-up Timer.
2: The entire data EEPROM will be erased when the code protection is turned off.
3: The entire program memory will be erased when the code protection is turned off.
4: When $\overline{\text{MCLR}}$ is asserted in INTOSC or RC mode, the internal clock oscillator is disabled.

REGISTER 4-2: CALIB1: CALIBRATION WORD (ADDRESS 2008h) (PIC16F91X/946)

U-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1
—	FCAL6	FCAL5	FCAL4	FCAL3	FCAL2	FCAL1
bit 13						bit 7

R/P-1	U-1	R/P-1	R/P-1	R/P-1	R/P-1	R/P-1
FCAL0	—	POR1	POR0	BOR2	BOR1	BOR0
bit 6						bit 0

Legend:			
R = Readable bit	W = Writable bit	P = Programmable	U = Unimplemented bit, read as ‘1’
-n = Value at POR	‘1’ = Bit is set	‘0’ = Bit is cleared	x = Bit is unknown

bit 13 **Unimplemented:** Read as ‘1’

bit 12-6 **FCAL<6:0>:** Internal Oscillator Calibration bits(1)
0111111 = Maximum frequency
.
.
0000001
0000000 = Center frequency
1111111
.
.
1000000 = Minimum frequency

bit 5 **Unimplemented:** Read as ‘1’

bit 4-3 **POR<1:0>:** POR Calibration bits
00 = Lowest POR voltage
11 = Highest POR voltage

bit 2-0 **BOR<2:0>:** BOR Calibration bits
000 = Reserved
001 = Lowest BOR voltage
111 = Highest BOR voltage

Note 1: This location does not participate in Bulk Erase operations if the procedure in Figure 3-21 is used.
2: Calibration bits are reserved for factory calibration. These values can and will change across the entire range, therefore, specific values and available adjustment range can not be specified.

REGISTER 4-3: CALIB2: CALIBRATION WORD 2 (ADDRESS 2009h)

U-1	U-1	U-1	U-1	U-1	U-1	U-1
—	—	—	—	—	—	—
bit 13						bit 7

U-1	U-1	U-1	U-1	R/P-1	R/P-1	R/P-1
—	—	—	—	LVD2	LVD1	LVD0
bit 6						bit 0

Legend:			
R = Readable bit	W = Writable bit	P = Programmable	U = Unimplemented bit, read as ‘1’
-n = Value at POR	‘1’ = Bit is set	‘0’ = Bit is cleared	x = Bit is unknown

bit 13-3 **Unimplemented:** Read as ‘1’

bit 2-0 **LVD<2:0>:** LVD Calibration bits(1)

111 = Maximum LVD voltage
110
101
100 = Center LVD voltage
000 = Center LVD voltage
001
010
011 = Minimum LVD voltage

Note 1: This location does not participate in Bulk Erase operations if the procedure in Figure 3-21 is used.

2: Calibration bits are reserved for factory calibration. These values can and will change across the entire range, therefore, specific values and available adjustment range can not be specified.

4.1 Device ID Word

The device ID word for the PIC16F91X/946 is located at 2006h. This location can not be erased.

TABLE 4-1: DEVICE ID VALUES

Device	Device ID Values	
	Dev	Rev
PIC16F917	01 0011 1000	xxxx
PIC16F916	01 0011 1010	xxxx
PIC16F914	01 0011 1100	xxxx
PIC16F913	01 0011 1110	xxxx
PIC16F946	01 0100 0110	xxxx

5.0 CODE PROTECTION

For PIC16F91X/946, once the $\overline{CP}$ bit is programmed to '0', all program memory locations read all '0's. Further programming is disabled for the entire program memory.

Data memory is protected with its own Code-Protect bit ($\overline{CPD}$). When enabled, the data memory can still be programmed and read using the EECON1 register (See the applicable data sheet for more information).

The user ID locations and the Configuration Word can be programmed and read out regardless of the state of the $\overline{CP}$ and $\overline{CPD}$ bits.

