PIC18F2458/2553/4458/4553
Data Sheet

28/40/44-Pin High-Performance, Enhanced Flash, USB Microcontrollers with 12-Bit A/D and nanoWatt Technology

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28/40/44-Pin High-Performance, Enhanced Flash, USB Microcontrollers with 12-Bit A/D and nanoWatt Technology

Universal Serial Bus Features:

- USB V2.0 Compliant
- Low Speed (1.5 Mb/s) and Full Speed (12 Mb/s)
- Supports Control, Interrupt, Isochronous and Bulk Transfers
- Supports up to 32 Endpoints (16 bidirectional)
- 1-Kbyte Dual Access RAM for USB
- On-Chip USB Transceiver with On-Chip Voltage Regulator
- Interface for Off-Chip USB Transceiver
- Streaming Parallel Port (SPP) for USB Streaming Transfers (40/44-pin devices only)

Power-Managed Modes:

- Run: CPU On, Peripherals On
- Idle: CPU Off, Peripherals On
- Sleep: CPU Off, Peripherals Off
- Idle mode Currents Down to 5.8 μA Typical
- Sleep mode Currents Down to 0.1 μA Typical
- Timer1 Oscillator: 1.1 μA Typical, 32 kHz, 2V
- Watchdog Timer: 2.1 μA Typical
- Two-Speed Oscillator Start-up

Special Microcontroller Features:

- C Compiler Optimized Architecture with Optional Extended Instruction Set
- 100,000 Erase/Write Cycle Enhanced Flash Program Memory Typical
- 1,000,000 Erase/Write Cycle Data EEPROM Memory Typical
- Flash/Data EEPROM Retention: > 40 Years
- Self-Programmable under Software Control
- Priority Levels for Interrupts
- 8 x 8 Single-Cycle Hardware Multiplier
- Extended Watchdog Timer (WDT):
  - Programmable period from 41 ms to 131s
- Programmable Code Protection
- Single-Supply 5V In-Circuit Serial Programming™ (ICSP™) via Two Pins
- In-Circuit Debug (ICD) via Two Pins
- Optional Dedicated ICD/ICSP Port (44-pin TQFP package only)
- Wide Operating Voltage Range (2.0V to 5.5V)

Flexible Oscillator Structure:

- Four Crystal modes, Including High-Precision PLL for USB
- Two External Clock modes, up to 48 MHz
- Internal Oscillator Block:
  - 8 user-selectable frequencies, from 31 kHz to 8 MHz
  - User-tunable to compensate for frequency drift
- Secondary Oscillator using Timer1 @ 32 kHz
- Dual Oscillator Options allow Microcontroller and USB module to Run at Different Clock Speeds
- Fail-Safe Clock Monitor:
  - Allows for safe shutdown if any clock stops

Peripheral Highlights:

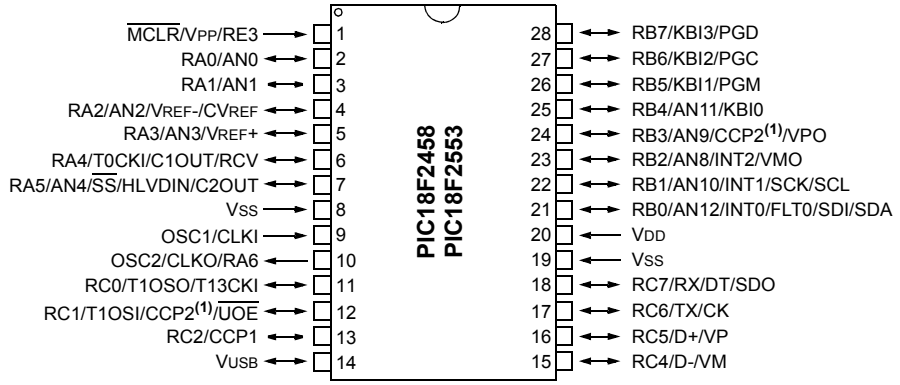
- High-Current Sink/Source: 25 mA/25 mA
- Three External Interrupts
- Four Timer modules (Timer0 to Timer3)
- Up to 2 Capture/Compare/PWM (CCP) modules:
  - Capture is 16-bit, max. resolution 5.2 ns (TCY/16)
  - Compare is 16-bit, max. resolution 83.3 ns (TCY)
  - PWM output: PWM resolution is 1 to 10-bits
- Enhanced Capture/Compare/PWM (ECCP) module:
  - Multiple output modes
  - Selectable polarity
  - Programmable dead time
  - Auto-shutdown and auto-restart
- Enhanced USART module:
  - LIN bus support
- Master Synchronous Serial Port (MSSP) module supporting 3-wire SPI (all 4 modes) and I^2C™ Master and Slave modes
- 12-Bit, up to 13-Channel Analog-to-Digital Converter module (A/D) with Programmable Acquisition Time
- Dual Analog Comparators with Input Multiplexing

Note: This document is supplemented by the *"PIC18F2455/2550/4455/4550 Data Sheet"* (DS39632). See **Section 1.0 "Device Overview"**.

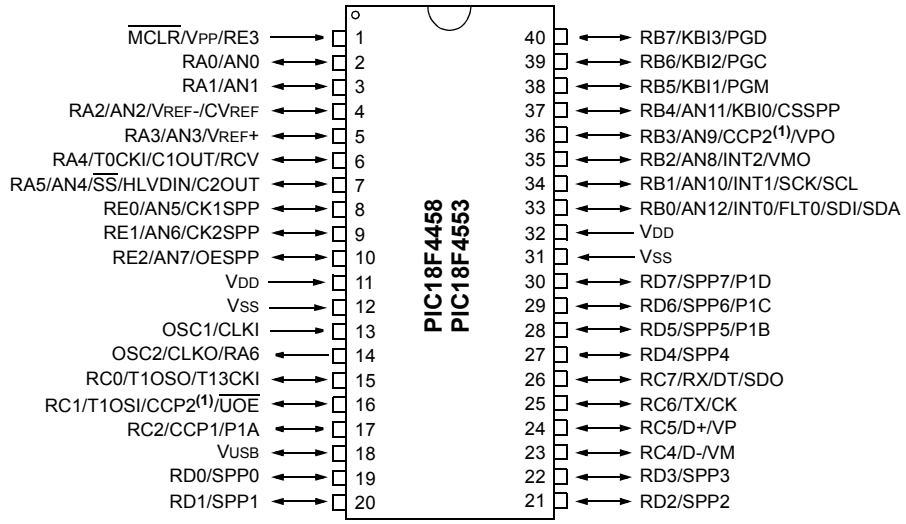
Device	Program Memory		Data Memory		I/O	12-Bit A/D (ch)	CCP/ECCP (PWM)	SPP	MSSP		EUSART	Comp.	Timers 8/16-Bit
	Flash (bytes)	# Single-Word Instructions	SRAM (bytes)	EEPROM (bytes)					SPI	Master I^2C™			
PIC18F2458	24K	12288	2048	256	24	10	2/0	No	Y	Y	1	2	1/3
PIC18F2553	32K	16384											
PIC18F4458	24K	12288			35	13	1/1	Yes					
PIC18F4553	32K	16384											

Pin Diagrams

28-Pin SPDIP, SOIC



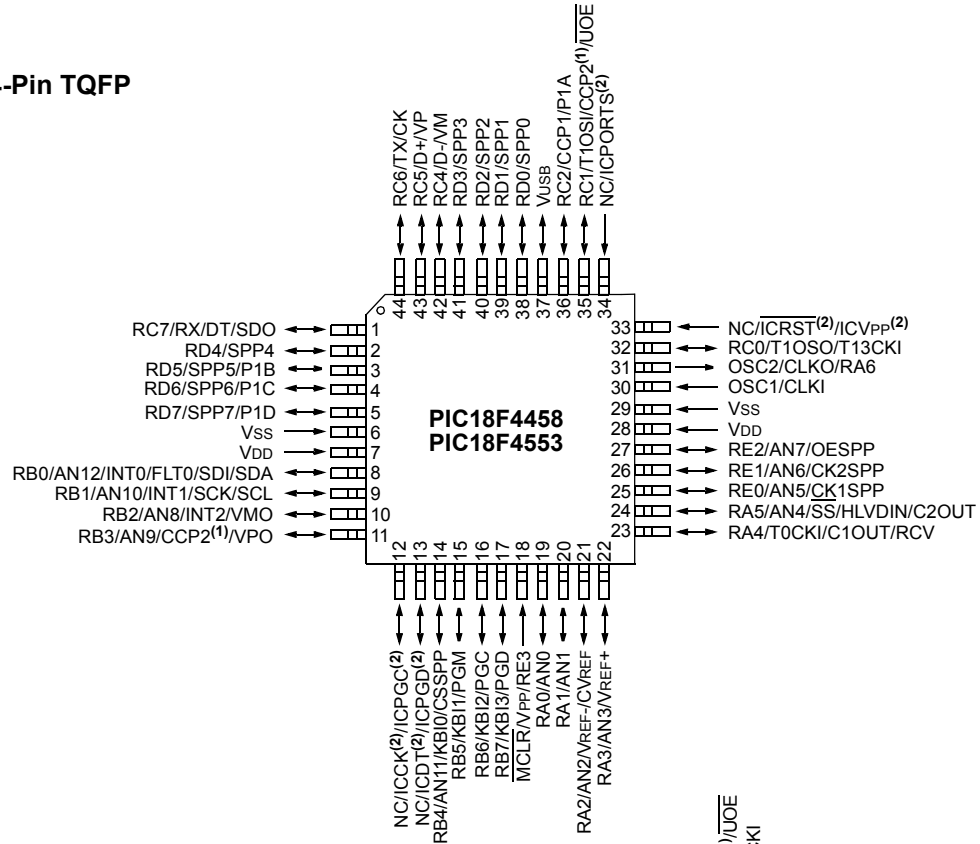
40-Pin PDIP



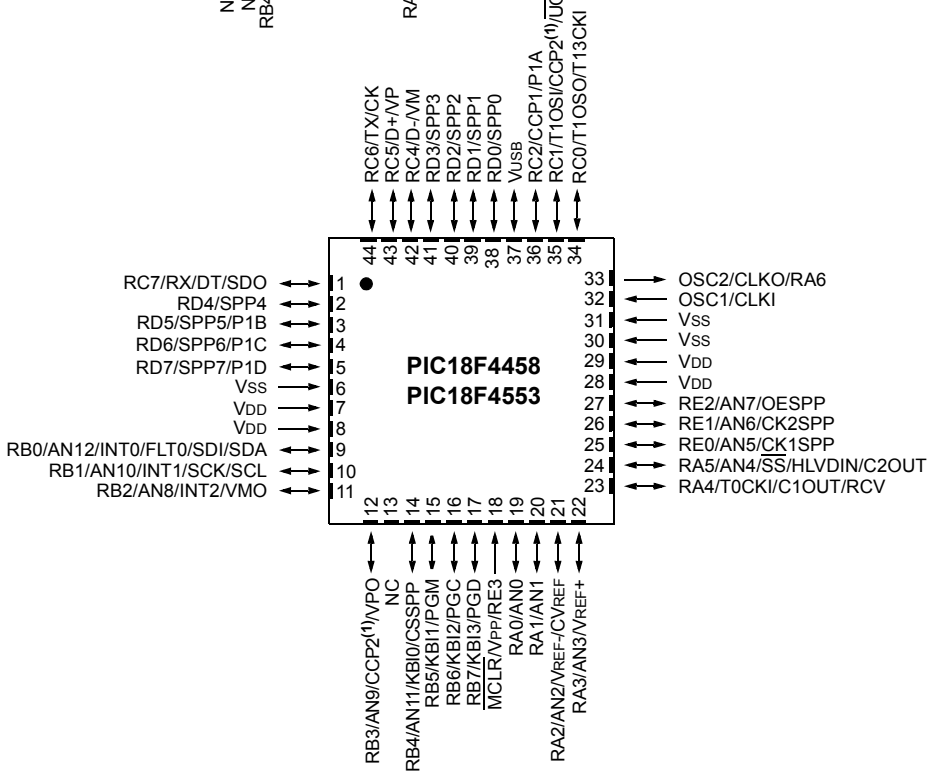
Note 1: RB3 is the alternate pin for CCP2 multiplexing.

