

IA186ES/IA188ES **8/16-BIT Microcontrollers**

Preliminary Data Sheet

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FEATURES

- Pin-for-Pin compatible with AMD® Am186ES/188ES devices
- All features are retained, including:
 - PLL allowing same crystal/system clock frequency
 - 8086/8088 instruction set with additional 186 instruction set extensions
 - Programmable interrupt controller
 - Two DMA channels
 - Three 16-bit timers
 - Programmable chip select logic and wait-state generator
 - Dedicated watch dog timer
 - Two independent asynchronous serial ports (UARTs)
 - DMA capability
 - Hardware flow control
 - 7, 8, or 9-bit data capability
 - Pulse Width Demodulator feature
 - Up to 32 programmable I/O pins (PIO)
- Pseudo-static/dynamic RAM controller
- Fully static CMOS design
- 40 MHz operation at industrial operating conditions
- +5 VDC power supply
- Available packages:
 - 100-pin Thin Quad Flat Pack (TQFP)
 - 100-pin Plastic Quad Flat Pack (PQFP)

The IA186ES/188ES is a form, fit, and function replacement for the original Advanced Micro Devices® Am186ES/188ES family of microcontrollers. InnovASIC produces replacement ICs using its MILES™, or Managed IC Lifetime Extension System, cloning technology. This technology produces replacement ICs far more complex than "emulation" while ensuring they are compatible with the original IC. MILES™ captures the design of a clone so it can be produced even as silicon technology advances. MILES™ also verifies the clone against the original IC so that even the "undocumented features" are duplicated.

This Data Sheet contains preliminary information for the IA186ES/188ES. The complete data sheet which documents all necessary engineering information about the IA186ES/188ES including functional and I/O descriptions, electrical characteristics, and applicable timing will be available when the device nears completion.

Description

The IA186ES/188ES family of microcontrollers replaces obsolete AMD® Am186ES/188ES devices, allowing customers to retain existing board designs, software compilers/assemblers, and emulation tools, thereby avoiding expensive redesign efforts.

The IA186ES/188ES microcontrollers are an upgrade for the 80C186/188 microcontroller designs, with integrated peripherals to provide increased functionality and reduce system costs. The InnovASIC devices are designed to satisfy requirements of embedded products designed for telecommunications, office automation and storage, and industrial controls.

A block diagram of the IA186ES/188ES microcontroller is depicted in Figure 1.

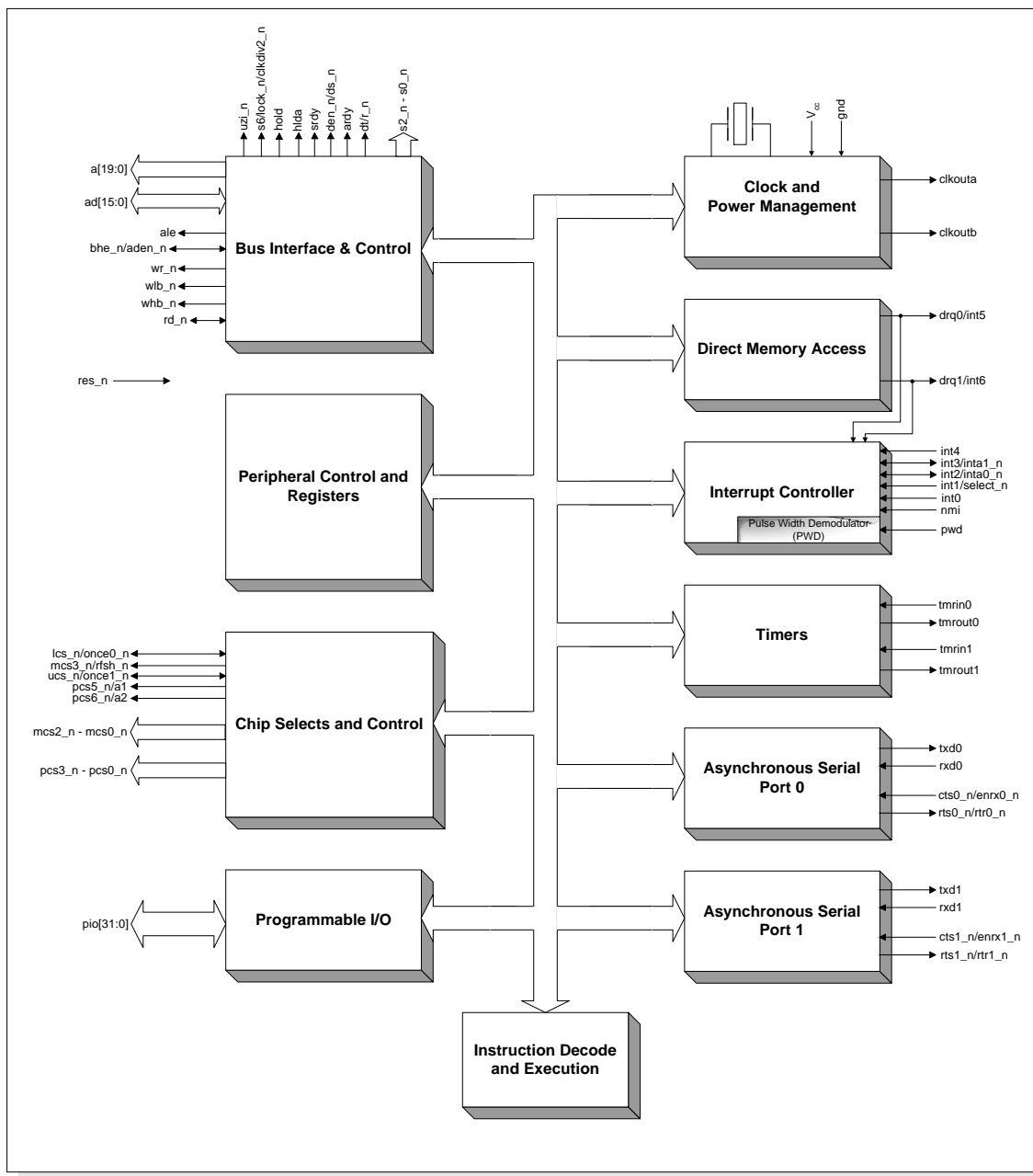


Figure 1. IA186EM Block Diagram

Note:

- See pin descriptions for pins that share other functions with PIO pins. pwd , $int5$, $int6$, $rts1_n/rtr1_n$, and $cts1_n/enrx1_n$ are multiplexed with $int2_n/inta0_n$, $drq0$, $drq0$, $pcs3_n$, and $pcs2_n$ respectively.

The IA186ES/188ES microcontroller consists of the following functional blocks:

- Bus Interface and Control
- Peripheral Control and Registers
- Chip Selects and Control
- Programmable I/O
- Clock and Power Management
- Direct Memory Access (DMA)
- Interrupt Controller
- Timers
- Asynchronous Serial Ports (2)

A brief description of each block follows:

Bus Interface and Control

Bus Interface and Control (BIC) manages all accesses to external memory and external peripherals. These peripherals may be mapped either in memory space or I/O space. The BIC supports both multiplexed and non-multiplexed bus operations. Multiplexed address and data are provided on the AD [15:0] bus, while a non-multiplexed address is provided on the A [19:0] bus. The A bus provides address information for the entire bus cycle (t1-t4), while the AD bus provides address information only during the first (t1) phase of the bus cycle. For more details regarding bus cycles, see the AC waveforms at the end of this datasheet.

The BIC provide the capability to dynamically alter the size of the data bus. By programming the auxiliary control register (AUXCON), a user may easily support external peripherals and memory devices of both 8 and 16 bit widths without specialized micro-code managing the data accesses. The AUXCON register contains 3 programmable bits for this purpose: *LSIZ*, *MSIZ*, and *IOSIZ*. For details regarding the operation of these bits, see the individual register descriptions under the Peripheral Control and Registers section of this datasheet. The IA186ESmicrocontroller provides two signals to support this functionality: write high byte (**whb_n**) and write low byte (**wlb_n**). Obviously, the IA188ES microcontroller requires only a single write byte (**wb_n**) signal to support its 8-bit data bus.

The BIC also provides support for Pseudo-Static RAM (PSRAM) devices. PSRAM is supported in the lower chip select (**lcs_n**) area only. In order to support PSRAM the Chip Selects and Control (CSC) must be appropriately programmed. For details regarding this operation see the Chips Selects and Control Section of this datasheet.

Peripheral Control and Registers

The on-chip peripherals in the IA186ES/188ES microcontroller are controlled from a 256-byte block of internal registers. Although these registers are actually located in the peripherals they control, they are addressed within a single 256-byte block of I/O spaced and are therefore treated as a functional unit for the purposes of this document.

A map of these registers is depicted in table 1.

All write operations performed on the IA188ES should be 8-bit writes, which will still result in 16-bit data transfers to the Peripheral Control Block (PCB) register even if the named register is an 8-bit register. Any read performed to the PCB registers should be word reads. Code written with these points in mind will run correctly on both the IA186ES and IA188ES.

However unpredictable behavior on both the IA186ES and IA188ES processors if unaligned read and write accesses are performed.

Register Name	Offset
Peripheral Control Block Registers	
PCB Relocation Register	FEh
Reset Configuration Register	F6h
Processor Release Level Register	F4h
Auxiliary Configuration Register	F2h
System Configuration Register	F0h
Watchdog Timer Control Register	E6h
Clock Prescaler Register	E4h
Memory Partition Register	E0h
DMA Registers	
DMA1 Control Register	DAh
DMA1 Transfer Count Register	D8h
DMA1 Destination Address High Register	D6h
DMA1 Destination Address Low Register	D4h
DMA1 Source Address High Register	D2h
DMA1 Source Address Low Register	D1h
DMA0 Control Register	CAh
DMA0 Transfer Count Register	C8h
DMA0 Destination Address High Register	C6h
DMA0 Destination Address Low Register	C4h
DMA0 Source Address High Register	C2h
DMA0 Source Address Low Register	C0h
Chip-Select Registers	
pcs_n and mcs_n Auxiliary Register	A8h
Mid-Range Memory Chip-Select Register	A6h
Peripheral Chip-Select Register	A4h
Low-Memory Chip-Select Register	A2h
Upper-Memory Chip-Select Register	A0h
Serial Port 0 Registers	
Serial Port 0 Baud Rate Divisor Register	88h
Serial Port 0 Receive Register	86h
Serial Port 0 Transmit Register	84h
Serial Port 0 Status Register	82h
Serial Port 0 Control Register	80h
PIO Registers	
PIO Data 1 Register	7Ah
PIO Direction Register	78h
PIO Mode 1 Register	76h
PIO Data 0 Register	74h
PIO Direction 0 Register	72h
PIO Mode 0 Register	70h

Register Name	Offset
Timer Registers	
Timer 2 Mode & Control Register	66h
Timer 2 Max Count Compare A Register	62h
Timer 2 Count Register	60h
Timer 1 Mode & Control Register	5Eh
Timer 1 Max Count Compare B Register	5Ch
Timer 1 Max Count Compare A Register	5Ah
Timer 1 Count Register	58h
Timer 0 Mode & Control Register	56h
Timer 0 Max Count Compare B Register	54h
Timer 0 Max Count Compare A Register	52h
Timer 0 Count Register	50h
Interrupt Registers	
Serial Port 0 Interrupt Control Register	44h
Serial Port 1 Interrupt Control Register	42h
INT4 Interrupt Control Register	40h
INT3 Interrupt Control Register	3Eh
INT2 Interrupt Control Register	3Ch
INT1 Interrupt Control Register	3Ah
INT0 Interrupt Control Register	38h
DMA1/INT6 Interrupt Control Register	36h
DMA0/INT5 Interrupt Control Register	34h
Timer Interrupt Control Register	32h
Interrupt Status Register	30h
Interrupt Request Register	2Eh
Interrupt In-Service Register	2Ch
Interrupt Priority Mask Register	2Ah
Interrupt Mask Register	28h
Interrupt Poll Status Register	26h
Interrupt Poll Register	24h
End-of-Interrupt (EOI) Register	22h
Interrupt Vector Register	20h
Serial Port 0 Registers	
Serial Port 0 Baud Rate Divisor Register	18h
Serial Port 0 Receive Register	16h
Serial Port 0 Transmit Register	14h
Serial Port 0 Status Register	12h
Serial Port 0 Control Register	10h

Table 1. Map of The Peripheral Control Registers.

RELREG (0feh) - The Peripheral Control Block *RE*Location *REG*ister maps the entire Peripheral Control Block Register Bank to either I/O or memory space. In addition, RELREG contains a bit which places the Interrupt Controller in either Master or Slave Mode.

The RELREG contains 20ffh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>RES</i>	<i>S/Mn</i>	<i>RES</i>	<i>IO/Mn</i>	<i>RA [19:8]</i>											

RES (bit 15) - Reserved.

S/Mn (bit 14) – A one in this bit places the Interrupt Controller into slave mode. When set to zero, the Interrupt Controller is in master mode.

RES (bit 13) - Reserved.

IO/Mn (bit 12)- A one in this bit maps the Peripheral Control Block Register Bank into IO space. When set to zero, the Peripheral Control Block is mapped into memory space.

RA [19:8] (bits 11-0) – Sets the base address (upper 12 bits) of the Peripheral Control Block Register Bank. *RA [7:0]* default to zero. Note that when bit 12 (*IO/Mn*) is a one, *RA [19:16]* are ignored.

RESCON (0f6h) - The *RE*Set *CON*figuration Register latches user-defined information present at specified pins at the rising edge of reset. The contents of this register are read only and remain valid until the next reset.

The RESCON contains user-defined information at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>RC [15:0]</i>															

RC [15:0] (bits 15-0) – At the rising edge of reset, the values of specified pins (**ad [15:0]** for the IA186ES and {**ao [15:8], ad [7:0]**} for the IA188ES) are latched into this register.

PRL (0f4h) - The Processor Release Level Register contains a code corresponding to the latest processor production release. The PRL is a Read-Only Register

The PRL contains 1100h.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>PRL [7:0]</i>								<i>RES</i>							

PRL [7:0] (bits 15-8) – The latest Processor Release Level.

<i>PRL Value</i>	<i>Processor Release Level</i>
10h	A
11h	B
12h	C
13h	D
14h	E

RES (bits 7-0) – Reserved.

AUXCON (0f2h) - The AUXillary CONfiguration Register configures the flow control signals for the asynchronous serial ports. In addition AUXCON controls data bus width (8 or 16 bit) for lower memory, middle memory, and IO accesses.

The AUXCON contains 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>RES</i>							<i>ENRX1</i>	<i>RTS1</i>	<i>ENRX0</i>	<i>RTS0</i>	<i>LSIZ</i>	<i>MSIZ</i>	<i>IOSIZ</i>		

RES (bit 15-7) - Reserved.

ENRX1 (bit 6) – When set to one, the **cts1_n/enrx1_n** pin functions as **cts1_n**. When zero, **cts1_n/enrx1_n** pin functions as **enrx1_n**.

RTS1 (bit 5) – When set to one, the **rtr1_n/rts1_n** pin functions as **rts1_n**. When zero, **rtr1_n/rts1_n** pin functions as **rtr1_n**.

ENRX0 (bit 4) – When set to one, the **cts0_n/enrx0_n** pin functions as **cts0_n**. When zero, **cts0_n/enrx0_n** pin functions as **enrx0_n**.

RTS0 (bit 3) – When set to one, the **rtr0_n/rts0_n** pin functions as **rts0_n**. When zero, **rtr0_n/rts0_n** pin functions as **rtr0_n**.

LSIZ (bit 2, IA186ES only) – When set to one, 8-bit data access are performed in lower chip-select (**lcs_n**) space. When set to zero, 16-bit data access are performed.

MSIZ (bit 1, IA186ES only) – When set to one, 8-bit data access are performed in middle chip-select (**mcs_n**) space and peripheral chip-select space (**psc_n**, if and only if **pcs_n** is mapped to memory). When set to zero, 16-bit data access are performed.

IOSIZ (bit 0, IA186ES only) – When set to one, 8-bit data access are performed in all I/O space. When set to zero, 16-bit data access are performed.

SYSCON (0f0h) - The *SYStem CONfiguration* Register controls several miscellaneous system I/O and timing functions.

The SYSCON contains 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>PSEN</i>	<i>MCSBIT</i>	<i>DSDEN</i>	<i>PWD</i>	<i>CBF</i>	<i>CBD</i>	<i>CAF</i>	<i>CAD</i>	<i>RES</i>				<i>F2</i>	<i>F1</i>	<i>F0</i>	

PSEN (bit 15) – When set to one, enables the power-save mode causing the internal operating clock to be divided by the value in *F2-F0*. External interrupts or interrupts from internal interrupts automatically clear *PSEN*. Software interrupts and exception do not clear *PSEN*. Please not that the value of *PSEN* is not restored upon execution of an IRET instruction.

MCSBIT (bit 14) – When set to one, *mcs0_n* is active over the entire MCS range, thus freeing **mcs2_n** and **mcs1_n** to be used as programmable I/O. When this bit is zero, *mcs0_n* behaves normally.

DSDEN (bit 13) – When set to one, the **ds_n/den_n** pin functions as **ds_n**. When this bit is zero, **ds_n/den_n** pin functions as **den_n**. See the individual pin descriptions for details of data strobe (**ds_n**) mode versus data enable (**den_n**) mode.

PWD (bit 12) – When set to one, the pulse width demodulator is enabled. When this bit is zero, the pulse width demodulator is disabled.

CBF (bit 11) – When set to one, the **clkoutb** output follows the input crystal (PLL) frequency. When this bit is zero, the **clkoutb** follows the internal clock frequency after the clock divider.

CBD (bit 10) – When set to one, the **clkoutb** output is driven low. When this bit is zero, the **clkoutb** is driven as an output per the *CBF* bit.

CAF (bit 9) – When set to one, the **clkouta** output follows the input crystal (PLL) frequency. When this bit is zero, the **clkouta** follows the internal clock frequency after the clock divider.

CAD (bit 8) – When set to one, the **clkouta** output is driven low. When this bit is zero, the **clkouta** is driven as an output per the *CBF* bit.

RES (bits 7-3) – Reserved. The bits read back as zeros.

F2-F0 (bits 2-0) – These bits control the clock divider as shown below. Note, *PSEN* must be one for the clock divider to function.

F2	F1	F0	Divider Factor
0	0	0	Divide by 1 (2^0)
0	0	1	Divide by 2 (2^1)
0	1	0	Divide by 4 (2^2)
0	1	1	Divide by 8 (2^3)
1	0	0	Divide by 16 (2^4)
1	0	1	Divide by 32 (2^5)
1	1	0	Divide by 64 (2^6)
1	1	1	Divide by 128 (2^7)

WDTCON (0e6h) - The WatchDog Timer *CON*trol Register provides control and status for the watchdog timer (WDT).

The WDTCON contains c080h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>ENA</i>	<i>WRST</i>	<i>RSTFLAG</i>	<i>NMIFLAG</i>	<i>TEST</i>	<i>RES</i>			<i>COUNT</i>							

ENA (bit 15) – When set to one, the watchdog timer is enabled. When set to zero, the watchdog timer is disabled.

WRST (bit 14) – When set to one, an internal WDT reset is generated when the WDT timeout count (*COUNT*) is reached. When this bit is zero, an NMI will be generated once WDT timeout count is reached and the *NMIFLAG* bit is zero. If the *NMIFLAG* bit is one, an internal WDT reset is generated when the WDT timeout count is reached.

RSTFLAG (bit 13) – When set to one, a WDT timeout event has occurred. This bit may be cleared by software or by an external reset.

NMIFLAG (bit 12) – When set to one, a WDT NMI event has occurred. This bit may be cleared by software or by an external reset. If this bit is one when WDT timeout occurs, an internal WDT reset is generated regardless of the state of *WRST*.

TEST (bit 11) – This bit is reserved for chip test and should always be set to zero.

RES (bits 10-8) – Reserved.

COUNT (bits 7-0) – Control the timeout period for the WDT as follows:

$$T_{\text{timeout}} = 2^{\text{exponent}} / \text{frequency}$$

Where:

T_{timeout} is the WDT timeout period in seconds.
 Frequency is the processor frequency in hertz.
 Exponent is based upon count as shown below:

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0	Exponent
0	0	0	0	0	0	0	0	NA
X	X	X	X	X	X	X	1	10
X	X	X	X	X	X	1	0	20
X	X	X	X	X	1	0	0	21
X	X	X	X	1	0	0	0	22
X	X	X	1	0	0	0	0	23
X	X	1	0	0	0	0	0	24
X	1	0	0	0	0	0	0	25
1	0	0	0	0	0	0	0	26

EDRAM (0e4h) - The Enable Dynamic RAM Refresh Control Register provides control and status for the refresh counter.

The EDRAM register contains 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>EN</i>	0	0	0	0	0	0	<i>T[8:0]</i>								

EN (bit 15) – When set to one, the refresh counter is enabled and **m3c3_n** is configured to act as **rfsh_n**. Clearing *EN* clears the refresh counter and disables refresh requests. The refresh address is unaffected by clearing *EN*.

RES (bits 14-9) – Reserved. These bits read back as zero.

T [8:0] (bits 8-0) – These bits hold the current value of the refresh counter. These bits are read-only.

CDRAM (0e2h) - The Count for Dynamic RAM Refresh Control Register determines the period between refresh cycles.

The CDRAM register is undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	<i>RC [8:0]</i>								

RES (bits 15-9) – Reserved. These bits read back as zero.

T [8:0] (bits 8-0) – These bits hold the clock count interval between refresh cycles. In power-save mode, the refresh counter value should be adjusted to account for the clock divider value in SYSCON.

MDRAM (0e0h) - The Memory Partition for Dynamic RAM Refresh Control Register holds the A19-A13 address bits of the 20-bit base refresh address.

The MDRAM register contains 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>M [6:0]</i>							0	0	0	0	0	0	0	0	0

M [6:0] (bits 15-9) – Upper bits corresponding to address bits **a19-a13** of the 20-Bit memory refresh address. These bits are not available on the **a19-a0** bus. When using PSRAM mode, *M6-M0* must be programmed to 0000000b.

Reserved [8:0] (bits 8-0) – Reserved. These bits read back as zero.

D1CON (0dah) - DMA CONTROL Registers.

D0CON (0cah)

DMA Control Registers control operation of the two DMA channels. The D0CON and D1CON registers are undefined at reset, except *ST* that is set to 0.

IA186ES/IA188ES

8/16-BIT MICROCONTROLLERS

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>DM/IO_n</i>	<i>DDEC</i>	<i>DINC</i>	<i>SM/IO_n</i>	<i>SDEC</i>	<i>SINC</i>	<i>TC</i>	<i>INT</i>	<i>SYN1- SYN0</i>		<i>P</i>	<i>TDRQ</i>	<i>EXT</i>	<i>CHG</i>	<i>ST</i>	<i>Bn/W</i>

DM/IO_n (bit 15) – Destination Address Space Select selects memory or I/O space for the destination address. When *DM/IO* is set to 1, the destination address is in memory space, while when set to 0, the destination address is in I/O space.

DDEC (bit 14) – Destination Decrement automatically decrements the destination address after each transfer when set to 1. The address is decremented by 1 or 2 depending on the byte/word bit (*Bn/W*, bit 0). The address does not change if the increment and decrement bits are set to the same value (00b or 11b).

DINC (bit 13) – Destination Increment, when set to 1, automatically increments the destination address after each transfer. The address is incremented by 1 or 2 depending on the byte/word bit (*Bn/W*, bit 0). The address does not change if the increment and decrement bits are set to the same value (00b or 11b).

SM/IO_n (bit 12) – Source Address Space Select selects memory or I/O space for the source address. When *SM/IO_n* is set to 1, the source address is in memory space, while when 0, the source address is in I/O space.

SDEC (bit 11) – Source Decrement, when set to 1, automatically decrements the destination address after each transfer. The address is decremented by 1 or 2 depending on the byte/word bit (*Bn/W*, bit 0). The address does not change if the increment and decrement bits are set to the same value (00b or 11b).

SINC (bit 10) – Source Increment, when set to 1, automatically increments the destination address after each transfer. The address is incremented by 1 or 2 depending on the byte/word bit (*Bn/W*, bit 0). The address does not change if the increment and decrement bits are set to the same value (00b or 11b).

TC (bit 9) – Terminal Count. *The DMA* decrements the transfer count for each DMA transfer. When *TC* is set to 1, the source or destination synchronized DMA transfers terminate when the count reaches 0, but when *TC* is set to 0, source or destination synchronized DMA transfers do not terminate when the count reaches 0. Unsynchronized DMA transfers always end when the count reaches 0, irrespective of the setting of this bit.

INT (bit 8) – Interrupt. The DMA channel generates an interrupt request on completion of the transfer count when this bit is set to 1. However, for an interrupt to be generated, the *TC* bit must also be set to 1.

SYN1-SYN0 (bits 7-6) – Synchronization Type bits select channel synchronization as shown in the following table. The value of these bits is ignored if *TDRQ* (bit 4) is set to 1. A processor reset causes these bits to be set to 11b.

<i>SYN1</i>	<i>SYN0</i>	Sync Type
0	0	Unsynchronized
0	1	Source Synchronized
1	0	Destination Synchronized
1	1	Reserved

P (bit 5) – Relative Priority. Selects high priority for this channel relative to the other channel during simultaneous transfers when set to 1.

TDRQ (bit 4) - Timer 2 Synchronization. Enables DMA requests from timer 2, when set to 1, but disables DMA requests from timer 2 when set to 0.

EXT (bit 3) – External Interrupt Enable Bit. The external pin is an **int** pin and the interrupt controller processes requests on the pin if this bit is set to 1 and the respective DMA channel does not respond to changes on the **drq** pin. However, when this bit is set to 0, the pin functions as a **drq** pin.

CHG (bit 2) – Change Start Bit. This bit must be set to 1, to allow modification of the *ST* bit during a write. During a write, when *CHG* is set to 0, *ST* is not changed when writing the control word. The result of reading this bit is always 0.

ST (bit 1) – Start/Stop DMA Channel. When the start bit is set to 1, the DMA channel is started. The *CHG* bit must be set to 1 for this bit to be modified and only during the same register write. A processor reset causes this bit to be set to 0.

Bn/W (bit 0) – Byte/Word Select. When set to 1 word transfers are selected, and when set to 0, byte transfers are selected. (The IA188ES does not support word transfers and furthermore they are not supported if the chip selects are programmed for 8-bit transfers.)

D1TC (0d8h) - DMA Transfer Count Registers.

D0TC (0c8h)

The DMA Transfer Count registers are maintained by each DMA channel. They are decremented after each DMA cycle. The state of the *TC* bit in the DMA control register has no influence on this activity. But, if unsynchronized transfers are programmed or if the *TC* bit in the DMA control word is set, DMA activity ceases when the transfer count register reaches 0.

The D0TC and D1TC registers are undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>TC15 – TC0</i>															

TC [15:0] (bits 15-0) – DMA Transfer Count contains the transfer count for the respective DMA channel. Its value is decremented after each transfer.

D1DSTH (0d6h) - The DMA DeSTination Address High Register.

D0DSTH (0c6h)

The 20-bit destination address consists of these four bits combined with the 16-bits of the respective Destination Address Low Register. A DMA transfer requires that two complete 16-bit registers (high and low registers) be used for both the source and destination addresses of each DMA channel involved. These four registers must be initialized. Each address may be incremented or decremented independently of each other after each transfer. The addresses are incremented or decremented by two for word transfers and incremented or decremented by 1 for byte transfers.

The D0DSTH and D1DSTH registers are undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>												<i>DDA19-DDA16</i>			

Reserved [15:4] (bits 15-4) – Reserved.

DDA [19:16] (bits 3-0) – DMA Destination Address High bits are driven onto A19-A16 during the write phase of a DMA transfer.

D1DSTL (0d4h) - DMA DeSTination Address Low Register.

D0DSTL (0c4h)

The sixteen bits of these registers are combined with the four bits of the respective DMA Destination Address High Register to produce a 20-bit destination address.

The D0DSTL and D1DSTL registers are undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>DDA15 – DDA0</i>															

DDA [15:0] (bits 15-0) – DMA Destination Address Low bits are driven onto A19-A16 during the write phase of a DMA transfer.

D1SRCH (0d2h) - DMA SouRCe Address High Register.

D0SRCH (0c2h)

The 20-bit source address consists of these four bits combined with the 16-bits of the respective Source Address Low Register. A DMA transfer requires that two complete 16-bit registers in the peripheral control block (high and low registers) be used for both the source and destination addresses of each DMA channel involved. Each DMA channel requires that all four address registers be initialized. Each address may be incremented or decremented independently of each other after each transfer. The addresses are incremented or decremented by 2 for word transfers and incremented or decremented by 1 for byte transfers.

The D0SRCH and D1SRCHL registers are undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>												<i>DSA1 – DSA16</i>			

Reserved [15:4] (bits 15-4) – Reserved

DSA [19:16] (bits 3-0) – DMA Source Address High bits are driven onto A19-A16 during the read phase of a DMA transfer.

D1SRCL (0d0h) - DMA SouRCe Address Low Register.

D0SRCL (0c0h)

The sixteen bits of these registers are combined with the four bits of the respective DMA Source Address High register to produce a 20-bit source address.

The D0SRCL and D1SRCL registers are undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>DSA15-DSA0</i>															

*DSA [15:0] (bits 15-0) – DMA Source Address Low bits are placed onto **a15-a0** during the read phase of a DMA transfer.*

MPCS (0a8h) - MCS and PCS Auxiliary Register.

This register controls more than one type of chip select, making it different from the other chip select control registers. The MPCS register contains information for the following, **mcs3_n - mcs0_n** as well as **pcs6_n - pcs5_n** and **pcs3_n - pcs0_n**.

The MPCS register also contains a bit that configures the **pcs6_n - pcs5_n** pins as either chip selects or as alternate sources for the A2 and A1 address bits. Either address bits **a1** & **a2** or **pcs6_n - pcs5_n** are selected to the exclusion of the other. When programmed for address bits, these outputs can be used to provide latched address bits for **a2** & **a1**

pcs6_n - pcs5_n are high and not active on processor reset. An access to the MPCS register causes the pins to activate, when the **pcs6_n - pcs5_n** are configured as address pins. The **pcs6_n - pcs5_n** pins do not require corresponding access to the PACS register to be activated.

The value of the MPCS register is undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	<i>M6-M0</i>							<i>EX</i>	<i>MS</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>R2</i>	<i>R1-R0</i>	

Reserved (bit 15) – Set to 1.

M [6:0] (bits14-8) MCS_n Block Size – These 7 bits determine the total block size for the MCS3_n - MCS0_n chip selects. The total block size is divided equally among the four chip selects. The following table shows the relationship between *M [6:0]* and the size of the memory block.

Total Block Size	Individual Select Size	M6 – M0
8K	2K	0000001b
16K	4K	0000010b
32K	8K	0000100b
64K	16K	0001000b
128K	32K	0010000b
256K	64K	0100000b
512K	128K	1000000b

EX (bit7) Pin Selector – This bit determines whether the **pcs6_n - pcs5_n** pins are configured as chip selects or as alternate outputs for **a2** & **a1**. When this bit is set to 1, **pcs6_n - pcs5_n** are configured as peripheral chip select pins, whereas when set to 0, **pcs6_n - pcs5_n** become address bit **a1** and address bit **a2** respectively.

MS (bit 6) Memory/ I/O Space Selector determines whether the **pcs_n** pins are active either during memory or I/O bus cycles. When *MS* is set to 1, the **pcs_n** outputs are active for memory bus cycles, and active for I/O bus cycles when set to 0.

Reserved (bits 5:3) – Set to 1.

R2 (bit 2) Ready Mode – This bit influences only the **pcs6_n - pcs5_n** chip selects. If *R2* is set to 0, external ready is required, while if *R2* is set to 1, external ready is ignored. In each case, the values of the *R1-R0* bits determine the number of wait states to be inserted.

R [1:0] (bits 1-0) Wait-State Value – These bits influence only the **pcs6_n - pcs5_n** chip selects. The value of *RI-R0* determines the number of wait states inserted into an access depending on whether its to the PCS_n memory or I/O area. Up to three wait states can be inserted (*RI - R0* = 00b to 11b).

MMCS (0a6h) - Midrange Memory Chip Select Register.

Four chip-select pins, **mcs3_n - mcs0_n**, are provided for use within a user-locatable memory block. The memory block base address can be located anywhere within the 1-Mbyte memory address space, excluding the areas associated with the **ucs_n** and **lcs_n** chip selects (and, if mapped to memory, the address range of the Peripheral Chip Selects, **pcs6_n - pcs5_n** and **pcs3_n to pcs0_n**). If the **pcs_n** chip selects are mapped to I/O space the **mcs_n** address range can overlap the **pcs_n** address range

Two registers program the Midrange Chip Selects. The Midrange Memory Chip Select (MMCS) register determines the base address, the ready condition and wait states of the memory block that are accessed through the **mcs_n** pins. The **pcs_n** and **mcs_n** Auxiliary (MPCS) register configures the block size. On reset the **mcs3_n - mcs0_n** pins

are not active. Accessing with a write both the MMCS and MPCS registers activates these chip selects.

The **mcs3_n - mcs0_n** outputs assert with the multiplexed AD address bus (**ad15 – ad0** or **ao15 – ao8** and **ad7 – ad0**) rather than the earlier timing of the **a19 – a0** bus unlike the **ucs_n** and **lcs_n** chip selects. The timing is delayed for a half cycle later than that for **ucs_n** and **lcs_n** if the **a19 – a0** bus is used for address selection.

The value of the MMCS register is undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>BA19 – BA13</i>							<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>R2</i>	<i>RI - R0</i>	

BA [15:9] (bits 15-9) – Base Address. The value of the BA19 – BA13 determines the Base Address of the memory block that is addressed by the **mcs_n** chip select pins. These bits correspond to bits **a19 – a13** of the 20-bit memory address. The remaining bits **a12 – a0** of the base address are always 0.

The base address may be any integer multiple of the size of the memory clock selected in the MPCS register. For example, if the midrange block is 32 Kbytes, the block could be located at 20000h or 28000h but not at 24000h.

If the **lcs_n** chip select is inactive, the base address of the midrange chip selects can be set to 00000h, because the **lcs_n** chip select is defined to be 00000h but is unused.

The further limitation that the base address must be an integer multiple of the block size means that a 512K MMCS block size can only be used with the **lcs_n** chip select inactive and the base address of the midrange chip selects set to 00000h.

Reserved [8:3] (bits 8-3) - Set to 1.

R2 (bit 2) – Ready mode. This bit determines the **mcs_n** chip selects ready mode. When *R2* is 0 an external ready is necessary, but if *R2* is 1 an external ready is ignored. In each case the number of wait states inserted in an access is determined by the value of the *R1* & *R0* bits.

R [1:0] (bits 1-0) – Wait-State Value. The number of wait states inserted in an access is determined by the value of the *R1* & *R0* bits. Up to three wait states can be inserted (*R1* - *R0* = 00b to 11b).

PACS (0a4h) - Peripheral Chip Select Register.

The Peripheral Chip Selects are asserted over 256-byte range with the same timing as the AD address bus. There are six chip selects, **pcs6_n - pcs5_n** and **pcs3_n - pcs0_n** that are utilized in either the user-locatable memory or I/O blocks. Excluding the areas utilized by the **ucs_n**, **lcs_n**, and **mcs_n** chip selects, the memory block can be located anywhere within the 1 Mbyte address space. These chip selects may also be configured to access the 64 Kbyte I/O space.

Programming the Peripheral Chip Selects uses two registers, The Peripheral Chip Select (PACS) register and the **pcs_n** and **mcs_n** Auxiliary (MPCS) register. The PACS register establishes the base address, configures the ready mode, and determines the number of wait states for the **pcs3_n - pcs0_n** outputs.

The MPCS register configures the **pcs6_n – pcs5_n** pins to be either chip selects or address pins **a1** and **a2**. When these pins are configured as chip selects, the MPCS register determines whether they are active during memory or I/O bus cycles and determines the ready state and wait states for these output pins. These pins are not active on reset but are activated as chip selects by writing to the two registers (PACS & MPCS). To configure and activate them as address pins it is necessary to write to both the PACS and MPCS registers. **pcs6_n – pcs5_n** can be configured for 0 to 3 wait states while **pcs3_n - pcs0_n** can be programmed for 0 to 15 wait states.

The value of the PACS register is undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>BA19 – BA11</i>										<i>1</i>	<i>1</i>	<i>1</i>	<i>R3</i>	<i>R2</i>	<i>R1 – R0</i>

BA [19:11] (bits 15-7) - Base Address bits determine the base address and correspond to bits 19 - 11 of the 20-bit programmable base address of the peripheral chip select block. However if the **PCS_n** chip selects are mapped to I/O space, these bits must be set to 0000b, as I/O addresses are only 16 bits wide.

PCS Address Ranges

PCSn Line	Range	
	Low	High
PCS0n	Base Address	Base Address + 255
PCS1n	Base Address + 256	Base Address + 511
PCS2n	Base Address + 512	Base Address + 767
PCS3n	Base Address + 768	Base Address + 1023
Reserved	N/A	N/A
PCS5n	Base Address + 1280	Base Address
PCS6n	Base Address + 1536	Base Address

Reserved [6:4] (bits 6-4) – Set to 1.

R [3] (bit 3) – Wait State Value. See following table.

R [2] (bit 2) – Ready Mode. When 0 and external ready is required. When 1, external ready is ignored, but in each case the number of wait states is determined as in the following table.

