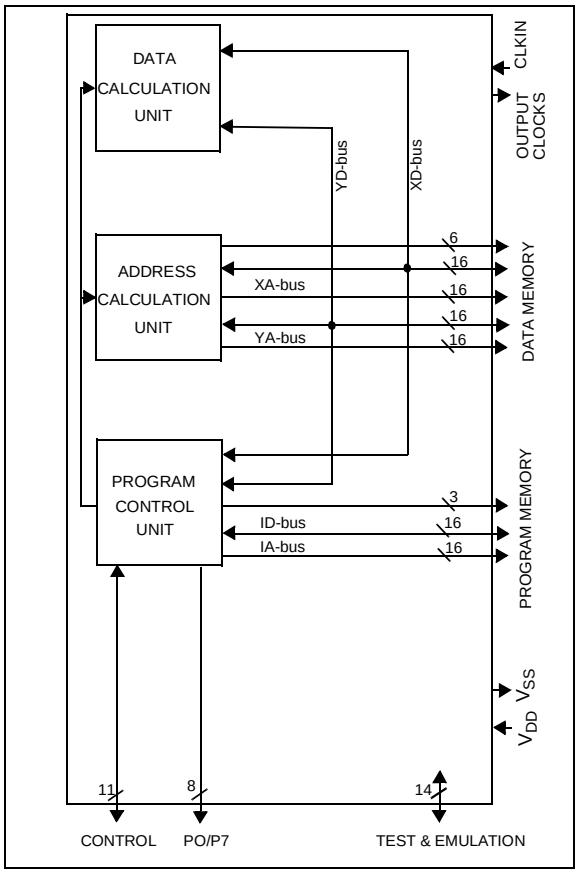
SGS-THOMSON MICROELECTRONICS

D950-CORE

16-Bit Fixed Point Digital Signal Processor (DSP) Core

PRELIMINARY DATA

- **Performance**
  - 66 Mips - 15ns instruction cycle time
- **Memory Organization**
  - HARVARD architecture
  - Two 64k x 16-bit data memory spaces
  - One 64k x 16-bit program memory space
  - 2 stacks in data memory spaces
- **Fast and Flexible Buses**
  - Two 16-bit address 16-bit data non-multiplexed data buses
  - One 16-bit address 16-bit data non-multiplexed instruction bus
- **Data Calculation Unit**
  - 16 x 16-bit parallel multiplier
  - 40-bit barrel shifter unit
  - 40-bit ALU
  - Two 40-bit extended precision accumulators
  - Fractional and integer arithmetic with support for floating point and multi-precision
  - 16-bit bit manipulation unit (BMU)
- **Address Calculation Unit**
  - Two address calculation units with modulo and bit-reverse capability
  - 2 x 16-bit address registers
  - 4 x 16-bit index registers
  - 2 x 16-bit base and maximum address registers for modulo addressing
- **Program Control Unit**
  - 16-bit program counter
  - 3 Hardware Loop Capabilities
- **Power Consumption**
  - Single 3.3V power supply
  - Low-power standby mode
- **Electrical Characteristics**
  - Operating frequency down to DC
- **Channels**
  - General purpose 8-bit I/O port
  - Dedicated hardware for Emulation and Test, IEEE 1149.1 (JTAG) interface compatible



- **Peripherals and Memory**
  - Macrocells for peripherals such as the bus switch unit, interrupt controller and DMA controller
  - Standard cells library, I/O library
  - Memory generators for RAM and ROM
- **Development Tools**
  - JTAG PC board with graphic windowed high level source debugger for AS-DSP emulation
  - Complete crash-barrier chain (assembler / simulator / linker) running on PC and SUN,
  - Complete GNU chain (assembler / simulator / linker / C compiler / C debugger) for SUN
  - VHDL model (SYNOPSYS & MENTOR)

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1 Introduction

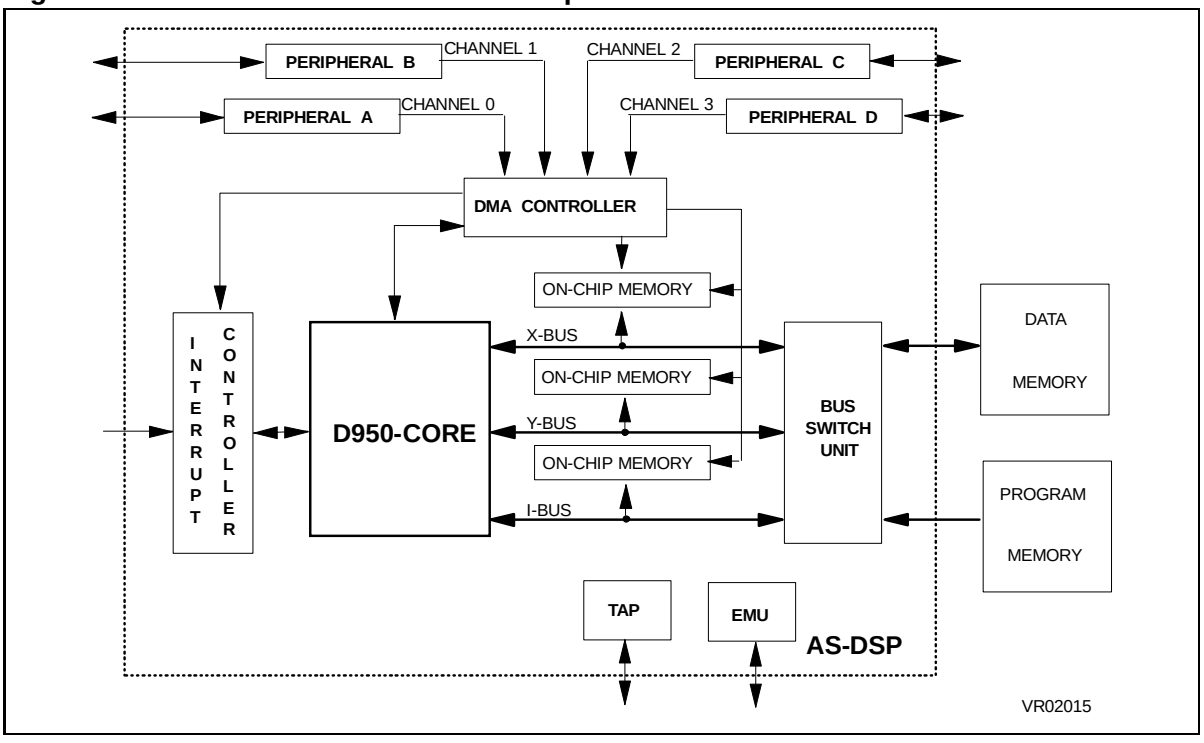
The D950-Core is a general purpose programmable 16-bit fixed point Digital Signal Processor Core, designed for multimedia, telecom and datacom applications. The D950-Core is a core product, used in combination with standard or custom peripherals from the standard cell library. The peripherals are implemented around the core on the same silicon die, for application specific DSP silicon chip design.

The main blocks of the D950-Core include an arithmetic data calculation unit, a program control unit and an address calculation unit, able to manage up to 64k (program) and 128k (data) x 16-bit memory spaces. Standard peripherals from the macrocell library include an Emulation Unit, a Bus Switch Unit, an Interrupt Controller, a DMA Controller, a Timer and a Synchronous Serial Port. Memory can be added for programs or data and dedicated memory cells can be generated by use of RAM and ROM memory generators. The development of application specific peripherals is simplified by using the standard cells library.

A set of high level hardware and software development tools and a complete design package, give the user a substantial advantages in the form of a performant design environment, rapid prototyping, first time silicon success and built-in test strategies for a global solution in AS-DSP development:

Figure 1.1 shows an architecture example for an AS-DSP used for audio decoding (Dolby AC3, MPEG).

Figure 1.1 AS-DSP Architecture Example



2 PIN DESCRIPTION

The following tables detail the D950-Core pin set. There is one table for each group of pins. The tables detail the pin name, type and a short description of the pin function. A diagram of the D950-Core I/O interface is contained at the end of the section.

Table 2.1 DATA BUSES (70 PINS)

Pin Name	Type	Description
XD0-XD15	I/O	X Data Bus. Hi-Z during cycles with no X-bus exchange.
XA0-XA15	O	X Address bus. Hi-Z when in Hold.
$\overline{XRD}$	O	X-bus read strobe. Active low. Hi-Z when in Hold.
$\overline{XWR}$	O	X-bus write strobe. Active low. Hi-Z when in Hold.
$\overline{XBS}$	O	X-bus strobe. Active low. Hi-Z when in Hold. Asserted low at the beginning of a valid X-bus cycle.
YD0-YD15	I/O	Y Data Bus. Hi-Z during cycles with no Y-bus exchange.
YA0-YA15	O	Y Address bus. Hi-Z when in Hold.
$\overline{YRD}$	O	Y-bus read strobe. Active low. Hi-Z when in Hold.
$\overline{YWR}$	O	Y-bus write strobe. Active low. Hi-Z when in Hold.
$\overline{YBS}$	O	Y-bus strobe. Active low. Hi-Z when in Hold. Asserted low at the beginning of a valid Y-bus cycle.

Table 2.2 PROGRAM BUS (35 PINS)

Pin Name	Type	Description
ID0-ID15	I/O	Instruction data bus. Hi-Z during cycles with no I-bus exchange.
IA0-IA15	O	Instruction address bus. Hi-Z when in Hold.
$\overline{IRD}$	O	I-bus read strobe. Active low. Hi-Z when in Hold.
$\overline{IWR}$	O	I-bus write strobe. Active low. Hi-Z when in Hold.
$\overline{IBS}$	O	I-bus strobe. Active low. Hi-Z in Hold. Asserted low at the beginning of a valid I-bus cycle.

Table 2.3 BUS CONTROL (3 PINS)

Pin Name	Type	Description
$\overline{DTACK}$	I	Data transfer acknowledge. Active low. Sampled on CLKIN rising edge. Controls bus cycle extension by insertion of wait-states.
$\overline{HOLD}$	I	Hold bus request signal. Active low. Asserted by a peripheral (DMA controller) requiring bus mastership. Halts program execution and tri-states buses.
$\overline{HOLDACK}$	O	Hold Acknowledge output. Active low. Indicates that all buses are in Hi-Z.

Table 2.4 GENERAL PURPOSE P-PORT (9 PINS)

Pin Name	Type	Description
P0-P7	I/O	8-bit bidirectional parallel port. Each pin can be individually programmed as input or output and as level or falling edge sensitive input conditions for test by branch and conditional instructions.
P_EN	O	Direction of Port

Table 2.5 CLOCK (4 PINS)

Pin Name	Type	Description
CLKIN	I	Clock input.
CLK_EMU	I	Emulation Clock input
DMA_CLK	O	DMA Clock output
BSU_CLK	O	BSU Clock output

Table 2.6 CONTROL (13 PINS)

Pin Name	Type	Description
$\overline{IT}$	I	Maskable Interrupt Request Input. Falling edge sensitive.
$\overline{ITACK}$	O	Maskable Interrupt Request Acknowledge. Active Low. Asserted low at the beginning of Interrupt servicing.
$\overline{EOI}$	O	End of maskable Interrupt routine output. Active low. Asserted low at the end of current interrupt request processing.
$\overline{LP}$	I	Low power. Falling edge sensitive. Stops the processor after execution of the currently decoded instruction and enters low-power standby state (in this state, the clock generator is stopped except for INCYCLE).
$\overline{LPACK}$	O	Low power Acknowledge. Active low. Asserted low at the end of execution of the last instruction following detection of $\overline{LP}$ falling edge or at the end of LP or STOP instruction.
$\overline{RESET}$	I	Reset input. Active low. Initializes the processor to the RESET state and the clock generator. Forces Program Counter value to reset address and execution of NOP instruction.
MODE	I	Mode input select. Forces reset address to 0x0000 (resp. 0xFC00) when low (resp. high).
VCI	O	Valid co-processor instruction decoded. Asserted high while decoding a co-processor dedicated instruction. Indicates that the co-processor instruction will be executed at the following instruction cycle.
IRD_WR	O	Indicates program memory RD/WR cycle during execution of Read or Write Program memory instruction.
INCYCLE	O	Instruction cycle. Asserted high at the beginning of cycle.
$\overline{RESET\_OUT}$	O	Hardware and Software Reset Output
STACKX	O	X Stack read/write instruction
STACKY	O	Y Stack read/write instruction

Table 2.7 EMULATION (9 PINS)

Pin Name	Type	Description
$\overline{ERQ}$	I	Emulator Halt Request. Active low. Halts program execution and enters emulation mode.
IDLE	O	Output flag indicating if the processor is halted or executing an instruction in Emulation mode.
HALTACK	O	Halt Acknowledge. Active high. Asserted high when the processor is halted and under control of the emulator.
SNAP	O	Snapshot output. Active high. Asserted high when executing an instruction in Snapshot mode.
HALT	I	Halt program execution request
EMI	I	Single Instruction Execute Command
MCI	O	Multicycle instruction flag
IDLE	O	Execution of emulation instruction/Halted
FNOP	O	Forced NOP instruction flag

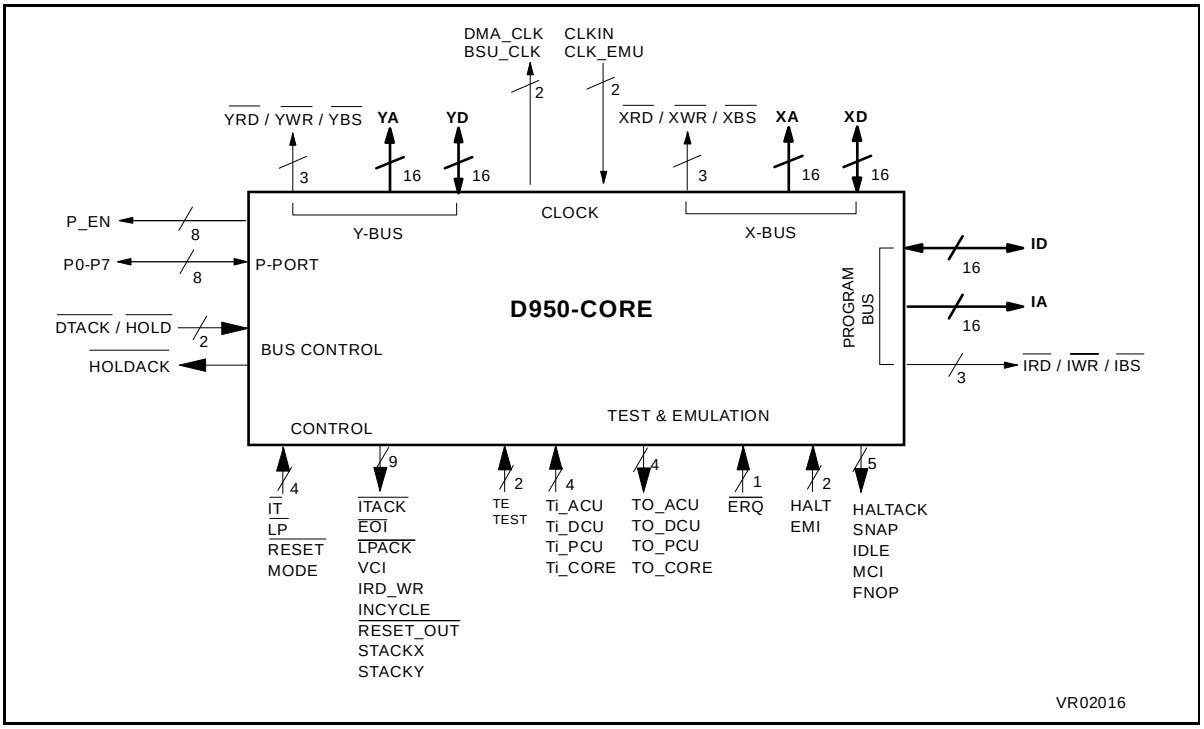
Table 2.8 TAP CONTROLLER INTERFACE (10 PINS)

Pin Name	Type	Description
TE	I	Test Enable
TEST	I	Test Scan Mode
TI_ACU	I	Test Input for ACU
TO_ACU	O	Test Output for ACU
TI_PCU	I	Test Input for PCU
TO_PCU	O	Test Output for PCU
TI_DCU	I	Test Input for DCU
TO_DCU	O	Test Output for DCU
TI_CORE	I	Scan Chain input
TO-CORE	O	Scan Chain output

Table 2.9 SUPPLY (2 PINS)

Pin Name	Type	Description
V_{DD}	I	Positive Supply.
V_{SS}	I	Ground pin.

Figure 2.1 D950-Core I/O Interface



3 FUNCTIONAL OVERVIEW

The D950-CORE is composed of three main units.

- Data Calculation Unit (DCU)
- Address Calculation Unit (ACU)
- Program Control Unit (PCU)

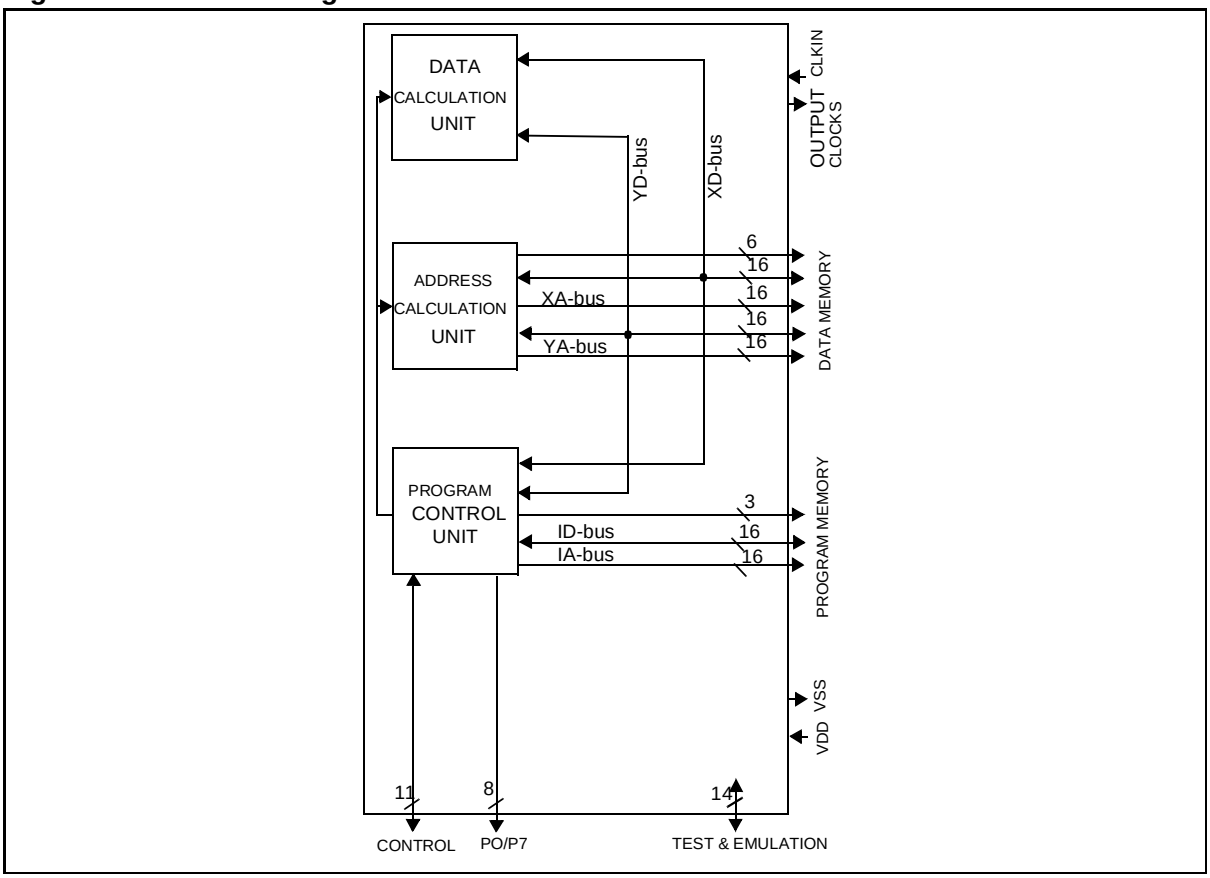
These units are organized in an HARVARD architecture around three bidirectional 16-bit buses, two for data and one for instruction. Each of these buses is dedicated to an uni-directional 16-bit address bus (XA/YA/IA).

An 8-bit general purpose parallel port (P0-P7) can be configured (input or output). A test condition is attached to each bit to test external events. Each of these functional blocks are discussed in detail in **Section 4"BLOCK DESCRIPTION"**.

Control of the chip is performed through interface pins related to interrupt, low-power mode, reset and miscellaneous functions.

Clock input is provided on the CLKIN pin which is buffered to the output clocks.

Figure 3.1 Block Diagram



Data buses (XD/YD and XA/YA) are provided externally. Data memories (RAM, ROM) and peripherals registers are to be mapped in these address spaces.

Instruction bus (ID/IA) gives access to program memory (RAM, ROM). Each bus has its own control interface

Table 3.1 Data/Instruction Bus and Corresponding Address Bus.

Data / Instruction Buses			Corresponding Address Bus		
XD	Bidirectional	16-bit	XA	Unidirectional	16-bit
YD	Bidirectional	16-bit	YA	Unidirectional	16-bit
ID	Bidirectional	16-bit	IA	Unidirectional	16-bit

Depending on the calculation mode, the D950-Core DCU computes operands which can be considered as 16 or 32-bit, signed or unsigned. It includes a 16 x 16-bit parallel multiplier able to implement MAC-based functions in one cycle per MAC. A 40-bit arithmetic and logic unit, including a 8-bit extension for arithmetic operations, implements a wide range of arithmetic and logic functions. A 40-bit barrel shifter unit and a bit manipulation unit are included.

Tables 3.2 and 3.3 illustrate the different types of word length and word format available for manipulation.

Table 3.2 Summary of Possible Word Lengths

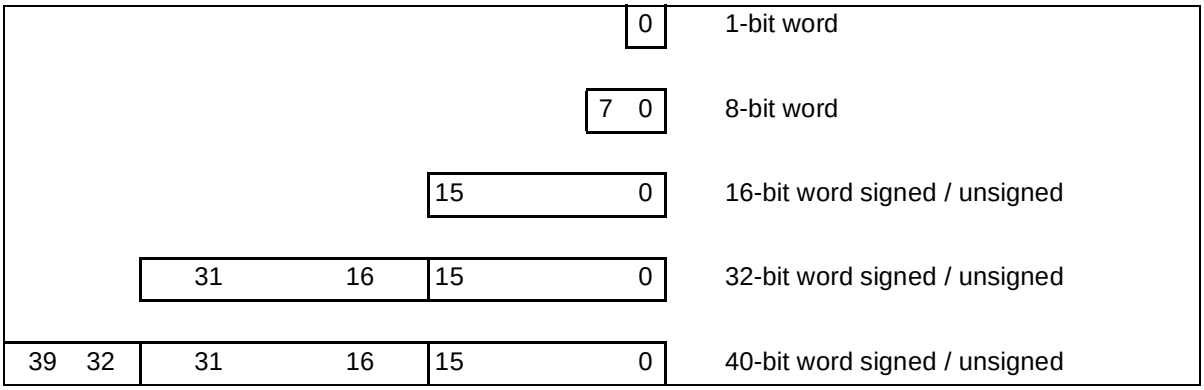


Table 3.3 Summary of Possible Word Formats

Format		Minimum	Maximum
fractional	signed	- 1	+ 0.999969481
	unsigned	0	+ 0.99996948
integer	signed	- 32768	+ 32767
	unsigned	0	+ 65535

4 BLOCK DESCRIPTION

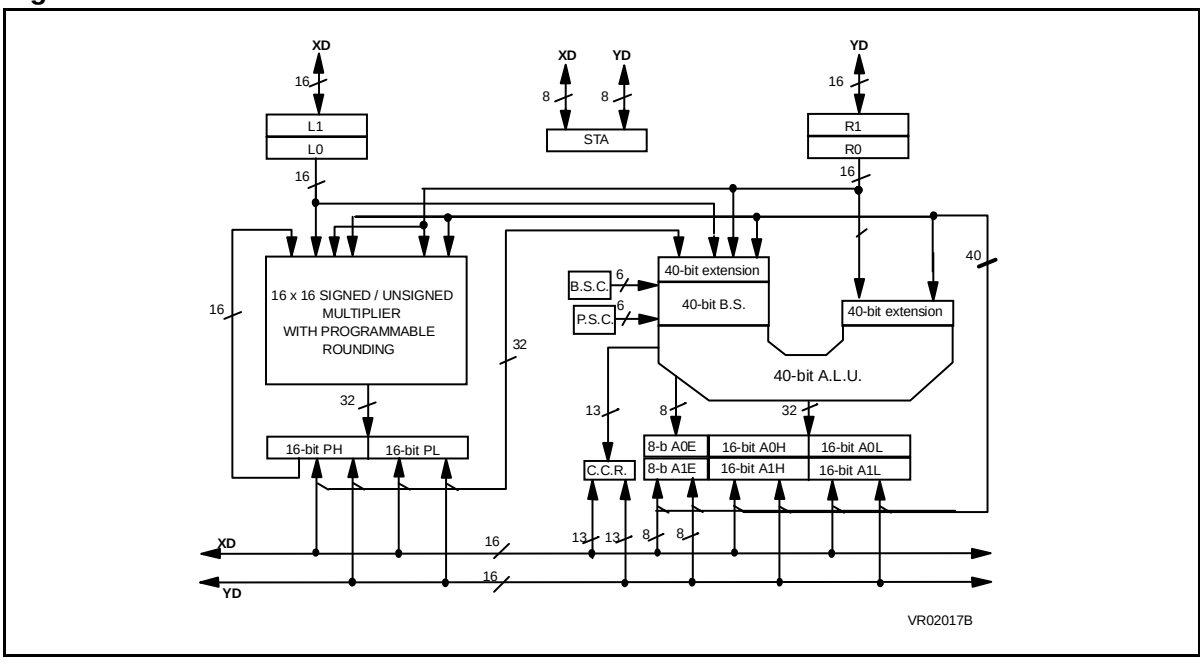
4.1 Data Calculation Unit (DCU)

4.1.1 Introduction

The D950-Core DCU includes the following main components:

- Register file - containing 16 data registers
- 4 Control Registers:
  - DCU0CR: Register
  - BSC: Shifter Control
  - PSC: Shifter Control
  - CCR: ALU Flags
- Multiplier - 16x16-bit signed/unsigned fractional/integer parallel multiplier.
- BSU - 40-bit Barrel Shifter Unit with a maximum right or left shift value of 32.
- ALU - 40-bit Arithmetic and Logic Unit implementing a wide range of arithmetic and logic functions with an 8-bit extension for arithmetic operations.
- BMU - 16-bit Bit Manipulation Unit implementing bit operations on internal registers and/or on 16-bit data RAM with an 8/16-bit mask.