Pin Diagrams (Continued)

44-Pin TQFP



44-Pin QFN



Note 1: RB3 is the alternate pin for CCP2 multiplexing.

2: Special ICPORT features are available only in 44-pin TQFP packages. See **Section 25.9 "Special ICPORT Features"** in the *"PIC18F2455/2550/4455/4550 Data Sheet"*.

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1.0 DEVICE OVERVIEW

This document contains device-specific information for the following devices:

- PIC18F2458
- PIC18F2553
- PIC18F4458
- PIC18F4553

Note:	This data sheet documents only the devices' features and specifications that are in addition to the features and specifications of the PIC18F2455/2550/4455/4550 devices. For information on the features and specifications shared by the PIC18F2458/2553/4458/4553 and PIC18F2455/2550/4455/4550 devices, see the *"PIC18F2455/2550/4455/4550 Data Sheet"* (DS39632).

The PIC18F4553 family of devices offers the advantages of all PIC18 microcontrollers – namely, high computational performance at an economical price – with the addition of high-endurance, Enhanced Flash program memory. In addition to these features, the PIC18F4553 family introduces design enhancements that make these microcontrollers a logical choice for many high-performance, power sensitive applications.

1.1 Special Features

- **12-Bit A/D Converter:** The PIC18F4553 family implements a 12-bit A/D Converter. The A/D Converter incorporates programmable acquisition time. This allows for a channel to be selected and a conversion to be initiated, without waiting for a sampling period and thus, reducing code overhead.

1.2 Details on Individual Family Members

The PIC18F2458/2553/4458/4553 devices are available in 28-pin and 40/44-pin packages. Block diagrams for the two groups are shown in Figure 1-1 and Figure 1-2.

The devices are differentiated from each other in the following ways:

1. Flash program memory (24 Kbytes for PIC18FX458 devices, 32 Kbytes for PIC18FX553).
2. A/D channels (10 for 28-pin devices, 13 for 40-pin and 44-pin devices).
3. I/O ports (3 bidirectional ports and 1 input only port on 28-pin devices, 5 bidirectional ports on 40-pin and 44-pin devices).
4. CCP and Enhanced CCP implementation (28-pin devices have two standard CCP modules, 40-pin and 44-pin devices have one standard CCP module and one ECCP module).
5. Streaming Parallel Port (present only on 40/44-pin devices).

All other features for devices in this family are identical. These are summarized in Table 1-1.

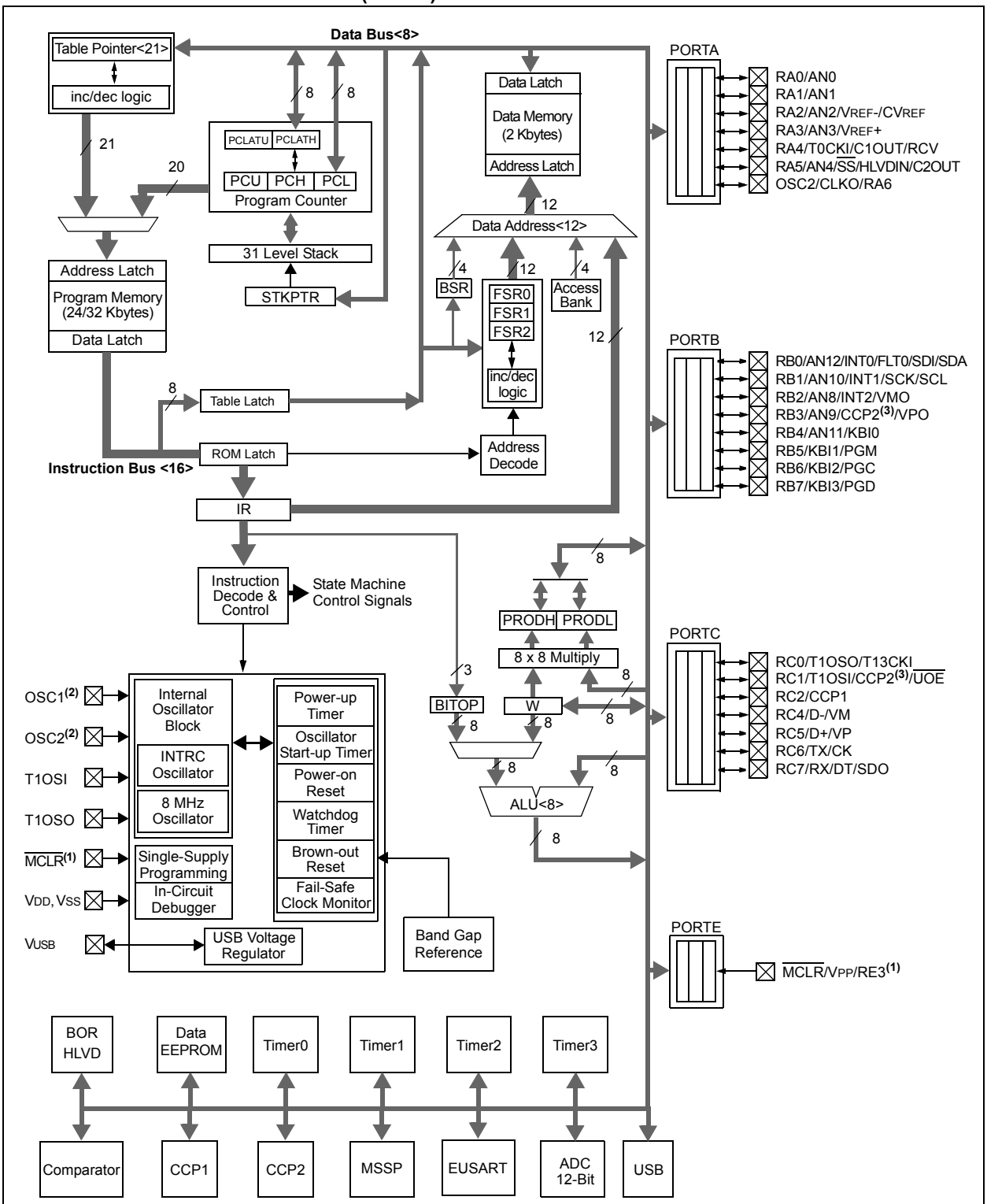
The pinouts for all devices are listed in Table 1-2 and Table 1-3.

Members of the PIC18F4553 family are available as both standard and low-voltage devices. Standard devices with Enhanced Flash memory, designated with an "F" in the part number (such as PIC18**F**2458), accommodate an operating V_{DD} range of 4.2V to 5.5V. Low-voltage parts, designated by "LF" (such as PIC18**LF**2458), function over an extended V_{DD} range of 2.0V to 5.5V.

TABLE 1-1: DEVICE FEATURES

Features	PIC18F2458	PIC18F2553	PIC18F4458	PIC18F4553
Operating Frequency	DC – 48 MHz	DC – 48 MHz	DC – 48 MHz	DC – 48 MHz
Program Memory (Bytes)	24576	32768	24576	32768
Program Memory (Instructions)	12288	16384	12288	16384
Data Memory (Bytes)	2048	2048	2048	2048
Data EEPROM Memory (Bytes)	256	256	256	256
Interrupt Sources	19	19	20	20
I/O Ports	Ports A, B, C, (E)	Ports A, B, C, (E)	Ports A, B, C, D, E	Ports A, B, C, D, E
Timers	4	4	4	4
Capture/Compare/PWM Modules	2	2	1	1
Enhanced Capture/ Compare/PWM Modules	0	0	1	1
Serial Communications	MSSP, Enhanced USART	MSSP, Enhanced USART	MSSP, Enhanced USART	MSSP, Enhanced USART
Universal Serial Bus (USB) Module	1	1	1	1
Streaming Parallel Port (SPP)	No	No	Yes	Yes
12-Bit Analog-to-Digital Converter Module	10 Input Channels	10 Input Channels	13 Input Channels	13 Input Channels
Comparators	2	2	2	2
Resets (and Delays)	POR, BOR, WDT, RESET Instruction, Stack Full, Stack Underflow, MCLR (optional), (PWRT, OST)	POR, BOR, WDT, RESET Instruction, Stack Full, Stack Underflow, MCLR (optional), (PWRT, OST)	POR, BOR, WDT, RESET Instruction, Stack Full, Stack Underflow, MCLR (optional), (PWRT, OST)	POR, BOR, WDT, RESET Instruction, Stack Full, Stack Underflow, MCLR (optional), (PWRT, OST)
Programmable High/ Low-Voltage Detect	Yes	Yes	Yes	Yes
Programmable Brown-out Reset	Yes	Yes	Yes	Yes
Instruction Set	75 Instructions; 83 with Extended Instruction Set Enabled	75 Instructions; 83 with Extended Instruction Set Enabled	75 Instructions; 83 with Extended Instruction Set Enabled	75 Instructions; 83 with Extended Instruction Set Enabled
Packages	28-Pin SPDIP 28-Pin SOIC	28-Pin SPDIP 28-Pin SOIC	40-Pin PDIP 44-Pin QFN 44-Pin TQFP	40-Pin PDIP 44-Pin QFN 44-Pin TQFP
Corresponding Devices with 10-Bit A/D	PIC18F2455	PIC18F2550	PIC18F4455	PIC18F4550

FIGURE 1-1: PIC18F2458/2553 (28-PIN) BLOCK DIAGRAM

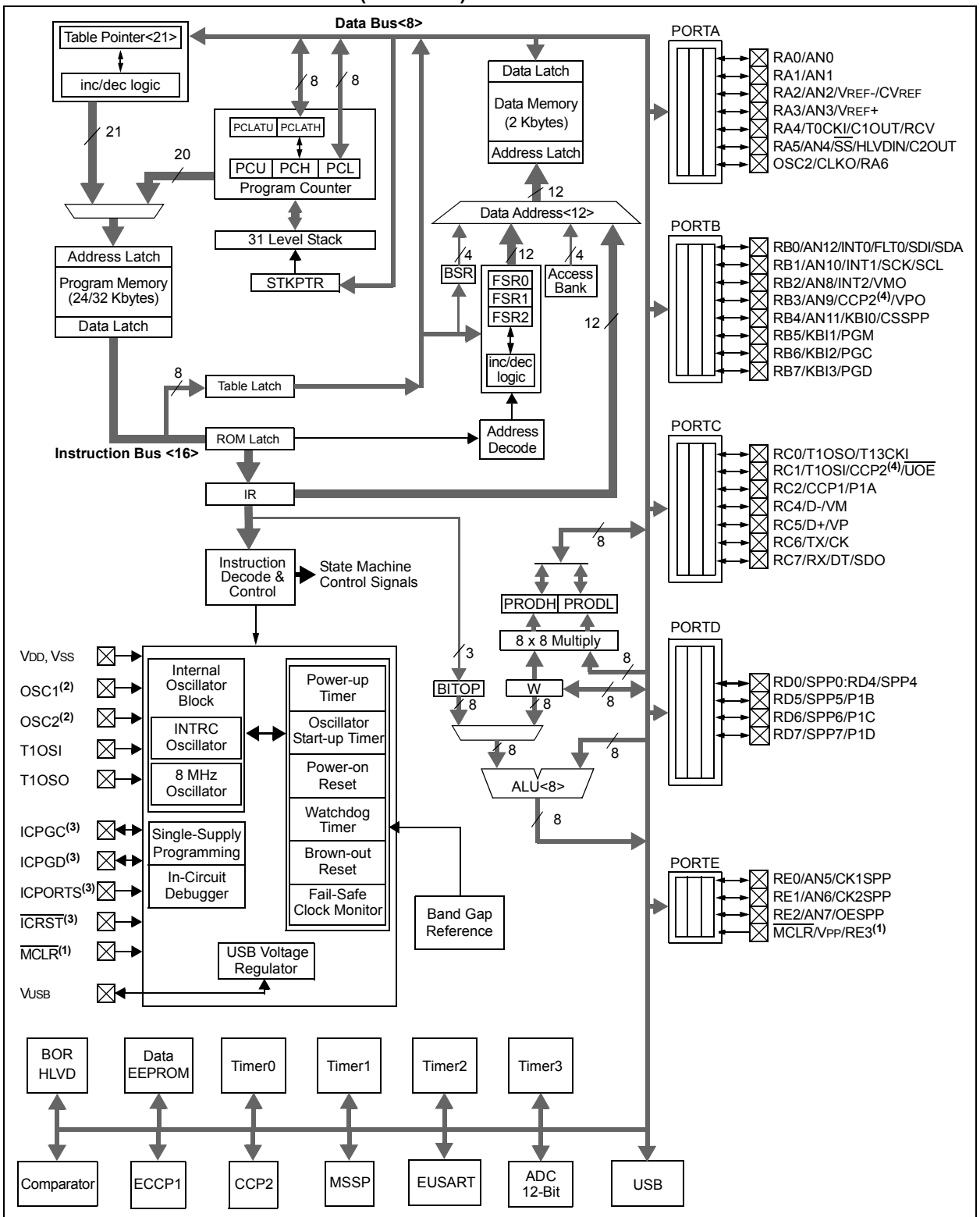


Note 1: RE3 is multiplexed with MCLR and is only available when the MCLR Resets are disabled.

