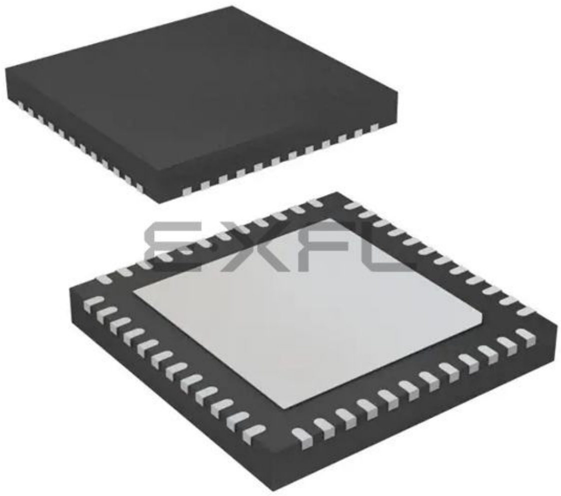

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What is "Embedded - Microcontrollers"?

"Embedded - Microcontrollers" refer to small, integrated circuits designed to perform specific tasks within larger systems. These microcontrollers are essentially compact computers on a single chip, containing a processor core, memory, and programmable input/output peripherals. They are called "embedded" because they are embedded within electronic devices to control various functions, rather than serving as standalone computers. Microcontrollers are crucial in modern electronics, providing the intelligence and control needed for a wide range of applications.

Applications of "Embedded - Microcontrollers"

Details	
Product Status	Obsolete
Core Processor	PIC
Core Size	16-Bit
Speed	32MHz
Connectivity	I²C, IrDA, LINbus, SPI, UART/USART
Peripherals	Brown-out Detect/Reset, LVD, POR, PWM, WDT
Number of I/O	38
Program Memory Size	16KB (5.5K x 24)
Program Memory Type	FLASH
EEPROM Size	512 x 8
RAM Size	1K x 8
Voltage - Supply (Vcc/Vdd)	1.8V ~ 3.6V
Data Converters	A/D 22x10b/12b
Oscillator Type	Internal
Operating Temperature	-40°C ~ 85°C (TA)
Mounting Type	Surface Mount
Package / Case	48-UFQFN Exposed Pad
Supplier Device Package	48-UQFN (6x6)
Purchase URL	https://www.e-xfl.com/product-detail/microchip-technology/pic24f16km104t-i-mv

TABLE 1-5: PIC24FV16KM204 FAMILY PINOUT DESCRIPTION (CONTINUED)

Function	F					FV					I/O	Buffer	Description
	Pin Number					Pin Number							
	20-Pin PDIP/ SSOP/ SOIC	28-Pin PDIP/ SSOP/ SOIC	28-Pin QFN	44-Pin QFN/ TQFP	48-Pin UQFN	20-Pin PDIP/ SSOP/ SOIC	28-Pin PDIP/ SSOP/ SOIC	28-Pin QFN	44-Pin QFN/ TQFP	48-Pin UQFN			
CTED1	11	20	17	7	7	11	2	27	19	21	I	ST	CTMU Trigger Edge Inputs
CTED2	15	23	20	10	11	15	23	20	10	11	I	ST	CTMU Trigger Edge Inputs
CTED3	—	19	16	6	6	—	19	16	6	6	I	ST	CTMU Trigger Edge Inputs
CTED4	13	18	15	1	1	13	18	15	1	1	I	ST	CTMU Trigger Edge Inputs
CTED5	17	25	22	14	15	17	25	22	14	15	I	ST	CTMU Trigger Edge Inputs
CTED6	18	26	23	15	16	18	26	23	15	16	I	ST	CTMU Trigger Edge Inputs
CTED7	—	—	—	5	5	—	—	—	5	5	I	ST	CTMU Trigger Edge Inputs
CTED8	—	—	—	13	14	—	—	—	13	14	I	ST	CTMU Trigger Edge Inputs
CTED9	—	22	19	9	10	—	22	19	9	10	I	ST	CTMU Trigger Edge Inputs
CTED10	12	17	14	44	48	12	17	14	44	48	I	ST	CTMU Trigger Edge Inputs
CTED11	—	21	18	8	9	—	21	18	8	9	I	ST	CTMU Trigger Edge Inputs
CTED12	5	5	2	22	24	5	5	2	22	24	I	ST	CTMU Trigger Edge Inputs
CTED13	6	6	3	23	25	6	6	3	23	25	I	ST	CTMU Trigger Edge Inputs
CTPLS	16	24	21	11	12	16	24	21	11	12	O	—	CTMU Pulse Output
CVREF	17	25	22	14	15	17	25	22	14	15	O	ANA	Comparator Voltage Reference Output
CVREF+	2	2	27	19	21	2	2	27	19	21	I	ANA	Comparator Voltage Reference Positive Input
CVREF-	3	3	28	20	22	3	3	28	20	22	I	ANA	Comparator Voltage Reference Negative Input
DAC1OUT	—	23	20	10	11	—	23	20	10	11	O	ANA	DAC1 Output
DAC1REF+	—	2	27	19	21	—	2	27	19	21	I	ANA	DAC1 Positive Voltage Reference Input
DAC2OUT	—	25	22	14	15	—	25	22	14	15	O	ANA	DAC2 Output
DAC2REF+	—	26	23	15	16	—	26	23	15	16	I	ANA	DAC2 Positive Voltage Reference Input
HLVDIN	15	23	20	10	11	15	23	20	10	11	I	ANA	External High/Low-Voltage Detect Input
IC1	14	19	16	6	6	11	19	16	6	6	I	ST	MCCP1 Input Capture Input
IC2	13	18	15	1	1	13	18	15	1	1	I	ST	MCCP2 Input Capture Input
IC3	—	23	20	13	14	—	23	20	13	14	I	ST	MCCP3 Input Capture Input
IC4	—	14	11	5	5	—	14	11	5	5	I	ST	SCCP4 Input Capture Input
IC5	—	15	12	12	13	—	15	12	12	13	I	ST	SCCP5 Input Capture Input
INT0	11	16	13	43	47	11	16	13	43	47	I	ST	External Interrupt 0 Input
INT1	17	25	22	14	15	17	25	22	14	15	I	ST	External Interrupt 1 Input
INT2	14	20	17	7	7	15	23	20	10	11	I	ST	External Interrupt 2 Input

Legend: ANA = Analog level input/output, ST = Schmitt Trigger input buffer, I^2C™ = I^2C/SMBus input buffer