Figure 4.1 D950-Core Data Calculation Unit



4.1.2 Registers

There are two types of registers: data registers and control registers. All registers are direct addressed. Registers can be read or written through the X and Y buses. All of the DCU parts (multiplier, BSU, ALU, BMU) operate on these registers.

Data registers

L0 / L1: 2 x 16-bit input Left registers.

R0 / R1: 2 x 16-bit input Right registers.

A0 / A1: 2 x 40-bit Accumulators, each made of the concatenation of an 8-bit extension A0E (resp. A1E), a 16-bit MSB A0H (resp. A1H) and a 16-bit LSB A0L (resp. A1L). These registers are dedicated to extended precision calculations, in order to provide up to 240 dB of dynamic range.

P: 32-bit multiplier result register made of the concatenation of PH (MSB) and PL (LSB) 16-bit registers

Table 4.1 Data Register Structure.

L		L1 (31 16)	L0 (15 0)	32-bit Input Left
R		R1 (31 16)	R0	32-bit Input Right
A0	A0E (39 32)	A0H (31 16)	A0L	40-bit Accumulator 0
A1	A1E (39 32)	A1H (31 16)	A1L (15 0)	40-bit Accumulator 1
P		PH (31 16)	PL (15 0)	32-bit Multiplier Result
L		L1 (31 16)	0 (15 0)	16-bit Input Left
L		L0 (31 16)	0 (15 0)	16-bit Input Left
R		R1 (31 16)	0 (15 0)	16-bit Input Right
R		R0	0	16-bit Input Right

Control registers

CCR: Bits 0 to 12 are dedicated to the DCU (see **Section 4.5.2**).

BSC: 6-bit Barrel Shifter Control register. The BSC contains a 6-bit signed shift value (2's complement). If the value is positive (resp. negative), all shifts using the BSC contents will provide a left (resp. right) shift. After reset, the BSC value is 0.

PSC: 6-bit Product Shift Control register. The PSC contains a 6-bit signed shift value. If the value is positive (resp. negative) there will be a left (resp. right) shift on the P-register. After reset, the PSC value is 0.

DCU0CR: Bits 0 to 7 are copied from bits 0 to 7 of the STA register. Bit 10 is used for clearing the lower part (bits 0 to 15) and sign extending bits 32 to 39 of the accumulator when its higher part (bits 16 to 31) is loaded.

4.1.3 Multiplier

The D950-Core multiplier performs 16 x 16-bit multiplications with the following implementations (see SL and SR bits of STA register):

SL	LL	SR	LR	Multiplication		
0	X	0	X	Unsigned L-source	X	Unsigned R-source
1	0	0	X	Signed L-source	X	Unsigned R-source
0	X	1	0	Unsigned L-source	X	Signed R-source
1	0	1	0	Signed L-source	X	Signed R-source
SL	1	SR	X	Unsigned L0	X	Unsigned R-source (dep on SR-bit)
					or	
				Signed/Unsigned L-source	X	Signed/Unsigned R-source
SL	X	SR	1	Signed/Unsigned L-source (depending on SL-bit)	X	Unsigned R0
					or	
				Signed/Unsigned L-source		Signed/Unsigned R-source

The 16 or 32-bit operands, are provided by a subset of the register file and stored in L1/L0 and R1/R0, and accessed through X and Y buses.

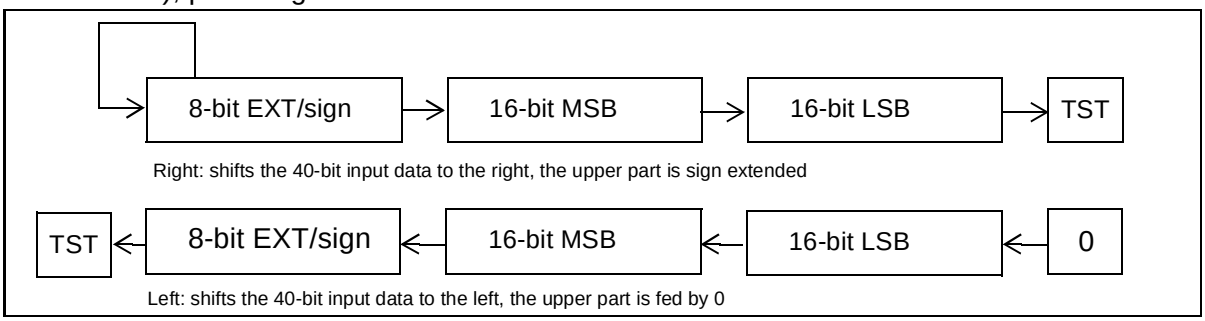
The multiplication is performed in one single instruction cycle and the result is loaded in the 32-bit P register. The product can be either integer or fractional (see I-bit of STA register). Rounding of the product is explicitly defined by the multiplication instructions (see **Section 5.4.2**).

I	Product		
0	Fractional L-source	X	Fractional R-source
1	Integer L-source	X	Integer R-source

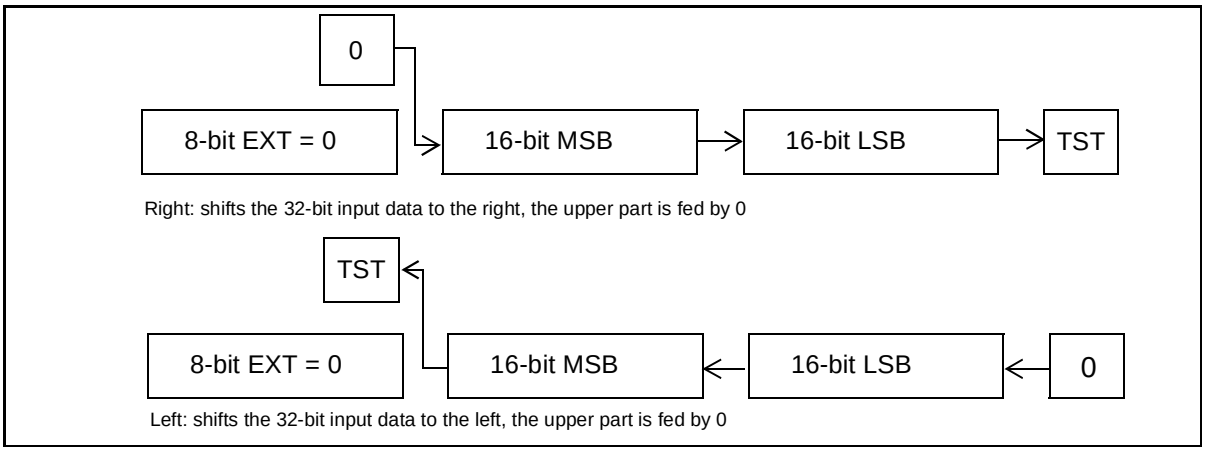
4.1.4 Barrel Shifter Unit (BSU)

The D950-Core BSU provides a complete set of shifting functions

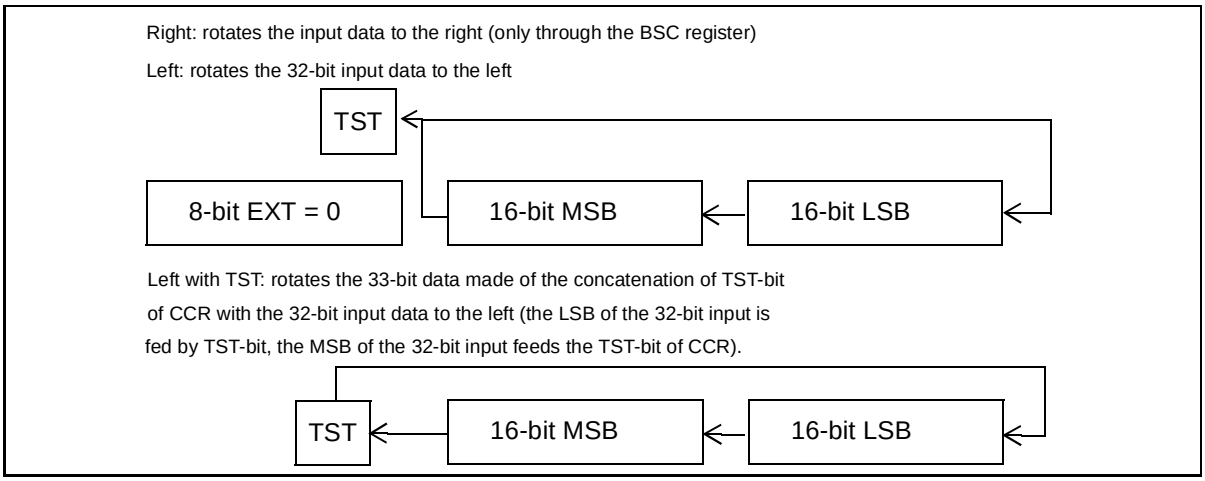
Arithmetic shift: 40-bit input (either a 32 bit operand sign extended to 40-bit, or a 40-bit accumulator), providing a valid result



Logical shift: provides a 32-bit result which is loaded into a 40-bit accumulator, the 8-bit extension of which is reset.



Rotation:



When using a pure shift instruction, the TST bit of the CCR is fed by the last bit shifted out. The shift value provided to the BSU is a signed value which may be provided in three different ways:

- By the instruction (shift defined in the instruction: see **Section 5.4.2**).
- By the BSC register (shift defined in the ALU code: if BSC contains a positive (resp. negative) value, all shifts using BSC content will provide a left (resp. right) shift).
- By the PSC register (shift defined in the MAC instruction: if PSC contains a positive (resp. negative) value, all shifts using BSC content will provide a left (resp. right) shift).

4.1.5 Arithmetic and Logic Unit (ALU)

The D950-Core ALU is 40-bit wide and implements about sixty ALU functions. It includes an 8-bit extension for arithmetical operations.

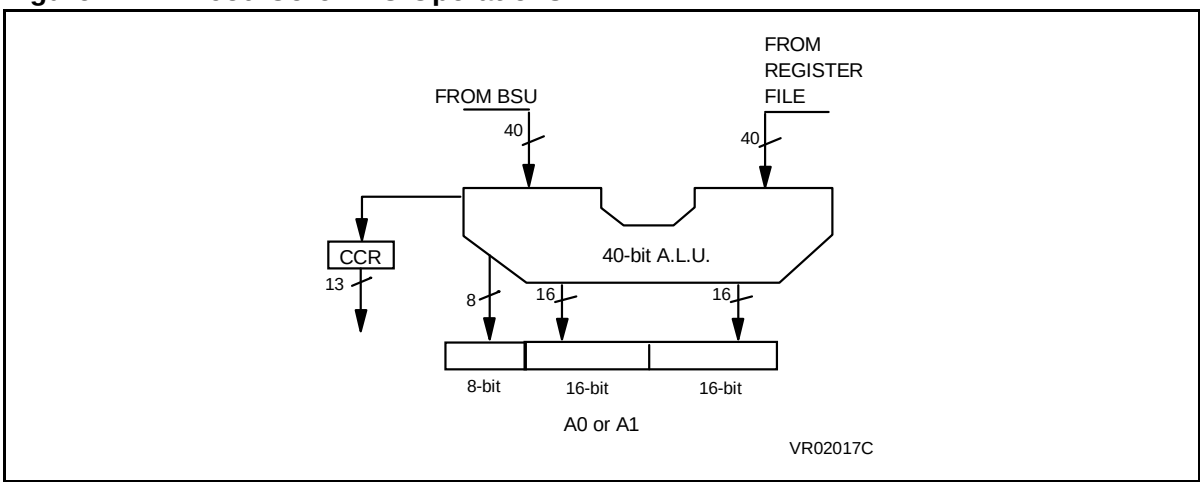
The calculation mode is controlled by both the instruction and the corresponding bits of the STA register (see **Section 4.5.1**). The ALU has two inputs (see **Figure 4.2**), the left (always the output of the BSU) and the right (fed by the registers making up the register file).

For logical operations, the ALU is fed with 32-bit wide operands, 0-extended to 40-bits. Then, the ALU generates a 40-bit result which is always stored in A0 or A1 (A0E and A1E extension registers being reset).

For arithmetical operations, the ALU is fed with 40-bit wide operands.

- If the operand is an accumulator, the entire 40-bit register (A0E/A0H/A0L or A1E/A1H/A1L) feeds the 40-bit ALU.
- If not, the 32-bit register is considered as sign extended to a 40-bit format. The extended ALU then generates a 40-bit wide result which is always stored in A0E/A0H/A0L or A1E/A1H/A1L

Figure 4.2 D950-Core ALU Operations



The ALU output is always made to one of the two accumulators and the CCR (with the exception of particular ALU codes which affect only CCR or an accumulator). The ALU operations can be partitioned into three different groups (see **Section 5.4.2**), depending on the number of operands the operation requires:

ALU Code	Number of Sources	Number of Destinations
3 operands	2	1
2 operands	1	1
1 operand	1 (source=destination)	1 (source=destination)

Specific ALU codes (see **Section 5.4.2**) are used to implement a non-restoring conditional add/subtract division algorithm. The division can be signed or unsigned. The dividend must be a 32-bit operand sign extended to 40-bit and located in the 40-bit accumulator. The divisor must be a 16-bit operand located in R0 or R1 (LR-bit of STA register must be low).

In order to obtain a valid result, the absolute value of the dividend must be strictly smaller than the absolute value of the divisor (considering operand is in a fractional format).

Special features are implemented in the D950-Core to process multi-precision data (see DMULT instruction for double-precision MAC operations).

Two overflow preventions exist in the D950-Core (see SAT and ES bits of STA register):

1: For the multiplier, when multiplying 0x8000 by 0x8000 in signed/signed fractional mode, the saturation block forces the multiplier result to 0x7FFFFFFF,

2: For the ALU, when the result overflows. Provided one of the two optional saturation modes (32-bit saturation or 40-bit saturation) has been selected, the accumulator destination is set to plus or minus the maximum value.

Two rounding operations are enabled in the D950-Core (see RND-bit of STA register):

1: The multiplier result stored in P register explicitly defined by the instruction. A two's complement rounding is performed on the result which is stored in the 16-bit PH register (see **Section 5.4.2**).

2: The 40-bit accumulator (either two's complement or convergent rounding) provided by ALU operation (see RND-bit of STA register).

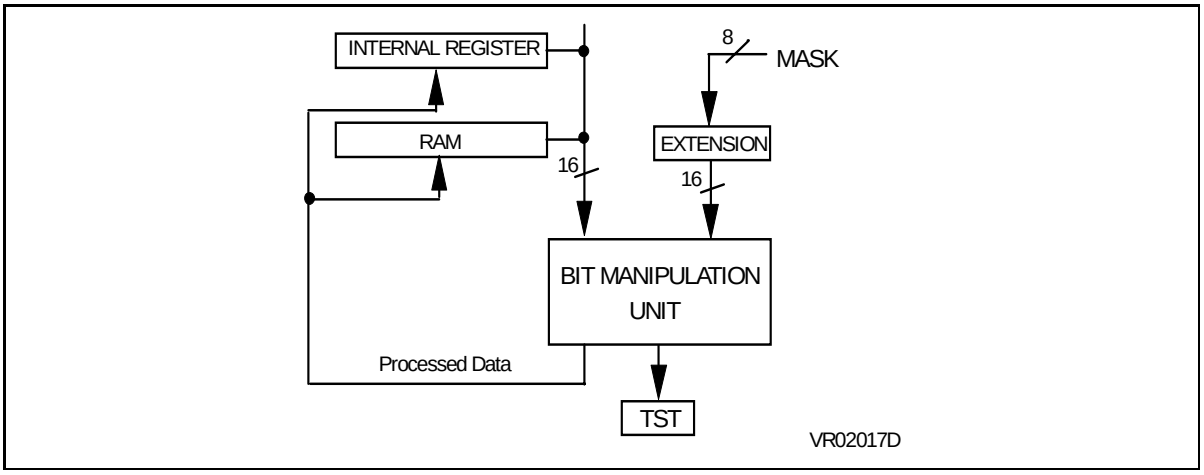
4.1.6 Bit Manipulation Unit (BMU)

The BMU allows bit manipulation operations on 16-bit data sources, accessed in 3 different modes: direct, indirect and register addressing, through dedicated instructions.

An 8-bit mask is applied to enable the following operations on a bit-per-bit basis:

- TSTL: bit test low.
- TSTH: bit test high.
- TSTHSET: bit test high and set.
- TSTLCLR: bit test low and reset.

Figure 4.3 D950-Core Bit Manipulation Unit



This 8-bit mask is extended to a 16-bit mask in three ways:

- 8-bit value on MSBs, 0x00 on LSBs,
- 0x00 on MSBs, 8-bit value on LSBs,
- 8-bit value on MSBs, 8-bit value on LSBs. (In this case, the mask value is the same on MSB and LSB.)

For registers with a length less than 16-bit (AIE, BSC, PSC), the signed value data is sign-extended to a 16-bit signed value data before being tested.

Figure 4.4 Extension of an 8-bit Mask to 16-bit Mask

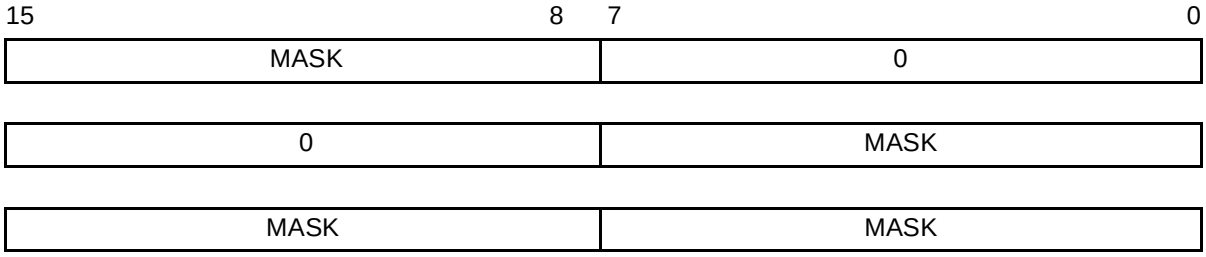
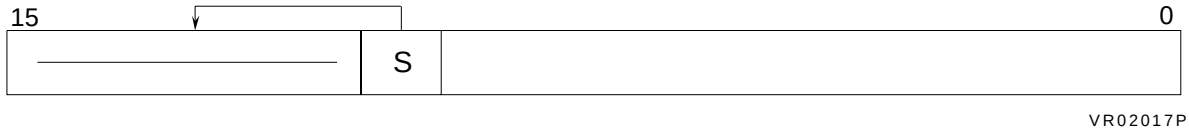


Figure 4.5 Sign Extension to a 16-bit Signed Value



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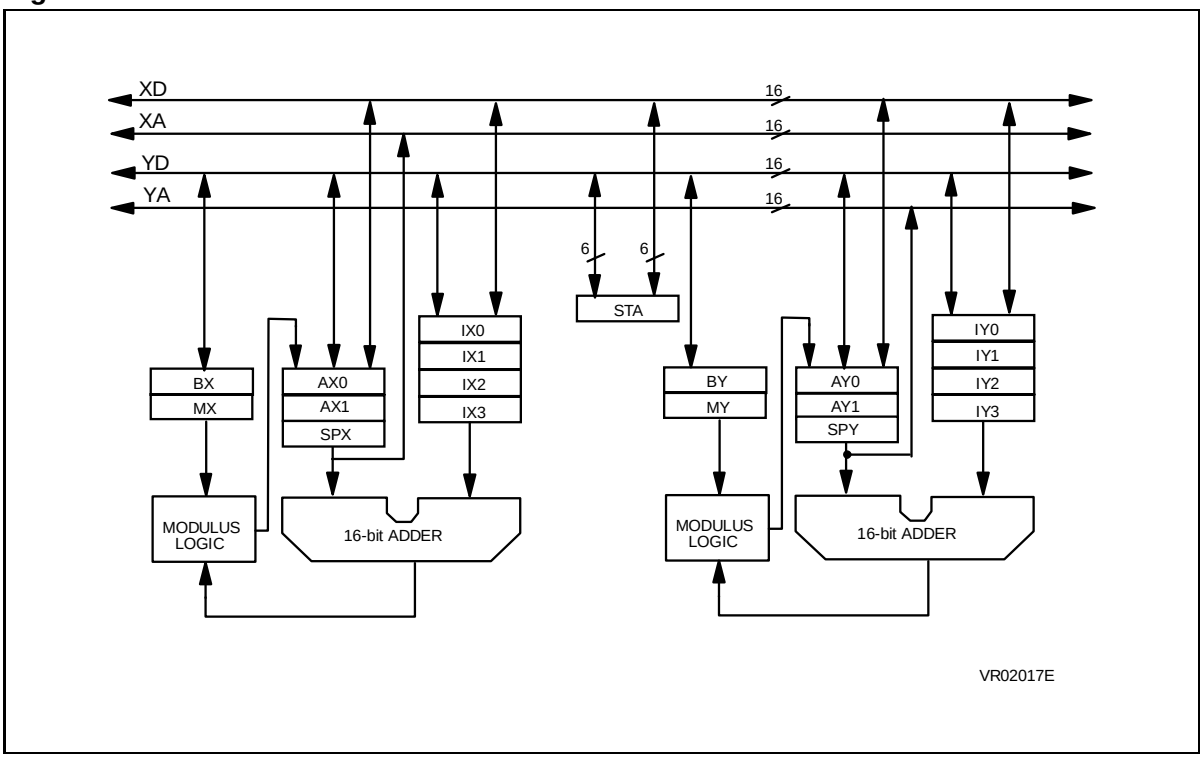
4.2 Address Calculation Unit (ACU)

4.2.1 Introduction

The D950-Core ACU includes two identical address generators (one for each data memory space), each containing:

- 2 x 16-bit address registers
- 4 x 16-bit index registers
- Adder for address register update
- 2 x 16-bit base and maximum address registers for modulo addressing. There is dedicated logic for address comparison and calculation.

Figure 4.6 D950-Core Address Calculation Unit



In addition to these two address generators, the D950-Core ACU includes:

- 16-bit Stack Pointer (SPX) register for the X-memory space mapped stack
- 16-bit Stack Pointer (SPY) register for the Y-memory space mapped stack
- 6 bits of STA register for addressing modes

4.2.2 Registers

The D950-Core ACU includes two types of registers: data registers and control registers

Data registers:

The following registers are directly addressed by instructions:

- 2 x 16-bit pointer registers and 4 x 16-bit index registers are dedicated for each data memory space:
  - AX0/AX1 (pointer), IX0/IX1/IX2/IX3 (index) for X-memory space,
  - AY0/AY1 (pointer), IY0/IY1/IY2/IY3 (index) for Y-memory space.

In addition to these registers, 16-bit SP registers address the stacks located in the X and Y-memory spaces.

The following four registers are mapped in Y-memory space:

- 2 x 16-bit base and maximum address registers are dedicated for each Data memory space:
  - BX (Base), MX (Maximum) for X-memory space,
  - BY (Base), MY (Maximum) for Y-memory space.

Control Register:

STA: Bits 8 to 13 are dedicated to ACU (see **Section 4.5.1**). Index register values are 16-bit signed.

4.2.3 Addressing modes

The D950-Core provides the following addressing modes:.

Addressing Modes	Type
DIRECT	
INDIRECT	LINEAR POST- INCREMENT
	MODULO POST-INCREMENT
	BIT-REVERSE POST-INCREMENT
	INDEXED
IMMEDIATE	
STACK	

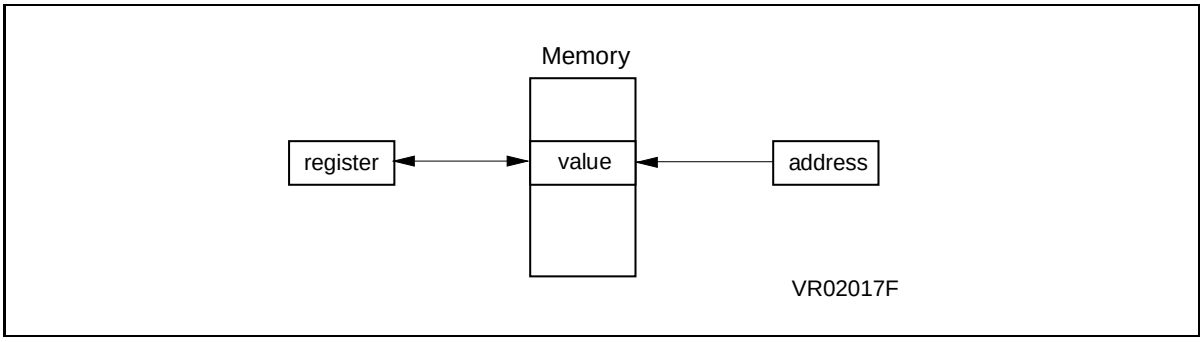
Direct addressing

Memory direct addressing instructions require one extension word to provide the memory address, and are executed in two cycles. They are used for data moves between memory and direct addressable registers.

Registers addressable by the instruction code include:

- 16 for DCU (L1/L0/R1/R0/A1E/A1H/A1L/A0E/A0H/A0L/PH/PL/BSC/PSC/STA/CCR),
- 13 for ACU (AX0/AX1/IX0/IX1/IX2/IX3/AY0/AY1/IY0/IY1/IY2/IY3/SPX),
- 3 for PCU (LS/LC/LE).

Figure 4.7 Direct Addressing



Indirect addressing

See RX1, RX0, MY1, MY0, MX1 and MX0 bits of the STA register. The instruction specifies the address register (AX0, AX1, AY0, AY1) of the operand to process, and the address calculation to be performed, according to STA register content.

At the end of the instruction, the new address register (AXi / AYi) contains the previously selected address (AXi / AYi), post-incremented by the corresponding index registers (IXi / IYi).