*R [1:0] (bits 1 – 0) – Wait-State Value. See following table. It should be noted that **pcs6_n** – **pcs5_n** and **pcs3_n** – **pcs0_n** pins are multiplexed with the programmable I/O pins and for them to function as chip selects, the PIO mode and direction settings for these pins must be set to 0 for normal operation.*

PCS3n – PCS0n Wait-State Encoding

<i>R3</i>	<i>R1</i>	<i>R0</i>	Wait States
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	5
1	0	1	7
1	1	0	9
1	1	1	15

LMCS (0a2h) - *Low Memory Chip Select* Register configures the Low Memory Chip Select that has been provided to facilitate access to the interrupt vector table located at 00000h or the bottom of memory. The **lcs_n** pin is not active at reset.

The width of the data bus for the **lcs_n** space should be configured in the AUXCON register before activating the **lcs_n** chip select pin, by any write access to the LMCS register.

The value of the LMCS register is undefined at reset except DA, which is set to 0.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	UB2 – UB0			1	1	1	1	DA	PSE	1	1	1	R2	R1-R0	

Reserved [15] (bit 15) – Set to 0

UB [2:0] (bits 14 – 12) - Upper Boundary. These bits define the upper boundary of memory accessed by the **lcs_n** chip select. The following table gives the possible configurations of block size (max 512Kbytes).

LMCS Block Size Programming Values

Memory Block Size	Ending Address	UB2 – UB0
64K	0FFFFh	000b
128K	1FFFFh	001b
256K	3FFFFh	011b
512K	7FFFFh	111b

Reserved [11:8] (bits 11-8) - Set to 1.

DA (bit 7) Disable Address - When set to 0 the address is driven onto the address bus (**ad15 – ad0**) during the address phase of a bus cycle, while if *DA* is set to 1, the address bus is disabled, providing some measure of power saving. This bit is set to 0 at reset.

If **BHE_n/ADEN_n** is held at 0 during the rising edge of **res_n**, then the address bus is always driven, independent of the setting of *DA*.

PSE (bit 6) PSRAM Mode Enable – PSRAM support for the **lcs_n** chip select memory space is enabled when the *PSE* is set to 1. The EDRAM, MDRAM, and CDRAM refresh control unit registers must be configured for auto refresh before PSRAM support is enabled. Setting the enable bit (*EN*) in the enable RCU register (EDRAM, offset e4h) configures the **mcs3_n/rfsh_n** as **rfsh_n**.

Reserved (bits 5-3) – Set to 1.

R2 (bit 2) - Ready Mode. When this bit is set to 0, an external ready is required, while when set to 1 the external ready is ignored. In either case however, the value of the *R1 - R0* bits determine the number of wait states inserted.

R [1:0] (bits R1-R0) - Wait-State Value. The number of wait states inserted into an access to the LCS memory area is determined by the value of these bits. This number ranges from 0 to 3 (*R1 – R0 = 00b to 11b*)

UMCS (0a0h) - Upper Memory Chip Select Register configures the Upper Memory Chip Select pin, which is used for the top of memory. On reset the first fetch takes place at memory location FFFF0h and thus this area of memory is usually used for instruction memory. With this in mind **ucs_n** defaults to an active state at reset with a memory range of 64 Kbytes (F0000h to FFFFh), external ready required, and three wait states automatically inserted. The upper end of the memory range always ends at FFFFh, whereas the lower end of this upper memory range is programmable.

The value of the UMCS register is F03Bh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
1	LB2 – LB0			0	0	0	0	DA	0	1	1	1	R2	R1-R0	

Reserved [15] (bit 15) – Set to 1.

LB [2:0] (bits 14–12) – Lower Boundary. These bits determine the bottom of the memory accessed by the **ucs_n** chip selects.

UMCS Block Size Programming Values

Memory Block Size	Starting Address	LB2 – LB0	Comments
64K	F0000h	111b	Default
128K	E0000h	110b	
256K	C0000h	100b	
512K	80000h	000b	

Reserved (bits 11 – 8)

DA (bit 7) – Disable Address. When set to 0 the address is driven onto the address bus (**ad15 – ad0**) during the address phase of a bus cycle when **ucs_n** is asserted, while if *DA* is set to 1, the address bus is disabled, and the address is not driven on the address bus when **ucs_n** is asserted, providing some measure of power saving. This bit is set to 0 at reset.

If **bhe_n/ad_n** is held at 0 during the rising edge of **res_n**, then the address bus is always driven independent of the setting of *DA*.

Reserved (bit 6) – Set to 0.

Reserved (bit 5 – 3) – Set to 1.

R2 (bit 2) Ready Mode – When this bit is set to 0, an external ready is required, while when set to 1 the external ready is ignored. In either case however, the value of the *RI - RO* bits determine the number of wait states inserted.

R [1:0] (bits 1-0) - Wait-State Value. The number of wait states inserted into an access to the **lcs_n** memory area is determined by the value of these bits. This number ranges from 0 to 3 (*RI - RO* = 00b to 11b).

SP0BAUD (088h) - Serial Port *BAUD* Rate Divisor Registers.

SP1BAUD (018h)

There are two baud rate divisor registers, one for each port, allowing the two ports to operate at different baud rates. The value in these registers determines the number of internal processor cycles in one phase (half-period) of the 16x serial clock.

The contents of these registers must be adjusted to reflect the new processor clock frequency if power-save mode is in effect.

The baud rate divisor may be calculated from:

$$\text{BAUDDIV} = (\text{Processor Frequency} / (16 \times \text{baud rate}))$$

By setting the BAUDDIV to 0001h, the maximum baud rate of 1/16 of the internal processor frequency clock is set. This provides a baud rate of 2500Kb at 40MHz. If the BAUDDIV is set to zero, transmission or reception of data does not occur. The baud rate tolerance is +3.0% and -2.5% with respect to the actual serial port baud rate, not the target baud rate.

Baud Rates

Baud Rate	Divisor Based on CPU Clock Rate			
	20 MHz	25 MHz	33 MHz	40 MHz
300	4166	5208	6875	8333
600	2083	2604	3437	4166
1050	1190	1488	1964	2380
1200	1041	1302	1718	2083
1800	694	868	1145	1388
2400	520	651	859	1041
4800	260	325	429	520
7200	173	217	286	347
9600	130	162	214	260
19200	65	81	107	130
28800	43	54	71	86
38400	33	40	53	65
56000	22	28	36	45
57600	22	27	35	43
76800	16	20	26	32
115200	10	13	18	22
128000	9	12	16	19
153600	8	10	13	16

Special	15 MHz	21 MHz	24 MHz	30 MHz
187500	5	7	8	10

The value of the SP0BAUD & SP1BAUD registers at reset is 0000h.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>BAUDDIV</i>															

BAUDDIV [15:0] (bits 15-0) – Baud Rate Divisor. Defines the divisor for the internal processor clock.

SP0RD (086h) - Serial Port Receive Registers.

SP1RD (016h)

Data received over the serial ports are stored in these registers until read. The data are received initially by the receive shift register (no software access) permitting data to be received while the previous data are being read.

The status of these registers is indicated by the *RDR* bit (Receive Data Ready) in the serial port status registers. When the *RDR* bit is set to 1 it indicates that there is valid data in the receive register. The *RDR* bit is automatically cleared when the receive register is read.

If handshaking is employed, the control signals *cts_n/enrx_n* are de-asserted while the receive register has valid unread data. The *cts_n/enrx_n* signal is reasserted after the data in the receive register is read.

The value of the SP0RD & SP1RD registers is undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>								<i>RDATA</i>							

Reserved (bits 15-8) – Reserved.

*RDATA [7:0] (bits 7-0) – Holds valid data while the *RDR* bit of the respective status register is set.*

SP0TD (084h) - Serial Port Transmit Registers.

SP1TD (014h)

Data is written to these registers, by software, with the values to be transmitted by the serial port. Double buffering of these transmitters allows for the transmission of data from the transmit shift registers (no software access), while the next data are written into the transmit registers.

The *TEMT* and *THRE* bits in the respective Serial Port Status registers indicate the status of these two pairs of registers.

Invoking handshaking requires that *rts_n/rtr_n* inputs be asserted before the transmitters can send any data which remain held in the transmit and shift registers without affecting the transmit pin.

The value of the SPTD registers is undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>								<i>TDATA</i>							

Reserved (bits 15-8) – Reserved.

TDATA [7:0] (bits 7-0) – Holds the data to be transmitted.

SP0STS (082h) – Serial Port *STatus* Register.

SP1STS (012h)

These registers store information concerning the current status of the respective ports. The status bits are described below.

The value of the SP0STS & SP1STS registers is undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>					<i>BRK1</i>	<i>BRK0</i>	<i>RB8</i>	<i>RDR</i>	<i>THRE</i>	<i>FER</i>	<i>OER</i>	<i>PER</i>	<i>TEMT</i>	<i>HS0</i>	<i>Res</i>

Reserved (bits 15-11) – Reserved.

BRK1 (bit 10) – Long Break Detected. A long break is a low signal level on the **rx**d pin for a period greater than $2M + 3$ bit times. $M = (\text{start bit} + \text{number of data bits} + \text{parity bits} + \text{stop bit})$. Should data reception be in progress when the break starts, the reception of the current word will be completed and then the timing for the break will begin. This will generate a framing error, as the stop bit will not be detected due to the break.

Detection of the break with the $2M + 3$ bit time period can only be guaranteed if the break commences outside of a frame.

NOTE: This bit should be reset by software.

BRK0 (bit 9) – Short Break Detected. A short break is a low on the **rx**d pin for a period greater than M bit times. $M = (\text{start bit} + \text{number of data bits} + \text{parity bits} + \text{stop bit})$. Should data reception be in progress when the break starts, the reception of the current word will be completed and then the timing for the break will begin. This will generate a framing error, as the stop bit will not be detected due to the break. Detection of the break with the M bit time period can only be guaranteed if the break commences outside of a frame.

NOTE: This bit should be reset by software.

RB8 (bit 8) – Received Bit 8. This is the ninth data bit received in modes 2 & 3. (See definition of the Serial Port Control Register).

NOTE: This bit should be reset by software.

RDR (bit 7) – Receive Data Ready. When this bit is 1 it indicates that the respective SPRD register contains valid data. This is a read only bit and can only be reset by reading the corresponding Receive register.

THRE (bit 6) – Transmit Holding Register Empty. When this bit is 1 it indicates that the corresponding transmit holding register is ready to accept data. This is a read only bit.

FER (bit 5) – Framing Error Detected. When the receiver samples the **rx**d line as low when a stop bit is expected (line high) a framing error is generated setting this bit.

NOTE: This bit should be reset by software.

OER (bit 4) – Overrun Error Detected. When new data overwrites valid data in the receive register (because it hasn't been read) an overrun error is detected setting this bit.

NOTE: This bit should be reset by software.

PER (bit 3) - Parity Error Detected. When a parity error is detected in either mode 1 or 3, this bit is set.

NOTE: This bit should be reset by software.

TEMT (bit 2) – Transmitter Empty. When both the transmit shift register and the transmit register are empty, this bit is set indicating to software that it is safe to disable the transmitter.

This bit is read only.

HS0 (bit 1) – Handshake Signal 0. This bit is the inverted value of **cts_n** and is read only.

RES (bit 0) – Reserved

SP0CT (080h) - Serial Port *ConTrol* Registers.

SP1CT (010h)

These registers control both transmit and receive parts of the respective serial ports.

The value of the SP0CT & SP1CT registers is 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>DMA</i>			<i>RSIE</i>	<i>BRK</i>	<i>TB8</i>	<i>FC</i>	<i>TXIE</i>	<i>RXIE</i>	<i>TMODE</i>	<i>RMODE</i>	<i>EVN</i>	<i>PE</i>	<i>MODE</i>		

DMA [15:13] (bits 15-13) – DMA Control Field. These bits set up the respective ports for use with DMA transfers as in the following table.

DMA Control Bits

DMA Bits	Receive	Transmit
000b	No DMA	No DMA
001b	DMA0	DMA1
010b	DMA1	DMA0
011b	Reserved	Reserved
100b	DMA0	No DMA
101b	DMA1	No DMA
110b	No DMA	DMA0
111b	No DMA	DMA1

DMA transfers to both serial ports are destination-synchronized operations. When the transmit holding register is empty, a new transfer is requested, corresponding with the assertion of the *THRE* bit in the status register in non-DMA mode. However when configured for DMA transfers, the respective transmit interrupt is disabled without regard for the *TXIE* bit.

DMA transfers from both serial ports are source-synchronized operations. When the receive holding register contains valid data, a new transfer is requested, corresponding with the assertion of the *RDR* bit in the status register in non-DMA mode. However when configured for DMA receives, the respective receive interrupt is disabled without regard for the *RXIE* bit, although the *RSIE* bit may still permit receive status interrupts depending on its setting.

DMA transfers do not preclude the use of hardware handshaking.

If either or both serial ports are configured for DMA transfers the DMA request is internally generated and the corresponding external DMA signals, **drq0** and/or **drq1** do not play a role.

RSIE (bit 12) – Receive Status Interrupt Enable. When an exception occurs during data reception an interrupt request is generated if enabled by this bit (*RSIE* = 1). Interrupt requests are made for the error conditions listed (*BRK0*, *BRK1*, *OER*, *PER*, and *FER*) in the serial port status register.

BRK (bit 11) – Send Break. When this bit is set to 1 the **txd** pin is driven low overriding any data that may be in the course of being shifted out of the transmit shift register.

See the definitions of long and short break in the Serial Port Status register definition.

TB8 (bit 10) – Transmit Bit 8. This is the ninth data bit transmitted when in modes 2 and 3. This bit is cleared at each transmitted word and is not buffered. To transmit data with this bit set high the following procedure is recommended.

1. The *TEMT* bit in the serial port status register must go high.
2. Set the *TB8* bit by writing it to the serial port control register.
3. Finally write the transmit character to the serial port transmit register.

FC (bit 9) – Flow Control Enable. This bit controls the hardware handshake (flow control) by enabling it when set to 1, and vice versa. The type of flow control depends on the value of the *ENRX0/ENRX1* and *RTS0/RTS1* bits in the *AUXCON* register.

Serial port 0 is a special case in that if this bit is 1 the associated pins are used for flow control overriding the Peripheral Chip Select signals.

This bit is 0 at reset.

TXIE (bit 8) – Transmitter Ready Interrupt Enable. This bit enables the generation of an interrupt requests whenever the transmit holding register is empty (*THRE* bit 1). The respective port does not generate interrupts when this bit is 0. Interrupts continue to be generated as long as *THRE* and the *TXIE* are 1.

RXIE (bit 7) – Receive Data Ready Interrupt Enable. This bit enables the generation of an interrupt requests whenever the receive register contains valid data (*RDR* bit 1). The respective port does not generate interrupts when this bit is 0. Interrupts continue to be generated as long as *RDR* and the *RXIE* are 1.

TMODE (bit 6) – Transmit Mode. The transmit section of the serial port is enabled when this bit is 1. Conversely the transmit section of the serial port is disabled when this bit is 0.

RMODE (bit 5) – Receive Mode. The receive section of the serial port is enabled when this bit is 1. Conversely the receive section of the serial port is disabled when this bit is 0.

EVN (bit 4) – Even Parity. When this bit is 1 even parity protocol is established, and conversely odd parity is established when this bit is 0.
 This bit is only valid when parity is enabled (*PE*).

PE (bit 3) – Parity Enable. Parity is enabled when this bit is 1 and disabled when this bit is 0.
MODE [2:0] (bit 2-0) – Mode of Operation. These three bits establish the mode of operation of the respective serial port. The following table shows the valid modes and their functions.

Serial Port MODE Settings

MODE	Description	Data Bits	Parity Bits	Stop Bits
0 *	Data Mode 0	7	n/a	2
1	Data Mode 1	7 or 8	1 or 0	1
2	Data Mode 2	9	n/a	1
3	Data Mode 3	8 or 9	1 or 0	1
4	Data Mode 4	7	n/a	1
5 *	Data Mode 5	7 or 8	1 or 0	2
6 *	Data Mode 6	9	0	2
7 *	Data Mode 7	8 or 9	1 or 0	2

Note: * these were originally reserved modes that have been implemented to provide 2 stop bits.

Mode 2 requires that the ninth data is set to a 1 state otherwise the character will be ignored by the receiver. The transmit section, however operates as if it were in mode 3.

This is designed to facilitate multi drop communication over a common serial data link. For this purpose the port in question is initially programmed to mode 2 and for each data received with the ninth bit (bit 8) set as 1, it is compared by software with a unique identifier for this port. If the identifier comparison does not find a match then the port is left in mode 2. In the case that the comparison finds an identifier match the port should be reprogrammed to mode 3 so that the ninth bit is allowed to be 0.

Handshaking should only be employed in such multidrop system by ports that are exchanging data (mode 3) to prevent multiple ports from attempting to drive the handshake signals. Mode 2 does not support handshaking for this reason and should not be enabled. If it is possible that more than 2 ports be configured in mode 3 at the same time then handshaking should not be implemented.

Mode 3 allows for 8 data bits if parity is enabled or 9 data bits if parity is not enabled. If parity is not used then the ninth data bit for the transmit section is set by writing a 1 to the TB8 bit in the serial port control register. The ninth bit is read at the receive port from the RB8 bit in the serial port status register.

Mode 4 simply allows for a start bit, 7 data bits, and a stop bit without parity, which is not available.

PDATA1 (07ah) - *PIO DATA* Registers.

PDATA0 (074h),

When a PIO pin is configured as an output the value in the corresponding PIO data register bit is driven onto the pin. On the other if the PIO pin is configured as an input then the value on the pin is put into the corresponding bit of the PIO data register.

The following table lists the default states for the PIO pins.

PIO Pin Assignments

PIO Number	Associated Pin Name	Power-On Reset Status
0	tmrin1	Input with pull-up
1	tmrout1	Input with pull-down
2	pcs6/A2	Input with pull-up
3	pcs5/A1	Input with pull-up
4	dt/r_n	Normal operation ^(c)
5	den_n/ds_n	Normal operation ^(c)
6	srdy	Normal operation _(d)
7 ^(a)	a17	Normal operation ^(c)
8 ^(a)	a18	Normal operation ^(c)
9 ^(a)	a19	Normal operation ^(c)
10	tmrout0	Normal operation ^(c)
11	tmrin0	Input with pull-up
12	drq0/int5	Input with pull-up
13	drq1/int6	Input with pull-up
14	mcs0_n	Input with pull-up
15	mcs1_n	Input with pull-up
16	pcs0_n	Input with pull-up
17	pcs1_n	Input with pull-up
18	pcs2_n/cts1_n/enrx1_n	Input with pull-up
19	pcs3_n/rts1_n/rtr1_n	Input with pull-up
20	rts0_n/rtr0_n	Input with pull-up
21	cts0_n/enrx0_n	Input with pull-up
22	txd0	Input with pull-up
23	rxid0	Input with pull-up
24	mcs2_n	Input with pull-up
25	mcs3_n/rfsh_n	Input with pull-up

PIO Pin Assignments - continued

PIO Number	Associated Pin Name	Power-On Reset Status
26 ^(a, b)	uzi	Input with pull-up
27	txd1	Input with pull-up
28	rxd1	Input with pull-up
29 ^(a, b)	s6/lock_n/clkdiv2_n	Input with pull-up
30	int4	Input with pull-up
31	int2/inta0_n/pwd	Input with pull-up

Notes: -

- a). Emulators use these pins. (s2_n-s0_n, res_n, nmi, clkouta, bhe_n, ale, ad15 – ad0, and a16 – a0 are used by emulators also.)
- b). If bhe_n/aden_n is held low during power-on reset these pins revert to normal operation.
- c). When used as a PIO pin, it is an input with an available pull-up option.
- d). When used as a PIO pin, it is an input with an available pull-down option.

The 32 PIO pins initialize to either 00b or 01b as shown in following table.

The value of the PDATA registers is undefined at reset.

PDATA 0

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>PDATA (15 – 0)</i>															

PDATA 1

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>PDATA (31 – 16)</i>															

PDATA [15:0] (bits 15-0) – PIO Data 0 Bits. This register contains the values of the bits that are either driven on or received from the corresponding PIO pins depending on its configuration each pin as either an output or an input. The values of these bits correspond to those in the PIO direction registers and PIO Mode registers.

PDATA [31:16] (bits 15-0) – PIO Data 1 Bits. This register contains the values of the bits that are either driven on, or received from, the corresponding PIO pins depending on its configuration each

pin as either an output or an input. The values of these bits correspond to those in the PIO direction registers and PIO Mode registers

The PIO pins may be operated as open-drain outputs by: -

1. Maintain the data constant in the appropriate bit of the PIO data register.
2. Writing the value of the data bit into the respective bit position of the PIO Direction register, so that the output is either 0 or disabled depending on the value of the data bit.

PDIR1 (078h) - PIO DIRection Registers.

PDIR0 (072h)

Each PIO pin is configured as an input or an output by the corresponding bit in the PIO direction register.

PIO Mode and PIO Direction Settings

PIO Mode	PIO Direction	Pin function
0	0	Normal operation
0	1	PIO input with pullup/pulldown
1	0	PIO output
1	1	PIO input without pullup/pulldown

PDIR0

The value of the PDIR0 register is FC0Fh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>PDIR (15 – 0)</i>															

PDIR1

The value of the PDIR1 register is FFFFh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>PDIR (31 – 16)</i>															

PDIR [15:0] (bits 15-0) – PIO Direction 0 Bits. For each bit, if the value is 1 then the pin is configured as an input and as an output if the value is 0. The values of these bits correspond to those in the PIO data registers and PIO Mode registers.

PDIR [31:16] (bits 15-0) – PIO Direction 1 Bits. For each bit, if the value is 1 then the pin is configured as an input and as an output if the value is 0. The values of these bits correspond to those in the PIO data registers and PIO Mode registers.

PMODE1 (076h) - PIO MODE Registers.

PMODE0 (070h)

Each PIO pin is configured as an input or an output by the corresponding bit in the PIO direction register.

The bit number of PMODE corresponds to the PIO number.

See the table *PIO Mode and PIO Direction Settings* in PDIR description above.

PMODE0

The value of the PDIR0 register is 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>PMODE (15 – 0)</i>															

PMODE1

The value of the PDIR1 register is 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>PMODE (31 – 16)</i>															

PMODE [15:0] (bits 15-0) – PIO Mode 0 Bits. For each bit, if the value is 1 then the pin is configured as an input and as an output if the value is 0. The values of these bits correspond to those in the PIO data registers and PIO Mode registers.

PMODE [31:16] (bits 15-0) – PIO Mode 1 Bits. For each bit, if the value is 1 then the pin is configured as an input and as an output if the value is 0. The values of these bits correspond to those in the PIO data registers and PIO Mode registers.

T1CON (05eh) - Timer 0 and Timer 1 Mode and CONTROL Registers.

T0CON (056h)

This registers controls the operation of the Timer 0 and Timer 1 respectively.

The value of the T0CON and T1CON registers is 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>EN</i>	<i>INHn</i>	<i>INT</i>	<i>RIU</i>	0	0	0	0	0	0	<i>MC</i>	<i>RTG</i>	<i>P</i>	<i>EXT</i>	<i>ALT</i>	<i>CONT</i>

EN (bit 15) – Enable Bit. The timer is enabled when the *EN* bit is 1. The timer count is inhibited when the *EN* bit is 0. Setting this bit to 1 by writing to the T2CON register requires that the *INHn* bit be set to 1 during the same write. This bit is write only, but with the *INHn* bit set to 1 in the same write operation.

INHn (bit 14) – Inhibit Bit. Gates the setting of the enable (*EN*) bit. This bit must be set to 1 in the same write operation that sets the enable (*EN*) bit. This bit always reads as 0.

INT (bit 13) – Interrupt Bit. An interrupt request is generated when the Count register reaches its maximum, *MC* = 1, by setting the *INT* bit to 1. In dual maxcount mode an interrupt request is generated when the count register reaches the value in maxcount A or maxcount B. No interrupt requests are generated if this bit is set to 0. If an interrupt request is generated and then the enable bit is cleared before said interrupt is serviced, the interrupt request will remain.

RIU (bit 12) – Register in Use Bit. This bit is set to 1 when the maxcount register B is used to compare to the timer count value. It is set to 0 when the maxcount compare A register is used.

Reserved (bits 11-6) – Set to 0.

MC (bit 5) – Maximum Count. When the timer reaches its maximum count this bit is set to 1 regardless of the interrupt enable bit. This bit is also set every time maxcount compare register A or B is reached, when in dual maxcount mode. This bit may be used by software polling to monitor timer status rather than through interrupts if desired.

RTG (bit 4) – Retrigger Bit.

P (bit 3) – Prescaler Bit. *P* is ignored if external clocking is enabled (*EXT* = 1). Timer 2 prescales the timer when *P* is set to 1. Otherwise the timer is incremented on every fourth CLKOUT cycle.

EXT (bit 2) – External Clock Bit. This bit determines whether an external or internal clock is used. *EXT* = 1, an external clock is used and *EXT* = 0, an internal is used.

ALT (bit 1) – Alternate Compare Bit. If set to 1, the timer will count to maxcount compare register A, reset the count register to 0, and then count to maxcount compare register B, reset the count register to 0 and begin again at maxcount compare register A.

If set to 0, the timer will count to maxcount compare register A, reset the count register to 0, and begin again at maxcount compare register A. Maxcount compare register B is not used in this case.

CONT (bit 0) – Continuous Mode Bit. The timer will run continuously when this bit is set to 1. The timer will stop after each count run and *EN* will be cleared if the *CONT* bit is set to 0. If *CONT* = 1 and *ALT* = 1, the respective timer counts to the maxcount compare A value and resets, then it commences counting to maxcount compare B value, resets and ceases counting.

T2CON (066h) - Timer 2 Mode and CONTROL Registers.

This register controls the operation of the Timer 2.

The value of the T2CON register is 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>EN</i>	<i>INH_n</i>	<i>INT</i>	0	0	0	0	0	0	0	<i>MC</i>	0	0	0	0	<i>CONT</i>

EN (bit 15) – Enable Bit. The timer is enabled when the *EN* bit is 1. The timer count is inhibited when the *EN* bit is 0. Setting this bit to 1 by writing to the T2CON register requires that the *INH* bit be set to 1 during the same write. This bit is write only, but with the *INH_n* bit set to 1 in the same write operation.

INH (bit 14) – Inhibit Bit. Gates the setting of the enable (*EN*) bit. This bit must be set to 1 in the same write operation that sets the enable (*EN*) bit. This bit always reads as 0.

INT (bit 13) – Interrupt Bit. An interrupt request is generated when the Count register reaches its maximum, *MC* = 1, by setting the *INT* bit to 1.

Reserved (bits 12-6) – Set to 0.

MC (bit 5) – Maximum Count. When the timer reaches its maximum count this bit is set to 1 regardless of the interrupt enable bit. This bit may be used by software polling to monitor timer status rather than through interrupts if desired.

Reserved (bits 4-1) – Set to 0.

CONT (bit 0) – Continuous Mode Bit. The timer will run continuously when this bit is set to 1. The timer will stop after each count run and *EN* will be cleared if this bit is set to 0.

T2COMPA (062h), - *Timer* Maxcount *COM*pare Registers.

T1COMPB (05ch)

T1COMPA (05ah)

T0COMPB (054h)

T0COMPA (052h)

These registers contain the maximum count value that is compared to the respective count register. Timer 0 and Timer 1 have two of these compare registers each.

If Timer 0 and/or Timer 1 is/are configured to count and compare firstly to register A and then register B, the TMROUT0 or TMROUT1 signals may be used to generate various duty-cycle wave forms.

Timer 2 has only one compare register, T2COMPA.

If one of these timer maxcount compare registers is set to 0000h, the respective timer will count from 0000h to FFFFh before generating an interrupt request. For example a timer configured in this manner with a 40MHz clock will interrupt every 6.5536 mS.

The value of these registers is 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>TC15 – TC0</i>															

TC [15:0] (bits 15-0) – Timer Compare Value. The timer will count to the value in the respective register before resetting the count value to 0.

T2CNT (060h) - *Timer Cou*NT Registers.

T1CNT (058h)

T0CNT (050h),

These registers are incremented by one every four internal clock cycles if the relevant timer is enabled.

The Increment of Timer 0 and Timer 1 may also be controlled by external signals tmrin0 and tmrin1 respectively, or prescaled by Timer 2.

Comparisons are made between the count registers and maxcount registers and action taken dependant on achieving the maximum count.

The value of these registers is 0000h at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>TC15 – TC0</i>															

TC [15:0] (bits 15-0) – Timer Count Value. This register has the value of the current count of the related timer that is incremented every fourth processor clock in internal clocked mode.

Alternatively the register is incremented each time the Timer 2 maxcount is reached if using Timer 2 as a prescaler. Timer 0 and Timer 1 may be externally clocked by *tmin0* and *tmin1* signals.

SP0CON (044h) - Serial Port Interrupt *CON*trol Registers.

SP1CON (042h)

(Master Mode)

These registers control the operation of the serial ports' interrupt source

The value of these registers is 001Fh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>											<i>Res</i>	<i>MSK</i>	<i>PR2</i>	<i>PR1</i>	<i>PR0</i>

Reserved (bits 15-5) – Set to 0.

Reserved (bit 4) – Set to 1.

MSK (bit 3) – Mask. This bit, when 0, enables the serial port to cause and interrupt. When this bit is 1 prevents the serial port from generating and interrupt.

PR [2:0] (bits 2-0) – Priority. These bits define the priority of the serial port interrupt in relation to other interrupt signals. The interrupt priority is the lowest at 7 at reset. The values of *PR2 – PR0* are shown in the following table.

Priority Level

Priority	<i>PR2 – PR0</i>
(High) 0	000b
1	001b
2	010b
3	011b
4	100b
5	101b
6	110b
(Low) 7	111b

I4CON (040h) – *INT4 CON*trol Register.

(Master Mode)

The **int4** signal is only intended for use in fully nested mode and is not available in cascade mode.

The value of the I4CON register is 000Fh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>											<i>LTM</i>	<i>MSK</i>	<i>PR2</i>	<i>PR1</i>	<i>PR0</i>

Reserved (bits 15-5) – Set to 0.

LTM (bit 4) – Level-Triggered Mode. The int4 interrupt may be edge or level triggered depending on the value of the bit. If *LTM* is 1, int4 is active high level sensitive interrupt and if *LTM* is 0, int4 is a rising edge triggered interrupt. The interrupt int4 must remain active (high) until serviced.

MSK (bit 3) – Mask. The int4 signal can cause an interrupt if the *MSK* bit is 0. The int4 signal cannot cause an interrupt if the *MSK* bit is 1.

PR [2:0] (bit 2-0) – Priority. These bits define the priority of the serial port interrupt in relation to other interrupt signals. The interrupt priority is the lowest at 7 at reset. The values of *PR2 – PR0* are shown in the above table (Priority Level).

I3CON (03eh) – INT2/INT3 CONTROL Register.

I2CON (03ch),

(Master Mode)

INT2 and INT3 are designated as interrupt type 0eh and 0fh respectively.

The **int2** and **int3** pins may be configured as the interrupt acknowledge pins inta0 and inta1 respectively in cascade mode.

The value of these registers is 000Fh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>											<i>LTM</i>	<i>MSK</i>	<i>PR2</i>	<i>PR1</i>	<i>PR0</i>

Reserved (bits 15-5) – Set to 0.

LTM (bit 4) – Level-Triggered Mode. The **int2** or **int3** interrupt may be edge or level triggered depending on the value of this bit. If *LTM* is 1, **int2** or **int3** is an active high level-sensitive interrupt and if *LTM* is 0, **int2** or **int3** is a rising edge triggered interrupt. The interrupt int2 or int3 must remain active (high) until acknowledged.

MSK (bit 3) – Mask. The int2 or int3 signal can cause an interrupt if the *MSK* bit is 0. The **int2** or **int3** signal cannot cause an interrupt if the *MSK* bit is 1. The Interrupt Mask Register has a duplicate of this bit.

PR [2:0] (bit 2-0) – Priority. These bits define the priority of the serial port interrupt **int2** or **int3** in relation to other interrupt signals. The interrupt priority is the lowest at 7 at reset. The values of *PR2 – PR0* are shown in the above table (Priority Level).

I1CON (03ah) – *INT0/INT1 CONtrol Register.*

I0CON (038h),

(Master Mode)

IINT0 and INT1 are designated as interrupt type 0ch and 0dh respectively.

The **int2** and **int3** pins may be configured as the interrupt acknowledge pins **inta0** and **inta1** respectively, the interrupt acknowledge signals for **int0** and **int1** in cascade mode.

The value of these registers is 000Fh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>									<i>SFNM</i>	<i>C</i>	<i>LTM</i>	<i>MSK</i>	<i>PR2</i>	<i>PR1</i>	<i>PR0</i>

Reserved (bits 15-7) – Set to 0.

SPNM (bit 6) – Special Fully Nested Mode. This bit enables fully nested mode for int0 or int1 when set to 1.

C (bit 5) – Cascade Mode. This bit enables cascade mode for int0 or int1 when set to 1.

LTM (bit 4) – Level-Triggered Mode. The **int0** or **int1** interrupt may be edge or level triggered depending on the value of the bit. If *LTM* is 1, **int0** or **int1** is an active high level-sensitive interrupt and if *LTM* is 0, **int0** or **int1** is a rising edge triggered interrupt. The interrupt **int0** or **int1** must remain active (high) until acknowledged.

MSK (bit 3) – Mask. The **int0** or **int1** signal can cause an interrupt if the *MSK* bit is 0. The **int0** or **int1** signal cannot cause an interrupt if the *MSK* bit is 1. The Interrupt Mask Register has a duplicate of this bit.

PR [2:0] (bit 2-0) – Priority. These bits define the priority of the serial port interrupt **int0** or **int1** in relation to other interrupt signals. The interrupt priority is the lowest at 7 at reset. The values of *PR2 – PR0* are shown in the above table (Priority Level).

TCUCON (032h) - *Timer Control Unit Interrupt CONtrol Register.*

(Master Mode)

The three timers, Timer2, Timer1, and Timer0, have their interrupts assigned to types 08h, 12h, and 13h and are configured by this register.

The value of these registers is 000Fh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>												<i>MSK</i>	<i>PR2</i>	<i>PR1</i>	<i>PR0</i>

Reserved (bits 15-4) – Set to 0.

MSK (bit 3) – Mask. Any of the interrupt sources may cause an interrupt if the *MSK* bit is 0. The interrupt sources cannot cause an interrupt if the *MSK* bit is 1. The Interrupt Mask Register has a duplicate of this bit.

PR [2:0] (bit 2-0) – Priority. These bits define the priority of the serial port interrupts in relation to other interrupt signals. The interrupt priority is the lowest at 7 at reset. The values of *PR2 – PR0* are shown in the above table (Priority Level).

T2INTCON (03ah) - Timer *INT*errupt *CON*trol Register.

T1INTCON (038h)

T0INTCON (032h)

(Slave Mode)

The three timers, Timer2, Timer1, and Timer0, each have an interrupt control register, whereas in master mode all three are masked and prioritized in one register (TCUCON).

The value of these registers is 000Fh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>												<i>MSK</i>	<i>PR2 - PR0</i>		

Reserved (bits 15-4) – Set to 0.

MSK (bit 3) – Mask. Any of the interrupt sources may cause an interrupt if the *MSK* bit is 0. The interrupt sources cannot cause an interrupt if the *MSK* bit is 1. The Interrupt Mask Register has a duplicate of this bit.

PR [2:0] (bit 2-0) – Priority. These bits define the priority of the serial port interrupts in relation to other interrupt signals. The interrupt priority is the lowest at 7 at reset. The values of *PR2 – PR0* are shown in the above table (Priority Level).

DMA1CON/INT6CON (036h) – DMA and INTerrupt CONtrol Register.

DMA0CON/INT5CON (034h)

(Master Mode)

The DMA0 and DMA1 interrupts have interrupt type 0ah and 0bh respectively. These pins are configured as external interrupts or DMA requests in the respective DMA Control register.

The value of these registers is 000Fh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>											<i>MSK</i>	<i>PR2 - PR0</i>			

Reserved (bits 15-4) – Set to 0.

MSK (bit 3) – Mask. Any of the interrupt sources may cause an interrupt if the *MSK* bit is 0. The interrupt sources cannot cause an interrupt if the *MSK* bit is 1. The Interrupt Mask Register has a duplicate of this bit.

PR [2:0] (bits 2-0) – Priority. These bits define the priority of the serial port interrupts in relation to other interrupt signals. The interrupt priority is the lowest at 7 at reset. The values of *PR2* – *PR0* are shown in the above table (Priority Level).

DMA1CON/INT6 (036h) – DMA and INTerrupt CONtrol Register.

DMA0CON/INT5 (034h)

(Slave Mode)

The two DMA control registers maintain their original functions and addressing that they possessed in Master Mode. . These pins are configured as external interrupts or DMA requests in the respective DMA Control register.

The value of these registers is 000Fh at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>											<i>MSK</i>	<i>PR2 - PR0</i>			

Reserved (bits 15-4) – Set to 0.

MSK (bit 3) – Mask. Any of the interrupt sources may cause an interrupt if the *MSK* bit is 0. The interrupt sources cannot cause an interrupt if the *MSK* bit is 1. The Interrupt Mask Register has a duplicate of this bit.