TABLE 4-3: CPU CORE REGISTERS MAP

File Name	Addr.	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	All Resets
WREG0	0h	WREG0																0000
WREG1	2h	WREG1																0000
WREG2	4h	WREG2																0000
WREG3	6h	WREG3																0000
WREG4	8h	WREG4																0000
WREG5	Ah	WREG5																0000
WREG6	Ch	WREG6																0000
WREG7	Eh	WREG7																0000
WREG8	10h	WREG8																0000
WREG9	12h	WREG9																0000
WREG10	14h	WREG10																0000
WREG11	16h	WREG11																0000
WREG12	18h	WREG12																0000
WREG13	1Ah	WREG13																0000
WREG14	1Ch	WREG14																0000
WREG15	1Eh	WREG15																0800
SPLIM	20h	SPLIM Register																xxxx
PCL	2Eh	PCL Register																0000
PCH	30h	—	—	—	—	—	—	—	—	PCH7	PCH6	PCH5	PCH4	PCH3	PCH2	PCH1	PCH0	0000
TBLPAG	32h	—	—	—	—	—	—	—	—	TBLPAG7	TBLPAG6	TBLPAG5	TBLPAG4	TBLPAG3	TBLPAG2	TBLPAG1	TBLPAG0	0000
PSVPAG	34h	—	—	—	—	—	—	—	—	PSVPAG7	PSVPAG6	PSVPAG5	PSVPAG4	PSVPAG3	PSVPAG2	PSVPAG1	PSVPAG0	0000
RCOUNT	36h	RCOUNT Register																xxxx
SR	42h	—	—	—	—	—	—	—	DC	IPL2	IPL1	IPL0	RA	N	OV	Z	C	0000
CORCON	44h	—	—	—	—	—	—	—	—	—	—	—	—	IPL3	PSV	—	—	0000
DISICNT	52h	—	—	DISICNT13	DISICNT12	DISICNT11	DISICNT10	DISICNT9	DISICNT8	DISICNT7	DISICNT6	DISICNT5	DISICNT4	DISICNT3	DISICNT2	DISICNT1	DISICNT0	xxxx

Legend: x = unknown, u = unchanged, — = unimplemented, q = value depends on condition, r = reserved.

TABLE 4-12: SCCP5 REGISTER MAP

File Name	Addr.	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	All Resets
CCP5CON1L(1)	1D0h	CCPON	—	CCPSIDL	r	TMRSYNC	CLKSEL2	CLKSEL1	CLKSEL0	TMRPS1	TMRPS0	T32	CCSEL	MOD3	MOD2	MOD1	MOD0	0000
CCP5CON1H(1)	1D2h	OPSSRC	RTRGEN	—	—	IOPS3	IOPS2	IOPS1	IOPS0	TRIGEN	ONESHOT	ALTSYNC	SYNC4	SYNC3	SYNC2	SYNC1	SYNC0	0000
CCP5CON2L(1)	1D4h	PWMRSEN	ASDGM	—	SSDG	—	—	—	—	ASDG7	ASDG6	ASDG5	ASDG4	ASDG3	ASDG2	ASDG1	ASDG0	0000
CCP5CON2H(1)	1D6h	OENSYNC	—	—	—	—	—	—	OCAEN	ICGSM1	ICGSM0	—	AUXOUT1	AUXOUT0	ICSEL2	ICSEL1	ICSEL0	0100
CCP5CON3H(1)	1DAh	OETRIG	OSCNT2	OSCNT1	OSCNT0	—	—	—	—	—	—	POLACE	—	PSSACE1	PSSACE0	—	—	0000
CCP5STATL(1)	1DCh	—	—	—	—	—	—	—	—	CCPTRIG	TRSET	TRCLR	ASEVT	SCEVT	ICDIS	ICOV	ICBNE	0000
CCP5TMRL(1)	1E0h	SCCP5 Time Base Register Low Word																0000
CCP5TMRH(1)	1E2h	SCCP5 Time Base Register High Word																0000
CCP5PRL(1)	1E4h	SCCP5 Time Base Period Register Low Word																FFFF
CCP5PRH(1)	1E6h	SCCP5 Time Base Period Register High Word																FFFF
CCP5RAL(1)	1E8h	Output Compare 5 Data Word A																0000
CCP5RBL(1)	1ECh	Output Compare 5 Data Word B																0000
CCP5BUFL(1)	1F0h	Input Capture 5 Data Buffer Low Word																0000
CCP5BUFH(1)	1F2h	Input Capture 5 Data Buffer High Word																0000

Legend: x = unknown, u = unchanged, — = unimplemented, q = value depends on condition, r = reserved.
Note 1: These registers are available only on PIC24F(V)16KM2XX devices.

7.1 Clock Source Selection at Reset

If clock switching is enabled, the system clock source at device Reset is chosen, as shown in Table 7-2. If clock switching is disabled, the system clock source is always selected according to the Oscillator Configuration bits. For more information, see **Section 9.0 "Oscillator Configuration"**.

TABLE 7-2: OSCILLATOR SELECTION vs. TYPE OF RESET (CLOCK SWITCHING ENABLED)

Reset Type	Clock Source Determinant
POR	FNOSC<2:0> Configuration bits (FOSCSEL<2:0>)
BOR	
$\overline{\text{MCLR}}$	COSC<2:0> Control bits (OSCCON<14:12>)
WDTO	
SWR	

7.2 Device Reset Times

The Reset times for various types of device Reset are summarized in Table 7-3. Note that the system Reset signal, $\overline{\text{SYSRST}}$, is released after the POR and PWRT delay times expire.

The time at which the device actually begins to execute code will also depend on the system oscillator delays, which include the Oscillator Start-up Timer (OST) and the PLL lock time. The OST and PLL lock times occur in parallel with the applicable $\overline{\text{SYSRST}}$ delay times.

The FSCM delay determines the time at which the FSCM begins to monitor the system clock source after the $\overline{\text{SYSRST}}$ signal is released.