5.1 Disabling Code Protection

It is recommended to use the procedure in Figure 3-21 to disable code protection of the device. This sequence will erase the program memory, data memory, Configuration Word (0x2007) and user ID locations (0x2000-0x2003). The Calibration Words (0x2008-0x2009) **will not** be erased.

Note:	To ensure system security, if $\overline{CPD}$ bit = 0, Bulk Erase Program Memory command will also erase data memory.

5.2 Embedding Configuration Word and User ID Information in the Hex File

To allow portability of code, the programmer is required to read the Configuration Word and user ID locations from the hex file when loading the hex file. If Configuration Word information was not present in the hex file, a simple warning message may be issued. Similarly, while saving a hex file, Configuration Word and user ID information must be included. An option to not include this information may be provided.

Specifically for the PIC16F91X/946, the data memory should also be embedded in the hex file (see **Section 5.3.2 "Embedding Data Memory Contents In Hex File"**).

Microchip Technology Incorporated feels strongly that this feature is important for the benefit of the end customer.

5.3 Checksum Computation

5.3.1 CHECKSUM

Checksum is calculated by reading the contents of the PIC16F91X/946 memory locations and adding up the opcodes up to the maximum user addressable location, (e.g., 0x1FFF for PIC16F917). Any carry bits exceeding 16 bits are neglected. Finally, the Configuration Word (appropriately masked) is added to the checksum. Checksum computation for the PIC16F91X/946 devices is shown in Table 5-1.

The checksum is calculated by summing the following:

- The contents of all program memory locations
- The Configuration Word, appropriately masked
- Masked user ID locations (when applicable)

The Least Significant 16 bits of this sum is the checksum.

The following table describes how to calculate the checksum for each device. Note that the checksum calculation differs depending on the code-protect setting. Since the program memory locations read out zeroes when code-protected, the table describes how to manipulate the actual program memory values to simulate values that would be read from a protected device. When calculating a checksum by reading a device, the entire program memory can simply be read and summed. The Configuration Word and user ID locations can always be read regardless of the code-protect setting.

Note:	Some older devices have an additional value added in the checksum. This is to maintain compatibility with older device programmer checksums.

TABLE 5-1: CHECKSUM COMPUTATIONS

Device	Code-Protect	Checksum*	Blank Value	0x25E6 at 0 and Max. Address
PIC16F913	OFF	SUM[0x0000:0x0FFF] + (CFGW & 1FFF)	0FFF	DBCD
	ON	(CFGW and 0x1FFF) + SUM_ID	2FBE	FB8C
PIC16F914	OFF	SUM[0x0000:0x0FFF] + (CFGW & 1FFF)	0FFF	DBCD
	ON	(CFGW and 0x1FFF) + SUM_ID	2FBE	FB8C
PIC16F916	OFF	SUM[0x0000:0x1FFF] + (CFGW & 1FFF)	FFFF	CBCD
	ON	(CFGW and 0x1FFF) + SUM_ID	1FBE	EB8C
PIC16F917	OFF	SUM[0x0000:0x1FFF] + (CFGW & 1FFF)	FFFF	CBCD
	ON	(CFGW and 0x1FFF) + SUM_ID	1FBE	EB8C
PIC16F946	OFF	SUM[0x0000:0x1FFF] + (CFGW & 1FFF)	FFFF	CBCD
	ON	(CFGW and 0x1FFF) + SUM_ID	1FBE	EB8C

Legend: CFGW = Configuration Word. Example calculations assume Configuration Word is erased (all '1's).
SUM[a:b] = [Sum of locations a to b inclusive]
SUM_ID = User ID locations masked by 0xF then made into a 16-bit value with ID0 as the Most Significant nibble.
For example, ID0 = 0x1, ID1 = 0x2, ID3 = 0x3, ID4 = 0x4, then SUM_ID = 0x1234.
The 4 LSbs of the unprotected checksum is used for the example calculations.
*Checksum = [Sum of all the individual expressions] MODULO [0xFFFF]
+ = Addition
& = Bitwise AND

5.3.2 EMBEDDING DATA MEMORY CONTENTS IN HEX FILE

The programmer should be able to read data memory information from a hex file and conversely (as an option), write data memory contents to a hex file along with program memory information and Configuration Word (0x2007) and user ID (0x2000-0x2003) information.