PR [2:0] (bits 2-0) – Priority. These bits define the priority of the serial port interrupts in relation to other interrupt signals. The interrupt priority is the lowest at 7 at reset. The values of *PR2 – PR0* are shown in the above table (Priority Level).

INTSTS (030h) – *INT*errupt *ST*atus Register.

(Master Mode)

The Interrupt status register contains the interrupt request status of each of the three timers, Timer2, Timer1, and Timer0.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>DHLT</i>	<i>Reserved</i>											<i>TMR2 - TMR0</i>			

DHLT (bit 15) – DMA Halt. DMA activity is halted when this bit is 1. It is set to 1 automatically when any non-maskable interrupt occurs and is cleared to 0 when an IRET instruction is executed. Interrupt handlers and other time critical software may modify this bit directly to disable DMA transfers. However, the *DHLT* bit should not be modified by software if the timer interrupts are enabled as the function of this register as an interrupt request register for the timers would be compromised.

Reserved (bits 14-3)

TMR [2:0] (bit 2-0) – Timer Interrupt Request. A pending interrupt request is indicated by the respective timer, when any of these bits is 1. (N.B. the *TMR* bit in the *REQST* register is a logical OR of these timer interrupt requests)

(Slave Mode)

When nonmaskable interrupts occur the interrupt status register controls DMA operation and the interrupt request status of each of the three timers, Timer2, Timer1, and Timer0.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>DHLT</i>	<i>Reserved</i>											<i>TMR2 - TMR0</i>			

DHLT (bit 15) – DMA Halt. DMA activity is halted when this bit is 1. It is set to 1 automatically when any non-maskable interrupt occurs and is cleared to 0 when an IRET instruction is executed. Interrupt handlers and other time critical software may modify this bit directly to disable DMA transfers. However, the *DHLT* bit should not be modified by software if the timer interrupts are enabled as the function of this register as an interrupt request register for the timers would be compromised.

Reserved (bits 14-3)

TMR [2:0] (bit 2-0) – Timer Interrupt Request. A pending interrupt request is indicated by the respective timer, when any of these bits is 1. (N.B. the *TMR* bit in the *REQST* register is a logical OR of these timer interrupt requests)

REQST (02eh) – Interrupt *REQueST* Register.

(Master Mode)

This is a read only register, and such a read results in the status of the interrupt request bits presented to the interrupt controller.

The *REQST* register is undefined on reset

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>					<i>SP0</i>	<i>SP1</i>	<i>I4</i>	<i>I3</i>	<i>I2</i>	<i>I1</i>	<i>IO</i>	<i>D1/I6</i>	<i>D0/I5</i>	<i>Res</i>	<i>TMR</i>

Reserved (bits 15 – 11)

SP0 (bit 10) – Serial Port 0 Interrupt Request. This is the serial port 0 interrupt state and when enabled is the logical OR of all the serial port 0 interrupt sources: - *THRE*, *RDR*, *BRK1*, *BRK0*, *FER*, *PER*, and *OER*.

SP1 (bit 9) – Serial Port 1 Interrupt Request. This is the serial port 1 interrupt state and when enabled is the logical OR of all the serial port 1 interrupt sources: - *THRE*, *RDR*, *BRK1*, *BRK0*, *FER*, *PER*, and *OER*.

I [4:0] (bits 8 - 4) Interrupt Requests. When any of these bits is set to 1 it indicates that the relevant interrupt has a pending interrupt.

D1/I6 (bit 3) DMA Channel 1/Interrupt 6 Request. When set to 1 it indicates that either the DMA channel 1 or int6 has a pending interrupt.

D0/I5 (bit 2) DMA Channel 0/Interrupt 5 Request. When set to 1 it indicates that either the DMA channel 0 or int5 has a pending interrupt.

Reserved (bit 1)

TMR (bit 0) – Timer Interrupt Request. This is the timer interrupt state and is the logical OR of the timer interrupt requests. When set to 1 it indicates that the timer control unit has a pending interrupt.

(Slave Mode)

This is a read only register, and such a read results in the status of the interrupt request bits presented to the interrupt controller. The status of these bits is available when this register is read. This register is read only.

When an internal interrupt request (*D1/I6*, *D0/I5*, *TMR2*, *TMR1*, or *TMR0*) occurs, the respective bit is set to 1. The internally generated interrupt acknowledge resets these bits.

The REQST register contains 0000h on reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>										<i>TMR2</i>	<i>TMR1</i>	<i>D1/I6</i>	<i>D0/I5</i>	<i>Res</i>	<i>TMR0</i>

Reserved (bits 15 – 6)

TMR2 (bit 5) Interrupt Requests. When set to 1 it indicates that timer 2 has a pending interrupt.

TMR1 (bit 4) Interrupt Requests. When set to 1 it indicates that timer 1 has a pending interrupt.

D1/I6 (bit 3) DMA Channel 1/Interrupt 6 Request. When set to 1 it indicates that either the DMA channel 1 or **int6** has a pending interrupt.

D0/I5 (bit 2) DMA Channel 0/Interrupt 5 Request. When set to 1 it indicates that either the DMA channel 0 or **int5** has a pending interrupt.

Reserved (bit 1)

TMR0 (bit 0) – Timer Interrupt Request. When set to 1 it indicates that timer 0 has a pending interrupt.

INSERV (02ch) – IN-SERVice Register.

(Master Mode)

The interrupt controller sets the bits in this register when the interrupt is taken.

The INSERV register contains 0000h on reset

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>					<i>SP0</i>	<i>SP1</i>	<i>I4</i>	<i>I3</i>	<i>I2</i>	<i>I1</i>	<i>I0</i>	<i>D1/I6</i>	<i>D0/I5</i>	<i>Res</i>	<i>TMR</i>

Reserved (bits 15 – 11)

SP0 (bit 10) – Serial Port 0 Interrupt Request. This is the serial port 0 interrupt state.

SP1 (bit 9) – Serial Port 1 Interrupt Request. This is the serial port 1 interrupt state.

I [4:0] (bits 8 - 4) Interrupt Requests. When any of these bits is set to 1 it indicates that the relevant interrupt has a pending interrupt.

D1/I6 (bit 3) DMA Channel 1/Interrupt 6 Request. When set to 1 it indicates that either the DMA channel 1 or **int6** has a pending interrupt.

D0/I5 (bit 2) DMA Channel 0/Interrupt 5 Request. When set to 1 it indicates that either the DMA channel 0 or **int5** has a pending interrupt.

Reserved (bit 1)

TMR (bit 0) – Timer Interrupt Request. This is the timer interrupt state and is the logical OR of the timer interrupt requests. When set to 1 it indicates that the timer control unit has a pending interrupt.

(Slave Mode)

This is a read only register, and such a read results in the status of the interrupt request bits presented to the interrupt controller. The status of these bits is available when this register is read. This register is read only.

When an internal interrupt request (*D1/I6*, *D0/I5*, *TMR2*, *TMR1*, and *TMR0*) occurs, the respective bit is set to 1. The internally generated interrupt acknowledge resets these bits.

The *REQST* register contains 0000h on reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>										<i>TMR2</i>	<i>TMR1</i>	<i>D1/I6</i>	<i>D0/I5</i>	<i>Res</i>	<i>TMR0</i>

Reserved (bits 15 – 6)

TMR2 (bit 5) Timer2 Interrupt In Service. Timer 2 is being serviced when this bit is set to 1.

TMR1 (bit 4) Timer1 Interrupt IN Service. Timer 1 is being serviced when this bit is set to 1.

D1/I6 (bit 3) DMA Channel Interrupt 6 In Service. DMA channel 1 or **int6** is being serviced when this bit is set to 1.

D0/I5 (bit 2) DMA Channel Interrupt 5 IN Service. DMA channel 0 or **int5** is being serviced when this bit is set to 1.

Reserved (bit 1)

TMRO (bit 0) – Timer Interrupt In Service. Timer 0 is being serviced when this bit is set to 1.

PRIMSK (02ah) – *PR*iority *Ma*SK Register.

(Master & Slave Mode)

This register contains a value that sets the minimum priority level at which an interrupt can be generated by a maskable interrupt.

The PRIMSK register contains 0007h on reset

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	PRM2 – PRM0		

Reserved (bits 15 – 3) – Set to 0.

PRM [2:0] (bits 2 - 0) Priority Field Mask. This three-bit field sets the minimum priority necessary for a maskable interrupt to generate an interrupt. Any maskable interrupt, with a numerically higher value than that contained by these three bits, are masked.

Priority Level

Priority	PR2 – PR0
(High) 0	0 0 0b
1	0 0 1b
2	0 1 0b
3	0 1 1b
4	1 0 0b
5	1 0 1b
6	1 1 0b
(Low) 7	1 1 1b

Any unmasked interrupt may generate an interrupt if the priority level is set to 7. On the other hand if the priority level is set to say 4 only unmasked interrupts with a priority of 0 to 5 are permitted to generate interrupts.

IMASK (028h) – Interrupt *MASK* Register.

(Master Mode)

The interrupt mask register is read/write. Setting a bit in this register is effectively the same as setting the *MSK* bit in the corresponding interrupt control register. Setting a bit to 1, masks the interrupt. The interrupt request is enabled when the corresponding bit is set to 0.

The IMASK register contains 07fdh on reset

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>					<i>SP0</i>	<i>SP1</i>	<i>I4</i>	<i>I3</i>	<i>I2</i>	<i>I1</i>	<i>IO</i>	<i>D1/I6</i>	<i>D0/I5</i>	<i>Res</i>	<i>TMR</i>

Reserved (bits 15 – 11)

SP0 (bit 10) – Serial Port 0 Interrupt Mask. Setting this bit to 1 is an indication that the serial port 0 interrupt is masked.

SP1 (bit 9) – Serial Port 1 Interrupt Mask. Setting this bit to 1 is an indication that the serial port 0 interrupt is masked.

I [4:0] (bits 8 - 4) Interrupt Mask. When any of these bits is set to 1 it is an indication that the relevant interrupt is masked.

D1/I6 (bit 3) DMA Channel 1/Interrupt 6 Mask. Setting this bit to 1 is an indication that either the DMA channel 1 or **int6** interrupt is masked.

D0/I5 (bit 2) DMA Channel 0/Interrupt 5 Mask. When set to 1 it indicates that either the DMA channel 0 or **int5** interrupt is masked.

Reserved (bit 1)

TMR (bit 0) – Timer Interrupt Mask. When set to 1 it indicates that the timer control unit interrupt is masked.

(Slave Mode)

The interrupt mask register is read/write. Setting a bit in this register is effectively the same as setting the *MSK* bit in the corresponding interrupt control register. Setting a bit to 1, masks the interrupt request. The interrupt request is enabled when the corresponding bit is set to 0.

The IMASK register contains 003dh on reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>Reserved</i>										<i>TMR2</i>	<i>TMR1</i>	<i>D1/I6</i>	<i>D0/I5</i>	<i>Res</i>	<i>TMR0</i>

Reserved (bits 15 – 6)

TMR2 (bit 5) Timer2 Interrupt Mask. This bit provides an indication of the state of the mask bit in the Timer Interrupt Control register. When it is set to 1, it indicates that the interrupt request is masked.

TMR1 (bit 4) Timer1 Interrupt Mask. This bit provides an indication of the state of the mask bit in the Timer Interrupt Control register. When it is set to 1, it indicates that the interrupt request is masked.

DI/I6 (bit 3) DMA Channel Interrupt 6 Mask. This bit provides an indication of the state of the mask bit in the DMA channel 0 or **int5** Interrupt Control register. When it is set to 1, it indicates that the interrupt request is masked.

D0/I5 (bit 2) DMA Channel Interrupt 5 Mask. This bit provides an indication of the state of the mask bit in the DMA channel 1 or **int6** Interrupt Control register. When it is set to 1, it indicates that the interrupt request is masked.

TMRO (bit 0) – Timer Interrupt Mask. This bit provides an indication of the state of the mask bit in the Timer Interrupt Control register. When it is set to 1, it indicates that the interrupt request is masked.

POLLST (026h) – *POLL* Status Register.

(Master Mode)

This register reflects the current state of the Poll register and can be read without affecting its contents. However when the Poll Register is read, it causes the current interrupt to be acknowledged and be replaced by the next interrupt.

The poll status register is read only.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>IREQ</i>	<i>Reserved</i>									<i>S4 – S0</i>					

IREQ (bit 15) – Interrupt Request. This bit is set to 1 when an interrupt is pending and during this state, the *S4 - S0* bits contain valid data.

Reserved (bits 14-6)

S [5:0] (bit 5-0) – Poll Status. These bits show the interrupt type of the highest priority pending interrupt.

POLL (024h) – *POLL* Register.

(Master Mode)

When the Poll Register is read, it causes the current interrupt to be acknowledged and be replaced by the next interrupt. The poll status register reflects the current state of the Poll register and can be read without affecting its contents.

The POLL register is read only.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>IREQ</i>	<i>Reserved</i>										<i>S4 – S0</i>				

IREQ (bit 15) – *Interrupt Request*. This bit is set to 1 when an interrupt is pending and during this state, the *S4 - S0* bits contain valid data.

Reserved (bits 14-6)

S [4:0] (bit 4-0) – *Poll Status*. These bits show the interrupt type of the highest priority pending interrupt.

EOI (022h) – *End-Of-Interrupt* Register.

(Master Mode)

The In Service flags of the In-Service register are reset when a write is made to the EOI register.

The interrupt service routine (ISR) should write to the EOI to reset the IS bit, in the In-Service register, for the interrupt before executing an IRET instruction than ends an interrupt service routine.

The Specific EOI reset is the preferred method for resetting the IS bits as it is the most secure.

The EOI register is write only.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
<i>NSPEC</i>	<i>Reserved</i>										<i>S4 – S0</i>				

NSPEC (bit 15) – *Non-Specific EOI*. This bit is set to 1 a non-specific EOI and when set to 0 it indicates the specific EOI.

Reserved (bits 14-5)

S [4:0] (bit 4-0) – *Source Interrupt Type*. These bits show the interrupt type of the highest priority pending interrupt.

EOI (022h) – Specific *End-Of-Interrupt* Register.

(Slave Mode)

An In Service flag of a specific priority, in the In-Service register, is reset when a write is made to the EOI register.

A three-bit user supplied priority-level value that points to the in-service bit that is to be reset. Writing this value to this register resets the specific bit.

The Specific EOI reset is the preferred method for resetting the IS bits as it is the most secure.

The EOI register is write only and undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	L2 – L0		

Reserved (bits 15-3) – Write as 0.

L [2:0] (bit 2-0) – *Interrupt Type*. The priority or the IS (interrupt service) bit to be reset is encoded in these three bits. Writing to these bits caused the issuance of an EOI for the interrupt type. See Table 3 - *Interrupt Types*.

INTVEC (020h) – *INT*errupt *VEC*tor Register.

(Slave Mode)

The CPU shifts left 2 bits (multiplies by 4) an 8-bit interrupt type, generated by the interrupt controller, to produce an offset into the interrupt vector table.

The INTVEC register is undefined at reset.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	T4 – T0					0	0	0

Reserved (bits 15-8) – Read as 0.

T [4:0] (bits 7-3) – *Interrupt Type*. These five bits contain the 5 most significant bits of the interrupt types used for the internal interrupt type. The least significant 3 bits of the interrupt type are supplied by the interrupt controller, as set by the priority level of the interrupt request.

Reserved (bits 2-0) – Read as 0.

Clock and Power Management

A phase-lock-loop (PLL) and a second programmable system clock output (CLKOUTB) are included in the clock and power management unit. The internal clock is the same frequency as the crystal but with a duty cycle of 45% - 55 %, as a worse case, generated by the PLL obviating the need for a 2X external clock. A power-on reset (POR) resets the PLL.

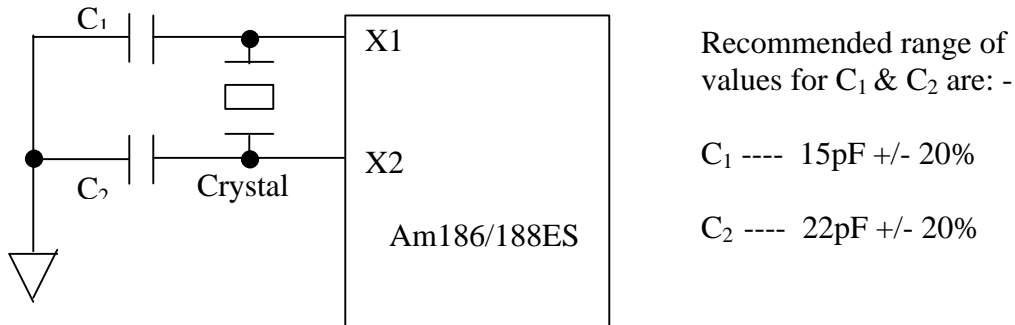


Figure 1. Crystal Configuration

System Clocks.

If required the internal oscillator may be driven by an external clock source that should be connected to X1, leaving X2 unconnected.

The clock outputs **clkouta** and **clkoutb** may be enabled or disabled individually (System Configuration register bits (11 – 8)). These clock control bits allow one clock output to run at PLL frequency and the other to run at the power-save frequency.

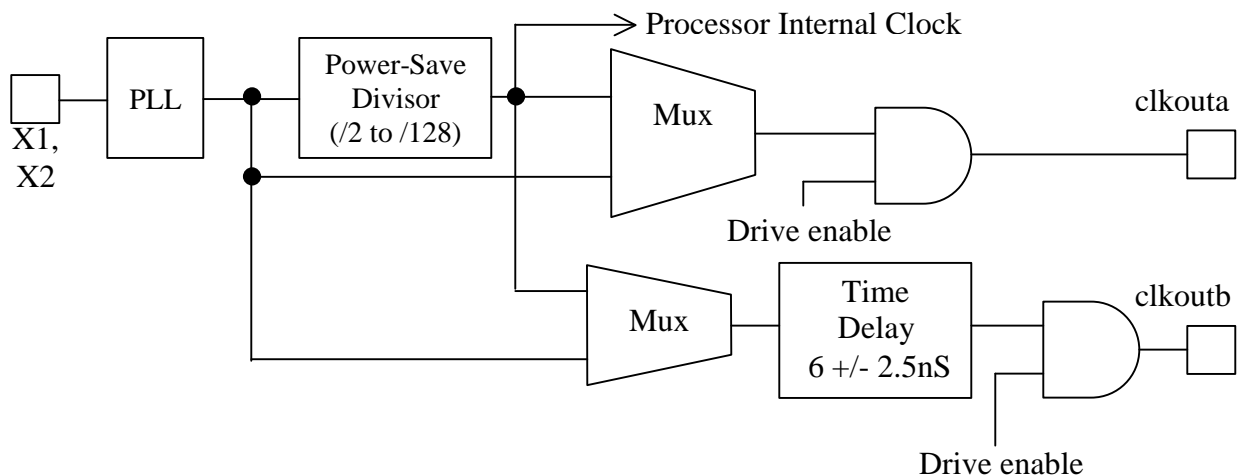


Figure 2. Organization of Clock

Power-Save Mode

The operation of the CPU and peripheral operate at a slower clock frequency when in power save mode reducing power consumption and thermal dissipation. Should an interrupt occur, the microcontroller returns to its normal operating frequency automatically on the internal clock's next rising edge in t_3 . Any clock dependant devices should be reprogrammed for the changed in frequency during the power-save mode period.

Initialization and Reset

res_n (Reset), the highest priority interrupt, must be held low for 1mS during power-up to initialize the microcontroller correctly. This operation makes the device cease all instruction execution and local bus activity. The microcontoller begins instruction execution at physical address FFFF0h when **res_n** becomes inactive and after an internal processing interval with **ucs_n** asserted and three wait states. Reset also sets up certain registers to predetermined values and resets the Watchdog timer.

Reset Configuration Register.

The data on the address/data bus (**ad15 – ad0** for the Am186ES and **ao15 – ao8** and **ad7 – ad0** for the Am188ES) are written into the Reset Configuration register when reset is low. This data is system dependant and is held in the Reset Configuration register after Reset is de-asserted. This configuration data may be placed on the address/data bus by using weak external pull-up and pull-down resistors or applied to the bus by an external driver, as the processor does not drive the bus during reset. It is a method of supplying the software with some initial data after a reset; for example, option jumper positions.

Chip-Selects

Chip-select generation is programmable for memories and peripherals. Programming is also available to produce ready and wait-state generation plus latched address bits **a1** and **a2**. For all memory and I/O cycles, the chip-select lines are active within their programmed areas, regardless of whether they are generated by the internal DMA unit or the CPU.

There are six chip-selects outputs for memories and a further six for peripherals whether in memory or I/O space. The memory chip-selects are able to address three memory ranges, whereas the peripheral chip-selects are used to address 256-byte blocks that are offset from a programmable base address. Writing to a chip-select register enables the related logic even in the event that the pin in question has another function, as for example in the case that the pin is programmed to be a PIO.

Chip-Select Timing

For normal timing, the **ucs_n** and **lcs_n** outputs are asserted with the non-multiplexed address bus.

Ready and Wait-State Programming

Each of the memory or peripheral chip-select lines can have a ready signal programmed that can be the **ardy** or **srdy** signal. The chip-select control registers (UMCS, LMCS, MMCS, PACS, and MPCS) have a single bit that selects if the external ready signal is to be used or not (*R2*, bit 2). *R1* & *R0* (bits 1-0) in these registers control the number of wait-states that are inserted during each access to a memory or peripheral location (from 0 to 3). The control registers for **pcs3_n** – **pcs0_n** utilize three bits, *R3*, *R1* – *R0* (bits 3, 1 – 0) to provide 5, 7, 9, and 15 wait-states in addition to the original values of 0 – 3 wait states.

In the case where an external ready has been selected as required, internally programmed wait-states will always be completed before the external ready can finish or extend a bus cycle. As an example, consider a system in which the number of wait-states to be inserted has been set to three; the external ready pin is sampled by the processor during the first wait cycle. The access is completed after seven cycles (4 cycles plus 3 wait-cycles) if the ready is asserted; alternatively if the ready is not asserted during the first wait cycle the access is prolonged until ready is asserted and two more wait-states are inserted followed by t_4 . The **ardy** signal is an asynchronous ready with a pin that is active high and accepts a rising edge asynchronous to **clkouta**. However, an additional clock period may be necessary if the falling edge of **ardy** is not synchronized to **clkouta**.

Chip-Select Overlap

Overlapping chip-selects are those configurations in which more than one chip-select is asserted for the same physical address. If for example PCS is configured in I/O space with LCS or any other chip select configured for memory, address 00000h is not overlapping the chip selects.

It is not recommended that multiple chip-select signals be asserted for the same physical address, although it may be inescapable in certain systems. If this is the case, then all overlapping chip-selects must have the same external ready configuration and the same number of wait-states to be inserted into access cycles.

Internal signals are employed to access the peripheral control block (PCB) and these signals serve as chip selects that are configured with no wait-states and no external ready. So the PCB may be programmed with addresses that overlap external chip-selects only if these chip selects are configured in the same manner.

Care should be exercised in the use of the Disable Address (*DA*) bit in the LMCS or UMCS registers when overlapping an additional chip-select with either the **lcs_n** or **ucs_n** chip-selects. Setting the *DA* bit to 1 prevents the address from being driven onto the AD bus for all accesses for which the respective chip-select is active, including those accesses for which the multiple selects are active.

The **mcs_n** and **pcs_n** pins are dual-purpose pins, either as chip-selects or PIO inputs or outputs, however their respective ready and wait-state configurations for their chip-select function will be in

effect no matter for which function these two pins are actually programmed. This requires that even if these pins are configured as PIO and enabled, (by writing to the MMCS and MPCS registers for the **mcs_n** chip-selects and to the PACS and MPCS registers for the **pcs_n** chip-selects), the ready and wait-state settings for these signals must agree with the settings for any over-lapping chip-selects as if they had been configured as chip-selects.

Even though **pcs4_n** is not available as an external pin it has ready and wait-state logic and must therefore follow the rules for overlapping chip-selects. **pcs6_n** and **pcs5_n** on the other hand have ready and wait-state logic that is disabled when these pins are configured as address bits **a2** and **a1** respectively.

If the chip-select configuration rules are not followed the processor may hang with the appearance of waiting for a ready signal even in a system in which ready (**ardy** or **srdy**) is always set to 1.

Upper Memory Chip Select

The **ucs_n** chip-select is for the top of memory. On reset the micro controller begins fetching and executing instructions at memory location FFFF0h, so upper memory is usually utilized for instruction memory. To this end **ucs_n** is active on reset and has a memory range of 64Kbytes (F0000h to FFFFFh) as default along with external ready required and three wait-states automatically inserted. The lower boundary of **ucs_n** is programmable to provide ranges of 64Kbytes to 512Kbytes.

Low Memory Chip Select

The **lcs_n** chip-select is for lower memory and may be configured for 8-bit or 16-bit accesses by the AUXCON register. As the interrupt vector table is at the bottom of memory beginning at 00000h, this pin is usually utilized for control data memory. Unlike **ucs_n** this pin is inactive on reset.

Midrange Memory Chip Selects

There are four midrange chip-selects, **mcs3_n-mcs0_n**, which may be used in a user-located memory block. The base address of the memory block may be located anywhere in the 1-Mbyte memory address space with some exceptions. The memory spaces used by the **ucs_n** and **lcs_n** chip-selects are excluded, as are the **pcs6_n**, **pcs5_n**, and **pcs3_n – pcs0_n**. If the **pcs_n** chip-selects are mapped to I/O space then the MCS address range can overlap the PCS address range.

The **mcs0_n** chip select may be programmed to be active over the entire MCS range leaving the **mcs3_n - mcs1_n** free for use as PIO pins.

The MCS may be configured for 8-bit or 16-bit accesses by the AUXCON register. The MCS range bus width is determined by the width of the non-UCS/non-LCS memory ranges. The assertion of the MCS outputs occurs with the same timing as the multiplexed AD address bus.

Peripheral Chip Selects

There are six peripheral chip-selects, **pcs6_n**, **pcs5_n**, and **pcs3_n – pcs0_n**, that may be used within a user defined memory or I/O block. The base address of this user defined memory block can be located anywhere within the 1-Mbyte memory address space except for the spaces associated with the **ucs_n**, **lcs_n**, and **mcs_n** chip selects, or it may be programmed to the 64Kbyte I/O space. **pcs4_n** is not available.

None of the **pcs_n** pins are active at reset. **pcs6_n**, **pcs5_n** may be programmed to have 0 to 3 wait-states, whereas **pcs3_n – pcs0_n** may be programmed to have these and 5, 7, 9, and 15 wait-states.

The PCS may be configured for 8-bit or 16-bit accesses by the AUXCON register. The PCS range bus width is determined by the width of the non-UCS/non-LCS memory range or by the width of the I/O space. The assertion of the PCS outputs occurs with the same timing as the multiplexed AD address bus. Each of the PCS operates over a 256-byte address range.

Refresh Control

The Refresh Control Unit (RCU) generates refresh bus cycles automatically with a fixed wait-state value of three for the PSRAM automatic refresh mode. The RCU generates a memory read request after a programmable period of time to the bus interface unit.

The *ENA* bit in the Enable RCU register (EDRAM) enables refresh cycles, operating off the processor internal clock. If the processor is in power-save mode, the RCU must be reconfigured for the new clock rate.

If the **hlda** pin is asserted when a refresh request is initiated (indicating a bus hold condition), the processor disables the **hlda** pin to allow a refresh cycle to be performed. The external circuit bus master must deassert the **hold** signal for at least one clock period to permit the execution of the refresh cycle.

Interrupt Control

Interrupt requests originate from a variety of internal and external sources, that are arranged by the internal interrupt controller in priority order and presented one by one to the processor.

Eight external interrupt sources, seven maskable and one nonmaskable (NMI) are connected to the processor, and eight internal interrupt sources (three timers, two DMA channels, two asynchronous serial ports, and the Watchdog Timer NMI) that are not brought out to external pins. Interrupts **int6** and **int5** are multiplexed with **drq1** and **drq0** and are available if the respective DMA is not enabled or is internally synchronized.

The seven external maskable interrupt request pins are, with the exception of **int0**, multifunction pins, one function being that of direct interrupt requests. **int4 – int0** may be level or edge triggered whereas **int6** and **int5** are edge triggered.

When configured in cascade mode, **int1** and **int0** interface with an external interrupt controller of the 82C59A type. When **int0** is configured for cascade mode, the function of **int2** is automatically switched to its **inta0_n** role and similarly, **int3** is switched to its **inta1_n** role when **int1** is configured for cascade mode. By programming the internal interrupt controller to slave mode, an external 82C59A compatible interrupt controller may be used as the system master, but in this case **int6 – int4** cannot be used.

When an interrupt is accepted, other interrupts are disabled, but may be re-enabled by setting the Interrupt Enable Flag (*IF*), in the Processor Status Flags register, during the Interrupt Service Routine (ISR). Setting *IF* permits interrupts of equal or greater priority to interrupt the currently running ISR.

Further interrupts from the same source will be blocked until the corresponding bit in the In-Service register (INSERV) is cleared. Special Fully Nested mode is invoked for **int0** and **int1** by the *SFNM* bit in the INT0 and INT1 Control register respectively, when this bit is set to 1. In this mode a new interrupt may be generated by these sources regardless of the in-service bit. The following table shows the priorities of the interrupts at power-on reset.

Interrupt Types

Interrupt Name	Interrupt Type	Vector Table Address	EOI Type	Overall Priority	Related Instructions
Divide Error Exception ⁽¹⁾	00h	00h	N/A	1	DIV, IDIV
Trace Interrupt ⁽²⁾	01h	04h	N/A	1A	All
Non-maskable Interrupt (NMI)	02h	08h	N/A	1B	
Breakpoint Interrupt ⁽¹⁾	03h	0ch	N/A	1	INT3
INT0 Detected Overflow Exception ⁽¹⁾	04h	10h	N/A	1	INT0
Array Bounds Exception ⁽¹⁾	05h	14h	N/A	1	BOUND
Unused Opcode Exception ⁽¹⁾	06h	18h	N/A	1	Undefined Opcodes
ESC Opcode Exception ^(1, 3)	07h	1ch	N/A	1	ESC Opcodes
Timer 0 Interrupt ^(4, 5)	08h	20h	08h	2A	
Timer 1 Interrupt ^(4, 5)	12h	48h	08h	2B	
Timer 2 Interrupt ^(4, 5)	13h	4ch	08h	2C	
Reserved	09h	24h			
DMA 0 Interrupt/INT5 ⁽⁵⁾	0ah	28h	0ah	3	
DMA 1 Interrupt/INT6 ⁽⁵⁾	0bh	2ch	0bh	4	
INT0 Interrupt	0ch	30h	0ch	5	
INT1 Interrupt	0dh	34h	0dh	6	
INT2 Interrupt	0eh	38h	0eh	7	
INT3 Interrupt	0fh	3ch	0fh	8	
INT4 Interrupt ⁽⁶⁾	10h	40h	10h	9	
Asynchronous Serial Port 1 Interface ⁽⁶⁾	11h	44h	11h	9	
Asynchronous Serial Port 0 Interface ⁽⁶⁾	14h	50h	14h	9	
Reserved	15h – 1fh	54h – 7ch			

Notes:

If the user does not changed priority levels then the default priority level will be used for the interrupt sources.

1. Instruction execution generates interrupts.
2. Performed in the same manner as for the 8086 & 8088.
3. An ESC opcode causes a trap.
4. Only one IRQ is generated for the three timers so they share priority level with regard to other sources. The timers themselves have an interrupt priority order among themselves (2A > 2B > 2C).
5. These interrupt types are programmable in Slave mode.
6. Not available in slave mode.

Timer Control

The IA186ES and IA188ES each have a watchdog timer and three 16 bit programmable timers. Timer0 and timer1 each have an input and an output connected to external pins that permit them to count or time events, produce variable duty-cycle waveforms or non-repetitive waveforms. These same timers are used to measure the high and low pulse widths of the Pulse Width Demodulator on the **pwd** pin.

Timer2 does not have any external connections so is confined to internal functions such as, real-time coding, time-delay applications, a prescaler for timer0 and timer1, or to synchronize DMA transfers.

The Peripheral Control Block contains eleven 16-bit registers to control the programmable timers. The present value of the timer is located in the associated timer-count register, which may be read from or written to at any time regardless of whether the timer is in operation or not. The value of the timer-count register is incremented by the microcontroller every time a timer event takes place.

The maximum value that each timer can reach is determined by the value stored in the associated maximum count register. Upon reaching this maximum count value; the timer count register is reset to 0 in the same clock cycle that this count was attained, so that the timer count register does not store this maximum value. Both timer0 and timer1 have two maximum count registers, a primary and a secondary register, permitting each timer to alternate between two discrete maximum values.

Timer0 and timer1 may have the maximum count registers configured in one of two ways, primary only or both primary and secondary. If only the primary is configured to operate then on reaching the maximum count the output pin will go low for one clock period. If both the primary and secondary registers are enabled then the output pin reflects the state of the whichever of the two registers is in control at the time, generating the required waveform that is dependant on the two values in the maximum count registers.

The timers can operate at a quarter of the internal clock frequency as they are polled every fourth clock period. Alternatively an external clock be used, but in this case the timer output may take six clock cycles to respond to the input.

Watchdog Timer

The Watchdog Timer (WDT) operates in real WDT fashion and may be used to prevent loss of control in the event that software does not respond in an expected manner. The WDT is active after reset, has a maximum timeout count, and is programmed for system reset mode. The WDT control register (WDTCON) may be written to only once after

reset. This is accomplished by writing 3333h then CCCCh followed by the new configuration data to the WDTCON register. Any number of other operations, including memory and I/O read and writes, may be performed between these two words provided they do not include an access to the WDTCON register.

Writing AAAAh then 5555h to the WDTCON register resets the current count. This count cannot be read. As before any number of other operations, including memory and I/O read and writes, may be performed between these two words provided they do not include an access to the WDTCON register. The use of these sequences is designed to prevent executing code from impeding a WDT event from occurring. In a 40MHz system, a maximum 1.67-second timeout period is possible with the WDT.

The WDT can be programmed to generate an NMI or a system reset when it times-out. If programmed to generate an NMI, the NMIFLAG (bit 12) in the WDTCON register will be set when an NMI occurs. This flag should be tested by the NMI interrupt service routine (ISR) to establish whether the interrupt was generated by the WDT or by an external source. The ISR should clear this flag, if set, by writing the 3333h and CCCCh sequence followed by the configuration data which includes clearing NMIFLAG. A WDT system reset is generated in place of a second NMI interrupt, if the NMIFLAG is set while a second WDT timeout occurs.

The RSTFLAG (bit 13) in the WDTCON register is set if a WDT reset is generated, due to one WDT occurrence while the WDT is programmed to generate resets, or because a

WDT event occurred with the NMIFLAG set. This permits system initialization code to distinguish between a WDT reset and hardware reset and take suitable action. The RSTFLAG is cleared by a read or write to the WDTCON register. During a WDT reset, the external pins are not re-sampled, ensuring that clocking, reset configuration register, and any other features that are user programmable during reset do not change when a WDT system reset occurs. All other activities are the same as those of a normal system reset.

Direct Memory Access (DMA)

Direct memory access (DMA) relieves the CPU of involvement in the transfer of data between memory and peripherals over either one or both high-speed DMA channels. Data may be transferred from memory to I/O, I/O to memory, memory-to-memory, or I/O-to-I/O. Furthermore the DMA channels may be connected to the asynchronous serial ports.

The IA186ES microcontroller supports the transfer of both bytes and words, to and from, even or odd addresses, but it does not support word transfers to memory that is configured for byte accesses. The IA188ES does not support word transfers at all. Each data transfer will take two bus cycles (a minimum of 8 clock cycles).

There are four sources of DMA requests for each DMA channel, the channel request pin (**drq1 – drq0**), Timer2, a serial port, or the system software. The two channels may be programmed to have different priorities to facilitate the resolution of simultaneous DMA requests or to interrupt a transfer on the other channel.

DMA Operation

The Peripheral Control Block contains six registers for each DMA channel to control and specify the operation of the channels. The six registers consist of a pair of registers to store a 20-bit source address, a pair of registers to store a 20-bit destination address, a 16-bit transfer count register, and a 16-bit control register.

The number of DMA transfers required is designated in the DMA Transfer Count register and may be up to 64K bytes or words and furthermore will end automatically. DMA channel function is defined by the Control registers, which along with the other 5 registers may be changed at any time including during a DMA transfer and are implemented immediately.

DMA Channel Control Registers

See **D1CON (0dah)** & **D0CON (0cah)** - DMA *CON*trol Registers above. Briefly, these registers specify the following:

- Whether the data destination is in memory or I/O space. (Bit 15).
- Whether the destination address is incremented, decremented, or unchanged after each transfer. (Bit 14 & 13).
- Whether the data source is in memory or I/O space. (Bit 12).
- Whether the source address is incremented, decremented, or unchanged after each transfer? (Bit 11 & 10).
- Whether DMA transfers cease upon reaching a designated count. (Bit 9).
- Whether the last transfer generates an interrupt. (Bit 8).
- Synchronization mode. (Bits 7 & 6).
- The relative priority of one DMA channel with respect to the other. (Bit 5).
- Acceptance of DMA requests from Timer2. (Bit 4).
- Configuration of DRQ pins as INT. (Bit 3).
- Byte or Word transfers. (Bit 0).