Four types of indirect addressing modes are implemented:

1: Linear addressing with post-modification.
Address modification is done using the normal 16-bit 2's complement linear arithmetic.

2: Modulo addressing with post-modification.
This mode can be selected individually for AX0, AX1, AY0, AY1 registers (see MX0, MX1, MY0, MY1 bits of STA register).
BX / MX: 16-bit register Base / Maximum address for AX0 / AX1,
BY / MY: 16-bit register Base / Maximum address for AY0 / AY1.
Base and maximum addresses can be defined to any value, provided that: the maximum address is greater than base address, the starting address is initialized within the base/maximum address range, the index absolute value is less than or equal to maximum address minus the base address.

3: Bit reverse addressing (on X-memory space only) with post-increment
This mode can be selected for AX0, AX1 (see RX0, RX1 bits of STA register). It generates the bit-reversed address for 2k point FFT implementation (Index value = 2k-1).

4: Indirect indexed addressing. The address of the operand is the sum of the contents of the address register (AXi, AYi, SPX or SPY) and the contents of the selected index register (IXi or IYi). This addition occurs before the operand is accessed and therefore requires an extra instruction cycle. The contents of the selected address and index registers are unchanged.

Figures **4.8** and **4.9** show the schematics for indirect addressing with and without post modification.

Figure 4.8 Indirect Addressing with Post-Modification

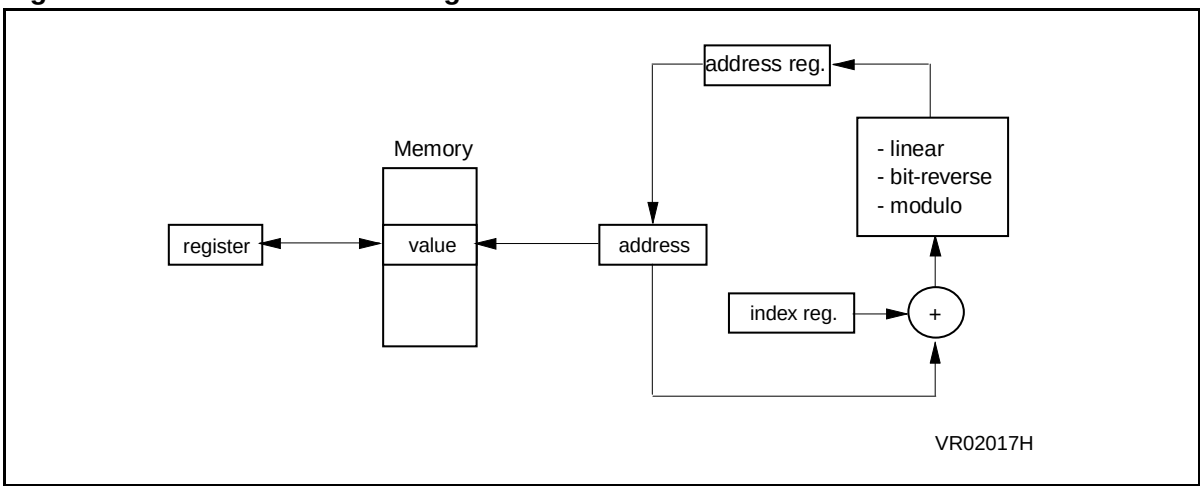
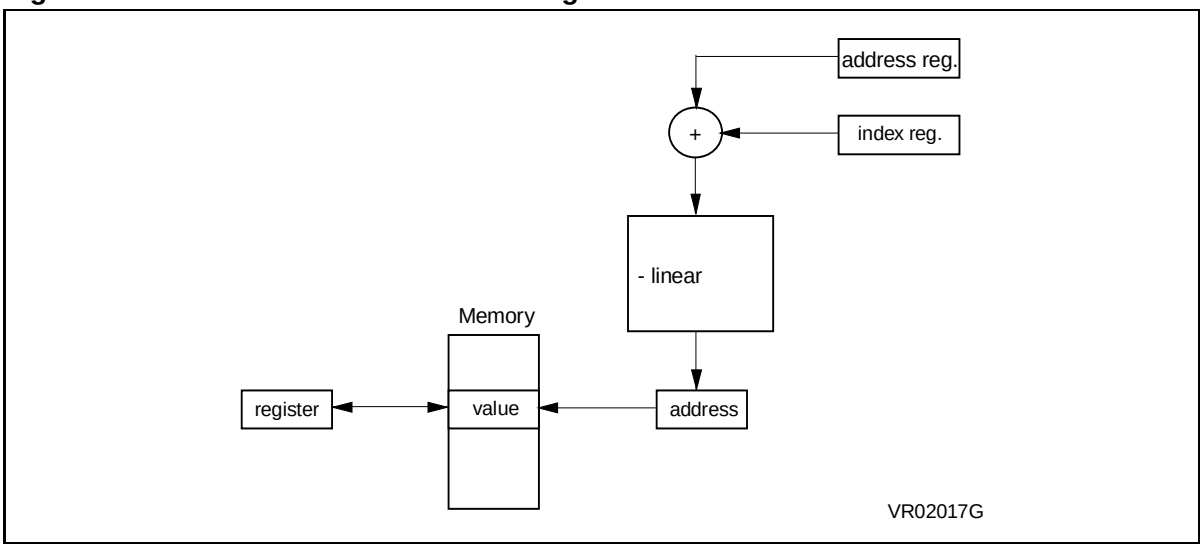


Figure 4.9 Indirect Indexed Addressing without Post-Modification



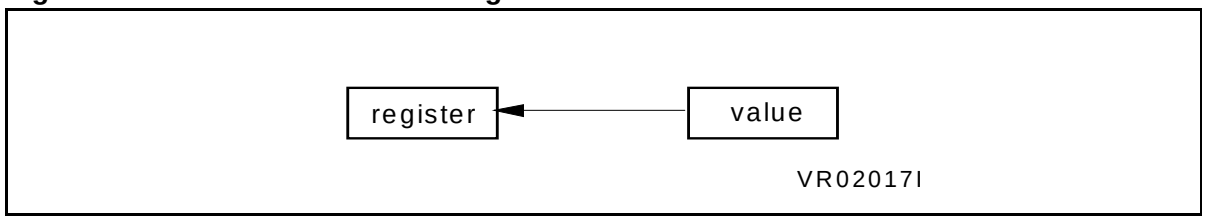
Immediate Data Addressing

This mode allows direct register loading. If the data is 16-bit long (see LR and LL bits of STA register), this mode requires one word of instruction extension to store the data.

Immediate short data addressing is possible on 6-bit data, without instruction extension:

If AXi, AYi or STA are concerned, the 6 LSB's are loaded from the instruction and the MSB's are unchanged. For all other registers, the MSB's are fed with 0

Figure 4.10 Immediate Addressing



Stack operation addressing

16-bit Stack Pointer register SPX is available for X-memory space and SPY for Y-memory space. It can be initialized to any value, provided it points to a stack dedicated memory area. The stack size is limited to the available memory. No provision is taken to detect stack overflows or underflows. After reset, the SP registers are not initialized.

The following addressing modes are possible with the 16-bit SP registers:

- For the X and Y stack pointer registers: PUSH (SP pre-decrement) or POP (SP post-increment) for register-to-stack move, memory-to-stack move and for immediate value-to-stack move.
  Double PUSH and double POP. In this operation, the PUSH or POP operation is performed simultaneously on the X and Y stack point register. This is used in a switching context.
- For the X stack pointer register only: Indirect indexed addressing for register-to-stack move.

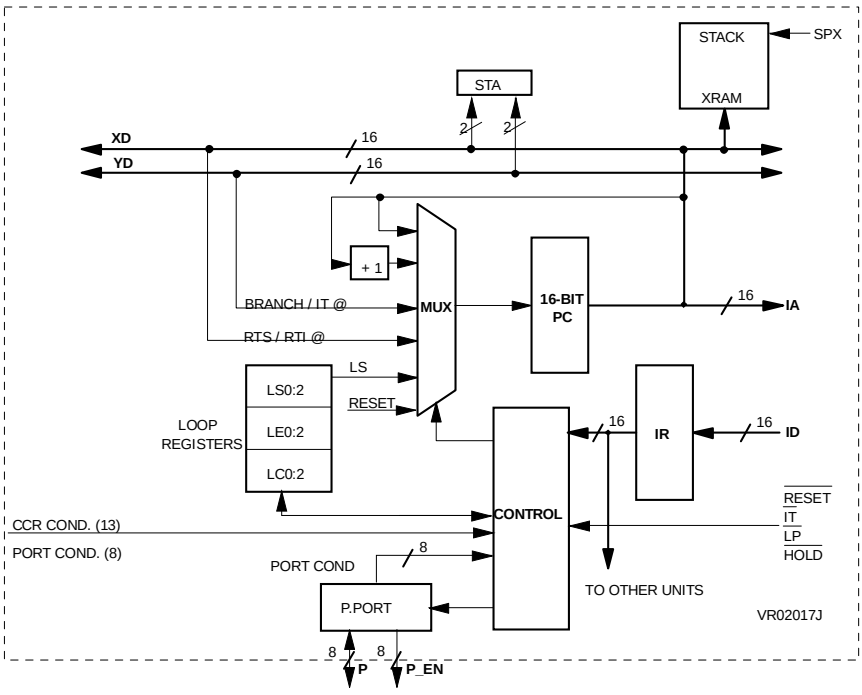
4.3 Program Control Unit (PCU)

4.3.1 Introduction

The D950-Core PCU includes the following components:

- 16-bit Program Counter (PC)
- 9 x 16-bit Loop registers (3 x LS, 3 x LE, 3 x LC)
- Branch and Hardware Loops control logic including CCR and PORT condition decoding
- 2 bits of STA register for interrupt control
- 2 bits of CCR for loop management
- Reset, Hold and Low-Power operation control logic
- Stack control logic for automatic PC save and restore in Subroutine Calls and Interrupts. (The Stack is implemented in a user-defined dedicated X-RAM area. The Stack pointer and its control logic are included in the ACU, see **Section 4.2.1**.)
- PPort

Figure 4.11 D950-Core Program Control Unit



4.3.2 Registers

Data registers

- LS0 / LS1 / LS2: 3 x 16-bit Loop Start address registers,
- LE0 / LE1 / LE2: 3 x 16-bit Loop End address registers,
- LC0 / LC1 / LC2: 3 x 16-bit Loop Count registers.

All these registers are addressed directly by the LSP instruction (see **Section 4.3.5**)

After reset, LSP = 0. (No hardware loop is selected).

Control registers

- STA: Bits 14 and 15 are dedicated to PCU (see **Section 4.5.1**).
- CCR: Bits 14 and 15 are dedicated to PCU (see **Section 4.5.2**).

4.3.3 Instruction pipeline

Instruction execution is performed in a 3-stage pipeline: fetch/decode/execute. While instruction n is executed, instruction n+1 is decoded and instruction n+2 is fetched.

The instruction cycle period is twice the CLKIN period.

According to the number of words used, D950-Core instructions can be of two types

- **One word instruction**: Inside this group, most D950-Core instructions are one cycle instructions (all arithmetic and logic instructions except instructions performing double precision multiplication and bit manipulations). Some instructions are multiple cycle instructions. Instructions causing a program flow change (JUMP, CALL, RTS, RTI, SWI, RESET, BREAK, CONTINUE) are executed in two or three cycles.
- **Instructions with extension words**: As one program memory word is fetched at each cycle, if an instruction needs extension words, they are fetched during the cycles following the first fetch.

4.3.4 Interrupt Sources

The D950-Core includes three interrupt sources. The following table orders the interrupt sources from highest to lowest priority

Table 4.2 Interrupt Sources and Priority

Sources		Priority
RESET	Non-Maskable	Highest
SWI	Non-Maskable	
INT	Maskable	Lowest

RESET

Non maskable (internally vectorized), either hardware or software (see **Table 6.3.3"Hardware Reset"**)

In hardware, when a low level is applied to the $\overline{\text{RESET}}$ input, the CLOCK generator is re-synchronized, the PC is reset, execution of NOP instructions is forced and control registers are initialized.

In order to get a valid reset, a low level must be applied for a minimum of ten CLKIN cycles (i.e five D950-Core cycles).

In software, the RESET instruction is a 3-cycle instruction having the same effects as a hardware reset, except the CLOCK generator is not re-synchronized.

The reset address is 0x0000. By setting the MODE pin to 1, the alternate reset address 0XFC00 is selected.

INT

Maskable external interrupt EI and IPE bits of STA register (see **Table 6.3.5"Interrupt"**)

Start of Interrupt: External interrupt is disabled on reset and is enabled by setting EI-bit to 1.

As soon as an $\overline{\text{IT}}$ falling edge is memorized and recognized by the PCU at the beginning of an instruction cycle, IPE-bit is set. Provided $\overline{\text{IT}}$ has been previously enabled, $\overline{\text{ITACK}}$ signal is asserted low to acknowledge the interrupt. $\overline{\text{ITACK}}$ stays at the low state for one cycle, allowing the interrupt vector to be provided by the controller on Y-bus. Then IPE-bit is reset. Interrupt start processing requires three cycles to read the interrupt vector and to fetch the corresponding instruction. Meanwhile, CCR register, STA and the return address are automatically saved onto the stack, located in X-memory space.

Return from Interrupt: Return from the interrupt is performed by the RTI instruction, a 3-cycle instruction during which the return address, STA register and CCR are retrieved from the stack. The $\overline{\text{EOI}}$ signal is then asserted low, allowing the controller to arbitrate pending interrupt requests and to issue, if required, the next interrupt request to the D950-Core.

An interrupt request that is recognized while decoding or executing a delayed branch instruction, is not acknowledged until all operations related to the branch have been completed.

In addition to this external interrupt source, a powerful interrupt controller is available as peripheral of the D950-Core (see **Section 7.3**).

SWI

Non maskable (internally vectorized) software interrupt SWI is a 3-cycle instruction whose interrupt routine address is 0x0002. Return from the SWI routine is performed through RTI. The SWI routine is non-interruptible by an external interrupt request.

Note: $\overline{IT}$ should not be asserted low if a previous request has not been acknowledged. In this case, the previous request will not be processed.
EI and IPE bits are not affected when STA register is restored.

4.3.5 Loop Controller

Table 4.3 Loop Instruction

Loop Instruction	Body of loop	Loop value
REPEAT	Single instruction	Immediate
	Block of instructions	Immediate
	Block of instructions	Computed

Hardware loop resources

The program sequencer includes a powerful hardware loop mechanism. This allows the nesting of up to three levels of loops by using nine 16-bit registers, organized in three banks of three registers.

Each bank includes one loop start address register (LS), one loop end address register (LE) and one loop count register (LC). These registers can be read and written by register move instructions, allowing extension of the number of nested loops by software.

The currently selected loop register bank is pointed to by bits LSP1 and LSP0 of the CCR. When the current level changes, this 2-bit register is incremented or decremented through dedicated instructions (see **Section 5.4.5"Conditional Assignment Instruction"**) to modify the bank.

Loop operation: REPEAT instruction

The REPEAT instruction performs automatic management of the different loop registers (LS, LC, LE and LSP) and defines the number of iterations and address of the last instruction of the loop.

The loop begins at the instruction following REPEAT. Conditional instructions CONTINUE and BREAK can be put within a loop. Their effect is to restart (resp. exit from) the loop when the condition is verified.

Notes 1: The maximum repeat count value of 2^{16}-1 is obtained by setting LC to 0xFFFF.

2: An endless loop can be set up by initializing LC to: 0x0000 for REPEAT block, 0x0001 for REPEAT single.

4.3.6 Sequence control

The PC is incremented at every cycle when the program flow is linear. Non linear sequencing occurs in the following cases:

- JUMP instructions
- CALL and RTS instructions (JUMP and CALL can be immediate or computed / delayed or not / conditional or not)
- CCR bit and PORT bit can be tested
- Interrupts and RTI instruction.
- Processing of automatic loops.

Extension of the program memory space to more than 64k x 16-bit, can be achieved by including a memory-mapped program page register (PPR) into the D950-Core glue logic. This register is read or written to by move instructions.

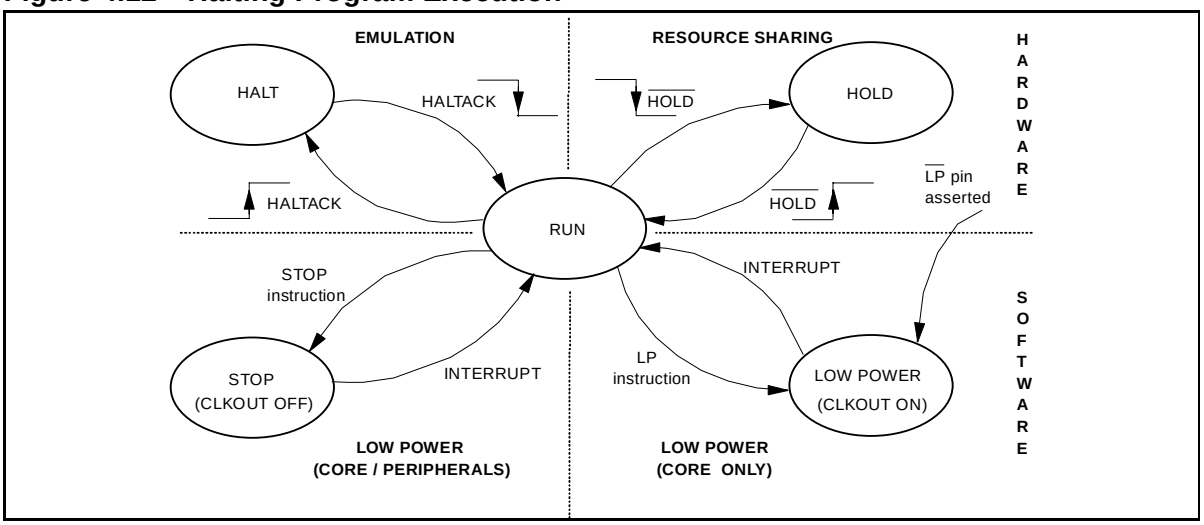
Due to the pipe-line of instruction execution, changing page by loading a value into PPR will be effective at the time of execution of the following instruction, which is read in the current page. This operation will work properly if no interrupt occurs between the PPR load and the JMP.

To avoid the need to disable interrupts by software, before page change, a special memory mapped register address has been defined for PPR at address 0x0062.Y. Whenever a write with direct address or a POP with direct address is attempted at this address, execution of the following instruction can not be interrupted.

4.3.7 Halting program execution

There are 4 ways to halt program execution: low power mode, stop mode, hold state and halt state. These 4 methods are detailed in the figure below and discussed in this section.

Figure 4.12 Halting Program Execution



Low Power Mode

There are two ways to enter the low power mode:

- Execution of LP instruction.
  The LP instruction is a 3-cycle conditional instruction. The Low Power mode is entered after the last execute cycle of the LP instruction.
- Driving $\overline{LP}$ to low state.
  $\overline{LP}$ is falling edge sensitive. Low Power mode can be entered only if the processor is not in HOLD state or in Emulation mode.

The instruction decoded at the time that a LP request is recognized, is executed. Entering Low Power mode is acknowledged by driving $\overline{LPACK}$ low.

When operating in Low Power mode, the D950-Core enters an idle state. In this state, the following events occur:

- The clock generator is stopped (internal cycle clock) and INCYCLE remains active. BSU_CLK, DMA_CLK are stopped.
- The internal state of the processor is frozen.
- X and Y data buses stay driven to Hi-Z.
- The bus address lines and control lines are driven to Hi-Z.

Exit of Low Power mode: Initiated by detecting a falling edge on $\overline{IT}$. The processor clock generator is restarted and $\overline{LPACK}$ is driven to a high state. If interrupts were disabled, program execution restarts from the current PC and interrupt handshake signals $\overline{ITACK}$ and $\overline{EOI}$ are not activated. If interrupts were enabled, a normal interrupt process starts.

STOP Mode

STOP mode is entered by use of the STOP instruction. The STOP instruction is processed as the LP instruction, all clocks are stopped at the same time as the internal clock is stopped. The $\overline{LPACK}$ signal is activated in the same way as for LP instruction.

Exit of the STOP mode is performed by detection of an interrupt request with the same conditions as for exit of LP. $\overline{LPACK}$ signal is activated in the same way as for $\overline{LP}$.

HOLD State

This function allows the release of the buses for another device such as a DMA controller (see **Section 6.3.6**).

Entering HOLD state: The HOLD signal is sampled at the beginning of every cycle. When $\overline{\text{HOLD}}$ is recognized low, the processor immediately releases the I-bus and then releases the X and Y buses after execution of the currently decoded instruction. Bus address, data and control lines are then tri-stated.

Program execution is stopped and $\overline{\text{HOLDACK}}$ is asserted low during HOLD state.

Note:HOLD state can not be entered when the processor is in emulation mode.

Exit of HOLD state: The processor recovers bus mastership as soon as $\overline{\text{HOLD}}$ is sampled high and next instruction is fetched.

HALT State

This function is used in emulation mode only. It is used to stop program execution by use of the peripheral emulator unit (see **Section 7.5**).

4.3.8 Memory Moves with Wait States

$\overline{\text{DTACK}}$ input is used to stretch instruction cycles, in order to access slower memory and/or peripherals. $\overline{\text{DTACK}}$ is sampled on the rising edge of CLKIN. If $\overline{\text{DTACK}}$ is high on the third rising edge of the cycle, the cycle is extended by two CLKIN cycles (see **Section 6.3.4**). Extension cycles are added by the clock generator until $\overline{\text{DTACK}}$ is recognized low.

Note:$\overline{\text{DTACK}}$ generation can be controlled by the Bus Switch Interface peripheral (see **Section 7.2**).

4.4 General Purpose P-Port

4.4.1 Introduction

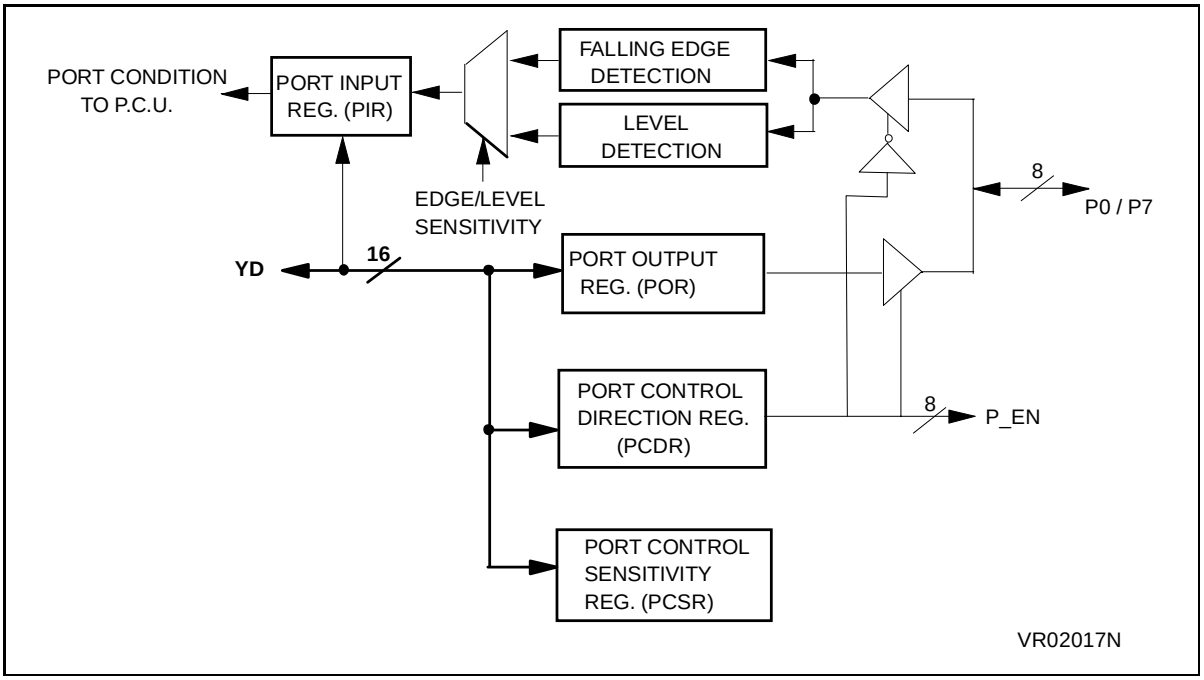
The P-Port is an 8-bit (P0/P7) general purpose parallel port in which each port pin can be individually programmed as input (level or falling edge sensitive) or output.[1]

The data direction and sensitivity for each bit are programmed through PCDR and PCSR 8-bit registers.

Port inputs are sampled on each INCYCLE rising edge. Detection of a level change is performed, provided the input remains at the same level for at least one INCYCLE cycle.[2]

The Port input data is stored into the 8-bit Port Input Register (PIR). The Port output data is stored into the 8-bit Port Output Register (POR).[3]

Figure 4.13 D950-Core Parallel I/O Port



Notes 1: PPort can be used as a branch condition.

2: PIR value is set to 1 on falling edge detection,until the port is tested.

3: The significant bit are 8-LSBs (8-MSBs=undefined when reading).

4.4.2 Registers

PCDR

The Port Control Direction register defines the data direction of each port pin. After reset, PCDR default value is 0 (Port pins are configured as inputs).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
-	-	-	-	-	-	-	-	P7D	P6D	P5D	P4D	P3D	P2D	P1D	P0D

PiD: Port pin direction

0: Input port pin (def.)

1: Output port pin

- : for bits 8 to 15 indicates RESERVED (read: undefined, write: don't care)

PCSR

The Port Control Sensitivity register defines sensitivity of each port pin. After reset, PCSR default value is 0 (Port pins are configured as level-sensitive).

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
-	-	-	-	-	-	-	-	P7S	P6S	P5S	P4S	P3S	P2S	P1S	P0S

PiS: Port pin sensitivity

0: Level sensitive (def.)

1: Edge sensitive

- : for bits 8 to 15 indicates RESERVED (read: undefined, write: don't care)

4.5 Common Control Registers

4.5.1 STA: Status register

STA is a 16-bit status register shared by both the DCU, the ACU and the PCU.

Bits 0 to 7 are dedicated to DCU which defines the calculation mode for certain instructions and specifies the type of operands to be used. Bits 8 to 13 are dedicated to the ACU which initializes circular and bit-reverse addressing modes. Bits 14 and 15 are dedicated to the PCU which controls interrupts.