TABLE 7-3: RESET DELAY TIMES FOR VARIOUS DEVICE RESETS

Reset Type	Clock Source	$\overline{\text{SYSRST}}$ Delay	System Clock Delay	Notes
POR[6]	EC	TPOR + TPWRT	—	**1, 2**
	FRC, FRCDIV	TPOR + TPWRT	TFRC	**1, 2, 3**
	LPRC	TPOR + TPWRT	TLPRC	**1, 2, 3**
	ECPLL	TPOR + TPWRT	TLOCK	**1, 2, 4**
	FRCPLL	TPOR + TPWRT	TFRC + TLOCK	**1, 2, 3, 4**
	XT, HS, SOSC	TPOR+ TPWRT	TOST	**1, 2, 5**
	XTPLL, HSPLL	TPOR + TPWRT	TOST + TLOCK	**1, 2, 4, 5**
BOR	EC	TPWRT	—	**2**
	FRC, FRCDIV	TPWRT	TFRC	**2, 3**
	LPRC	TPWRT	TLPRC	**2, 3**
	ECPLL	TPWRT	TLOCK	**2, 4**
	FRCPLL	TPWRT	TFRC + TLOCK	**2, 3, 4**
	XT, HS, SOSC	TPWRT	TOST	**2, 5**
	XTPLL, HSPLL	TPWRT	TFRC + TLOCK	**2, 3, 4**
All Others	Any Clock	—	—	**None**

Note 1: TPOR = Power-on Reset delay.
2: TPWRT = 64 ms nominal if the Power-up Timer is enabled; otherwise, it is zero.
3: TFRC and TLPRC = RC Oscillator start-up times.
4: TLOCK = PLL Lock time.
5: TOST = Oscillator Start-up Timer (OST). A 10-bit counter waits 1024 oscillator periods before releasing the oscillator clock to the system.
6: If Two-Speed Start-up is enabled, regardless of the Primary Oscillator selected, the device starts with FRC, and in such cases, FRC start-up time is valid.

Note: For detailed operating frequency and timing specifications, see **Section 27.0 "Electrical Characteristics"**.

15.0 UNIVERSAL ASYNCHRONOUS RECEIVER TRANSMITTER (UART)

Note:	This data sheet summarizes the features of this group of PIC24F devices. It is not intended to be a comprehensive reference source. For more information on the Universal Asynchronous Receiver Transmitter, refer to the *"PIC24F Family Reference Manual"*, **"UART"** (DS39708).

The Universal Asynchronous Receiver Transmitter (UART) module is one of the serial I/O modules available in this PIC24F device family. The UART is a full-duplex, asynchronous system that can communicate with peripheral devices, such as personal computers, LIN/J2602, RS-232 and RS-485 interfaces. This module also supports a hardware flow control option with the $\overline{\text{UxCTS}}$ and $\overline{\text{UxRTS}}$ pins, and also includes an IrDA® encoder and decoder.

The primary features of the UART module are:

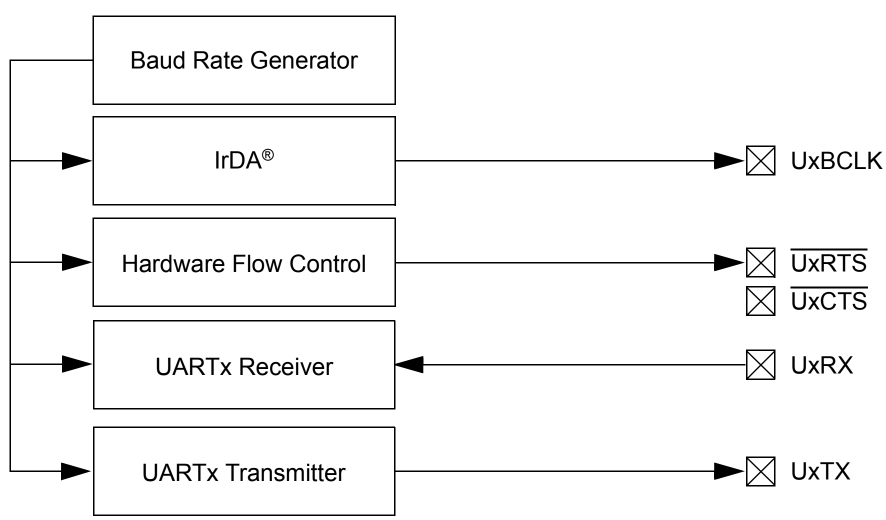
- Full-Duplex, 8-Bit or 9-Bit Data Transmission through the UxTX and UxRX Pins
- Even, Odd or No Parity Options (for 8-bit data)
- One or Two Stop bits
- Hardware Flow Control Option with $\overline{\text{UxCTS}}$ and $\overline{\text{UxRTS}}$ Pins
- Fully Integrated Baud Rate Generator (IBRG) with 16-Bit Prescaler
- Baud Rates Ranging from 1 Mbps to 15 bps at 16 MIPS
- 4-Deep, First-In-First-Out (FIFO) Transmit Data Buffer
- 4-Deep FIFO Receive Data Buffer
- Parity, Framing and Buffer Overrun Error Detection
- Support for 9-Bit mode with Address Detect (9^{th} bit = 1)
- Transmit and Receive Interrupts
- Loopback mode for Diagnostic Support
- Support for Sync and Break Characters
- Supports Automatic Baud Rate Detection
- IrDA® Encoder and Decoder Logic
- 16x Baud Clock Output for IrDA Support

A simplified block diagram of the UARTx module is shown in Figure 15-1. The UARTx module consists of these important hardware elements:

- Baud Rate Generator
- Asynchronous Transmitter
- Asynchronous Receiver

Note:	Throughout this section, references to register and bit names that may be associated with a specific USART module are referred to generically by the use of 'x' in place of the specific module number. Thus, "UxSTA" might refer to the USART Status register for either USART1 or USART2.

FIGURE 15-1: UARTx MODULE SIMPLIFIED BLOCK DIAGRAM



REGISTER 16-3: ALCFGRPT: ALARM CONFIGURATION REGISTER

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
ALRMEN	CHIME	AMASK3	AMASK2	AMASK1	AMASK0	ALRMPTR1	ALRMPTR0
bit 15							bit 8

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
ARPT7	ARPT6	ARPT5	ARPT4	ARPT3	ARPT2	ARPT1	ARPT0
bit 7							bit 0

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

bit 15 **ALRMEN:** Alarm Enable bit

1 = Alarm is enabled (cleared automatically after an alarm event whenever ARPT<7:0> = 00h and CHIME = 0)
0 = Alarm is disabled

bit 14 **CHIME:** Chime Enable bit

1 = Chime is enabled; ARPT<7:0> bits are allowed to roll over from 00h to FFh
0 = Chime is disabled; ARPT<7:0> bits stop once they reach 00h

bit 13-10 **AMASK<3:0>:** Alarm Mask Configuration bits

0000 = Every half second
0001 = Every second
0010 = Every 10 seconds
0011 = Every minute
0100 = Every 10 minutes
0101 = Every hour
0110 = Once a day
0111 = Once a week
1000 = Once a month
1001 = Once a year (except when configured for February 29th, once every 4 years)
101x = Reserved – do not use
11xx = Reserved – do not use

bit 9-8 **ALRMPTR<1:0>:** Alarm Value Register Window Pointer bits

Points to the corresponding Alarm Value registers when reading the ALRMVALH and ALRMVALL registers. The ALRMPTR<1:0> value decrements on every read or write of ALRMVALH until it reaches ‘00’.