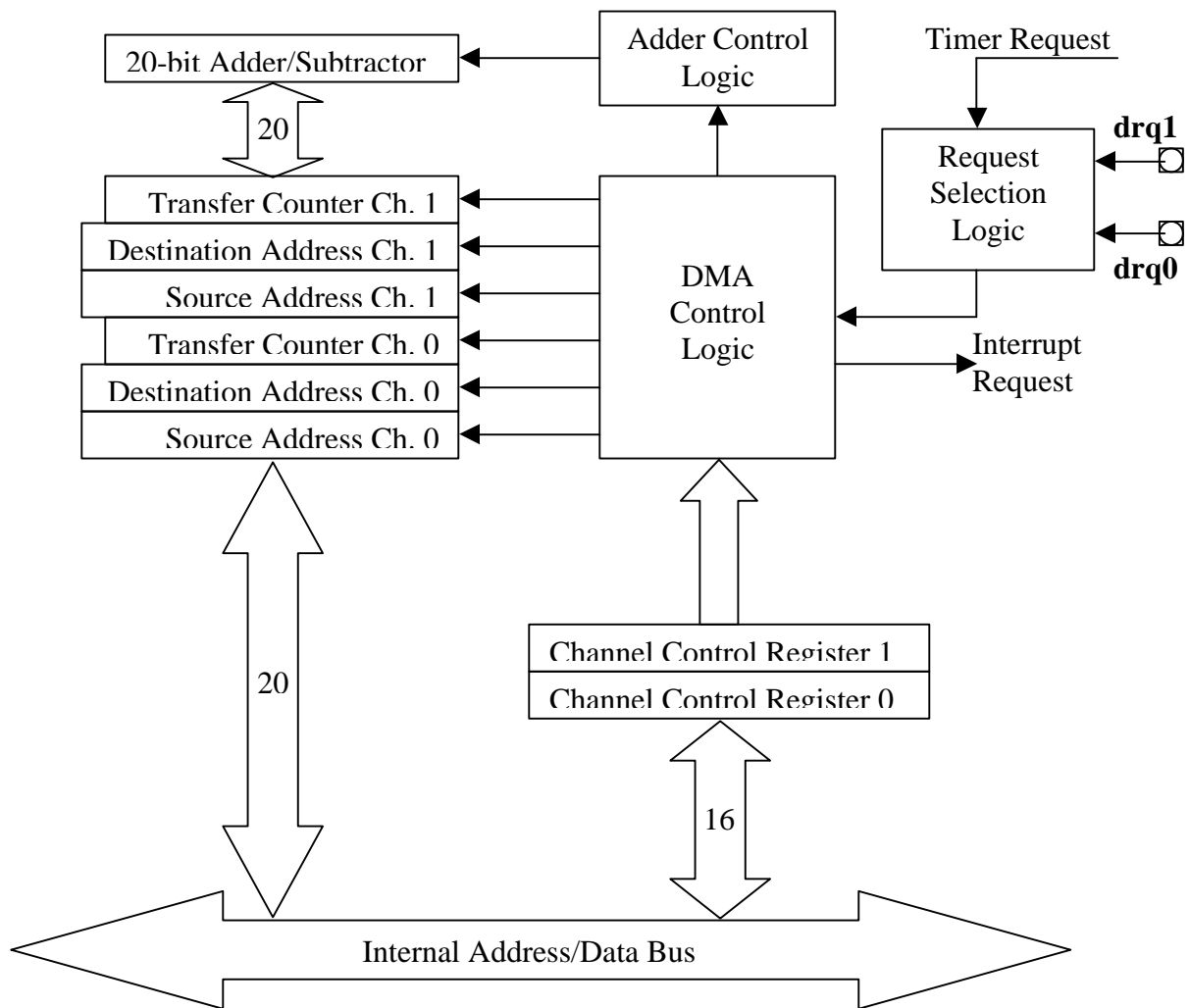


Figure 3. DMA Unit

DMA Priority

DMA transfers have a higher priority than CPU transfers with the exception of word accesses to odd memory locations or between locked memory addresses. The CPU cannot access memory during a DMA transfer and a DMA transfer cannot be suspended by an interrupt request; continuous DMA activity will thus cause interrupt latency to suffer. However an NMI request halts any DMA activity, enabling the CPU to respond promptly to the request.

Pulse Width Demodulation

It should be noted that there is no support for analog to digital conversion. This feature provides a means of measuring the width of a pulse in both its high and low phases and is enabled by the PWD bit (Bit 6) in the System Configuration Register (SYSCON).

TMRIN0, TMRIN1, INT2, and INT4 are internally configured to support the detection of rising and falling edges on the PWD pin (**int2/int0_n/pwd**) and to enable either timer0 or timer1 depending on whether the signal is high or low respectively. The **tmrin0**, **tmrin1**, and **int4** pins are available as PIO pins in this mode as they are not used.

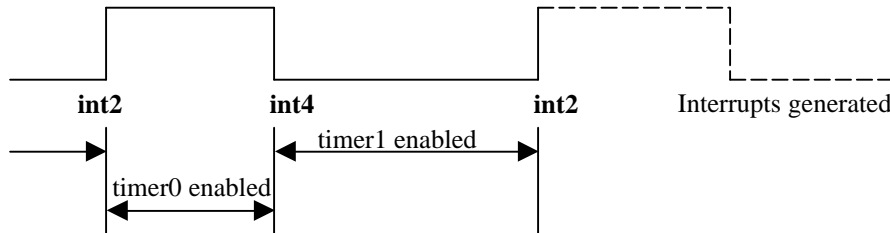


Figure 4. Typical Waveform at the int2/int0_n/pwd pin

The current count of the respective timer, timer1 for INT2 and timer0 for INT4 should be inspected by the Interrupt Service Routine (ISR) to determine the pulse width. The timer count register should then be reset by the ISR in readiness for the next pulse.

The maximum resolution of the timers is determined by the timer count rate, which is $\frac{1}{4}$ of the processor clock rate. To avoid the overhead in servicing a timer interrupt in cases in which the pulse width is short, the INT2 and INT4 request bits in the Interrupt Request register may be polled. On the other hand, in cases in which the pulse width is greater than the maximum count of the timer, detection is achieved by monitoring the Maximum Count (MC) bit of the respective timer or by enabling the timer interrupt requests by setting the INT bit in the respective Timer Mode and Control Register.

Asynchronous Serial Ports

There are two independent asynchronous serial ports that employ standard industry communication protocols in their implementation of full duplex, bi-directional data transfers. These ports may be the sources or destinations of DMA transfers independently of each other.

The following features are supported:

- Full-duplex data transfers
- 7, 8, or 9-Bit data transfers
- Odd, even, or no parity
- One or two stop bits.
- Break characters of two lengths
- Error detection provided by Parity, Framing, or Overrun errors
- Hardware handshaking is achieved with the following selectable control signals:
 - Clear-to-send (**cts_n**)
 - Enable receiver request (**enrx_n**)

Ready to send (**rts_n**)
Ready to receive (**rtr_n**)

- DMA to and from the ports
- Each port has its own maskable interrupts
- 9-Bit multidrop protocol
- Each port has an independent baud rate generator
- Maximum baud rate is 1/16 of the processor clock
- Transmit and Receive lines are double buffered

Programmable I/O (PIO)

32 pins are programmable as I/O signals. The following tables list these pins with their pin name and PIO number, in firstly PIO numerical order, and then in pin name alphabetical order. Programming a pin as a PIO should only be performed if the normal pin function is not required as the normal function is disabled and no longer has any affect on the pin. A PIO pin can be programmed as an input or output with or without either a weak pull-up or pull-down, or as an open-drain output. Following a power on reset the PIO pins have default status as shown in the following tables.

PIO No.	Associated Pin	Power-On Reset Status
0	tmrin1	Input with pullup
1	tmrout1	Input with pulldown
2	pcs6_n/a2	Input with pullup
3	pcs5_n/a1	Normal operation ⁽³⁾
4	dt/r_n	Normal operation ⁽³⁾
5	den_n/ds_n	Normal operation ⁽³⁾
6	srdy	Normal operation ⁽³⁾
7 ⁽¹⁾	a17	Normal operation ⁽³⁾
8 ⁽¹⁾	a18	Normal operation ⁽³⁾
9 ⁽¹⁾	a19	Normal operation ⁽³⁾
10	tmrout0	Input with pulldown
11	tmrin0	Input with pullup
12	drq0/int5	Input with pullup
13	drq1/int6	Input with pullup
14	mcs0_n	Input with pullup
15	mcs1_n	Input with pullup
16	pcs0_n	Input with pullup
17	pcs1_n	Input with pullup
18	pcs2_n/cts1_n/enrx1_n	Input with pullup
19	pcs3_n/rts1_n/rtr1_n	Input with pullup
20	rts0_n/rtr0_n	Input with pullup
21	cts0_n/enrx0_n	Input with pullup
22	rxd0	Input with pullup
23	rxd0	Input with pullup
24	mcs2_n	Input with pullup
25	mcs3_n/rfsh_n	Input with pullup
26 ^(1,2)	uzi_n	Input with pullup
27	txd1	Input with pullup
28	rxd1	Input with pullup
29 ^(1,2)	s6/lock_n/clkdiv2	Input with pullup
30	int4	Input with pullup
31	int2/inta0_n/pwd	Input with pullup

Associated Pin	PIO No.	Power-On Reset Status
a17	7	Normal operation ⁽³⁾
a18	8	Normal operation ⁽³⁾
a19	9	Normal operation ⁽³⁾
cts0_n/enrx0_n	21	Input with pullup
den_n/ds_n	5	Normal operation ⁽³⁾
drq0/int5	12	Input with pullup
drq1/int6	13	Input with pullup
dt/r_n	4	Normal operation ⁽³⁾
int2/inta0_n/pwd	31	Input with pullup
int4	30	Input with pullup
mcs0_n	14	Input with pullup
mcs1_n	16	Input with pullup
mcs2_n	24	Input with pullup
mcs3_n/rfsh_n	25	Input with pullup
pcs0_n	16	Input with pullup
pcs1_n	17	Input with pullup
pcs2_n/cts1_n/enrx1_n	18	Input with pullup
pcs3_n/rts1_n/rtr1_n	19	Input with pullup
pcs5_n/a1	3	Input with pullup
pcs6_n/a2	2	Input with pullup
rts0_n/rtr0_n	20	Input with pullup
rxd0	23	Input with pullup
rxd1	28	Input with pullup
s6/lock_n/clkdiv2	29	Input with pullup
srdy	6	Normal operation ⁽⁴⁾
timerin0	11	Input with pullup
tmrin1	0	Input with pullup
tmrout0	10	Input with pulldown
tmrout1	1	Input with pulldown
txd0	22	Input with pullup
txd1	27	Input with pullup
uzi_n	26	Input with pullup

NOTES:

These notes apply to both tables

1. Emulators use these pins and also **s2_n-s0_n, res_n, nmi, clkouta, bhe_n ale, ad15-ad0, and a16-a0**.
2. If **bhe_n/aden_n** (IA186ES) or **rfsh_n/aden_n** (IA188ES) is held low during power-on reset then these pins will revert to normal operation.
3. Input with pullup when used as PIO.
4. Input with pulldown option available when used as PIO.

These default status setting may be changed as desired.

The three most significant bits of the address bus (**a19 – a17**) start with their normal function on power on reset, permitting the processor to begin fetching instructions from the boot address FFFF0h. Furthermore, normal function is the default setting for **dt/r_n, den_n,** and **srdy** on power on reset.

s6/clkdiv2_n and **uzi_n** automatically return to normal operation in the event that the **ad15-ad0** bus override is enabled. The **ad15-ad0** bus override is enabled if the **bhe_n/aden_n** for the IA186ES, or the **rfsh2_n/aden_n** for the IA188ES, is held low during power on reset.

Pin Descriptions

a19/pio9, a18/pio8, a17/pio7, a16 – a0 Address Bus (synchronous outputs with tristate)

These pins are the system's source of non-multiplexed I/O or memory addresses and occur a half CLKOUTA cycle before the multiplexed address/data bus (**ad15-ad0** for the IA186ES or **ao15_ao8** and **ad7-ad0** for the IA188ES).

The address bus is tristated during a bus hold or reset.

ad15 – ad8 IA186ES Address/Data bus (level-sensitive synchronous inouts with tristate)

These pins are the system's source of time-multiplexed I/O or memory addresses and data. The address function of these pins may be disabled. (See **bhe_n/aden_n** pin description.) If the address function of these pins is enabled, the address will be present on this bus during t_1 of the bus cycle and data will be present during t_2 , t_3 , and t_4 of the same bus cycle.

If **whb_n** is not active then these pins are tristated during t_2 , t_3 , and t_4 of the bus cycle.

The address/data bus is tristated during a bus hold or reset.

These pins may be used to load the internal Reset Configuration register (RESCON, offset 0F6h) with configuration data during a power-on reset.

ao15 – ao8 IA188ES Address bus (level-sensitive synchronous outputs with tristate)

The Address bus will contain valid high order address bits during the bus cycle (t_1 , t_2 , t_3 , and t_4) if the bus is enabled by the AD bit in the Upper and Lower Memory Chip Select registers (UMCS, offset 0a0h and LMCS, offset 0a2h).

These pins are combined with **ad7-ad0** to complete the multiplexed address bus and are tristated during a bus hold or reset condition.

ad7 – ad0 Address/Data bus (level-sensitive synchronous inouts with tristate)

These pins are the system's source of time-multiplexed low order byte of the addresses for I/O or memory and 8-bit data. The low order address byte will be present on this bus during t_1 of the bus cycle and the 8-bit data will be present during t_2 , t_3 , and t_4 of the same bus cycle.

The address function of these pins may be disabled. (See **bhe_n/aden_n** pin description.)

If **wlb_n** is not active, these pins are tristated during t_2 , t_3 , and t_4 of the bus cycle. The address/data bus is tristated during a bus hold or reset.

ale Address Latch Enable (synchronous output)

This signal indicates the presence of an address on the address bus (**ad15-ad0** for the IA186ES or **ao15-ao8** and **ad7-ad0** for the AI188ES), which is guaranteed to be valid on the falling edge of **ale**.

In ONCE mode this pin is tristated but not during bus hold or reset.

ardy Asynchronous Ready (level-sensitive asynchronous input)

This asynchronous signal provides an indication to the microcontroller that the addressed I/O device or memory space will complete a data transfer. This active high signal is asynchronous with respect to **clkouta** and if the falling edge of **ardy** is not synchronized to **clkouta** and additional clock cycle may be added. **ardy** or **srdy** must be synchronized to **clkouta** to guarantee the number of inserted wait states.

ardy should be tied high to maintain a permanent assertion of the ready condition. On the other hand if the **ardy** signal is not used by the system it should be tied low which passes control to the **srdy** signal.

bhe_n/aden_n IA186ES only Bus High Enable (synchronous output with tristate) /Address Enable (input with internal pullup)

bhe_n - **bhe_n** and address bit **ad0** or **a0** inform the system which bytes of the data bus (upper, lower, or both) are involved in the current memory access bus cycle as shown in the following table.

bhe_n	ad0	Type of Bus Cycle
0	0	Word Transfer
0	1	High Byte Transfer (Bits 15-8)
1	0	Low Byte Transfer (Bits 7-0)
1	1	Refresh

bhe_n does not require latching and during bus hold and reset is tristated. It is asserted during t_1 and remains so through t_3 and t_w .

The high and low byte write enable functions of **bhe_n** and **ad0** are performed by **whb_n** and **wlb_n** respectively.

When using the **ad** bus, DRAM refresh cycles are indicated by **bhe_n/aden_n** and **ad0** both being high. During refresh cycles the **a** and **ad** busses may not have the same address during the address phase of the **ad** bus cycle necessitating the use of **ad0** as a determinant for the refresh cycle rather than **A0**.

An additional signal is utilized for PSRAM refreshes (see **mcs3_n/rfsh_n** pin description).

aden_n

There is a weak internal pullup on **bhe_n/aden_n** obviating the need for an external pullup and reducing power consumption.

Holding **aden_n** high or letting it float during power-on reset passes control of the address function of the **ad** bus (**ad15-ad0**) during LCS and UCS bus cycles from **aden_n** to the DA bit in LMCS and UMCS registers. When the address function is selected the memory address is placed on the **a19-a0** pins.

Holding **aden_n** low during power-on reset, both the address and data are driven onto the **ad** bus independently of the DA bit setting. This pin is normally sampled on the rising edge of **res_n** and the condition of **s6** and **uzi_n** default to their normal functions.

clkouta – Clock Output A (synchronous output)

This pin is the internal clock output to the system. Bits 9, 8, and 2-0 of the System Configuration register control the output of this pin, which may be disabled, output the PLL frequency, or output the power save frequency (internal processor frequency after divisor). **clkouta** may be used as a full speed clock source in power-save mode. The A.C. timing specifications that are clock related refer to **clkouta**, which remains active during reset and hold conditions.

clkoutb – Clock Output B (synchronous output)

This pin is an additional clock output to the system with and output delayed with respect to **clkouta**. Bits 11, 10, and 2-0 of the System Configuration register control the output of this pin, which may be disabled, output the PLL frequency, or may output the power save frequency (internal processor frequency after divisor). **clkoutb** may be used as a full speed clock source in power-save mode, and remains active during reset and hold conditions.

cts0_n/enrx0_n/pio21 – Clear-to-Send 0 / Enable-Receive-Request 0 (both are asynchronous inputs)

cts0_n – This is the Clear-to-Send signal for asynchronous serial port 0 provided that bit 4 (ENRX0) in the AUXCON register is 0, and bit 9 (FC) in the SPOCT register is 1. **cts0_n** controls the transmission of data from asynchronous serial port 0; when it is

asserted the transmitter begins transmitting the next frame of data and when not asserted the data to be transmitted is held in the transmit register. This signal is only checked at the start of data frame transmission.

enrx0_n – This is the Enable-Receiver-Request for asynchronous serial port 0 for the case when bit 4 (ENRX0) in the AUXCON register is 1, and bit 9 (FC) in the SPOCT register is 1, and it enables the asynchronous serial port receiver.

den_n/ds_n/pio5 – Data Enable /Data Strobe (both are synchronous outputs with tristate)

den_n – This signal is asserted during I/O, memory, and interrupt acknowledge processes and is deasserted when **dt/r_n** undergoes a change of state. It is tristated for a bus hold or reset. After reset this pin defaults to **den_n**.

ds_n – The data strobe is used under conditions in which a write cycle has the same timing as a read cycle. It is used with other control signals to interface with 68K-type peripherals without further system interface logic. When it is asserted, addresses are valid, and during a write the data is valid, while during a read data may be applied to the **ad** bus.

drq0/int5/pio12 – DMA Request 0 (synchronous level-sensitive input) / Maskable Interrupt Request 5 (asynchronous edge-triggered input)

drq0 – An external device, that is ready for DMA channel 0 to carry out a transfer, indicates to the microcontroller this readiness on this pin. It is not latched and must remain asserted until it is dealt with.

int5 - If DMA channel 0 is not required, then it may be used as an extra interrupt request sharing the DMA0 interrupt type (0ah) and control bits. It is not latched and must remain asserted until it is dealt with.

drq1/int6/pio13 – DMA Request 1 (synchronous level-sensitive input) / Maskable Interrupt Request 6 (asynchronous edge-triggered input)

drq1 – An external device, that is ready for DMA channel 1 to carry out a transfer, indicates to the microcontroller this readiness on this pin. It is not latched and must remain asserted until it is dealt with.

int6 - If DMA channel 1 is not required, then it may be used as an extra interrupt request sharing the DMA1 interrupt type (0bh) and control bits. It is not latched and must remain asserted until it is dealt with.

dt/r_n/pio4 – Data Transmit or Receive (synchronous output with tristate)

The microcontroller transmits data when **dt/r_n** is pulled high and receives data when this pin is pulled low. It floats during a reset or bus hold condition.

gnd – Ground

Six or seven pins, depending on package, connect the microcontroller to the system ground.

hlda – Bus Hold Acknowledge (synchronous output)

This pin is pulled high to signal the system that the microcontroller has ceded control of the local bus, in response to a high on the **hold** signal by an external bus master, after the microcontroller has completed the current bus cycle. The assertion of **hlda** is accompanied by the tristating of **den_n**, **rd_n**, **wr_n**, **s2-s0**, **ad15-ad0**, **s6**, **a19-a0**, **bhe_n**, **whb_n**, **wlb_n**, and **dr/r_n**, followed by the driving high of the chip selects **ucs_n**, **lcs_n**, **mcs3_n - mcs0_n**, **pcs6_n – pcs5_n**, and **pcs3_n – pcs0_n**. The external bus master releases control of the local bus by the deassertion of **hold** that in turn induces the microcontroller to deassert the **hlda**. The microcontroller may take control of the bus if necessary, (to execute a refresh for example), by deasserting **hlda** without the bus master first deasserting **hold**. This requires that the external bus master must be able to deassert **hold** to permit the microcontroller to access the bus.

int0 – Maskable Interrupt Request 0 (asynchronous input)

The **int0** pin provides an indication that an interrupt request has occurred, and provided that **int0** is not masked, program execution will continue at the location specified by the INT0 vector in the interrupt vector table. Although interrupt requests are asynchronous, they are synchronized internally and may be edge or level triggered. The assertion of the interrupt request must be maintained until it is handled, to ensure that it is recognized.

int1/select_n – Maskable Interrupt Request 1/Slave Select (both are asynchronous inputs)

int1 - The **int1** pin provides an indication that an interrupt request has occurred, and provided that **int1** is not masked, program execution will continue at the location specified by the INT1 vector in the interrupt vector table. Although interrupt requests are asynchronous, they are synchronized internally and may be edge or level triggered. The assertion of the interrupt request must be maintained until it is handled, to ensure that it is recognized.

select_n – This pin provides an indication to the microcontroller that an interrupt type has been placed on the address/data bus when the internal Interrupt Control Unit is slaved to an external interrupt controller. Before this occurs however, the **int0** pin must have indicated an interrupt request has occurred.

int2/inta0_n/pwd/pio31 – Maskable Interrupt Request 2 (asynchronous input) / Interrupt Acknowledge 0 (synchronous output) / Pulse Width Demodulator (Schmitt trigger input)

int2 - The **int2** pin provides an indication that an interrupt request has occurred, and provided that **int1** is not masked, program execution will continue at the location

specified by the **int1** vector in the interrupt vector table. Although interrupt requests are asynchronous, they are synchronized internally and may be edge or level triggered. The assertion of

the interrupt request must be maintained until it is handled, to ensure that it is recognized. When **int0** is configured to be in cascade mode, **int2** changes its function to **inta0_n**.

inta0_n – this function indicates to the system that the microcontroller requires an interrupt type in response to the interrupt request **int0** when the microcontroller's Interrupt Control Unit is in cascade mode.

pwd - processes a signal via the Schmitt trigger when pulse width demodulation is enabled. It drives **timerin0** and **int2** and its inverse signal drives **timerin1** and **int4**. Provided that **int2** and **int4** are enabled and **timer0** and **timer1** are configured correctly, the pulse width of the alternating signal on **pwd** may be calculated from the values in **timer0** and **timer1**.

While in **pwd** mode, **TIMERIN0/PIO11**, **TIMERIN1/PIO0**, and **INT4/PIO31** signals are free for use as PIOs or may be simply ignored. The level on this pin is held in the PIO data register in the **PIO31** position, just as if it were a PIO.

int3/inta1_n/irq – Maskable Interrupt Request 3 (asynchronous input) / Interrupt Acknowledge 1 (synchronous output) / Interrupt Acknowledge (synchronous output)

int3 - The **int3** pin provides an indication that an interrupt request has occurred, and provided that **int3** is not masked, program execution will continue at the location specified by the **int3** vector in the interrupt vector table. Although interrupt requests are asynchronous, they are synchronized internally and may be edge or level triggered. The assertion of the interrupt request must be maintained until it is handled, to ensure that it is recognized. When **int1** is configured to be in cascade mode, **int3** changes its function to **inta1_n**.

inta1_n – this function indicates to the system that the microcontroller requires an interrupt type in response to the interrupt request **int1** when the microcontroller's Interrupt Control Unit is in cascade mode.

irq – With the Interrupt Control Unit of the microcontroller in slave mode, the signal on this pin allows the microcontroller to output an interrupt request to the external master interrupt controller.

int4/pio30 – Maskable Interrupt Request 4 (asynchronous input)

int4 - The **int4** pin provides an indication that an interrupt request has occurred, and provided that **int4** is not masked, program execution will continue at the location specified by the **int4** vector in the interrupt vector table. Although interrupt requests are asynchronous, they are synchronized internally and may be edge or level triggered. The assertion of the interrupt request must be maintained until it is handled, to ensure that it is recognized. In the case where **PWD** mode is selected, **INT4** indicates a High-to-Low transition of the **PWD** signal, and conversely in the event that **PWD** mode is not selected **INT4** may be used as a PIO.

lcs_n/once0_n – Lower Memory Chip Select (synchronous output with internal pullup) / ONCE Mode Request (input)

lcs_n - The **lcs_n** pin provides an indication that a memory access is in train to the lower memory block. The size of the Lower Memory Block and its base address are programmable, with the size adjustable up to 512 Kbytes. **lcs_n** may be configured for either 8 or 16-bit bus width for the IA186ES microcontroller by the Auxiliary Configuration Register (AUXCON bit 2) and is held high during bus hold.

once0_n – (ONCE – *ON* Circuit Emulation). This pin and its companion pin **once1_n** define the microcontroller mode during reset. These two pins are sampled on the rising edge of **res_n** and if both are asserted low the microcontroller starts in ONCE mode, else it starts normally. In ONCE mode all pins are tristated and remain so until a subsequent reset. To prevent the microcontroller from entering ONCE mode inadvertently, this pin has a weak pullup that is only present during reset. Finally this pin is not tristated during bus hold.

mcs0_n/pio14 – Midrange Memory Chip Select (synchronous output with internal pullup)

mcs0_n - The **mcs0_n** pin provides an indication that a memory access is in train to the midrange memory block. The size of the Midrange Memory Block and its base address are programmable. **mcs0_n** may be configured for either 8 or 16-bit bus width for the IA186ES microcontroller by the Auxiliary Configuration Register (AUXCON bit 1) and is held high during bus hold. **mcs0_n** may be programmed as the chip select for the whole middle chip select address range. Furthermore this pin has a weak pullup that is only present during reset.

mcs2_n – mcs1_n (pio24 – pio 15) – Midrange Memory Chip Selects (synchronous outputs with internal pullup)

mcs0_n - The **mcs2_n** and **mcs1_n** pins provide an indication that a memory access is in train to the either the second or third midrange memory block. The size of the Midrange Memory Block and its base address are programmable. **mcs2_n** and **mcs1_n** may be configured for either 8 or 16-bit bus width for the IA186ES microcontroller by the Auxiliary Configuration Register (AUXCON bit 1) and are held high during bus hold. Furthermore these pins have weak pullups that are only present during reset. If **mcs0_n** has been programmed as the chip select for the whole middle chip select address range, these pins may be used as PIOs.

mcs3_n/rfsh_n/pio25 – Midrange Memory Chip Select (synchronous outputs with internal pullup) / Automatic Refresh (synchronous output)

mcs3_n - The **mcs3_n** pin provides an indication that a memory access is in train to the fourth region of the midrange memory block. The size of the Midrange Memory Block and its base address are programmable. **mcs3_n** may be configured for either 8 or 16-bit bus width for the IA186ES microcontroller by the Auxiliary Configuration Register (AUXCON bit 1) and is held high during bus

hold. If **mcs0_n** has been programmed as the chip select for the whole middle chip select address range, this pin may be used as PIO. Furthermore this pin has a weak pullup that is only present during reset.

rfsh_n – This signal is timed for auto refresh to PSRAM or DRAM devices. The refresh pulse is only output when the PSRAM or DRAM mode bit is set (EDRAM register bit 15). This pulse is of 1.5 clock pulse duration with the rest of the refresh cycle made up of a deassertion period such that the overall refresh time is met. Finally this pin is not tristated during a bus hold.

nmi – Nonmaskable Interrupt (synchronous edge-sensitive input)

This is the highest priority interrupt signal and cannot be masked, unlike **int6 – int0**.

Program execution is transferred to the nonmaskable interrupt vector in the interrupt vector table, upon the assertion of this interrupt (transition from Low to High), and this interrupt is initiated at the next instruction boundary. For recognition to be assured the **nmi** pin must be held high for at least a **clkouta** period.

The NMI is not involved in the priority resolution process, that deals with the maskable interrupts, and does not have an associated interrupt flag. This allows for a new NMI request to interrupt an NMI service routine that is already underway. The interrupt flag IF is cleared, disabling the maskable interrupts, when an interrupt is taken by the processor. If, during the NMI service routine, the maskable interrupts are re-enabled, by use of STI instruction for example, the priority resolution of maskable interrupts will be unaffected by the servicing of the NMI. It is strongly recommended, for this reason, that the NMI interrupt service routine does not enable the maskable interrupts.

pcs1_n - pcs0_n (pio17 – pio16) – Peripheral Chip Selects 1-0 (synchronous outputs)

These pins provide an indication that a memory access is under way for the second and first regions respectively of the peripheral memory block (I/O or memory address space). The base address of the Peripheral memory block is programmable. **pcs3_n – pcs0_n** are held high during both bus hold and reset. These outputs are asserted with the **ad** address bus over a 256-byte range each.

pcs2_n/cts1_n/enrx1_n/pio18 – Peripheral Chip Select 2 (synchronous output) / Clear-to-Send 1 (asynchronous input) / Enable-Receiver-Request 1 (asynchronous input)

pcs2_n – This signal provides an indication that a memory access is under way for the third region of the peripheral memory block (I/O or memory address space). The base address of the Peripheral memory block is programmable. **pcs2_n** is held high during both bus hold and reset. This output is asserted with the **ad** address bus over a 256-byte range.

cts1_n – This is the Clear-to-Send signal for asynchronous serial port 1 when the ENRX1 bit (bit 6) in the auxiliary control register (AUXCON) is 0 and hardware flow control is enabled for this port (FC

bit (bit 9) in the serial port 1 control register (SP1CT)). This signal controls the transmission of data from the serial port transmit register 1. When this signal is asserted, the transmitter begins sending out a frame of data if any is in the transmit register, whereas if the signal is de-asserted the data will be held in the transmit register. The signal is checked at the beginning of each frame of transmit data.

enrx1_n – This is the Enable-Receiver-Request for asynchronous serial port 1 when the ENRX1 bit (bit 6) in the auxiliary control register (AUXCON) is 1 and hardware flow control is enabled for this port (FC bit (bit 9) in the serial port 1 control register (SP1CT)). This signal enables the receiver of asynchronous serial port 1.

pcs3_n/rts1_n/rtr1_n/pio18 – Peripheral Chip Select 3 (synchronous output) / Ready-to-Send 1 (asynchronous output) / Ready-to-Receive 1 (asynchronous input)

pcs3_n – This signal provides an indication that a memory access is under way for the fourth region of the peripheral memory block (I/O or memory address space). The base address of the Peripheral memory block is programmable. **pcs3_n** is held high during both bus hold and reset. This output is asserted with the **ad** address bus over a 256-byte range.

rts1-n – This is the Ready-to-Send signal for asynchronous serial port 1 when the RTS1 bit (bit 5) in the auxiliary control register (AUXCON) is 1 and hardware flow control is enabled for this port (FC bit (bit 9) in the serial port 1 control register (SP1CT)). This signal is asserted when the serial port transmit register contains untransmitted data.

rtr1-n – This is the Ready-to-Receive signal for asynchronous serial port 1 when the RTS1 bit (bit 5) in the auxiliary control register (AUXCON) is 0 and hardware flow control is enabled for this port (FC bit (bit 9) in the serial port 1 control register (SP1CT)). This signal is asserted when the serial port receive register does not contain valid, unread data.

pcs5_n/A1/pio3 – Peripheral Chip Select 5 (synchronous output) / latched Address Bit 1 (synchronous output)

pcs5_n – This signal provides an indication that a memory access is under way for the sixth region of the peripheral memory block (I/O or memory address space). The base address of the Peripheral memory block is programmable. **pcs5_n** is held high during both bus hold and reset. This output is asserted with the **ad** address bus over a 256-byte range.

A1 – This pin provides and internally latched address bit 1 to the system when the EX bit (bit 7) in the MCS_n and PCS_n auxiliary (MPCS) register is 0. It retains its previously latched value during a bus hold.

pcs6_n/A2/pio2 – Peripheral Chip Select 6 (synchronous output) / latched Address Bit 2 (synchronous output)

pcs6_n – This signal provides an indication that a memory access is under way for the seventh region of the peripheral memory block (I/O or memory address space). The base address of the Peripheral memory block is programmable. **pcs6_n** is held high during both bus hold and reset. This output is asserted with the **ad** address bus over a 256-byte range.

A2 – This pin provides and internally latched address bit 2 to the system when the EX bit (bit 7) in the MCS_n and PCS_n auxiliary (MPCS) register is 0. It retains its previously latched value during a bus hold.

pio31 – pio0 Programmable I/O Pins (asynchronous input/output open –drain)

32 individually programmable I/O pins are provided. See page 63.

rd_n - Read strobe (synchronous output with tristate)

This pin provides an indication to the system that a memory or I/O read cycle is under way. It will not be asserted before the **ad** bus is floated during the address to data transition. **rd_n** is tristated during bus hold.

res_n - Reset (asynchronous level-sensitive input)

This pin forces a reset on the microcontroller. It has a Schmitt trigger to allow power-on reset generation via an RC network. When this signal is asserted, the microcontroller immediately terminates its present activity, clears its internal logic, and transfers CPU control to the reset address, FFFF0h.

res_n must be asserted for at least 1ms and may be asserted asynchronously to **clkouta** as it is synchronized internally. Furthermore, V_{cc} must be within specification and **clkouta** must be stable for more than four of its clock periods for the period that **res_n** is asserted.

The microcontroller starts to fetch instructions 6.5 **clkouta** clock periods after the deassertion of **res_n**.

rfsh2_n/aden_n - IA188ES only - Refresh 2 (synchronous output with tristate) / Address Enable (input with internal pullup)

rfsh2_n – Indicates that a DRAM refresh cycle is being performed when it is asserted low. However this is not valid in PSRAM mode where **mcs3_n/rfsh_n** is used instead.

aden_n – If this pin is held high during power-on reset, the **ad** bus (**ao15-ao8 & ad7-ad0**) is controlled during the address portion of the LCS and UCS bus cycles by the DA bit (bit 7) in the LMCS and UMCS registers. If the DA bit is 1 the address is accessed on the **a19-a0** pins reducing power consumption. The weak pullup on this pin obviates the necessity of an external pullup.

If this pin is held low during power-on reset, the ad bus is used for both addresses and data without regard for the setting of the DA bits. **rfs2_n/ad_n** is sampled one crystal clock cycle after the rising edge of **res_n** and is tristated during bus holds and ONCE mode.

rts0_n/rtr0_n/pio20 – Ready-to-Send 0 (asynchronous output) / Ready-to-Receive 0 (asynchronous input)

rts0-n – This is the Ready-to-Send signal for asynchronous serial port 0 when the RTS0 bit (bit 3) in the auxiliary control register (AUXCON) is 1 and hardware flow control is enabled for this port (FC bit (bit 9) in the serial port 0 control register (SPOCT)). This signal is asserted when the serial port transmit register contains untransmitted data.

rtr0-n – This is the Ready-to-Receive signal for asynchronous serial port 0 when the RTS0 bit (bit 3) in the auxiliary control register (AUXCON) is 0 and hardware flow control is enabled for this port (FC bit (bit 9) in the serial port 0 control register (SPOCT)). This signal is asserted when the serial port receive register does not contain valid, unread data.

rxd0_n/pio23 - Receive Data 0 (asynchronous input)

This signal connects asynchronous serial receive data from the system to the asynchronous serial port 0.

rxd1_n/pio28 - Receive Data 1 (asynchronous input)

This signal connects asynchronous serial receive data from the system to the asynchronous serial port 1.

s2_n-s0_n - Bus Cycle Status (synchronous outputs with tristate)

These three signals inform the system of the type of bus cycle is in progress. **s2_n** may be used to indicate whether the current access is to memory or I/O, and **s1_n** may be used to indicate whether data is being transmitted or received. These signals are tristated during bus hold and hold acknowledge.

The coding for these pins is shown in the following table.

s2_n	s1_n	s0_n	Bus Cycle
0	0	0	Interrupt acknowledge
0	0	1	Read data from I/O
0	1	0	Write data to I/O
0	1	1	Halt
1	0	0	Instruction fetch
1	0	1	Read data from memory
1	1	0	Write data to memory
1	1	1	None (passive)

s6/lock_n/clkdiv2_n/pio29 - Bus Cycle Status Bit 6 (synchronous output) / Bus Lock (synchronous output) / Clock Divide by 2 (input with internal pullup)

s6 - This signal is high during the second and remaining cycle periods, i.e. $t_2 - t_4$, indicating that a DMA – initiated bus cycle is under way. **s6** is tristated during bus hold or reset.

lock_n - This signal is held low to indicate to other system bus masters that the system bus is being used and that no attempt should be made to try to gain control of it. This signal is only available during t_1 and is intended for emulator use.

clkdiv2_n – The microcontroller enters clock divide-by-2 mode, if this signal is held low during power-on-reset. In this mode, the PLL is disabled and the processor receives the external clock divided by 2. Sampling of this pin occurs on the rising edge of **res_n**. Should this pin be used as **pio29** configured as an input, care should be taken that it is not driven low during power-on-reset. This pin has an internal pullup so it is not necessary to drive the pin high even though it defaults to an input PIO.

srdy/pio6 - Synchronous Ready (synchronous level-sensitive input)

This signal is an active high input synchronized to **clkouta** and indicates to the microcontroller that a data transfer will be completed by the addressed memory space or I/O device.