After reset, STA default value is 0x004C.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EI	IPE	RX1	RX0	MY1	MY0	MX1	MX0	RND	ES	SAT	I	SR	SL	LR	LL
PCU		ACU						DCU							

EI: Enable Interrupt

0: Interrupt is disabled (def.)

1: Interrupt is enabled

IPE: Interrupt Pending: Set and reset by software only using the bit manipulation instruction.

0: Reset by hardware when the interrupt is acknowledged (def.)

1: Set by hardware when the trigger event occurs or by the programmer to generate an interrupt.

RX1: Bit reverse addressing mode for AX1

0: No bit reverse addressing mode for AX1 (def.)

1: Bit reverse addressing mode is selected for AX1

RX0: Bit reverse addressing mode for AX0

0: No bit reverse addressing mode for AX0 (def.)

1: Bit reverse addressing mode is selected for AX0

MY1: Modulo addressing mode for AY1

0: No modulo addressing mode for AY1 (def.)

1: Modulo addressing mode is selected for AY1. AY1 is updated through the Y-memory space modulo logic.

MY0: Modulo addressing mode for AY0

0: No modulo addressing mode for AY0 (def.)

1: Modulo addressing mode is selected for AY0. AY0 is updated through the Y-memory space modulo logic.

MX1: Modulo addressing mode for AX1

0: No modulo addressing mode for AX1 (def.)

1: Modulo addressing mode is selected for AX1. AX1 is updated through the X-memory space modulo logic.

MX0: Modulo addressing mode for AX0

0: No modulo addressing mode for AX0 (def.)

1: Modulo addressing mode is selected for AX0. AX0 is updated through the X-memory space modulo logic.

RND: Rounding type for ALU operation

0: Convergent rounding (def.)

1: Two's complement rounding

ES: Extended Saturation

0: The saturation is active when a 32-bit overflow occurs (if SAT=1)

1: The saturation is active when a 40-bit overflow occurs (if SAT=1) (def.)

SAT: Saturation

0: ALU is not in saturated mode (def.)

1: ALU is in saturated mode

I: Integer Product

0: Product is in fractional format (if signed * signed, one bit is shifted left before storing the result into P register) (def.)

1: Product is in integer format (no shift and direct transfer into P register)

SR: Right side operand type (only used for product calculation and division)

0: Right side operand is unsigned

1: Right side operand is signed (def.)

SL: Left side multiplicand type (only used for product calculation)

0: Left side multiplicand is unsigned

1: Left side multiplicand is signed (def.)

LR: Right side long data

0: Normal 16-bit data mode (def.)

1: Data contained in R0 and R1 is long 32-bit data (the 16 MSB's in R1, the 16 LSB's in R0)

LL: Left side long data

0: Normal 16-bit data mode (def.)

1: Data contained in L0 and L1 is long 32-bit data (the 16 MSB's in L1, the 16 LSB's in L0)

4.5.2 CCR: Condition Code Register

CCR is a 16-bit register shared by both the DCU (bits 0 to 12) and the PCU (bits 14 and 15).

This register is affected each time an ALU operation occurs, and gives information on the last result stored in A0 or A1 accumulator.

After reset, CCR default value is 0.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LSP1	LSP0	-	TST	C31	NQ	CS	PAR	MN	N	EXT	MOVF	OVF	Z	C	S
PCU		-	DCU												

LSP1/LSP0 Loop Stack Pointer

00: No loop / Bank 1 (def.)

01: Loop level 1 / Bank 1

10: Loop level 2 / Bank 2

11: Loop level 3 / Bank 3

TST: Result of the test instructions in bit manipulation or last bit shifted out in pure shift operations

C31: Carry value generated out of bit 31 during the last ALU operation (always loaded except for DMULT instruction)

NQ: 1's complement of next quotient bit (only affected by DIVS and DIVQ instructions)

CS: Compared sign updated by CMPS instruction as the XOR of the two ALU operand signs (bit 31) (used also by DIVS, RESQ and RESR instructions)

PAR: Parity of the last ALU result.

0: Bit 16 of the last 40-bit ALU result is 0 (def.)

1: Bit 16 of the last 40-bit ALU result is 1

MN: Memorized normalized

0: Reset when tested by a conditional instruction (def.)

1: Set when ALU result is normalized

N: Normalized

0: ALU result is not normalized (def.)

1: ALU result is normalized (bits 31 to 39 are equal & opposed to bit 30)

EXT: Extension

0: The 8-bit extension is the sign of the 32-bit ALU result

1: The last ALU result overflows the 32-bit format

MOVF: Memorized overflow

0: Reset when tested by a conditional instruction (def.)

1: Set when the last ALU result overflows the 40-bit format

OVF: Overflow

0: An arithmetic overflows does not occur for the last 40-bit ALU result (def.)

1: An arithmetic overflow occurs for the last 40-bit ALU result

Z: Zero

0: ALU result is different from zero (def.)

1: ALU result is zero

C: Carry value generated out of bit 39 during the last ALU operation

S: Sign

0: ALU result is positive (def.)

1: ALU result is negative

Note:'-' for bit 13 indicates RESERVED (read: 0, write: don't care)

Table 4.4 Table of Conditions

	Notation		Description
	ALWAYS	**NEVER**	
Test of CCR bits	Z	NOZ	Zero bit of CCR
	LT	GTE	S XOR OVF bits of CCR
	LTE	GT	(S XOR OVF) OR Z bits
	C	NOC	Carry bit of CCR (bit 39)
	S	NOS	Sign bit of CCR
	EXT	NOEXT	Extension bit of CCR
	OVF	NOOVF	Overflow bit of CCR
	MOVF	NOMOVF	Memorized overflow
	N	NON	Normalised bit of CCR
	MN	NOMN	Memorized Normalised
	PAR	NOPAR	Parity bit of CCR
	C31	NOC31	Carry bit of CCR (bit 31)
	TEST	NOTEST	Test bit of CCR
Test of Port bits	P0	NOP0	Bit 0 of Parallel Port
	P1	NOP1	Bit 1 of Parallel Port
	P2	NOP2	Bit 2 of Parallel Port
	P3	NOP3	Bit 3 of Parallel Port
	P4	NOP4	Bit 4 of Parallel Port
	P5	NOP5	Bit 5 of Parallel Port
	P6	NOP6	Bit 6 of Parallel Port
	P7	NOP7	Bit 7 of Parallel Port

Table 4.5 Direct Address Register Table

Register Name	Function	Location
AX0	X address register	ACU
AX1	X address register	ACU
AY0	Y address register	ACU
AY1	Y address register	ACU
IX0	X index register	ACU
IX1	X index register	ACU
IX2	X index register	ACU
IX3	X index register	ACU
IY0	Y index register	ACU
IY1	Y index register	ACU
IY2	Y index register	ACU
IY3	Y index register	ACU
SPX	Stack Pointer register	ACU
LS	Loop Start register	PCU
LC	Loop Count register	PCU
LE	Loop End register	PCU
L0	DCU input left register (LSB)	DCU
L1	DCU input left register (MSB)	DCU
R0	DCU input right register (LSB)	DCU
R1	DCU input right register (MSB)	DCU
PL	Product register (LSB)	DCU
PH	Product register (MSB)	DCU
CCR	Condition Code Register	DCU
STA	Status register	DCU
A0L	Accumulator 0 (LSB)	DCU
A0H	Accumulator 0 (MSB)	DCU
A0E	Accumulator 0 (Extension)	DCU
BSC	Barrel Shifter Control register	DCU
A1L	Accumulator 1 (LSB)	DCU
A1H	Accumulator 1 (MSB)	DCU
A1E	Accumulator 1 (Extension)	DCU
PSC	Product Shift Control register	DCU

Note: Memory mapping is described in the appendix (see **Section 8**)

5 SOFTWARE ARCHITECTURE

5.1 Introduction

Instruction execution is performed in a 3-stage pipeline: fetch/decode/execute. While instruction n is executed, instruction n+1 is decoded and instruction n+2 is fetched. The instruction cycle period is twice the CLKIN period. According to the number of words used, D950-Core instructions can be of two types: one word intructions or extension word instructions.

One Word Instructions:

Most of D950-Core instructions are one cycle instructions:

- All arithmetic and logic instructions with or without parallel data moves, excepted instructions performing double precision multiplication and bit manipulations.
- Register to register data move.
- Memory to register indirect data move.

The following are multiple cycle instructions:

- Double precision MAC (two cycles).
- Indirect indexed register move (two cycles).
- Indirect indexed register to stack move (two cycles).
- Register to Program memory transfer (four cycles).

Instructions causing a program flow change (RTS, RTI, SWI, RESET, BREAK, CONTINUE) are executed in one to three cycles.

Extension Word Instructions:

One program memory word is fetched at each cycle, therefore, if an instruction needs extension words, they are fetched during the cycles following the first fetch. Execution of the instruction starts two cycles after its first fetch cycle.

- Memory to register data move in direct addressing mode (2-words/2-cycles) (second word = address value).
- Immediate register load (2-words/2-cycles) (second word = register value).
- Repeat block up to 511 times (2-words/2-cycles) (second word = LE).
- Repeat single up to 2^{16}-1 times (2-words/2-cycles) (second word = LC).
- Repeat block computed (2-words/2-cycles) (second word = LC).
- Bit manipulations (2-words/2-cycles) (second word = mask).

- Immediate push (2-words/3-cycles) (second word = immediate value).
- Push/pop direct addressing mode(2-words/3-cycles)(2nd word=direct address).
- Repeat block up to 2^{16}-1 times (3-words/3-cycles)(2nd word = LC, 3rd word = LE).
- JUMP and CALL instructions.

5.2 Register List

The registers used in the D950-Core instruction set are:

- AX0, AX1, AY0, AY1 address pointers.
- IX0, IX1, IX2, IX3, IY0, IY1, IY2, IY3 index registers.
- SPX SPY stack pointers.
- LS, LC, LE loop registers.
- A0E, A0H, A0L, A1E, A1H, A1L accumulator registers.
- PH, PL product registers.
- CCR code condition register.
- STA status register.
- BSC barrel shifter control register.
- PSC product shift control register.
- DCU0CR DCU control register.

5.3 Condition List

A table of conditions is contained in **Table 4.4**

5.4 Instruction set

The D950-Core instruction set is divided into different groups, according to operation type.

- Assignment
- ALU
- Bit Manipulation
- Program control
- Loop control
- Co-processor
- Stack.

Inside this instruction set, following notations are used:

- reg: D950-Core internal register
- AX (resp. AY): address pointer for X (resp. Y) memory space
- IX (resp. IY): index pointer for X (resp. Y) memory space
- L: input left register of DCU (L1 16-MSBs / L0 16-LSBs)
- R: input right register of DCU (R1 16-MSBs / R0 16 LSBs)
- A: 40-bit accumulator (A0 or A1)
- AiH: 16-MSB of the Ai accumulator
- P: Product result of the multiplier
- i,j,k,m,n,p,q,x,y: 0 or 1
- r,: 0,1,2 or 3
- xx: 0,1,2,3,4,5,6,7,8,9,10,11,12,13,14 or 15

5.4.1 Assignment Instructions

Figure 5.1 Assignment Operations

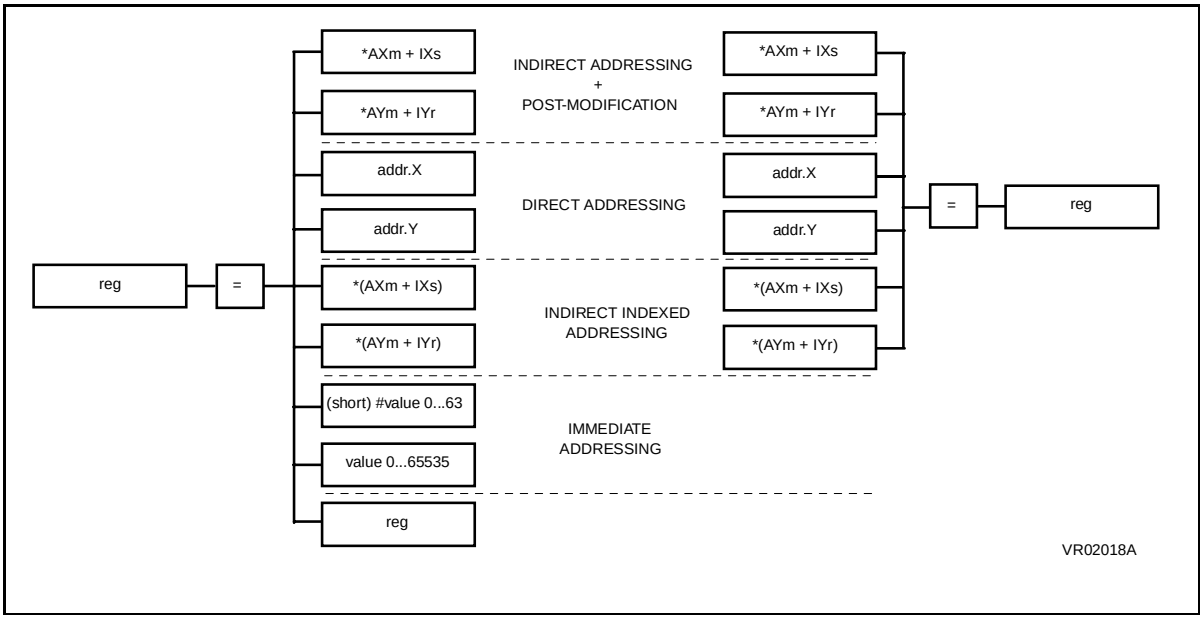


Figure 5.2 Assignment Operations

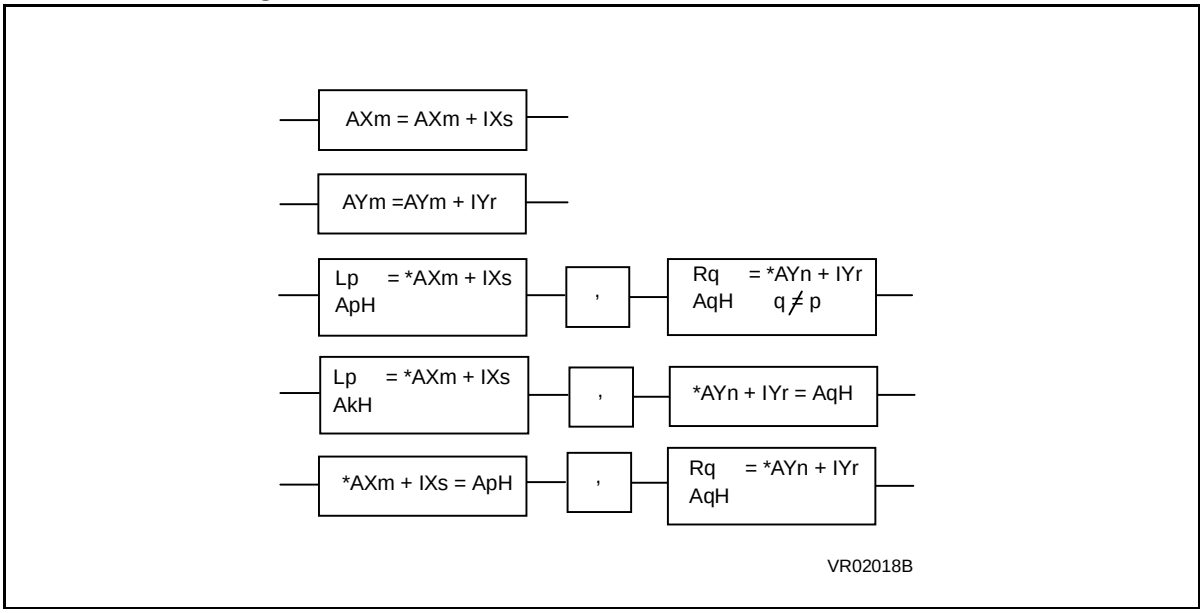


Figure 5.3 Assignment Operation Control System Register

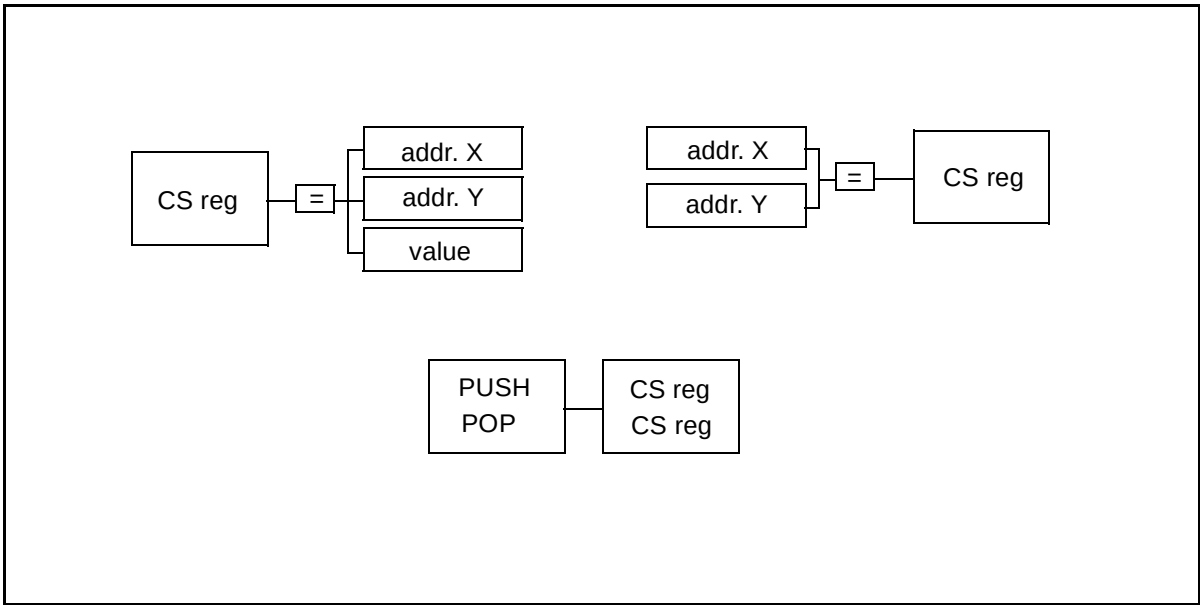
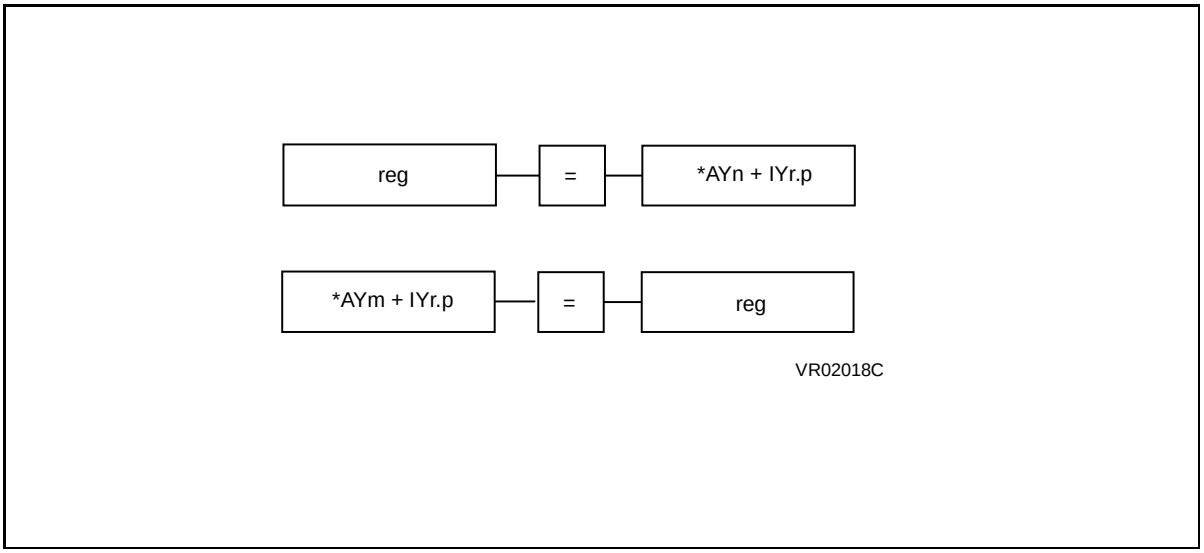


Figure 5.4 Register/Program Memory Assignment Operations



5.4.2 ALU Instructions

One-word Operand (oper_1)

CLR Clear Accumulator (AiE:AiH:AiL = 0)

CLRH Clear 24 MSBs of Accumulator (AiE:AiH = 0)

CLRL Clear 16 LSBs of Accumulator (AiL = 0)

CLRE Clear 8 Extension bits of Accumulator (AiE = 0)

SET Set Accumulator (AiE:AiH:AiL = 0xFF FFFF FFFF)

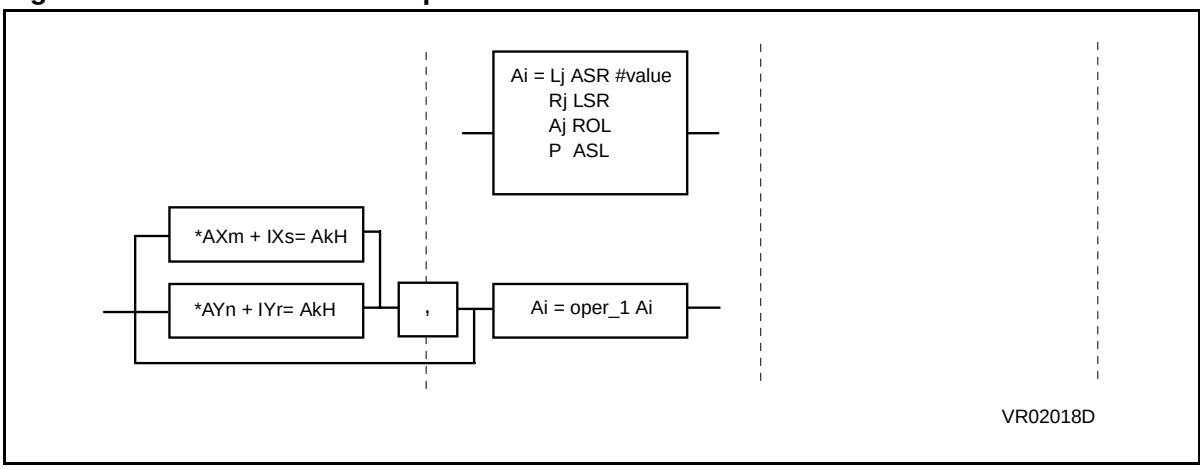
SETH Set 24 MSBs of Accumulator (AiE:AiH = 0xFF FFFF)

SETL Set 16 LSBs of Accumulator (AiL = 0xFFFF)

SEXT Accumulator is sign extended (AiE loaded with 8 times the MSB of AiH:AiL)

ROUND Rounds the 40-bit accumulator value

Figure 5.5 ALU One-word Operand



Note: value=1...32 for ASR, value=0...32 for ROL,
value=1...32 for LSR and value=0...31 for ASL

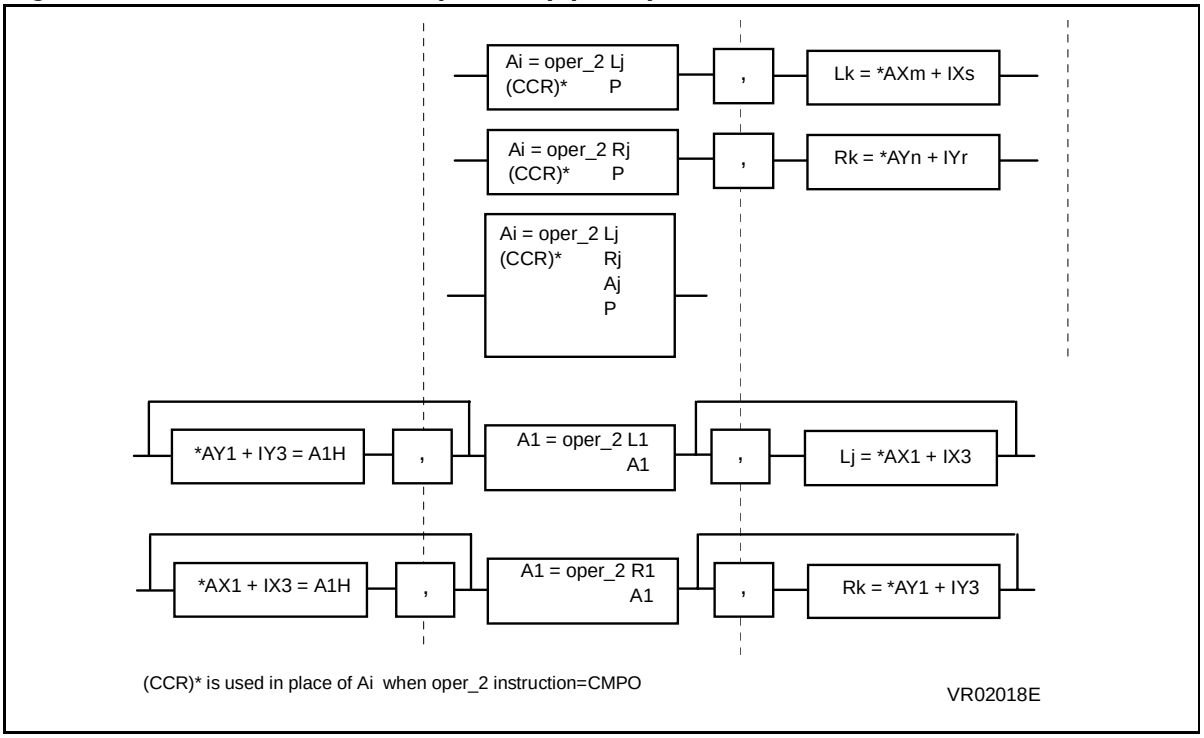
Two-word Operand (oper_2)