<u>ALRMVAL<15:8>:</u>
00 = ALRMMIN
01 = ALRMWD
10 = ALRMMNTH
11 = Unimplemented

<u>ALRMVAL<7:0>:</u>
00 = ALRMSEC
01 = ALRMHR
10 = ALRMDAY
11 = Unimplemented

bit 7-0 **ARPT<7:0>:** Alarm Repeat Counter Value bits

11111111 = Alarm will repeat 255 more times
.
.
.
00000000 = Alarm will not repeat
The counter decrements on any alarm event; it is prevented from rolling over from 00h to FFh unless CHIME = 1.

16.2.6 ALRMVAL REGISTER MAPPINGS

REGISTER 16-8: ALMTHDY: ALARM MONTH AND DAY VALUE REGISTER(1)

U-0	U-0	U-0	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x
—	—	—	MTHTEN0	MTHONE3	MTHONE2	MTHONE1	MTHONE0
bit 15							bit 8

U-0	U-0	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x
—	—	DAYTEN1	DAYTEN0	DAYONE3	DAYONE2	DAYONE1	DAYONE0
bit 7							bit 0

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

bit 15-13 **Unimplemented:** Read as ‘0’

bit 12 **MTHTEN0:** Binary Coded Decimal Value of Month’s Tens Digit bit
Contains a value of ‘0’ or ‘1’.

bit 11-8 **MTHONE<3:0>:** Binary Coded Decimal Value of Month’s Ones Digit bits
Contains a value from 0 to 9.

bit 7-6 **Unimplemented:** Read as ‘0’

bit 5-4 **DAYTEN<1:0>:** Binary Coded Decimal Value of Day’s Tens Digit bits
Contains a value from 0 to 3.

bit 3-0 **DAYONE<3:0>:** Binary Coded Decimal Value of Day’s Ones Digit bits
Contains a value from 0 to 9.

Note 1: A write to this register is only allowed when RTCWREN = 1.

REGISTER 16-9: ALWDHR: ALARM WEEKDAY AND HOURS VALUE REGISTER(1)

U-0	U-0	U-0	U-0	U-0	R/W-x	R/W-x	R/W-x
—	—	—	—	—	WDAY2	WDAY1	WDAY0
bit 15							bit 8

U-0	U-0	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x	R/W-x
—	—	HRTEN1	HRTEN0	HRONE3	HRONE2	HRONE1	HRONE0
bit 7							bit 0

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

bit 15-11 **Unimplemented:** Read as ‘0’

bit 10-8 **WDAY<2:0>:** Binary Coded Decimal Value of Weekday Digit bits
Contains a value from 0 to 6.

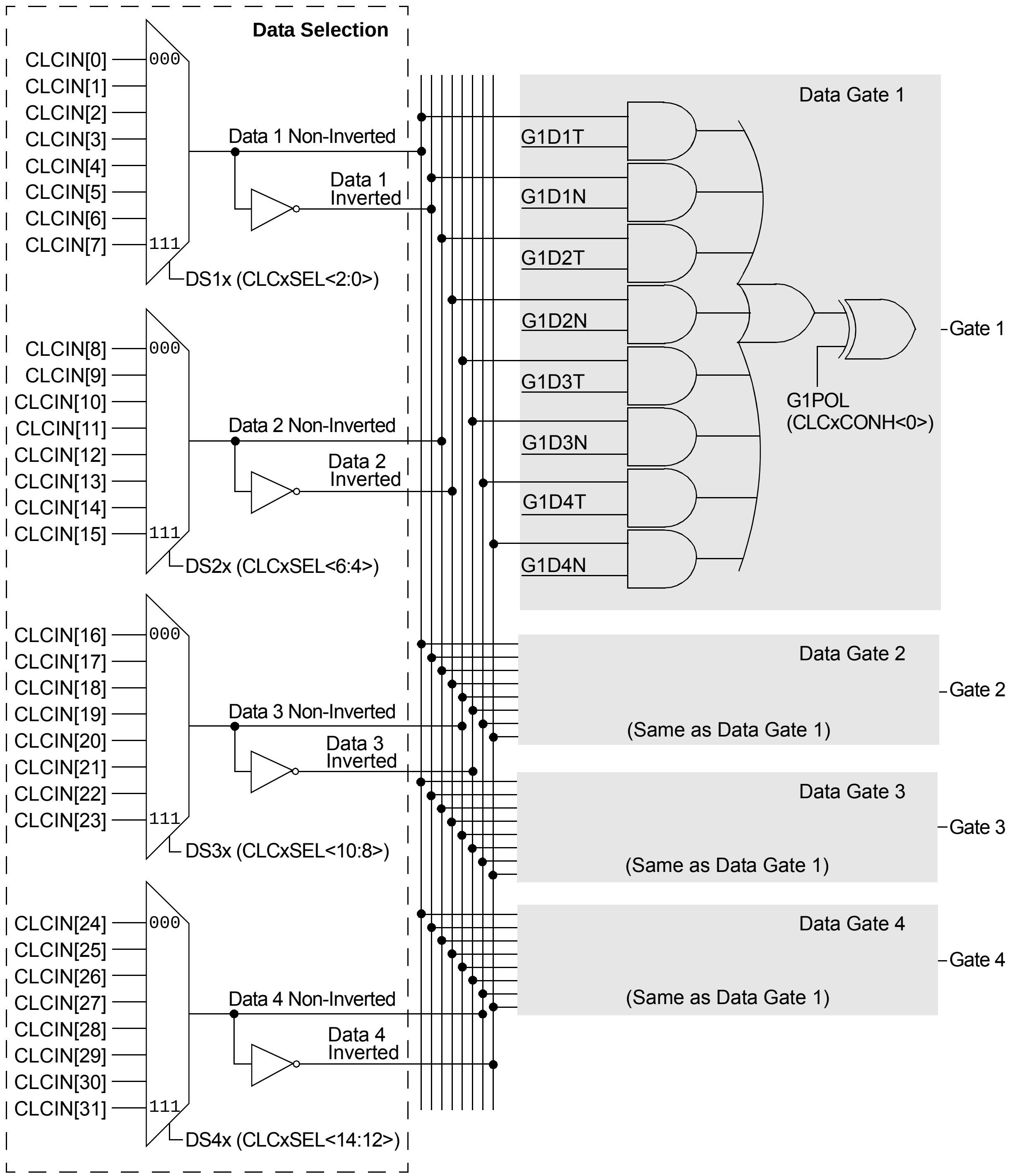
bit 7-6 **Unimplemented:** Read as ‘0’

bit 5-4 **HRTEN<1:0>:** Binary Coded Decimal Value of Hour’s Tens Digit bits
Contains a value from 0 to 2.

bit 3-0 **HRONE<3:0>:** Binary Coded Decimal Value of Hour’s Ones Digit bits
Contains a value from 0 to 9.