In contrast to the Asynchronous Ready (**ardy**), which requires internal synchronization, **srdy** permits easier system timing as it already synchronized. Tying **srdy** high will always assert this ready condition, whereas tying it low will give control to **ardy**.

tmrin0/pio11 - Timer Input 0 (synchronous edge-sensitive input)

This signal may be either a clock or control signal for the internal timer 0. The timer is incremented by the microcontroller after it synchronizes a rising edge of **tmrin0**. When not used, **tmrin0** must be tied high, or when used as **pio11** it is pulled up internally.

When Pulse Width Demodulation mode is enabled, **tmrin0** is driven internally by **int2/inta0_n/pwd** allowing for the pin to be configured as **pio11**.

tmrin1/pio0 - Timer Input 1 (synchronous edge-sensitive input)

This signal may be either a clock or control signal for the internal timer 1. The timer is incremented by the microcontroller after it synchronizes a rising edge of **tmrin1**. When not used, **tmrin1** must be tied high, or when used as **pio0** it is pulled up internally.

When Pulse Width Demodulation mode is enabled, **tmrin1** is driven internally by **int2/inta0_n/pwd** allowing for the pin to be configured as **pio0**.

tmrout0/pio10 - Timer Output 0 (synchronous output)

This signal provides the system with a single pulse or a continuous waveform with a programmable duty cycle. It is tristated during a bus hold or reset.

tmrout1/pio1 - Timer Output 1 (synchronous output)

This signal provides the system with a single pulse or a continuous waveform with a programmable duty cycle. It is tristated during a bus hold or reset.

txd0/pio22 - Transmit Data 0 (asynchronous output)

This pin provides the system with asynchronous serial transmit data from serial port 0.

txd1/pio27 - Transmit Data 1 (asynchronous output)

This pin provides the system with asynchronous serial transmit data from serial port 1.

ucs_n/once1_n - Upper Memory Chip Select (synchronous output) / ONCE Mode Request 1 (input with internal pullup)

ucs_n - This pin provides an indication that a memory access is in train to the upper memory block. The size of the Upper Memory Block and its base address are programmable, with the size adjustable up to 512 Kbytes. **ucs_n** is held high during bus hold.

After reset, **ucs_n** is active for the 64 Kbyte memory range from F0000h to FFFFFh, which includes the reset address at FFFF0h.

once1_n – (ONCE – *ON* Circuit Emulation). This pin and its companion pin **once0_n** define the microcontroller mode during reset. These two pins are sampled on the rising edge of **res_n** and if both are asserted low the microcontroller starts in ONCE mode, else it starts normally. In ONCE mode all pins are tristated and remain so until a subsequent reset. To prevent the microcontroller from entering ONCE mode inadvertently, this pin has a weak pullup that is only present during reset. Finally this pin is not tristated during bus hold.

uzi_n/pio26 – Upper Zero Indicate (synchronous output)

This pin allows the designer to determine if an access to the interrupt vector table is in progress by ORing it with bits 15-10 of the address and data bus (**ad15-ad10** on the AI186 and **ao15-ao10** on the AI188). **uzi_n** is the logical AND of the inverted **a19-a16** bits. It asserts in the first period of a bus cycle and is held throughout the cycle.

v_{cc} – Power Supply (input)

These pins supply power (+5V) to the microcontroller.

whb_n – Write High Byte - IA186ES only - (synchronous output with tristate)

This pin and **wlb_n** provide an indication to the system of which bytes of the data bus (upper, lower, or both) are taking part in a write cycle. **whb_n** is asserted with **ad15_ad8** and is the logical OR of **bhe_n** and **wr_n**. It is tristated during reset.

**wlb_n/wb_n – Write Low Byte - IA186ES only - (synchronous output with tristate)
/ Write Byte – IA188ES only - (synchronous output with tristate)**

wlb_n - **wlb_n** and **whb_n** provide an indication to the system of which bytes of the data bus (upper, lower, or both) are taking part in a write cycle. **wlb_n** is asserted with **ad7_ad0** and is the logical OR of **ad0** and **wr_n**. It is tristated during reset.

wb_n – On the IA188ES microcontroller, **wb_n** provides an indication that a write to the bus is occurring. It shares the same early timing as that of the non-multiplexed address bus, and is associated with **ad7-ad0**. It is tristated during reset.

wr_n – Write Strobe (synchronous output)

This pin provides an indication to the system that the data currently on the bus is to be written to a memory or I/O device. It is tristated during a bus hold or reset.

x1 – Crystal Input (input)

This pin and **x2** are the connections for a fundamental mode or third-overtone, parallel-resonant crystal used by the internal oscillator circuit. An external clock source for the microcontroller is connected to **x1** while the **x2** pin is left unconnected.

x2 – Crystal Input (input)

This pin and **x1** are the connections for a fundamental mode or third-overtone, parallel-resonant crystal used by the internal oscillator circuit. An external clock source for the microcontroller is connected to **x1** while the **x2** pin is left unconnected.

Pins Used by Emulators

The following pins are used by emulators:

a19-a0

ao15-ao8

ad7-ad0

ale

bhe_n

aden_n (on the AI186)

clkouta

rfsh2_n/aden_n (on the AI188)

rd_n

s2_n-s0_n

s6/lock_n/clkdiv2_n

uzi_n

Emulators require that **s6/lock_n/clkdiv2_n** and **uzi_n** be configured as their normal functions, i.e. as **s6** and **uzi_n** respectively. Holding **bhe_n/aden_n** (AI186) or **rfsh_n/aden_n** (AI188) low during the rising edge of **res_n**, **s6** and **uzi_n** will be configured in their normal functions instead of as PIOs, at reset.

Instruction Set Summary

(Key to abbreviations appears at the end of the table)

Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
AAA	ASCII adjust AL after add	37	-	-	8	8	U	-	-	-	U	U	R	U	R
AAD	ASCII adjust AX before divide.	D5	0A	-	15	15	U	-	-	-	R	R	U	R	U
AAM	ASCII adjust AL after multiply	D4	0A	-	19	19	U	-	-	-	R	R	U	R	U
AAS	ASCII adjust AL after subtract	3F	-	-	7	7	U	-	-	-	U	U	R	U	R
ADC	Add imm8 to AL with carry	14	ib	-	3	3	R	-	-	-	R	R	R	R	R
	Add imm16 to AX with carry	15	iw	-	4	4									
	Add imm8 to r/m8 with carry	80	/2 ib	-	4/16	4/16									
	Add imm16 to r/m16 with carry	81	/2 iw	-	4/16	4/20									
	Add sign extended imm8 to r/m16 with carry	83	/2 ib	-	4/16	4/20									
	Add byte reg to r/m8 with carry	10	/r	-	3/10	3/10									
	Add word reg to r/m16 with carry	11	/r	-	3/10	3/14									
	Add r/m8 to byte reg with carry	12	/r	-	3/10	3/10									
Add r/m16 to word reg with carry	13	/r	-	3/10	3/14										
ADD	Add imm8 to AL	04	ib	-	3	3	R	-	-	-	R	R	R	R	R
	Add imm16 to AX	05	iw	-	4	4									
	Add imm8 to r/m8	80	/0 ib	-	4/16	4/16									
	Add imm16 to r/m16	81	/0 iw	-	4/16	4/20									
	Add sign extended imm8 to r/m16	83	/0 ib	-	4/16	4/20									
	Add byte reg. to r/m8	00	/r	-	3/10	3/10									
	Add word reg. to r/m16	01	/r	-	3/10	3/14									
	Add r/m8 to byte reg	02	/r	-	3/10	3/10									
Add r/m16 to word reg	03	/r	-	3/10	3/14										
AND	And imm8 with AL	24	ib		3	3	0	-	-	-	R	R	U	R	0
	And imm16 with AX	25	iw		4	4									
	And imm8 with r/m8	80	/4 ib		4/16	4/16									
	And imm16 with r/m16	81	/4 iw		4/16	4/20									
	And sign-extended imm8 with r/m16	83	/4 ib		4/16	4/20									
	And byte reg. with r/m8	20	/r		3/10	3/10									
	And word reg. with r/m16	21	/r		3/10	3/14									
	And r/m8 with byte reg	22	/r		3/10	3/10									
And r/m16 with word reg	23	/r		3/10	3/14										

IA186ES/IA188ES

8/16-BIT MICROCONTROLLERS

Preliminary Data Sheet

Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
BOUND	Check array index against bounds	62	/r	-	33-35	33-35	-	-	-	-	-	-	-	-	-
CALL	Call near, disp relative to next instruction	E8	cw	-	15	19	-	-	-	-	-	-	-	-	-
	Call near, reg indirect mem	FF	/2	-	13/19	17/27									
	Call far to full address given	9A	cd	-	23	31									
	Call far to address at m16:16 word	FF	/3	-	38	54									
CBW	Convert byte integer to word	98	-	-	2	2	-	-	-	-	-	-	-	-	-
CLC	Clear carry flag	F8	-	-	2	2	-	-	-	-	-	-	-	-	-
CLD	Clear direction flag	FC	-	-	2	2	-	0	-	-	-	-	-	-	-
CLI	Clear interrupt-enable flag	FA	-	-	2	2	-	-	0	-	-	-	-	-	-
CMC	Complement carry flag	F5	-	-	2	2	-	-	-	-	-	-	-	-	R
CMP	Compare imm8 to AL	3C	ib	-	3	3	R	-	-	-	R	R	R	R	R
	Compare imm16 to AX	3D	iw	-	4	4									
	Compare imm8 to r/m8	80	/7	ib	3/10	3/10									
	Compare imm16 to r/m16	81	/7	iw	3/10	3/14									
	Compare sign-extended imm8 to r/m16	83	/7	ib	3/10	3/14									
	Compare byte reg to r/m8	38	/r	-	3/10	3/10									
	Compare word reg to r/m16	39	/r	-	3/10	3/14									
	Compare r/m8 to byte reg	3A	/r	-	3/10	3/10									
	Compare r/m16 to word reg	3B	/r	-	3/10	3/14									
CMPS	Compare byte ES: [DI] to byte segment: [SI]	A6	-	-	22	22	R	-	-	-	R	R	R	R	R
	Compare word ES: [DI] to word segment: [SI]	A7	-	-	22	26									
CMPSB	Compare byte ES: [DI] to byte DS: [SI]	A6	-	-	22	22	R	-	-	-	R	R	R	R	R
CMPSW	Compare word ES: [DI] to word DS: [SI]	A7	-	-	22	26	R	-	-	-	R	R	R	R	R
CS	CS segment reg override prefix	2E	-	-	-	-	-	-	-	-	-	-	-	-	-
CWD	Convert word integer to double word	99	-	-	4	4	-	-	-	-	-	-	-	-	-
DAA	Decimal adjust AL after addition	27	-	-	4	4	?	-	-	-	R	R	R	R	R
DAS	Decimal adjust AL after subtraction	2F	-	-	4	4	?	-	-	-	R	R	R	R	R
DEC	Subtract 1 from r/m8	FE	/1	-	3/15	3/15	R	-	-	-	R	R	R	R	R
	Subtract 1 from r/m16	FF	/1	-	3/15	3/19									
	Subtract 1 from word reg	48+ rw			3	3									
DIV	Divide unsigned numbers	F6	mod 110 r/m	-	29/35	29/35	U	-	-	-	U	U	U	U	U
DS	DS segment override prefix	3E	-	-	-	-	-	-	-	-	-	-	-	-	-

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Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
ENTER	Create stack frame for nested procedure	C8	iw ib	-	22+16 (n-1)	26+20 (n-1)									
	Create stack frame for non-nested procedure	C8	iw 00	-	15	19	-	-	-	-	-	-	-	-	-
	Create stack frame for nested procedure	C8	iw 01	-	25	29									
ES	ES segment reg override prefix	26	-	-	-	-	-	-	-	-	-	-	-	-	-
ESC	Escape - takes a Trap 7	D8	/0	-	-	-									
	Escape - takes a Trap 7	D9	/1	-	-	-									
	Escape - takes a Trap 7	DA	/2	-	-	-									
	Escape - takes a Trap 7	DB	/3	-	-	-			0	0	-	-	-	-	-
	Escape - takes a Trap 7	DC	/4	-	-	-									
	Escape - takes a Trap 7	DD	/5	-	-	-									
	Escape - takes a Trap 7	DE	/6	-	-	-									
HLT	Suspend instruction execution	F4	-	-	2	2	-	-	-	-	-	-	-	-	-
IDIV	Divide Integers AL = AX/(r/m8); AH = remainder	F6	/7	-	44-52 / 50-58	44-52 / 50-58	U	-	-	-	U	U	U	U	U
	Divide Integers AX = DX : AX/(r/m16); DX = remainder	F7	/7	-	53-61 / 59-67	53-61 / 63-71									
IMUL	Multiply Integers AX=(r/m8)*AI	F6	/5	-	25-28 / 31-34	25-28 / 31-34									
	Multiply Integers DX=(r/m16)*AX	F7	/5	-	34-37 / 40-43	34-37 / 44-47									
	Multiply Integers (word reg) = (r/m16)*(sign-ext. byte integer)	6B	/r ib	-	22-25	22-25	R	-	-	-	U	U	U	U	R
	Multiply Integers (word reg) = (word reg)*(sign-ext. byte integer)	6B	/r ib	-	22-25	22-25									
	Multiply Integers (word reg) = (r/m16)*(sign-ext. byte integer)	69	/r iw	-	29-32	29-32									
Multiply Integers (word reg) = (word reg)*(sign-ext. byte integer)	69	/r iw	-	29-32	29-32										

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Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
IN	Input byte from imm port to AL	E4	ib	-	10	10									
	Input word from imm port to AX	E5	ib	-	10	14									
	Input byte from port in DX to AL	EC		-	8	8	-	-	-	-	-	-	-	-	-
	Input word from port in DX to AX	ED		-	8	12									
INC	Increment r/m8 by 1	FE	/0	-	3/15	3/15									
	Increment r/m16 by 1	FF	/0	-	3/15	3/19	R	-	-	-	R	R	R	R	R
	Increment word reg by 1	40+rw	-	-	3	3									
INS	Input byte from port in DX to ES : [DI]	6C													
	Input word from port in DX to ES : [DI]	6D													
INSB	Input byte from port in DX to ES : [DI]	6C	-	-	14	14	-	-	-	-	-	-	-	-	-
INSW	Input word from port in DX to ES : [DI]	6D													
INT 3	Generate interrupt 3 (trap to debug)	CC	-	-	45	45									
INT	Generate type of interrupt specified by imm8	CD	ib	-	47	47	-	-	0	0	-	-	-	-	-
INTO	Generate interrupt 4 if Overflow Flag (O) is 1	CE	-	-	48, 4	48, 4									
IRET	Interrupt return	CF	-	-	28	28	Restores value of flags reg that was stored on the stack when the interrupt was taken								
JA	Jump short if above (C & Z = 0)	77	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JNBE	Jump short if not below or equal														
JAE	Jump short if above or equal (C=0)														
JNB	Jump short if not below (C=0)	73	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JNC	Jump short if not carry (C=0)														
JB	Jump short if below (C=1)														
JC	Jump short if carry (C=1)	72	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JNAE	Jump short if not above or equal (C=1)														
JBE	Jump short if below or equal (C & Z = 0)	76	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JNA	Jump short if not above (C & Z = 0)														

Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
JCXZ	Jump short if CX reg is 0	E3	cb	-	15,5	15,5	-	-	-	-	-	-	-	-	-
JE	Jump short if equal (Z=1)	74	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JZ	Jump short if 0 (Z=1)														
JG	Jump short if greater (Z & S = 0)	7F	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JNLE	Jump short if not less or equal (Z & S = 0)														
JGE	Jump short if greater or equal (S=0)	7D	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JNL	Jump short if not less (S = 0)														
JLE	Jump short if less or equal (Z & S = 0)	7E	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JNG	Jump short if not greater (Z & S = 0)														
JMP	Jump short direct, disp relative to next instruction	EB	cb	-	14	14	-	-	-	-	-	-	-	-	-
	Jump near direct, disp relative to next instruction	E9	cw	-	14	14									
	Jump near indirect	FF	/4	-	11/17	11/21									
	Jump far direct to doubleword imm address	EA	cd	-	14	14									
	Jump m16: 16 indirect and far	FF	/5	-	26	34									
JNE	Jump short if not equal (Z=0)	75	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JNZ	Jump short if not zero (Z=0)														
JNO	Jump short if not overflow (O=1)	71	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JNP	Jump short if not parity (P=0)	7B	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JPO	Jump short if parity odd (P=0)														
JNS	Jump short if not sign (S=0)	79	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JO	Jump short if overflow (O=1)	70	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JP	Jump short if parity (P=1)	7A	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
JPE	Jump short if parity (P=1)														
JS	Jump short if sign (S=1)	78	cb	-	13, 4	13, 4	-	-	-	-	-	-	-	-	-
LAHF	Load AH with low byte of flags reg	9F	-	-	2	2	-	-	-	-	-	-	-	-	-
LDS	Load DS:r16 with segment :offset from memory	C5	/r	-	18	26	-	-	-	-	-	-	-	-	-
LEA	Load offset for m16 word in 16-bit reg	8D	/r	-	6	6	-	-	-	-	-	-	-	-	-
LEAVE	Destroy procedure stack frame	C9	-	-	8	8	-	-	-	-	-	-	-	-	-
LES	Load ES:r16 with segment offset from memory	C4	/r	-	18	26	-	-	-	-	-	-	-	-	-
LOCK	Asserts lock_n during an instruction execution	F0	-	-	1	1	-	-	-	-	-	-	-	-	-

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Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
LODS	Load byte segment :[SI] in AL	AC			12	12									
	Load word segment :[SI] in AX	AD			12	16									
LODSB	Load byte DS: [SI] in AL	AC	-	-	12	12									
LODSW	Load word DS: [SI] in AX	AD			12	16									
LOOP	Decrement count ; jump short if CX ≠ 0	E2	-	-											
LOOPE	Decrement count ; jump short if CX ≠ 0 and Z = 1	E1	cb	-	16, 6	16, 6									
LOOPZ	Decrement count ; jump short if CX ≠ 0 and Z = 1														
LOOPNE	Decrement count ; jump short if CX ≠ 0 and Z = 0	E0	cb	-	16, 6	16, 6									
LOOPNZ	Decrement count ; jump short if CX ≠ 0 and Z = 0														
MOV	Copy reg to r/m8	88	/r	-	2/12	2/12									
	Copy reg to r/m16	89	/r	-	2/12	2/16									
	Copy r/m8 to reg	8A	/r	-	2/9	2/9									
	Copy r/m16 to reg	8B	/r	-	2/9	2/13									
	Copy segment reg to r/m16	8C	/sr	-	2/11	2/15									
	Copy r/m16 to segment reg	8E	/sr	-	2/9	2/13									
	Copy byte at segment offset to AL	A0	-	-	8	8									
	Copy word at segment offset to AX	A1	-	-	8	12									
	Copy AL to byte at segment offset	A2	-	-	9	9									
	Copy AX to word at segment offset	A3	-	-	9	13									
	Copy imm8 to reg	B0 +rb	-	-	3	3									
	Copy imm16 to reg	B8 +rw				3	4								
	Copy imm8 to r/m8	C6	/0	-	12	12									
	Copy imm16 to r/m16	C7	/0	-	12	13									
MOVS	Copy byte segment [SI] to ES:[DI]	A4	-	-	14	14									
	Copy word segment [SI] to ES:[DI]	A5	-	-	14	18									
MOVSB	Copy byte DS:[SI] to ES:[DI]	A4	-	-	14	14									
MOVSW	Copy word DS:[SI] to ES:[DI]	A5	-	-	14	18									
MUL	AX = (r/m8) * AL	F6	/4		26-28 / 32-34	26-28 / 32-34	R	-	-	-	-	-	-	-	R
	DX :: AX = (r/m16) * AX	F7	/4		35-37 / 41-43	35-37 / 45-47									
NEG	Perform 2's complement negation of r/m8	F6	/3	-	3/10	3/10	R	-	-	-	R	R	R	R	R
	Perform 2's complement negation of r/m16	F7	/3	-	3/10	3/14									

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Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
NOP	Perform no operation	90	-	-	3	3	-	-	-	-	-	-	-	-	-
NOT	Complement each bit in r/m8	F6	/2	-	3/10	3/10	-	-	-	-	-	-	-	-	-
	Complement each bit in r/m16	F7	/2	-	3/10	3/14	-	-	-	-	-	-	-	-	-
OR	OR imm8 with AL	0C	ib	-	3	3	0	-	-	-	R	R	U	R	O
	OR imm16 with AX	0D	iw	-	4	4									
	OR imm8 with r/m8	80	/1 ib	-	4/16	4/16									
	OR imm16 with r/m16	81	/1 iw	-	4/16	4/20									
	OR imm8 with r/m16	83	/1 ib	-	4/16	4/20									
	OR byte reg with r/m8	08	/r	-	3/10	3/10									
	OR word reg with r/m16	09	/r	-	3/10	3/14									
	OR r/m8 with byte reg	0A	/r	-	3/10	3/10									
	OR r/m16 with word reg	0B	/r	-	3/10	3/14									
OUT	Output AL to imm port	E6	ib	-	9	9	-	-	-	-	-	-	-	-	-
	Output AX to imm port	E7	ib	-	9	13									
	Output AL to port in DX	EE	-	-	7	7									
	Output AX to port in DX	EF	-	-	7	11									
OUTS	Output byte DS:[SI] to port in DX	6E	-	-	14	14	-	-	-	-	-	-	-	-	-
	Output word DS:[SI] to port in DX	6F	-	-											
OUTSB	Output byte DS:[SI] to port in DX	6E	-	-											
OUTSW	Output word DS:[SI] to port in DX	6F	-	-											
POP	Pop top word of stack into memory word	8F	/0	-	20	24	-	-	-	-	-	-	-	-	-
	Pop top word of stack into word reg	58+ rw	-	-	10	14									
	Pop top word of stack into DS	1F	-	-	8	12									
	Pop top word of stack into ES	07	-	-											
	Pop top word of stack into SS	17	-	-											
POPA	Pop DI, SI, BP, BX, DX, CX, & AX	61	-	-	51	83	Values in word at top of stack are copied into FLAGS reg bits								
POPF	Pop top word of stack into Processor Status Flags reg	9D	-	-	8	12									
PUSH	Push memory word onto stack	FF	/6	-	16	20	-	-	-	-	-	-	-	-	-
	Push reg word onto stack	50+ rw	-	-	10	14									
	Push sign-extended imm8 onto stack	6A	-	-	10	14									
	Push imm16 onto stack	68	-	-	10	14									
	Push CS onto stack	0E	-	-	9	13									
	Push SS onto stack	16	-	-	9	13									
	Push DS onto stack	1E	-	-	9	13									
	Push ES onto stack	06	-	-	9	13									

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Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
PUSHA	Push AX, CX, DX, BX, original SP, BP, SI, and DI	60	-	-	36	68	-	-	-	-	-	-	-	-	-
PUSHF	Push Processor Status Flags reg	9C	-	-	9	13	-	-	-	-	-	-	-	-	-
RCL	Rotate 9 bits of C and r/m8 left once	D0	/2	-	2/15	2/15									
	Rotate 9 bits of C and r/m8 left CL times	D2	/2	-	5+n/ 17+n	5+n/ 17+n									
	Rotate 9 bits of C and r/m8 left imm8 times	C0	/2 ib	-	5+n/ 17+n	5+n/ 17+n									
	Rotate 17 bits of C and r/m16 left once	D1	/2	-	2/15	2/15	-	-	-	-	-	-	-	-	-
	Rotate 17 bits of C and r/m16 left CL times	D3	/2	-	5+n/ 17+n	5+n/ 17+n									
	Rotate 17 bits of C and r/m16 left imm8 times	C1	/2 ib	-	5+n/ 17+n	5+n/ 17+n									
RCR	Rotate 9 bits of C and r/m8 right once	D0	/3	-	2/15	2/15									
	Rotate 9 bits of C and r/m8 right CL times	D2	/3	-	5+n/ 17+n	5+n/ 17+n									
	Rotate 9 bits of C and r/m8 right imm8 times	C0	/3 ib	-	5+n/ 17+n	5+n/ 17+n									
	Rotate 17 bits of C and r/m16 right once	D1	/3	-	2/15	2/15	-	-	-	-	-	-	-	-	-
	Rotate 17 bits of C and r/m16 right CL times	D3	/3	-	5+n/ 17+n	5+n/ 17+n									
	Rotate 17 bits of C and r/m16 right imm8 times	75	/3 ib	-	5+n/ 17+n	5+n/ 17+n									
REP INS	Input CX bytes from port in DX to ES : [DI]	F3	6C	-	8+8n	8+8n									
	Input CX bytes from port in DX to ES : [DI]	F3	6D	-	8+8n	12+8n	-	-	-	-	-	-	-	-	-
REP LODS	Load CX bytes from segment :[SI] in AL	F3	AC	-	6+11n	6+11n									
	Load CX words from segment :[SI] in AX	F3	AD	-	6+11n	10+ 11n	-	-	-	-	-	-	-	-	-
REP MOVS	Copy CX bytes from segments : [SI] to ES:[DI]	F3	A4	-	8+8n	8+8n									
	Copy CX words from segments : [SI] to ES:[DI]	F3	A5	-	8+8n	12+8n	-	-	-	-	-	-	-	-	-
REP OUTS	Output CX bytes from DS:[SI] to port in DX	F3	6E	-	8+8n	8+8n									
	Output CX bytes from DS:[SI] to port in DX	F3	6F	-	8+8n	12+8n	-	-	-	-	-	-	-	-	-

Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
REP	Fill CX bytes at ES:[DI] with AL	F3	AA	-	8+8n	8+8n	-	-	-	-	-	-	-	-	-
STOS	Fill CX words at ES:[DI] with AL	F3	AB	-	8+8n	12+8n	-	-	-	-	-	-	-	-	-
REPE	Find non-matching bytes in ES:[DI] and segment :[SI]	F3	A6	-	5+22n	5+22n									
CMPS	Find non-matching words in ES:[DI] and segment :[SI]	F3	A7	-	5+22n	9+22n									
REPE	Find non-AL byte starting at ES:[DI]	F3	AE	-	5+15n	5+15n									
SCAS	Find non-AX word starting at ES:[DI]	F3	AF	-	5+15n	9+15n	-	-	-	-	-	-	-	-	-
REPZ	Find non-matching bytes in ES:DI and segment :[SI]	F3	A6	-	5+22n	5+22n									
CMPS	Find non-matching words in ES:DI and segment :[SI]	F3	A7	-	5+22n	9+22n									
REPZ	Find non-AL byte starting at ES:DI	F3	AE	-	5+15n	5+15n									
SCAS	Find non-AX word starting at ES:DI	F3	AF	-	5+15n	9+15n									
REPNE	Find matching bytes in ES:[DI] and segment :[SI]	F2	A6	-	5+22n	5+22n									
CMPS	Find matching words in ES:[DI] and segment :[SI]	F2	A7	-	5+22n	9+22n									
REPZ	Find AL byte starting at ES:[DI]	F2	A6	-	5+22n	5+22n									
CMPS	Find AX word starting at ES:[DI]	F2	A7	-	5+22n	9+22n	-	-	-	-	-	-	-	-	-
REPNE	Find matching bytes in ES:DI and segment :[SI]	F2	AE	-	5+15n	5+15n									
SCAS	Find matching words in ES:DI and segment :[SI]	F2	AF	-	5+15n	9+15n									
REPZ	Find AL byte starting at ES:DI	F2	AE	-	5+15n	5+15n									
SCAS	Find AX word starting at ES:DI	F2	AF	-	5+15n	9+15n									
RET	Return near to calling procedure	C3			16	20									
	Return far to calling procedure	CB	data low	data high	22	30									
	Return near; pop imm16 parameters	C2			18	22	-	-	-	-	-	-	-	-	-
	Return far; pop imm16 parameters	CA	data low	data high	25	33									
ROL	Rotate 8 bits of r/m8 left once	D0	/0	-	2/15	2/15									
	Rotate 8 bits or r/m8 left CL times	D2	/0	-	5+n/ 17+n	5+n/ 17+n	U	-	-	-	-	-	-	-	R
	Rotate 8 bits or r/m8 left imm8 times	C0	/0 ib	data 8	5+n/ 17+n	5+n/ 17+n									
	Rotate 16 bits of r/m8 left once	D1	/0	-	2/15	2/15									

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Instruction		Opcode - Hex			Clock Cycles		Flags Affected									
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C	
ROL	Rotate 16 bits or r/m8 left CL times	D3	/0	-	5+n/ 17+n	5+n/ 17+n	U	-	-	-	-	-	-	-	R	
	Rotate 16 bits or r/m8 left imm8 times	C1	/0 ib	data 8	5+n/ 17+n	5+n/ 17+n										
ROR	Rotate 8 bits of r/m8 right once	D0	/1	-	2/15	2/15										
	Rotate 8 bits or r/m8 right CL times	D2	/1	-	5+n/ 17+n	5+n/ 17+n										
	Rotate 8 bits or r/m8 right imm8 times	C0	/1 ib	data 8	5+n/ 17+n	5+n/ 17+n	U	-	-	-	-	-	-	-	R	
	Rotate 16 bits of r/m8 right once	D1	/1	-	2/15	2/15										
	Rotate 16 bits or r/m8 right CL times	D3	/1	-	5+n/ 17+n	5+n/ 17+n										
	Rotate 16 bits or r/m8 right imm8 times	C1	/1 ib	data 8	5+n/ 17+n	5+n/ 17+n										
SAHF	Show AH in low byte of the Status Flags reg	9E	-	-	3	3	-	-	-	-	R	R	R	R	R	
SAL/SHL	Multiply r/m8 by 2, once	D0	/4	-	2/15	2/15										
	Multiply r/m8 by 2, CL times	D2	/4	-	5+n/ 17+n	5+n/ 17+n										
	Multiply r/m8 by 2, imm8 times	C0	/4 ib	data 8	5+n/ 17+n	5+n/ 17+n	U	-	-	-	-	R	R	R	R	
	Multiply r/m16 by 2, once	D1	/4	-	2/15	2/15										
	Multiply r/m16 by 2, CL times	D3	/4	-	5+n/ 17+n	5+n/ 17+n										
	Multiply r/m16 by 2, imm8 times	C1	/4 ib	data 8	5+n/ 17+n	5+n/ 17+n										
	Multiply r/m8 by 2, once	D0	/4	-	2/15	2/15							R	R	R	R
	Multiply r/m8 by 2, CL times	D2	/4	-	5+n/ 17+n	5+n/ 17+n										
	Multiply r/m8 by 2, imm8 times	C0	/4 ib	data 8	5+n/ 17+n	5+n/ 17+n										
	Multiply r/m16 by 2, once	D1	/4	-	2/15	2/15										
	Multiply r/m16 by 2, CL times	D3	/4	-	5+n/ 17+n	5+n/ 17+n										
	Multiply r/m16 by 2, imm8 times	C1	/4 ib	data 8	5+n/ 17+n	5+n/ 17+n										

IA186ES/IA188ES

8/16-BIT MICROCONTROLLERS

Preliminary Data Sheet

Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
SAR	Perform a signed division of r/m8 by 2, once	D0	/7	-	2/15	2/15									
	Perform a signed division of r/m8 by 2, CL times	D2	/7	-	5+n/ 17+n	5+n/ 17+n									
	Perform a signed division of r/m8 by 2, imm8 times	C0	/7 ib	data 8	5+n/ 17+n	5+n/ 17+n	U	-	-	-	R	R	U	R	R
	Perform a signed division of r/m16 by 2, once	D1	/7	-	2/15	2/15									
	Perform a signed division of r/m16 by 2, CI times	D3	/7	-	5+n/ 17+n	5+n/ 17+n									
	Perform a signed division of r/m16 by 2, imm8 times	C1	/7 ib	data 8	5+n/ 17+n	5+n/ 17+n									
SBB	Subtract imm8 from AI with borrow	1C	ib	-	3	3									
	Subtract imm16 from AX with borrow	1D	iw	data 8	4	4									
	Subtract imm8 from r/m8 with borrow	80	/3 ib	-	4/16	4/16									
	Subtract imm16 from r/m16 with borrow	81	/3 iw	-	4/16	4/20									
	Subtract sign-extended imm8 from r/m16 with borrow	83	/3 ib	-	4/16	4/20	R	-	-	-	R	R	R	R	R
	Subtract byte reg from r/m8 with borrow	18	/r	data 8	3/10	3/10									
	Subtract word reg from r/m16 with borrow	19	/r	-	3/10	3/14									
	Subtract r/m8 from r/m8 with borrow	1A	/r	-	3/10	3/10									
	Subtract r/m8 reg from byte with borrow	1B	/r	data 8	3/10	3/14									
SCAS	Compare byte AL to ES:[DI]; update DI	AE	-	-	15	19									
	Compare word AL to ES:[DI]; update DI	AF	-	-	15	19	R	-	-	-	R	R	R	R	R
SCASB	Compare byte AL to ES:[DI]; update DI	AE	-	-	15	19									
SCASW	Compare word AL to ES:[DI]; update DI	AF	-	-	15	19									

IA186ES/IA188ES

8/16-BIT MICROCONTROLLERS

Preliminary Data Sheet

Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
SHR	Divide unsigned of r/m8 by 2, once	D0	/7	-	2/15	2/15	U	-	-	-	R	R	U	R	0
	Divide unsigned of r/m8 by 2, CL times	D2	/7	-	5+n/ 17+n	5+n/ 17+n									
	Divide unsigned of r/m8 by 2, imm8 times	C0	/7 ib	data 8	5+n/ 17+n	5+n/ 17+n									
	Divide unsigned of r/m16 by 2, once	D1	/7	-	2/15	2/15									
	Divide unsigned of r/m16 by 2, CL times	D3	/7	-	5+n/ 17+n	5+n/ 17+n									
	Divide unsigned of r/m16 by 2, imm8 times	C1	/7 ib	data 8	5+n/ 17+n	5+n/ 17+n									
SS	SS segment reg override prefix	36	-	-	-	-	-	-	-	-	-	-	-	-	-
STC	Set the Carry Flag to 1	F9	-	-	2	2	-	-	-	-	-	-	-	-	1
STD	Set the Direction Flag so the source Index (SI) and/or the Destination Index (DI) regs will decrement during string instructions	FD	-	-	2	2	-	1	-	-	-	-	-	-	-
STI	Enable maskable interrupts after the next instruction	FB	-	-	2	2	-	-	1	-	-	-	-	-	-
STOS	Store AL in byte ES:[DI]; update DI	AA	-	-	10	10	-	-	-	-	-	-	-	-	-
	Store AX in word ES:[DI]; update DI	AB	-	-	10	14									
STOSB	Store AL in byte ES:[DI]; update DI	AA	-	-	10	10									
STOSW	Store AX in word ES:[DI]; update DI	AB	-	-	10	14									
SUB	Subtract imm8 from AL	2C	ib	-	3	3	R	-	-	-	R	R	R	R	R
	Subtract imm16 from AX	2D	iw	-	4	4									
	Subtract imm8 from r/m8	80	/5 ib	-	4/16	4/16									
	Subtract imm16 from r/m16	81	/5 iw	-	4/16	4/20									
	Subtract sign-extended imm8 from r/m16	83	/5 ib	-	4/16	4/20									
	Subtract byte reg from r/m8	28	/r	-	3/10	3/10									
	Subtract word reg from r/m16	29	/r	-	3/10	3/14									
	Subtract r/m8 from byte reg	2A	/r	-	3/10	3/10									
	Subtract r/m16 from word reg	2B	/r	-	3/10	3/14									

IA186ES/IA188ES

8/16-BIT MICROCONTROLLERS

Preliminary Data Sheet

Instruction		Opcode - Hex			Clock Cycles		Flags Affected								
Mnemonic	Description	byte 1	byte 2	byte 3-6	IA186	IA188	O	D	I	T	S	Z	A	P	C
TEST	AND imm8 with AL	A8	ib	-	3	3	0	-	-	-	R	R	U	R	0
	AND imm16 with AX	A9	iw	-	4	4									
	AND imm8 with r/m8	F6	/0 ib	data 8	4/10	4/10									
	AND imm16 with r/m16	F7	/0 iw	-	4/10	4/14									
	AND byte reg with r/m8	84	/r	-	3/10	3/10									
	AND word reg with r/m16	85	/r	data 8	3/10	3/14									
WAIT	Performs a NOP	9B	-	-	-	-	-	-	-	-	-	-	-	-	-
XCHG	Exchange word reg with AX	90	-	-	3	3	-	-	-	-	-	-	-	-	-
	Exchange AX with word reg	+rw	-	-	3	3									
	Exchange byte reg with r/byte	86	-	-	4/17	4/17									
	Exchange r/m8 with byte reg	/r	-	-	4/17	4/17									
	Exchange word reg with r/m16	87	-	-	4/17	4/21									
	Exchange r/m16 with word reg	/r	-	-	4/17	4/21									
XLAT	Set AL to memory byte segment :[BX+unsigned AL]	D7	-	-	11	15	-	-	-	-	-	-	-	-	-
XLATB	Set AL to memory byte DS :[BX+unsigned AL]	D7	-	-	11	15	-	-	-	-	-	-	-	-	-
XOR	XOR imm8 with AL	34	ib	-	3	3	0	-	-	-	R	R	U	R	0
	XOR imm16 with AX	35	iw	-	4	4									
	XOR imm8 with r/m8	80	/6 ib	-	4/16	4/16									
	XOR imm16 with r/m16	81	/6 iw	-	4/16	4/20									
	XOR sign-extended imm8 with r/m16	83	/6 ib	-	4/16	4/20									
	XOR byte reg with r/m8	30	/r	-	3/10	3/10									
	XOR word reg with r/m16	31	/r	-	3/10	3/14									
	XOR r/m8 with byte reg	32	/r	-	3/10	3/10									
	XOR r/m16 with word reg	33	/r	-	3/10	3/14									

Key to Abbreviations Used in Above Table

The Operand Address byte is configured as follows.