ABS	Absolute value
ASB	Arithmetical Shift with BSC
ASL	1-bit Arithmetic Shift Left
ASR	1-bit Arithmetic Shift Right
ASR16	16-bit Arithmetic Shift Right
CHKDIV	Check Validity of Division
CMP0	Compare to 0
COM	Logical Complement
DEC	Decrement Accumulator
DECH	Decrement 24 MSBs of Accumulator
DIVQ	One Step of Division
DIVS	First Step of Division
EDGE	Exponent value of a number
EQU	Equal
INC	Increment
INCH	Increment 24 MSBs of Accumulator
LSB	Logical Shift with BSC
LSL	1-bit Logical Shift Left
LSL16	16-bit Logical Shift Left
LSR	1-bit Logical Shift Right
LSR16	16-bit Logical Shift Right
MAX	Maximum value of determination
MIN	Minimum value of determination
NEG	Negation
ROB	Rotation with BSC (Left or Right)
ROL	1-bit Rotation Left
ROLTEST	1-bit Rotation Left with Test
ROL16	16-bit Rotation Left
RESQ	Restore Quotient
RESR	Restore Remainder

+= Last Step of Positive MAC (PSC used for shift value)

-= Last Step of Negative MAC (PSC used for shift value)

Figure 5.6 ALU Two-Word Operand (oper_2)



Three-word Operand (oper_3)

ADD Addition

ADDCAddition with Carry

ADDS Addition with Shift

AND Logical AND

CMP Compare

CMPS Compare Sign

OR Logical OR

SUB Subtraction

SUBC Subtraction with Carry

SUBR Reversed Subtraction

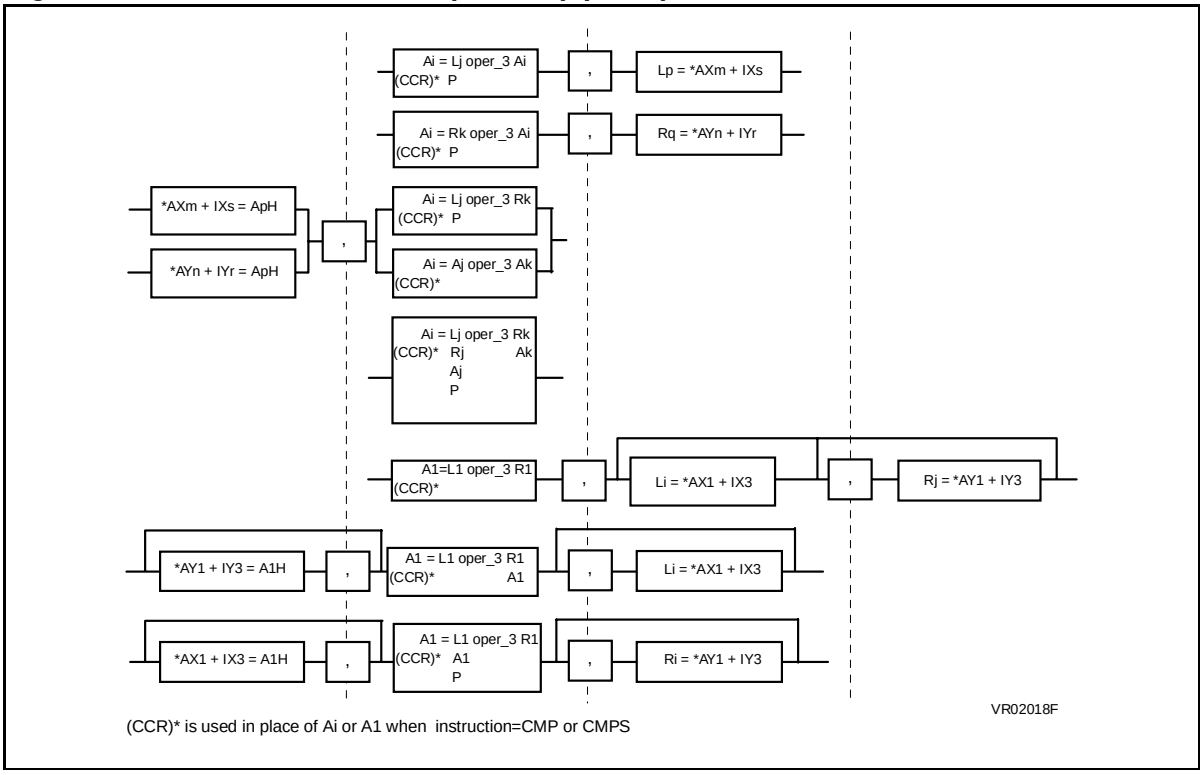
SUBRC Reversed Subtraction with Carry

SUBRS Reversed Subtraction with Shift

SUBS Subtraction with Shift

XOR Exclusive OR

Figure 5.7 ALU Three-Word Operand (oper_3)



Multiplier Operations

DMULT Double precision multiplication

MULT Multiplication

SQR Square

Figure 5.8 Double precision multiplication

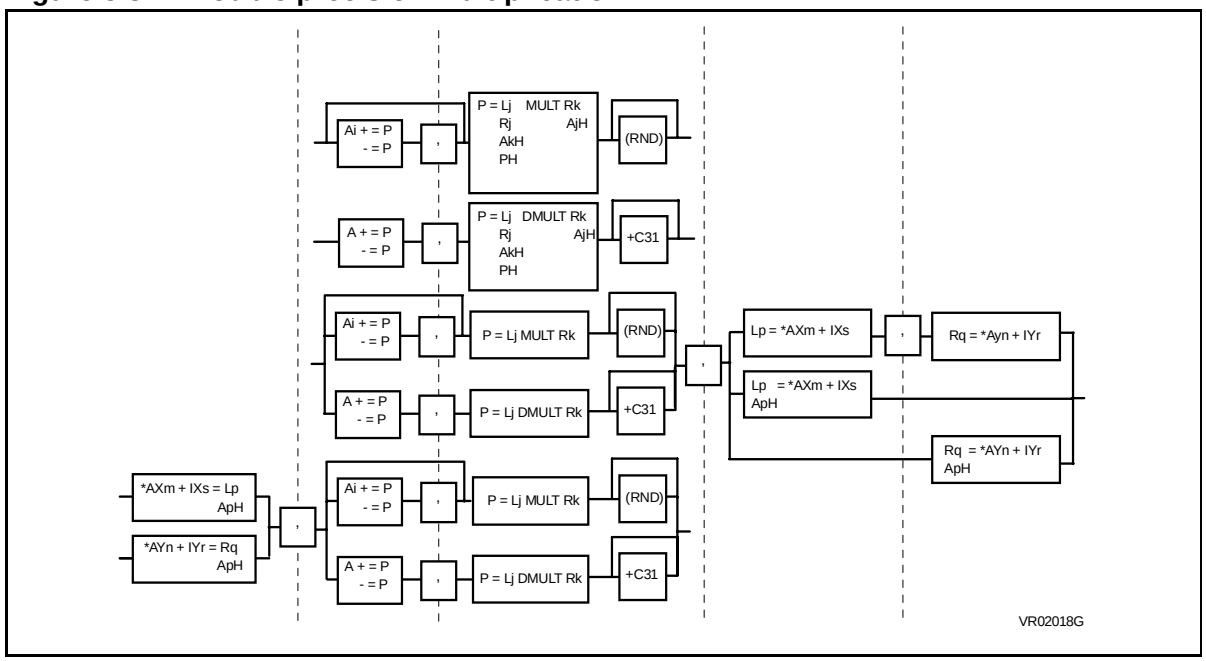


Figure 5.9 Multiplication

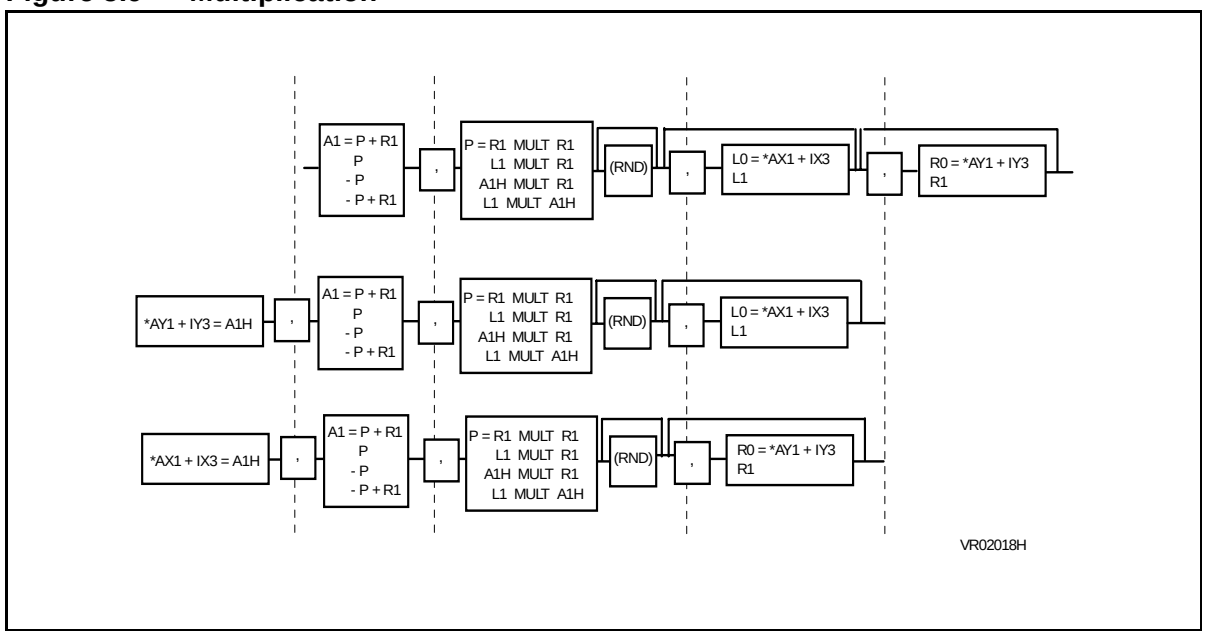
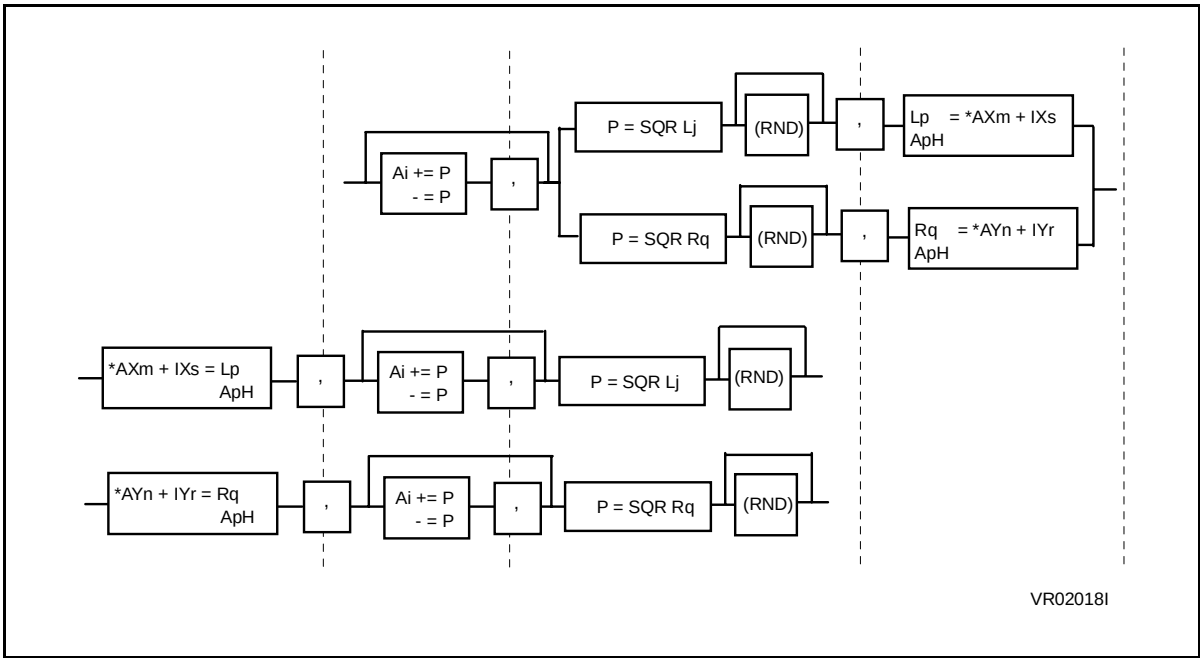


Figure 5.10 Square



5.4.3 Bit Manipulation Instructions

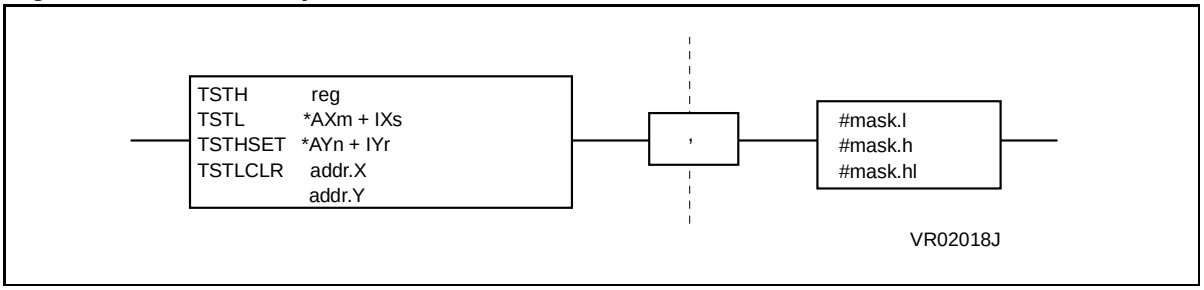
TSTH Bit Test High

TSTL Bit Test Low

TSTHSET Bit Test High and Set

TSTLCLR Bit Test Low and Reset

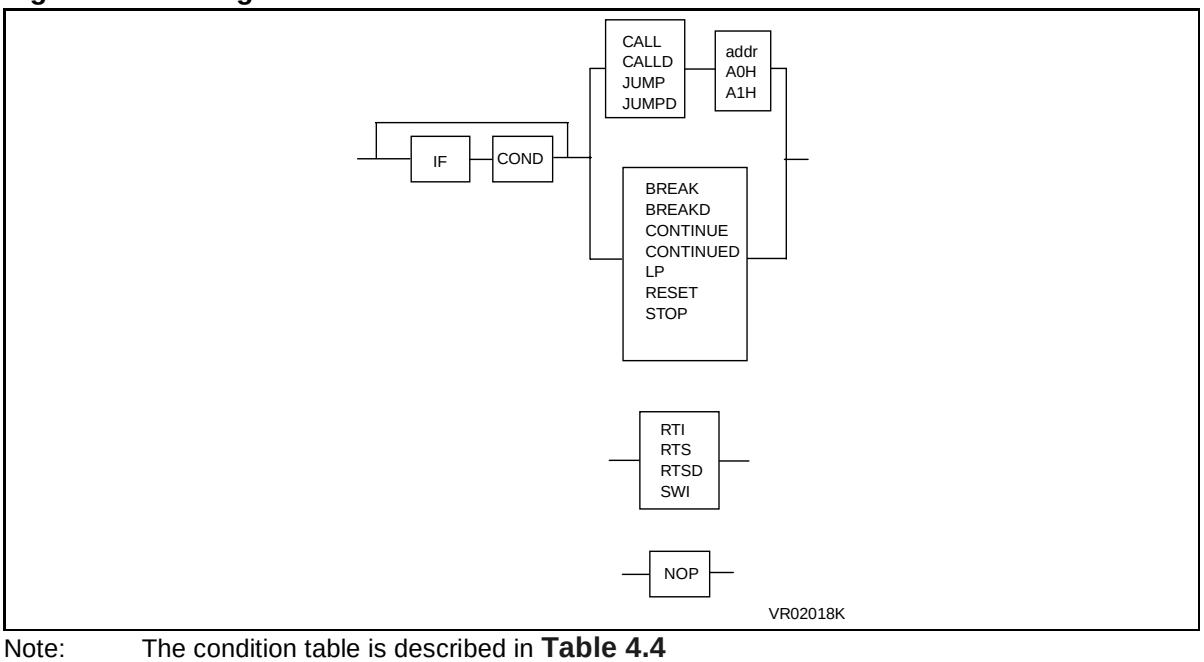
Figure 5.11 Bit Manipulation



5.4.4 Program Control Instructions

BREAK	Break
BREAKD	Break Delayed
CALL	Jump to Subroutine
CALLD	Call Delayed
CONTINUE	Continue
CONTINUED	Continue Delayed
JUMP	Jump
JUMPD	Jump Delayed
LP	Low Power
NOP	No operation
RESET	Reset
RTI	Return from interrupt
RTS	Return from subroutine
RTSD	Return from subroutine Delayed
STOP	Stop
SWI	Software interrupt

Figure 5.12 Program Control

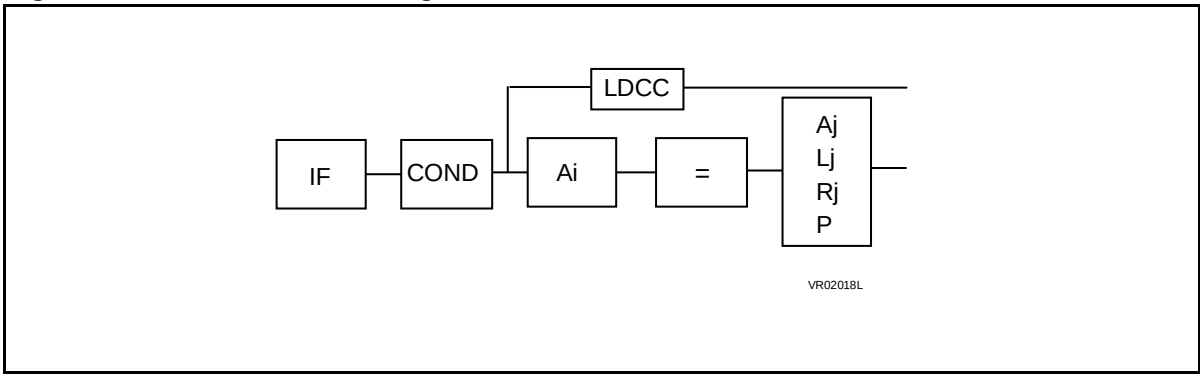


Note: The condition table is described in **Table 4.4**

5.4.5 Conditional Assignment Instruction

LDCC Load conditional: This instruction performs multiple assignment operations, depending on whether the conditions evaluate to be true or false. For full details of the instruction, refer to the programming manual.

Figure 5.13 Conditional Assignment



Note: The condition table is described in **Table 4.4**

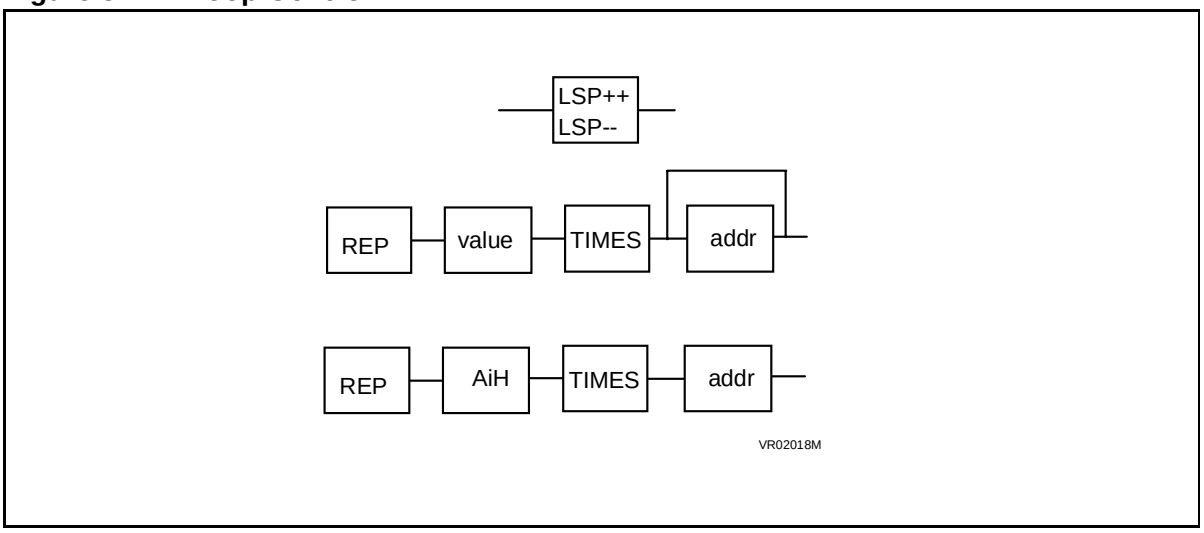
5.4.6 Loop Control Instructions

REP Automatic management of the loop registers (LS, LC, LE and SP)

LSP-- Decrement LSP 2-bit register

LSP++ Increment LSP 2-bit register

Figure 5.14 Loop Control

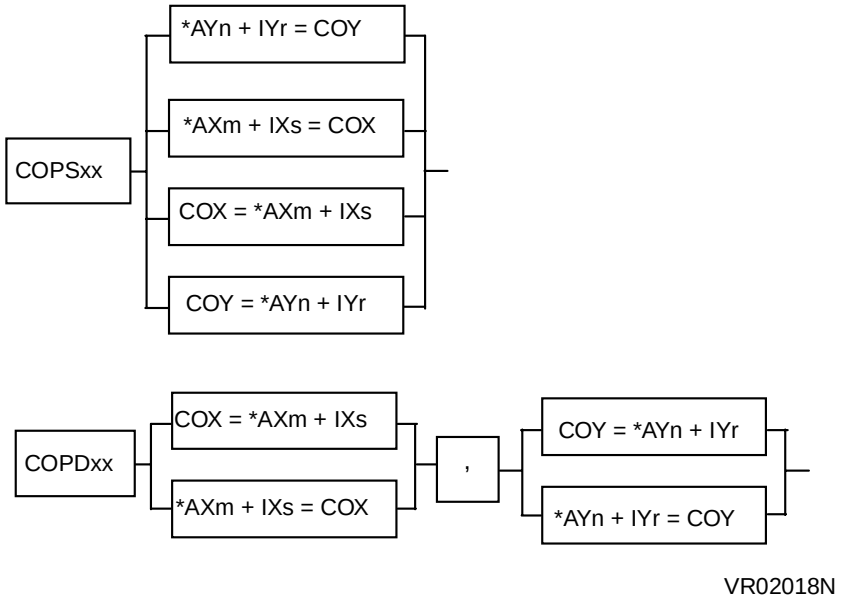


5.4.7 Co-processor Instructions

COPD Co-processor Double Move

COPS Co-processor Simple Move

Figure 5.15 Co-processor



Note: Increments allowed, depend on the register used (for COPD instruction only):

AX0:IX0/IX1

AX1:IX2/IX3

AY0:IY0/IY1

AY1:IY2/IY3

5.4.8 Stack Instructions

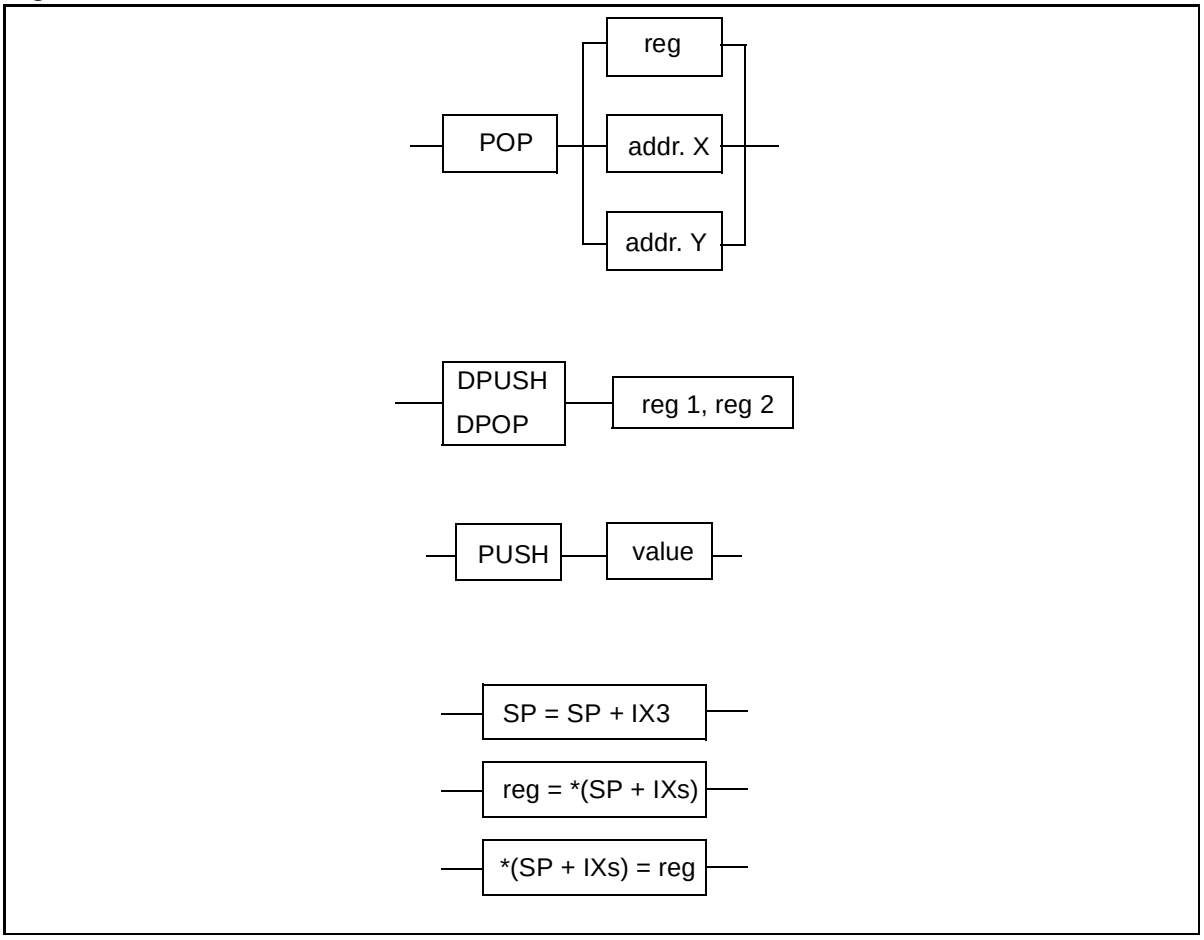
POP Retrieved from Stack

DPOP Double POP

PUSH Saved on the Stack

DPUSH Double PUSH

Figure 5.16 Stack



Note: All references to SP are taken by the assembler to be SPX.I

Register Pair	0:IX0,IY0	4:L1,L0	8:A0H,A0L	12:BSC/PSC,LC
	1:IX1,IY1	5:R0,R0	8:A1H,A1L	13:AOE/A1E,LE
	2:IX2,IY2	6:AX0,AY0	9:PH,PL	14:BX,BY
	3:IX3,IY3	7:AX1,AY1	10:CCR,LS	15:MX,MY