Note 1: A write to this register is only allowed when RTCWREN = 1.

FIGURE 17-3: CLCx INPUT SOURCE SELECTION DIAGRAM



Note: All controls are undefined at power-up.

REGISTER 17-3: CLCxSEL: CLCx INPUT MUX SELECT REGISTER (CONTINUED)

bit 6-4 **DS2<2:0>:** Data Selection MUX 2 Signal Selection bits

`111` = MCCP2 Compare Event Flag (CCP2IF)
`110` = MCCP1 Compare Event Flag (CCP1IF)
`101` = Digital logic low
`100` = A/D end of conversion event

For CLC1:
`011` = UART1 TX
`010` = Comparator 1 output
`001` = CLC2 output
`000` = CLCINB I/O pin

For CLC2:
`011` = UART2 TX
`010` = Comparator 1 output
`001` = CLC1 output
`000` = CLCINB I/O pin

bit 3 **Unimplemented:** Read as ‘`0`’

bit 2-0 **DS1<2:0>:** Data Selection MUX 1 Signal Selection bits

`111` = SCCP5 Compare Event Flag (CCP5IF)
`110` = SCCP4 Compare Event Flag (CCP4IF)
`101` = Digital logic low
`100` = 8 MHz FRC clock source
`011` = LPRC clock source
`010` = SOSC clock source
`001` = System clock (T_{CY})
`000` = CLCINA I/O pin

19.0 12-BIT A/D CONVERTER WITH THRESHOLD DETECT

Note:	This data sheet summarizes the features of this group of PIC24F devices. It is not intended to be a comprehensive reference source. For more information on the 12-Bit A/D Converter with Threshold Detect, refer to the *"PIC24F Family Reference Manual"*, **"12-Bit A/D Converter with Threshold Detect"** (DS39739).

The PIC24F 12-bit A/D Converter has the following key features:

- Successive Approximation Register (SAR) Conversion
- Conversion Speeds of up to 100 ksps
- Up to 32 Analog Input Channels (internal and external)
- Multiple Internal Reference Input Channels
- External Voltage Reference Input Pins
- Unipolar Differential Sample-and-Hold (S/H) Amplifier
- Automated Threshold Scan and Compare Operation to Pre-Evaluate Conversion Results
- Selectable Conversion Trigger Source
- Fixed-Length (one word per channel), Configurable Conversion Result Buffer
- Four Options for Results Alignment
- Configurable Interrupt Generation
- Operation During CPU Sleep and Idle modes

The 12-bit A/D Converter module is an enhanced version of the 10-bit module offered in some PIC24 devices. Both modules are Successive Approximation Register (SAR) converters at their cores, surrounded by a range of hardware features for flexible configuration. This version of the module extends functionality by providing 12-bit resolution, a wider range of automatic sampling options and tighter integration with other analog modules, such as the CTMU, and a configurable results buffer. There is a legacy 10-bit mode on this A/D to allow the option to run with lower resolution in order to obtain higher throughput. This module also includes a unique Threshold Detect feature that allows the module itself to make simple decisions based on the conversion results.

A simplified block diagram for the module is illustrated in Figure 19-1.

TABLE 19-2: NUMERICAL EQUIVALENTS OF VARIOUS RESULT CODES: 12-BIT FRACTIONAL FORMATS

VIN/VREF	12-Bit Output Code	16-Bit Fractional Format/ Equivalent Decimal Value		16-Bit Signed Fractional Format/ Equivalent Decimal Value	
+4095/4096	0 1111 1111 1111	1111 1111 1111 0000	0.999	0111 1111 1111 1000	0.999
+4094/4096	0 1111 1111 1110	1111 1111 1110 0000	0.998	0111 1111 1110 1000	0.998
• • •					
+1/4096	0 0000 0000 0001	0000 0000 0001 0000	0.001	0000 0000 0000 1000	0.001
0/4096	0 0000 0000 0000	0000 0000 0000 0000	0.000	0000 0000 0000 0000	0.000
-1/4096	1 0111 1111 1111	0000 0000 0000 0000	0.000	1111 1111 1111 1000	-0.001
• • •					
-4095/4096	1 0000 0000 0001	0000 0000 0000 0000	0.000	1000 0000 0000 1000	-0.999
-4096/4096	1 0000 0000 0000	0000 0000 0000 0000	0.000	1000 0000 0000 0000	-1.000

FIGURE 19-5: A/D OUTPUT DATA FORMATS (10-BIT)

RAM Contents:							d09	d08	d07	d06	d05	d04	d03	d02	d01	d00
Read to Bus:																
Integer	0	0	0	0	0	0	d09	d08	d07	d06	d05	d04	d03	d02	d01	d00
Signed Integer	s0	s0	s0	s0	s0	s0	d09	d08	d07	d06	d05	d04	d03	d02	d01	d00
Fractional (1.15)	d09	d08	d07	d06	d05	d04	d03	d02	d01	d00	0	0	0	0	0	0
Signed Fractional (1.15)	s0	d09	d08	d07	d06	d05	d04	d03	d02	d01	d00	0	0	0	0	0

TABLE 19-3: NUMERICAL EQUIVALENTS OF VARIOUS RESULT CODES: 10-BIT INTEGER FORMATS

VIN/VREF	10-Bit Differential Output Code (11-bit result)	16-Bit Integer Format/ Equivalent Decimal Value		16-Bit Signed Integer Format/ Equivalent Decimal Value	
+1023/1024	011 1111 1111	0000 0011 1111 1111	1023	0000 0001 1111 1111	1023
+1022/1024	011 1111 1110	0000 0011 1111 1110	1022	0000 0001 1111 1110	1022
• • •					
+1/1024	000 0000 0001	0000 0000 0000 0001	1	0000 0000 0000 0001	1
0/1024	000 0000 0000	0000 0000 0000 0000	0	0000 0000 0000 0000	0
-1/1024	101 1111 1111	0000 0000 0000 0000	0	1111 1111 1111 1111	-1
• • •					
-1023/1024	100 0000 0001	0000 0000 0000 0000	0	1111 1110 0000 0001	-1023
-1024/1024	100 0000 0000	0000 0000 0000 0000	0	1111 1110 0000 0000	-1024

REGISTER 21-1: AMPxCON: OP AMP x CONTROL REGISTER(1)

R/W-0	U-0	R/W-0	R/W-0	U-0	U-0	U-0	U-0
AMPEN	—	AMPSIDL	AMPSLP	—	—	—	—
bit 15							bit 8

R/W-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0
SPDSEL	—	NINSEL2	NINSEL1	NINSEL0	PINSEL2	PINSEL1	PINSEL0
bit 7							bit 0