7	6	5	4	3	2	1	0
mod field		aux field			r/m field		

mod field (Modifier Field)

mod Description

11	r/m is treated as a register field
00	DISP = 0, disp-low and disp-high are absent - address displacement is 0.
01	DISP = disp-low sign-extended to 16-bits, disp-high is absent.
10	DISP = disp-high: disp-low.

aux field (Auxiliary Field)

aux	If mod = 11 and word = 0	If mod = 11 and word = 1
000	AL	AX
001	CL	CX
010	DL	DX
011	BL	BX
100	AH	SP
101	CH	BP
110	DH	SI
111	BH	DI

When mod ≠ 11, depends on instruction

r/m field

r/m Description

000	EA = (BX) + (SI) + DISP [where EA is the Effective Address]
001	EA = (BX) + (DI) + DISP
010	EA = (BP) + (SI) + DISP
011	EA = (BX) + (DI) + DISP
100	EA = (SI) + DISP
101	EA = (DI) + DISP
110	EA = (BP) + DISP [except if mod = 00, then EA = disp-high: disp-low]
111	EA = (BX) + DISP

Displacement

The displacement is an 8 or 16 bit value added to the offset portion of the address.

Immediate

The immediate bytes consist of up to 16 bits of immediate data.

Segment Override Prefix

The Operand Address byte is configured as follows.

7	6	5	4	3	2	1	0
0	0	1	SR	SR	1	1	0

SR Segment Register

00	ES
01	CS
10	SS
11	DS

Notation

Parameter Indication

- : The component of the left is the segment for a component located in memory. The component on the right is the offset.

- :: The component of the left is concatenated with the component on the right.

Operand Translation

imm8	Immediate byte: signed number between –128 and 127
imm16	Immediate word: signed number between –32768 and 32767
m	Operand in memory
m8	Byte string in memory pointed to by DS:SI or ES:DI
m16	Word string in memory pointed to by DS:SI or ES:DI
r/m8	General byte register or a byte in memory
r/m16	General word register or a word in memory

Opcode

Parameter

/0 - /7 The Auxiliary Field in the Operand Address byte specifies an extension (from 000 to 111, i.e. 0 to 7) to the opcode instead of a register. Thus the opcode for adding (AND) an immediate byte to a general byte register or a byte in memory is ‘80 /4 ib’. This indicates that the second byte of the opcode is ‘*mod 100 r/m*’.

/r	The Auxiliary Field in the Operand Address byte specifies a register rather than an opcode extension. The opcode byte specifies which register, either byte size or word size, is assigned as in the aux code above.
/sr	This byte is placed before the instruction as shown above under Segment Override Prefix.
cb	The byte following the Opcode byte specifies the offset.
cd	The double-word following the Opcode byte specifies the offset and in some cases a segment.
ib	Immediate byte – signed or unsigned determined by the Opcode byte.
iw	Immediate word – signed or unsigned determined by the Opcode byte.
rw	Word register operand as determined by the Opcode byte, aux field.

Flags Affected After Instruction

U	Undefined
-	Unchanged
R	Result dependent

Absolute Maximum Ratings

Storage Temperature **-65°C to +125°C**
Voltage on any pin with respect to ground **-0.5 V to V_{CC} +0.5 V**

Operating Range

Industrial (T_A) **-40°C to +85°C**

T_A = ambient temperature

DC Characteristics Over Commercial Operating Ranges

Symbol	Parameter Description	Test Conditions	Preliminary		Unit
			Min	Max	
V _{IL}	Input Low Voltage (Except X1)		-0.5	0.8	V
V _{IL1}	Clock Input Low Voltage (X1)		-0.5	0.8	V
V _{IH}	Input High Voltage (Except res_n and X1)		2.0	V _{CC} + 0.5	V
V _{IH1}	Input High Voltage (res_n)		2.4	V _{CC} + 0.5	V
V _{IH2}	Clock Input High Voltage (X1)		V _{CC} - 0.8	V _{CC} + 0.5	V
V _{OL}	Output Low Voltages	I _{OL} = 2.5 mA (s2_n -s0_n)		0.45	V
		I _{OL} = 2.0 mA (other)		0.45	V
V _{OH}	Output High Voltages^(a)	I _{OH} = -2.4 mA @ 2.4 V	2.4	V _{CC} + 0.5	V
		I _{OH} = -200 μA @ V _{CC} - 0.5	V _{CC} - 0.5	V _{CC}	V
I _{CC}	Power Supply Current @ 0°C	V _{CC} = 5.5 V ^(b)		5.9	mA/MHz
I _{LI}	Input Leakage Current @ 0.5 MHz	0.45 V ≤ V _{IN} ≤ V _{CC}		±10	μA
I _{LO}	Output Leakage Current @ 0.5 MHz	0.45 V ≤ V _{OUT} ≤ V _{CC} ^(c)		±10	μA
V _{CLO}	Clock Output Low	I _{CLO} = 4.0 mA		0.45	V
V _{CHO}	Clock Output High	I _{CHO} = -500 μA	V _{CC} - 0.5		V

Notes:

- The **lcs_n/once0_n**, **mcs3_n – mcs0_n**, **ucs_n/once1_n**, and **rd_n** pins have weak internal pullup resistors. Loading the **lcs_n/once0_n** and **ucs_n/once1_n** pins in excess of I_{OH} = -200 μA during reset can cause the device to go into ONCE mode.
- Current is measured with the device in reset with the **x1** and **x2** driven and all other non-power pins open but held High or Low.
- Testing is performed with the pins floating, either during **hold** or by invoking the ONCE mode.

AC Characteristics

Alphabetic Key to Waveform Parameters

No.	Name	Description	MIN	MAX	Units
49	tARYCH	ardy Resolution Transition Setup Time	9		ns
51	tARYCHL	ardy Inactive Holding Time	6		ns
52	tARYLCL	ardy Setup Time	9		ns
87	tAVBL	a Address Valid to whb_n/wlb_n Low	tCHCL-1.5	tCHCL	ns
14	tAVCH	ad Address Valid to Clock High	0		ns
12	tAVLL	ad Address Valid to ale Low	tCHCL		ns
66	tAVRL	a Address Valid to rd_n Low	tCLCL+tCHCL		ns
65	tAVWL	a Address Valid to wr_n Low	tCLCL+tCHCL		ns
24	tAZRL	ad Address Float to rd_n Active	0		ns
45	tCH1CH2	clkoutA Rise Time	0	3	ns
68	tCHAV	clkoutA High to a Address Valid	0	8	ns
38	tCHCK	X1 High Time	7.5		ns
44	tCHCL	clkoutA High Time	tCLCL/2		ns
67	tCHCSV	clkoutA High to lcs_n/usc_n Valid	0	9	ns
18	tCHCSX	mcs_n/pcs_n Inactive Delay	0	12	ns
22	tCHCTV	Control Active Delay 2	0	10	ns
64	tCHCV	Command Lines Valid Delay (after Float)	0	12	ns
63	tCHCZ	Command Lines Float Delay	0	12	ns
8	tCHDX	Status Hold Time	0		ns
9	tCHLH	ale Active Delay	0	8	ns
11	tCHLL	ale Inactive Delay	0	8	ns
79	tCHRFD	clkoutA High to rfsh_n Valid	0	12	ns
3	tCHSV	Status Active Delay	0	6	ns
69	tCICOA	X1 to clkoutA Skew		25	ns
70	tCICOB	X1 to clkoutB Skew		35	ns
39	tCKHL	X1 Fall Time		5	ns
36	tCKIN	X1 Period	25	66	ns
40	tCKLH	X1 Rise time		5	ns
46	tCL2CL1	clkoutA Fall Time		3	ns
50	tCLARX	ardy Active Hold Time	4		ns
5	tCLAV	ad Address Valid Delay	0	12	ns
6	tCLAX	Address Hold	0	12	ns
15	tCLAZ	ad Address Float Delay	0	12	ns
43	tCLCH	clkoutA Low Time	tCLCL/2		ns
37	tCLCK	X1 Low Time	7.5		ns
42	tCLCL	clkoutA Period	25		ns
80	tCLCLX	lcs_n Inactive Delay	0	9	ns
81	tCLCSL	lcs_n Active Delay	0	9	ns
16	tCLCSV	mcs_n/pcs_n Inactive Delay	0	12	ns
30	tCLDOX	Data Hold Time	0		ns

No.	Name	Description	MIN	MAX	Units
7	tCLDV	Data Valid Delay	0	12	ns
2	tCLDX	Data in Hold	0		ns
62	tCLHAV	hlda Valid Delay	0	7	ns
82	tCLRf	clkoutA High to rfsh_n Invalid	0	12	ns
27	tCLRh	rd_n Inactive Delay	0	10	ns
25	tCLRL	rd_n Active Delay	0	10	ns
4	tCLSH	Status Inactive Delay	0	6	ns
48	tCLSRy	srdy Transition Hold Time	3		ns
55	tCLTMV	Timer Output Delay	0	12	ns
83	tCOAOB	clkoutA to clkoutB Skew	3	1	ns
20	tCVCTV	Control Active Delay 1		10	ns
31	tCVCTX	Control Inactive Delay	0	10	ns
21	tCVDEX	den_n Inactive Delay	0	9	ns
17	tCXCSX	mcs_n/pcs_n Hold from Command Inactive	tCLCH		ns
98	tDSHDiW	ds_n High to Data Invalid - (Write)	0	tCHCL	ns
41	tDSHLH	ds_n Inactive to ale Inactive	tCLCH		ns
1	tDVCL	Data in Setup	10		ns
19	tDXDL	den_n Inactive to dt_r_n Low	0		ns
58	tHVCL	hld Setup Time	10		ns
53	tINVCH	Peripheral Setup Time	10		ns
54	tINVCL	drq Setup Time	10		ns
86	tLCRF	lcs_n Inactive to rfsh_n Active Delay	2tCLCL		ns
23	tLHAV	ale High to Address Valid	7.5		ns
10	tLHLL	ale Width	tCLCH-5		ns
13	tLLAX	ad Address Hold from ale Inactive	tCHCL		ns
61	tLOCK	Maximum PLL Lock Time		0.5	ns
84	tLRLl	lcs_n Precharge Pulse Width	tCLCL+ tCLCHH		ns
57	tRESIN	res_n Setup Time	10		ns
85	tRFCY	rfsh_n Cycle Time	6tCLCL		ns
29	tRHAV	rd_n Inactive to ad Address Active	tCLCL		ns
59	tRHDX	rd_n High to Data Hold on ad Bus	0		ns
28	tRHLH	rd_n Inactive to ale High	tCLCH		ns
26	tRLRH	rd_n Pulse Width	tCLCL		ns
47	tSRyCL	srdy Transition Setup Time	10		ns
35	tWHDEX	wr_n Inactive to den_n Inactive	tCLCH		ns
34	tWHDX	Data Hold after wr_n	tCLCL		ns
33	tWHLH	wr_n Inactive to ale High	tCLCH		ns
32	tWLWH	wr_n Pulse Width	2tCLCL		ns

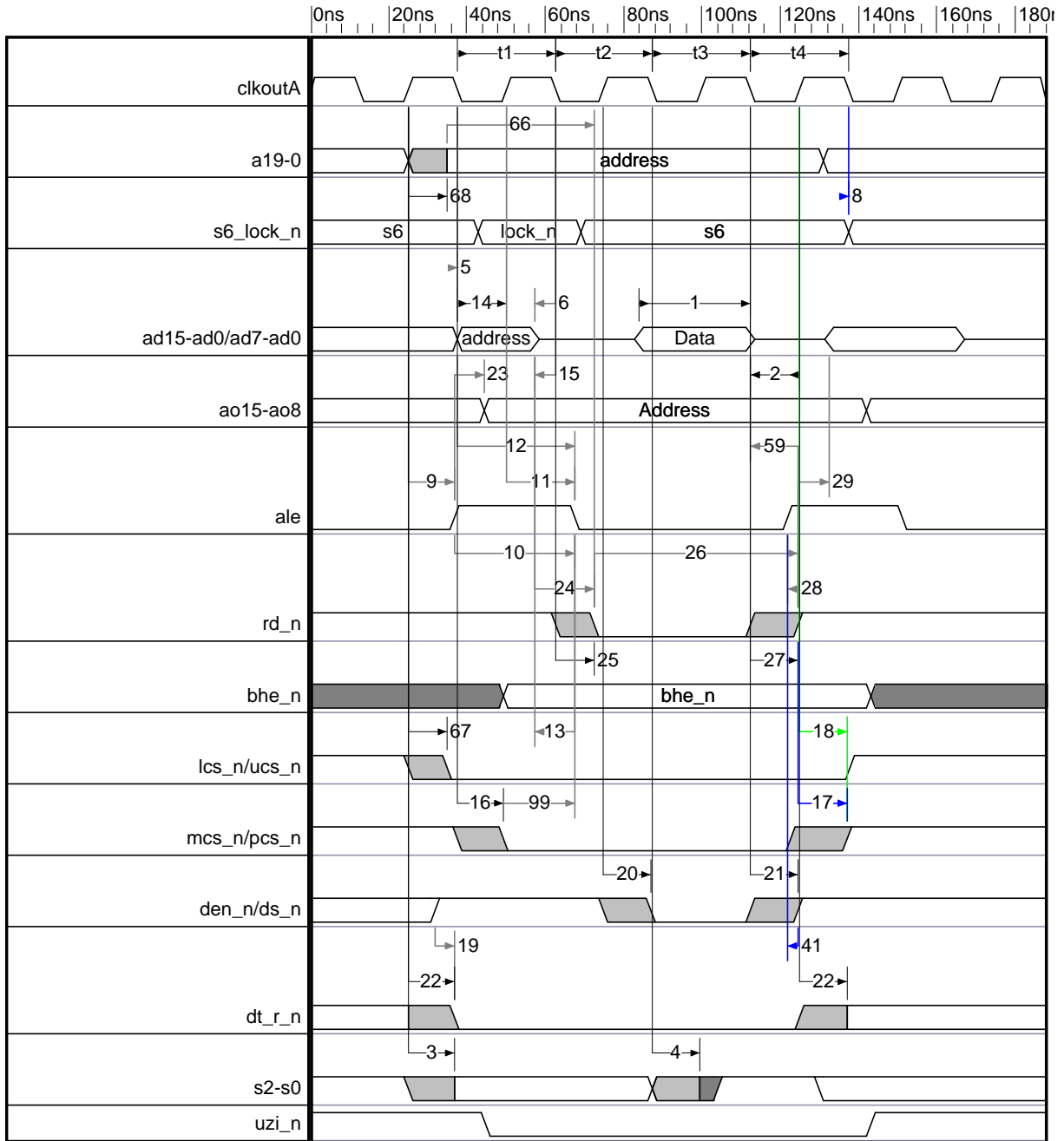
Numeric Key to Waveform Parameters

No.	Name	Description	MIN	MAX	Units
1	tDVCL	Data in Setup	10		ns
2	tCLDX	Data in Hold	0		ns
3	tCHSV	Status Active Delay	0	6	ns
4	tCLSH	Status Inactive Delay	0	6	ns
5	tCLAV	ad Address Valid Delay	0	12	ns
6	tCLAX	Address Hold	0	12	ns
7	tCLDV	Data Valid Delay	0	12	ns
8	tCHDX	Status Hold Time	0		ns
9	tCHLH	ale Active Delay	0	8	ns
10	tLHLL	ale Width	tCLCH-5		ns
11	tCHLL	ale Inactive Delay	0	8	ns
12	tAVLL	ad Address Valid to ale Low	tCLCH		ns
13	tLLAX	ad Address Hold from ale Inactive	tCHCL		ns
14	tAVCH	ad Address Valid to Clock High	0		ns
15	tCLAZ	ad Address Float Delay	0	12	ns
16	tCLCSV	mcs_n/pcs_n Inactive Delay	0	12	ns
17	tCXCSX	mcs_n/pcs_n Hold from Command Inactive	tCLCH		ns
18	tCHCSX	mcs_n/pcs_n Inactive Delay	0	12	ns
19	tDXDL	den_n Inactive to dt_r_n Low	0		ns
20	tCVCTV	Control Active Delay 1	0	10	ns
21	tCVDEX	den_n Inactive Delay	0	9	ns
22	tCHCTV	Control Active Delay 2	0	10	ns
23	tLHAV	ale High to Address Valid	7.5		ns
24	tAZRL	ad Address Float to rd_n Active	0		ns
25	tCLRL	rd_n Active Delay	0	10	ns
26	tRLRH	rd_n Pulse Width	tCLCL		ns
27	tCLRH	rd_n Inactive Delay	0	10	ns
28	tRHLH	rd_n Inactive to ale High	tCLCH		ns
29	tRHAV	rd_n Inactive to AD Address Active	tCLCL		ns
30	tCLDOX	Data Hold Time	0		ns
31	tCVCTX	Control Inactive Delay	0	10	ns
32	tWLWH	wr_n Pulse Width	2tCLCL		ns
33	tWHLH	wr_n Inactive to ale High	tCLCH		ns
34	tWHDX	Data Hold after wr_n	tCLCL		ns
35	tWHDEX	wr_n Inactive to den_n Inactive	tCLCH		ns
36	tCKIN	X1 Period	25	66	ns
37	tCLCK	X1 Low Time	7.5		ns

No.	Name	Description	MIN	MAX	Units
38	tCHCK	X1 High Time	7.5		ns
39	tCKHL	X1 Fall Time		5	ns
40	tCKLH	X1 Rise time		5	ns
41	tDSHLH	ds_n Inactive to ale Inactive	tCLCH		ns
42	tCLCL	clkoutA Period	25		ns
43	tCLCH	clkoutA Low Time	tCLCL/2		ns
44	tCHCL	clkoutA High Time	tCLCL/2		ns
45	tCH1CH2	clkoutA Rise Time		3	ns
46	tCL2CL1	clkoutA Fall Time		3	ns
47	tSRYCL	srdy Transition Setup Time	10		ns
48	tCLSRY	srdy Transistion Hold Time	3		ns
49	tARYCH	ardy Resolution Transition Setup Time	9		ns
50	tCLARX	ardy Active Hold Time	4		ns
51	tARYCHL	ardy Inactive Holding Time	6		ns
52	tARYLCL	ardy Setup Time	9		ns
53	tINVCH	Peripheral Setup Time	10		ns
54	tINVCL	drq Setup Time	10		ns
55	tCLTMV	Timer Output Delay	0	12	ns
57	tRESIN	res_n Setup Time	10		ns
58	tHVCL	hld Setup Time	10		ns
59	tRHDX	rd_n High to Data Hold on ad Bus	0		ns
61	tLOCK	Maximum PLL Lock Time		0.5	ms
62	tCLHAV	hlda Valid Delay	0	7	ns
63	tCHCZ	Command Lines Float Delay	0	12	ns
64	tCHCV	Command Lines Valid Delay (after Float)	0	12	ns
65	tAVWL	a Address Valid to wr_n Low	tCLCL+tCHCL		ns
66	tAVRL	a Address Valid to rd_n Low	tCLCL+tCHCL		ns
67	tCHCSV	clkoutA High to lcs_n/usc_n Valid	0	9	ns
68	tCHAV	clkoutA High to A Address Valid	0	8	ns
69	tCICOA	X1 to clkoutA Skew		25	ns
70	tCICOB	X1 to clkoutB Skew		35	ns
79	tCHRFD	clkoutA High to rfsn_n Valid	0	12	ns
80	tCLCLX	lcs_n Inactive Delay	0	9	ns
81	tCLCSL	lcs_n Active Delay	0	9	ns
82	tCLRF	clkoutA High to rfsn_n Invalid	0	12	ns
83	tCOAOB	clkoutA to clkoutB Skew	3	11	ns
84	tLRLL	lcs_n Precharge Pulse Width	tCLCL+tCLCH		ns
85	tRFCY	rfsn_n Cycle Time	6tCLCL		ns
86	tLCRF	lcs_n Inactive to rfsn_n Active Delay	2tCLCL		ns
87	tAVBL	a Address Valid to whb_n/wlb_n Low	tCHCL-1.5	tCHCL	ns
98	tDSHDIW	ds_n High to Data Invalid - (Write)	0	tCLCL	ns
99	tPLAL	pcs Low to ale Low		tCLCH	ns

Waveforms

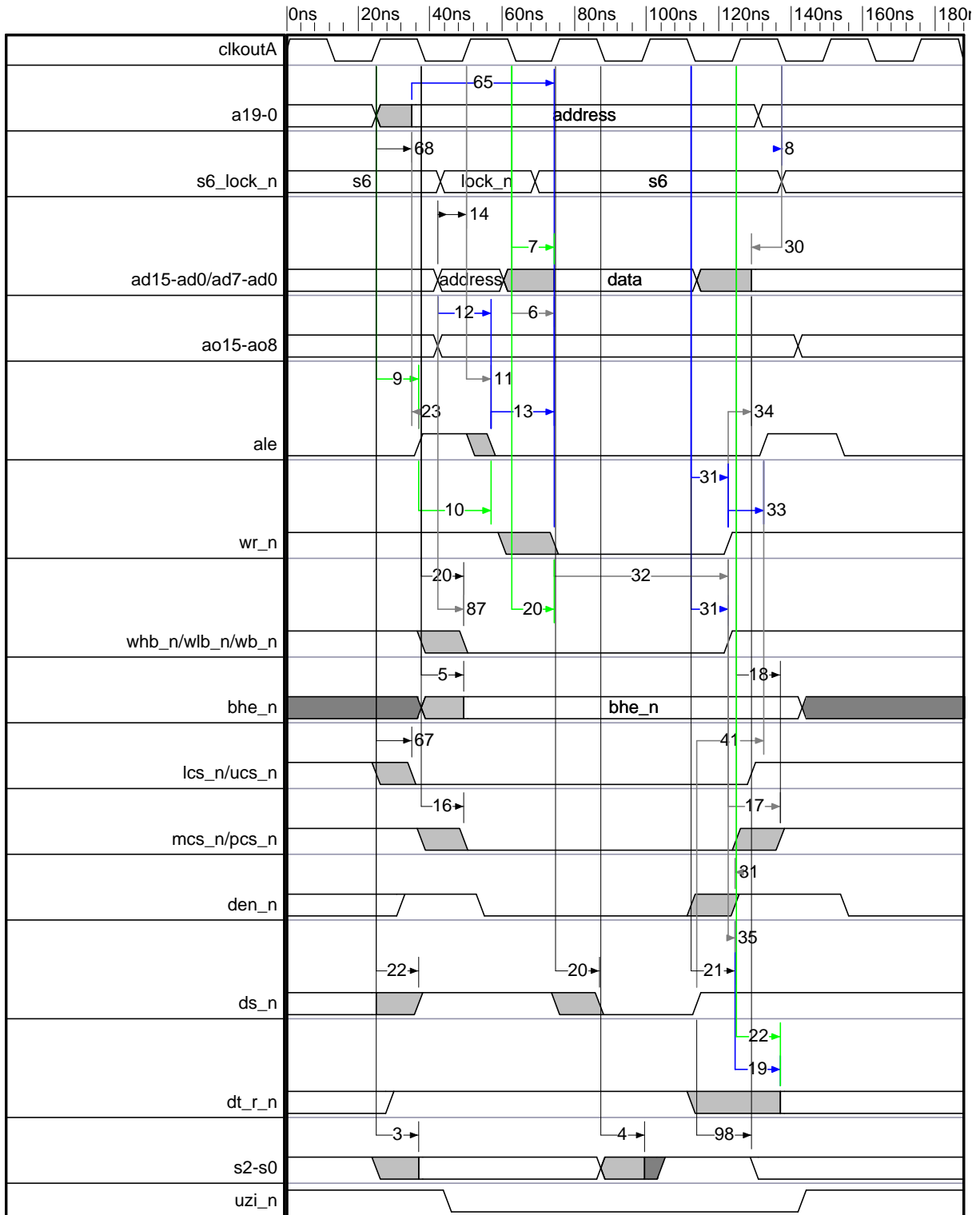
Read Cycle



Read Cycle Timing

No.	Name	Description	MIN	MAX	Units
General Timing Requirements					
1	tDVCL	Data in Setup	10		ns
2	tCLDX	Data in Hold	0		ns
General Timing Responses					
3	tCHSV	Status Active Delay	0	6	ns
4	tCLSH	Status Inactive Delay	0	6	ns
5	tCLAV	ad Address Valid Delay	0	12	ns
6	tCLAX	Address Hold	0	12	ns
8	tCHDX	Status Hold Time	0		ns
9	tCHLH	ale Active Delay	0	8	ns
10	tLHLL	ale Width	tCLCH-5		ns
11	tCHLL	ale Inactive Delay	0	8	ns
12	tAVLL	ad Address Valid to ale Low	tCLCH		ns
13	tLLAX	ad Address Hold from ale Inactive	tCHCL		ns
14	tAVCH	ad Address Valid to Clock High	0		ns
15	tCLAZ	ad Address Float Delay	0	12	ns
16	tCLCSV	mcs_n/pcs_n Inactive Delay	0	12	ns
17	tCXCSX	mcs_n/pcs_n Hold from Command Inactive	tCLCH		ns
18	tCHCSX	mcs_n/pcs_n Inactive Delay	0	12	ns
19	tDXDL	den_n Inactive to dt_r_n Low	0		ns
20	tCVCTV	Control Active Delay 1	0	10	ns
21	tCVDEX	den_n Inactive Delay	0	9	ns
22	tCHCTV	Control Active Delay 2	0	10	ns
23	tLHAV	ale High to Address Valid	7.5		ns
99	tPLAL	PCS Low to ale Low		tCLCH	ns
Read Cycle Timing Responses					
24	tAZRL	ad Address Float to rd_n Active	0		ns
25	tCLRL	rd_n Active Delay	0	10	ns
26	tRLRH	rd_n Pulse Width	tCLCL		ns
27	tCLRH	rd_n Inactive Delay	0	10	ns
28	tRHLH	rd_n Inactive to ale High	tCLCH		ns
29	tRHAV	rd_n Inactive to AD Address Active	tCLCL		ns
41	tDSHLH	ds_n Inactive to ale Inactive	tCLCH		ns
59	tRHDX	rd_n High to Data Hold on ad Bus	0		ns
66	tAVRL	a Address Valid to rd_n Low	tCLCL+tCHCL		ns
67	tCHCSV	clkoutA High to lcs_n/usc_n Valid	0	9	ns
68	tCHAV	clkoutA High to a Address Valid	0	8	ns

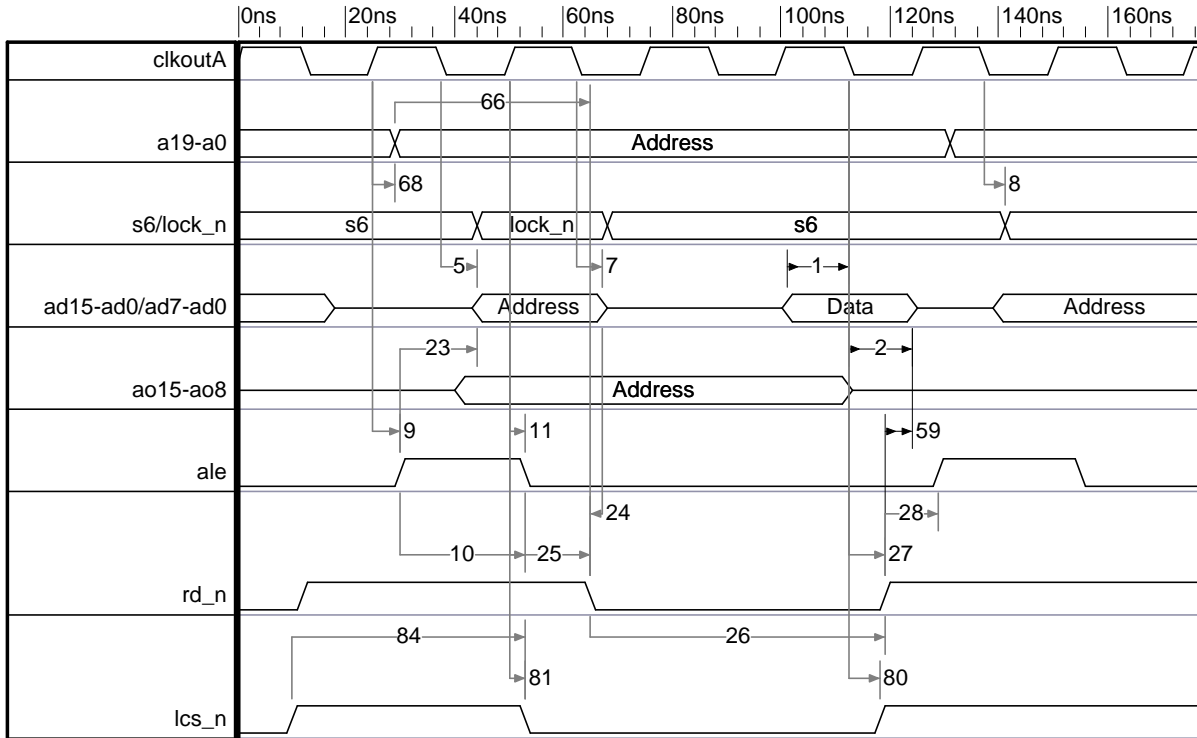
Write Cycle



Write Cycle Timing

No.	Name	Description	MIN	MAX	Units
General Timing Requirements					
1	tDVCL	Data in Setup	10		ns
2	tCLDX	Data in Hold	0		ns
General Timing Responses					
3	tCHSV	Status Active Delay	0	6	ns
4	tCLSH	Status Inactive Delay	0	6	ns
5	tCLAV	ad Address Valid Delay	0	12	ns
6	tCLAX	Address Hold	0	12	ns
8	tCHDX	Status Hold Time	0		ns
9	tCHLH	ale Active Delay	0	8	ns
10	tLHLL	ale Width	tCLCH-5		ns
11	tCHLL	ale Inactive Delay	0	8	ns
12	tAVLL	ad Address Valid to ale Low	tCLCH		ns
13	tLLAX	ad Address Hold from ale Inactive	tCHCL		ns
14	tAVCH	ad Address Valid to Clock High	0		ns
15	tCLAZ	ad Address Float Delay	0	12	ns
16	tCLCSV	mcs_n/pcs_n Inactive Delay	0	12	ns
17	tXCXSX	mcs_n/pcs_n Hold from Command Inactive	tCLCH		ns
18	tCHCSX	mcs_n/pcs_n Inactive Delay	0	12	ns
19	tDXDL	den_n Inactive to dt_r_n Low	0		ns
20	tCVCTV	Control Active Delay 1	0	10	ns
21	tCVDEX	den_n Inactive Delay	0	9	ns
22	tCHCTV	Control Active Delay 2	0	10	ns
23	tLHAV	ale High to Address Valid	7.5		ns
99	tPLAL	pcs Low to ale Low		tCLCH	ns
Write Cycle Timing Responses					
30	tCLDOX	Data Hold Time	0		ns
31	tCVCTX	Control Inactive Delay	0	10	ns
32	tWLWH	wr_n Pulse Width	2tCLCL		ns
33	tWHLH	wr_n Inactive to ale High	tCLCH		ns
34	tWHDX	Data Hold after wr_n	tCLCL		ns
35	tWHDEX	wr_n Inactive to den_n Inactive	tCLCH		ns
41	tDShLH	ds_n Inactive to ale Inactive	tCLCH		ns
65	tAVWL	a Address Valid to wr_n Low	tCLCL+tCHCL		ns
67	tCHCSV	clkoutA High to lcs_n/usc_n Valid	0	9	ns
68	tCHAV	clkoutA High to a Address Valid	0	8	ns
87	tAVBL	a Address Valid to whb_n/wlb_n Low	tCHCL-1.5	tCHCL	ns
98	tDShDIW	ds_n High to Data Invalid - (Write)	0	tCLCL	ns

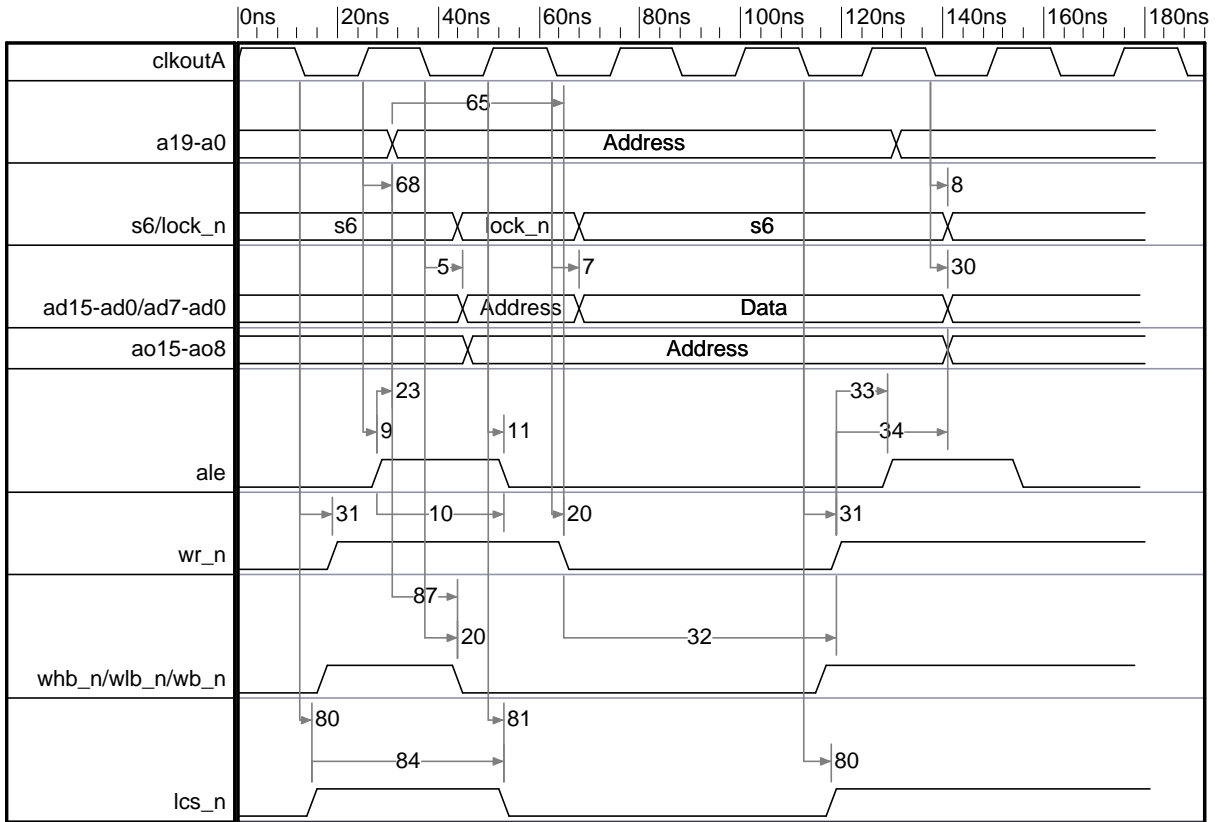
PSRAM Read Cycle



PSRAM Read Cycle Timing

No.	Name	Comment	MIN	MAX	Units
General Timing Requirements					
1	tDVCL	Data in Setup	10		ns
2	tCLDX	Data in Hold	0		ns
General Timing Responses					
5	tCLAV	ad Address Valid Delay	0	12	ns
6	tCLAX	Address Hold	0	12	ns
8	tCHDX	Status Hold Time	0		ns
9	tCHLH	ale Active Delay	0	8	ns
10	tLHLL	ale Width	tCLCH-5		ns
11	tCHLL	ale Inactive Delay	0	8	ns
12	tAVLL	ad Address Valid to ale Low	tCLCH		ns
13	tLLAX	ad Address Hold from ale Inactive	tCHCL		ns
14	tAVCH	ad Address Valid to Clock High	0		ns
15	tCLAZ	ad Address Float Delay	0	12	ns
16	tCLCSV	mcs_n/pcs_n Inactive Delay	0	12	ns
17	tCXCSX	mcs_n/pcs_n Hold from Command Inactive	tCLCH		ns
18	tCHCSX	mcs_n/pcs_n Inactive Delay	0	12	ns
19	tDXDL	den_n Inactive to dt_r_n Low	0		ns
20	tCVCTV	Control Active Delay 1	0	10	ns
21	tCVDEX	den_n Inactive Delay	0	9	ns
22	tCHCTV	Control Active Delay 2	0	10	ns
23	tLHAV	ale High to Address Valid	7.5		ns
99	tPLAL	PCS Low to ALE Low		tCLCH	ns
Read Cycle Timing Responses					
30	tCLDOX	Data Hold Time	0		ns
31	tCVCTX	Control Inactive Delay	0	10	ns
32	tWLWH	wr_n Pulse Width	2tCLCL		ns
33	tWHLH	wr_n Inactive to ale High	tCLCH		ns
34	tWHDX	Data Hold after wr_n	tCLCL		ns
35	tWHDEX	wr_n Inactive to den_n Inactive	tCLCH		ns
41	tDSHLH	ds_n Inactive to ale Inactive	tCLCH		ns
65	tAVWL	a Address Valid to wr_n Low	tCLCL +tCHCL		ns
67	tCHCSV	clkoutA High to lcs_n/usc_n Valid	0	9	ns
68	tCHAV	clkoutA High to a Address Valid	0	8	ns
87	tAVBL	a Address Valid to whb_n/wlb_n Low	tCHCL-1.5	tCHCL	ns
98	tDSHDIW	ds_n High to Data Invalid - (Write)	0	tCLCL	ns