5.5 Instruction Cycle and Word Count

Table 5.1 Instruction Cycle and Word Count

Instruction Group / Subgroup	Words	Cycles
Assignment indirect single	1	1
Assignment indirect double	1	1
Assignment direct	2	2
Assignment indirect indexed	1	2
Assignment immediate short	1	1
Assignment immediate long	2	2
Assignment register to register	1	1
Assignment register / PRAM	1	4
ALU 1-word operand	1	1
ALU 2-word operand	1	1
ALU 3-word operand	1	1
MULT	1	1
DMULT	1	2
ALU Multiplication	1	1
SQR	1	1
Bit Manipulation	2	2
Program Control Non Delayed	1	2 or 3
Program Control Delayed	1	1 or 2
Conditional Assignment	1	1
LDCC	1	2
REPEAT (single) < 512	1	1
REPEAT (single) $\geq$ 512	2	2
REPEAT (block) < 512	2	2
REPEAT (block) $\geq$ 512	2 or 3	2 or 3
COPD	1	1
COPS	1	1
PUSH / POP register	1	1
DPUSH / DPOP register	1	1
PUSH / POP direct address	2	3
DPUSH / DPOP direct address	2	3
PUSH immediate value	2	3
DPUSH immediate value	2	3
INC SP	1	1
Register / Stack indirect indexed	1	2

6 ELECTRICAL SPECIFICATIONS

6.1 DC ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
VDD	Power Supply Voltage	-0.3 / 3.9	V
VIN	Input Voltage	-0.3 / 3.9	V
T_j	Operating Junction Temperature Range	-40 / +125	°C
TSTG	Storage Temperature Range	-55 / +150	°C

6.2 DC ELECTRICAL CHARACTERISTICS (core level)

Junction temperature : -40°C to +125°C

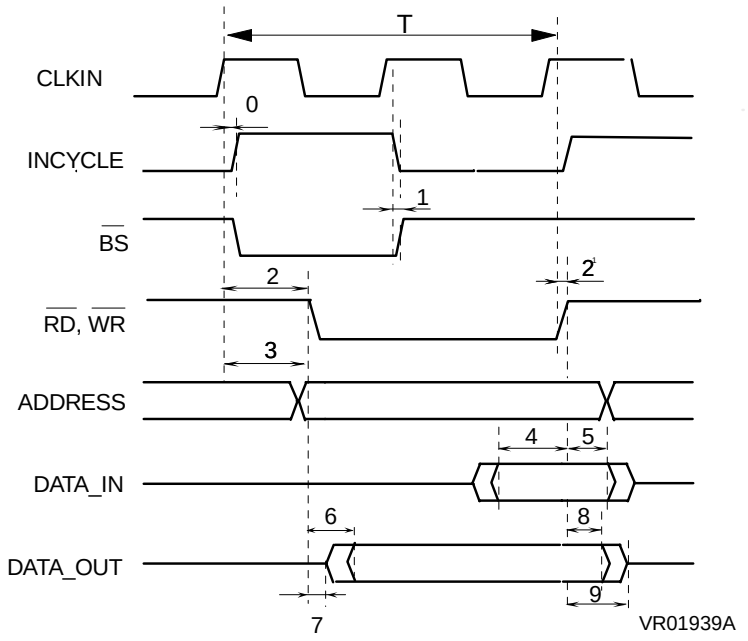
Symbol	Parameter	Min	Typ	Max	Unit
VDD	Power supply	2.7	3.3	3.6	V
VIL	Input low level	-0.3			V
VIH	Input high level			V_{DD} + 0.3	V
VOL	Output low level I_{OL} = 0			0.2	V
VOH	Output high level I_{OH} = 0	V_{DD}- 0.2			V
IDD	Operating current		0.6		mA/MIPS
ILP	Low Power current		0.1		mA/MHz
ISTOP	Stop current		10		µA

6.3 AC CHARACTERISTICS

Conditions : VDD= 2.7V - 3.6V, Junction temperature : -40°C to +125°C

6.3.1 Bus AC Electrical Characterstics (for X, Y and I buses)

Figure 6.1 Bus AC Electrical Characterstics (for X, Y and I buses)

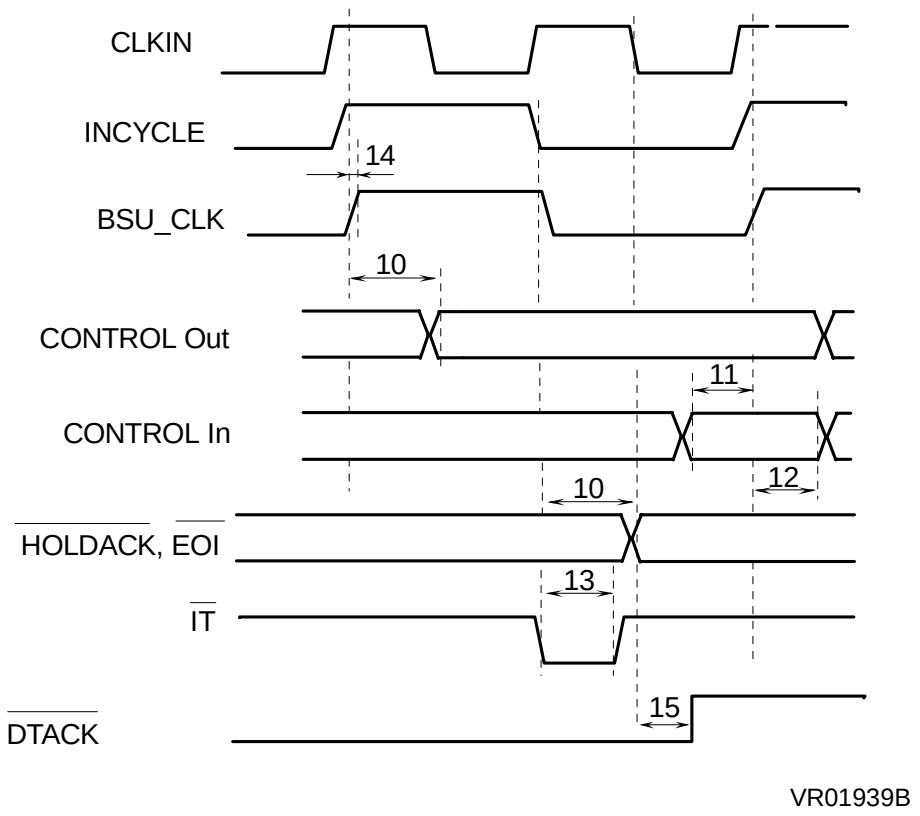


Num	Parameter		Min	Typ	Max.	Unit
T0	CLKIN High to INCYCLE High			2.3		ns
T1	INCYCLE High to BS Low/High			0		ns
T2	INCYCLE HiGH to $\overline{RD}/\overline{WR}$ Lo			T/4		ns
T2[1]	INCYCLE HiGH to $\overline{RD}/\overline{WR}$ High			0		
T3	INCYCLE High to Address Valid	I		1.0		ns
		XY		2.3		ns
T4	DATA_IN Setup to $\overline{RD}$ High	I		1.0		ns
		XY		1.5		ns
T5	DATA_IN Hold from $\overline{RD}$ High			0		ns
T6	$\overline{WR}$ Low to DATA_OUT Valid			1.5		ns
T7	$\overline{WR}$ Low to DATA_OUT Lo-Z			1.0		ns
T8	$\overline{WR}$ High to DATA_OUT invalid			0		ns
T9	$\overline{WR}$ High to DATA_OUT Hi-Z			0		ns

Note: C_load = 3 pF for all outputs

6.3.2 Control I/O Electrical Characteristics

Figure 6.2 Control I/O Electrical Characteristics

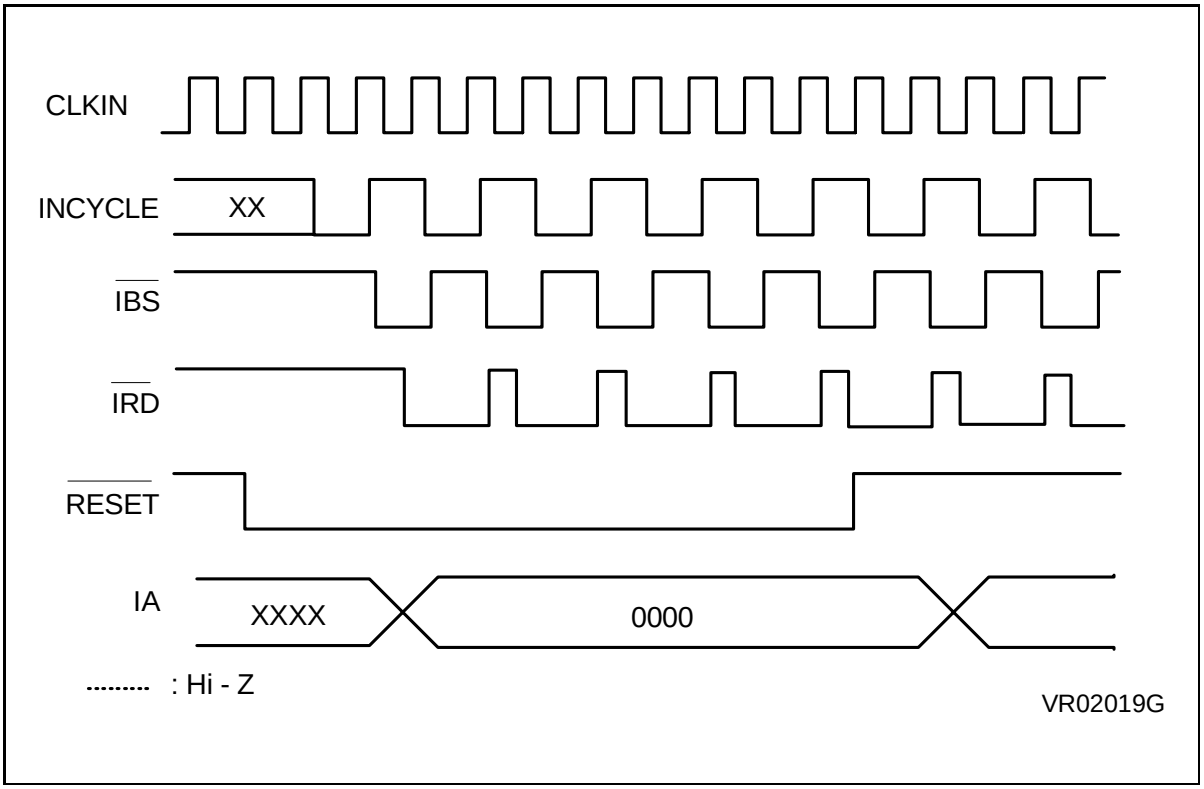


Num	Parameter	Min	Typ	Max.	Unit
T10	INCYCLE High to CONTROL out valid		2.5		ns
T11	CONTROL In Setup to INCYCLE High		2		ns
T12	CONTROL In Hold from INCYCLE High		0		ns
T13	$\overline{IT}$ pulse min. duration		3		ns
T14	INCYCLE High to BSU_CLK High		0		ns
T15	$\overline{DTACK}$ setup to CLKIN low		-1.4		ns

Note: C_load = 3 pF for all outputs
CONTROL In/Out are those defined in pin description tables **2.6** and **2.7**.

6.3.3 Hardware Reset

Figure 6.3 Hardware Reset



6.3.4 Wait States

Figure 6.4 Write X-bus with 1 Wait-state

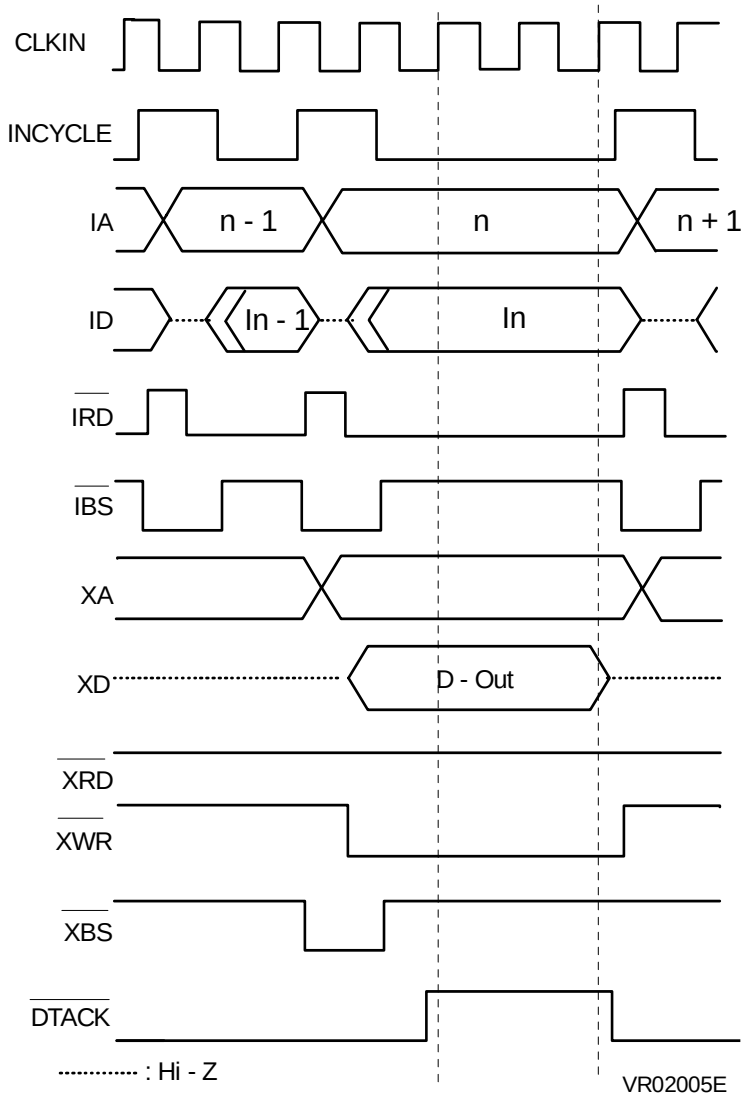
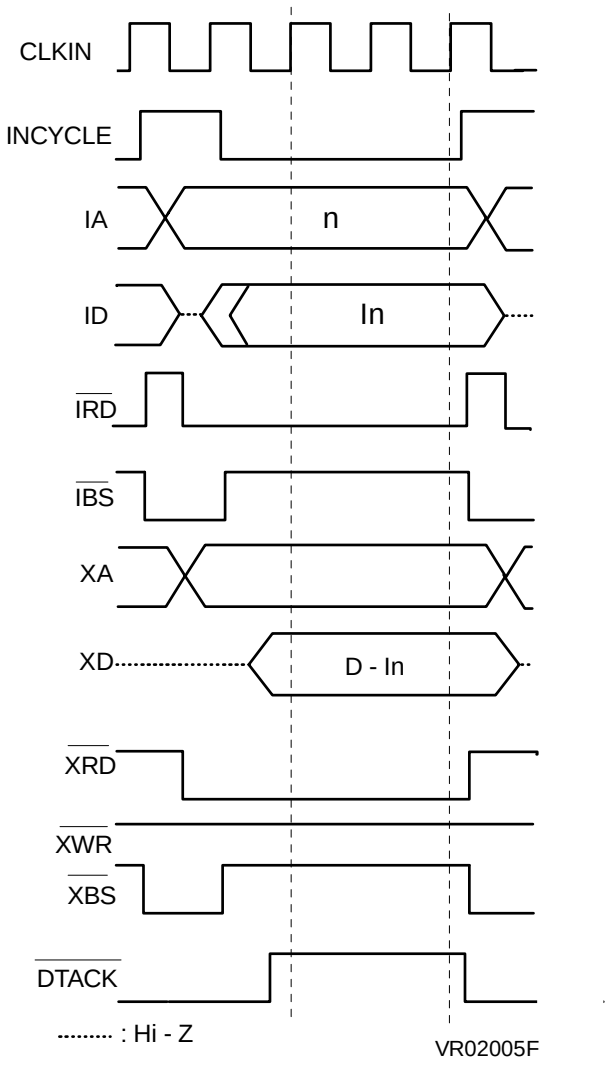


Figure 6.5 Read X-bus with 1 Wait-state



6.3.5 Interrupt

Figure 6.6 Start of Interrupt

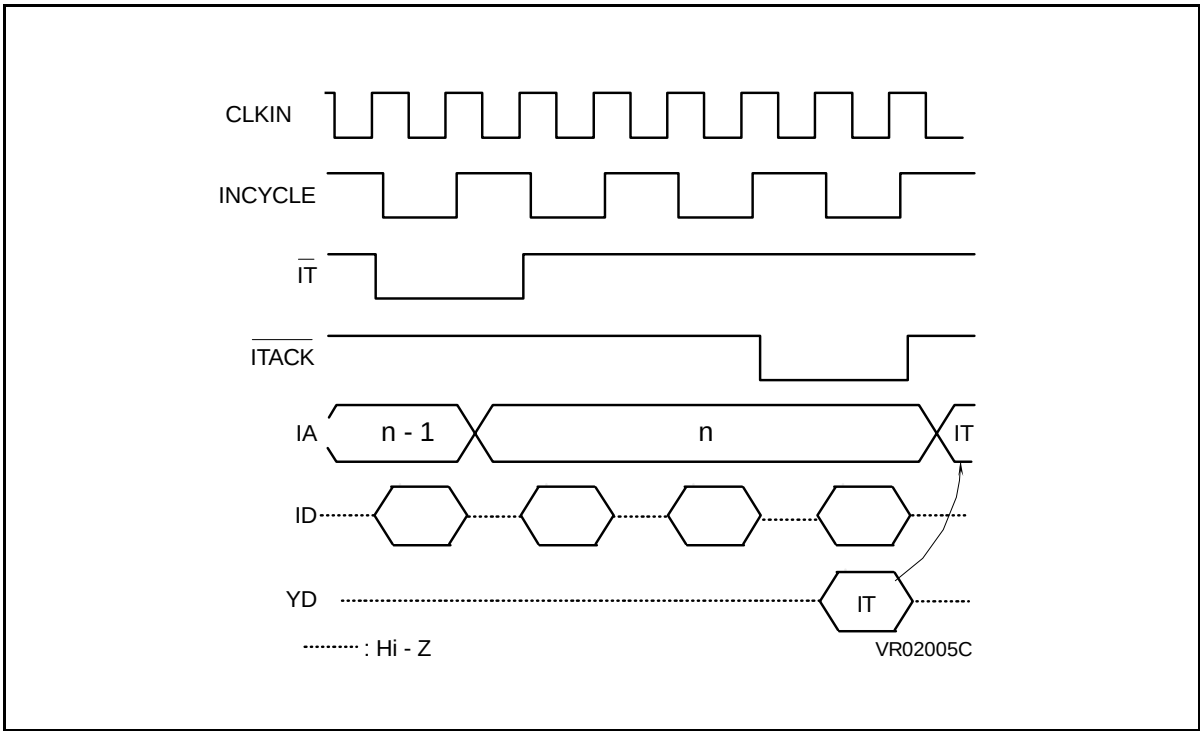
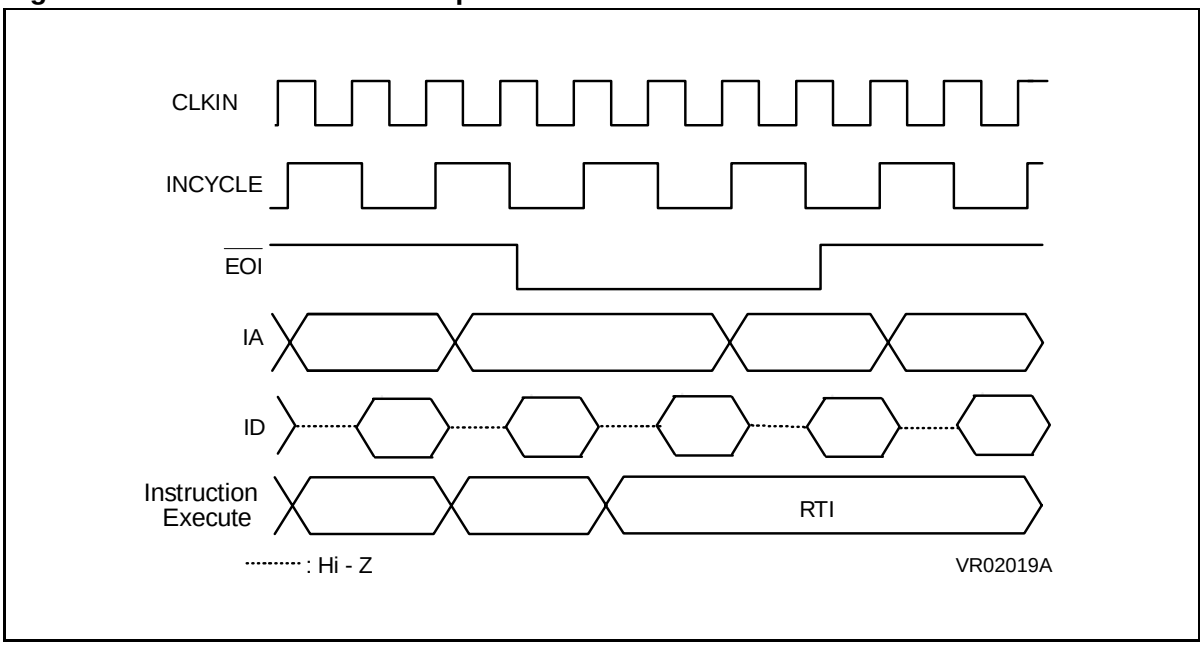


Figure 6.7 Return from Interrupt



6.3.6 HOLD

Figure 6.8 HOLD (1)