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

bit 15 **AMPEN:** Op Amp x Control Module Enable bit
1 = Module is enabled
0 = Module is disabled

bit 14 **Unimplemented:** Read as '0'

bit 13 **AMPSIDL:** Op Amp x Peripheral Stop in Idle Mode bit
1 = Discontinues module operation when device enters Idle mode
0 = Continues module operation in Idle mode

bit 12 **AMPSLP:** Op Amp x Peripheral Enabled in Sleep Mode bit
1 = Continues module operation when device enters Sleep mode
0 = Discontinues module operation in Sleep mode

bit 11-8 **Unimplemented:** Read as '0'

bit 7 **SPDSEL:** Op Amp x Power/Speed Select bit
1 = Higher power and bandwidth (faster response time)
0 = Lower power and bandwidth (slower response time)

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

bit 5-3 **NINSEL<2:0>:** Negative Op Amp Input Select bits
111 = Reserved; do not use
110 = Reserved; do not use
101 = Op amp negative input is connected to the op amp output (voltage follower)
100 = Reserved; do not use
011 = Reserved; do not use
010 = Op amp negative input is connected to the OAxIND pin
001 = Op amp negative input is connected to the OAxINB pin
000 = Op amp negative input is connected to AV_{SS}

bit 2-0 **PINSEL<2:0>:** Positive Op Amp Input Select bits
111 = Op amp positive input is connected to the output of the A/D input multiplexer
110 = Reserved; do not use
101 = Op amp positive input is connected to the DAC1 output for OA1 (DAC2 output for OA2)
100 = Reserved; do not use
011 = Reserved; do not use
010 = Op amp positive input is connected to the OAxINC pin
001 = Op amp positive input is connected to the OAxINA pin
000 = Op amp positive input is connected to AV_{SS}

Note 1: This register is available only on PIC24F(V)16KM2XX devices.

NOTES:

26.6 MPLAB X SIM Software Simulator

The MPLAB X SIM Software Simulator allows code development in a PC-hosted environment by simulating the PIC MCUs and dsPIC DSCs on an instruction level. On any given instruction, the data areas can be examined or modified and stimuli can be applied from a comprehensive stimulus controller. Registers can be logged to files for further run-time analysis. The trace buffer and logic analyzer display extend the power of the simulator to record and track program execution, actions on I/O, most peripherals and internal registers.

The MPLAB X SIM Software Simulator fully supports symbolic debugging using the MPLAB XC Compilers, and the MPASM and MPLAB Assemblers. The software simulator offers the flexibility to develop and debug code outside of the hardware laboratory environment, making it an excellent, economical software development tool.

26.7 MPLAB REAL ICE In-Circuit Emulator System

The MPLAB REAL ICE In-Circuit Emulator System is Microchip's next generation high-speed emulator for Microchip Flash DSC and MCU devices. It debugs and programs all 8, 16 and 32-bit MCU, and DSC devices with the easy-to-use, powerful graphical user interface of the MPLAB X IDE.

The emulator is connected to the design engineer's PC using a high-speed USB 2.0 interface and is connected to the target with either a connector compatible with in-circuit debugger systems (RJ-11) or with the new high-speed, noise tolerant, Low-Voltage Differential Signal (LVDS) interconnection (CAT5).

The emulator is field upgradable through future firmware downloads in MPLAB X IDE. MPLAB REAL ICE offers significant advantages over competitive emulators including full-speed emulation, run-time variable watches, trace analysis, complex breakpoints, logic probes, a ruggedized probe interface and long (up to three meters) interconnection cables.

26.8 MPLAB ICD 3 In-Circuit Debugger System

The MPLAB ICD 3 In-Circuit Debugger System is Microchip's most cost-effective, high-speed hardware debugger/programmer for Microchip Flash DSC and MCU devices. It debugs and programs PIC Flash microcontrollers and dsPIC DSCs with the powerful, yet easy-to-use graphical user interface of the MPLAB IDE.

The MPLAB ICD 3 In-Circuit Debugger probe is connected to the design engineer's PC using a high-speed USB 2.0 interface and is connected to the target with a connector compatible with the MPLAB ICD 2 or MPLAB REAL ICE systems (RJ-11). MPLAB ICD 3 supports all MPLAB ICD 2 headers.

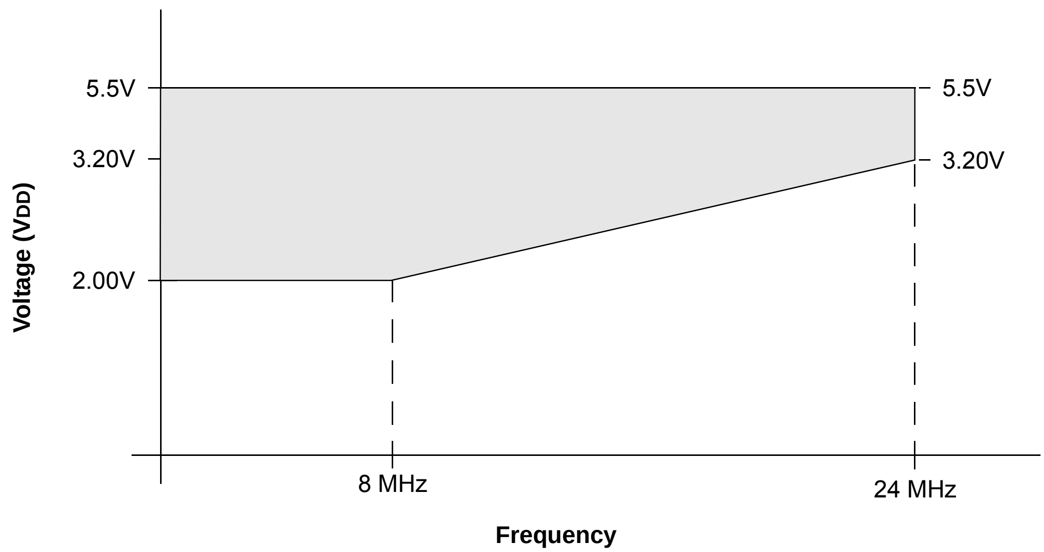
26.9 PICkit 3 In-Circuit Debugger/Programmer

The MPLAB PICkit 3 allows debugging and programming of PIC and dsPIC Flash microcontrollers at a most affordable price point using the powerful graphical user interface of the MPLAB IDE. The MPLAB PICkit 3 is connected to the design engineer's PC using a full-speed USB interface and can be connected to the target via a Microchip debug (RJ-11) connector (compatible with MPLAB ICD 3 and MPLAB REAL ICE). The connector uses two device I/O pins and the Reset line to implement in-circuit debugging and In-Circuit Serial Programming™ (ICSP™).