The physical address range of the 256 data memory is 0x0000-0x00FF. However, these addresses are logically mapped to address 0x2100-0x21FF for use in writing assembly code. This provides a way of differentiating between the data and program memory locations in this range. The format for data memory storage is one data byte per address location, LSb aligned. A simple example of data memory is given below:

```
org 0x2100
de “My Prgram, v1.0”, 0
```

6.0 PROGRAM/VERIFY MODE ELECTRICAL CHARACTERISTICS

TABLE 6-1: AC/DC CHARACTERISTICS TIMING REQUIREMENTS FOR PROGRAM/VERIFY MODE

AC/DC CHARACTERISTICS		Standard Operating Conditions (unless otherwise stated) Operating Temperature -40°C ≤ TA ≤ +85°C Operating Voltage 4.5V ≤ VDD ≤ 5.5V				
Sym.	**Characteristics**	**Min.**	**Typ.**	**Max.**	**Units**	**Conditions/Comments**
General						
VDD	VDD level for read/write operations, program and data memory	2.0	—	5.5	V	
	VDD level for Bulk Erase operations, program and data memory	4.5	—	5.5	V	
VPP	High voltage on $\overline{\text{MCLR}}$ for Program/Verify mode entry	10	—	12	V	
TVHHR	$\overline{\text{MCLR}}$ rise time (VSS to VHH) for Program/Verify mode entry	—	—	1.0	μs	
TPPDP	Hold time after VPP changes	5	—	—	μs	
VIH1	(ICSPCLK, ICSPDAT) input high level	0.8 VDD	—	—	V	
VIL1	(ICSPCLK, ICSPDAT) input low level	0.2 VDD	—	—	V	
TSET0	ICSPCLK, ICSPDAT setup time before $\overline{\text{MCLR}}$↑ (Program/Verify mode selection pattern setup time)	100	—	—	ns	
THLD0	Hold time after VDD changes	5	—	—	μs	
Serial Program/Verify						
TSET1	Data in setup time before clock↓	100	—	—	ns	
THLD1	Data in hold time after clock↓	100	—	—	ns	
TDLY1	Data input not driven to next clock input (delay required between command/data or command/command)	1.0	—	—	μs	
TDLY2	Delay between clock↓ to clock↑ of next command or data	1.0	—	—	μs	
TDLY3	Clock↑ to data out valid (during a Read Data command)		—	80	ns	
TERA	Erase cycle time	—	5	6	ms	
TPROG1	Programming cycle time (internally timed)	3 6	— —	— —	ms ms	Program memory Data memory
TPROG2	Programming cycle time (externally timed)	3	—	—	ms	10°C ≤ TA ≤ +40°C Program memory
TDIS	Time delay from program to compare (HV discharge time)	100	—	—	μs	

APPENDIX A: REVISION HISTORY

Rev D Document (8/2005)
Corrected PIC16F946 pin diagram callout, latch operation and miscellaneous formatting.

Rev E Document (4/2006)
Updated TPROG1 and TPROG2 timings.

Rev F Document (10/2009)
Updated sections 2.3, 3.1.4, 3.1.5; Updated the Note in section 3.1.3; Updated Figures 3-16, 3-17, 3-18, 3-19, 3-21; Added Figure 3-22; Other minor corrections.

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

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India - Pune
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Japan - Yokohama
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Korea - Daegu
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Fax: 82-53-744-4302

Korea - Seoul
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Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
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Fax: 60-3-6201-9859

Malaysia - Penang
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Fax: 60-4-227-4068

Philippines - Manila
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Taiwan - Hsin Chu
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Taiwan - Kaohsiung
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