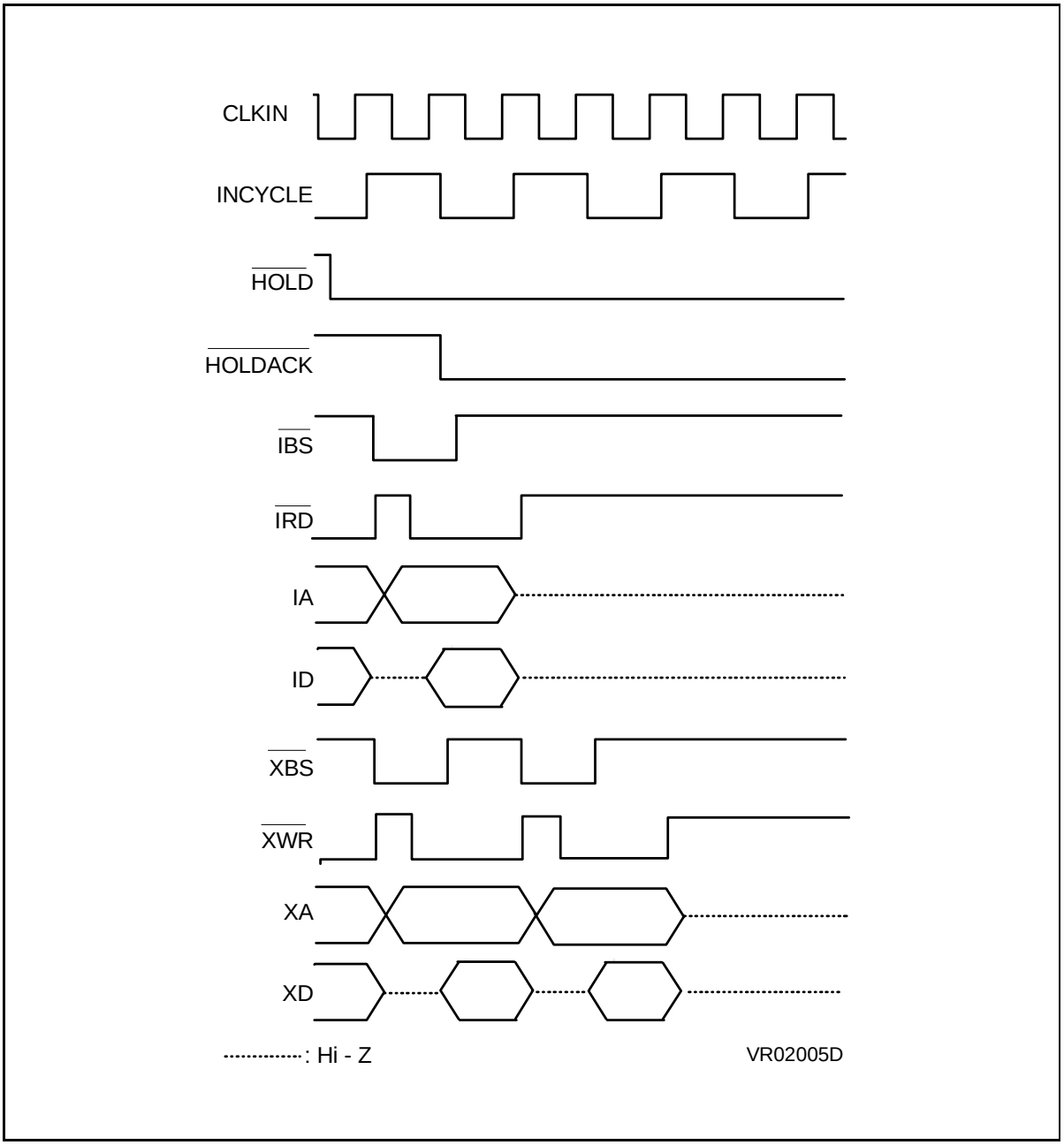
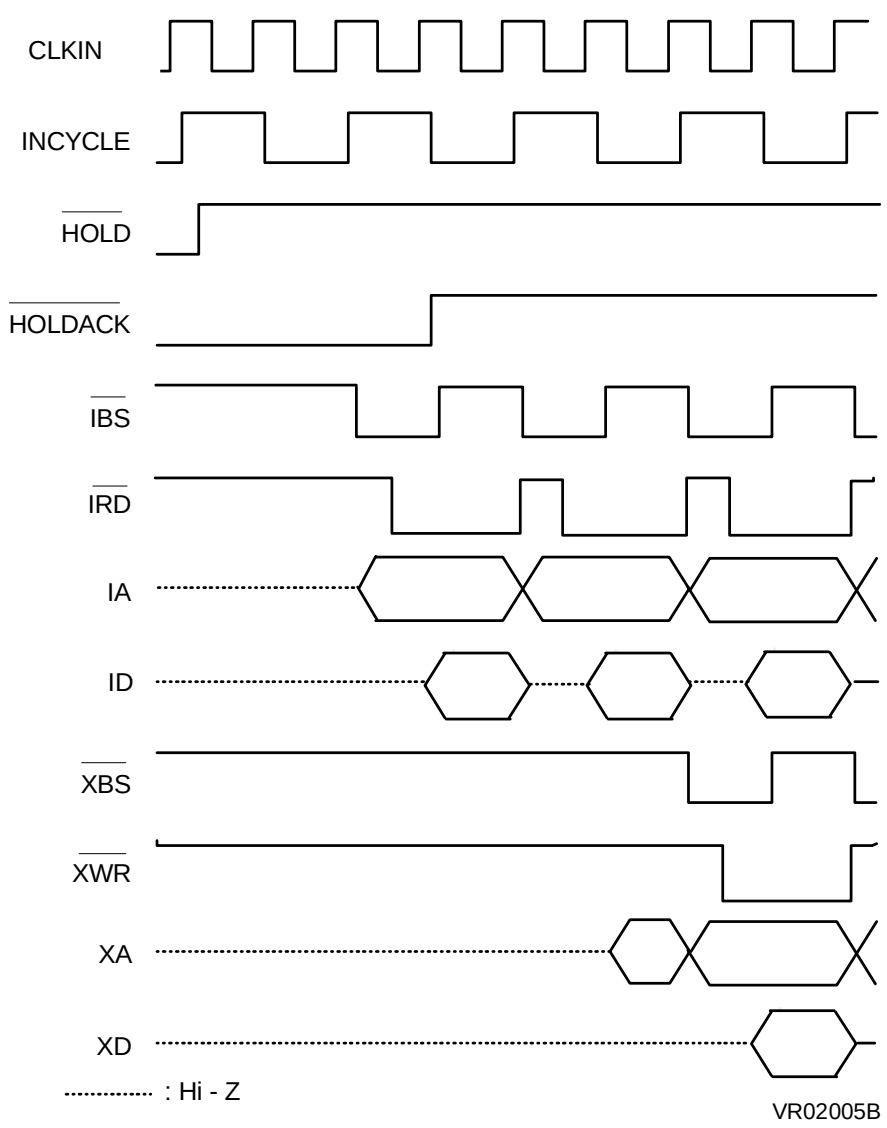
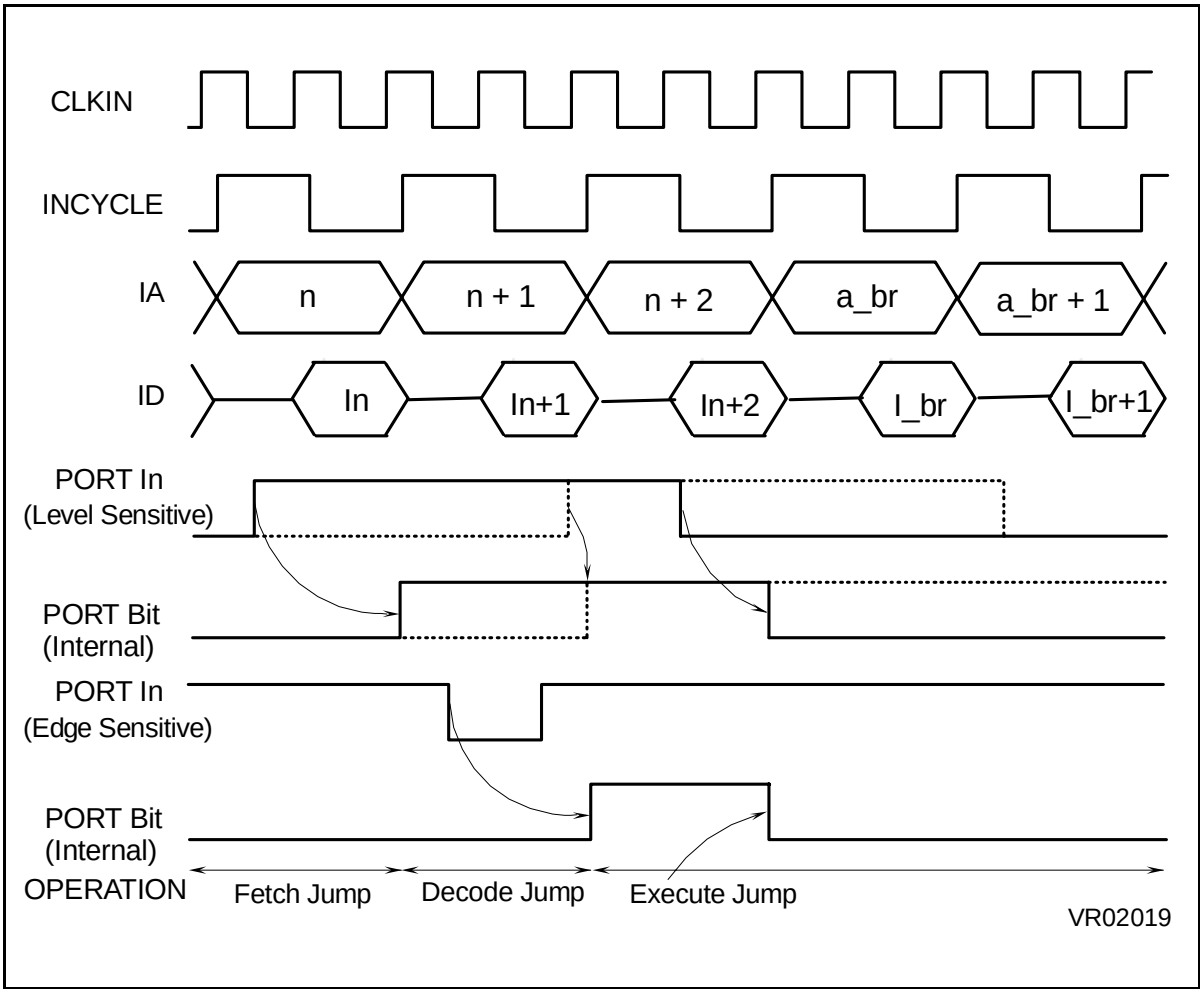


Figure 6.9 HOLD (2)



6.3.7 JUMP on Port Condition



7 ANNEX - HARDWARE PERIPHERAL LIBRARY

Specifications for peripheral functions designed for integration with the D950-Core, are given in this chapter. An example of an AS-DSP built around the D950-Core and associated peripherals, is given at the beginning of this data sheet. Other peripherals are available. Contact your local marketing support for additional information.

The peripherals detailed in this section are:

- Co-processor
- Bus Switch Unit (BSU)
- Interrupt controller
- DMA controller.

7.1 CO-PROCESSOR

Dedicated co-processors can be designed by SGS-Thomson, by customer request.

The D950-Core instruction set includes two co-processor dedicated one-word instructions, allowing one (COPS) or two (COPD) parallel data moves between X or Y-memory space and co-processor registers.

While a co-processor instruction is decoded by the D950-Core, the VCI output is asserted high, indicating to the co-processor that such an instruction will be executed at the next cycle.

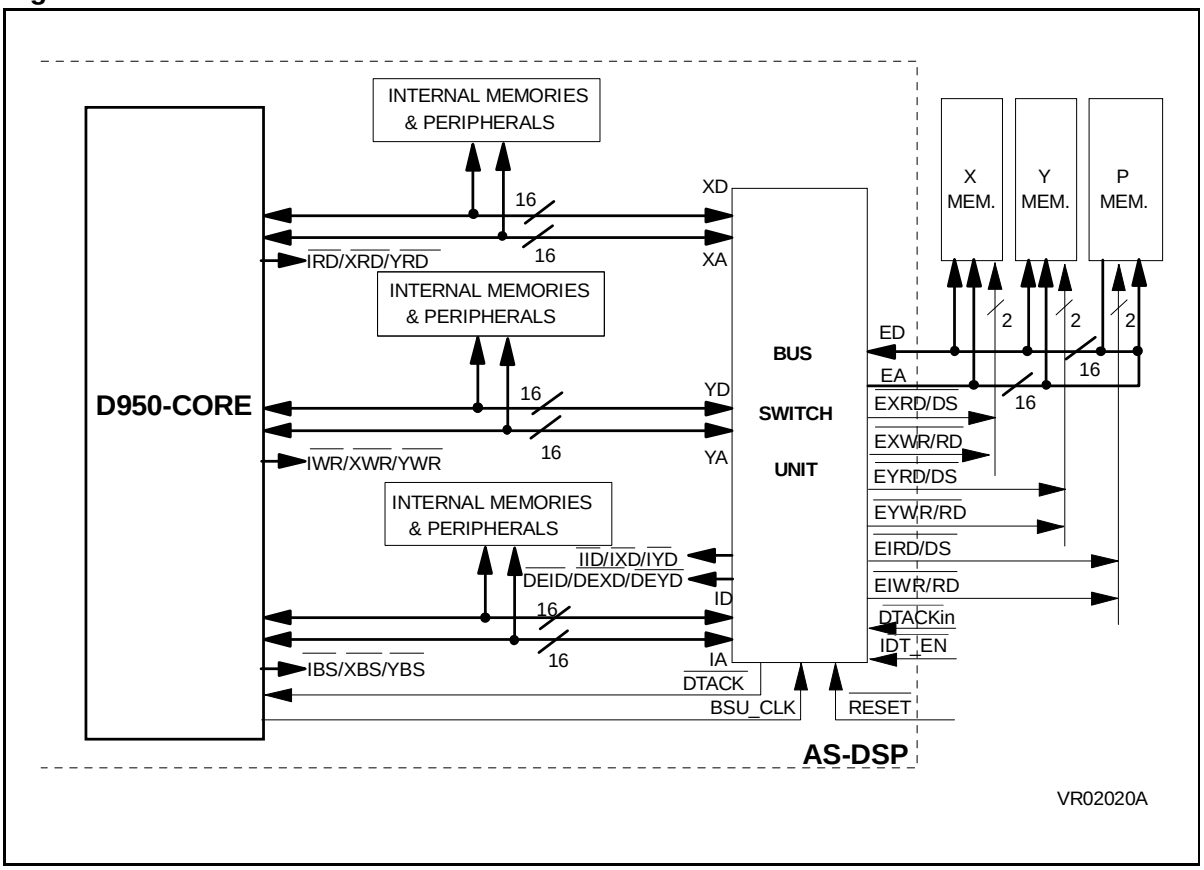
Control and status registers, at least one of each, must be included in the co-processor. This allows initialization in various operating modes and gives information to the D950-Core on operations in progress and status.

7.2 BUS SWITCH UNIT (BSU)

7.2.1 Introduction

The D950-Core Bus Switch Unit (BSU) is a multiplexed interface between the D950-Core and external memory. It enables extension of X, Y and I memories off-chip, allowing multiple possible configurations for an AS-DSP built around the D950-Core. The figure below shows the layout of the D950-Core BSU.

Figure 7.1 D950-Core Bus Switch Unit



7.2.2 I/O interface

In this section, the terms input and output are related to BSU, and the terms internal and external are related to the AS-DSP.

The BSU I/O interface signals are of two types:

On the D950-Core side:

IA0/IA15 (I address bus) and ID0/ID15 (I data bus) with their associated control signals:

$\overline{IRD}$ (read / input)

$\overline{IWR}$ (write / input)

$\overline{IBS}$ (bus strobe / input)

XA0/XA15 (X address bus) and XD0/XD15 (X data bus) with their associated control signals:

$\overline{XRD}$ (read / input)

$\overline{XWR}$ (write /input)

$\overline{XBS}$ (bus strobe / input)

YA0/YA15 (Y address bus) and YD0/YD15 (Y data bus) with their associated control signals:

$\overline{YRD}$ (read / input)

$\overline{YWR}$ (write / input)

$\overline{YBS}$ (bus strobe / input)

$\overline{DTACK}$ (data transfer acknowledge / output)

BSU_CLK (clock / input)

On the internal memory side:

$\overline{IID}$ (internal I-memory space deselect / output)

$\overline{IXD}$ (internal X-memory space deselect / output)

$\overline{IYD}$ (internal Y-memory space deselect / output)

On the external side:

EA0/EA15 (external address bus) and ED0/ED15 (external data bus) with their associated control signals

$\overline{EXRD}$/$\overline{DS}$ (external X-bus read (*) or data strobe (**) / output)

$\overline{EXWR}$/$\overline{RD}$ (external X-bus write (*) or read/write (**) / output)

$\overline{EYRD}$/$\overline{DS}$ (external Y-bus read (*) or data strobe (**) / output)

$\overline{EYWR}$/$\overline{RD}$ (external Y-bus write (*) or read/write (**) / output)

$\overline{EIRD}$/$\overline{DS}$ (external I-bus read (*) or data strobe (**) / output)

$\overline{EIWR}$/$\overline{RD}$ (external I-bus write (*) or read/write (**) / output)

$\overline{DEID}$ (direct access external I memory enable)

$\overline{DEXD}$ (direct access external X memory enable)

$\overline{DEYD}$ (direct access external Y memory enable)

Note: (*) INTEL type interface
(**) MOTOROLA type interface
$\overline{RESET}$ (reset / input)
$\overline{DTACKin}$ (data transfer acknowledge/input)

7.2.3 Operation

The BSU recognizes a bus cycle when $\overline{IBS}$, $\overline{XBS}$ or $\overline{YBS}$ is activated. It decodes the address value to determine if an external memory access is requested on the I, X or Y-bus and generates the appropriate signals on the external bus side. The BSU can also generate the DTACK signal only, depending on a control register bit value.

If more than one external memory access is attempted at one instruction cycle, they are serviced sequentially in the following order: I-bus, X-bus, Y-bus.

If one or more external memory accesses are attempted in read mode, the corresponding internal memory space can be disabled using $\overline{IID}$ (for I-bus), $\overline{IXD}$ (for X-bus) or $\overline{IYD}$ (for Y-bus), assigned low until the end of the instruction cycle.

Each external access requires one basic instruction clock cycle (two CLKIN cycles), extended by, at least, one wait-state (one BSU_CLK cycle). The number of wait-states can be extended, either by software with the BSU control registers (see **Section 7.2.4**), or by hardware with the $\overline{DTACKin}$ signal.

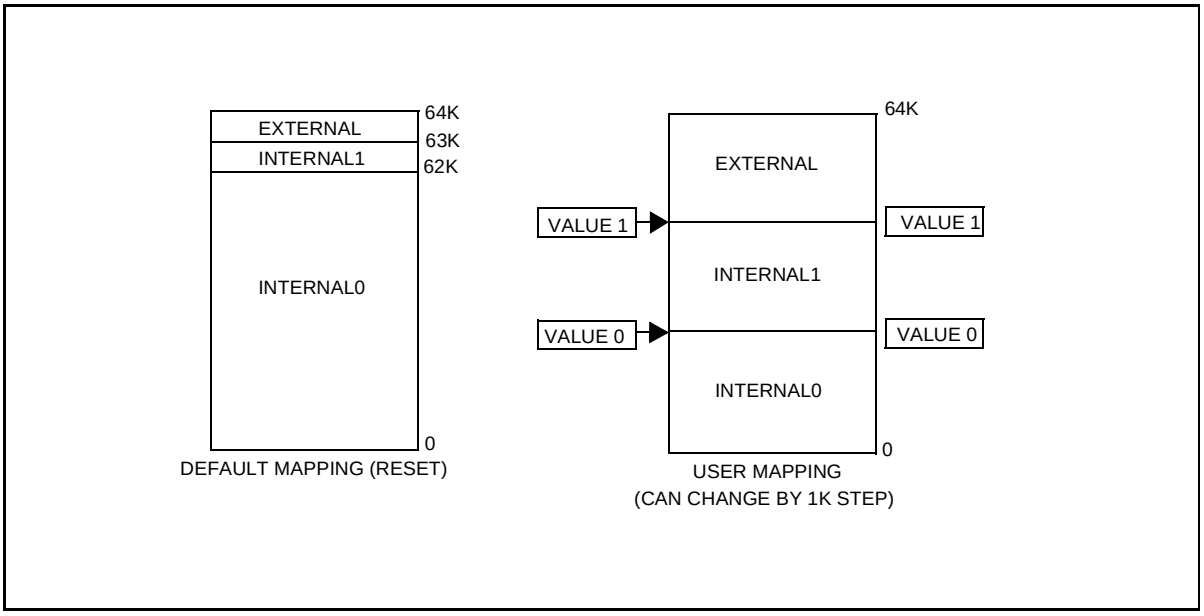
During each external memory access and according to the selected interface (INTEL or MOTOROLA) and bus (X, Y or I), the corresponding external control signals are assigned low and synchronized to the rising edge of BSU_CLK.

7.2.4 BSU control registers

The BSU is software controlled by six control registers mapped in the Y-memory space. These define the type of memory used, internal to external boundary address crossing and software wait-states count.

There are 2 registers per memory space, making it possible to define 2 sets of boundries and wait state numbers.

Figure 7.2 Default and User Mapping Examples



The BSU control registers include a reference address on bits 4 to 9, where the internal/ external memory boundary value is stored (see **Figure 7.2**), and software wait-states count on bits 0 to 3, allowing up to 16 wait-states.

External addressing is recognized by comparing these address bits for each valid address from IA, XA and YA, to the reference address contained into the corresponding control register.

If the address is greater or equal to the reference value, an external access proceeds.

For the following examples, '-' means RESERVED (read: 0, write: don't care)

XER0/1: X-memory space control registers

After reset, XER0/1 default values are 0x83EF/0x83FF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IM	EN_X	-	-	-	-	XA15	XA14	XA13	XA12	XA11	XA10	W3	W2	W1	W0

IM: Intel/ Motorola

0: Motorola type for memories

1: Intel type for memories (def.)

EN_X: Enable for X-space data exchanges

XA15 / XA10 X-memory space map for boundary on-chip or off-chip

W3 / W0: Wait state count (1 to 16) for off-chip access (X-memory space)

YER0/1: Y-memory space control registers

After reset, YER0/1 default values are 0x83EF/0x83FF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IM	EN_Y	-	-	-	-	YA15	YA14	YA13	YA12	YA11	YA10	W3	W2	W1	W0

IM: Intel / Motorola

0: Motorola type for memories

1: Intel type for memories (def.)

EN_Y: Enable for Y-space data exchanges

YA15 / YA10: Y-memory space Map for boundary on-chip or off-chip

W3 / W0: Wait state count (1 to 16) for off-chip access (Y-memory space)

IER0/1: Instruction memory control registers

After reset, IER0/1 default values are 0x83EF/0x83FF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IM	EN_I	-	-	-	-	IA15	IA14	IA13	IA12	IA11	IA10	W3	W2	W1	W0

IM: Intel / Motorola

0: Motorola type for memories

1: Intel type for memories (def.)

EN_I: Enable for I-space data exchanges

IA15 / IA10: I-memory space Map for boundary on-chip or off-chip

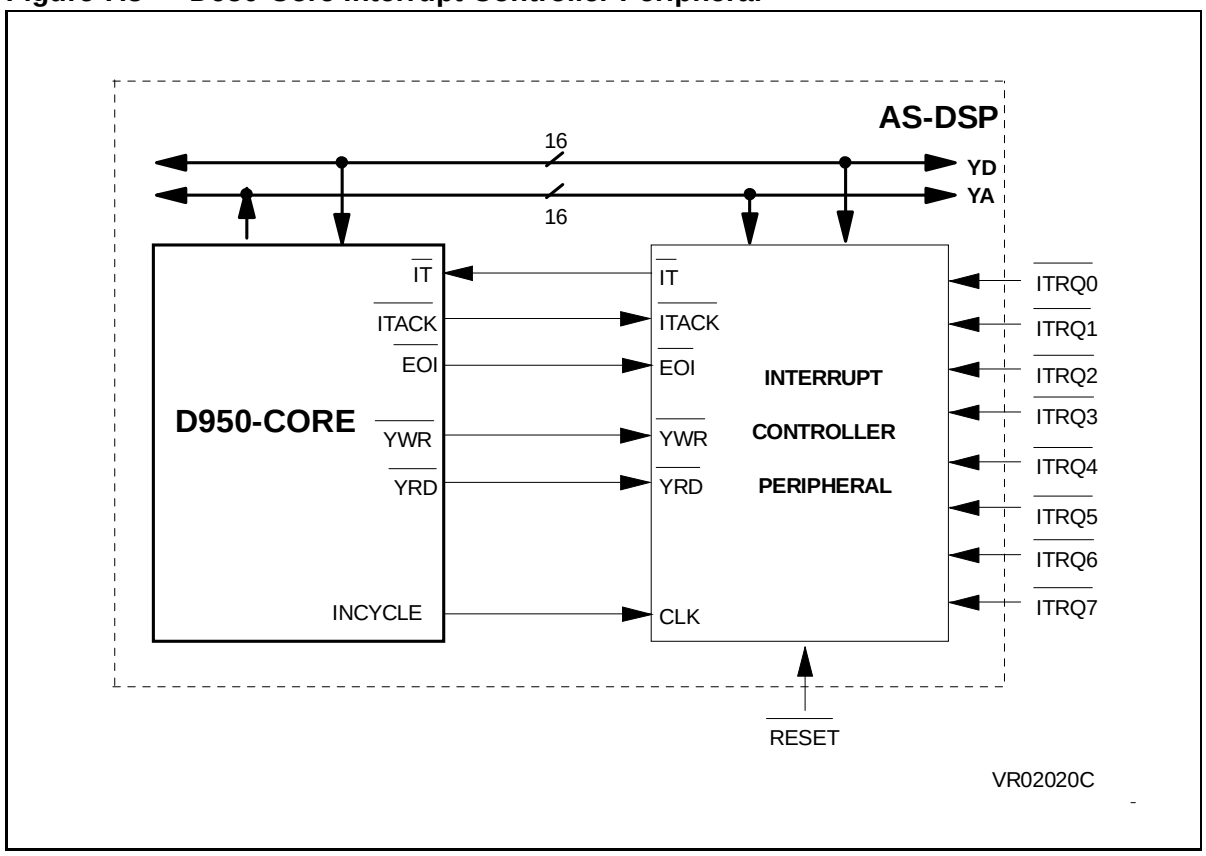
W3 / W0: Wait state count (1 to 16) for off-chip access (I-memory space)

7.3 INTERRUPT CONTROLLER

7.3.1 Introduction

The D950-Core interrupt controller is a peripheral that manages up to eight interrupt sources.

Figure 7.3 D950-Core Interrupt Controller Peripheral



7.3.2 I/O interface

In this section, the terms input and output are related to the interrupt controller, and the term external is related to the AS-DSP.

The interrupt controller I/O interface signals are of two types:

On the D950-Core Side

- $\overline{IT}$ (maskable interrupt request / output)
- $\overline{ITACK}$ maskable interrupt request acknowledge / input)
- $\overline{EOI}$ (end of maskable interrupt routine / input)
- YA0/YA15 (Y address bus) and YD0/YD15 (Y data bus) with their associated control signals:
  $\overline{YRD}$ (read / input)
  $\overline{YWR}$ (write / input)
- CLK clock / input

On the External Side

- $\overline{ITRQ}$ (7:0) (8 interrupt requests / inputs)
- $\overline{RESET}$ (reset / input)

7.3.3 Interrupt Controller Peripheral Registers

The interrupt controller interface is software controlled by thirteen status/control registers mapped in the Y-memory space. Status registers are not protected against writing:

IVi: Interrupt Vector Register

One register is associated to each external interrupt.

IVi contains the first address of the interrupt routine associated to each $\overline{ITRQi}$ interrupt input (with $0 \leq i \leq 7$). The register content of the interrupt under service is assigned on the YD-bus during the cycle following the $\overline{ITACK}$ falling edge where CLK=0.

After reset, IVi default value is 0.

IMR: Interrupt Mask Register

Each interrupt $\overline{ITRQi}$ can be masked individually when the IMi corresponding bit is set. In this case, no activity on $\overline{ITRQi}$ is taken into account.

$\overline{ITRQi}$ can be activated on a low level or on a falling edge, according to associated ISi status.

When associated ISi-bit is reset (def. value), $\overline{ITRQi}$ must stay low for one period.

After reset, IMR default value is 0x5555.

For the following examples, '-' means RESERVED (read: 0, write: don't care)

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IS7	IM7	IS6	IM6	IS5	IM5	IS4	IM4	IS3	IM3	IS2	IM2	IS1	IM1	IS0	IM0

IMi: Interrupt Mask

0: Interrupt i is not masked

1: Interrupt i is masked (def.)

ISi: Sensitivity

0: $\overline{\text{ITRQi}}$ is active on a low level (def.)

1: $\overline{\text{ITRQi}}$ is active on a falling edge

IPR: Interrupt Priority Register

IPR contains the priority level of each $\overline{\text{ITRQi}}$ interrupt input.

Interrupt priority level is a 2-bit value, so can be 0,1,2 or 3 (0 lowest priority, 3 highest priority).

When two $\overline{\text{ITRQi}}$ of same priority level are requested during the same cycle, the first acknowledged interrupt is the interrupt corresponding to the lowest numberical value.

After reset, IPR default value is 0.

15 - 14	13 - 12	11 - 10	9 - 8	7 - 6	5 - 4	3 - 2	1 - 0
IP7	IP6	IP5	IP4	IP3	IP2	IP1	IP0

IPi: Interrupt Priority level (0, 1, 2 or 3) (def. 0)

ICR: Interrupt Control Register

ICR displays the current priority level and up to four stacked priority levels.

The current priority level is coded using 3 bits but only five different values are available:

PRIORITY LEVEL	CODING	ACCEPTABLE IT LEVEL PRIORITY
- 1	111	0,1,2,3
0	000	1,2,3
1	001	2,3
2	010	3
3	011	
Reserved	100 - 110	

Note: The D950-Core interrupts (SWI, RESET) are priority level 4 (highest level).

An interrupt request is acknowledged when its priority level is strictly higher than the current priority level. In this case, the current priority level becomes the interrupt priority level and the previous current priority level is pushed onto the stack and displayed as SPL1.