26.10 MPLAB PM3 Device Programmer

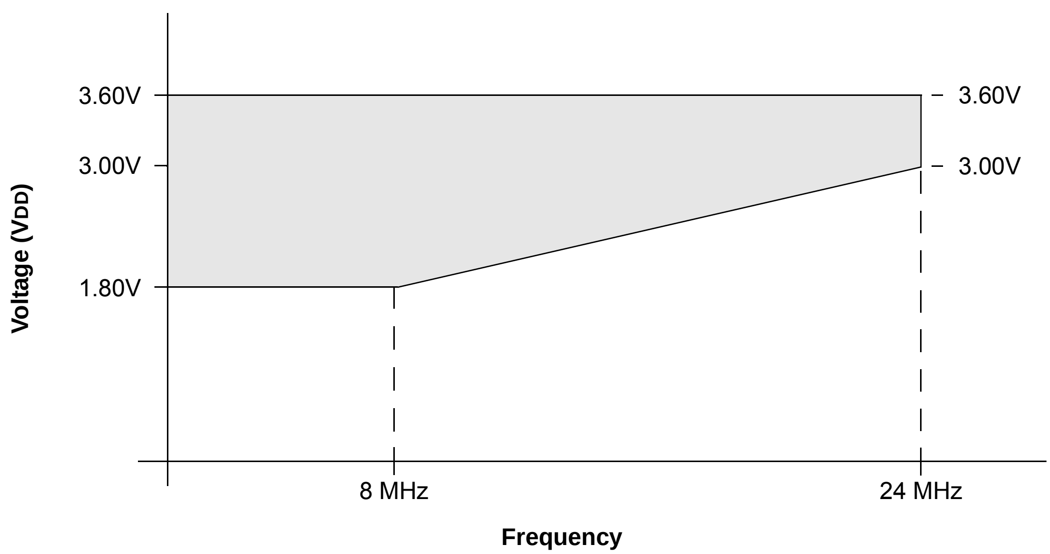
The MPLAB PM3 Device Programmer is a universal, CE compliant device programmer with programmable voltage verification at V_{DDMIN} and V_{DDMAX} for maximum reliability. It features a large LCD display (128 x 64) for menus and error messages, and a modular, detachable socket assembly to support various package types. The ICSP cable assembly is included as a standard item. In Stand-Alone mode, the MPLAB PM3 Device Programmer can read, verify and program PIC devices without a PC connection. It can also set code protection in this mode. The MPLAB PM3 connects to the host PC via an RS-232 or USB cable. The MPLAB PM3 has high-speed communications and optimized algorithms for quick programming of large memory devices, and incorporates an MMC card for file storage and data applications.

FIGURE 27-3: PIC24FV16KM204 FAMILY VOLTAGE-FREQUENCY GRAPH (EXTENDED)



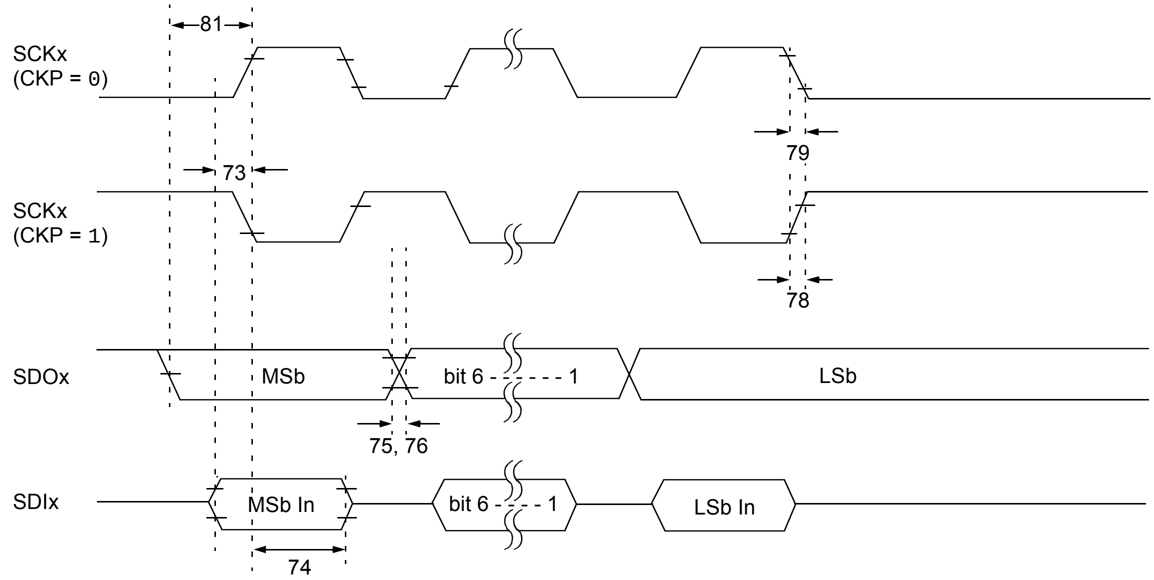
Note: For frequencies between 8 MHz and 24 MHz, FMAX = 13.33 MHz * (VDD – 2.0) + 8 MHz.

FIGURE 27-4: PIC24F16KM204 FAMILY VOLTAGE-FREQUENCY GRAPH (EXTENDED)



Note: For frequencies between 8 MHz and 24 MHz, FMAX = 13.33 MHz * (VDD – 1.8) + 8 MHz.

FIGURE 27-12: EXAMPLE SPI MASTER MODE TIMING (CKE = 1)