2: OSC1/CLKI and OSC2/CLKO are only available in select oscillator modes and when these pins are not being used as digital I/O.

3: RB3 is the alternate pin for CCP2 multiplexing.

FIGURE 1-2: PIC18F4458/4553(40/44-PIN) BLOCK DIAGRAM



Note 1: RE3 is multiplexed with $\overline{\text{MCLR}}$ and is only available when the $\overline{\text{MCLR}}$ Resets are disabled.
2: OSC1/CLKI and OSC2/CLKO are only available in select oscillator modes and when these pins are not being used as digital I/O.
3: These pins are only available on 44-pin TQFP packages under certain conditions.
4: RB3 is the alternate pin for CCP2 multiplexing.

TABLE 1-2: PIC18F2458/2553 PINOUT I/O DESCRIPTIONS

Pin Name	Pin Number	Pin Type	Buffer Type	Description
	SPDIP, SOIC			
$\overline{MCLR}$/VPP/RE3	1			Master Clear (input) or programming voltage (input).
$\overline{MCLR}$		I	ST	Master Clear (Reset) input. This pin is an active-low Reset to the device.
VPP		P		Programming voltage input.
RE3		I	ST	Digital input.
OSC1/CLKI	9			Oscillator crystal or external clock input.
OSC1		I	Analog	Oscillator crystal input or external clock source input.
CLKI		I	Analog	External clock source input. Always associated with pin function OSC1. (See OSC2/CLKO pin.)
OSC2/CLKO/RA6	10			Oscillator crystal or clock output.
OSC2		O	—	Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO		O	—	In select modes, OSC2 pin outputs CLKO which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
RA6		I/O	TTL	General purpose I/O pin.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX Configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX Configuration bit is set.

TABLE 1-2: PIC18F2458/2553 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number	Pin Type	Buffer Type	Description
	SPDIP, SOIC			
				PORTA is a bidirectional I/O port.
RA0/AN0	2			
RA0		I/O	TTL	Digital I/O.
AN0		I	Analog	Analog input 0.
RA1/AN1	3			
RA1		I/O	TTL	Digital I/O.
AN1		I	Analog	Analog input 1.
RA2/AN2/VREF-/CVREF	4			
RA2		I/O	TTL	Digital I/O.
AN2		I	Analog	Analog input 2.
VREF-		I	Analog	A/D reference voltage (low) input.
CVREF		O	Analog	Analog comparator reference output.
RA3/AN3/VREF+	5			
RA3		I/O	TTL	Digital I/O.
AN3		I	Analog	Analog input 3.
VREF+		I	Analog	A/D reference voltage (high) input.
RA4/T0CKI/C1OUT/RCV	6			
RA4		I/O	ST	Digital I/O.
T0CKI		I	ST	Timer0 external clock input.
C1OUT		O	—	Comparator 1 output.
RCV		I	TTL	External USB transceiver RCV input.
RA5/AN4/$\overline{SS}$/ HLVDIN/C2OUT	7			
RA5		I/O	TTL	Digital I/O.
AN4		I	Analog	Analog input 4.
$\overline{SS}$		I	TTL	SPI slave select input.
HLVDIN		I	Analog	High/Low-Voltage Detect input.
C2OUT		O	—	Comparator 2 output.
RA6	—	—	—	See the OSC2/CLKO/RA6 pin.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX Configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX Configuration bit is set.

TABLE 1-2: PIC18F2458/2553 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number	Pin Type	Buffer Type	Description
	SPDIP, SOIC			
				PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-ups on all inputs.
RB0/AN12/INT0/FLT0/ SDI/SDA	21			
RB0		I/O	TTL	Digital I/O.
AN12		I	Analog	Analog input 12.
INT0		I	ST	External interrupt 0.
FLT0		I	ST	PWM Fault input (CCP1 module).
SDI		I	ST	SPI data in.
SDA		I/O	ST	I^2C™ data I/O.
RB1/AN10/INT1/SCK/ SCL	22			
RB1		I/O	TTL	Digital I/O.
AN10		I	Analog	Analog input 10.
INT1		I	ST	External interrupt 1.
SCK		I/O	ST	Synchronous serial clock input/output for SPI mode.
SCL		I/O	ST	Synchronous serial clock input/output for I^2C mode.
RB2/AN8/INT2/VMO	23			
RB2		I/O	TTL	Digital I/O.
AN8		I	Analog	Analog input 8.
INT2		I	ST	External interrupt 2.
VMO		O	—	External USB transceiver VMO output.
RB3/AN9/CCP2/VPO	24			
RB3		I/O	TTL	Digital I/O.
AN9		I	Analog	Analog input 9.
CCP2(1)		I/O	ST	Capture 2 input/Compare 2 output/PWM 2 output.
VPO		O	—	External USB transceiver VPO output.
RB4/AN11/KBI0	25			
RB4		I/O	TTL	Digital I/O.
AN11		I	Analog	Analog input 11.
KBI0		I	TTL	Interrupt-on-change pin.
RB5/KBI1/PGM	26			
RB5		I/O	TTL	Digital I/O.
KBI1		I	TTL	Interrupt-on-change pin.
PGM		I/O	ST	Low-Voltage ICSP™ Programming enable pin.
RB6/KBI2/PGC	27			
RB6		I/O	TTL	Digital I/O.
KBI2		I	TTL	Interrupt-on-change pin.
PGC		I/O	ST	In-Circuit Debugger and ICSP programming clock pin.
RB7/KBI3/PGD	28			
RB7		I/O	TTL	Digital I/O.
KBI3		I	TTL	Interrupt-on-change pin.
PGD		I/O	ST	In-Circuit Debugger and ICSP programming data pin.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX Configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX Configuration bit is set.

TABLE 1-2: PIC18F2458/2553 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number: SPDIP, SOIC	Pin Type	Buffer Type	Description
				PORTC is a bidirectional I/O port.
RC0/T1OSO/T13CKI	11			
RC0		I/O	ST	Digital I/O.
T1OSO		O	—	Timer1 oscillator output.
T13CKI		I	ST	Timer1/Timer3 external clock input.
RC1/T1OSI/CCP2/$\overline{UOE}$	12			
RC1		I/O	ST	Digital I/O.
T1OSI		I	CMOS	Timer1 oscillator input.
CCP2**(2)**		I/O	ST	Capture 2 input/Compare 2 output/PWM2 output.
$\overline{UOE}$		—	—	External USB transceiver $\overline{OE}$ output.
RC2/CCP1	13			
RC2		I/O	ST	Digital I/O.
CCP1		I/O	ST	Capture 1 input/Compare 1 output/PWM1 output.
RC4/D-/VM	15			
RC4		I	TTL	Digital input.
D-		I/O	—	USB differential minus line (input/output).
VM		I	TTL	External USB transceiver VM input.
RC5/D+/VP	16			
RC5		I	TTL	Digital input.
D+		I/O	—	USB differential plus line (input/output).
VP		O	TTL	External USB transceiver VP input.
RC6/TX/CK	17			
RC6		I/O	ST	Digital I/O.
TX		O	—	EUSART asynchronous transmit.
CK		I/O	ST	EUSART synchronous clock (see RX/DT).
RC7/RX/DT/SDO	18			
RC7		I/O	ST	Digital I/O.
RX		I	ST	EUSART asynchronous receive.
DT		I/O	ST	EUSART synchronous data (see TX/CK).
SDO		O	—	SPI data out.
RE3	—	—	—	See $\overline{MCLR}$/VPP/RE3 pin.
VUSB	14			Internal USB transceiver power supply.
		O	—	When the internal USB regulator is enabled, VUSB is the regulator output.
		P	—	When the internal USB regulator is disabled, VUSB is the power input for the USB transceiver.
VSS	8, 19	P	—	Ground reference for logic and I/O pins.
VDD	20	P	—	Positive supply for logic and I/O pins.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX Configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX Configuration bit is set.

TABLE 1-3: PIC18F4458/4553 PINOUT I/O DESCRIPTIONS

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
MCLR/VPP/RE3	1	18	18			Master Clear (input) or programming voltage (input).
MCLR				I	ST	Master Clear (Reset) input. This pin is an active-low Reset to the device.
VPP				P		Programming voltage input.
RE3				I	ST	Digital input.
OSC1/CLKI	13	32	30			Oscillator crystal or external clock input.
OSC1				I	Analog	Oscillator crystal input or external clock source input.
CLKI				I	Analog	External clock source input. Always associated with pin function OSC1. (See OSC2/CLKO pin.)
OSC2/CLKO/RA6	14	33	31			Oscillator crystal or clock output.
OSC2				O	—	Oscillator crystal output. Connects to crystal or resonator in Crystal Oscillator mode.
CLKO				O	—	In RC mode, OSC2 pin outputs CLKO which has 1/4 the frequency of OSC1 and denotes the instruction cycle rate.
RA6				I/O	TTL	General purpose I/O pin.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX Configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX Configuration bit is set.

3: These pins are No Connect unless the ICPRT Configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the DEBUG Configuration bit is cleared.

TABLE 1-3: PIC18F4458/4553 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
						PORTA is a bidirectional I/O port.
RA0/AN0	2	19	19			
RA0				I/O	TTL	Digital I/O.
AN0				I	Analog	Analog input 0.
RA1/AN1	3	20	20			
RA1				I/O	TTL	Digital I/O.
AN1				I	Analog	Analog input 1.
RA2/AN2/VREF-/CVREF	4	21	21			
RA2				I/O	TTL	Digital I/O.
AN2				I	Analog	Analog input 2.
VREF-				I	Analog	A/D reference voltage (low) input.
CVREF				O	Analog	Analog comparator reference output.
RA3/AN3/VREF+	5	22	22			
RA3				I/O	TTL	Digital I/O.
AN3				I	Analog	Analog input 3.
VREF+				I	Analog	A/D reference voltage (high) input.
RA4/T0CKI/C1OUT/RCV	6	23	23			
RA4				I/O	ST	Digital I/O.
T0CKI				I	ST	Timer0 external clock input.
C1OUT				O	—	Comparator 1 output.
RCV				I	TTL	External USB transceiver RCV input.
RA5/AN4/$\overline{SS}$/HLVDIN/C2OUT	7	24	24			
RA5				I/O	TTL	Digital I/O.
AN4				I	Analog	Analog input 4.
$\overline{SS}$				I	TTL	SPI slave select input.
HLVDIN				I	Analog	High/Low-Voltage Detect input.
C2OUT				O	—	Comparator 2 output.
RA6	—	—	—	—	—	See the OSC2/CLKO/RA6 pin.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX Configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX Configuration bit is set.