The process is repeated over a range of four interrupt requests and the four previous current priority levels are displayed as SPL1, SPL2, SPL3 and SPL4. If less than four interrupts are pushed onto the stack, the unused Stack Priority Level words are reset to ‘000’.

At the end of the interrupt routine, the priority levels are popped from the stack.

If the SPLi values are directly written, the register content is not more significant but the interrupt routine procedure is not affected. The only way to affect this is to reset the AS-DSP.

After reset, ICR default value is 0x000B.

15 - 14 - 13	12 - 11 - 10	9 - 8 - 7	6 - 5 - 4	3	2 - 1 - 0
SPL4	SPL3	SPL2	SPL1	ES	CPL

SPL4: 3-bit 4th stacked priority level

SPL3: 3-bit 3rd stacked priority level

SPL2: 3-bit 2nd stacked priority level

SPL1: 3-bit 1st stacked priority level

ES: Empty Stack flag

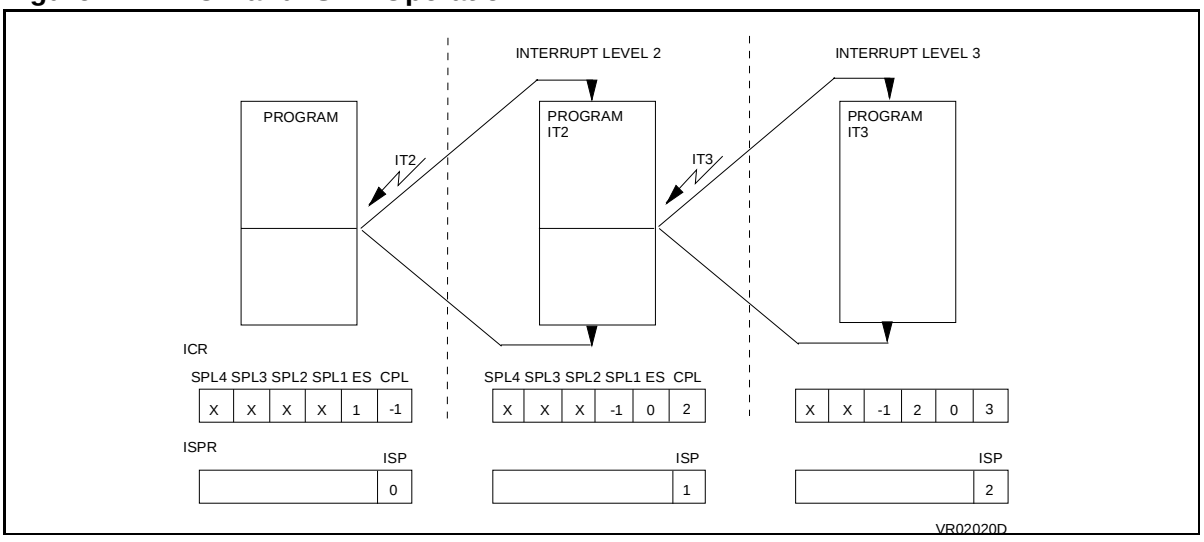
0: Stack is used

1: Stack is not used (def.)

CPL: Current Priority level (-1, 0, 1, 2 or 3) (def. 011)

Note:After reset, no interrupt request from interrupt controller is acknowledged.
‘-’ means RESERVED (read: 0, write: don't care)

Figure 7.4 ICR and ISPR Operation



ISPR Interrupt Stack Pointer Register

ISPR contains the number of stacked priority levels. If the ISPR value is directly written, the SPLi/CPL values are modified. So the ICR register content is no longer significant but the interrupt routine procedure is not affected. After reset, ISPR default value is 0.

15	14	13	12	11	10	9	8	7	6	5	4	3	2 - 1 - 0
-	-	-	-	-	-	-	-	-	-	-	-	-	ISPR

ISPR: Number of stacked priority levels (0, 1, 2 or 3)

Note:'-' is RESERVED (read: 0, write: don't care)

ISR Interrupt Status Register

ISR contains the eight interrupt pending bits, each being associated to one $\overline{\text{ITRQi}}$ interrupt input.

IPEi-bit is set when the interrupt request is recorded and is reset when the interrupt request is acknowledged ($\overline{\text{ITACK}}$ falling edge).

An interrupt request will not be acknowledged when IPEi-bit is reset by direct register write.

An interrupt request will be generated whatever the state of $\overline{\text{ITRQi}}$ when IPEi-bit is set by a direct register write.

When only some pending interrupt requests need to be acknowledged, the IPEi bits of the other $\overline{\text{ITRQi}}$ interrupt inputs must be reset.

When none of the pending interrupt requests need to be acknowledged, the IPE-bit of CCR register must be first reset and ISR must be reset.

When IMi-bit is set, the corresponding IPEi-bit is reset. After reset, ISR default value is 0.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
-	-	-	-	-	-	-	-	IPE7	IPE6	IPE5	IPE4	IPE3	IPE2	IPE1	IPE0

IPEi: Interrupt Pending bit

0: Reset when interrupt request is acknowledged (def.)

1: Set when interrupt request is recorded

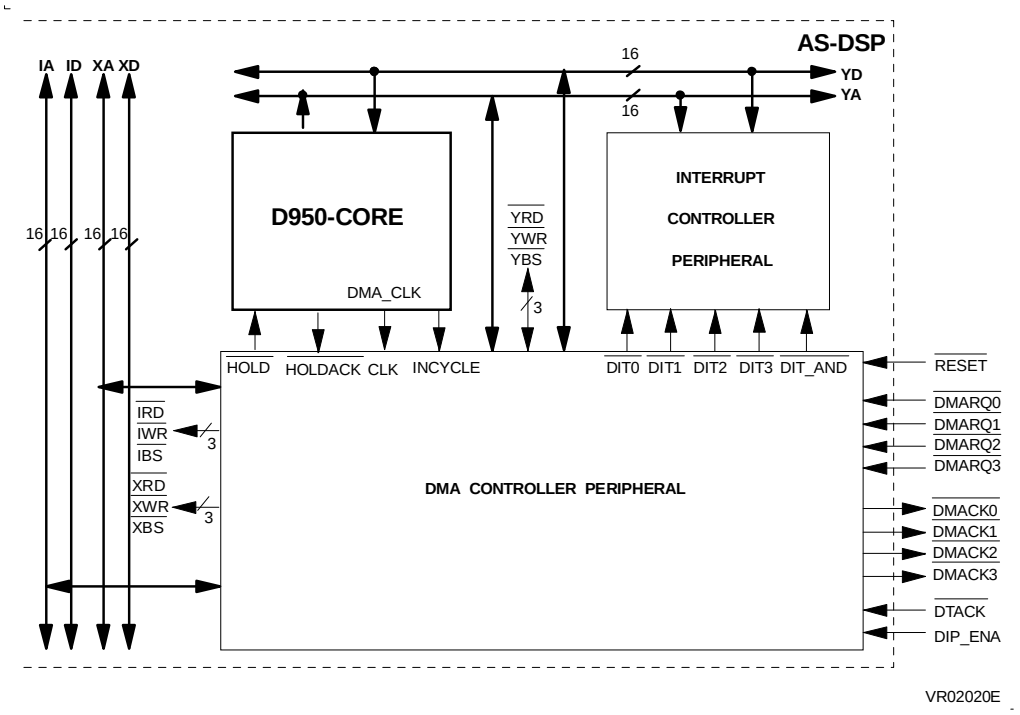
Note:'-' is RESERVED (read: 0, write: don't care)

7.4 DMA CONTROLLER

7.4.1 Introduction

The D950-Core DMA controller manages data transfer between AS-DSP memories and external peripherals, without using AS-DSP capabilities.

Figure 7.5 D950-Core DMA Controller Peripheral



7.4.2 I/O interface

The terms input and output are related to the DMA controller, external is related to the AS-DSP.

Referring to the D950-Core pin description, the interrupt controller I/O interface signals are of different types:

On the D950-Core Side

- $\overline{\text{HOLD}}$ (hold request / output)
- $\overline{\text{HOLDACK}}$ (hold acknowledge / input)
- CLK (clock / input)
- INCYCLE (clock / input)

On the Internal Memory Side

- XA0/XA15 (Y address bus) with associated control signals (output):
  $\overline{\text{XRD}}$ (read / output)
  $\overline{\text{XWR}}$ (write / output)
  $\overline{\text{XBS}}$ (bus strobe / output)
- YA0/YA15 (Y address bus) and YD0/YD15 (Y data bus) with their associated control signals (clock / input):
  $\overline{\text{YRD}}$ (read / input/output)
  $\overline{\text{YWR}}$ (write / input/output)
  $\overline{\text{YBS}}$ (bus strobe / output)
- IA0/IA15 (I address bus) with associated control signals (output):
  $\overline{\text{IRD}}$ (read / output)
  $\overline{\text{IWR}}$ (write / output)
  $\overline{\text{IBS}}$ (bus strobe / output)

On the Interrupt Controller Side

- $\overline{\text{DIT}}$(3:0) (interrupt request / output)
- $\overline{\text{DIT\_AND}}$ (common interrupt request / output)

On the External Side

- $\overline{\text{DMARQ}}$(3:0) (request / one input per channel)
- $\overline{\text{DMACK}}$(3:0) (acknowledge / one output per channel)
- DIP_ENA (DITi output enable / input)
- $\overline{\text{RESET}}$ (reset / input)
- $\overline{\text{DTACK}}$ (cycle extension / input),

7.4.3 Operation

The DMA controller interface contains four independent channels allowing data transfer on I-memory space and simultaneous data transfer on X and Y-memory spaces. When requests occur at the same time on different channels, to transfer data on the same bus, the requests are concatenated to be acknowledged during the same transfer, according to the following fixed priority (see table):

Table 7.1 DMA Controller Interface Priority Levels

Priority	Channel	Level
0	0	Highest
1	1	
2	2	
3	3	Lowest

The DMA transfer is based on a DSP cycle stealing operation:

- The DMA controller generates a ‘hold request’ to the AS-DSP.
- The AS-DSP sends back a ‘hold acknowledge’ to the DMA controller and enters the hold state (bus released).
- The DMA controller, manages the transfer and enters its idle state at the end of the transfer, until reception of a new DMA request. The ‘hold request’ signal is removed.

The data transfer duration is n+2 cycles, split into:

- One cycle inserted at the beginning of the transfer when bus controls are released by the D950-Core, n cycles for the number of data words to be transferred.
- Another cycle is inserted at the end of the transfer when bus controls are released by the DMA controller.

Single or block data can be transferred. The ‘DMA request’ signal is well adapted to such data transfers by being either edge (single) or level (block) sensitive. Nevertheless, data blocks can be transferred one data at time using an edge sensitive request signal.

A double buffering mechanism is available to deal with data blocks requiring the allocation of 2N addresses for the transfer of a N data block.

An interrupt can be used to warn AS-DSP that a predefined number of data have been transferred and are ready to be processed. Interrupt requests are sent from the DMA controller to the interrupt controller. The selected channels must be edge sensitive and the user has to define the proper priority.

There are two ways to connect the DMA and the interrupt controllers, depending on the state on the DIP_ENA static pin:

- DIP_ENA = 0, there are enough available interrupt sources in the interrupt controller: connect each DMA channel interrupt request ($\overline{\text{DITi}}$, active on falling

edge) to an interrupt input ($\overline{ITRQi}$).

- DIP_ENA = 1, the number of available interrupt sources in the interrupt controller is low: Connect the logical AND of the $\overline{DITi}$ signals ($\overline{DIT\_AND}$) to a single interrupt input (ITRQi), the interrupt pending bits (DIPi) of the DAIC register distinguish the which of the four possible interrupt sources caused the interrupt. (see 7.4.4).

7.4.4 DMA Peripheral Registers

Address Registers

Two 16-bit registers (unsigned) are dedicated per channel for transfer address:

- DIA: initial address. This register contains the initial address of the selected address bus (see DBC-bit of DGC).
- DCA: current address. This register contains the value to be transferred to the selected address bus (see DBC-bit of DGC) during the next transfer. The different DCA values are:

RESET	DAI	DLA	DCC = 0	DCA(n+1)
1	X	X	X	0
0	0	X	X	DCA(n)
0	1	0	X	DCA(n) + 1
0	1	1	0	DCA(n) + 1
0	1	1	1	DIA

Note: See DAIC register for DAI and DLA definitions

Counting Registers

Two 16-bit registers (unsigned) per channel are dedicated for transfer count.

For a transfer of a N data block, DIC and DCC registers have to be loaded with N-1.

When DCC content is 0 (valid transfer count), it is loaded with DIC content for the next transfer.

- DIC: initial count. This register contains the total number of transfers of the entire block
- DCC: current count. This register contains the remaining number of transfers to be done to fill the entire block. It is decremented after each transfer. The DCC values are:

RESET	DCC = 0	DCA(n+1)
1	X	0
0	0	DCA(n) - 1
0	1	DIC

Control Registers

Three 16-bit control registers are dedicated to the DMA controller interface. These are the general control register, the address interrupt control register and the Mask sensitivity control register. They are detailed as follows:

DGC: General control register

Three bits are dedicated for each DMA channel (bits 0 to 2 to channel 0, bits 4 to 6 to channel 1, bits 8 to 10 to channel 2, bits 12 to 14 to channel 3). After reset, DGC default value is 0.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
-	DRW3	DBC1	DBC0	-	DRW2	DBC1	DBC0	-	DRW1	DBC1	DBC0	-	DRW0	DBC1	DBC0

DBC1/DBC0: Bus choice for data transfer

0 : X-bus (def.)

01: Y-bus

10: I-bus

11: reserved

DRWi: Data transfer direction

0: Write access (def.)

1: Read access

DAIC: Address/Interrupt control register

Four bits are dedicated for each DMA channel (bits 0 to 3 to channel 0, bits 4 to 7 to channel 1, bits 8 to 11 to channel 2, bits 12 to 15 to channel 3). After reset, DAIC default value is 0.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DAI3	DLA3	DIP3	DIE3	DAI2	DLA2	DIP2	DIE2	DAI1	DLA1	DIP1	DIE1	DAI0	DLA0	DIP0	DIE0

DAIi: Address increment
0: DCAi content unchanged (def.)
1: DCAi content modified according to DLAi state

DLAi: Load address
0: DCAi content incremented after each data transfer (def.)
1: DCAi content loaded with DIA content if DCCi value is 0 or DCAi content incremented if DCCi value not equal to 0

DIPi: Interrupt pending
0: No pending interrupt on channel i (def.)
1: Pending interrupt on channel i (enabled if DIP_ENA input is high)

DIEi: Enable Interrupt
0: Interrupt request output associated to channel i is masked (def.)
1: Interrupt request output associated to channel i is not masked

DMS: Mask Sensitivity control register

Two bits are dedicated to each DMA channel (bits 0 and 1 to channel 0, bits 4 and 5 to channel 1, bits 8 and 9 to channel 2, bits 12 and 13 to channel 3). After reset, DMS default value is 0x3333.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
-	-	DSE3	DMK3	-	-	DSE2	DMK2	-	-	DSE1	DMK1	-	-	DSE0	DMK0

DSEi: DMA Sensitivity

0: Low level

1: Falling edge (def.)

DMKi: DMA Mask

0: DMA channel not masked

1: DMA channel masked (def.)

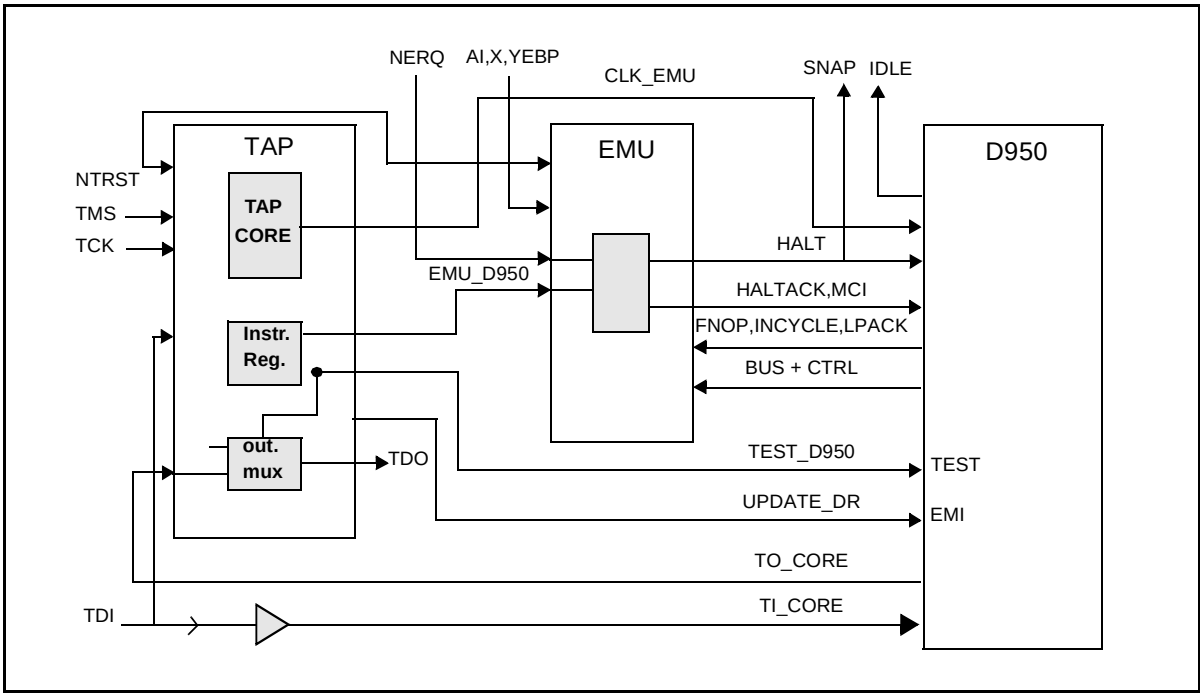
7.5 Emulation and Test Unit (EMU)

7.5.1 Introduction

The D950-Core EMU is a peripheral which performs functions dedicated to emulation and test through the external IEEE 1149.1 JTAG interface.

The emulation and test operations are controlled by an off-core Test Access Port (TAP) and an off-core emulator by means of dedicated control I/Os.

Figure 7.6 D950-Core Emulation and Test



Emulation mode can entered in two ways:

- Asserting $\overline{\text{ERQ}}$ input pin low.
- Meeting a valid breakpoint condition or executing an instruction in single step mode.

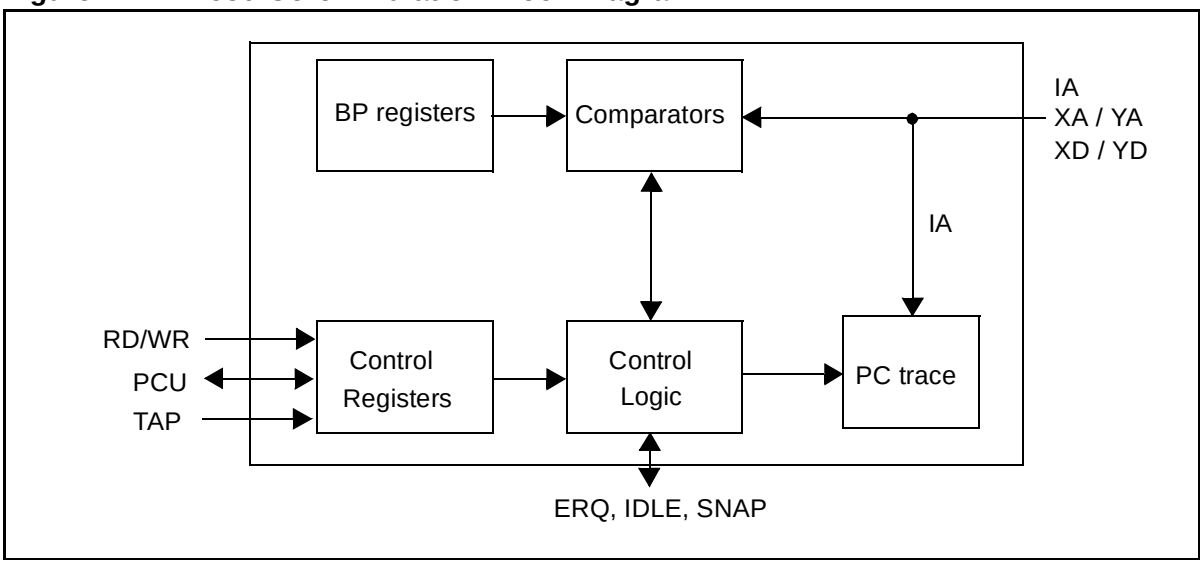
Most of D950-Core instructions can be executed in emulation mode, including arithmetic/logic, JUMP/CALL and MOVE. These instructions are used to display the processor status (memories and registers) and restore the context.

Exiting the emulation mode is controlled by the PC-board emulator through the JTAG interface.

The Emulation resources (see **Figure 7.7**) include:

- Four Breakpoint registers (BP0, BP1, BP2, BP3) which can be affected by Program or Data memory.
- Breakpoint counter (BPC).
- Program Counter Trace Buffer (PCB) able to store the address of the 6 last executed instructions.
- Three control registers for Breakpoint condition programming.
- Control logic for instruction execution through the PC-board emulator control.

Figure 7.7 D950-Core Emulation Block Diagram



The emulation and TAP controller interfaces (see **Table 2.7** and **Table 2.8**) include pins of different types:

- Scan control (TDI, TDO, TCK).
- TAP instructions
- TAP controller states (UPDATE).
- Emulation control (ERQ, IDLE, SNAP, HALTACK, AIEBP, AXEBP, AYEBP).

7.5.2 Registers

There are two types of registers for the EMU, data registers, and control and status registers. They are mapped in the Y-memory space.

Data Registers

BP0, BP1, BP2, BP3: Breakpoint registers
0, 1, 2, 3 values. 16-bit breakpoint registers allowing breakpoints.

BPC: Breakpoint Counter register. This 16-bit register is initialized by a load instruction and decremented each time a valid condition is met on a count enabled breakpoint. Breakpoints with and without a count condition can be set simultaneously. After reset, BPC is not initialized.

PCB: Program Counter Trace Buffer register allows the user to keep trace of the PC value for the six last executed instructions. PCB stores one address value per instruction, whatever the instruction type (single cycle, single word, multiple cycles, multiple words)

Control and Status Registers

Three breakpoint control registers allow simple or multiple breakpoints (conditional or not) to be set and counting breakpoint events to be enabled..

Breakpoint Register	Breakpoint Location	Bus
BP3	Program memory address	IA or YD
BP2	or Data memory data	IA or XD
BP1	Data memory	XA or
BP0	Address	YA

8 APPENDIX

8.1 MEMORY MAPPING (Y-memory space)

8.1.1 General mapping

Miscellaneous	006F 0060
Bus Switch Unit	005F 0050
DMA CONTROLLER	004F 0030
IT Controller	002F 0020
DSP Core	001F 0000

8.1.2 Registers Related to the D950-CORE

Register Address	Register Name	Function	Location
0x0000	BX	Modulo base address for X-memory space	ACU
0x0001	MX	Modulo maximum address for X-memory space	ACU
0x0002	BY	Modulo base address for Y-memory space	ACU
0x0003	MY	Modulo maximum address for Y-memory space	ACU
0x0004	POR	Port Output Register	PORT
0x0005	PIR	Port Input Register	PORT
0x0006	PCDR	Port Control Direction Register	PORT
0x0007	PCSR	Port Control Sensitivity Register	PORT
0x0008 to 0x001F	Reserved for test and emulation		
0x0062	PPR	Program Page Register	Peripherals

8.1.3 Registers related to the interrupt controller

Register Address	Register Name	Function	Location
0x0020	IV0	Interrupt Vector 0 address	IT Controller
0x0021	IV1	Interrupt Vector 1 address	IT Controller
0x0022	IV2	Interrupt Vector 2 address	IT Controller
0x0023	IV3	Interrupt Vector 3 address	IT Controller
0x0024	IV4	Interrupt Vector 4 address	IT Controller
0x0025	IV5	Interrupt Vector 5 address	IT Controller
0x0026	IV6	Interrupt Vector 6 address	IT Controller
0x0027	IV7	Interrupt Vector 7 address	IT Controller
0x0028	ICR	Interrupt Control Register	IT Controller
0x0029	IMR	Interrupt Mask / Sensitivity Register	IT Controller
0x002A	IPR	Interrupt Priority Register	IT Controller
0x002B	ISPR	Interrupt Stack Pointer Register	IT Controller
0x002C	ISR	Interrupt Status Register	IT Controller

8.1.4 Registers related to the DMA controller

Register Address	Register Name	Function	Location
0x0030	DIA0	DMA channel 0 initial address	DMA controller
0x0031	DIA1	DMA channel 1 initial address	DMA controller
0x0032	DIA2	DMA channel 2 initial address	DMA controller
0x0033	DIA3	DMA channel 3 initial address	DMA controller
0x0034	DCA0	DMA channel 0 current address	DMA controller
0x0035	DCA1	DMA channel 1 current address	DMA controller
0x0036	DCA2	DMA channel 2 current address	DMA controller
0x0037	DCA3	DMA channel 3 current address	DMA controller
0x0038	DIC0	DMA channel 0 initial count	DMA controller
0x0039	DIC1	DMA channel 1 initial count	DMA controller
0x003A	DIC2	DMA channel 2 initial count	DMA controller
0x003B	DIC3	DMA channel 3 initial count	DMA controller
0x003C	DCC0	DMA channel 0 current count	DMA controller
0x003D	DCC1	DMA channel 1 current count	DMA controller
0x003E	DCC2	DMA channel 2 current count	DMA controller
0x003F	DCC3	DMA channel 3 current count	DMA controller
0x0040	DGC	DMA General Control	DMA controller
0x0041	DMS	DMA Mask Sensitivity	DMA controller
0x0042	DAIC	DMA Address / Interrupt Control	DMA controller

8.1.5 Registers related to the Bus Switch Unit

Register Address	Register Name	Function	Location
0x0050	IER0	External I-bus control register 0	BSU
0x0051	XER0	External X-bus control register 0	BSU
0x0052	YER0	External Y-bus control register 0	BSU
0x0053	IER1	External I-bus control register 1	BSU
0x0054	XER1	External X-bus control register 1	BSU
0x0055	YER1	External Y-bus control register 1	BSU