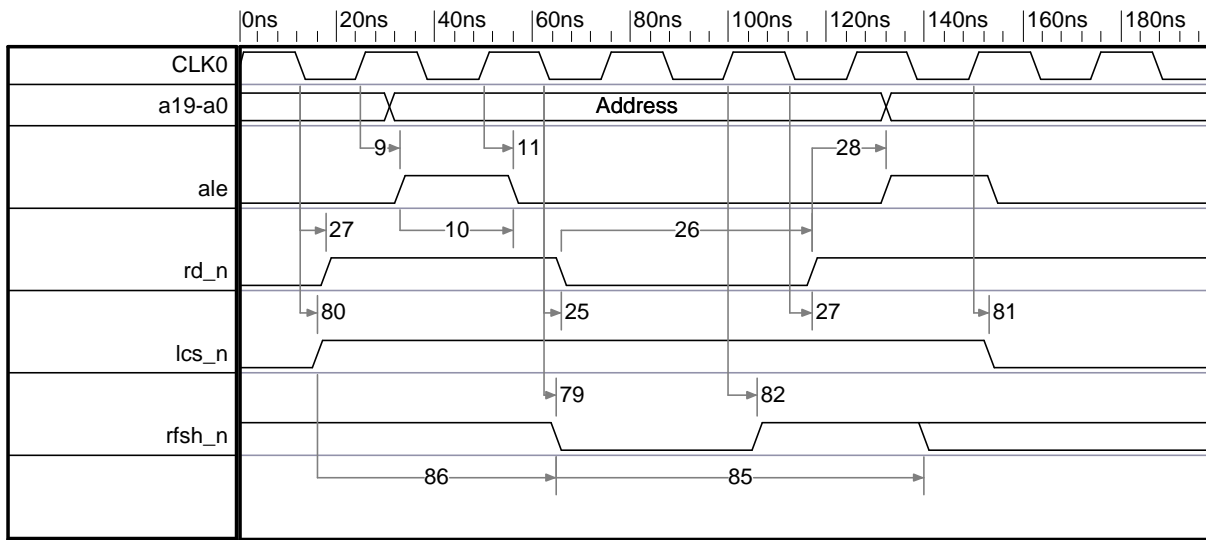
PSRAM Write Cycle



PSRAM Write Cycle Timing

No.	Name	Comment	MIN	MAX	Units
General Timing Requirements					
1	tDVCL	Data in Setup	10		ns
2	tCLDX	Data in Hold	0		ns
General Timing Responses					
5	tCLAV	ad Address Valid Delay	0	12	ns
7	tCLDV	Data Valid Delay	0	12	ns
8	tCHDX	Status Hold Time	0		ns
9	tCHLH	ale Active Delay	0	8	ns
10	tLHLL	ale Width	tCLCH-5		ns
11	tCHLL	ale Inactive Delay	0	8	ns
20	tCVCTV	Control Active Delay 1	0	10	ns
23	tLHAV	ale High to Address Valid	7.5		ns
80	tCLCLX	lcs_n Inactive Delay	0	9	ns
81	tCLCSL	lcs_n Active Delay	0	9	ns
84	tLRLL	lcs_n Precharge Pulse Width	tCLCL+tCLCH		ns
Write Cycle Timing Responses					
30	tCLDOX	Data Hold Time	0		ns
31	tCVCTX	Control Inactive Delay	0	10	ns
32	tWLWH	wr_n Pulse Width	2tCLCL		ns
33	tWHLH	wr_n Inactive to ale High	tCLCH		ns
34	tWHDX	Data Hold after wr_n	tCLCL		ns
65	tAVWL	a Address Valid to wr_n Low	tCLCL+tCHCL		ns
68	tCHAV	clkoutA High to a Address Valid	0	8	ns
87	tAVBL	a Address Valid to whb_n/wlb_n Low	tCHCL-1.5	tCHCL	ns

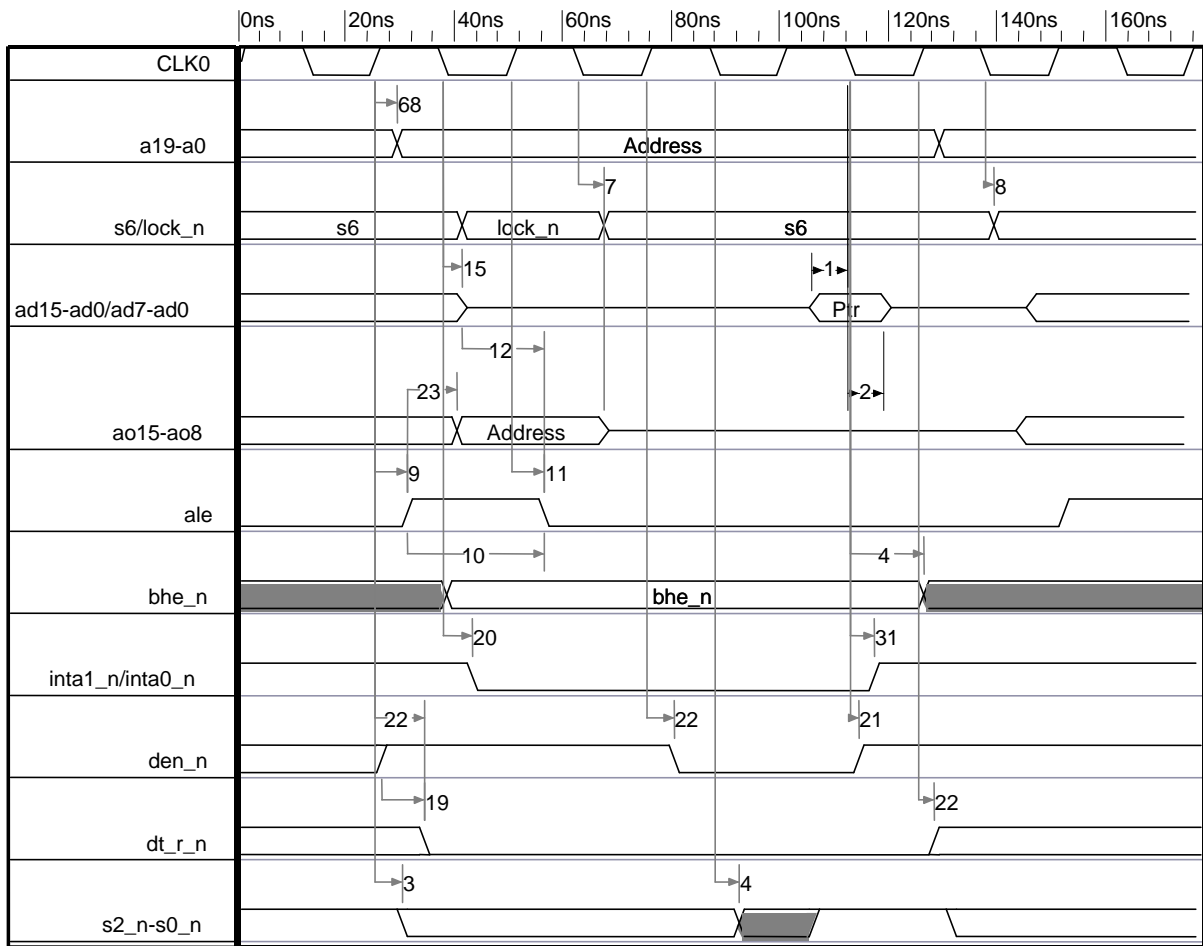
PSRAM Refresh Cycle



PSRAM Refresh Cycle

No.	Name	Comment	MIN	MAX	Units
General Timing Requirements					
1	tDVCL	Data in Setup	10		ns
2	tCLDX	Data in Hold	0		ns
General Timing Responses					
9	tCHLH	ale Active Delay	0	8	ns
10	tLHLL	ale Width	tCLCH-5		ns
11	tCHLL	ale Inactive Delay	0	8	ns
Read/Write Cycle Timing Responses					
25	tCLRL	rd_n Active Delay	0	10	ns
26	tRLRH	rd_n Pulse Width	tCLCL		ns
27	tCLRH	rd_n Inactive Delay	0	10	ns
28	tRHLH	rd_n Inactive to ALE High	tCLCH		ns
80	tCLCLX	lcs_n Inactive Delay	0	9	ns
81	tCLCSL	lcs_n Active Delay	0	9	ns
Refresh Cycle Timing Responses					
79	tCHRFD	clkoutA High to rfsh_n Valid	0	12	ns
82	tCLRF	clkoutA High to rfsh_n Invalid	0	12	ns
85	tRFCY	rfsh_n Cycle Time	6tCLCL		ns
86	tLCRF	lcs_n Inactive to rfsh_n Active Delay	2tCLCL		ns

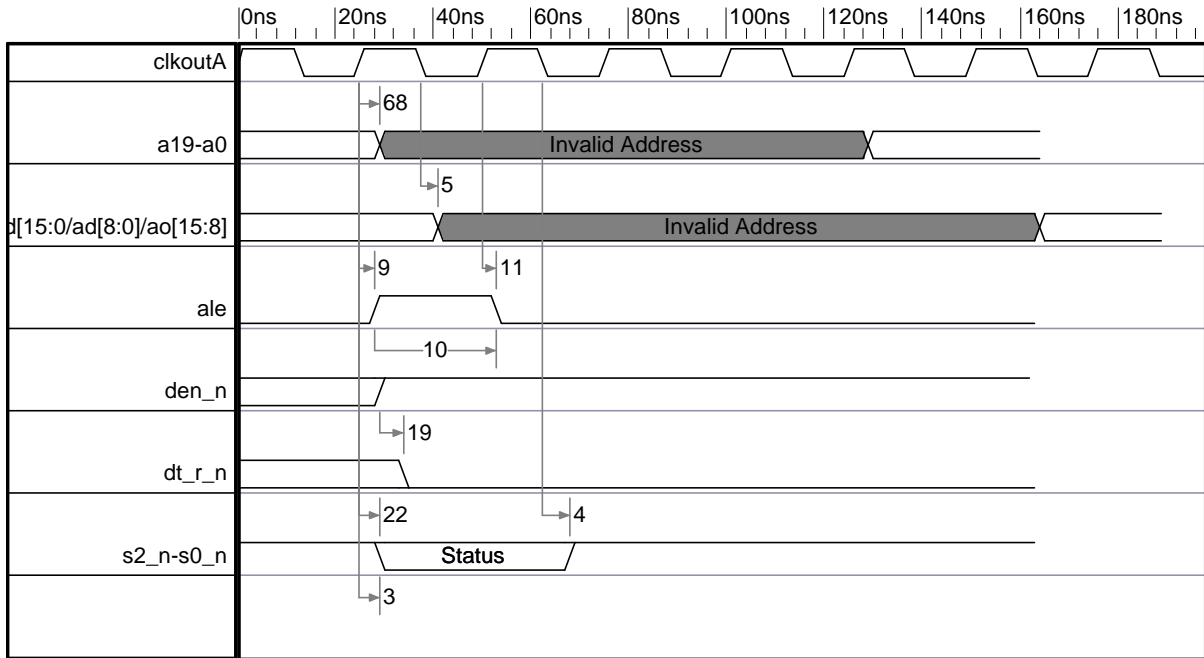
Interrupt Acknowledge Cycle



Interrupt Acknowledge Cycle Timing

No.	Name	Description	MIN	MAX	Units
General Timing Requirements					
1	tDVCL	Data in Setup	10		ns
2	tCLDX	Data in Hold	0		ns
General Timing Responses					
3	tCHSV	Status Active Delay	0	6	ns
4	tCLSH	Status Inactive Delay	0	6	ns
5	tCLAV	ad Address Valid Delay	0	12	ns
9	tCHLH	ale Active Delay	0	8	ns
10	tLHLL	ale Width	tCLCH-5		ns
11	tCHLL	ale Inactive Delay	0	8	ns
19	tDXDL	den_n Inactive to dt_r_n Low	0		ns
22	tCHCTV	Control Active Delay 2	0	10	ns
68	tCHAV	clkoutA High to a Address Valid	0	8	ns

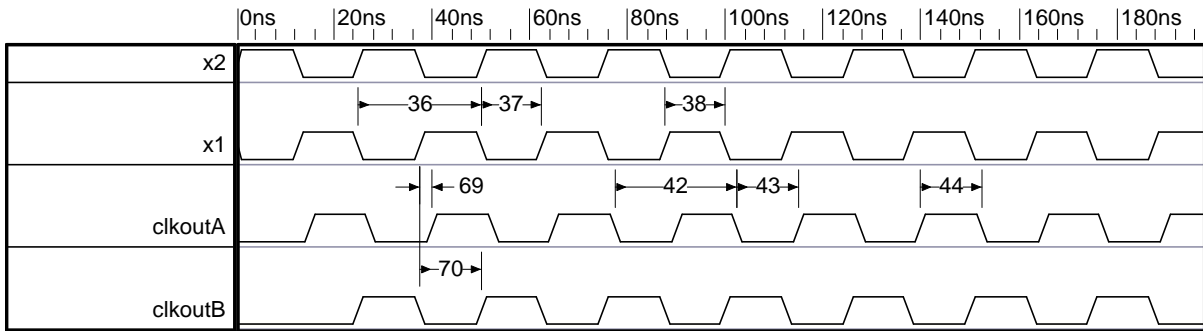
Software Halt Cycle



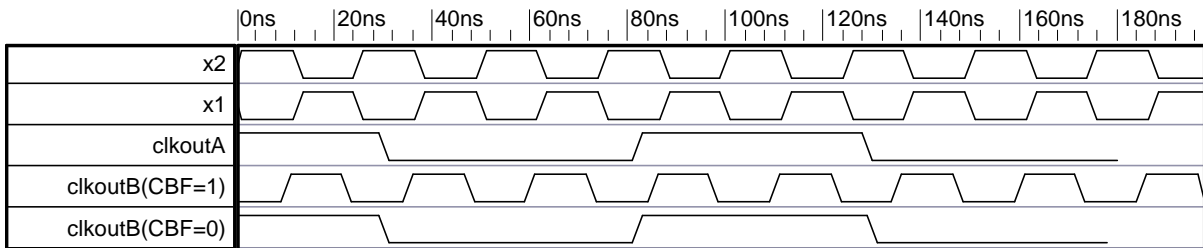
Software Halt Cycle Timing

No.	Name	Description	MIN	MAX	Units
General Timing Responses					
3	tCHSV	Status Active Delay	0	6	ns
4	tCLSH	Status Inactive Delay	0	6	ns
7	tCLDV	Data Valid Delay	0	12	ns
8	tCHDX	Status Hold Time	0		ns
9	tCHLH	ale Active Delay	0	8	ns
10	tLHLL	ale Width	tCLCH-5		ns
11	tCHLL	ale Inactive Delay	0	8	ns
12	tAVLL	ad Address Valid to ALE Low	tCLCH		ns
15	tCLAZ	ad Address Float Delay	0	12	ns
16	tCLCSV	mcs_n/pcs_n Inactive Delay	0	12	ns
17	tCXCSX	mcs_n/pcs_n Hold from Command Inactive	tCLCH		ns
18	tCHCSX	mcs_n/pcs_n Inactive Delay	0	12	ns
19	tDXDL	den_n Inactive to dt_r_n Low	0		ns
20	tCVCTV	Control Active Delay 1	0	10	ns
21	tCVDEX	den_n Inactive Delay	0	9	ns
22	tCHCTV	Control Active Delay 2	0	10	ns
23	tLHAV	ale High to Address Valid	7.5		ns
31	tCVCTX	Control Inactive Delay	0	10	ns
68	tCHAV	clkoutA High to a Address Valid	0	8	ns

Clock – Active Mode



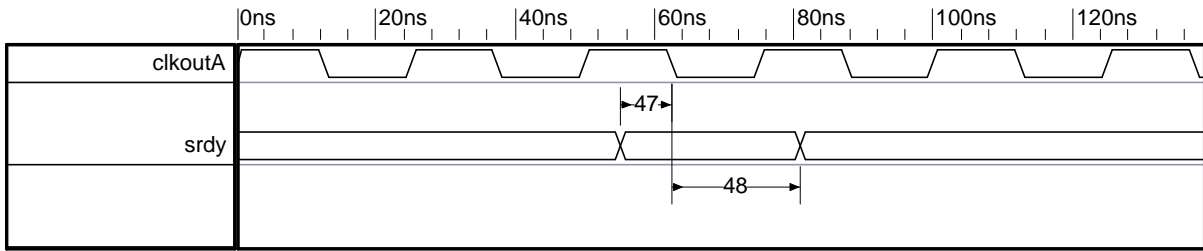
Clock – Power-Save Mode



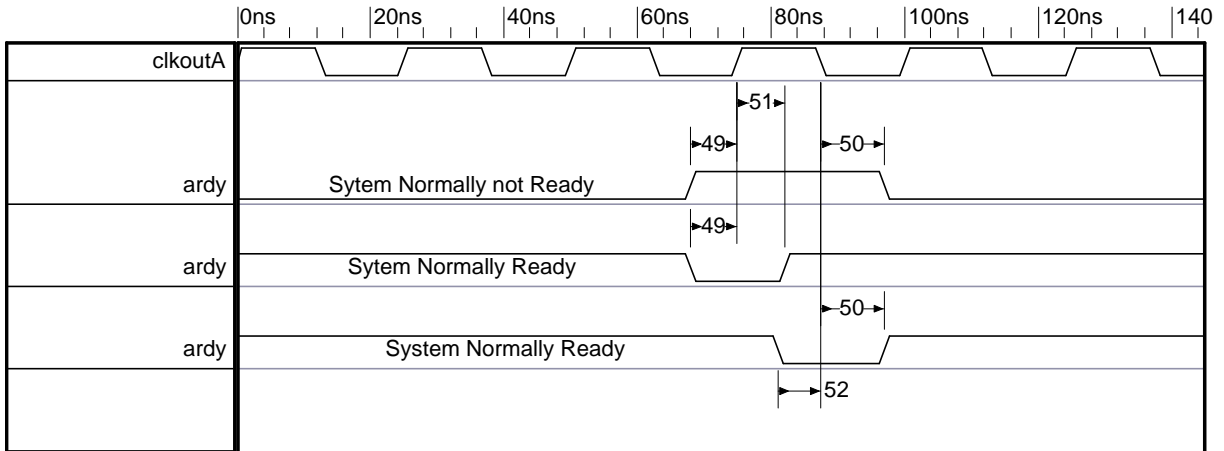
Clock Timing

No.	Name	Description	MIN	MAX	Units
CLKIN Requirements					
36	tCKIN	X1 Period	25	66	ns
37	tCLCK	X1 Low Time	7.5		ns
38	tCHCK	X1 High Time	7.5		ns
39	tCKHL	X1 Fall Time		5	ns
40	tCKLH	X1 Rise time		5	ns
CLKOUT Timing					
42	tCLCL	clkoutA Period	25		ns
43	tCLCH	clkoutA Low Time	tCLCL/2		ns
44	tCHCL	clkoutA High Time	tCLCL/2		ns
45	tCH1CH2	clkoutA Rise Time	0	3	ns
46	tCL2CL1	clkoutA Fall Time	0	3	ns
61	tLOCK	Maximum PLL Lock Time		0.5	ms
69	tCICOA	X1 to clkoutA Skew		25	ns
70	tCICOB	X1 to clkoutB Skew		35	ns

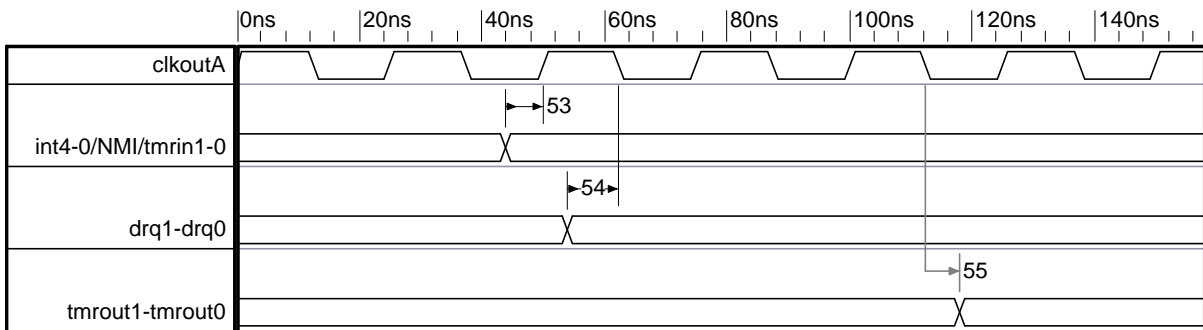
srdy – Synchronous Ready



ardy - Asynchronous Ready



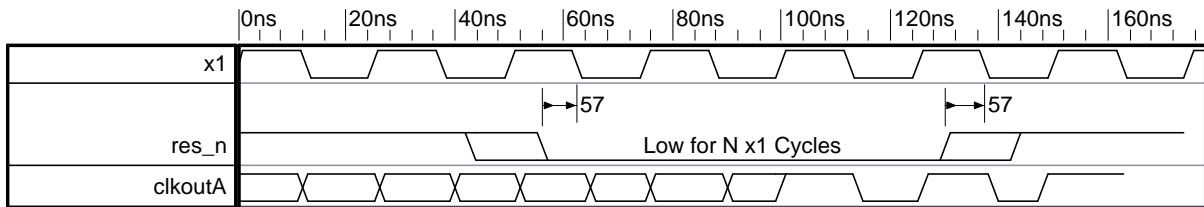
Peripherals



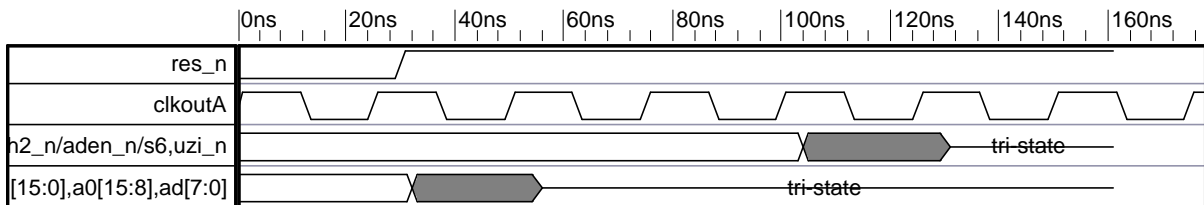
Ready and Peripheral Timing

No.	Name	Description	MIN	MAX	Units
Ready and Peripheral Timing Requirements					
47	tSRYCL	srdy Transition Setup Time	10		ns
48	tCLSRy	srdy Transition Hold Time	3		ns
49	tARYCH	ardy Resolution Transition Setup Time	9		ns
50	tCLARX	ardy Active Hold Time	4		ns
51	tARYCHL	ardy Inactive Holding Time	6		ns
52	tARYLCL	ardy Setup Time	9		ns
53	tINVCH	Peripheral Setup Time	10		ns
54	tINVCL	drq Setup Time	10		ns
Peripheral Timing Responses					
55	tCLTMV	Timer Output Delay	0	12	ns

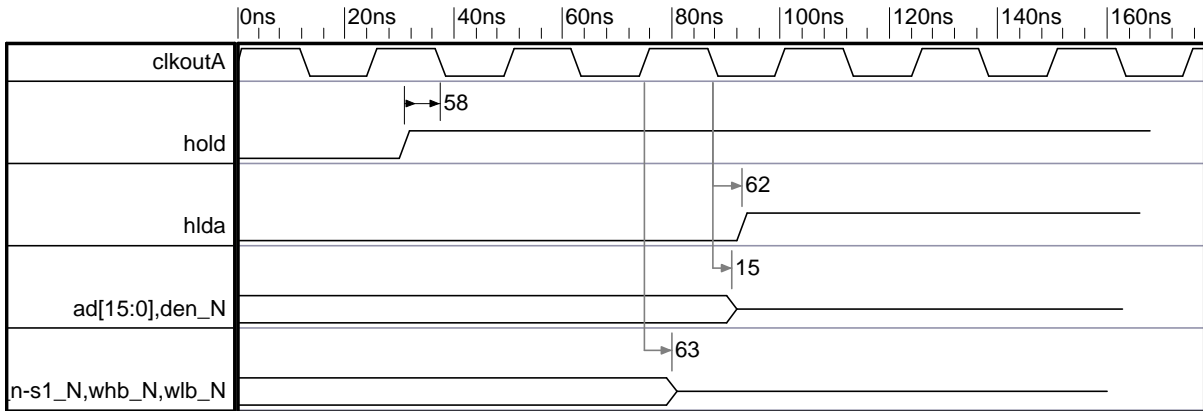
Reset 1



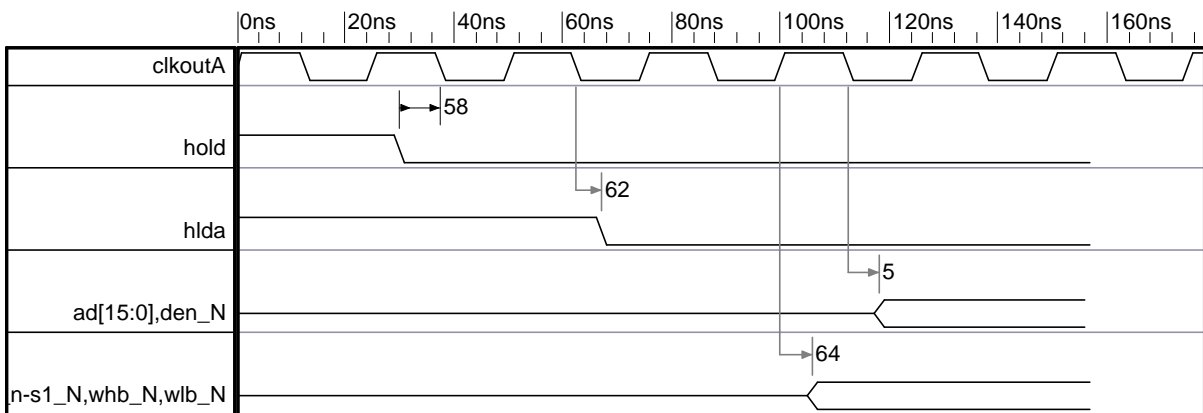
Reset 2



Bus Hold Entering



Bus Hold Leaving



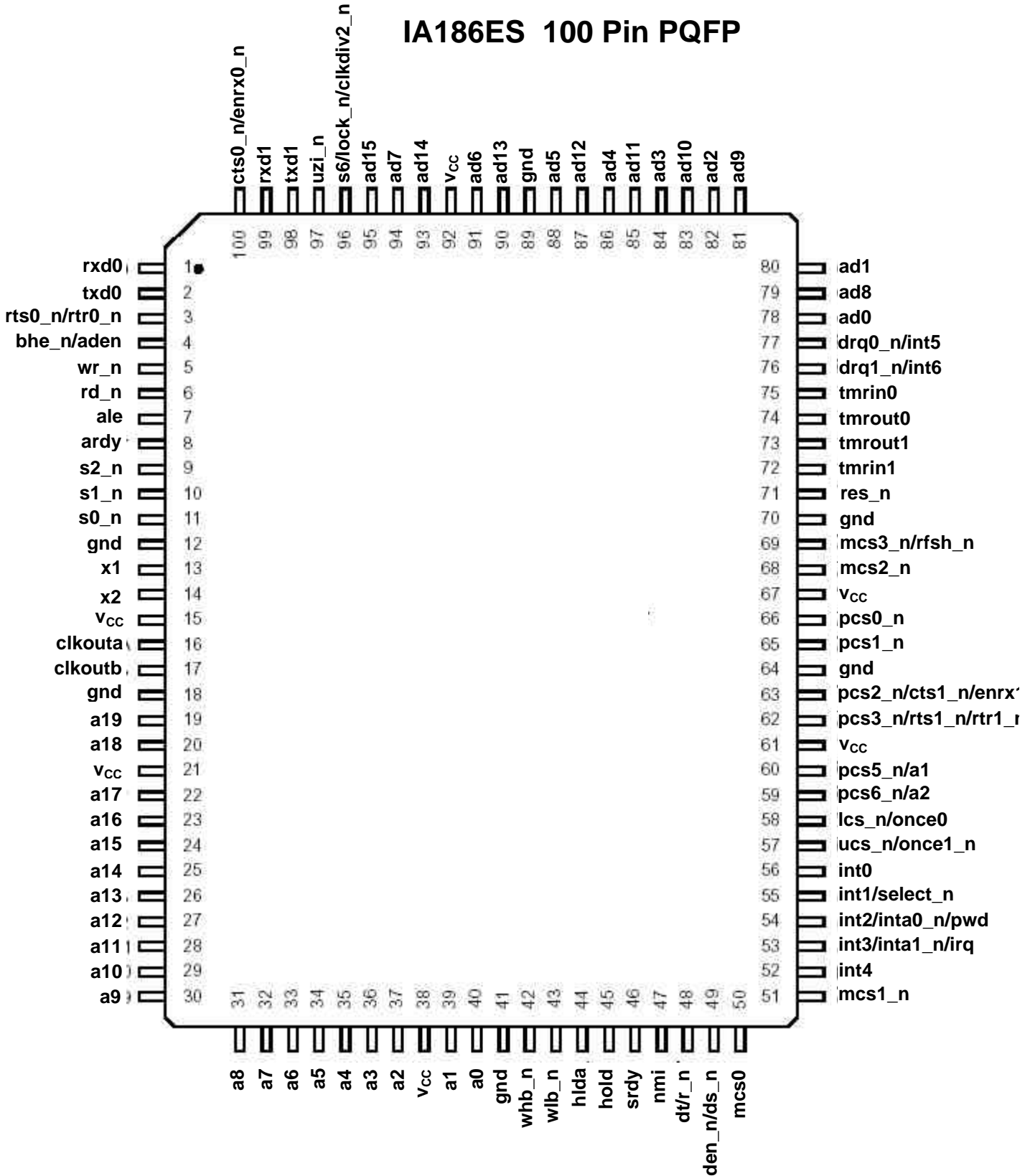
Reset and Bus Hold Timing

No.	Name	Description	MIN	MAX	Units
Reset and Bus Hold Timing Requirements					
5	tCLAV	ad Address Valid Delay	0	12	ns
15	tCLAZ	ad Address Float Delay	0	12	ns
57	tRESIN	res_n Setup Time	10		ns
58	tHVCL	hld Setup Time	10		ns
Reset and Bus Hold Timing Responses					
62	tCLHAV	hlda Valid Delay	0	7	ns
63	tCHCZ	Command Lines Float Delay	0	12	ns
64	tCHCV	Command Lines Valid Delay (after Float)	0	12	ns

IA186ES/IA188ES

8/16-BIT MICROCONTROLLERS

Preliminary Data Sheet



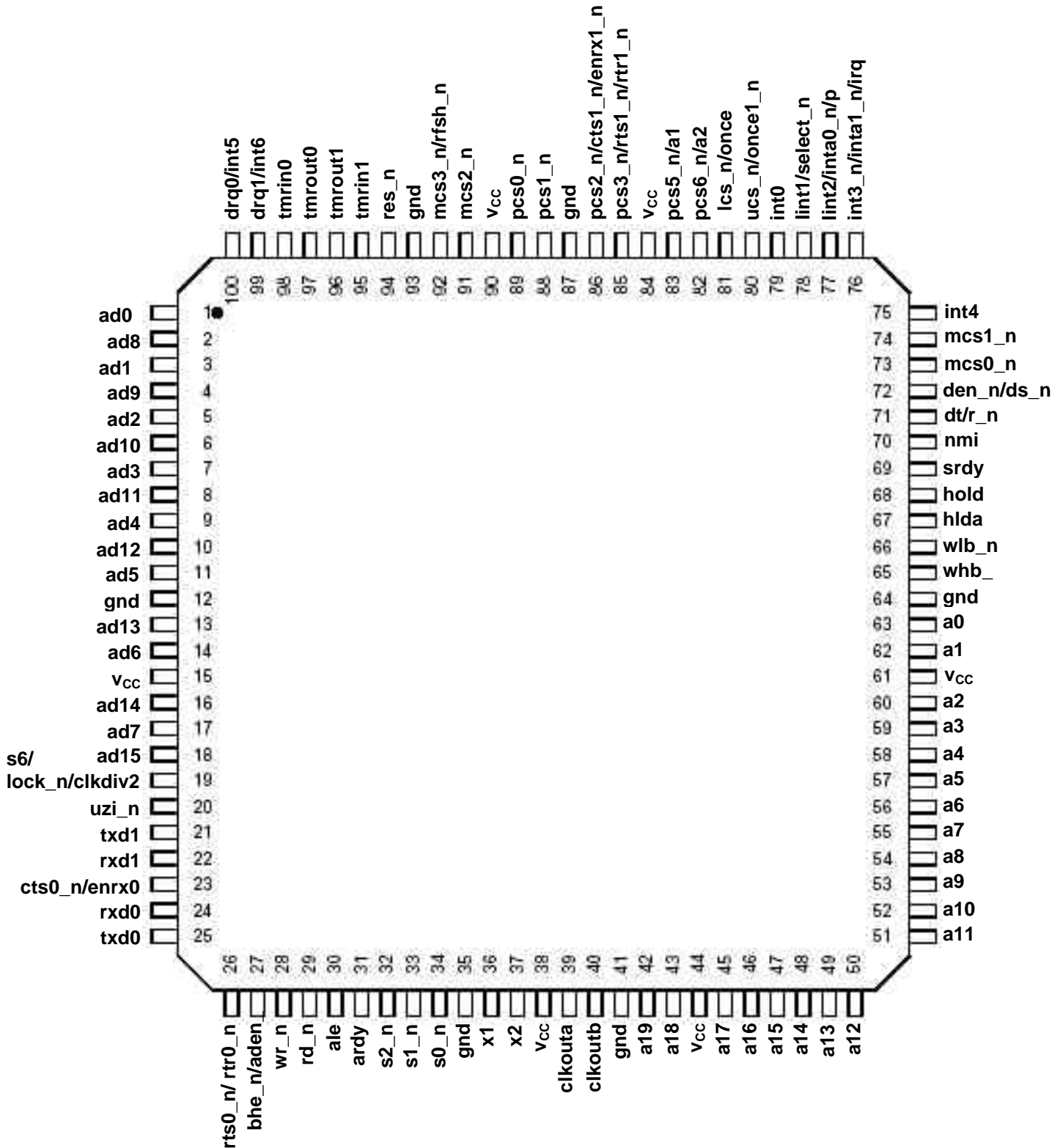
IA186ES 100 Pin PQFP Assignments (sorted by Pin number)

Pin #	Name	Pin #	Name
1	rxd0/pio23	51	mcs1_n/pio15
2	txd0/pio22	52	int4/pio30
3	rts0_n/rtr0_n/pio20	53	int3/inta1_n/irq
4	bhe_n/aden_n	54	int2/inta0_n/pwd/pio31
5	wr_n	55	int1/select_n
6	rd_n	56	int0
7	ale	57	ucs_n/once1_n
8	ardy	58	lcs_n/once0_n
9	s2_n	59	pcs6_n/a2/pio2
10	s1_n	60	pcs5_n/a1/pio3
11	s0_n	61	vcc
12	gnd	62	pcs3_n/rts1_n/rtr1_n/pio19
13	x1	63	pcs2_n/cts1_n/enrx1_npio
14	x2	64	gnd
15	vcc	65	pcs1_n/pio17
16	clkouta	66	pcs0_n/pio16
17	clkoutb	67	vcc
18	gnd	68	mcs2_n/pio24
19	a19/pio29	69	mcs3_n/rfsh_n/pio25
20	a18/pio8	70	gnd
21	vcc	71	res_n
22	a17/pio7	72	tmin1/pio25
23	a16	73	tmrout1/pio1
24	a15	74	tmrout0/pio10
25	a14	75	tmin1/pio11
26	a13	76	drq1/int6/pio13
27	a12	77	drq0/int5/pio12
28	a11	78	ad0
29	a10	79	ad8
30	a9	80	ad1
31	a8	81	ad9
32	a7	82	ad2
33	a6	83	ad10
34	a5	84	ad3
35	a4	85	ad11
36	a3	86	ad4
37	a2	87	ad12
38	vcc	88	ad5
39	a1	89	gnd
40	a0	90	ad13
41	gnd	91	ad6
42	whb_n	92	vcc
43	wlb_n	93	ad14
44	hlda	94	ad7
45	hold	95	ad15
46	srdy/pio6	96	s6/lock_n/clkdir2_n/pio29
47	nmi	97	uzi_n/pio26
48	dt/r_n/pio4	98	txd1/pio27
49	den_n/ds_n/pio5	99	rxid1/pio28
50	mcs0_n/pio14	100	cts0_n/enrx0_n/pio21