3: These pins are No Connect unless the ICPRT Configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the $\overline{DEBUG}$ Configuration bit is cleared.

TABLE 1-3: PIC18F4458/4553 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
						PORTB is a bidirectional I/O port. PORTB can be software programmed for internal weak pull-ups on all inputs.
RB0/AN12/INT0/FLT0/SDI/SDA	33	9	8			
RB0				I/O	TTL	Digital I/O.
AN12				I	Analog	Analog input 12.
INT0				I	ST	External interrupt 0.
FLT0				I	ST	Enhanced PWM Fault input (ECCP1 module).
SDI				I	ST	SPI data in.
SDA				I/O	ST	I^2C™ data I/O.
RB1/AN10/INT1/SCK/SCL	34	10	9			
RB1				I/O	TTL	Digital I/O.
AN10				I	Analog	Analog input 10.
INT1				I	ST	External interrupt 1.
SCK				I/O	ST	Synchronous serial clock input/output for SPI mode.
SCL				I/O	ST	Synchronous serial clock input/output for I^2C mode.
RB2/AN8/INT2/VMO	35	11	10			
RB2				I/O	TTL	Digital I/O.
AN8				I	Analog	Analog input 8.
INT2				I	ST	External interrupt 2.
VMO				O	—	External USB transceiver VMO output.
RB3/AN9/CCP2/VPO	36	12	11			
RB3				I/O	TTL	Digital I/O.
AN9				I	Analog	Analog input 9.
CCP2(1)				I/O	ST	Capture 2 input/Compare 2 output/PWM 2 output.
VPO				O	—	External USB transceiver VPO output.
RB4/AN11/KBI0/CSSPP	37	14	14			
RB4				I/O	TTL	Digital I/O.
AN11				I	Analog	Analog input 11.
KBI0				I	TTL	Interrupt-on-change pin.
CSSPP				O	—	SPP chip select control output.
RB5/KBI1/PGM	38	15	15			
RB5				I/O	TTL	Digital I/O.
KBI1				I	TTL	Interrupt-on-change pin.
PGM				I/O	ST	Low-Voltage ICSP™ Programming enable pin.
RB6/KBI2/PGC	39	16	16			
RB6				I/O	TTL	Digital I/O.
KBI2				I	TTL	Interrupt-on-change pin.
PGC				I/O	ST	In-Circuit Debugger and ICSP programming clock pin.
RB7/KBI3/PGD	40	17	17			
RB7				I/O	TTL	Digital I/O.
KBI3				I	TTL	Interrupt-on-change pin.
PGD				I/O	ST	In-Circuit Debugger and ICSP programming data pin.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX Configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX Configuration bit is set.

3: These pins are No Connect unless the ICPRT Configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the DEBUG Configuration bit is cleared.

TABLE 1-3: PIC18F4458/4553 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
						PORTC is a bidirectional I/O port.
RC0/T1OSO/T13CKI	15	34	32			
RC0				I/O	ST	Digital I/O.
T1OSO				O	—	Timer1 oscillator output.
T13CKI				I	ST	Timer1/Timer3 external clock input.
RC1/T1OSI/CCP2/$\overline{UOE}$	16	35	35			
RC1				I/O	ST	Digital I/O.
T1OSI				I	CMOS	Timer1 oscillator input.
CCP2(2)				I/O	ST	Capture 2 input/Compare 2 output/PWM2 output.
$\overline{UOE}$				O	—	External USB transceiver $\overline{OE}$ output.
RC2/CCP1/P1A	17	36	36			
RC2				I/O	ST	Digital I/O.
CCP1				I/O	ST	Capture 1 input/Compare 1 output/PWM1 output.
P1A				O	TTL	Enhanced CCP1 PWM output, channel A.
RC4/D-/VM	23	42	42			
RC4				I	TTL	Digital input.
D-				I/O	—	USB differential minus line (input/output).
VM				I	TTL	External USB transceiver VM input.
RC5/D+/VP	24	43	43			
RC5				I	TTL	Digital input.
D+				I/O	—	USB differential plus line (input/output).
VP				I	TTL	External USB transceiver VP input.
RC6/TX/CK	25	44	44			
RC6				I/O	ST	Digital I/O.
TX				O	—	EUSART asynchronous transmit.
CK				I/O	ST	EUSART synchronous clock (see RX/DT).
RC7/RX/DT/SDO	26	1	1			
RC7				I/O	ST	Digital I/O.
RX				I	ST	EUSART asynchronous receive.
DT				I/O	ST	EUSART synchronous data (see TX/CK).
SDO				O	—	SPI data out.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX Configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX Configuration bit is set.

3: These pins are No Connect unless the $\overline{ICPRT}$ Configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the $\overline{DEBUG}$ Configuration bit is cleared.

TABLE 1-3: PIC18F4458/4553 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
						PORTD is a bidirectional I/O port or a Streaming Parallel Port (SPP). PORTD can be software programmed for internal weak pull-ups on all inputs. These pins have TTL input buffers when the SPP module is enabled.
RD0/SPP0	19	38	38			
RD0				I/O	ST	Digital I/O.
SPP0				I/O	TTL	Streaming Parallel Port data.
RD1/SPP1	20	39	39			
RD1				I/O	ST	Digital I/O.
SPP1				I/O	TTL	Streaming Parallel Port data.
RD2/SPP2	21	40	40			
RD2				I/O	ST	Digital I/O.
SPP2				I/O	TTL	Streaming Parallel Port data.
RD3/SPP3	22	41	41			
RD3				I/O	ST	Digital I/O.
SPP3				I/O	TTL	Streaming Parallel Port data.
RD4/SPP4	27	2	2			
RD4				I/O	ST	Digital I/O.
SPP4				I/O	TTL	Streaming Parallel Port data.
RD5/SPP5/P1B	28	3	3			
RD5				I/O	ST	Digital I/O.
SPP5				I/O	TTL	Streaming Parallel Port data.
P1B				O	—	ECCP1 PWM output, channel B.
RD6/SPP6/P1C	29	4	4			
RD6				I/O	ST	Digital I/O.
SPP6				I/O	TTL	Streaming Parallel Port data.
P1C				O	—	ECCP1 PWM output, channel C.
RD7/SPP7/P1D	30	5	5			
RD7				I/O	ST	Digital I/O.
SPP7				I/O	TTL	Streaming Parallel Port data.
P1D				O	—	ECCP1 PWM output, channel D.

Legend: TTL = TTL compatible input CMOS = CMOS compatible input or output
ST = Schmitt Trigger input with CMOS levels I = Input
O = Output P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX Configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX Configuration bit is set.

3: These pins are No Connect unless the ICPRT Configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the DEBUG Configuration bit is cleared.

TABLE 1-3: PIC18F4458/4553 PINOUT I/O DESCRIPTIONS (CONTINUED)

Pin Name	Pin Number			Pin Type	Buffer Type	Description
	PDIP	QFN	TQFP			
						PORTE is a bidirectional I/O port.
RE0/AN5/CK1SPP	8	25	25			
RE0				I/O	ST	Digital I/O.
AN5				I	Analog	Analog input 5.
CK1SPP				O	—	SPP clock 1 output.
RE1/AN6/CK2SPP	9	26	26			
RE1				I/O	ST	Digital I/O.
AN6				I	Analog	Analog input 6.
CK2SPP				O	—	SPP clock 2 output.
RE2/AN7/OESPP	10	27	27			
RE2				I/O	ST	Digital I/O.
AN7				I	Analog	Analog input 7.
OESPP				O	—	SPP output enable output.
RE3	—	—	—	—	—	See $\overline{MCLR}$/VPP/RE3 pin.
VSS	12, 31	6, 30, 31	6, 29	P	—	Ground reference for logic and I/O pins.
VDD	11, 32	7, 8, 28, 29	7, 28	P	—	Positive supply for logic and I/O pins.
VUSB	18	37	37			Internal USB transceiver power supply.
				O	—	When the internal USB regulator is enabled, VUSB is the regulator output.
				P	—	When the internal USB regulator is disabled, VUSB is the power input for the USB transceiver.
NC/ICCK/ICPGC(3)	—	—	12			No Connect or dedicated ICD/ICSP™ port clock.
ICCK				I/O	ST	In-Circuit Debugger clock.
ICPGC				I/O	ST	ICSP programming clock.
NC/ICDT/ICPGD(3)	—	—	13			No Connect or dedicated ICD/ICSP port clock.
ICDT				I/O	ST	In-Circuit Debugger data.
ICPGD				I/O	ST	ICSP programming data.
NC/$\overline{ICRST}$/ICVPP(3)	—	—	33			No Connect or dedicated ICD/ICSP port Reset.
$\overline{ICRST}$				I	—	Master Clear (Reset) input.
ICVPP				P	—	Programming voltage input.
NC/ICPORTS(3)	—	—	34	P	—	No Connect or 28-pin device emulation.
ICPORTS						Enable 28-pin device emulation when connected to VSS.
NC	—	13	—	—	—	No Connect.

Legend: TTL = TTL compatible input; CMOS = CMOS compatible input or output; ST = Schmitt Trigger input with CMOS levels; I = Input; O = Output; P = Power

Note 1: Alternate assignment for CCP2 when CCP2MX Configuration bit is cleared.

2: Default assignment for CCP2 when CCP2MX Configuration bit is set.

3: These pins are No Connect unless the $\overline{ICPRT}$ Configuration bit is set. For NC/ICPORTS, the pin is No Connect unless ICPRT is set and the $\overline{DEBUG}$ Configuration bit is cleared.

2.0 12-BIT ANALOG-TO-DIGITAL CONVERTER (A/D) MODULE

The Analog-to-Digital (A/D) Converter module has 10 inputs for the 28-pin devices and 13 for the 40-pin and 44-pin devices. This module allows conversion of an analog input signal to a corresponding 12-bit digital number.

The module has five registers:

- A/D Result High Register (ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register 0 (ADCON0)
- A/D Control Register 1 (ADCON1)
- A/D Control Register 2 (ADCON2)

The ADCON0 register, shown in Register 2-1, controls the operation of the A/D module. The ADCON1 register, shown in Register 2-2, configures the functions of the port pins. The ADCON2 register, shown in Register 2-3, configures the A/D clock source, programmed acquisition time and justification.

REGISTER 2-1: ADCON0: A/D CONTROL REGISTER 0

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
—	—	CHS3	CHS2	CHS1	CHS0	GO/$\overline{\text{DONE}}$	ADON
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 7-6 **Unimplemented:** Read as '0'

bit 5-2 **CHS3:CHS0:** Analog Channel Select bits
0000 = Channel 0 (AN0)
0001 = Channel 1 (AN1)
0010 = Channel 2 (AN2)
0011 = Channel 3 (AN3)
0100 = Channel 4 (AN4)
0101 = Channel 5 (AN5)**(1,2)**
0110 = Channel 6 (AN6)**(1,2)**
0111 = Channel 7 (AN7)**(1,2)**
1000 = Channel 8 (AN8)
1001 = Channel 9 (AN9)
1010 = Channel 10 (AN10)
1011 = Channel 11 (AN11)
1100 = Channel 12 (AN12
1101 = Unimplemented**(2)**
1110 = Unimplemented**(2)**
1111 = Unimplemented**(2)**

bit 1 **GO/$\overline{\text{DONE}}$:** A/D Conversion Status bit
When ADON = 1:
1 = A/D conversion in progress
0 = A/D Idle

bit 0 **ADON:** A/D On bit
1 = A/D Converter module is enabled
0 = A/D Converter module is disabled

Note 1: These channels are not implemented on 28-pin devices.
2: Performing a conversion on unimplemented channels will return a floating input measurement.