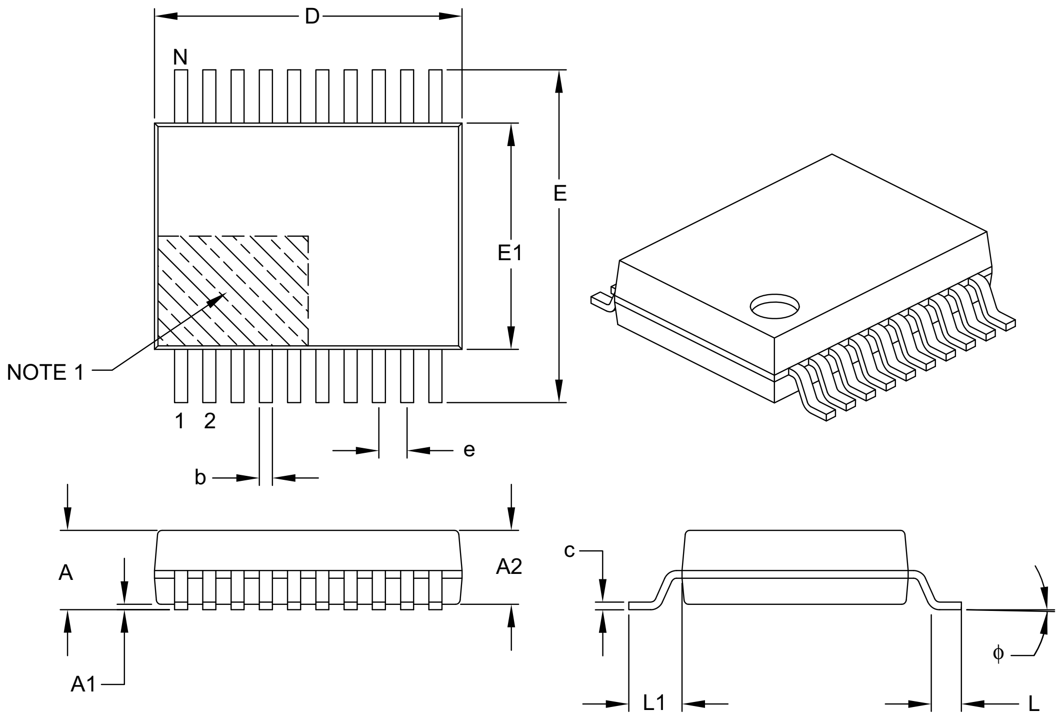
Note: Refer to Figure 27-5 for load conditions.

TABLE 27-30: EXAMPLE SPI MODE REQUIREMENTS (MASTER MODE, CKE = 1)

Param. No.	Symbol	Characteristic	Min	Max	Units	Conditions
73	TDIV2SCH, TDIV2SCL	Setup Time of SDIx Data Input to SCKx Edge	35	—	ns	
74	TSCH2DIL, TSCL2DIL	Hold Time of SDIx Data Input to SCKx Edge	40	—	ns	
75	TDOR	SDOx Data Output Rise Time	—	25	ns	
76	TDOF	SDOx Data Output Fall Time	—	25	ns	
78	TSCR	SCKx Output Rise Time (Master mode)	—	25	ns	
79	TSCF	SCKx Output Fall Time (Master mode)	—	25	ns	
81	TDOV2SCH, TDOV2SCL	SDOx Data Output Setup to SCKx Edge	TCY	—	ns	
	FSCK	SCKx Frequency	—	10	MHz	

20-Lead Plastic Shrink Small Outline (SS) – 5.30 mm Body [SSOP]

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



		Units	MILLIMETERS		
		Dimension Limits	MIN	NOM	MAX
Number of Pins	N			20	
Pitch	e			0.65 BSC	
Overall Height	A		–	–	2.00
Molded Package Thickness	A2		1.65	1.75	1.85
Standoff	A1		0.05	–	–
Overall Width	E		7.40	7.80	8.20
Molded Package Width	E1		5.00	5.30	5.60
Overall Length	D		6.90	7.20	7.50
Foot Length	L		0.55	0.75	0.95
Footprint	L1			1.25 REF	
Lead Thickness	c		0.09	–	0.25
Foot Angle	ϕ		0°	4°	8°
Lead Width	b		0.22	–	0.38

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.20 mm per side.
3. Dimensioning and tolerancing per ASME Y14.5M.

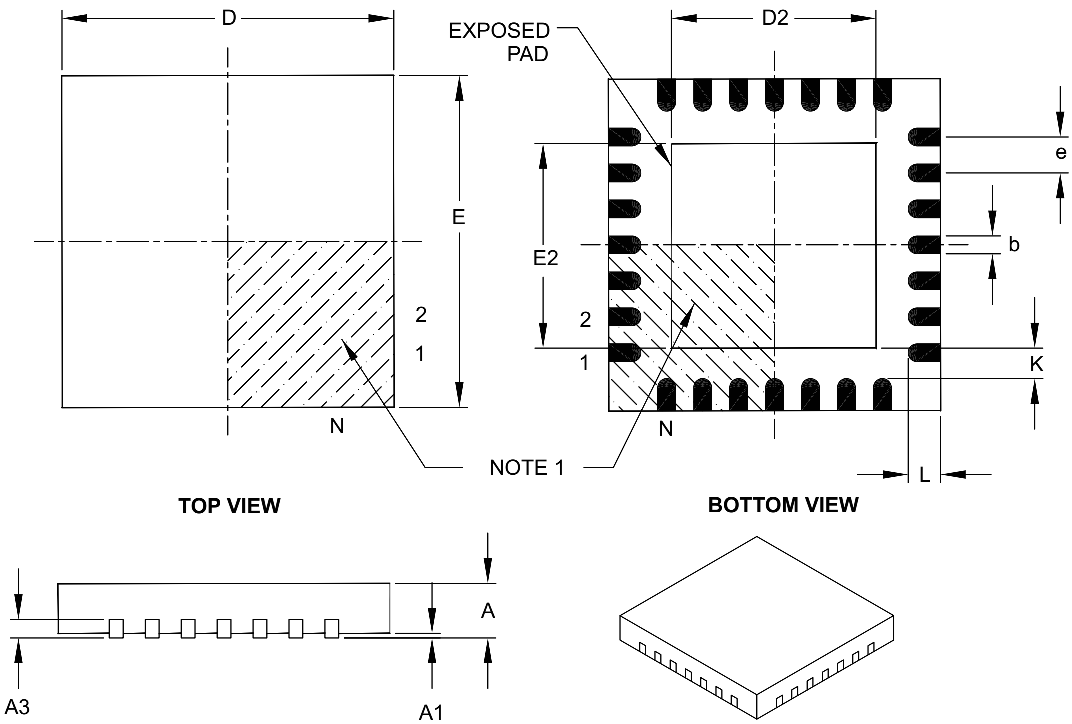
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-072B

28-Lead Plastic Quad Flat, No Lead Package (ML) – 6x6 mm Body [QFN] with 0.55 mm Contact Length

Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		28	
Pitch	e		0.65 BSC	
Overall Height	A	0.80	0.90	1.00
Standoff	A1	0.00	0.02	0.05
Contact Thickness	A3		0.20 REF	
Overall Width	E		6.00 BSC	
Exposed Pad Width	E2	3.65	3.70	4.20
Overall Length	D		6.00 BSC	
Exposed Pad Length	D2	3.65	3.70	4.20
Contact Width	b	0.23	0.30	0.35
Contact Length	L	0.50	0.55	0.70
Contact-to-Exposed Pad	K	0.20	–	–

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated.
3. Dimensioning and tolerancing per ASME Y14.5M.

   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-105B

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