IA186ES 100 Pin PQFP Pin Assignments (sorted by Pin Name)

Pin Name	Number	Pin Name	Number
a0	40	gnd	70
a1	39	gnd	89
a2	37	hlda	44
a3	36	hold	45
a4	35	int0	56
a5	34	int1/select_n	55
a6	33	int2/inta0_n/pwd/pio31	54
a7	32	int3/inta1_n/irq	53
a8	31	int4/pio30	52
a9	30	lcs_n/once0_n	58
a10	29	mcs0_n/pio14	50
a11	28	mcs1_n/pio15	51
a12	27	mcs2_n/pio24	68
a13	26	mcs3_n/rfsh_n/pio25	69
a14	25	nmi	47
a15	24	pcs0_n/pio16	66
a16	23	pcs1_n/pio17	65
a17/pio7	22	pcs2_n/cts1_n/enrx1_n/pio18	63
a18/pio8	20	pcs3_n/rts1_n/rtr1_n/pio19	62
a19/pio9	19	pcs5_n/a1/pio3	60
ad0	78	pcs6_n/a2/pio2	59
ad1	80	rd_n	6
ad2	82	res_n	71
ad3	84	rts0_n/rtr0_n/pio20	3
ad4	86	rx0/pio23	1
ad5	88	rx1/pio28	99
ad6	91	s0_n	11
ad7	94	s1_n	10
ad8	79	s2_n	9
ad9	81	s6/lock_n/clkdiv2/pio29	96
ad10	83	srady/pio6	46
ad11	85	tmin0/pio11	75
ad12	87	tmin1/pio0	72
ad13	90	tmrout0/pio10	74
ad14	93	tmrout1/pio1	73
ad15	95	txd0/pio22	2
ale	7	txd1/pio27	98
ardy	8	ucs_n/once1_n	57
bhe_n/aden_n	4	uzi_n/pio26	97
clkouta	16	Vcc	15
clkoutb	17	Vcc	21
cts0_n/enrx0_n/pio21	100	Vcc	38
den_n/ds_n/pio5	49	Vcc	61
drq0/int5/pio12	77	Vcc	67
drq1/int6/pio13	76	Vcc	92
dt/r_n/pio4	48	whb_n	42
gnd	12	wlb_n	43
gnd	18	wr_n	5
gnd	41	x1	13
gnd	64	x2	14

IA186ES - TQFP 100 Pin



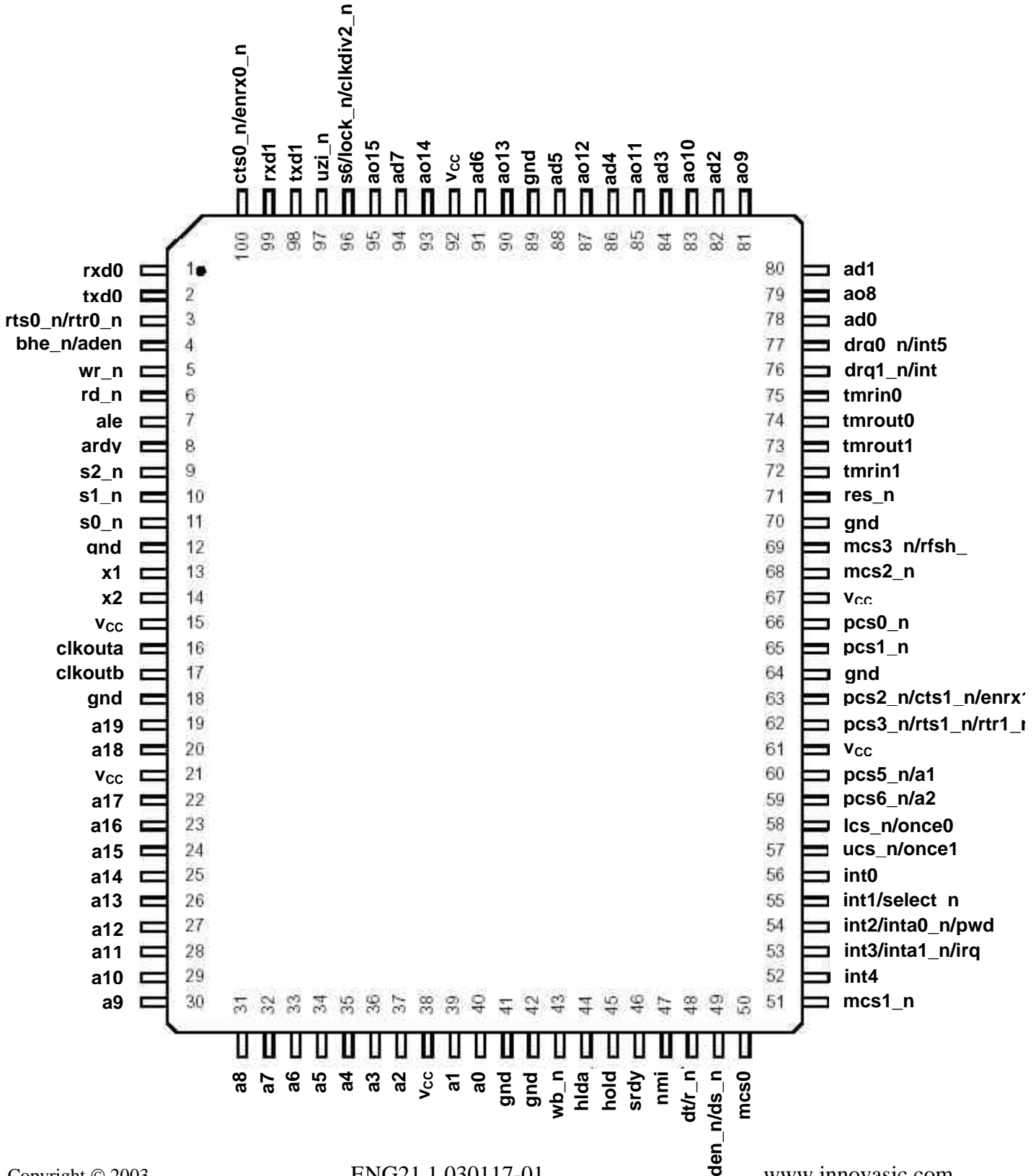
IA186ES 100 Pin TQFP Pin Assignments (sorted by Pin number)

Pin #	Name	Pin #	Name
1	ad0	51	a11
2	ad8	52	a10
3	ad1	53	a9
4	ad9	54	a8
5	ad2	55	a7
6	ad10	56	a6
7	ad3	57	a5
8	ad11	58	a4
9	ad4	59	a3
10	ad12	60	a2
11	ad5	61	vcc
12	gnd	62	a1
13	ad13	63	a0
14	ad6	64	gnd
15	vcc	65	whb_n
16	ad14	66	wlb_n
17	ad7	67	hlda
18	ad15	68	hold
19	s6/lock_n/clkdiv2/pio29	69	srdy/pio6
20	uzi_n/pio26	70	nmi
21	txd1/pio27	71	dt/r_n/pio4
22	rx1/pio28	72	den_n/ds_n/pio5
23	cts0_n/enrx0_n/pio21	73	mcs0_n/pio14
24	rx0/pio23	74	mcs1_n/pio15
25	tx0/pio22	75	int4/pio30
26	rts0_n/rtr0_n/pio20	76	int3/inta1_n/irq
27	bhe_n/aden_n	77	int2/inta0_n/pwd/pio31
28	wr_n	78	int1/select_n
29	rd_n	79	int0
30	ale	80	ucs_n/once1_n
31	ardy	81	lcs_n/once0_n
32	s2_n	82	pcs6_n/a2/pio2
33	s1_n	83	pcs5_n/a1/pio3
34	s0_n	84	vcc
35	gnd	85	pcs3_n/rts1_n/rtr1_n/pio19
36	x1	86	pcs2_n/cts1_n/enrx1_n/pio18
37	x2	87	gnd
38	vcc	88	pcs1_n/pio17
39	clkouta	89	pcs0_n/pio16
40	clkoutb	90	vcc
41	gnd	91	mcs2_n/pio24
42	a19/pio9	92	mcs3_n/rfsh_n/pio25
43	a18/pio8	93	gnd
44	vcc	94	res_n
45	a17/pio7	95	tmin1/pio0
46	a16	96	tmrout1/pio1
47	a15	97	tmrout0/pio10
48	a14	98	tmin0/pio11
49	a13	99	drq1/int6/pio13
50	A12	100	drq0/int5/pio12

IA186ES 100 Pin TQFP Pin Assignments (sorted by Pin Name)

Pin Name	Number	Pin Name	Number
a0	63	gnd	87
a1	62	gnd	93
a2	60	hlda	67
a3	59	hold	68
a4	58	int0	79
a5	57	int1/select_n	78
a6	56	int2/inta0_n/pwd/pio31	77
a7	55	int3/inta1_n/irq	76
a8	54	int4/pio30	75
a9	53	lcs_n/once0_n	81
a10	52	mcs0_n/pio14	73
a11	51	mcs1_n/pio15	74
a12	50	mcs2_n/pio24	91
a13	49	mcs3_n/rfsh_n/pio25	92
a14	48	nmi	70
a15	47	pcs0_n/pio16	89
a16	46	pcs1_npio	88
a17/pio7	45	pcs2_n/cts1_n/enrx1_n/pio18	86
a18/pio8	43	pcs3_n/rts1_n/rtr1_n/pio19	85
a19/pio9	42	pcs5_n/a1/pio3	83
ad0	1	pcs6_n/a2/pio2	82
ad1	3	rd_n	29
ad2	5	res_n	94
ad3	7	rts0_n/rtr0_n/pio20	26
ad4	9	rx0/pio23	24
ad5	11	rx1/pio28	22
ad6	14	s0_n	34
ad7	17	s1_n	33
ad8	2	s2_n	32
ad9	4	s6/lock_n/clkdiv2/pio29	19
ad10	6	srdy/pio6	69
ad11	8	tmrin0/pio11	98
ad12	10	tmrin1/pio0	95
ad13	13	tmrout0/pio10	97
ad14	16	tmrout1/pio1	96
ad15	18	tx0/pio22	25
ale	30	tx1/pio27	21
ardy	30	ucs_n/once1_n	80
bhe_n/aden_n	27	uzi_n/pio26	20
clkouta	39	V _{CC}	15
clkoutb	40	V _{CC}	38
cts0_n/enrx0_n/pio21	23	V _{CC}	44
den_n/ds_n/pio5	72	V _{CC}	61
drq0/int5/pio12	100	V _{CC}	84
drq1/int6/pio13	99	V _{CC}	90
dt/r_n/pio4	71	whb_n	65
gnd	12	wlb_n	66
gnd	36	wr_n	28
gnd	41	x1	36
gnd	64	x2	37

IA188ES 100 Pin PQFP



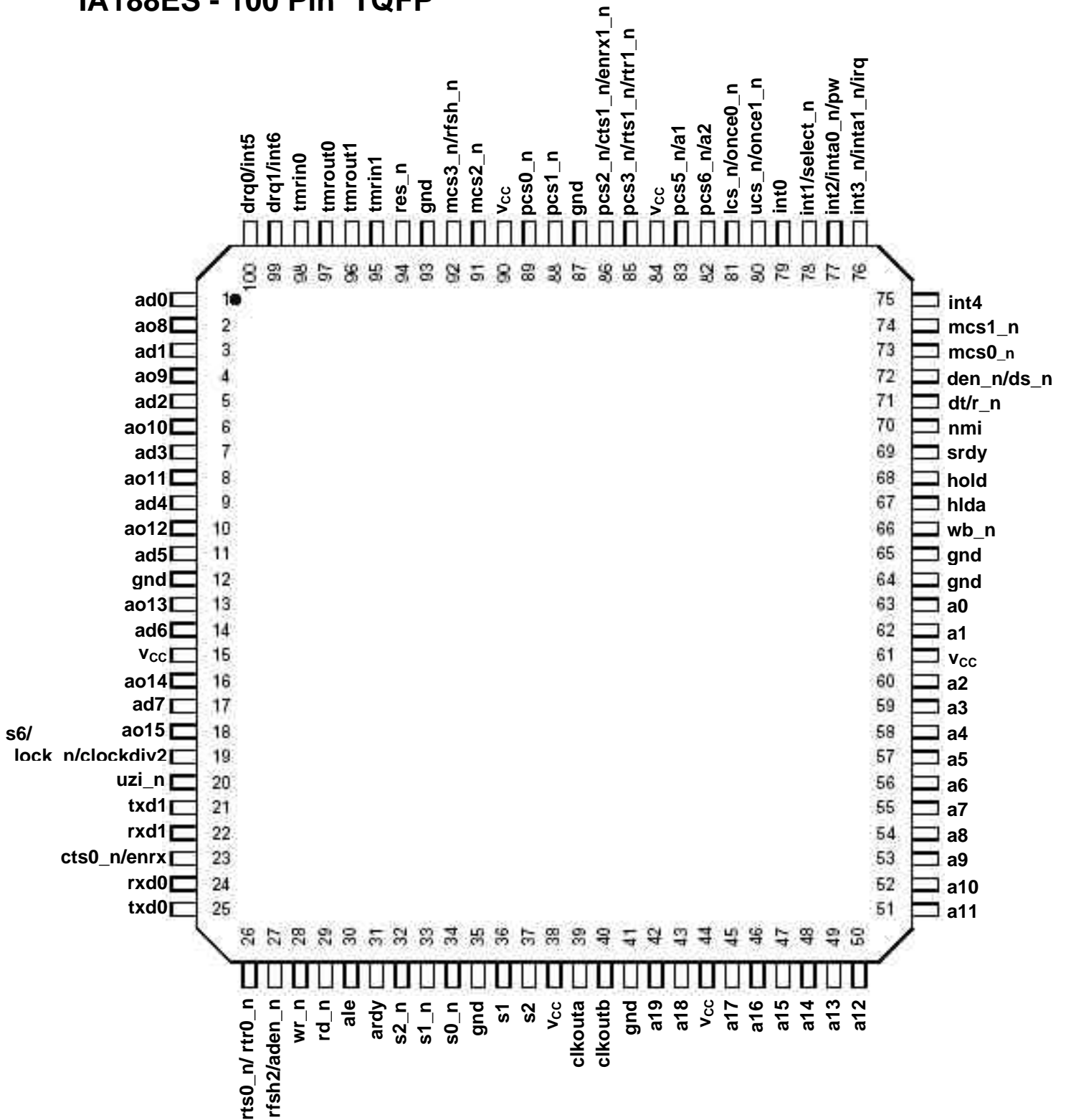
IA188ES 100 Pin PQFP Assignments (sorted by Pin number)

Pin #	Name	Pin #	Name
1	rx_d0/pio23	51	mcs1_n/pio15
2	tx_d0/pio22	52	int4/pio30
3	rts0_n/rtr0_n/pio20	53	int3/inta1_n/irq
4	bhe_n/aden_n	54	int2/inta0_n/pwd/pio31
5	wr_n	55	int1/select_n
6	rd_n	56	int0
7	ale	57	ucs_n/once1_n
8	ardy	58	lcs_n/once0_n
9	s2_n	59	pcs6_n/a2/pio2
10	s1_n	60	pcs5_n/a1/pio3
11	s0_n	61	vcc
12	gnd	62	pcs3_n/rts1_n/rtr1_n/pio19
13	x1	63	pcs2_n/cts1_n/enrx1_n/pio18
14	x2	64	gnd
15	vcc	65	pcs1_n/pio17
16	clkouta	66	pcs0_n/pio16
17	clkoutb	67	vcc
18	gnd	68	mcs2_n/pio24
19	a19/pio29	69	mcs3_n/rfsh_n/pio25
20	a18/pio8	70	gnd
21	vcc	71	res_n
22	a17/pio7	72	tmrin1/pio25
23	a16	73	tmrout1/pio1
24	a15	74	tmrout0/pio10
25	a14	75	tmrin1/pio11
26	a13	76	drq1/int6/pio13
27	a12	77	drq0/int5/pio12
28	a11	78	ad0
29	a10	79	ao8
30	a9	80	ad1
31	a8	81	ao9
32	a7	82	ad2
33	a6	83	ao10
34	a5	84	ad3
35	a4	85	ao11
36	a3	86	ad4
37	a2	87	ao12
38	vcc	88	ad5
39	a1	89	gnd
40	a0	90	ao13
41	gnd	91	ad6
42	gnd	92	vcc
43	wb_n	93	ao14
44	hlda	94	ad7
45	hold	95	ao15
46	sr_d/pio6	96	s6/lock_n/clkdiv2_n/pio29
47	nmi	97	uzi_n/pio26
48	dt/r_n/pio4	98	tx_d1/pio27
49	den_n/ds_n/pio5	99	rx_d1/pio28
50	mcs0_n/pio14	100	cts0_n/enrx0_n/pio21

IA188ES 100 Pin PQFP Pin Assignments (sorted by Pin Name)

Pin Name	Number	Pin Name	Number
a0	40	gnd	70
a1	39	gnd	89
a2	37	hlda	44
a3	36	hold	45
a4	35	int0	56
a5	34	int1/select_n	55
a6	33	int2/inta0_n/pwd/pio31	54
a7	32	int3/inta1_n/irq	53
a8	31	lint4/pio30	52
a9	30	lcs_n/once0_n	58
a10	29	mcs0_n/pio14	50
a11	28	mcs1_n/pio15	51
a12	27	mcs2_n/pio24	68
a13	26	mcs3_n/rfsh_n/pio25	69
a14	25	nmi	47
a15	24	pcs0_n/pio16	66
a16	23	pcs1_n/pio17	65
a17/pio7	22	pcs2_n/cts1_n/enrx1_n/pio18	63
a18/pio8	20	pcs3_n/rts1_n/rtr1_n/pio19	62
a19/pio9	19	pcs5_n/a1/pio3	60
ad0	78	pcs6_n/a2/pio2	59
ad1	80	rd_n	6
ad2	82	res_n	71
ad3	84	rts0_n/rtr0_n/pio20	3
ad4	86	rxd0/pio23	1
ad5	88	rxd1/pio28	99
ad6	91	s0_n	11
ad7	94	s1_n	10
ale	7	s2_n	9
ao8	79	s6/lock_n/clkdiv2/pio29	96
ao9	81	srDY/pio6	46
ao10	83	tmrin0/pio11	75
ao11	85	tmrin1/pio0	72
ao12	87	tmrout0/pio10	74
ao13	90	tmrout1/pio1	73
ao14	93	txd0/pio22	2
ao15	95	txd1/pio27	98
ardy	8	ucs_n/once1_n	57
bhe_n/aden_n	4	uzi_n/pio26	97
clkouta	16	VCC	15
clkoutb	17	VCC	21
cts0_n/enrx0_n/pio21	100	VCC	38
den_n/ds_n/pio5	49	VCC	61
drq0/int5/pio12	77	VCC	67
drq1/int6/pio13	76	VCC	92
dt/r_n/pio4	48	whb_n	42
gnd	12	wlb_n	43
gnd	18	wr_n	5
gnd	41	x1	13
gnd	64	x2	14

IA188ES - 100 Pin TQFP



IA188ES 100 Pin TQFP Pin Assignments (sorted by Pin number)

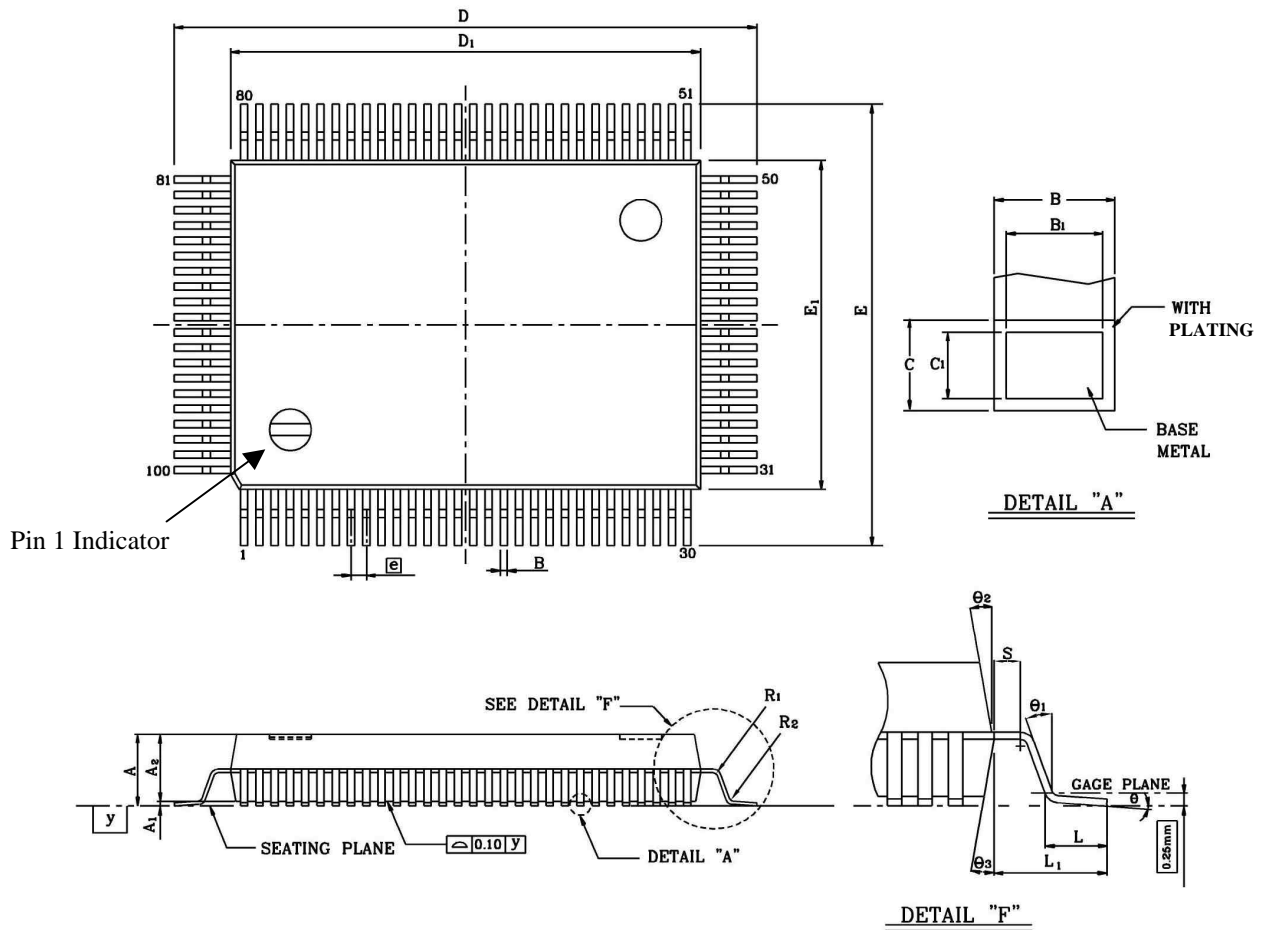
Pin #	Name	Pin #	Name
1	ad0	51	a11
2	ao8	52	a10
3	ad1	53	a9
4	ao9	54	a8
5	ad2	55	a7
6	ao10	56	a6
7	ad3	57	a5
8	ao11	58	a4
9	ad4	59	a3
10	ao12	60	a2
11	ad5	61	v _{cc}
12	gnd	62	a1
13	ao13	63	a0
14	ad6	64	gnd
15	v _{cc}	65	gnd
16	ao14	66	wb_n
17	ad7	67	hlda
18	ao15	68	hold
19	s6/lock_n/clkdiv2/pio29	69	srdy/pio6
20	uzi_n/pio26	70	nmi
21	txd1/pio27	71	dt/r_n/pio4
22	rxid1/pio28	72	den_n/ds_n/pio5
23	cts0_n/enrx0_n/pio21	73	mcs0_n/pio14
24	rxid0/pio23	74	mcs1_n/pio15
25	txid0/pio22	75	int4/pio30
26	rts0_n/rtr0_n/pio20	76	int3/inta1_n/irq
27	rfsh2_n/aden_n	77	int2/inta0_n/pwd/pio31
28	wr_n	78	int1/select_n
29	rd_n	79	int0
30	ale	80	ucs_n/once1_n
31	ardy	81	lcs_n/once0_n
32	s2_n	82	pcs6_n/a2/pio2
33	s1_n	83	pcs5_n/a1/pio3
34	s0_n	84	v _{cc}
35	gnd	85	pcs3_n/rts1_n/rtr1_n/pio19
36	x1	86	pcs2_n/cts1_n/enrx1_n/pio18
37	x2	87	gnd
38	v _{cc}	88	pcs1_n/pio17
39	clkouta	89	pcs0_n/pio16
40	clkoutb	90	v _{cc}
41	gnd	91	mcs2_n/pio24
42	a19/pio9	92	mcs3_n/rfsh_n/pio25
43	a18/pio8	93	gnd
44	v _{cc}	94	res_n
45	a17/pio7	95	tmrin1/pio0
46	a16	96	tmrout1/pio1
47	a15	97	tmrout0/pio10
48	a14	98	tmrin0/pio11
49	a13	99	drq1/int6/pio13
50	a12	100	drq0/int5/pio12

IA188ES 100 Pin TQFP Pin Assignments (sorted by Pin Name)

Pin Name	Number	Pin Name	Number
a0	63	gnd	87
a1	62	gnd	93
a2	60	hlda	67
a3	59	hold	68
a4	58	int0	79
a5	57	int1/select_n	78
a6	56	int2/inta0_n/pwd/pio31	77
a7	55	int3/inta1_n/irq	76
a8	54	int4/pio30	75
a9	53	lcs_n/once0_n	81
a10	52	mcs0_n/pio14	73
a11	51	mcs1_n/pio15	74
a12	50	mcs2_n/pio24	91
a13	49	mcs3_n/rfsh_n/pio25	92
a14	48	nmi	70
a15	47	pcs0_n/pio16	89
a16	46	pcs1_n/pio17	88
a17/pio7	45	pcs2_n/cts1_n/enrx1_n/pio18	86
a18/pio8	43	pcs3_n/rts1_n/rtr1_n/pio19	85
a19/pio9	42	pcs5_n/a1/pio3	83
ale	30	pcs6_n/a2/pio2	82
ad0	1	rd_n	29
ad1	3	res_n	94
ad2	5	rfsh_n/aden_n	27
ad3	7	rts0_n/rtr0_n/pio20	26
ad4	9	rx0/pio23	24
ad5	11	rx1/pio28	22
ad6	14	s0_n	34
ad7	17	s1_n	33
ao8	2	s2_n	32
ao9	4	s6/lock_n/clkdiv2/pio29	19
ao10	6	sr0/pio6	69
ao11	8	tmin0/pio11	98
ao12	10	tmin1/pio0	95
ao13	13	tmrout0/pio10	97
ao14	16	tmrout1/pio1	96
ao15	18	tx0/pio22	25
ardy	30	tx1/pio27	21
clkouta	39	ucs_n/once1_n	80
clkoutb	40	uzi_n/pio26	20
cts0_n/enrx0_n/pio21	23	vcc	15
den_n/ds_n/pio5	72	vcc	38
drq0/int5/pio12	100	vcc	44
drq1/int6/pio13	99	vcc	61
dt/r_n/pio4	71	vcc	84
gnd	12	vcc	90
gnd	35	wb_n	66
gnd	41	wr_n	28
gnd	64	x1	36
gnd	65	x2	37

Physical Dimensions

PQFP 100



Symbol	Dimensions in Inches			Dimensions in mm		
	Minimum	Nominal	Maximum	Minimum	Nominal	Maximum
A	----	----	0.134	----	----	3.40
A ₁	0.010	----	----	0.25	----	----
A ₂	0.107	0.112	0.117	2.73	2.85	2.97
B	0.010	0.012	0.015	0.25	0.30	0.38
B ₁	0.009	0.012	0.013	0.22	0.30	0.33
C	0.005	0.006	0.009	0.13	0.15	0.23
C ₁	0.004	0.006	0.007	0.11	0.15	0.17
D	0.906	0.913	0.921	23.00	23.20	23.40
D ₁	0.783	0.787	0.791	19.90	20.00	20.10
E	0.669	0.677	0.685	17.00	17.20	17.40
E ₁	0.547	0.551	0.555	13.90	14.00	14.10
\square	0.026 BSC			0.65 BSC		
L	0.029	0.035	0.041	0.73	0.88	1.03
L ₁	0.063 BSC			1.60 BSC		
R ₁	0.005	----	----	0.13	----	----
R ₂	0.005	----	0.012	0.13	----	0.30
S	0.008	----	----	0.20	----	----
Y	----	----	0.004	----	----	0.10
θ	0°	----	7°	0°	----	7°
θ_1	0°	----	----	0°	----	----
θ_2	9°	10°	11°	9°	10°	11°
θ_3	9°	10°	11°	9°	10°	11°

NOTE:

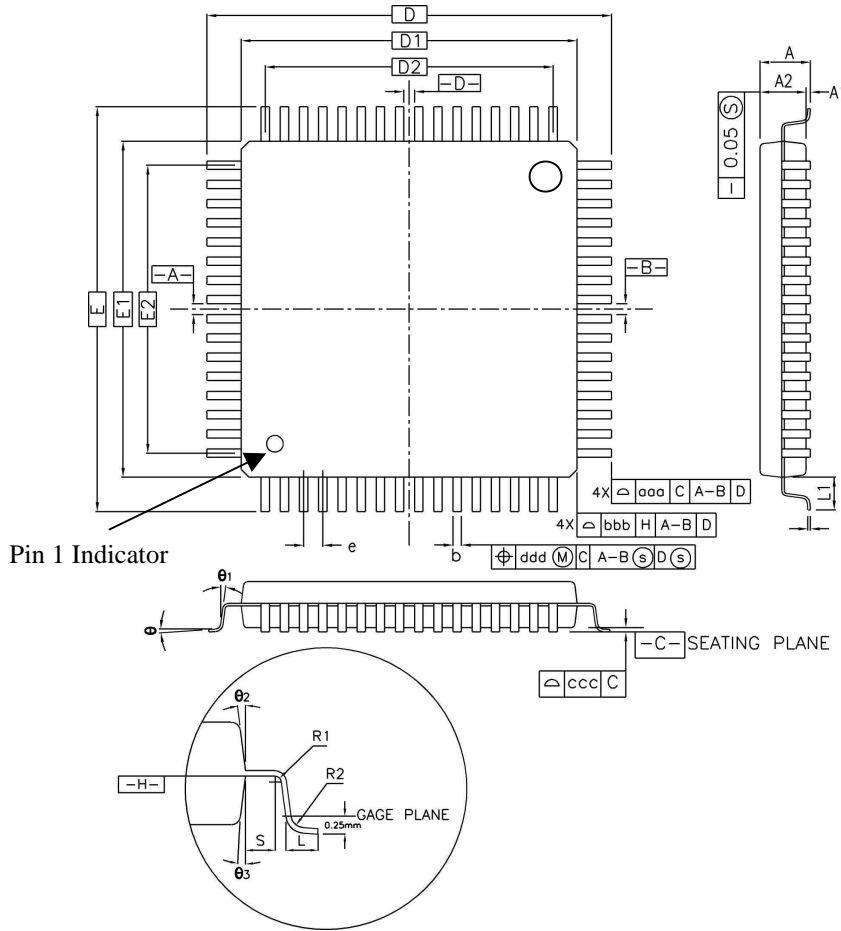
1. Dimensions D₁ and E₁ do not include mold protrusion. But mold mismatch is included. Allowable Protrusion is 0.25mm/0.010" per side.
2. Dimension B does not include Dambar protrusion. Allowable protrusion is 0.08mm/0.003" total in excess of the B dimension at maximum material condition. Dambar cannot be located on the lower radius or the foot.
3. Controlling dimension: millimeter.

IA186ES/IA188ES

8/16-BIT MICROCONTROLLERS

Preliminary Data Sheet

TQFP 100



CONTROL DIMENSIONS ARE IN MILLIMETERS.

SYMBOL	MILLIMETER			INCH		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	—	—	1.20	—	—	0.047
A1	0.05	—	0.15	0.002	—	0.006
A2	0.95	1.00	1.05	0.037	0.039	0.041
D	16.00 BSC.			0.630 BSC.		
D1	14.00 BSC.			0.551 BSC.		
E	16.00 BSC.			0.630 BSC.		
E1	14.00 BSC.			0.551 BSC.		
R2	0.08	—	0.20	0.003	—	0.008
R1	0.08	—	—	0.003	—	—
θ	0°	3.5°	7°	0°	3.5°	7°
θ_1	0°	—	—	0°	—	—
θ_2	11°	12°	13°	11°	12°	13°
θ_3	11°	12°	13°	11°	12°	13°
c	0.09	—	0.20	0.004	—	0.008
L	0.45	0.60	0.75	0.018	0.024	0.030
L ₁	1.00 REF			0.039 REF		
S	0.20	—	—	0.008	—	—

Symbol	Dimensions in mm			Dimensions in Inches		
	Minimum	Nominal	Maximum	Minimum	Nominal	Maximum
b	0.17	0.20	0.27	0.007	0.008	0.011
e	0.50 BSC			0.02 BSC		
D2	12.00			0.472		
E2	12.00			0.472		
aaa	0.20			0.008		
bbb	0.20			0.008		
ccc	0.08			0.003		
ddd	0.08			0.003		

Ordering Information

innovASIC^o Part Number	Standard Packages	Temperature Grade
IA186ES-PQF100I	100 Pin Plastic Quad Flat Package (PQFP)	Industrial
IA186ES-PTQ100I	100 Pin Thin Quad Flat Package (TQFP)	Industrial
IA188ES-PQF100I	100 Pin Plastic Quad Flat Package (PQFP)	Industrial
IA188ES-PTQ100I	100 Pin Thin Quad Flat Package (TQFP)	Industrial

Other packages and temperature grades may be available for an additional cost and lead-time.

Cross Reference to OEM Part Numbers

innovASIC^o Part Number	AMD^o Part Number
IA186ES-PQF100I	<ul style="list-style-type: none"> ▪ AM186ES-20KC\W ▪ AM186ES-20KI\W ▪ AM186ES-25KC\W ▪ AM186ES-25KI\W ▪ AM186ES-33KC\W ▪ AM186ES-40KC\W
IA186ES-PTQ100I	<ul style="list-style-type: none"> ▪ AM186ES-20VC\W ▪ AM186ES-25VC\W ▪ AM186ES-33VC\W ▪ AM186ES-40VC\W
IA188ES-PQF100I	<ul style="list-style-type: none"> ▪ AM188ES-20KC\W ▪ AM188ES-20KI\W ▪ AM188ES-25KC\W ▪ AM188ES-25KI\W ▪ AM188ES-33KC\W ▪ AM188ES-40KC\W
IA188ES-PTQ100I	<ul style="list-style-type: none"> ▪ AM188ES-20VC\W ▪ AM188ES-25VC\W ▪ AM188ES-33VC\W ▪ AM188ES-40VC\W

Errata

Version –P00:

1. Problem: In certain customer systems, the device powers up in divide-by-two mode rather than normal (divide-by-one) mode.

Analysis: The s6_clkdiv2_n signal is sampled at the rising edge of reset to determine whether the part powers up in normal (divide-by-one mode) or divide-by-two mode. Some customer systems rely on the devices internal pull-up resistor to ensure that the s6_clkdiv2_n is sampled as a one rather than actively driving the pin. The internal pull-up resistor does not become active until after the rising edge of reset.

Workaround: A weak, external pull-up resistor connected to the s6_clkdiv2_n pin will ensure the device powers up in normal mode. Recommended pull-up value = 50K ohms to 75K ohms. *Please note this issue has been corrected in Version-01.*

2. Problem: MCS chip select signals (MCS0-3) are intermittently suppressed. All other signals in bus cycle appear correct (i.e. address, data, write/read strobes)

Analysis: Anomaly occurs when an access to I/O space is immediately followed by an MCS access. Given the way instruction prefetches naturally separate such accesses, the only known scenario for this anomaly is via a DMA sequence. Possible combinations are: (1) DMA write to destination is followed by previously scheduled MCS read or write, (2) DMA from I/O space to MCS space

Customers using the UART DMA feature of the ES products may be particularly sensitive to this, because when the TX data register of the PCB is in I/O space, eventually an MCS access will be corrupted.

The PCB register block and the PCS address spaces are the only areas that can be assigned to I/O space. The PCB register block is configured by bit 12 of the RELREG, and defaults to I/O space. PCS space is configured by bit 6 of the MPCS, and must be initialized by the user.

Workaround: If possible, assign PCB and PCS address locations to memory space instead of I/O space.

Version –01:

1. Problem: MCS chip select signals (MCS0-3) are intermittently suppressed. All other signals in bus cycle appear correct (i.e. address, data, write/read strobes)

Analysis: Anomaly occurs when an access to I/O space is immediately followed by an MCS access. Given the way instruction prefetches naturally separate such accesses, the only known scenario for this anomaly is via a DMA sequence. Possible combinations are: (1) DMA write to destination is followed by previously scheduled MCS read or write, (2) DMA from I/O space to MCS space

Customers using the UART DMA feature of the ES products may be particularly sensitive to this, because when the TX data register of the PCB is in I/O space, eventually an MCS access will be corrupted.

The PCB register block and the PCS address spaces are the only areas that can be assigned to I/O space. The PCB register block is configured by bit 12 of the RELREG, and defaults to I/O space. PCS space is configured by bit 6 of the MPCS, and must be initialized by the user.

Workaround: If possible, assign PCB and PCS address locations to memory space instead of I/O space.