REGISTER 2-2: ADCON1: A/D CONTROL REGISTER 1

U-0	U-0	R/W-0	R/W-0	R/W-0	R/W(1)	R/W(1)	R/W(1)
—	—	VCFG1	VCFG0	PCFG3	PCFG2	PCFG1	PCFG0
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 7-6 **Unimplemented:** Read as '0'

bit 5 **VCFG1:** Voltage Reference Configuration bit (V_{REF-} source)
1 = V_{REF-} (AN2)
0 = V_{SS}

bit 4 **VCFG0:** Voltage Reference Configuration bit (V_{REF+} source)
1 = V_{REF+} (AN3)
0 = V_{DD}

bit 3-0 **PCFG3:PCFG0:** A/D Port Configuration Control bits:

PCFG3: PCFG0	AN12	AN11	AN10	AN9	AN8	AN7(2)	AN6(2)	AN5(2)	AN4	AN3	AN2	AN1	AN0
0000(1)	A	A	A	A	A	A	A	A	A	A	A	A	A
0001	A	A	A	A	A	A	A	A	A	A	A	A	A
0010	A	A	A	A	A	A	A	A	A	A	A	A	A
0011	D	A	A	A	A	A	A	A	A	A	A	A	A
0100	D	D	A	A	A	A	A	A	A	A	A	A	A
0101	D	D	D	A	A	A	A	A	A	A	A	A	A
0110	D	D	D	D	A	A	A	A	A	A	A	A	A
0111(1)	D	D	D	D	D	A	A	A	A	A	A	A	A
1000	D	D	D	D	D	D	A	A	A	A	A	A	A
1001	D	D	D	D	D	D	D	A	A	A	A	A	A
1010	D	D	D	D	D	D	D	D	A	A	A	A	A
1011	D	D	D	D	D	D	D	D	D	A	A	A	A
1100	D	D	D	D	D	D	D	D	D	D	A	A	A
1101	D	D	D	D	D	D	D	D	D	D	D	A	A
1110	D	D	D	D	D	D	D	D	D	D	D	D	A
1111	D	D	D	D	D	D	D	D	D	D	D	D	D

A = Analog input D = Digital I/O

Note 1: The Reset value of the PCFG bits depends on the value of the PBADEN Configuration bit. When PBADEN = 1, PCFG<3:0> = 0000; when PBADEN = 0, PCFG<3:0> = 0111.

2: AN5 through AN7 are available only on 40-pin and 44-pin devices.

REGISTER 2-3: ADCON2: A/D CONTROL REGISTER 2

R/W-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
ADFM	—	ACQT2	ACQT1	ACQT0	ADCS2	ADCS1	ADCS0
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 7 **ADFM:** A/D Result Format Select bit
1 = Right justified
0 = Left justified

bit 6 **Unimplemented:** Read as '0'

bit 5-3 **ACQT2:ACQT0:** A/D Acquisition Time Select bits
111 = 20 TAD
110 = 16 TAD
101 = 12 TAD
100 = 8 TAD
011 = 6 TAD
010 = 4 TAD
001 = 2 TAD
000 = 0 TAD(1)

bit 2-0 **ADCS2:ADCS0:** A/D Conversion Clock Select bits
111 = FRC (clock derived from A/D RC oscillator)(1)
110 = FOSC/64
101 = FOSC/16
100 = FOSC/4
011 = FRC (clock derived from A/D RC oscillator)(1)
010 = FOSC/32
001 = FOSC/8
000 = FOSC/2

Note 1: If the A/D FRC clock source is selected, a delay of one TCY (instruction cycle) is added before the A/D clock starts. This allows the SLEEP instruction to be executed before starting a conversion.

The analog reference voltage is software selectable to either the device's positive and negative supply voltage (V_{DD} and V_{SS}), or the voltage level on the RA3/AN3/V_{REF+} and RA2/AN2/V_{REF-}/CV_{REF} pins.

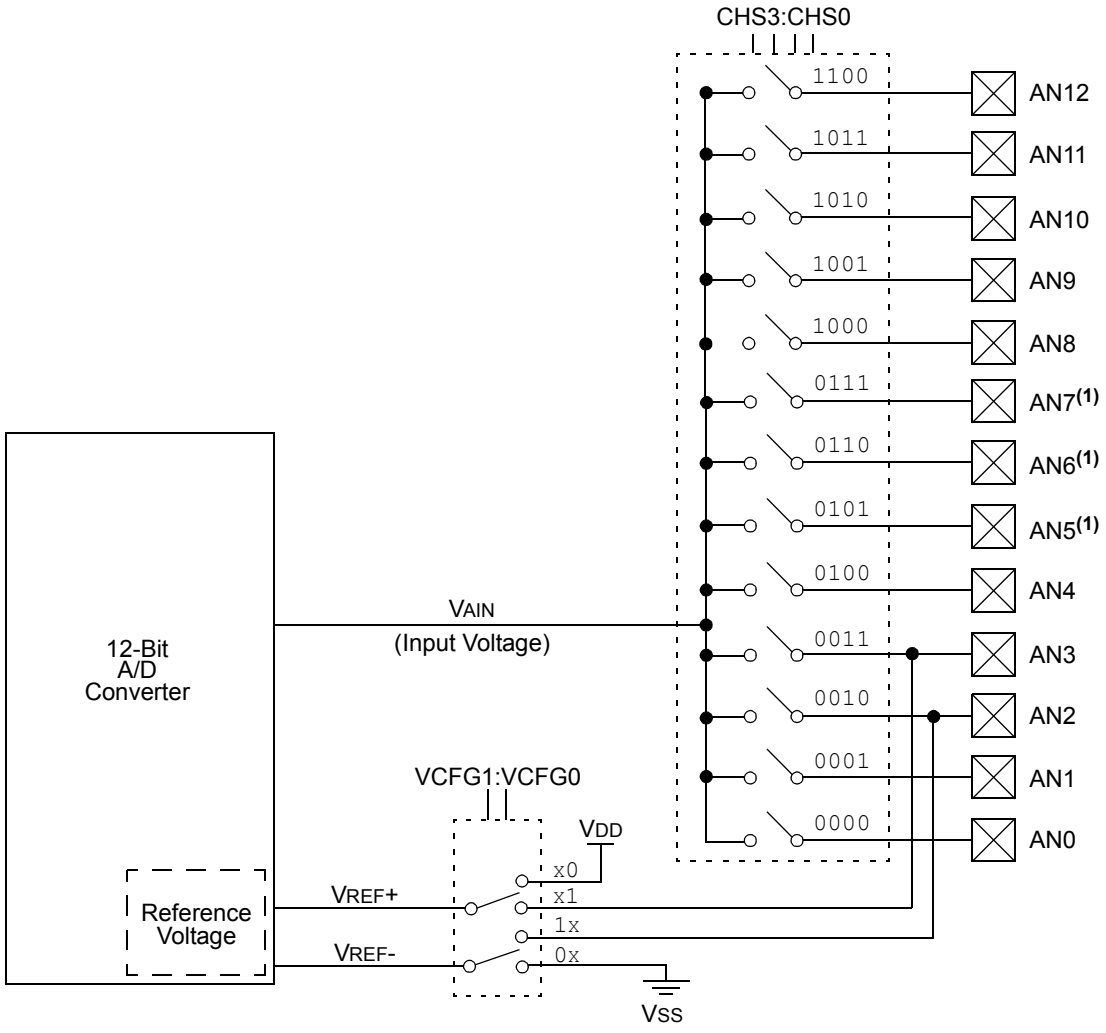
The A/D Converter has a unique feature of being able to operate while the device is in Sleep mode. To operate in Sleep, the A/D conversion clock must be derived from the A/D's internal RC oscillator.

The output of the sample and hold is the input into the Converter, which generates the result via successive approximation.

A device Reset forces all registers to their Reset state. This forces the A/D module to be turned off and any conversion in progress is aborted.

Each port pin associated with the A/D Converter can be configured as an analog input or as a digital I/O. The ADRESH and ADRESL registers contain the result of the A/D conversion. When the A/D conversion is complete, the result is loaded into the ADRESH:ADRESL register pair, the GO/$\overline{\text{DONE}}$ bit (ADCON0 register) is cleared and the A/D Interrupt Flag bit, ADIF, is set. The block diagram of the A/D module is shown in Figure 2-1.

FIGURE 2-1: A/D BLOCK DIAGRAM



Note 1: Channels AN5 through AN7 are not available on 28-pin devices.

The value in the ADRESH:ADRESL registers is unknown following Power-on and Brown-out Resets, and is not affected by any other Reset.

After the A/D module has been configured as desired, the selected channel must be acquired before the conversion is started. The analog input channels must have their corresponding TRIS bits selected as an input. To determine acquisition time, see **Section 2.1 "A/D Acquisition Requirements"**. After this acquisition time has elapsed, the A/D conversion can be started. An acquisition time can be programmed to occur between setting the GO/$\overline{\text{DONE}}$ bit and the actual start of the conversion.

The following steps should be followed to perform an A/D conversion:

1. Configure the A/D module:
   - Configure analog pins, voltage reference and digital I/O (ADCON1)
   - Select A/D input channel (ADCON0)
   - Select A/D acquisition time (ADCON2)
   - Select A/D conversion clock (ADCON2)
   - Turn on A/D module (ADCON0)
2. Configure A/D interrupt (if desired):
   - Clear ADIF bit
   - Set ADIE bit
   - Set GIE bit
3. Wait the required acquisition time (if required).
4. Start conversion:
   - Set GO/$\overline{\text{DONE}}$ bit (ADCON0 register)
5. Wait for A/D conversion to complete, by either:
   - Polling for the GO/$\overline{\text{DONE}}$ bit to be cleared

   OR
   - Waiting for the A/D interrupt
6. Read A/D Result registers (ADRESH:ADRESL); clear bit ADIF, if required.
7. For next conversion, go to step 1 or step 2, as required. The A/D conversion time per bit is defined as TAD. A minimum wait of 2 TAD is required before the next acquisition starts.

FIGURE 2-2: A/D TRANSFER FUNCTION

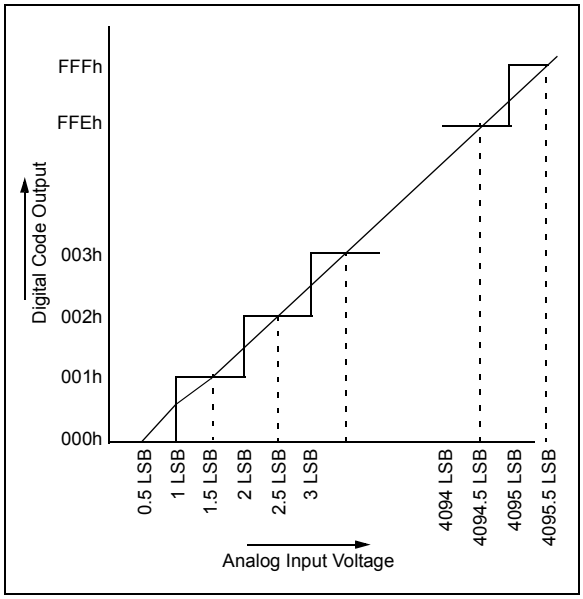
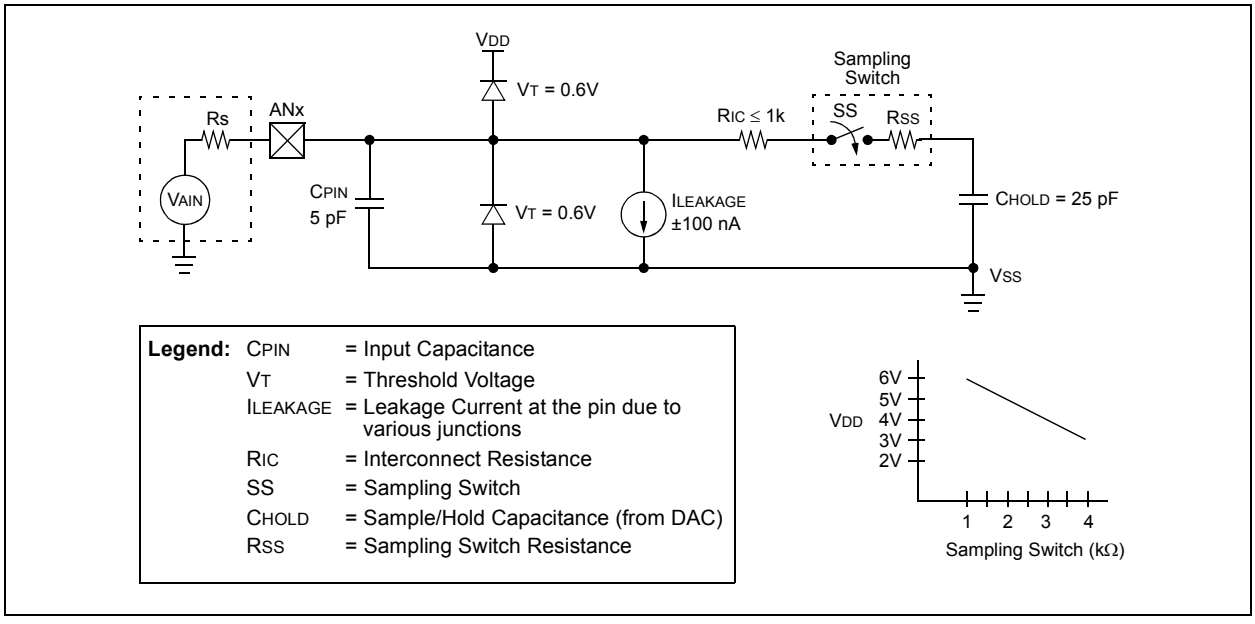


FIGURE 2-3: ANALOG INPUT MODEL



2.1 A/D Acquisition Requirements

For the A/D Converter to meet its specified accuracy, the charge holding capacitor (CHOLD) must be allowed to fully charge to the input channel voltage level. The analog input model is shown in Figure 2-3. The source impedance (RS) and the internal sampling switch (RSS) impedance directly affect the time required to charge the capacitor CHOLD. The sampling switch (RSS) impedance varies over the device voltage (VDD). The source impedance affects the offset voltage at the analog input (due to pin leakage current). **The maximum recommended impedance for analog sources is 2.5 kΩ**. After the analog input channel is selected (changed), the channel must be sampled for at least the minimum acquisition time before starting a conversion.

Note:	When the conversion is started, the holding capacitor is disconnected from the input pin.

To calculate the minimum acquisition time, Equation 2-1 may be used. This equation assumes that 1/2 LSb error is used (4096 steps for the 12-bit A/D). The 1/2 LSb error is the maximum error allowed for the A/D to meet its specified resolution.

Example 2-3 shows the calculation of the minimum required acquisition time, TACQ. This calculation is based on the following application system assumptions:

CHOLD	=	25 pF
Rs	=	2.5 kΩ
Conversion Error	≤	1/2 LSb
VDD	=	3V → Rss = 4 kΩ
Temperature	=	85°C (system max.)

EQUATION 2-1: ACQUISITION TIME

$$T_{ACQ} = \text{Amplifier Settling Time} + \text{Holding Capacitor Charging Time} + \text{Temperature Coefficient}$$
$$= T_{AMP} + T_C + T_{COFF}$$

EQUATION 2-2: A/D MINIMUM CHARGING TIME

$$V_{HOLD} = (V_{REF} - (V_{REF}/4096)) \cdot (1 - e^{(-T_C/C_{HOLD}(R_{IC} + R_{SS} + R_S))})$$
or
$$T_C = -(C_{HOLD})(R_{IC} + R_{SS} + R_S) \ln(1/4096)$$

EQUATION 2-3: CALCULATING THE MINIMUM REQUIRED ACQUISITION TIME

$$T_{ACQ} = T_{AMP} + T_C + T_{COFF}$$
$$T_{AMP} = 0.2\ \mu s$$
$$T_{COFF} = (\text{Temp} - 25°C)(0.02\ \mu s/°C)$$
$$(85°C - 25°C)(0.02\ \mu s/°C)$$
$$1.2\ \mu s$$

Temperature coefficient is only required for temperatures > 25°C. Below 25°C, $T_{COFF} = 0\ \mu s$.

$$T_C = -(C_{HOLD})(R_{IC} + R_{SS} + R_S) \ln(1/4096)\ \mu s$$
$$-(25\ pF)\ (1\ k\Omega + 4\ k\Omega + 2.5\ k\Omega) \ln(0.0002441)\ \mu s$$
$$1.56\ \mu s$$

$$T_{ACQ} = 0.2\ \mu s + 1.56\ \mu s + 1.2\ \mu s$$
$$2.96\ \mu s$$

2.2 Selecting and Configuring Acquisition Time

The ADCON2 register allows the user to select an acquisition time that occurs each time the GO/DONE bit is set. It also gives users the option to use an automatically determined acquisition time.

Acquisition time may be set with the ACQT2:ACQT0 bits (ADCON2<5:3>), which provides a range of 2 to 20 TAD. When the GO/DONE bit is set, the A/D module continues to sample the input for the selected acquisition time, then automatically begins a conversion. Since the acquisition time is programmed, there may be no need to wait for an acquisition time between selecting a channel and setting the GO/DONE bit.

Manual acquisition is selected when ACQT2:ACQT0 = 000. When the GO/DONE bit is set, sampling is stopped and a conversion begins. The user is responsible for ensuring the required acquisition time has passed between selecting the desired input channel and setting the GO/DONE bit. This option is also the default Reset state of the ACQT2:ACQT0 bits and is compatible with devices that do not offer programmable acquisition times.

In either case, when the conversion is completed, the GO/DONE bit is cleared, the ADIF flag is set and the A/D begins sampling the currently selected channel again. If an acquisition time is programmed, there is nothing to indicate if the acquisition time has ended or if the conversion has begun.

2.3 Selecting the A/D Conversion Clock

The A/D conversion time per bit is defined as TAD. The A/D conversion requires 13 TAD per 12-bit conversion. The source of the A/D conversion clock is software selectable. There are seven possible options for TAD:

- 2 TOSC
- 4 TOSC
- 8 TOSC
- 16 TOSC
- 32 TOSC
- 64 TOSC
- Internal RC Oscillator

For correct A/D conversions, the A/D conversion clock (TAD) must be as short as possible, but greater than the minimum TAD (see parameter 130 for more information).

Table 2-1 shows the resultant TAD times derived from the device operating frequencies and the A/D clock source selected.

TABLE 2-1: TAD vs. DEVICE OPERATING FREQUENCIES

A/D Clock Source (TAD)		Assumes TAD Min. = 0.8 μs
Operation	**ADCS2:ADCS0**	**Maximum FOSC**
2 TOSC	000	2.50 MHz
4 TOSC	100	5.00 MHz
8 TOSC	001	10.00 MHz
16 TOSC	101	20.00 MHz
32 TOSC	010	40.00 MHz
64 TOSC	110	48.00 MHz
RC(1)	x11	1.00 MHz(2)

Note 1: The RC source has a typical TAD time of 2.5 μs.

2: For device frequencies above 1 MHz, the device must be in Sleep for the entire conversion or a FOSC divider should be used instead; otherwise, the A/D accuracy specification may not be met.

2.4 Operation in Power-Managed Modes

The selection of the automatic acquisition time and A/D conversion clock is determined in part by the clock source and frequency while in a power-managed mode.

If the A/D is expected to operate while the device is in a power-managed mode, the ADCS2:ADCS0 bits in ADCON2 should be updated in accordance with the clock source to be used. The ACQT2:ACQT0 bits do not need to be adjusted as the ADCS2:ADCS0 bits adjust the T_{AD} time for the new clock speed. After entering the mode, an A/D acquisition or conversion may be started. Once started, the device should continue to be clocked by the same clock source until the conversion has been completed.

If desired, the device may be placed into the corresponding Idle mode during the conversion. If the device clock frequency is less than 1 MHz, the A/D RC clock source should be selected.

Operation in Sleep mode requires the A/D F_{RC} clock to be selected. If bits ACQT2:ACQT0 are set to '000' and a conversion is started, the conversion will be delayed one instruction cycle to allow execution of the SLEEP instruction and entry to Sleep mode. The IDLEN bit (OSCCON<7>) must have already been cleared prior to starting the conversion.

2.5 Configuring Analog Port Pins

The ADCON1, TRISA, TRISB and TRISE registers all configure the A/D port pins. The port pins needed as analog inputs must have their corresponding TRIS bits set (input). If the TRIS bit is cleared (output), the digital output level (V_{OH} or V_{OL}) will be converted.

The A/D operation is independent of the state of the CHS3:CHS0 bits and the TRIS bits.

Note 1: When reading the PORT register, all pins configured as analog input channels will read as cleared (a low level). Analog conversion on pins configured as digital pins can be performed. The voltage on the pin will be accurately converted.

2: Analog levels on any pin defined as a digital input may cause the digital input buffer to consume current out of the device's specification limits.

3: The PBADEN bit in Configuration Register 3H configures PORTB pins to reset as analog or digital pins by controlling how the PCFG3:PCFG0 bits in ADCON1 are reset.

2.6 A/D Conversions

Figure 2-4 shows the operation of the A/D Converter after the GO/$\overline{\text{DONE}}$ bit has been set and the ACQT2:ACQT0 bits are cleared. A conversion is started after the following instruction to allow entry into Sleep mode before the conversion begins.

Figure 2-5 shows the operation of the A/D Converter after the GO/$\overline{\text{DONE}}$ bit has been set and the ACQT2:ACQT0 bits are set to '010', and selecting a 4 TAD acquisition time before the conversion starts.

Clearing the GO/$\overline{\text{DONE}}$ bit during a conversion will abort the current conversion. The A/D Result register pair will NOT be updated with the partially completed A/D conversion sample. This means the ADRESH:ADRESL registers will continue to contain the value of the last completed conversion (or the last value written to the ADRESH:ADRESL registers).

After the A/D conversion is completed or aborted, a 2 TCY wait is required before the next acquisition can be started. After this wait, acquisition on the selected channel is automatically started.

Note: The GO/$\overline{\text{DONE}}$ bit should **NOT** be set in the same instruction that turns on the A/D. Code should wait at least 2 μs after enabling the A/D before beginning an acquisition and conversion cycle.

2.7 Discharge

The discharge phase is used to initialize the value of the holding capacitor. The array is discharged before every sample. This feature helps to optimize the unity gain amplifier, as the circuit always needs to charge the capacitor array, rather than charge/discharge based on previous measure values.

FIGURE 2-4: A/D CONVERSION TAD CYCLES (ACQT<2:0> = 000, TACQ = 0)

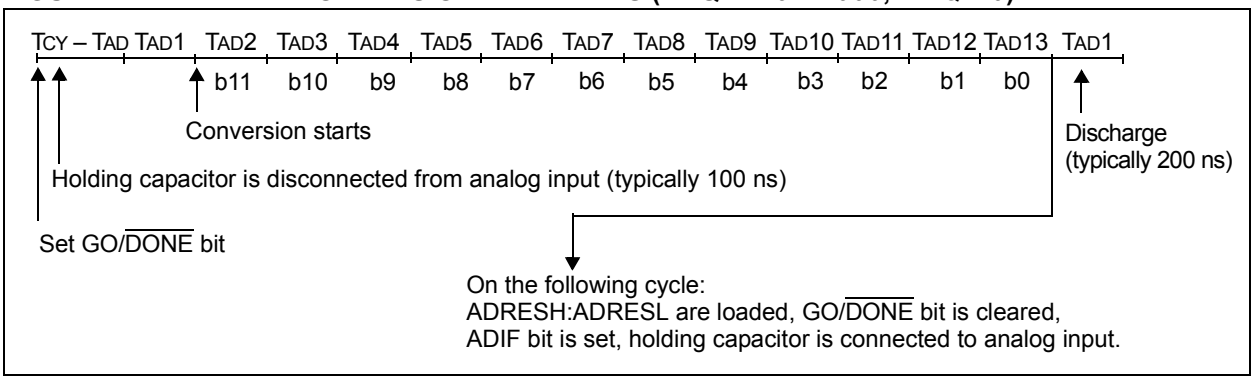
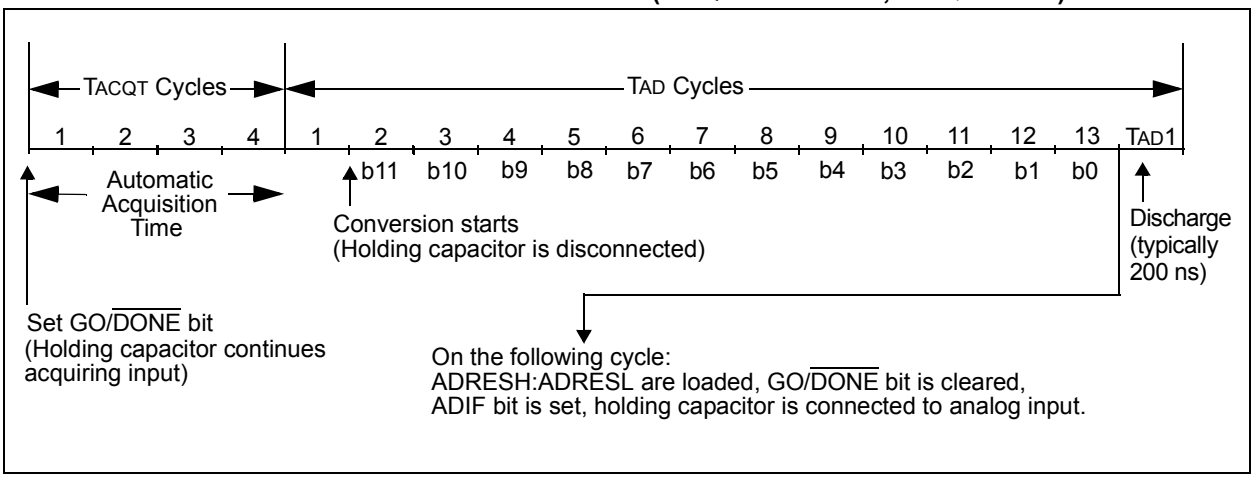


FIGURE 2-5: A/D CONVERSION TAD CYCLES (ACQT<2:0> = 010, TACQ = 4 TAD)



2.8 Use of the CCP2 Trigger

An A/D conversion can be started by the Special Event Trigger of the CCP2 module. This requires that the CCP2M3:CCP2M0 bits (CCP2CON<3:0>) be programmed as '1011' and that the A/D module is enabled (ADON bit is set). When the trigger occurs, the GO/DONE bit will be set, starting the A/D acquisition and conversion, and the Timer1 (or Timer3) counter will be reset to zero. Timer1 (or Timer3) is reset to automatically repeat the A/D acquisition period with minimal software overhead (firmware must move ADRESH:ADRESL to the desired location). The appropriate analog input channel must be selected and the minimum acquisition period is either timed by the user, or an appropriate TACQ time selected before the Special Event Trigger sets the GO/DONE bit (starts a conversion).

If the A/D module is not enabled (ADON is cleared), the Special Event Trigger will be ignored by the A/D module, but will still reset the Timer1 (or Timer3) counter.

TABLE 2-2: REGISTERS ASSOCIATED WITH A/D OPERATION

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Reset Values on Page:
INTCON	GIE/GIEH	PEIE/GIEL	TMR0IE	INT0IE	RBIE	TMR0IF	INT0IF	RBIF	(4)
PIR1	SPPIF(1)	ADIF	RCIF	TXIF	SSPIF	CCP1IF	TMR2IF	TMR1IF	(4)
PIE1	SPPIE(1)	ADIE	RCIE	TXIE	SSPIE	CCP1IE	TMR2IE	TMR1IE	(4)
IPR1	SPPIP(1)	ADIP	RCIP	TXIP	SSPIP	CCP1IP	TMR2IP	TMR1IP	(4)
PIR2	OSCFIF	CMIF	USBIF	EEIF	BCLIF	HLVDIF	TMR3IF	CCP2IF	(4)
PIE2	OSCFIE	CMIE	USBIE	EEIE	BCLIE	HLVDIE	TMR3IE	CCP2IE	(4)
IPR2	OSCFIP	CMIP	USBIP	EEIP	BCLIP	HLVDIP	TMR3IP	CCP2IP	(4)
ADRESH	A/D Result Register High Byte								(4)
ADRESL	A/D Result Register Low Byte								(4)
ADCON0	—	—	CHS3	CHS2	CHS1	CHS0	GO/DONE	ADON	21
ADCON1	—	—	VCFG1	VCFG0	PCFG3	PCFG2	PCFG1	PCFG0	22
ADCON2	ADFM	—	ACQT2	ACQT1	ACQT0	ADCS2	ADCS1	ADCS0	23
PORTA	—	RA6(2)	RA5	RA4	RA3	RA2	RA1	RA0	(4)
TRISA	—	TRISA6(2)	PORTA Data Direction Control Register						(4)
PORTB	RB7	RB6	RB5	RB4	RB3	RB2	RB1	RB0	(4)
TRISB	PORTB Data Direction Control Register								(4)
LATB	PORTB Data Latch Register (Read and Write to Data Latch)								(4)
PORTE(1)	RDPU	—	—	—	RE3(3)	RE2(1)	RE1(1)	RE0(1)	(4)
TRISE(1)	—	—	—	—	—	TRISE2	TRISE1	TRISE0	(4)
LATE(1)	—	—	—	—	—	PORTE Data Latch Register			(4)

Legend: — = unimplemented, read as '0'. Shaded cells are not used for A/D conversion.

Note 1: These registers and/or bits are not implemented on 28-pin devices and are read as '0'.

2: RA6 and its associated latch and data direction bits are enabled as I/O pins based on oscillator configuration; otherwise, they are read as '0'.

3: RE3 port bit is available only as an input pin when the MCLRE Configuration bit is '0'.

4: For these Reset values, see the *"PIC18F2455/2550/4455/4550 Data Sheet"*.

3.0 SPECIAL FEATURES OF THE CPU

Note: For additional details on the Configuration bits, refer to the *"PIC18F2455/2550/4455/4550 Data Sheet"*, **Section 25.1 "Configuration Bits"**. Device ID information presented in this section is for PIC18F2458/2553/4458/4553 only.

PIC18F2458/2553/4458/4553 devices include several features intended to maximize reliability and minimize cost through elimination of external components. These include:

- Device ID Registers

3.1 Device ID Registers

The Device ID registers are "read-only" registers. They identify the device type and revision to device programmers, and can be read by firmware using table reads.

TABLE 3-1: DEVICE IDs

File Name		Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Default/ Unprogrammed Value
3FFFFEh	DEVID1	DEV2	DEV1	DEV0	REV4	REV3	REV2	REV1	REV0	xxxx xxxx(1)
3FFFFFh	DEVID2	DEV10	DEV9	DEV8	DEV7	DEV6	DEV5	DEV4	DEV3	xxxx xxxx(1)

Legend: x = unknown, u = unchanged

Note 1: See Register 3-1 and Register 3-2 for DEVID values. DEVID registers are read-only and cannot be programmed by the user.

REGISTER 3-1: DEVID1: DEVICE ID REGISTER 1 FOR PIC18F2458/2553/4458/4553 DEVICES

R	R	R	R	R	R	R	R
DEV2	DEV1	DEV0	REV4	REV3	REV2	REV1	REV0
bit 7							bit 0

Legend:		
R = Read-only bit	P = Programmable bit	U = Unimplemented bit, read as ‘0’
-n = Value when device is unprogrammed		u = Unchanged from programmed state

bit 7-5 **DEV2:DEV0:** Device ID bits
See Register 3-2 for a complete listing.

bit 4-0 **REV3:REV0:** Revision ID bits
These bits are used to indicate the device revision.

REGISTER 3-2: DEVID2: DEVICE ID REGISTER 2 FOR PIC18F2458/2553/4458/4553 DEVICES

R	R	R	R	R	R	R	R
DEV10	DEV9	DEV8	DEV7	DEV6	DEV5	DEV4	DEV3
bit 7							bit 0

Legend:		
R = Read-only bit	P = Programmable bit	U = Unimplemented bit, read as ‘0’
-n = Value when device is unprogrammed		u = Unchanged from programmed state

bit 7-0 **DEV10:DEV3:** Device ID bits

DEV10:DEV3 (DEVID2<7:0>)	**DEV2:DEV0 (DEVID1<7:5>)**	**Device**
0010 1010	011	PIC18F2458
0010 1010	010	PIC18F2553
0010 1010	001	PIC18F4458
0010 1010	000	PIC18F4553

4.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings (†)

Ambient temperature under bias ..... -40°C to +125°C
Storage temperature ..... -65°C to +150°C
Voltage on any pin with respect to V_{SS} (except V_{DD} and $\overline{MCLR}$) ..... -0.3V to (V_{DD} + 0.3V)
Voltage on V_{DD} with respect to V_{SS} ..... -0.3V to +7.5V
Voltage on $\overline{MCLR}$ with respect to V_{SS} **(Note 2)** ..... 0V to +13.25V
Total power dissipation **(Note 1)** 1.0W
Maximum current out of V_{SS} pin ..... 300 mA
Maximum current into V_{DD} pin ..... 250 mA
Input clamp current, I_{IK} (V_I < 0 or V_I > V_{DD}) ..... ±20 mA
Output clamp current, I_{OK} (V_O < 0 or V_O > V_{DD}) ..... ±20 mA
Maximum output current sunk by any I/O pin ..... 25 mA
Maximum output current sourced by any I/O pin ..... 25 mA
Maximum current sunk by all ports ..... 200 mA
Maximum current sourced by all ports ..... 200 mA

Note 1: Power dissipation is calculated as follows:
$P_{dis} = V_{DD} \times \{I_{DD} - \sum I_{OH}\} + \sum \{(V_{DD} - V_{OH}) \times I_{OH}\} + \sum(V_{OL} \times I_{OL})$

2: Voltage spikes below V_{SS} at the $\overline{MCLR}$/V_{PP}/RE3 pin, inducing currents greater than 80 mA, may cause latch-up. Thus, a series resistor of 50-100Ω should be used when applying a "low" level to the $\overline{MCLR}$/V_{PP}/RE3 pin, rather than pulling this pin directly to V_{SS}.

† **NOTICE:** Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operation listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

FIGURE 4-1: PIC18F2458/2553/4458/4553 VOLTAGE-FREQUENCY GRAPH (INDUSTRIAL)

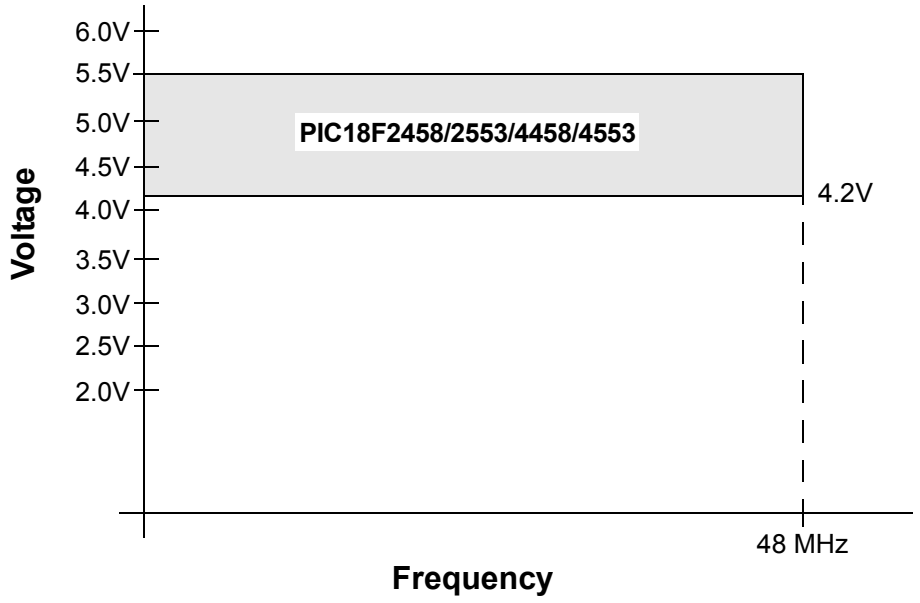
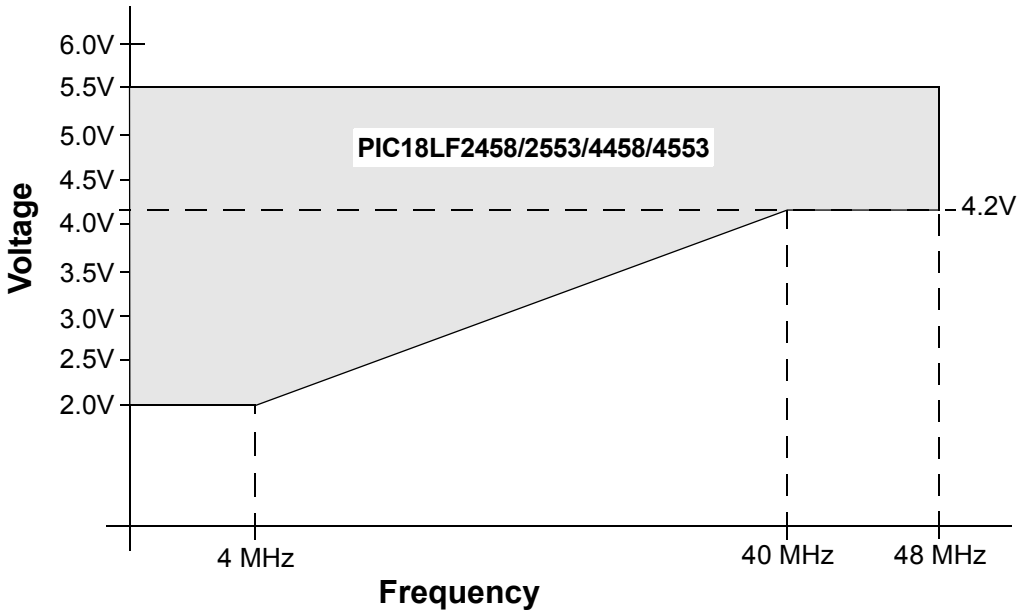


FIGURE 4-2: PIC18LF2458/2553/4458/4553 VOLTAGE-FREQUENCY GRAPH (INDUSTRIAL)



For 2.0V ≤ V_{DD} < 4.2V: F_{MAX} = (16.36 MHz/V) ($V_{DDAPPMIN}$ – 2.0V) + 4 MHz
For 4.2V ≤ V_{DD}: F_{MAX} = 48 MHz

Note: $V_{DDAPPMIN}$ is the minimum voltage of the PIC® device in the application.

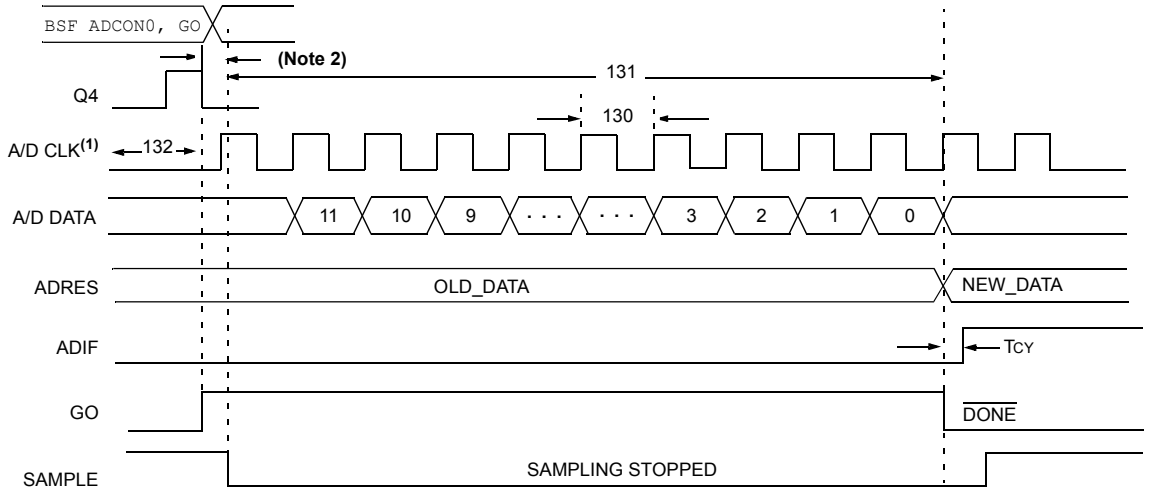
TABLE 4-1: A/D CONVERTER CHARACTERISTICS: PIC18F2458/2553/4458/4553 (INDUSTRIAL)
PIC18LF2458/2553/4458/4553 (INDUSTRIAL)

Param No.	Sym	Characteristic	Min	Typ	Max	Units	Conditions	
A01	NR	Resolution	—	—	12	bit		ΔVREF ≥ 3.0V
A03	EIL	Integral Linearity Error	—	±1	±2.0	LSB	VDD = 3.0V	ΔVREF ≥ 3.0V
			—	—	±2.0	LSB	VDD = 5.0V	
A04	EDL	Differential Linearity Error	—	±1	+1.5/-1.0	LSB	VDD = 3.0V	ΔVREF ≥ 3.0V
			—	—	+1.5/-1.0	LSB	VDD = 5.0V	
A06	EOFF	Offset Error	—	±1	±5	LSB	VDD = 3.0V	ΔVREF ≥ 3.0V
			—	—	±3	LSB	VDD = 5.0V	
A07	EGN	Gain Error	—	±1	±1.25	LSB	VDD = 3.0V	ΔVREF ≥ 3.0V
			—	—	±2.00	LSB	VDD = 5.0V	
A10	—	Monotonicity	Guaranteed(1)			—		VSS ≤ VAIN ≤ VREF
A20	ΔVREF	Reference Voltage Range (VREFH – VREFL)	3	—	VDD – VSS	V		For 12-bit resolution
A21	VREFH	Reference Voltage High	VSS + 3.0V	—	VDD + 0.3V	V		For 12-bit resolution
A22	VREFL	Reference Voltage Low	VSS – 0.3V	—	VDD – 3.0V	V		For 12-bit resolution
A25	VAIN	Analog Input Voltage	VREFL	—	VREFH	V		
A30	ZAIN	Recommended Impedance of Analog Voltage Source	—	—	2.5	kΩ		
A50	IREF	VREF Input Current(2)	— —	— —	5 150	μA μA		During VAIN acquisition. During A/D conversion cycle.

Note 1: The A/D conversion result never decreases with an increase in the input voltage and has no missing codes.

2: VREFH current is from the RA3/AN3/VREF+ pin or VDD, whichever is selected as the VREFH source. VREFL current is from the RA2/AN2/VREF-/CVREF pin or VSS, whichever is selected as the VREFL source.

FIGURE 4-3: A/D CONVERSION TIMING



Note 1: If the A/D clock source is selected as RC, a time of TCY is added before the A/D clock starts. This allows the SLEEP instruction to be executed.

2: This is a minimal RC delay (typically 100 ns), which also disconnects the holding capacitor from the analog input.

TABLE 4-2: A/D CONVERSION REQUIREMENTS

Param No.	Symbol	Characteristic		Min	Max	Units	Conditions
130	TAD	A/D Clock Period	PIC18**F**XXXX	0.8	12.5(1)	µs	TOSC based, VREF ≥ 3.0V
			PIC18**LF**XXXX	1.4	25.0(1)	µs	VDD = 3.0V; TOSC based, VREF full range
			PIC18**F**XXXX	—	1	µs	A/D RC mode
			PIC18**LF**XXXX	—	3	µs	VDD = 3.0V; A/D RC mode
131	TCNV	Conversion Time (not including acquisition time)(2)		13	14	TAD	
132	TACQ	Acquisition Time(3)		1.4	—	µs	
135	TSWC	Switching Time from Convert → Sample		—	**(Note 4)**		
137	TDIS	Discharge Time		0.2	—	µs	

Note 1: The time of the A/D clock period is dependent on the device frequency and the TAD clock divider.

2: ADRES registers may be read on the following TCY cycle.

3: The time for the holding capacitor to acquire the "New" input voltage when the voltage changes full scale after the conversion (VDD to VSS or VSS to VDD). The source impedance (RS) on the input channels is 50Ω.

4: On the following cycle of the device clock.

5.0 PACKAGING INFORMATION

For packaging information, see the *"PIC18F2455/2550/4455/4550 Data Sheet"* (DS39632).

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (May 2007)

Original data sheet for the PIC18F2458/2553/4458/4553 devices.

Revision B (June 2007)

Changes to Figure 4-2: PIC18LF2458/2553/4458/4553 Voltage-Frequency Graph (Industrial).

Revision C (October 2009)

Removed “Preliminary” marking.

APPENDIX B: DEVICE DIFFERENCES

The differences between the devices listed in this data sheet are shown in Table B-1.

TABLE B-1: DEVICE DIFFERENCES

Features	PIC18F2458	PIC18F2553	PIC18F4458	PIC18F4553
Program Memory (Bytes)	24576	32768	24576	32768
Program Memory (Instructions)	12288	16384	12288	16384
Interrupt Sources	19	19	20	20
I/O Ports	Ports A, B, C, (E)	Ports A, B, C, (E)	Ports A, B, C, D, E	Ports A, B, C, D, E
Capture/Compare/PWM Modules	2	2	1	1
Enhanced Capture/Compare/ PWM Modules	0	0	1	1
Parallel Communications (SPP)	No	No	Yes	Yes
12-Bit Analog-to-Digital Module	10 Input Channels	10 Input Channels	13 Input Channels	13 Input Channels
Packages	28-Pin SPDIP 28-Pin SOIC	28-Pin SPDIP 28-Pin SOIC	40-Pin PDIP 44-Pin TQFP 44-Pin QFN	40-Pin PDIP 44-Pin TQFP 44-Pin QFN

APPENDIX C: MIGRATION FROM MID-RANGE TO ENHANCED DEVICES

A detailed discussion of the differences between the mid-range MCU devices (i.e., PIC16CXXX) and the enhanced devices (i.e., PIC18FXXX) is provided in *AN716, "Migrating Designs from PIC16C74A/74B to PIC18C442"*. The changes discussed, while device specific, are generally applicable to all mid-range to enhanced device migrations.

This Application Note is available as Literature Number DS00716.

APPENDIX D: MIGRATION FROM HIGH-END TO ENHANCED DEVICES

A detailed discussion of the migration pathway and differences between the high-end MCU devices (i.e., PIC17CXXX) and the enhanced devices (i.e., PIC18FXXX) is provided in *AN726, "PIC17CXXX to PIC18CXXX Migration"*.

This Application Note is available as Literature Number DS00726.

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Device: PIC18F2458/2553/4458/4553 Literature Number: DS39887C

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3. Do you find the organization of this document easy to follow? If not, why?

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To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.	X	/XX	XXX
Device	Temperature Range	Package	Pattern

Device	PIC18F2458/2553(1), PIC18F4458/4553(1), PIC18F2458/2553T(2), PIC18F4458/4553T(2); VDD range 4.2V to 5.5V PIC18LF2458/2553(1), PIC18LF4458/4553(1), PIC18LF2458/2553T(2), PIC18LF4458/4553T(2); VDD range 2.0V to 5.5V
Temperature Range	I = -40°C to +85°C (Industrial) E = -40°C to +125°C (Extended)
Package	PT = TQFP (Thin Quad Flatpack) SO = SOIC SP = Skinny PDIP P = PDIP ML = QFN
Pattern	QTP, SQTP, Code or Special Requirements (blank otherwise)

Examples:

a) PIC18LF4553-I/P 301 = Industrial temp., PDIP package, Extended VDD limits, QTP pattern #301.

b) PIC18LF2458-I/SO = Industrial temp., SOIC package, Extended VDD limits.

c) PIC18F4458-I/P = Industrial temp., PDIP package, normal VDD limits.

Note 1: F = Standard Voltage Range
LF = Wide Voltage Range

2: T = In tape and reel TQFP packages only.

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